Top Smart Thermostats for Preference and Usability

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Powering forward. Together.

Why Thermostats Matter

- Thermostats manage ~25% of annual electricity use at SMUD
- Residential AC is responsible for >30% of SMUD peak

Why Smart Thermostats Matter

**Summer Conservation Impacts**
(% of whole-house energy use)

<table>
<thead>
<tr>
<th></th>
<th>Standard rate + load control PCT</th>
<th>Standard rate + optimizing PCT</th>
<th>TOU-CPP + optimizing PCT</th>
<th>TOU-CPP + customer-controlled PCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Summer Energy Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=508</td>
<td>-3.0%</td>
<td>-2.6%</td>
<td>-6.1%</td>
<td>-7.9%</td>
</tr>
<tr>
<td>N=33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=106</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=255</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Herter Energy, SMUD’s Load Impact Calculator

**Summer Demand Response Impacts**
(Whole-house kW impacts)

<table>
<thead>
<tr>
<th></th>
<th>TOU-CPP (no PCT)</th>
<th>TOU-CPP + PCT (no automation)</th>
<th>Standard rate + utility PCT automation</th>
<th>TOU-CPP + utility PCT automation</th>
<th>TOU-CPP + customer-controlled PCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Participant Peak Load Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=79</td>
<td>-0.5</td>
<td>-1.4</td>
<td>-1.4</td>
<td>-1.1</td>
<td>-2.2</td>
</tr>
<tr>
<td>N=196</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>N=308</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=352</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=155</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Source: Herter Energy, SMUD’s Load Impact Calculator
Thermostats Tested (2013)

Honeywell FocusPro (Non-communicating)

Lux Smart Temp (Non-communicating)

RCS TZ-45

Radio Thermostat CT30

Nest

Ecobee SmartSi

Energate Foundation

Energate Pioneer Z100

Computime CTW218

Emerson Smart Energy

Carrier Comfort Choice Touch

Cooper-Honeywell Utility Pro

Research Questions

1. How do thermostats compare in terms of:
   - Efficiency (time-on-task)
   - Preference (of two tested thermostats)
   - Satisfaction (ratings of standard features)

2. How do participants rate advanced features?

Methodology

- 12 thermostats tested
  - 10 communicating “smart” thermostats (6 with apps)
  - 2 standard non-communicating thermostats
- Simultaneous multi-user, paired-comparison test
  - 163 participants x 2 units per participant = 326 tests
  - >95% of possible ordered pairs tested
- 90-minute sessions
  - Video recording of thermostat tests
  - Surveys
  - Group discussions

Laboratory Layout
Efficiency = Time on Task

The same 7 tasks were performed for each thermostat

1. Identify the current indoor temperature
2. Set to cool. Identify the current target cooling temperature
3. Change the current target cooling temperature to 79
4. Identify the scheduled cooling temperature for Saturday at 8 am
5. Set to heat. Identify the current target heating temperature
6. Change the current target heating temperature to 63
7. Identify the scheduled heating temperature for Saturday at 8 am

Task Efficiency = 2s / (1+e^t)

Where
• s = Success = 0 for failed tasks; 1 for completed tasks
• t = Time-on-Task = time to complete the task, in minutes.

Results: Efficiency

Preference

Imagine that the thermostat in your home suddenly dies and your mechanic offers a choice between the thermostats you just reviewed - at the same price. Please circle the thermostat you would choose to have installed.

Results: Preference
Satisfaction (with Standard Features)

1. Rate EASE OF USE AND UNDERSTANDING
   a. Information on the screen
   b. Buttons, dials, and switches
   c. Meanings of words and symbols
   d. Menus, navigation
   e. Overall ease of use

2. Rate how the Thermostat FEELS and SOUNDS
   a. Buttons
   b. Touchscreen
   c. Bush
   d. Switches
   e. Overall feel and sound

3. Rate how the Thermostat LOOKS
   a. Layout of the screen and buttons
   b. Size of the screen
   c. Color(s)
   d. Readability of the smallest text
   e. Overall appearance of the Thermostat

Results: Satisfaction

<table>
<thead>
<tr>
<th>ID</th>
<th>Thermostat</th>
<th>Overall feel and sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>7.6</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>7.3</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>6.8</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>6.2</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>6.0</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>5.6</td>
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<tr>
<td>7</td>
<td>6</td>
<td>4.9</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>4.8</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>4.7</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Statistical significance bounds: ± 2.6 (p<0.01)

Regression of Standard Features Ratings on Efficiency and Preference

- Color display → higher Preference scores
- Larger screen → higher Efficiency scores
- Higher Feel & Sound ratings → higher Preference
- Youth → higher Efficiency scores
- Home owners → higher Efficiency scores
- Youth → higher Efficiency scores
- Rated higher by younger users
- Not significant in predicting efficiency or preference
- Not significant
- Not significant

Perceived Usefulness of Potential Advanced Features

<table>
<thead>
<tr>
<th>Average Advanced Feature Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Temp</td>
</tr>
<tr>
<td>Home Energy</td>
</tr>
<tr>
<td>Efficiency Indication</td>
</tr>
<tr>
<td>App Access</td>
</tr>
<tr>
<td>Wi-Fi, Energy</td>
</tr>
<tr>
<td>Touchscreen</td>
</tr>
<tr>
<td>Key Display</td>
</tr>
<tr>
<td>Web Access</td>
</tr>
<tr>
<td>Process</td>
</tr>
<tr>
<td>Auto-Raise</td>
</tr>
<tr>
<td>Time to Trigger</td>
</tr>
<tr>
<td>Price Response</td>
</tr>
<tr>
<td>Auto-Schedule</td>
</tr>
<tr>
<td>Phoenix</td>
</tr>
</tbody>
</table>
Top Ranking Smart Thermostats 2013

1. Carrier Comfort Choice Touch

1. Emerson Smart Energy

1. Ecobee Smart Si

Thermostats being Tested (2015)

1. ecobee3
2. Honeywell Lyric
3. Honeywell RTH9520WF
4. Emerson Sensi

1. Venstar ColorTouch
2. Trane XL824
3. Lux GEO
4. Carrier Cor

1. Nest 3rd generation
2. Schneider Wiser Air
3. American Standard AZone950
4. Allure Eversense

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