



# The Evolution of the PJM Market in the United States: Looking Back to Look Forward

Feasibility Study for ASEAN Multilateral Power Trade  
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# The PJM Model...What Makes It Work?

## Topics

- History: Evolution, Progress and Pitfalls
- Industry Players
- Market Fundamentals
- IP and Physical Infrastructure Requirements
- Lessons Learned



## Topic One: PJM History, Evolution, Progress and Pitfalls

*Looking forward  
by looking back...*

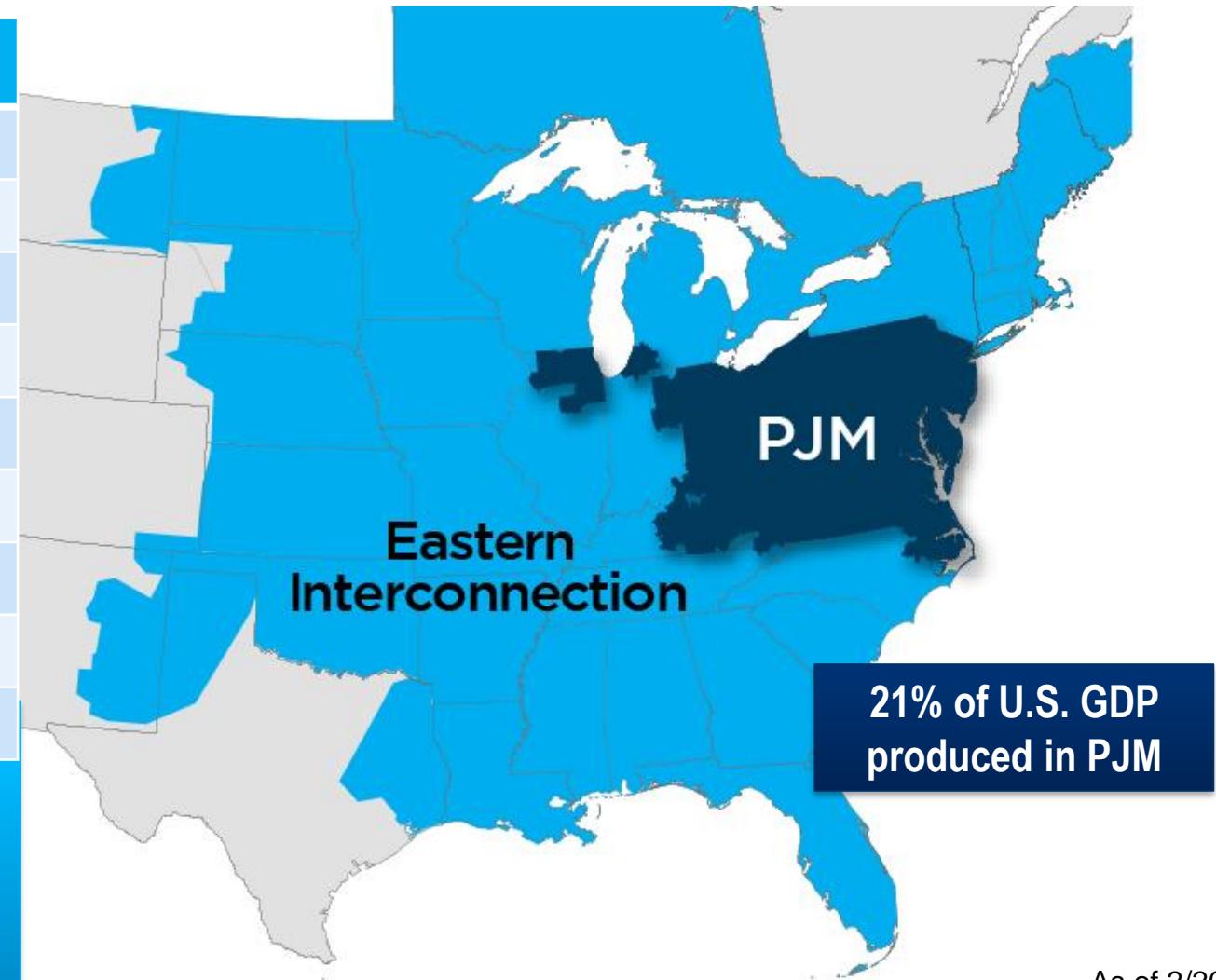


# PJM as Part of the Eastern Interconnection

## Key Statistics

Member companies	1,040+
Millions of people served	65
Peak load in megawatts	165,492
MW of generating capacity	178,563
Miles of transmission lines	84,042
2017 GWh of annual energy	773,522
Generation sources	1,379
Square miles of territory	243,417
States served	13 + DC

- 27% of generation in Eastern Interconnection
- 28% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection



As of 2/2018

# PJM Evolution

Joined in 1927

Joined in 1956

Joined in 1965

Joined in 1981

Joined in 2002

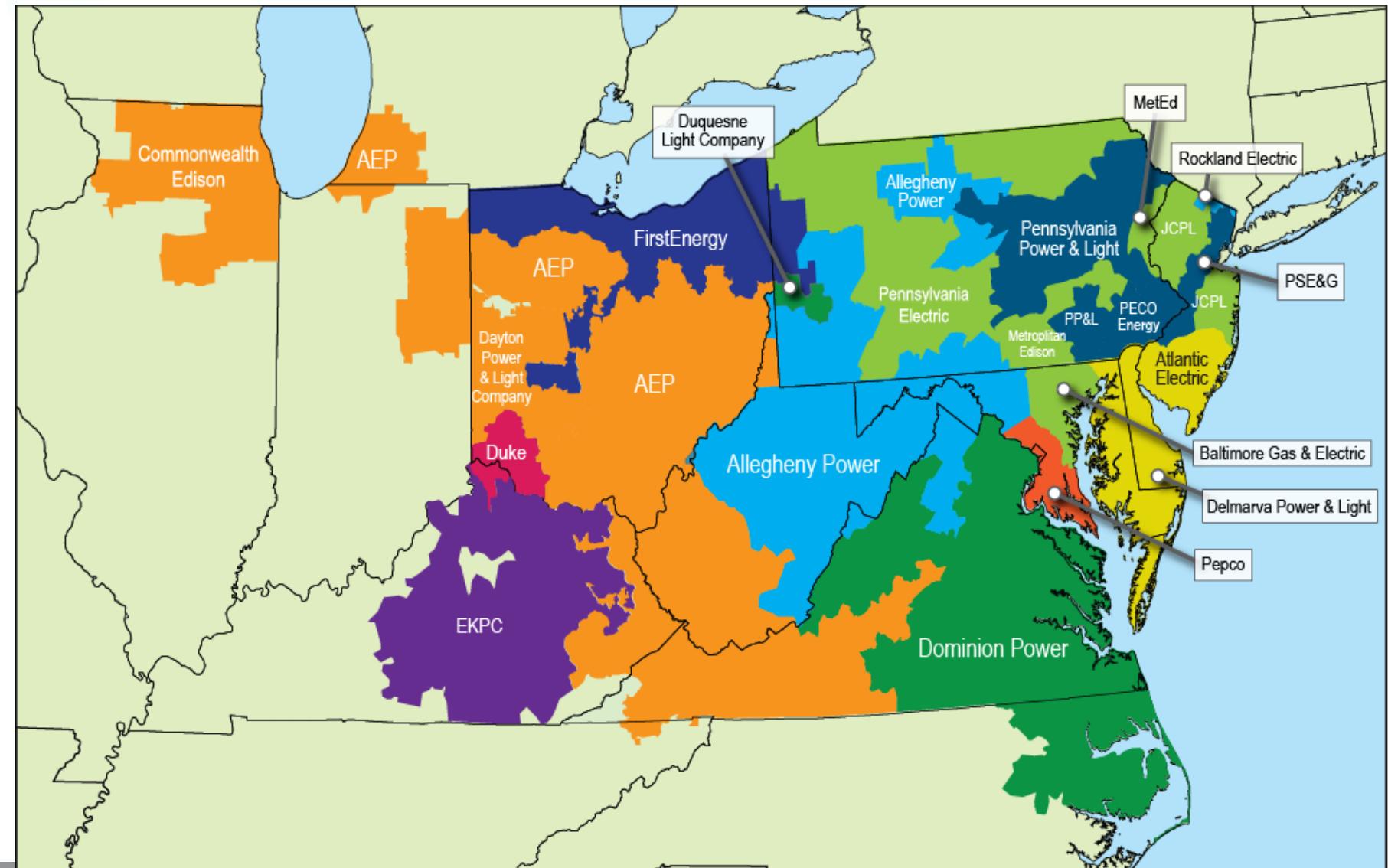
Joined in 2004

Joined in 2005

Joined in 2011

Joined in 2012

Joined in 2013



## PJM East and PJM West—Two Different Evolutions

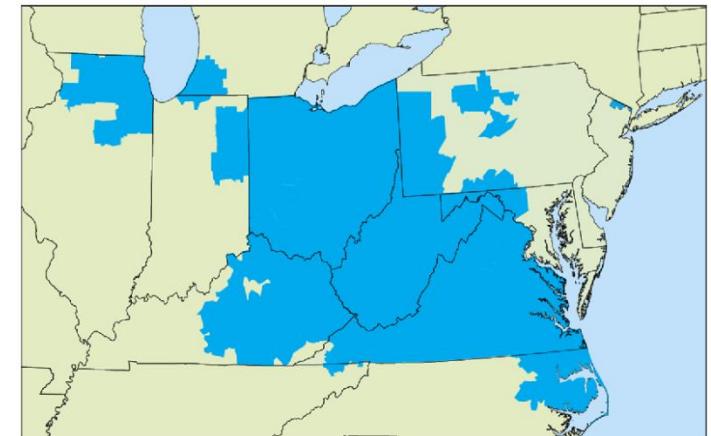
- 1. PJM West:** Vertically Integrated Utilities
  - Each utility plans and dispatches its own system
  - Trading only when opportunity arises/split the savings
  - Investment arrangements: Long-term contracts available but utility has obligation to build/procure
- 2. PJM East (Traditional PJM Region):**  
Power Pools for Sharing of Capacity and Single Dispatch

# A Look Back in History... PJM Western Region Evolution

## Original Model in the PJM Western Region:

Vertically Integrated Utilities with Limited Cross-Border Trading

- State regulator reviewed utility builds
  - Originally after-the fact prudence reviews 1970's to 1980's
  - Moved in the 1980's to integrated resource planning 1980's to 1990's
- Rate-making treatment required crediting to customers of percentage of off-system sales and timely recovery of purchased power costs
- Cross-border trades approved by federal regulator (FERC)



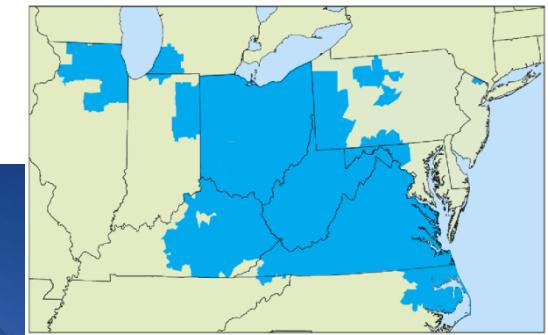
# A Look Back in History...PJM Western Region Evolution

## Advantages of the Model:

- Maintained individual state sovereignty over utility decisions
- Localized planning and expansion meant individual state needs

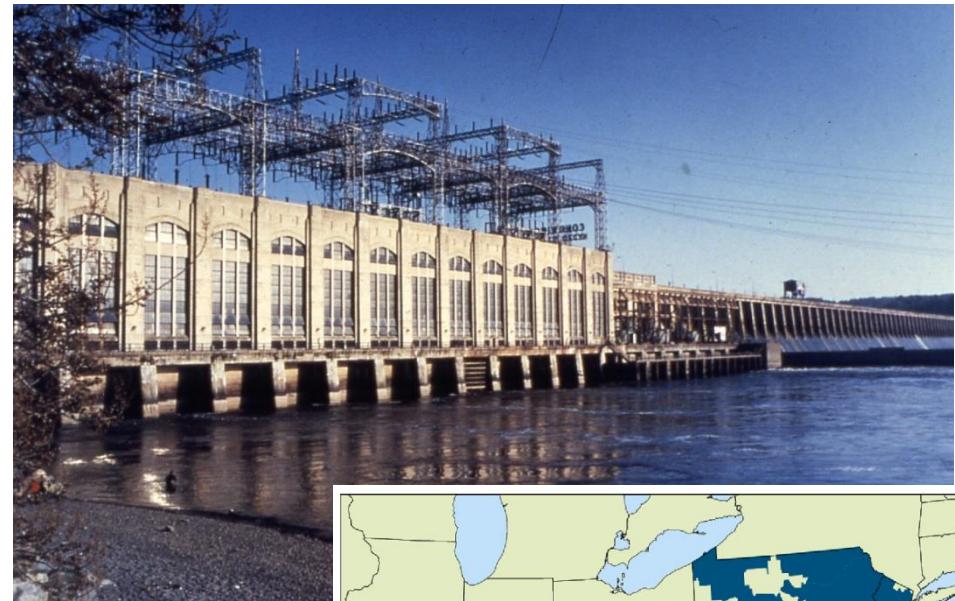
## Disadvantages of the Model:

- Costly, inefficient power plant and transmission development
- Burden on customers due to their having to pay full infrastructure build-out costs with limited recognition of offsetting benefits



## PJM Eastern Region: Power Pool Arrangement

- Utilities agree to share reserves from large hydro-electric project
- Cost sharing of transmission lines
- Single dispatch of the hydro plant as a whole so as to optimize dispatch with individual utility needs



# A Look Back in History...PJM Eastern Region Evolution

## Original Model in the PJM Eastern Region:

### Power Pool Arrangement (continued)

- Transmission and purchased power cost sharing agreement approved by the federal regulator
- Individual state regulators cannot change rates for interstate wholesale transactions but can question prudence of utility entering into individual transactions to meet their customer's demand
- Rates originally set at cost as determined by federal regulator



## Power Pools: Advantages

- Sharing of hydroelectric project and transmission build-out costs
- Single dispatch maximized use of each pool member's generation
- Transmission planning maximized transfer capabilities
- Smoothed out 'lumpy' investment
- Advantages of diversity of peaks/weather conditions and customer profile (agricultural vs. urban vs. government)
- Allowed each utility to meet its customer's needs at least cost



## Power Pools: Disadvantages

- Structure was closed to IPPs
- Required agreements on new builds
- Challenges if each participant does not meet its obligations to the pool
- Degree of savings depended on each individual utilities' resource choices—potential for cost shifting within the region
- Large customers bore costs of subsidies to agriculture, government or residential customers



## The 1980s: History Fast Forward

- Cracks in the regulatory framework cause review of the traditional model
- Worldwide demands for new capital bring into question the government-owned model



# **Major Changes in PJM:**

## Introduction of Wholesale and Retail Competition: 1990's



- Market participants (utilities, customers) came forward under pressure from state and federal regulators to open the power pool single dispatch to competition
- Creation of a real-time market: 1998
- Regulator finds market model the basis to move away from regulated cost-of-service rates and depend on the market to discipline prices.

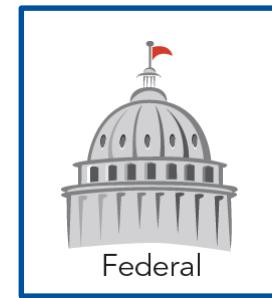


# Development of PJM Markets – Drivers

1996

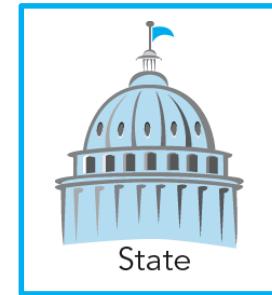
1998-Present

Future Outlook



## FERC Landmark Orders 888/889

- Promote wholesale competition
- Transmission open access
- Functional Separation of generation/marketing from transmission
- Mandated unbundling of electric services



## Retail Competition starting in several States (PA, NJ, MD, DE)

- Wholesale competition necessary to support effective retail competition



Initial mandate was to provide a platform for wholesale energy trading that also supported open access to transmission system

## Topic 2: Who Participates in the Market?



- **Self Supply**
  - Load serving entities that own generation assets to serve their load
- **Vertically Integrated Utilities**
  - Typically incumbents that own and operate assets through the entire supply chain
- **Independent Power Producers (IPP)**
- **Demand Response and Energy Efficiency**
  - Curtailment Service Providers
- **Financial Players**
  - Use Financial Transmission Rights (FTRs) or virtual bids to provide market liquidity

# Topic 3:

## How Did the PJM Market Evolve?

### Early attempts and reforms along the way...





Initially a ‘simple’ pricing mechanism (single zone) and trading rules to promote bilateral trading

- Minimized interaction between market incentives and physical power system operation
- Result was market failure – generators were incented to act in a manner contrary to system reliability
- PJM had to initiate emergency procedures to direct generation reductions

Market design was abandoned and replaced with flow-based Locational Marginal Pricing (LMP) system on April 1, 1998.

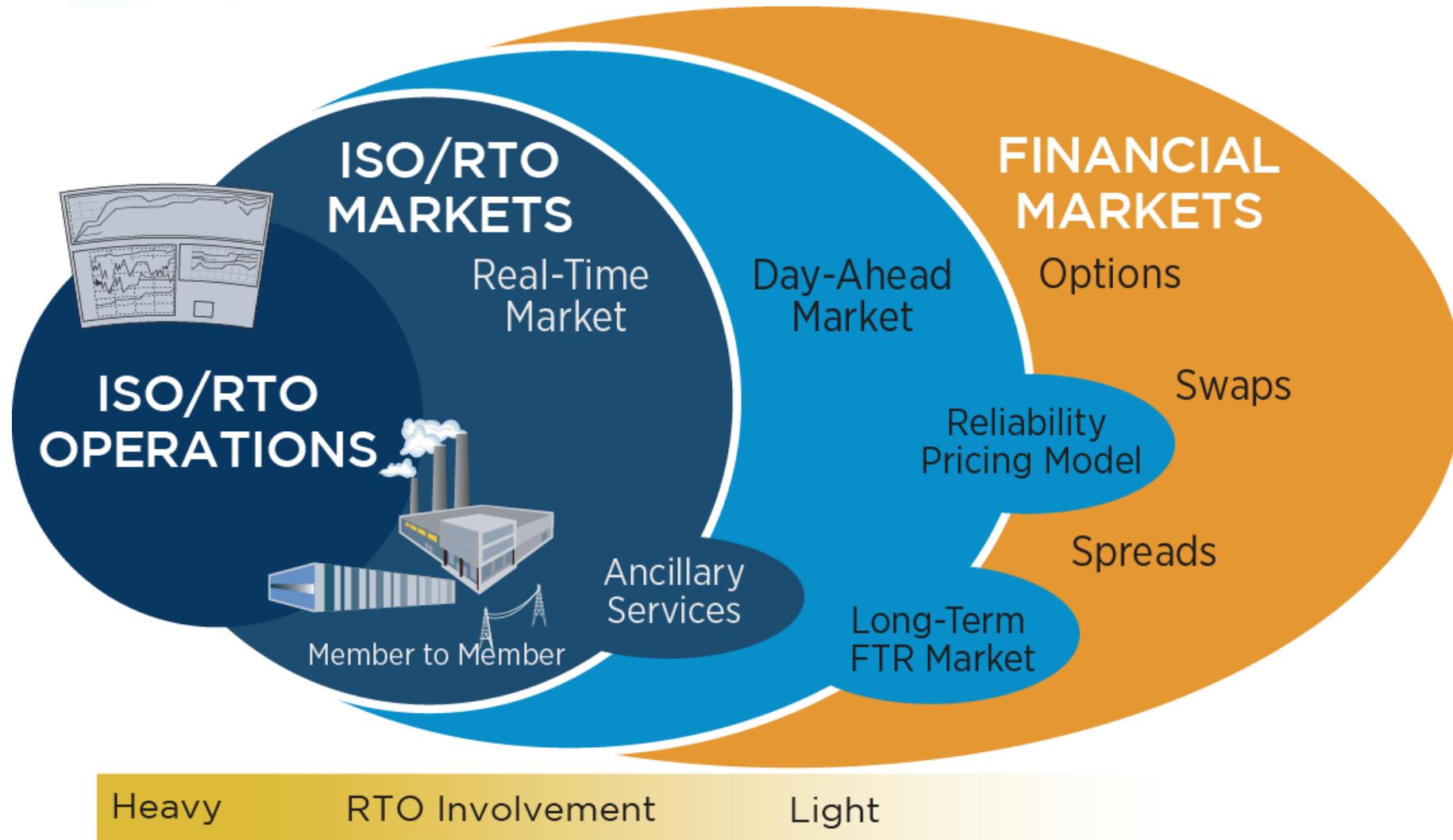
1996

**1998-Present****Future Outlook**

Introduction, and progressive evolution, of:

- Real-time locational marginal pricing (LMP) market
- Day-ahead market
- Financial transmission rights (FTR) auctions
- Resource capacity market
- Ancillary services markets
- Coordinated regional transmission expansion planning
- Demand response/distributed resource programs

# Evolution of Markets



- **Day-Ahead Energy Market** (June 1, 2000)
- **Real-Time Energy Market** (April 1, 1997, April 1, 1998)
- **Capacity (January 1999) RPM** (June 2007)
- **Financial Transmission Rights** (June 1, 1999)
- **Ancillary Services Markets**
  - Regulation (June 1, 2000)
  - Synchronized (Spinning) Reserve Market (December 1, 2002)
  - Day-Ahead Scheduling Reserve (June 2008)
  - Black Start Services (December 1, 2002)
  - Reactive Services

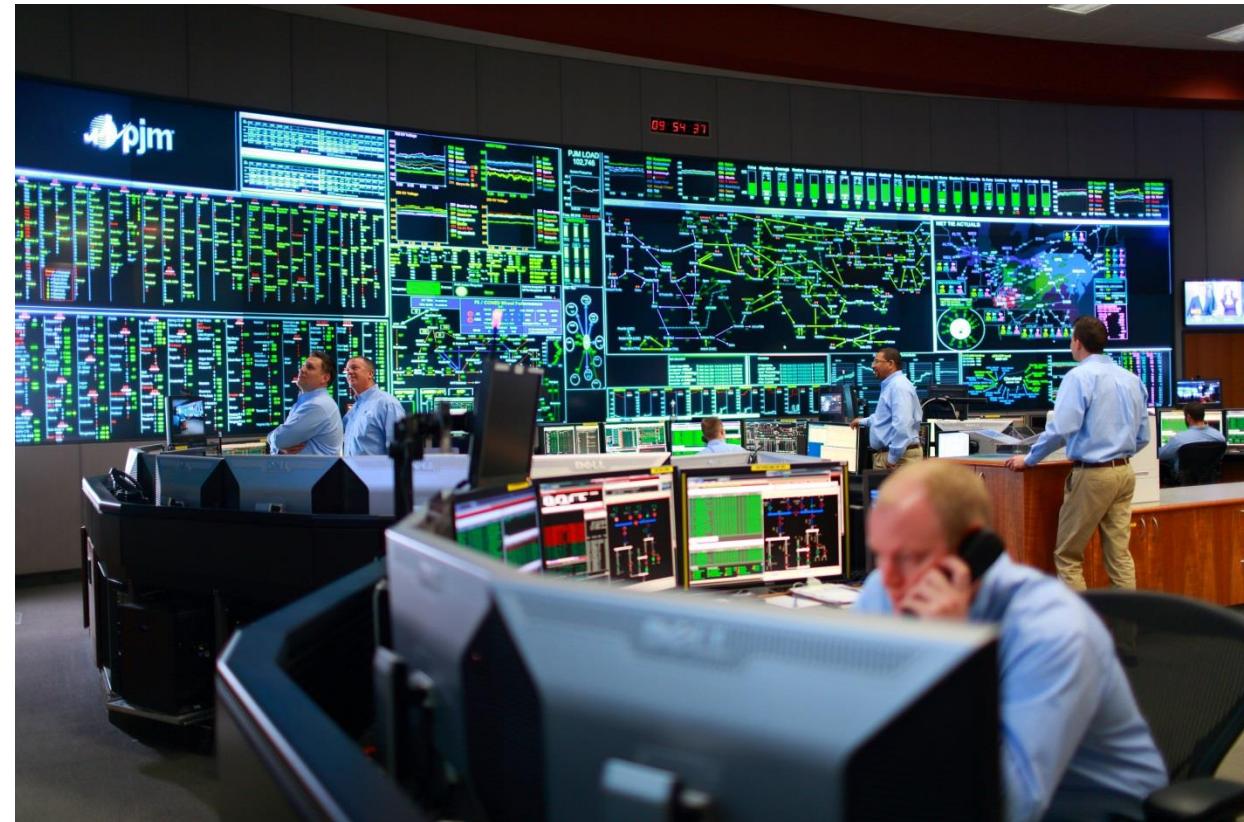
## Topic 4:

### Infrastructure Requirements

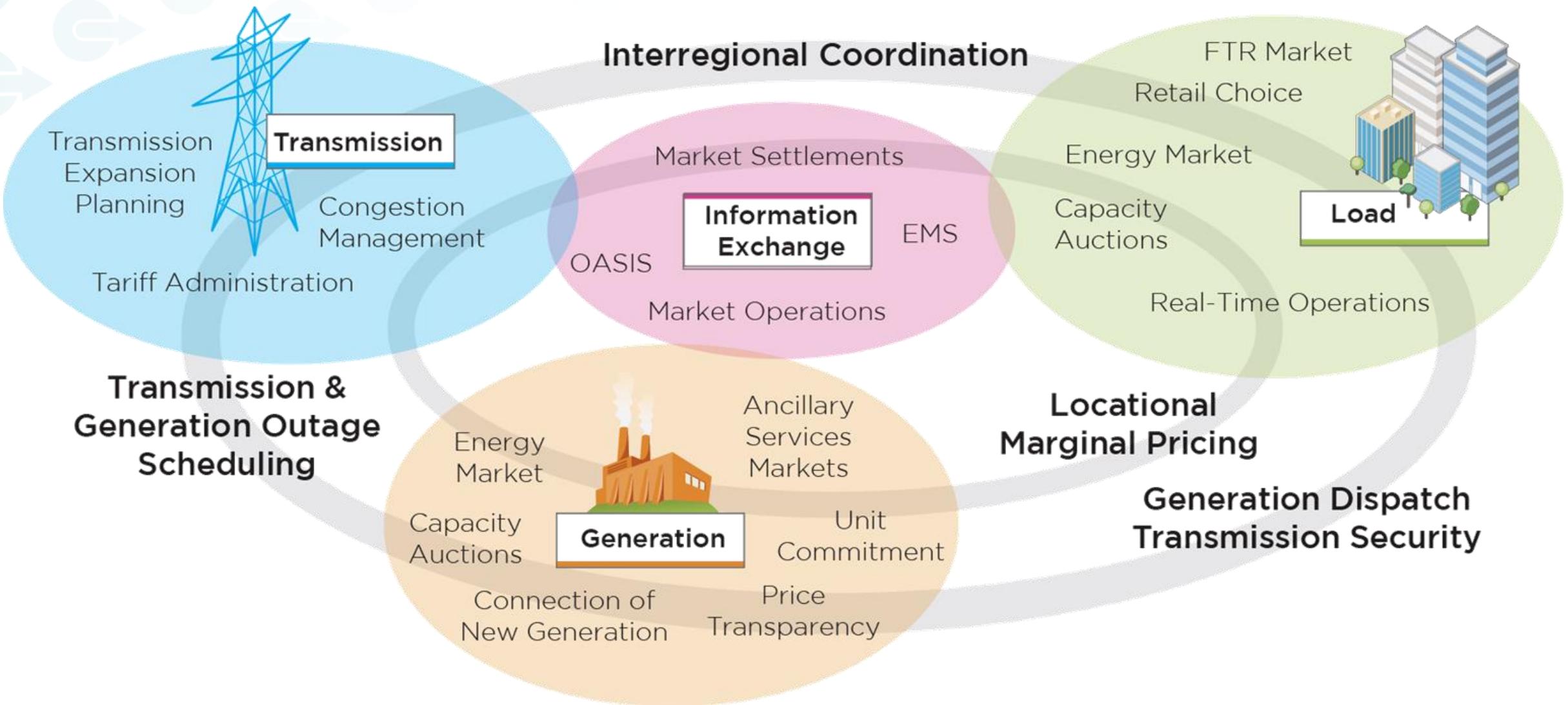
### Infrastructure Needed to Synchronize a Market with Dispatch

# Infrastructure Requirements

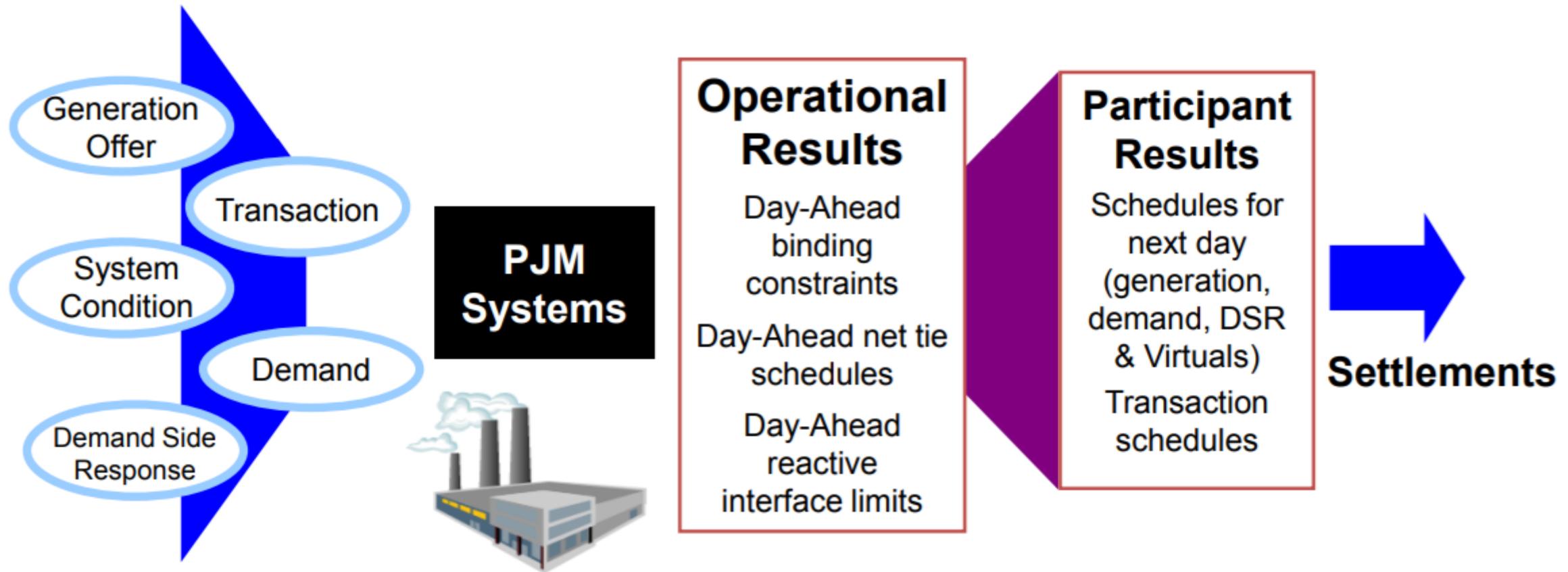
- All members required to provide and receive data to and from PJM
  - System Control and Monitoring
  - Billing (Accumulator data)
- Metering must meet ANSI and higher standards depending on application
- Data Provided over Inter-Control Center Communications Protocol (ICCP) or Distributed Network Protocol (DNP)



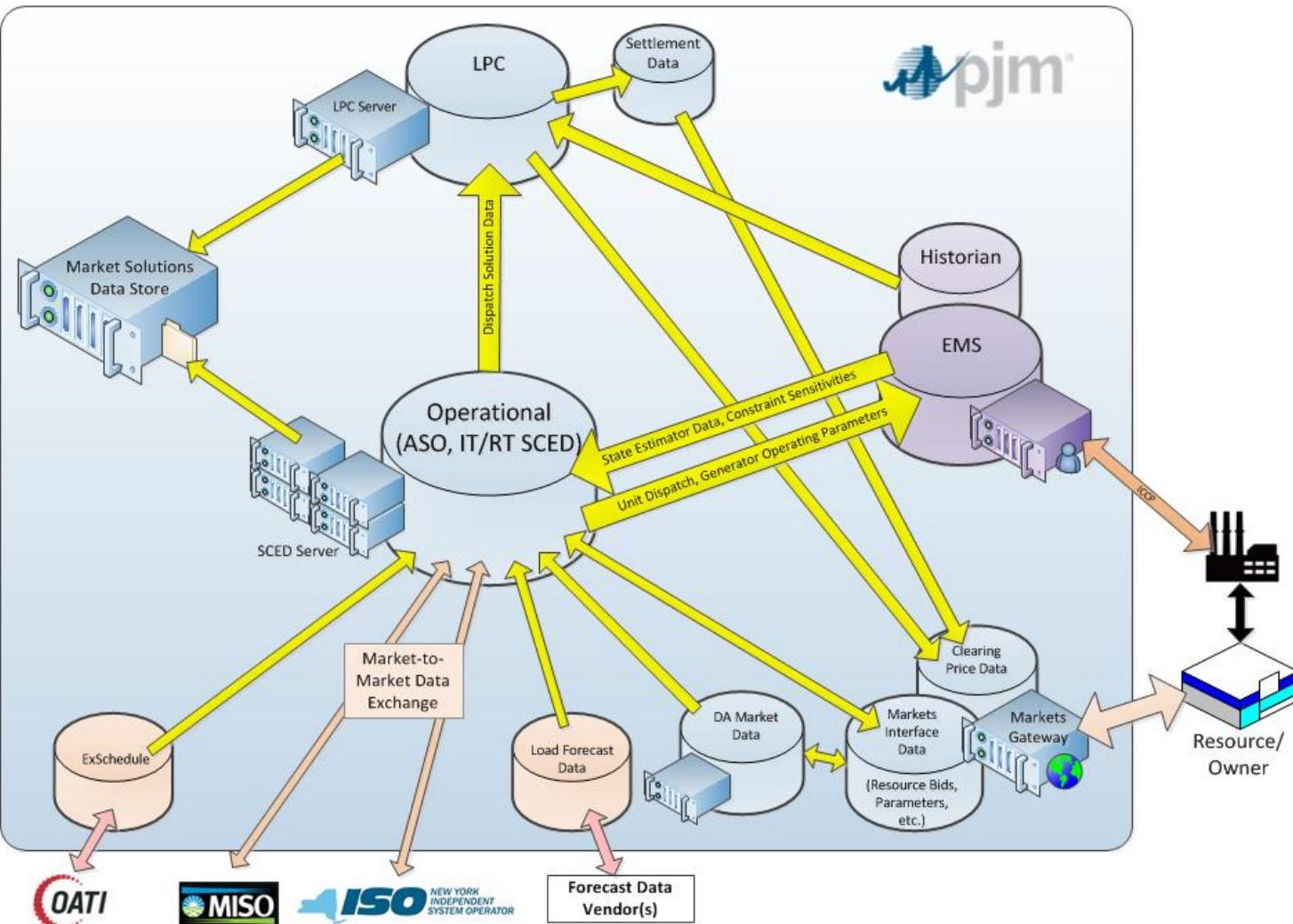
# RTO Operation



# Day-Ahead Energy Market Information Flow



# Real-Time Operations and Markets Functionality



- X % of scheduling determined in the Day Ahead Market
- Real-time system operations and markets work hand in hand to ensure reliability in the most efficient manner possible
- Market prices are calculated on a nodal (locational) basis for each 5-minute interval.
- Corresponding generation dispatch signals are sent back to resource owners.

## Topic 5: Lessons Learned...

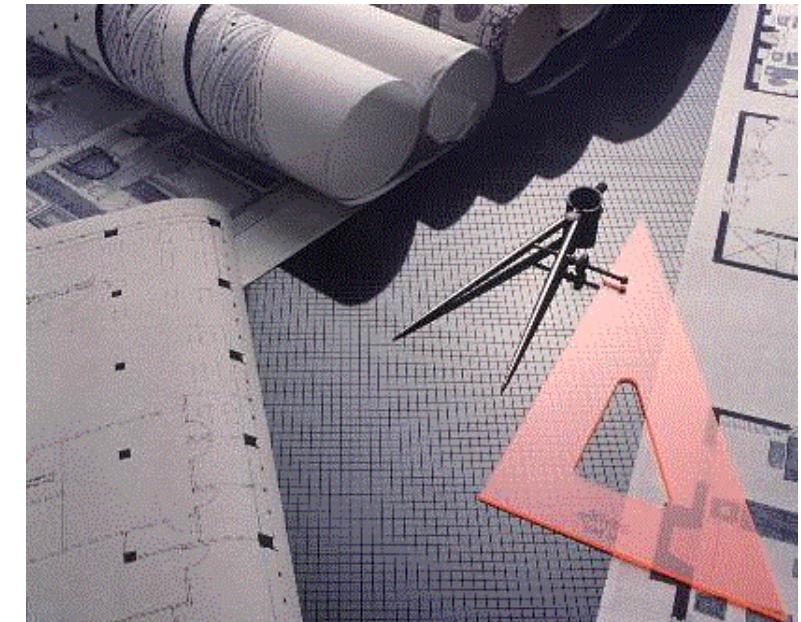


## **Market establishment is a complex challenge, with high stakes**

Electricity market establishment programs are large, high-profile, multi-disciplinary undertakings, critical to the overall market reform agenda.

## **Scope is a moving target**

Often processes are being defined, and systems specified, while the market design and rules are still being finalised. This is a frequently unavoidable reality, that must be carefully managed.



## **Capability involves more than just systems**

Establishing the market involves not just complex IT, but significant organizational change and process development.

## Provide a soft landing

Where participants are unfamiliar with market constructs, they face substantial commercial risk at market opening. Constructs such as ‘vesting’ contracts are essential in managing this

## Lack of participant readiness is a frequent cause of market delay

It is essential to involve participants early in the market establishment process, and frequently assess their readiness to ensure they are commercially prepared:

- Provide extensive training and certification
- Track ongoing readiness
- Conduct Market Simulations and Market Trials prior to go-live





# LET'S TALK...



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## Technical Appendix

- Topic 1: “A Day in the Life of the System Operator”
- Topic 2: PJM Governance Structure
- Topic 3: Technical Requirements on Market Participants
- Topic 4: Looking Back—Market Development in Hindsight
- Topic 5: Future Challenges

# Topic 1:

## A Review of Markets and Operations Today...

### *A Day in the Life of a System Operator...*



# Overall Market Timeline

## Long Term

Up to 4 years ahead | Hours Ahead

## Week Ahead

## Day Ahead

## Real Time (operating day)

Hours Ahead | Minutes Ahead

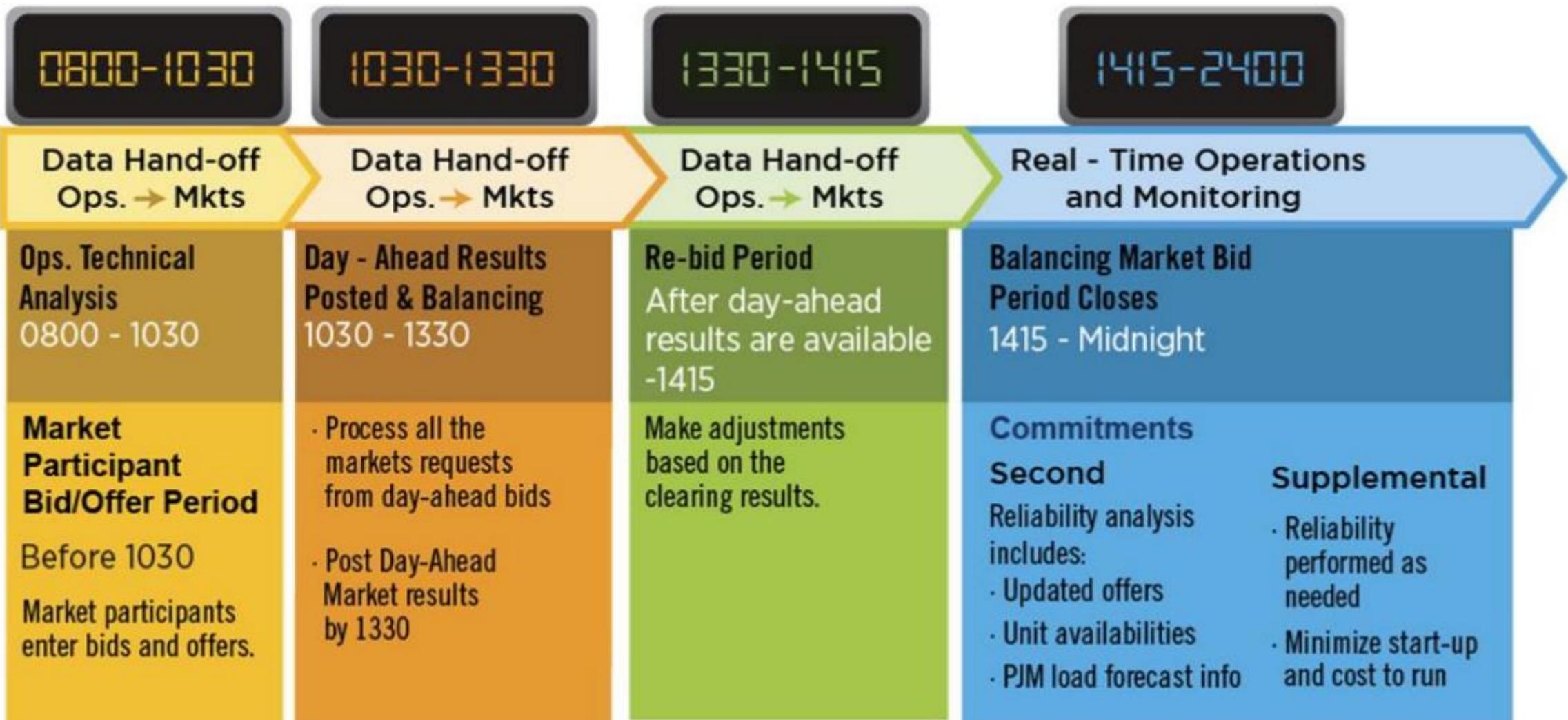
- Bilateral forward contracts/ over the counter
- Transmission reservations
  - ARR allocations
  - Annual FTR auctions
  - FTR secondary market
    - Monthly FTR auctions
  - Generation capacity market

- Outage analysis
- Load forecast
- Forward reliability analysis

- Day-ahead market
- Reliability analysis
- Unit commitment

- Near-term reliability analysis
- Real-time market
- Unit dispatch system
- Ancillary service markets

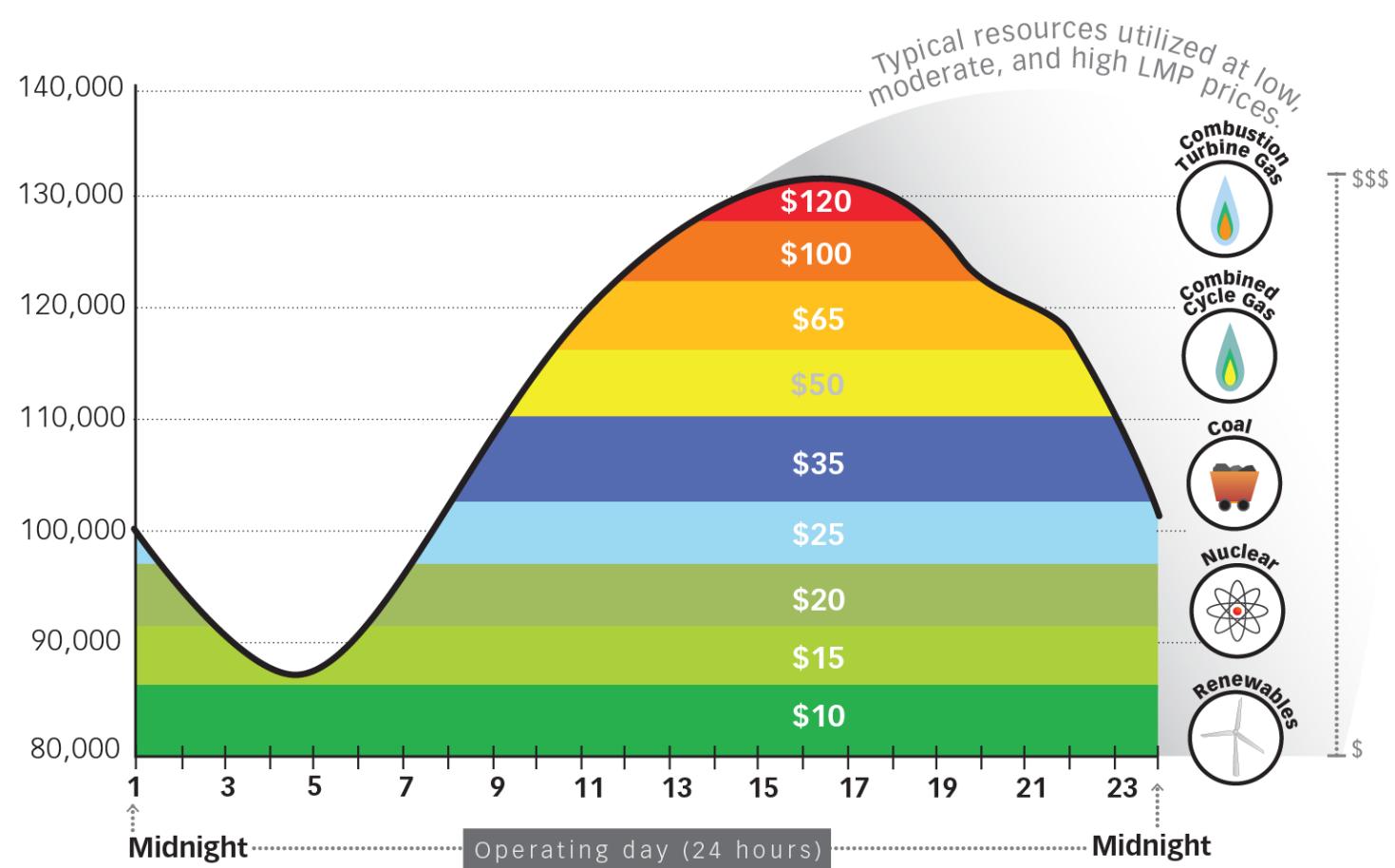
# Energy Market Cycle (Cont.)



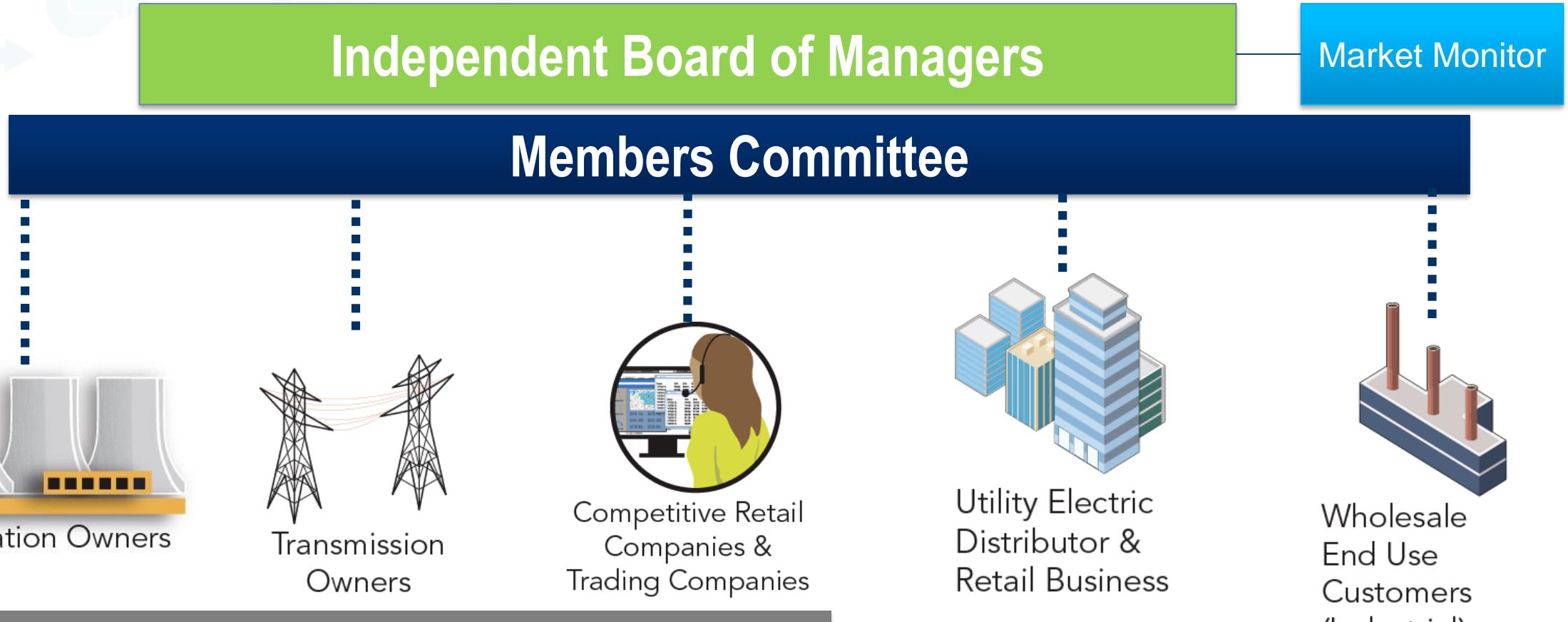
# Marginal Pricing

Almost all modern electricity markets utilize the concept of 'marginal pricing':

- Represents the cost of the last flexible increment of supply.
- All buyers pay, and all sellers are paid, the marginal price, regardless of their individual bids/offers.
- Typically determined through a periodic auction, with a price set for each trading period.







- Independent Board of Managers
- Stakeholder process – provide balanced stakeholder input
- Established process for discussion of market evolution
- ISO funding and startup

# Participating in PJM's Markets

PJM's business manuals clearly establish roles, responsibilities, and timelines for action

- Participants submit required information (bids and other information) ahead of the operating window through web based portals
- Lead time requirement for submission depends on the parameter and market product

The screenshot shows the PJM Markets Gateway web application. On the left, there is a sidebar with various menu items: Bilaterals, Demand, Demand Response, Generator, Interface Pricing, Opportunity Cost Calculator, Parameter Limits (which is currently selected and highlighted in red), Price Responsive Demand, Public, System Utilities, Up-To-Transaction, Virtual, and Weather Forecast. The main content area has a header with filters: Market Day (2/9/2016), Start Day (2/9/2016), End Day (2/10/2016), Portfolio (Western), Refresh, and Save buttons. Below the header is a table with columns: Participant, Request ID, Location, Min. MW, Max. MW, Min. Runtime Limit, Min. Downtime Limit, Max. Daily Starts Limit, Max. Weekly Starts Limit, Turn Down Ratio Limit, Request Type, Start Date, End Date, Justification, Status, and eDART Ticket Number. The 'Participant' column contains two buttons: 'Exception' (highlighted with a red box) and 'Approve'.

## Topic 3:

# Technical Requirements on Market Participants



# Unit Parameters in Markets Gateway

## Unit

- Unit Status
- Resource Type
- MW Operating Limits
- Ramp Rates
- Weather and Wind Forecasts
- Startup & No-Load Costs for **price-based units**

## Schedule

- Schedule Types and Selection
- Offer Curves
- MW Operating Limits
- Startup & No-Load Cost for **cost-based schedules**
- Startup/No-Load switch
- Startup and Notification times
- Min and Max Data
- Condenser Data

## Hourly Updates

- Commit Status
- MW Operating Limits

# Locational Marginal Pricing (Nodal Pricing)

- Spot market with flow-based pricing at individual transmission buses (nodes), based on actual power system security constraints.
- Implemented via security-constrained economic dispatch (Real Time) and security-constrained unit commitment (Day Ahead).

**LMP: A method to price energy purchases and sales**

- Generators get paid at generation bus LMP
- Loads pay at load bus LMP
- Transactions pay differential between source and sink LMP

## LMP Timeline

**LMP** =  
Locational Marginal Pricing



**1998:** Used in Real-Time Energy Market

**2000:** Implemented Day-Ahead Energy Market

**2012:** Shortage Pricing

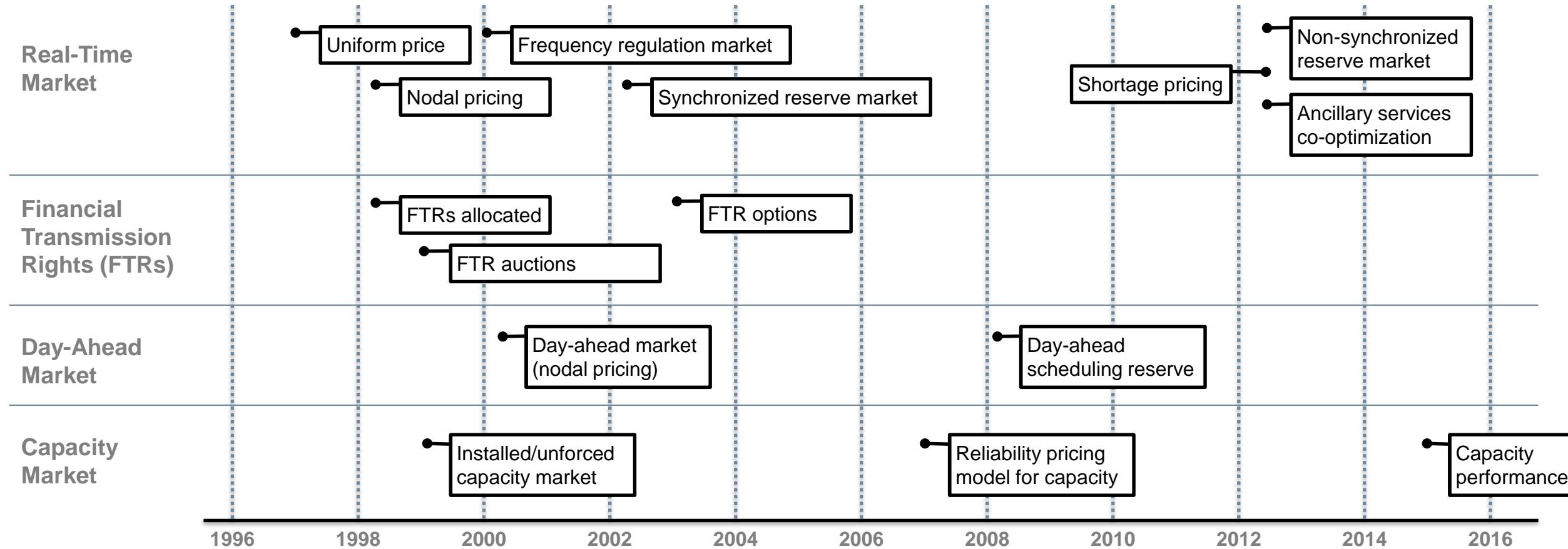
## Topic 4:

### Looking Back—Market Development in Hindsight



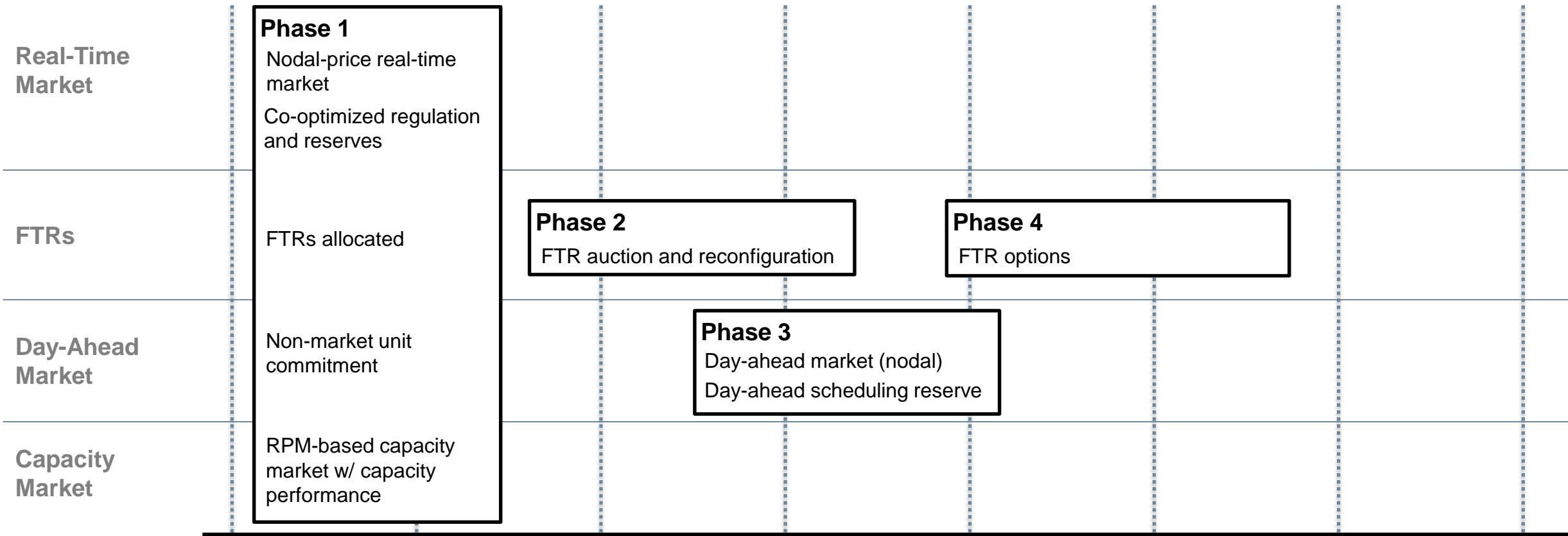
# Incremental Market Development

PJM's markets have developed in an evolutionary fashion, rather than a "big bang" – a deliberate risk management strategy.



# Incremental Market Development – in Perfect Hindsight

With perfect hindsight, and the technology now available, we would still implement incrementally, but would probably group implementation activities as shown below.



## Topic 5: Future Challenges in PJM...



## Challenges

- Integrations
- Coordinating Loop Flow
- Co-optimization of Energy and ancillary services
- Gas/Electric Coordination
- Demand Response
- Capacity Product Quality
- Subsidies and Efficient Market Pricing
- Distributed Energy Resources





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