



# MISO Futures Report

## SERIES 1A



- Published November 1, 2023 -

## Highlights

- Electric utilities in the MISO region are responding to the energy industry's ongoing transition in different ways. At an aggregate level, there is a dramatic and rapid transformation underway of the resource mix in MISO's footprint.
- The three Series 1A MISO Futures encompass scenarios that refresh input data used in the Series 1 MISO Futures developed in 2019-20.
- Analysis of three scenarios allows for insights to the MISO system with transformation in peak seasons, as renewable energy penetration and projected demand increase.



[misoenergy.org](http://misoenergy.org)



<b>Executive Summary .....</b>	<b>2</b>
<b>MISO Futures Purpose and Assumptions .....</b>	<b>9</b>
<i>Changing Energy Across MISO.....</i>	<i>11</i>
<i>Retirement and Repowering Assumptions .....</i>	<i>21</i>
<i>Load Assumptions.....</i>	<i>27</i>
<i>Electrification.....</i>	<i>38</i>
<i>New Resource Additions.....</i>	<i>47</i>
<i>Resource Siting Process .....</i>	<i>49</i>
<i>JuiceBox: Generation Resource Portal.....</i>	<i>53</i>
<b>MISO Expansion Results .....</b>	<b>54</b>
<i>MISO – Future 1A .....</i>	<i>56</i>
<i>MISO – Future 2A .....</i>	<i>72</i>
<i>MISO – Future 3A .....</i>	<i>89</i>
<b>Appendix .....</b>	<b>105</b>
<i>EGEAS Modeling .....</i>	<i>105</i>
<i>Additional MISO Assumptions .....</i>	<i>107</i>
<i>External Assumptions and Modeling .....</i>	<i>111</i>
<i>Study Areas.....</i>	<i>111</i>
<i>Presentation Materials .....</i>	<i>122</i>



# Executive Summary

The energy industry is evolving in profound ways, with MISO members and states announcing increasingly advanced decarbonization and clean energy goals due to changing economics, environmental regulations, technological advancements, state and federal policies, and consumer preferences for cleaner energy. Over 75% of MISO's load is served by member utilities with such ambitious plans, creating new challenges and complexities in the realm of resource planning. Although MISO is not a resource planner and does not have authority over generation planning decisions or resource procurement, member and state plans often do not provide resource information for the full 20-year study period. This creates a resource "gap" which MISO fills through resource expansion analysis. To hedge uncertainty and "bookend" a range of economic, political, and technological possibilities over the 20-year study period, MISO's regional resource expansion analysis is performed on multiple planning scenarios called the MISO Futures. The MISO Futures resource expansion analysis seeks to find the optimal resource buildout that minimizes the overall system cost while meeting reliability and policy requirements.

As a key element of the Long-Range Transmission Planning (LRTP) initiative and the Reliability Imperative, the MISO Futures and their respective resource expansion plans set the foundation for MISO's long-term transmission planning analysis in identifying valuable transmission solutions that help enable members' and states' plans in a reliable and cost-effective manner. As part of Tranche 1 of the LRTP initiative, MISO collaborated with stakeholders to develop a cohort of three future planning scenarios, which are now referred to as the Series 1 Futures. This cohort of Futures was developed over an 18-month period beginning in mid-2019 through the end of 2020 and was the foundation of the LRTP Tranche 1 analysis, used to justify a \$10.3 billion portfolio of new transmission investments unanimously approved by the MISO Board of Directors on July 25, 2022.

Since the completion of the Series 1 Futures, members' and states' plans were refined, new legislation and policies took effect, and prices, along with incentives for various resources, saw significant changes. These developments required MISO to update the Series 1 Futures with the latest input data while maintaining their original number and defining characteristics. To help distinguish the updated Futures from the original Series 1 Futures, the "refreshed" cohort is referred to as the Series 1A Futures. The effort to refresh the Futures began during the summer of 2022 and concluded during the fall of 2023. Results from the Series 1A refresh continue to reflect a significant fleet transition over the next 20 years. However, compared to the Series 1 Futures, the pace of the transition is accelerating. This report documents the process and results of the refreshed Series 1A Futures, which continue to enable the diverse plans and goals of MISO's members and states.

Future 2A, within the Series 1A Futures cohort, is the focus of the LRTP Tranche 2 analysis. While developing Future 2A, MISO observed an opportunity to add value by performing an energy validation of the Future 2A resource expansion results. PROMOD, a production cost modeling tool, provided hourly (annual) chronological security-constrained unit commitment and economic dispatch, to identify any energy adequacy shortfall needs that may not have been captured in the MISO Series 1A Future 2A expansion results produced by EGEAS, an unconstrained (transmission-less) non-chronological resource expansion modeling tool. Generation shortfalls were identified for 3-4 hours per day during twilight hours (before sunrise or at sunset) in up to 26 days of the modeled year, with a maximum shortfall of 29 GW in a single hour.

To address this energy shortfall, the Futures team added 29 GW of Flexible Attribute Unit capacity to the Future 2A expansion and siting. These "Flex" units are proxy resources that refer to a non-exhaustive range



of existing and nascent technologies, representing potential generation that is highly available, highly accredited, low- or non-carbon emitting, and long in duration. As a proxy, potential Flex resources could be, but are not limited to: RICE<sup>1</sup> units, long-duration battery (>4 hours), traditional peaking resources, combined-cycle with carbon capture and sequestration, nuclear SMRs,<sup>2</sup> green hydrogen, enhanced geothermal systems, and other emerging technologies.

## MISO's Generation Fleet Transition

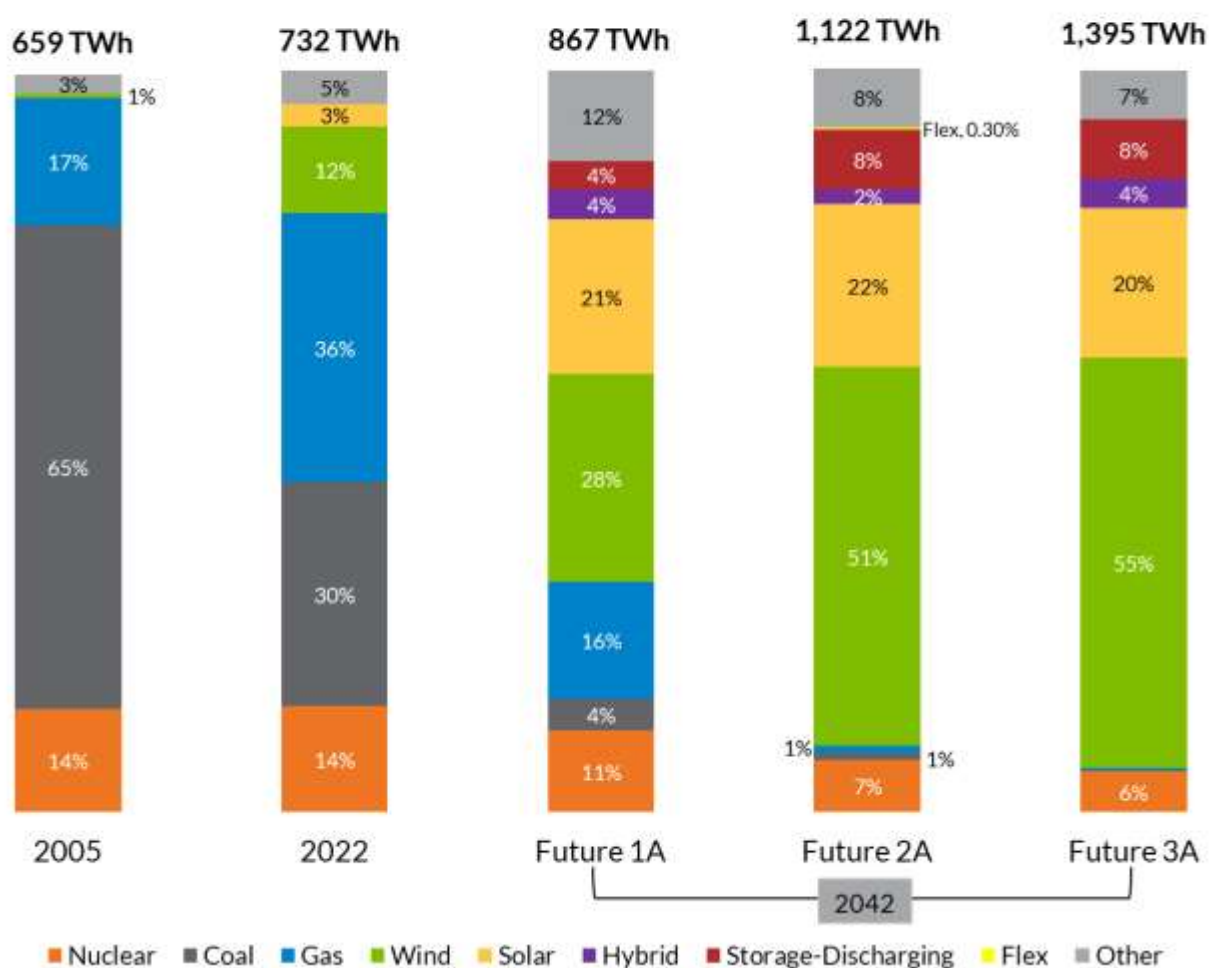


Figure 1: Overview of MISO's Generation Fleet Mix Transition<sup>3</sup>

<sup>1</sup>RICE: Stationary Reciprocating Internal Combustion Engines (gas-powered)

<sup>2</sup>SMR: Small Modular Reactor

<sup>3</sup>Storage energy percentages reflect discharge energy output. Overall energy production chart includes energy required for storage charging. Total energy production, net storage-charging, can be found for each Future in the expansion results section of this report.

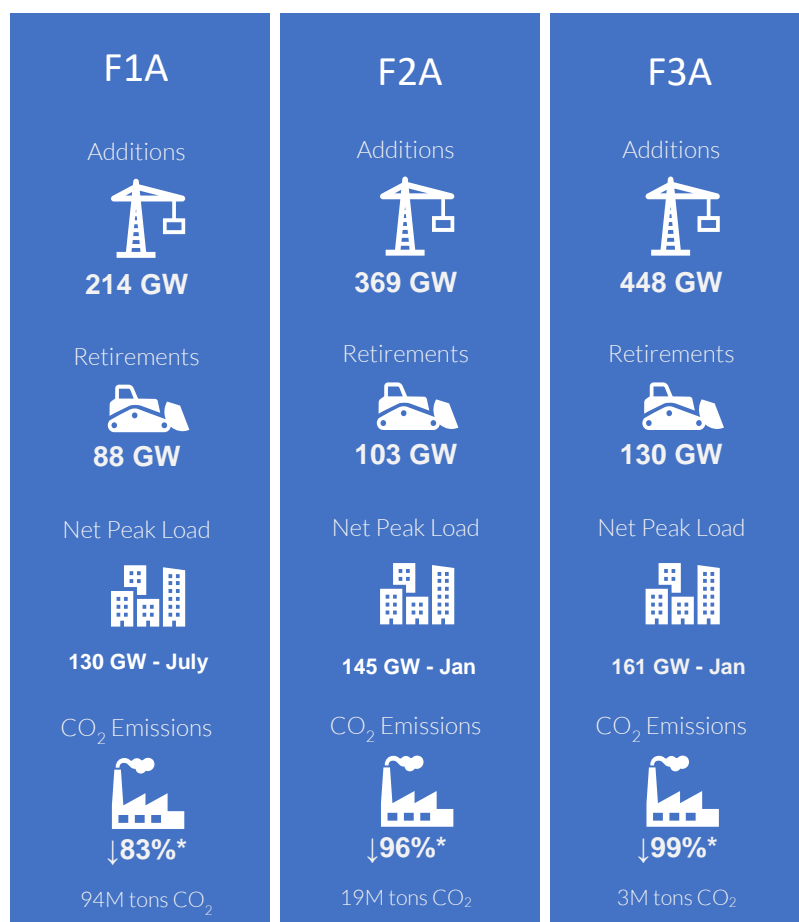


**Future 1A Assumptions** – Future 1 reflected substantial achievement of state and utility announcements, with a 40% decarbonization assumption.<sup>4</sup> Future 1A continues to incorporate 100% of updated utility integrated resource plan (IRP) announcements and state legislation. Updated non-IRP utility goals and non-legislated state goals are applied at 85% of their respective levels to hedge the uncertainty of meeting them. Accordingly, Future 1A incorporates 71% decarbonization for the MISO system. Future 1A assumes that demand and energy growth are driven by existing economic factors, with small increases in EV adoption, resulting in an annual energy growth rate<sup>5</sup> of 0.22%.

**Future 2A Assumptions** – Future 2 incorporated 100% of utility IRPs and announced state and utility goals within their respective timelines, and a 60% decarbonization assumption. To align with 100% achievement of updated member utility goals, F2A therefore incorporates 76% decarbonization for the MISO system. Future 2A introduces an increase in electrification, driving an approximate 0.8% annual energy growth rate.

**Future 3A Assumptions** – This Future incorporates 100% of utility IRPs and announced state and utility goals within their respective timelines, while also including an 80% carbon dioxide reduction since the updated member utility goals in aggregate did not exceed this level of MISO-wide decarbonization. Future 3A requires a minimum penetration of 50% wind and solar and introduces a larger electrification scenario, driving an approximate 1.08% annual energy growth rate.<sup>105</sup>

The Futures utilized announced goals and other input assumptions through October 2022 to represent a snapshot in time. Since the modeling of the Series 1A Future scenarios, new announcements and updates to utility and state goals have been publicized. While the Futures assumptions above summarize each scenario's inputs, Figure 2 details several key results of the modeling. For example, while Future 1A included a 71% carbon reduction trajectory, the model resulted in 83% carbon reduction. Additionally, “net peak load” results refer to peak load values, net of load-modifying resources.



**Figure 2: Summary of Future Scenario Impacts (Dec 31, 2042)**

<sup>4</sup> Carbon emission reduction in Future scenarios refer to power sector emissions across the MISO footprint from a 2005 baseline.

<sup>5</sup> Futures energy growth rates are compound annual growth rates (CAGR).



## A Note on Data Reporting within this Report —

The Futures resource expansion modeling tool assumes that all new units are installed on January 1 and retiring units are retired on December 31, regardless of the actual unit addition/retirement date. Timing of unit additions and retirements determines the resulting annual fleet installed and estimated accredited capacity snapshots, depending on selection of beginning- or end-of-year reporting (BOY, EOY respectively).

Materials presented during the development of the Futures Refresh, prior to the publication of this report, utilized a BOY outlook.<sup>6</sup> To standardize data reporting across vintages of Futures cohorts and to capture all additions and retirements taking place between 2023 and 2042, the data and charts following this section of the report will use an EOY annual snapshot, reflecting retirement of units within the illustrated year.<sup>7</sup>

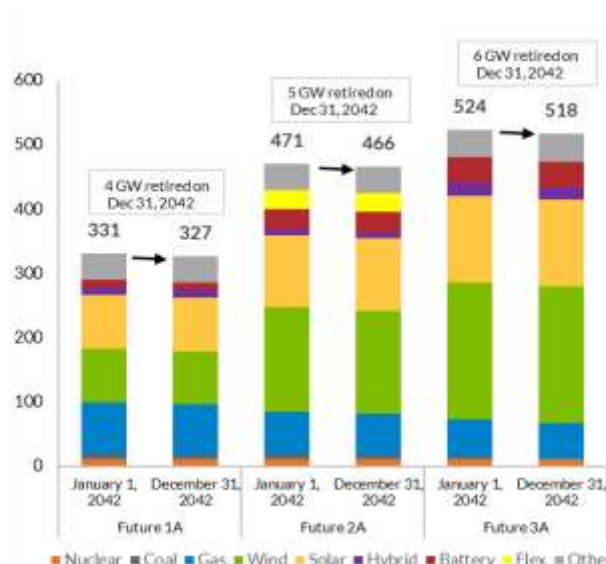


Figure 3: 2042 annual fleet installed capacity snapshot utilizing both beginning- and end-of-year reporting.

Figure 3 shows the difference in BOY and EOY 2042 installed capacity across all three Futures, due to unit retirements in the Futures resource expansion modeling tool taking place at 24:00, December 31, 2042. Figure 4 provides the BOY (left) and EOY (right) view of Future 2A, the focus of the L RTP Tranche 2 analysis.

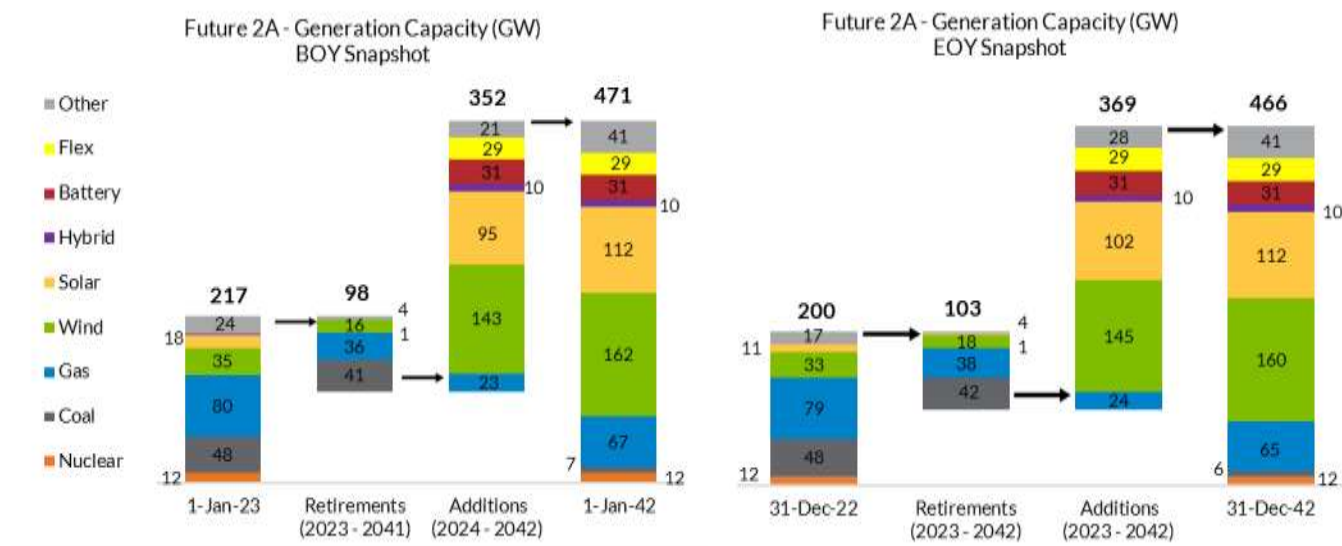


Figure 4: BOY and EOY Outlook for Future 2A Generation Capacity (GW)

<sup>6</sup> [Presentation Materials](#) for development of Series 1A Futures

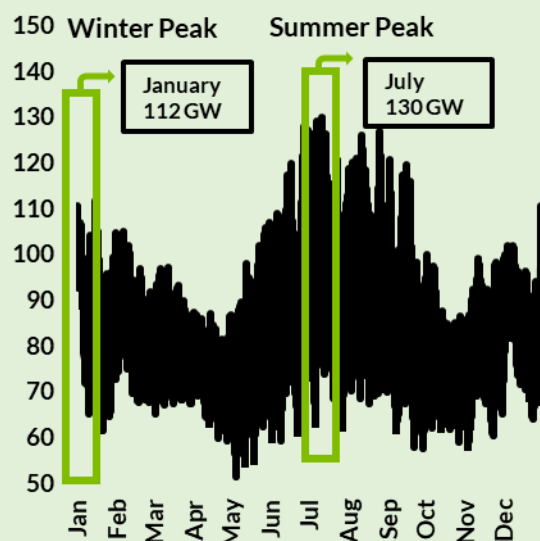
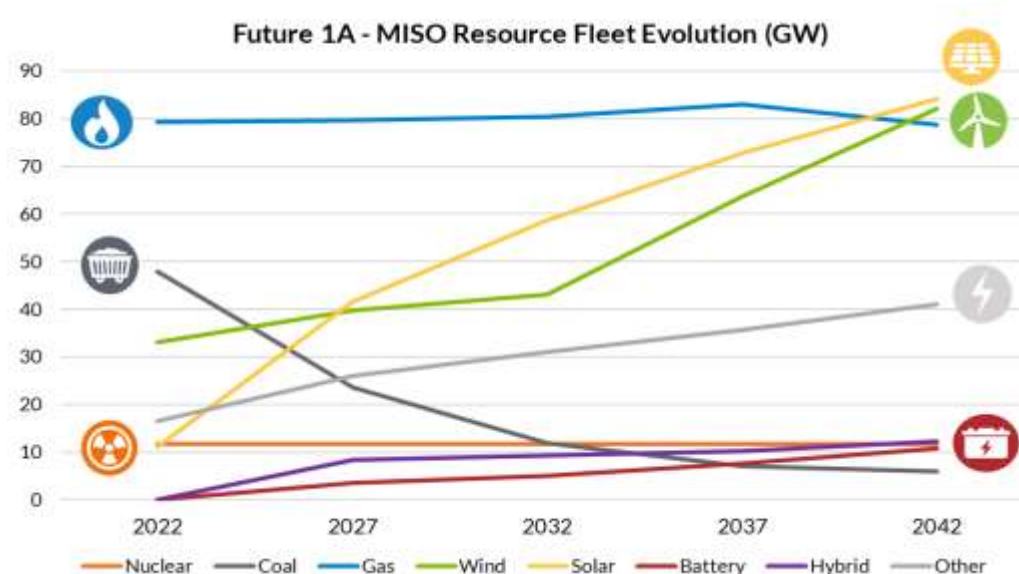
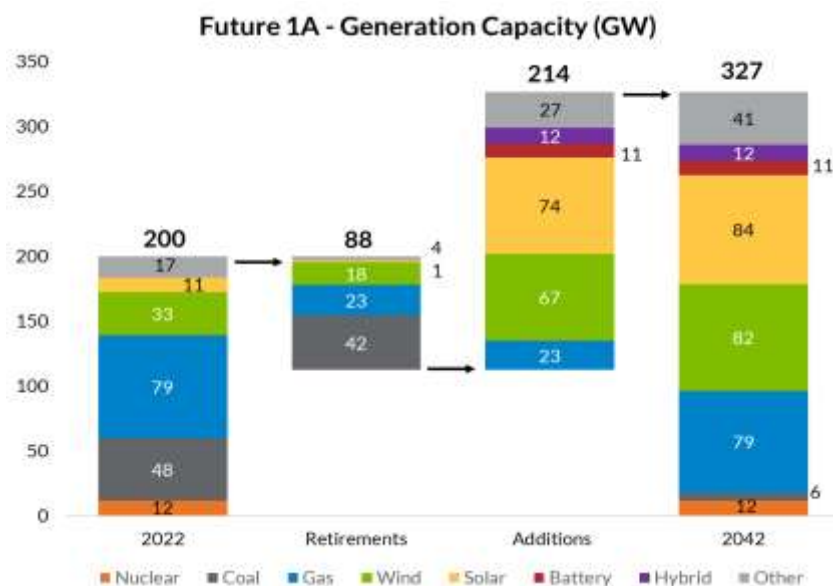
<sup>7</sup> Estimated Accredited Capacity with net load, in each respective Futures' expansion results, are reported utilizing a BOY snapshot for consistency with net load output reporting from the resource expansion modeling tool, EGEAS.



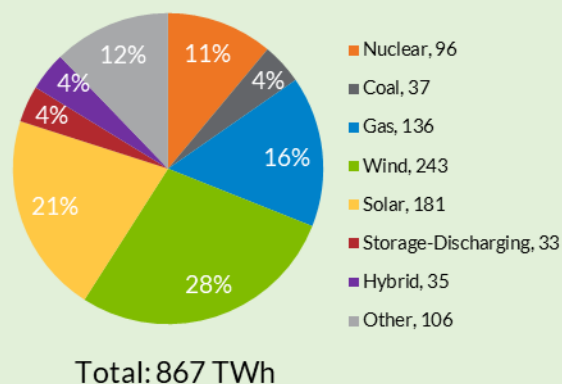


## Future 1A Results

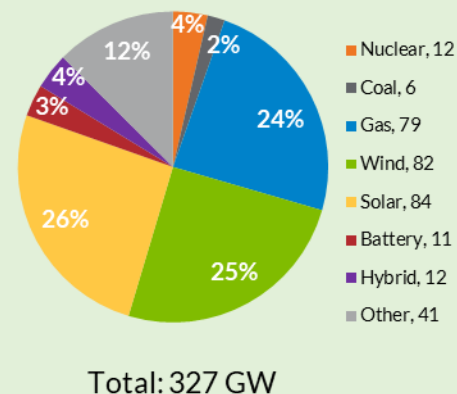
This Future assumes demand and energy growth are driven by existing economic factors, with small increases in EV adoption. Modeling for Future 1A results in the retirement of 88 GW and the addition of 214 GW of resources to the MISO footprint.



### Energy (TWh, 2042)



### Capacity (GW, 2042)



### Decarbonization

Input: 71%

Results: 83%

**Announced Plans**

Goals Met: 85%

IRPs: 100%

**Forecast % Increase**

Energy: 4.4%

Demand: 7.5%

**Compound Annual**

**Growth Rates**

Energy: 0.22%

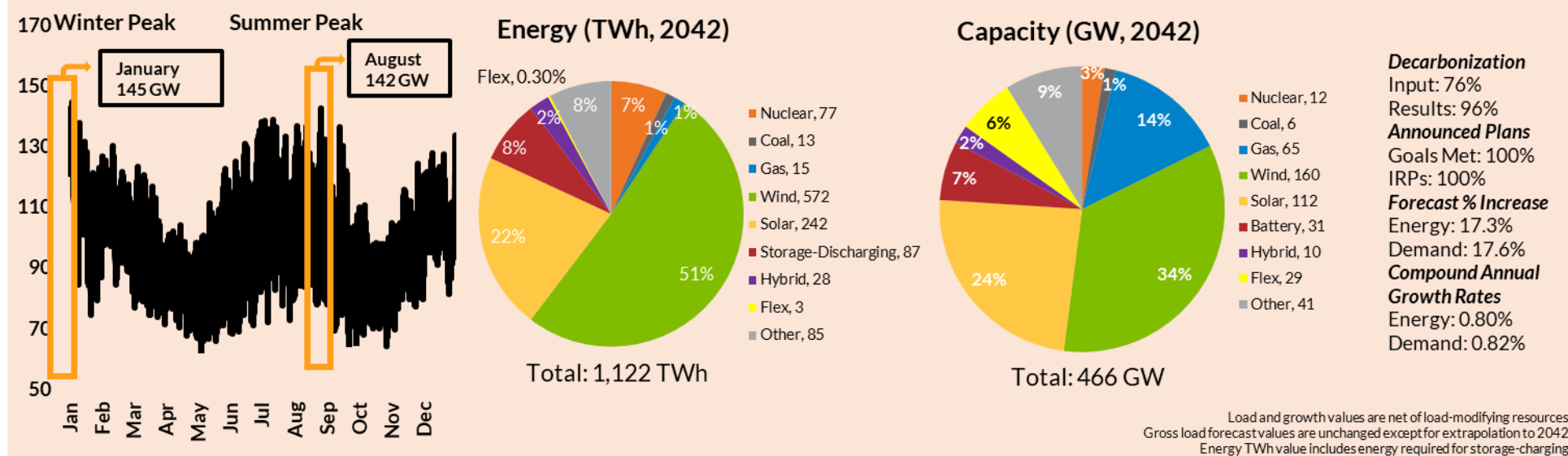
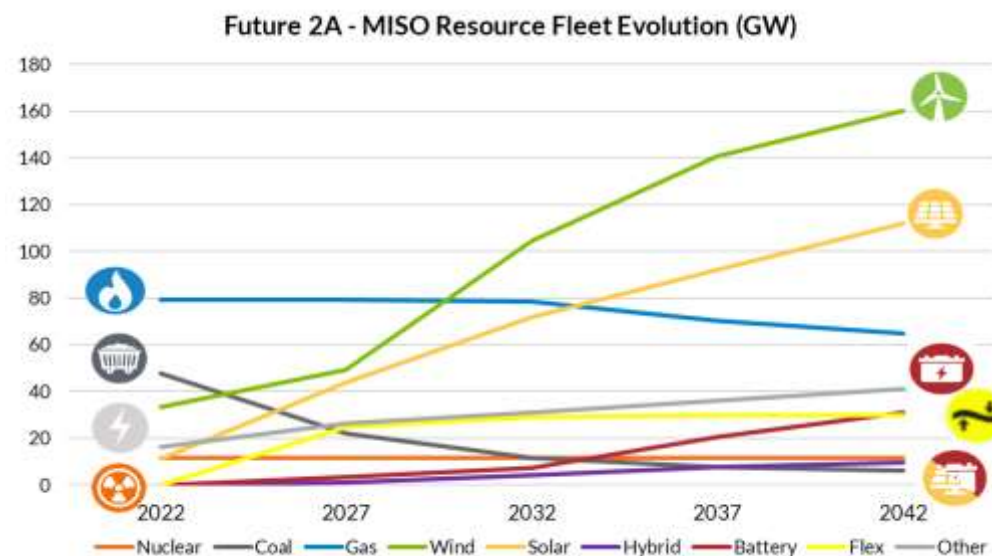
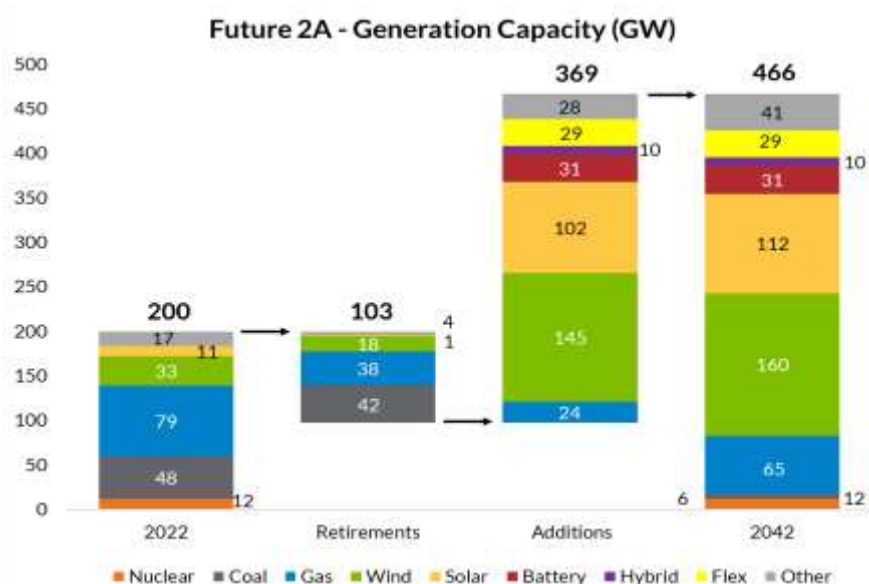
Demand: 0.36%

Load and growth values are net of load-modifying resources  
Gross load forecast values are unchanged except for extrapolation to 2042  
Energy TWh value includes energy required for storage-charging



## Future 2A Results

Due to retirements and increased electrification, moderate increases in demand and energy cause Future 2A's load shape to have a slightly larger peak in the winter but remain relatively dual-peaking. Modeling of Future 2A results in the retirement of 103 GW and the addition of 369 GW of resources to the MISO footprint.

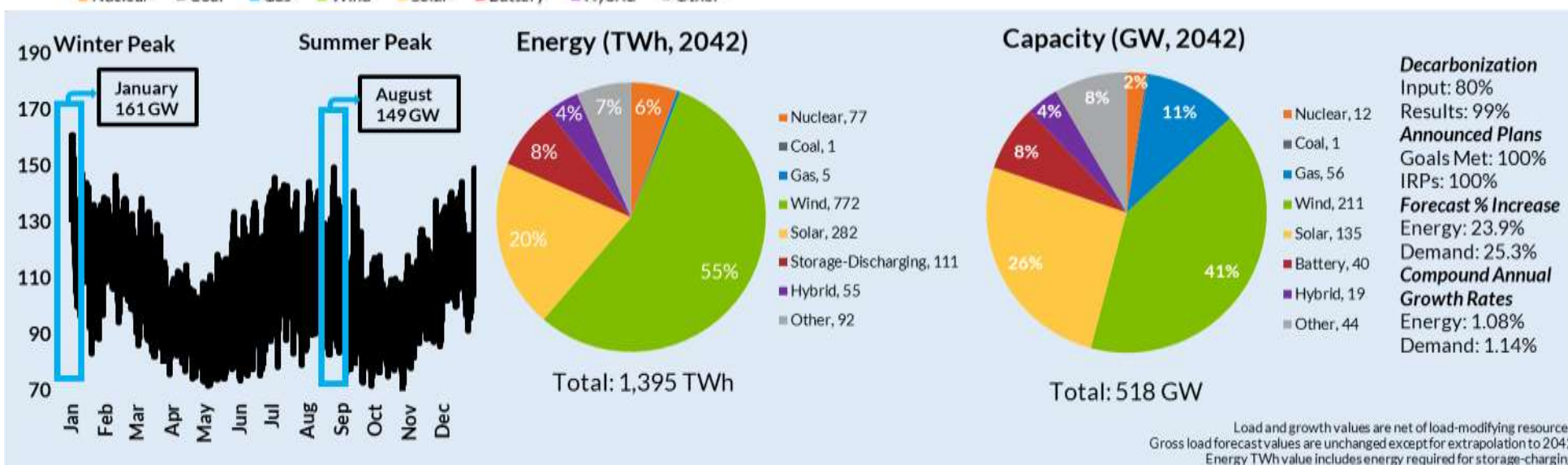
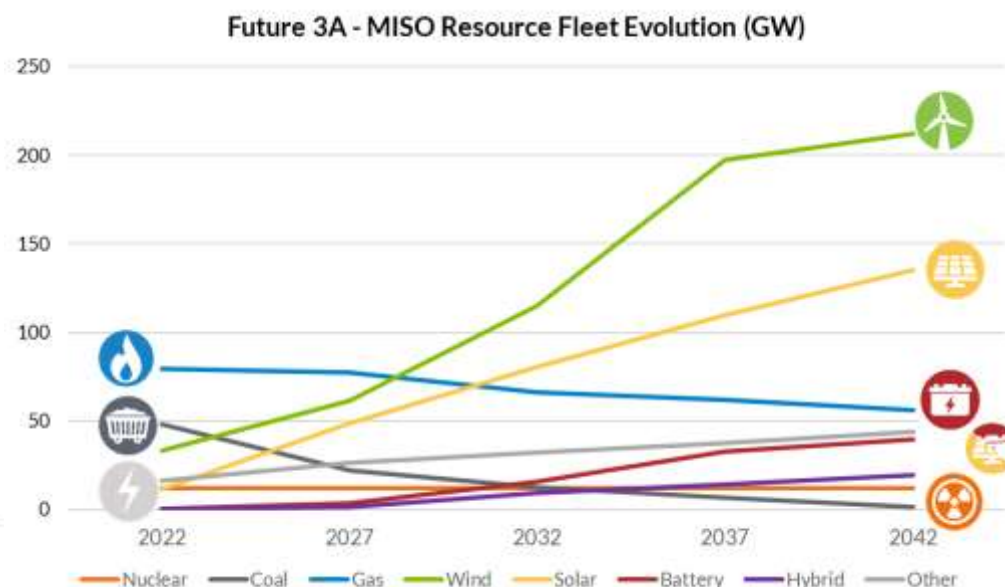
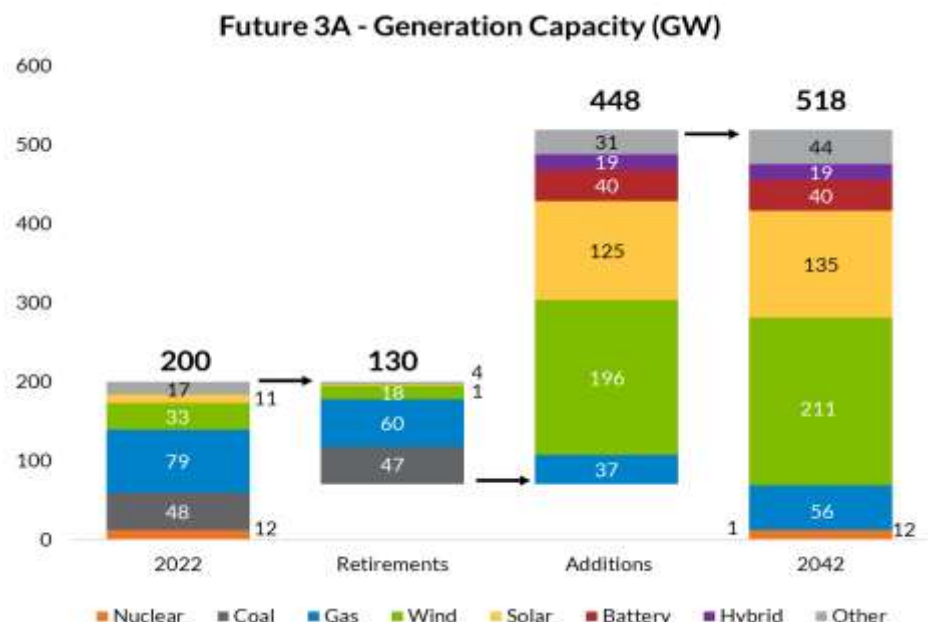






## Future 3A Results

Due to retirements, decarbonization, and electrification, large increases in demand and energy cause Future 3A's load shape to peak in the winter. Modeling of Future 3A results in the retirement of 130 GW and the addition of 448 GW of resources to the MISO footprint.





# MISO Futures Purpose and Assumptions

The energy industry is evolving in profound ways, with MISO members and states announcing increasingly advanced decarbonization and clean energy goals due to changing economics, environmental regulations, technological advancements, state and federal policies, and consumer preferences for cleaner energy. Over 75% of MISO's load is served by member utilities with such ambitious plans, creating new challenges and complexities in the realm of resource planning. Although MISO is not a resource planner and does not have authority over generation planning decisions or resource procurement, member and state plans often do not provide resource information for the full 20-year study period. This creates a resource "gap" which MISO fills through resource expansion analysis. To hedge uncertainty and "bookend" a range of economic, political, and technological possibilities over the 20-year study period, MISO's regional resource expansion analysis is performed on multiple planning scenarios called the MISO Futures. The MISO Futures resource expansion analysis seeks to find the optimal resource buildout that minimizes the overall system cost while meeting reliability and policy requirements.

As a key element of the Long-Range Transmission Planning (LRTP) initiative and the Reliability Imperative, the MISO Futures and their respective resource expansion plans set the foundation for MISO's long-term transmission planning analysis in identifying valuable transmission solutions that help enable members' and states' plans in a reliable and cost-effective manner. As part of Tranche 1 of the LRTP initiative, MISO collaborated with stakeholders to develop a cohort of three future planning scenarios, which are now referred to as the Series 1 Futures. This cohort of Futures was developed over an 18-month period beginning in mid-2019 through the end of 2020 and was the foundation of the LRTP Tranche 1 analysis, used to justify a \$10.3 billion portfolio of new transmission investments unanimously approved by the MISO Board of Directors on July 25, 2022.

The Future scenarios in this document represent a "refresh" of the Series 1 Futures, in which the original number and defining characteristics of that cohort of Futures is preserved while providing an opportunity to update the input data. To help distinguish the *updated* Series 1 Futures from the *original* Series 1 Futures, the "refreshed" Series 1 Futures are now referred to as the Series 1A Futures. Series 1A was necessary because members' and states' plans were refined, new legislation and policies took effect, and prices, along with incentives, for various resources saw significant changes since the development of the Series 1 Futures three years ago. The collaborative effort to refresh Series 1 to create the Series 1A Futures began during the summer of 2022 and concluded during the fall of 2023. Results from the Series 1A Futures refresh continues to reflect that a significant fleet transition is underway over the next 20 years. However, when compared to the Series 1 Futures results, the pace of the transition is accelerating.

This report documents the process and results of Series 1A, which continues to enable the diverse plans and goals of MISO's members and states. Assumptions within the three Future scenarios vary to encompass reasonable bookends of the MISO footprint over the next two decades. Future 1 represents a scenario driven by state and members' plans, with demand and energy growth driven by existing economic factors. Future 2 builds upon Future 1 by fully incorporating state and members' plans and includes a significant increase in load driven by electrification (discussed in the Electrification section of this report). In the final scenario analyzed, Future 3 advances from Future 2, evaluating the effects of large load increases due to electrification, increased penetration of wind and solar, and decarbonization.

Series 1A and subsequent Futures series will continue to capture transformation within the MISO footprint, reflecting updates and serving as the foundation for forthcoming MISO initiatives. The "A" suffix signifies



the first round of studies with refreshed input data, albeit without changing the assumptions of the parent study. F1A, F2A, and F3A thus update the original Series 1 MISO Futures with refreshed input data, while maintaining their definitions. As illustrated in the diagram below, if MISO elected to perform another refresh on Series 1, those Futures would be called F1B, F2B, and F3B. These iterations are a product of continued collaboration between MISO and its stakeholders.

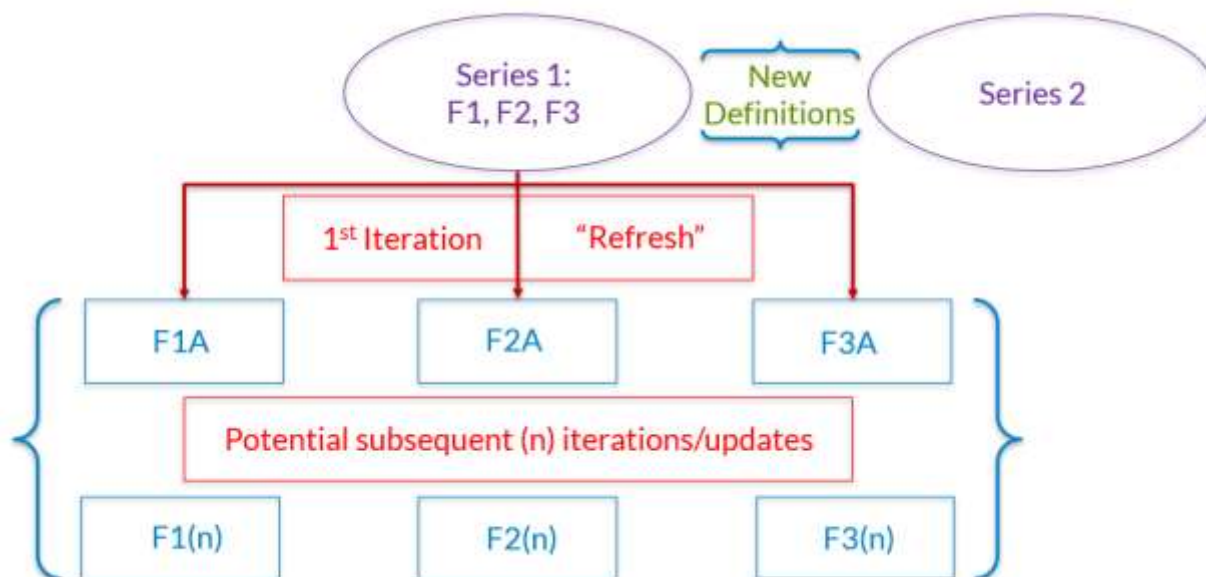


Figure 5: Potential Futures Series



## Changing Energy Across MISO

Cities, states, large commercial and industrial corporations, and utilities are exploring and setting decarbonization goals that often include reaching 100% clean energy supply or net-zero carbon emissions by 2050. Although not all states and utilities share these clean energy goals, a fleet transition of this magnitude will have implications on what transmission will be needed across the MISO footprint to ensure reliability of the grid. The role of MISO is to remain resource-agnostic and to ensure a reliable and economic Bulk Electric System in an ever-changing environment.

Throughout the analysis of each Future scenario, MISO incorporated specific state and utility goals relative to carbon and renewable energy percentages into the models. Decarbonization was modeled in three aspects per Future. First, models converted utility goals into relative percentages of MISO and aggregated them into system-wide reduction trajectories. Second, state-specific reductions were applied, depending on generating resource locations. Third, to capture impacts of the Climate and Equitable Jobs Act (CEJA), unit-specific emissions were modeled for eligible units in Illinois.

Similarly, renewable goals were modeled by converting utility/state goals into relative percentages of MISO and taking the summation of these values to create footprint trajectories. Resources were assigned to their respective areas in the siting process.

Internal analysis indicates the MISO footprint has decarbonized by 35% since 2005. Early thermal retirements, public announcements, and evolving IRPs support MISO's preparation for a broad range of Future scenarios, enabling continual adaptation to the changing energy landscape while ensuring better grid reliability.

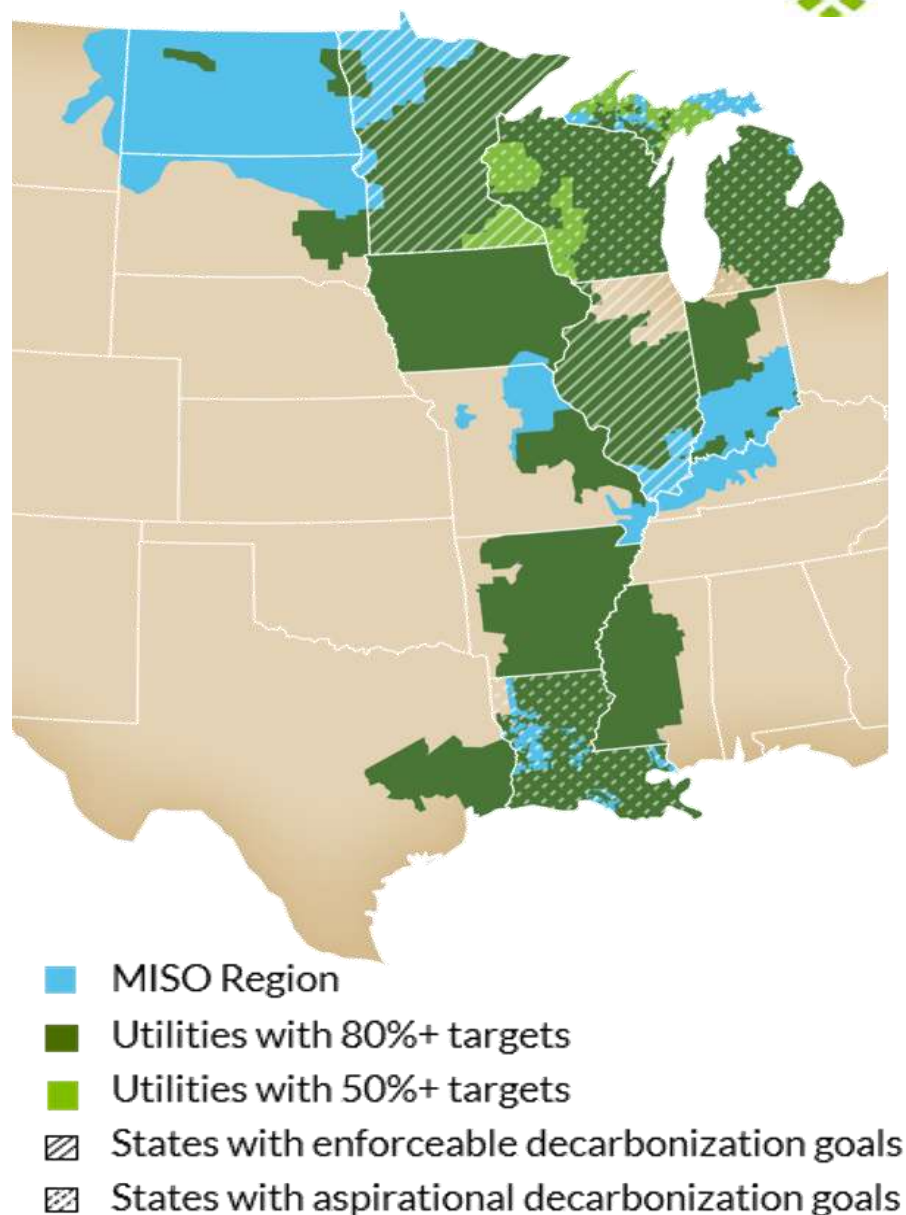


Figure 6: Clean Energy Goals above 50% Across Footprint



## State and Utility Clean Energy Goals

Today, state and utility policies and goals are changing rapidly and continued to do so during the Series 1A process, regarding decarbonization, renewable energy, and unit retirements. To best account for these changes, MISO continuously updated these announced goals until the Series 1A stakeholder feedback window closed in April 2023.

When collecting goal announcements, MISO staff examined companies' IRPs, state publications, and results from the MISO/OMS State Data Survey. (OMS refers to the Organization of MISO States). Survey data from MISO's 2022 Regional Resource Assessment (RRA) was incorporated. Once this information was compiled, MISO compared unit addition announcements with signed generation interconnection agreements (GIA) in its queue to ensure that these units would not be double counted. MISO then added planned units into the base model to account for MISO members' and states' plans. These units had a variety of fuel types and contained announced additions throughout the study period (2023-2042). Throughout the model-building process, from July to October 2022, MISO also adjusted goals and incorporated unit-level revisions to planned and existing resources received through direct stakeholder engagement and feedback. Further base model updates were made considering stakeholder feedback during the siting process, starting in Spring 2023.

From Figure 6, it is apparent that much of the footprint has a clean energy goal greater than 50% (whether from decarbonization, renewable energy or both).<sup>8</sup>

Table 1 displays state and utility goals within the model, overlapping by service area. When considered together, over 75% of MISO's load is being served in states or by members with such ambitious plans. In this analysis, MISO considered current trends but also had the opportunity to look beyond and plan for a range of Future scenarios to bookend plausible possibilities over the next 20 years.

## Climate and Equitable Jobs Act (CEJA)

The previous section noted that the Futures process endeavors to account for rapidly changing policies and goals among MISO's member states and utilities. One particular policy incorporated by the Series 1A Futures is Illinois' Climate and Equitable Jobs Act (CEJA), enacted in September 2021. Among other provisions of the law, the ones that significantly impact our Futures models are the following:

- ***Slash climate-changing carbon pollution by phasing out fossil fuels in the energy sector.*** This provision requires Illinois to achieve a 100% zero-emissions energy sector by 2045, with significant emission reductions before then. Although the legislation does not spell out any annual statewide carbon emissions cap trajectory to attain the 100% zero-emission mark by 2045, it does mention certain guidelines on how to phase out the carbon emissions, with interim milestones applicable to certain units. These guidelines prioritize the ownership of the units, fuel category, and environmental justice in charting out a trajectory for Illinois to join the ranks of states with carbon-free power by 2050. All natural gas facilities must eliminate greenhouse gas (GHG) emissions by 2045 and all coal facilities must eliminate emissions by 2035. Additionally, there are intermediate deadlines based on characteristics of the facilities that stipulate accelerated phaseout dates for some plants.

- Private oil and coal generating facilities must phase out by 2030.

<sup>8</sup> Utility goals are represented with green shading while enforceable state goals of 100% are given white stripe and aspirational state goals of 100% are given white dots.





- Public oil and coal facilities are allowed to continue operation until 2045. Any source or plant with such units must also reduce their carbon dioxide equivalent (CO<sub>2</sub>e) emissions by 45% from existing emissions by no later than January 1, 2035.
- Public natural gas facilities must phase out by 2045.
- The phaseout of private natural gas facilities is somewhat more involved to expedite the reduction in emissions output and the retirement of resources that produce higher levels of air quality emissions and that are nearer to environmental justice communities.<sup>9</sup> In addition to the phaseout depicted below, private natural gas facilities may not emit, in any 12-month period, CO<sub>2</sub> or co-pollutants more than that unit's existing emissions for those pollutants. The specifications for fossil phaseout required by CEJA are illustrated below.

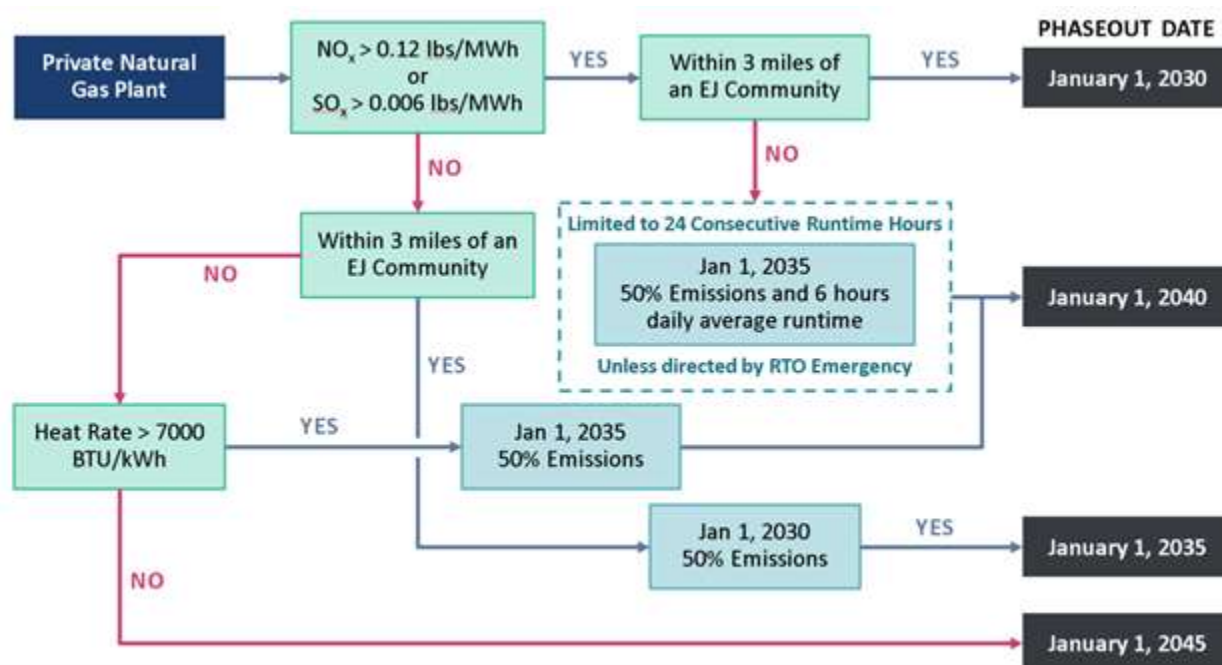


Figure 7: CEJA decarbonization guidelines for private natural gas facilities

- **Grow renewable energy generation.** The CEJA expands investments in clean energy and targets a transition to 40% of electricity provided by renewable energy by 2030, 50% by 2040 and 100% from carbon-free sources by 2050.

These provisions under CEJA were applied to the Series 1A Futures. In the study, all Illinois generation facilities fired by coal, oil, and natural gas were set to reduce their emissions (both 100% and any applicable interim targets) based on their fuel type, ownership, heat rates, NO<sub>x</sub> and SO<sub>x</sub> emissions,<sup>10</sup> and proximity to environmental justice communities per the CEJA guidelines mentioned above. The emission caps for all the Illinois GHG units were implemented in MISO and PJM models by enabling unit emission constraints in EGEAS. The CEJA-mandated RPS goals for Illinois were also used in the study to satisfy the state's targeted transition to 40% of electricity being provided by renewable energy by 2030, and 50% by 2040.

<sup>9</sup> Environmental Justice communities are communities that are most impacted by environmental harms and risks.

<sup>10</sup> Oxides of nitrogen and sulfur





State Clean Energy Goals & RPS <sup>5F11</sup> (source linked)	State	Utility	Utility Decarbonization Goals (2005 Baseline) <sup>6</sup>	Utility Renewable Energy Goals
RPS: 15% RE by 2021 (IOUs)	Missouri	Ameren Missouri	60% by 2030, 85% by 2040, Net Zero by 2045	15% by 2021
		Columbia Missouri Water and Light Department	-	30% by 2029
		Missouri River Energy Services	-	22% by 2027
100% Clean Energy by 2050 RPS: 25% by 2025, 50% by 2042, 100% by 2050	Illinois	Ameren Illinois	Carbon Free by 2050 <sup>12</sup>	100% by 2050 <sup>12</sup>
		Springfield Illinois – City Water Light & Power	Carbon Free by 2050 <sup>12</sup>	100% by 2050 <sup>12</sup>
		Southern Illinois Power Co-operative	Carbon Free by 2050 <sup>12</sup>	100% by 2050 <sup>12</sup>
RPS: 105 MW (completed 2007)	Iowa	MidAmerican Energy	7% of MEC's load subject to Illinois state bill SB 2408 which requires 100% clean energy by 2050. <sup>12</sup>	97% by 2025
		Cedar Falls Utilities	45% by 2030 (2010 Baseline) .Net Zero by 2050	-
		Alliant Energy	50% by 2030. Carbon Free by 2050	30% by 2030
		Dairyland Power	50% by 2030	12% by 2026
Carbon Free by 2050 (Governor) RPS: 10% by 2020	Wisconsin	WEC Energy Group	Carbon Neutral by 2050	10% by 2020
		Madison Gas & Electric	80% by 2030. Net Zero by 2050	30% by 2030. 40% by 2050
Carbon Neutral by 2050 (Executive Goal) RPS: 15% by 2021 (standard), 35% by 2025 (goal, including EE & DR), 50% by 2030 (MI Healthy Climate Plan)	Michigan	Consumers Energy	Net Zero by 2040	15% by 2021
		DTE Energy	80% by 2040	15% by 2021
		Michigan Upper Peninsula	Carbon Neutral by 2050	15% by 2021. 35% by 2025
		Upper Peninsula Power	Net Zero by 2050	50% by 2025
Voluntary clean energy RPS, 10% RE by 2025	Indiana	Duke Energy	50% by 2030. Net Zero by 2050	-
		Hoosier Energy	-	10% by 2025
		Southern Indiana Gas & Electric	Net Zero by 2035	-
		Wabash Valley Power Association	50% by 2031. 70% by 2040. Net Zero by 2050	-
		NIPSCO	90% by 2030	-
Carbon Free by 2040 <sup>13</sup> RPS: 25% by 2025, 55% by 2035	Minnesota	Xcel Energy	80% Reduction by 2030. Carbon Free by 2050	60% by 2030
		SMMPA	90% by 2030	75% by 2030
		Minnesota Power	Carbon Free by 2050	70% by 2030
		Otter Tail Power Company	80% by 2042	35% by 2023
		Great River Energy	80% by 2050	50% by 2030
	Montana	Montana Dakota Utilities Co.	45% by 2030	-
Net Zero GHG by 2050 (Governor) RPS: 80% by 2050 (Executive Order)	Louisiana	CLECO	37.8% by 2030. Net Zero by 2050. (2011 Baseline)	-
		Entergy	50% by 2030. Net Zero by 2050. (2000 baseline)	-
City Clean Energy Goals & RPS <sup>5F</sup> (source linked)	City			
RPS: 70% by 2025, 100% by 2040	New Orleans			

**Table 1: Modeled State & Utility Goals - Service Area Overlay**

<sup>11</sup> DR: demand response; EE: energy efficiency; GHG: greenhouse gas; IOU: investor-owned utility; PS: portfolio standard; RE: renewable energy; RPS: renewable portfolio standard

<sup>12</sup> State of Illinois, state bill SB 2408

<sup>13</sup> MN Clean Energy Legislation passed February 2023. Utility goals developed before MN legislation were honored, in addition to the statewide legislation.



## Inflation Reduction Act

In August 2022, President Joe Biden signed into law the Inflation Reduction Act of 2022 (IRA). Its chief areas of focus pertaining to the energy sector include expediting the shift from fossil fuels to clean energy, decarbonizing the American economy, and accelerating domestic production of renewable energy infrastructure. The IRA will achieve these ends primarily via economic incentives, such as tax credits for clean energy, electric vehicles, and upgrades related to energy efficiency and building electrification; totaling over \$370 billion in all. These provisions are accompanied by a series of bonus credits that reward developers who use domestically sourced input materials, conform to fair labor practices, and promote energy justice via infrastructure growth and economic development in historically underserved communities and those negatively impacted by decarbonization.

The most direct effects of the IRA on MISO's Futures occur due to the Act's expansion of the Production Tax Credit (PTC) and Investment Tax Credit (ITC). Both of these tax credits provide enhanced economic incentives for qualifying wind, solar PV, and other renewable energy facilities. While the PTC and ITC were already in effect prior to the IRA's passage, they were scheduled to gradually phase out by the end of 2022. The IRA restores them to their full amount and extends them both for a minimum of 10 years, with the possibility of phaseout contingent upon attaining economy-wide decarbonization goals. Furthermore, the resources that qualify for the tax credits have been expanded: while the PTC was originally only applicable to wind projects, it can now also be applied to solar and solar hybrid projects; and the ITC is now also available for standalone storage facilities.

Both the PTC and ITC are subject to numerous credit-modifying provisions, which can either reduce or enhance their value. By default, both credits are reduced by 80% from their original value. However, the credits are restored to their full amount for all projects whose development meets prevailing wage and apprenticeship requirements; as these requirements are well-established standards in their respective industries, Series 1A models use the full value of each tax credit as its baseline assumption. PTC- and ITC-eligible projects that are constructed with a minimum threshold of domestically sourced content and/or that are sited in an IRA-defined "energy community" can also receive a 10% bonus credit for meeting each requirement.

The IRA contains numerous other provisions unrelated to the PTC and ITC that may still have an impact on the MISO footprint, though not as directly on the Futures. A host of low-carbon, no-carbon, and clean energy resources are also eligible for tax credits; new resources may appear with greater frequency in the Generator Interconnection Queue as they become more economical. Several economic incentives are directed at individual ratepayers rather than developers. Many consumers who make a qualifying purchase of an electric vehicle (EV) will be eligible for a tax rebate, potentially leading to an increase in EV sales, and thus load. Additional investment is also provided for building electrification, weatherization, and energy efficiency upgrades.

Ultimately, the economic components of the IRA will accelerate the energy transition. As the PTC and ITC return to their full, pre-phaseout values, developers will be able to take advantage of decreased capital costs, increasing growth in renewable capacity in the MISO footprint, especially of wind and solar resources. However, the availability of bonus credits for domestic content may delay the full impact of the IRA, as domestic supply chains for wind, solar, and battery infrastructure are still comparatively nascent; as such, supply chains may need to mature further in order for developers to take full advantage of the IRA's economic benefits. Series 1A assumes an incremental expansion of eligibility for bonus credits; a table depicting the implementation of these bonus credits can be found in the Futures Refresh Assumptions Book.

Other provisions of the IRA will also impact load. Tax credits for EVs and for building electrification will likely increase the total load on the MISO footprint.



## System-Wide CO<sub>2</sub> Modeling

In addition to state and utility renewable goals, each Future scenario applied decarbonization goals. Each of the three Futures contained a minimum decarbonization floor; Future 1A was 40%, Future 2A was 60%, and Future 3A was 80%. Although there was a predefined decarbonization floor, each Future could exceed that floor based upon members' and states' goals as well as the economically selected resources within each Futures' expansion.

Unless otherwise noted in

Table 1, all MISO utility and state carbon calculations used a 2005 CO<sub>2</sub> emissions baseline. Consistent with Futures assumptions, decarbonization included 100% of IRPs and 85% of other announced goals for Future 1A, while Futures 2A and 3A reflected 100% of members' and states' goals.

From analysis of the current fleet in 2005, MISO emitted 533 million (M) tons of CO<sub>2</sub>. Figure 8 below illustrates decarbonization for each Future scenario, displaying the tons of carbon emitted (bars) and the percentage of carbon reduction from the 2005 baseline (lines). The dotted line projects the historical trend of carbon emissions that MISO is assumed to have for comparison. The Future scenarios in this document allow for insights on how quickly carbon reduction across the footprint may occur. By the end of the study period, emissions reduced by 83% in Future 1A, 96% in Future 2A, and 99% in Future 3A.

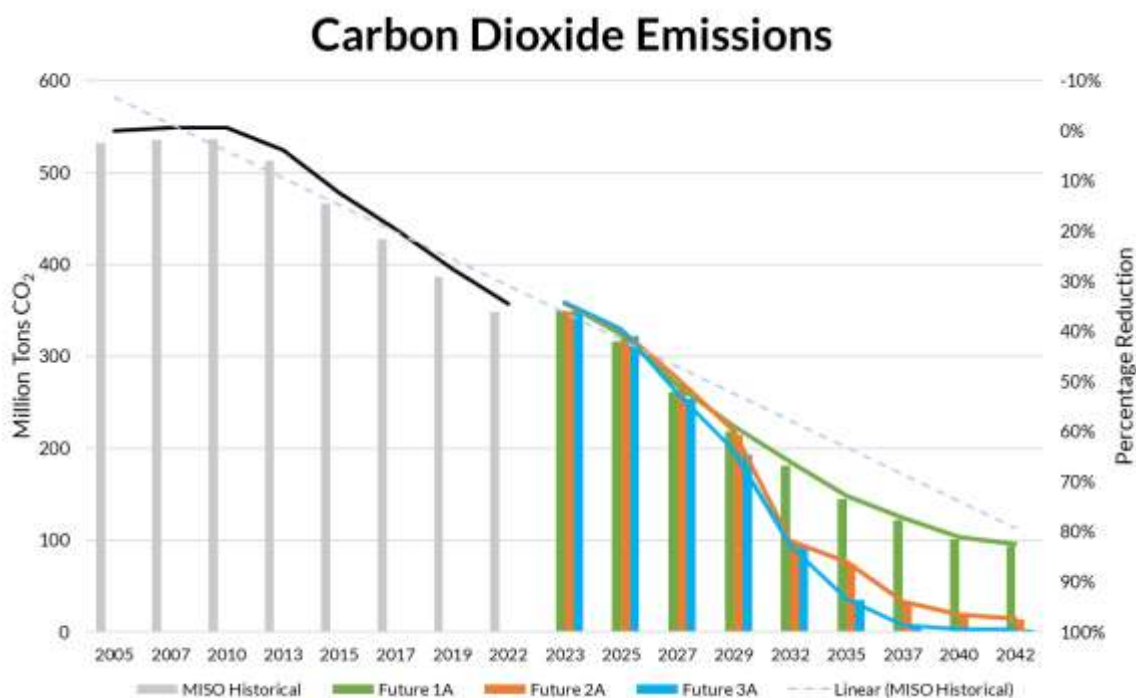


Figure 8: CO<sub>2</sub> Reduction Results (from 2005 Baseline)



## Resulting Wind and Solar Penetration Levels

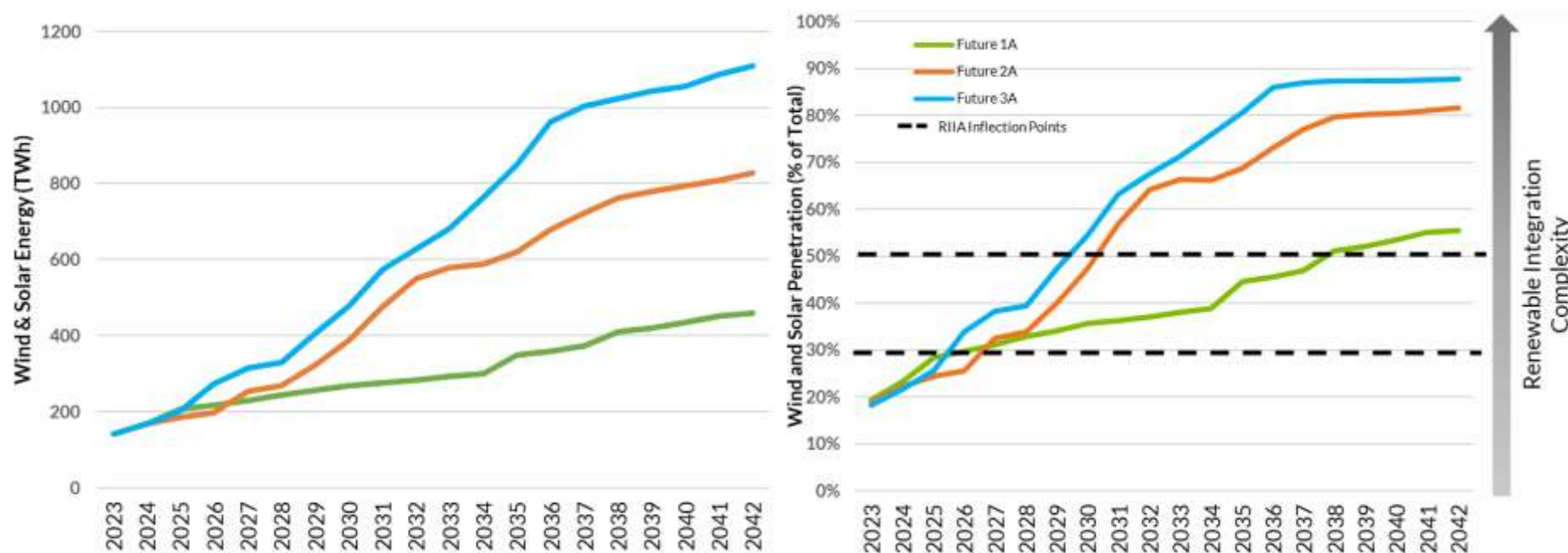


Figure 9: Wind and Solar Energy Generation Throughout Study<sup>14</sup>

<sup>14</sup> Wind and Solar Penetration (% of Total) reflected is based on total energy production, net storage-charging.



## Future Capacity Factor Trends

As renewable penetration rises across the MISO footprint, renewable resources are called upon with higher frequency to meet load while ensuring compliance with member RPS and carbon reduction goals. Increased deployment of batteries and other storage resources allows those renewables to be utilized with greater efficacy, serving customer load even during periods of low generation. Consequently, thermal resources are dispatched progressively less across each Future, resulting in a gradual decrease in capacity factor for these resources.

Figure 10 illustrates the average capacity factor of coal and natural gas resources across the study period. In Future 1A, remaining coal and natural gas resources maintain a de-facto role as baseload generation throughout much of the planning period; coal resources regularly operate at a capacity factor in excess of 60%, while natural gas resources, varying by plant type, behave more similarly to “peaker” plants, operating when wind and solar generation is sparse. In both Future 2A and Future 3A, there is an initial increase in capacity factor for coal to accommodate a changing energy mix before utilization of thermal resources steeply declines from 2030 onwards. As outlined in

Table 1, many emission goals do not take effect until 2030; thermal resources are utilized to meet increased load assumptions before more renewable capacity is added to the system and emission reduction targets take effect.

By the middle of the study period in F2A and F3A, significantly expanded renewable capacity and heightened levels of thermal retirements, discussed subsequently, lead to dramatically reduced capacity factor across all thermal resource types. In Future 3A specifically, remaining thermal resources are only dispatched during a handful of hours throughout the year. As determined by the chronological energy validation, and subsequent addition of flexible attribute units conducted during Future 2A, clean firm generation may be required to address shortfalls during select hours, specifically twilight periods before sunrise or sunset. The Series 1A results provide insight into the value of having flexible resources available to support reliability when needed, even if these units run infrequently in increasingly renewable Futures.

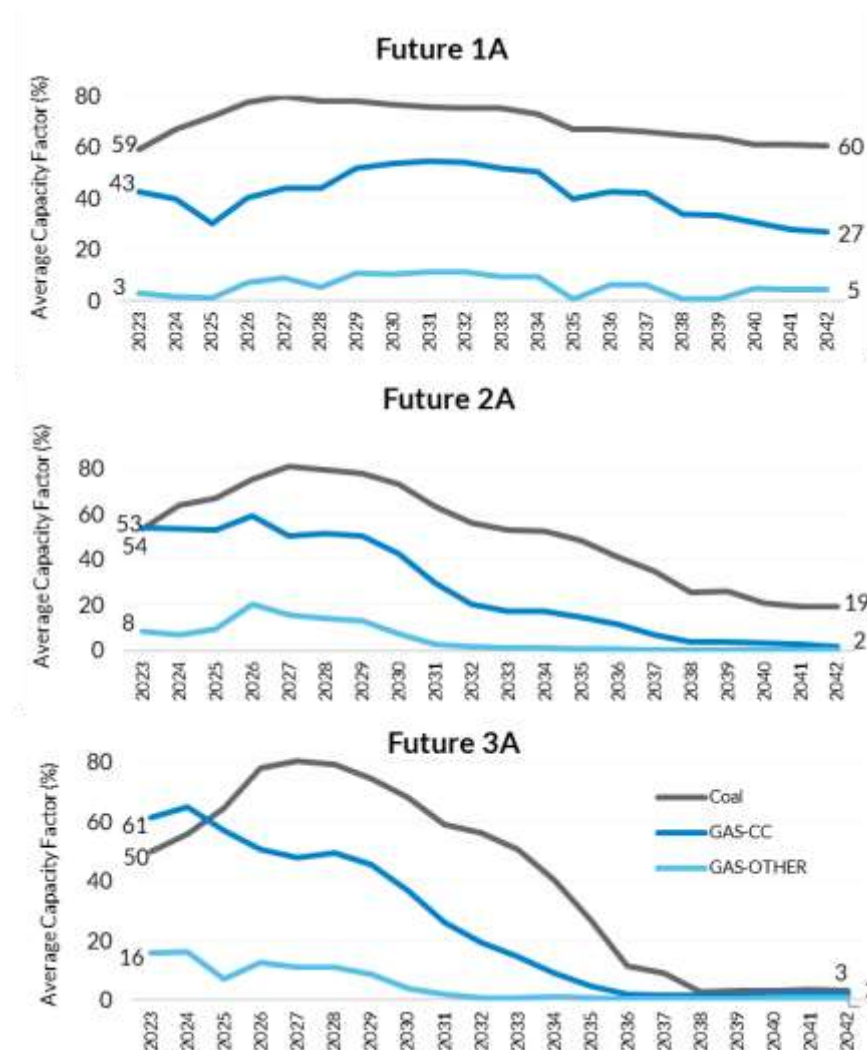


Figure 10: Average capacity factor of coal and natural gas resources across study period.





## Divergence of Installed Capacity and Accredited Capacity

Figure 11 provides the projected capacity change (2022 baseline) for all three Futures based on existing and member-planned resources only. Differences in the net change of installed and estimated accredited capacity are driven by the varying age-based retirement assumptions applied to existing resources across Futures.

MISO members include a significant quantity of new resources – primarily wind and solar – increasing total installed nameplate capacity. Having the most conservative age-based retirement assumptions, Future 1A sees nearly a 70 GW increase of installed capacity by 2042 with member-planned resources alone. Future 3A, despite having the most aggressive age-based retirement assumptions, sees an approximate 25 GW increase in installed capacity.

Heightened levels of renewable penetration, when considered with the permanent retirement of thermal resources, result in a substantially higher percentage of renewables amongst MISO members' resources. While this transition may allow members to achieve RPS and decarbonization goals, it also carries implications for accredited capacity. Estimated accredited capacity reflects how much energy resources are expected to produce to meet tight conditions after accounting for historic performance, such as forced outage rates and availability due to weather.

In the model, retiring thermal resources enjoy an accreditation of 95% or greater of their nameplate capacity; in contrast, wind is accredited at 16.6%, while solar accreditation declines to 20% and battery storage receives as low as 75% accreditation by 2042. As the total resource mix shifts towards renewables and away from thermal resources, the average accreditation of resources on MISO's footprint reduces significantly, leading to a net decrease in total estimated accredited capacity despite the significant increase in nameplate capacity. With each Future increasing the total retirement of highly accredited thermal resources, this negative net change in estimated accredited capacity is more pronounced across Futures; Future 1A projects an 18 GW negative change in estimated accredited capacity across the study period, F2A projects a 32 GW negative net change, and F3A projects a 53 GW negative net change.

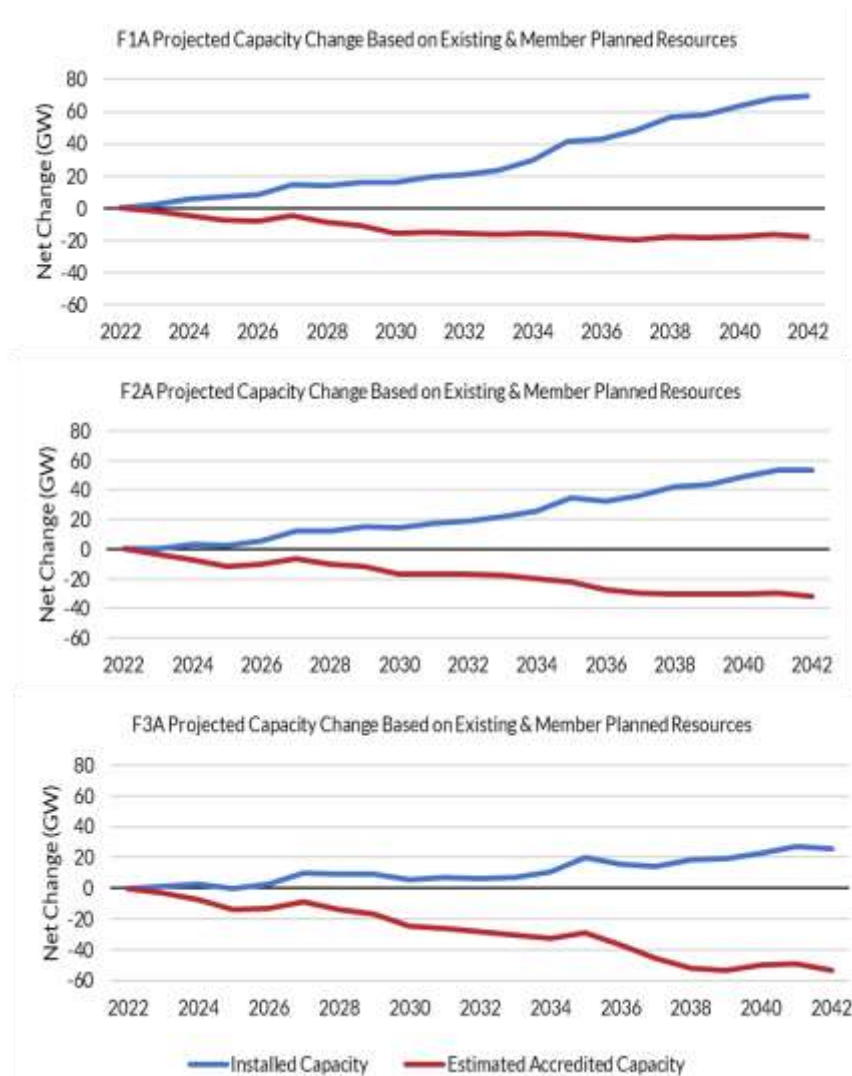


Figure 11: Projected capacity change based on existing resources and member plans (2022 Baseline).



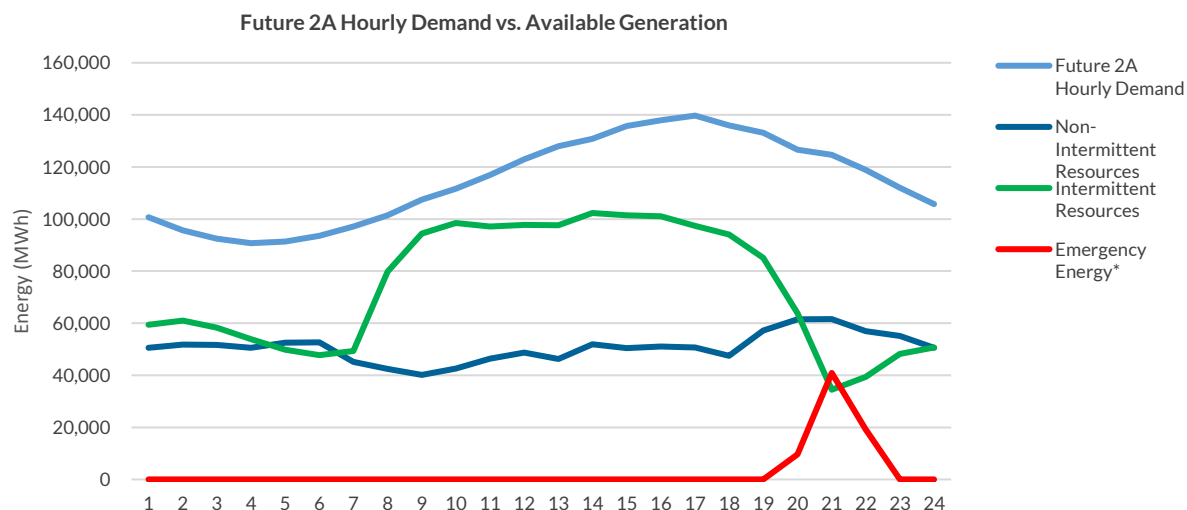
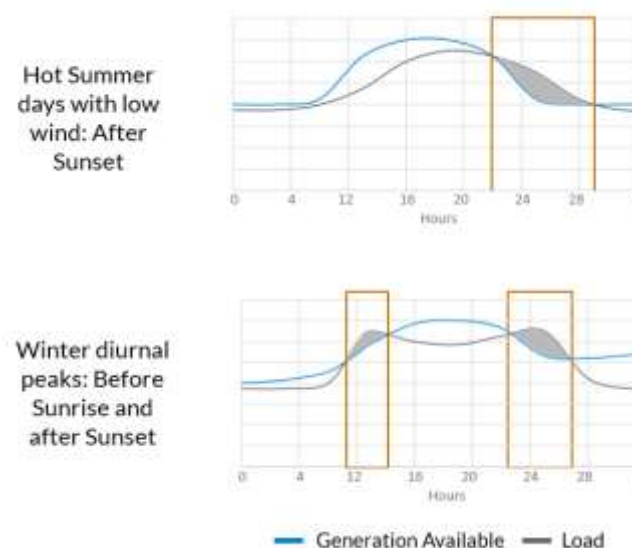


## Chronological Energy Validation & Flex Units

In developing Future 2A, MISO observed an opportunity to add value in performing an energy validation of the Future 2A resource expansion results. PROMOD, a production cost modeling tool provided hourly (annual) chronological security constrained unit-commitment and economic dispatch, to identify any energy adequacy shortfall needs that may not have been captured in the MISO Series 1A Future 2A expansion results produced by EGEAS, an unconstrained (transmission-less) non-chronological resource modeling tool. Generation shortfalls were identified for 3-4 hours per day during twilight hours (before sun rise or at sunset) in up to 26 days of the modeled year, with a maximum shortfall of 29 GW in a single hour.

To address this energy shortfall, the Futures team added 29 GW of Flexible Attribute Unit capacity to the Future 2A expansion and siting. These “Flex” units are proxy resources that refer to a non-exhaustive range of existing and nascent technologies, representing potential generation that is highly available, highly accredited, low- or non-carbon emitting, and long in duration. As a proxy, potential Flex resources could be, but is not limited to: RICE<sup>15</sup> units, long-duration battery (>4 hours), traditional peaking resources, combined-cycle with carbon capture and sequestration, nuclear SMRs,<sup>16</sup> green hydrogen, enhanced geothermal systems, and other emerging technologies.

Flexible attribute units do not displace the need for previously identified resources and, instead, supplement them in periods of energy inadequacy.



<sup>15</sup> RICE: Stationary Reciprocating Internal Combustion Engines (gas-powered)

<sup>16</sup> SMR: Small Modular Reactor



# Retirement and Repowering Assumptions

## Base Retirement Assumptions

**Nuclear and Hydroelectric** – Retirement of nuclear and hydroelectric units will occur when a unit has a publicly announced retirement plan or is listed to retire in an IRP. Otherwise, these units will remain active throughout the study across all Futures.

## Age-Based Retirement Assumptions

Age-based assumptions were applied to all the units that fall into any of the categories listed below. However, in cases where these assumptions cause older units in the MISO system to retire before the start of the study period (2023), units will be retired by 2025.

**Coal** – Retirement ages of coal units progressively decrease with each Future. It is assumed that with changing policies and emission standards, coal usage will decline further. The coal retirement ages modeled in the three Futures respectively are: 46, 36, and 30 years. The Future 1A retirement age of 46 years is based on the average age of coal units noted by the Energy Information Administration ([EIA](#)).

- Coal retirements in each Future are approximately a 80/20, 77/23, and 70/30 split respectively (Future 1A, Future 2A, and Future 3A) between base and age-based retirement assumptions.

**Gas** – Retirements for gas units were split into two categories, Combined Cycle (CC) and Other-Gas (e.g., Combustion Turbine [CT], IC [Internal Combustion] Renewable, and Integrated Gasification Combined Cycle [IGCC]). Both unit types were given retirement ages that decreased across the Futures scenarios; retirement ages for CC gas units are: 50, 45, and 35 years and retirements for Other-Gas units are: 46, 36, and 30 years respectively.

- Gas retirements in Future 2A are approximately a 33/67 split between base and age-based retirement assumptions.

**Oil** – Retirement ages of oil units decrease across each Future scenario and are 45, 40, and 35 years respectively.

- Oil retirements in Future 2A are approximately a 17/83 split between base and age-based retirement assumptions.

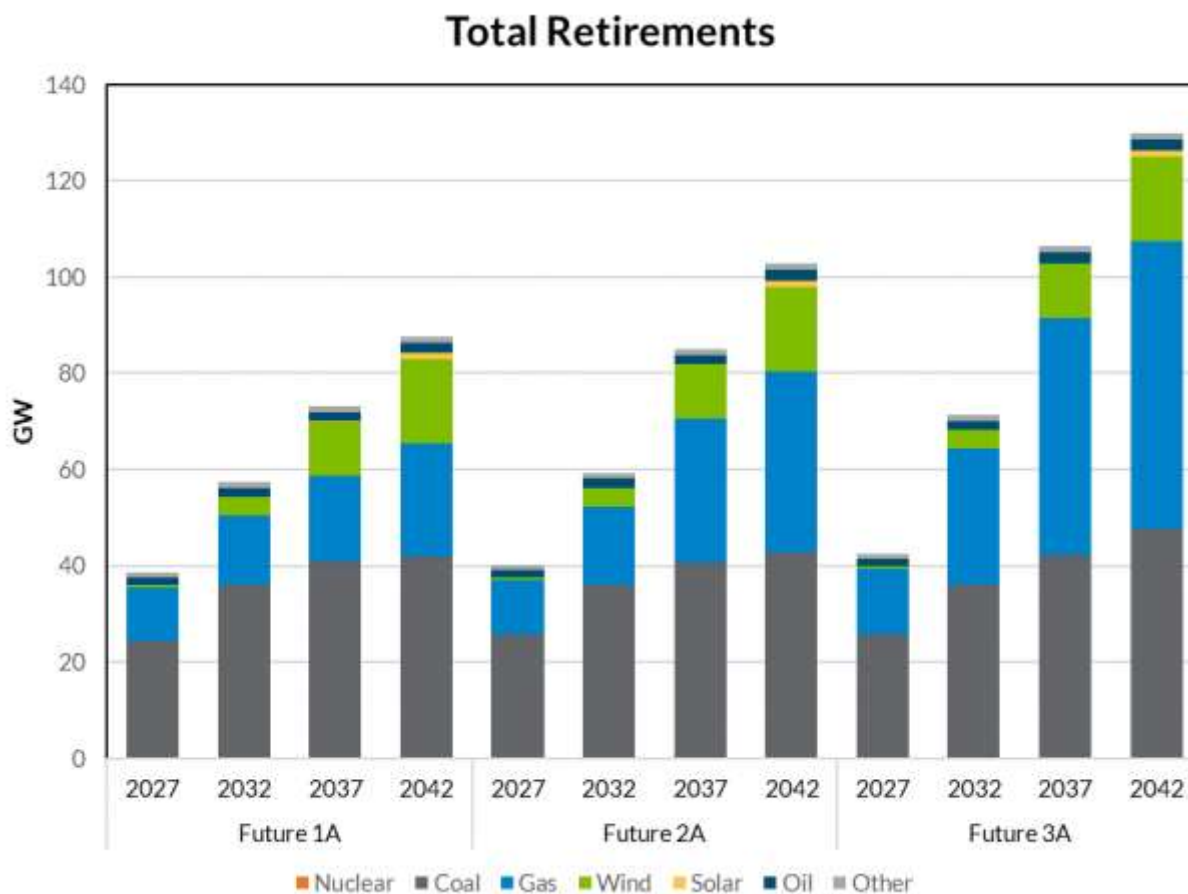
**Wind and Solar** – Retirements for utility-scale wind and solar will occur once a unit reaches 25 years of age. However, wind units will be repowered the year following retirement. These will be replaced by a new 100-meter hub height wind turbine with the same capacity as the previous unit but will receive new wind profiles, dependent on location. New profiles have updated capacity factors that are higher than existing wind turbines.

	Future 1A	Future 2A	Future 3A
Coal	46	36	30
Natural Gas – CC	50	45	35
Natural Gas – Other	46	36	30
Oil	45	40	35
Nuclear & Hydro	Retire if Publicly Announced	Retire if Publicly Announced	Retire if Publicly Announced
Solar – Utility-Scale	25	25	25
Wind – Utility-Scale	25	25	25



**Table 2: Age-Based Retirement Assumptions**

Figure 12 through Figure 14 display the results of differing retirement assumptions across each of the three Future scenarios. Retirement totals were calculated by applying age-based assumptions, announced retirements, and adjusting generation units per stakeholder feedback provided to MISO. Age-based assumptions are the product of Future-specific retirement assumptions, while base retirements are announced by the generator owner, stated in an IRP, or filed with MISO's Attachment Y.<sup>17</sup>



**Figure 12: Total Retirements per Future (Cumulative by Year), Equal to Age-Based + Base**

<sup>17</sup> MISO's retirement notification process



## Age-Based Retirements

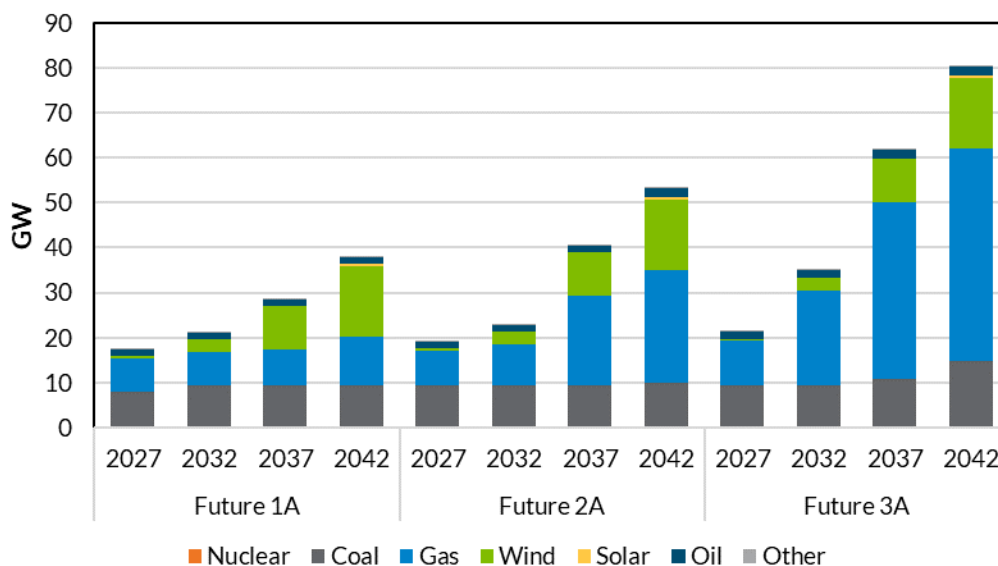


Figure 13: Age-Based Retirements per Future (Cumulative per Year)

## Announced Retirements

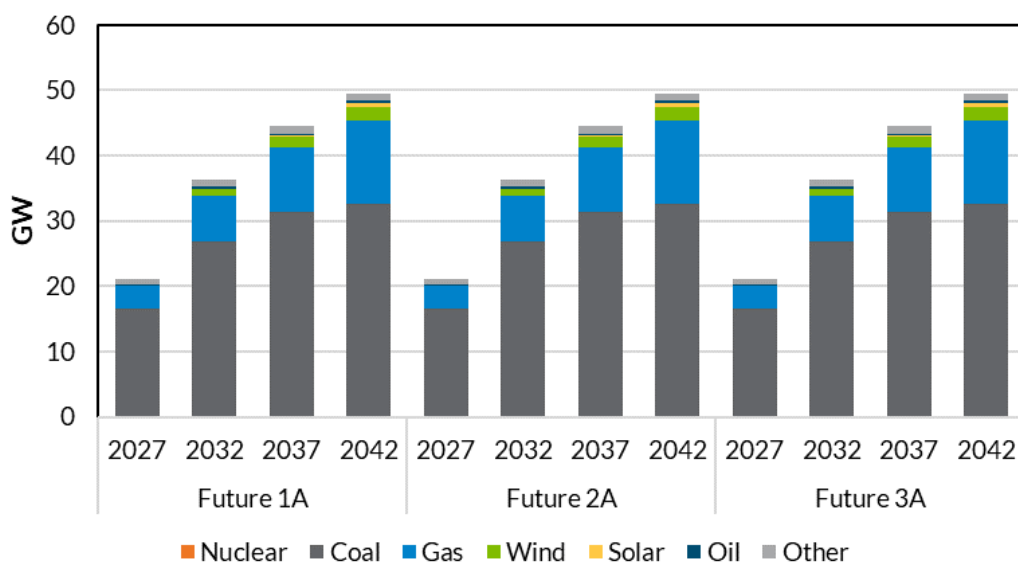


Figure 14: Base Retirements per Future (Cumulative per Year)

Figure 15 through Figure 17 display the results of the Future scenarios' retirement assumptions geographically throughout the MISO footprint. It is important to note that the wind units seen in these figures are assumed to be repowered with the same capacity.



## F1A Retirement Assumptions

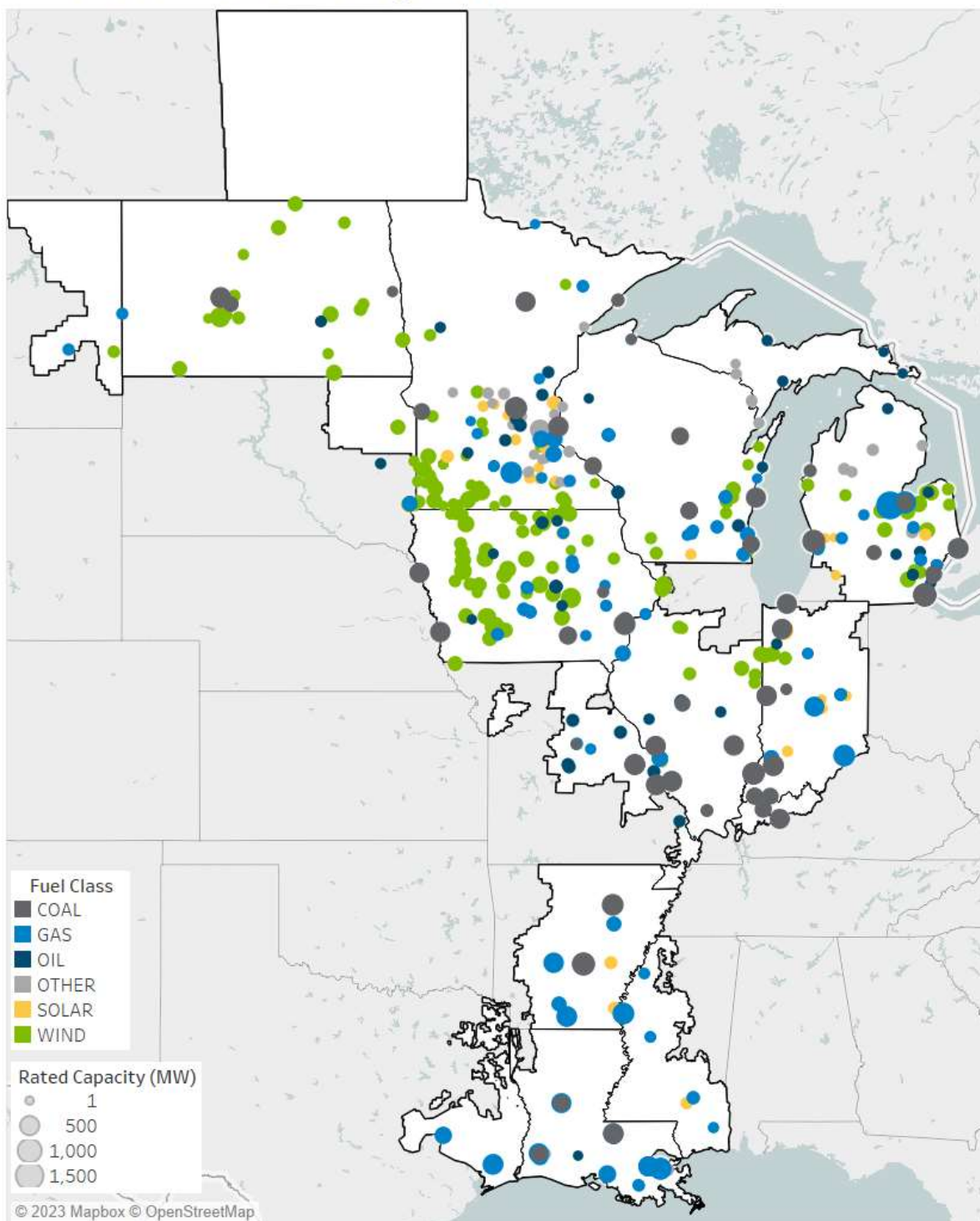


Figure 15: Future 1A Retirements by Fuel Type





## F2A Retirement Assumptions

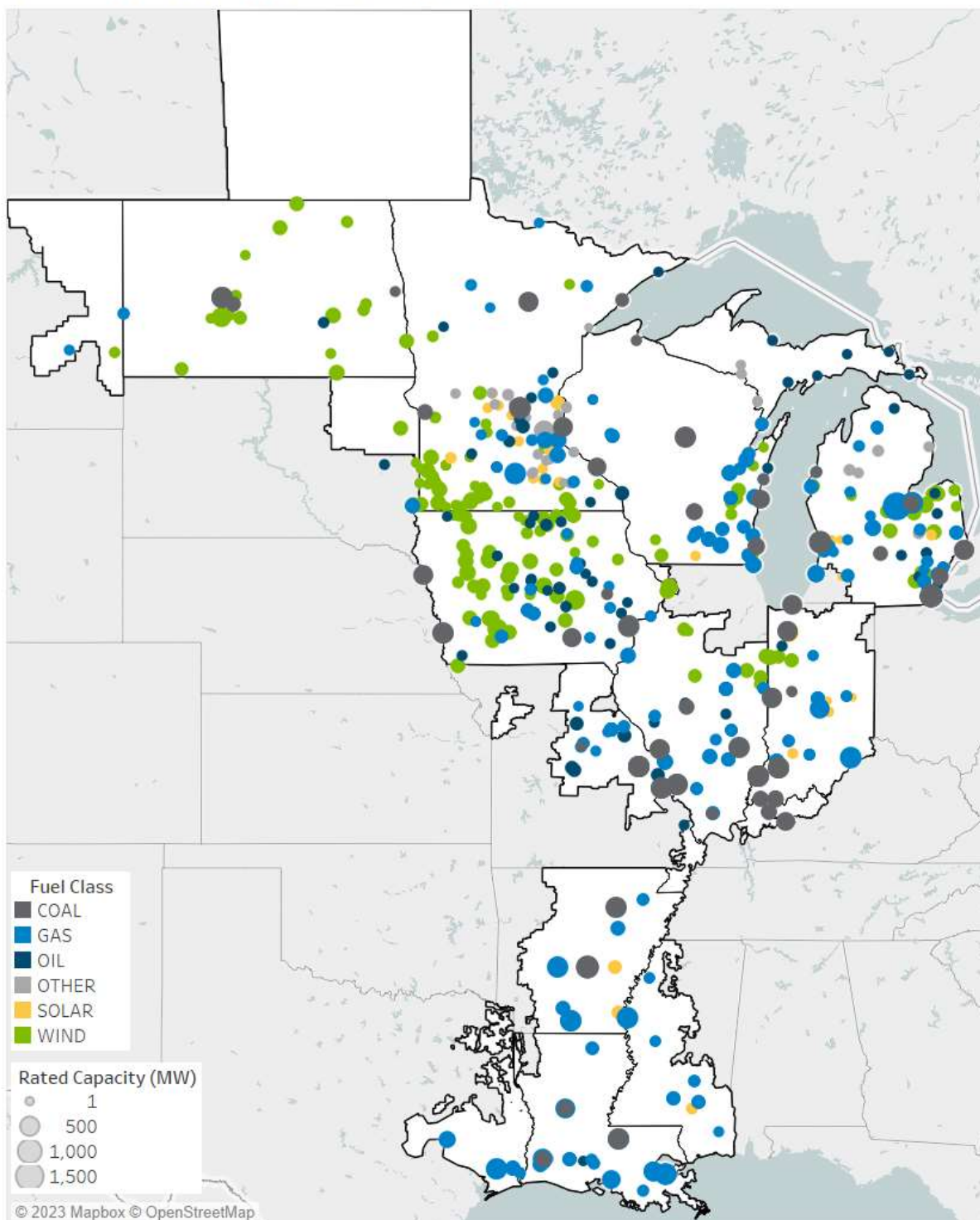


Figure 16: Future 2A Retirements by Fuel Type





## F3A Retirement Assumptions

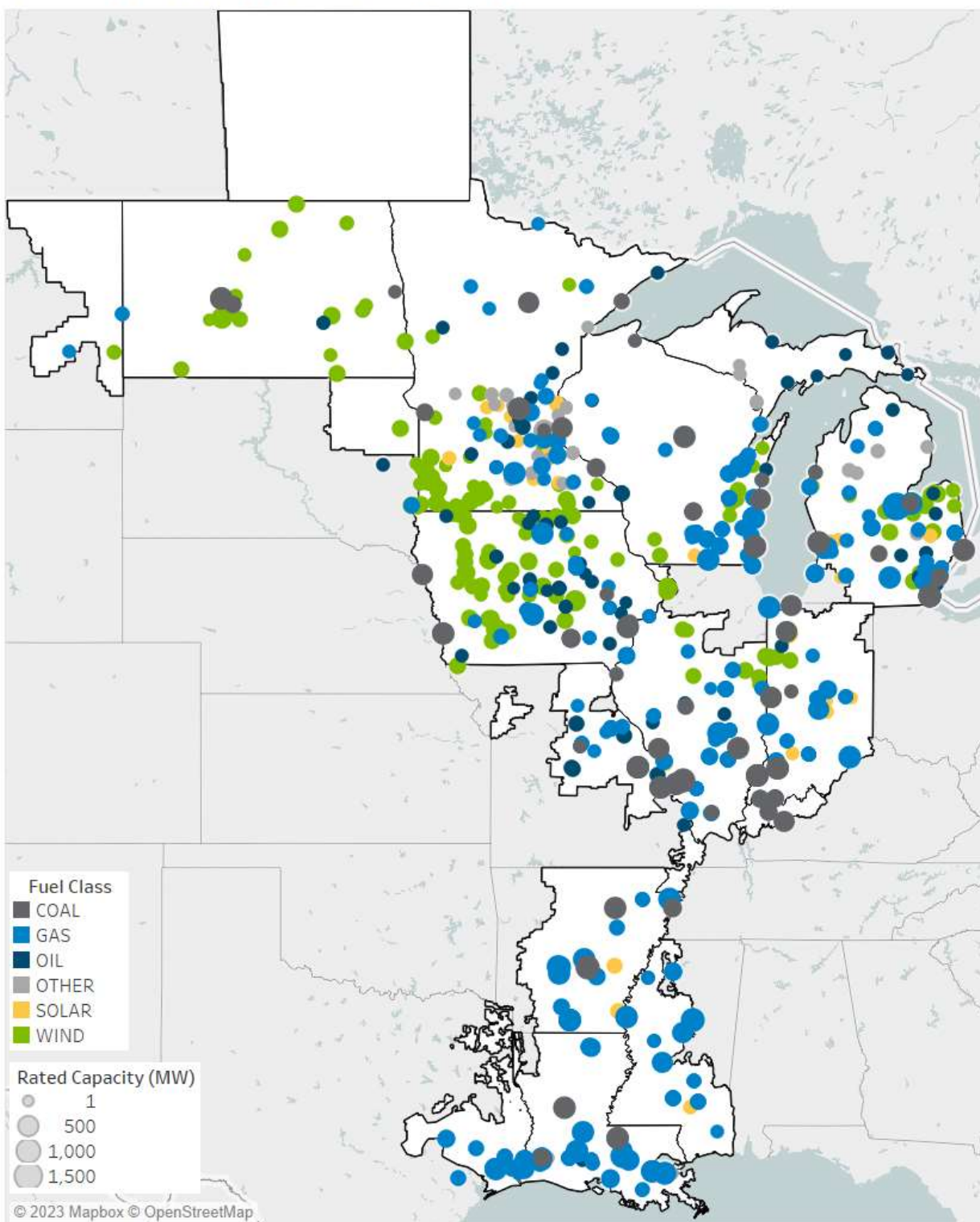


Figure 17: Future 3A Retirements by Fuel Type



## Load Assumptions

The gross load assumptions developed as part of the Series 1 Futures were used in the Series 1A Futures Refresh. Since the Series 1 forecast only went to 2039, it was modified by extrapolating the forecast to 2042. Therefore, the gross annual energy and coincident peak load for the Series 1 and Series 1A Futures are the same except for the portion extrapolated, causing a slight difference when calculating the growth rates for Series 1A.

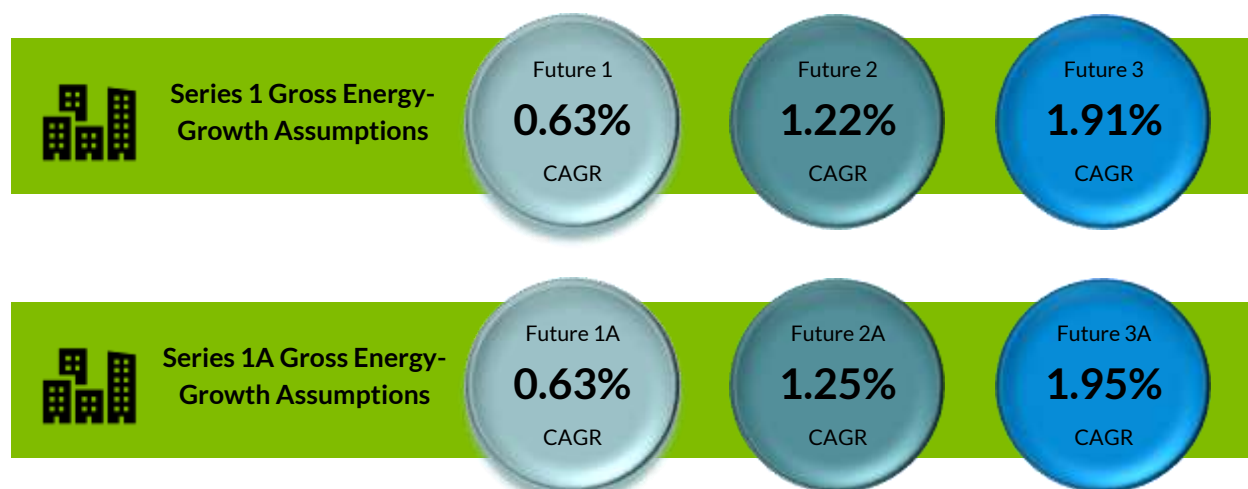


Figure 18: Gross Annual Energy Growth Comparison

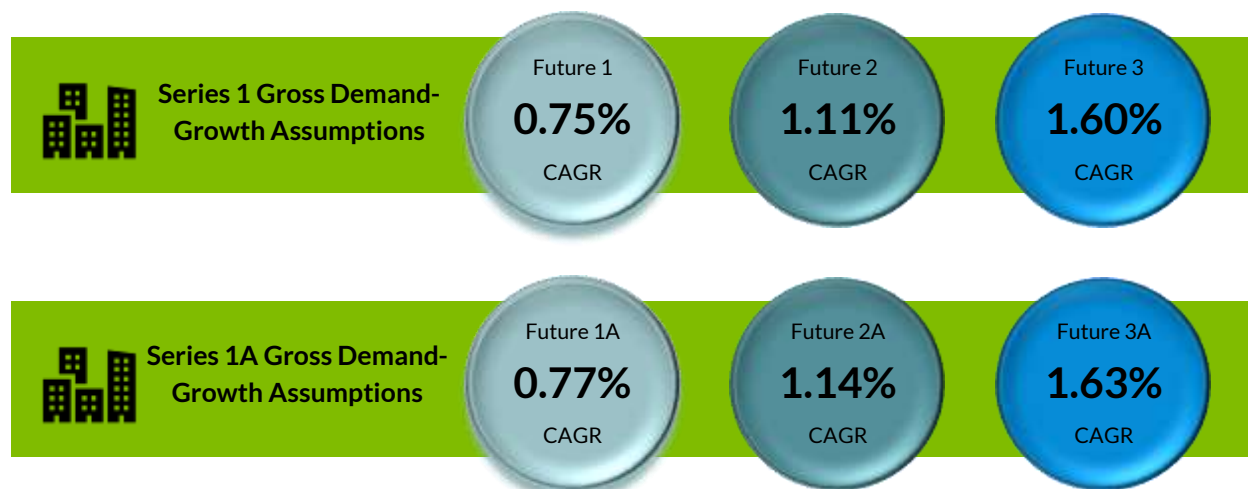


Figure 19: Gross Coincident Peak Demand Growth Comparison



The final net load results differ between Series 1 and Series 1A, as they incorporate the Distributed Energy Resources (DERs) that were included in the final resource expansion of each respective series and Future, as described in the Distributed Energy Resources (DERs) section of this report.

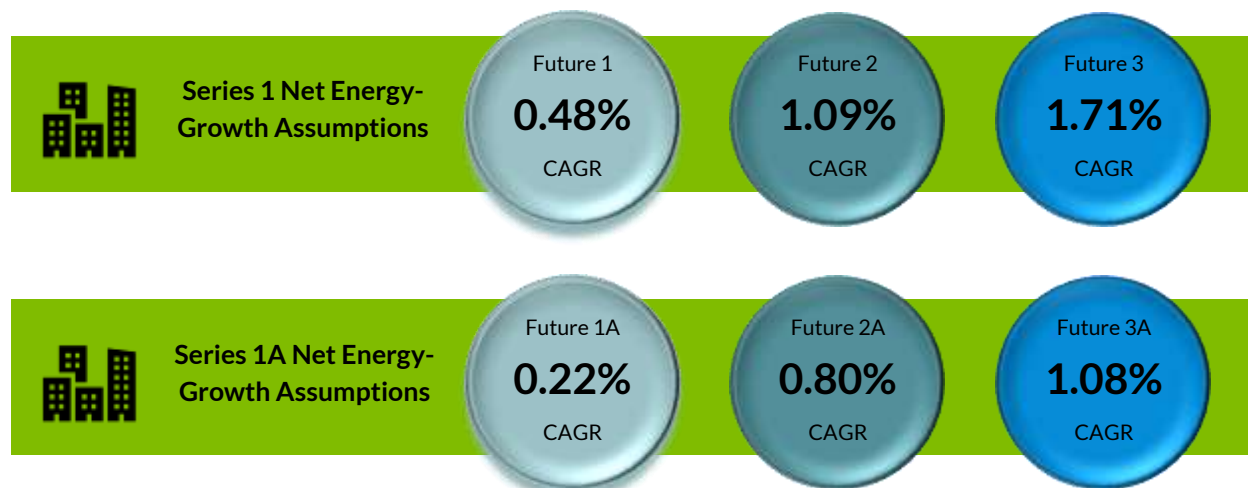


Figure 20: Net Annual Energy Growth Comparison

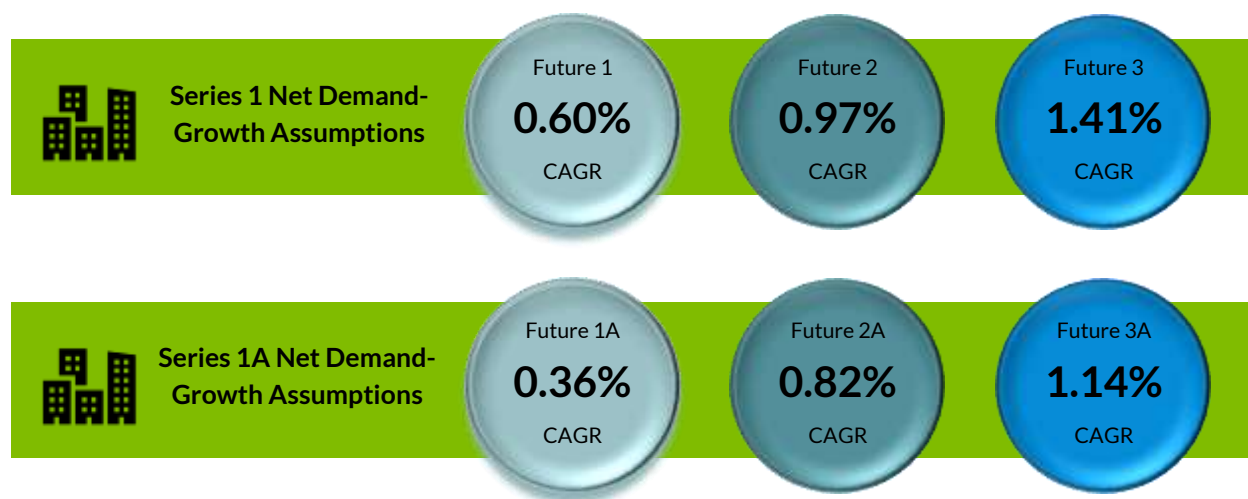


Figure 21: Net Coincident Peak Demand Growth Comparison



## MISO Forecast Development

The development of the EGEAS-Ready Coincident Peak (CP) Demand and Energy Forecasts for each Future began with MISO's load-serving entities' 20-year demand and energy forecasts<sup>18</sup> and ended with the application of the various Future-driven assumptions, creating Future- and year-specific forecasts.

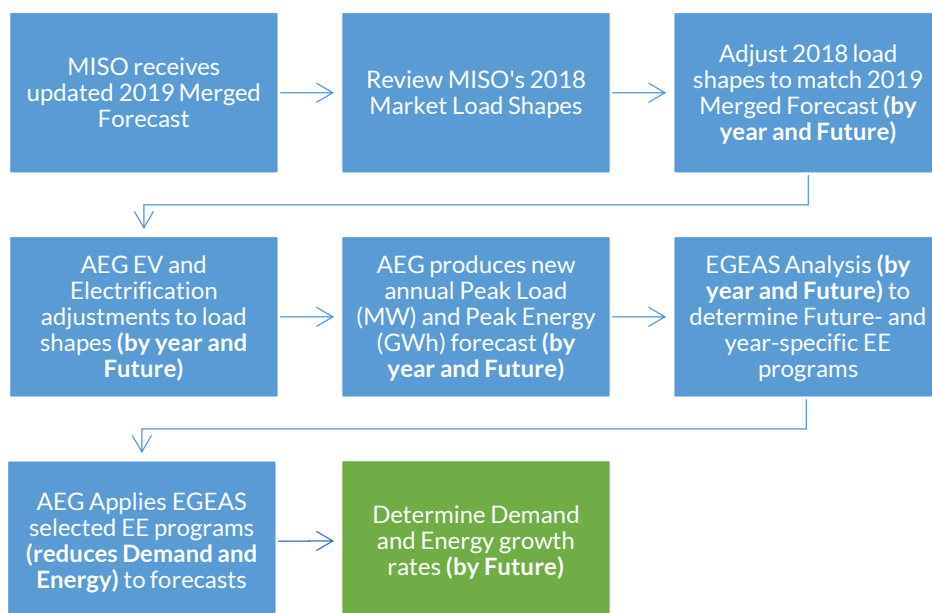


Figure 22: MISO's Forecast Development High-Level Process Flow Chart<sup>19</sup>

## Base Forecast and Load Shapes

The 2019 Merged Load Forecast for Energy Planning forecast was reviewed for updates by stakeholders December 17, 2019 through January 10, 2020, and the updates received were incorporated. To accompany the forecast, MISO evaluated its 2018 load shapes for the impact of abnormal outages in operational load shape data due to weather anomalies. MISO evaluated the impact of Atlantic Tropical Cyclones which entered the MISO footprint according to the National Oceanic and Atmospheric Administration and determined that the 2018 shapes are suitable for MISO Futures.<sup>20</sup> MISO's 2018 load shapes also align with wind and solar shapes based on the most current data.

As a Futures process improvement, MISO used PROMOD to adjust each Load Balancing Authority's (LBA) 2018 load shape to meet Peak Load (MW) and Annual Energy (GWh) requirements set by the updated 2019 Merged Load Forecast for Energy Planning forecast. The benefit of this improvement was to create 20 years' worth of unique load shapes for the EGEAS analysis, as well to establish a common load shape for the EGEAS and Market Congestion Planning Studies (MCPS) analyses.

<sup>18</sup> If a particular MISO Load-Serving Entity (LSE) did not provide a 20-year demand and energy forecast, data from the State Utility Forecasting Group's Independent Load Forecast was used for it, creating the 2019 Merged Load Forecast for Energy Planning CP.

<sup>19</sup> Demand and Energy forecast process currently at box highlighted green.

<sup>20</sup> <https://www.nhc.noaa.gov/data/tcr/index.php?season=2018&basin=atl>

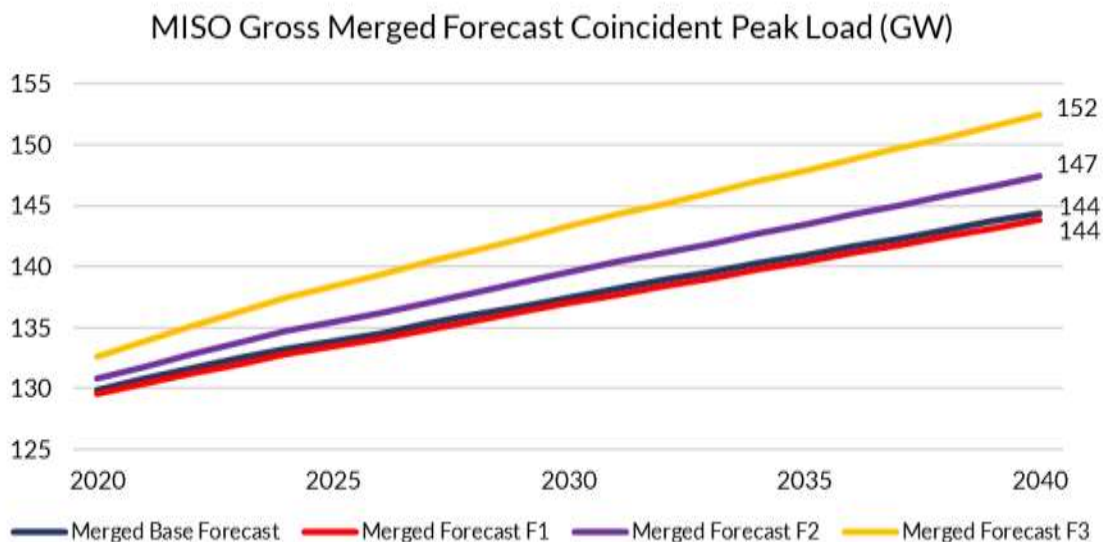


Figure 23: 2019 Merged Load Forecast Peak Load (GW)

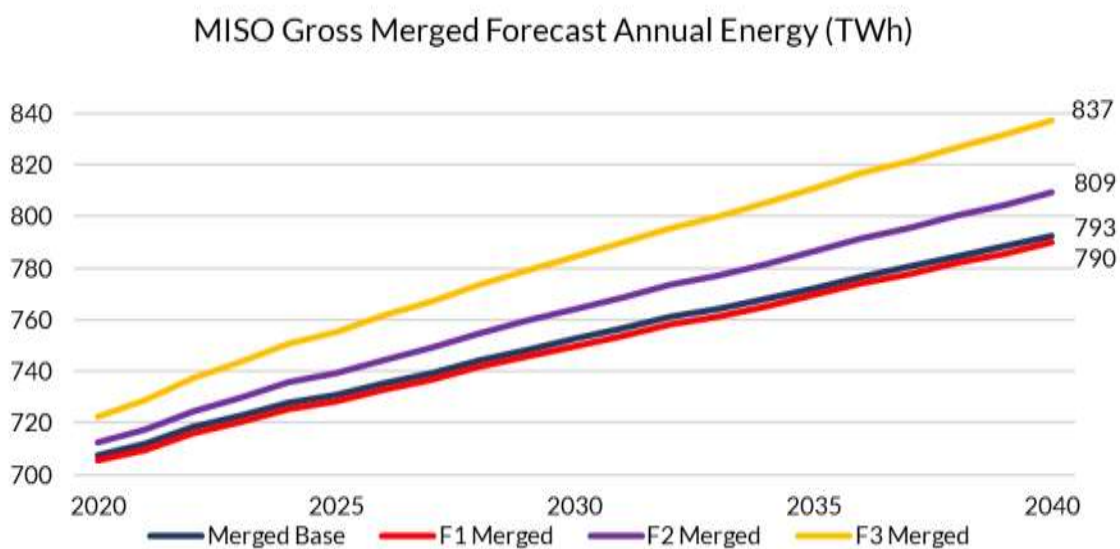


Figure 24: 2019 Merged Load Forecast Annual Energy (TWh)





## Future-Specific Forecasts and Load Shapes

Applied Energy Group (AEG) used PROMOD-adjusted load shapes for their base input assumptions and then further modified these load shapes to achieve Future-specific electrification assumptions (EV growth and charging assumptions, residential electrification, and commercial and industrial electrification), ultimately creating 20 years of load shapes for each Future. A representation of the load shape modification from the original Futures cohort is shown in Figure 31.

These Future-specific load shapes were used to calculate the associated Peak Load (MW) and Annual Energy (GWh) forecast for each year to be used in the EGEAS analysis. Refer to the following figures for MISO Footprint and Local Resource Zone (LRZ) representation of this forecast.



Figure 25: Final AEG Modified MISO Gross Coincident Peak Load (GW) Forecast by Future<sup>21, 22</sup>



Figure 26: Final AEG Modified MISO Gross Annual Energy (TWh) Forecast by Future<sup>23</sup>

<sup>21</sup> Values shown do not include load and energy modifiers determined by EGEAS analysis.

<sup>22</sup> Dips in Future 3 are due to different peak times of reference, EV charging, and electrification load forecasts.

<sup>23</sup> Differences in annual energy forecast and energy generation by Future are attributed to energy utilized for storage-charging and dumped energy. Total energy generation, net storage-charging, can be found for each Future in the expansion results section of this report.



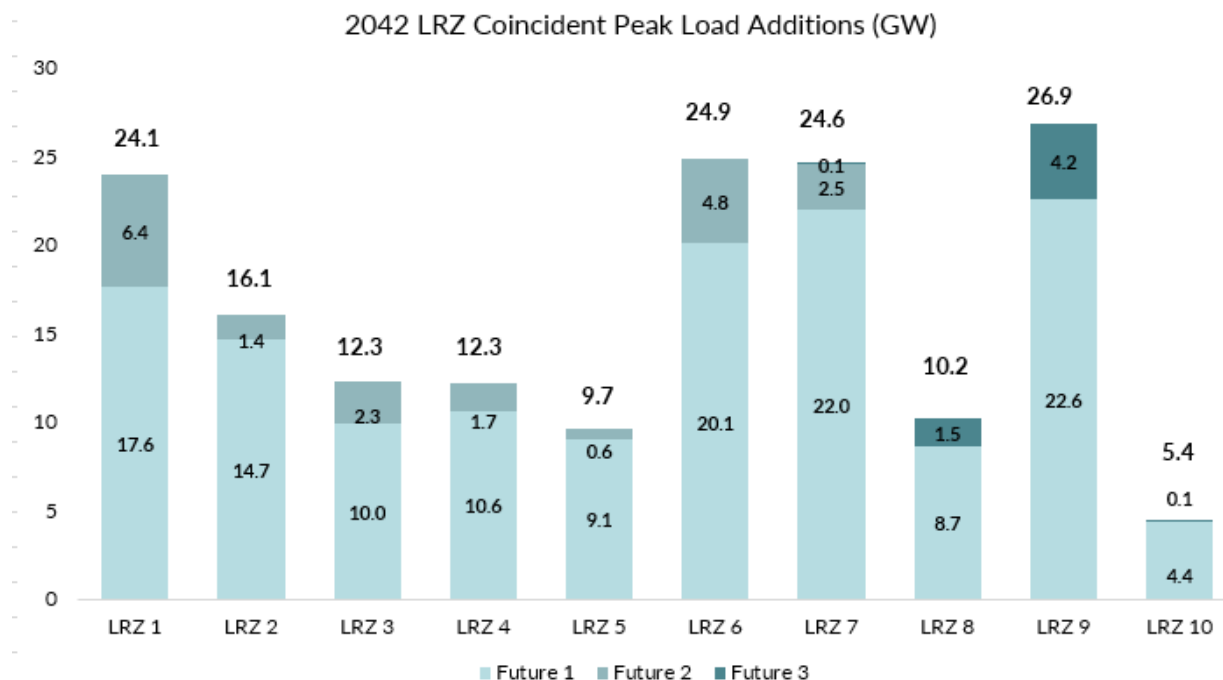


Figure 27: Final AEG Modified LRZ Coincident Peak Load (GW) Forecast<sup>24,25</sup>

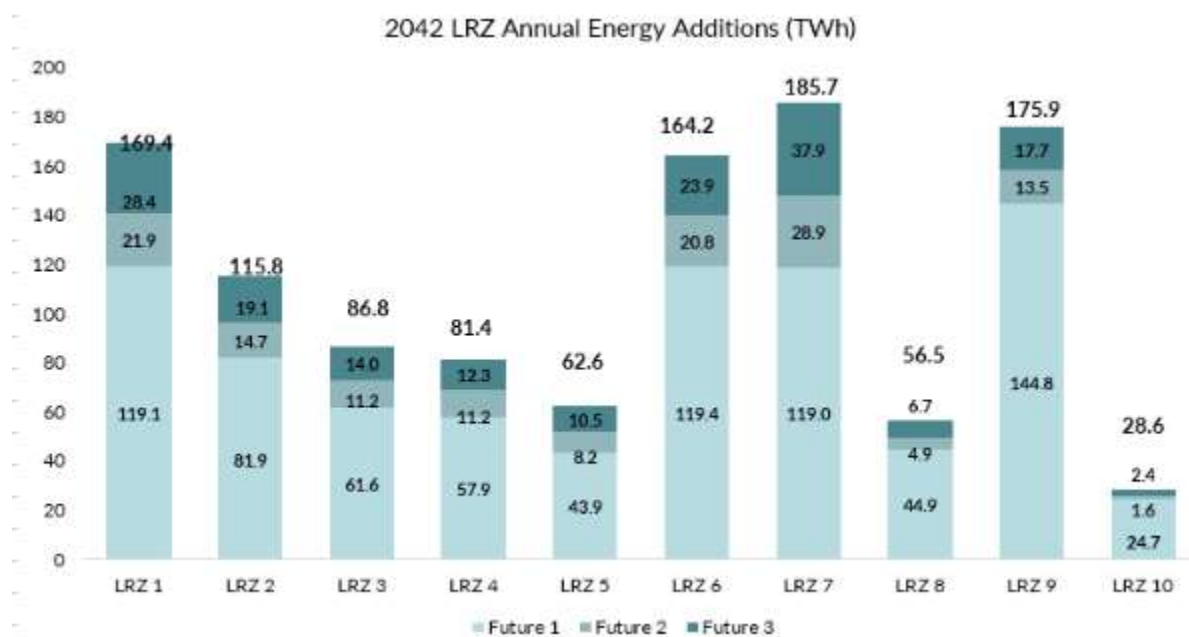


Figure 28: Final AEG Modified LRZ Annual Energy (TWh) Forecast<sup>25</sup>

<sup>24</sup> In LRZs 8 and 9, CP values decrease in Future 3, making the total shown less than the sum of values for Futures 1 and 2.

<sup>25</sup> Values shown do not include load and energy modifiers determined by EGEAS analysis.



## Forecast Growth Assumptions

Demand and energy growth values are based on Futures assumptions and were determined once the analysis was finalized EGEAS having selected hourly load (MW) and energy (GWh) modifiers and programs applied to each Future scenario's Coincident Peak forecast. The following figures represent compound annual growth rates (CAGR) and forecast increases pre- and post-analysis.

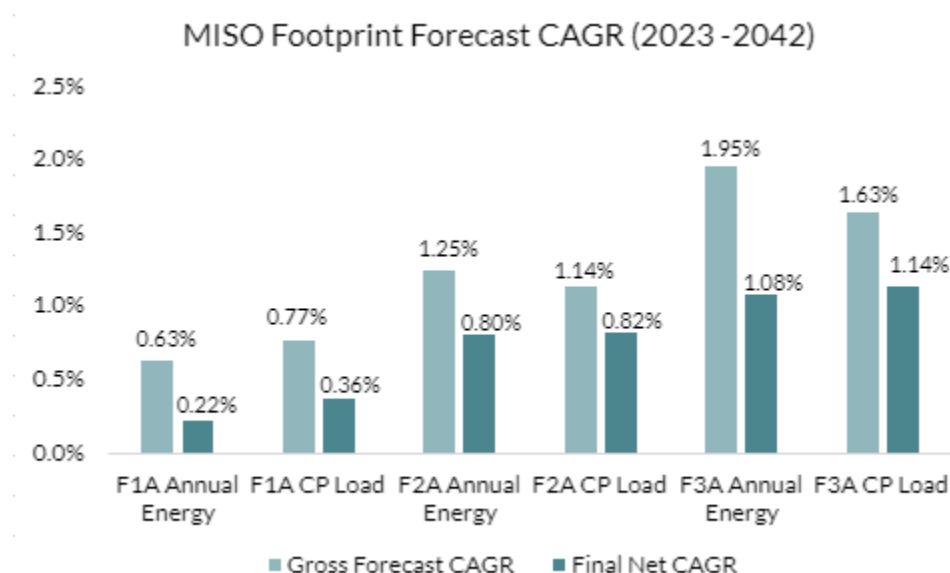


Figure 29: Final AEG Modified MISO Footprint Forecast Compound Annual Growth Rates (CAGR)

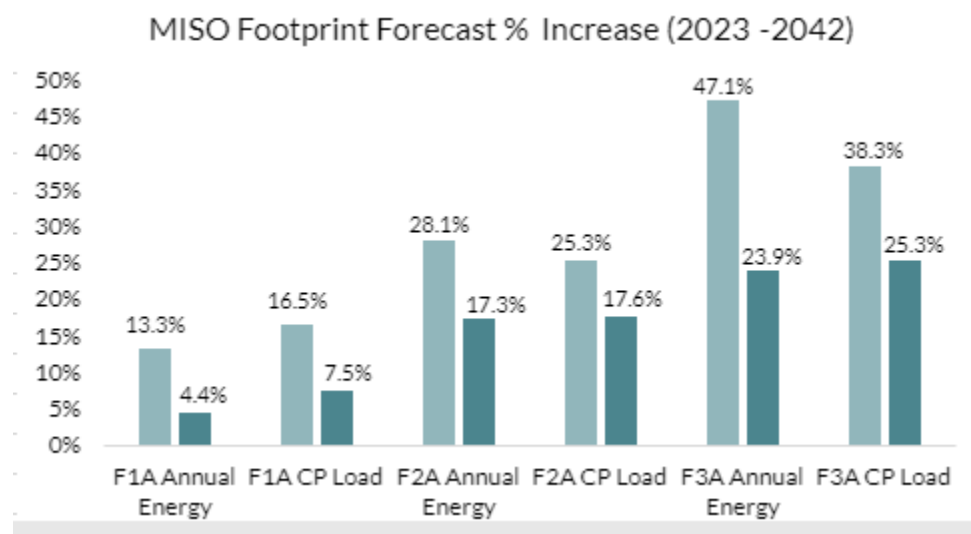


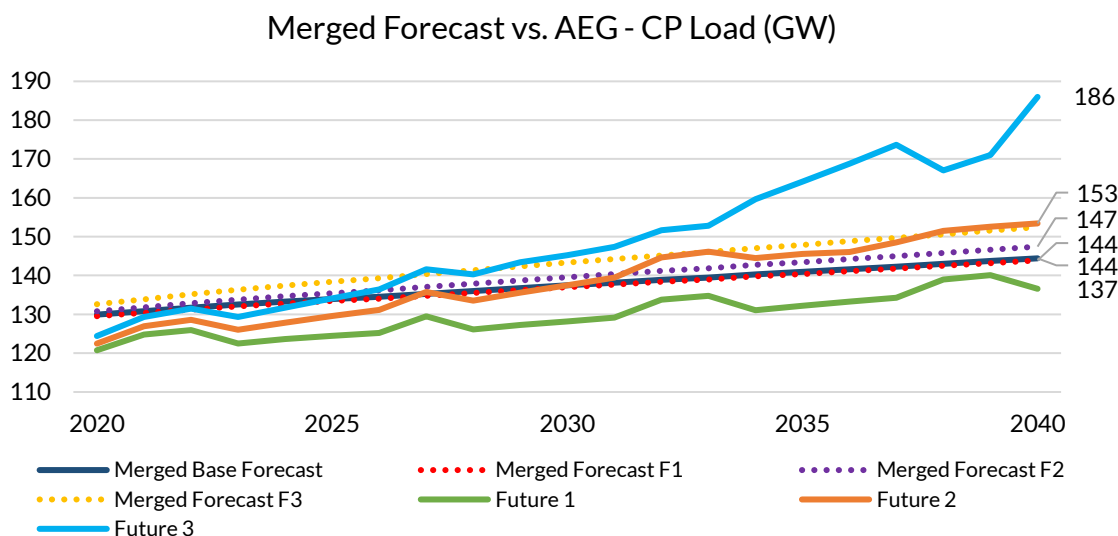
Figure 30: Final AEG Modified MISO Footprint Forecast % Increase.<sup>26</sup>

<sup>26</sup> Gross values do not include load and energy modifiers determined by EGEAS analysis, while Net values include EE programs that were selected during modeling.

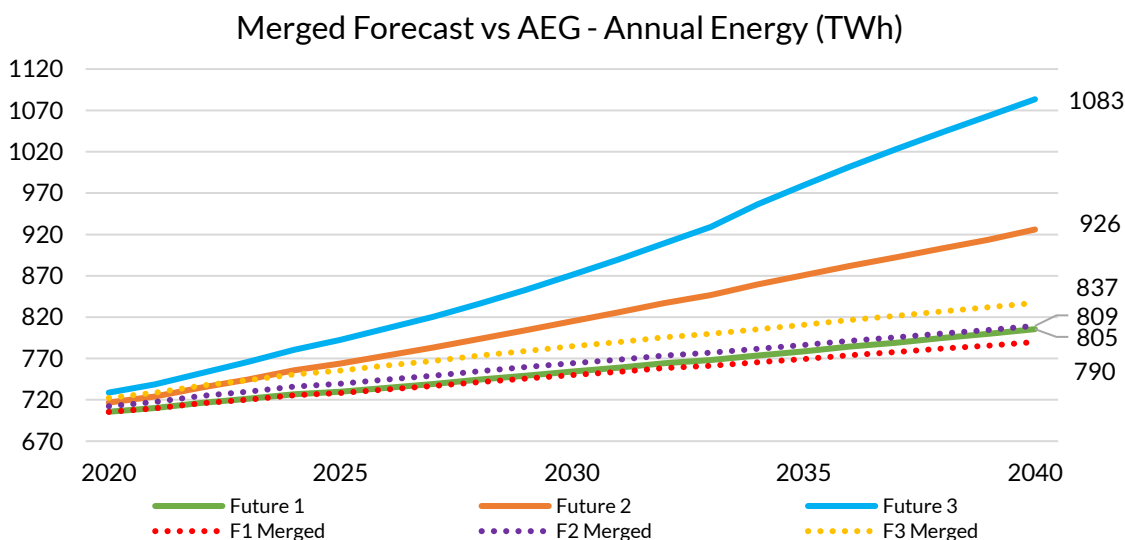


## Forecast Evolution

To ensure the Futures update has effectively created broad and realistic bookends, especially with demand and energy assumptions as key drivers, the original Futures cohort compared the 2019 Merged Forecast (pre-application of EV and Electrification assumptions), MTEP21 Coincident Peak (CP) Future-specific forecasts (post-application of EV and Electrification assumptions), and MTEP19 Future forecasts.



**Figure 31: Merged Forecast vs. Future-Specific Adjustments – CP Load (GW)** <sup>27, 28</sup>



**Figure 32: Merged Forecast vs. Future-Specific Adjustments – Annual Energy (TWh)**

<sup>27</sup> Values shown do not include load and energy modifiers determined by EGEAS analysis.

<sup>28</sup> Merged Forecast CP Load (GW) values are calculated from monthly peak data while the AEG Peak Load (GW) values are calculated from hourly data. This has the illusory effect of the Merged Forecast CP Load (GW) being reduced.

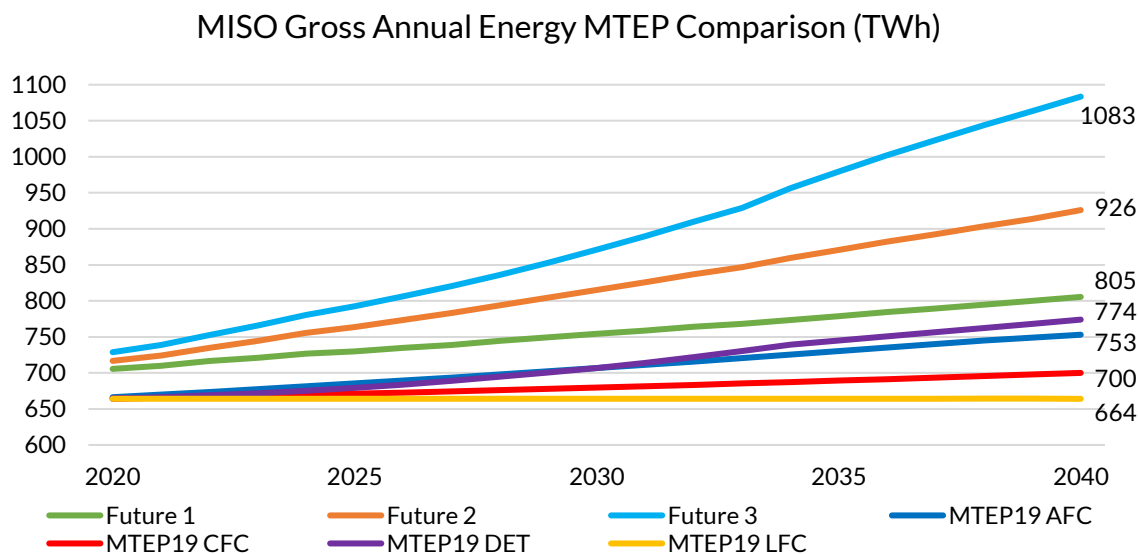


Figure 33: MTEP19 & MTEP21 MISO Annual Energy (TWh) Compare<sup>29</sup>

## Final Load Shapes

Upon conclusion of the EGEAS analysis, MISO removed energy proportionate with selected energy efficiency (EE) programs in each Future scenario's load shape to produce final net load shapes. In Figure 35 through Figure 37, the evolution of each Future load shape is shown, comparing the final input load shape for year 2042 from AEG that includes electrification assumptions against the 2042 load shape post modeling of each scenario that nets out EE programs selected. Figure 34 displays each Future scenario's post-modeling load shape in the final year of the study, for comparison.

<sup>29</sup> Values shown do not include load and energy modifiers determined by EGEAS analysis.

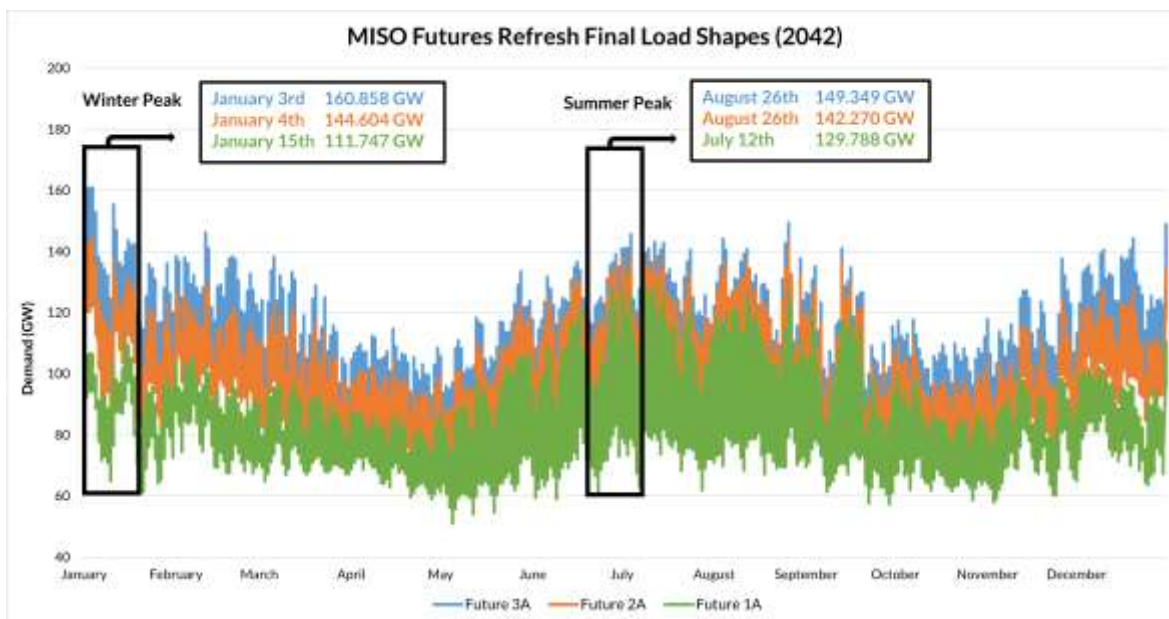


Figure 34: All Futures Final Load Shapes

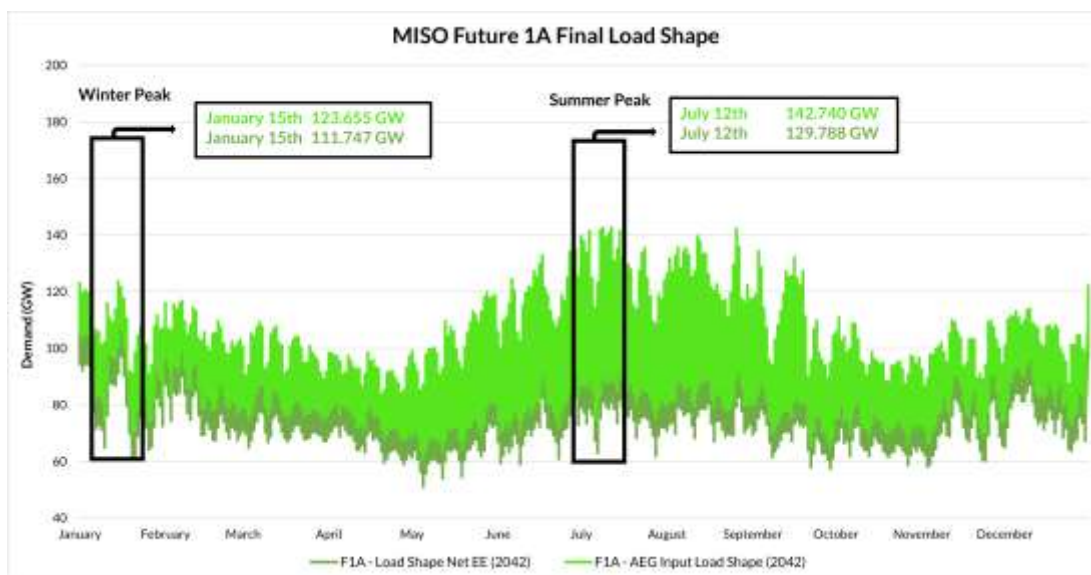


Figure 35: Future 1A Load Shape Evolution



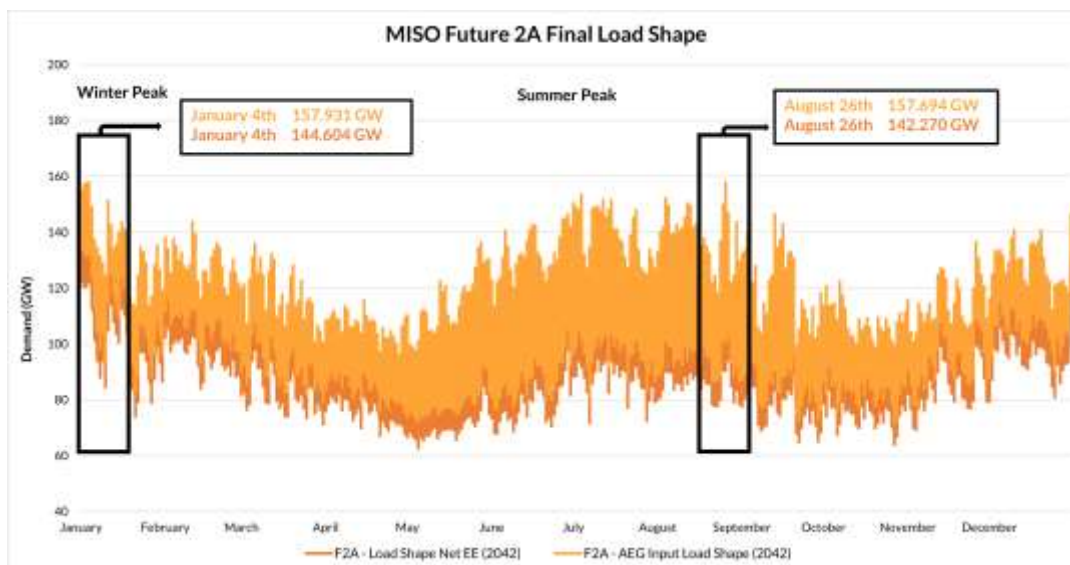


Figure 36: Future 2A Load Shape Evolution

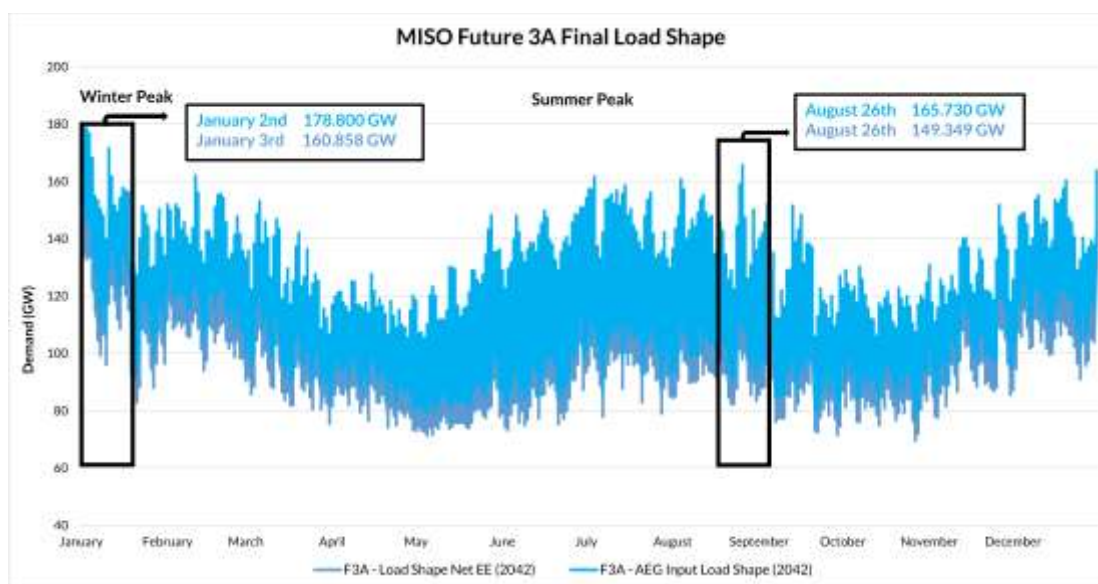


Figure 37: Future 3A Load Shape Evolution

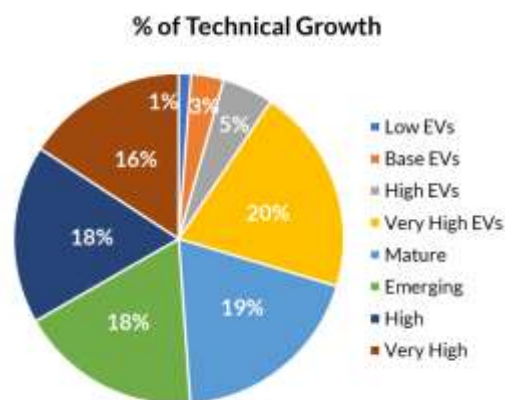


## Electrification

A primary driver of load growth in Futures 2 and 3 is electrification. Electrification is the conversion of an end-use device to be powered with electricity, such that it displaces another fuel, (e.g., natural gas or propane). The increased energy assumptions of 30% (F2 & F2A) and 50% (F3 & F3A) were selected by MISO to create a wide but plausible range of growth scenarios. Although electrification drives the load increase in two of the Futures, it is not the sole source of each scenario's load growth. A more detailed discussion of each Future's load growth and electrification assumptions is provided below and in the Electrification Section of this report.

MISO contracted Applied Energy Group (AEG) to evaluate the MISO footprint on its potential to electrify. Electrification is the conversion of an end-use device to be powered with electricity, such that it displaces another fuel, (e.g., natural gas or propane). In this study, electrification is calculated as a percentage of technical potential that a given LRZ could achieve. The figure to the right shows the categories of electrification and what percentages of the technical potential they comprise. More details on the assumptions for the categories are included below.

To estimate the available market for electrification, AEG started with the end-use load forecasting models developed for MTEP20 (previous set of MISO Futures), which include market data for each state in the MISO footprint. These market data included estimates of the penetration of many types of electric equipment. To estimate the total technical electrifiable load, AEG assumed that 90% of a particular end-use customer load was capable of being electrified, and then subtracted the electric equipment saturations (the load that is already electrified) from that value.



**Figure 38: Electrification Categories**

### Electrification Categories

AEG identified each electrifiable technology and considered how likely or feasible it would be to be adopted before assigning it to one of four categories: mature technologies, emerging, high, and very high.<sup>30</sup> AEG considered how widespread the technology currently is, whether there are utility EE programs, and whether or not there are known market barriers. Since both mature and emerging versions of known technologies (e.g., traditional air-source heat pumps vs. cold-climate heat pumps) can coexist, AEG distributed the electrification potential for different technologies over more than one category. These are represented by the percentages below.

Additionally, AEG considered the certainty around each assumption. For example, industrial process loads are very customizable and would require a “bottom-up” approach to implementation, considering each industry and state individually. To capture this uncertainty, electrification of industrial process loads was assigned to higher electrification levels.

Each category is described below however, additional insights into the details of these categories may be found in [MISO's Electrification Insights Report](#).

### Mature Technologies

The “Mature Technologies” electrification category includes technologies that are widely available on the market today and are the most likely to electrify in the future. One example is an air-source heat pump,

<sup>30</sup> AEG's 2019 Presentation on Electrification



which is already found in many homes throughout the United States. Electric cooking equipment, such as induction ovens, is another example of an existing technology that is popular and relatively straightforward to install. Technologies in this category include:

- Air-Source Heat Pumps (50% of single-family [SF], 50% of multi-family [MF], 50% of Commercial and Industrial [C&I])
- Geothermal Heat Pumps (50% of SF, 50% of C&I)
- Heat Pump Water Heaters (50% of SF)
- Clothes Dryers
- Dishwashers
- Stoves

To better understand how much of these technologies are being electrified in each category, it is best to give an example. For air-source heat pumps, this section is saying that 50% of single-family, multi-family, and commercial and industrial heat pumps that can electrify will be electrified in this category.

### Emerging Technologies

The “Emerging Technologies” category represents electrification load that is beginning to become available or is more mature but limited by known market barriers. For example, while air-source heat pumps are a mature technology, they may not be easily installable without reconfiguring the ductwork. Gas forced-air furnaces provide hotter air and require smaller ducts, requiring an invasive modification to expand the ductwork to keep a home warm in the winter. Process loads also begin to appear in this category.

Technologies in this category include:

- Air-Source Heat Pumps (50% of SF, 50% of MF, 50% of C&I)
- Geothermal Heat Pumps (50% of SF, 50% of MF, 50% of C&I)
- Heat Pump Water Heaters (50% of SF, 50% of MF, 50% of C&I)
- Industrial Process (25% of C&I)

### High Electrification Scenario Technologies

This category represents the point where substantial market barriers exist or where technologies are new or still in development. An example is a large-scale air-source heat pump that would be necessary to replace a large gas boiler heating a hospital. These are not readily available—gas is the most common fuel source in large-scale applications. However, if high levels of electrification are to be achieved, electrification using these new and in-development technologies would need to take place. Technologies in this category include:

- Air-Source Heat Pump (50% of C&I)
- Geothermal Heat Pump (50% of MF, 50% of C&I)
- Heat Pump Water Heaters (50% of MF, 50% of C&I)
- Industrial Process (25% of C&I)

### Very High Electrification Scenario Technologies

This category represents the highest levels of uncertainty in the analysis and is only applied in the highest-growth cases. As noted above, much of the industrial process electrification is present in this category. The only technology in this category is noted below:

- Industrial Process (50% of C&I)



## Technologies Electrified

### HVAC Heat Pumps - Air-source and geothermal heat pumps

- Lower-growth scenarios electrify many residential homes and some businesses, where this technology is already available (rooftop units and residential systems)
- Higher-growth scenarios assume large-scale replacements are available for technologies like gas boilers

### Heat Pump Water Heaters - Efficient water heaters with a vapor-compression refrigeration cycle

- Lower-growth scenarios electrify tanks in both the residential and commercial sectors
- Higher-growth scenarios include the electrification of large-scale gas water heaters

### Residential Appliances - Clothes dryers, dishwashers, and stoves

- Dishwasher electrification occurs when no existing dishwasher is present

### Industrial Process - High growth potential, but only certain processes can be electrified

- Due to the complexity involved in electrifying industrial processes, AEG assumed that most of this occurs in the higher-growth scenarios
- Examples of technologies that may be electrified within industrial processes include ultraviolet (UV) curing and drying, machine drives, and process-specific heating and cooling
- Electric boiler, industrial heat pump, resistance heating industrial heat pump, induction furnace, etc.

### LBNL PEV Forecasts<sup>31</sup> - All four forecasts were used in development of these scenarios

- These include combinations of uncontrolled and V2G versions of the: Low, Base, High, and Very High scenarios
- Merged PEV forecasts were selected for each growth scenario – adoption curves and load shapes specific to the selected forecast were used

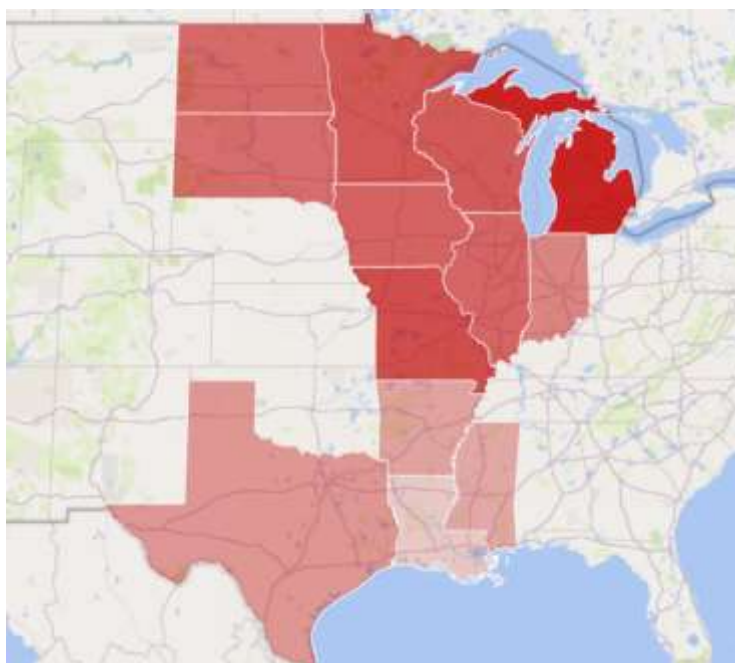
Figure 40 through Figure 45 display the results of these electrification assumptions across each Future scenario in the MISO footprint. The charts present a detailed view of the results showing yearly cumulative increases in energy from electrification for the footprint, electrification totals for each Local Resource Zone for the entire study, and the proportion of electrification from each technology.

<sup>31</sup> Lawrence Berkeley National Lab EV Forecast Report



## Electrification Potential Across MISO Footprint

This analysis was conducted at the state level in the MISO footprint then aggregated by LRZ. AEG's end-use forecasting and Demand-Side Management (DSM) potential model was used to conduct this analysis, providing estimates of electric equipment penetrations as well as consumption for MISO's fraction of each state. Since local weather and equipment penetration data were used in this analysis, each state will have different end-use consumption patterns and a different electrifiable load. These are high-level findings based on the end-use models and a result of the differences noted above. The three main drivers of technical potential for electrification are:



**Figure 39: Electrification Potential by State**

- **Latitude:** The northern states in the MISO footprint are generally colder than the southern states, resulting in larger space-heating loads. Since the heating end-uses represent some of the largest electrification potential, additional new loads are expected in the northern MISO states.
- **Gas Infrastructure:** Along with latitude, existing gas infrastructure heavily influences the electrifiable load. AEG utilized the state-level market data listed above to estimate gas equipment penetrations by state. If the load in a state is already mostly electric, there would be fewer non-electric units to convert, lowering potential.
- **Cooling Presence:** The final notable factor is the presence of existing cooling equipment. Similar to the gas infrastructure note above, high penetrations of existing cooling equipment limit electrification potential since the remaining non-electric market is smaller. In the warmer southern states, many homes already have cooling equipment installed, so their potential is lower.





## Future 1 Electrification

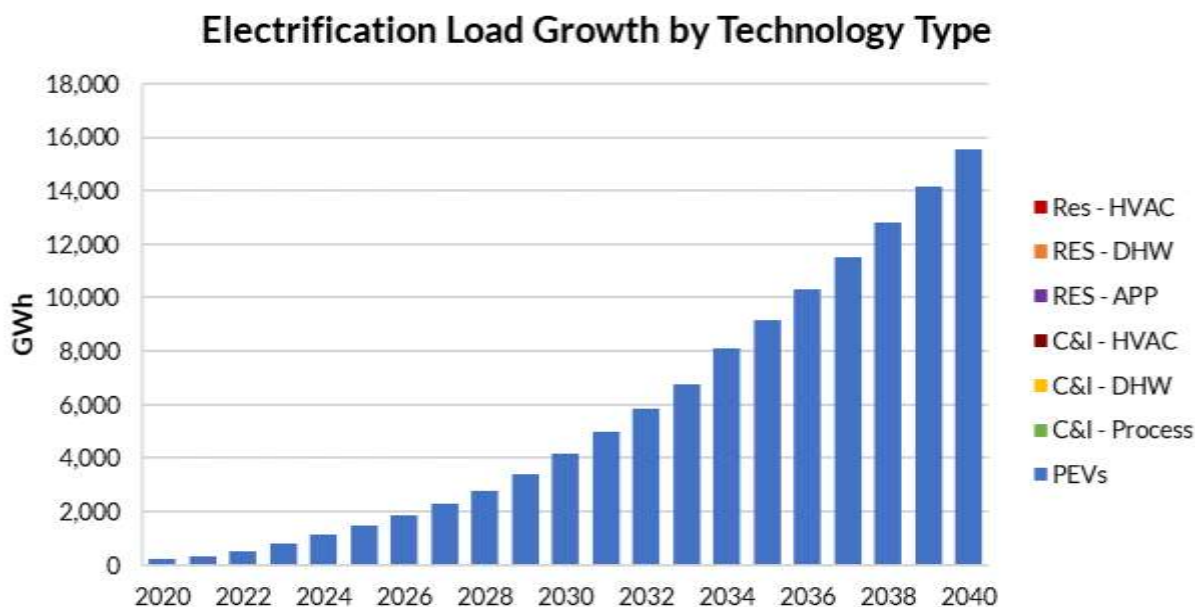


Figure 40: Future 1 Electrification by End-Use (Cumulative per Year) – Entire MISO Footprint

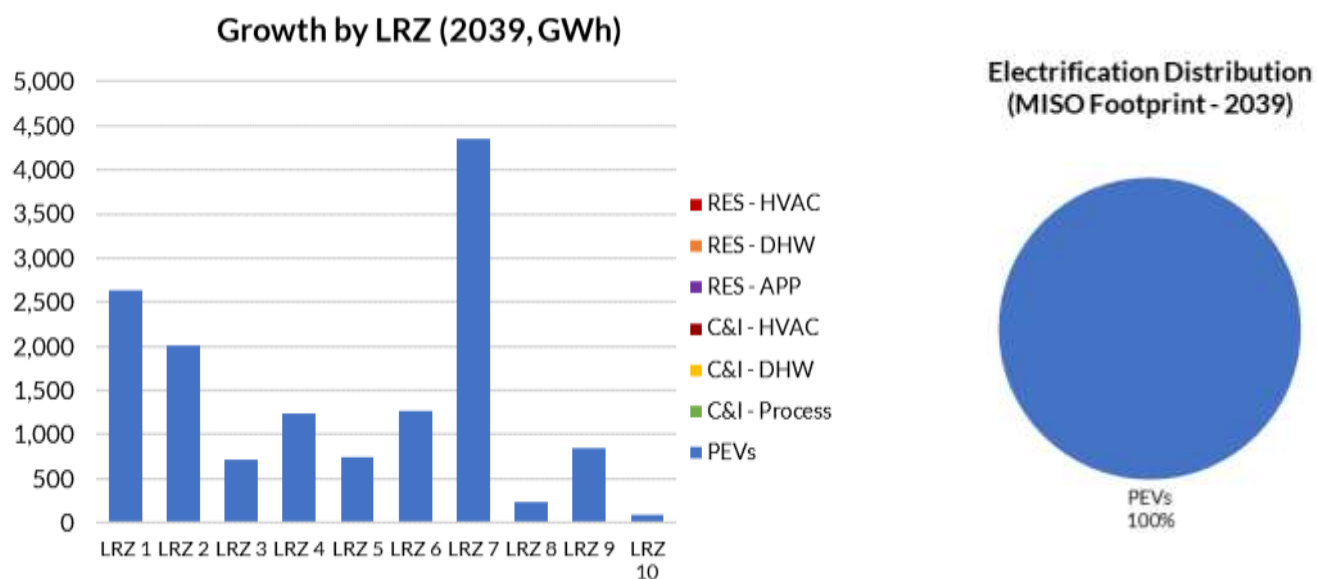


Figure 41: Future 1 Electrification Broken Down by End-Use



## Future 2 Electrification

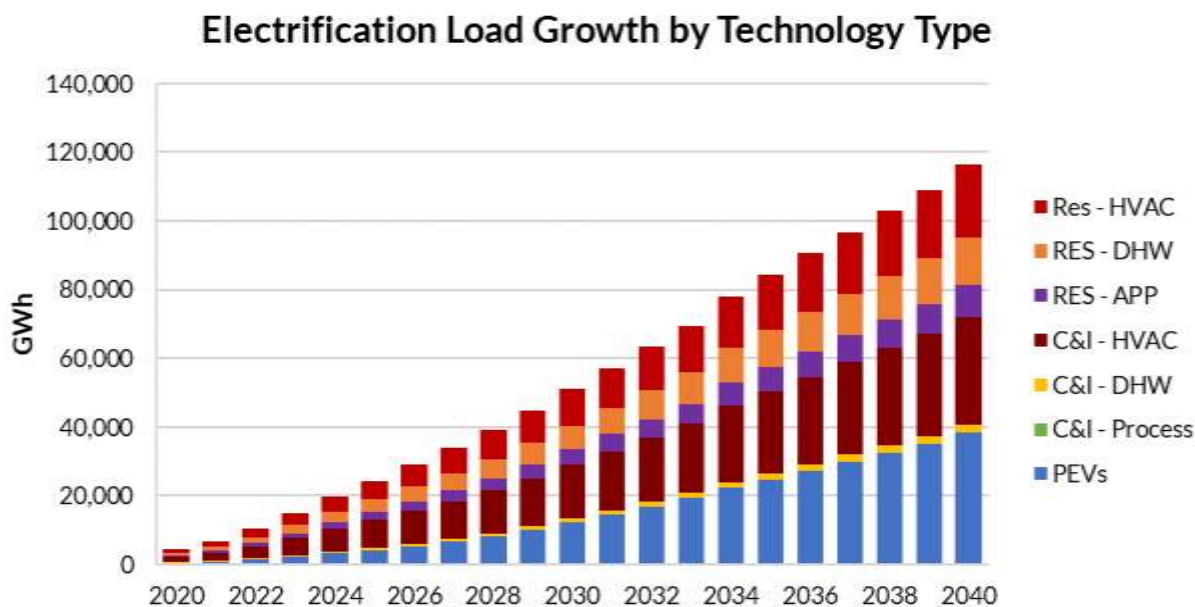


Figure 42: Future 2 Electrification by End-Use (Cumulative per Year) – Entire MISO Footprint

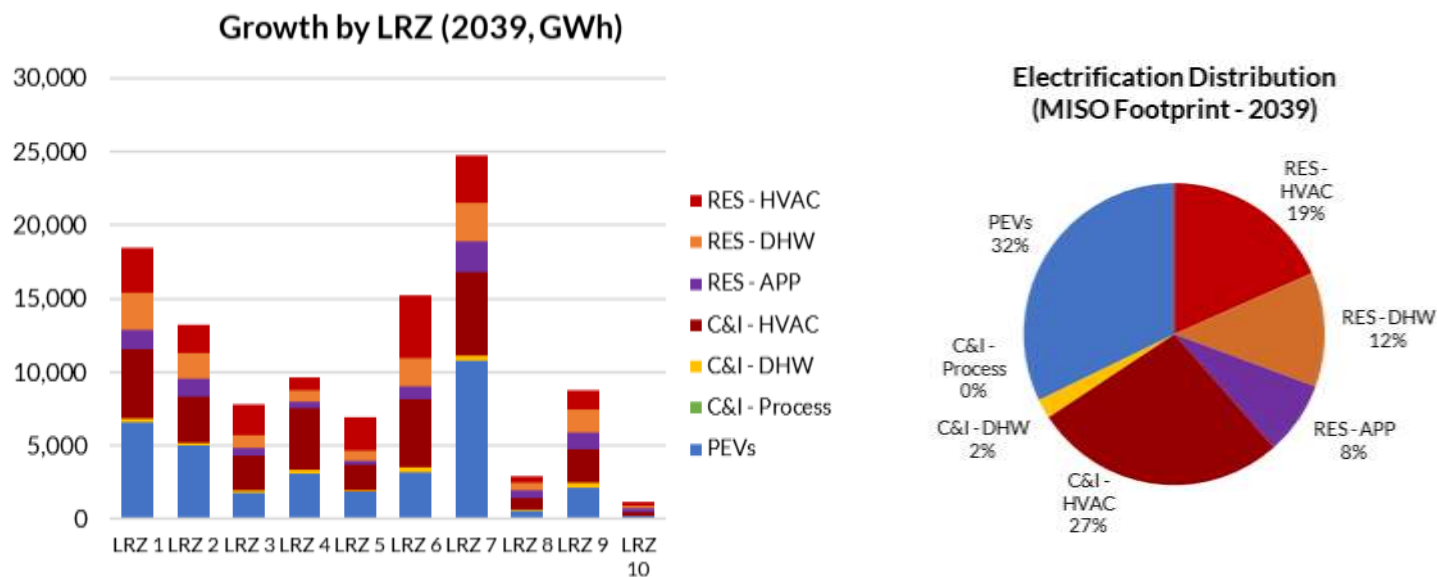


Figure 43: Future 2 Electrification Broken Down by End-Use



## Future 3 Electrification

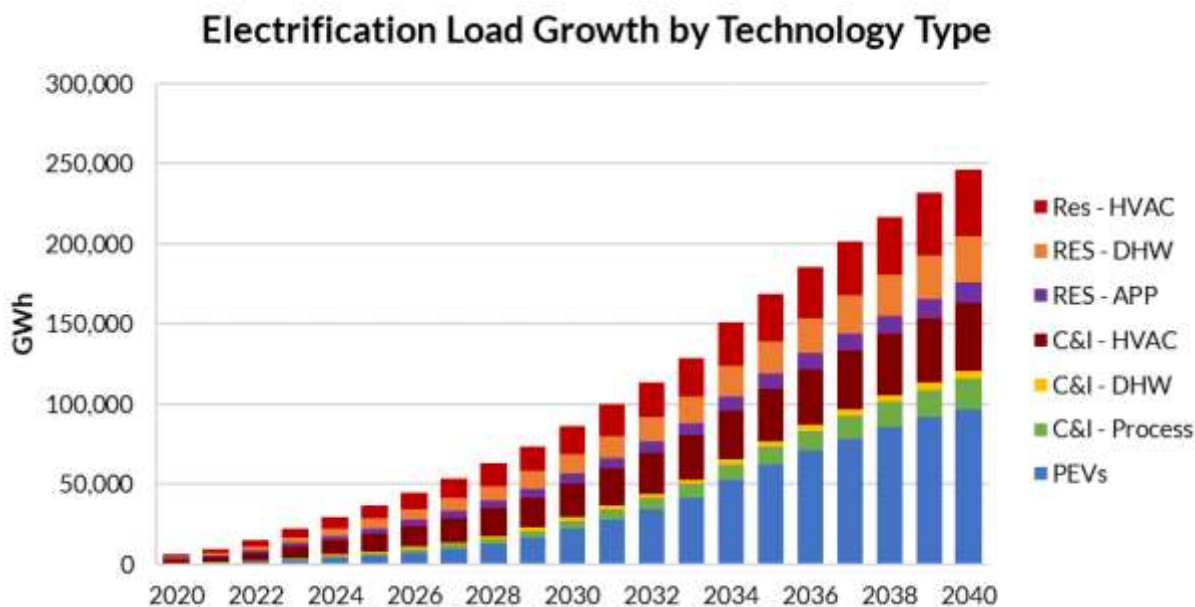


Figure 44: Future 3 Electrification by End-Use (Cumulative per Year) – Entire MISO Footprint

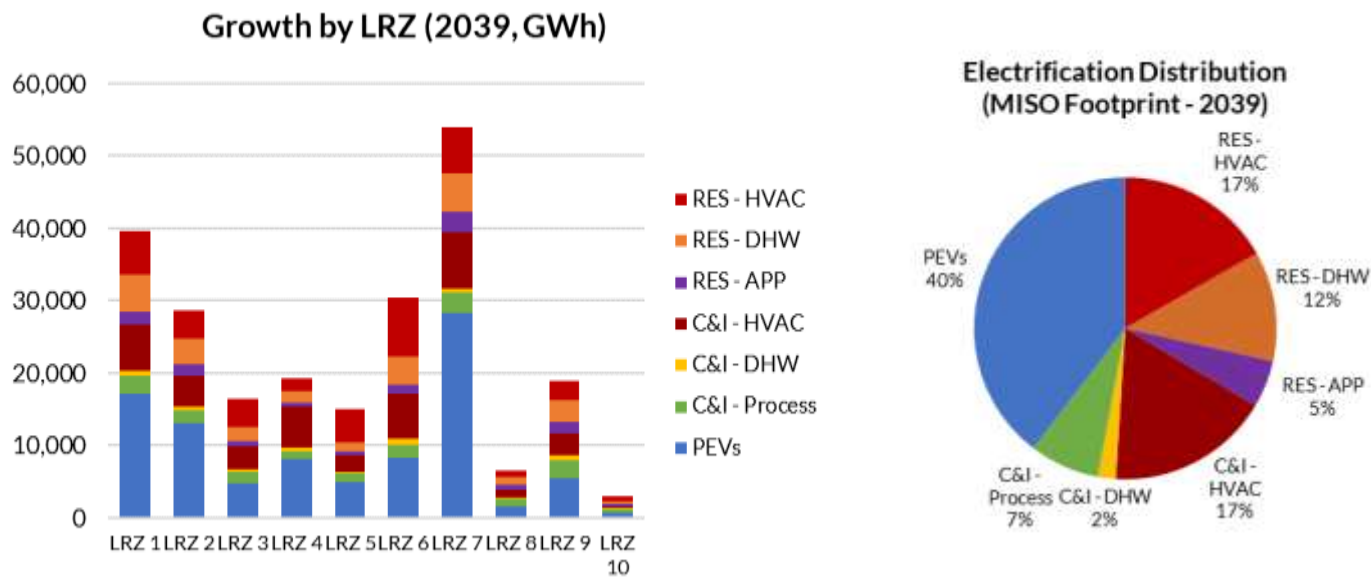


Figure 45: Future 3 Electrification Broken Down by End-Use



## Electric Vehicle Forecasts

MISO collaborated with [Lawrence Berkeley National Laboratory \(LBNL\)](#) on a study to determine the potential for EVs within the MISO footprint. This study categorized the projected growth of EVs in into four scenarios: low, base, high, and very high. Each of the three Futures used merged forecasted EV growth scenarios to include different amounts of light-duty EVs. All Futures explored a variety of EV growth and charging scenarios within every LRZ across the 20-year study period.

Future 1 evaluated only uncontrolled charging methods, Future 2 included vehicle-to-grid (V2G) charging after 2035, and Future 3 incorporated V2G charging after 2030. Figure 47 through Figure 49 detail the number of EVs in each scenario, MISO footprint and LRZ.

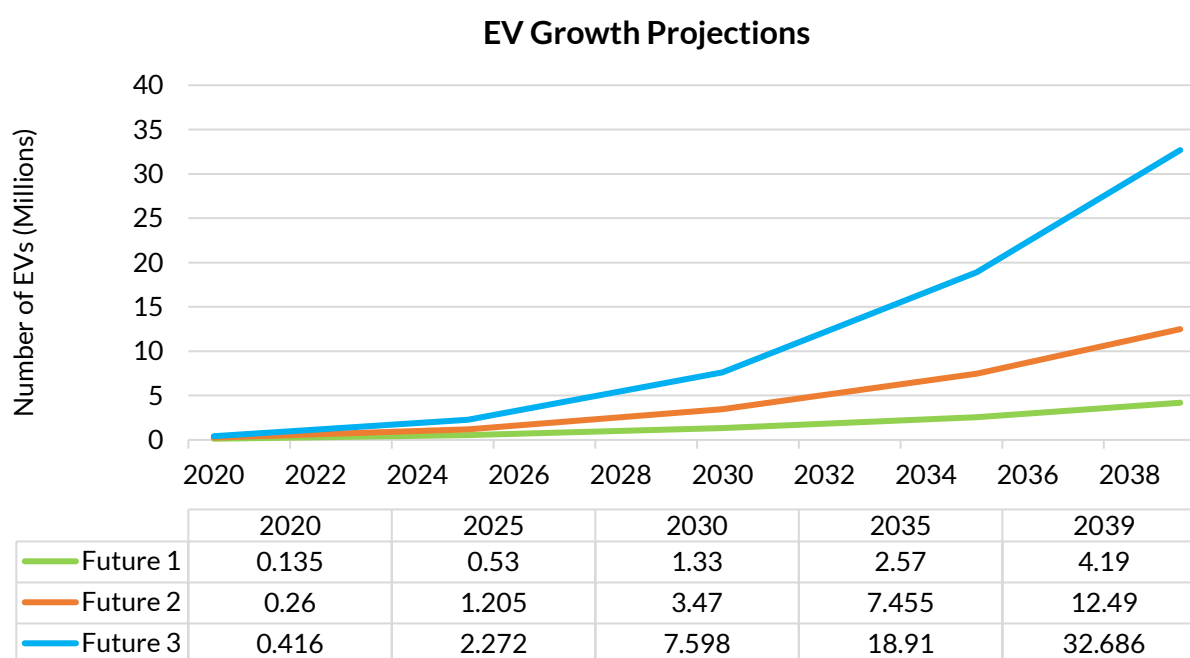


Figure 46: EV Growth per Future (MISO footprint)

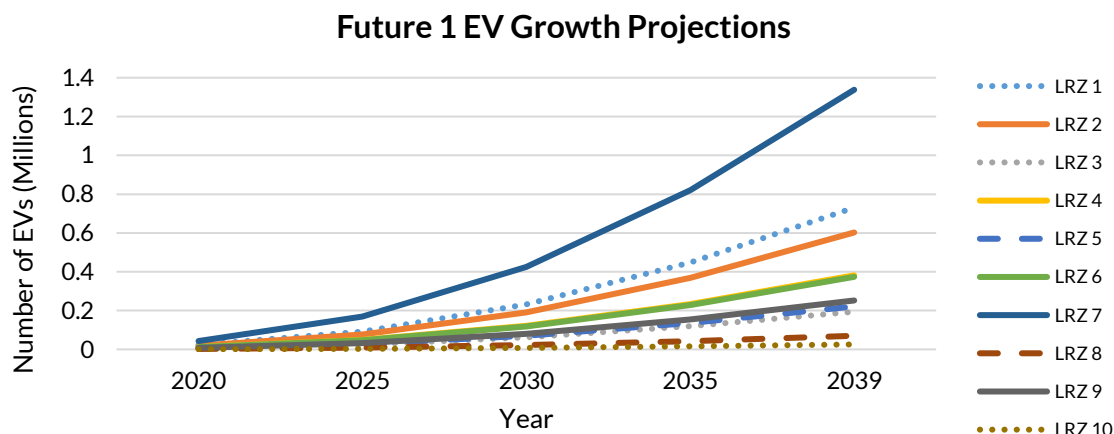


Figure 47: Future 1 EV Growth per LRZ

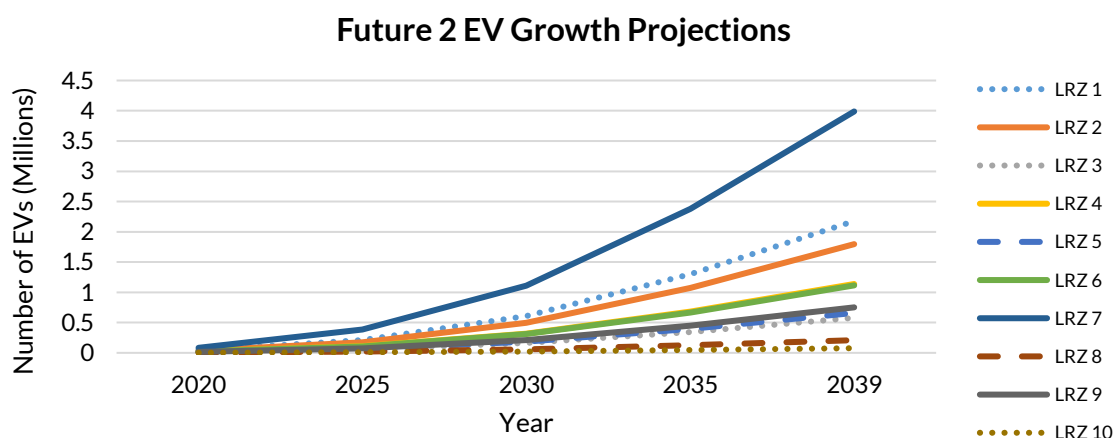


Figure 48: Future 2 EV Growth per LRZ

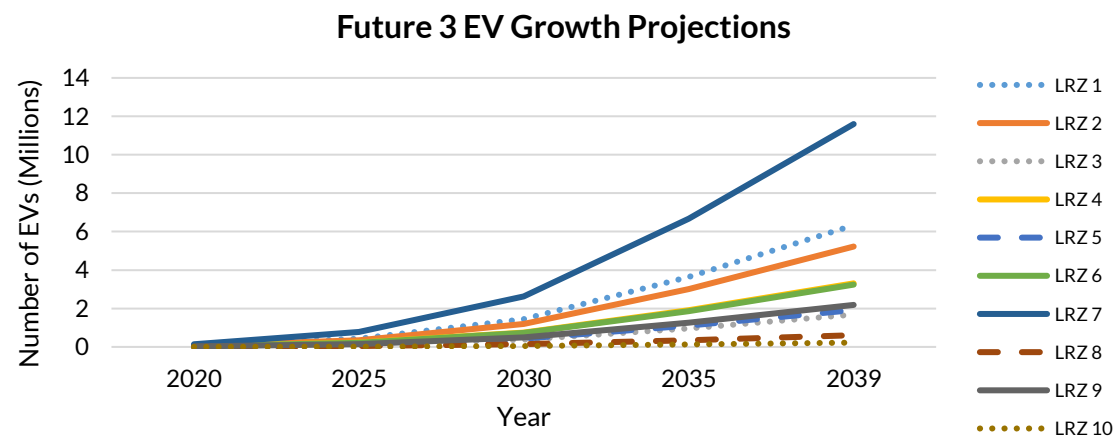


Figure 49: Future 3 EV Growth per LRZ





## New Resource Additions

Regional Resource Forecast Units (RRF Units) are various resource types that are defined in and selected by MISO's capacity expansion tool, EGEAS, to achieve each of the Futures scenarios. The RRF units used in MISO Futures are discussed in further detail below.

### Wind

[Vibrant Clean Energy \(VCE\)](#) 2018 hourly profiles were used as the base data. New RRF units were built at 100m hub height throughout the study period. Existing units used representative wind profiles developed from 2018 historical data. All wind units assumed 16.6% capacity credit.

### Solar

Vibrant Clean Energy (VCE) 2018 hourly profiles were used as the base data. Existing units used representative solar profiles developed from 2018 historical data. All solar units assumed 50% capacity credit at the beginning of the study period and decreased by 3% starting in year 2028, until the capacity credit reached a minimum of 20%.

### Hybrid: Utility-Scale Solar PV + Storage

Hybrid solar profiles were created by modifying VCE 2018 hourly profiles for solar units. Hybrid units were modeled as a 1200 MW inverter attached to 1500 MW of solar panels, resulting in an over-panel of 25%. When solar output exceeded the inverter capacity, the battery charged. Once solar output reached 20% or lower of the max capacity (max capacity is 1500 MW making 20%, 300 MW), the battery discharged until empty. Hybrid units assumed a 60% capacity credit at the beginning of the study period and decreased by 3% starting in 2028, until the capacity credit reached a minimum of 30%.

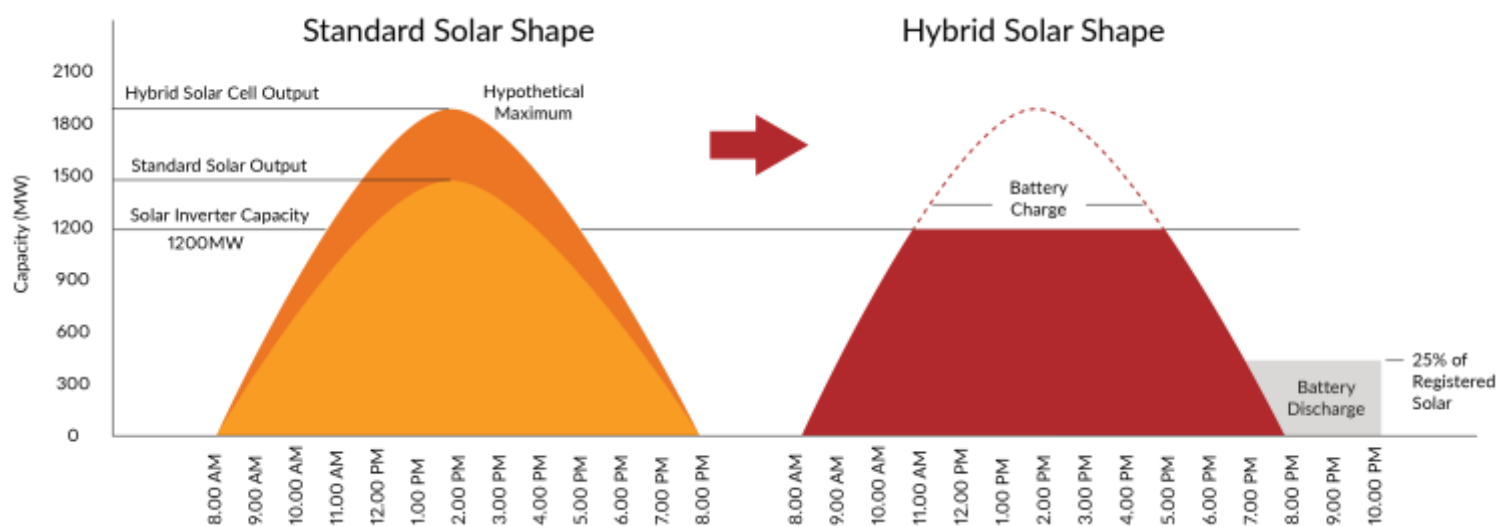


Figure 50: Solar + Storage Hybrid Profile



## Storage: Lithium-Ion Battery (4-hour)

Batteries modeled in the capacity expansion were 4-hour duration lithium-ion batteries. Units were sited with a minimum capacity of 50 MW and a maximum capacity of 400MW across all Future scenarios.

## Distributed Energy Resources (DERs)

For Series 1, MISO commissioned Applied Energy Group (AEG) to develop new DER technical potential. AEG developed estimates of DER impacts through survey of load-serving entities (LSE) and secondary research. To support Series 1A modeling, AEG compiled DER programs by type and cost into program blocks for EGEAS through study period ending in 2042. According to AEG data, Future 1 DER program levels represent minimum expected resource levels. Therefore, Future 1A programs are included as minima within the base model of all Series 1A scenarios. Futures 2A and 3A employ all F1A program amounts and allow incremental program blocks (the difference of total F2A or F3A programs and F1A levels) for selection.

Previously referred to as demand-side additions or management (DSM), these resources were modeled as program blocks in three main categories: Demand Response (DR), Energy Efficiency (EE), and Distributed Generation (DG). Programs also fall into two sectors: Residential and Commercial and Industrial (C&I).

During the program selection phase for the F2A and F3A models, incremental program blocks were offered against supply-side alternatives to determine economic viability. For both F2A and F3A, EGEAS selected the following program blocks: C&I Price Response, Residential Direct Load Control, and Residential Price Response. F2A also selected C&I Demand Response. Additionally, F3A selected C&I Utility Incentive PV; C&I High-, Mid-, and Low-Cost Energy Efficiency; and Residential High- and Low-Cost Energy Efficiency. Specific EE programs were grouped by cost into three tiers for C&I and two tiers for Residential. A complete list of detailed AEG programs mapped to EGEAS program blocks is below in Table 5.

Announced resources were included in Futures base assumptions. Several stakeholders submitted feedback detailing DERs they intend to add to their systems; these are also included in the totals below. F1A minima, F2A- and F3A-selected incremental programs, and stakeholder additions were implemented in the Futures models. Table 3 and Table 4 show total DER technical potential and additions modeled in MISO by the end of the study period.

Series 1A DERs Capacity (GW) Technical Potential & Added	Future 1A	Future 2A		Future 3A	
	Added	Potential	Added	Potential	Added
Demand Response (DR)	10.8	11.2	11.2	11.2	11
Energy Efficiency (EE)	17.7	19.4	17.7	20.5	20.5
Distributed Generation (DG)	19.9	19.9	19.9	28.6	20.5

**Table 3: DER Capacity (GW): 20-Year Technical Potential & Additions in MISO**

Series 1A DERs Energy (GWh) Technical Potential & Added	Future 1A	Future 2A		Future 3A	
	Added	Potential	Added	Potential	Added
Demand Response (DR)	1,051	1,147	1,147	1,154	1,142
Energy Efficiency (EE)	75,620	80,247	75,620	78,763	78,763
Distributed Generation (DG)	34,977	34,977	34,977	48,173	35,993

**Table 4: DER Energy (GWh): 20-Year Technical Potential & Additions in MISO**



DER Type	EGEAS Program Block	DER Program(s) Included
DR	C&I Demand Response*	Curtailable & Interruptible, Other DR, Wholesale Curtailable
DR	C&I Price Response*	C&I Price Response
DR	Residential Direct Load Control*	Res. Direct Load Control
DR	Residential Price Response*	Res. Price Response
EE	C&I High-Cost EE*	Customer Incentive High, New Construction High
EE	C&I Low-Cost EE*	Customer Incentive Low, Lighting Low, New Construction Low, Prescriptive Rebate Low, Retro commissioning Low
EE	C&I Mid-Cost EE*	Customer Incentive Mid, Lighting Mid, New Construction Mid, Prescriptive Rebate Mid, Retro commissioning Mid
EE	Residential High-Cost EE*	Appliance Incentives High, Appliance Recycling, Low Income, Multifamily High, New Construction High, School Kits, Whole Home Audit High
EE	Residential Low-Cost EE*	Appliance Incentives Low, Behavioral Programs, Lighting, Multifamily Low, New Construction Low, Whole Home Audit Low
DG	C&I Customer Solar PV	C&I Customer Solar PV
DG	C&I Utility Incentive Distributed Generation	Combined Heat and Power, Community-Based DG, Customer Wind Turbine, Thermal Storage, Utility Incentive Battery Storage
DG	C&I Utility Incentive Solar PV*	C&I Utility Incentive Solar PV
DG	Residential Customer Solar PV	Res. Customer Solar PV
DG	Residential Utility Incentive Distributed Generation	Customer Wind Turbines, Electric Vehicle Charging, Thermal Storage, Utility Incentive Battery Storage
DG	Residential Utility Incentive Solar PV	Res. Utility Incentive Solar PV

**Table 5: EGEAS Program Block/Specific DER Program Mapping**

\* Program increment was selected as economically viable and utilized by EGEAS in the resource expansion.

## Natural Gas Resources

Combined Cycle (CC) and Combustion Turbine (CT) were the two gas resource types modeled. Site priority levels for these units remained the same when selecting a site. However, CC units were given a higher priority over CT units.

## Resource Siting Process

RRF unit siting processes were developed to help identify where future generation would likely be located. While different RRF unit types need their own siting processes, there are universal criteria that apply to each resource type's unique siting process. These universal siting criteria and resource-specific processes are discussed below.<sup>32</sup>

<sup>32</sup> All capacities referenced in this section are (MW).



## Universal Siting Criteria

To help improve siting measures, the following criteria underlie all resource-specific siting processes.

1. The same sites were used for each Future and site differences only occurred due to Future-specific renewable capacity needs and expansion timing. This included only using sites that were found in both the Year 5 and Year 10 MTEP Powerflow models.
2. Radial lines and associated buses were identified in the MTEP Powerflow models and excluded from potential resource sites.
3. Sited capacity could not exceed a site's N-1 capacity amount. This means the summation of all the transmission elements, excluding the highest rated capacity element, could not have a lower capacity than the resource capacity. Exception applies to units sited at buses selected by direct stakeholder feedback or site-specific planned resources.
4. Units were sited at MISO-owned transmission elements with the exception of several planned wind resources in MISO South due to stakeholder feedback.
5. Stakeholders had the opportunity to review and provide feedback on Future 2A resource siting. Usability of bus and alternatives provided by stakeholders were considered and referenced for subsequent Future 1A and 3A siting.
6. Resources were sited to ensure each Local Resource Zone (LRZ) met its Local Clearing Requirement (LCR) on an estimated accredited capacity basis in each milestone year.
  - The Planning Reserve Margin Requirement (PRMR) for each LRZ was evaluated and some manual adjustments to resource siting was made to address any significant surplus or deficits on an LRZ-level basis.
7. The 80/20 distribution between Generation Interconnection (GI) and VCE/Greenfield Sites for renewable resources developed during Series 1, was maintained to the extent feasible given GI site capacity availability as well as stakeholder feedback solicited in Future 2A and implemented in Future 1A, 2A, and 3A.
  - High renewable capacity expansions identified in Series 1A exhausted GI site availability for some resources. This resulted in a higher distribution of capacity to lower priority sites than the foundational 80/20 methodology.
  - Alternative buses provided by stakeholder feedback on queue sites were considered and counted towards the 80% GI queue split.

## Wind and Solar PV

Resources of this type were modeled as a collector system, representing an aggregated capacity potential that can be installed within 10-30 miles of each site. Renewable capacity was first allocated to address LBA-scale RPS goals for each 5-year milestone (2027, 2032, 2037, 2042), with the remaining model-built capacity sited according to the following site priorities:

1. 80% of model-built capacity was distributed to Active DPP Phase 1, 2, or 3 GI sites and Tranche 1 enabled sites.
  - If 80% of model-built capacity exceeded GI queue site availability, GI sites were utilized to their maximum site capacity with the remaining capacity distributed to lower priority sites.
  - GI projects were ranked based on GI queue status (projects further along in the GI study process were ranked higher)
2. The remaining 20% of model-built capacity was distributed among LBAs in proportion to the LBA's percentage of total GI queue capacity for each resource type, with the following site priorities:



- Vibrant Clean Energy<sup>33</sup> (VCE) results. Collector buses represent a 20- to 30- mile aggregated capacity potential.
- Greenfield siting criteria at available, high-capacity buses.
- Alternative buses provided by stakeholder feedback on either VCE, or greenfield sites were considered and counted towards the 20% distribution of renewable capacity.

## Utility-Scale Solar PV + Storage (Hybrid)

Hybrid units were sited the same as Solar PV units. Only 80% of Hybrid generation allocated for RPS goal fulfillment was counted towards total sited RPS-eligible generation to account for solar vs. battery eligibility on an RPS-by-RPS basis.

## Distributed Solar PV Generation (DGPV)

Distributed solar PV resources (DGPV) siting methodology utilized the National Renewable Energy Laboratory's (NREL) [Distributed Generation Market Demand Model \(dGen\)](#) and consisted of the following:

- Used dGen to identify top 25 counties by DGPV potential within each LRZ.
- Identified (up to) top 30 load buses for each county.
- Distributed county capacity using dGen results weighting.
- DGPV sites were capped at a maximum capacity of 25 MW for MISO and 50 MW for external pools based on stakeholder feedback received during Future 2A siting.

## Lithium-Ion Battery (4-hour)

Batteries were restricted to a minimum 2042 cumulative capacity of 50 MW and capped at a maximum capacity of 400 MW (PROMOD performance reasons).

1. 80% of model-built capacity was distributed to Active DPP Phase 1,2, or 3 GI sites.
  - If 80% of model-built capacity exceeded GI queue site availability, GI sites were utilized to their maximum site capacity with the remaining capacity distributed to lower priority sites.
  - GI projects were ranked based on GI queue status (projects further along in the GI study process were ranked higher)
2. The remaining 20% of model-built capacity was distributed among LRZs in proportion to the LRZ's percentage of total GI queue capacity for battery resources, with the following split:
  - 80% of battery capacity was sited at identified top load buses greater than 100 kV.
  - 20% of battery capacity was sited at the highest N-1 capacity buses near generation.
  - If an LRZ needed more than one battery site, the next bus selected would be from a different county to maintain geographical distribution.

## Demand Response

Demand Response was sited at top load buses per LBA. Stakeholders had the opportunity to review and provide feedback on the buses identified. Alternative buses provided by stakeholder feedback were utilized in lieu of top load bus previously selected.

<sup>33</sup> [VCE Report - https://cdn.misoenergy.org/2018%20VCE%20Study\\_Results536959.pdf](https://cdn.misoenergy.org/2018%20VCE%20Study_Results536959.pdf)





## Combined Cycle and Combustion Turbine

Combined Cycle and Combustion Turbine siting largely remained the same as in past MTEP cycles with site rankings as follows:

- Combined Cycle units got higher priority sites over Combustion Turbine
- Priority 1: Active Definitive Planning Phase (DPP) Phase 1, 2, 3 Generator Interconnection Queue
- Priority 2: Brownfield – Existing and Retired Sites
  - Retired sites ranked by earliest commission date.
  - Retired sites had to be 50 MW and greater.
- Priority 3.1: SPA or Canceled/Postponed GI Queue
- Priority 3.2: Greenfield Siting Criteria

## Flex Units

Flexible Attribute Units were sited at brownfield retirement sites not utilized for thermal model-built capacity siting, with the following site priorities:

- Priority 1: Retirement sites were selected to address LRZ-level deficits in the Planning Reserve Margin Requirement (PRMR) after all other resource types had been sited. Within deficit LRZ site selection, sites were ranked by earliest commission date.
- Priority 2: After PRMR site selection, retirement sites were ranked and utilized by earliest commission date.
- For Future 2A, the timing of Flex unit siting was driven by the above priorities, resulting in most Flex capacity being sited within Year 5 of the study period (2027). A small portion of Flex units were sited in later milestone years due to either a lack of available retirement sites with earlier commission dates or site selection based on PRMR.
- As a proxy resource representing a non-exhaustive range of existing and nascent technologies, Flexible Attribute Units were not restricted to thermal brownfield sites in state and local balancing authorities without clean energy goals.



## JuiceBox: Generation Resource Portal

MISO partnered with the software company JuiceBox on the development of a [public, interactive, online portal](#) to host the Futures Series 1A expansion and siting results.

The portal is populated with existing, planned, and model-built generation for each Future, allowing users to explore Series 1A expansion and siting results using maps and charts (Figure 51). Generation units are displayed according to user-defined filters, including region, zone, fuel class, unit name, and status (existing, planned, model-built, retiring, and non-retiring). Following filter selection, results over the study period are available for generation (TWh), installed capacity (MW), and production cost (Mil\$) by fuel type. Users can switch between charts using a dropdown menu located in the chart area. Annual generation, capacity, and utilization data is available for individual units by selecting the unit within the map display.



Figure 51: Screenshot of Future 1A expansion and siting as visualized in the Generation Resource Portal (JuiceBox).



# MISO Expansion Results

While comparing the expansion results of the MISO footprint across each Future scenario, there are several key findings of note:

- All scenarios have relatively large amounts of renewable additions. Generally, this reflects industry-wide fleet evolution. More specifically, it owes to clean energy trajectories that incorporate decarbonization and renewable energy goals from member utilities and states, bolstered by policy innovation from the IRA and CEJA.
- Given lower accreditation of renewable resources compared to thermal generation, Future 1A and 3A result in a lower planning reserve margin (PRM) at the end of the study period than the start. Future 2A's PRM grows given addition of 29 GW of Flexible Attribute Units following the chronological energy validation in PROMOD. All Futures maintain a minimum 18.05% PRM for each year of the study period.
- All scenarios include 199 GW of member-planned resources. These planned resources account for 93% of the total expansion for Future 1A, 54% for Future 2A, and 44% for Future 3A. Within each Future's expansion results, total installed capacity is provided for each study year, broken out by existing, planned, and model-built resources.
- As the scenarios progress from F1A to F2A and F3A, more capacity is built due to increases in load and decarbonization.
- Futures 2A and 3A add significantly more wind than in F1A; this is primarily due to the increase in load, wind energy production and resulting PTC advantage, and respective shifts to dual- and winter-peaking systems.
- In Future 2A, Hybrid selection is somewhat offset by Battery selection. Battery installation is driven by increased load and decarbonization.
- Age-based retirement assumptions for nuclear, wind, solar, and "other" resources remain the same across all scenarios. Additionally, all retired wind is repowered and reflected in the resource addition totals.
- Distributed generation, energy efficiency (EE), and demand response (DR) resources are composed of both DER programs and specific member feedback.

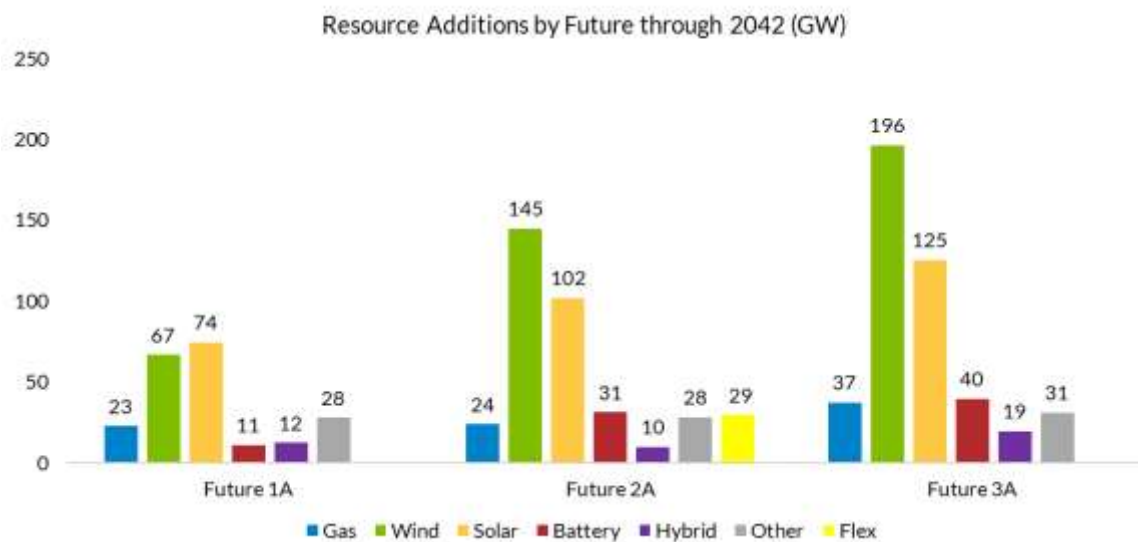


Future Resource Additions (MW)															
	CT	CC	ST Gas	IC Gas	ST Coal	Wind	Solar	Hybrid	Battery	Distributed Solar	DR	EE	UDG	Flex	Totals
Future 1A	7,858	10,000	2,964	1,839	163	66,634	57,102	12,225	10,799	17,138	7,327	17,589	2,688	0	214,326
Future 2A	9,058	10,000	2,964	1,839	163	144,634	84,702	9,825	31,099	17,137	7,770	17,589	2,688	29,800	369,269
Future 3A	18,658	13,600	2,964	1,839	163	196,234	107,502	19,425	39,599	17,794	7,511	20,448	2,688	0	448,425

Future Resource Retirements (MW)								
	Coal	Gas	Nuclear	Oil	Wind	Solar	Other	Totals
Future 1A	42,048	23,348	0	1,971	17,638	1,262	1,243	87,510
Future 2A	42,639	37,608	0	2,351	17,638	1,262	1,243	102,741
Future 3A	47,510	59,813	0	2,436	17,638	1,262	1,243	129,903

**Table 6: MISO Resource Additions and Retirement Totals**

Figure 52Figure 50 details the results from each Future scenario's resource additions as displayed in the table above. Solar resources are comprised of utility-scale solar PVand distributed solar resources. Wind totals include expansion wind units and repowered wind assumptions. The other resource category includes energy efficiency and demand side management programs selected within each Future. Gas resources include CC, CT, IC Gas, and ST Gas units.



**Figure 52: MISO Resource Addition Summary by Future**



## MISO – Future 1A

### Future 1A – Retirements and Additions

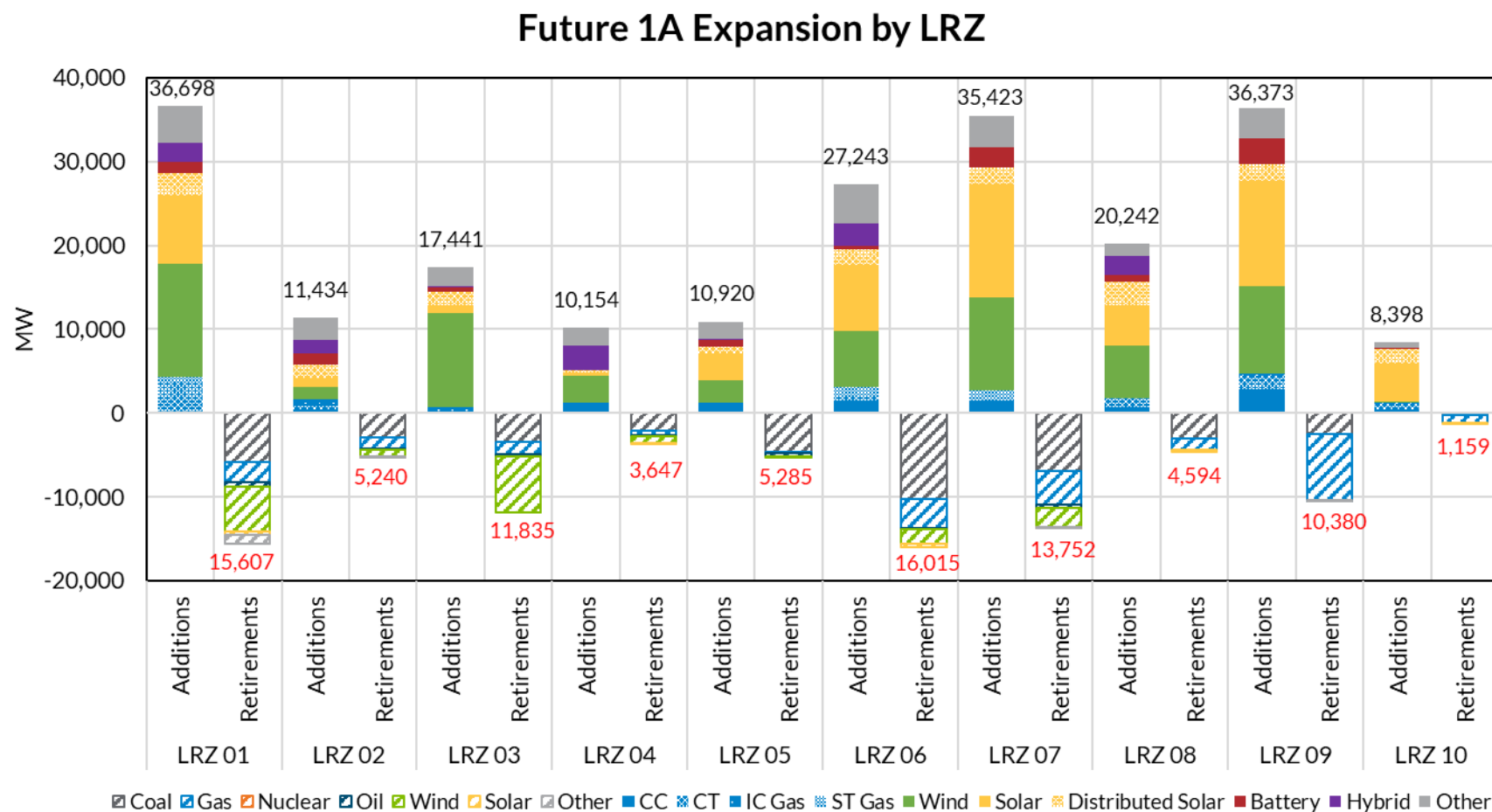


Figure 54: MISO Future 1A Resource Retirement and Addition Summary

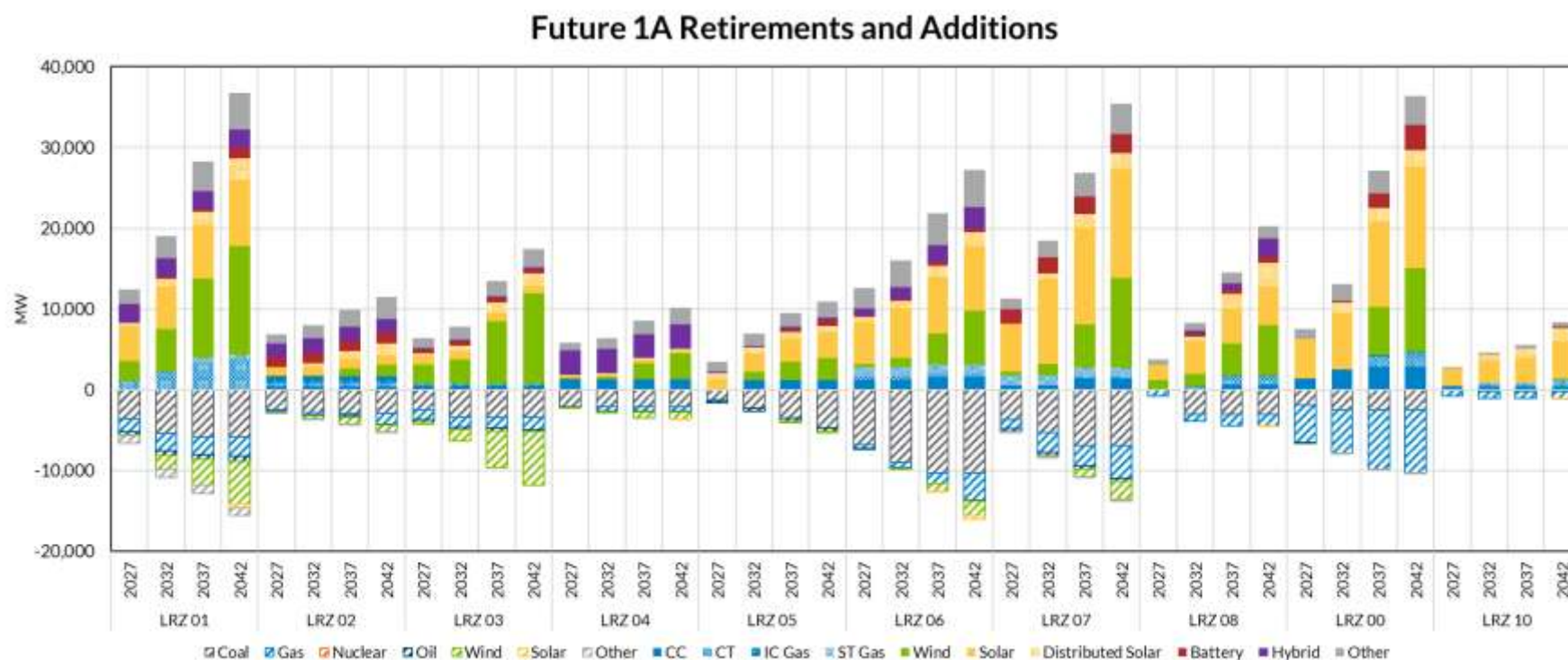


Figure 55: Future 1A Resource Retirement and Addition Summary by Milestone Year





## Future 1A – Installed Capacity

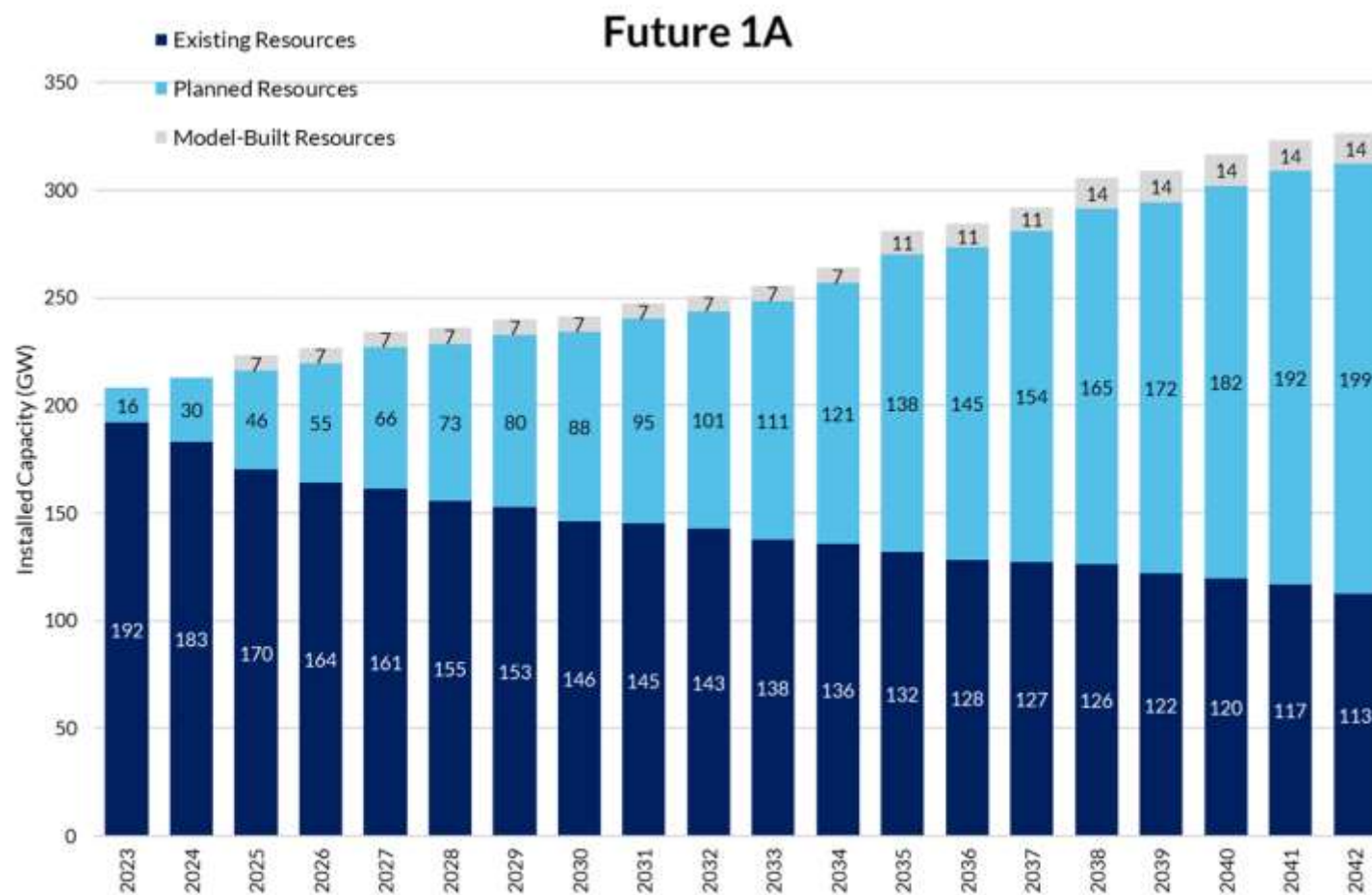
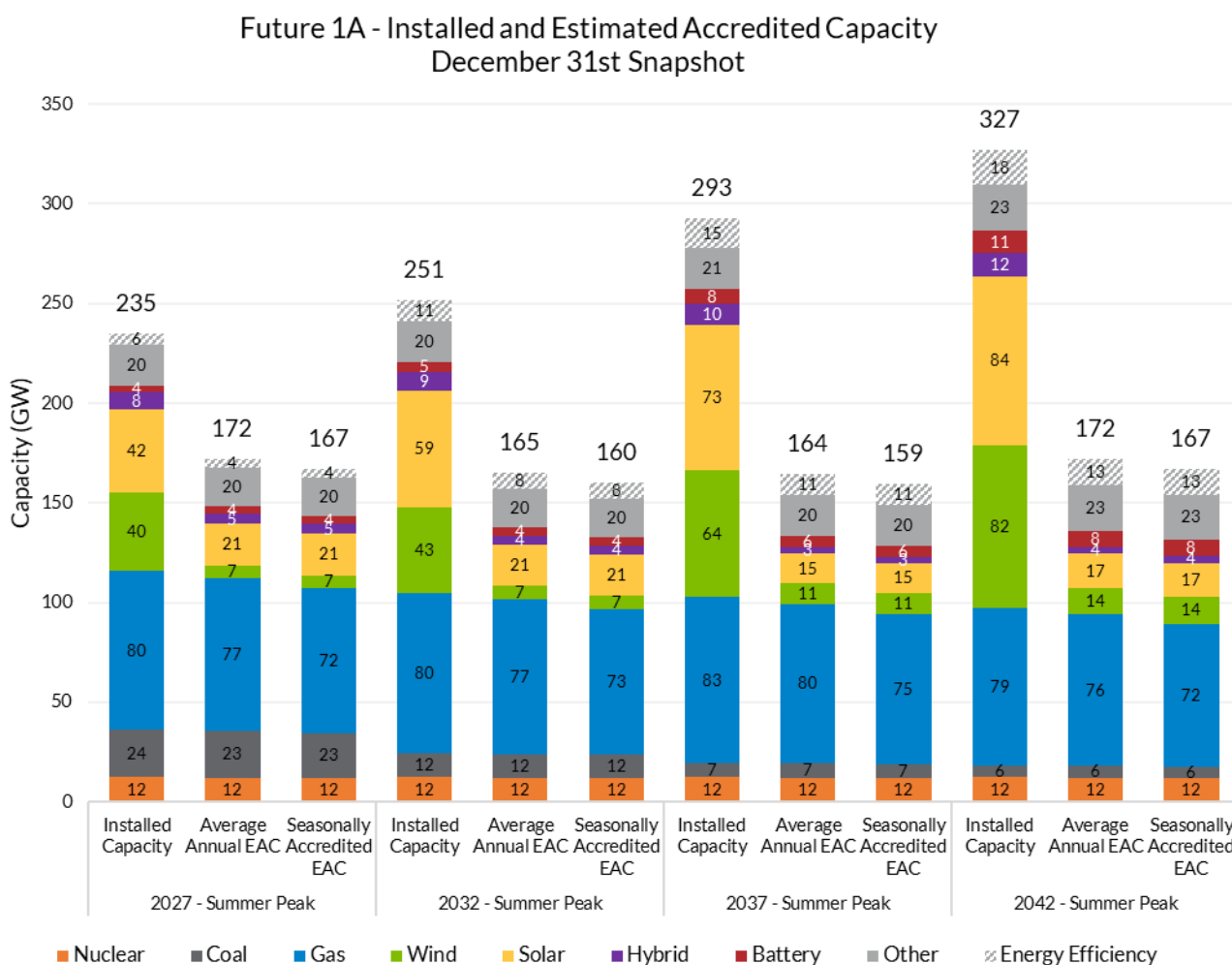


Figure 56: MISO F1A installed capacity of existing, planned, and model-built resources (GW).



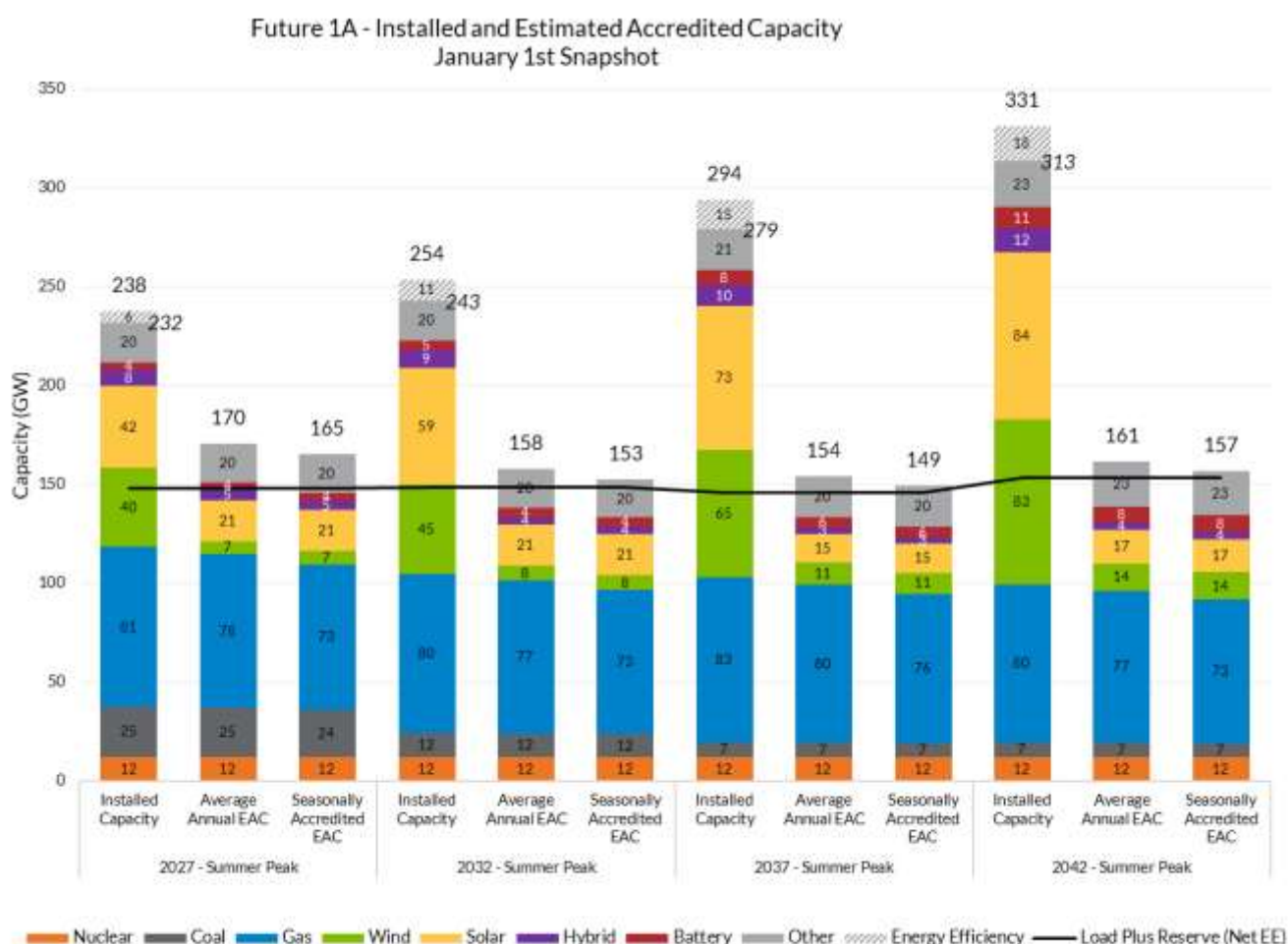
## Future 1A – Estimated Accredited Capacity

Figure 57 provides the end-of-year (EOY) installed and estimated accredited capacity (EAC)<sup>34</sup> for Future 1A. Figure 58 provides a beginning-of-year (BOY) outlook, overlaid with the load plus reserve. This alternative outlook aligns with the capacity expansion tool's output reporting for net load and attainment of a minimum 18.05% planning reserve margin (PRM) throughout the study period.



**Figure 57: Installed, Seasonally Accredited<sup>34</sup> and Average Annual Estimated Accredited Capacity for Future 1A.**  
Values reflect an end-of-year (December 31st) snapshot.

<sup>34</sup> Accreditation of thermal resources includes seasonal multipliers to align thermal capacity with seasonal peak; Future 1A is summer-peaking for the duration of the study period. Accordingly, thermal resources are seasonally de-rated from their average annual reserve capacity, resulting in a lower total estimated accredited capacity than the average annual EAC for all milestone years.



**Figure 58: Installed, Seasonally Accredited<sup>34</sup> and Average Annual Estimated Accredited Capacity, with load plus reserve (net EE) for Future 1A. Installed capacity (net EE) totals are provided in *italics* for direct comparison with EAC.<sup>35,36</sup>**

<sup>35</sup> The capacity expansion tool, EGEAS, utilizes the seasonal estimated accredited capacity in the calculation and attainment of a minimum 18.05% planning reserve margin (PRM) for all study years. Load plus reserve reflects netting of EE for calculation of PRM.

<sup>36</sup> Values reflect a beginning-of-year (Jan 1st) snapshot to align with the capacity expansion tool's output reporting for net load. Resources retiring in the reflected year are assumed to be in commission during system's summer peak given EGEAS' assumptions around retirement timing on December 31st.



## Future 1A – Energy Production

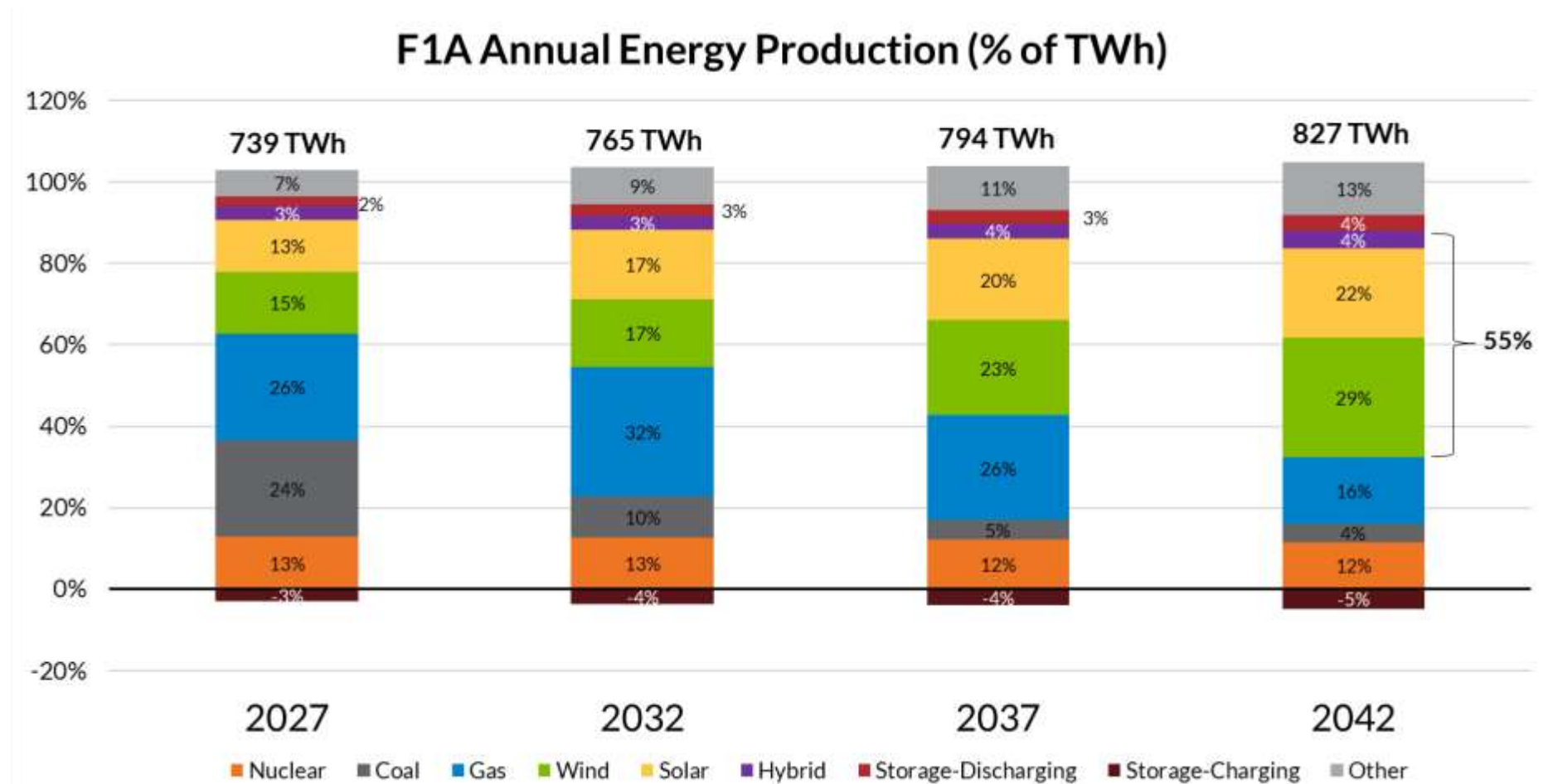


Figure 59: Future 1A Total Annual Energy Production by Milestone Year. Total energy production values are reported net storage-charging.



## Future 1A – Generation Siting

### Future 1A: Solar & Hybrid Expansion

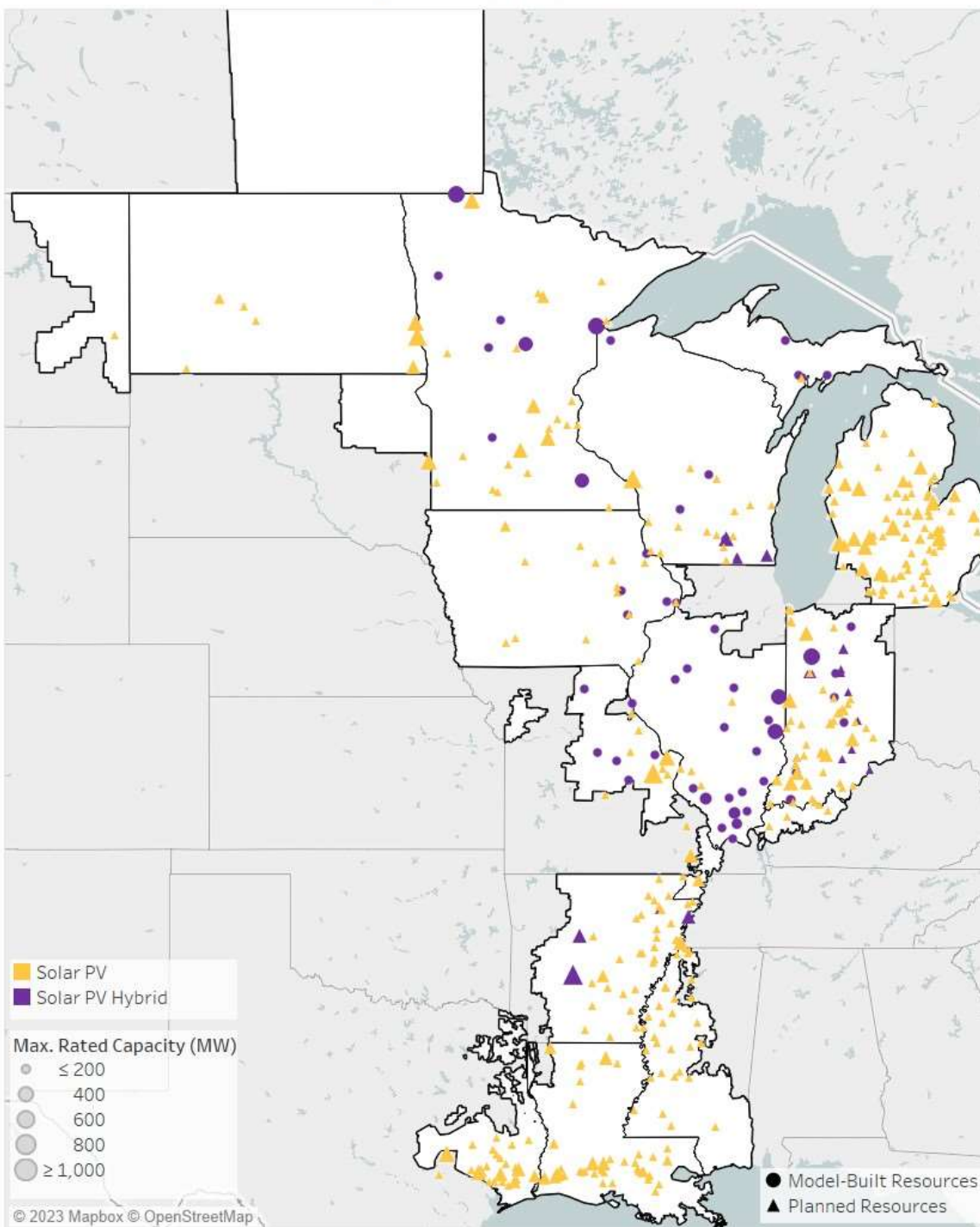


Figure 60: MISO Future 1A Solar and Hybrid Siting





## Future 1A: Distributed Solar Expansion

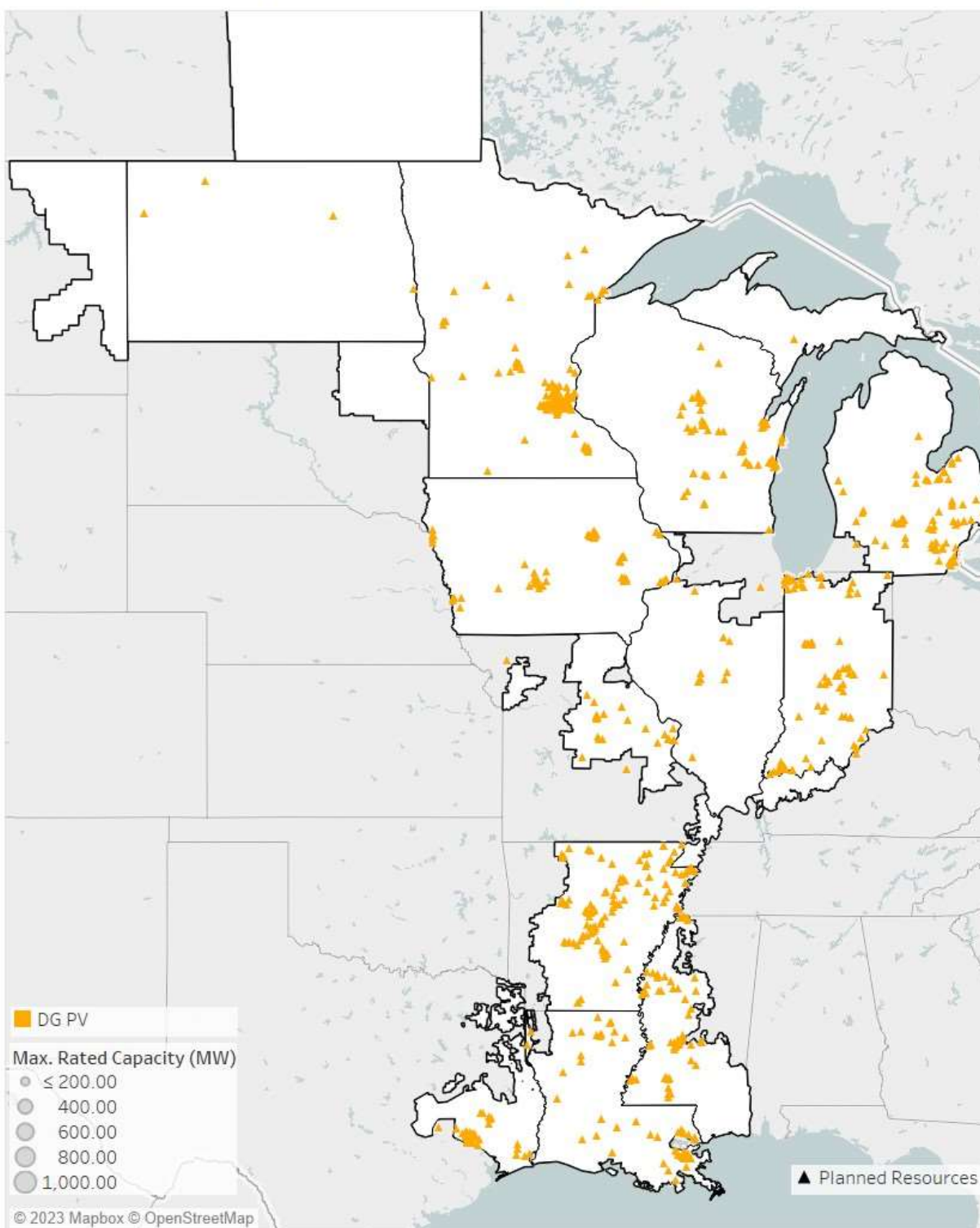


Figure 61: MISO Future 1A Distributed Solar Siting





## Future 1A: Wind Expansion

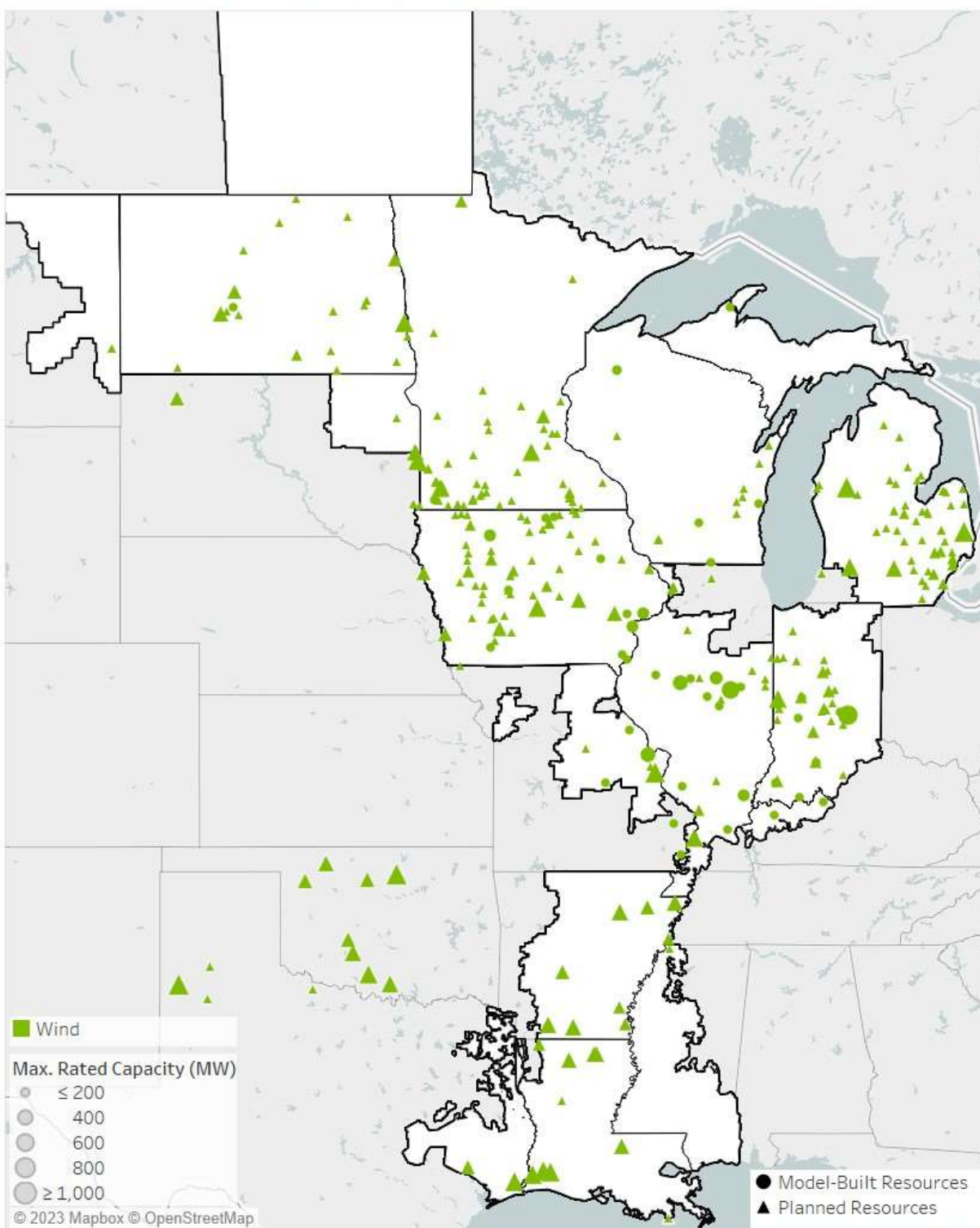


Figure 62: MISO Future 1A Wind Siting



## Future 1A: Battery Expansion

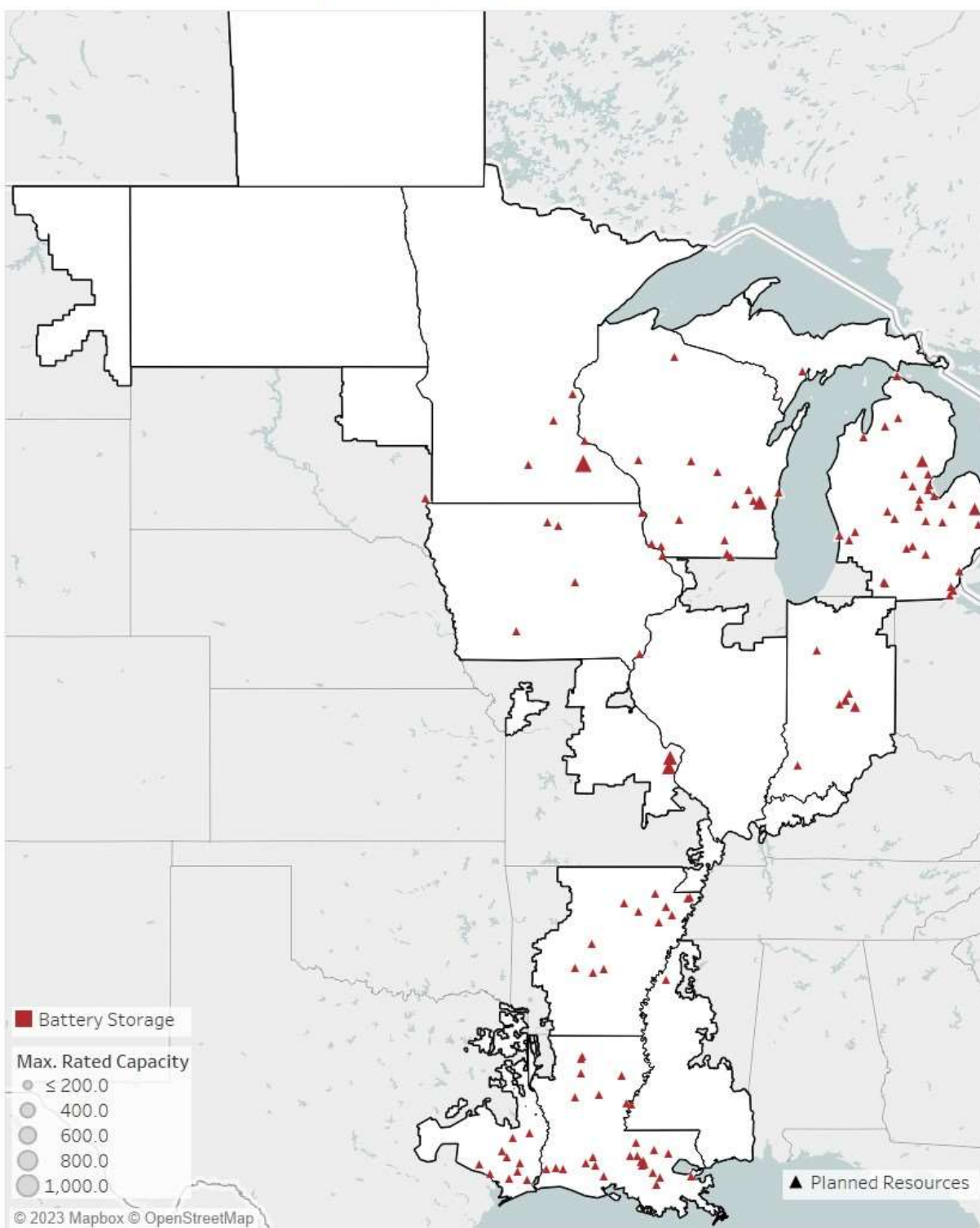


Figure 63: MISO Future 1A Battery Siting



## Future 1A: Thermal Expansion

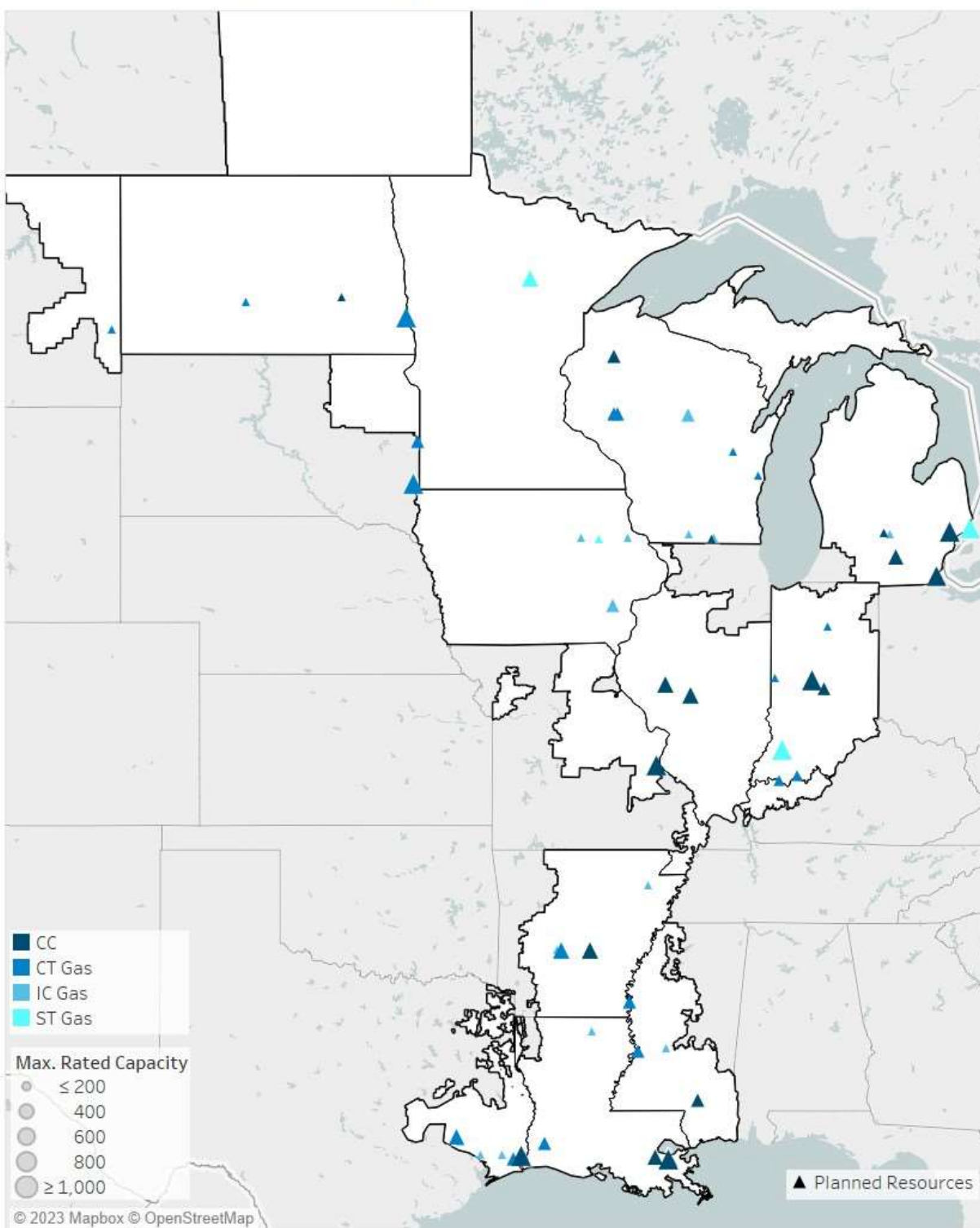


Figure 64: MISO Future 1A Thermal Siting



## Future 1A: Model-Built Expansion

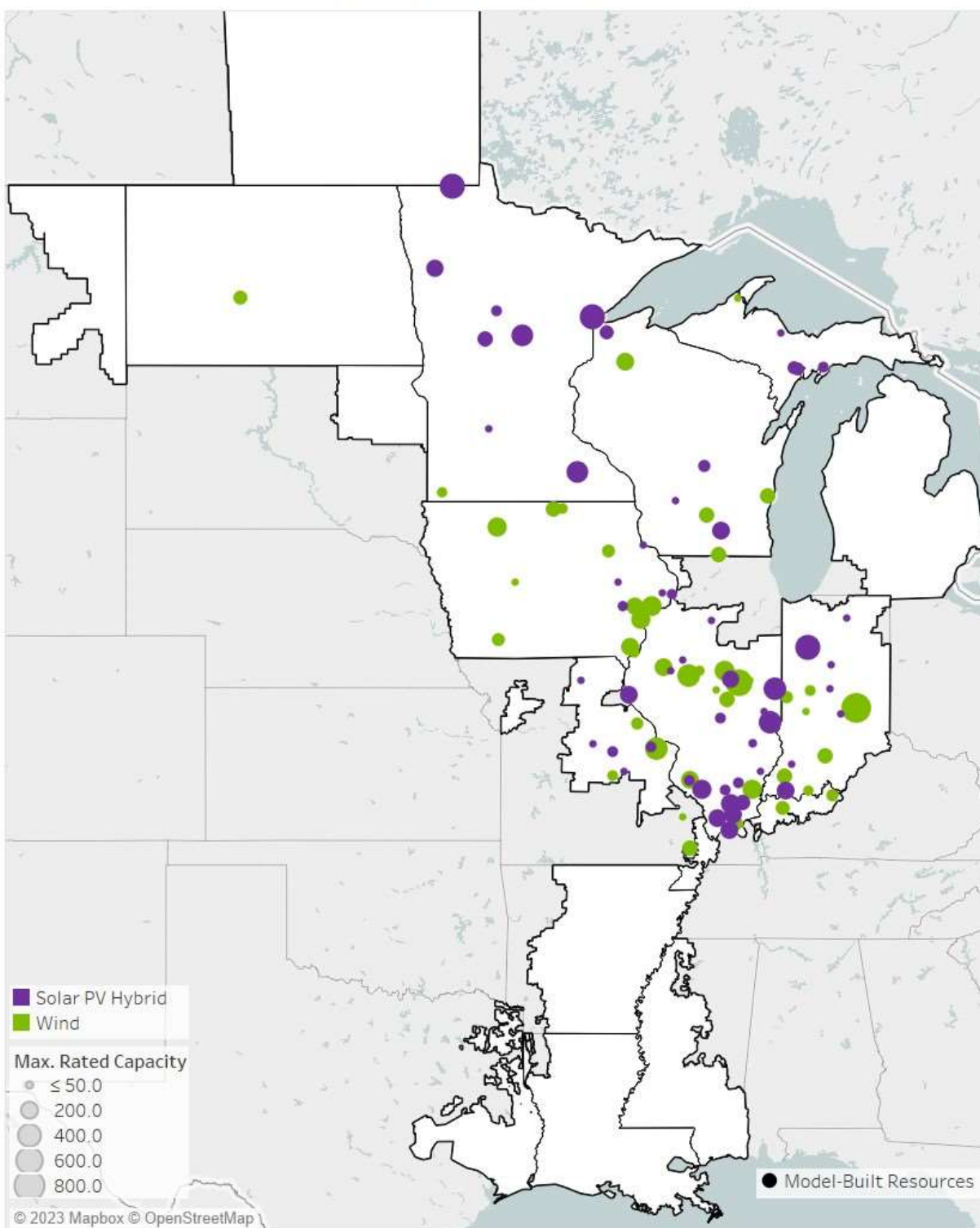


Figure 65: MISO Future 1A Complete EGEAS Expansion Siting





## Future 1A: Planned Expansion

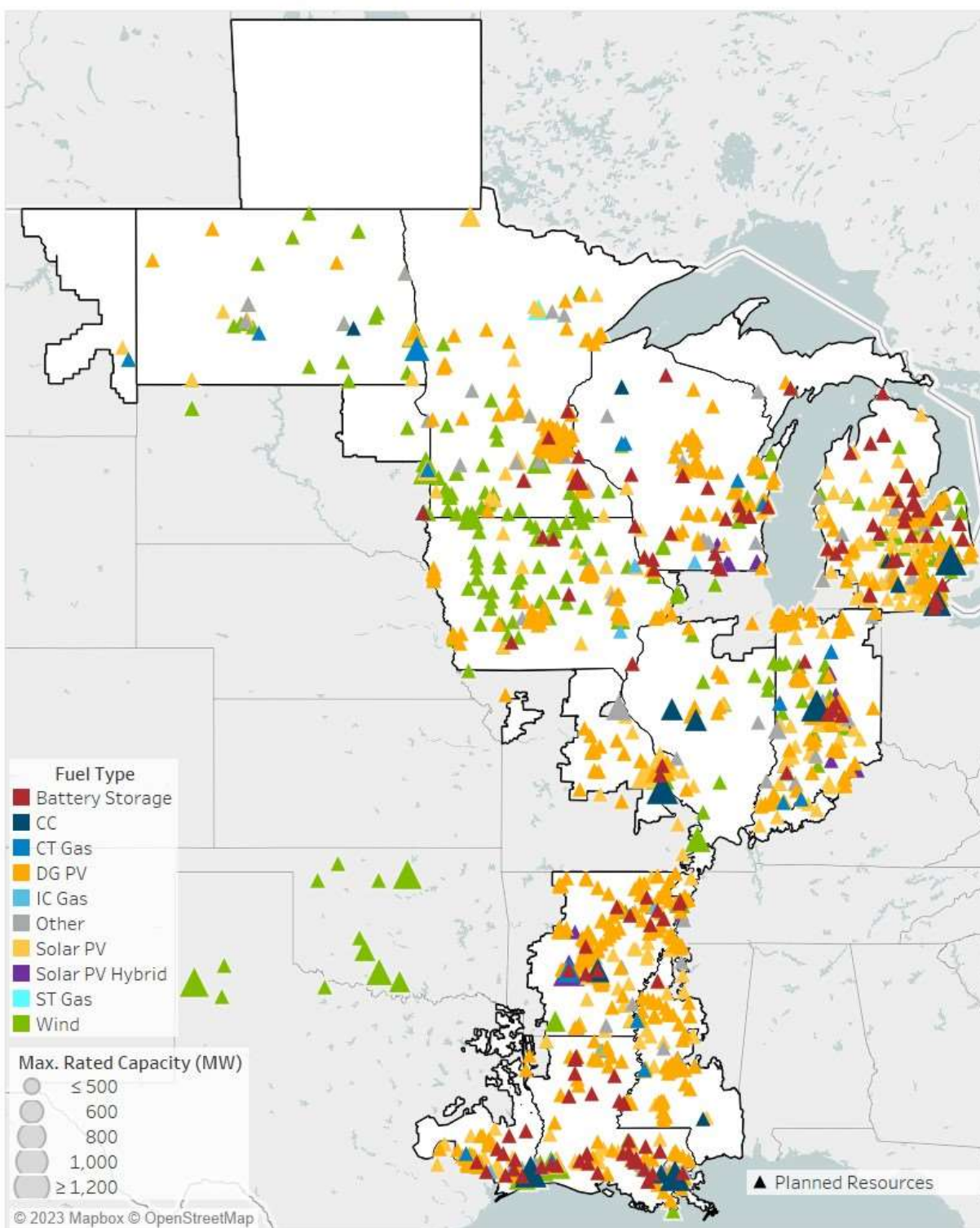


Figure 66: MISO Future 1A Non-EGEAS Expansion Siting



## Future 1A: Total Expansion

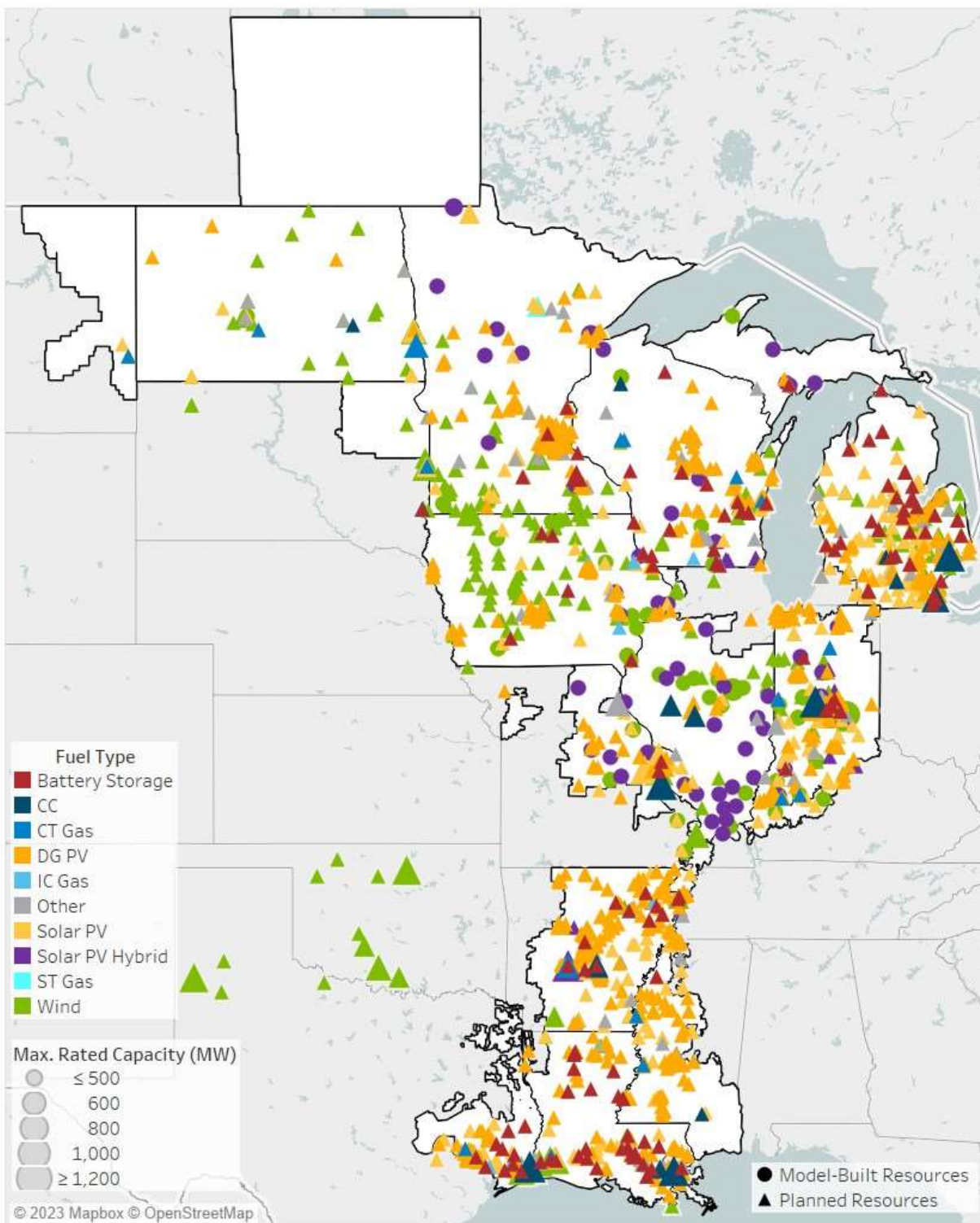


Figure 67: MISO Future 1A Non-EGEAS and EGEAS Expansion Siting





Future 1A Resource Additions (MW) - Cumulative															
Zone	Milestone	Battery	CC	CT Gas	Demand Response	DGPV	IC Gas	Solar	Hybrid	ST Coal	ST Gas	Wind	EE	UDG	Totals
LRZ 1	2027	20	100	981	845	375	0	4,375	2,285	163	0	2,445	804	18	12,411
	2032	270	100	2,103	940	925	0	5,225	2,285	163	0	5,343	1,579	42	18,975
	2037	270	100	3,225	1,255	1,675	0	6,625	2,285	163	595	9,795	2,128	115	28,231
	2042	1,270	100	3,599	1,411	2,675	0	8,175	2,285	163	595	13,490	2,559	376	36,698
LRZ 2	2027	1,179	487	300	550	30	843	1,039	1,734	0	0	122	572	13	6,869
	2032	1,312	487	300	563	405	843	1,139	1,734	0	0	122	1,048	30	7,983
	2037	1,312	487	300	568	967	843	1,139	1,734	0	0	1,023	1,440	82	9,896
	2042	1,312	487	300	634	1,555	843	1,139	1,734	0	0	1,413	1,748	269	11,434
LRZ 3	2027	475	0	0	800	418	670	1,000	153	0	50	2,403	400	9	6,378
	2032	575	0	0	824	675	670	1,000	153	0	50	3,060	733	21	7,761
	2037	575	0	0	854	1,375	670	1,000	153	0	50	7,744	1,008	58	13,486
	2042	575	0	0	898	1,500	670	1,000	153	0	50	11,184	1,223	188	17,441
LRZ 4	2027	0	1,277	0	561	0	0	375	2,983	0	0	250	400	9	5,855
	2032	0	1,277	0	586	150	0	375	2,983	0	0	258	733	21	6,384
	2037	0	1,277	0	621	250	0	375	2,983	0	0	2,013	1,008	58	8,584
	2042	0	1,277	0	651	275	0	375	2,983	0	0	3,182	1,223	188	10,154
LRZ 5	2027	0	0	0	800	725	0	1,270	242	0	0	35	343	8	3,423
	2032	0	1,200	0	800	725	0	2,270	242	0	0	1,035	629	18	6,919
	2037	400	1,200	0	800	725	0	2,970	242	0	0	2,237	864	49	9,487
	2042	800	1,200	0	800	725	0	3,170	242	0	0	2,773	1,049	161	10,920
LRZ 6	2027	80	1,221	513	1,655	680	0	5,158	978	0	1,052	404	858	20	12,617
	2032	300	1,221	513	1,655	881	0	6,208	1,428	0	1,052	1,134	1,571	45	16,007
	2037	480	1,546	513	1,655	1,317	0	7,058	2,103	0	1,052	3,827	2,159	123	21,833
	2042	460	1,546	513	1,655	1,795	0	7,858	2,628	0	1,052	6,712	2,622	403	27,243
LRZ 7	2027	1,842	509	0	351	0	0	5,965	0	0	1,267	426	915	21	11,295
	2032	1,974	509	0	402	650	0	10,524	0	0	1,267	1,426	1,676	48	18,476
	2037	2,215	1,455	0	462	1,650	0	12,016	0	0	1,267	5,321	2,303	132	26,821
	2042	2,376	1,455	0	527	1,975	0	13,516	0	0	1,267	11,081	2,796	430	35,423
LRZ 8	2027	0	0	0	300	0	95	1,935	0	0	0	1,100	343	8	3,781
	2032	400	0	380	305	550	95	4,035	400	0	0	1,500	629	18	8,312
	2037	550	667	1,047	320	1,775	95	4,335	800	0	0	3,944	864	49	14,446
	2042	760	667	1,047	340	2,900	95	4,835	2,200	0	0	6,188	1,049	161	20,242
LRZ 9	2027	10	1,215	0	339	0	173	4,885	0	0	0	0	915	21	7,558
	2032	195	2,317	0	349	1,300	173	7,035	0	0	0	0	1,676	48	13,093
	2037	1,730	2,866	1,260	374	1,750	173	10,535	0	0	0	5,956	2,303	132	27,079
	2042	3,060	2,866	1,640	411	2,050	173	12,535	0	0	0	10,412	2,796	430	36,373
LRZ 10	2027	0	402	0	0	0	58	2,150	0	0	0	0	172	4	2,786
	2032	0	402	380	0	700	58	2,750	0	0	0	0	314	9	4,613
	2037	0	402	380	0	1,150	58	3,050	0	0	0	0	432	25	5,497
	2042	185	402	760	0	1,688	58	4,500	0	0	0	200	524	81	8,398
MISO Total	2027	3,606	5,211	1,793	6,200	2,228	1,839	28,151	8,375	163	2,369	7,184	5,721	131	72,972
	2032	5,026	7,513	3,675	6,425	6,961	1,839	40,560	9,225	163	2,369	13,878	10,589	300	108,522
	2037	7,533	10,000	6,724	6,909	12,634	1,839	49,102	10,300	163	2,964	41,861	14,508	823	165,359
	2042	10,799	10,000	7,858	7,327	17,138	1,839	57,102	12,225	163	2,964	66,634	17,589	2,688	214,326

Table 7: MISO Future 1A Resource Additions by LRZ and Footprint



Future 1A Resource Retirements (MW) - Cumulative									
Zone	Milestone	Coal	Gas	Nuclear	Oil	Wind	Solar	Other	Totals
LRZ 1	2027	3,639	1,604	0	325	123	0	962	6,653
	2032	5,396	2,136	0	570	1,772	0	996	10,870
	2037	5,885	2,136	0	570	3,178	24	1,014	12,807
	2042	5,885	2,381	0	584	5,274	470	1,014	15,607
LRZ 2	2027	2,515	166	0	76	102	0	20	2,879
	2032	2,844	299	0	76	385	0	20	3,623
	2037	2,960	299	0	139	823	0	20	4,241
	2042	2,960	1,263	0	139	823	11	44	5,240
LRZ 3	2027	2,462	1,269	0	240	311	0	0	4,283
	2032	3,407	1,269	0	240	1,468	0	0	6,385
	2037	3,407	1,363	0	319	4,582	0	0	9,672
	2042	3,407	1,481	0	319	6,628	0	0	11,835
LRZ 4	2027	2,123	0	0	117	20	0	0	2,260
	2032	2,123	564	0	117	28	0	0	2,832
	2037	2,123	564	0	117	698	0	0	3,502
	2042	2,123	564	0	117	823	20	0	3,647
LRZ 5	2027	1,251	67	0	345	0	0	0	1,663
	2032	2,257	67	0	345	0	0	0	2,669
	2037	3,471	67	0	345	169	0	0	4,052
	2042	4,704	67	0	345	169	0	0	5,285
LRZ 6	2027	6,838	475	0	50	0	0	0	7,363
	2032	8,986	693	0	50	131	0	0	9,860
	2037	10,256	1,331	0	50	942	2	0	12,581
	2042	10,256	3,468	0	71	1,742	475	0	16,015
LRZ 7	2027	3,692	1,163	0	390	0	0	38	5,283
	2032	5,297	2,446	0	390	113	0	147	8,392
	2037	6,922	2,524	0	390	929	0	147	10,911
	2042	6,922	4,061	0	390	2,180	54	147	13,752
LRZ 8	2027	0	788	0	0	0	0	0	788
	2032	3,089	788	0	0	0	0	0	3,877
	2037	3,089	1,324	0	0	0	0	0	4,413
	2042	3,089	1,324	0	0	0	181	0	4,594
LRZ 9	2027	1,880	4,627	0	7	0	0	0	6,515
	2032	2,496	5,352	0	7	0	0	28	7,883
	2037	2,496	7,358	0	7	0	0	39	9,900
	2042	2,496	7,838	0	7	0	0	39	10,380
LRZ 10	2027	0	816	0	0	0	0	0	816
	2032	206	816	0	0	0	0	0	1,022
	2037	206	816	0	0	0	0	0	1,022
	2042	206	901	0	0	0	52	0	1,159
MISO Total	2027	24,401	10,975	0	1,549	556	0	1,020	38,502
	2032	36,101	14,430	0	1,795	3,896	0	1,190	57,413
	2037	40,815	17,782	0	1,937	11,321	26	1,219	73,100
	2042	42,048	23,348	0	1,971	17,638	1,262	1,243	87,514

Table 8: MISO Future 1A Resource Retirements by LRZ and Footprint



## MISO – Future 2A

### Future 2A – Retirements and Additions

#### Future 2A Expansion by LRZ

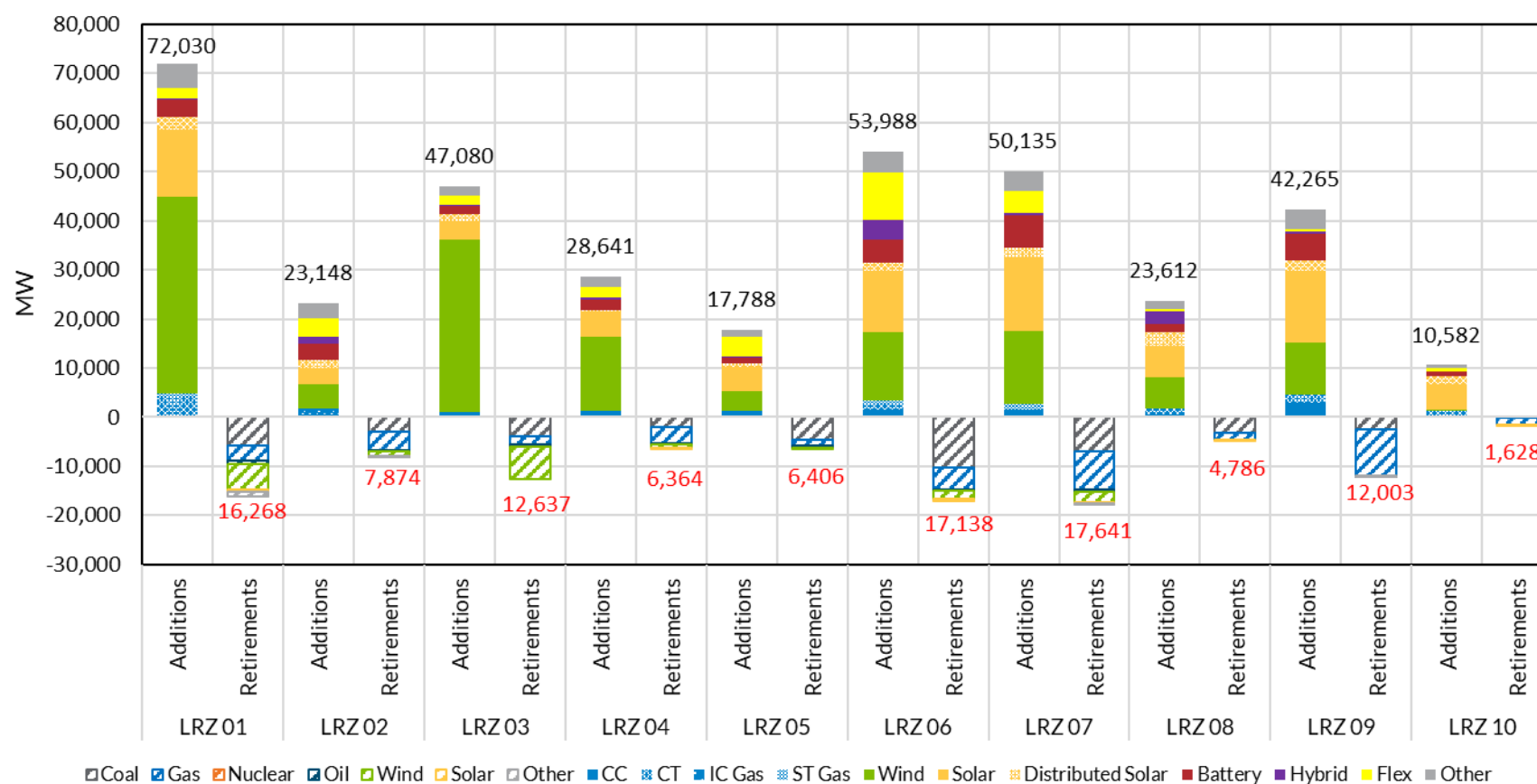


Figure 68: MISO Future 2A Resource Retirement and Addition Summary

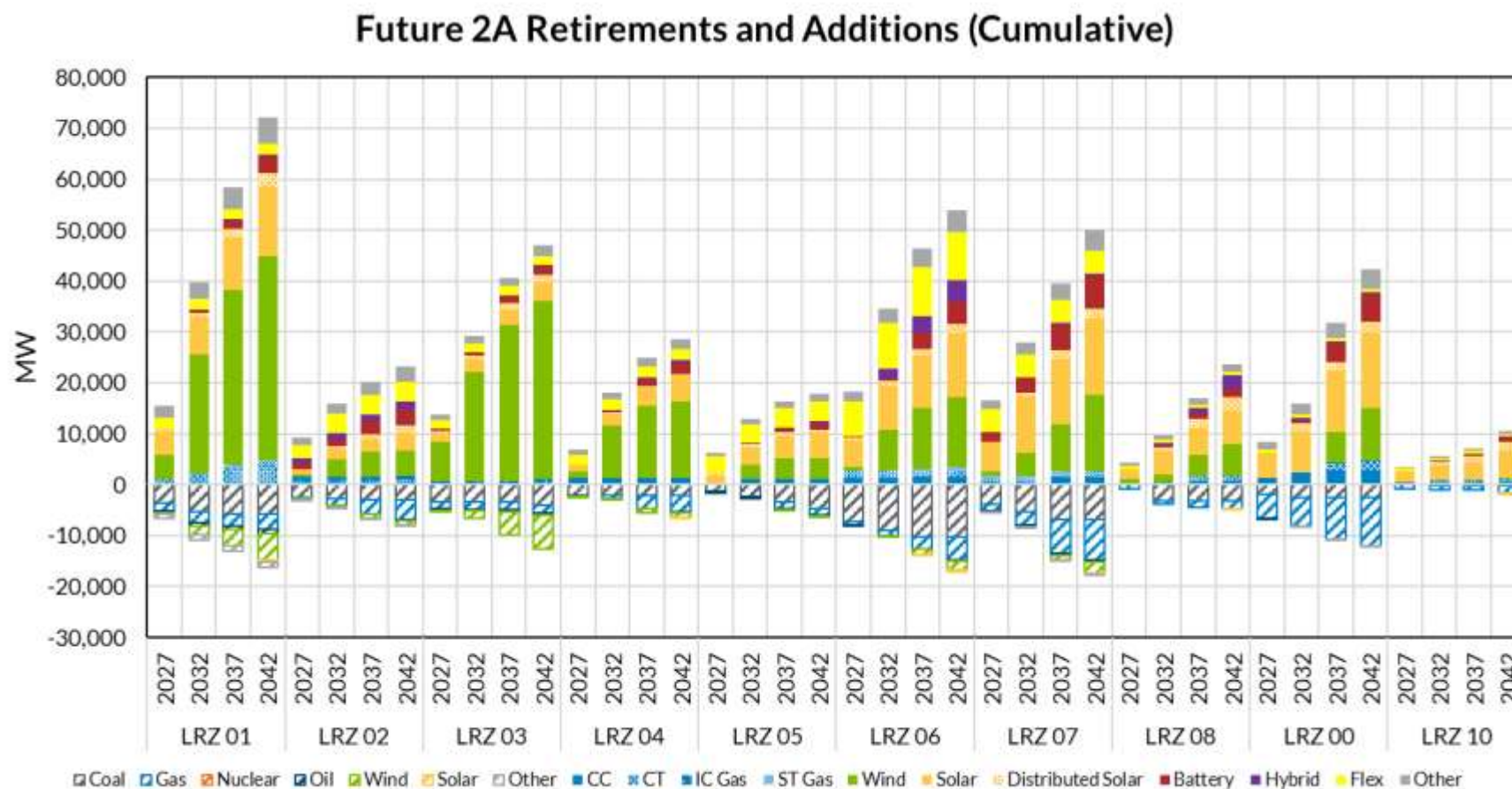


Figure 69: MISO Future 2A Resource Retirement and Addition Summary by Milestone Year



## Future 2A – Installed Capacity

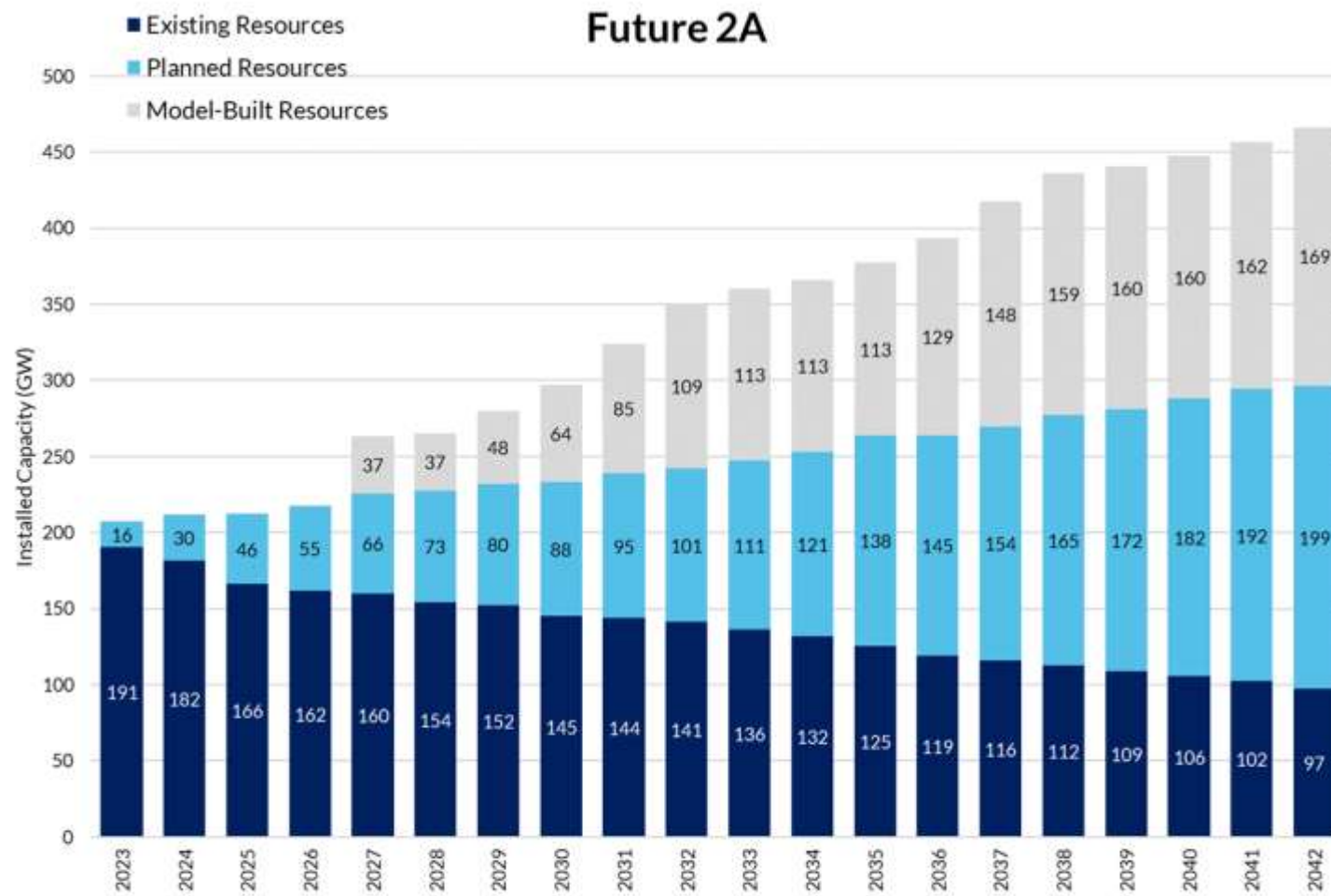
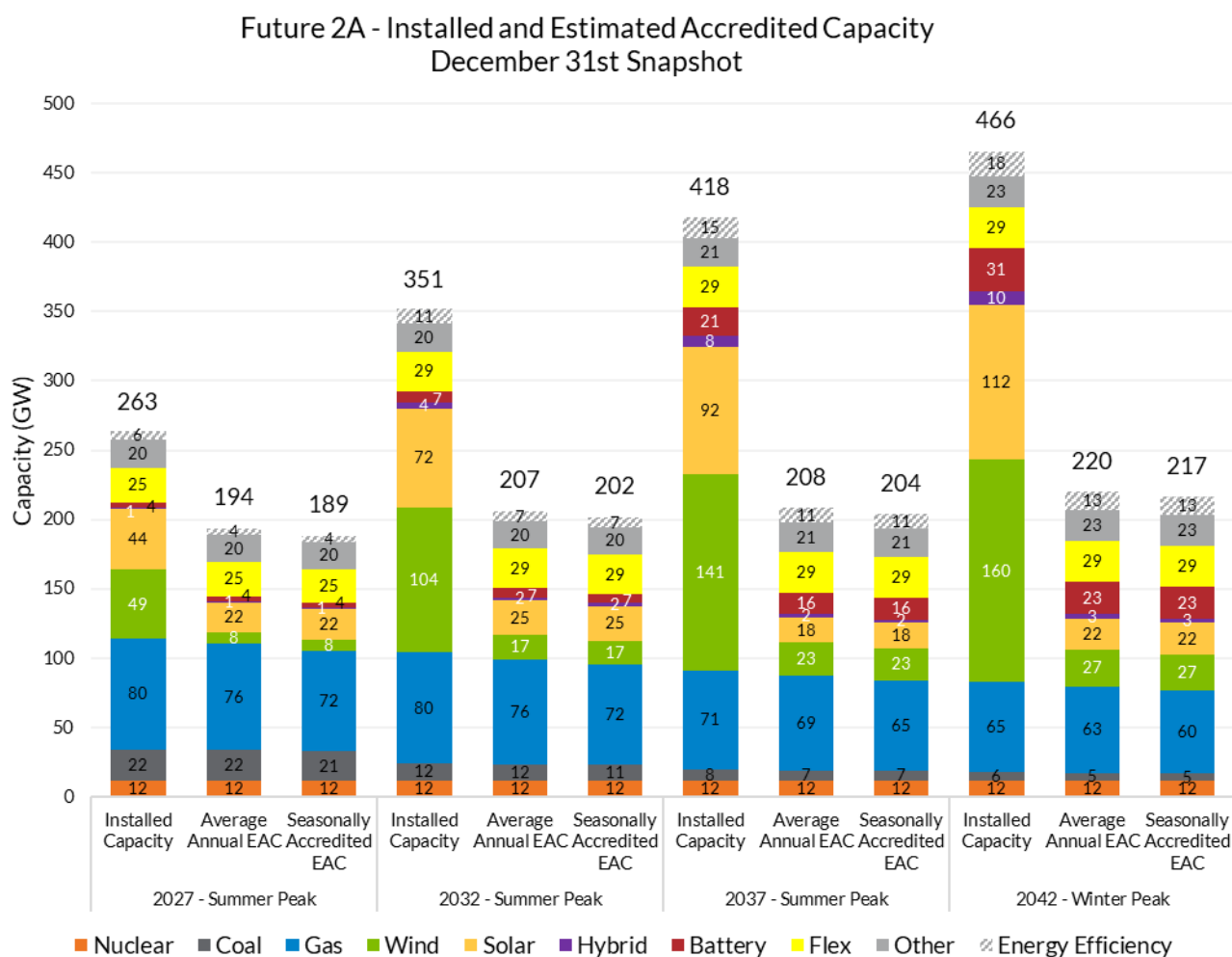


Figure 70: MISO F2A installed capacity of existing, planned, and model-built resources (GW)



## Future 2A – Estimated Accredited Capacity

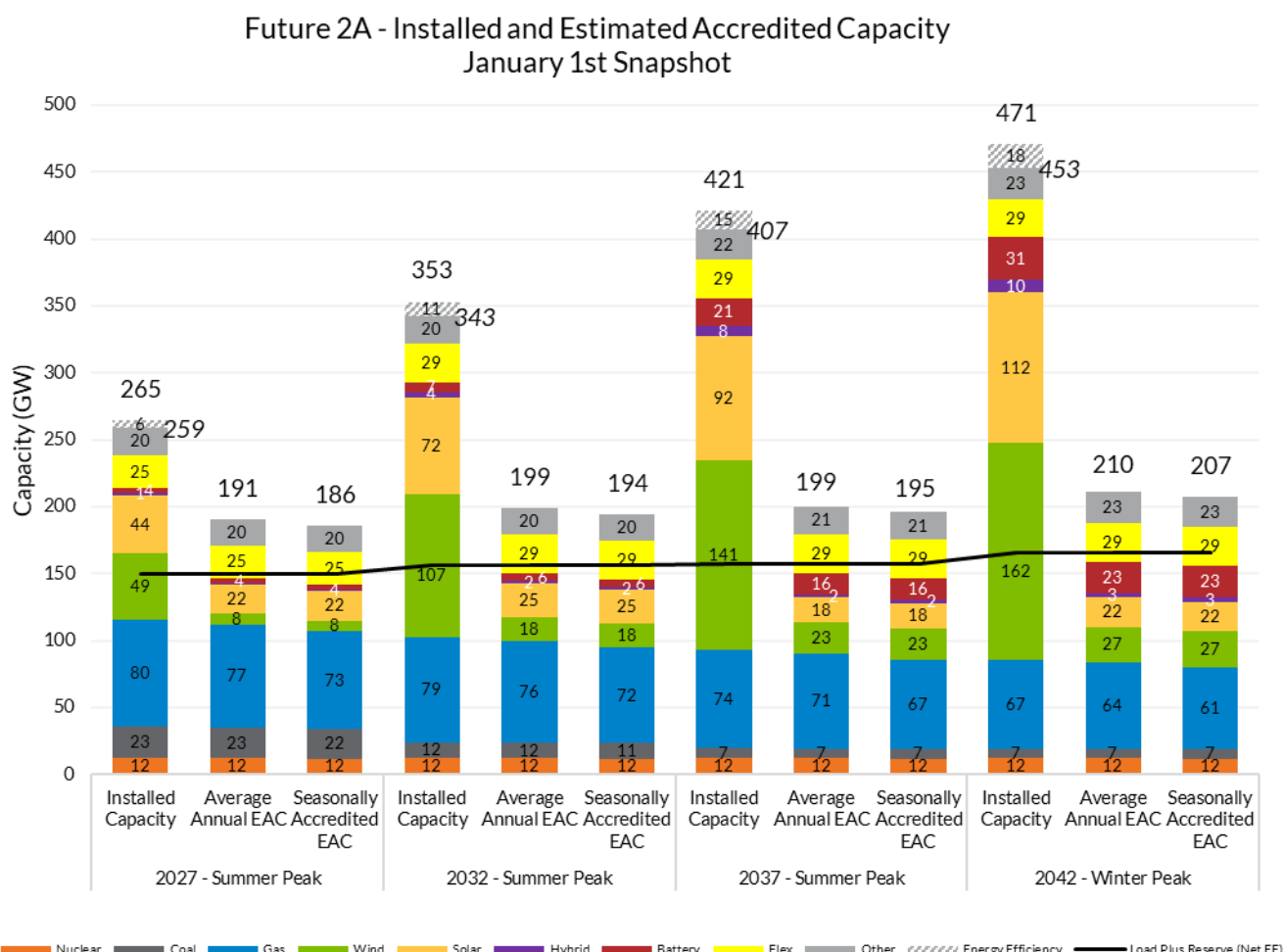
Figure 71 provides the end-of-year (EOY) installed and estimated accredited capacity (EAC)<sup>38</sup> for Future 2A. Figure 72 provides a beginning-of-year (BOY) outlook, overlaid with the load plus reserve. This alternative outlook aligns with the capacity expansion tool's output reporting for net load and attainment of a minimum 18.05% planning reserve margin (PRM) throughout the study period.



**Figure 71: Installed, Seasonally Accredited<sup>37</sup> and Average Annual Estimated Accredited Capacity for Future 2A.**  
Values reflect an end-of-year (December 31st) snapshot.

<sup>37</sup> Accreditation of thermal resources includes seasonal multipliers to align thermal capacity with seasonal peak; Future 2A is summer-peaking for 2027, 2032, and 2037 and winter-peaking for 2042. Annual reserve capacity is based on the season in which reserve capacity is the lowest; as a result, F2A exhibits a lower seasonal EAC than the average annual EAC for all milestone years.





**Figure 72: Installed, Seasonally Accredited<sup>37</sup> and Average Annual Estimated Accredited Capacity, with load plus reserve (net EE) for Future 2A. Installed capacity (net EE) totals provided in *italics* for direct comparison with EAC.<sup>38,39</sup>**

<sup>38</sup> The capacity expansion tool, EGEAS, utilizes the seasonal estimated accredited capacity in the calculation and attainment of a minimum 18.05% planning reserve margin (PRM) for all study years. Load plus reserve reflects netting of EE for calculation of PRM.

<sup>39</sup> Values reflect a beginning-of-year (Jan 1st) snapshot to align with the capacity expansion tool's output reporting for net load. Resources retiring in the reflected year are assumed to be in commission during system's summer peak and January 2042 winter peak, given EGEAS' assumptions around retirement timing on December 31st.



## Future 2A – Energy Production

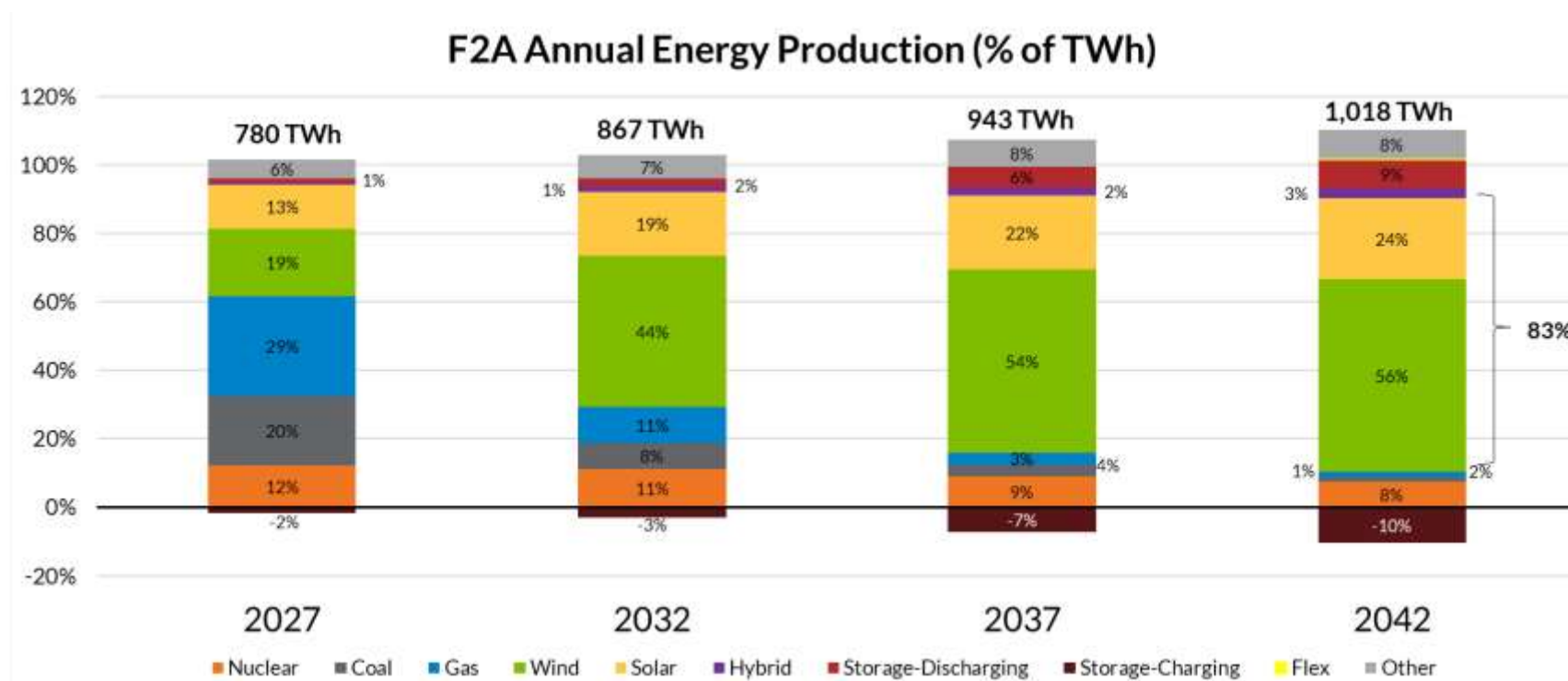


Figure 73: Future 2A Total Annual Energy Production by Milestone Year. Total energy production values are reported net storage-charging.



## Future 2A – Generation Siting

### Future 2A: Solar & Hybrid Expansion

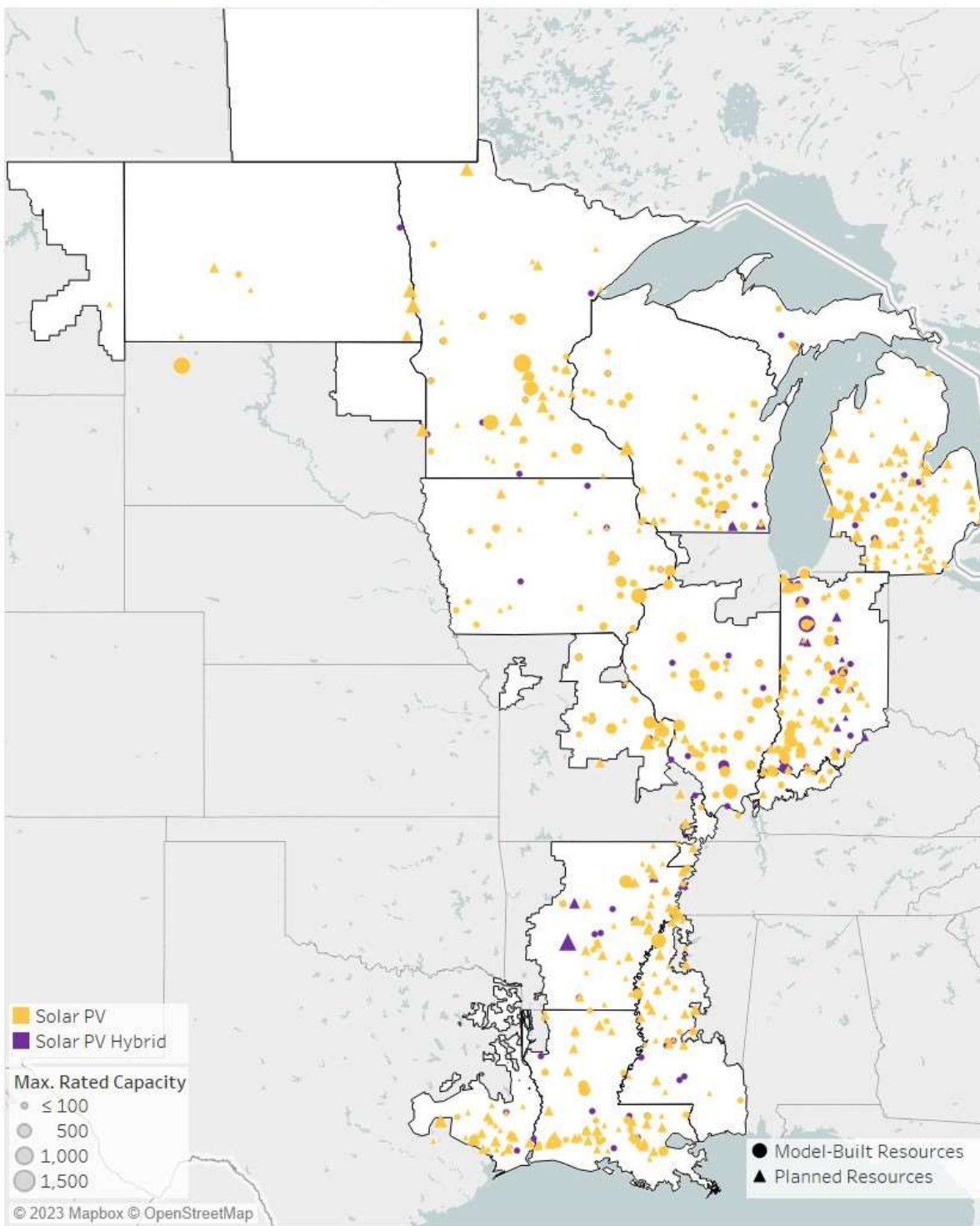


Figure 75: MISO F2A Solar PV and Hybrid Siting



## Future 2A: Distributed Solar Expansion

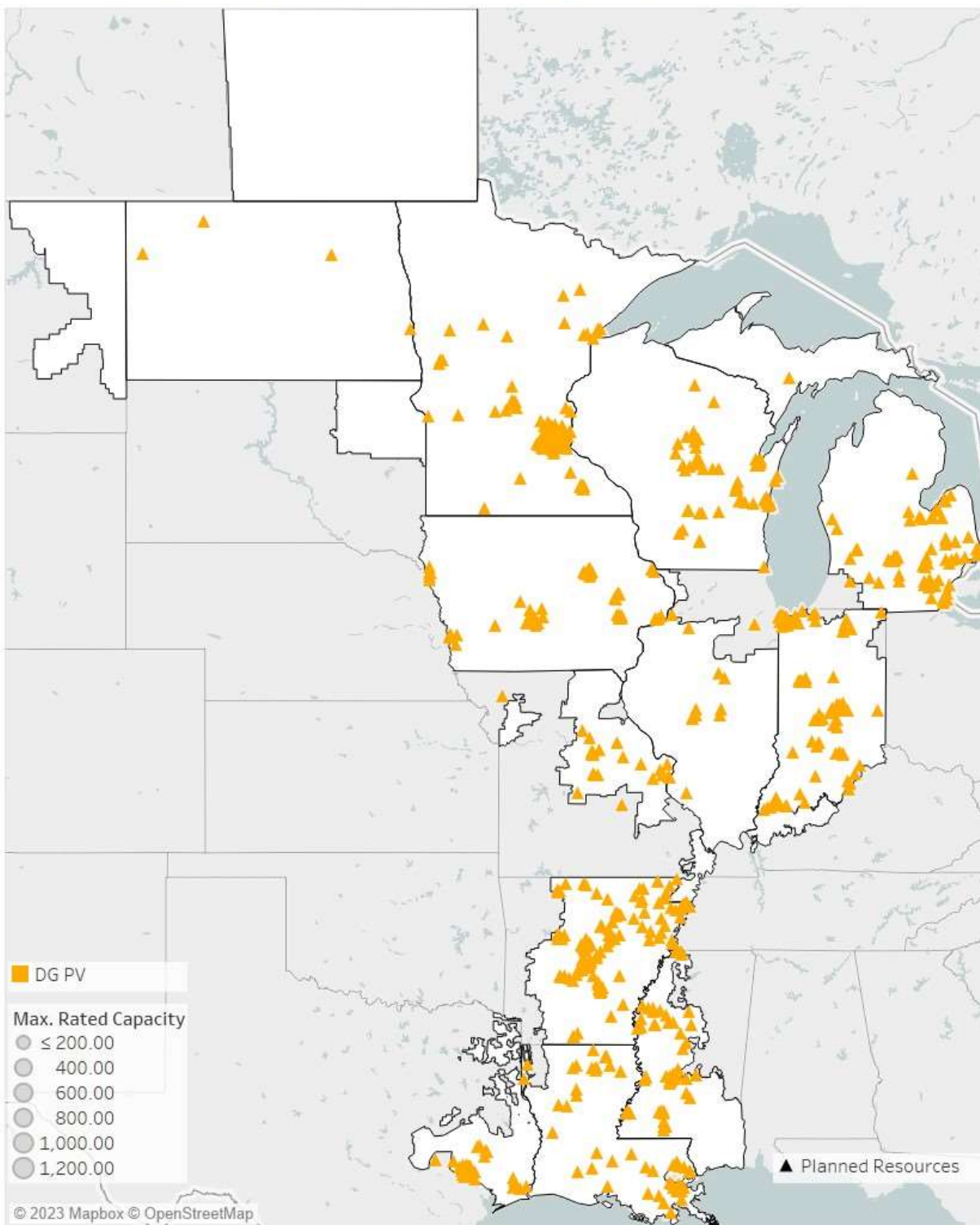


Figure 76: MISO Future 2A Distributed Solar Siting





## Future 2A: Wind Expansion

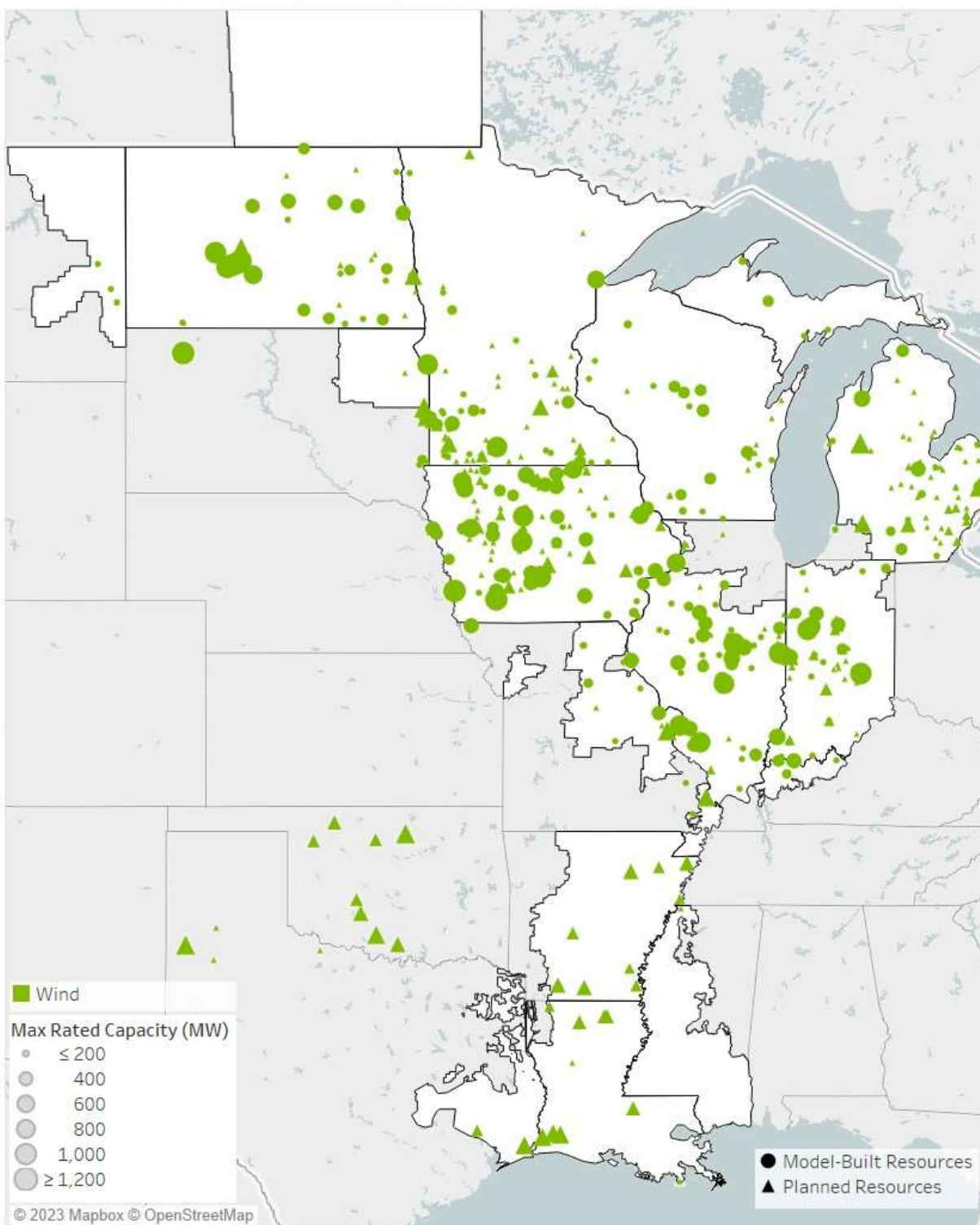


Figure 77: MISO Future 2A Wind Siting



## Future 2A: Battery Expansion

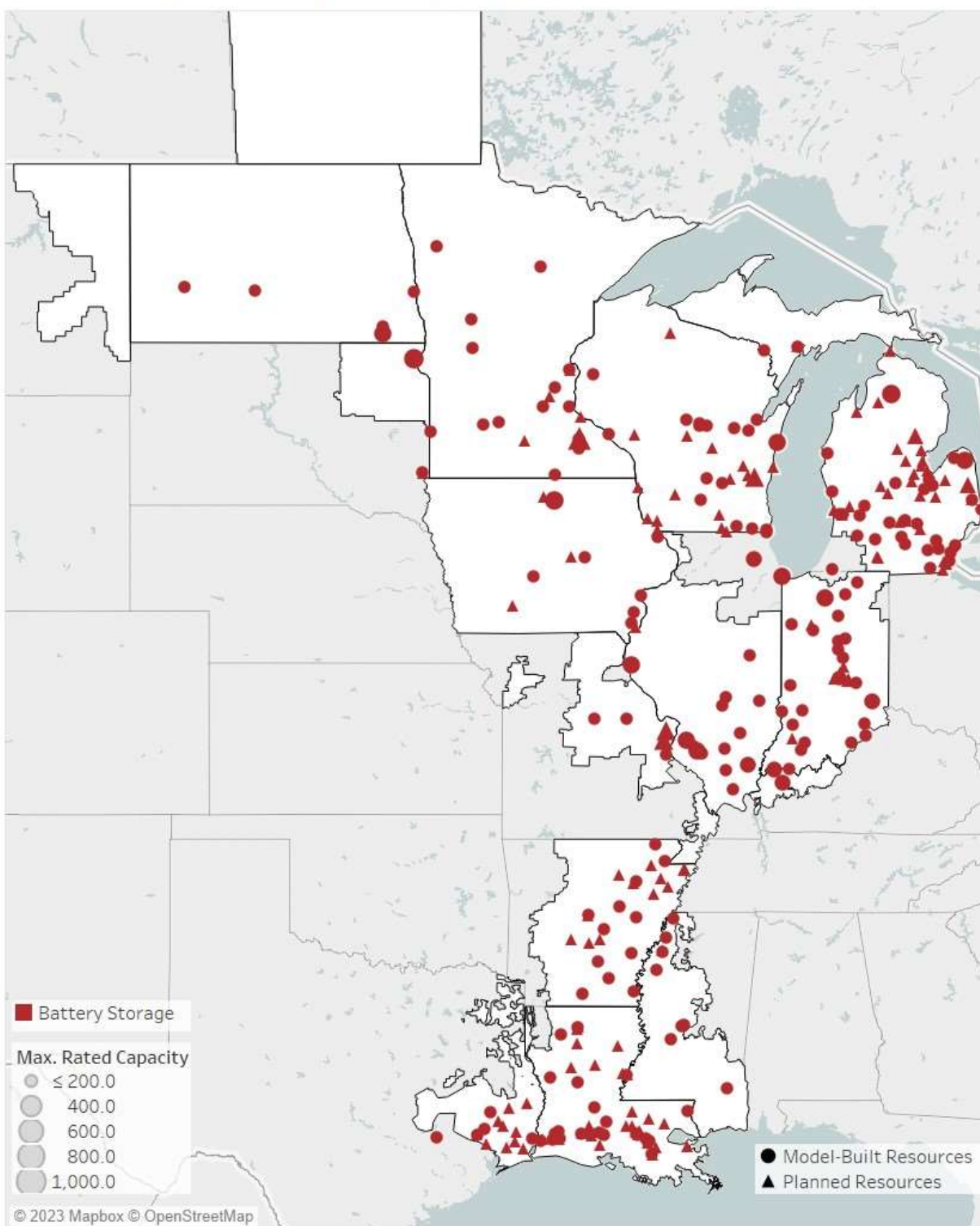


Figure 78: MISO Future 2A Battery Siting





## Future 2A: Thermal Expansion

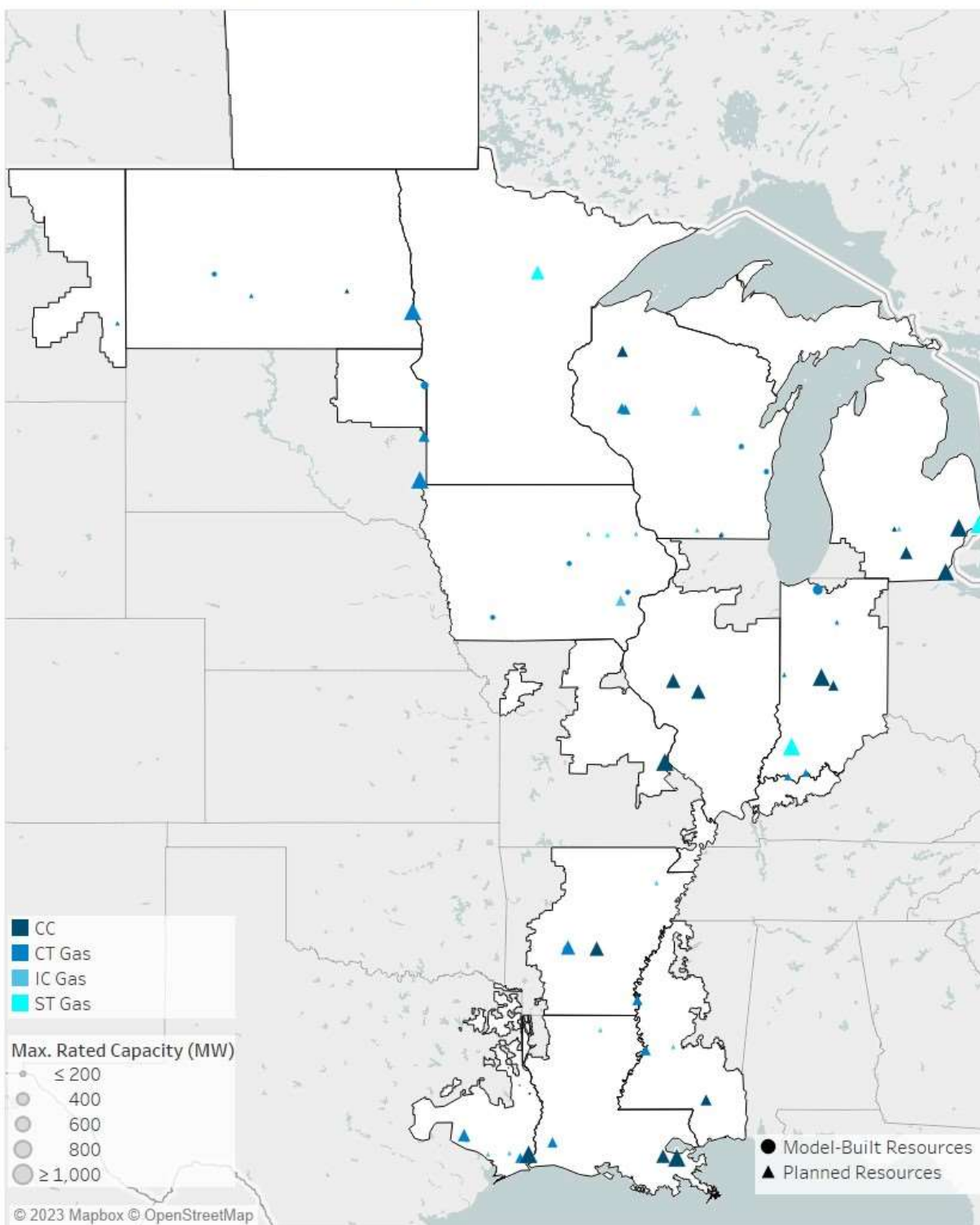


Figure 79: MISO Future 2A Thermal Siting



## Future 2A: Flex Expansion

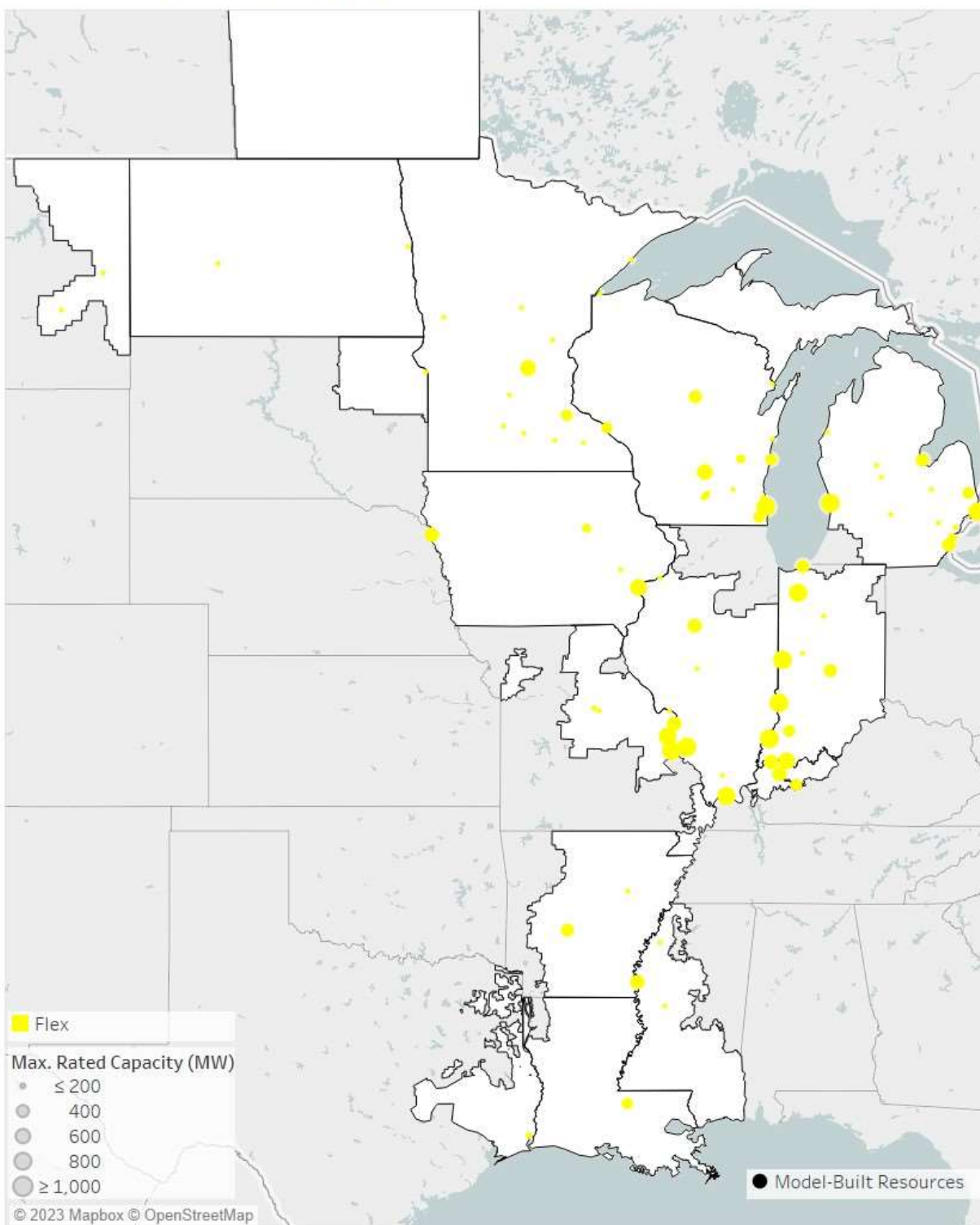


Figure 80: MISO F2A Flex Siting



## Future 2A: Model-Built Expansion

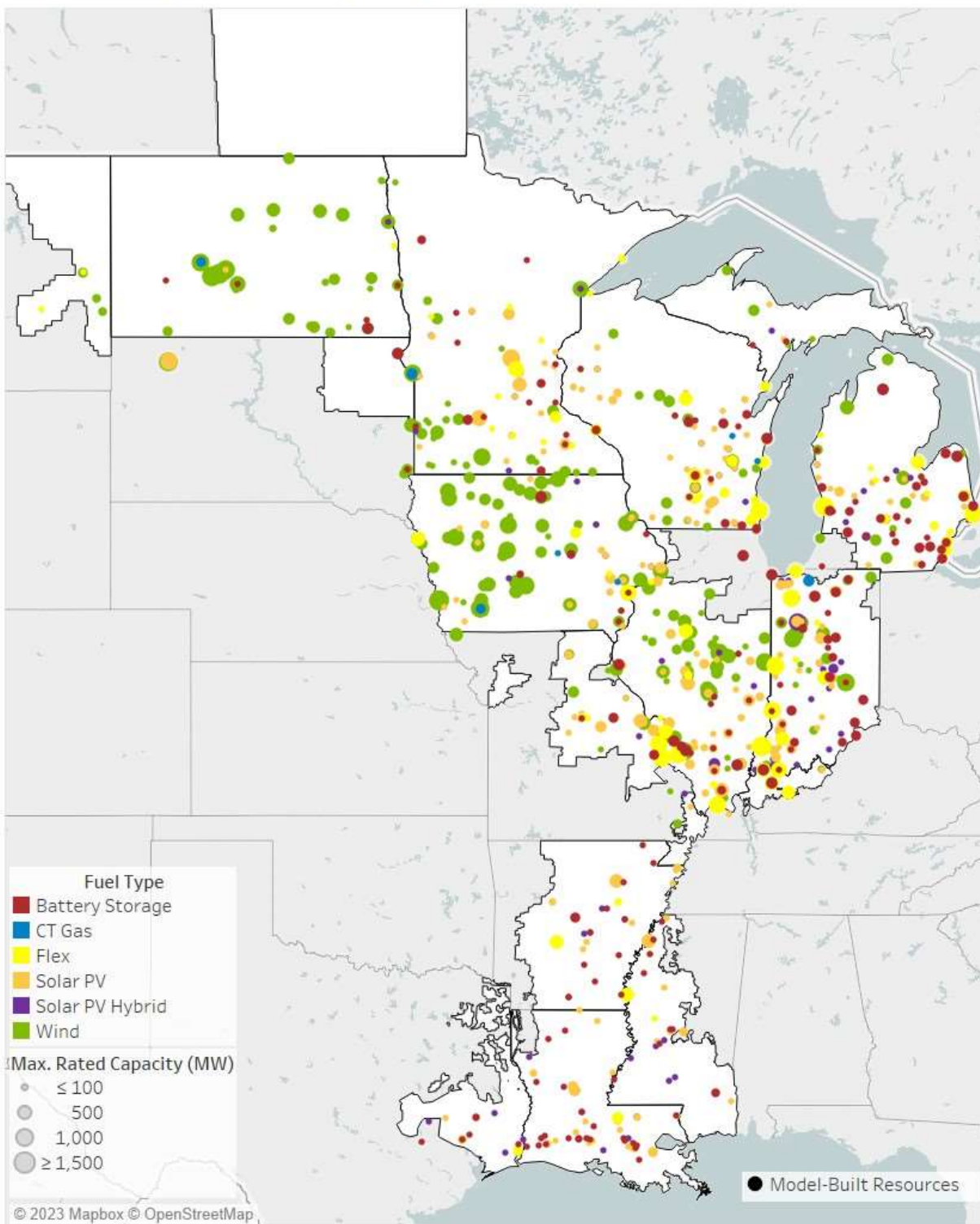


Figure 81: MISO Future 2A Complete EGEAS Expansion Siting





## Future 2A: Planned Expansion

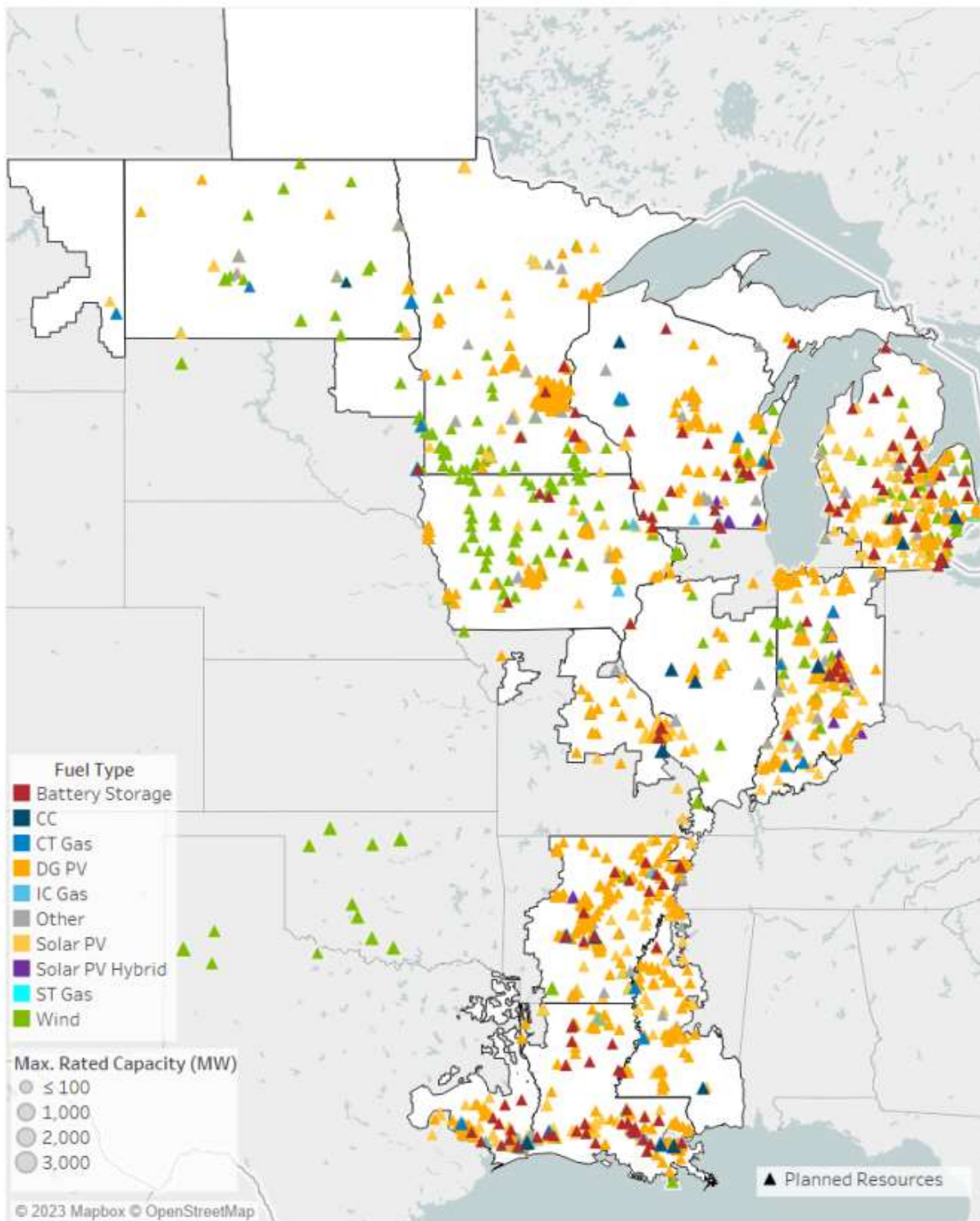


Figure 82: MISO Future 2A Non-EGEAS Expansion Siting



## Future 2A: Total Expansion

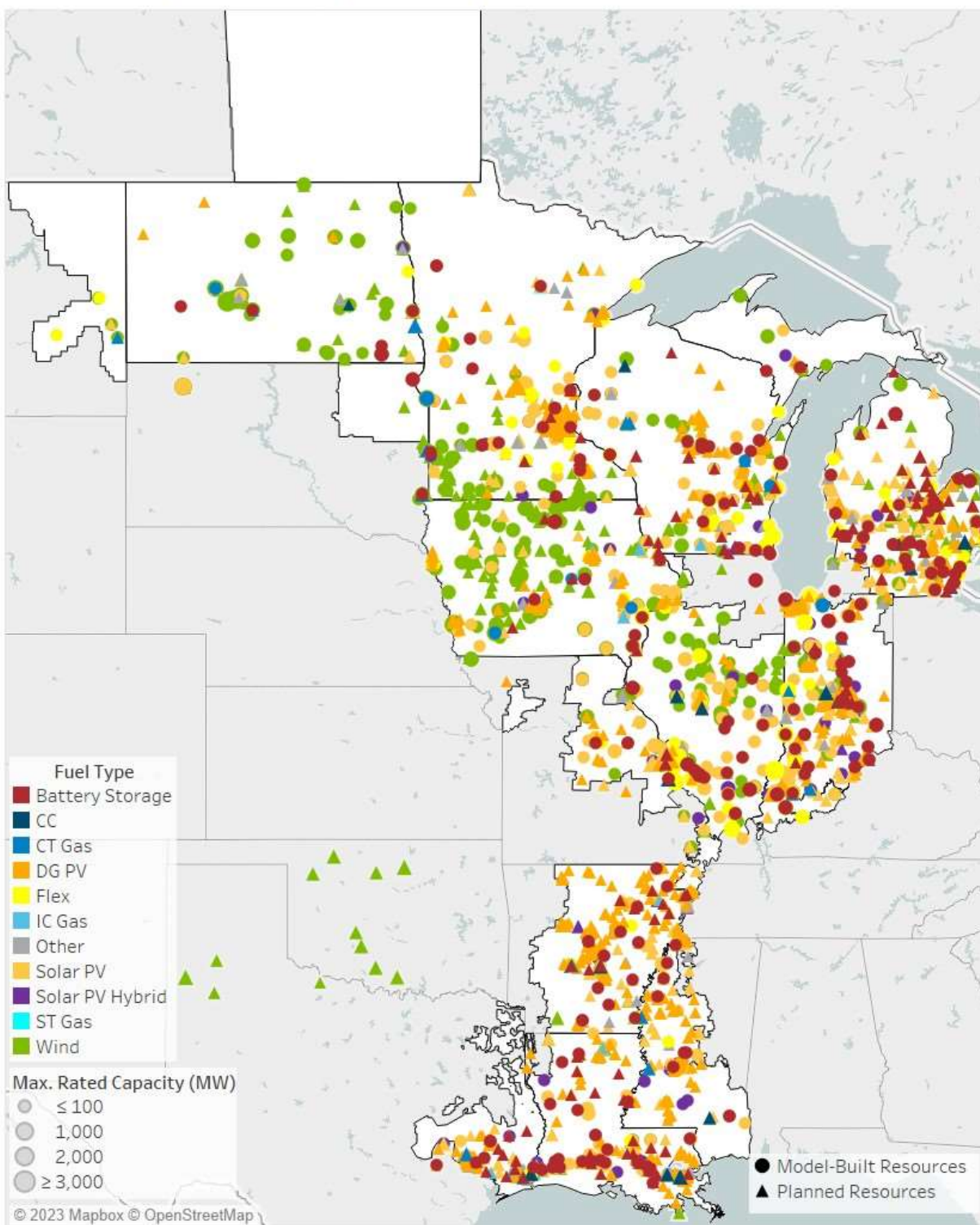


Figure 83: MISO Future 2A Non-EGEAS and EGEAS Expansion Siting



### Future 2A Resource Additions (MW) - Cumulative

Zone	Milestone	Battery	CC	CT Gas	Demand Response	DGPV	IC Gas	Solar	Hybrid	ST Coal	ST Gas	Wind	Flex	EE	UDG	Totals
LRZ 1	2027	20	100	981	1,446	375	0	4,867	0	163	0	4,651	2,123	804	18	15,548
	2032	540	100	2,103	1,533	925	0	7,200	70	163	0	23,444	2,123	1,579	42	39,822
	2037	1,616	100	3,225	1,807	1,675	0	10,264	219	163	595	34,388	2,123	2,128	115	58,418
	2042	3,493	100	4,029	1,919	2,675	0	13,654	219	163	595	40,125	2,123	2,559	376	72,030
LRZ 2	2027	1,179	487	300	826	30	843	1,065	1,100	0	0	269	2,570	572	13	9,254
	2032	1,349	487	300	862	405	843	2,166	1,177	0	0	3,376	3,897	1,048	30	15,940
	2037	2,541	487	300	920	967	843	2,534	1,383	0	0	4,779	3,897	1,440	82	20,174
	2042	3,253	487	400	989	1,555	843	3,395	1,383	0	0	4,929	3,897	1,748	269	23,148
LRZ 3	2027	375	0	0	552	418	670	1,720	0	0	50	7,675	1,872	400	9	13,741
	2032	611	0	0	576	675	670	2,505	14	0	50	21,388	1,872	733	21	29,115
	2037	1,222	0	0	614	1,375	670	3,034	181	0	50	30,604	1,872	1,008	58	40,687
	2042	1,634	0	370	685	1,500	670	3,704	181	0	50	35,003	1,872	1,223	188	47,080
LRZ 4	2027	0	1,277	0	552	0	0	1,155	0	0	0	1,414	2,087	400	9	6,894
	2032	285	1,277	0	577	150	0	2,481	184	0	0	10,325	2,087	733	21	18,121
	2037	1,249	1,277	0	616	250	0	3,654	516	0	0	14,141	2,087	1,008	58	24,855
	2042	2,155	1,277	0	663	275	0	5,237	516	0	0	15,020	2,087	1,223	188	28,641
LRZ 5	2027	0	0	0	276	725	0	1,417	0	0	0	313	3,225	343	8	6,307
	2032	11	1,200	0	289	725	0	3,456	14	0	0	2,686	3,839	629	18	12,867
	2037	759	1,200	0	309	725	0	4,425	290	0	0	3,885	3,839	864	49	16,345
	2042	1,256	1,200	0	332	725	0	4,851	290	0	0	4,085	3,839	1,049	161	17,788
LRZ 6	2027	80	1,221	513	1,163	680	0	5,263	75	0	1,052	620	6,798	858	20	18,342
	2032	494	1,221	513	1,188	880	0	8,746	1,976	0	1,052	7,920	8,947	1,571	45	34,553
	2037	3,125	1,546	513	1,228	1,317	0	10,369	3,342	0	1,052	11,899	9,632	2,159	123	46,305
	2042	4,687	1,546	813	1,274	1,794	0	12,449	3,867	0	1,052	13,849	9,632	2,622	403	53,988
LRZ 7	2027	1,842	509	0	679	0	0	5,975	0	0	1,267	743	4,527	915	21	16,477
	2032	2,764	509	0	752	650	0	11,229	179	0	1,267	4,439	4,527	1,676	48	28,040
	2037	4,997	1,455	0	812	1,650	0	12,931	386	0	1,267	9,064	4,527	2,303	132	39,524
	2042	6,553	1,455	0	906	1,975	0	15,016	386	0	1,267	14,824	4,527	2,796	430	50,135
LRZ 8	2027	0	0	0	275	0	95	1,950	0	0	0	1,100	622	343	8	4,393
	2032	437	0	380	287	550	95	4,730	491	0	0	1,500	622	629	18	9,739
	2037	1,151	667	1,047	306	1,775	95	5,378	1,022	0	0	3,944	622	864	49	16,920
	2042	1,760	667	1,047	329	2,900	95	6,372	2,422	0	0	6,188	622	1,049	161	23,612
LRZ 9	2027	10	1,215	0	551	0	173	4,965	0	0	0	0	601	915	21	8,451
	2032	825	2,317	0	575	1,300	173	8,165	290	0	0	0	601	1,676	48	15,970
	2037	3,528	2,866	1,260	626	1,750	173	12,145	431	0	0	5,956	601	2,303	132	31,771
	2042	5,389	2,866	1,640	673	2,050	173	14,804	431	0	0	10,412	601	2,796	430	42,265
LRZ 10	2027	0	402	0	0	0	58	2,175	0	0	0	0	600	172	4	3,411
	2032	10	402	380	0	700	58	3,083	30	0	0	0	600	314	9	5,586
	2037	444	402	380	0	1,150	58	3,569	130	0	0	0	600	432	25	7,190
	2042	918	402	760	0	1,688	58	5,221	130	0	0	200	600	524	81	10,582
MISO Total	2027	3,506	5,211	1,793	6,320	2,228	1,839	30,551	1,175	163	2,369	16,784	25,025	5,721	131	102,816
	2032	7,326	7,513	3,675	6,640	6,960	1,839	53,760	4,425	163	2,369	75,078	29,115	10,589	300	209,753
	2037	20,633	10,000	6,724	7,238	12,634	1,839	68,302	7,900	163	2,964	118,66	29,800	14,508	823	302,188
	2042	31,099	10,000	9,058	7,770	17,137	1,839	84,702	9,825	163	2,964	144,63	29,800	17,589	2,688	369,269

Table 9: MISO Future 2A Resource Additions by LRZ and Footprint





Future 2A Resource Retirements (MW) - Cumulative									
Zone	Milestone	Coal	Gas	Nuclear	Oil	Wind	Solar	Other	Totals
LRZ 1	2027	3,612	1,604	0	325	123	0	962	6,625
	2032	5,355	2,141	0	570	1,772	0	996	10,834
	2037	5,844	2,362	0	584	3,178	24	1,014	13,005
	2042	5,844	2,988	0	678	5,274	470	1,014	16,268
LRZ 2	2027	2,515	171	0	76	102	0	20	2,884
	2032	2,844	1,170	0	76	385	0	20	4,495
	2037	2,960	2,744	0	139	823	0	20	6,686
	2042	3,019	3,778	0	200	823	11	44	7,874
LRZ 3	2027	3,407	1,363	0	240	311	0	0	5,322
	2032	3,407	1,481	0	319	1,468	0	0	6,676
	2037	3,407	1,513	0	319	4,582	0	0	9,822
	2042	3,980	1,573	0	455	6,628	0	0	12,637
LRZ 4	2027	2,123	0	0	117	20	0	0	2,260
	2032	2,123	564	0	117	28	0	0	2,832
	2037	2,123	2,534	0	117	698	0	0	5,472
	2042	2,123	3,222	0	176	823	20	0	6,364
LRZ 5	2027	1,251	67	0	345	0	0	0	1,663
	2032	2,257	67	0	345	0	0	0	2,669
	2037	3,471	1,177	0	345	169	0	0	5,162
	2042	4,704	1,188	0	345	169	0	0	6,406
LRZ 6	2027	7,255	543	0	50	0	0	0	7,848
	2032	8,986	963	0	50	131	0	0	10,130
	2037	10,256	2,356	0	71	942	2	0	13,627
	2042	10,256	4,591	0	71	1,742	475	0	17,135
LRZ 7	2027	3,787	1,248	0	390	0	0	38	5,463
	2032	5,357	2,532	0	390	113	0	147	8,538
	2037	6,922	6,535	0	390	929	0	147	14,922
	2042	6,922	7,920	0	419	2,180	54	147	17,641
LRZ 8	2027	0	788	0	0	0	0	0	788
	2032	3,089	788	0	0	0	0	0	3,877
	2037	3,089	1,418	0	0	0	0	0	4,507
	2042	3,089	1,516	0	0	0	181	0	4,786
LRZ 9	2027	1,880	4,627	0	7	0	0	0	6,515
	2032	2,496	5,582	0	7	0	0	28	8,113
	2037	2,496	8,171	0	7	0	0	39	10,712
	2042	2,496	9,461	0	7	0	0	39	12,003
LRZ 10	2027	0	816	0	0	0	0	0	816
	2032	206	901	0	0	0	0	0	1,107
	2037	206	901	0	0	0	0	0	1,107
	2042	206	1,370	0	0	0	52	0	1,628
MISO Total	2027	25,831	11,227	0	1,549	556	0	1,020	40,183
	2032	36,120	16,190	0	1,874	3,896	0	1,190	59,270
	2037	40,774	29,711	0	1,971	11,321	26	1,219	85,022
	2042	42,639	37,608	0	2,351	17,638	1,262	1,243	102,741

Table 10: MISO Future 2A Resource Retirements by LRZ and Footprint



## MISO – Future 3A

### Future 3A – Retirements and Additions

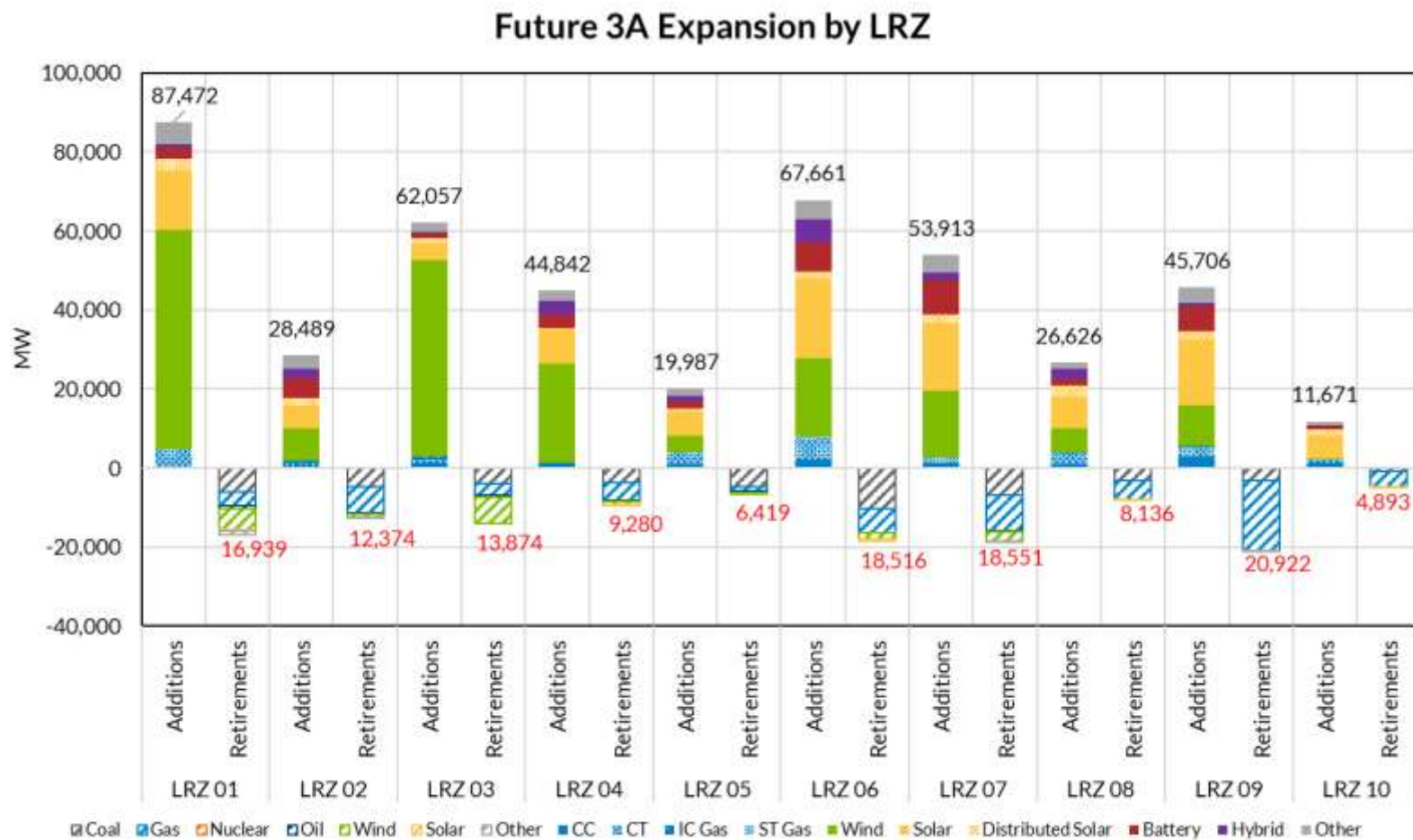


Figure 84: MISO Future 3A Resource Retirement and Addition Summary

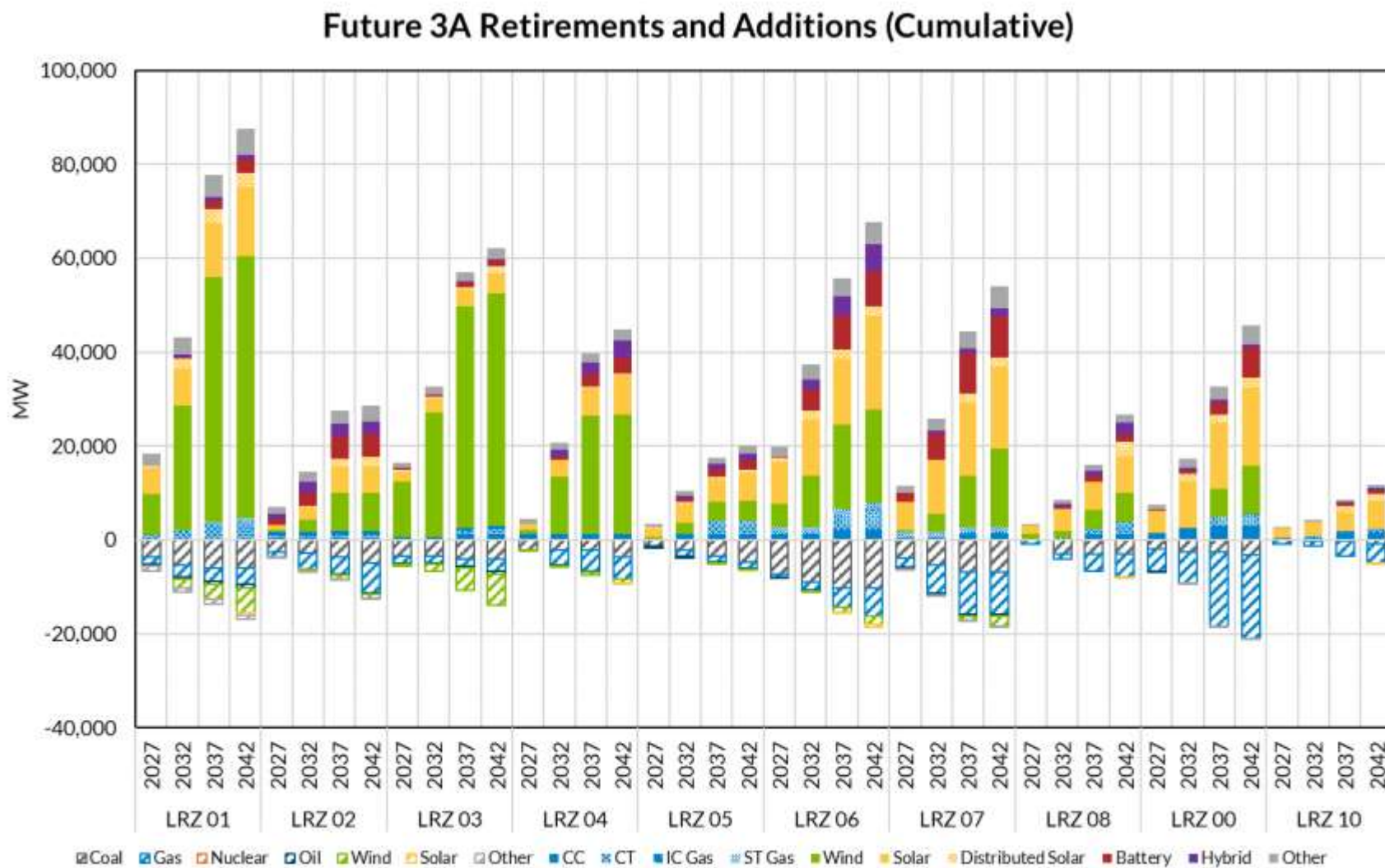


Figure 85: MISO Future 3A Resource Retirement and Addition Summary



## Future 3A – Installed Capacity

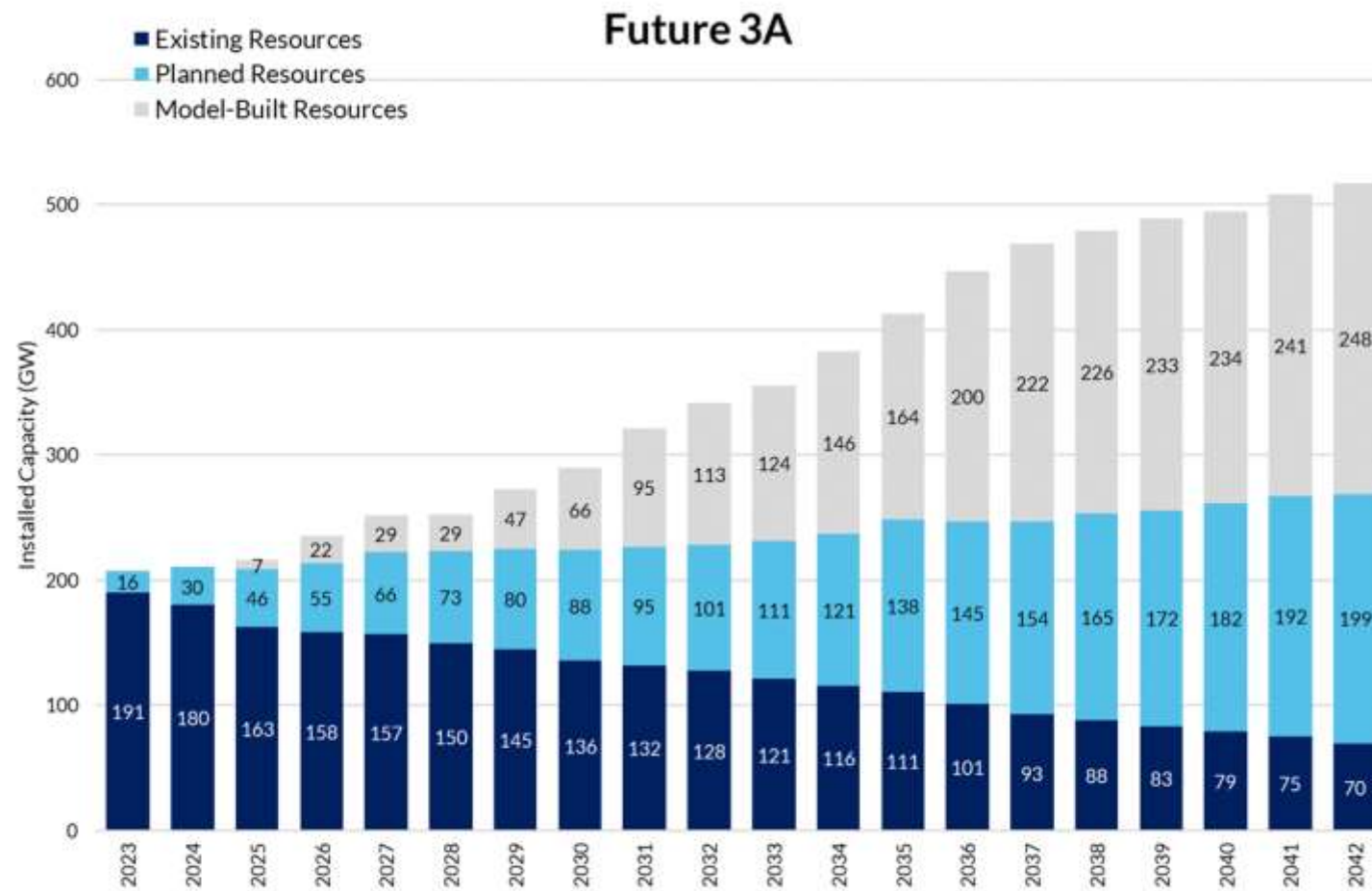
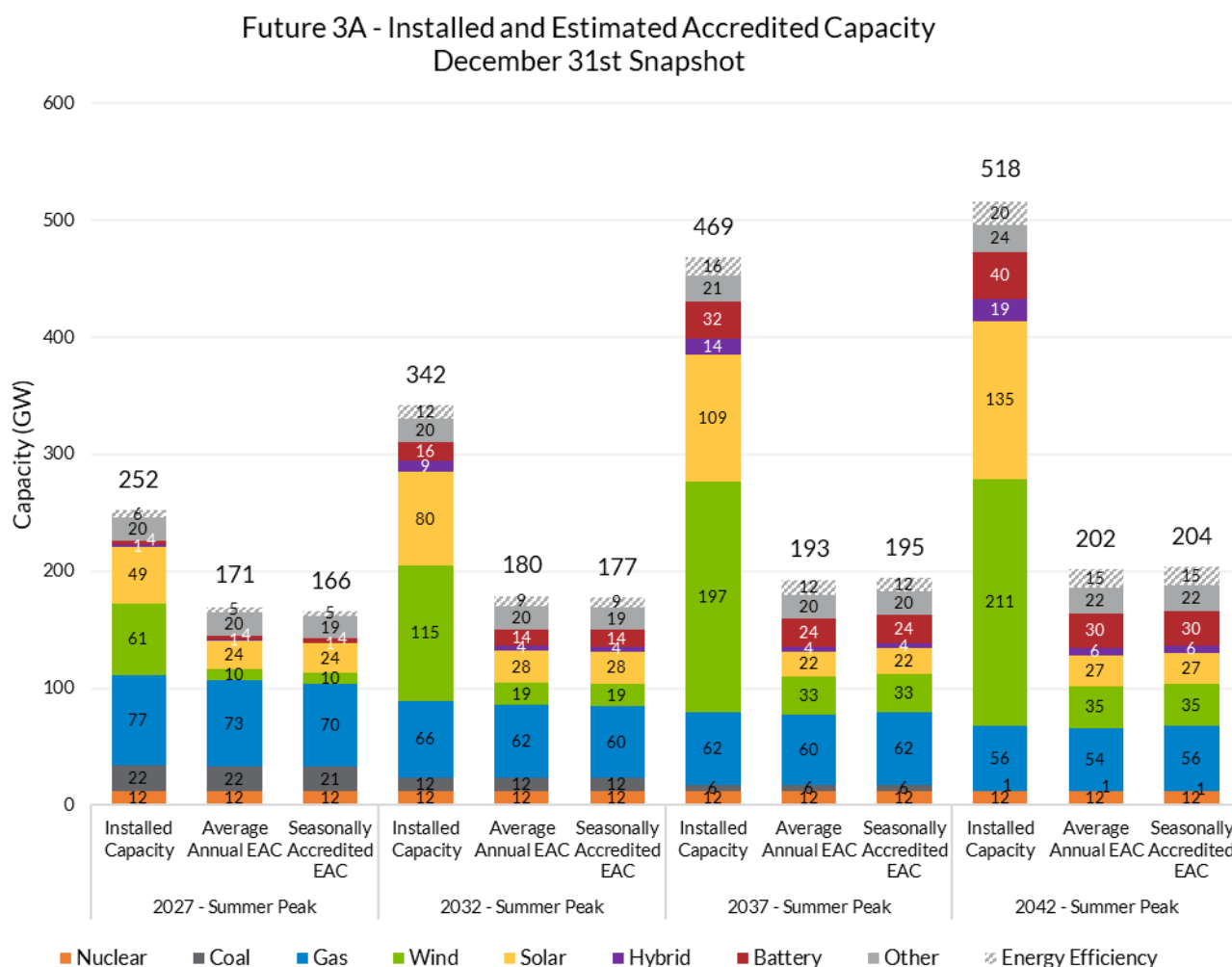


Figure 86: MISO F3A installed capacity of existing, planned, and model-built resources (GW).



## Future 3A – Estimated Accredited Capacity

Figure 87 provides the end-of-year (EOY) installed and estimated accredited capacity (EAC)<sup>40</sup> for Future 3A. Figure 88 provides a beginning-of-year (BOY) outlook, overlaid with the load plus reserve. This alternative outlook aligns with the capacity expansion tool's output reporting for net load and attainment of a minimum 18.05% planning reserve margin (PRM) throughout the study period.



**Figure 87: Installed, Seasonally Accredited<sup>40</sup> and Average Annual Estimated Accredited Capacity for Future 3A. Values reflect an end-of-year (December 31<sup>st</sup>) snapshot.**

<sup>40</sup> Accreditation of thermal resources includes seasonal multipliers to align thermal capacity with seasonal peak; Future 3A is summer-peaking for 2027/2032 and winter-peaking for 2037/2042. Seasonal accreditation of thermal resources results in a lower total EAC during summer-peaking years and a higher total EAC during winter-peaking years than the average annual EAC.

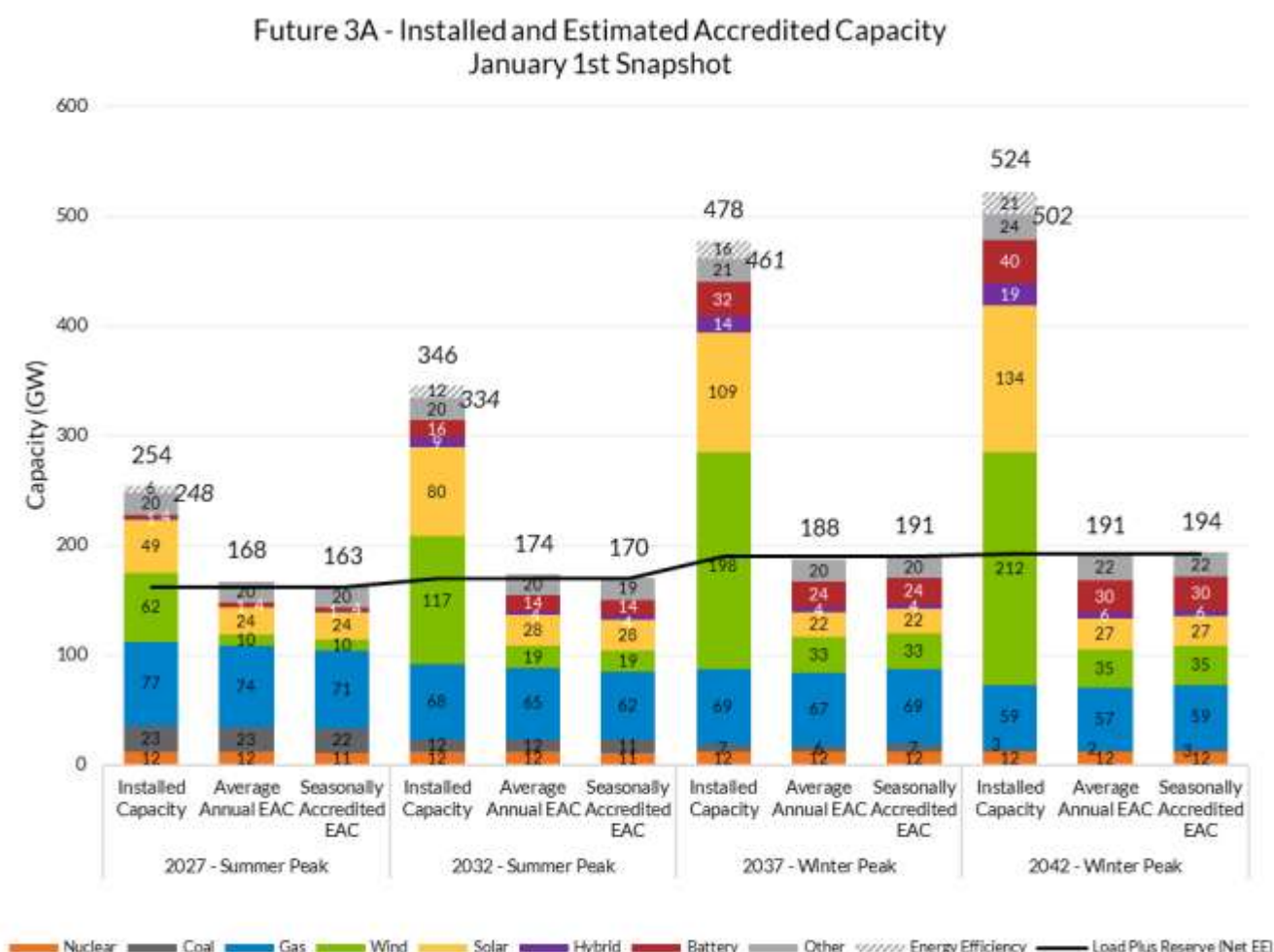


Figure 88: Installed, Seasonally Accredited<sup>40</sup> and Average Annual Estimated Accredited Capacity, with load plus reserve (net EE) for Future 3A. Installed capacity (net EE) totals are provided in *italics* for direct comparison with EAC.<sup>41,42</sup>

<sup>41</sup> The capacity expansion tool, EGEAS, utilizes the seasonal estimated accredited capacity in the calculation and attainment of a minimum 18.05% planning reserve margin (PRM) for all study years. Load plus reserve reflects netting of EE for calculation of PRM.

<sup>42</sup> Values reflect a beginning-of-year (Jan 1st) snapshot to align with the capacity expansion tool's output reporting for net load. Resources retiring in the reflected year are assumed to be in commission during system's summer peak and January 2037/2042 winter peak given EGEAS' assumptions around retirement timing on December 31st.





## Future 3A – Energy Production

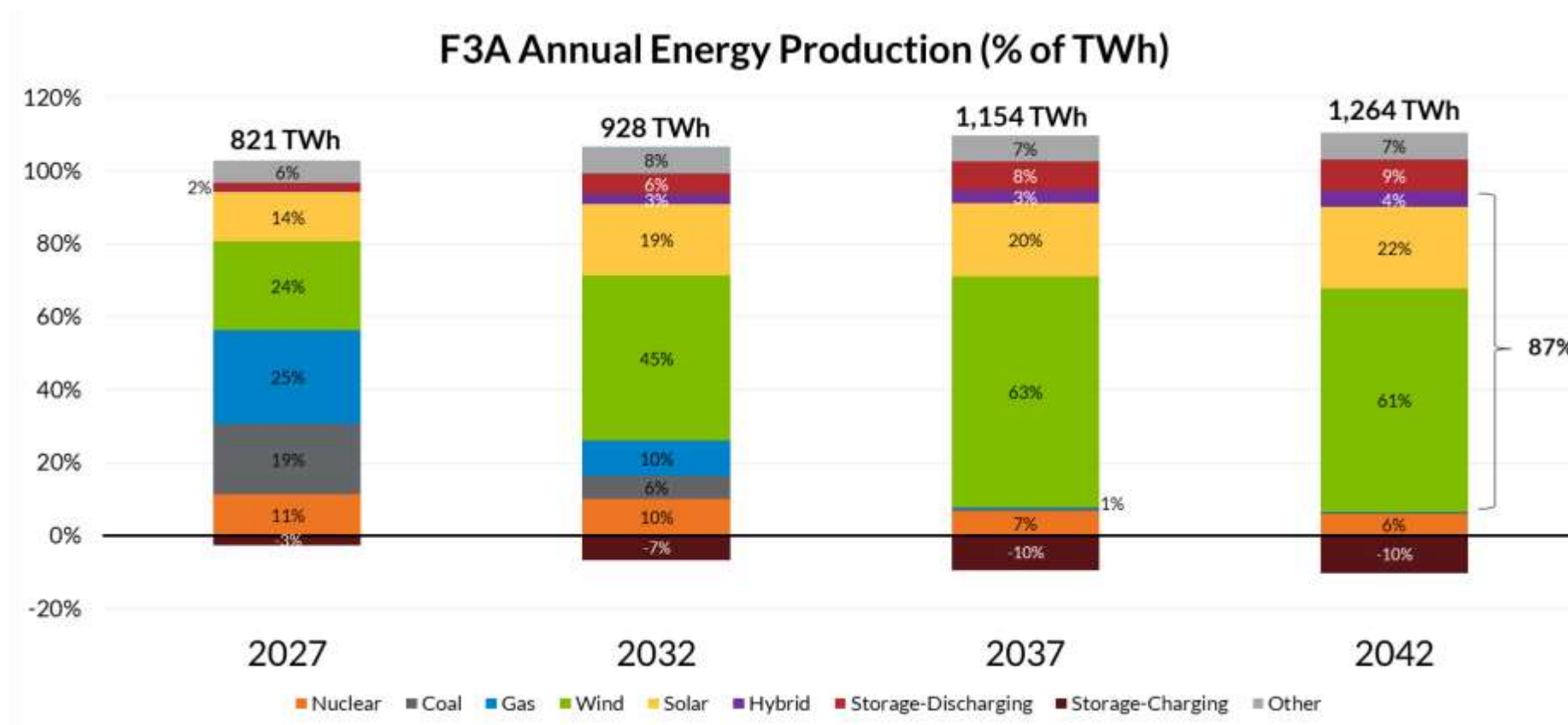


Figure 89: Future 3A Total Annual Energy Production by Milestone Year. Total energy production values are reported net storage-charging.



## Future 3A – Generation Siting

### Future 3A: Solar & Hybrid Expansion

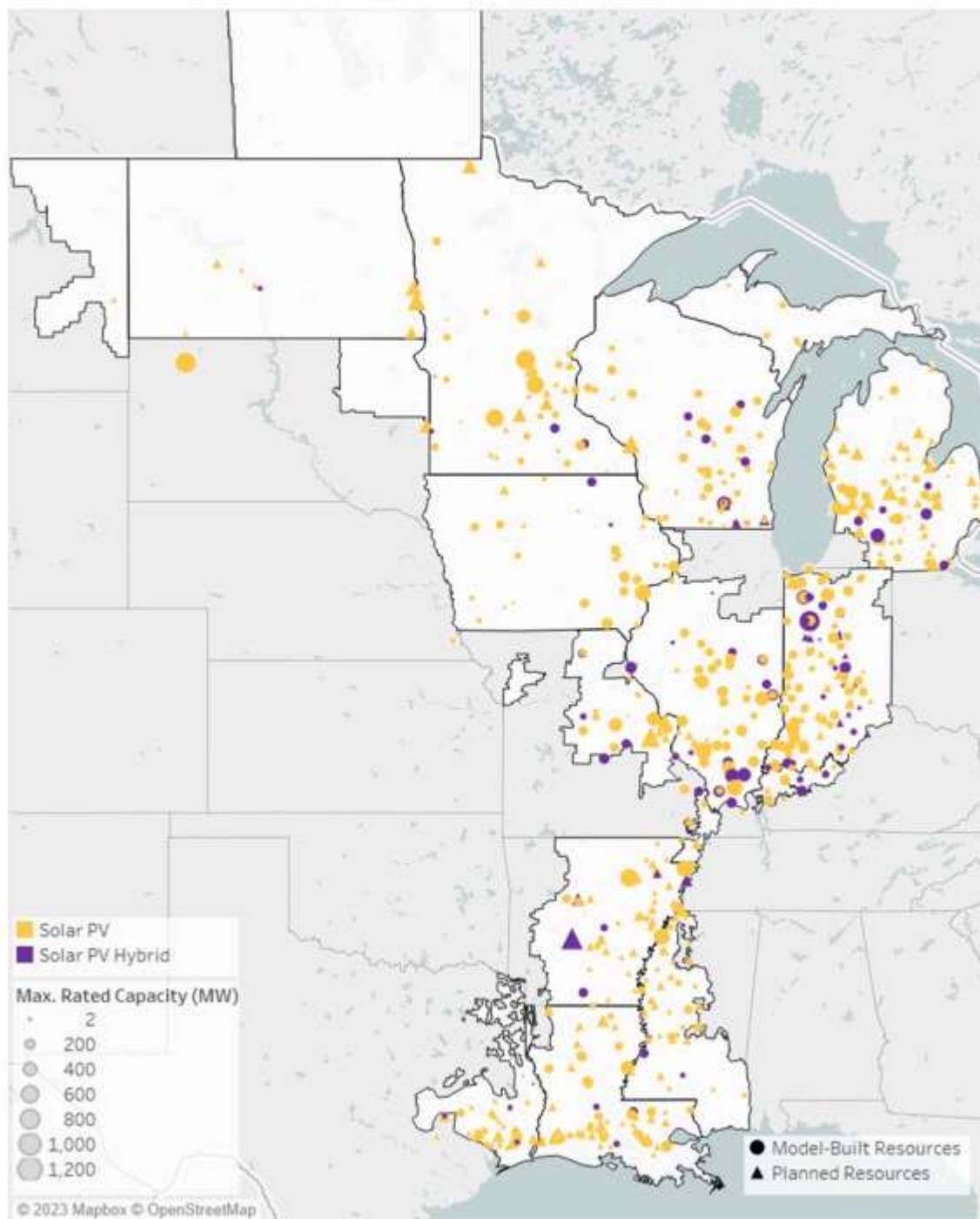


Figure 90: MISO Future 3A Solar and Hybrid Siting



## Future 3A: Distributed Solar Expansion

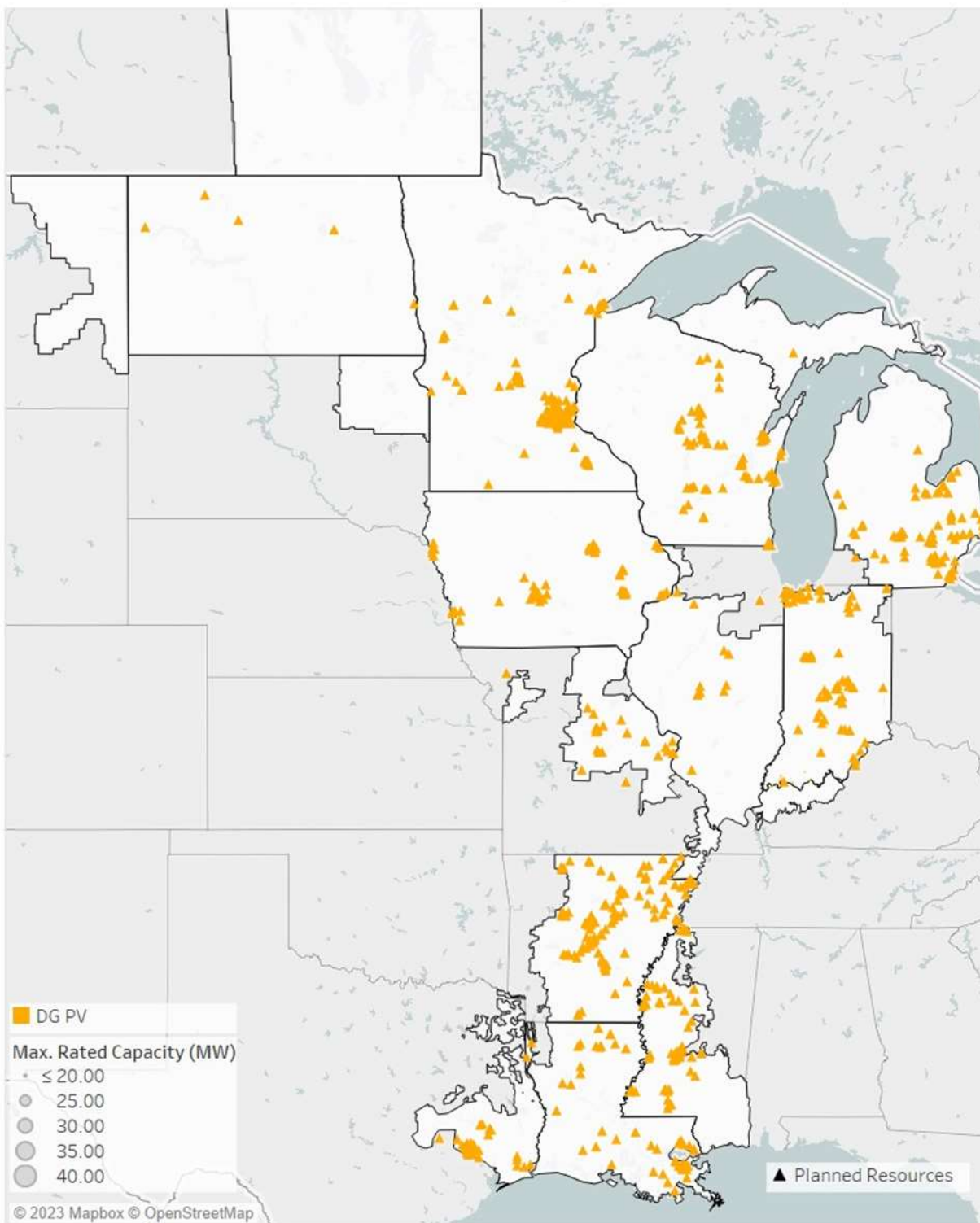


Figure 91: MISO Future 3A Distributed Solar Siting



## Future 3A: Wind Expansion

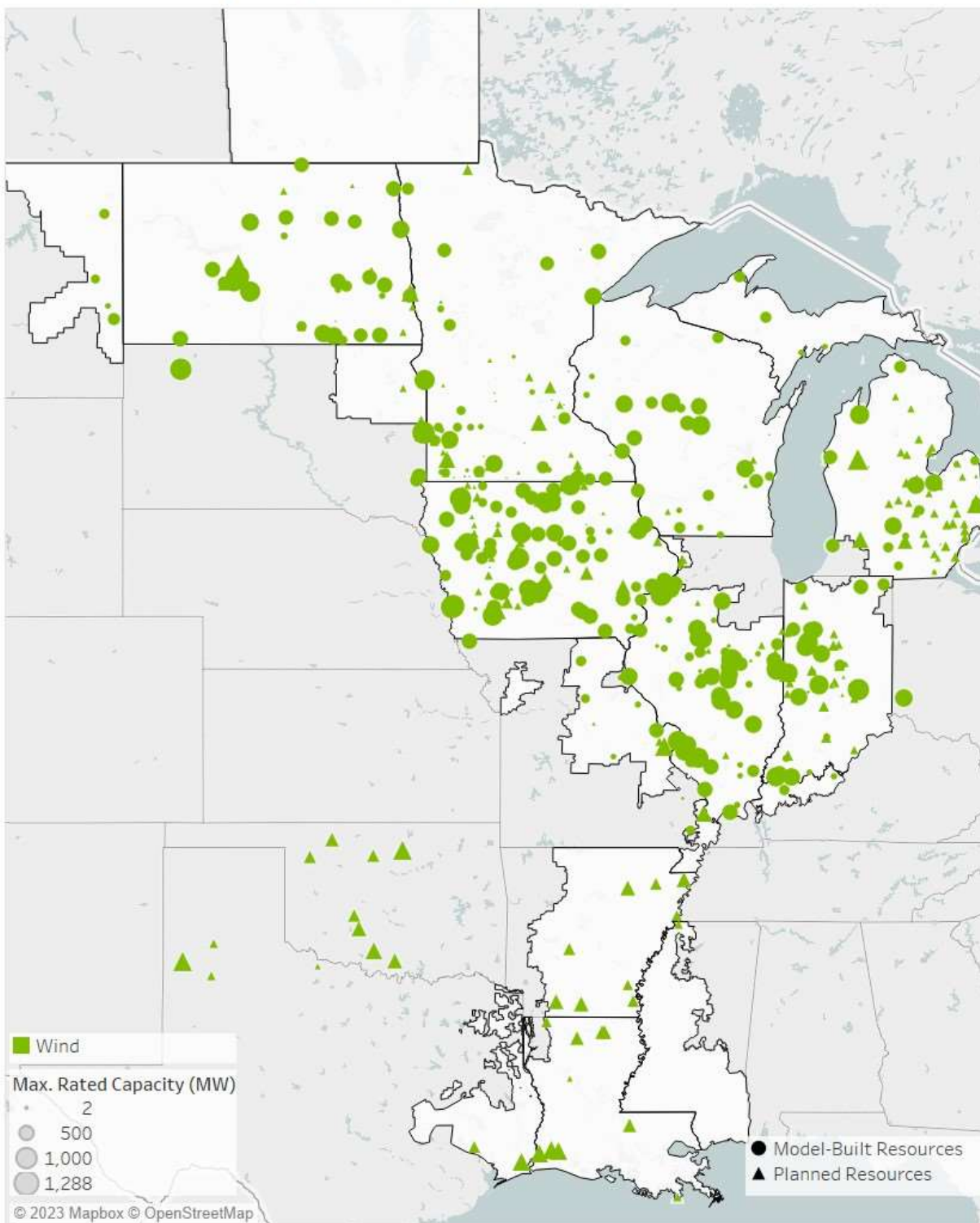


Figure 92: MISO Future 3A Wind Siting





## Future 3A: Battery Expansion

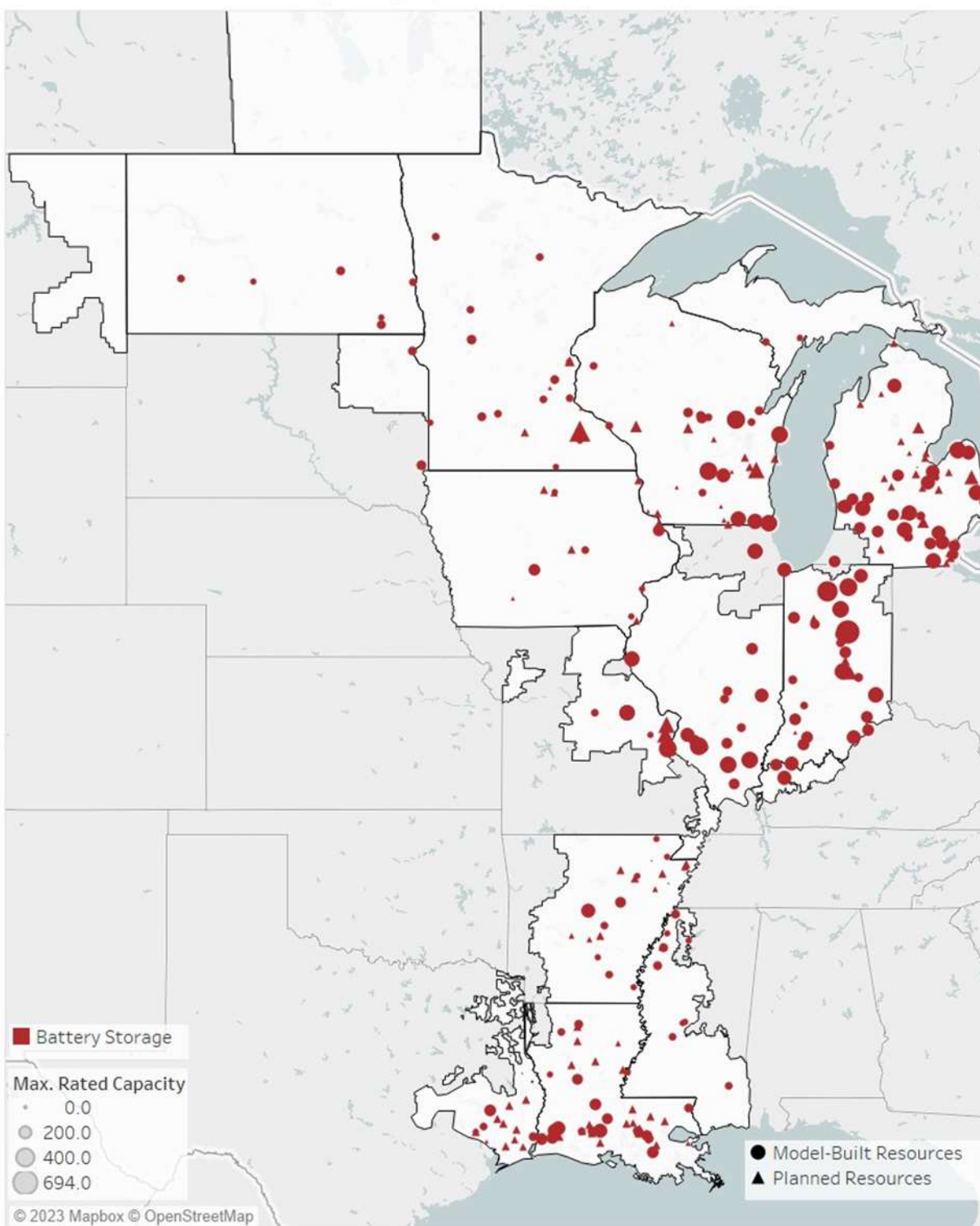


Figure 93: MISO Future 3A Battery Siting





## Future 3A: Thermal Expansion

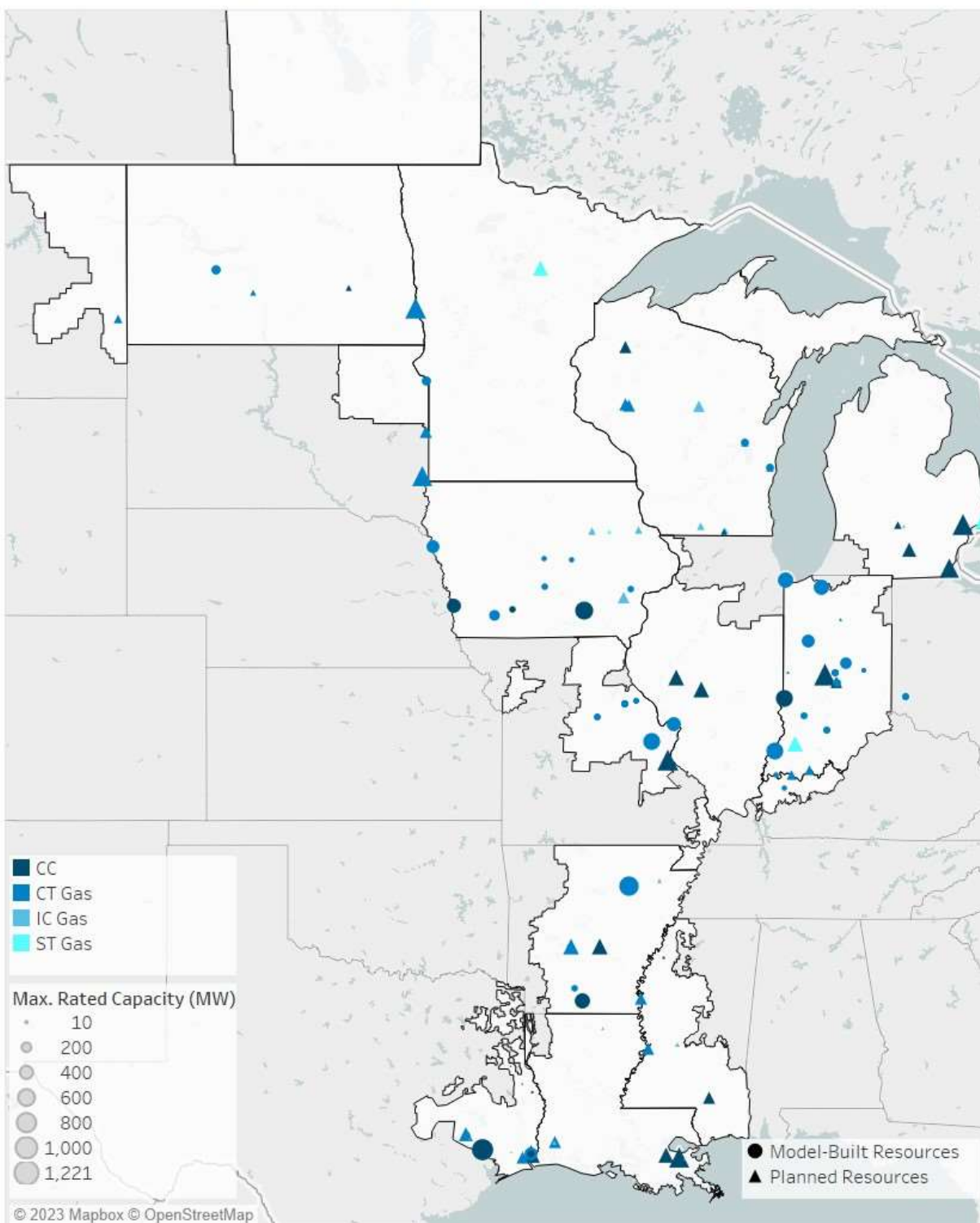


Figure 94: MISO Future 3A Thermal Siting



## Future 3A: Model-Built Expansion

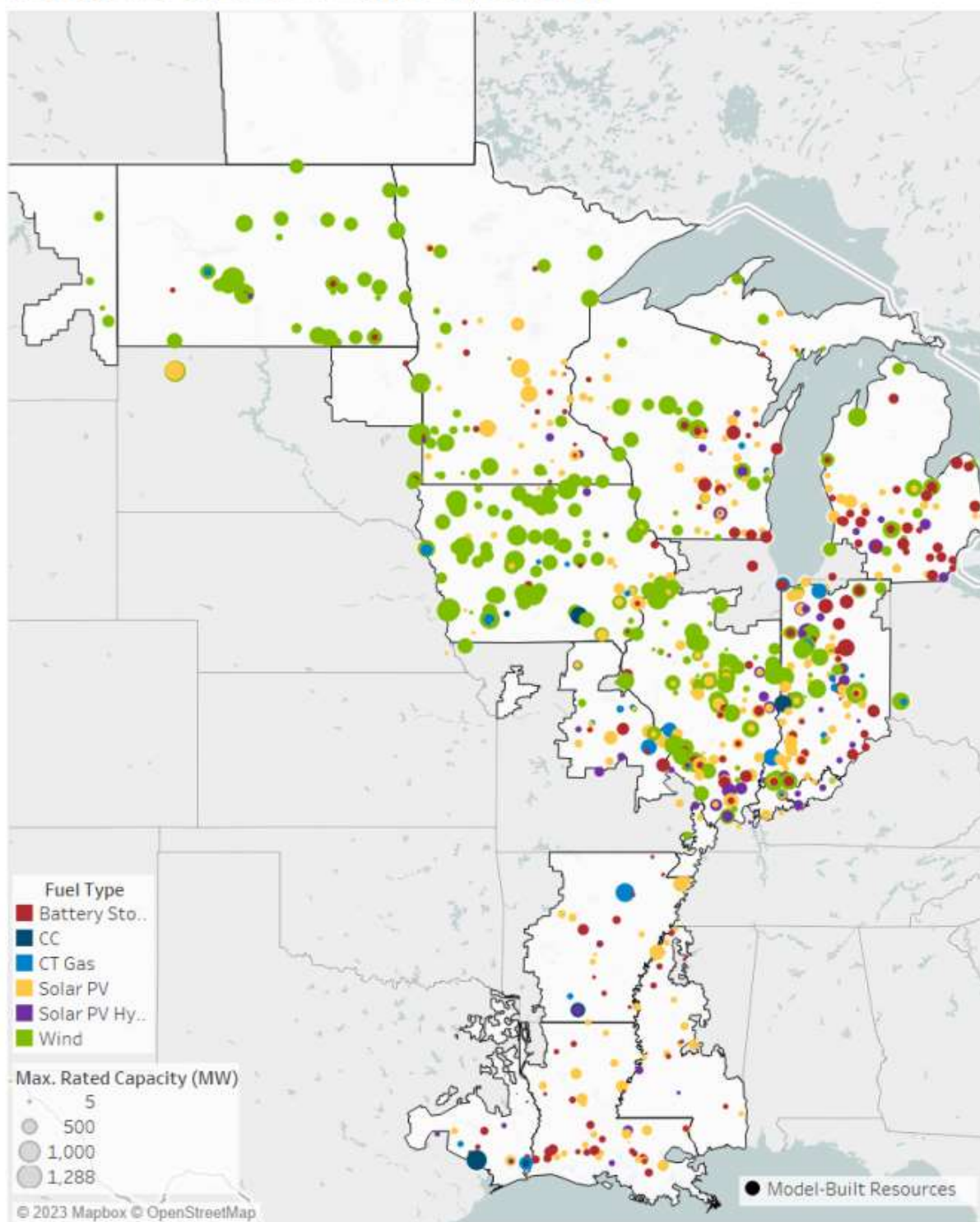


Figure 95: MISO Future 3A Complete EGEAS Expansion Siting



## Future 3A: Planned Expansion

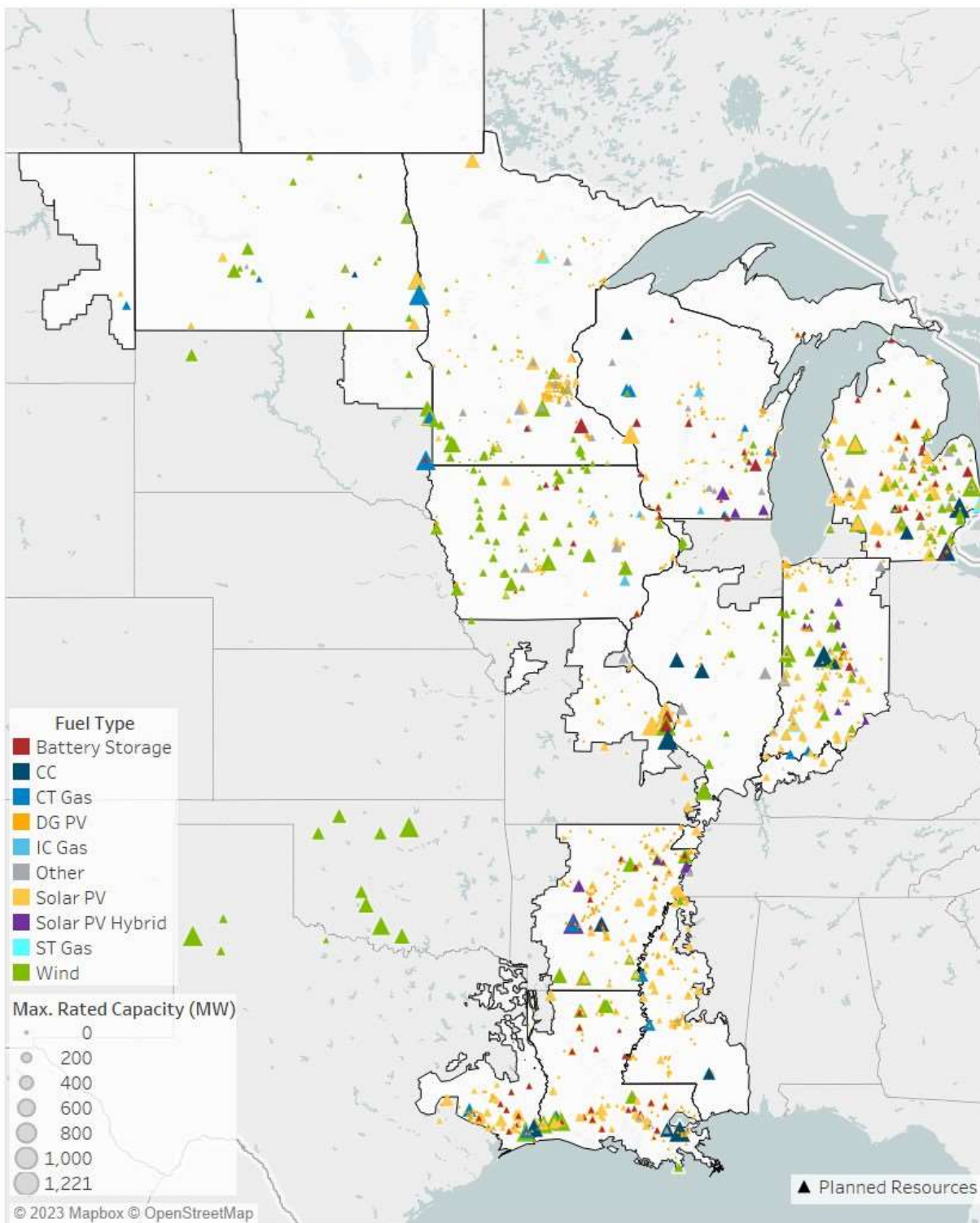


Figure 96: MISO Future 3A Non-EGEAS Expansion Siting





## Future 3A: Total Expansion

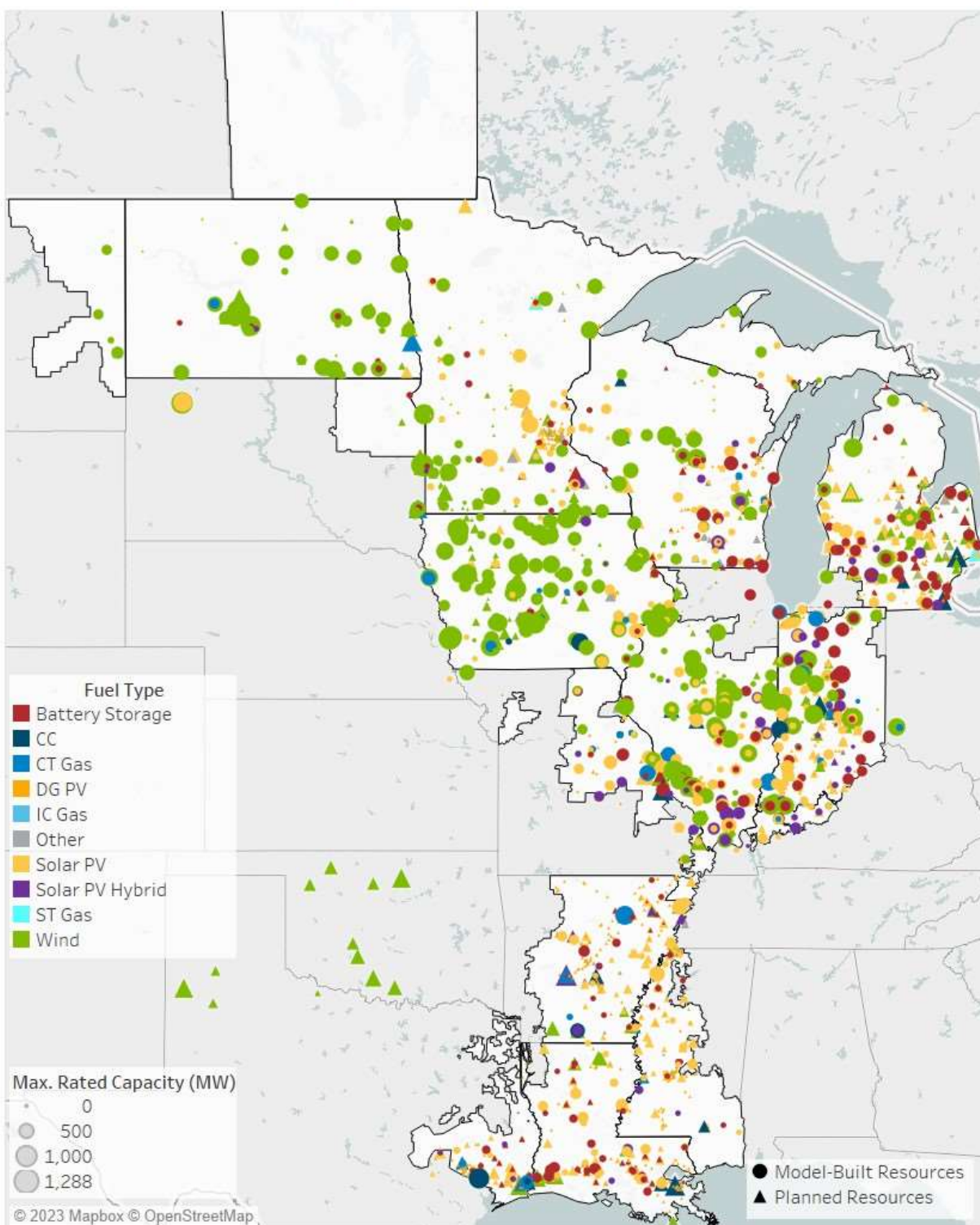


Figure 97: MISO Future 3A Non-EGEAS and EGEAS Expansion Siting



Future 3A Resource Additions (MW) - Cumulative															
Zone	Milestone	Battery	CC	CT Gas	Demand Response	DGPV	IC Gas	Solar	Hybrid	ST Coal	ST Gas	Wind	EE	UDG	Totals
LRZ 1	2027	20	100	981	1,603	393	0	5,440	0	163	0	8,783	851	18	18,352
	2032	270	100	2,103	1,642	2,102	0	7,991	655	163	0	26,295	1,718	42	43,081
	2037	1,896	100	3,225	1,853	2,930	0	11,587	826	163	595	51,919	2,389	115	77,598
	2042	3,013	100	4,029	1,919	2,931	0	14,895	878	163	595	55,614	2,960	376	87,472
LRZ 2	2027	1,179	487	300	989	30	843	1,039	1,100	0	0	522	606	13	7,108
	2032	2,745	487	300	989	405	843	2,582	2,296	0	0	2,681	1,147	30	14,505
	2037	5,009	487	600	989	1,780	843	5,544	2,483	0	0	7,994	1,626	82	27,438
	2042	5,052	487	600	989	1,780	843	5,922	2,491	0	0	8,022	2,034	269	28,489
LRZ 3	2027	475	0	0	685	425	670	2,126	0	0	50	11,596	424	9	16,460
	2032	575	0	0	685	425	670	2,957	14	0	50	26,352	803	21	32,552
	2037	1,216	1,269	614	685	456	670	3,620	181	0	50	47,047	1,138	58	57,004
	2042	1,302	1,269	984	685	1,488	670	4,240	194	0	50	49,564	1,424	188	62,057
LRZ 4	2027	0	1,277	0	663	0	0	1,192	0	0	0	827	424	9	4,392
	2032	529	1,277	0	663	0	0	3,755	1,602	0	0	12,070	803	21	20,720
	2037	2,904	1,277	0	663	275	0	5,871	2,288	0	0	25,166	1,138	58	39,639
	2042	3,304	1,277	0	863	275	0	8,672	3,549	0	0	25,291	1,424	188	44,842
LRZ 5	2027	0	0	0	332	525	0	1,680	0	0	0	571	363	8	3,479
	2032	578	1,200	0	332	725	0	3,684	663	0	0	2,476	688	18	10,364
	2037	1,560	1,200	2,827	332	725	0	4,667	1,105	0	0	4,120	976	49	17,561
	2042	1,972	1,200	2,827	332	725	0	5,925	1,305	0	0	4,320	1,220	161	19,987
LRZ 6	2027	80	1,221	513	1,286	880	0	8,940	75	0	1,052	4,960	908	20	19,934
	2032	4,553	1,221	513	1,286	1,786	0	12,053	2,222	0	1,052	10,796	1,720	45	37,245
	2037	7,209	2,188	3,442	1,286	1,892	0	14,064	4,160	0	1,052	17,917	2,439	123	55,772
	2042	7,426	2,188	4,604	1,286	1,895	0	20,081	5,810	0	1,052	19,867	3,050	403	67,661
LRZ 7	2027	1,842	509	0	538	0	0	5,965	0	0	1,267	426	969	21	11,536
	2032	5,441	509	0	574	0	0	11,639	701	0	1,267	3,708	1,835	48	25,721
	2037	8,499	1,455	0	901	2,050	0	15,444	1,065	0	1,267	10,997	2,602	132	44,412
	2042	8,736	1,455	0	901	2,050	0	17,378	1,685	0	1,267	16,757	3,254	430	53,913
LRZ 8	2027	0	0	0	0	0	95	1,935	0	0	0	1,100	363	8	3,501
	2032	400	0	380	184	0	95	4,672	525	0	0	1,500	688	18	8,462
	2037	1,295	1,203	1,047	184	0	95	6,159	1,044	0	0	3,944	976	49	15,996
	2042	1,590	1,203	2,570	184	2,900	95	7,952	2,563	0	0	6,188	1,220	161	26,626
LRZ 9	2027	10	1,215	0	136	0	173	4,885	0	0	0	0	969	21	7,409
	2032	735	2,317	0	136	1,700	173	9,864	462	0	0	0	1,835	48	17,269
	2037	2,527	3,014	1,790	136	1,700	173	14,029	583	0	0	5,956	2,602	132	32,642
	2042	6,377	3,014	2,285	352	2,050	173	16,655	704	0	0	10,412	3,254	430	45,706
LRZ 10	2027	0	402	0	0	0	58	2,150	0	0	0	0	182	4	2,796
	2032	0	402	380	0	0	58	2,964	85	0	0	0	344	9	4,242
	2037	617	1,407	380	0	1,325	58	4,118	165	0	0	0	488	25	8,583
	2042	826	1,407	760	0	1,700	58	5,783	246	0	0	200	610	81	11,671
MISO Total	2027	3,606	5,211	1,793	6,231	2,253	1,839	35,351	1,175	163	2,369	28,784	6,060	131	94,967
	2032	15,826	7,513	3,675	6,492	7,143	1,839	62,160	9,225	163	2,369	85,878	11,578	300	214,161
	2037	32,733	13,600	13,924	7,029	13,133	1,839	85,102	13,900	163	2,964	175,061	16,375	823	376,645
	2042	39,599	13,600	18,658	7,511	17,794	1,839	107,502	19,425	163	2,964	196,234	20,448	2,688	448,425

Table 11: MISO Future 3A Resource Additions by LRZ and Footprint





Future 3A Resource Retirements (MW) - Cumulative									
Zone	Milestone	Coal	Gas	Nuclear	Oil	Wind	Solar	Other	Totals
LRZ 1	2027	3,612	1,609	0	325	123	0	962	6,630
	2032	5,355	2,498	0	584	1,772	0	996	11,204
	2037	6,011	2,748	0	678	3,178	24	1,014	13,654
	2042	6,020	3,466	0	695	5,274	470	1,014	16,939
LRZ 2	2027	2,515	1,042	0	76	102	0	20	3,756
	2032	2,844	3,280	0	76	385	0	20	6,605
	2037	3,573	3,737	0	200	823	0	20	8,353
	2042	4,822	6,474	0	200	823	11	44	12,374
LRZ 3	2027	3,407	1,481	0	319	311	0	0	5,519
	2032	3,407	1,513	0	319	1,468	0	0	6,708
	2037	3,980	1,573	0	455	4,582	0	0	10,591
	2042	4,012	2,710	0	524	6,628	0	0	13,874
LRZ 4	2027	2,123	0	0	117	20	0	0	2,260
	2032	2,123	3,222	0	117	28	0	0	5,490
	2037	2,123	4,505	0	176	698	0	0	7,502
	2042	3,752	4,508	0	176	823	20	0	9,280
LRZ 5	2027	1,251	67	0	345	0	0	0	1,663
	2032	2,257	1,188	0	345	0	0	0	3,790
	2037	3,471	1,201	0	345	169	0	0	5,186
	2042	4,704	1,201	0	345	169	0	0	6,419
LRZ 6	2027	7,255	745	0	50	0	0	0	8,050
	2032	8,986	1,786	0	71	131	0	0	10,974
	2037	10,256	4,037	0	71	942	2	0	15,308
	2042	10,256	5,972	0	71	1,742	475	0	18,516
LRZ 7	2027	3,787	2,000	0	390	0	0	38	6,214
	2032	5,357	5,959	0	390	113	0	147	11,965
	2037	6,922	8,830	0	419	929	0	147	17,246
	2042	6,922	8,830	0	419	2,180	54	147	18,551
LRZ 8	2027	0	788	0	0	0	0	0	788
	2032	3,089	931	0	0	0	0	0	4,020
	2037	3,089	3,485	0	0	0	0	0	6,574
	2042	3,089	4,865	0	0	0	181	0	8,136
LRZ 9	2027	1,880	4,857	0	7	0	0	0	6,745
	2032	2,496	6,656	0	7	0	0	28	9,187
	2037	2,496	15,897	0	7	0	0	39	18,438
	2042	3,157	17,719	0	7	0	0	39	20,922
LRZ 10	2027	0	901	0	0	0	0	0	901
	2032	206	1,119	0	0	0	0	0	1,325
	2037	206	3,218	0	0	0	0	0	3,424
	2042	775	4,066	0	0	0	52	0	4,893
MISO Total	2027	25,831	13,491	0	1,628	556	0	1,020	42,526
	2032	36,120	28,153	0	1,908	3,896	0	1,190	71,268
	2037	42,127	49,232	0	2,351	11,321	26	1,219	106,277
	2042	47,510	59,813	0	2,436	17,638	1,262	1,243	129,903

Table 12: MISO Future 3A Resource Retirements by LRZ and Footprint



# Appendix

## EGEAS Modeling

### Description

The Electric Generation Expansion Analysis System (EGEAS) is a program developed by EPRI which MISO uses to conduct its expansion analysis studies. The primary function of EGEAS is the creation of the lowest cost generation expansion plan that meets system requirements specified by inputs, assumptions, and constraints.

### Modeling Procedure

The modeling process can be broken down into three main stages: definition of the model through inputs, computational analysis and solution processing, and consolidation of the results in the output file.

### Inputs

Listed below are some of the key input parameters that EGEAS uses when selecting the optimal expansion solution. EGEAS allows users to input a variety of variables however, the inputs below include some of the more important parameters when setting up an economic expansion model.

- Hourly load shape files for the system and NDTs
- Projected peak yearly values of demand and energy
- Planning Reserve Margin (PRM) percentage requirement
- Renewable Portfolio Standard (RPS) percentage trajectories
- Decarbonization trajectories, may be input in short tons or \$/short ton
- Existing unit data including planned additions and retirements
- Cost of unserved energy
- Available expansion resources and respective cost and emission data

### Computational Analysis

To find the optimal resource expansion plan, EGEAS solves two objective functions:

1. Present value of the revenue requirements
2. The levelized average system rates (\$/MWh)

The bulk of the work done by EGEAS is in solving these functions. It is an iterative process that progresses through the study year by year. Retaining only the feasible solutions each year, a single expansion plan that satisfies all input constraints and limitations over the study period is selected after the final year of study.

### Output

The final report file is a text output file containing a report on the generic units EGEAS built to meet the system constraints in every year of the study. Metrics such as PRM, RPS, systemwide CO<sub>2</sub> emissions, resource generation, and cost data are also included in the report file.

From this information, MISO staff acquires its resource expansion and sites these resources throughout the footprint based on generator availability and other criteria discussed in the [New Resource Addition Siting Process](#) section of this report.



An important metric used in the Futures process is the RPS which EGEAS calculates as the ratio of Renewable Energy Generation (from wind, solar, and solar hybrid resources) to Net System Energy. In this calculation, net system energy is the sum of forecasted and storage charging energy minus energy from demand side management programs. While this may be how EGEAS calculated required contribution from renewable resources when defining an economic expansion, MISO displays these results differently so that energy generation from all resources may be seen. The calculation used by MISO is (Renewable Energy GWh / Total Generation GWh).

Shown below is an example of the EGEAS and MISO calculation to meet the RPS in Future 3, year 2039. MISO values appear less than EGEAS calculated values because total generation includes energy from DSM programs and curtailed renewable energy from low demand periods.

### EGEAS Calculation

Forecasted System Energy (GWh)	Storage Charging (GWh)	DSM Energy (GWh)	Net System Energy (GWh)	Renewable Energy Generation (GWh)	RPS %
1,063,465	176,423	56,665	1,183,223	622,241	53%

$$\left( \frac{\text{Renewable}}{\text{Forecasted} + \text{Storage} - \text{DSM}} \right) \times 100 = \text{RPS}\%$$

$$\left( \frac{622,241}{1,063,465 + 176,423 - 56,665} \right) \times 100 = 52.59$$

### MISO Calculation

Total Energy Generation (GWh)	Renewable Energy Generation (GWh)	RPS %
1,352,519	622,241	46%

$$\left( \frac{\text{Renewable}}{\text{Total Generation}} \right) \times 100 = \text{RPS}\%$$

$$\left( \frac{622,241}{1,352,519} \right) \times 100 = 46.01$$



# Additional MISO Assumptions

## Futures Assumptions Summary

Table 13 and Table 14 detail Future-specific input assumptions. Many of these variables were direct inputs to the model; however, selected DERs, retirements, and addition totals are results of the analysis.

Variables		Future 1A	Future 2A	Future 3A
<b>Gross Load<sup>43</sup></b> Total Growth <b>Energy (CAGR)</b> Input/Result <b>Demand (CAGR)</b> Input/Result <b>Electrification Growth &amp; Technologies</b> Growth from Electrification		Low-Base EV Growth 94,275 GWh	30% Total Energy Growth by 2040 196,996 GWh	50% Total Energy Growth by 2040 334,692 GWh
		0.63% / 0.22%	1.25% / 0.80%	1.95% / 1.08%
		0.77% / 0.36%	1.14% / 0.82%	1.63% / 1.14%
		2% of Total Growth 14,147 GWh	15.2% of Total Growth 109,101 GWh	31.8% of Total Growth 231,513 GWh
Electrification Technologies		PEVs	PEVs RES-HVAC RES-DHW RES-Appliances C&I-HVAC C&I-DHW	PEVs RES-HVAC RES-DHW RES-Appliances C&I-HVAC C&I-DHW C&I-Process
Selected DERs	DR	10.8 GW	11.2 GW	11 GW
	EE	17.7 GW	17.7 GW	20.5 GW
	DG	19.9 GW	19.9 GW	20.5 GW
Carbon Reduction (2005 baseline) MISO Footprint currently at 29%		71% <i>83% realized in results</i>	76% <i>96% realized in results</i>	80% <i>99% realized in results</i>
Wind & Solar Generation Percentage <sup>14</sup>		Resulted in 55% with No Minimum Enforced	Resulted in 83% with No Minimum Enforced	87%
Utility Announced Plans		85% Goals Met 100% IRPs Met	100% Goals Met 100% IRPs Met	100% Goals Met 100% IRPs Met

**Table 13: MISO Futures Assumptions**

<sup>43</sup> Total Growth is based on 2039 values due to the original study period ending on 12/31/2039.



Variables		Future 1A	Future 2A	Future 3A
<b>Retirement Age-Based Criteria</b>	Coal	46 years. <sup>44</sup>	36 years	30 years
	Natural Gas-CC	50 years	45 years	35 years
	Natural Gas-Other	46 years	36 years	30 years
	Oil	45 years	40 years	35 years
	Nuclear	Retire if Publicly Announced	Retire if Publicly Announced	Retire if Publicly Announced
	Wind & Solar - Utility Scale	25 years	25 years	25 years
<b>Retirements</b>	Coal	42 GW	42.6 GW	47.5 GW
	Gas	23.3 GW	37.6 GW	59.8 GW
	Oil	2 GW	2.4 GW	2.4 GW
	Nuclear	0 GW	0 GW	0 GW
	Wind	17.6 GW	17.6 GW	17.6 GW
	Solar	1.3 GW	1.3 GW	1.3 GW
	Other	1.2 GW	1.2 GW	1.2 GW
	Total	87.5 GW	102.7 GW	130 GW
<b>Additions</b>	CC	10 GW	10 GW	13.6 GW
	CT	7.9 GW	9.1 GW	18.7 GW
	Gas Other <sup>45</sup>	4.8 GW	4.8 GW	4.8 GW
	Wind <sup>46</sup>	66.6 GW	144.6 GW	196.2 GW
	Solar	74.2 GW	101.8 GW	125.3 GW
	Hybrid	12.2 GW	9.8 GW	19.4 GW
	Battery	10.8 GW	31.1 GW	39.6 GW
	Flex	0 GW	29.8 GW	0 GW
	Total (Including DERs)	214.3 GW	369.3 GW	448.4 GW

**Table 14: MISO Futures Assumptions and Expansion Results**

<sup>44</sup> EIA Source for Coal Retirement Age, Future 1A: <https://www.eia.gov/todayinenergy/detail.php?id=40212>

<sup>45</sup> Gas Other includes ST Gas (3.0 GW) and IC Gas (1.8 GW) across all Futures.

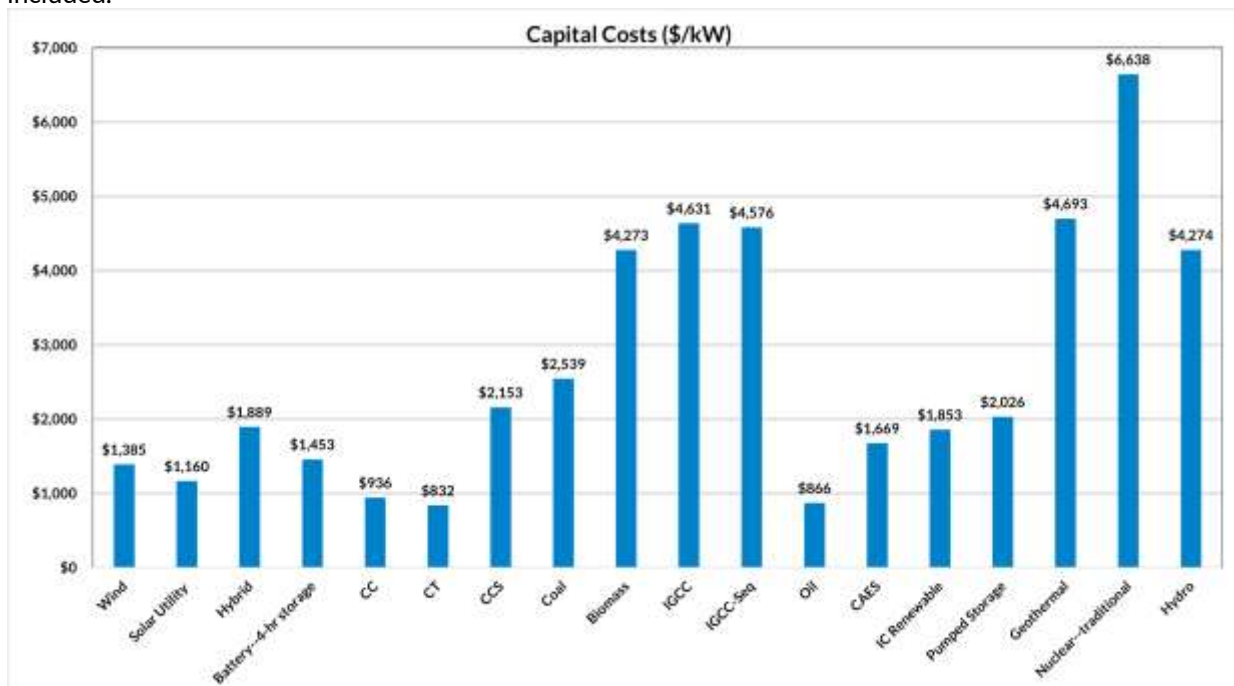
<sup>46</sup> All Futures include 17.1 GW of repowered wind and 44.4 GW of wind from planned additions.





## Capital Costs

MISO used the 2022 National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB)<sup>47</sup> to calculate the capital costs for all resources except for oil,<sup>48</sup> compressed air energy storage (CAES),<sup>49</sup> and internal combustion (IC) renewable.<sup>50</sup> costs. MISO utilized moderate cost values within the 2022 ATB, which are in 2020 dollars. These values were converted to 2022 dollars and projected into the 20-year study period to create cost trajectories. For Hybrid unit costs, 2022 ATB Solar PV + Battery costs are included.



All relevant resource types are presented prior to factoring in the effects of the PTC and ITC.

**Figure 98: Annual Capital Cost Assumptions by Fuel Type**

<sup>47</sup> NREL 2022 ATB: <https://atb.nrel.gov/electricity/2022/data>

<sup>48</sup> EIA costs were used and adjusted for 2022 dollars: <https://www.eia.gov/electricity/generatorcosts/>

<sup>49</sup> Costs from the Pacific Northwest National Laboratory 2020 Grid Energy Storage Technology Cost and Performance Assessment: <https://www.pnnl.gov/sites/default/files/media/file/Final%20-%20ESGC%20Cost%20Performance%20Report%202012-11-2020.pdf>

<sup>50</sup> Capital expenses from the EPA Landfill Gas Energy Project Development Handbook, <https://www.epa.gov/lmop/landfill-gas-energy-project-development-handbook>. O&M costs from EIA Annual Energy Outlook, [https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital\\_cost\\_AEO2020.pdf](https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2020.pdf)



## Production Tax Credits (PTC) and Investment Tax Credits (ITC)

Production Tax Credit (PTC) and Investment Tax Credit (ITC) effects on wind, utility-scale solar PV, and hybrid units are displayed below. Since the battery in the hybrid unit modeled is charged from solar resources 100% of the time, it may qualify for 100% of ITC benefits.<sup>51,52</sup>

<b>Consolidated Appropriations Act of 2016 PTC with 2022 Extensions</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>	<b>2024 &amp; onward</b>
<b>PTC</b>	Full	80%	60%	40%	60%	60%	Full	Full	Full
<b>ITC</b>	30%	30%	30%	30%	26%	26%	30%	30%	30%

**Table 15: PTC and ITC Schedule**

Accreditations of PTC and ITC benefits are seen for wind, solar, hybrid, and battery units since the extensions of the tax credits facilitated by the Inflation Reduction Act. The model representation differs due to the assumed construction time of each of these units, in order to ensure their safe harbor provisions. MISO used the values in the model representation section to build cost trajectories for these resources in EGEAS.

In the original Futures cohort, both the PTC and ITC gradually phased out over the course of the planning period. Due to the passage of the Inflation Reduction Act in August 2022, both tax credits are assumed to be extended indefinitely. For more information on the effects of the IRA on the Futures, see the Inflation Reduction Act section of this report. Additional information on the implementation of the PTC and ITC in EGEAS models can be found in the Futures Refresh Assumptions Book.

## Natural Gas Price Forecasting

MISO used the Gas Pipeline Competition Model (GPCM) base price forecast across the three Futures, instead of the Henry Hub price (HH) as in past cycles. GPCM outputs the gas price at a level of monthly granularity and produces unit-specific gas prices. The gas forecast per unit remained the same for all Futures modeled in EGEAS. As part of the Futures Refresh, the natural gas price was updated utilizing GPCM 2022 Q2 data.

<sup>51</sup> Source for PTC and ITC for Wind & Solar PV: <https://fas.org/sgp/crs/misc/R43453.pdf>

<sup>52</sup> NREL - ITC accreditation for Hybrids: <https://www.nrel.gov/docs/fy18osti/70384.pdf>



# External Assumptions and Modeling

## General Assumptions

### Study Areas

For purposes of resource expansion, the areas being analyzed with the Futures assumptions are:

- Midcontinent Independent System Operator (MISO)
- PJM Interconnection (PJM)
- Southwest Power Pool (SPP)
- Southeast (which includes the following)
  - Duke Energy Carolinas (Duke)
  - Progress Energy Carolinas East (CPLE)
  - Progress Energy Carolinas West (CPLW)
  - South Carolina Electric & Gas Company (SCEG)
  - Santee Cooper (SC)
  - Alabama Power Company [SOCO]
  - Georgia Power [SOCO]
  - Gulf Power Company
  - Mississippi Power Company [SOCO]
  - PowerSouth Energy Coop
- TVA-Other (which includes the following)
  - Associated Electric Cooperative Inc. (AECI)
  - Louisville Gas & Electric/Kentucky Utilities (LG&E/KU)
  - Tennessee Valley Authority (TVA)

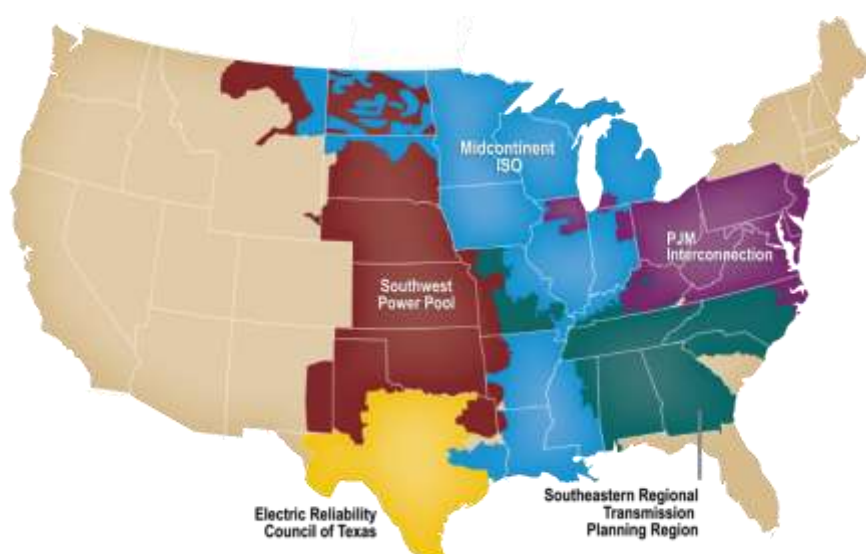


Figure 99: MISO Footprint & Neighboring Systems



## External Areas Forecasts Development

The 2019 Merged Load Forecast for Energy Planning forecast did not include External (non-MISO) companies' forecasts, so when available, External areas utilized respective regional model forecasts, and when no regional forecast was available, the latest Multiregional Modeling Working Group (MMWG) model was used to create associated forecasts. Additionally, External areas utilized ABB's Velocity Suite 2018 load shapes.

## External Expansion Results

While comparing the expansion results of the External regions across each Future scenario, there are several key findings of note:

- All scenarios have very different expansions; this is due to large contrasts among the regions with respect to geography, resource retirements, and current resource mixes.
- Wind, solar, and hybrid resource expansion is largely driven by decarbonization and each underlying load shape. For the External areas, Future 3A sees more buildout of all resource types, with notably larger increases in wind and PV; this is primarily due to an increase in projected load, as well as heightened carbon reduction goals. For the External areas, Future 3A sees more buildout of all resource types, with notably larger increases in wind and PV; this is primarily due to an increase in projected load, as well as increased decarbonization goals.
- Age-based retirement assumptions for nuclear, wind, solar, and "other" resources remain the same across areas. Additionally, all retired wind is repowered and reflected in the resource addition totals.
- As with the MISO footprint, DER programs included in each of the External areas in Future 1A are considered the minimum and were included across all three Futures, while incremental additions of each program were offered in F2A and F3A. PJM and SPP each incorporated ten DER programs in their base assumptions, while TVA-Other incorporated six. PJM selected incremental additions in five out of six DERs offered in F2A and eight out of ten in F3A. SPP selected five out of six incremental DER additions in F2A and six out of ten in F3A. TVA-Other selected four out of four incremental DER additions in F2A and six out of six in F3A. A list of EGEAS-offered and selected programs for the External regions is found below in Table 17.

Over the course of the following pages (Table 16 through Table 19) the detailed expansion results of each External Future scenario are displayed. Following the figures in each section are resource-specific retirement and addition (R&A) tables, each table details R&A capacities applicable for each region and milestone year.



Future Resource Additions (MW)														
Area	Future	CC	CT	ST Gas	Wind	Solar	Distributed Solar	Hybrid	Nuclear	Demand Response	EE	UDG	Flex	Total
PJM	Future 1A	6,591	3,600	1,926	81,828	16,416	16,616	18,000	0	12,796	40,361	604	0	198,737
	Future 2A	6,591	18,000	1,926	164,628	23,616	16,616	32,400	0	16,668	50,342	604	37,671	369,061
	Future 3A	28,191	54,000	1,926	222,228	102,816	17,048	50,400	0	16,841	52,597	604	0	546,650
SPP	Future 1A	198	0	287	182,473	39,600	6,616	0	0	2,346	3,457	2,402	0	237,378
	Future 2A	198	8,400	287	109,273	37,200	6,616	0	0	3,154	4,126	2,401	3,648	175,302
	Future 3A	3,798	21,600	287	175,273	43,200	7,047	10,800	0	2,434	4,275	2,402	0	271,116
TVA-Other	Future 1A	0	720	0	123,582	40,360	1,340	18,000	1,100	1,680	588	9,061	0	196,430
	Future 2A	0	43,920	0	123,582	36,760	1,340	28,800	1,100	1,860	645	9,061	3,225	250,293
	Future 3A	3,600	83,520	0	285,582	43,960	2,769	32,400	1,100	1,978	674	9,061	0	464,645
Future Resource Retirements (MW)														
Area	Future	Coal		Gas		Nuclear	Oil		Biomass	Solar	Wind	Total		
PJM	Future 1A	49,432		13,697		18,092	6,708		91	1,266	10,413	99,699		
	Future 2A	50,401		37,347		18,092	7,064		91	1,266	10,413	124,674		
	Future 3A	51,983		57,451		18,092	7,079		91	1,266	10,413	146,375		
SPP	Future 1A	19,528		2,812		766	1,026		0	314	18,564	43,010		
	Future 2A	19,743		8,990		766	1,227		0	314	18,564	49,604		
	Future 3A	22,691		20,153		766	1,327		0	314	18,564	63,816		
TVA-Other	Future 1A	41,283		9,276		16,257	1,910		0	2,439	1,182	72,346		
	Future 2A	42,593		34,526		16,257	1,990		0	2,439	1,182	98,987		
	Future 3A	44,598		61,558		16,257	1,990		0	2,439	1,182	128,023		

**Table 16: External Resource Additions and Retirements Summary**





## External Areas Expansion 2023 - 2042

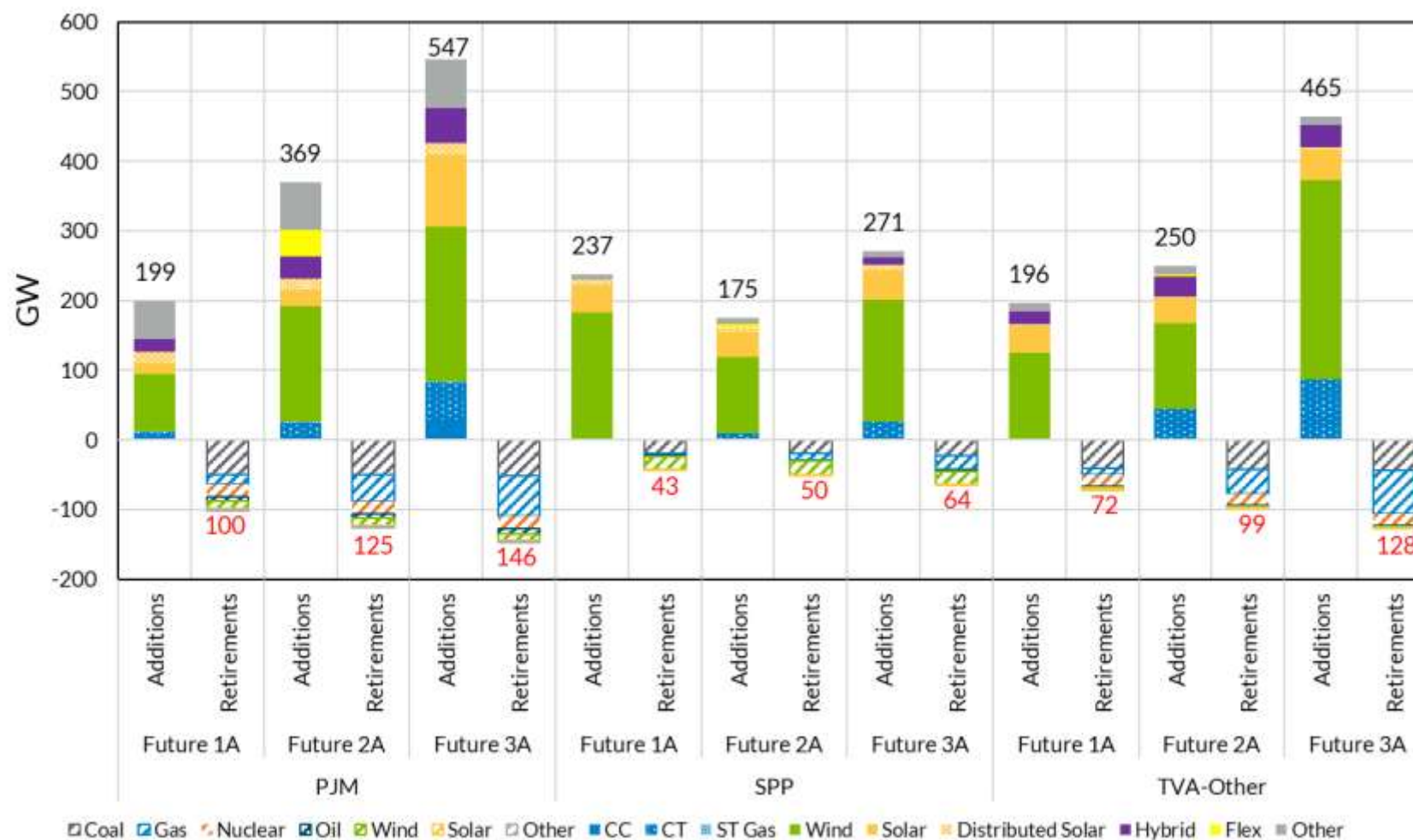


Figure 100: External Region Expansion Summary



## External Retirements and Additions

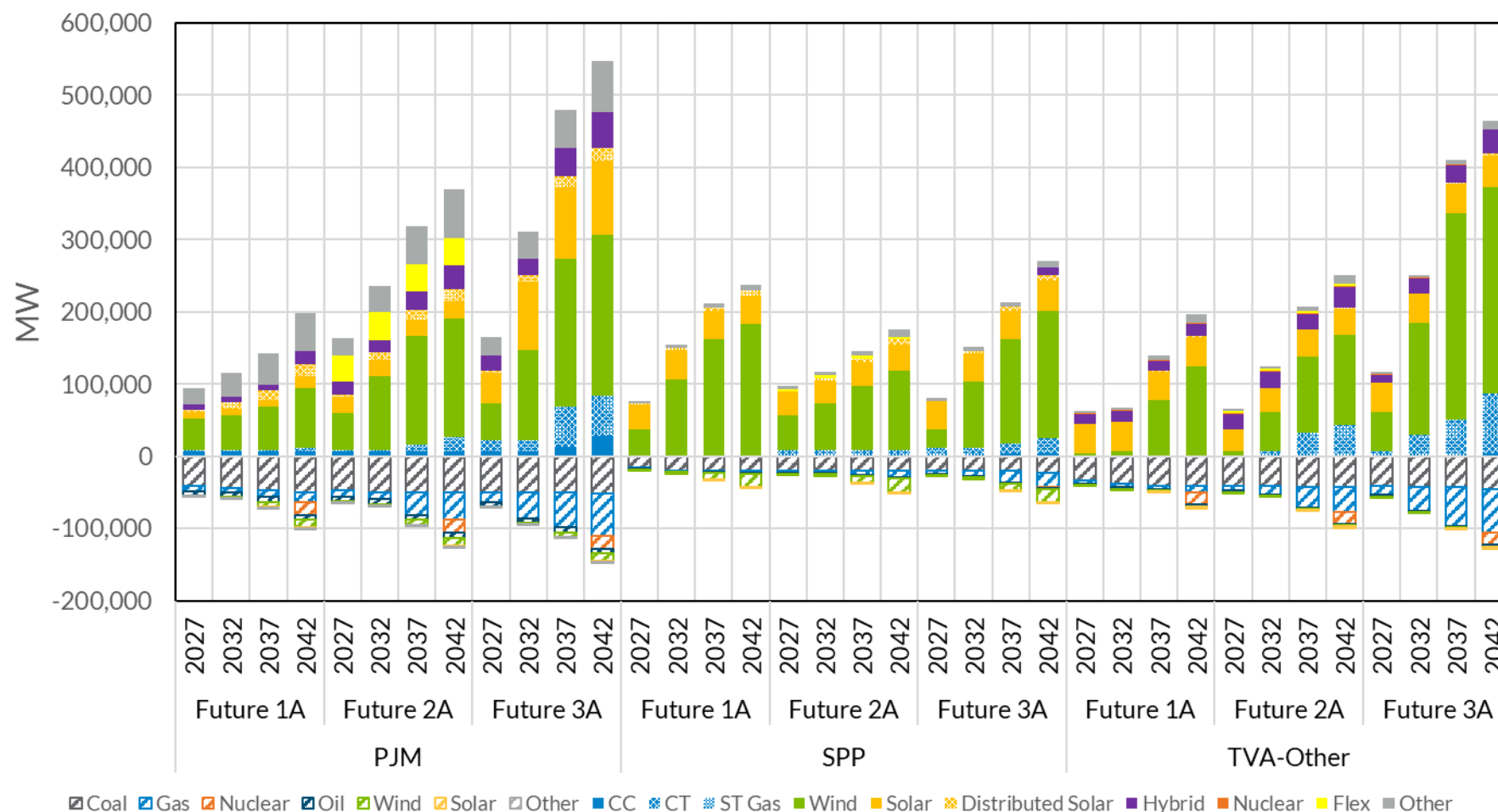


Figure 101: External Resource Additions and Retirements per Milestone Year (Cumulative)



## PJM Expansion

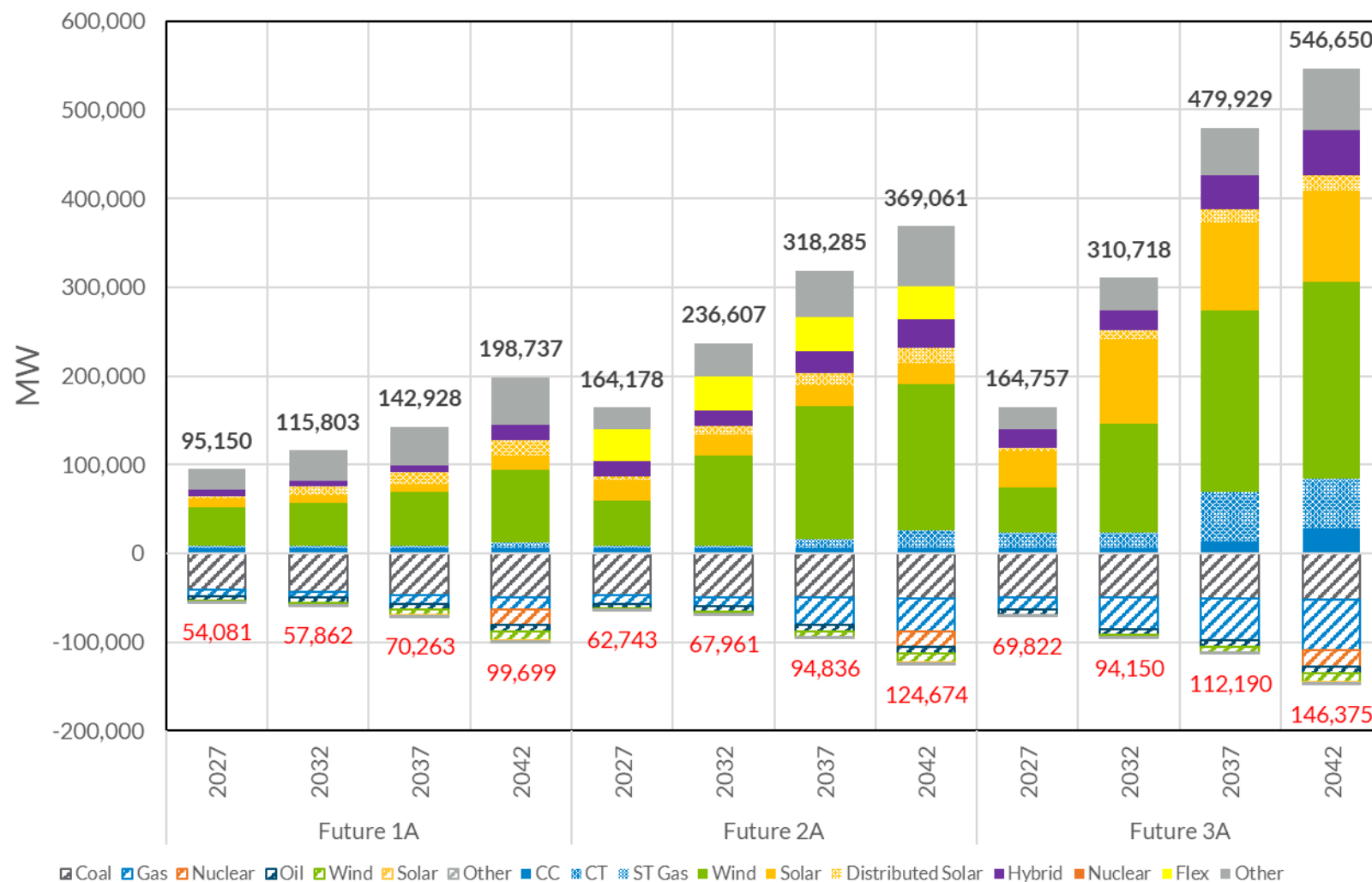


Figure 102: PJM Resource Additions and Retirements per Milestone Year (Cumulative)



## SPP Expansion

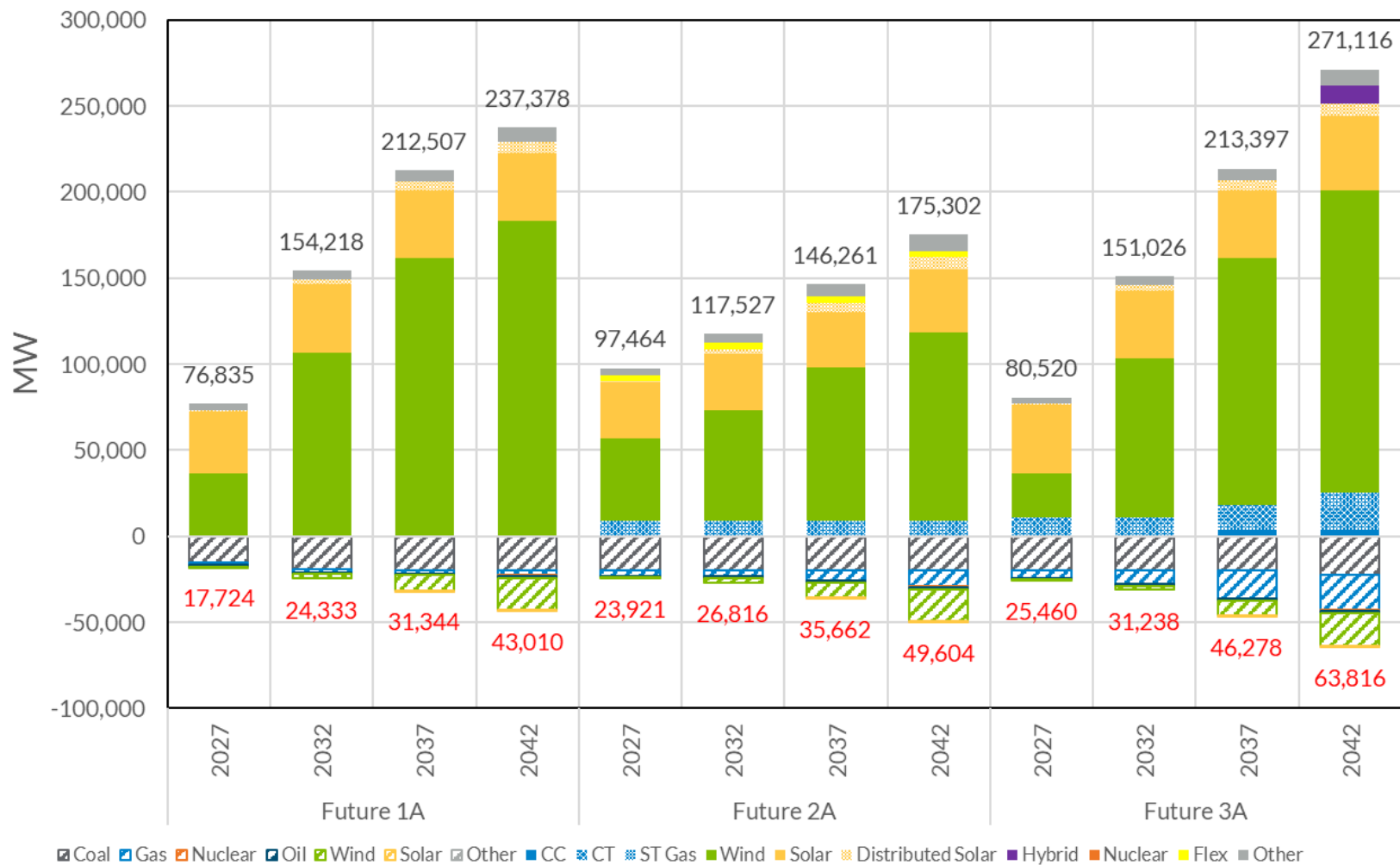


Figure 103: SPP Resource Additions and Retirements per Milestone Year (Cumulative)



## TVA-Other Expansion

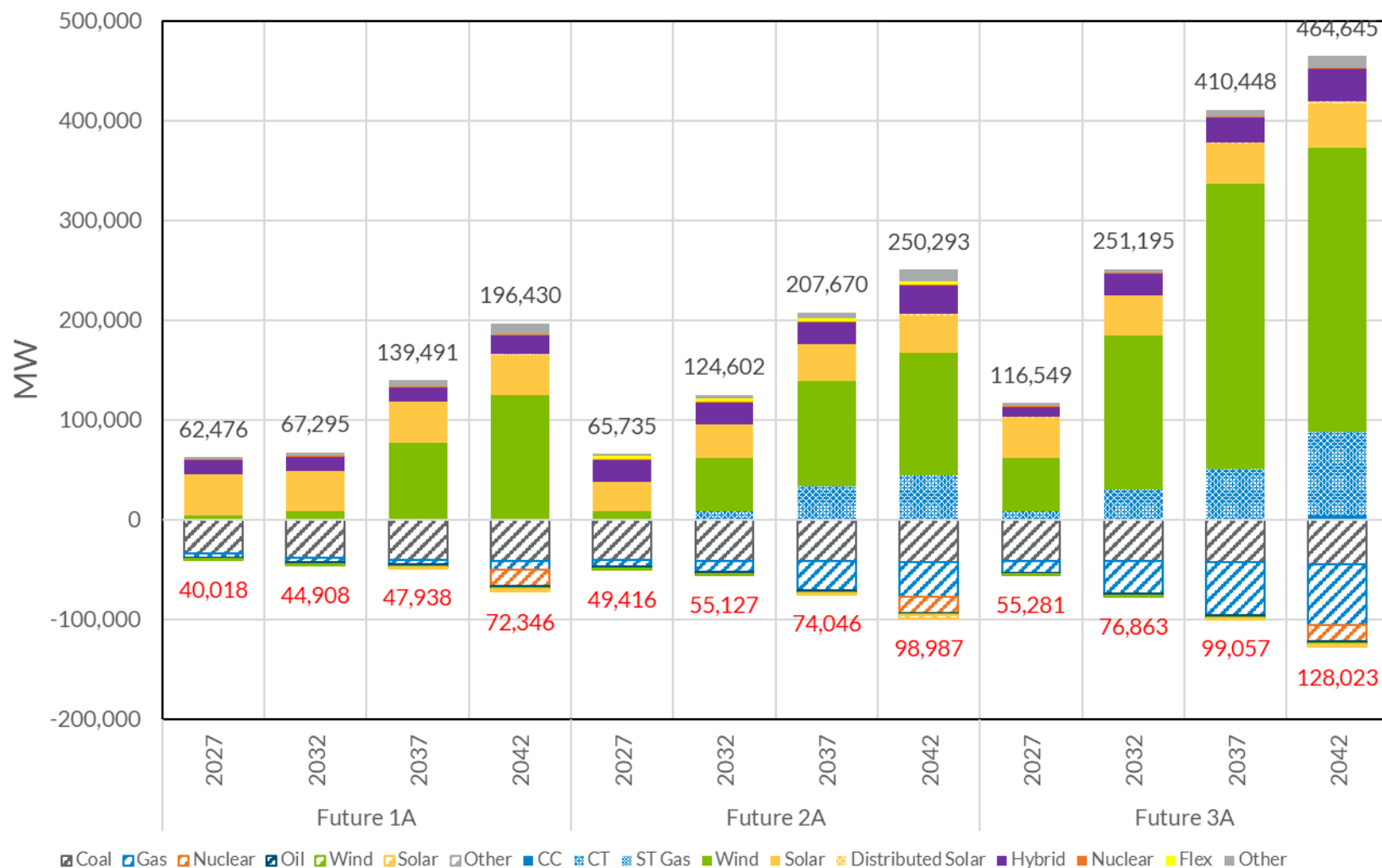


Figure 104: TVA-Other Resource Additions and Retirements per Milestone Year (Cumulative)





## External DER Programs: Respective Offerings and Selections

DER Type	EGEAS Program Block	DER Program(s) Included	PJM			SPP			TVA-Other		
			Base	Incremental Addition		Base	Incremental Addition		Base	Incremental Addition	
			F1A	F2A	F3A	F1A	F2A	F3A	F1A	F2A	F3A
DR	C&I Demand Response	Curtailable & Interruptible, Other DR, Wholesale Curtailable	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
DR	C&I Price Response	C&I Price Response	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
DR	Res. Direct Load Control	Res. Direct Load Control	Yes	N/A	Yes	Yes	Yes	No	N/A	N/A	N/A
DR	Res. Price Response	Res. Price Response	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A
EE	C&I EE	Custom Incentive, Lighting, New Construction, Prescriptive Rebate, Retro commissioning	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
EE	Res. EE	Appliance Incentives, Appliance Recycling, Behavioral Programs, Lighting, Low Income, Multifamily, New Construction, School Kits, Whole Home Audit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DG	C&I Customer Solar PV	C&I Customer Solar PV	Yes	N/A	No	Yes	N/A	No	Yes	N/A	Yes
DG	C&I Utility Incentive Distributed Generation	Combined Heat and Power, Community-Based DG, Customer Wind Turbine, Thermal Storage, Util Incentive Batt Storage	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DG	C&I Utility Incentive Solar PV	C&I Utility Incentive Solar PV	Yes	No	Yes	Yes	N/A	Yes	N/A	N/A	N/A
DG	Res. Customer Solar PV	Res. Customer Solar PV	Yes	N/A	No	Yes	N/A	No	Yes	N/A	Yes
DG	Res. Utility Incentive Distributed Generation	Customer Wind Turbines, Electric Vehicle Charging, Thermal Storage, Util Incentive Batt Storage	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DG	Res. Utility Incentive Solar PV	Res. Utility Incentive Solar PV	Yes	N/A	Yes	Yes	N/A	Yes	N/A	N/A	N/A

Yes = selected. No = offered, not selected. N/A = not offered.  
F1A Base DER programs are included across all three models (F1A, F2A, F3A); Incremental additions are only included in the specified Future.

**Table 17: External DER Program Mapping, with Respective Offerings and Selection by Future in EGEAS**



External Area Resource Additions per Future (MW) - Cumulative														
Future/Area	Milestone	CC	CT	ST Gas	Wind	Solar	Distributed Solar	Hybrid	Nuclear	Demand Response	EE	UDG	Flex	Totals
PJM Future 1A	2027	6,591	0	1,926	43,656	9,216	3,171	7,200	0	12,796	10,482	112	0	95,150
	2032	6,591	0	1,926	47,984	9,216	9,328	7,200	0	12,796	20,530	232	0	115,803
	2037	6,591	0	1,926	60,386	9,216	13,547	7,200	0	12,796	30,882	384	0	142,928
	2042	6,591	3,600	1,926	81,828	16,416	16,616	18,000	0	12,796	40,361	604	0	198,737
PJM Future 2A	2027	6,591	0	1,926	50,856	23,616	3,171	18,000	0	13,498	11,183	112	35,225	164,178
	2032	6,591	0	1,926	101,984	23,616	9,328	18,000	0	14,302	22,957	232	37,671	236,607
	2037	6,591	7,200	1,926	150,386	23,616	13,547	25,200	0	15,438	36,326	384	37,671	318,285
	2042	6,591	18,000	1,926	164,628	23,616	16,616	32,400	0	16,668	50,342	604	37,671	369,061
PJM Future 3A	2027	6,591	14,400	1,926	50,856	41,616	3,200	21,600	0	13,191	11,264	112	0	164,757
	2032	6,591	14,400	1,926	123,584	95,616	9,431	21,600	0	14,012	23,325	232	0	310,718
	2037	13,791	54,000	1,926	204,386	99,216	13,816	39,600	0	15,445	37,365	384	0	479,929
	2042	28,191	54,000	1,926	222,228	102,816	17,048	50,400	0	16,841	52,597	604	0	546,650
SPP Future 1A	2027	198	0	287	36,192	36,000	650	0	0	2,307	921	281	0	76,835
	2032	198	0	287	106,414	39,600	2,978	0	0	2,318	1,798	625	0	154,218
	2037	198	0	287	161,137	39,600	5,084	0	0	2,330	2,656	1,215	0	212,507
	2042	198	0	287	182,473	39,600	6,616	0	0	2,346	3,457	2,402	0	237,378
SPP Future 2A	2027	198	8,400	287	48,192	32,400	649	0	0	2,444	966	281	3,648	97,464
	2032	198	8,400	287	64,414	32,400	2,977	0	0	2,620	1,958	626	3,648	117,527
	2037	198	8,400	287	89,137	32,400	5,083	0	0	2,873	3,019	1,216	3,648	146,261
	2042	198	8,400	287	109,273	37,200	6,616	0	0	3,154	4,126	2,401	3,648	175,302
SPP Future 3A	2027	198	10,800	287	25,392	39,600	676	0	0	2,315	971	281	0	80,520
	2032	198	10,800	287	92,014	39,600	3,176	0	0	2,344	1,982	625	0	151,026
	2037	3,798	14,400	287	143,137	39,600	5,481	0	0	2,387	3,091	1,215	0	213,397
	2042	3,798	21,600	287	175,273	43,200	7,047	10,800	0	2,434	4,275	2,402	0	271,116
TVA-Other Future 1A	2027	0	720	0	3,629	40,360	20	14,400	1,100	1,680	151	417	0	62,476
	2032	0	720	0	7,262	40,360	114	14,400	1,100	1,680	299	1,361	0	67,295
	2037	0	720	0	76,582	40,360	508	14,400	1,100	1,680	446	3,695	0	139,491
	2042	0	720	0	123,582	40,360	1,340	18,000	1,100	1,680	588	9,061	0	196,430
TVA-Other Future 2A	2027	0	720	0	7,229	29,560	20	21,600	1,100	1,710	155	417	3,225	65,735
	2032	0	7,920	0	54,062	33,160	114	21,600	1,100	1,747	313	1,361	3,225	124,602
	2037	0	33,120	0	105,382	36,760	508	21,600	1,100	1,802	478	3,695	3,225	207,670
	2042	0	43,920	0	123,582	36,760	1,340	28,800	1,100	1,860	645	9,061	3,225	250,293
TVA-Other Future 3A	2027	0	7,920	0	54,029	40,360	55	10,800	1,100	1,712	156	417	0	116,549
	2032	0	29,520	0	154,862	40,360	298	21,600	1,100	1,776	318	1,361	0	251,195
	2037	0	51,120	0	285,382	40,360	1,214	25,200	1,100	1,885	492	3,695	0	410,448
	2042	3,600	83,520	0	285,582	43,960	2,769	32,400	1,100	1,978	674	9,061	0	464,645

Table 18: External Resource Additions by Milestone Year



External Area Resource Retirements per Future (MW) - Cumulative									
Future/Area	Milestone	Coal	Gas	Nuclear	Oil	Wind	Solar	Biomass	Total
PJM Future 1A	2027	41,256	6,674	0	6,011	90	0	50	54,081
	2032	43,238	6,698	0	6,025	1,835	0	67	57,862
	2037	47,446	9,151	0	6,553	6,813	210	91	70,263
	2042	49,432	13,697	18,092	6,708	10,413	1,266	91	99,699
PJM Future 2A	2027	47,446	9,133	0	6,025	90	0	50	62,743
	2032	49,432	10,074	0	6,553	1,835	0	67	67,961
	2037	49,612	31,402	0	6,708	6,813	210	91	94,836
	2042	50,401	37,347	18,092	7,064	10,413	1,266	91	124,674
PJM Future 3A	2027	49,432	13,697	0	6,553	90	0	50	69,822
	2032	49,612	35,928	0	6,708	1,835	0	67	94,150
	2037	50,401	47,611	0	7,064	6,813	210	91	112,190
	2042	51,983	57,451	18,092	7,079	10,413	1,266	91	146,375
SPP Future 1A	2027	15,344	1,388	0	782	210	0	0	17,724
	2032	19,208	1,817	0	782	2,526	0	0	24,333
	2037	19,528	2,264	0	923	8,579	50	0	31,344
	2042	19,528	2,812	766	1,026	18,564	314	0	43,010
SPP Future 2A	2027	19,528	3,401	0	782	210	0	0	23,921
	2032	19,528	3,839	0	923	2,526	0	0	26,816
	2037	19,528	6,480	0	1,026	8,579	50	0	35,662
	2042	19,743	8,990	766	1,227	18,564	314	0	49,604
SPP Future 3A	2027	19,528	4,799	0	923	210	0	0	25,460
	2032	19,528	8,158	0	1,026	2,526	0	0	31,238
	2037	19,743	16,679	0	1,227	8,579	50	0	46,278
	2042	22,691	20,153	766	1,327	18,564	314	0	63,816
TVA-Other Future 1A	2027	33,873	4,206	0	1,910	29	0	0	40,018
	2032	38,544	4,290	0	1,910	163	0	0	44,908
	2037	40,268	4,499	0	1,910	1,182	78	0	47,938
	2042	41,283	9,276	16,257	1,910	1,182	2,439	0	72,346
TVA-Other Future 2A	2027	40,448	7,029	0	1,910	29	0	0	49,416
	2032	41,463	11,591	0	1,910	163	0	0	55,127
	2037	41,993	28,883	0	1,910	1,182	78	0	74,046
	2042	42,593	34,526	16,257	1,990	1,182	2,439	0	98,987
TVA-Other Future 3A	2027	41,283	12,059	0	1,910	29	0	0	55,281
	2032	41,813	32,977	0	1,910	163	0	0	76,863
	2037	43,013	52,794	0	1,990	1,182	78	0	99,057
	2042	44,598	61,558	16,257	1,990	1,182	2,439	0	128,023

Table 19: External Resource Retirements by Milestone Year



## Presentation Materials

### Series 1A Futures Workshops & MISO Stakeholder Presentations:

June 22, 2022: PAC Presentation – [Futures Data Refresh](#)

October 19, 2022: PAC Presentation – [Futures Data Refresh Update](#)

November 29, 2022: PAC Presentation – [Preliminary Future F2A Expansion Results](#)

March 8, 2023: PAC Presentation – [Futures Refresh Update](#)

March 10, 2023: LRTP Workshop – [Future 2A Expansion and Preliminary Siting](#)

April 28, 2023: LRTP Workshop – [Future 2A Siting Presentation](#)

October 2, 2023: LRTP Workshop – [LRTP Workshop Presentation - Sensitivities](#)

**Full Futures Material, including Series 1 results and development, available at: [MISOEnergy.org](https://MISOEnergy.org)**

The copyright in all material published in this report by the Midcontinent Independent System Operator, Inc. (MISO), including all portions of the content, design, text, graphics and the selection and arrangement of the material within the report (the "material"), is owned by MISO, or legally licensed to MISO, unless otherwise indicated. The material may not be reproduced or distributed, in whole or in part, without the prior written permission of MISO. Any reproduction or distribution, in whatever form and by whatever media, is expressly prohibited without the prior written consent of MISO.

© 2023 MISO. All rights reserved.



[misoenergy.org](https://misoenergy.org)