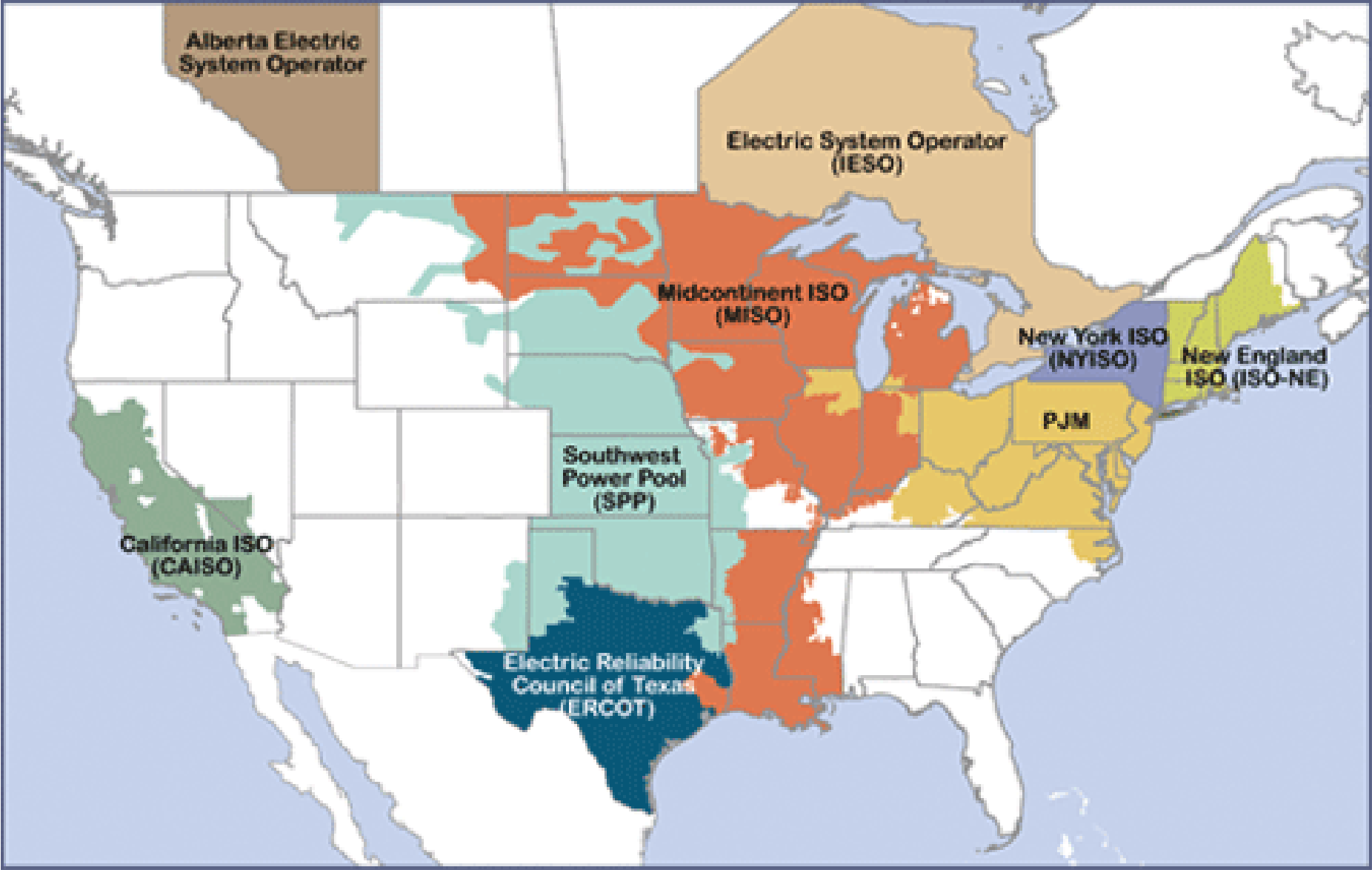




# Topics for Today

- **Session 1: The many meanings and drivers of electricity “restructuring” or “deregulation”**
- **Session 2: The wild world of markets for power**
- **Session 3: Designing the grid by democracy: planning and governance**

# Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs)



Source: <https://www.ferc.gov/industries-data/electric/power-sales-and-markets/rtos-and-isos>

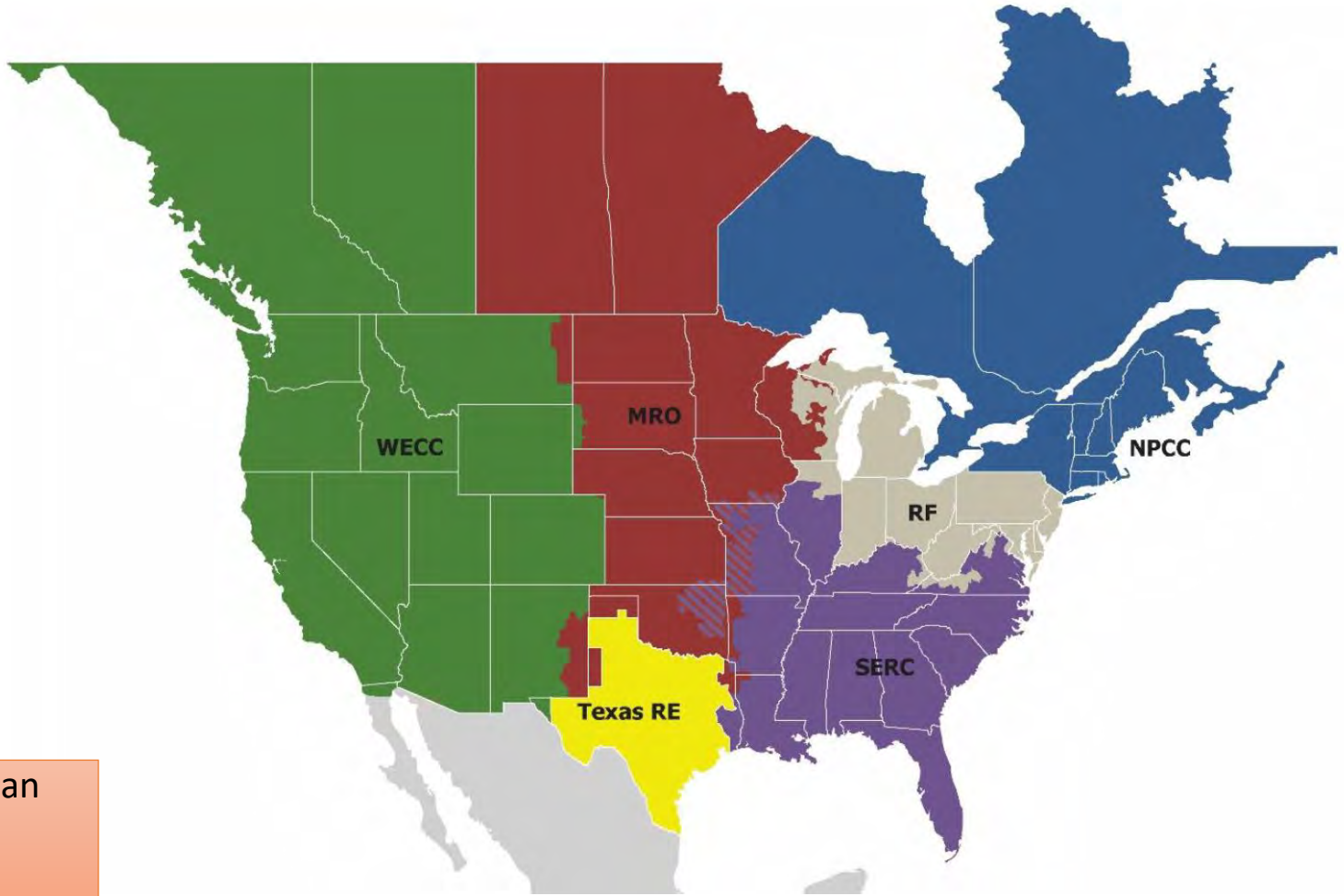
## U.S. electric power regions

Source: EIA  
<http://www.eia.gov>



- The Eastern Interconnection encompasses the area east of the Rocky Mountains and a portion of northern Texas. The Eastern Interconnection consists of 36 balancing authorities: 31 in the United States and 5 in Canada.
- The Western Interconnection encompasses the area from the Rockies west and consists of 37 balancing authorities: 34 in the United States, 2 in Canada, and 1 in Mexico.
- The Electric Reliability Council of Texas (ERCOT) covers most, but not all, of Texas and consists of a single balancing authority.

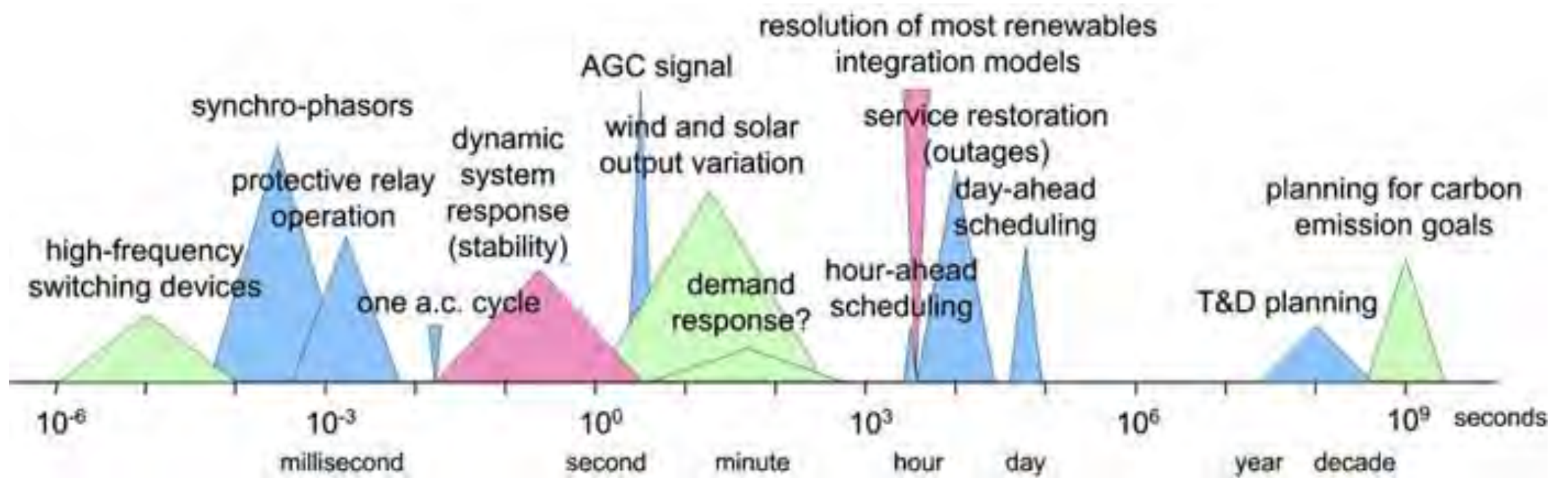
RTOs should not be confused with Interconnection or Reliability (NERC) Regions



Source: North American Electric Reliability Corporation

- [Midwest Reliability Organization \(MRO\)](#)
- [Northeast Power Coordinating Council \(NPCC\)](#)
- [ReliabilityFirst \(RF\)](#)
- [SERC Reliability Corporation \(SERC\)](#)
- [Texas Reliability Entity \(Texas RE\)](#)
- [Western Electricity Coordinating Council \(WECC\)](#)

# Why do RTOs Use Markets?



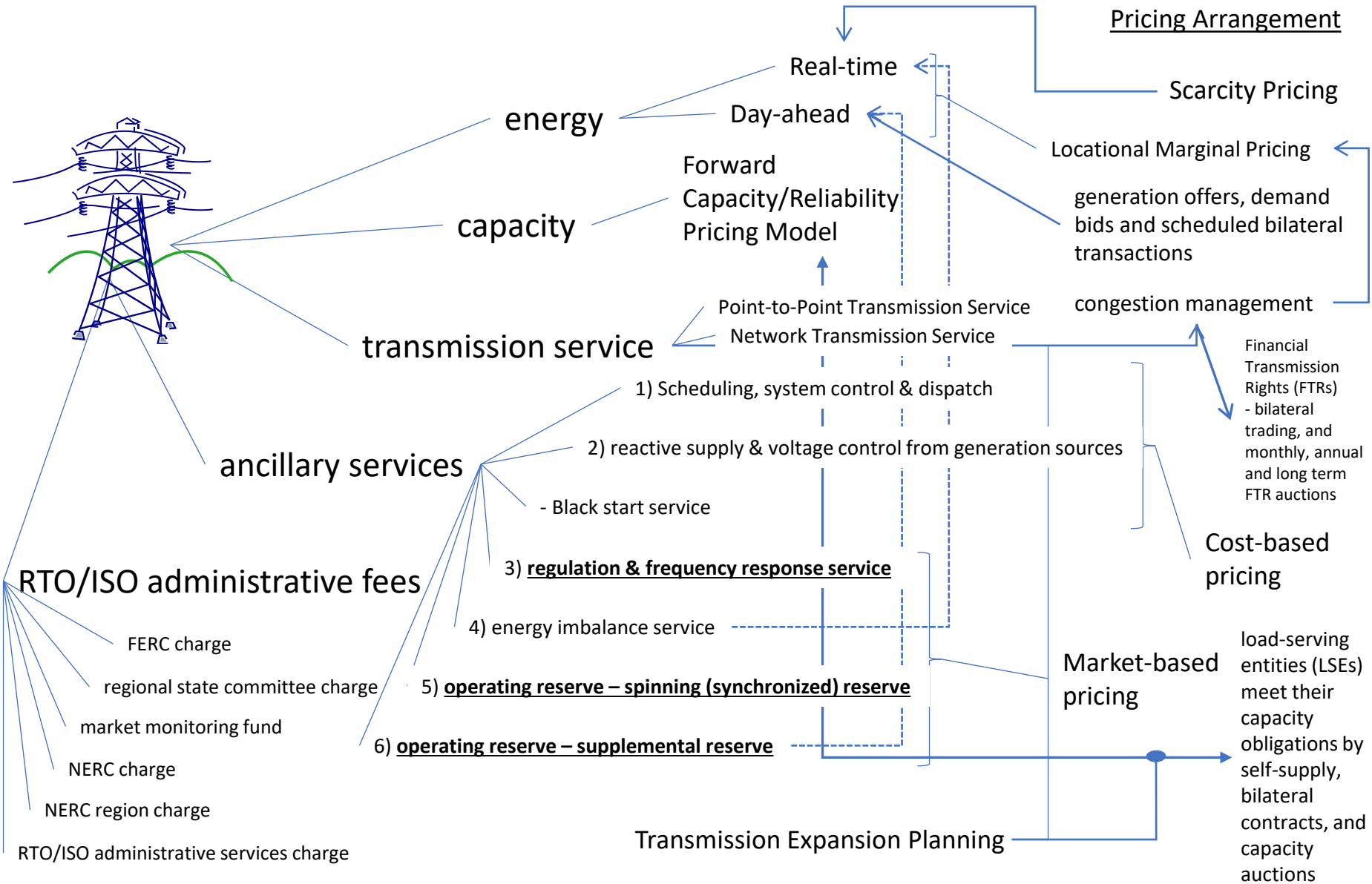
RTOs are responsible for many of these decisions, but own no physical assets and can't take long or short positions. For many of these functions they use markets to provide financial incentives for asset owners to offer services.



# Energy, capacity, and ancillary services markets and allocation rules.

- RTOs have developed a mix of complex wholesale market mechanisms designed to simulate the operations of competitive markets (energy, ancillary services, and transmission congestion-based transmission rights)
- These market mechanisms operate within a complex framework of RTO operating rules overseen by FERC

# RTO Wholesale Electricity Markets





# Spot markets for real-time energy and ancillary services

- Most power bought and sold through long-term bilateral contracts between buyers and sellers
- For last-minute sales or purchases for system reliability, ISOs and RTOs use real-time markets to resolve energy imbalances
- They also have day-ahead markets and a market for various ancillary services

# Poll #3

Which of the following NOT an example of a market run by a typical RTO?

- a) Day-ahead energy
- b) Transmission congestion rights
- c) Carbon emissions permits
- d) Regulation and frequency response

# Electricity market price behavior (I)

- The “locational marginal price” (LMP) is defined as the marginal cost of supplying power to a specific location.
  - ✓ A shortage of power in a transmission-constrained location will result in a higher LMP at that location.
  - ✓ A surplus of power in a transmission-constrained location will result in a lower LMP at that location.
  - ✓ If there were no transmission constraints in the RTO market (and if transmission losses are small), LMPs at all locations would be the same.

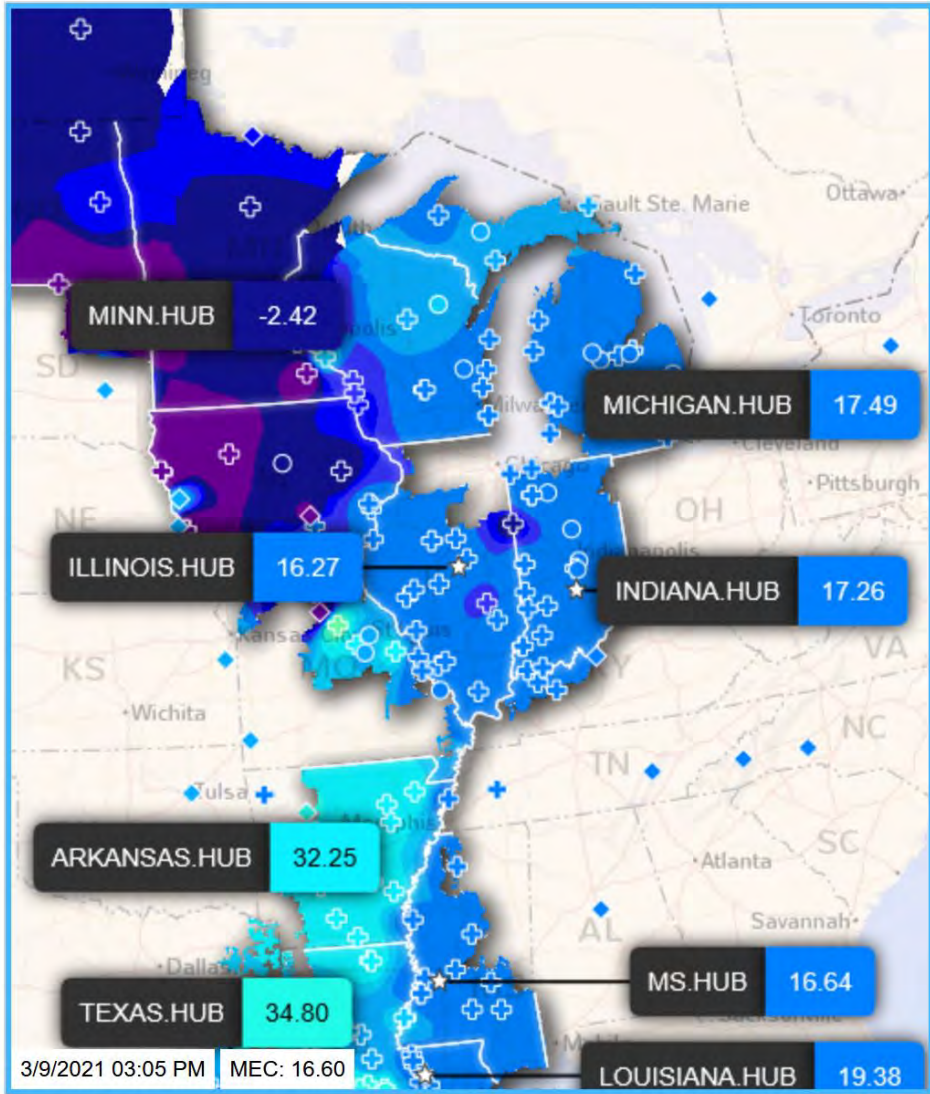
# Electricity market price behavior (II)

- A few things that we generally observe about LMPs in RTO electricity markets:
  - ✓ LMPs can be very volatile, even in periods of low demand
  - ✓ LMPs in some areas can become negative, especially in areas with a lot of renewable power output (why?)
  - ✓ The cost of natural gas is a major driver of LMPs (why?)
  - ✓ The “net load” (electricity demand *less renewables output*) is also a major driver of LMPs.

# LMP Contour Map



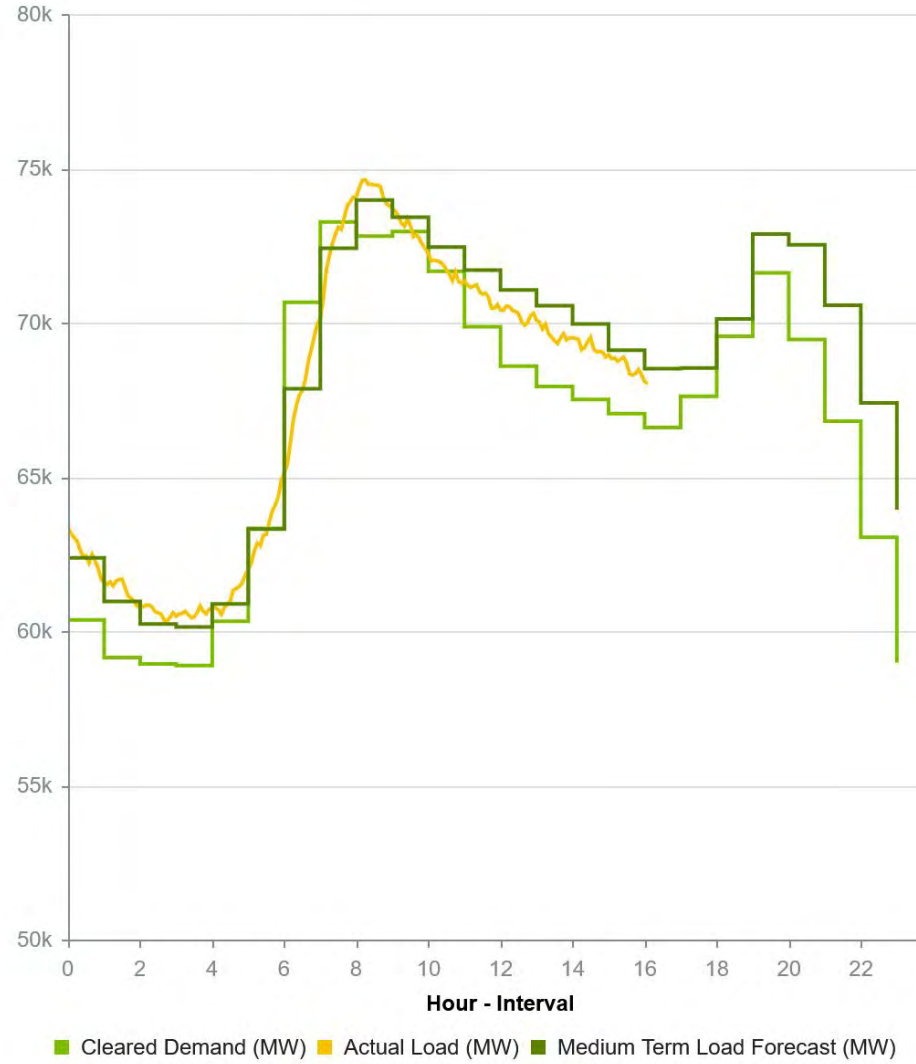
9-Mar-2021 - 16:05 EST



# Real-Time Total Load



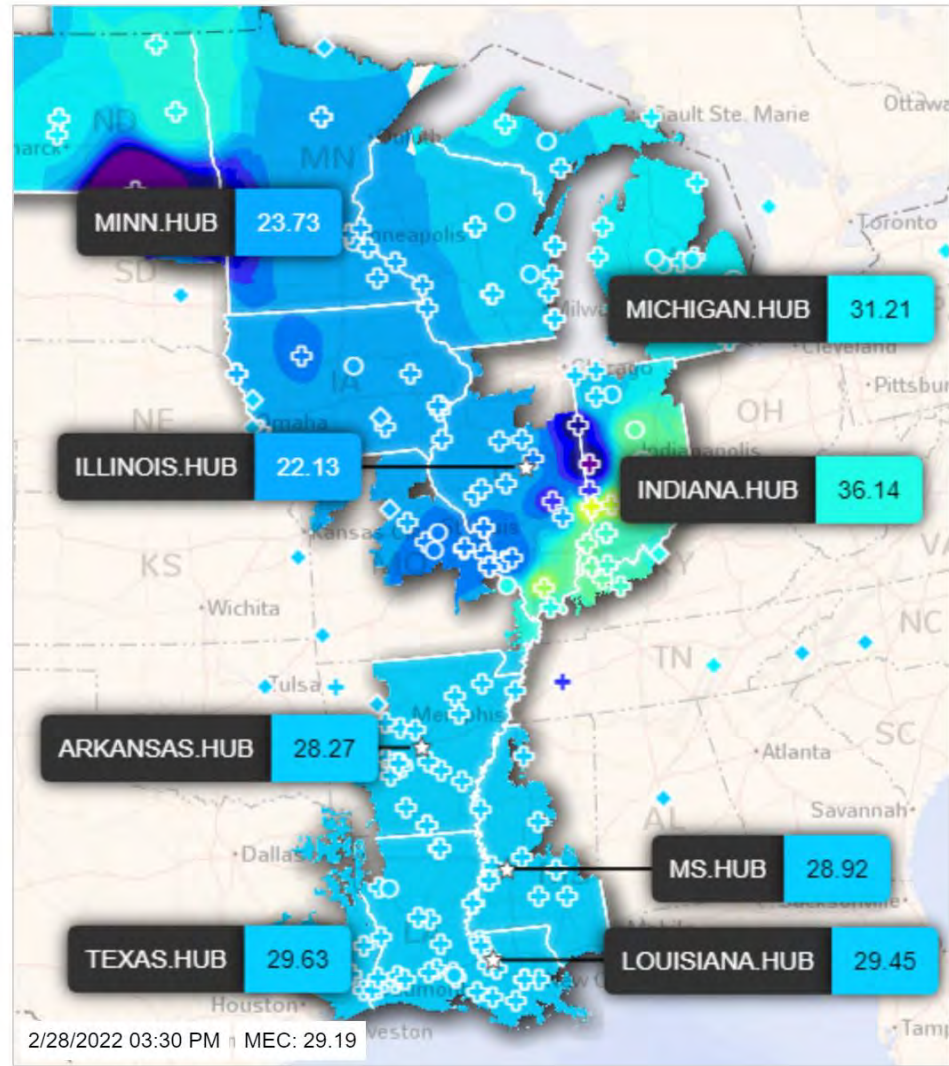
09-Mar-2021 - Interval 16:05 EST



# LMP Contour Map



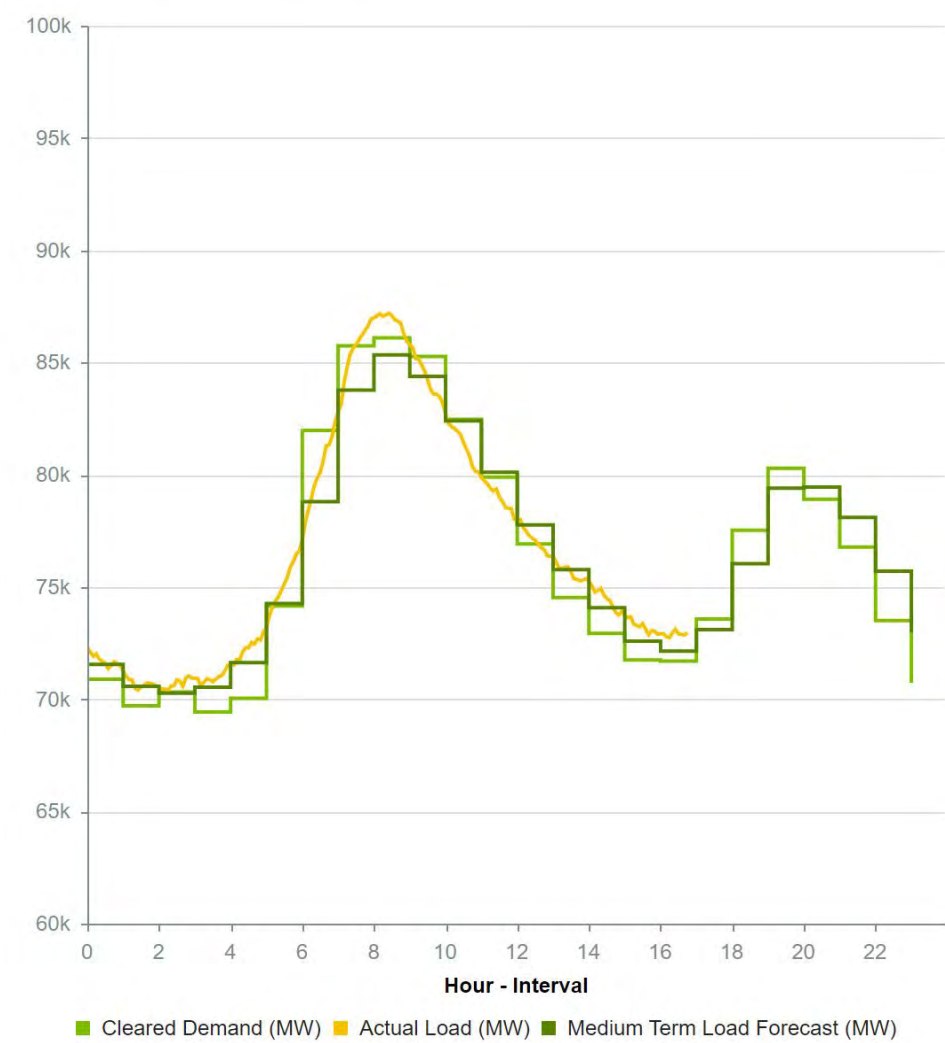
28-Feb-2022 - 16:30 EST



# Real-Time Total Load

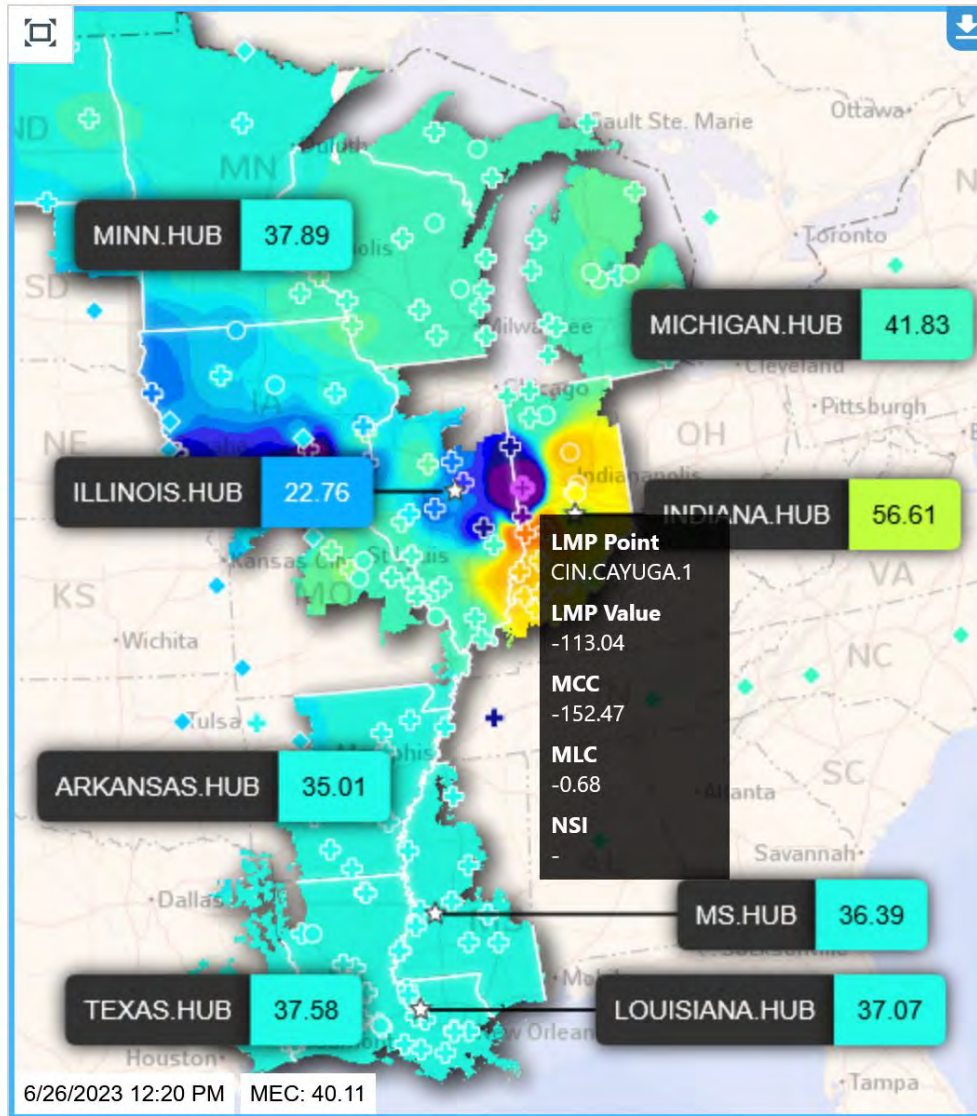


28-Feb-2022 - Interval 16:45 EST





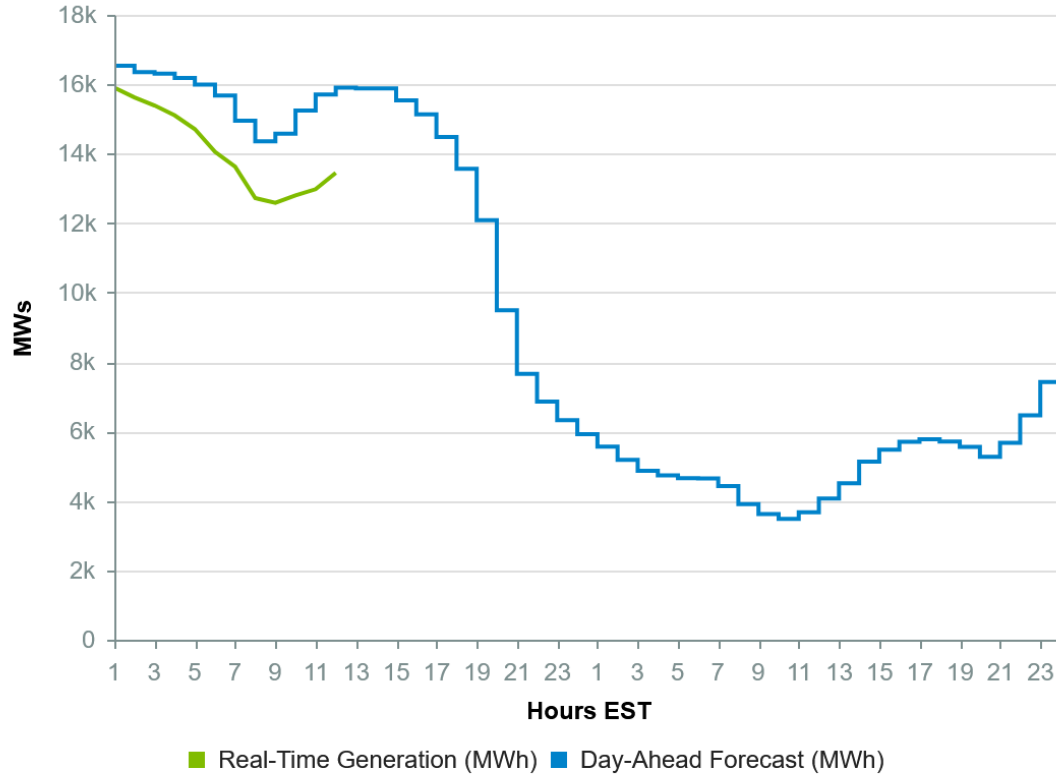
26-Jun-2023 - 12:20 EST



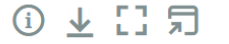
## Wind Day-Ahead Forecast and Real-Time Generation



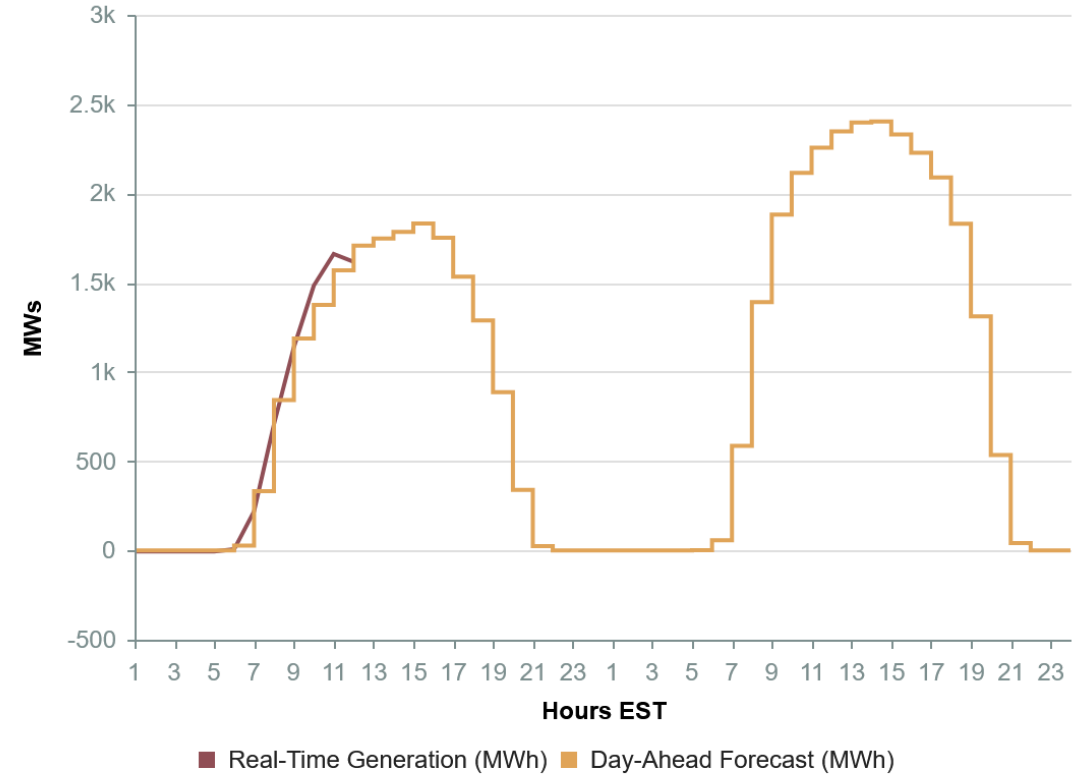
26-Jun-2023 - Interval 12:00 EST



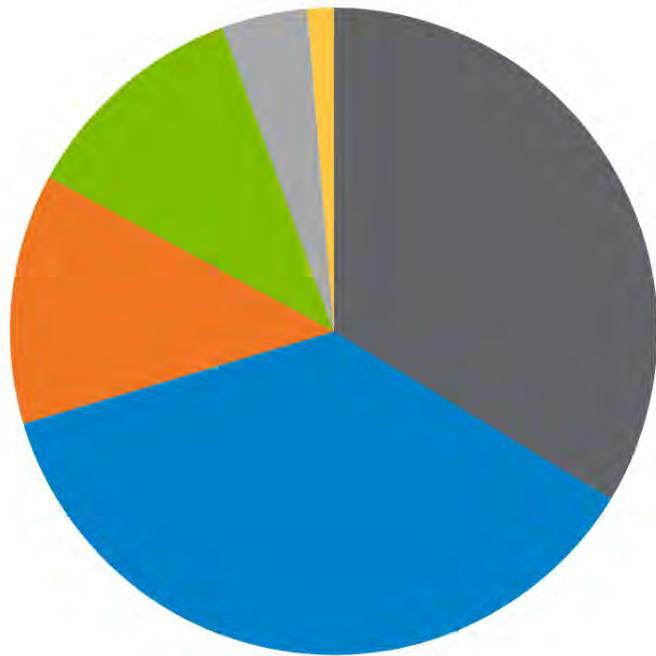
## Solar Day-Ahead Forecast and Real-Time Generation



26-Jun-2023 - Interval 12:00 EST



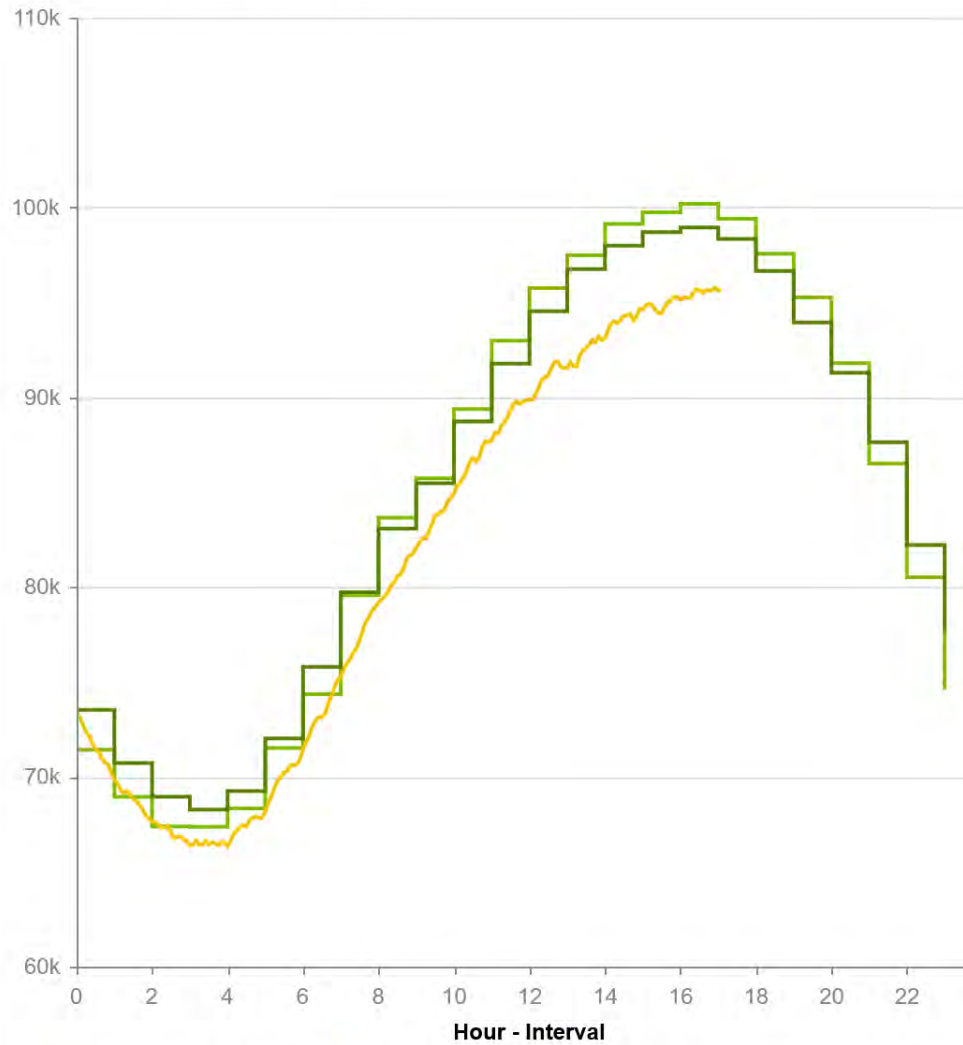
26-Jun-2023 - Interval 17:05 EST



Total Megawatts  
**93,409**

- Coal (31,439 MW)
- Natural Gas (34,320 MW)
- Nuclear (11,682 MW)
- Wind (10,749 MW)
- Other (4,002 MW)
- Solar (1,217 MW)

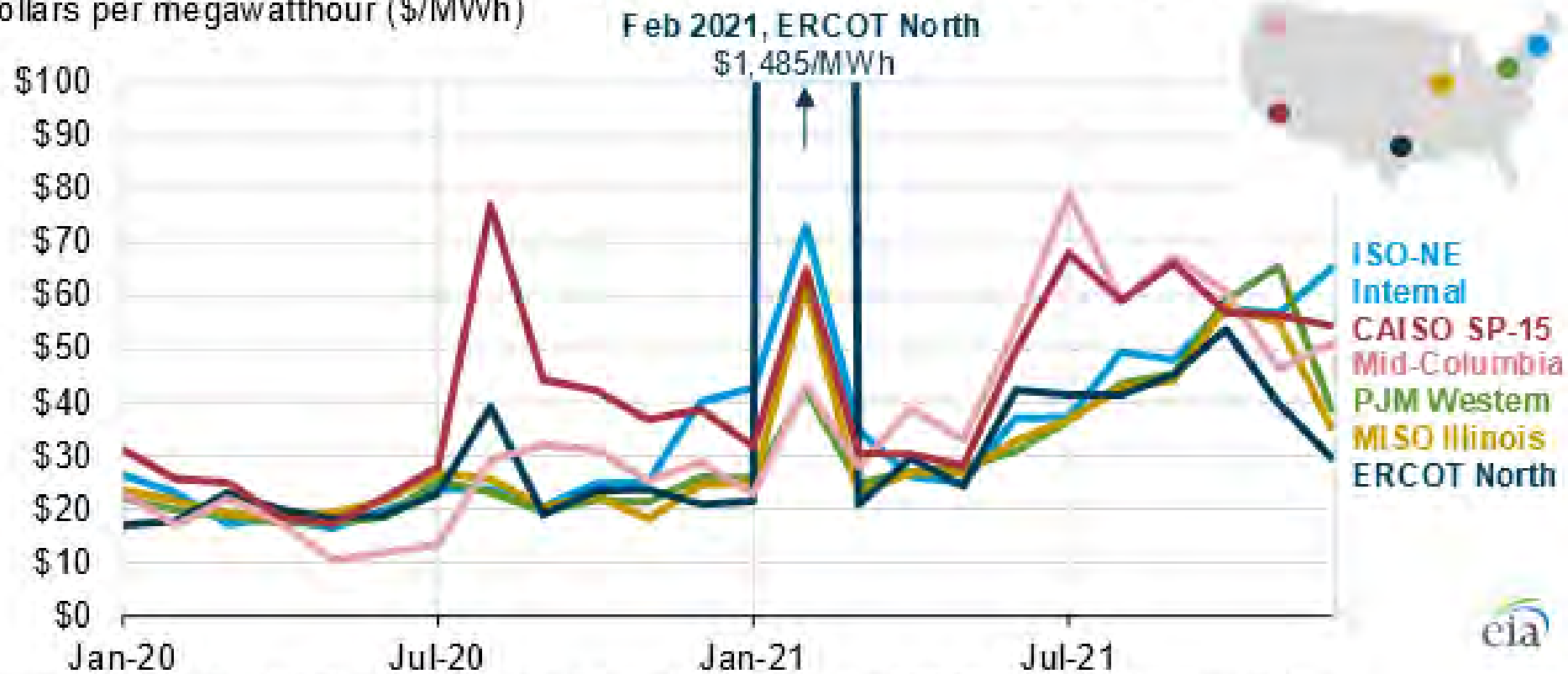
26-Jun-2023 - Interval 17:05 EST



■ Cleared Demand (MW) ■ Actual Load (MW) ■ Medium Term Load Forecast (MW)

# Wholesale electricity prices trended higher in 2021 due to increasing natural gas prices

Monthly average wholesale electricity prices at selected trading hubs (2020–2021)  
dollars per megawatthour (\$/MWh)



Source: Graph by the U.S. Energy Information Administration, based on S&P Global Market Intelligence data

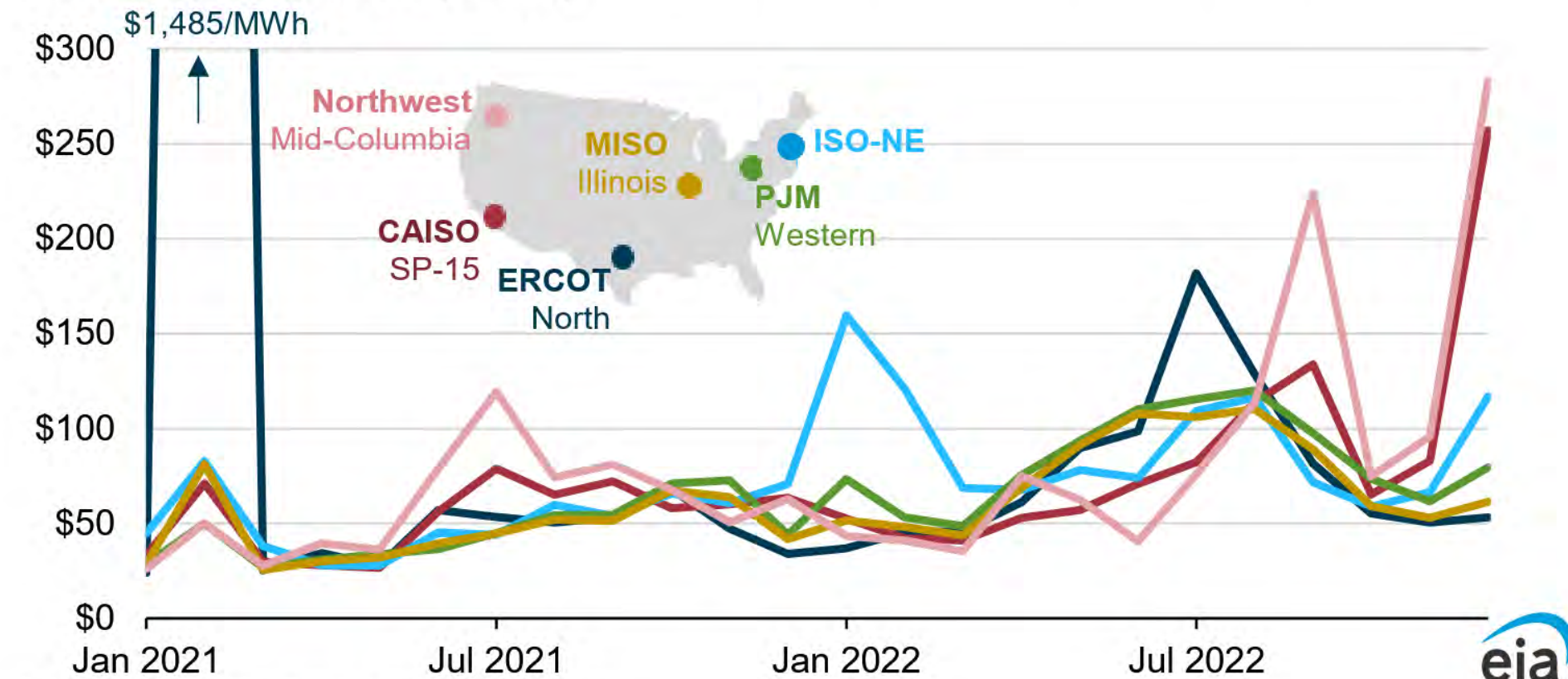




# Wholesale U.S. electricity prices were volatile in 2022

## Monthly average wholesale electricity prices at selected trading hubs (Jan 2021–Dec 2022)

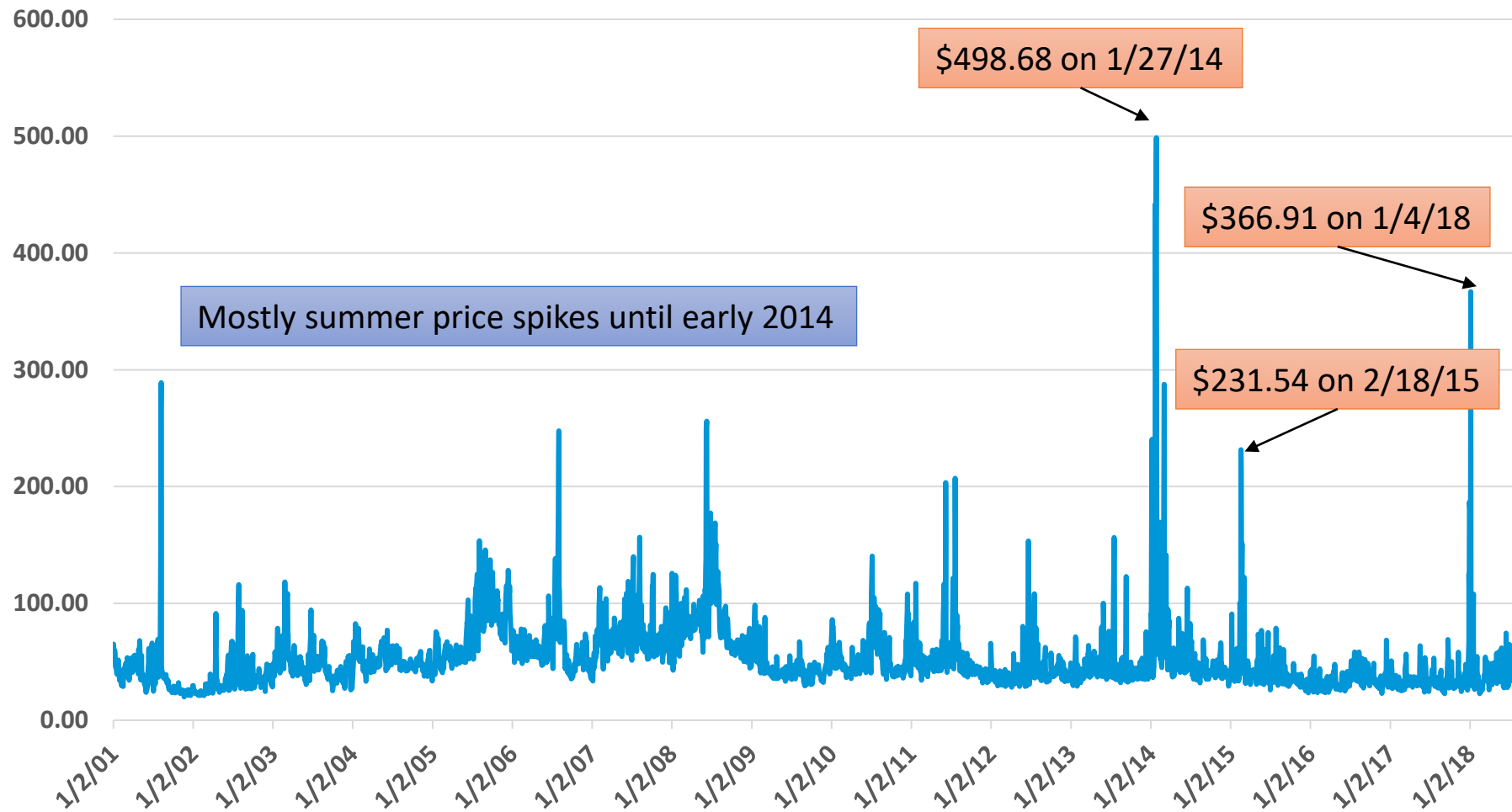
dollars per megawatthour (\$/MWh)



Data source: S&P Global Market intelligence

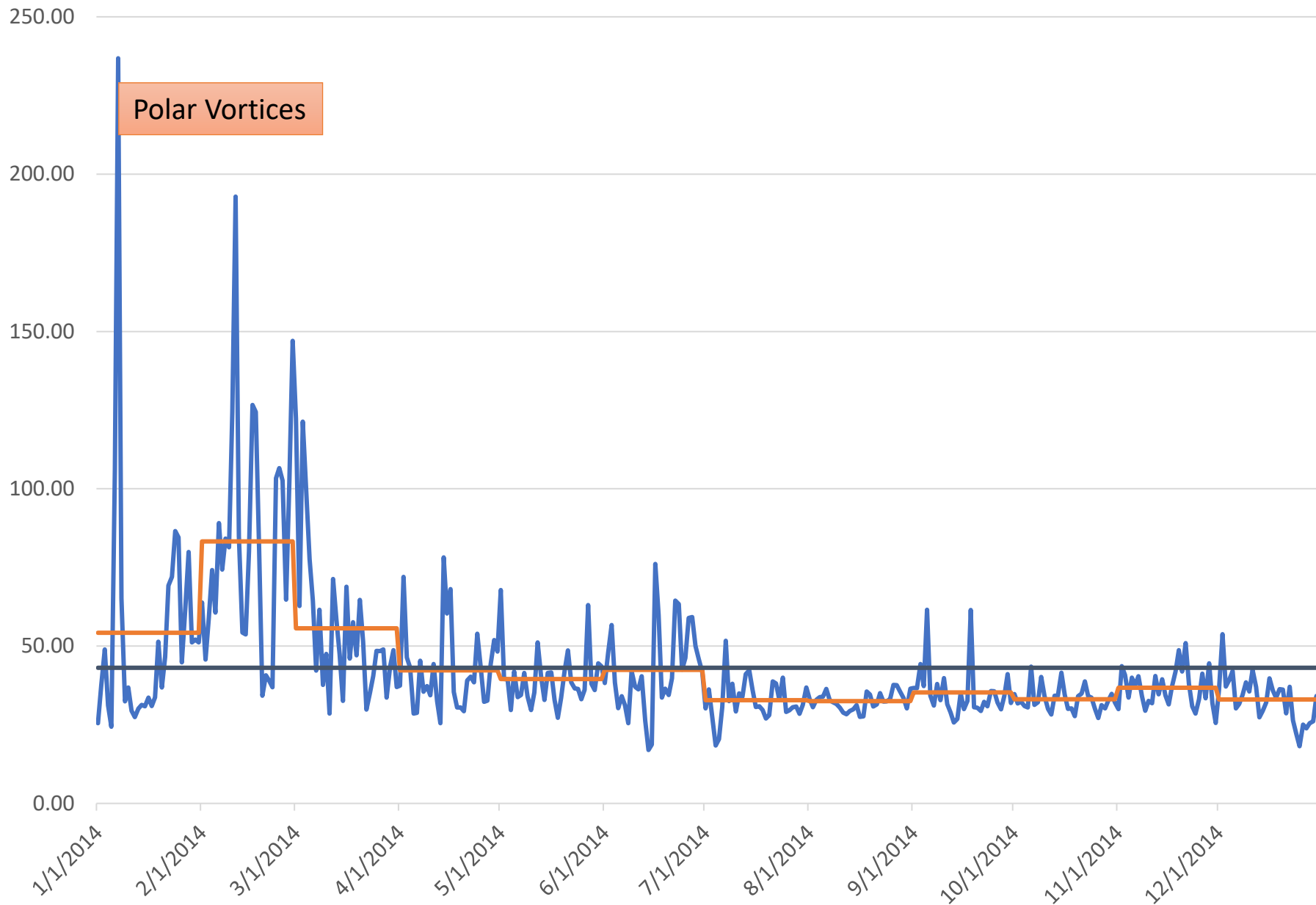


# PJM West Hub Weighted Average Price (\$/MWh)

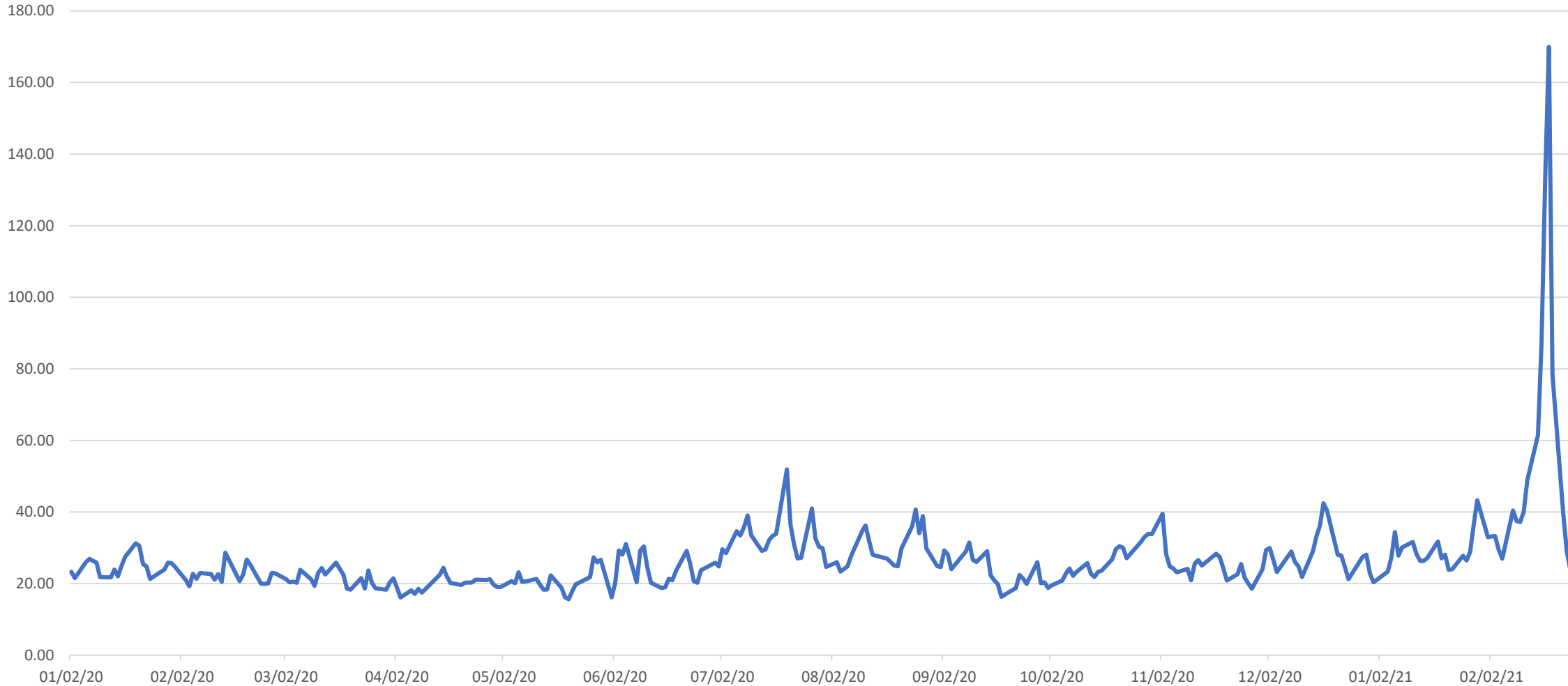




# MISO regional LMPs, January through December 2014

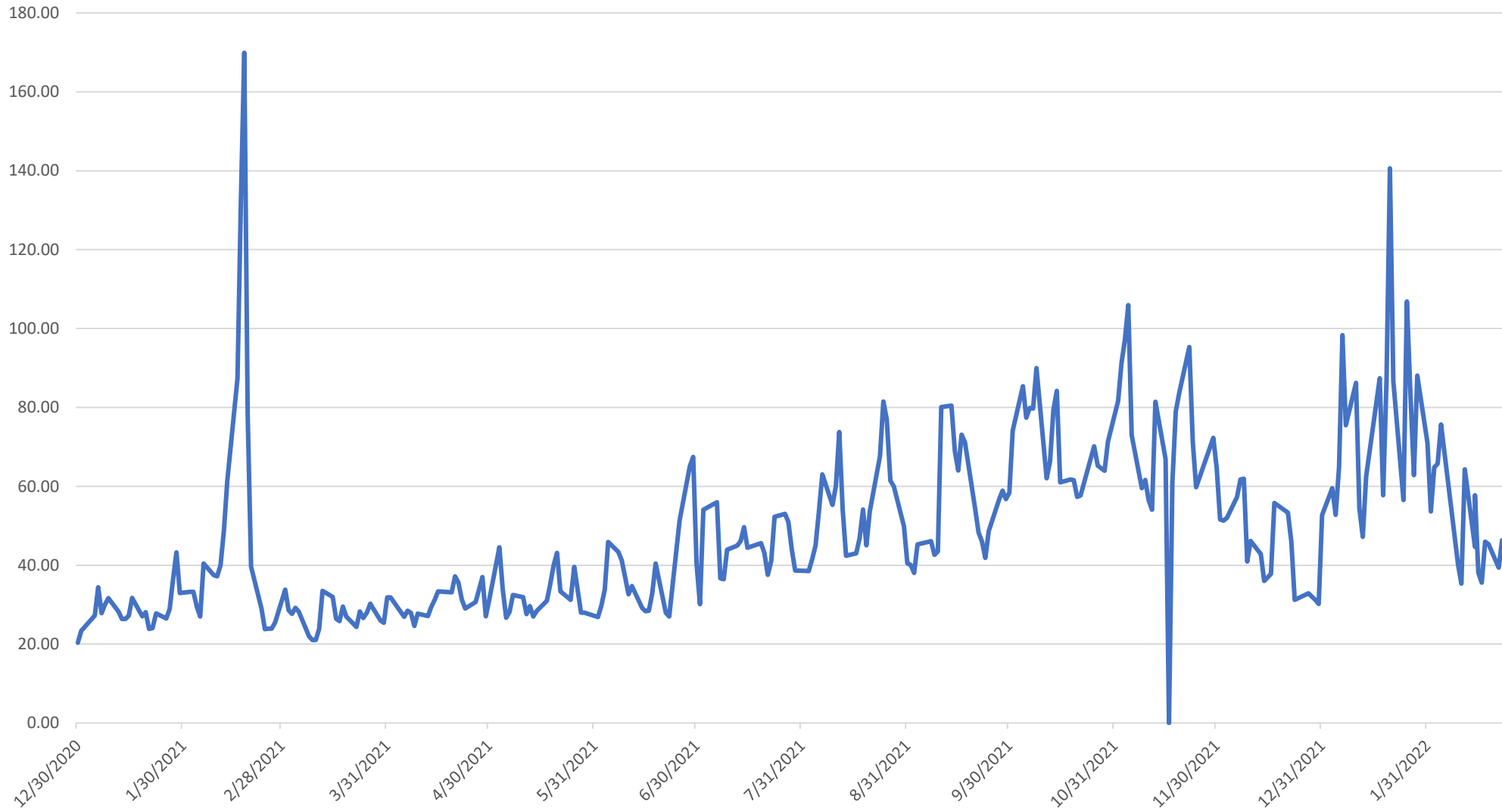


# PJM Western Hub Real Time Peak Price Wtd avg price \$/MWh

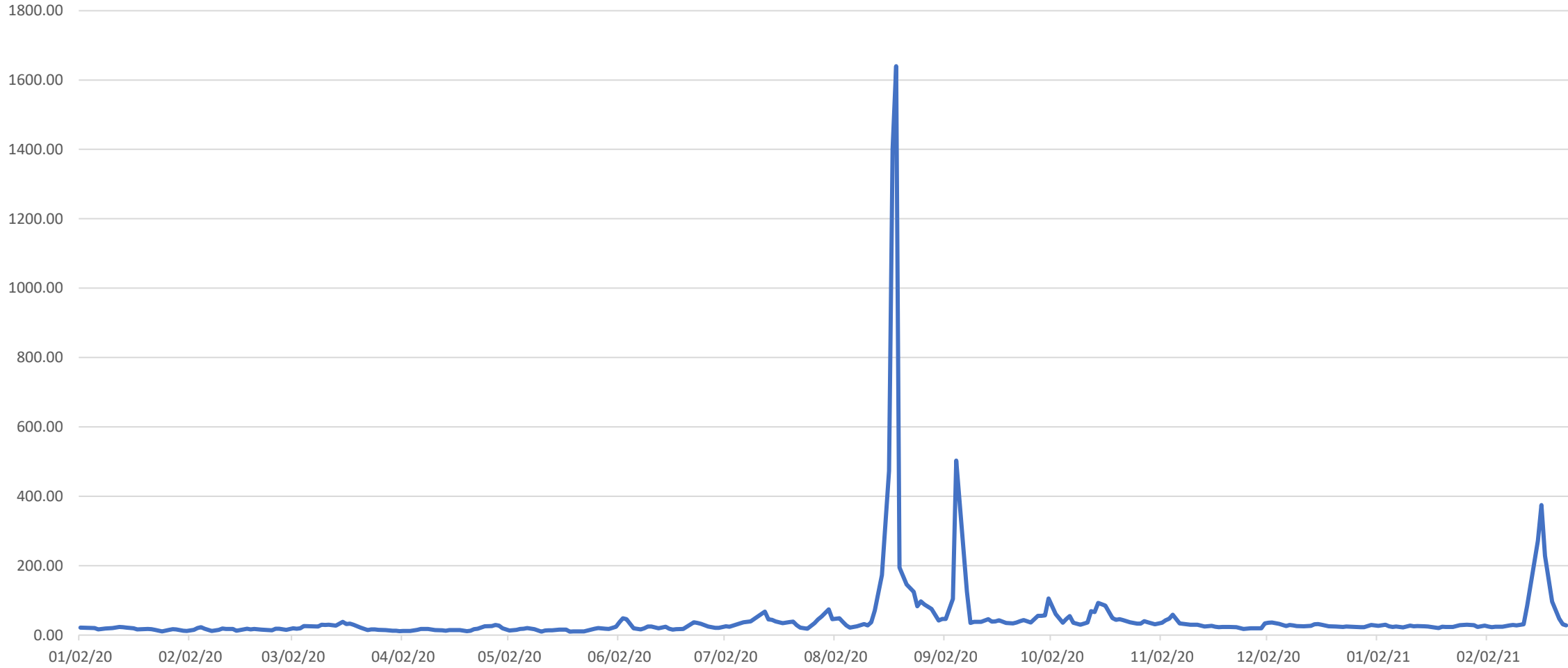


Data Source: [www.eia.gov](http://www.eia.gov) of Intercontinental Exchange (ICE) prices.

PJM WH Real Time Peak  
Wtd avg price \$/MWh

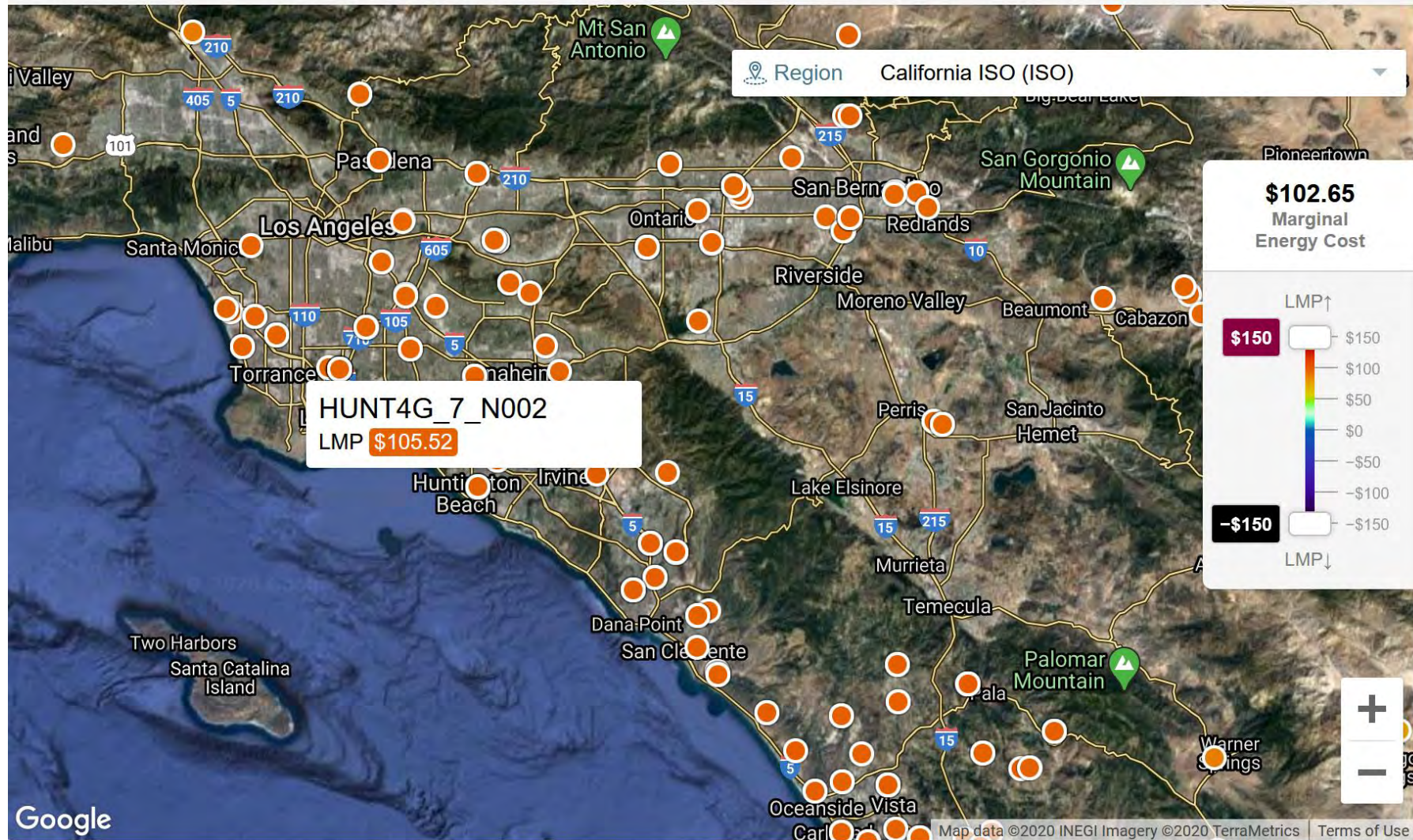


# Palo Verde Peak Price Wtd avg price \$/MWh



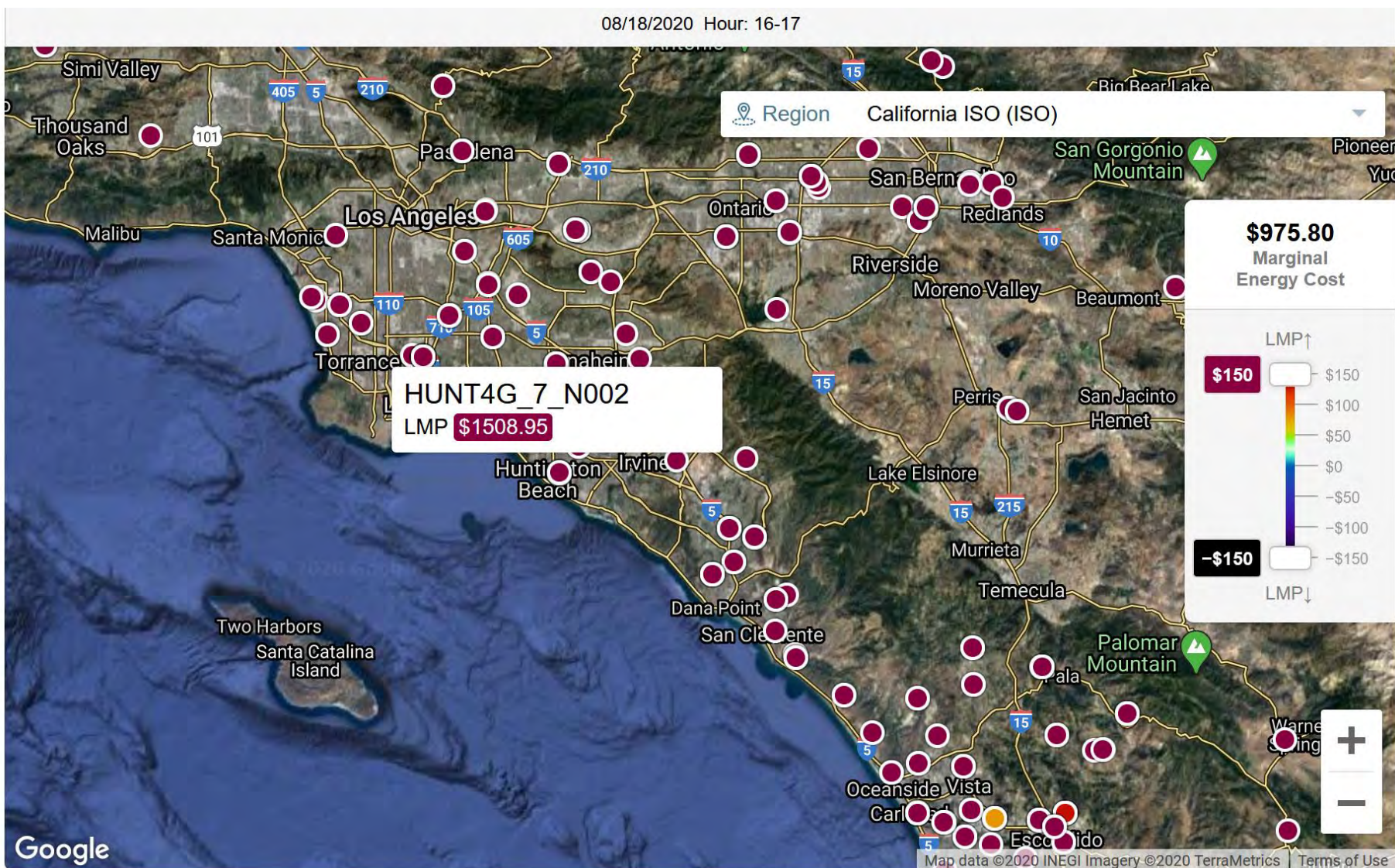
Data Source: [www.eia.gov](http://www.eia.gov) of Intercontinental Exchange (ICE) prices.

08/18/2020 Hour: 12-13 Interval: 1



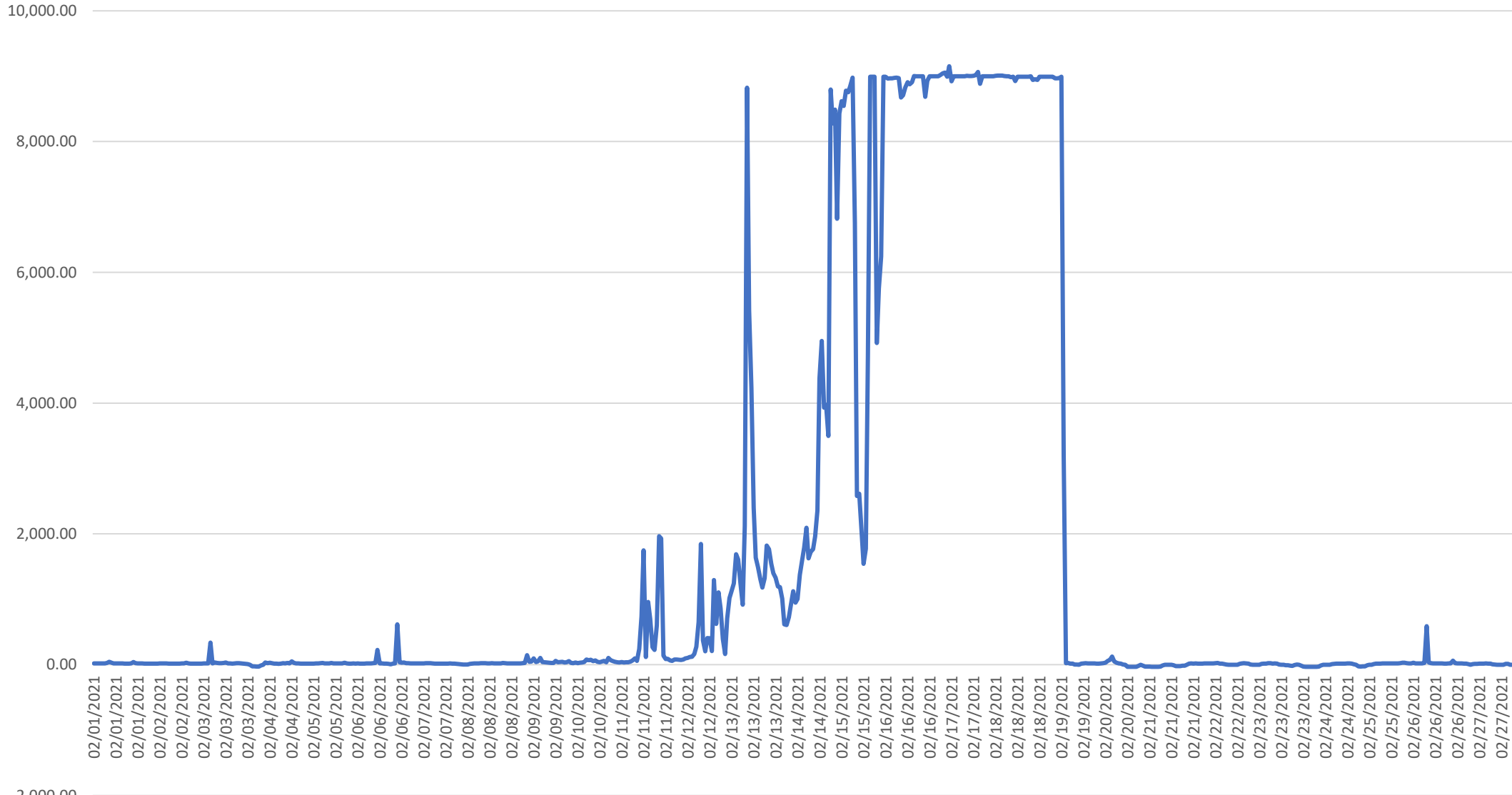


08/18/2020 Hour: 16-17





# Real-Time Market (RTM) Houston Hub Price

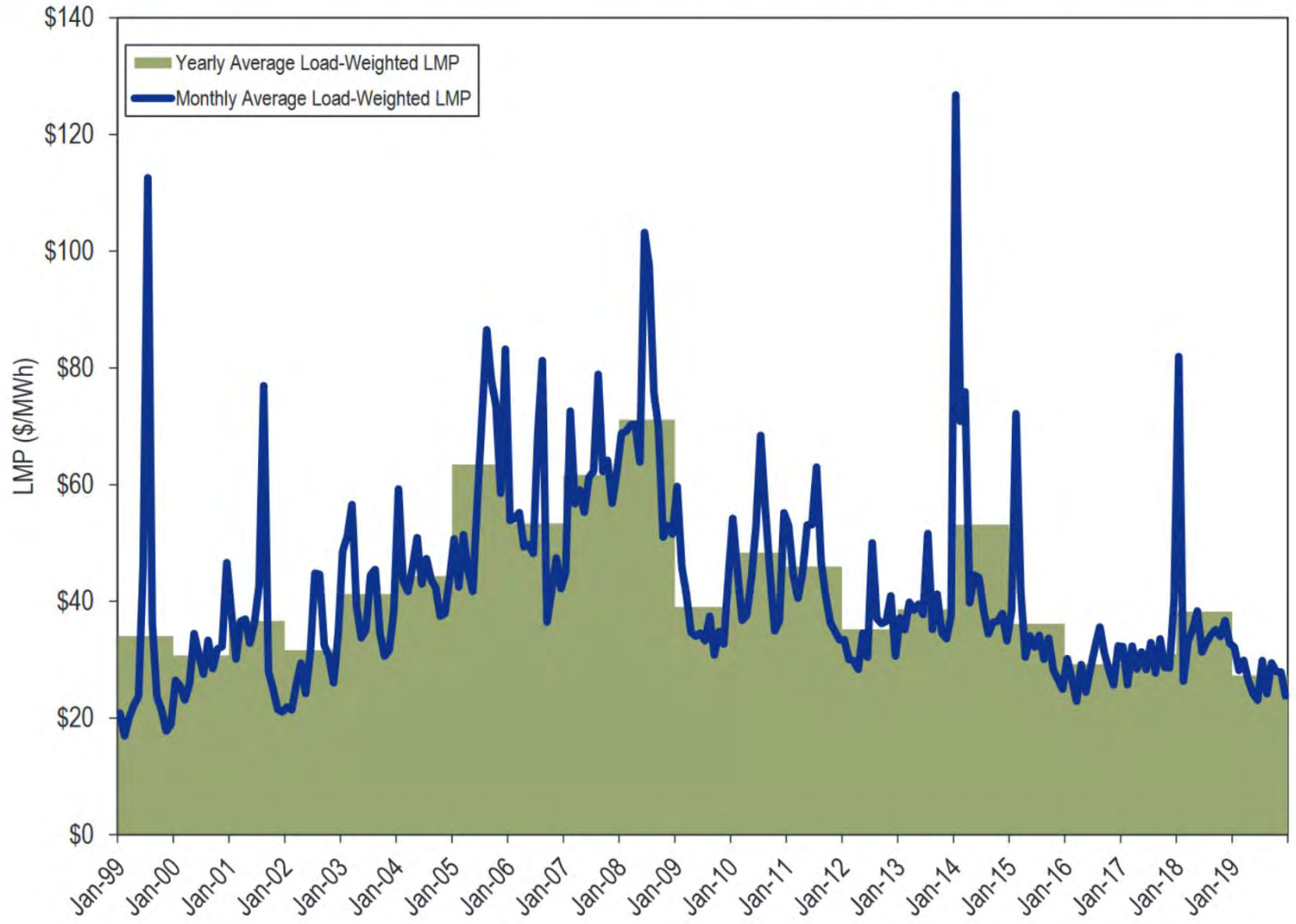


Data Source: Electric Reliability Council of Texas, Inc.

<http://www.ercot.com/mktinfo/prices>

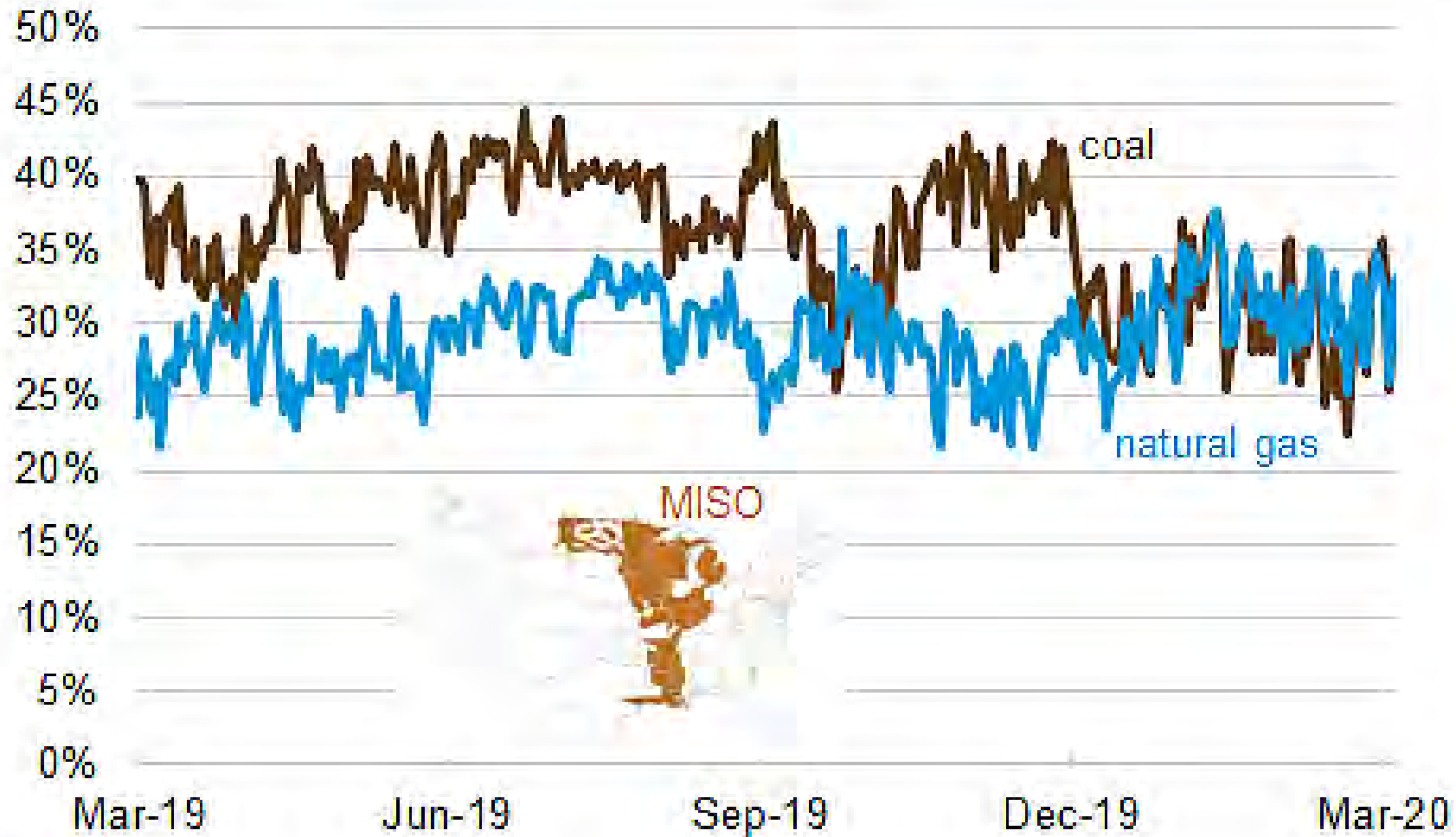
Source: "State of the Market Report for PJM," Monitoring Analytics, LLC, March 2020.

### Figure 7 Real-time, monthly and annual, load-weighted, average LMP: January 1999 through December 2019



# MISO electricity generation shares

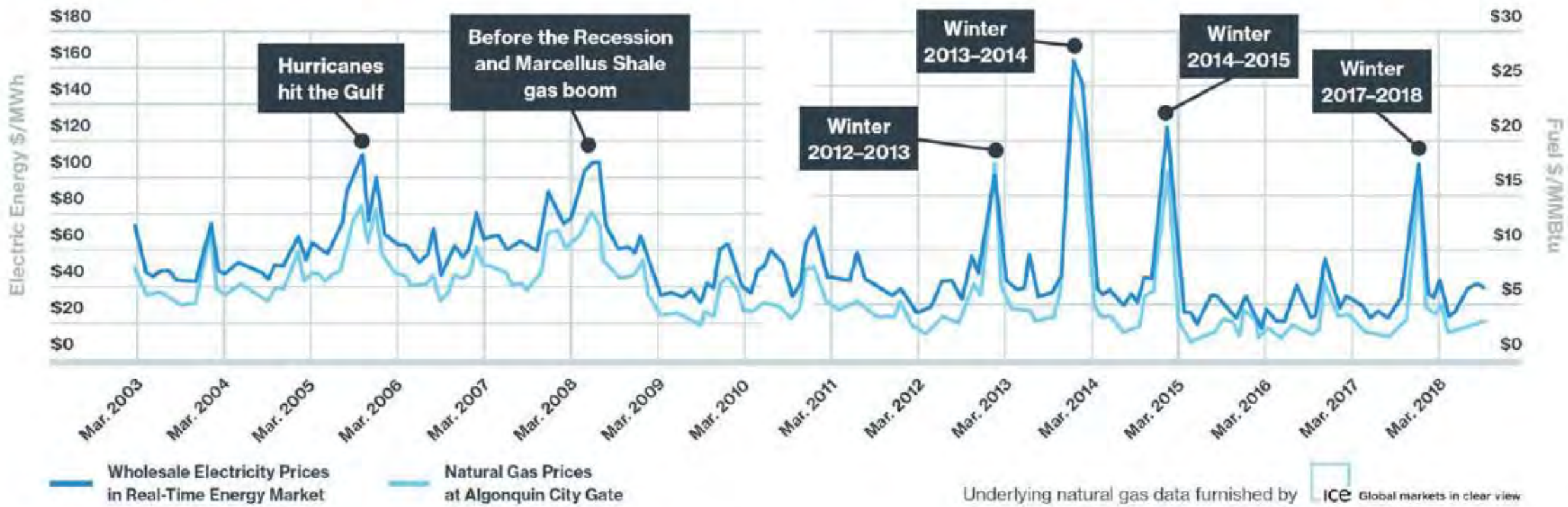
percent



Source: U.S. Energy Information Administration, U.S. Electric System Operating Data

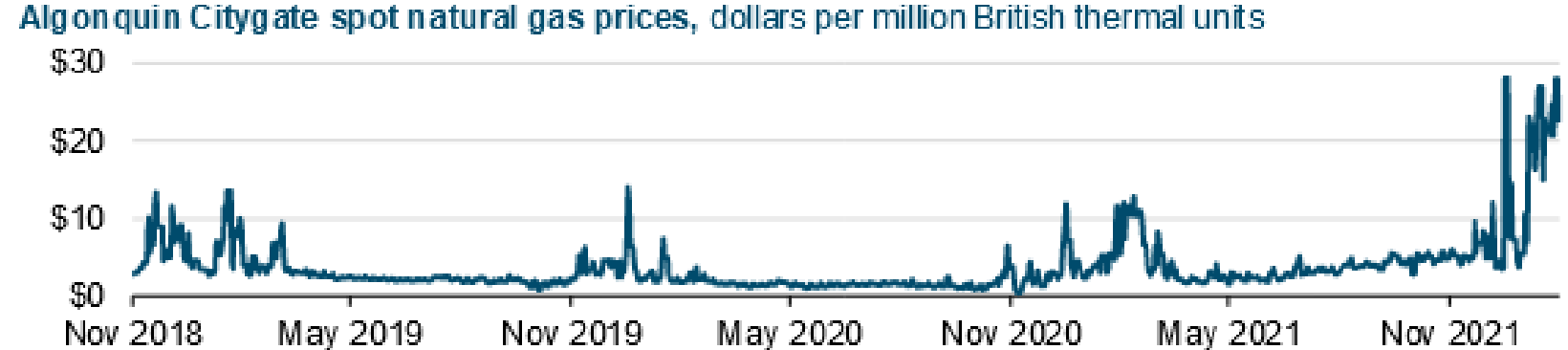
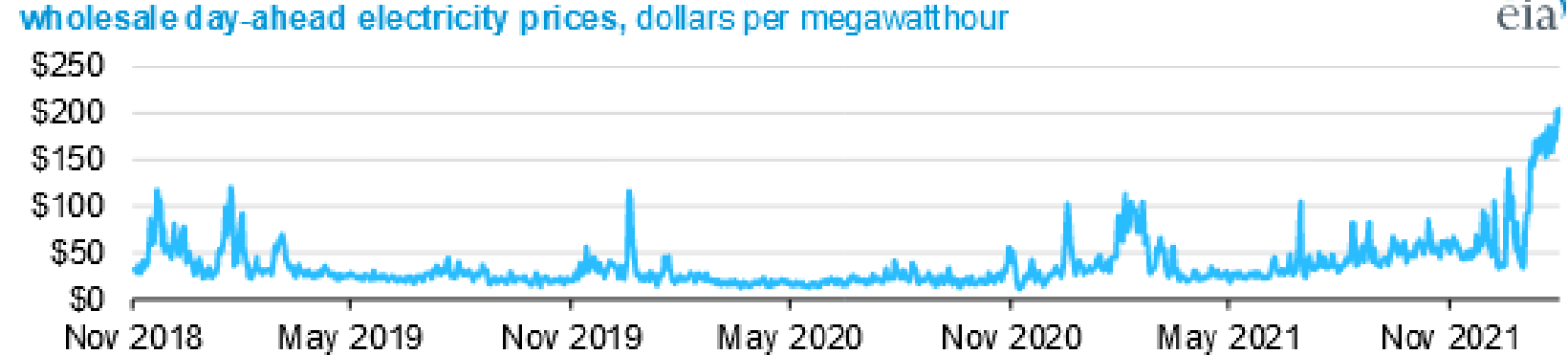
Source: ISO New England Inc.

## The Largest Driver of Wholesale Energy Costs is the Price of Fuel Used to Generate Electricity



# New England natural gas and electricity prices increase on supply constraints, high demand

**New England daily natural gas and electricity prices (Nov 1, 2018–Jan 31, 2022)**



Source: Graph created by the U.S. Energy Information Administration, based on data from Natural Gas Intelligence and S&P Capital IQ

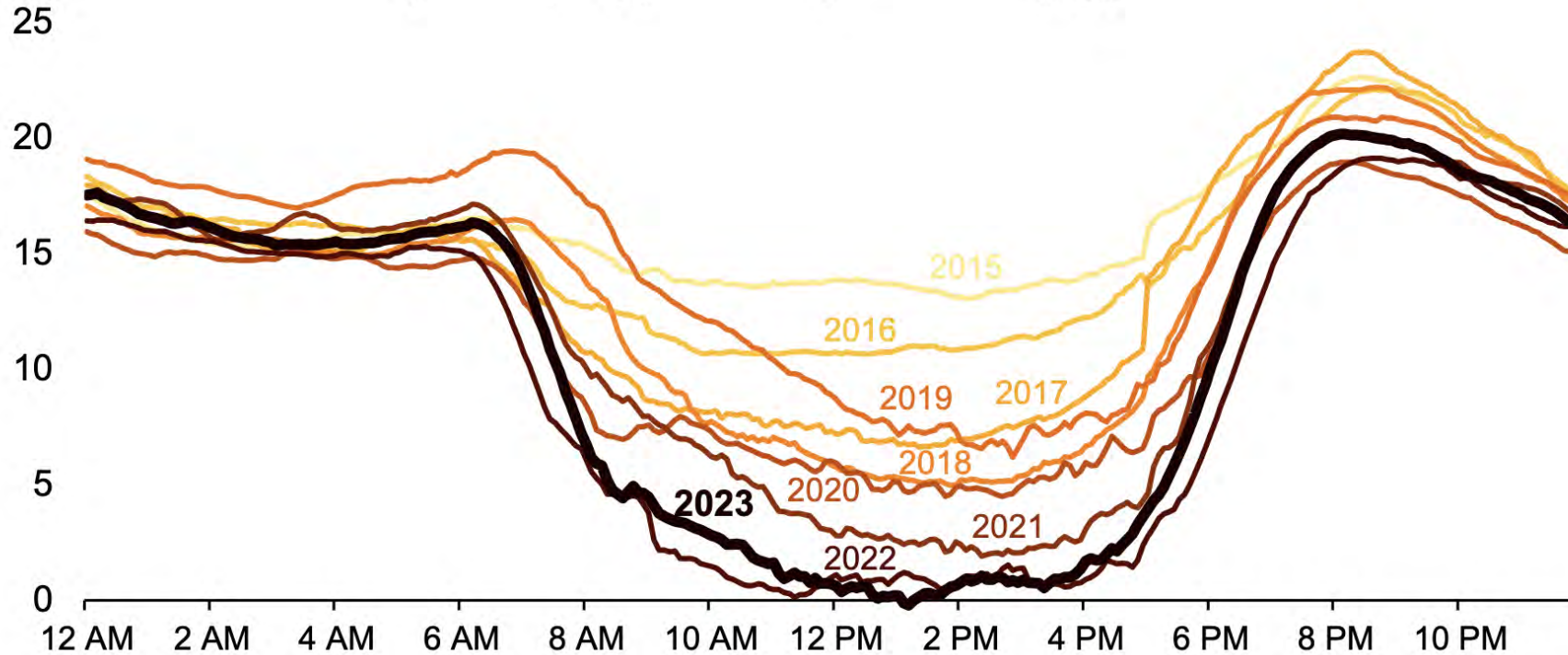


JUNE 21, 2023

## As solar capacity grows, duck curves are getting deeper in California

### California's duck curve is getting deeper

CAISO lowest net load day each spring (March–May, 2015–2023), gigawatts



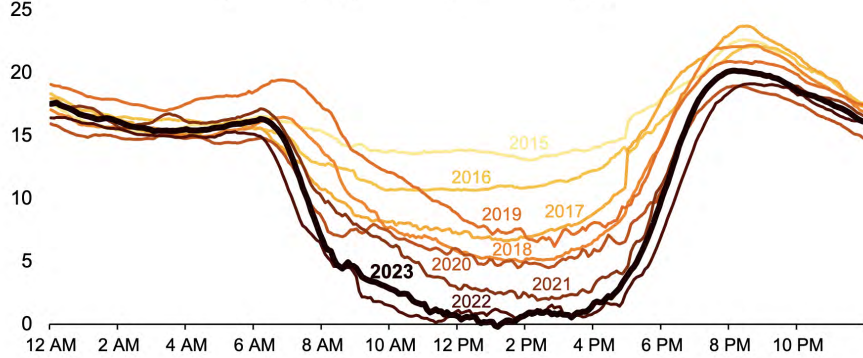


JUNE 21, 2023

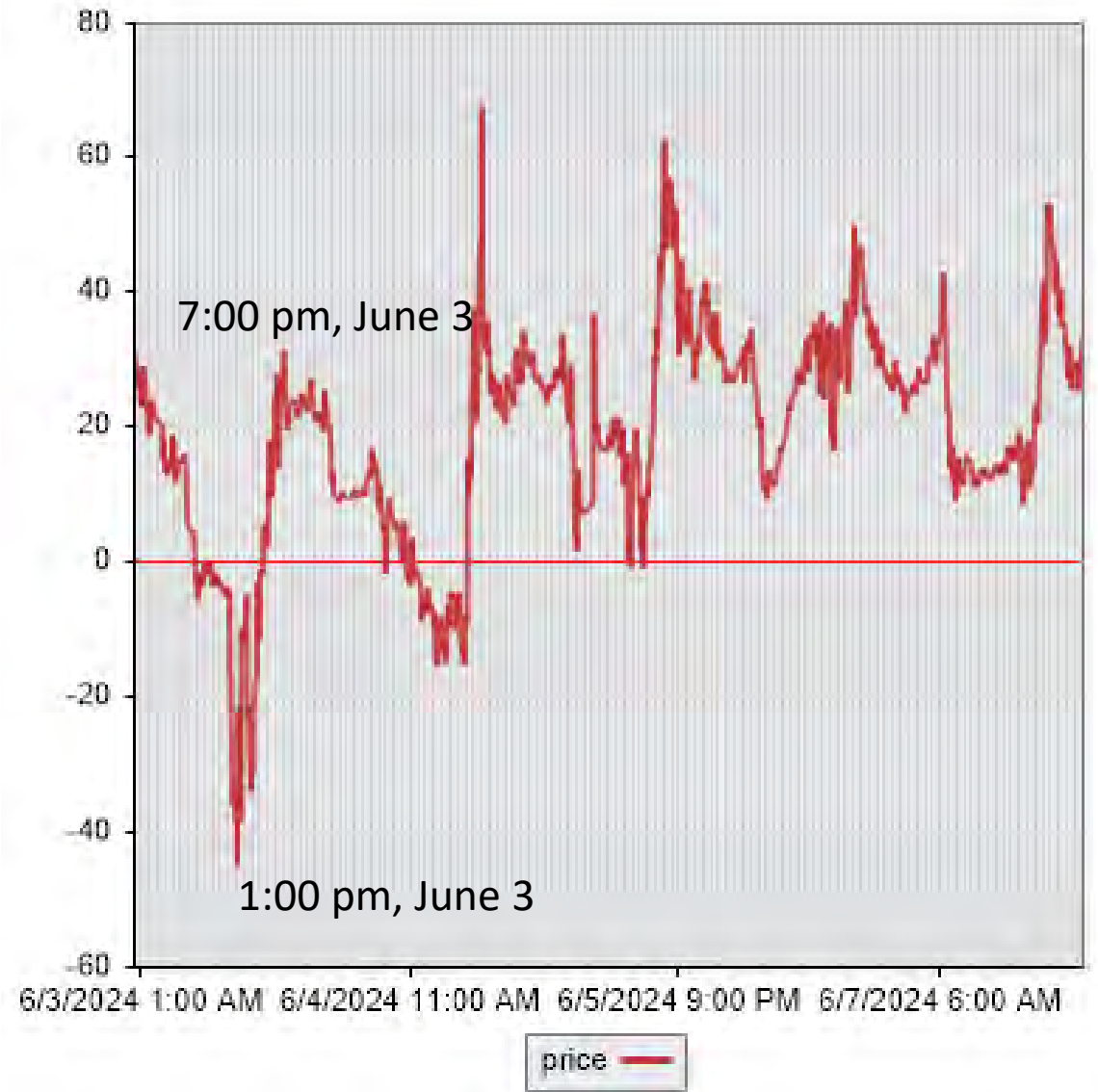
### As solar capacity grows, duck curves are getting deeper in California

#### California's duck curve is getting deeper

CAISO lowest net load day each spring (March–May, 2015–2023), gigawatts



The graph on the right shows wholesale prices in the California RTO from June 3 to June 7, 2024. The lowest prices are actually in the middle of the day.



# Poll #4

Which of the following was discussed as an important factor influencing price behavior in RTO spot electricity markets?

- The behavior of OPEC (the global oil cartel)
- The next presidential election
- Plans to build new transmission
- The price of natural gas

# RTO capacity markets

- Many RTOs--PJM, ISO New England, New York ISO, Midcontinent ISO (MISO) have developed “locational” (or sub-regional) capacity markets. The capacity markets in PJM, ISO New England and New York are considered to be “mandatory” in the sense that the capacity market is the mechanism by which the RTO demonstrates that it has met its installed capacity requirements for reliability.
- These are intended to encourage building new capacity, retaining existing capacity, and permit other resources, such as demand-response programs, to also participate in the market

# Reasons given for creating RTO capacity markets

- Capacity markets are odd, and very controversial. Almost no other industry has them. They are justified on several bases:
  - ✓ Energy and ancillary services markets have price caps, which create revenue shortfalls for high-cost power plants that are otherwise needed for peak-time reliability;
  - ✓ Electric rates don't reflect market prices on a day to day basis, giving consumers little incentive to conserve energy during peak demand periods;
  - ✓ In states that have introduced retail competition (more on that later), the obligation for meeting resource adequacy requirements has moved away from the utility (the utility no longer has the obligation to meet all peak demand, so it also doesn't have the obligation to build enough capacity to meet all peak demand)

# Capacity Market Basic Elements

- They include similar basic elements:
  - 1) an obligation on those responsible for serving end-use customers (load) to have sufficient capacity to reliability serve that load;
  - 2) a methodology to determine a capacity reserve margin and future capacity needs for sub-regions within the RTO and for the entire RTO;

# Capacity Market Basic Elements (*continued*)

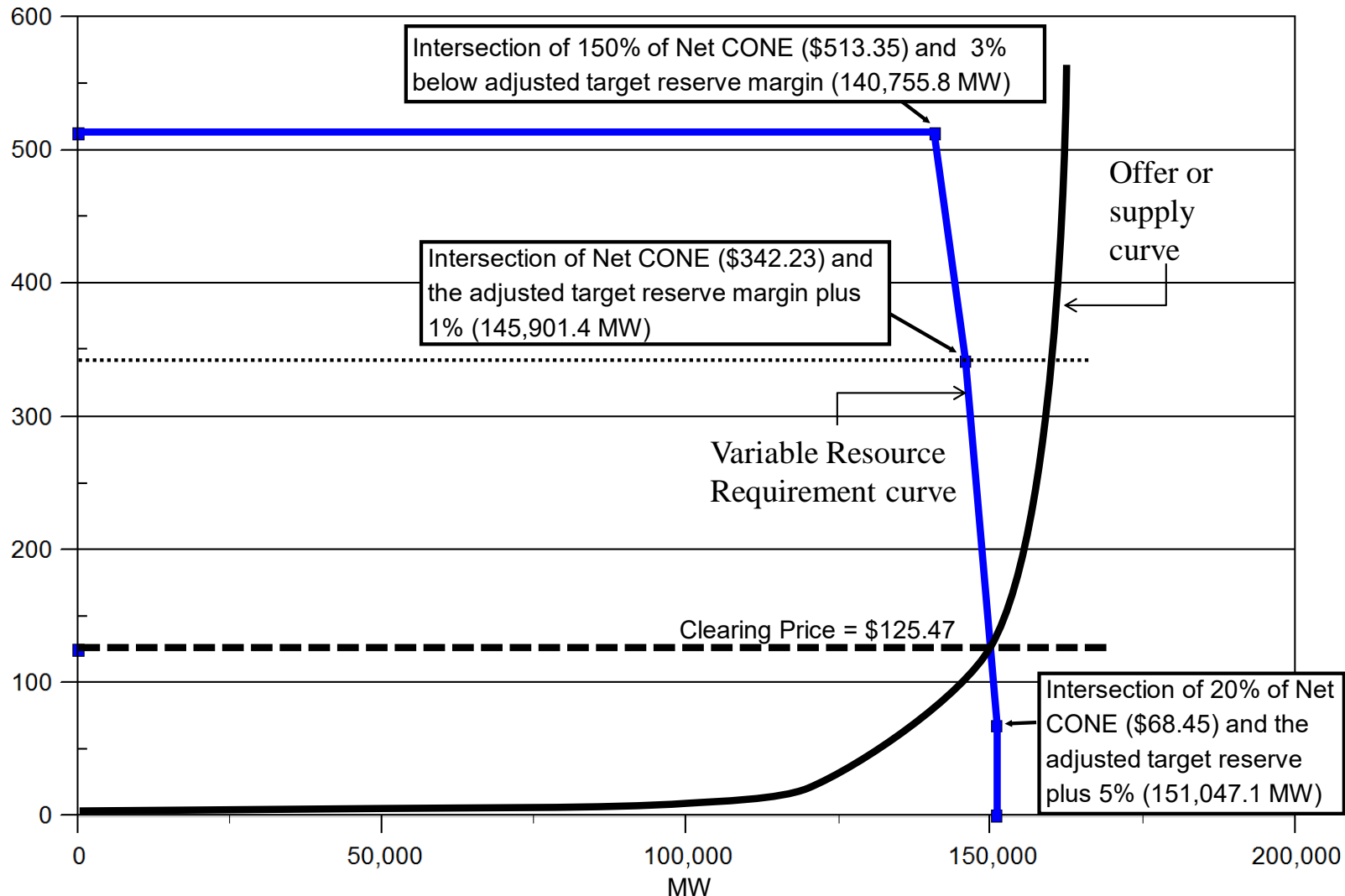
- 3) a process for soliciting qualified supply (and demand) resources to meet future capacity needs (for constructing an offer or supply curve);
- 4) some type of benchmark to judge the cost of new capacity;
- 5) a methodology or approach for setting a limit on the amount of capacity required or creating a “demand curve”; and
- 6) a process (such as an auction) to select resources and determine a capacity “price”



# Capacity Market Example

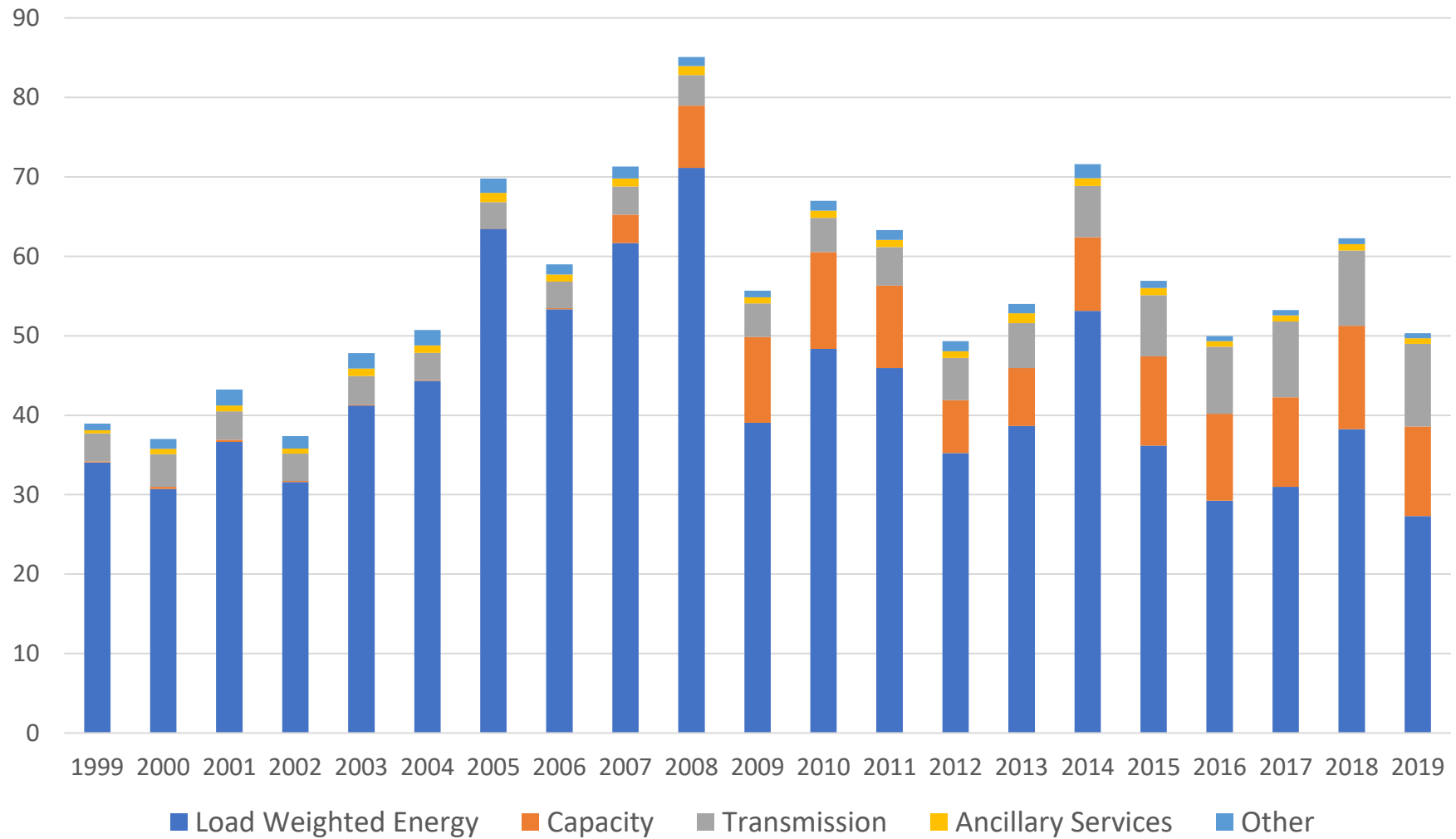
- PJM's Reliability Pricing Model (RPM)
  - replaced the Capacity Credit Market ("CCM")
  - RPM uses locational capacity pricing
  - three-year-forward obligations and commitments for capacity
  - auctions (began April 2007) where capacity prices are determined with offer-based supply curves cleared against downward-sloping "demand curves"

# PJM 2014/2015 Base Residual Auction (\$/MW-Day)



Source: Based on information from PJM, <http://www.pjm.com/markets-and-operations/rpm/rpm-auction-user-info.aspx>.

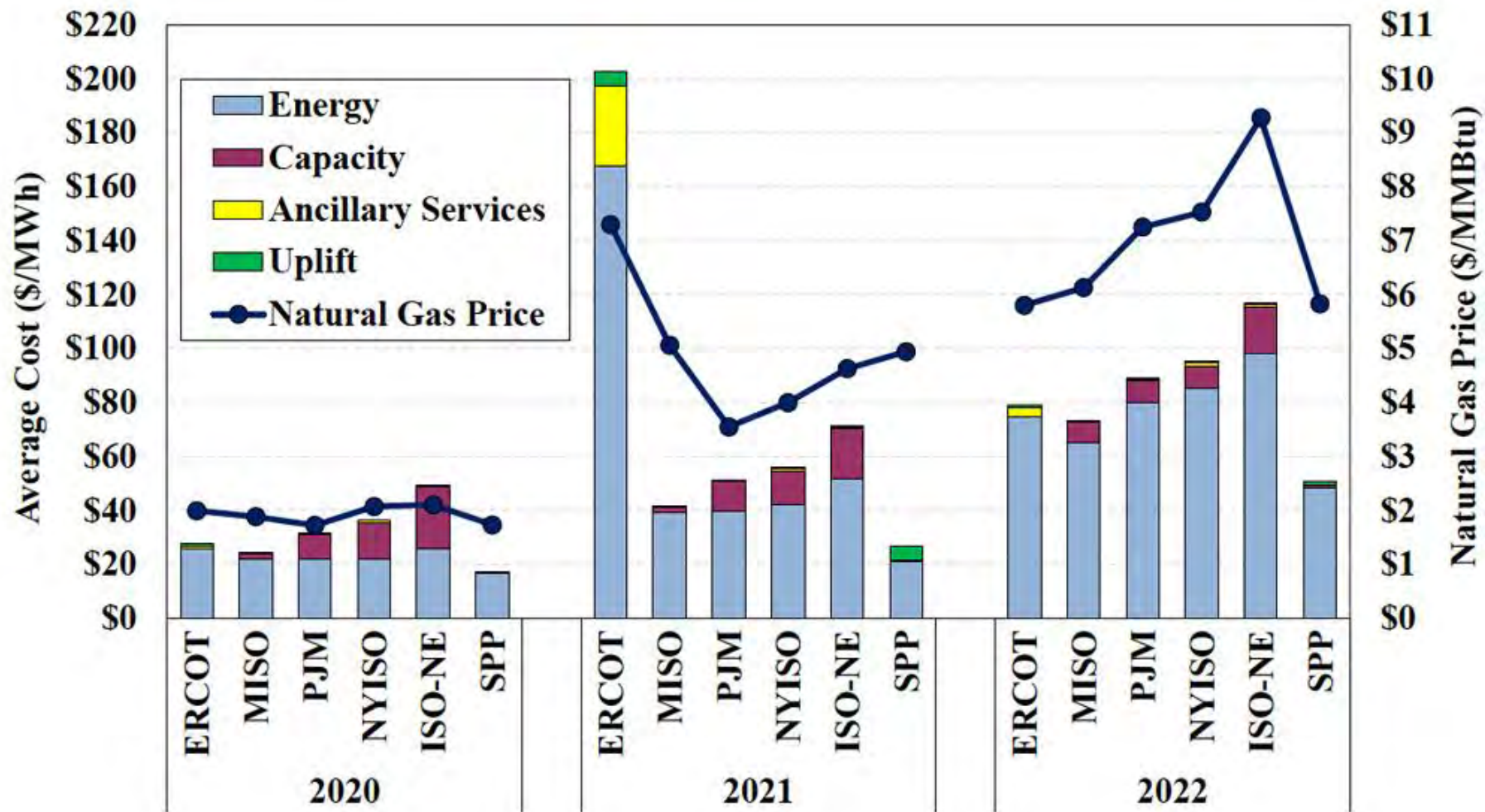
# Total price per MWh by category, 1999 through 2019 (\$/MWh)



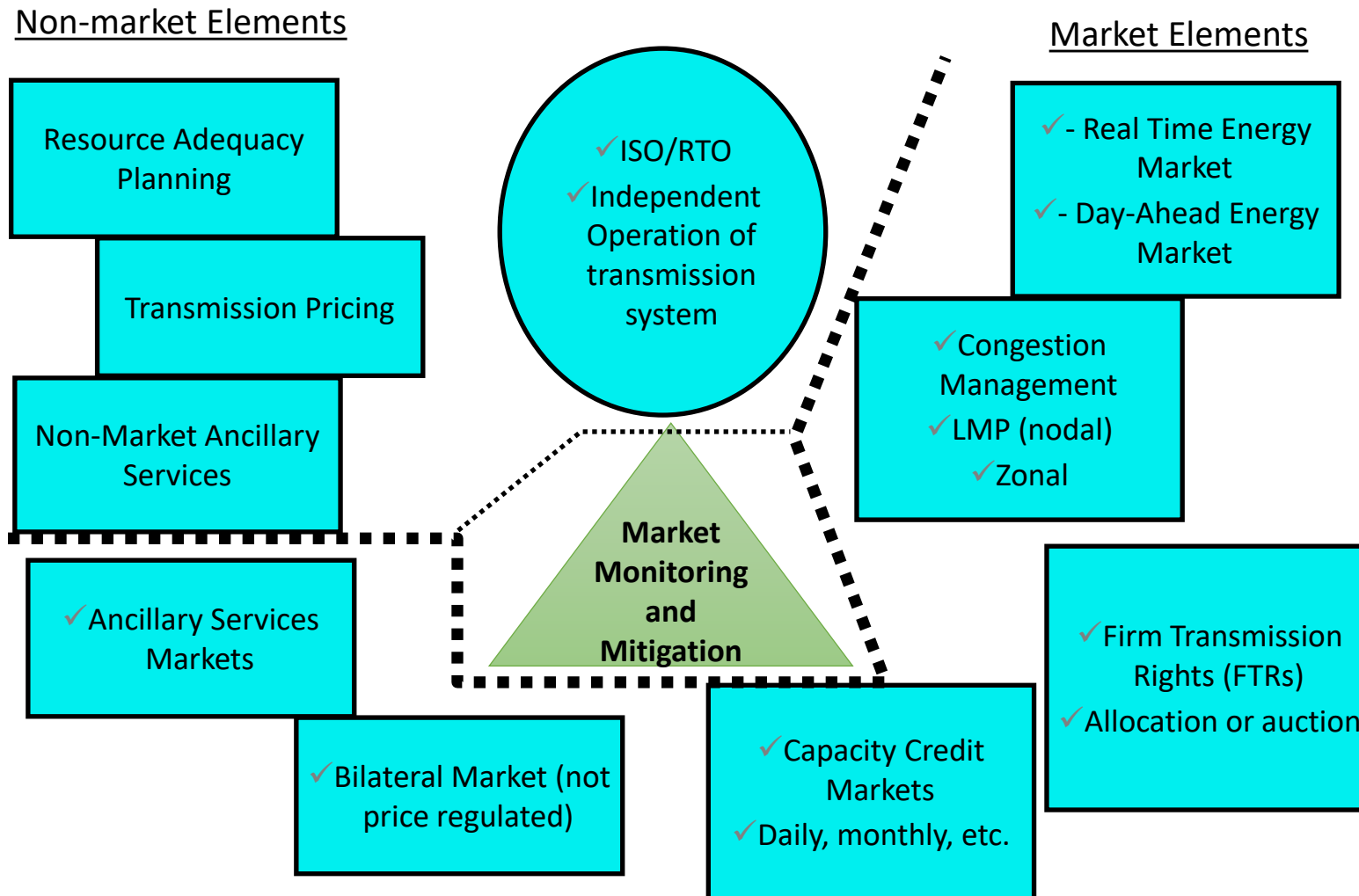
Data Source: Monitoring Analytics, LLC, 2019 State of the Market Report for PJM, March 2020.

# Annual Value of Wholesale Electricity Markets





# The Role of “Market Monitors”





# The Role of “Market Monitors”

- Electricity markets are highly susceptible to manipulation, because of transmission constraints, high cost of storage and low “price elasticity of demand” (in the short term there are no substitutes for electricity)
- The “old” method of manipulating electricity markets (a la California circa 2000/2001) would be to physically withhold supply from the market, jacking up prices.
- More recent market manipulation cases have involved “cross-market” manipulation – influencing the outcome in one RTO market (e.g. day-ahead energy) in order to earn higher profits in a different RTO market (e.g. congestion hedges)

# The Role of “Market Monitors”

- Each RTO has an independent market monitor that evaluates several things and will flag potentially uncompetitive behavior:
  - supply/demand conditions
    - entry barriers, transmission access/constraints, new entry and entry conditions, price responsiveness
  - prices
  - market power detection
  - market manipulation by market participants
- Evaluate each of the ISO/RTO's markets and other relevant markets (e.g., neighbors with significant interchange)

## Market Monitoring (*continued*)

- Reporting
  - to RTO governing bodies, FERC, states, public, etc.
  - annual and other regular reports
  - reports on special issues or topics
- Suggesting improvements in market structure, procedures, regulations, etc.
- Can identify problems with liquidity, access, or performance in markets and suggest solutions

## What is Market Power?

- Market power is the ability of a firm or group of firms to raise *and maintain* the product price *significantly* above a competitive level
- This is the price leverage ability a firm must have to raise the price above a competitive price
- Must be large enough and persist for an appreciable amount of time to be of concern
- Many firms have some degree of market power -- but it usually does not warrant government intervention

## Market Analysis Tools Used by FERC and RTOs

- Market concentration measures
  - Herfindahl-Hirschman Index (HHI), wholesale market share, pivotal supplier index
- Monitor for market manipulation (deception and fraud) or affiliate abuse
- Vertical structural requirements for transmission operation
- *FERC's emphasis is on concentration measures, behavior (manipulation and fraud), and transmission operational control and vertical market power*

# What is the structure of wholesale markets and how does it contribute to market power?

- Markets are concentrated regionally and highly concentrated locally
- Significant entry barriers still exist
  - for new generation capacity
  - from transmission constraints
- Inelastic demand
- Continuous interaction of suppliers and knowledge about other suppliers' cost
  - increases the likelihood of strategic bidding and tacit collusion (not covered in FERC "Market Behavior Rules")