

Not Just Hot Air: Hydrogen Opportunities in a Transforming Texas

Prepared for the Texas Hydrogen Alliance

November 2, 2023

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Energy+Environmental Economics



- + Introduction
- + State of the Market: ERCOT in Transition
- + What Can the Grid Do for Hydrogen?
- + What Can Hydrogen Do for the Grid?

Who is E3?

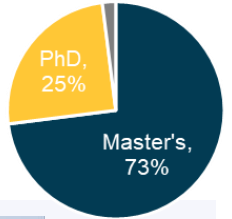


Energy+Environmental Economics



Who is E3?

Thought Leadership, Fact Based, Trusted.



100+ full-time consultants | 30 years of deep expertise | Engineering, Economics, Mathematics, Public Policy...



San Francisco



New York



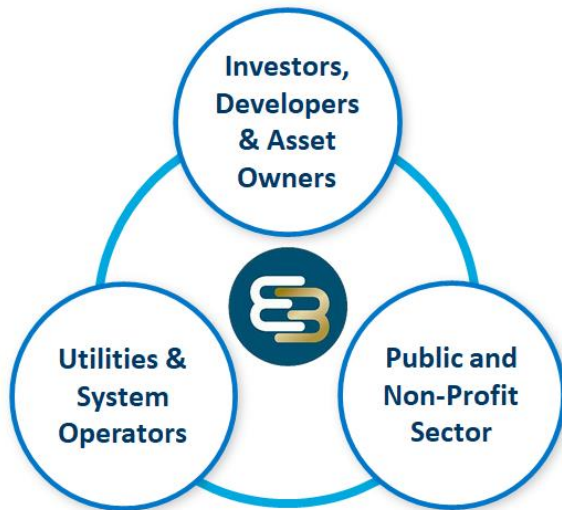
Boston



Calgary

E3 Clients

300+ projects per year across our diverse client base



Recent Examples of E3 Projects

Buy-side diligence support on multiple large-scale investments in **electric utilities** (~\$10B in total)

Market advisory and revenue forecasts for several **stand-alone storage** platforms and individual assets across North America (10+ GW | ~\$1B)

Market advisory and revenue forecasts for generation portfolios and individual **gas-fired, renewable, and storage assets** (20+ GW | ~\$2B)

Acquisition support for investment in a **residential demand response company** (~\$100M)

Southwest: Resource Adequacy Study

PJM: Capacity Market Design Support

California: State Integrated Resource Plan (IRP)

New England: Net Zero New England Study

New York: NYSERDA 100% clean energy planning

Pacific Northwest: 100% renewables and resource adequacy studies for multiple utilities

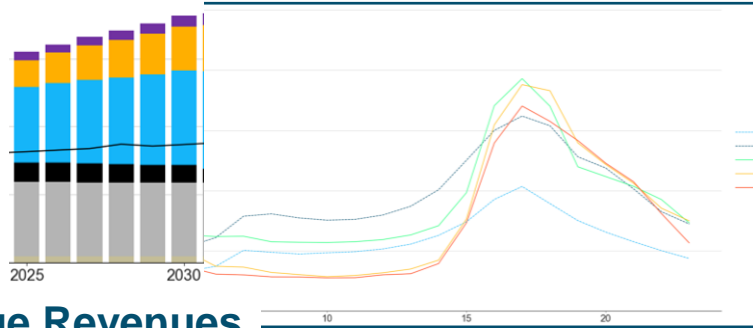


E3's Work in Texas

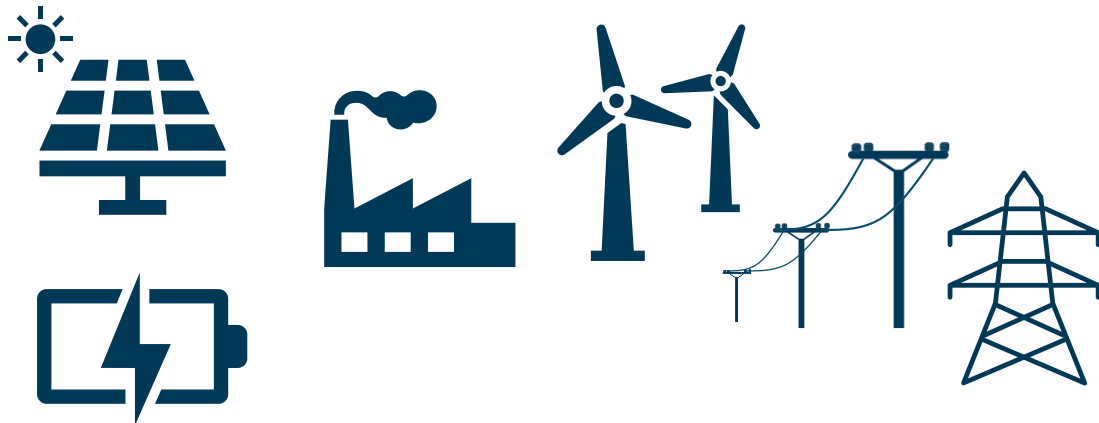
Market Forecasting + Advisory

Market Price + Asset Revenue Forecasts

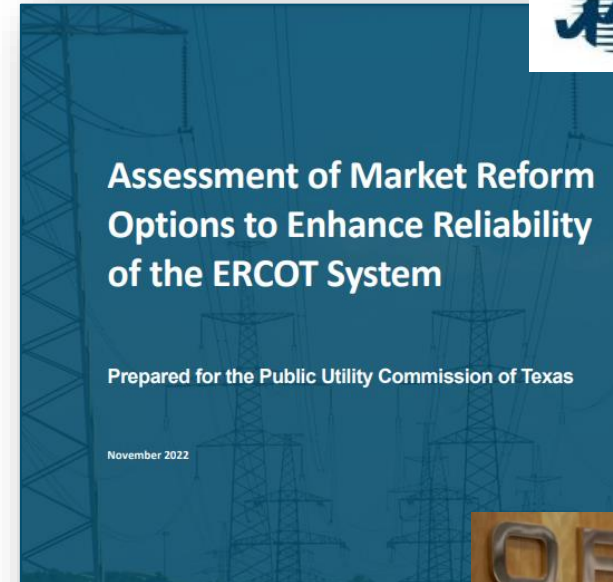
- Hub Prices
- AS Products
- Nodal LMPs
- RECs
- Battery Storage Revenues



Project Development, Due Diligence, Strategy



Market Design



State of the Market: ERCOT in Transition





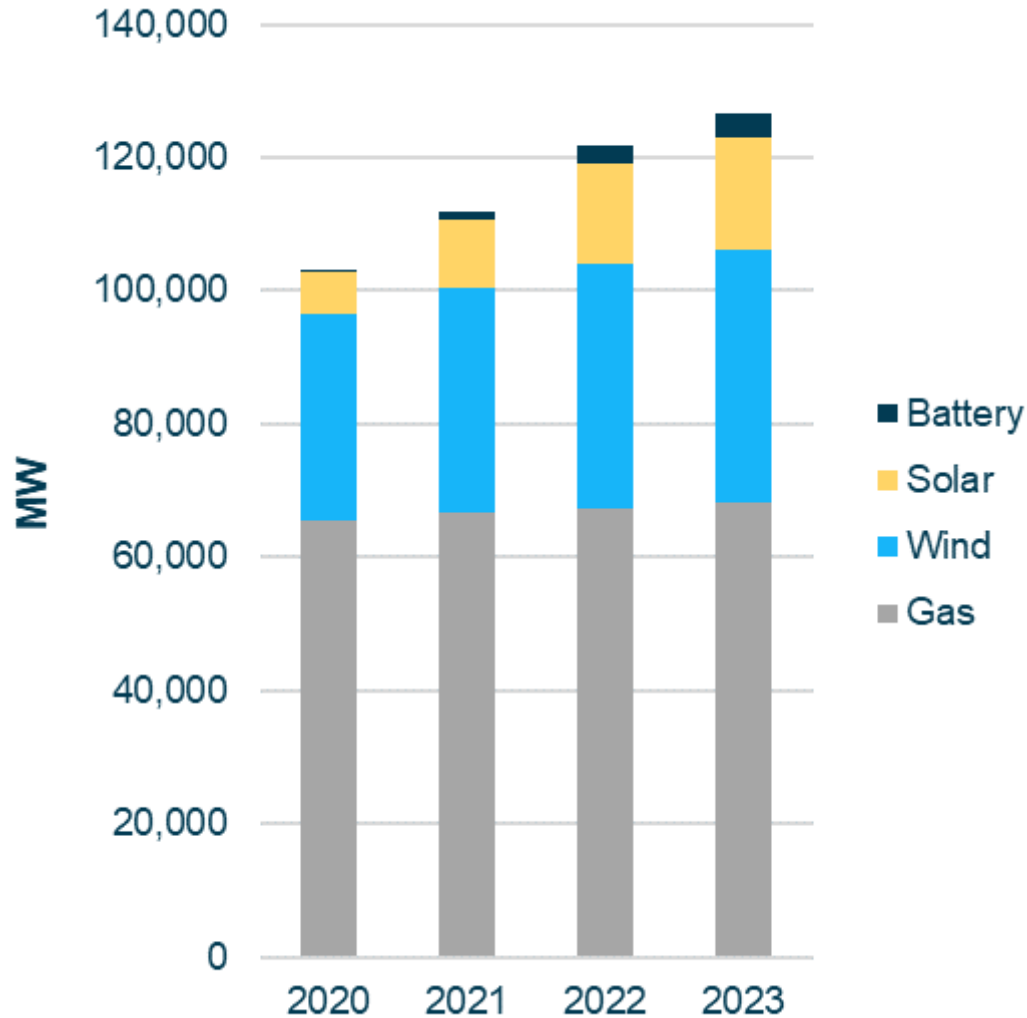
ERCOT is Changing Rapidly

- + Texas is the **largest renewable energy market in the U.S.** and still growing rapidly.
- + Texas is experiencing **massive load growth** from large users and more extreme weather.
- + Texas is experiencing **increasingly volatile energy prices...and increasing reliability challenges.**
- + ERCOT is implementing market changes to support reliability...but there is **much uncertainty on the road ahead.**



Renewable Energy is Big and Getting Bigger in TX

Total Installed Capacity



From 2021 to Now...

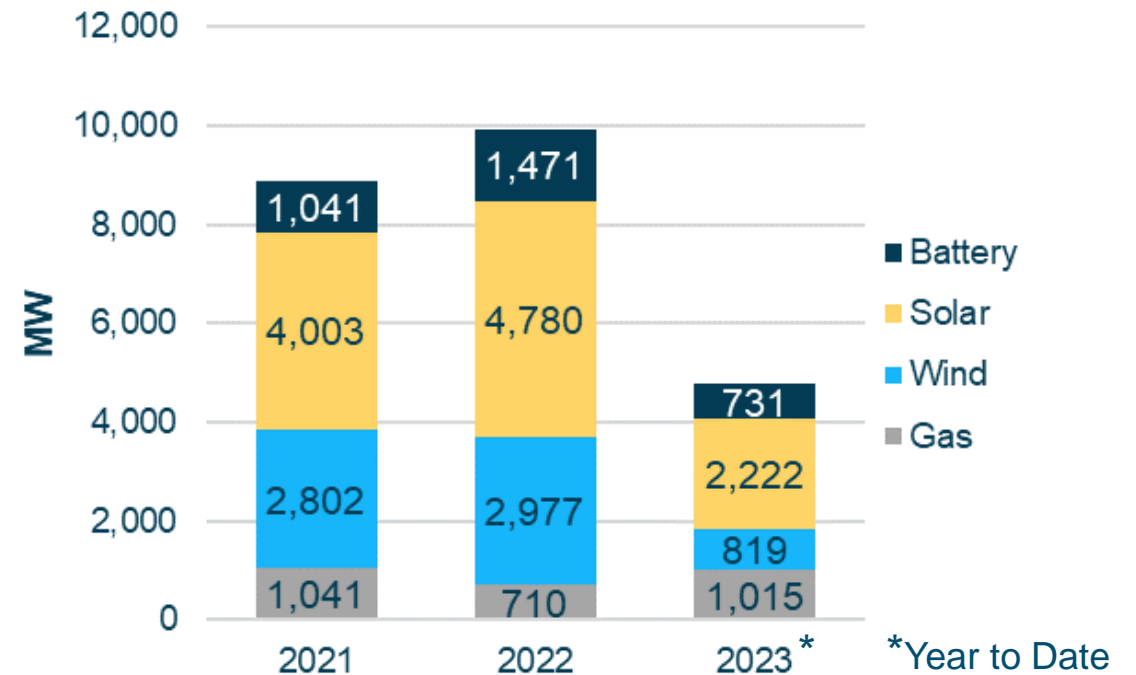
+ 11 GW Solar

+ 3.2 GW Batteries

+ 6.5 GW Wind

+ 2.8 GW Gas

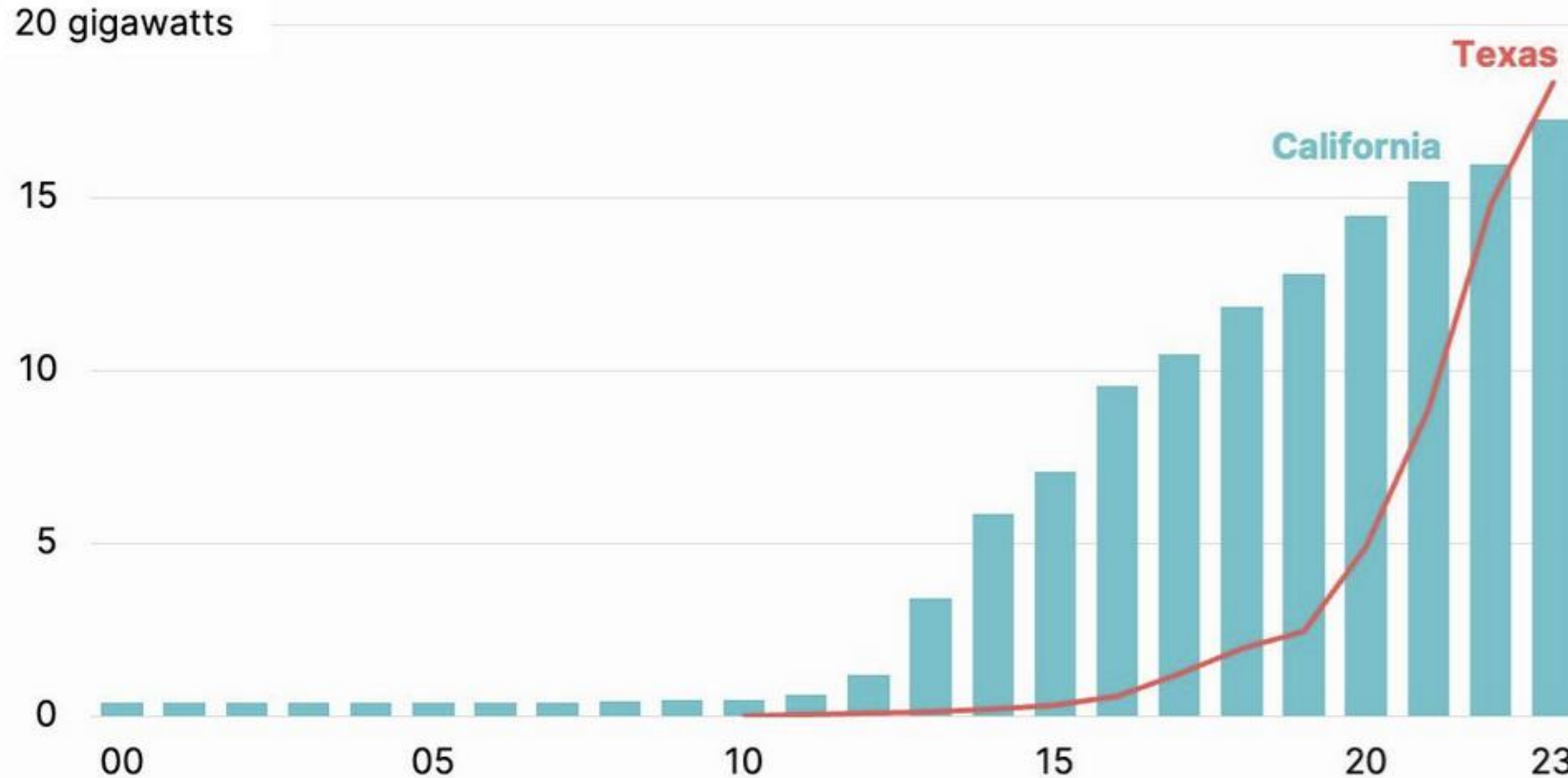
Annual Additions





Texas Now Has More Solar than California!

This year, Texas passed California in total utility-scale solar in operation on the grid.



Source: EIA, ERCOT, CAISO

Note: Data as of October 22, 2023



Texas already has 5x more wind (~38 GW) than California (~7 GW).**

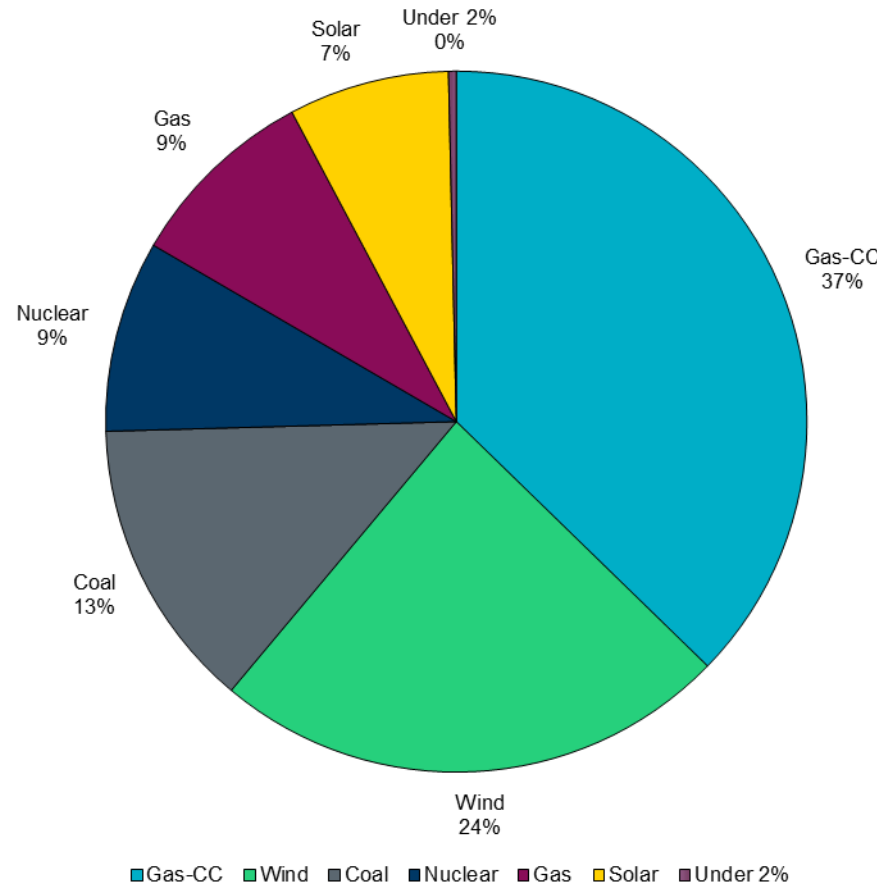


Changing Energy Mix in Texas

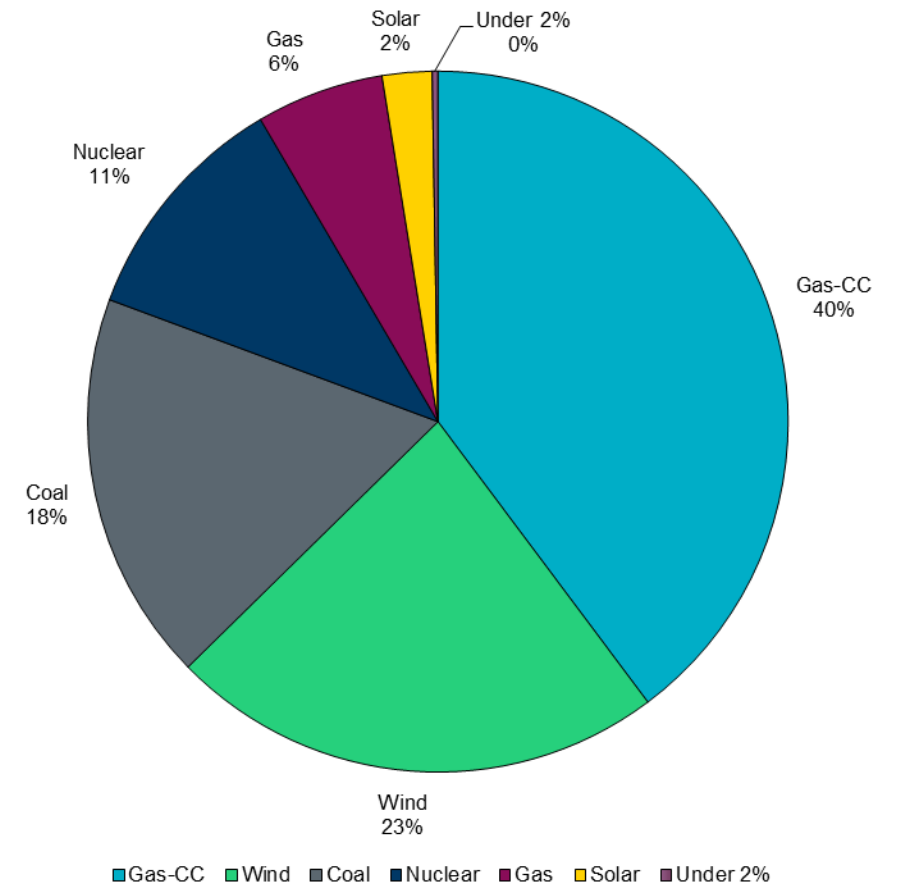
From 2020 to 2023...

- + Solar generation rose from 2% to 7% of total
- + Coal generation declined from 18% to 13%
- + Wind remained steady at 23-24% of total
- + Gas generation remains dominant energy source for now...

Energy by Fuel for 2023



Energy by Fuel for 2020

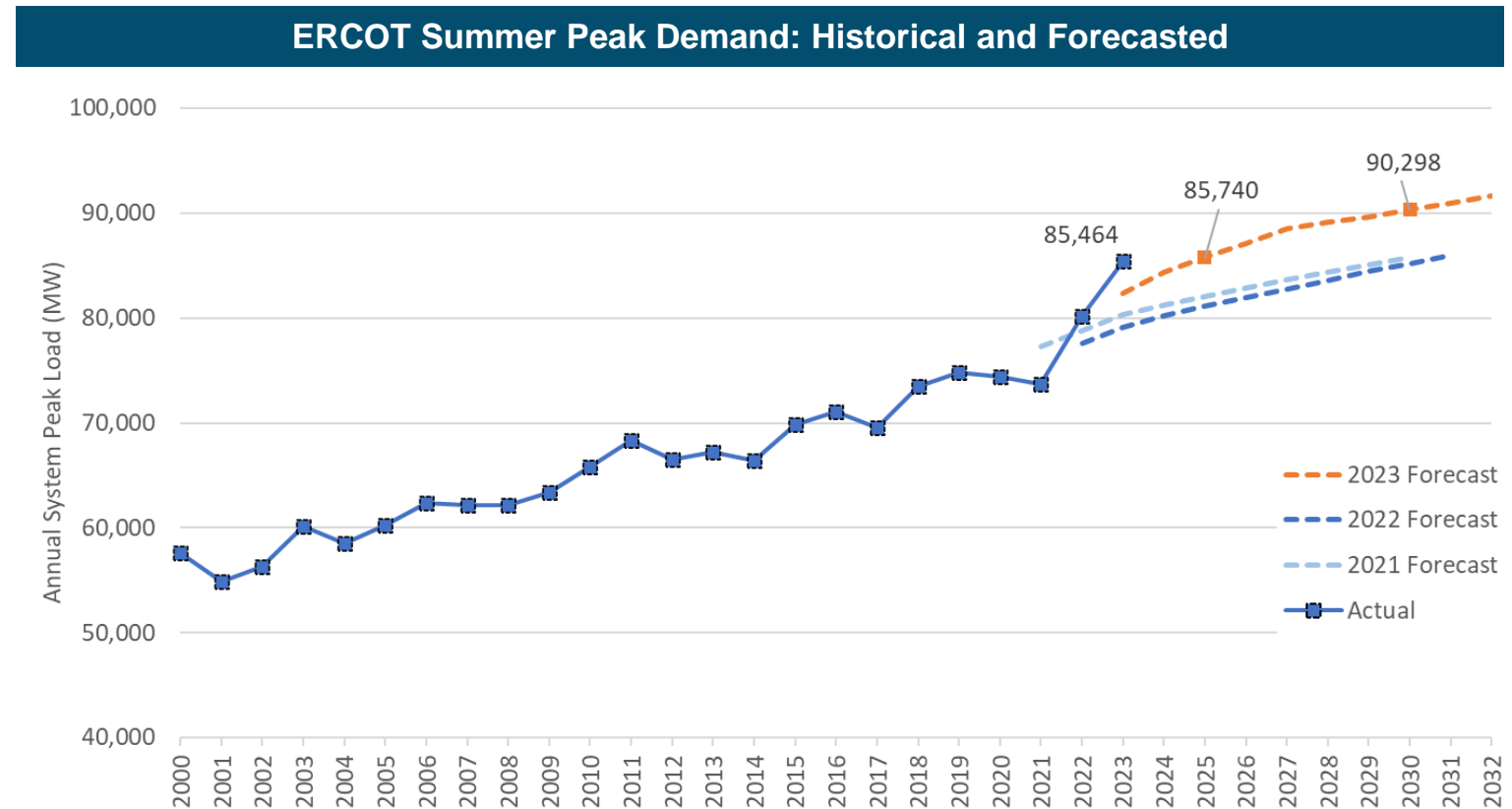


Source: ERCOT Fuel Mix Reports for 2023 and 2020. [Generation \(ercot.com\)](https://www.ercot.com/generation)



ERCOT Forecasts Significant Peak Load Growth

- + ERCOT's peak load surged in 2022 and 2023, significantly exceeding projections
- + ERCOT's 10-yr forecast in 2023 is significantly higher than the 2022 or 2021 vintage forecasts
 - 2023 forecast predicts 85.7 GW peak load in 2025...
...but August 2023 saw 85.5 GW (setting an all-time system record)
- + Extreme temperatures (high and extended summer heat) and large load additions (data centers and industry) are driving up expectations of even higher load growth in the future



Source: Load projections through 2031 are directly from ERCOT's 2022 System Planning Report; [Long-Term Load Forecast \(ercot.com\)](https://www.ercot.com/long-term-load-forecast)

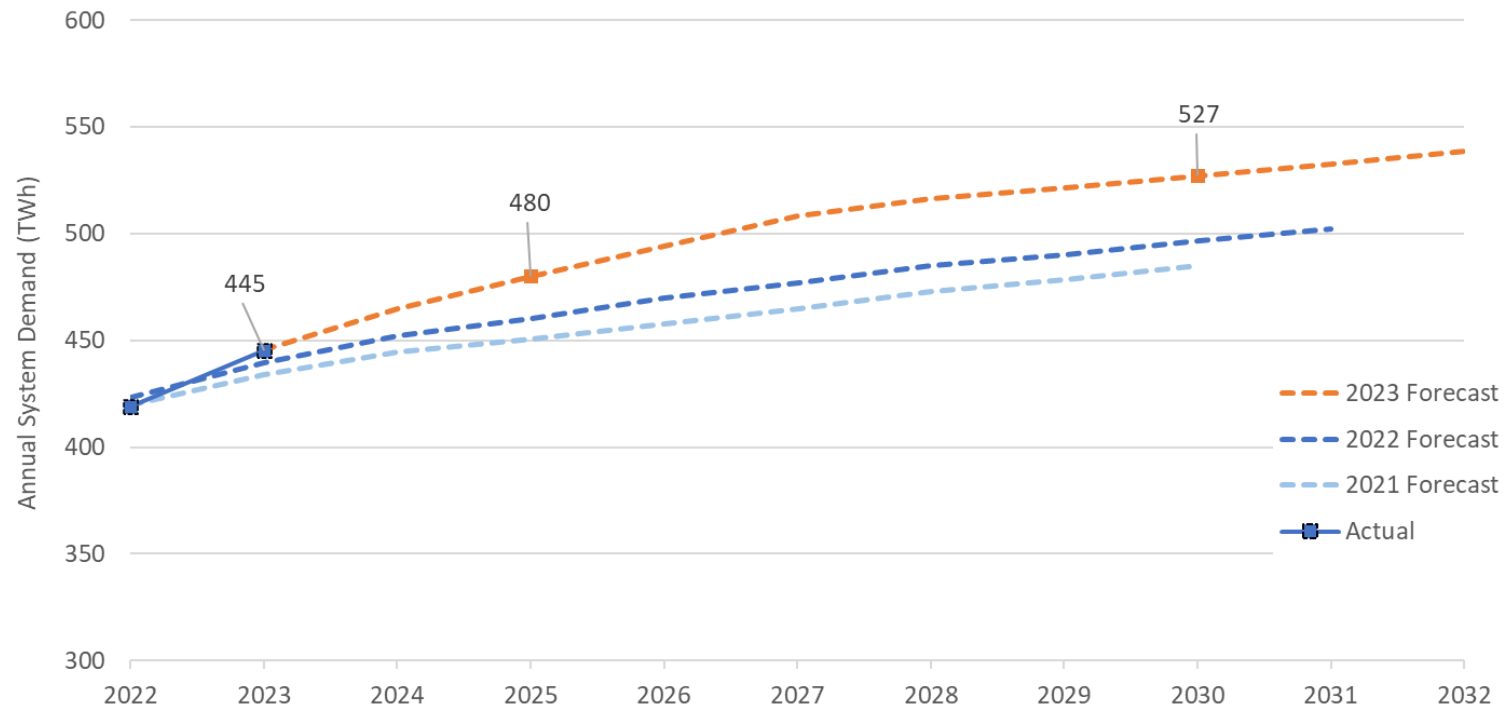


ERCOT Forecasts Continued Growth in Energy Demand

- + **ERCOT forecasts continued growth in total energy demand**
 - ERCOT projects energy demand to grow from 445 TWh today to 480 TWh by 2025 and 527 TWh by 2030.
- + **Total energy demand is growing and is more aligned with forecasts than peak demand.**
- + **Peak demand is a more critical challenge to the system than total energy use...**

...new generation is certainly needed to meet both energy and capacity demands in the future.

ERCOT Annual Electricity Demand: Current and Forecasted



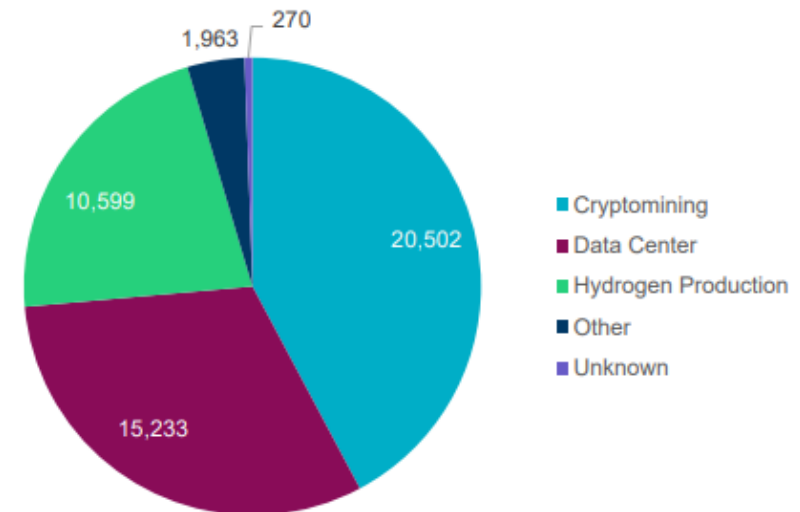
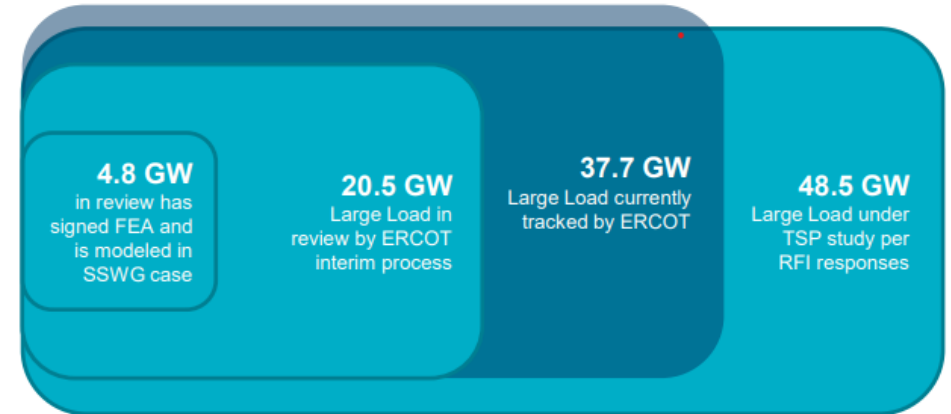
Source: Load projections through 2031 are directly from ERCOT's 2022 System Planning Report; [Long-Term Load Forecast \(ercot.com\)](https://www.ercot.com/long-term-load-forecast)



Large Load Interconnection Requests are Growing

- + Large loads are major drivers of new energy demand in Texas
- + 48.5 GW of new large load interconnection responses to ERCOT's Transmission Service Provider (TSP) survey.
 - 20.5 GW of load has submitted studies to ERCOT for review.
 - Majority of responses were from crypto-mining facilities, followed by data centers and H₂ production
- + E3 expects data centers to make up the majority of near-term load additions, followed by H₂ production and crypto-mining.

Large Load Status and Type February 2023



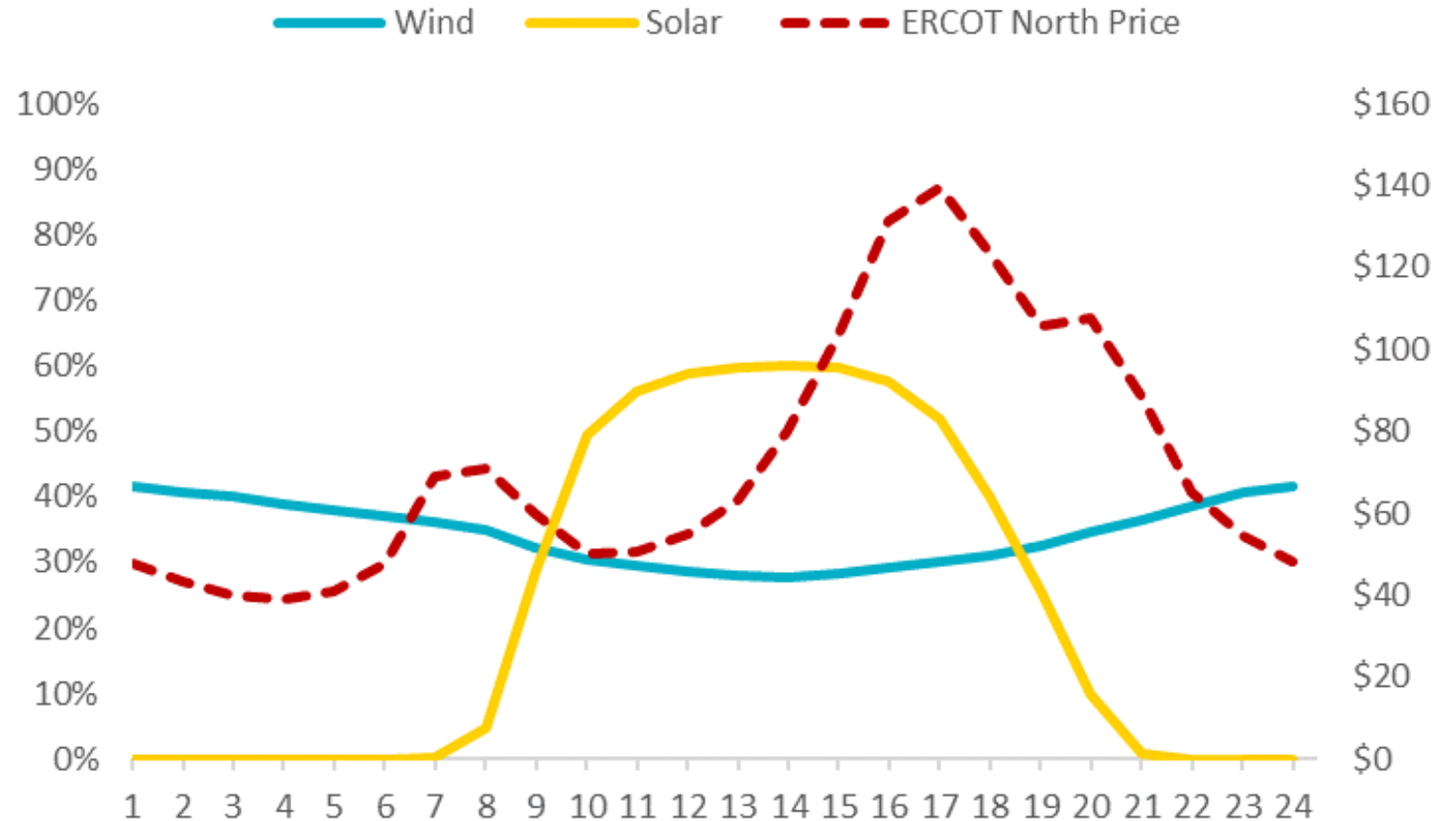
Source: <https://www.ercot.com/files/docs/2023/02/17/LLI%20Queue%20Status%20Update%20-%202023-02-17.pdf>



Renewable Additions are Driven by Energy Value

- + Wind and solar have complementary generation profiles to serve load across all hours of the day
 - Wind is highest in morning and evening
 - Solar is highest midday
- + As more wind and solar are added...these resources will lower energy prices during their hours of highest output
- + As long as annual average wind- and solar-weighted prices exceed the cost of these resources...more renewables will enter the system.

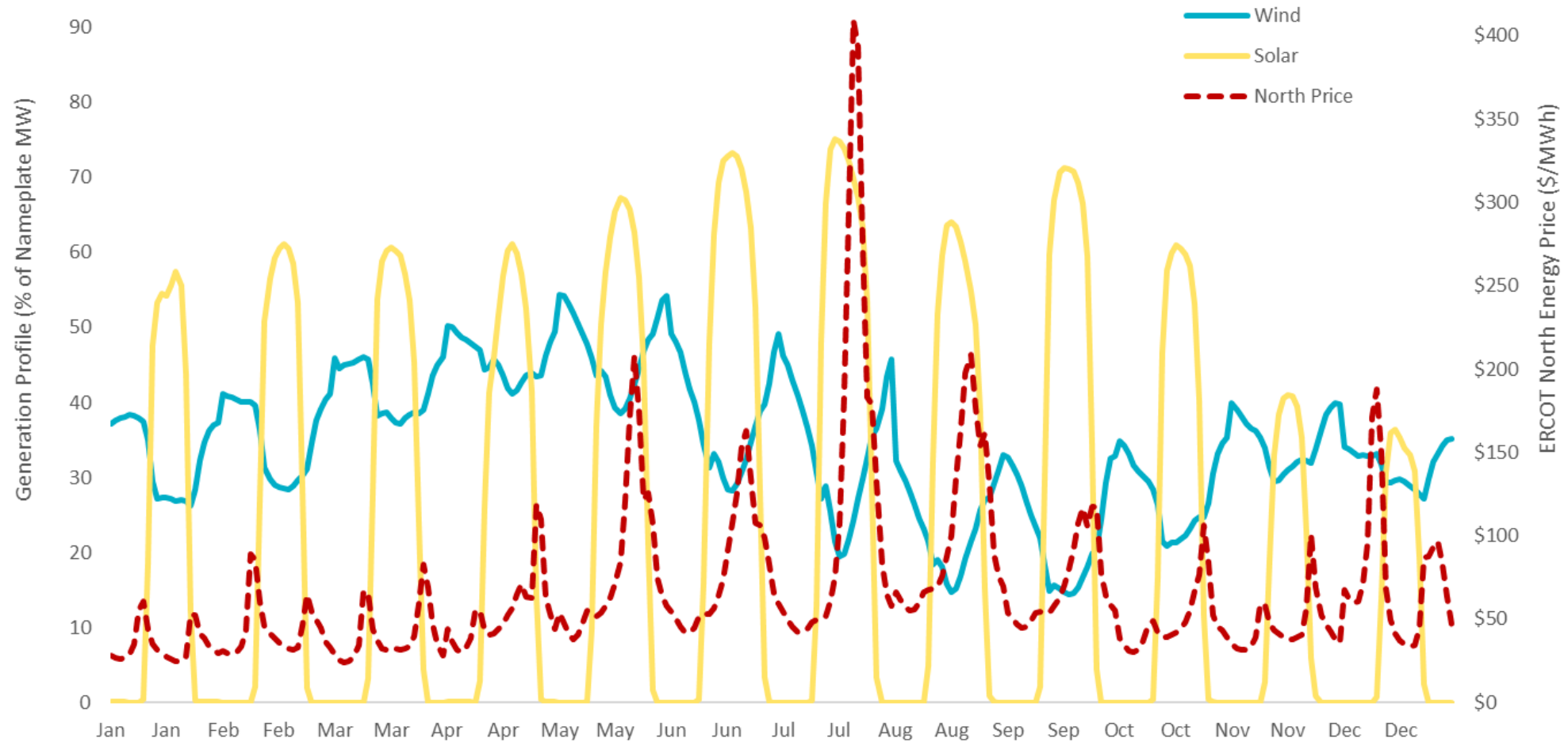
2022 Average Hourly Wind and Solar Generation Profiles vs. ERCOT North Prices





Renewable Generation + Energy Value Varies (A Lot!)

2022 Average Hourly Wind and Solar Generation Profiles vs. ERCOT North Prices by Month



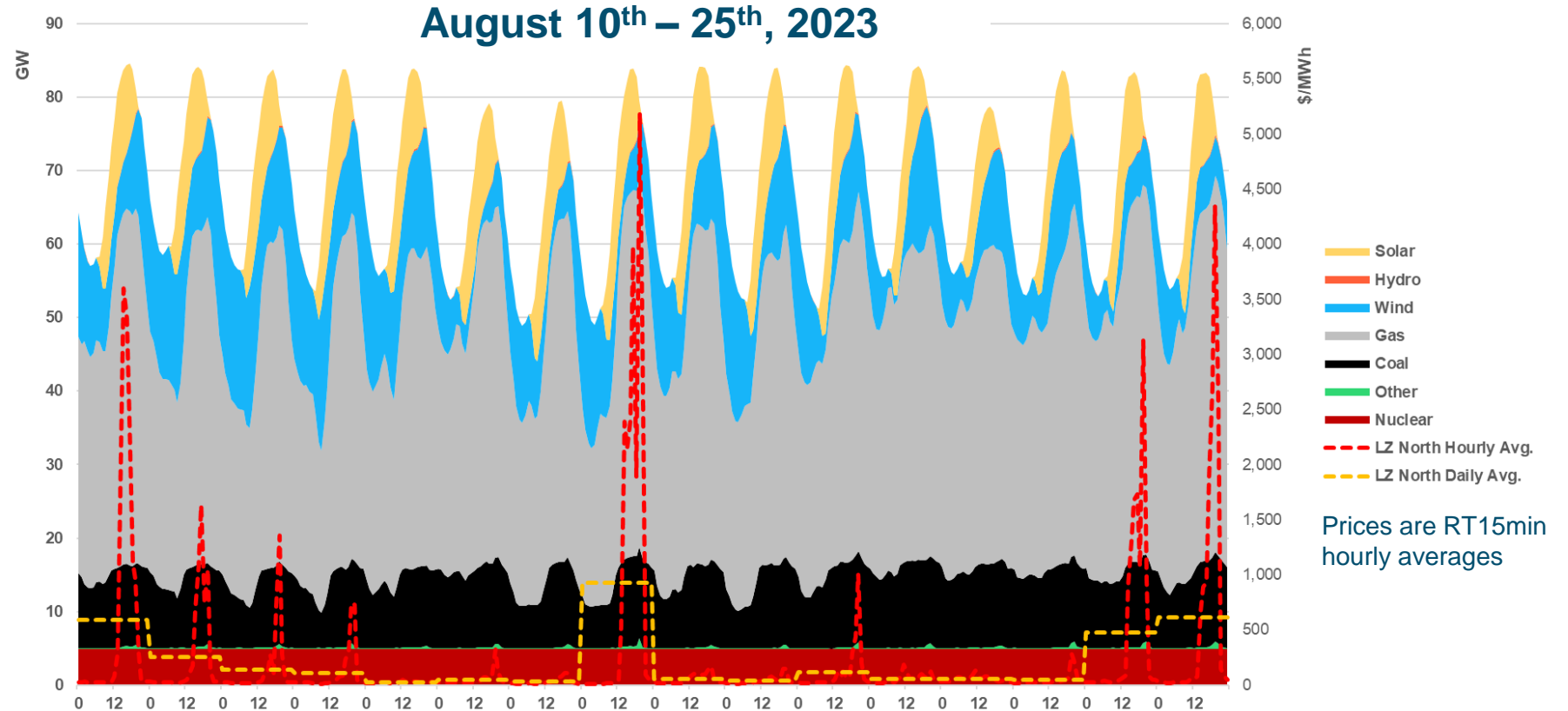


Renewable Energy Lowers Prices, Boosts Reliability

ERCOT has broken record after record while maintaining reliability and moderate prices

Top 10 Days

Rank	Time	MW
1	August 10, 2023 at 3:05 PM PDT	85,612
2	August 18, 2023 at 1:25 PM PDT	85,448
3	August 20, 2023 at 2:45 PM PDT	85,280
4	August 14, 2023 at 2:15 PM PDT	85,097
5	August 11, 2023 at 2:15 PM PDT	85,065
6	August 13, 2023 at 2:55 PM PDT	84,976
7	August 19, 2023 at 3:00 PM PDT	84,966
8	August 17, 2023 at 2:50 PM PDT	84,956
9	August 21, 2023 at 1:15 PM PDT	84,792
10	August 12, 2023 at 3:10 PM PDT	84,768



Without renewables, the grid would have needed 85+ GW of firm resources... renewables generated ~20 GW during the system's peak hours!



But Something is Needed for Dispatchable Power...



Increasing renewable penetration lowers market prices...



...which reduces margins for dispatchable resources...



...which leads to their exit from the market.

Multiple options exist

Higher Scarcity Pricing



Bilateral Capacity Market



Centralized Capacity Market



Backstop



PCM

WHAT THE HECK IS THAT!?



Pending Market Changes to Improve Reliability

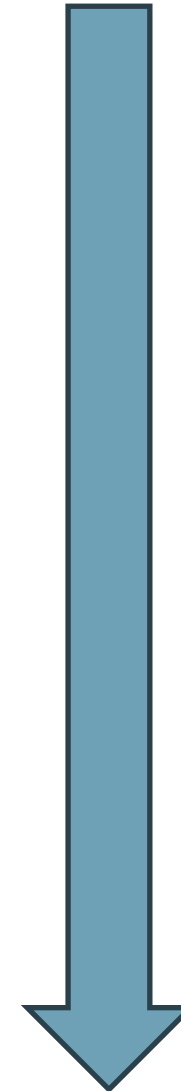
- + ERCOT rolls out the ERCOT Contingency Reserve Service (ECRS)**
- + Operating Reserve Demand Curve (ORDC) Changes**
 - New ORDC floor price of \$20 / MWh @ 3 – 6.5 GW reserves
 - New ORDC floor price of \$10 / MWh @ 6.5 – 7 GW reserves
- + Dispatchable Reliability Reserve Service (DRRS)**
 - Resources must be available within 2 hours and capable of operating for continuous 4-hour period
- + Performance Credit Mechanism (PCM)**
 - Payment mechanism for dispatchable generation which is online and available during critical reliability hours
 - Achieves objectives of SB3 and guidelines of HB1500

2023 – Now Live!

Q4 2023 – Q1 2024

Dec. 1st 2024

~2026



What Can the Grid Do for Hydrogen?





So What Can the Grid Do for Hydrogen?

+ Low-cost, low-carbon electricity...

- for **green** hydrogen production from electrolysis
- for **blue** or **gray** hydrogen production facilities

+ Reliable and high-quality electricity supply

- Reliable = always power when you need it
- High-quality = voltage and frequency are maintained within tolerances

+ Timely and cost-effective interconnections for new large loads

+ Geographic diversity for high-quality power supply (and large load interconnection)

- Example: good power sources across Texas could enable hydrogen production across the state, allowing for a more optimal H₂ supply network to support end-uses such as long-haul trucking

+ Price signals and market incentives for hydrogen uses on the grid, such as...

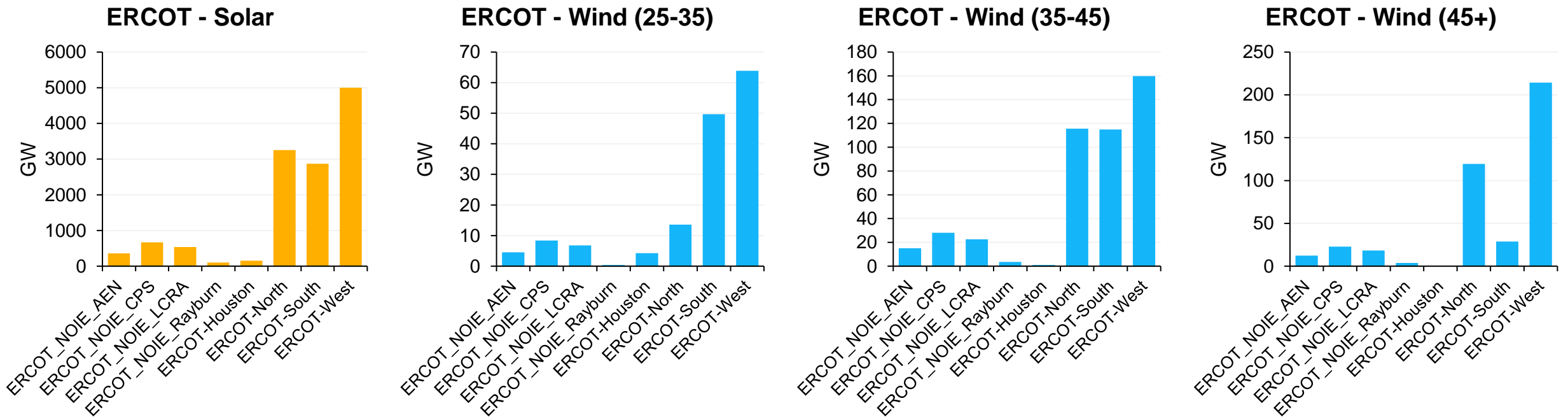
- Flexible loading of hydrogen production (and demand response), allowing hydrogen producers to decrease load during peak system hours and be compensated for their actions
- Hydrogen-fueled power generation to support grid reliability, augmenting gas supplies and gas-fired generation during peak system hours



Renewable Energy is Abundant in Texas

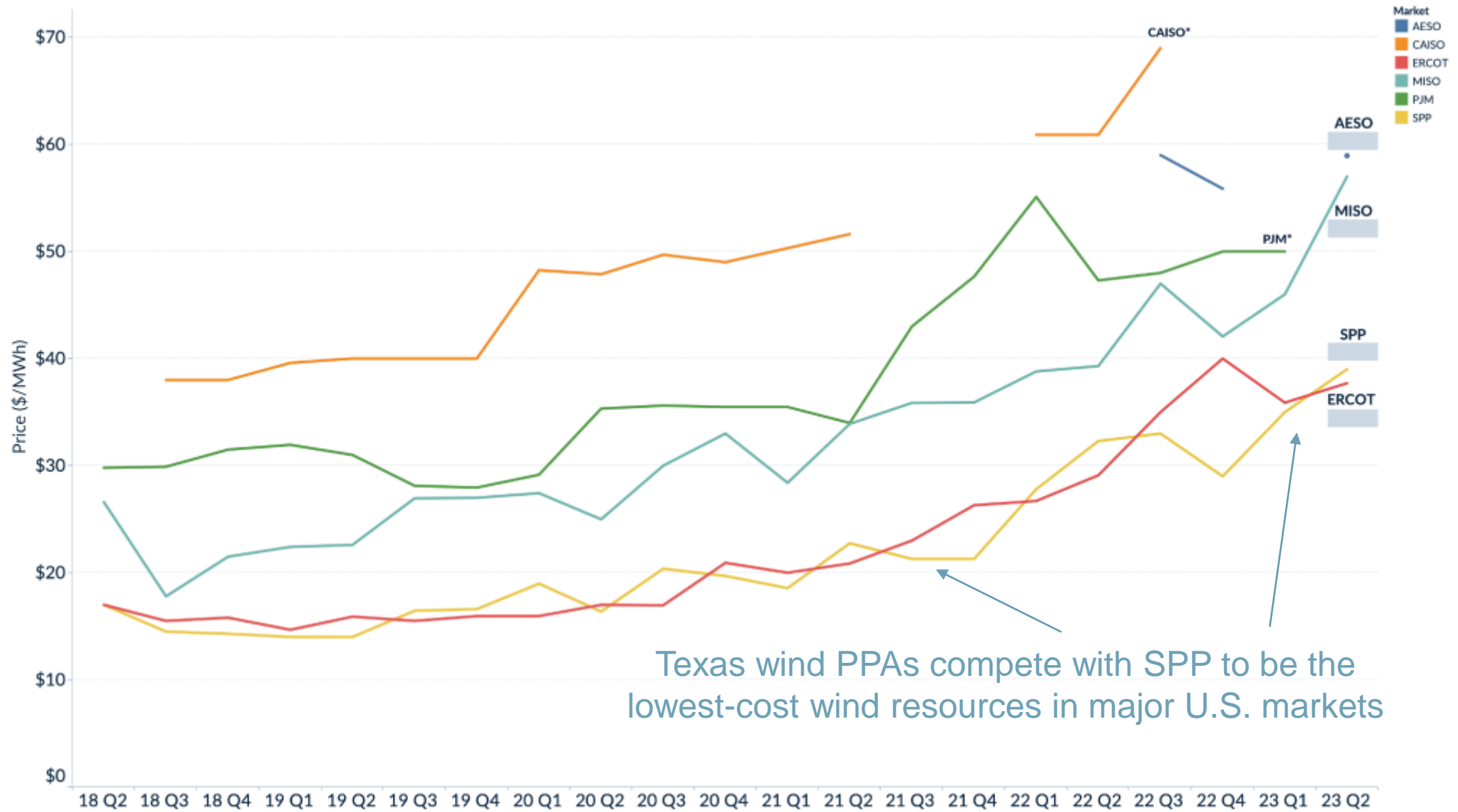
- + The National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy estimates renewable energy potential by region across the United States
- + E3 mapped wind and solar technical potential to various zones in Texas using NREL's Regional Energy Deployment System (ReEDS) dataset
- + Wind is categorized according to resource quality by capacity factor (e.g. 25-35%, 35-45%)

ERCOT Renewable Resource Potential



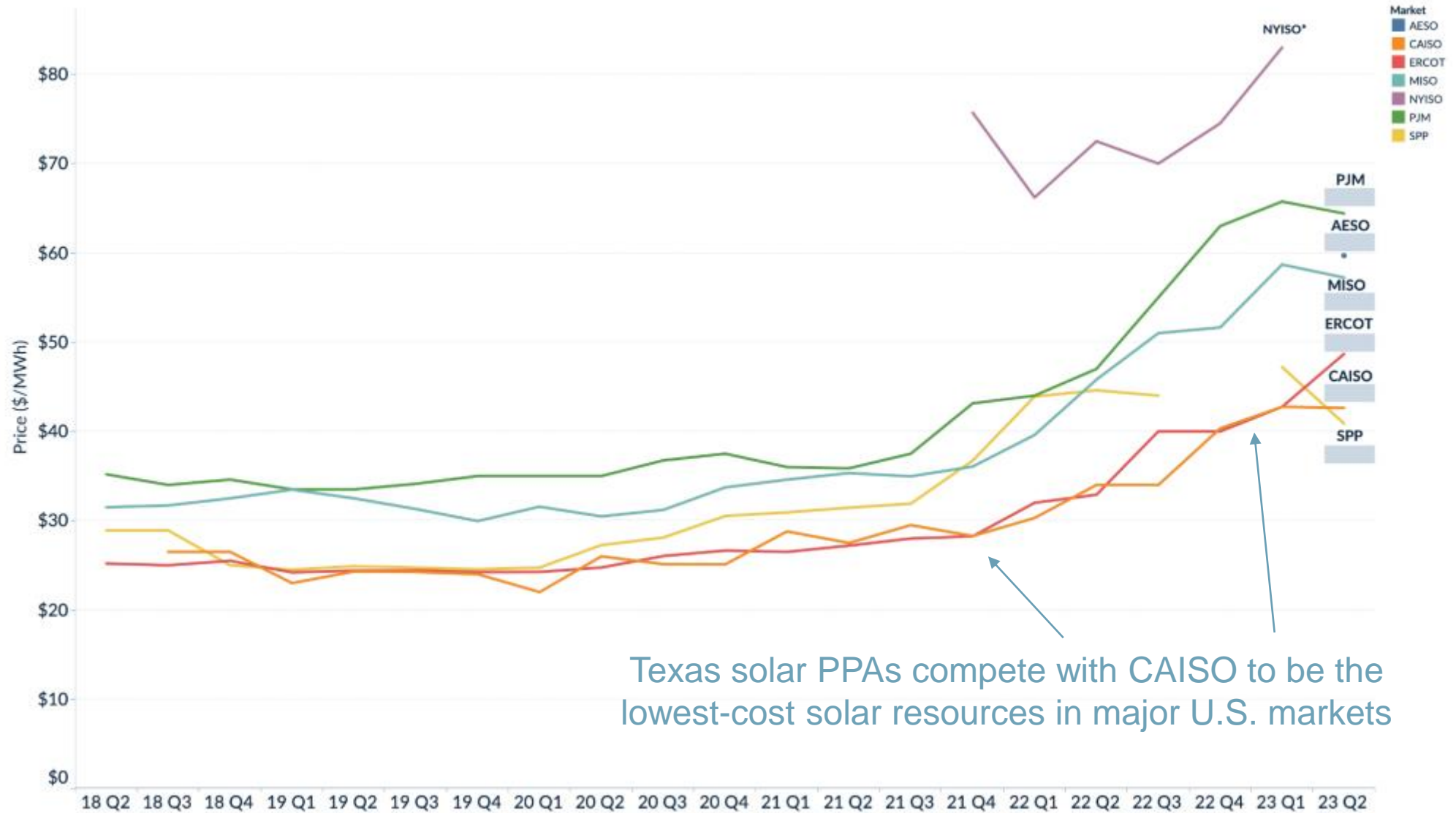


Texas Leads Major ISOs in Low-Cost Wind Resources





Texas Leads Major ISOs in Low-Cost Solar Resources

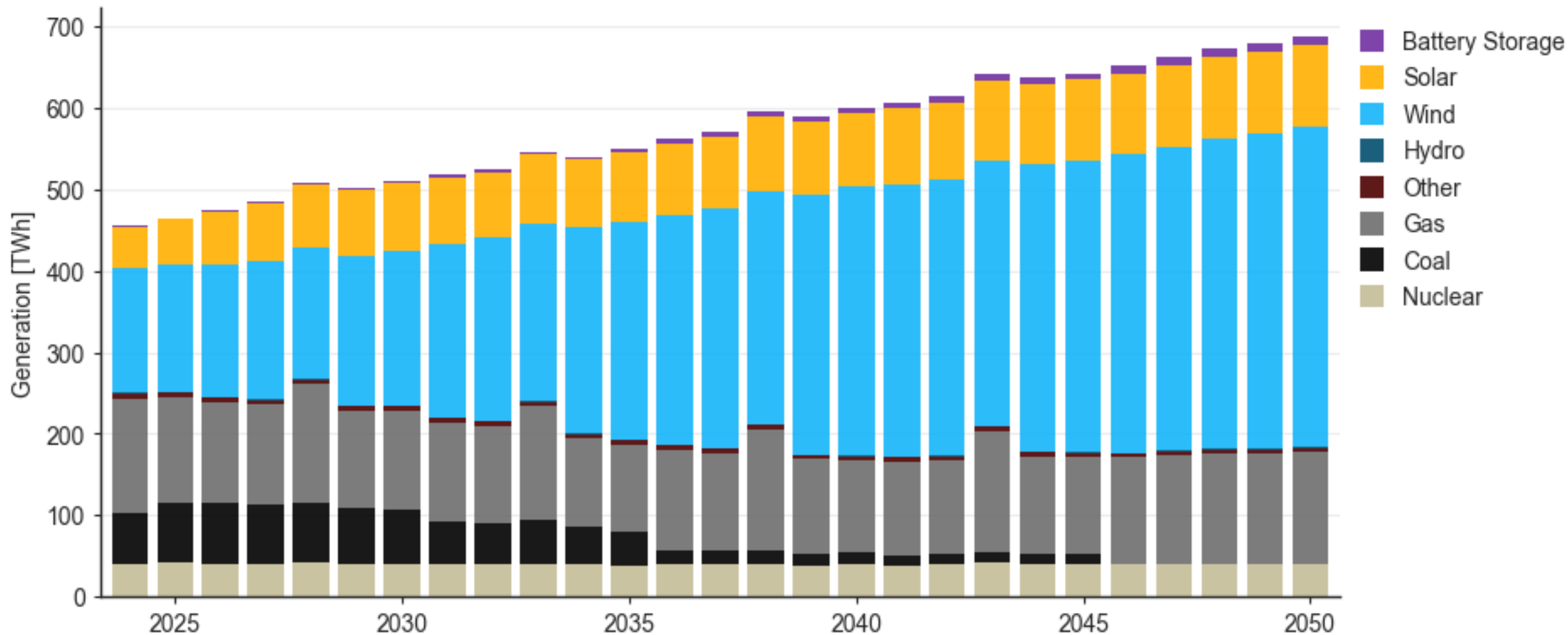


Texas solar PPAs compete with CAISO to be the lowest-cost solar resources in major U.S. markets



E3 Forecasts ERCOT's Continual Transformation...

+ E3's 2023 ERCOT Core Case market forecast shows that ERCOT is poised to reach ~50% renewable generation by the late 2020s and 70% by 2040 → driven entirely by economics.





Large Load Assumptions in E3's Market Forecasts

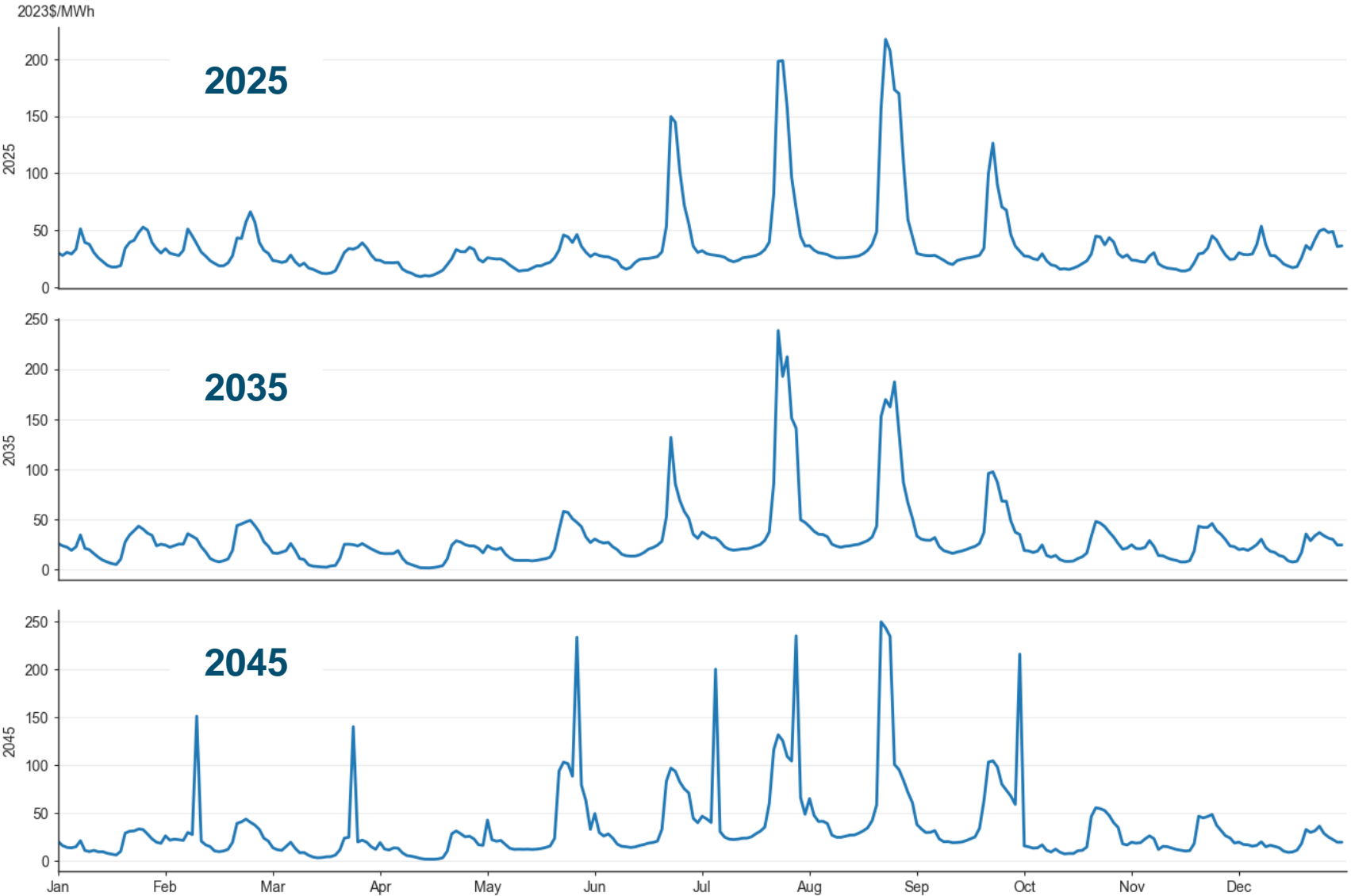
- + E3 assumes 4.8 GW of new large users load from the LLI queue is added on top of growing system loads from other customer classes/segments
- + E3 High Case models impacts of more aggressive load growth from data centers and H2 production...

Cumulative Large Load (GW)

Year	ERCOT				E3 Core Case	E3 High Case
	Reported	Tracked by ERCOT	Under Review	Modeled in Load Forecast		
2027	48.5	37.7	20.5	4.8	4.8	7.5
2031						8.2
2034						10.3
2040						10.5
2050						12.3



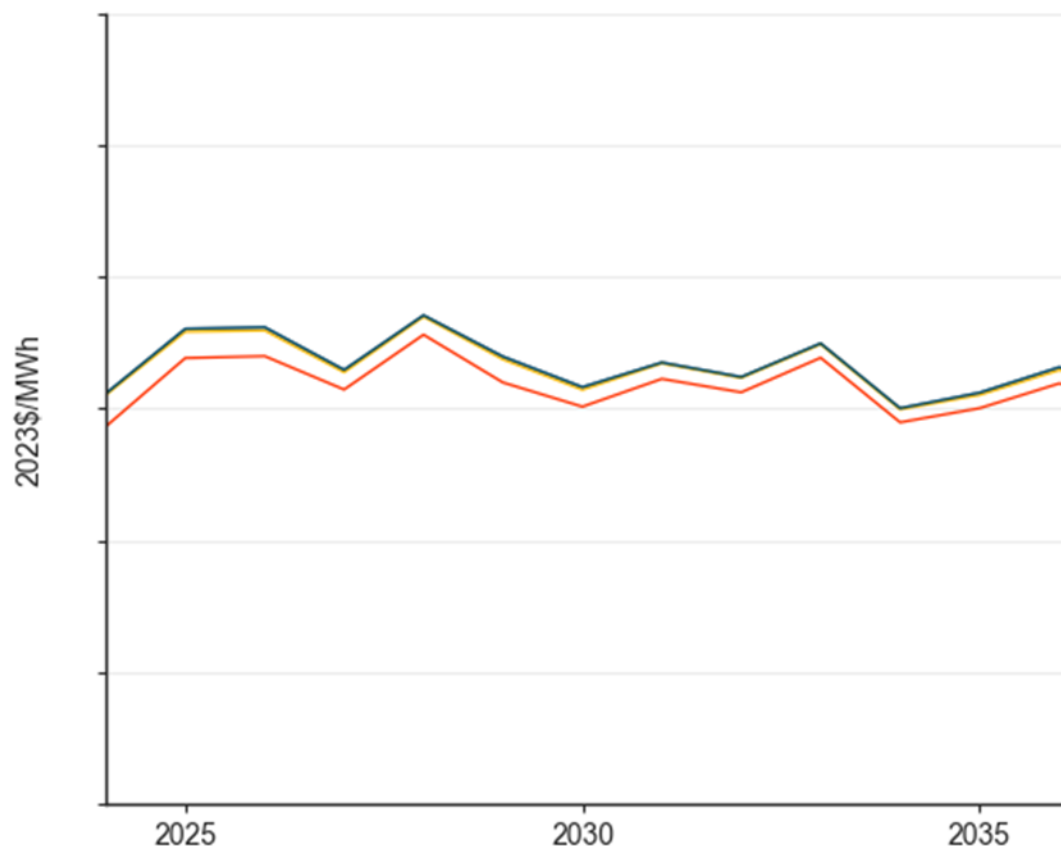
E3 Forecast of Day-Ahead Daily (Hr 1-24) Average Energy Price by Month for ERCOT North



- + Increased wind and solar penetration leads to low daytime prices across all months and years...
- + ...but peak summer pricing continues to remain high...and peak pricing expands over time to fall and winter months during hours of low renewable output and limited thermal capacity.
- + Energy prices become more volatile over time even as average system prices remain stable or declining.



E3 Forecast of Annual Average ERCOT Energy Price



- + Average annual electricity prices remain relatively stable, even as daily and seasonal variability increase...
- + Wind and solar continue to be added to meet increasing load...bringing down energy prices during renewable-heavy hours
- + Battery storage continues to support peak hour generation and operating reserves
- + Scarcity pricing during peak hours pulls average prices up, but is balanced by renewable-driven lower energy prices during non-peak hours

What Can Hydrogen Do for the Grid?





What Can Hydrogen Do for the Grid?

- + **The most important value that hydrogen can provide to ERCOT is load growth with load flexibility**
 - **Load growth** = more demand for power (especially during low-priced, low-demand hours in low-demand locations)
→ supports more investment in new generation (including new renewables)
 - **Load flexibility** = reducing H2 production load during times of system stress (peak hours)
→ H2 producers save \$\$\$ and support grid reliability
- + **Demand growth in generation-heavy areas (e.g. West Texas) relieves congestion and defers need for transmission investments**
- + **H2 can augment gas supply as backup/alternative fuel for power generation during extreme weather events and stressed grid conditions**
- + **Support continued growth of Texas economy**
 - H2 production (and exports) will boost Texas state revenue + GDP, creating jobs
 - H2 production (and renewable supply) could bring local tax revenues to low-income communities across Texas
 - H2 supply in Texas supports continued growth of industry + businesses (including tech) by providing green fuel supply to meet corporate environmental goals
 - H2 long-haul transport can reduce local air emissions and improve public health



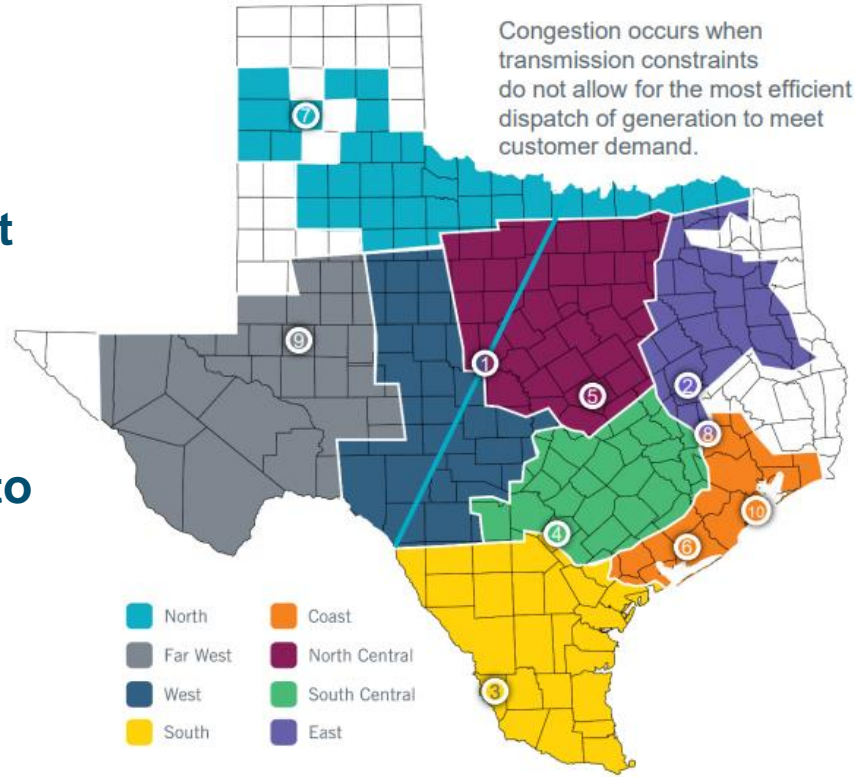
ERCOT Transmission Constraints

- + Constraints in ERCOT are spread out across most zones...
- + However, the West Texas Export is by far the largest system transmission constraint.
- + Internal western zone constraints are expected to worsen as more wind is developed in the region.

Recent Constraints

Top 10 constraints on the ERCOT system

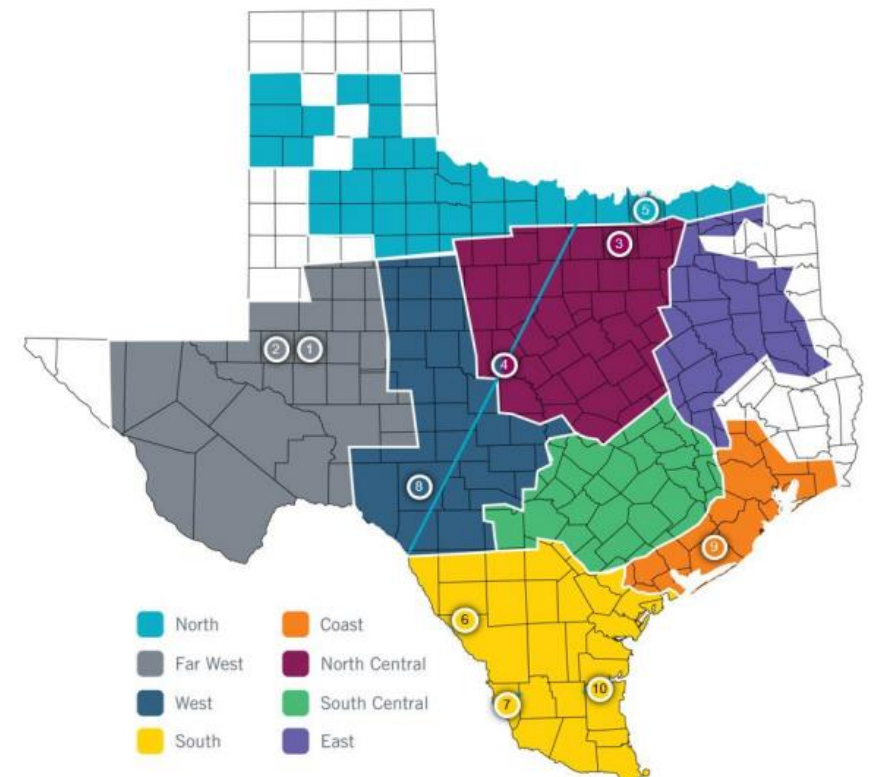
Oct. 2021 to Sept. 2022, based on real-time data



Projected Constraints

Top 10 projected constraints on the ERCOT system for 2024 and 2027

Based on economic analysis conducted for the 2022 RTP



Source: https://www.ercot.com/files/docs/2022/12/22/2022_Report_on_Existing_and_Potential_Electric_System_Constraints_and_Needs.pdf



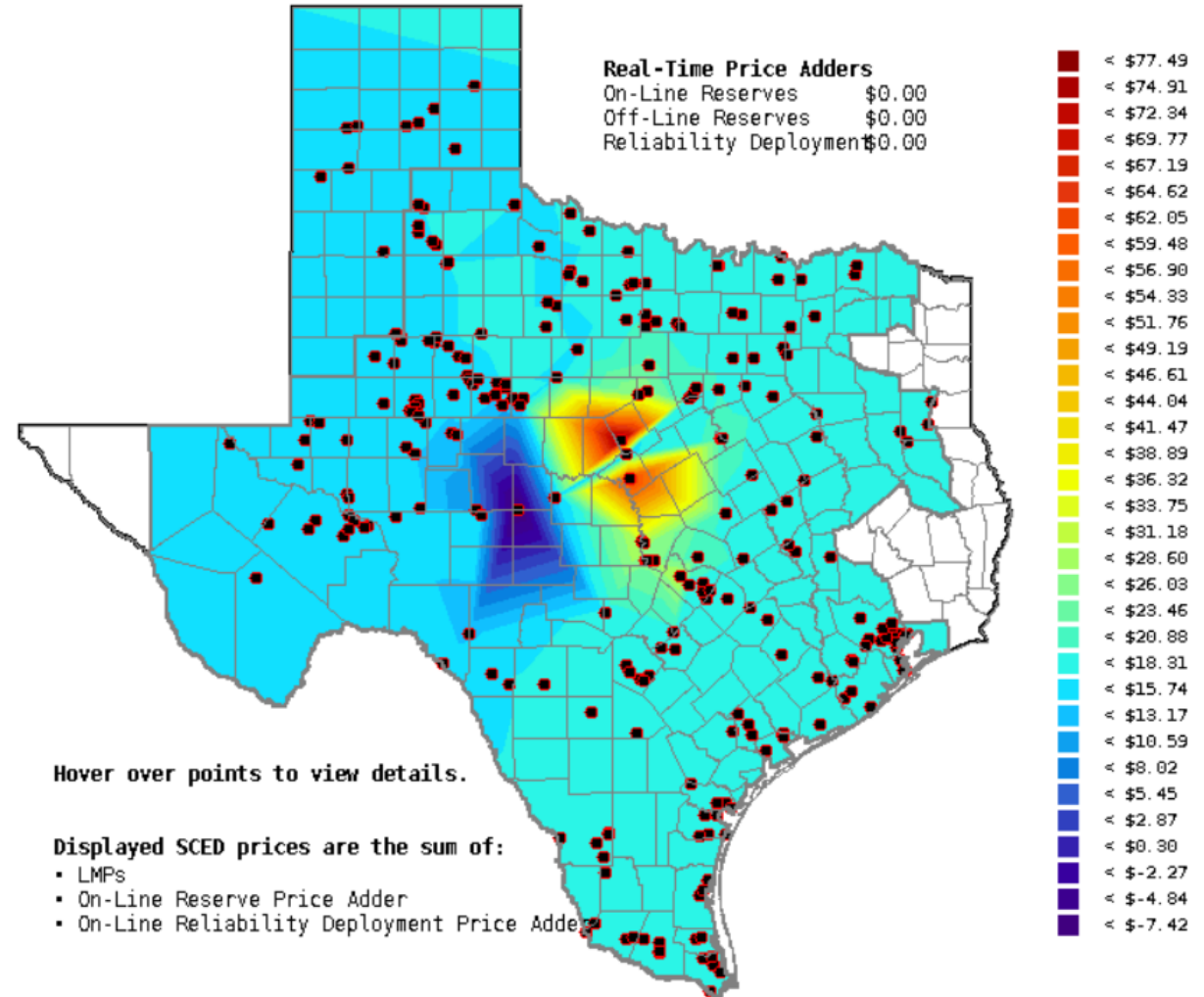
Energy Prices Differ Widely by Location in Texas

Real-Time Locational Prices: Real-Time Market - SCED Pricing

[Help?](#)

Last Updated: Nov 02, 2023 10:30

- + Transmission constraints drive differences in locational marginal prices (LMPs) for electricity
- + Energy prices tend to be lower in wind-heavy areas: West Texas and South Texas
- + Energy prices tend to be higher in load-heavy areas: Houston and the North Load Zone

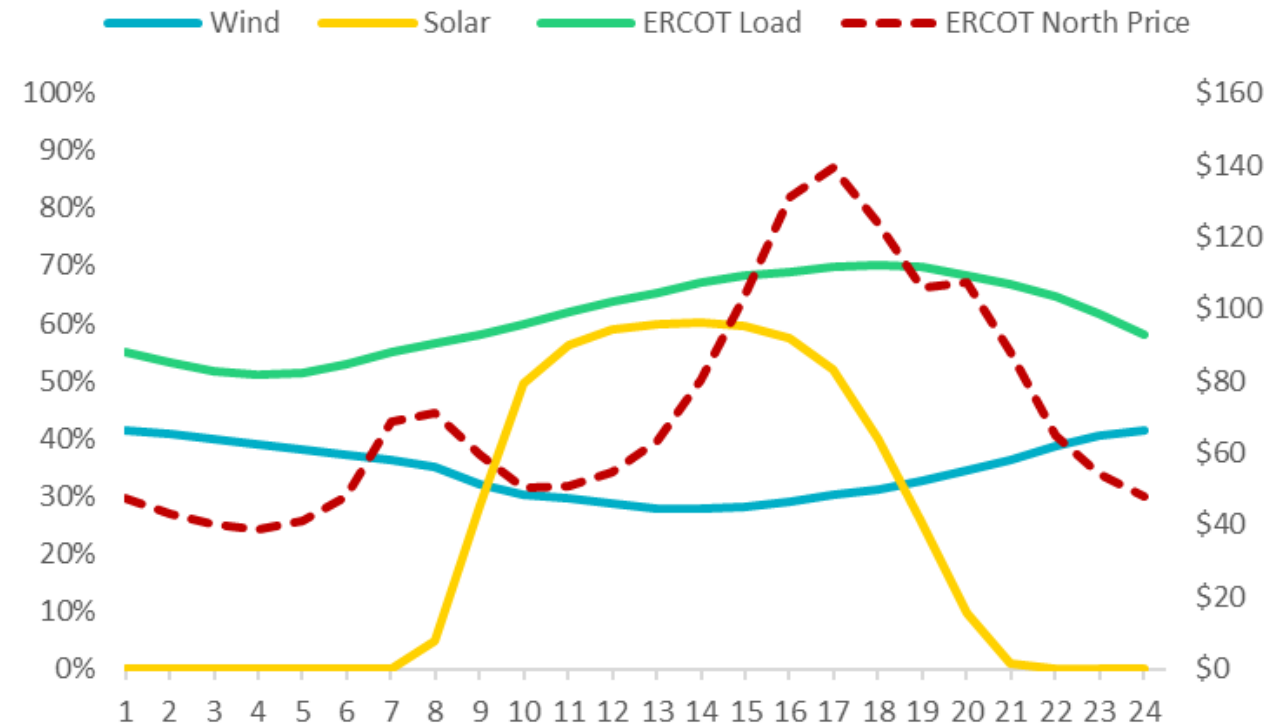
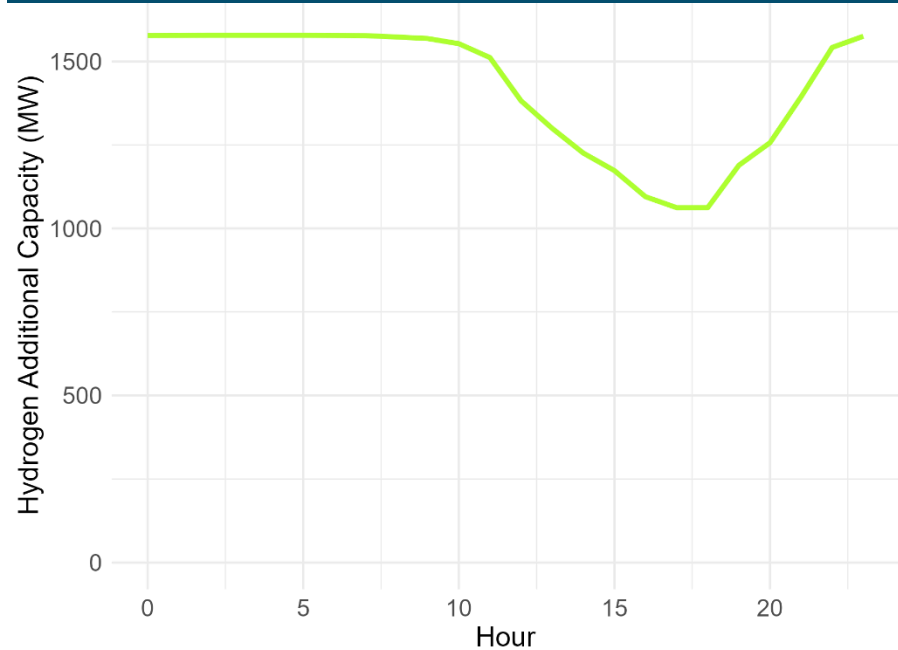




Flexible Loads Support Renewables + Reliability

- + Flexible H2 production loads can increase demand in periods of renewable oversupply and reduce demand when grid needs are high and generation resources are scarce
- + In effect, H2 loads can help to increase ERCOT's load factor (hourly load as a share of peak load) Increasing load factor + geographic load diversity >> improves energy price stability, renewable economics, local congestion, and reliability

Illustrative Flexible H2 Production Load





Energy+Environmental Economics

Thank You!

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