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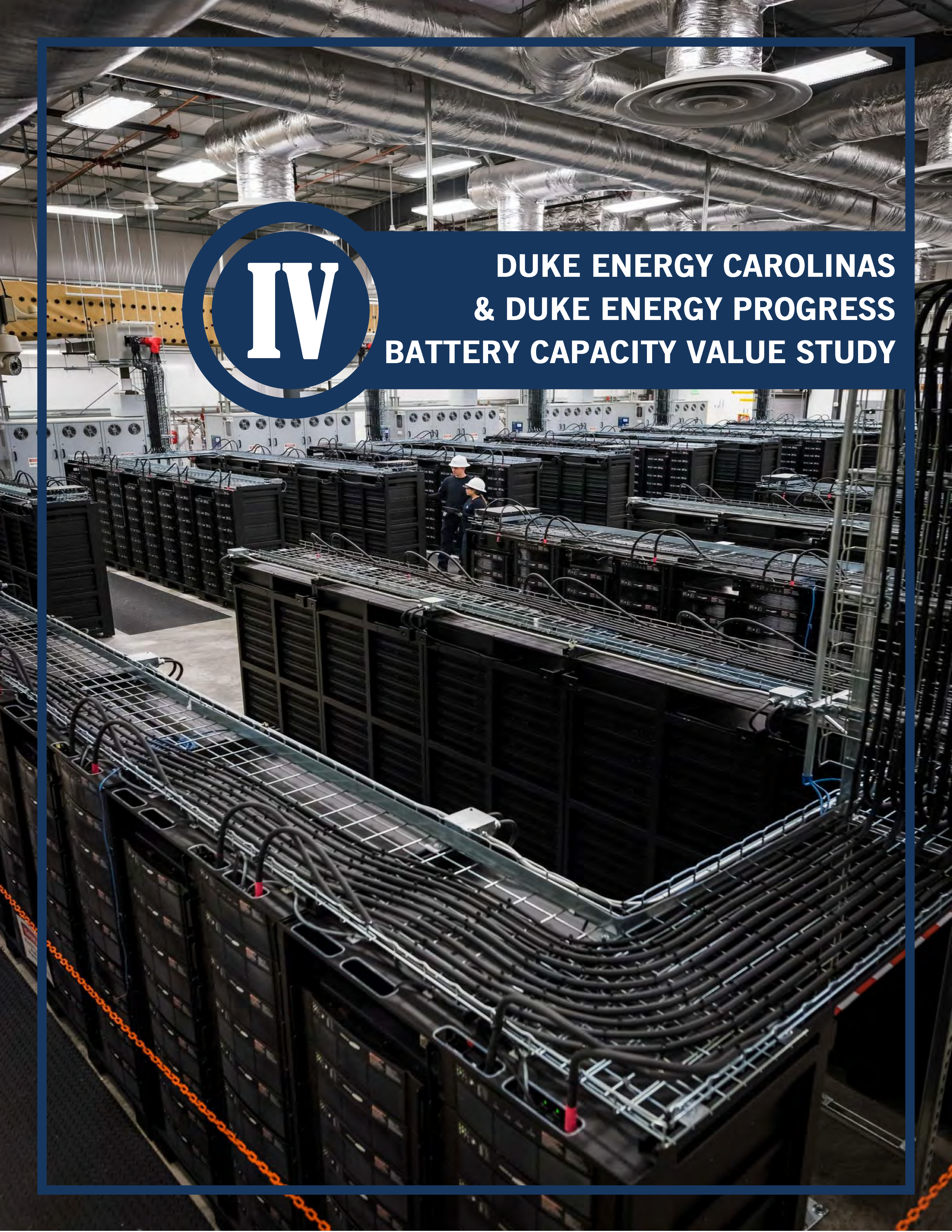
# DUKE ENERGY CAROLINAS

## INTEGRATED RESOURCE PLAN

2020

## ATTACHMENT IV

## DUKE ENERGY CAROLINAS AND DUKE ENERGY PROGRESS STORAGE EFFECTIVE LOAD CARRYING CAPABILITY (ELCC) STUDY



# IV

# DUKE ENERGY CAROLINAS & DUKE ENERGY PROGRESS BATTERY CAPACITY VALUE STUDY

# Duke Energy Carolinas and Duke Energy Progress Storage Effective Load Carrying Capability (ELCC) Study

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# I. Summary of Methodology and Results

This study was requested by Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) to analyze the capacity value of battery technology within each system. Capacity value is the reliability contribution of a generating resource and is the fraction of the rated capacity considered to be firm. This value is used for reserve margin calculation purposes. Because battery systems have limited energy storage capability and must be recharged, either from the grid or a dedicated generation resource, a battery's ability to reliably provide MW capacity when it is needed will differ from that of a fully dispatchable resource such as a gas-fired turbine, which can be called upon in any hour to produce energy, notwithstanding unit outages. Imperfect foresight of factors such as generator outages, load, and renewable energy generation leads to suboptimal battery charge and discharge scheduling, which can further impact the capacity contribution of energy storage resources. This study addresses the effects of both stored energy limits and imperfect foresight on the capacity value of battery energy storage systems. The study results provide the capacity value for battery energy storage systems used in the DEC and DEP Integrated Resource Plans.

Both DEC and DEP experience the majority of reliability risks in the winter, and battery energy storage systems are well-suited, up to certain penetration levels, to provide energy during the short peaks seen on cold winter mornings. This study analyzes the capacity contribution of 2-hour, 4-hour, and 6-hour stand-alone energy storage projects, and of paired battery plus solar systems, at several levels of market penetration by batteries, and two different levels of market penetration by solar for each utility. As market penetration increases, the system's net load peaks are flattened.

This lowers the capacity value of incremental energy storage as battery systems must discharge for longer periods to serve the wider net load peak.

## A. Methodology

Astrapé performed this Effective Load Carrying Capacity (ELCC) study using the Strategic Energy Risk Valuation Model (SERVM) which is the same model used for the DEC and DEP 2020 Resource Adequacy Studies. The underlying load and resource modeling are documented in the Resource Adequacy Reports. Additional details of the model setup and assumptions are included in the Technical Modeling Appendix of this report.

The Effective Load Carrying Capacity (ELCC) methodology was used to calculate the capacity value of energy storage resources. A "base" case of the system is first established which involves calibrating DEC and DEP to the 1 day in 10-year industry standard of 0.1 Loss of Load Expectation (LOLE). This is a common industry standard as documented in the Resource Adequacy Reports and ensures that battery capacity is being valued within a reliable system. It is expected that battery energy storage would not perform well as a capacity resource in a system with LOLE much greater than 0.1, because periods in which firm load shed occurs would be longer in duration. Once the "base" case is established, the battery energy storage resources are added to the system. The additional resources improve LOLE to less than 0.1. Next, load is increased by adding a perfectly negative resource[1], until the LOLE is returned to 0.1 days per year[2]. The ratio of the additional

[1] Within the modeling, a perfectly negative unit is added to the system which is a unit that produces the same negative output in every hour of the year. This is equivalent to adding load in every hour of the year.

[2] Because it is difficult to return cases back to exactly 0.1 days per year, several load levels were analyzed for each battery setup and interpolation was performed to estimate the amount of load added to return to the Base Case LOLE.

load MW to the battery MW is the reliability contribution or capacity value of the battery resource. For example, if 100 MW of battery is added and achieves the same Base Case LOLE after adding 90 MW of load, the capacity value is 90 MW divided by 100 MW which equals 90%.

## B. Study Scope

Astrapé calculated the average capacity value of battery energy storage systems with three different storage durations and at four levels of cumulative battery capacity for each utility (DEP and DEC). Tables 1 and 2 below show the different combinations of cumulative battery capacity and energy storage duration modeled for each utility. In addition, each capacity/duration combination was simulated with base and high total solar capacity assumption as indicated in the table headings.

**Table 1. DEP Run Matrix (Base Solar = 4,000; High Solar = 5,500 MW)**

| | Standalone Battery Duration (hrs) | | |
|---|---|---|---|
| Duration / Cumulative Battery Capacity | 2 | 4 | 6 |
| 800 MW | | | |
| 1,600 MW (incr 800) | | | |
| 2,400 MW (incr 800) | | | |
| 3,200 MW (incr 800) | | | |

**Table 2. DEC Run Matrix (Base Solar = 2,700; High Solar = 4,500 MW)**

| | Standalone Battery Duration (hrs) | | |
|---|---|---|---|
| Duration / Cumulative Battery Capacity | 2 | 4 | 6 |
| 400 MW | | | |
| 800 MW (incr 400) | | | |
| 1,200 MW (incr 400) | | | |
| 1,600 MW (incr 400) | | | |

Combined storage plus solar projects were also analyzed. Capacity contributions for 500 MW and 1,000 MW solar projects were analyzed for DEC, and 800 MW and 1,600 MW for DEP. The maximum MW output of each combined solar plus storage system was capped at the project's AC solar capacity, which is common for solar plus storage resources. Three different battery-to-solar MW capacity ratios were modeled, and it was assumed that the battery could be charged only from the solar array, and not from the grid. The solar generation profiles used were based on single-axis tracking systems with 1.5 inverter loading ratios. The individual permutations are shown in Tables 3 and 4 below and were replicated for both 2-hour and 4-hour storage durations.

**Table 3. DEP Storage Plus Solar Permutations**

| Project Max Capacity (MW) | Solar Capacity (MW) | Battery Capacity (MW/% of solar) | Existing Standalone Solar Capacity (MW) |
|---|---|---|---|
| 800 | 800 | 80 (10%) | 3,200 |
| 800 | 800 | 240 (30%) | 3,200 |
| 800 | 800 | 400 (50%) | 3,200 |
| 1,600 | 1,600 | 160 (10%) | 3,900 |
| 1,600 | 1,600 | 480 (30%) | 3,900 |
| 1,600 | 1,600 | 800 (50%) | 3,900 |

**Table 4. DEC Storage Plus Solar Permutations**

| Project Max Capacity (MW) | Solar Capacity (MW) | Battery Capacity (MW/% of solar) | Existing Standalone Solar Capacity (MW) |
|---|---|---|---|
| 500 | 500 | 80 (10%) | 2,200 |
| 500 | 500 | 240 (30%) | 2,200 |
| 500 | 500 | 400 (50%) | 2,200 |
| 1,000 | 1,000 | 160 (10%) | 3,200 |
| 1,000 | 1,000 | 480 (30%) | 3,200 |
| 1,000 | 1,000 | 800 (50%) | 3,200 |

## C. Battery Modeling

For this study, battery resources were modeled in three operating modes using SERVM. We describe these as (1) Preserve Reliability Mode (2) Economic Arbitrage Mode and (3) Fixed Dispatch Mode based on a set rate schedule.

The objective of Preserve Reliability Mode is to provide energy only during reliability events. In this mode, SERVM maintains full charge on the storage resource at all times and only dispatches the resource during these reliability events. This mode allows the battery to run a small number of days per year but provides a high degree of reliability. This option assumes that the utility has full control of the battery and that it would be used in the most conservative way possible. While this method would provide the most capacity value, it provides little to no economic value and is not how batteries are typically expected to be run on the system. For this reason, Preserve Reliability Mode is largely an academic exercise that provides a theoretical maximum capacity value but is not directly useful for planning purposes.

The objective of Economic Arbitrage Mode is to maximize the economic value of the battery. In this mode, SERVM schedules the battery to charge at times when system energy costs are low, and to discharge when system energy costs are high. Generally, this type of dispatch aligns well with resource adequacy risks, meaning the battery will be available to discharge during peak net load conditions when loss of load events are most likely to occur. In this mode, SERVM offers recourse options during a reliability event. In other words, SERVM allows the schedule of the battery to be adjusted in real time, and discharge if its state of charge is greater than zero to avoid firm load shed. This method also assumes the utility has full control of the battery and best represents how stand-alone batteries are expected to be operated.

Operation in Fixed Dispatch Mode assumes that the utility has no control over battery operations and that the battery owner simply charges and discharges to maximize net revenue based on a set rate schedule. A battery operating in this mode provides much less capacity value than a battery controlled by the utility. It is not anticipated that stand-alone batteries would be operated in this mode, but Fixed Dispatch is an appropriate assumption for solar plus storage projects that are subject to Public Utility Regulatory Policies Act (PURPA) avoided cost contracts and rates. The study results show that the capacity value of batteries operated in Fixed Dispatch Mode declines significantly over time if the rate structure remains fixed, because loss of load hours will shift out of alignment with the hours in which the rate structure incentivizes battery discharging as the system evolves.

For all three modes, batteries were assumed to have no limits on ramping capability or constraints on number of cycles per day outside of the ability to charge the battery. Capacity values were calculated for stand-alone batteries under all three modes described above. Astrapé recommends capacity values used in the IRPs to reflect the results for Economic Arbitrage Mode for stand-alone batteries and for solar plus storage projects over which the utility has full dispatch rights. For solar plus storage projects subject to PURPA rates, Astrapé recommends that IRP capacity values reflect the results for Fixed Dispatch Mode.

## D. Imperfect Foresight for Unit Commitment

SERVM does not have perfect day-ahead foresight around generator outages, load, and solar generation as it commits and dispatches resources. This imperfect knowledge does not impact the commitment and dispatch of batteries modeled under the Preserve Reliability Mode or Fixed Dispatch Mode. However, these uncertainties do impact batteries modeled in Economic Arbitrage Mode because SERVM is scheduling to minimize production costs, and day-ahead schedules will be sub-optimal to the extent that day-ahead forecasts do not perfectly match real time conditions. The day ahead solar and load uncertainty distributions are included in the Technical Appendix. Generator forced outages used in this study are the same as those used in the 2020 Resource Adequacy Study. The impact of these forecast uncertainties on the capacity value of batteries in Economic Arbitrage Mode can be estimated by comparing the difference between the capacity value of batteries in this mode and that of batteries in Preserve Reliability Mode, which maximizes capacity value at the expense of economic value.

## E. Stand Alone Battery Results

Tables 5 and 6 shows the average capacity value results for stand-alone batteries in DEP up to cumulative system battery capacity of 3,200 MW, assuming two different levels of cumulative solar capacity. As discussed above, the capacity value for batteries in Preserve Reliability Mode is approximately 5-10% greater than that of batteries in Economic Arbitrage Mode. This is due to the fact that the Economic Arbitrage Mode schedules the resource day ahead to flatten the net load shape. As load, solar generation, or generator availability changes, the hours in which the resource may be needed for a reliability event could change as well, reducing the reliability of the battery resource to the extent that state of charge is misaligned with the new reliability event hours. If the battery is forced to follow a fixed dispatch schedule with no ability to respond during reliability events, the capacity value is substantially lower. This effect, combined with the fact that battery capacity values decline as cumulative battery capacity increases, indicates that it is imperative for the utility to have control of these resources as battery penetrations increase. Although as stated previously, stand-alone batteries are not expected to operate in Fixed Dispatch Mode, and it is likely that rate structures would be adjusted as cumulative battery capacity increased so as to maintain alignment between fixed dispatch scheduling and resource adequacy needs. Because of this, it is expected that the capacity values in the higher battery penetration cases with fixed dispatch are unreasonably low.

**Table 5. DEP Standalone Capacity Value Results**

| | | | Full control and reserved for LOLE events (Academic Only) | Full control, dispatched for economic arbitrage - allowed to change dispatch during reliability events (Recommended) | No control, dispatch based on rate schedule; no change in dispatch during reliability events (Academic Only) |
|---|---|---|---|---|---|
| **Solar Capacity (MW)** | **Duration (hr)** | **Battery Capacity (MW)** | **Average Capacity Value - Preserve Reliability** | **Average Capacity Value - Economic Arbitrage** | **Average Capacity Value -Fixed Schedule** |
| 4,000 | 2 | 800 | 95% | 88% | 55% |
| 4,000 | 4 | 800 | 97% | 94% | 62% |
| 4,000 | 6 | 800 | 97% | 95% | 62% |
| 4,000 | 2 | 1,600 | 77% | 66% | 37% |
| 4,000 | 4 | 1,600 | 93% | 87% | 40% |
| 4,000 | 6 | 1,600 | 95% | 90% | 40% |
| 4,000 | 2 | 2,400 | 65% | 57% | 27% |
| 4,000 | 4 | 2,400 | 86% | 78% | 27% |
| 4,000 | 6 | 2,400 | 92% | 84% | 28% |
| 4,000 | 2 | 3,200 | 56% | 50% | 22% |
| 4,000 | 4 | 3,200 | 76% | 69% | 22% |
| 4,000 | 6 | 3,200 | 86% | 78% | 23% |
| 5,500 | 2 | 800 | 96% | 90% | 60% |
| 5,500 | 4 | 800 | 100% | 97% | 69% |
| 5,500 | 6 | 800 | 100% | 98% | 75% |
| 5,500 | 2 | 1,600 | 80% | 72% | 39% |
| 5,500 | 4 | 1,600 | 94% | 88% | 41% |
| 5,500 | 6 | 1,600 | 97% | 93% | 41% |
| 5,500 | 2 | 2,400 | 68% | 60% | 29% |
| 5,500 | 4 | 2,400 | 86% | 80% | 29% |
| 5,500 | 6 | 2,400 | 94% | 87% | 28% |
| 5,500 | 2 | 3,200 | 57% | 52% | 21% |
| 5,500 | 4 | 3,200 | 80% | 72% | 21% |
| 5,500 | 6 | 3,200 | 89% | 82% | 21% |

The DEC results for stand-alone batteries are shown in the following table.

**Table 6. DEC Standalone Capacity Value Results**

| | | | Full control and reserved for LOLE events (Academic Only) | Full control, dispatched for economic arbitrage - allowed to change dispatch during reliability events (Recommended) | No control, dispatch based on rate schedule; no change in dispatch during reliability events (Academic Only) |
|---|---|---|---|---|---|
| Solar Capacity (MW) | Duration (hr) | Battery Capacity (MW) | Average Capacity Value - Preserve Reliability | Average Capacity Value - Economic Arbitrage | Average Capacity Value -Fixed Schedule |
| 2,700 | 2 | 400 | 91% | 85% | 74% |
| 2,700 | 4 | 400 | 98% | 92% | 80% |
| 2,700 | 6 | 400 | 100% | 100% | 82% |
| 2,700 | 2 | 800 | 88% | 75% | 59% |
| 2,700 | 4 | 800 | 96% | 91% | 66% |
| 2,700 | 6 | 800 | 96% | 93% | 79% |
| 2,700 | 2 | 1,200 | 74% | 64% | 48% |
| 2,700 | 4 | 1,200 | 94% | 84% | 56% |
| 2,700 | 6 | 1,200 | 95% | 90% | 73% |
| 2,700 | 2 | 1,600 | 65% | 57% | 39% |
| 2,700 | 4 | 1,600 | 88% | 80% | 41% |
| 2,700 | 6 | 1,600 | 95% | 89% | 57% |
| 4,500 | 2 | 400 | 96% | 90% | 74% |
| 4,500 | 4 | 400 | 100% | 100% | 80% |
| 4,500 | 6 | 400 | 100% | 100% | 83% |
| 4,500 | 2 | 800 | 92% | 81% | 62% |
| 4,500 | 4 | 800 | 97% | 90% | 69% |
| 4,500 | 6 | 800 | 97% | 93% | 79% |
| 4,500 | 2 | 1,200 | 81% | 66% | 53% |
| 4,500 | 4 | 1,200 | 94% | 87% | 58% |
| 4,500 | 6 | 1,200 | 95% | 93% | 75% |
| 4,500 | 2 | 1,600 | 73% | 65% | 42% |
| 4,500 | 4 | 1,600 | 92% | 86% | 45% |
| 4,500 | 6 | 1,600 | 94% | 91% | 61% |

## F. Sensitivity – 6-Hour Standalone Battery at Higher Market Penetration Levels

Finally, sensitivity analysis was performed on stand-alone battery capacity to assess the effect of adding additional battery capacity above the 1,600 MW for DEC and 3,200 MW for DEP 4-hour configurations. Two 800 MW blocks of 6-hour battery capacity were added to DEP, and two 400 MW blocks of 6-hour battery capacity were added to DEC. The results in Tables 7 and 8 show that despite the additional storage having 6-hour duration, the overall average capacity value for storage still declines.

**Table 7. DEP Sensitivity Results**

| DEP | Battery Penetration | Capacity Value - Economic Arbitrage |
|---|---|---|
| all 4-hour | 800 | 97% |
| all 4-hour | 1,600 | 88% |
| all 4-hour | 2,400 | 80% |
| all 4-hour | 3,200 | 72% |
| additional 6-hour | 4,000 | 67% |
| additional 6-hour | 4,800 | 63% |

**Table 8. DEC Sensitivity Results**

| DEC | Battery Penetration | Capacity Value - Economic Arbitrage |
|---|---|---|
| all 4-hour | 400 | 100% |
| all 4-hour | 800 | 90% |
| all 4-hour | 1,200 | 87% |
| all 4-hour | 1,600 | 86% |
| additional 6-hour | 2,000 | 82% |
| additional 6-hour | 2,400 | 79% |

## G. Combined Solar Plus Storage Battery Results

The combined solar plus storage results are shown in Table 9 and 10 below. For these runs, only the Economic Arbitrage Mode and the Fixed Schedule Mode analyses were conducted. The capacity values are shown as a percentage of the MW capacity of the paired solar project. Because solar capacity value in the winter is minimal, it is likely that the battery contributes most of the value shown for the combined solar plus storage system. Solar provides slightly more value in DEC, where there is a very small amount of summer LOLE that corresponds well to solar generation. Because the penetration of battery capacity wasn't increased as high as the standalone battery analysis, the battery capacity remained high. It is expected that battery capacity value would decline as cumulative installed battery capacity, whether coupled with solar or charged solely from the grid, increased further, as indicated by the standalone battery analysis.

**Table 9. DEP Solar Plus Storage Results**

| Standalone Solar Capacity (MW) | Duration (hr) | Project Max Capacity (MW) | Battery Capacity (MW / % of Solar) | Solar Capacity Paired with Storage (MW) | Economic Arbitrage - Utility Controlled Average Capacity Value (% of Project Max Capacity) | No Dispatch Rights - Fixed Schedule Average Capacity Value (% of Project Max Capacity) |
|---|---|---|---|---|---|---|
| 3,200 | 2 | 800 | 80 (10%) | 800 | 12% | 8% |
| 3,200 | 2 | 800 | 240 (30%) | 800 | 31% | 21% |
| 3,200 | 2 | 800 | 400 (50%) | 800 | 45% | 25% |
| 3,200 | 4 | 800 | 80 (10%) | 800 | 12% | 11% |
| 3,200 | 4 | 800 | 240 (30%) | 800 | 31% | 27% |
| 3,200 | 4 | 800 | 400 (50%) | 800 | 49% | 34% |
| 3,900 | 2 | 1,600 | 160 (10%) | 1,600 | 12% | 8% |
| 3,900 | 2 | 1,600 | 480 (30%) | 1,600 | 30% | 17% |
| 3,900 | 2 | 1,600 | 800 (50%) | 1,600 | 46% | 23% |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3,900 | 4 | 1,600 | 160 (10%) | 1,600 | 12% | 11% |
| 3,900 | 4 | 1,600 | 480 (30%) | 1,600 | 31% | 23% |
| 3,900 | 4 | 1,600 | 800 (50%) | 1,600 | 51% | 27% |

**Table 10. DEC Solar Plus Storage Results**

| Standalone Solar Capacity (MW) | Duration (hr) | Project Max Capacity (MW) | Battery Capacity (MW / % of Solar) | Solar Capacity Paired with Storage (MW) | Economic Arbitrage - Utility Controlled Average Capacity Value (% of Project Max Capacity) | No Dispatch Rights - Fixed Schedule Average Capacity Value (% of Project Max Capacity) |
|---|---|---|---|---|---|---|
| 2,200 | 2 | 500 | 50 (10%) | 500 | 11% | 8% |
| 2,200 | 2 | 500 | 150 (30%) | 500 | 28% | 20% |
| 2,200 | 2 | 500 | 250 (50%) | 500 | 43% | 28% |
| 2,200 | 4 | 500 | 50 (10%) | 500 | 14% | 14% |
| 2,200 | 4 | 500 | 150 (30%) | 500 | 30% | 28% |
| 2,200 | 4 | 500 | 250 (50%) | 500 | 44% | 43% |
| 3,200 | 2 | 1,000 | 100 (10%) | 1,000 | 9% | 7% |
| 3,200 | 2 | 1,000 | 300 (30%) | 1,000 | 26% | 19% |
| 3,200 | 2 | 1,000 | 500 (50%) | 1,000 | 41% | 30% |
| 3,200 | 4 | 1,000 | 100 (10%) | 1,000 | 10% | 9% |
| 3,200 | 4 | 1,000 | 300 (30%) | 1,000 | 28% | 25% |
| 3,200 | 4 | 1,000 | 500 (50%) | 1,000 | 43% | 41% |

To further illustrate the potential misalignment between a fixed dispatch schedule and Expected Unserved Energy (EUE) hours, Figures 1 and 2 below show the solar plus storage profiles for January of systems operating according to a fixed dispatch schedule (primary axis) with the EUE hours (secondary axis). The fixed dispatch schedule aligns better with the EUE hours for DEC than for DEP, resulting in a higher capacity value for these systems in DEC. The misalignment shown in both charts would be expected to increase over time if rate schedules were not adjusted, as battery storage is added to the system or other factors change.

**Figure 1. DEP Fixed Dispatch for Combined Cases**

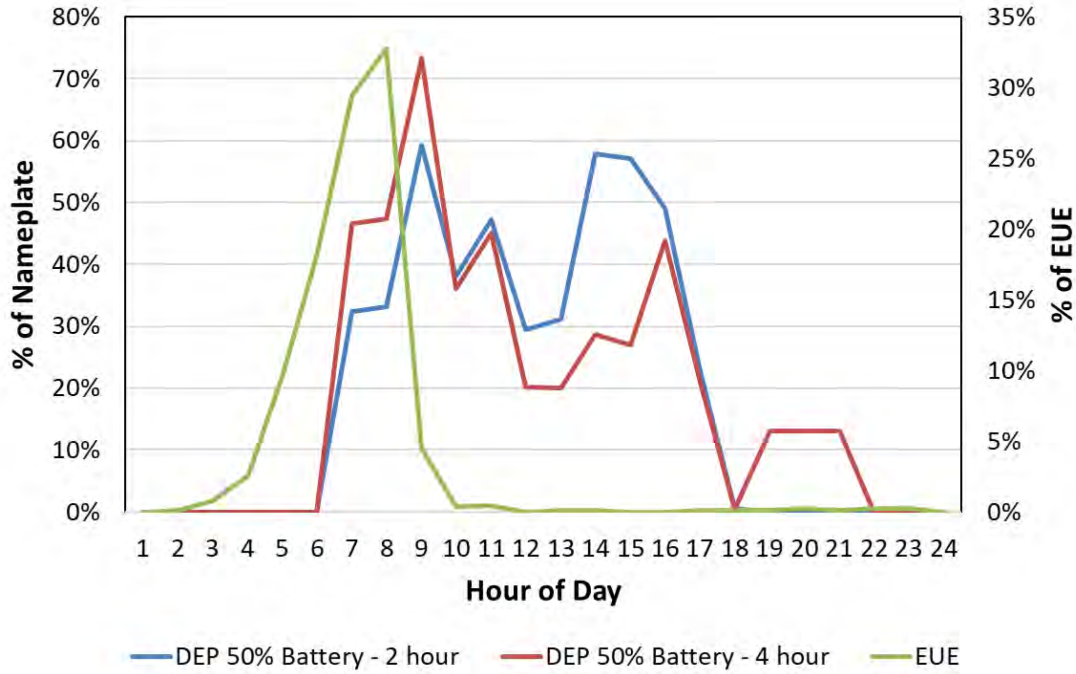
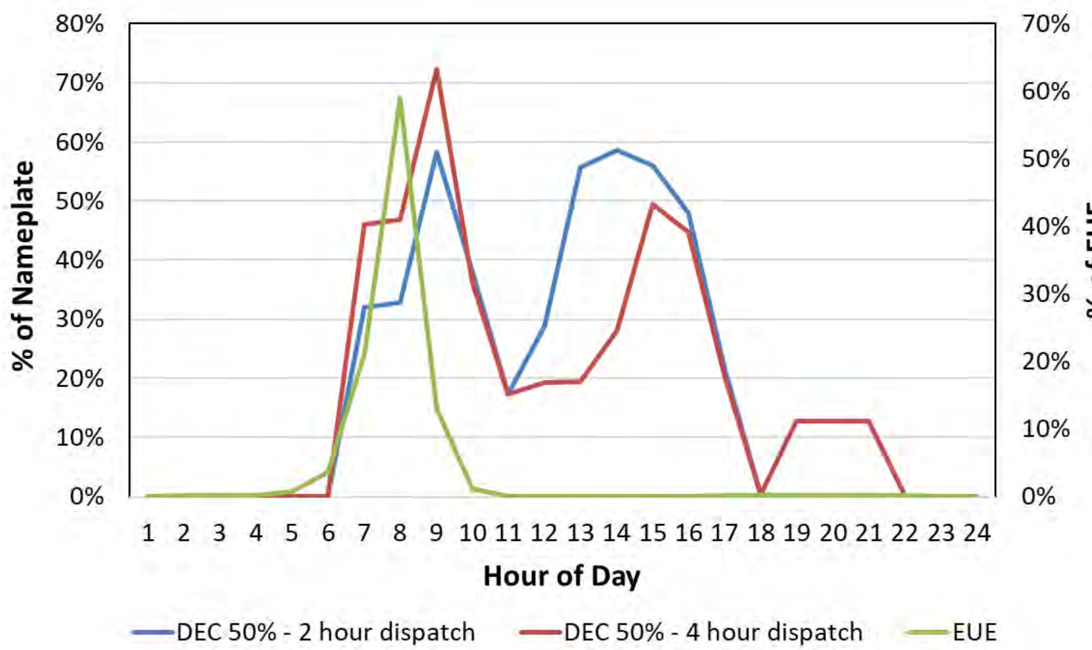



**Figure 2. DEC Fixed Dispatch for Combined Cases**



## H. Conclusions

The results of the ELCC Study estimate significant capacity value, that reduces as penetration increases, for 4-hour and 6-hour storage for both Companies to assist in offsetting the winter reliability risks. In DEP, 2,400 MW of 4-hour storage is estimated to have an average capacity value of 80%. In DEC, 1,600 MW of 4 – hour storage is estimated to have an average capacity value of greater than 85%. The study reveals significant capacity value in scenarios where the utility had dispatch rights over the storage compared to the owner discharging or charging based only on an economic rate schedule. The combined solar plus storage projects, including those with a battery to solar ratio of 50%, showed capacity values commensurate with the battery size. While this study does include some level of operator uncertainty due to day-ahead dispatch of storage, there are potentially additional operational constraints of storage technology that were not explored in this study. For example, there were no charging/discharging constraints, ramping constraints, daily cycle constraints, or degradation assumed in this Study. As the Companies and industry gain experience about the large-scale deployment of storage, these estimates should be revisited.

# II. Technical Modeling Appendix

The following sections include a discussion on the setup and assumptions used to evaluate the capacity value of battery. The Study utilized the load and resource assumptions from the 2020 Resource Adequacy Study and Framework which are detailed in Sections III and IV of those reports.[3]

## A. SERVM Framework and Cases

The study uses the same 2024 study year framework as the Base Case 2020 Resource Adequacy Study and includes 39 weather years (1980 – 2018), five load forecast error multipliers, and Monte Carlo generator outages. For capacity value studies in which significant levels of cumulative battery capacity are analyzed, the number of iterations and run times are extensive. For example, each of the weather year and load forecast error multipliers was simulated with 100 generator outage iterations. Two measures were taken to reduce the number of iterations and the simulation time.

First, since the capacity value is calculated from only cases that contain LOLE, weather years with zero LOLE were removed from the analysis. This trimmed down the simulations from 39 years to 24 years. Each weather year was still given a 1/39 chance of occurring. Second, instead of modeling all external neighbors, an hourly purchase resource was developed based on the Base Case reserve margin study which allowed external neighbors to be eliminated from the modeling

[3] Duke Energy Carolinas 2020 Resource Adequacy Study
Duke Energy Progress 2020 Resource Adequacy Study

to significantly reduce run time. To develop the market purchase resource, hourly purchase reports from the Base Case were used and the relationship between net load and purchases was estimated by hour of day and month. This relationship expressing purchases as a function of net load was then applied to all the weather years in the modeling. Because the Base Case simulations target 0.1 LOLE, this assumption is reasonable and was used for all the incremental battery simulations. With these two changes, the run times were reduced significantly. Each level of battery was studied with 24 weather years, five load forecast error multipliers, and 100 iterations of generator outage draws.

## B. Load and Solar Uncertainty

Historical hourly load and solar generation were compared to day-ahead forecasts to determine day ahead forecast uncertainty. The following tables show the data that was used. The first column of values displays the forecast error and the columns to the right show probabilities of the forecast error occurring. As one would expect, the day ahead forecast for load was fairly low while the solar error was much higher. As discussed in the summary, SERVM draws from this set of forecast error to develop day ahead net load forecasts to commit and dispatch units. Then in real time the actual net load is realized, and the fleet must adjust to meet net load.

**Table 11. DEP Day Ahead Load Uncertainty**

| | | DEP Normalized Load | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 30%-40% | 40%-50% | 50%-60% | 60%-70% | 70%-80% | 80%-90% | 90%-100% |
| Over- Forecast (Negative is Under-Forecast) in Normalized Load | -20% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -18% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -16% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -14% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -12% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -10% | 0% | 0% | 1% | 1% | 0% | 0% | 0% |
| | -8% | 0% | 0% | 1% | 2% | 2% | 1% | 0% |
| | -6% | 1% | 2% | 4% | 6% | 6% | 4% | 0% |
| | -4% | 6% | 11% | 14% | 16% | 15% | 17% | 3% |
| | -2% | 53% | 40% | 32% | 28% | 28% | 24% | 9% |
| | 0% | 36% | 38% | 34% | 26% | 25% | 24% | 32% |
| | 2% | 4% | 7% | 12% | 14% | 12% | 13% | 32% |
| | 4% | 0% | 1% | 3% | 6% | 8% | 7% | 14% |
| | 6% | 0% | 0% | 0% | 1% | 3% | 7% | 8% |
| | 8% | 0% | 0% | 0% | 0% | 1% | 1% | 1% |
| | 10% | 0% | 0% | 0% | 0% | 0% | 1% | 1% |
| | 12% | 0% | 0% | 0% | 0% | 0% | 1% | 0% |
| | 14% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 16% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 18% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 20% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

## Table 12. DEC Day Ahead Load Uncertainty

| | | DEC Normalized Load | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 30%-40% | 40%-50% | 50%-60% | 60%-70% | 70%-80% | 80%-90% | 90%-100% |
| Over- Forecast (Negative is Under-Forecast) in Normalized Load | -20% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -18% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -16% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -14% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -12% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -10% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -8% | 0% | 0% | 0% | 1% | 1% | 0% | 0% |
| | -6% | 0% | 1% | 2% | 2% | 3% | 3% | 0% |
| | -4% | 5% | 6% | 8% | 13% | 16% | 14% | 3% |
| | -2% | 56% | 37% | 31% | 30% | 24% | 26% | 9% |
| | 0% | 40% | 49% | 44% | 30% | 30% | 25% | 38% |
| | 2% | 0% | 6% | 12% | 16% | 14% | 12% | 16% |
| | 4% | 0% | 0% | 2% | 6% | 7% | 9% | 12% |
| | 6% | 0% | 0% | 0% | 2% | 4% | 4% | 7% |
| | 8% | 0% | 0% | 0% | 0% | 1% | 5% | 5% |
| | 10% | 0% | 0% | 0% | 0% | 0% | 2% | 5% |
| | 12% | 0% | 0% | 0% | 0% | 0% | 0% | 6% |
| | 14% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 16% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 18% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 20% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

## Table 13. DEP Day Ahead Solar Uncertainty

| | | Normalized Solar | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0%-10% | 10%-20% | 20%-30% | 30%-40% | 40%-50% | 50%-60% | 60%-70% | 70%-80% | 80%-90% | 90%-100% |
| Over- Forecast (Negative is Under-Forecast) in Normalized Solar Output | -60% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -55% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -50% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% |
| | -45% | 0% | 0% | 1% | 3% | 1% | 1% | 0% | 0% | 0% | 0% |
| | -40% | 0% | 0% | 1% | 3% | 5% | 2% | 0% | 0% | 0% | 0% |
| | -35% | 0% | 1% | 2% | 4% | 9% | 6% | 1% | 0% | 0% | 0% |
| | -30% | 0% | 0% | 6% | 9% | 12% | 9% | 8% | 0% | 0% | 0% |
| | -25% | 0% | 1% | 8% | 10% | 17% | 15% | 17% | 4% | 0% | 0% |
| | -20% | 0% | 4% | 9% | 12% | 17% | 16% | 23% | 21% | 1% | 0% |
| | -15% | 0% | 13% | 14% | 14% | 14% | 18% | 25% | 36% | 38% | 0% |
| | -10% | 1% | 15% | 16% | 11% | 11% | 17% | 13% | 25% | 42% | 20% |
| | -5% | 68% | 23% | 13% | 15% | 5% | 9% | 7% | 9% | 9% | 59% |
| | 0% | 30% | 25% | 14% | 8% | 4% | 3% | 4% | 2% | 6% | 20% |
| | 5% | 1% | 14% | 8% | 5% | 2% | 2% | 1% | 1% | 2% | 0% |
| | 10% | 0% | 3% | 7% | 2% | 1% | 2% | 0% | 1% | 1% | 2% |
| | 15% | 0% | 0% | 2% | 2% | 1% | 0% | 1% | 0% | 1% | 0% |
| | 20% | 0% | 0% | 0% | 1% | 0% | 1% | 0% | 0% | 0% | 0% |
| | 25% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 30% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 35% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 40% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 14. DEC Day Ahead Solar Uncertainty**

| | | Normalized Solar | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0%-10% | 10%-20% | 20%-30% | 30%-40% | 40%-50% | 50%-60% | 60%-70% | 70%-80% | 80%-90% | 90%-100% |
| Over- Forecast (Negative is Under-Forecast) in Normalized Solar Output | -50% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -45% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| | -40% | 0% | 0% | 1% | 1% | 1% | 1% | 0% | 0% | 0% | 0% |
| | -35% | 0% | 0% | 1% | 2% | 2% | 2% | 2% | 0% | 0% | 0% |
| | -30% | 0% | 0% | 1% | 3% | 3% | 5% | 3% | 1% | 0% | 0% |
| | -25% | 0% | 2% | 4% | 5% | 4% | 7% | 6% | 2% | 0% | 0% |
| | -20% | 0% | 3% | 7% | 10% | 7% | 9% | 9% | 6% | 3% | 0% |
| | -15% | 0% | 8% | 9% | 13% | 9% | 10% | 16% | 18% | 16% | 0% |
| | -10% | 1% | 9% | 16% | 13% | 20% | 11% | 17% | 23% | 18% | 5% |
| | -5% | 35% | 18% | 13% | 15% | 22% | 19% | 14% | 18% | 14% | 16% |
| | 0% | 63% | 22% | 14% | 13% | 12% | 18% | 14% | 14% | 19% | 23% |
| | 5% | 1% | 20% | 11% | 9% | 10% | 9% | 10% | 7% | 16% | 17% |
| | 10% | 0% | 15% | 13% | 9% | 6% | 5% | 5% | 7% | 8% | 17% |
| | 15% | 0% | 2% | 9% | 3% | 2% | 1% | 2% | 1% | 3% | 10% |
| | 20% | 0% | 0% | 1% | 3% | 1% | 1% | 2% | 1% | 1% | 8% |
| | 25% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 0% | 0% | 3% |
| | 30% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| | 35% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 40% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 45% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 50% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

## C. Stand Alone Battery Fixed Dispatch

Although the fixed dispatch analysis for a stand-alone battery is not used in the IRP, the fixed dispatch schedule based on North Carolinas Utilities Commission Docket No. E-100 Sub 158 ("Sub 158") avoided cost rates are shown below. The tables represent the dispatch of a 100 MW battery for 2, 4, and 6 hour durations.

**Table 15. DEP Stand Alone Fixed Dispatch 2-Hour**

| 2-Hour (MW) | | Hour | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Calendar | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 2 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 3 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 4 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 1 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 2 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 3 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 4 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |

## Table 16. DEP Stand Alone Fixed Dispatch 4-Hour & 6-Hour

| 4-Hour, 6-Hour (MW) | | Hour | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Calendar | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | Weekday | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 2 | Weekday | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 3 | Weekday | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 4 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekday | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 1 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 2 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 3 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 4 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |

## Table 17. DEC Stand Alone Fixed Dispatch 2-Hour

| 2-Hour (MW) | | Hour | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Calendar | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 2 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 3 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 4 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekday | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 50 | 50 | 0 | 0 | 0 | -20 |
| 7 | Weekday | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 50 | 50 | 0 | 0 | 0 | -20 |
| 8 | Weekday | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 50 | 50 | 0 | 0 | 0 | -20 |
| 9 | Weekday | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 50 | 50 | 0 | 0 | 0 | -20 |
| 10 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekday | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 1 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 2 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 3 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |
| 4 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Weekend | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 50 | 50 | 0 | 0 | 0 | -20 |
| 8 | Weekend | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 50 | 50 | 0 | 0 | 0 | -20 |
| 9 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekend | -39 | -39 | -39 | -39 | -39 | 0 | 67 | 67 | 67 | 0 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 67 | 67 | 67 | 0 | 0 | -39 |

## Table 18. DEC Stand Alone Fixed Dispatch 4-Hour

| 4-Hour (MW) | | Hour | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Calendar | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | Weekday | -78 | -78 | -78 | -78 | -78 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 50 | 100 | 100 | 100 | 50 | 0 | -78 |
| 2 | Weekday | -78 | -78 | -78 | -78 | -78 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 50 | 100 | 100 | 100 | 50 | 0 | -78 |
| 3 | Weekday | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 4 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekday | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 7 | Weekday | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 8 | Weekday | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 9 | Weekday | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 10 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekday | -78 | -78 | -78 | -78 | -78 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 50 | 100 | 100 | 100 | 50 | 0 | -78 |
| 1 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 2 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 3 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 4 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Weekend | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 8 | Weekend | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 9 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |

## Table 19. DEC Stand Alone Fixed Dispatch 6-Hour

| 6-Hour (MW) | | Hour | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Calendar | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | Weekday | -98 | -98 | -98 | -98 | -98 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 100 | 100 | 0 | -98 |
| 2 | Weekday | -98 | -98 | -98 | -98 | -98 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 100 | 100 | 0 | -98 |
| 3 | Weekday | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 4 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekday | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 33 | 33 | 33 | 33 | 100 | 100 | 100 | 100 | 33 | 33 | 0 | -59 |
| 7 | Weekday | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 33 | 33 | 33 | 33 | 100 | 100 | 100 | 100 | 33 | 33 | 0 | -59 |
| 8 | Weekday | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 33 | 33 | 33 | 33 | 100 | 100 | 100 | 100 | 33 | 33 | 0 | -59 |
| 9 | Weekday | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 33 | 33 | 33 | 33 | 100 | 100 | 100 | 100 | 33 | 33 | 0 | -59 |
| 10 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekday | -98 | -98 | -98 | -98 | -98 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 100 | 100 | 0 | -98 |
| 1 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 2 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 3 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |
| 4 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Weekend | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 8 | Weekend | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | -39 | 0 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | -39 |
| 9 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Weekend | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Weekend | -59 | -59 | -59 | -59 | -59 | 0 | 100 | 100 | 100 | 0 | -59 | -59 | -59 | -59 | -59 | -59 | 0 | 0 | 100 | 100 | 100 | 0 | 0 | -59 |

## D. Combined Solar Plus Storage Fixed Dispatch

The fixed dispatch profiles for solar plus storage were provided by Duke Energy using internal dispatch optimization models. Figure 3 and Figure 4 show the average dispatch of these resources for January and July. Battery charging and discharging were optimized to capture clipped DC solar energy and to maximize revenue based on Sub 158 avoided cost rates. The models utilize "perfect foresight" of solar generation over 3-day periods. As stated in the summary, for combined solar plus storage projects that are subject to PURPA, Astrapé recommends these capacity values; however, for utility-controlled projects Astrapé recommends the capacity values using the Economic Arbitrage Mode.

**Figure 3. DEP Combined Solar Plus Storage Fixed Dispatch**

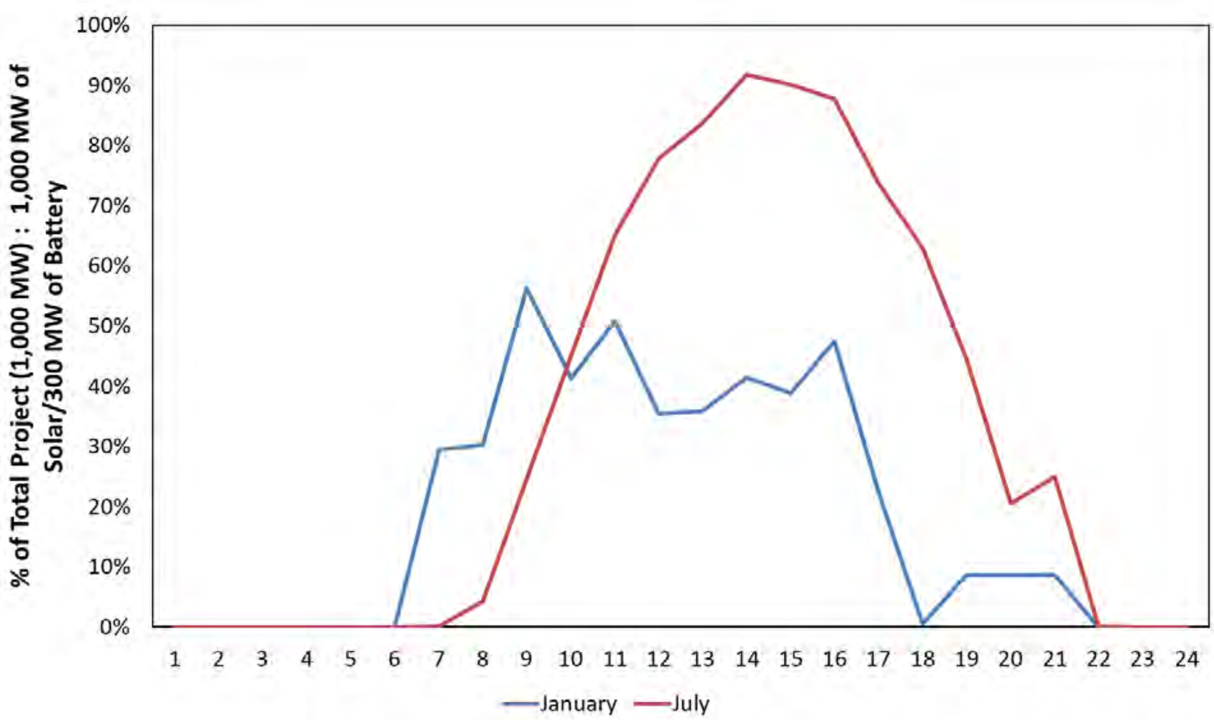
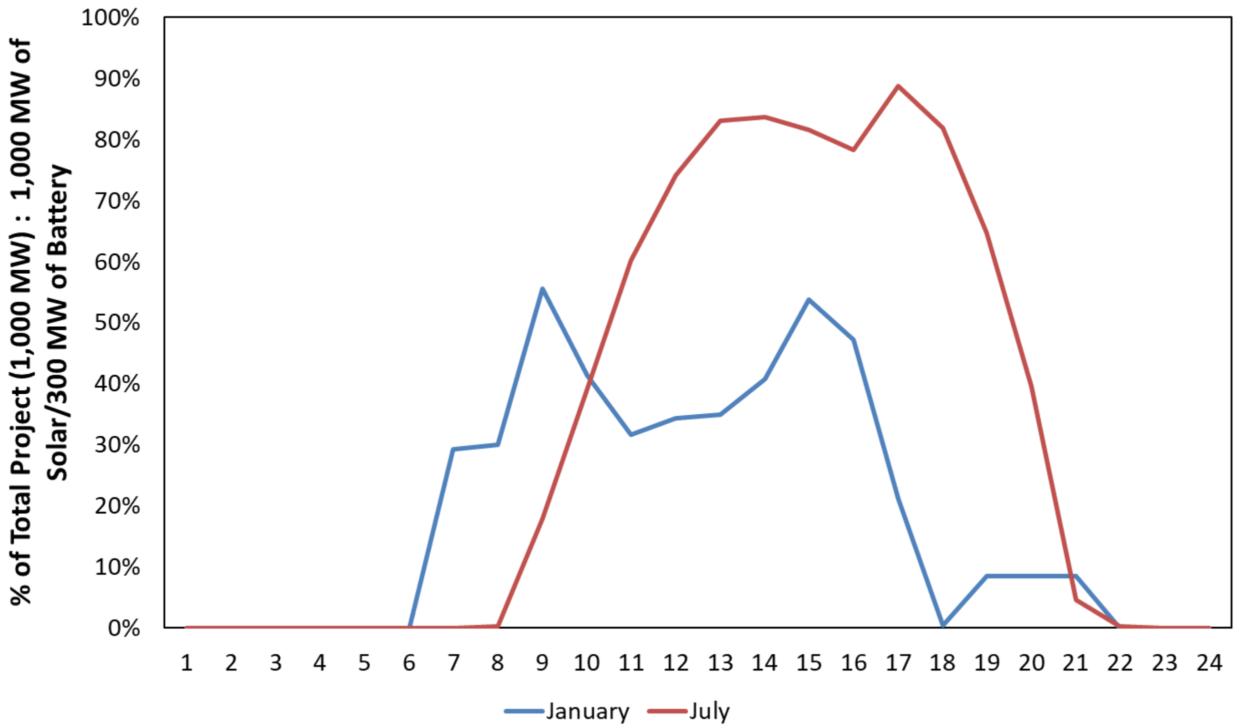


**Figure 4. DEC Combined Solar Plus Storage Fixed Dispatch**




## E. Firm Load Shed Event

Loss of Load Expectation is defined as any day that has hourly firm load shed and is consistent with the Resource Adequacy Studies. A firm load shed event is defined as any day in which resources could not meet load, even after utilizing neighbor assistance and demand response programs, regardless of the number of hours affected. Regulating reserves of 218 MW in DEC and 150 MW in DEP were always maintained. Batteries were allowed to serve regulating reserves.

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