ENERGY STAR Connected Thermostats

CT Metrics Stakeholder Meeting Slides

December 18, 2020

Attendees

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Diane Jakobs, Rheem
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Chris Puranen, Rheem
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John Sartain, Emerson
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John Hughes, Trane
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Dan Baldewicz, Energy Solutions for CA IOUs
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Dan Poplawski, Braeburn
Natasha Reid, Mysa
Peter Gifford, Mysa
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Agenda

- Software V2.0
  - Goals & Requests
  - Updates and installation
- Mini-split remotes
- Variable capacity metrics – continued from previous meeting
- Connected Thermostat Use Cases – continued from previous meeting

Software V2.0 Alpha Release: Goals

- Flush out bugs!
  - Does software crash when given real world data?
  - Are there thermostats that can run through the V1.7.2 software but not V2.0?
  - Are the results for the metric and RHU wildly different?
  - Are the number of thermostats included in the statistics roughly equal?
- Note there are some reasons that the results may not be identical: weather station lookup, zip-codes, Pandas version etc.
- Do the additional capabilities of the V2 software work?
  - Does the system crash when given real world 2-speed system data?
  - Do a reasonable number of 2-speed systems make it through the statistics module?
- Are the metric or RHU results substantially different for 2-speed systems?

Software V2.0 Alpha Release: Requests

- Install the V2.0.a1 software
- Run the sample that you have for the 02/2021 resubmission through the V2.0.a1 software
  - Put data in the V2.0 input format, using V1.0 to V2.0 translator
  - Does the software run? Are the metric results and RHU the same?
- Select another sample, of installations controlling 2-speed furnaces, air conditioners, and heat pumps and run it through the V2.0 software.
  - V2.0 input format includes stage 1 and stage 2 run time, and equivalent full load run time IF you know the relative capacity of the stages.
  - Does the software run? Any differences in the metric or RHU results?
- If you have access to variable capacity furnace data, please contact us – we'd like to see if we can use the V2.0 software for it.

Software V2.0: Updates and Installation

- thermostat-2.0.0a1 is released (alpha release)
  - You will need to create a new virtual environment to run 2.0.0a1 (updated packages)
  - `pip install thermostat==2.0.0a1` will install the alpha version (need to supply version number)
  - Documentation is available at [https://epathermostat.readthedocs.io/en/feature-epathermostat_2.0/], and includes of explanation the V2.0 input file format
  - V1.7.x to V2.0 translator: https://github.com/EPAENERGYSTAR/epathermostat/blob/feature/epathermostat_2.0/scripts/thermostat_converter.py
- Email craig@Intellovations.com if you run into issues.

Software V2.0: Updates and Installation

- pipenv
  - First, thank you for the feedback and insight into your environments. Very helpful!
  - We have removed pipenv from the 2.0 release
    - (this means the Pipfile and Pipfile.lock files)
  - You may still use pipenv but will need to build your own Pipfile and Pipfile.lock
  - Still publishing packages to PyPI and updating documentation on readthedocs.io (no change)

Discussion: Software V2.0

- For variable capacity, are you interested only in fossil fuel fired furnaces, or are you intending to expand to variable capacity heat pumps and air conditioners? How do you define variable capacity fossil fueled fired furnace? In some cases, the efficiency of the furnace may depend on capacity – for instance 90 AFUE plus, you rate burner efficiency differently.
  - From other OEM, efficiency can very slightly (1-1.5 point), but the difference is far less than for compressor driven systems, partly because of coordinated control of other parts of the furnace
  - One more OEM, furnaces have fixed, stepped, and variable speed as well with similar efficiency
  - Note that fan efficiency will change significantly with capacity, but it's small energy use compared to gas energy use
- The only thing **required** for February is the 1.7.2 resubmission, including data from calendar year 2020. Everything else is **optional**.

Mini-Split Remotes: Beyond the scope of ENERGY STAR Version 1.0 specification

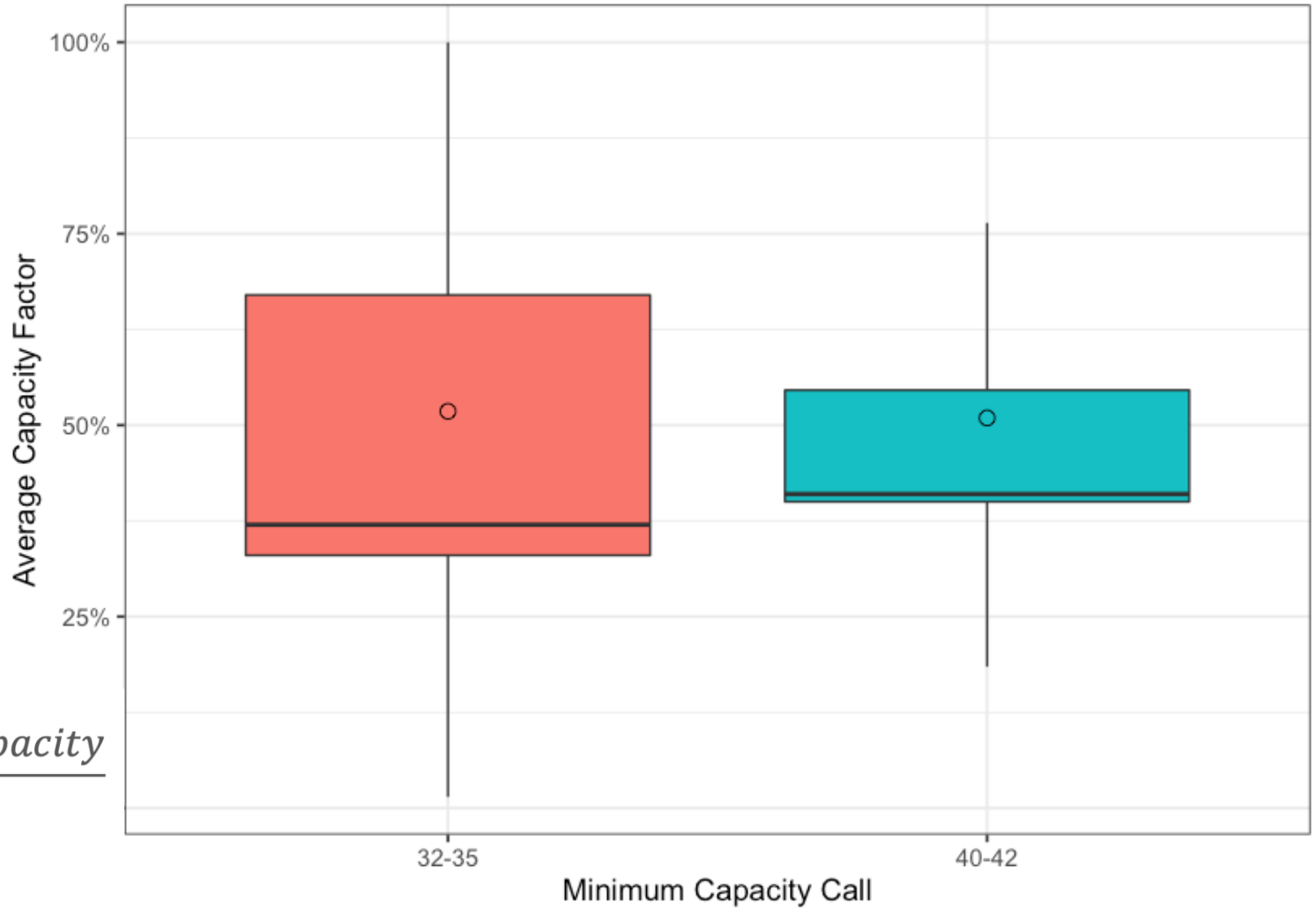
- New product category in 2016 when spec was published
- Mini-splits are mostly variable capacity units
- Variable capacity units unlikely to meet assumptions underlying field data analysis
  - Equipment run time is a good proxy for equipment energy use
  - Run time is linearly related to building heating/cooling load
  - Setting the thermostat up or back is the primary way to save energy

Variable capacity metrics: Controlling for variability

- Last meeting, we discussed different ways to control for variability in estimating the average capacity factor (ACF)
- Today's call we hope to:
  - Continue discussion of controlling for minimum capacity call (proxy for how low system capacity can go) in the ACF analysis
  - Presentation of initial results of deriving relative system sizing from data

From last time: minimum capacity call does not explain ACF variation

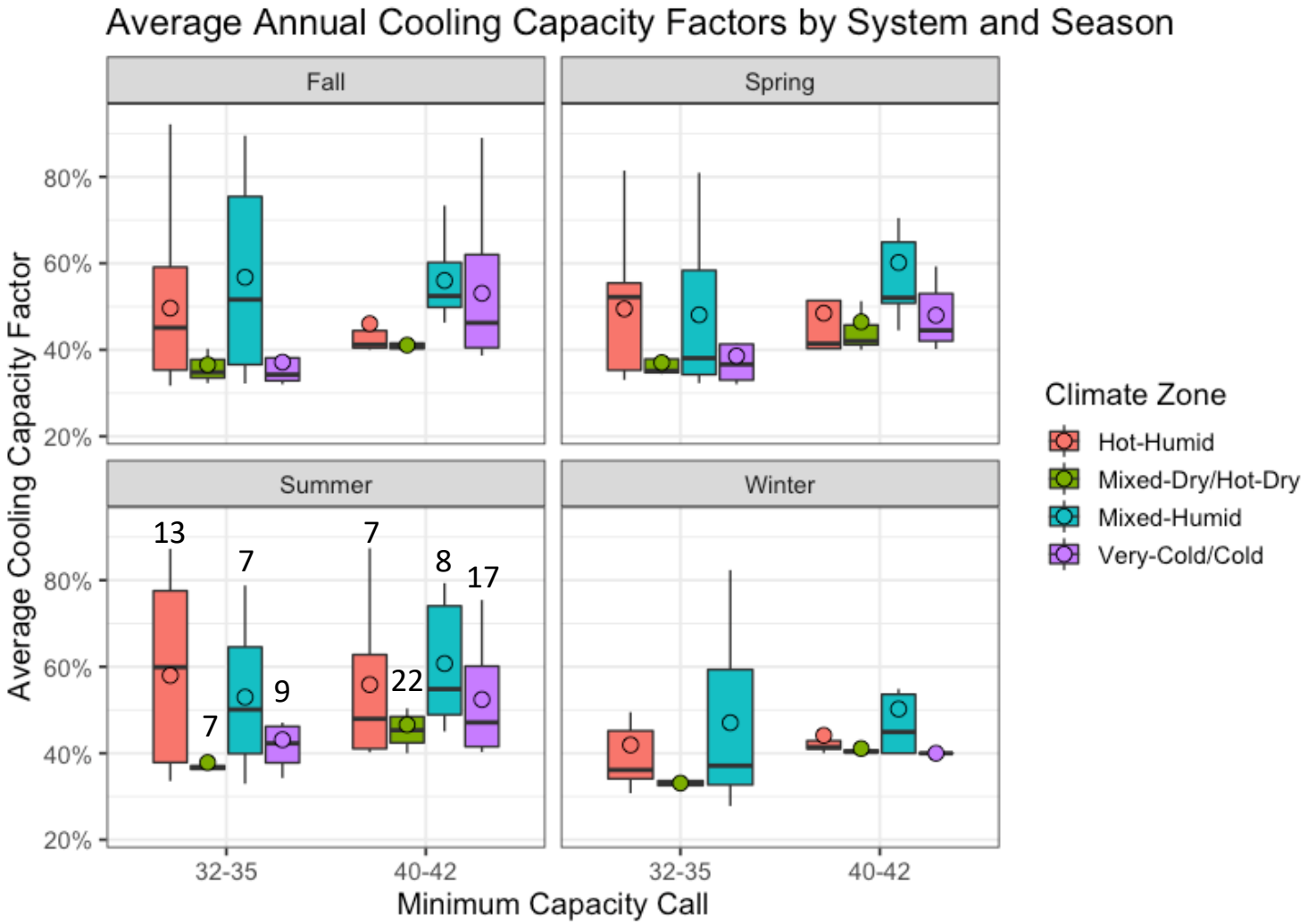
- When looking at the variability in cooling capacity factors across systems for two different minimum capacity calls, we concluded that turndown ratio does not explain much variability in ACF
- Question was raised: are we seeing variation between climates?



$$ACF = \frac{ERT}{RT} = \frac{\sum_{time} run\ time * relative\ capacity}{\sum_{time} run\ time}$$

Adding climate zone to minimum capacity calls explains ACF more

- More variability for Mixed-Humid climate zone across all seasons
- More variability in summer and fall
- Turndown ratio (capacity call) combined with climate is an important feature

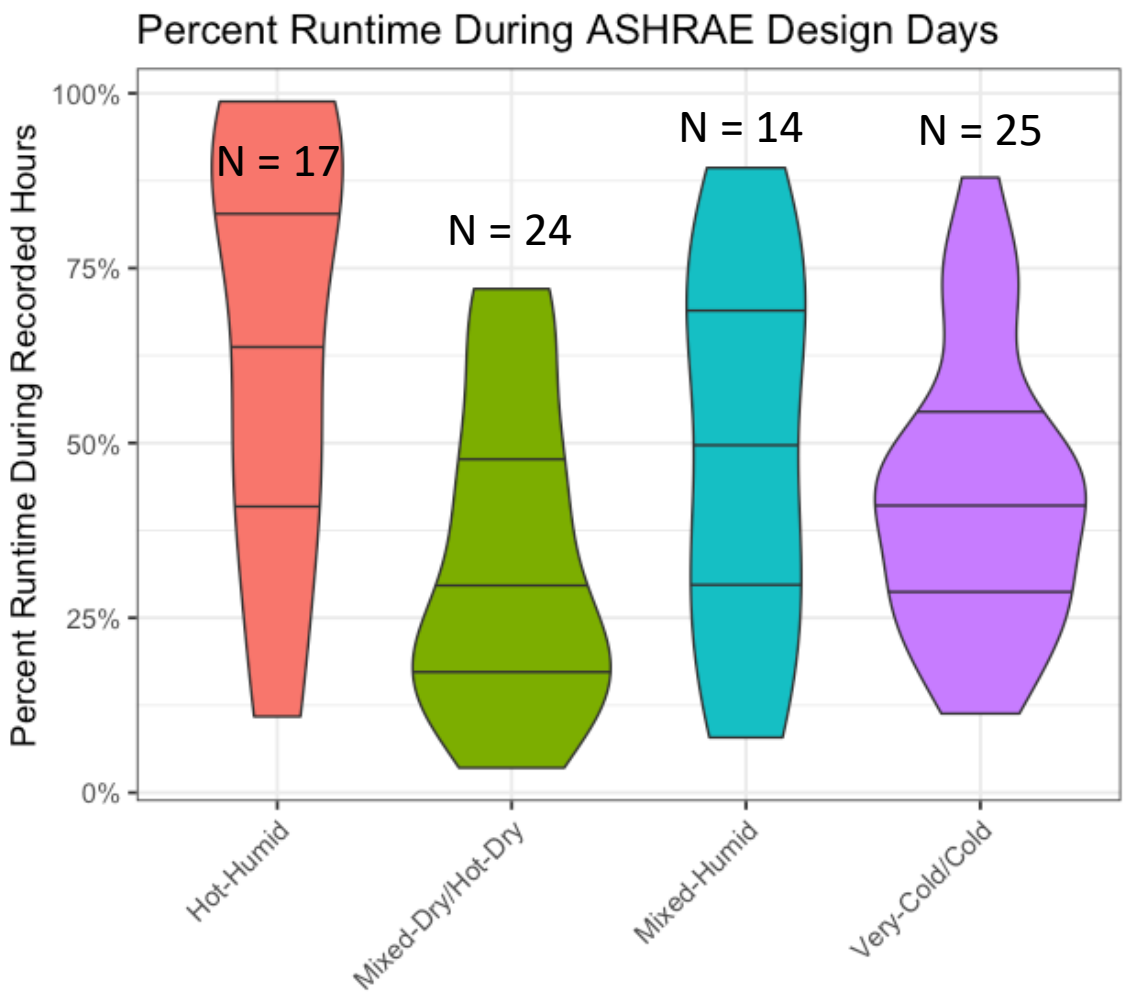


System Sizing: Why and How?

- System sizing affects several metrics stakeholders proposed, e.g., outside temperature at which system can't run continuously and starts cycling
- Controls vendors have little or no influence on system sizing
- If we want to control for sizing, we need to be able to derive it from the data
- In previous meetings we discussed some methods to do so
- Suggested method:
  - Look at run time on "design days", when system should be running near maximum capacity for substantial periods of time
  - Design day defined by the top 1% of temperatures
  - Look at percent runtime for the recorded data for all design days
- Currently have looked at cooling; heating analysis forthcoming

Comparing relative system sizing interesting, but no clear "oversized"

- Distributions across systems are suggestive but do not clearly show a group of "oversized" units
- Could try using some variant of quantity on y-axis to control for sizing in metrics



Relative sizing methodology

- Determine the heating and cooling design temperatures:
  - Use the 1% cooling dry bulb temperature from the appendix of chapter 16 of ASHRAE manual based on closest matching entry
  - Use the 99th percentile dry bulb temperature measured in the city where the HVAC system is installed
  - Use the 99th percentile measured outdoor temperature from the HVAC system
- Determine the heating and cooling day selection:
  - Select the days in which the **maximum** temperature measured by the city's weather station crosses the cooling or heating design temperature
  - Select the days in which the HVAC system's **maximum** measured temperature crosses the cooling or heating design temperature
- Deal with missing data:
  - Estimate the percent of the recorded hours that HVAC system is running

Poll

- For a properly sized variable speed system, what behavior would you expect from on design days? (10 cooling design days = 240 hours total potential runtime)
  - Running most of the time (> 75 %) at high capacity
  - Running most of the time (> 75 %) at low capacity
  - Running less than 75% of the time at high capacity
  - Running less than 75% of the time at low capacity
  - None of the above

Discussion: Variable capacity metrics, normalizing ACF

- Not sure we can resolve much for such small sample sizes with relatively small differences in minimum capacity call
- In this case, the minimum capacity call (as a % of full available capacity) is being used as a proxy for turndown ratio. Turndown ratio is the ratio of maximum to minimum capacity the equipment can deliver.

Discussion: Variable capacity metrics, normalizing ACF

- How much difference in turndown ratio would we really expect to see? CT team will pursue this question with individual stakeholders.
  - Lowest minimum speed from each OEM is different, because running the compressor at low speed can create other problems in the CA/HP, and some OEMs have better technology for dealing with this. [That's exactly why we wanted to use this as a control factor.]
  - Building design will also affect what the thermostat can deliver – but if controls are proprietary to the OEM, perhaps it is fair to take equipment capability into account when considering whether to label the control
  - Other opinions? Turndown ratio may vary between product families as well. Are we trying to be perfect when all we need is a "good-enough" metric? Maybe just knowing that the equipment is turning down a significant amount for substantial periods of time is all we need.
  - Can't really separate controls from equipment anyway.
  - Note that within an OEM, controls and equipment aren't matched up 1:1 – various controls can be used for carious systems.
  - Is there any evidence that the thermostat matters?

Discussion: Variable capacity metrics, normalizing ACF

- In this case, the minimum capacity call (as a % of full available capacity) is being used as a proxy for turndown ratio. Turndown ratio is the ratio of maximum to minimum capacity the equipment can deliver.
- Clarification: this data is all from matched variable speed equipment and manufacturer recommended controls – but we could use data from a wider variety of OEMs
- From program administrator: would there be differentiation between the various controls that are recommended for a given variable speed system? Would it make sense for a utility to just not incent controllers for installations with variable speed equipment? Higher tier product (e.g. occupancy sensors) would possibly be worth incenting.
  - Not necessarily, but there is a distinction between performance of a variable speed system with 3rd party controllers and with the recommended controllers
  - Distinctions between controllers based on DR capability will exist
  - Problem of messaging to consumer: don't get an E* thermostat with this high-efficiency E* CAC/HP
  - One OEM encourages solving that problem with different messaging, and possibly with rethinking of incentive programs

Discussion: Variable capacity metrics, normalizing ACF

- Brainstorming: Maybe there is a lab test relevant to this, looking at whether equipment + control can recover from setback (or decide not to) in a way that saves energy.
- [quickly got into space relevant to dynamic load testing and EXP07 for CAC/HP test]
- Possibly there is a way to do a (relatively) simple procedure validating set points for DOE testing as a way of recognizing controls that work well.
- EPA points out the advocates commented on the CAC/HP V6.0 Draft Final that there was a need to validate controls in low load situations.
- An in-between state would be to define a test sequence that units could run through in real installations to evaluate behavior in specific circumstances, without affecting user experience, to decide on certification
- Propose EPA reach out to AHRI to get more data (maybe anonymized) from a wider mix of manufacturers, with a template for what we are looking for.
- Another wild idea: can variable speed units just use estimate of energy consumption rather than all these proxies?

Connected Thermostat Use-Cases

ENERGYSTAR's goal is to maintain a level playing field for vendors. To this end, it will consider various strategies to prevent distorted results.

CTs are being used in situations beyond the simple single-family home. These alternative use-cases can influence the vendor's calculation of the metric in two ways:

- Certain use-cases will result in misleading metrics
- A vendor will have a distribution of use-cases that differ from other vendors

Does the metric accurately capture CT performance in common use-cases?

How are CTs being used?

- Building types (single-family, apartments, vacation homes)
- Ownership scenarios (one per home, multiple)
- Other (home and customer different)

Does the existence of these configurations suggest alternative sampling procedures?

Which inputs will generate a misleading metric calculation?

- Unrealistic comfort temperatures?
- Unusual indoor or outdoor temperatures?
- Unusual relationship between temperature and runtimes?
- Other?

#	Use Case	Does Current ES metric make sense? (Y/N/ Maybe)	Notes/ Explanation/ Drawbacks	Fraction of CTs in this category	Type of problem (Sample or metric calculation)

#	Use Case	Does Current ES metric make sense? (T_{90}, runtime, ΔT)	Notes/ Explanation/ Drawbacks	Fraction of CTs in this category	Problem in Sample or Metric?
1	SF detached home (1 tstat)		Our base case, single or dual-speed, unspecified auxiliary heating source,		
2	Vacation home				
3	SF home (>1 tstat)				
4	Multiple thermostats on a single account		(like a motel? Dorm?)		
5	SF home with multiple temperature sensors				
6	Small commercial with own HVAC				
7	Apartment with own HVAC				
8	Duplex home, multiple thermostats, different accounts, same dwelling		Variation on the Apartment idea above		
9	Variable capacity heating or cooling		We’re investigating a metric for effectiveness of variable capacity		
10	2-stage system				
11	Dual fuel		They are currently excluded		

Discussion: Connected thermostat use cases

- Do you have many customers using your thermostats in small commercial buildings?
  - Yes, separate line of business, different SKUs, not part of ENERGY STAR submissions. Same capabilities, different UI, can do fleet-wide control. Use cases range from churches, restaurants, restaurant chains (fleet may or may not all be in one location) – primary value is to the property manager. Believe they DO bear the ENERGY STAR. Some residential t'stats could also be going into those installations, but that's not recommended, b/c opportunities for savings are different, schedules more fixed.
  - DR for multiple OEMs – t'stat for this market (multifamily/light commercial) would benefit from ENERGY STAR labeling. Fleet control key here too.
  - Small strip shops with individual HVAC systems that could be using a residential style HVAC system as well as thermostat. Res thermostats could also be controlling small RTUs. No more than 5% of installations, as a guess.
  - Another OEM – low single-digit % of owners self-report business use, and many likely to be chiropractor's office or such. Do expect MUCH higher HS and CS scores from that use case
  - Concur with low-digit single percentage of residential-style t'stats used in small businesses

Discussion: Connected thermostat use cases

- Do you expect savings to be different? Will the metric scores be meaningful?
  - Another OEM – low single-digit % of owners self-report business use, and many likely to be chiropractor's office or such. Do expect MUCH higher HS and CS scores from that use case
  - Gentle start-up for heat pump can still be useful
  - Expect that most operators would set a schedule whether or not they have a smart thermostat, which you can't rely on in residential
  - On the other hand, the comfort temperature may be less energy conserving than a residence – depending on the type of establishment.
  - Some businesses also would also have high cooling loads and little/no heating load (restaurant, to a lesser extent gym)
  - One OEM will run small business segment through metric score

Discussion: Connected thermostat use cases

- Vacation homes: at least 1/3 of year in eco or away mode (with many continuous days away) (<10% of homes) showed 7% higher heating savings and cooling savings (not very different comfort temps but very different average temps)
- Common def of vacation homes could be useful
- Distinction between vacation homes and AirBNB

- Well, we didn't finish, so we'll need to revisit this once more.