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New England Winter Gas-Electric Forum

Extreme Weather Risks to ISO-NE, Presentation of the EPRI Study

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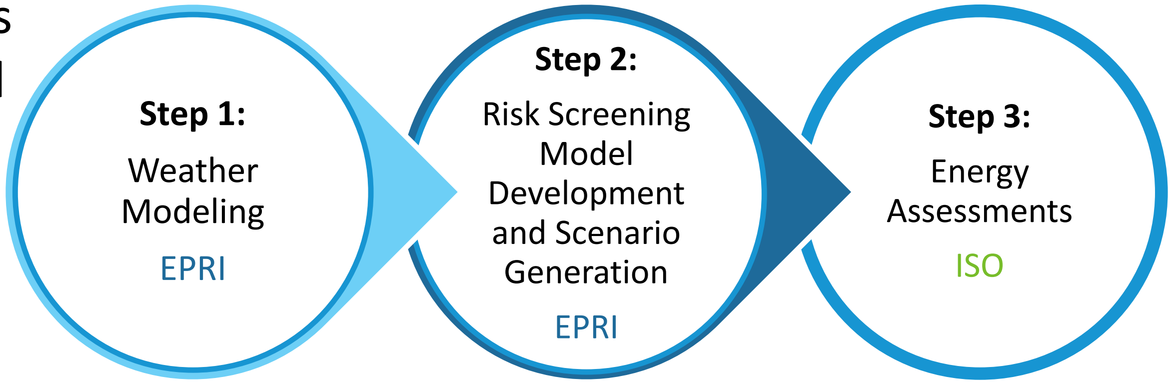
Key Takeaways

- The collaboration between the ISO and EPRI has resulted in the development of an innovative analytic platform that is capable of quantifying regional energy adequacy risk in terms of magnitude and probabilities
- The 2027 study results show that, even in scenarios without Everett and the New England Clean Energy Connect, energy shortfalls are manageable
  - These results are a function of significant quantities of solar PV installations, additional renewables in the form of off-shore wind and storage, and minimal retirements and load growth
  - They also reflect an increased reliance on primarily oil-fired generators
- ISO expects to continually monitor the dynamic energy adequacy risk profile using this framework
- This platform gives the region the ability to discuss and establish an acceptable level of energy adequacy risk

Operational Impact of Extreme Weather Events – Energy Adequacy Study

- ISO is working with EPRI to conduct a probabilistic energy adequacy study for New England under extreme weather events; initial studies are focused on 2027 and 2032
- Study results are intended to inform the region on energy adequacy risks
  - These results may help in 'quantifying' a problem statement on energy adequacy, against which possible solutions can be assessed
- Study establishes a framework for risk analysis that can be updated as climate projections are refined and the resource mix evolves
- This presentation reviews the study framework and preliminary results of the energy assessments completed for 2027 winter events



In Step 1, Historical Weather Trends and Climate Projections Were Reviewed

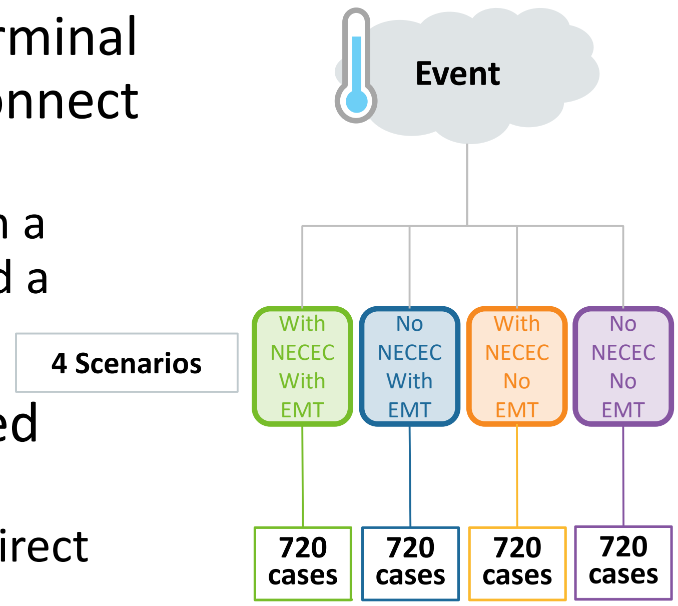
- This step included a review of New England's historical weather (1950 – 2021), analysis of global climate model projections, and development of hourly weather variable and resource profiles
- EPRI used five global climate models spanning a range of climate sensitivities and two emissions pathways to project changes to weather variables for use in subsequent steps in the study

In Step 2, Risk Screening Model Was Developed to Facilitate Selection of Extreme Events for Study

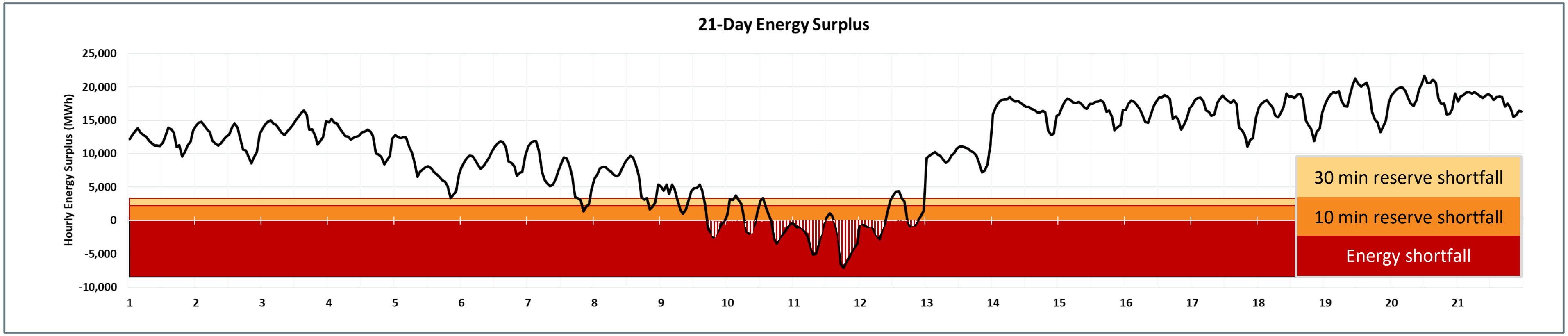
- The objective of the Risk Screening Model is to search the weather data set and select a set of 21-day events that appear most stressful (extreme) to the future New England power system in terms of energy availability
  - This risk screening model is a measure of system risk (including supply and demand)
- For each study year, the initial input to the risk screening model is 37,440 events, based on 72 weather years (1950 – 2021), climate-adjusted according to five climate models and two socio-economic pathways
  - Output of risk screening model is 1,470 high risk events (top ~4% of 37,440 events)
- A clustering algorithm was used to group the 1,470 events into multiple clusters consisting of similar types of events
  - Multiple events are selected for study from each cluster (*see* slide no. 9 for cluster descriptions and selected events)

In Step 2, Following the Selection of Events, Power System Scenarios Were Generated for Use in Energy Assessments

- Each selected event is studied with a combination of two key variables – the Everett Marine Terminal (EMT) and the New England Clean Energy Connect (NECEC) facility
  - Each combination of the two variables results in a "scenario", each of which has not been assigned a probability of occurrence
- Each of the four possible scenarios is modeled using 720 "cases"
  - Each case reflects different combinations of indirect weather-related uncertainties (LNG and fuel-oil inventories, imports, forced outages, etc.), each having an assigned probability of occurrence
  - Uncertainty assumptions vary based on the unique characteristics of each 21-day event (e.g. event start date, temperatures, etc.)



In Step 3, ISO's 21-Day Energy Assessment Forecasts Hourly Energy Surplus for Each Case



*The figure above is an example illustration of a 21-day energy assessment forecast

- For each case, energy assessment results include:
  - Energy surplus (black curve)
  - Energy shortfall (red/white striped area): quantity in MWh and duration
  - Reserve shortfalls (black curve in yellow/orange): quantity in MWh and duration
- For each scenario, energy assessment results are a statistical summary across all 720 cases within scenario:
  - "Expected" energy shortfall = probability-weighted average across all cases
  - "Worst-case" energy shortfall = case with highest energy shortfall quantity

2027 STUDY YEAR SELECTED EVENTS AND SCENARIO MODELING

Events Selected by the Risk Screening Model for Study Year 2027

- For 2027, two winter clusters were identified
  - Winter Cluster 1: consists of longer-duration events with low winds and low solar irradiance
  - Winter Cluster 2: consists of shorter-duration events with low winds and low solar irradiance
- This presentation highlights two 2027 winter events which have the largest worst-case energy shortfall amounts in each cluster (additional results can be found in the appendix to this presentation):
  - Winter Cluster 1: Jan 22, 1961
  - Winter Cluster 2: Jan 14, 1982
- Additional 2027 and 2032 winter and summer studies are ongoing

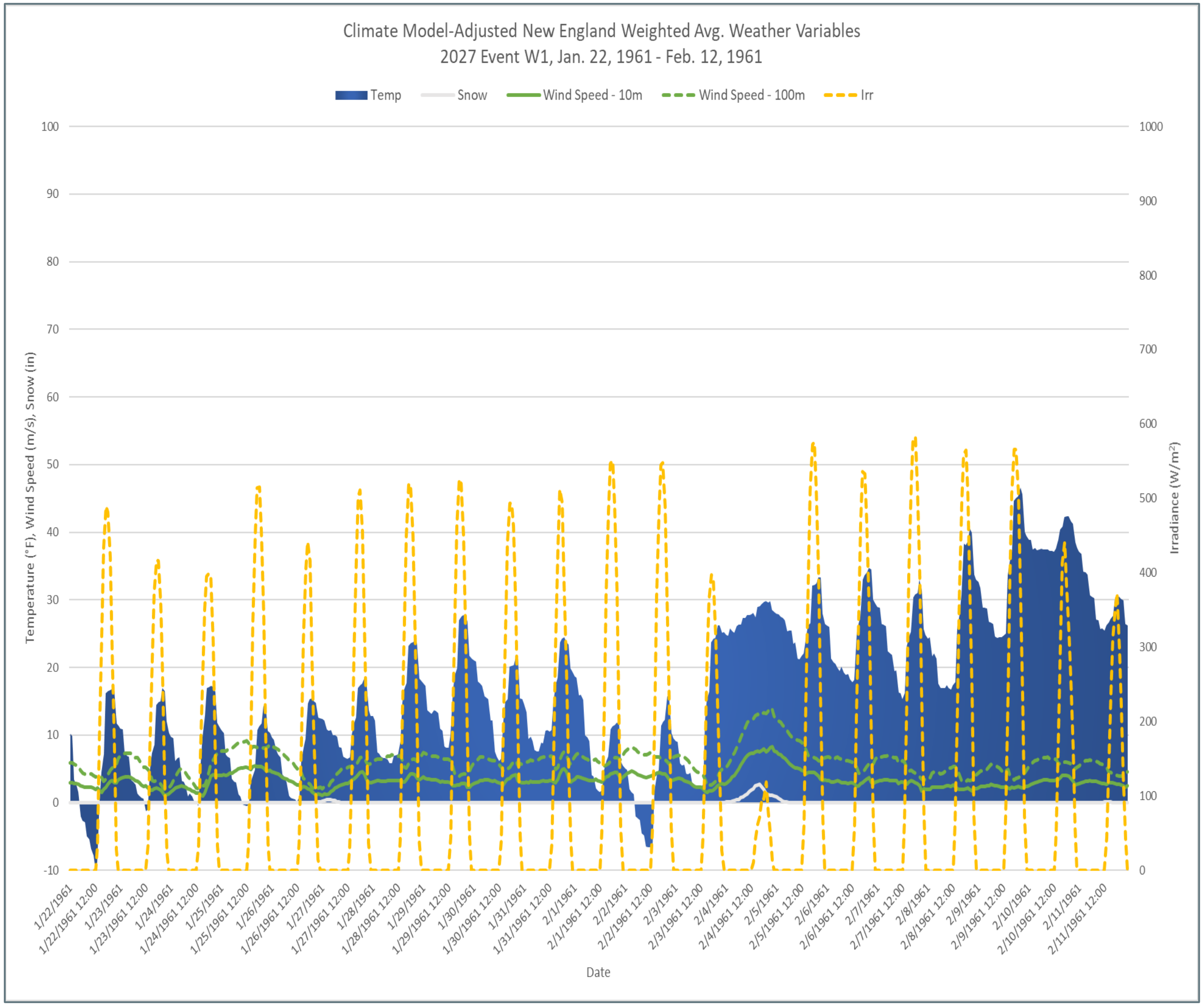
Scenario Modeling of Everett Marine Terminal and New England Clean Energy Connect

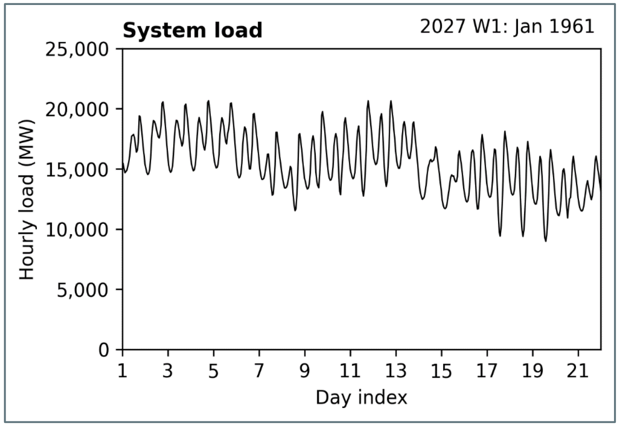
- Scenarios with NECEC in-service allow up to an additional 1,080 MW/hr of max imports from Hydro-Québec
- Scenarios with EMT in-service allow an additional 0.4 Bcf/day of max LNG injection to pipelines
  - LNG inventories are similar in with EMT and without EMT scenarios

	NECEC **in-service**	NECEC **not in-service**	
EMT **in-service**	With NECEC, With EMT	No NECEC, With EMT	**Max inj. 1.2 Bcf/d**
EMT **not in-service**	With NECEC, No EMT	No NECEC, No EMT	**Max inj. 0.8 Bcf/d**
	Max imports 5,625 MW/hr	**Max imports 4,545 MW/hr**	

2027 WINTER CLUSTER 1 (W1) RESULTS
JAN 22, 1961 EVENT

Jan 22, 1961 Event Consisted of a 12-Day Cold Wave Coincident with Low Wind and Very Low Solar





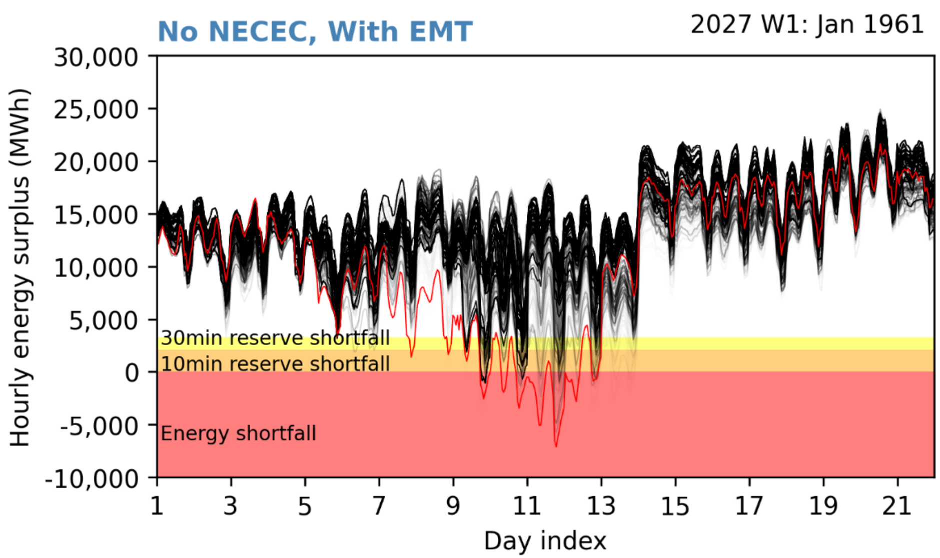
- **Min/Mean/Max (°F):** -9.8/15.8/45.7
- **Mean 100m Wind Speed (m/s):** 6.0
  - Offshore Wind avg. 800 MW/hr
  - Onshore Wind avg. 370 MW/hr
- **Mean Irradiance (W/m²):** 118.8
  - Utility Scale PV avg. 230 MW/hr
  - BTM PV avg. ~800 MW/hr
- **Avg. Energy From Renewables:** ~2,200 MW/hr
- **Peak Load:** 20,655 MW (day 4)
- **Peak Energy Demand:** ~424,000 MWh (day 5)
- **Total 21-Day Energy Demand:** 7.82 TWh
- **Historical Relevance:** Coldest 21-day period since 1950; includes two of the top 10 coldest 5-day periods since 1950

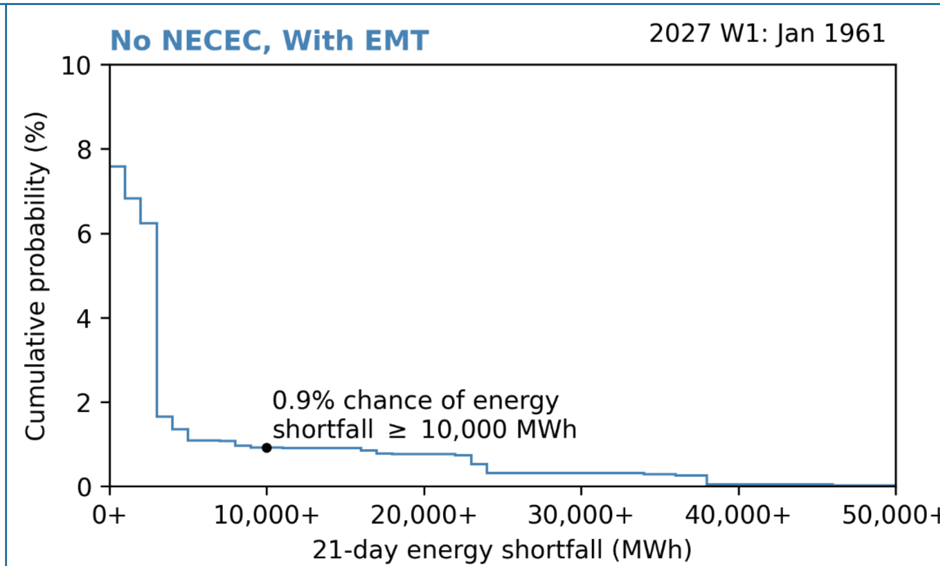
*temperatures, wind speeds, and irradiance are based on a New England ten-city weighted average

Summary of 21-Day Energy Analysis Results

Jan 22, 1961 Event; Scenario: no NECEC, with EMT

In the energy surplus chart below, the red highlighted trace represents the case that has the highest energy shortfall amount (MWhs); otherwise, the lower the probability of a case, the lighter its corresponding trace

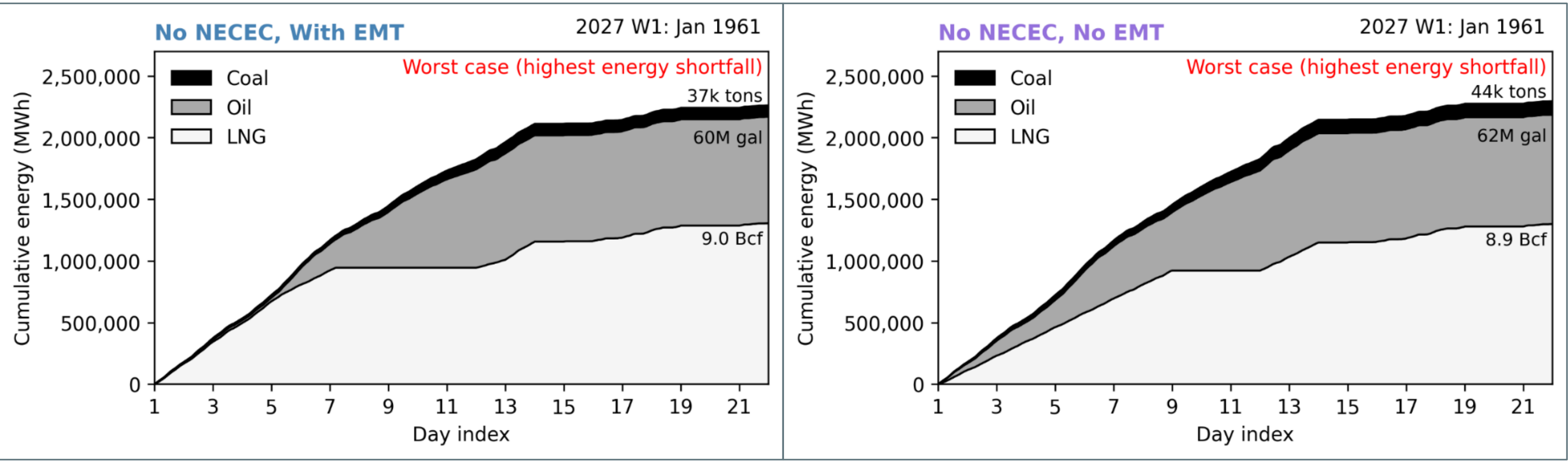




- **In the case with the highest total energy shortfall, the total energy shortfall is ~1.5% of demand across the 21-day period days**

# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
233	111,353	36	421	7.58%	0.0006%

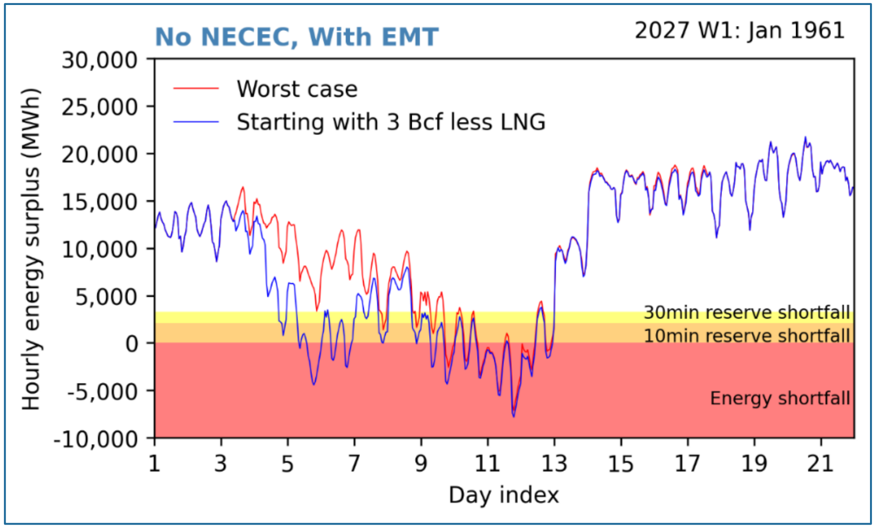
In Worst Case Energy Shortfalls, Increases in Fuel Oil and Coal Usage Are Notable



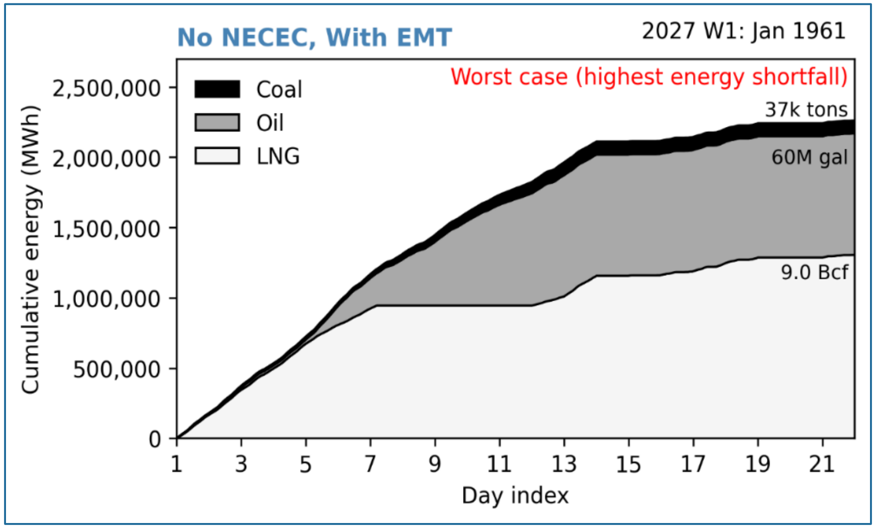
ISO-NE PUBLIC

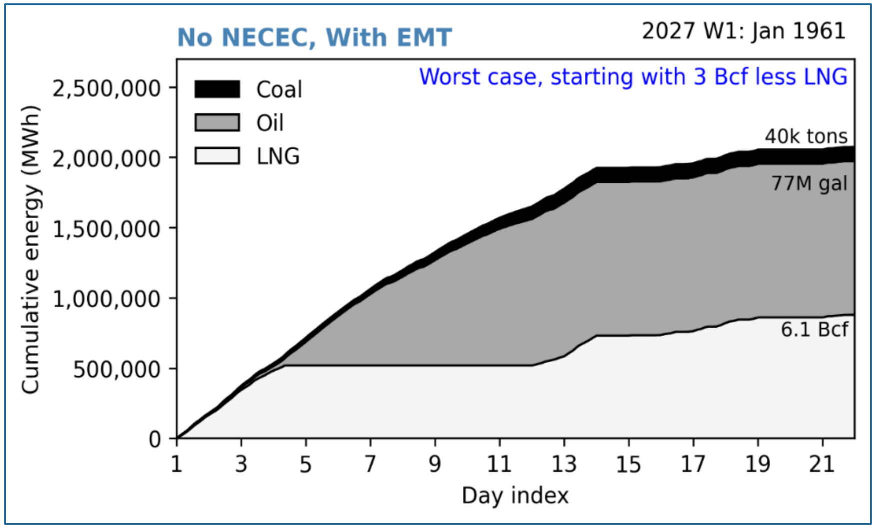
Results Exhibit Sensitivity to Starting LNG Inventory

Jan 22, 1961 Event; Scenario: no NECEC, with EMT; Case: Low LNG, Low Oil, NG Price < Oil Price, Low Imports



- To illustrate the sensitivity of total energy shortfall to LNG inventories, ISO studied a sensitivity case* with a 3 Bcf lower starting LNG inventory
  - In this sensitivity case, the starting LNG inventory of ~6.5 Bcf is reduced to ~3.5 Bcf
  - Similar to the un-adjusted case, LNG replenishment of ~2.4 Bcf and ~1.7 Bcf occurs on days 12 and 13, respectively
- **Worst case energy shortfall increases to ~200K MWh (~80%); results were similar in a sensitivity case run on the No NECEC, No EMT scenario**

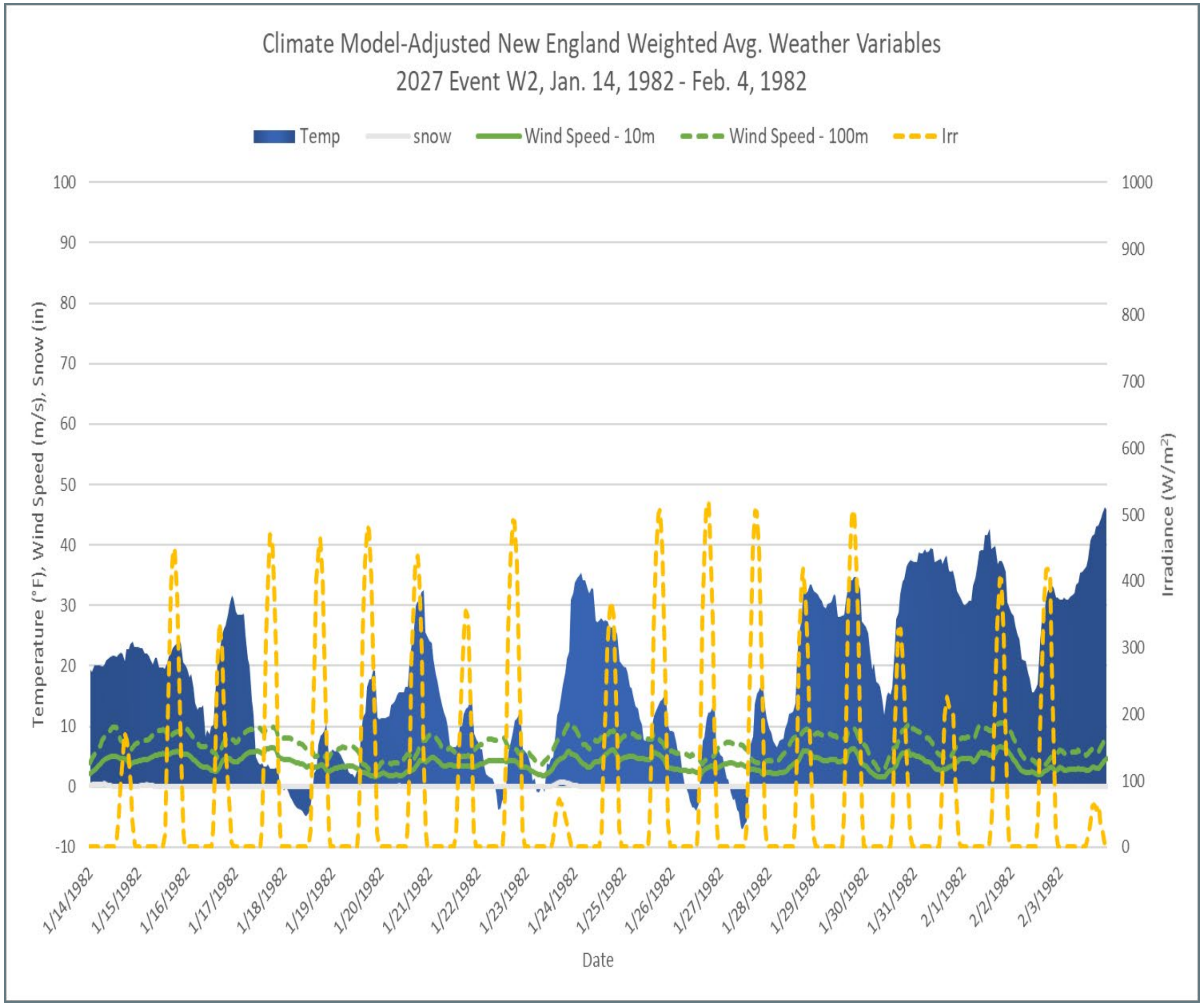


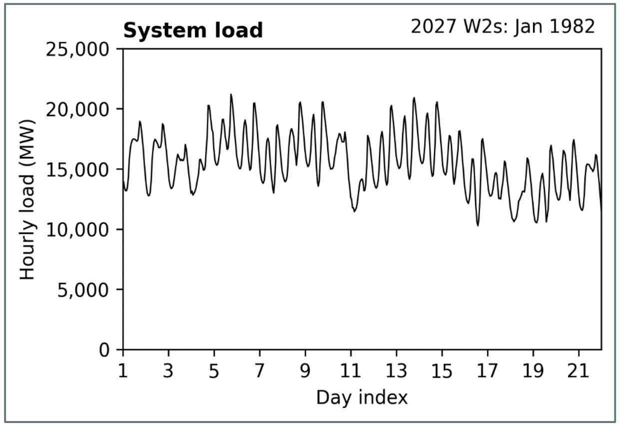


*no probability is associated with this sensitivity case

2027 WINTER CLUSTER 2 (W2) RESULTS JAN 14, 1982 EVENT

Jan 14, 1982 Event Consisted of Multiple Short-Duration Cold Waves Coincident with Low Wind and Very Low Solar





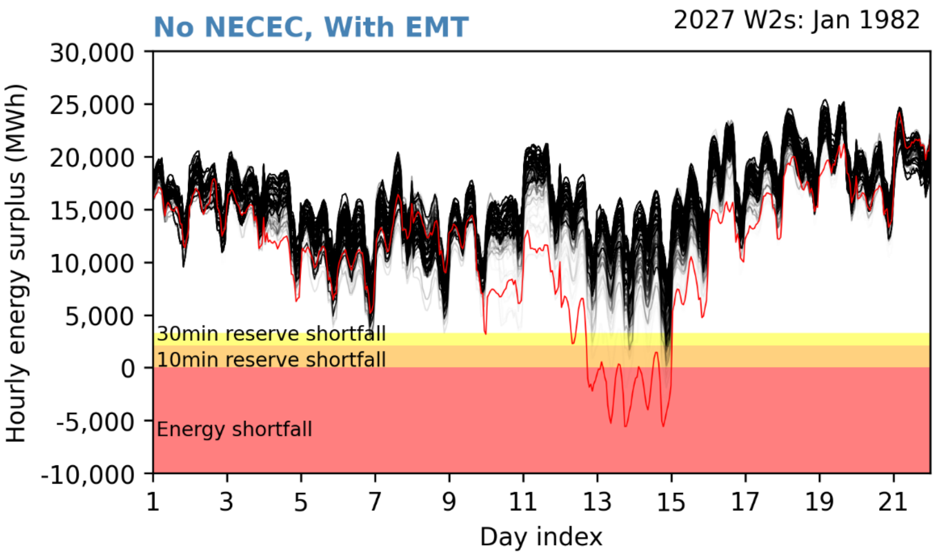
- **Min/Mean/Max (°F):** -7.0/18.4/46.2
- **Mean 100m Wind Speed (m/s):** 6.9
  - Offshore Wind avg. 1,090MW/hr
  - Onshore Wind avg. 510 MW/hr
- **Mean Irradiance (W/m²):** 91.0
  - Utility Scale PV avg. 160 MW/hr
  - BTM PV avg. ~650 MW/hr
- **Avg. Energy From Renewables:** ~2,410 MW/hr
- **Peak Load:** 21,195 MW (day 5)
- **Peak Energy Demand:** ~423,000 MWh (day 5)
- **Total 21-Day Energy Demand:** 7.84 TWh
- **Historical Relevance:** One of Top 10 coldest 21-day periods since 1950

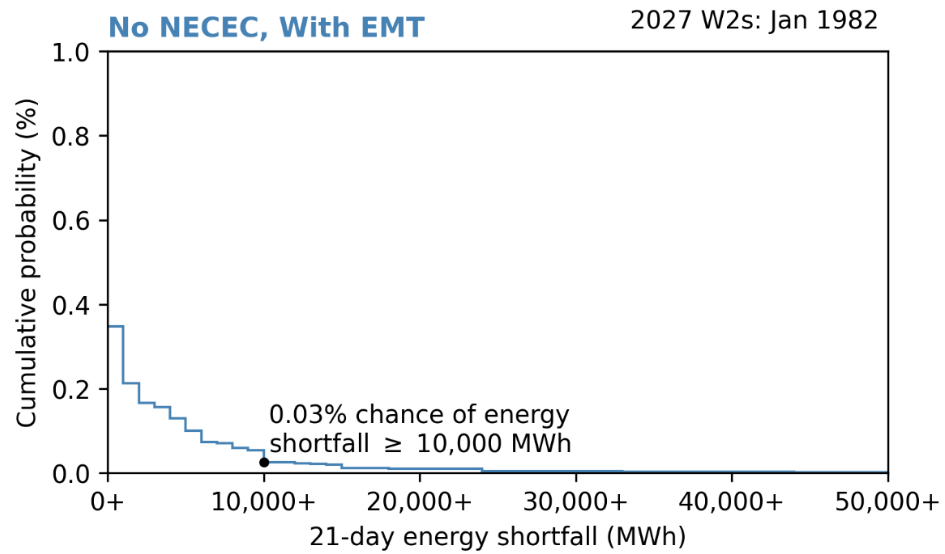
*temperatures, wind speeds, and irradiance are based on a New England ten-city weighted average

Summary of 21-Day Energy Analysis Results

Jan 14, 1982 Event; Scenario: no NECEC, with EMT

In the energy surplus chart below, the red highlighted trace represents the case that has the highest energy shortfall amount (MWhs); otherwise, the lower the probability of a case, the lighter its corresponding trace





- **In the case with the highest total energy shortfall, the total energy shortfall is ~1.5% of demand across the 21-day period days**

# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
139	114,715	32	15	0.35%	0.00004%

APPENDIX

Additional assumptions and study results from Winter Cluster 1 and Winter Cluster 2

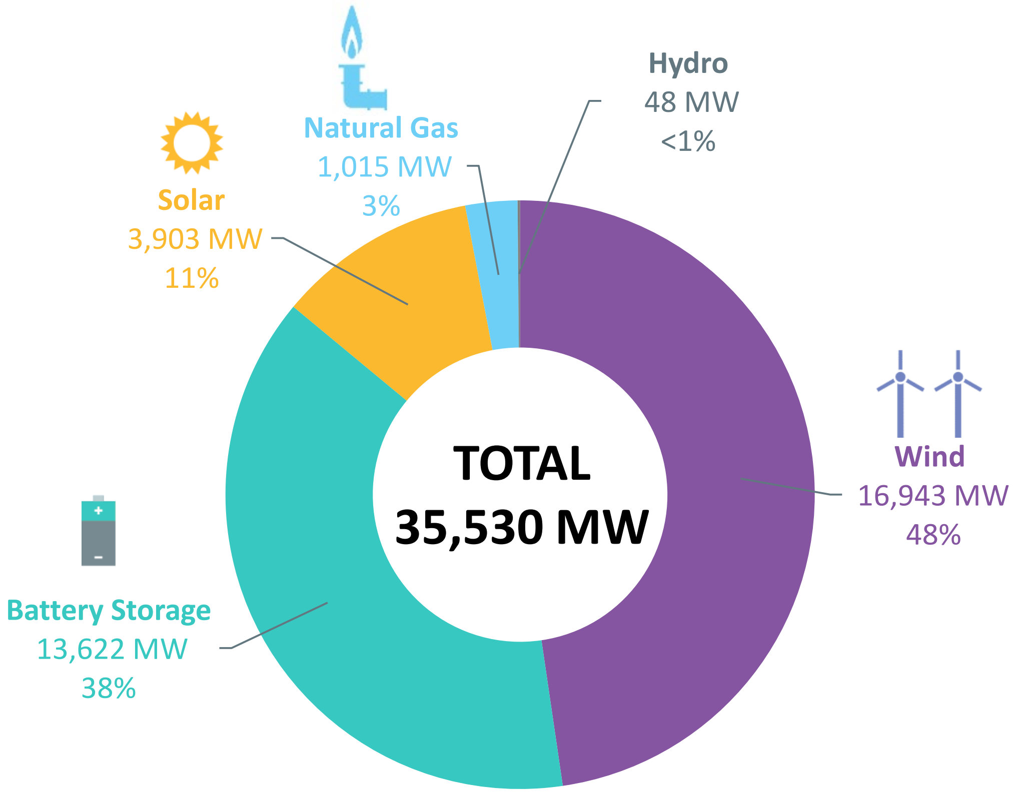
Assumptions for Study Year 2027

- Generation assumptions include resources that cleared ISO's Forward Capacity Auction 16* (FCA16) and state-sponsored resources that are under contract or have been selected under recent RFP's
  - Key changes from today's generation fleet include:
    - Addition of ~600 MW of utility-scale PV
    - ~1,400 MW of battery storage
    - ~1,600 MW of offshore wind
    - Retirements totaling ~2,100 MW (including Mystic 8 and 9)
- Demand forecasts incorporate ISO's 2022 heating and transportation electrification forecasts
  - Forecasts include the effects of additional behind-the-meter (BTM) PV for a total of ~9,500 MW

*Forward Capacity Auction 16 is for the period between 6/1/25 and 5/31/26

Beginning in Late 2023, ISO Anticipates an Increase in Energy from Wind Power Resources

All Proposed Resources



Source: ISO Generator Interconnection Queue (June 2023)
FERC Jurisdictional Proposals; Nameplate Capacity Ratings
Note: Some natural gas proposals include dual-fuel units (with oil backup).
Some natural gas, wind, and solar proposals include battery storage. Other includes hydro, biomass, fuel cells and nuclear uprate.

Proposals by State

(all proposed resources)

State	Megawatts (MW)
Massachusetts	19,700
Connecticut	7,125
Maine	5,461
Rhode Island	1,574
New Hampshire	1,295
Vermont	375
Total	**35,530**

Source: ISO Generator Interconnection Queue (June 2023)
FERC Jurisdictional Proposals

A Return Period Is Determined for Each Cluster

- A "return period" is the expected interval between event recurrences (e.g., "a 1-in-5 year" event)
  - Return periods are commonly used in flood, storm, rainfall reporting, and design criteria
  - Calculated for discrete events as the observation period divided by the number of observations
- A return period of ~8 to 10 years has been determined for events in 2027 Winter Cluster 1 and ~3 to 5 years for events in 2027 Winter Cluster 2

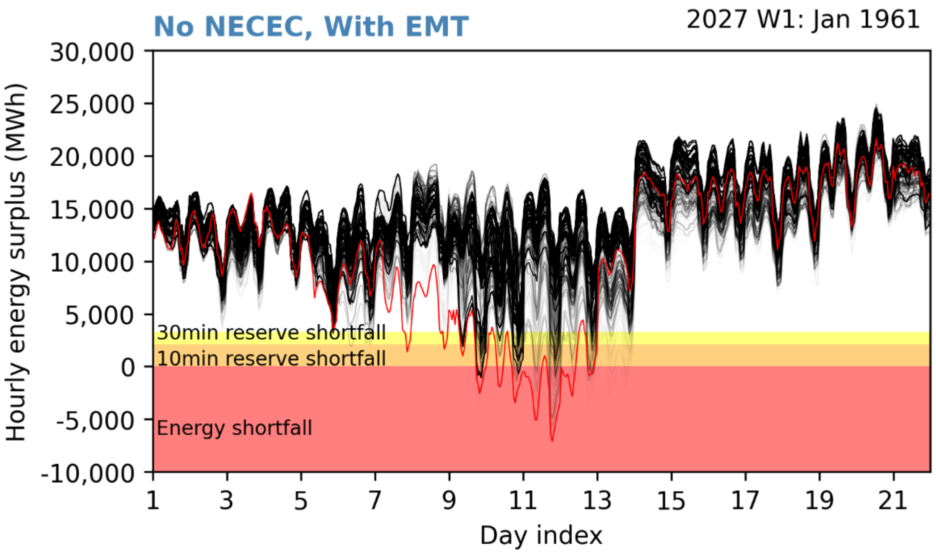
Cluster	Return Period	Most Recent Occurrence
Winter Cluster 1 (2027)	~8-10 years	Dec 23, 2017 – Jan 13, 2018
Winter Cluster 2 (2027)	~3-5 years	Feb 14, 2015 – Mar 7, 2015

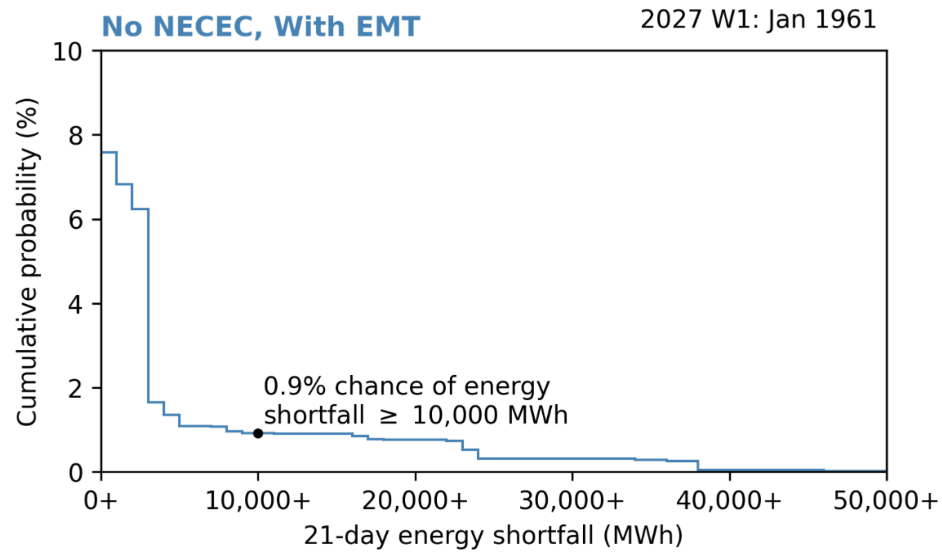
Considerations for Scenario Modeling of the Everett Marine Terminal

- Similar to ISO's 2024/2025 deterministic winter scenario analysis, 2027 scenarios without EMT assume that its capacity to provide energy to the system is picked up by the remaining LNG facilities and the capacity of fuel-oil burning resources
- The primary difference between with EMT and without EMT scenarios is the maximum daily LNG injection rate (0.8 Bcf/d without EMT, 1.2 Bcf/d with EMT)
- LNG inventories are similar in with EMT and without EMT scenarios; ISO has not attempted to quantify the extent to which regional LNG inventories might vary based on EMT's operational status
  - The LNG model for this study is based upon the seasonal (Dec-Mar) LNG demand profiles developed for the Resource Capacity Accreditation (RCA) project
- Results of with and without EMT scenarios are highly dependent on the unique characteristics of a given event, including the timing of the highest energy demands, starting LNG inventories, and timing of LNG replenishment
  - Higher rates of LNG injection (i.e., LNG injection rates in scenarios with EMT) may deplete LNG inventories prior to replenishment, leading to larger energy shortfalls in some cases with EMT than in similar cases without EMT

Summary of 21-Day Energy Analysis Results

Jan 22, 1961 Event; Scenario: no NECEC, with EMT



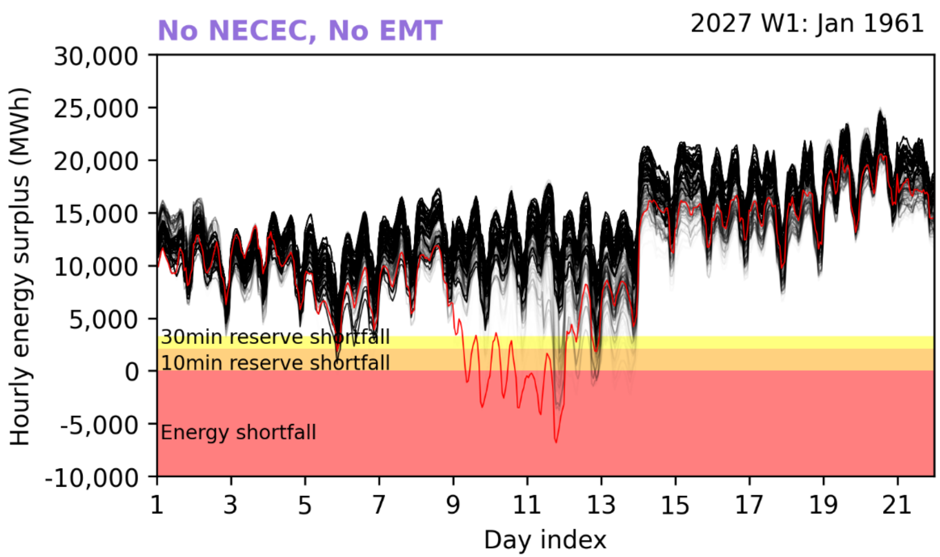


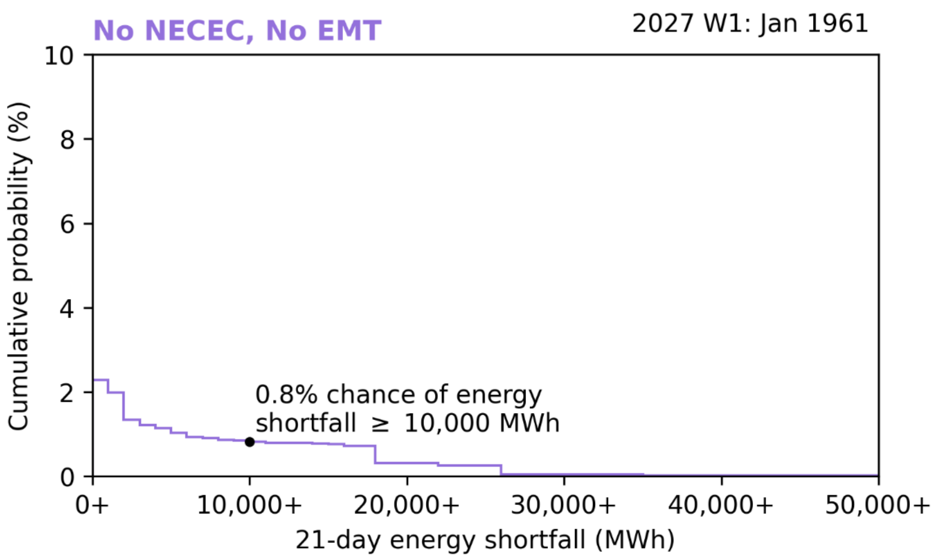
*in the energy surplus chart above (upper-left), the red highlighted trace represents the case that has the highest energy shortfall amount (MWhs); otherwise, the lower the probability of a case, the lighter its corresponding trace

# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
233	111,353	36	421	7.6%	0.0006%

Summary of 21-Day Energy Analysis Results

Jan 22, 1961 Event; Scenario: no NECEC, no EMT





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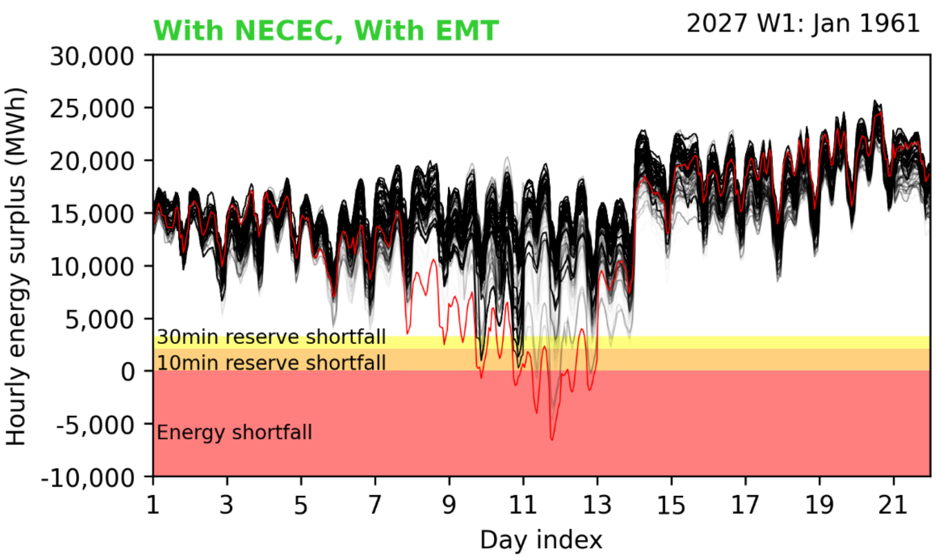
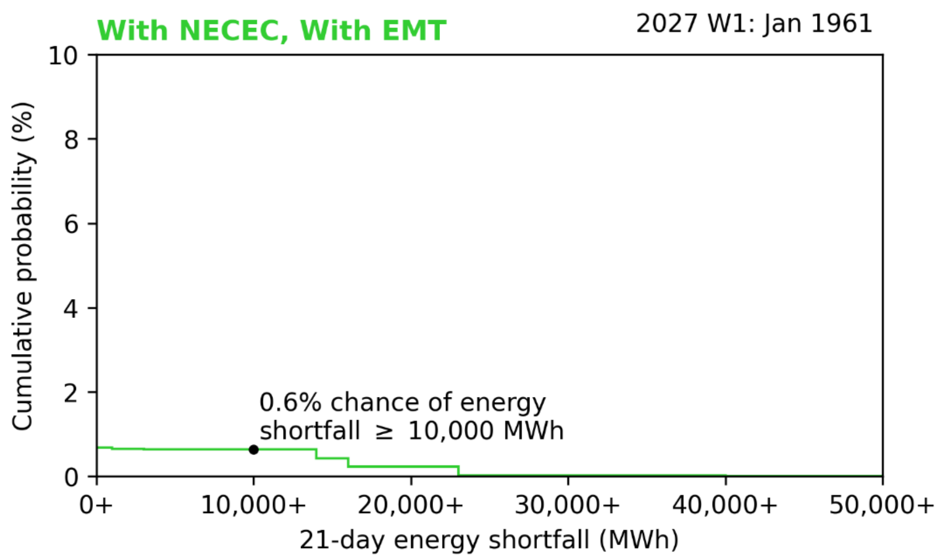
172	95,888	1	202	2.3%	0.0006%

Summary of 21-Day Energy Analysis Results

Jan 22, 1961 Event; Scenario: with NECEC, with EMT





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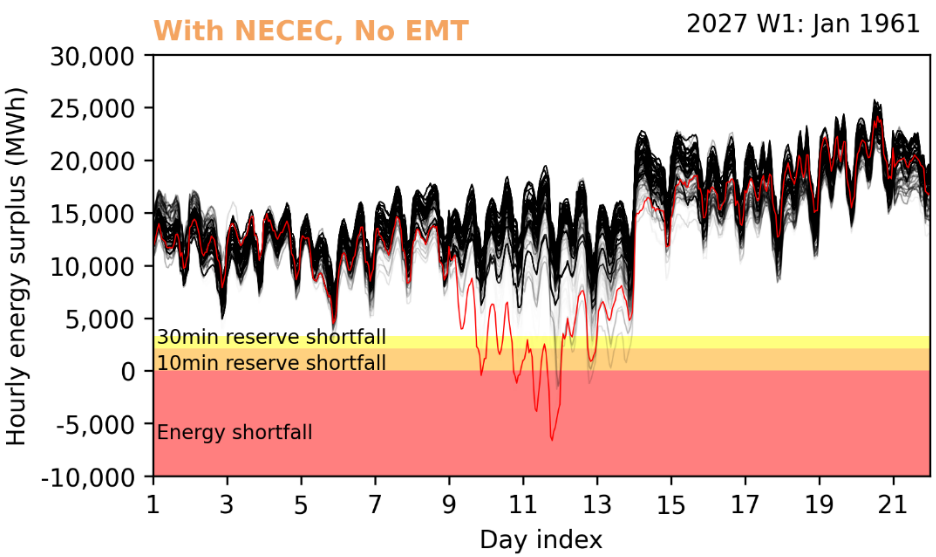
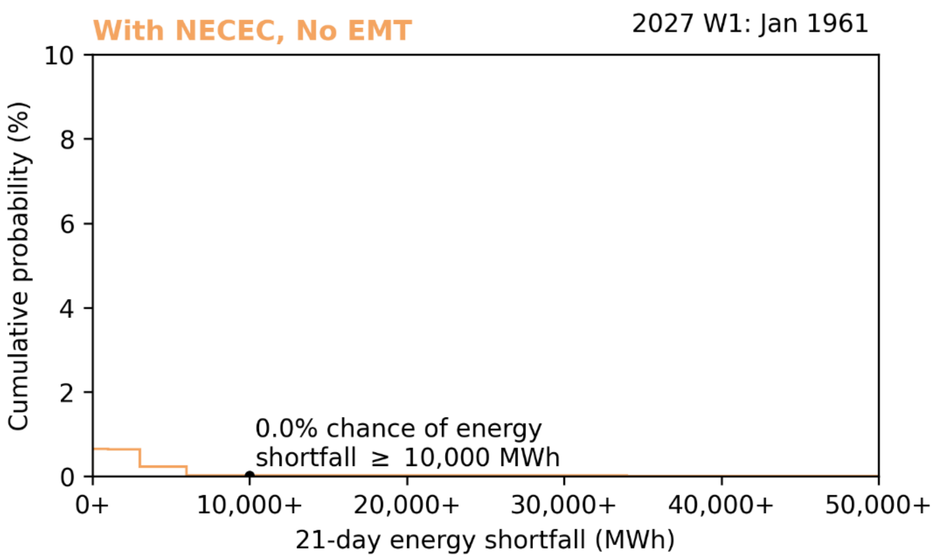
30	68,932	1	113	0.67%	0.004%

Summary of 21-Day Energy Analysis Results

Jan 22, 1961 Event; Scenario: with NECEC, no EMT





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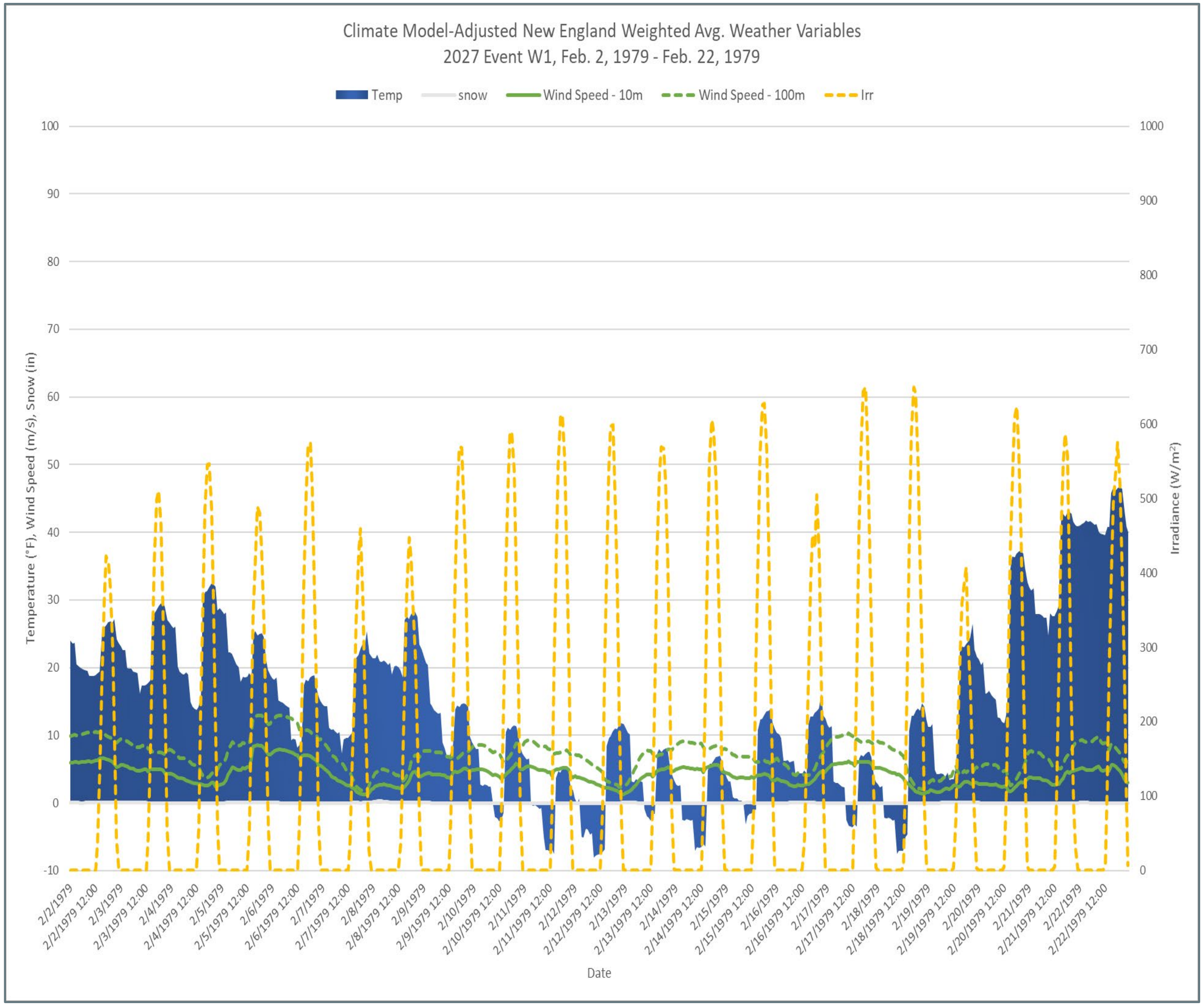
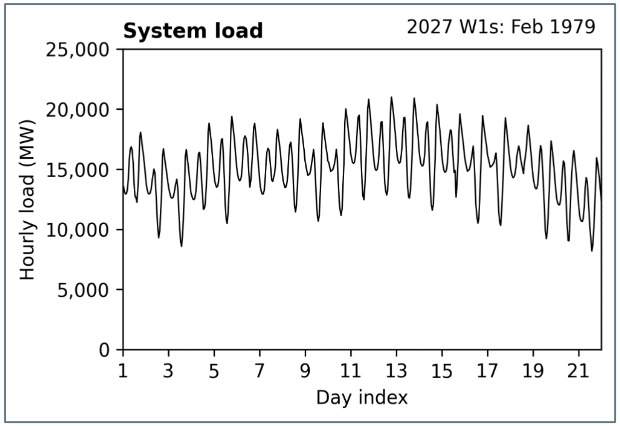
25	53,518	143	28	0.64%	0.0044%

Feb 2, 1979 Winter Event Overview

~10-Day Cold Wave Coincident With Low Winds and Low Solar



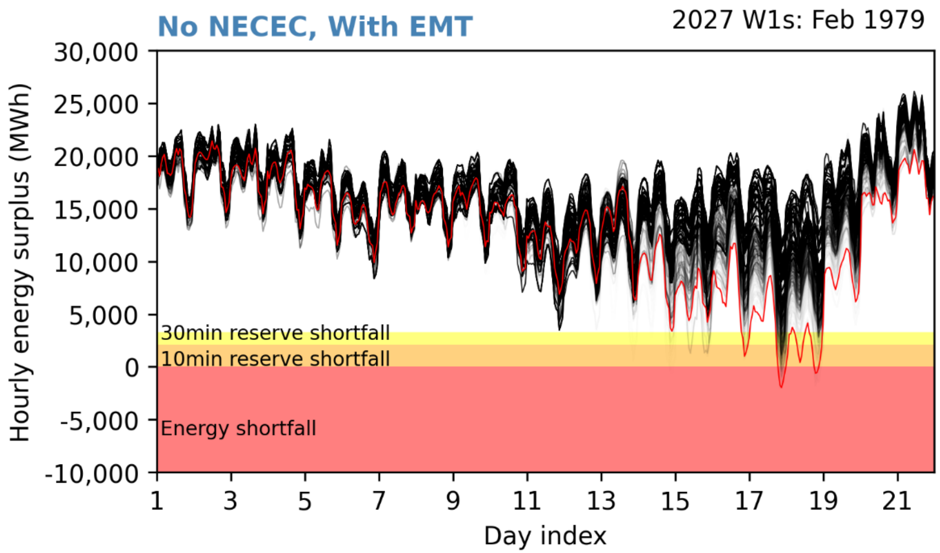


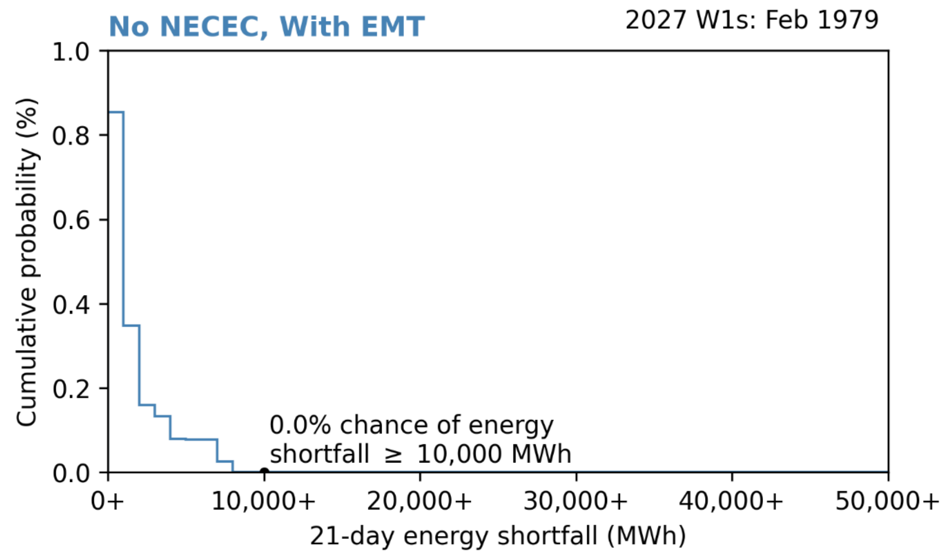
- **Min/Mean/Max (°F):** -8.1/14.3/46.6
- **Mean 100m Wind Speed (m/s):** 7.1
  - Offshore Wind avg. 1,120MW/hr
  - Onshore Wind avg. 580 MW/hr
- **Mean Irradiance (W/m²):** 142.0
  - Utility Scale PV avg. 280 MW/hr
  - BTM PV avg. ~1,400 MW/hr
- **Avg. Energy From Renewables:** ~3,380 MW/hr
- **Peak Load:** 20,994 MW (day 11)
- **Peak Energy Demand:** ~403,000 MWh (day 12)
- **Total 21-Day Energy Demand:** 7.59 TWh
- **Historical Relevance:** The actual weather during this stretch included the coldest 5-day and 10-day period since 1950

*temperatures, wind speeds, and irradiance are based on a New England ten-city weighted average

Summary of 21-Day Energy Analysis Results

Feb 2, 1979 Event; Scenario: no NECEC, with EMT





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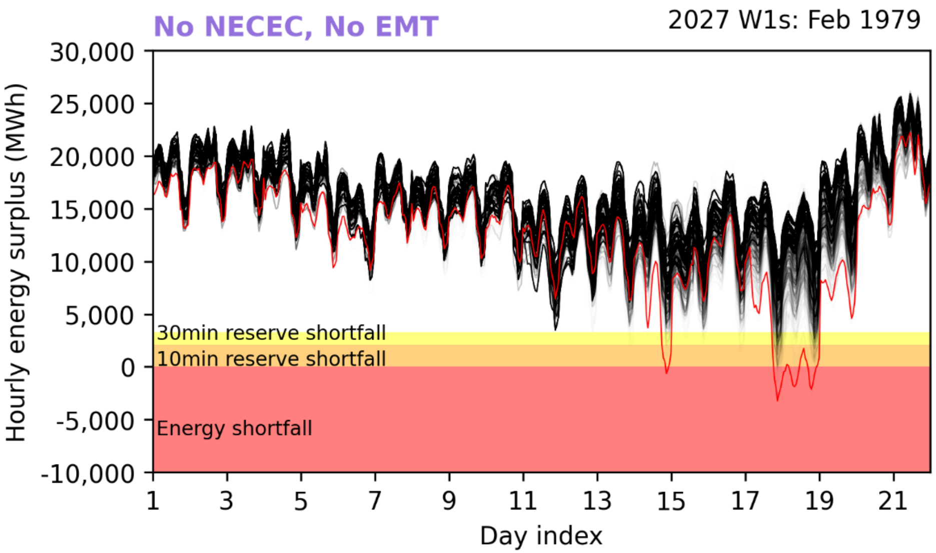
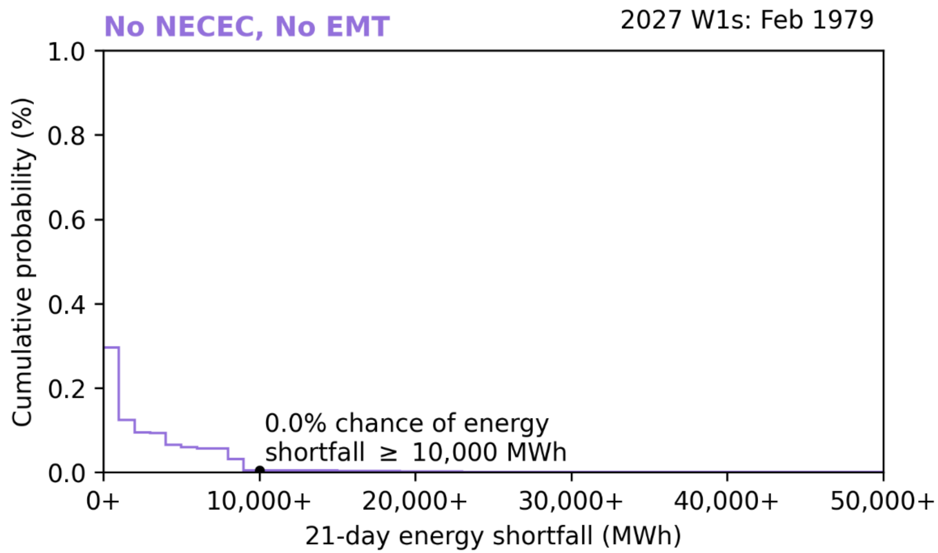
48	7,545	74	13	0.85%	0.026%

Summary of 21-Day Energy Analysis Results

Feb 2, 1979 Event; Scenario: no NECEC, no EMT





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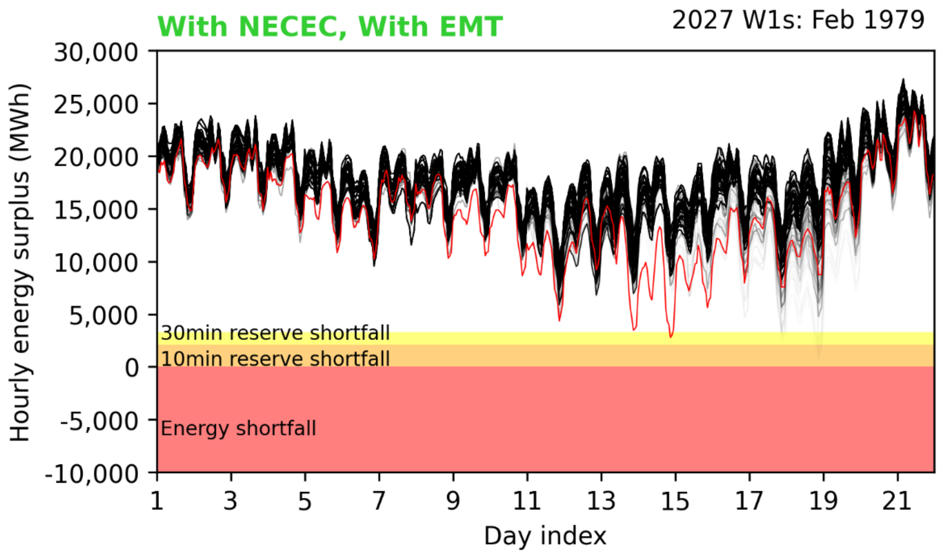
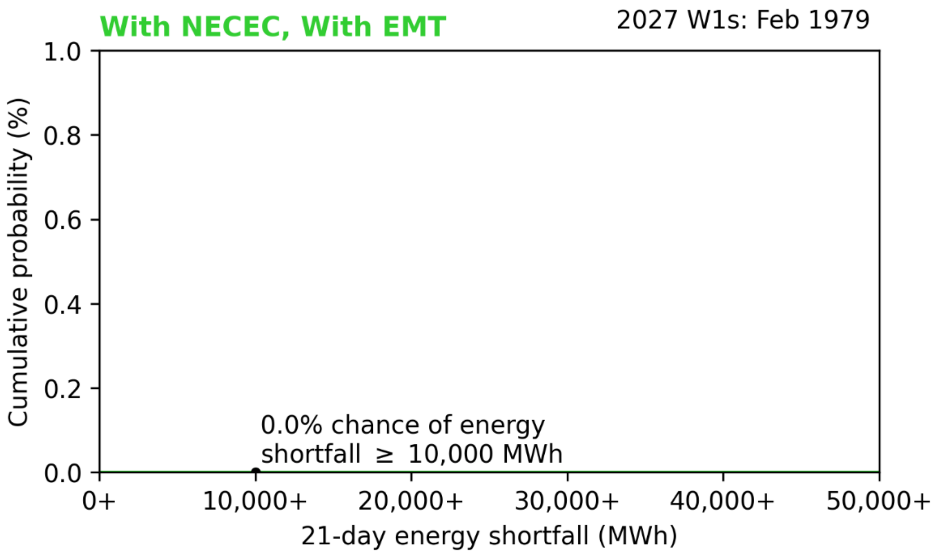
67	28,348	18	7	0.30%	0.0006%

Summary of 21-Day Energy Analysis Results

Feb 2, 1979 Event; Scenario: with NECEC, with EMT

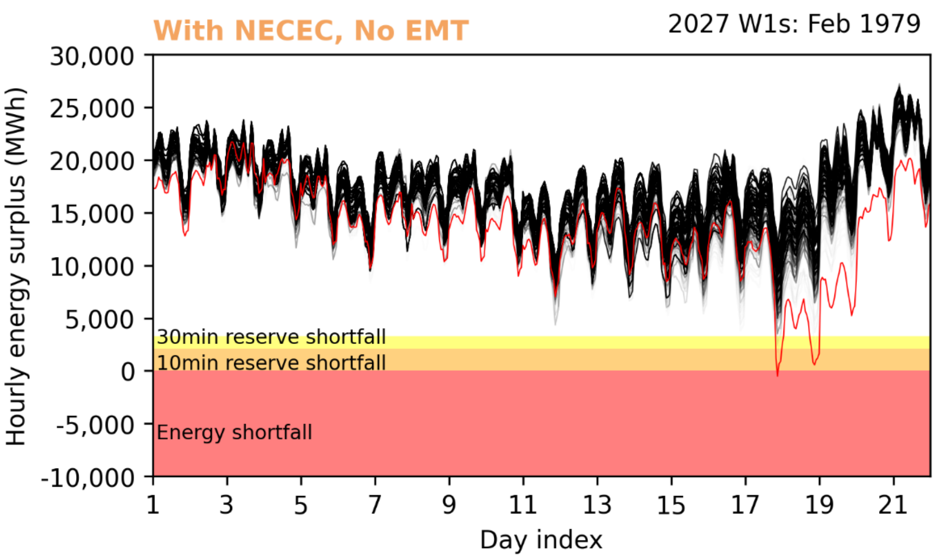


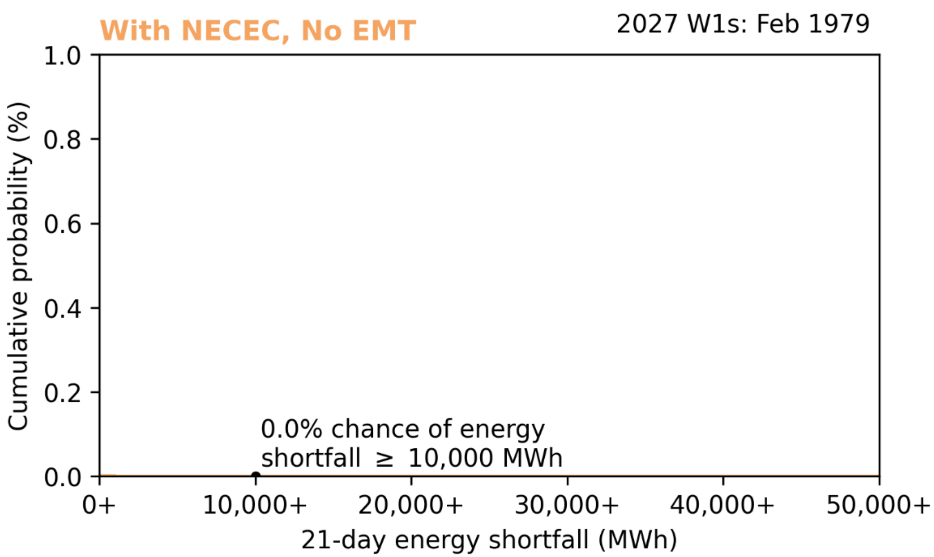


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
0	0	0	0	0.0%	0.0%

Summary of 21-Day Energy Analysis Results

Feb 2, 1979 Event; Scenario: with NECEC, no EMT

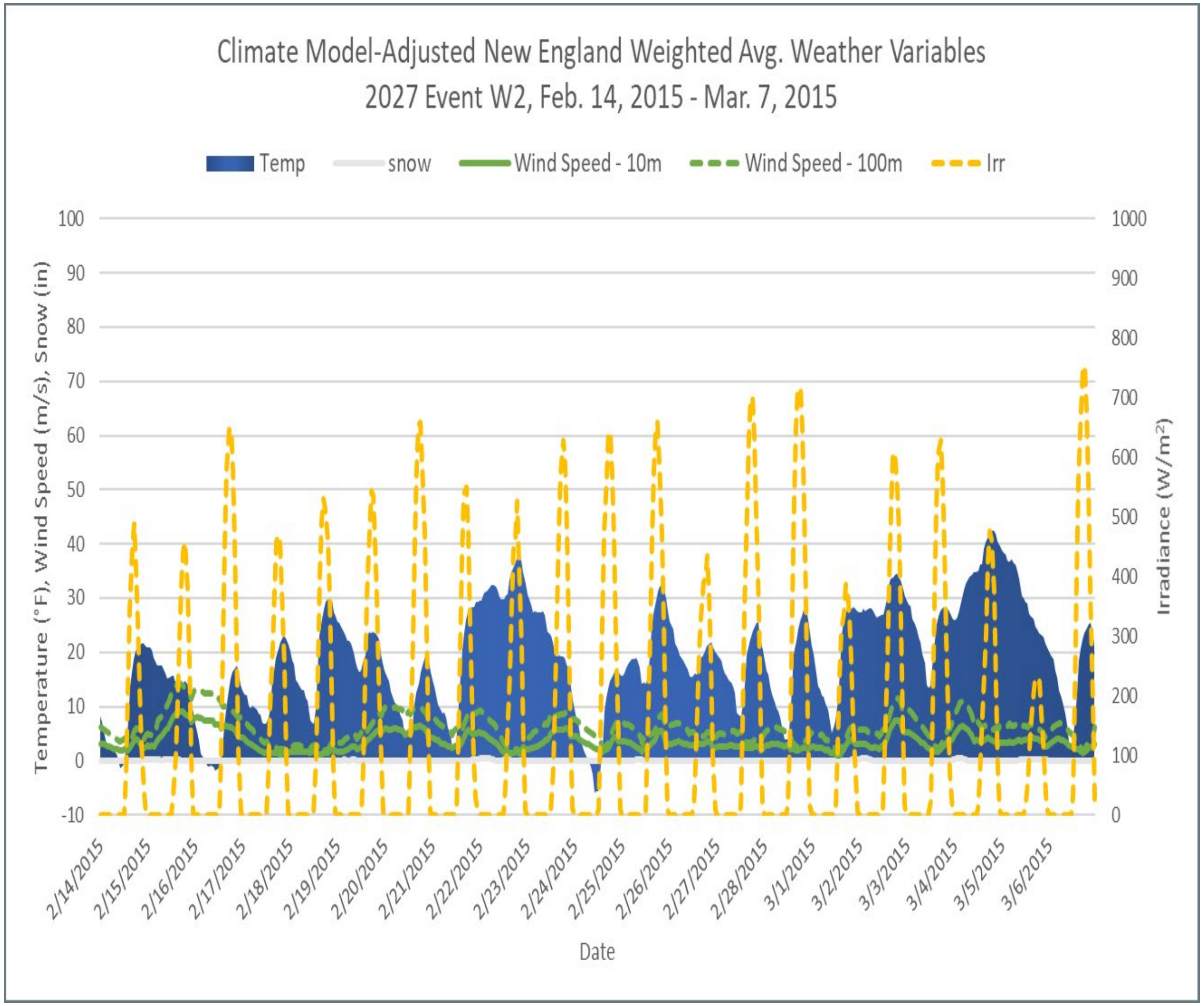


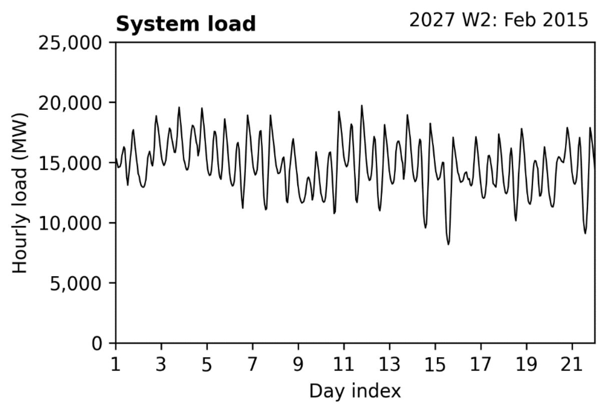


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2	522	10	0	0.001%	0.0006%

Feb 14, 2015 Winter Event Overview

Multiple Short-Duration Cold Waves Coincident With Low Wind and Low Solar



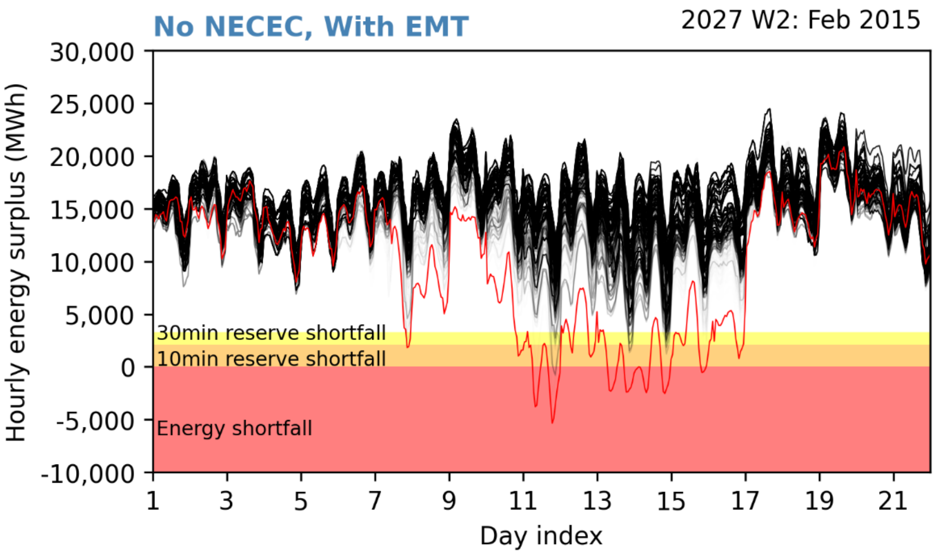


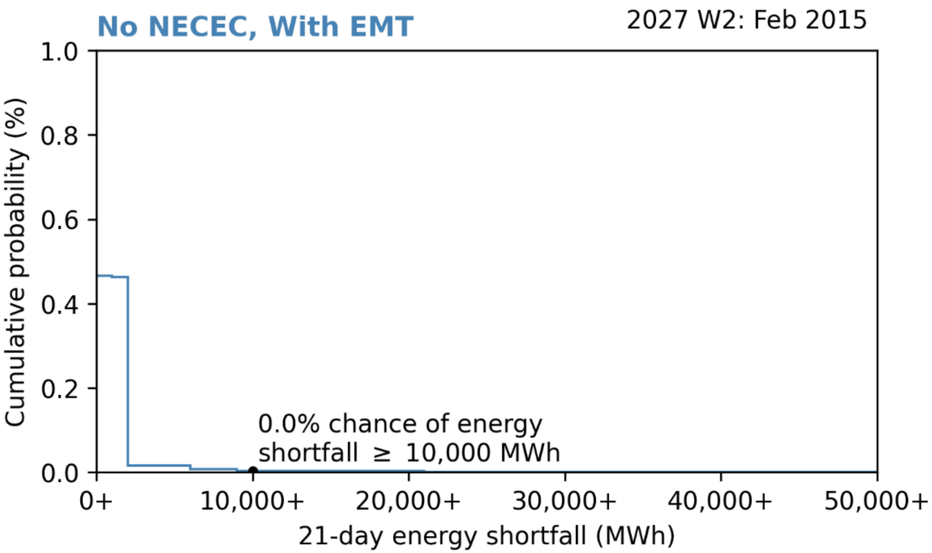
- **Min/Mean/Max (°F):** -5.8/19.0/42.5
- **Mean 100m Wind Speed (m/s):** 6.0
  - Offshore Wind avg. 740 MW/hr
  - Onshore Wind avg. 410 MW/hr
- **Mean Irradiance (W/m²):** 147.6
  - Utility Scale PV avg. 280 MW/hr
  - BTM PV avg. ~1,100 MW/hr
- **Avg. Energy From Renewables:** ~2,530 MW/hr
- **Peak Load:** 19,730 MW (day 11)
- **Peak Energy Demand:** ~399,000 MWh (day 3)
- **Total 21-Day Energy Demand:** 7.43 TWh
- **Historical Relevance:** One of Top 10 coldest 21-day periods since 1950

*temperatures, wind speeds, and irradiance are based on a New England ten-city weighted average

Summary of 21-Day Energy Analysis Results

Feb 14, 2015 Event; Scenario: no NECEC, with EMT

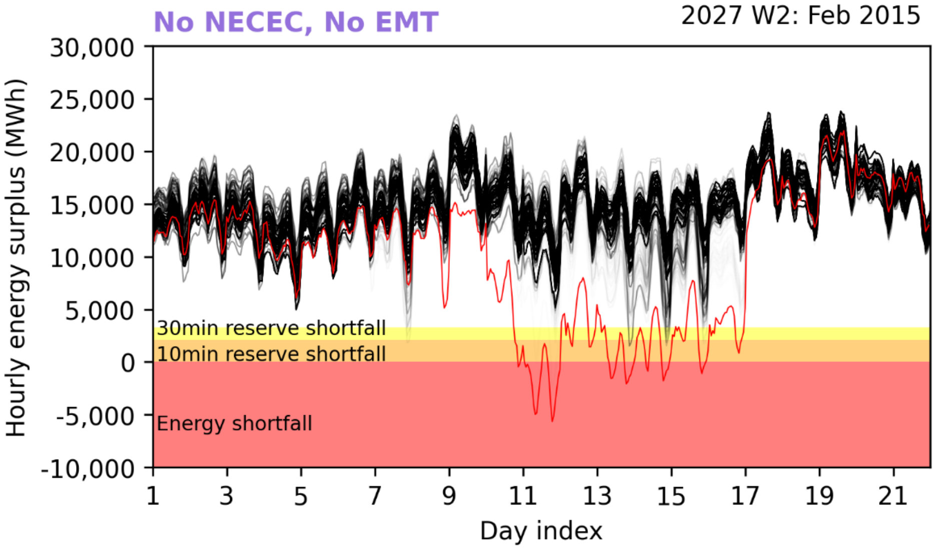


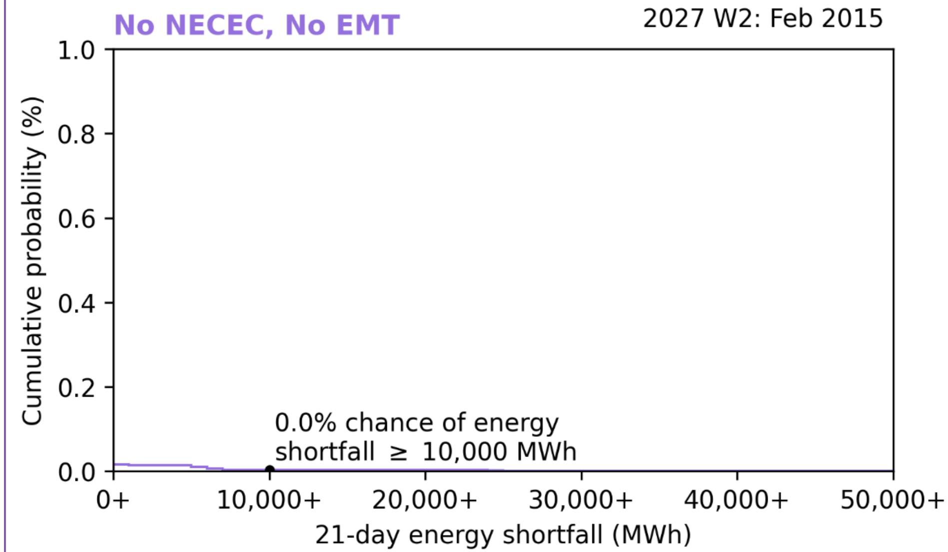


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
33	78,148	18	7	0.47%	0.000005%

Summary of 21-Day Energy Analysis Results

Feb 14, 2015 Event; Scenario: no NECEC, no EMT

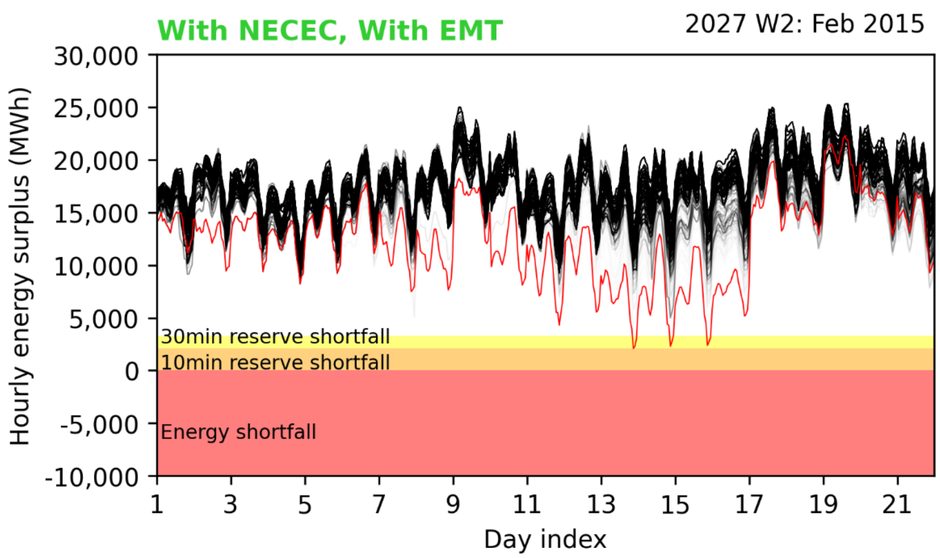


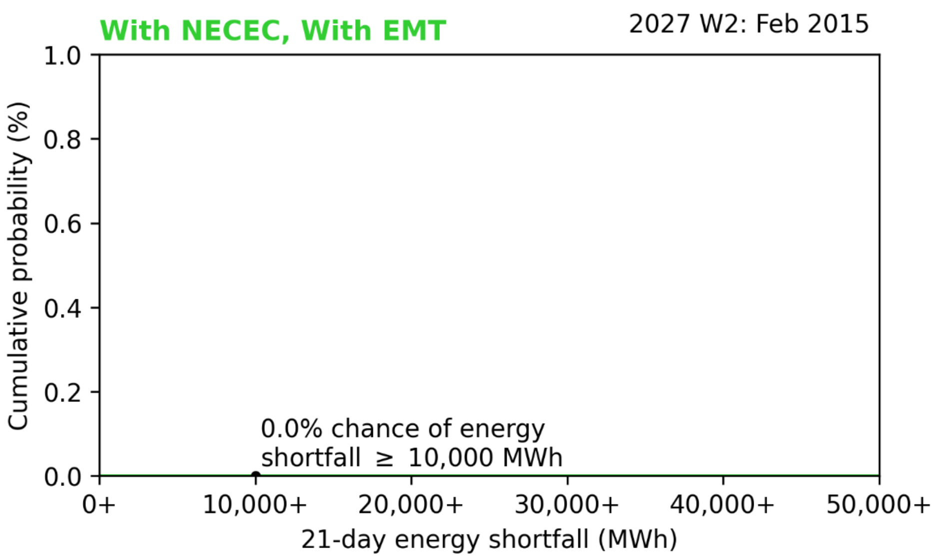


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
18	71,255	10	1	0.02%	0.000005%

Summary of 21-Day Energy Analysis Results

Feb 14, 2015 Event; Scenario: with NECEC, with EMT

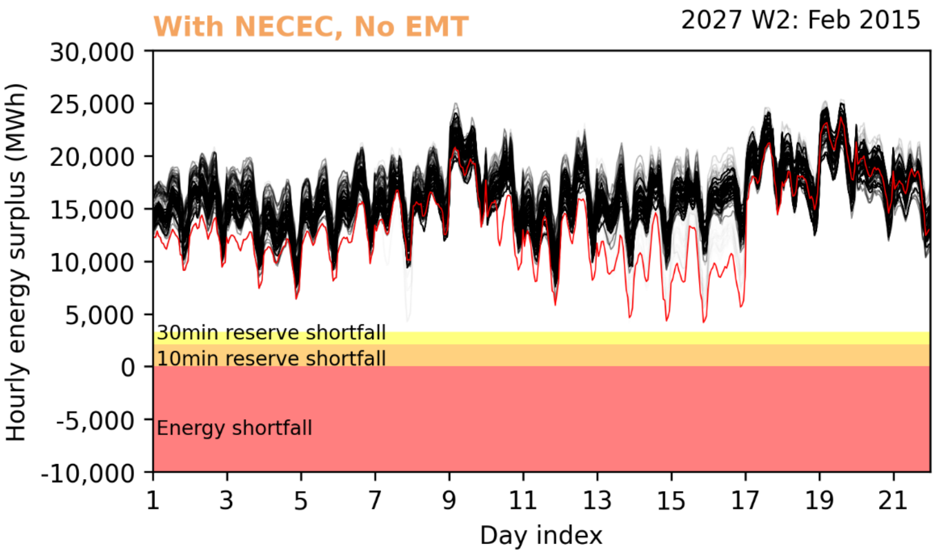


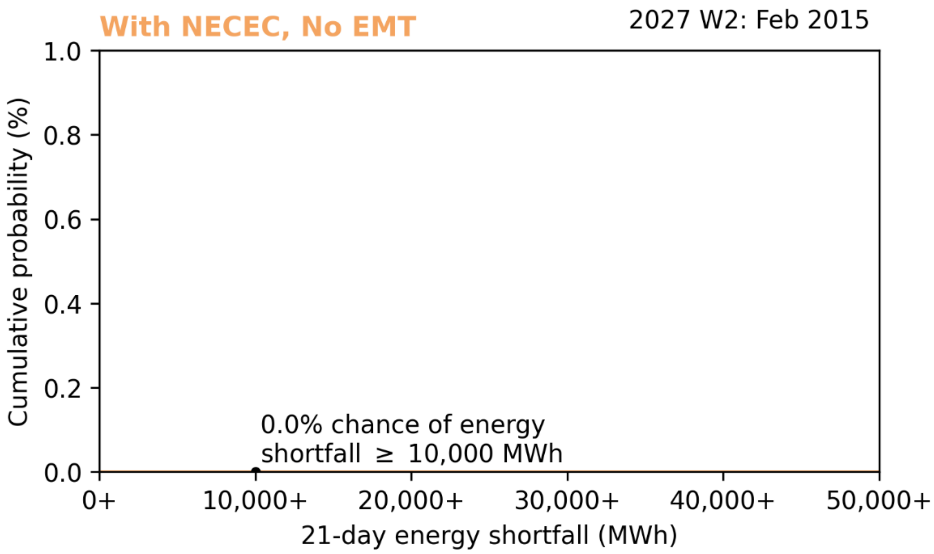


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
0	0	0	0	0.0%	0.0%

Summary of 21-Day Energy Analysis Results

Feb 14, 2015 Event; Scenario: with NECEC, no EMT

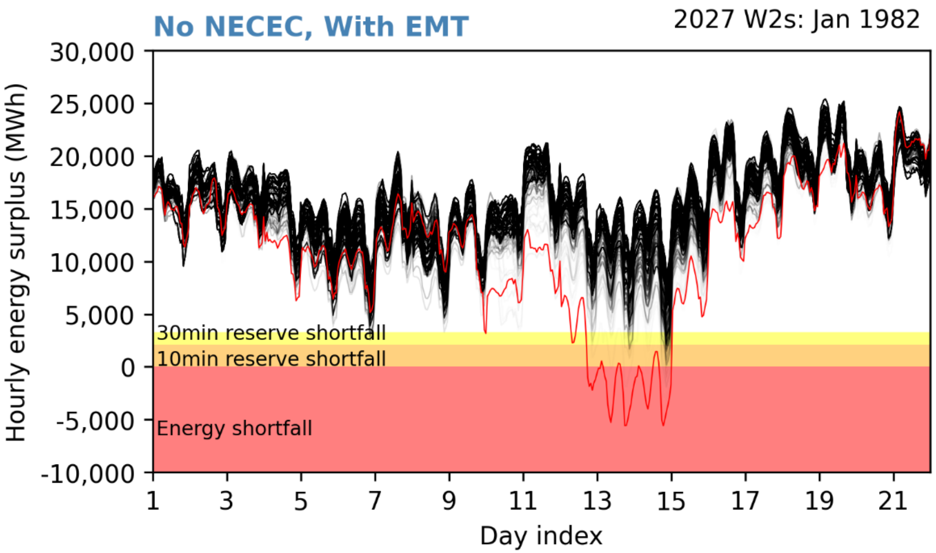


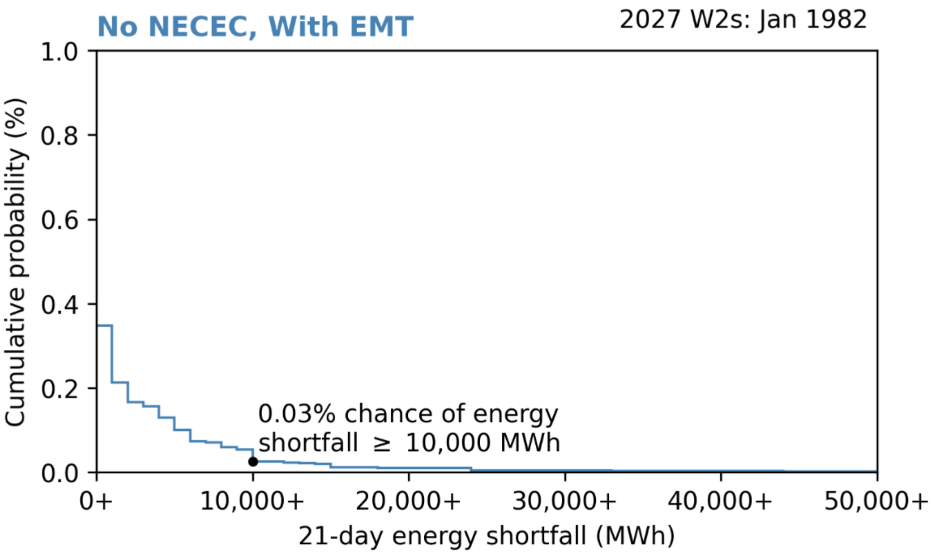


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
0	0	0	0	0.0%	0.0%

Summary of 21-Day Energy Analysis Results

Jan 14, 1982 Event; Scenario: no NECEC, with EMT

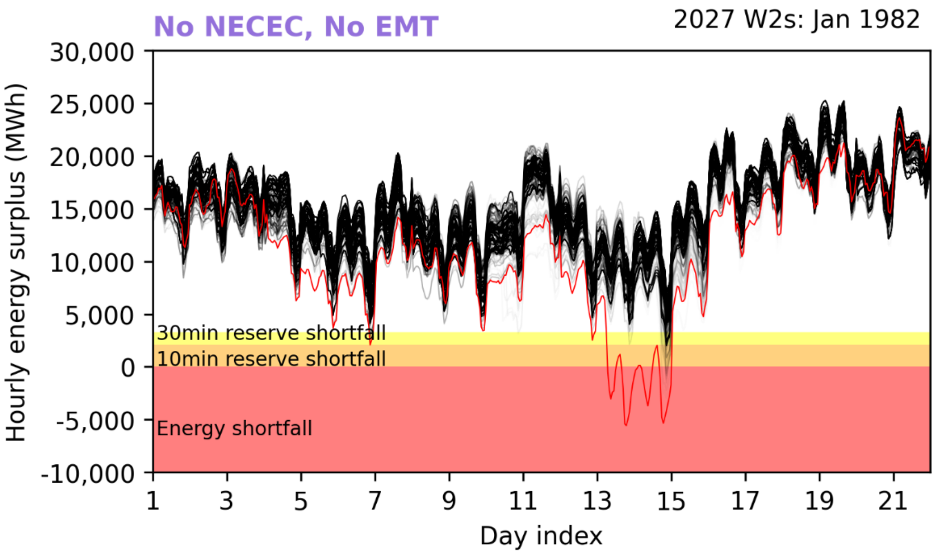


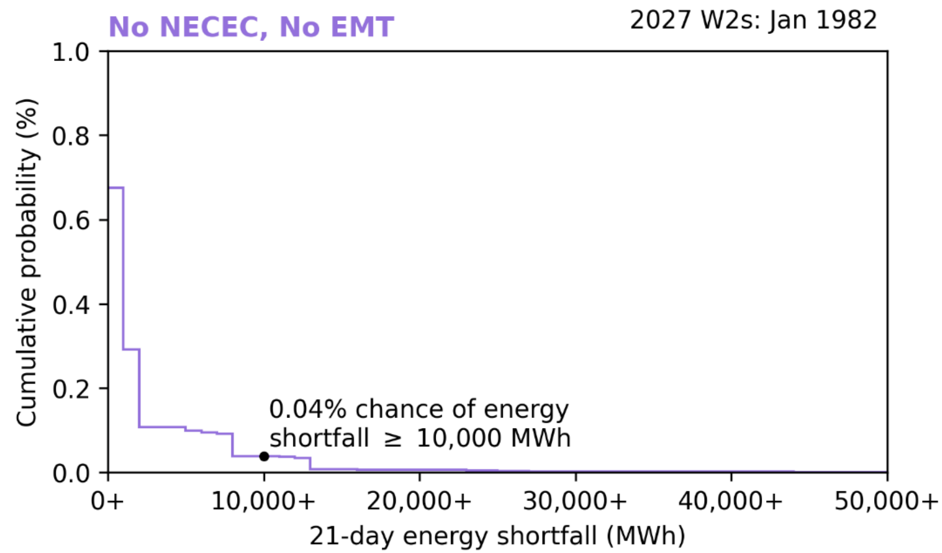


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
139	114,715	32	15	0.35%	0.00004%

Summary of 21-Day Energy Analysis Results

Jan 14, 1982 Event; Scenario: no NECEC, no EMT

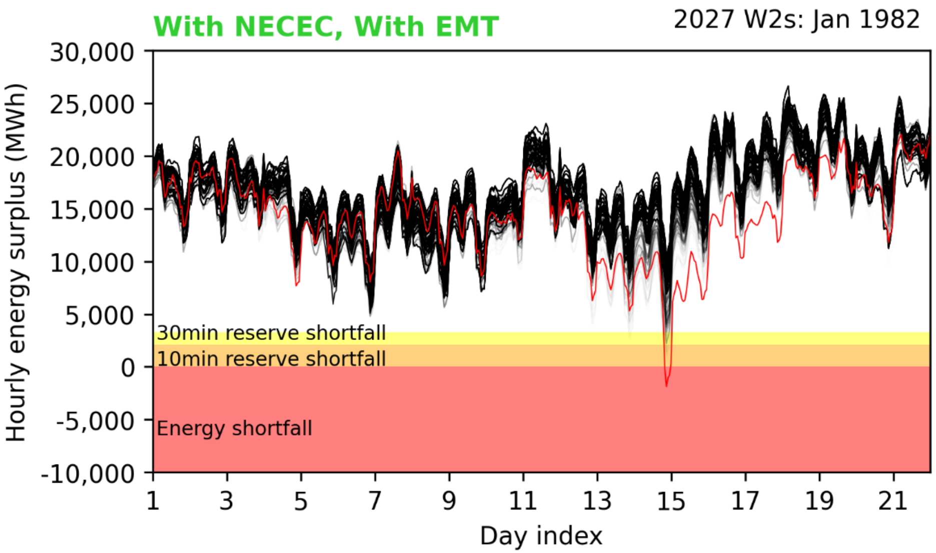


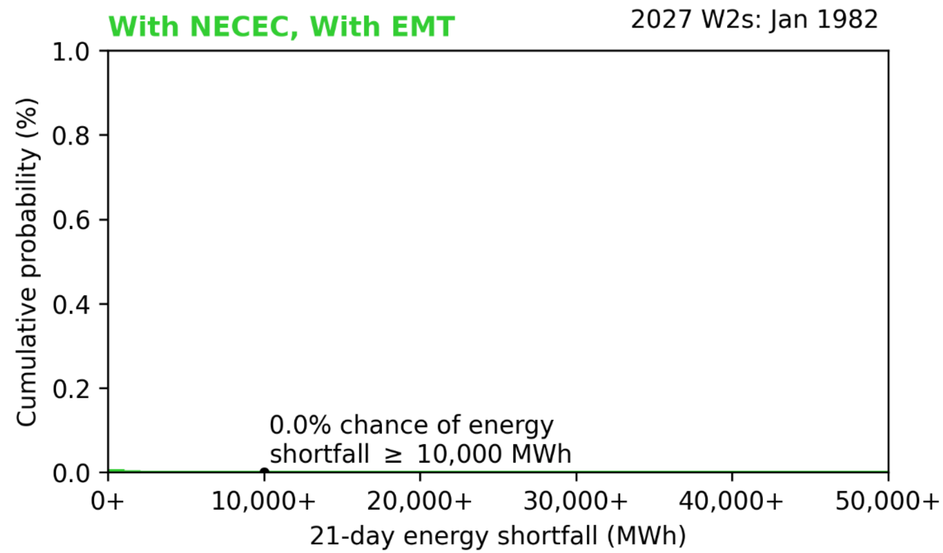


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
95	82,540	72	16	0.68%	0.0006%

Summary of 21-Day Energy Analysis Results

Jan 14, 1982 Event; Scenario: with NECEC, with EMT

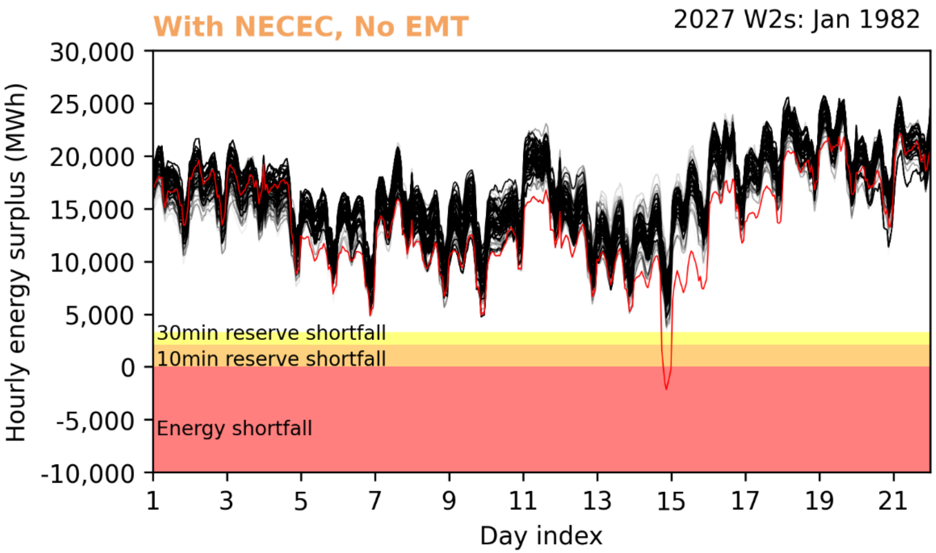


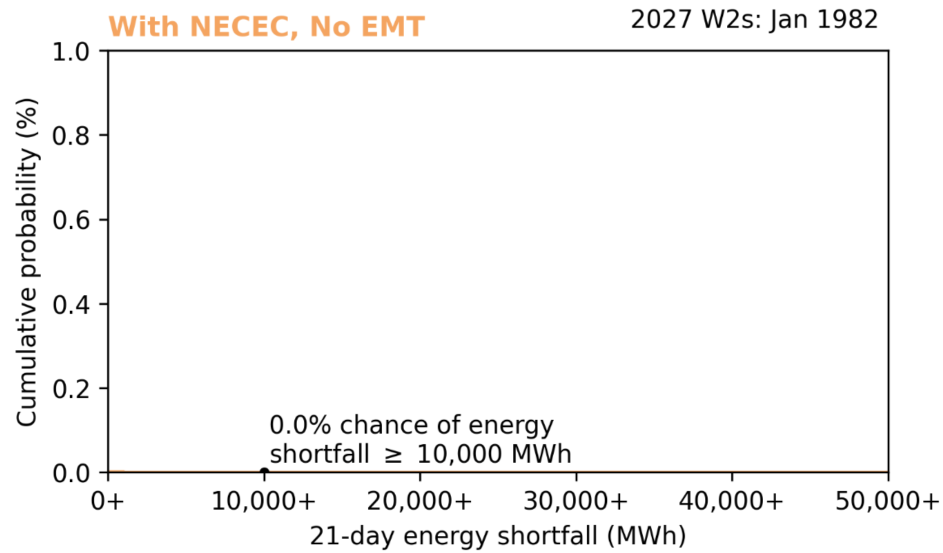


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
7	3,987	320	0	0.004%	0.0006%

Summary of 21-Day Energy Analysis Results

Jan 14, 1982 Event; Scenario: with NECEC, no EMT





# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
3	6,356	610	0	0.0016%	0.0006%