

APPENDIX D – ENERGY ADEQUACY ANALYSIS

I. INTRODUCTION

The electric grid is undergoing a significant transformation, moving away from traditional thermal baseload sources to more variable energy sources like wind, solar, and battery energy storage. This shift brings new challenges and complexities in maintaining grid resilience and reliability.

We are increasingly focused on ensuring that our system remains reliable, so that we can continue to deliver the power our customers demand, while responsibly meeting the State’s carbon reduction goals. Our focus on reliability is particularly important because, as we are planning to retire our entire coal fleet (over 2,000 MW of baseload generation), we have nearly 1,700 MW of power purchase agreements (PPAs) set to expire between 2025 and 2028. At the same time, our neighbors are also retiring firm capacity, which makes relying on the market more difficult. Given these challenges, traditional reserve margins and capacity-based estimates are no longer sufficient to ensure our system is prepared for the challenges of extreme weather and changing grid dynamics. To ensure reliability, enhanced planning and energy adequacy assessments are necessary.

In addition to planning to meet our planning obligations without reliance on MISO, we have taken steps to further refine our energy adequacy analysis. We conducted energy adequacy back casting analysis to ensure our system has the reliable energy it needs to serve all customers at every hour of every day. We also examined the inertial floor of our system to assess how the grid would perform in the absence of traditional baseload generation. Our studies go beyond traditional EnCompass modeling to verify the need for firm dispatchable resources and inertia to ensure reliable service for our customers.

II. UTILITY PLANNING FOR SYSTEM NEEDS

Minnesota law requires that we demonstrate that we have sufficient capacity to meet our obligations for a five-year period consistent with Minn. Stat. § 216B.2422. Historically, we planned to have enough resources to meet our load serving needs. Though MISO plays a critical role in ensuring the reliable and efficient operation of the electric grid in the Midwest region of the United States by managing the grid and determining the availability and need for capacity, energy, and ancillary services, we cannot simply rely on MISO to address our capacity needs and ensure the reliability of our system.

MISO's Resource Adequacy (RA) construct will not necessarily ensure there is sufficient firm capacity online to cover the needs of load serving entities. The MISO region relies on Load Serving Entities (LSEs) and market participants to supply the generation resources needed to serve load. MISO also oversees a market to ensure the resources that are available are used efficiently to serve load across the MISO footprint. While MISO can manage the distribution of resources, it cannot ensure that there is enough power generation to meet demand and does not guarantee that there will be enough firm capacity to meet the needs of LSEs.

MISO's role in generation planning is limited. Generation planning is reserved for the states (except in IL). MISO has the ability to set a reserve margin but not the ability to determine what resources will be procured to meet it. While we utilize MISO market energy purchases when they are more cost-effective than our own resources, these purchases are non-firm and do not contribute to our capacity for meeting our seasonal Planning Reserve Margin Requirements (PRMR) obligations as a MISO market participant. Compliance with PRMR obligations is for single-year periods, and the acquisition of new generation capacity often spans multiple years. Our most cost-effective and responsible strategy is to plan for the acquisition of generation capacity several years in advance.

Relying on the MISO Planning Resource Auction (PRA) for securing capacity for single-year periods is not a viable resource planning option. Therefore, it is crucial that we continue to plan for a system with sufficient capacity to meet our customer's energy needs.

A. Navigating the Challenges of Changing Energy Landscapes and Extreme Weather Conditions

The challenges and considerations for maintaining reliability in the face of changing energy landscapes and extreme weather conditions underscores the importance of long-term planning and the integration of new technologies and resources into the grid. Utilities are facing mounting pressure to keep pace with accelerating electricity demand, energy needs, and transmission system adequacy as the resource mix transitions.¹ Extreme weather events continue to pose the greatest risk to its reliability and stability. The North American Reliability Corporation (NERC) concluded that much of North America is again at an elevated risk of having insufficient energy supplies to meet

¹ 2023 Long-Term Reliability Assessment (LTRA): North American Electric Reliability Corporation, 2023 Long-Term Reliability Assessment (2023).
https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_Infographic_2023.pdf.

demand in extreme operating conditions.² As the resource mix on the grid continues to evolve, the risk associated with continuity of energy supply must be managed.

For many years, the regional energy supply has relied on large generators located near large load centers. However, in recent years, there has been a marked shift toward renewable and distributed resources that may be distant from major load centers or may provide variable production profiles. This transition toward more variable resources located far away from load has only increased in recent years.

Consistent with our 2019 Plan, we recently retired Sherco Unit 2, and will retire Sherco Unit 1 in 2026, King in 2028, and Sherco 3 in 2030. Ultimately, the retirements of all the Sherco and King units will remove a total of 2,400 MWs of from our system by 2030. Others are also removing base load from their system. For example, according to the most recent MISO Regional Resource Assessment (RRA)³ in LRZ1, coal generation is expected to decline by more than 3,200 MWs from 2027 to 2037. This generation is being replaced by less than 1.5 GWs of dispatchable generation. While a substantial amount of non-dispatchable resources is also replacing this retiring generation, MISO is still forecasting a 1 GWs reduction in accredited capacity from 2027-2032 for LRZ1. These forecasted replacements create a systemic risk that the market for capacity and energy in MISO LRZ1 will not be enough to serve the load in LRZ1—including that of Xcel Energy—under certain weather conditions. This situation could lead to an energy shortfall, disrupting the supply to consumers and potentially causing widespread outages. Moreover, similar risk extends to areas immediately adjacent to LRZ1 – LRZ2 and LRZ3 – as shown in Figure D-1 below.

² 2023–2024 Winter Reliability Assessment: North American Electric Reliability Corporation, 2023-2024 Winter Energy Market and Electric Reliability Assessment (2023), <https://www.nerc.com/news/Pages/Generator-Fuel-Supplies,-Power-Plant-Winterization,-Load-Forecasting-Complexity-Increase-Reliability-Risk-in-North-America.aspx>

³ 2023 Regional Resource Assessment, MISO. (November 2023). [RAN Reliability Requirements and Sub-annual Construct \(misoenergy.org\)](https://www.misoenergy.org/RAN-Reliability-Requirements-and-Sub-annual-Construct)

Figure D-1: Local Resource Zones⁴

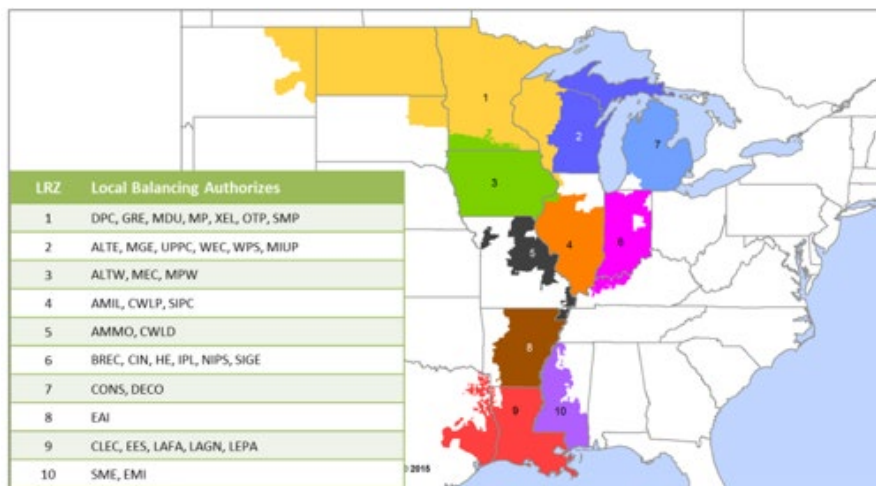


Table D-1 shows RRA projections of no excess capacity in LRZ3 and an even larger capacity shortfall than LRZ1 in the same period. These adjacent LRZs are critical for the Company’s market interactions and reduction of available capacity in these locations further threatens the reliability of the energy supply for LRZ1, as it suggests they may not always be able to provide support to LRZ1 if needed. This scenario underscores the need for strategic planning and robust risk management measures to ensure the uninterrupted operation of the energy market.

Table D-1: Estimated Net Change in Resource Type for Surrounding Load Balancing Authorities

	2027 GW Surplus or (Gap) in Accredited Capacity	2032 GW Surplus or (Gap)
LRZ 1 (Company’s LRZ)	1.0	(1.0)
LRZ 2	(1.0)	(3.0)
LRZ 3	1.0	0.0

In the face of these challenges, it is imperative that we explore and implement solutions that can effectively mitigate these risks. The amount of dispatchable capacity that is scheduled to retire from our system in the next several years requires that we earnestly analyze the reliability of our system to ensure that we can continue to be resilient and that our customers continue to experience the high levels of reliability they expect. It is

⁴ Source, [MTEP18 Book 2 Resource Adequacy264875.pdf \(misoenergy.org\)](#)

important that we plan to meet our energy and capacity obligations without overreliance on the market or exposing our customers to excessive risk.

III. ENERGY ADEQUACY ANALYSIS

To ensure we would have sufficient capacity on our system to meet our customers' needs across hours of the year, we stress tested our Preferred Plan against historical hourly load and renewable production data using Encompass modeling software. The Encompass modeling reflects actual system and market conditions and hourly production cost analysis. We use the model's full chronological modeling capabilities to run dispatch and cost analyses for the years 2027 to 2030, 2033, 2034 and 2040.

Using each historical year from 2016 to 2022, we developed an 8,760-hour historical demand shape, along with monthly peak and energy forecasts, to calculate the future system level demand and shape to use in the Encompass model. All existing wind and solar resources were dispatched based on their actual historical 8,760-hour production profiles or an 8,760-hour profile from a nearby facility. Generic facilities were given a random 8,760-hour profile. Using this historical data, we conducted a special study on four plans to ensure we would have sufficient capacity on our system to meet our customers' needs under varying weather conditions:

- (1) Reference Case (Scenario 1),
- (2) Preferred Plan (Scenario 3),
- (3) Low Load (Scenario 3), and
- (4) Market Access Optimization (Scenario 3 optimized with 2,300 MW of hourly market access).

This analysis allows us to assess the capacity and energy adequacy of our plans. We evaluated these plans on six different measures:

1. Native Capacity Shortfall: Hours of insufficient system capacity in each year.
2. Average Shortfall Intensity: Average Shortfall in MW during the shortfall events in each year.
3. Longest Shortfall Event: Longest duration in hours of the shortfall events in each year.
4. Peak Capacity Shortfall: Peak capacity shortfall in MW of the capacity shortfall events in each year.
5. MISO Market Reliance Hours: Total number of hours the plan is reliant on the market to serve load.
6. MISO Market Reliance Energy: Total amount of MWh the plan is reliant on the market to serve load.

The results for each scenario in 2030 and 2040 are shown below in Table D-2:

Table D-2: Summary of 2030 Energy Adequacy Special Study Scenario

Plan	Historical Year - Hourly Conditions in 2030	Capacity Adequacy Metrics				Energy Adequacy Metrics**	
		Native Capacity Shortfall (Hrs.)	Average Shortfall Intensity (MW)	Longest Shortfall Event (Hrs.)	Peak Capacity Shortfall (MW)	MISO Market Reliance Hours	MISO Market Reliance (MWh)
Reference Case (Scenario 1)	2016 Historical	2	76	1	94	2	153
	2017 Historical	0	0	0	0	0	0
	2018 Historical	0	0	0	0	0	0
	2019 Historical	0	0	0	0	0	0
	2020 Historical	0	0	0	0	0	0
	2021 Historical	0	0	0	0	1	192
	2022 Historical	0	0	0	0	0	0
Preferred Plan (Scenario 3)	2016 Historical	1	83	1	83	1	83
	2017 Historical	0	0	0	0	0	0
	2018 Historical	0	0	0	0	0	0
	2019 Historical	0	0	0	0	0	0
	2020 Historical	1	219	1	219	2	590
	2021 Historical	0	0	0	0	1	204
	2022 Historical	0	0	0	0	0	0
Low Load (Scenario 3)	2016 Historical	1	33	1	33	1	33
	2017 Historical	0	0	0	0	0	0
	2018 Historical	0	0	0	0	0	0
	2019 Historical	2	94	2	174	2	188
	2020 Historical	2	150	2	294	2	736
	2021 Historical	0	0	0	0	2	487
	2022 Historical	0	0	0	0	0	0

Plan	Historical Year - Hourly Conditions in 2030	Capacity Adequacy Metrics				Energy Adequacy Metrics**	
		Native Capacity Shortfall (Hrs.)	Average Shortfall Intensity (MW)	Longest Shortfall Event (Hrs.)	Peak Capacity Shortfall (MW)	MISO Market Reliance Hours	MISO Market Reliance (MWh)
Market Access Optimization (Scenario 3 Market On Expansion Plan)	2016 Historical	54	484	7	1,684	61	32,204
	2017 Historical	48	272	5	953	69	25,023
	2018 Historical	65	344	6	1,312	102	40,769
	2019 Historical	74	463	6	1,368	94	45,356
	2020 Historical	83	415	7	1,479	109	57,072
	2021 Historical	61	269	5	1,082	100	41,205
	2022 Historical	20	290	3	1,144	24	7,254
** LOLH is higher than capacity shortfall due to batteries having available capacity, but no stored energy (MWh)							

As shown in the table above, the Preferred Plan performs well across energy adequacy metrics. There are only two hours of native capacity shortfall across the seven historic years tested, resulting in limited dependence on the market. There are only four hours across the seven historical test years where the Preferred Plan requires market purchases in order to meet load serving needs. The Reference Case and Low Load scenarios also result in limited market dependence.

In contrast, under the Market Access Optimization, which allows the capacity expansion to optimize assuming market access of 2300 MWs in all hours of the year, the results show that the plan exposes our customers to excessive risk. There are 405 hours across the seven historic years where the plan has insufficient capacity to meet needs. This results in 509 hours where the plan cannot meet load serving needs and must rely on market purchases of nearly 250,000 MWhs of energy.

Our analysis of 2040, below, shows similar results as displayed in Table D-3 below:

Table D-3: Summary of 2040 Energy Adequacy Special Study Scenario

Plan	Historical Year - Hourly Conditions in 2040	Capacity Adequacy Metrics				Energy Adequacy Metrics**	
		Native Capacity Shortfall (Hrs.)	Average Shortfall Intensity (MW)	Longest Shortfall Event (Hrs.)	Peak Capacity Shortfall (MW)	MISO Market Reliance Hours	MISO Market Reliance (MWh)
Reference Case (Scenario 1)	2016 Historical	5	202	2	335	17	7,037
	2017 Historical	0	0	0	0	0	0
	2018 Historical	2	182	1	317	9	3,543
	2019 Historical	0	0	0	0	2	44
	2020 Historical	0	0	0	0	18	8,348
	2021 Historical	1	554	1	554	19	15,476
	2022 Historical	2	20	1	40	2	40
Preferred Plan (Scenario 3)	2016 Historical	5	190	2	310	14	4,622
	2017 Historical	0	0	0	0	0	0
	2018 Historical	1	271	1	271	5	1,667
	2019 Historical	0	0	0	0	0	0
	2020 Historical	0	0	0	0	7	1,671
	2021 Historical	1	323	1	323	22	10,166
	2022 Historical	1	6	1	6	1	6
Low Load (Scenario 3)	2016 Historical	5	249	3	489	5	1,436
	2017 Historical	0	0	0	0	0	0
	2018 Historical	2	171	1	299	3	1,026
	2019 Historical	2	298	2	489	2	595
	2020 Historical	2	98	1	135	9	787
	2021 Historical	1	45	1	45	15	3,527
	2022 Historical	2	118	1	158	2	237
Market Access Optimization	2016 Historical	31	667	4	1,557	58	45,347
	2017 Historical	12	210	3	387	40	18,674

Plan	Historical Year - Hourly Conditions in 2040	Capacity Adequacy Metrics				Energy Adequacy Metrics**	
		Native Capacity Shortfall (Hrs.)	Average Shortfall Intensity (MW)	Longest Shortfall Event (Hrs.)	Peak Capacity Shortfall (MW)	MISO Market Reliance Hours	MISO Market Reliance (MWh)
	2018 Historical	38	347	6	1,461	122	67,535
	2019 Historical	41	410	4	1,164	77	41,561
	2020 Historical	32	318	4	954	100	69,543
	2021 Historical	34	452	7	1,627	91	64,575
	2022 Historical	12	299	2	1,153	13	5,380
	** LOLH is higher than capacity shortfall due to batteries having available capacity, but no stored energy (MWh)						

Similar to the results for 2030, the Preferred Plan performs well across energy adequacy metrics in 2040. There are only 8 hours of native capacity shortfall across the seven historic years tested, resulting in limited dependence on the market. There are 36 hours across the seven historical test years where the Preferred Plan requires market purchases in order to meet load serving needs. The Reference Case and Low Load scenarios also result in limited market dependence.

In contrast, under the Market Access Optimization, which allows the capacity expansion to optimize assuming market access of 2300 MWs in all hours of the year, the results exposes our customers to excessive risk. There are 200 hours across the seven historic years where the plan has insufficient capacity to meet needs. This results in 501 hours where the plan cannot meet load serving needs and must rely on market purchases of over 300,000 MWhs of energy.

Limiting market dependence is important for both cost and reliability. During hours when system resources cannot meet load serving needs, purchases from the market are the only option to meet needs. During these hours, we are exposed to the prevailing Locational Marginal Energy Prices (LMPs) at load. If LMPs are high, those high cost will increase customer bills. If LMPs are high over multiple hours, those impact could be significant. More importantly, if resources are not available in the market, customers may be subjected to reliability impacts. As one of the largest utilities in MISO Zone 1, the potential for reliability impacts in the region are greater if we have insufficient resources to meet our load serving needs.

Figures D-2 through D-5 below provide additional insight into the energy adequacy of the four plans analyzed.

Figure D-2: Reference Case (Scenario 1)

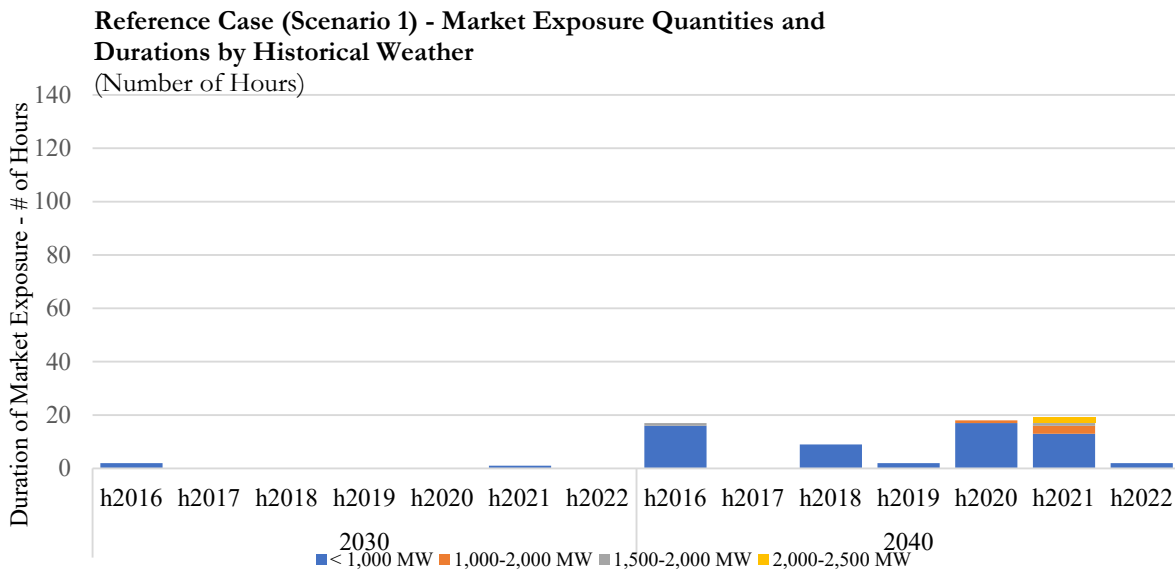


Figure D-3: Preferred Plan (Scenario 3)

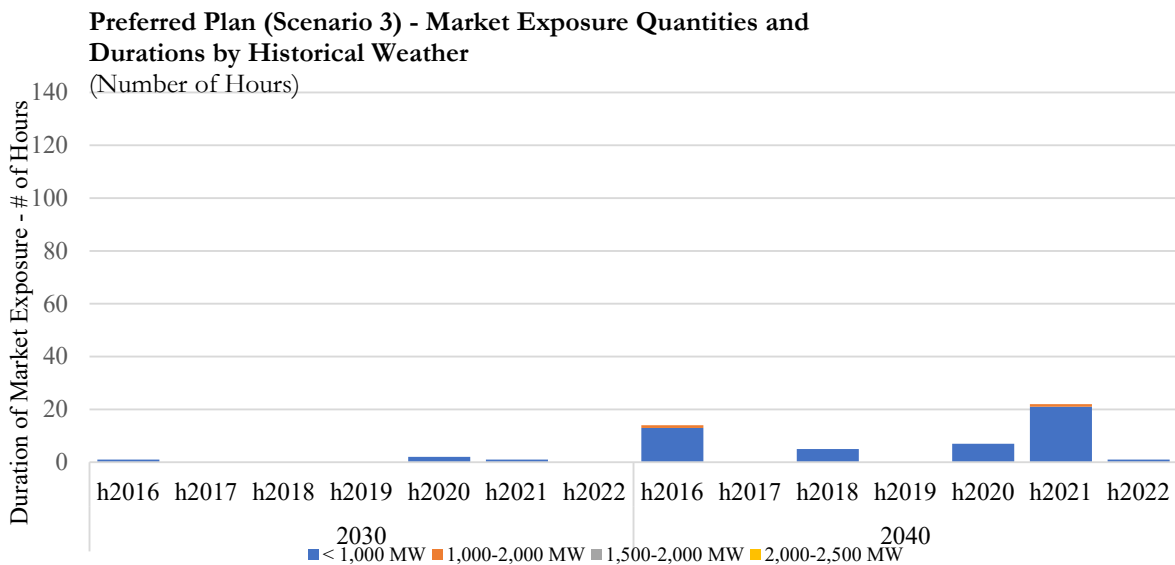


Figure D-4: Low Load (Scenario 3)

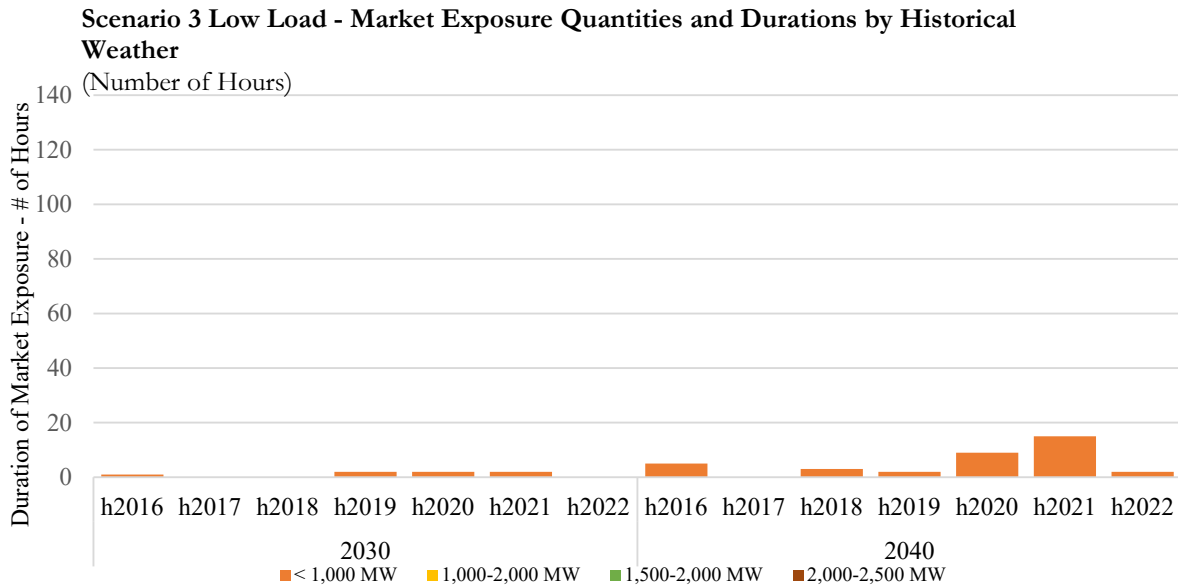
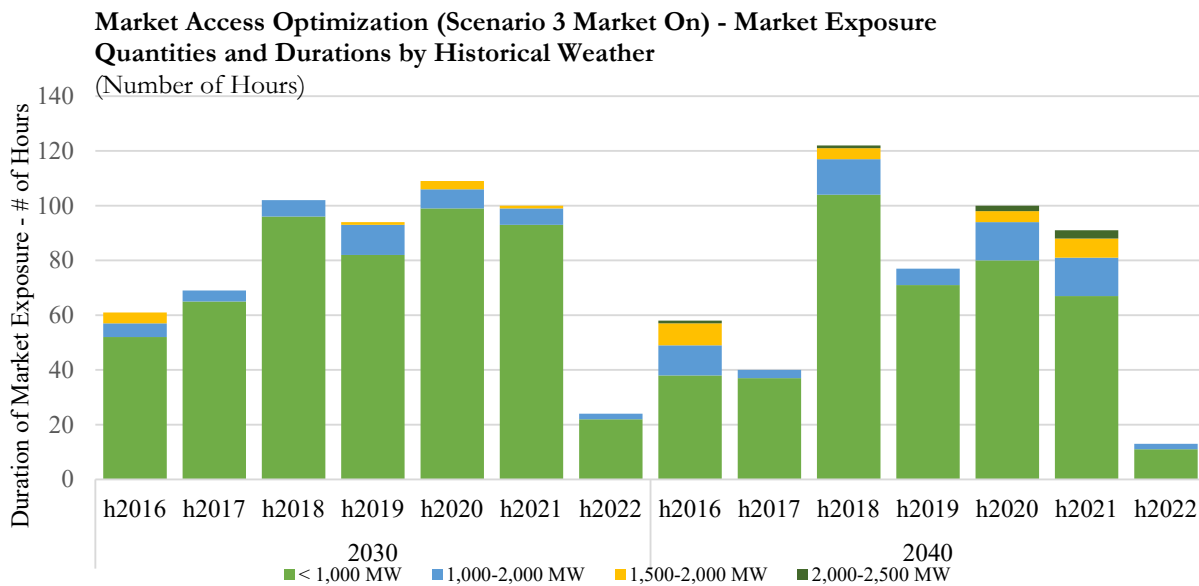


Figure D-5: Market Access Optimization
 (Scenario 3 optimized with 2,300 MW of hourly market access).



The figures above show the market dependence of each scenario analyzed. The bar for each historic year shows the impact in 2030 in 2040 both in terms of the number of hours of market dependence and the magnitude of those hours. The darkest green

shows hours where over the system must rely on the market for over 2,000 MWs of purchases in order to serve load. Consistent with the results above, the Preferred Plan, Reference Case and Low Load scenarios also result in limited market dependence. In contrast, the Market Optimization analysis shows significant market dependence.

The tests and metrics above focus on limiting market dependence. There are many reasons market exposure can occur, including fluctuations in pricing, weather, load, or generation that last for a few acute hours or for 1–2-day periods. However, in addition to limiting market dependence across all events, different plans can also differ starkly in terms of how they weather a longer period – 4 days – of lower than expected solar and wind generation.

The need for our resources to be able to cover energy needs over an elongated period of time is important because we have seen historical, and projected instances of low renewable output that could create havoc for reliability were there not a sufficient amount of firm capacity to cover energy needs. For instance, recently customers in Oahu were asked to reduce use of electricity to avoid rolling blackouts across Oahu due to a shortage of reserve generation capacity.⁵ Two large generating units at Waiiau Power Plant went offline, and repairs were not expected to be completed by the end of the day. Heavy cloud cover and rainy conditions reduced the production from solar energy systems and prevented battery energy storage systems from charging to full capacity. As a result, Hawaiian Electric began load shedding in various areas around the island to avoid a more widespread outage or damage to the electric system from an imbalance of demand versus available generation.

Further, the Moon Shoot study⁶ by GridLab, emphasized the importance of firm dispatchable generation to support a clean energy policy. The study noted that short storage duration batteries (typically 4 to 10 hours) can provide a significant amount of capacity for reliability, but they cannot be the only capacity resource on the system (unless systems are upsized in terms of solar and wind resources, or capacity expansions are planned through a regional optimization approach). There may be long periods—potentially spanning multiple days—where solar and wind are unavailable, requiring other resources (such as hydrogen capacity) to be available in these times. During this time, even relatively long, 10-hour duration battery storage does not bridge the gap between periods of renewable production and demand.

⁵ <https://www.hawaiianelectric.com/update-rolling-oahu-outages-initiated-customers-asked-to-reduce-use-of-electricity>.

⁶ The Moonshot 100% clean electricity study:
Assessing the tradeoffs among clean portfolios with a PNM case study, Grid Lab
<https://gridlab.org/moonshot-study/>.

In conclusion, energy adequacy analysis is a critical tool in resource planning. It helps ensure that we have a diverse and resilient energy portfolio capable of meeting demand. This not only ensures the continuous supply of power but also contributes to the broader goals of affordability, carbon reduction and job creation.

IV. THE IMPORTANCE OF FIRM DISPATCHABLE RESOURCES IN OUR PREFERRED PLAN

As we work to decarbonize our system, our models indicate the need for the addition of approximately 3,600 MWs of cumulative firm dispatchable resources between 2027 and 2040 to ensure long-duration, affordable energy when our intermittent renewables are not able to fully meet our customers' needs. Of this modeled need, 2,244 MWs of firm dispatchable resources are needed by 2030. These resources are split between 748 MWs in 2027, 748 MWs in 2028, and 748 MWs in 2030. Approximately 374 MWs of the 2028 need is located on our re-optimized Sherco Generation tie line.

We note that the Commission is considering firm dispatchable resources additions in Docket No. E002/CN-23-212. Additional firm dispatchable resources above 800 MWs have bid into the acquisition proceeding to serve our up to 800 MW need identified in our 2019 Plan. As noted here, firm dispatchable resources provide numerous benefits, including near-instant availability, making them ideal for peak power supply and when intermittent wind and solar generation are not producing energy.

The value of firm dispatchable resources and fuel diversity becomes evident during periods of extreme weather. During the 2019 Plan, it was observed that firm dispatchable resources were crucial during severe cold spells when wind resources underperformed. Even with a hypothetical doubling of wind output, there were periods of low renewable output. Hence, having diverse resources is essential to meet customer needs during such events. A diverse mix of firm dispatchable resources ensures our ability to provide reliable electric service under all conditions. With the increasing frequency of extreme weather events, it is crucial to manage the transformation of our generation portfolio while preserving system reliability and stability. Though our nuclear units remain a major source of reliable, carbon-free generation for our system, our modeling shows a need for additional firm dispatchable generation.

Extreme events can span all or nearly all of MISO's footprint, limiting the ability to rely on the broader MISO system in times of need. To meet the shortfall in the output of variable resources; at such times, we may have to rely on our resource diversity and our dispatchable generation, including units fueled by natural gas and fuel oil. With the increasing frequency of extreme weather events, such as the 2019 polar vortex and

Winter Storm Uri in 2021, it is crucial to manage the transformation of our generation portfolio while preserving system reliability and stability. Any disruption in electric service during similar future events could have serious impacts on our customers, public safety and to overall grid operations.

In sum, from a high-level capacity and reliability standpoint, the importance of firm, dispatchable resources in our energy strategy is undeniable. As we transition towards a more sustainable energy future, these resources provide the reliability and stability necessary to ensure uninterrupted service under all conditions. While advancements in transmission technologies, renewable energy sources, and energy storage resources are promising, they cannot at this time fully replace the need for firm dispatchable resources due to their current technological maturity, regulatory complexities, and the challenges in large-scale deployment. Therefore, a balanced approach that includes a diverse mix of firm, dispatchable resources, is crucial in meeting the growing energy demand while also progressing towards decarbonization.

VI. INERTIAL FLOOR STUDY

In addition to considering the value of various resources from a high-level capacity and reliability view, the Company is assessing the electrical engineering impacts of moving from a system built around large, centrally located baseload units to one based more on remotely located renewable generators. Studies that the Company and others have conducted show that the inertia historically provided by these baseload units is crucial to help the system oscillations dampen out. To help inform decisions for future generation transformation from traditional coal-based generation, the Company's Transmission Planning engineers performed a study to evaluate the NSP system's transient stability response with all of the baseload coal generation in the region offline and replaced by renewable generation (wind and solar) and other thermal generation. Unlike traditional MISO generator replacement studies, this study considers not only what happens to our system as we retire Company-owned coal generation but also potential retirements of neighboring coal generation. At this time, MISO only studies system impacts of unit retirements based on unit-specific requests made by the owners of such units. However, we understand that the vast majority of utilities within MISO are considering similar renewable initiatives to the Company. Therefore, while MISO's studies currently reflect the transmission system as being reliable and stable, they do not provide a forward-looking regional assessment of stability as coal retirements continue.

We include as an attachment to this appendix, our NSP Power System Inertial Floor Study Report, showing how the grid would perform in the absence of traditional baseload generation, mainly coal and nuclear. This Inertial Floor study is run annually to

update the analysis and evaluate the impacts to our system reliability, system stability, angular stability and inertia. This analysis allows us to determine the necessary levels of spinning mass and/or dispatchable generation necessary to keep the system stable and reliable to serve our customers.

Our study shows that inertia is crucial to help the system remain stable, and as we and other owners of baseload generation in the region retire those units, we begin to see regional stability issues. This demonstrates that it will be critical that we acquire resources capable of providing inertia as we retire our coal-fleet.

VI. CONCLUSION

Preparation and planning are key to delivering reliable power to our customers. As a Company, we take this responsibility seriously. Recent events have shown that it is important to plan for how we can provide electricity to our customers under all conditions. In addition to planning to meet our planning obligations without reliance on MISO, we have taken steps to further refine our energy adequacy analysis. We conducted energy adequacy back casting analysis to ensure our system has the reliable energy it needs to serve all customers at every hour of every day. We also examined the inertial floor of our system to assess how the grid would perform in the absence of traditional baseload generation. Our studies go beyond traditional EnCompass modeling to verify the need for firm dispatchable resources and inertia to ensure reliable service for our customers. Our Preferred Plan satisfies these concerns and will provide for the reliability our system needs to adequately ensure continued service to our customers.