JULY 2025

Operation of PJM and MISO Power Grid During the June 2025 Heatwave

ENERGY VENTURES ANALYSIS

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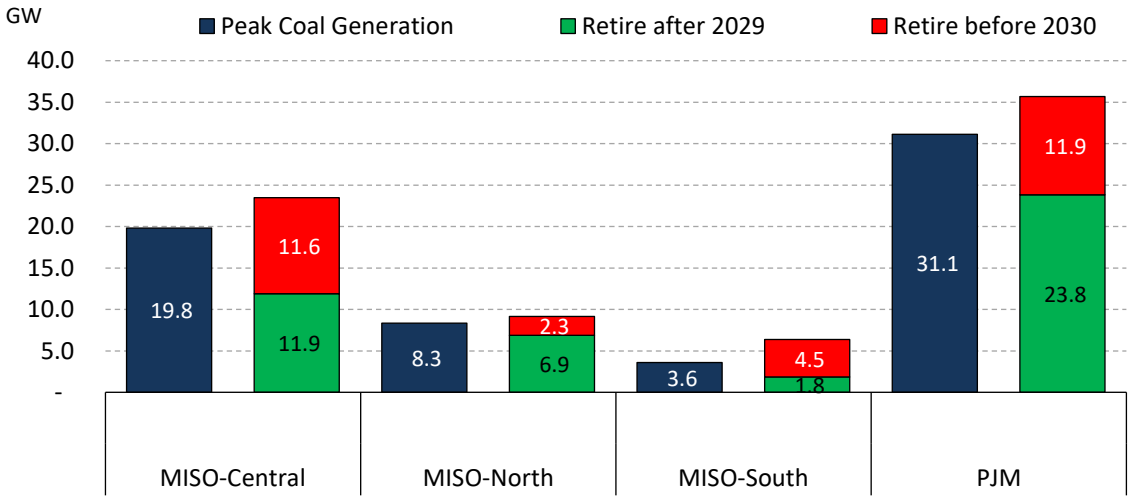
Executive Summary

The June 2025 Heatwave brought extreme temperatures across the Eastern U.S., pushing electricity demand in PJM and MISO to the highest levels in nearly a decade. Peak hourly demand reached 160.6 GW in PJM and 116.4 GW in MISO, placing significant stress on grid operations. System reliability was maintained through the full dispatch of available thermal resources.

• **Coal and Natural Gas Were the Backbone of Reliability**: Coal and natural gas generation were indispensable during the event. In PJM, coal output more than doubled (from 14.5 GW to 31 GW) and gas increased by 70% (from 41 GW to 71 GW). MISO Central saw similar trends, with coal and gas capacity factors rising to 63% and 60%, respectively. These resources provided the majority of the incremental generation, helping to balance the system when electricity demand peaked and variable renewable generation was unable to respond due to time-of-day and weather limitations.

• **Impending Retirements Threaten Future Response Capability**: A critical portion of the coal fleet that operated during the heatwave is slated for retirement by 2030. As shown in the accompanying chart, in every region analyzed (PJM, MISO Central, MISO North, and MISO South), the remaining coal units would have been unable to match the coal generation level achieved during the most recent heatwave. Without adequate firm replacements, extreme future events may result in electricity shortages and reliability emergencies.

Peak coal generation during June 2025 heatwave vs. retiring coal capacity



Source: EIA Hourly Grid Monitor & EVA Power Plant Tracking System

• **Extreme Price Volatility Highlighted System Constraints**: Real-time prices surged. LMPs at PJM's Western Hub peaked at $1,904/MWh, and MISO's Indiana Hub hit $1,046/MWh, compared to typical June averages below $30/MWh.

• **PJM's Export Capability Was Severely Reduced:** Historically, PJM exports ~5 GW during summer months. During the heatwave, exports fell below 1 GW as internal needs consumed all available generation—a sharp departure from prior years and an indication of tightening margins for regional reliability coordination.

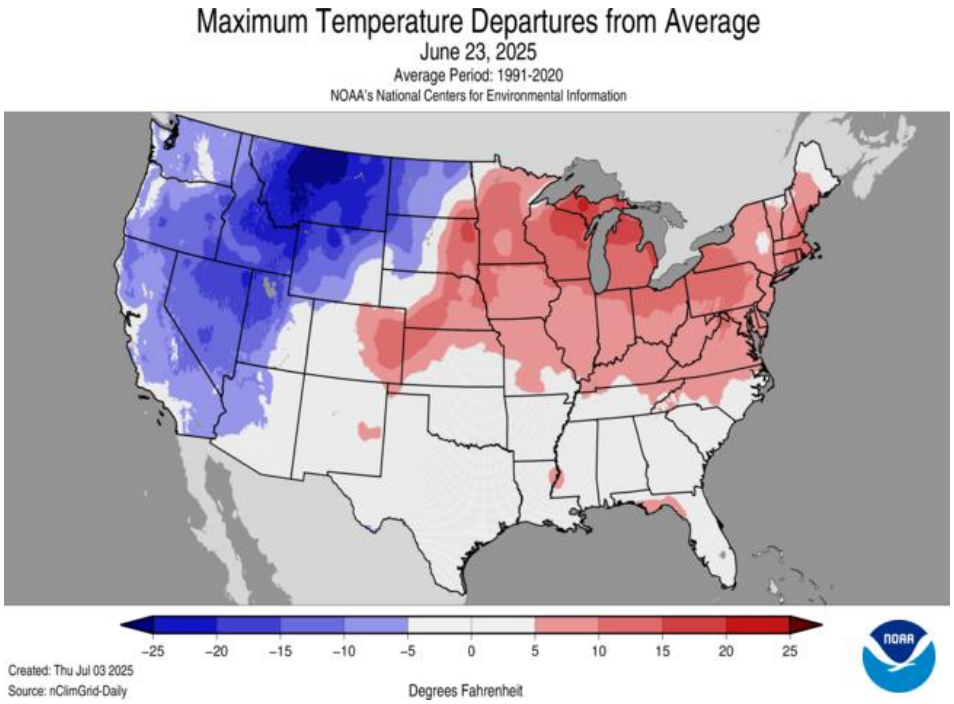
Table of Contents

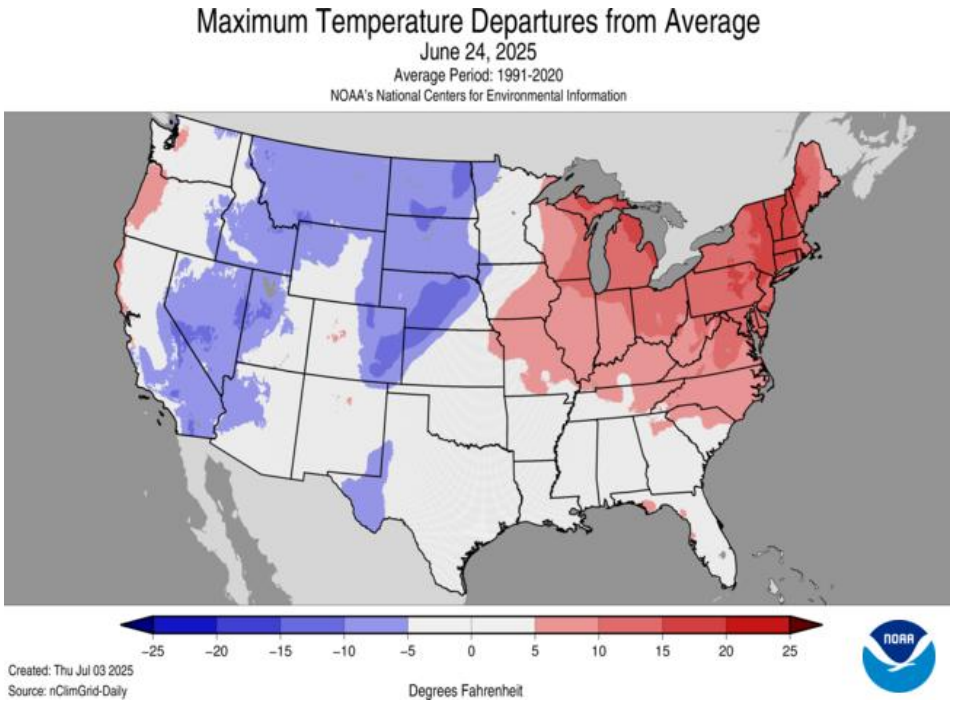
Table of Exhibits

Introduction

A severe heatwave affected the eastern United States in late June 2025, breaking numerous temperature records and creating dangerous conditions across the region. The heatwave, driven by a "heat dome," brought extremely high temperatures and humidity, with heat indices exceeding 110°F in some areas. It caused record-breaking temperatures in cities such as Baltimore, Newark, Boston, and Philadelphia. For this report, EVA considers the peak temperatures from June 23rd to June 25th as the duration of the heatwave and refers to it as the "June 2025 Heatwave" event.

EXHIBIT 1: U.S. MAXIMUM TEMPERATURE DEPARTURES ON JUNE 23 AND JUNE 24, 2025, FROM 1991–2020 AVERAGE

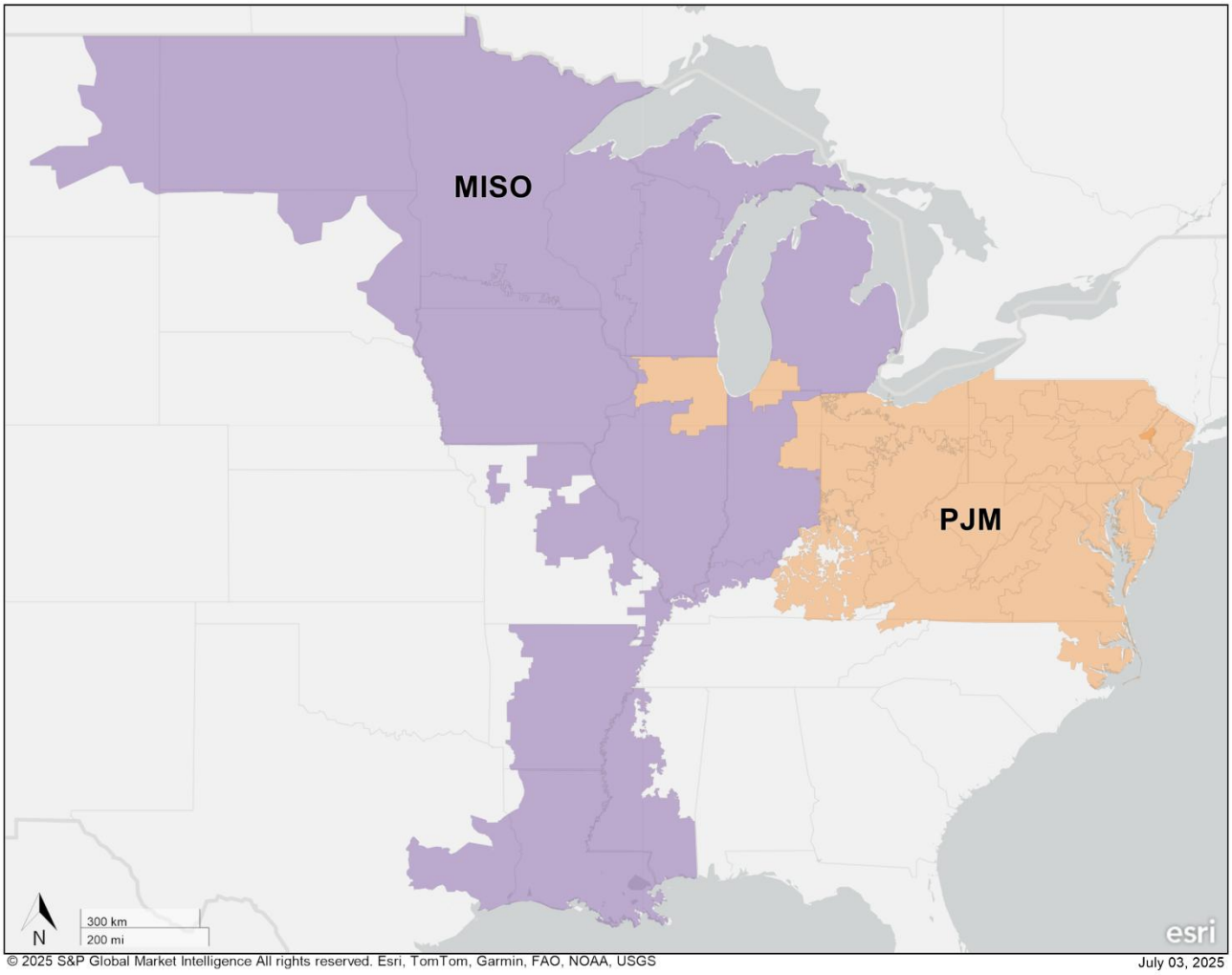




Regional Analysis

Using EIA's regional data from the Hourly Electric Grid Monitor, EVA performed analyses of the impact and performance of the power market regions called PJM and MISO as shown in **EXHIBIT *2***.

EXHIBIT 2: MAP OF MISO AND PJM

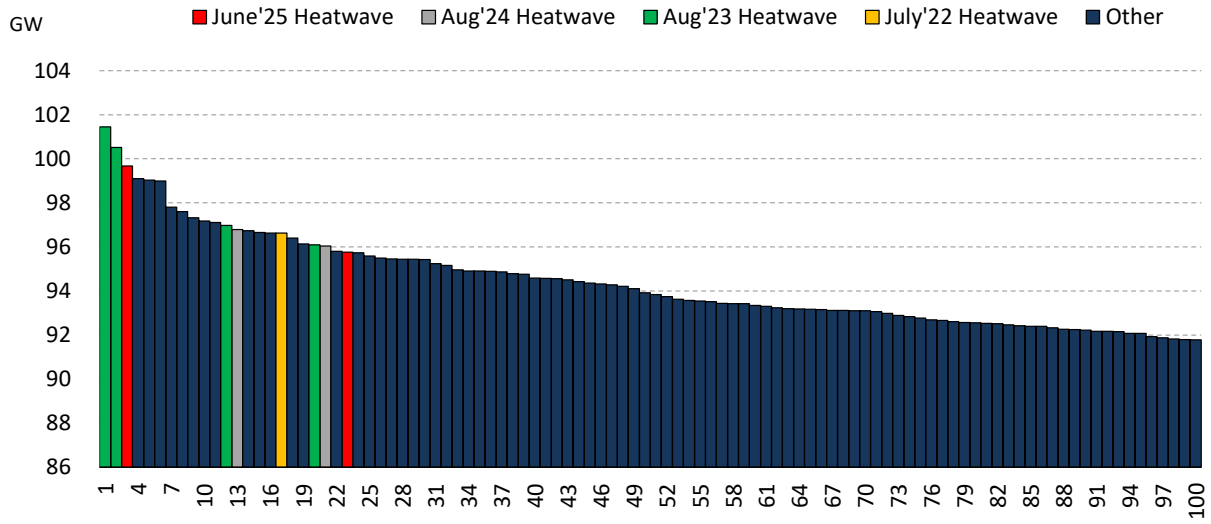


MISO

The Midcontinent Independent System Operator (MISO) is the second-largest Independent System Operator in the United States, overseeing the reliable operation of the bulk power system across 15 states and serving over 45 million customers.

While electricity demand in the MISO region rose steadily during the early part of summer 2025, the system experienced one of its most significant load events on June 23, when high temperatures drove average demand to 99.5 GW and peak hourly demand to 116.4 GW in the evening. As shown in **EXHIBIT *3***, this marked the third-highest summer demand day in the past decade, exceeded only by the peak average daily demand of 101.3 GW during the August 2023 heatwave.

EXHIBIT 3: MISO - TOP 100 SUMMER ELECTRICITY DEMAND DAYS IN THE PAST DECADE

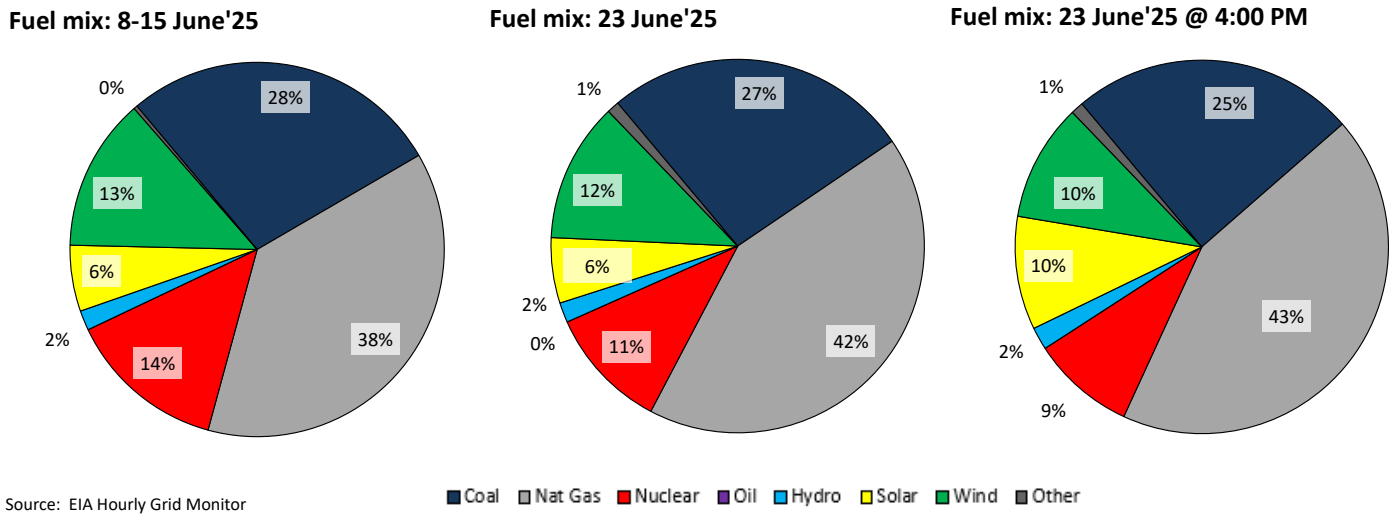


Source: EIA Hourly Grid Monitor

EXHIBIT *4* presents a comparison of the average generation mix in the MISO region for the period of June 8–15, the peak demand day of the heatwave (June 23), and the peak demand hour at 4:00 p.m. on that day. Under typical conditions, coal and natural gas generation together account for approximately 66% of the total mix, with wind contributing around 13% and solar roughly 6%.

During the critical demand period on June 23, the overall composition of the generation mix remained relatively consistent, with coal, natural gas, and wind generation all increasing proportionally to meet higher system demand. Given that the peak occurred in the early evening, solar generation also played a more prominent role, contributing 10% of the total during the peak hour, higher than its typical share earlier in the month.

EXHIBIT 4 MISO - GENERATION MIX

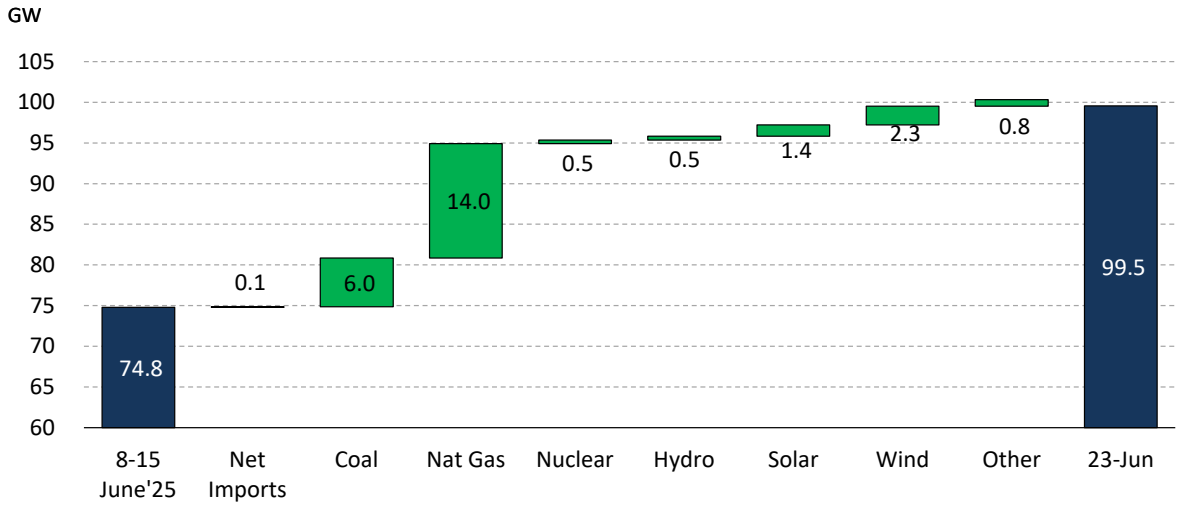


Source: EIA Hourly Grid Monitor

EXHIBIT *5* compares generation profiles between the average demand during the week of June 8–15 and the peak demand day on June 23, 2025, during the heatwave. Average system demand on June 23 reached 99.5 GW—approximately 25 GW higher than the 74.8 GW average recorded during the week of June 8–15.

Due to elevated temperatures throughout the month, coal-fired generation was already operating at higher-than-normal levels. On June 23, in response to the additional system load, coal generation increased by 6 GW, reaching approximately 26 GW. Natural gas generation also rose sharply, climbing from an average of 27 GW during the second week of June to 41 GW on June 23, marking a 51% increase.

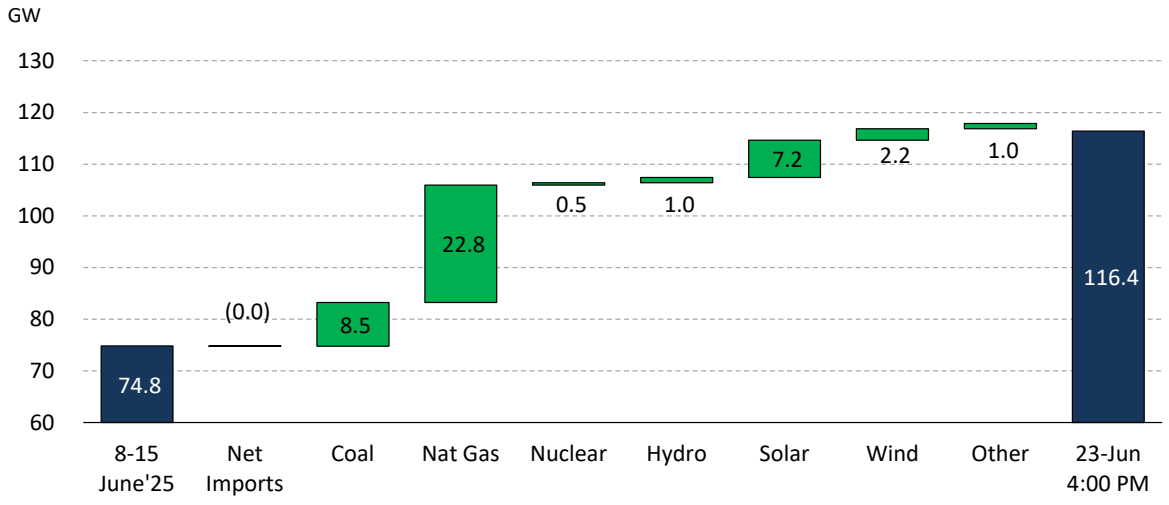
EXHIBIT 5 : MISO - AVG. OPERATIONS VS. DURING PEAK DEMAND DAY



Source: EIA Hourly Grid Monitor

EXHIBIT *6* compares the generation mix during the second week of June (June 8-15) with the peak demand hour during the June 2025 Heatwave. The peak demand reached 116.4, one of the highest in MISO's history. Occurring during early evening daylight hours, solar generation increased by 7.2 GW, contributing over 11 GW at peak. Despite this solar ramp-up, natural gas and coal plants needed to increase output further, rising by 22.8 GW and 8.5 GW, respectively. This scenario highlights the importance of dispatchable sources, such as natural gas and coal, which were crucial in meeting the high demand despite significant contributions from solar and wind energy during peak hours.

EXHIBIT 6: MISO - AVG. OPERATIONS VS. DURING PEAK DEMAND HOUR

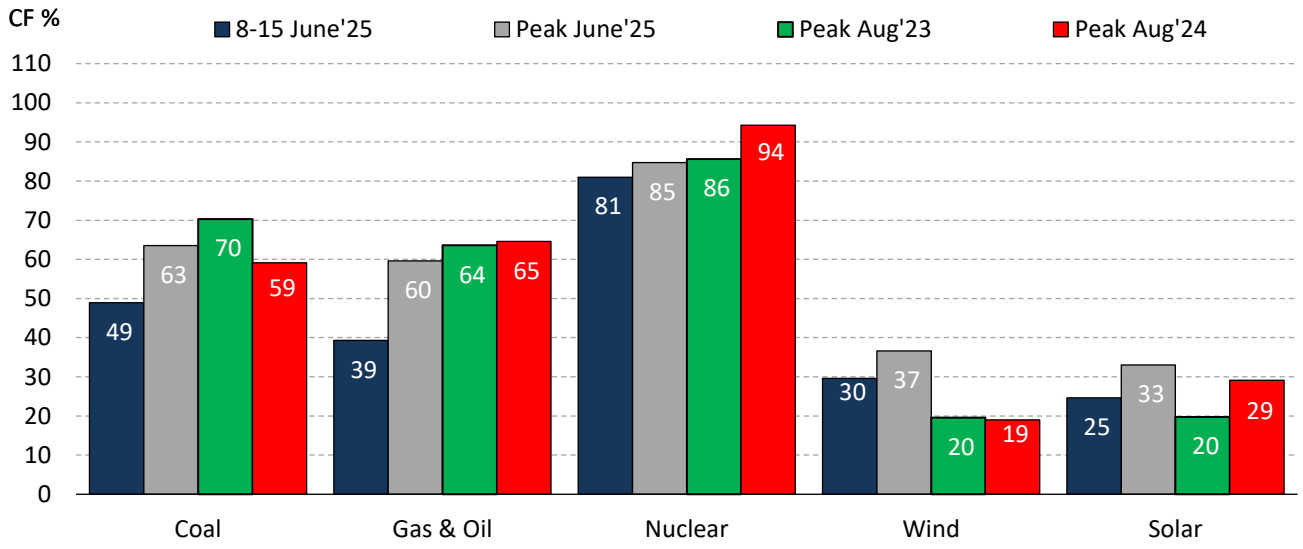


Source: EIA Hourly Grid Monitor

EXHIBIT *7* compares the capacity factors of various electricity generation resources during the peak demand day of the June 2025 Heatwave in the MISO region to those observed in the second week of June 2025 and other such summer events of peak electricity demand. During the heatwave, both coal and natural gas showed significantly higher capacity factors, recording 63% and 60% respectively. In contrast, their capacity factors during the week of June 8-15 were only 49% and 39%.

On June 23, favorable weather conditions resulted in improved wind and solar generation performance. Average wind generation reached 11.8 GW, with output peaking at 19.4 GW during the early morning hours, prior to the system's peak demand period. This represented a noticeable increase from the previous week, when wind capacity factors averaged around 30%. Similarly, solar conditions were favorable, with solar capacity factors rising to 33%, compared to approximately 25% during the week of June 8–15.

EXHIBIT 7: MISO - CAPACITY FACTOR BY FUEL TYPE DURING PEAK DEMAND TIMES



Source: EIA Hourly Grid Monitor & EIA 860 data

MISO is generally divided into three regions: North, Central, and South. Of these, the MISO Central region is expected to account for the majority of planned coal retirements over the next five years. The following section presents EVA's analysis of the MISO Central region's demand and system response during the June 2025 extreme weather event.

MISO Central

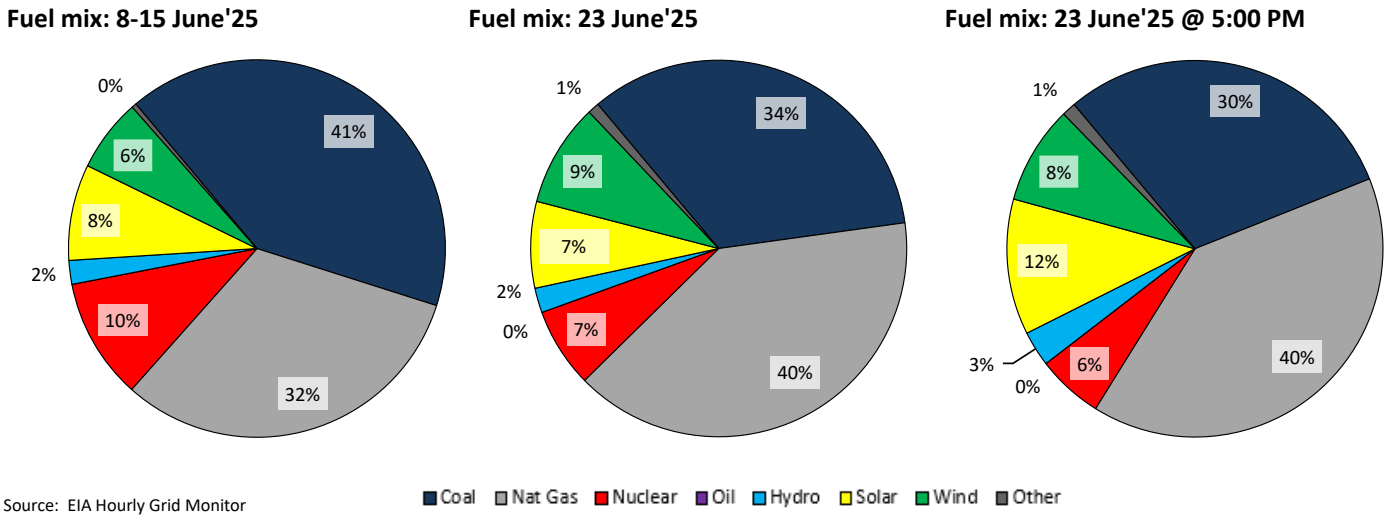
The MISO Central region serves as a key hub within the MISO footprint, representing one of the system's highest demand areas. With major load centers, extensive transmission infrastructure, and a diverse generation mix, it plays a central role in maintaining reliability and supporting efficient market operations.

A comparison of the generation mix in the MISO Central region during average summer demand days (June 5–18) reveals a consistent reliance on dispatchable resources—primarily coal, natural gas, and nuclear, which together accounted for approximately 83% of total generation. Coal was the dominant source during this period, accounting for approximately 41%.

On June 23, the peak demand day during the June 2025 Heatwave, the generation mix remained broadly consistent. Natural gas supplied 40% of the region's electricity, followed by coal at 34%, and nuclear at 7%. Solar generation, supported by favorable seasonal and weather conditions, maintained a steady share of 7–8% on average, with output rising proportionally during peak hours. During the early evening peak, solar contributed approximately 12% of the

generation mix, while the combined share of coal and natural gas remained stable, indicating both sources ramped up output in line with increased system demand.

EXHIBIT 8: MISO -CENTRAL GENERATION MIX

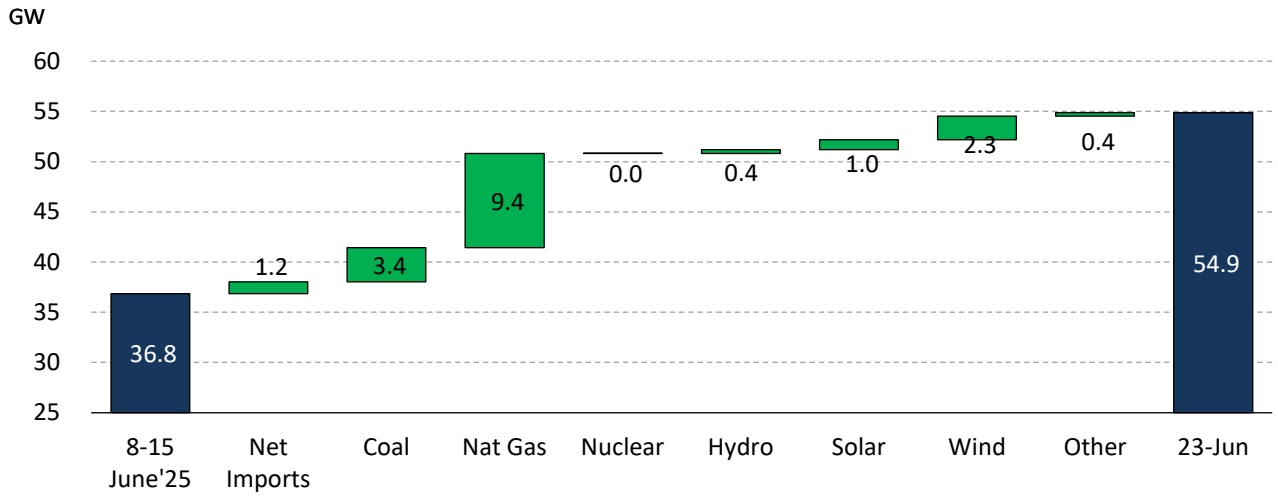


Source: EIA Hourly Grid Monitor

EXHIBIT 9 compares the generation profiles between average electricity demand during the week of June 8–15 and the peak demand day on June 23, 2025, during the heatwave. Average demand during the week of June 8–15 was approximately 36.8 GW. As temperatures rose, demand surged by nearly 20 GW, reaching 54.9 GW on June 23.

In response, natural gas generation increased by an average of 9.4 GW, while coal generation rose by 3.4 GW to reach 16.7 GW on the peak day. Notably, system demand had been climbing steadily since late May, leading to elevated coal generation levels even before the peak event. During the second week of June, coal output averaged higher than natural gas, reflecting the early and sustained response of coal units to the prolonged period of rising demand.

EXHIBIT 9: MISO- CENTRAL - AVG. OPERATIONS VS. DURING PEAK DEMAND DAY

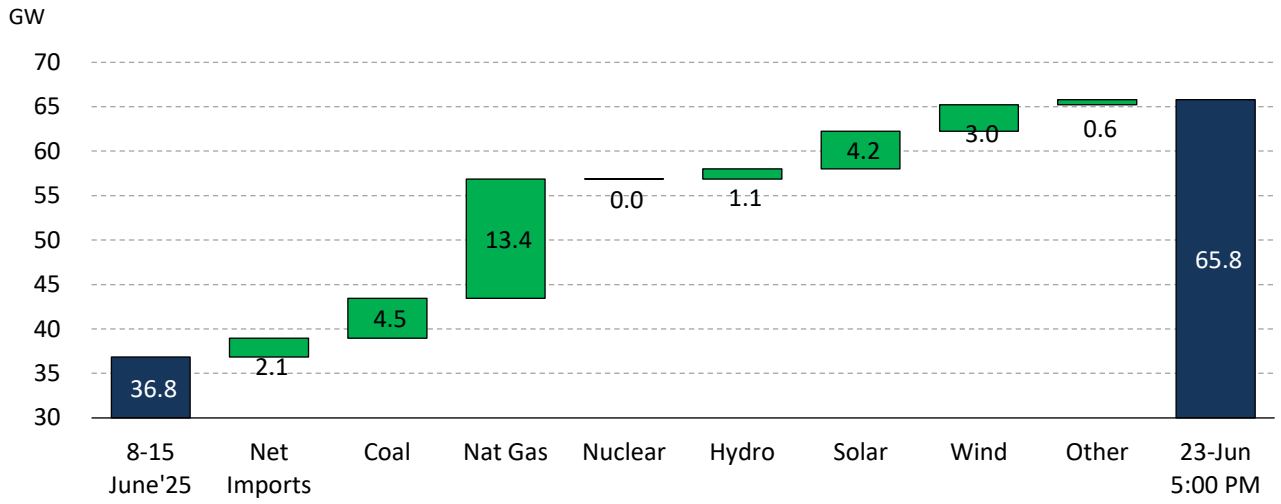


Source: EIA Hourly Grid Monitor

As shown in **EXHIBIT 10**, during the peak hour of the June 2025 Heatwave, electricity demand in the MISO Central region surged to approximately 65.8 GW, prompting increased output from all available generation resources. Natural gas provided the most significant response, increasing by 13.4 GW to reach 23.7 GW. Coal generation rose by 4.5 GW to 17.8 GW—an increase of more than 34% compared to average levels during the second week of June, highlighting its critical

role during system stress. Favorable daylight conditions also supported solar output, which increased to nearly 7 GW during the peak hour, making a meaningful contribution to the overall supply mix. Despite this substantial ramp-up in internal generation, the region was unable to meet demand solely through local resources. To close the gap, MISO Central relied on an additional 2.1 GW of electricity imports, bringing total net imports to 6.3 GW during the peak hour, highlighting the region's dependence on external supply during extreme weather events.

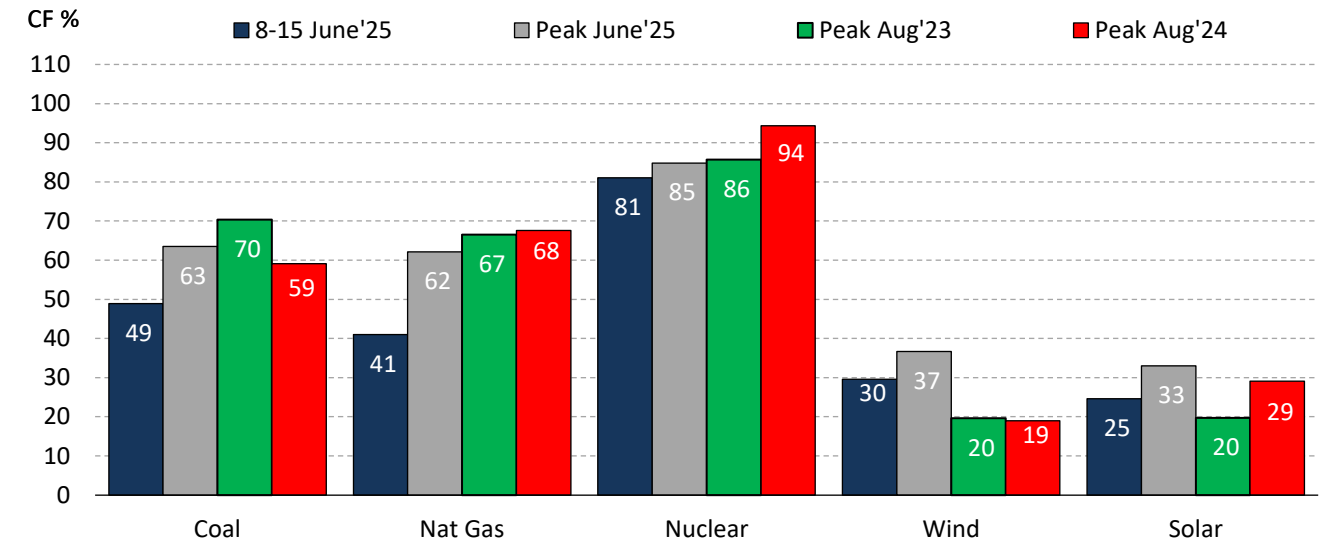
EXHIBIT 10: MISO CENTRAL - AVG. OPERATIONS VS. DURING PEAK DEMAND HOUR



Source: EIA Hourly Grid Monitor

As shown in Exhibit 11, coal and natural gas have consistently played a critical role in supporting system reliability during extreme heatwave events in the MISO Central region. In contrast, wind and solar output have been more variable, largely dependent on time of day and weather conditions. Coal-fired units, which typically operate at a capacity factor of around 50% during regular summer conditions, have reliably ramped up to 60% or higher during periods of elevated demand. Similarly, natural gas-fired generation has demonstrated strong responsiveness, increasing output by approximately 20 percentage points in capacity factor during extreme weather events.

EXHIBIT 11: MISO-CENTRAL - CAPACITY FACTOR BY FUEL TYPE DURING PEAK DEMAND TIME



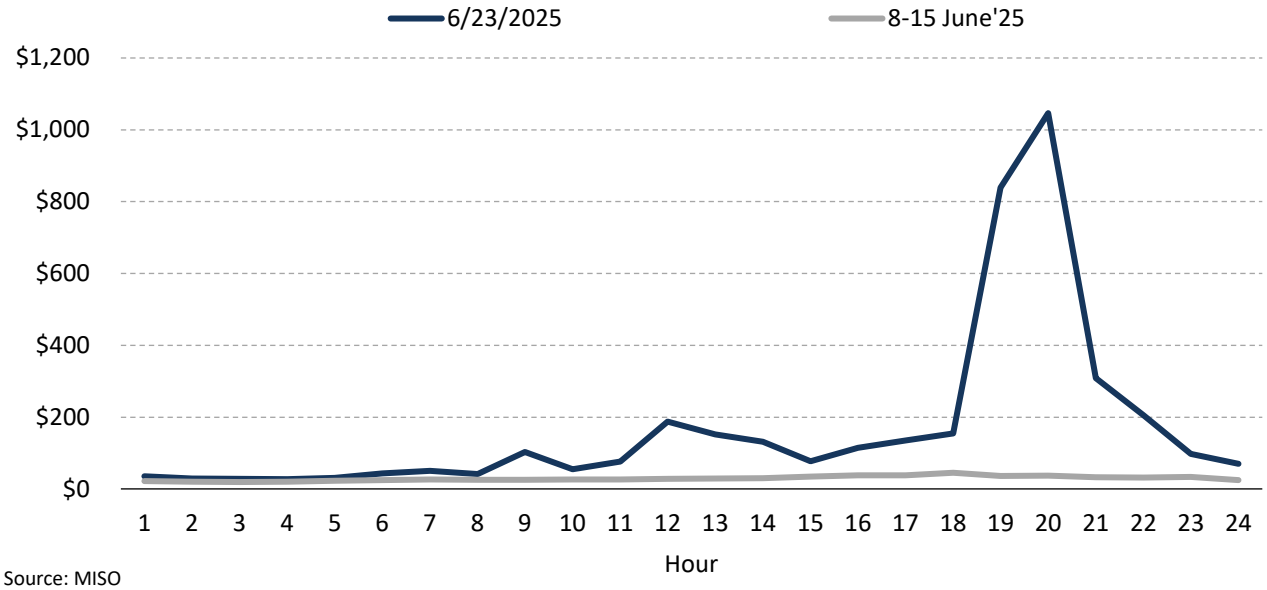
Source: EIA Hourly Grid Monitor & EIA 860 data

As evidenced in the preceding exhibits, the MISO Central region, which typically relies on electricity imports from neighboring regions to meet demand during normal operating conditions, faced even greater dependence on imports during the June 2025 Heatwave. During the peak demand hour on June 23, imports accounted for approximately 10% of total regional demand. This elevated level of reliance on external supply persisted for several hours, contributing to a sharp spike in real-time Locational Marginal Pricing (LMP).

Between June 8 and 15, the average LMPs in MISO Central hovered around $29/MWh, peaking at $45/MWh during periods of high demand. On June 23, however, average LMPs surged to $168/MWh, with hourly prices spiking as high as $1,046/MWh—a dramatic increase compared to mid-June levels, as shown in **EXHIBIT *12***.

Notably, this price escalation occurred despite coal and natural gas plants operating at elevated capacity factors. With approximately 11.5 GW of coal capacity expected to retire in the MISO Central region over the next five years, the system's ability to manage future extreme events may be further strained. In the absence of sufficient replacement capacity or enhanced grid flexibility, future heatwaves could drive LMPs even higher, posing serious reliability risks to the region.

EXHIBIT 12: REAL TIME LOCATIONAL MARGINAL PRICING (LMP) OF INDIANA HUB IN MISO



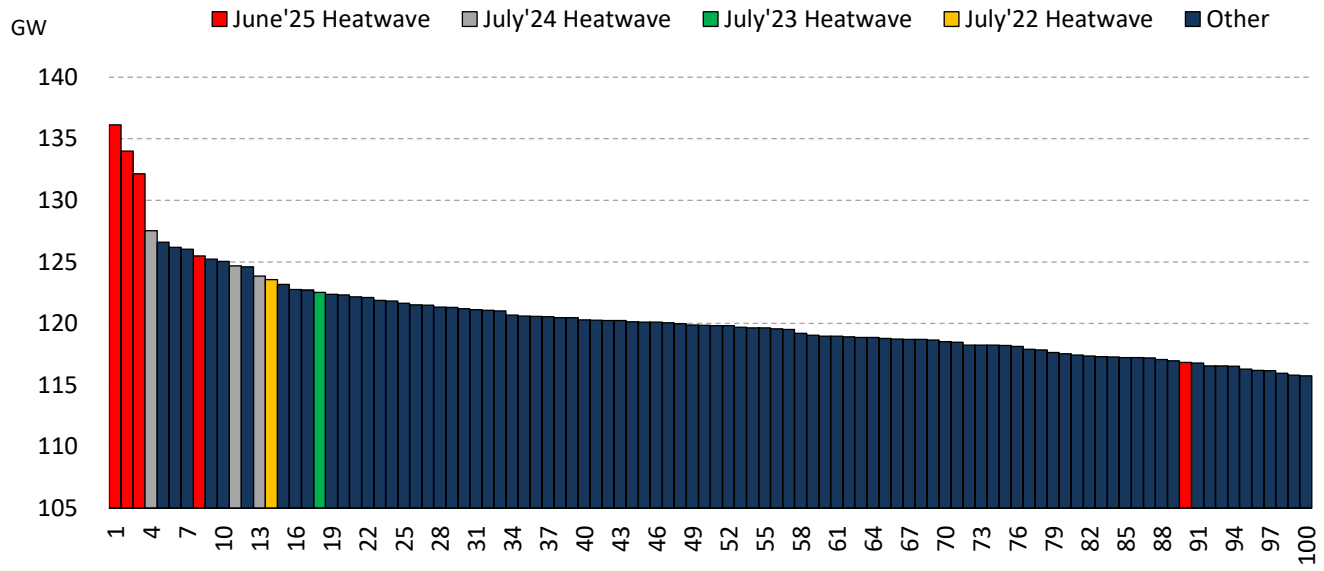
Source: MISO

PJM

The PJM Interconnection, the largest Independent System Operator (ISO) in the nation by capacity, serves approximately 65 million customers across 13 states and the District of Columbia. During the early summer months, PJM typically experiences an average hourly demand of nearly 80 GW, with demand in July and August regularly exceeding 100 GW.

In June 2025, an intense heatwave drove electricity demand in the PJM region to some of the highest levels seen in the past decade. Peak daily demand surpassed 136 GW, placing multiple days among the top three highest demand days in nearly 10 years, as illustrated in **EXHIBIT 13**. Notably, peak hourly demand exceeded 160 GW—an unprecedented level for the last decade. This event outpaced even the July 2024 heatwave, which had previously reached a peak of 127 GW.

EXHIBIT 13: PJM - TOP 100 SUMMER ELECTRICITY DEMAND DAYS



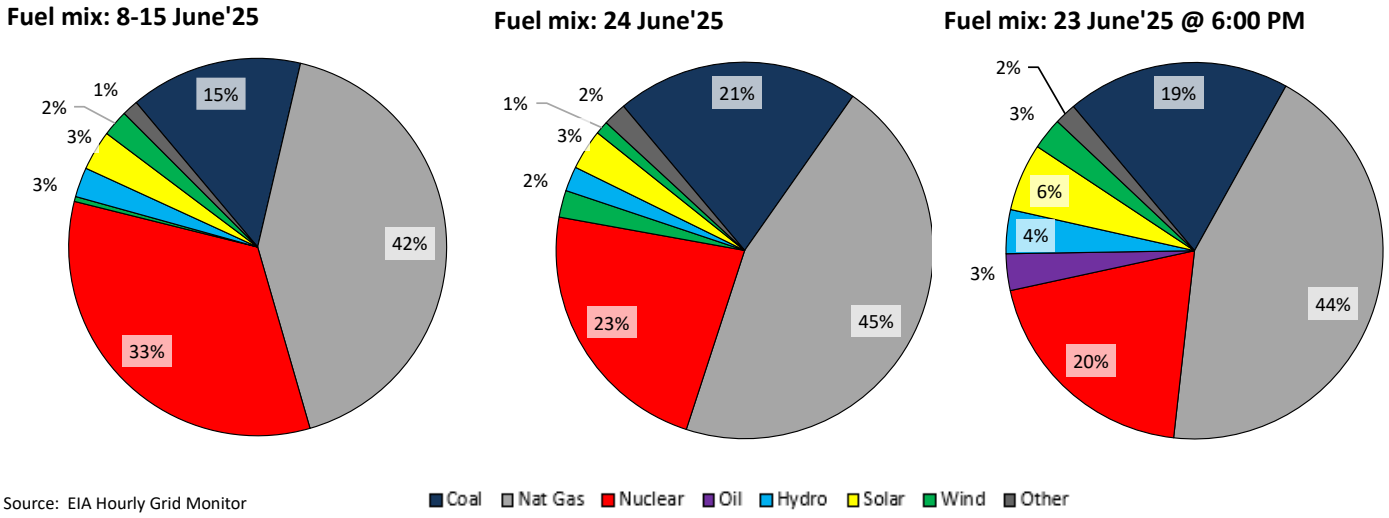
Source: EIA Hourly Grid Monitor

In PJM, nuclear power typically accounts for nearly one-third of total generation capacity. However, during the June 2025 Heatwave, the sharp increase in electricity demand led to a notable shift in the generation mix, as illustrated in **EXHIBIT 14**. Because nuclear units generally operate at or near full capacity, their output remained relatively constant, resulting in a reduced share of nuclear generation within the overall mix as other resources ramped up to meet demand.

Coal-fired generation increased significantly, contributing 21% of the fuel mix on the peak demand day, approximately 6 percentage points higher than its share in mid-June 2025. Natural gas generation also rose in absolute terms, maintaining a steady share of the mix in line with typical summer conditions. Oil-fired generation, which had been minimal earlier in the month, increased markedly to support system reliability during peak hours.

At the peak of the heatwave, multiple resource types were called upon to maintain grid stability. Since the peak occurred prior to sunset, solar output contributed significantly, tripling its average share from early June 2025. Hydro generation also rose during the peak hour, providing critical flexible support. Overall, fossil fuel resources supplied more than two-thirds of total generation.

EXHIBIT 14: PJM - GENERATION MIX



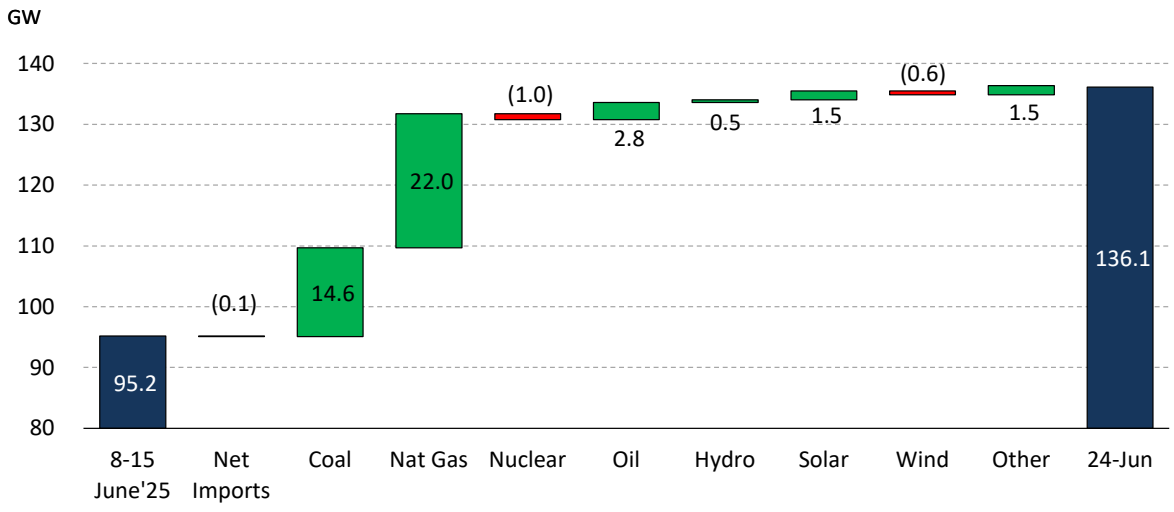
Source: EIA Hourly Grid Monitor

EXHIBIT 15 compares average hourly demand and generation by fuel type in PJM between the week of June 8–15, 2025, and the peak demand day of June 24, 2025. During this heatwave event, PJM's average hourly demand surged by approximately 41 GW, increasing from 95.2 GW to 136.1 GW.

To meet this substantial increase, nearly all dispatchable generation resources ramped up output. Natural gas provided the largest contribution, increasing by 22 GW, followed by coal, which added 14.6 GW. Oil-fired generation also rose by 2.8 GW, while solar and hydro contributed an additional 1.5 GW and 0.5 GW, respectively. Other sources contributed an additional 1.5 GW to the mix.

While PJM typically exports electricity to neighboring regions during normal and even stressed conditions, often supporting reliability in the Southeast and Midwest, the extreme internal demand on June 24 required full utilization of available generation within the region. As a result, net exports dropped marginally by 0.1 GW, effectively keeping the additional supply internal to support PJM's own reliability needs during the peak event.

EXHIBIT 15: PJM - AVG. OPERATIONS VS. DURING PEAK DEMAND DAY



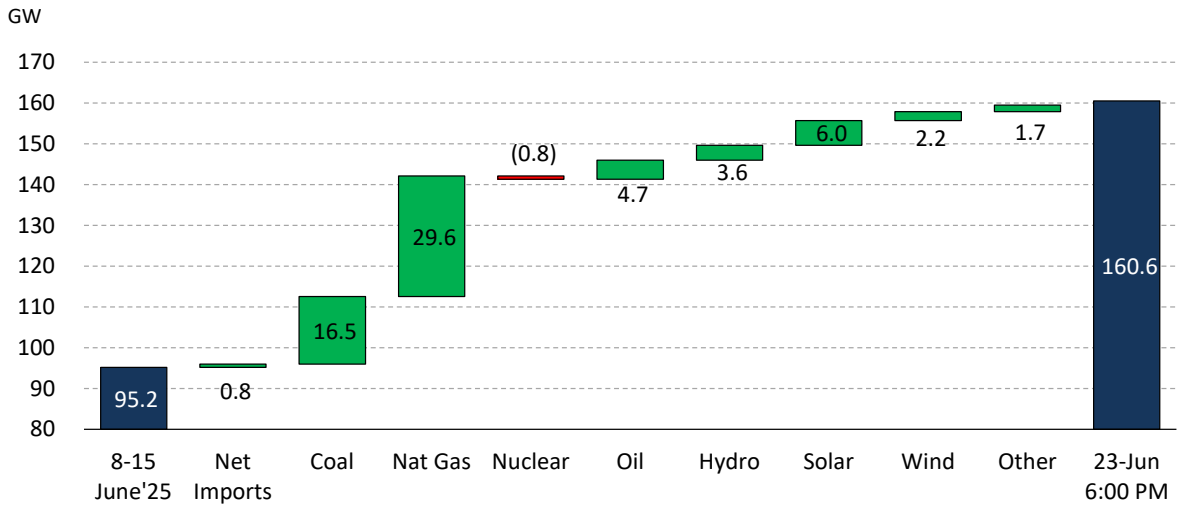
Source: EIA Hourly Grid Monitor

EXHIBIT 16 presents a comparative analysis of average hourly generation by fuel type in PJM between the week of June 8–15, 2025, and the peak demand hour on June 23, 2025, at 6:00 PM during the extreme heatwave. During this peak hour, electricity demand surged by nearly 70%, reaching one of the highest levels observed in the past decade.

To meet this sharp increase, PJM significantly ramped up output across all available generation sources. Natural gas generation increased from 41 GW to 71 GW, representing a nearly 70% rise, and contributed the largest share of the incremental supply. Coal-fired generation more than doubled, increasing from 14.5 GW to 31 GW, highlighting its essential role in maintaining grid reliability under stressed conditions. Oil-fired units also scaled up meaningfully, along with moderate increases in hydro and other dispatchable sources.

Solar generation quadrupled from early June averages, contributing an additional 6 GW during the late-afternoon peak, aided by favorable daylight conditions.

EXHIBIT 16: PJM - AVG. OPERATIONS VS. DURING PEAK DEMAND HOUR



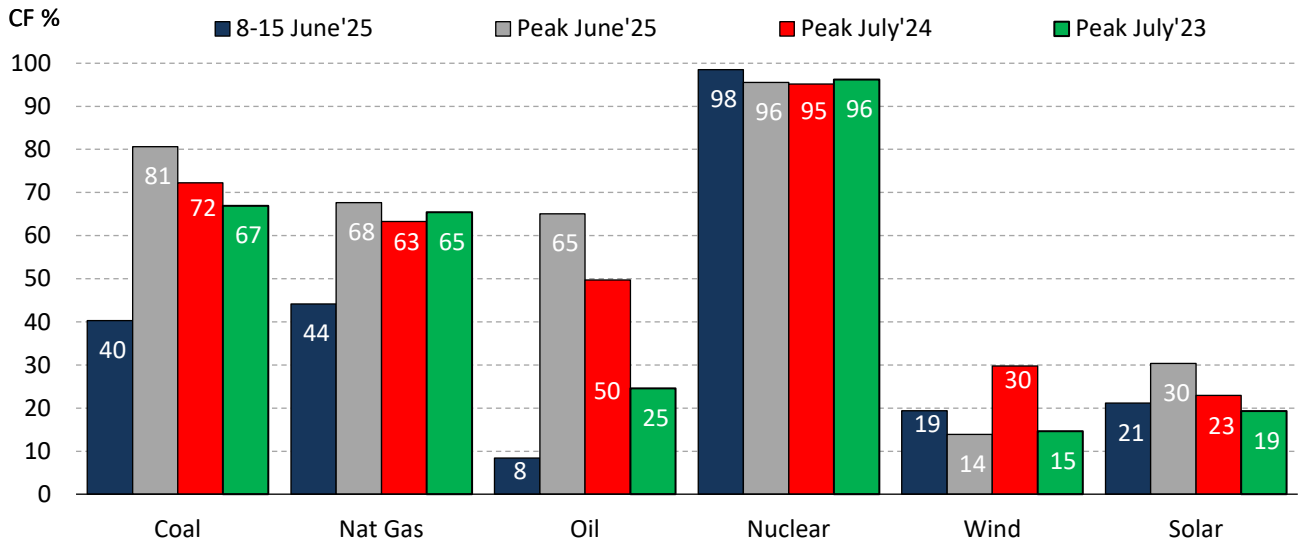
Source: EIA Hourly Grid Monitor

EXHIBIT 17 illustrates capacity factors by fuel type in PJM across several periods, highlighting how generation resources respond during peak demand conditions. Among all fuel types, coal-fired generation exhibited the most pronounced increase, with its capacity factor rising from 40% during the week of June 8–15 to 81% during the June 2025 peak day. This doubling of utilization underscores coal's critical role as a reliable and dispatchable resource during periods of system stress.

Natural gas also played a significant role, with its CF increasing from 44% to 68%, demonstrating strong operational flexibility. Oil-fired generation, which typically remains idle during normal conditions with just 8% CF, surged to 65% during the peak, serving as a vital backup resource when system needs were most acute.

Nuclear generation remained consistently high across all periods, maintaining capacity factors in the 95–98% range, reflecting its role as a stable baseload resource. In contrast, wind and solar resources were more variable. Wind CF ranged between 14–30%, and solar varied from 19–30%, reflecting their dependence on weather and time-of-day conditions. While renewables contribute meaningfully during favorable conditions, their intermittency limits their reliability during extreme events.

EXHIBIT 17: PJM - CAPACITY FACTOR BY FUEL TYPE DURING PEAK DEMAND TIMES



Source: EIA Hourly Grid Monitor & EIA 860 data

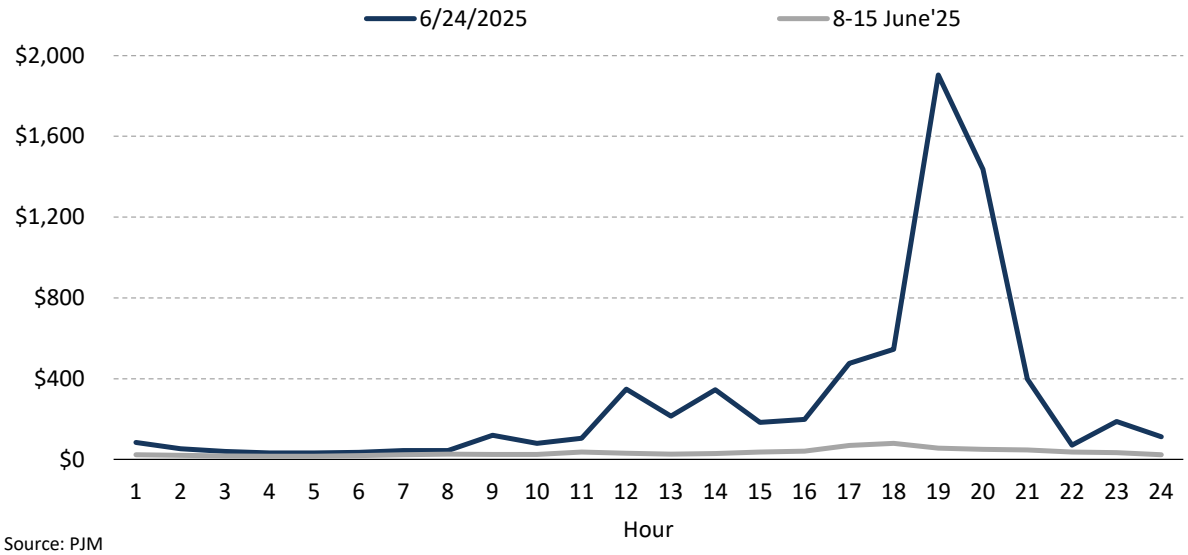
EXHIBIT 18 illustrates hourly Locational Marginal Prices (LMPs) at the PJM Western Hub on June 24, 2025, compared to average prices during the week of June 8–15, 2025. The Western Hub—one of PJM's primary trading points—serves as a representative price signal for the broader PJM footprint. It is also geographically significant due to the concentration of coal-fired generation assets, particularly in states like Ohio, Pennsylvania, and West Virginia, making it a key node in understanding the impact of fossil resource performance on market prices.

During the June 2025 Heatwave, LMPs at the Western Hub rose steadily through the day, surpassing $100/MWh by late morning and peaking near $1,904/MWh in the evening, a 30-fold increase over typical levels. By comparison, prices during June 8–15 remained relatively stable, mostly between $20–$70/MWh.

These extreme price movements occurred despite full utilization of coal, natural gas, and oil-fired units, as discussed earlier. The sharp increase in prices reflects the high marginal cost of meeting incremental demand during extreme events and highlights the system's limited flexibility when operating near its limits.

With approximately 11.5 GW of coal capacity expected to retire in PJM over the next five years, these reliability and price pressures are likely to intensify. The Western Hub's exposure to coal generation makes it particularly vulnerable to such structural changes. As coal resources decline, PJM may face growing challenges in managing peak events without incurring severe price volatility, especially if adequate replacement capacity and flexible resources are not brought online in time.

EXHIBIT 18: REAL TIME LMP OF PJM - WESTERN HUB



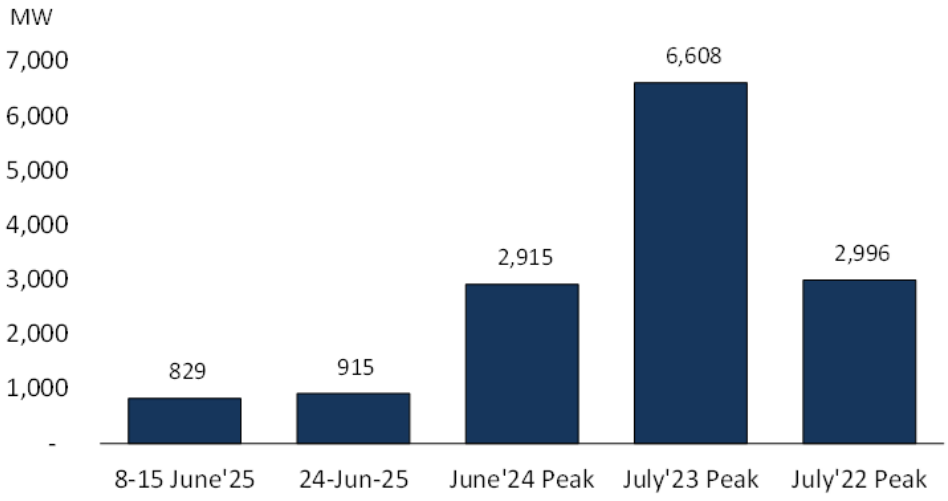
Source: PJM

EXHIBIT 19 highlights PJM's electricity exports during recent peak summer demand events. During the June 2025 Heatwave, PJM exports remained under 1 GW, significantly lower than previous extreme events, including over 6.6 GW during the July 2023 peak and nearly 3 GW during June 2024 and July 2022 peaks.

Historically, PJM has exported an average of 5 GW during the summer months (May–August) between 2020 and 2024, often serving as a critical supply source for neighboring regions during periods of high demand. However, the June 2025 event marked a turning point: with system-wide demand surging and nearly all dispatchable capacity operating near full output, PJM was largely unable to support external markets, instead relying on every available resource to meet internal needs.

This decline in export capability underscores a growing reliability challenge. With over 11 GW of coal capacity scheduled to retire in the coming years, PJM's ability to maintain reliability under extreme conditions and to continue serving as a regional support provider may become increasingly strained.

EXHIBIT 19: PJM EXPORT DURING EXTREME SUMMER EVENTS



Source: : EIA Hourly Grid Monitor