What can we learn from high-frequency appliance-level energy metering? Results from a field experiment

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Highlights

• We monitored appliance-level electricity usage at a CA field site for 124 similar apartments for 24 months.
• Behavior accounts for a significant source of appliance usage variation.
• Households overestimate lighting and HVAC use by 75% and underestimate plug load usage by 29%.
• Plug load accounts for the largest share of electricity use at all hours of the day.
• Savings of 11% were achieved by replacing old refrigerators.

The Field Site: Los Angeles

ENGAGE System Design and Dashboard

Predicted versus actual share of appliance usage

N= 132 households out of 137 households

Survey Prediction

Actual Appliance Usage

Correct Guesses = 0 out of 137 households
6 out of 132 correctly guessed Heating and Cooling share
2 out of 132 correctly guessed Plug Load
6 out of 132 correctly guessed Lighting

Appliance Shares of Total Electricity Usage versus National Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>ENGAGE Field Site California</th>
<th>Residential Energy Consumption Survey 2009 (RECS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating/cooling</td>
<td>18.14 (S.D. 10.9)</td>
<td>Heating/cooling 18.83 (S.D. 16.08) p=0.61</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>24.93 (S.D. 10.5)</td>
<td>Refrigerator 18.25 (S.D. 7.26) p=0</td>
</tr>
<tr>
<td>Lighting</td>
<td>14.45 (S.D. 9.43)</td>
<td>All others 62.91 (S.D. 14.92) p=0</td>
</tr>
<tr>
<td>Plug load</td>
<td>36.9 (S.D. 12.9)</td>
<td></td>
</tr>
<tr>
<td>Dishwasher</td>
<td>2.72 (S.D. 2.28)</td>
<td></td>
</tr>
<tr>
<td>Other kitchen</td>
<td>8.86 (S.D. 6.76)</td>
<td></td>
</tr>
</tbody>
</table>

NATIONAL DATA
Appliance Shares by Time of Day

Plug Load is the largest share of appliance usage.

Average Hourly Electricity Use by Season

Savings from new Refrigerators

Refrigerators were replaced if more than 10 years old

<table>
<thead>
<tr>
<th>Appliance</th>
<th>N</th>
<th>Mean (kWh)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>New refrigerator</td>
<td>7452</td>
<td>0.82</td>
<td>1.05</td>
<td>0.39</td>
<td>2.72</td>
</tr>
<tr>
<td>Old refrigerator</td>
<td>11,155</td>
<td>1.35</td>
<td>1.91</td>
<td>0.69</td>
<td>4.79</td>
</tr>
</tbody>
</table>

Conclusions

- Household’s estimations of their appliance usage are inaccurate (Consistent with Attari et.al. 2010, Armel et.al. 2013)
- Lighting and HVAC are over-estimated and Plug Load is under-estimated
- Behavior accounts for 25–58% of variation
- Replacing refrigerators with more energy efficient models led to overall energy savings of 11%
Thank you for listening!

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