Long-Term Load Forecast

December 2024

Highlights

- MISO has updated its long-term load forecast approach, incorporating new methods, metrics and models to provide greater visibility into factors driving the anticipated load growth.

- Data centers, new domestic industry and green hydrogen are primary drivers of the anticipated load growth. This is a change from previous MISO outlooks which focused on electric vehicle (EV) adoption and building electrification. MISO's peak demand is expected to increase by approximately 1 - 2% per year until 2044, on a compound annual growth rate (CAGR) basis. This is materially higher than the 0.4 - 1.1% CAGR forecast in previous MISO Futures scenarios.

- The most recent stakeholder load forecast data submitted through the 2023 Organization of MISO States (OMS) survey indicates a 1% CAGR of peak load growth, which is substantially higher than the 2019 submission of 0.25% CAGR and aligns with MISO's low trajectory.

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Executive Summary

MISO has updated its load forecast approach to address a range of industry developments expected to result in substantial load growth within the next 5-20 years. Based on this updated process, MISO expects its coincident peak load to increase by approximately 1% to 2% compound annual growth rate (CAGR) from 122 GW in 2024 to between 152 and 186 GW in 2044, a substantial increase from the 0.4% to 1.1% CAGR reported in the November 2023 MISO Futures Series 1A report.

Economic development prompted by supportive state and federal policies such as the Inflation Reduction Act (IRA), Infrastructure Investment and Jobs Act, and the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act are expected to drive electricity demand by encouraging building electrification, data centers, electric vehicles (EVs), new industry development and reshoring, and green hydrogen. Increased deployment of distributed energy resources (DER) and shifting climate patterns are also expected to affect load profiles in the MISO region. The degree of growth will vary across MISO's 10 Local Resource Zones (LRZs) due to diverse economic conditions, environmental regulations and consumer preferences. LRZs 1 (Minnesota and North Dakota), 6 (Indiana) and 9 (East Texas and Louisiana) are expected to experience the most growth. Data centers are expected to drive most of the load growth in the north, with new domestic industry development driving growth in the south.

MISO's stakeholders have begun to account for rapidly evolving industry drivers. Stakeholder-submitted forecasts through the 2024 Organization of MISO States (OMS) survey (illustrated by the dashed line in Figure 1) indicate a 1% CAGR of expected coincident peak load growth from 2024 to 2033 — a significant increase over the 0.25% CAGR from 2019 to 2028 (submitted in 2019). Furthermore, MISO is experiencing a surge in Expedited Project Review requests driven by load additions. The number of Expedited Project Review requests grew from one in the 2020 MISO Transmission Expansion Plan (MTEP) study cycle to 15 in the 2024 study cycle.

Between 2009 and 2024, MISO's peak load remained essentially flat, with an average CAGR of 0.5%. Load forecasting during this period relied heavily on methods that assumed that historical trends and relationships between economic variables and electricity demand would persist into the future. The pace and scale of recent industry developments signal the end of this low load-growth era. MISO's updated process draws on the progressive forecasts used in the MISO Futures Series 1A scenarios to project load across three trajectories (Figure 1):

> **Low Trajectory** – Assumes modest growth from load drivers and aligns closely with stakeholder-submitted load forecasts, resulting in a coincident peak load growth of 1.1% CAGR from 2024 to 2044.
>
> **Current Trajectory** – Accounts for technology adoption trends and assumes that future policy incentives and an increase in data centers, domestic manufacturing and green hydrogen facilities result in a coincident peak load growth of 1.6% CAGR from 2024 to 2044.
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> **High Trajectory** – Assumes accelerated EV adoption and additional buildouts of data centers, domestic manufacturing and green hydrogen facilities results in a coincident peak load growth of 2.0% CAGR from 2024 to 2044.

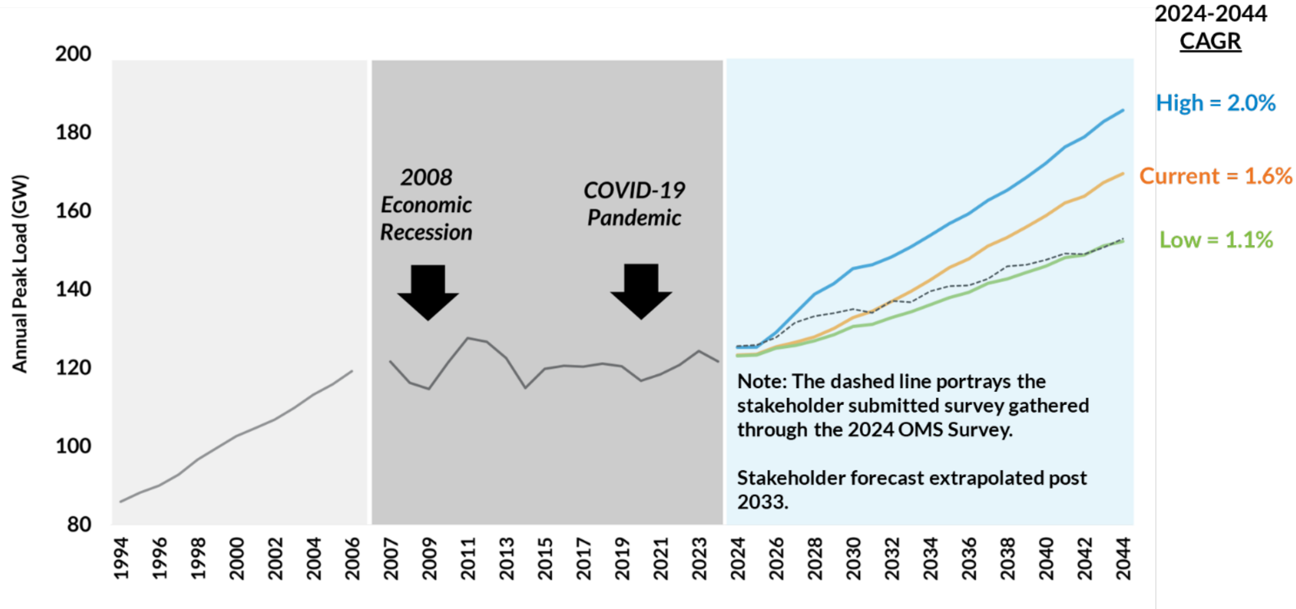


Figure 1: MISO's Net Peak Load Expectations Over Time (1994 to 2044)

MISO's updated load forecast incorporates the expected load additions arising from five key drivers, accounts for system energy contributions from Distributed Energy Resources (DERs) and considers relevant technological and political uncertainties (Figure 2).

Building Electrification: Federal and state policies are driving the electrification of heating systems and appliances, increasing energy demand by 36-43 TWh by 2044.

Artificial Intelligence (AI) Revolution and Data Centers: The expansion of data centers, fueled by AI and cloud-based applications, will raise MISO's energy demand by 149-241 TWh by 2044.

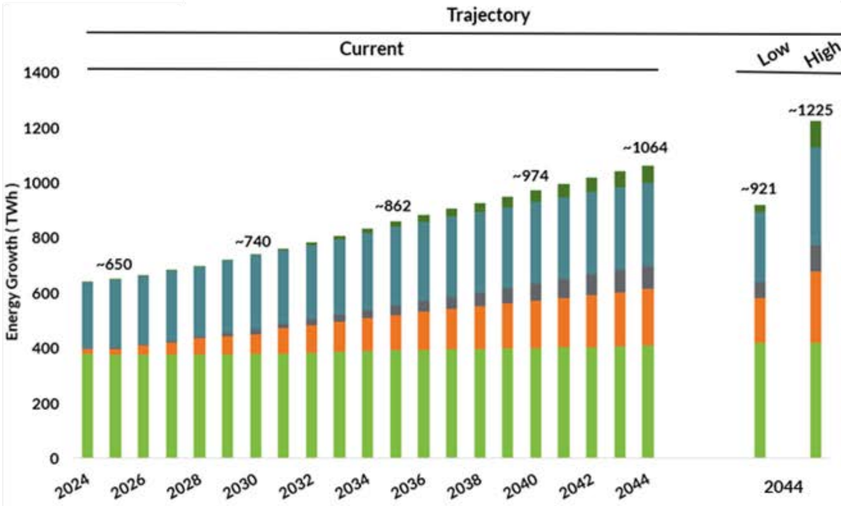
Electric Vehicles (EV): The growth of EVs, driven by federal incentives and declining battery costs, is projected to add 54-91 TWh of demand by 2044, with rapid adoption between 2030-2040.

New Industry Development and Reshoring: Electrification of oil and gas industries and reshoring efforts are expected to increase energy demand by 21-105 TWh by 2044.

Green Hydrogen: Green hydrogen production, supported by federal incentives, could increase MISO's energy demand by 26-95 TWh by 2044, contingent on sustained policy support.

Distributed Energy Resources (DERs): The rise of rooftop solar, energy storage and other DERs is expected to contribute 69-78 TWh of capacity to MISO's system by 2044.

MISO will continue to update its load forecast approach using more granular stakeholder insights for future iterations, which can provide valuable insights into large-load behaviors and better align forecasts with industry needs.



	CAGR* % Low-High (2024-44)	Growth** TWh Low-High (2024-44)	Level of Certainty***
Hydrogen	27-32	26-95	
Industry Development & Reshoring	3-7	21-105	
EVs	14-17	54-91	
Data Centers	12-15	149-241	
Building Electrification	0.45-0.54	36-43	

Figure 2: Driver Segmentation Based on Gross Energy in Current Trajectory[1]

[1] Notes:
*, ** - CAGR Values and Energy Growth Rates Reflect Low to High Trajectories
*** - Level of Certainty Based on Expected Likelihood of Load Growth Materializing
****, ***** - Low and High Trajectories in 2044

Introduction

MISO's updated load forecast approach incorporates new methods, metrics and models to improve the accuracy of long-term forecasts. These updates enable MISO to align emerging trends with actual historical outputs to better keep pace with rapid industry shifts. Central to these updates is a shift toward end-use modeling and refined industry segmentation, allowing for a deeper assessment of critical load growth drivers.

Load forecasts serve as inputs into several important MISO processes and products, including 20-year scenarios like MISO Futures and resource adequacy assessments. MISO plans to incorporate its updated forecast approach to its future planning assessments.

As the power industry evolves within a landscape of dynamic political, regulatory and economic influences, it is essential for MISO to maintain adaptive, high-quality forecasting capabilities. These efforts empower MISO and its stakeholders with the insights to anticipate and navigate rapid load growth, allowing them to plan critical infrastructure needs.

The industry faces various uncertainties, so it is more critical than ever to continually develop a range of scenarios for planning purposes, of which load forecasts are a vital component. These efforts allow MISO to prioritize initiatives under its Reliability Imperative — a shared commitment among MISO, electricity providers and states to address the region's urgent and complex reliability challenges.

DEMAND SURGE PROMPTS UPDATED LOAD FORECAST

Since the last update to the MISO Futures Report: Series 1A in 2023, the energy landscape has experienced rapid and unprecedented shifts. The updated load forecast indicates that from 2024 to 2044, MISO's peak demand is expected to increase by approximately 1% and 2% compound annual growth rate (CAGR) relative to the 0.4% to 1.1% CAGR forecast in the previous MISO Futures Report: Series 1A scenarios (Figure 3).

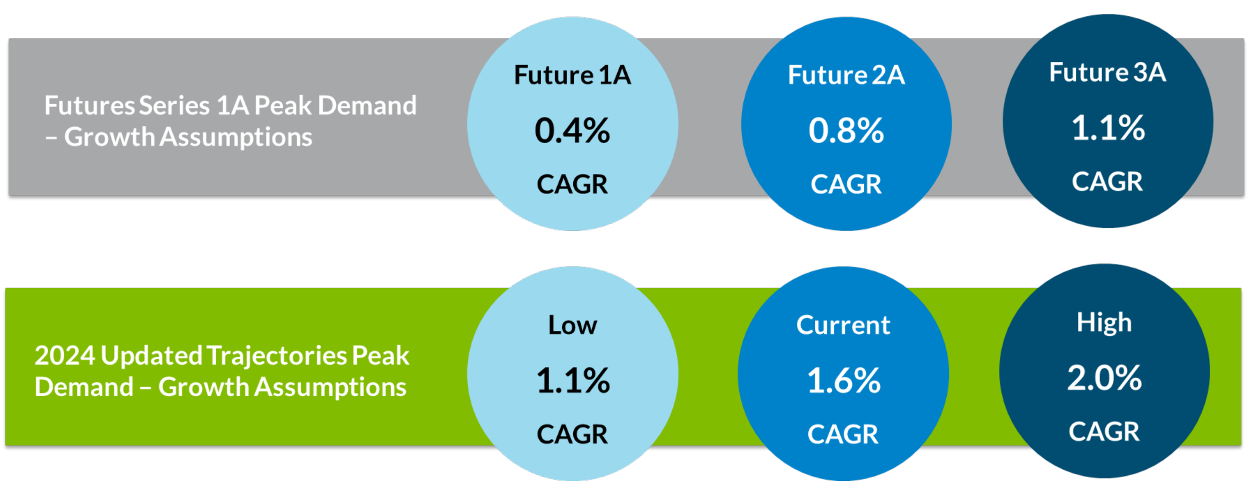


Figure 3: MISO's Forecast Peak Demand Growth Forecast

State-level economic development and energy policy directives, including the introduction of mandates and financial incentives in Illinois, Minnesota and Michigan will likely result in increased electrification in transportation and buildings.[2] At the same time, supportive federal policies such as the IRA, Infrastructure Investment and Jobs Act and the CHIPS Act are expected to drive electricity demand through the accelerated deployment of data centers, green hydrogen and energy-intensive manufacturing such as semiconductors, batteries and solar panels.

Sector	Projected Energy Demand Increase (TWh)	Level of Certainty High to Low	Key Drivers
Building Electrification	36-43		State and federal incentives, including adoption of heat pumps, and appliances.
AI and Data Centers	149-241		Expansion of data centers driven by AI and cloud computing needs.
Electric Vehicles	54-91		IRA incentives, declining battery costs, and rapid EV adoption between 2030-2044.
New Industry & Reshoring	21-105		Electrification in oil and gas, CHIPS Act, and reshoring of industries.
Green Hydrogen	26-95		Electrolysis-based hydrogen production contingent on sustained IRA incentives.
Distributed Energy Resources (DERs)	69-78		Growth in rooftop solar, energy storage, and demand response via DERs.

Figure 4: Expected Segmented Energy Growth Increase by 2044 with Level of Certainty

MISO's updated load forecast accounts for load growth across five key drivers and incorporates the expected system impacts arising from Distributed Energy Resources (DERs) (Figure 4). Accounting for a range of possible technology and policy outcomes, these drivers are organized by most certain to least certain below:

- **Building Electrification**: Incentivized through state- and federal-level policies which aim to increase efficiencies and lower carbon emissions, the electrification of heating systems and other building appliances is expected to increase energy demand by 36-43 TWh by 2044. One federal program offers household rebates of up to $14,000 for efficiency measures, heat pumps and other appliances. In Illinois, municipal adoption of the Stretch Energy Code will encourage decarbonization through the electrification of household appliances.
- **Artificial Intelligence (AI) Revolution and Data Centers:** Demand for enhanced computing power arising from the adoption of AI and cloud-based applications is resulting in a rapid expansion of data centers. These facilities are expected to increase MISO's energy demand by 149-241 TWh by 2044.
- **Electric Vehicles (EV)**: Spurred by federal incentives in the IRA and declining battery costs, the electrification of the transportation sector, including passenger cars, commercial fleets and buses, is expected to add 54-91 TWh of additional energy demand by 2044. The adoption of EVs is expected

[2] Mandates and incentives include **Illinois**: Climate and Equitable Jobs Act (CEJA PA 102-0662), including rebates for electric vehicles and charging stations, and the allowance for municipalities to adopt stringent building codes (see section R408 of the Illinois Residential Stretch Energy Code); **Minnesota:** HF 2083 including the electric vehicle rebates included in Minnesota Statute 216C.401; and **Michigan**: The MI Vehicle Rebate (for new electric, hybrid and traditional vehicle sales), and the Michigan Home Energy Rebates program (MiHER).

to occur most rapidly between 2030-2044, reaching a compound annual growth rate (CAGR) of 10% to 11%.

- **New Industry Development and Reshoring:** Electrification in the oil and gas industries is expected to result in 16-94 TWh of additional energy demand by 2044. At the same time, reshoring of industries, spurred by federal policies such as the CHIPS Act and the IRA, are expected to increase energy demand by 5-11 TWh by 2044.
- **Green Hydrogen:** Recent federal policies and initiatives have sought to expand the use of hydrogen sourced from renewable energy (green hydrogen) across several hard-to-decarbonize sectors of the economy. Electrolysis-based green hydrogen production could increase MISO's demand by 26-95 TWh by 2044, but it is highly contingent upon sustained IRA-based incentives that help offset the high costs of electrolyzers and renewable energy.
- **Distributed Energy Resources (DERs):** The growth of rooftop solar, energy storage and other DERs presents challenges and opportunities for MISO, complicating operations while enhancing demand response options. The contribution of DERs to MISO's demand is expected to increase by 69-78 TWh by 2044.

MISO must also account for potential economic headwinds and recessionary pressures which could temper the rate of load growth from these industry developments. At the same time, emerging future load drivers such as green hydrogen production and the anticipated cost parity of EVs introduces further complexity to load projections. Shifting climate patterns and the expanding role of distributed energy resources will also continue to affect load profiles across the region, requiring MISO to remain adaptive in managing these evolving demands.

HISTORICAL TRENDS AND EVOLUTION OF LOAD DRIVERS

Since the 2008 economic recession, MISO's peak load demand growth has remained essentially flat, in stark contrast to the 2% to 3% annual increases seen prior to the downturn. Between 2009 and 2024, MISO's peak load had an average annual growth rate of 0.5%. Load forecasting during this period relied heavily on econometric-based evaluations of gross load, using standard economic indicators such as gross domestic product (GDP), population and employment rates. These methods, while useful, rest on the premise that historical trends and relationships between economic variables and electricity demand will persist into the future. During times of economic instability or periods of rapid industry transformation, these relationships no longer hold, requiring the development of new load forecast methodologies.

In 2019, MISO developed a new set of forward-looking futures scenarios to guide the Long-Range Transmission Plan (LRTP) and other planning studies. This effort considered a range of possible economic, political, and technological outcomes to project load growth over a 20-year study period, addressing uncertainties related to electrification, carbon policies, generator retirements, renewable energy levels, natural gas prices and generation capital costs. Since then, dynamic macroeconomic conditions and new state and federal policies have initiated the need to further expand upon these scenarios to incorporate evolving drivers such as data centers and hydrogen.

DEVELOPMENT APPROACH AND SCENARIO EVOLUTION

For the 2024 updated load forecast, MISO utilized a comprehensive approach that combined multiple data sources and stakeholder outreach to forecast future demand. Additionally, MISO engaged a range of third-party consultants, academic institutions and data providers to contribute specialized expertise and industry insights, lending depth and validation to MISO's forecasts.

Outreach with MISO's stakeholders signaled the need for an updated load forecast, indicating:

- MISO's members are incorporating large load additions into their near-term forecasts.
- The large scale and rapid development of these additions create challenges for members in integrating large loads in a timely manner.
- Submitted requests for Expedited Project Reviews have rapidly increased as a result of large load additions, from one in the MTEP 2020 study cycle to 15 in the 2024 study cycle.
    - The Expedited Project Review process enables MISO to evaluate transmission needs too urgent for a full MTEP cycle, such as the many upgrades required by individual large loads.
    - Additionally, MTEP has seen an increasing number of load growth projects, including reliability projects driven by individual large loads or aggregated additions.
- The most recent stakeholder-provided load forecast through the 2024 OMS Survey indicates a 1% CAGR of expected peak load growth from 2023 to 2033—a significant increase over the 0.25% CAGR submitted in 2019. MISO conducted analyses of these inputs to develop a consolidated stakeholder forecast which revealed expected load growth at rates similar to MISO's other trajectories in the near term (mid-2030s).
- The rapid pace of large load additions will likely continue, as well as the expansion of flexible load resources.

Considering stakeholder and other inputs, MISO developed an end-use-based customer segmentation framework to address the urgency inherent to rapidly evolving load growth by relying upon these objectives:

- Develop and maintain a series of future load projections based on a range of possible industry developments.
- Consolidate load forecast methods across time horizons to produce internally consistent outlooks.
- Better discern load growth by specific drivers and customer classes.
- Enable actual historical load information to serve as a starting point for future load forecasts.
- Ensure alignment with evolving regulatory and Tariff needs.

MISO draws on the progressive forecast methodologies used in the MISO Futures Series 1A scenarios while incorporating the predicted impact from several emerging drivers, including EVs, building electrification, data centers, new industry manufacturing and green hydrogen. The updated forecast load trajectories — Low Trajectory, Current Trajectory and High Trajectory — correlate loosely with Futures 1A, 2A and 3A (Figure 5). Comparison of MISO's updated load forecast trajectories and the MISO Futures Series 1A scenarios reveals similar expectations for load growth in the near term (by 2030), with more substantial variation occurring in the later years (Figure 6 and Figure 7).

MISO Future Series Scenarios	Updated Forecast Trajectories
Future 1A assumed that demand and energy growth are driven by existing economic factors, with small increases in electric vehicle (EV) adoption	Low Trajectory closely aligns with the stakeholder forecast and includes modest load driver additions
Future 2A accounted for an increase in electrification	Current Trajectory accounts for load driver additions based on technology adoption trends and future industry policy. This scenario reflects load growth from data centers, domestic manufacturing, and green hydrogen production
Future 3A introduced a larger electrification scenario	High Trajectory assumes aggressive adoption of EVs, buildouts of data centers, green hydrogen and other domestic commercial and industrial processes, which directionally align to state, regulatory and customer goals

Figure 5: Description of Future Series Scenarios and Updated Forecast Trajectories

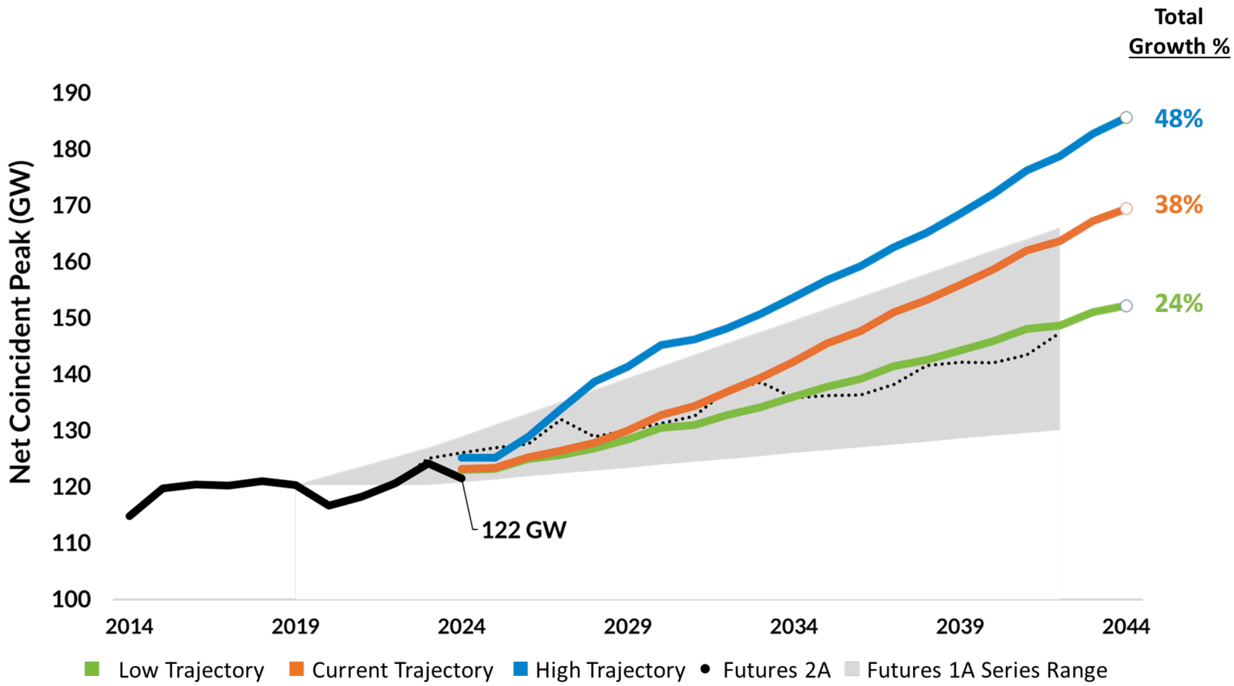


Figure 6: MISO Annual Coincident Peak Demand Forecast with Total Percent Change

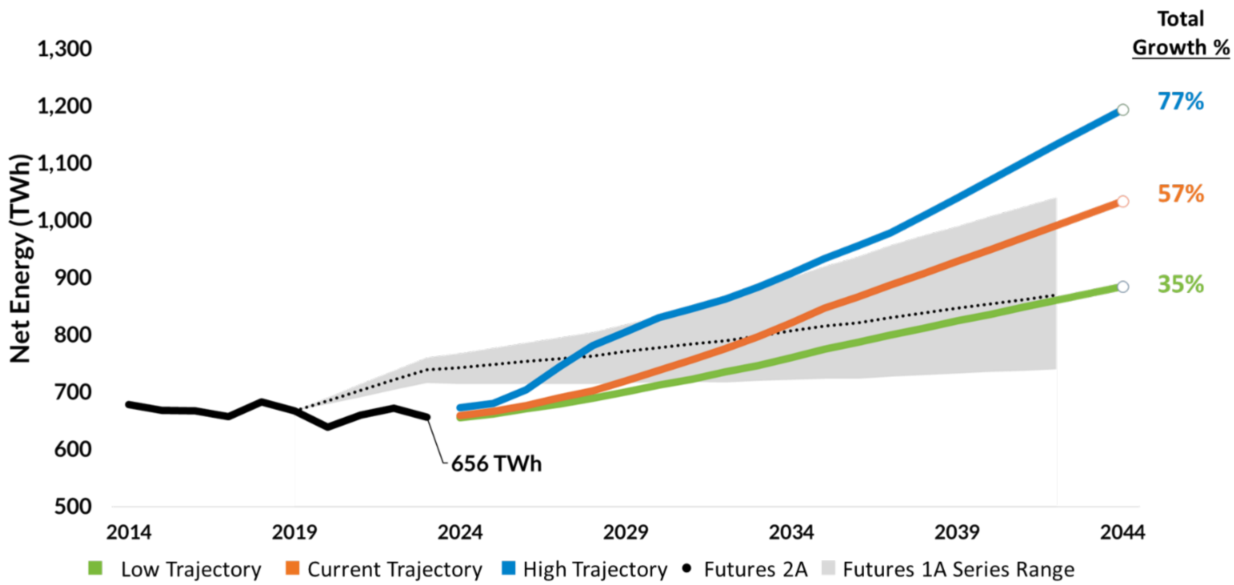


Figure 7: MISO Annual Net Energy Forecast with Total Percent Change

INCORPORATING CHANGING CLIMATE AND WEATHER IMPACTS

Climatic changes in MISO's footprint will likely result in significant fluctuations in cooling and heating demands arising from shifts in temperature patterns. Warming trends in MISO's footprint are expected to increase weather-sensitive loads, particularly among residential and commercial air conditioning and data centers, which have high cooling needs. Conversely, in the near term, milder winters may reduce the need for heating, resulting in lower electricity use during winter. Climate models predict an increase in average temperatures across MISO regions, leading to higher cooling degree days and a potential decrease in heating degree days (Figure 8).

To account for anticipated climatic changes, MISO's updated load forecast approach integrates climate change impacts by adjusting demand projections for key sectors such as residential and commercial cooling and heating and data centers. These adjustments account for expected regional temperature increases, allowing MISO to better consider weather sensitivities over the forecast period.

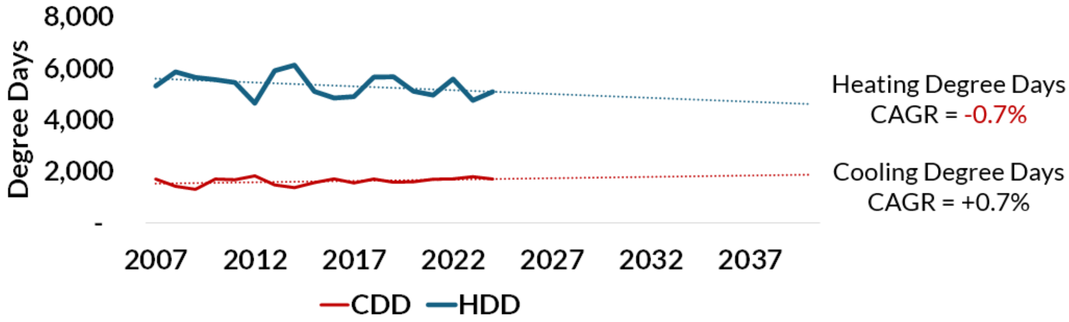


Figure 8: MISO Historical and Projected Cooling and Heating Degree Days

MISO FORECASTS BY LOCAL RESOURCE ZONE

MISO is organized into Local Resource Zones (LRZs), which are geographic areas within MISO's footprint that help manage resource adequacy and reliability. The LRZ structure supports MISO's planning, forecasting, and resource allocation by allowing it to analyze and respond to demand, capacity, and reliability requirements on a more localized basis. Each LRZ reflects specific regional characteristics, such as local energy needs, available generation resources, transmission constraints, and environmental regulations (Figure 9).

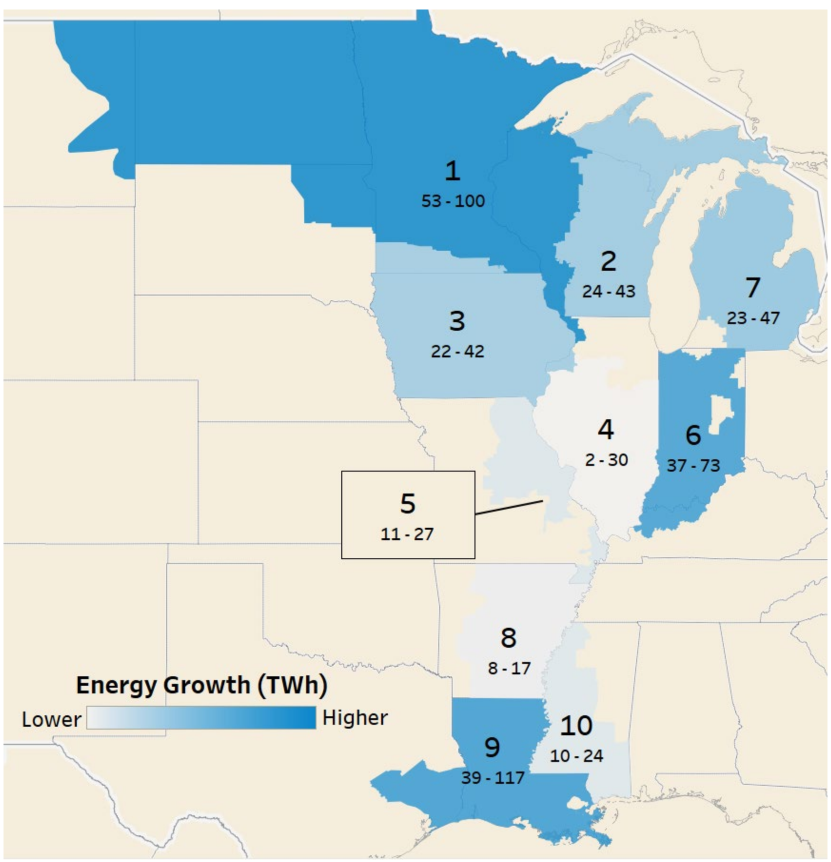


Figure 9: 2024 -2044 Expected Load Growth by MISO Local Resource Zones (LRZs) Low-High Ranges

MISO anticipates varied load growth across its footprint due to diverse economic conditions, environmental regulations, and consumer preferences. The updated load forecast approach allows MISO to assess each Local Resource Zone (LRZ) independently, capturing unique drivers behind regional load forecasts.

By 2044, MISO expects LRZs 1 (Minnesota and North Dakota), 6 (Indiana), and 9 (Louisiana and East Texas) to see the highest demand growth, driven by distinct regional factors. Electrified space heating and favorable economic incentives for data centers are projected to raise demand in LRZs 1 and 6. MISO forecasts LRZs 1 and 7 (Southern Michigan) will lead in EV demand by 2044, bolstered by state-level incentives for EV purchases, charger installation, and charging rates in Minnesota and Michigan. Under MISO's Current Trajectory, MISO is projected to experience an 82 TWh growth in EV energy demand by 2044.

Data center expansion will also drive growth throughout several LRZs. LRZ 1 is expected to see an additional 4 GW of demand throughout the forecast period, mainly from a burgeoning data center market in Minnesota and North Dakota. Similarly, LRZ 3 (Iowa) will continue to attract data centers in the Des Moines area due to low construction costs, ample wind energy, and strong telecommunications infrastructure, with additional demand coming from ethanol refineries that benefit from fuel-blending requirements. In LRZ 6, data center growth aligns with incentives for heavy industries such as steel and aluminum manufacturing. LRZ 2 (Wisconsin and Northern Michigan) will likely attract hyperscale data centers to align with relevant zoning requirements and incentives that have been implemented.

While MISO's northern states will see increased demand from data centers and building electrification in addition to manufacturing, southern states are projected to grow primarily from industrial drivers. LRZ 9, covering Louisiana and eastern Texas, is expected to experience load growth primarily from electrification in the oil and gas sectors and the rise of green hydrogen production.

Every LRZ within MISO's footprint is expected to experience some load growth, though its extent remains uncertain. Load growth projections in LRZs 1, 6 and 9 exhibit wide ranges of potential outcomes, largely due to uncertainties around consumer adoption of high-cost technologies such as heat pumps, EVs, and the stability of IRA incentives, particularly for green hydrogen production in LRZ 9.

As industry developments continue to drive load growth on a region-specific basis, MISO remains committed to continually improving its load forecast approach to account for the most recent economic developments and energy policy directives.

NEXT STEPS

As the energy industry continues to evolve rapidly, MISO remains committed to improving its load forecast methodology. MISO seeks to integrate best practices that enhance adaptability and responsiveness to emerging trends. Key enhancements will include more granular stakeholder inputs to gain valuable insights into large load behaviors and better align forecasts with industry needs.

Additionally, MISO will improve its visibility into Distributed Energy Resource (DER) growth, facilitating more efficient transmission planning and offering a clearer understanding of load-modifying trends. MISO has historically had little visibility into the impact of DERs, given their placement on distribution systems. MISO plans to strengthen monitoring capabilities to track emerging technologies and changing behaviors, such as the growth of DERs, the flexibility of data centers, the impact of weather patterns, and the timing of green hydrogen facility development.

Finally, MISO will enhance forecasting automation by leveraging historical data to project future load drivers, ensuring more consistent and MISO-specific load forecasts in the future.

While MISO recognizes the range of load values forecast in this report, it remains comfortable that these values accommodate the broad extent of possible economic, technological and political changes which could alter the rate of load growth in its footprint.

Changing Load Driver Dynamics

The rapidly evolving energy landscape, driven by the demand for data centers, economic growth, key federal legislation such as the IRA, Infrastructure Investment and Jobs Act, and CHIPS Act, and domestic manufacturing incentives, has introduced new complexities to long-term load forecasting. MISO's forecast summaries explain the expected load impacts arising from evolving industry developments and provide brief descriptions of the uncertainties surrounding their impact within MISO's footprint.

BUILDING ELECTRIFICATION

OUTLOOK

Building electrification, driven by heat pumps and electric appliances, and supported by federal rebates and state policies, is expected to drive load growth within MISO.

- Electrification, particularly from heat pumps, is expected to increase demand during colder months.
- Federal incentives, such as IRA rebates for heat pumps, promote this shift.

Building electrification is emerging as a key load growth segment for MISO, driven by the replacement of fossil fuel-based heating systems with electrified heat pumps, as well as the widespread adoption of electric appliances and tools (Figure 10).

- Energy demand from residential and commercial buildings is projected to grow by 36-43 TWh by 2044, with appliances and space cooling accounting for the largest share.
    - Through 2030, building electrification is not anticipated to result in load growth, while demand post-2030 is expected to rise more significantly, reaching 36-43 TWh as customers transition to electrified end uses.
- Energy demand from building electrification is estimated by analyzing key drivers, including floor space per household, technology efficiency and technology mix. This approach factors in urbanization, economic trends and the uptake of consumer electronics.
- Key uncertainties in building electrification arise from the long-term stability of IRA incentives, possible future improvements in consumer technology, and the rate of adoption of high-cost technologies, particularly on an interregional basis.

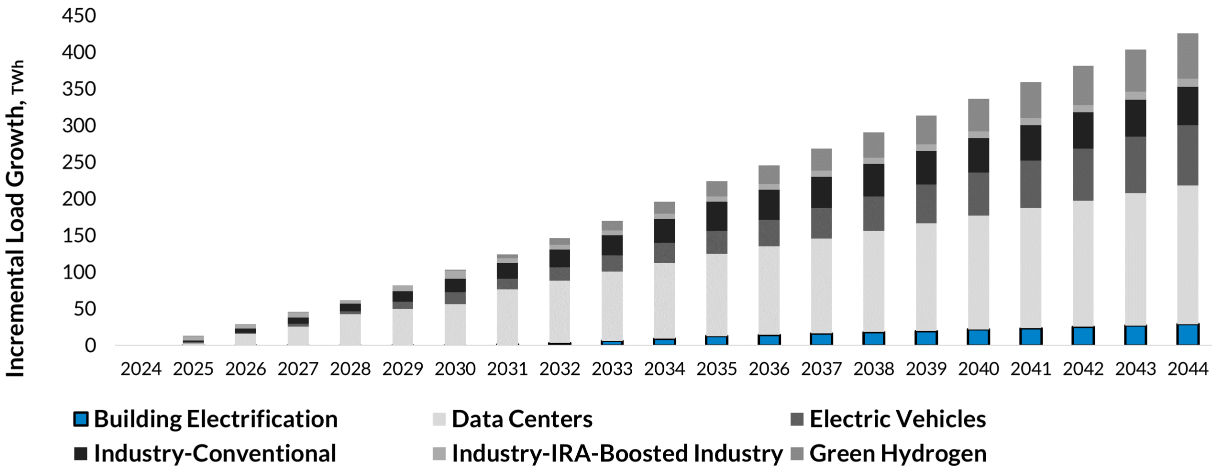


Figure 10: MISO Current Trajectory Incremental Load Growth Forecasts by Segment (TWh) – Building Electrification Highlighted

Heat pumps, increasingly favored over traditional natural gas or oil-based heating systems due to their higher efficiency and lower greenhouse gas emissions, may result in altered load profiles, with higher demand during colder months due to the increased use of electric heating. The IRA incentivizes the installation of heat pumps and other home efficiency upgrades through rebates and tax credits available to both homeowners and renters. One prominent program, the Home Electrification and Appliances Rebate, offers participants up to $14,000 in total rebates. The push to electrify buildings is being further supported by state-level policy objectives, like Illinois' Climate and Equitable Jobs Act, which promotes equitable energy transitions by providing access to certain technologies for disadvantaged communities.

While the building sector presents a relatively higher certainty for load growth, uncertainties remain regarding consumer adoption of high-cost technologies and the durability of IRA incentives amidst changes in presidential administration. The willingness of consumers to embrace technologies such as heat pumps may hinge on continued policy support and cost reductions. Across each of the end uses examined in the building segment, fluctuating or decreasing load is expected to occur, but to differing extents. This is primarily caused by projected climate impacts and efficiency improvements over time.

MISO's building electrification segment incorporates projections across these end uses:

- Appliances
- Cooking
- Lighting
- Space cooling
- Space heating
- Water heating

FORECAST METHODOLOGY FOR BUILDING ELECTRIFICATION

MISO's load forecast approach accounts for building electrification by analyzing four main drivers across critical end uses in residential and commercial buildings, including space heating/cooling, water heating, lighting, appliances and cooking (Figure 11). These drivers are:

(1) Floor space/number of households, based on urbanization, demographic trends and housing preferences

(2) Technology efficiency, which considers the adoption of more efficient technologies and regional user preferences which in some cases results in decreasing load over the forecast period
(3) Welfare, which reflects material ownership and energy use increases linked to economic development trends
(4) Technology mix, forecasted from existing technology stocks, their lifespan, turnover rate and consumer adoption of new technologies

Consumer adoption is modeled using total cost of ownership (TCO), accounting for capital expenditures, operating costs, fuel expenses, and emissions costs, where applicable.

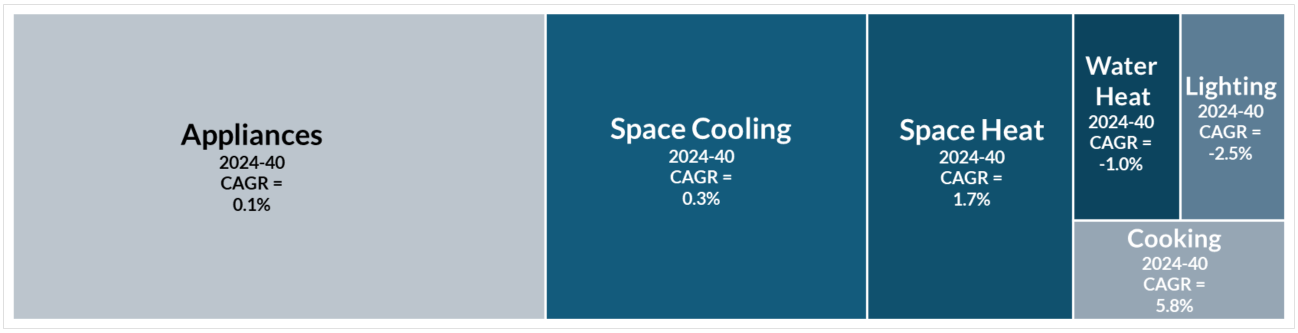


Figure 11: MISO Total Energy Consumption by End-Use in 2040: Building Electrification Segment – Current Trajectory Scenario (Box Size Indicates Share of Total Energy Use from End Use)

AI REVOLUTION AND DATA CENTERS

OUTLOOK

MISO expects rapid data center demand growth, driven by the rise of AI, cloud technologies and web services. While data centers may result in increased power needs due to their constant operations and cooling, delays in site selection, construction and supply chain issues could impact growth timelines.

- MISO's favorable infrastructure and relatively low energy costs make it ideal for data center expansion.
- Growing AI and cloud services are expected to significantly boost electricity demand.

MISO is poised for rapid data center demand growth due to low energy costs and favorable generation and transmission capacity relative to other regions. The development of data centers for AI applications, cloud technologies, and web-based services require constant power to operate servers, cool equipment, and ensure uninterrupted service, and it may result in a dramatically increased load factor within MISO's footprint.

The growing use of AI is expected to significantly increase energy growth in MISO's region as new data centers take advantage of relatively low renewable energy costs to meet sustainability targets.

- By 2044, data center energy demand in the MISO region is projected to grow by 149-241 TWh across the three trajectories (Figure 12).
    - Near-term growth (by 2030) is estimated at 42-80 TWh.

- Long-term growth (post-2030) is estimated at 107-161 TWh.
- Data center energy demand projections are based on project-level capacity announcements, MISO's Expedited Process Review requests and technological trend analysis to capture growth in emerging markets. Attrition rates varied by trajectory, and Power Usage Effectiveness (PUE) metrics were applied to account for total power consumption, including cooling and lighting needs.
- Key uncertainties in AI-driven load growth include site selection challenges, supply chain bottlenecks for critical equipment, and construction delays due to limited labor availability.

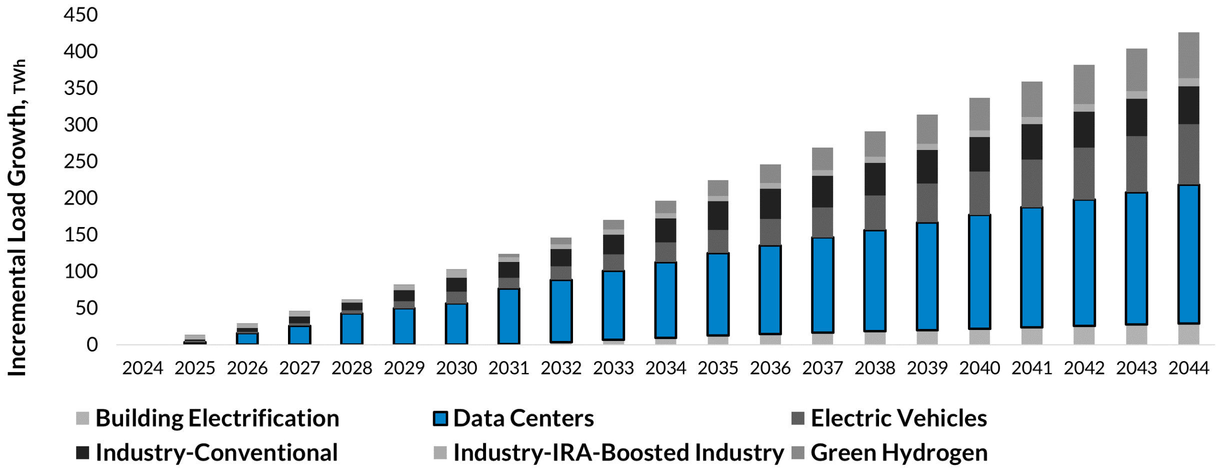


Figure 12: MISO Current Trajectory Incremental Load Growth Forecasts by Segment (TWh) – Data Centers Highlighted

Uncertainty surrounding load growth from AI and data centers is influenced by project developers' ability to identify optimal construction sites that offer low operational risk, reliable connectivity, and access to skilled labor. Delays can occur when developers struggle to secure such sites, which can prolong the go-to-market timing for new data centers. Furthermore, protracted timelines for acquiring critical long lead equipment, along with supply chain constraints and insufficient vendor management, may contribute to extended construction schedules, creating variability in the projected rate of load growth from data centers.

FORECAST METHODOLOGY FOR AI REVOLUTION AND DATA CENTERS

MISO uses a multifaceted approach to forecasting potential growth in data centers and other large energy loads, integrating various information sources to build a comprehensive view of future demand. Public announcements provide early insights into new data center projects and expansions, keeping MISO informed of upcoming demand. Data center capacities are validated against the large load additions in the MISO footprint by monitoring the large loads submitted through the Expedited Process Review projects.

Additionally, contracted third-party consultants and data providers contribute specialized expertise and industry insights, lending depth and validation to MISO's forecasts. All gathered data is consolidated to support MISO trend analysis, comparison of forecasts and informed decision-making (Figure 13). In the future, coordination with stakeholders, including data center operators and local governments, will enable MISO to gather precise demand projections and align infrastructure needs effectively.

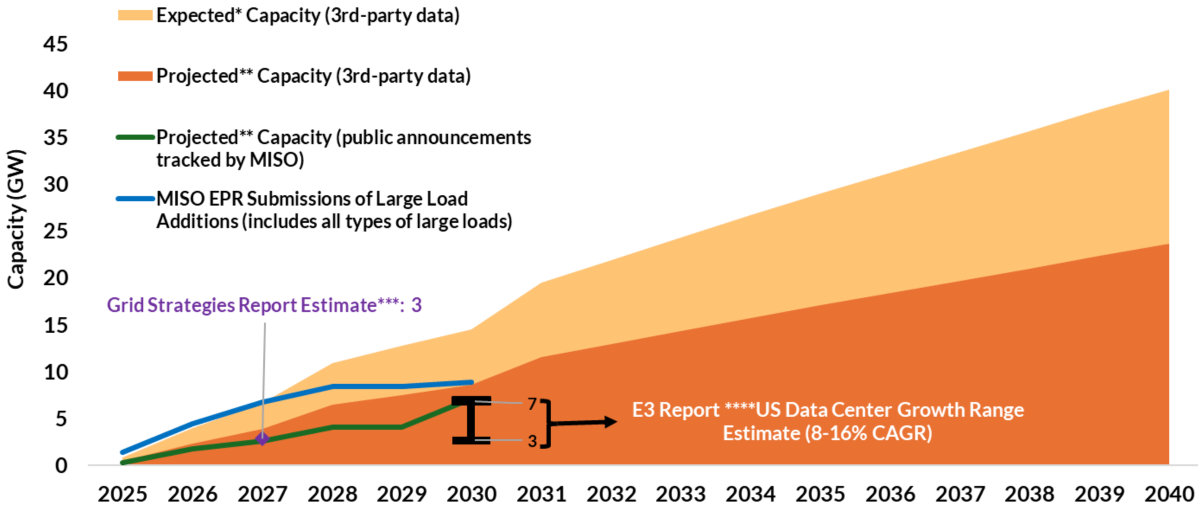


Figure 13: Incremental Data Center Capacity (GW) – Data Center Source Compendium on Current Trajectory Scenario[3]

Accurately forecasting data center growth presents significant challenges. Confidentiality practices among developers often restrict access to specific information about load expectations, equipment and operational timelines. Data centers are frequently developed in multi-year phases, with progress depending on factors such as construction timelines, technology integration and market demand. Publicly available information is typically limited to land transactions, which provide little insight into a data center's power needs or operational timeline. Though developers and municipalities may share preliminary figures on anticipated size or power consumption, these estimates may be based on unrelated projects and often require validation. Rapid advancements in server technology and cooling systems can alter a data center's power consumption profile, and many data centers are designed with scalability to accommodate fluctuating demand.

Furthermore, geographic factors like climate and access to renewable energy sources can also influence energy requirements. To address these challenges and improve forecast accuracy, MISO leverages a combination of public announcements, stakeholder partnerships, third-party expertise and a comprehensive data resource to evaluate trends and refine projections. Analyzing technological trends allows MISO to anticipate future demand shifts, proactively planning infrastructure to meet the evolving needs of data centers and other large energy loads. Through this integrated approach, MISO aims to enhance its responsiveness to the dynamic landscape of energy demand driven by data center growth.

[3] Sources:
*'Expected Capacity' = announced capacity of data centers in MISO footprint (third-party data).
**'Projected Capacity' = 'Expected Capacity' *(1- Attrition Rate (41%))
**https://gridstrategiesllc.com/wp-content/uploads/2023/12/National-Load-Growth-Report-2023.pdf
***https://www.ethree.com/wp-content/uploads/2024/07/E3-White-Paper-2024-Load-Growth-Is-Here-to-Stay-but-Are-Data-Centers-2.pdf

ELECTRIC VEHICLES

OUTLOOK

Electric vehicle (EV) adoption in the MISO region is projected to drive up electricity demand over time, supported by federal incentives and declining battery costs, though near-term growth is hampered by slower sales and economic factors.

- Long-term EV adoption will increase MISO energy demand, but near-term growth is limited by economic challenges.
- Federal incentives and lower battery costs support EV growth, though infrastructure and production constraints remain.

The growing adoption of EVs in MISO's footprint is expected to increase electricity demand, though slower sales in the region have led to a reduction in the projected near-term rate of penetration, compared to earlier forecasts.

- EV energy growth is expected to increase by 54-91 TWh by 2044, with the greatest portion of this increase materializing post-2030, when the adoption rate of EVs is expected to occur at a rate of 6% to 11% CAGR (Figure 14).
    - 13-35 TWh in the near term, by 2030
    - 41-56 TWh in the long term, post-2030
- MISO's EV forecast combines public data, third-party resources and state-level vehicle registrations, using a Sigmoid S-curve model for penetration rates. Local adjustments are made at the LRZ and LBA levels based on historical data. Key factors like miles driven are sourced from the U.S. DOE, while hourly charging profiles are generated using NREL's EVI-Pro model with customized inputs.
- Uncertainty in MISO's EV forecast arises from the pace and scale of public charging infrastructure, resource shortages which may be alleviated or exacerbated by domestic manufacturing and future duties on imports, the persistently higher costs of EV over internal combustion engine models, and potential policy shifts on emissions standards.

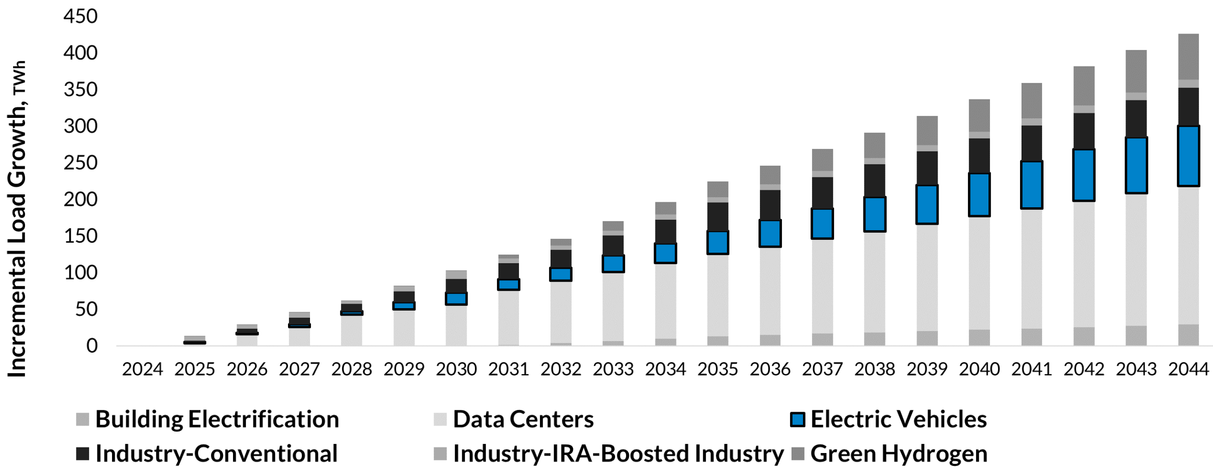


Figure 14: MISO Current Trajectory Incremental Load Growth Forecasts by Segment (TWh) – Electric Vehicles Highlighted

EV adoption in the MISO footprint is projected to significantly increase energy demand over time, as well as potentially alter how and when electricity is consumed as illustrated in the MISO Electrification Insights report. Recent federal incentives provided in the IRA, coupled with declining costs of EV batteries, also signal an increase in sales for EV adoption. However, sales within MISO's footprint have been relatively slow in comparison to other ISO territories, given recent inflationary pressures and the comparatively low incomes of the states within MISO relative to rest of the country. This resulted in a delay in the rate of EV adoption from the 2019 future assumptions, especially in the near term.

Several factors contribute to uncertainty in MISO's EV forecast. Delays in developing public charging infrastructure slow EV adoption, especially as the market reaches segments with limited home charging access. Production remains constrained by resource shortages, such as semiconductors and raw materials, while the total cost of ownership for lower-priced EV models still exceeds that of comparable internal combustion engine vehicles. Additionally, policy and regulatory shifts concerning emissions standards create long-term uncertainty.

FORECAST METHODOLOGY FOR ELECTRIC VEHICLES

MISO's EV forecast incorporates projections across these end uses:

- Buses
- Heavy-duty trucks
- Light commercial vehicles
- Light-duty trucks
- Medium-duty trucks
- Passenger vehicles

MISO employs a combination of techniques and data sources to develop its EV forecast. Aggregate forecasts for EV penetration are drawn from public data and contracted third-party resources, then consolidated into a comprehensive set of results to establish baseline expectations and range estimates. EV penetration rates are derived from historical state-level data on vehicle registrations collected by the Department of Energy and are projected using a standard Sigmoid S-curve model. MISO refines EV adoption rate expectations at its Local Resource Zone (LRZ) and Local Balancing Authority (LBA) levels based on historical data ratios. Key volume determinants, such as average miles driven per year, are sourced from the U.S. Department of Energy's Alternative Fuels Data Center and other publicly available sources. Hourly EV charging profiles by customer segment are generated using NREL's EVI-Pro model, which incorporates customized inputs such as temperatures and utility rate plans for residential, commercial and public charging scenarios (Figure 15, Figure 16).

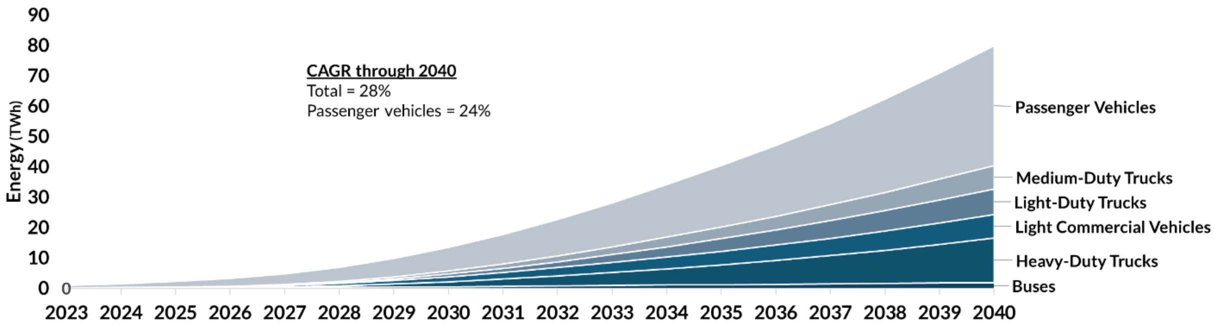


Figure 15: MISO Current Trajectory Energy Consumption (TWh) by Vehicle Type

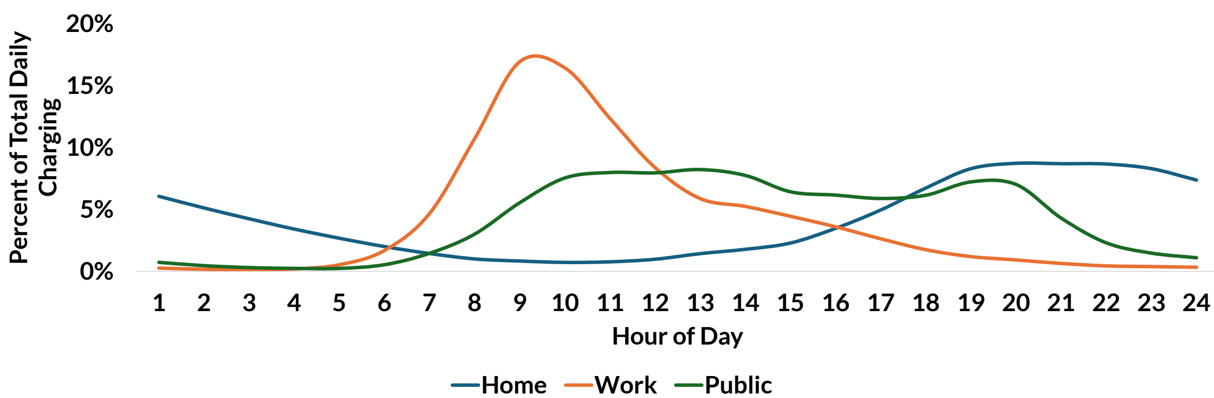


Figure 16: Average Hourly Electric Vehicle Charging Profile Across MISO's Service Area

NEW INDUSTRY DEVELOPMENT AND RESHORING

OUTLOOK

Industry reshoring is expected to drive load growth in MISO as energy-intensive manufacturing sectors expand, though the pace remains uncertain.

- Federal initiatives such as the CHIPS Act and IRA are spurring growth in sectors such as semiconductors and renewable energy.
- MISO's low renewable energy costs attract industrial developments seeking sustainable, affordable power.

MISO's 2024 load forecast categorizes industry segments into "conventional" and "IRA-boosted" groups to more clearly highlight the load impacts driven by recent IRA provisions (Figure 17).

Conventional Industry:

- Growth in conventional industry demand is projected to be largely driven by electrification in the oil, gas and chemical/petrochemical sectors along the Gulf Coast, with energy demand expected to rise by 16-94 TWh within the MISO footprint by 2044.
  - Near-term growth (by 2030) is projected at 8-44 TWh.
  - Long-term growth (post-2030) is projected at 8-50 TWh.
- Industrial energy demand projections and fuel mix are estimated using baseline consumption and fuel mix data from the International Energy Agency, combined with market forecasts, GDP/population-based regressions, and industry-specific modeling for heat and non-heat applications. Additional oil and gas electrification is incorporated based on sector-specific decarbonization goals.

IRA-Boosted Industry:

- Industrial energy load growth in MISO's region, primarily driven by carbon capture and battery manufacturing and reliant on sustained incentives, is projected to increase by 5-11 TWh by 2044.
- MISO's IRA-boosted industry forecast focuses on North American Industry Classification System (NAICS) code 33 industries, with data sourced from public resources, industry news, and consulting. The approach considers economic conditions, energy infrastructure, and targeted sectors like semiconductors and EV manufacturing.
- Key uncertainties in IRA-driven load growth relate to the durability of federal incentives and challenges arising from the shift away from foreign-dominated manufacturing sectors, especially in solar photovoltaics (PV).

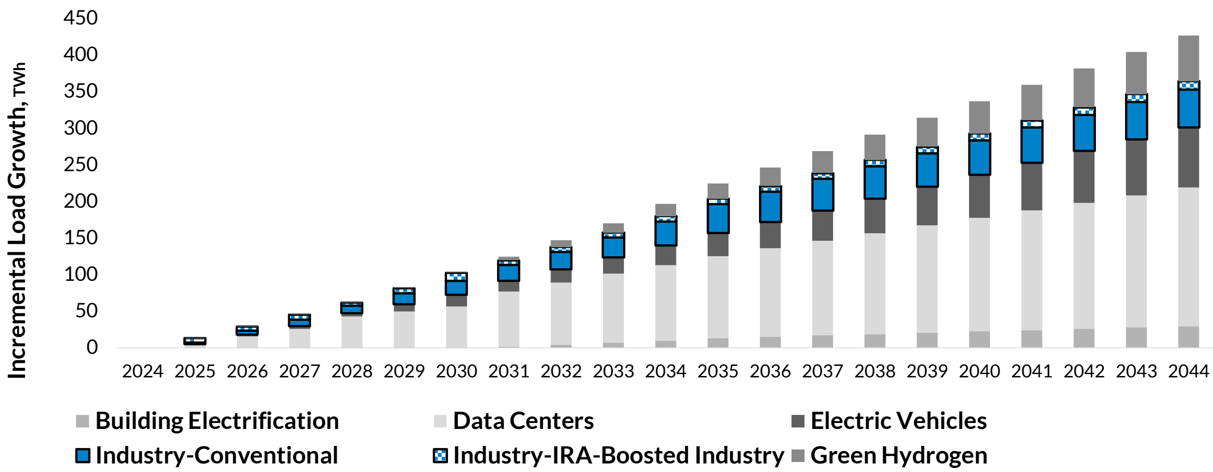


Figure 17: MISO Current Trajectory Incremental Load Growth Forecasts by Segment (TWh) – Conventional and IRA-Boosted Industry Highlighted

The term "industry reshoring" refers to the process of bringing manufacturing and other industrial operations back to domestic locations from overseas. The return of both conventional and new industries to the U.S. is expected to contribute significantly to load growth in MISO's footprint. Federal legislation such as the CHIPS Act and the IRA, in addition to concern about supply chain disruptions and geopolitical tensions, have prompted many industries to bring production back to the U.S., particularly in sectors such as advanced manufacturing, semiconductors and renewable energy technologies. The CHIPS Act alone has allocated $52 billion for semiconductor research, development and manufacturing, which is expected to lead to the establishment of new, energy-intensive semiconductor fabrication facilities. Recent pledges to enact duties on imports may further encourage the reshoring of certain industries but could result in elevated domestic production costs and further supply chain shocks in the near term.

Recent federal and state legislation is expected to contribute to the growth of new manufacturing sectors focused on emerging technologies. By providing financial incentives for the domestic production of technologies like solar panels, batteries and EVs, these policies are expected to result in increased electricity demand from industrial processes. As these industries expand, many companies will prioritize regions with affordable and sustainable energy options. The MISO region's comparatively low energy costs make it a prime candidate to attract new manufacturing plants, as companies seek to lower both operational costs and their carbon footprint by integrating wind, solar and other renewable energy sources into their power supply.

Uncertainties around load growth occurring from industry reshoring primarily stem from the ability of federal incentives to survive future policy shifts. At the same time, the diverse geographic nature of new, domestic industry projects receiving federal funds may result in load growth that is somewhat invulnerable to future political changes. Although reshoring-focused incentives aim to reduce reliance on foreign manufacturing, especially in solar PV, the supply chain remains dominated by foreign entities, and the transition to domestic production could be slower than projected.

MISO's conventional industry segment incorporates projections across these end uses:

- Agriculture and forestry
- Chemicals and petrochemicals
- Mining
- Non-ferrous metals

- Energy industry own use – oil and gas
- Food and tobacco
- Non-metallic minerals
- Additional oil and gas electrification

MISO's industry segments affected by the IRA incorporate projections across these end uses:

- Battery manufacturing
- Carbon capture, usage, and storage (CCUS)
- Direct air capture (DAC)
- Electrolyzer manufacturing
- Semiconductor manufacturing
- Solar manufacturing

FORECAST METHODOLOGY FOR NEW INDUSTRY DEVELOPMENT AND RESHORING

MISO's forecast strategy involves baseline establishment and segmentation on a level specific to the Local Balancing Authority (LBA), focusing on NAICS code 33 industries such as electronics, metals, and transportation equipment. Data collection relies on public sources, industry news and external consulting, with future enhancements aimed at refining insights on an LBA-specific basis. MISO's manufacturing growth analysis considers economic conditions, energy infrastructure and targeted sectors, such as semiconductors and EVs (Figure 18). Industrial energy demand projections, including fuel mix estimates, are derived from baseline consumption data and market forecasts. This approach, evolving through enhanced data collection and industry collaboration, will guide MISO's infrastructure planning amid capital and recessionary uncertainties.

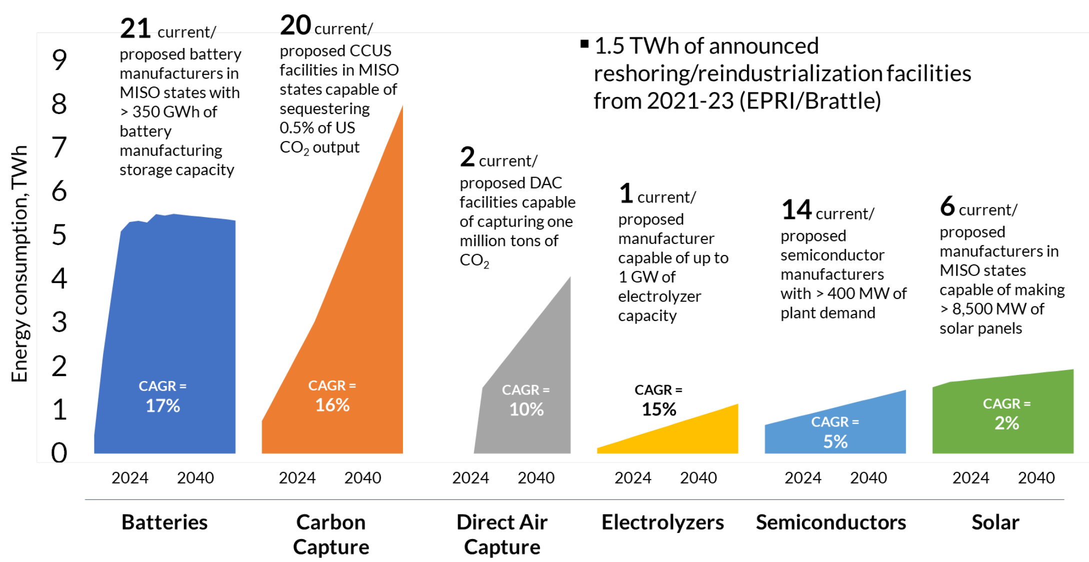


Figure 18: Current, Announced and Proposed Facilities Included in MISO's IRA-Boosted Industry Segment

Key infrastructure investment drivers include federal laws — the Infrastructure Investment and Jobs Act, CHIPS Act and IRA — which aim to revitalize manufacturing, enhance technology security, and foster an electrified, low-carbon economy. The northern states in MISO's footprint are especially positioned for accelerated manufacturing growth due to transmission capacity and low-cost resources.

GREEN HYDROGEN

OUTLOOK

Green hydrogen production, supported by federal policies, has the potential to drive load growth in MISO, though high production costs and infrastructure challenges impact its economic viability.

- Federal incentives are crucial for making green hydrogen competitive and supporting decarbonization.
- High costs and limited infrastructure present growth challenges for the industry.

The production of green hydrogen is expected to be a major driver of load growth in the coming decade. Federal policies and initiatives, particularly those outlined in the IRA and the Department of Energy's (DOE) Hydrogen Shot, attempt to expand the use of green hydrogen across hard-to-decarbonize sectors of the economy by providing crucial subsidies to make green hydrogen more cost-competitive (Figure 19).

- MISO's load forecast estimates green hydrogen-related energy demand to grow by 26-95 TWh by 2040.
    - Near-term growth (by 2030) is projected at 1-2 TWh.
    - Long-term growth (post-2030) is projected at 25-93 TWh.
- Power demand for green hydrogen is calculated using the levelized cost of hydrogen (LCOH) on a state-specific basis using public data and DOE analyses.
- Key uncertainties for green hydrogen include rising capital costs, transport infrastructure limitations, and potential bottlenecks in electrolyzer manufacturing capacity.

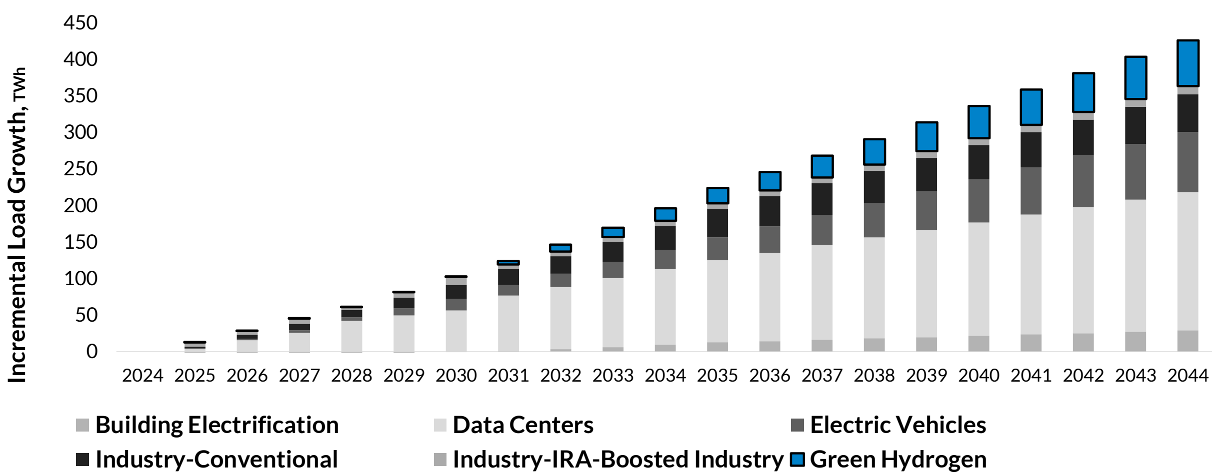


Figure 19: MISO Current Trajectory Incremental Load Growth Forecasts by Segment (TWh) – Green Hydrogen Highlighted

The future of the green hydrogen industry is closely tied to the economics of producing the fuel, given the current high costs of electrolyzers and the intermittent nature of renewable energy sources. The ongoing provision of federal subsidies will therefore play a crucial role in mitigating these economic challenges, helping to offset the costs of renewable energy and electrolyzer technology, and making green hydrogen more cost competitive. Recent challenges in the green hydrogen industry have included higher-than-expected capital expenditures and increasing costs of renewable power purchase agreements, which have challenged the economic viability of green hydrogen across many applications. Infrastructure challenges, including the limited pipeline network for hydrogen transport and permitting obstacles, add to the uncertainty.

Additionally, potential bottlenecks in electrolyzer manufacturing capacity could slow the industry's ability to scale as quickly as anticipated. Despite the uncertainties surrounding the growth trajectory of green hydrogen, MISO must account for the possibility of rapid load growth associated with electrolyzer technologies given the sizable grid impacts inherent to even the most conservative of hydrogen growth scenarios.

FORECAST METHODOLOGY FOR GREEN HYDROGEN

The green hydrogen forecast includes data and analysis from a range of sources, including public announcements and third-party data on the production capacities of green hydrogen projects (Figure 20). For the forecast period of 2024 to 2030, publicly available analyses from the DOE are referenced to estimate the future allocation of hydrogen across end uses, and to determine the share of green hydrogen to be produced via renewable-derived electrolysis within the MISO footprint. Given the current technological, policy and supply-chain related constraints which add significant uncertainty to this driver, the "projected" capacity of green hydrogen is calculated by assigning an attrition rate of 90% to the production capacities of each announced project. Energy demand from green hydrogen production is then calculated by multiplying the total projected electrolyzer production capacity by an energy conversion ratio of 33.3 TWh per million metric tons (MMT) of hydrogen, using a fixed electrolyzer efficiency of 65%.

For the period after 2030, the "projected" energy demand from green hydrogen production is determined by examining state-specific factors relevant to the LCOH, including renewable energy costs, capital and operational expenses for storage and electrolyzers, and efficiency factors. Based on these factors, green hydrogen demand is allocated in inverse proportion to each state's expected LCOH.

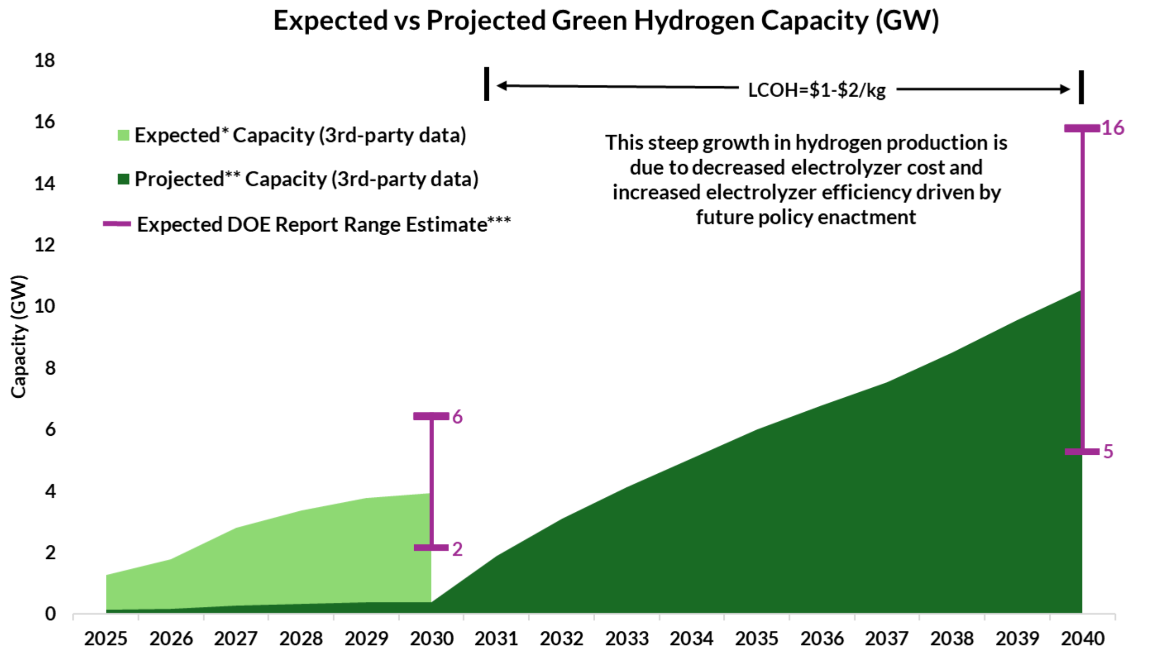


Figure 20: Expected vs. Projected Green Hydrogen Capacity (GW) – Green Hydrogen Source Compendium on Current Trajectory Scenario[4]

[4] * 'Expected' based on publicly announced green hydrogen pilots within the MISO footprint (third-party data).
** 'Projected' pre-2030 based on attrition rate of 90% falling post-2030 as the level of speculation declines. 'Projected' post-2030 is based on allocated green hydrogen production to MISO zones based on current announced projects and relative cost to produce green hydrogen) (third-party data).
*** 'Expected DOE Report Range Estimate' Sources:
1) *Clean Hydrogen - Pathways to Commercial Liftoff*, liftoff.energy.gov/wp-content/uploads/2023/05/20230523-Pathways-to-Commercial-Liftoff-Clean-Hydrogen.pdf. Accessed 11 Dec. 2024.
2) Third-party data and analysis DOE Estimate Range: Low is based on the MISO share of currently announced clean hydrogen production projects (2.5% of US) and High is the MISO expected demand share based on projects with electrolysis (7.5% of US).

DISTRIBUTED ENERGY RESOURCES

OUTLOOK

The growth of rooftop solar, energy storage and other DERs brings challenges and opportunities for MISO, potentially complicating operations but supporting demand response and peak reliability.

- A 2024 survey indicates approximately 14 GW of load-modifying DERs exist within in MISO, with two-thirds registered.

MISO commissioned Applied Energy Group (AEG) to evaluate the technical potential of DERs for previous MISO Futures series modeling. AEG estimated DER impacts by surveying LSEs and conducting secondary research, followed by economic analyses to project growth adoption rates across MISO's footprint. For this analysis, MISO retained assumptions provided by AEG, with a primary focus on intermittent behind-the-meter resources. The contribution of DERs to MISO's demand is expected to increase by 69-78 TWh by 2044.

The 2024 OMS Distributed Energy Resource survey indicates that approximately 14 (13.6) GW of load modifiers currently exist within the MISO system, two-thirds of which are registered with MISO. Despite high uncertainty regarding these resources' performance, efforts are underway to enhance the availability, accreditation and effectiveness of demand and load modifiers through improved rules and operational conditions which are detailed in the Load Modifying Resource Reform white paper. Additionally, visibility challenges persist, especially regarding the data granularity required for accurate resource modeling, as noted in the MISO and DER Visibility white paper.