End-Use Forecasting Models for Monthly Energy

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NEW YORK INDEPENDENT SYSTEM OPERATOR

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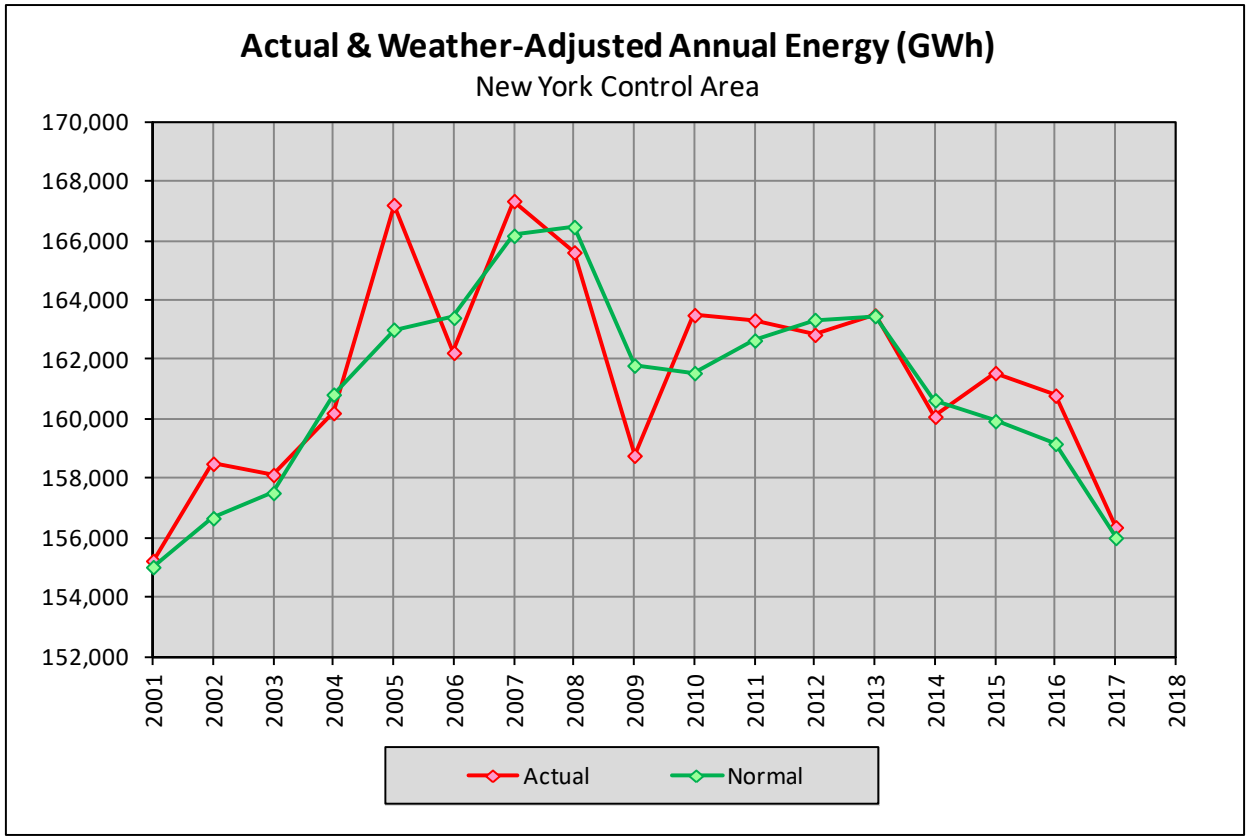
Overview

- Comparison of econometric and end-use models – why end-use models are employed;
- Data sources for end-use models;
  - Commercial sector data development.
  - Residential sector data development.
- Example of a statewide end-use model for all sectors.

Comparison of Econometric & End-Use Models



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Econometric Models

Two possible forms of an econometric model of monthly energy, one with just GDP and one with a trend on GDP.

Energy = Constant + a*GDP + b*HDD + c*CDD + err

Energy = Constant + a*GDP +b*GDP*Trend+ c*HDD + d*CDD + err

- There are many other possible model forms and variables to include, such as households, price, and other variables.
- Technology and efficiency trends are usually not explicitly addressed.

Statistically-Adjusted End-Use Models

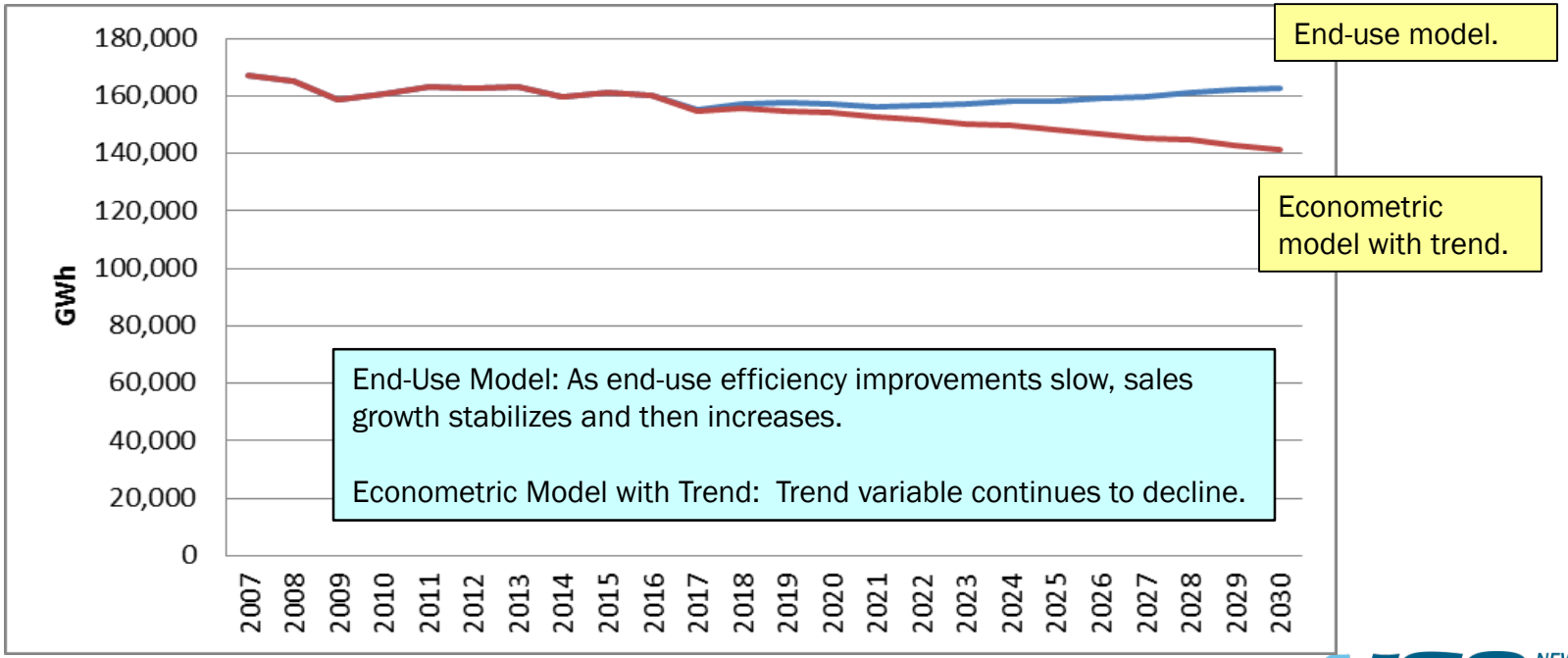
One possible form of an end-use model of monthly energy:

$$\text{Energy} = a_1 * \text{Heating} + a_2 * \text{Cooling} + a_3 * \text{Other} + \text{err}$$

where Heating, Cooling and Other are functions of population growth, economic activity, weather, price, and end-use intensity trends.

The coefficients a_1, a_2, and a_3 are estimated using least-squares estimation technique. The coefficients statistically adjust the end-use estimates to observed system energy – thus, the term SAE model.

End-Use Model vs. Econometric Model With a Trend



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Statewide SAE Model for All Sectors

- Ideally, monthly energy by sector could be used for residential and commercial models in each Transmission District.
- However, EIA monthly energy usage data separates New York electric utilities from other load serving entities. As a result, commercial and residential use per account data are not representative of a Transmission District.
- NYISO has accurate data for the entire Transmission District, so the end-use data for all sectors are combined into a single model.

Combining End-Use Data from Multiple Sectors

- Construct XHeat, XCool and XOther data for residential and commercial classes for entire state.
  - Include data for industrial sector in XOther.
  - Convert to indexes referenced to a specific year.
- Combine residential and commercial variables in proportion to the residential and commercial shares of annual energy for that year.
- Result is a set of Xheat, XCool and XOther variables that represent all energy sectors.
- These variables are used to model statewide monthly energy.

Data Sources for End-Use Models

Data Sources

- **Energy Information Administration (EIA)**
  - 2017 Annual Energy Outlook
- **Itron SAE Model Database for 2017 for Mid-Atlantic**
  - Historical and forecast trends in end-use saturations and efficiencies
- **New York data used to calibrate Mid-Atlantic data SAE data**
  - EIA monthly energy data by sector for New York
  - DOE 2009 Residential Energy Consumption Survey
  - Census Bureau data on New York housing stocks
  - NYSERDA Residential Market Baseline Study
- **NYISO monthly usage data by Transmission District**

EIA 2016 Annual Energy Usage and Accounts In New York State

2016 Annual Energy - GWh

Segment	Res	Com	Ind	Oth	Total
Major Utilities	39,187	23,869	3,570	339	66,965
Other ESCO's	11,571	52,239	13,487	2,417	79,714
Total	50,758	76,108	17,057	2,756	146,679

2016 Electric Accounts

Segment	Res	Com	Ind	Oth	Total
Major Utilities	5,644,796	720,035	2,417	5	6,367,253
Other ESCO's	1,475,219	353,241	5,183	4	1,833,647
Total	7,120,015	1,073,276	7,600	9	8,200,900

2016 MWh/Account

Segment	Res	Com	Ind	Oth	Total
Major Utilities	6.94	33.15	1,477	67,800	10.52
Other ESCO's	7.84	147.88	2,602	604,250	43.47
Total	7.13	70.91	2,244	306,222	17.89

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EIA 2016 Percentages of Energy and Accounts In New York State

2016 Annual Energy Shares

Segment	Res	Com	Ind	Oth	Total
Major Utilities	77%	31%	21%	12%	46%
Other ESCO's	23%	69%	79%	88%	54%

2016 Electric Account Shares

Segment	Res	Com	Ind	Oth	Total
Major Utilities	79%	67%	32%	57%	78%
Other ESCO's	21%	33%	68%	43%	22%

US Census: New York Housing Units - 2010

Housing Structure	New York State	New York City	Westchester	Suffolk	Nassau	All Other Areas
1-unit, Detached	3,399,808	314,225	169,079	453,759	353,058	2,109,687
1-unit, Attached	390,965	226,671	19,611	23,826	12,575	108,282
2 Units	869,382	453,855	32,737	22,551	36,645	323,594
3 or 4 Units	613,621	356,925	29,162	14,877	11,931	200,726
5 to 9 Units	442,856	234,178	19,617	15,432	9,007	164,622
10 or More Units	2,190,385	1,777,884	99,974	33,642	43,971	234,914
Mobile Home & Other	201,194	6,909	568	5,934	1,009	186,774
Total Units	8,108,211	3,370,647	370,748	570,021	468,196	3,328,599
Occupied Units	7,317,755	3,109,784	347,232	499,922	448,528	2,912,289

Housing Structure	New York State	New York City	Westchester	Suffolk	Nassau	All Other Areas
1 to 2 units	57%	30%	60%	88%	86%	76%
3 to 4 units	8%	11%	8%	3%	3%	6%
5 to 9 units	5%	7%	5%	3%	2%	5%
10 or more	27%	53%	27%	6%	9%	7%
Mobile Home & Other	2%	0%	0%	1%	0%	6%
Total	100%	100%	100%	100%	100%	100%

http://www.usa.com/new-york-ny-housing.htm#Units-in-Structure

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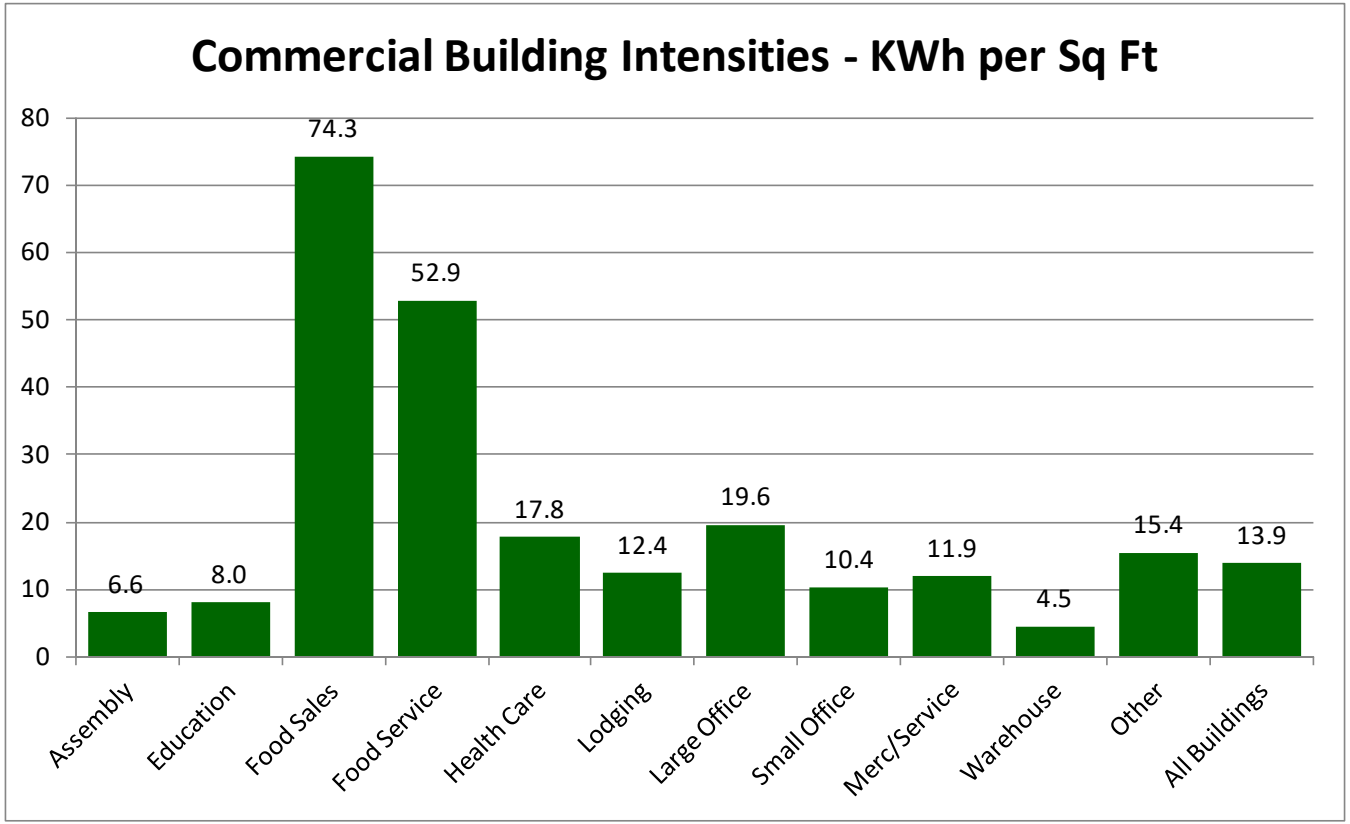
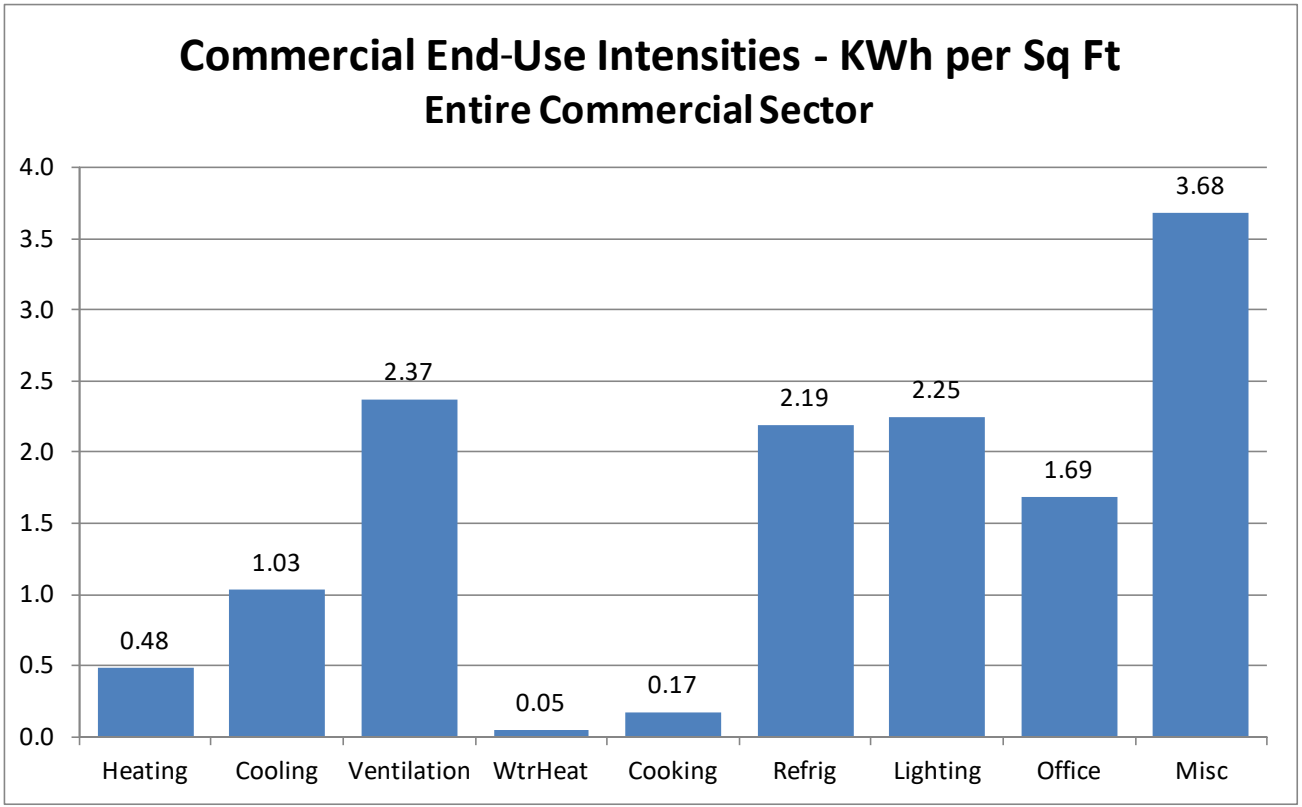
NYSERDA Residential Market Baseline Study - Cooling Saturations, 2013 & Earlier

Utility	No	Yes	CAC	HP/OTH	RAC	Total
Central Hudson	14%	86%	34%	3%	49%	100%
ConEd	7%	93%	14%	0%	79%	100%
LIPA	6%	94%	48%	3%	43%	100%
National Grid	26%	74%	27%	1%	46%	100%
NYSEG	25%	75%	22%	2%	51%	100%
O&R	9%	91%	49%	0%	42%	100%
RG&E	14%	86%	43%	1%	42%	100%
Grand Total	19%	81%	27%	2%	52%	100%

Commercial Sector End-Use Data for New York



Reference year is 2013



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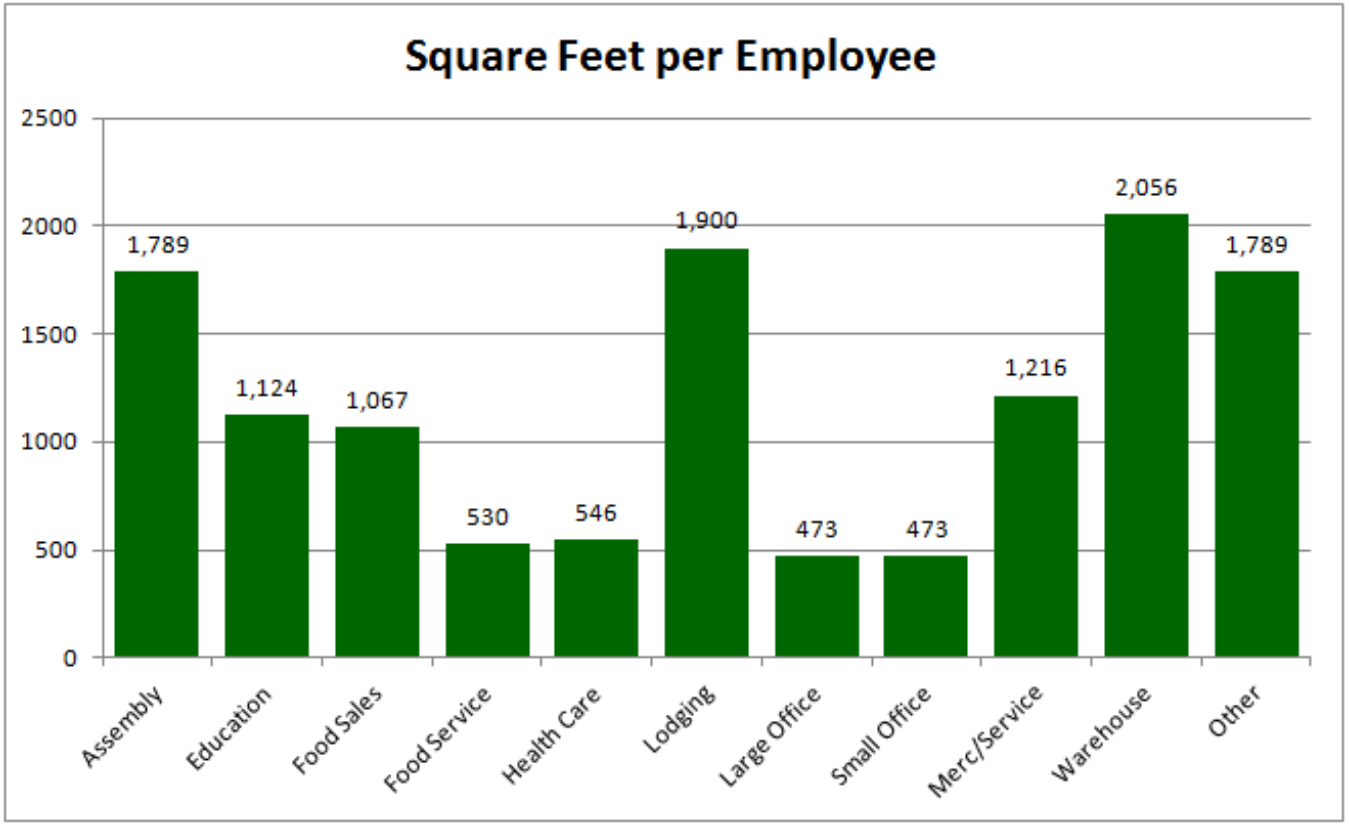
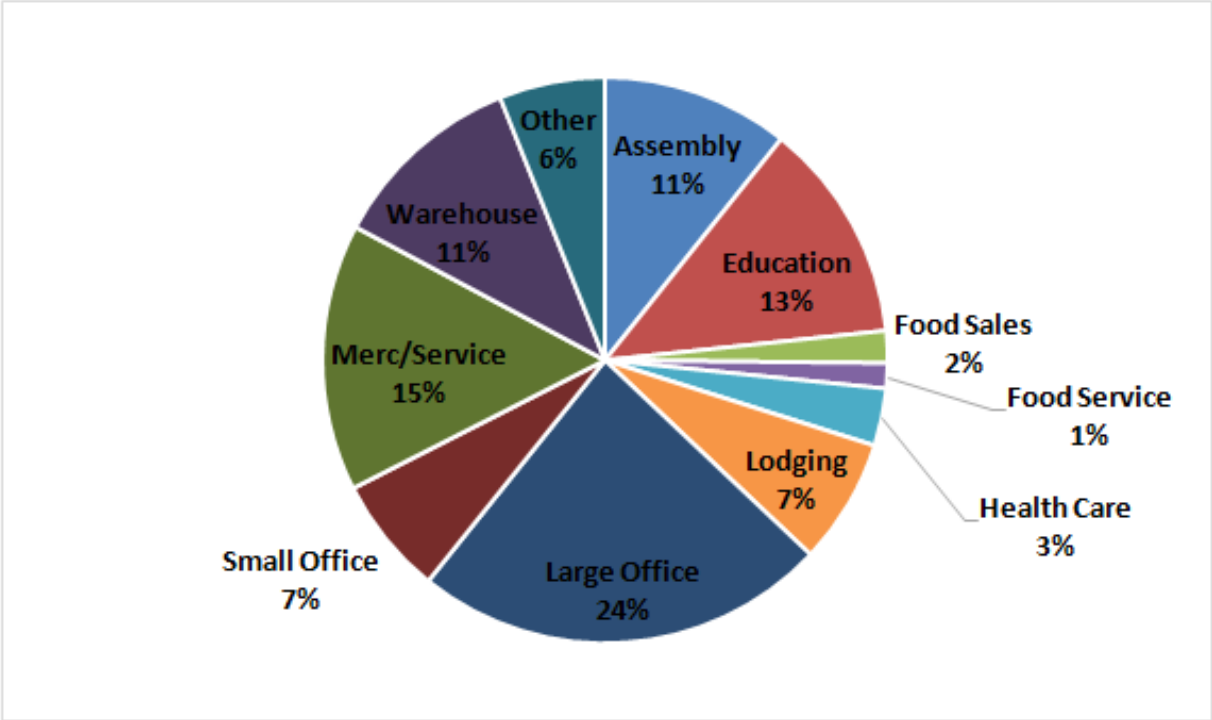


Reference year is 2013

Percentage of Square Footage by Building Type



Reference year is 2013

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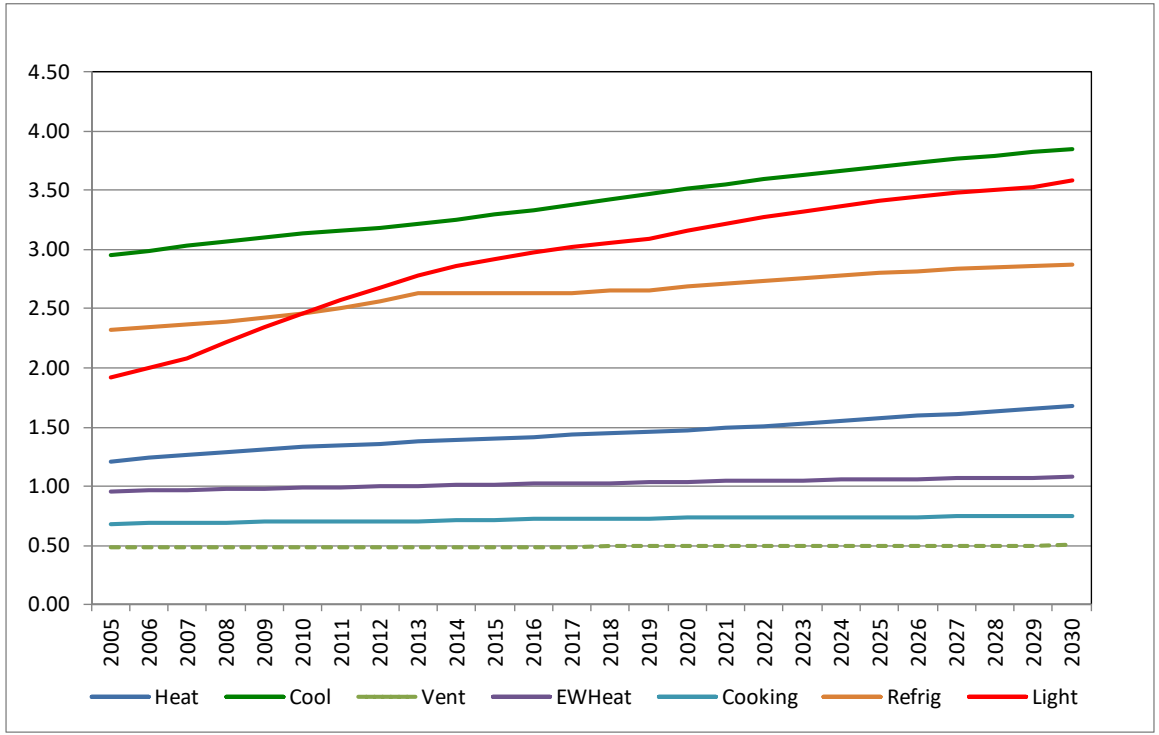
Commercial Sector End-Use Efficiency Indexes



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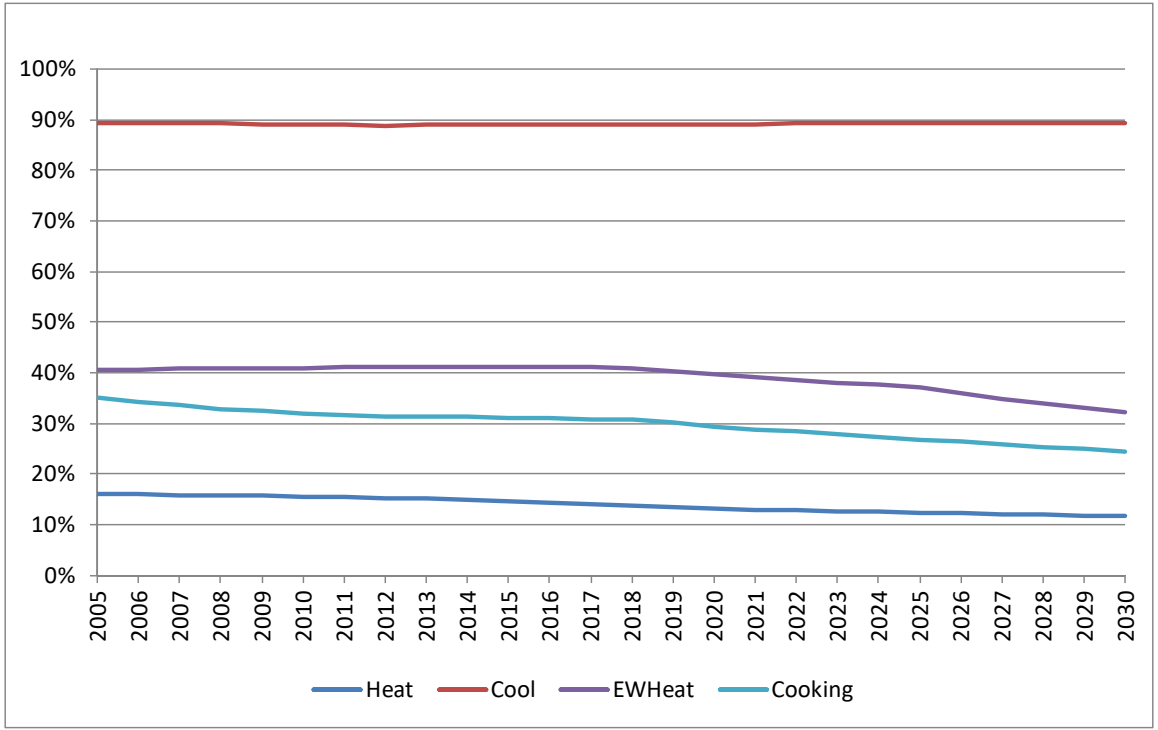
Commercial Sector End-Use Saturations



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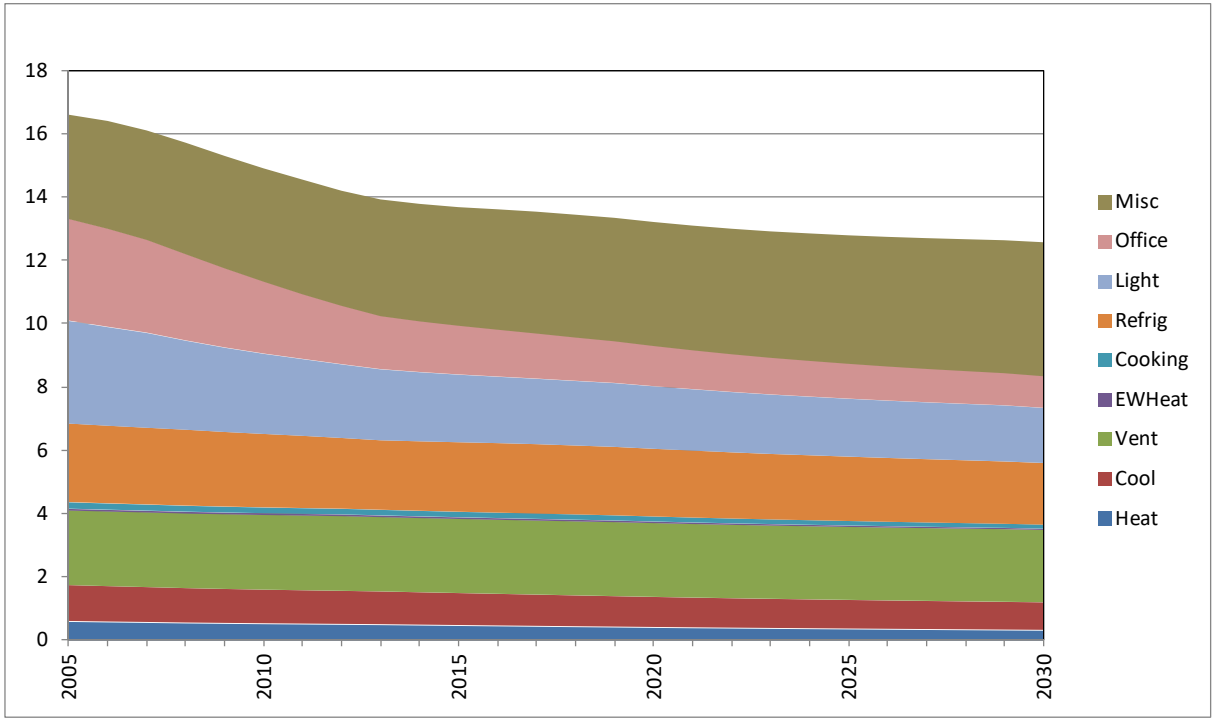
Commercial Sector Intensities – KWh/Sq Ft



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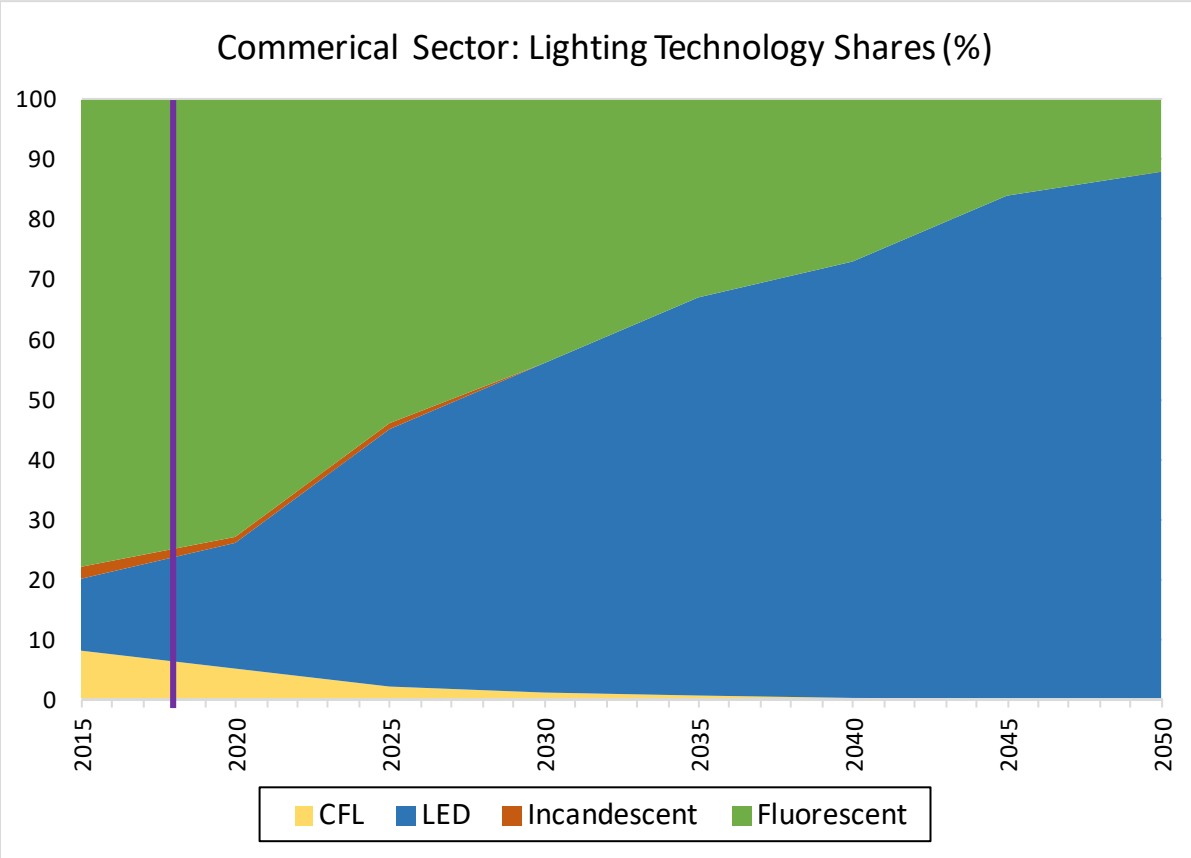

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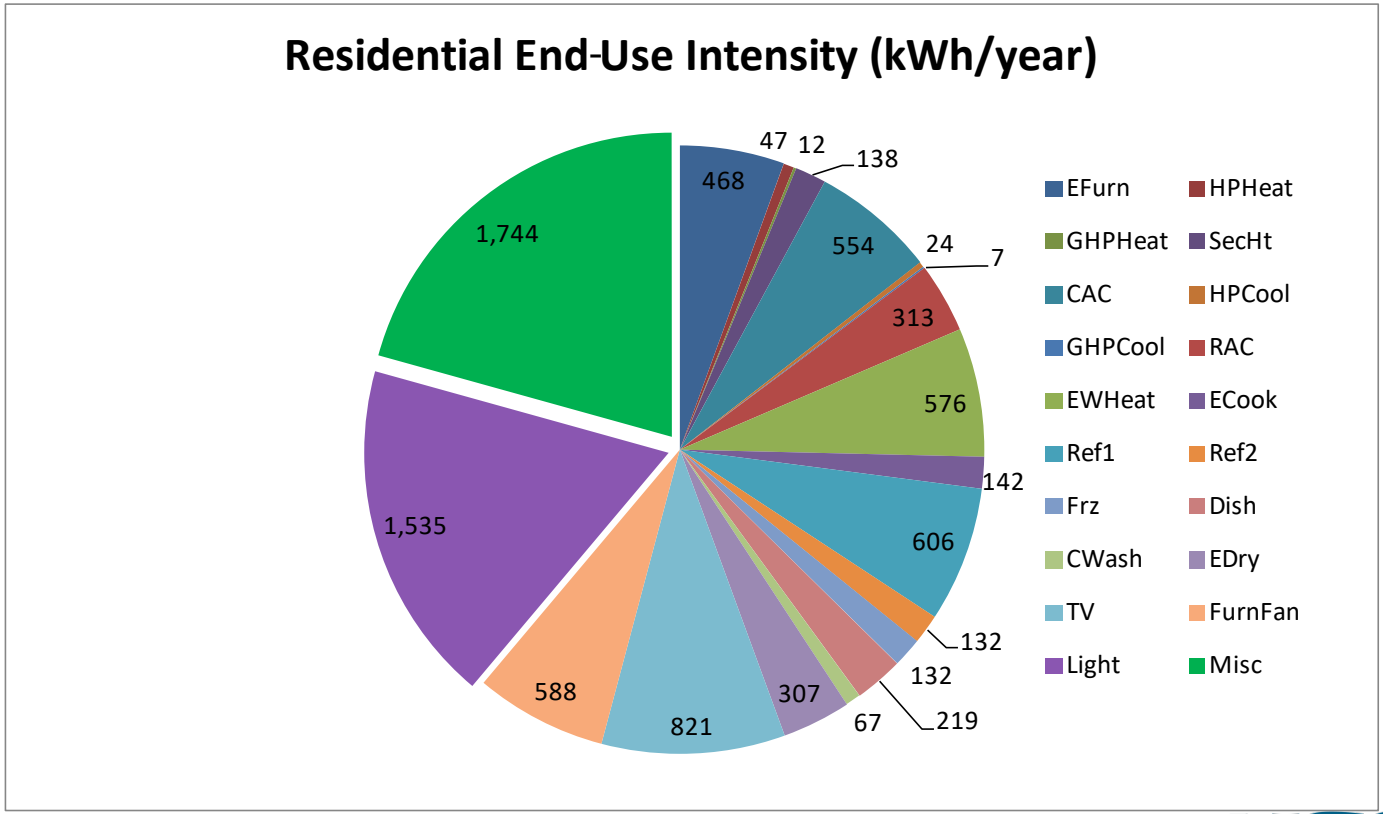
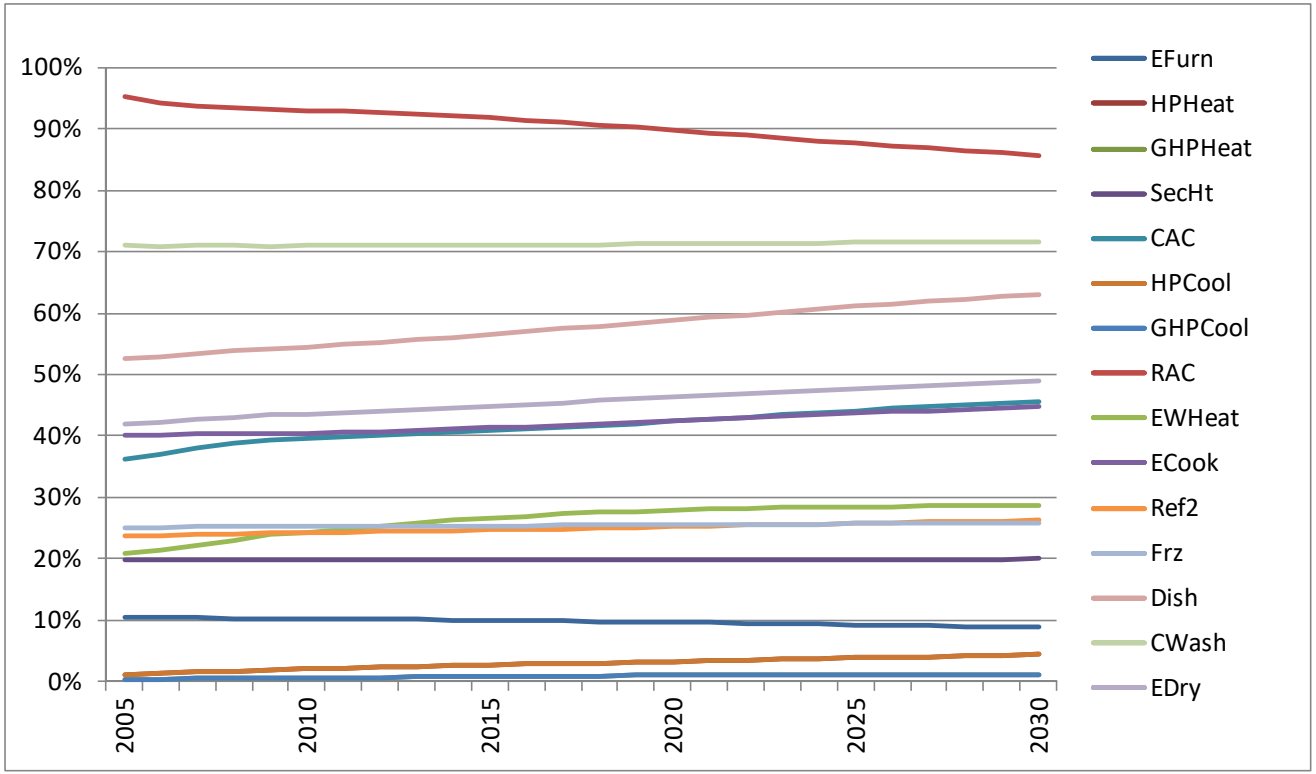
Residential Sector End-Use Data for New York



Reference year is 2009

Residential Appliance Saturations



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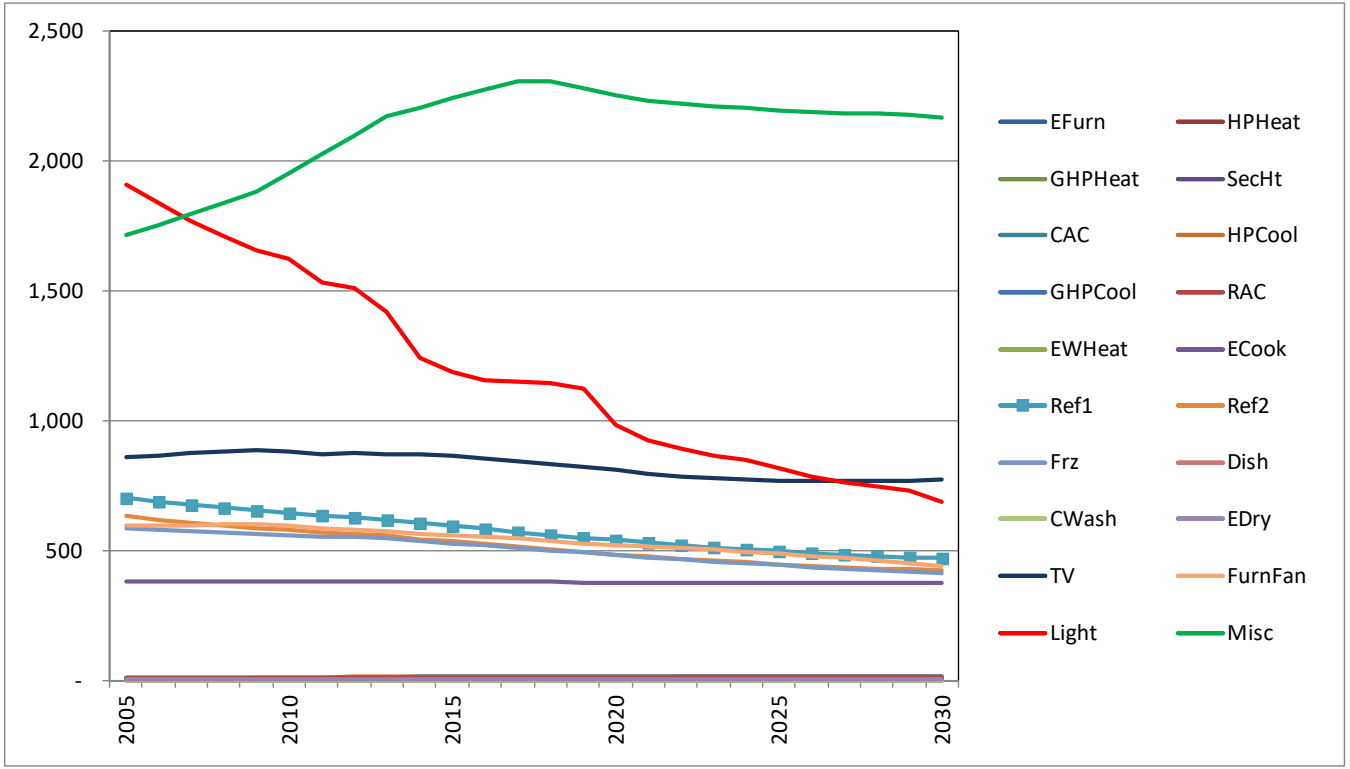
Residential Appliance Efficiency Levels



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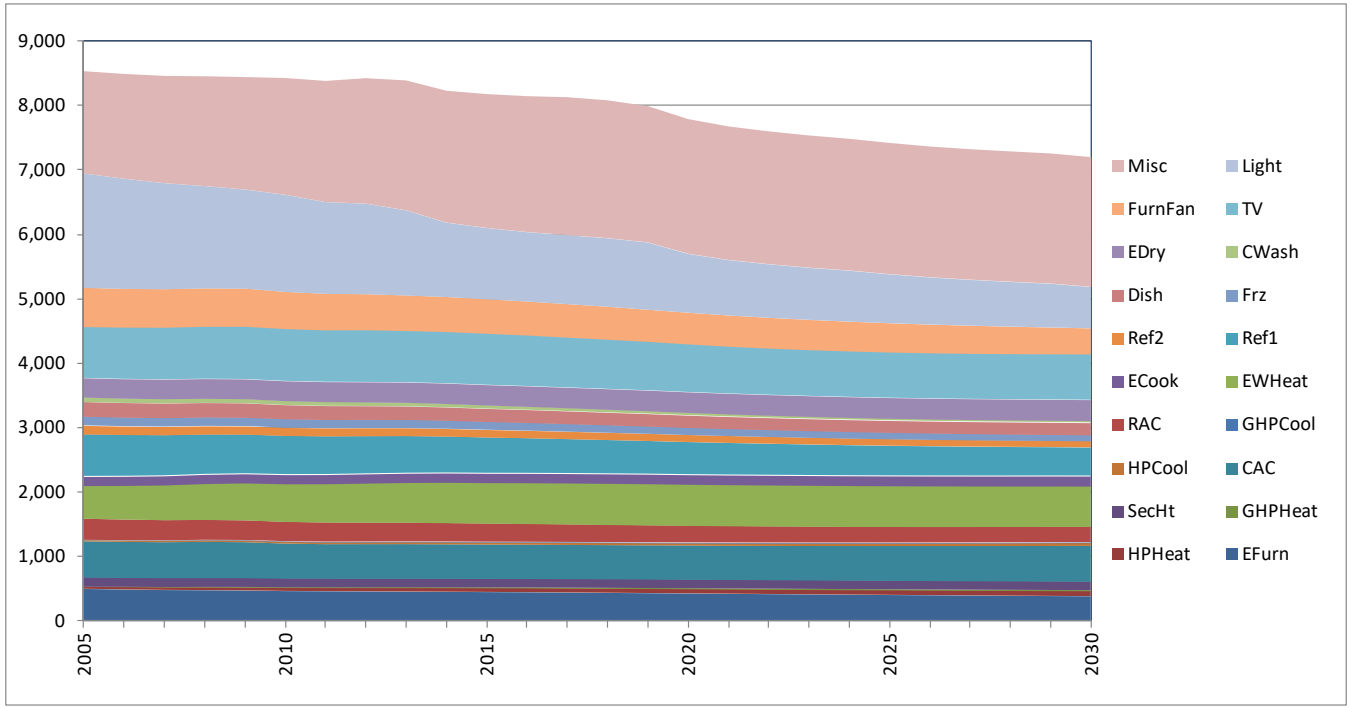
Residential Sector Intensities – KWh/Household



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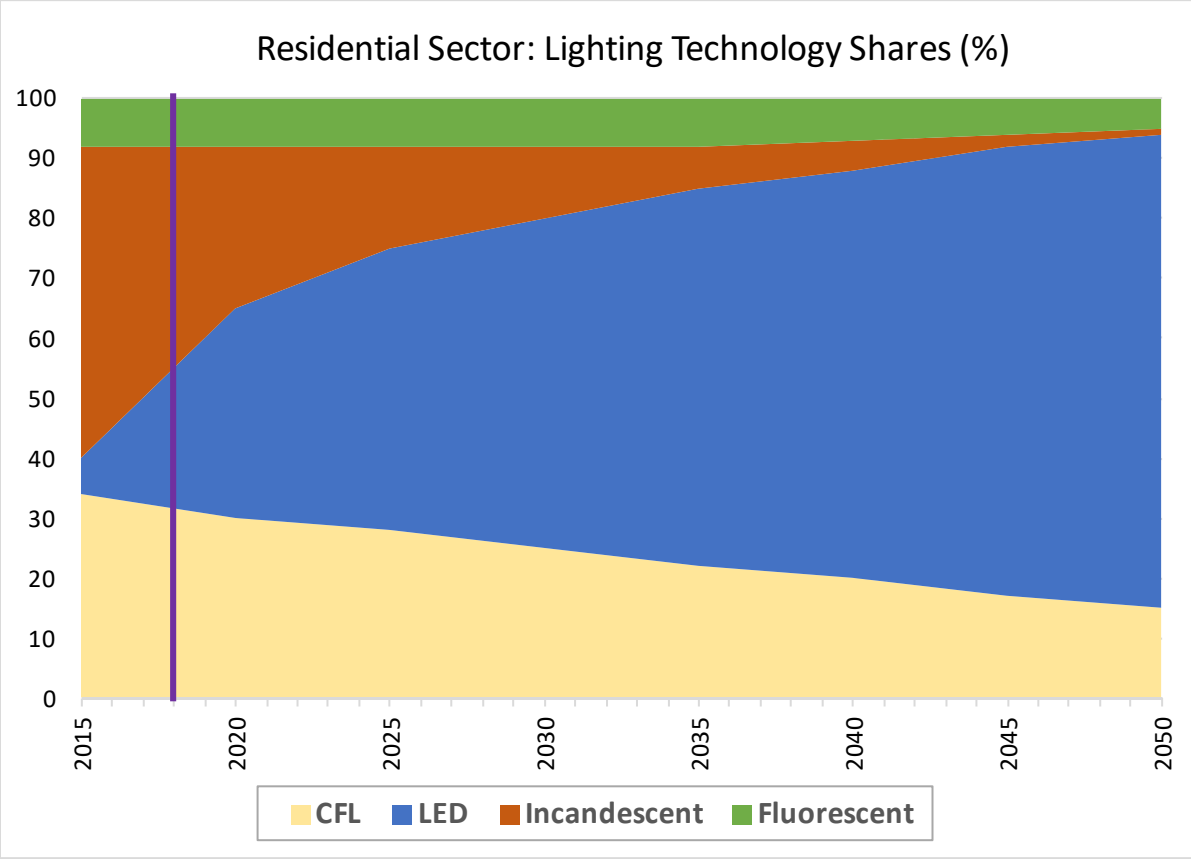


EIA 2018 Annual Energy Outlook

An Example of a Statewide SAE Model for All Sectors

Process Steps for Producing an SAE Model

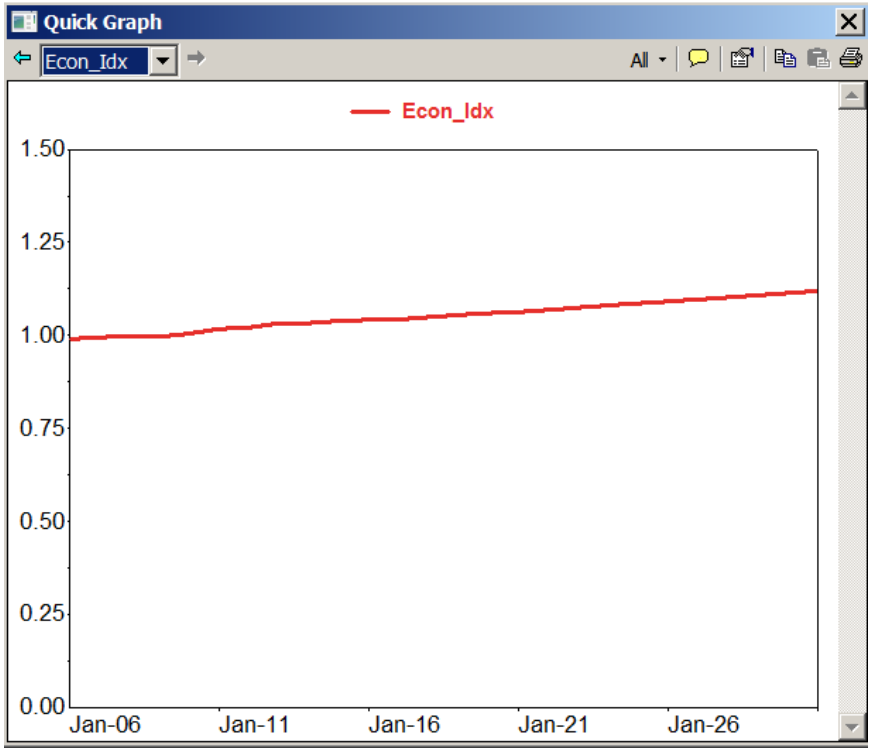
Note: Example is only for discussion purposes. This model was not used in the development of the 2018 Gold Book forecast.

- Model type is Ordinary Least Squares. Autoregressive / moving average (ARMA) terms added as needed.
- Shows how to specify economic drivers to use in the model.
- Provides model statistics and graphical summary of monthly and annual energy forecasts.

Selection of Economic Variables

Transform Table: mEcon

```
Price =      (Prices.Res_MA^0.35)*(Prices.Com_MA^0.53)^(Prices.Ind_MA'
Price_Idx =  mEcon.Price/value(mEcon.Price,BaseValues.BaseYear,BaseV

GDP =        Economics.GDP_Tot
GDP_Trend =  mBin.TrendVar*mEcon.MA_GDP

MA_GDP =     ma(Economics.GDP_Tot,12)
GDP_Idx =    mEcon.MA_GDP/value(mEcon.MA_GDP,2009,6)

Pop =        Economics.Pop
Pop_Idx =    mEcon.Pop/value(mEcon.Pop,2009,6)

HH =         Economics.HH
HH_Idx =     mEcon.HH/value(mEcon.HH,2009,6)

Econ_Idx =  (mEcon.Pop_Idx^0.7)*(mEcon.GDP_Idx^0.3)
```



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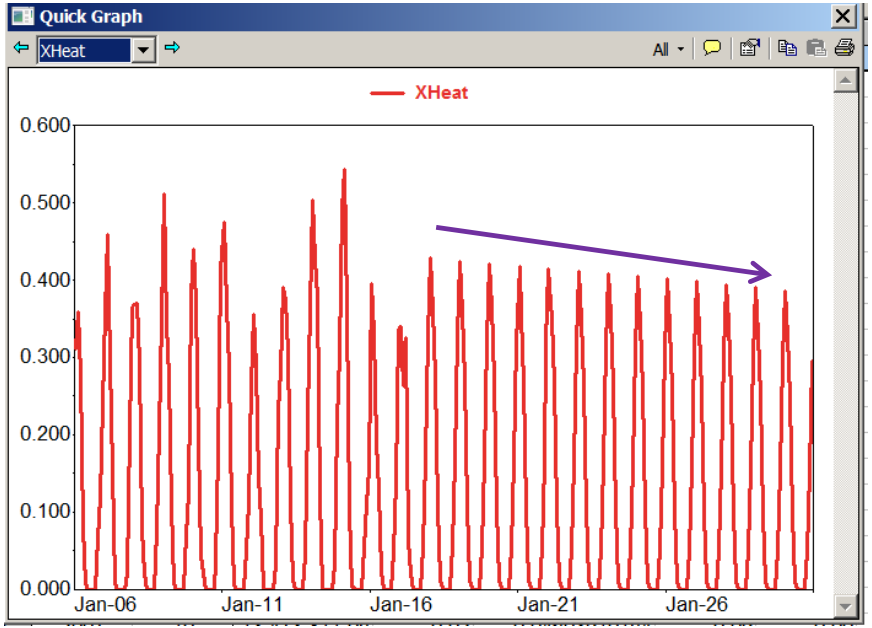
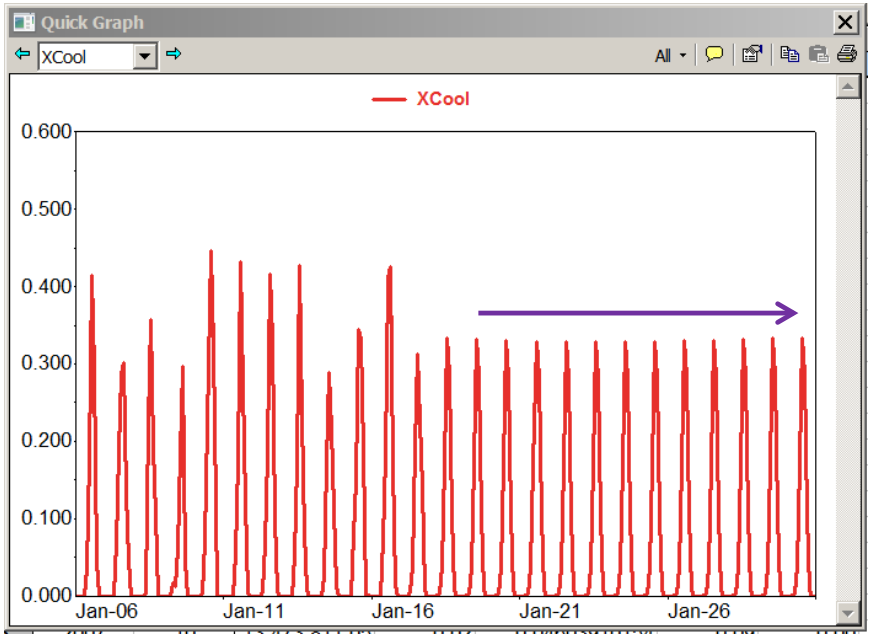
XHeat & XCool With Embedded Economic and Technology Trends





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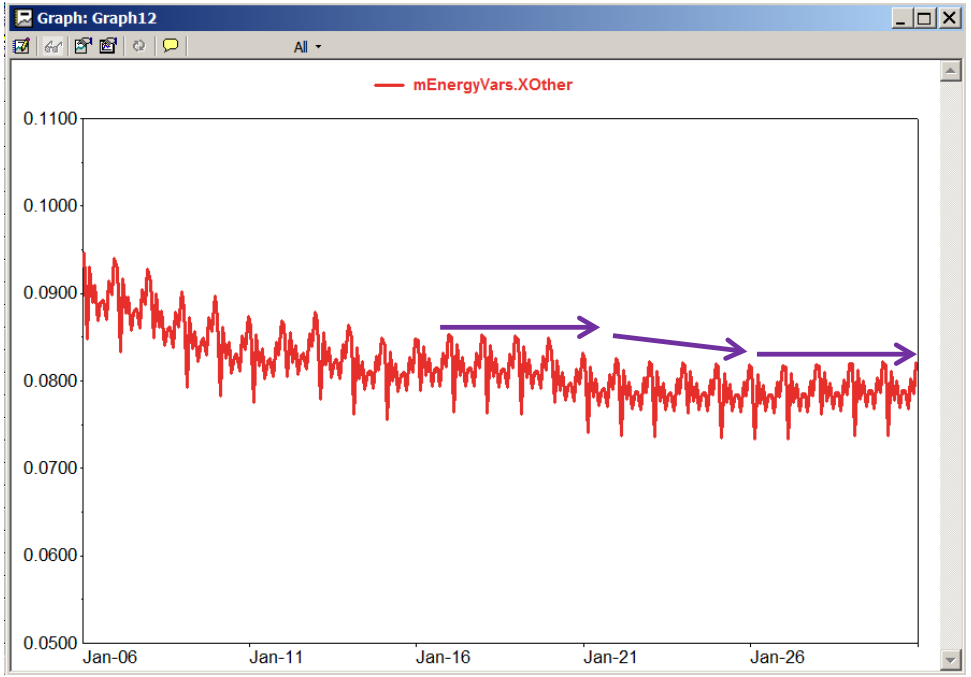
XOther With Embedded Economic and Technology Trends



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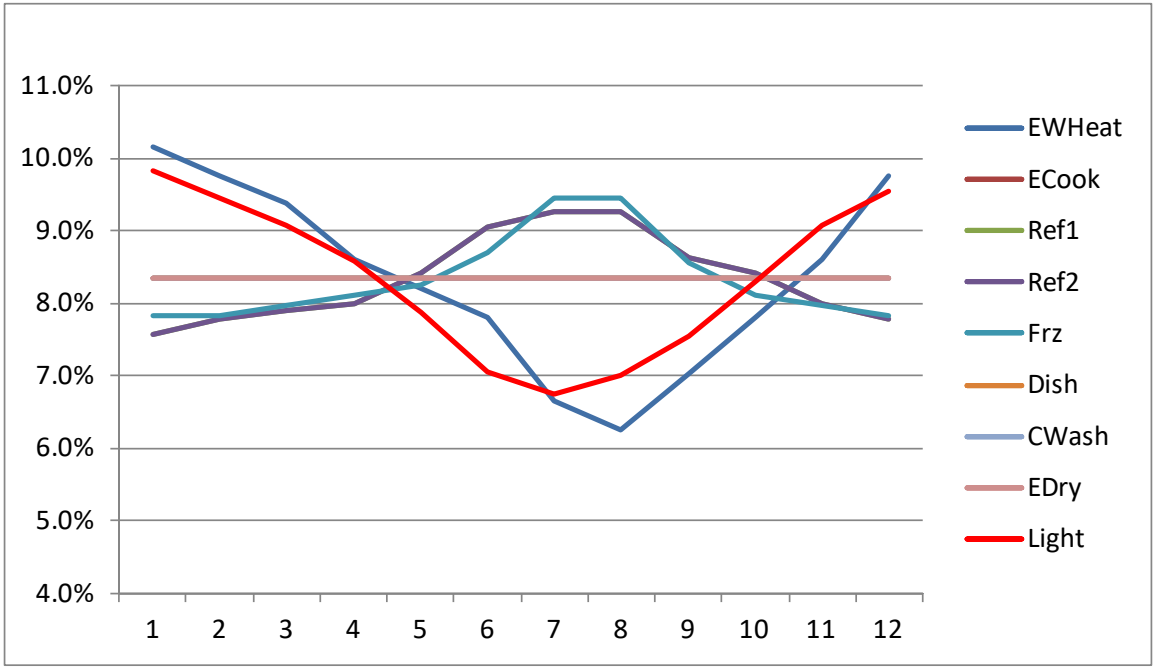
Monthly Distribution of Annual Energy – Selected End-Uses



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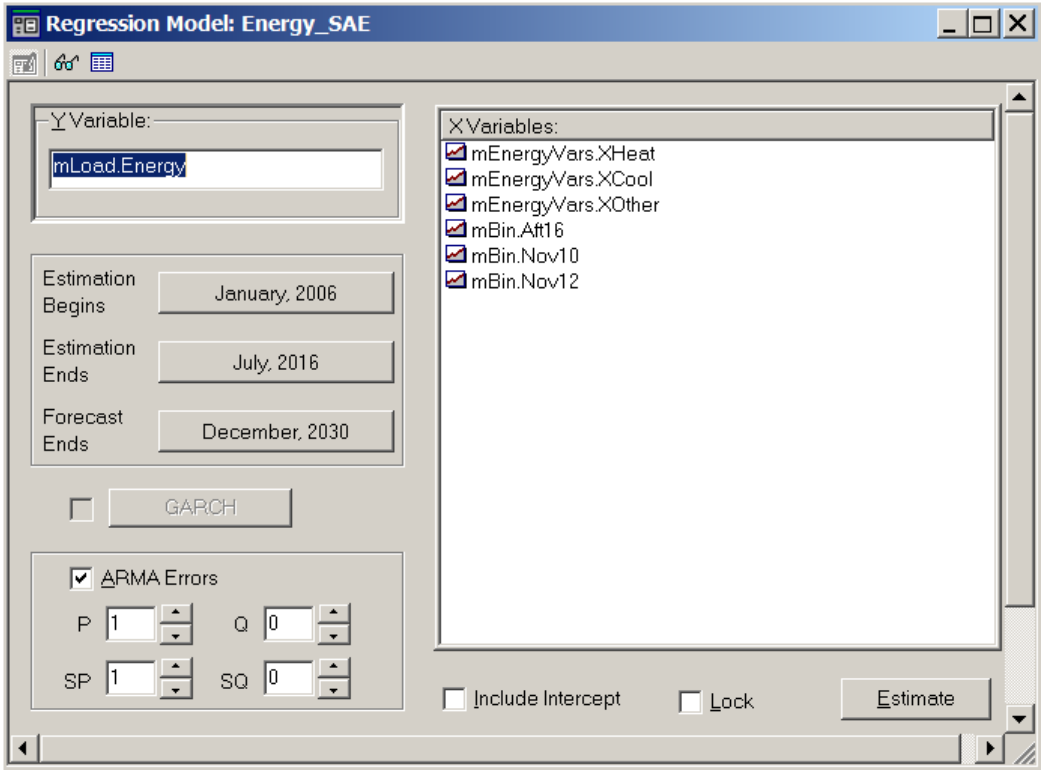
Ordinary Least Squares Model with ARMA Terms



Model Coefficients

Regression Model: Energy_SAE

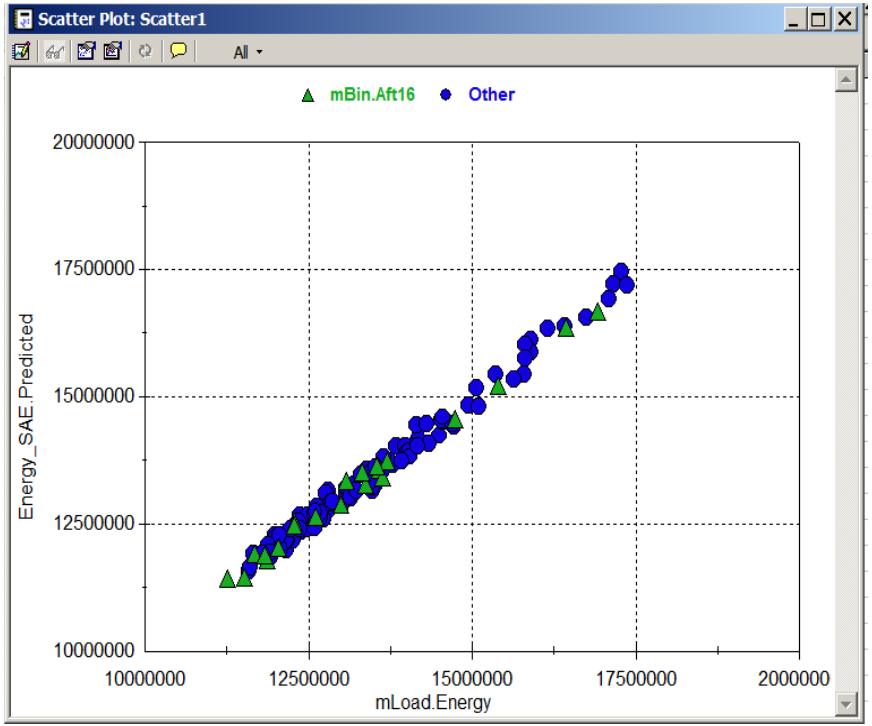
	A	B	C	D	E	F
1	Variable	Coefficient	StdErr	T-Stat	P-Value	Units
2	mEnergyVars.XHeat	4326847.928	281421.908	15.375	0.00%	
3	mEnergyVars.XCool	11540818.483	300254.730	38.437	0.00%	
4	mEnergyVars.XOther	146938742.490	2280397.403	64.436	0.00%	
5	mBin.Aft16	-364770.398	104038.062	-3.506	0.07%	
6	mBin.Nov10	-2586973.343	109101.743	-23.712	0.00%	
7	mBin.Nov12	-369840.625	111897.510	-3.305	0.13%	
8	AR(1)	0.501	0.082	6.137	0.00%	
9	SAR(1)	0.793	0.046	17.091	0.00%	
10						
11						
12						
13						
14						
15						

In-Sample & Out-of-Sample Statistics

Regression Model: Energy_SAE

	A	B	D	E	F
1	Model Statistics		Forecast Statistics		
2	Iterations	18	Forecast Observations	14	
3	Adjusted Observations	114	Mean Abs. Dev. (MAD)	137,331.14	
4	Deg. of Freedom for Error	106	Mean Abs. % Err. (MAPE)	1.03%	
5	R-Squared	0.988	Avg. Forecast Error	-13,926.79	
6	Adjusted R-Squared	0.987	Mean % Error	-0.18%	
7	AIC	24.088	Root Mean-Square Error	159,228.02	
8	BIC	24.280	Theil's Inequality Coefficient	0.0060	
9	F-Statistic	#NA	-- Bias Proportion	0.77%	
10	Prob (F-Statistic)	#NA	-- Variance Proportion	34.71%	
11	Log-Likelihood	-1,526.76	-- Covariance Proportion	64.52%	
12	Model Sum of Squares	227,369,061,536,724.00			
13	Sum of Squared Errors	2,864,845,414,999.01			
14	Mean Squared Error	27,026,843,537.73			
15	Std. Error of Regression	164,398.43			
16	Mean Abs. Dev. (MAD)	130,928.19			
17	Mean Abs. % Err. (MAPE)	0.97%			
18	Durbin-Watson Statistic	2.163			
19	Durbin-H Statistic	#NA			
20	Ljung-Box Statistic	26.68			
21	Prob (Ljung-Box)	0.3198			
22	Skewness	0.047			
23	Kurtosis	2.386			
24	Jarque-Bera	1.835			
25	Prob (Jarque-Bera)	0.3996			

Data | DStat | Corr | Coef | MStat | Err | Elas | BX



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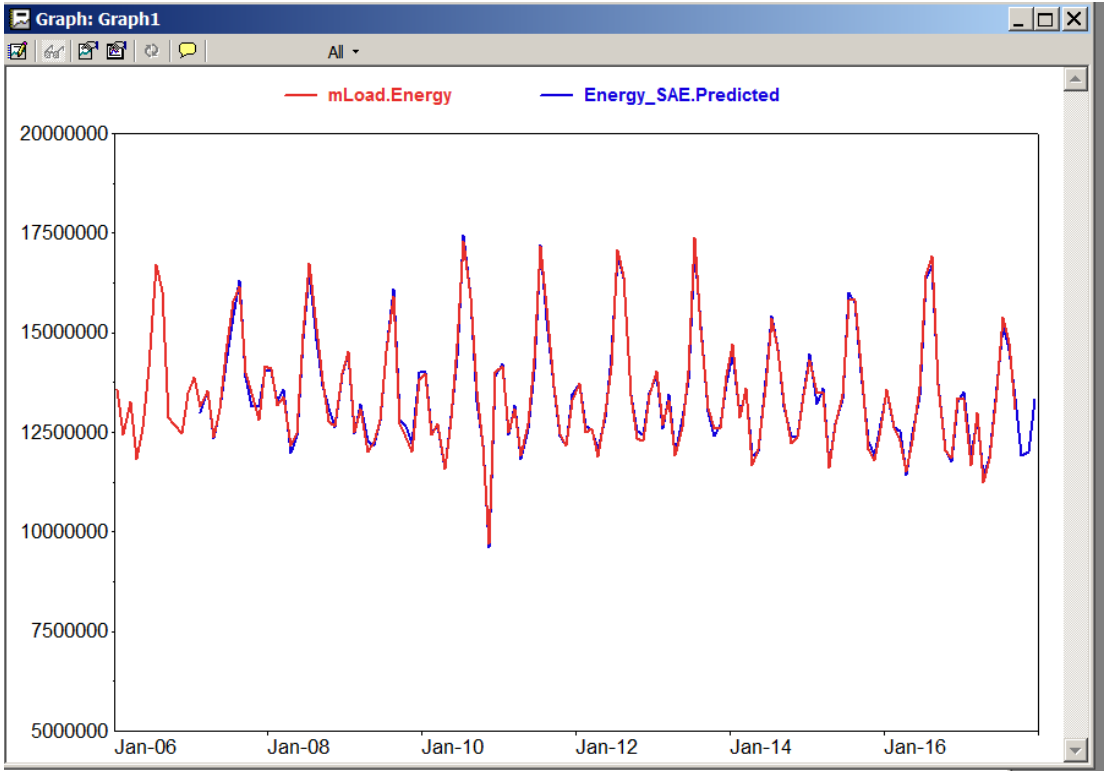
Actual & Predicted Monthly Statewide Energy (MWh)



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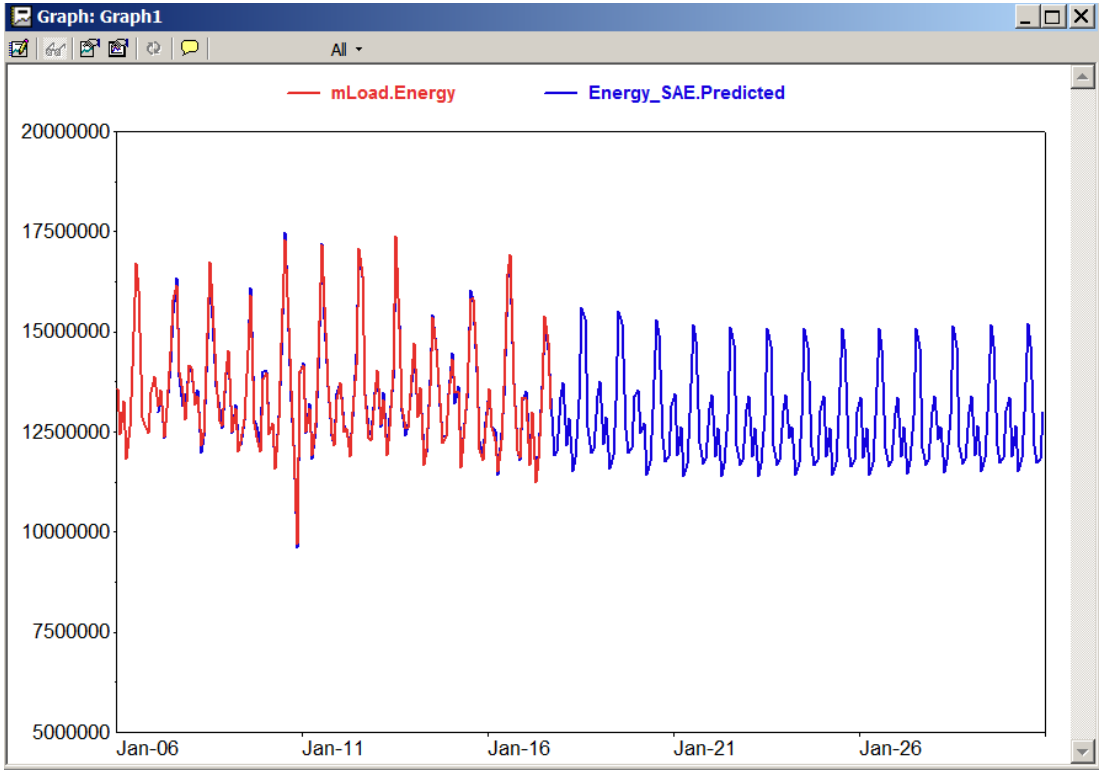
Actual & Forecast Monthly Statewide Energy (MWh)



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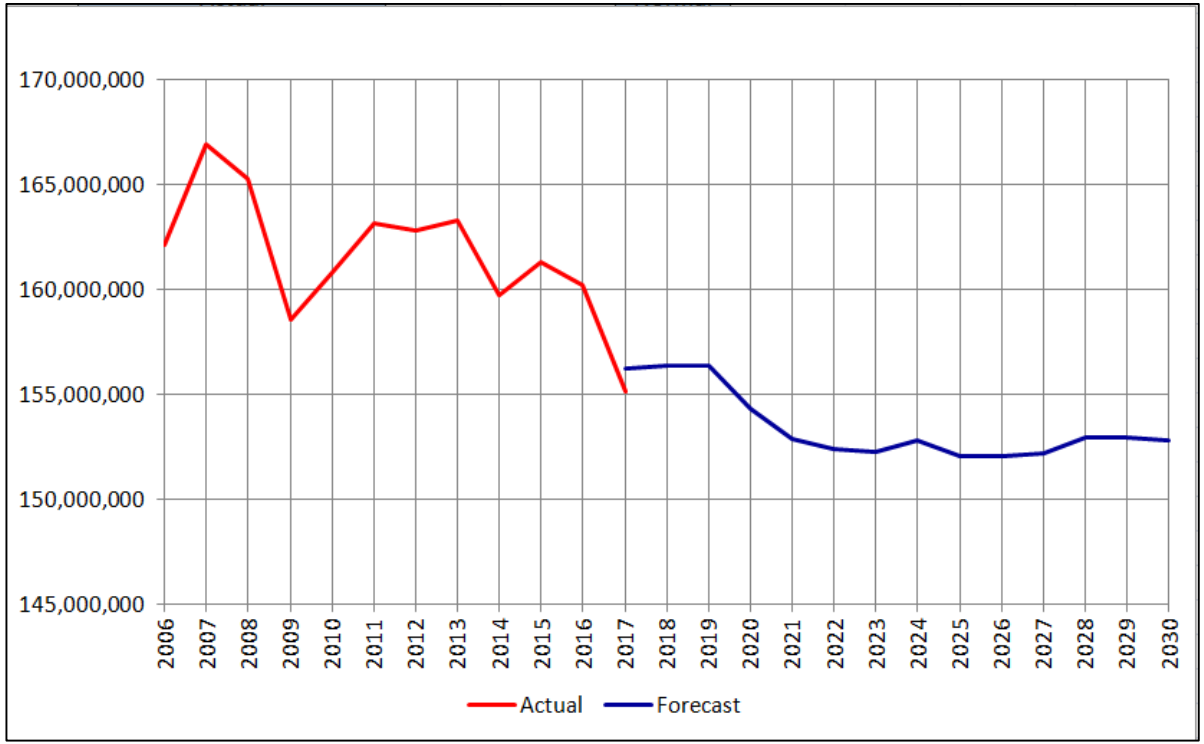
Actual & Forecast Annual Statewide Energy (MWh)



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Next Steps

- Exchange information with Transmission Owners on specific technology trends in their respective Transmission Districts.
- Discuss availability of monthly data for residential, commercial and industrial sectors.
- Examine effect on the forecast using longer historic time periods and other economic variables.

The Mission of the New York Independent System Operator, in collaboration with its stakeholders, is to serve the public interest and provide benefits to consumers by:

- Maintaining and enhancing regional reliability
- Operating open, fair and competitive wholesale electricity markets
- Planning the power system for the future
- Providing factual information to policy makers, stakeholders and investors in the power system

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