2022 Grid in Transition Study: A Study of Expected Ramp Rates

A Report by the
New York Independent System Operator

19 December 2022

DRAFT FOR DISCUSSION PURPOSES ONLY

Table of Contents

EXECUTIVE SUMMARY **3**
BACKGROUND **4**
Study Structure 4
Metrics Used 6
Three- and Five-Hour Ramping Needs 6
Multi-Hour Ramp Metric 6
PHASE 2 RESULTS **7**
Net Load Shapes 7
Net Load Ramps and Metrics 9
CONCLUSION **15**
Appendix 1 - Data Sources and Metric 16
Description of Wind Data Collection and Analysis used in Phase 1 16
Net Load and Ramp Calculations- Phase 1 20
Net Load and Ramp Calculation- Phase 2 21
Assumptions- Solar (BTM and FTM)- Phase 1 21
Assumptions- Solar (BTM and FTM) and Wind- Phase 2 22
Appendix 2: Phase 1 analysis 23
Introduction 23
Phase 1 Net Load Results 23
Phase 1 Ramp Analysis Results 26
Appendix 3: Additional Phase 2 Data 35

Executive Summary

A rapid transition is underway in New York State from a power grid where energy is largely produced by central-station fossil fuel generation, towards a grid with increased intermittent renewable resources and distributed generation. This study looks at future net load variability to inform the NYISO and its stakeholders on the need for wholesale market mechanisms to enhance grid resilience. As such, the study is focused on the future ramp needs.

The study looks at net load (load net of the output from all intermittent resources on the wholesale and distribution systems) to understand the variability that the grid will require future flexible generation to respond to.

Using the information from the *2021-2040 System & Resource Outlook* (The Outlook) and its two Policy Cases, Scenario 1 and Scenario 2, this Grid in Transition study points to increasing ramp needs over time but also finds differences over two distinct timeframes. In the next 8-9 years (the "near future"), the average ramp up needs increase, but the maximum ramp needs are flat and comparable to those observed in 2021. Beyond that period, the study finds that both the average and maximum ramp up needs are increasing. This result stems directly from the uncertainty of the constituents of the net load forecast and the underlying linear input assumptions.

Given the near flat maximum ramp up needs, at levels comparable to current maximum ramp need, and the current set of NYCA resources, the NYISO does not see an urgent need to incentivize resources to provide additional hourly ramp in the near future. The increase in the average multi-hour ramp up over this same time period does, however, point to an increased need for sustained ramp over the day. The *2023 Balancing Intermittency Project* will provide the opportunity to examine possible evolutions of the existing market rules to address this need.

Due to the high degree of uncertainty over the longer-term horizon of this study, future load forecasts, planning studies and the insights provided by new information will provide a better understanding of ramping needs beyond 2030.

Background

A reliable grid characterized by high levels of intermittent renewable resources and distributed generation will require new thinking. Looking to the future, the NYISO approaches potential market enhancement efforts with two guiding principles:

1. all aspects of grid reliability must be maintained; and
2. competitive wholesale electricity markets should continue to maximize economic efficiency and minimize the cost of maintaining reliability while supporting the achievement of New York's climate policy codified in the 2019 Climate Leadership and Community Protection Act (CLCPA).

This study intends to inform the NYISO's planning, forecasting, and operations, as well as the development of wholesale market mechanisms to enhance grid resilience.

Using the work completed to date across various NYISO studies and initiatives, this study provides information on the grid attributes needed and quantifies the potential level of ramping and sustained energy needs necessary to reliably maintain system balance. The *2023 Balancing Intermittency Project* will continue this work by examining the existing NYISO market structures, including the level of dispatchability and ramping capability that may be needed to balance intermittency. This 2023 effort will also assess existing market rules and will determine appropriate compensation mechanisms to incent such attributes, including the potential for new market products, such as ramping or new reserve products, or other market changes needed to support reliability.

Study Structure

This Grid in Transition study is split into two phases. Phase 1 leverages the *Climate Change Phase 1*[1] "CLCPA Case" hourly load data and the *2021-2040 System & Resource Outlook* (The Outlook)[2] capacity expansion buildout, while Phase 2 uses all inputs directly from the Outlook study (for example, load, renewable buildout, wind, and solar output). Both study phases leverage the two Outlook study Policy Cases, Scenario 1 and Scenario 2.

- **Scenario 1 (S1)** - Utilizes industry data and NYISO load forecasts, representing a future with high demand (57,144 MW winter peak and 208,679 GWh energy demand in 2040) and

[1] Itron, New York ISO Climate Change Impact Study, Phase 1: Long-term Load Impact, December 2019 https://www.nyiso.com/documents/20142/16884550/NYISO-Climate-Impact-Study-Phase1-Report.pdf/4311bdd4-a389-afbe-9ee9-b6bf523b0a36

[2] NYISO, 2021-2040 System & Resource Outlook (The Outlook) September 22, 2022. https://www.nyiso.com/documents/20142/33384099/2021-2040-Outlook-Report.pdf/a6ed272a-bc16-110b-c3f8-0e0910129ade

assumes less restrictions in renewable generation buildout options.

- **Scenario 2 (S2)** - Utilizes various assumptions more closely aligned with the Climate Action Council Integration Analysis and represents a future with a moderate peak but a higher overall energy demand (42,301 MW winter peak and 235,731 GWh energy demand in 2040). These cases have different load assumptions and therefore different buildouts and different hourly renewable energy production.[3]

The differences between these two policy scenarios, especially in the renewable resource buildouts, lead to different outcomes as will be explained in the metrics of this study.

In this study's Phase 1, the underlying data for the load and the buildout of renewable resources come from two different sources which can result in mismatches (see the discussion in the

Data section). This does not occur in Phase 2 because of the single source for the data. For this reason, the study focuses on the Phase 2 results. The Phase 1 results can be found in Appendix 2: Phase 1 analysis.

Data

The study focuses on the variability that dispatchable resources will face in the future. This leads to a somewhat broader net load definition than is usually used.[4] The metric used here looks at the hourly variability of load net of the output of *all* renewables (solar behind-the-meter, wholesale solar, land-based wind and offshore wind).

Net Load =

Load forecast

minus Front-of-the-meter solar output

minus Offshore wind output

minus Land-based wind output

As mentioned above, in Phase 1, the buildout of renewables is not closely tied to the assumed load and can lead to hours with apparent negative net loads, which do not materialize in operations. This can lead to larger than reasonable ramps. This comes about because the buildout from the Outlook capacity expansion is not matched to the load used in this portion of the study. The result is apparent "negative load" events. Operationally this would be a significant concern and highlights the need for a sufficient number of resources to be in front-of-the-meter for the NYISO to manage these events,[5] therefore, the

[3] NYISO, *2021-2040 System & Resource Outlook* (The Outlook), page 9.

[4] Net Load is commonly used to refer to load net of behind-the-meter generation.

[5] Operationally the NYISO would never see "negative net load" events. Instead, there would either be an increase in net exports, an increased in price responsive load or renewables would be curtailed. One way to approximate that is to bring all instances of negative net load to zero in the analysis.

study is focused on the Phase 2 results.[6]

The renewable outputs are derived from the capacity expansion portion of the Outlook study combined with the same wind and solar "shapes" used in the Outlook and other planning studies. Detailed information about these inputs is available in Appendix 1 - Data Sources and Metric.

Metrics Used

Although looking at hourly ramps is informative, the ramp up is particularly useful when considering the future needs of the grid. The ability to ramp up is expected to become increasingly scarce as the grid transitions from primarily flexible fossil resources to large amounts of intermittent resources that are dependent on the availability of wind and the sun. Because the NYISO requires most generation to be on dispatch, ramp down events are of lesser operational concern because of the ability to dispatch down renewable resources and to curtail over production.

In addition to hourly ramps, the analysis looks at several additional metrics, including three- and five-hour ramping needs and a multi-hour ramping metric.

Three- and Five-Hour Ramping Needs

The three- and five-hour ramp metrics are rolling metrics that look at the in-day net ramp (including all intermittent resources) over three- and five-hours.

Multi-Hour Ramp Metric

Because ramping events do not necessarily fit into nice one-, three-, or five-hour boxes, these metrics looks at the ramp needs over the entire up or down in-day ramp period. This metric quantifies the entirety of each ramp event. For example, if over a 24-hour period the net load ramps down for 6, up for 8- hours, down for 2, then up again for 5, and down for 3 the metric would show three down ramp events for 6, 2, and 3-hours and two up events for 8 and 5-hours.

This metric conveys the full magnitude of ramp up events and is particularly important when considering what conditions flexible generators will have to respond to.

[6] The Phase 1 results can be found in Appendix 2: Phase 1 analysis.

Phase 2 Results

Net Load Shapes

The summer, winter, and shoulder peak net load shapes (Figures 1 through 3 below) are provided for Policy Cases S1 and S2 for the years 2030 and 2040 to provide a snapshot of the expected loads. The figures also include the actual 2021 load shapes for reference. The dates for the summer and winter peak net load shapes were chosen based on the hour of the highest and lowest net load values over the entire year, while the date for the shoulder peak net load shape was chosen to be the first day of May.

The impact of the different assumptions of Policy Case S1 and S2 in the later years can be clearly seen in the 2040 load shapes for summer (Figure 1) and winter (Figure 2). The load shapes for the two Policy Cases are generally very similar in 2030, which is to be expected given the similar buildouts for that year. By 2040 the renewable buildouts have diverged enough to show very different net load forecasts for the two Policy Cases in summer and winter. The load shapes of the shoulder period (Figure 3) are not easy to characterize. The load shapes are relatively tightly grouped. They are about half of the actual 2021 load levels from midnight until HB18 but are comparable in the evening hours.

Figure 1: Summer Peak Net Load Shapes for 2030, 2040 (and actual 2021)

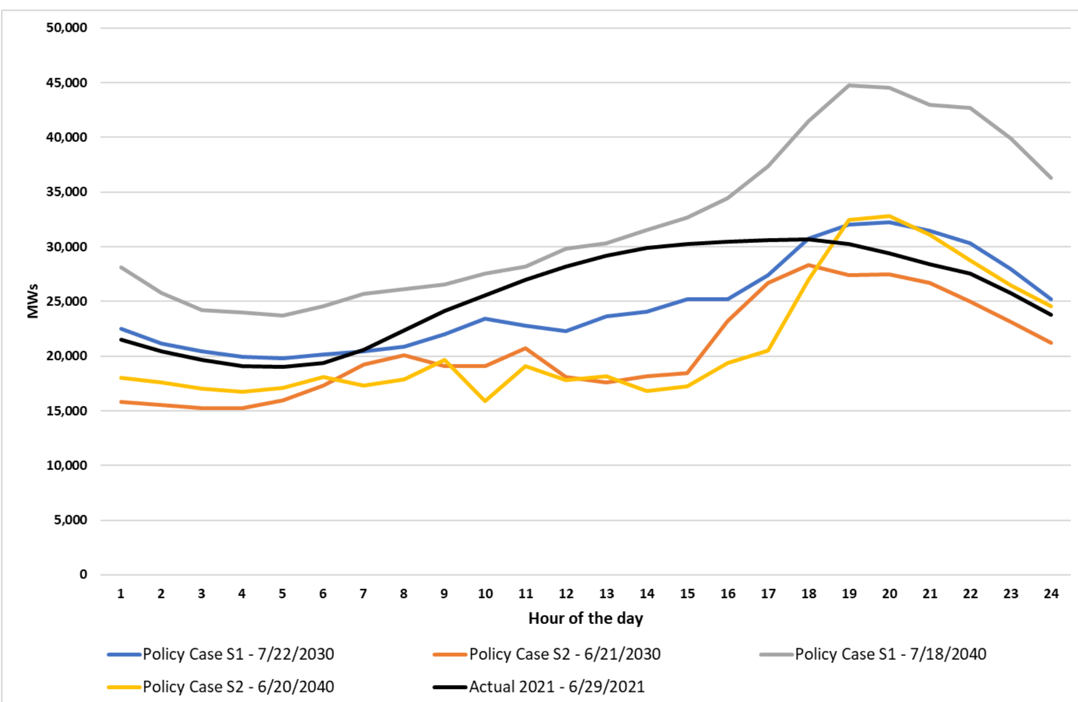


Figure 2: Winter Peak Net Load Shapes for 2030, 2040 (and actual 2021)

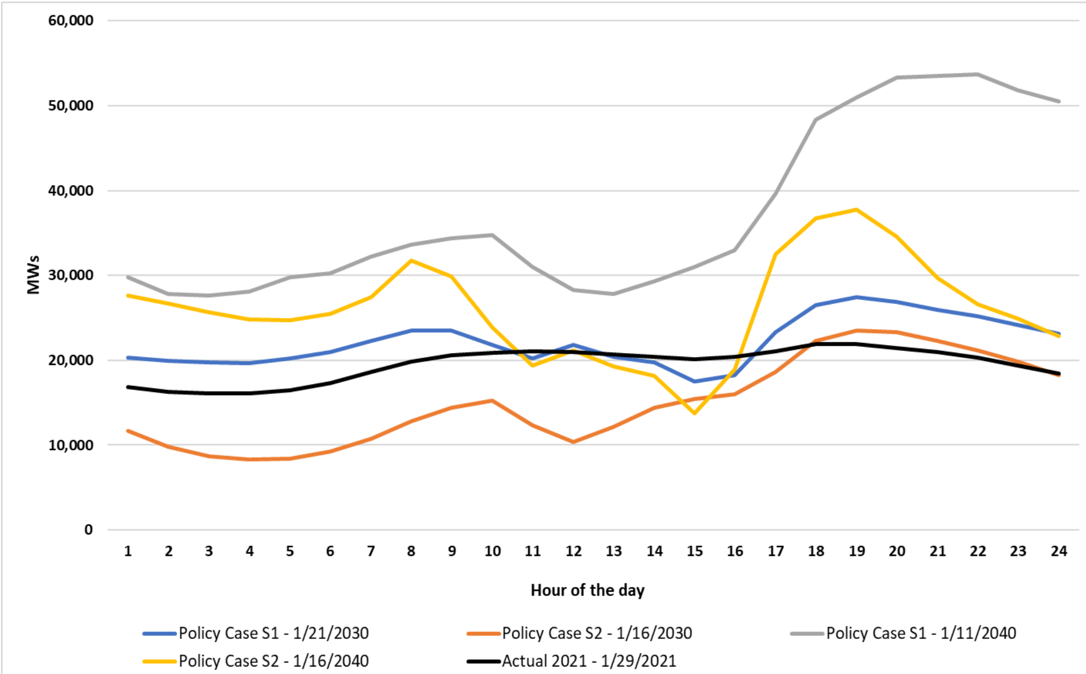


Figure 3: Shoulder Peak Net Load Shapes for 2030, 2040 (and actual 2021)

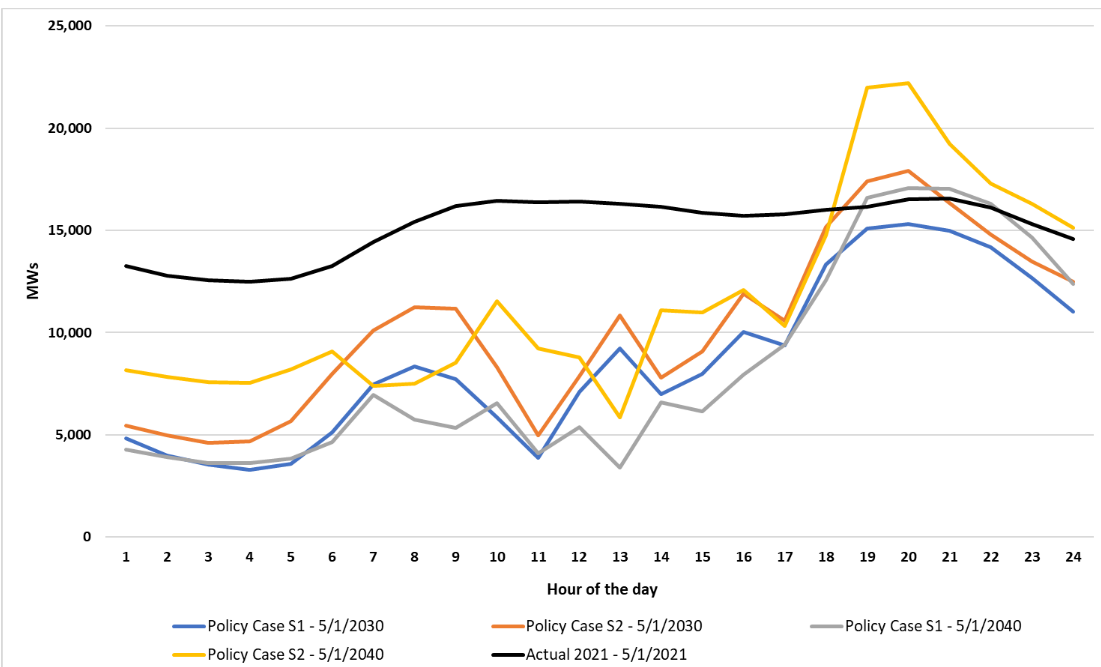
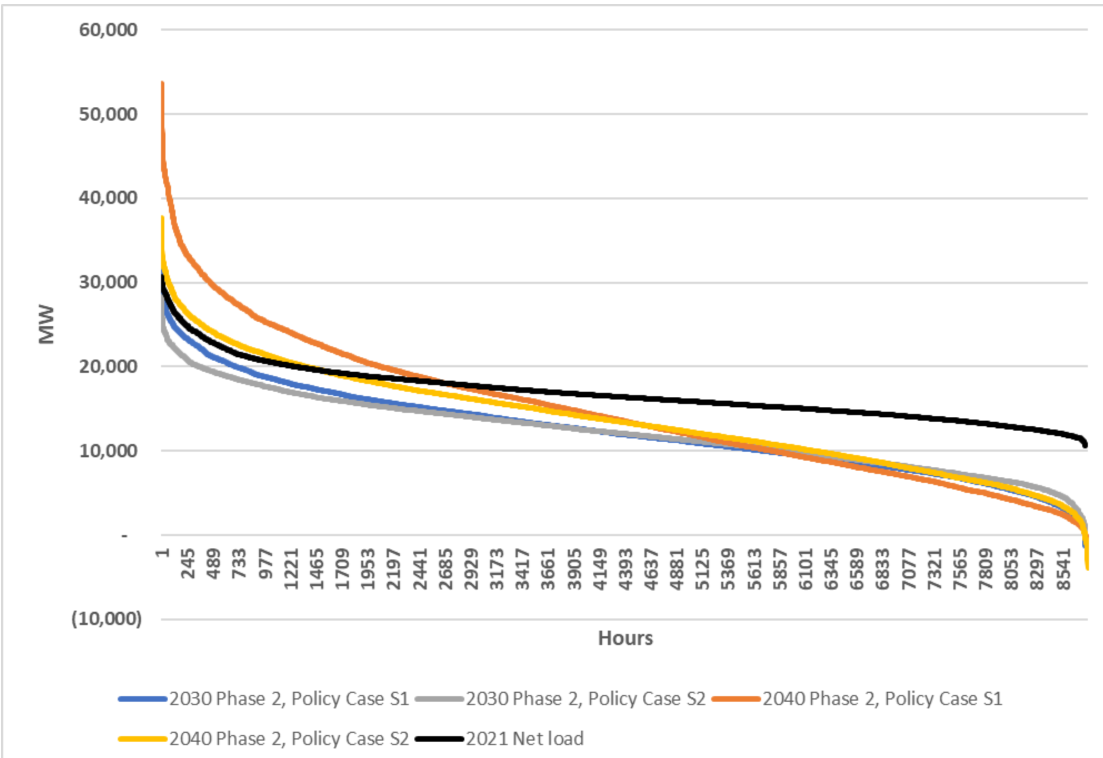


Figure 4 shows the net load duration curves over the entire year for 2030, 2040, and the 2021 actual net load. Here too, the differences between Policy Cases S1 and S2 can be seen in 2040. The shape of the net load duration curves in 2030 shows little differentiation between the Policy Cases and is similar to the 2021 curves in the upper portion of the net load curve, however, there are many more low load hours in 2030 than are currently experienced. This is consistent with the expected buildout of renewables.

Figure 4: Net Load Duration Curves



Net Load Ramps and Metrics

The key to this Grid in Transition study is that the expected ramp requirements can be derived from the net loads and what they can tell us to expect in the future. To understand this, we looked at hourly, three-hour, five-hour, and multi-hour ramp needs.[7]

Figures 5 and 6 provide the hourly net load ramp distribution curves for Policy Cases S1 and S2 for every 5 years from 2025 to 2040. From this it can be seen that both the ramp up and ramp down events are increasing over time.

[7] More information on the metrics can be found in the Appendix.

Figure 5: Net Load Single Hour Ramp Distribution Curves Policy Case S1

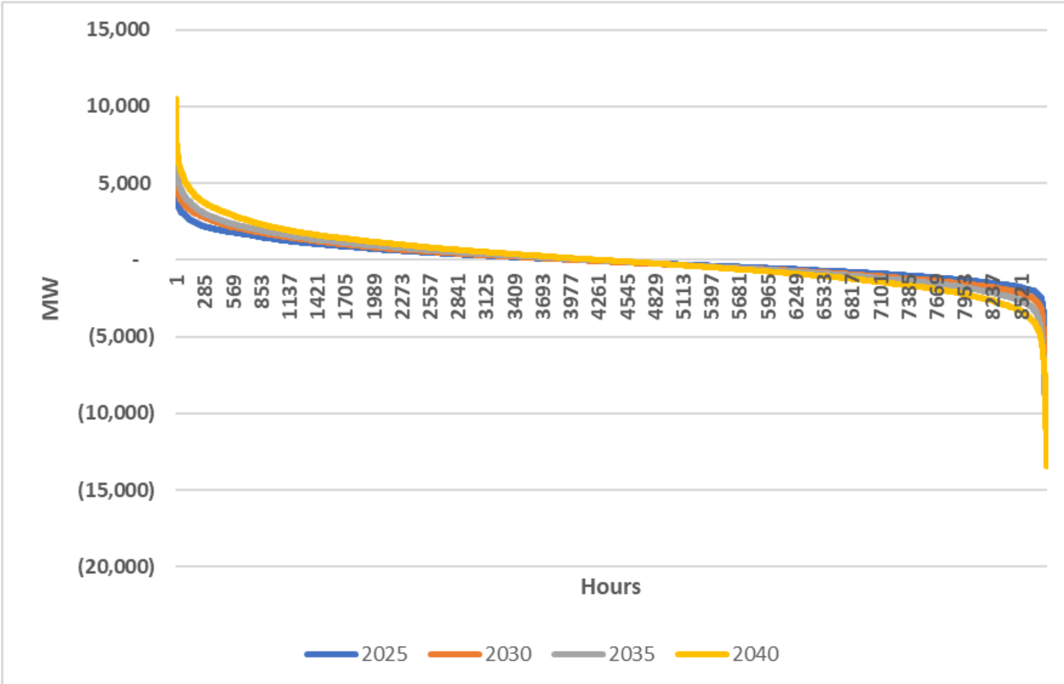
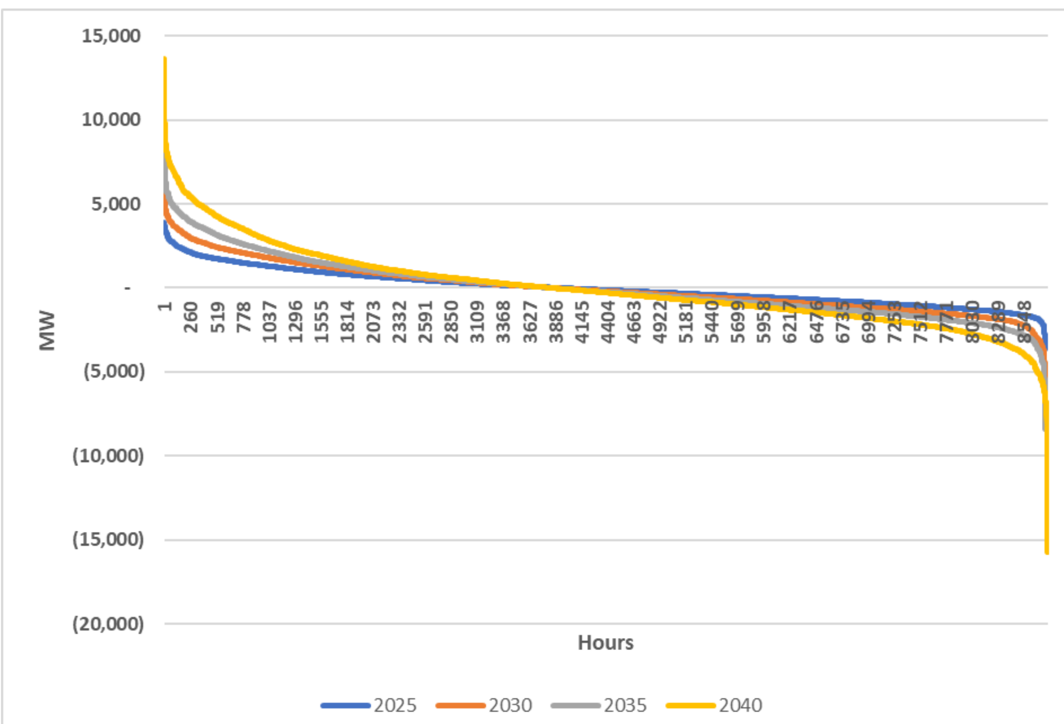


Figure 6: Net Load Single Hour Ramp Distribution Curves Policy Case S2

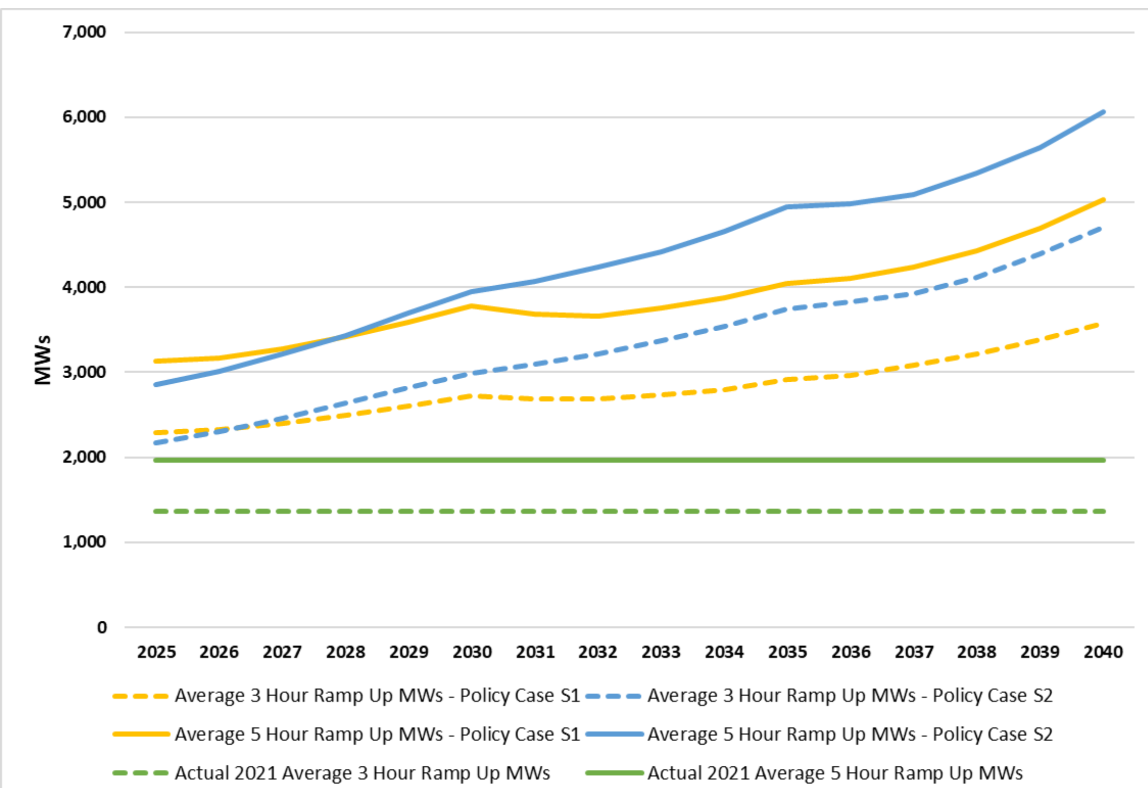


Although looking at both ramp up and ramp down is informative, the ramp up is particularly useful when considering the future needs of the grid and will be the focus of the metrics. Since the NYISO requires most generation to be on dispatch, ramp down events are of lesser operational concern.

Figures 7 and 8 provide the three- and five- hour ramp up average and maximum metrics for the two Policy Cases and also provide the metrics calculated with actual 2021 observed net load for comparison,[8] In 2025, both the average and maximum three- and five-hour ramps are higher than those observed in 2021 and they increase from there. Consistent with the underlying buildouts, the two Policy Cases three- and five-hour metrics start out at similar points and their divergence increases over time as the buildouts diverge.

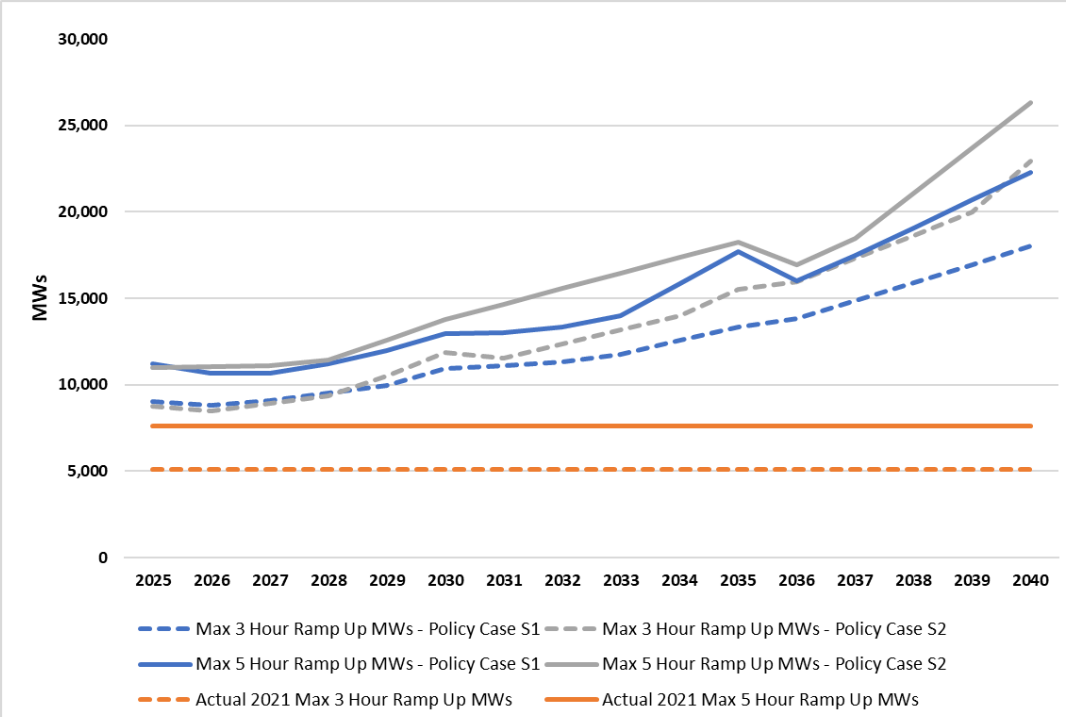
The three- and five-hour maximum ramp up trends over time show some differences in the initial years, whereas the average ramps are nearly uniformly increasing. The three-hour maximum ramp shows a steady increase in the first few years, while the five-hour maximum ramp appears to be somewhat flat (even decreasing slightly in the case of Policy Case S1). After approximately 2030 the five-hour maximum ramp increases over time.

Figure 7: Phase 2 Analysis - Three- and Five-Hour Average Ramp Ups Over Time and 2021 Actual



[8] Annual metrics can be found in Appendix 3: Additional Phase 2 Data.

Figure 8: Phase 2 Analysis - Three- and Five-Hour Maximum Ramp Ups Over Time and 2021 Actual



The multi-hour ramp metric provides information for the entirety of the ramp up and ramp down events. Because of this, it is the metric that most closely speaks to the amount of variability that future flexible generation will have to respond to over the course of the day.

Table 1: Multi-Hour Ramps Over Time

Scenario	Year	No. of Instances	Ramp up or down?	Average number of Ramp hours	25%ile Number of Hours	50%ile Number of Hours	75%ile Number of Hours	Max number of hours	Min number of ramp hours
Policy Case S1	2030	1051	Ramp Up	3.8	2	4	5	17	1
Policy Case S1	2040	1162	Ramp Up	3.7	1	3	5	16	1
Policy Case S2	2030	1074	Ramp Up	3.6	1	4	5	9	1
Policy Case S2	2040	1265	Ramp Up	3.0	1	3	4	11	1
Policy Case S1	2030	1053	Ramp Down	4.5	1	4	8	16	1
Policy Case S1	2040	1161	Ramp Down	3.9	1	3	6	14	1
Policy Case S2	2030	1074	Ramp Down	4.6	1	4	7	18	1
Policy Case S2	2040	1265	Ramp Down	3.9	1	3	6	16	1

No trends in the average ramp hours, up or down, were noted (Table 1). Similar to the three- and five-hour metrics, Figures 9 and 10 provide the average and maximum ramp up metrics though 2040 and the actual 2021 metric for reference. In this metric, we again see the increasing ramp needs in the average ramp; however, it is notable that the observed flat period in the five-hour maximum ramp metric is even more pronounced in this multi-hour metric (Figure 10). Over the next eight- to nine-years the multi-hour ramp up events remain approximately the same as what the system currently faces.

Table 2 focuses on the larger ramp up events and the seasonal distribution of those events. Surprisingly, there is no evidence of seasonality in the larger ramp up events. The large ramp up events are spread throughout the year.

Figure 9: Multi-hour Metric Average Ramp Up Over Time and 2021 Actual

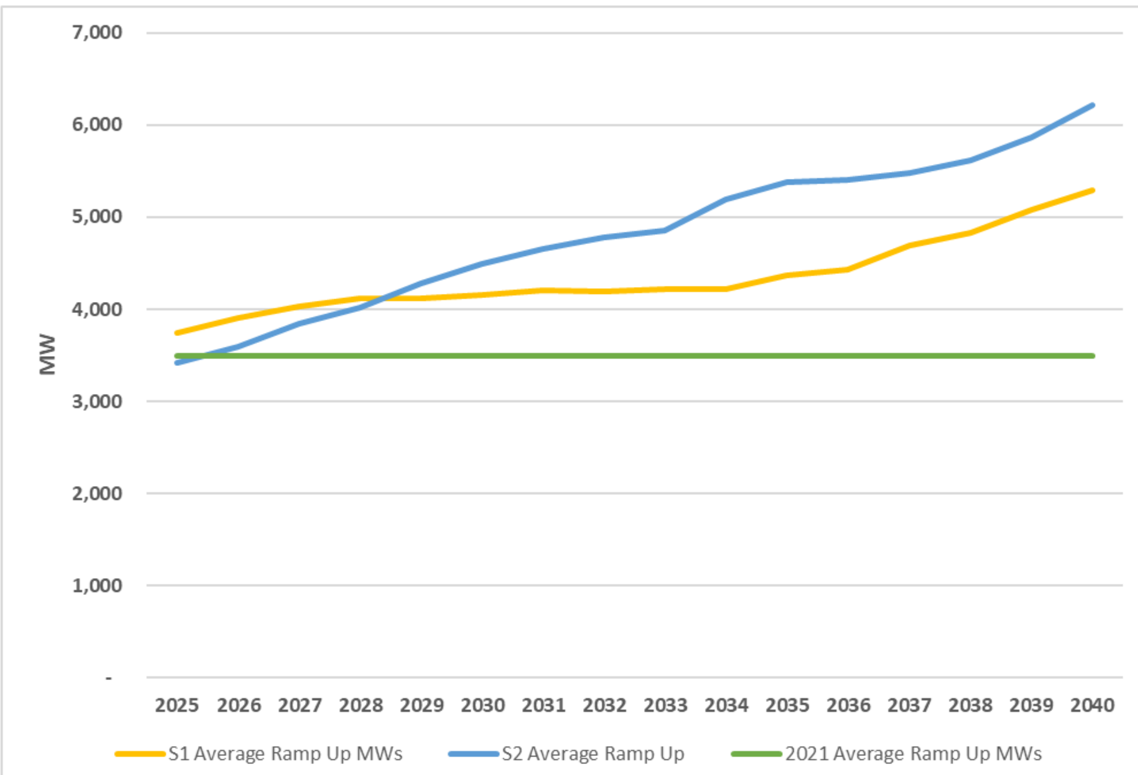


Figure 10: Multi-Hour Metric Maximum Ramp Up Over Time and 2021 Actual

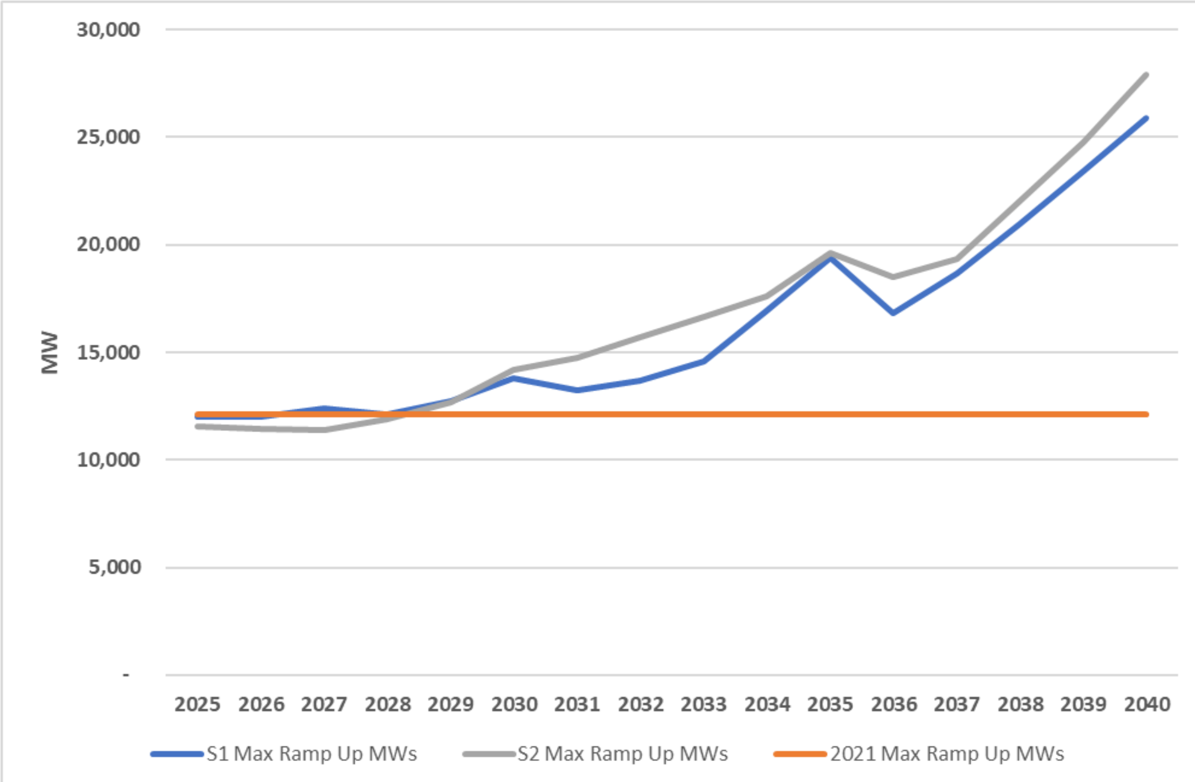


Table 2: Multi-Hour Ramp Up Needs – Focusing on greater than 5GW and 10 GW Ramps

Scenario	Year	No. of Instances	Ramp MWs	Average number of Ramp up hours	Average ramp MWs	Shoulder % (6 months)	Winter %	Summer %	25 %ile Ramp MWs	50 %ile / Median Ramp MWs	75 %ile Ramp MWs
Policy Case S1	2030	364	>5000	6.1	8428	48%	29%	24%	6763	8392	9920
Policy Case S1	2040	461	>5000	6.0	10613	47%	29%	24%	7287	10161	13420
Policy Case S2	2030	441	>5000	5.2	8081	50%	28%	22%	6144	7773	9691
Policy Case S2	2040	550	>5000	4.5	11828	49%	29%	21%	7471	11219	15195
Policy Case S1	2030	86	>10000	7.2	11266	42%	30%	28%	10569	11077	11767
Policy Case S1	2040	239	>10000	6.9	13729	37%	33%	30%	11489	13306	15402
Policy Case S2	2030	94	>10000	5.8	11263	54%	31%	15%	10398	11051	11923
Policy Case S2	2040	314	>10000	5.1	15323	48%	28%	24%	12180	14391	17597

Conclusion

This study unsurprisingly points to increasing ramp needs over time but finds different needs in two timeframes. The first timeframe is the next 8-9 years (the “near future”) when there is more information about the constituents of net load and the second timeframe is the period beyond that when there is more uncertainty. Current trends and government commitments to load electrification and to the buildout wind and solar are much better understood over the next decade. However, looking beyond that period is useful to analyze the impact of longer-term policies, such as the CLCPA goal of a 100% zero-emissions electricity grid by 2040, but there is more uncertainty in the net load projections.

Over the near future, the ramp metrics looked at in this study are somewhat mixed. They exhibit either a fairly flat or a very slight growth in maximum ramp while at the same time showing a growth in overall ramping needs as evidenced by growth in the average ramp needs. This holds for both the Outlook Policy Cases.

Beyond the near future, all the metrics and the two Policy Cases are in agreement that the average and maximum ramps will be growing. However, the uncertainty of the forecasts for this period mean that it is very dependent on the underlying assumptions of the studies. Since little or no information is available that far out, many of the underlying assumptions project linear growth and that translates to the growth seen in the ramping metrics.

The next 8-9 years is the time period to focus on because there is more information for that period and because we need to understand if there are urgent operational or market design needs and where these needs fit within the project cycle timeframe.

Of all the data and metrics examined in this study, the multi-hour metric is the one that most closely speaks to the amount of variability that future flexible generation will have to respond to because it looks at the entirety of the ramp event. In this near future timeframe, the multi-hour metric shows an essentially flat maximum ramp need while at the same time an increasing average ramp need. From this metric, and with the current set of NYCA resources, the NYISO does not see an urgent need to incentivize resources to provide additional *hourly* ramp. We are, however, seeing that the increasing average multi-hour ramp translates to a sustained ramp need over the day. The *2023 Balancing Intermittency Project* will provide the opportunity to examine possible evolutions of the existing market rules to address this need. Finally, it is worth noting that this study is based on currently available information and projections. Future studies and the insights provided by new information will provide more understanding of longer-term ramp needs.

Appendices

Appendix 1 - Data Sources and Metric

Description of Wind Data Collection and Analysis used in Phase 1

Data sources

- Offshore Wind Annual Hourly data for 2009 from NREL
- Land-Based Wind Annual Hourly data for 2009 from NREL
- 2019 Wind Unit Profile data from NYISO Planning
- Land Based Wind New York Counties' Capacity data from NREL
- Offshore Cluster Capacity Zonal POI data from NYISO Planning
- Wind Forecasted Capacity data from System and Resource Outlook
- Wind facilities that have completed Class Year studies and CRIS requests from Gold Book 2022
- Wind facilities from NYSERDA database that are in the pipeline
- Current Wind capacity data from NYISO marketplace
- Hourly zonal load from the Climate Change Phase 1 data (For Phase 1)
- Hourly zonal generation and load data for Policy Cases S1 & S2 for 2025, 2030, 2035, and 2040 from the System and Resource Outlook

Data collection and forecasting for Land Based Wind

1. From the 2019 Wind unit profile data, the maximum generation of each wind unit was taken to calculate the average percentage of the wind units' capacity from NYISO marketplace that the current units were generating in 2019. This average percentage is not to be confused with the capacity factor which is calculated considering the total actual generation of the wind units and total generation of the wind units if wind was blowing all the time.

2. The hourly data in the Land Based Wind Annual Hourly data for 2009 from NREL was normalized to a value between 0 and 1 for each county and is used to scale the wind production shape to the actual wind production data for each year based on that year's wind capacity.

3. The counties of the current and future wind facilities were noted, and the capacity was distributed based on the year of entry to each county until the final year of incoming wind facilities.

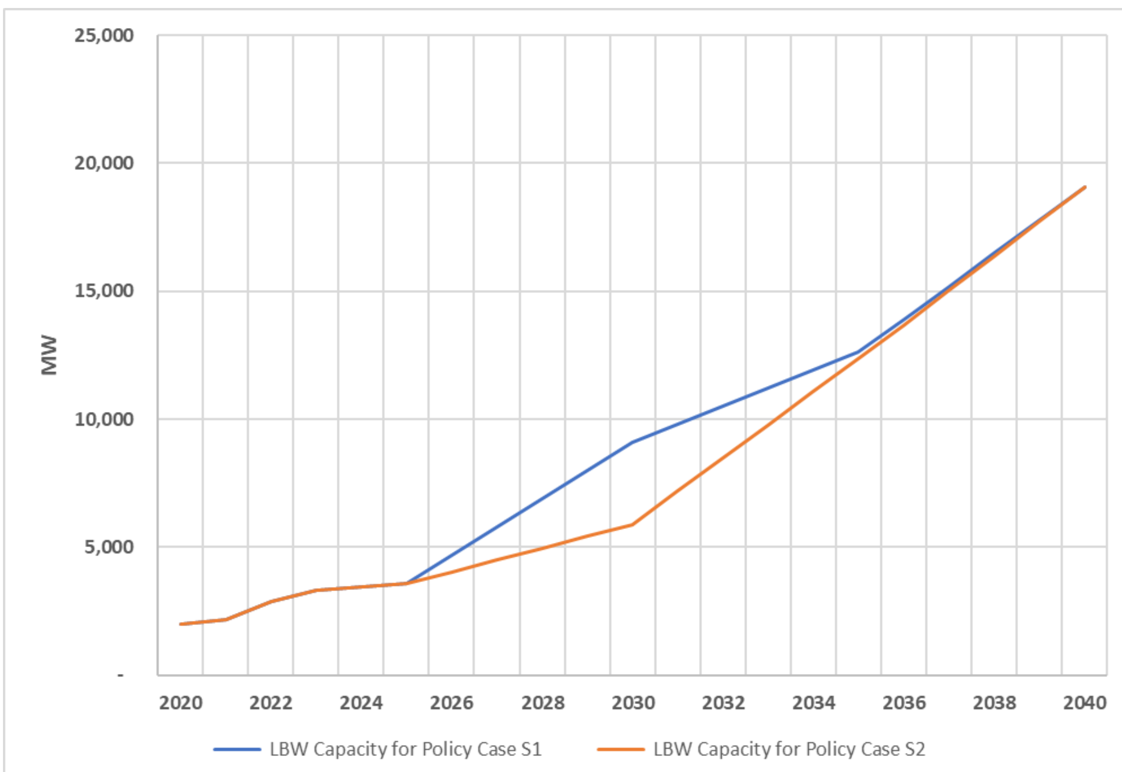
4. Beyond the final year of incoming land-based wind facilities, the capacity was linearly

forecasted using interpolation methods for the future years based on land-based wind forecasted capacity from System and Resource Outlook study for Policy Case S1 and Policy Case S2 scenarios until 2040.

5. This forecasted capacity was distributed using a weighted average method across the counties where the existing and incoming wind facilities' capacity was distributed towards. This was done for both Policy Case S1 and Policy Case S2 scenarios.

6. The forecasted capacity across the counties for each year was multiplied with the normalized values to produce the hourly wind production data and summed together to produce an NYCA wide hourly wind production data for each year.

Figure 1-1 Land Base Wind Capacity



Data Collection and Forecasting for Offshore Wind

1. From the Offshore Cluster Capacity Zonal POI data, the clusters were identified where new offshore wind facilities would be coming online in the future years.

2. The hourly data in the Offshore Wind Annual Hourly data for 2009 from NREL was normalized to a value between 0 and 1 for the clusters identified in the previous step. These normalized

values would be used to scale the wind production shape to the wind production data for each year based on that year's offshore wind capacity.

3. Beyond the final year of incoming offshore wind facilities, the capacity was linearly forecasted using interpolation methods for the future years based on offshore wind forecasted capacity from System and Resource Outlook study for Policy Case S1 and Policy Case S2 until 2040.
4. This forecasted capacity was distributed using a weighted average method across the clusters where the incoming offshore wind facilities' capacity was distributed towards. This was done for both Policy Case S1 and Policy Case S2 scenarios.
5. The forecasted capacity across the counties for each year was multiplied with the normalized values to produce the hourly wind production data and summed together to produce an NYCA wide hourly wind production data for each year.

Figure 1- 2 Offshore Wind Capacity

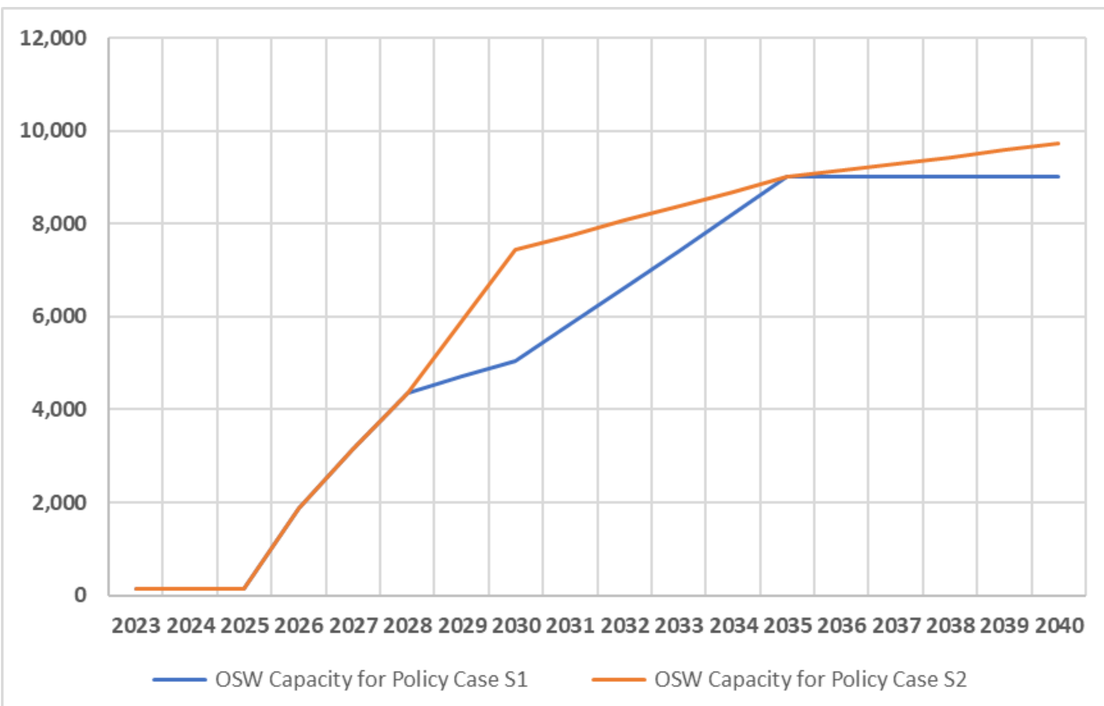


Figure 1- 3: Land Based and Offshore Wind Output Over the Seasons for 2030 – Policy Case S1

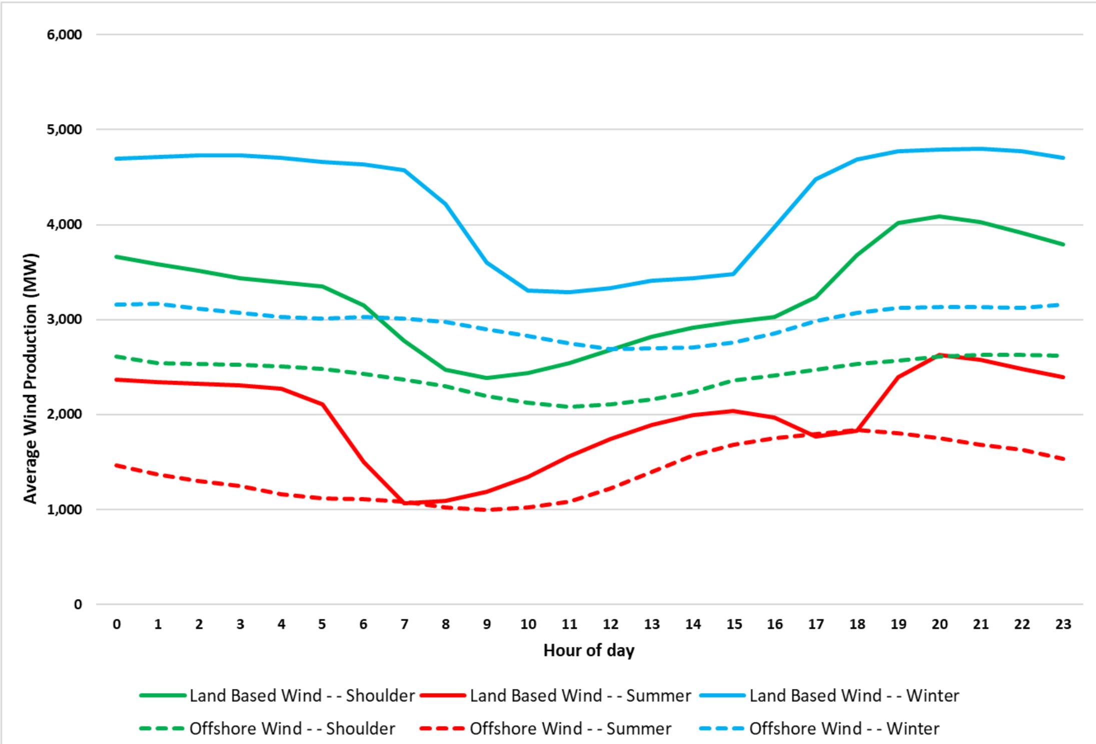


Figure 1- 4: Land Based and Offshore Wind Largest/Lowest Production Day Profiles for 2030 – Policy Case S1

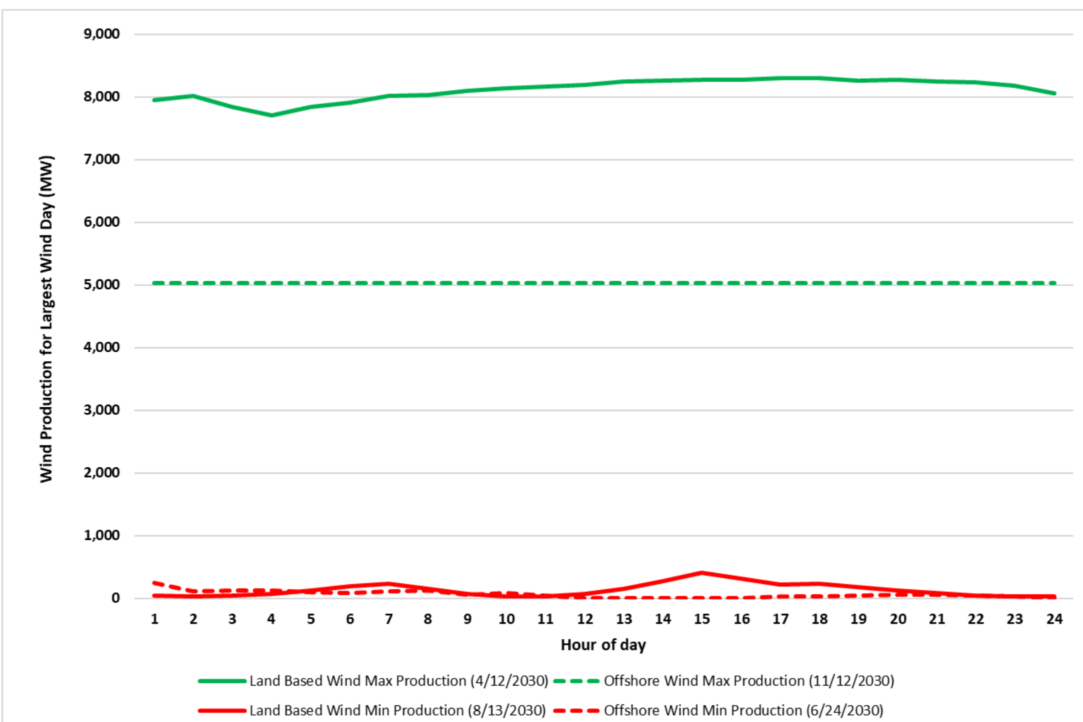


Table 1-1: Land Based and Offshore Wind Capacities over the years

Year	LBW Capacity for Policy Case S1	LBW Capacity for Policy Case S2	OSW Capacity for Policy Case S1	OSW Capacity for Policy Case S2
2020	1986	1986		
2021	2192	2192		
2022	2862	2862		
2023	3332	3332	136	136
2024	3477	3477	136	136
2025	3590	3590	136	136
2026	4689	4050	1876	1876
2027	5788	4510	3136	3136
2028	6887	4970	4366	4366
2029	7987	5430	4701	5901
2030	9086	5890	5036	7436
2031	9791	7185	5829	7749
2032	10496	8480	6622	8062
2033	11202	9776	7414	8374
2034	11907	11071	8207	8687
2035	12612	12366	9000	9000
2036	13907	13710	9000	9144
2037	15202	15054	9000	9288
2038	16497	16399	9000	9432
2039	17792	17743	9000	9576
2040	19087	19087	9000	9720

Net Load and Ramp Calculations- Phase 1

1. The solar, land-based wind, and offshore wind output was subtracted from the hourly load data for each year to create the net loads for both Policy Case S1 and Policy Case S2 scenarios until the year 2040.
2. Two scenarios were looked at: a) Including negative net loads and b) excluding negative net loads. [See Appendix 2 for more information]
3. For the Phase 1 ramp metric, the ramps over midnight were not considered because the over-midnight loads were discontinuous from one day to the next leading at times to irrational ramps. The Phase 2 Outlook load did not exhibit the same discontinuities so the over midnight ramps where included.
4. The single-hour ramp metric was calculated by subtracting the current interval’s datapoint from the next interval’s datapoint.
5. The three-hour and five-hour ramp metric was calculated by subtracting the current interval’s datapoint from the fourth interval’s datapoint and sixth interval’s datapoint respectively.

6. The multi-hour ramp metric was calculated by looking at the entirety of the ramp up or down events without considering specific time intervals.

Net Load and Ramp Calculation- Phase 2

1. The data obtained from the Outlook is on a zonal basis for selected years. The utility solar, BTM solar, land-based wind, and offshore wind columns are subtracted from the load column to obtain the net load data. The curtailment column is added on to this net load column to account for the renewable generation that had been curtailed down.
2. The net load data across the zones is combined on the interval to produce an NYCA wide hourly net load data for the years 2025, 2030, 2035, and 2040 for both the Policy Cases.
3. The net load data for the years in between the above years was calculated by interpolation methods.
4. The single hour, three-hour, five-hour, and multi-hour ramp metrics were calculated identically to the Phase 1 calculations.

Assumptions- Solar (BTM and FTM)- Phase 1

Behind-the-Meter (BTM) PV

The Climate Change Phase 1 CLCPA case assumption of 6GW was increased to 10 GW consistent with current policy[9]. The existing shape and path of adoption assumed in the Climate Change Phase 1 CLCPA Case[10] was maintained until 2025 then scaled to reach 10 GW from 2026 until 2030.

Front-of-the-meter (FTM) PV

Existing and planned capacity based on the installed in-service date provided in the 2021 Gold Book. Approximately 30 MW of existing and planned FTM Solar:

- Facilities that have completed Class Year Facilities Study (2021 Gold Book[11])
- Facilities that have completed CRIS Request (2021 Gold Book)
- Future and Non-Class Year Facilities Reported to NYSERDA[12] Beyond 2023 adjusted the assumed MW to be in line with the System and Resource Outlook Study Policy Cases S1 and S2

[9] https://www.nyserda.ny.gov/About/Newsroom/2022-Announcements/2022-04-14-Governor-Hochul-Announces-New-Framework-to-Achieve-Ten-Gigawatts-of-Distributed-Solar

[10] Itron, New York ISO Climate Change Impact Study, Phase 1: Long-term Load Impact

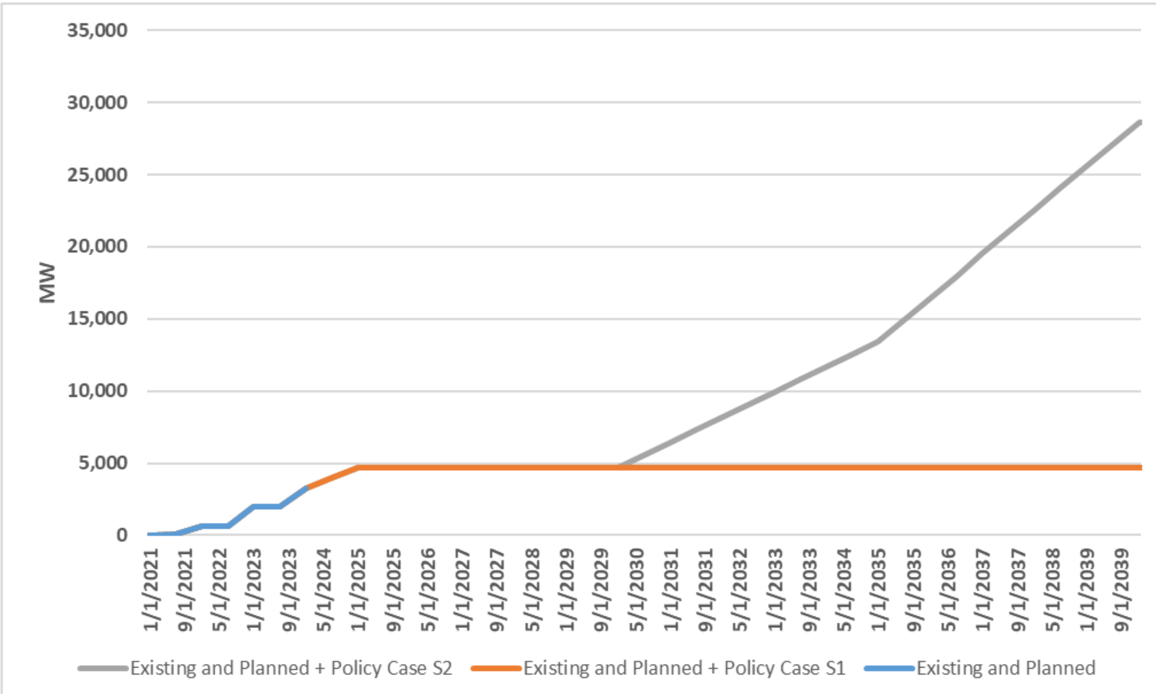
[11] NYISO, 2021 Load and Capacity Data, April 2021 https://www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64

[12] https://data.ny.gov/Energy-Environment/Large-scale-Renewable-Projects-Reported-by-NYSERDA/dprp-55ye

grid scale solar resources (see the April 26 ESPWG presentation[13])

Using the 2006 Solar Planning Shape for upstate zones and the actual 2019 production data shape for zone K

Figure 1-5: Phase 1 Assumed front-of-the-meter PV Capacity – Policy Case S1 & S2



[13] NYISO, Assumptions Matrix for 2021-2040 System & Resource Outlook, Draft for Discussion at the April 26, 2022 ESPWG, April 2022. https://www.nyiso.com/documents/20142/30198298/06%20Outlook_Capacity_Expansion_Assumptions_Matrix.pdf/eebdbd06-e40e-7ef3-905b-94011acde890

[14] See the System & Resource Outlook Appendices for more information.

Appendix 2: Phase 1 analysis

Introduction

The Phase 1 analysis is based on the Climate Change Phase 1 CLCPA Case load forecast data. Phase 1 analysis involves the study of the hourly variability of the Net Load data which is the difference between the Climate Change Phase 1 load forecast and the intermittent renewable output (the front-of-the-meter solar output, Offshore Wind output, and Land Based Wind output). The analysis is carried out for two policy cases from the Outlook study — Policy Case S1 and Policy Case S2. These two Policy Cases differ on the assumptions on the renewable buildout and hence output. Policy Case S2 has a larger solar buildout while the wind buildout is similar in both cases.

Land Based Wind, Offshore Wind, and Front the Meter Solar outputs are calculated from using the existing and planned capacity from 2021 Gold Book and NYSERDA's database on future large-scale renewable projects. Beyond the years mentioned in these databases, the forecasted MW is in line with the data from the System and Resource Outlook Study. The load shapes for land based and offshore wind is based on the 2009 NREL Land Based Hourly Wind data and 2009 NREL Offshore Hourly Wind data respectively. The load shapes for solar is based on the 2006 Solar Planning shape for upstate zones and the actual 2019 production data shape for zone K.

Phase 1 Net Load Results

The summer, winter, and shoulder peak net load shapes are shown in Figures 2-1, 2-2 and 2-3 for policy cases S1 and S2 for the years 2030 and 2040. The actual 2021 peak net load shapes were also included as a reference. The dates for the summer and winter peak net load shapes were chosen based on the interval of the highest seasonal net load values while the date for the shoulder peak net load shape was chosen to be the first day of May.

Figure 2-1: Summer Peak Net Load Shapes (Including all Intermittent Resources) Policy Cases S1 & S2, 2030, 2040 (and actual 2021)

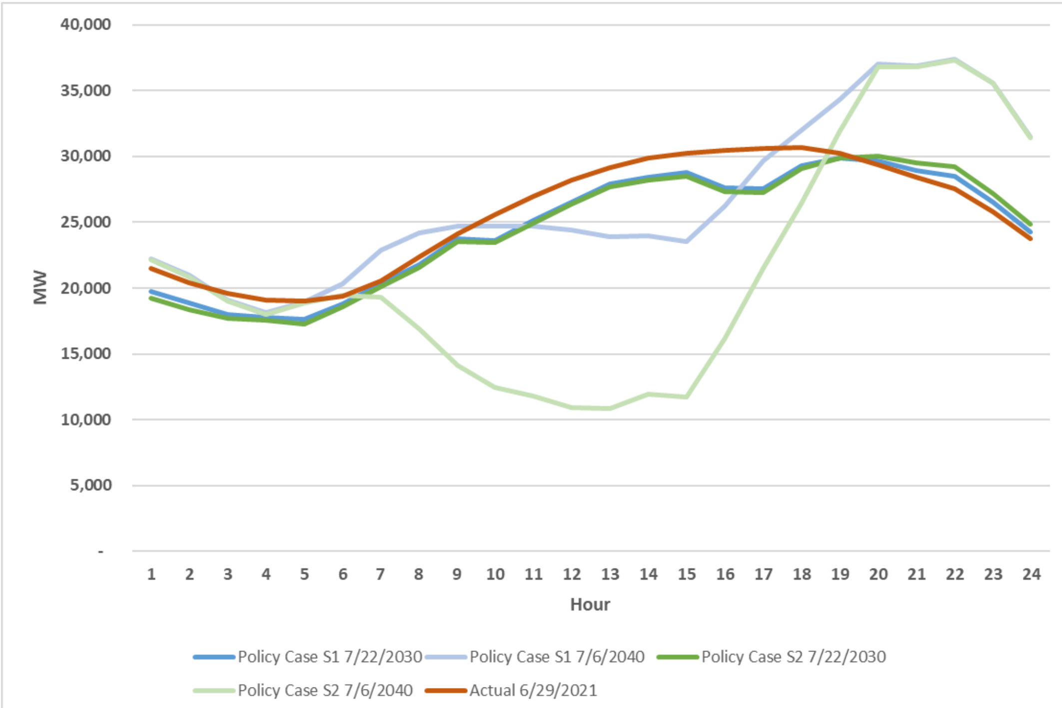


Figure 2-2: Winter Peak Net Load Shapes (Including all Intermittent Resources) Policy Cases S1 & S2, 2030, 2040, and actual 2021

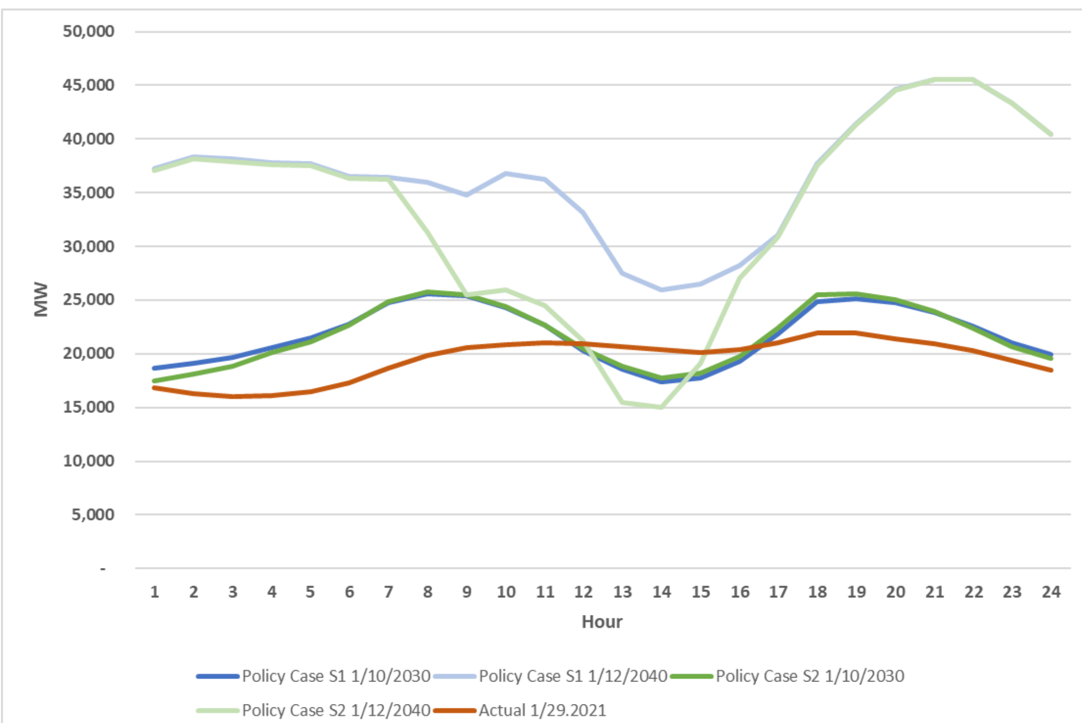
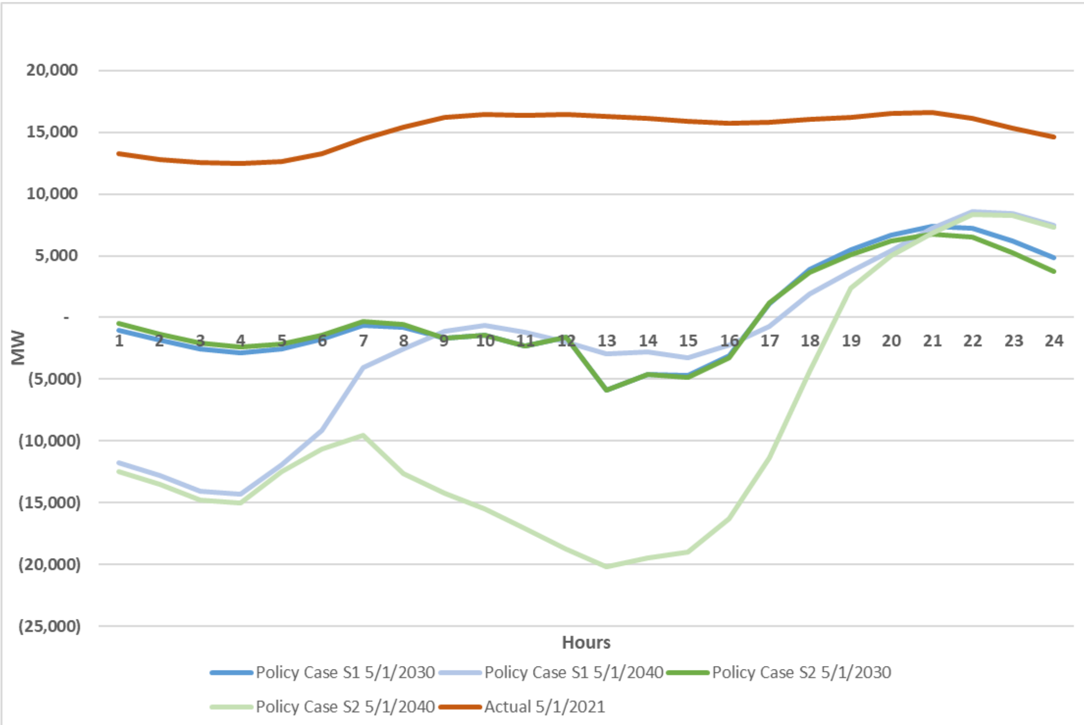


Figure 2-3: Shoulder Peak Net Load Shapes (Including all Intermittent Resources), Policy Case S1 & S2, 2030, 2040. and actual 2021



The peak net load shapes for Policy Case S1 and S2 for the year 2030 look very similar due to the relatively similar buildout of intermittent resources until 2030. The impact of intermittent resources' output on the load is not seen in the net load shapes for 2030 due to the output of the intermittent resources being much lower when compared to the large load values for those instances. The peak net load shapes for Policy Case S1 and S2 for the year 2040 look very different due to the higher buildout of solar in Policy Case S2 when compared to that of Policy Case S1. This difference is prominent for all the seasons during the daylight hours when the net load looks lower in Policy Case S2 than in Policy Case S1.

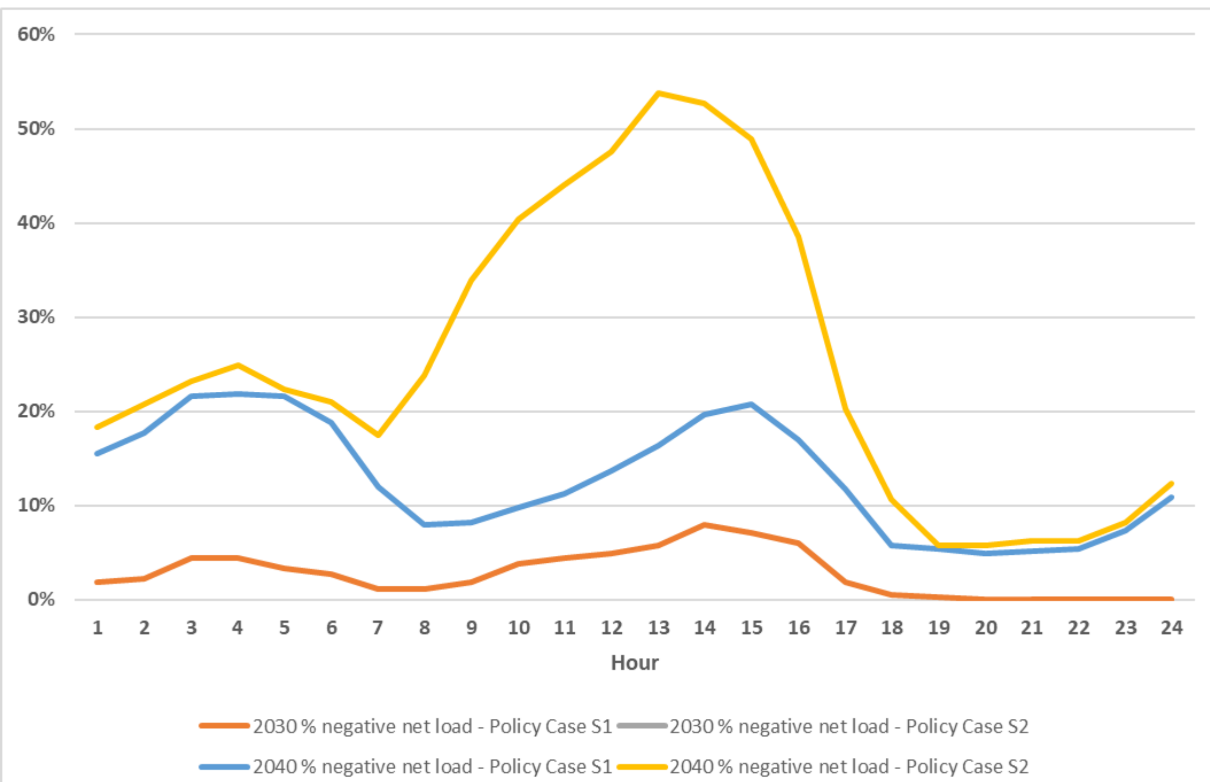
It can be observed that the shoulder peak net load shapes for 2030 and 2040 appear to be negative (Figure 2-3) due to the lower amount of load and higher amount of intermittent resources' output during those periods of time. This is an artifact of the study and is addressed in the next section. The actual 2021 peak net load shape in all the charts appear similar to the net load shape in Summer and Winter due to the low number of intermittent resources in the current market.

Phase 1 Ramp Analysis Results

Negative Net Loads zeroed out

The Phase 1 analysis resulted in hours with negative net loads due to a mismatch between the net loads and the buildout of resources. This happened in both Policy Cases, but the mismatch was greater in Policy Case S2 than S1 due to the larger buildout of intermittent resources. Operationally this would never happen. Either there would be exports, loads would increase to use the excess renewable production, or the output of the intermittent resources would be curtailed. To approximate these outcomes, the study zeroed out all these negative net loads so as not to have inflated ramp hours from these negative load periods[15]. The hours with negative net load account for approximately 9% of hours over all the years of the study however that changes over time from 3% in 2030 to 13% to 25% in 2040. Figure 2-4 shows the percent of negative net load hours for 2030 and 2040. In 2030 there are almost no differences between the two policy cases (see Figure 2-5) however by 2040 the increase in renewable buildout in Policy Case S2 increases the hours with negative net load relative to Policy Case S1 (Figure 2-6).

Figure 2-4: Percent of Negative Load Hours by Hour and Policy Case for 2030 and 2040



[15] The results of the analysis when the negative load periods were not zeroed out are and can be found in the June 28, 2022 ICAP/MIWG presentation https://www.nyiso.com/documents/20142/31830389/Grid%20in%20Transition%20Study%20ICAPMIWG%20June%2028%20FOR%20POSTING.pdf/2bad7f89-9bdd8f8-2880-bd3bd1409b52 .

Figure 2-5: Phase 1 Net Load Single Hour Ramp Distribution Curves for 2030 (and actual 2021) with and without negative net load hours

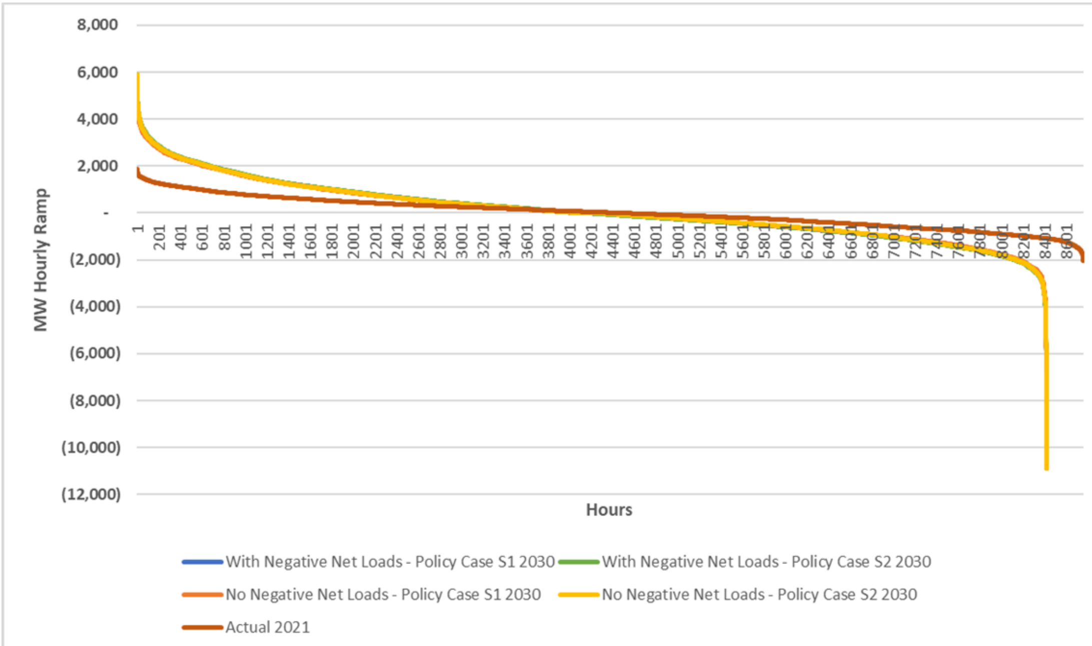
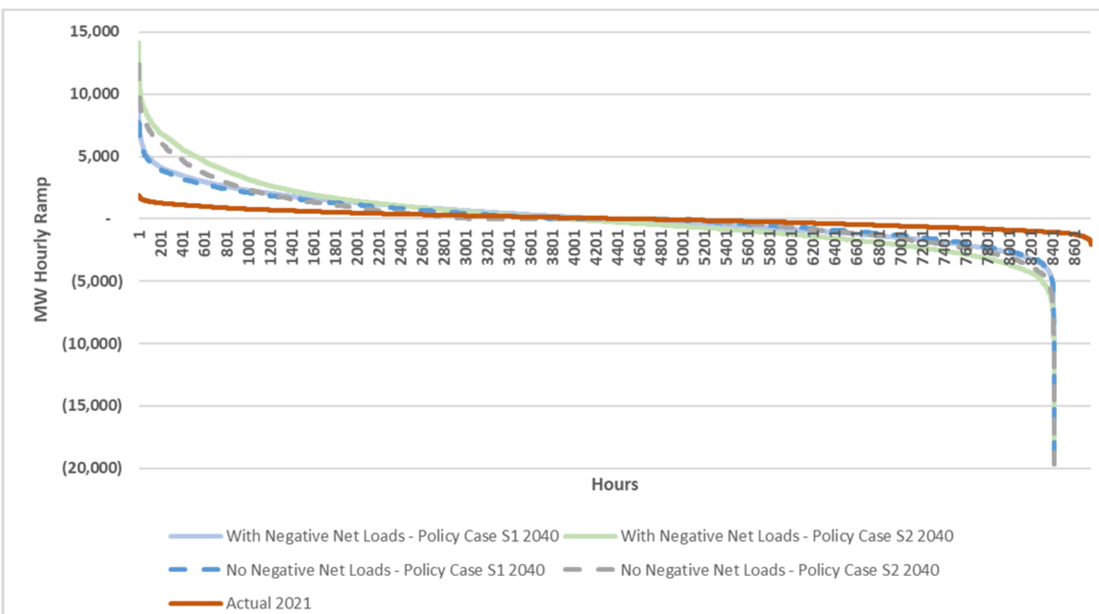


Figure 2-6: Phase 1 Net Load Single Hour Ramp Distribution Curves for 2040 (and actual 2021) with and without negative net load hours



The single hour net load ramp distribution curves for the years 2030 and 2040 are provided for the two Policy Cases (Figures 2-5 and 2-6). For 2030, the single hour ramps for the two policy cases cannot be distinguished because their net load curves are so similar. For 2040, the magnitude of the ramp events for

Policy Case S2 is greater than the magnitude of the ramp events in Policy Case S1. It can also be observed that there are a higher number of ramp up events with magnitudes greater than 5000 MWs for 2040 when compared to that of 2030 for both the policy cases. There are also a higher number of these ramp up events in 2040 with magnitudes greater than 5000 MWs for Policy Case S2 when compared to that of Policy Case S1.

The three-hour (Figures 2-9 and 2-10) and five-hour ramps (Figures 2-11 and 2-12) metrics are provided for the years 2030 and 2040.

Figure 2-7: Hourly Ramp Distribution Curves for Policy Case S1 – 2030 and 2040

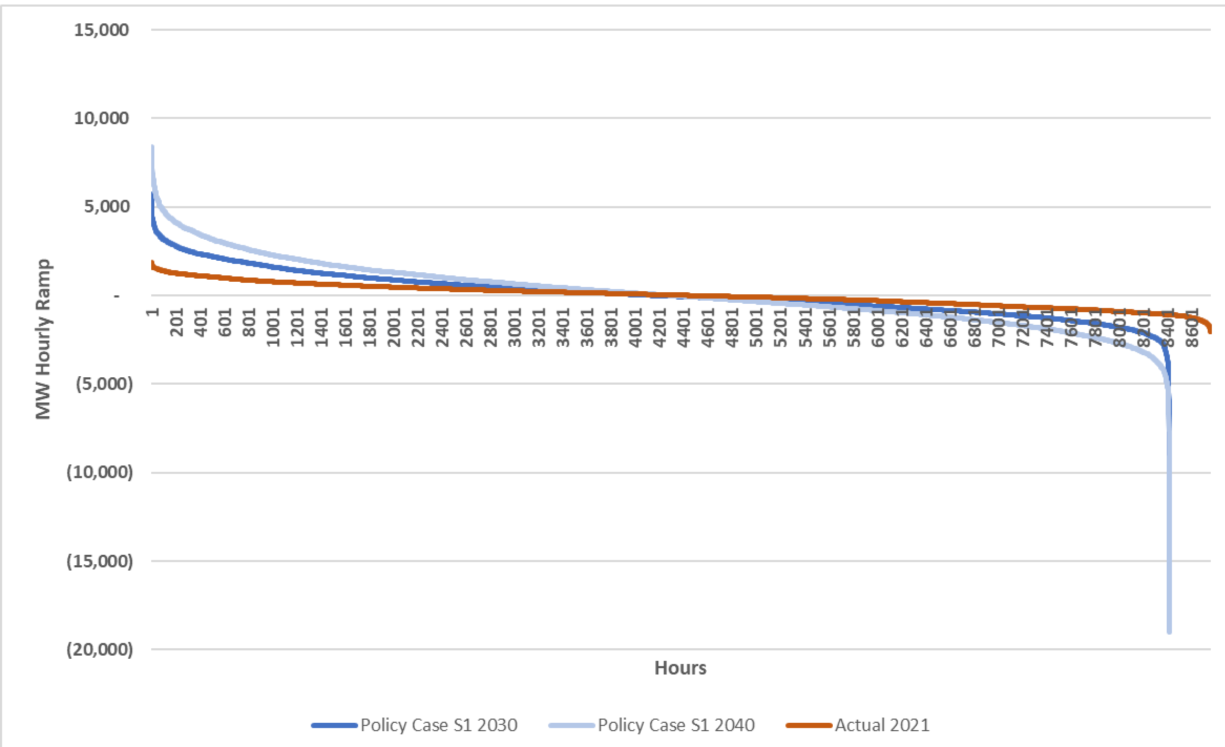


Figure 2-8: Hourly Ramp Distribution Curve for Policy Case S2 – 2030 and 2040

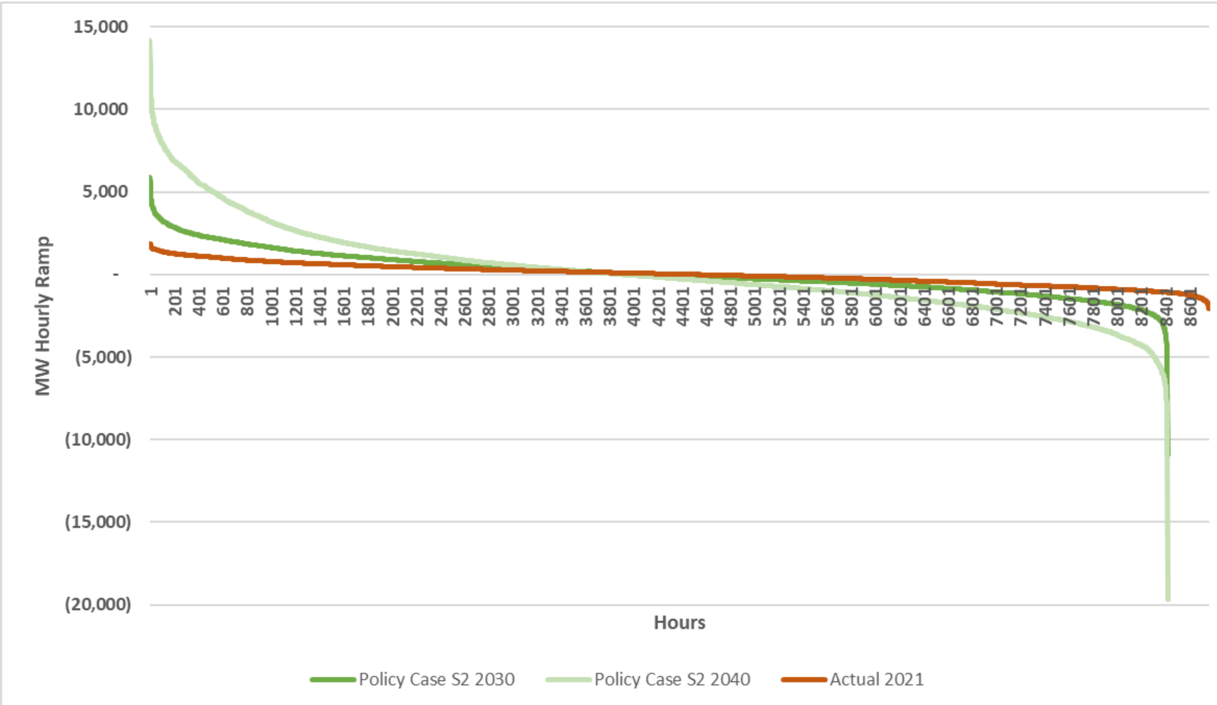


Figure 2-9: Three-Hour Ramp Distribution Curve for Policy Case S1

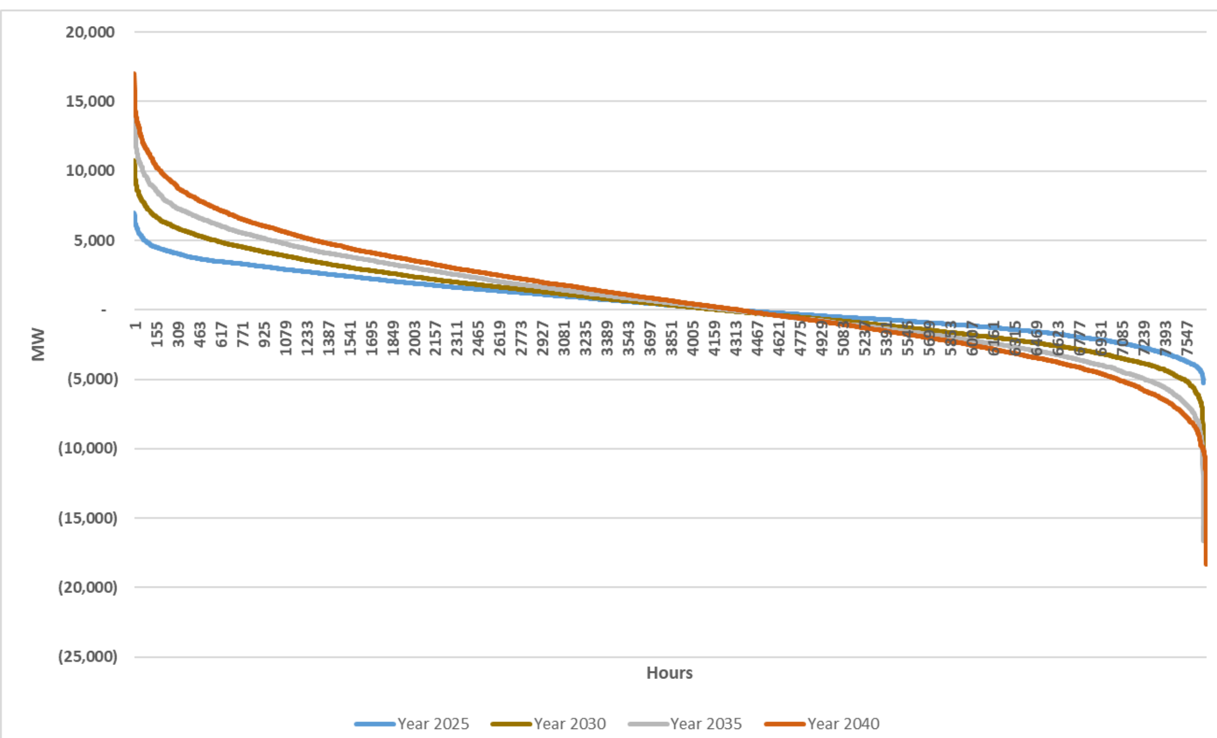


Figure 2-10: Three-Hour Ramp Distribution Curve for Policy Case S2

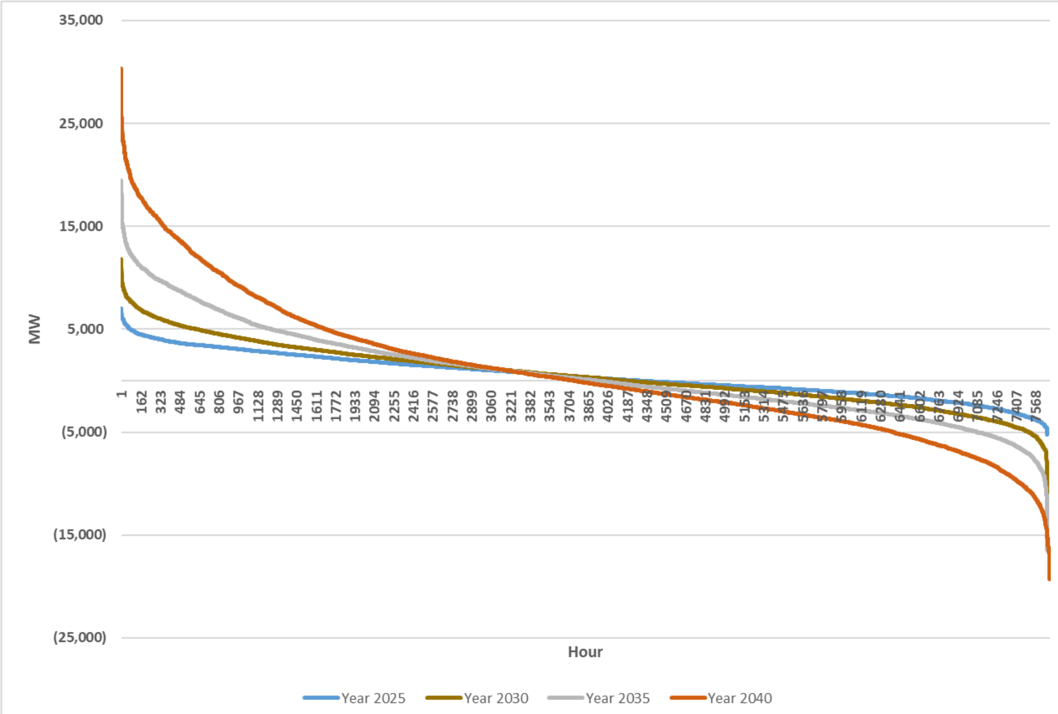


Figure 2-11: Five-Hour Ramp Distribution Curve for Policy Case S1

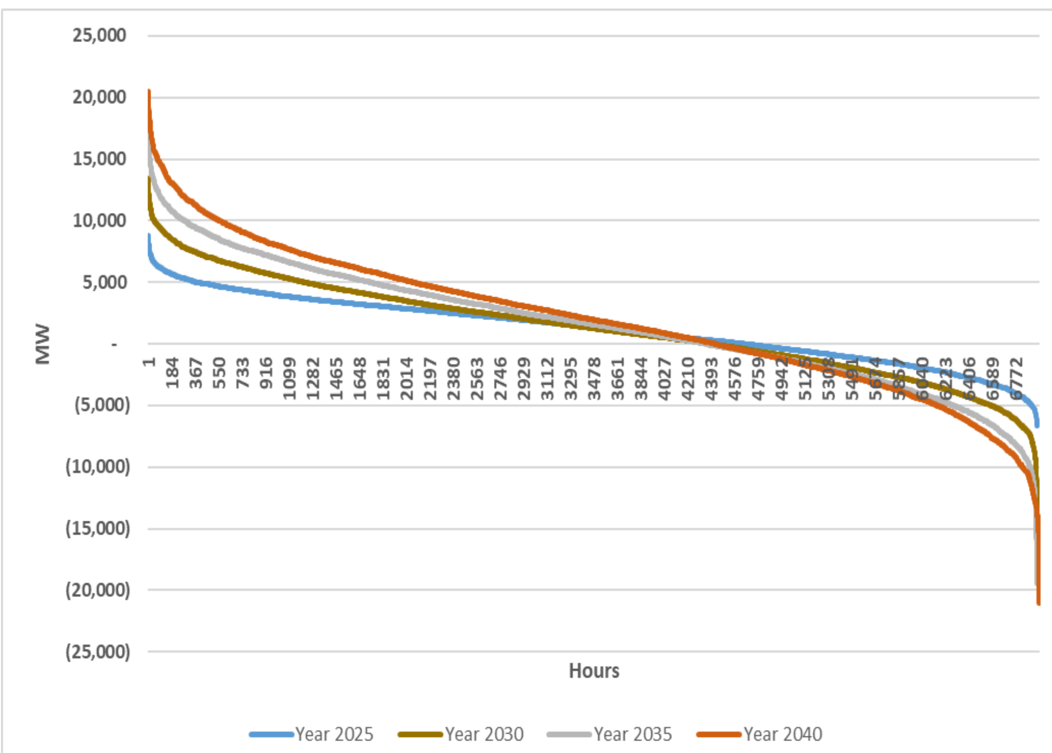


Figure 2-12: Five-Hour Ramp Distribution Curve for Policy Case S2

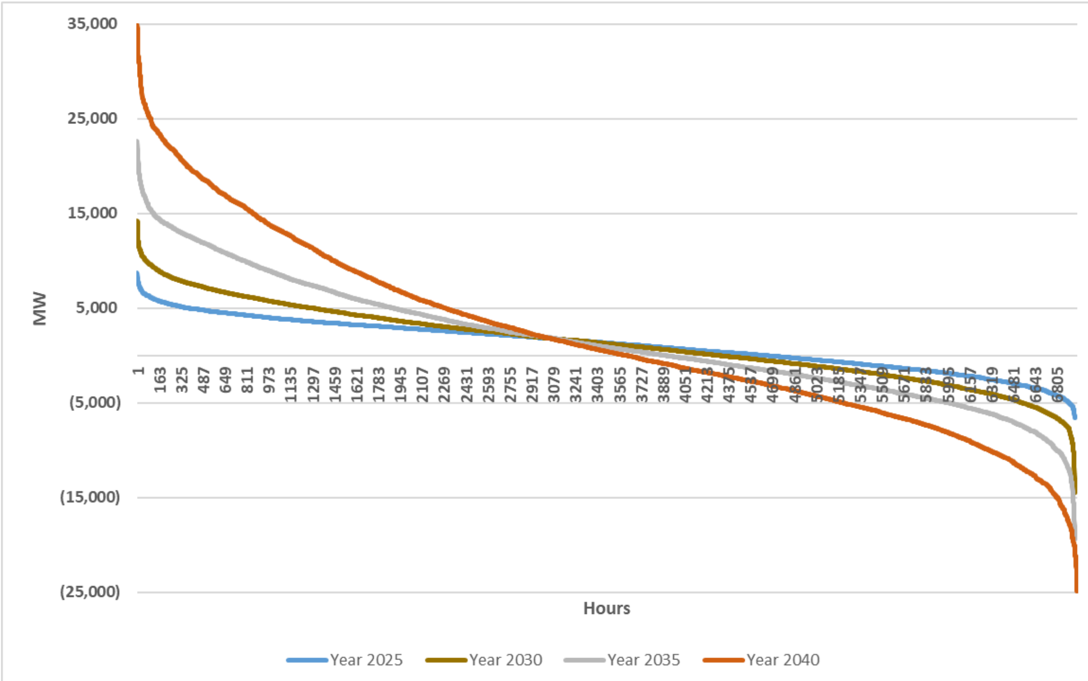


Figure 2-13: Phase 1 Analysis - Three- and Five-Hour Average Ramp Ups Over Time and 2021 Actual

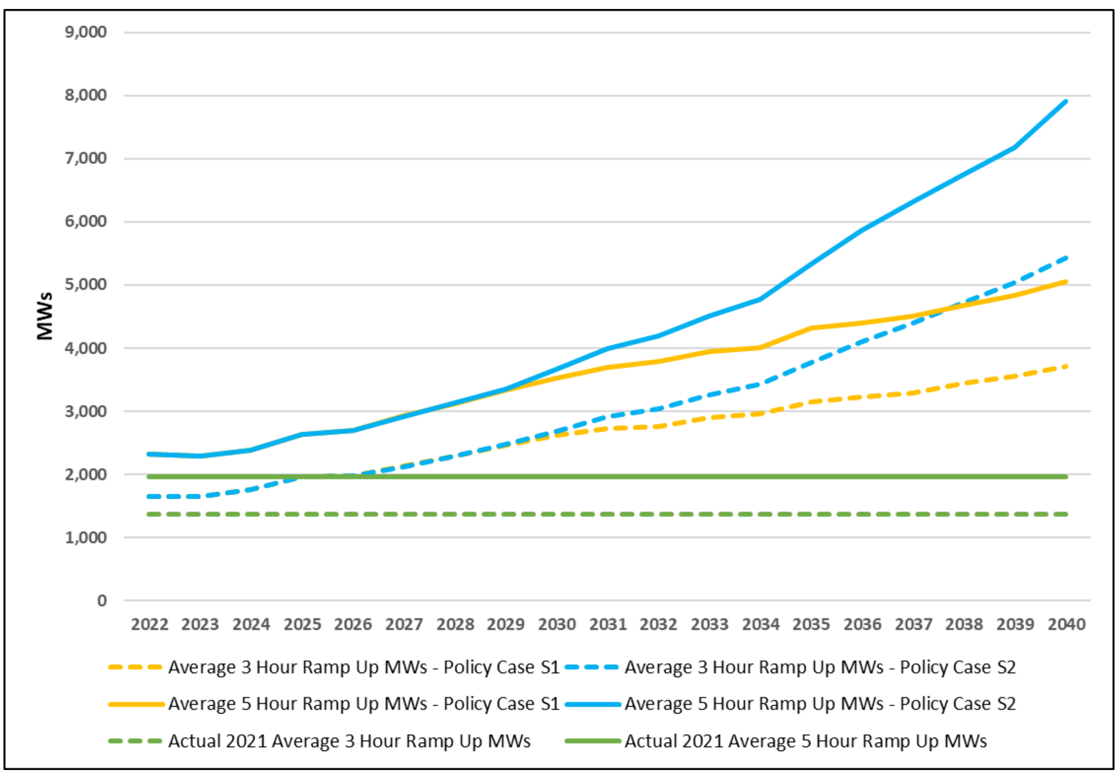
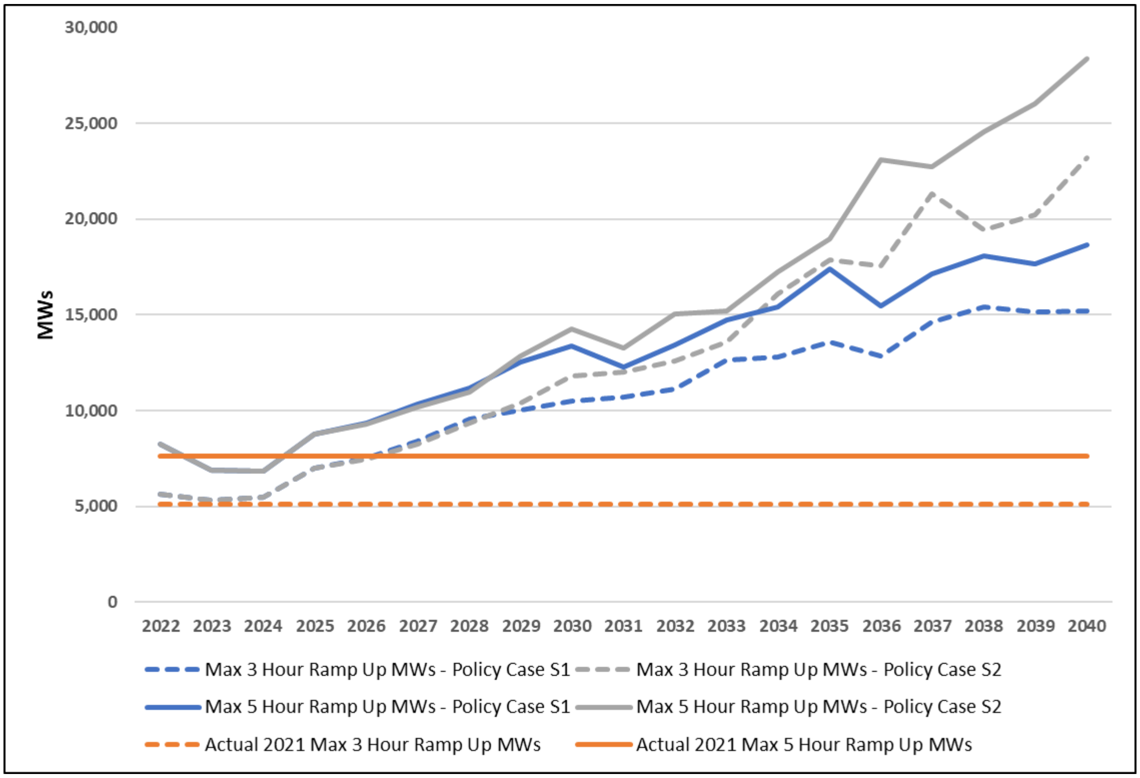


Figure 2-14: Phase 1 Analysis - Three- and Five-Hour Maximum Ramp Ups Over Time and 2021 Actual



Similar to the observations made in the single hour metrics, the ramp events are of a higher magnitude in Policy Case S2 for 2040 when compared to that of Policy Case S1 for both three-hour and five-hour metrics. The metrics for Policy Case S1 and S2 are similar for 2030 due to their net load shapes being alike for 2030. The three-hour and five-hour ramp magnitudes are greater than that of the single hour metrics and the ramp magnitudes of the five-hour metrics are greater than that of the three-hour metrics which is all to be expected. There are a lot more instances of five-hour ramps greater than 10,000 MWs for 2040 than that of 2030 and a lot more instances of these 10,000 MW five-hour ramps being present in Policy Case S2 than in Policy Case S1 for 2040 (Figures 2-11 and 2-12).

Over all of the years, the multi-hour ramp metrics (Table 2-1), the average ramp MWs, and single hour metric are very similar to each other for both the policy cases. The maximum ramp up and ramp down needs are greater for Policy Case S2 than for Policy Case S1, implying higher ramp needs in the extremes of the distribution for both ramp up and ramp down events. However, this hides the annual trends (Figure 2-13) which are broadly consistent with the Phase 2 results.

Table 2-1: Multi Hour Ramp Statistics with No Negative Net Loads

Scenario	Year	No. of Instances	Average number of Ramp up hours	Average ramp MWs	25 %ile Ramp MWs	50 %ile / Median Ramp MWs	75 %ile Ramp MWs	Max Ramp	Min Ramp	Max number of ramp hours	Min number of ramp hours
Policy Case S1	Overall (2022-2040)	45881	3.5	317.8	-2238	-168	2668	21367	-20771	23	1
Policy Case S2	Overall (2022-2040)	45027	3.5	324.1	-2398	-159	2300	30466	-29637	23	1

Table 2-2: Multi Hour Ramp Statistics for high ramp periods with No Negative Net Loads

Scenario	Year	No. of Instances	Ramp MWs	Average number of Ramp up hours	Average ramp MWs	Shoulder % (6 months)	Winter %	Summer %	25 %ile Ramp MWs	50 %ile / Median Ramp MWs	75 %ile Ramp MWs
Policy Case S1	2030	389	>5000	5.8	7533	47%	29%	25%	6124	7298	8581
Policy Case S1	2040	498	>5000	5.5	9638	44%	28%	28%	6833	9003	11745
Policy Case S2	2030	397	>5000	5.9	7769	48%	28%	24%	6280	7649	8915
Policy Case S2	2040	407	>5000	5.3	14079	45%	31%	24%	8167	13147	18973
Policy Case S1	2030	37	>10000	6.7	10887	54%	41%	5%	10270	10514	11182
Policy Case S1	2040	200	>10000	6.4	13061	35%	38%	28%	10953	12584	14523
Policy Case S2	2030	49	>10000	7.0	11266	55%	31%	14%	10399	10680	11557
Policy Case S2	2040	264	>10000	5.9	17772	37%	30%	33%	13455	17180	21541

Table 2-2 shows multi-hour ramp statistics calculated for instances consisting of ramp up needs greater than 5,000 MW and 10,000 MWs. It can be observed here again that the ramp up needs are larger in 2040 than in 2030 and that the ramp up needs are greater under the Policy Case S2 than S1 because of the larger amounts of assumed intermittent resources. This table also looks at seasonality and we observe more large ramp events in the winter, especially the largest ramp events over 10GW. This is because of the low winter loads combined with high wind output.

Figure 2-13: Phase 1 Analysis - Multi-Hour Average Ramp Ups Over Time and 2021 Actual

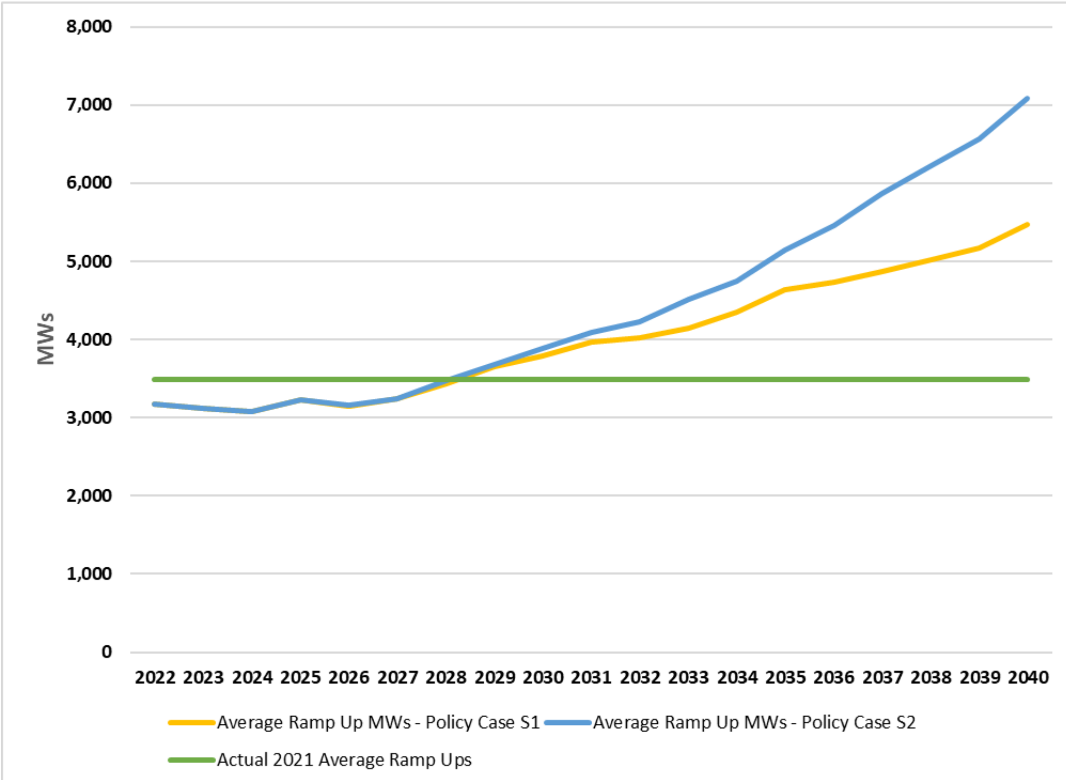
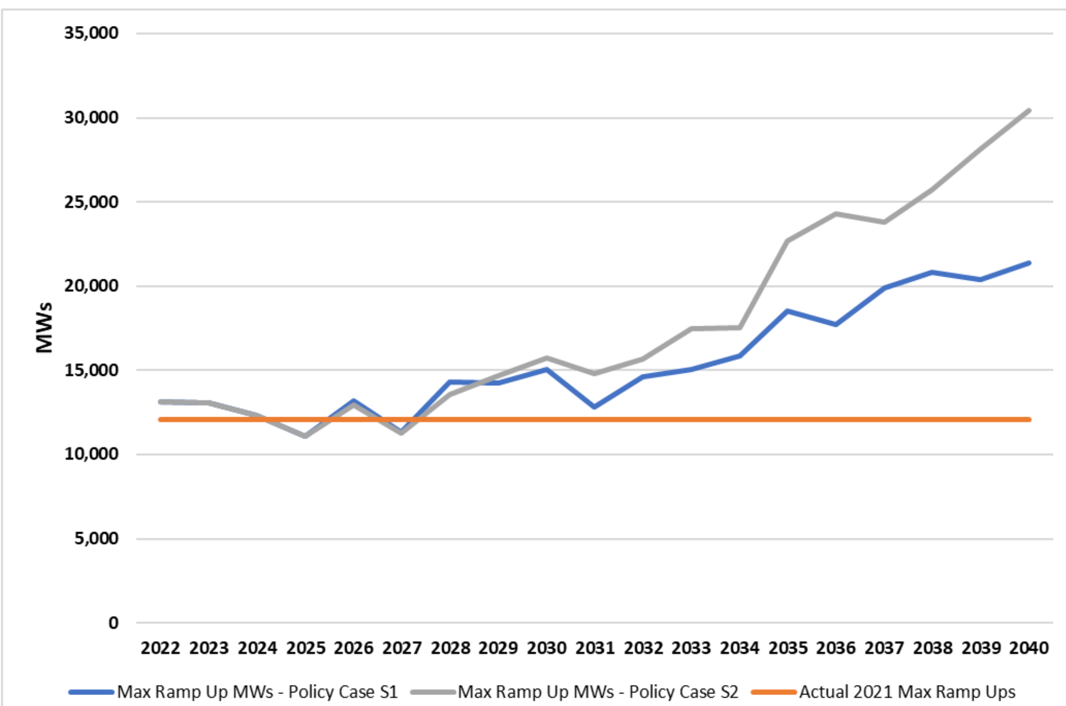


Figure 2-14: Phase 1 Analysis - Multi-Hour Maximum Ramp Ups Over Time and 2021 Actual



Appendix 3: Additional Phase 2 Data

Table 3-1: Phase 2 Three-Hour Metrics by Year and Policy Case

Scenario	Year	Ramp Up Instances	Ramp Down Instances	Average Ramp Up MWs	Average Ramp Down MWs	Max Ramp Ups MWs	Max Ramp Down MWs
Policy Case S1	2025	4167	4593	2285	-2074	9038	-10499
Policy Case S1	2026	4144	4616	2330	-2092	8801	-9343
Policy Case S1	2027	4131	4629	2397	-2140	9089	-9333
Policy Case S1	2028	4122	4662	2495	-2207	9520	-10230
Policy Case S1	2029	4113	4647	2604	-2306	9951	-11126
Policy Case S1	2030	4127	4633	2728	-2429	10944	-12023
Policy Case S1	2031	4145	4615	2687	-2413	11100	-10659
Policy Case S1	2032	4189	4595	2681	-2444	11316	-10935
Policy Case S1	2033	4186	4574	2733	-2500	11783	-12253
Policy Case S1	2034	4247	4513	2796	-2631	12554	-13571
Policy Case S1	2035	4284	4476	2914	-2790	13324	-14974
Policy Case S1	2036	4294	4490	2969	-2840	13827	-15578
Policy Case S1	2037	4260	4500	3087	-2923	14872	-16182
Policy Case S1	2038	4297	4463	3211	-3092	15918	-16787
Policy Case S1	2039	4329	4431	3381	-3303	16963	-17391
Policy Case S1	2040	4393	4388	3575	-3569	18008	-17995
Policy Case S2	2025	4126	4634	2167	-1930	8765	-5847
Policy Case S2	2026	4041	4719	2297	-1968	8475	-5846
Policy Case S2	2027	3995	4765	2453	-2057	8909	-6032
Policy Case S2	2028	3967	4817	2639	-2174	9343	-6357
Policy Case S2	2029	3970	4790	2813	-2332	10488	-7415
Policy Case S2	2030	4003	4757	2990	-2516	11854	-8814
Policy Case S2	2031	3920	4840	3093	-2505	11565	-8191
Policy Case S2	2032	3902	4882	3213	-2567	12370	-8826
Policy Case S2	2033	3869	4891	3377	-2671	13176	-9488
Policy Case S2	2034	3898	4862	3541	-2838	13981	-10150
Policy Case S2	2035	3921	4839	3746	-3036	15547	-12000
Policy Case S2	2036	3895	4889	3828	-3051	15980	-11233
Policy Case S2	2037	3900	4860	3922	-3148	17311	-12716
Policy Case S2	2038	3888	4872	4121	-3289	18642	-14219
Policy Case S2	2039	3874	4886	4394	-3485	19972	-16315
Policy Case S2	2040	3889	4892	4704	-3738	22938	-19108

Table 3-2: Phase 2 – Five-Hour Metrics by Year and Policy Case

Scenario	Year	Ramp Up Instances	Ramp Down Instances	Average Ramp Up MWs	Average Ramp Down MWs	Max Ramp Ups MWs	Max Ramp Down MWs
Policy Case S1	2025	4355	4405	3135	-3101	11209	-12741
Policy Case S1	2026	4364	4396	3172	-3151	10661	-11428
Policy Case S1	2027	4338	4422	3271	-3210	10682	-11437
Policy Case S1	2028	4309	4475	3420	-3295	11193	-12469
Policy Case S1	2029	4277	4483	3585	-3421	11954	-13599
Policy Case S1	2030	4257	4503	3779	-3571	12981	-14845
Policy Case S1	2031	4328	4432	3685	-3598	13020	-13308
Policy Case S1	2032	4395	4389	3662	-3666	13325	-13575
Policy Case S1	2033	4367	4393	3757	-3734	13985	-15158
Policy Case S1	2034	4390	4370	3876	-3893	15840	-16741
Policy Case S1	2035	4419	4341	4042	-4115	17695	-18374
Policy Case S1	2036	4448	4336	4108	-4215	16042	-18967
Policy Case S1	2037	4450	4310	4240	-4379	17471	-19560
Policy Case S1	2038	4467	4293	4434	-4615	19086	-20153
Policy Case S1	2039	4469	4291	4698	-4894	20701	-20746
Policy Case S1	2040	4474	4305	5032	-5211	22316	-21339
Policy Case S2	2025	4368	4392	2858	-2843	11018	-8138
Policy Case S2	2026	4295	4465	3011	-2896	11075	-8013
Policy Case S2	2027	4220	4540	3218	-2991	11133	-8159
Policy Case S2	2028	4200	4584	3435	-3148	11416	-8770
Policy Case S2	2029	4153	4607	3690	-3327	12588	-9724
Policy Case S2	2030	4141	4619	3954	-3544	13760	-10922
Policy Case S2	2031	4075	4685	4068	-3538	14661	-11210
Policy Case S2	2032	4047	4737	4231	-3614	15563	-11555
Policy Case S2	2033	4036	4724	4415	-3771	16464	-11900
Policy Case S2	2034	4032	4728	4654	-3968	17366	-12757
Policy Case S2	2035	4035	4725	4942	-4221	18267	-14700
Policy Case S2	2036	4043	4741	4982	-4250	16934	-14621
Policy Case S2	2037	4040	4720	5095	-4362	18474	-15490
Policy Case S2	2038	4014	4746	5347	-4523	21094	-16667
Policy Case S2	2039	4029	4731	5642	-4806	23713	-19356
Policy Case S2	2040	4028	4751	6062	-5135	26333	-22294

Table 3-3: Phase 2 Multi Hour Metrics by Year and Policy Case

Scenario	Year	Ramp Up Instances	Ramp Down Instances	Average Ramp Up Hours	Average Ramp Down Hours	Average Ramp Up MWs	Average Ramp Down MWs	Max Ramp Up MWs	Max Ramp Down MWs
Policy Case S1	2025	975	976	4.1	4.9	3739	-3730	12030	-15048
Policy Case S1	2026	934	933	4.2	5.1	3906	-3911	11998	-13673
Policy Case S1	2027	924	925	4.3	5.2	4036	-4033	12403	-13486
Policy Case S1	2028	945	943	4.2	5.1	4121	-4131	12091	-14943
Policy Case S1	2029	994	994	4.0	4.8	4121	-4122	12728	-16492
Policy Case S1	2030	1051	1053	3.8	4.5	4155	-4148	13768	-18162
Policy Case S1	2031	1009	1009	4.0	4.7	4212	-4216	13231	-16191
Policy Case S1	2032	1017	1016	4.0	4.7	4198	-4201	13703	-16013
Policy Case S1	2033	1035	1035	3.9	4.6	4223	-4222	14554	-18081
Policy Case S1	2034	1091	1091	3.7	4.3	4217	-4216	16923	-20154
Policy Case S1	2035	1129	1129	3.7	4.1	4366	-4367	19414	-22802
Policy Case S1	2036	1121	1122	3.7	4.1	4437	-4434	16812	-23387
Policy Case S1	2037	1089	1089	3.8	4.2	4688	-4681	18655	-23971
Policy Case S1	2038	1109	1109	3.8	4.1	4834	-4831	20976	-24555
Policy Case S1	2039	1122	1124	3.7	4.1	5087	-5090	23401	-25139
Policy Case S1	2040	1162	1161	3.7	3.9	5298	-5291	25863	-25906
Policy Case S2	2025	1026	1026	3.8	4.7	3419	-3412	11581	-10946
Policy Case S2	2026	1001	1001	3.8	4.9	3588	-3589	11454	-11899
Policy Case S2	2027	988	988	3.9	5.0	3840	-3841	11377	-12268
Policy Case S2	2028	1018	1018	3.8	4.9	4019	-4020	11912	-12696
Policy Case S2	2029	1035	1036	3.7	4.8	4279	-4276	12660	-14540
Policy Case S2	2030	1074	1074	3.6	4.6	4496	-4501	14186	-17324
Policy Case S2	2031	1031	1031	3.7	4.8	4651	-4650	14739	-15839
Policy Case S2	2032	1031	1031	3.7	4.8	4778	-4777	15695	-16220
Policy Case S2	2033	1061	1061	3.6	4.7	4859	-4858	16651	-16598
Policy Case S2	2034	1062	1062	3.6	4.6	5196	-5195	17607	-18388
Policy Case S2	2035	1110	1108	3.5	4.4	5384	-5395	19609	-20977
Policy Case S2	2036	1126	1126	3.4	4.4	5408	-5409	18520	-22079
Policy Case S2	2037	1151	1151	3.3	4.3	5478	-5480	19344	-23175
Policy Case S2	2038	1193	1193	3.2	4.2	5617	-5618	22028	-24365
Policy Case S2	2039	1230	1230	3.1	4.0	5872	-5864	24743	-25698
Policy Case S2	2040	1265	1265	3.0	3.9	6211	-6220	27920	-27032