Estimating Hourly Load Shapes for 50 States by Customer Class

September 25, 2009

Josh Bode
Paul Mangasarian
Freeman, Sullivan & Co.

FSC FREEMAN, SULLIVAN & CO.
A MEMBER OF THE FSC GROUP

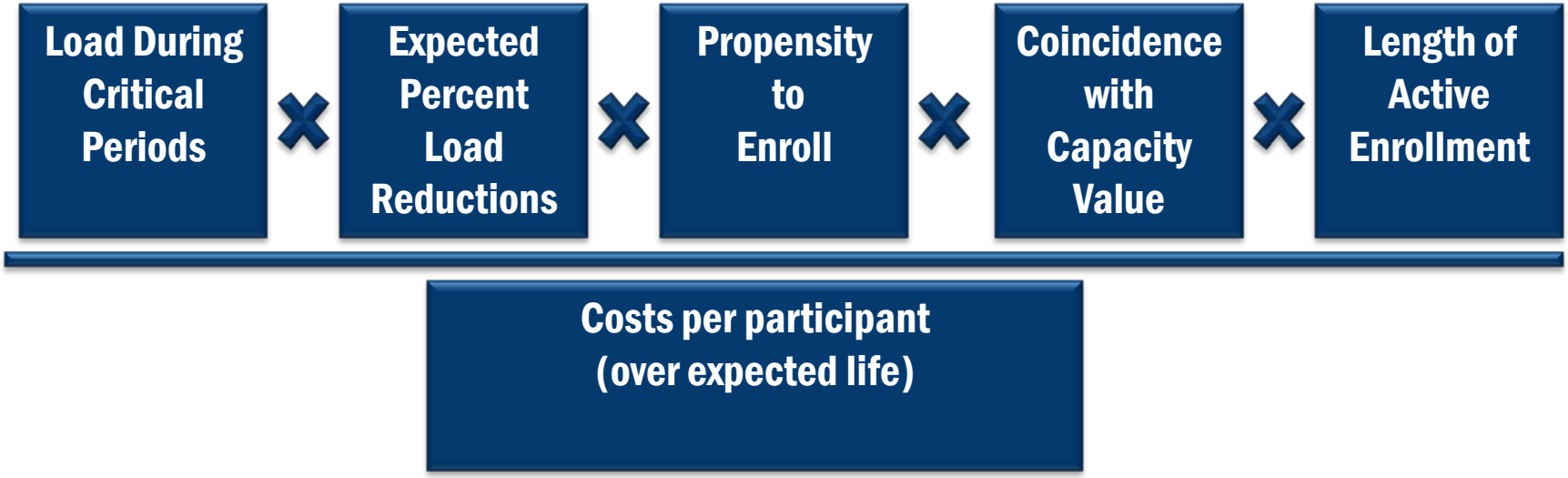
Overview

- **Why do hourly load shapes matter and why aren't they widely available?**
- **Why were hourly load shapes developed for all 50 states?**
- **How were they estimated and what was the logic for the methodology?**
- **Results and implications**
- **Potential for improvements and future collaboration**

Why do hourly load shapes matter?

- **They have many uses in a planning context**
  - Better understanding of the drivers of coincident system peak
  - Long term forecasting
  - Assess the potential for demand response and energy efficiency
  - Assess the expected impacts of price response and/or direct control programs at the program design stage
- **Why average weekday load shapes are insufficient for many applications**
  - Load patterns in average days can be substantially different than load patterns on system peaking days – particularly for a/c use
  - Average weekdays do not reflect the coincidence of multiple classes on system load

Any Estimates of Peak Load Reduction Potential and Cost-effectiveness Starts with the Coincident Load

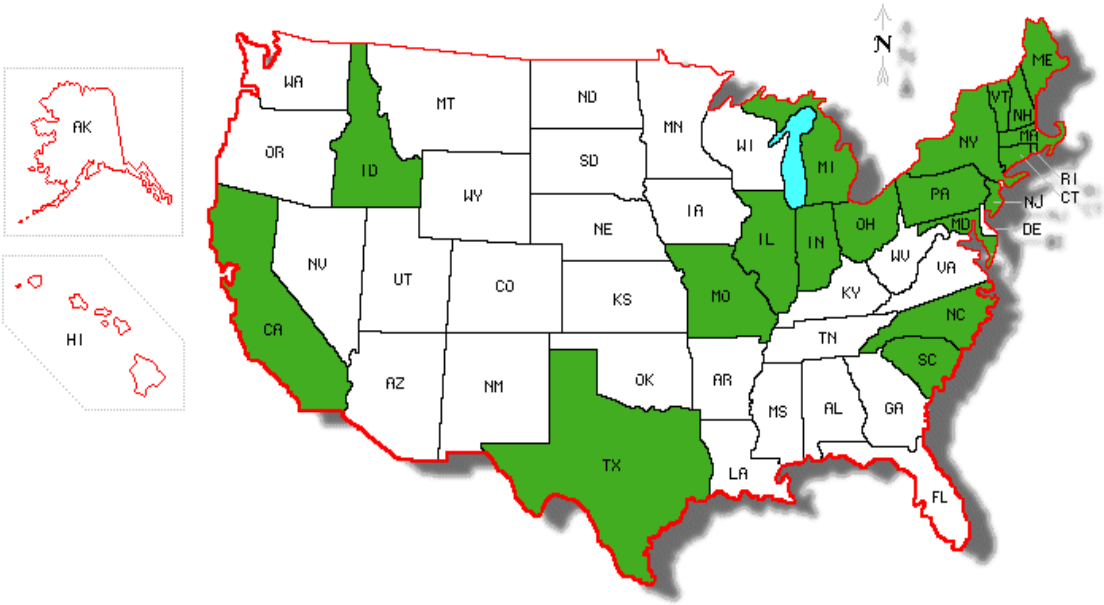


- **Resources can be used to improve load reduction and energy savings (PCTs, IHDs), increase propensity to enroll, or retain participants**
- **The expected load and percent load reductions will vary across hours and months of the year due to weather and other factors – their coincidence with the factors that drive the need for capacity matters**

Aren't hourly load shapes widely available?

- Surprisingly, NO
- Even when they are available for some utilities, they are often confidential and are not available for regional and national planning purposes
- We conducted a systematic search for publicly available hourly load shapes – load shapes were publicly available for 21 states
- For some states, the available hourly load shapes are not representative of the entire state
- What about commercially available products?
  - Methodology is not always transparent
  - Usually rely of building modeling and calibration to the system load
  - Building modeling inherently has assumptions about occupancy, and operations that may or may not be calibrated to actual behavior

Available Hourly Load Profile Data was Concentrated Among States with a De-regulated Retail Market



- Collected hourly load profile data from utilities in 21 states
- For some states (e.g., NY) the hourly load profile data is not representative of the entire state
- How do you calculate the load data for the other states?
- How do calculate load with and without central A/C?

The four options

1. **Ask for hourly load profile data that is not publicly available**
   - We tried it and picked up data for 4 states with that approach
   - Coordination requires time and we had a strict deadline
2. **Apply load shapes from neighboring states**
   1. There are substantial differences even among neighboring states
   2. Some states don't have similar states with hourly load data
3. **Rely on private hourly load data**
   1. Not publicly available
   2. Based on building simulation models = unknown assumptions about behavior and operating schedules
4. **Use the variation in the data available to calculate the load shapes for states that without the publicly available hourly load data**

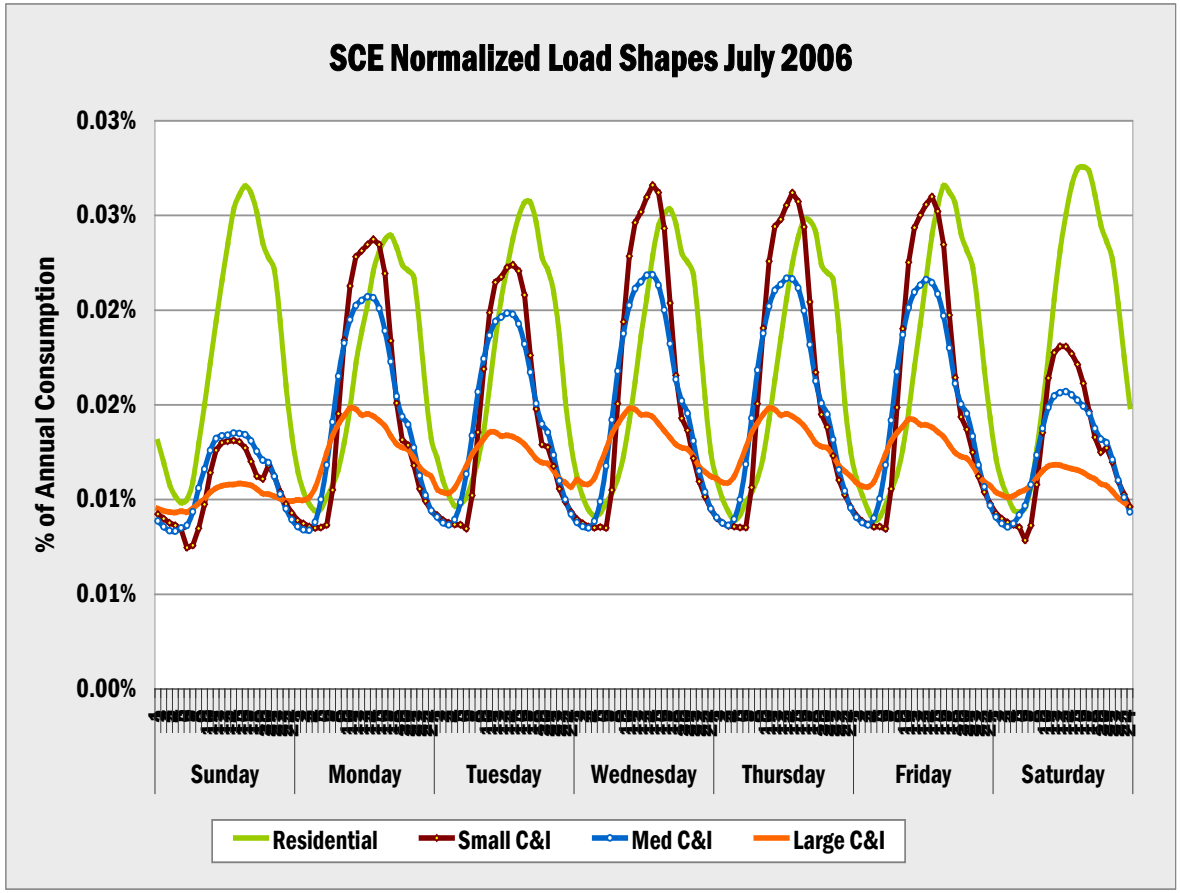
The Goal and the Challenges

- **Hourly load profiles for 50 states plus DC**
  - Residential with A/C
  - Residential without A/C
  - Small C&I (<20 kw)
  - Medium C&I (20-200 kW)
  - Large C&I (200 kW)
- **How do we explain the variation given…**
  - Differences and measurement error for central a/c saturation
  - Differences in weather
  - Differences in other end uses – i.e., electric heating, water heating, and pool pumps
  - Diverse service territories (e.g. every single utility from SDG&E to PSE)
  - Inconsistencies in size classification across rates and utilities
  - Substantial variation in the size of customers due to business mix, housing size, and codes

What about the other challenges?

- **The central a/c data was collected from census bureau MSA surveys and RASS studies (with much help from GEP)**
  - Difference in the timing and sampling have measurement error embedded
  - Regions with older homes (the NorthEast) have older home without central ducts, which no central a/c but lot of room a/c. Room a/c saturation data was far more sporadic
- **Hourly profiles are usually tied to rates and we used the FERC Form -1 data and an assumption of 0.60 load factor to assign hourly load data to customer categories**
- **Mapped NDCC weather station data to utilities**
  - For geographically diverse states, we weighted weather station data based on population at the major MSAs
- **What about the variation in customer size – i.e. square footage, housing vintage, codes?**

Load Shapes Were Normalized as the Percent of Annual Consumption in Each Hour

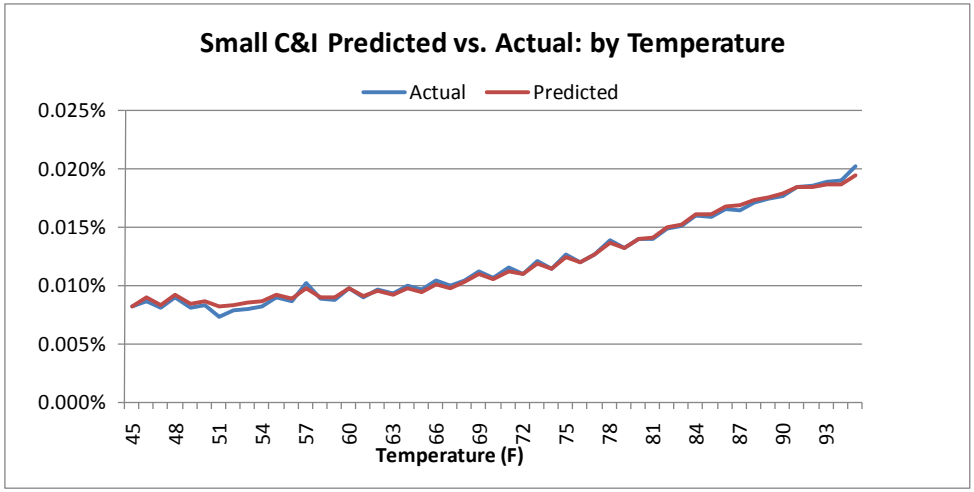


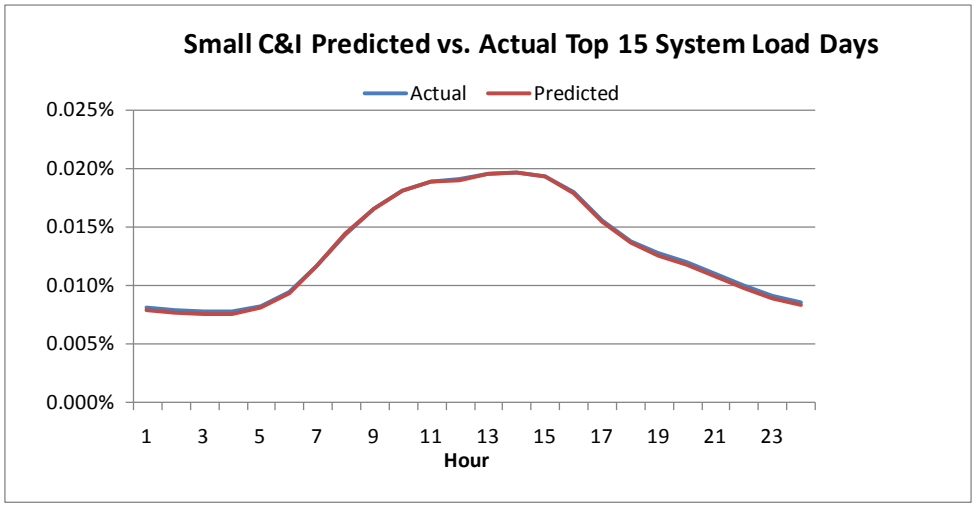
- Normalizing reduces variation – you only need to explain variation in the shape
- Load shapes can be scaled up and down for similar customers based on annual usage
- To make use of the cross section and the time series, as well as retain the ability to predict for other regions, we needed reduce the variation.

The Approach for Filling in the Gaps

- **Used panel regressions on normalized load shapes to predict variation of a load shapes as a function of temperature, central AC saturation, occupancy and operation patterns and other explanatory variables**
- **Use models to predict normalized load shapes for all states, for customers with and w/o AC**
- **Combine normalized load shapes with sector-specific, average annual energy use (FERC Form 1) to develop hourly load profiles by customer segment**
- **Combine it with system load data submitted to FERC to connect customer load with its coincidence with system load**

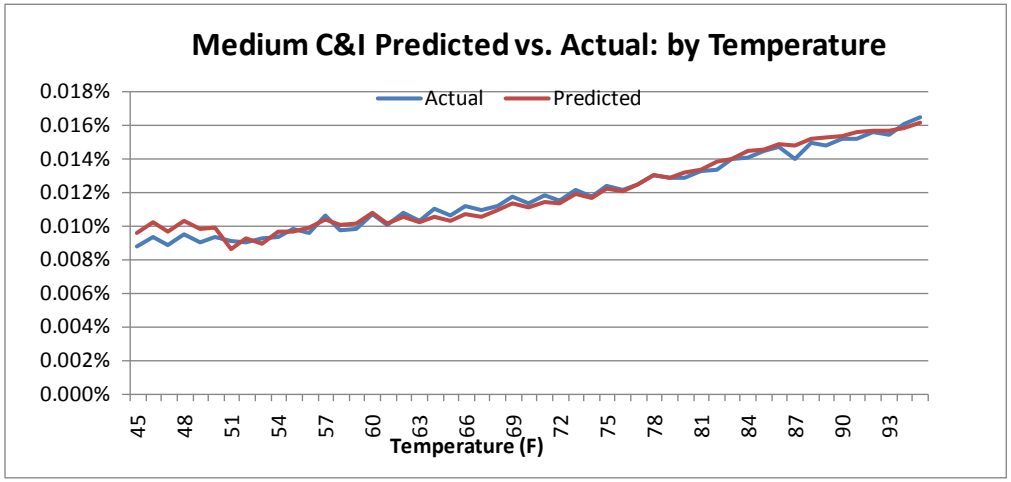
How well did we do? – Small C&I

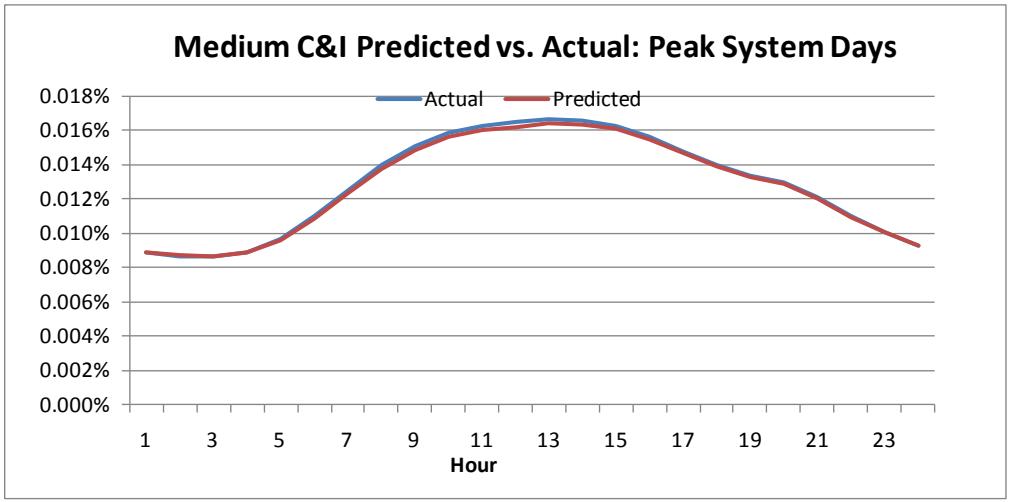




- **The predicted load mirrors actual loads across the temperature spectrum**
- **Predicted load also matches actual load for the highest 15 system load days**

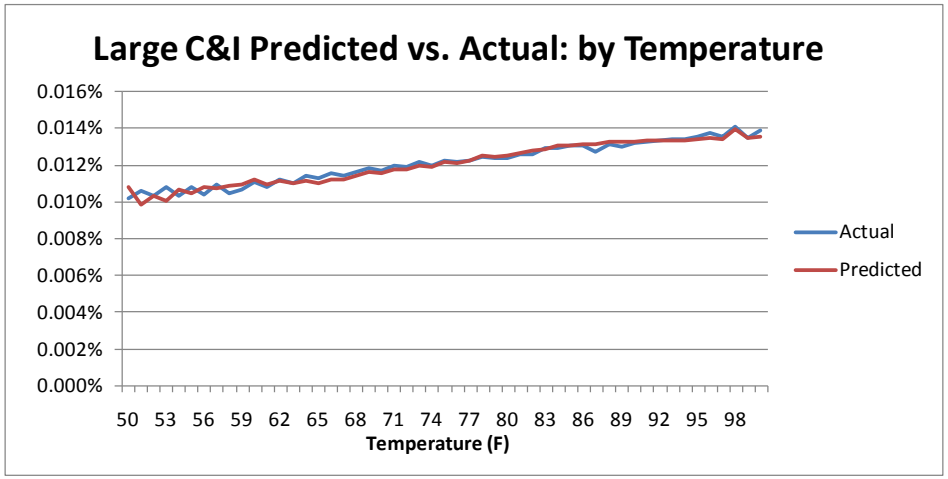
How well did we do? – Medium C&I

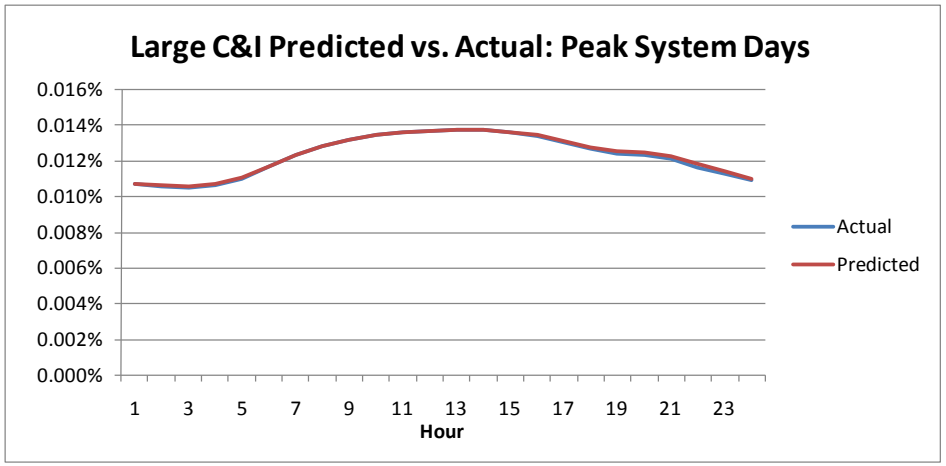




- **We are beginning to see a trend…**
- **Getting the predictions right for higher temperatures and high system load days may be more important than getting it right for the average weekday**

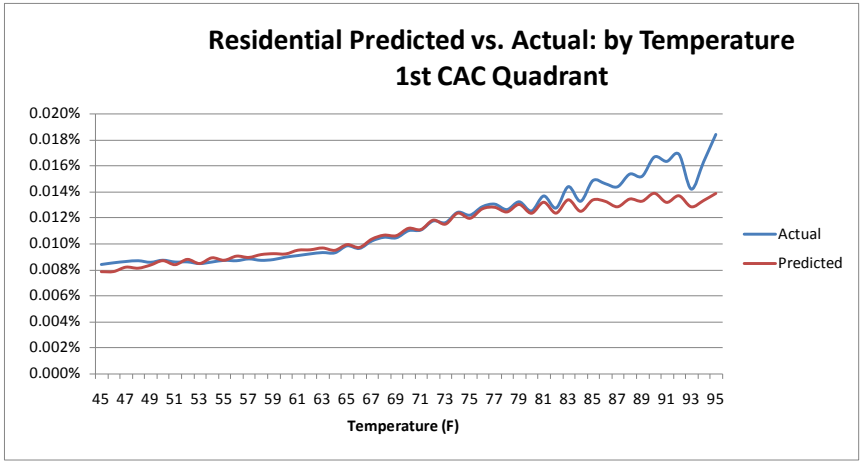
How well did we do? – Large C&I

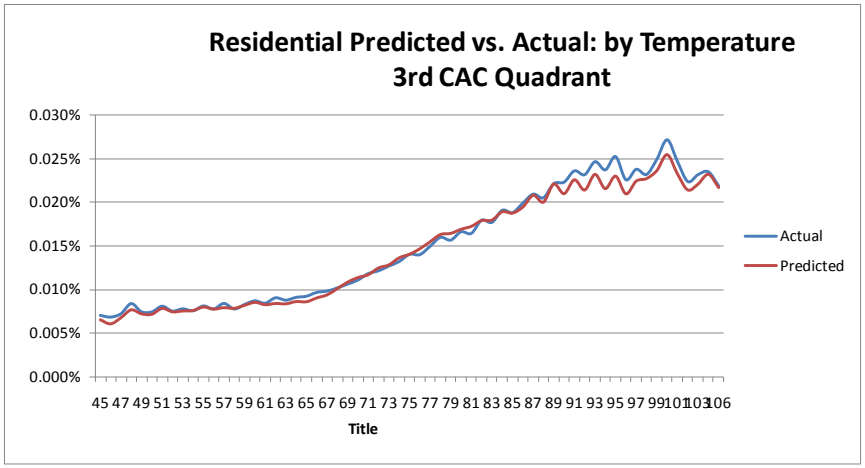


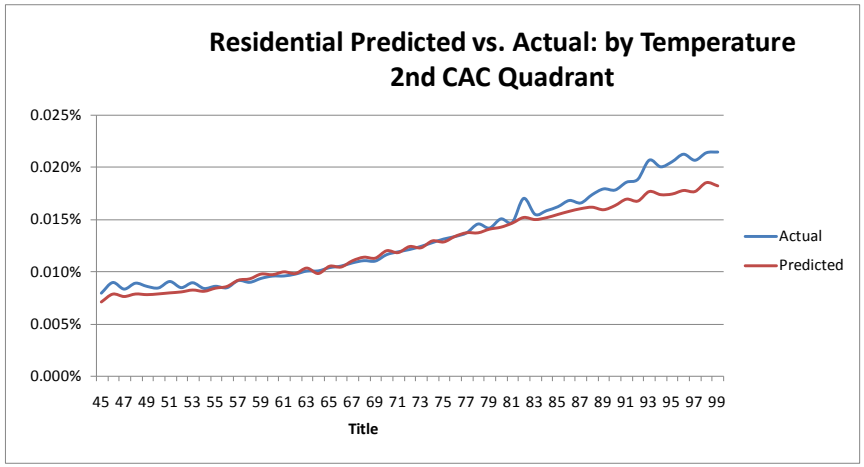


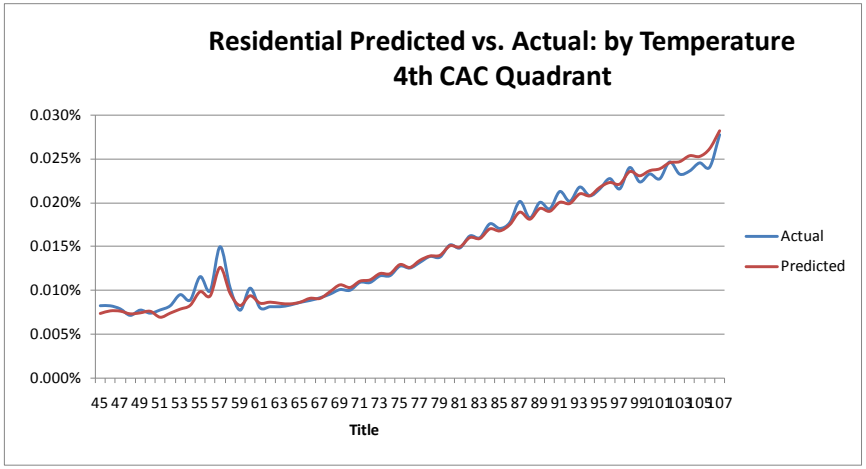
- **Do we have a trend???**
- **Results are accurate for the average utility, but there will be error for individual utility predictions**

How well did we do? - Residential

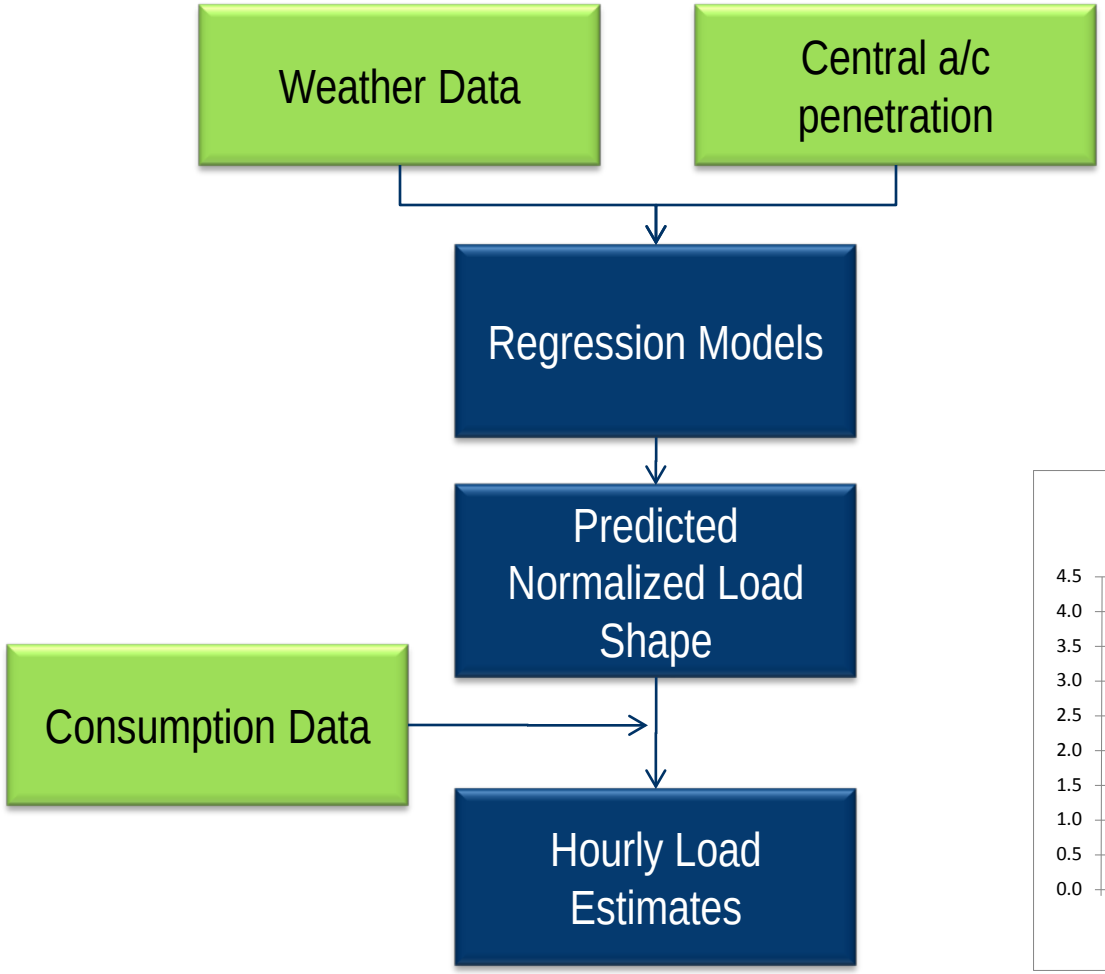






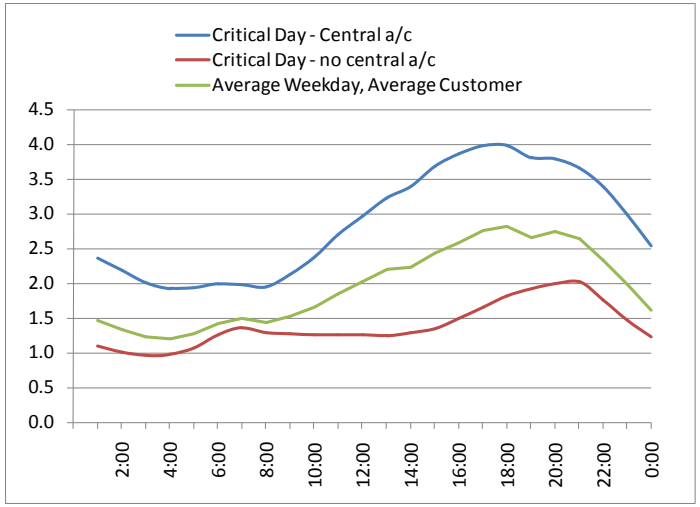


Using what we know to predict where we don't know

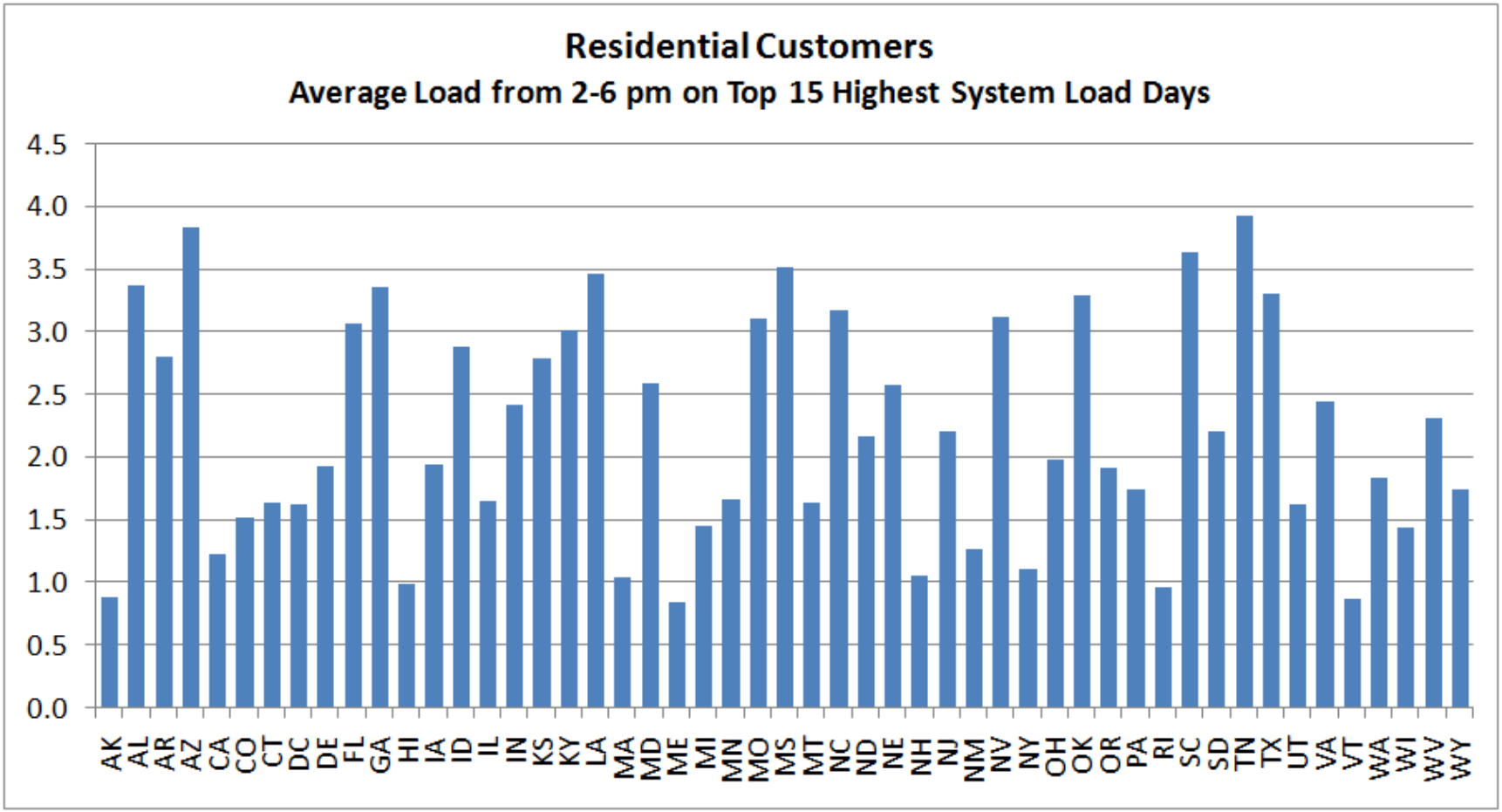


2 Models

- Hourly output for all fifty states with the information used for FERC DR potential study
- Predicts hourly load given load shape, weather, a/c saturation, and annual usage



What did we get across 50 states?



Potential for improvements and future collaboration

- **Increase the amount of hourly load profiles includes in dataset**
- **More time, better regression specifications**
- **Reduce error for input values**
  - Weather allocation
  - Central a/c penetration
- **Increase the explanatory variables and end-uses included**
  - Electric heating, water heating, pool pumps, prices, and more
  - Business mix, central a/c numbers for non-residential customers
- **Develop a publicly available dataset on hourly load shapes that can be used for planning**

If you have questions, please contact

Josh Bode, M.P.P.
Senior Consultant

Freeman, Sullivan & Co.
101 Montgomery Street, 15th Floor
San Francisco, CA 94104

joshbode@fscgroup.com
415 948-2326