JULY 18-19, 2023 | NEWPORT, RHODE ISLAND
NEPOOL RELIABILITY AND TRANSMISSION COMMITTEES SUMMER MEETING

Operational Impact of Extreme Weather Events

Update - Preliminary Results of Energy Adequacy Studies for Summer 2027

Revision 1

Stephen George
DIRECTOR, OPERATIONAL PERFORMANCE, TRAINING & INTEGRATION
Jinye Zhao
TECHNICAL MANAGER, ADVANCED TECHNOLOGY SOLUTIONS

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
- This presentation reviews preliminary results for 2027 summer events

DESCRIPTION OF ASSUMPTIONS, SELECTED EVENTS, AND SCENARIO MODELING FOR STUDY YEAR 2027

Assumptions for Study Year 2027

- Generation assumptions include resources that cleared FCA16 and state-sponsored resources 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

Summer Weather Events Selected By Risk Screening Model For Study Year 2027

- The 2027 summer events are characterized by short to long-duration heat waves, low winds, and low solar irradiance
  - Summer Cluster 1 – characterized by longer-duration events
    - **July 5, 2010 (highest avg. system risk*)**
    - July 13, 1979 (highest severity index*)
    - July 25, 1995 (medoid event*)
  - Summer Cluster 2 – characterized by short to mid-duration events
    - July 13, 1979 (highest avg. system risk)
    - July 26, 1984 (highest severity index)
    - August 17, 1953 (medoid event)
  - Summer Cluster 3 – characterized by events with moderate summer temperatures with very low winds and solar
    - July 28, 2008 (highest avg. system risk and severity index)
    - July 19, 1984 (medoid event)
  - Note that a July 13, 1979 event appears in two different clusters; two distinct climate model/emissions pathways combinations resulted in different outcomes in terms of the characteristics of this event which resulted in the event appearing in two summer clusters
- **This presentation of Summer 2027 study results focuses primarily on the July 5, 2010 event**

*Average System Risk, Severity Index, and medoid are metrics determined 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 2027 Summer 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
- Return periods for 2027 summer events have been determined and are shown in the following table

Cluster	Return period
Summer Cluster 1 (2027)	2.5-12 years
Summer Cluster 2 (2027)	2-3 years
Summer Cluster 3 (2027)	2-2.5 years

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

- Each weather 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
- 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**	

Scenario Modeling of the Everett Marine Terminal

- 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)
- Regional aggregate 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 by Consultants
- 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 quicker prior to replenishment, leading to larger energy shortfalls in some cases with EMT than in similar cases without EMT

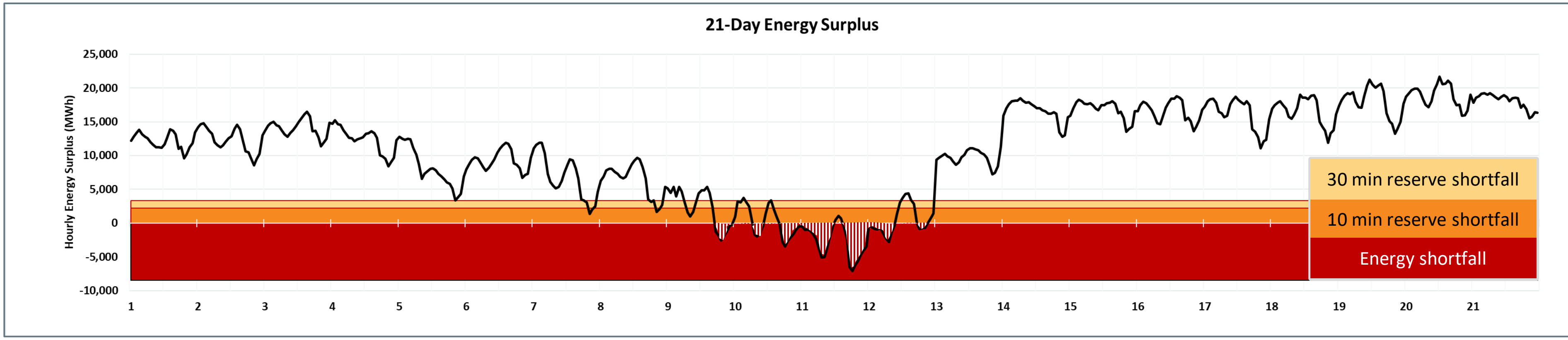
Scenarios for 2027 Study Year, cont.

	NECEC **in-service**	NECEC **not in-service**
EMT **in-service**	With NECEC, With EMT	No NECEC, With EMT
EMT **not in-service**	With NECEC, No EMT	No NECEC, No EMT

- Each of the four possible scenarios is modeled using 20 “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
  - Summer events have 20 cases (as compared to 720 for winter events) since the LNG, fuel-oil, and fuel price uncertainties have only one possible value in summer cases
  - Uncertainty assumptions vary based on the unique characteristics of each 21-day event (e.g. event start date, temperatures, etc.)

Introduced May 2023 RC Meeting

21-Day Energy Assessment Calculates Energy Surplus



*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 20 cases within summer scenario:
  - "Expected" energy shortfall = probability-weighted average across cases
  - "Worst-case" energy shortfall = case with highest energy shortfall quantity

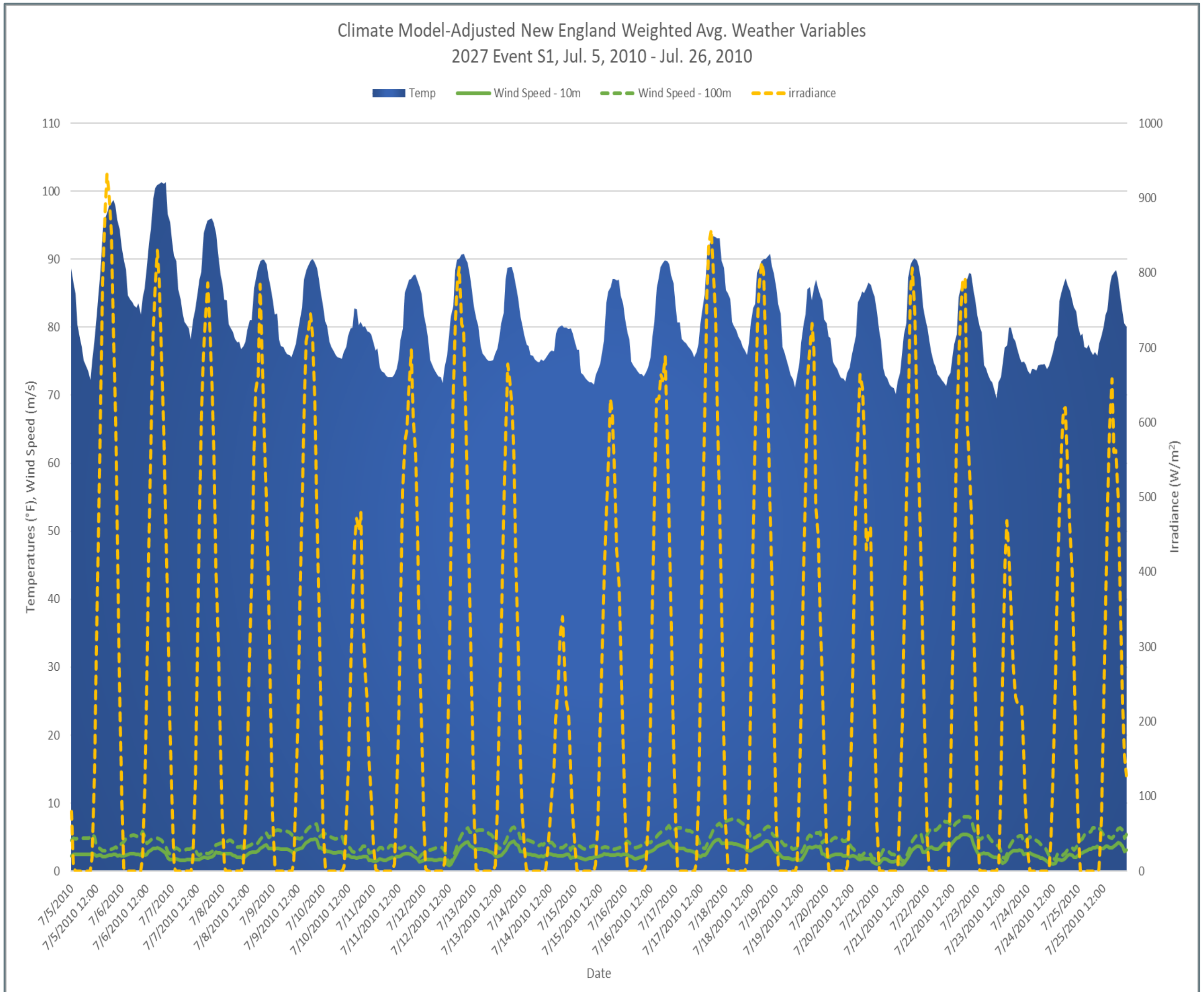
STEP 3: PRELIMINARY RESULTS OF 2027 SUMMER EVENTS

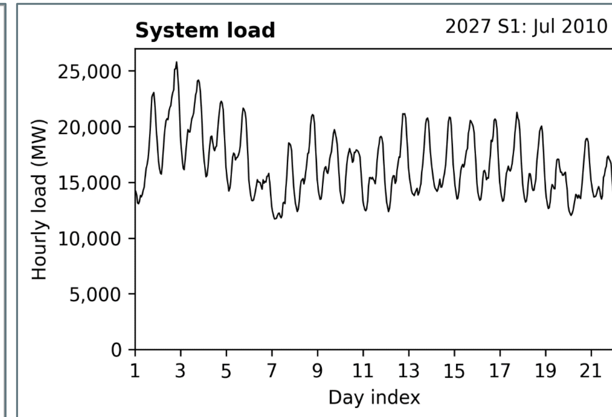
Summary of 2027 Summer Event Studies

- ISO studied the following 2027 Summer Events
  - Summer Cluster 1 (longer-duration events)
    - July 5, 2010 (highest avg. system risk)
    - July 13, 1979 (highest severity index)
    - July 25, 1995 (medoid event)
  - Summer Cluster 2 (short to mid-duration events)
    - July 13, 1979 (highest avg. system risk)
    - July 26, 1984 (highest severity index)
    - Aug 17, 1953 (medoid event)
  - Summer Cluster 3 (moderate temperature events with very low winds and solar)
    - July 28, 2008 (highest avg. system risk and highest severity index)
    - July 19, 1984 (medoid event)
- No energy shortfall was observed in any of these events
- Reserve shortfall was observed only in the July 5, 2010 event; results of those studies are summarized on the following slides

July 5, 2010 Summer Event Overview

Long Duration Heat Wave Coincident With Low Winds





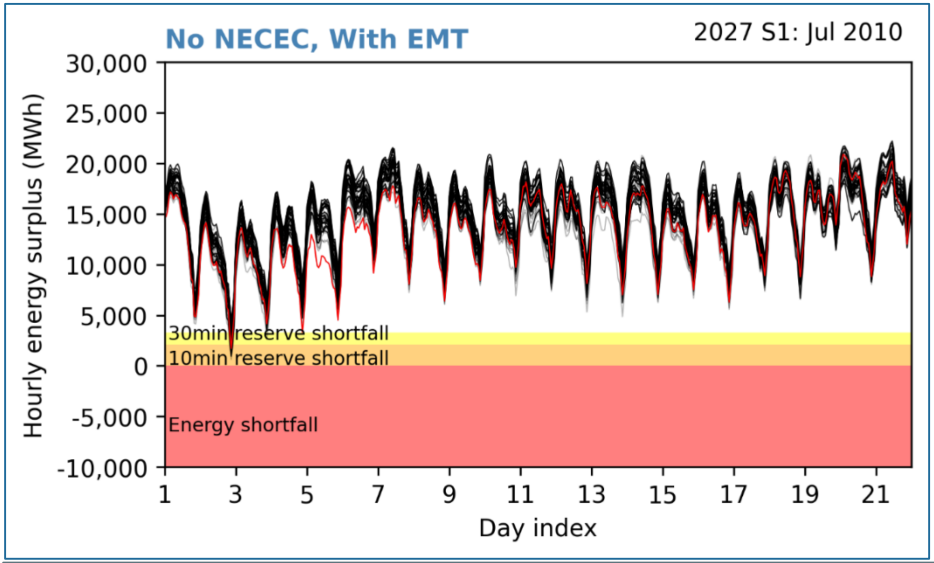
- **Min/Mean/Max (°F):** 69.5/81.4/101.4
- **Mean 100m Wind Speed (m/s):** 4.4
  - Offshore Wind avg. 420 MW/hr
  - Onshore Wind avg. 160 MW/hr
- **Mean Irradiance (W/m²):** 239.9
  - Utility Scale PV avg. 390 MW/hr
  - BTM PV avg. ~1,860 MW/hr
- **Avg. Energy From Renewables:** ~2,830 MW/hr
- **Peak Load:** 25,793 MW (day 2)
- **Peak Energy Demand:** ~499,500 MWh (day 2)
- **Total 21-Day Energy Demand:** 8.38 TWh
- **Historical Relevance:** One of the top 10 warmest 1, 3, 5, 10, and 21-day periods since 1950.

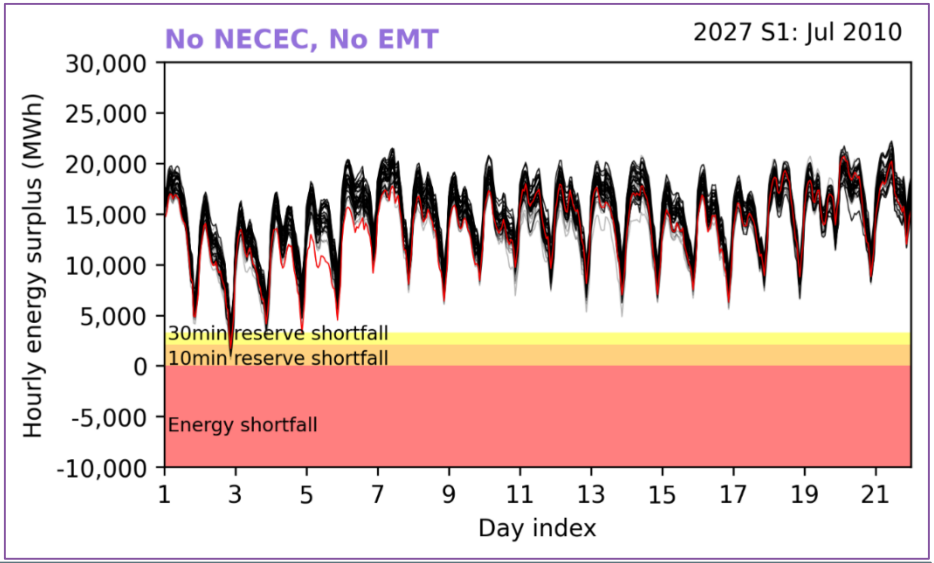
*temperatures, wind speeds, and irradiance are based on a New England ten-city weighted average

Summary of 21-Day Energy Analysis Results

July 5, 2010 Event; Scenarios: No NECEC, With and Without EMT

- Results with and without EMT are similar as there is minimal depletion of stored fuels in any cases; limited amounts of 10 and 30 minute reserve shortfalls occur in the worst cases and no energy shortfall is observed in any cases
- Cases where reserve shortfalls occur are representative of capacity deficiency conditions, which are managed through ISO's Operating Procedure No. 4 (OP-4), Actions During a Capacity Deficiency



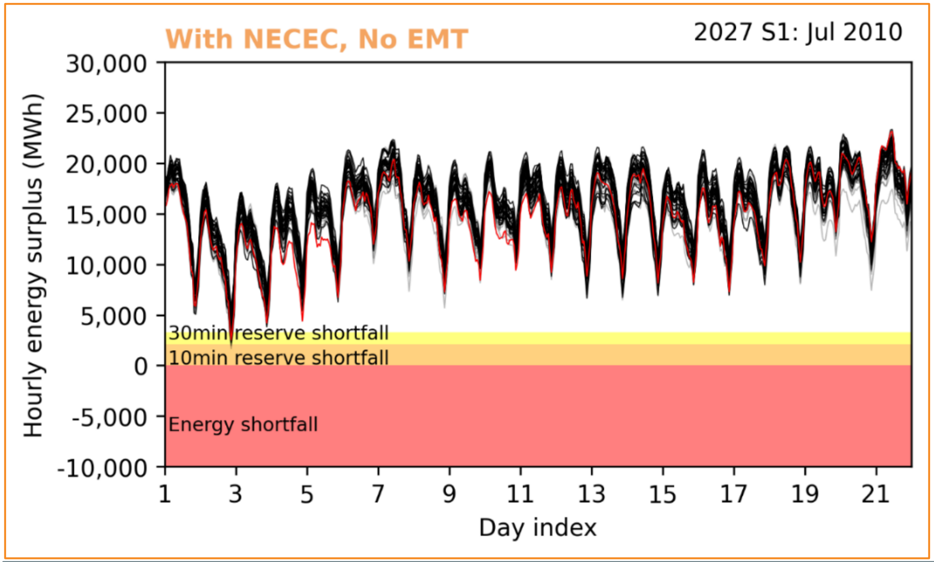


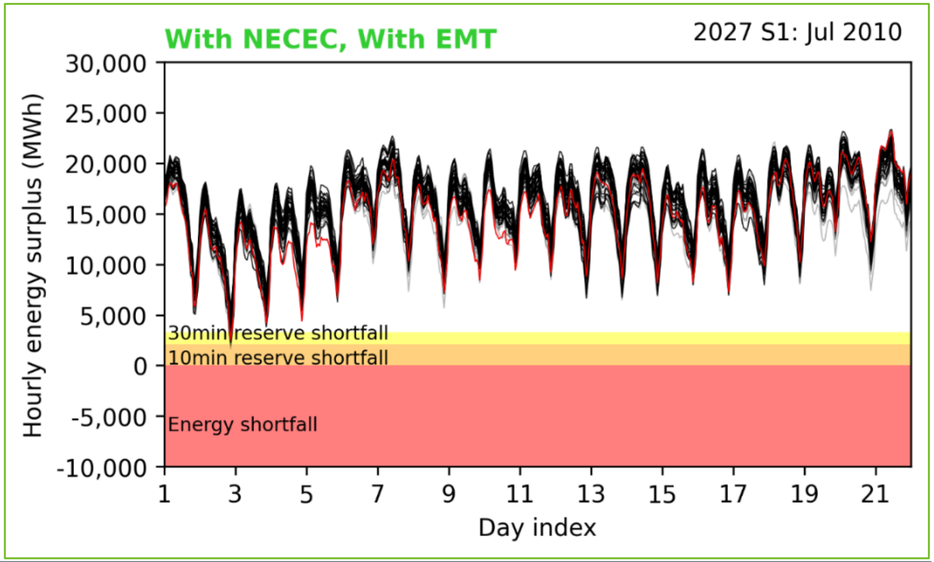
*in the energy surplus chart above (upper-left), the red highlighted trace represents the case that has the highest shortfall amount (MWhs); otherwise, the lower the probability of a case, the lighter its corresponding trace

Summary of 21-Day Energy Analysis Results

July 5, 2010 Event; Scenarios: With NECEC, With and Without EMT

- NECEC helps to reduce reserve shortfalls in worst cases and no energy shortfall is observed in any cases; results with and without EMT are similar as there is minimal depletion of stored fuels in any cases

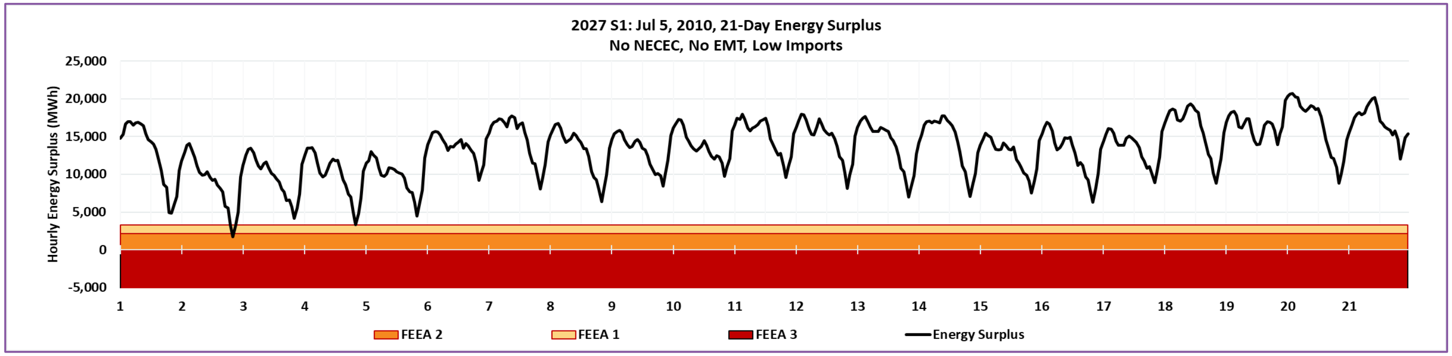


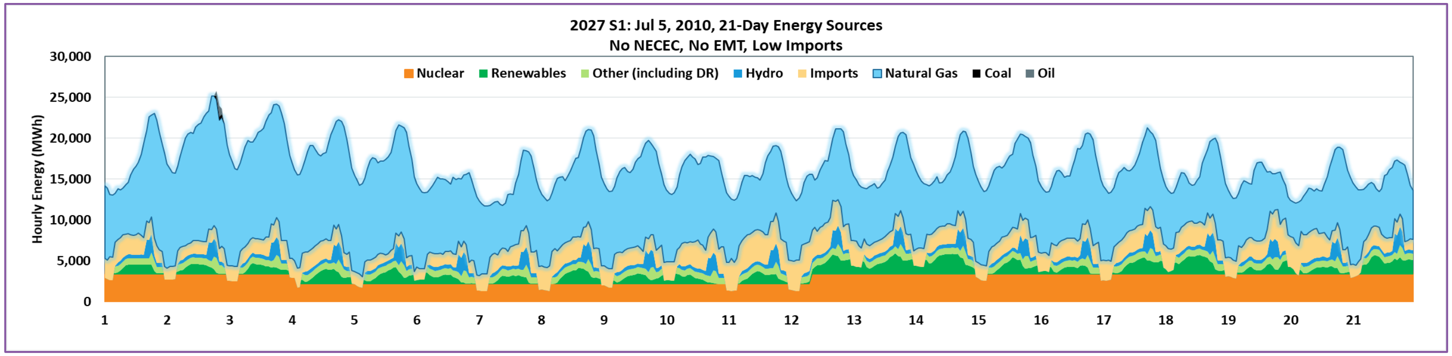


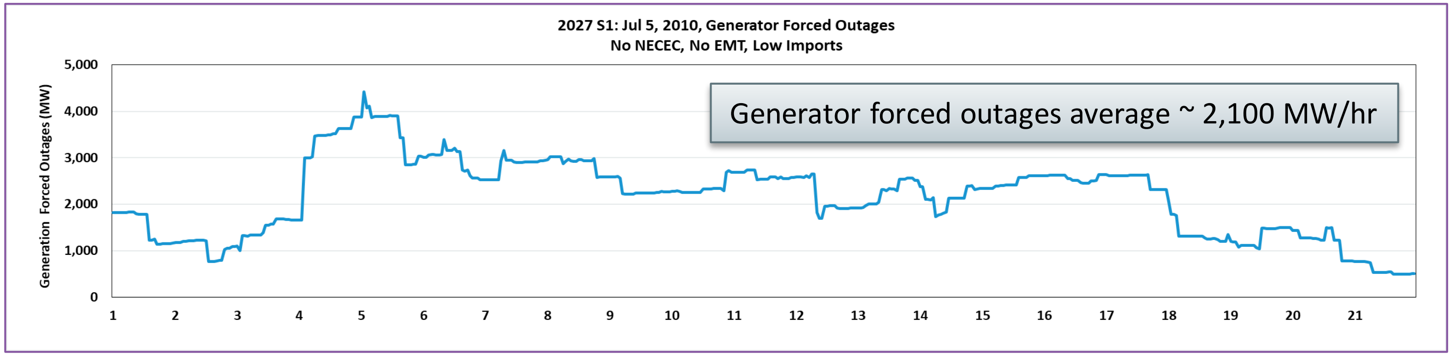
*in the energy surplus chart above (upper-left), the red highlighted trace represents the case that has the highest shortfall amount (MWhs); otherwise, the lower the probability of a case, the lighter its corresponding trace

July 5, 2010 Event Worst-Case Reserve Shortfall

Scenario: no NECEC, no EMT; Case: Low Imports







Energy Shortfall – FEEA3 (MWh)	0
10-Min Reserve Shortfall – FEEA2 (MWh)	1,793
30-Min Reserve Shortfall – FEEA1 (MWh)	4,056
Starting Inventory – LNG (Bcf)	5.4
LNG Replenishment (Bcf), on days 12 & 13	0
LNG Usage (Bcf)	<0.1
Fuel Oil Starting Inventory (gal)	~128 M
Fuel Oil Replenishment (gal), as needed	~0.57 M
Fuel Oil Usage (gal)	~0.59 M

KEY TAKEAWAYS AND FOLLOW-UP ON STAKEHOLDER QUESTIONS & COMMENTS

Revision 1: New Slide

Key Takeaways From 2027 Summer Event Studies

- Preliminary results of Summer 2027 studies reveal no energy shortfall risk
  - These results are consistent with the significant quantities of PV (BTM and utility scale), offshore wind, and storage expected while experiencing minimal load growth
  - Results reveal similar energy adequacy risk with and without EMT in-service as minimal stored fuels are needed
  - Risks are mitigated by incremental imports from New England Clean Energy Connect
- This energy adequacy study framework provides a much needed foundation to study the system as it continues to evolve, though it is not a guarantee of any future outcomes or future risks
  - The ISO intends to continually monitor the energy adequacy risk, particularly as the changes in the regional supply and demand profiles ramp up
  - The aim of the study is to quantify the risks for the regions' consideration

Request for Probabilities

- Some stakeholders requested that the ISO provide the probabilities associated with the studies run to date
- Once the 2032 results are complete, the ISO plans to deliver those for reference on the full set of results

Revision 1: New Slide

Reasonability of LNG Inventory Assumptions

- Winter and summer 2027 studies consider a range of possible LNG inventories
- The LNG assumptions are reasonable for a number of reasons:
  - The starting inventory level for the coldest 21-day stretch is assumed to be at ~6.5 Bcf (which is less than 50% of the available capacity, with and without Everett)
  - The ISO studied the sensitivity of the analysis to lower starting LNG inventories
    - A sensitivity case run on the Jan 22, 1961 event (No NECEC, With EMT scenario; Low LNG, Low Oil, Low Imports case) in which the starting LNG inventory was reduced by 3 Bcf (to ~3.5 Bcf), showed that worst-case energy shortfall amounts increase to ~200,000 MWh
  - The Winter 2027 studies also assessed the impact of higher starting LNG inventories
    - The amount of energy shortfall in the Jan 22, 1961 event (No NECEC, With EMT scenario; Mid LNG, Low Oil, Low Imports case) in which the starting LNG inventory is ~13 Bcf, was ~46,000 MWh
  - They are based on ISO's experience and observations regarding LNG replenishment at the prediction and/or onset of cold weather over the past decade
- Energy shortfall quantities in these studies are similar in cases with and without EMT and the risks appear manageable over a 21-day period
  - The manageability of these events is enhanced by the 21-day situational awareness tool, and the low likelihood of the worst-case events (0.0006% for January 22, 1961)
  - As an example, the energy shortfalls resulting from worst-cast scenarios in the 2027 results is based on a combination of Low LNG, Low Oil, Low Imports, and High Forced Outages

Revision 1: New Slide

Resource Mix and Demand Forecast Assumptions for 2032

- The 2032 resource mix is identical to the 2027 resource mix (*see* slide 5) with the exception of an additional 3,200 MW (total of 4,800 MW) of state-sponsored offshore wind capacity
- 2032 studies will also incorporate ISO's 2022 heating and transportation electrification forecasts
  - The 2032 studies assume a winter peak load of ~23,200 MW
  - An additional 2,500 MW of BTM PV capacity (total of ~12,000 MW) has been incorporated to reflect expectations for continued growth
- ISO is completing sensitivity analysis of 2032 events to better understand impacts of changes in the 2032 resource mix and demand profiles and, in addition, plans to accept stakeholder input on additional sensitivities (*see* slide 23 for details)

Revision 1: New Slide

Stakeholder Input to 2032 Sensitivity Cases

- Recognizing interest in assumptions to the region's resource mix and demand projections for 2032, ISO is planning to accept stakeholder input regarding additional sensitivity cases
- At the August RC meeting ISO plans to:
  - Provide specific details on parameters that ISO will consider adjusting as part of a sensitivity analysis, the method by which ISO will solicit feedback, and the date by which it must be submitted
  - Provide a complete list of input parameters that ISO could modify as part of a sensitivity analysis; examples include: generator retirements, 21-day profiles of renewable resources, starting LNG inventories, daily LNG vaporization rates, and load profiles
- At the September RC meeting ISO plans to provide an overview of feedback received from stakeholders and to review the list of sensitivity analyses that will be performed
- ISO plans to review the sensitivity results at the November RC meeting

Revision 1: New Slide

Next Steps

- ISO intends to continue reviewing the outputs of the 2027 winter and summer events while completing studies of winter and summer events for 2032
- Winter 2032 study results are expected to be shared at the August RC meeting; summer 2032 results will be shared at the September RC
- Stakeholder sensitivity analysis results of 2032 events will be shared at the November RC

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

Revision 1:
Added September/
November Dates

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
Reliability Committee November 14, 2023	Review results of sensitivity analyses