Connected Thermostats
Smart and Sensible
or Dumb and Dumber?
November 13, 2017
Housekeeping

Welcome
- Safety
- Bathrooms
- Cell phones
Session Survey Instructions

At the end of each session, you will be given 5 minutes to complete the session survey.

1. Open the “HEF2017” app
2. Navigate to “Agenda” and select the session
3. Scroll down to “Session Feedback”
4. For each question, select answer and hit “Submit”
5. Show completed survey to BetterBuiltNW rep to earn points
6. Prizes awarded Friday to the top point earners
   - See “Challenge” section in the app for activities
7. Assistance available at the BetterBuiltNW table
About This Session

- Few answers
- Lots of questions
- ...and some advice
Thermostat Groups

- All Thermostats
  - Non Programmable
    - Digital
    - Non digital
  - Programmable
    - Setbacks engaged
    - Used as switch
  - Learning, Internet connected
    - Are you home?
    - Remote Control
    - Cool Stuff
    - Black box stuff
# What are Smart Thermostats?

<table>
<thead>
<tr>
<th>Programmable thermostats</th>
<th>Occupants set schedules and setbacks to match their lifestyle; programmable thermostats do not have occupancy or proximity sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ability to maintain comfortable temperatures in a structure</td>
</tr>
<tr>
<td></td>
<td>Displays temperatures and operating modes</td>
</tr>
<tr>
<td></td>
<td>Wi-Fi-enabled</td>
</tr>
<tr>
<td></td>
<td>Online dashboard and/or mobile app connected to the user account</td>
</tr>
<tr>
<td></td>
<td>Intuitive user interface, or UI, that may include touchscreen or buttons</td>
</tr>
<tr>
<td>Wi-Fi thermostats</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Occupancy sensing that directly detects occupants by internal sensor and adjusts the thermostat accordingly</td>
</tr>
<tr>
<td></td>
<td>Proximity sensing that indirectly detects occupants by external device, like a smart phone, and adjusts thermostat accordingly</td>
</tr>
<tr>
<td></td>
<td>Algorithms that learn occupant behavior to improve schedules and learn characteristics of the structure to improve performance of the system</td>
</tr>
<tr>
<td></td>
<td>Basic demand response capabilities that allow remote connection with utilities, who can adjust thermostat settings during peak demand periods (optional)</td>
</tr>
</tbody>
</table>

**Smart thermostats**
ENERGY STAR Smart Thermostat

- Must have certain features
- Must have some evidence of actual change in set points
- Must somehow have the ENERGY STAR logo
ENERGY STAR Smart Thermostat

Required to:

• Work as a basic thermostat in the absence of connectivity
• Give user feedback about the energy consequences of their settings
• Provide information about HVAC energy use
• Provide the ability to set a schedule
• Provide the ability to work with utility programs to prevent brownouts and blackouts
  • Preserve consumers’ ability to override these grid requests
# ENERGY STAR Smart Thermostat

## Performance Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Performance Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static temperature accuracy</td>
<td>≤ ±2.0 °F</td>
</tr>
<tr>
<td>Network standby average power consumption</td>
<td>≤ 3.0 W average</td>
</tr>
<tr>
<td>Time to enter network standby after user interaction (on device, remote or occupancy detection)</td>
<td>≤ 5.0 minutes</td>
</tr>
</tbody>
</table>
Thermostats Can Be Smart and Not Save Energy

**Definition**

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55). Thermal environment is those characteristics of the environment which affects a person's heat loss. In terms of bodily sensations, thermal comfort is a sensation of hot, warm, slightly warmer, neutral, slightly cooler, cool and cold.

<table>
<thead>
<tr>
<th>Comfort</th>
<th>Convenience</th>
<th>Peace of mind</th>
</tr>
</thead>
<tbody>
<tr>
<td>(could increase energy use)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A Short History of the Thermostat: Hardware to Software

Cornellis Drebbel
1592

The “magic oven”

1885 the “damper Flapper”

Warren Johnson
More Recent History

1st Programmable Thermostat
1906

The Chronotherm II Adaptive intelligent Recovery

Ecobee
2007

1953 T—87

Vision Pro

1906

1953

2007
Smart Thermostats are Not A Commodity

- Term *commodity* is specifically used to describe a class of goods for which there is demand, but which is supplied without qualitative differentiation across a market.
Smart Thermostats: Key Differences

- User interface
- Motion sensor
- Ability to control other devices
- Demand response capabilities
- Report capabilities
- Behavioral prodding

- Control algorithm
- Data sharing
- Geo-fencing
- App reliant
- Design appeal
Pilots: Yes, Smart Thermostats Can Save Energy
Completed Pilots

Energy Trust of Oregon
- DI Nest t-stats for 200 homes with heat pumps and 200 control homes
- Installed by Pilot staff
  - Installation Method: Installed by CLEAResult staff
  - Issues Faced: Bricked product: Close calls on customer service

Franklin PUD
- 176 homes, small control group
- Installed by HVAC contractors
  - Installation method: Installed by 3rd party HVAC contractor
  - Issues faced: Contractor training hurdles

Energy Trust of Oregon
- Gas heated homes
- DIY/Self-install, with Geo Fencing
### Savings From The ETO Heat Pump Pilot

#### Table 15. Nest weather-normalized annual electric savings by home construction type.

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Participant N / Comparison N</th>
<th>Annual Savings (90% CI)</th>
<th>Std. Err.</th>
<th>p-value</th>
<th>Annual Usage</th>
<th>% Savings (90% CI)</th>
<th>Realization Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufactured</td>
<td>21 / 54</td>
<td>1,172 (470, 1874)</td>
<td>388</td>
<td>0.013</td>
<td>13,521</td>
<td>8.7% (3.5, 13.9)</td>
<td>140%</td>
</tr>
<tr>
<td>Site-built</td>
<td>92 / 157</td>
<td>669 (105, 1232)</td>
<td>311</td>
<td>0.057</td>
<td>17,532</td>
<td>3.8% (0.6, 7.0)</td>
<td>80%</td>
</tr>
</tbody>
</table>

Data and Graphics From Energy Trust of Oregon and Apex Analytics
Increased Comfort

Figure 24. Comfort of home temperature compared to pre-Nest thermostat period

Data and Graphics From Energy Trust of Oregon and Apex Analytics
What Were They Programmed To Do?

Table 22. Nest weather-normalized annual electric savings by prior thermostat type (Comparison N=211).

<table>
<thead>
<tr>
<th>Prior Thermostat Type</th>
<th>Participant N</th>
<th>Annual Savings (90% CI)</th>
<th>Std. Err.</th>
<th>p-value</th>
<th>Annual Usage</th>
<th>% Savings (90% CI)</th>
<th>Realization Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not programmable</td>
<td>28</td>
<td>423 (-384, 1230)</td>
<td>445</td>
<td>0.365</td>
<td>14,656</td>
<td>2.9% (-2.6, 8.4)</td>
<td>51%</td>
</tr>
<tr>
<td>Programmable</td>
<td>82</td>
<td>1,151 (621, 1681)</td>
<td>293</td>
<td>0.003</td>
<td>17,619</td>
<td>6.5% (3.5, 9.5)</td>
<td>138%</td>
</tr>
</tbody>
</table>

Prior Thermostat Type     % Savings (90% CI)
-------------------------------
Non programmable            2.9% (-2.6, 8.4)
Programmable               6.5% (3.5, 9.5)

Data and Graphics From Energy Trust of Oregon and Apex Analytics
Franklin PUD Project
The Answer is…..

<table>
<thead>
<tr>
<th>N</th>
<th>Total Annual Savings (kWh)</th>
<th>95% Lower C.I.</th>
<th>95% Upper C.I.</th>
<th>R-Squared Criteria</th>
<th>Pre Install Consumption</th>
<th>% Total Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>167</td>
<td>885</td>
<td>381</td>
<td>1388</td>
<td>All</td>
<td>21804</td>
<td>4.06%</td>
</tr>
<tr>
<td>130</td>
<td>824</td>
<td>314</td>
<td>1333</td>
<td>&gt;= .50</td>
<td>21016</td>
<td>3.92%</td>
</tr>
<tr>
<td>115</td>
<td>959</td>
<td>419</td>
<td>1498</td>
<td>&gt;= .60</td>
<td>20930</td>
<td>4.58%</td>
</tr>
<tr>
<td>97</td>
<td>1103</td>
<td>599</td>
<td>1607</td>
<td>&gt;= .70</td>
<td>21110</td>
<td>5.23%</td>
</tr>
</tbody>
</table>

Data from Phillip Kelsven, Franklin PUD and Robert Weber, BPA
## Findings on the Energy Trust of Oregon DIY Gas Furnace Pilot

<table>
<thead>
<tr>
<th>Thermostat</th>
<th>Annual Therm Savings</th>
<th>SE</th>
<th>90% Conf. Interval</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest</td>
<td>34</td>
<td>11</td>
<td>13, 55</td>
<td>0.018*</td>
</tr>
<tr>
<td>Lyric</td>
<td>-29</td>
<td>14</td>
<td>-55, -3</td>
<td>0.071*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermostat</th>
<th>% Savings</th>
<th>% Heating Savings</th>
<th>Annual Therm Usage</th>
<th>Heating Therm Usage</th>
<th>% Heating Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest</td>
<td>4.5%</td>
<td>6.0%</td>
<td>761</td>
<td>566</td>
<td>74%</td>
</tr>
<tr>
<td>Lyric</td>
<td>-3.7%</td>
<td>-4.9%</td>
<td>784</td>
<td>596</td>
<td>76%</td>
</tr>
</tbody>
</table>

Data and Graphics From Energy Trust of Oregon and Apex Analytics
Considerations For Selecting the Best Fit Smart Thermostat
Avoid Homeowner Confusion and Call Backs
User Interface

- User Interface are like jokes; if you have to explain them, they aren’t any good
Proprietary Thermostats

- High End HVAC Systems Usually Need a Proprietary Thermostat To Have Full Functionality
- Modulating Gas Furnaces
- Variable Refrigerant Heat Pumps and Air Conditioners
Smart Thermostats and Ductless Heat Pumps

- DHPs already have smart algorithms. It may not be a good idea to layer another set on top.

- If available, use the manufacturers Wi-Fi thermostat.
Nest 3 vs. Nest E

- Same basic features
- The “E” only has 6 wire terminals limiting equipment types and HVAC accessories
Whose Job is it?

Connected thermostats require someone to connect them to the homeowners Wi-Fi:

- The homeowner
- The Builder
- The HVAC Technician
- The Rater/Verifier
Compatibility With Other Smart Stuff

Can the system grow?

- Security
- Smoke and Carbon Monoxide detectors
- Alexa or other hubs
- Home Kit – works with Nest
- Smart Fans, smart doggie doors, etc.
Energy Reports: Built in Data Logging

So much data, who has access?

- The builder?
- The verifier?
- The owner?
- The HVAC contractor?
Remote Monitoring and Service Alerts
Can be Viewed Remotely or On Site
Remote Quality Control and Data Logging
What’s Next: Smart T-stat as QC
What’s Next: Smart T-stat as QC

Heat Pump Aux Heat Ratio vs. Outdoor Temperature
US Jan-Mar 2015

Aux Heat Ratio (Aux / Compressor)

95%tile
75%tile
Median
25%tile

Outdoor Temperature (°F)
What was found

<table>
<thead>
<tr>
<th>Site ID</th>
<th>City</th>
<th>Year Built</th>
<th>Sq. ft.</th>
<th>MH Type</th>
<th>Tonnage</th>
<th>Annual kWh in pre-period</th>
<th>Strip Heat Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>683853</td>
<td>Bend</td>
<td>1996</td>
<td>1400</td>
<td>Double-wide</td>
<td>2</td>
<td>10452</td>
<td>49%</td>
</tr>
<tr>
<td>683890</td>
<td>Bend</td>
<td>1997</td>
<td>1400</td>
<td>Double-wide</td>
<td>2</td>
<td>19685</td>
<td>14%</td>
</tr>
<tr>
<td>677995</td>
<td>Bend</td>
<td>1997</td>
<td>1620</td>
<td>Double-wide</td>
<td>2.5</td>
<td>23871</td>
<td>9%</td>
</tr>
<tr>
<td>139287</td>
<td>Oregon City</td>
<td>1991</td>
<td>1292</td>
<td>Double-wide</td>
<td>2</td>
<td>15114</td>
<td>7%</td>
</tr>
<tr>
<td>25106</td>
<td>Oregon City</td>
<td>1991</td>
<td>1080</td>
<td>Double-wide</td>
<td>2</td>
<td>18094</td>
<td>5%</td>
</tr>
<tr>
<td>690344</td>
<td>Terrebonne</td>
<td>1997</td>
<td>1296</td>
<td>Double-wide</td>
<td>2</td>
<td>13630</td>
<td>4%</td>
</tr>
<tr>
<td>689461</td>
<td>Bend</td>
<td>1997</td>
<td>1200</td>
<td>Double-wide</td>
<td>2</td>
<td>16089</td>
<td>3%</td>
</tr>
<tr>
<td>543542</td>
<td>Oregon City</td>
<td>1995</td>
<td>1800</td>
<td>Double-wide</td>
<td>3</td>
<td>13377</td>
<td>2%</td>
</tr>
<tr>
<td>497998</td>
<td>Oregon City</td>
<td>1995</td>
<td>1290</td>
<td>Double-wide</td>
<td>2</td>
<td>11861</td>
<td>2%</td>
</tr>
<tr>
<td>325913</td>
<td>Bend</td>
<td>1988</td>
<td>1980</td>
<td>Double-wide</td>
<td>3</td>
<td>17161</td>
<td>2%</td>
</tr>
<tr>
<td>690383</td>
<td>Oregon City</td>
<td>1996</td>
<td>1296</td>
<td>Double-wide</td>
<td>2</td>
<td>7230</td>
<td>1%</td>
</tr>
<tr>
<td>689451</td>
<td>Bend</td>
<td>1995</td>
<td>1810</td>
<td>Double-wide</td>
<td>3</td>
<td>Not found</td>
<td>1%</td>
</tr>
<tr>
<td>583813</td>
<td>Oregon City</td>
<td>1987</td>
<td>1296</td>
<td>Double-wide</td>
<td>2</td>
<td>17410</td>
<td>0%</td>
</tr>
<tr>
<td>562026</td>
<td>Oregon City</td>
<td>1990</td>
<td>1568</td>
<td>Double-wide</td>
<td>2.5</td>
<td>10711</td>
<td>0%</td>
</tr>
<tr>
<td>520339</td>
<td>Portland</td>
<td>2014</td>
<td>1500</td>
<td>Double-wide</td>
<td>2.5</td>
<td>13310</td>
<td>0%</td>
</tr>
<tr>
<td>467510</td>
<td>Bend</td>
<td>1997</td>
<td>1400</td>
<td>Single-wide</td>
<td>2</td>
<td>23871</td>
<td>0%</td>
</tr>
<tr>
<td>231255</td>
<td>Oregon City</td>
<td>1990</td>
<td>1400</td>
<td>Double-wide</td>
<td>2.5</td>
<td>12601</td>
<td>0%</td>
</tr>
<tr>
<td>467251</td>
<td>Bend</td>
<td>1997</td>
<td>1400</td>
<td>Double-wide</td>
<td>2.5</td>
<td>13761</td>
<td>0%</td>
</tr>
<tr>
<td>683842</td>
<td>Oregon City</td>
<td>2013</td>
<td>1917</td>
<td>Double-wide</td>
<td>3</td>
<td>14744</td>
<td>0%</td>
</tr>
</tbody>
</table>

[[1] Annual kWh in pre-period is metered use reported to the utility.]
## What We Found

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Aux Heat Ratio</th>
<th>Delta Capacity</th>
<th>% Below or Above</th>
<th>Thermostat Settings</th>
<th>ACH at 50Pa</th>
<th>Duct Leakage CFM</th>
<th>Reasons for high aux heat ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1173489</td>
<td>0</td>
<td>2114</td>
<td>9%</td>
<td>Strip heat locked out at 35F.</td>
<td>6.8</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>1156226</td>
<td>0</td>
<td>-6009</td>
<td>-20%</td>
<td>Max Savings</td>
<td>19.4</td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>231255</td>
<td>0</td>
<td>-3272</td>
<td>-11%</td>
<td>Max Savings</td>
<td>7.2</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>562026</td>
<td>0</td>
<td>-5961</td>
<td>-20%</td>
<td>Max Savings</td>
<td>5.1</td>
<td>707</td>
<td></td>
</tr>
<tr>
<td>1171519</td>
<td>4</td>
<td>54</td>
<td>0%</td>
<td>Max Savings</td>
<td>10.0</td>
<td>274</td>
<td></td>
</tr>
<tr>
<td>139287</td>
<td>7</td>
<td>-5427</td>
<td>-23%</td>
<td>Max comfort</td>
<td>10.3</td>
<td>238</td>
<td>Set to Max Comfort, 23% low on capacity</td>
</tr>
<tr>
<td>1138572</td>
<td>9</td>
<td>-11966</td>
<td>-40%</td>
<td>Max comfort -</td>
<td>5.4</td>
<td>250</td>
<td>Set to Max Comfort, Very low capacity</td>
</tr>
<tr>
<td>1156212</td>
<td>14</td>
<td>-1709</td>
<td>-7%</td>
<td>Max Savings</td>
<td>10.4</td>
<td>225</td>
<td>Homeowner used deep set backs</td>
</tr>
<tr>
<td>1156132</td>
<td>49</td>
<td>3721</td>
<td>16%</td>
<td>Locked out compressor at 35F</td>
<td>9.0</td>
<td>176</td>
<td>Locked out compressor</td>
</tr>
</tbody>
</table>
Preliminary Conclusions

- All thermostats can cause control problems
  - But connected thermostats can find them!

- Maybe by comparing run times and using connected thermostats “problem” homes or systems can be found
Our Best Advice

- Choose a compatible thermostat for your HVAC system
- Decide who will commission the thermostat
- User friendly is better
- Ask the owner for data access
- Educate the homeowner
Evaluations Matter: Both Teams Have the Same Features
Thank You

Bruce Manclark

info@betterbuilt nw.com