Using Load Research Data to Develop Long-Term Peak Demand Forecasts

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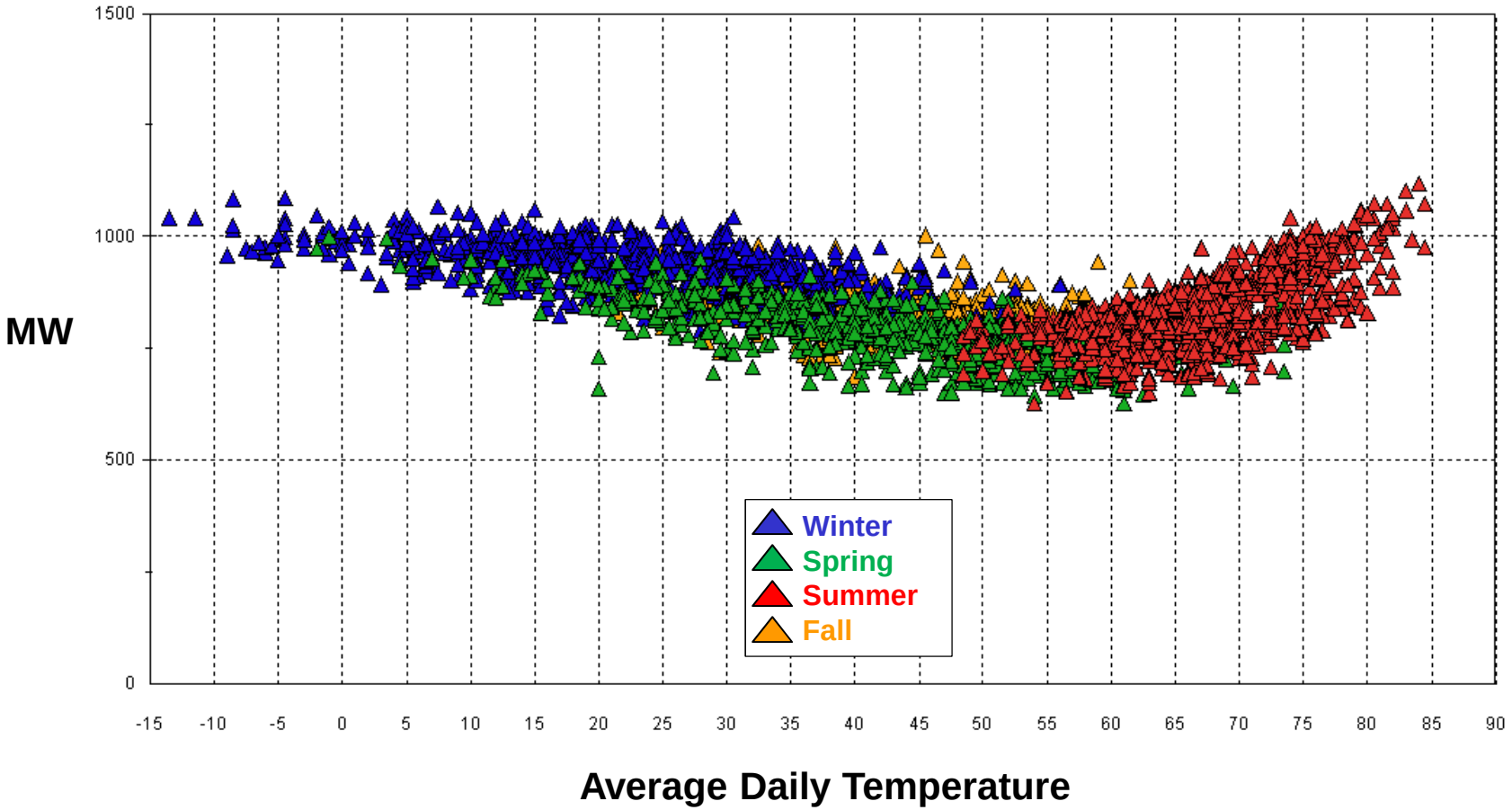
Overview

- Every three years, the Vermont Electric Company (VELCo) is required to develop a long-term transmission capacity plan, including a long-term demand forecast for the system and twelve delivery points.
- The challenge is to develop a demand forecast that incorporates differences in customer class sales growth resulting from new efficiency standards, efficiency tax credits, and aggressive state-wide efficiency program activity.
- This presentation evaluates two demand forecasting approaches for achieving this goal.

Vermont Load Characteristics

- Relatively flat system load profile
  - Large base load relative to heating and cooling loads
- Recently shifted from winter to summer peaking
- Peak demand has been growing faster than energy
  - Strong growth in residential room air conditioning saturation
  - Declining saturation of electric space heating
  - Large statewide efficiency program that has been focused on lighting
    - 80% of residential program savings from lighting
    - 60% of commercial program savings from lighting

VELCO Daily Peak Demand (MW)



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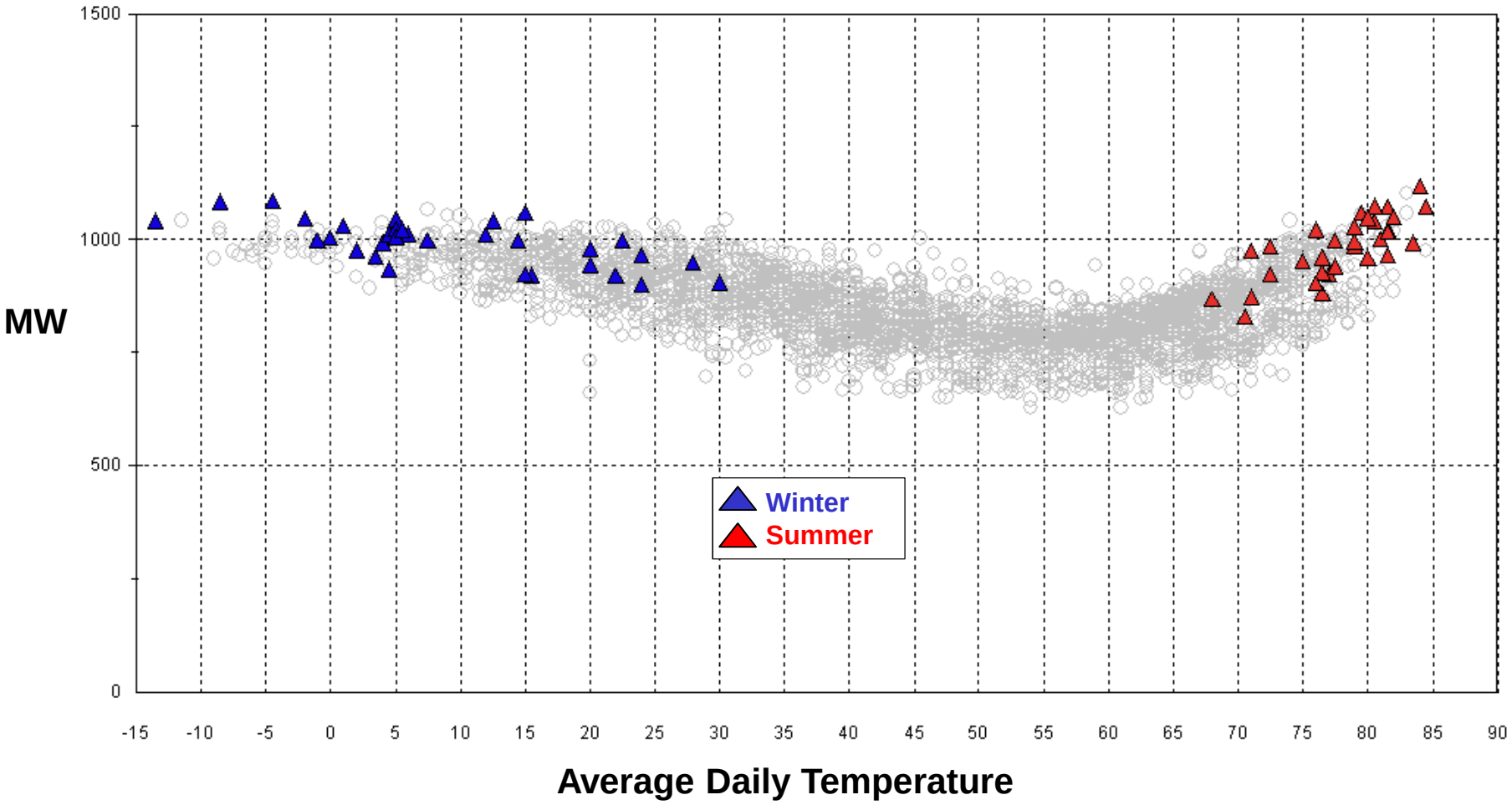
VELCO Winter and Summer Month Peaks (MW)



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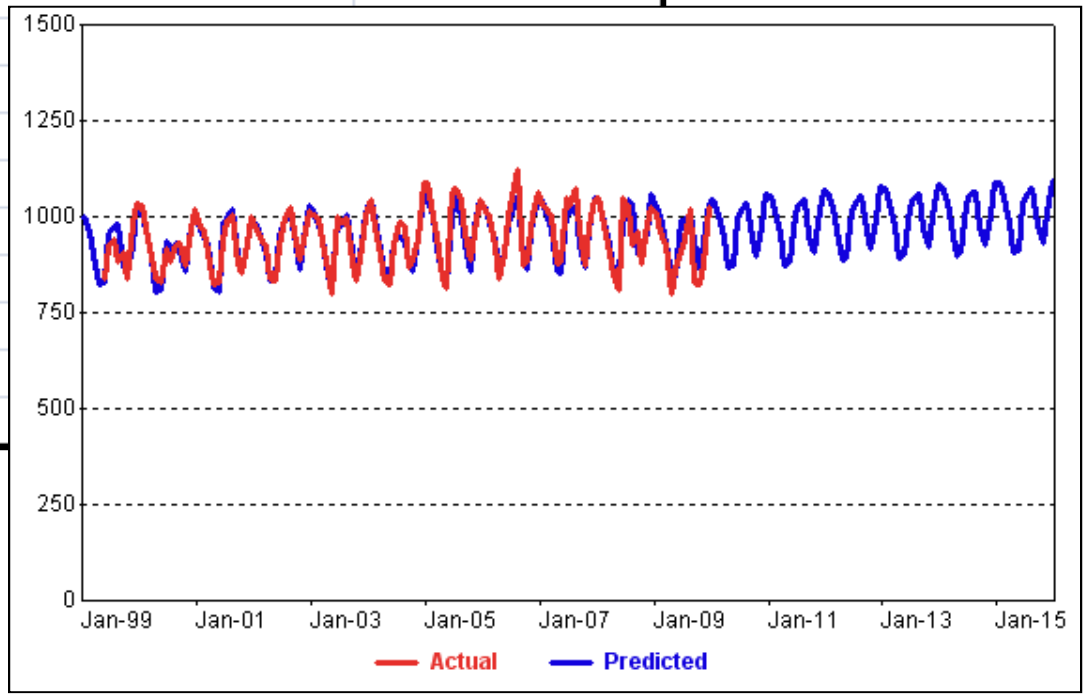
Typical Peak Demand Model Specification

Variable	Coefficient	StdErr	T-Stat
CONST	795.616	50.302	15.817
GDP	9.728	2.571	3.784
PkDayHDD	1.453	0.445	3.262
PkDayTHI	12.794	2.37	5.398
Jan	-19.253	12.953	-1.486
Feb	-49.333	14.615	-3.376
Mar	-95.254	14.947	-6.373
Apr	-157.224	18.204	-8.637
May	-149.654	24.059	-6.22
Jun	-91.409	30.091	-3.038
Jul	-83.4	31.447	-2.652
Aug	-92.091	33.201	-2.774
Sep	-125.186	27.086	-4.622
Oct	-124.141	20.171	-6.154
Nov	-58.807	15.126	-3.888
Sep02	44.902	32.562	1.379
Nov06	57.692	33.16	1.74
Jul02	-51.392	34.707	-1.481
MA(1)	0.285	0.091	3.121

Regression Statistics	
Adjusted Observations	128
Deg. of Freedom for Error	109
R-Squared	0.843
Adjusted R-Squared	0.818
F-Statistic	32.611
Prob (F-Statistic)	0
Mean Abs. Dev. (MAD)	22.37
Mean Abs. % Err. (MAPE)	2.39%
Durbin-Watson Statistic	1.865



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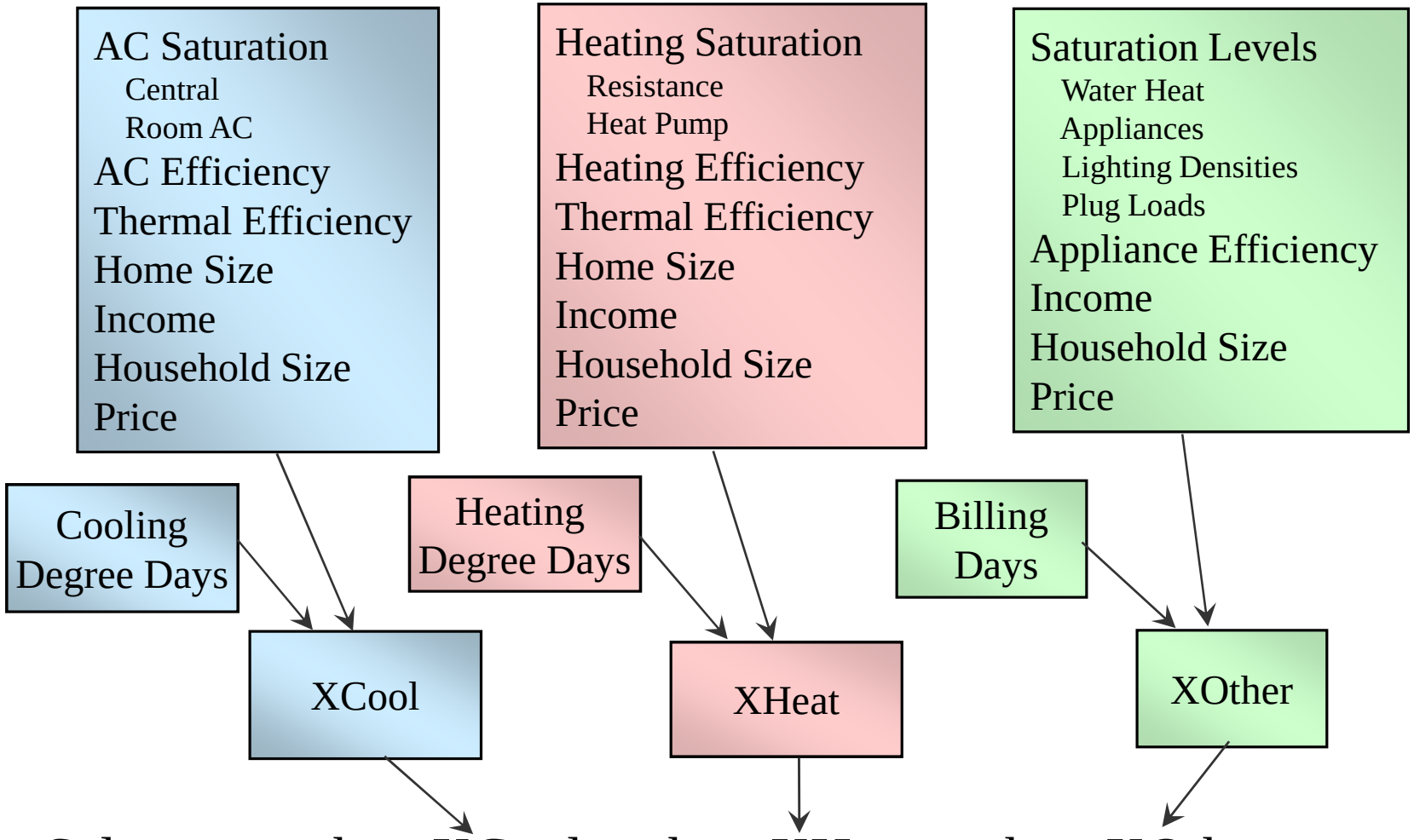
Forecasting Peak Demand

- Standard approach
  - Build a daily or monthly peak forecast regression model with peak-day weather, day of the week, season, and an economic driver (such as GDP, Population).
  - Or drive monthly or annual peak based on energy forecast.

- Problem
  - Approach works well for near-term demand forecast, but over the longer timeframe does not adequately capture the impact of changes in class and end-use load diversity on peak hour demand.

- Solution
  - First capture the impact of end-use saturation and efficiency trends in the class energy forecast and use resulting class level and end-use forecasts to drive peak demand.

Statistically Adjusted End-Use (SAE) Framework



$$Sales_m = a + b_c \times XCool_m + b_h \times XHeat_m + b_o \times XOther_m + e_m$$

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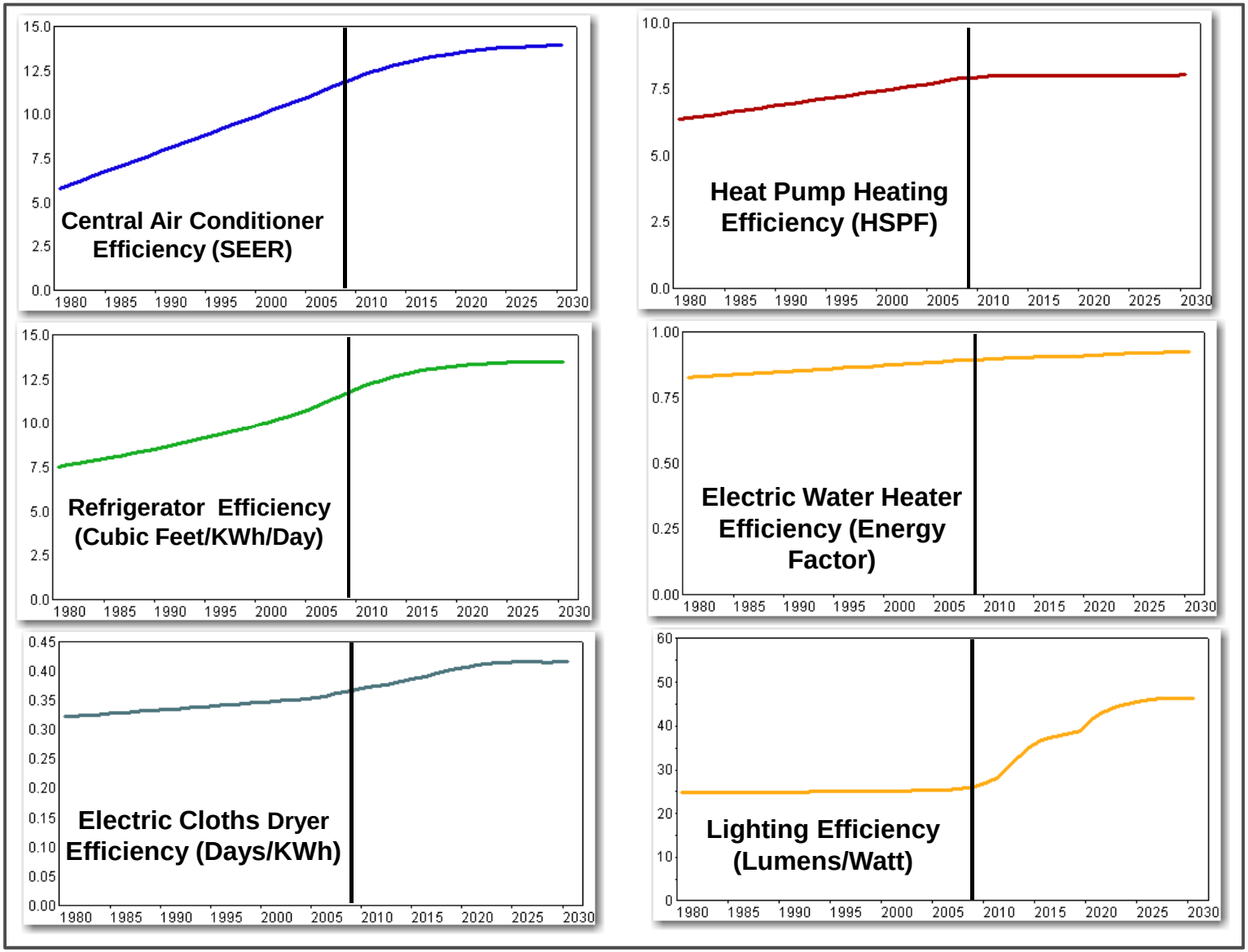
Changes in Residential Equipment Efficiency



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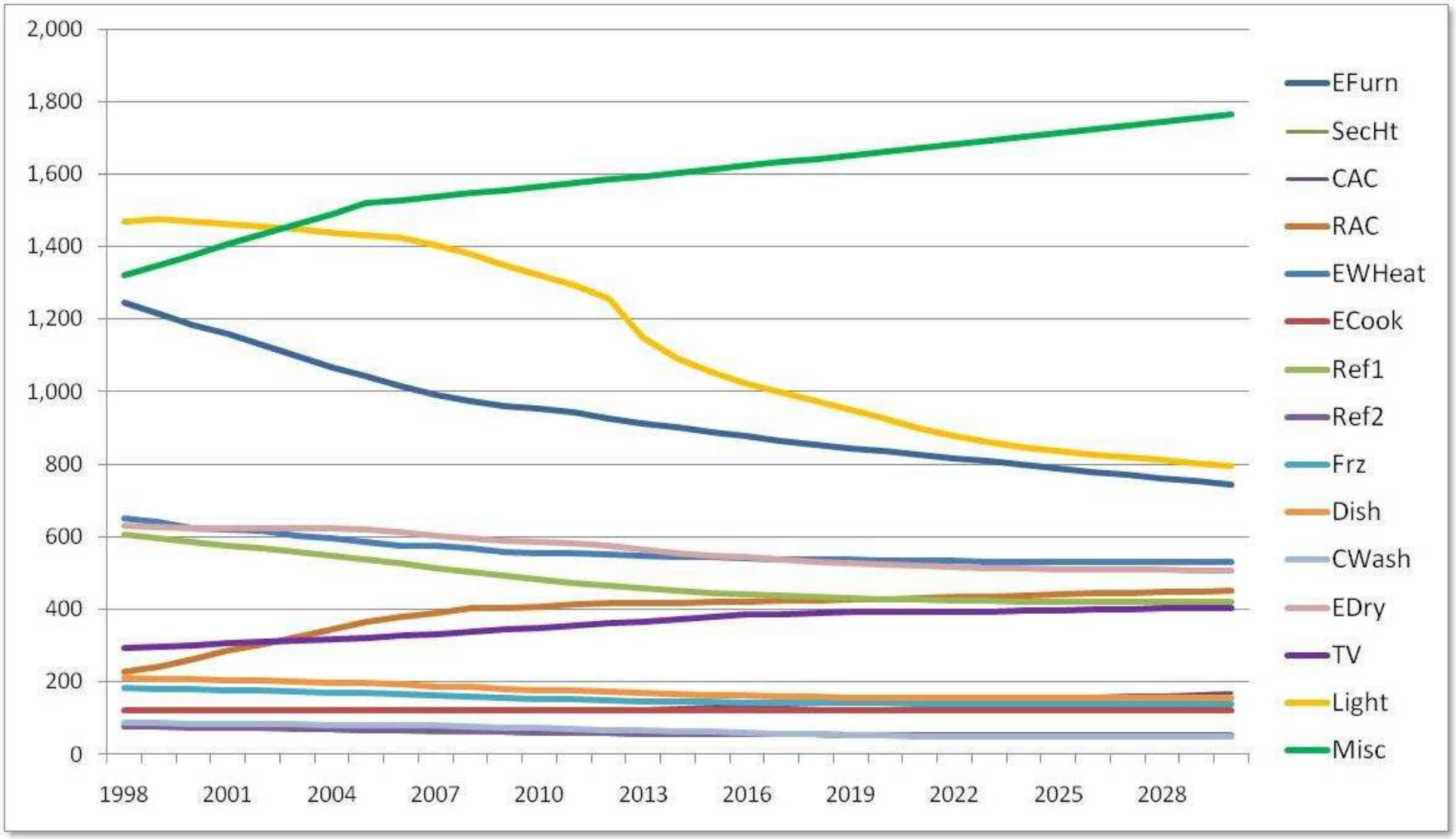
Example of SAE Inputs (KWh/Household)



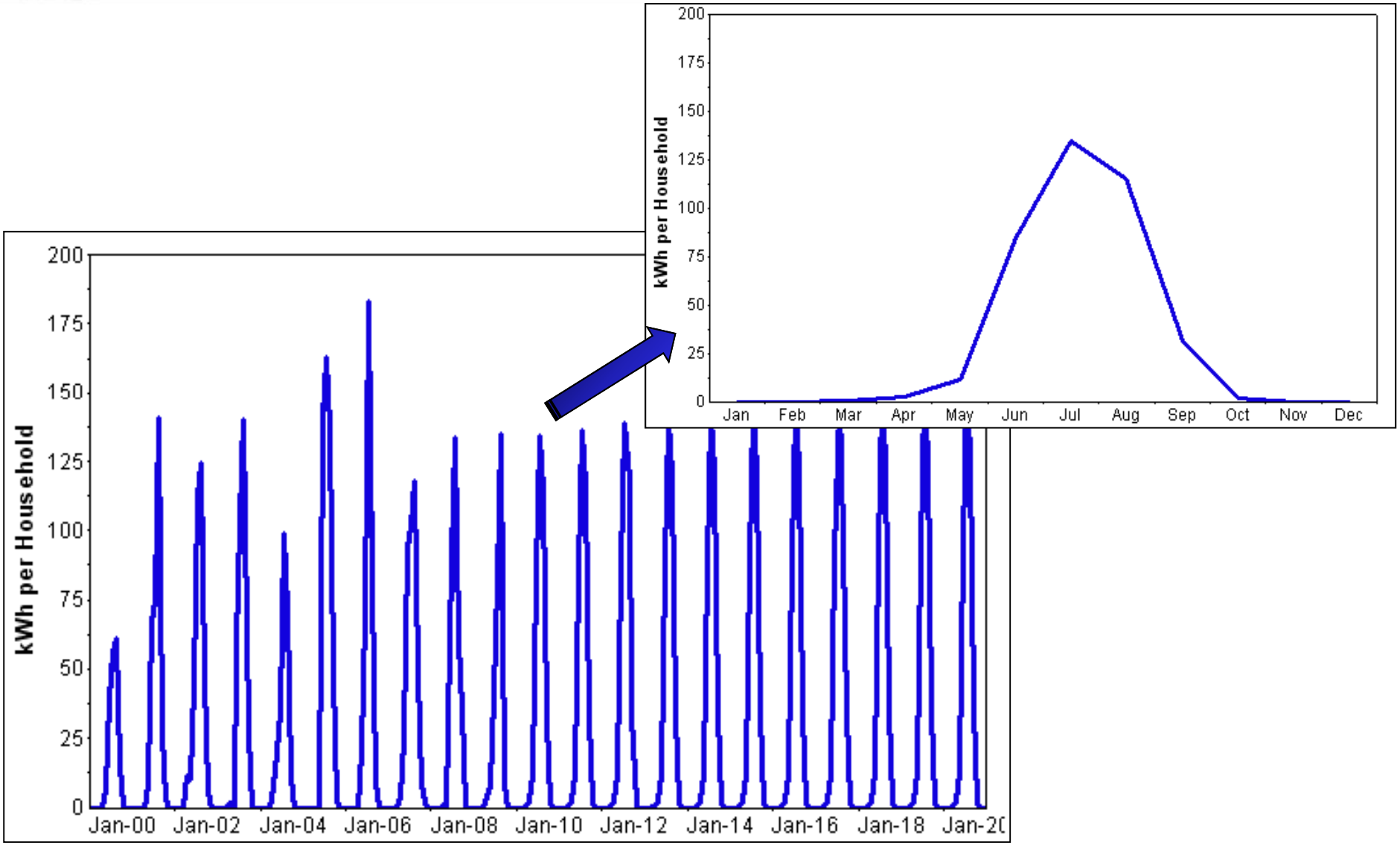
End-Use Variable - Cooling

$$XCool_{y,m} = CoolIndex_{y} \times CoolUse_{y,m}$$

$$\text{CoolIndex}_{y} = \text{StructuralIndex}_{y} \times \sum_{\text{Type}} \text{Weight}_{y}^{\text{Type}} \times \frac{\left(\text{Sat}_{y}^{\text{Type}} \Big/ \text{Eff}_{y}^{\text{Type}} \right)}{\left(\text{Sat}_{05}^{\text{Type}} \Big/ \text{Eff}_{05}^{\text{Type}} \right)}$$

$$\text{CoolUse}_{y,m} = \left(\frac{\text{CDD}_{y,m}}{\text{CDD}_{05}} \right) \times \left(\frac{\text{HHSize}_{y,m}}{\text{HHSize}_{05}} \right)^{0.20} \times \left(\frac{\text{Income}_{y,m}}{\text{Income}_{05}} \right)^{0.20} \times \left(\frac{\text{Price}_{y,m}}{\text{Price}_{05}} \right)^{-0.15}$$

Residential XCool Variable



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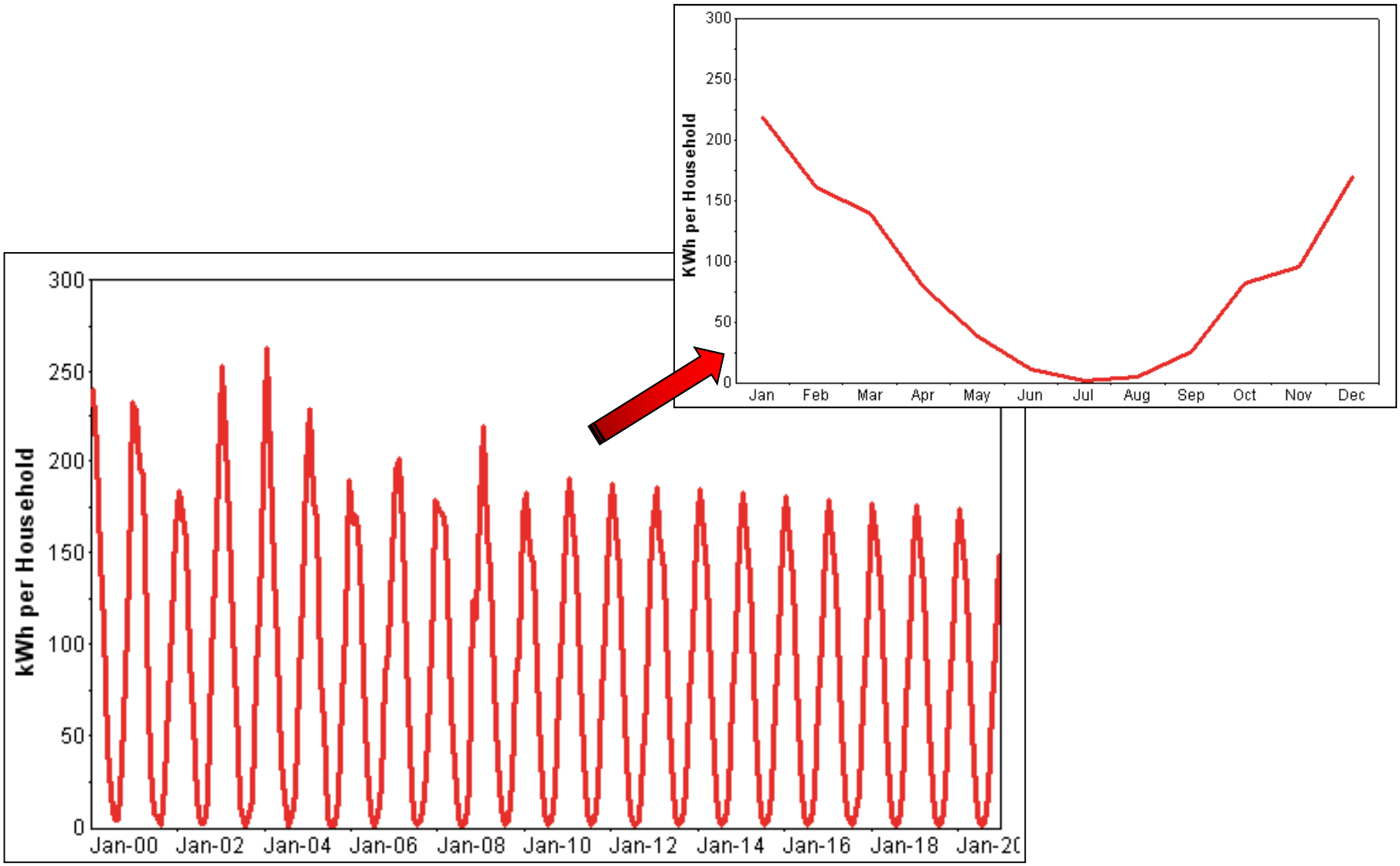
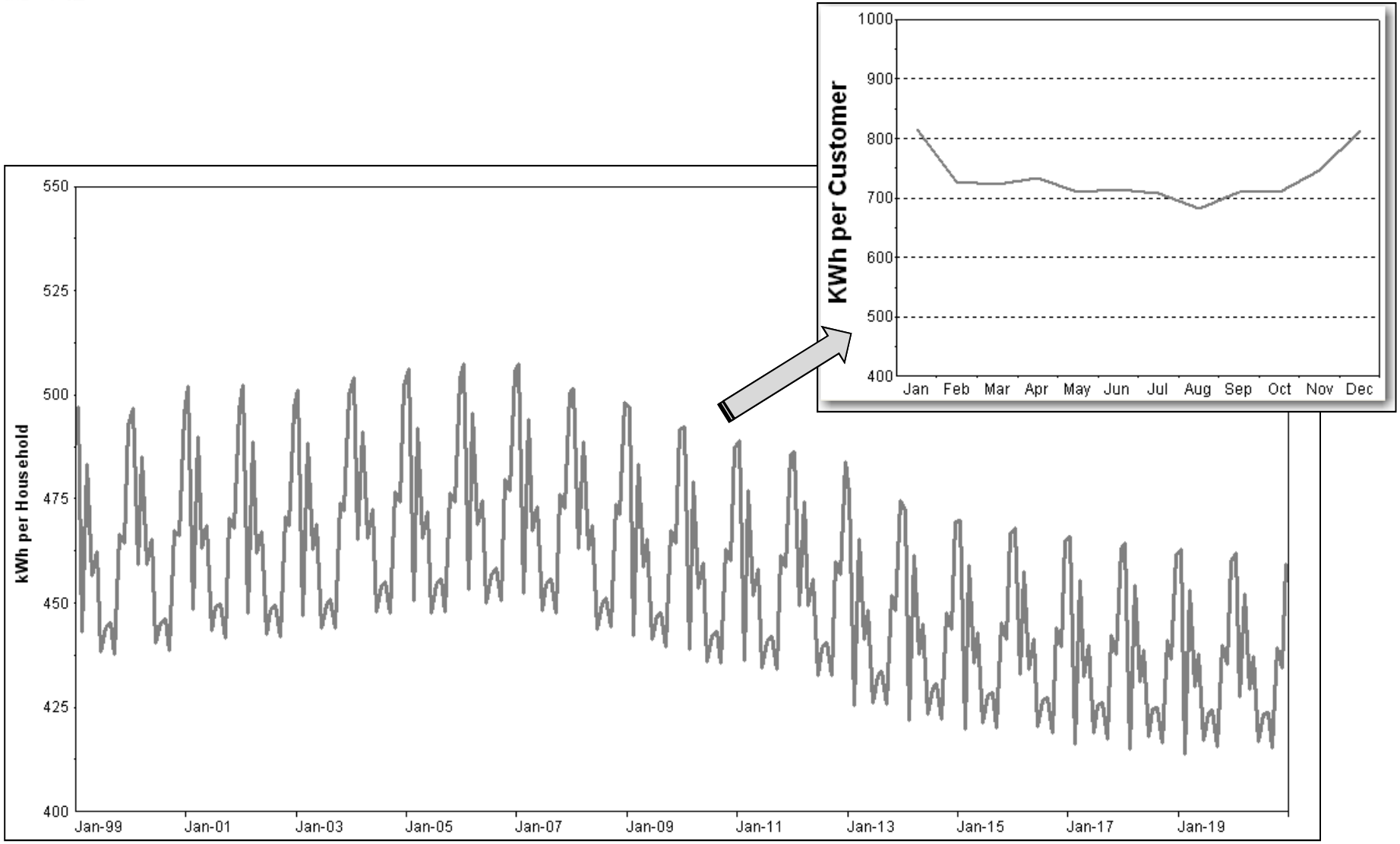
Residential XHeat Variable



Residential XOther Variable



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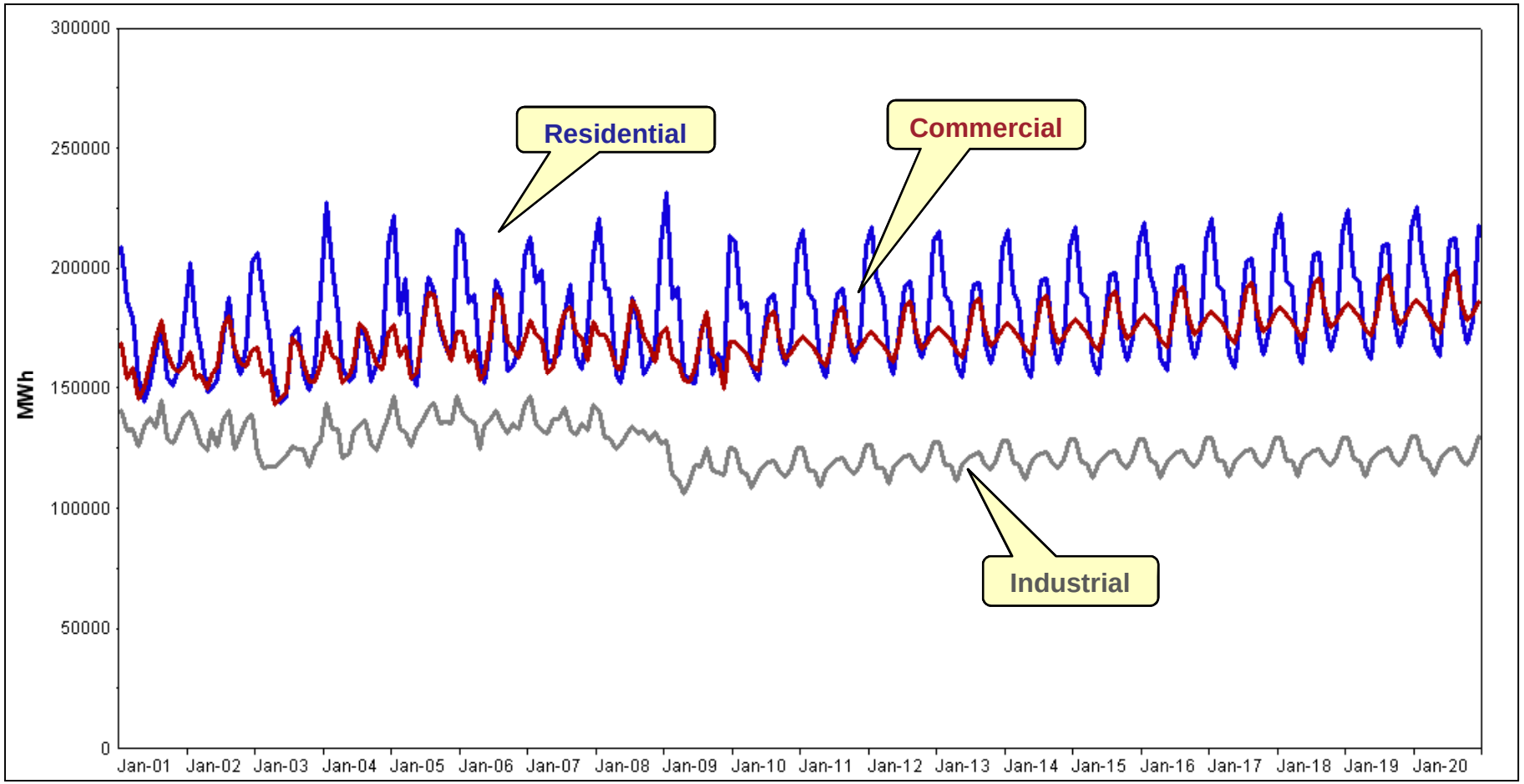
VELCO Class Energy Forecast (MWh)



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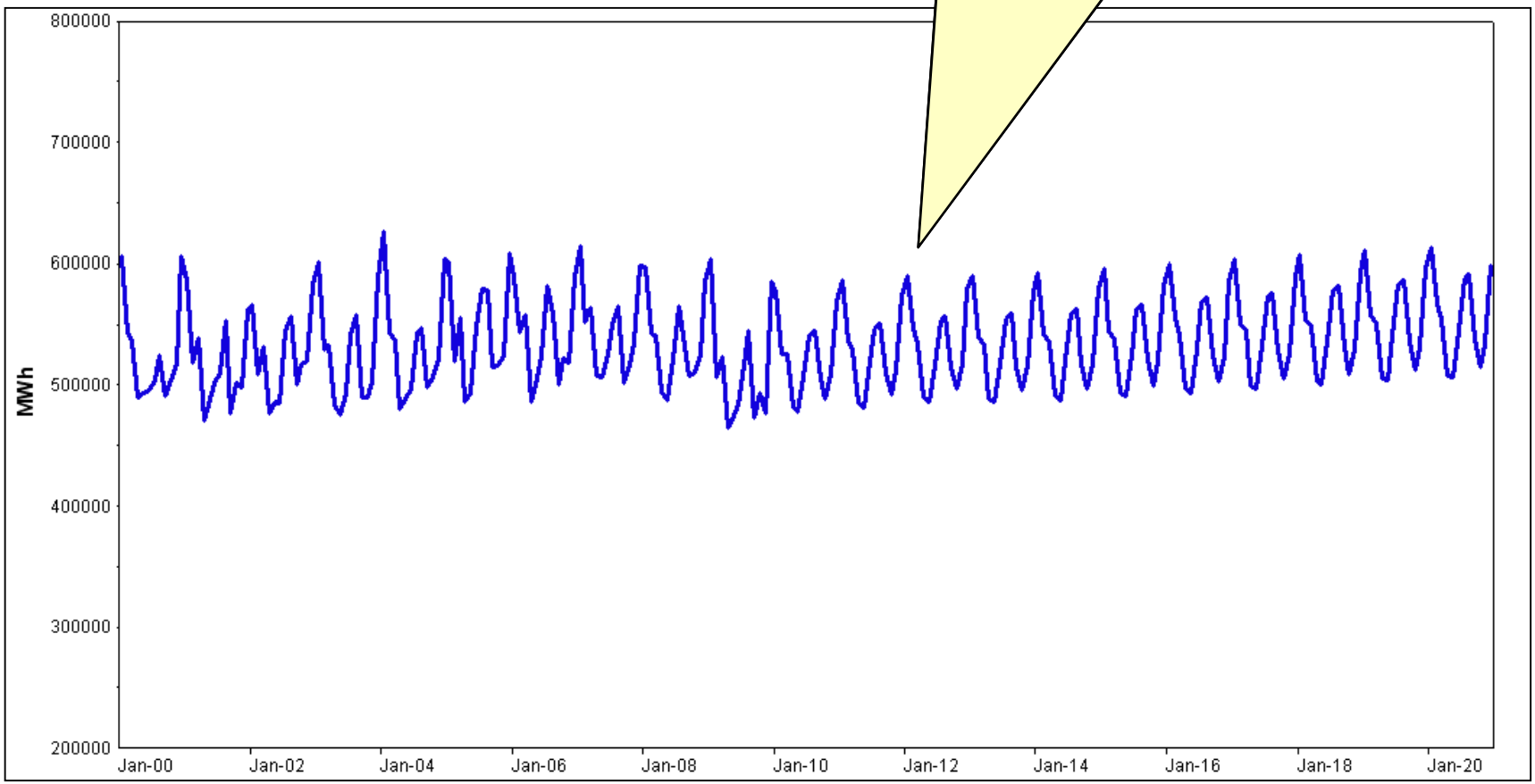
VELCO Monthly Energy Projections (MWh)

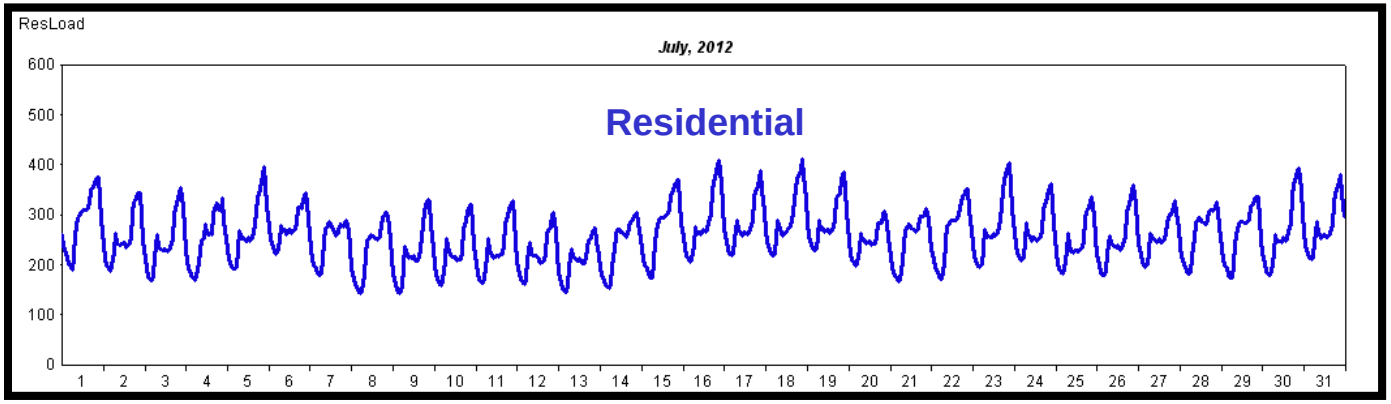
Long-Term Energy Forecast Reflects End-Use Saturation and Efficiency Trends as well as Price and Economic Projections

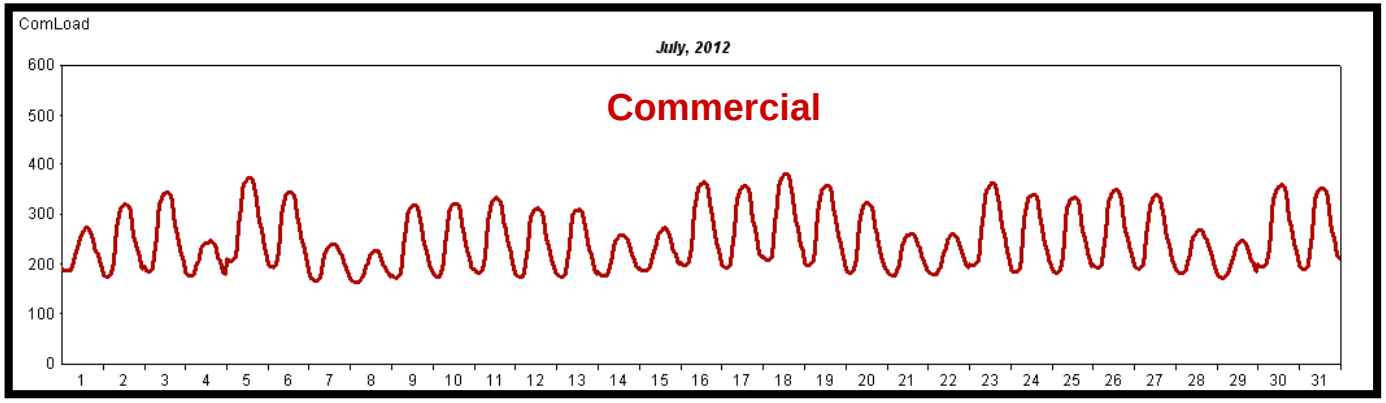


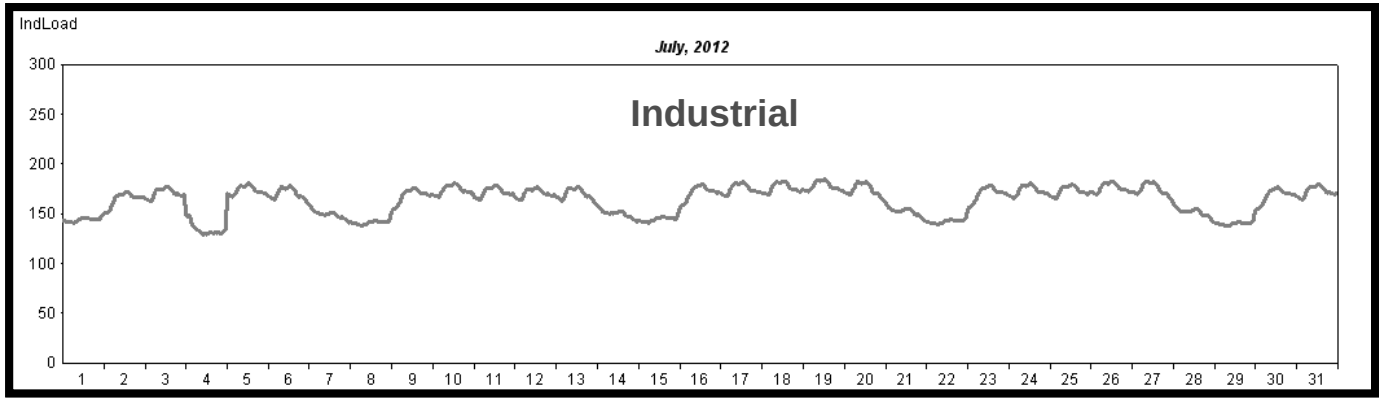
Going from Energy to Peak

- Approach 1: Build-up hourly load system forecast from forecasted hourly customer class loads (The HELM approach)
  - Estimate customer class hourly load profiles from load research data
    - Hourly profiles that capture the impact of weather conditions and calendar events – day of the week, season, holidays
  - Combine with monthly class energy forecast that reflects changing end-use energy composition with class load profiles
  - Aggregate monthly class profiles and scale to actual system load
  - Find monthly peaks from build-up load profile forecast

Class Hourly Load Forecasts (MW) – July 2012







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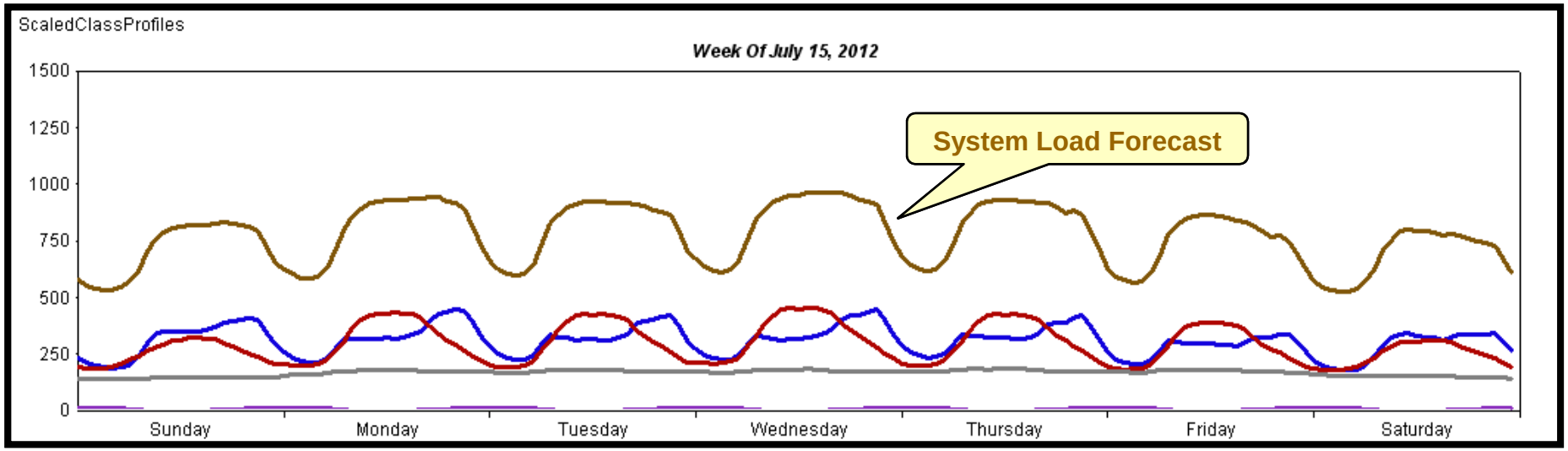
System Load Forecast – Summer Peak 2012



2012 Summer Peak Demand
964 MW
July 18, 4:00 PM

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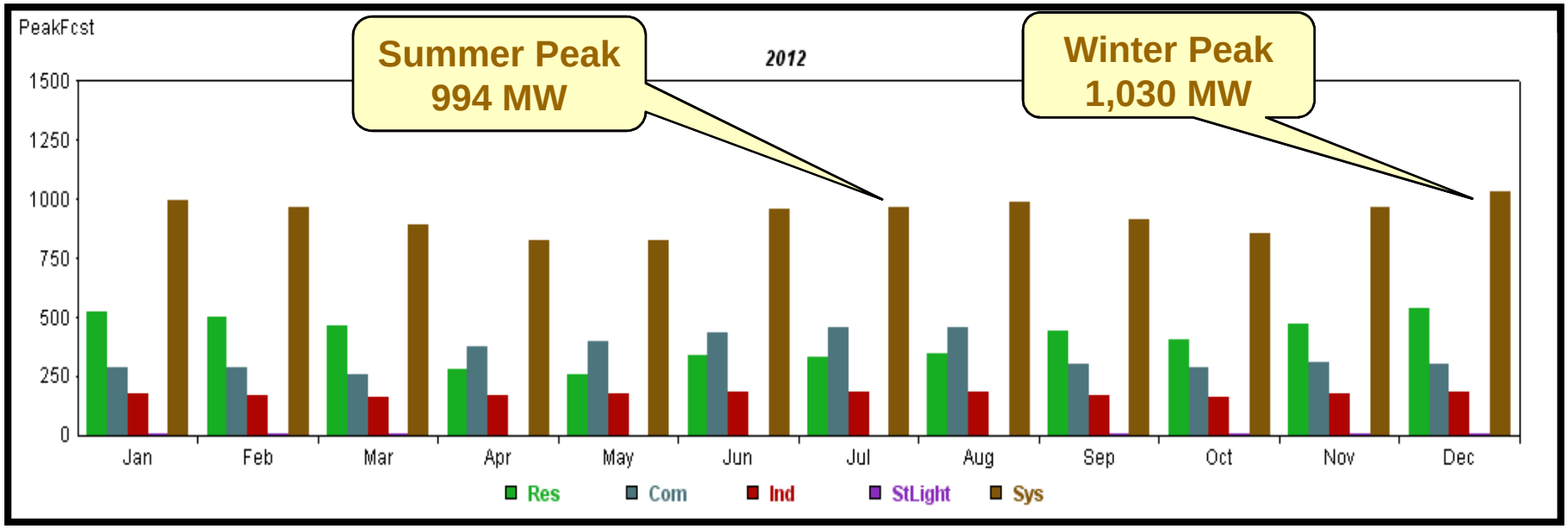
Problem with the Build-up Model

- Model was generating winter annual peaks even though the recent trend has shifted to summer peaks
  - Hourly load models tend to under-predict peak demand
  - Not adequately capturing the end-use impacts on demand
    - Spreading cooling and lighting load across too many hours



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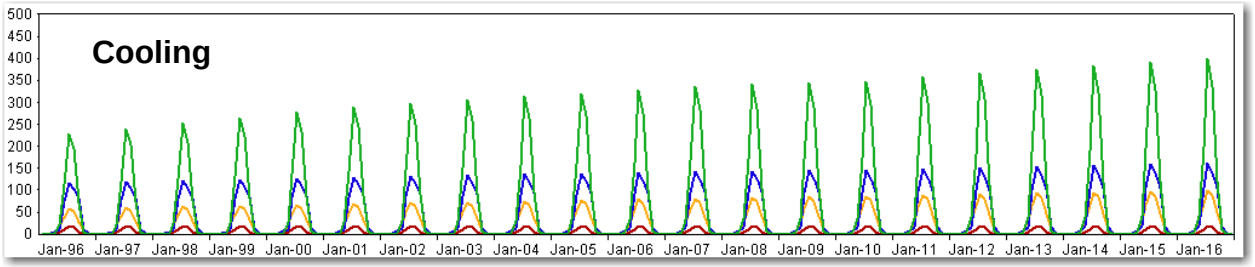
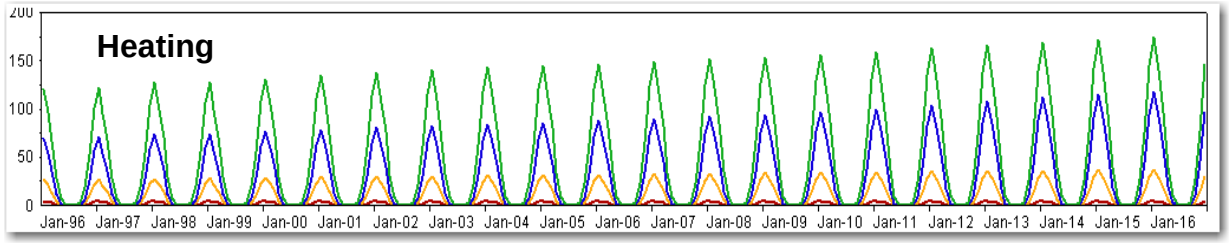
SAE Peak Model

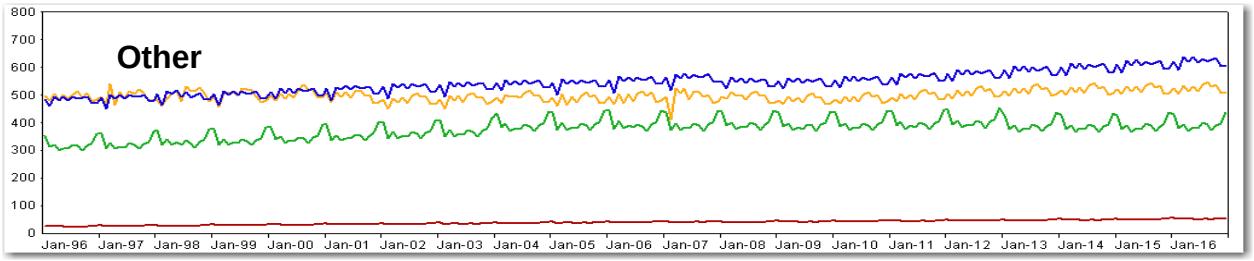
- Approach 2: Explicitly capture end-use impacts on monthly peak demand (SAE Peak Model)
  - Estimate monthly peak regression model that incorporates end-use load forecasts and peak-day weather conditions
- Model variable construction
  - Estimate historical and projected heating, cooling, and other use energy requirements from the class sales models
  - Use the heating and cooling energy estimates (weather-normalized and forecast) to construct peak-day heating and cooling variables
  - Combine other use sales with end-use load profile data to build a monthly base-use load variable

Calculate heating, cooling, and other use energy (MWh for normal weather conditions)

$$Sales_m = a + b_c \times XCool_m + c_c \times Trend_m \times CDD_m + b_h \times XHeat_m + c_h \times Trend_m \times HDD_m + b_o \times XOther_m + c_o \times Trend_m + e_m$$







- Residential
- Small C&I
- Large C&I
- Municipal

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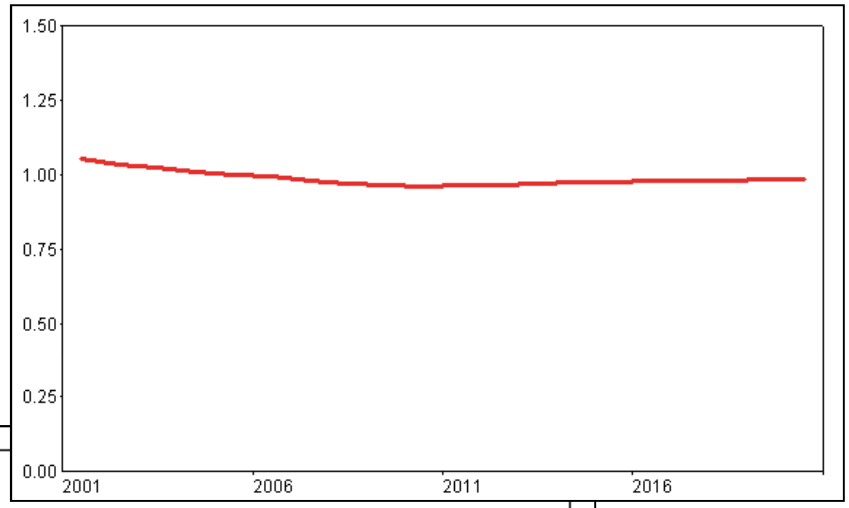
Construct Peak-Day Heating Variable

Heat Index:

Sum monthly heating values from the sales model.

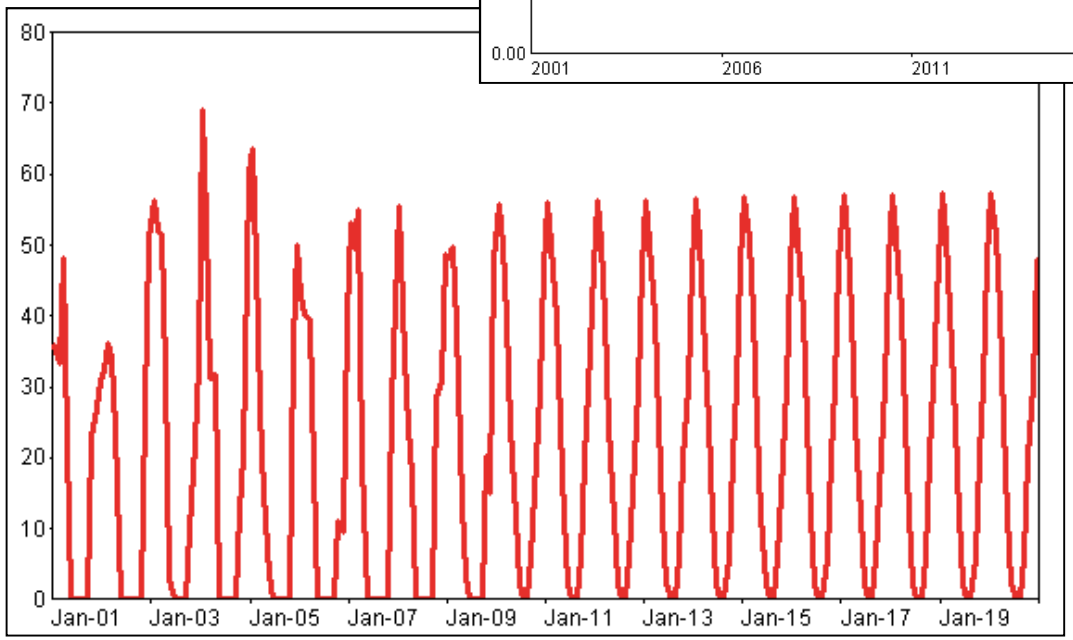
1. $Heat_t = ResHeat_t + ComHeat_t$
2. $Heat\_Idx_t = Heat_t / Heat_{05}$



Heat Model Variable:

$HeatVar_m = PkDayHDD_m * Heat\_Idx_t$

Interact Heat Index with peak day HDD.



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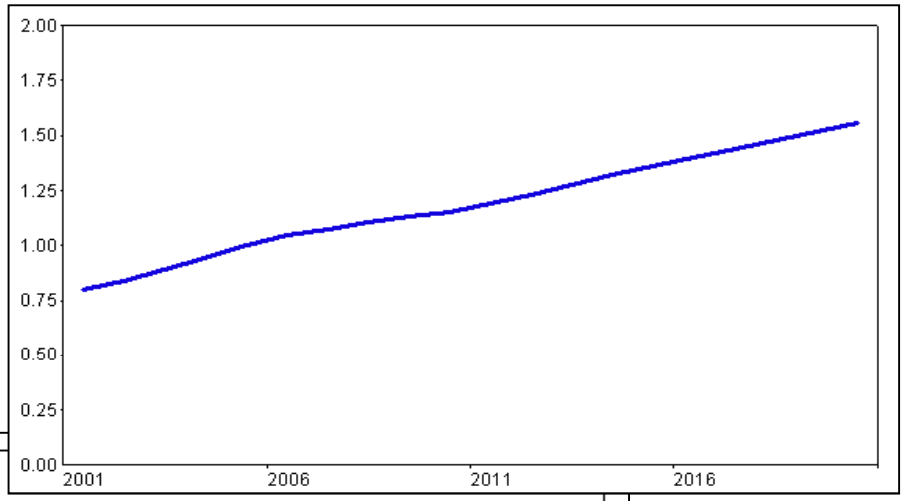
Construct Peak-Day Cooling Variable

Cool Index:

1. $Cool_t = ResCool_t + ComCool_t$

2. $Cool\_Idx_t = Cool_t / Cool_{05}$

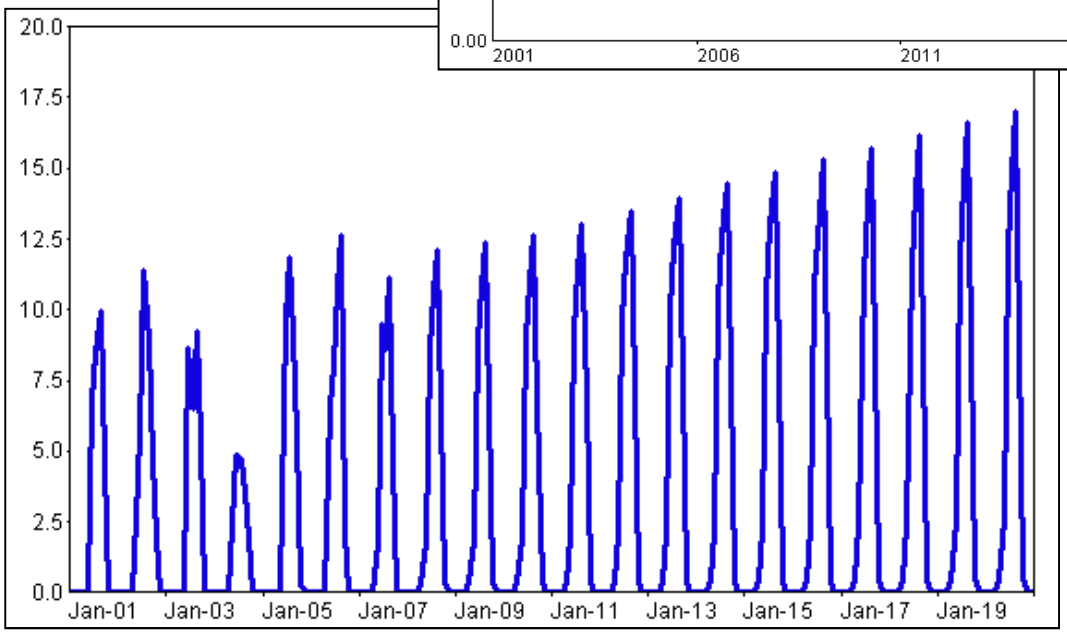
Sum monthly cooling values from the sales model.



Cool Model Variable:

$CoolVar_m = PkDayTHI_m * Cool\_Idx_t$

Interact Cool Index with peak day CDD.



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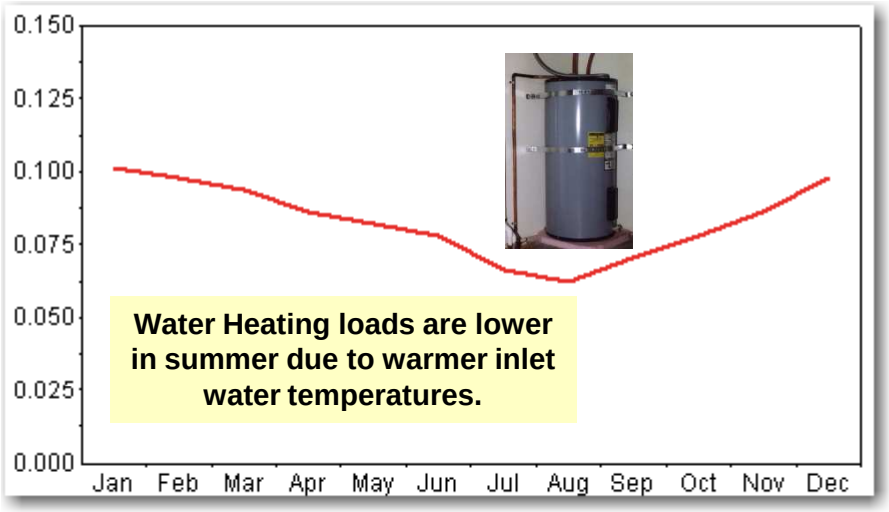
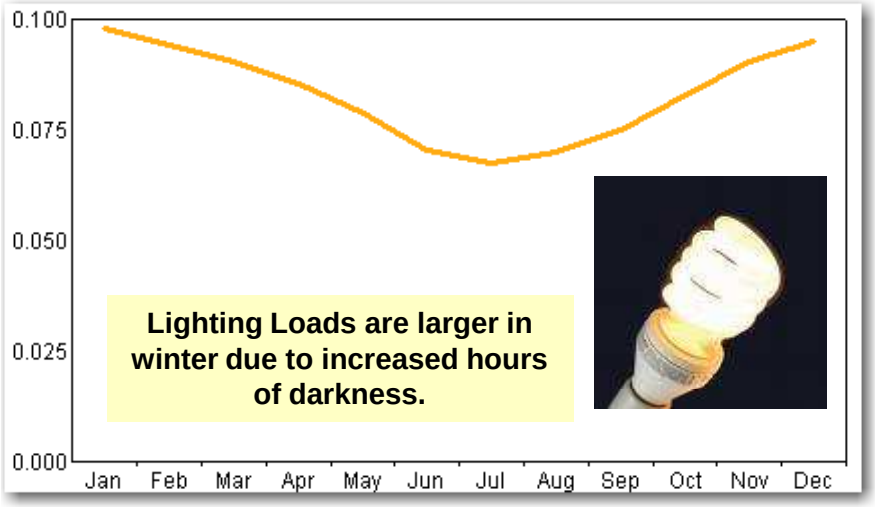
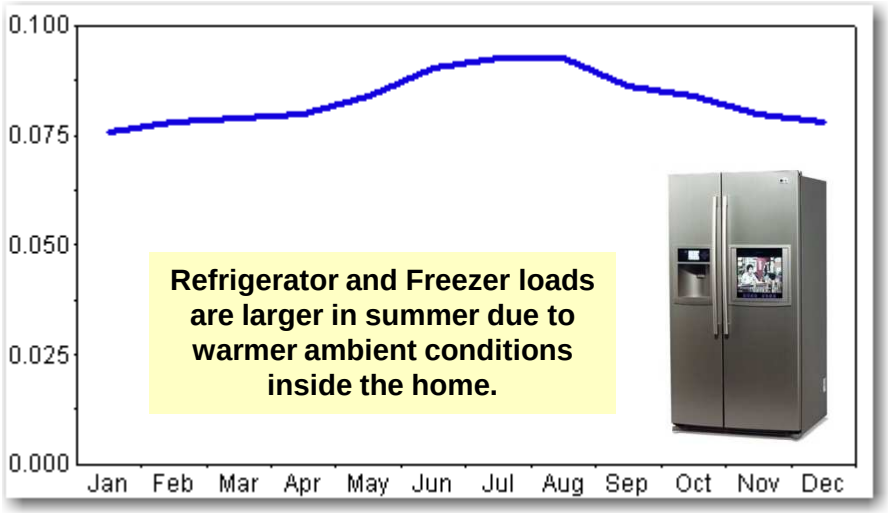
Construct Base Use Load Variable

- Start with typical end-use load profiles







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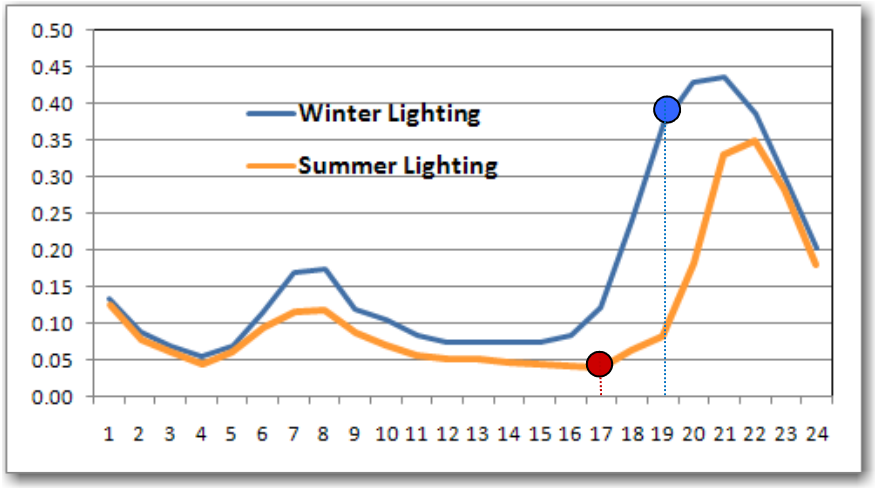
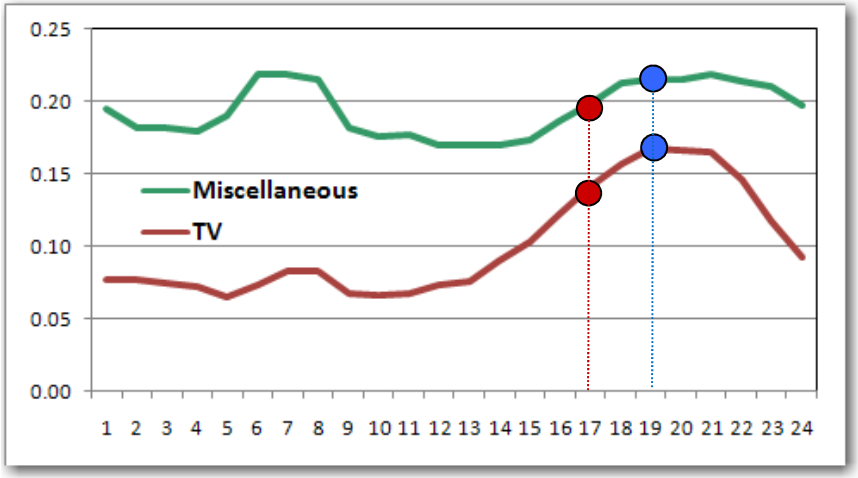
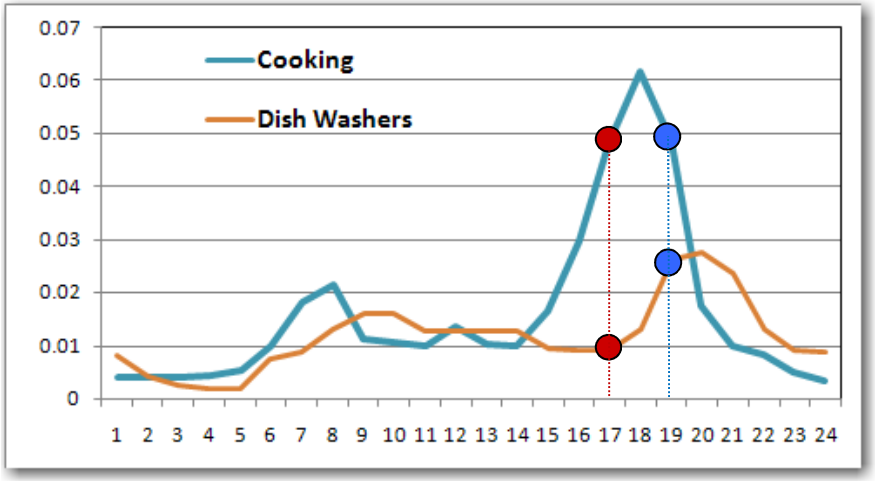
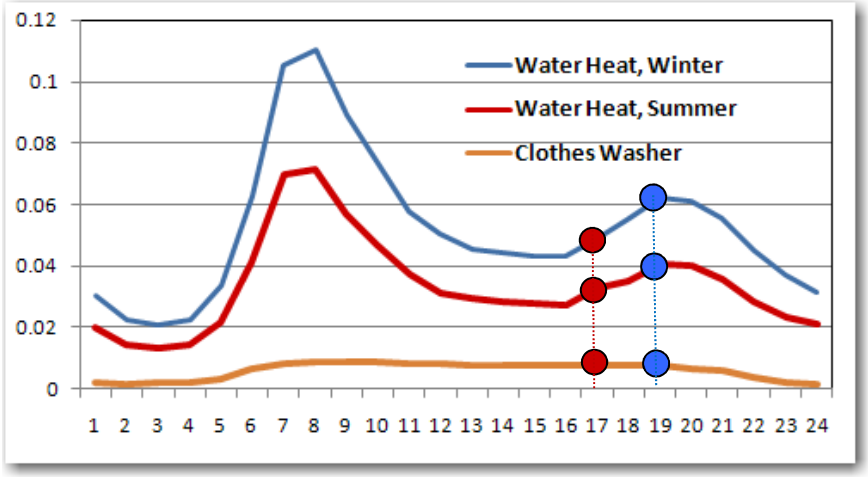
Find End-Use Coincident Peak Loads









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Calculate End-Use Coincident Peak Variables

- Estimate peak fractions

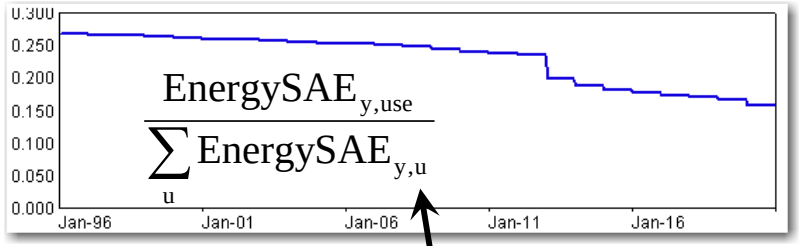
$$PeakFrac_{m,use} = \frac{CPk_{m,use}}{Energy_{a,\,use}}$$

- Apply to end-use energy estimates

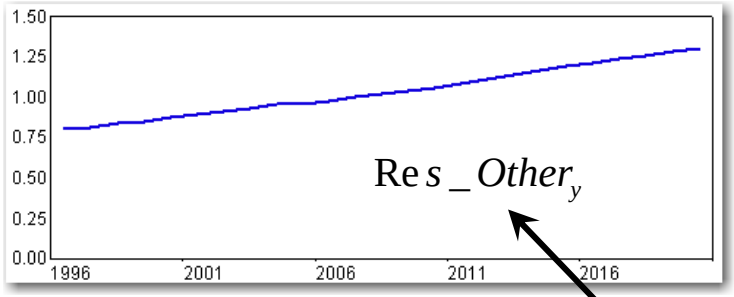
$$\mathrm{Re}\,sCP_{m,use} = \mathrm{Re}\,s\_Other_{y} \times \frac{EnergySAE_{y,use}}{\sum_{u} EnergySAE_{y,u}} \times PeakFrac_{use}$$

$$ComCP_{m,use} = Com\_Other_{y} \times \frac{EnergySAE_{y,use}}{\sum_{u} EnergySAE_{y,u}} \times PeakFrac_{use}$$

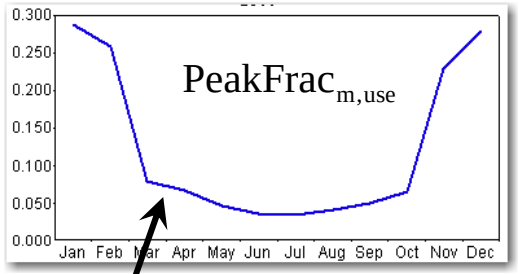
Example of Transformations – Res Lighting



$$\frac{EnergySAE_{y,use}}{\sum_{u} EnergySAE_{y,u}}$$

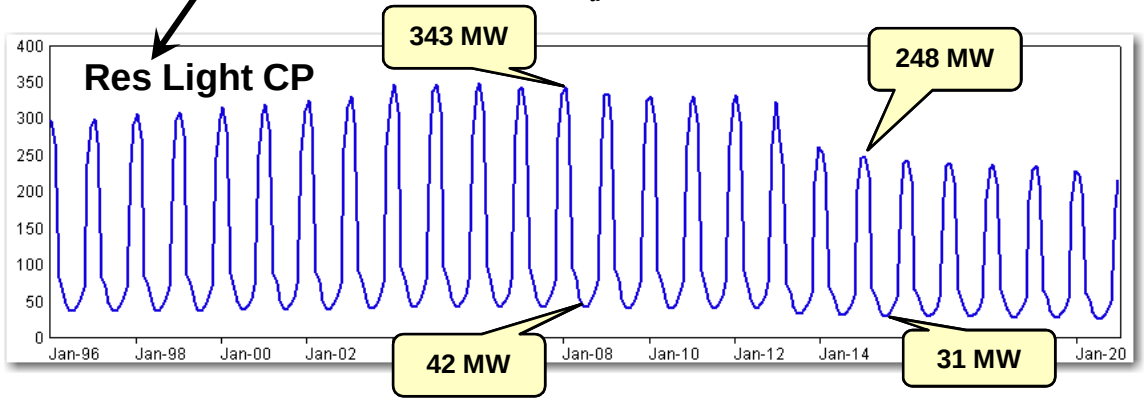


$$Res\_Other_{y}$$



$$PeakFrac_{m,use}$$

$$CP_{m,use} = Res\_Other_{y} \times \frac{EnergySAE_{y,use}}{\sum_{u} EnergySAE_{y,u}} \times PeakFrac_{m,use}$$



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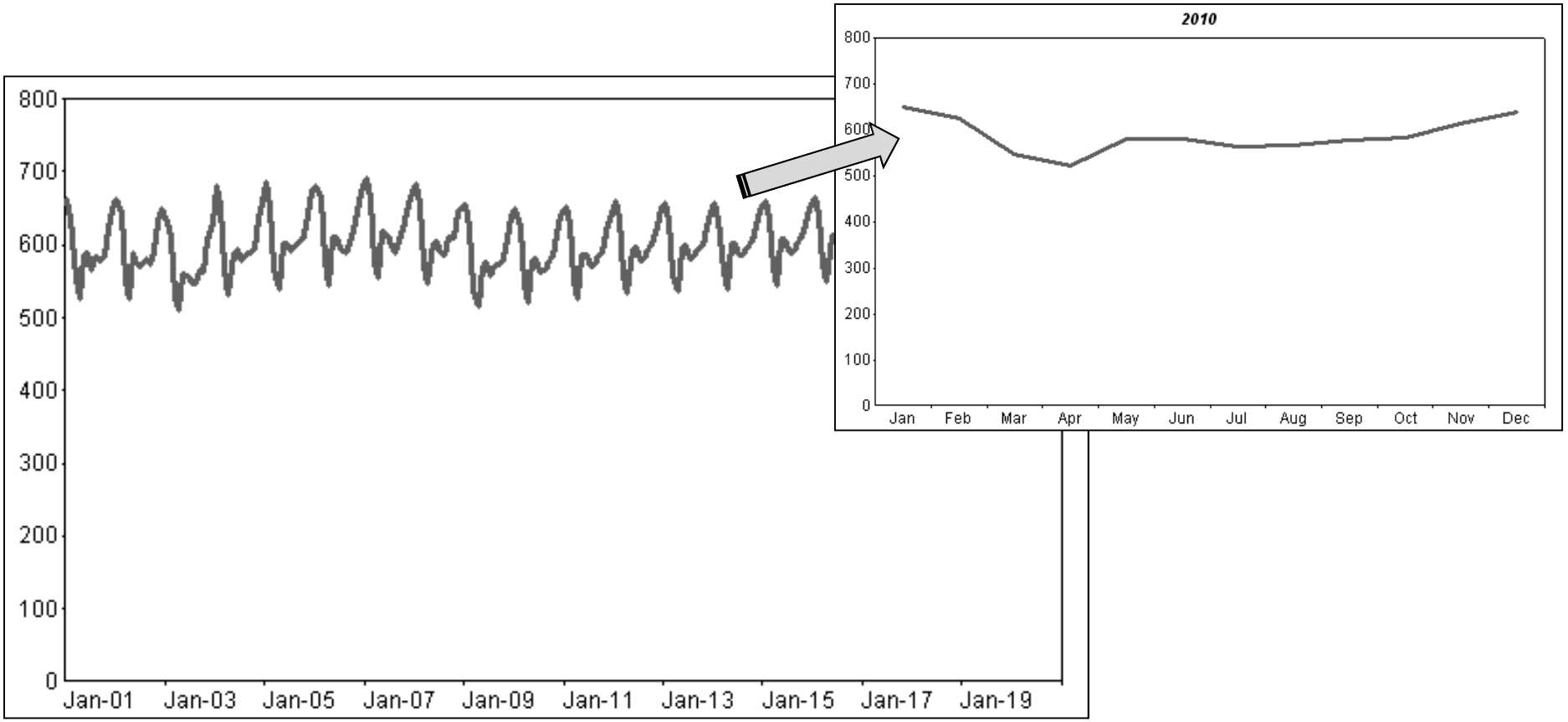
Add Class Coincident Peak Load Estimates

$$BaseVar_m = ResCP_m + COMCP_m + IndCP_m + OtherCP_m$$



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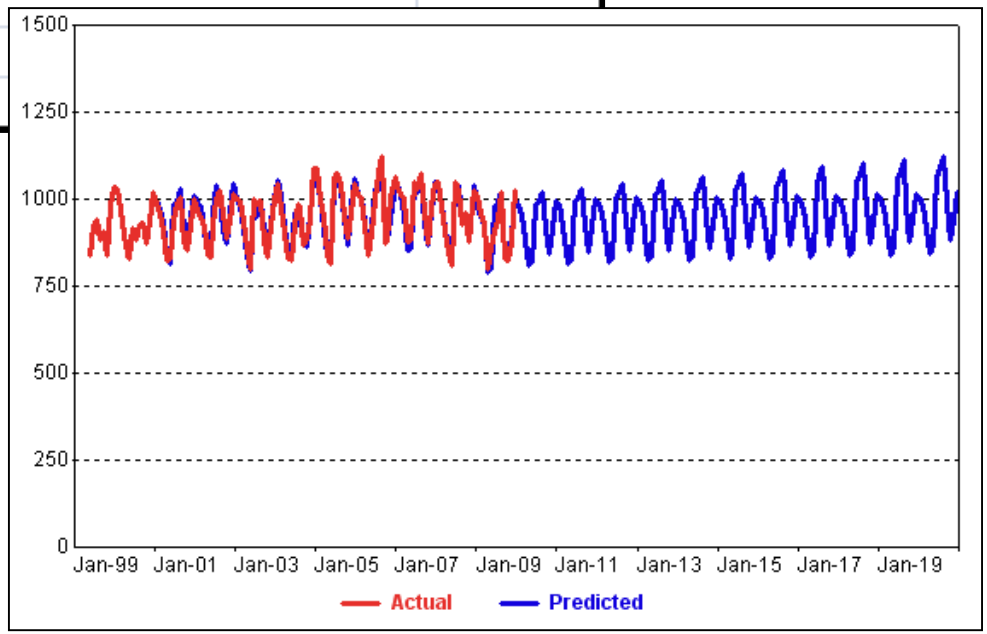
Estimate Peak Model

Variable	Coefficient	StdErr	T-Stat
CONST	461.718	55.411	8.333
BaseVar	0.723	0.091	7.93
HeatVar	1.429	0.248	5.751
CoolVar	14.304	1.157	12.359
Apr	-38.272	12.574	-3.044
May	-75.951	11.583	-6.557
Sep	-35.558	10.858	-3.275
Oct	-45.553	11.169	-4.079
Dec	37.131	10.002	3.712
Aug08	-135.666	26.801	-5.062
Sep09	-75.871	28.76	-2.638
Yr2009Plus	-32.177	8.75	-3.677

Regression Statistics	
Adjusted Observations	108
Deg. of Freedom for Error	95
R-Squared	0.904
Adjusted R-Squared	0.891
F-Statistic	74.245
Prob (F-Statistic)	0
Mean Abs. Dev. (MAD)	19.24
Mean Abs. % Err. (MAPE)	2.03%
Durbin-Watson Statistic	1.608



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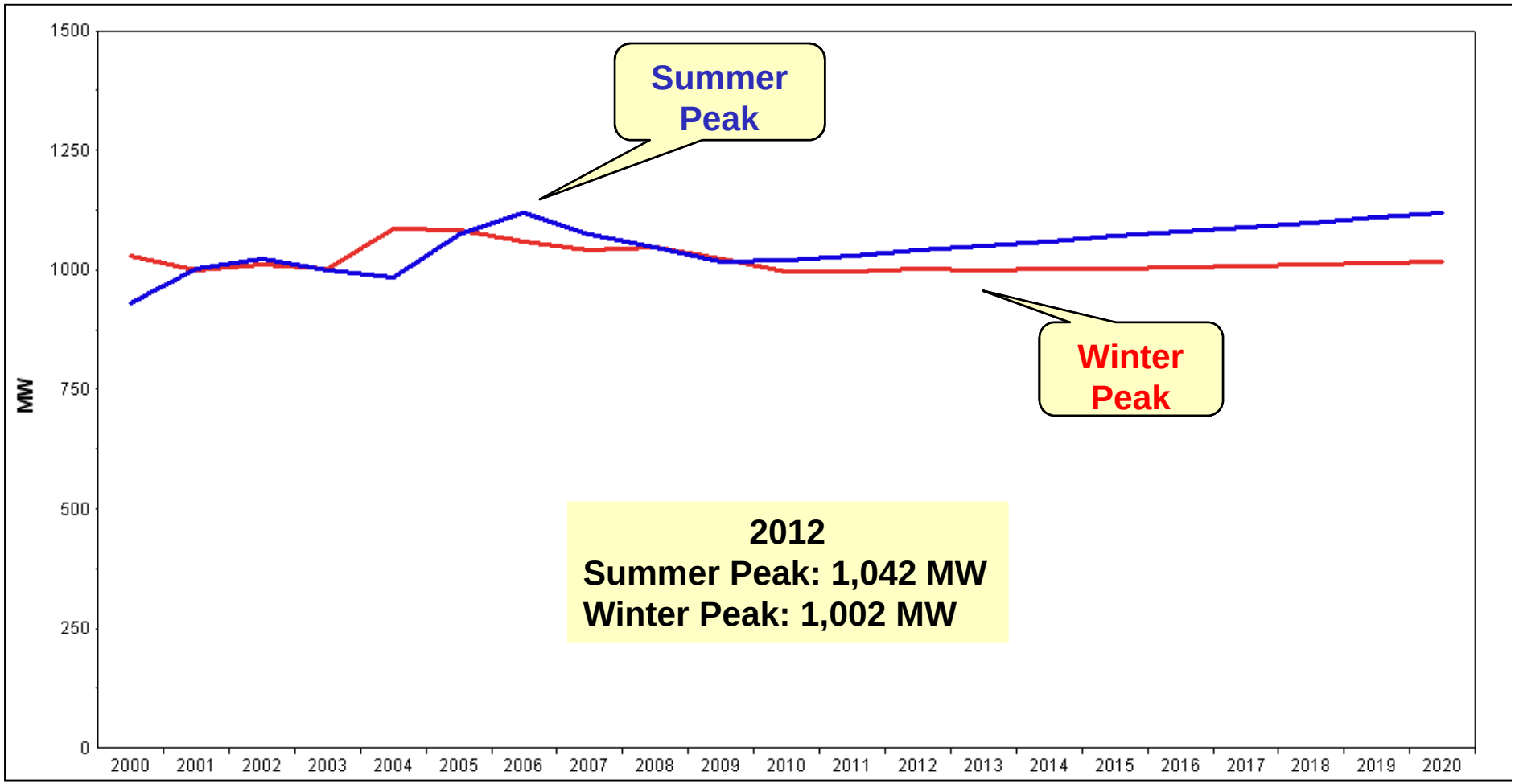
SAE Peak Demand Model Forecast



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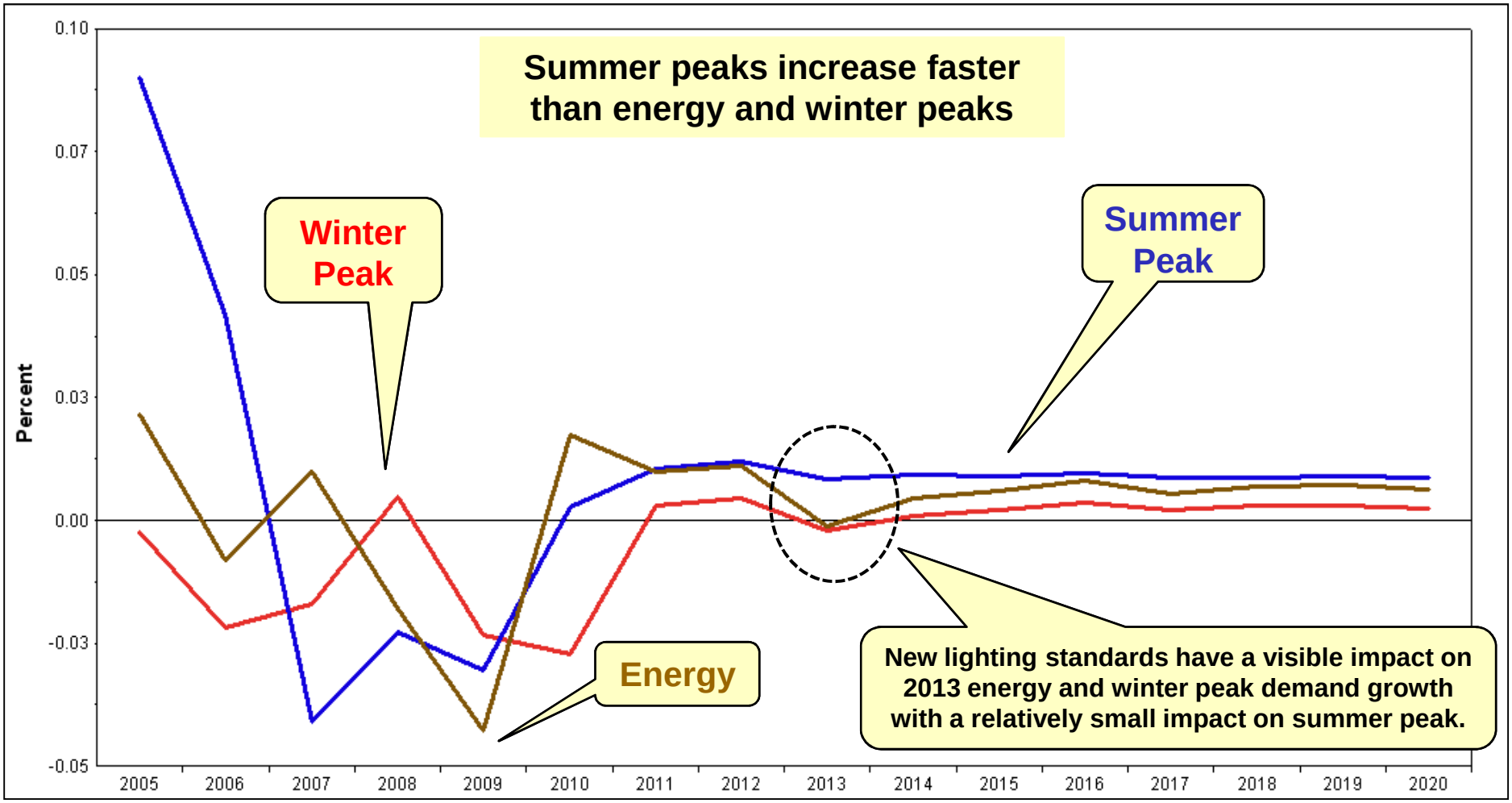
Forecasted Annual Growth



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Summary

- Both the hourly load build-up approach and the SAE peak model provide a framework for capturing the impact of class load diversity, and end-use saturation & efficiency trends on system peak demand
  - The load build-up model will do a slightly better job of capturing the impact of load diversity over time
  - The SAE model will do a better job capturing the impact of change in end-use loads
- Good load research data is required to support both modeling approaches.