NOVEMBER 14, 2023| NEPOOL RELIABILITY COMMITTEE |
DOUBLETREE HOTEL, WESTBOROUGH, MA

Operational Impact of Extreme Weather Events

Probabilistic Energy Adequacy Tool (PEAT) - Results of Stakeholder-Informed Winter 2032 Sensitivity Analysis

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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, were presented for the 2027 summer events in July, were presented for the 2032 winter events in August, and were presented for the 2032 summer events in September
- This presentation reviews results of Step 3 energy assessments which were responsive to stakeholder sensitivity analysis requests focused on the worst case 2032 winter event

Overview of Stakeholder-Informed Sensitivity Analysis

- Recognizing interest in assumptions related to the region's resource mix and demand projections for 2032, ISO accepted stakeholder input regarding additional sensitivity analysis focused on the 2032 winter based the worst case of the Jan 22, 1961 event
  - Stakeholder sensitivity requests reflected significant interest in sensitivities related to the impacts of additional renewables and generator retirements
- ISO performed analysis of 30 unique sensitivity requests and results are summarized in the following presentation
  - ISO performed 13 additional sensitivity analyses in order to help provide additional context to some of the stakeholder sensitivity requests
- Each sensitivity is a deterministic analysis that incorporates the modification of one or more specific inputs; probabilistic data has not been generated as part of the sensitivity analysis
- Results and takeaways should be considered in the context of the specific assumptions of each case studied and the attributes of the worst case of the Jan 22, 1961 event

Overview of Stakeholder-Informed Sensitivity Analysis, cont.

- Stakeholder feedback regarding sensitivity analysis indicated a strong preference for performance of sensitivity analysis using a baseline that incorporates ISO's 2023 CELT load forecast and a resource mix aligned with ISO's FCA17 sensitivity analysis
- All sensitivity analysis was performed using ISO's Jan 22, 1961 event "2032 FCA 17/2023 CELT" sensitivity study[1] as a baseline
  - This baseline incorporates results of FCA 17 and the 2023 CELT load forecast
  - All modifications performed in order to accommodate sensitivity requests are incremental to those included in the baseline
- ISO's FCA 17 modeling includes resources that obtained a CSO in FCA 17 or were selected under state RFP's[2]; resources that de-listed in FCA 17 and did not obtain a CSO are assumed to be retired
  - Modeled retirements total ~1,600 MW of capacity[3], including 375 MW of natural gas-only, ~450 MW of coal, and ~750 MW of RFO resources; retired capacity of generators is replaced with new capacity based on a 1:1 nameplate MW ratio[4]

1: For details on ISO's "2032 FCA17/2023 CELT" sensitivity study, see slide 44 of the "Operational Impact of Extreme Weather Events" presentation given at the August 15, 2023 RC Meeting
2: This includes Millstone Station which is currently on a state contract
3: In addition to the ~2,100 MW of retirements from FCA 16
4: Replacement capacity is based on the percentage of resource types currently in ISO's interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)

Overview of Stakeholder-Informed Sensitivity Analysis, cont.

- All sensitivities include the NECEC in-service; this is due to the high likelihood of NECEC being in-service by 2032
- Storage batteries are all modeled as 2-hour duration resources as this best represents existing resources; future modeling enhancements will enable the incorporation of longer-duration storage
- Nameplate capacity quantities utilized in ISO's sensitivity analysis are outlined in the table below; resource types not included in a table on the following slides that summarize results can be assumed to have the nameplate capacity shown in the table below

Sensitivity Analysis Baseline Assumptions (values are nameplate capacity, MW)

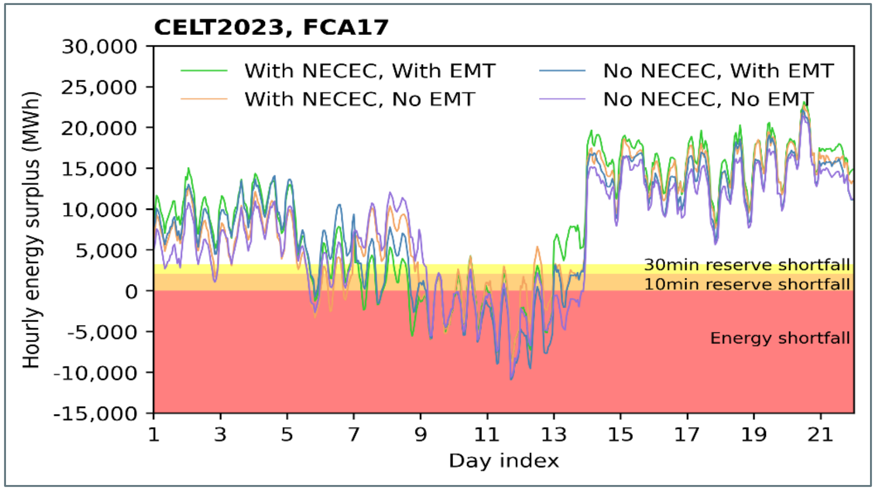
	CELT	FCA	Onshore Wind (LBW)	Offshore Wind (OFW)	Battery Storage	Utility-Scale PV	BTM PV	Demand Response (DR)	Nuclear	NG Only	Dual Fuel (DF)	RFO	DFO Only
FCA 17 Baseline	2023	FCA 17	1,500	5,600	2,050	1,450	12,000	260	3,350	8,830	7,180	3,150	1,110

REVIEW OF “2032 FCA 17/2023 CELT” SENSITIVITY STUDY RESULTS

Baseline for Stakeholder-Informed Sensitivity Analysis

Sensitivity Analysis Results – Jan 22, 1961 Event

FCA17 Resource Mix and 2023 CELT Load Forecast[1]



Sensitivity Analysis Assumptions	
CELT Load Forecast Year	2023
FCA Results	FCA 17
Retired Generating Capacity	+1,600 MW/3,700 MW total
Offshore Wind Capacity	+800 MW/5,600 MW total
Battery Storage 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 FCA17/2023 CELT	**189,550**	**137,587**	**272,796**	**215,733**

- The sensitivity "2032 FCA17/2023 CELT" is referred to as "FCA 17 Baseline" on the following slides describing results of stakeholder-informed sensitivity analysis
- Total energy demand across the 21-day study period is ~ 9.3 TWh; in cases with NECEC in-service, **the total energy shortfall in this sensitivity is ~1.5 - 2.0% of the total 21-day energy demand**

1: results previously presented at the August 15, 2023 RC Meeting; see slide 44 of the "Operational Impact of Extreme Weather Events" presentation

RESULTS OF STAKEHOLDER-INFORMED SENSITIVITY ANALYSIS

Modifications of Load Profiles

Key Assumptions					Sensitivity Analysis Results	
Sensitivity	Retirement Replacement Strategy	Peak Hourly Load (MW)	Avg. Hourly Load (MW)	21-Day Energy Demand (TWh)	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	n/a	26,515	18,512	9.3	189,550	137,587
-10% Load	n/a	**23,864**	**16,661**	**8.4**	30,048 **(-84%)**	17,964 **(-87%)**
-20% Load	n/a	**21,212**	**14,810**	**7.5**	0 **(-100%)**	0 **(-100%)**
+10% Load	n/a	**29,167**	**20,363**	**10.3**	485,481 **(+156%)**	401,143 **(+192%)**
In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities						

- Load profile sensitivities were modeled as adjustments to hourly load profiles used in the FCA 17 baseline

Modifications of Imports

Key Assumptions				Sensitivity Analysis Results	
Sensitivity[3]	Retirement Replacement Strategy	Maximum Hourly Imports (MW)	Average Hourly Imports (MW)	Energy Shortfall – With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	n/a	5,610	3,378	189,550	137,587
-20% Imports	n/a	**4,488**	**2,702**	256,726 **(+35%)**	196,478 **(+43%)**
+20% Imports[2]	n/a	**5,625**	**4,015**	132,823 **(-30%)**	94,206 **(-32%)**
+50% Imports[2]	n/a	**5,625**	**4,759**	70,904 **(-63%)**	49,037 **(-64%)**
+50% Imports, no cap[1]	n/a	**8,415**	**5,066**	64,980 **(-66%)**	46,600 **(-66%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- Import sensitivities were modeled as adjustments to hourly net interchange levels used in the FCA 17 baseline
- The +20% and +50% increase in imports contributes an additional ~321,000 and ~696,000 MWh, respectively, over the 21-day time period, or ~3.5 and ~7.5% of the total 21-day energy demand
- As mentioned, all sensitivities include the NECEC in-service; additional import capability would be required to accommodate transfer levels above 5,625 MW in the +50% imports, no cap sensitivity

(1) In this sensitivity, imports are not capped at maximum transfer capability of ~5,625 MW w/ NECEC in-service; additional import capability would be needed to accommodate these transfer levels
(2) In these sensitivities, imports are capped at maximum transfer capability of ~5,625 MW w/ NECEC in-service, as needed
(3) The FCA 17 Baseline sensitivity and all other sensitivities shown include the NECEC in-service

Addition of BTM PV Nameplate Capacity, No Additional Retirements

Key Assumptions (nameplate capacity values in MW)			**Sensitivity Analysis Results**	
Sensitivity	**Retirement Replacement Strategy**	**BTM PV**	**Energy Shortfall – With EMT (MWh)**	**Energy Shortfall – No EMT (MWh)**
FCA 17 Baseline	n/a	12,000	189,550	137,587
+20% BTM PV	n/a	**14,400**	170,343 **(-10%)**	127,842 **(-7%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- Additional BTM PV is incremental to ~12,000 MW of nameplate capacity modelled in ISO’s 2032 studies for a total of 14,400 MW
- Incremental installation of PV resources can aid in the preservation of stored fuels during cold weather events; in this event, the additional 2.4 GW of nameplate BTM PV capacity contributes an additional ~130,000 MWh over the 21-day time period, or ~1.5% of the total 21-day energy demand; 130,000 MWh is equivalent to ~9M gallons of fuel oil

Addition of Active Demand Response Nameplate Capacity, No Additional Retirements

Key Assumptions (nameplate capacity values in MW)			**Sensitivity Analysis Results**	
Sensitivity	Retirement Replacement Strategy	Active Demand Response	Energy Shortfall – With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	n/a	**260**	189,550	137,587
+0.5 GW DR	n/a	**760**	147,011 **(-22%)**	106,500 **(-23%)**
+1.0 GW DR	n/a	**1,260**	116,656 **(-38%)**	83,467 **(-39%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- Additional active demand response capacity is incremental to the ~300 MW of real-time demand response capacity modelled in the FCA 17 baseline
- Active demand response is the last resource type to be dispatched in ISO's 21-day energy simulator; it is modeled as a dispatchable resource with no weather dependency, which may overestimate the capacity factor of these resources

Retirements of Fossil Fuel Resources and QC-based Addition of Renewable Resources

Key Assumptions (nameplate capacity values in MW)										**Sensitivity Analysis Results**	
Sensitivity	Retirement Replacement Strategy	LBW	OFW	Battery Storage	Utility-Scale PV	NG Only[3]	Dual Fuel[3]	RFO[3]	DFO Only[3]	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	n/a	1,500	5,600	2,050	1,450	8,830	7,180	3,150	1,110	189,550	137,587
1 GW Fossil Retirement, + OFW	1:1 QC[1,2]	1,500	**7,267**	2,050	1,450	**8,360**	**6,860**	**2,960**	**1,060**	119,492 **(-37%)**	79,813 **(-42%)**
1 GW Fossil Retirement, + LBW	1:1 QC[1,2]	**3,881**	5,600	2,050	1,450	**8,360**	**6,860**	**2,960**	**1,060**	142,006 **(-25%)**	102,572 **(-25%)**
1 GW Fossil Retirement, + Utility-Scale PV	1:1 QC[1,2]	1,500	5,600	2,050	**3,950**	**8,360**	**6,860**	**2,960**	**1,060**	181,002 **(-5%)**	133,616 **(-3%)**
In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities											

(1) Retirements are comprised of fossil-fuel resources based on the proportions of each type of resource available to be retired in sensitivity scenarios
(2) Qualified Capacity (QC) values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(3) Retirement quantities may not add exactly to 1 GW due to rounding to nearest whole unit

Retirements of Fossil Fuel Resources and QC-based Addition of Renewable Resources, cont.

Key Assumptions (nameplate capacity values in MW)										Sensitivity Analysis Results	
Sensitivity	Retirement Replacement Strategy	LBW	OFW	Battery Storage	Utility-Scale PV	NG Only[3]	Dual Fuel[3]	RFO[3]	DFO Only[3]	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	n/a	1,500	5,600	2,050	1,450	8,830	7,180	3,150	1,110	189,550	137,587
1 GW Fossil Retirement, + Battery Storage	1:1 QC[1,2]	1,500	5,600	**3,050**	1,450	**8,360**	**6,860**	**2,960**	**1,060**	210,586 **(+11%)**	163,052 **(+19%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- Retirement of a mix of fossil fuel resources accompanied by QC-based addition of onshore wind, offshore wind, and utility-scale PV has a positive impact on energy shortfall
  - 1,667 MW of additional OFW nameplate capacity results in a ~37-42% decrease, 2,381 MW of additional LBW nameplate capacity results in a ~25% decrease, and 2,500 MW of additional utility-scale PV nameplate capacity results in a 3-5% decrease
- QC-based addition of 2-hour battery storage resources results in an ~11-19% increase in energy shortfall amounts; notably ISO has not modeled the impact of longer-duration battery storage, but expects to enhance the storage modeling capability of the PEAT framework in the future

(1) Retirements are comprised of fossil-fuel resources based on the proportions of each type of resource available to be retired in sensitivity scenarios
(2) Qualified Capacity (QC) values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(3) Retirement quantities may not add exactly to 1 GW due to rounding to nearest whole unit

Retirement of 1.5 GW of Natural Gas-Only Resources

Key Assumptions (nameplate capacity values in MW)						**Sensitivity Analysis Results**	
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	Natural Gas-Only	Energy Shortfall - With EMT (MWh)	Energy Shortfall - No EMT (MWh)
FCA 17 Baseline	-	5,600	2,050	1,450	8,830	189,550	137,587
1.5 GW natural gas-only retirement	None	5,600	2,050	1,450	**7,330**	192,646 **(+2%)**	137,964 *(negligible change)*
1.5 GW natural gas-only retirement	1:1 nameplate, ISO renewable mix[1]	**6,360**	**2,640**	**1,650**	**7,330**	143,426 **(-24%)**	104,449 **(-24%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- In this sensitivity, the retirement of 1.5 GW of natural gas-only resources and replacement with a mix of renewable resources results in reduced energy shortfall; this is caused by the retirement of relatively high heat-rate natural gas-fired resources that had been unavailable (i.e. not operating), at times, in the FCA 17 baseline due to a lack of gas availability
  - ISO's additional sensitivity where there is no replacement of retired resources demonstrates that it is the additional renewables that reduce the energy shortfall quantities

(1) ISO renewable mix is based on the percentage of resource types currently in ISO's interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)

Retirement of 1.6 GW of Residual Fuel Oil Resources

Key Assumptions (nameplate capacity values in MW)						**Sensitivity Analysis Results**	
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	RFO	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	-	5,600	2,050	1,450	3,150	189,550	137,587
1.6 GW RFO retirement	None	5,600	2,050	1,450	**1,550**	314,229 **(+66%)**	245,429 **(+78%)**
1.6 GW RFO retirement[1]	1:1 nameplate, ISO renewable mix[2]	**6,400**	**2,650**	**1,650**	**1,550**	245,763 **(+30%)**	197,520 **(+44%)**
1.6 GW RFO retirement	1:1 QC[3], ISO renewable mix	**6,933**	**2,690**	**1,850**	**1,550**	206,878 **(+9%)**	158,834 **(+15%)**
1.6 GW RFO retirement	1:1 QC, new renewable mix[4]	**7,330**	**2,450**	**1,850**	**1,550**	177,844 **(-6%)**	140,346 **(+2%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- With the exception of the QC-based sensitivity (with EMT) that incorporates the "new renewable mix", which includes higher penetrations of offshore wind than the "ISO renewable mix", each 1.6 GW RFO retirement sensitivity results in increased energy shortfall

(1) This sensitivity is identical to ISO's sensitivity analysis "2032 FCA17/2023 CELT", as presented at the September 2023 Reliability Committee Meeting, is shared here for comparison purposes with other RFO sensitivity results
(2) ISO renewable mix is based on the percentage of resource types currently in ISO's interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)
(3) QC values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(4) New renewable mix is based on a stakeholder sensitivity request; a blend of offshore wind (~65%), utility-scale PV (~10%), and battery storage capacity (~25%)

Retirement of all Residual Fuel Oil Resources

Key Assumptions (nameplate capacity values in MW)						**Sensitivity Analysis Results**	
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	RFO	Energy Shortfall - With EMT (MWh)	Energy Shortfall - No EMT (MWh)
FCA 17 Baseline	-	5,600	2,050	1,450	3,150	189,550	137,587
All RFO retirement	None	5,600	2,050	1,450	**0**	505,381 **(+167%)**	416,237 **(+203%)**
All RFO retirement	1:1 nameplate, new renewable mix[3]	**7,680**	**2,840**	**1,760**	**0**	282,054 **(+49%)**	233,780 **(+70%)**
All RFO retirement	1:1 QC[2], ISO renewable mix[1]	**8,230**	**3,310**	**2,240**	**0**	224,846 **(+19%)**	187,295 **(+36%)**
All RFO retirement	1:1 QC, new renewable mix[3]	**9,010**	**2,840**	**2,240**	**0**	165,337 **(-13%)**	125,663 **(-9%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- With the exception of the QC-based sensitivity that incorporates the “new renewable mix”, each “all RFO retirement” sensitivity results in increased energy shortfall

(1) ISO renewable mix is based on the percentage of resource types currently in ISO’s interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)
(2) QC values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(3) New renewable mix is based on a stakeholder sensitivity request; a blend of offshore wind (~65%), utility-scale PV (~10%), and battery storage capacity (~25%)

Retirement of 1.0 GW of Nuclear Resources

Key Assumptions (nameplate capacity values in MW)						**Sensitivity Analysis Results**	
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	Nuclear	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline[4]	-	5,600	2,050	1,450	3,350	189,550	137,587
1.0 GW nuclear retirement	None	5,600	2,050	1,450	**2,350**	292,555 **(+54%)**	232,275 **(+69%)**
1.0 GW nuclear retirement	1:1 nameplate, new renewable mix[3]	**6,250**	**2,300**	**1,550**	**2,350**	245,715 **(+30%)**	192,149 **(+40%)**
1.0 GW nuclear retirement	1:1 QC[2], ISO renewable mix[1]	**6,430**	**2,450**	**1,700**	**2,350**	233,012 **(+23%)**	184,164 **(+34%)**
1.0 GW nuclear retirement	1:1 QC, new renewable mix[3]	**6,680**	**2,300**	**1,700**	**2,350**	218,105 **(+15%)**	166,939 **(+21%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

(1) ISO renewable mix is based on the percentage of resource types currently in ISO's interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)
(2) QC values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(3) New renewable mix is based on a stakeholder sensitivity request; a blend of offshore wind (~65%), utility-scale PV (~10%), and battery storage capacity (~25%)
(4) One ~1,200 MW nuclear unit was on a forced outage in the FCA17 baseline case for 198 hours (~8.25 days)

Retirement of all Nuclear Resources

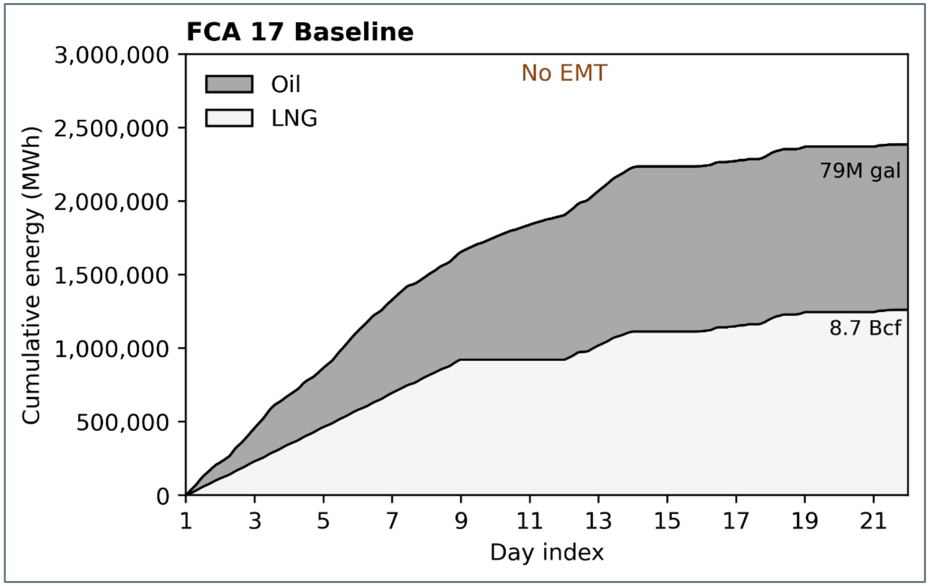
Key Assumptions (nameplate capacity values in MW)						Sensitivity Analysis Results	
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	Nuclear	Energy Shortfall - With EMT (MWh)	Energy Shortfall - No EMT (MWh)
FCA 17 Baseline[4]	-	5,600	2,050	1,450	3,350	189,550	137,587
All nuclear retirement	None	5,600	2,050	1,450	**0**	541,769 **(+185%)**	470,487 **(+242%)**
All nuclear retirement	1:1 nameplate, new renewable mix[3]	**7,778**	**2,887**	**1,785**	**0**	341,804 **(+80%)**	294,623 **(+114%)**
All nuclear retirement	1:1 QC[2], ISO renewable mix[1]	**8,390**	**3,390**	**2,280**	**0**	285,722 **(+50%)**	241,812 **(+76%)**
All nuclear retirement	1:1 QC, new renewable mix[3]	**9,230**	**2,890**	**2,280**	**0**	231,766 **(+22%)**	185,642 **(+35%)**

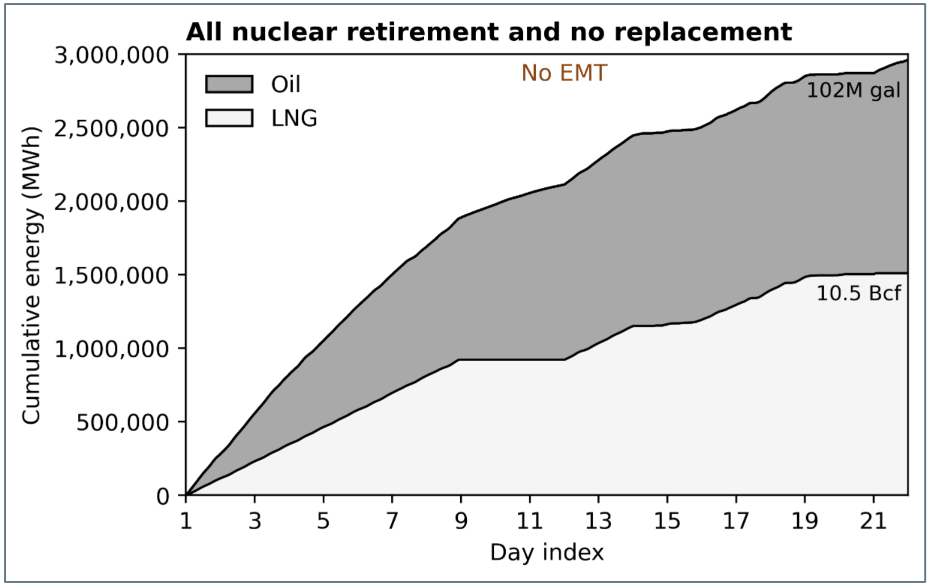
In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- Each sensitivity that considers retirement of nuclear capacity, regardless of quantity of retirements (1.0 GW or all) or retirement replacement strategy, results in increased energy shortfall; the magnitude of energy shortfall in the all nuclear retirement/no replacement sensitivity is ~5.1-5.8% of 21-day total energy demand

(1) ISO renewable mix is based on the percentage of resource types currently in ISO's interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)
(2) QC values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(3) New renewable mix is based on a stakeholder sensitivity request; a blend of offshore wind (~65%), utility-scale PV (~10%), and battery storage capacity (~25%)
(4) One ~1,200 MW nuclear unit was on a forced outage in the FCA17 baseline case for 198 hours (~8.25 days)

Energy From Stored Fuels Increases ~25% in the All Nuclear Retirement/No Replacement Sensitivity





- In the all nuclear retirement/no replacement sensitivity, energy from stored fuels serves ~32% of the 21-day total energy demand
- Increases in cumulative energy from stored fuels are similar in sensitivities with and without EMT
- Relative to the FCA 17 baseline sensitivity, fuel oil usage increases ~29% (including an additional 9M gallons of replenishment) in the all nuclear/no replacement sensitivity

Cap Offshore Wind at 1.6 GW Nameplate Capacity

Key Assumptions (nameplate capacity values in MW)			**Sensitivity Analysis Results**	
Sensitivity	**Retirement Replacement Strategy**	**OFW**	**Energy Shortfall – With EMT (MWh)**	**Energy Shortfall – No EMT (MWh)**
FCA 17 Baseline	-	5,600	189,550	137,587
Cap OFW at 1.6 GW	n/a	**1,600**	502,043 **(+165%)**	403,435 **(+193%)**
In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities				

- In terms of magnitude of energy shortfall, this sensitivity is similar to the all nuclear retirement/no replacement and the all RFO retirement/no replacement sensitivities

Cap OFW at 1.6 GW Nameplate Capacity and Retirement of All Nuclear Resources

Key Assumptions (nameplate capacity values in MW)				**Results of Sensitivity Analysis**	
Sensitivity	Retirement Replacement Strategy	OFW	Nuclear	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline[1]	-	5,600	3,350	189,550	137,587
Cap OFW at 1.6 GW & Retirement of all nuclear	None	1,600	**0**	1,009,279 **(+432%)**	903,760 **(+557%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- This sensitivity conveys the impact to energy shortfall amounts due to significant nuclear capacity retirement and delayed buildout of offshore wind with no additional capacity added to the system
- The retirement of all 3.35 GW of existing nuclear capacity and the capping of offshore wind at 1.6 GW of nameplate capacity would result in ~29.0 GW of capacity to serve a ~32.6 GW ICR[2] in 2032; this level of capacity would likely lead to year-round concerns with meeting system load and reserve requirements

(1) One ~1,200 MW nuclear unit was on a forced outage in the FCA17 baseline case for 198 hours (~8.25 days)
(2) Representative net ICR for 2032 based on Net Installed Capacity Requirements (ICRs), Representative Net ICRs, and Operable Capacity (Op Cap) Analysis, presented at the PAC on June 15, 2023

Reduction of Renewable Nameplate Capacity

Key Assumptions (nameplate capacity values in MW)					**Results of Sensitivity Analysis**	
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	Energy Shortfall – With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	-	5,600	2,050	1,450	189,550	137,587
25% Reduction of OFW, Battery, Utility-Scale PV	n/a	**4,210**	**1,550**	**1,090**	277,590 **(+46%)**	220,853 **(+61%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

Reduction of Renewable Nameplate Capacity & 1.6 GW Retirement of RFO Resources

Key Assumptions (nameplate capacity values in MW)						**Results of Sensitivity Analysis**	
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	RFO	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	-	5,600	2,050	1,450	3,150	189,550	137,587
25% reduction of OFW, Battery, Utility-Scale PV & 1.6 GW RFO retirement	1:1 nameplate, ISO renewable mix[1]	**5,000**	**2,138**	**1,288**	**1,550**	371,438 **(+96%)**	287,580 **(+109%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- In this sensitivity the 25% reduction in renewables is taken from the nameplate capacities used in the FCA 17 baseline sensitivity and then replacements due to RFO retirements are added back in to the total nameplate capacities

(1) ISO renewable mix is based on the percentage of resource types currently in ISO's interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)

Modification of Fuel Oil Inventories

Key Assumptions (nameplate capacity values in MW)							**Results of Sensitivity Analysis**	
Sensitivity	Retirement Replacement Strategy	Dual Fuel Nameplate Capacity	DFO Only Nameplate Capacity	RFO Capacity	DFO Inventory (gallons)	RFO Inventory (gallons)	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	-	7,180	1,110	3,150	31.5 M	55.1 M	189,550	137,587
Fill DFO tanks	n/a	7,180	1,110	3,150	**79.8 M**	55.1 M	88,608 **(-53%)**	66,870 **(-51%)**
Fill DFO tanks and retire all RFO	n/a	7,180	1,110	**0**	**79.8 M**	**0**	295,215 **(+56%)**	232,362 **(+69%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- Filling the DFO fleet's fuel oil storage tanks (an additional ~48 M gallons) at the start of the event reduces overall energy shortfall by ~50%, however given the increase in energy shortfall when all RFO capacity is retired (and not replaced), full DFO tanks do not appear to be adequate replacements for the capacity from RFO units

Modification of LNG Inventories and Replenishment in "No EMT" cases only

Key Assumptions (nameplate capacity values in MW)								**Results of Sensitivity Analysis**
Sensitivity	Retirement Replacement Strategy	OFW	Battery Storage	Utility-Scale PV	RFO	Starting LNG Inventory (Bcf)	LNG Replenish-ment (Bcf)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	-	5,600	2,050	1,450	3,150	6.5	4.1	137,587
30% reduction of starting LNG inventory and replenishment	n/a	5,600	2,050	1,450	3,150	**4.55**	**2.87**	236,301 **(+72%)**
30% reduction of starting LNG inventory and replenishment & 1.6 GW RFO retirement	1:1 nameplate, ISO renewable mix[1]	**6,400**	**2,650**	**1,650**	**1,550**	4.55	2.87	331,408 **(+141%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- As expected, energy shortfall risk is sensitive to starting LNG inventories and shortfall amounts increase with lower LNG starting inventories; the magnitude of energy shortfall increase is consistent with observations from similar sensitivities previously run and shared with stakeholders (e.g. 3 Bcf lower starting inventory sensitivity, shared in May as part of the winter 2027 preliminary study results, *see* slide no. 25)
- In this event, the reduction of replenishment quantities by 30% does not impact energy shortfall due to the timing of replenishment
- ISO continues to expect that the reduced LNG injection capability modelled in the "no EMT" scenario would be able to be made up by the other LNG facilities in the region and/or by additional fuel oil burn

(1) ISO renewable mix is based on the percentage of resource types currently in ISO's interconnection queue; a blend of offshore wind (~50%), utility-scale PV (~10%), and battery storage capacity (~40%)

Addition of Renewable Resources and Imports, with Corresponding Retirements of Fossil Fuels

Key Assumptions (nameplate capacity values in MW)												Results of Sensitivity Analysis	
Sensitivity	Retirement Replacement Strategy	LBW	OFW	Battery Storage	Utility-Scale PV	NG Only[3]	Dual Fuel[3]	RFO[3]	DFO Only[3]	Max Hourly Imports (MW)	Avg. Hourly Imports (MW)	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA 17 Baseline	n/a	1,500	5,600	2,050	1,450	8,830	7,180	3,150	1,110	5,610	3,378	189,550	137,587
Additional imports and additional renewables	1:1 QC[1,2]	**2,450**	**7,000**	**4,000**	**1,650**	**7,430**	**5,980**	**2,670**	**920**	**6,810**	**4,578**	37,960 **(-80%)**	12,866 **(-91%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- This sensitivity examines the impact of ~4.5 GW of additional nameplate capacity from renewables and a corresponding retirement of fossil fuel resources, and an additional 1,200 MW/hr of imports
  - The addition of 1,200 MW/hr of imports represents a ~36% increase in average hourly imports, or an additional ~605,000 MWh of energy which is ~6.5% of the total 21-day energy demand
  - In this sensitivity there is no cap placed on the maximum levels of imports; based on the ~5,625 MW of import transfer capability available with NECEC in-service, additional transfer capability would be needed to accommodate transfer levels in some hours

(1) Retirements are comprised of fossil-fuel resources based on the proportions of each type of resource available to be retired in sensitivity scenarios
(2) QC values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(3) Retirement quantities may not add exactly to 1 GW due to rounding to nearest whole unit

Pathways Study: Addition of Renewable Resources with Corresponding Retirements of Fossil Fuel

Key Assumptions (nameplate capacity values in MW)										Results of Sensitivity Analysis	
Sensitivity	Retirement Replacement Strategy	LBW	OFW	Battery Storage	Utility-Scale PV	NG Only[3]	Dual Fuel[3]	RFO[3]	DFO Only[3]	Energy Shortfall - With EMT (MWh)	Energy Shortfall – No EMT (MWh)
FCA17 Baseline	n/a	1,500	5,600	2,050	1,450	8,830	7,180	3,150	1,110	189,550	137,587
Pathways Study	1:1 QC[1,2]	**2,465**	**8,841**	**4,251**	**4,602**	**6,282**	**5,132**	**2,231**	**791**	25,774 **(-86%)**	23,117 **(-83%)**

In the table above, blue rows indicate FCA 17 baseline, gray rows indicate stakeholder sensitivities, and yellow rows (if any) indicate ISO sensitivities

- This sensitivity request, modeled after renewable resource capacity from the Pathways Study, Status Quo Policy, examines the impact of ~9.5 GW of additional nameplate capacity from renewables and retirement of ~5.8 GW of fossil fuel resources
  - In addition to the 1,465 MW of onshore wind included in the Pathways Study, Status Quo Policy, 1,000 MW more onshore wind nameplate capacity has been added per the sensitivity request for a total of 2,465 MW of onshore wind

(1) Retirements are comprised of fossil-fuel resources based on the proportions of each type of resource available to be retired in sensitivity scenarios
(2) QC values used in these sensitivities: onshore wind, offshore wind, and utility-scale PV, QC values are 42%, 60%, and 40%, respectively (values are consistent with FGRS study)
(3) Retirement quantities may not add exactly to 1 GW due to rounding to nearest whole unit

2032 SUMMER SENSITIVITY ANALYSIS

Follow-up to September RC Meeting

Summer 2032 Sensitivity Analysis

- ISO presented a summary of preliminary results of Summer 2032 events at the September 19 RC Meeting
  - No energy shortfall was observed in any of the Summer 2032 events; only 1 hour of thirty-minute reserve shortfall was observed in one July 13, 1979 case and in one July 26, 1984 case
  - Baseline studies of Summer 2032 events indicate an energy shortfall risk similar to that of the Summer 2027 events
- Following the September 19 RC Meeting, in order to assess the impact of the higher loads associated with the 2023 CELT load forecast, ISO performed a 2023 CELT sensitivity analysis on the July 13, 1979 case
  - No energy shortfall was observed, however two hours of ten-minute reserve shortfall and five hours (up from one hour in the baseline) of thirty-minute reserve shortfall was observed

KEY TAKEAWAYS OF STAKEHOLDER-INFORMED SENSITIVITY ANALYSIS

Key Takeaways of Stakeholder-Informed Sensitivity Analysis

- Sensitivity analysis highlights the dynamic nature of the region's energy adequacy risk profile
  - Based on a variety of stakeholder-requested assumptions, results of sensitivity analysis reveal a range of energy shortfall risks and highlight the increasing energy shortfall risk between 2027 and 2032
  - Sensitivity analysis results are useful for highlighting directional changes in energy shortfall risk under various assumptions; results should be considered in the context of the specific assumptions made and the attributes of the Jan 22, 1961 21-day event
- Sensitivities that evaluate resource retirements without replacement generally show increased energy shortfall risk as compared to the FCA 17 baseline; depending on the specifics of the resource retirements and the replacement methodology employed, some or all of the increased energy shortfall risk is mitigated
  - As expected, QC-based replacement of retired resources results in reduced energy shortfall risks as compared to nameplate-based replacement
  - In sensitivities that evaluate the retirement of nuclear capacity, the increased energy shortfall risk is not fully offset by additional renewables regardless of the replacement strategy ("1:1 nameplate" vs. "1:1 QC-based") or renewable mix ("ISO" vs. "new") employed
- Energy from resources that burn stored fuels will continue to be important in terms of minimizing energy shortfall as the region transitions to higher penetrations of renewable resources
- Timely additions of BTM and utility-scale PV, offshore wind, and incremental imports from NECEC are critical to mitigate energy shortfall risks that result from significant winter load growth and retirements
- The PEAT 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

Next Steps

- ISO expects to release a final report that summarizes all aspects of the PEAT study framework and results in late November/early December
- ISO will present a proposed scope of work for developing a Regional Energy Shortfall Threshold (REST) at the December RC meeting
- Throughout 2024, using PEAT results, the ISO plans to work with regional stakeholders to establish a REST that determines the region's acceptable level of reliability risk; the ISO can then evaluate if meeting the REST requires development of specific regional solutions
  - Possible solutions could range from market designs to infrastructure investments to dynamic retail pricing and responsiveness by end-use consumers
- Further analysis of scope, timing, and feasibility of any such solutions would follow in 2024-2025, as needed

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 stakeholder-informed sensitivity analyses