Weather Variable for Winter Load

LFU Phase 3 Analysis

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Electric System Planning Working Group/Load Load Forecasting Task Force

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Agenda

- Background and Objectives
- Problem Statement
- Methodology
- Results

Background and Objective

- NYISO has historically been a summer peaking system
- Primary emphasis has been on summer Load Forecast Uncertainty (LFU) modeling
- With more electrification of heating load in the future, the system is projected to transition to winter peaking
- The objective is to develop an improved weather variable for predicting winter peak load
  - Univariate approach provides simple framework for defining uncertainty and calculations are simpler than multivariate approach
  - Simple weather normalization calculation
  - Simple interpretation of weather sensitivity

Preliminary analysis was presented at the 9/27/2022 LFTF (Link)

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Assumption

- **Winter peak load is a quadratic function of weather variable**
  - $peak = \beta_0 + \beta_1 \boldsymbol{X} + \beta_2 \boldsymbol{X}^2 + binary\ terms + e$

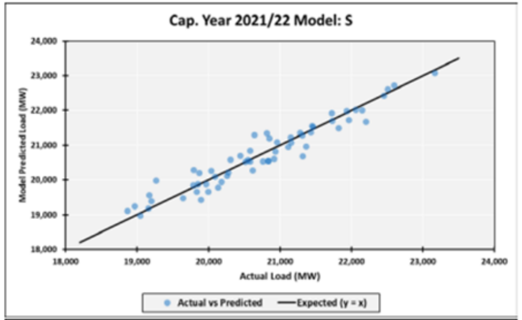
  Where $\boldsymbol{X}$ is weather variable

  - 2020 variable: HDD_55
  - 2022 variable: Combination of daily maximum, minimum and 6pm temperature
  - In both cases, the winter peak load showed a quadratic relationship with the winter variable

2022 Winter LFU (Link)

Mult. R: 96.2% R-sq: 92.5% Adj R-sq: 91.8%

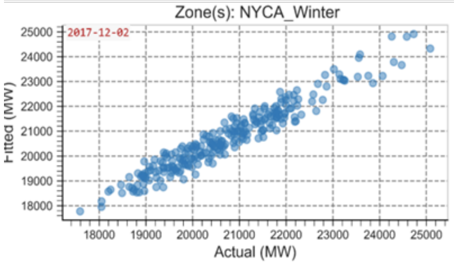
	Coef.	Std.Err.	t - Stat	p - Value
Intercept	19343.2	175.6	110.17	0.00%
WinterVar	62.3	14.0	4.46	0.00%
WinterVar_2	0.8	0.3	2.37	2.13%
Fri	-379.43	96.45	-3.93	0.02%
Dec	-198.4	113.0	-1.76	8.47%
Feb	-374.2	101.5	-3.69	0.05%



2020 Winter LFU (Link)

Adjusted R-Squared: 0.927

	Coef.	Std.Err.	t	P>|t|
Intercept	19500.95	128.6435	151.5891	0
HDD_55	43.0524	9.7942	4.3957	0
HDD_552	1.308	0.1968	6.6479	0
CP_2017_18	651.6266	59.6048	10.9324	0
CP_2018_19	387.0183	58.3658	6.6309	0
Jan	-255.984	58.6974	-4.3611	0
Feb	-795.702	58.551	-13.5899	0
WkEnd	-1489.18	53.9265	-27.615	0
Fri	-425.439	69.1682	-6.1508	0



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Problem Statement

- Main Assumption: Winter peak load (Y) is a function of variable, say $\boldsymbol{X}$ and $\boldsymbol{X^2}$ and other non-weather sensitive variables
  - $\boldsymbol{X}$ is a linear combination different weather variables $X_1, X_2, X_3, \dots, X_n$

$$Y = \beta_0 + \beta_1 \boldsymbol{X} + \beta_1 \boldsymbol{X^2} + other\ non\ weather\ terms + e$$

$$\boldsymbol{X} = \sum_{i=1}^{n} \boldsymbol{w_i} X_i = \boldsymbol{w_1} X_1 + \boldsymbol{w_2} X_2 + \boldsymbol{w_3} X_3 + \cdots + \boldsymbol{w_n} X_n$$

Our goal is to find optimal set of weights ($\boldsymbol{w_1}, \boldsymbol{w_2}, \boldsymbol{w_3}, \dots, \boldsymbol{w_n}$)

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Initial Summary Variables

Variable	Explored in 9/27/2022 Analysis
Average Morning Dry Bulb (DB) Temperature	X
Average Morning Wind Chill (WC)	
Average Afternoon Dry Bulb Temperature	X
Average Afternoon Wind Chill	
Average Evening Dry Bulb Temperature	X
Average Evening Wind Chill	
Average Lag Evening Dry Bulb Temperature	X

$$X_{Mor} = Avg(X_{HB06} \sim X_{HB11})$$
$$X_{Aft} = Avg(X_{HB12} \sim X_{HB17})$$
$$X_{Eve} = Avg(X_{HB18} \sim X_{HB23})$$

$Wind\ Chill, WC = f(\mathbf{DB}, \mathbf{WS})$

- DB = Dry Bulb Temperature (°F)
- WS = Wind Speed (mph)

$$WC = 35.74 + 0.6215(DB) - 35.75(WS^{0.16}) + 0.4275(DB)(WS^{0.16})$$

https://www.weather.gov/ama/windchill

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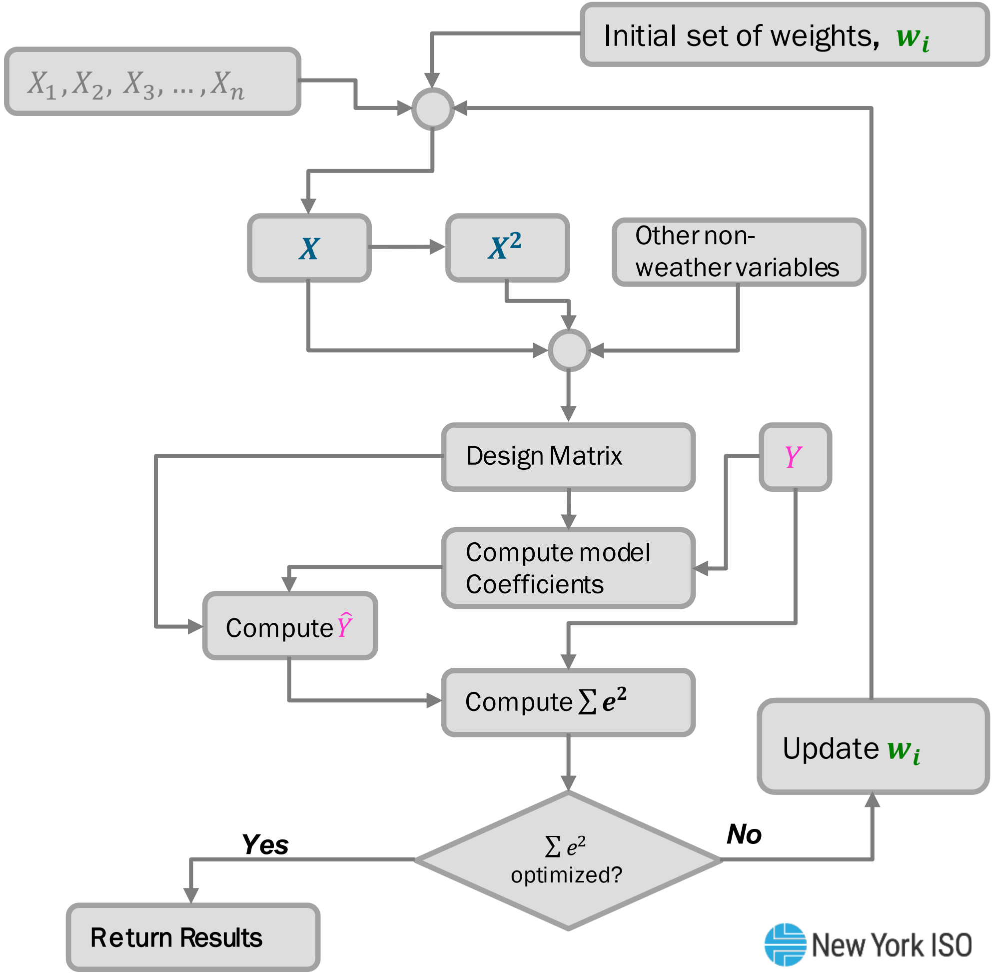
Methodology

- Start with a random set of values of $w_1, w_2, w_3, \ldots, w_n$ and calculate X as $\sum_{i=1}^{n} w_i X_i$
- Make a regression model with winter peak as dependent variable Y and X, X^2 as independent variables, along with other non-weather variables.
  - ❑ Data:
    - Dec, Jan, Feb
    - 2017-18, 2018-19, 2021-22, 2022-23
    - Weekends included
    - Holidays removed
- Calculate coefficients of the regression model.
- Using the coefficients and design matrix, calculate predicted peak load $\hat{Y}$
- Calculate sum of squared error, as $\sum e^2 = \sum(Y_i - \hat{Y}_i)^2$
- Vary $w_1, w_2, w_3, \ldots, w_n$ so that $\sum e^2$ is minimized



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Candidate Variables

Candidate 1	Candidate 2
Pass 1 ❑ All seven summary variables (including lag evening temperature) were considered for initial optimization ❑ Optimization was performed for all zones ❑ A weight set was chosen based on the load weighted average ❑ Initial optimization provided an "in-day" metric ***Pass 2*** ❑ Second round optimization was performed to investigate lag impact of the initial optimized weather metric ❑ A weight set (applicable for the in-day and 2 lag terms) was chosen based on the load weighted average	❑ Initially 6 variables (w/o lag evening temperature) were used to the in-day metric ❑ Final weather metric was built by taking a weighted average of three days (in-day metric and 2 lag terms) ❑ One round of optimization ❑ Weight set was chosen guided by the load weighted average

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Results – Candidate 1

- Candidate 1 – Pass 1

	Morning		Afternoon		Evening		Lag 1 Evening
Zone	DB	WC	DB	WC	DB	WC	DB
A	0.0%	6.6%	0.0%	85.4%	0.0%	7.8%	0.2%
B	7.9%	0.0%	1.2%	48.3%	0.0%	17.4%	25.3%
C	12.3%	0.0%	12.2%	35.6%	0.0%	15.4%	24.6%
D	9.3%	3.2%	0.0%	27.0%	16.8%	14.3%	29.4%
E	0.0%	1.6%	0.0%	45.2%	0.0%	13.2%	40.0%
F	0.0%	0.0%	44.5%	26.7%	0.0%	3.1%	25.7%
G	6.0%	0.0%	54.3%	6.6%	0.0%	13.4%	19.6%
H	0.0%	0.0%	72.7%	2.5%	0.0%	4.9%	19.8%
I	0.0%	11.5%	36.2%	16.5%	0.0%	12.3%	23.4%
J	0.0%	0.0%	46.1%	8.5%	0.0%	14.2%	31.1%
K	0.0%	1.1%	32.2%	26.3%	7.9%	11.7%	20.7%
Load Wgt Avg	2.5%	1.4%	29.7%	27.9%	1.6%	12.4%	24.5%
Recommended	0.0%	0.0%	35.0%	25.0%	0.0%	15.0%	25.0%

	R-Sq Value	
Zone	Optimized	Recommended
A	86.9%	85.4%
B	89.1%	88.9%
C	91.2%	91.0%
D	92.0%	91.8%
E	88.5%	87.1%
F	89.4%	88.9%
G	90.0%	89.6%
H	77.5%	75.8%
I	83.1%	82.9%
J	95.2%	95.0%
K	93.1%	93.0%
Load Wgt Avg	91.2%	90.8%

In-Day Var for day i, $v_i = 0.35DB_{aft_i} + 0.25WC_{aft_i} + 0.15WC_{eve_i} + 0.25DB_{aft_{i-1}}$

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Results – Candidate 1

- Candidate 1 – Pass 2

	Variable v		
Zone	In Day (i)	Lag 1 (i-1)	Lag 2 (i-2)
A	100.0%	0.0%	0.0%
B	88.8%	0.0%	11.2%
C	87.4%	0.0%	12.6%
D	87.3%	6.9%	5.8%
E	80.1%	5.4%	14.5%
F	84.1%	0.0%	15.9%
G	88.0%	0.0%	12.0%
H	88.1%	2.2%	9.7%
I	85.4%	0.0%	14.6%
J	83.8%	5.7%	10.5%
K	88.8%	0.0%	11.2%
Load Wgt Avg	87.1%	2.3%	10.6%
Recommended	85.0%	0.0%	15.0%

	R-Sq Value	
Zone	Optimized	Recommended
A	85.4%	84.2%
B	89.6%	89.5%
C	92.0%	92.0%
D	91.9%	91.9%
E	88.9%	88.8%
F	90.6%	90.6%
G	90.5%	90.4%
H	76.5%	76.4%
I	83.8%	83.8%
J	95.7%	95.7%
K	93.6%	93.5%
Load Wgt Avg	91.6%	91.4%

$Candiate_1$ for day $i = 0.85v_i + 0.15v_{i-2}$

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Results – Candidate 2

- Single Pass

	Morning		Afternoon		Evening		Lag 1 Evening		
Zone	DB	WC	DB	WC	DB	WC	*In-Day*	*Lag 1*	*Lag 2*
A	0.0%	6.6%	0.0%	85.7%	0.0%	7.7%	99.8%	0.2%	0.0%
B	27.0%	0.0%	3.1%	51.3%	0.0%	18.6%	81.6%	7.8%	10.6%
C	31.2%	0.0%	16.7%	35.8%	0.0%	16.3%	81.4%	7.1%	11.4%
D	30.2%	0.1%	0.0%	33.4%	17.2%	19.1%	75.5%	21.9%	2.6%
E	6.0%	23.4%	0.0%	57.4%	0.2%	13.0%	70.2%	17.6%	12.2%
F	24.8%	0.0%	1.6%	61.0%	0.0%	12.6%	78.5%	9.5%	12.1%
G	22.8%	0.0%	54.9%	7.7%	0.0%	14.7%	82.4%	5.0%	12.7%
H	3.6%	0.0%	90.6%	2.4%	1.3%	2.1%	80.2%	11.4%	8.4%
I	0.0%	30.0%	46.8%	10.3%	0.0%	12.9%	77.4%	6.7%	15.9%
J	17.4%	4.6%	53.3%	9.4%	0.0%	15.3%	74.9%	15.1%	10.1%
K	8.1%	7.0%	40.0%	28.6%	3.6%	12.7%	80.3%	5.4%	14.3%
Load Wgt Avg	16.4%	5.4%	30.9%	32.2%	1.1%	14.0%	79.8%	10.0%	10.2%
Recommended	15.0%	0.0%	35.0%	35.0%	0.0%	15.0%	80.0%	10.0%	10.0%

	R-Sq Value	
Zone	Optimized	Recommended
A	86.9%	85.2%
B	89.5%	89.3%
C	91.8%	91.5%
D	92.1%	91.7%
E	88.5%	87.3%
F	89.7%	89.9%
G	90.8%	90.2%
H	77.9%	75.9%
I	84.1%	83.6%
J	95.6%	95.3%
K	93.9%	93.7%
Load Wgt Avg	91.7%	91.2%

In-Day Var for day i, $v_i = 0.15DB_{mor_i} + 0.35DB_{aft_i} + 0.35WC_{aft_i} + 0.15WC_{eve_i}$

$Candiate_2$ for day $i = 0.8v_i + 0.1v_{i-1} + 0.1v_{i-2}$

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LFU Model Comparison

WinVar = HDD55				
	Coefficient	StdErr	T-Stat	P-Value
CONST	18429.006	151.477	121.662	0.00%
WinVar	88.405	14.472	6.109	0.00%
WinVar_sq	0.411	0.354	1.159	24.89%
HDD55.CY_21_22	356.84	67.683	5.272	0.00%
Calendar.Feb	-548.651	78.55	-6.985	0.00%
Calendar.Jan	-136.782	79.359	-1.724	8.75%
Calendar.Fri	-187.627	82.982	-2.261	2.57%
R-Sq	88.80%			

WinVar = combination of max, min and HB18 temp				
	Coefficient	StdErr	T-Stat	P-Value
CONST	18626.267	121.082	153.832	0.00%
WinVar	87.623	12.585	6.963	0.00%
WinVar_sq	0.491	0.344	1.427	15.63%
HDD55.CY_21_22	372.534	64.236	5.799	0.00%
Calendar.Feb	-499.481	74.582	-6.697	0.00%
Calendar.Jan	-148.708	75.563	-1.968	5.15%
Calendar.Fri	-353.113	78.495	-4.499	0.00%
R-Sq	89.90%			

WinVar = Candidate_1_55				
	Coefficient	StdErr	T-Stat	P-Value
CONST	18399.032	124.525	147.754	0.00%
WinVar	85.091	12.128	7.016	0.00%
WinVar_sq	0.607	0.294	2.061	4.16%
HDD55.CY_21_22	326.783	51.046	6.402	0.00%
Calendar.Feb	-550.54	59.546	-9.246	0.00%
Calendar.Jan	-223.657	60.79	-3.679	0.04%
Calendar.Fri	-302.949	62.508	-4.847	0.00%
R-Sq	93.60%			

WinVar = Candidate_2_55				
	Coefficient	StdErr	T-Stat	P-Value
CONST	18467.695	113.095	163.294	0.00%
WinVar	82.464	10.564	7.806	0.00%
WinVar_sq	0.476	0.249	1.914	5.82%
HDD55.CY_21_22	347.808	50.474	6.891	0.00%
Calendar.Feb	-559.535	59	-9.484	0.00%
Calendar.Jan	-229.814	60.228	-3.816	0.02%
Calendar.Fri	-342.889	61.887	-5.541	0.00%
R-Sq	93.70%			

- Data: 2021-22, 2022-23, weekday, Dec – Feb, holidays removed
- Candidate variables were referenced to 55

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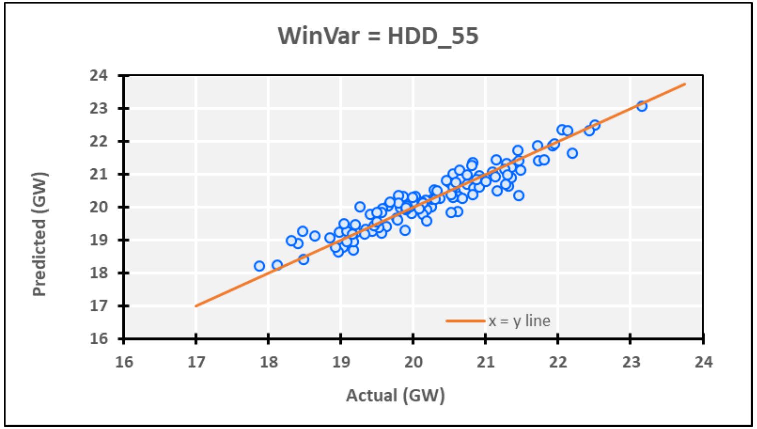
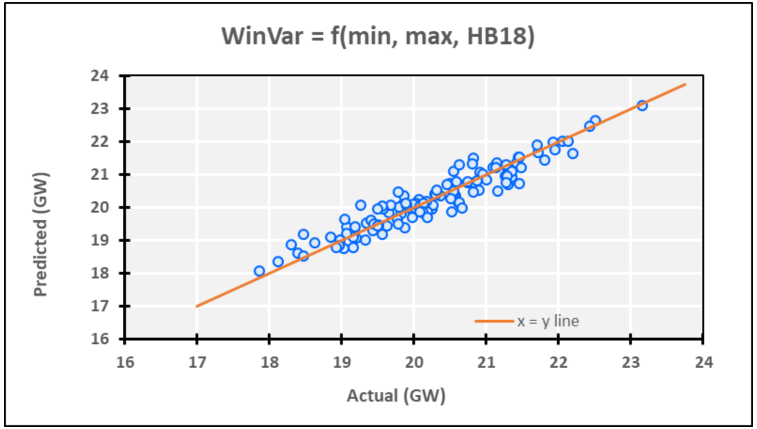
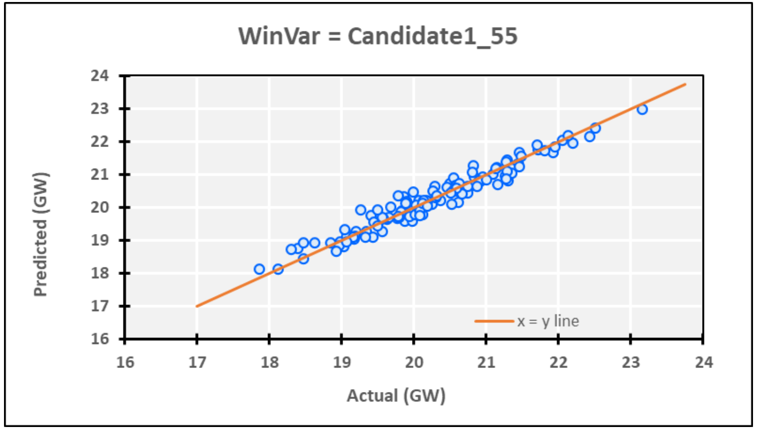
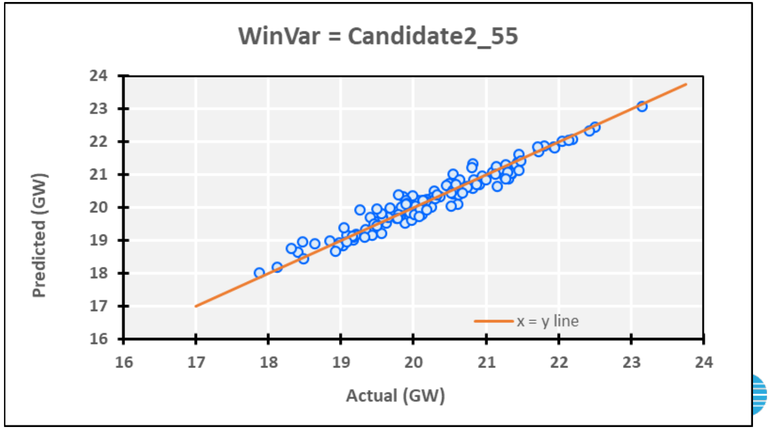
LFU Model Comparison









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Recommendation

- Both candidate 1 and 2 show significant improvement in overall fits relative to the variables used in prior years
- Both candidates have “lag” component
- NYISO proposes to use candidate 2 for winter LFU to be used in IRM 2024 LFU
  - Candidate 2 calculation is simpler
  - Candidate 2 lag weights are more intuitive

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