MISO Futures

April 2021

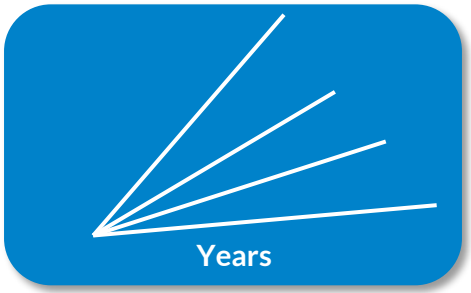
Updated December 2021

Purpose of MISO Futures

- It's very difficult to accurately predict the future, so we created three scenarios to hedge uncertainty and "bookend" a range of economic, political, and technological possibilities.
- These Future scenarios establish different ranges of economic, policy, and technological possibilities – such as load growth, electrification, carbon policy, generator retirements, renewable energy levels, natural gas price, and generation capital cost – over a twenty-year period.

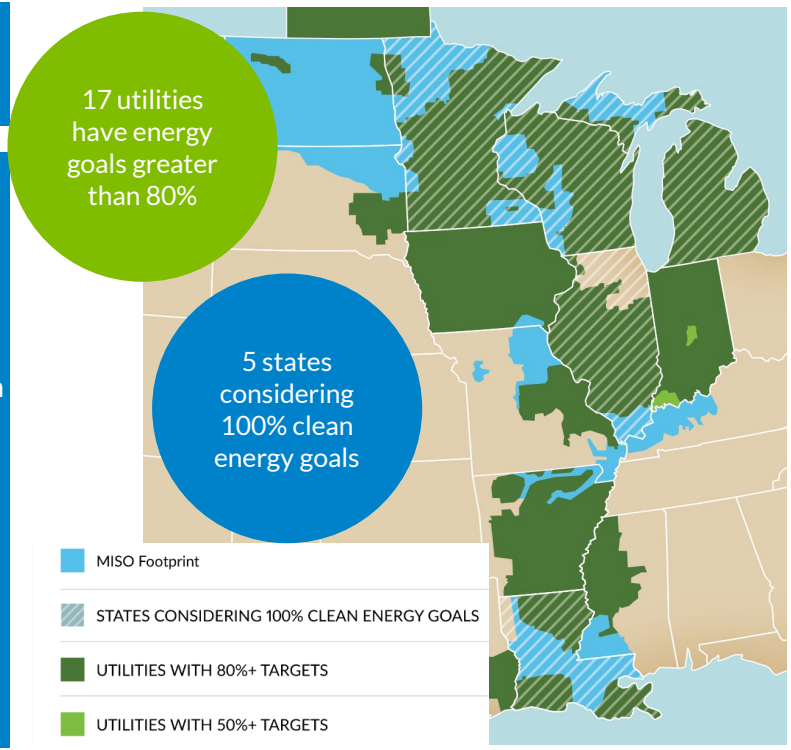
Narrow and less useful

Broad and more useful



Three Futures incorporate & bookend uncertainty with members' plans

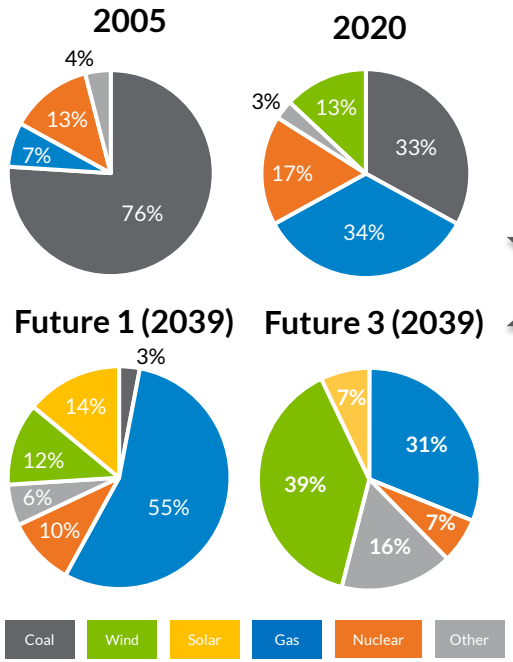
Future 1	Future 2	Future 3
• The footprint develops in line with 100% of utility IRPs and 85% of utility announcements, state mandates, goals, or preferences. • Emissions decline as an outcome of utility plans. • Load growth consistent with current trends.	• Companies/states meet their goals, mandates and announcements. • Changing federal and state policies support footprint-wide carbon emissions reduction of 60% by 2040. • Energy increases 30% footprint-wide by 2040 driven by electrification	• Changing federal and state policies support footprint-wide carbon emissions reduction of 80% by 2040. • Increased electrification drives a footprint-wide 50% increase in energy by 2040.



April 2021; changing rapidly.

MISO's actions as part of the Reliability Imperative address emerging operational needs on the system

GENERATOR ENERGY MIX



MISO FORWARD

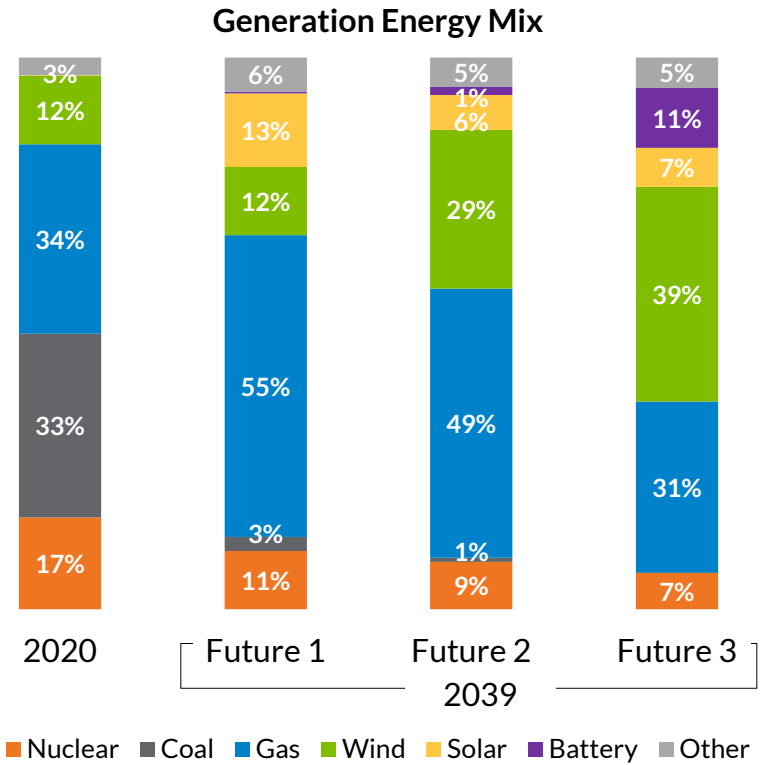
RELIABILITY IMPERATIVE

- Market Redefinition
- **Long-Range Transmission Planning**
- Operations of the Future
- Market System Enhancement

List is not representative of all efforts

MISO is actively pursuing multiple workstreams to ensure ongoing reliability and value creation

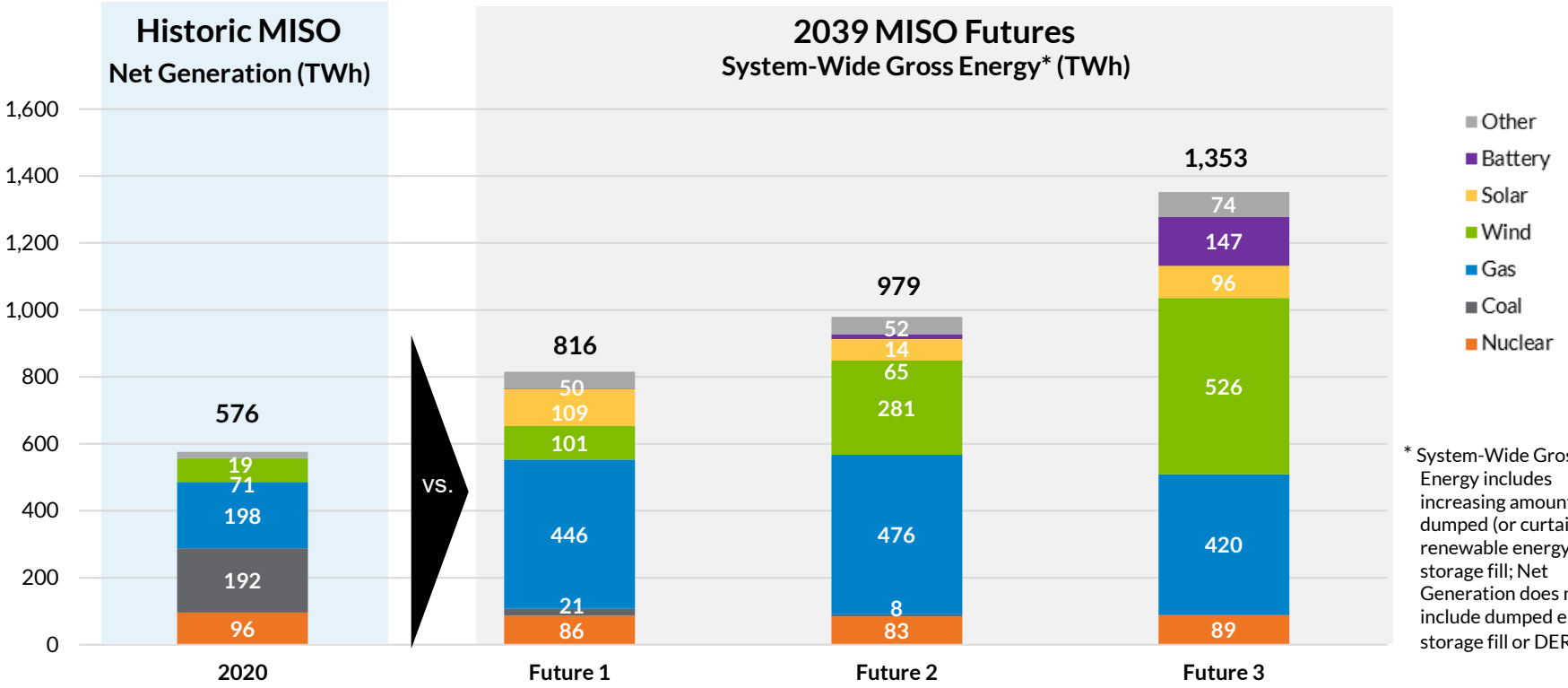
New Futures incorporate and build upon member plans to inform the resource transition and changing demand patterns



	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%

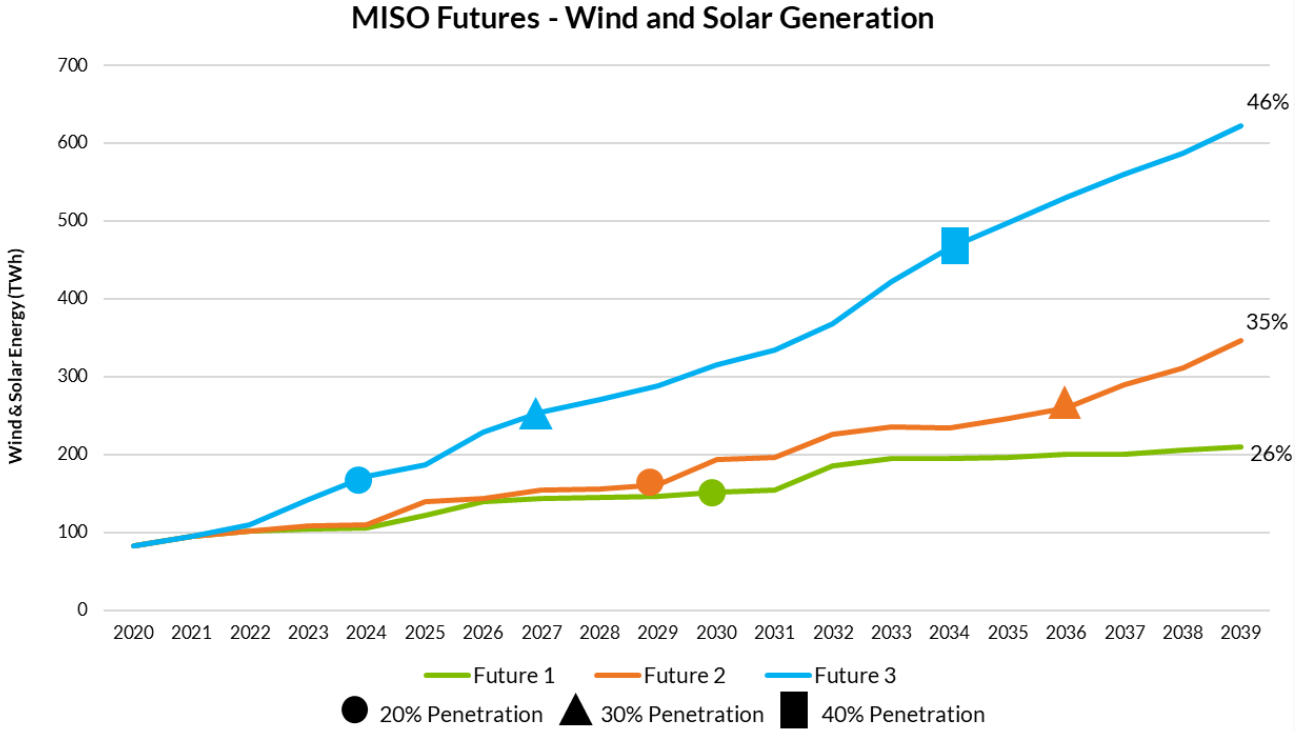
*Resulting emission reductions based upon 2005 levels

Futures energy mix transforms throughout the study to reflect announced plans and changing assumptions



* System-Wide Gross Energy includes increasing amounts of dumped (or curtailed) renewable energy and storage fill; Net Generation does not include dumped energy, storage fill or DERs.

MISO's "Futures" reflect a broad range of how the fleet evolution may unfold, including large increases in renewables



Future 1

Future 1

CO_2 Emissions	Solar	Wind	Nuclear	Gas	Coal	Battery Storage
↓63%*	24%	14%	5%	48%	5%	0.3%
199 MMT CO_2	50.8 GW	31 GW	11.2 GW	103.6 GW	10.3 GW	0.6 GW

2039

**Capacity Values

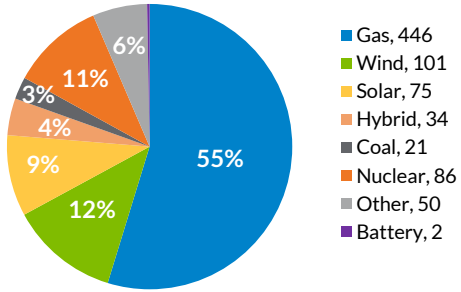
Carbon-free energy: ~43%

Carbon-based energy: ~57%

85% of announced state and utility goals and 100% of utility IRPs were included in Future 1

Stakeholder plans exceeded original MISO assumptions: Future 1 original assumption of 40% decarbonization, reached 63%* due to plans and retirements

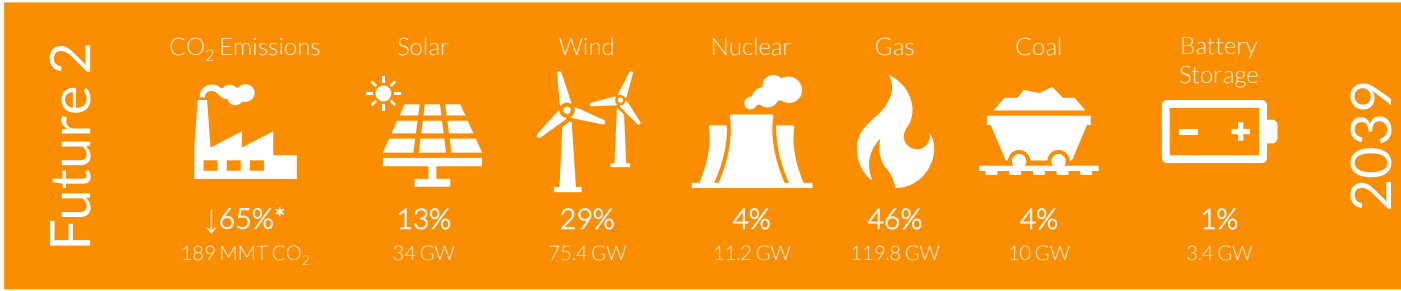
Energy Mix (TWh, 2039)



Future 1 Details		
Gross Load		Low-Base, EV Growth
Total Growth		94,275 GWh
Energy		0.48% CAGR
Demand		0.60% CAGR
Electrification Growth & Technologies	Growth	2% of Total Growth; 14,147 GWh
	Technologies	PEVs
Carbon Reduction*		40%
Wind & Solar Generation Percentage		26% with no minimum enforced
Utility Announced Plans		85% Goals Met, 100% IRPs met
Retirement Age-Based Criteria	CC	50 years
	Coal, CT	46 years
	Oil	45 years
	Nuclear	Retire if Publicly Announced
	Wind & Solar	25 years
Retirements	Coal	44.8 GW
	Gas	18.6 GW
	Oil	2 GW
	Nuclear	2.4 GW
	Wind	9.2 GW
	Solar	0.02 GW
	Other	0.04 GW
Additions	CC	37.1 GW
	CT	14.1 GW
	CC+CCS	0 GW
	Wind	18.7 GW
	Solar	34.7 GW
	Hybrid	12 GW
	DGPV	3.5 GW
	EE/DR	8.8 GW
	Hydro	0.1 GW
	Battery	0.6 GW

*Reduction from 2005 baseline; MISO Footprint currently at 29%

Future 2



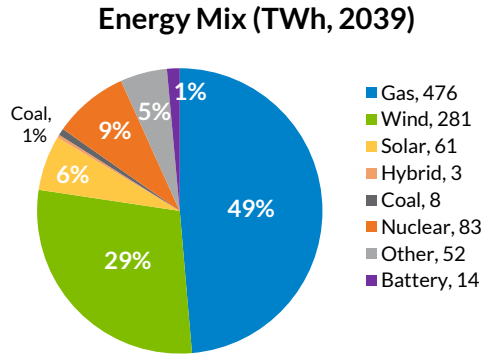
**Capacity Values

Carbon-free energy: ~47%

Carbon-based energy: ~53%

100% of utility IRPs and announced state and utility goals were included in Future 2. Goals surpassed MISO assumptions: Future 2 original assumption of 60% decarbonization, reached 65%* due to plans and retirements

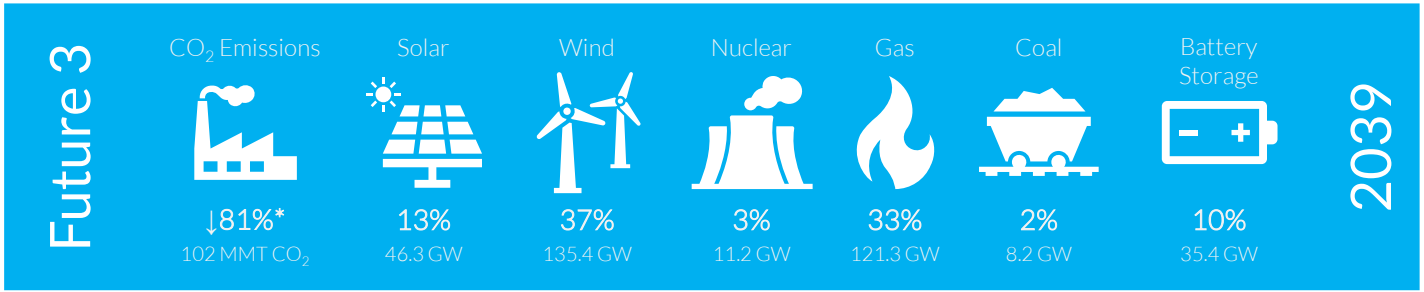
Energy growth of 30% by 2040 in Future 2



Future 2 Details		
Gross Load		30% Total Energy Growth by 2040
	Total Growth	196,996 GWh
	Energy	1.09% CAGR
	Demand	0.97% CAGR
Electrification Growth & Technologies	Growth from Electrification	15% of Total Growth; 109,101 GWh
	Electrification Technologies	PEVs; RES-HVAC, DHW, Appliances; C&I-HVAC, DHW
Carbon Reduction*		60%
Wind & Solar Generation Percentage		35% with no minimum enforced
Utility Announced Plans		100% Goals & IRPs Met
Retirement Age-Based Criteria	CC	45 years
	Coal, CT	36 years
	Oil	40 years
	Nuclear	Retire if Publicly Announced
	Wind & Solar	25 years
Retirements	Coal	45.1 GW
	Gas	21.6 GW
	Oil	2 GW
	Nuclear	2.4 GW
	Wind	9.2 GW
	Solar	0.02 GW
	Other	0.04 GW
Additions	CC	58.7 GW
	CT	10.5 GW
	CC+CCS	1.2 GW
	Wind	63.1 GW
	Solar	28.7 GW
	Hybrid	1.2 GW
	DGPV	3.5 GW
	EE/DR	9 GW
	Hydro	0.1 GW
	Battery	3.4 GW

*Reduction from 2005 baseline; MISO Footprint currently at 29%

Future 3



Carbon-free energy: ~63%

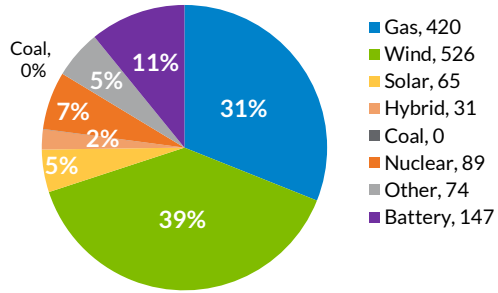
Carbon-based energy: ~37%

**Capacity Values

100% of utility IRPs and announced state and utility goals were included in Future 3. Original assumption of 80% decarbonization, reached 81%* due to plans and retirements

Energy growth of 50% by 2040 in Future 3

Energy Mix (TWh, 2039)



Future 3 Details		
Gross Load		50% Total Energy Growth by 2040
Total Growth		334,692 GWh
Energy		1.71% CAGR
Demand		1.41% CAGR
Electrification Growth & Technologies	Growth from Electrification	32% of Total Growth; 231,513 GWh
	Electrification Technologies	PEVs; RES-HVAC, DHW, Appliances; C&I-HVAC, DHW, Process
Carbon Reduction*		80%
Wind & Solar Generation Percentage		46%
Utility Announced Plans		100% Goals & IRPs Met
Retirement Age-Based Criteria	CC	35 years
	Coal, CT	30 years
	Oil	35 years
	Nuclear	Retire if Publicly Announced
	Wind & Solar	25 years
Retirements	Coal	47 GW
	Gas	51.4 GW
	Oil	2.3 GW
	Nuclear	2.4 GW
	Wind	9.2 GW
	Solar	0.02 GW
	Other	0.04 GW
Additions	CC	41.9 GW
	CT	17.7 GW
	CC+CCS	42 GW
	Wind	123.1 GW
	Solar	28.7 GW
	Hybrid	10.8 GW
	DGPV	6.2 GW
	EE/DR	12.7 GW
	Hydro	0.1 GW
	Battery	35.4 GW

*Reduction from 2005 baseline; MISO Footprint currently at 29%

MISO Futures include 14-232 TWh of electrifiable load across multiple technologies and consumer classes

Future 1

14 TWh of electrifiable load

- Plug-in electric hybrids

Future 2

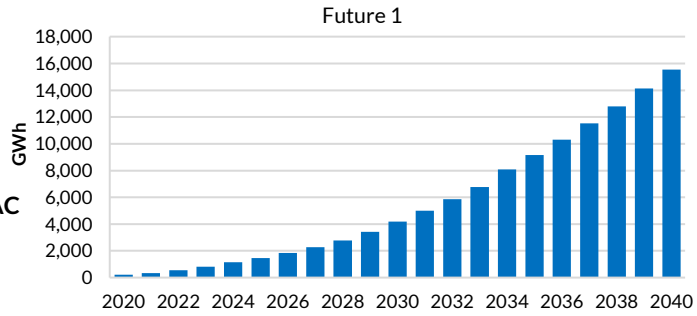
109 TWh of electrifiable load

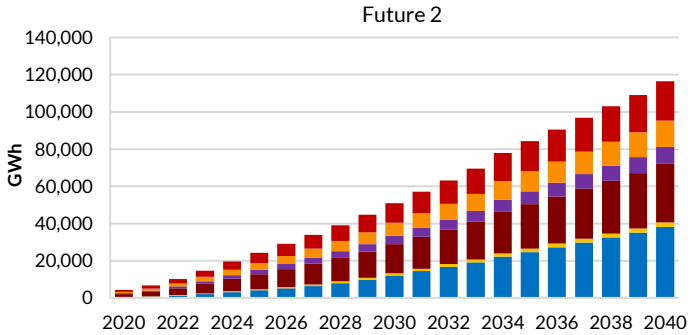
- Plug-in electric hybrids
- Commercial & industrial HVAC
- Residential HVAC
- Residential water heating
- Residential appliances
- Commercial & industrial water heating

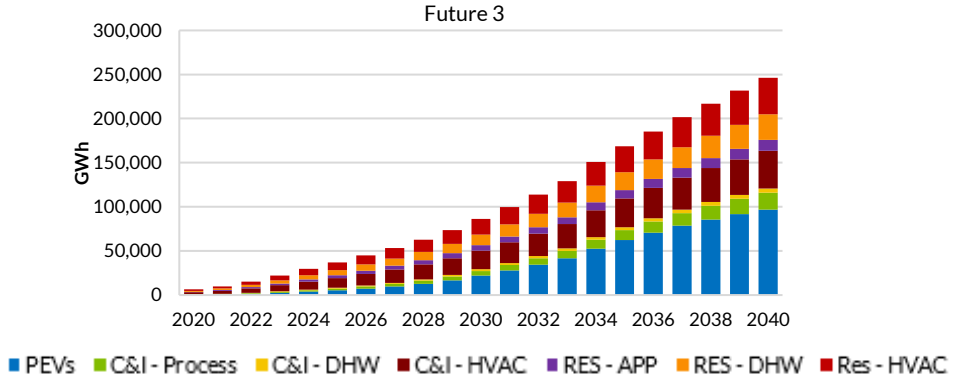
Future 3

232 TWh of electrifiable load

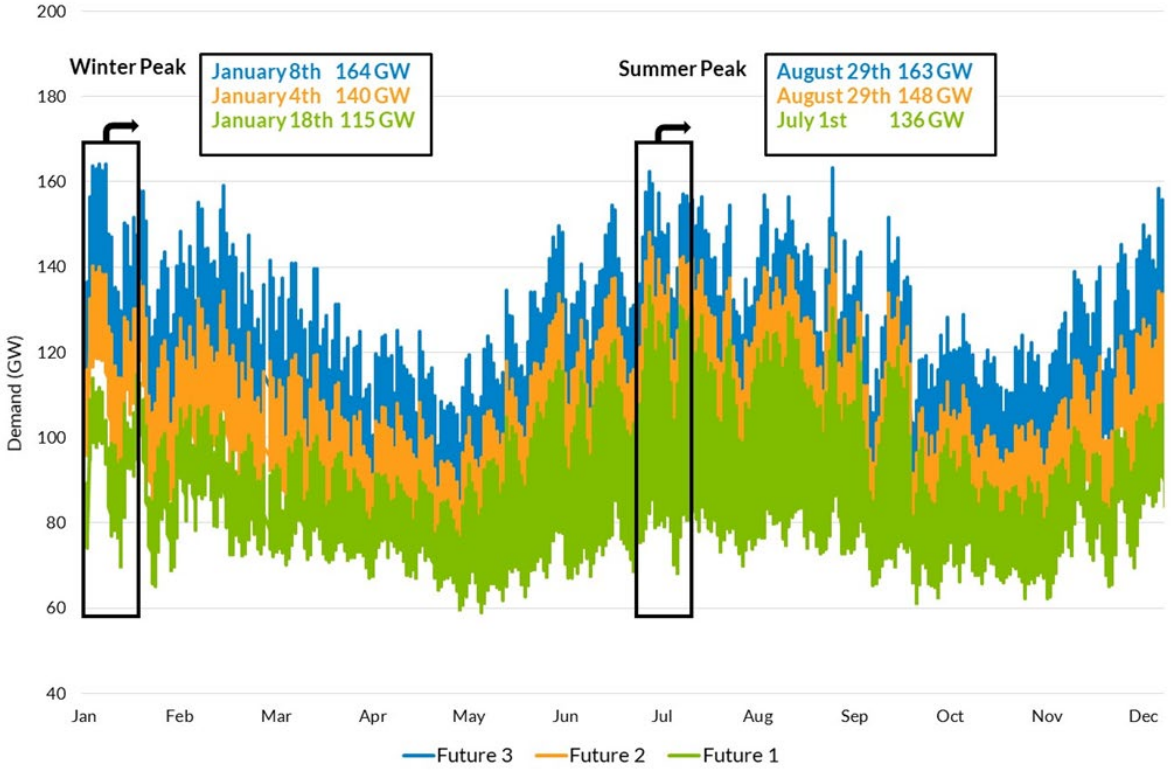
- Plug-in electric hybrids
- Commercial & industrial HVAC
- Residential HVAC
- Residential water heating
- Residential appliances
- Commercial & industrial water heating
- Commercial & industrial processes







Significant increase in electrifiable loads transforms MISO into a dual summer and winter peaking system by 2039



Key Findings of Expansion Results

- All scenarios have relatively large amounts of gas additions; this is due to increasing amounts of coal and gas retirements and the system's need for base generation to replace retired units. CC and CT gas units emit approximately half the amount of CO_2 that coal units emit. Decarbonization and load growth allow for gas to comprise 40% of the total expansion in Future 1, while CC+CCS comprises 40% of the gas units built in Future 3's expansion, illustrating the model's need for a low-carbon, high-capacity factor proxy resource.
- Wind, solar, and hybrid resource expansion is largely driven by decarbonization and each underlying load shape. In Future 3 there is significantly more wind than the other two cases; this is primarily due to the increase in load, 80% carbon reduction, and dual peaking system.
- 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 solar and energy efficiency (EE) resources are composed of both selected DER programs and specific member feedback. No demand response (DR) resources were selected in the model but are present in the expansion due to member feedback.

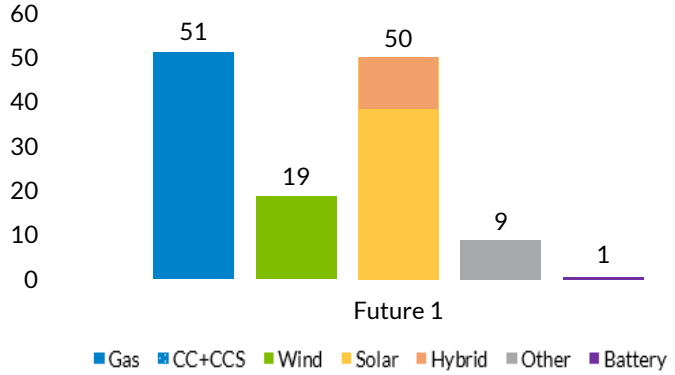




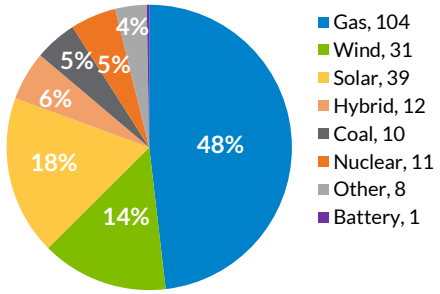

Future 1 Expansion Summary

- This Future incorporated 100% of utility IRPs and 85% of announced state and utility goals within their respective timelines, while also including an 40% carbon dioxide reduction. Modeling of Future 1 results in the retirement of 77 GW, addition of 121 GW of resources, and 9 GW of DSM programs to the footprint.

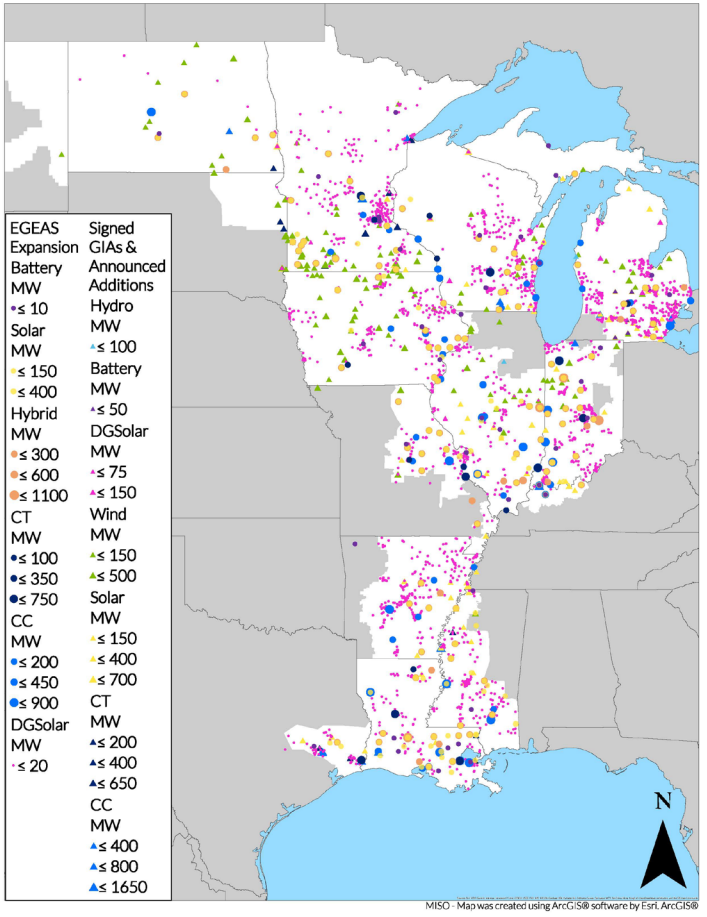
2020-2039 Expansion (GW)



Capacity Mix (GW,2039)

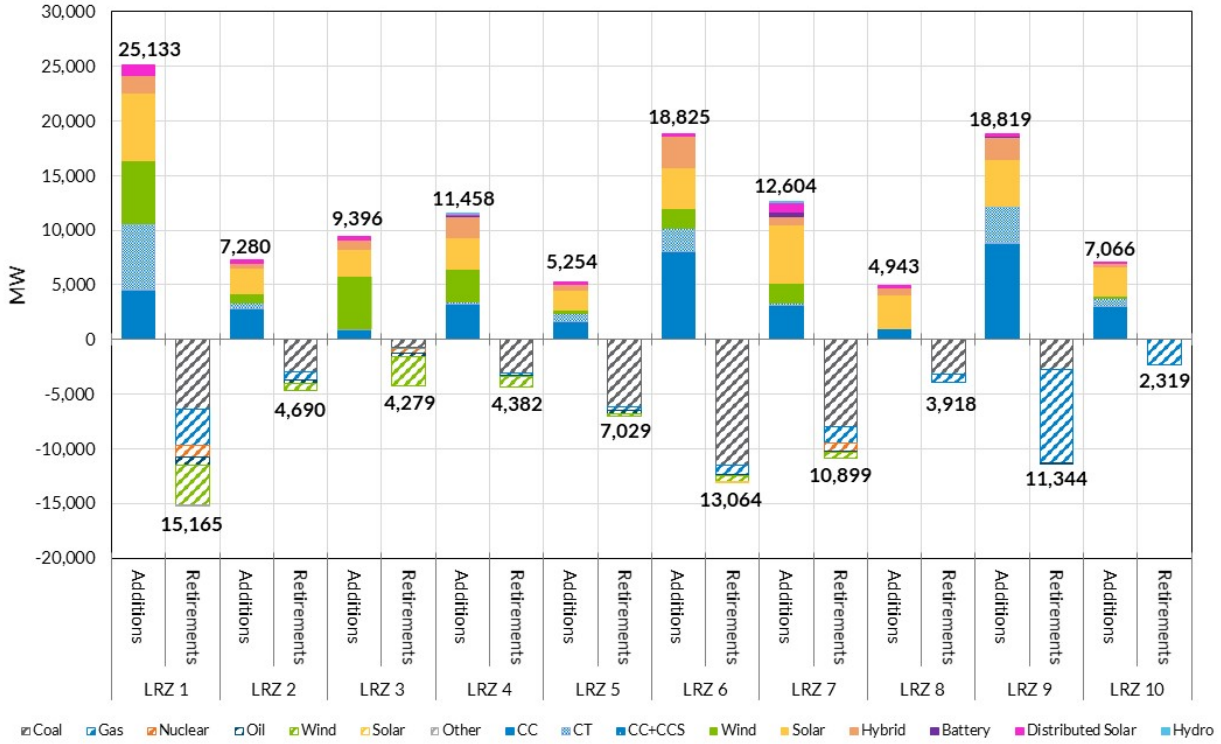


**Capacity mix includes existing and resource additions



IRP – Integrated Resource Plan
DSM – Demand Side Management Program
*No CC+CCS was selected in Future 1

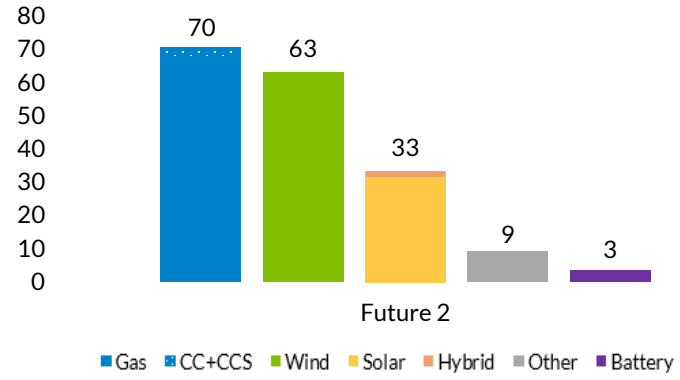
Future 1 LRZ Addition and Retirement Totals



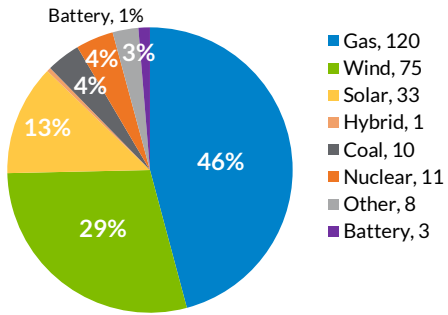
Future 2 Expansion Summary

- This Future incorporated 100% of utility IRPs and announced state and utility goals within their respective timelines, while also including an 60% carbon dioxide reduction. Modeling of Future 2 results in the retirement of 80 GW, addition of 170 GW of resources, and 9 GW of DSM programs to the footprint.

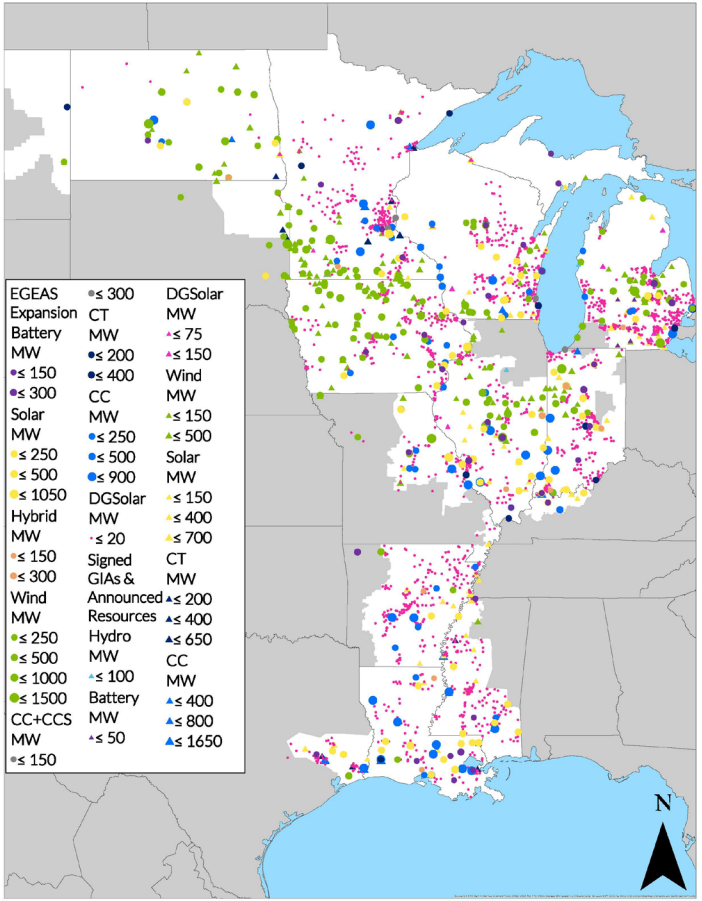
2020-2039 Expansion (GW)



Capacity Mix (GW, 2039)

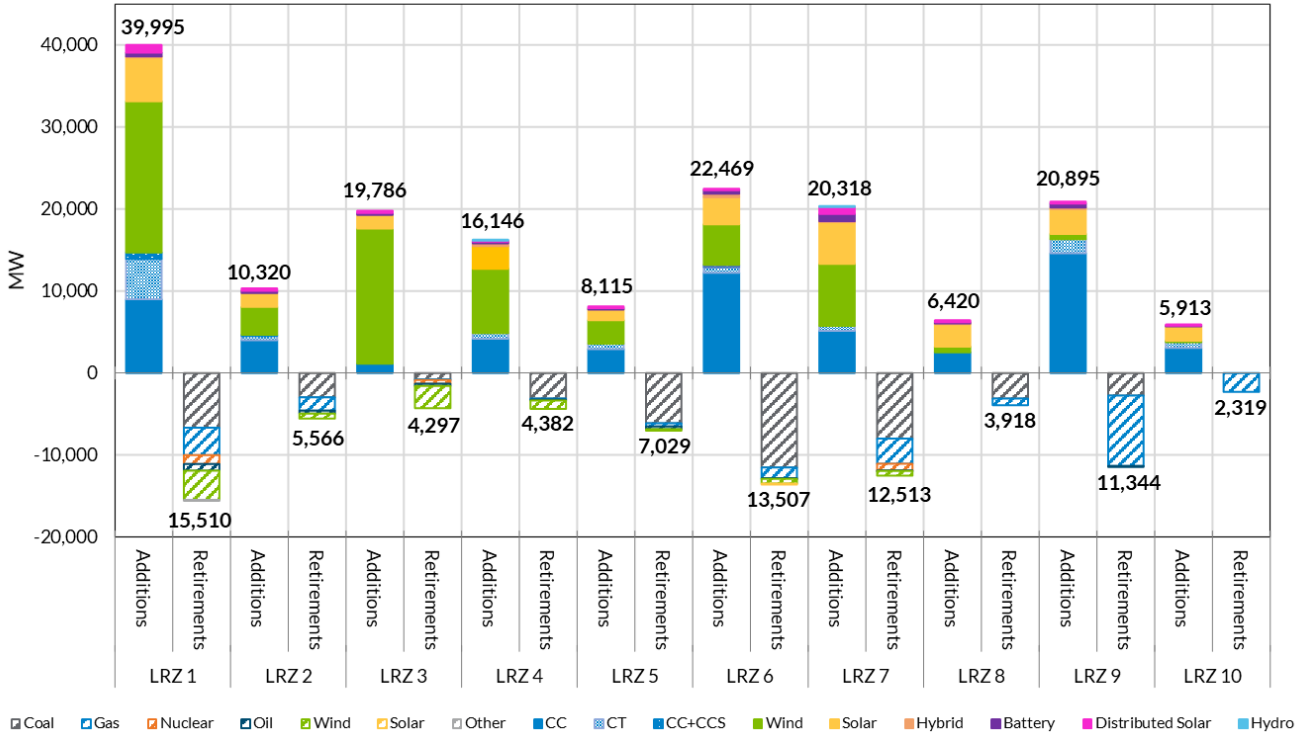


**Capacity mix includes existing and resource additions



IRP – Integrated Resource Plan
DSM – Demand Side Management Program

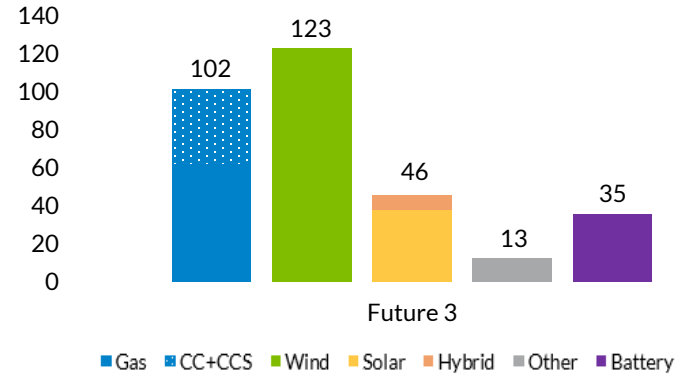
Future 2 LRZ Addition and Retirement Totals



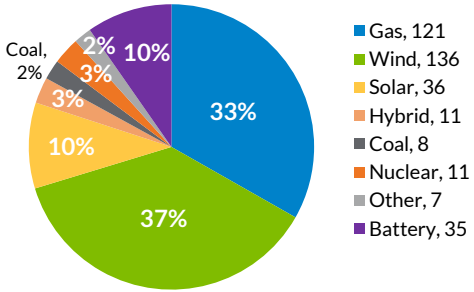
Future 3 Expansion Summary

- This Future incorporated 100% of utility IRPs and announced state and utility goals within their respective timelines, while also including an 80% carbon dioxide reduction. Modeling of Future 3 results in the retirement of 112 GW, addition of 306 GW of resources, and 13 GW of DSM programs to the footprint.

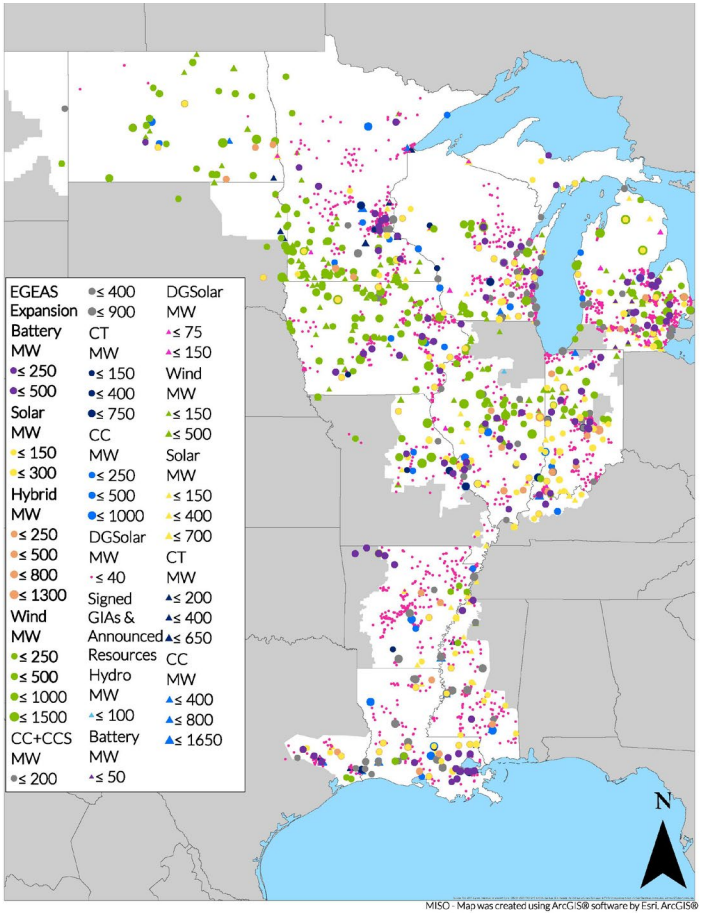
2020-2039 Expansion (GW)



Capacity Mix (GW, 2039)



**Capacity mix includes existing and resource additions



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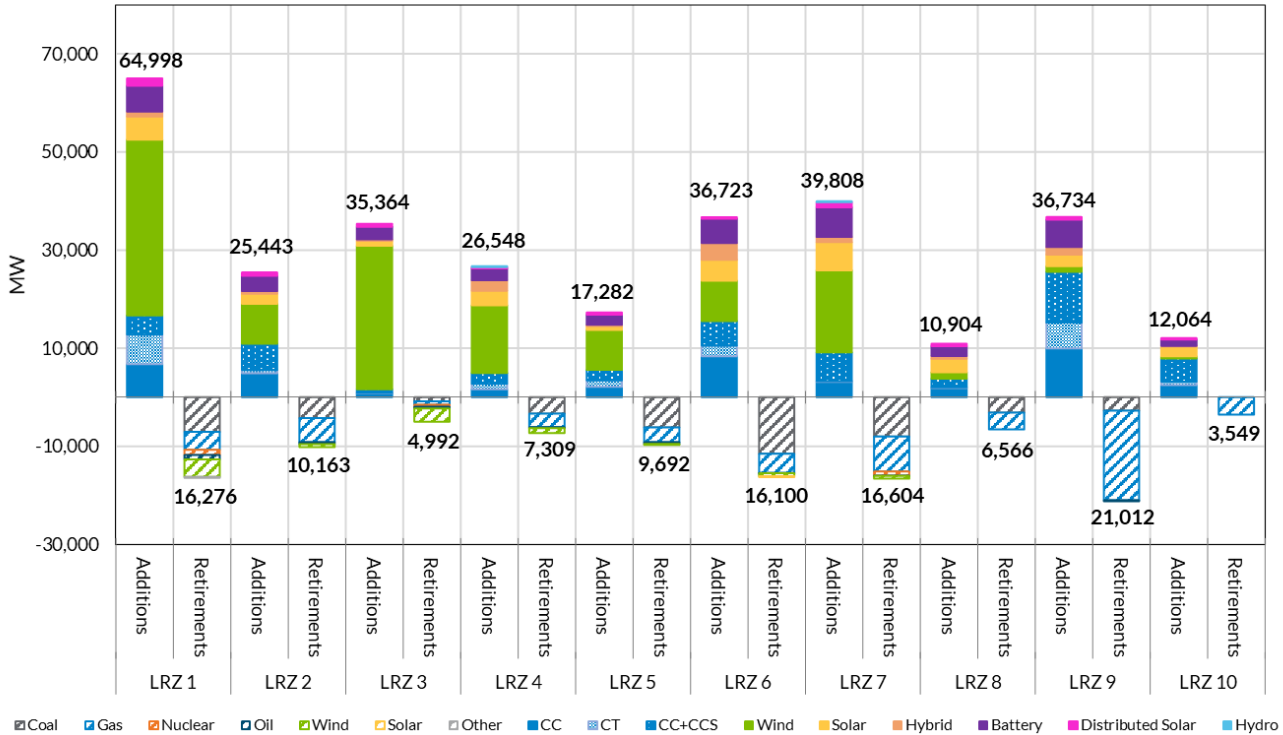
Future 3 LRZ Addition and Retirement Totals



Contact Information

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