Thermostat Behavior in the Low-Income Weatherization Assistance Program

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Outline

• Overview of DOE’s Weatherization Assistance Program
• Overview of ORNL’s Retrospective Evaluation
• Overview of ORNL’s Indoor Air Quality Study
• Temperature Monitoring Protocol
• Monitored Results – Pre & Post Weatherization
• Consistency with Occupant Self-reports
• Comparison of Results to Previous Research
• Conclusions
Overview of Retrospective WAP Evaluation (PY 2007 & 2008)

- Impact Evaluation
  - Program Characterization
  - Energy and Cost Savings
  - Cost Effectiveness
  - Non-Energy Impacts
  - National Occupant Survey*
  - National Training Center Survey*
  - National Weatherization Staff Survey*

* Being conducted in PY 2010-2011
Overview of Retrospective WAP Evaluation

• Process Evaluation
  – Field Studies*
    • Audits
    • Client Education
    • Training Observations and Recommendations
  – Case Studies*
    • Weatherization
      Beyond the Numbers

* Being conducted in PY 2010-2011
Indoor Air Quality Study

- Radon
- Carbon Monoxide
- Formaldehyde
- Relative Humidity
- Indoor Temperature
- Treatment & Control Groups
Sampled Geographic Areas (77 Agencies)
Indoor Temperature Measurement Protocol

- Winter 2010-2011
- Only Single Family Homes
- Closed Home Conditions
- Hobo U-10 logger deployed at main thermostat
- Recorded temperature every 10 minutes
- Median of 3 weeks (10 days – 2 months) of pre-and post-weatherization data
  - post-WX data exclude one-week transition period following completion of work
  - low temperatures suggestive of prolonged absences also removed (<1% of data)
Results from 478 homes, weighted to reflect all PY08 single-family homes. Normalized to typical Dec-Feb outdoor temperature. Treatment and control groups are pooled.
One in four households showed evidence of thermostat setback before Weatherization

<table>
<thead>
<tr>
<th>Thermostat type</th>
<th>% of homes with Evidence of Setback</th>
<th>Mean indoor temperature (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall – all households (100%)</td>
<td>24% ±5</td>
<td>70.3 ±0.5</td>
</tr>
<tr>
<td>Thermostat type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual or none (74%)</td>
<td>19% ±4</td>
<td>70.8 ±0.4</td>
</tr>
<tr>
<td>Programmable (26%)</td>
<td>34% ±9</td>
<td>69.2 ±0.5</td>
</tr>
<tr>
<td>Empirical evidence of setback behavior?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (76%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (24%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example of Hourly profile for Setback

Example of Hourly profile for no Setback
## Pre & Post-weatherization Indoor Temperature Measurements

<table>
<thead>
<tr>
<th>Degrees F</th>
<th>Treatment (n=292)</th>
<th>Control (n=168)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Pre weatherization</td>
<td>70.2</td>
<td>70.7</td>
</tr>
<tr>
<td>Mean Post weatherization</td>
<td>70.3</td>
<td>70.6</td>
</tr>
<tr>
<td>Mean Change</td>
<td>+0.14 ± 0.17</td>
<td>-0.13 ± 0.17</td>
</tr>
<tr>
<td>Minimum Change</td>
<td>-6.6</td>
<td>-5.7</td>
</tr>
<tr>
<td>Maximum Change</td>
<td>+5.9</td>
<td>+5.2</td>
</tr>
</tbody>
</table>

Excludes days with outdoor temperature > 55F

Results are normalized to Dec-Feb average outdoor temperature
Pre & Post-weatherization Indoor Temperature Measurements

Control

Treatment

Pre-weatherization indoor temperature, F

Normalized to typical Dec-Feb outdoor temperature.
Main Finding

• The net change in the treatment group temperature is an average increase of 0.27 °F ± 0.34 °F
Change in indoor temperature by pre-weatherization temperature quintile.

Results from 460 homes, weighted to reflect all PY08 single-family homes. Normalized to typical Dec-Feb outdoor temperature. Quintiles based on pooled treatment and control groups.
Post-weatherization thermostat type and evidence of temperature setback.

<table>
<thead>
<tr>
<th>Evidence of setback?</th>
<th>Treatment group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thermostat not replaced (n=256)</td>
</tr>
<tr>
<td>Pre-Weatherization</td>
<td>Post-Weatherization</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>
## IAQ Occupant Survey Responses

### Main Source of Heating for the Home (n= 502)

<table>
<thead>
<tr>
<th>Source of Heating</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Furnace with Ducts to Individual Rooms</td>
<td>72%</td>
</tr>
<tr>
<td>Steam/hot water system with radiators or pipes in each room</td>
<td>6%</td>
</tr>
<tr>
<td>Built-in room heater burning gas, oil, or kerosene</td>
<td>6%</td>
</tr>
<tr>
<td>Built-in electric units in each room installed in walls, ceilings</td>
<td>5%</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>3%</td>
</tr>
<tr>
<td>Heating stove burning wood, coal, or coke</td>
<td>3%</td>
</tr>
<tr>
<td>Portable Heaters</td>
<td>3%</td>
</tr>
<tr>
<td>Built-in floor/wall pipeless furnace</td>
<td>2%</td>
</tr>
<tr>
<td>Cooking Stove used to heat your home as well as to cook</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>None</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

In the past 12 months, main heating equipment was broken and unable to be used: 14%

32% of respondents reported use of Portable Heaters as secondary heat source
IAQ Occupant Survey

- Indoor Air Temperature
  - Average Thermostat Temp setting:
    - WINTER HEAT:
      - During the Day:
        - When someone is home - 69.6
        - When no one is home - 66.9
      - At Night: 67.8
    - SUMMER AIR CONDITIONING:
      - During the Day:
        - When someone is home - 71.5
        - When no one is home - 72.2
      - At Night: 71.6
### IAQ Occupant Survey

*Which of the following statements best describes the indoor air temperature of your home during.......?*

<table>
<thead>
<tr>
<th>Season</th>
<th>Description</th>
<th>WINTER (n=502)</th>
<th>SUMMER (n=502)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>Percent</td>
</tr>
<tr>
<td></td>
<td>Very Cold</td>
<td>9%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td>36%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Comfortable</td>
<td>51%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>Hot</td>
<td>1%</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td>Very Hot</td>
<td>&lt;1%</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td></td>
<td>Don’t Know/Not Sure</td>
<td>&lt;1%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Total Qualified</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
IAQ Occupant Survey

• **In the past 12 months, how often did your household keep your home at a temperature that you felt was unsafe or unhealthy?**

![Bar chart showing the frequency of keeping the home at a temperature felt to be unsafe or unhealthy.](chart.png)

- **Almost Every Month:** 3.3%
- **Some Months:** 8.2%
- **1 or 2 Months:** 6.8%
- **Never:** 80.7%
- **Refused:** 0.1%
- **Don’t Know/Not Sure:** 1.1%
**IAQ Occupant Survey**

In the past 12 months, has anyone in the household needed medical attention because your home was too cold?

| Yes | 25 Respondents | 6% |

In the past 12 months, has anyone in the household needed medical attention because your home was too hot?

| Yes | 11 Respondents | 3% |
Previous Findings RE Rebound or Take-back Effect *

- Previous research using econometric models finds space heating take back could range from as low at 1.4% of savings to over 50%

- Previous research using quasi-experimental models involving temperature changes suggests much lower take-back effect estimates re space heating
  - Hirst et al. (1985): +2.34°F low income households (not statistically significant) (U.S.)
  - Ternes & Stovall (1988): no change in daytime; +0.36°F increase at night (U.S.)
  - Dinan & Trumble (1989): +0.72°F low income households (U.S.)
  - Levins and Ternes (1994): -0.09°F low-income households (U.S.)
  - Henderson et al. (2003): +0.72°F (U.K.)
  - Martin and Watson (2006): +0.88°F low income households (not statistically significant) (U.K.)

Conclusions

- This study found a slight 0.27 ± 0.34 F increase in indoor temperature associated with weatherization.

- Occupants reported that they were generally comfortable in the winter.

- This study only addresses the potential for short-run behavior change, not the long-run.

- Additional statistical analysis of utility bills in a large national sample of homes will assess whether installing a setback thermostat is associated with energy savings from the program.