New York ISO
Independent System Operator

DRAFT for ICAP/MIWG Comment

2022 Grid in Transition Study: A study of ramp rates implicit in different forecasts

A Report by the
New York Independent System Operator

TBD 2022

New York ISO

Table of Contents

Executive Summary

[To be added]

Background

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.

A 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 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 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

The study is split into two phases. Phase 1 leverages the Climate Change Phase 1.[1] "CLCPA Case" hourly

[1] CITE

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 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 the two policy scenarios, especially the different renewable resource buildouts, lead to different outcomes as will be seen 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 next 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.

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 off-shore wind).

Net Load =

Load forecast
minus Front of the meter solar output
minus Off-Shore 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, that could

[2] https://www.nyiso.com/documents/20142/33384099/2021-2040-Outlook-Report.pdf/a6ed272a-bc16-110b-c3f8-0e0910129ade

[3] [Outlook report page 9 for both bullets]

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

lead to larger than expected 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 study is focused on the Phase 2 results. The Phase 1 results can be found in Appendix 2.

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 planning studies. Detailed information about these inputs is available in Appendix 1.

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, this 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.

[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. Appendix 2 includes the results of this analysis.

Phase 2 Results

Net load shapes

The summer, winter, and shoulder peak net load shapes (Figures 1 through 3) 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. The load shapes of the shoulder period show no differentiation by Policy Case or by year (Figure 3). Notably, the load shapes are relatively flat, similar to the actual 2021 load shapes but at about half of the load level up until HB18.

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

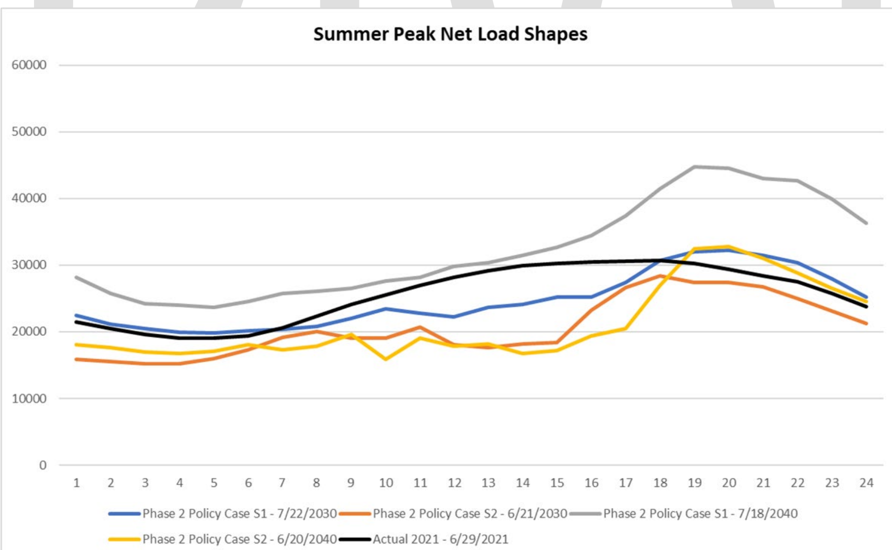


Figure 2: Winter Peak Net Load Shapes for 2030, 2040 (and actual 2021)

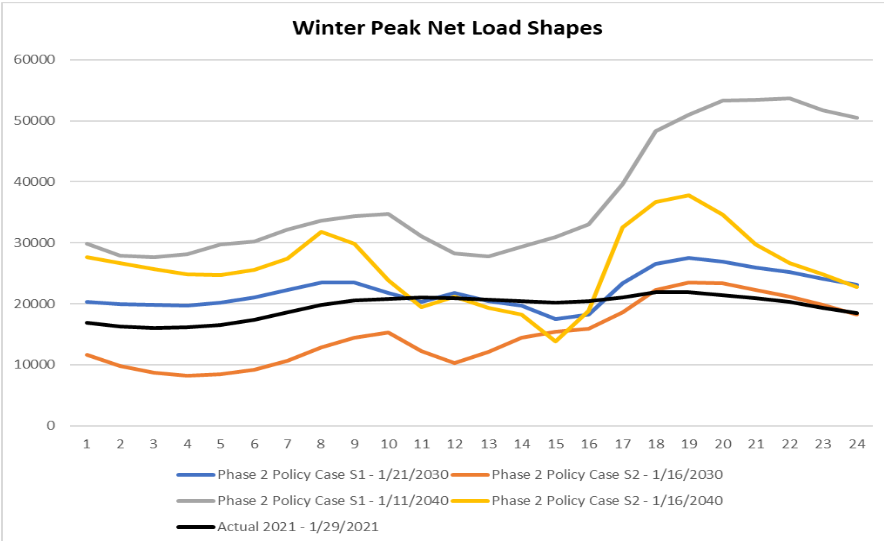


Figure 3: Shoulder Peak Net Load Shapes for 2030, 2040 (and actual 2021)

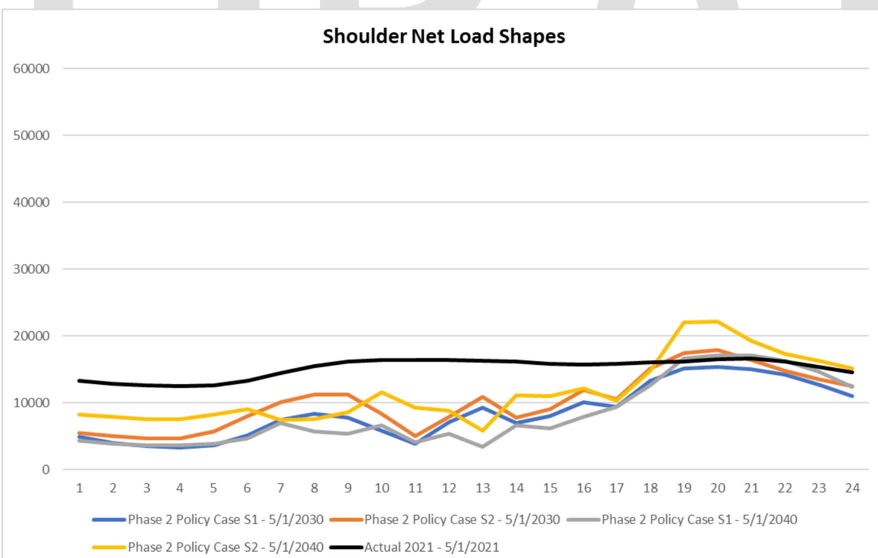
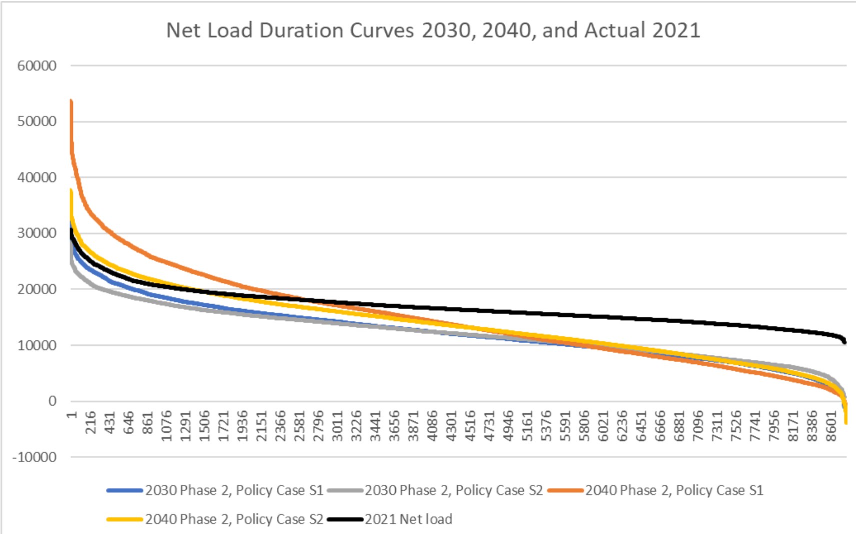


Figure 4 shows the net load duration curves over the entire year for 2030, 2040 and 2021. Here too, the differences between Policy Cases S1 and S2 can be seen in 2040. The shape of the net load duration curves in 2030 is similar to the 2021 curves in the upper portion of the net load curve, however,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

Figure 4: Net Load Duration Curves



Net load ramps

The key to this 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. Figures 5 and 6 provide the hourly net load ramp distribution curves for Policy Cases S1 and S2 for every two years from 2026 to 2040. From this, both the ramp up and ramp down events are increasing over time. Similar results were observed for three- and five-hour ramps.

The multi hour ramp metric provides information for the entirety of the ramp up and ramp down events. Table 1 provides an overview of the metric for ramp up and ramp down periods. Additional annual metrics can be found in Appendix 3. Although looking at the ramps is informative, the total ramp up is particularly useful when considering the future needs of the grid. Figure 8 shows that although increasing in the longer term, in the next eight to ten years the multi-hour ramp up events will remain approximately the same as the system currently faces.

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

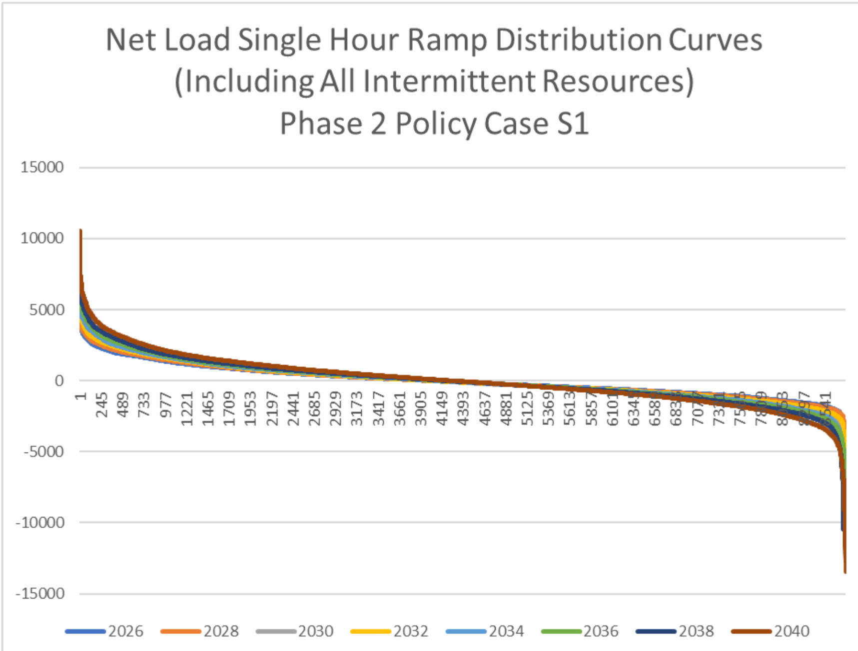


Figure 6: Net Load Single Hour Ramp Distribution Curves Policy Case S2

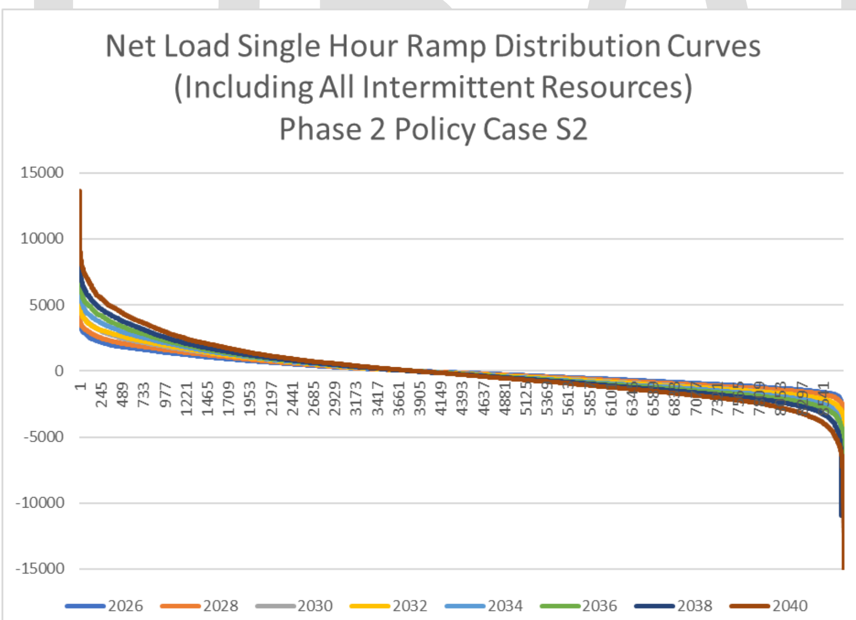


Table 1 Multi Hour Ramp Summary Statistics (2025-2040)

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	Max Ramp	Max number of hours	Min number of ramp hours
Policy Case S1	Overall	33431	4.2	0.2	-3127	0	3270	25863	-25906	17	1
Policy Case S2	Overall	34807	4.0	-0.2	-4316	0	3924	27920	-27032	18	1

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

Figure 7: Net Load Average Ramp Over Time and 2021 Actual

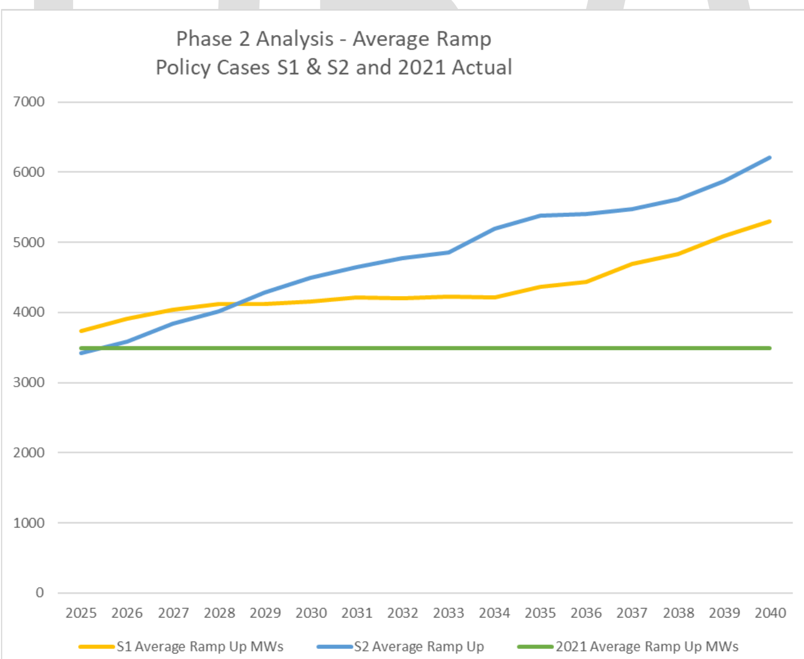
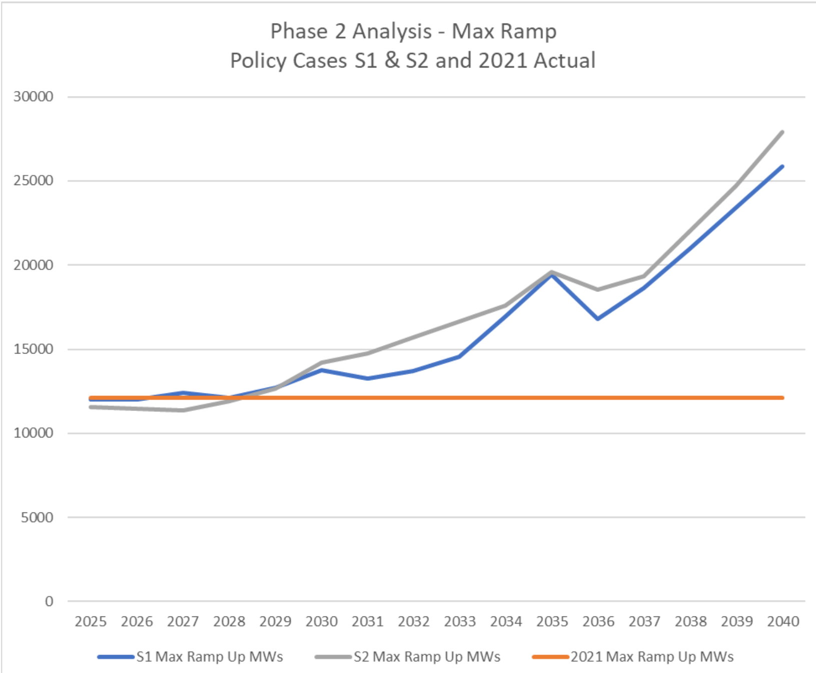


Figure 8: Net Load Maximum Ramp Over Time and 2021 Actual



Conclusions

High level takeaways that will be discussed in the final report:

- The studies and all the metrics point to increasing net load over time, however, this should be looked at in two time periods
    - The next 8 -10 years when there is less uncertainty
        - The ramp metrics here are somewhat mixed showing either a fairly flat or a slight growth in maximum ramp
        - The metrics show growth in overall ramping needs as seen in the growth in the average ramp needs
    - Beyond 10 years, there is more uncertainty
        - All the metrics and the two Policy Cases are in agreement that the average and maximum ramps will be growing.
        - However, this period is very dependent on the methodology used in the studies– since little or no information is available that far out, many of the underlying

assumptions assume linear growth that translates to the growth seen in the ramping metrics

- The next 8-10 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 needs and if there are needs within the project cycle timeframe.
- We believe that the multi-hour metric is the one that most closely speaks to the amount of variability that flexible generation will have to respond to
  - From the multi-hour metric, and with the current set of resources the NYISO does not see an urgent need for additional hourly ramp.
  - We are however seeing increasing sustained ramp needs which means that we need to have sustained energy capability throughout the day
  - We believe that the 2023 Balancing Intermittency project will provide the opportunity to examine possible evolutions of the existing market rules.
- Future studies and the insights provided by new information will provide more understanding longer-term ramping needs.

Appendices

Appendix 1 Data sources and Metrics

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 presentation.[6]
- 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 which would be 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.

[6] Cite

Figure 1-1 Land Base Wind Capacity

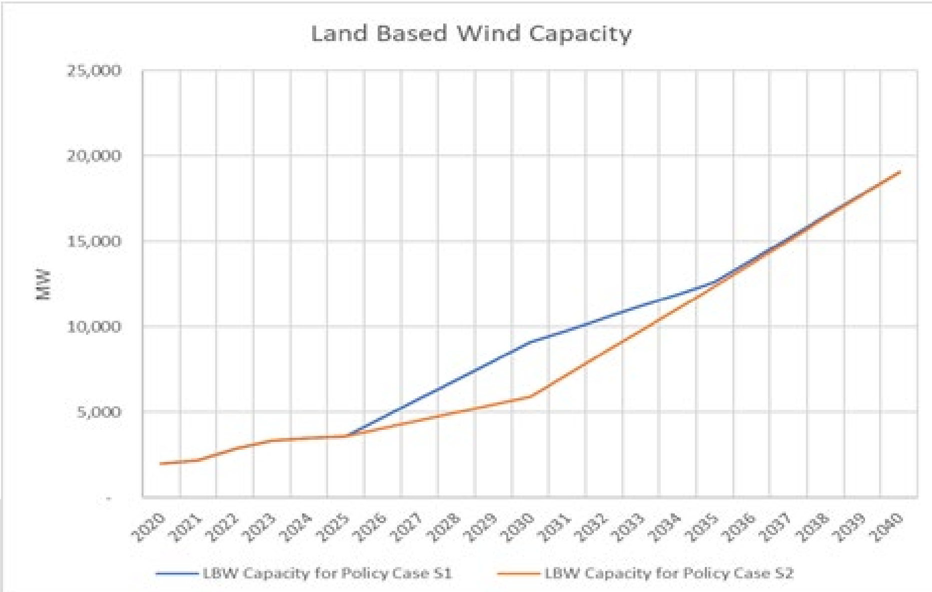


Figure 1-2 Land Base Wind Output

[Insert figure]

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- 3 Offshore Wind Capacity

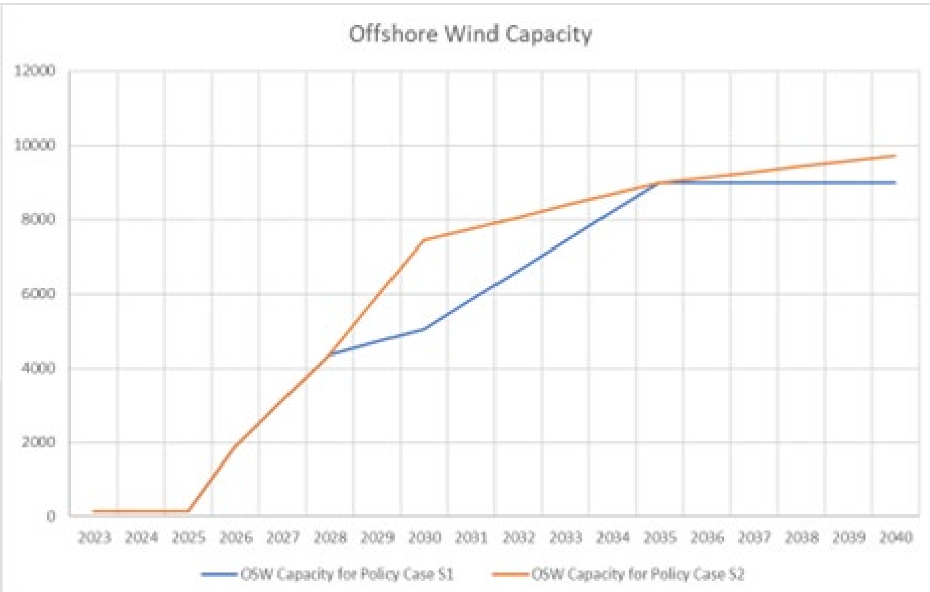


Figure 1- 4 Offshore Wind Output

[Chart to be added]

Net Load and Ramp Calculations- Phase 1

1. The solar, land-based wind, and offshore wind 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 all 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 to 10GW consistent with current policy[7]. The existing shape and path of adoption assumed in the Climate Change Phase 1 CLCPA Case[8] 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)
- Facilities that have completed CRIS Request (2021 Gold Book)
- Future and Non-Class Year Facilities Reported to NYSERDA (https://data.ny.gov/Energy-

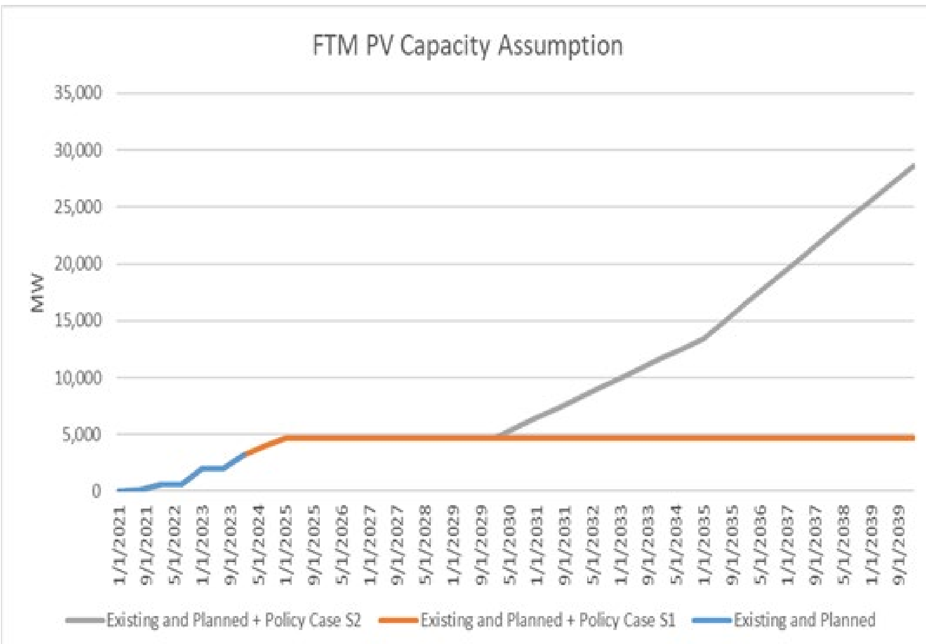
[7] [Cite state policy]
[8] [Cite CLCPA study]

Environment/Large-scale-Renewable-Projects-Reported-by-NYSERDA/dprp-55ye)

Beyond 2023 adjusted the assumed MW to be in line with the System and Resource Outlook Study Policy Cases S1 and S2 grid scale solar resources (see the April 26 ESPWG presentation)

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



Assumptions- Solar (BTM and FTM) and Wind- Phase 2

The Phase 2 used the Outlook Policy Cases S1 and S2 study assumptions[9].

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 – Front of the meter solar

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

output, Offshore Wind output, and Land Based Wind output. It is to be noted that the ramp up events are of higher operational importance since the intermittent resources are on dispatch and can be ramped down to accommodate the ramp down needs. 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 to provide a reference. The dates for the summer and winter peak net load shapes were chosen based on the interval of the highest net load value in the entire year 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 for 2030, 2040 (and actual 2021)

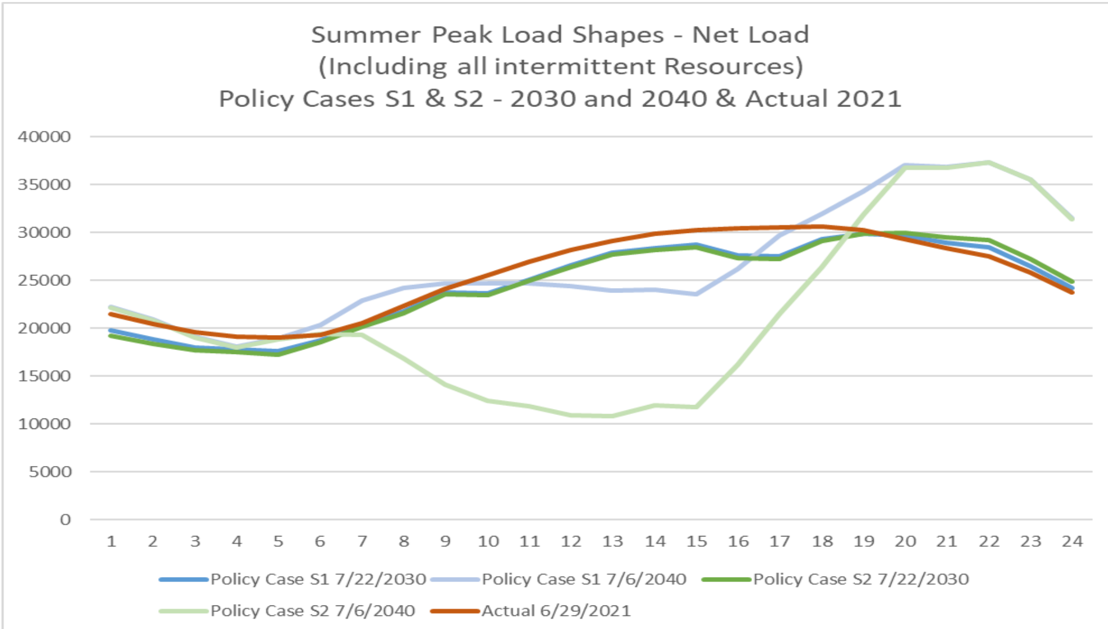


Figure 2-2: Winter Peak Net Load Shapes for 2030, 2040 (and actual 2021)

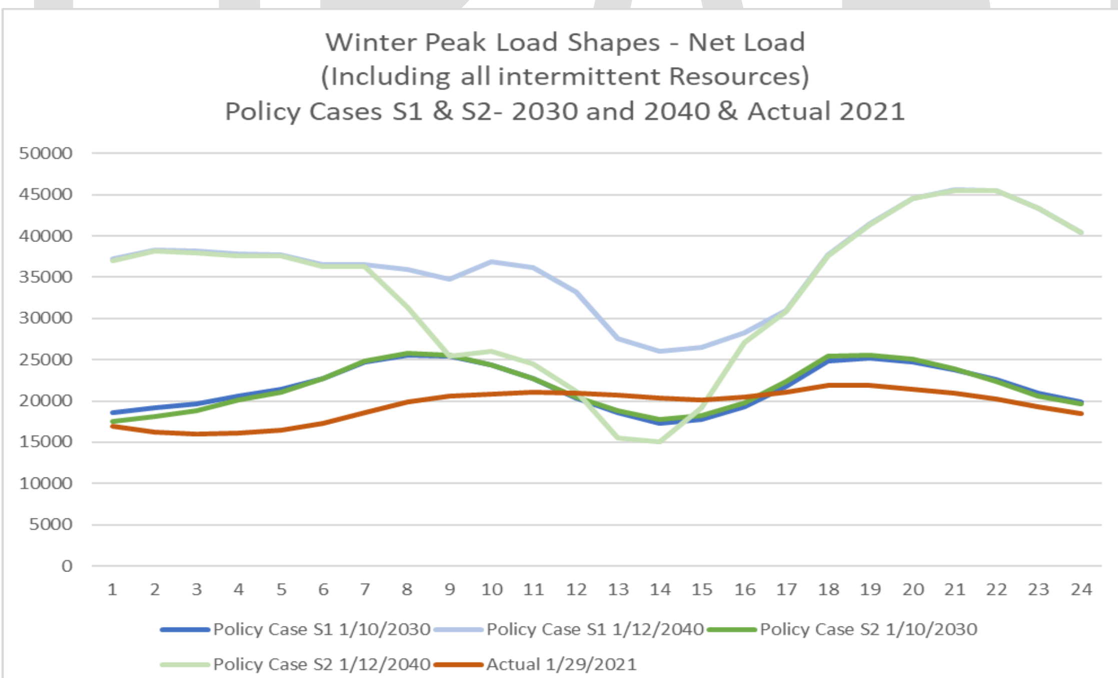
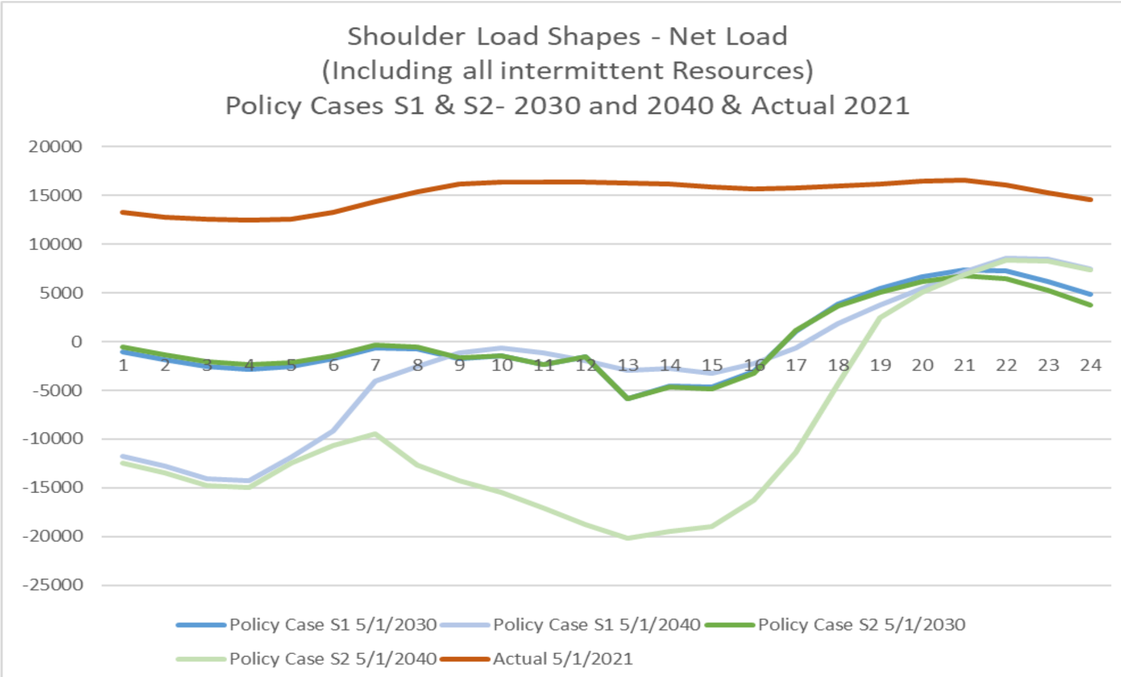


Figure 2-3: Shoulder Peak Net Load Shapes for 2030, 2040 (and actual 2021)



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 far more depressed 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.

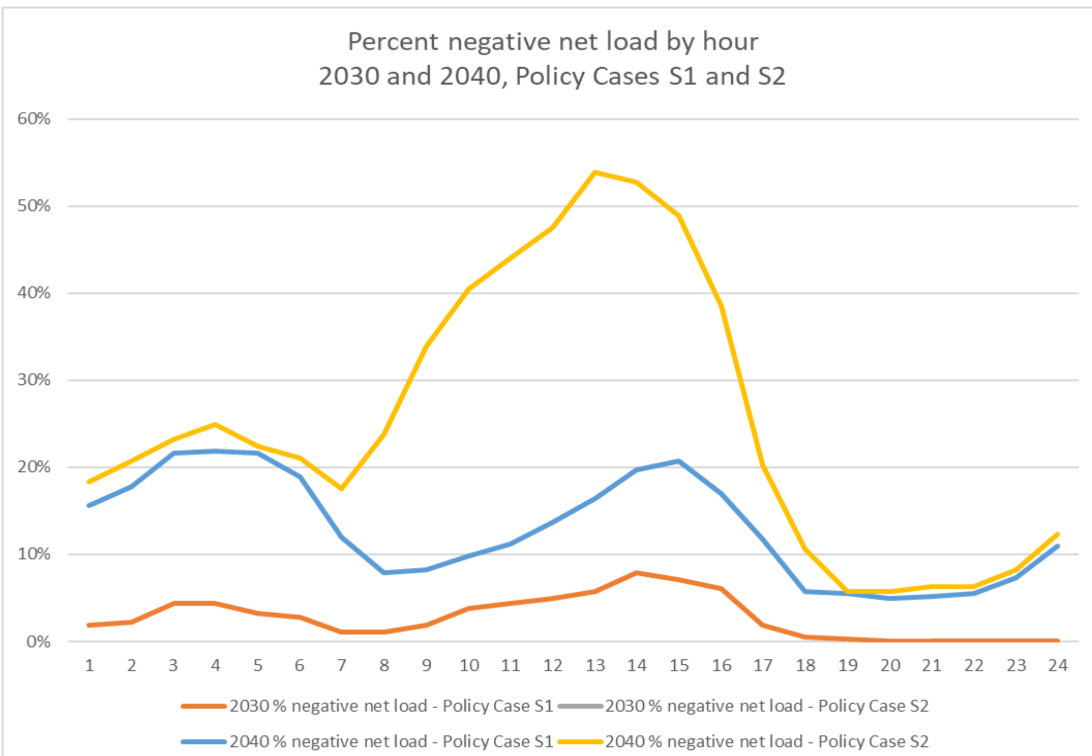
Phase 1 Ramp Analysis Results

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 [10]. 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 the percent of negative load hours by hour and Policy Case buildout for 2030 and 2040



[10] The results of the analysis when the negative load periods were not zeroed out are also provided later in this appendix.

Figure 2-5: Phase 1 Net Load Single Hour Ramp Distribution Curves for 2030 (and actual 2021)

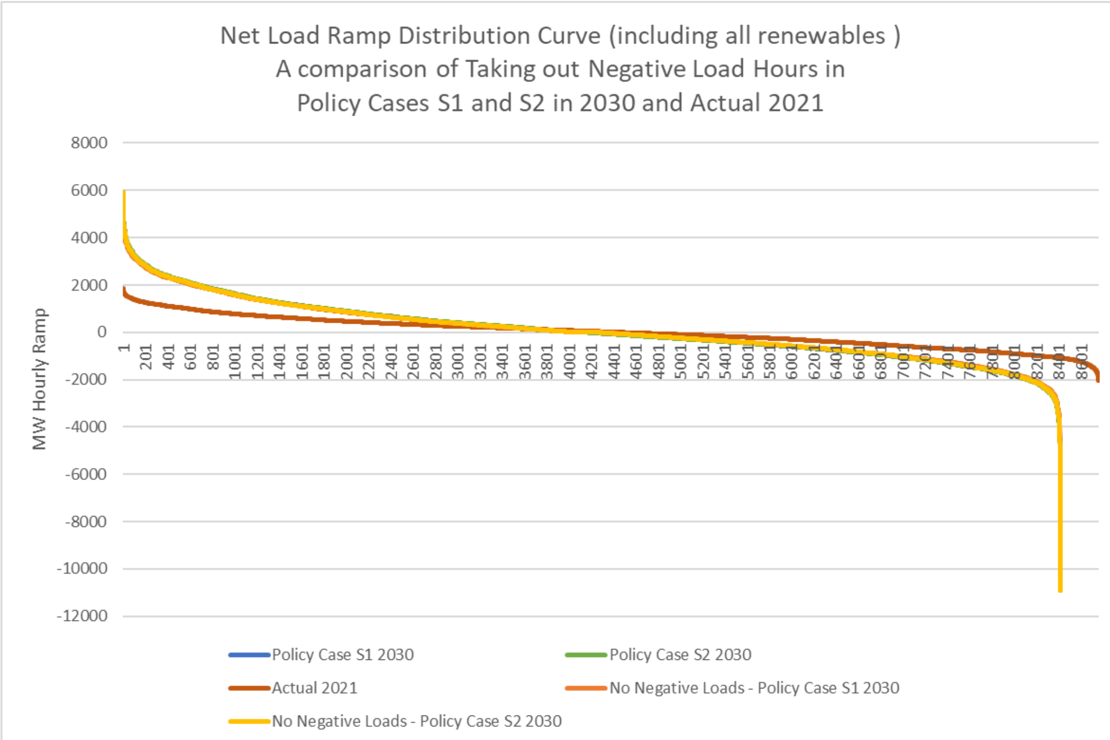
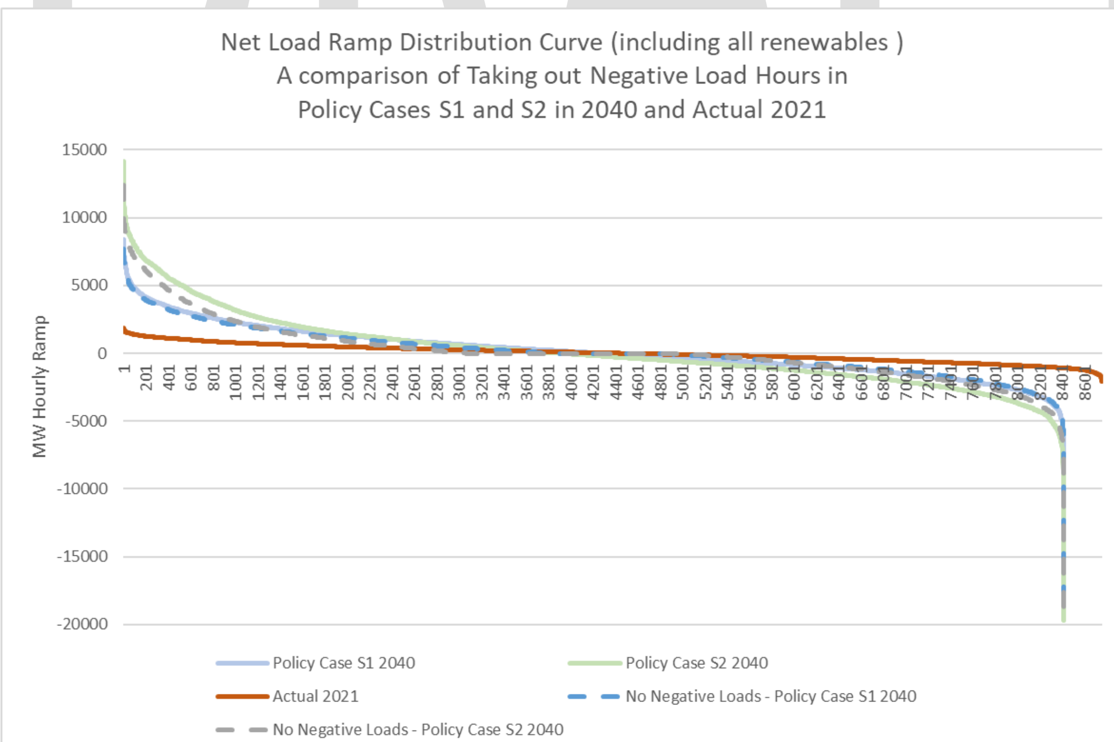


Figure 2-6: Phase 1 Net Load Single Hour Ramp Distribution Curves for 2040 (and actual 2021)



The single hour net load ramp distribution curves for the years 2030 and 2040 are provided for the two Policy Cases. For 2030, the single hour ramps for the two policy cases overlap each other. This is due to their net load curves being similar which was observed in the Phase 1 Net Load Results section. 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. This is due to the net load curves being more depressed by the higher amount of solar in Policy Case S2 which was observed in the Phase 1 Net Load Results section. 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 and five-hour ramps are also charted into separate multiple charts of net load ramp distribution curves for the years 2030 and 2040 for the two policy cases to study the distribution of the ramp magnitudes and observe the differences between three-hour and five-hour metrics.

Figure 2-7: Hourly Ramp Distribution Curve for Policy Case S1

[Add figure]

Figure 2-8: Hourly Ramp Distribution Curve for Policy Case S2

[Add figure]

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

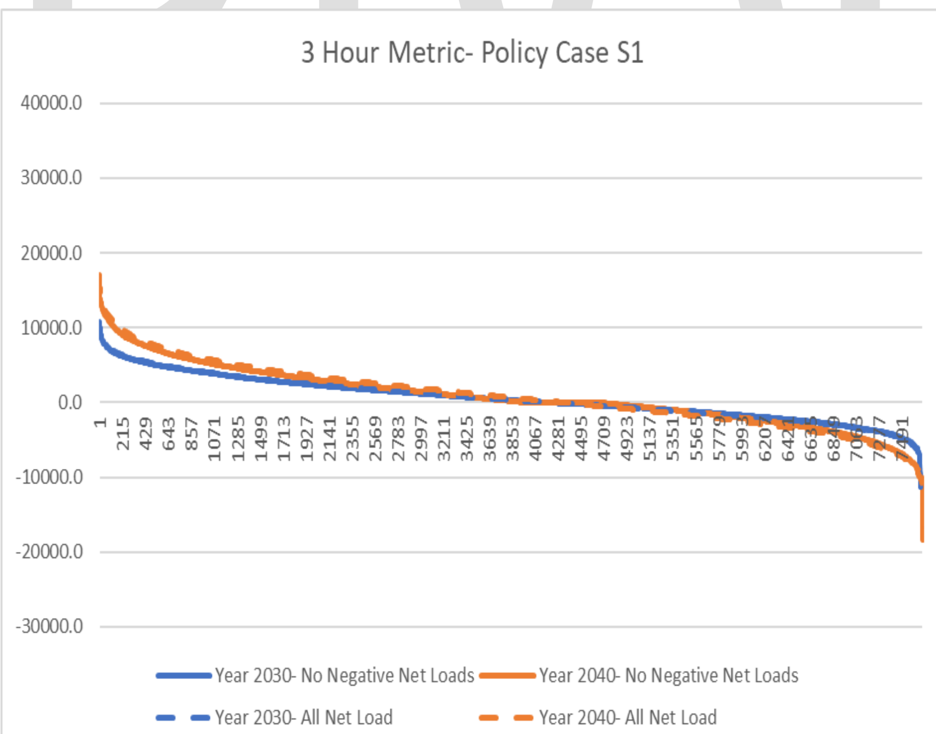


Figure 2-10: Three-Hour Ramp Distribution Curve for Policy Case S2

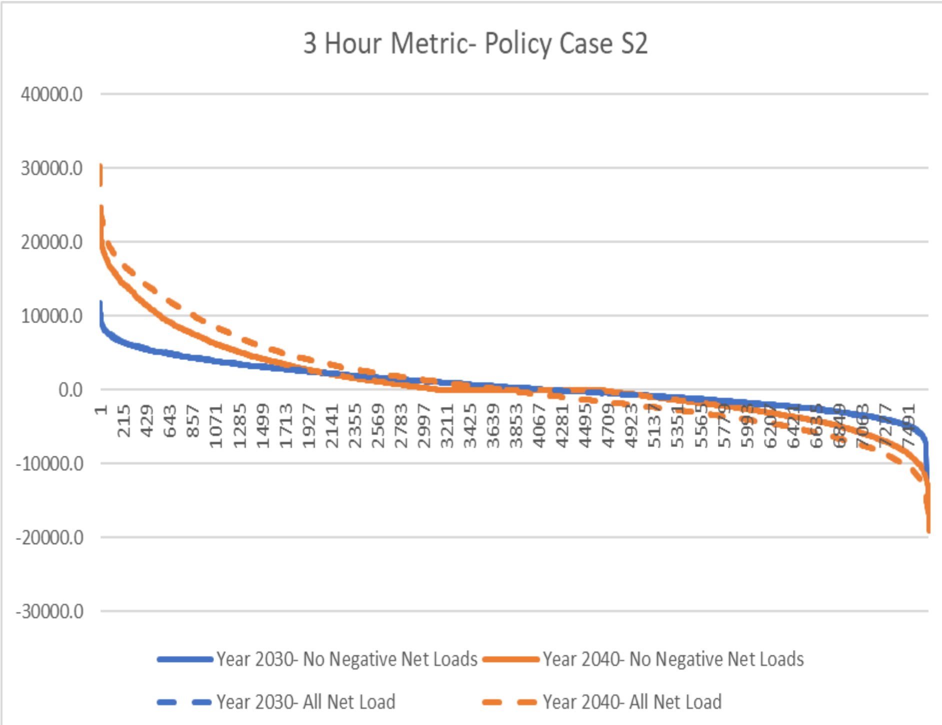


Figure 2-11: Five-Hour Ramp Distribution Curve for Policy Case S1

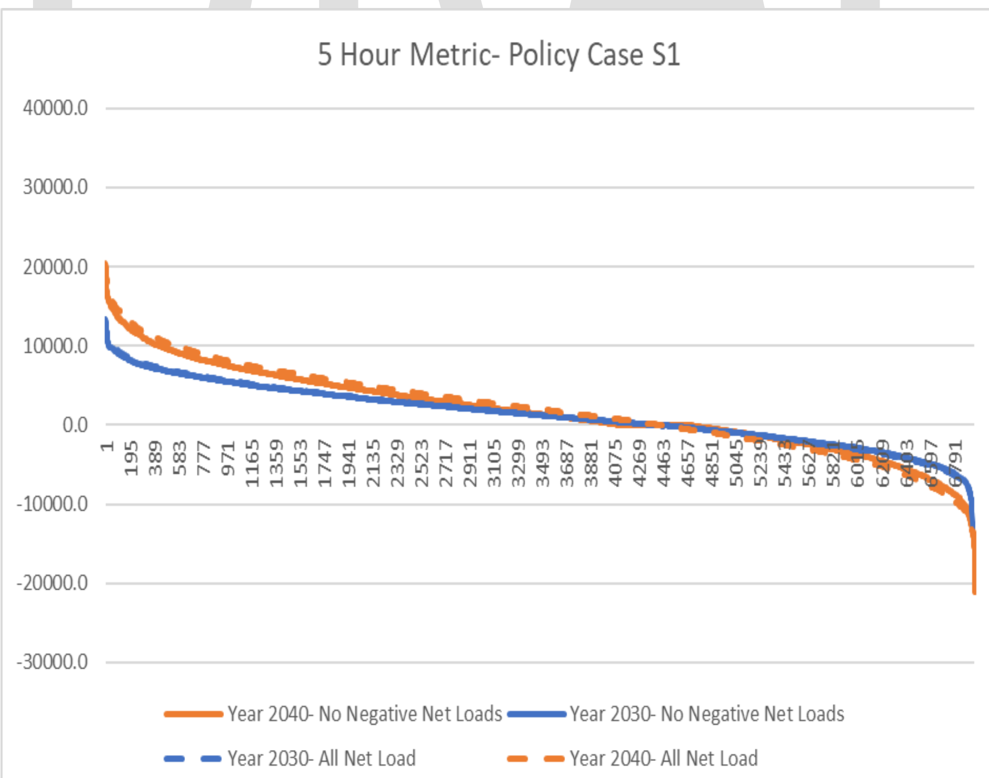
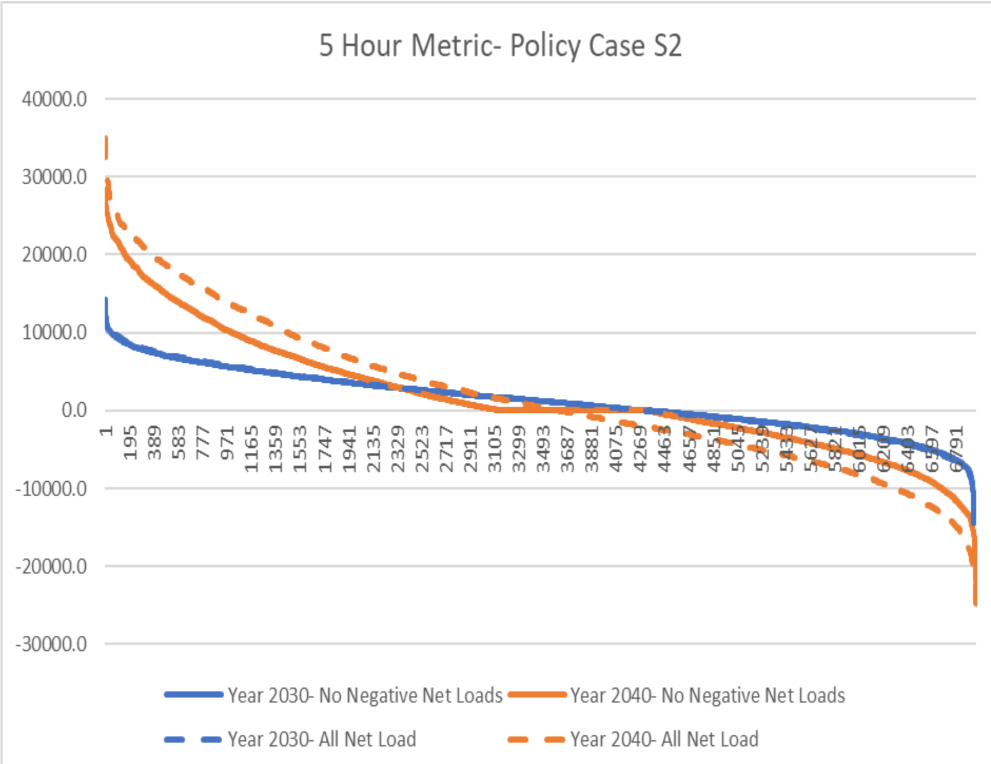


Figure 2-12: Five-Hour Ramp Distribution Curve for Policy Case S2



From the Figures 2-9 through 2-12, 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. There is an overlap between the ramp curves for the respective metrics for Policy Case S1 and S2 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 being greater than 10000 MWs for 2040 than that of 2030 and a lot more instances of these 10000 MW five-hour ramps being present in Policy Case S2 than in Policy Case S1 for 2040.

For the multi-hour ramp metrics (need to add Table), the average ramp MWs and hours 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 that of Policy Case S1 implying higher ramp needs in the extremes of the distribution for both ramp up and ramp down events. This is consistent with the net load shapes and hourly ramp distributions seen earlier.

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

[Add table]

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 5000 MW and 10000 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.

Including Negative Net Loads

In this stage, the negative net loads were not zeroed out and the ramp analysis was carried out the same as Stage 1. The number of instances with negative net loads seemed relatively smaller than the total number of instances for all the ramp metrics. This did not lead to any major differences in the conclusions drawn from Stage 1. The charts and statistics for this analysis are included below.

[Need to add Figures and Tables]

Appendix 3: Additional Phase 2 data and analysis

Table 3-X 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

[This section currently being drafted]