MISO's Electrification Futures

Anupam Thatte

Sr. Engineer, R&D

Midcontinent Independent System Operator (MISO)

ESIG LTTF

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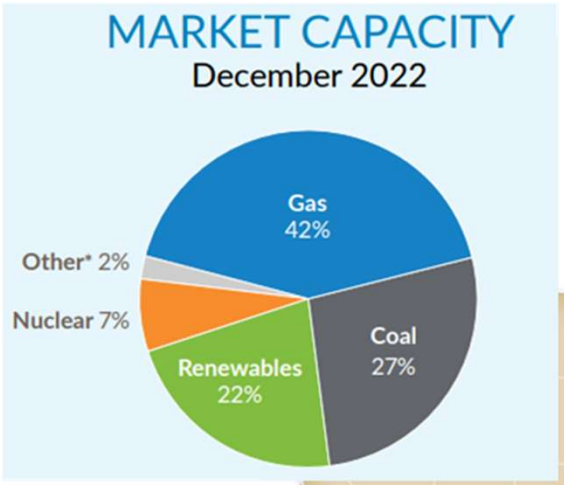
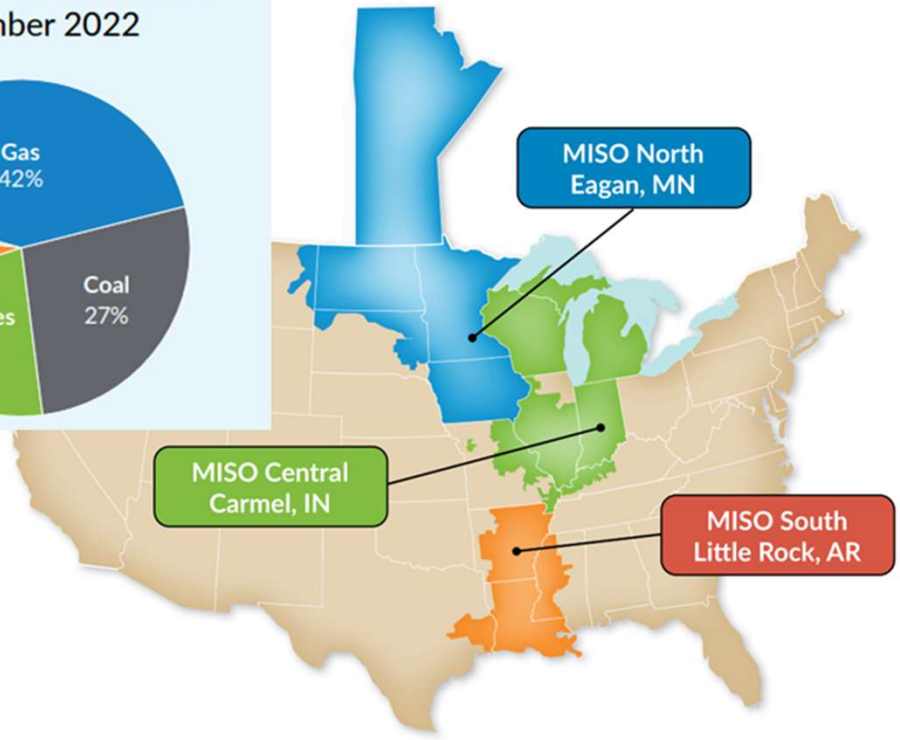
Key Takeaways

- MISO is facing an increased pace of resource transition due to a variety of drivers.
- MISO supports its members and policymakers by providing forward-looking scenarios, known as ‘Futures’.
- MISO Futures are being used in several efforts to provide more insights.
- MISO will continue to monitor a range of inputs and refine its analyses.

Midcontinent Independent System Operator (MISO): Key Facts





MISO's reliability footprint and locations of regional control centers.

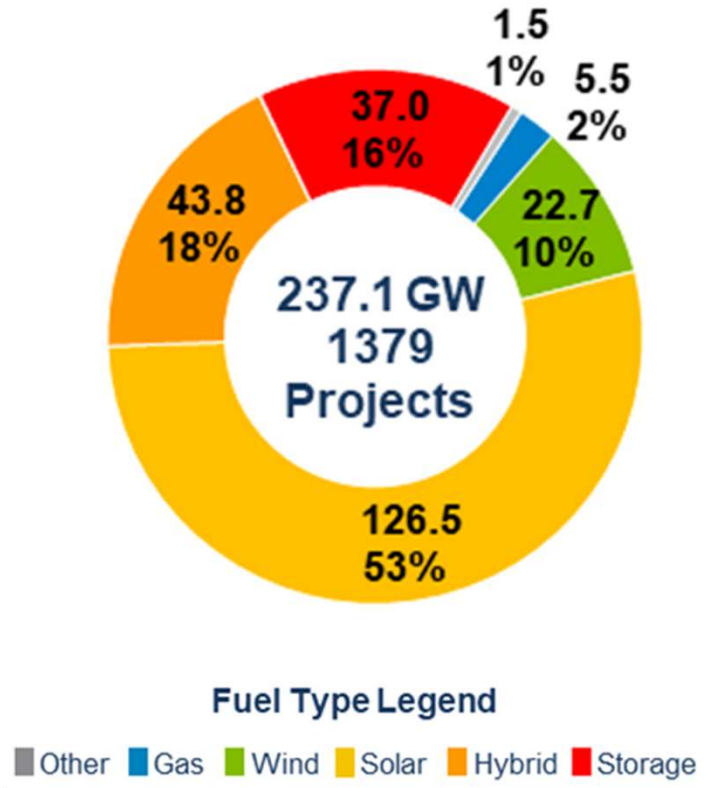
- Generation Capacity (market): 190 GW
- Historic Summer Peak Load (7/20/11): 127.1 GW
- 38 Local Balancing Authorities
- 6,800+ generating units
- 15 US States + Manitoba (not in market footprint)
- Population served: 45 Mn

MISO Fact Sheet

Several drivers are accelerating the pace of the energy transition

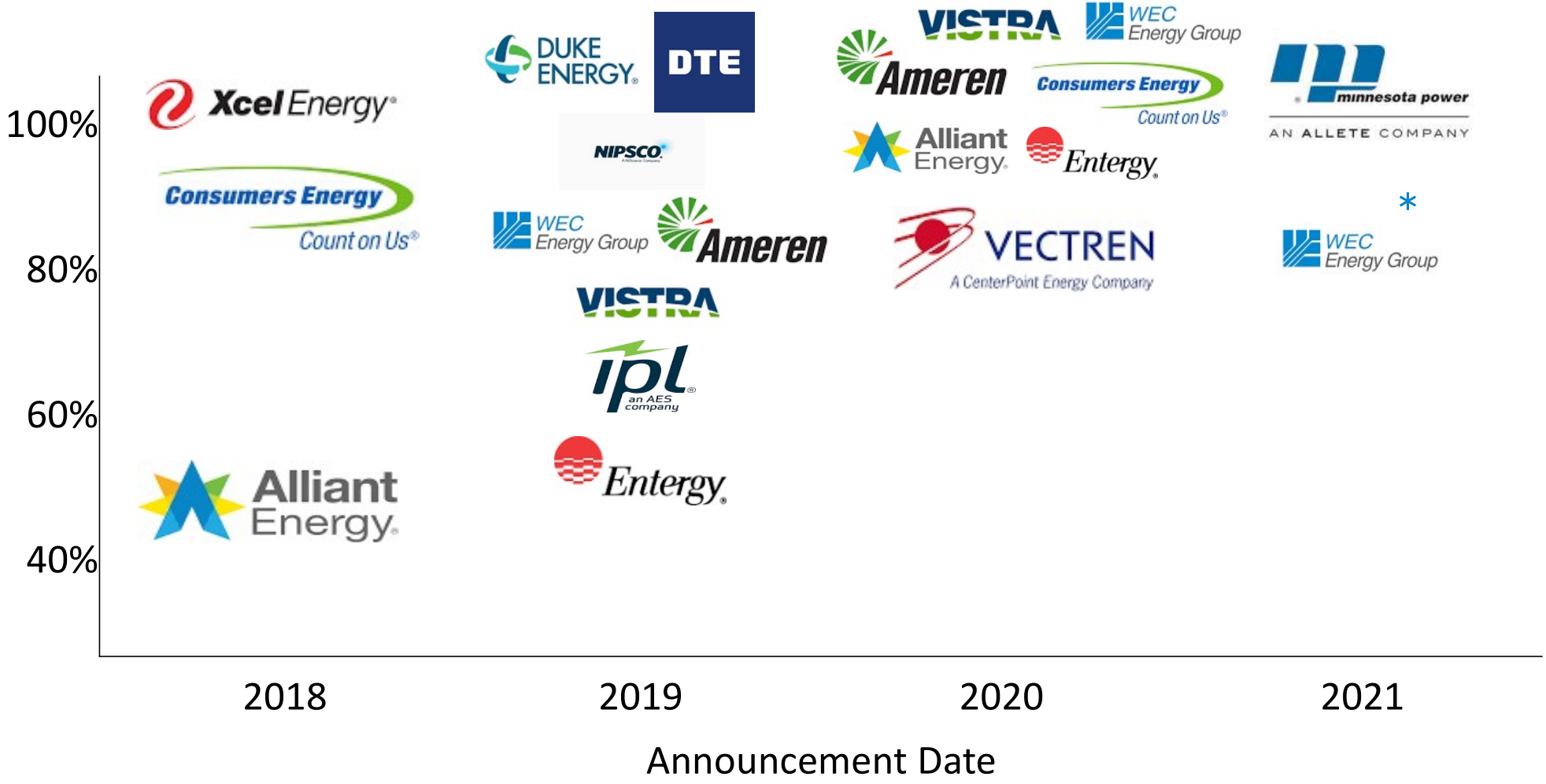
- Retirement of fossil-fuel units over past decade
- Large growth in renewables capacity
- Decarbonization or clean energy member goals
- Changing customer preferences
- More frequent extreme weather events
- Increased electrification

MISO Generation Interconnection Queue (Updated: 05/01/2023)



Aggressive utility decarbonization goals signaling significant change by 2030-50

Utility Decarbonization Goal Announcements by Year



** WEC accelerated its 2030 goal to 80% and added a new goal of 60% reduction by 2025; net zero goal by 2050 remains*

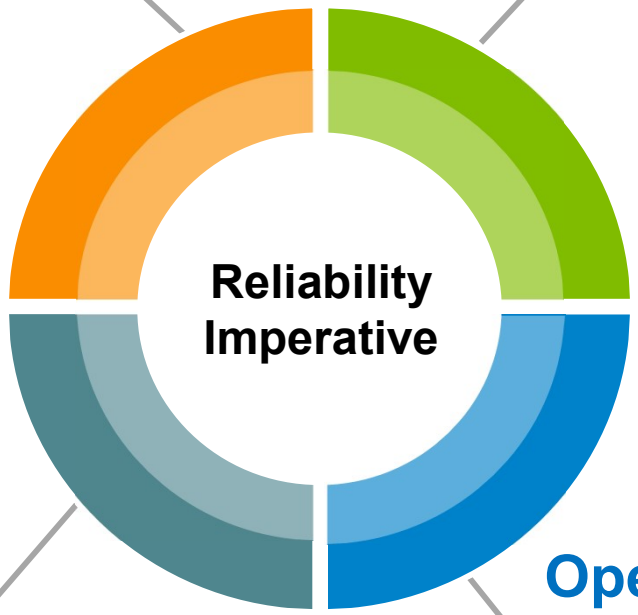
MISO working on multiple areas to address the challenges

Market Redefinition

Develops significant market enhancements and optimizations to ensure continued reliability and value in anticipation of the changing resource mix, more frequent extreme weather events, and increasing electrification.

Transmission Evolution

Assesses the region's future transmission needs and associated cost allocation holistically, including transmission to support utility and state plans for existing and future generation resources.



System Enhancements

Creates flexible, upgradeable, and secure systems that integrate advanced technologies to process increasingly complex information and evolve with the industry.

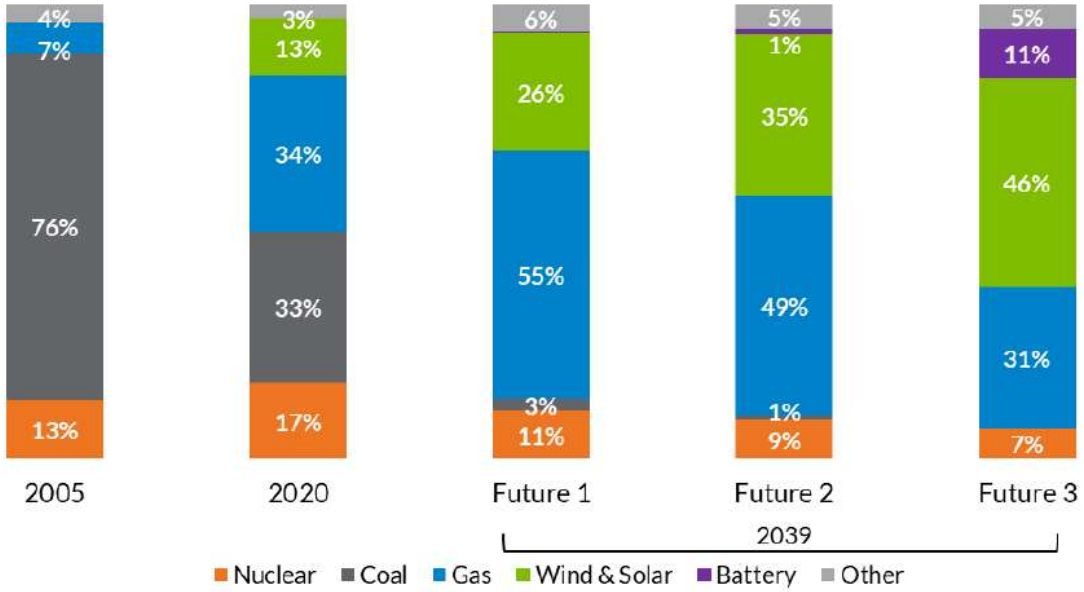
Operations of the Future

Focuses on the skills, processes and technologies needed to ensure MISO can effectively manage the grid of the future under increased complexity.

‘Futures’ incorporate and build upon member plans and changing demand

Different load growth in 3 Futures driven by range of electrification assumptions.

MISO Generation Energy Mix



	Future 1	Future 2	Future 3
Additions	121 GW	170 GW	306 GW
Retirements	77 GW	80 GW	112 GW
Peak Load	136 GW	148 GW	164 GW
Emissions*	↓63%	↓65%	↓81%

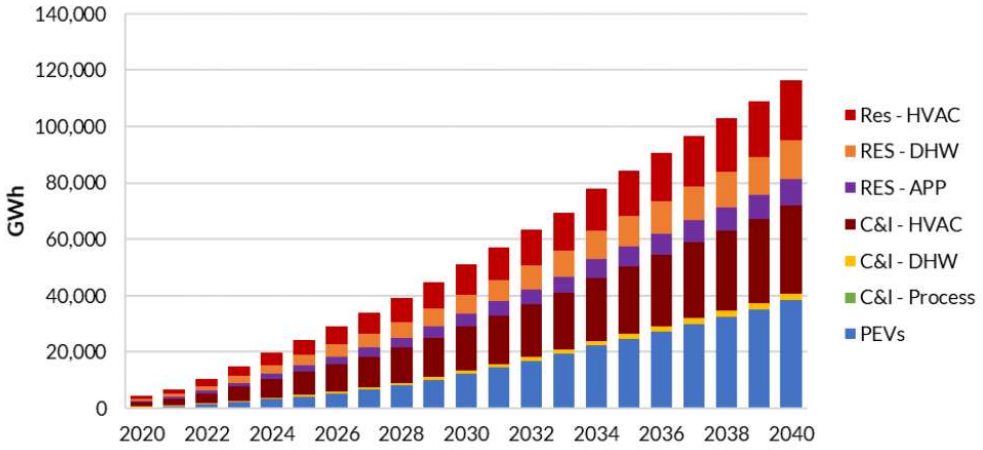
*Resulting emission reductions based upon 2005 levels

Used in multiple MISO projects, including:

- Long Range Transmission Planning (LRTP)
- MISO Transmission Expansion Planning (MTEP)
- Regional Resource Assessment (RRA)

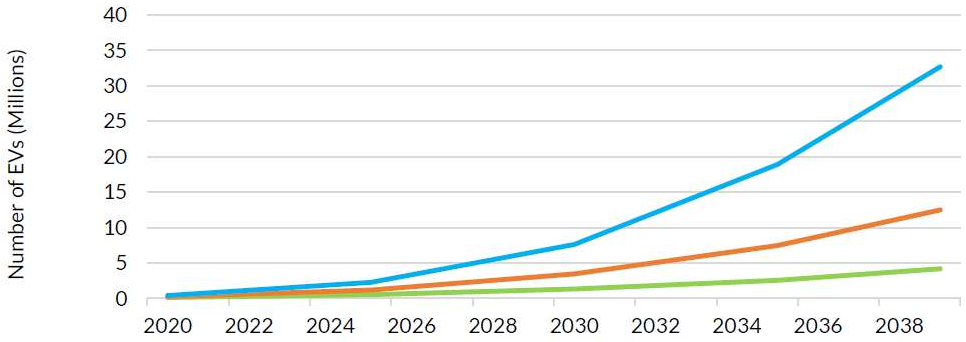
Identified estimates of the market for electrification of various technologies

MISO Future 2: Electrification Load Growth



MISO contracted Applied Energy Group (AEG) to evaluate the Electrification potential for Heat Pumps, Water Heaters, EVs, Dryers, Industrial Processes, etc.

LBNL EV Growth Projection – MISO footprint



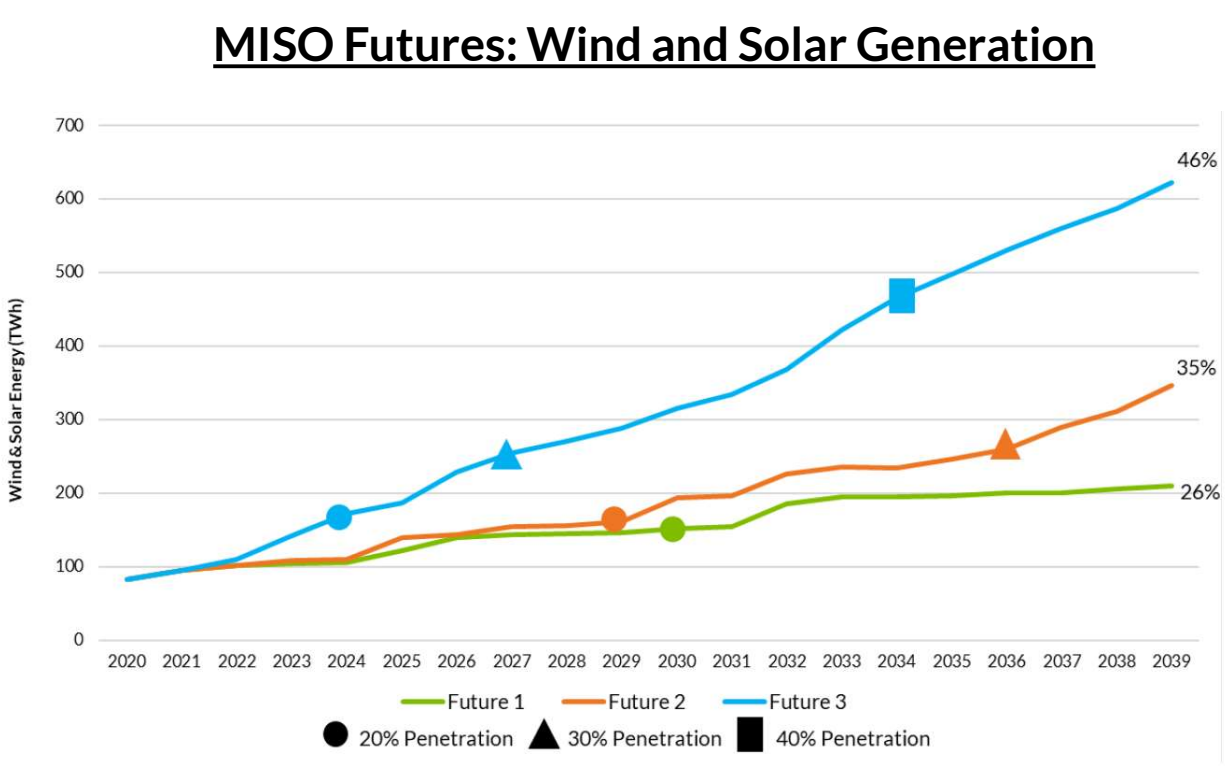
	2020	2025	2030	2035	2039
Future 1	0.135	0.53	1.33	2.57	4.19
Future 2	0.26	1.205	3.47	7.455	12.49
Future 3	0.416	2.272	7.598	18.91	32.686

MISO collaborated with LBNL on a study to determine the potential for light-duty EVs.

AEG Report

LBNL Study

Renewables projections range from 26% in Future 1 to 46% in Future 3

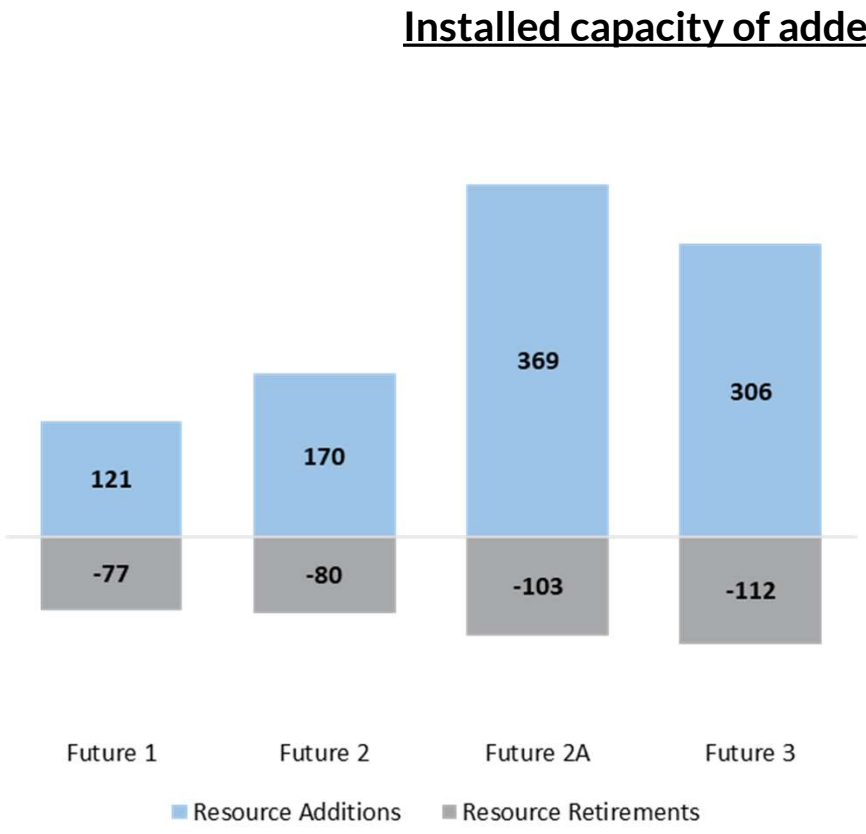


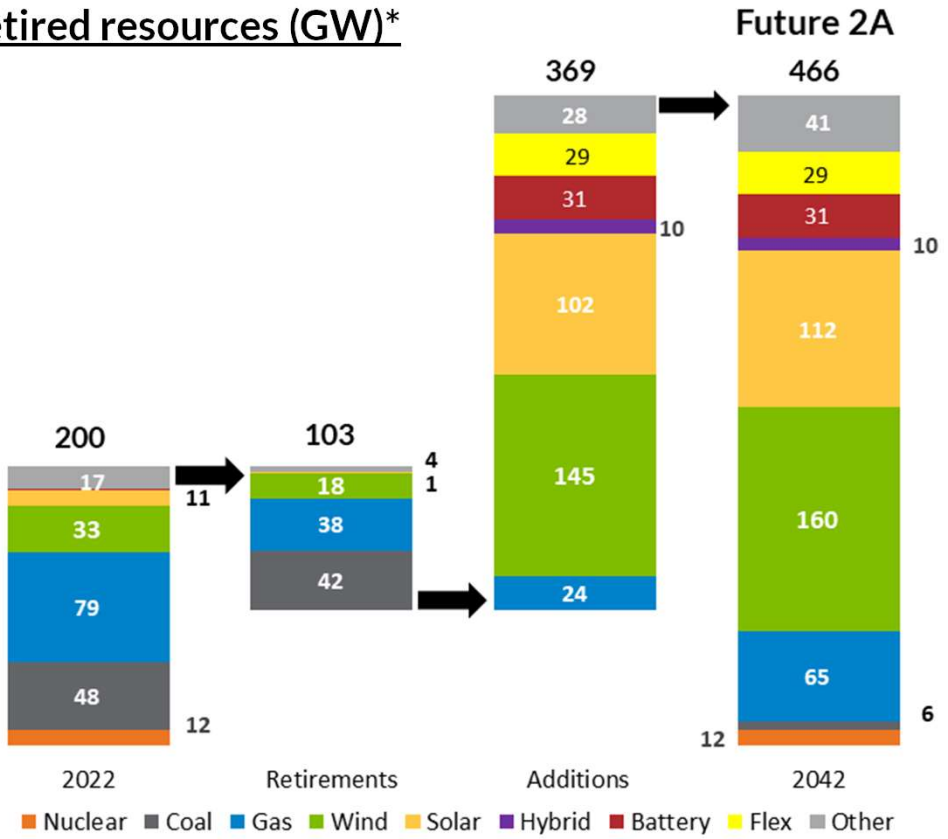
MISO's Renewable Integration Impact Assessment (RIIA) Study indicated an inflection point between renewable penetrations of 30% and 40%, where planning and operating the grid will become significantly more complex and challenging.

MISO is currently refreshing the MISO Futures

The updated Future 2 (F2A) expansion & retirements approach or surpass levels seen in the original Future 3

Installed capacity of added and retired resources (GW)*





* Data as of April 26, 2023. Futures do not account for all operational-level reliability needs and attributes that may require different levels of dispatchable resources. Resource additions may be subject to adjustment based on new accreditation rules. "Other" includes biomass, geothermal, hydro, oil, pumped hydro storage, demand response, non-pv distributed generation, and energy efficiency.

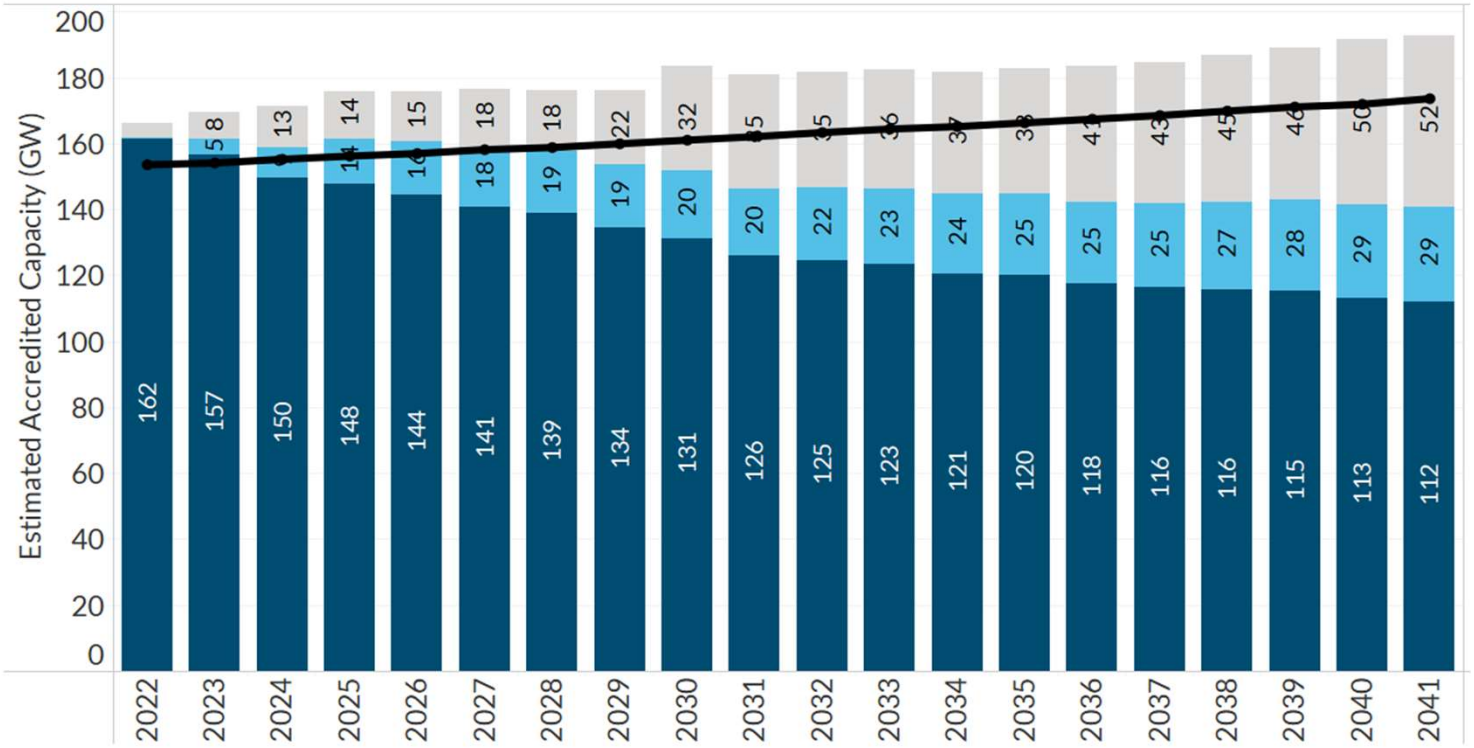
MISO has conducted several major studies relating to the energy transition

Study/Report	Links
Markets of the Future	https://cdn.misoenergy.org/MISO%20Markets%20of%20the%20Future604872.pdf
MISO Futures Report	https://cdn.misoenergy.org/MISO%20Futures%20Report538224.pdf
Renewable Integration Impact Assessment (RIIA)	https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf
Electrification Insights Report	https://cdn.misoenergy.org/Electrification%20Insights538860.pdf

MISO will continue to monitor the evolution of the energy landscape:

- 1st version of Regional Resource Assessment (RRA) released in 2021
- MISO is currently working on the 2023 version

The RRA provides a collective view of how resource plans are evolving



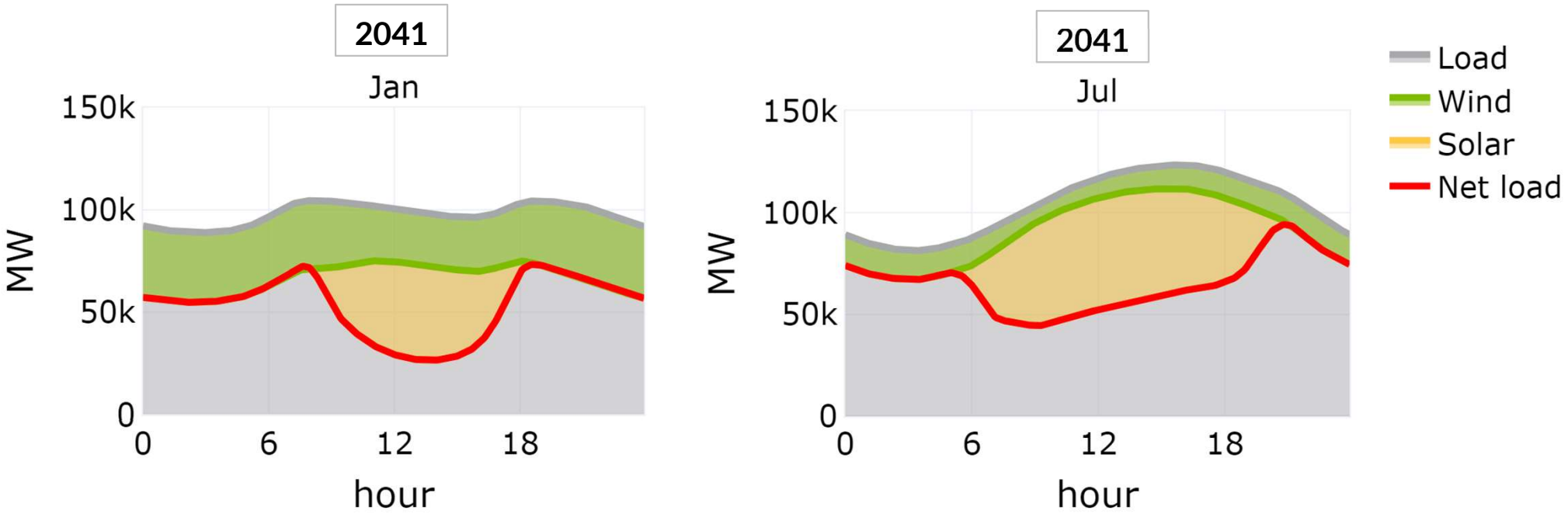
Model-built resources : Based on analysis conducted by MISO, which is informed by capital costs, emissions and other assumptions.

- Gaps may occur as utilities may not provide info for 20-year period
- Other differences due to load assumptions, accreditation assumptions, and incomplete survey participation

Note: Over the study period, RRA assumes wind accreditation stays at ~16.7%, solar declines from 50% to 20%, hybrid declines from 60% to 30%, and battery declines from 100% to 75%. Thermal units are accredited between 90% and 100%. The assumptions in RRA should not be taken as indicative of the outcomes of the non-thermal accreditation reform effort underway

RRA projects that by 2041, a “duck curve” pattern emerges in the winter

The *net load* (i.e., load minus renewables) could have a different diurnal and seasonal shape in the future



Potential disrupters will require continued monitoring and adjustments

- Risk of retirements of fossil-fuel units due to policy
- More aggressive decarbonization goals from states, cities, utilities
- Pace and scale of electrification and load shifts
  - EV growth may accelerate given policy support
  - Data centers, crypto-miners, DERs, microgrids, etc.
- Pace of transmission system development
- New and emerging technologies, such as modular nuclear reactors, long-duration storage, hydrogen-based resources, etc.

Thank you

Anupam Thatte
athatte@misoenergy.org