

Ercot Market Outlook

Everything depends on Bitcoin

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Executive summary

The Texas power market has a new force: Bitcoin mining. Load growth from these facilities and extreme temperatures brought demand to record-breaking levels in 2022. In this outlook, we explore where prices could go in 2023 and 2024 and the key fundamentals shaping the market:

- **Bitcoin mining:** The wave of new Bitcoin mining facilities added 1.8 gigawatts (GW) to baseload and contributed to record demand in 2022. This wave could grow to a tsunami as there are 5GW to 10GW of planned mines through 2024. The critical factor in Ercot's future will be the rapid scale of build and mines' operational behaviors.
- **Solar build:** The flourishing solar fleet will shift peak net load to evening hours in 2023. Solar's predictable generation profile balances wind's volatility that has historically dictated price spikes in Ercot. The solar fleet is set to grow by at least 4GW annually through 2030 and will be the key balancing force to Bitcoin mining build.
- **Weather:** Texas temperatures continue to defy norms and reach extreme levels. The four-month stretch between April and July 2022 saw the hottest temperatures on record. Regulators have implemented changes to Ercot's scarcity adder and proposed new market designs to improve grid reliability and avoid a repeat of February 2021's Winter Storm Uri.
- **Prices:** Ercot power prices will be a function of new Bitcoin mining facilities. BloombergNEF's price model shows that the difference between a bullish and bearish scenario for these facilities sways power prices by 40% in 2024. Ercot will likely witness elevated shoulder season power prices and higher off-peak prices when solar comes offline.

86GW

Projected peak demand for summer 2023

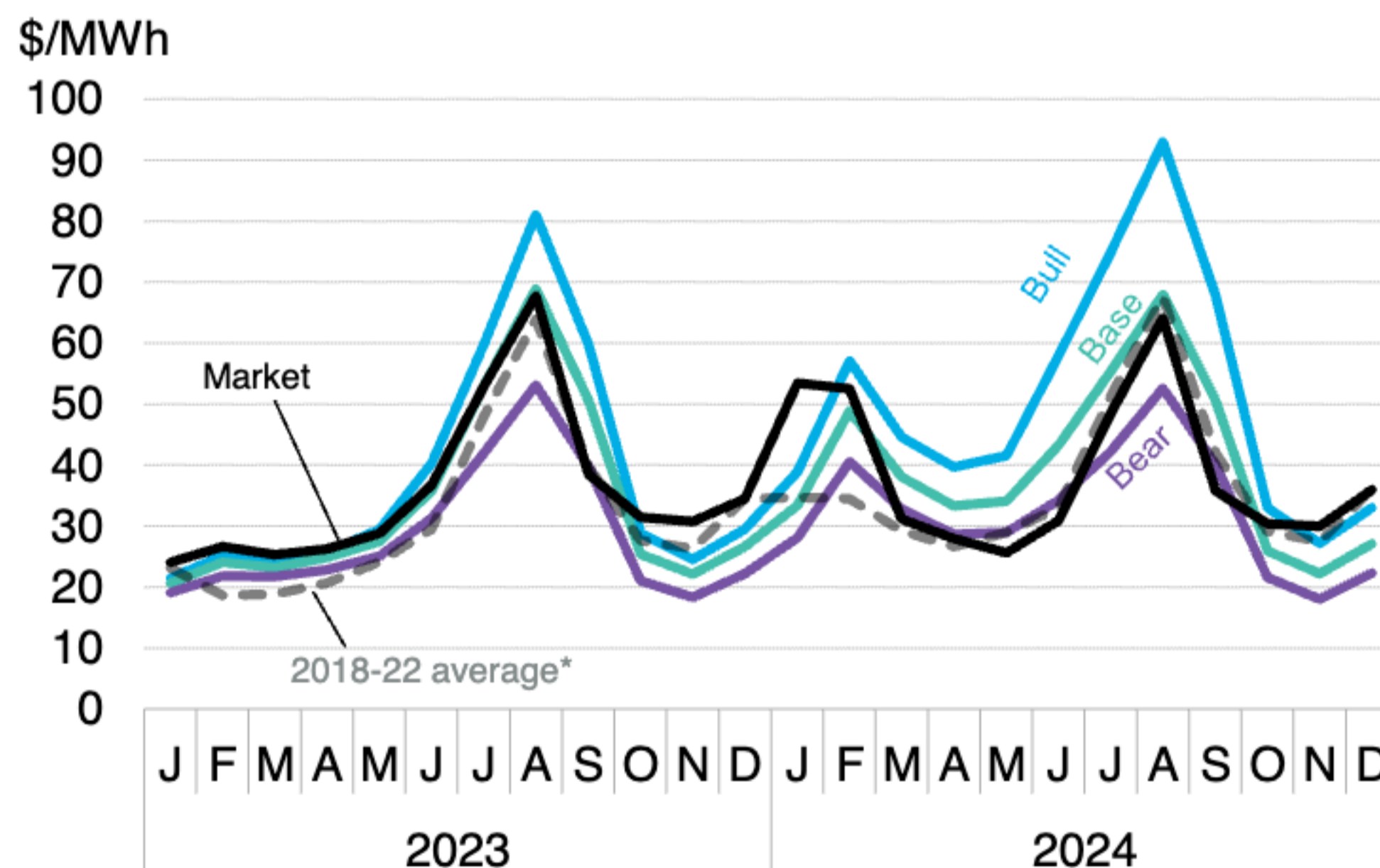
17GW

Total solar capacity for summer 2023

\$94/MWh

Projected Ercot on-peak price for August 2023

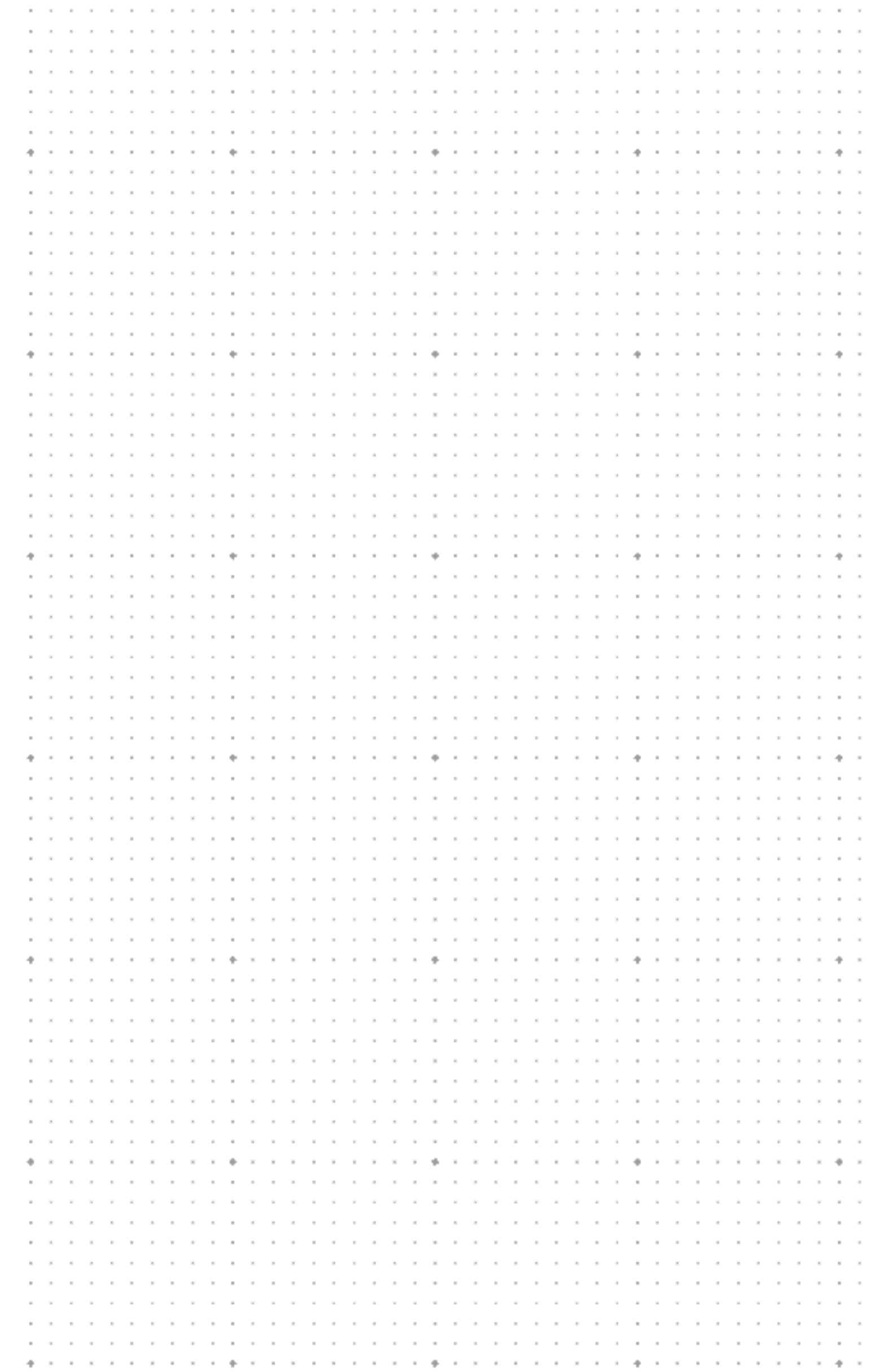
Ercot Hub average ATC price forecast



Source: BloombergNEF. Note: ATC = around-the-clock. The forecast scenarios shown in this chart exclude July 2022 weather as an input. "Market" refers to the forward curve (at the time of publication) except for the historic average for January and February 2023.

Demand

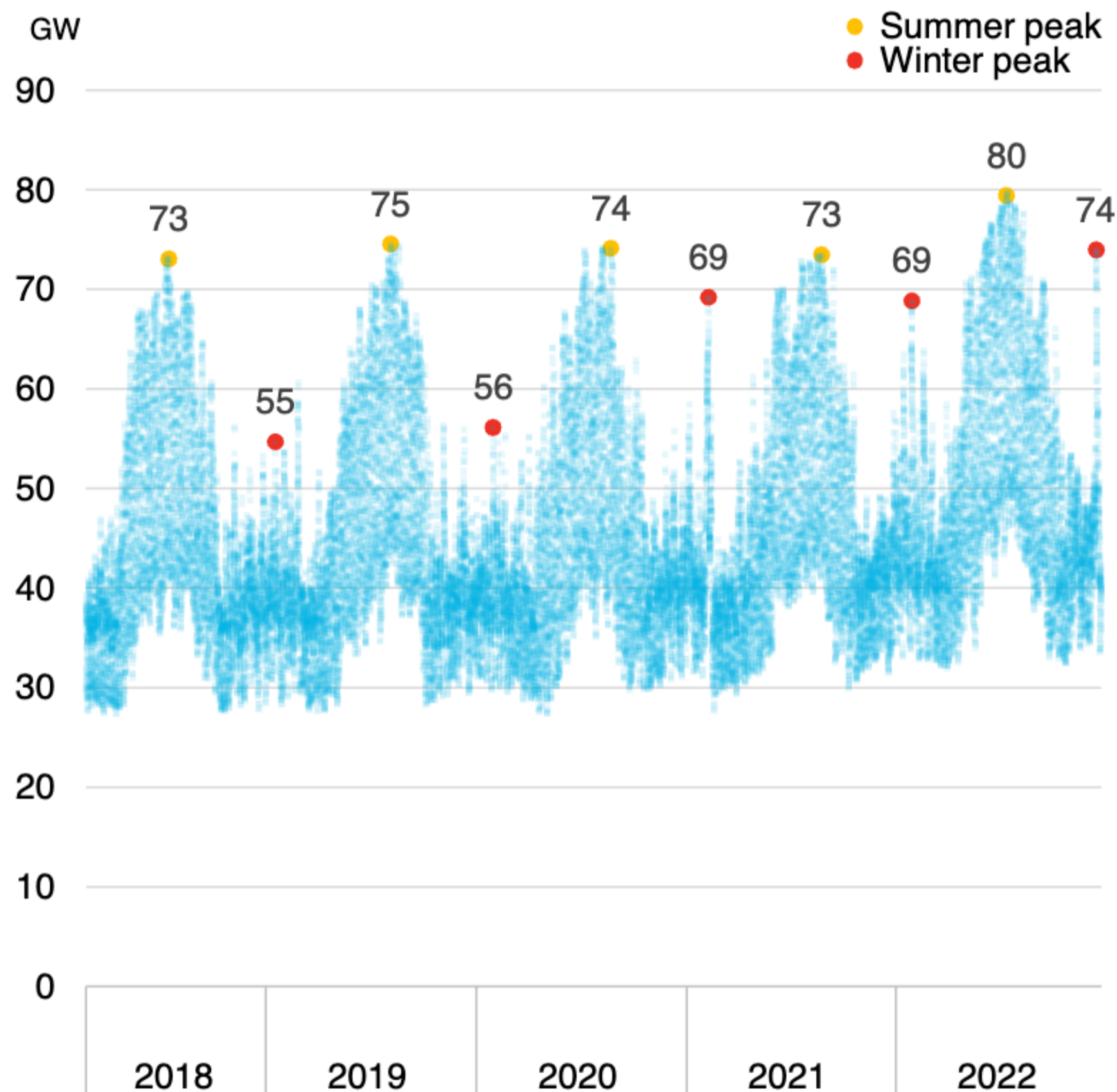
An unprecedented new trend



Looking back

A record-breaking year

Hourly Ercot demand 2018-2022



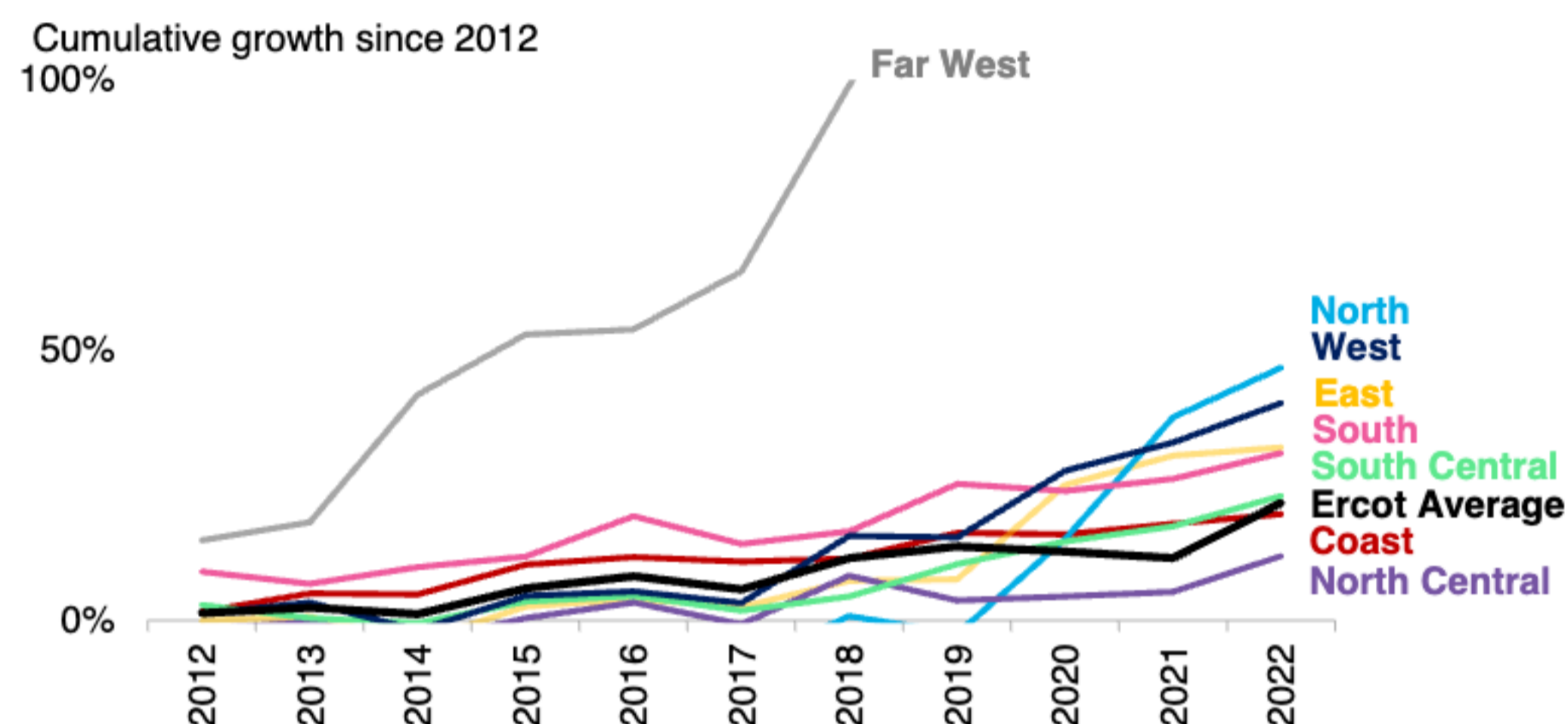
Demand overwhelmingly exceeded Ercot's expectations for 2022. Extreme temperatures and new load from Bitcoin mining facilities were the culprits for this staggering demand.

- A slew of scorching days with temperatures over 100F broke demand records 11 times in June and July. Peak demand topped at 80GW on July 20, 2022.
- Beyond these peak days, newly constructed Bitcoin mining facilities added 1.8GW to baseload demand. These mines operate around-the-clock and typically only shut down when prices reach uneconomical levels, about \$180/MWh last July. With this, average summer demand grew from 61GW in 2018-2021 to 69GW in 2022 during peak hours (3 p.m.-8 p.m.).
- Ercot fell short in estimating last summer's peak demand. Their forecast for the summer peak was 77.4GW. Meanwhile, 49 hours in July and August were above this anticipated demand.
- Ercot continues to be poor in gauging system demand during cold snaps. Winter Storm Elliot beckoned demand to 74GW on December 23, 2022 – 6GW above Ercot's winter peak forecast of 67.4GW. Strong wind generation helped prevent system-wide blackouts during the winter storm. The recent trend of abnormally cold weather has shrunk the gap between Ercot's summer peak and winter peak demand.

Source: BloombergNEF, Ercot

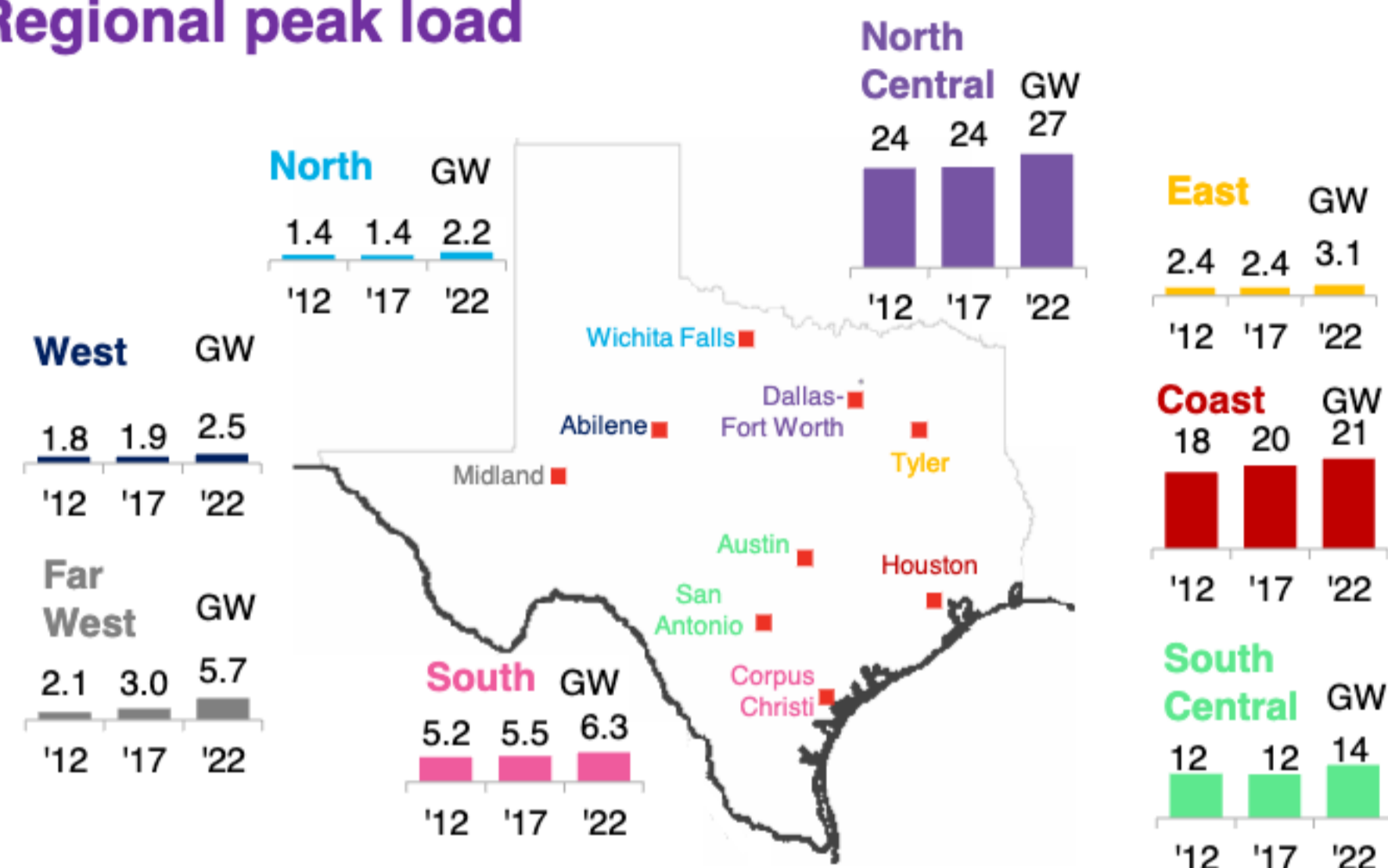
Regional demand Growth is ubiquitous

Peak load growth



Source: BloombergNEF, Ercot

Regional peak load



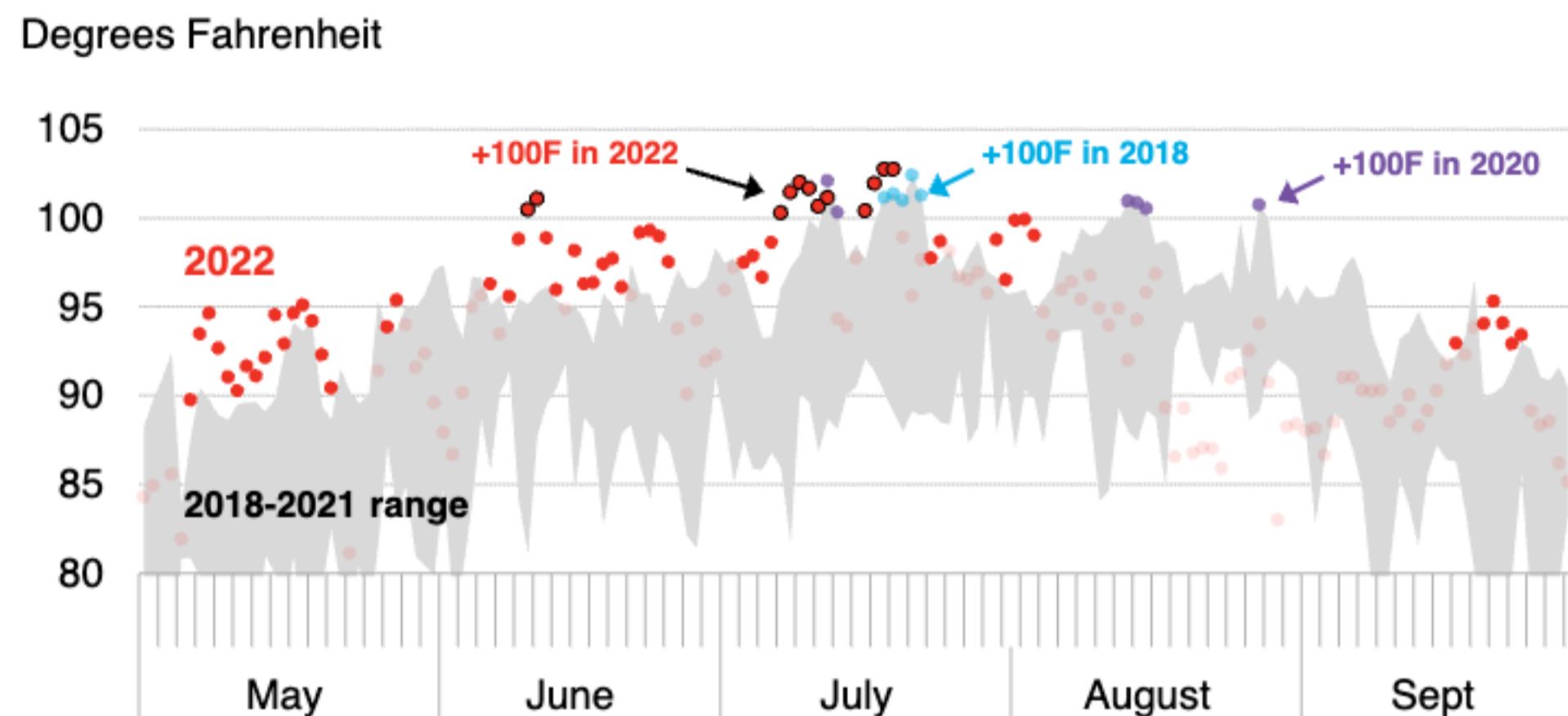
Source: BloombergNEF, Ercot

- The western edge of Texas has experienced explosive load growth in the last decade. Oil and gas production in the Permian Basin has almost tripled demand in Ercot's Far West zone this past decade. BNEF estimates Permian oil production will continue to expand and reach 5.8 million barrels per day (b/d) the end of 2024, up from October 2022's 5.4 million b/d. Electric demand will likely mirror this growth.
- Unlike other zones, the majority of Far West electricity demand comes from pumps and rigs instead of households and traditional industrial activity. These oil and gas operations run around-the-clock producing higher and flatter load factors. In addition, with a recent ESG push, frackers are electrifying their operations, which may add greater electric demand.
- Bitcoin mining facilities have found their new home in Texas. While some mines have found residence in remote western Texas, many mines have addresses in Central Texas. This is driving demand in zones that already have high baseload demand because of metropolitan areas like Dallas Fort Worth, Austin and San Antonio.

Texas weather

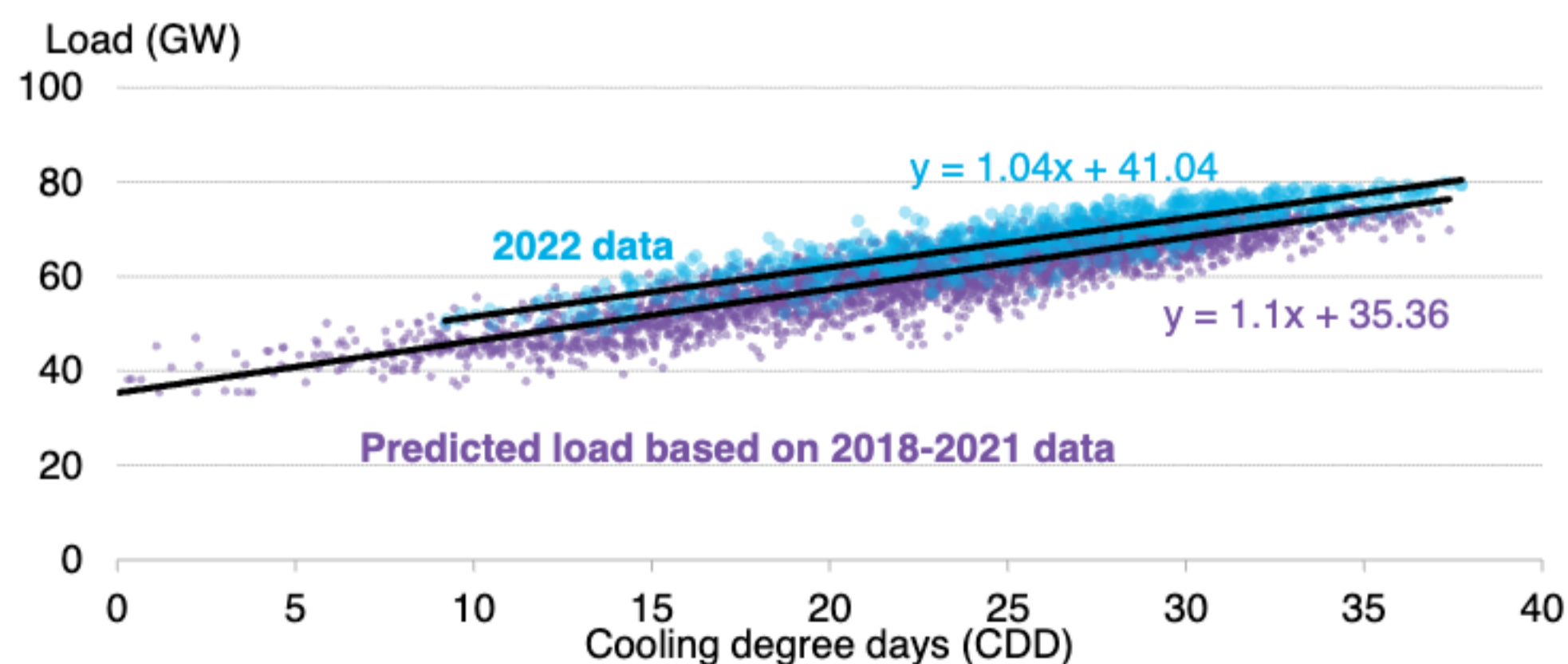
A historically hot summer

Daily peak temperatures



Source: BloombergNEF. Note: Temperatures are population weighted.

Peak hour temperature-load relationship



Source: BloombergNEF. Note: Peak hours were defined as 3 p.m.-8 p.m. Cooling degree days counts the number of degrees above 65F.

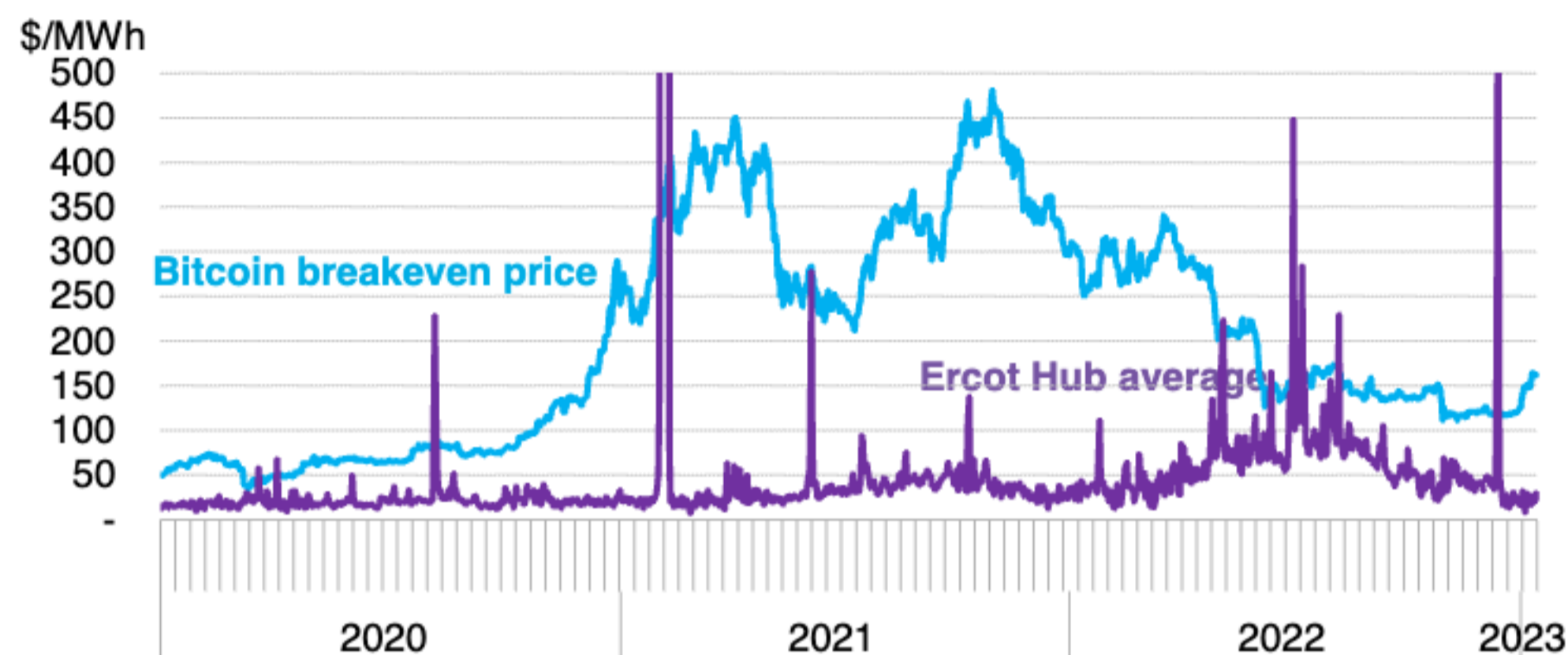
Texas had an unforgivably hot summer. The four-month stretch between April and July had the hottest temperatures on record and drove up system-wide demand in Ercot.

- Temperatures undoubtedly played a role in Ercot's record-breaking summer. There were 61 days in 2022 that were the hottest in the last five years. The hot weather also started earlier – May had temperatures typically seen in July and August. The hot weather contributed to 2.9GW of power plants to trip offline on May 13. Since plants typically do maintenance in the shoulder seasons, hot weather earlier in the year increases the risk of grid stress.
- However, the load was higher than expected based on temperature-load data from 2018-2021 (bottom chart). This suggests that temperatures only partially explained the sustained demand. Rather, other load factors such as Bitcoin mining facilities added to this heightened demand.
- July proved to be the most challenging month:
 - July had 10 days that had temperatures over 100F. This heat wave prompted Ercot to issue conservation appeal to Texans on July 11, 2022, and July 13, 2022.
 - There was demand response from Bitcoin mines that helped relieve the grid. Lee Bratcher, the president of the Texas Blockchain Council, said for that “over 95% of industrial-scale Bitcoin mines curtailed their power consumption during peak demand” in the July heat wave.

Bitcoin mining facilities

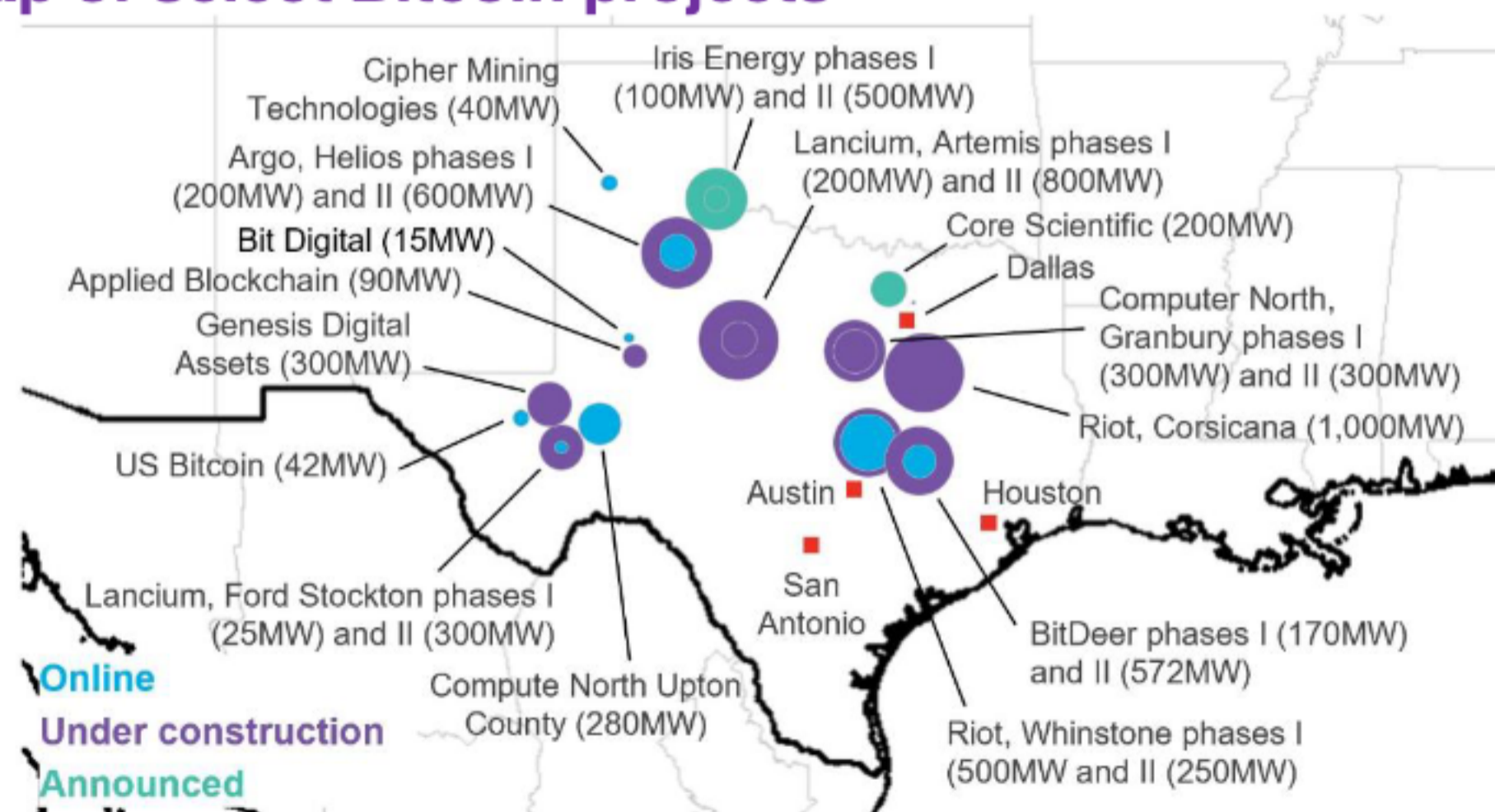
A new force enters Texas

Bitcoin breakeven price



Source: BloombergNEF, Bloomberg Terminal ticker XBT, ERDAHBBU Index

Map of select Bitcoin projects



Source: BloombergNEF Note: The project database from which this map was created can be found in the Excel file accompanying this report.

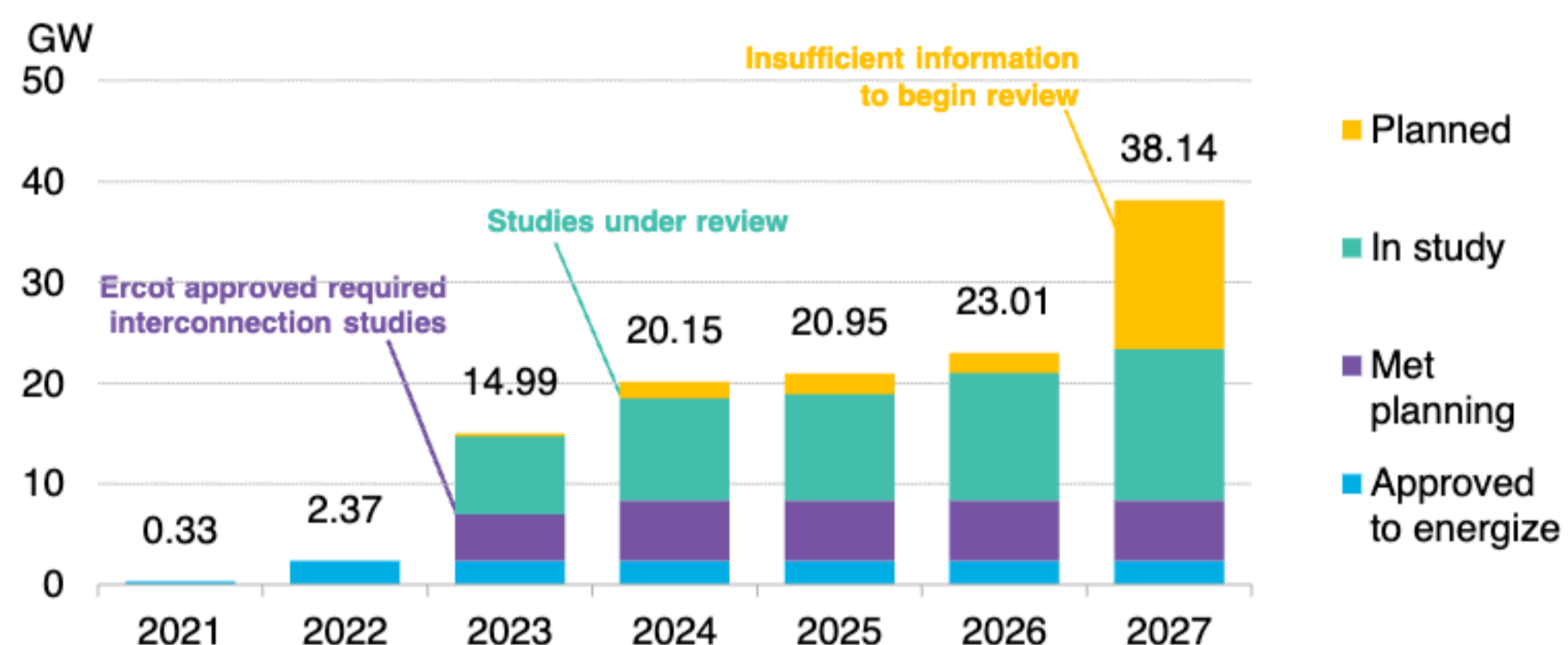
Bitcoin mining companies have flocked to Texas in the last year and have made a material impact on power demand. Ercot has quickly responded by proposing protocols to integrate these large, flexible loads to the system.

- There are 1.8GW of mines operating in Ercot and 10GW of planned capacity. Many of these projects began development in 2021 when Bitcoin was \$40,000-\$60,000 in value. Though the price of Bitcoin has fallen in 2022, mines can still economically operate below \$180/MWh (most hours, except during extreme price spikes).
- Ercot is attempting to leverage these Bitcoin mining facilities to improve grid operations and stability:
 - A minority of Bitcoin mines have registered as controllable load resources (CLRs) that can respond to frequency signals and participate in real-time dispatch and ancillary services.
 - Ercot has established an interim, voluntary curtailment program for Bitcoin mines to reduce their power during peak hours in exchange for payouts until long-term rules are established.
 - Ercot is proposing having these interruptible load as part of their scarcity conditions operation (before issuing Energy Emergency Alerts), a last resort during a transmission emergency.
 - Ercot has created a Large Flexible Load Task Force (LFLTF) to develop policy recommendations and nodal protocols for these facilities. The LFLTF has a backlog of issues spanning interconnection, planning and markets operations, which will bring more certainty on Ercot's long-term plan.

Bitcoin mining facilities

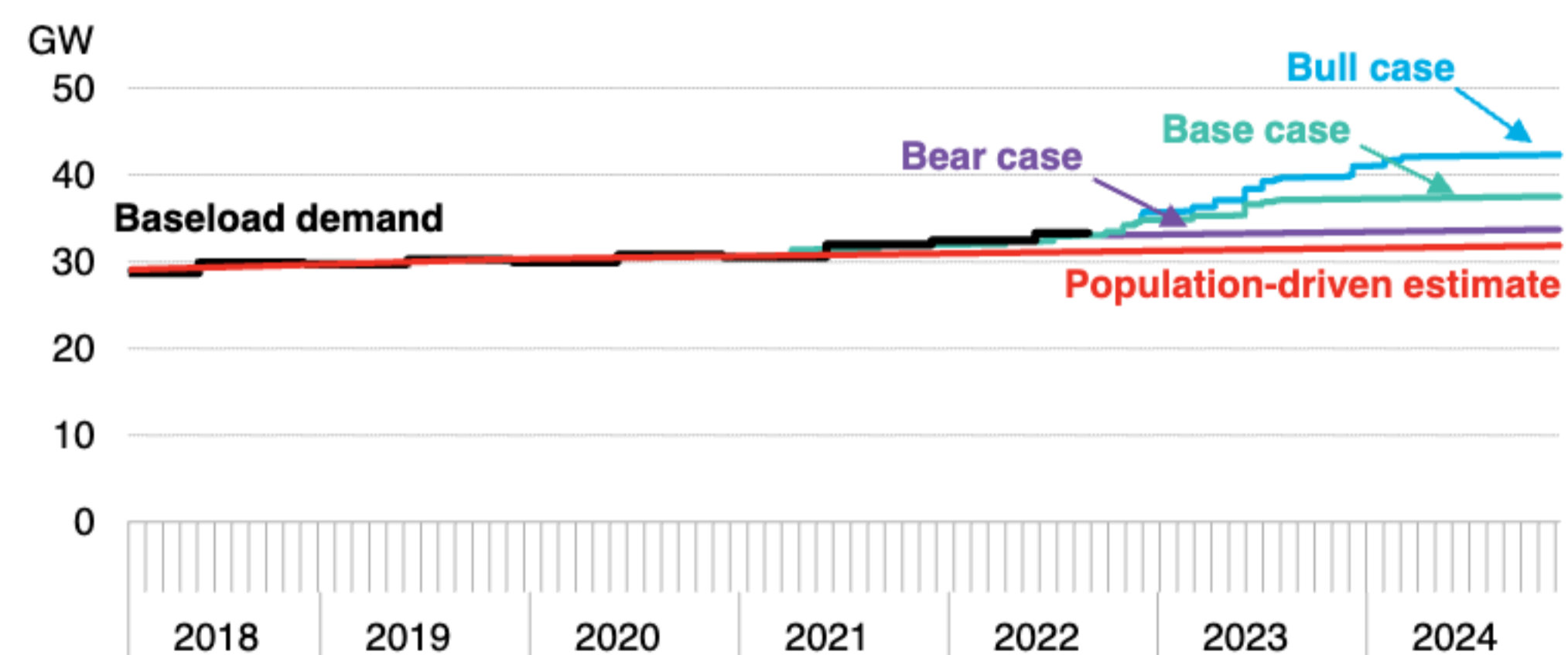
An uncertain outlook

Ercot Large Load Interconnection Status



Source: BloombergNEF, Ercot, Large Flexible Load Task Force (LFLTF) Meeting January 2023

Bitcoin build cases affecting baseload demand



Source: BloombergNEF. Note: Baseload refers to power that is not dependent on time of day or temperature.

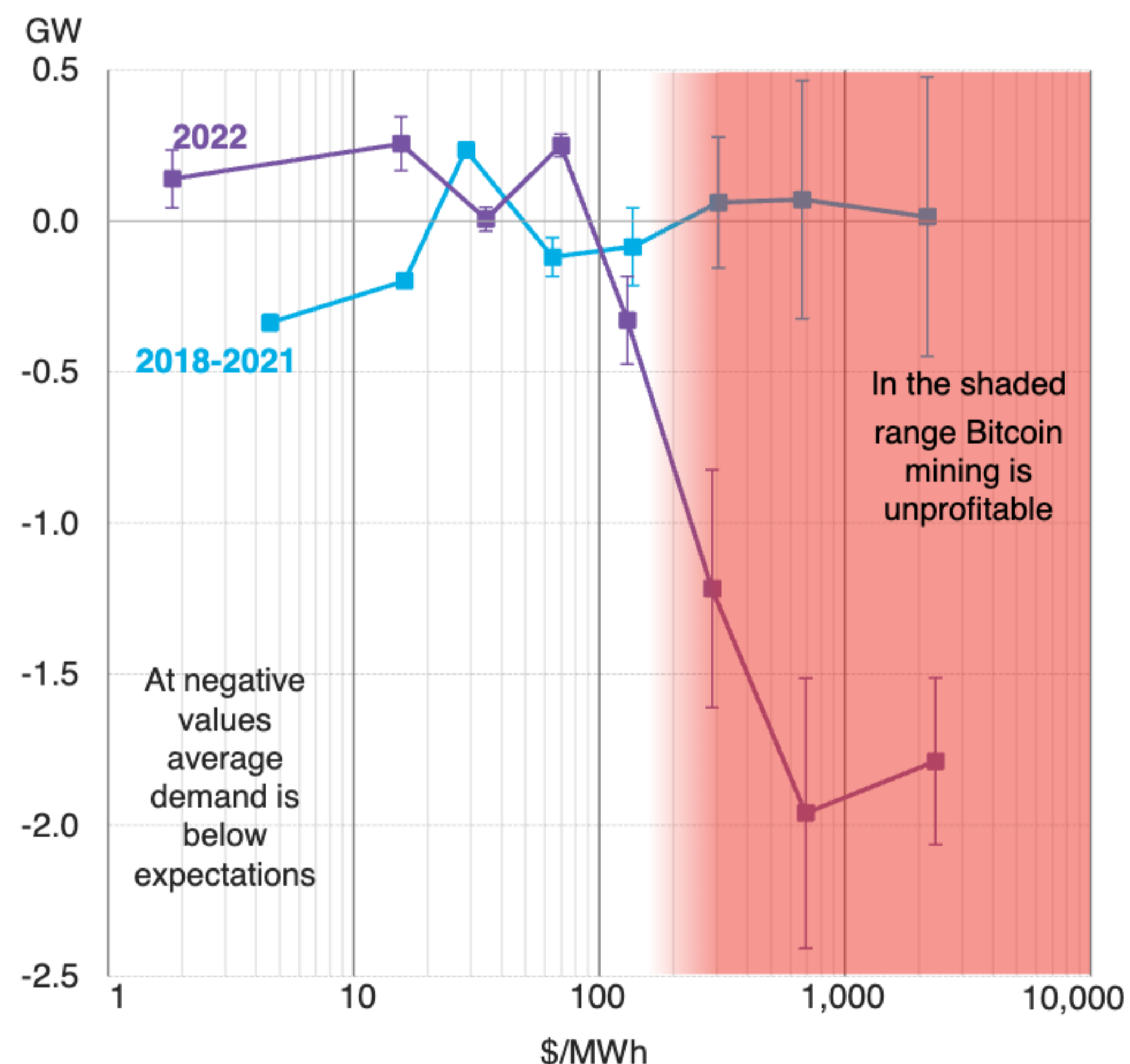
Bitcoin mining facilities are set to be permanent residents. The key question remains how many and how quickly these projects will be built. The potential scale of these mines could completely shape the power market over the next few years.

- There are 38GW in Ercot's large load interconnection queue:
 - This queue doubled between April 2022 (17GW) to August 2022 (35GW), indicating the growing demand for projects. However, there are likely multiple applications for the same mining site as applications don't require deposits.
 - 78% of projects in the queue are standalone, compared with 22% of projects being co-located with another resource.
 - Projects in the "met planning" stage are most likely to come online. There is a total of 4.5GW for 2023 and 6GW for 2024.
- Bitcoin is a volatile market and companies have announced delays and cancellations which brings an uncertain outlook on build. BNEF has three scenarios to have an outlook on what could happen:
 - **Bear case:** 1.8GW of existing mines continue to operate and no additional mines come online.
 - **Base case:** 3.5GW of new mines come online by summer 2023 (5.3GW total). Summer 2024 will have 4.1GW of added demand (5.9GW total).
 - **Bull case:** 5.5GW of new mines come online by summer 2023 (7.3GW total). Summer 2024 will have 8.5GW of added demand (10.6GW total).

Bitcoin mining facilities

Price responsive

Mean difference between actual and expected Ercot demand, versus power price



Source BloombergNEF. Note: The squares represent mean value within a price range. Error bars indicate standard error of the mean. Analysis is based on real-time prices.

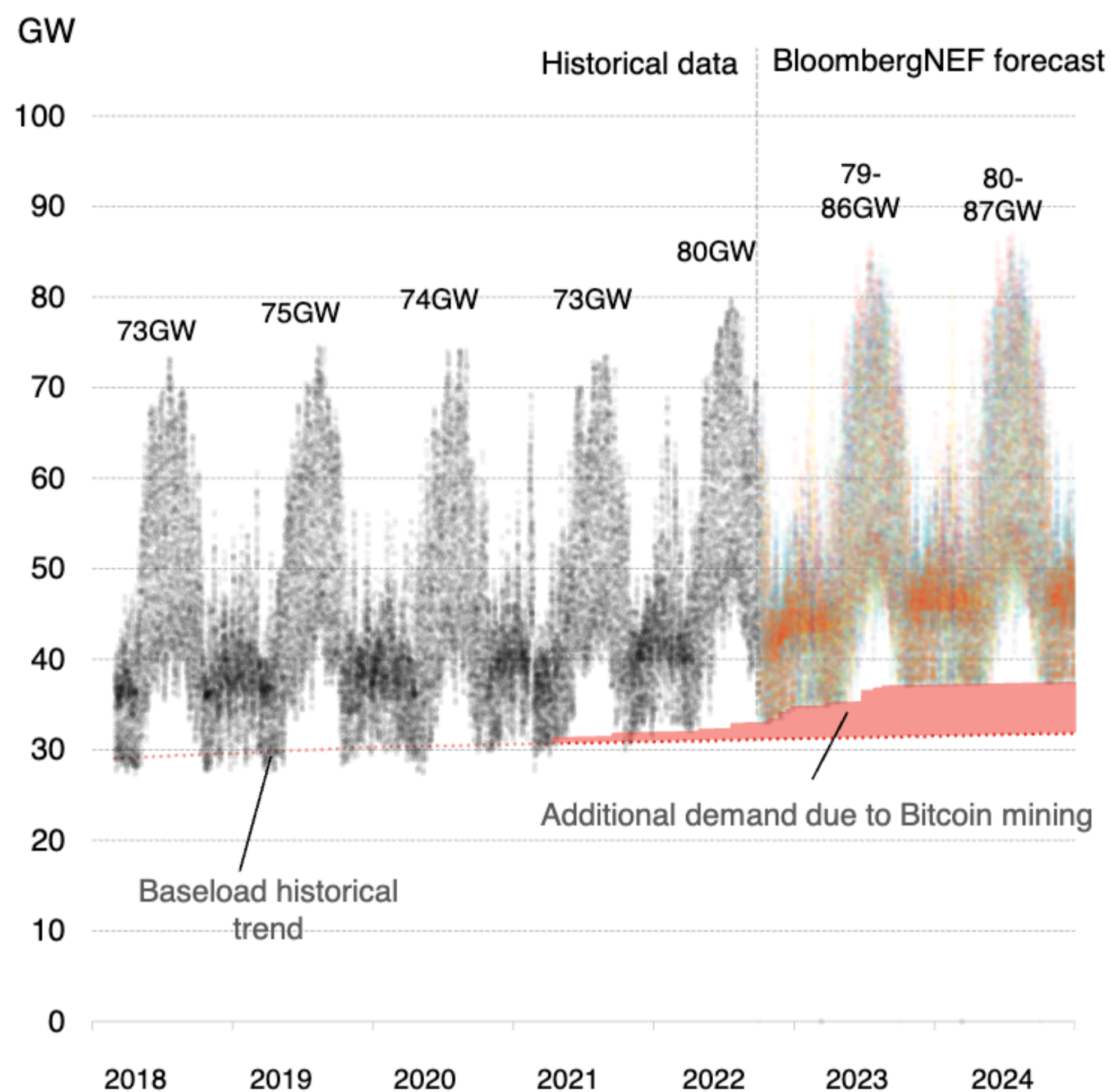
Bitcoin mining facilities are well-suited to turning on and off when prices reach uneconomic levels. This brings a large volume of demand elasticity to Ercot.

- Our analysis shows that Texan Bitcoin miners are responding to price signals. In 2022, Ercot load fell significantly below expectations – as defined by BNEF modeling of hourly demand – whenever real-time prices were above a threshold of around \$180/MWh last July.
- The gap between modeled and actual demand reached 1.8GW to 2GW during the hours of highest pricing. This gap is inferred to be the 1.8GW of mines turning off and a new dynamic – an analysis for 2018-2021 has no suggestion of load responding to prices.
- This price-responsiveness has led to significant payouts. During last summer's heat waves, Riot Blockchain (operates a 450MW mine) announced that it made around \$9.5 million by curtailing operations and selling electricity back to Ercot in July. This is more than the \$5.6 million the company made from selling Bitcoin that month.
- The \$180/MWh is an observed estimate for the fleet of mines in Texas. Each mine has its own efficiency and potential hedges against the real-time market. Ercot is also in the process of implementing nodal pricing for CLRs that will introduce another layer of price optimization. Though this breakeven price is continually changing, it is evident that there is a certain threshold where mines shut off.

Ercot demand outlook

Base case

Hourly Ercot demand forecast



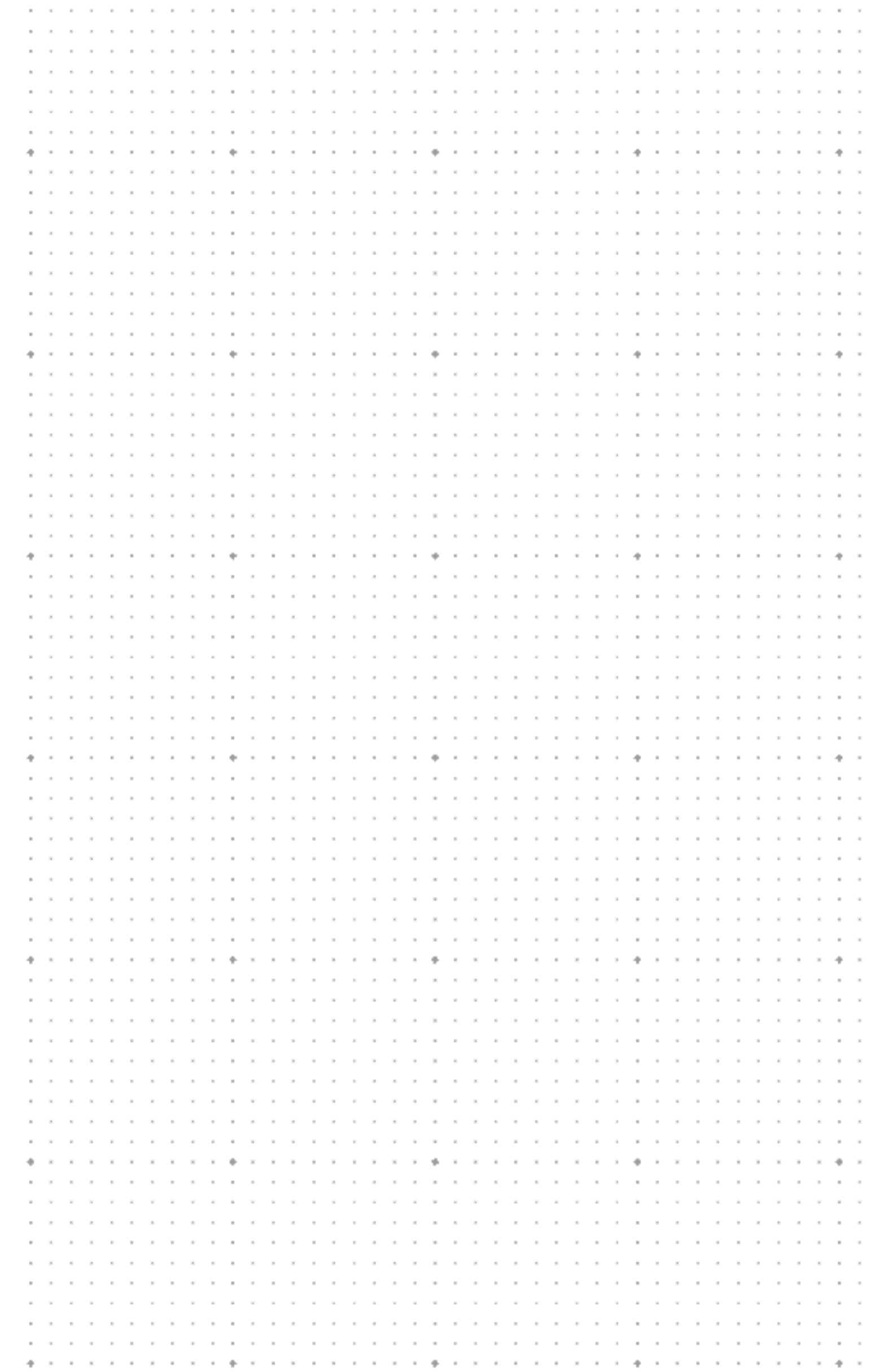
Source: Ercot, BloombergNEF. Note: Different colors in the forecast represent different weather assumptions.

Our base-case scenario forecasts that Ercot peak demand could reach a whopping 86GW this summer and 87GW next summer. The base case has 3.5GW and 4.1GW of Bitcoin mining added to baseload demand for these summers.

- The forecasted demand assumes that mines are still operating during these peak demand hours. Mines operation largely depends on how high prices reach in these hours. Strong renewable generation could suppress prices to a range that remains economical for these mines to continue to be online. We assume demand response in our later discussed price model.
- Weather, especially extreme heat waves and winter storms, remains a powerful force that could sway the peak demand by 7GW.
 - If temperatures reach those seen during last July’s heat wave then peak demand will reach the 86-87GW range.
 - More mild weather – even accounting for the additional baseload demand from Bitcoin mines – could bring demand to 79-80GW, which is comparable to this past summer.
- Ercot’s forecast for summer peaks is 83GW in 2023 and 85GW in 2024. However, Ercot could continue to underestimate peak demand. Winter peak is estimated to be 69GW for winter 2023/2024 and 71.6GW for winter 2024/2025. This past December already surpassed their estimate at 73GW.

Supply

A solar boom

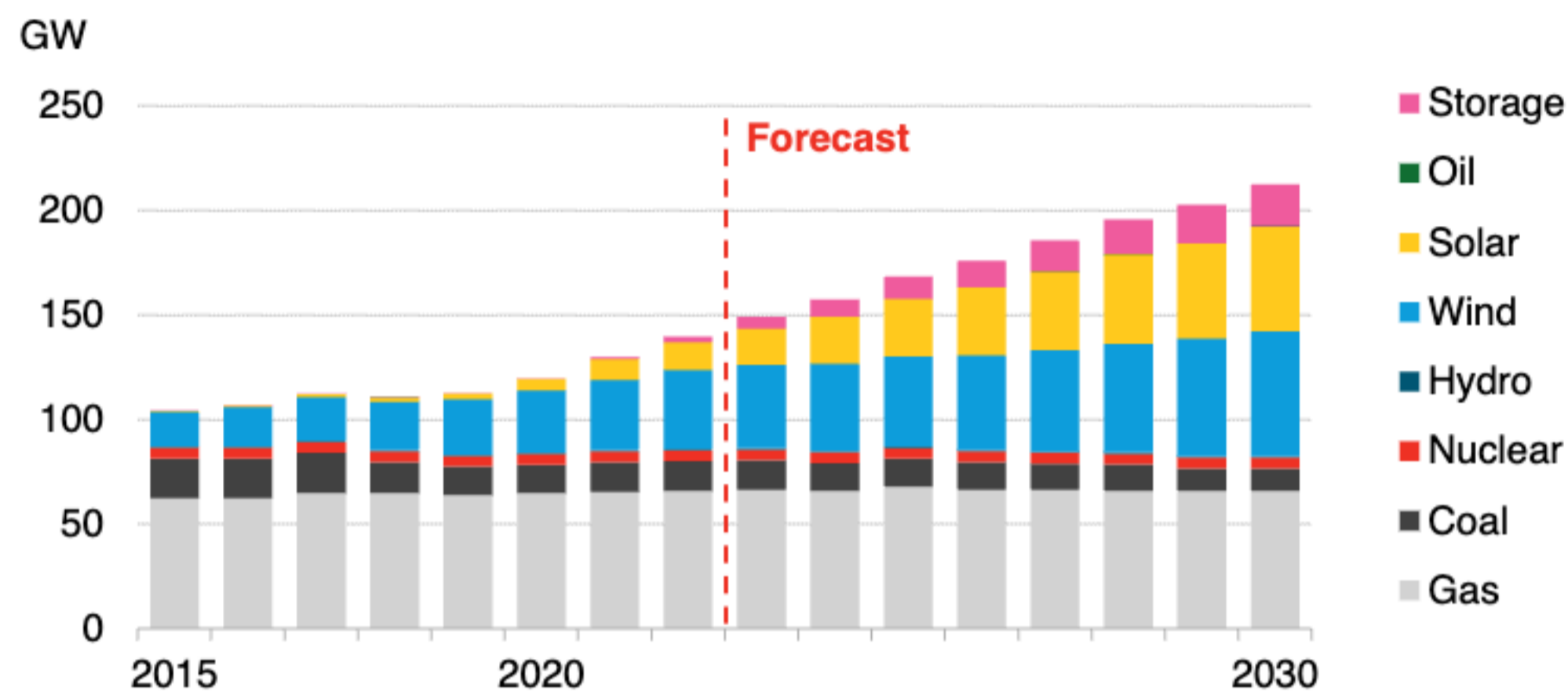




Ercot capacity mix

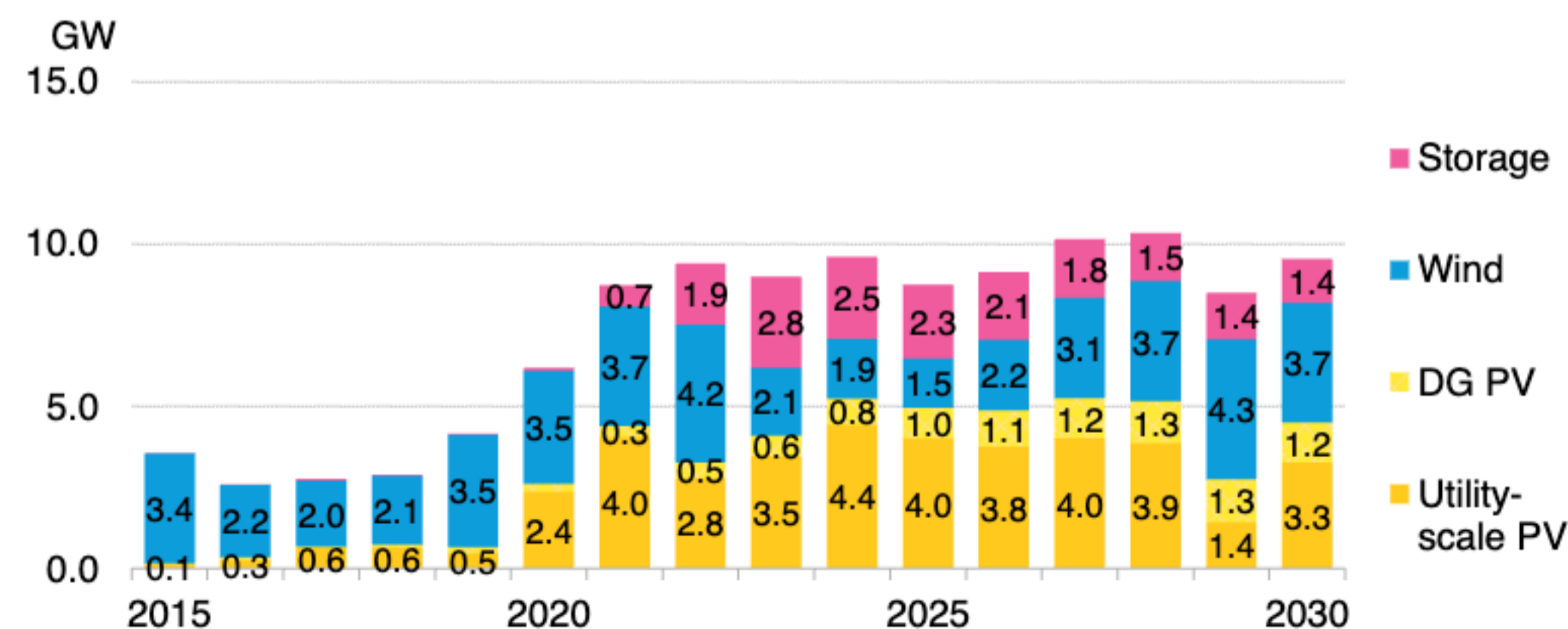
Renewables dominate future build

Ercot's resource mix



Source: BloombergNEF, US Energy Information Administration. Note: EIA 860A, EIA 860M November 2022 for thermal capacity. Wind, solar and storage outlooks from 2H 2022 US Clean Energy Market Outlook ([web](#) | [terminal](#)).

Ercot's clean energy additions



Source: BloombergNEF. Note: Data from 2H 2022 Clean Energy Market Outlook ([web](#) | [terminal](#)), solar capacity is converted to AC.

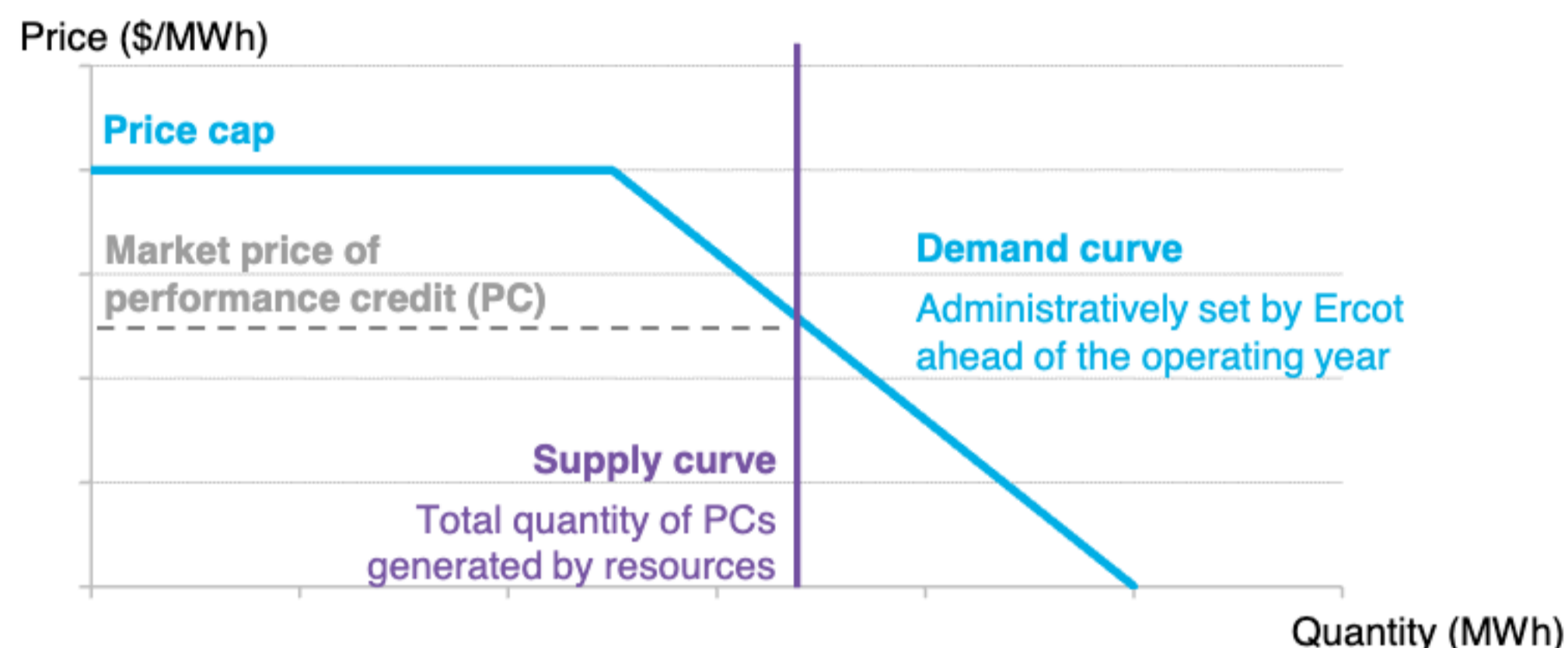
Ercot's generation mix will decarbonize steadily over the next decade as wind and solar constitute the bulk of capacity additions. In 2030, 60% of the installed capacity fleet will be renewables.

- Natural gas and coal-fired power plants were 57% of installed capacity in 2022. These thermal assets are set to be relatively stable through 2030. However, the Public Utilities Commission of Texas (PUCT) voted on introducing a new payout to thermal generators which will likely favor gas economics and build.
- Solar will catch up to wind's dominating presence in Ercot. BNEF expects 4-5GW of annual utility-scale solar additions, totaling 40GW by the end of the decade (20% of supply).
- Texas's residential solar market will grow substantially as homeowners look to rooftop solar for resiliency. BNEF estimates 10GW of behind-the-meter solar by 2030. This high penetration of solar will accelerate a duck curve emerging in Texas, pushing peak load further into the evening hours.
- Despite the lucrative Production Tax Credit (PTC) through the US Inflation Reduction Act (IRA), BNEF expects wind capacity additions in Texas to slow down in the next few years as existing generators face high levels of congestion.
- BNEF's current outlook for wind has a total 60GW of capacity in 2030 (30% of supply). Wind's outlook may pick up more steam if windy regions experience more demand growth (for example, if more Bitcoin mining facilities move to western Texas).

Ercot thermal fleet

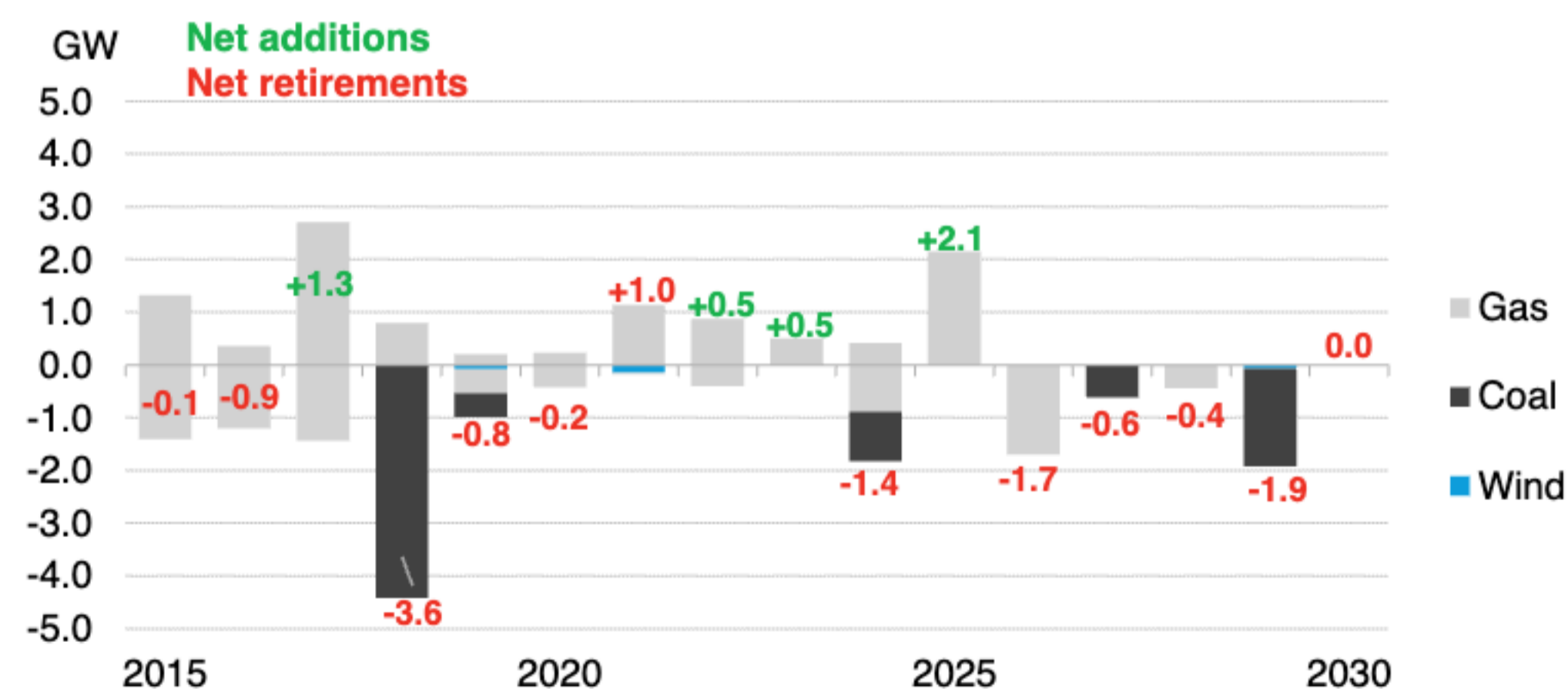
Proposed payouts to gas plants

Proposed performance credit mechanism design



Source: *Assessment of Market Reform options to Enhance Reliability of the Ercot System*, Energy and Environmental Economics (E3)

Planned Ercot retirements and additions



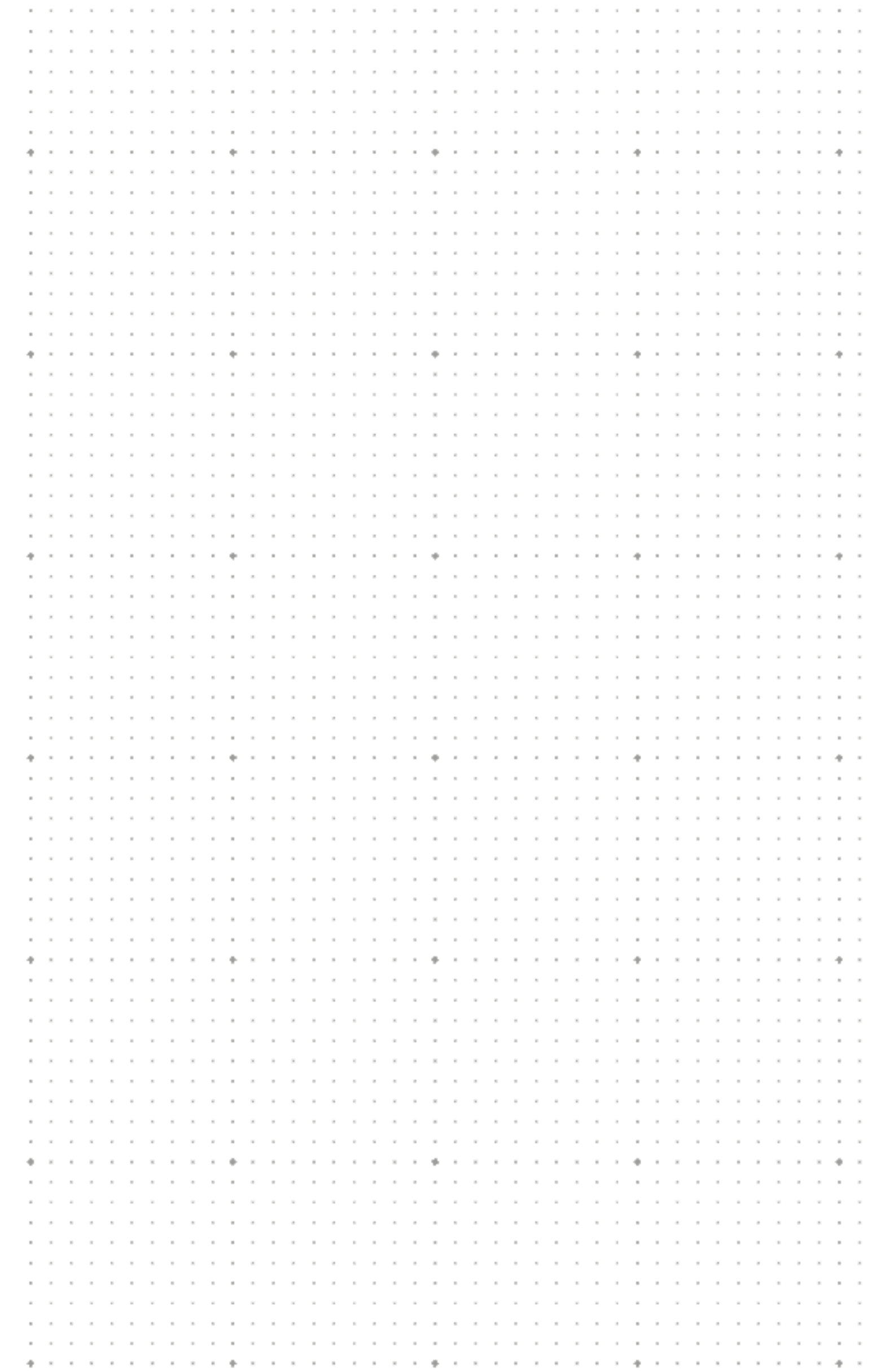
Source: BloombergNEF, Energy Information Administration (EIA 860A and EIA 860M). Note: EIA data is from November 2022.

Texas is posed to depart from its famous energy-only market and introduce payments to power plants to be online during critical times. The hope is to drive new investments in natural gas plants and avoid a repeat of Winter Storm Uri.

- The Public Utility Commission of Texas (PUCT) unanimously voted on these incentives last January. This payout is based on the “Performance Credit Mechanism” (PCM) proposed by Energy and Environmental Economics (E3), the consulting firm contracted to review proposed long-term market redesigns.
- Texas lawmakers are skeptical that these payouts will successfully attract new build and address reliability issues. This plan will need approval from the state House and Senate.
- Gas generators committed to building 4.5GW of capacity in support of this payout. This would shake up the current planned 3.5GW of net retirements through 2030.
- The so-called PCM aims to provide price stability and more predictable revenue stream to generators. E3 theorizes that more resources will enter the market because of the PCM, which will decrease scarcity pricing events. They expect the costs to net out higher performance credit costs and lower energy and ancillary service costs.
- The PUCT has said it could take two to three years to implement and a “bridge mechanism” will be implemented in the meantime. In parallel, Ercot has offered more ancillary service products to improve reliability.

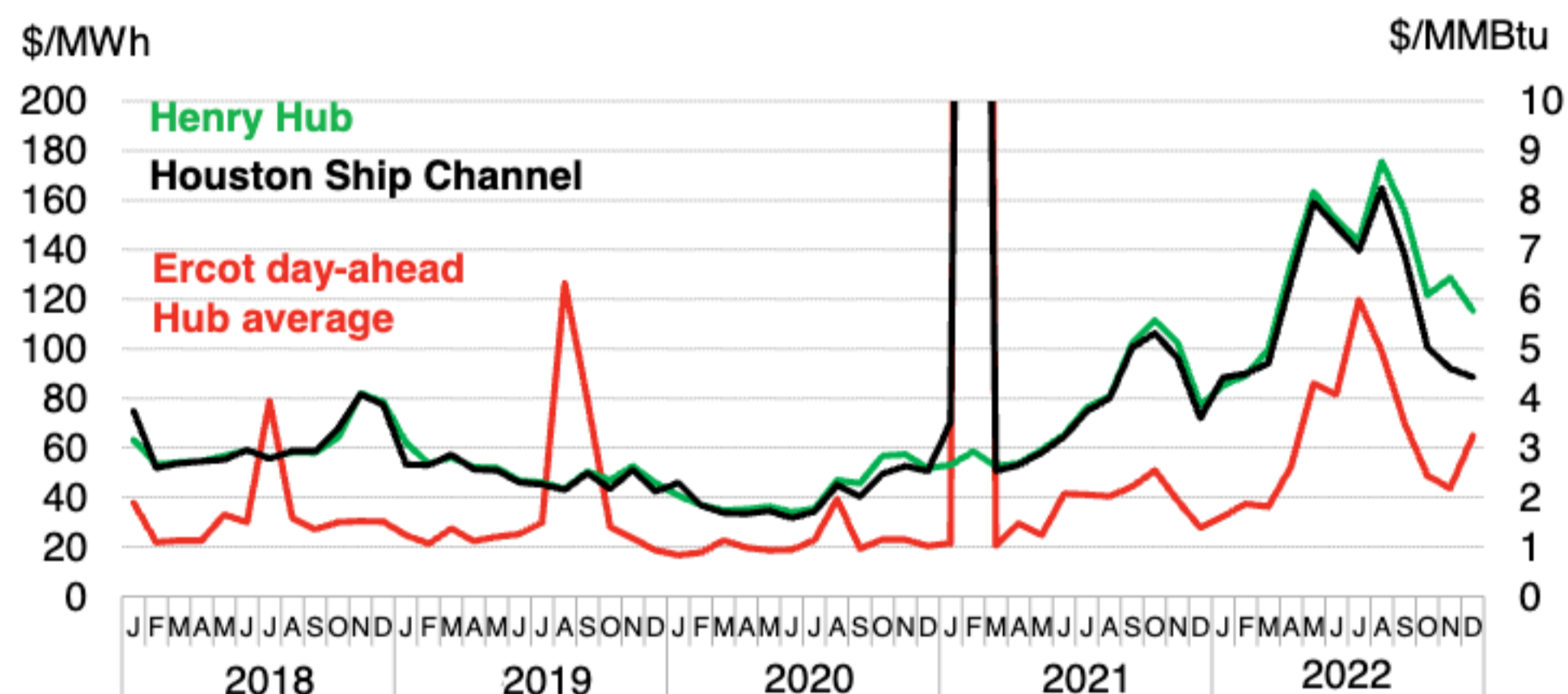
Prices

Higher prices and greater volatility



Ercot power prices Elevated and volatile

Average gas and day-ahead power prices



Source: Ercot, BloombergNEF. Bloomberg Terminal ticker ERDAHBBU Index, NGGCHOUS SCOV Index, NGUSHHUB BGAP Index

Real-time power prices in July

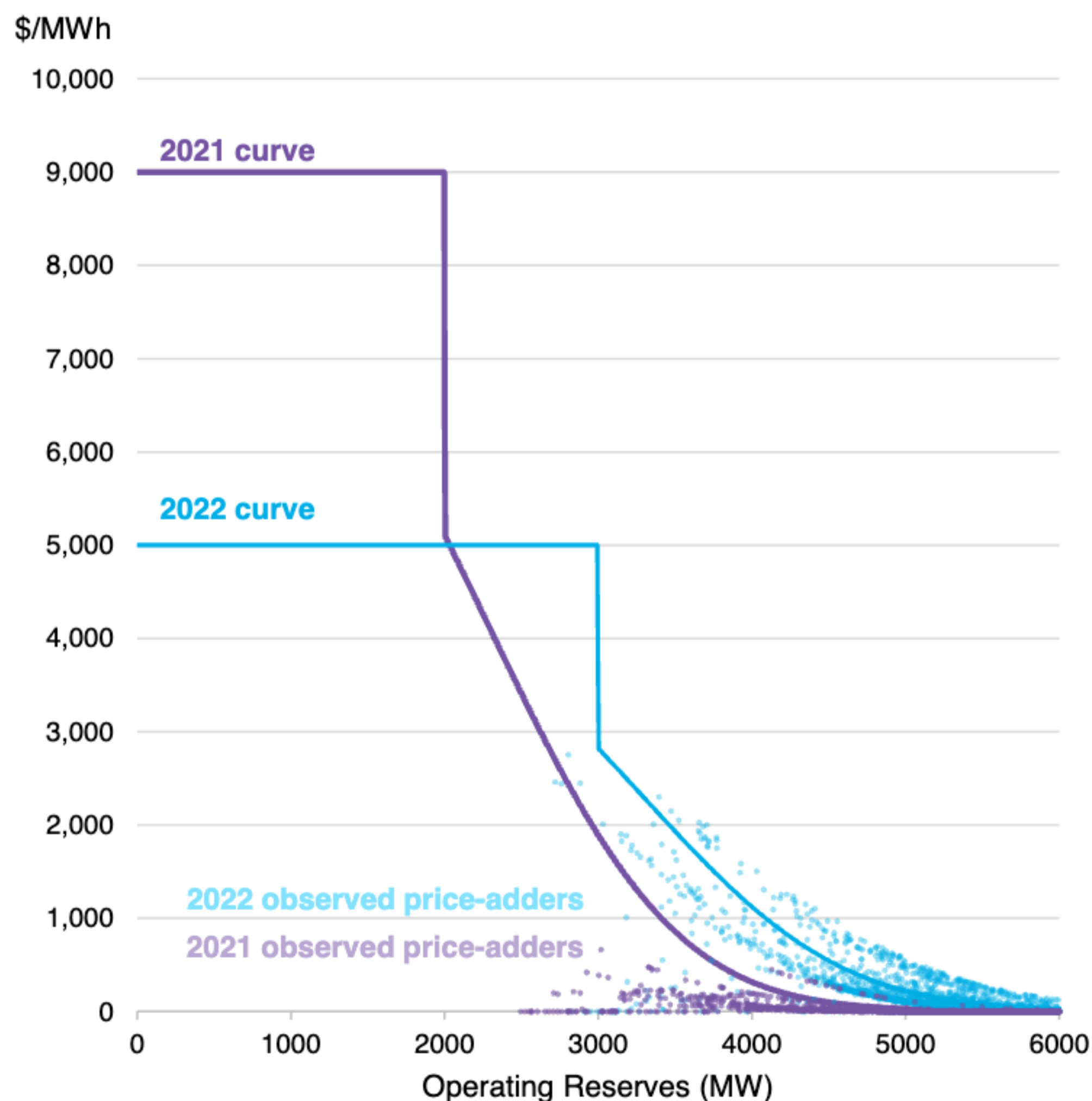


Source: Ercot, BloombergNEF. Note: Prices are 15-minute settlements and hub average.

- The era of cheap US natural gas looked like it was ending in 2022. Henry Hub almost tripled from its 2018-2021 average of \$2.90 per million British thermal units (MMBtu) to \$6.50/MMBtu for 2022.
- However, natural gas prices did fall in the second half of 2022. In the first week of February, a mild winter and high gas production crashed prices below \$3/MMBtu for the first time in almost two years. The forward curve for Henry Hub has an average of \$3/MMBtu for the remainder of 2023. For our latest on US gas see ([web](#) | [terminal](#)).
- The high natural gas prices of 2022 directly translated into elevated Ercot power prices. The Day-Ahead Hub average doubled from \$31/MWh in 2018-2021 (excluding Winter Storm Uri) to \$64/MWh in 2022. This despite the past year seeing a record 30% of generation from solar and wind, which push down power prices.
- Price spikes are a feature of Ercot's energy-only market design and occurs when reserves are low. The reserve adder is become a greater share of overall price following changes to the Operating Reserve Demand Curve (ORDC, see next slide) in 2022. The Independent Market Monitor estimated these changes have increased real-time energy revenues by \$1.7 billion through November 2022.
- July experienced the bulk of 2022's price spikes. Extreme temperatures and low wind generation brought net load to 65GW and real-time prices hit the system cap of \$5,000/MWh on July 13. July would likely have had higher prices if Freeport LNG (690MW) had not shut down in June.

Operating Reserve Demand Curve Changes have a sizeable impact

ORDC curve changes



Source: Ercot, BloombergNEF. Note 2021 data points exclude Winter Storm Uri.

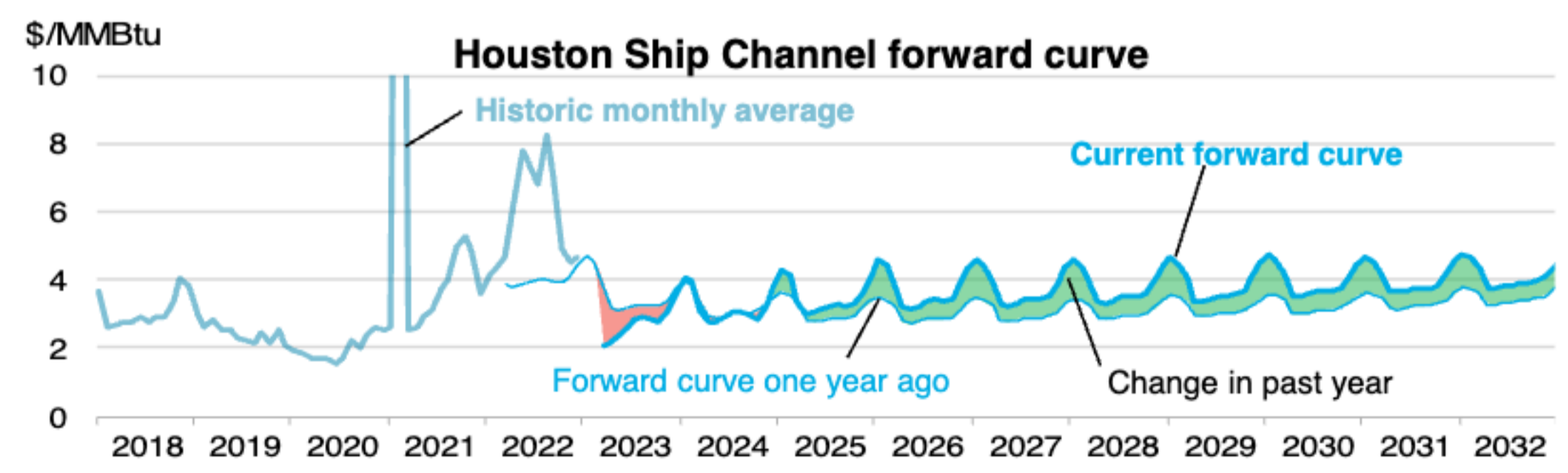
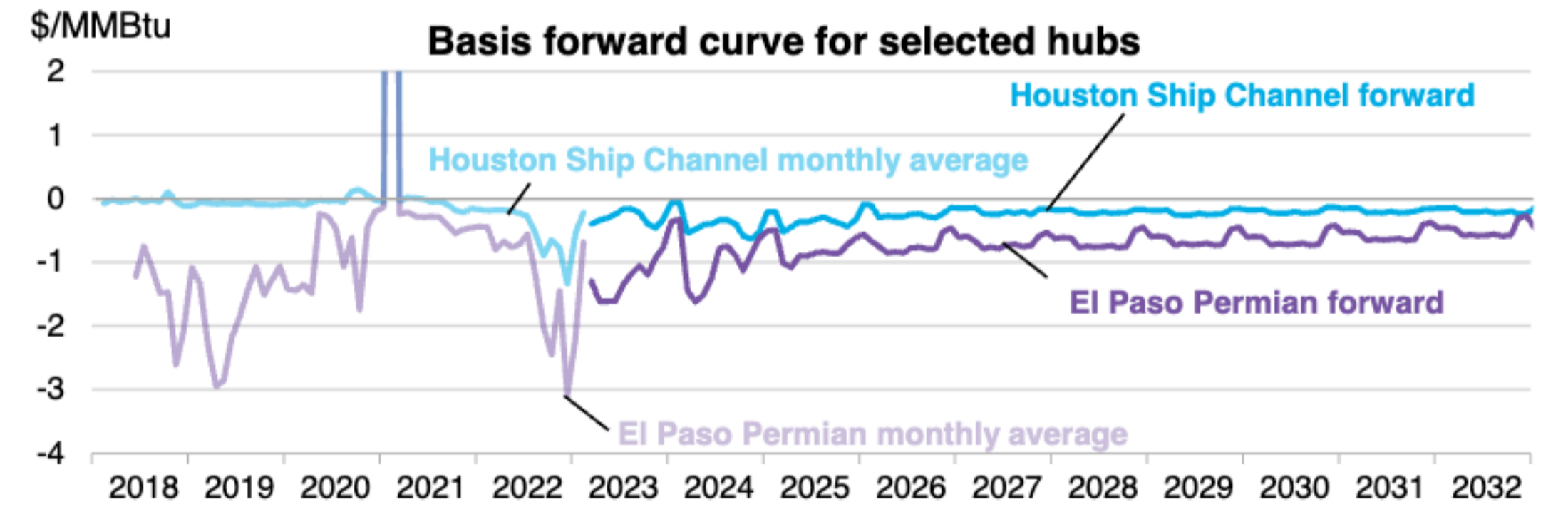
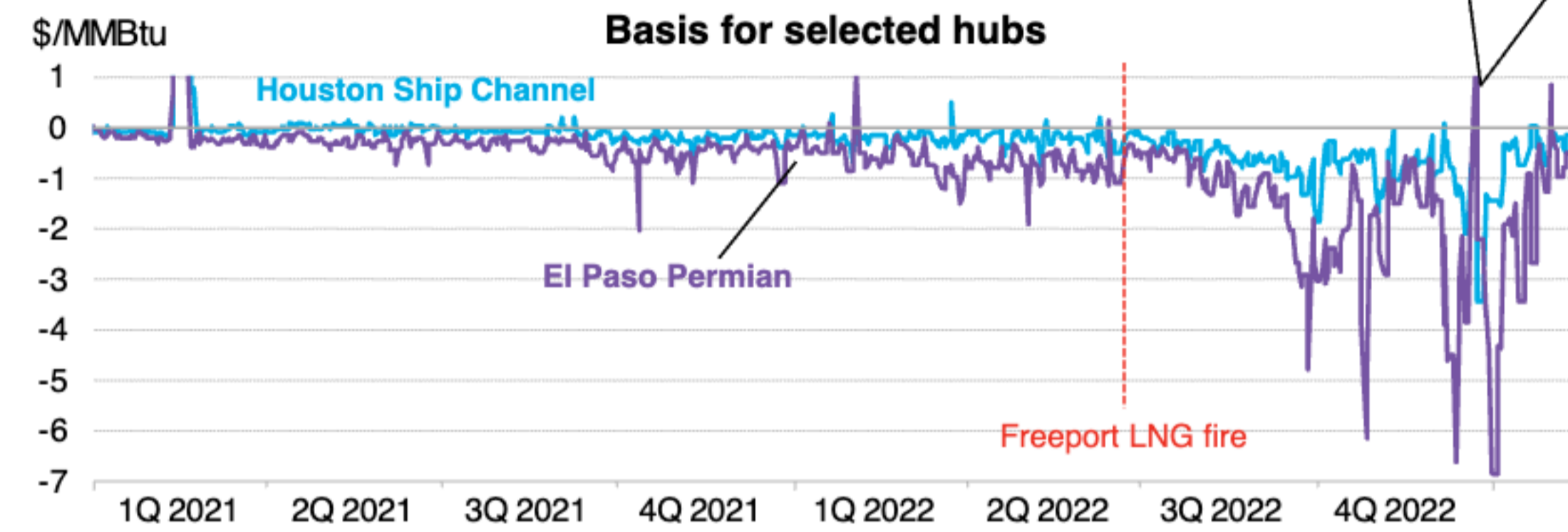
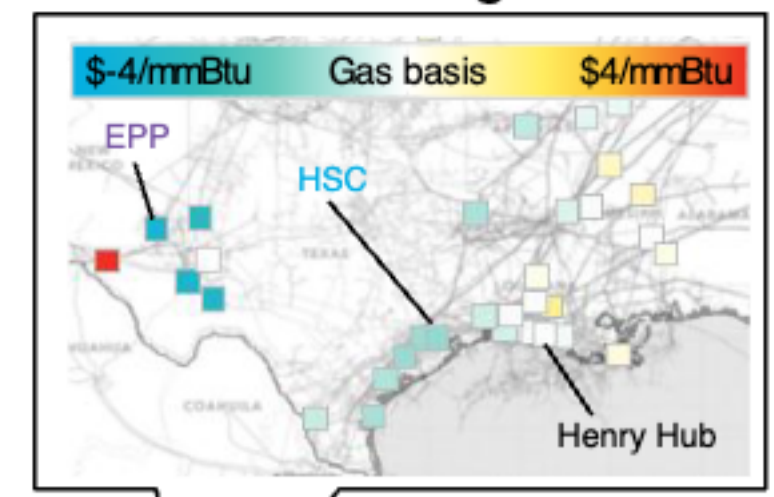
The scarcity price-adder has become a more significant contributor to wholesale energy prices following changes implemented by the PUCT at the start of 2022.

- The changes to the Operating Reserve Demand Curve (ORDC) was a large part of the PUCT's broader goal to improve grid reliability post Winter Storm Uri. The PUCT made two major modifications:
 1. The high system-wide price cap (HCAP) decreased from \$9,000/MWh to \$5,000/MWh.
 2. The price cap is now reached when reserves drop below 3GW, up from the previously set level of 2GW (the Minimum Contingency Level).
- Ercot's price-adder is a defining feature of the energy-only market as it causes extreme power prices. However, these new changes have made the adder more important in real-time prices beyond scarcity hours.
 - According to Ercot's biennial ORDC report, the price-adder's time-weighted contribution for 2021 (excluding Winter Storm Uri) was \$0.41/MWh compared to \$6.33/MWh in 2022 through September (8.1% of the all-in price).
 - The price-adder's impact is pronounced during hours of low Physical Responsive Capability (PRC) levels. PRC levels are related to operational reserves but measured slightly differently. The price-adder averaged \$22/MWh January-September 2022 compared to \$6.29/MWh for March 2020-March 2021 when PRC levels were below 4,500MW.

Gas basis and prices

Basis dislocation

Dec-Jan average basis



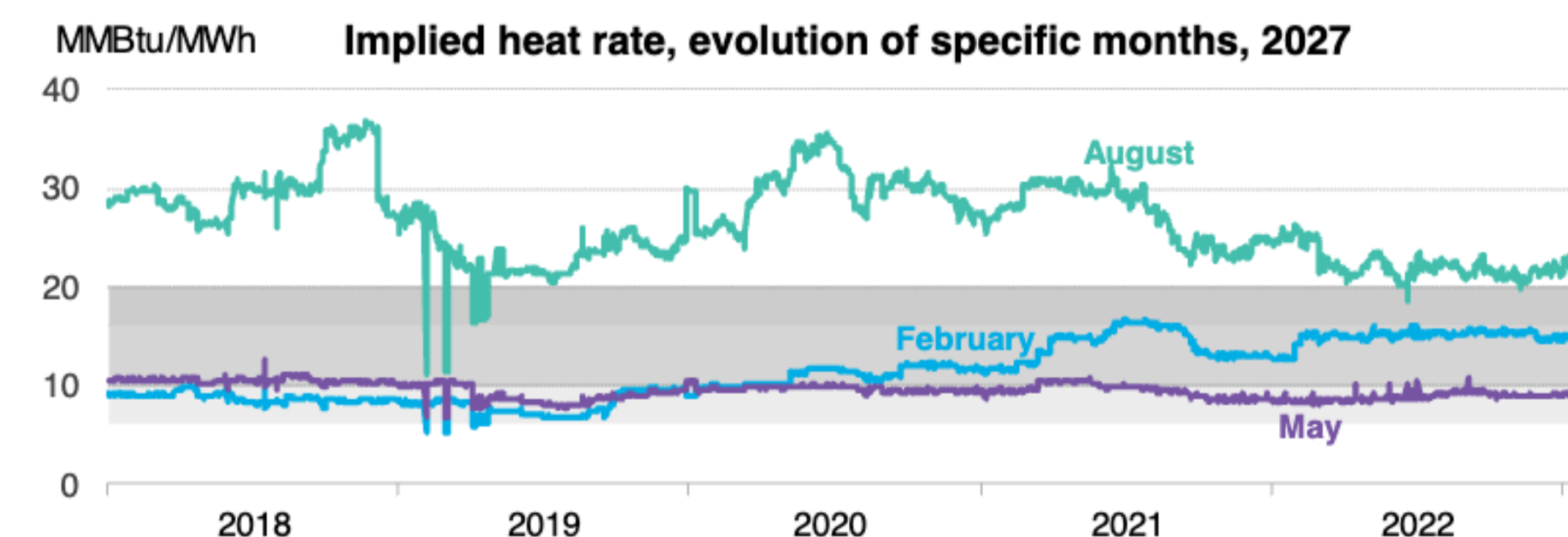
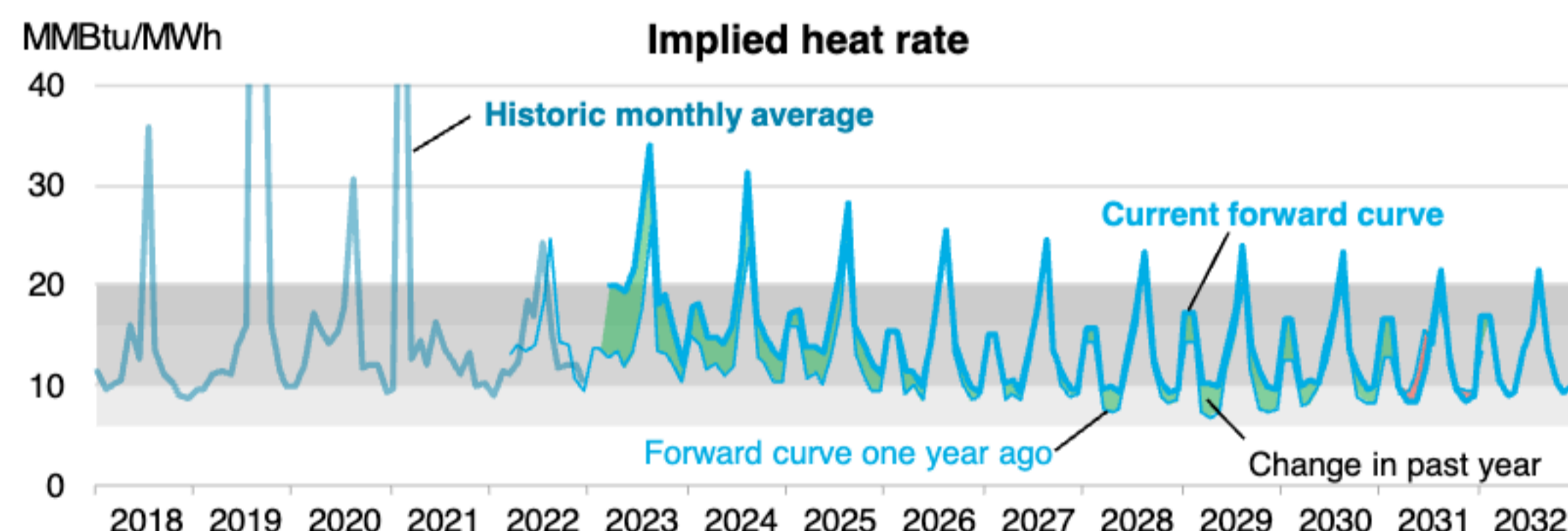
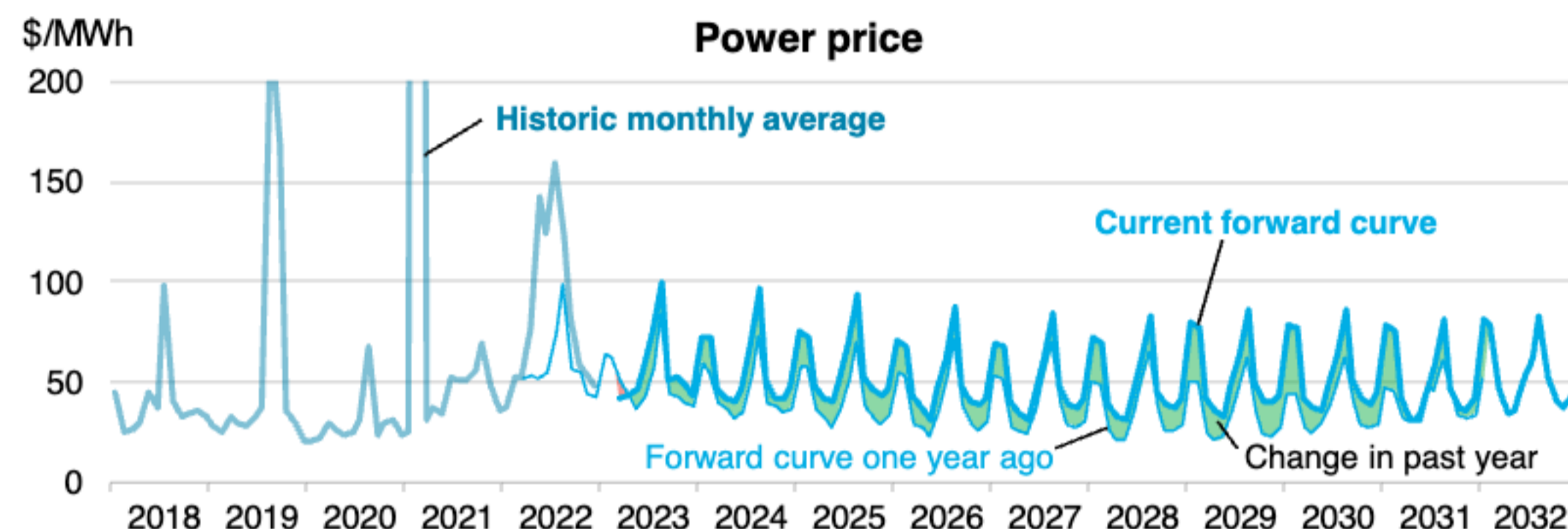
- Prices for the Houston Ship Channel (HSC) regional pricing point have historically tracked the Henry Hub benchmark, but that changed in June of 2022. The fire incident at the Freeport LNG export terminal just south of Houston removed almost 2 billion cubic feet per day (Bcf/d) of demand from the region.
- With the prospect of growing LNG export capacity, Texas has seen a lot of infrastructure investment to increase pipeline capacity from the growing Permian production basin to the Houston area and the Gulf coast. However, there is limited capacity to move gas out of the region.
- After Freeport LNG shut down, HSC started trailing Henry Hub averaging \$0.50/MMBtu lower for the month of August despite high seasonal demand. Prices needed to move lower to incentivize gas flows out of the region or into storage.
- Until Freeport LNG returns to full capacity, HSC remains at risk of congestion pricing as Permian producers push gas southeast and storage inventory in the area is at the high end of the season range. The forward curve suggests that HSC will continue to trade at a noticeable discount to Henry Hub for the next three years or so.
- Despite trading at a discount to Henry Hub, the current forward curve for HSC has, beyond 2024, shifted significantly higher compared to a year ago, in line with Henry Hub futures and other regional markets. Winter 2032-33 prices are almost \$1/MMBtu higher than a year ago even as the front month contract for March 2023 delivery has moved lower by \$1.84/MMBtu. For our latest on US gas see ([web](#) | [terminal](#)).

Source: Ercot, BloombergNEF. Note: Gas basis is the price difference between a given Hub and Henry Hub, which is the benchmark US price. (The top chart headline was corrected and missing headlines added on February 14, 2023.)

Houston Hub forward curve

On-peak

Click for:	View forecast for:
Forecast discussion	Off-peak
Forward curve discussion	Around-the-clock
Forecast methodology	On-peak

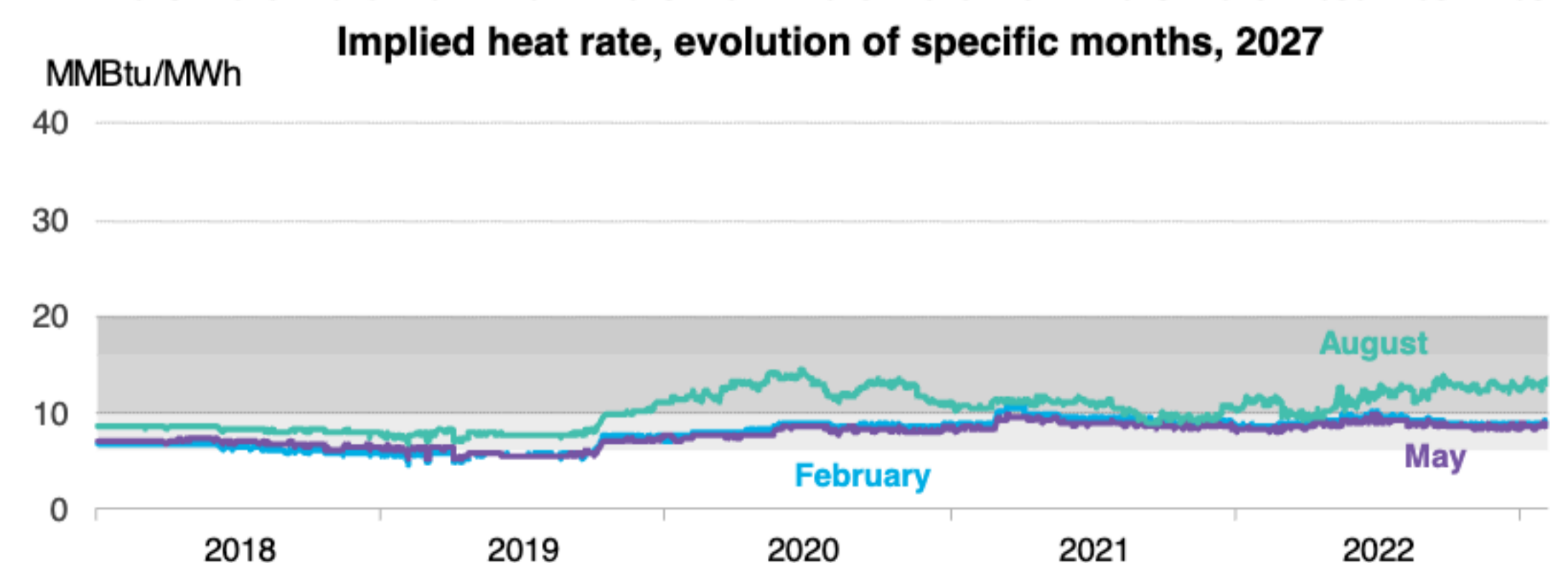
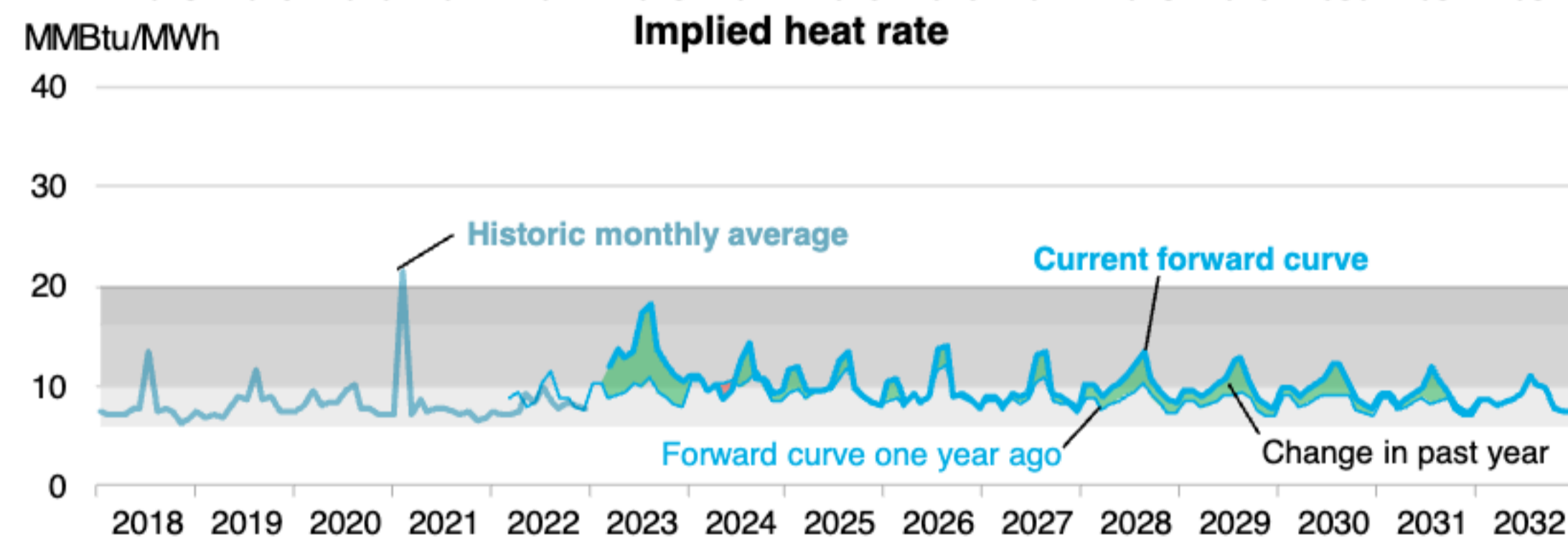
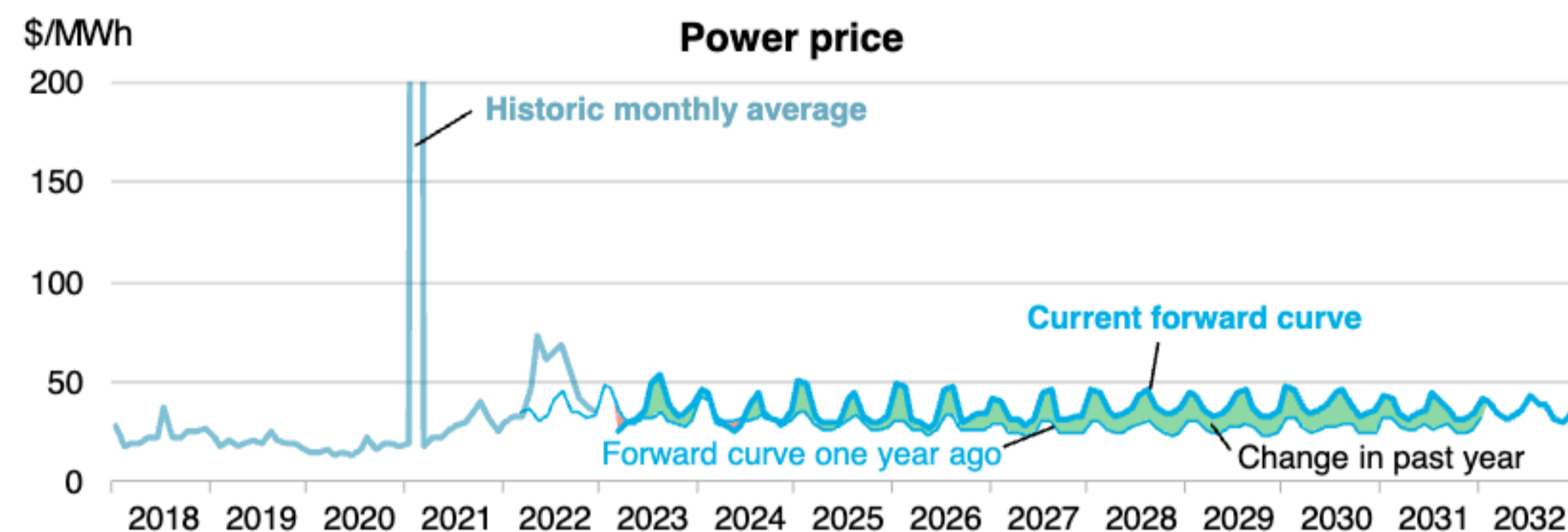


Source: Ercot, BloombergNEF. Note: Gray areas on implied heat rate charts represent the range from most efficient to least efficient gas plant heat rates.

- Over the past year the entire forward curve for both on- and off-peak power prices has shifted upwards. This is to be expected, given the upward shift in the forward curve for natural gas during the same period, which itself is a result of nationwide trends in the gas market. For our latest on US gas see [\(web | terminal\)](#).
- It is noteworthy that in terms of implied heat rate (IHR) the forward curve has shifted upwards more substantially in the near term (2023-25). This might be a transient effect – in December 2022 both Houston Ship Channel gas forwards and the equivalent Houston Hub power forwards began to fall. The power market may not have found equilibrium with the more liquid gas market.
- There is a decline in summer on-peak prices between now and 2028. The current on-peak price for August 2028, for example, is 17% below the equivalent price for 2023. The decline would be greater were it not for a rise in gas prices during that period – in terms of IHR, the drop is even greater, at 32%. This is consistent with the view that the growing penetration of PV should depress on-peak prices – between 2023 and 2028 we expect PV capacity in Ercot to grow from 17GW to 43GW.
- The forward curve suggests that over the next decade on-peak winter prices will reach similar levels to those in the summer. This is the result of the growing recognition of solar’s negative impact on summer peaks and the increase in winter prices that can be traced back to Winter Storm Uri in February 2021 (see bottom chart). Although the IHR is lower for the winter (suggesting the power system is under less stress in winter than in summer) the higher expectation of winter gas prices brings winter and summer power prices to the same level.

Houston Hub forward curve Off-peak

Click for:	View forecast for:
Forecast discussion	Off-peak
Forward curve discussion	Around-the-clock
Forecast methodology	On-peak

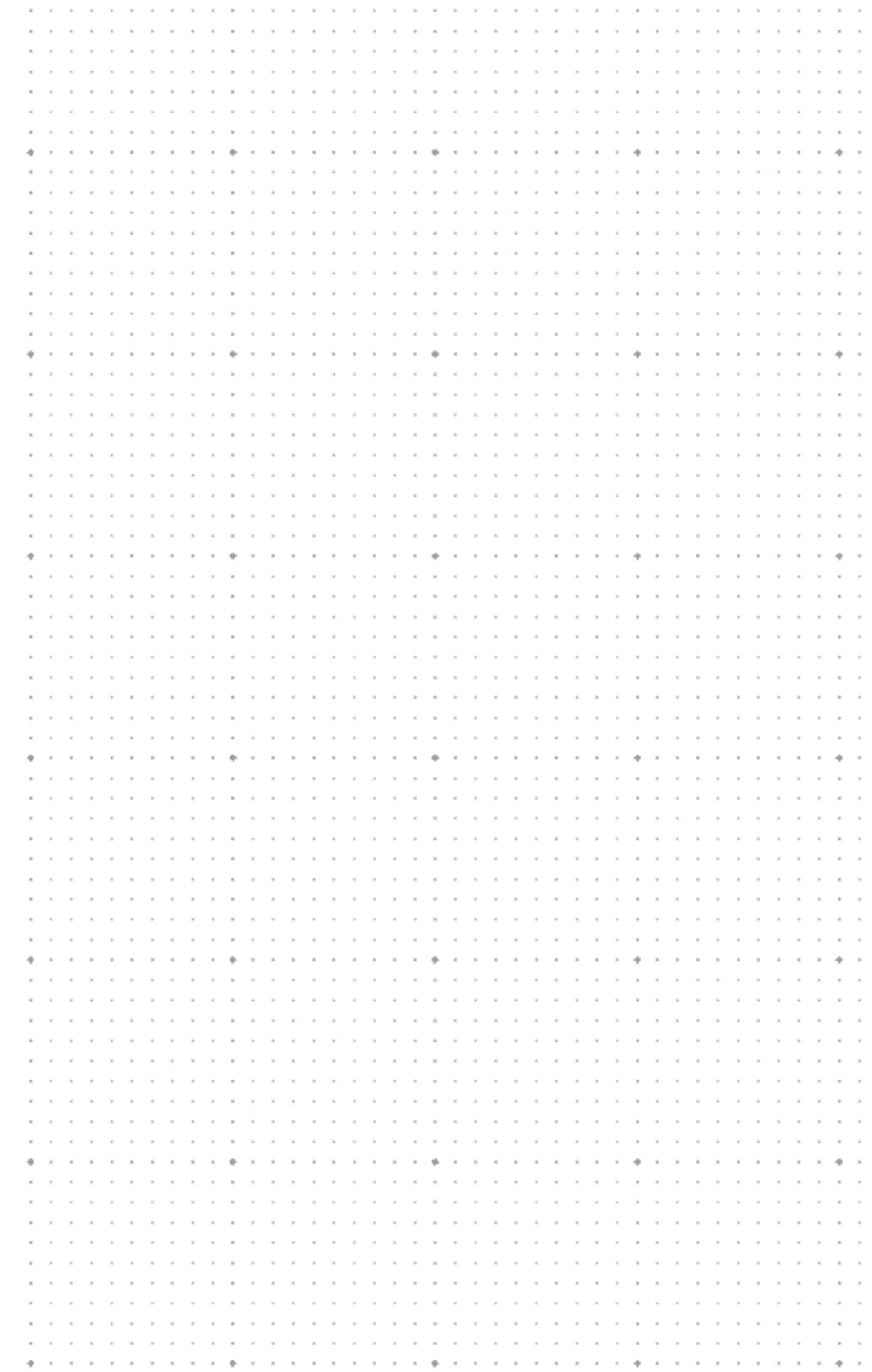


Source: Ercot, BloombergNEF

- There are less noteworthy trends in the off-peak Houston Hub forward curve than there are for its on-peak equivalent. The price curve does not point up or down, and in-terms of IHR it points just slightly down. Solar only impacts off-peak prices at weekends, dampening its depressive effect. Wind, on the other hand, impacts both on- and off-peak prices and so the slight downward trends we see in IHR over the next decade could reflect the expectation of wind capacity increasing from 38GW currently to 60GW by the end of 2030.
- The near-term increase in IHR could be a transient effect, as discussed on the previous page for on-peak prices.
- The increased load due to Bitcoin mining should have a significant impact on off-peak prices, given that mines would be running around the clock and would particularly impact periods where prices are lower. However, it is not clear from the changes in the curve over the past year that this is the case – for the most part the IHR has not shifted significantly for 2024-27.
- An arguable exception to the above could be the trend that off-peak IHR has increased during the summer, a trend that began in early 2022 (see bottom chart). This may reflect expectations of higher prices in the evening – at 11 p.m. temperatures are still quite high and if there is no solar available to offset new demand from Bitcoin-mining, the system will be moderately stressed, leading to an increase in IHR.

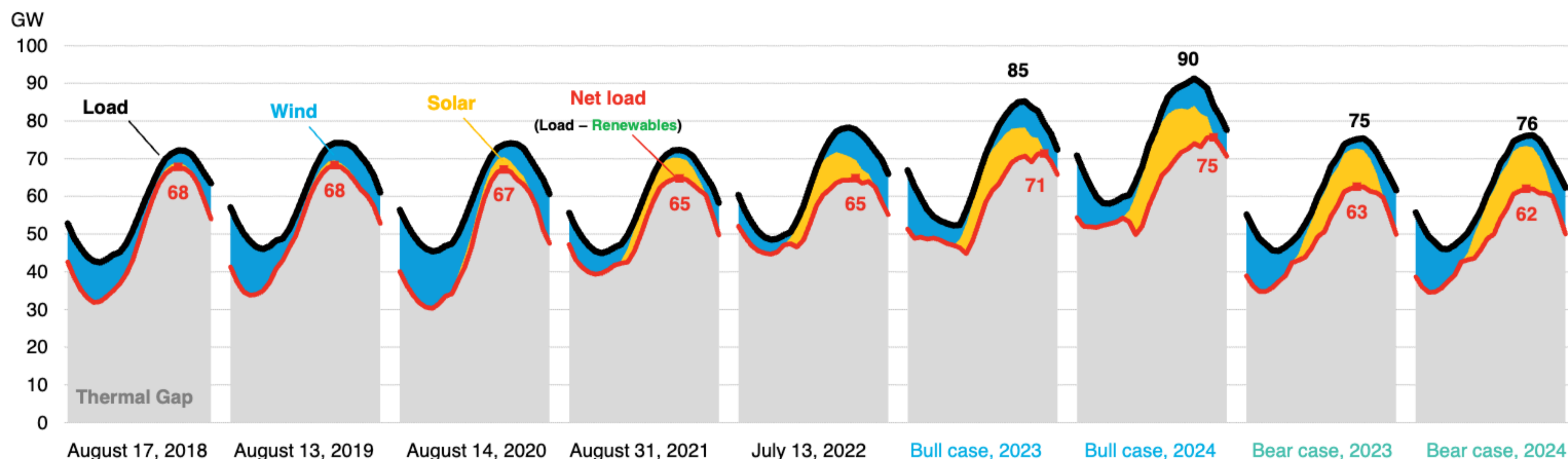
Outlook

A multitude of scenarios



Summer net load

Evening peaks are on the horizon

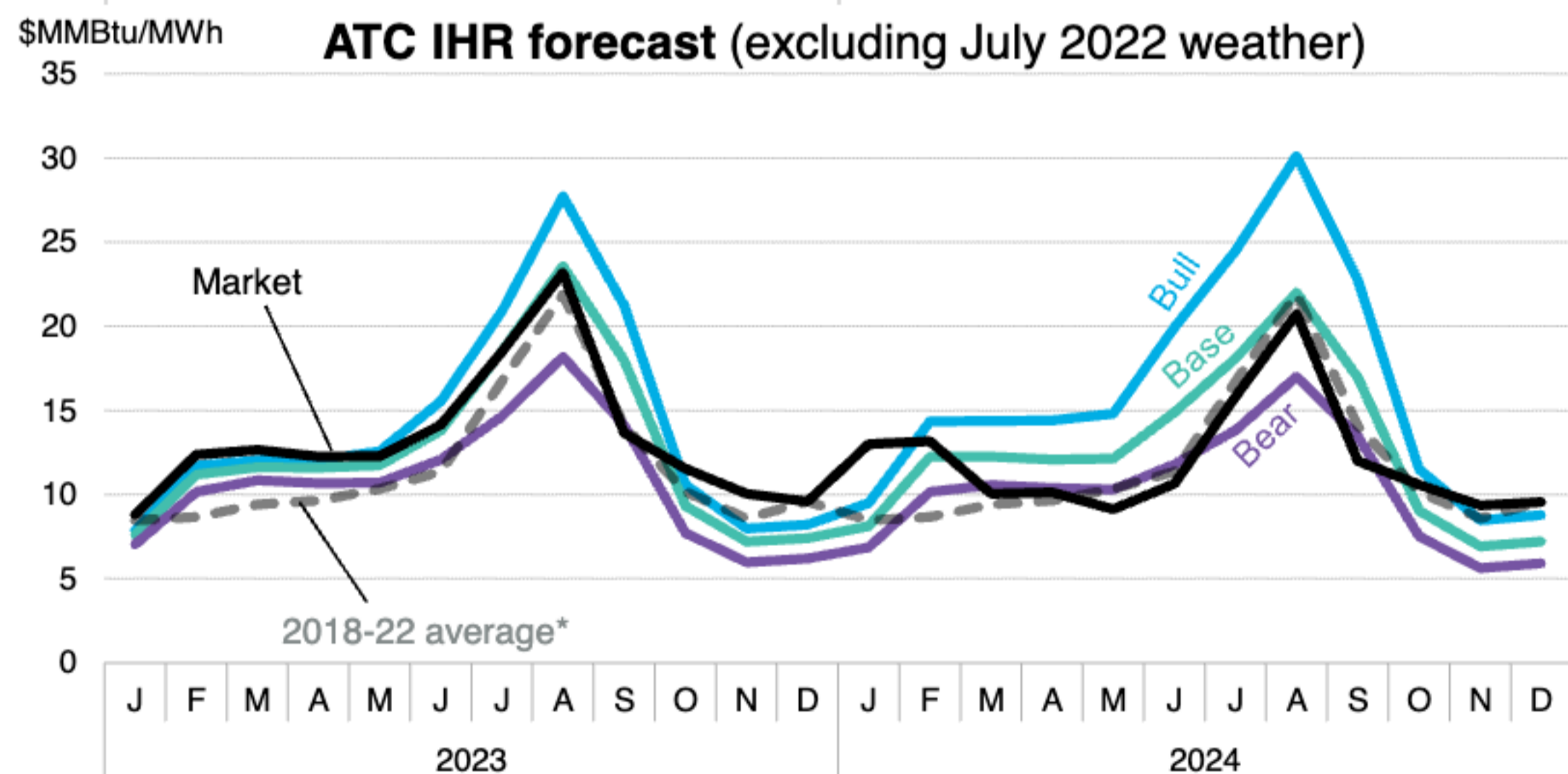
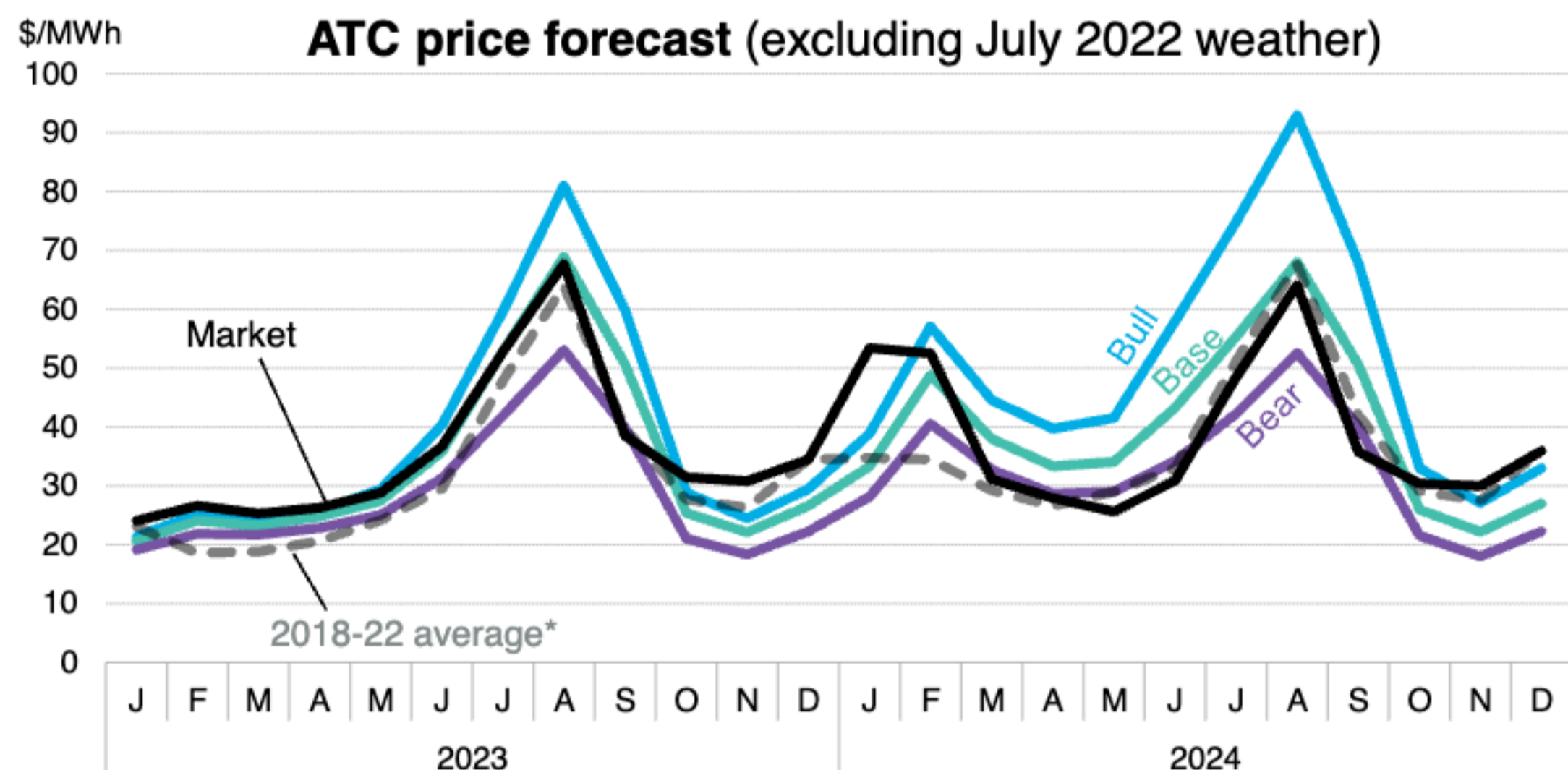


- Hours of peak net load in Ercot are synonymous with system-wide physical scarcity and extreme price spikes. These critical hours have historically been dictated by poor wind speeds in the late afternoon.
- However, the recent wave of solar build and its predictable generation is balancing wind's volatility. Ercot is now home to 13.2GW of solar that reliably contributes 8-10GW in peak hours.
- On the flip side, solar's growth will likely shift peak net load to evening hours (typically non-peak times). Ercot will need to prepare for challenges brought by high solar adoption, such as quick ramp rates. This will also bring greater arbitrage opportunities for energy storage.
- Our bull case has peak net load in 70GW+ territory:
 - We forecast 2023 summer load peaking at 85GW at 6 p.m. In this hour, renewables contribute 15GW bringing net load to 70GW. After sunset, net load peaks at 71GW from 8 p.m.-10 p.m. Summer of 2024 will follow a similar pattern of net load peaking at 75GW in the evening.
- Our bear case estimates peak net load below 65GW:
 - We estimate peak load to be 75GW this upcoming summer if there is milder weather and no new mines come online. Strong renewable contribution will bring a peak net load of 63GW during the 5 p.m.-7.p.m. window.

Source: Ercot, BloombergNEF. Note: Bull case uses 2022 weather; bear case uses 2021 weather. Assumes no demand response from Bitcoin mines.

Price and IHR forecast Ercot Hub average

Click for:	View forecast for:
Forecast discussion	Off-peak
Forward curve discussion	Around-the-clock
Forecast methodology	On-peak

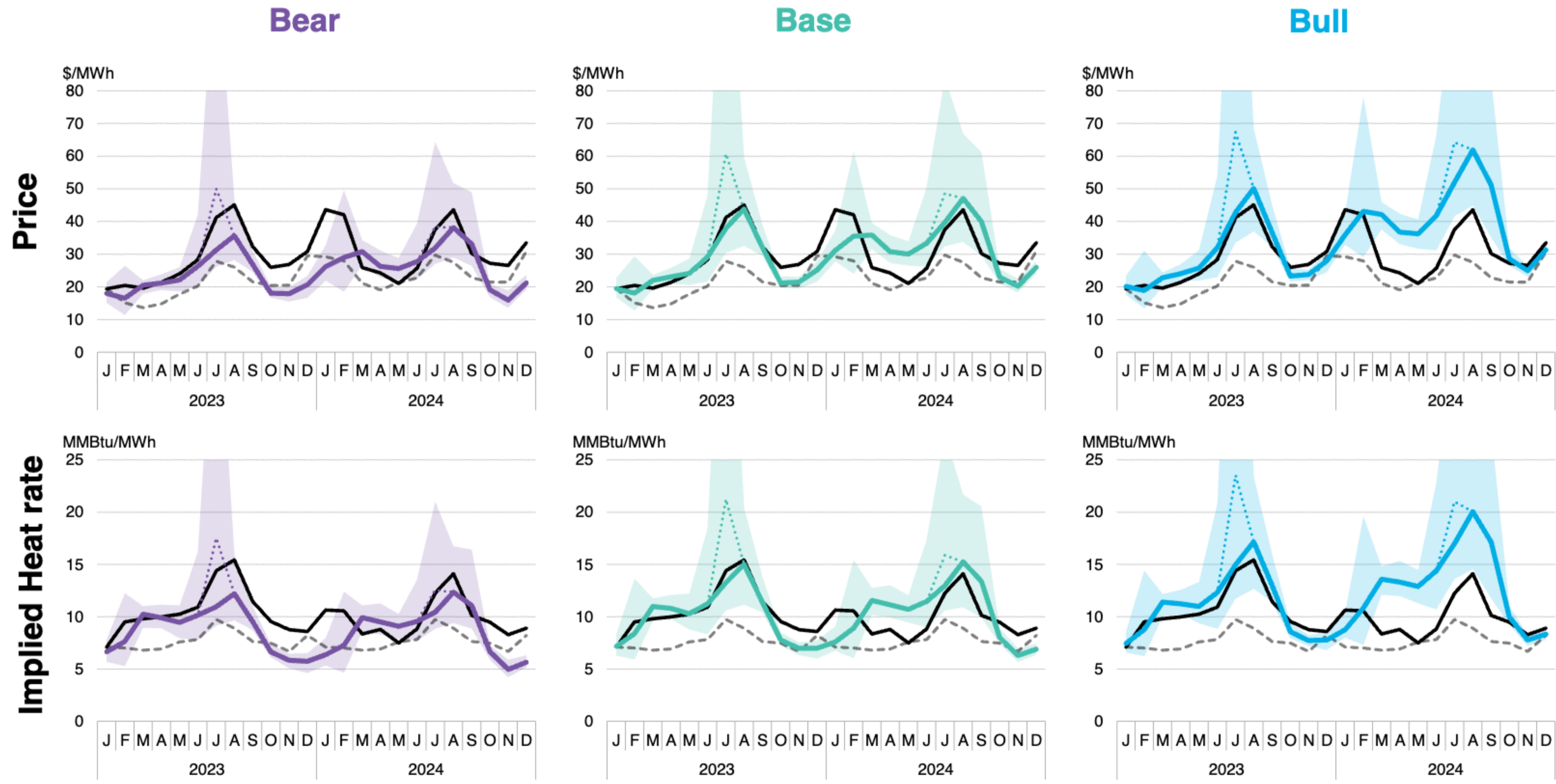


Source: BloombergNEF. Note: ATC = around-the-clock. Monthly 2018-2022 average does not include February 2021, and on the price chart it is the IHR average multiplied by the gas forward curve (Houston Ship Channel). For January and February 2023 market refers to historic prices.

- The charts on the left show the average of our price and IHR forecasts produced using weather from 2018-2022. To see the weather-related range within each Bitcoin scenario, use the top-right tab to navigate between the detailed forecast slides.
- It is clear from the charts on the left that what one believes about the future of Ercot power prices depends strongly on what one believes about the future of Bitcoin in Texas (and hence which of our three Bitcoin scenarios one believes to be most likely). This is particularly true for 2024 where the year-round average price is 56% higher in the bull scenario than in the base scenario.
- The shape of the forecast curve (see methodology) means that for the most part uncertainty weather presents considerably more upside risk than downside risk. Abnormally hot or cold weather in the summer or winter could drive prices far above the prices presented here, whereas mild weather only drags the average down moderately.
- On that note, the averages presented on this page exclude the forecast produced by applying the extreme weather conditions of July 2022. The combination of additional Bitcoin load and July 2022 weather produces forecasts that are so high (in the bull scenario the July 2024 on-peak average is above \$500/MWh) that they distort the entire outlook.
- The true averages (including July 2022) are shown as dotted lines on the detailed forecast slides. If one believes that the hot weather of July 2022 was not an anomaly, one should adjust expectations for summer prices to these levels or higher.

Price and IHR forecast Off-peak

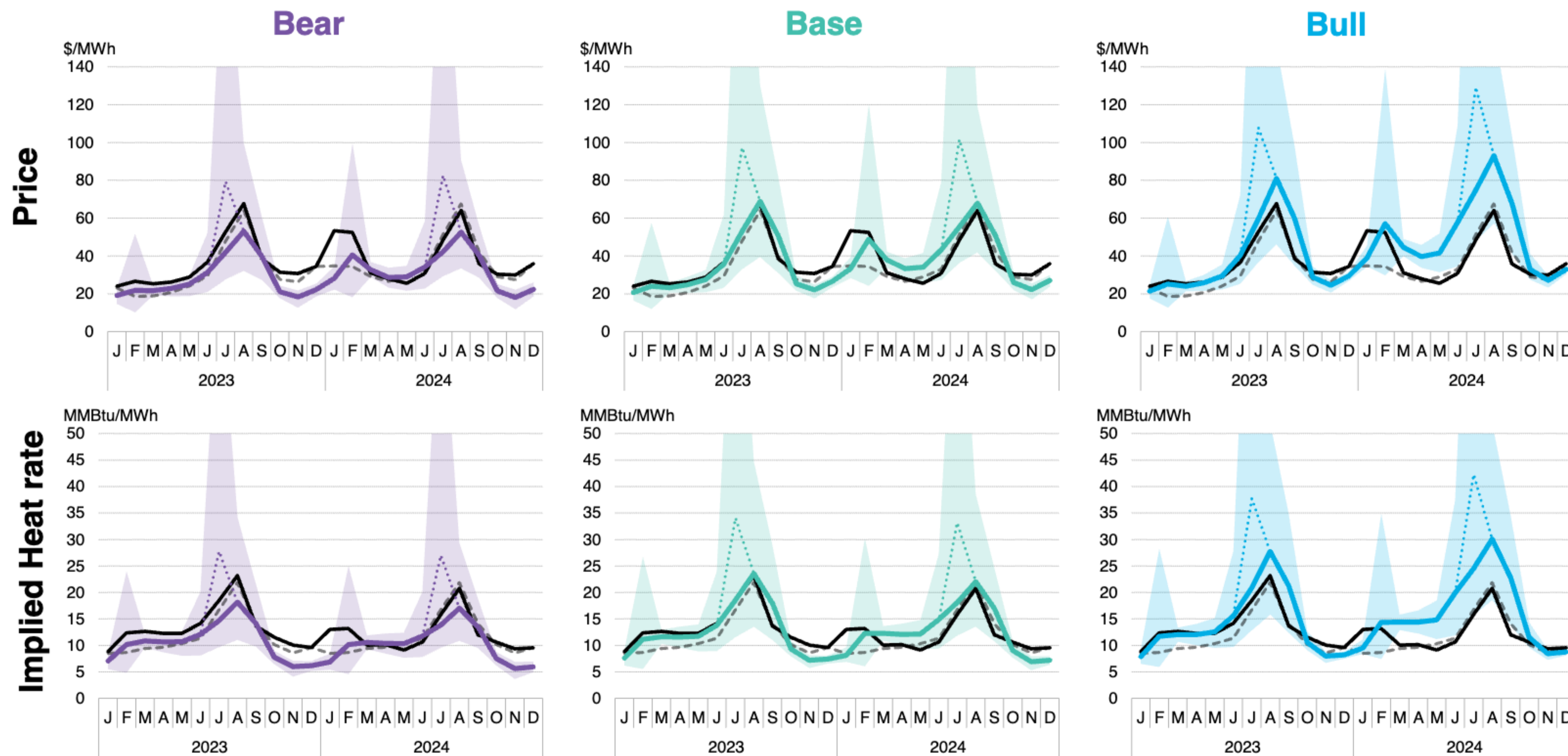
Click for:		View forecast for:	
Forecast discussion	Forward curve discussion	Off-peak	Around-the-clock
Forecast methodology		On-peak	



Source: BloombergNEF. Note: "Market" refers to forward curve as of February 8, 2023, except for January and February 2023 in which case it refers to historic averages as of that date. "Historic average" represents the monthly 2018-2022 average of implied heat rate (not including February 2021), multiplied by Houston Ship Channel gas prices.

Price and IHR forecast Around-the-clock

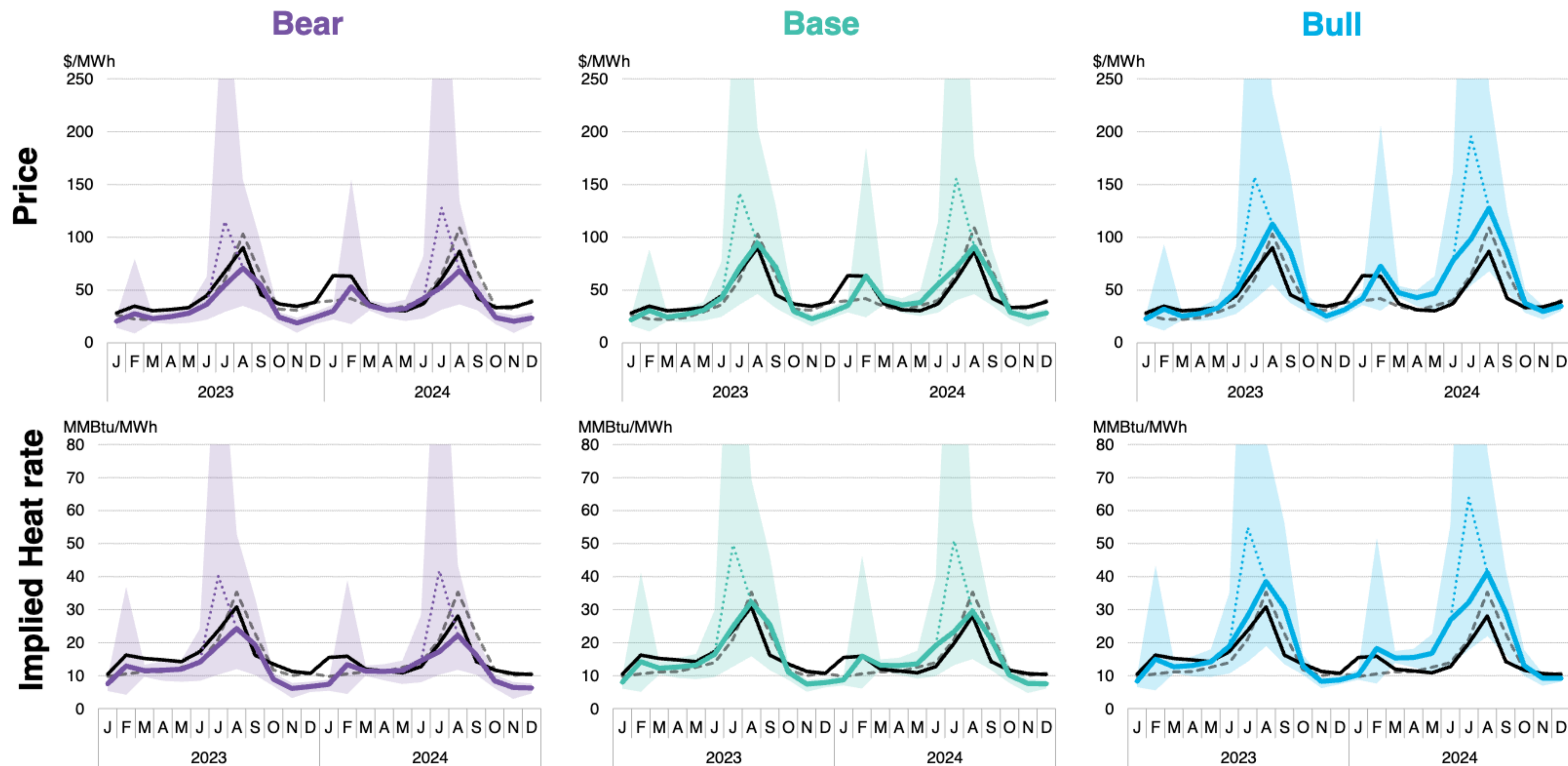
Click for:		View forecast for:	
Forecast discussion	Forward curve discussion	Off-peak	On-peak
Forecast methodology		Around-the-clock	



Source: BloombergNEF. Note: "Market" refers to forward curve as of February 8, 2023, except for January and February 2023 in which case it refers to historic averages as of that date. "Historic average" represents the monthly 2018-2022 average of implied heat rate (not including February 2021), multiplied by Houston Ship Channel gas prices. (The y-axis labels on the charts above were corrected on February 14, 2023).

Price and IHR forecast On-peak

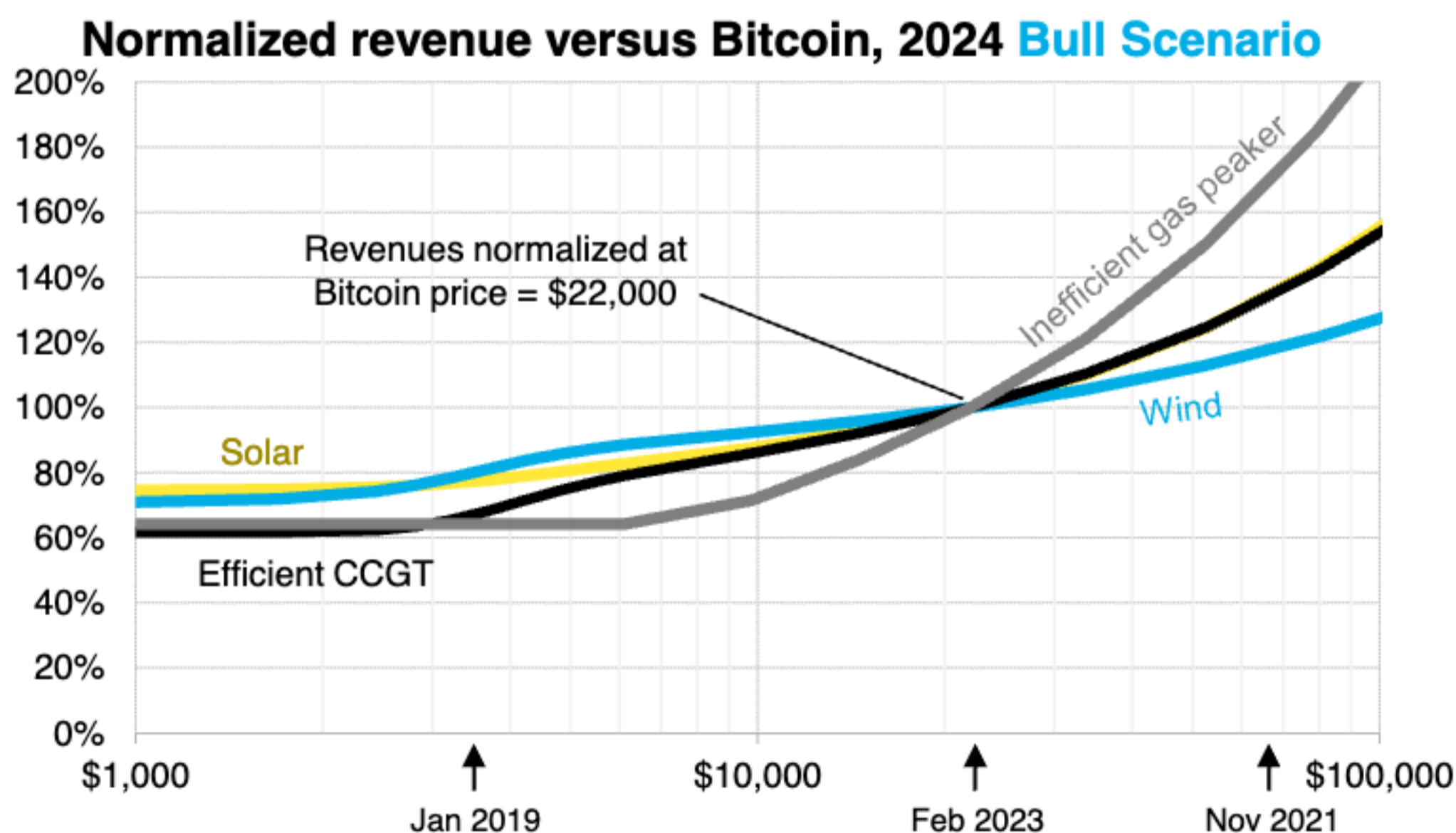
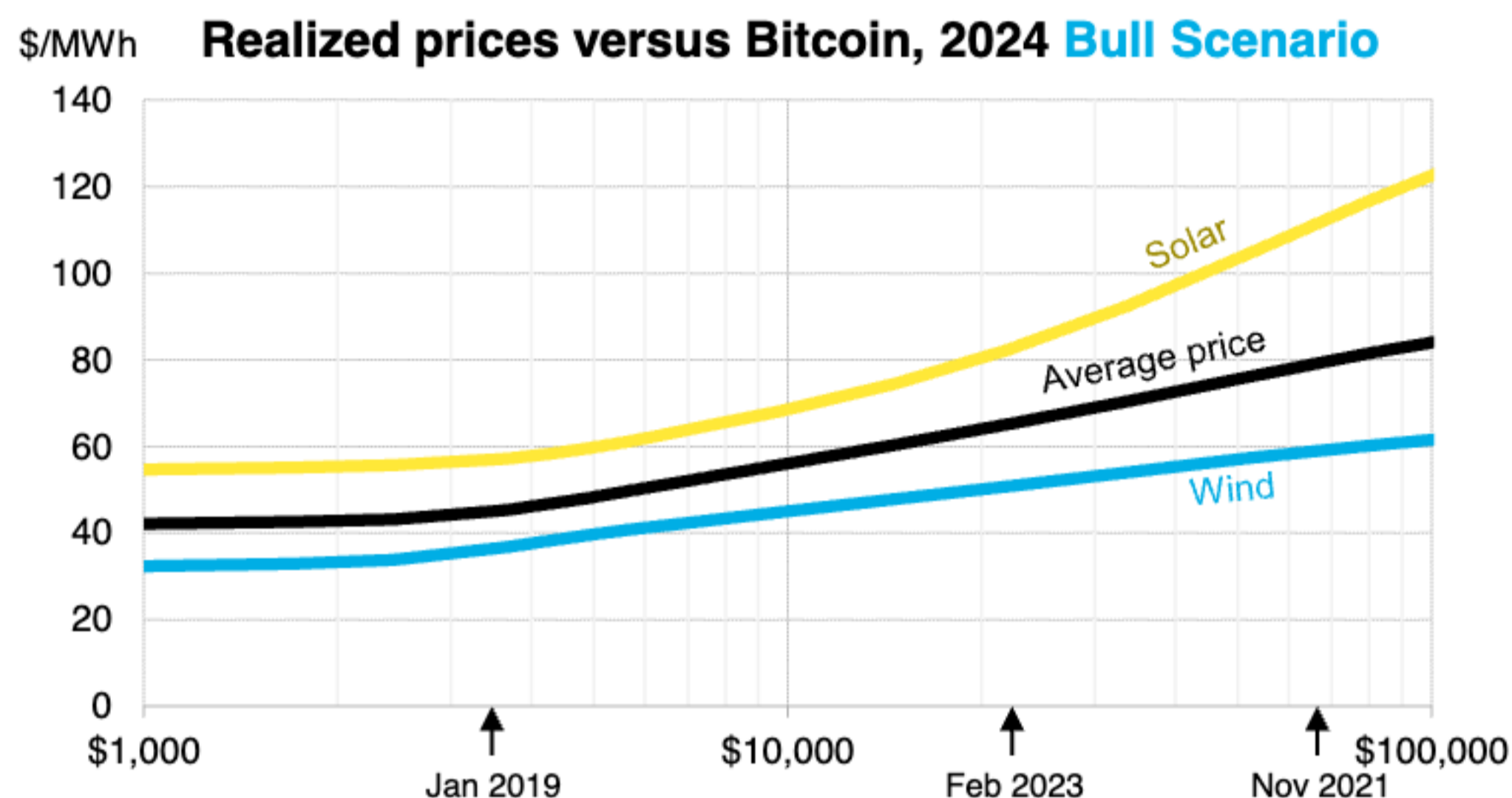
Click for:		View forecast for:	
Forecast discussion	Forecast discussion	Off-peak	Off-peak
Forward curve discussion	Forward curve discussion	Around-the-clock	Around-the-clock
Forecast methodology	Forecast methodology	On-peak	On-peak



Source: BloombergNEF. Note: "Market" refers to forward curve as of February 8, 2023, except for January and February 2023 in which case it refers to historic averages as of that date. "Historic average" represents the monthly 2018-2022 average of implied heat rate (not including February 2021), multiplied by Houston Ship Channel gas prices. (The y-axis labels on the charts above were corrected on February 14, 2023).

The impact of Bitcoin's price

A new energy commodity?

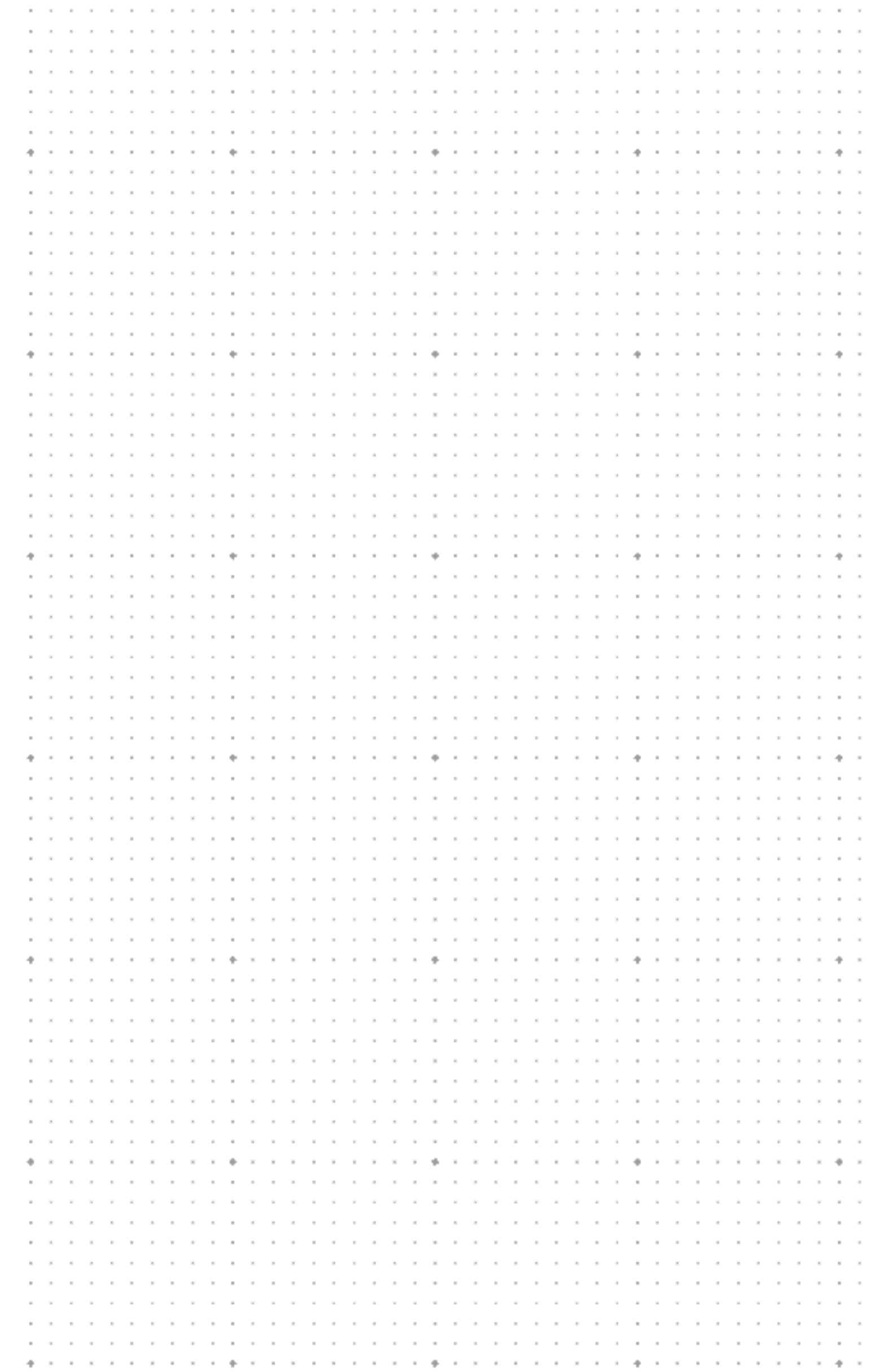


Source: BloombergNEF

- On slide 9 we used both anecdotal evidence and our own analysis to show that Bitcoin miners operate their loads on a flexible basis, and that they ramp down operations when prices reach approximately \$180/MWh. Our price forecasting model takes Bitcoin this miner behavior into account, adjusting our demand estimates at or above this price threshold.
- If we assume this threshold represents a rough breakeven for the median Bitcoin miner, then we should also assume that as the price of Bitcoin changes, so should our threshold (there are other factors such as Bitcoin's "difficulty adjustment", which for now we ignore). So, if adjusting the threshold impacts our forecast, then the power price is affected by the price of Bitcoin.
- The charts on the left show the impact – on the basis outlined above – that Bitcoin price could have on power prices and generator economics. A factor to consider is how volatile and unpredictable Bitcoin prices are – November 2021 prices were a factor of 17 higher than those in January 2019. The results suggest that parties exposed to Ercot are, whether they like it or not, exposed to these Bitcoin price swings.
- The bottom chart shows that high Bitcoin prices benefit wind and solar, but they benefit inefficient gas peakers *even more*. Hence, the claim that Bitcoin mining can benefit the energy transition (by ramping up to consume excess generation and in so doing providing a price signal for renewables) is not totally true – or at least, the benefits may be outweighed by the additional gas consumption. However, there may be merit to the claim in a low Bitcoin price/high Bitcoin capacity/high gas price scenario.

Appendix

Methodology



Net load forecast

Click for:	View forecast for:
Forecast discussion	Off-peak
Forward curve discussion	Around-the-clock
Forecast methodology	On-peak

Demand

Inputs

Baseload, **BL**

Hour

Day (weekday/end)

Temperature



Scenarios

There are 3 Bitcoin-mining build cases that affect baseload demand:

BL_{Bear}, **BL_{Base}**, **BL_{Bull}**

Hourly temperatures from 2018 – 2022 was used to simulate 5 possible weather scenarios for the forecast.

W₂₀₁₈, **W₂₀₁₉**, **W₂₀₂₀**, **W₂₀₂₁**, **W₂₀₂₂**



Demand forecast

The demand model forecasts the hourly load for each Bitcoin build and weather scenario. There is a total of 15 possible demand cases. For example:

$$BL_{Bull} \times W_{2022} = Load_{Bull \times 22}$$

Renewable supply

Capacity factor (Historical)

$$Capacity = \frac{Hourly\ generation}{Total\ capacity}$$

A capacity factor for solar and wind was calculated for each hour of 2018 – 2022:

CF₂₀₁₈, **CF₂₀₁₉**, **CF₂₀₂₀**, **CF₂₀₂₁**, **CF₂₀₂₂**



Capacity forecast

BNEF's outlook for solar and wind buildout for 2023 and 2024. This uses our project-by-project pipeline database. Read more about forecast methodology [here](#).

RE_MW₂₀₂₃₋₂₄

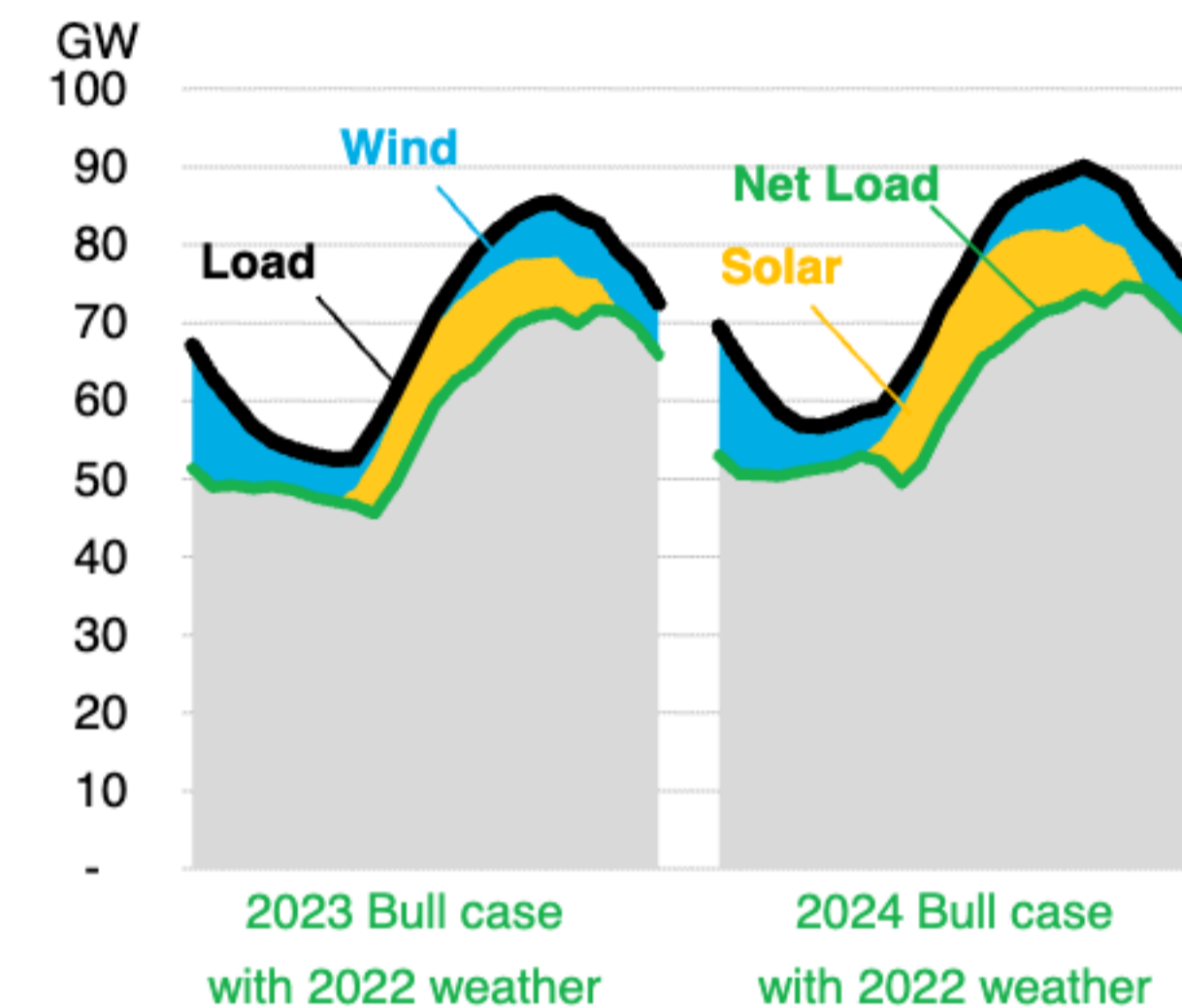


Generation forecast

There are 5 hourly generation forecasts based on the historical capacity factors. For example:

$$CF_{2022} \times RE_MW_{2023-24} = RE_{2022}$$

Net load



Net load forecast

Each weather scenario for demand and supply is matched to forecast hourly net load for 2023-2024. There are 15 net load scenarios. This simulates historical weather patterns and the observed relationship between temperatures and solar/wind generation.

For example, our bull scenario if 2023-2024 has weather like 2022:

$$Load_{Bull \times 2022} - RE_{2022} = Net_Load_{Bull \times 2022}$$

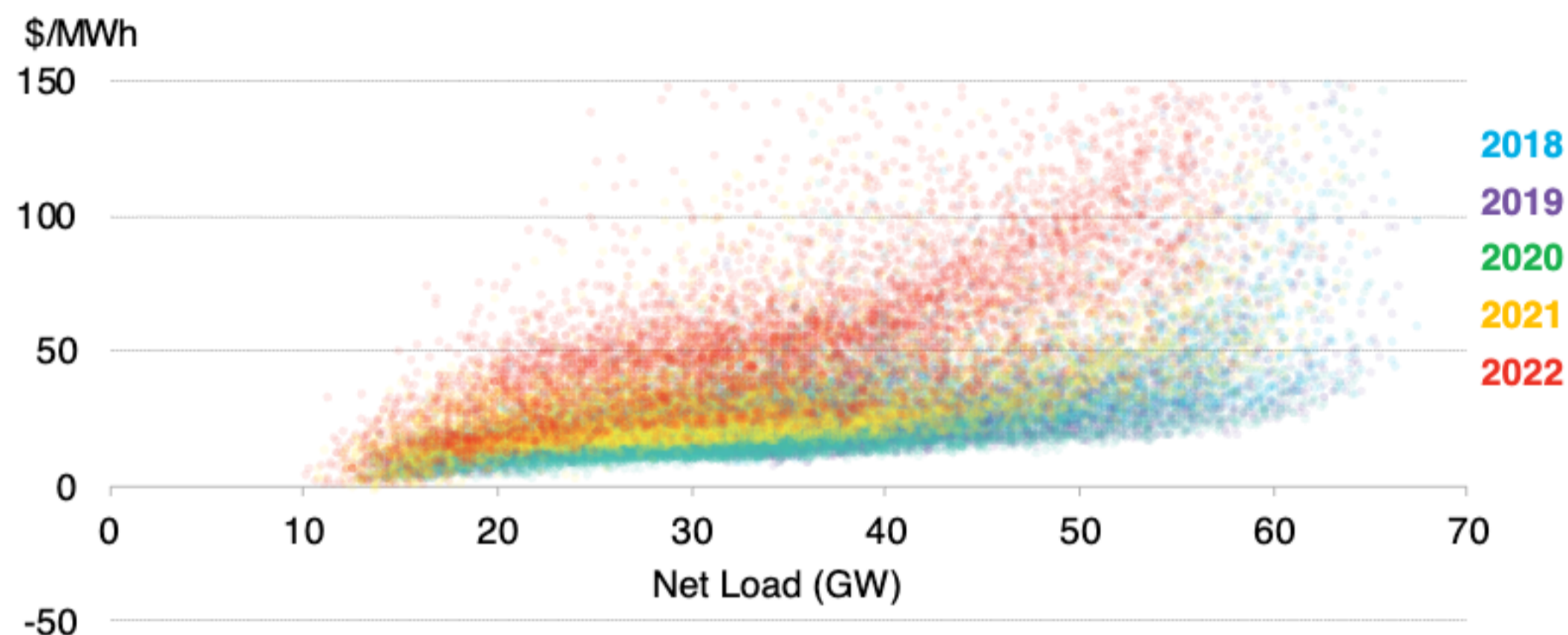
Methodology

Implied heat rate forecast



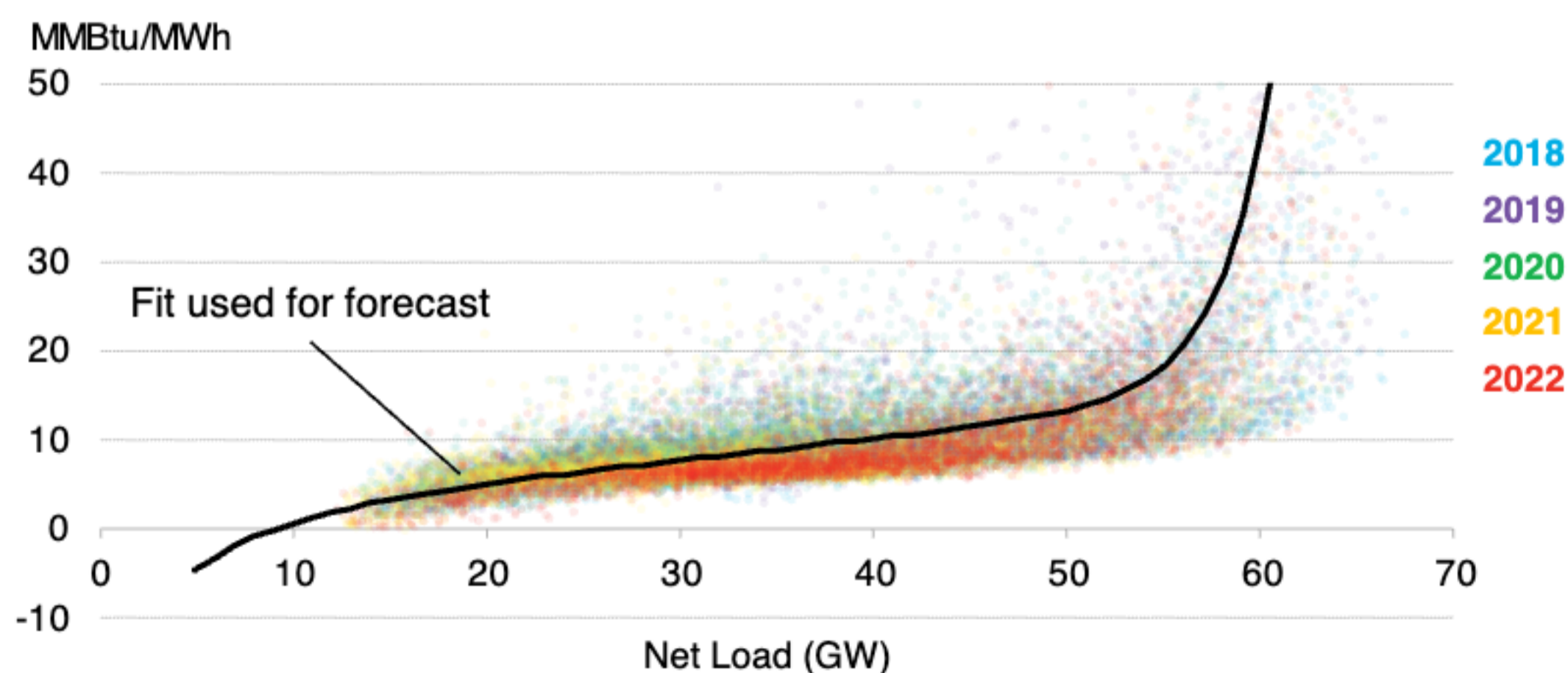
Click for:	View forecast for:
Forecast discussion	Off-peak
Forward curve discussion	Around-the-clock
Forecast methodology	On-peak

Figure 1: Hourly day-ahead price and net load by year



Source: BloombergNEF Note: Data do not include shoulder season (March-May).

Figure 2: Hourly implied heat rate and net load by year



Source: BloombergNEF Note: Data do not include shoulder season (March-May).

Historical net load vs. implied heat rate fit

- Net load determines power prices in Ercot. (Figure 1). The spread in yearly net load-price curve is driven by gas prices. To account for this, we use the implied heat rate.
- We take the **historical fit** between implied heat rate and net load for our forecast (Figure 2). This fit excludes the shoulder season to account for plant outages. We have a separate fit (not shown) for shoulder seasons.



Net load forecast

- We have an **hourly net load forecast** for each scenario as discussed in the previous slide. Each Bitcoin build scenario uses weather from 2018 – 2022. For example:
Net_Load Bull x 2018, Bull x 2019, Bull x 2020, Bull x 2021, Bull x 2022



Implied heat rate and price forecast

- We apply the forecasted hourly net load to the historical fit to get the forecasted implied heat rate for each scenario. This forecast also assumes that Bitcoin mines turn down above a certain price threshold (we defaulted to \$180/MWh).
- This hourly forecast is aggregated to get the monthly on-peak, off-peak and around-the-clock implied heat price.
- The forecasted implied heat rate is multiplied by the Houston Ship Channel forward curve to get the forecasted power price.

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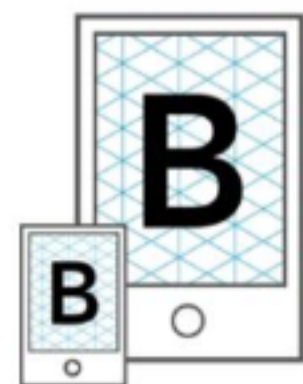
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