EMTP Training
Session 6
PJM Wholesale Electricity Markets

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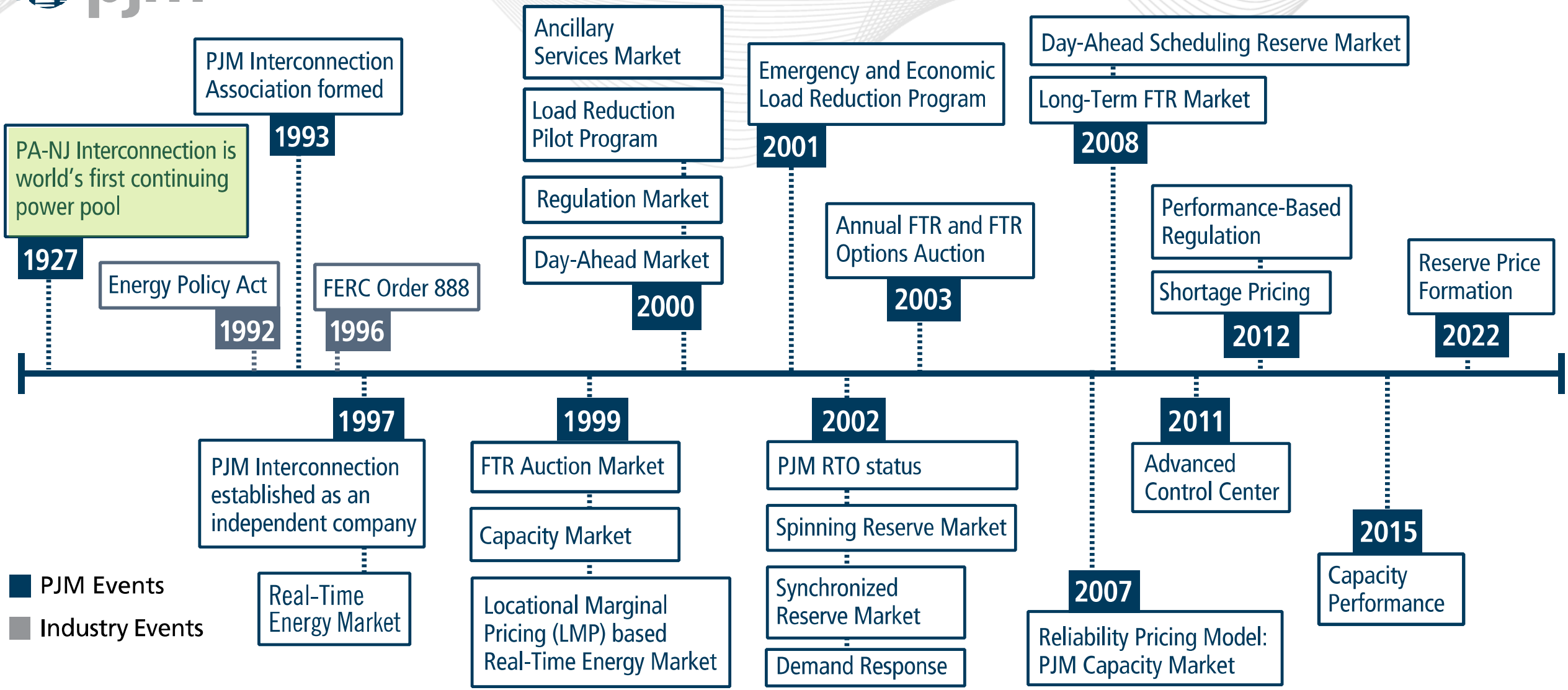
Evolution of PJM Markets



1920s PJM

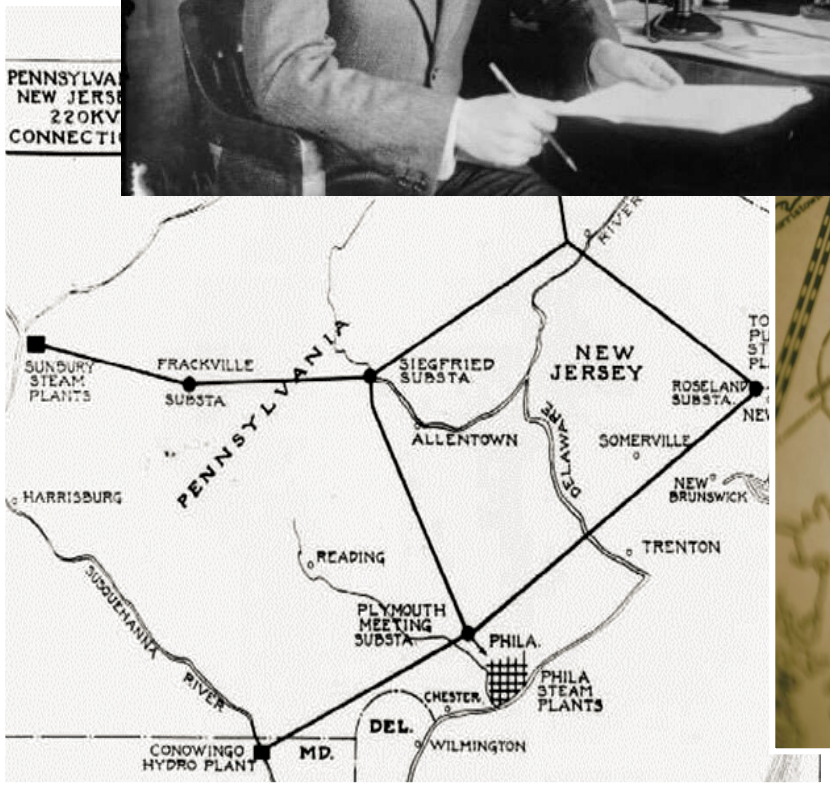
BIGGEST POWER POOL TO SERVE 2 STATES

Three Utility Companies Form System for Pennsylvania and New Jersey.

TO BE IN OPERATION BY 1930

3 Transmission Lines Totaling 208 Miles to Cost $26,000,000 —New Plant at Conowingo.

Formation of what is probably the world's largest electric power pool was announced yesterday. This latest and greatest of superpower systems will cover the industrial districts and main cities of New Jersey and, with the exception of Pittsburgh, most of the important cities in Pennsylvania. It will involve the



Early State of the Industry

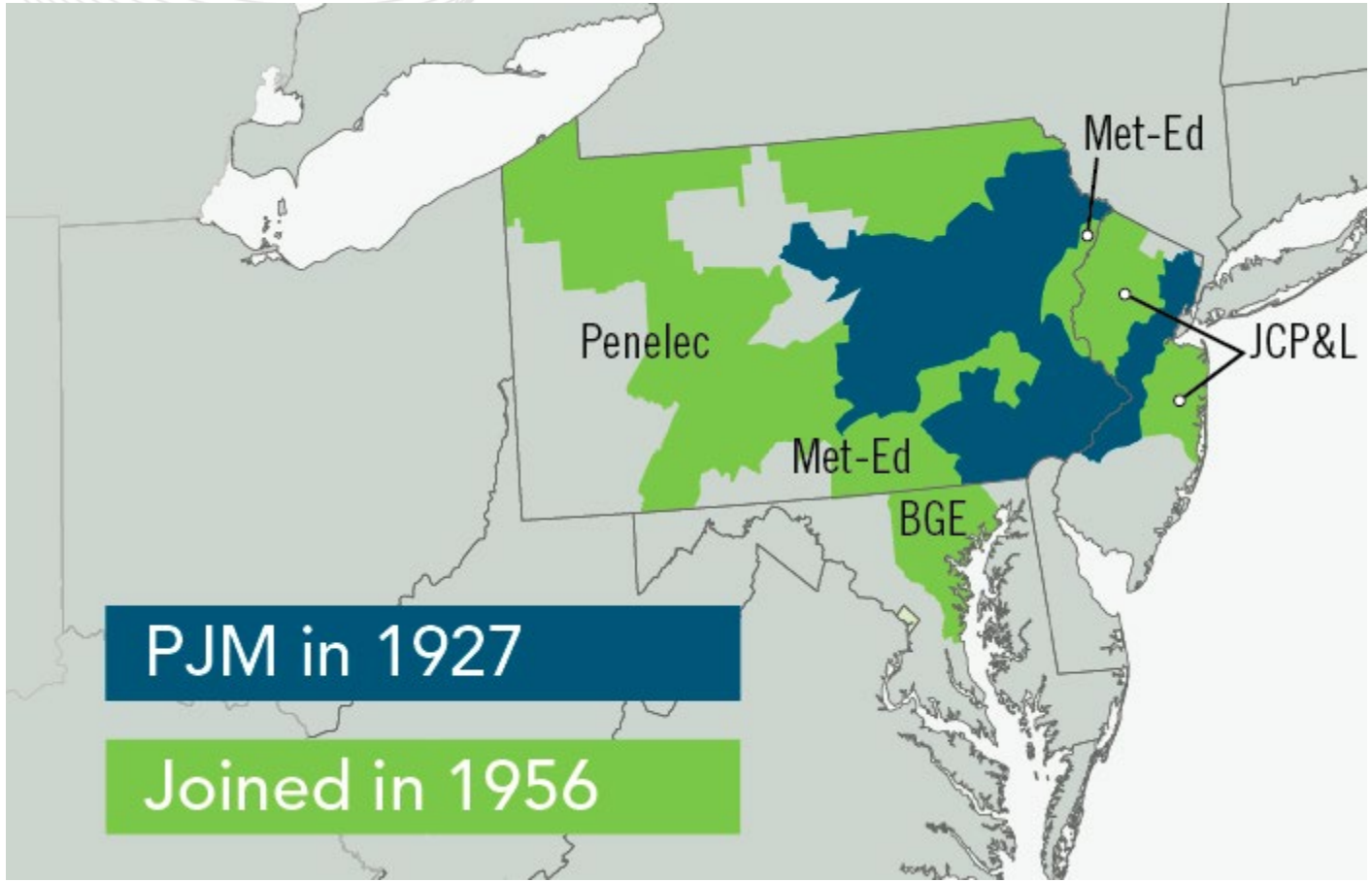
Vertically Integrated Utilities

Reserve Sharing

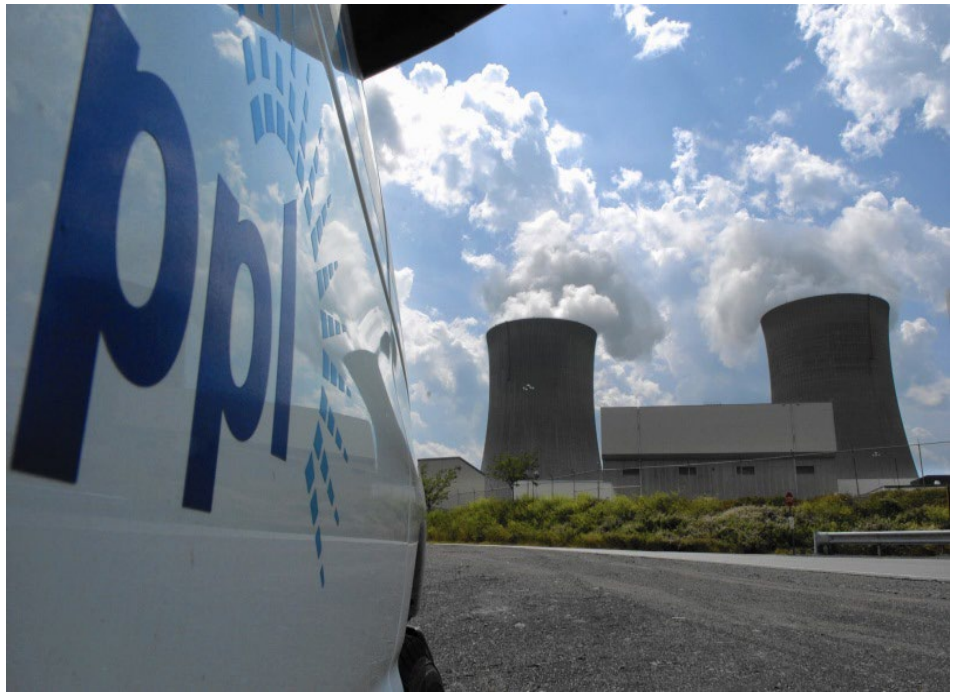
Coordinated Transmission Planning

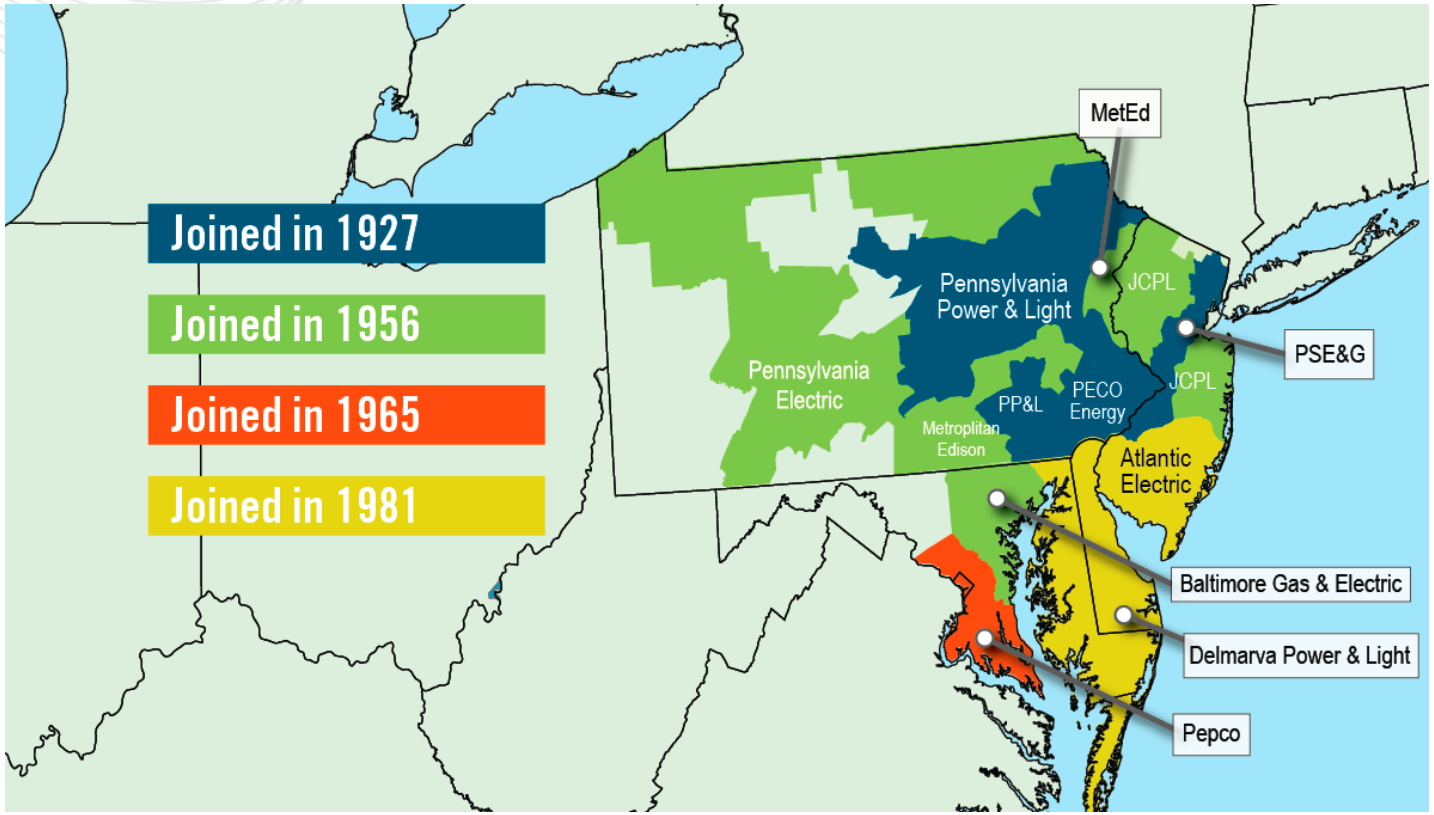
Integrated Resource Planning

1950s PJM



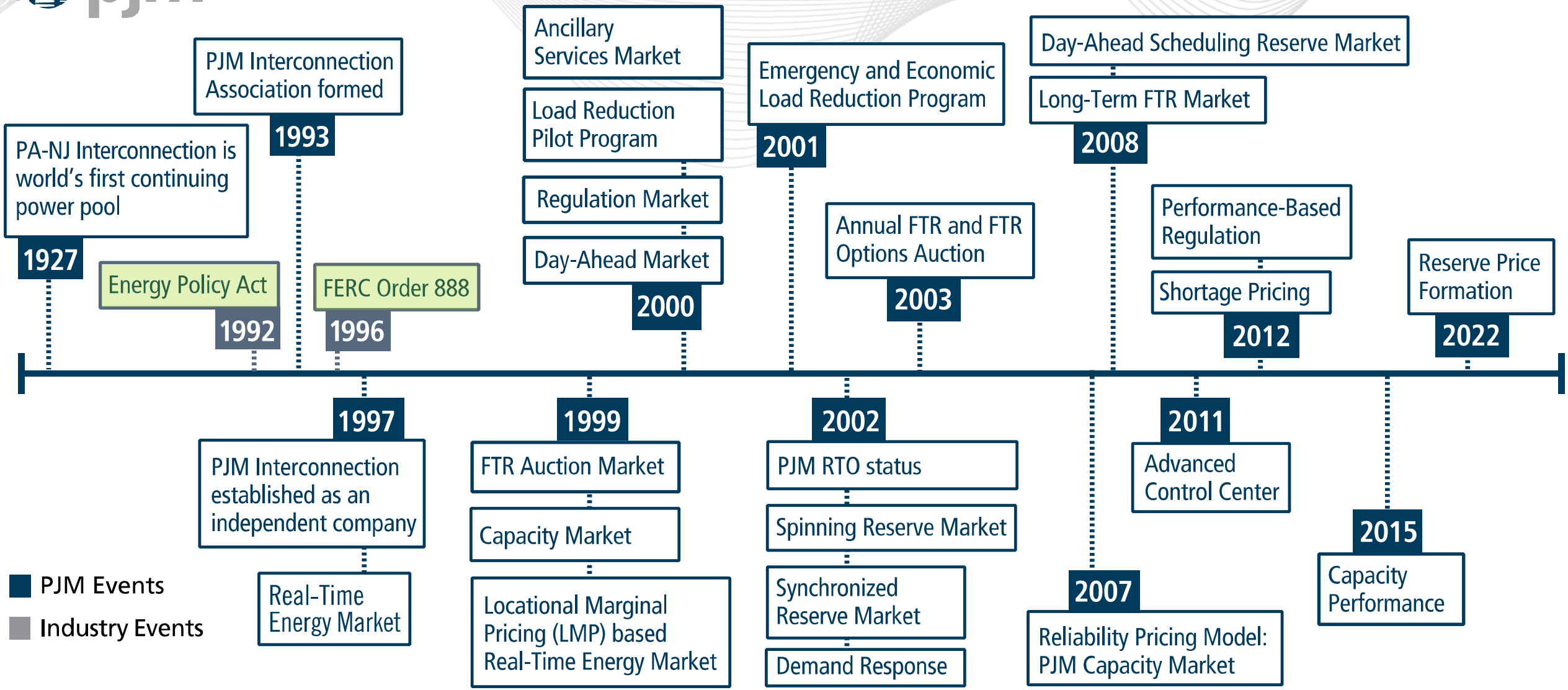
1980s PJM





PJM participants = Transmission Owners

Evolution of PJM Markets



Game Changers . . .

Energy PACT 1992

Push Buttons

The Energy Policy Act of 1992 promoted the development of spot markets for electrical power because it required facilities to open their transmission system to wholesale power sales

FERC Order 888 1996

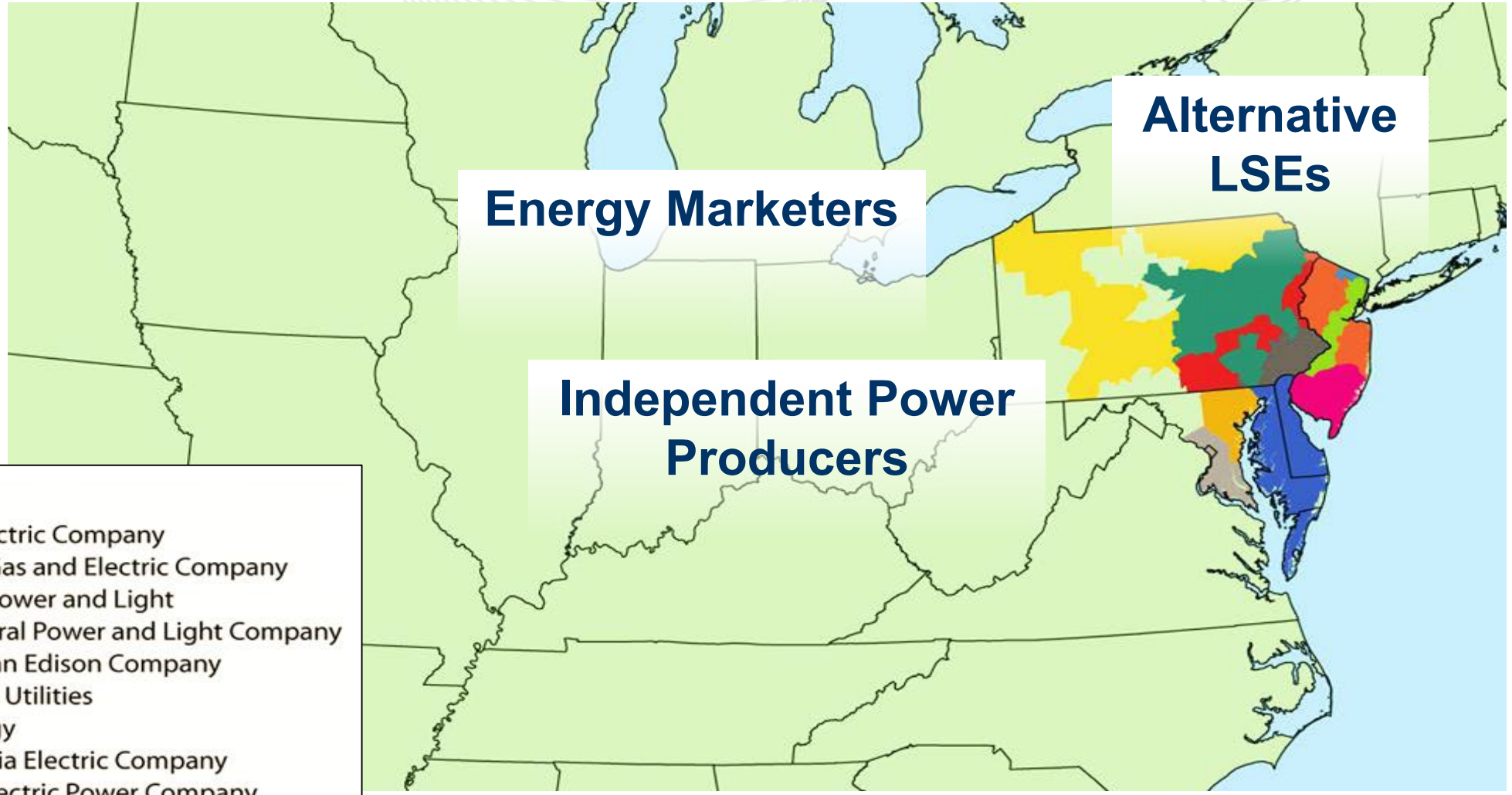
Iconic Flair

Deregulation: Remedy undue discrimination in access to the monopoly owned transmission wires that control whether and to whom electricity can be transported in interstate commerce.

Retail Markets

Mobile access

“Unbundling” Leads to Whole New Classes of Market Participants



Organized Competitive Wholesale Markets

Increase Reliability

RELIABILITY

Locational Prices
(Prices signal system needs; participants respond)

Information Exchange and Transparency

Grid Management

Organized Competitive Wholesale Markets

Reduce Costs to Customers

Ability to share resources reduces required reserve margins

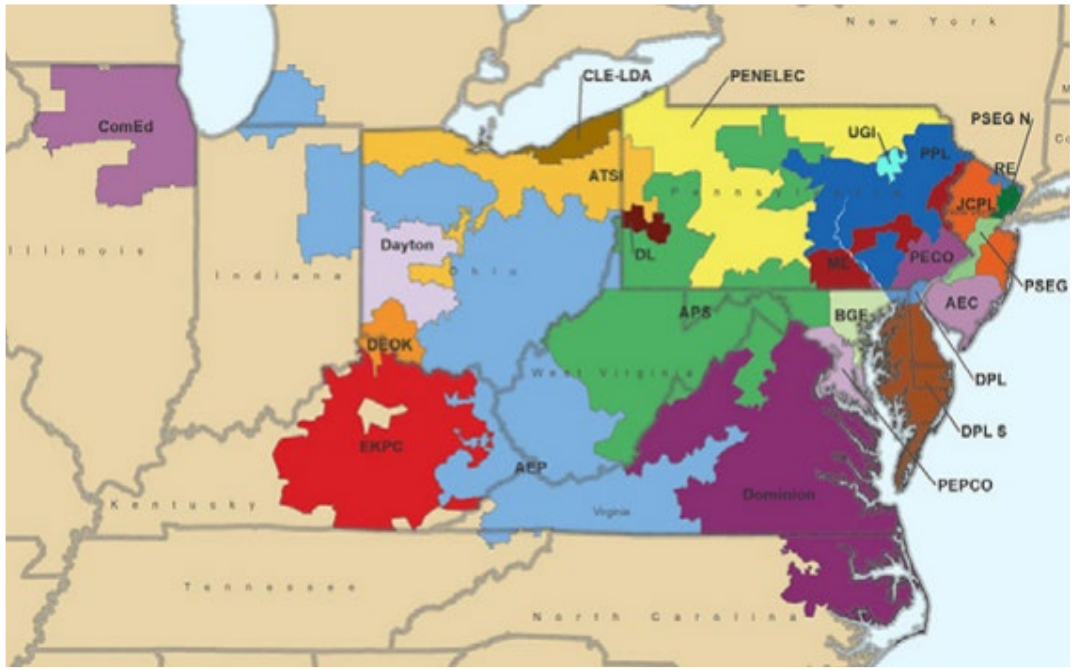
Prices are lower than they would have been under regulation

PJM's breadth increases access to lower-priced, diverse supply resources

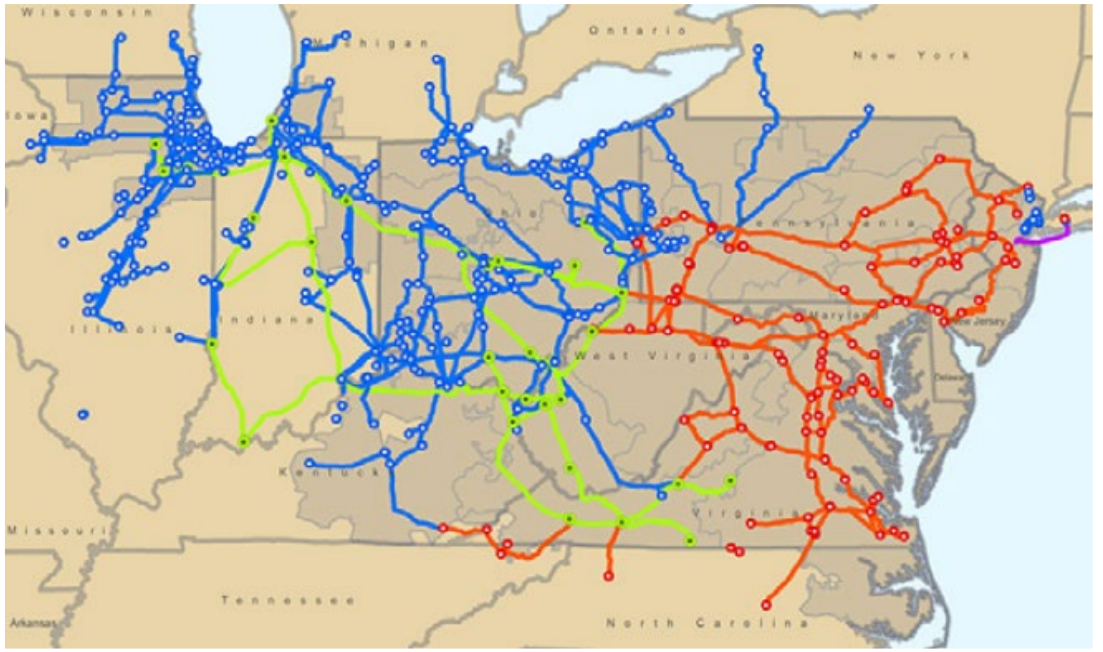
The average residential customer pays about 24 cents a month for PJM's broad array of reliability and market services.

Organized Competitive Wholesale Markets

Regional Planning Process



Broad system view that looks out 15 years over the entire geographic area

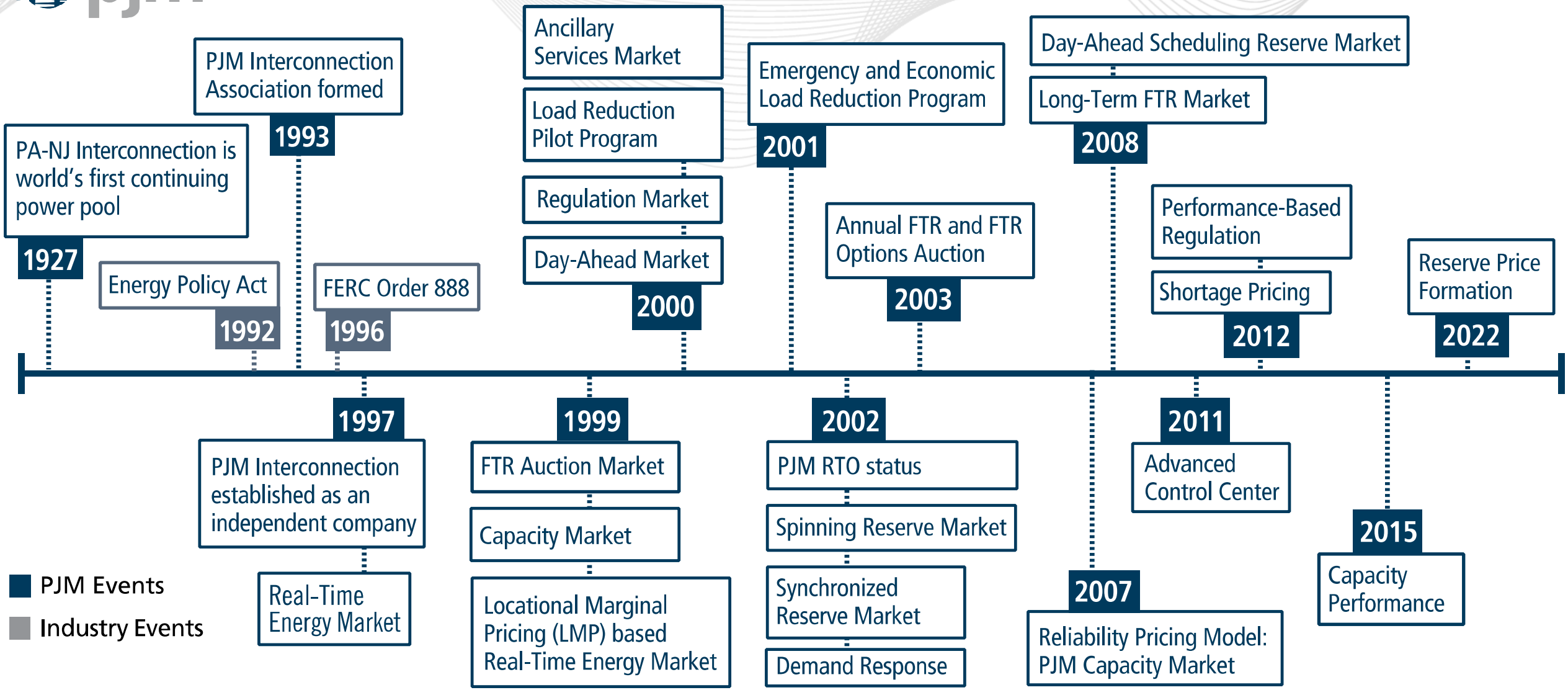


The RTEP process identifies upgrades to meet customers' requirements:

operational	economic	reliability requirements

PJM Market Implementations

Evolution of PJM Markets



PJM Market Design Philosophy

Market prices reflect actual operating conditions

Market incentives — market participants are partners with RTO to maintain reliability through price signals

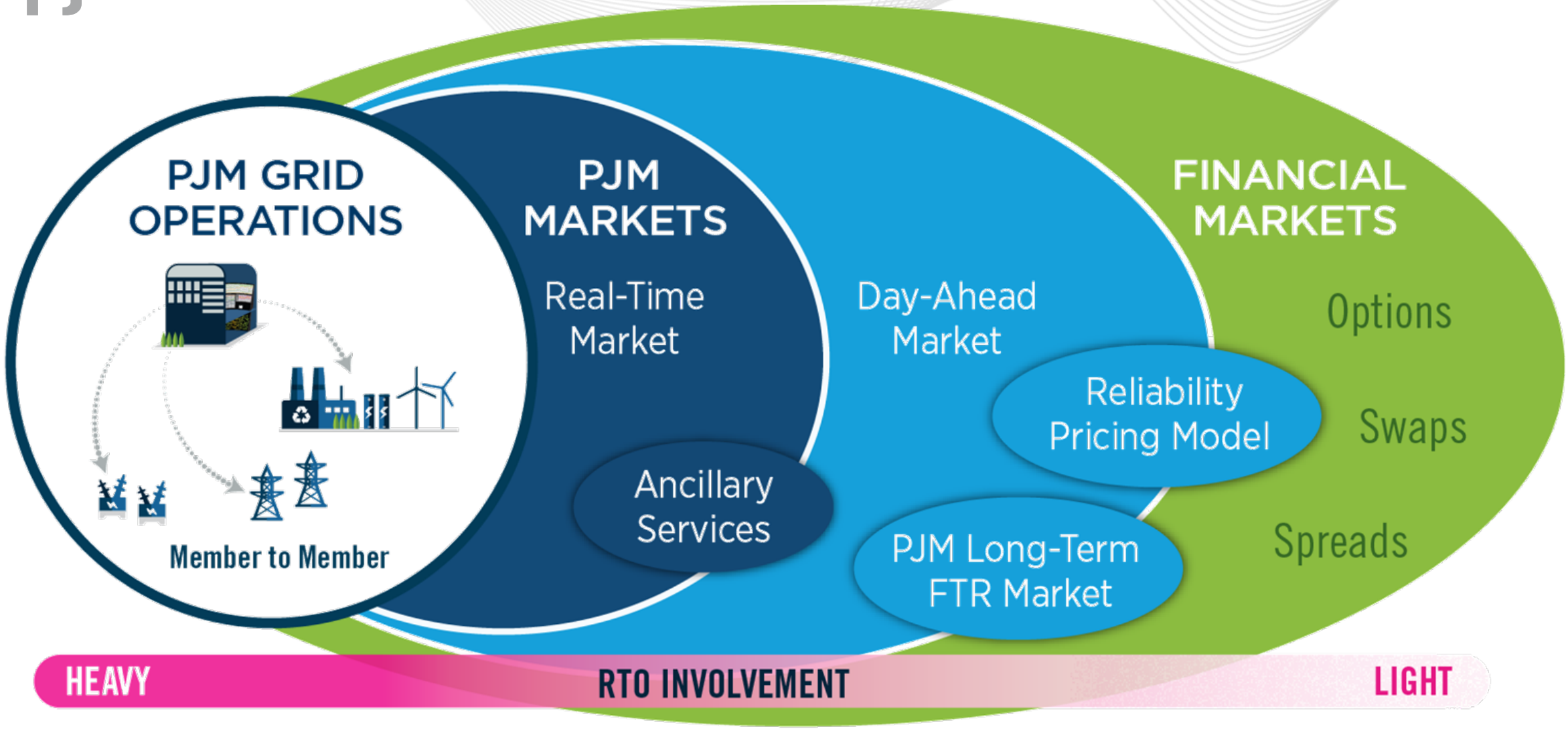
- **Financial product development**
- **Information transparency**
- **Price rationalization**

Result for physical market participants:

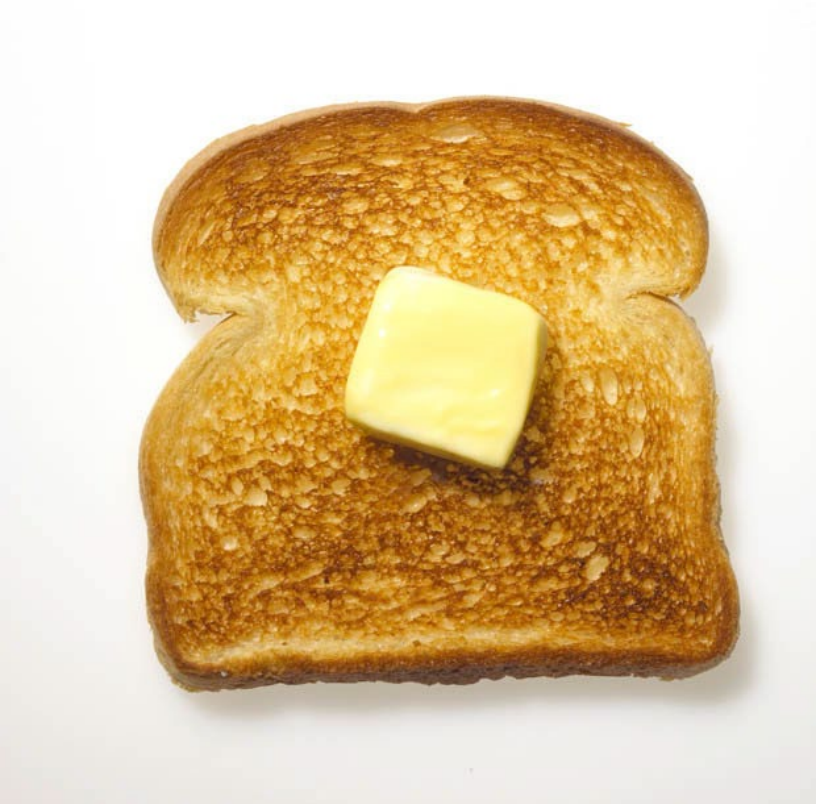
- Transmission hedges more valuable than congestion exposure
- Transfer capability of transmission system is maximized

Bilateral trades properly form the bulk of market activity

PJM Markets



1998 & 1999: Real-Time Energy Market & Financial Transmission Rights



- The beginning…
  - F. C. Schweppe's LMP
  - Hogan's FTRs
- LMP provides the most direct, efficient price signal of the value of electricity
  - The energy market is designed such that a supplier maximizes their revenue by following PJM's dispatch instructions.
  - There are shortcomings, though.
- FTRs insulate loads from the costs of congestion
  - At this time they settle against RT LMPs.

Background: Excitement for deregulation resulting in irrational over-build of generation.

2000: Day-ahead Energy Market

- Rationale for implementation…
  1. Risk mitigation
  2. Increase competition (virtual trading)
  3. Facilitate forward contracting
- Two-settlement provides stronger incentives to follow Real-time dispatch
- Positions taken in the Day-ahead Market are liquidated in Real-time
- Largely unchanged (except for timing) since 2000

2015: Reducing Day-ahead Market Clearing Time

- Reducing the Day-ahead Market solution time reduces the price-risk gas generation owners are exposed to
- Reducing this risk hypothetically resulted in a reduction in the risk adders included in offers
- A modest reduction in offer prices of gas units will result in significant overall cost savings

Gas Generator Offer Reduction	Cost Savings (millions)
0.5%	$38.8
1.0%	$77.7
3.0%	$233.1

Regulation Market Evolution

PJM has two regulation signals: Regulation A and Regulation B (for hydroelectric units)

Moved to an RTO regulation market
- Between 2002–2005 PJM footprint expansions, calculated regulation by zones and aggregate zones
- Requirement was 1% of on/off peak load forecast

2002 AP
2004 AEP,CE,DAY
2005 DUQ, DOM
2011 ATSI
2012 DEOK
2013 EKPC

COST-BASED
48,444 MW
PEAK
LOAD

MARKET-BASED →
133,974 MW

154,388 MW

PJM implemented the Regulation Market on June 1

FERC Order 755, Performance Based Regulation (PBR)
- Implementation of performance based regulation, Regulation A and Regulation D
- Able to decrease regulation requirement from enhanced regulation performance

Source: March RMDSTF 2022

Capacity vs. Energy

Capacity

- A commitment of a resource to provide energy during PJM emergency.
- Capacity revenues paid to committed resource independent of energy produced by resource.
- Long-term commitment
- Annual / Daily product

Energy

- Generation of electric power over a period of time
- Energy revenues paid to resource based on participation in Day-Ahead or Real-Time energy market
- Daily / hourly commitment
- Hourly or real-time product

Capacity, energy & ancillary services revenues are expected, in the long term, to meet the fixed and variable costs of generation resources to ensure that adequate generation is maintained for reliability of the electric grid.

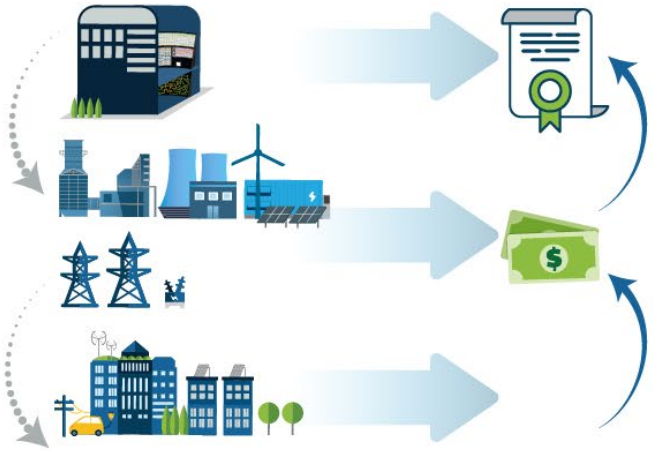
2006/2007: Reliability Pricing Model

- The excitement for deregulation resulting in the irrational over-build of generation had **stopped**.
- Load kept growing though.
- PJM planning detected reliability violations in certain areas of the footprint due to resource adequacy issues.
- No long-term price signals indicating the need for new capacity in a specific location.
  - LMPs only cover a portion of a resource's revenue.
- No resources being built.

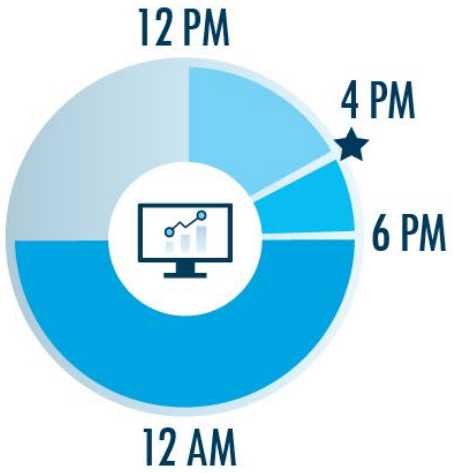
PJM's Markets Work Together

Resource Adequacy

Transportation



Day-Ahead Market

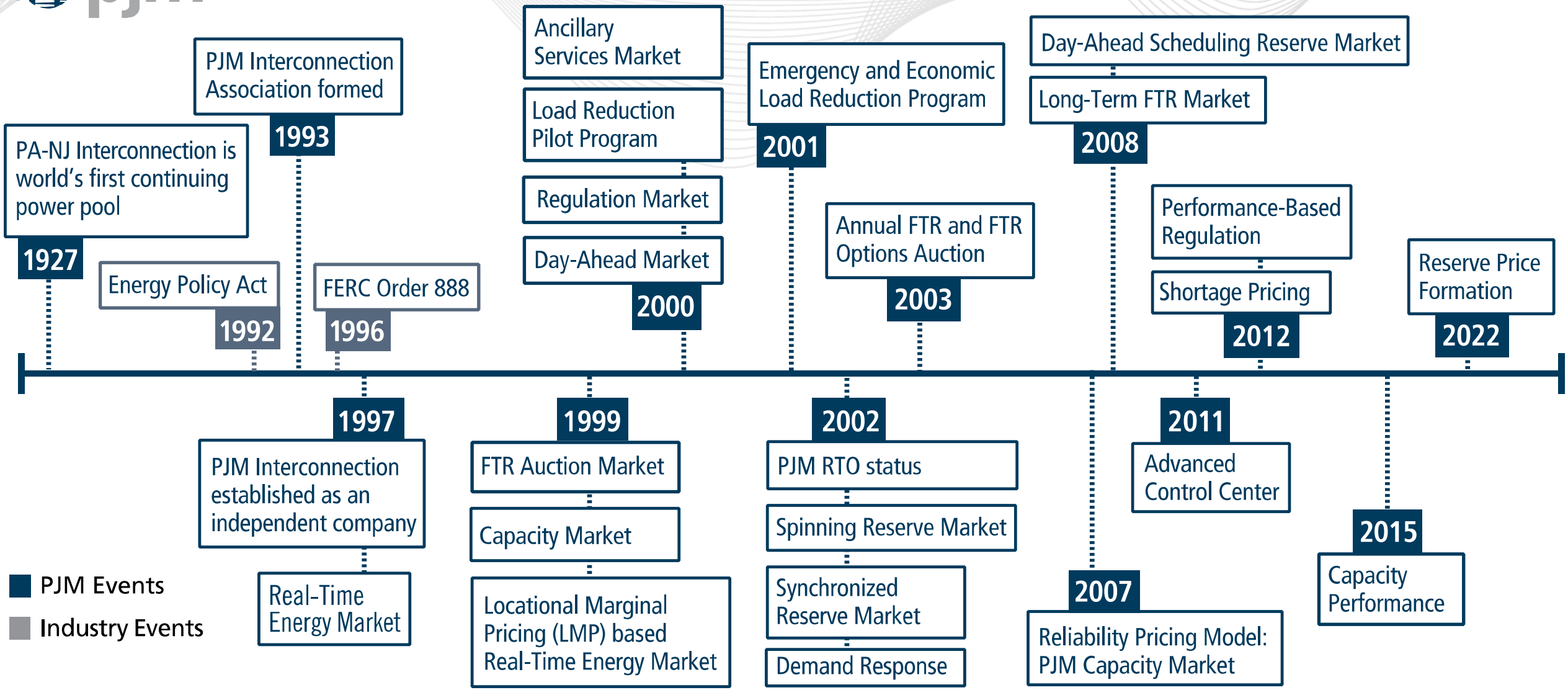


Real Time Ops.

Ancillary Services

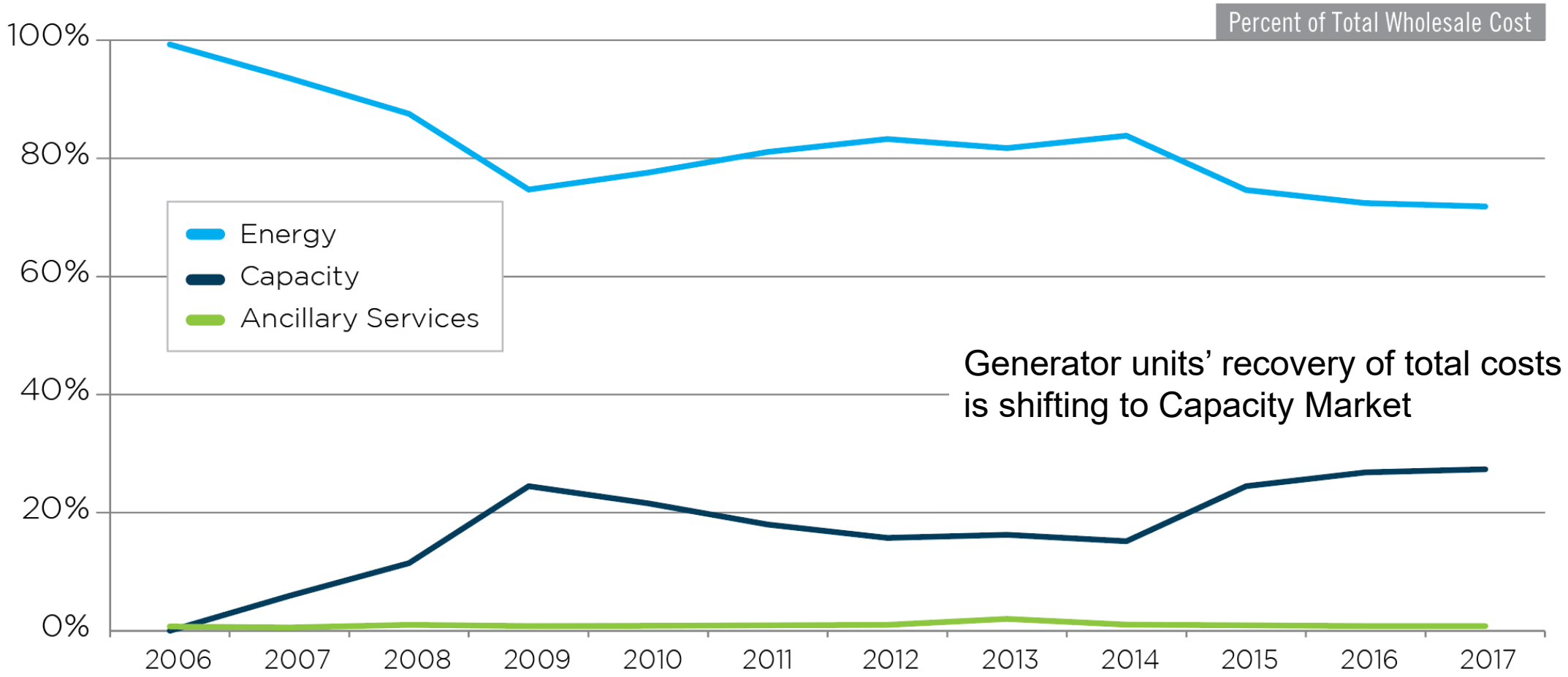
3 years | 1 year | 1 day | 5 min. | 5 min.

Evolution of PJM Markets



What’s next?

Price Formation: Shift in Costs and Need for Change



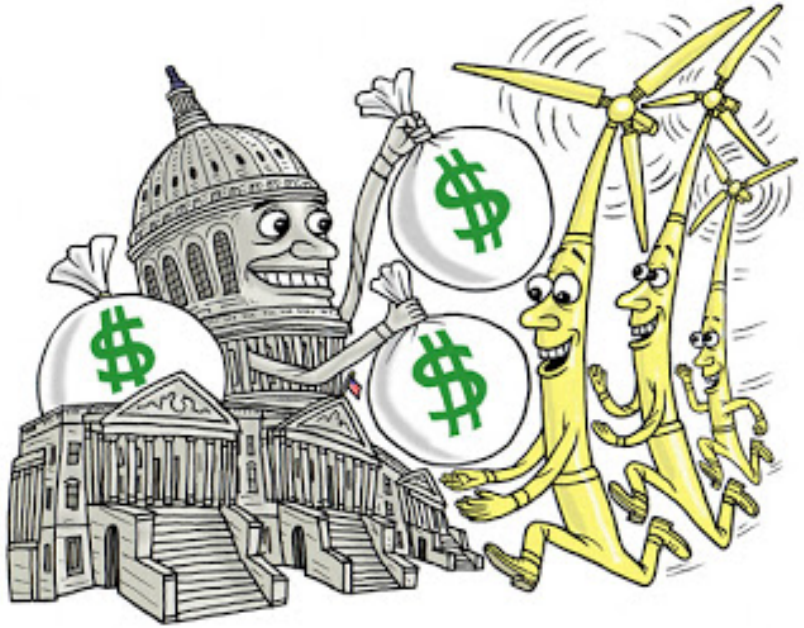
Generator units' recovery of total costs is shifting to Capacity Market

*Proper price incentives and resource attributes achieved when cost recovery properly proportioned between different markets

Subsidies are more difficult…

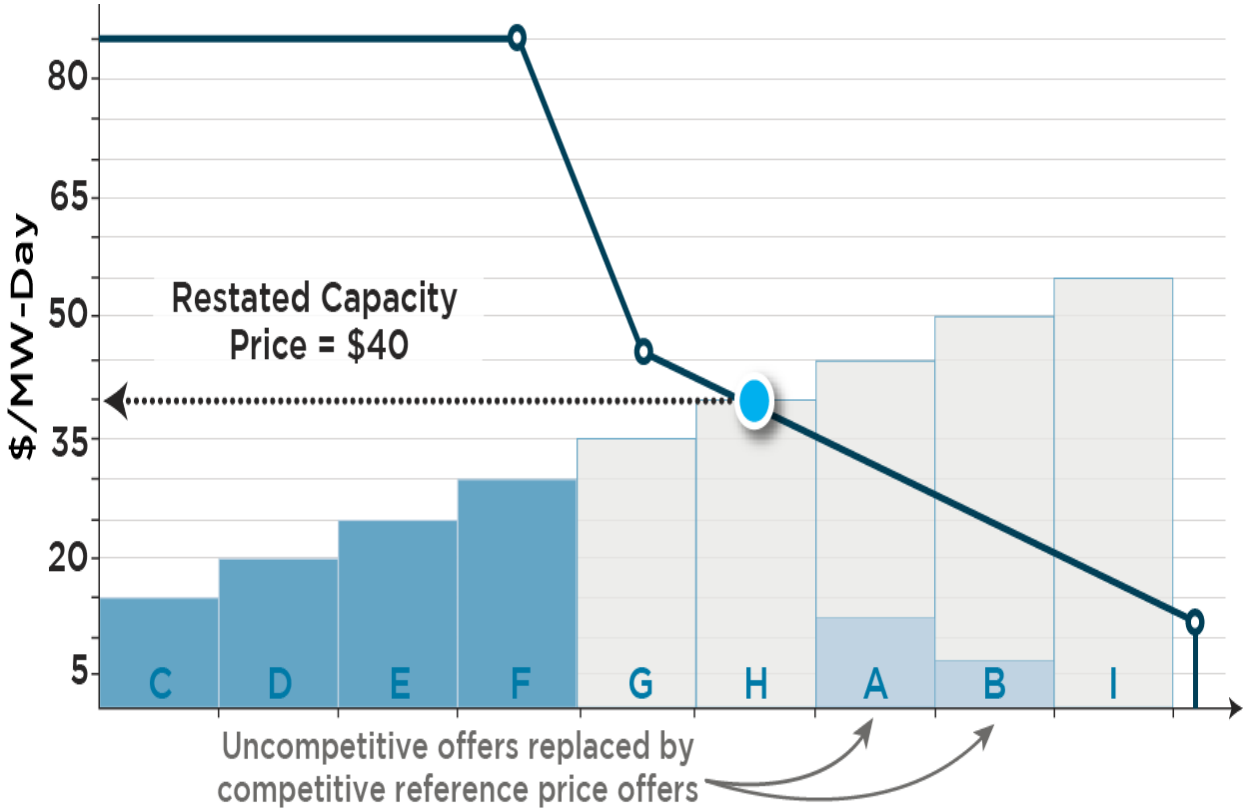
Challenges

1. Subsidies result in out of market payments from government
2. Suppresses market clearing prices
   - Detrimental effect to merchant assets wholly dependent on the market for survival
3. Pushes out the economic entrant
   - New, more efficient, resources are kept out of the market by maintaining uneconomic resources



Capacity Market Repricing to account for Subsidies

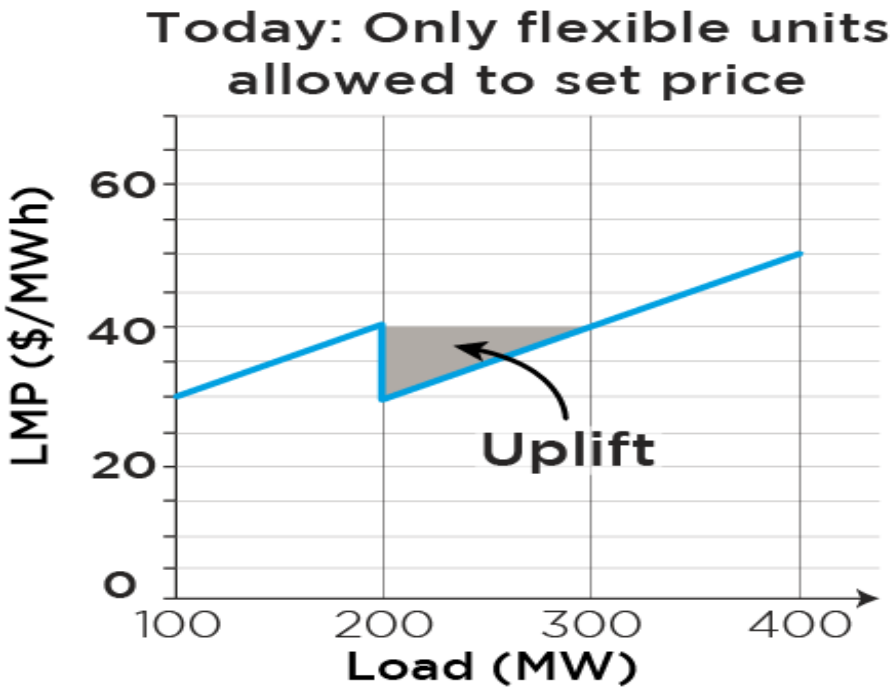
- (Rejected by FERC)

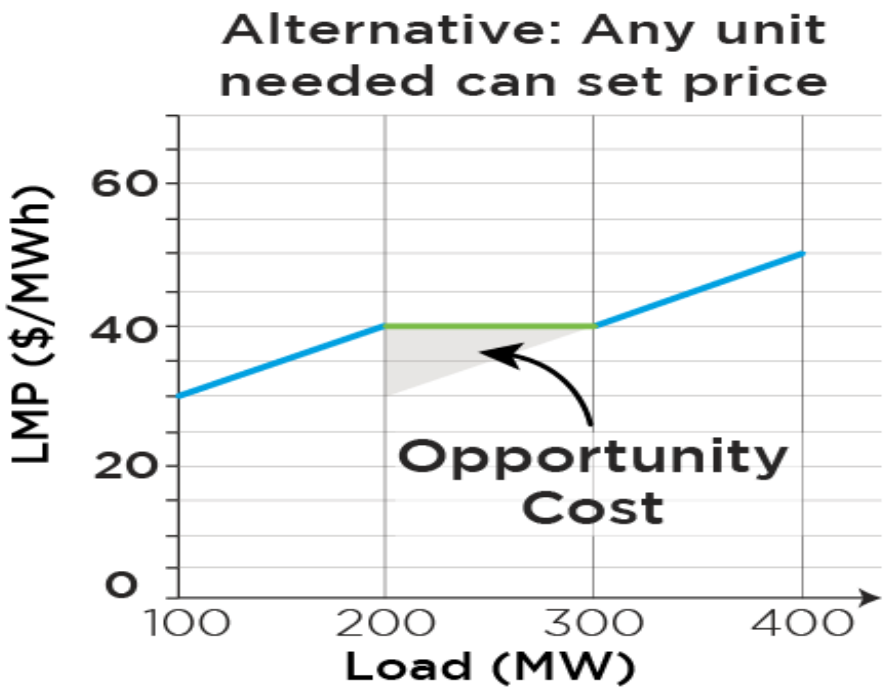


Key Point:
The theoretical “best” solution might not always be achievable in the “Real” world

Energy Market Price Formation

– Fast-Start pricing implemented in 2020



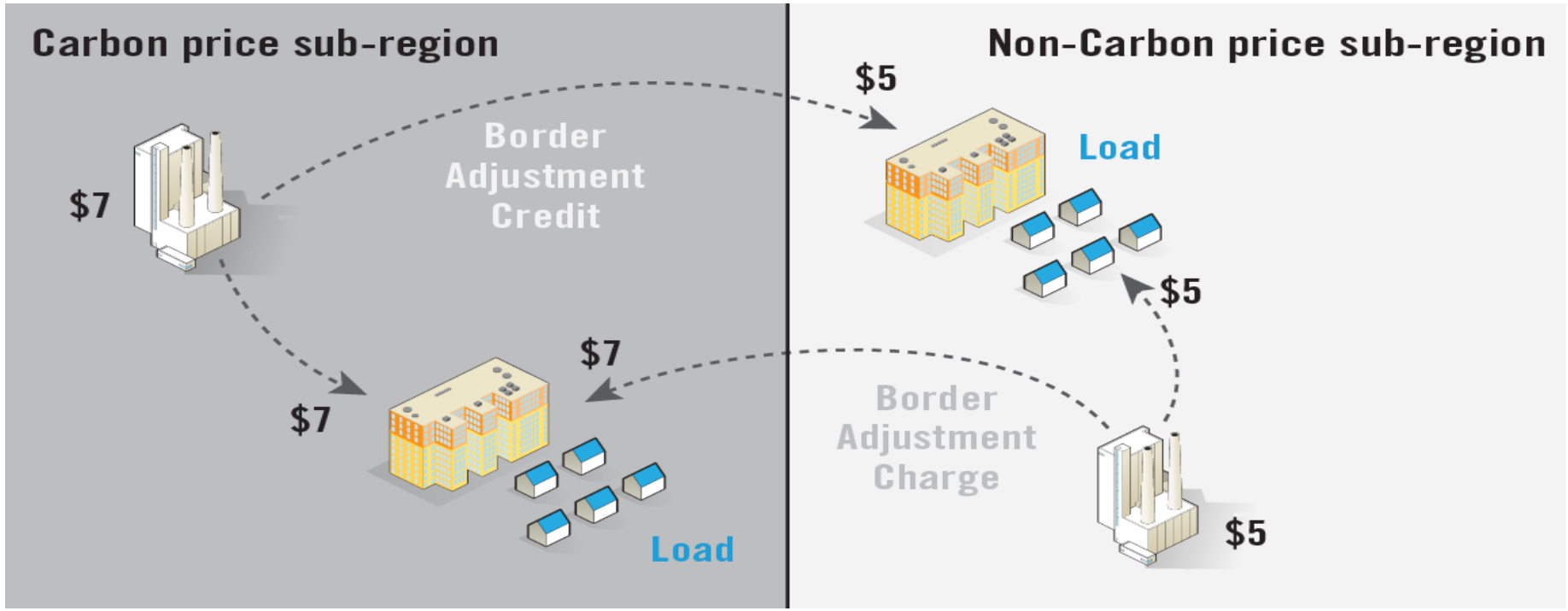


Inflexible unit offer: 100 MW @ $40

Flexible unit offer: $20 + $0.1/MW

Carbon Pricing

- Under Review



Lessons Learned – Tim's Point of View

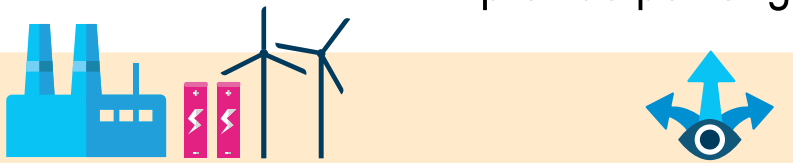
The PJM Markets continue to evolve and change but what have we learned?

- First is not always best
- Collaboration with neighbors and industry is critical
- The perfect solution is not always the best solution
- Don't overcomplicate rules

Continuing Industry Evolution

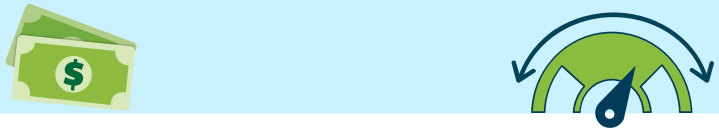
Evolution of Supply

Less flexible → Intermittent → Less capability to provide power grid services



Evolution of Demand

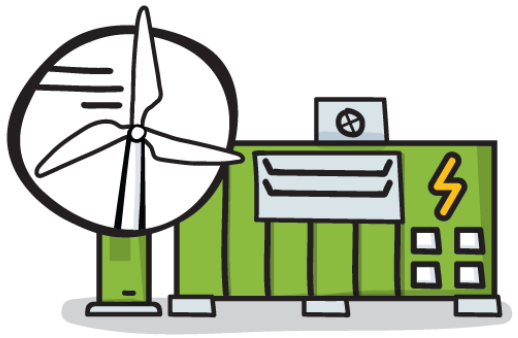
Technology enabled flexibility → Alternative resource growth → Enhanced capability to provide grid services



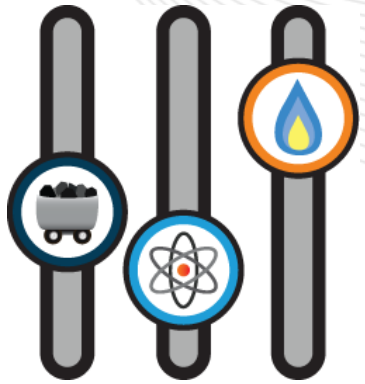
Market Evolution

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

Unprecedented number of changes in the power industry



Storage and renewables



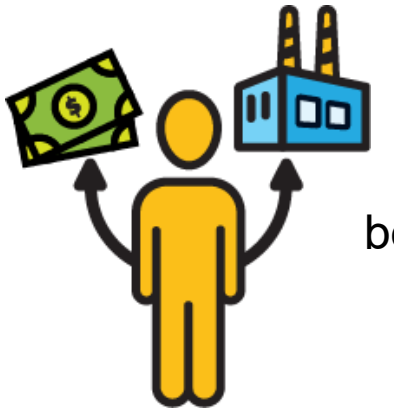
Changing fuel mix

Regulatory uncertainty

Energy efficiency

Renewable and distributed energy resource integration

Cybersecurity and system resiliency



Customer behavior and choice