Better Buildings Residential Network Peer Exchange Call Series: *Incorporating Weather Data into Energy Savings Calculations*

Call Slides and Discussion Summary

February 26, 2015

Agenda

- Call Logistics and Introductions
- Opening Poll
- Residential Network and Peer Exchange Call Overview
- Featured Speakers:
  - Ben Polly, National Renewable Energy Laboratory (NREL)
  - Ethan Goldman, Vermont Energy Investment Corporation (VEIC)
- Discussion
  - What approaches has your organization used in incorporating weather data to calculate energy savings?
  - Are there other tools in addition to those discussed today that are useful for normalizing energy savings data with weather data?
  - Have you encountered any challenges in incorporating weather data into energy savings? What helped you overcome those challenges?
  - What questions do you have about how to incorporate weather data to calculate energy savings?
  - Other?
- Closing Poll

Call Participants

- Boulder County
- Center for Sustainable Energy
- City and County of Denver
- City of Bloomington Utilities
- City of Takoma Park, Maryland
- Civic Works/Retrofit Baltimore
- Clean Energy Works
- Elevate Energy
- Energy Efficiency Specialists, LLC
- Energy Pioneer Solutions
- Energy Smart
- Greater Cincinnati Energy Alliance
- Holy Cross Energy
- International Center for Appropriate and Sustainable Technology
- MPower Oregon
- New York State Energy Research and Development Authority
- Terracel Energy/ResiSpeak
- University of Illinois

Opening Poll Results

- What experience does your organization have with incorporating weather data to calculate energy savings?
  - Some experience but still learning – **37%**
  - No experience – **21%**
  - Limited experience – **21%**
  - Very experienced – **21%**
  - Other (please explain) – **0%**

Better Buildings Residential Network

- **Better Buildings Residential Network**: Connects energy efficiency programs and partners to share best practices to increase the number of American homes that are energy efficient.
  - Membership: Open to organizations committed to accelerating the pace of existing residential upgrades. Commit to providing DOE with annual number of residential upgrades, and information about benefits associated with them.
  - Benefits:
    - Peer Exchange Calls
    - Tools, templates, & resources
    - Newsletter updates on trends
    - Recognition: Media, materials
    - Optional benchmarking
    - Residential Solution Center

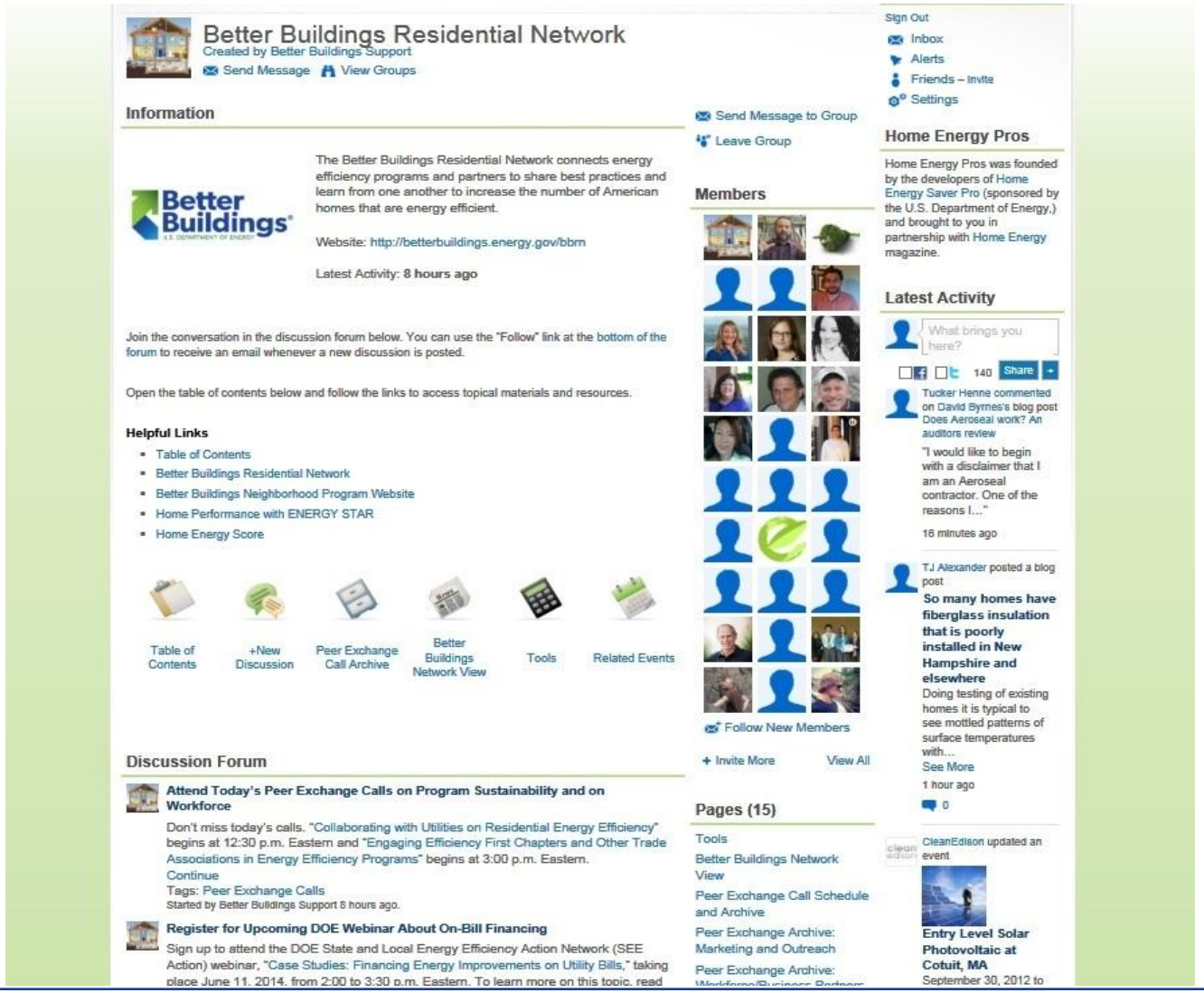
For more information & to join, email bbresidentialnetwork@ee.doe.gov.

- **Better Buildings Residential Network Group on Home Energy Pros**

  Join to access:
  - Peer exchange call summaries and calendar
  - Discussion threads with energy efficiency programs and partners
  - Resources and documents for energy efficiency programs and partners

http://homeenergypros.lbl.gov/group/better-buildings-residential-network

Better Buildings Residential Network Group on Home Energy Pros Website



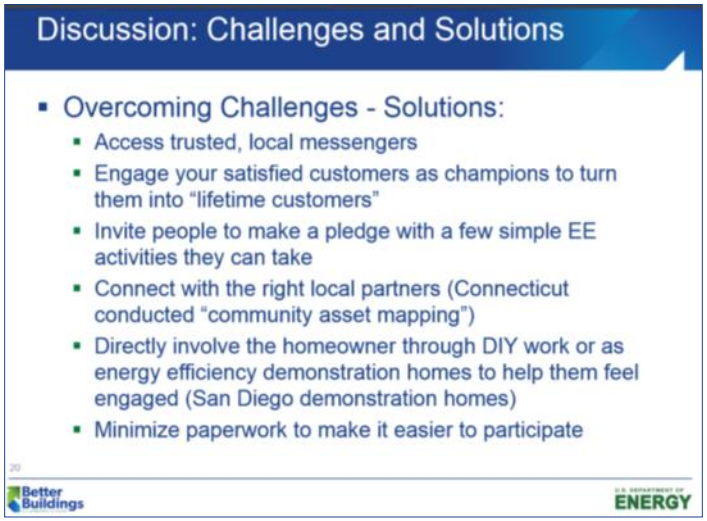
Better Buildings U.S. DEPARTMENT OF ENERGY

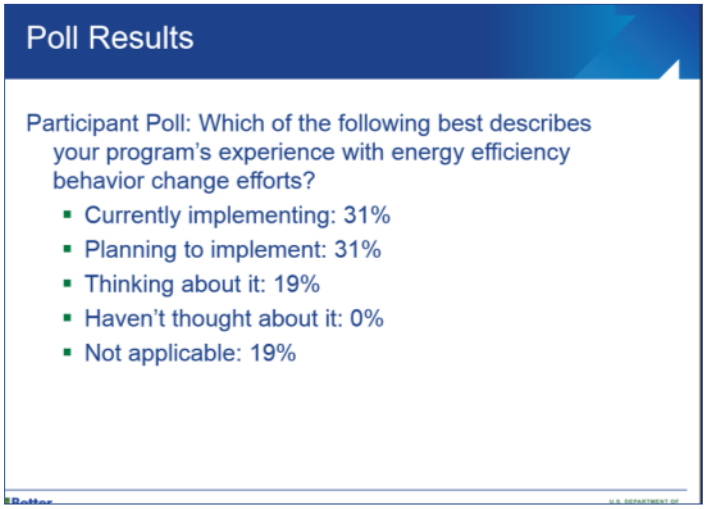
U.S. DEPARTMENT OF ENERGY

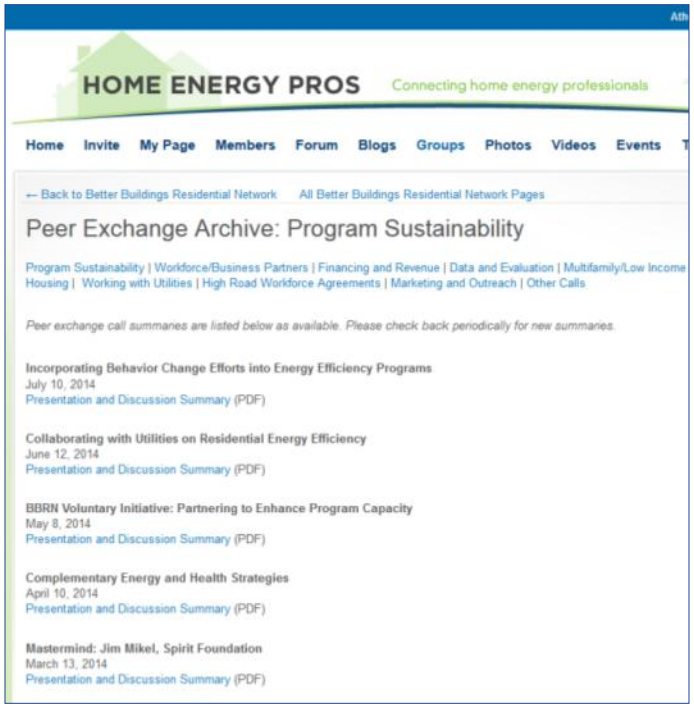
Peer Exchange Call Series

- Calls are held the 2nd and 4th Thursday of every month at 12:30 and 3:00 ET
- Calls cover a range of topics, including financing & revenue, data & evaluation, business partners, multifamily housing, and marketing & outreach for all stages of program development and implementation
- Upcoming calls:
  - March 12, 12:30 ET: Networking Call for Residential Network Members
  - March 12, 3:00 ET: Using Mobile Applications to Generate Customer Demand
  - March 26, 12:30 ET: Voluntary Initiative on Incentives: Toolkit Training Webinar
  - March 26, 3:00 ET: Fostering Behavior Change in the Energy Efficiency Market
- Send call topic ideas to peerexchange@rossstrategic.com

Peer Exchange Call Summaries







How do you eat an elephant? One bite at a time. A slight shift in perspective goes a long way.

Understanding how EE can solve a financial, public relation, or customer service problem for the utility is the right place to start.

Residential Program Solution Center

Web portal of residential EE upgrade program resources, & lessons learned to plan better, avoid reinventing the wheel.

- BB Neighborhood Program, Home Performance with ENERGY STAR Sponsors+
- Provides:
  - Step-by-step guidance
  - Examples
  - Tools
  - Templates
  - Lessons learned
  - Best practices
  - Tips
- Continually add content to support residential EE upgrade programs—member ideas wanted!

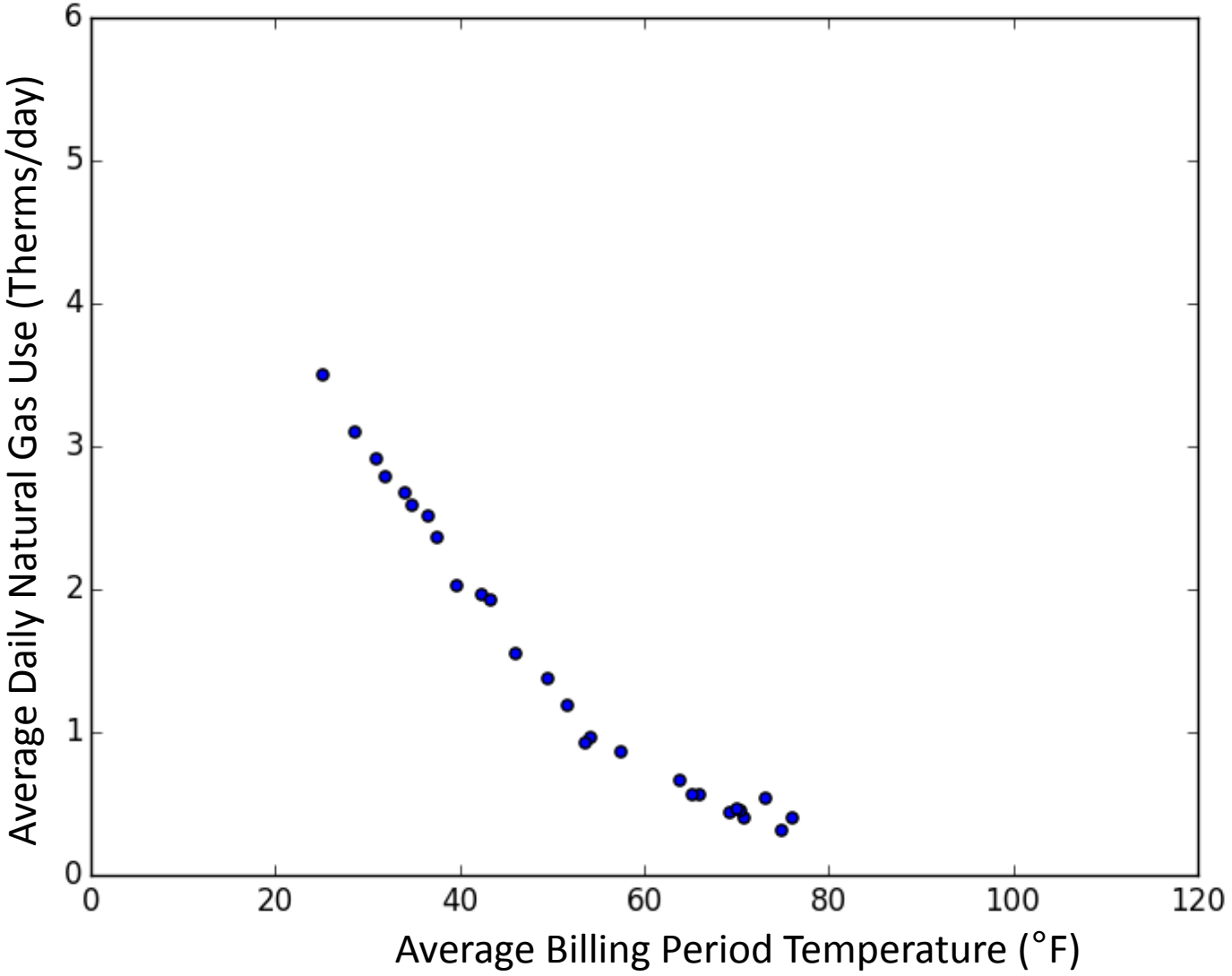
https://bbnp.pnnl.gov/

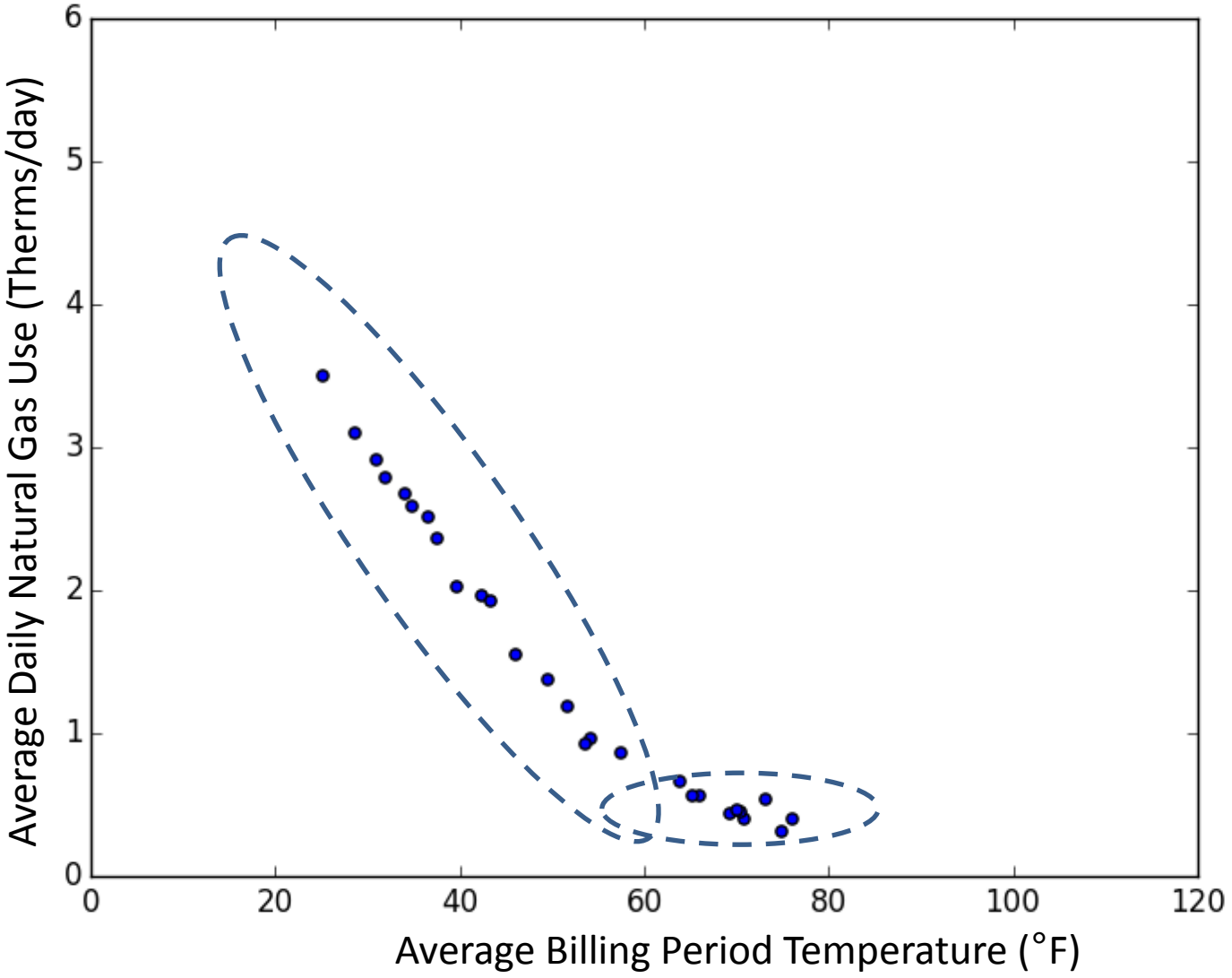
Program Experience:
Ben Polly
National Renewable Energy Laboratory (NREL)

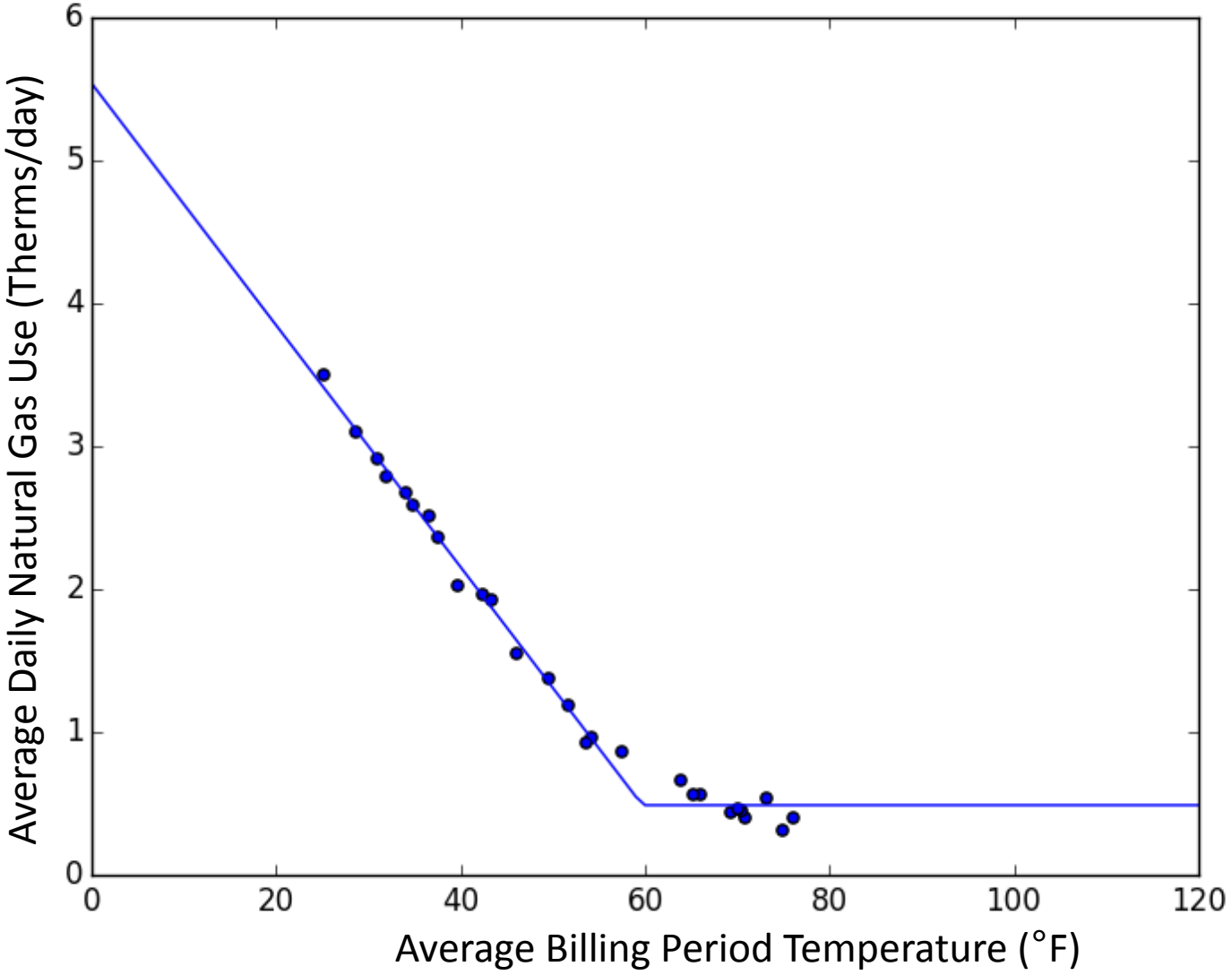
U.S. DEPARTMENT OF ENERGY

Outline

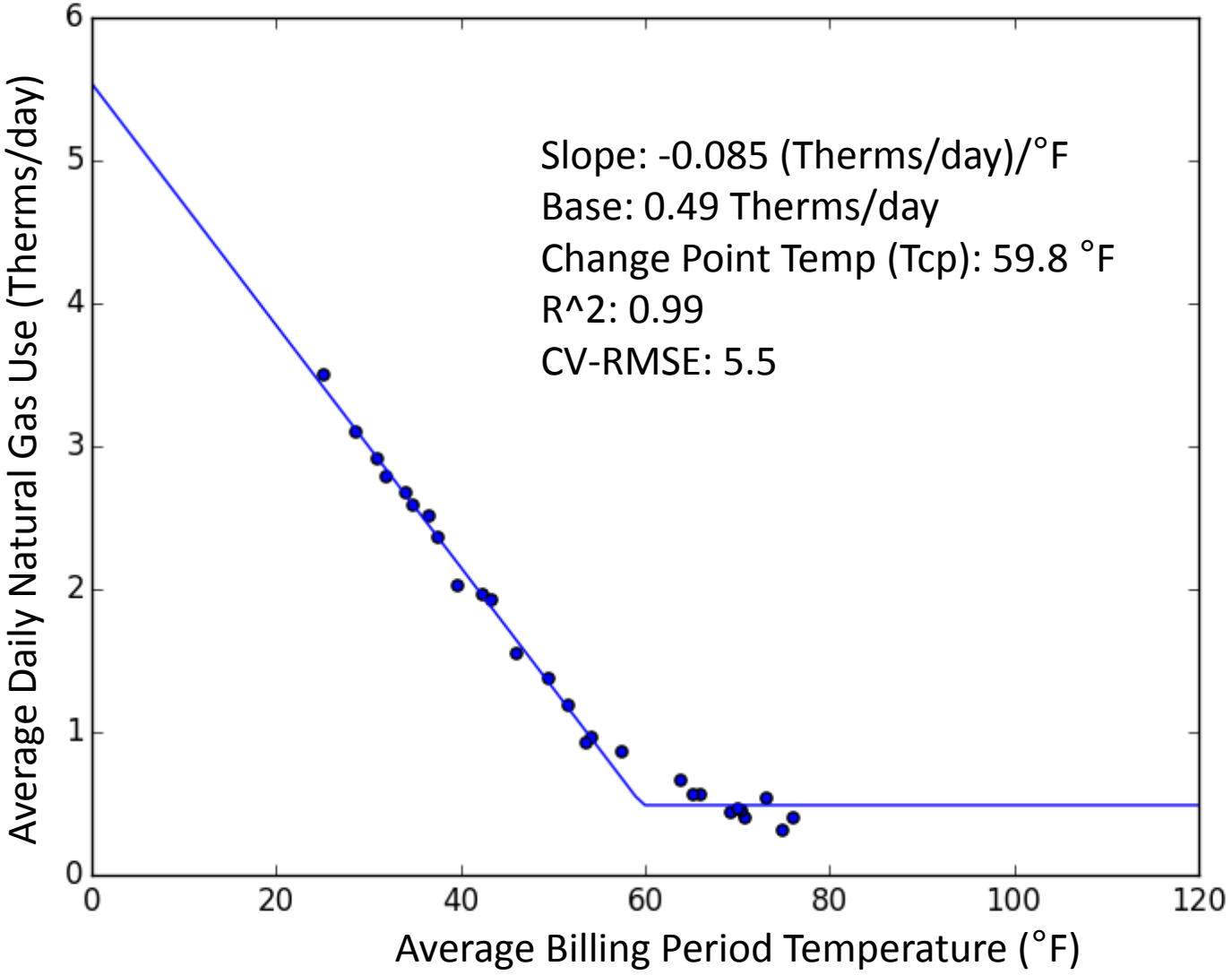
- Background: weather normalization
- Example: natural gas in heating-dominated climate
- Automated normalization procedures


Average Daily Natural Gas Use (Therms/day)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
Average Billing Period Temperature (°F)

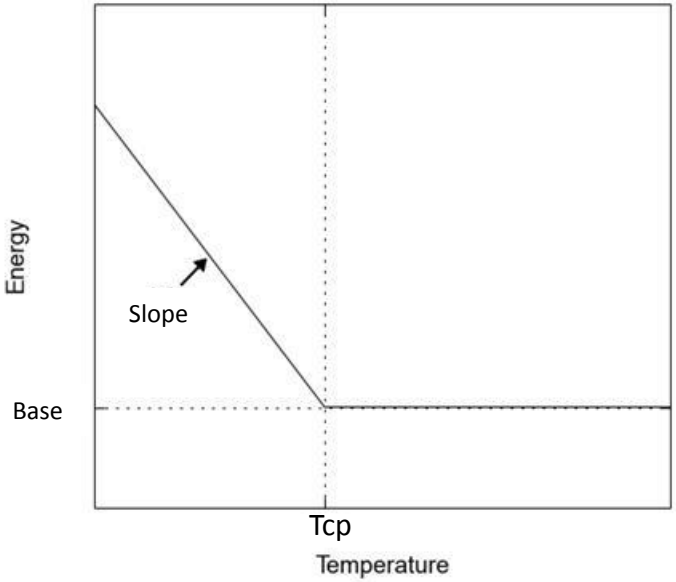

Average Daily Natural Gas Use (Therms/day)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
Average Billing Period Temperature (°F)


Average Daily Natural Gas Use (Therms/day)
Average Billing Period Temperature (°F)
0
1
2
3
4
5
6
0
20
40
60
80
100
120

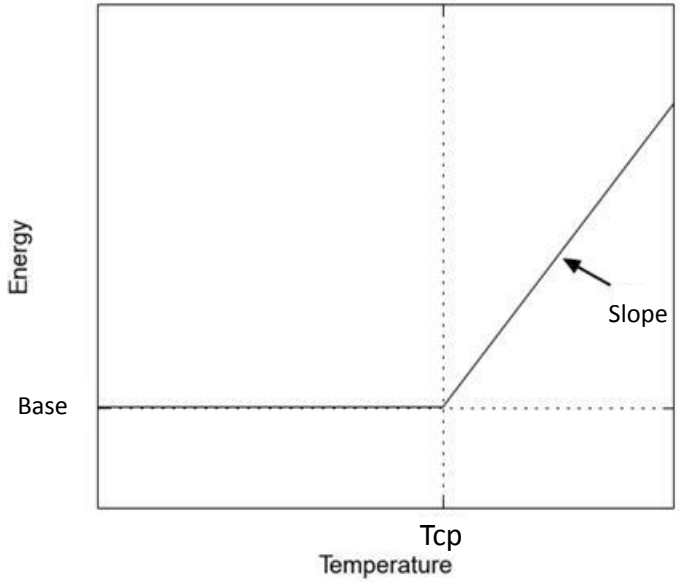
$$Therms/day = \begin{cases} Base + Slope(Tavg - Tcp), & Tavg < Tcp \\ Base, & \text{otherwise} \end{cases}$$



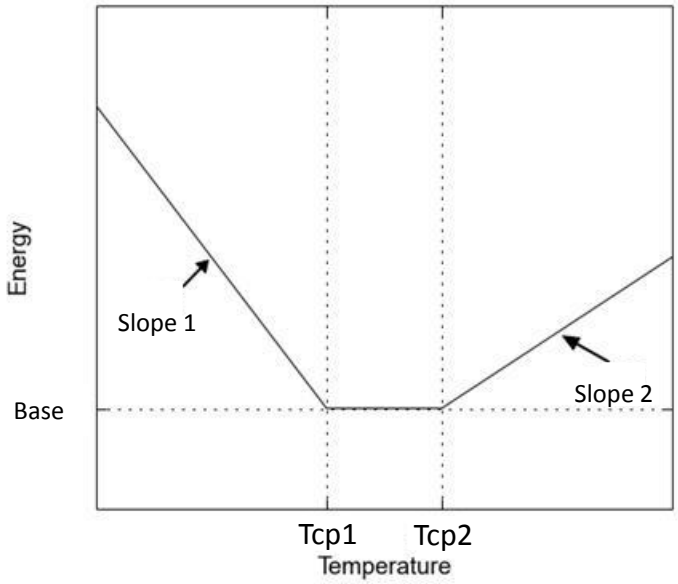
3-Parameter Heating



3-Parameter Cooling



5-Parameter



Automated Procedure

1. Pull electric and natural gas utility data for a given project
2. Identify the normalization scenarios for each project (up to four)
3. Prepare utility data and weather data for IMT
4. Call IMT and apply filters
   - Natural Gas: 3-parameter heating
   - Electricity: mean, 3-p heating, 3-p cooling, 5-p
5. Calculate TMY3 normalized energy uses

National Renewable Energy Laboratory

Some Basics of Normalizing Energy Usage with Weather Data

- Building energy consumption is dependent on many factors, including (but not limited to) occupant behavior, building characteristics, and weather (e.g., ambient temperature, solar radiation, wind)
- Weather normalization is important when comparing the energy usage of a home between two different time periods (e.g., pre- and post-retrofit consumption).
  - Without weather normalization, calculated differences in energy consumption can be largely due to differences in weather between the two time periods.
- A common approach is to normalize energy consumption based on outdoor ambient temperatures experienced during the time periods.

National Renewable Energy Laboratory

Some Basics of Normalizing Energy Usage with Weather Data

- One approach NREL has used to weather normalize energy usage data involves developing building-specific statistical regression models that predict the average daily energy consumption as a function of average daily ambient temperature.
  - NREL has also used closely-related approaches that model energy consumption as a function of heating and/or cooling degree days.
- Using the model and local weather data, one can estimate how much energy the home would have used during the post-retrofit period if no upgrade had been performed, and compare the results to the actual energy usage to estimate the savings due to the upgrades.

National Renewable Energy Laboratory

Tips for Modeling Professionals

- Different types of statistical regression models can be fit to the energy usage data. NREL described one project in which they used a variety of model types, each with different fit parameters:
  - Mean model: assumes no temperature-dependent consumption; one parameter.
  - 3-parameter heating: assumes temperature-dependent energy consumption below a change-point temperature.
  - 3-parameter cooling: assumes temperature-dependent energy consumption above a change-point temperature.
  - 5-parameter: combines 3-parameter heating and cooling models.
- A range of change-point temperatures were investigated for the 3- and 5-parameter model fits.
- NREL examined the goodness-of-fit (R^2, CV-RMSE) and the fit parameter values when selecting between model types.
- NREL obtained weather data from NOAA weather stations by pulling hourly data from their FTP site.

Program Experience:
Ethan Goldman
Vermont Energy Investment Corporation (VEIC)

U.S. DEPARTMENT OF ENERGY

VEIC's Weather Normalization Applications

Ethan Goldman
Greg Fanslow
Jake Jurmain

Feb 26, 2015

Vermont Energy Investment Corporation

Vermont Energy Investment Corporation

- Mission-driven nonprofit
- Over 25 years reducing economic, environmental costs of energy
- Energy efficiency, renewable energy & transportation
- Consulting & implementation
- 3 energy efficiency utilities

How VEIC Uses Weather Normalization

- Estimating typical year energy use
- Calculating savings
- Selecting optimal balance points
- Calculating model uncertainty
- Heating/cooling energy disaggregation
- Development and testing of time-series models

Streamlined Weather Normalization

Load Data | View Results

Step 1: Import Usage Data

Browse...

Must be a CSV file.
First row must be labels.
First column must be bill dates.
Second column must be usage.
Additional columns are ignored.

Review data (Optional)

Step 2: Choose Building's Balance Point (See Table for Recommendations)

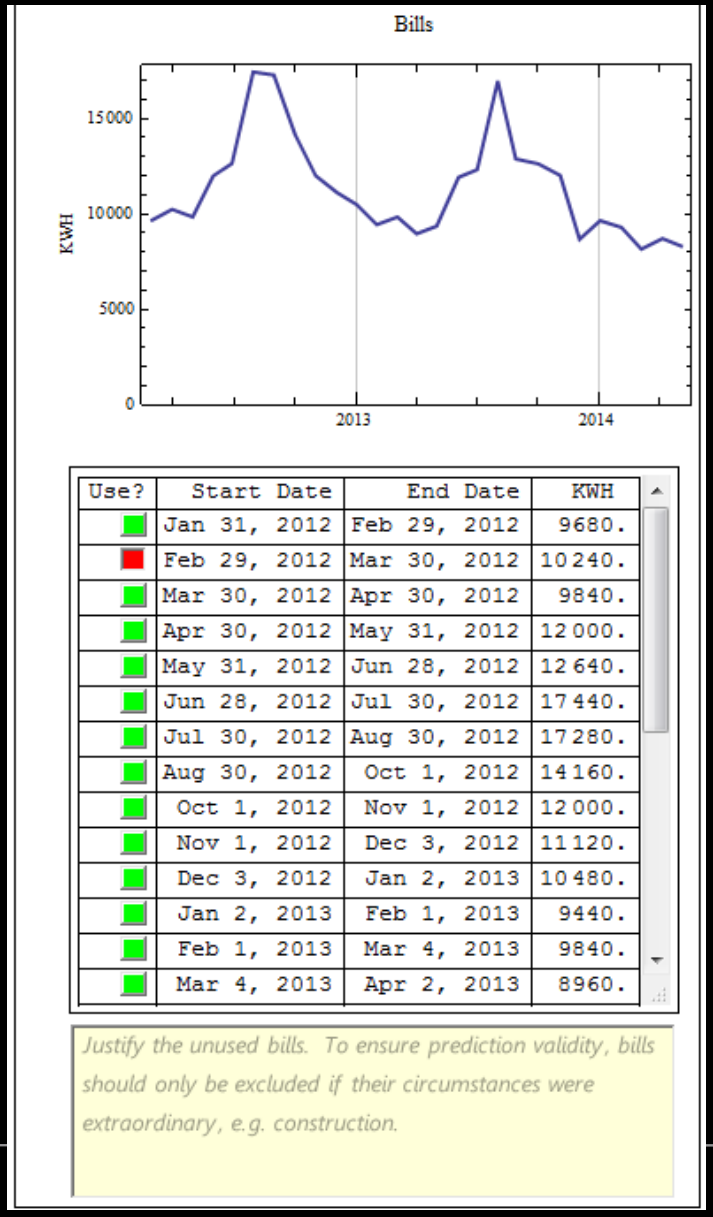
Suggested Balance Points			
	<10,000 ft²	10 - 50,000 ft²	>50,000 ft²
School	60	60	50
Small Healthcare	50	50	40
Multifamily	60	60	60
Municiple Office	55	50	50
Municiple Garage	60	60	55

Enter Balance Point: 55 (Hit Enter or just click outside the box)

Step 3: Find Nearest Weather Station

Enter customer site zip code: 05401 Find station

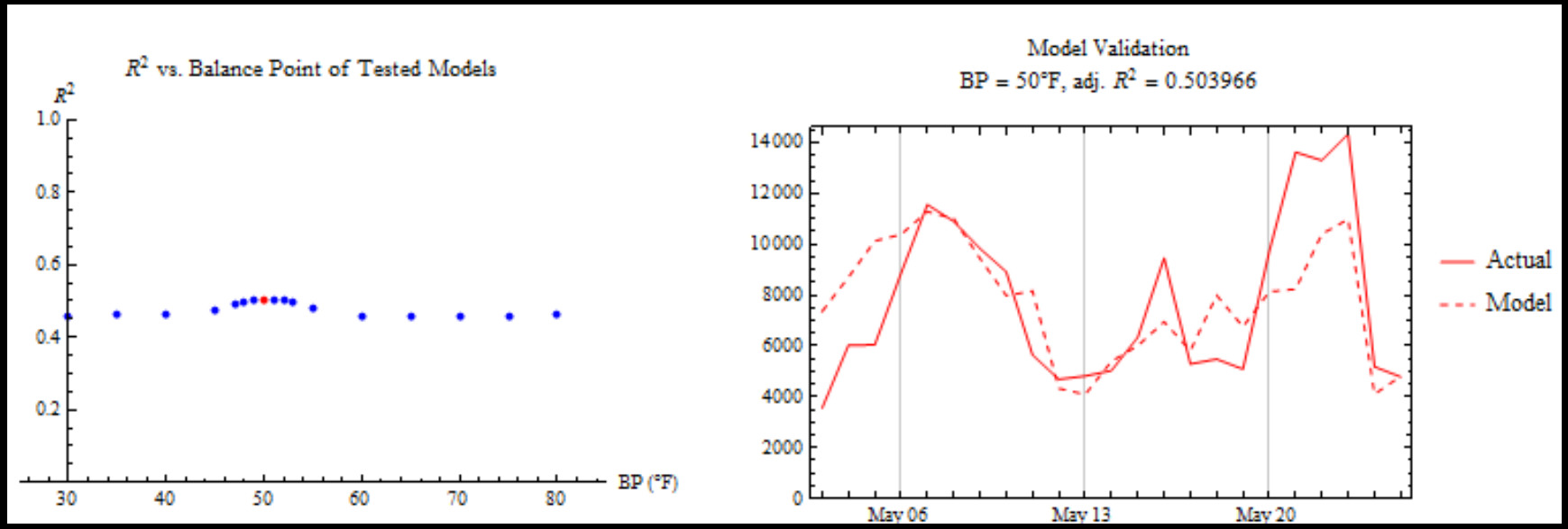
Streamlined Weather Normalization



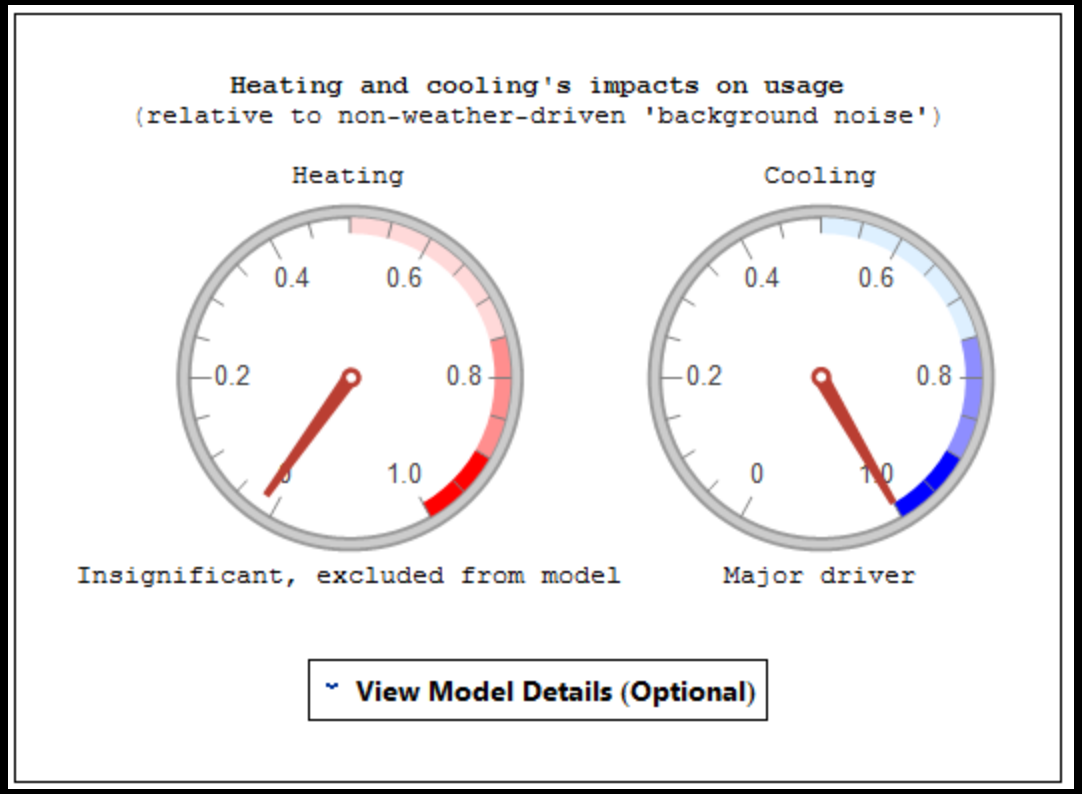
Use?	Start Date	End Date	KWH
■	Jan 31, 2012	Feb 29, 2012	9680.
■	Feb 29, 2012	Mar 30, 2012	10240.
■	Mar 30, 2012	Apr 30, 2012	9840.
■	Apr 30, 2012	May 31, 2012	12000.
■	May 31, 2012	Jun 28, 2012	12640.
■	Jun 28, 2012	Jul 30, 2012	17440.
■	Jul 30, 2012	Aug 30, 2012	17280.
■	Aug 30, 2012	Oct 1, 2012	14160.
■	Oct 1, 2012	Nov 1, 2012	12000.
■	Nov 1, 2012	Dec 3, 2012	11120.
■	Dec 3, 2012	Jan 2, 2013	10480.
■	Jan 2, 2013	Feb 1, 2013	9440.
■	Feb 1, 2013	Mar 4, 2013	9840.
■	Mar 4, 2013	Apr 2, 2013	8960.

Justify the unused bills. To ensure prediction validity, bills should only be excluded if their circumstances were extraordinary, e.g. construction.

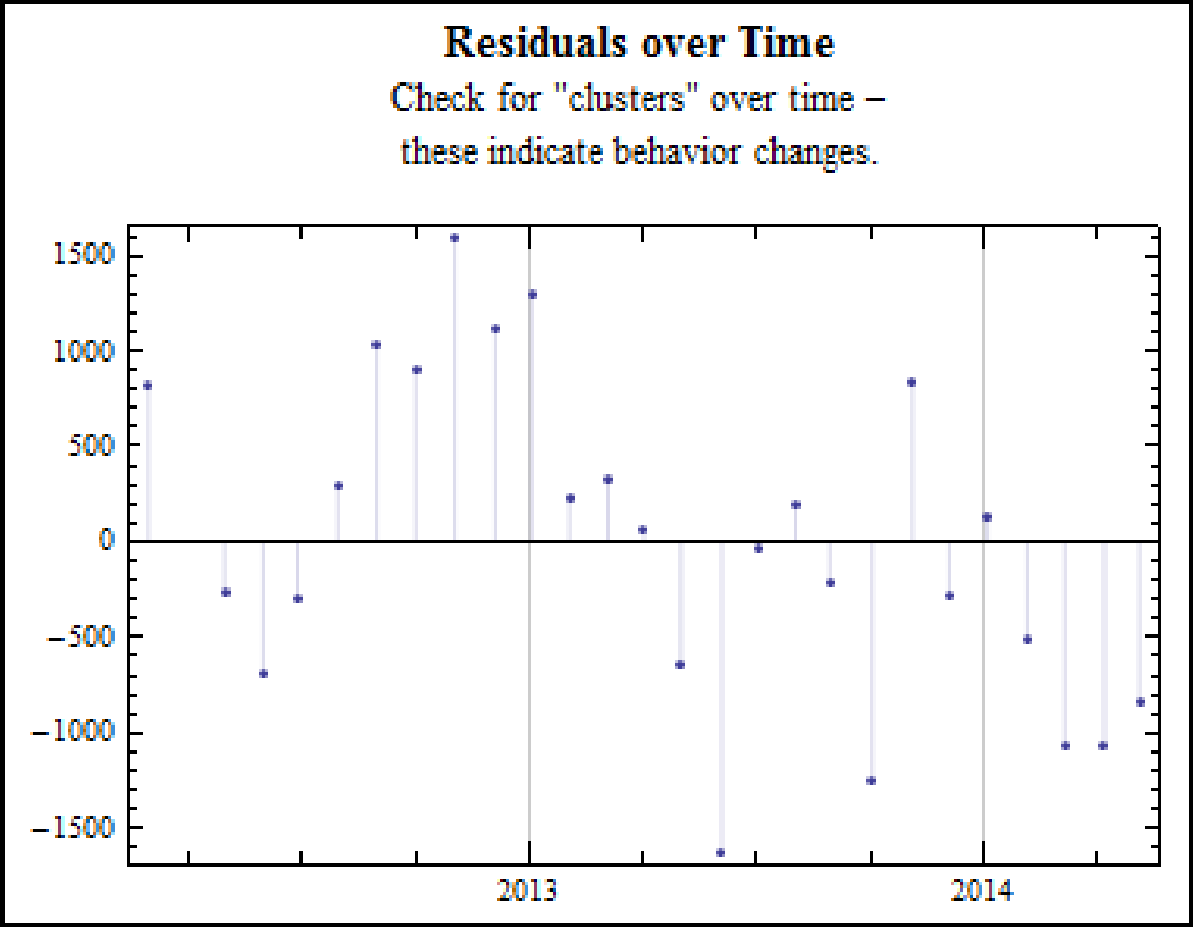
Selecting Balance Point



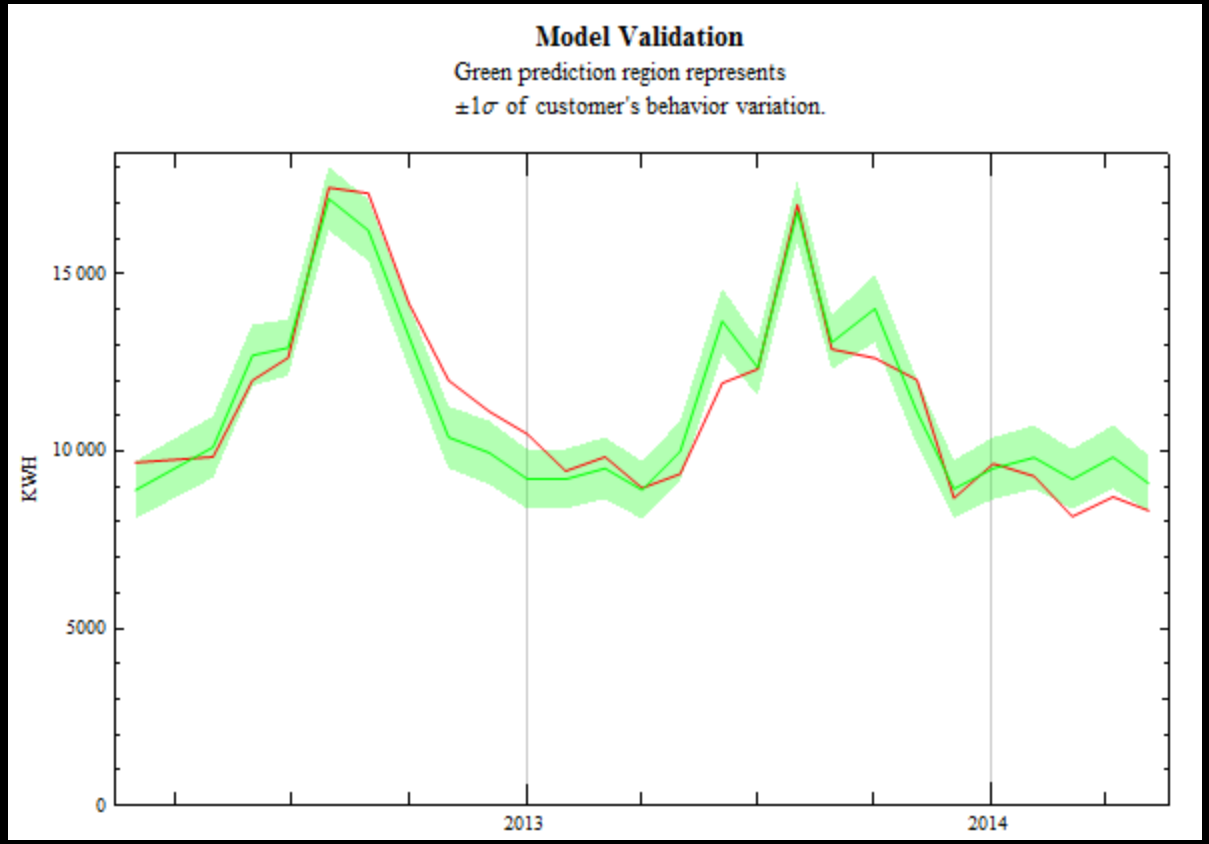
Model Validation



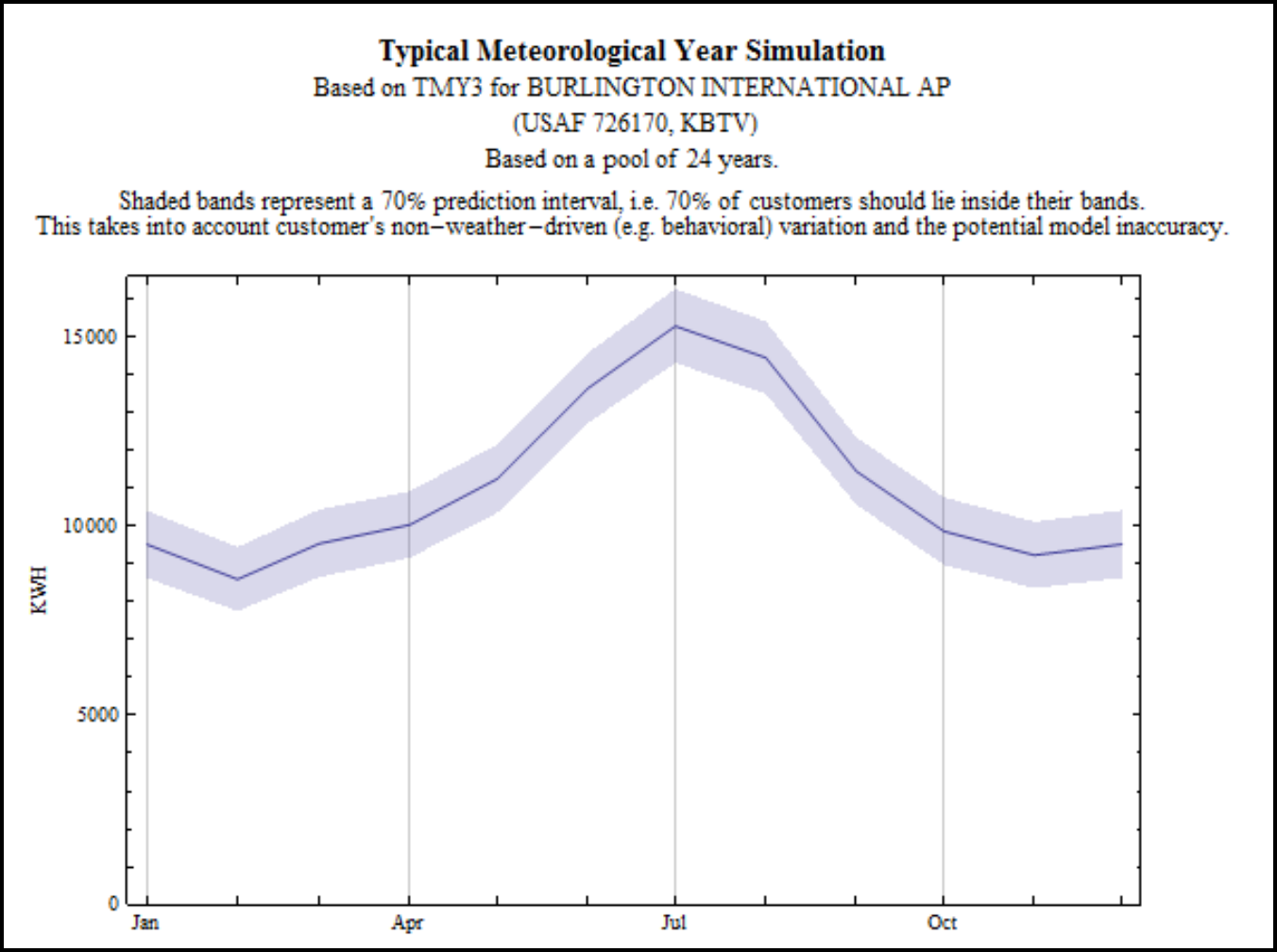
Model Validation



Model Validation



TMY3 Simulation

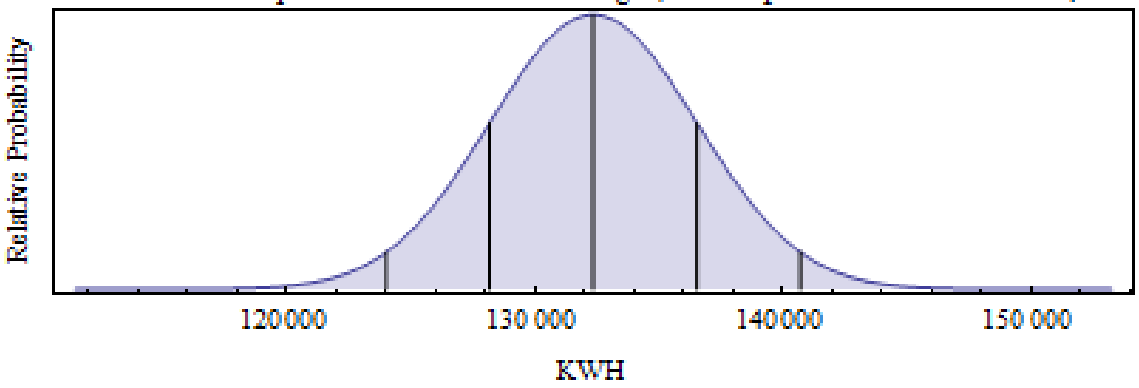


Uncertainty Calculation and Visualization

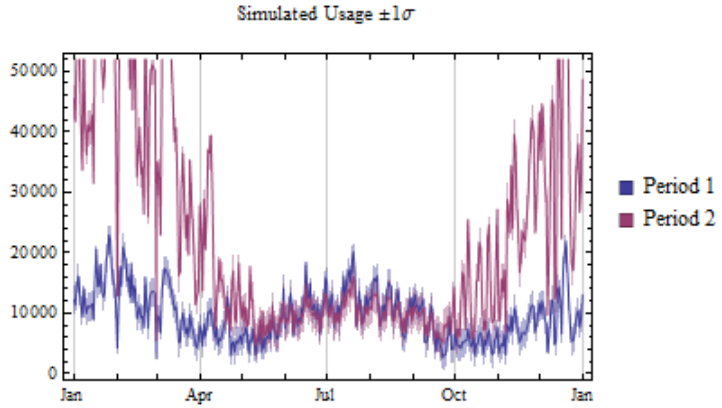
After adjusting for weather during the bills you've provided, and allowing for the customer's typical month-to-month variations in usage not due to weather, predict usage in a model year will be:

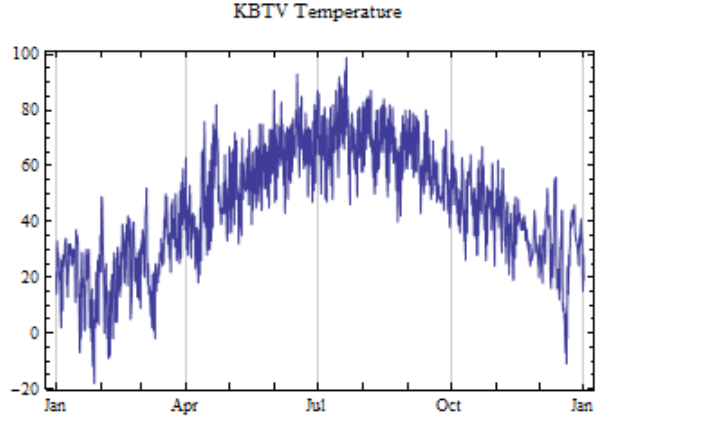
Very likely (95%) to be between 123,991 KWH and 140,720 KWH
Pretty likely (70%) to be between 128,174 KWH and 136,538 KWH
Equally likely to fall on either side of 132,356 KWH.
This represents a coefficient of variation (σ/μ) of 3.2%.

Bell curve of predicted normalized usage (i.e. the prediction distribution).

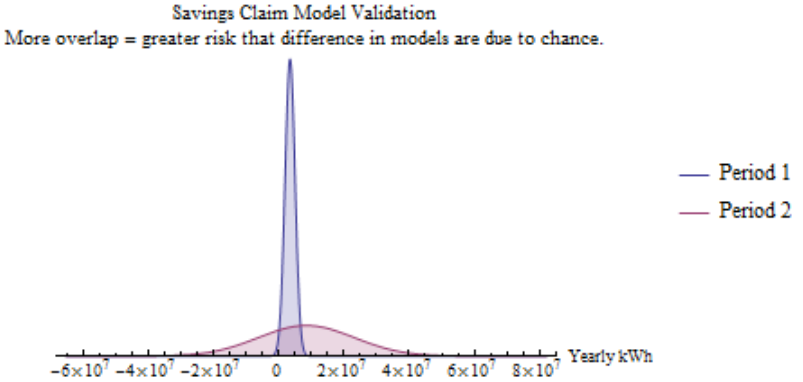


Calculating Energy Savings

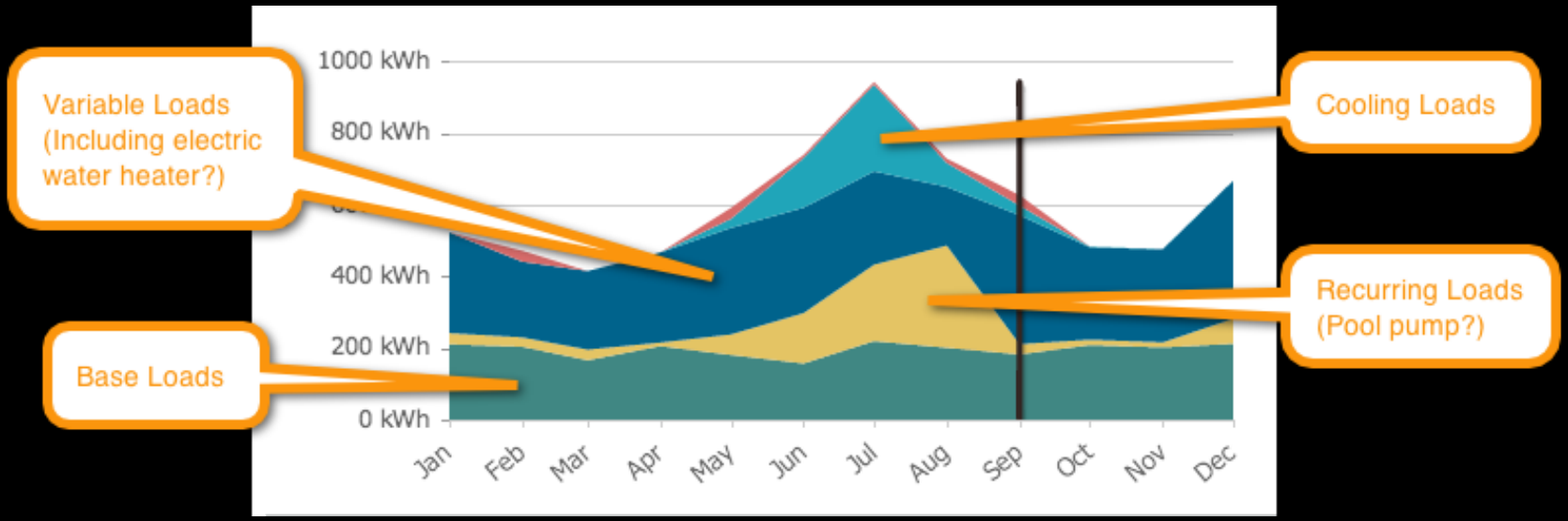




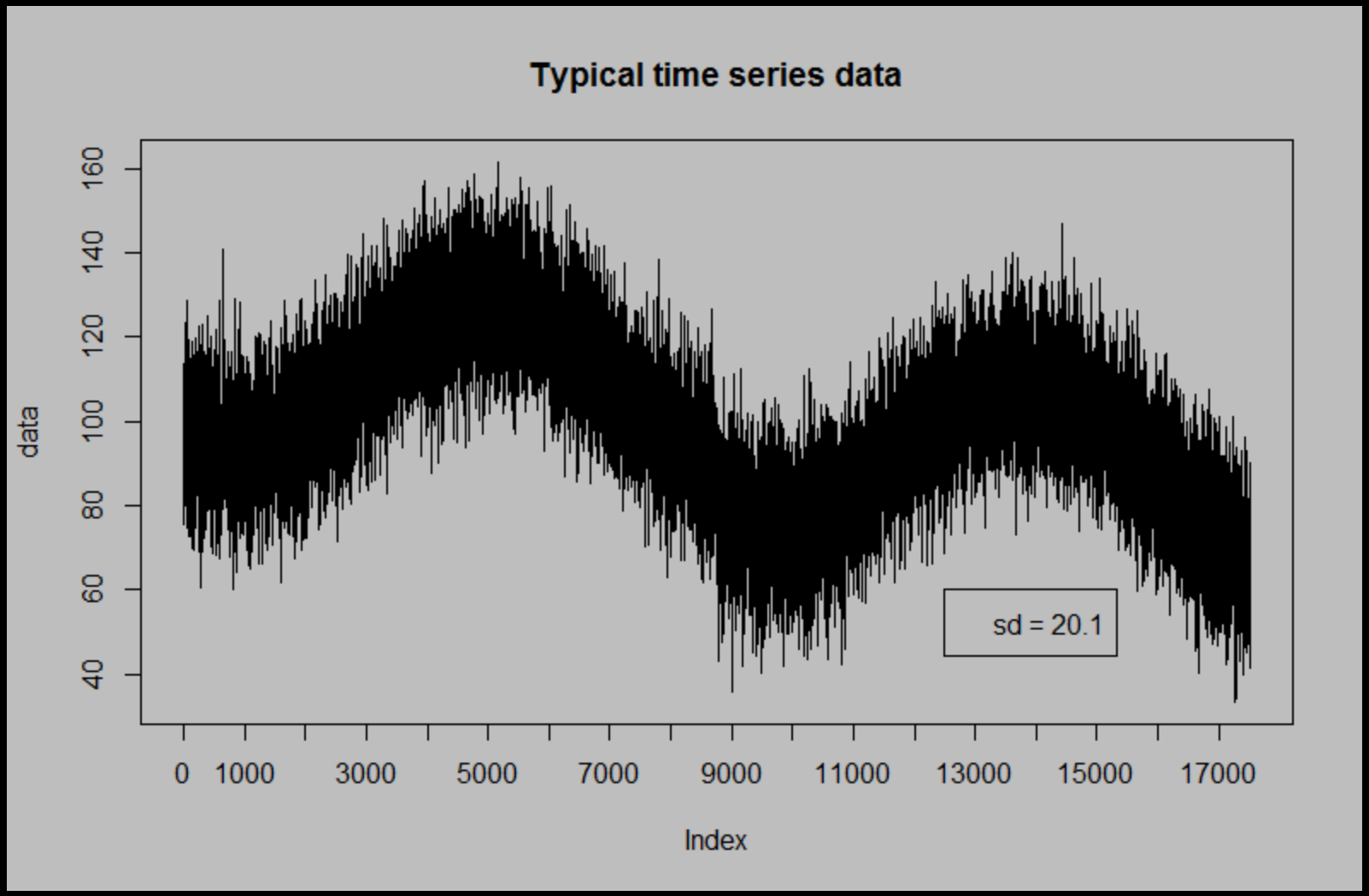
	Period 1		Period 2	
Totals:				
HDDs:	4,017		4,017	
CDDs:	2,251		2,251	
Total Usage:	3,525,837	± 45,286 (1σ)	8,517,943	± 55,658 (1σ)
		± 1,521,480 (1SE)		± 14,732,709 (1SE)
Usage Components:				
Baseload:	778,296	± 609,426 (1SE)	1,455,673	± 524,080 (1SE)
Heating:	1,525,143	± 1,368,536 (1SE)	6,240,225	± 14,722,044 (1SE)
Cooling:	1,222,397	± 265,725 (1SE)	822,043	± 198,692 (1SE)

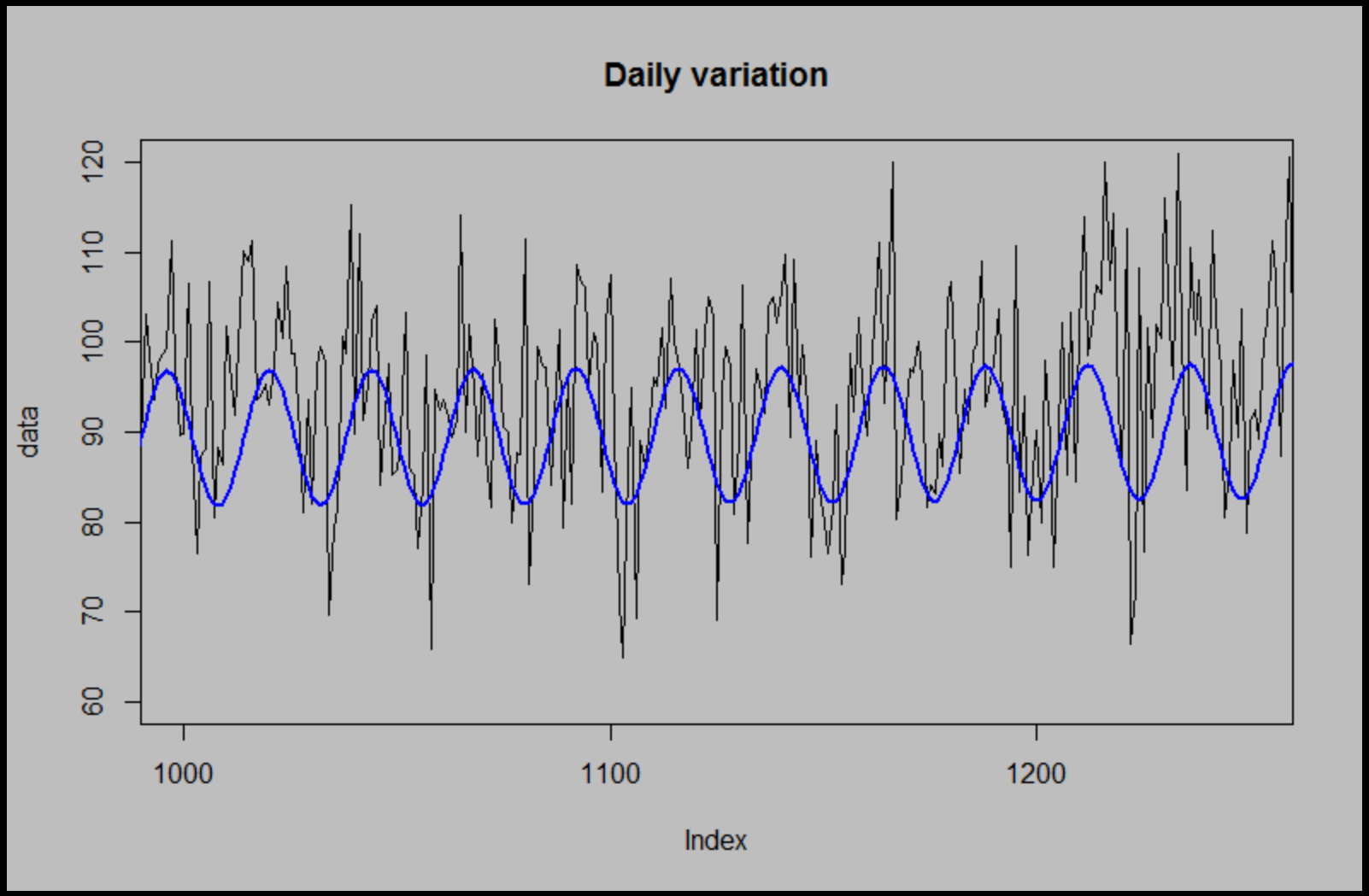


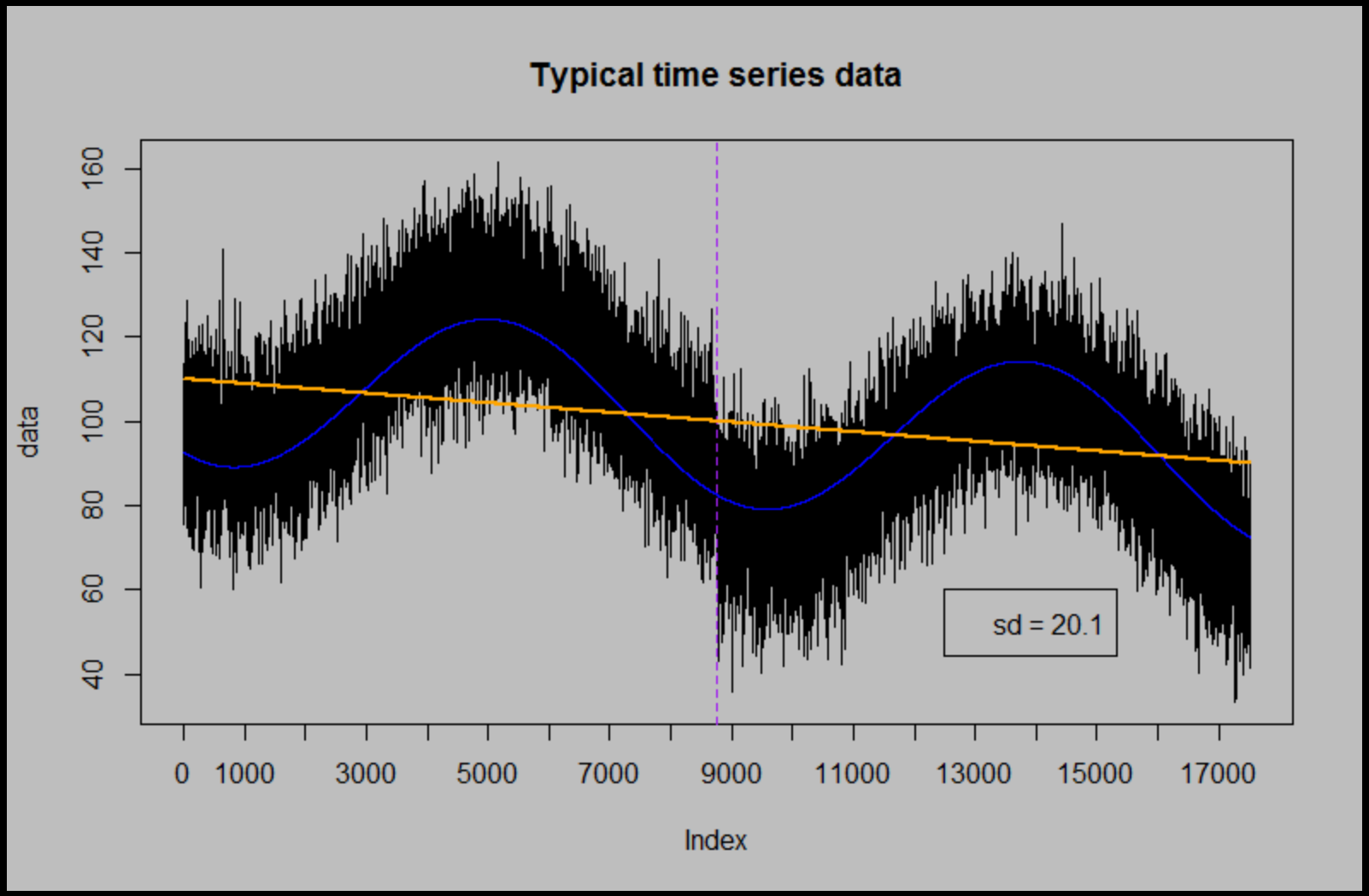
Estimating Loads from Weather Models

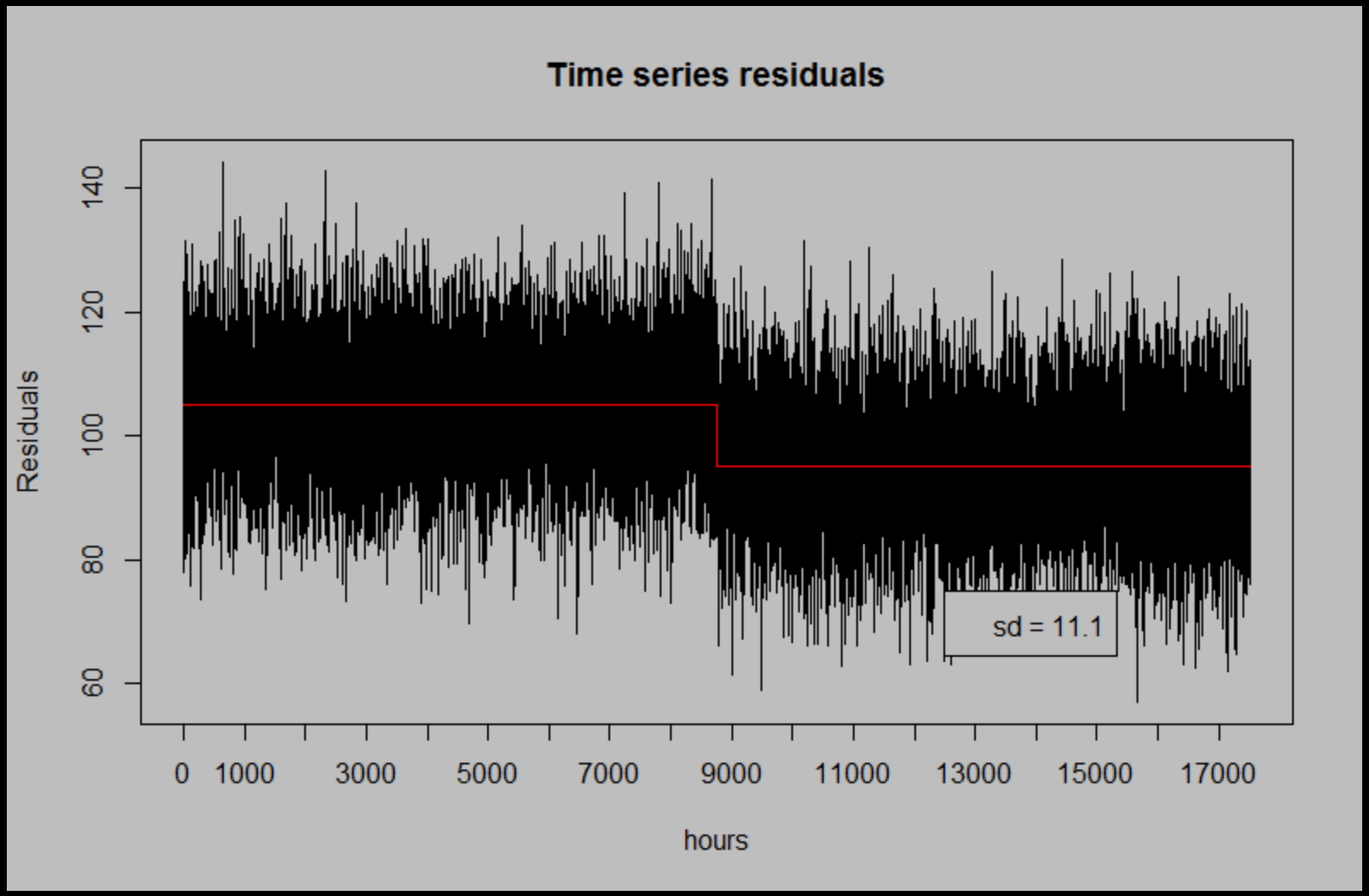


From an online customer report by *Home Energy Analytics*


Typical time series data
data
40
60
80
100
120
140
160
0
1000
3000
5000
7000
9000
11000
13000
15000
17000
Index
sd = 20.1


Daily variation
data
60
70
80
90
100
110
120
1000
1100
1200
Index


Typical time series data
data
40
60
80
100
120
140
160
0
1000
3000
5000
7000
9000
11000
13000
15000
17000
Index
sd = 20.1


Time series residuals
Residuals
60
80
100
120
140
0
1000
3000
5000
7000
9000
11000
13000
15000
17000
hours
sd = 11.1

Questions?

www.veic.org

Vermont Energy Investment Corporation

Program Experience: VEIC

- VEIC uses weather data to estimate energy savings opportunities, which they use to market to both residential and commercial buildings owners.
  - Once the VEIC model eliminates variability due to diurnal and seasonal weather changes, noise, etc., it predicts the effect that a major change (e.g. retrofit) has on a building's energy usage (see slide 37).
  - By removing the influence of weather on energy usage, VEIC identifies how accurate the models are, which is especially important for their pay-for-performance programs.
- VEIC developed a Streamlined Weather Normalization tool:
  - The tool is intended to be used by all user types, not only professionals.
  - The tool provides several presentations of feedback as the user progresses, allowing for many opportunities to confirm that the model is a fit. For example, if the tool shows that the amount of variation due to weather is close to or more than the predicted savings, it is not safe to use the model to project future savings (see slide 32).
  - The tool can be used to estimate base-load consumption, seasonal variations, and to present the owner with measures that will have the most impact and be most cost-effective.

Discussion Questions

- What approaches has your organization used in normalizing weather data to calculate energy savings?
- Are there other tools in addition to those discussed today that are useful for normalizing weather data?
- Have you encountered any challenges in incorporating weather data into energy savings? What helped you overcome those challenges?
- What questions do you have about how to normalize weather data for energy savings?
- Other?

Discussion Highlights

- Balance points used by VEIC:
  - 65°F for residential buildings
  - 55°F for smaller commercial and industrial buildings
- Autocorrelation is the practice of using the previous week's or day's energy usage to look for trends:
  - Autocorrelation is best used on the daily, or weekly scales (rather than monthly or longer). Buildings have strong 7-day variations due to occupants' weekly schedules; try using autocorrelation with multiples of 7 days.
- A high performance home's low energy consumption is usually dominated by the occupant, and is thus difficult to model.
- Open-source time series modeling is being used in many other industries, for example in consumer purchasing.

Closing Poll Results

- After today's call, what will you do?
  - Try an idea or approach discussed on this call in your work – **60%**
  - Tell a colleague or partner something you learned – **20%**
  - Other - **20%**
    - *Would like to learn more about the topic*
  - Consider changes to how you incorporate weather data in energy calculations – **0%**
  - Make no changes to your approach to calculating energy savings – **0%**

Thank you!

Please send any follow-up questions or future call topic ideas to:
peerexchange@rossstrategic.com