Smart Grid Overview

Carnegie Mellon
Conference on the Electricity Industry

March 9-10, 2009

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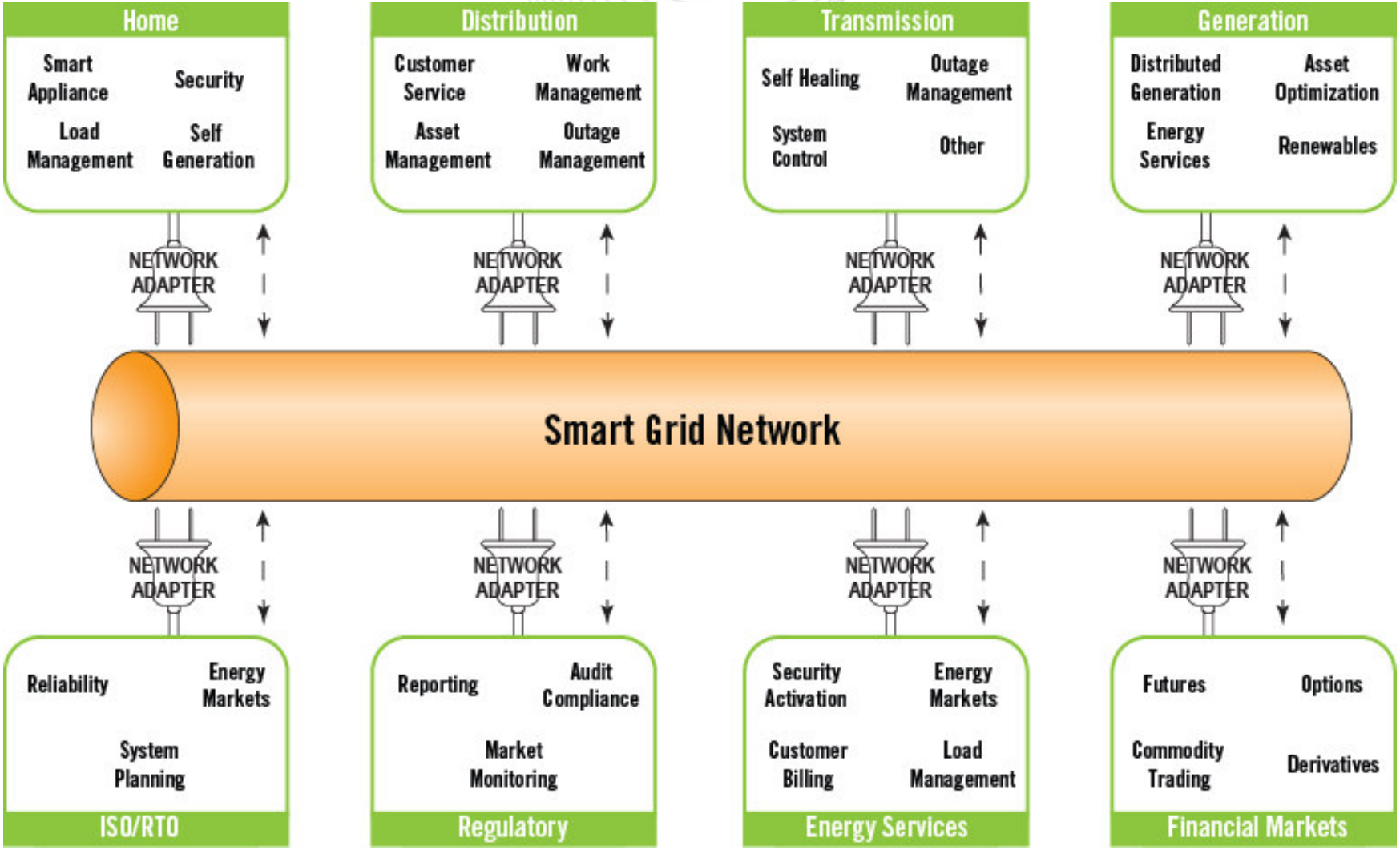
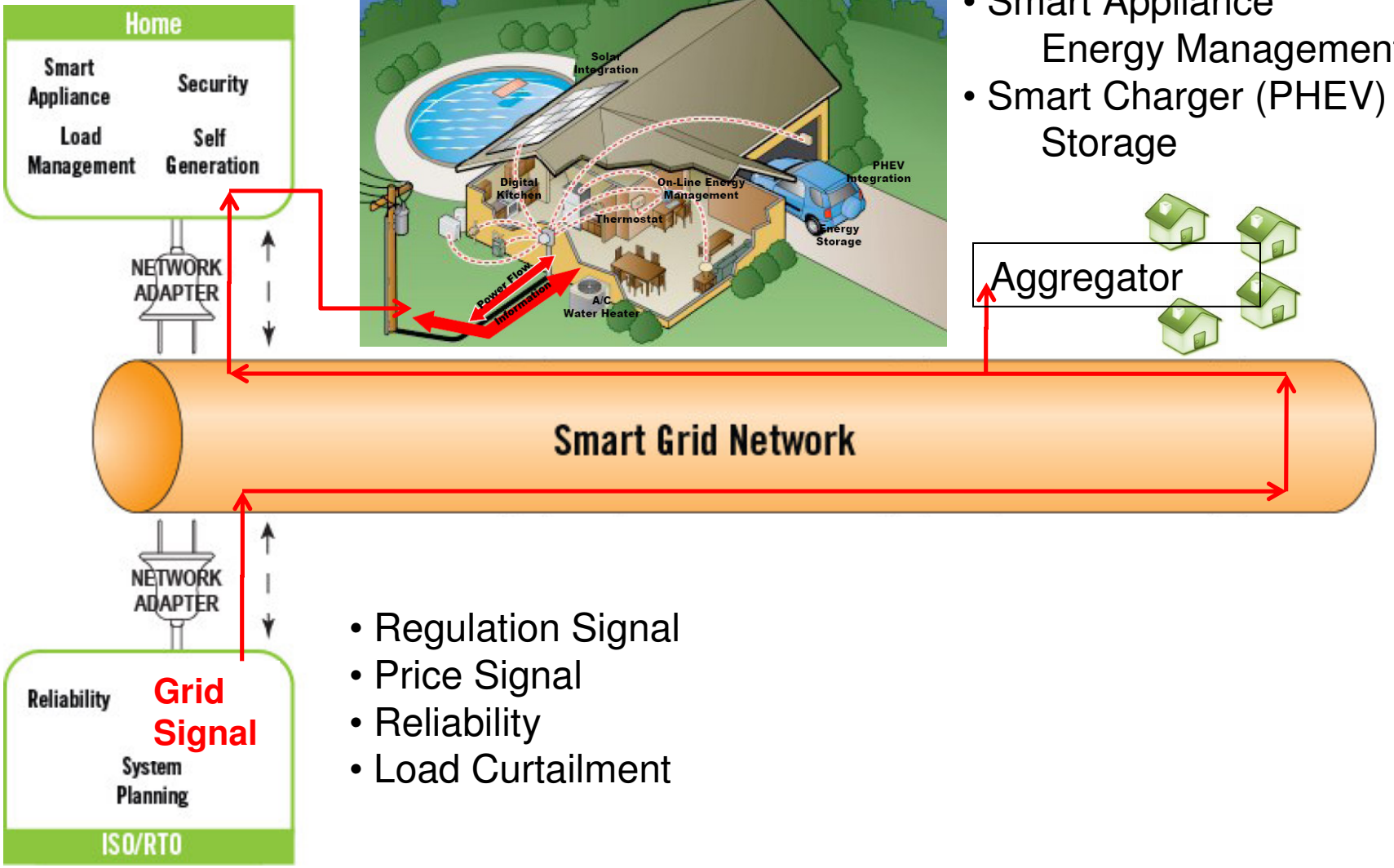
Dimensions of the Smarter Grid

20th Century Grid	21st Century Grid
Electromechanical/Analog	Digital
One-way communications (if any)	Two-way communications
Built for centralized generation	Accommodates distributed generation
Radial topology	Network topology
Few sensors	Monitors and sensors throughout
"Blind"	Self-monitoring
Manual restoration	Semi-automated restoration and eventually, self-healing
Prone to failures and blackouts	Adaptive protection and islanding
Check equipment manually	Check equipment remotely
Emergency decisions by committee and phone	Decision support systems, predictive reliability
Limited control over power flows	Pervasive control systems
Limited price information	Full price information
Few consumer choices	Many consumer choices

Smart Grid Network



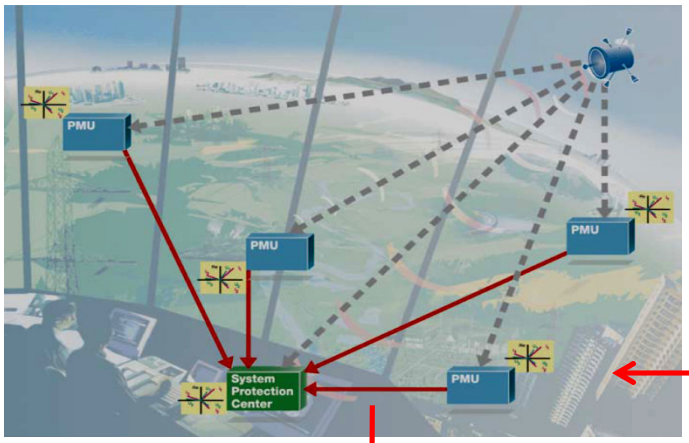
Smart Grid Network - Smart Home



- Smart Appliance Energy Management
- Smart Charger (PHEV) Storage

- Regulation Signal
- Price Signal
- Reliability
- Load Curtailment

Smart Grid Network – Grid Reliabiltiy



Synchrophasors
- Measuring voltages and currents
- Outputting accurately GPS time-stamped voltage and current phasors

1-2 years
- **Angle / Frequency Monitoring**
- **Disturbance Analysis**
- **Voltage Stability Analysis**

3-5 years
- **Improved State Estimation (Boundary conditions)**
- **Rapid Restoration**

The Future
- **Real-Time Control**
- **Early Cascade Detection**

Smart Grid Network
Alternative Generation / Demand Response

Generation

- Distributed Generation
- Asset Optimization
- Energy Services
- Renewables

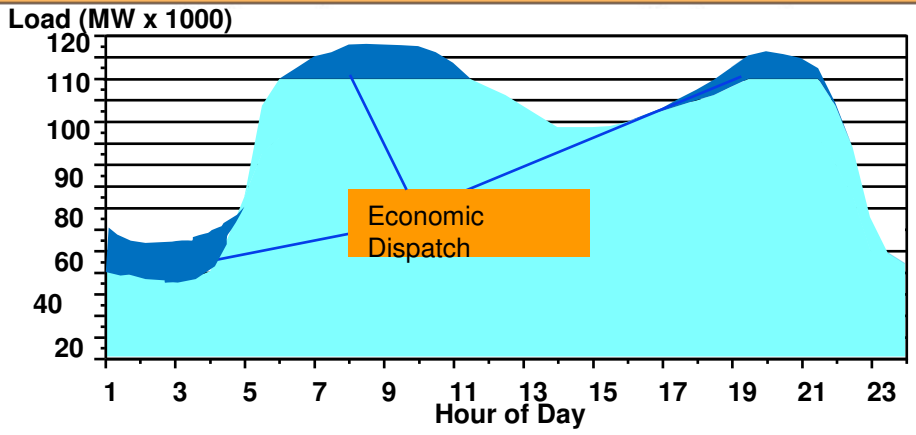
NETWORK ADAPTER

Smart Grid Network

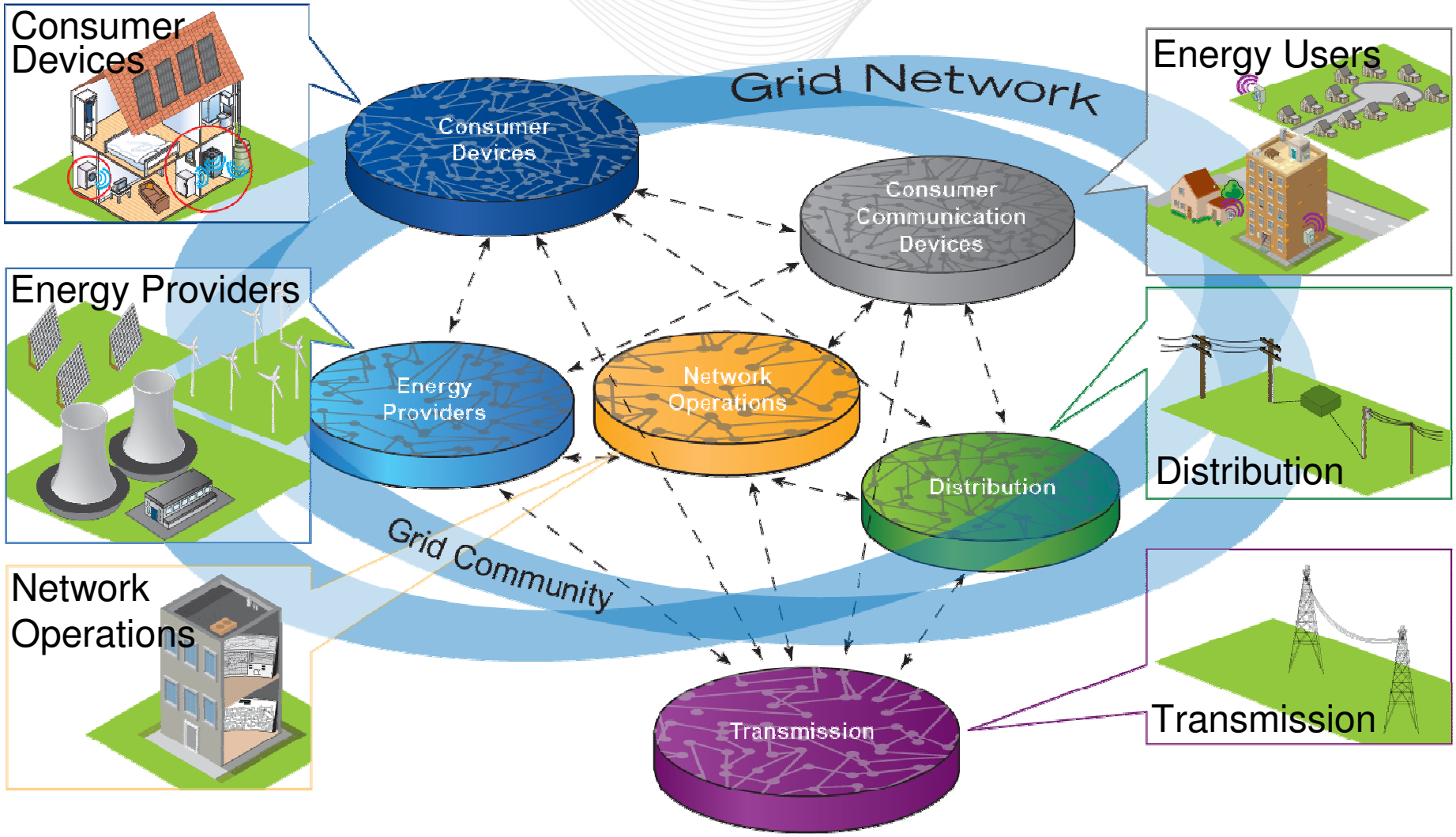
NETWORK ADAPTER

ISO/RTO

- Reliability
- Energy Markets
- System Planning

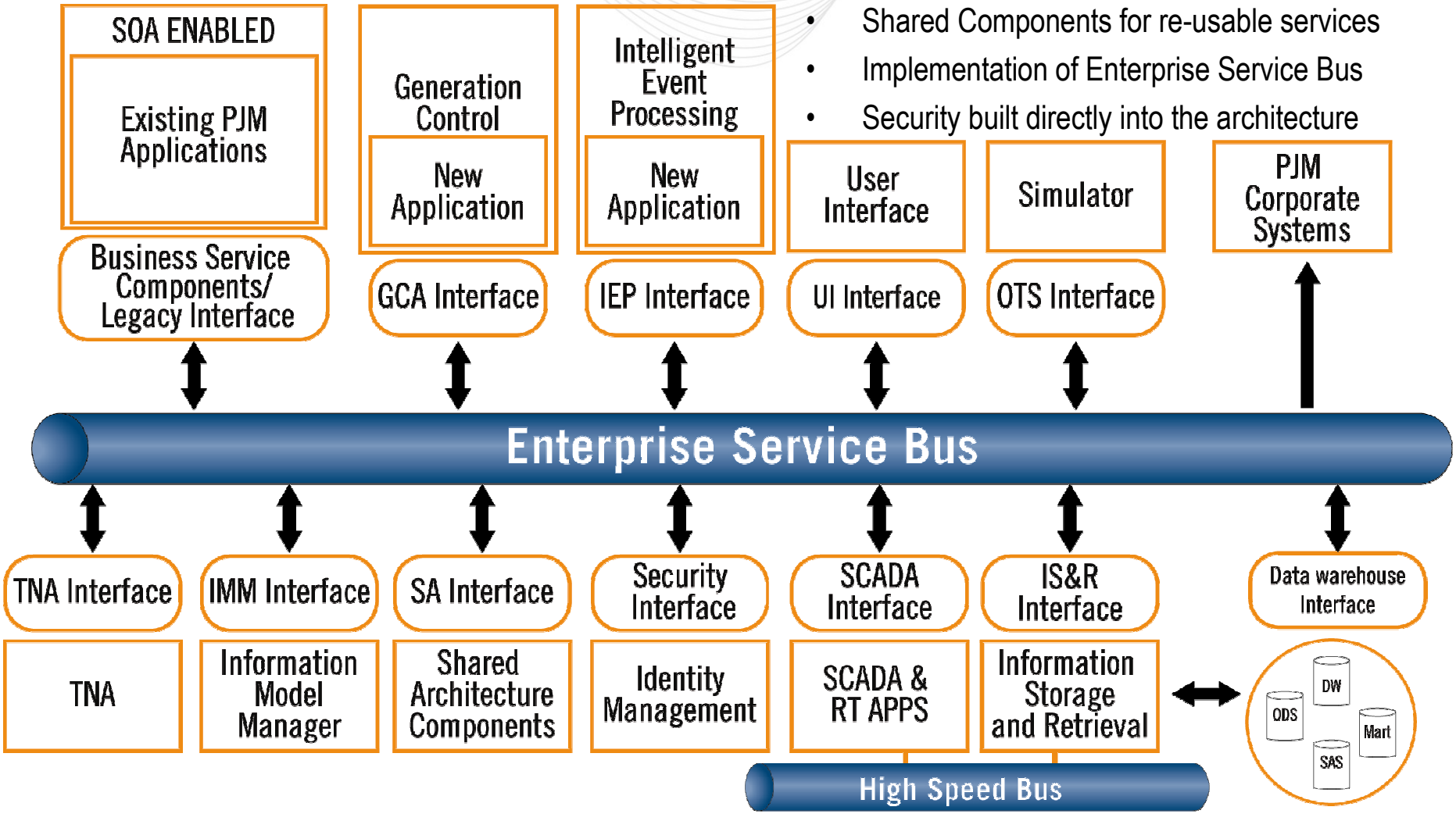


Smart Grid



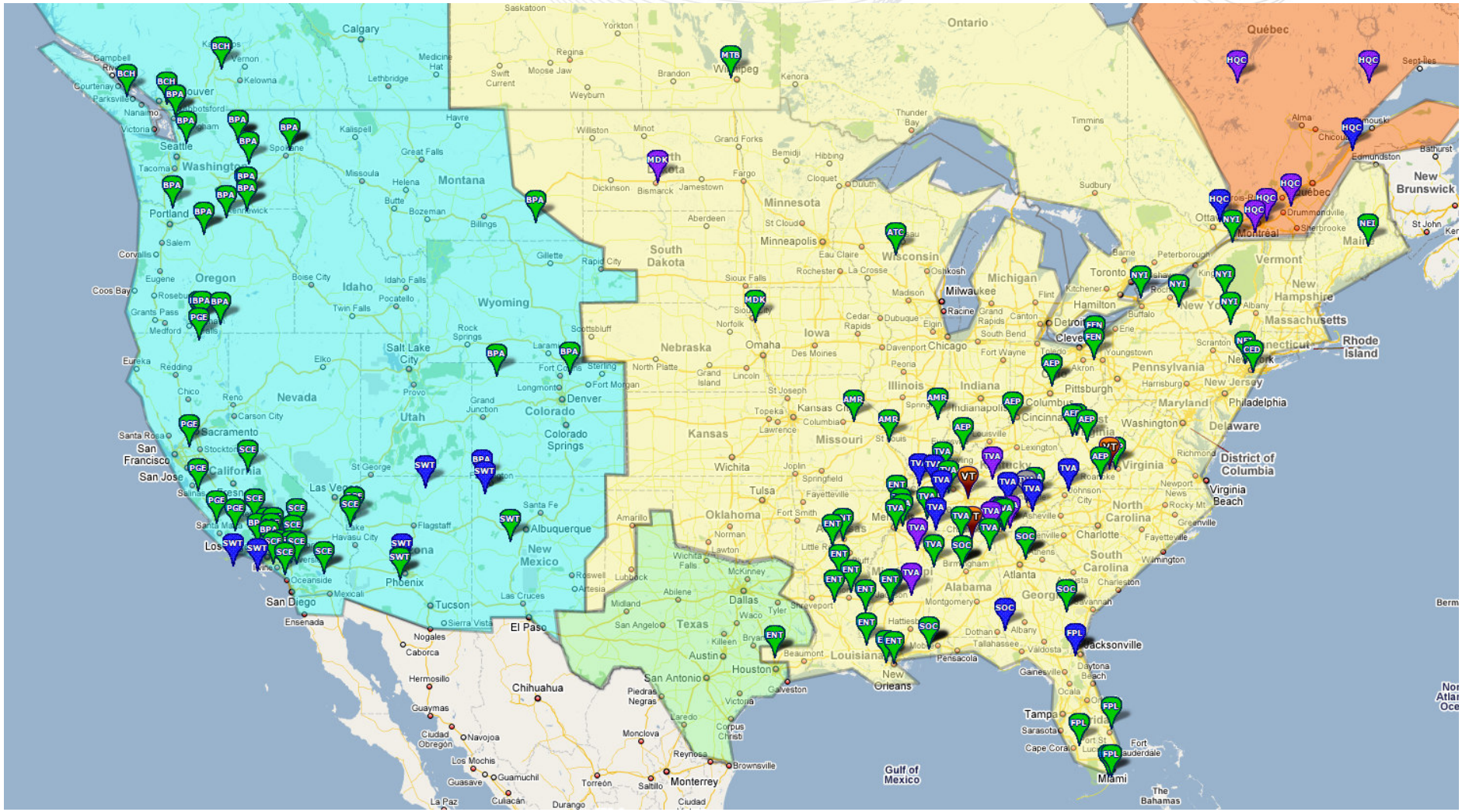
AC² Service Oriented Architecture

- Development of Industry standard messaging architecture
- Shared Components for re-usable services
- Implementation of Enterprise Service Bus
- Security built directly into the architecture

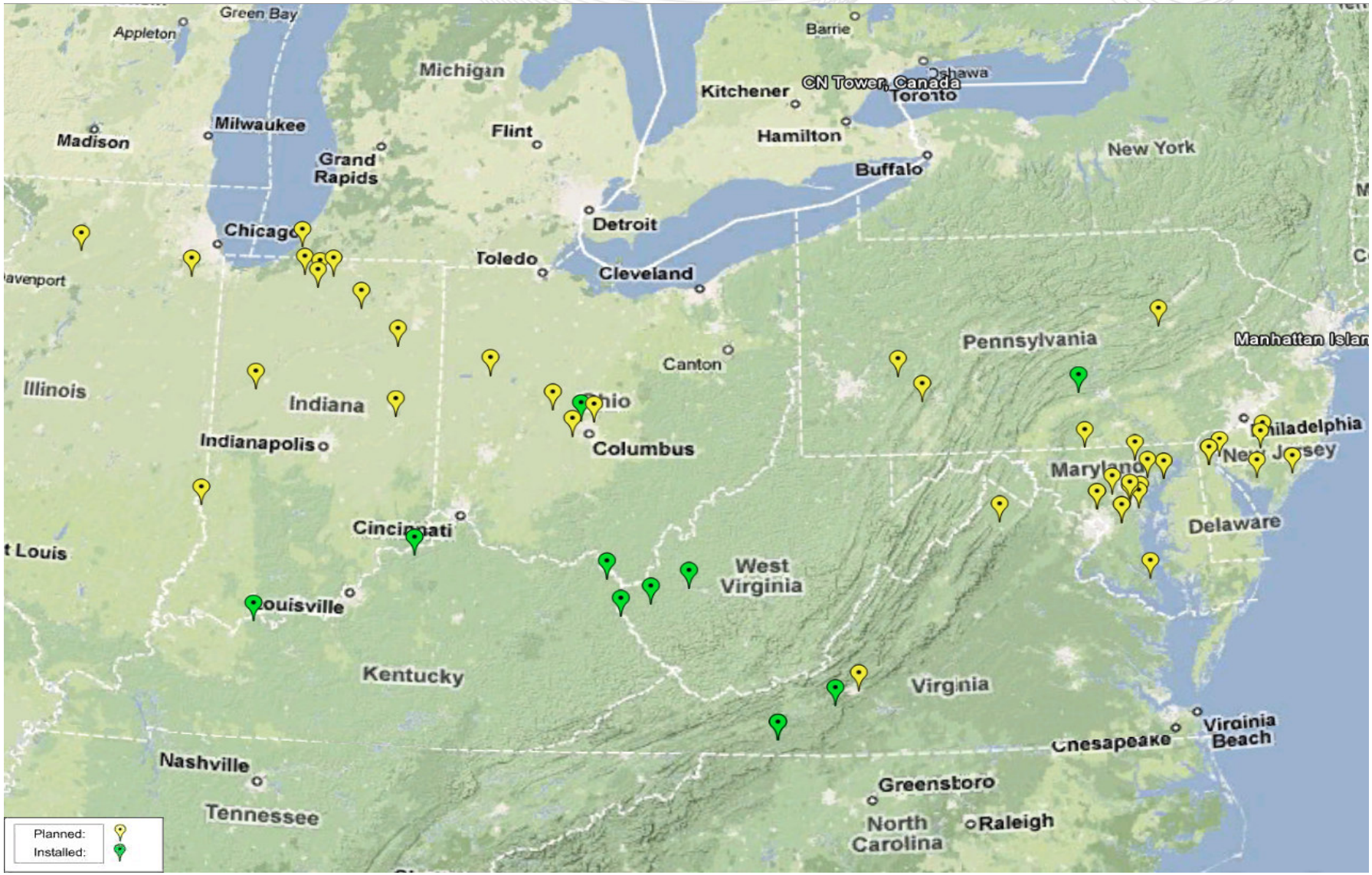


- Regional Transmission Expansion Planning Process (RTEPP)
- Transmission Owner Responsibilities / Siting
- Cost Allocation
- Integration of Economic Projects
- Inter-Regional Processes
- New Calls for Interconnection-wide Planning Agency

PMU Installations in USA



PMUs in PJM



Integrate SMART Grid/Price Responsive Demand

- Enable greater penetration of Price Responsive Demand through coordination with state retail tariff innovation and SMART Grid initiatives
- Develop real-time forecasting techniques to enable real-time recognition of Price Responsive Demand
- Develop real-time operational tools to enable real-time recognition of Price Responsive Demand
- Relationship between Price Responsive Demand development and Plug-in Hybrid Vehicle development.

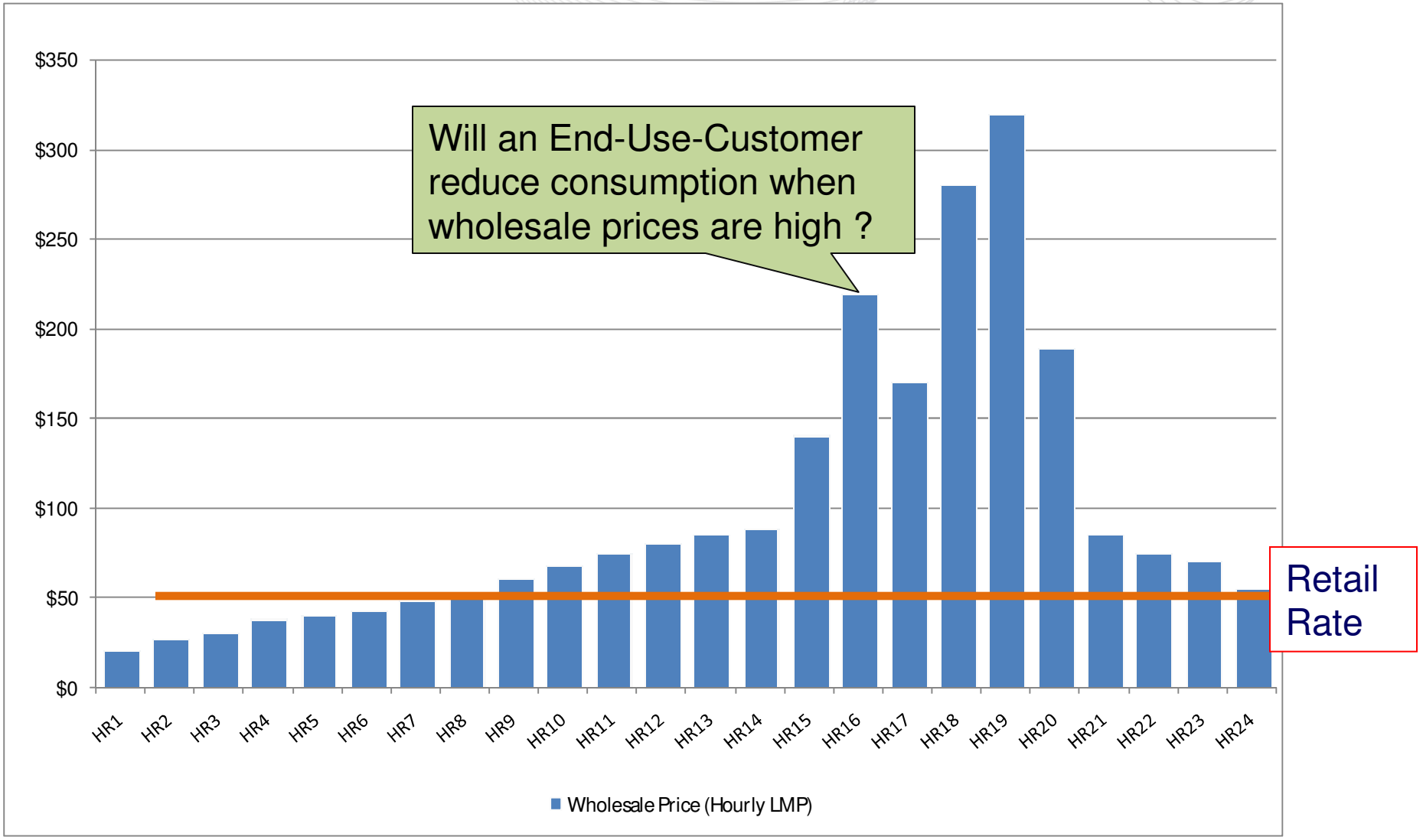
Price Responsive Demand - Characteristics

- Provide the opportunity for consumers, including residential and small commercial customers, to voluntarily reduce their consumption when prices rise in the regional wholesale electricity market
- Enabled through AMI and dynamic retail rate structures
- Aggregate response of many small customers
- Not directly dispatchable, but response to price can be measured and deployed through intelligent load forecast.
- Not necessarily offered as a resource into wholesale market, benefit achieved through reduction in energy use and capacity obligation

Price Responsive Demand - Requirements

- Dynamic or time-based retail rate
- Advanced Meter Infrastructure
- Wholesale / retail coordination in setting scarcity price /curtailment price triggers
- Develop intelligent load forecast in short term grid operations
- Recognize price responsive load forecast in transmission planning
- Recognize price responsive load reduction in capacity obligation

Wholesale vs. Retail Price?



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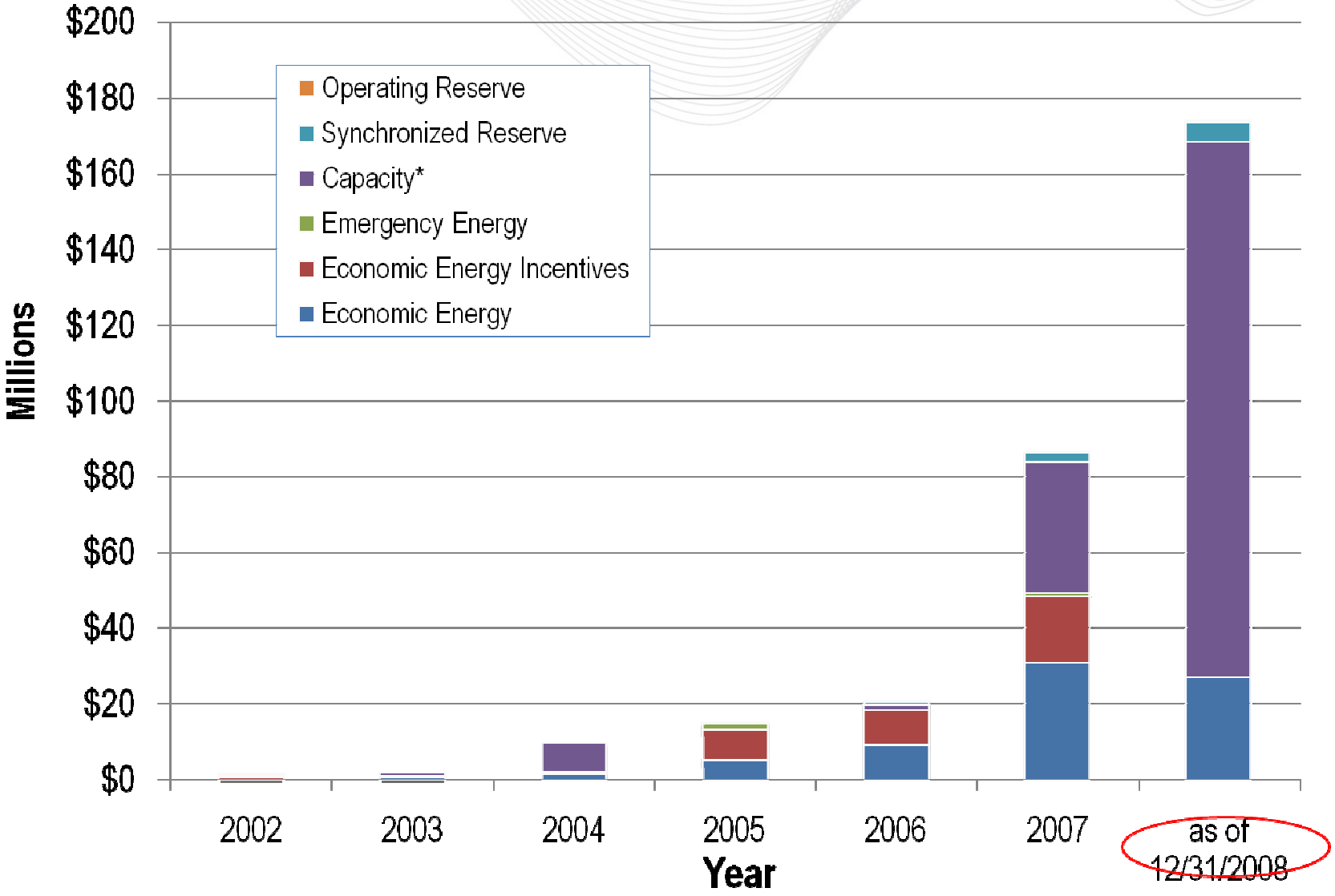
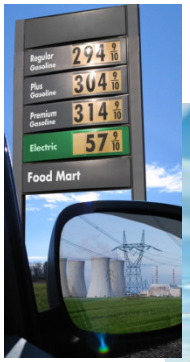
Demand Response Payments



Integrate SMART Grid with PHEVs



57¢ (PJM Off-peak Price)

~~75¢~~ per "Gallon"

- Develop Vehicle to grid / Plug-in hybrid electric vehicles (PHEVs) protocol
- Participate in Mid-Atlantic Grid Aware Car (MAGIC) consortium – electric companies, research institutes, and vehicle manufacturers
- Test storage batteries in regulation markets

- Enable greater penetration of PHEVs through coordination with state SMART Grid and retail tariff innovation initiatives
- Develop infrastructure to support non-traditional demand based regulation resources
- Develop operational tools and forecasting techniques to enable PHEV deployment

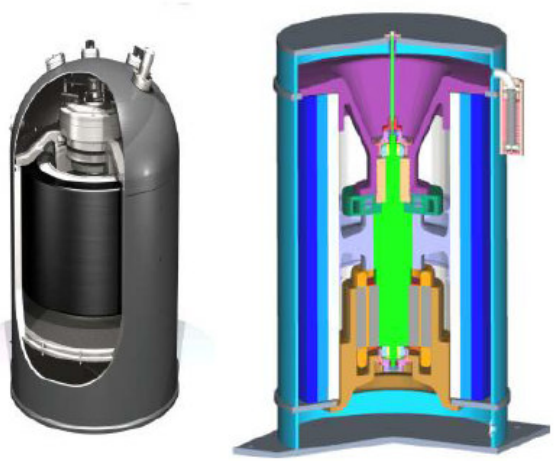
AES grid-scale energy storage system

Operational Details

- Power: 1 MW for 15 minutes
- Energy: 300 kWh
- Efficiency: 90% round trip

Attributes

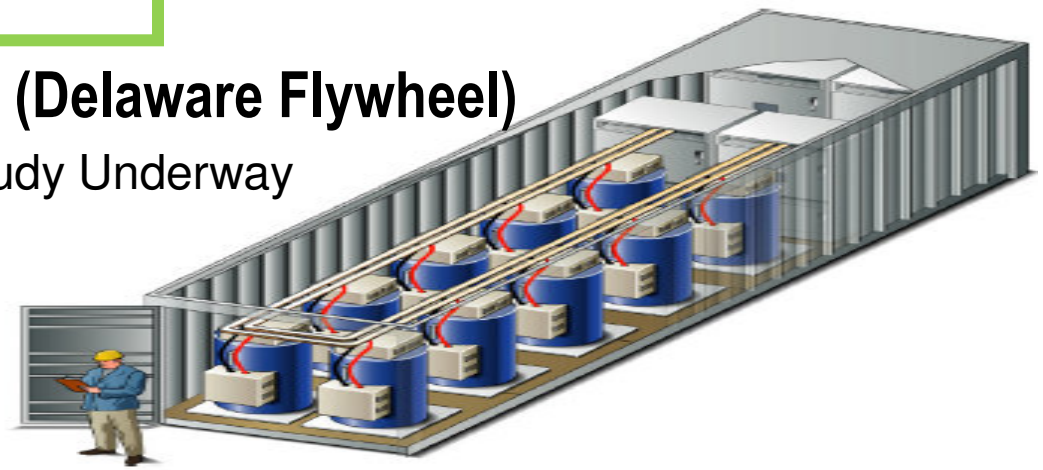
- Life expectancy ~20 years
- No capacity decreases over life.
- No overcharge and over-discharge
- Rapid charging – minutes



Price of 1 MW System = $1,500 K
Return on Investment = 23%
(assumes average regulation price of $40/MWh)

Status in PJM Generation Queue (Delaware Flywheel)

– T187: Reybold 20 MW - Impact Study Underway

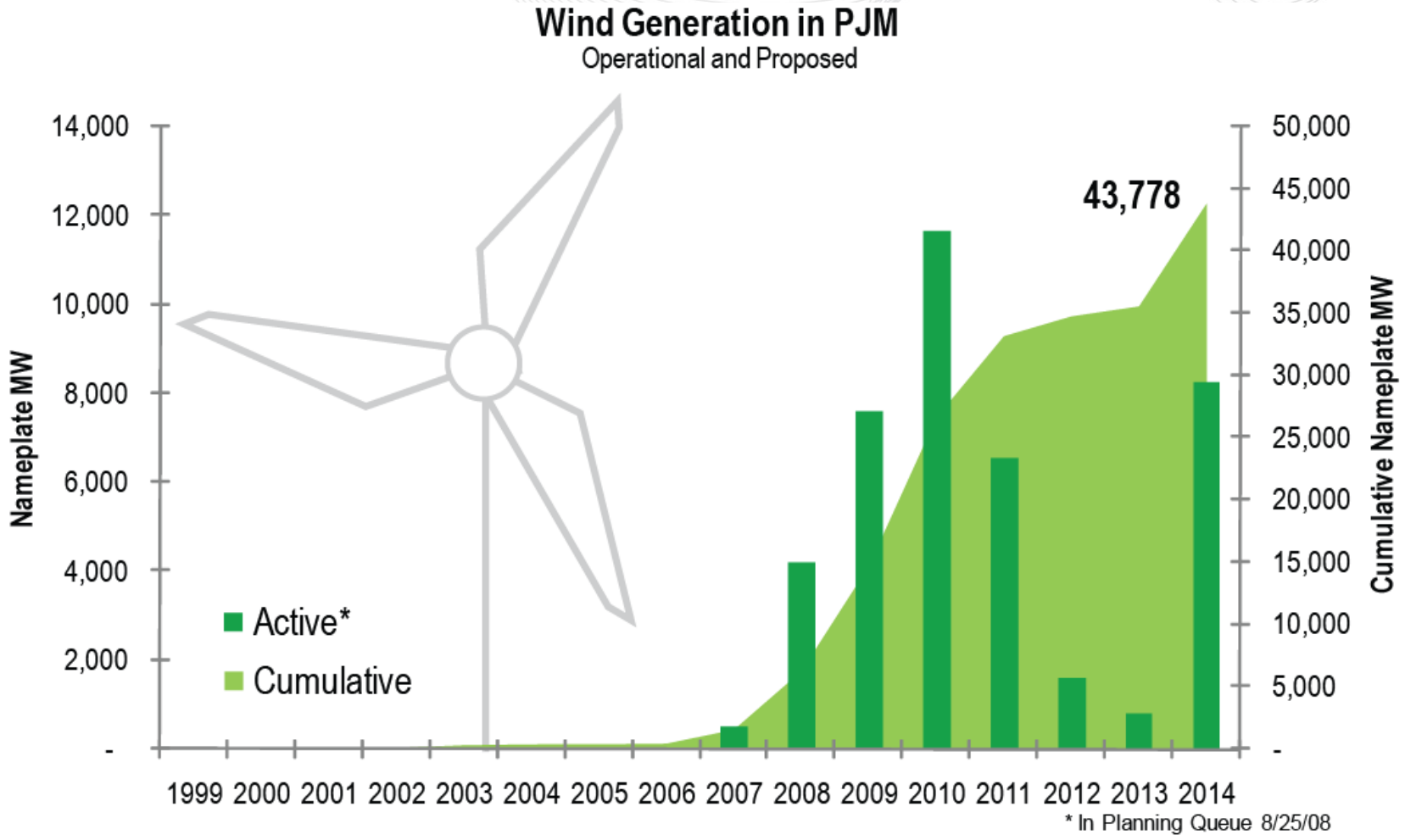


Energy Efficiency

- Provide opportunity for Energy Efficiency and Renewables supply resources
- Incorporate Energy Efficiency as a resource in capacity markets
- Develop measurement and verification standards to ensure reliable integration
- Obtain an agreement among States and FERC on the term of capacity payments

… Integrate Energy Efficiency into PJM Markets

Wind Generation in PJM Queue



In Conclusion: Smarter Grid

Technology….Two Way Communications….Intelligence

	Today	Future	Enabled by
Transmission	Monitor via State Estimation	Monitor via State Measurement	Synchrophasors
	Monitor local control area	Monitor wide area including neighbors	Communications and enhanced data exchange standards
Distribution	Traditional / Centralized Generation Mix	Distributed & Emerging Generation / Demand Response	Storage Technology MicroGrids Distribution Automation
	Traditional Residence	Smarter Home	Two-way communications Advanced Meter Infrastructure Smart PHEV Charging

Industry Will Move at the Speed of Value and Standards

Supporting the PJM members in their Smart Grid Activities

- Wind Generation
- Demand Response
- Pepco Holdings and Comverge --- MAGICC Vehicle-to-Grid
- AES Corporation --- 1 MW Battery
- Allegheny Power --- Consumer Household Pilot
- Vision Power Systems --- Flywheel
- Transmission Owners – Phasor Working Group

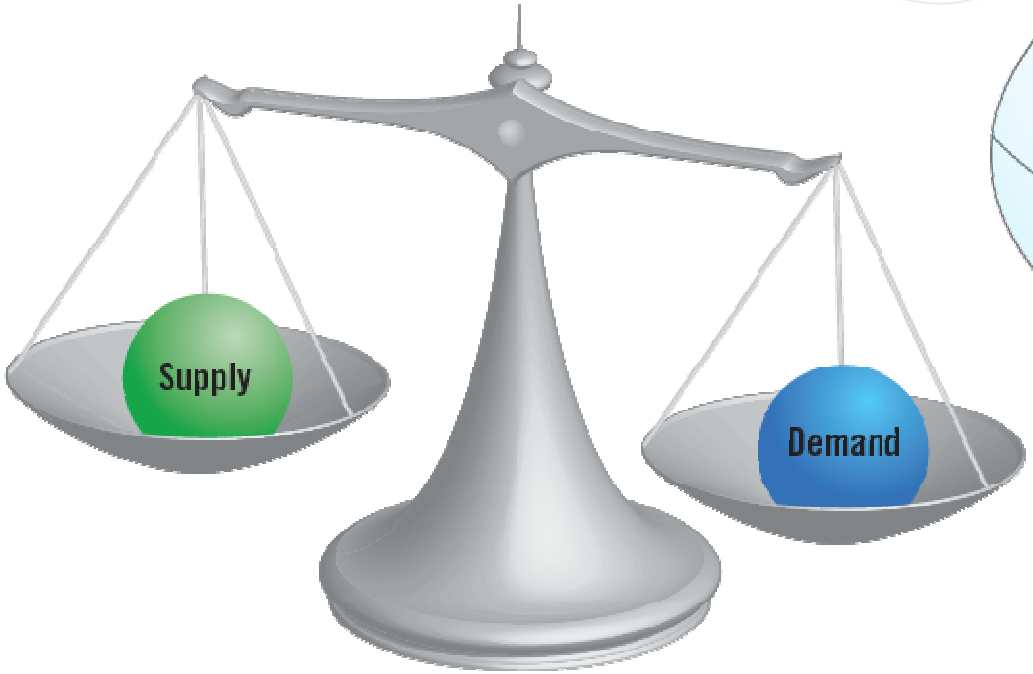
Why Do We Need Smart Grid?

To Avoid This !

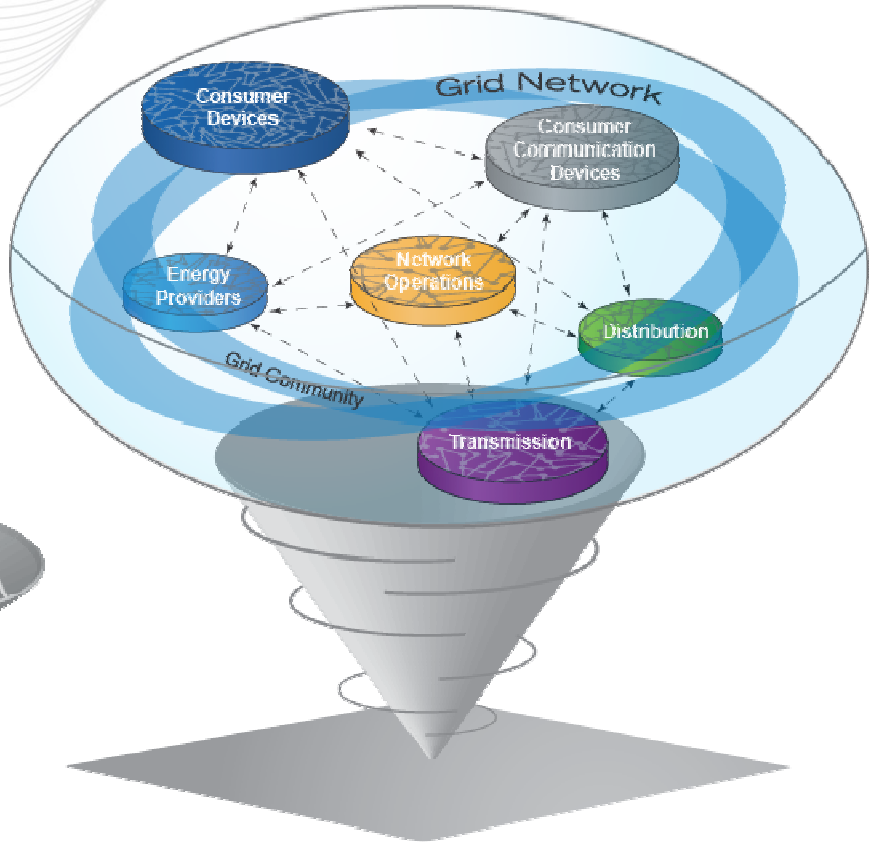
- Expand the Grid
- Smart Grid
- New Technologies
  - Storage/PHEV
  - Wide-Area View
  - Controllability/smart wires

We Can't Afford To Foreclose On any Option

Reliability is Maintained by Keeping Power in Balance



Reliability in
Historic Grid Operations



Reliability in
Future Grid Operations