ENERGY STAR Connected Thermostats

Communicating Controls for Variable Capacity HVAC Workshop, Part 1

April 3, 2020
Webinar Audio Access

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• Feel free to ask questions at any time by typing in the Question box or wait for the Q&A session
Agenda

• Context and background:
  – Abi Daken, EPA: The Existing Connected Thermostat Specification and What Do We Need in a Metric?
  – Dave Winningham, Lennox: Variable Capacity HVAC Technology
• Discussion
  – Scope
  – Context setting questions: typical communicating controller installations, and what data are available on the installations?
  – Savings Mechanisms: what are they, and which shall we focus on?
• Wrap up, Next Steps: Looking Ahead to Monday 4/6 Workshop
The Current Connected Thermostat Specification, since 2016

• **Connected Thermostat definition**: the CT product includes the CT device in the home with associated firmware, as well as a CT service supported by hardware and software outside of the home.
  – Note that communicating controllers for variable capacity HVAC are **in scope**
• Certification relies on three types of criteria
  – Device criteria, applying to the physical hardware, including standby power and temperature accuracy
  – Product criteria (device and service), including scheduling, energy feedback, etc.
  – Submission of analyzed and aggregated field data showing set back/set up
• Enthusiastic response to the specification
  – More than 38 million US households (32%) can get rebates for purchase and/or installation of an ENERGY STAR thermostat, through 197 programs
  – In 2018, 58% of smart thermostats sold were ENERGY STAR certified
  – All major third party brands have most of their models certified
Clarification of Terms: Connected vs. Communicating

- Most variable capacity systems require communicating controls
- Communicating controls can also be used to control any HVAC, and have some advantages for such
- Ductless mini-splits often have a remote which is only a user interface; all other control functions are in the HVAC, so “communication” is not applicable.
Field Data Analysis

- Savings metric is % run time reduction compared to run time for constant comfort temperature for that particular home
- Several assumptions in the EPA method:
  - Run time as a proxy for energy use
  - Set back and set up primary opportunities for savings; more use = more savings
  - In core heating (cooling) season, roughly linear relationship between indoor-outdoor temp difference and heating (cooling) equipment run time/energy use
- Limited installations analyzed to those wired as single capacity systems
- From beginning, have advised using proprietary, non-ENERGY STAR certified controls for variable capacity HVAC, but never really sufficient
- As of 2019, certified thermostat required for ENERGY STAR SHEMS, exacerbating problem
Including proprietary controllers for variable capacity systems

- Understand what is typically keeping them from certifying
- If we set different specs, need definition of these controllers – will discuss later, along with possibility of a “system” spec instead
- Differentiate controls that are savings consumers with variable capacity HVAC energy
  - For this, we need one or more metrics
  - Also need to understand where to apply those metrics
  - And need to establish a baseline to compare accomplishment to
What we need in a metric

• “Good enough” means
  – Representative of HVAC energy use
  – Demonstrates acceptable performance; able to ID a level considered “good”
  – Applicable to the majority of installations using the product
  – Fairly compares one vendor to another
• Would be nice but do not need
  – Absolute measurement of energy savings
  – Can distinguish excellent performance
• What do we have to start with?
  – Data that can be known about the operation of the system, to sufficient precision to differentiate
  – Need not necessarily be stored in the cloud
The Critical Role of Baselines

• Choosing the right baseline for comparison is critically important to both the fairness and the usefulness of the metric

• Consider baseline in current specification: per home comfort temperature
  – Using a temperature baseline means we only capture savings from temperature settings, not from opening windows, for example
  – Using a constant comfort temperature baseline is known to be unrealistic, but fair between vendors; utilities may correct to use locally
  – Adopted per-home baseline in case of different user groups between vendors: supports fairness, but means that savings from more energy-conserving comfort temp is not rewarded

• In this case, to reward controls only, need to use variable capacity performance with poor controls as baseline; may not be able to use total energy use as metric

• For systems, could use performance of fixed or dual capacity system as baseline, and total energy use as a metric
Complicated discussion – keeping on track

• This will be a complicated discussion, because we are trying to solve a hard problem. Some principles that we’ve found useful in the technical discussions of the current specification, to avoid rabbit holes:
  – Do not let the perfect be the enemy of the good: we are looking for a solution that is good enough, not a perfect solution. To that end...
  – Does this introduce a bias between vendors?
  – What are the FIRST ORDER effects? If we are considering the need to capture an effect, first ask how substantial the energy savings/cost is compared to other effects.
• We will maintain a parking lot, and there will be an opportunity to comment broadly.
EPA ENERGY STAR
Communicating Controller Workshop

April 3, 2020
## HVAC System Technology

### Single Stage
- Base Efficiency
- No System Communication

### Enhanced Single Stage
- Improved Efficiency
- Limited System Communication
- Limited Commissioning and Diagnostics

### Multi-Capacity
- Good Efficiency
- Improved Comfort
- Expanded System Communication
- Improved Commissioning and Diagnostics

### Variable Capacity
- Best Efficiency
- Best Comfort
- Full System Communication
- Full Commissioning and Diagnostics

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**EPA ENERGY STAR Thermostat Specification**
Energy Benefits - Variable Speed Communicating Systems

- Field data from Lennox variable speed communicating systems indicate they operate greater than 60% of the time at less than 50% capacity and only approximately 10% of the time near full capacity.


- Lennox communicating system offer additional diagnostic and prognostic features which allow for timely problem identification and resolution, in turn, saving energy.
Comparison of System Run Times at Different Loads
FIELD DATA FROM LENNOX COMMUNICATING SYSTEMS

<table>
<thead>
<tr>
<th>System Type</th>
<th>SEER Level</th>
<th>Avg. Tons</th>
<th>No. of Systems</th>
<th>Avg. Runtime (min.)</th>
<th>% of Total Runtime in each LOAD Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(=40% &lt;=50% &lt;=60% &lt;=70% &lt;=80% &lt;=90% &lt;=100%)</td>
<td></td>
</tr>
<tr>
<td>Single Speed</td>
<td>17</td>
<td>2.9</td>
<td>107</td>
<td>38852</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>3.0</td>
<td>1065</td>
<td>35199</td>
<td>100</td>
</tr>
<tr>
<td>Two Speed</td>
<td>21</td>
<td>3.6</td>
<td>1105</td>
<td>52104</td>
<td>73 27</td>
</tr>
<tr>
<td>Variable Speed</td>
<td>20</td>
<td>3.8</td>
<td>1569</td>
<td>99858</td>
<td>36 33 8 6 4 3 10</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>3.8</td>
<td>2360</td>
<td>112456</td>
<td>58 12 7 6 4 3 10</td>
</tr>
</tbody>
</table>

1 – Single speed systems operate at 100% demand when ON
2 – Two Speed Systems operate at 70% or 100% demand when ON

- **Variable Speed Systems Run Longer BUT at much Lower Capacities**
- **System Efficiency Increases as Capacity is Decreased**
Energy Simulation in Homes in Different Regions

Process

- Simulation at 1 minute time step, with data exchange between modules at every time-step
- TMY3 weather data
Energy Savings Comparison

SIMULATION RESULTS

Cooling Energy: Constant cooling setpoint at 75 F

<table>
<thead>
<tr>
<th></th>
<th>Dallas kWh</th>
<th>Savings</th>
<th>Phoenix kWh</th>
<th>Savings</th>
<th>Chicago kWh</th>
<th>Savings</th>
<th>Miami kWh</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single stage XC21¹</td>
<td>3091</td>
<td></td>
<td>4649</td>
<td></td>
<td>1308</td>
<td></td>
<td>4474</td>
<td></td>
</tr>
<tr>
<td>Two stage XC21</td>
<td>2749</td>
<td>11 %</td>
<td>4385</td>
<td>6 %</td>
<td>1140</td>
<td>13 %</td>
<td>3866</td>
<td>14 %</td>
</tr>
<tr>
<td>Variable speed XC20²</td>
<td>2178</td>
<td>30 %</td>
<td>3706</td>
<td>20 %</td>
<td>884</td>
<td>32 %</td>
<td>2931</td>
<td>35 %</td>
</tr>
</tbody>
</table>

1 – XC21 operated as a single stage unit

2 – XC20 coil is slightly smaller than XC21 coil, so the savings are purely due to variable speed technology
## Energy Saving – Run Time Correlation

### RESULTS – RUNTIMES

#### Simulated Cooling Runtimes: Constant cooling setpoint at 75 F

<table>
<thead>
<tr>
<th></th>
<th>Dallas</th>
<th>Phoenix</th>
<th>Chicago</th>
<th>Miami</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minutes</td>
<td>ON time</td>
<td>Minutes</td>
<td>ON time</td>
</tr>
<tr>
<td>Single stage XC21¹</td>
<td>81493</td>
<td>16 %</td>
<td>115004</td>
<td>22 %</td>
</tr>
<tr>
<td>Two stage XC21</td>
<td>112604</td>
<td>21 %</td>
<td>160428</td>
<td>31 %</td>
</tr>
<tr>
<td>Variable speed XC20</td>
<td>198051</td>
<td>38 %</td>
<td>258466</td>
<td>49 %</td>
</tr>
</tbody>
</table>

¹ – XC21 operated as a single stage unit

2 – XC17 is same as XC21 operated as a single stage unit

#### Field average cooling runtimes for systems

<table>
<thead>
<tr>
<th></th>
<th>Avg. Minutes</th>
<th>ON time</th>
<th>No. of units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single stage XC17²</td>
<td>38852</td>
<td>8 %</td>
<td>107</td>
</tr>
<tr>
<td>Two stage XC21</td>
<td>52104</td>
<td>11 %</td>
<td>1105</td>
</tr>
<tr>
<td>Variable speed XC20</td>
<td>99858</td>
<td>21 %</td>
<td>1569</td>
</tr>
</tbody>
</table>

² – XC17 is same as XC21 operated as a single stage unit
Description of the Communicating System

The Lennox iComfort Communicating system recognizes and configures equipment, measures the room temperature and humidity and communicates with the indoor equipment (i.e.: furnace) and outdoor equipment (air conditioner) and other system components.
Lennox Communicating Controls

- Designed as an integral component of Lennox communicating equipment
- Dealer Commissioning app for installation
- Installation reports
- Performance reports and emails
- Humidity control for enhanced comfort
- Zoning compatible
- “Feels Like” temperature adjusts temperature and humidity levels
- “Allergen Defender” filters the air depending upon air area quality levels
- Smart alerts to dealer when system is in need of maintenance
- Dealer Dashboard with remote monitoring, debug and diagnostics
- Ultra Smart thermostat with Schedule IQ that does the programming for you
- Wireless Access for complete control anywhere you go
- Wi-Fi remote monitoring and control via any smart device
- One-Touch Away Mode
- “Smart Away” geo-fencing technology setback while you are away
- 7-day weather and allergen forecast display to always keep you informed
- Voice control and Home Automation compatible
Lennox Communicating Controls

- Communicating Products that are designed as part of a system provide many future opportunities to improve:
  - Installation
  - Efficiency Analysis
  - Performance Optimization
  - Comfort
  - Demand Response
  - Diagnostics
  - Prognostics

"The Ultimate Controller for precise comfort."
Scope of this discussion

• Communicating controls, assumed but not required to be proprietary, with 2-way digital communication between the control and the controlled equipment. Does not assume that the “control” is all in one piece of equipment.
• POSSIBLY system of controls and HVAC
• Equipment subcategories may need to be treated differently:
  – Modulating fossil fuel fired heating equipment (warm air furnaces, possibly boilers if we can ignore zoning)
  – Variable capacity centrally ducted compressor-based heating and cooling (CAC, air source heat pumps, GHP) and 1:1 mini-splits with separate controllers
  – 1:1 mini-splits with controls inherent to device (out of scope?)
  – 1:many multi-splits (how to deal with zoning?)
  – Did I miss anything?
Discussion 1: Context-setting questions

• What proportion of communicating controllers are installed with single capacity systems? Dual capacity? Variable capacity?

• What data do systems generally have available? (set aside for the moment whether they are collected in the vendor’s cloud, as we’re likely to be able to work around that)

• Of the data available, are the meaning/methods/accuracy similar between vendors?
Discussion 2: Savings Mechanisms

- From many previous discussions, strong interest in a program that recognizes controls and HVAC together, rather than trying to separate out controls.
- In fact, significant pushback that it’s even possible to consider savings attributable to the controls rather than the HVAC.
- EPA is definitely open to this, but having a hard time imagining how to set up and administer such a program.
  - Quick checking for consensus: This is the better way to do it if we can.
- Plan to discuss this more on Monday.
- However, whether the program refers to the control plus HVAC or just the control, we still need to ID the savings mechanisms we want to target.
- Field data and lab testing in various places has shown that even for equipment which is capable of savings, much of it isn’t achieved in the field – focus on savings mechanisms affected by controls.
Savings Mechanisms

- Set back and set up when possible
  - This is very simple to track, but very hard to know if it's really saving energy
  - Could also just check if the unit knows about occupancy and sleep/wake
  - Could also check for intelligent recovery from setback
- Keep controlled AC and HP in lower capacity states when possible
  - "when possible" can be tricky
  - In some cases, may not save energy, but usually will
  - Related: temperature at which starts running uninterrupted for long periods of time (not including defrost)
- Avoid short cycling
  - Related: when cycling to maintain temp, come back on at lower capacity
  - Related, evaluating design for multi-splits: Can compressor deliver low enough capacity for single indoor head? Do indoor heads coordinate?
- Fan control [needs clarification – what makes for “good” fan control?]
- Lockout temperatures [there are several to consider]
Evaluating which savings mechanisms to focus on

• In a minute, everyone is going to have a chance to give feedback about what savings mechanisms make the most sense to focus on

• When thinking about this, here are some ideas about what make a particular mechanism a good choice:
  – Affected by control strategies and algorithms
  – Able to be examined with either prescriptive requirements (better to avoid) or with data as we’ve talked about it
  – Can identify a reasonable baseline to compare data to
  – Some products on the market are significantly better at it than others
  – Actual savings are significant in each home and/or apply to every home so that the total savings are significant

• Do we need to consider different mechanisms for different equipment types?