Load Forecast Uncertainty Models for the 2023 IRM and 2022 RNA Studies

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Demand Forecasting & Analysis

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LFU Definition - NYSRC Policy 5-14

Section 3.5.1 NYCA Load Model: Load Forecast Uncertainty Model

The load forecast uncertainty (LFU) model captures the impacts of weather conditions on future loads. The LFU gives the MARS program information regarding seven load levels (three loads lower and three loads higher than the median peak) and their respective probabilities of occurrence. For each modeled hour, the MARS program determines the resource adequacy and calculates an average loss of load expectation for the capability year for each of the seven load levels. MARS uses this information to evaluate a probability weighted-average LOLE for each area. Recognizing the unique LFU nature of individual NYCA zones, the LFU model is subdivided into five separate areas: New York City (Zone J), Long Island (Zone K), Zones H and I, Zones F and G, and the rest of New York State (Zones A-E).

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LFU Definition - NYSRC Policy 5-14 (cont'd)

Preparation of the LFU model is coordinated by the NYISO in collaboration with the TOs. The process used to develop the LFU model generally follows the procedure used to calculate the forecasted NYCA ICAP peak as described in the NYISO Load Forecasting Manual. This process follows the development of the NYCA peak, insofar as the LFU is a distribution, not a point estimate. Following acceptance from the NYISO Load Forecasting Task Force, the NYISO submits the final LFU model to be used in MARS to ICS for review and approval…

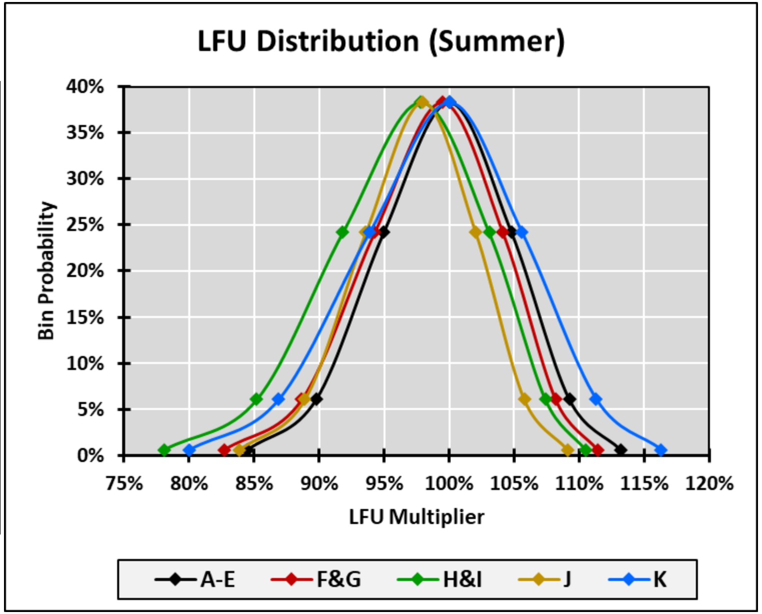
Overview

- Summary of Load Forecast Uncertainty (LFU) Results
- Summer LFU
  - Zones A-E, Zones F&G, Zones H&I, Zone J, Zone K
- Winter LFU – NYCA
- Questions/Discussion

Summary of Load Forecast Uncertainty (LFU) Results

Recommended LFU

			New Recommended LFU Multipliers					
			Summer					Winter
Bin	Bin z	Bin Probability	A-E	F&G	H&I	J	K	NYCA
Bin 1	2.74	0.62%	113.18%	111.42%	110.50%	109.10%	116.30%	110.29%
Bin 2	1.79	6.06%	109.25%	108.20%	107.41%	105.78%	111.32%	106.26%
Bin 3	0.89	24.17%	104.80%	104.14%	103.08%	102.05%	105.60%	102.65%
Bin 4	0.00	38.29%	100.00%	99.46%	97.82%	97.98%	100.00%	99.37%
Bin 5	-0.89	24.17%	94.96%	94.28%	91.83%	93.60%	93.87%	96.32%
Bin 6	-1.79	6.06%	89.75%	88.67%	85.21%	88.90%	86.89%	93.46%
Bin 7	-2.74	0.62%	84.49%	82.72%	78.09%	83.89%	80.04%	90.74%



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LFU Comparison

			Existing LFU Multipliers					
			Summer					Winter
Bin	Bin z	Bin Probability	A-E	F&G	H&I	J	K	NYCA
Bin 1	2.74	0.62%	114.78%	115.85%	112.55%	109.95%	115.63%	111.01%
Bin 2	1.79	6.06%	110.01%	110.53%	108.40%	106.49%	110.73%	106.89%
Bin 3	0.89	24.17%	105.06%	105.01%	103.36%	102.33%	105.30%	103.25%
Bin 4	0.00	38.29%	100.00%	99.36%	97.68%	97.67%	100.00%	100.00%
Bin 5	-0.89	24.17%	94.88%	93.61%	91.50%	92.58%	92.96%	97.05%
Bin 6	-1.79	6.06%	89.73%	87.77%	84.89%	87.13%	84.32%	94.34%
Bin 7	-2.74	0.62%	84.63%	81.88%	77.98%	81.38%	76.60%	91.85%

			Delta (Recommended - Existing)					
			Summer					Winter
Bin	Bin z	Bin Probability	A-E	F&G	H&I	J	K	NYCA
Bin 1	2.74	0.62%	-1.59%	-4.42%	-2.05%	-0.85%	0.67%	-0.73%
Bin 2	1.79	6.06%	-0.77%	-2.32%	-0.99%	-0.71%	0.59%	-0.63%
Bin 3	0.89	24.17%	-0.26%	-0.86%	-0.28%	-0.29%	0.29%	-0.60%
Bin 4	0.00	38.29%	0.00%	0.10%	0.14%	0.31%	0.00%	-0.63%
Bin 5	-0.89	24.17%	0.08%	0.66%	0.33%	1.02%	0.91%	-0.72%
Bin 6	-1.79	6.06%	0.02%	0.90%	0.32%	1.78%	2.58%	-0.88%
Bin 7	-2.74	0.62%	-0.14%	0.84%	0.12%	2.51%	3.44%	-1.11%

Note: Recommended winter LFU values are now calculated relative to 57^{th} percentile-based reference load, based on aggregate TO design conditions. Prior winter LFU was based on 50^{th} percentile reference load only. Winter LFU values now consider the same design conditions as summer.

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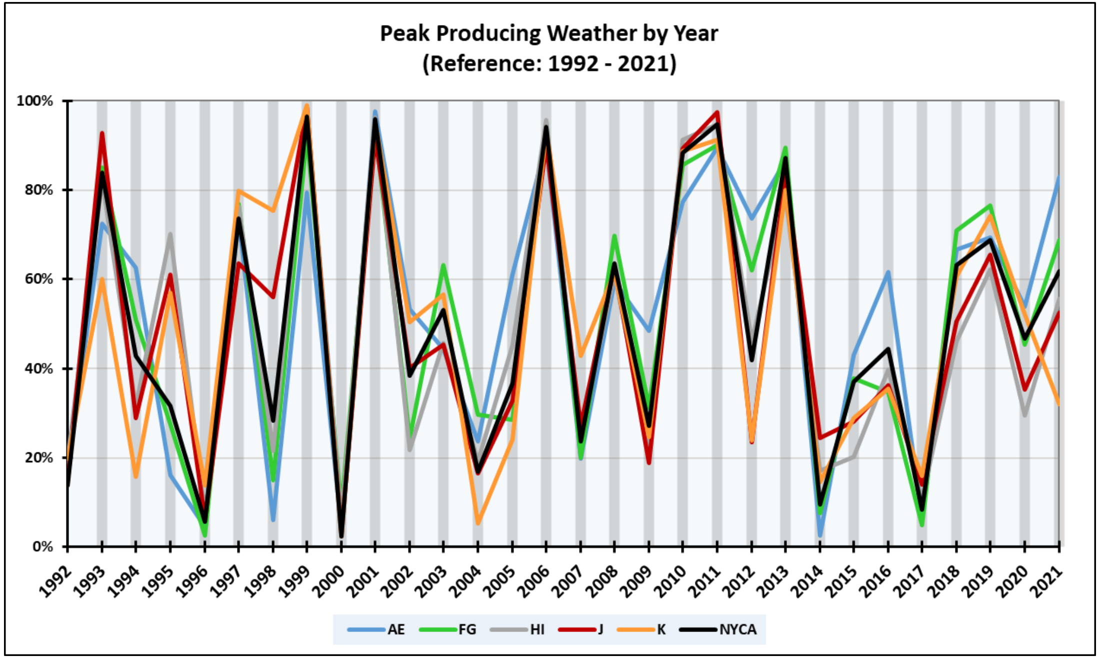
Peak Producing Weather Review



	AE	FG	HI	J	K	NYCA
2021	*83%*	*69%*	*56%*	*52%*	*32%*	*62%*

- Year 2021 exhibited above average peak producing weather (62nd percentile) for the NYCA
- Upstate and western areas experienced the hotter conditions relative to the NYCA as a whole

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Summary of Methodology

Summer LFU Modeling

- Load-weather relationship was established through polynomial regression model.
  - Demand response MWs have been added back to the load.
- For each LFU area, pooled models were developed using summer (June-August) data from 2018, 2019 and 2021. A single year model with only 2021 data was also developed. Weekends and holidays were excluded, along with influential points/outliers.
- A pooled/single year model was selected based on model accuracy, statistical stability, overall response and weather sensitivity.
- Iterative process. Multiple combinations of model structure were investigated (e.g., variable weather sensitivity for different years).
- Weather uncertainty (calculated from 30 years of history of peak producing conditions) was applied to the established load-weather relationship.

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Key Changes in Methodology

Item	Existing LFU	New LFU	Note
Data	2018, 2019	2018, 2019, 2021	Added most recent year
Summer months	May - Sep	Jun – Aug	Temperature and load levels are relatively lower in May and September
Weekends	Included	Excluded	Load levels are lower during weekends
Historical weather distribution	20 years	30 years	30-year window offers more stability

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Peak Weather Variability

- Historical peak producing weather (average and standard deviation) is an important contributor to the final LFU value

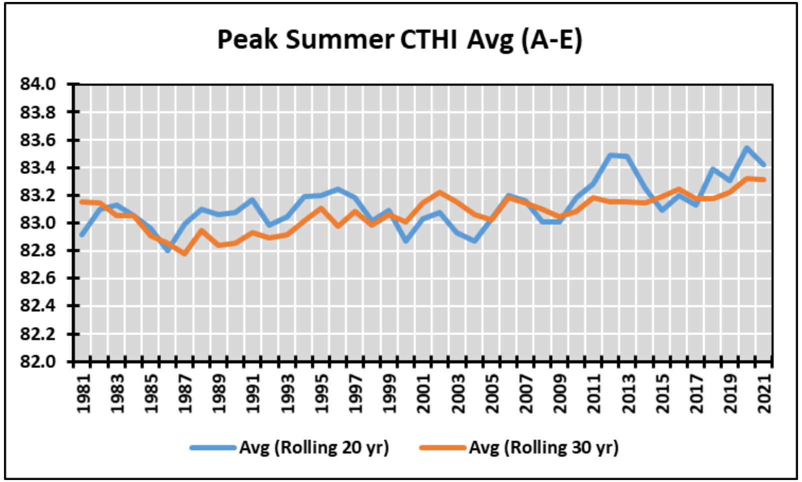
$$LFU_{bin\ k} = \frac{load\ at\ (\boldsymbol{avg} + z_{bin\ k} * \boldsymbol{SD})}{load\ at\ (\boldsymbol{avg} + z_{design} * \boldsymbol{SD})}$$

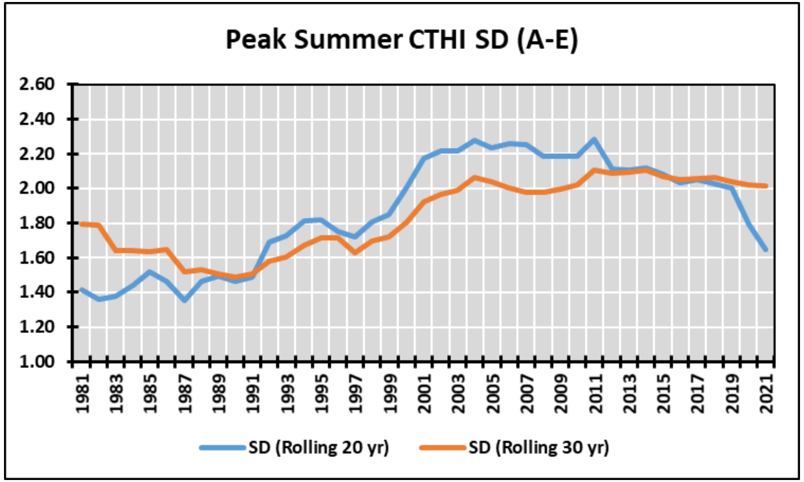
- In general, LFU values at the upper bins;
  - decrease with the increase of average
  - increase with the increase of standard deviation (SD)
- Using more years of weather history offers more stable statistics and reduces year-to-year random fluctuation of LFU

Peak Producing CTHI Year to Year Variation

	20/20 Change (Ending in 2019 vs 2021)					
	AE	FG	HI	J	K	NYCA
Avg	0.1%	0.0%	-0.1%	0.0%	0.0%	0.1%
Std Dev	-16.5%	-10.9%	-14.6%	-15.5%	-17.8%	-18.1%

	30/30 Change (Ending in 2019 vs 2021)					
	AE	FG	HI	J	K	NYCA
Avg	0.3%	0.1%	-0.1%	-0.2%	-0.1%	0.1%
Std Dev	-0.6%	-0.9%	0.5%	-2.3%	-1.3%	-0.5%

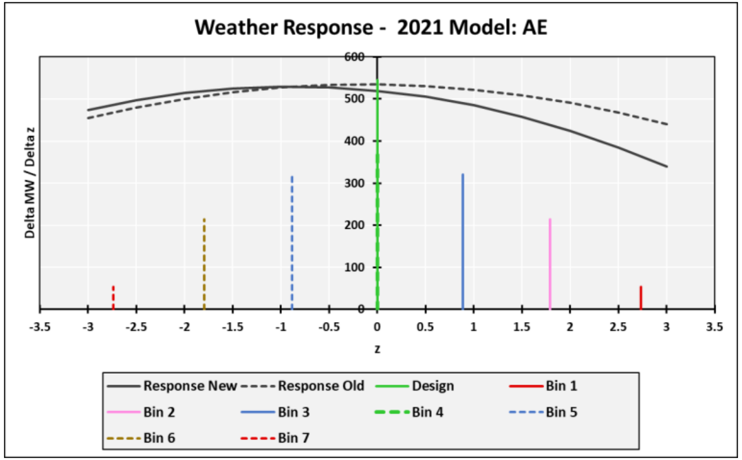




Summer LFU

Zones A-E

Summer LFU: Zones A-E



Bin	Bin z	Bin Probability	MW	New LFU	Current LFU
Bin 1	2.74	0.62%	10,408	113.18%	114.78%
Bin 2	1.79	6.06%	10,046	109.25%	110.01%
Bin 3	0.89	24.17%	9,636	104.80%	105.06%
Bin 4	0.00	38.29%	9,195	100.00%	100.00%
Bin 5	-0.89	24.17%	8,732	94.96%	94.88%
Bin 6	-1.79	6.06%	8,253	89.75%	89.73%
Bin 7	-2.74	0.62%	7,769	84.49%	84.63%
		Design	***9,195***		

- Slightly suppressed base load (-0.5%)(1)
- Stronger saturation of the regression line at extreme conditions contributed to the decrease in LFU at higher temperatures

(1) Relative to prior base load, which was calculated for prior reference year (2019)

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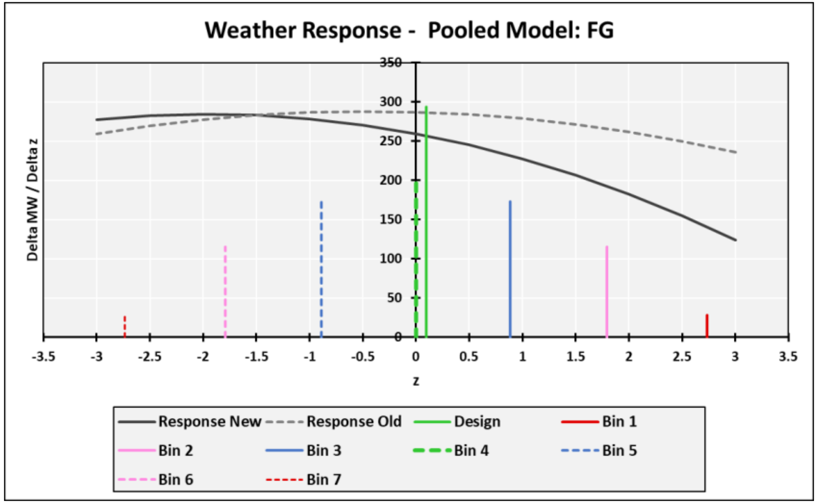
Summer LFU

Zones F&G

Summer LFU: Zones F&G



Bin	Bin z	Bin Probability	MW	New LFU	Current LFU
Bin 1	2.74	0.62%	5,030	111.42%	115.85%
Bin 2	1.79	6.06%	4,884	108.20%	110.53%
Bin 3	0.89	24.17%	4,701	104.14%	105.01%
Bin 4	0.00	38.29%	4,490	99.46%	99.36%
Bin 5	-0.89	24.17%	4,256	94.28%	93.61%
Bin 6	-1.79	6.06%	4,003	88.67%	87.77%
Bin 7	-2.74	0.62%	3,734	82.72%	81.88%
		Design	***4,514***		

- Elevated base load (+1.6%)
- Stronger saturation of the regression line at design conditions and beyond
- The factors above contributed to lower LFU multipliers above design conditions

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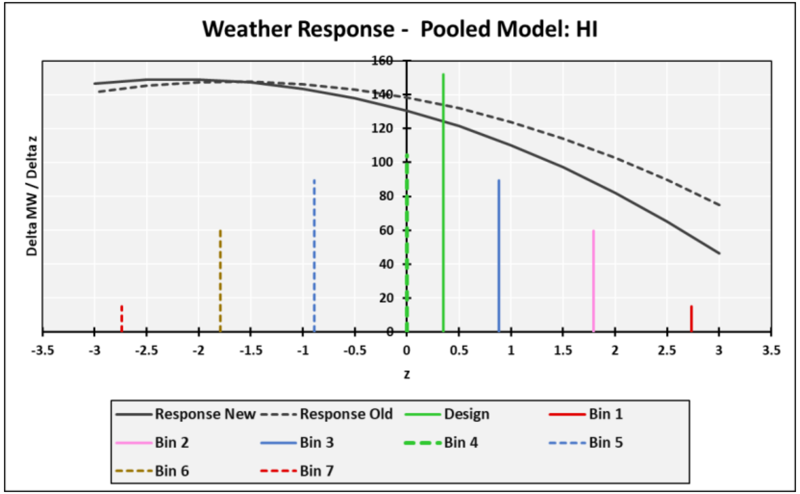
Summer LFU

Zones H&I

Summer LFU: Zones H&I



Bin	Bin z	Bin Probability	MW	New LFU	Current LFU
Bin 1	2.74	0.62%	2,181	110.50%	112.55%
Bin 2	1.79	6.06%	2,120	107.41%	108.40%
Bin 3	0.89	24.17%	2,035	103.08%	103.36%
Bin 4	0.00	38.29%	1,931	97.82%	97.68%
Bin 5	-0.89	24.17%	1,813	91.83%	91.50%
Bin 6	-1.79	6.06%	1,682	85.21%	84.89%
Bin 7	-2.74	0.62%	1,542	78.09%	77.98%
		Design	***1,974***		

- Decreased base load (-1.7%)
- Stronger saturation of the regression line at extreme conditions

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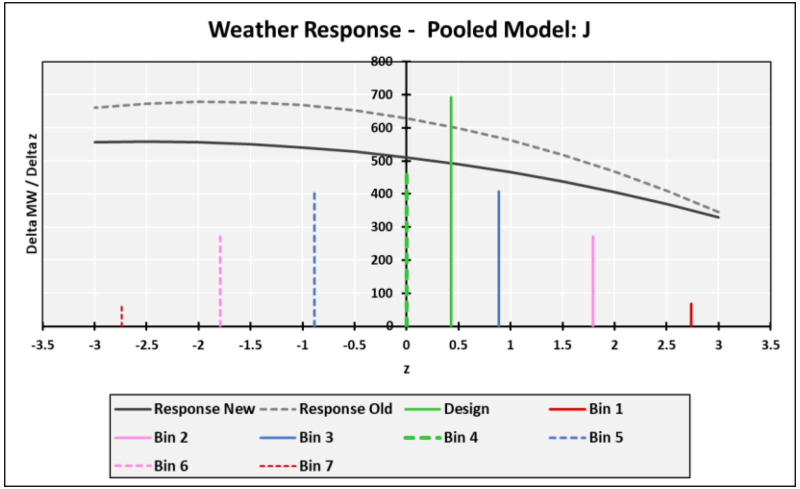
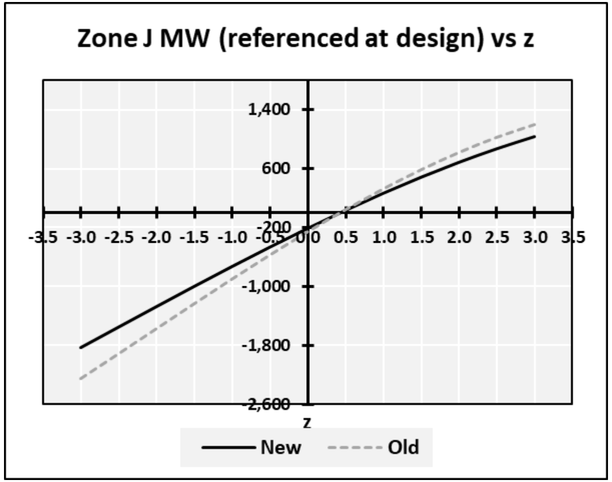
Summer LFU

Zone J

Summer LFU: Zone J



Bin	Bin z	Bin Probability	MW	New LFU	Current LFU
Bin 1	2.74	0.62%	11,417	109.10%	109.95%
Bin 2	1.79	6.06%	11,069	105.78%	106.49%
Bin 3	0.89	24.17%	10,679	102.05%	102.33%
Bin 4	0.00	38.29%	10,253	97.98%	97.67%
Bin 5	-0.89	24.17%	9,795	93.60%	92.58%
Bin 6	-1.79	6.06%	9,303	88.90%	87.13%
Bin 7	-2.74	0.62%	8,779	83.89%	81.38%
		Design	***10,464***		



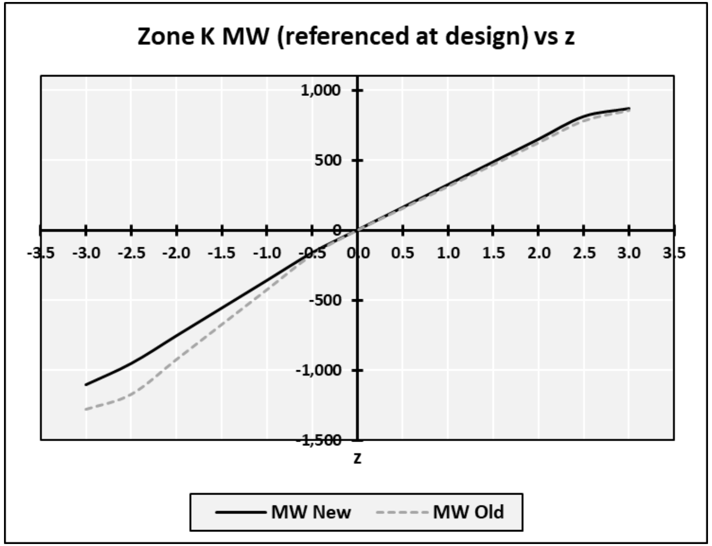
- Decreased base load (-5.9%)
- Overall decreased load in the most extreme bins

Summer LFU

Zone K

Summer LFU: Zone K

- Developed by LIPA
- Independent NYISO model had similar results



Bin	Bin z	Bin Probability	MW	New LFU	Current LFU
Bin 1	2.74	0.62%	5,975	116.30%	115.63%
Bin 2	1.79	6.06%	5,719	111.32%	110.73%
Bin 3	0.89	24.17%	5,425	105.60%	105.30%
Bin 4	0.00	38.29%	5,138	100.00%	100.00%
Bin 5	-0.89	24.17%	4,823	93.87%	92.96%
Bin 6	-1.79	6.06%	4,464	86.89%	84.32%
Bin 7	-2.74	0.62%	4,112	80.04%	76.60%
		Design	*5,138*		

- Decreased base load (-1.7%)
- The additional MW relative to base load is very similar to current model
- The upward movement in multipliers at higher bin temperatures is driven mainly by a comparison to a lower base load in the new model

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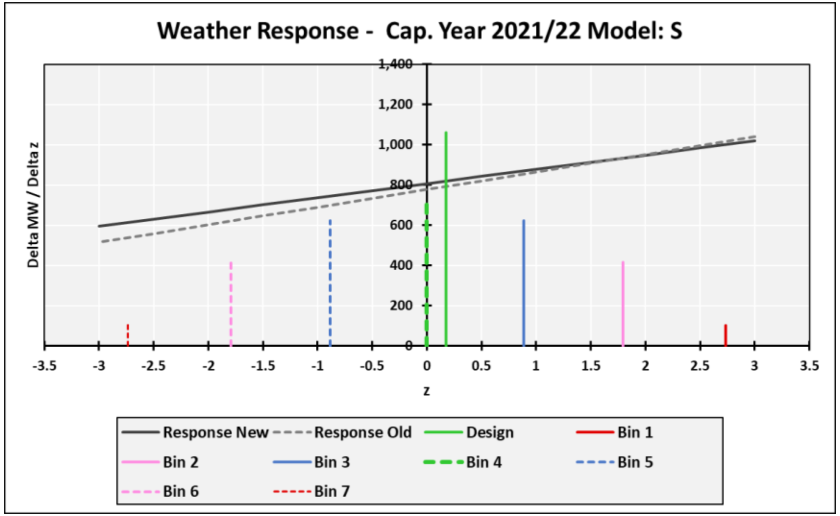
Winter LFU

NYCA Model

Winter LFU: NYCA



Bin	Bin z	Bin Probability	MW	New LFU	Current LFU
Bin 1	2.74	0.62%	25,458	110.29%	111.01%
Bin 2	1.79	6.06%	24,529	106.26%	106.89%
Bin 3	0.89	24.17%	23,696	102.65%	103.25%
Bin 4	0.00	38.29%	22,938	99.37%	100.00%
Bin 5	-0.89	24.17%	22,235	96.32%	97.05%
Bin 6	-1.79	6.06%	21,574	93.46%	94.34%
Bin 7	-2.74	0.62%	20,947	90.74%	91.85%
		Design	***23,084***		

- Base load has been calculated at 57th percentile
- Very similar weather response resulted in LFU multipliers similar to current values

Note: Recommended winter LFU values are now calculated relative to 57th percentile-based reference load, based on aggregate TO design conditions. Prior winter LFU was based on 50th percentile reference load only. Winter LFU values now consider the same design conditions as summer.

Questions?

Our Mission & Vision

Mission
Ensure power system reliability and competitive markets for New York in a clean energy future

Vision
Working together with stakeholders to build the cleanest, most reliable electric system in the nation

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Reference Slides

LFU Model Development

Two key steps:

Determine Load Weather Relationship

- Identify weather variable (e.g., CTHI*) with predictive power to predict peak load
- Develop model to establish the load-weather relationship accounting for effects of calendar events (e.g., Month, Day of Week)
- From the relationship, find the predicted load at various weather values based on recent hot weather conditions

Apply Uncertainty due to Peak Producing (PP) Weather Variation

- Create design condition and bin scenarios from historical peak producing weather conditions
- Evaluate load levels at various weather conditions from the load curve developed in the previous step
- Find ratios of load levels at different weather conditions relative to the design condition and report with the associated probabilities

CTHI – Cumulative Temperature and Humidity Index

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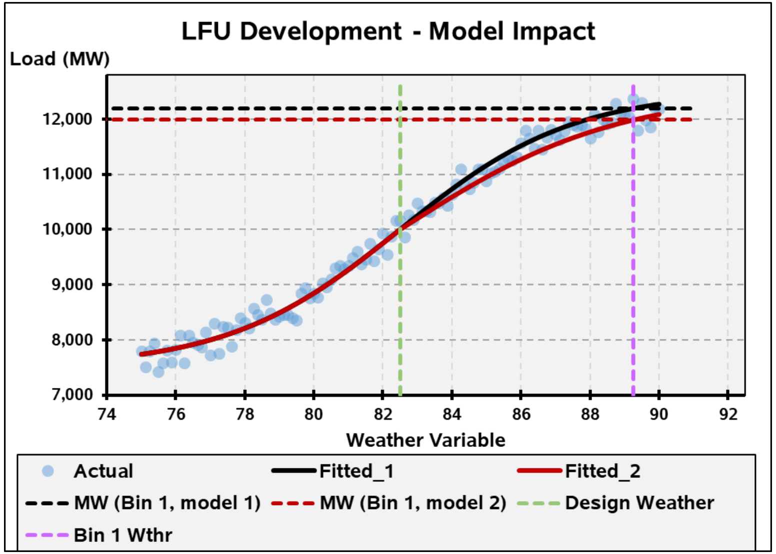
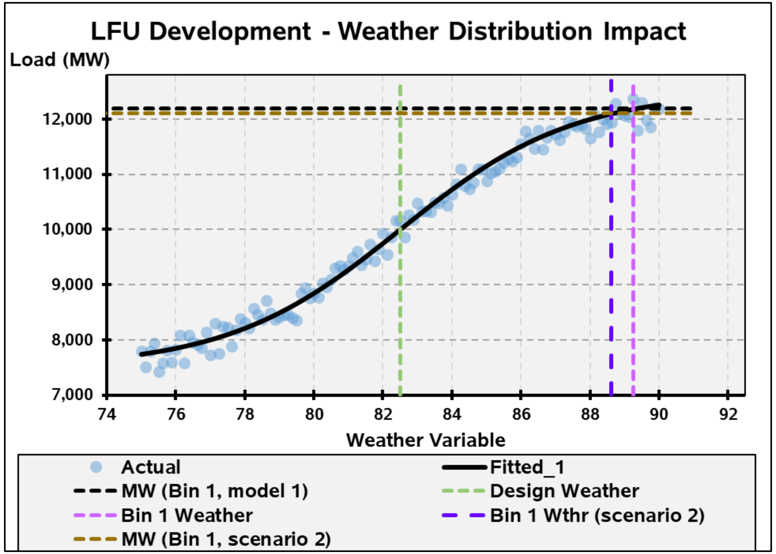
LFU Model Development - Sensitivity

Both steps are important contributors to the model results:



- Same weather distribution
- Same base load
- Updated load weather relationship



- Same load weather relationship
- Same base load
- Updated weather distribution

CTHI

Cumulative Temperature and Humidity Index (CTHI) computation:

Step 1: Calculate hourly THI as a weighted average of the dry bulb temperature (DB) and the wet bulb temperature (WB). There are 24 values per day:

For any day d,

$$(THI)_{di} = 0.6 \times (DB)_{di} + 0.4 \times (WB)_{di}$$

Where $i = 0, 1, 2, \ldots, 23$ indicate the hours of a day

Step 2: Calculate the THI_max for a day. This is the maximum hourly THI value for that day:

$$(THI\_max)_d = \max((THI)_{di})$$

Step 3: Calculate the daily CTHI using a weighted average of three days (the day for which the CTHI is being calculated and the two preceding days):

$$(CTHI)_d = 0.7 \times (THI\_max)_d + 0.2 \times (THI\_max)_{d-1} + 0.1 \times (THI\_max)_{d-2}$$

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Winter Variable

Winter Variable Computation:

Weighted average of daily minimum dry bulb temperature (DB_{min}), daily maximum dry bulb temperature (DB_{max}) and dry bulb temperature at 6 pm (DB_{6pm})

$$\boldsymbol{WinterVar = 55 - a \times DB_{min} + b \times DB_{max} + c \times DB_{6pm}}$$

$$\boldsymbol{where,\ a = 0.2, b = 0.5, c = 0.3}$$

New York ISO

Regression Model Results

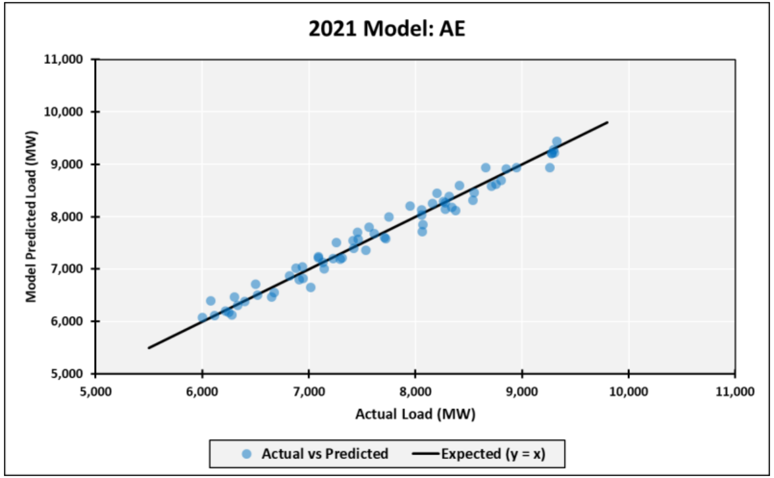
Summer LFU: Zones A-E

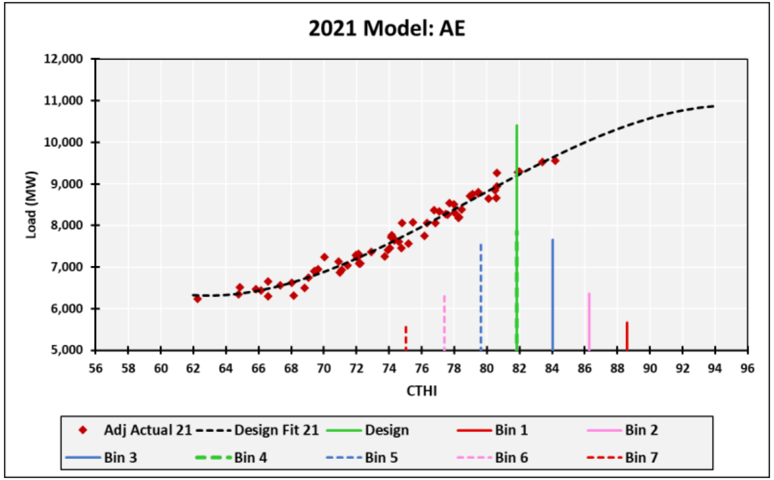
- **NYISO developed model**
  - 2021 standalone model
- **Primary weather variable: CTHI[1]**

Mult. R: 98.6%	*R-sq: 97.2%*		*Adj R-sq: 97.0%*	
	Coef.	**Std.Err.**	**t - Stat**	**p - Value**
Intercept	*127356.8*	*46156.9*	*2.76*	*0.77%*
CTHI	*-4936.6*	*1895.0*	*-2.61*	*1.16%*
CTHI_2	*65.2*	*25.9*	*2.52*	*1.44%*
CTHI_3	*-0.275*	*0.117*	*-2.34*	*2.24%*
Jun	*-229.4*	*49.0*	*-4.68*	*0.00%*

(1) CTHI – Cumulative Temperature and Humidity Index

Note: Adjusted actual values in charts represent loads adjusted for binary effects

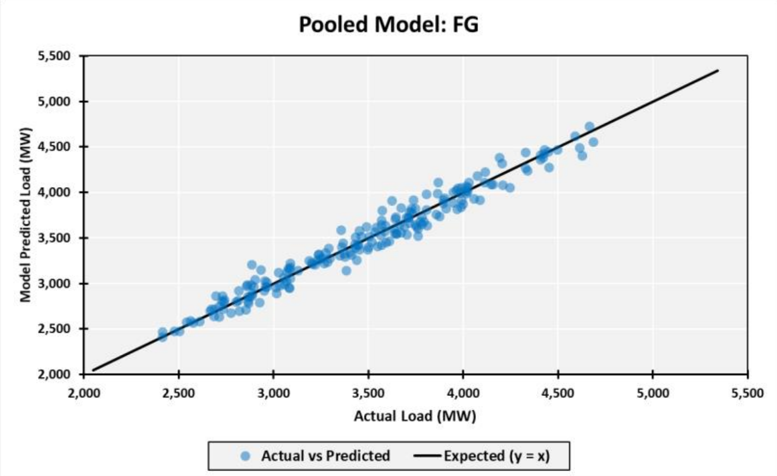


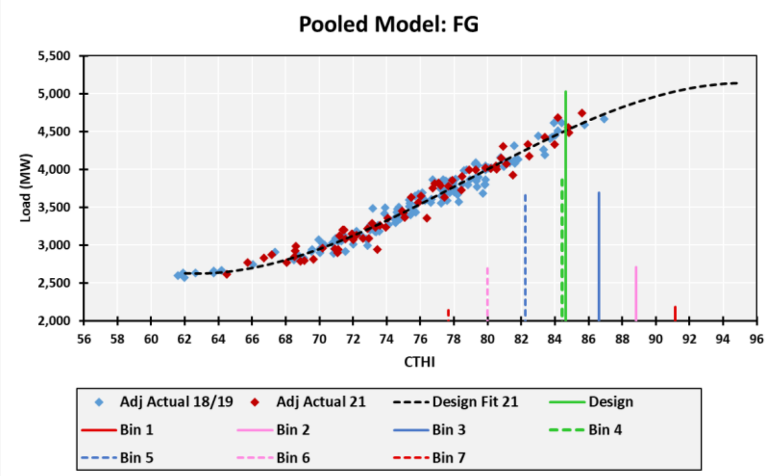


Summer LFU: Zones F&G

- NYISO developed model
  - Pooled model (2018, 2019, 2021)
- Primary weather variable: CTHI

Mult. R: 98.2%	*R-sq: 96.5%*		*Adj R-sq: 96.4%*	
	Coef.	**Std.Err.**	**t - Stat**	**p - Value**
Intercept	*66051.1*	*12340.2*	*5.35*	*0.00%*
CTHI	*-2592.8*	*504.1*	*-5.14*	*0.00%*
CTHI_2	*34.3*	*6.8*	*5.02*	*0.00%*
CTHI_3	*-0.145*	*0.031*	*-4.70*	*0.00%*
Jun	*-56.6*	*19.4*	*-2.91*	*0.41%*
Fri	*-61.2*	*18.4*	*-3.33*	*0.10%*
Y_2019	*-99.8*	*16.0*	*-6.25*	*0.00%*

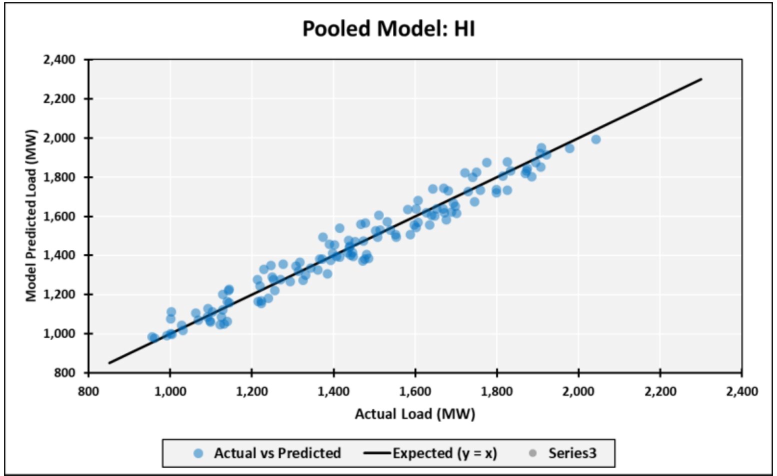


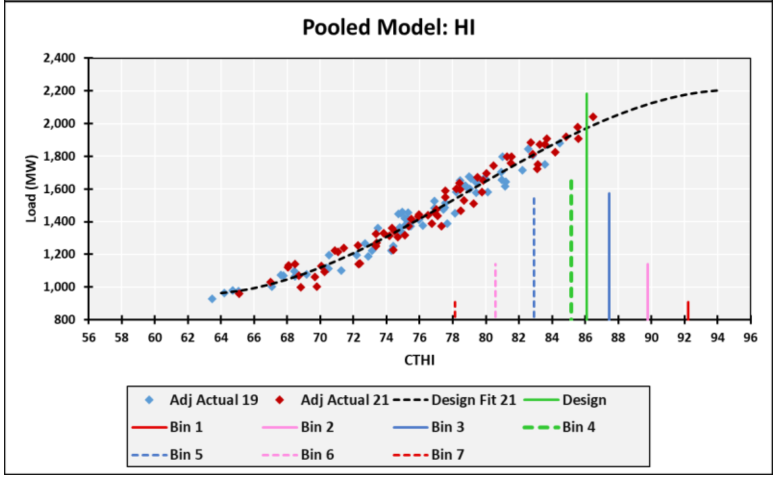


Summer LFU: Zones H&I

- NYISO-Con Ed collaborative approach
  - Pooled model (2019, 2021)
- Primary weather variable: CTHI

Mult. R: 97.8%	*R-sq: 95.7%*		*Adj R-sq: 95.6%*	
	Coef.	**Std.Err.**	**t - Stat**	**p - Value**
Intercept	*33371.9*	*11283.1*	*2.96*	*0.37%*
CTHI	*-1325.3*	*453.3*	*-2.92*	*0.41%*
CTHI_2	*17.5*	*6.1*	*2.90*	*0.44%*
CTHI_3	*-0.074*	*0.027*	*-2.76*	*0.66%*
Y_2019	*25.4*	*10.4*	*2.45*	*1.59%*



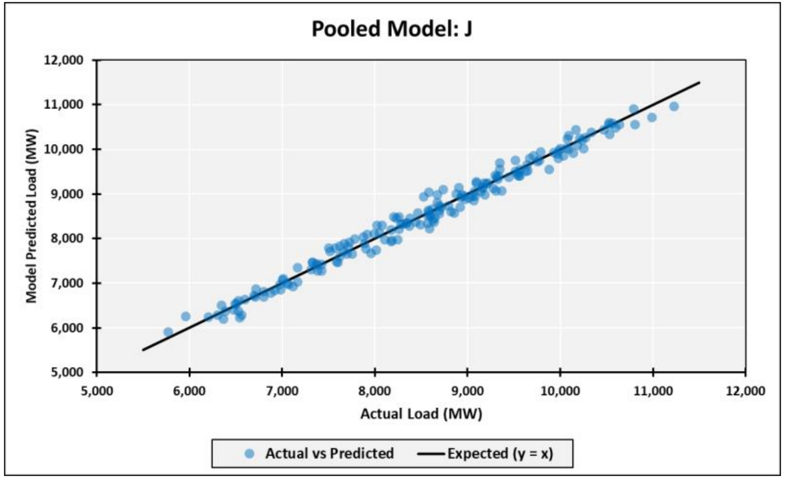


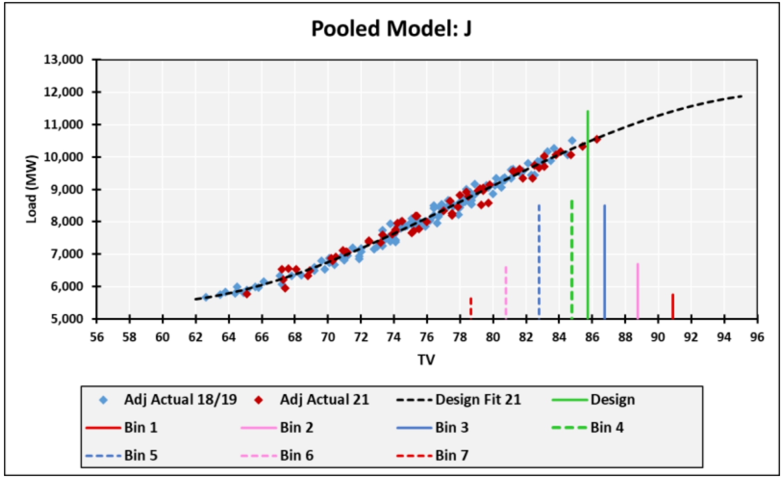
Summer LFU: Zone J

- NYISO-Con Ed collaborative approach
  - Pooled model (2018, 2019, 2021)
- Primary weather variable: TV(1)

Mult. R: 99.1%	*R-sq: 98.3%*		*Adj R-sq: 98.2%*	
	Coef.	**Std.Err.**	**t - Stat**	**p - Value**
Intercept	*96035.7*	*26619.4*	*3.61*	*0.04%*
TV	*-3836.3*	*1077.9*	*-3.56*	*0.05%*
TV_2	*52.1*	*14.5*	*3.59*	*0.04%*
TV_3	*-0.221*	*0.065*	*-3.41*	*0.08%*
MTWT_2019	*641.2*	*31.9*	*20.09*	*0.00%*
MTWT_2018	*716.4*	*32.6*	*21.95*	*0.00%*
Fri_2019	*364.0*	*52.1*	*6.99*	*0.00%*
Fri_2018	*515.9*	*48.9*	*10.54*	*0.00%*

(1) TV – Temperature Variable, developed and used by Con Ed





Winter LFU: NYCA

- Developed by NYISO
- A single weather variable was developed using daily min temperature, max temperature and temperature at specific hour
- Used Winter 2021-22 data, excluding weekends and holidays

Mult. R: 96.2%	*R-sq: 92.5%*		*Adj R-sq: 91.8%*	
	Coef.	**Std.Err.**	**t - Stat**	**p - Value**
Intercept	*19343.2*	*175.6*	*110.17*	*0.00%*
WinterVar	*62.3*	*14.0*	*4.46*	*0.00%*
WinterVar_2	*0.8*	*0.3*	*2.37*	*2.13%*
Fri	*-379.43*	*96.45*	*-3.93*	*0.02%*
Dec	*-198.4*	*113.0*	*-1.76*	*8.47%*
Feb	*-374.2*	*101.5*	*-3.69*	*0.05%*