AEG
Applied Energy Group

MISO ELECTRIFICATION LOAD-GROWTH ASSESSMENT

RESIDENTIAL, COMMERCIAL, INDUSTRIAL, AND LIGHT-DUTY VEHICLES

Project Director:
Ingrid Rohmund, Senior Vice President

Project Manager:
Kurtis Kolnowski, Director

Analysts:
Fuong Nguyen, Senior Energy Analyst
Brielle Bushong, Energy Engineer

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BACKGROUND

Electrification is the powering of an end use by electricity, oftentimes displacing another fuel

- When converting from another fuel, electrification typically does not result in a BTU increase

Interest in this topic has grown in recent years

- Many automakers are now producing Plug-In Electric Vehicles (PEVs) and/or pledging to go all electric
- Regulators passing emissions regulations (and ZNE goals)

If this occurs, electrification could have significant impacts on hourly energy consumption (and system loads)

- Natural gas infrastructure is deeply embedded in northern states
  - Oil extraction/fracking exists across the footprint
- Transportation is one of the largest energy-users in the country

This study is intended to provide an initial estimate on electrifiable loads and the impact they may have on the MISO system

EXAMPLE HOURLY GRID IMPACTS
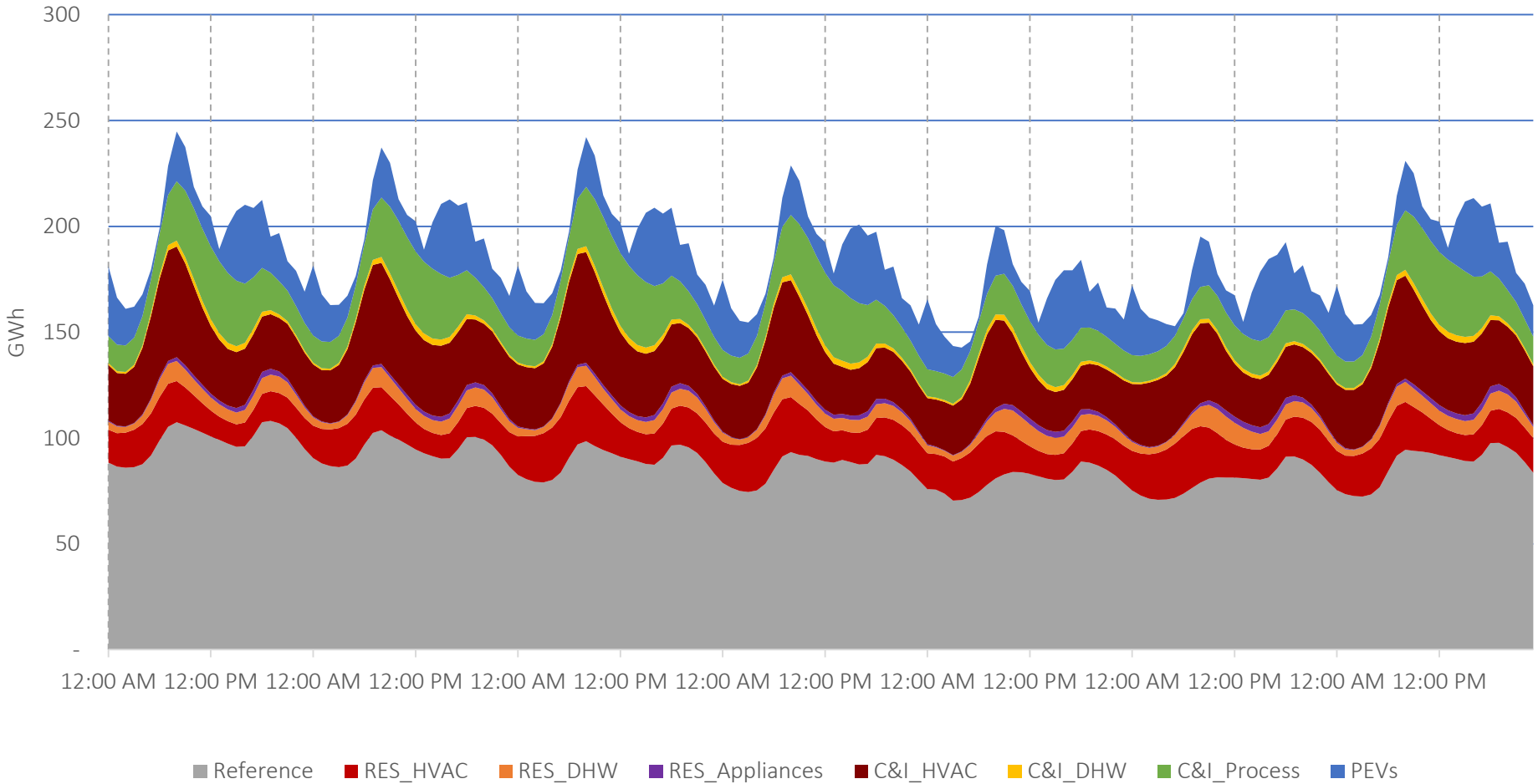## TEMPORAL VALUE OF LOAD GROWTH, 70% SCENARIO

Load Profile in 2040, Technical Case
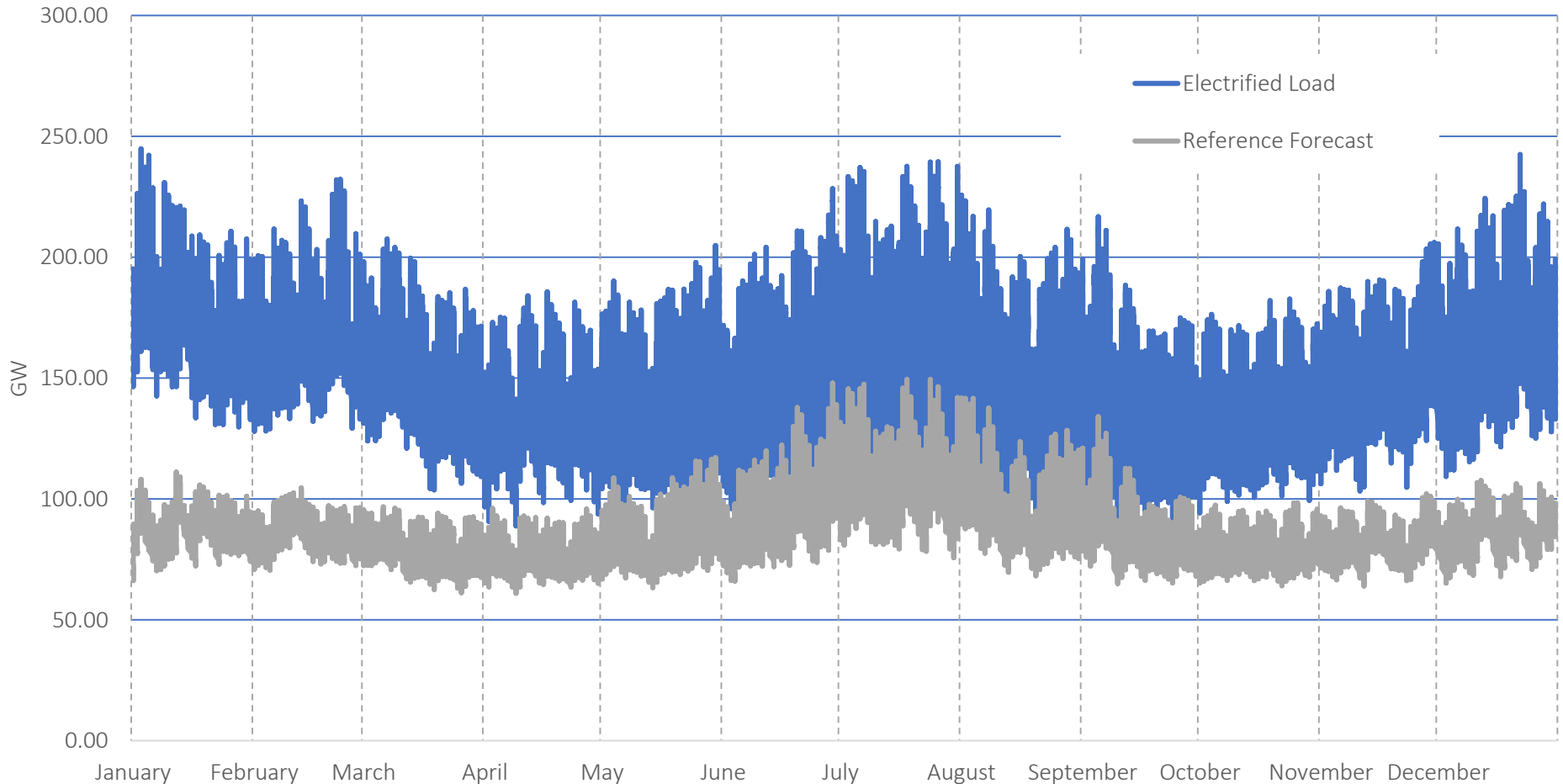
EXAMPLE HOURLY GRID IMPACTS
TEMPORAL VALUE OF LOAD GROWTH, 70% SCENARIO

End-Use Contribution to Load During Winter Peak

Legend: Reference · RES_HVAC · RES_DHW · RES_Appliances · C&I_HVAC · C&I_DHW · C&I_Process · PEVs

METHODOLOGY
ELECTRIFICATION OPPORTUNITY OVERVIEW

This analysis is intended to identify <u>new load-growth</u> generated by residential, commercial, industrial, and light-duty transportation electrification within the MISO footprint.
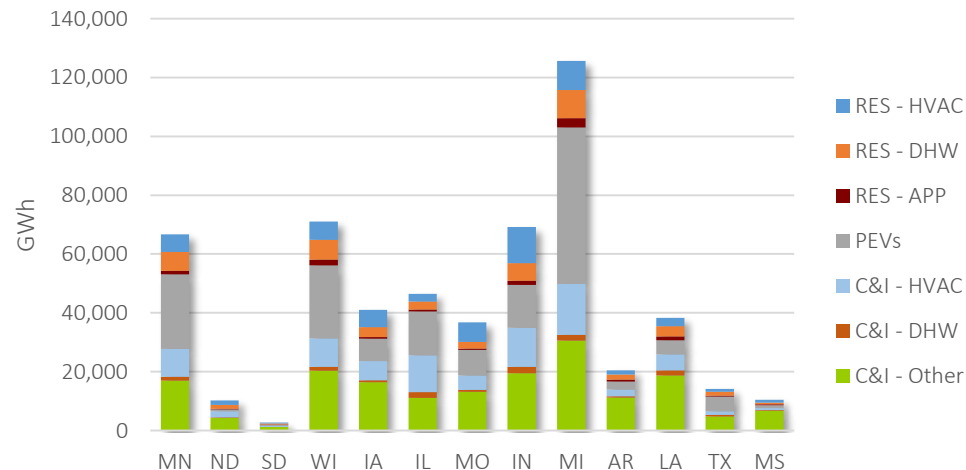
We considered seven potential future growth scenarios simulating various levels of electrification uptake but do not attribute specific interventions to each.

- Scenarios are incremental to the Purdue "Base" forecast

Technical Growth by End Use

Legend: Res - HVAC, RES - DHW, RES - APP, RES - PEVs, C&I - HVAC, C&I - DHW, C&I - Other
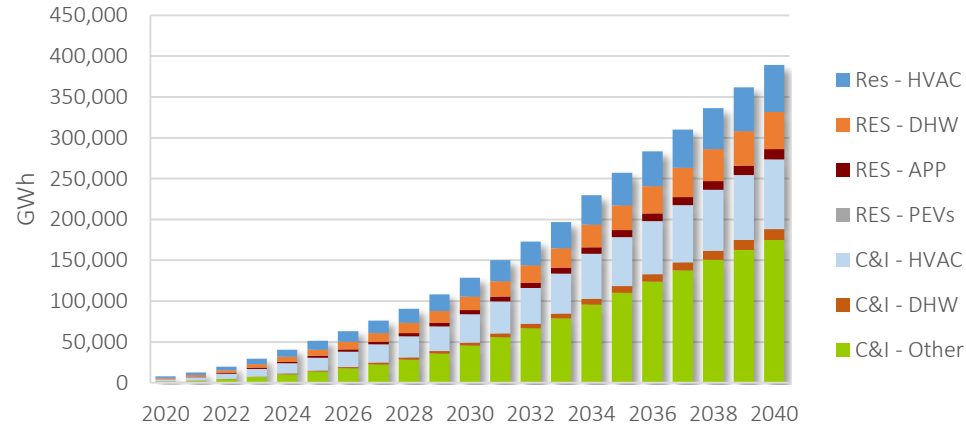
Technical Growth by State, 2040

Legend: RES - HVAC, RES - DHW, RES - APP, PEVs, C&I - HVAC, C&I - DHW, C&I - Other

ELECTRIFICATION POTENTIAL BY STATE
PERCENT OF CONSUMPTION IN MISO FOOTPRINT

Potential to electrify varies by state, generally driven by a few characteristics, examples include:

- **Latitude:** electrification of the northern states with more heating load increases potential

- **Gas Infrastructure:** states with more gas heating increase potential

- **Cooling:** states with higher cooling loads reduce the electrifiable portion of load
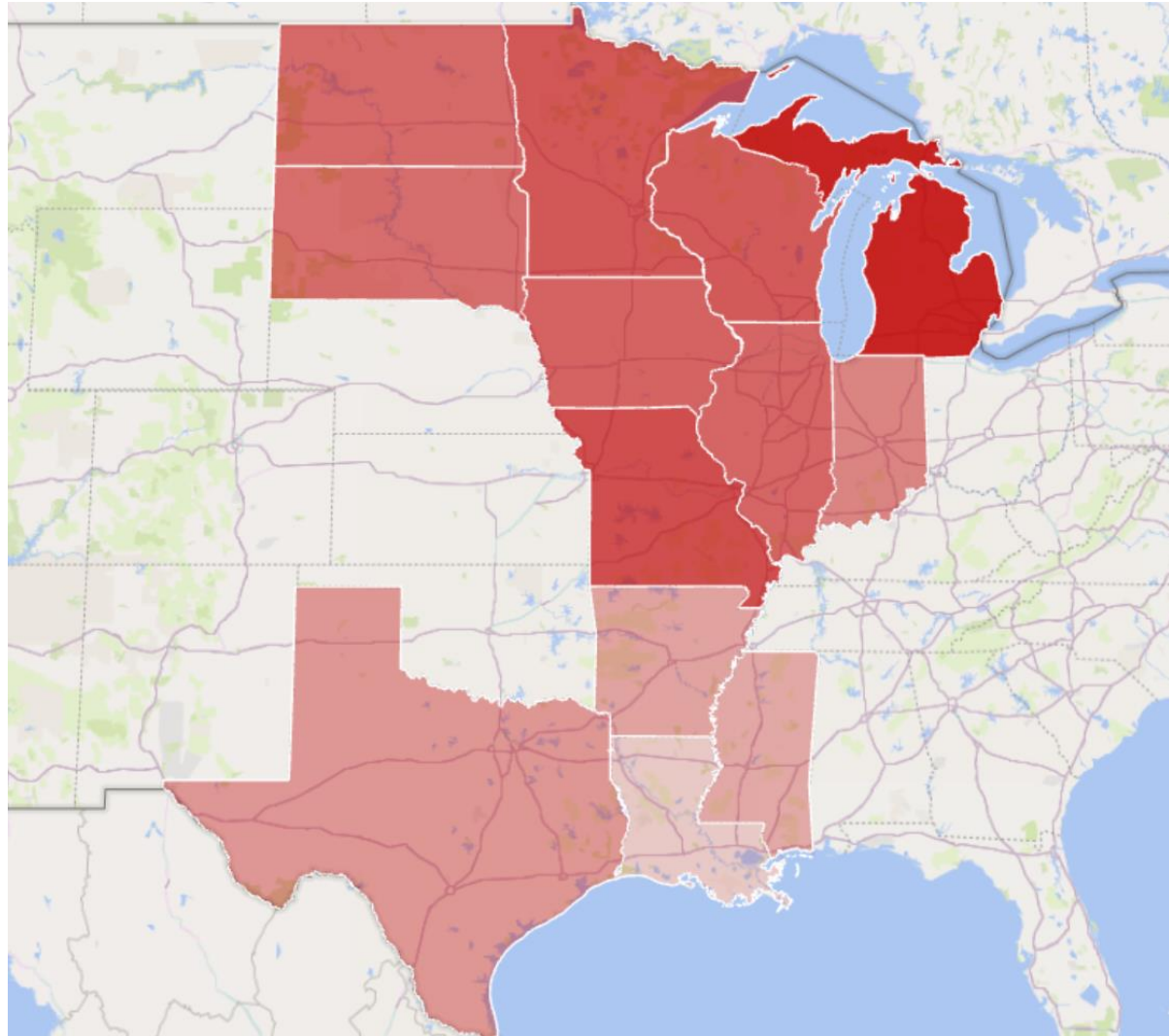
Scenario Definitions
Residential and Commercial Buildings, Light-Duty Vehicles

AEG modeled a total of seven scenarios, reflecting a different growth as percent of the reference forecast in 2040. Those include

- Percentage growth scenarios – 10%, 20%, 30%, 40%, 50%, and 60%
- Technical growth scenario – ~70%

These represent annual consumption growth in 2040, not peak, since each measure may have a different peak impact

- E.g. space heating would represent no load growth during the existing summer peak

We have selected three scenarios below to represent relevant bookends for potential MISO electrification load growth, incremental to the reference baseline:

- **10% Growth:** 10% load growth compared to the reference forecast in 2040. *Note that this is not a conservative estimate since 10% growth is substantial. The 99%/1% forecasts from SUFG are similar in magnitude.*
- **40% Growth:** 40% load growth. This includes a significant amount of new load in all sectors analyzed and would be expected to transform the energy landscape if it transpires.
- **Technical Growth:** Approximately 70% load growth. This includes an electrification of about 90% of relevant non-electric building loads and a similar level of light-duty vehicles. Note that this does not include heavy duty vehicles or buses since those were not present in the LBNL study.

AEG considered the following technologies for electrification:

- **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 (RTUs and residential-style systems)
  - Higher-growth scenarios assume larger-scale replacements come online for technologies like gas boilers

- **Heat Pump Water Heaters** – Efficient water heaters with a vapor-compression refrigeration cycle
  - Lower growth scenarios electrify residential-style tanks in both the residential and commercial sectors
  - Higher-growth scenarios impact larger-scale gas water heaters

AEG assumes that approximately 90% of a given end use can electrify, accounting for technical barriers present in existing buildings. These may be alleviated over time as new construction designs become commonplace.

- **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 process, we have assumed that most of this occurs in the higher-growth scenarios

- **All four LBNL PEV forecasts** were used in development of these scenarios.

  - These include uncontrolled versions of the: Low, Base, High, and Very High scenarios

  - One PEV forecast was selected for each growth scenario – adoption curves and load shapes specific to the selected forecast were used

We assigned diffusion curves by technology based on level of growth

- Rates are limited to a prescribed percentage of technical turnover in the long-term
- These were adapted from the LBNL electrification study, which developed a set of diffusion curves that appear comparable to other sources.
  - Although the High and Very High curves appear more backloaded compared to Low, these are used in the higher growth scenarios and represent more emerging technologies.


Diffusion Curves
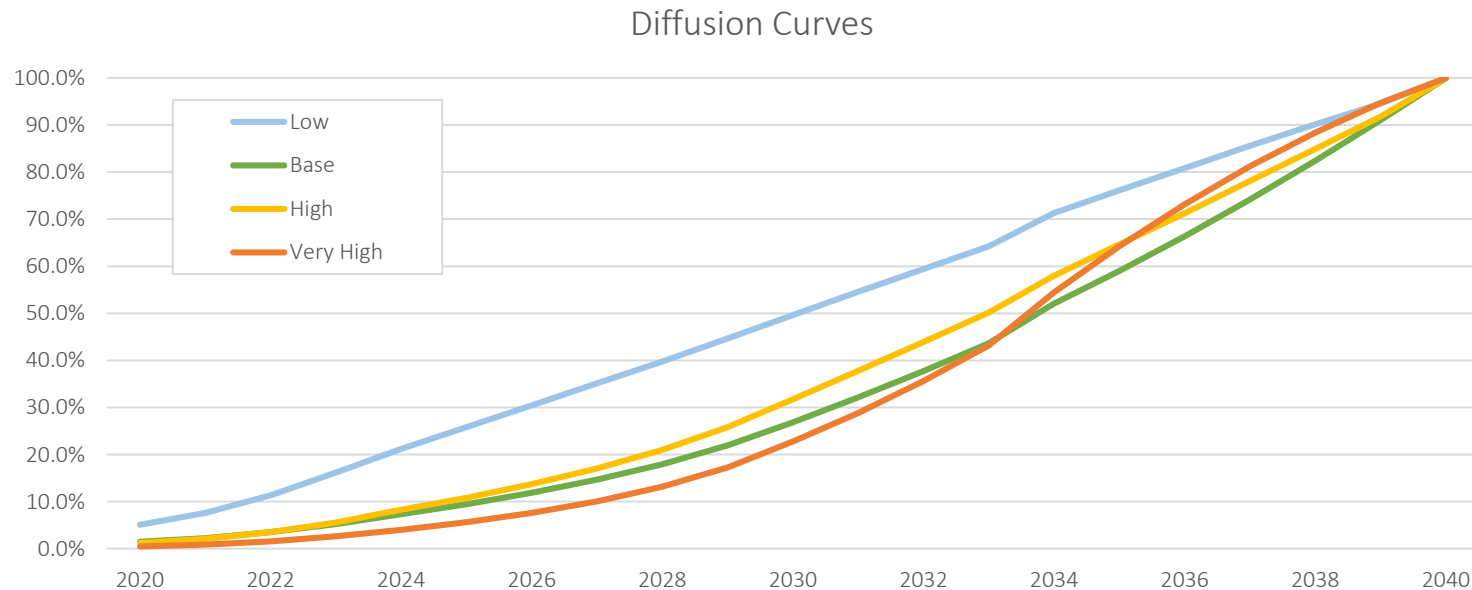
TECHNICAL GROWTH

The Technical Growth for electrification in the MISO by 2040 is presented below.

- Light-duty vehicle electrification makes up over a quarter of the load opportunity
- Michigan (LRZ 7) provides the highest opportunity for electrification, followed by Wisconsin and Minnesota (LRZs 1 and 2)
- This does not include heavy-duty vehicles or buses, which may represent significant additional growth

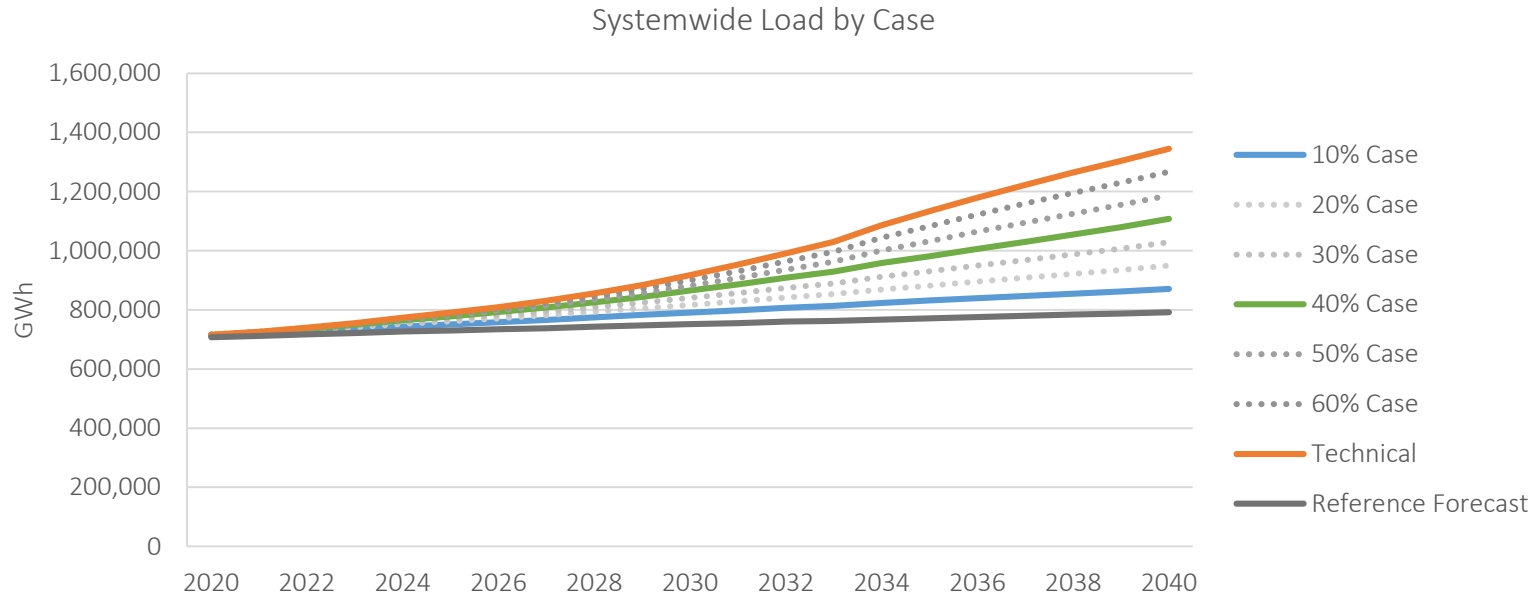MISO Technical Growth by End Use, 2040
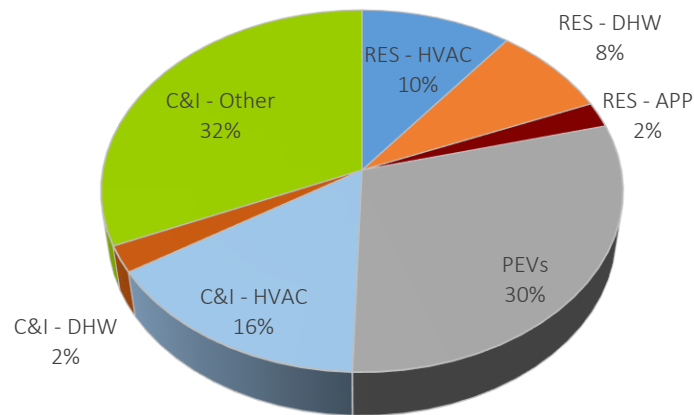
Technical Growth by LRZ, 2040
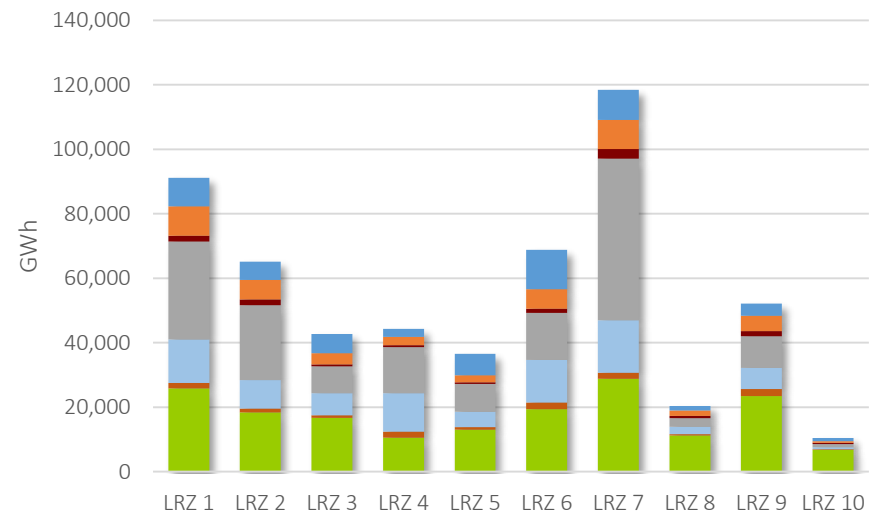
ELECTRIFICATION LOAD GROWTH RESULTS

LOAD GROWTH RESULTS
ALL SCENARIOS

Systemwide Load by Case

Case	2020	2021	2022	2030	2040	CAGR
Reference	707,326	711,842	716,979	751,569	791,501	0.6%
10% Case	711,324	717,837	725,959	790,801	870,651	1.0%
20% Case	713,281	720,803	730,486	817,173	949,801	1.4%
30% Case	714,350	722,515	733,258	839,995	1,028,951	1.8%
40% Case	715,306	724,153	736,051	865,077	1,108,101	2.2%
50% Case	715,554	724,626	736,973	881,717	1,187,251	2.6%
60% Case	715,914	725,284	738,191	899,697	1,266,401	2.9%
Technical	716,269	725,933	739,393	917,432	1,344,474	3.2%

LOAD GROWTH OPPORTUNITY
10% LOAD GROWTH SCENARIO RESULTS

10% Cumulative Load Growth, MISO
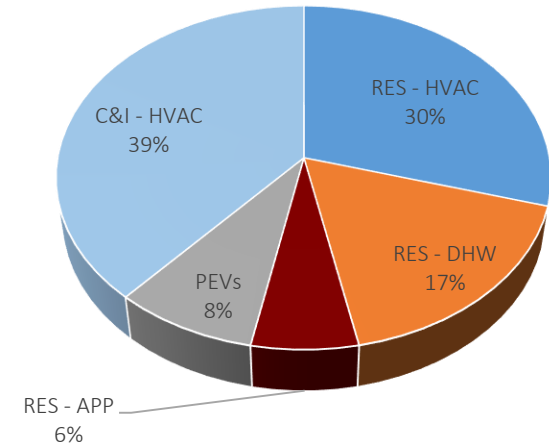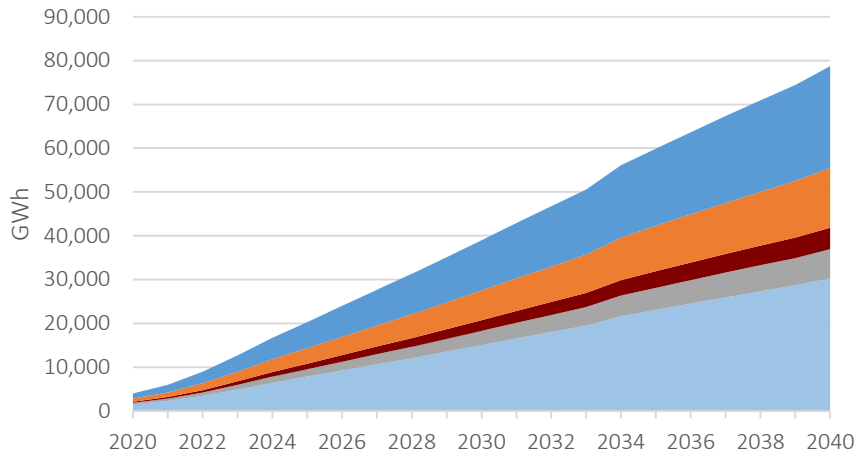
10% Cumulative Growth (GWh)

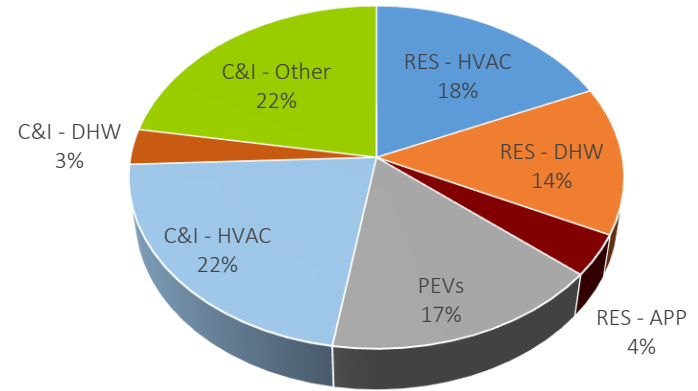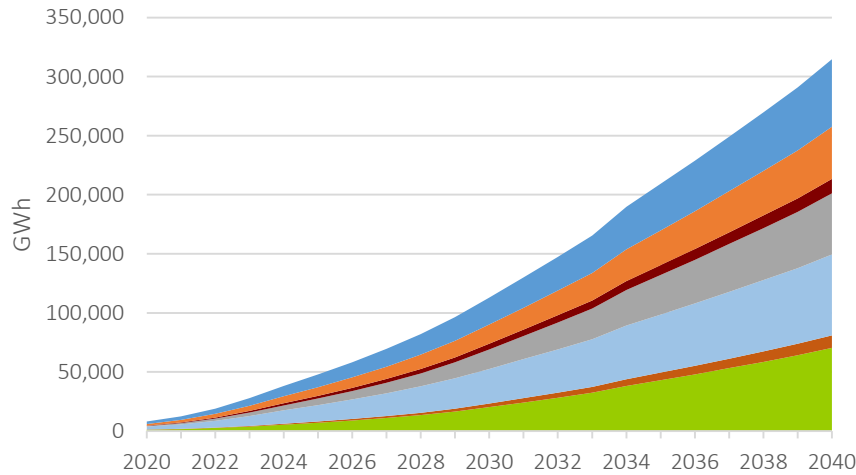| End Uses	2020	2021	2022	2030	2040	% of Ref. Forecast
New Loads (GWh)	**3,998**	**5,995**	**8,980**	**39,232**	**79,150**	**10.0%**
RES – HVAC	1,178	1,766	2,646	11,560	23,322	2.9%
RES – Water Heating	693	1,040	1,558	6,805	13,729	1.7%
RES – Appliances	251	376	563	2,460	4,964	0.6%
Plug-In Electric Vehicles	336	504	755	3,297	6,653	0.8%
C&I – HVAC	1,540	2,309	3,458	15,109	30,482	3.9%
C&I – Water Heating	0	0	0	0	0	0.0%
C&I – Other (Process)	0	0	0	0	0	0.0%

10% Growth by LRZ, 2040
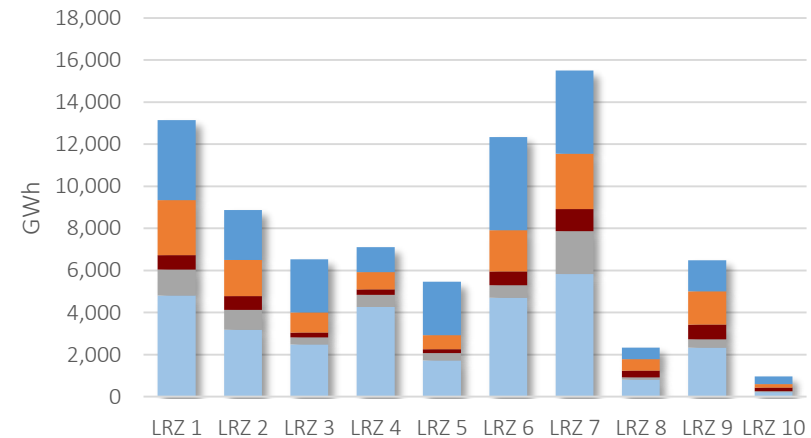
LOAD GROWTH OPPORTUNITY
40% LOAD GROWTH SCENARIO RESULTS

40% Cumulative Load Growth, MISO

40% Cumulative Growth (GWh)

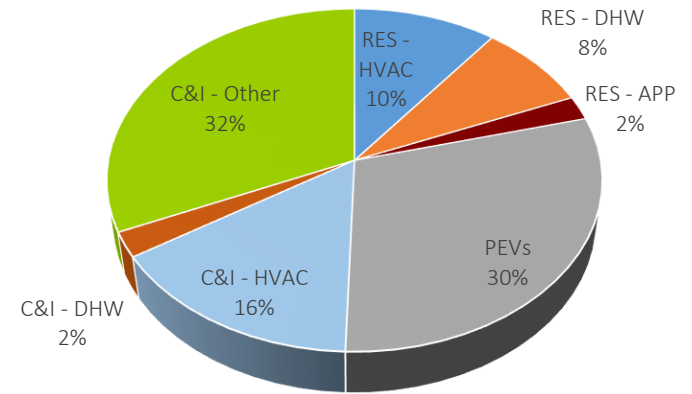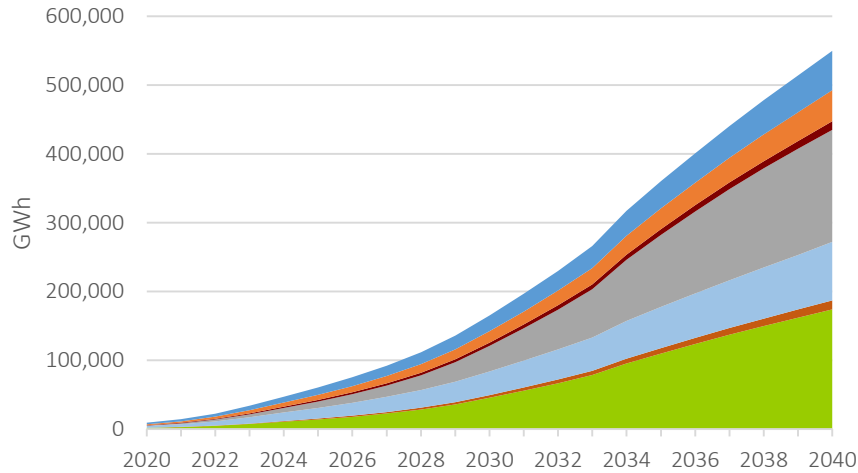| End Uses	2020	2021	2022	2030	2040	% of Ref. Forecast
New Loads (GWh)	7,980	12,311	19,072	113,508	316,600	40.0%
RES – HVAC	2,014	3,034	4,582	22,928	57,713	7.3%
RES – Water Heating	1,328	2,009	3,053	16,337	44,159	5.6%
RES – Appliances	430	647	978	4,899	12,354	1.6%
Plug-In Electric Vehicles	630	1,079	1,840	16,518	52,123	6.6%
C&I – HVAC	2,477	3,782	5,777	29,516	69,026	8.7%
C&I – Water Heating	144	229	370	3,037	10,583	1.3%
C&I – Other (Process)	958	1,531	2,473	20,273	70,641	8.9%

40% Growth by LRZ, 2040
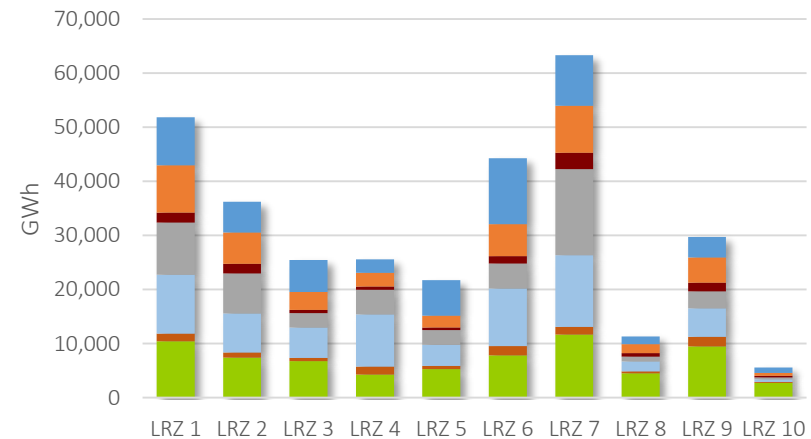
LOAD GROWTH OPPORTUNITY
## TECHNICAL LOAD GROWTH SCENARIO RESULTS

Cumulative Technical Load Growth, MISO

Technical Cumulative Growth (GWh)

End Uses	2020	2021	2022	2030	2040	% of Ref. Forecast
New Loads (GWh)	**8,942**	**14,092**	**22,414**	**165,863**	**552,973**	**69.9%**
RES – HVAC	2,014	3,034	4,582	22,929	57,715	7.3%
RES – Water Heating	1,344	2,037	3,100	16,764	45,508	5.7%
RES – Appliances	430	647	978	4,899	12,354	1.6%
Plug-In Electric Vehicles	745	1,362	2,522	37,211	163,808	20.7%
C&I – HVAC	2,676	4,122	6,358	34,734	85,493	10.8%
C&I – Water Heating	174	282	460	3,837	13,108	1.7%
C&I – Other (Process)	1,560	2,607	4,415	45,489	174,988	22.1%

Technical Growth by LRZ, 2040
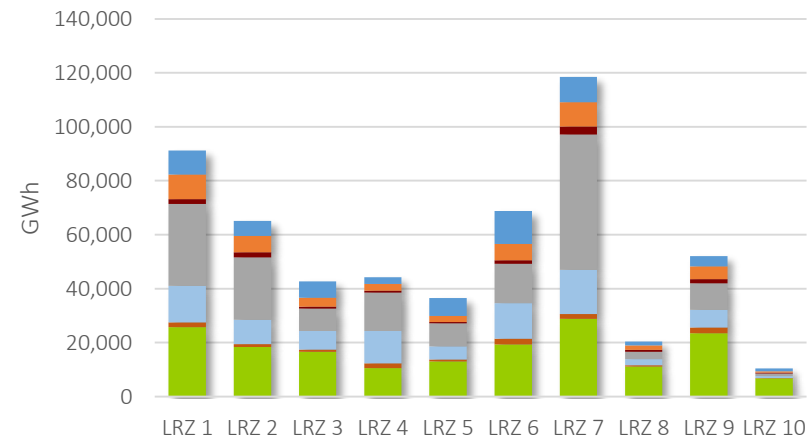
LOAD GROWTH OPPORTUNITY

NEW LOAD – INCLUDES RESIDENTIAL, COMMERCIAL, INDUSTRIAL, AND LIGHT-DUTY VEHICLES

Load Projections by Technology and Case (GWh)

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Residential - Appliances	251	376	563	2,460	4,964	0.6%
Light-Duty Vehicles	336	504	755	3,297	6,653	0.8%
Commercial - HVAC	1,540	2,309	3,458	15,109	30,482	3.9%
Commercial - Water Heating	0	0	0	0	0	0.0%
Commercial - Other	0	0	0	0	0	0.0%
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