Statewide Smart Thermostat Device Measure

CALIFORNIA
TECHNICAL FORUM

NEST LABS, INC.
SEPTEMBER, 2016

Agenda

1. Refresh on the project, what we've already discussed
   - Quick reminder of what we've already discussed
   - Summary of the amount of data being utilized
2. Smart thermostats: what are the energy saving features?
   - Navigant definition
   - Nest Learning Thermostat
3. RASS baseline calibration factor: updating our estimates based on prior CalTF feedback
4. NTG and EUL (time-permitting)

Brief Project Summary

Why is this work paper needed?

- Electric savings
- Gas savings
- Across all CA climate zones
- In-time to support AB 793 smart thermostat roll-out
- This is a statewide work paper for electric and gas savings across all climate zones

What data did we use?

- 150,000 thermostats across CA
- Temperature Set points
- HVAC Runtime
- 6M days of heating
- 7M days of cooling

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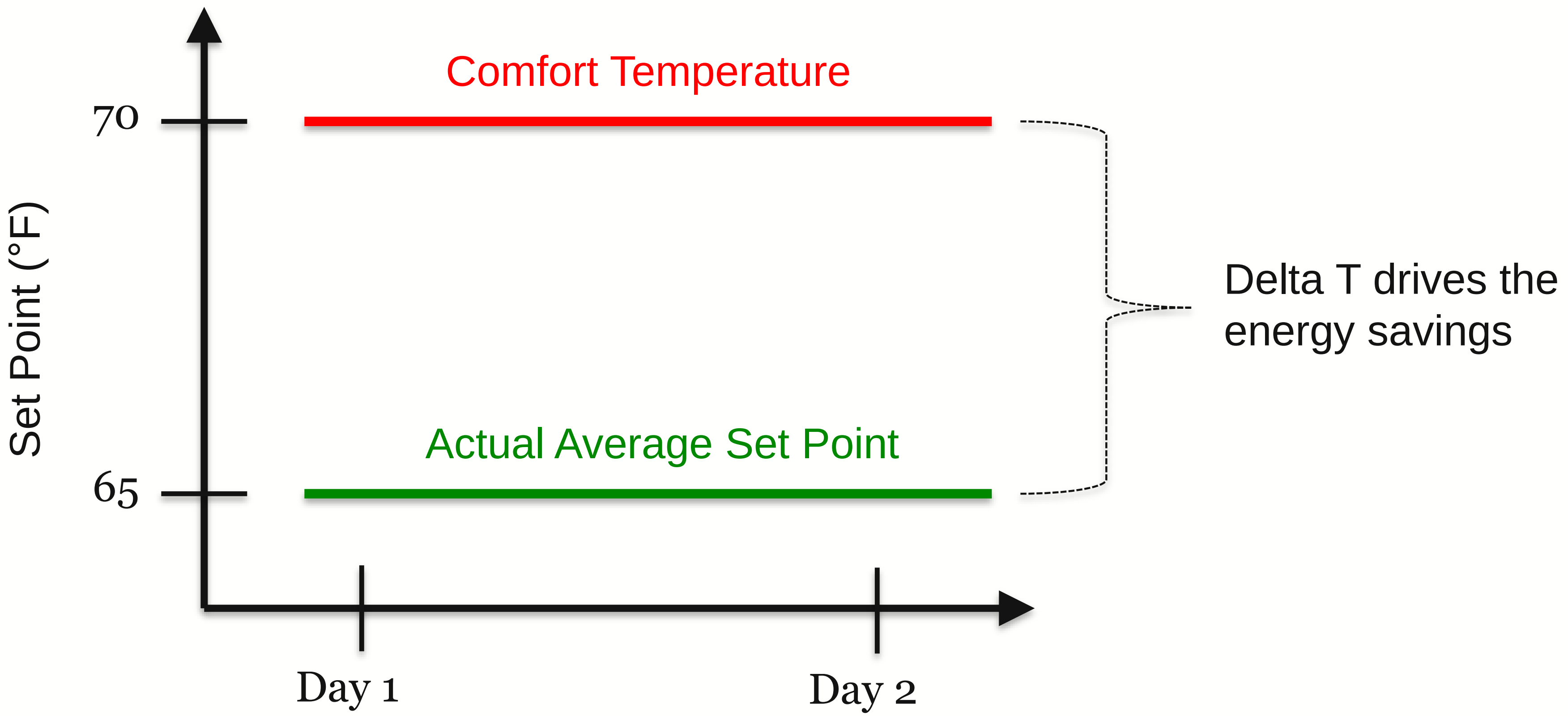
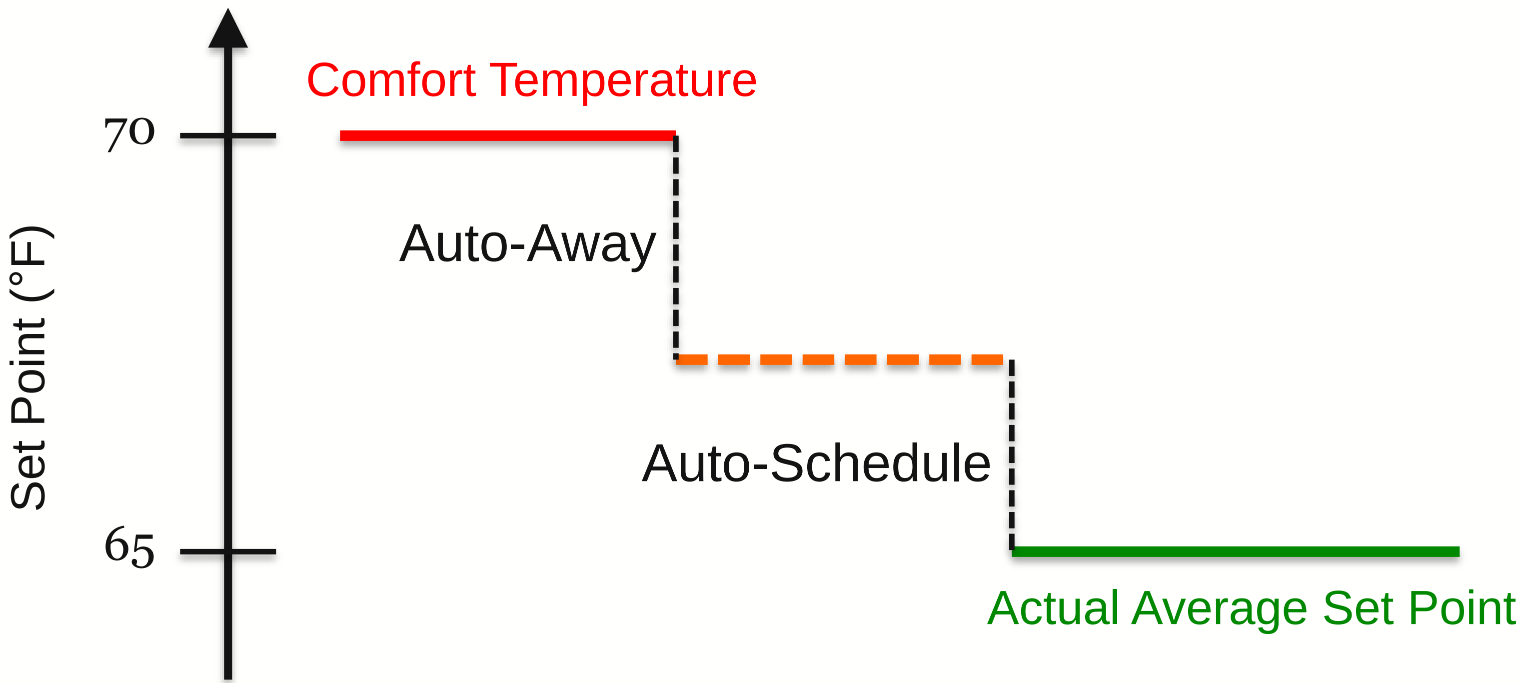
What data did we do?

- Fixed effects regression using actual average set points
  - EPA approach but using set points instead of indoor air temp
- Calculate savings compared to a flat comfort temperature baseline
  - Comfort temperature is calculated on-board every Nest Thermostat, as per EPA methodology
  - None of this data is self-reported data point, i.e. no response bias

Simple Heating Example



Simple Heating Example



Project Summary

… But the baseline isn't actually flat

And we'll come back to that with our RASS baseline calibration factor.

Nest Learning Thermostat Energy Savings Features

Nest's Energy-Saving Features

Auto-Schedule

Nest remembers what temperatures the customer likes and builds a custom schedule for the home in about a week.

Want to edit the schedule? It can be done in seconds from the Web or Mobile app.

Auto-Away

No more heating or cooling an empty home.

With Auto-Away, Nest automatically turns to an energy-saving temperature when the home is unoccupied.

Nest Leaf

The Nest Leaf appears when the customer is using settings that save energy, relative to their typical settings.

Airwave

Airwave turns off the AC a few minutes early, but keeps the fan running. Customers stay cool while the AC runs up to 30% less.

Smart Thermostat Category Energy Savings Features from U.S. Programs

Category Definition

Thermostat must have:

1. Occupancy detection
2. Two-way communication

And 2 additional features from this list:

1. Schedule learning
2. Heat pump auxiliary heat optimization
3. Upstaging/down-staging optimization
4. Humidity control
5. Weather-enabled optimization
6. Free cooling/economizer capability

RASS Baseline Calibration Factor

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What data did we do?

- Fixed effects regression using actual average set points
- Calculate savings compared to a flat comfort temperature baseline

Project Summary

… But the baseline isn't actually flat

- RASS baseline calibration factor

RASS Baseline Calibration Factor

CA homeowners:

how much more efficient are they than a flat baseline?

Key RASS Survey Questions

B6 If your main heating system is controlled by a thermostat, what is the average thermostat temperature usually set for each time period during the heating season? *(Choose one answer for each time period. Provide the average setting if it varies.)*

	Off	Below 55°F	55 – 60°F	61 – 65°F	66 – 70°F	71 – 75°F	Over 75°F
Morning *(6am-9am)* (HMRNSET)	1	1	1	1	1	1	1
Day *(9am-5pm)* (HDAYSET)	1	1	1	1	1	1	1
Evening *(5pm-9pm)* (HEVNSET)	1	1	1	1	1	1	1
Night *(9pm-6am)* (HNITESET)	1	1	1	1	1	1	1

C5 What is the typical thermostat temperature setting of your main central cooling system for each time period during the cooling season? *(Choose one answer for each time period.)*

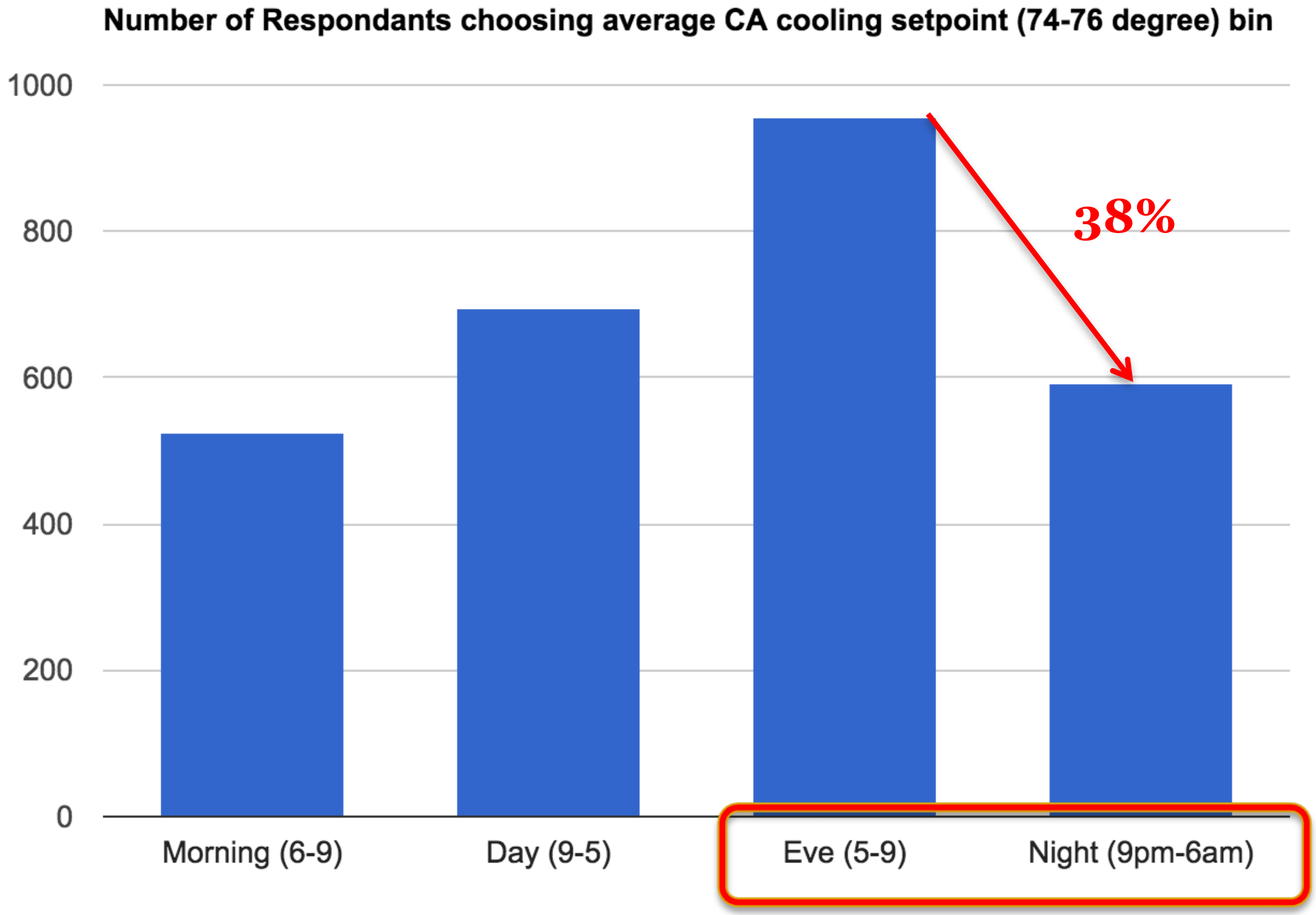
	Off	Below 70°F	70 – 73°F	74 – 76°F	77 – 80°F	Over 80°F
Morning *(6am–9am)* (CMRNSET)	1	1	1	1	1	1
Day *(9am-5pm)* (CDAYSET)	1	1	1	1	1	1
Evening *(5pm-9pm)* (CEVNSET)	1	1	1	1	1	1
Night *(9pm-6am)* (CNITESET)	1	1	1	1	1	1

RASS Baseline Calibration Factor

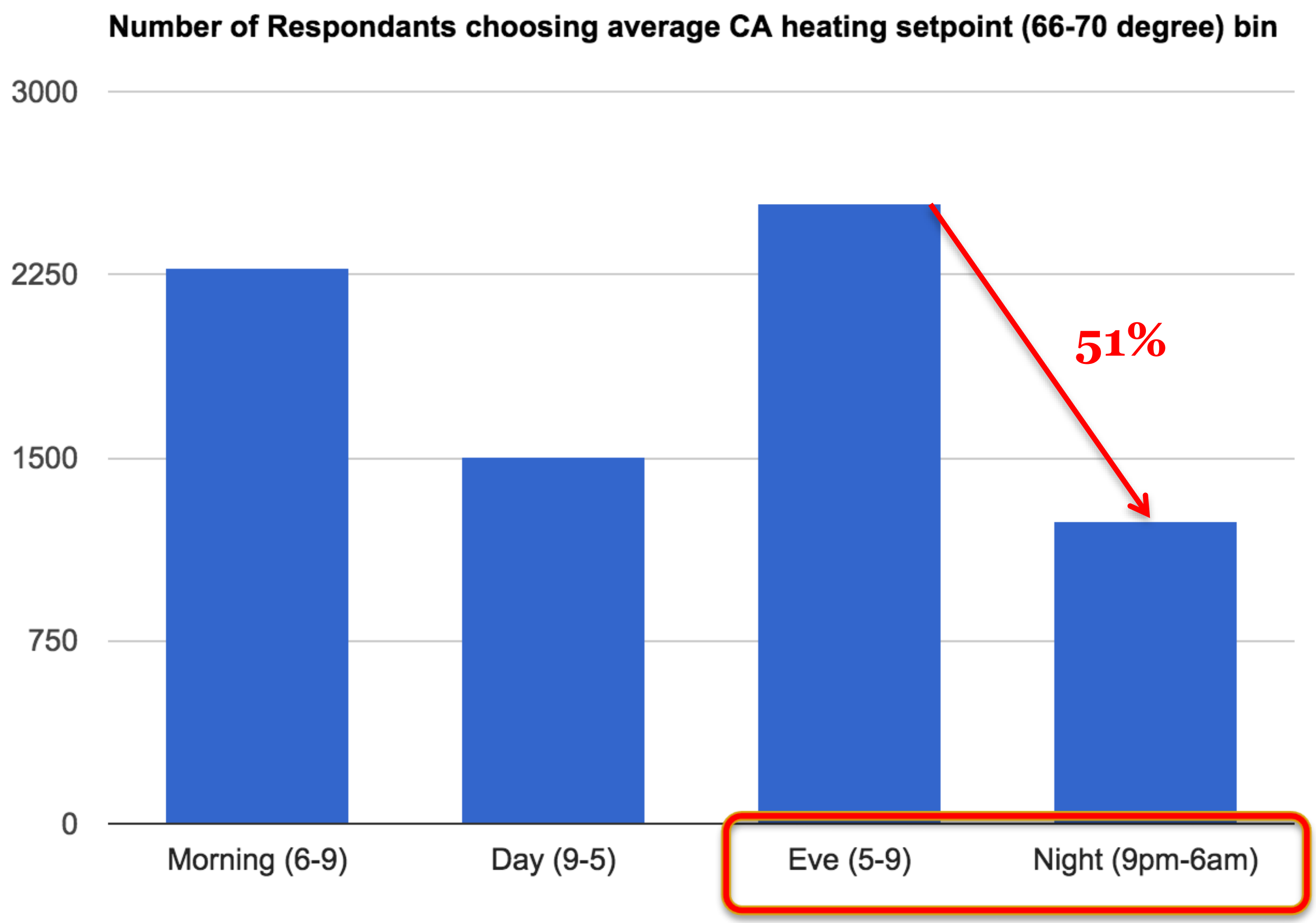
Did customers indicate a flat schedule, or demonstrate setback behavior?

Customer responses indicating movement out of the average RASS temperature bands suggest setback behavior that will drive our calibration factor.

RASS Cooling: % of customers moving out of average temperature band, exhibiting nighttime set back behavior



RASS Heating: % of customers moving out of average temperature band, exhibiting nighttime set back behavior



RASS Baseline Calibration Factor

Reduce our flat-baseline savings estimates by:

- Cooling: 38%
- Heating: 51%

These are conservative assumptions using best-available data:

- % of customers moving out of other temperature bands was lower, so we're applying the biggest savings reduction possible based on RASS data
- Assumes everyone who moves out of the average temperature band does so in an efficient direction, although we know some customers move to inefficient temperatures at night (i.e. some make their homes cooler at night in the Summer)
- Assumes *none of the* customers showing setback behavior will save from features like Auto-Away and Auto-Schedule
- Likely over-estimates setback behavior given customer bias in survey responses over-estimating efficient behavior

EUL & NTG Background

- **EUL = 11 Years**
- **NTG = 0.85** (CA emerging technology)

- **NTG for smart thermostats across the US**
  - ComEd - 0.96
  - Illinois TRM = 1.0
  - Enbridge Gas DSM Plan = 0.96
  - CA emerging technology = 0.85

- **We are many years away from market saturation**
  - Smart thermostats have small single digits of adoption
  - Working now to move from early adopters to early mass
  - This is exactly the kind of market transformation opportunity that utility programs seek

Discussion

Archive – Previous Two Presentations

Presentation Overview

Three Objectives:

1. Provide an update on the pooled fixed effects regression model built by Michael Blasnik, based on methodology and data presented at previous meeting
2. Show results that will be used as the foundation for the second Smart Thermostat work paper in CA
3. Seeking TF review and approval of methodology for developing a work paper based on this methodology and results

Supporting AB793 Timing:

- This analysis provides robust heating and cooling savings estimates for the smart thermostat category with enough time still remaining in 2016 to allow for planning of AB793 program efforts.

Measure Description

Base Case	Measure Case
Existing Conditions as analyzed through RCT and supporting studies	Smart Thermostat*

Smart Thermostat*

- Two way communication
- Automatic Scheduling
- Software algorithms that make automatic schedule changes that save energy

* For full proposed definition see Appendix A

Measure Description

- **Units:** per unit
- **Measure Application and Delivery Type**
  - Downstream Deemed (NEW/ROB)
- **Eligibility**
  - Climate Zones: All
  - Building Types: Residential
- **Target Market**
  - Residential
- **Market Potential**
  - Assumed Total Addressable Market (Upper-Bound Estimate): **~7,000,000** residential customers across 3 CA IOU's. Using 64% Electric Space Cooling from 2009 California Residential Appliance Saturation Survey
  - Growing market, but still early. Utility Program incentives have significant impact on adoption pace
  - 8 -15% heating and cooling system savings – ACEEE New Horizons for Energy Efficiency 2015

Measure Description

- **Measure Costs** (preliminary analysis)
  - Baseline cost (material): $101 (mix of programmable and non-programmable devices)
  - Measure cost: $226
  - Incremental cost: $125
- **EUL**
  - 11 year (based on DEER EUL ID: Programmable Thermostat)
  - Technology-driven
- **NTG**
  - 0.85 for CA emerging technology
  - Nest program data in other states suggests NTG may exceed 0.85

EUL & NTG Background

- **EUL = 10 Years**
- **NTG = 0.85**

- **NTG for smart thermostats across the US**
  - ComEd - 0.96
  - Illinois TRM = 1.0
  - Enbridge Gas DSM Plan = 0.96
  - CA emerging technology = 0.85

- **We are many years away from market saturation**
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Pooled Fixed Regression Model

Large scale analysis of the efficiency of Nest customer thermostat set point schedules with projected heating and cooling savings compared to baseline behavior using pooled Fixed Regression Model and Comfort Temperature Analysis

Methodology presented to CalTF by Michael Blasnik

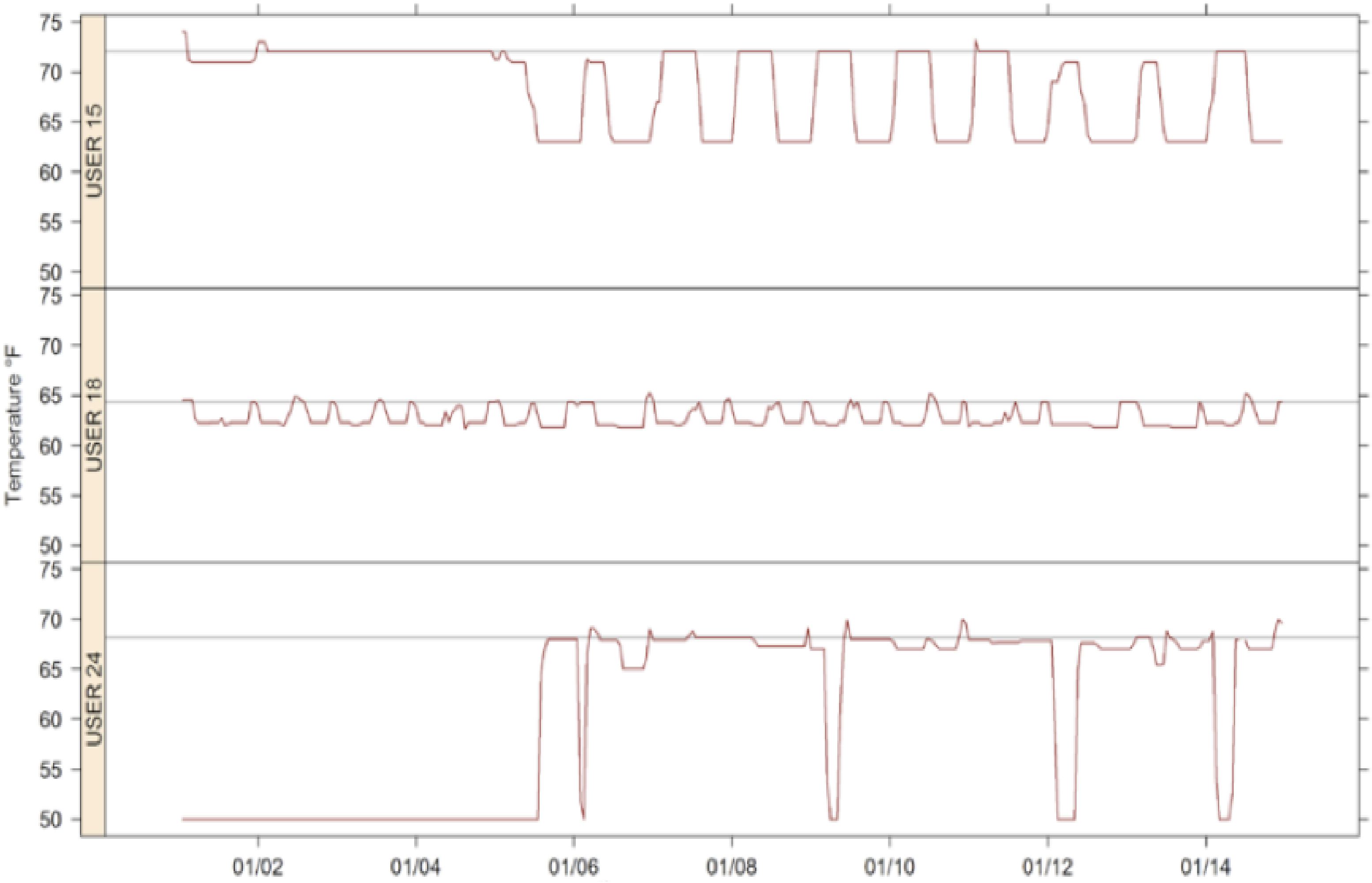
Input Data

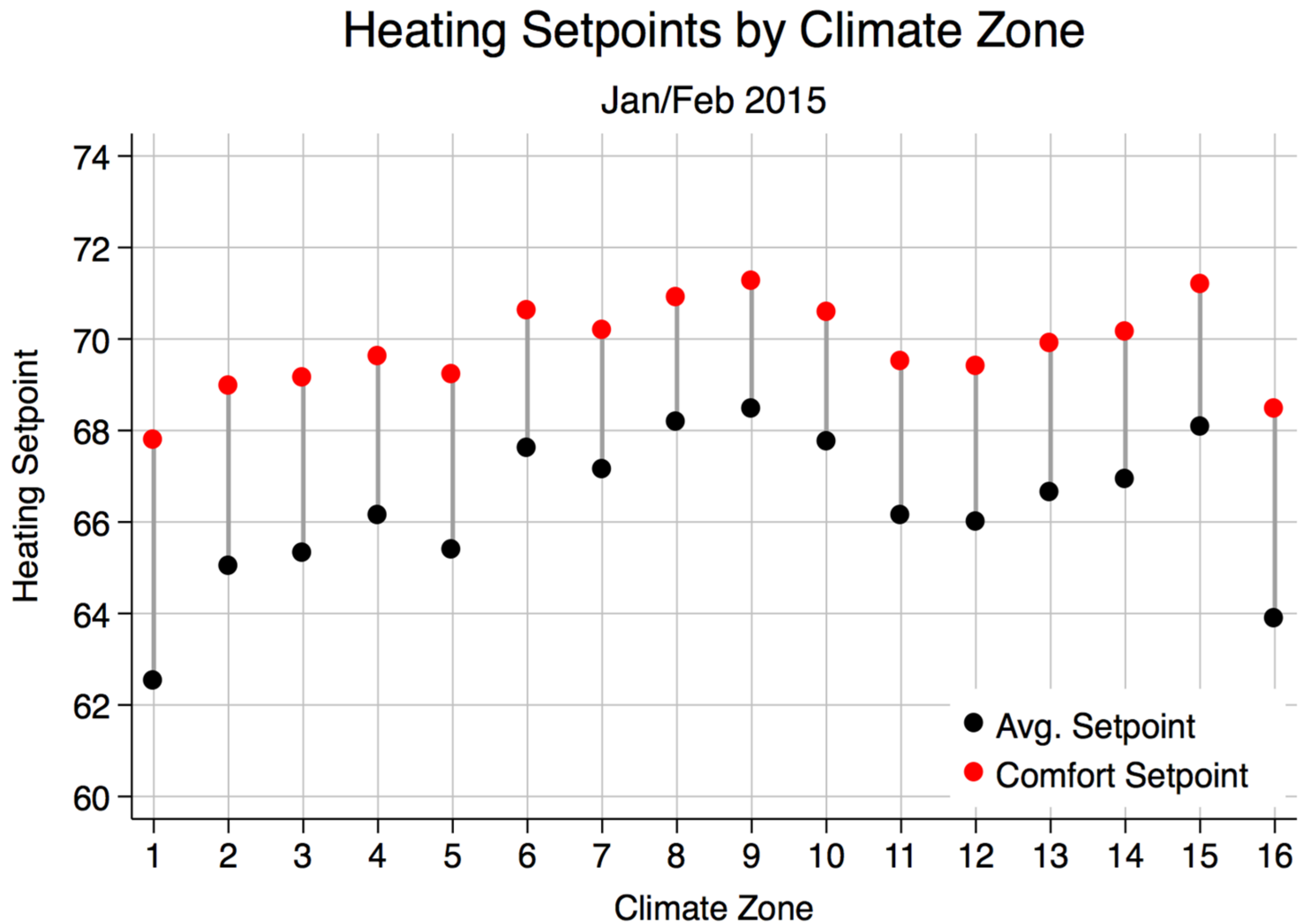
- Over 150,000 Nest Thermostats across CA climate zones
- 13 million days of data
  - 6M device days of heating data: January – February 2016
  - 7M device days of cooling data: July 2015 – September 2015
- Only single stage HVAC systems (to avoid the uncertainty introduced by the unknown relative capacities of the stages).

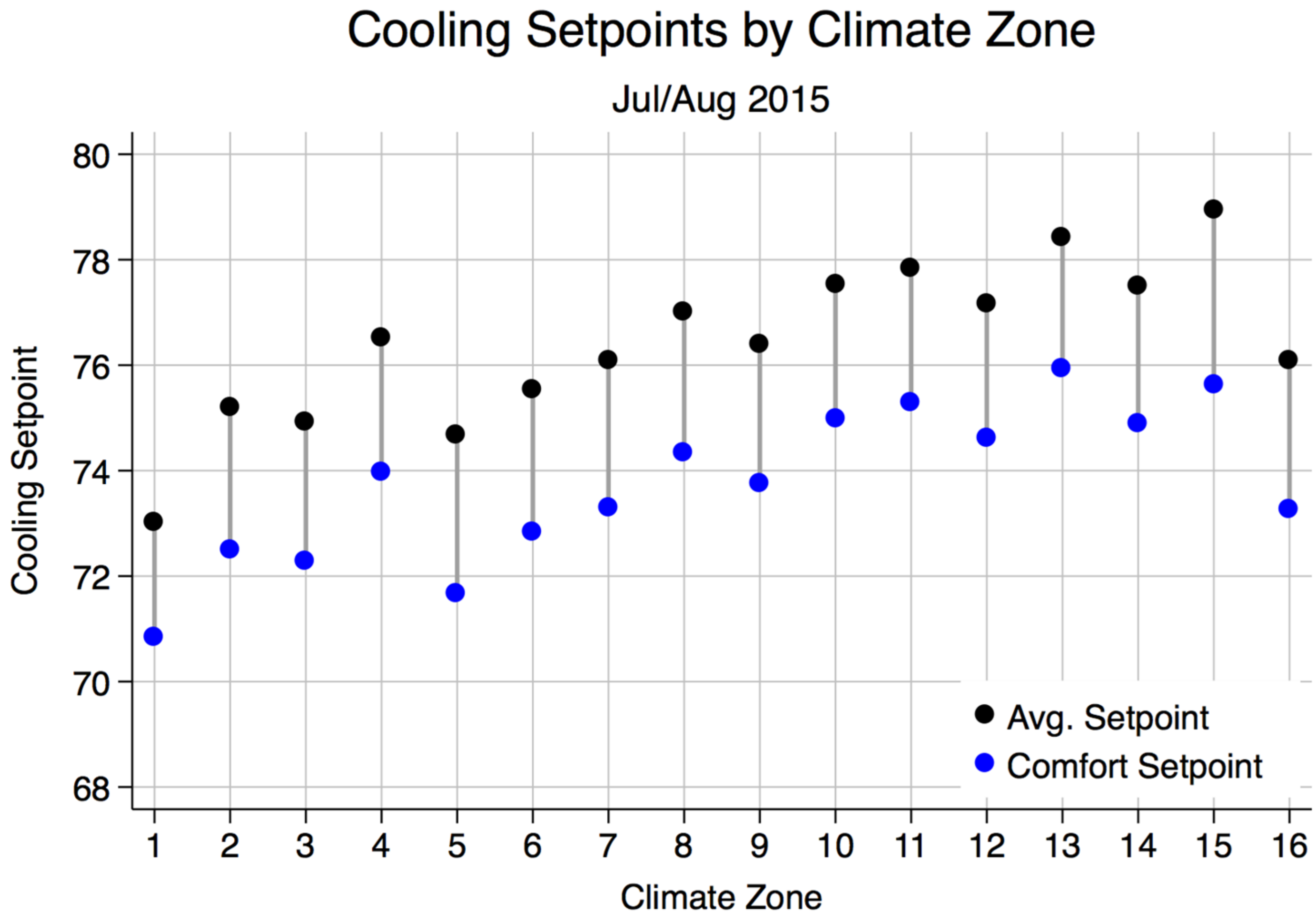
Energy Savings Calculation Methodology: EnergySTAR®

1. Analyze Nest customer temperature set points to assess the efficiency of their schedules.
   - The "comfort" temperatures -- defined as the 90th percentile of the customer's heating set points and the 10th percentile of their cooling set points
2. Estimate the percent change in heating and cooling runtime per degree change in temperature set point using a regression model fit separately for each climate zone.
3. Estimate the heating and cooling energy savings compared to a constant set point at the comfort temperature.
   - The savings are calculated based on the savings per degree set point change found in step 2 and the difference between the average and comfort temperatures calculated in step 1.
4. Adjust the overall savings calculated in step 3 to account for customer's maintaining more efficient average baseline set points than a constant comfort temperature.

“Comfort” Temperature = 90%tile of heating setpoints




Heating Setpoints by Climate Zone
Jan/Feb 2015
Heating Setpoint
74
72
70
68
66
64
62
60
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Climate Zone
Avg. Setpoint
Comfort Setpoint



Cooling Setpoints by Climate Zone
Jul/Aug 2015
Cooling Setpoint
80
78
76
74
72
70
68
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Climate Zone
Avg. Setpoint
Comfort Setpoint

Energy Savings Baseline

- Savings calculated from a flat set point baseline
- Savings estimates reduced by a factor of 1/3 to account for more efficient existing behaviors
- Baseline can be updated as a next-step using two sources:
  - Results from Nest's customer survey that is currently in-field
  - DEER baseline for programmable thermostats

Results

Climate Zone	Cooling			Heating			
	T-diff °F (comfort -actual)	% Savings /°F (regression)	Savings (kWh)	T-diff °F (comfort -actual)	% Savings /°F (regression)	Savings (therms)	Savings (kWh Fan)
CA1	sample too small						
CA2	-2.79	-8.1%	**133**	3.96	9.5%	**43**	**35**
CA3	-2.77	-7.6%	**91**	3.91	9.5%	**40**	**25**
CA4	-2.63	-7.8%	**103**	3.54	8.7%	**29**	**23**
CA5	-2.71	-6.1%	**83**	4.27	7.9%	**27**	**19**
CA6	-2.64	-7.8%	**114**	3.08	9.1%	**14**	**11**
CA7	-2.68	-7.6%	**121**	3.14	9.6%	**13**	**11**
CA8	-2.60	-7.5%	**154**	2.79	8.0%	**11**	**10**
CA9	-2.60	-7.0%	**223**	2.89	7.5%	**16**	**19**
CA10	-2.56	-8.2%	**211**	2.88	8.2%	**13**	**15**
CA11	-2.56	-10.1%	**281**	3.29	9.7%	**31**	**38**
CA12	-2.57	-9.0%	**191**	3.26	9.4%	**31**	**34**
CA13	-2.50	-9.6%	**343**	3.11	9.8%	**25**	**31**
CA14	-2.70	-8.9%	**295**	3.22	9.0%	**35**	**37**
CA15	-2.86	-9.2%	**421**	2.99	10.8%	**10**	**15**
CA16	-2.93	-8.4%	**180**	4.56	7.8%	**77**	**47**

System Sizing Assumptions

California Climate Zone	Air Conditioner kW	Furnace Btu/hr	Furnace Fan kW
CA1	Not used		
CA2	3.43	58895	0.49
CA3	2.28	53397	0.33
CA4	2.62	55165	0.44
CA5	2.30	57544	0.41
CA6	2.03	45723	0.37
CA7	2.33	48991	0.41
CA8	2.74	51543	0.48
CA9	3.75	54349	0.66
CA10	3.64	55694	0.64
CA11	4.09	60441	0.72
CA12	3.78	59338	0.66
CA13	4.15	60476	0.73
CA14	4.28	71035	0.75
CA15	4.27	54380	0.77
CA16	3.52	81337	0.50

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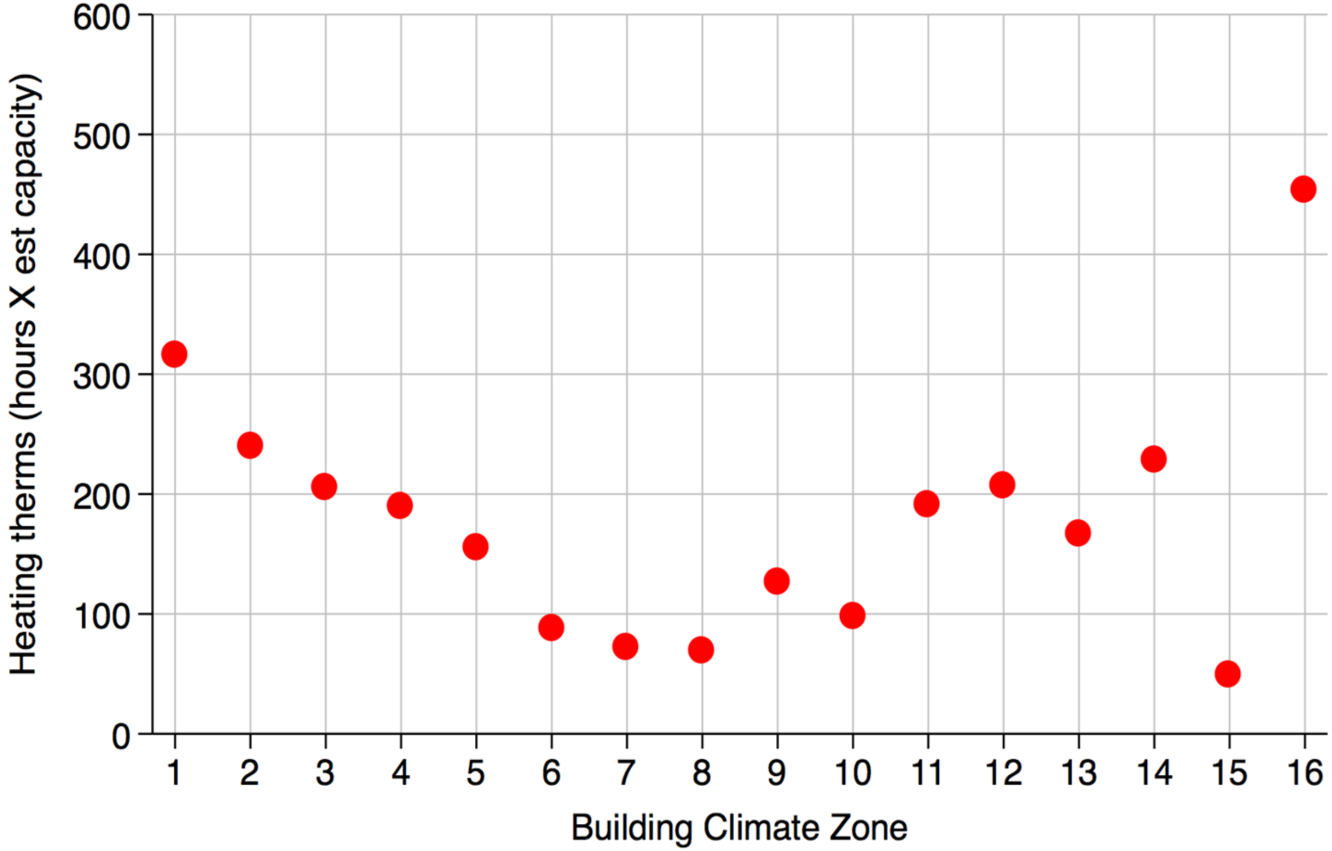
Appendix

Additional Nest Data in CA

Presented by Michael Blasnik at previous CalTF meeting

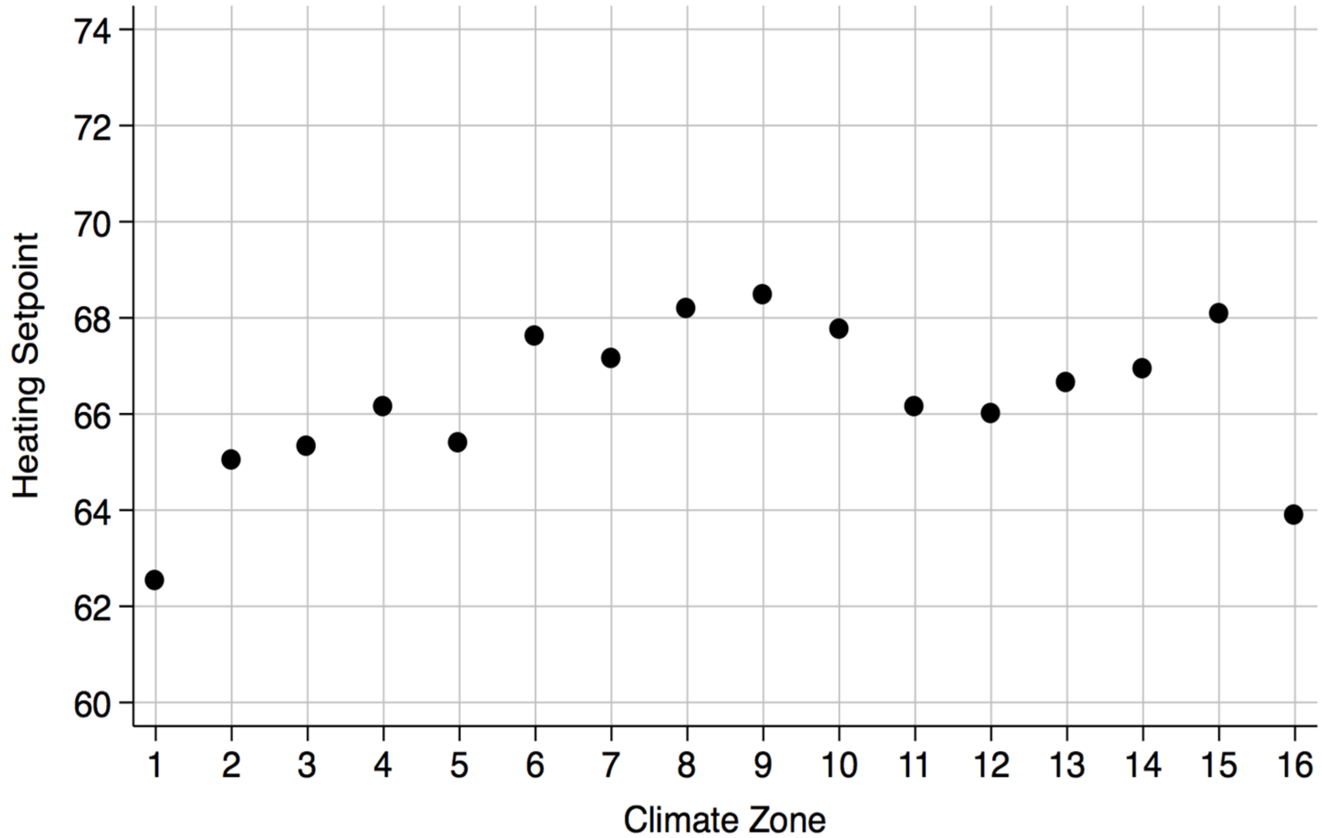
Heating Gas Use th/home by Climate Zone

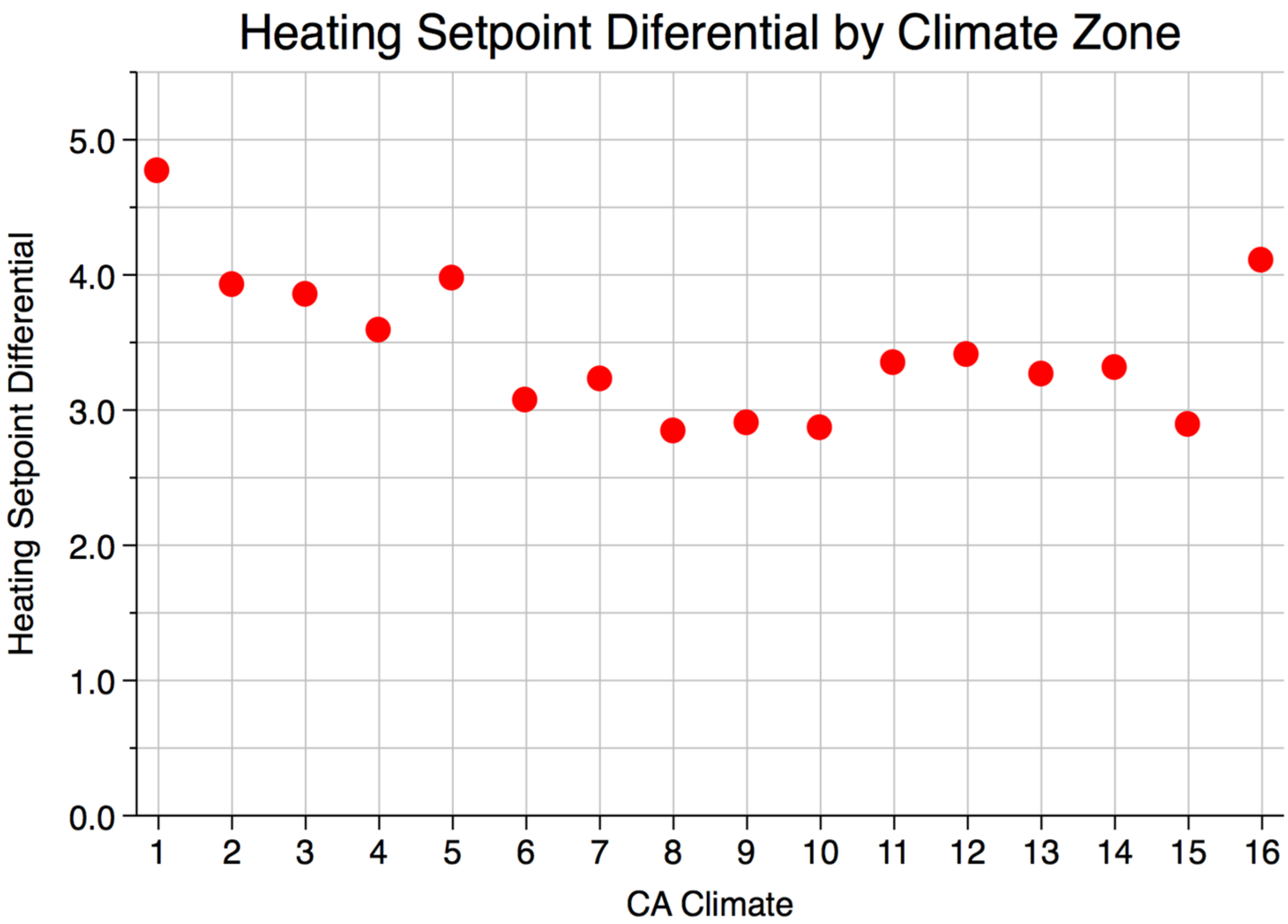
for homes that heat, CY2015



Average Heating Setpoint by Climate Zone

Jan/Feb 2015





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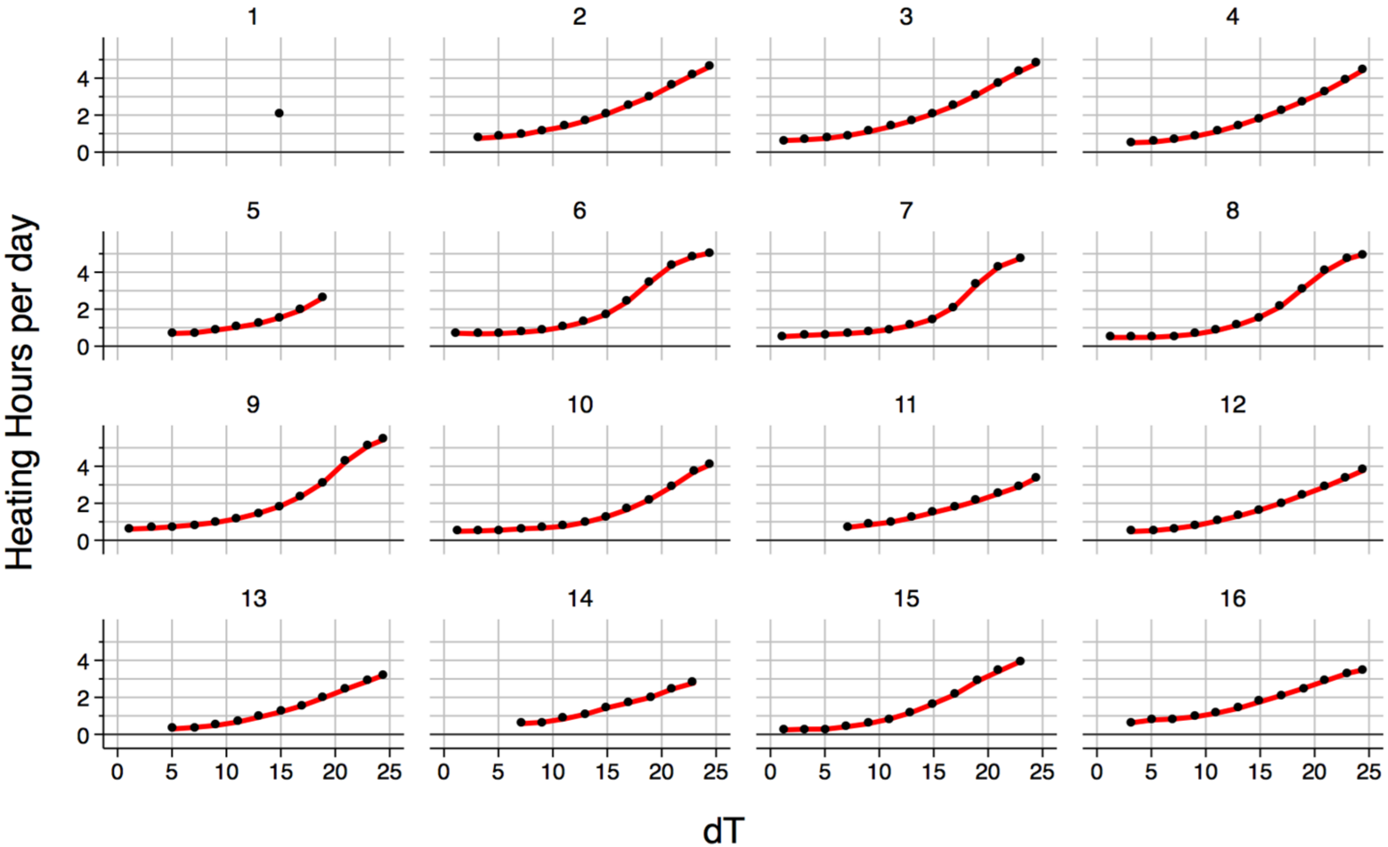
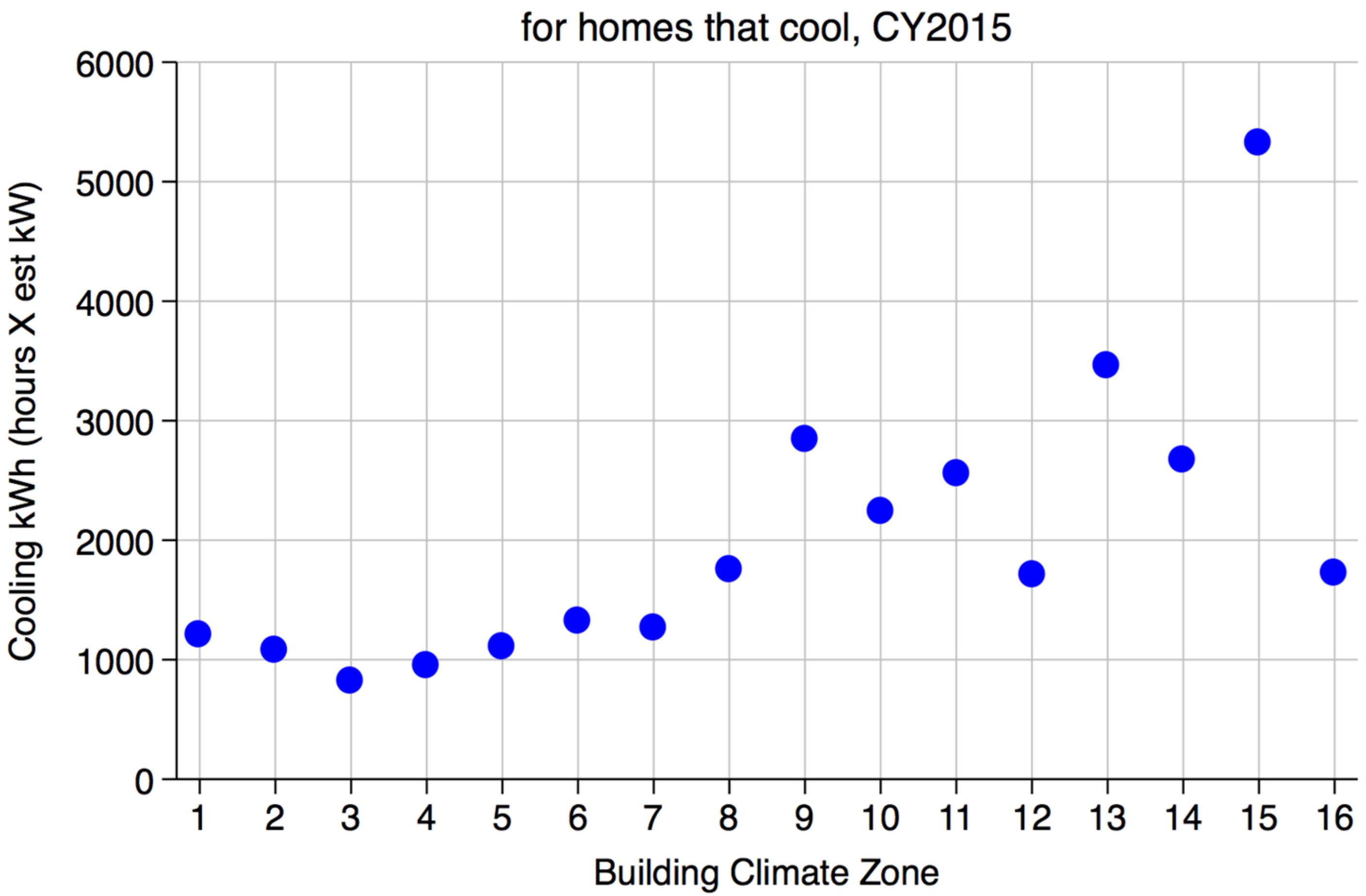
Heating Run Time vs. dT(in-out) by CA Climate Zone Jan/Feb 2015



averages across all devices in California

Cooling kWh/home by Climate Zone



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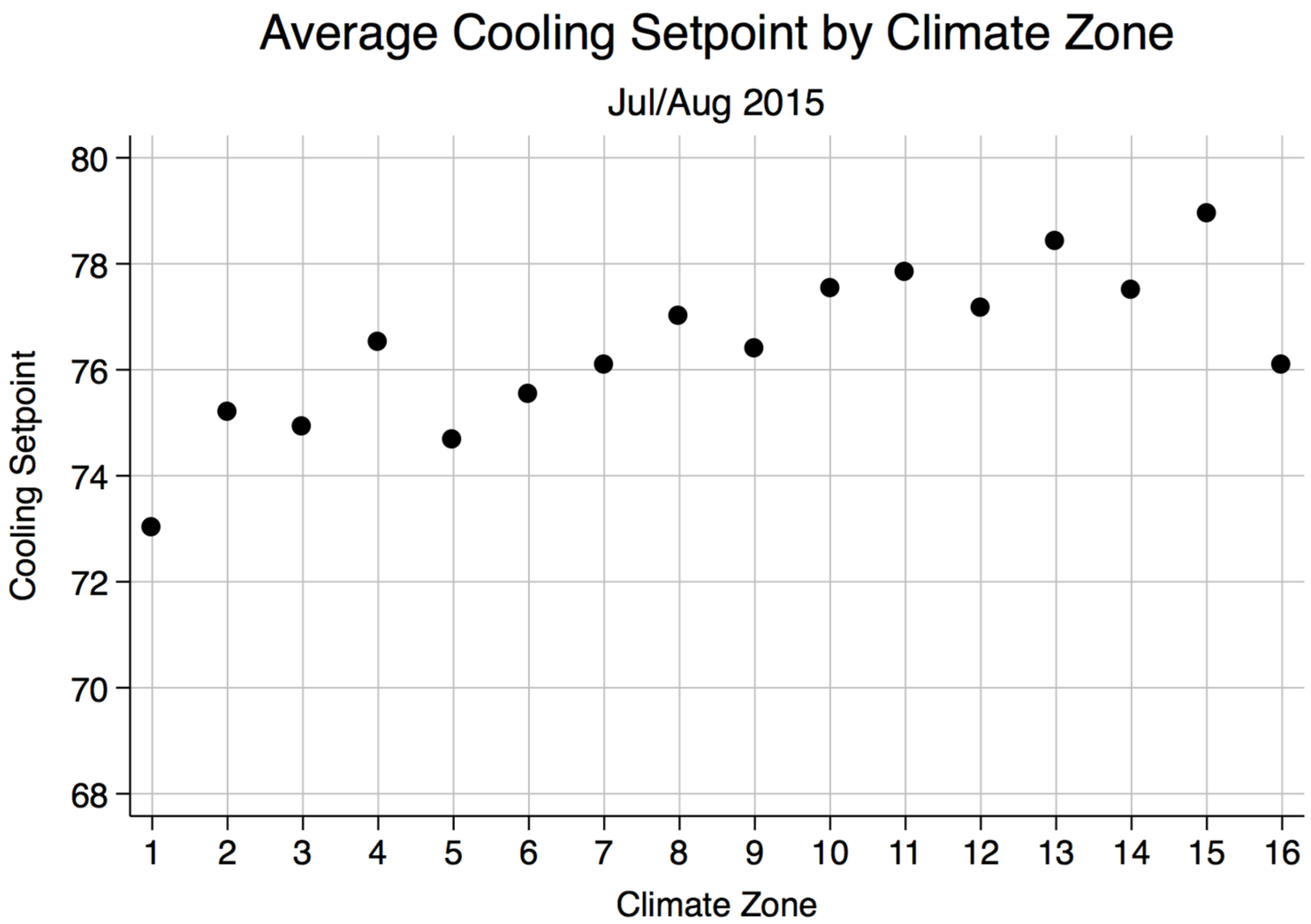

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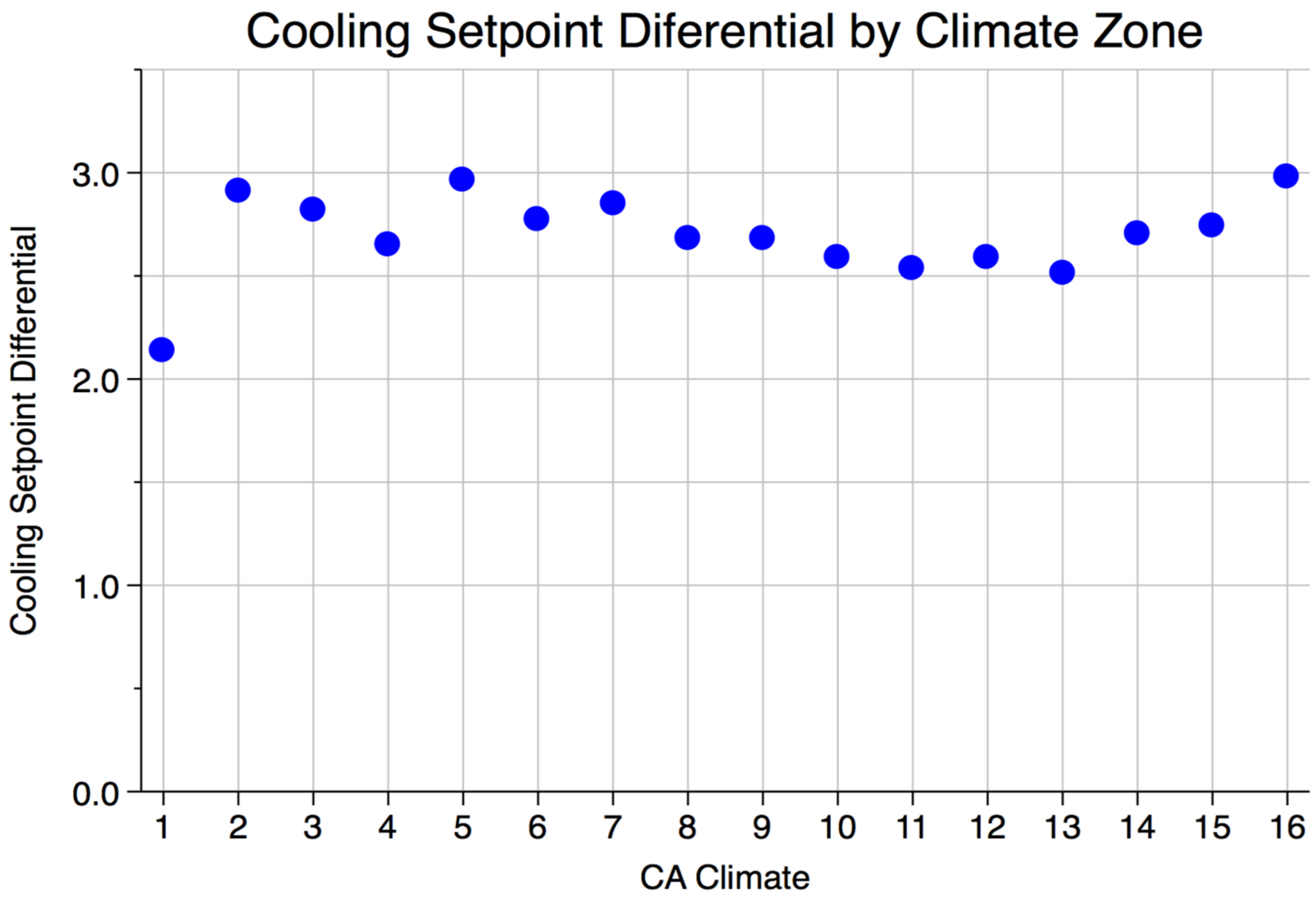

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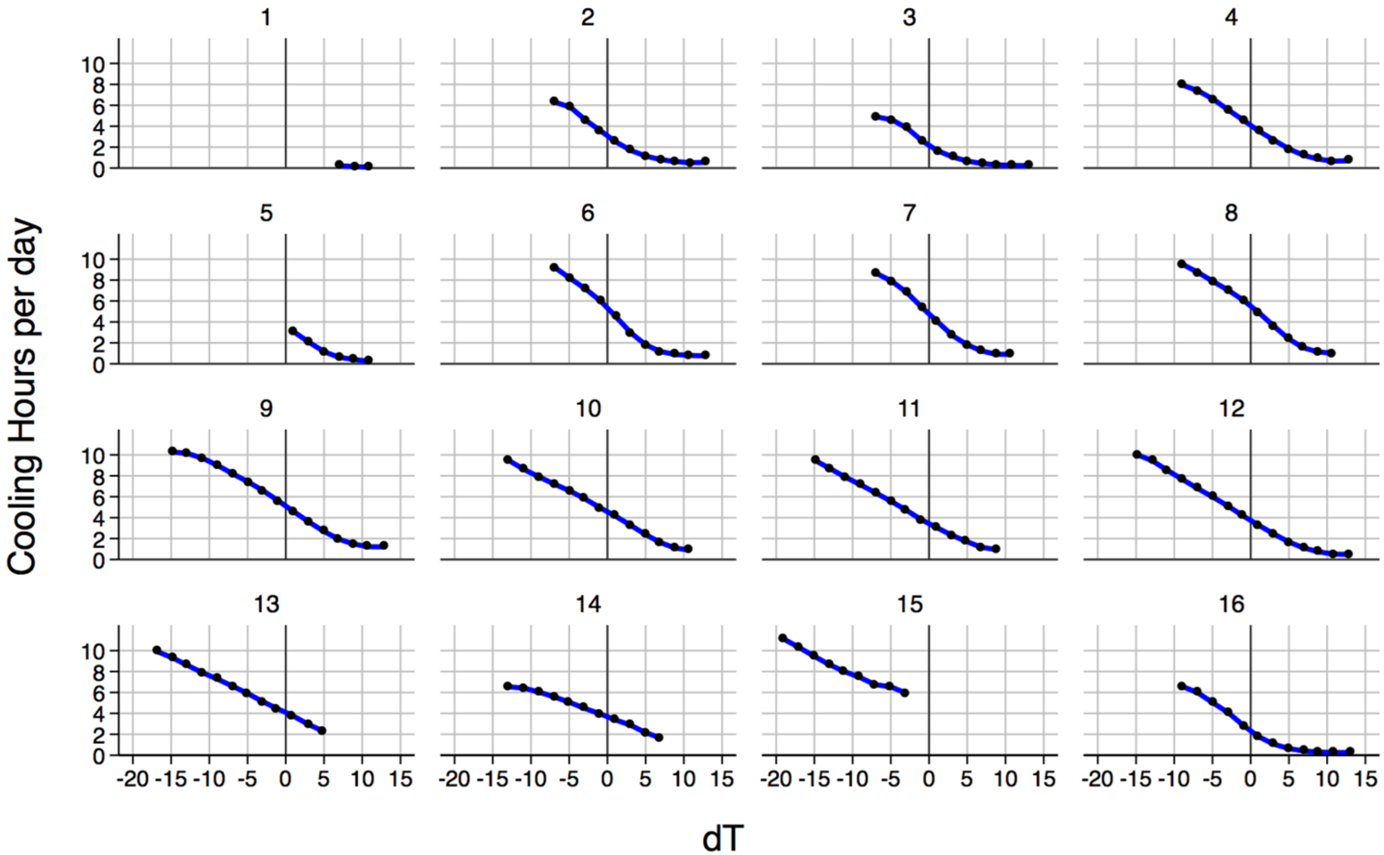
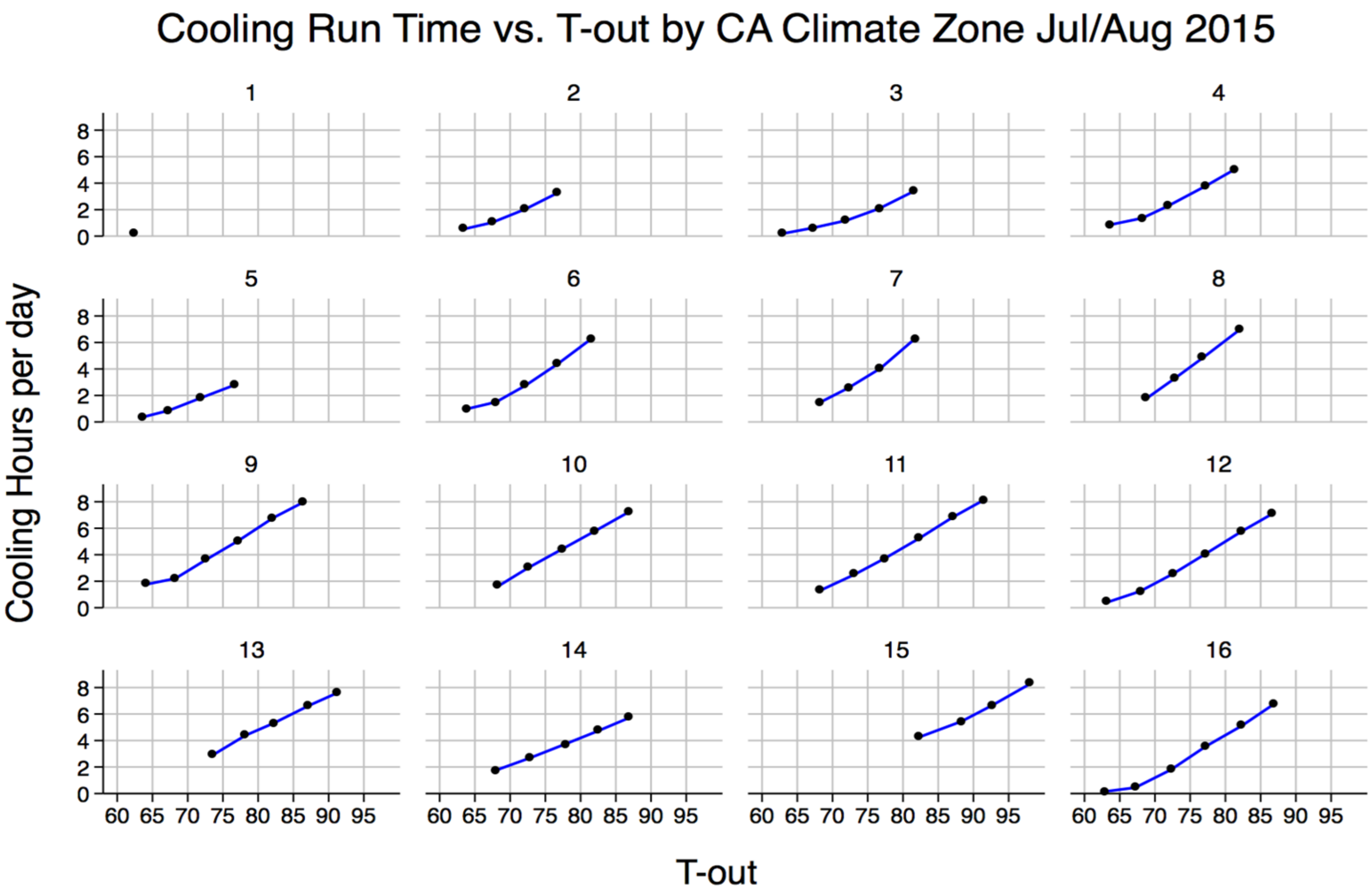
Cooling Run Time vs. dT(in-out) by CA Climate Zone Jul/Aug 2015



averages across all devices in California



averages across all devices in California

Supplemental Vendor Data Analysis

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Nest Labs proposes adding supplemental data to the statewide work paper effort in 2016:

1. Nest customer survey
   a. Identify prior thermostat type
   b. Study pre-Nest behavior (Setbacks? Schedules?)
   c. Compile pre-Nest scenarios
2. Nest device data from existing CA install base
   a. Set points, run times, etc.
   b. Data separated by CA climate zone or other groupings
   c. Pre-post analysis
3. Combine items 1 and 2 to supplement statewide efforts, particularly in 2016
4. Proposal: Nest works with stakeholders to build survey

Data will be aggregated to protect customer privacy

Questions or Comments?

Appendix A – Smart Thermostat Device Measure Definition

This measure characterizes the household heating and cooling energy savings from the installation of a smart thermostat(s). These thermostats reduce energy consumption using a combination of features described below. Smart Thermostat: A device that controls heating, ventilation, and air-conditioning (HVAC) equipment to regulate the temperature of the room or space in which it is installed, has the ability to make smart and automated adjustments for the customer to drive energy savings, and has the ability to communicate with sources external to the HVAC system.

For connection, the device may rely on a home area network (e.g. Wi-Fi) and an internet connection that is independent of the Smart Thermostat. A smart thermostat has the functionality to make automatic adjustment decisions regarding heating and cooling, using the following functions:

a. Two way communication between the thermostat and a utility, energy aggregator, or other home energy management service.

b. Automatic scheduling where the thermostat or the connected service automatically creates a configurable schedule of temperature set points and automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs.

These schedules must be established through user interaction where the thermostat learns user temperature setting preferences over time, and can be changed manually at the device or remotely through a web or mobile app.

c. Automatic variations to that schedule driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, historical and population energy usage trends, weather data and forecasts.

Presentation Follow-up Discussion

Nest Team: Michael Blasnik, Jeff Gleeson, Aaron Berndt

Agenda

1. EPA methodology: update from Michael Blasnik
   1. Status of EPA work
   2. How our regression approach differed
2. Indoor temperature vs. setpoints in regression model
3. Baseline Methodology
4. EUL and market penetration
5. Next-steps
   1. Additional discussion of SoCal Gas paper disposition
   2. Nest analysis and share-out (to CalTF) customer survey data
   3. Work paper submission with inclusion of customer survey data and comparison to billing analysis studies to inform baseline

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EPA Methodology Update

1. Status of EPA work
2. How our regression approach differed

Indoor Temp vs. Setpoint

1. We can't survey customers about their pre-Nest indoor temperature fluctuations because it isn't something they know
2. We can, however, ask them about their setpoint and setback behavior
3. Indoor temperature exists in Nest data set but is a significantly more complicated variable to pull so may not be ready in time for work paper effort

Baseline Methodology

1. Calibration factor
    1. Adjusts flat baseline to account for people’s existing behavior, which we expect to be slightly more efficient than a flat schedule
    2. Should bring the savings % (not absolute savings) in-line with widely accepted 3^{rd} party billing analyses
    3. Can be informed by Nest’s customer survey (analysis ongoing)

Sample of 3rd Party Billing Study Results

Study	Description	Heating Savings	Cooling Savings
Energy Trust of Oregon - Performed by Apex Analytics	Natural gas heating study	Control group adjusted: 6%	N/A
		Non-Control Group Adjusted: 10%	N/A
Florida Solar Energy Center - Performed by Florida Solar Energy Center	Heating, cooling and coincident demand study	9.5%	9.5%
		-	0.39 kW (4PM - 5PM)
NIPSCO Indiana - performed by Cadmus	Natural gas heating and cooling	11% - 16%	10% - 20%

EUL & Market Penetration

Effective and Remaining Useful Life

Standard/Code technology After RUL:

The standard/code technology before and after the RUL are the same for this measure because smart thermostat technology is so new, and in such an early stage of market adoption (see research summary below). It is worth noting that the definition of smart thermostats, for the purpose of this work paper, only includes those devices that provide enough software intelligence, combined with hardware features, to help customers automatically save energy. This definition very purposefully does not include those thermostats that are simply *connected* to the internet**. It is tempting to assume that *smart* thermostats are close to being a standard technology given the volume of products and discussion surrounding *connected* thermostats.**

Here is the research summarizing the early stages of adoption of the smart thermostats:

- Market penetration for Smart Thermostats, while growing each year, remains on the order of magnitude that places it in the early-adopter stage of the technology adoption cycle. Research by Berg Insights estimates that smart thermostats were installed in **4.5 million North American homes as of 2015[(1)]. Given the total number of households in the US - close to 125 million - this single-digit adoption percentage shows that the market is still predominantly comprised of early adopters**, and that it will take many years for the technology to become standard.
- Indeed, a report by Business Insider found that "the **US smart home market as a whole is in the 'chasm'** of the tech adoption curve..."[(3)]
- A report by Parks Associates found the market penetration, measured by the adoption of smart-home energy management technologies (which includes smart thermostats), to be on the order **of 7% of all U.S. broadband households[(2)]. It is worth noting that this includes additional smart home technology, not just smart thermostats.**
- The Business Insider research, and an additional report by Parks Associates[(4)], found that **high up-front product costs and low overall familiarity are two significant barriers to adoption.**

Next-Steps

1. Additional discussion of SoCal Gas paper disposition
2. Nest analysis and share-out (to CalTF) customer survey data
3. Work paper submission with inclusion of:
   1. Additional data discussed here
   2. Updated baseline
   3. Previous CalTF follow-ups