AUGUST 15, 2023| NEPOOL RELIABILITY COMMITTEE |
DOUBLETREE HOTEL, WESTBOROUGH, MA

Operational Impact of Extreme Weather Events

Preliminary Results of Energy Adequacy Studies for Winter 2032

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Operational Impact of Extreme Weather Events – Energy Adequacy Study

- ISO is working with EPRI to conduct a probabilistic energy adequacy study for the New England region in the operational time frame under extreme weather events
- Study results are intended to inform the region on risks
  - These results may help in ‘quantifying’ a problem statement on energy adequacy, against which possible solutions can be assessed
- This study has established a framework for risk analysis under extreme weather events
  - This framework will be essential as climate projections are refined and the resource mix evolves

Operational Impact of Extreme Weather Events – Energy Adequacy Study, cont.

- There are three major steps in this framework:
  - Step 1: Weather Modeling (performed by EPRI)
  - Step 2: Risk Screening Model Development and Scenario Generation (performed by EPRI)
  - Step 3: Energy Assessments (performed by the ISO)
- The ISO has been reviewing and discussing each step of the process with the Reliability Committee
- Preliminary results of Step 3 energy assessments were presented for the 2027 winter events in May and were presented for the 2027 summer events in July
- This presentation reviews preliminary results of Step 3 energy assessments completed for 2032 winter events

ASSUMPTIONS, SELECTED EVENTS, AND SCENARIO MODELING FOR STUDY YEAR 2032

Resource and Demand Assumptions for Study Year 2027 and 2032

- 2032 baseline studies include resources that cleared FCA16 and state-sponsored resources under contract or have been selected under recent RFP's
  - ISO's 2032 baseline studies assume all FCA 16 cleared resources, including Millstone Station, which is currently on a state contract
- 2032 baseline studies incorporate ISO's 2022 CELT heating and transportation electrification forecasts
- The use of **"baseline studies"** in this presentation is intended to differentiate between studies performed without modification of the default assumptions (as shown on the table to the right) and 2032 studies described later in this presentation which incorporate sensitivity analysis

Baseline Study Assumptions		
	2027 Study Year	2032 Study Year
CELT Load Forecast Year	2022	2022
FCA Results	FCA16	FCA16
Retired Capacity*	2,100	2,100 (no change from 2027)
Offshore Wind Capacity*	1,600	4,800
Storage Battery Capacity*	1,450	1,450 (no change from 2027)
Utility-scale PV Capacity*	1,250	1,250 (no change from 2027)
BTM PV Capacity*	9,500	12,000

**capacity values listed in the table above, in MW, are based on nameplate and are approximate*

21-Day Weather Events Selected By Risk Screening Model For Study Year 2032

- The 2032 winter events selected for study are characterized by short and long-duration extreme cold, low winds, and low solar irradiance
- This presentation reviews the following 2032 winter events:
  - Winter Cluster 1 (longer-duration events)
    - Jan 22, 1961 (event with highest average system risk*)
    - Jan 12, 2004 (event with highest severity index*)
  - Winter Cluster 2 (shorter-duration events)
    - Feb 14, 2015 (event with highest average system risk)
    - Jan 7, 1982 (event with highest severity index)
  - Medoid events for each cluster were also studied; results are briefly summarized later in this presentation
  - Note that the Jan 22, 1961 and Feb 14, 2015 events were also included in 2027 winter studies and, where possible, changes from 2027 to 2032 are highlighted

*Average System Risk and Severity Index are metrics calculated by EPRI's Risk Screening Model; these metrics are used to rank events and aid in the selection of events for study

Return Periods for Study Year 2032 Events

- A "return period" has been determined for these events
  - 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
  - Additional information on return periods is provided in the appendix to this presentation
- A return period of ~3 to 7 years has been determined for 2032 Winter Cluster 1 events and ~2 to 5 years for 2032 Winter Cluster 2 events

Cluster	Return Period (2027)	Return Period (2032)
Winter Cluster 1	8-10 years	3-7 years
Winter Cluster 2	3-5 years	2-5 years

Introduced
May 2023
RC Meeting

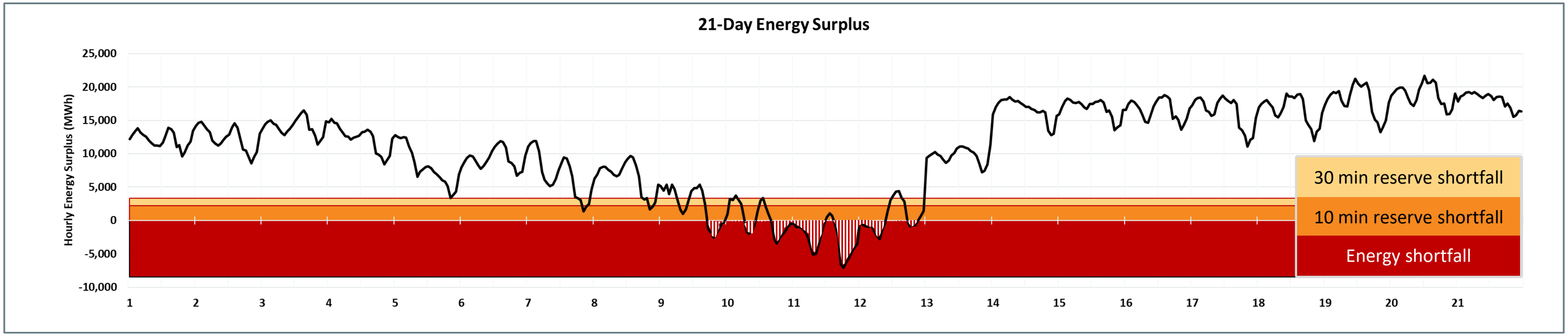
Scenario Modeling of Everett Marine Terminal and New England Clean Energy Connect

- Each event is studied with a combination of two key variables – Everett Marine Terminal (EMT) and the New England Clean Energy Connect (NECEC) facility; each combination is a scenario which has not been assigned a probability of occurrence
- Scenario modeling of EMT and NECEC in 2032 baseline studies is identical to the methodology used in 2027 studies
  - Scenarios with NECEC in-service allow up to an additional 1,080 MW/hr of max imports
  - 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
- Based on the most recent information regarding expectations for NECEC construction, ISO is focused largely on 2032 scenarios that consider NECEC in-service

	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**	

21-Day Energy Assessment Calculates Energy Surplus

Introduced May 2023 RC Meeting



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

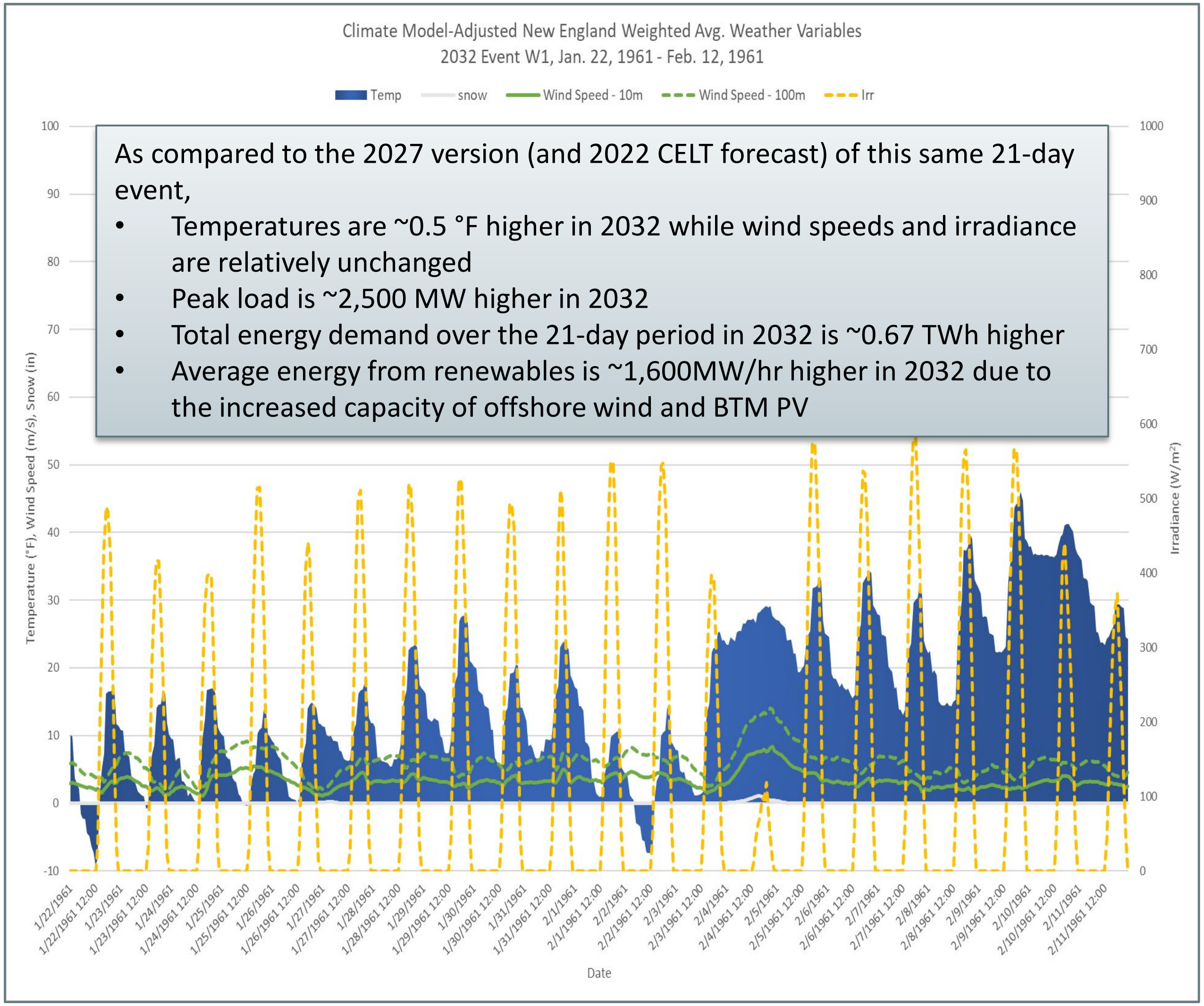
- For each case, energy assessment results include:
  - Energy surplus (black curve)
  - Energy shortfall (red/white striped area): quantity in MWh and duration
  - Reserve shortfalls (black curve in yellow/orange): quantity in MWh and duration
- For each scenario, energy assessment results are a statistical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

STEP 3: 2032 WINTER CLUSTER 1 (W1) PRELIMINARY RESULTS

Jan 22, 1961 (highest average system risk event) &
Jan 12, 2004 (highest severity index event)

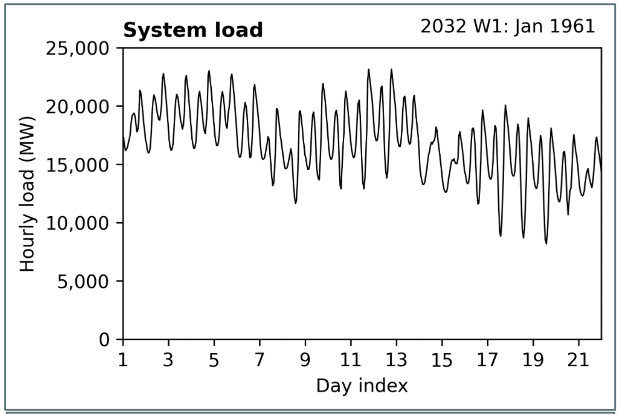
Jan 22, 1961 Winter Event Overview

~12-Day Cold Wave Coincident With Low Wind and Very Low Solar



As compared to the 2027 version (and 2022 CELT forecast) of this same 21-day event,

- Temperatures are ~0.5 °F higher in 2032 while wind speeds and irradiance are relatively unchanged
- Peak load is ~2,500 MW higher in 2032
- Total energy demand over the 21-day period in 2032 is ~0.67 TWh higher
- Average energy from renewables is ~1,600MW/hr higher in 2032 due to the increased capacity of offshore wind and BTM PV

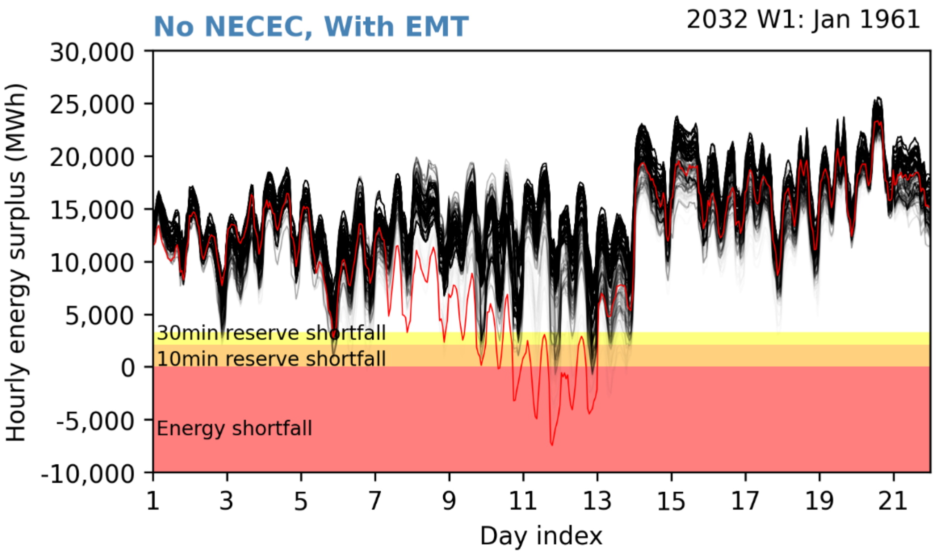


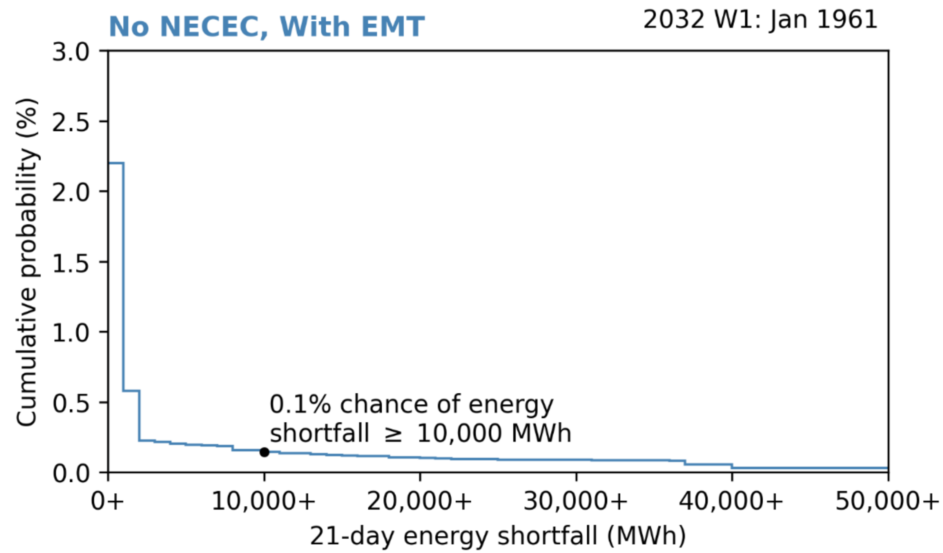
- **Min/Mean/Max (°F):** -9.2/16.2/46.0
- **Mean 100m Wind Speed (m/s):** 6.0
  - Offshore Wind avg. ~2,225 MW/hr
  - Onshore Wind avg. ~340 MW/hr
- **Mean Irradiance (W/m²):** 118.8
  - Utility Scale PV avg. ~220 MW/hr
  - BTM PV avg. ~1,020 MW/hr
- **Avg. Energy From Renewables:** ~3,805 MW/hr
- **Peak Load:** 23,144 MW (day 11)
- **Peak Daily Energy Demand:** ~466,000 MWh (day 5)
- **Total 21-Day Energy Demand:** 8.49 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



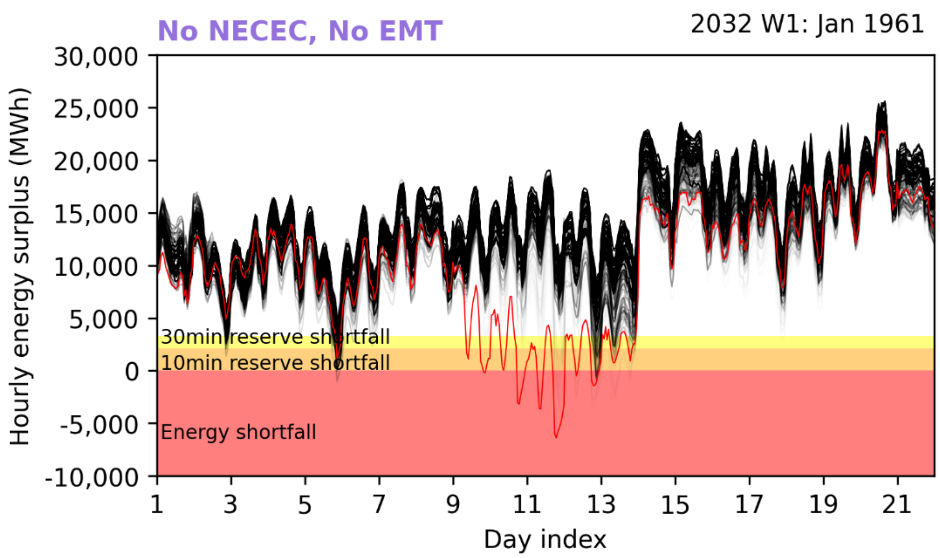


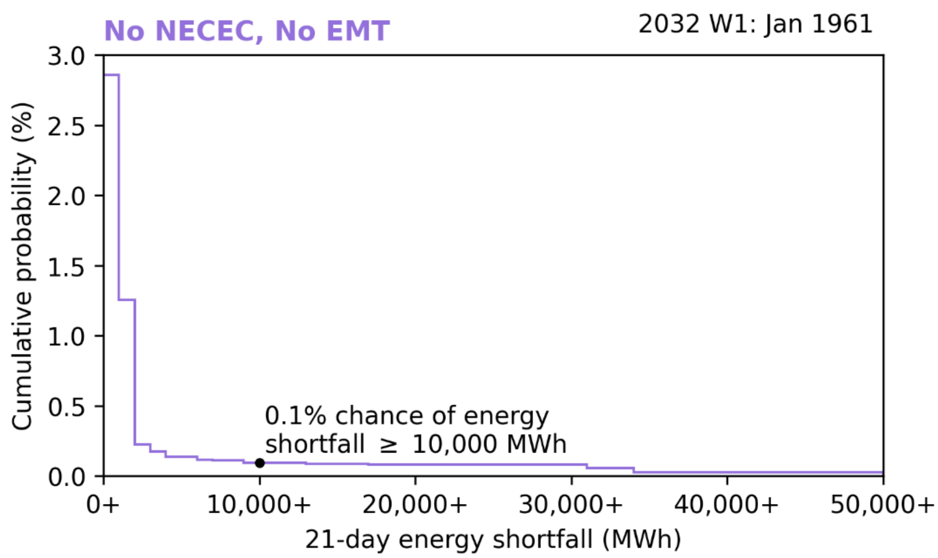
Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	232	115,642	21	69	2.2%	0.00055%
2027*	233	111,353	36	421	7.6%	0.00055%

*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

Summary of 21-Day Energy Analysis Results

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



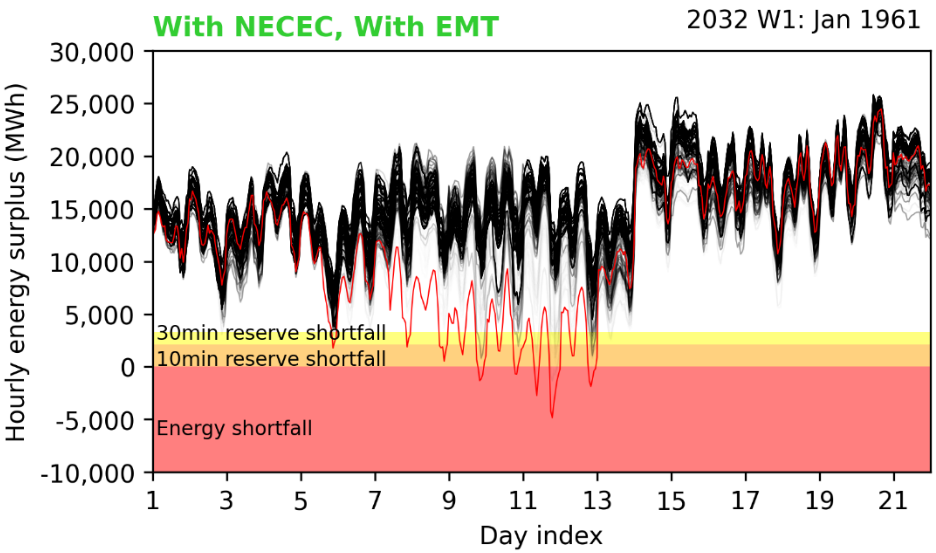


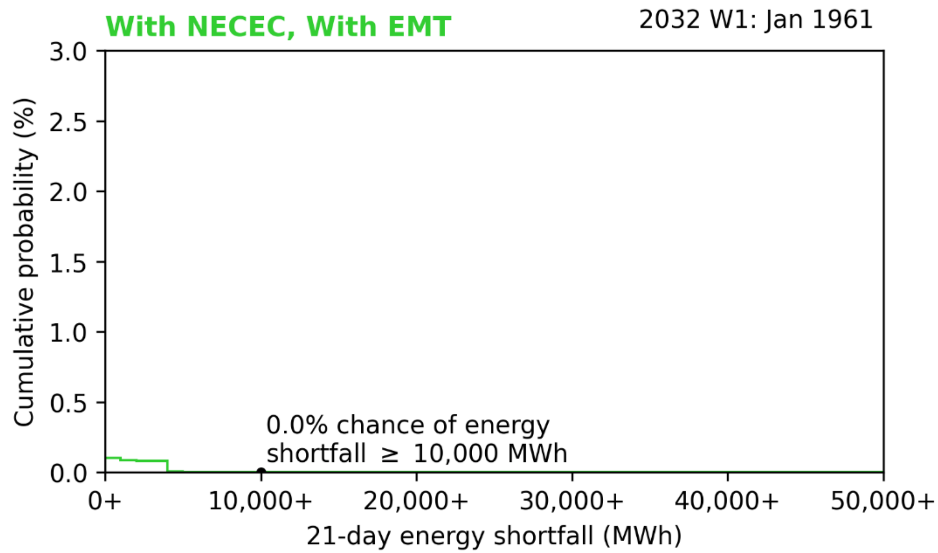
Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	209	63,781	1	57	2.9%	0.0000038%
2027*	172	95,888	1	202	2.3%	0.00055%

*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

Summary of 21-Day Energy Analysis Results

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



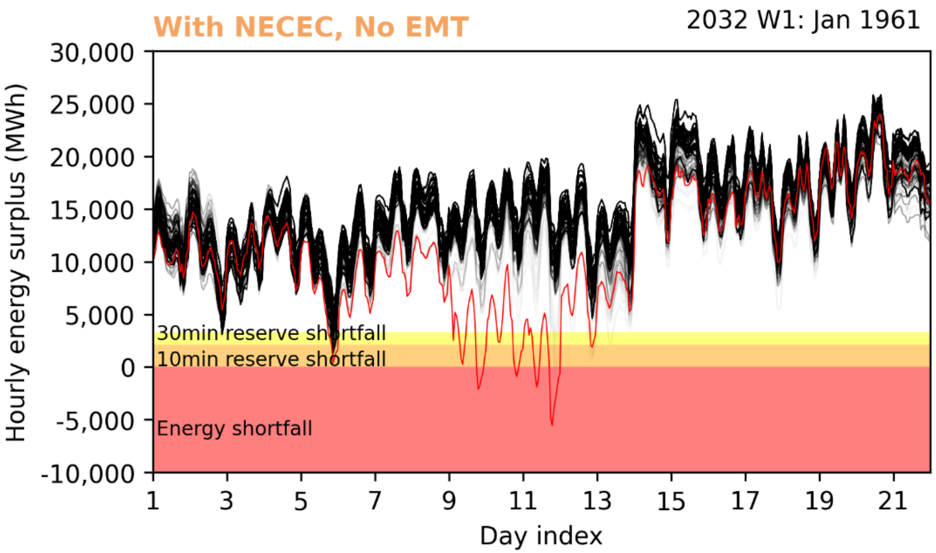


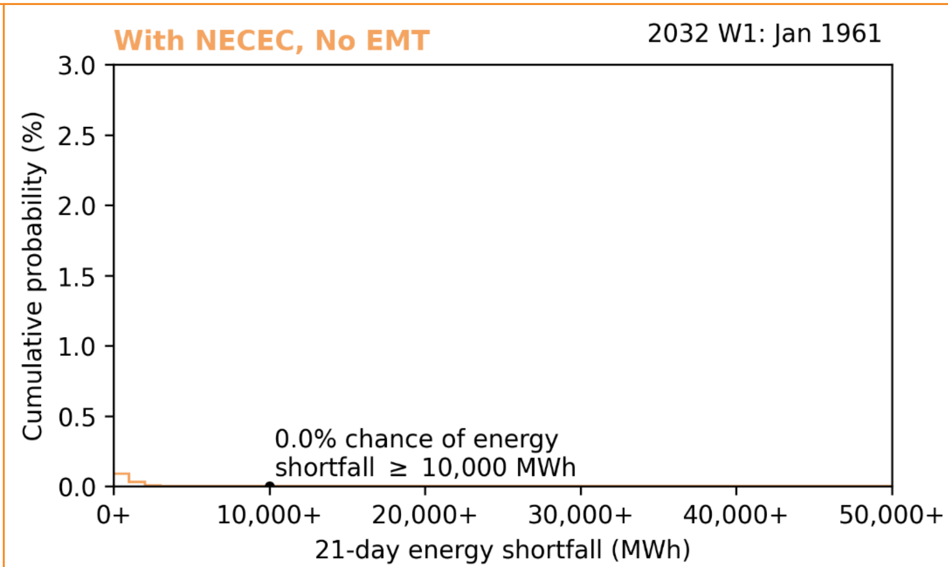
Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	57	31,974	29	3	0.10%	0.0000038%
2027*	30	68,932	1	113	0.67%	0.0044%

*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

Summary of 21-Day Energy Analysis Results

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

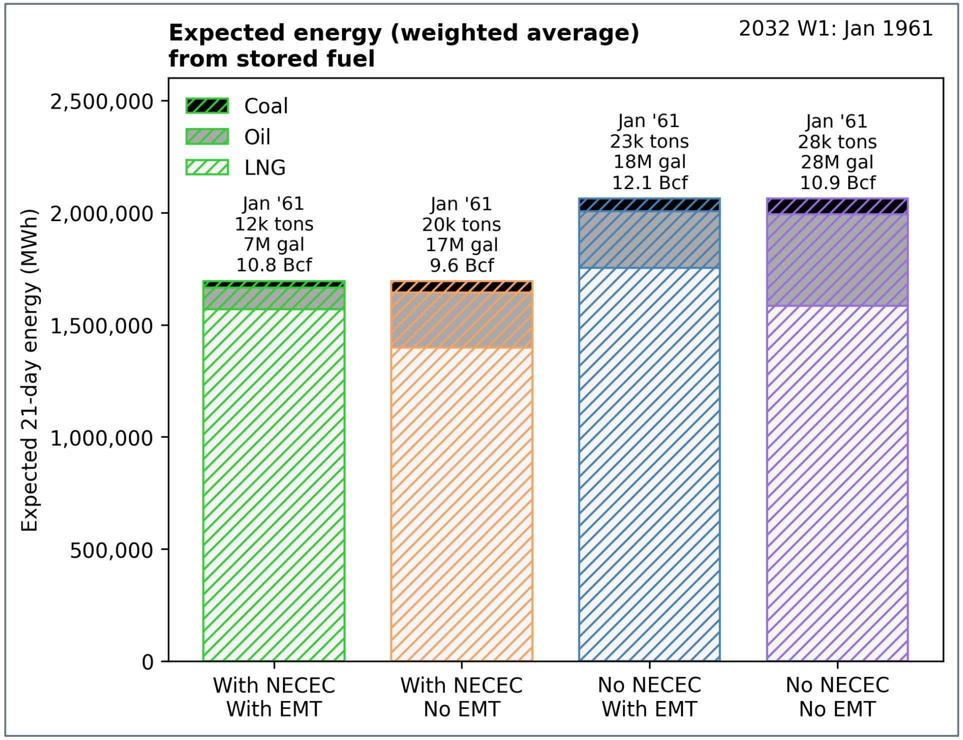




Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	30	33,019	47	1	0.09%	0.0000038%
2027*	25	53,518	143	28	0.64%	0.0044%

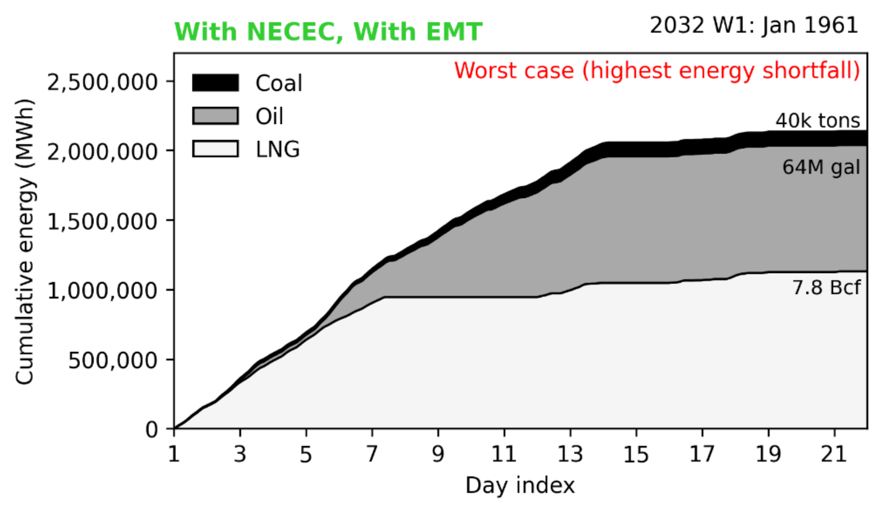
*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

As Seen in 2027 Studies, In Worst Case Energy Shortfalls, Increases in Stored Fuel Usage Are Notable



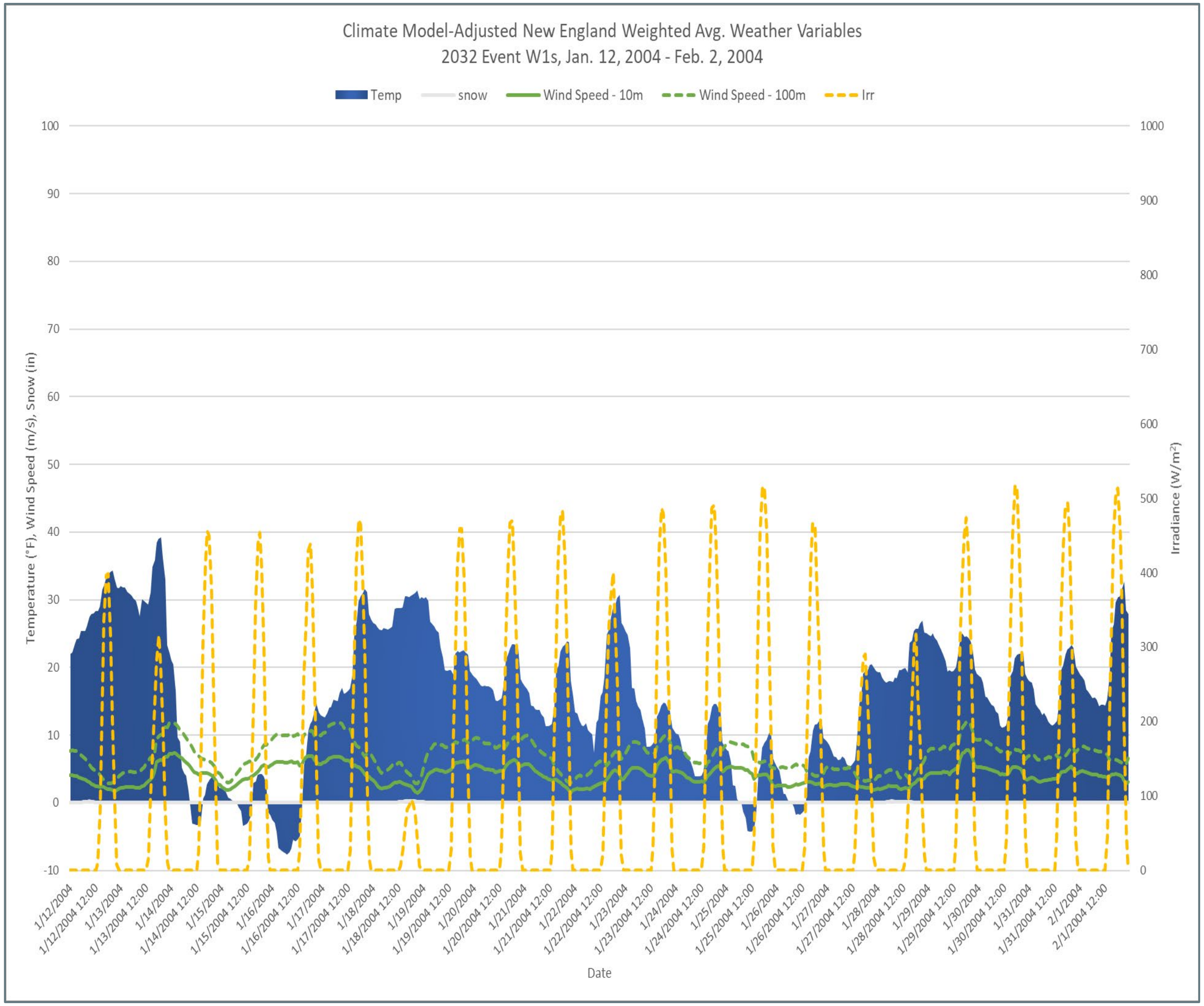
In the figure above, the expected energy from stored fuel is the weighted avg. quantity of stored fuels used across all cases in a given scenario and the figure to the right are for the worst case

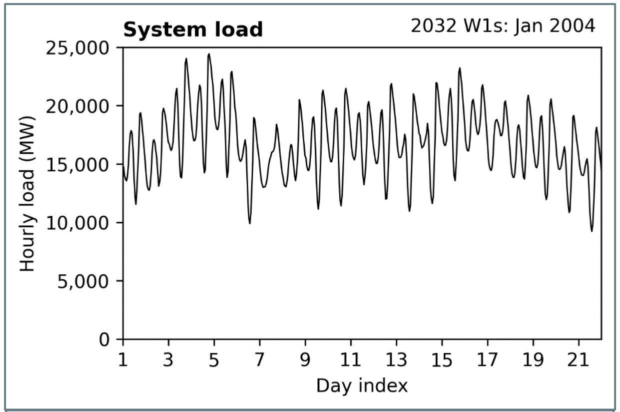
- Similar to results of 2027 studies of the same event, stored fuel usage in the 2032 baseline studies of this event increases significantly in worst cases
- As shown in the figure below, increased energy from stored fuels is notable even in scenarios with NECEC in-service



Jan 12, 2004 Winter Event Overview

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



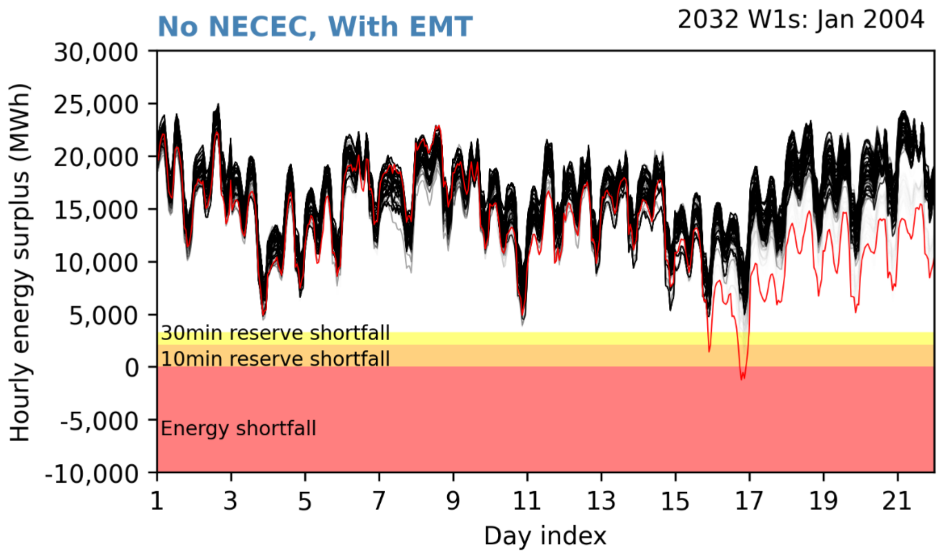


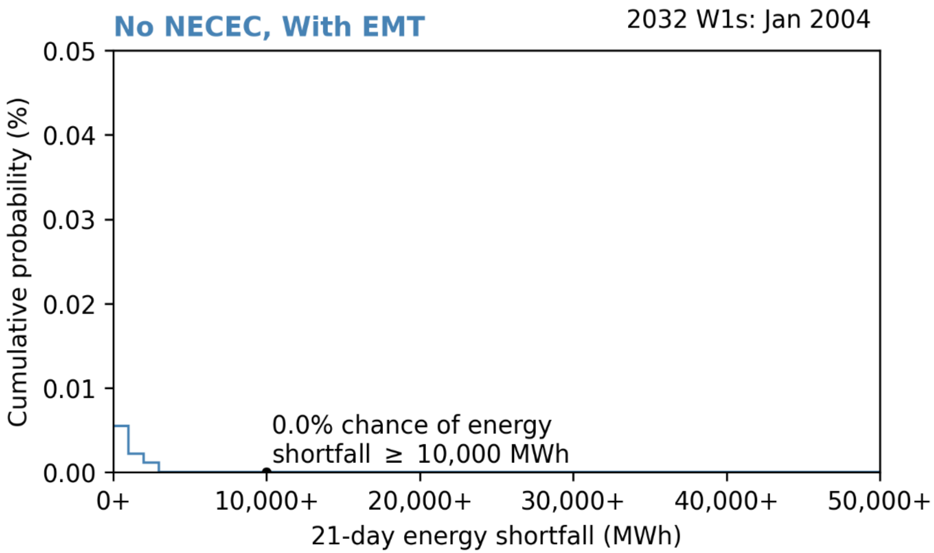
- **Min/Mean/Max (°F):** -7.6/15.7/39.3
- **Mean 100m Wind Speed (m/s):** 7.0
  - Offshore Wind avg. ~3,090 MW/hr
  - Onshore Wind avg. ~535 MW/hr
- **Mean Irradiance (W/m²):** 102.0
  - Utility Scale PV avg. ~200 MW/hr
  - BTM PV avg. ~1,300 MW/hr
- **Avg. Energy From Renewables:** ~5,125 MW/hr
- **Peak Load:** 24,429 MW (day 4)
- **Peak Daily Energy Demand:** ~468,000 MWh (day 4)
- **Total 21-Day Energy Demand:** 8.49 TWh
- **Historical Relevance:** The actual weather during this stretch was included in the top ten coldest 21-day and 10-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 12, 2004 Event; Scenario: no NECEC, with EMT

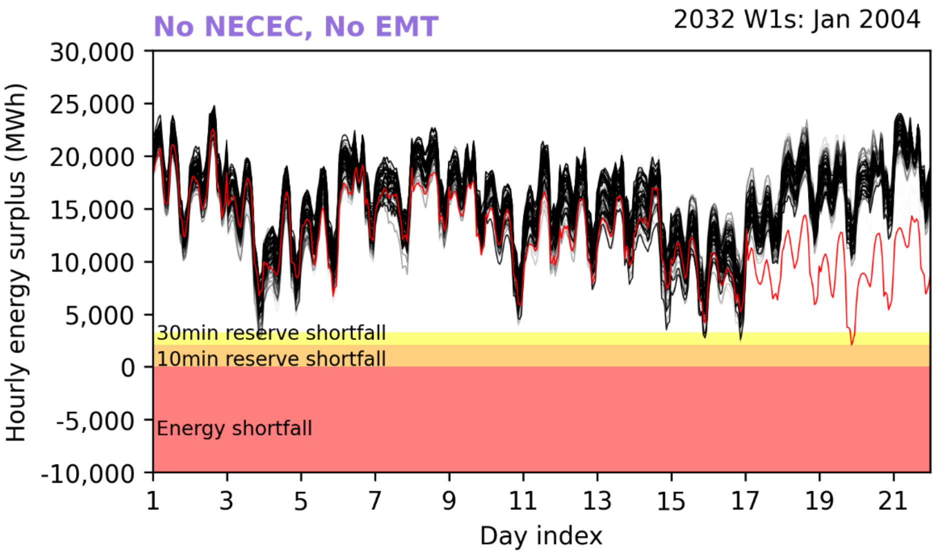


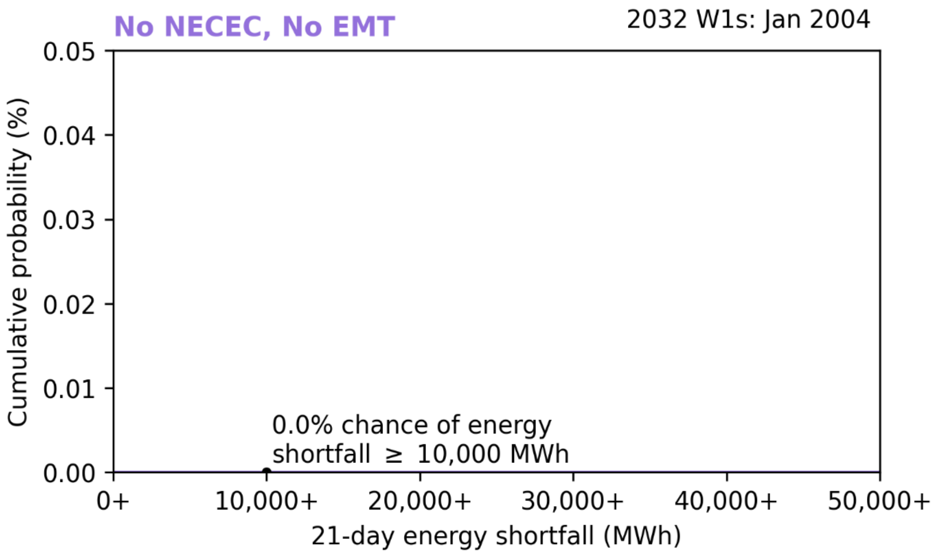


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
10	2,906	25	0	0.01%	0.00055%

Summary of 21-Day Energy Analysis Results

Jan 12, 2004 Event; Scenario: no NECEC, no EMT





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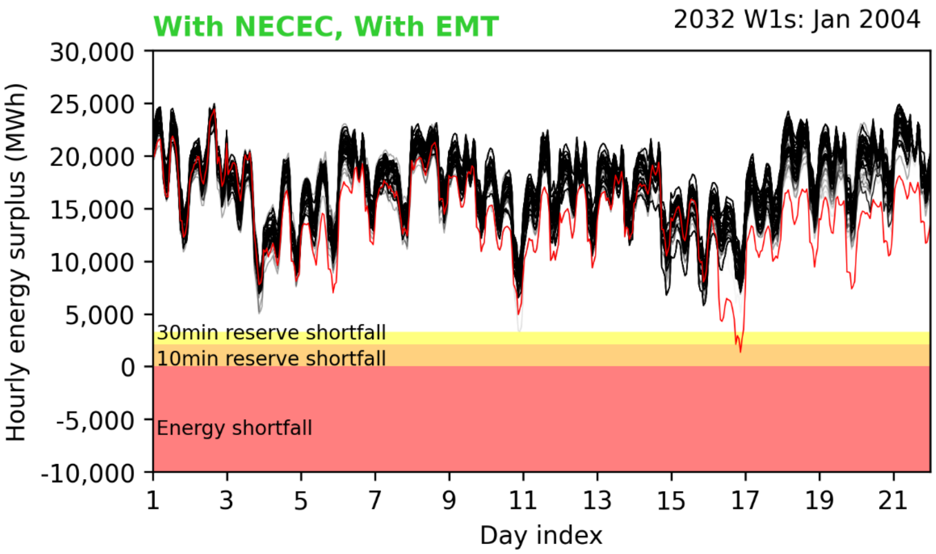
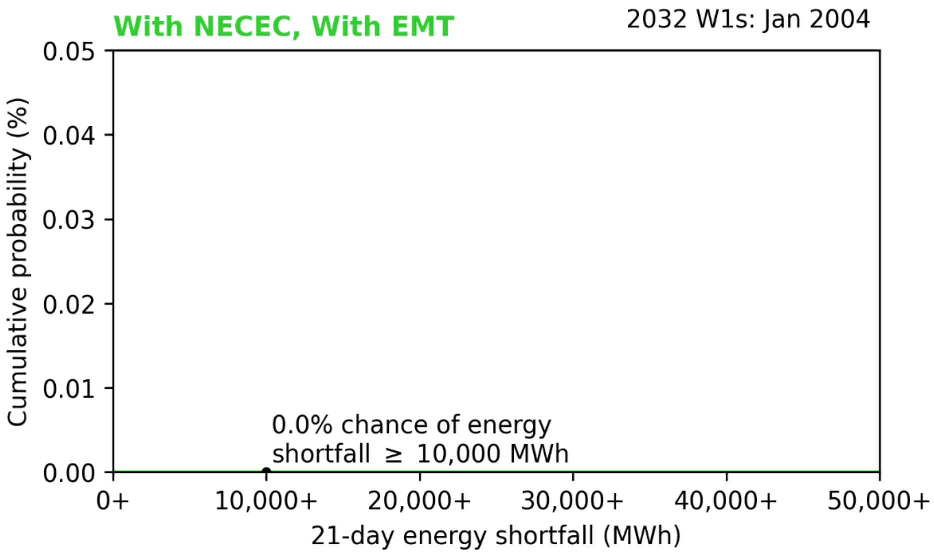
0	0	0	0	0.0%	0.0%

Summary of 21-Day Energy Analysis Results

Jan 12, 2004 Event; Scenario: with NECEC, with EMT

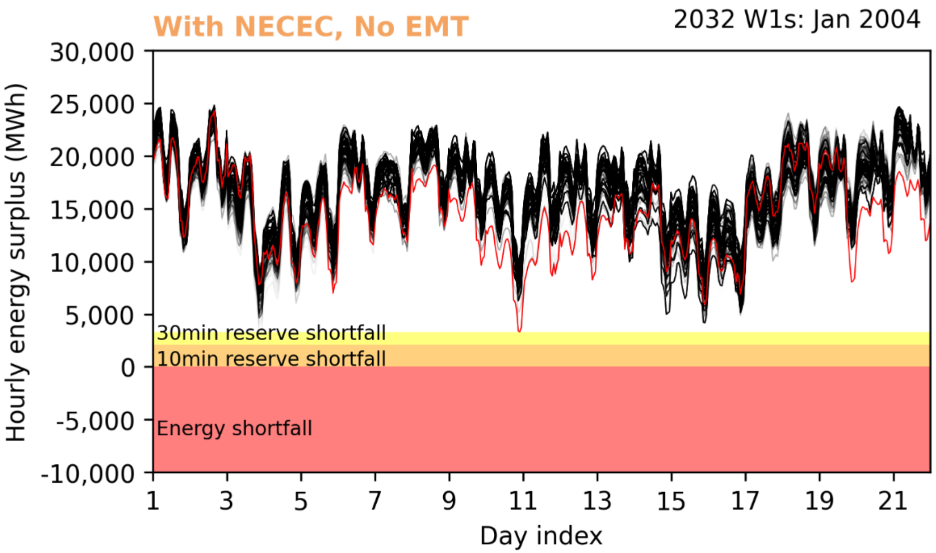


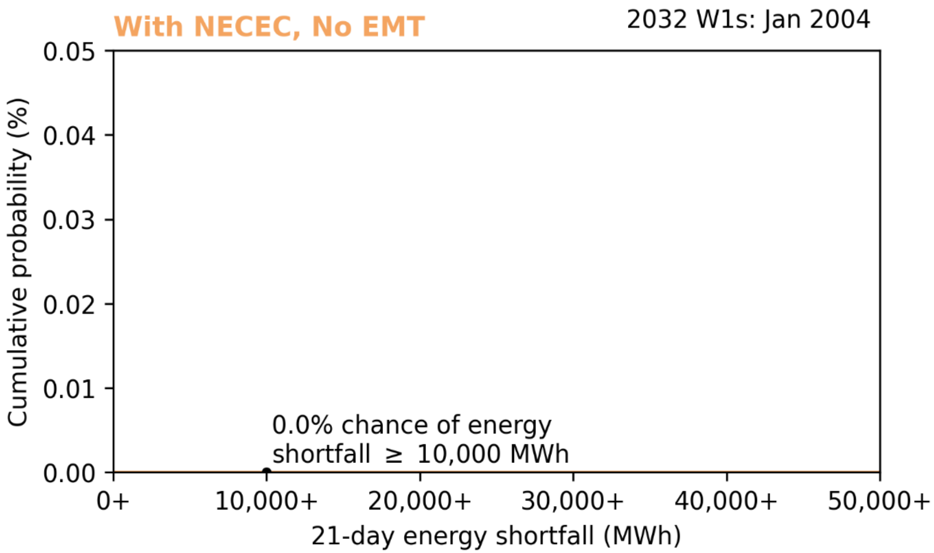


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day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

Summary of 21-Day Energy Analysis Results

Jan 12, 2004 Event; Scenario: with NECEC, no EMT

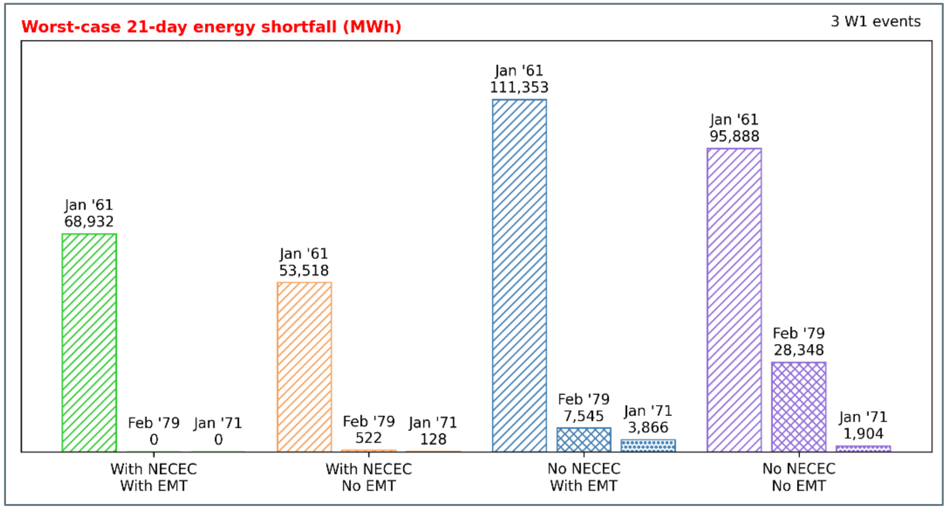




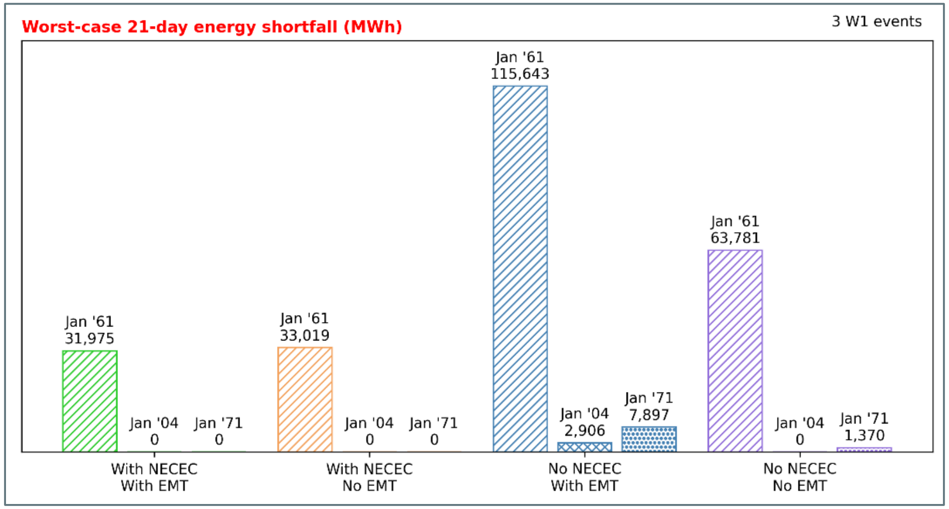
# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day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

2027 and 2032 Winter Cluster 1 Events - Comparison of Energy Shortfall Quantities

2027 Winter Cluster 1 Events



2032 Winter Cluster 1 Events



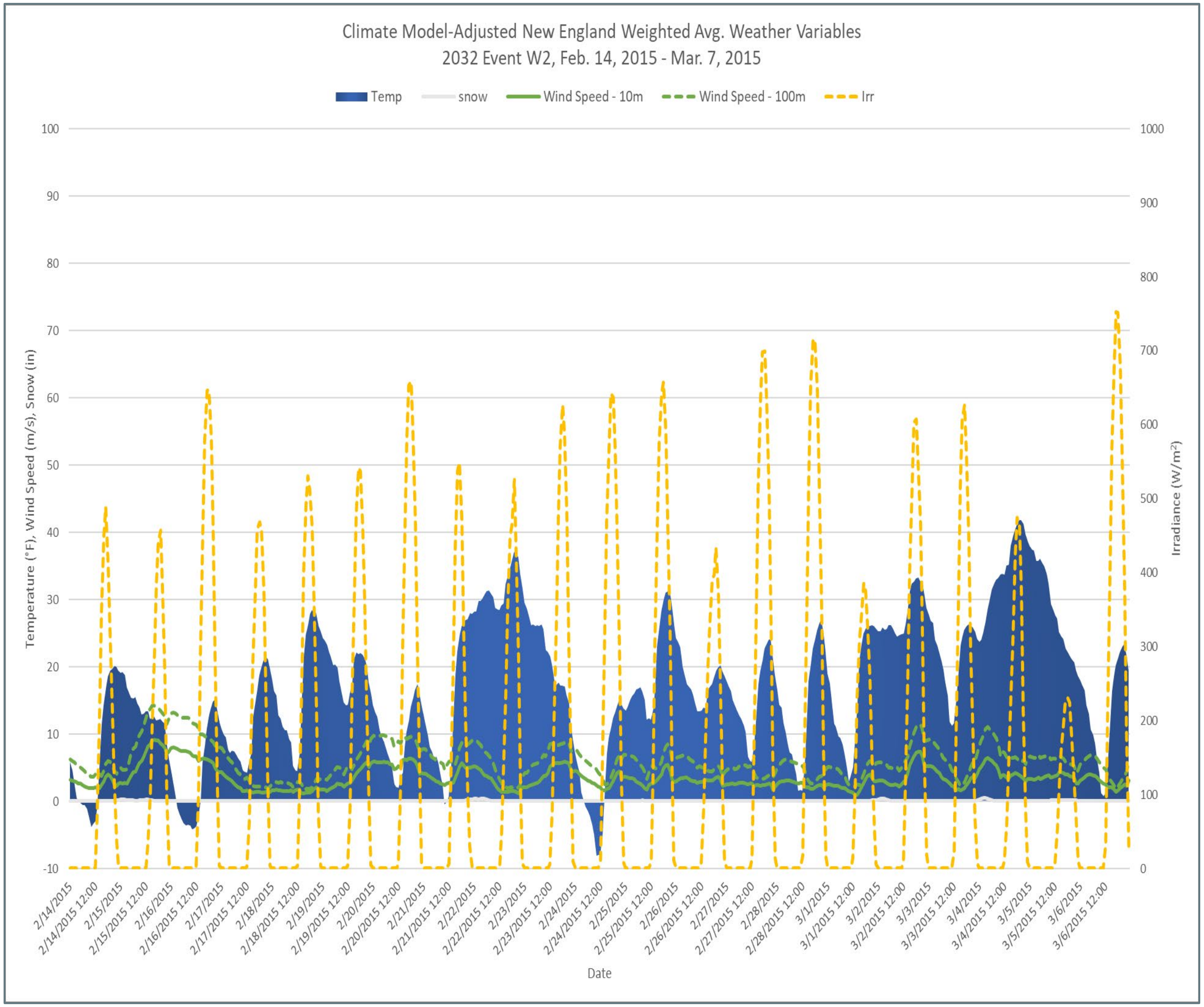
- Results of the Winter Cluster 1 medoid event (Jan 15, 1971) are included in the figures above; energy shortfall risk in the medoid events is negligible
- Results of 2032 Winter Cluster 1 baseline studies reveal energy shortfall risk comparable to 2027 event studies

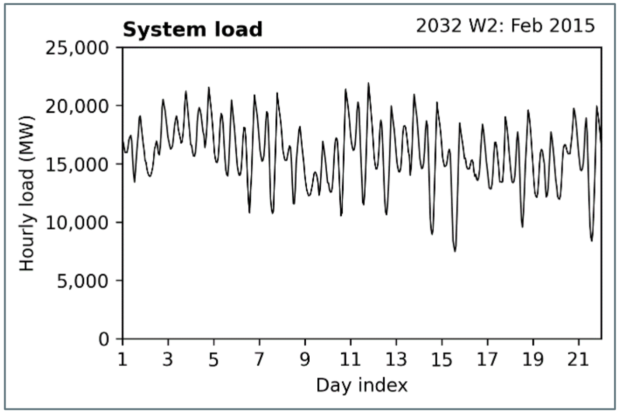
STEP 3: 2032 WINTER CLUSTER 2 (W2) PRELIMINARY RESULTS

Feb 14, 2015 (highest average system risk event) &
Jan 7, 1982 (highest severity index event)

Feb 14, 2015 Winter Event Overview

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



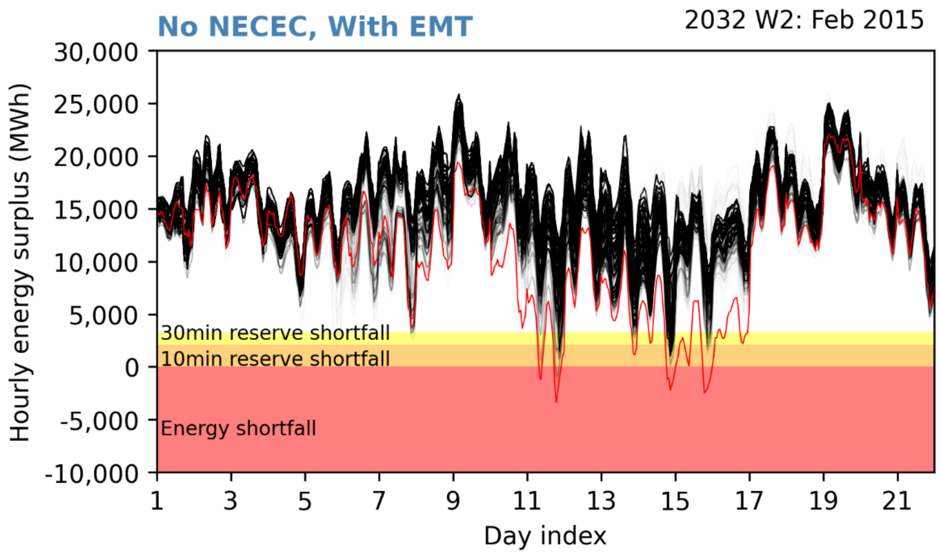


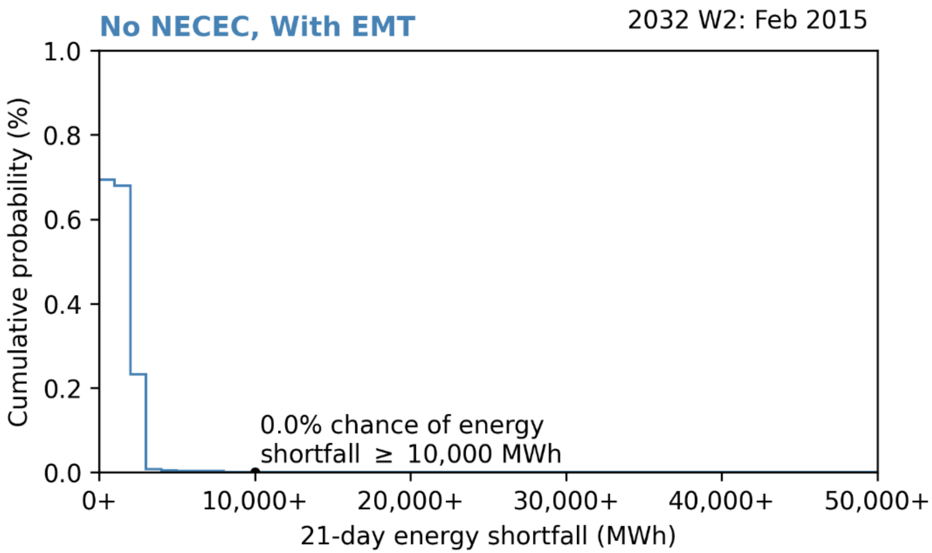
- **Min/Mean/Max (°F):** -8.1/17.1/41.9
- **Mean 100m Wind Speed (m/s):** 6.1
  - Offshore Wind avg. ~2,070 MW/hr
  - Onshore Wind avg. ~380 MW/hr
- **Mean Irradiance (W/m²):** 147.6
  - Utility Scale PV avg. ~270 MW/hr
  - BTM PV avg. ~1,395 MW/hr
- **Avg. Energy From Renewables:** ~4,115 MW/hr
- **Peak Load:** 22,361 MW (day 11)
- **Peak Daily Energy Demand:** ~435,000 MWh (day 4)
- **Total 21-Day Energy Demand:** 8.17 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



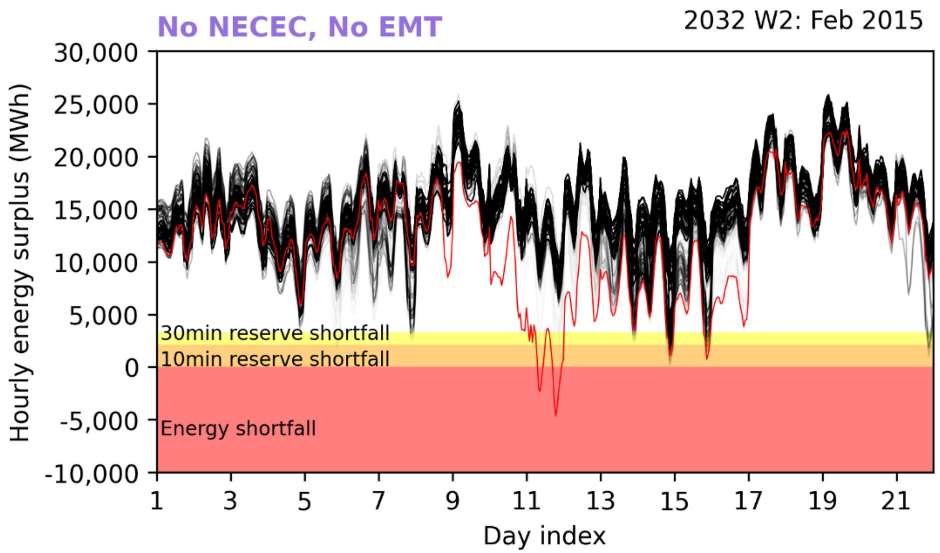


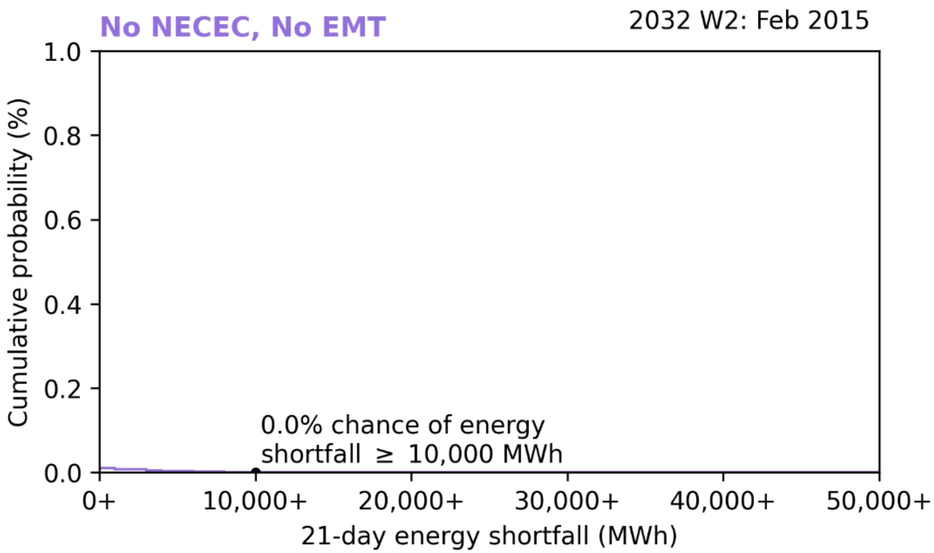
Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	81	27,749	1	13	0.69%	0.000005%
2027*	33	78,148	18	7	0.47%	0.000005%

*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

Summary of 21-Day Energy Analysis Results

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



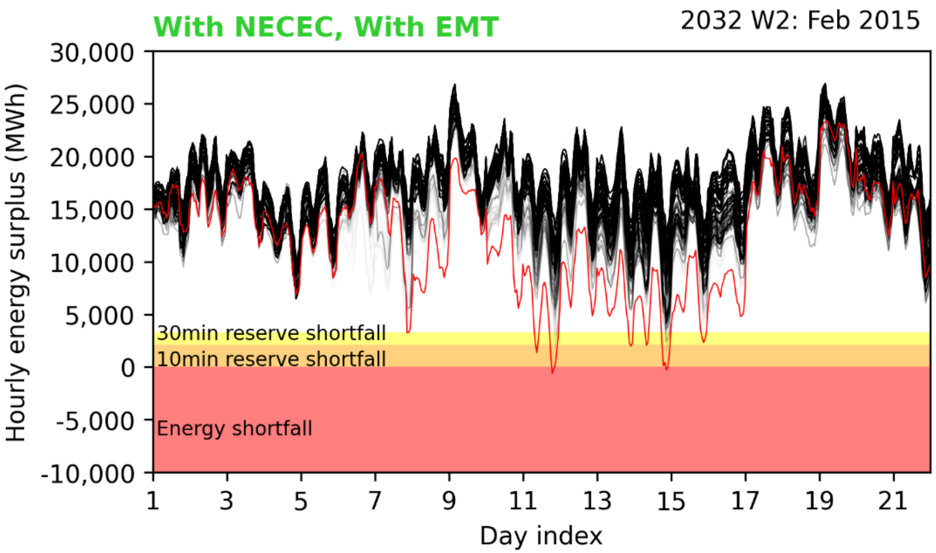


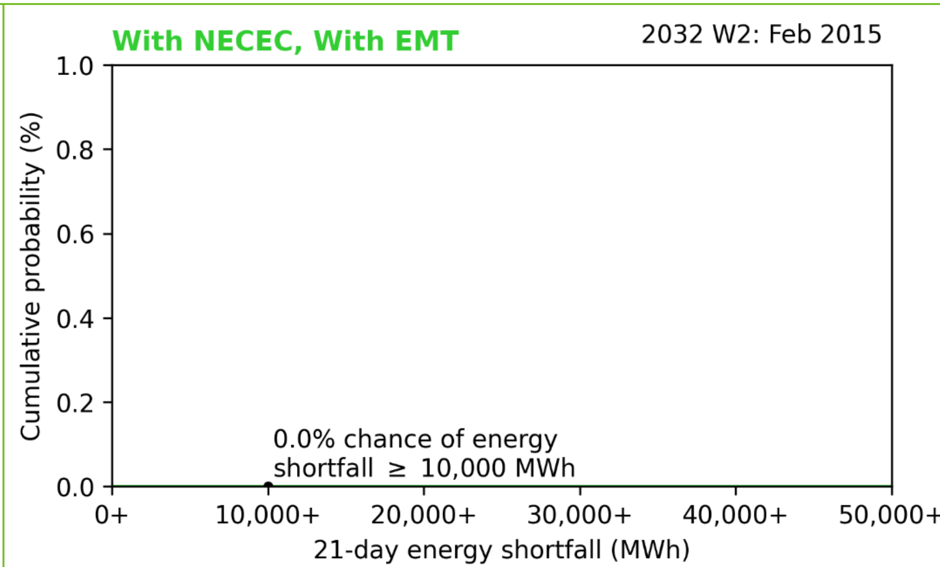
Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	67	20,008	6	0	0.01%	0.000005%
2027*	18	71,255	10	1	0.02%	0.000005%

*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

Summary of 21-Day Energy Analysis Results

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



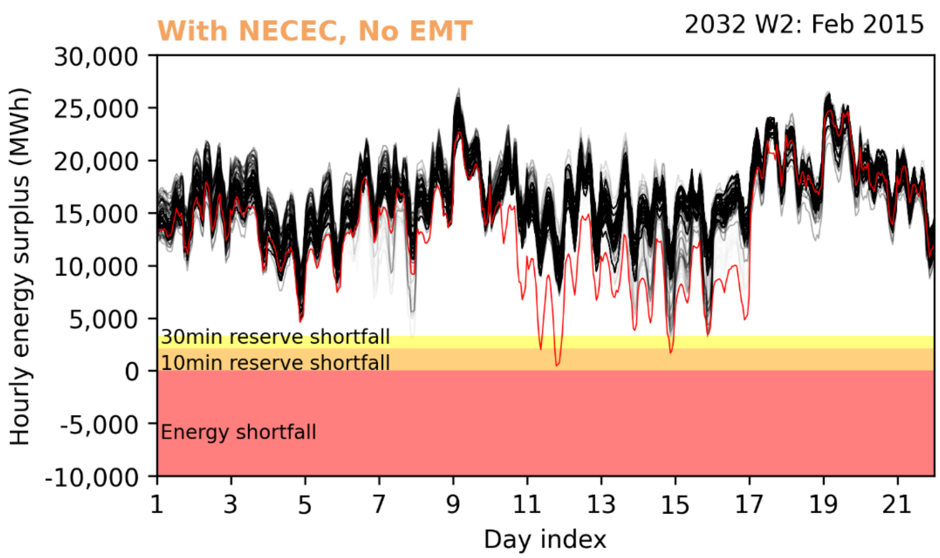


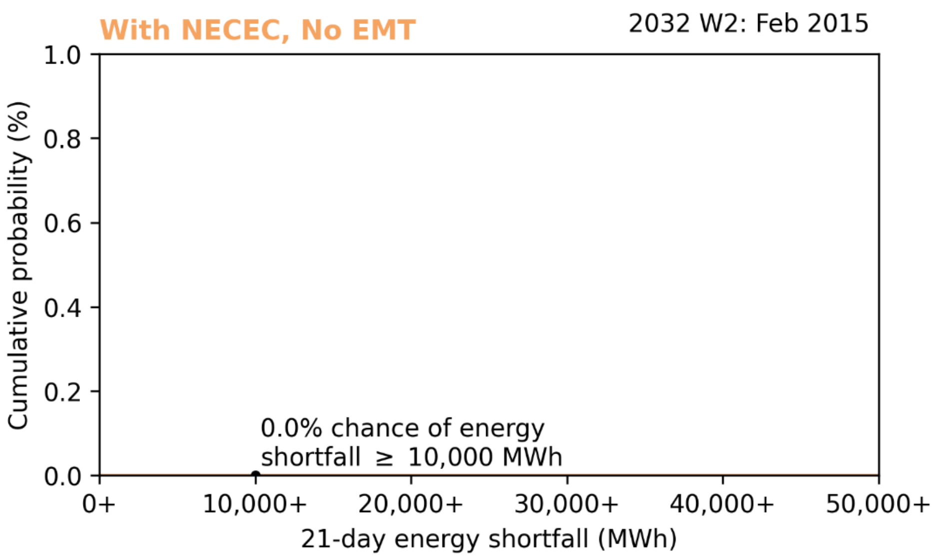
Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	3	1,078	282	0	0.00001.6%	0.000005%
2027*	0	0	0	0	0.0%	0.0%

*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

Summary of 21-Day Energy Analysis Results

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



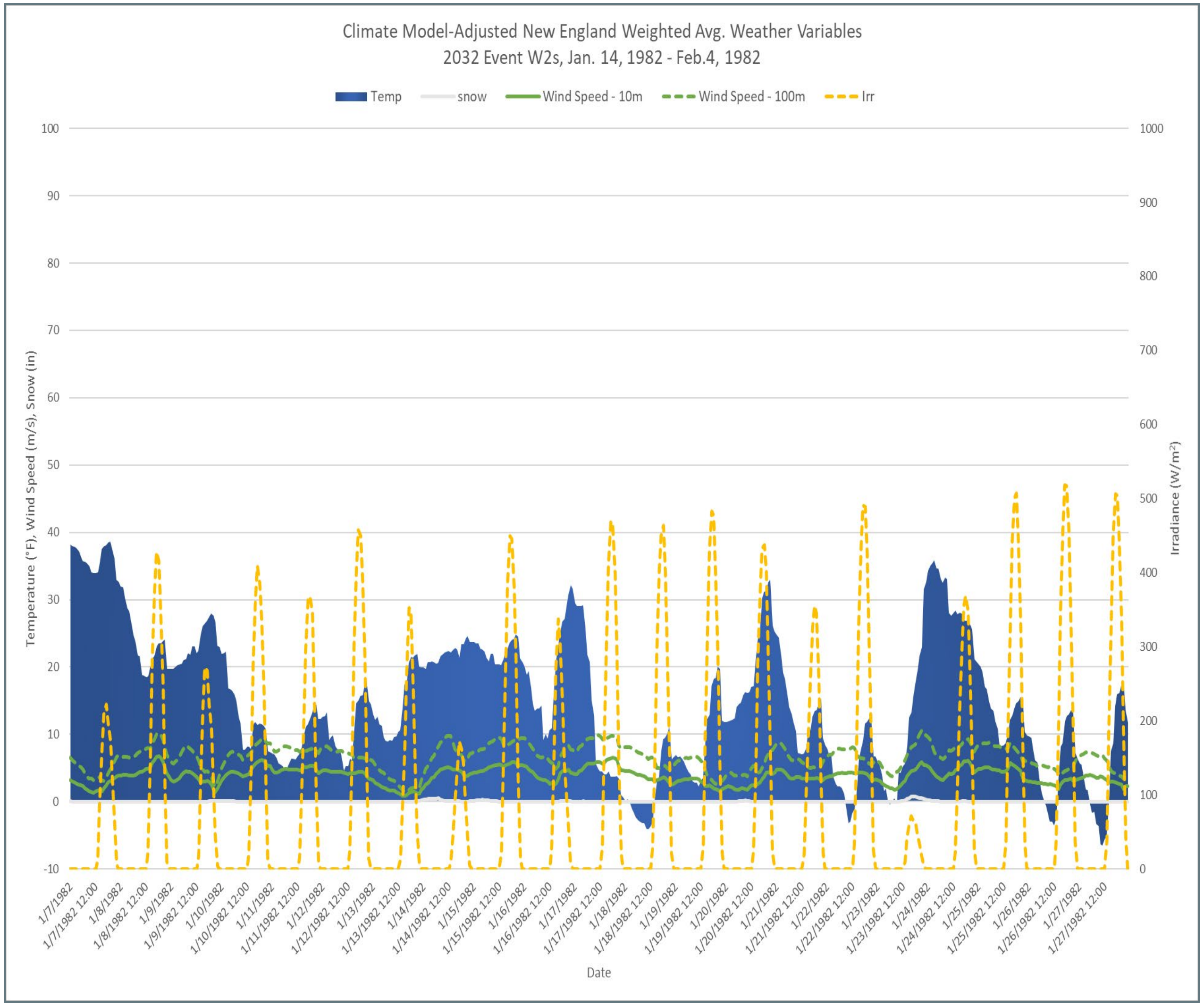


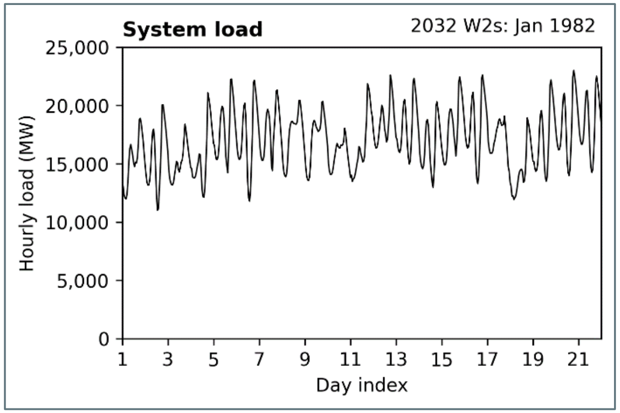
Study Year	# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
2032	0	0	0	0	0.0%	0.0%
2027*	0	0	0	0	0.0%	0.0%

*Throughout this presentation, where 21-day events have been evaluated for both study years (2027 & 2032), results from both years are provided for comparison

Jan 7, 1982 Winter Event Overview

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



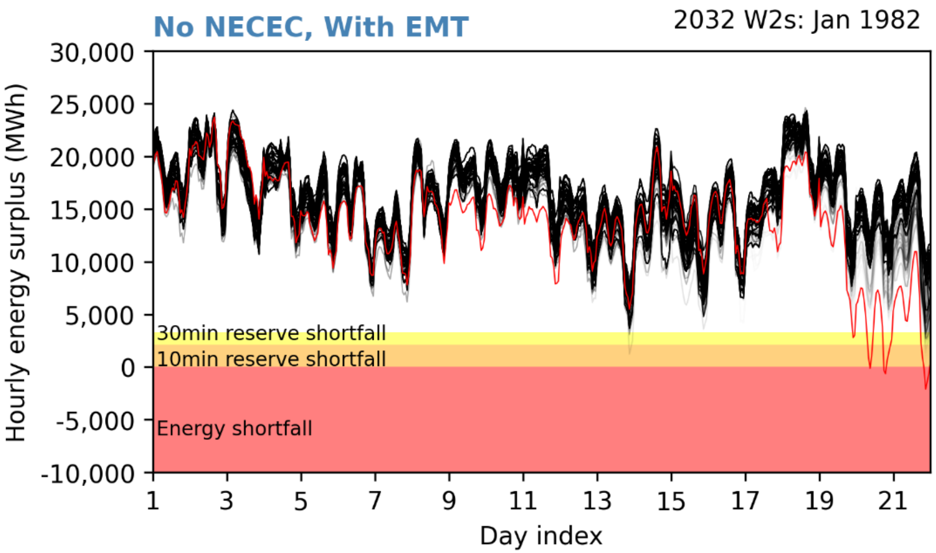


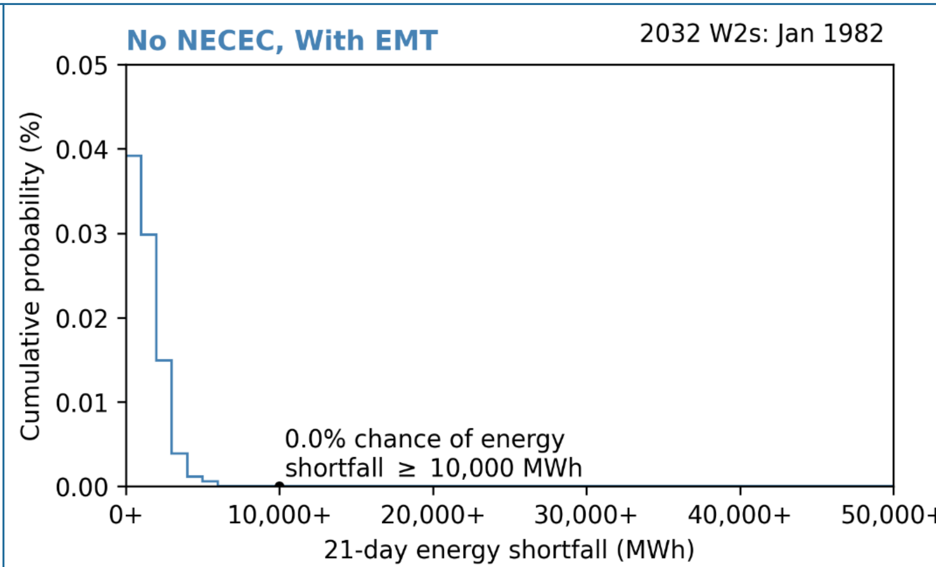
- **Min/Mean/Max (°F):** -6.5/15.0/38.6
- **Mean 100m Wind Speed (m/s):** 6.6
  - Offshore Wind avg. ~2,960MW/hr
  - Onshore Wind avg. ~450MW/hr
- **Mean Irradiance (W/m²):** 91.2
  - Utility Scale PV avg. ~160 MW/hr
  - BTM PV avg. ~920 MW/hr
- **Avg. Energy From Renewables:** ~4,490 MW/hr
- **Peak Load:** 23,554 MW (day 20)
- **Peak Daily Energy Demand:** ~445,000 MWh (day 12)
- **Total 21-Day Energy Demand:** 8.76 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 7, 1982 Event; Scenario: no NECEC, with EMT

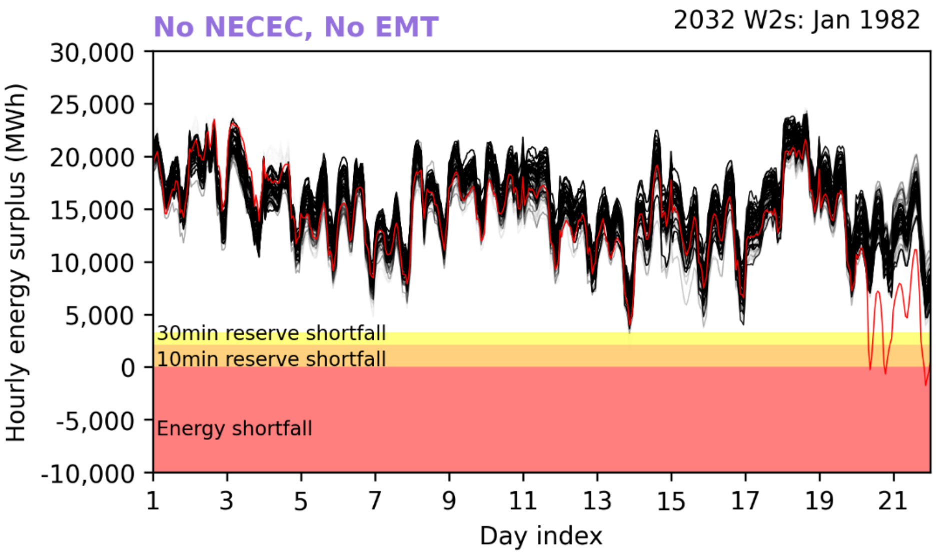


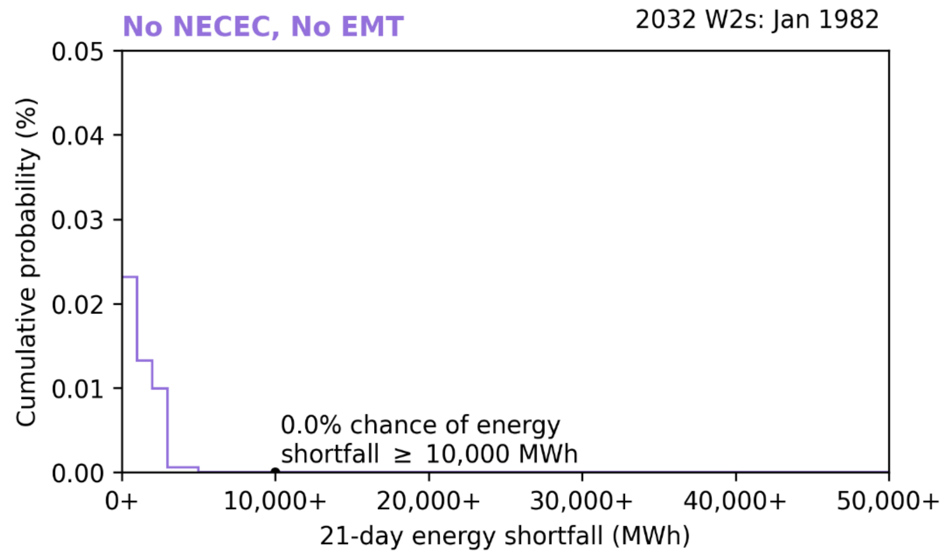


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
51	5,537	117	1	0.04%	0.00055%

Summary of 21-Day Energy Analysis Results

Jan 7, 1982 Event; Scenario: no NECEC, no EMT

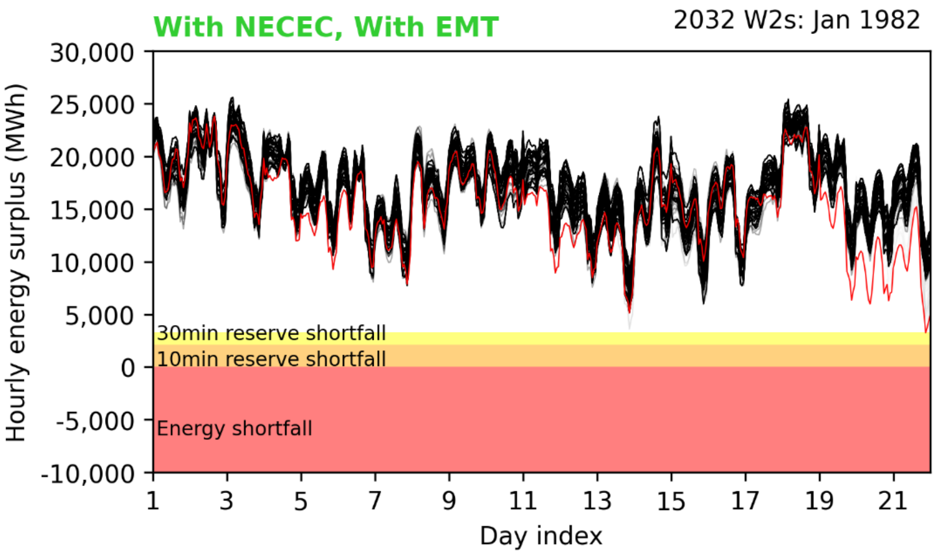


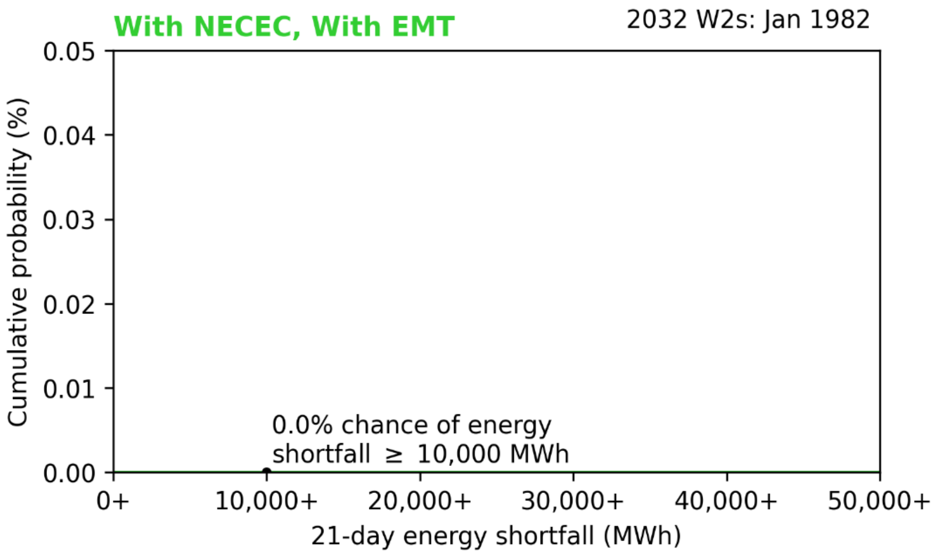


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
35	4,243	13	0	0.02%	0.00055%

Summary of 21-Day Energy Analysis Results

Jan 7, 1982 Event; Scenario: with NECEC, with EMT

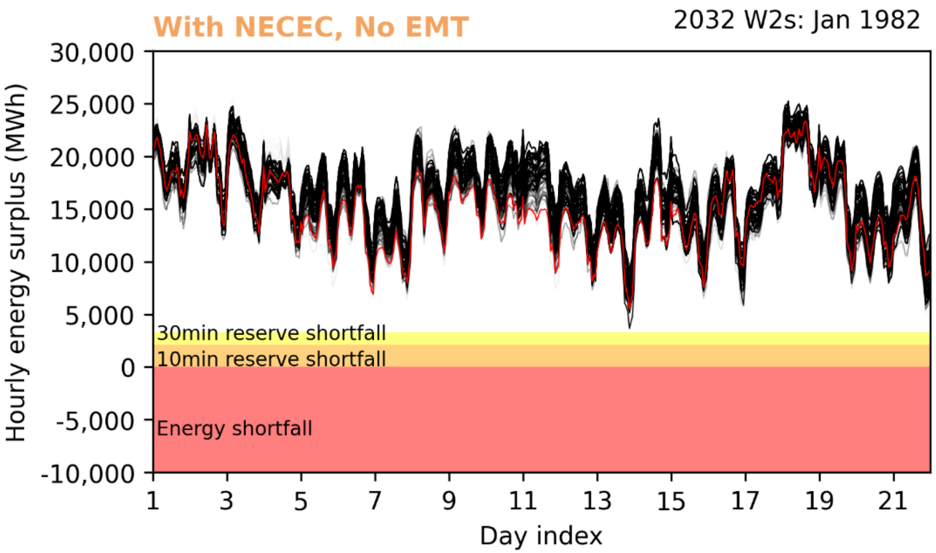


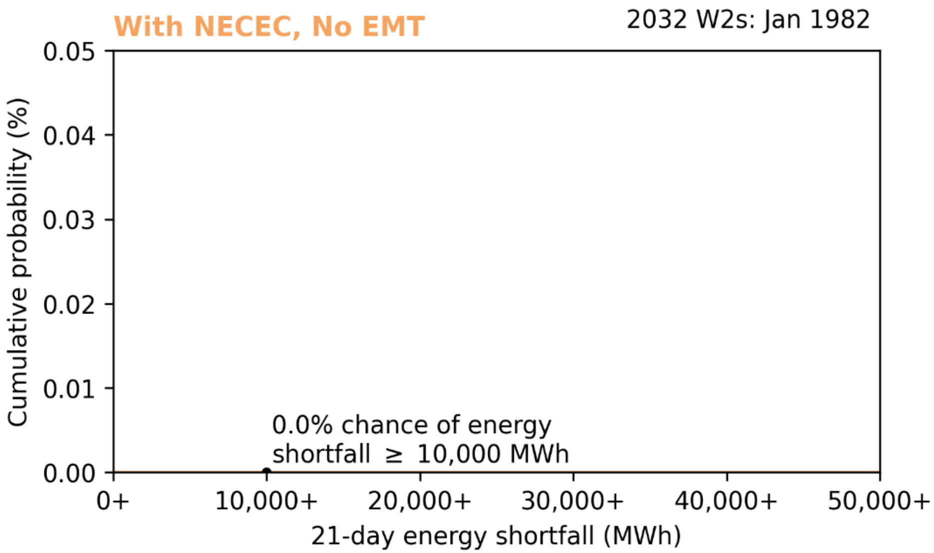


# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day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

Summary of 21-Day Energy Analysis Results

Jan 7, 1982 Event; Scenario: with NECEC, no EMT

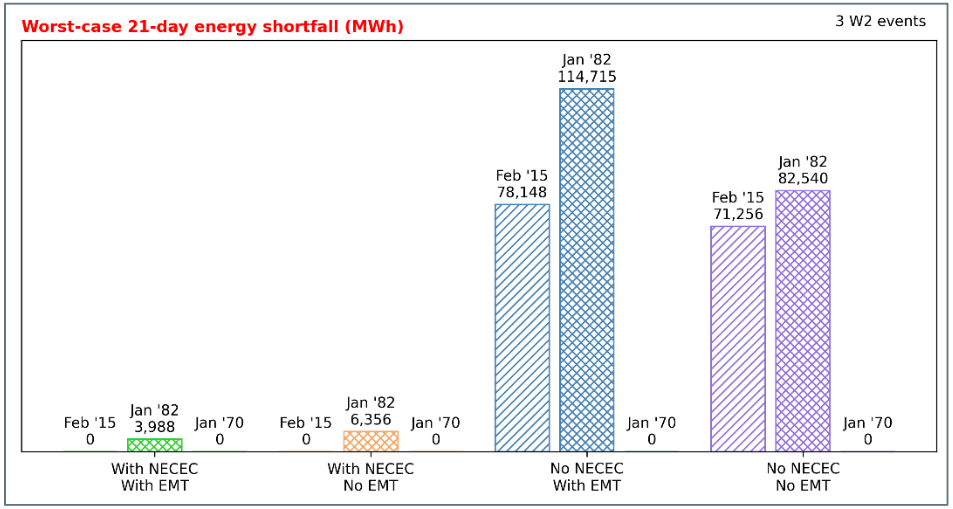




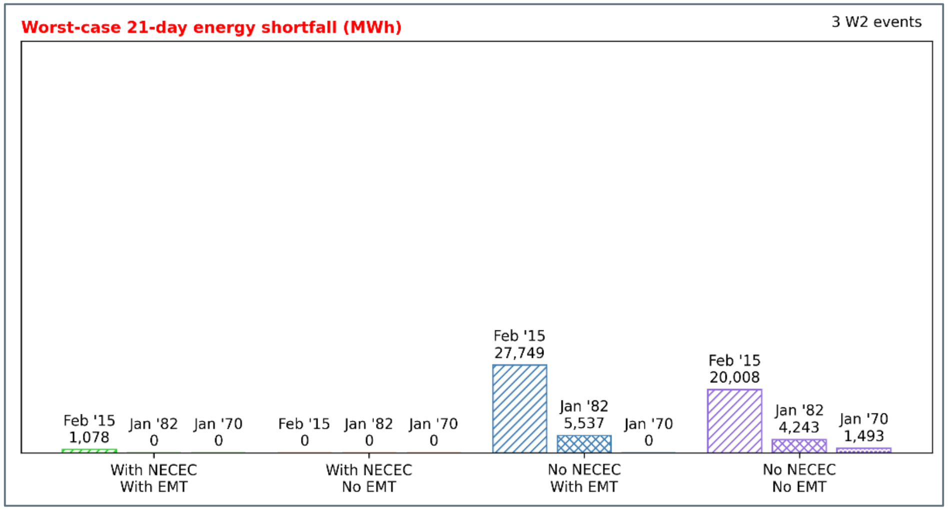
# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day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

2027 and 2032 Winter Cluster 2 Events - Comparison of Energy Shortfall Quantities

2027 Winter Cluster 2 Events



2032 Winter Cluster 2 Events



- Feb 14, 2015 and Jan 11, 1970 (medoid) events were selected for study in both 2027 and 2032
  - In 2032, Jan 7, 1982 was selected and in 2027, Jan 14, 1982 was selected
  - Results of the medoid events are included in the figures above; energy shortfall in medoid events is negligible in both study years
- Magnitude of energy adequacy risk in Winter Cluster 2 events decreases from 2027 to 2032

2032 WINTER EVENT SENSITIVITY ANALYSIS

Based on 2032 study year version of the Jan 22, 1961 event

Description of Sensitivity Analysis

- In order to assess energy shortfall amounts under a broad range of assumptions, ISO performed a variety of sensitivity studies based upon the 2032 study year version of the Jan 22, 1961 event
- Sensitivity studies were run on all four scenarios (all four combinations of EMT and NECEC statuses)
- Each sensitivity study uses the worst case of the Jan 22, 1961 event as a baseline; the baseline study incorporates the FCA16 resource mix and ISO's 2022 CELT heating and transportation electrification forecast
  - Based on results of 720 simulations of each scenario, the worst case results from the combination of low imports, low oil inventories, low LNG inventories, and high generator forced outage assumptions
- Building upon the baseline study, sensitivity studies incorporate variations based on three key factors:
  - FCA17 resource mix
  - Retirement of additional at-risk resources
  - ISO's 2023 CELT heating and transportation electrification forecast
- Statistical analysis is not performed on sensitivity studies because the probability associated with each input variation is unknown

Description of Sensitivity Analysis, cont.

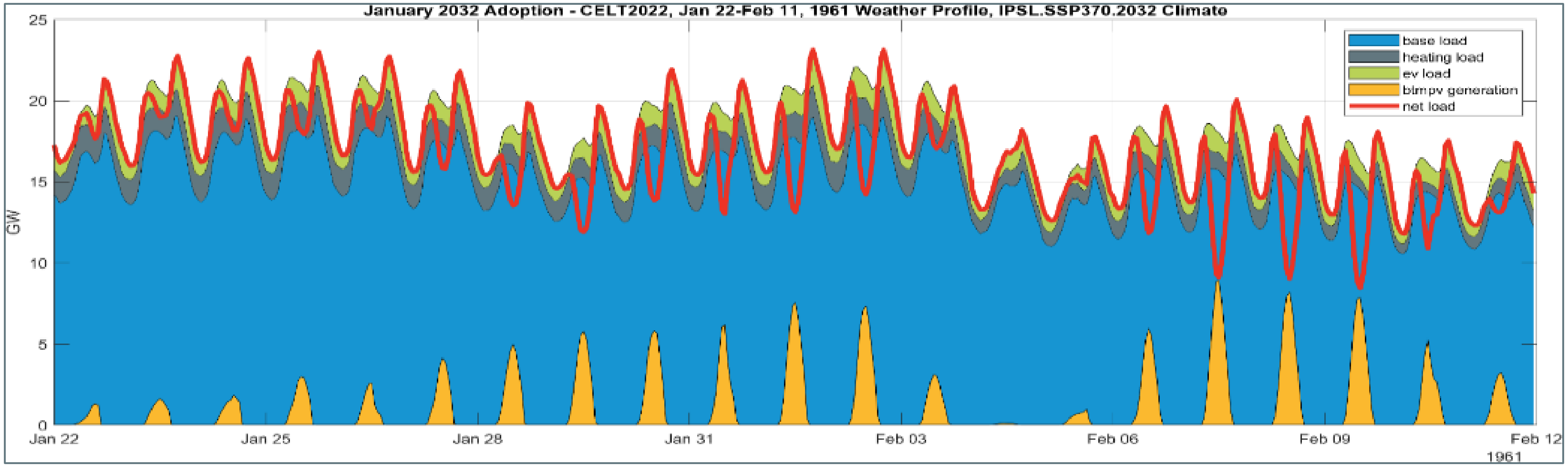
- Sensitivities that incorporate FCA17 results assume:
  - Retirement of resources that de-listed and did not obtain a Capacity Supply Obligation in FCA17; modelled resource retirements total ~1,600 MW of capacity
- Sensitivities that incorporate additional generator retirements (in addition to those from FCA17) assume:
  - Retirement of an additional ~1,600 MW of Residual Fuel Oil (RFO) resources
- Retirement replacement assumptions:
  - Retired capacity of generators is replaced with new generating capacity based on a 1:1 nameplate MW ratio
  - The replacement capacity is based on the percentage of resource types currently in ISO's interconnection queue and is a blend of offshore wind (~50%), utility-scale PV (~10%), and storage battery capacity (~40%)

Description of Sensitivity Analysis, cont.

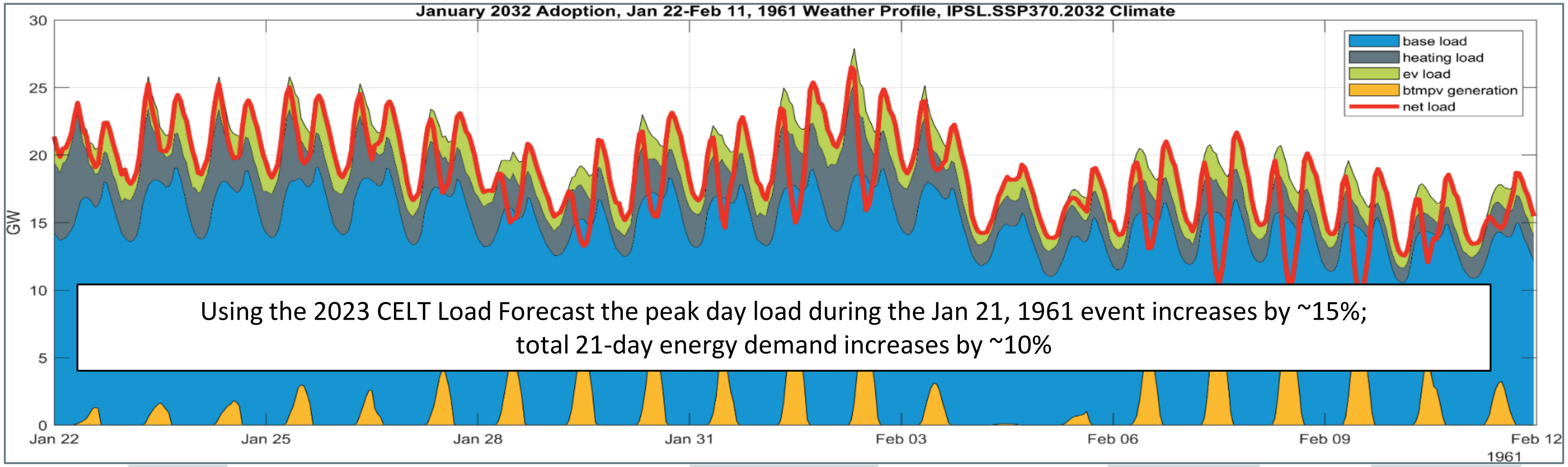
- Sensitivities that incorporate use of the 2023 CELT load forecasts include ISO's most recent heating and transportation electrification forecasts
  - The peak 21-day load for the Jan 21, 1961 event increases to 26,515 MW from 23,144 MW (+ 3,371 MW) in the 2023 CELT sensitivities; average hourly loads increase by ~1,700 MW to 18,512 MW
- Across all sensitivity cases, the replacement capacity is intended to approximately meet the installed capacity requirement (ICR)
  - The ICR value increases with the growth of load between 2027 and 2032
  - The models and inputs do not include the current Resource Capacity Accreditation design
  - The resource scenarios are approximate and do not consider the various uncertainties over the next decade
- The results of the sensitivity analysis are intended to provide a range of possible outcomes

Load Increases Significantly When 2023 CELT Electrification Load Forecast is Used

2022 CELT Load Forecast

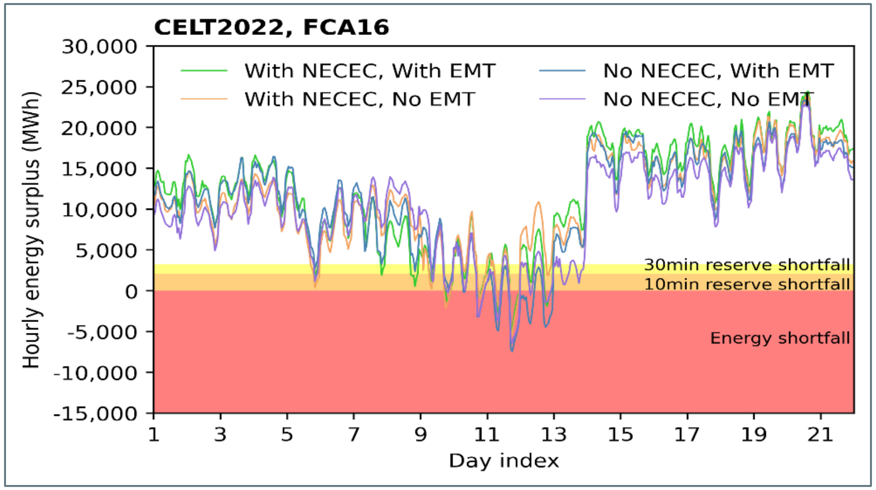


2023 CELT Load Forecast



Sensitivity Analysis Results – Jan 22, 1961 Event

FCA16 Resource Mix and 2022 CELT



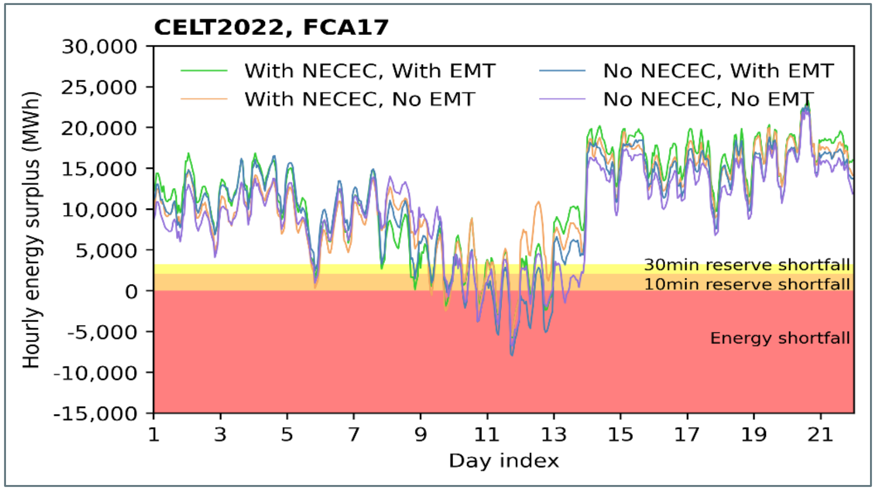
Key Assumptions	
CELT Load Forecast Year	2022
FCA Results	FCA16
Retired Capacity	2,100 MW total
Offshore Wind Capacity	4,800 MW total
Storage Battery Capacity	1,450 MW total
Utility-scale PV Capacity	1,250 MW total
BTM PV Capacity	12,000 MW

Study Year/ Sensitivity Name	With EMT, With NECEC (energy shortfall, MWh)	No EMT, With NECEC (energy shortfall, MWh)	With EMT, No NECEC (energy shortfall, MWh)	No EMT, No NECEC (energy shortfall, MWh)
2027 Baseline*	68,932	53,518	111,353	95,888
2032 FCA16/2022 CELT*	**31,974**	**33,019**	**115,642**	**63,781**

*2027 Baseline Study results are as presented at the May RC; 2032 FCA16/2022 CELT results are as described on slides 12-15

Sensitivity Analysis Results – Jan 22, 1961 Event

FCA17 Resource Mix and 2022 CELT

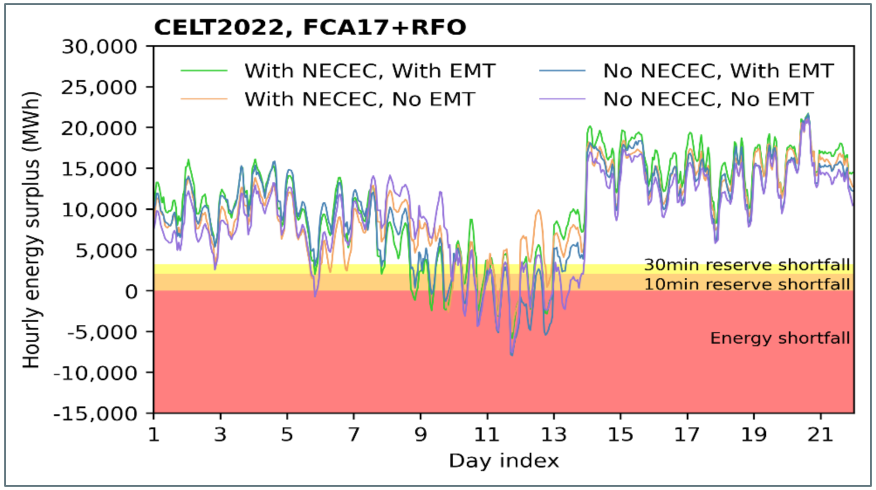


Key Assumptions	
CELT Load Forecast Year	2022
FCA Results	**FCA17**
Retired Capacity	**+1,600 MW/3,700 MW total**
Offshore Wind Capacity	**+800 MW/5,600 MW total**
Storage Battery Capacity	**+600 MW/2,050 MW total**
Utility-scale PV Capacity	**+200 MW/1,450 MW total**
BTM PV Capacity	12,000 MW

Study Year/ Sensitivity Name	With EMT, With NECEC (energy shortfall, MWh)	No EMT, With NECEC (energy shortfall, MWh)	With EMT, No NECEC (energy shortfall, MWh)	No EMT, No NECEC (energy shortfall, MWh)
2027 Baseline	68,932	53,518	111,353	95,888
2032 FCA16/2022 CELT	31,974	33,019	115,642	63,781
2032 FCA17/2022 CELT	**49,843**	**44,095**	**134,343**	**78,772**

Sensitivity Analysis Results – Jan 22, 1961 Event

FCA17 Resource Mix + RFO Retirement, 2022 CELT

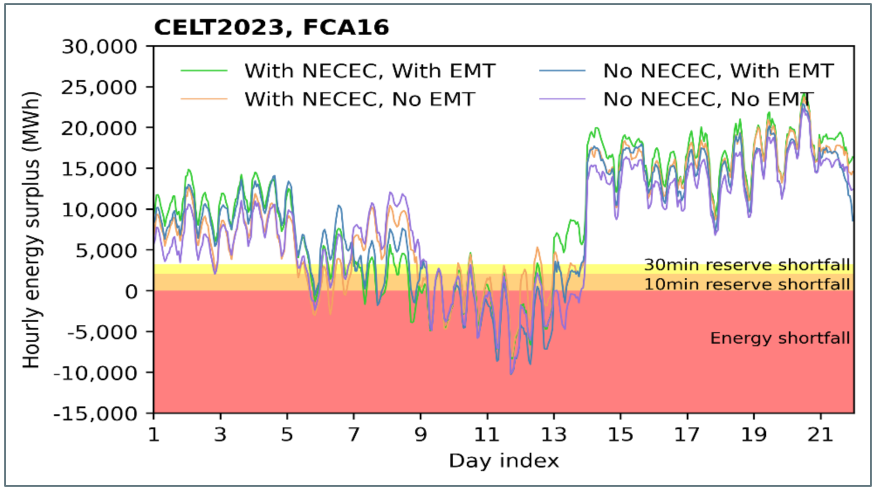


Key Assumptions	
CELT Load Forecast Year	2022
FCA Results	FCA17
Retired Capacity	+1,600 MW/5,300 MW total
Offshore Wind Capacity	+800 MW/6,400 MW total
Storage Battery Capacity	+600 MW/2,650 MW total
Utility-scale PV Capacity	+200 MW/1,650 MW total
BTM PV Capacity	12,000 MW

Study Year/ Sensitivity Name	With EMT, With NECEC (energy shortfall, MWh)	No EMT, With NECEC (energy shortfall, MWh)	With EMT, No NECEC (energy shortfall, MWh)	No EMT, No NECEC (energy shortfall, MWh)
2027 Baseline	68,932	53,518	111,353	95,888
2032 FCA16/2022 CELT	31,974	33,019	115,642	63,781
2032 FCA17/2022 CELT	49,843	44,095	134,343	78,772
2032 FCA17+RFO/2022 CELT	**67,710**	**45,712**	**140,706**	**102,142**

Sensitivity Analysis Results – Jan 22, 1961 Event

FCA16 Resource Mix and 2023 CELT Load Forecast

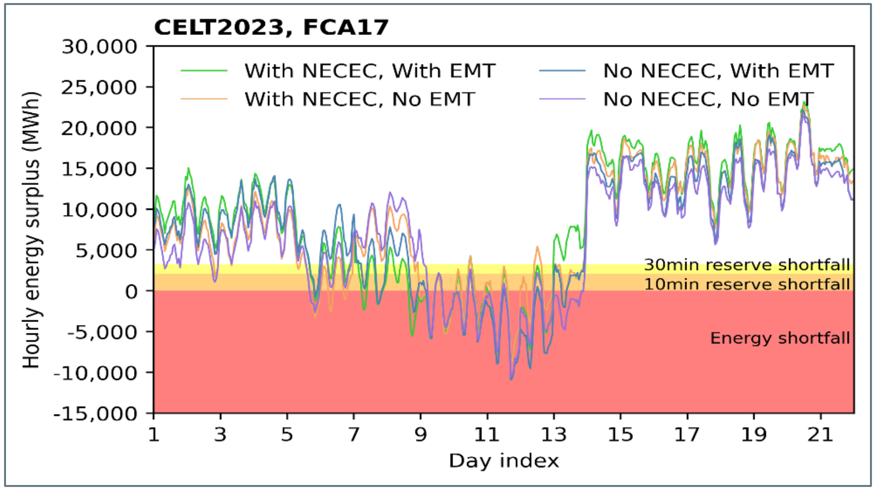


Key Assumptions	
CELT Load Forecast Year	**2023**
FCA Results	FCA16
Retired Capacity	2,100 MW total
Offshore Wind Capacity	4,800 MW total
Storage Battery Capacity	1,450 MW total
Utility-scale PV Capacity	1,250 MW total
BTM PV Capacity	12,000 MW

Study Year/ Sensitivity Name	With EMT, With NECEC (energy shortfall, MWh)	No EMT, With NECEC (energy shortfall, MWh)	With EMT, No NECEC (energy shortfall, MWh)	No EMT, No NECEC (energy shortfall, MWh)
2027 Baseline	68,932	53,518	111,353	95,888
2032 FCA16/2022 CELT	31,974	33,019	115,642	63,781
2032 FCA17/2022 CELT	49,843	44,095	134,343	78,772
2032 FCA17+RFO/2022 CELT	67,710	45,712	140,706	102,142
2032 FCA16/2023 CELT	**151,717**	**112,519**	**239,350**	**182,485**

Sensitivity Analysis Results – Jan 22, 1961 Event

FCA17 Resource Mix and 2023 CELT Load Forecast

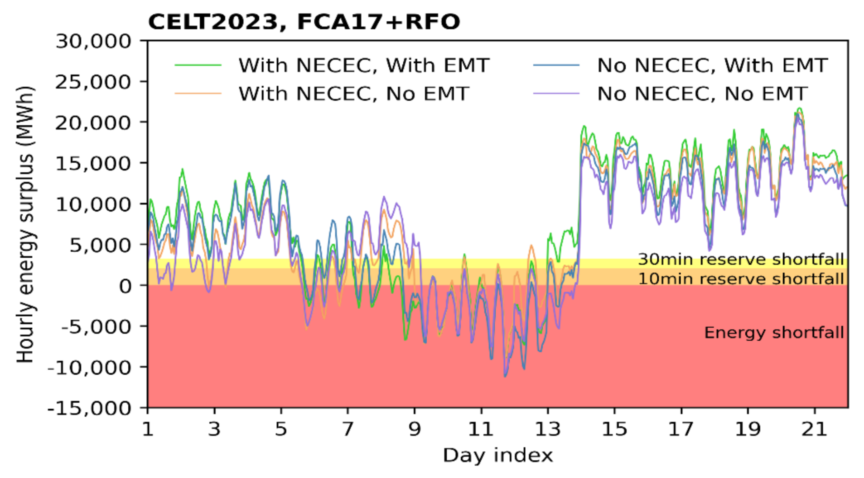


Key Assumptions	
CELT Load Forecast Year	2023
FCA Results	FCA17
Retired Capacity	+1,600 MW/3,700 MW total
Offshore Wind Capacity	+800 MW/5,600 MW total
Storage Battery Capacity	+600 MW/2,050 MW total
Utility-scale PV Capacity	+200 MW/1,450 MW total
BTM PV Capacity	12,000 MW

Study Year/ Sensitivity Name	With EMT, With NECEC (energy shortfall, MWh)	No EMT, With NECEC (energy shortfall, MWh)	With EMT, No NECEC (energy shortfall, MWh)	No EMT, No NECEC (energy shortfall, MWh)
2027 Baseline	68,932	53,518	111,353	95,888
2032 FCA16/2022 CELT	31,974	33,019	115,642	63,781
2032 FCA17/2022 CELT	49,843	44,095	134,343	78,772
2032 FCA17+RFO/2022 CELT	67,710	45,712	140,706	102,142
2032 FCA16/2023 CELT	151,717	112,519	239,350	182,485
2032 FCA17/2023 CELT	**189,550**	**137,587**	**272,796**	**215,733**

Sensitivity Analysis Results – Jan 22, 1961 Event

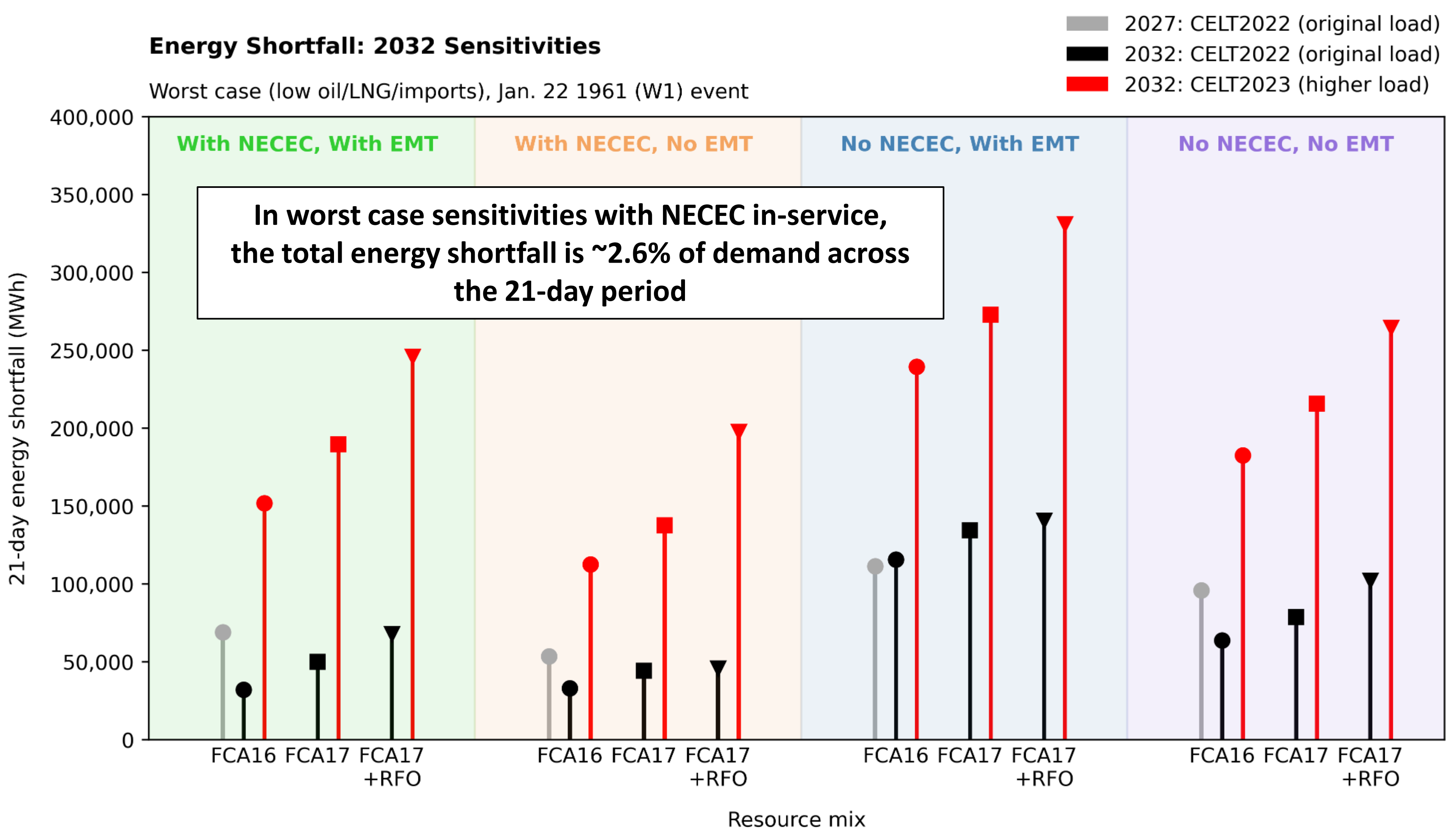
FCA17 Resource Mix + RFO Retirement, 2023 CELT Load Forecast



Key Assumptions	
CELT Load Forecast Year	2023
FCA Results	FCA17
Retired Capacity	+1,600 MW/5,300 MW total
Offshore Wind Capacity	+800 MW/6,400 MW total
Storage Battery Capacity	+600 MW/2,650 MW total
Utility-scale PV Capacity	+200 MW/1,650 MW total
BTM PV Capacity	12,000 MW

Study Year/ Sensitivity Name	With EMT, With NECEC (energy shortfall, MWh)	No EMT, With NECEC (energy shortfall, MWh)	With EMT, No NECEC (energy shortfall, MWh)	No EMT, No NECEC (energy shortfall, MWh)
2027 Baseline	68,932	53,518	111,353	95,888
2032 FCA16/2022 CELT	31,974	33,019	115,642	63,781
2032 FCA17/2022 CELT	49,843	44,095	134,343	78,772
2032 FCA17+RFO/2022 CELT	67,710	45,712	140,706	102,142
2032 FCA16/2023 CELT	151,717	112,519	239,350	182,485
2032 FCA17/2023 CELT	189,550	137,587	272,796	215,733
2032 FCA17+RFO/2023 CELT	**245,763**	**197,520**	**330,760**	**264,356**

Results Highlight the Impact of Retirements and Electrification on Energy Shortfall Amounts



Key Takeaways of 2032 Winter Event Studies

- The energy adequacy risk profile is dynamic and will be a function of the evolution of both supply and demand profiles
  - 2032 winter study results reveal the range of energy shortfall risk under a variety of resource mix and demand assumptions
- In terms of magnitude and probability, baseline studies of 2032 winter events indicate an energy shortfall risk profile similar to that of the 2027 winter event studies
- Sensitivity analysis of 2032 worst-case scenarios indicate an increasing energy shortfall risk profile between 2027 and 2032
  - This increasing risk profile is particularly observable with the 2023 CELT load forecast
- BTM and Utility Scale PV, offshore wind, and incremental imports from the NECEC are critical to mitigate energy shortfall risks that result from significant peak winter load growth and retirements
- This energy adequacy study framework provides a much needed foundation to study the system as it continues to evolve
  - The ISO will continually monitor the energy adequacy risk, particularly as the changes in the regional supply and demand profiles ramp up

STAKEHOLDER INPUT TO 2032 SENSITIVITY ANALYSIS

Overview of Stakeholder-Informed Sensitivity Analysis

- Recognizing interest in assumptions related to the region's resource mix and demand projections for 2032, ISO is planning to accept stakeholder input regarding additional sensitivity analysis
- This round of sensitivity analysis will focus on the modification of a few key input variables
  - ISO expects to perform ~20-30 sensitivity simulations as part of this analysis; selection of specific sensitivities will be based upon the frequency of specific requests submitted by stakeholders
  - ISO will also evaluate whether requested sensitivities have already been accomplished via analysis that has previously been completed
  - All requests will be subject to reasonability checks, *i.e.* requests that exceed physical capabilities of resources, facilities, or the like will not be considered

Overview of Stakeholder-Informed Sensitivity Analysis, cont.

- Unless specified otherwise, sensitivity cases will:
  - Include the modification of a single input variable (*i.e.* one uncertainty per case will be modified)
  - Be performed by varying the value of specific variables from those used in the 2032 baseline study of the Jan. 22, 1961 event worst case
  - Be evaluated with the 2022 CELT electrification forecasts (similar to the sensitivities ISO has already completed and shared in this presentation)
  - Focus on scenarios that include the NECEC in-service; this is due to the high likelihood of NECEC being in-service by 2032
- Probabilistic data will not be generated as part of the sensitivity analysis because probabilities of certain modified input data may be unavailable

Input Variables Subject to Modification for Purposes of Sensitivity Analysis

- The following variables can be modified in order to perform sensitivity analysis:
  - Incremental Resource Retirement Quantities
  - Load Profile Adjustments
  - Initial LNG Inventory and Replenishment Amounts
  - LNG Replenishment Date
  - LNG Daily Vaporization Limit
  - Initial Oil Inventory
  - Interchange
- Details regarding each of these variables is provided on the following slides

Input Variable for Sensitivity Analysis: Resource Retirements

- This sensitivity allows for the retirement of generation capacity in 500 MW increments; retirement requests will be performed based on generator fuel types
  - Fuel types eligible for retirement sensitivity analysis include nuclear, distillate fuel oil (DFO), residual fuel oil (RFO), natural gas only, dual fuel (natural gas-primary fuel, DFO-secondary fuel), and coal
  - As needed, ISO may round to a MW value that allows for retirement of entire generators (*i.e.* partial retirement of generators cannot be accommodated)
  - ISO will also ensure that sensitivity analysis is performed in such a manner that results do not convey the impact of the retirement of a single specific generator
- Generator retirement requests should be accompanied by a replacement strategy; unless otherwise specified by the stakeholder submitting a specific sensitivity request, ISO will replace the retired capacity with new generating capacity based on a 1:1 nameplate MW ratio
  - The replacement capacity is based on the percentage of resource types currently in ISO's interconnection queue and is a blend of offshore wind (~50%), utility-scale PV (~10%), and storage battery capacity (~40%)
- As applicable, fuel inventories associated with retired generators will be removed in the sensitivity analysis, but inventories of non-retired stations will not be altered
- For reference, the amount of generating capacity of each fuel type as used in the baseline studies and eligible for adjustment is provided on the following slide

Baseline Generating Capacity Eligible for Resource Retirement Sensitivities

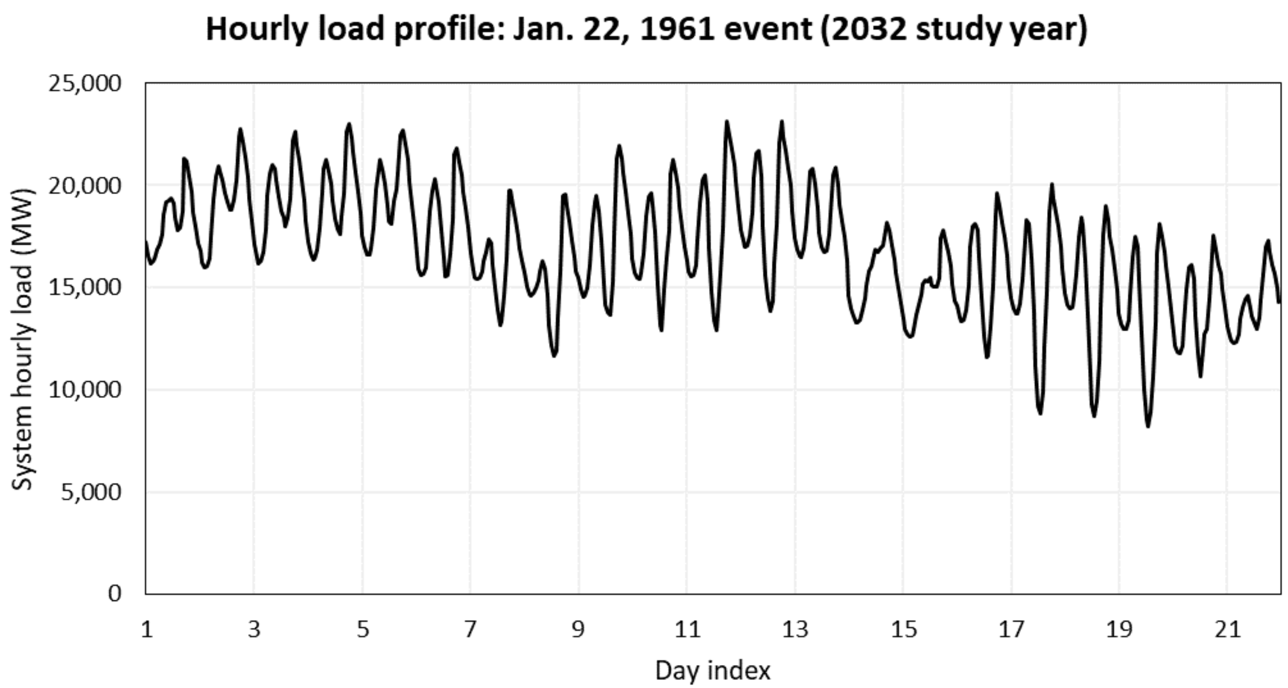
- Nuclear: 3,350 MW
- Natural Gas Only: 9,200 MW
- Dual Fuel: 7,200 MW
  - For purposes of this analysis, dual fuel is defined as a generator that burns natural gas as a primary fuel and DFO as a secondary fuel
- RFO: 3,400 MW
- DFO Only: 1,170 MW
- Coal: 440 MW

Input Variable for Sensitivity Analysis: Load Profiles

- This sensitivity allows for the adjustment of hourly load profiles across the 21-day event
- Stakeholders requesting this sensitivity will provide ISO with a direction of load change (higher or lower) and the increment of adjustment (in 10% increments)
  - Direction of load change and increment of adjustment will be applied uniformly to each hour of the 21-day period
- For reference, the 21-day hourly load profile used in the baseline studies is provided on the following slide

21-day Hourly Load Profile – Jan. 22, 1961 Event

- Shown below is the 21-day hourly load profile utilized in baseline studies of the Jan. 22, 1961 event (2032 study year); adjustments will be based off of these values



Input Variable for Sensitivity Analysis: Initial LNG Inventory and LNG Replenishment Amount

- This sensitivity allows for the adjustment of initial LNG inventory and/or LNG replenishment amount in 10% increments
- Stakeholders requesting the initial LNG inventory sensitivity will provide ISO with a direction of LNG inventory change (higher or lower) and the increment of adjustment (in 10% increments)
- Stakeholders requesting the LNG replenishment sensitivity will provide ISO with a direction of LNG replenishment amount change (higher or lower) and the increment of adjustment (in 10% increments)
  - This sensitivity analysis does not include changes to LNG replenishment dates
- For this sensitivity, stakeholders can request a change to both the initial inventory and the replenishment amount, if desired
- For reference, the initial aggregate LNG inventory used in the baseline studies was 6.5 Bcf and LNG replenishment amounts were 1.7 Bcf and 2.4 Bcf

Input Variable for Sensitivity Analysis: LNG Replenishment Date

- This sensitivity allows for the adjustment of LNG replenishment dates
- Stakeholders requesting the LNG replenishment date sensitivity will provide ISO with an adjusted date of LNG replenishment (date can be earlier or later)
  - This set of sensitivity analysis does not include changes to LNG replenishment amount
- For reference, dates of LNG replenishment as used in the baseline studies were:
  - Feb. 2, 1961 (1.7 Bcf) – day 12 of 21
  - Feb. 3, 1961 (2.4 Bcf) – day 13 of 21

Input Variable for Sensitivity Analysis: LNG Daily Vaporization Limit

- This sensitivity allows for the adjustment of the LNG daily vaporization limits
  - The LNG daily vaporization limit is the aggregate capability of all LNG facilities
- Stakeholders requesting the LNG daily vaporization limit sensitivity will provide ISO with a direction of change (higher or lower), the increment of adjustment (in 0.2 Bcf/d increments), the scenarios (with or without EMT) to which the adjustment applies
- For reference, the LNG daily vaporization limits used in the baseline studies were 0.8 Bcf/d without EMT and 1.2 Bcf/d with EMT

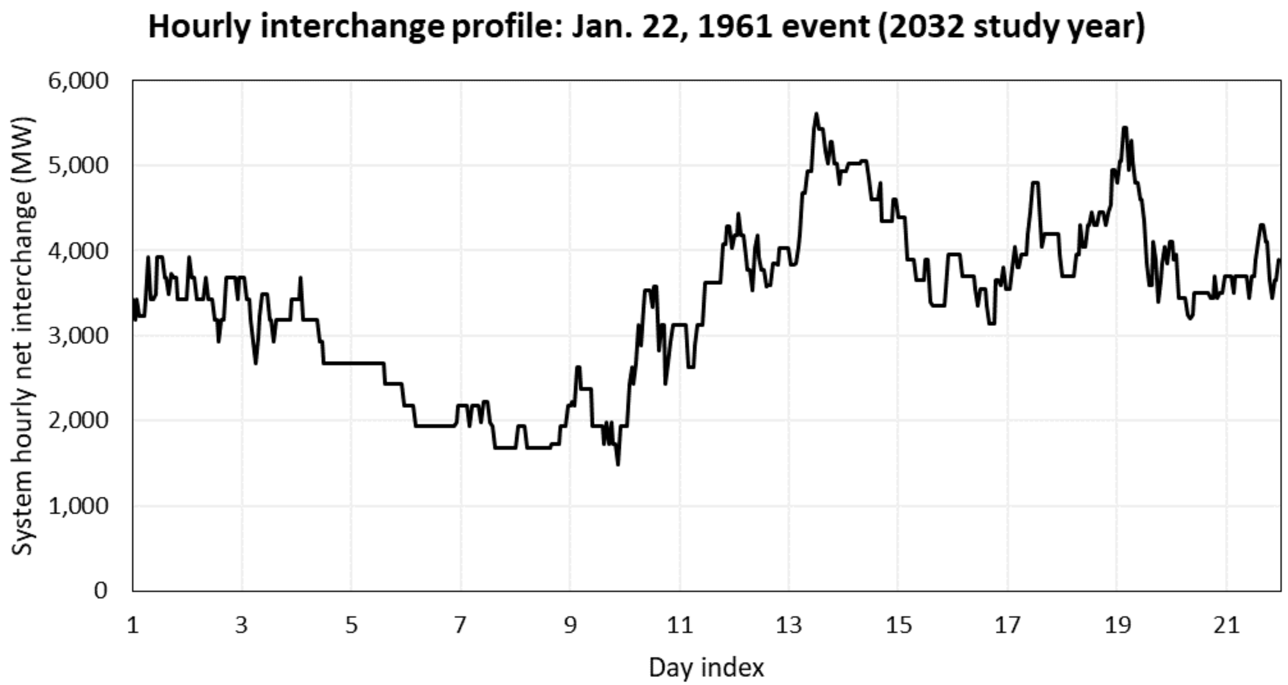
Input Variable for Sensitivity Analysis: Initial Oil Inventory

- This sensitivity allows for the adjustment of aggregate initial oil inventories
- Stakeholders requesting the initial oil inventory sensitivity will provide ISO with a direction of change (higher or lower) and the increment of adjustment (increments of 10%)
  - The increment of adjustment will be uniformly applied to the initial inventory of all oil stations and will not alter the oil replenishment model
- For reference, the initial oil inventory used in the baseline studies was ~96.5M gallons (~40% of maximum storage capacity)

Input Variable for Sensitivity Analysis: Interchange

- This sensitivity allows for the adjustment of hourly net interchange across the 21-day event
- Stakeholders requesting this sensitivity will provide ISO with a direction of net interchange change (higher or lower) and the increment of adjustment (in 10% increments)
  - Direction of net interchange change and increment of adjustment will be applied uniformly to each hour of the 21-day period
- For reference, the 21-day hourly net interchange profile used in the baseline studies is provided on the following slide

21-day Hourly Interchange Profile – Jan.22, 1961 Event



Process for Submitting Requests and Next Steps

- ISO intends to provide a provide a questionnaire by email to stakeholders no later than Friday, August 18; this will be the primary means by which stakeholder input will be gathered
  - Sensitivity requests that have already been submitted by other means do not have to be re-submitted
- ISO intends to request that all input be provided no later than September 1
- At the September RC meeting, ISO intends to provide an overview of feedback received from stakeholders and to review the list of sensitivity analyses that will be performed
- ISO intends to review the sensitivity results at the November RC meeting

Stakeholder Schedule

***Schedule is subject to change based on modeling progress**

Stakeholder Committee and Date	Scheduled Project Milestone
Reliability Committee February 15, 2022	Initial presentation
Reliability Committee March 15, 2022	Summary of EPRI's historical weather analysis deliverables and discussion of macro assumptions
Reliability Committee May 17, 2022	Share results of Step 1 (Extreme Weather Modeling) report. Review and discuss Step 2 (Risk Model Development and Scenario Generation) activities
Reliability Committee July 19, 2022	Review progress on Step 2 activities
Reliability Committee September 20, 2022	Continue to gather feedback with respect to Step 2 activities
Reliability Committee November 16, 2022	Continue to gather feedback with respect to Step 2 activities
Reliability Committee January 18, 2023	Discuss preliminary results of Step 2 Risk Screening Model
Reliability Committee February 14, 2023	Continued discussion of Step 2 Risk Screening Model results

Stakeholder Schedule

Schedule is subject to change based on modeling progress

Stakeholder Committee and Date	Scheduled Project Milestone
Reliability Committee March 14, 2023	Review outage draw and categorical branching methodologies (including LNG, fuel inventory, imports, etc.)
Reliability Committee April 18, 2023	Review 21-day energy assessment simulator, review return period methodology, and follow-up on stakeholder questions regarding modeling
Reliability Committee May 16, 2023	Review Step 3 winter 2027 preliminary results
Reliability Committee July 18-19, 2023	Review Step 3 summer 2027 preliminary results, address stakeholder feedback, outline plan for accepting stakeholder input to additional studies
Reliability Committee August 15, 2023	Review Step 3 winter 2032 preliminary results
Reliability Committee September 19, 2023	Review Step 3 summer 2032 preliminary results and review stakeholder sensitivity requests selected for analysis
Reliability Committee November 14, 2023	Review results of sensitivity analyses

Questions

APPENDIX

Follow-up on stakeholder questions and requests for additional information

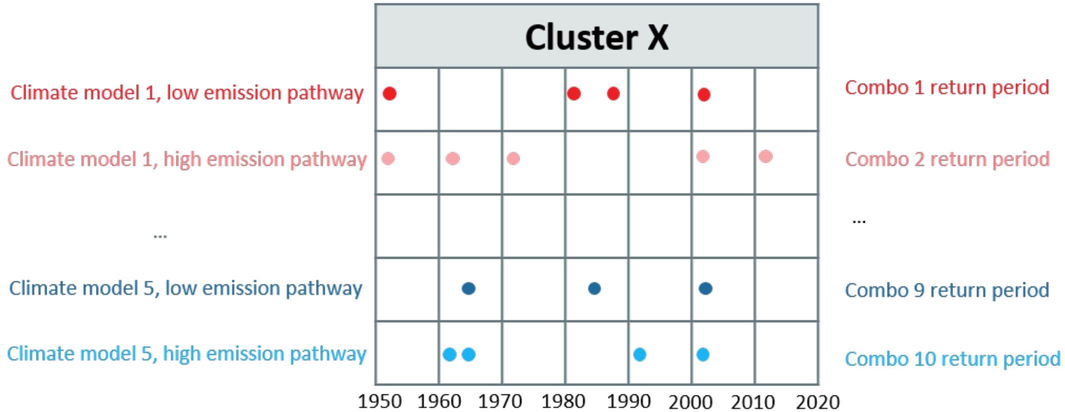
RETURN PERIOD OF WEATHER EVENTS

Estimate the Return Period of Weather Events at the Cluster Level

- A return period is the expected interval between event recurrences
  - A 1-in-5 year event means the average time between similar events is 10 years over a long period of time
  - A 1-in-5 year event has a probability of 20% of occurring in any one year
- Return period is not a guarantee of when an event would occur, but it is a representative figure to show the rareness and extremeness of an event
- The return period of events are estimated at the cluster level
  - Extreme events in the same clusters are considered to have similar weather attributes
  - Cluster-level return period estimation improves the number of observations of similar extreme events

Method Used to Estimate Return Periods for Weather Events

- For each cluster return period estimates are developed for each climate model and emission pathway combination
  - There are five climate models and two emission pathways
  - The return period of each combination is equal to the average of elapsed time between two consecutive events in the combination



Each dot in the figure above represents a 21-day event in Cluster X

- Return period consensus ranges are developed based upon the smallest range that 70% of combinations can agree on
  - For example, a return period consensus range of ~3 to 7 years has been determined for 2032 Winter Cluster 1 events and ~2 to 5 years for 2032 Winter Cluster 2 events

PROBABILITIES OF UNCERTAINTIES

Probabilities of Uncertainties Used in 2027 and 2032 Events

- As described in prior presentations, probabilities have been determined for various uncertainties including LNG inventory, oil inventory, imports, and fuel price
- The table below describes probabilities for various levels of uncertainties as used in winter event studies
  - "low" fuel price means that natural gas price is greater than the oil price
  - Import probabilities vary slightly by the case being studied

Winter Events (2027 and 2032)									
LNG Inventory			Oil Inventory			Imports		Fuel Price	
Low	Med	High	Low	Med	High	Low	High	Low	High
0.3%	14.1%	85.6%	33.3%	33.3%	33.3%	11-14%	86-89%	1%	99%

- LNG inventory, oil inventory, and fuel price uncertainties only have one possible value in summer event studies therefore no probabilities are assigned.
  - Probabilities have been determined for low and high imports; probability of low imports ranges from 21-29%, high imports range from 71-79%