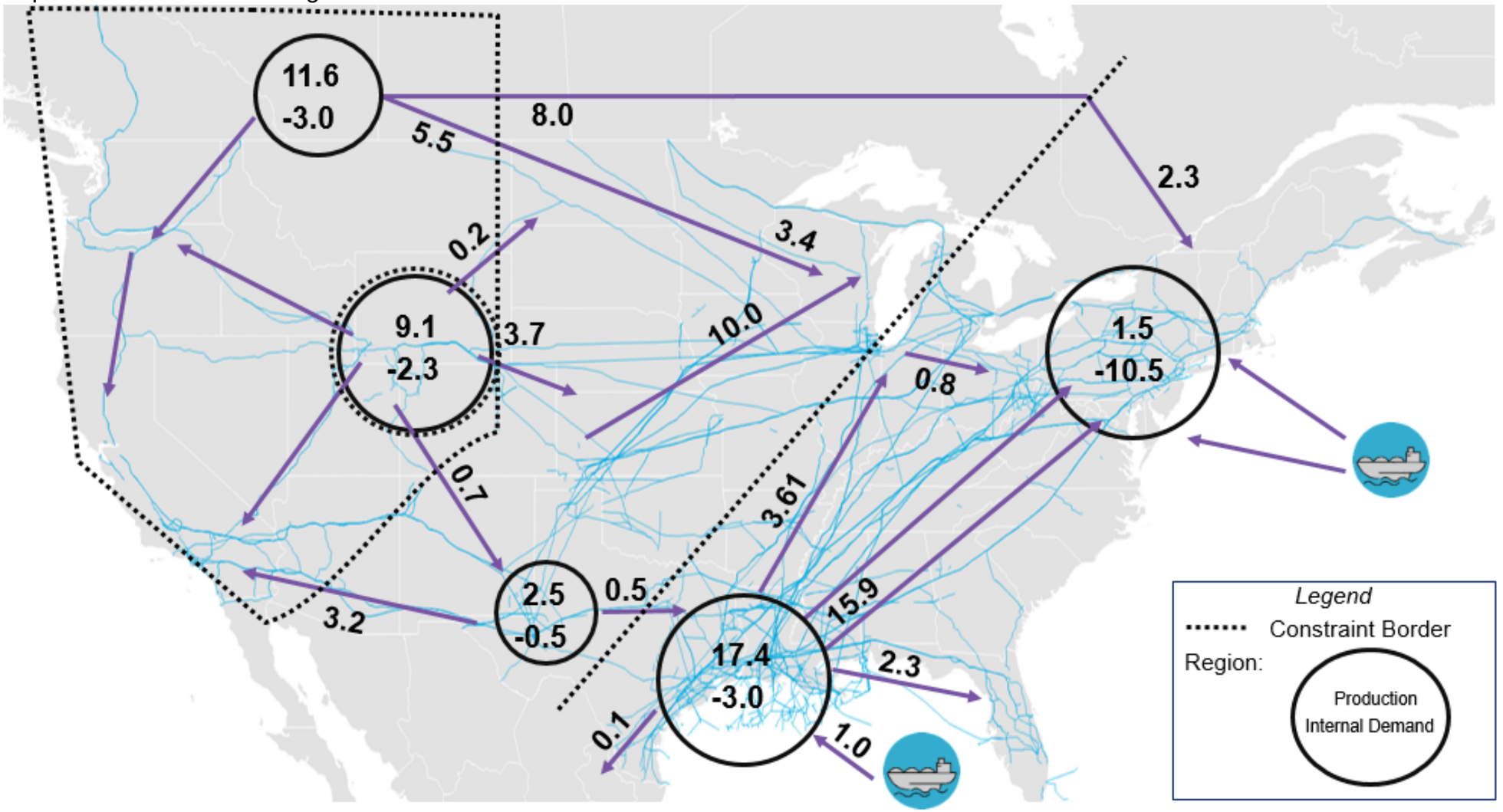
Contents

The Shale Revolution

10 Years of Manufacturing US Natural Gas

Historical Gas Markets (Winter '08-'09)

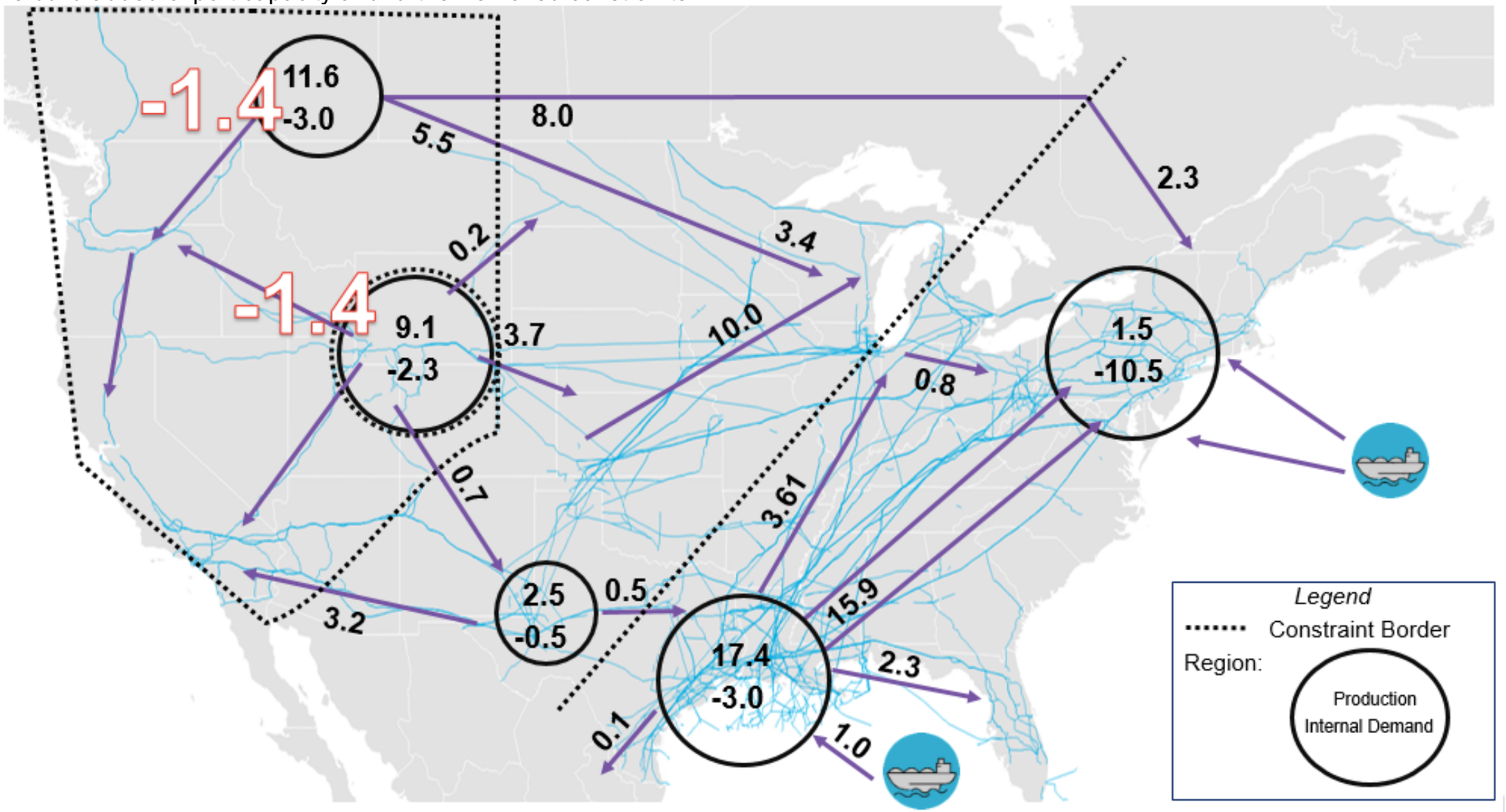
- Regional dynamics were isolated
- Market participants focused on local regions



Source: BloombergNEF. For general illustrative purposes only. Does not include storage in any region, or the Midwest, Midcontinent, and California markets.

Transition to Today

- Western Supply regions became shorter by 2.8 Bcf/d combined
- New pipeline build added export capacity and further removed constraints



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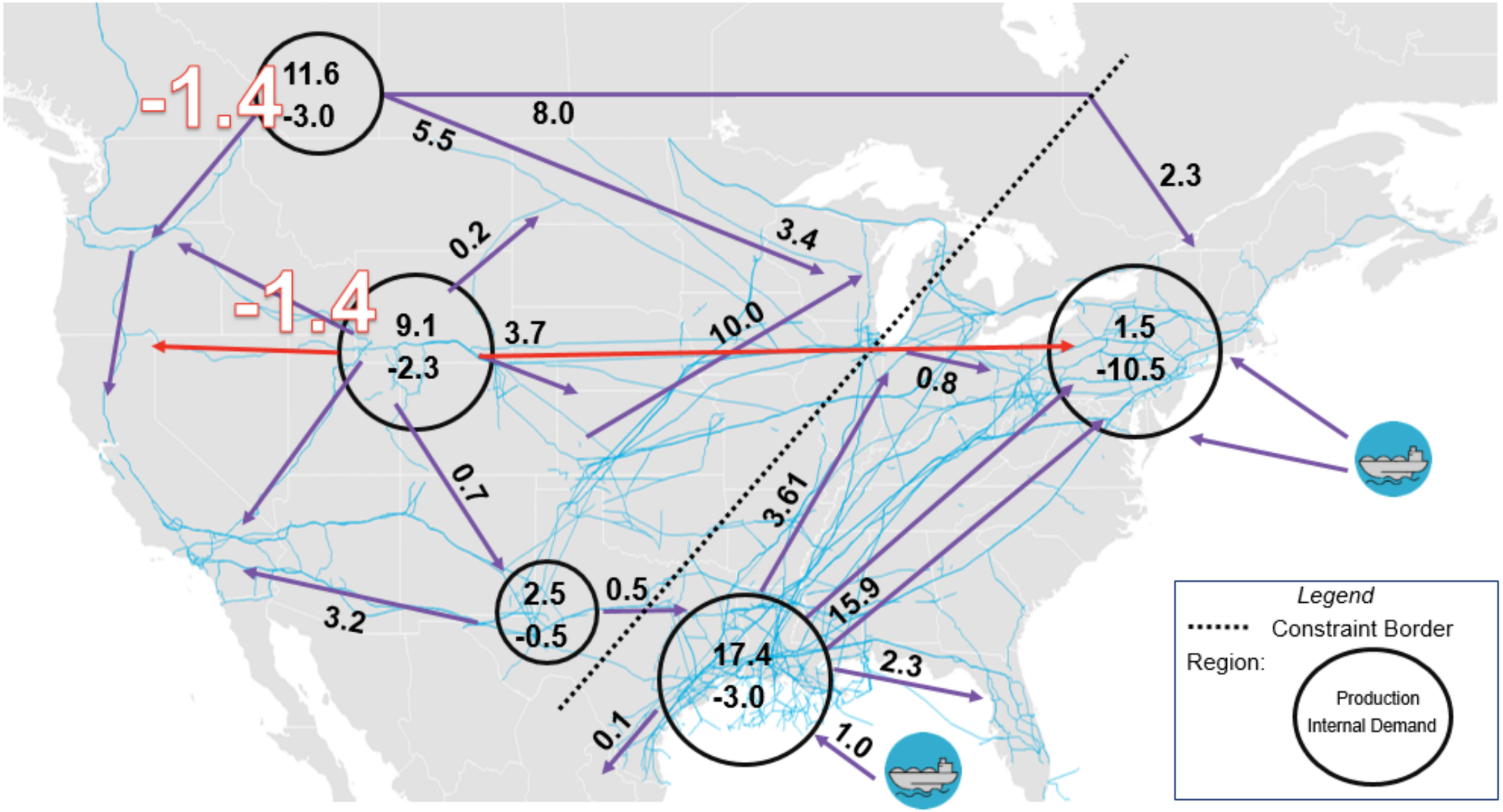
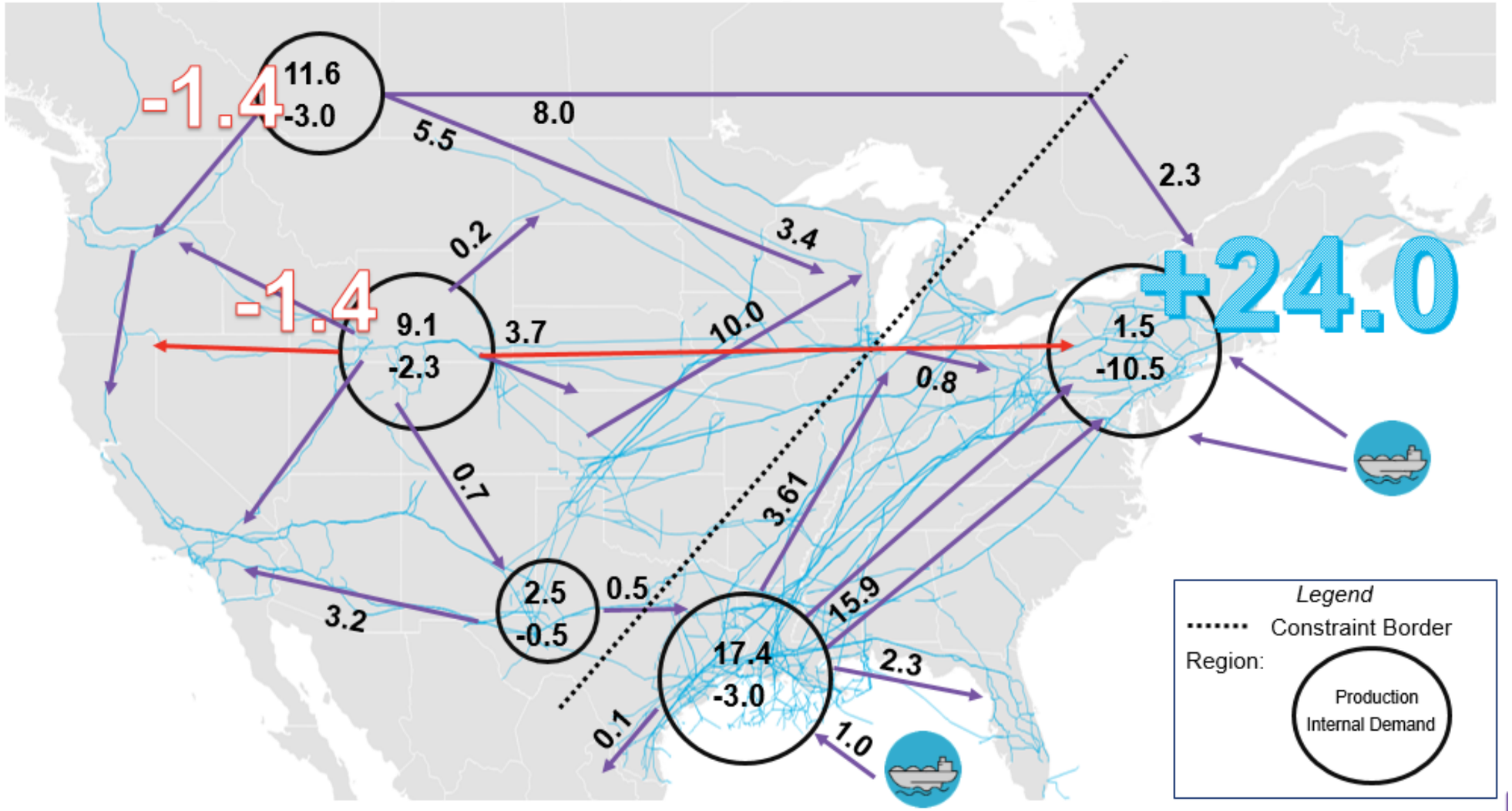


Source: BloombergNEF. For general illustrative purposes only. Does not include storage in any region or the Midwest, Midcontinent, and California markets.

Transition to Today

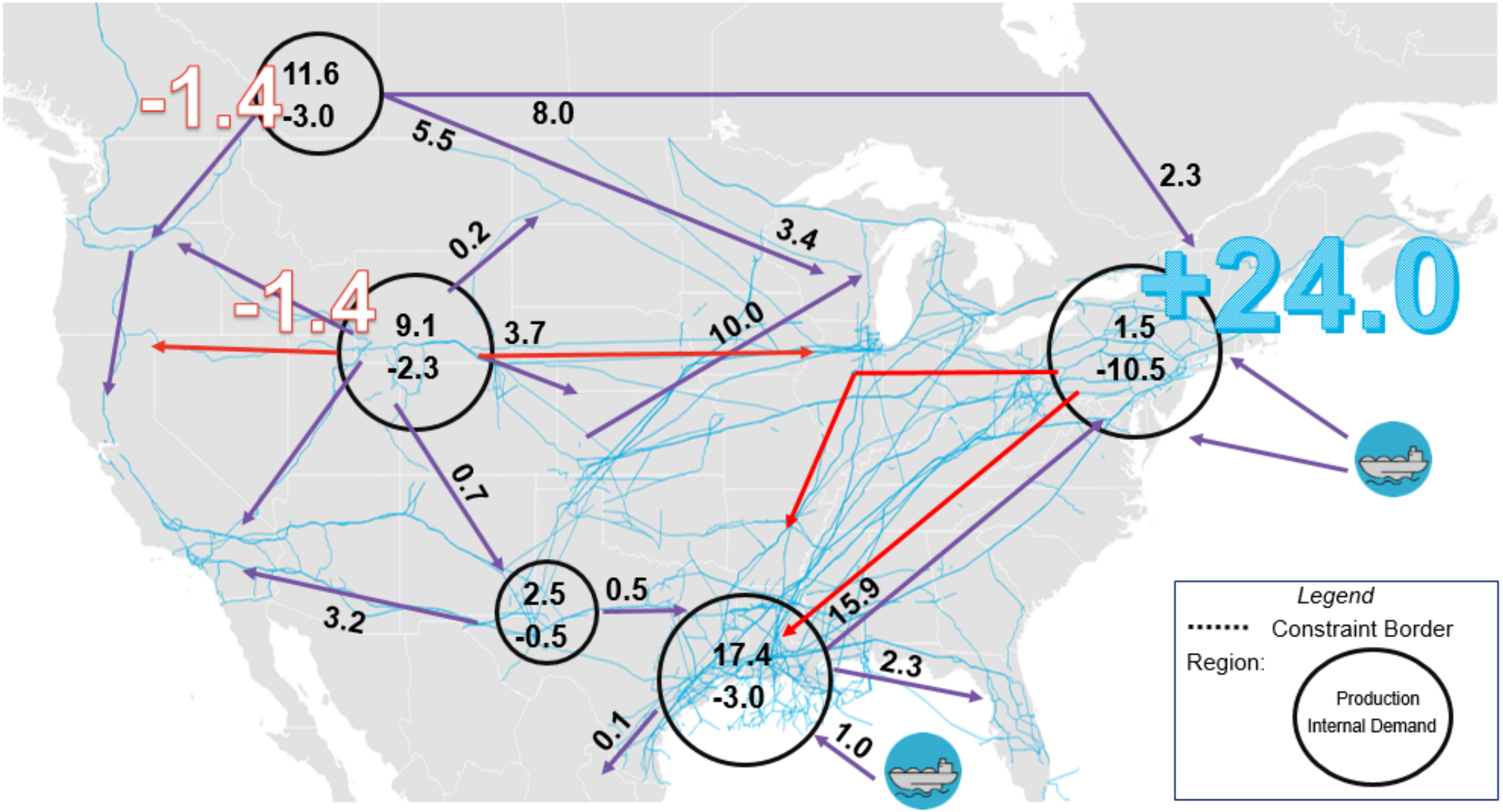
- Unfortunately, the largest western export pipe delivered gas to what became the heart of the Marcellus production region
- Production in the Northeast region increased by more than 29 Bcf/d; demand also grew and the net change for the region was +24 Bcf/d



Source: BloombergNEF. For general illustrative purposes only. Does not include storage in any region or the Midwest, Midcontinent, and California markets.

Transition to Today

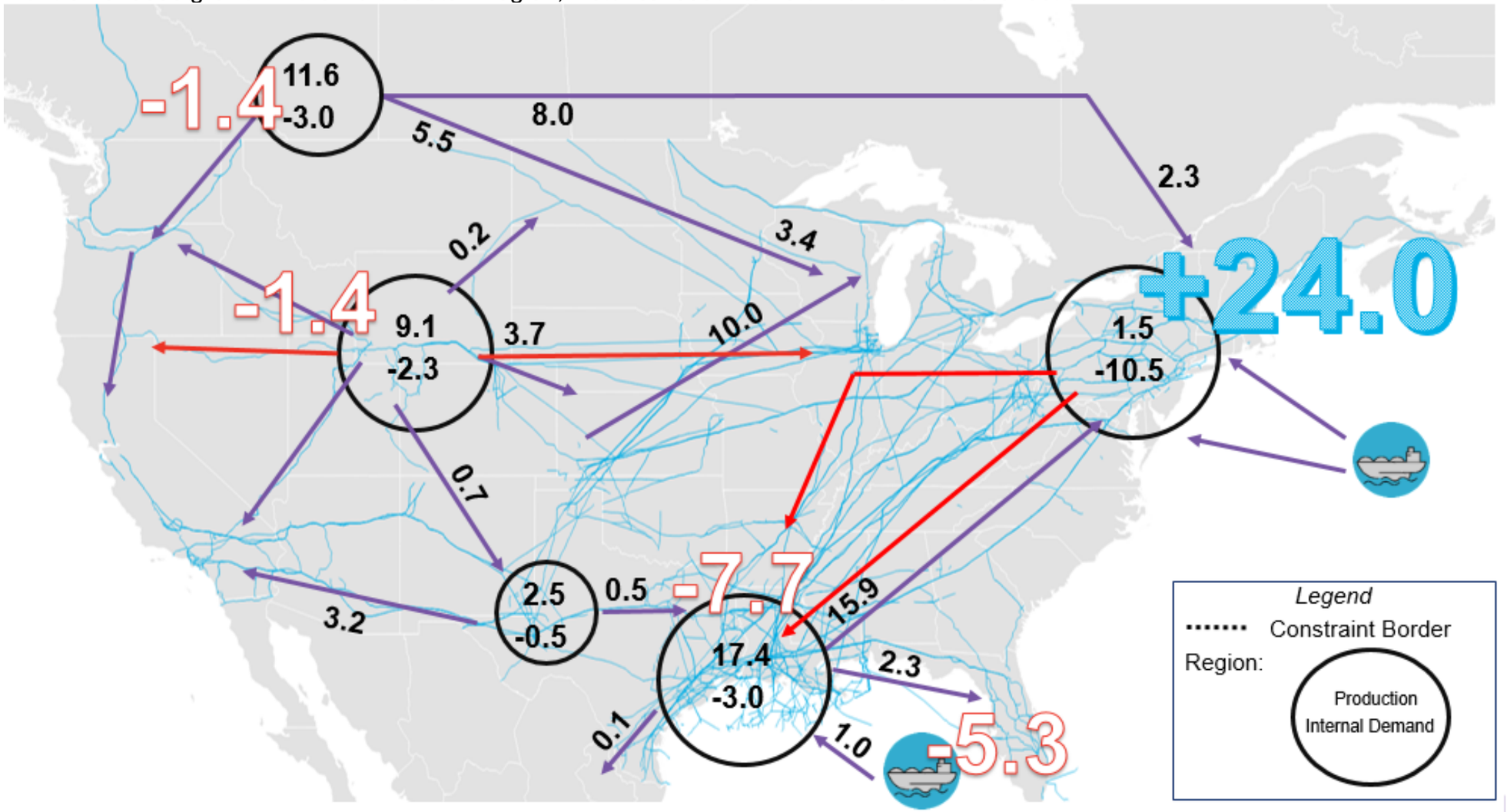
- Marcellus growth pushed back the imported gas
- Regions became well connected; both spread margins and volatility were low



Source: BloombergNEF. For general illustrative purposes only. Does not include storage in any region or the Midwest, Midcontinent, and California markets.

Transition to Today

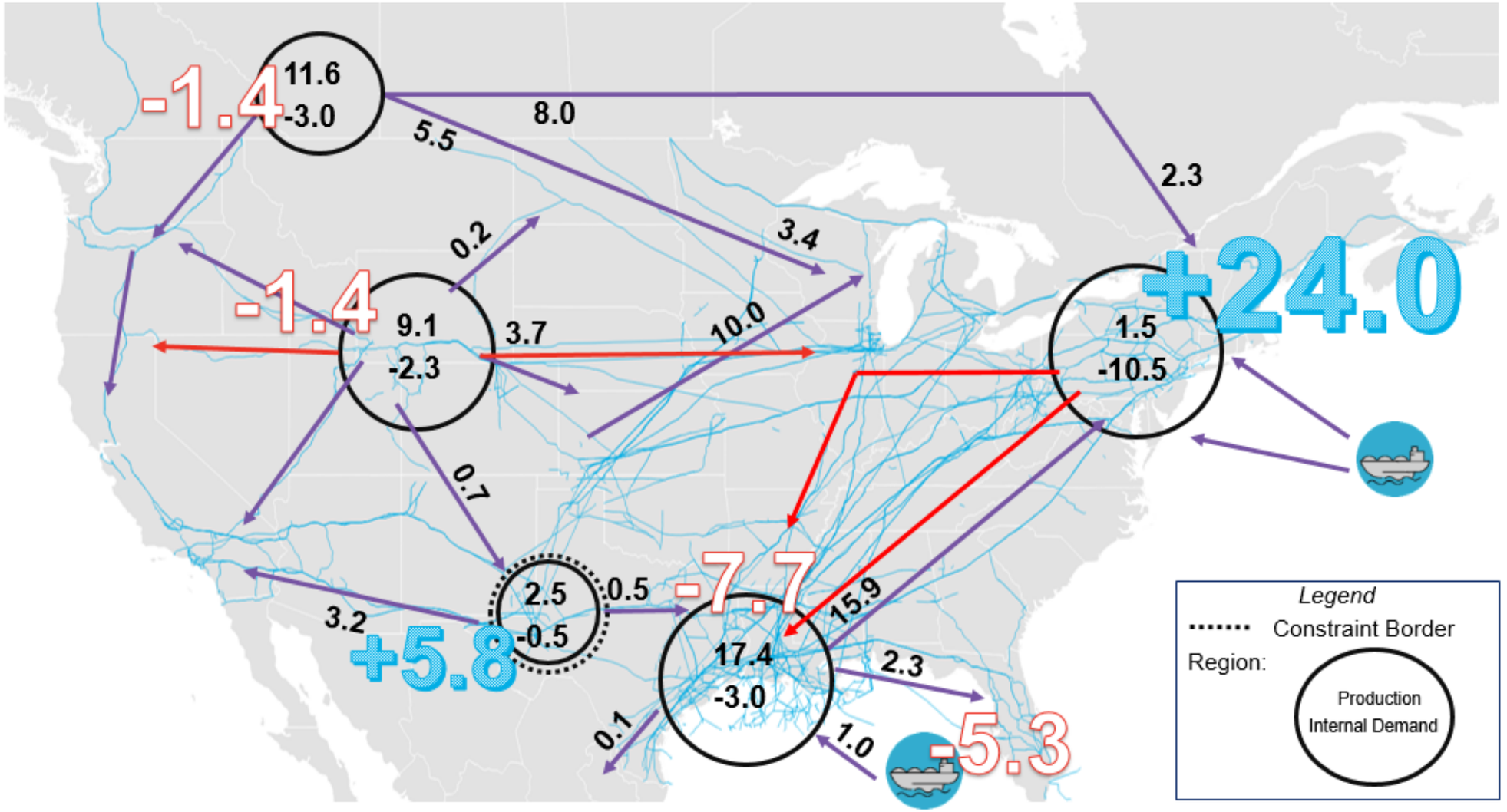
- Net supply in the gulf (including LNG switching to export) was reduced by 13.5 Bcf/d
- Combined with tremendous growth in the Northeastern region, historical south to north flows switched direction



Source: BloombergNEF. For general illustrative purposes only. Does not include storage in any region or the Midwest, Midcontinent, and California markets.

Transition to Today

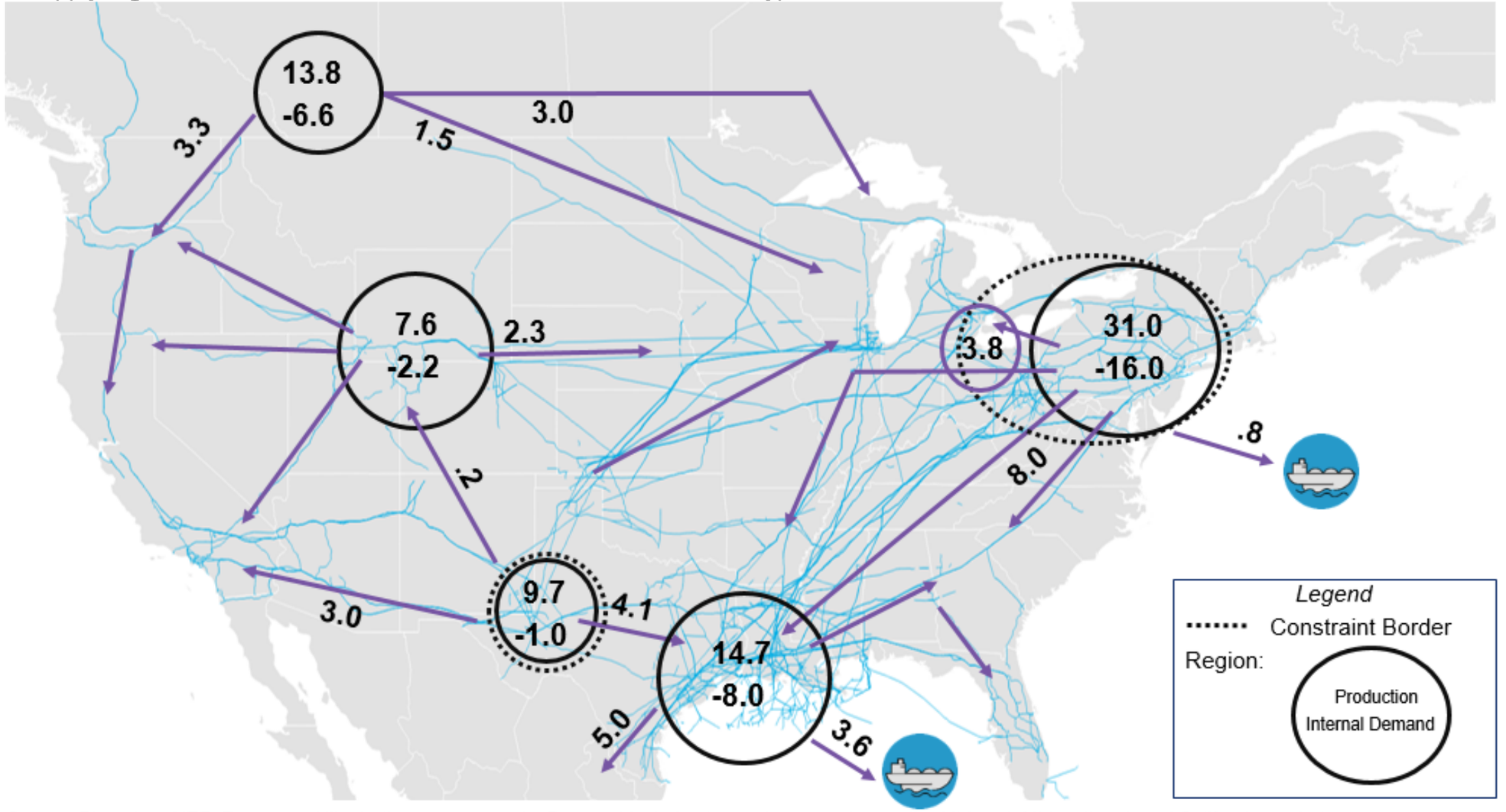
- Most recently, net supply in the Permian is now the big growth story and this continues to change flow dynamics



Source: BloombergNEF. For general illustrative purposes only. Does not include storage in any region or the Midwest, Midcontinent, and California markets.

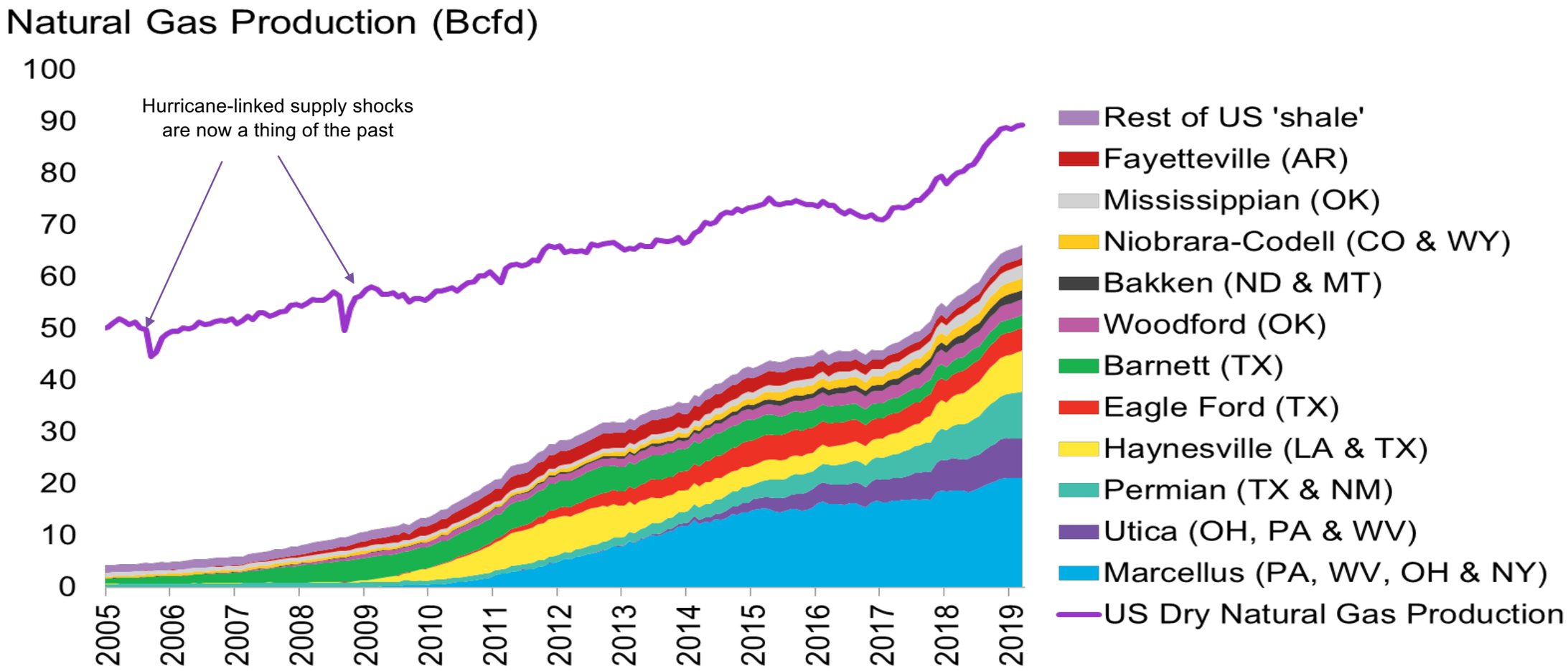
Today's Market (Winter '18-'19)

- Regional dynamics are inter-related and many traditional flow paths are now bi-directional
- Constrained supply regions are now located where demand used to dominate. Hyper-localized winter demand still exist in NYC and Boston.



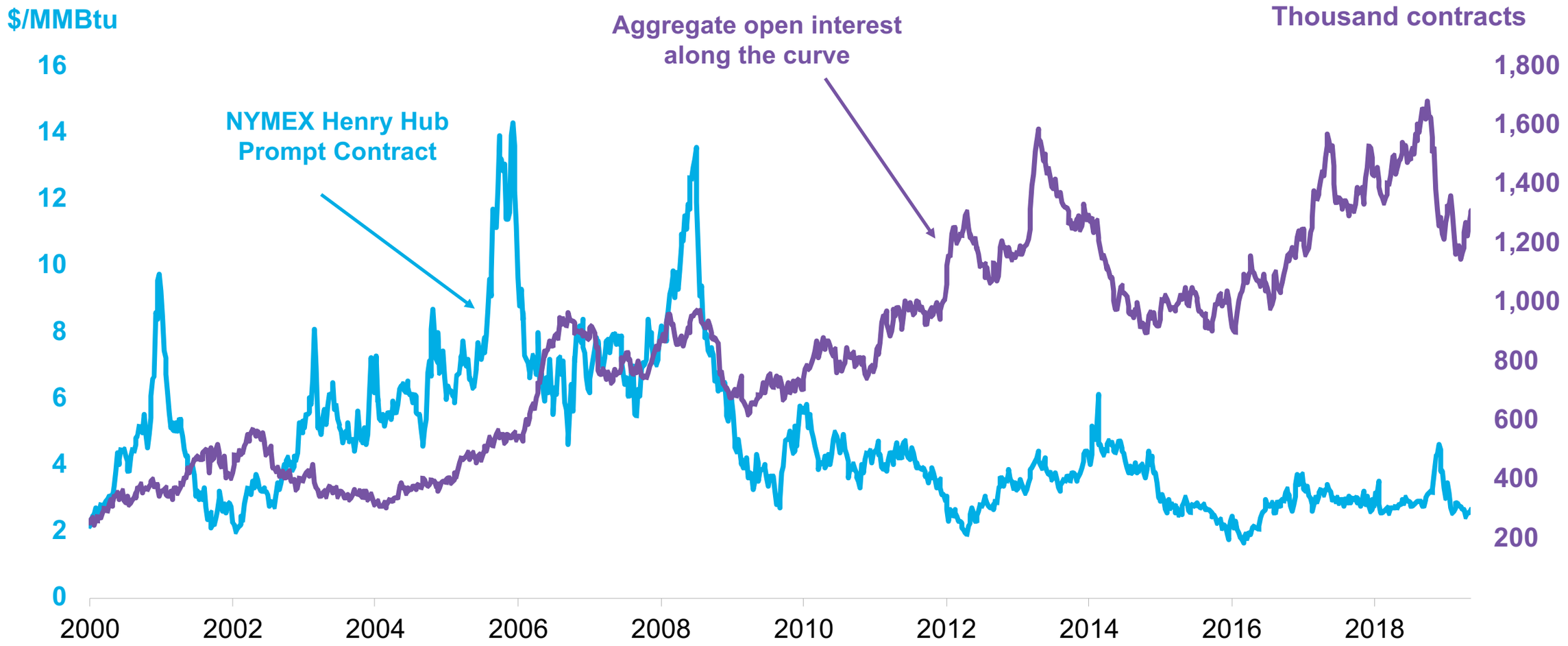
Source: BloombergNEF. For general illustrative purposes only. Does not include storage in any region, or the Midwest, Midcontinent, and California markets.

Dry Shale Gas Production is now 75% of Total Supply Volumes



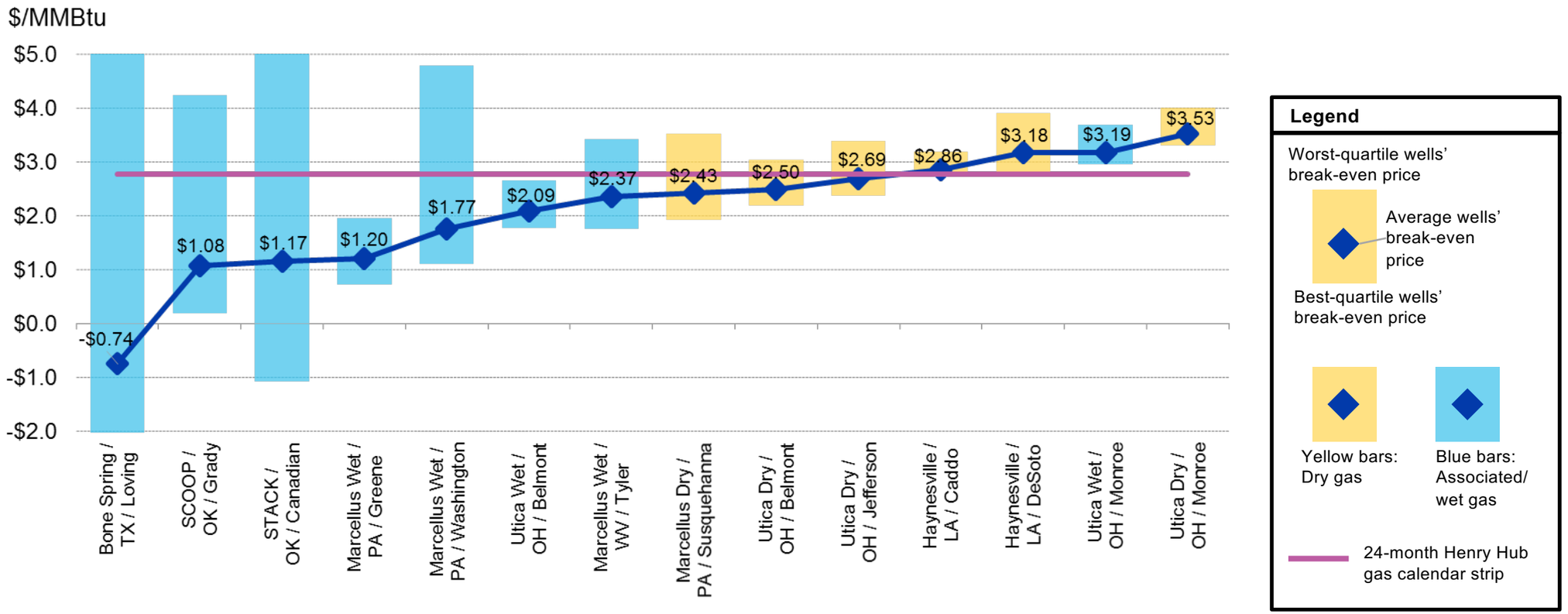
Source: EIA, DrillingInfo

Production Hedging Pressure



Source: NYMEX, Bloomberg

Production Breakeven Prices for New Wells



Source: Bloomberg estimates, ICE Futures U.S. Energy Division. Note: Estimated 24-month calendar strip gas prices for Henry Hub as of August 30, 2018.

The Winners and Losers of the Shale Revolution

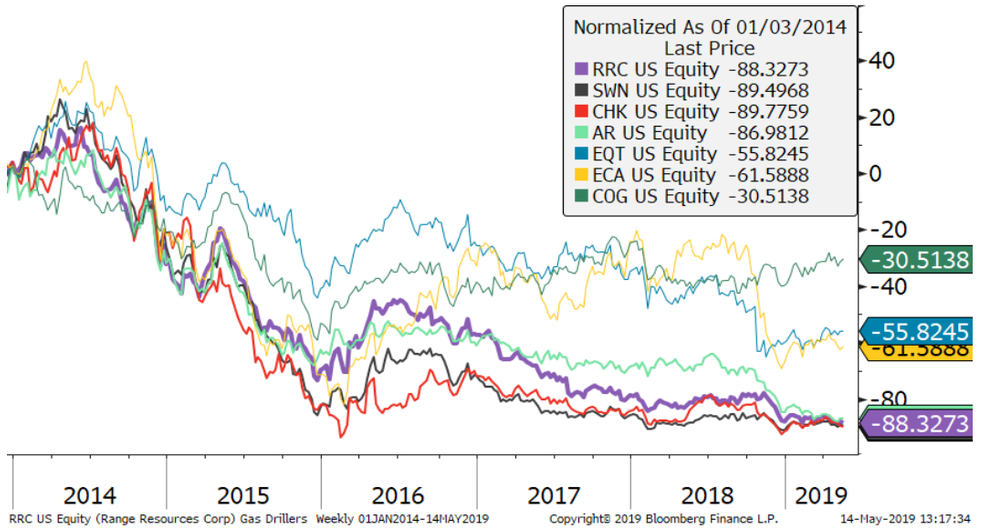
The victims

- Imports
  - Canadian pipeline deliveries
  - LNG import terminals
- Legacy production assets:
  - Coal-bed methane
  - Offshore
  - Vertical wells
- Competing fuel power plants
  - Coal and nuclear generation margins were crushed by resulting low whole-sale electricity prices
- E&Ps investors
  - Shale drilling requires CASH, but: It turns an exploration/production model with a 50% hit rate into a manufacturing process with 99% hit rate
  - 2009-2019 low interest rates regime lured investors and also eased the access to capital for more drilling.
    - The “drill at any cost” mentally prevailed over the last decade.
  - A decade of equity depreciation has resulted in a new philosophy of belt-tightening and focus on free-cash-flow generation through a shift to oil drilling

The winners

- Consumers
  - Industrials
  - NG-fired power producers
  - LNG export projects
- Some pipeline capacity holders
  - Benefited from wide basis differentials

Percentage “appreciation” of a basket of gas drillers’ equity

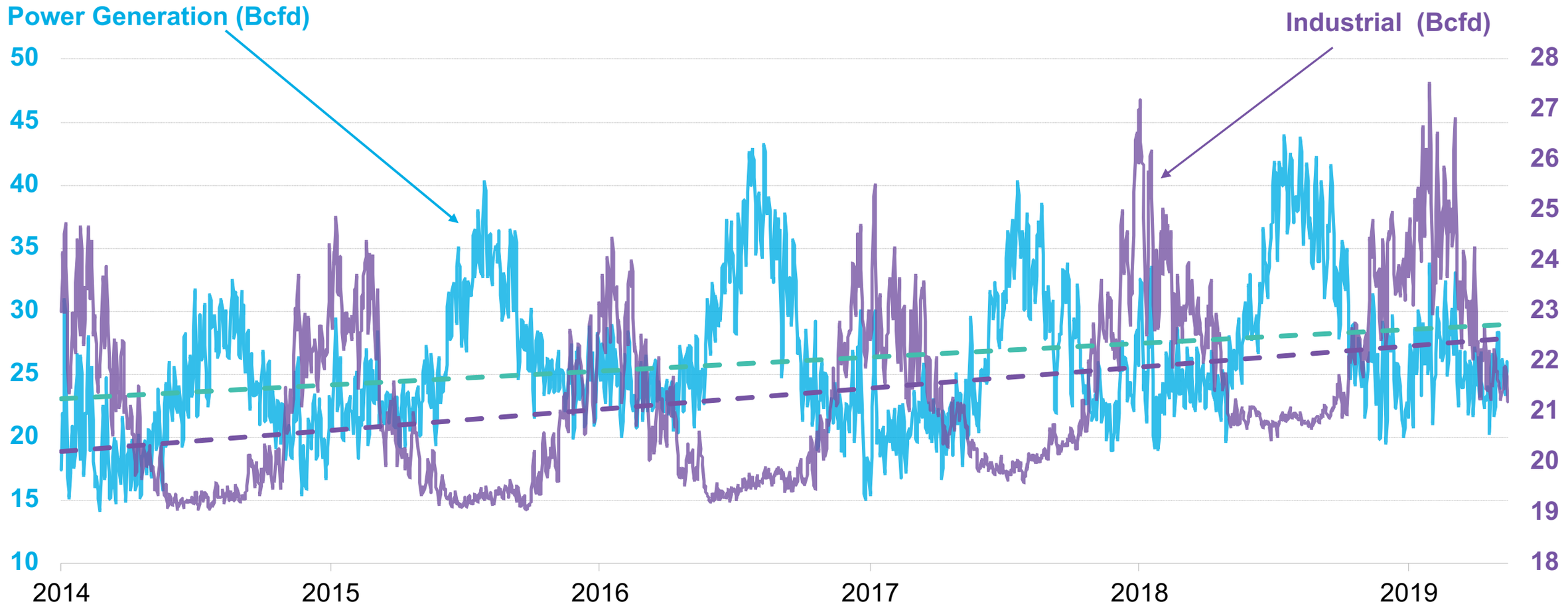


Source: Bloomberg

Demand Creation

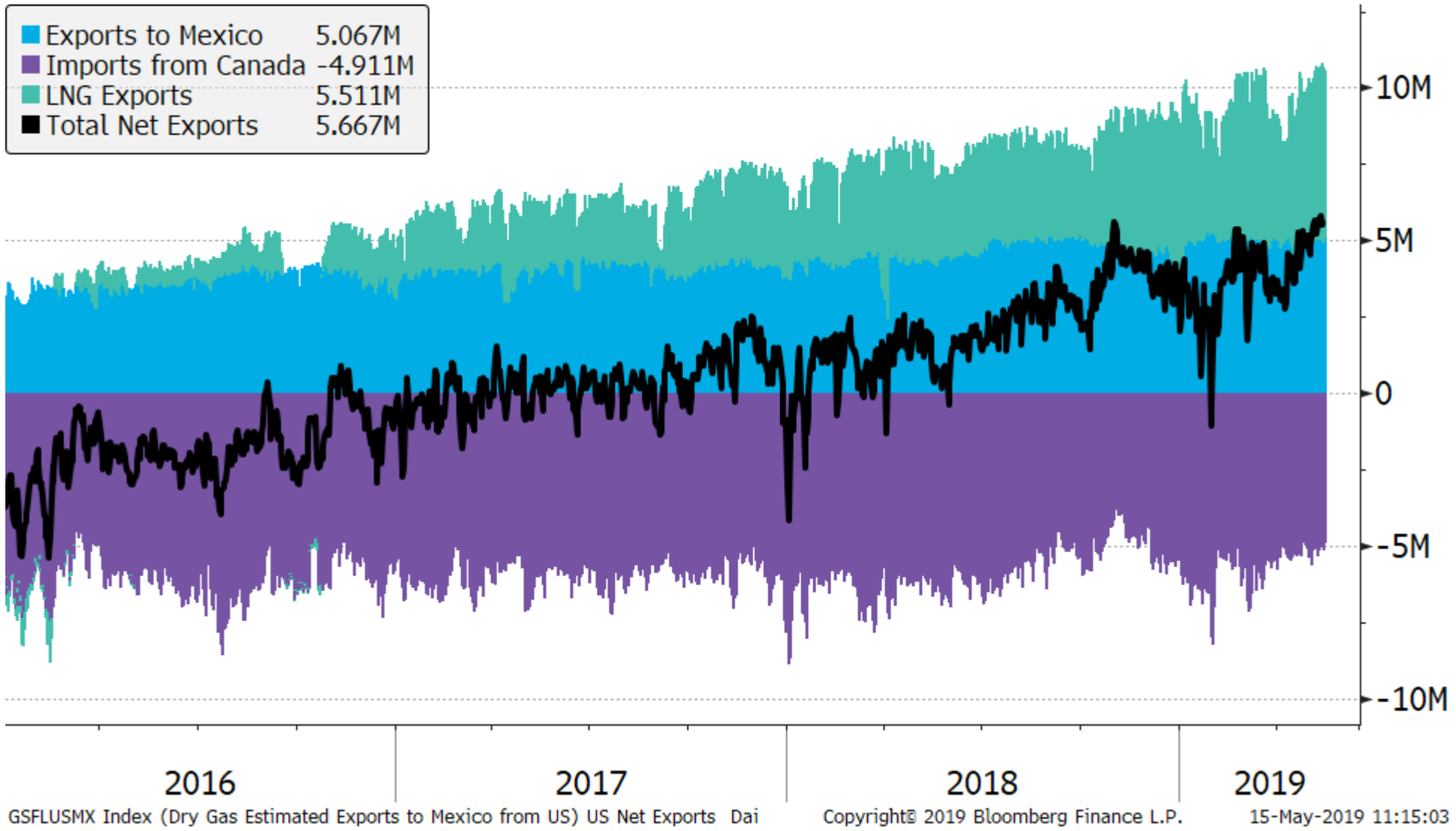
Exploiting Differentials versus Competing Fuels

A Slow Up-Trend in Domestic Use



Source: BloombergNEF, Genscape, EIA

Turning to International trade

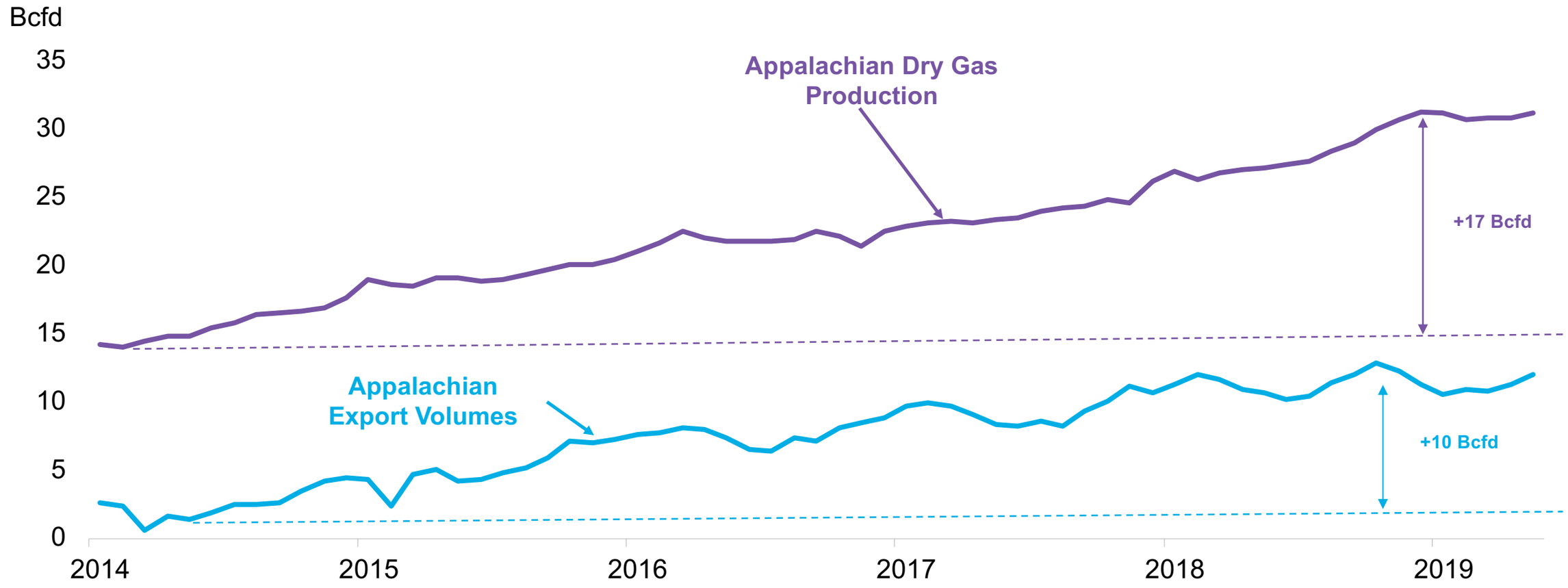


Source: BloombergNEF, Genscape

Regional Drilldown – Appalachia

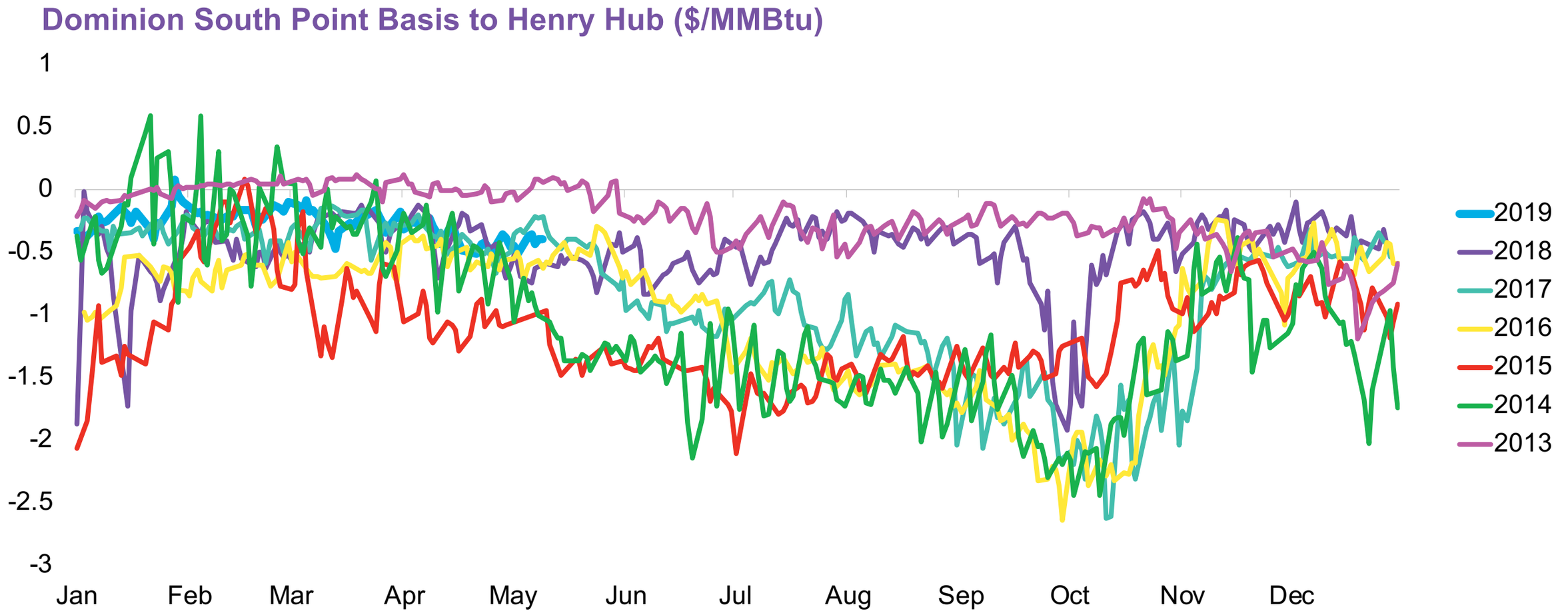
How the Appalachian Basin Reshaped the US Domestic Market

Bridging Basis Differentials



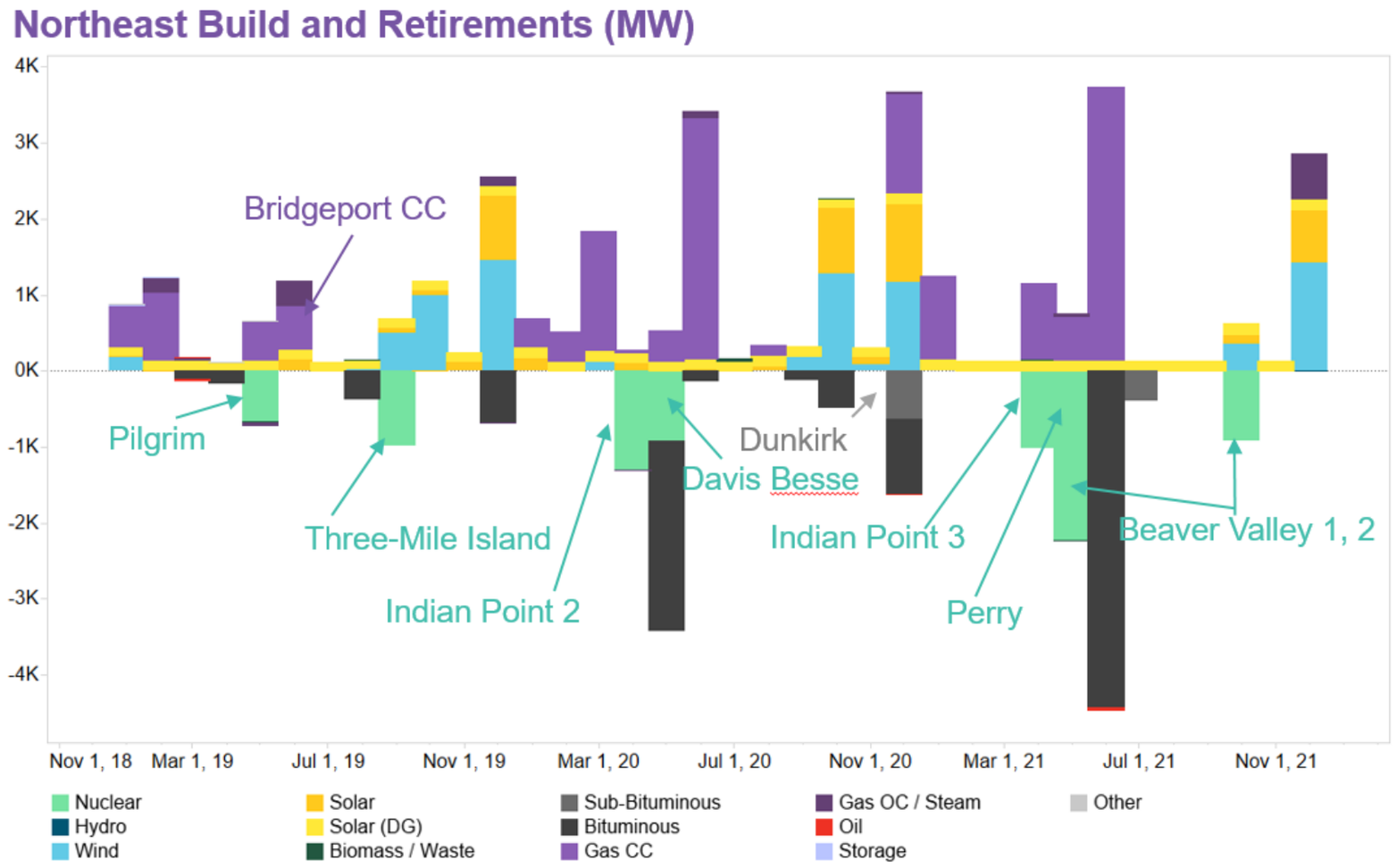
Source: BloombergNEF, LINE <GO>

Price Signal for Export and Demand Growth



Source: Bloomberg, BGAS <GO>

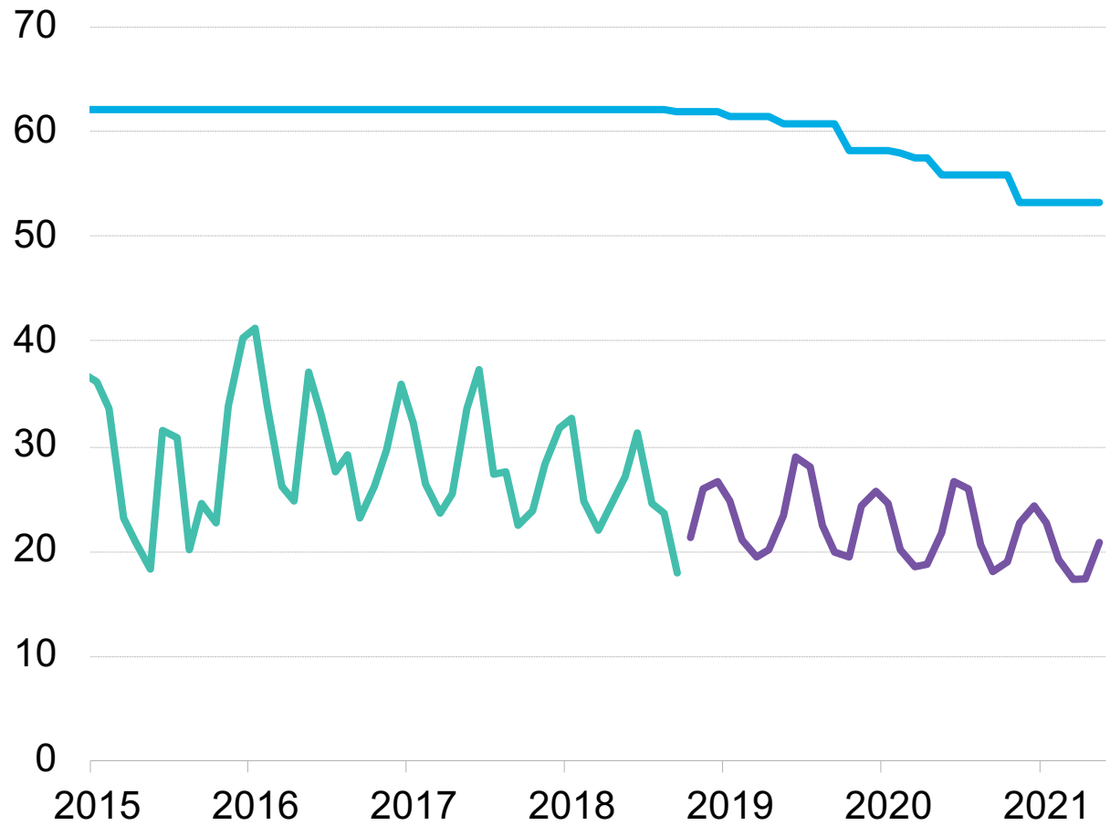
Northeast Plant Stack Evolution: Coal and Nuclear Shut-ins vs. Gas Additions



Source: BloombergNEF Plant Stack, EIA

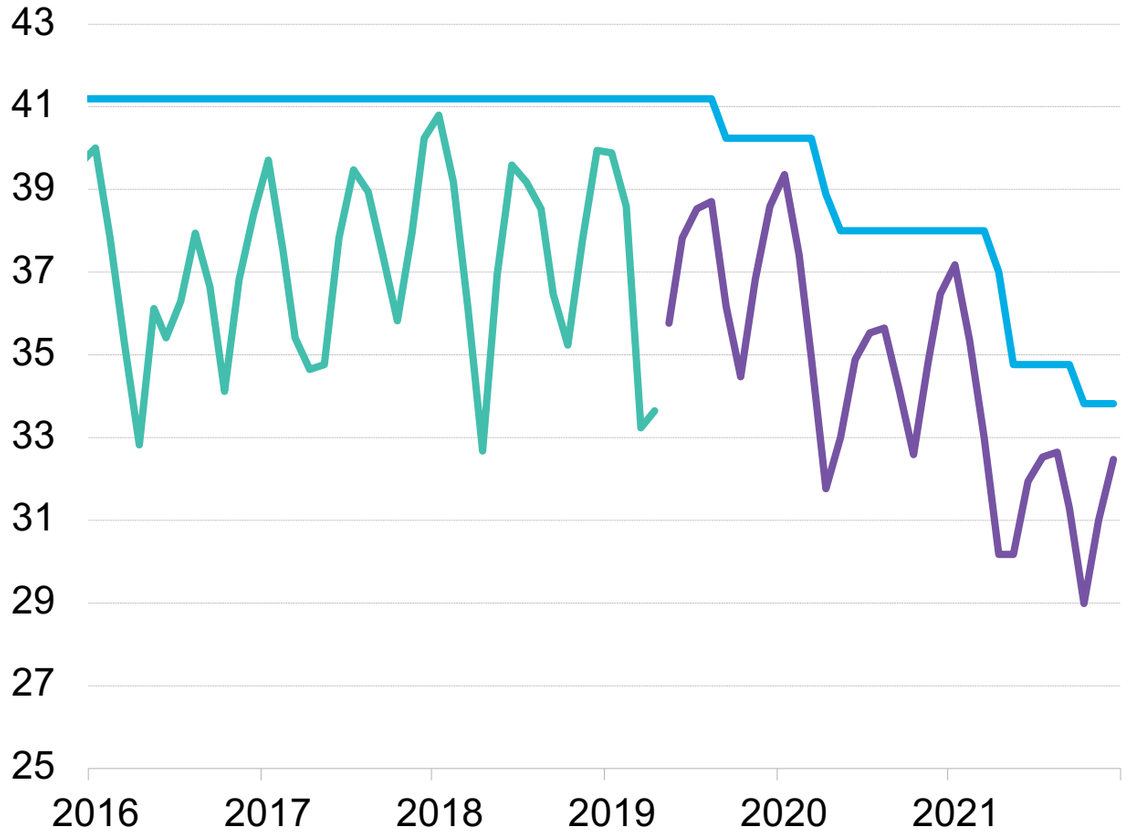
Coal and Nuclear Capacity Retirements – Generation Forecast

Coal Capacity (GW) / Generation (aGW)



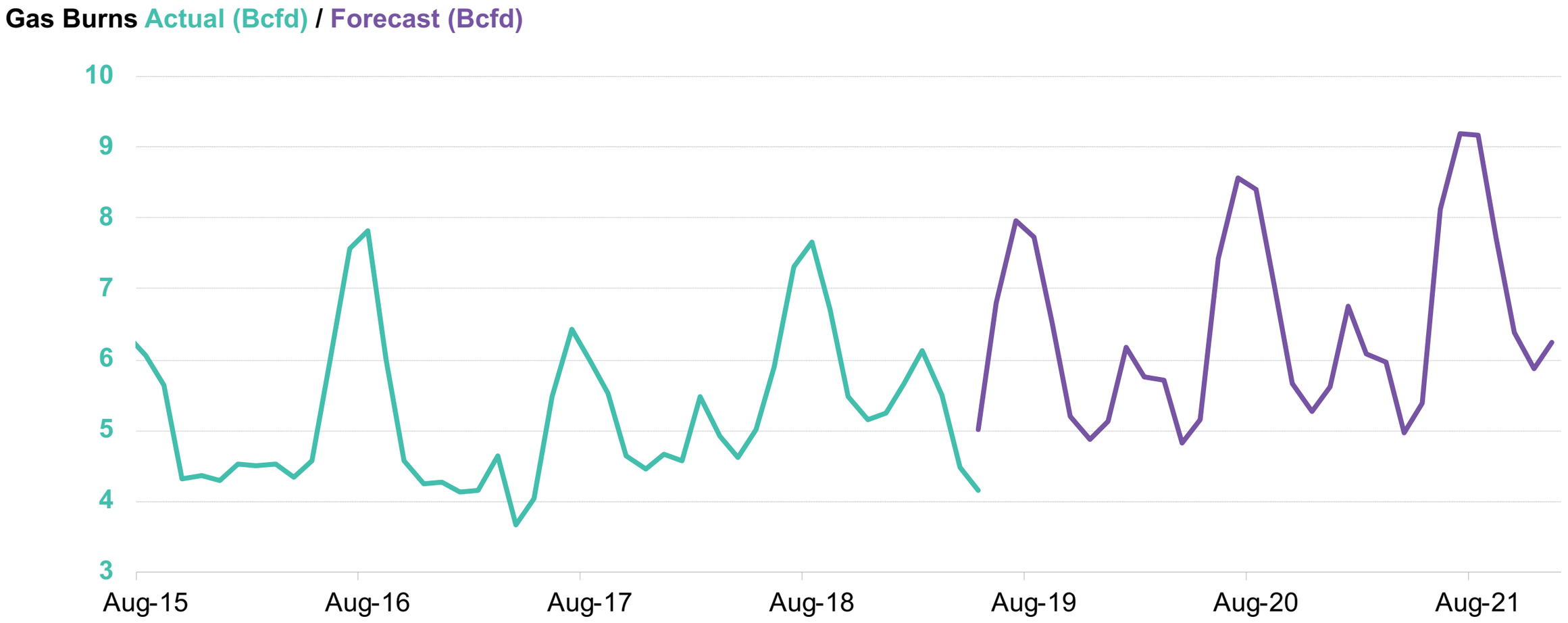
Source: PJM, NYISO, BloombergNEF

Nuclear Capacity (GW) / Generation (aGW)



Source: PJM, NYISO, BloombergNEF

Coal and Nuclear Capacity Retirements – Impact on Gas Demand for Power Generation

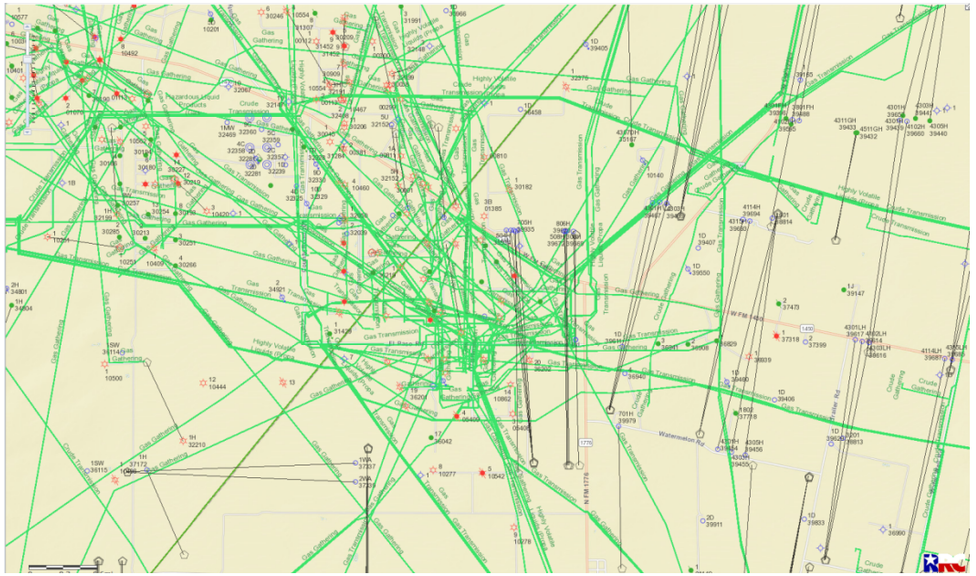


Source: PJM, NYISO, BloombergNEF

Regional Drilldown – Permian

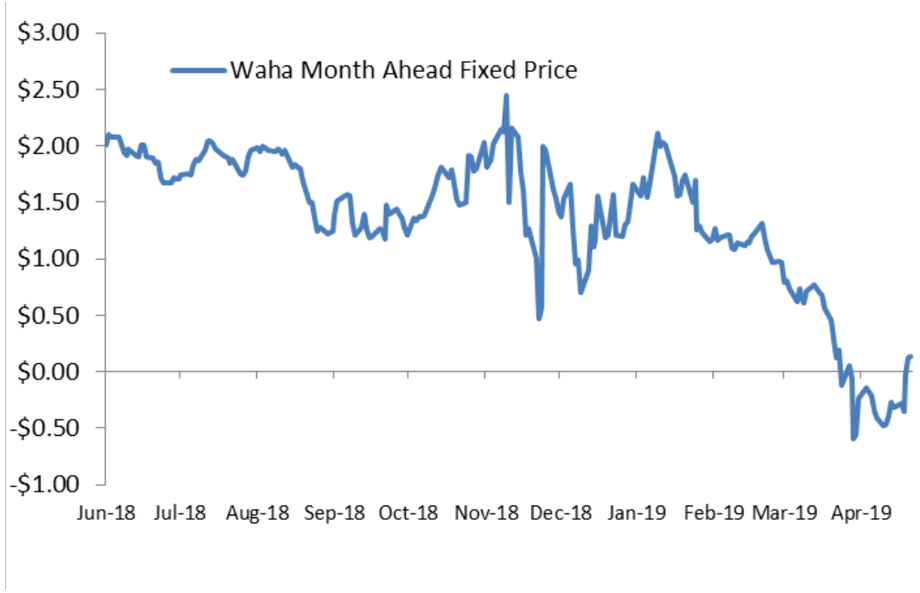
Stranded Supplies

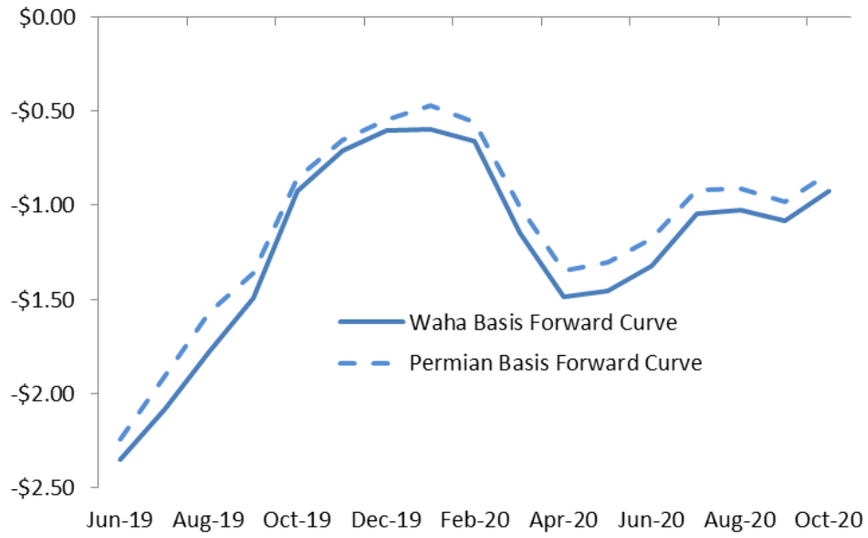
Permian Gas Flows at Waha: Crystal Clear



- What defines a pricing point?
  - Not all pools are created equal
  - Constant pipeline and processing plant outages dictate daily pricing within the Permian basin and help create an illusion of under or over supply
  - Cash trading wags the dog daily

Basis Extremes: Baseloading at negative prices, daily prices reaching -$8/mmbtu





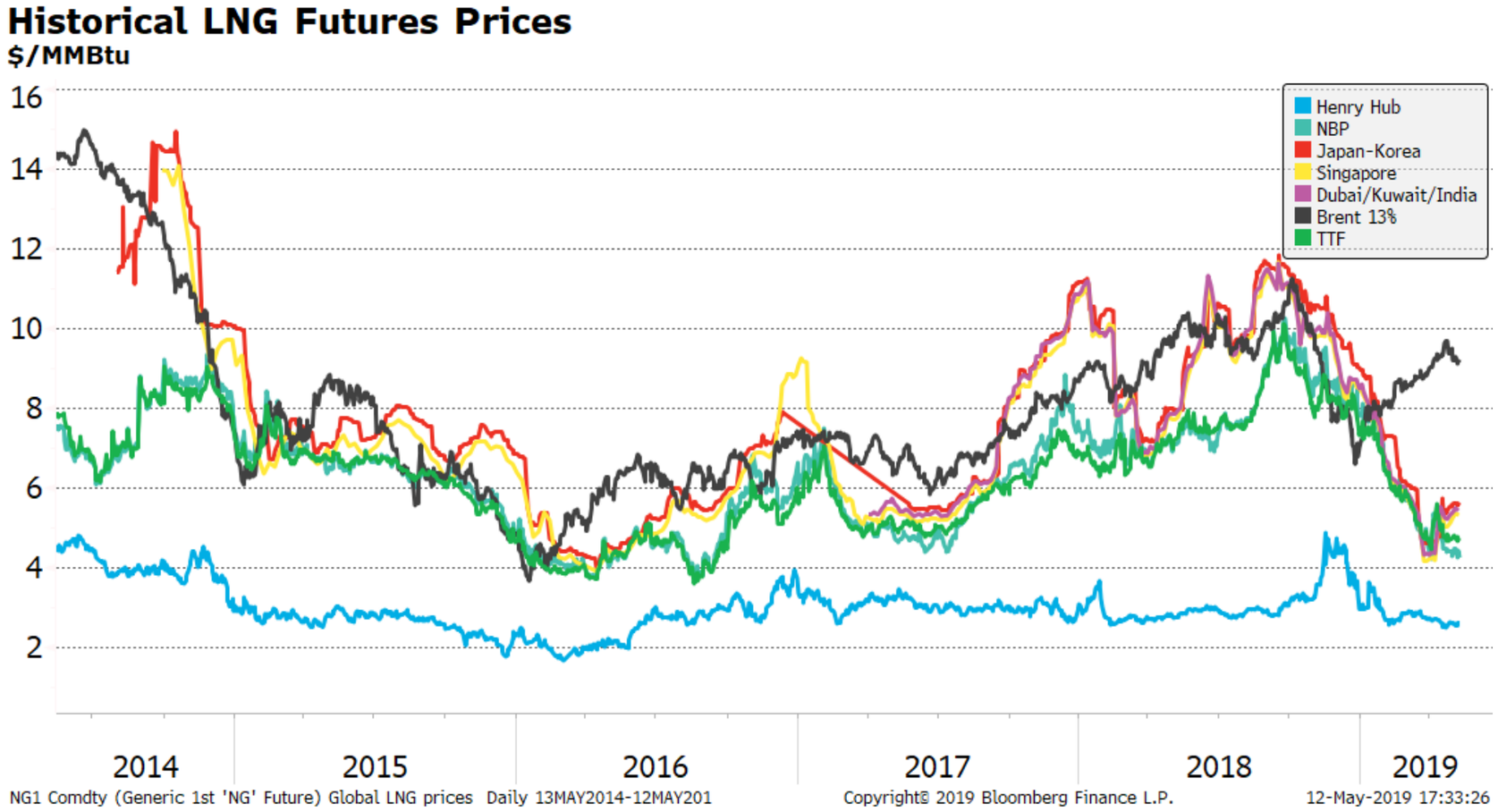
- Waha May negative basis exceeded Nymex Fixed Price for much of April
  - Summer basis prices a sharp improvement in values, primarily on the expectation of improving power load, Mexican takeaway and pipeline improvements in West Texas during July and August.
  - If GCX de-bottlenecks West Texas, is South Texas ready to absorb the gas?

Source: PJM, NYISO, BloombergNEF

Opening to the World

The Global Market can be a Double-Edge Sword

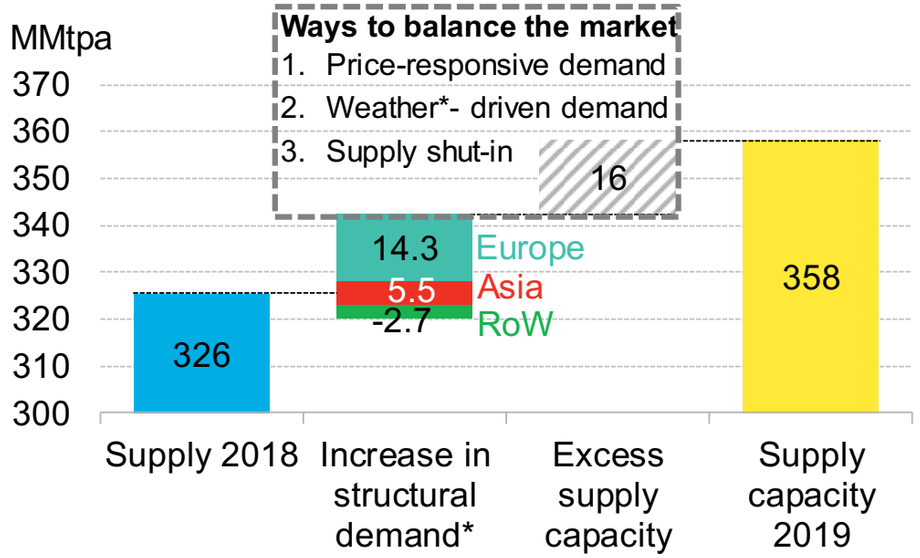
International Trade: Bridging the Gap with Oil and LNG Prices



Source: NYMEX, ICE, BloombergNEF

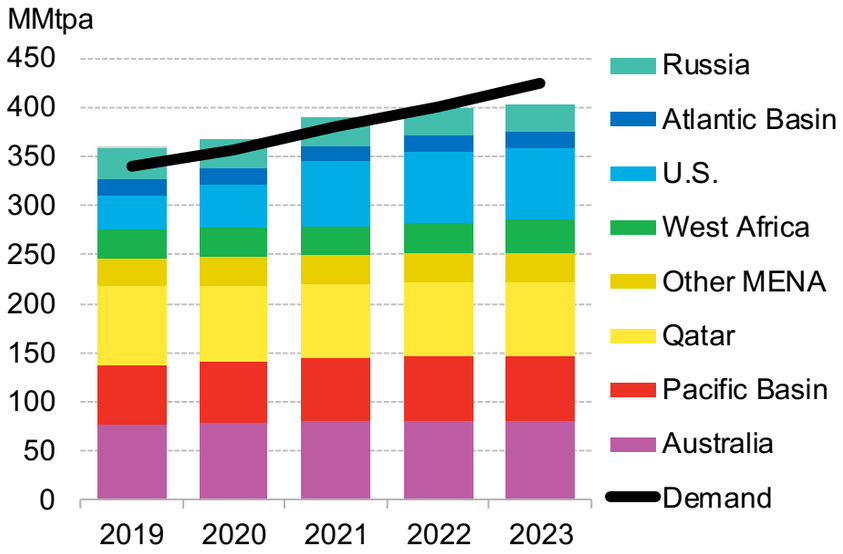
Outlook for New Exports
Can the global market take it?

LNG supply capacity and demand in 2019



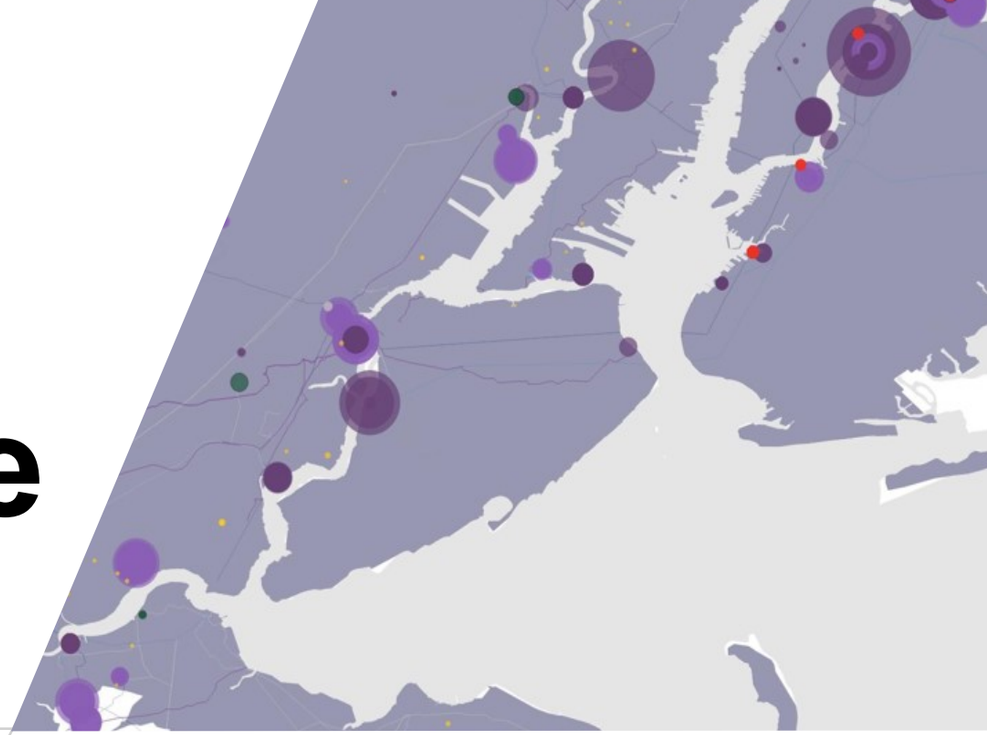
*Source: BloombergNEF. Note: *Structural demand is the demand based on current prices and normal weather. Normal weather is assumed to be 30 year averages. RoW stands for rest of the world.*

Global LNG supply* and demand outlook



*Source: BloombergNEF. Note: *Available supply capacity – prorated nameplate capacity of newly commissioned trains and 3% maintenance factored in for existing trains.*

Homage to Wholesale Power Prices



New York Energy Forum

William Nelson

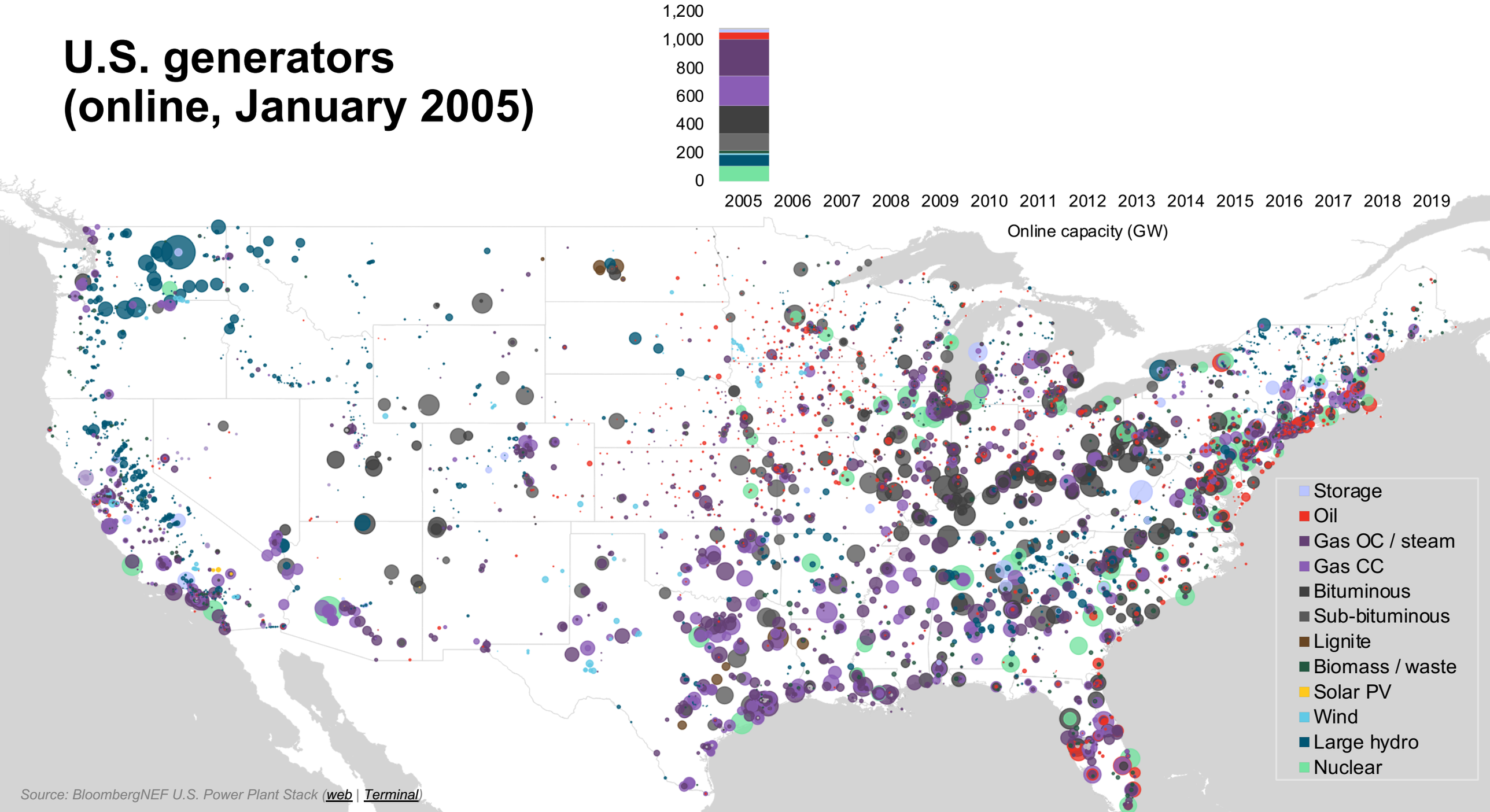
May 16, 2019

BloombergNEF

Plant stack

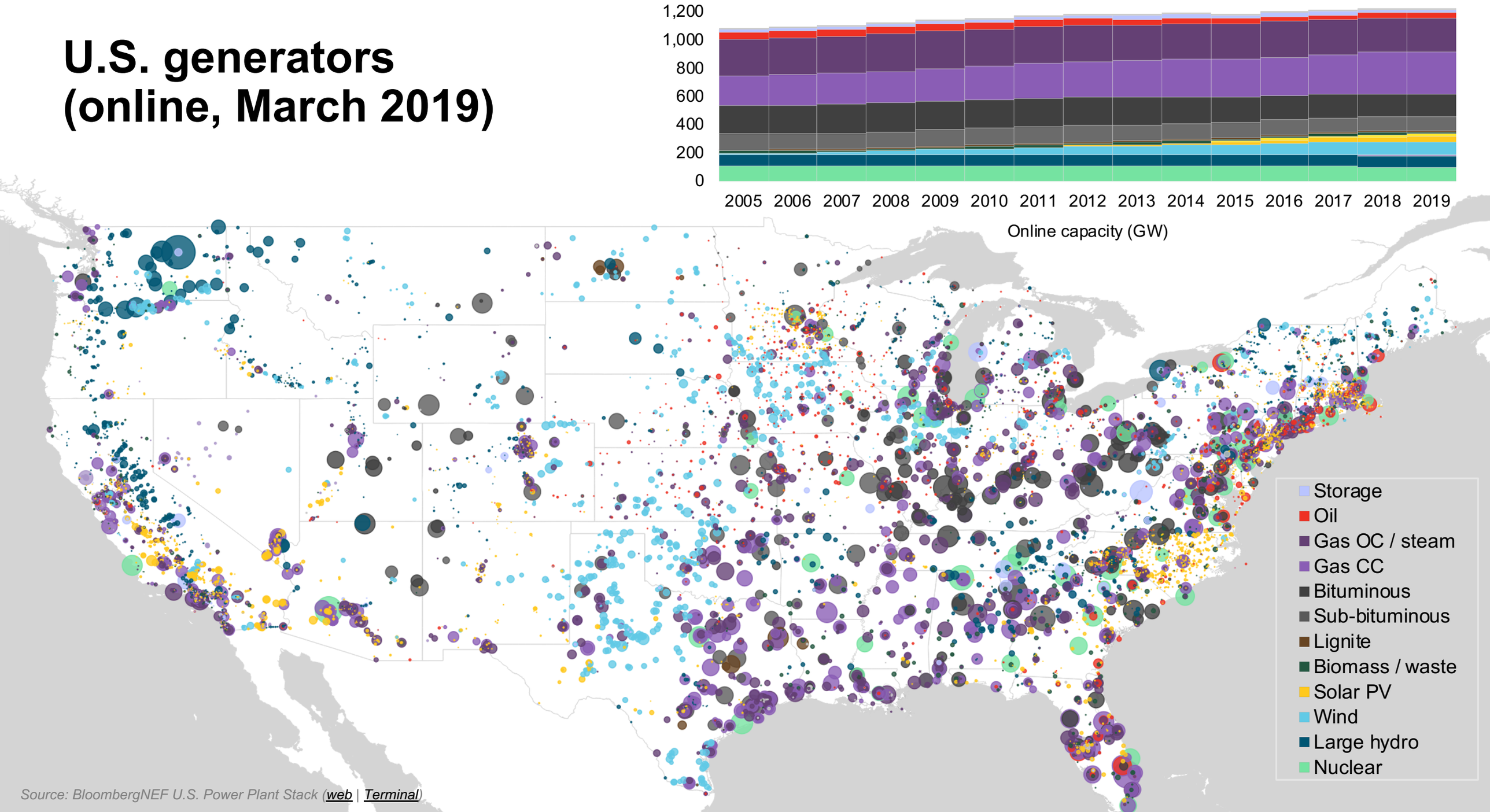
Existing fleet governs future value

U.S. generators (online, January 2005)



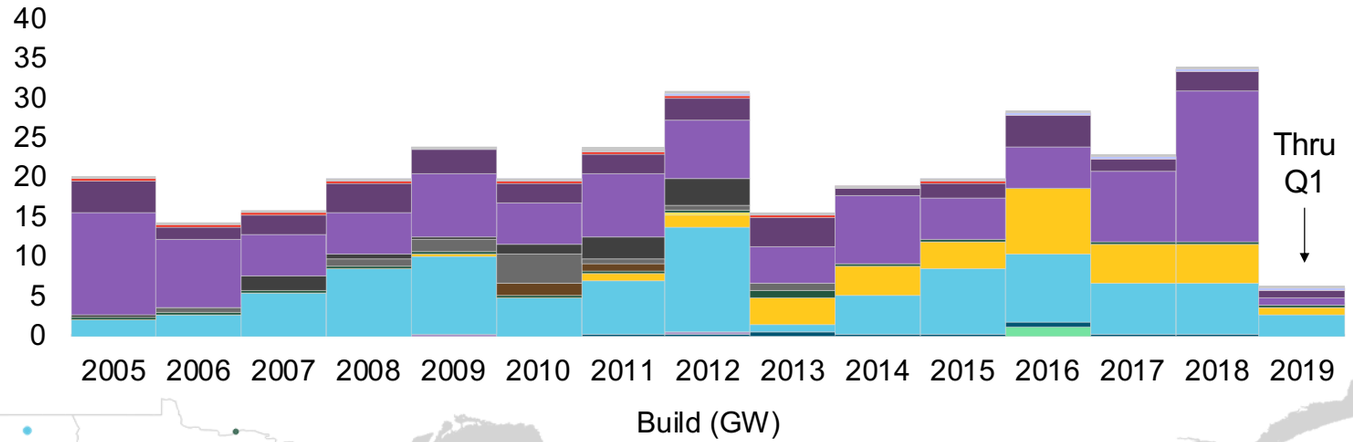
Source: BloombergNEF U.S. Power Plant Stack (web | Terminal)

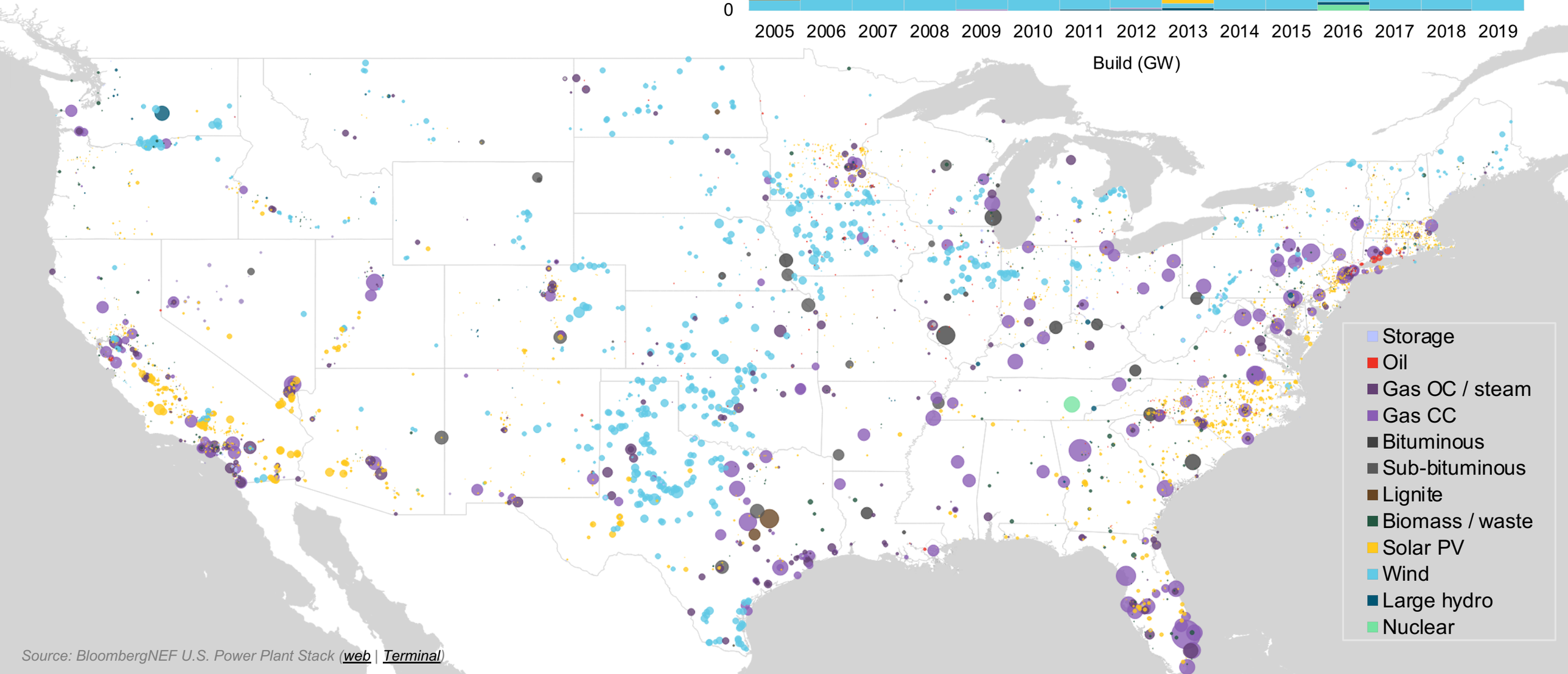
U.S. generators (online, March 2019)



Source: BloombergNEF U.S. Power Plant Stack (web | Terminal)

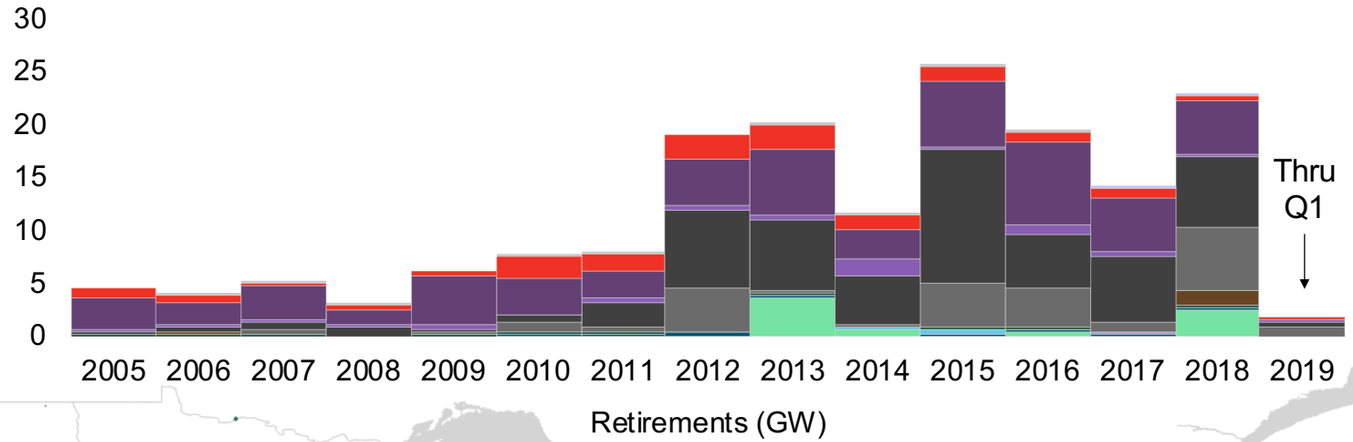
U.S. generators (built since 2005)

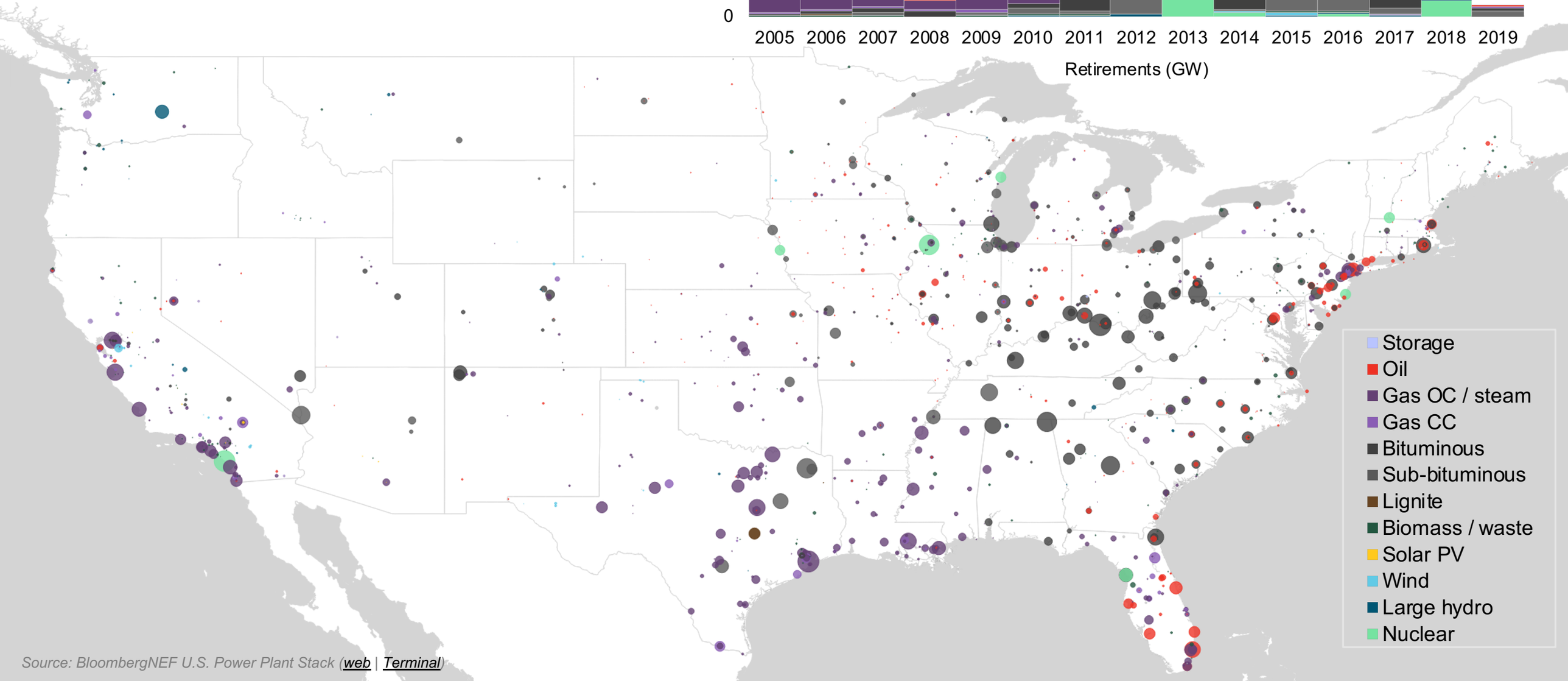




Source: BloombergNEF U.S. Power Plant Stack (web | Terminal)

U.S. generators (retired since 2005)

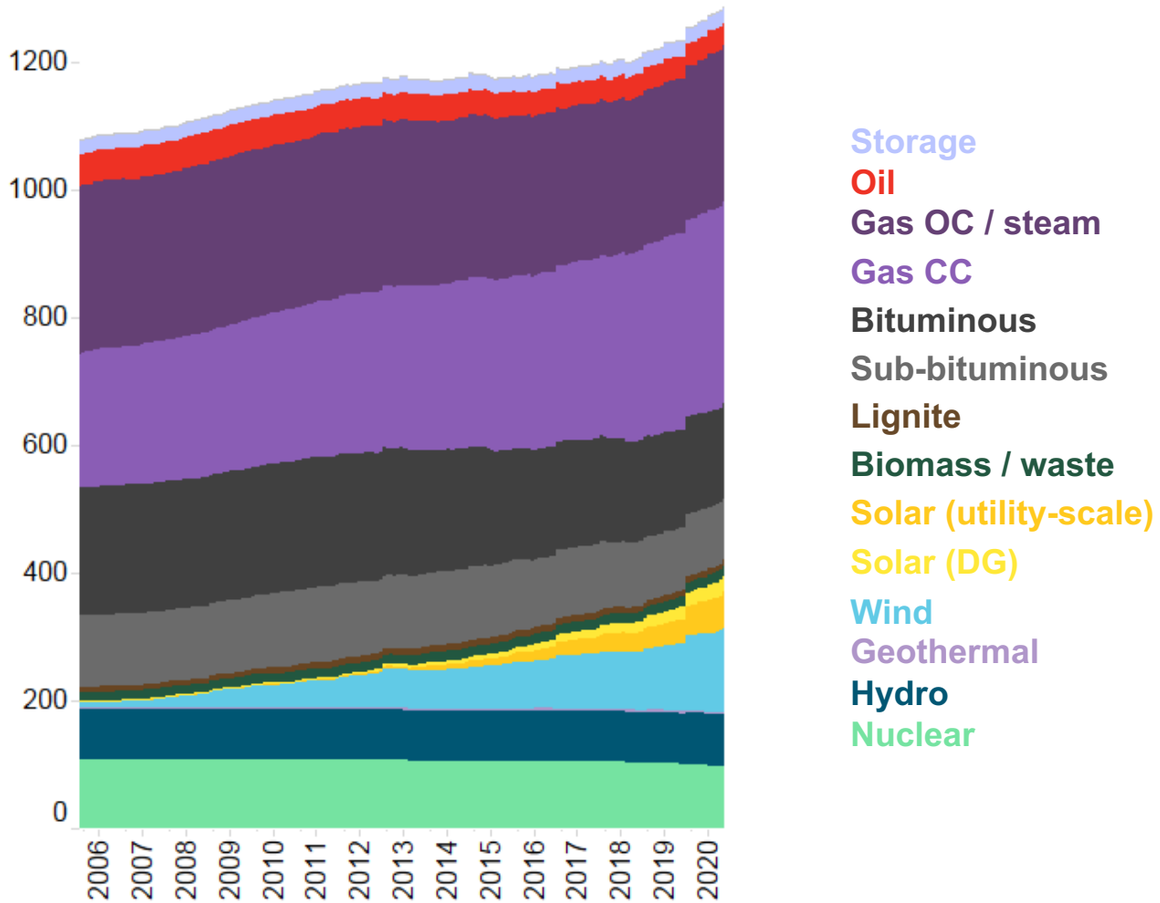




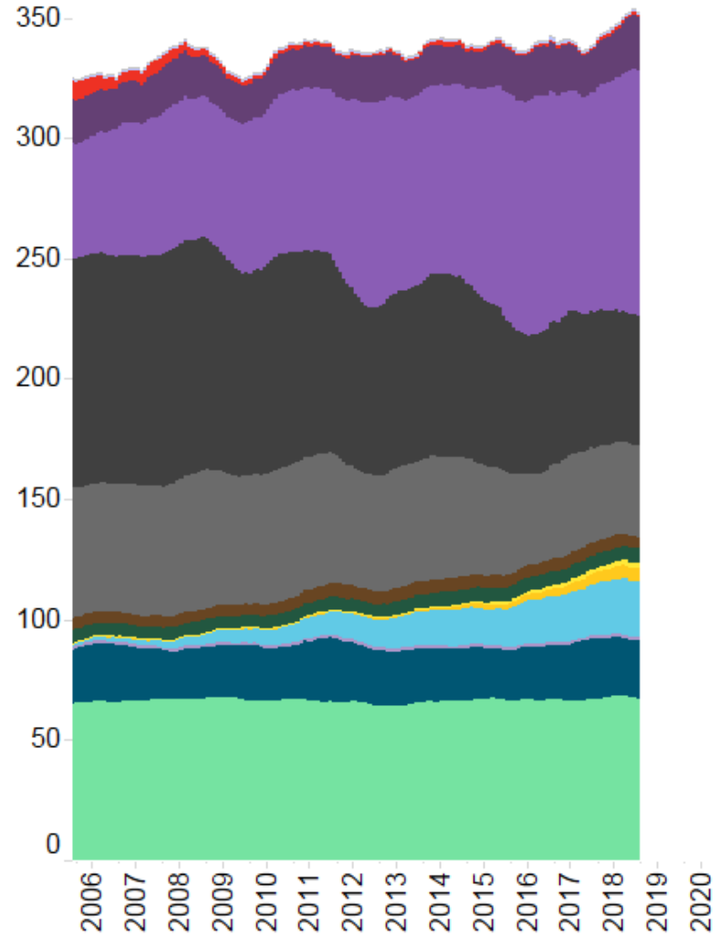
Source: BloombergNEF U.S. Power Plant Stack (web | Terminal)

U.S. capacity and generation

Plant stack: operational capacity
(GW)



Power mix: generation
(TWh/month | 12-month rolling average)

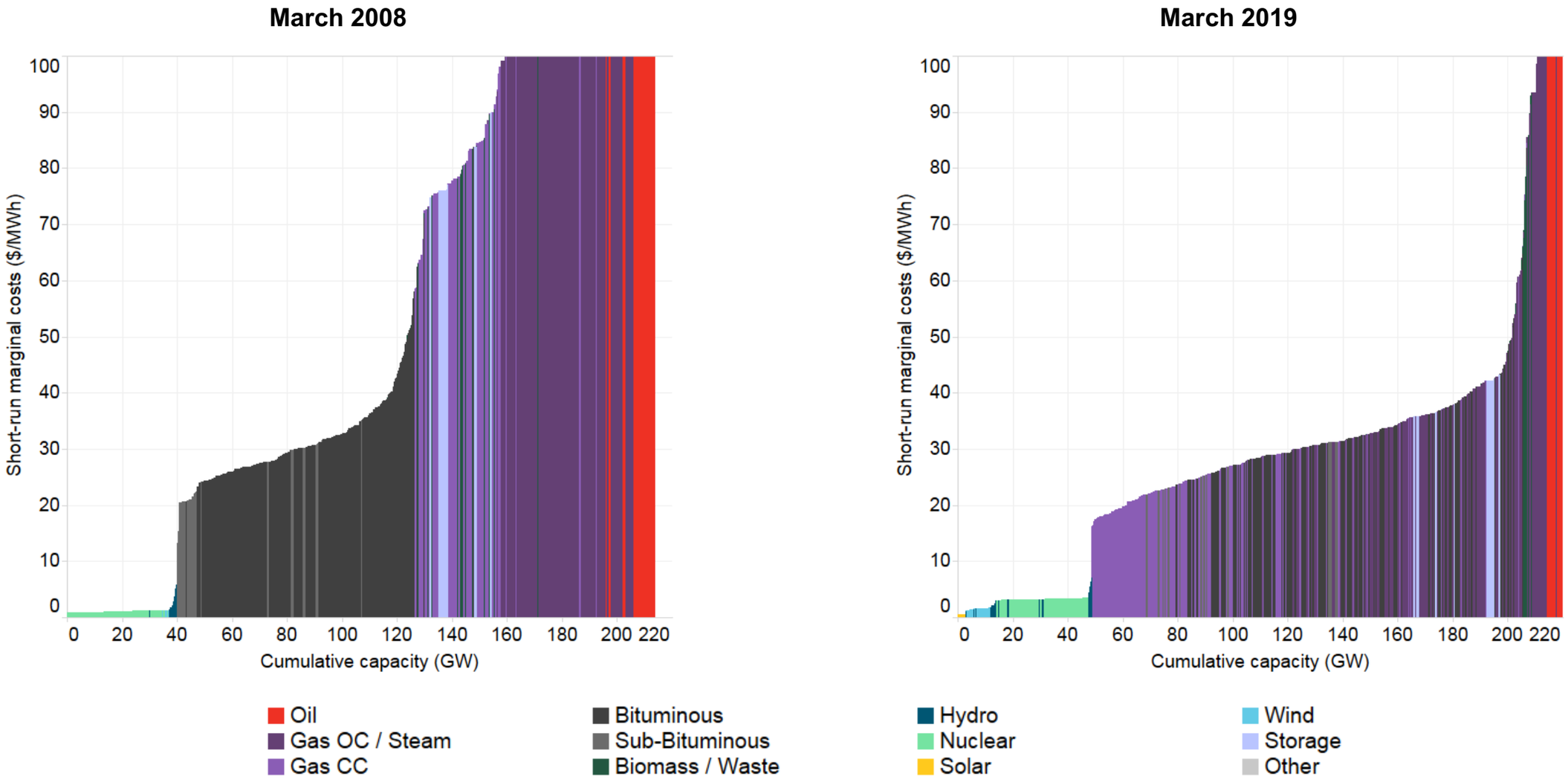


Source: BloombergNEF U.S. Power Plant Stack (web | Terminal)

Fuel switching

Operational versus structural

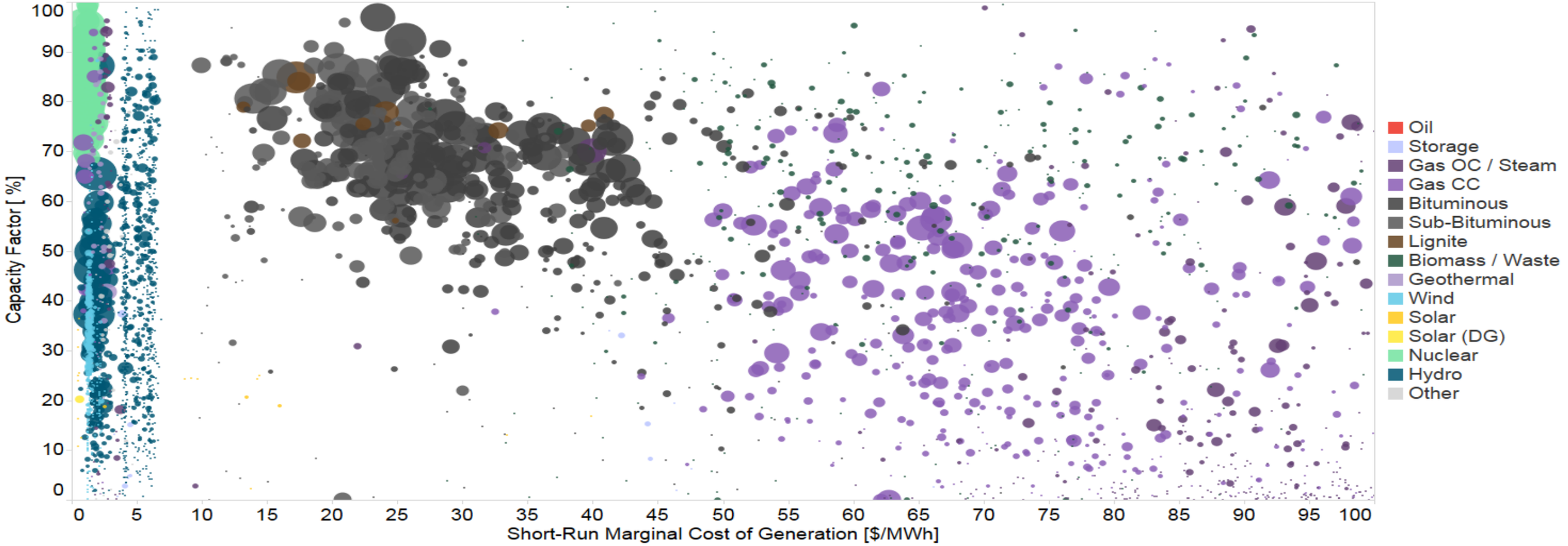
PJM merit order



Source: BloombergNEF Merit Order Maker: U.S. Power Supply Curves (web | Terminal)

Coal-to-gas collision course

2008 – U.S. power plants, capacity factors versus short-run marginal cost



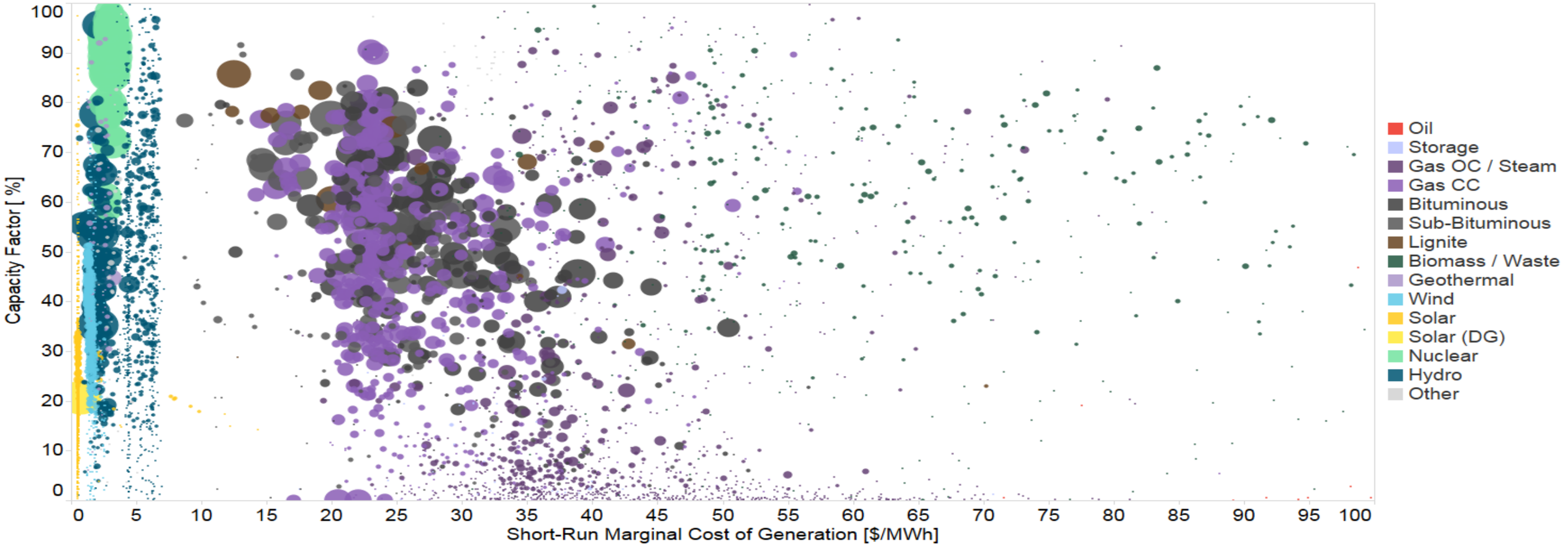
Coal- minus gas-fired generation – 30-day average output (GW)

2008

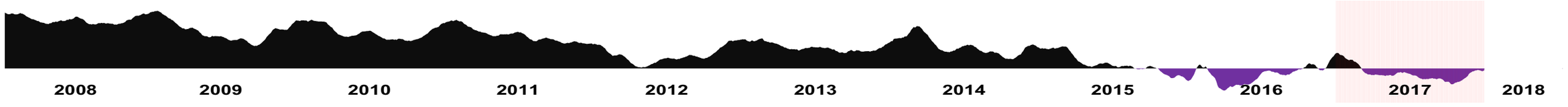
BloombergNEF

Coal-to-gas collision course

2017 – U.S. power plants, capacity factors versus short-run marginal cost



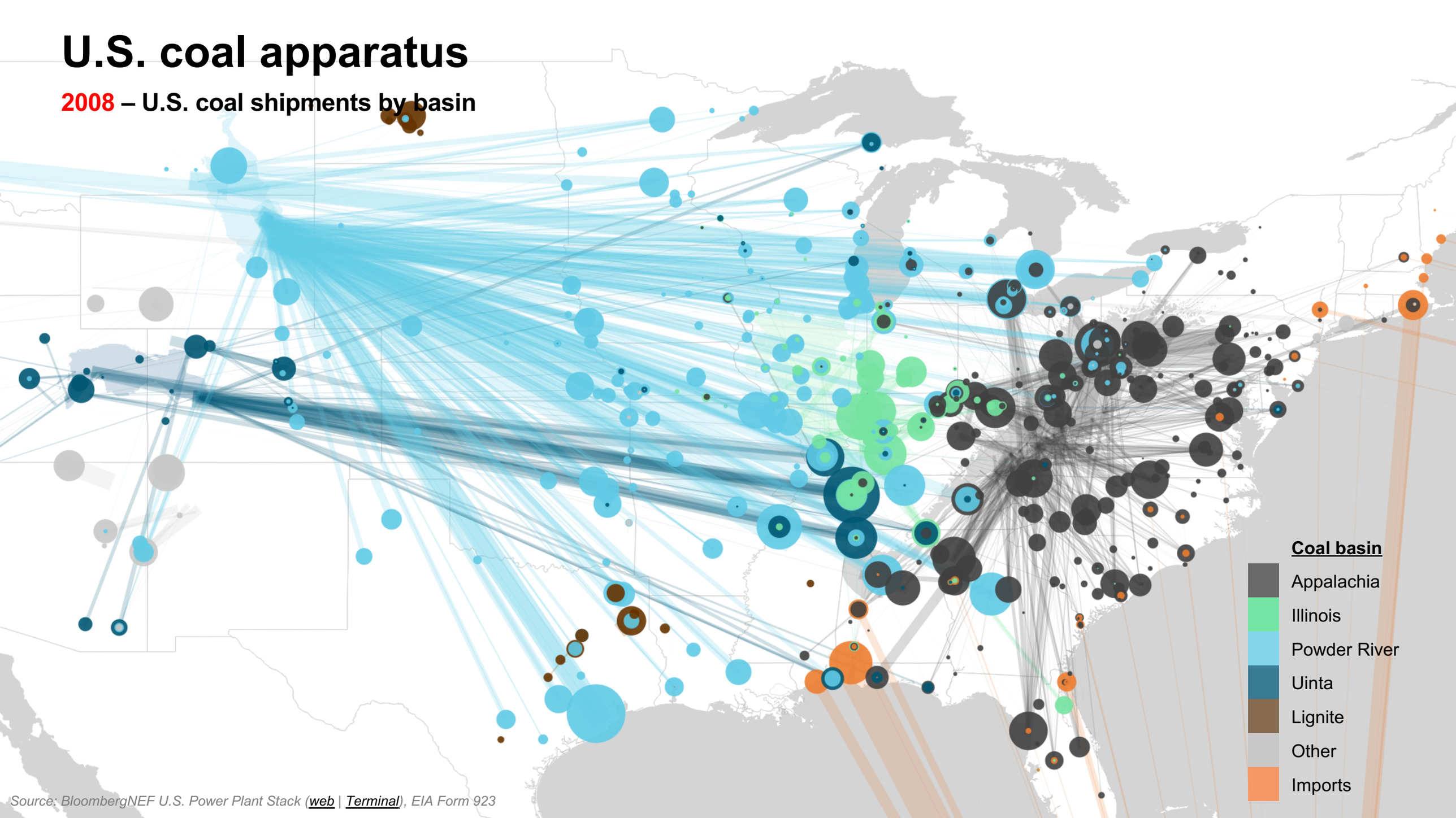
Coal- minus gas-fired generation – 30-day average output (GW)



BloombergNEF

U.S. coal apparatus

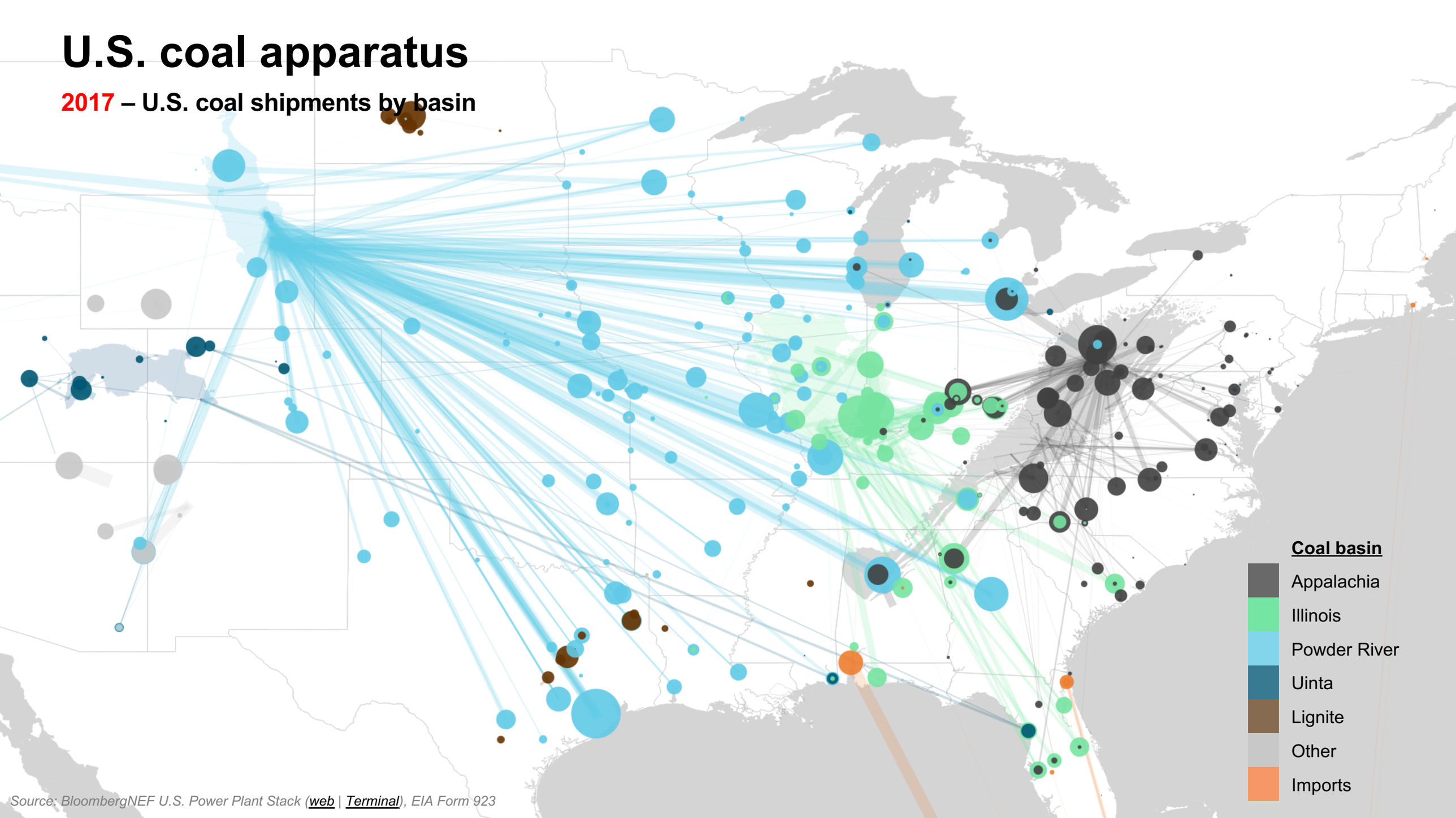
2008 – U.S. coal shipments by basin



Source: BloombergNEF U.S. Power Plant Stack (web | Terminal), EIA Form 923

U.S. coal apparatus

2017 – U.S. coal shipments by basin



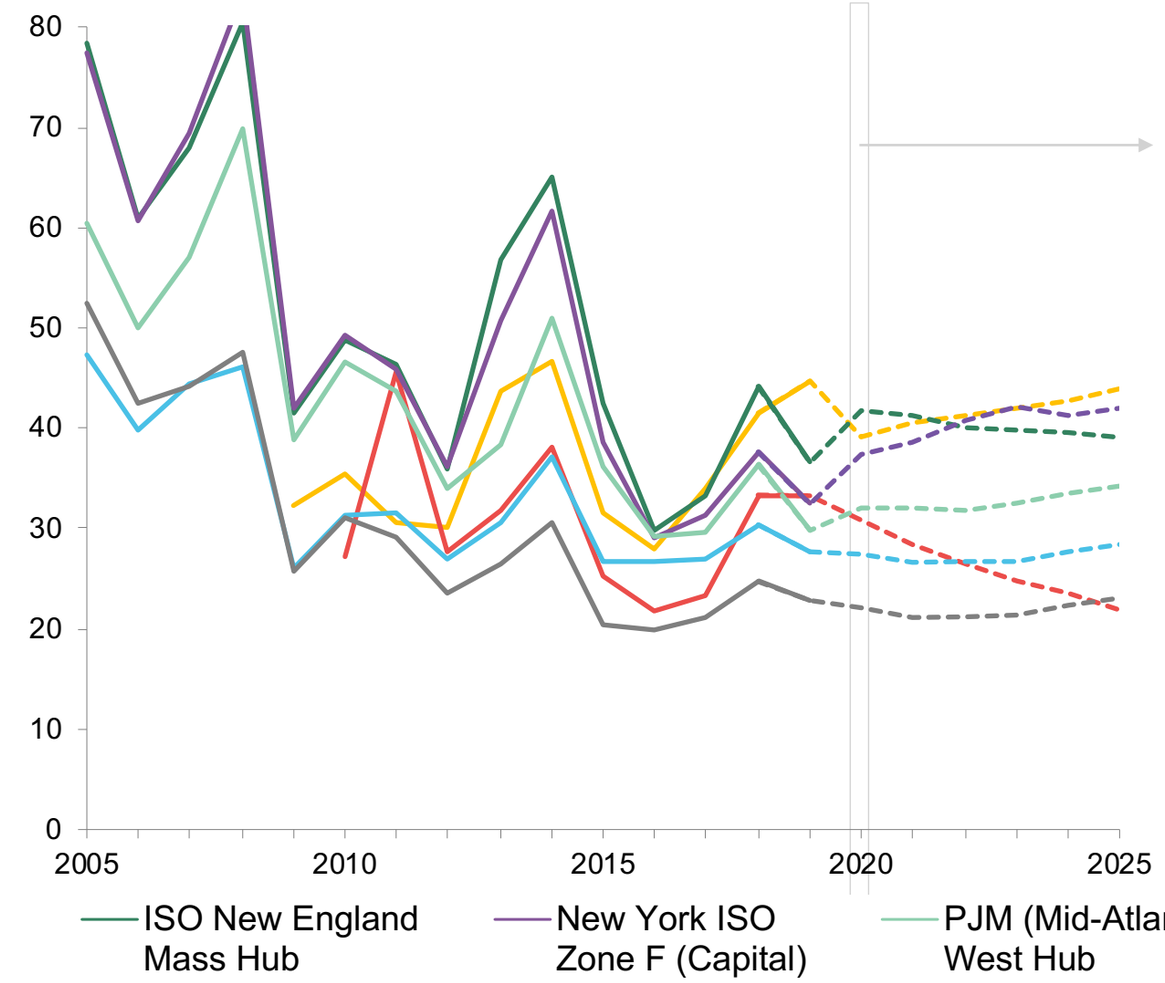
Source: BloombergNEF U.S. Power Plant Stack (web | Terminal), EIA Form 923

Power fundamentals

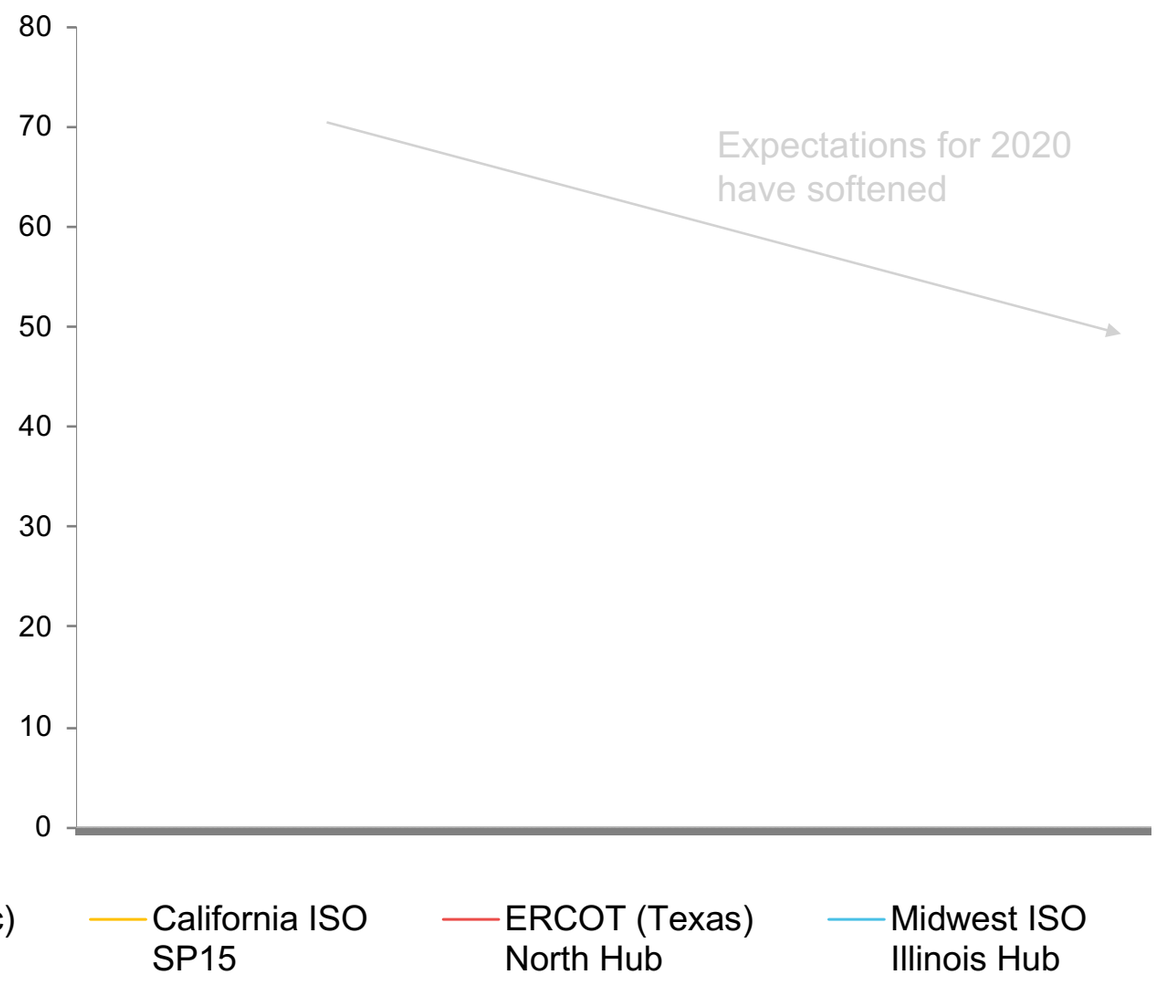
What is driving prices

Spots and futures in decline

Wholesale power prices at benchmark hubs
Around-the-clock (ATC) averages ($/MWh)



Expectations for 2020
Around-the-clock, 30-day average fair values ($/MWh)

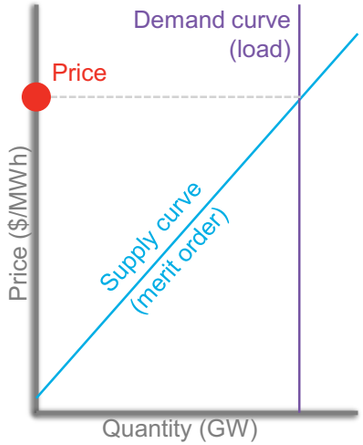


Source: BloombergNEF U.S. Power & Fuel Price Dashboard (web | Terminal)

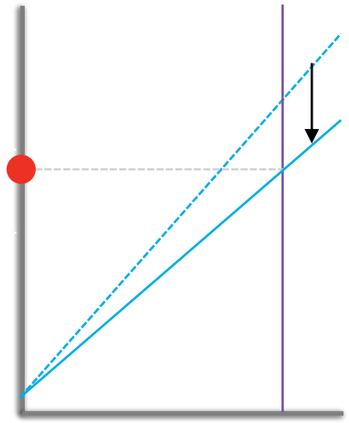
BloombergNEF

Eulogy and re-birth of wholesale power prices

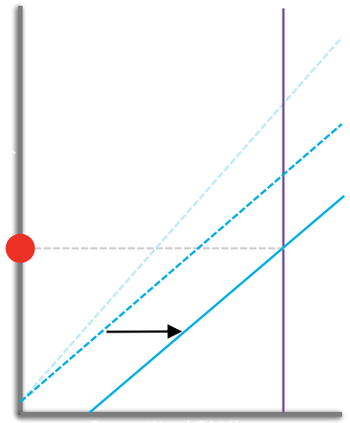
Starting point



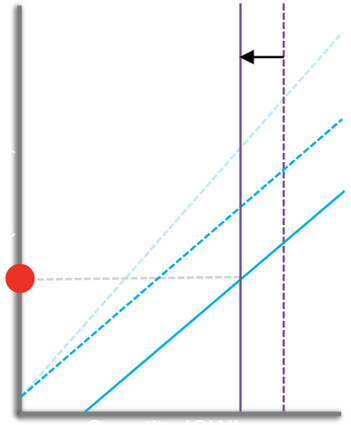
Fuel prices fall
(short-run cost cuts)



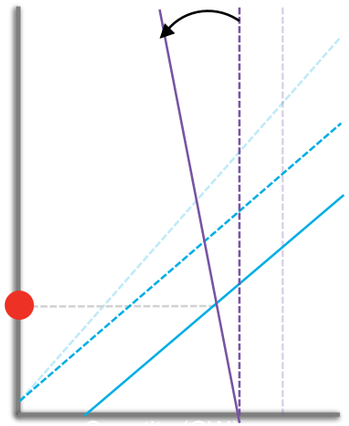
Renewable build-out
(merit order effect)



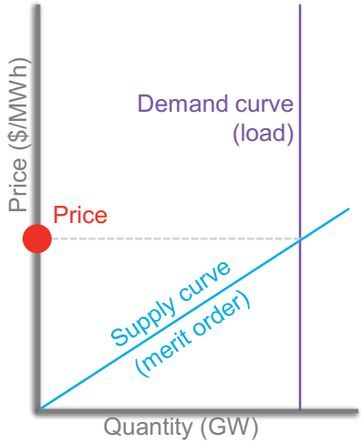
Load reductions
(efficiency)



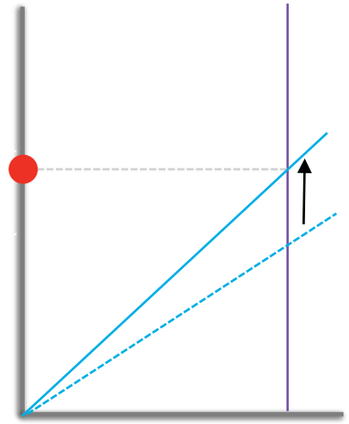
Demand elasticity
(consumer empowerment)



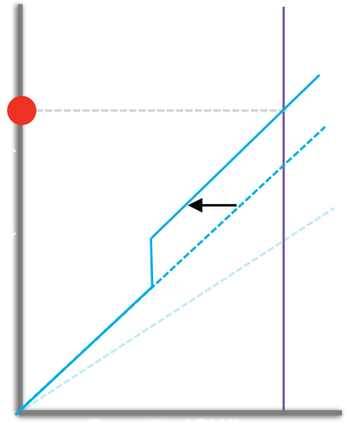
Starting point



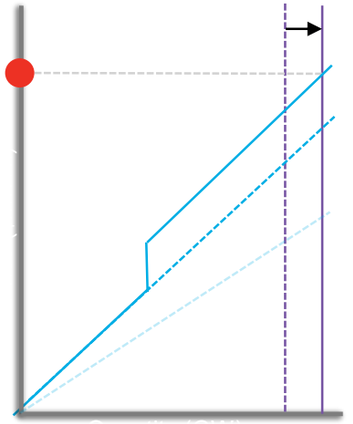
Fuel and carbon prices rise



Retirements



Load growth

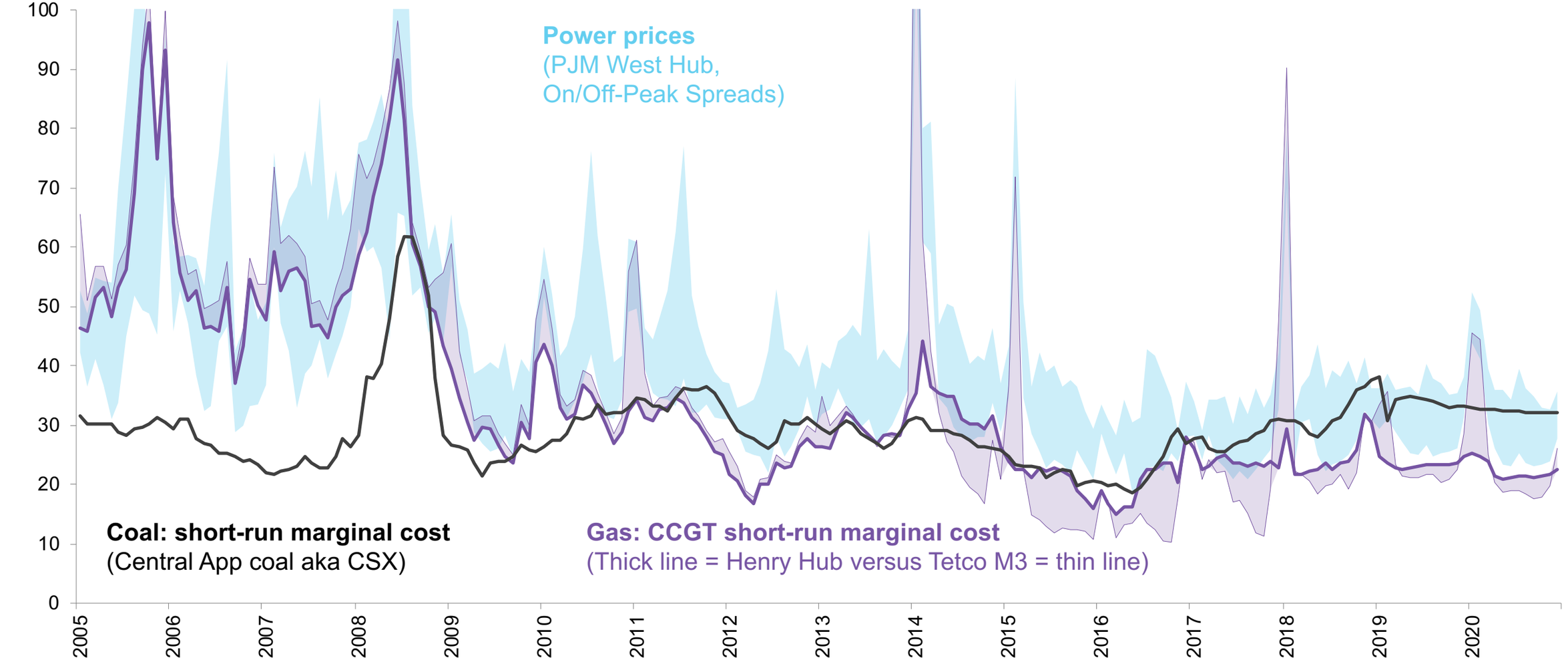


Source: BloombergNEF A Eulogy for U.S. Wholesale Power Prices (web | Terminal)

BloombergNEF

Relative economics of power, gas and coal

PJM West Hub power versus short-run marginal costs of coal and gas ($/MWh)



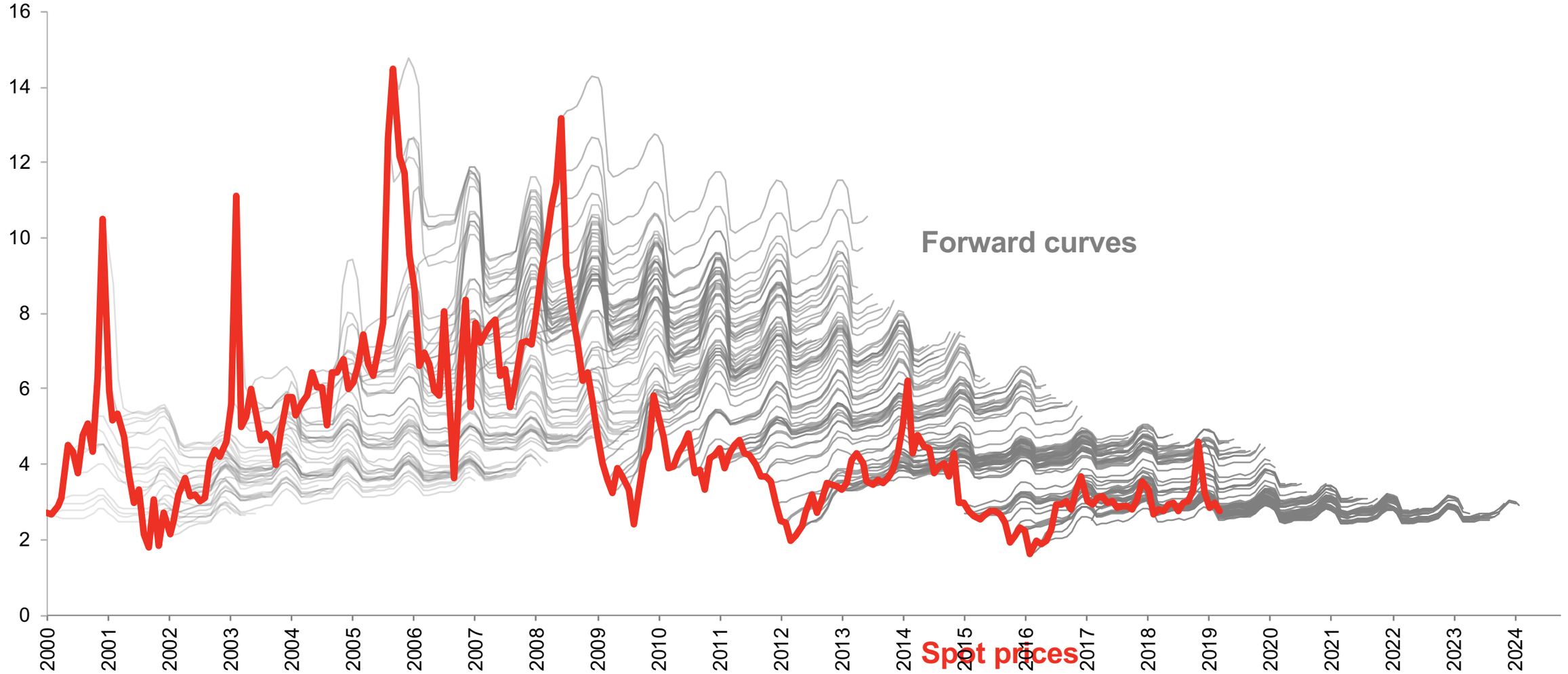
Source: BloombergNEF Power and Fuel Price Dashboard (web | Terminal)

Futures market

Trading track record

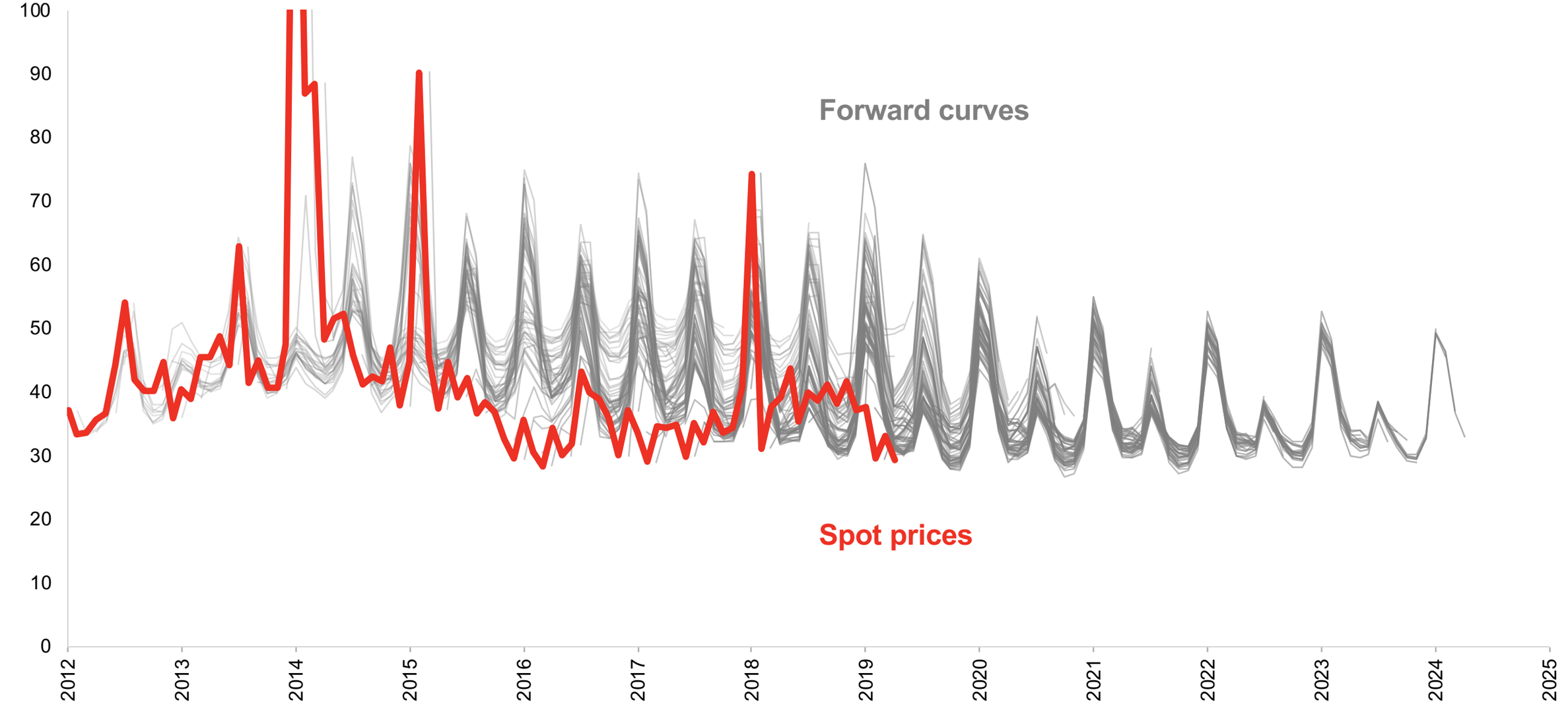
Gas trading track record

Monthly Henry Hub spots and futures ($/MMBtu)



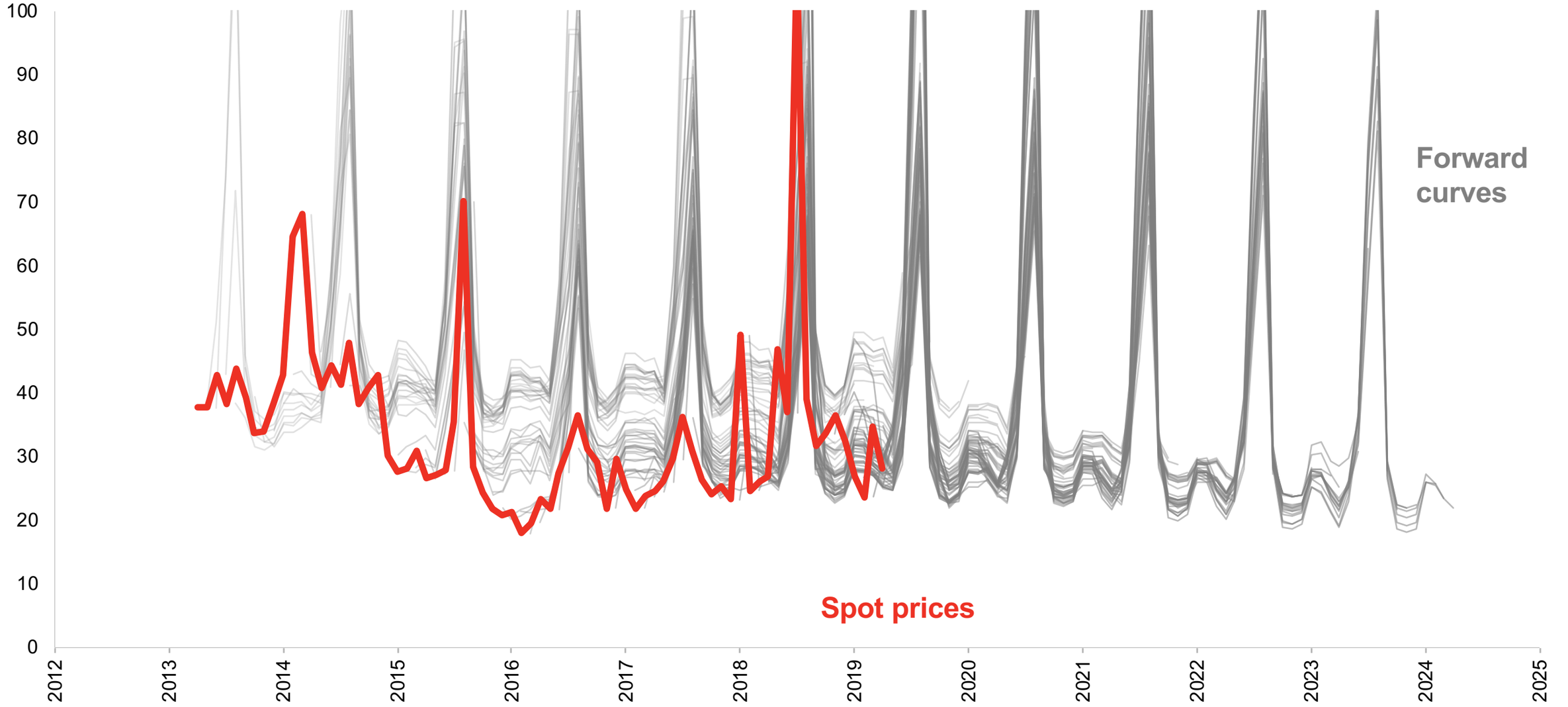
PJM power trading track record

Monthly PJM West Hub on-peak spots and futures ($/MWh)



ERCOT power trading track record

Monthly ERCOT North Hub on-peak spots and futures ($/MWh)



[enter renewables]

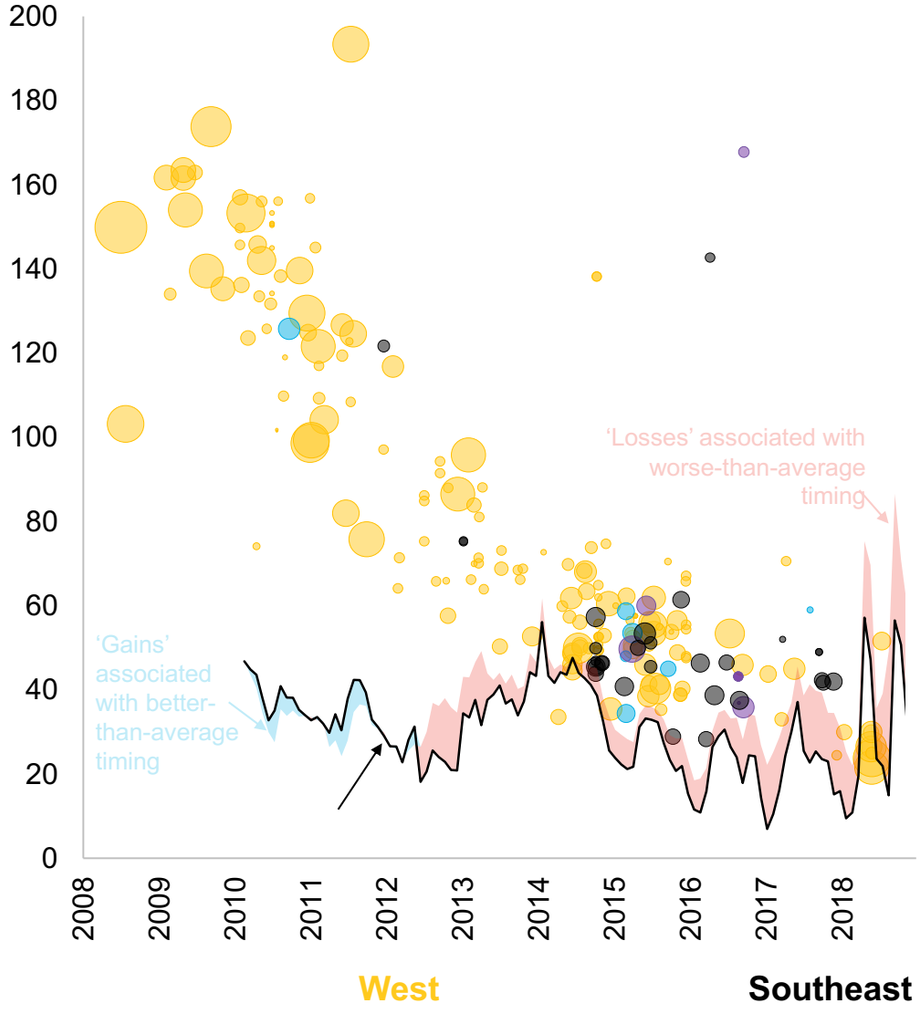
BloombergNEF

Power purchase agreements (PPAs)

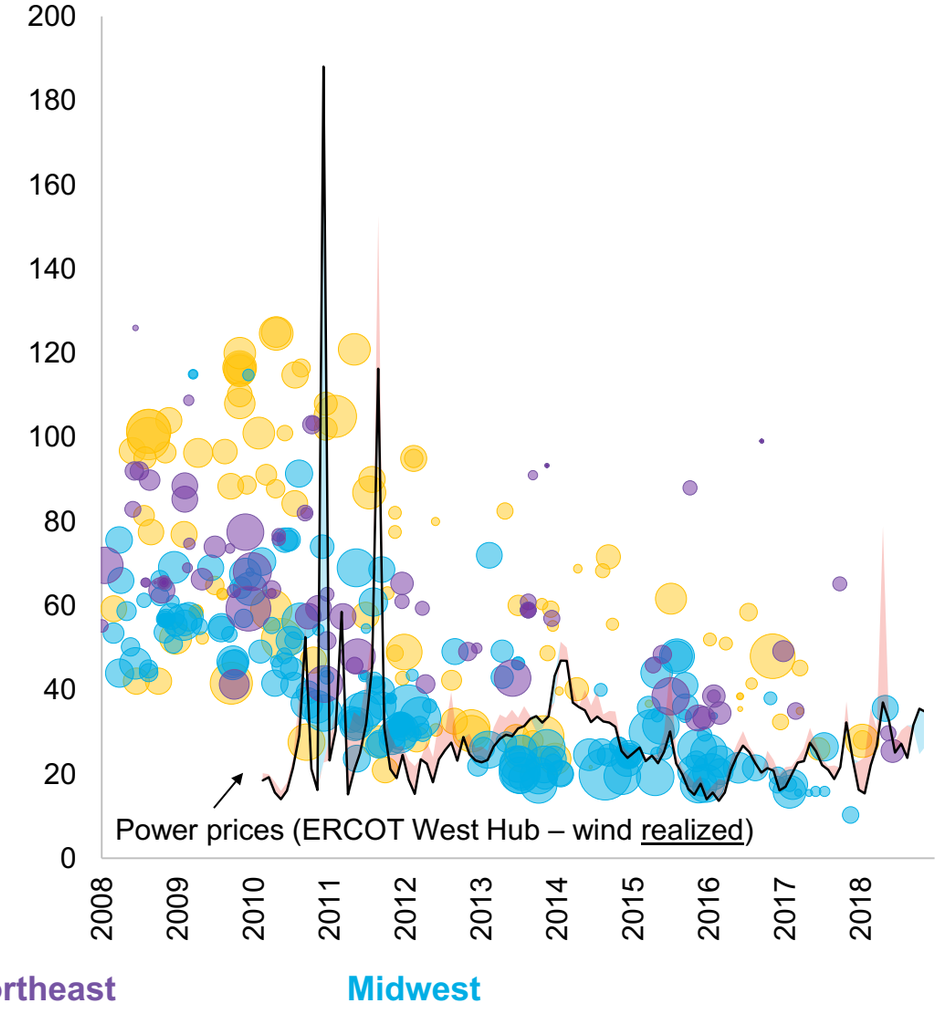
Renewables' lifeblood, wholesale market interface

U.S. power purchase agreements

Solar PPAs by signing date ($/MWh)



Wind PPAs by signing date ($/MWh)



Sources: BloombergNEF U.S. Renewable PPA Dashboard (web | Terminal), BloombergNEF Merchant Revenue Calculator for U.S. Renewables (web | Terminal)

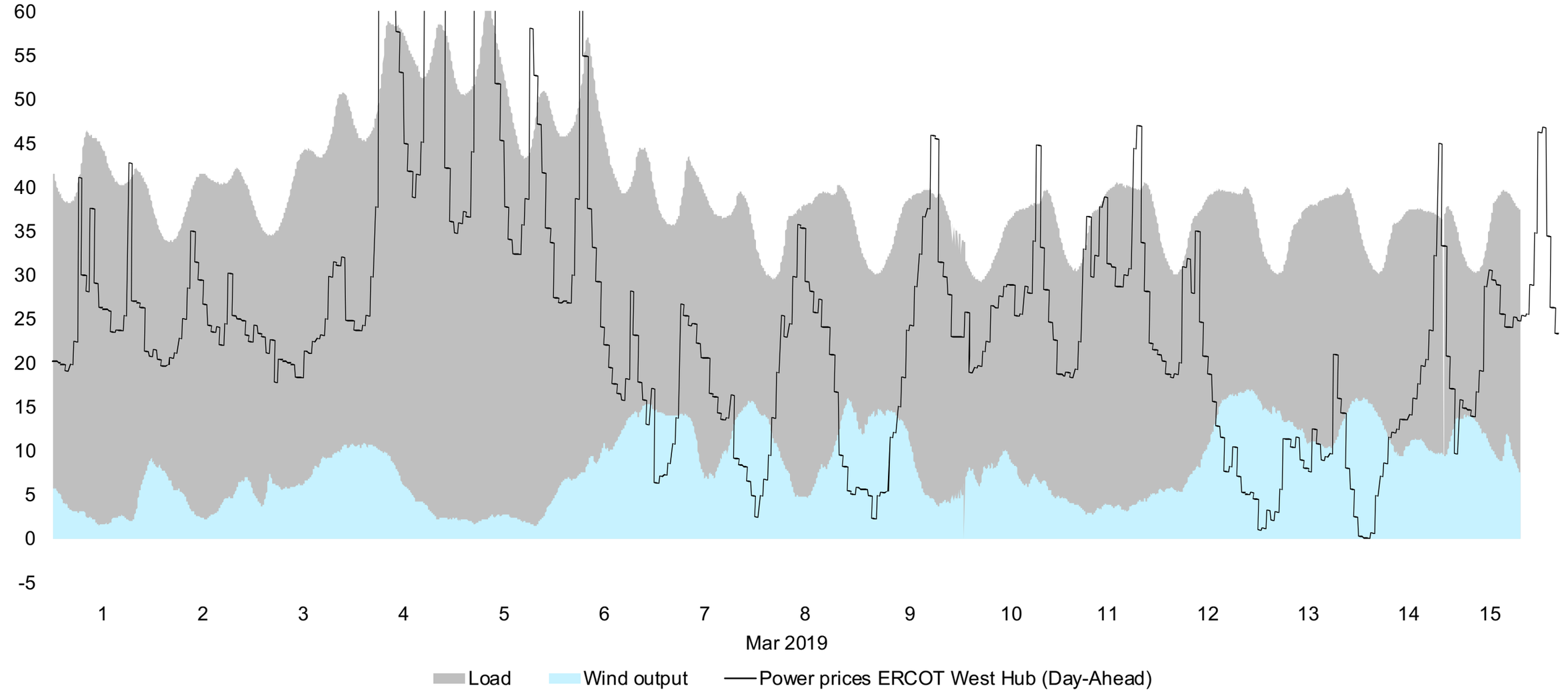
BloombergNEF

ERCOT

Widening DA-RT spreads, windswept grid

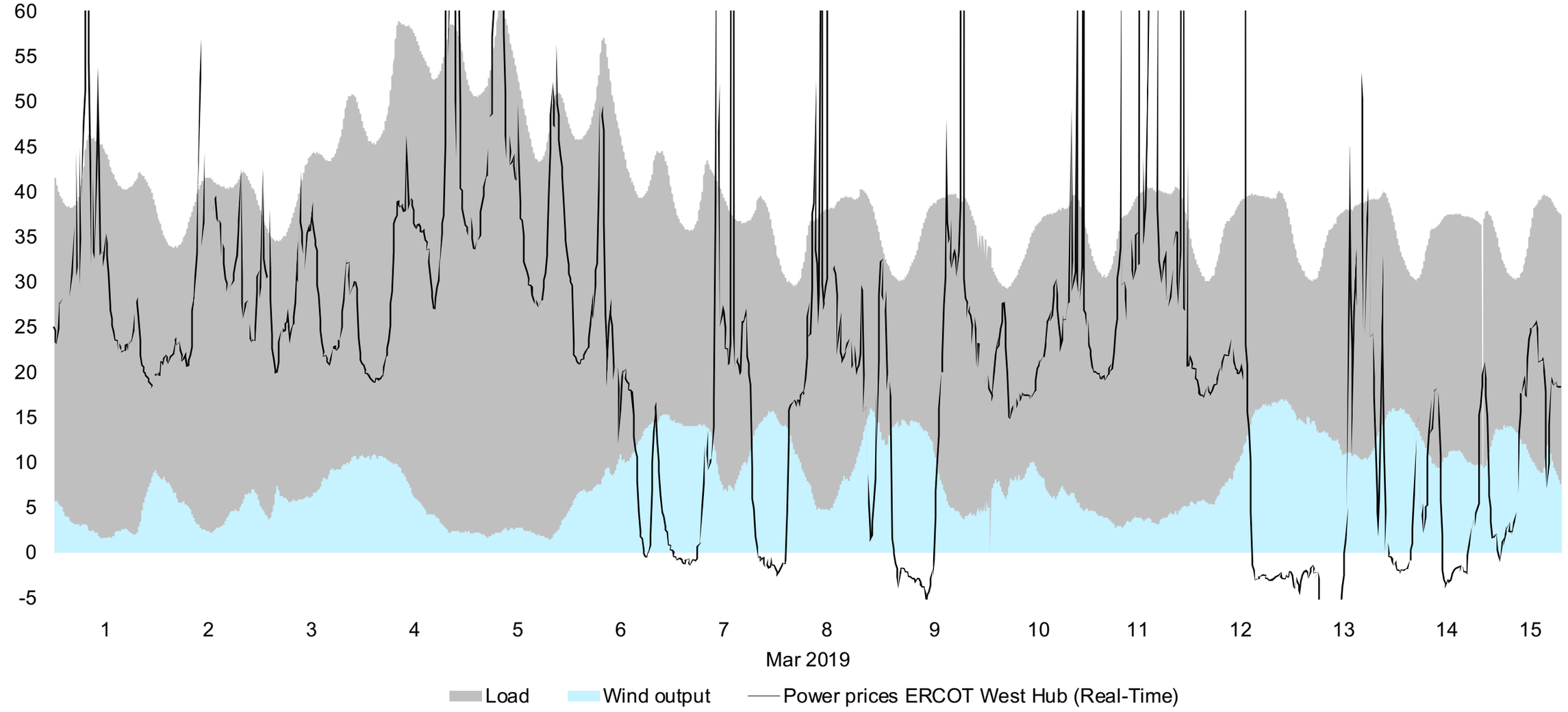
ERCOT recently

ERCOT load, wind output and day-ahead power prices (GW and $/MWh)



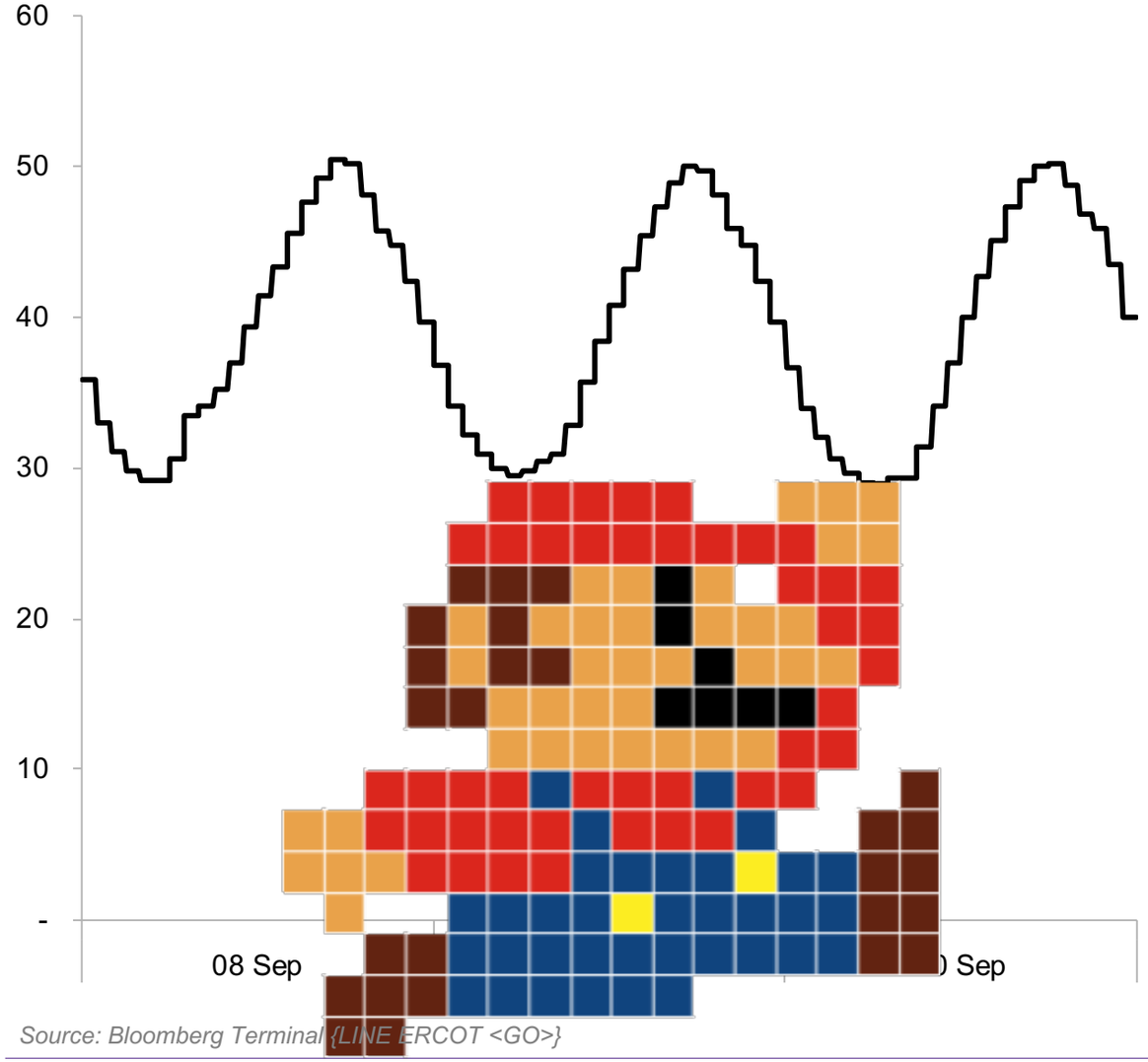
ERCOT recently

ERCOT load, wind output and real-time power prices (GW and $/MWh)

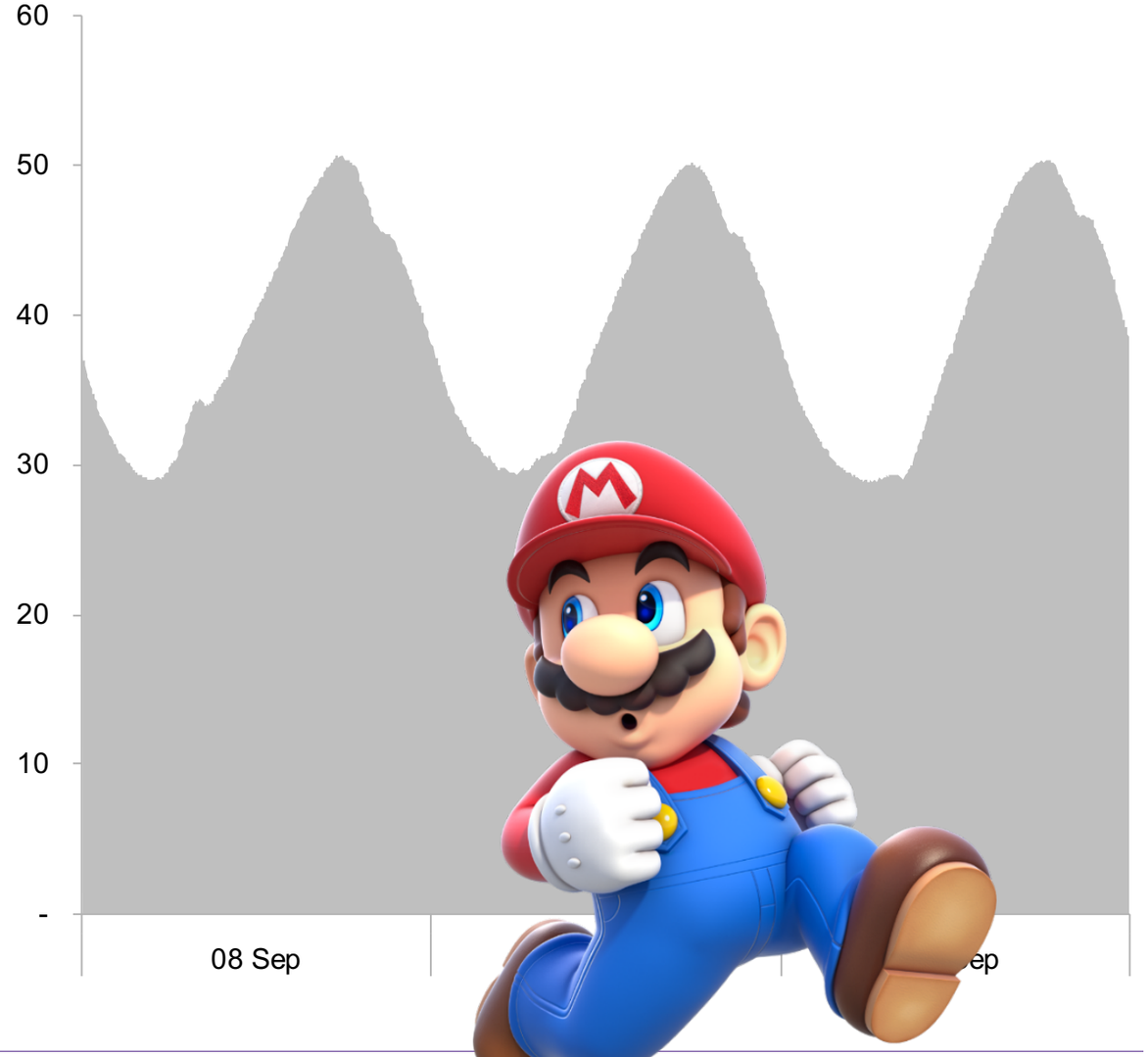


ERCOT load

Day-Ahead – forecast (GW)



Real-Time – actual (GW)



Source: Bloomberg Terminal {LINE ERCOT <GO>}

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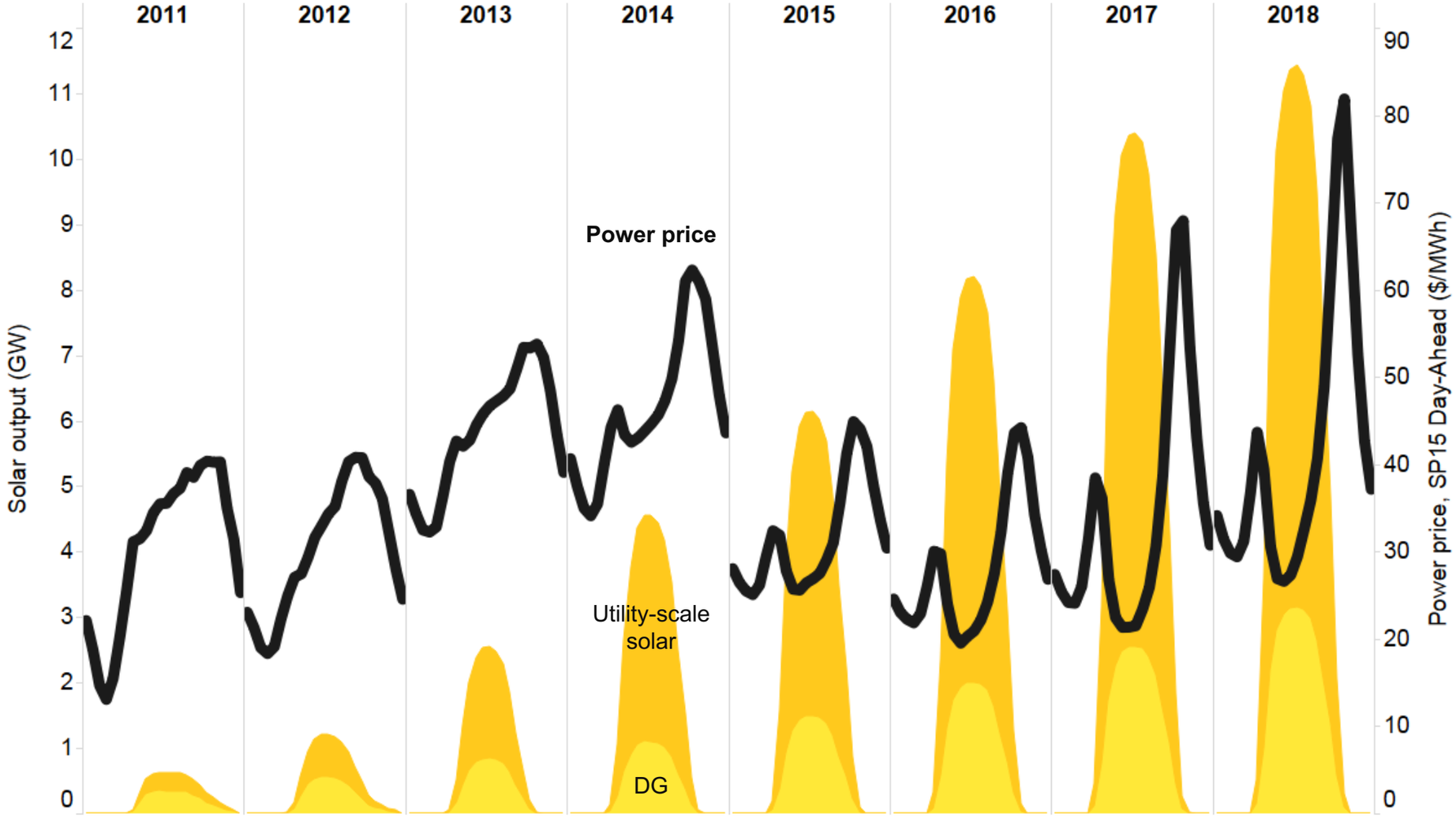
California

Duck-curve dynamics

Average day in California

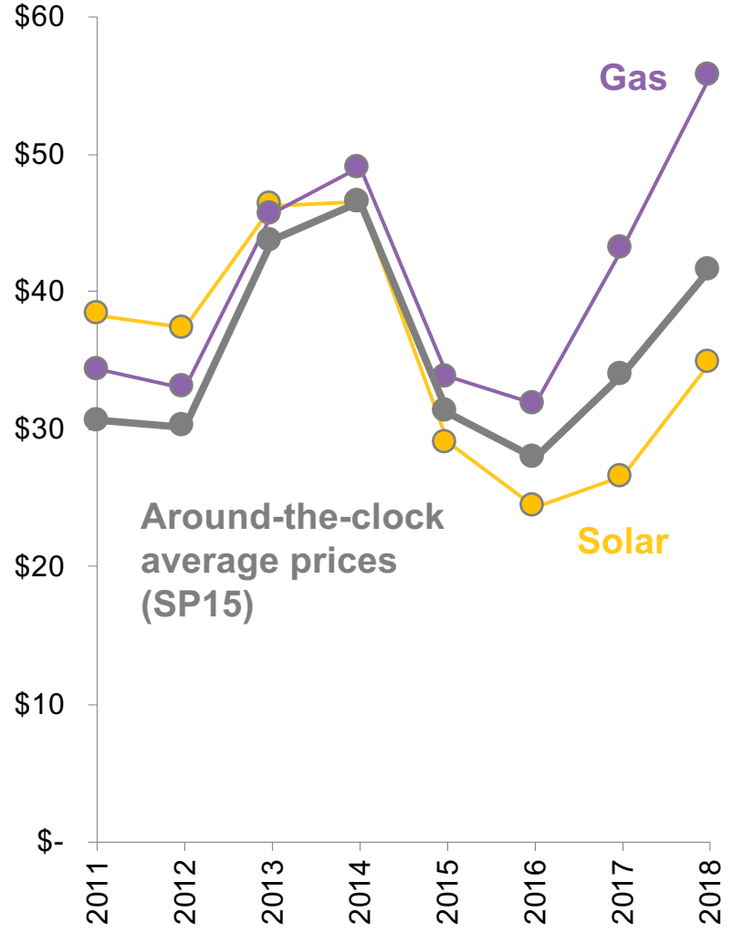
CAISO solar output versus wholesale power price



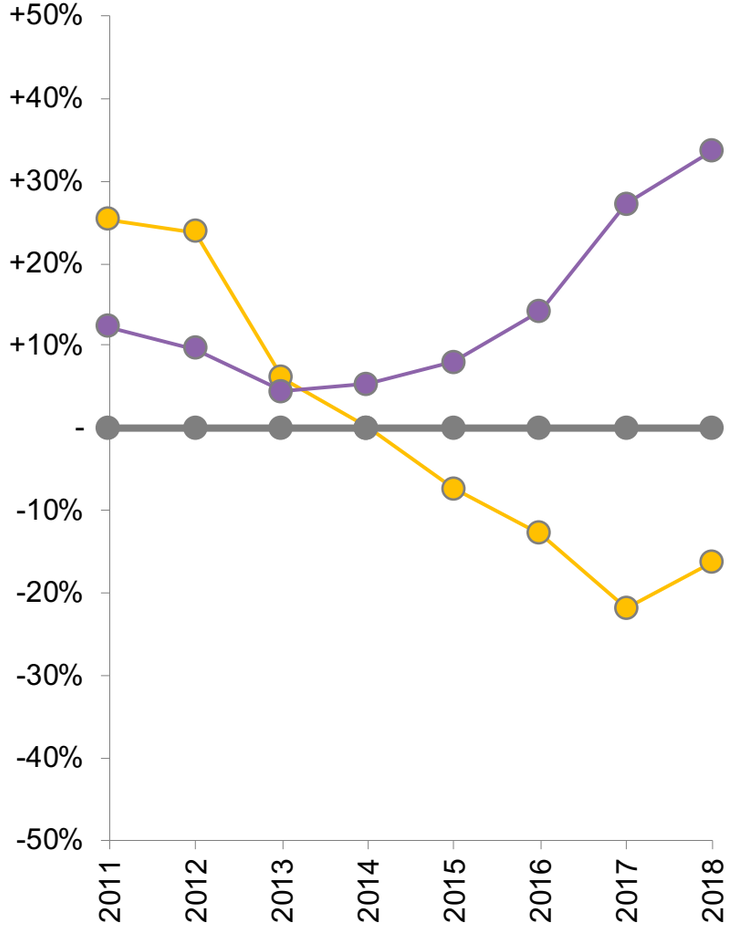
Bloomberg Terminal: {ALLX CARN <GO>, LINE CAISO <GO>}

Fading (and resurging) value of CAISO solar

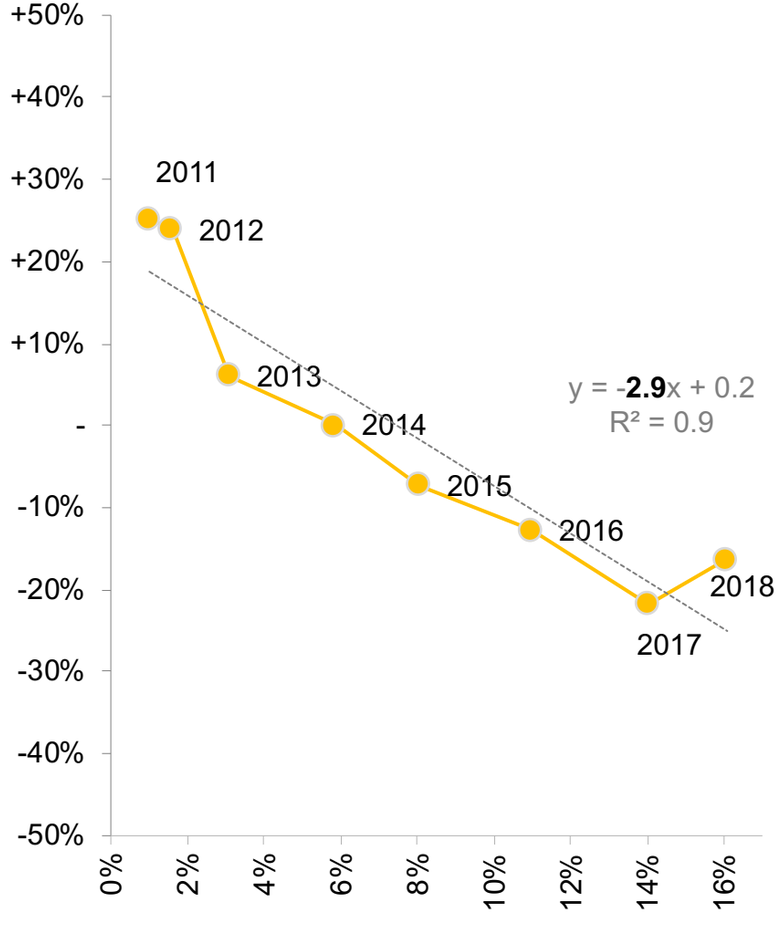
Realized power prices ($/MWh)



Scalars (realized price relative to ATC)



Scalars versus penetration



Source: Fading Value of Solar (and Midday Power) in California (web | Terminal)

Note: penetration includes in-state utility-scale and DG solar

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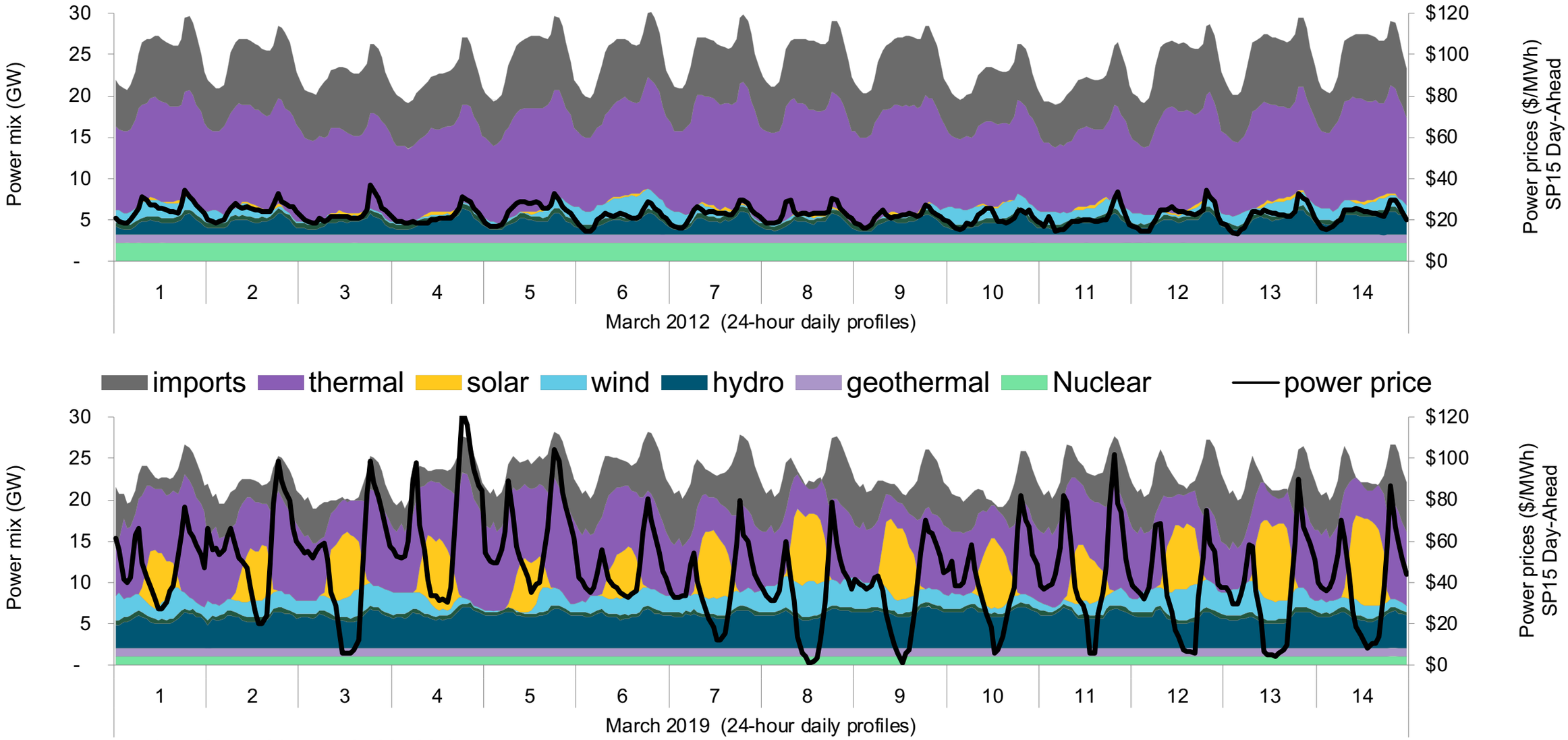
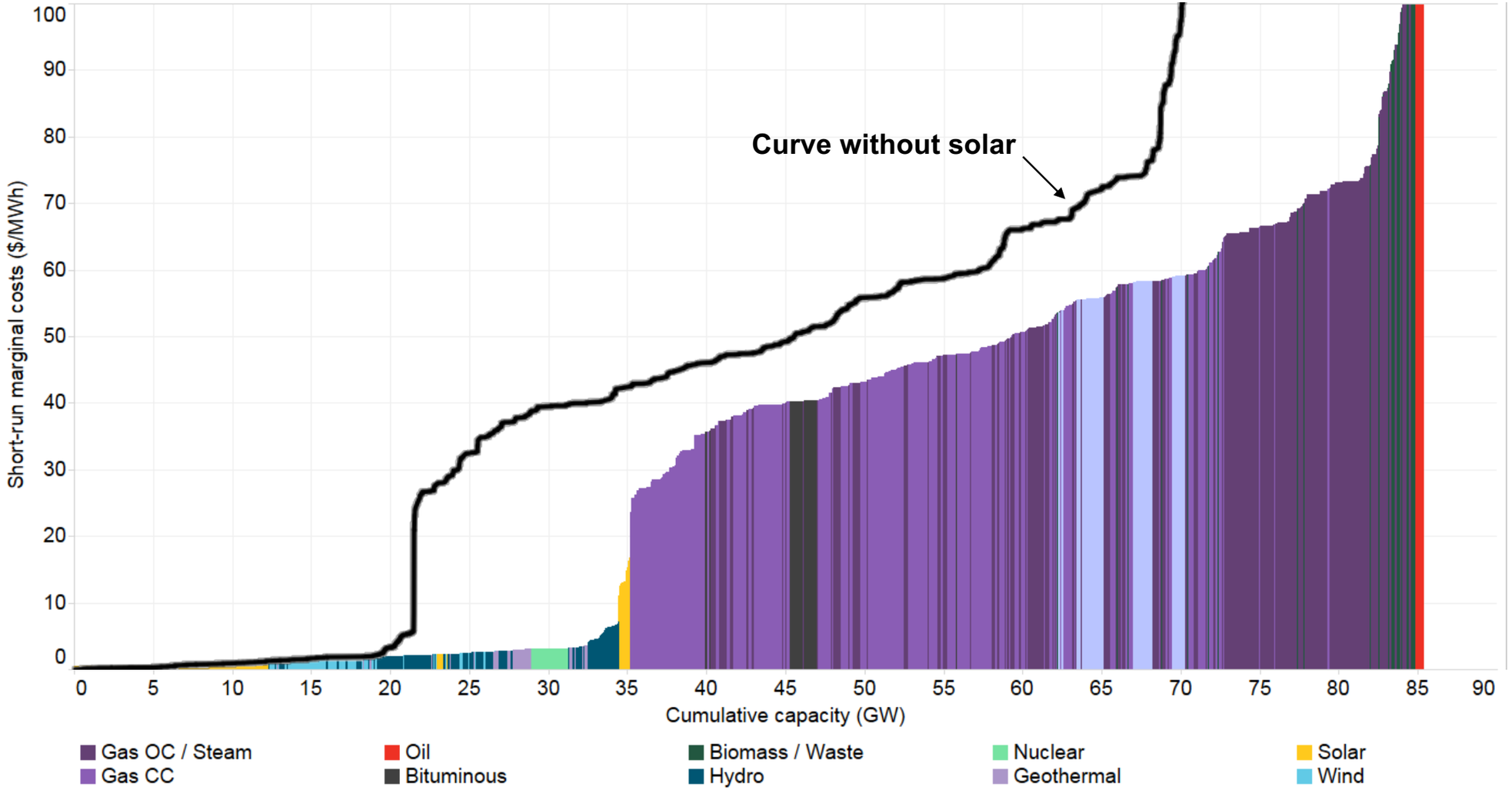
CAISO power mix and price profile



Bloomberg Terminal: {ALLX CARN <GO>, LINE CAISO <GO>}

CAISO merit order

March 2019

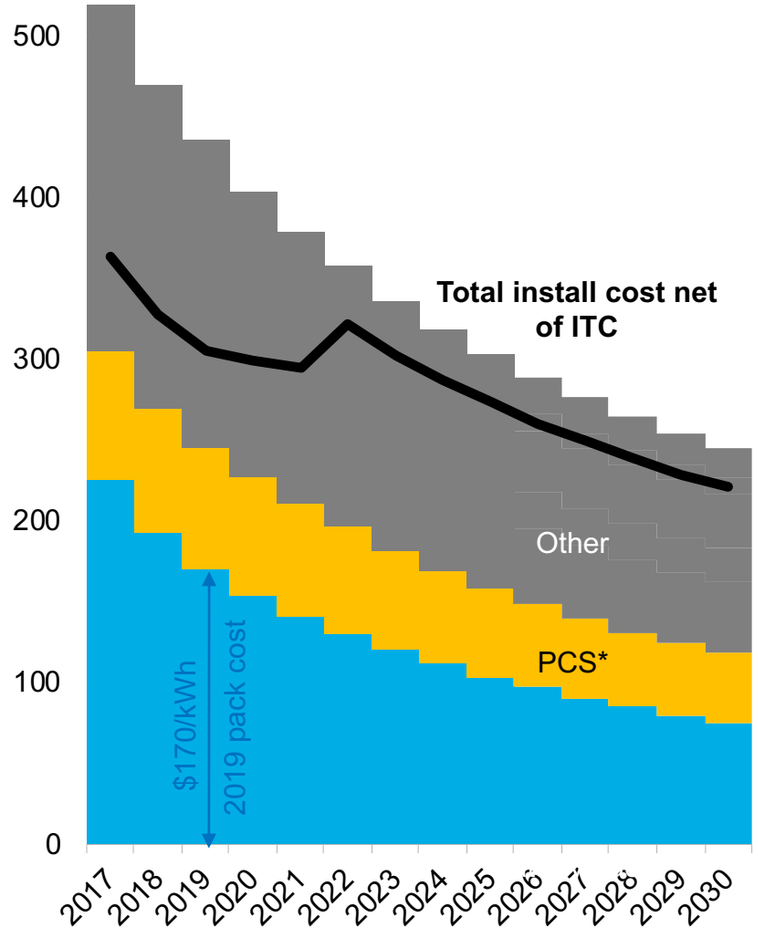


Storage

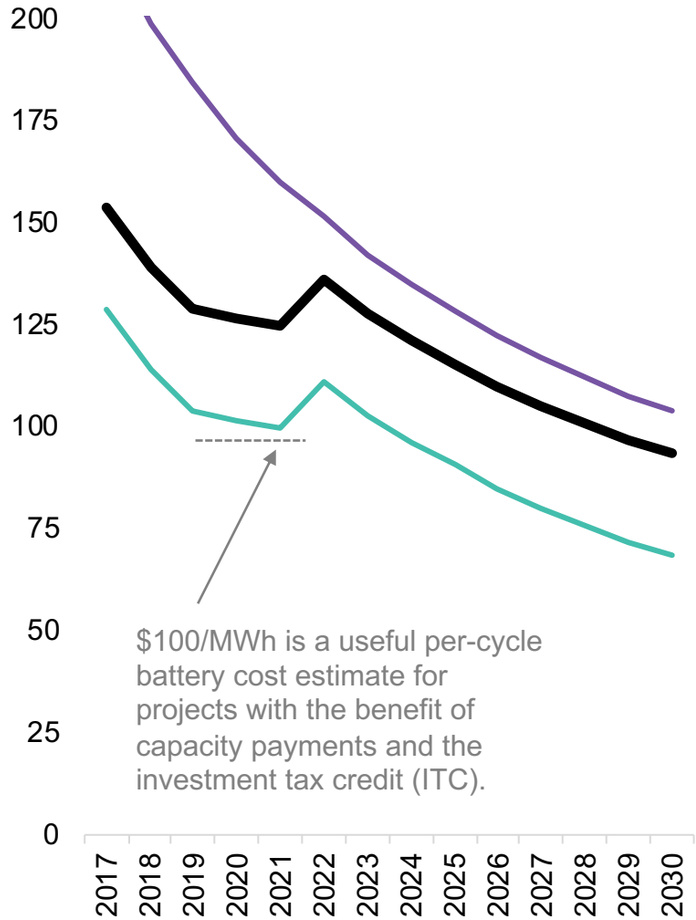
Savior or side-show?

Battery cost conversions

Grid-scale battery capex ($/kWh)
1-hour dispatch duration



Per-cycle break-evens ($/MWh)
Revenue requirements for each charge-discharge cycle



Without ITC

With ITC

With ITC + $100/MW-day capacity payment

- Note that battery configurations vary substantially. This slide uses benchmark cost estimates for standard configurations.

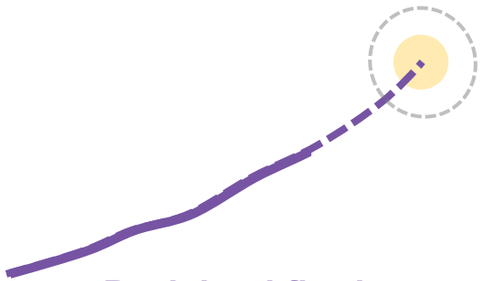
Assumptions		
Technology		Lithium-ion
Battery Duration	Cycles	6,000
Battery efficiency	%	85%
Depth of discharge	%	85%
Cycles per day		1.00
WACC		8%
Discharge duration	hours	1.00
System Size		80MWh

BloombergNEF

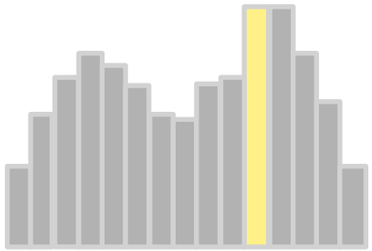
Notes: 'PCS' stands for 'power conversion system

Markets deliver different things over different timescales…

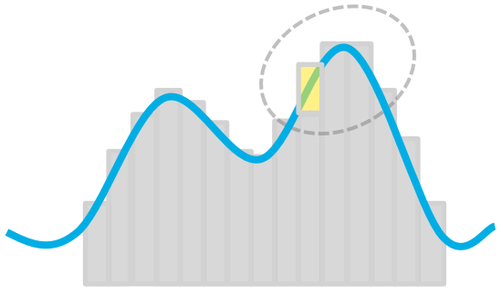
Market	Capacity markets / resource adequacy	Energy (day-ahead)	Energy (real-time)	Ancillary services
Delivery window	Years	Hours	Minutes	Seconds



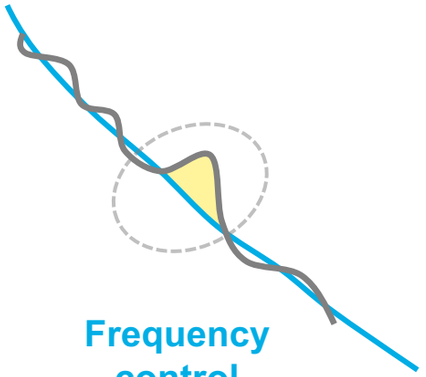
Peak load firming



Daily dispatch



Intra-hourly adjustments



Frequency control

Passive market

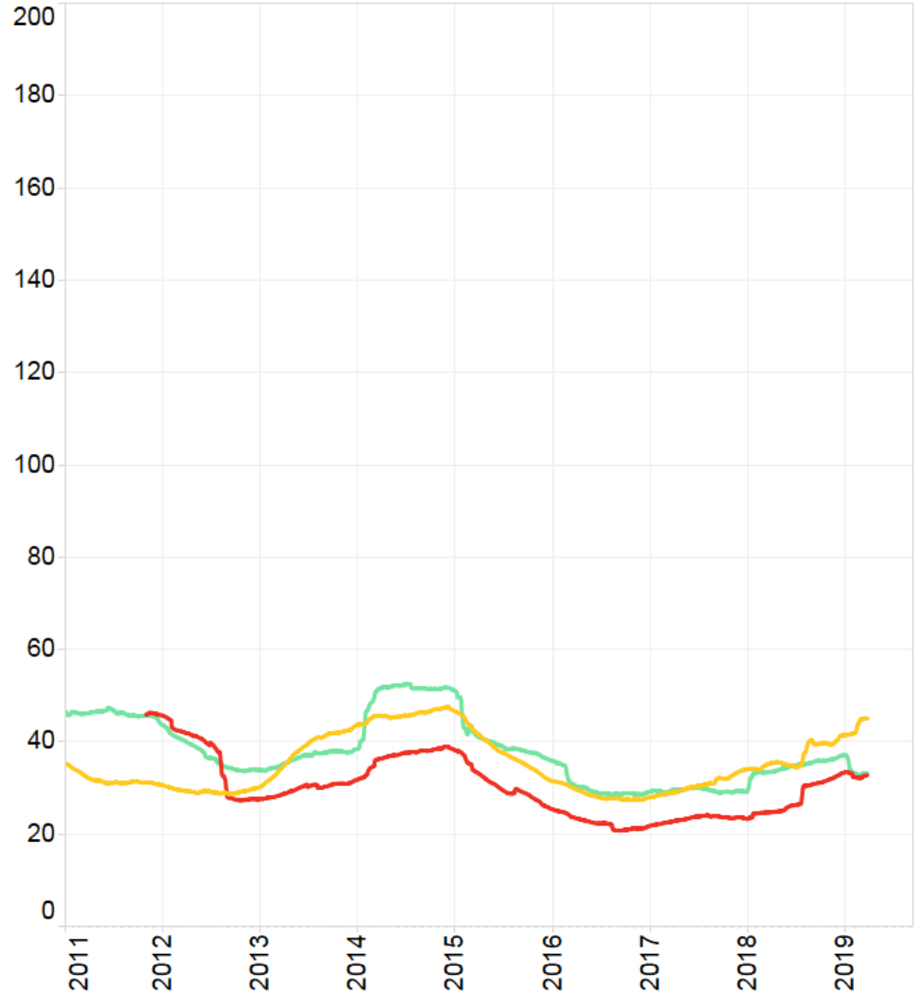
Active markets

…Batteries can play in all markets simultaneously

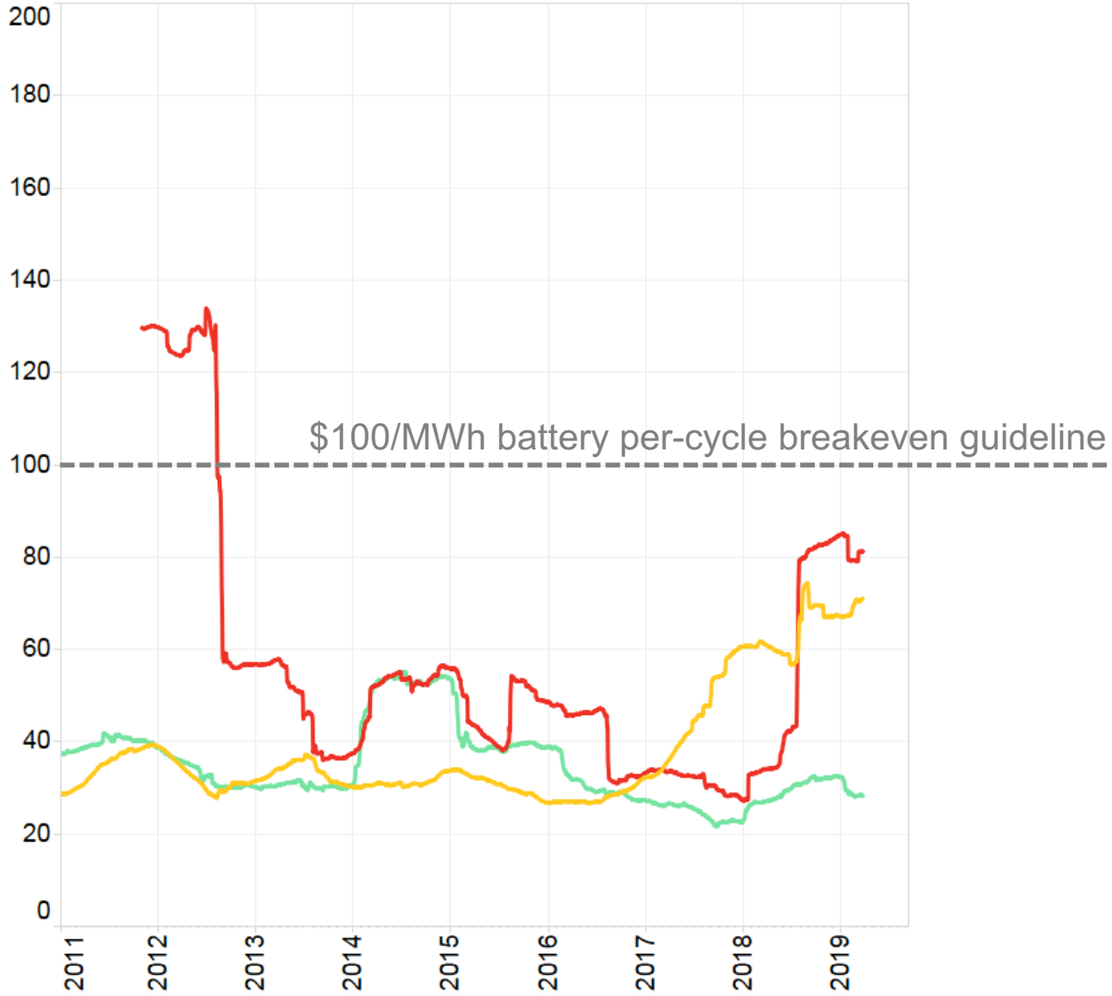
Source: BloombergNEF, Energy Arbitrage: A Battery's Guide to U.S. Power Prices (web | Terminal)

Day-ahead power price versus arbitrage opportunity

Around-the-clock average power prices
– Day-ahead, 365-day rolling average ($/MWh)



Daily minimum-to-maximum hourly price spreads
– Day-ahead, 365-day rolling average ($/MWh)



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Source: BloombergNEF, Energy Arbitrage: A Battery's Guide to U.S. Power Prices (web | Terminal)

Day-ahead power price versus arbitrage opportunity

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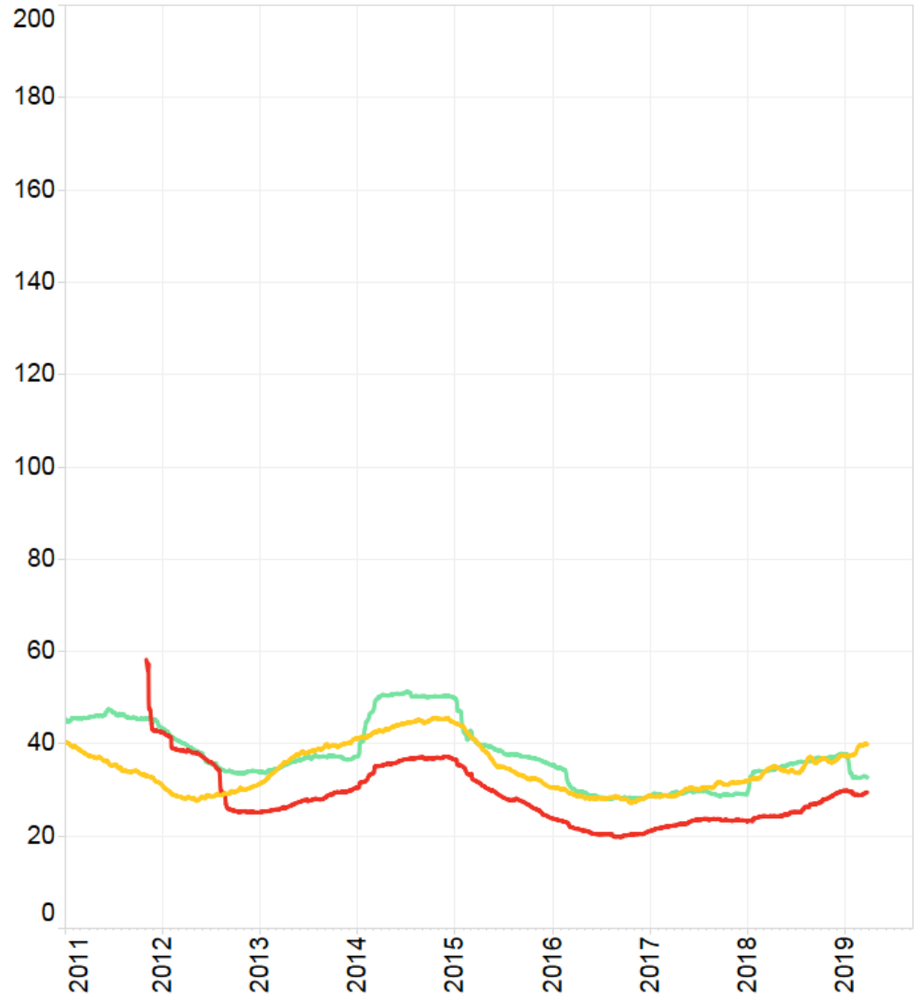
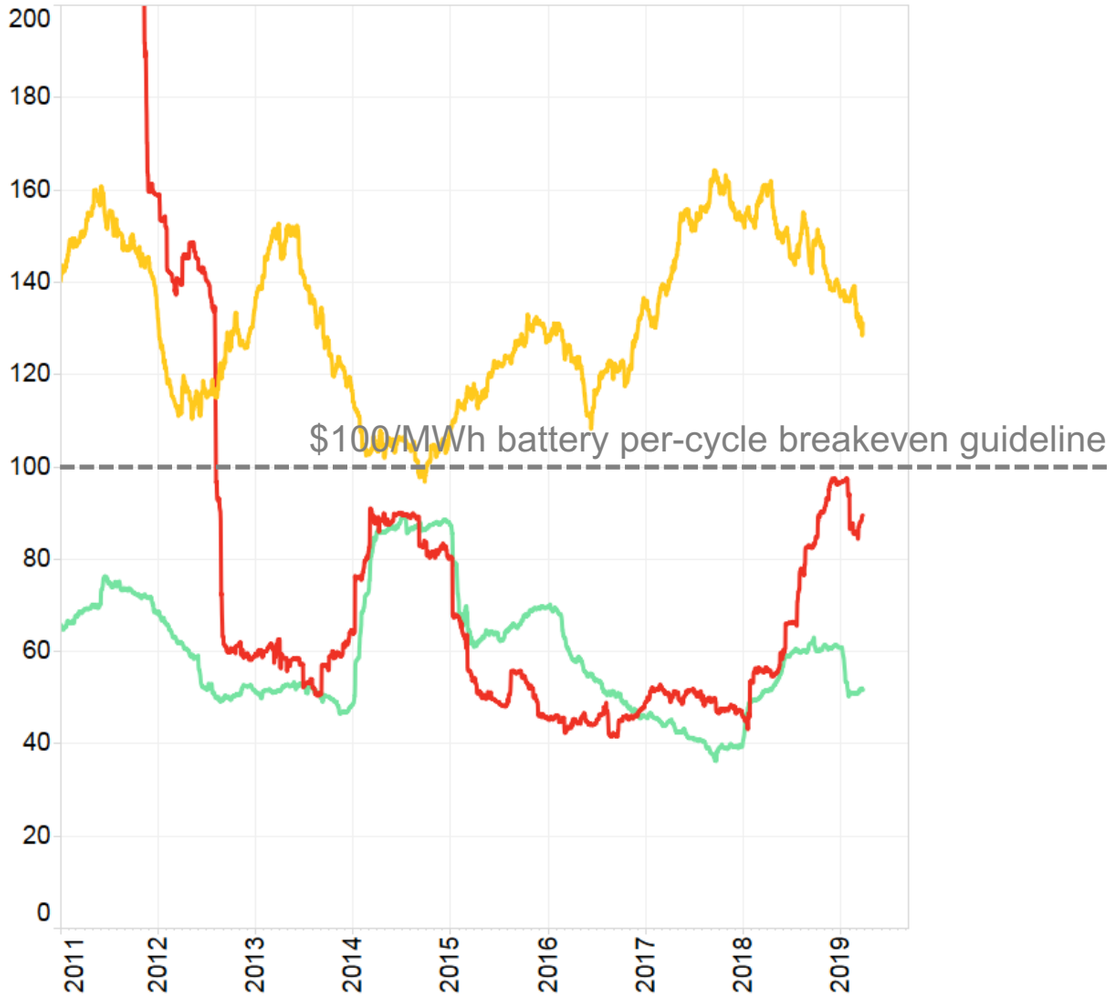


Daily minimum-to-maximum hourly price spreads
– Day-ahead, 365-day rolling average ($/MWh)



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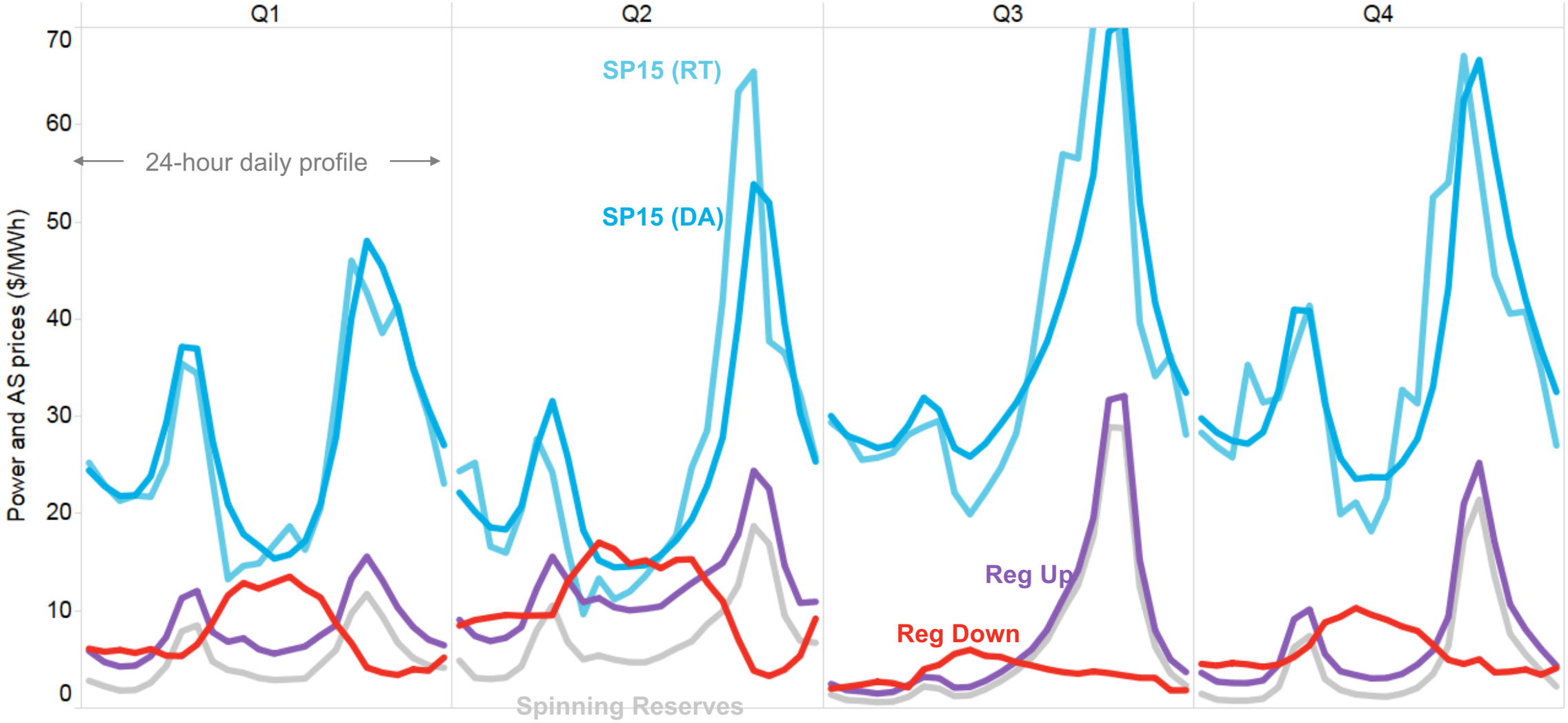
Source: BloombergNEF, Energy Arbitrage: A Battery's Guide to U.S. Power Prices (web | Terminal)

Ancillary services

CAISO power prices and ancillary services, 2015 – H1 2018



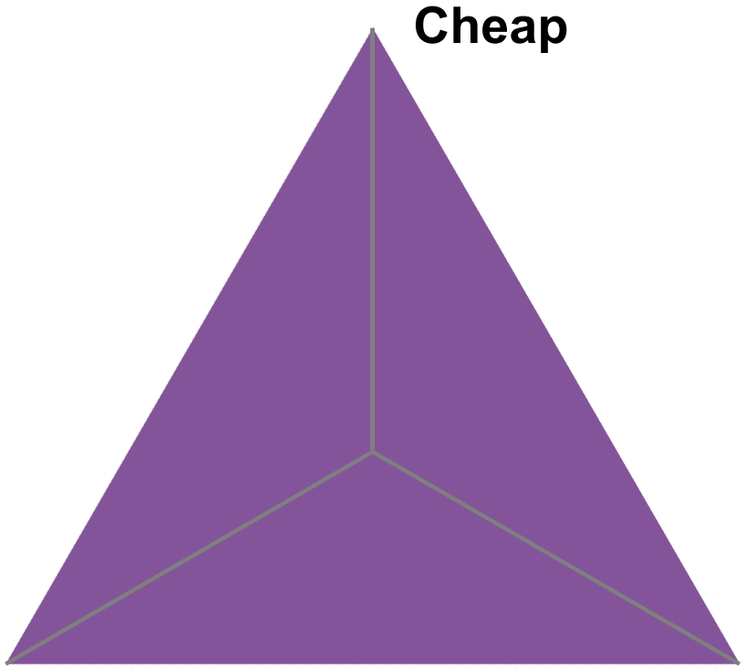
Source: BloombergNEF, Energy Arbitrage: A Battery's Guide to U.S. Power Prices (web | Terminal)

Conclusion

Electricity end-game

Optimal grid

Objective of wholesale **power markets**



Objective of **capacity markets**

Objective of **environmental incentives**

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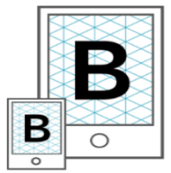

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