AUGUST 18, 2021 | WEBEX

Transmission Planning for the Clean Energy Transition

Pilot Study Results and Proposed Changes to Assumptions

Dan Schwarting, P.E.

MANAGER, TRANSMISSION PLANNING

Objectives of Today's Presentation

- Share further details on results of the Transmission Planning for the Clean Energy Transition (TPCET) Pilot Study
- Summarize results of the TPCET Pilot Study
- Propose final assumptions for load, wind, and solar for Needs Assessments, Solutions Studies, and Requests for Proposals for transmission solutions

Presentation Outline

- Overview of TPCET Pilot Study
- Stability Analysis Update
- Steady-State Analysis Results
- Summary of TPCET Pilot Study Results
- Adjustments to Previously Proposed Assumptions
- Proposed Assumptions
- Conclusion & Next Steps

Note: in order to maximize stakeholder involvement, this presentation does not contain Critical Energy Infrastructure Information (CEII). As a result, information about the exact contingencies causing concerns is not being shared at this time. A document supplementing previous PAC presentations on the TPCET Pilot Study with CEII information, such as contingency definitions from stability analysis, is currently being prepared, and will be distributed to the PAC when it is complete.

OVERVIEW OF TPCET PILOT STUDY

Overview of the TPCET Pilot Study

- New England continues to lead many industry trends
  - Development of Distributed Energy Resources (DER)
  - Integration of renewable resources, including offshore wind
  - Increasing imports via HVDC interconnections
  - Integration of battery energy storage resources
- To quantify trade-offs between cost and ability of the transmission system to accommodate high amounts of renewable resources, ISO-NE has conducted a “pilot” study of certain key system conditions
- The Pilot Study aided in developing assumptions for use in Needs Assessments, Solutions Studies, and Requests for Proposals for transmission solutions, and explored reliability concerns that may arise under these system conditions

Scope of Changes Proposed in Pilot Study

- The TPCET Pilot Study is focused on the ten-year reliability study time frame, and studies the year 2030
  - In contrast to longer-term studies such as Future Grid Reliability Study and the 2050 study, TPCET is not examining longer-term future scenarios beyond the ten-year planning horizon
- The assumption changes and analysis discussed today will apply to Needs Assessments, Solutions Studies, and Requests for Proposals for transmission solutions
  - Other studies, such as interconnection studies, System Impact Studies, cluster interconnection studies, and resource qualification studies, may adopt the assumptions described here at a later date, or may continue to use other assumptions specific to those study types

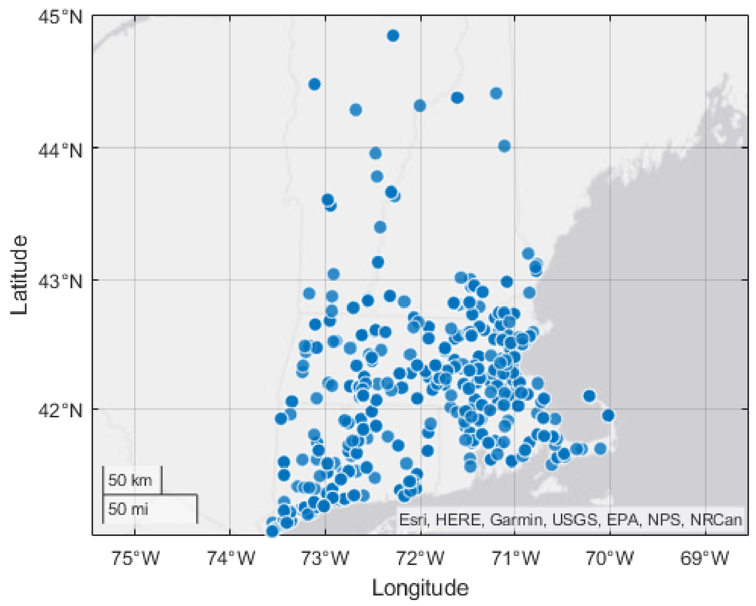
Past PAC Presentations on TPCET Initiative

- Sep. 2020: Introductory Presentation
- Nov. 2020: Updated Assumptions and Pilot Study Proposal
- Dec. 2020: System Conditions and Dispatch Assumptions
- Jan. 2021: Generation Dispatch Details
- Jun. 2021: Preliminary Results
- Jul. 2021: Pilot Study Results

STABILITY ANALYSIS UPDATE

Review of Previous Stability Results

- Legacy DER (interconnected under IEEE Std. 1547-2003) trips offline for transmission faults under daytime minimum load conditions
- Up to 1,855 MW (of a total of 2,689 MW of legacy DER) trips for a 345 kV fault in SEMA/RI with a breaker failure



Each blue dot represents a substation where DER solar generation was tripped. DER in the New York system was not explicitly modeled.

Review of Previous Stability Results

- In addition to tripping, other faults show over 5,000 MW of DER entering temporary power reduction
  - DER in temporary power reduction will return to full power in seconds
  - The temporary reduction introduces large power swings between New England and neighboring areas
- The July PAC presentation reviewed some options for mitigation strategies:
  - Use of existing generation as synchronous condensers
  - Use of DER voltage control capability
  - Addition of synchronous condensers (still being investigated)
- Mitigation strategies examined so far have had a minimal effect on the amount of DER tripped, and almost no effect on the amount of DER experiencing temporary power reduction

Outstanding Questions for Stability Analysis

- Many questions related to stability are still being investigated:
  - Is the assumption used so far for DER protection settings reasonable, and is better data available?
  - How quickly will DER inverters installed under IEEE 1547-2003 be replaced with those compliant with IEEE 1547-2018?
  - Does the amount of DER tripped for transmission contingencies need to be limited to a level below 1,200 MW?
  - Is a limit on the amount of DER temporary power reduction necessary?
  - How does temporary power reduction affect inter-area stability?
  - Are there characteristics of synchronous condensers or FACTS devices that will make them more effective at keeping DER from tripping?
  - What mitigation strategies are most effective for limiting the amount of DER tripped or entering temporary power reduction?
- These issues primarily concern modeling and performance criteria, and are not directly related to the assumptions tested in the TPCET Pilot Study
- Further investigation on these issues will continue, and updates will be shared with stakeholders as they become available

STEADY-STATE ANALYSIS RESULTS

Generator Outage Sensitivity Analysis

Treatment of Generator Outages at Peak Load

- A stakeholder comment near the beginning of the TPCET effort pointed out the difference between:
  - TPCET cases, set up according to a likely peak load generation dispatch
  - Needs Assessment cases, which consider outages of key generators
- To address this comment, the TPCET Pilot Study included sensitivity cases with transfer and generator outage conditions similar to those studied in recent Needs Assessments
  - These sensitivity cases were based on the Summer Weekday Evening Peak Load condition, since DER will push the peak net load later in the day
  - Summer Weekday Mid-Day Peak cases do not need to be analyzed, since compared to current Needs Assessment assumptions, they have:
    - Equal power consumption (load before reduction for solar)
    - Higher solar output
    - Lower net load

Comparison of TPCET with Needs Assessments

- In addition to the new load, wind, and PV assumptions, there are other differences between the TPCET Pilot Study and past Needs Assessments
  - CELT updates: different peak gross load, EE, and nameplate PV capacity
  - Distributed PV location: previous Needs Assessments used the same distribution as load, while the TPCET Pilot Study used a geographic estimate based on town/city boundaries
  - Generator retirements: retirement bids received since the Needs Assessments were reflected in the TPCET Pilot Study
  - Generator additions: generators and active DR that obtained CSOs or binding contracts through FCA 14 were included in TPCET
- Due to generator retirements and additions, the probabilistic calculation of outages may vary in future Needs Assessments
  - To provide a direct comparison, the probabilistic calculations from previous Needs Assessments were re-used without modifications

Sensitivity Cases with Generator Outages

- Four dispatch conditions from two past Needs Assessments were selected for comparison

Needs Assessment	Dispatch ID	Major Gen. Outages
Upper Maine 2029/ Lower Maine 2030	D1A	Yarmouth #4, Newington G1
	D2A	Westbrook, Yarmouth #3, Newington G1
Southwest Connecticut 2027	D3A	Towantic, Middletown #4
	D3B	Towantic, New Haven Harbor #1 & #2

- These dispatch conditions yielded the most stressed system conditions in their respective Needs Assessments

Generator Outages in TPCET Pilot Study Cases

- Although generator outages were not explicitly considered in the TPCET Pilot Study, a number of generators were offline in peak load cases due to excess generation
- In some areas, the TPCET Pilot Study had generator outages exceeding those in recent Needs Assessments
- Example: Generator Outages in Maine
  - Needs Assessment Dispatch D1A: Yarmouth 4
  - Needs Assessment Dispatch D5A: Yarmouth 3, ECO Maine, Cape 4, Cape 5, AEI Livermore, SEA Stratton
  - TPCET Summer Weekday Evening Peak Load case: Yarmouth 4, Yarmouth 3, Bucksport 4, SEA Stratton, Athens, PERC, Indeck 5

Generator Outage Sensitivity Results: SWCT

- N-1 overload observed on line 1443 (Middletown-Portland)
  - Loading was due to high exports from the Middletown 115 kV station, and lower load in the Middletown area than in past Needs Assessments
  - Alleviated by reducing generation at the Middletown 115 kV station
  - Since it can be resolved through generation reduction, this would not be considered a need in a hypothetical future Needs Assessment
- No N-1-1 overloads observed
- No N-1 or N-1-1 voltage violations observed

Generator Outage Sensitivity Results: Maine

- No N-1 or N-1-1 overloads observed within Maine
- N-1-1 loading on Section 80 (Coopers Mills – Highland 115 kV) decreased from 145.8 MVA in the 2029 Upper Maine Solutions Study to 136.9 MVA in the TPCET Pilot Study
  - Net load in the Mid-Coast area is slightly lower in the TPCET Pilot Study, due to the 95% load assumption and more accurate modeling of distributed solar generation
  - Upgrade proposed in the 2029 Upper Maine Solutions Study is still required, and loading is still within the proposed new rating of the line
- No voltage violations observed within Maine under peak load conditions

STEADY-STATE ANALYSIS RESULTS

Resolving Steady-State High Voltage Violations

High Voltages under Minimum Load Conditions

- As first presented at the June PAC meeting, high voltage violations were observed under minimum load conditions
  - Predominantly observed in the Spring Weekend Daytime Minimum Load condition
  - Some minor high voltage violations also observed in the Spring Weekend Nighttime Minimum Load condition
- High voltage violations were caused by lower net load served from the transmission system, leading to two factors:
  - Fewer centrally-located synchronous generators online to control transmission system voltage
  - Relatively lightly-loaded transmission lines and transformers (lower reactive power losses)

High Voltages under Minimum Load Conditions

- ISO-NE's initial approach to these violations was to wait for stability results, since solutions for stability analysis may also provide steady-state voltage control capability
- While work on DER modeling and inter-regional coordination is ongoing, the extent of steady-state upgrades to address these violations was also investigated
  - If further information on DER modeling and stability performance criteria leads to the conclusion that stability performance is acceptable, this would be the extent of required upgrades
- These needs and solutions are intended to be representative only
  - Future Needs Assessments may identify additional needs not addressed by this solution, or may not identify all of the needs addressed here
  - A more efficient solution than the one proposed here may exist
  - It may be prudent to "oversize" some solution components to accommodate reduced loads due to future distributed PV development

High Voltages under Minimum Load Conditions

- The high voltage violations identified in this study could be addressed with shunt reactors at the following locations:

Location	Minimum Size (MVAR)
Scovill Rock 345 kV	15
Montville 345 kV	25
Orrington 345 kV	75
County Road 115 kV	25
Deblois 115 kV	20

- Costs of recent shunt reactor installations and estimates of proposed installations have ranged from $5-$10 million per fixed shunt reactor (slightly higher for variable reactors)
- The total cost of all solutions to address the high voltage violations would be approximately $50 million

SUMMARY OF TPCET PILOT STUDY RESULTS

Overview of TPCET Pilot Study Results

- Thermal results
  - No potential needs identified as a result of the assumptions proposed as part of the TPCET effort
  - Results of generator outage sensitivities similar to results of comparable Needs Assessments
- Steady-state voltage results
  - No potential needs identified related to low voltage violations
  - Needs may arise due to high voltage results under minimum load conditions
  - Under the future system predictions used for the TPCET Pilot Study, potential steady-state high voltage needs identified can likely be resolved for a cost of approximately $50 million

Overview of TPCET Pilot Study Results

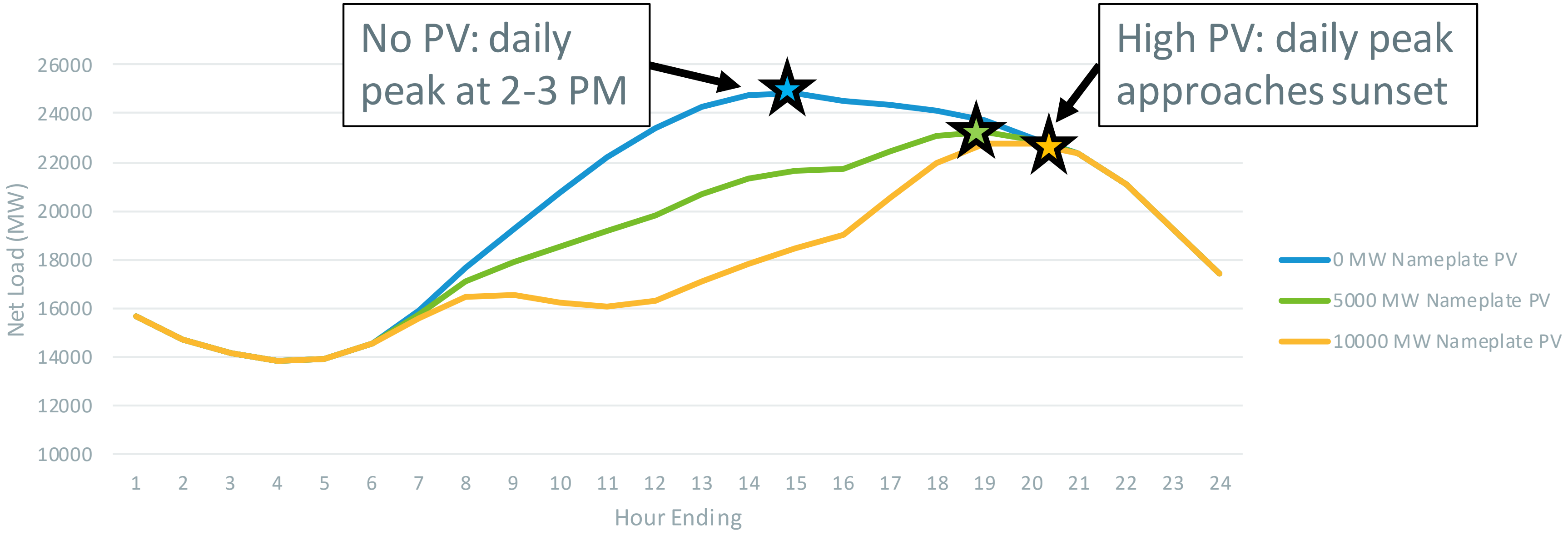
- Stability results
  - Initial analysis has revealed the potential for needs related to performance of DER during and after transmission system faults
  - Future stability analysis in Needs Assessments will depend on answering questions about the details of DER modeling and performance criteria (see Slide 11)
  - Work to answer these questions will continue
- Addressing potential stability concerns
  - Stability concerns are not easily observed or addressed in real-time
  - Large amounts of DER could trip or enter temporary power reduction during a significant number of hours per year*
  - To the extent that needs do exist related to stability, they will need to be addressed through system upgrades

* See slide 16 in the July 2021 PAC presentation on the TPCET Pilot Study

ADJUSTMENTS TO PREVIOUSLY PROPOSED ASSUMPTIONS

Summer Net Load Peak Timing

- The Summer Weekday Evening Peak condition is intended to capture the highest net load on a summer peak day
- Increases in behind-the-meter PV will push this peak progressively later in the day, and eventually past sunset



Summer Net Load Peak Timing

- The timing of the evening net load peak may change from one study to the next, due to:
  - Varying levels of PV penetration in different study areas
  - Varying forecasted PV installation in different years of study
- The original evening peak assumptions were based on area-wide PV and load numbers, as forecasted in the 2020 CELT
  - PV is not spread evenly among all six states in New England
  - 2021 CELT shows a major increase in the PV forecast in some states
- The Summer Weekday Evening Peak condition is being adjusted to better accommodate varying levels of PV and load in different study areas and years of study

Adjustment to Summer Evening Peak Condition

- The Summer Weekday Evening Peak Load condition will reflect whichever of the following conditions results in the highest net load in the area under study:
  - 100% of forecasted 90/10 load, minus 26% of PV output
  - 95% of forecasted 90/10 load, minus 10% of PV output
  - 92% of forecasted 90/10 load, minus 0% of PV output
- By choosing the highest of these three net loads, studies will examine the highest net load while accommodating variations in PV penetration
- In study areas with uneven levels of PV penetration, more than one of these combinations may be used to fully evaluate all conditions

For additional details on the calculations used to obtain these assumptions, please see Appendix A of this presentation.

Use of Updated Weather Data from DNV GL

- In 2020, ISO-NE engaged DNV GL to create and analyze a stochastic weather dataset based on 2000-2019 data
- DNV GL's report, presented to PAC in February 2021, includes an analysis of onshore and offshore wind output on peak and minimum load days
- The assumptions for the TPCET Pilot Study were originally based only on seven years of historical data, but align fairly well with the $10^{th}/90^{th}$ percentile of wind conditions listed in the DNV GL report*
  - DNV GL's report shows higher output for offshore wind under daytime minimum conditions. The offshore wind assumption will be increased to 90% in this study condition, consistent with the data in DNV GL's report
  - In the pilot study, offshore wind was not fully utilized due to a New England-wide oversupply of megawatts in this study condition, so this change in assumptions does not affect the pilot study results

** For additional details, please see Appendix B of this presentation.*

PROPOSED ASSUMPTIONS

Proposal for Updated Study Assumptions

- ISO-NE proposes to adopt the assumptions used in the TPCET Pilot Study for Needs Assessments, Solutions Studies, and competitive Requests for Proposals for transmission solutions
  - Adjustments described on the previous slides will be incorporated
- Results of the Pilot Study have shown that these assumptions are not likely to lead to thermal or steady-state low voltage needs that are more extensive than with today's assumptions
- Steady-state high voltage needs are not overly severe
  - Addressing these needs is relatively inexpensive
- These new assumptions will help to maintain reliability as the New England power system evolves to accommodate greater amounts of clean, intermittent, and distributed energy

Proposed Study Assumptions: Load, PV, Wind

Scenario (Base Case) Name	Power Consumption (before reductions due to behind-the-meter solar)	Solar Output*	Wind Output*	Study Type
Spring Weekend Nighttime Minimum Load (High Renewables)	8,000 MW	0%	65% Onshore 90% Offshore	Steady-State and Stability
Spring Weekend Nighttime Minimum Load (Low Renewables)	8,000 MW	0%	5% Onshore 15% Offshore	Steady-State only
Spring Weekend Mid-Day Minimum Load	12,000 MW	90%	55% Onshore 90% Offshore	Steady-State and Stability
Summer Weekday Mid-Day Peak Load (High Renewables)	100% of 90/10 Peak Load	65%	30% Onshore 90% Offshore	Steady-State and Stability
Summer Weekday Mid-Day Peak Load (Low Renewables)	100% of 90/10 Peak Load	40%	5% Onshore 5% Offshore	Steady-State only
Summer Weekday Evening Peak Load	The highest net load resulting from: 100% of 90/10 Peak Load 95% of 90/10 Peak Load 92% of 90/10 Peak Load	 26% 10% 0%	5% Onshore 5% Offshore	Steady-State and Stability

** All transmission-connected generation, including wind and solar, may be dispatched below its maximum availability assumption to mitigate thermal overloads on transmission lines and transformers.*

CONCLUSION & NEXT STEPS

Conclusion

- ISO-NE proposes to use the assumptions described in this presentation in Needs Assessments, Solutions Studies, and competitive Requests for Proposals for transmission solutions
- Ongoing transient stability work regarding modeling of DER and performance criteria will continue, but will not affect assumptions on resource availability
- These assumptions will ensure the continued reliability of the New England transmission system as the levels of clean, distributed, and intermittent resources increase

Next Steps

- Feedback on these proposed assumption changes may be submitted to pacmatters@iso-ne.com by September 2, 2021
- ISO-NE will consider and respond to any written feedback received in September 2021
- A document supplementing previous PAC presentations on the TPCET Pilot Study with CEII information, such as contingency definitions from stability analysis, will be distributed to the PAC when complete
- A draft revision to the Transmission Planning Technical Guide (TPTG) is expected to be made available for comment in September 2021
- A final revision to the TPTG, including consideration of written feedback received, is expected to be published in September 2021
- Any Needs Assessments beginning after the final revisions to the TPTG are published would use the new assumptions described here
- Draft and final reports documenting the analysis performed in the TPCET Pilot Study are expected to be published in Q4 2021

APPENDIX A

Adjustment to Summer Weekday Evening Peak Condition: Additional Details

Details on Three Possibilities for Evening Peak

- 100% Load, 26% PV
  - Current assumption for Needs Assessments
  - Intended to capture times between 4 and 6 PM, when solar output begins to decrease but power consumption is still at or near peak
- 95% Load, 10% PV
  - Intended to capture times between 6 and 8 PM, when solar output is fairly low and power consumption has begun to decrease
  - Based on the following analysis:
    - Began with hourly data for all days at or above 50/50 summer peak conditions from 2000-2019 (from 2020 VER Data Set)
    - For each of these days, eliminated hours with solar output >10%, and chose the remaining hour with the highest power consumption
    - Divided the power consumption in the chosen hour by that day's peak power consumption, to obtain a percentage of the daily peak
    - Percentages ranged from 89.2% to 98.4%, with an average of 94.3%

Details on Three Possibilities for Evening Peak

- 92% Load, 0% PV
  - Intended to capture times after 8 PM, when the sun has set, solar output is at zero, and power consumption has continued to decrease
  - Based on the following analysis:
    - Began with hourly data for all days at or above 50/50 summer peak conditions from 2000-2019 (from 2020 VER Data Set)
    - For each of these days, eliminated hours with solar output >1%, and chose the remaining hour with the highest power consumption
    - Divided the power consumption in the chosen hour by that day's peak power consumption, to obtain a percentage of the daily peak
    - Percentages ranged from 83.9% to 97.6%, with an average of 91.8%

APPENDIX B

Comparison of New Wind Output Assumptions with DNV GL Stochastic Data Set

TPCET Wind Assumptions vs. DNV GL Data

Study Condition	TPCET Assumption	DNV GL P10/P90 Value[1]	DNV GL P1/P99 Value[2]	Source[3]
Spring Weekend Nighttime Minimum (High Renewables)	Onshore Wind: 65% Offshore Wind: 90%	Onshore Wind: 41.4-42.8% Offshore Wind: 83.1-85.1%	Onshore Wind: 61.4-62.3% Offshore Wind: 92.3%	Table A-15, HE 2-5 Table A-11, HE 2-5
Spring Weekend Nighttime Minimum (Low Renewables)	Onshore Wind: 5% Offshore Wind: 15%	Onshore Wind: 9.6-11.2% Offshore Wind: 4.3-4.8%	Onshore Wind: 5.2-6.9% Offshore Wind: 1.0-1.2%	Table A-15, HE 2-5 Table A-11, HE 2-5
Spring Weekend Mid-Day Minimum	Onshore Wind: 55% Offshore Wind: 90% (previously 60%)[4]	Onshore Wind: 39.9-46.3% Offshore Wind: 82.4-84.0%	Onshore Wind: 66.0-71.7% Offshore Wind: 92.0-92.3%	Table A-16, HE 12-15 Table A-12, HE 12-15
Summer Weekday Mid-Day Peak (High Renewables)	Onshore Wind: 30% Offshore Wind: 90%	Onshore Wind: 33.8-36.3% Offshore Wind: 80.8-87.6%	Onshore Wind: 57.8-67.1% Offshore Wind: 91.2-92.7%	Table A-7, HE 14-17 Table A-3, HE 14-17
Summer Weekday Mid-Day Peak (Low Renewables)	Onshore Wind: 5% Offshore Wind: 5%	Onshore Wind: 7.1-9.1% Offshore Wind: 3.5-4.9%	Onshore Wind: 4.9-5.4% Offshore Wind: 1.0-2.3%	Table A-7, HE 14-17 Table A-3, HE 14-17
Summer Weekday Evening Peak	Onshore Wind: 5% Offshore Wind: 5%	Onshore Wind: 9.1-13.3% Offshore Wind: 6.3-8.5%	Onshore Wind: 4.8-8.3% Offshore Wind: 1.4-2.2%	Table A-8, HE 19-22 Table A-4, HE 19-22

[1] *Wind output in the DNV GL data set was more extreme than these values on 10% of the peak/minimum load days.*
[2] *Wind output in the DNV GL data set was more extreme than these values on 1% of the peak/minimum load days.*
[3] *All references are to the DNV GL Report – Analysis of Stochastic Data Set, dated March 2021. "HE" stands for Hour Ending.*
[4] *60% was previously proposed for the TPCET Pilot Study. DNV GL's data indicates that 90% is a better assumption for this condition.*