Title

Exploring Wholesale Energy Price Trends: The Renewables and Wholesale Electricity Prices (ReWEP) tool, Version 2024.1

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The Renewables and Wholesale Electricity Prices (ReWEP) tool, Version 2024.1

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The Renewables and Wholesale Electricity Prices (ReWEP) visualization tool from Berkeley Lab has been updated with nodal electricity pricing and wind and solar generation data through the end of 2023. ReWEP users can explore trends in wholesale electricity prices and their relationship to wind and solar generation. ReWEP includes nodal pricing trends across locations, regions, and different timeframes. The tool consists of maps, time series, and other interactive figures that provide: (1) a general overview of how average pricing, negative price frequency, and extreme high prices vary over time, and (2) a summary of how pricing patterns are related to wind and solar generation. Interactive functionality allows investigation by year, season, time of day, and region, where region is defined as the Independent System Operators (ISO) or Regional Transmission Organizations (RTO) region. ReWEP also contains prices throughout much of the western United States from the Western Energy Imbalance Market and the Western Energy Imbalance Service Market.

New feature – data download

A number of users have requested the option to download the underlying data behind ReWEP. Though a commercial data agreement limits our ability to share all our input data, we have added the option to download much of the aggregated data presented in the figures. To download the data, scroll to the bottom of the ReWEP tool and simply click the download link.

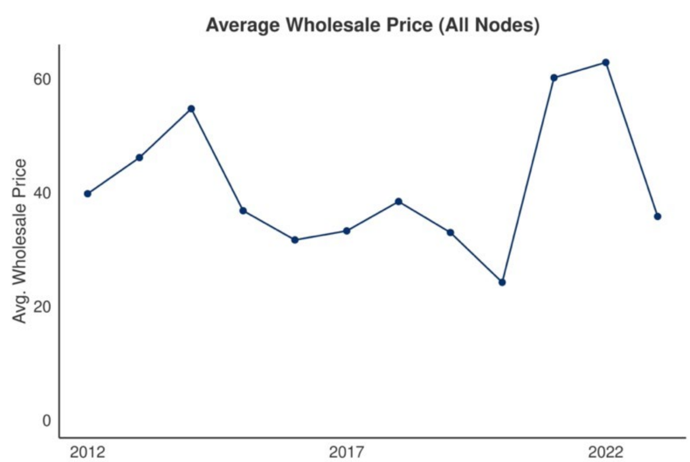

Figure 1. Average wholesale electricity price (2023$/MWh) declined in 2023 compared to 2021 and 2022. Average prices are calculated based on all nodes and hours within each of the 7 major ISOs/RTOs, and represent hourly average prices in the real time markets.

Notable trends in 2023

Introduction

Wholesale electricity prices are driven by numerous forces, including a growing amount of wind and solar power. Market forces can include generation costs affected by fuel prices (especially natural gas), or high levels of demand driven by hot weather (such as air conditioning), or tight markets where demand is nearly equal to all available supply. Wind and solar can drive down prices since (1) they can have coincident production in a given area, such as a large wind event across a region; (2) their output can be constrained by inadequate transmission connecting them to load centers, creating localized low or negative prices; and (3) their output can periodically be high relative to load, such as solar power output on cool spring afternoons. By tracking average prices, episodes of very high prices, and the frequency of negative prices, along with wind, solar, and overall electricity demand, ReWEP can be used able to illustrate these dynamics.

2023 wholesale electricity prices declined versus 2021 and 2022

Figure 1, available from ReWEP, shows the average price in 2023 was $36/MWh, down from $63/MWh in 2022. One driver of declining prices was the declining cost of natural gas. The Energy Information Administration (EIA) reported natural gas prices declined from $6.45 in 2022 to $2.54 in 2023 (based on the annual average per Million Btu spot price at the Henry Hub). Natural gas prices, of course, respond to global, domestic, and regional factors, and high prices in 2021 and 2022 were in part due to a combination of the invasion of Ukraine, sanctions on Russia, and impacts from the Covid pandemic. High natural gas prices helped drive up wholesale electricity prices in 2021 and 2022, but the prices receded in 2023.

Prices varied across regions

Figure 2 shows that average annual prices in ERCOT (Texas), CAISO (California), and the broader western region were high relative to other regions of the country. Prices in SPP (the region in the center of the country) were particularly low, with the lowest prices in SPP located near the highest levels of wind generation.

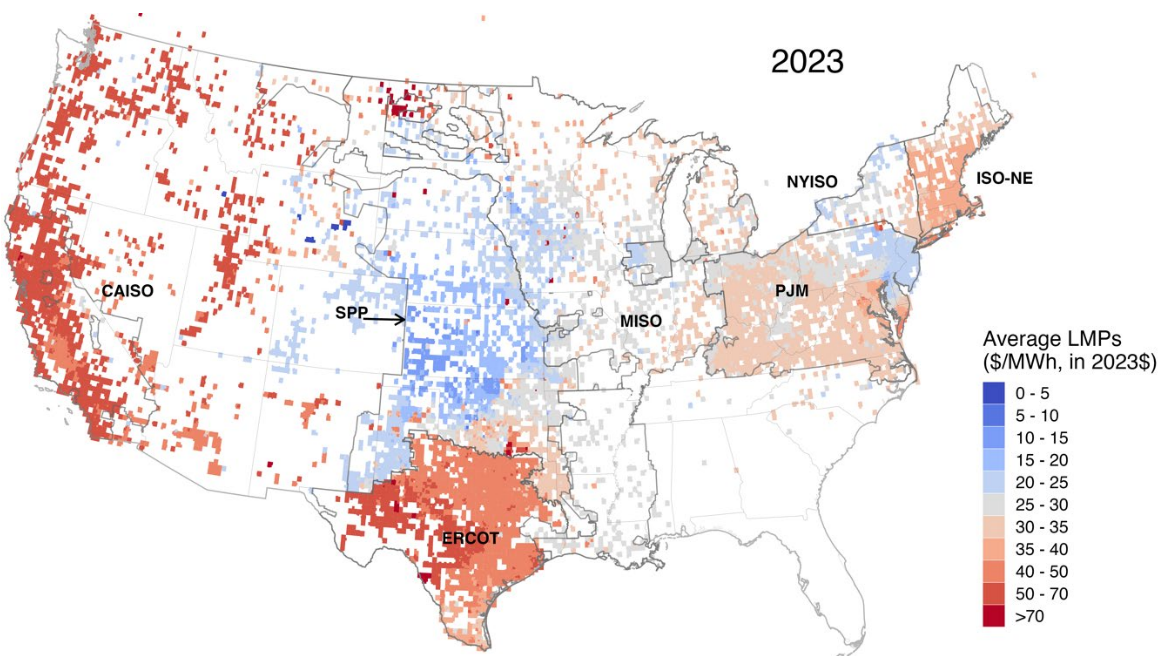

Figure 2. In 2023, average wholesale electricity prices (2023$/MWh) varied strongly by region. Shown are annual average real time electricity market prices based on data from all locational marginal price (LMP) nodes in 2023.

High wholesale electricity prices in ERCOT and CAISO were driven by different phenomena. In CAISO, high annual prices in 2023 were driven mostly by the high hourly prices in January 2023 (see Figure 3). The unique high price pattern found in January 2023 was due to high regional gas prices (gas prices rose starting in late 2022). Southern California Gas Company reported, for example, that monthly procurement prices for natural gas in January 2023 were 7 times larger than procurement prices in January 2024. High natural gas prices in California and the west were a regional issue, but not a national issue, as prices at Henry Hub (a common price hub used to describe U.S. gas price trends) were not meaningfully different between January 2023 and January 2024.

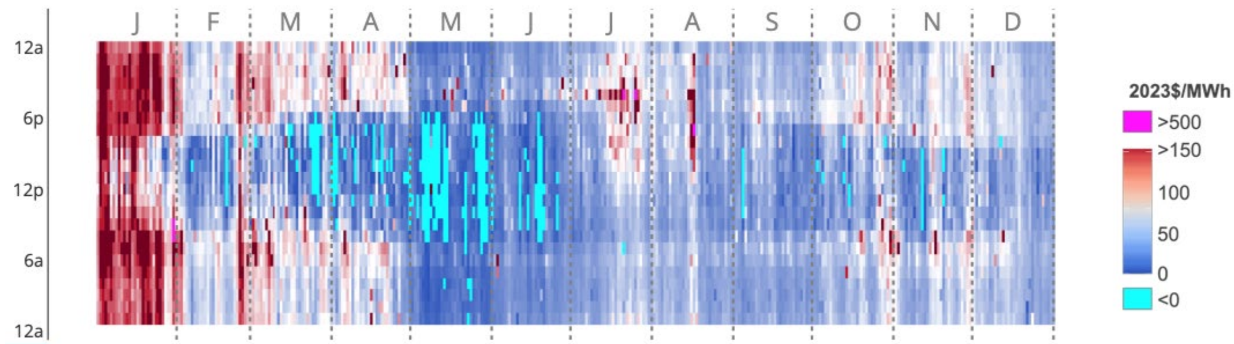

Figure 3. Prices in CAISO (California) peaked in January 2023 with regionally high natural gas prices, and prices declined to minimum levels during spring daytime hours flush with solar and hydropower generation resources. Wholesale prices can vary widely by hour and season, from over $500 per MWh (shown in hot pink) to negative prices (light blue). This screen-shot from the ReWEP tool shows the regional average hourly price by day and hour (365X24).

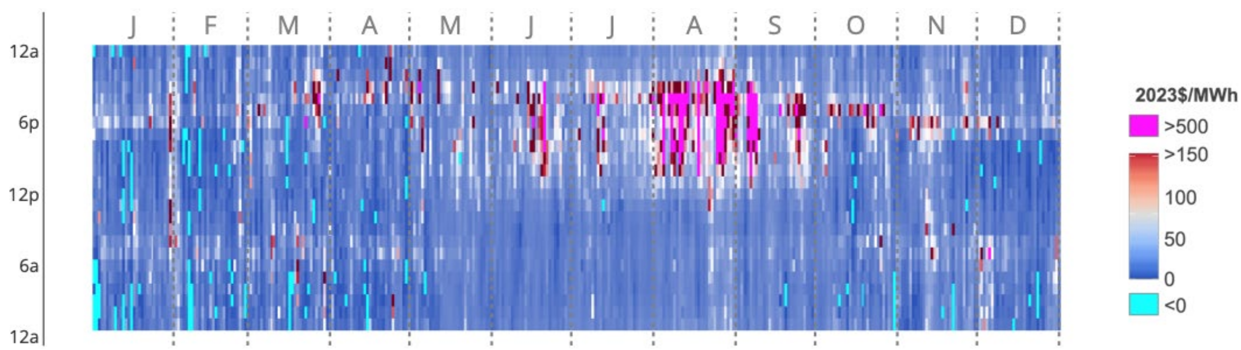

Figure 4. Prices in ERCOT (Texas) peaked in the summer early evening periods coinciding with record high electricity demand (e.g., air conditioning demand). The Texas market has very high price caps, allowing high prices due to scarcity to incentivize new supply and lower demand. Episodes of negative prices (light blue) are scattered in winter months as high amounts of wind power coincide with lower electricity demand. This screen-shot from the ReWEP tool shows the regional average hourly price by day and hour (365X24).

The dampening of daytime prices due to solar generation is particularly evident in CAISO, with relatively low prices seen during sunny hours, even including many daytime hours in January through April when prices during other hours were particularly high. Negative prices (the lightest blue color) were found almost exclusively during sunny hours in late spring and early summer.

In contrast to CAISO, high annual prices in ERCOT in 2023 were driven by high afternoon and early evening prices in June through September (Figure 4). These high prices were driven by record high electricity demand (at least partially associated with record summer heat in Texas in 2023).

The [ReWEP] tool can be used to investigate how renewable generation and electricity demand interacted to affect prices by comparing prices to net load trends. “Net load” describes the amount of electricity demand that is not met by wind and solar generation, which is a proxy for the amount of load met by resources like gas, coal, and nuclear. High renewable generation therefore reduces net load. An example of how net load interacts with prices can be seen in ERCOT. While ERCOT saw record renewable energy output during 2023 summer (Figure 5, top left panel), demand also set records pushing net load to new heights in evening and nighttime hours (Figure 5, top right panel). Prices spiked during hours with the highest net load (Figure 5, bottom panel).

It will be interesting to track summer trends in ERCOT's renewable output, netload, and prices over the next years because of the expected growth in solar and battery storage (for example, see https://www.ercot.com/gridinfo/resource). Storage capacity (in MW) has roughly doubled each year since 2020 and is expected to continue doubling through 2025. Solar capacity in ERCOT (already >23GW) is also expected to continue its phenomenal growth rate. A key question to track is whether the growth in these combined resources can outpace growth in demand and dull the price spikes observed during summer midday (as seen in past years) or summer early evenings (as seen in 2023). A related question is about how battery storage is used in ERCOT, will batteries begin to play a major role in shifting load across hours within each day, or will batteries continue to be used primarily to provide 'ancillary' services (that is, to provide services that help maintain reliability and stability on the grid but do not shift the overall load shape).

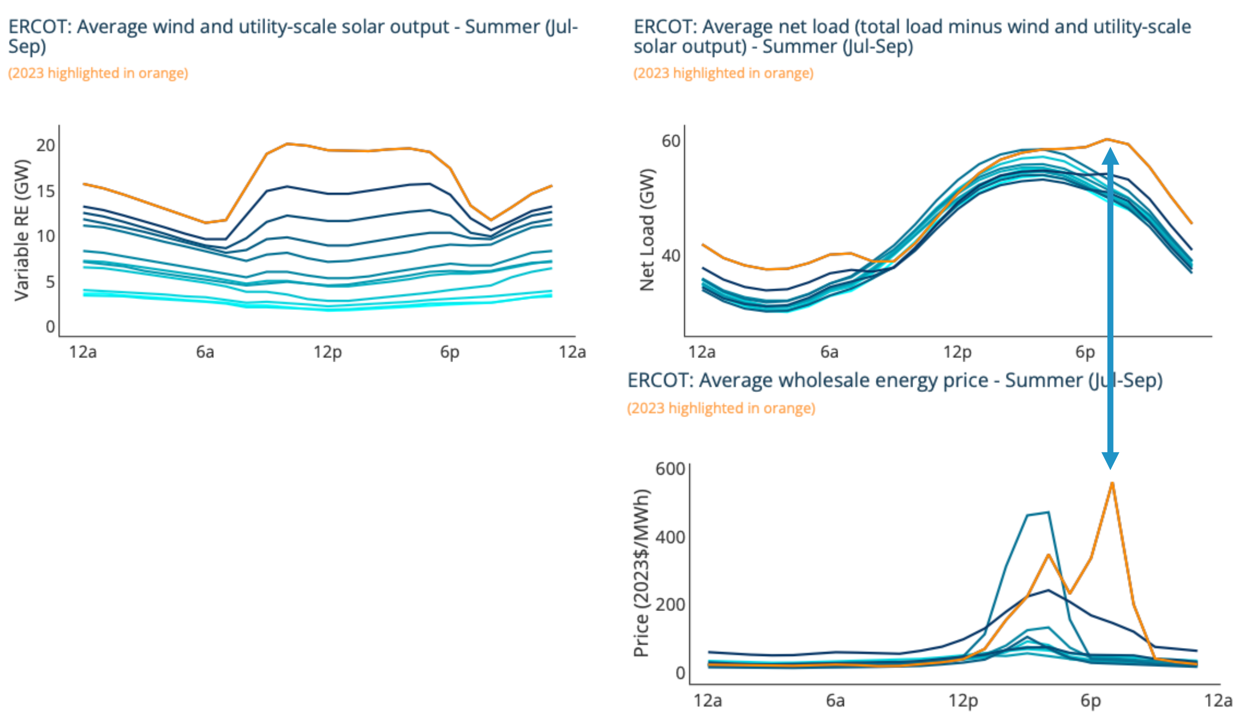

Figure 5. Despite record renewable energy production in ERCOT (Texas) in the summer of 2023 (top left panel), net load increased during the evening with peak net loads occurring in the early evening (top right panel). The peak net load periods coincided with price spikes, which have shifted later in the day compared to prior years (bottom panel).

Renewable generation fell in spring but rebounded in summer

Summing the wind and solar generation across all ISOs we find that winter 2023 totals were similar to those from winter 2022. Generation totals fell in spring (though spring 2023 still had the second highest levels of renewable generation on record), but rebounded to new records in summer and fall. The seasonal average generation totals (by hour of day) are shown in Figure 6 for the spring and summer seasons. ReWEP offers the option to explore winter and fall seasons as well. Wind output drove these patterns – weather conditions across much of the country were less conducive than average for producing high wind speeds and associated wind energy generation in the spring of 2023. These conditions eased by summer, and continued growth in both wind and solar capacity (i.e., more new power plants) led to an increase in overall renewable generation.

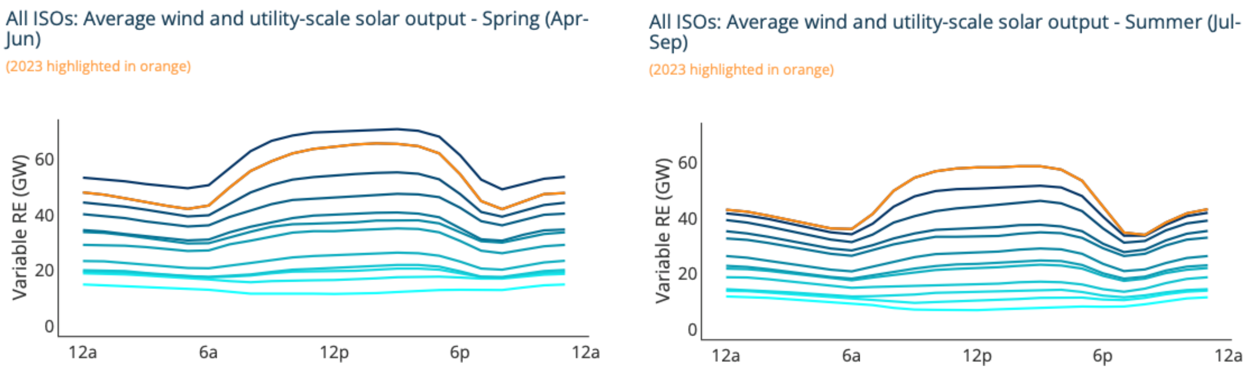

Figure 6. Due to poor weather conditions, combined wind and solar production declined year-over-year in spring 2023 (left panel), but rebounded by summertime to new record heights (right panel). The summer increase in output occurred due to improved weather conditions and continued growth of wind and solar capacity. This figure shows results summed across all seven major ISOs/RTOs.

Net load declined during daytime hours, but not evening hours

As we discussed above, record renewable generation in ERCOT in 2023 was not sufficient to offset new demand during summer evenings, leading to overall growth in net load during those hours. When we look at net load from a multi-regional perspective, taking the sum across all the 7 major ISOs and the full year, we see net load declined in 2023 to record lows during the daytime hours (due to new solar deployments outstripping new demand), but held steady at recent levels during nighttime hours (Figure 7). That nighttime netload held roughly steady represents a balance of expanding demand versus expanding wind generation. Additionally, and as mentioned above, wind output was dampened in 2023 due to weather conditions during the spring.

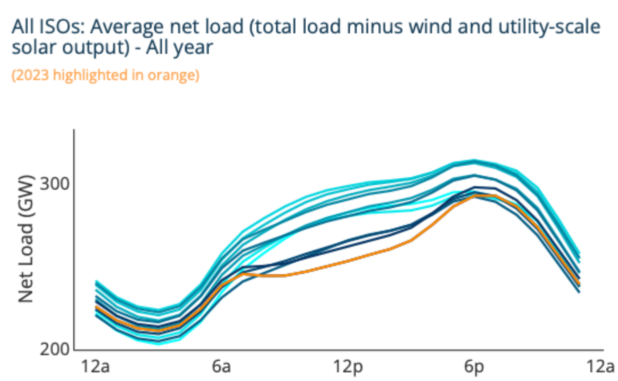

Figure 7. Net load declined during the daytime with the expansion of solar power, but held steady during nighttime hours. This figure shows results summed across all seven major ISOs/RTOs.

The ReWEP tool can be found at:
https://emp.lbl.gov/renewables-and-wholesale-electricity-prices-rewep

Acknowledgements

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