SIM Home Testing:
Device Use Profile Approach

Dr. Joy Pixley
Dr. Michael Klopfer
Saniya Syed
Mahejabeen Kauser
G.P. Li
California Plug Load Research Center
University of California, Irvine

Southern California Edison

www.calplug.org
Electrification Exacerbates the Plug Load Energy Problem

**Figure 10: Idle (Always-On) Loads by Major Product Category in 10 Homes Audited**

- **Electronics**: 51%
- **Other Miscellaneous**: 34%
- **Kitchen and Laundry Appliances**: 6%
- **Lighting**: 5%
- **Heating and Cooling**: 4%
- **Electric Vehicle Charger**: 1%

Source: Delforge, Schmidt, and Schmidt 2015

Standard Testing Approach

One use profile across many devices
Device Use Profile Approach

One device across many use profiles
Device Use Profiles Concept

Vary on 3 aspects:

- Active use
- Pattern of use
- Power management

More relevant to some devices than others
Devices Studied

- Televisions: HD and 4K
- Sound bar
- Set-top box
- Streaming device
- Video game console
- Desktop computer
- Laptop computer
- Pod coffee makers (2)
- Rice cooker
Methods

- Determine states for each device
- Test power for all states of each device
- Develop a set of usage profiles for each device
- Use PLSim tool to calculate energy use for each profile

Analysis:

- Range of outcomes – size, and direction relative to the standard profile
- Variation of outcomes – how much is attributed to each of the three aspects
Constructing Device Use Profiles

- **Active use**
  - low = 10th percentile
  - moderate = median usage
  - high = 90th percentile

- **Pattern of use**
  - low = all at once
  - moderate = same amount in two usage periods
  - high = same amount in four usage periods
  - alternates, e.g., for amount of time between uses

- **Power management**
  - low = sleep settings disabled / no manual PM
  - moderate = default sleep settings / no manual PM
  - high = default sleep settings / user always turns off
  - alternates, e.g., other sleep settings

- "Standard" profile: mod-low-mod
- Typical profile set: 3 aspects x 3 levels = 27 profiles

Typical profile set:
3 aspects x 3 levels = 27 profiles
## Profile Aspects

### Example: Rice Cooker

<table>
<thead>
<tr>
<th>Active use</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1 cup</td>
</tr>
<tr>
<td>Moderate</td>
<td>2 cups</td>
</tr>
<tr>
<td>High</td>
<td>3 cups</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pattern</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1 use per day</td>
</tr>
<tr>
<td>Moderate</td>
<td>2 uses per day (5 hours in between)</td>
</tr>
<tr>
<td>High</td>
<td>3 uses per day (5 hours in between)</td>
</tr>
</tbody>
</table>

| Power Management | | |
|------------------|--|
| Low              | User leaves on warm all day, no matter how many pots they make (user turns off at hour 16) |
| Moderate         | User leaves on warm for 1 hour then turns off |
| High             | User turns off immediately after cooking is completed |
Run the Numbers through PLSim

### Methods

Run the Numbers through PLSim

```python
from schedulerlib.input import make_input_generators, NameGenerator, input_int, input_str
from schedulerlib.write import write_to_file, write_to_paramfile
from schedulerlib.parse import parse_data, parse_groupings, search_data, reorder_tree
from pprint import pprint
import pickle
import sys
from pathlib import Path

# NOTICE: Run through project "PLSim 1.2" as the set default location within the entire project.
# Accordingly if this is run in a new project each input and output file may need to have a
# modified file path corresponding to this new file structure ***

# input files
INPUT_XML = "simulationfiles/device_databases/xmls/PLSim2Format.xml"  # This is the input power usage "database" format
INPUT_XML = "simulationfiles/device_databases/xmls/DeviceList_dummy.xml"

# output files
OUTPUT_PICKLE = "simulationfiles/scheduledata/run_params"  # This is the pickled object file passed with the selected device
OUTPUT_CONF = "simulationfiles/scheduledata/csvs/run_params.cfg"  # This is the list of parameters for the scheduler run
OUTPUT_CSV = "simulationfiles/scheduledata/csvs/test_group.csv"  # This is the generated schedule for device operation

# Simulation Builder/Scheduler Main Menu:
# a: Add a device to simulation
# d: Delete a from simulation
# p: Print current devices in simulation
# r: Run scheduler on selected devices, display output, Quit
```
Pattern of Energy Use
Example: Rice Cooker

Rice Cooker
Daily Energy Usage (Wh)

Wh

#1  #2  #3  #4  #5  #6  #7  #8  #9  #10  #11  #12  #13  #14  #15  #16  #17  #18  #19  #20  #21  #22  #23  #24  #25  #26  #27

low  low  low  low  low  low  low  low  low  mod  mod  mod  mod  mod  mod  mod  mod  high  high  high  high  high  high  high  high

low  low  low  mod  mod  mod  mod  mod  mod  high  high  high  high  high  high  high  high  low  low  low  low  mod  mod  mod  mod

low  low  mod  mod  mod  mod  high  high  high  low  low  low  low  low  low  low  low  mod  mod  mod  mod  high  high  high  high


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Pattern of Energy Use
Example: Rice Cooker

Rice Cooker
Daily Energy Usage (Wh)

Active Pattern PM

#1 low low low
#2 low low low
#3 low low low
#4 low low low
#5 low low low
#6 low low low
#7 mod mod mod
#8 mod mod mod
#9 mod mod mod
#10 mod mod mod
#11 mod mod mod
#12 mod mod mod
#13 high high high
#14 high high high
#15 high high high
#16 high high high
#17 high high high
#18 high high high
#19 high high high
#20 high high high
#21 high high high
#22 high high high
#23 high high high
#24 high high high
#25 high high high
#26 high high high
#27 high high high

Wh
0 100 200 300 400 500 600 700 800 900 1000

Device-level Profile Results Range
Example: Rice Cooker

<table>
<thead>
<tr>
<th></th>
<th>Standard (Wh)</th>
<th>Median (Wh)</th>
<th>Min (Wh)</th>
<th>Max (Wh)</th>
<th>Range (Wh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Cooker</td>
<td>282.2</td>
<td>529.4</td>
<td>249.0</td>
<td>937.9</td>
<td>688.9</td>
</tr>
<tr>
<td>% from standard</td>
<td>-12%</td>
<td>+232%</td>
<td></td>
<td></td>
<td>244%</td>
</tr>
</tbody>
</table>

- Is a large range necessarily bad? No: we should see some range.

<table>
<thead>
<tr>
<th></th>
<th>Standard (Wh)</th>
<th>Median (Wh)</th>
<th>Min (Wh)</th>
<th>Max (Wh)</th>
<th>Range (Wh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set-top Box</td>
<td>669.9</td>
<td>684.6</td>
<td>654.1</td>
<td>699.7</td>
<td>45.7</td>
</tr>
<tr>
<td>% from standard</td>
<td>-2%</td>
<td>+4%</td>
<td></td>
<td></td>
<td>7%</td>
</tr>
</tbody>
</table>

- But a range much higher than the standard is a concern.
Range of Energy Use Across Profiles

- Highest profile
- Lowest profile
● Standard

- 4K Television
- HD Television
- Sound Bar
- Set-top Box
- Video Game Console
- Streaming Device
- Desktop Computer
- Laptop Computer
- Pod Coffee Maker A
- Pod Coffee Maker B
- Rice Cooker
### Multivariate Regression Analyses

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Active Model</th>
<th>Pattern Model</th>
<th>PM Model</th>
<th>Full Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>P</td>
<td>B</td>
</tr>
<tr>
<td>Active Low</td>
<td>-416.35</td>
<td>311.10</td>
<td>0.1899</td>
<td></td>
</tr>
<tr>
<td>Ref: Active</td>
<td>Moderate</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Active High</td>
<td>506.78</td>
<td>285.77</td>
<td>0.0854</td>
<td></td>
</tr>
<tr>
<td>Ref: Pattern</td>
<td>Low</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Pattern</td>
<td>Moderate-1</td>
<td>-139.23</td>
<td>393.94</td>
<td>0.7262</td>
</tr>
<tr>
<td>Pattern</td>
<td>Moderate-2</td>
<td>126.92</td>
<td>393.94</td>
<td>0.7495</td>
</tr>
<tr>
<td>Pattern</td>
<td>High-1</td>
<td>216.94</td>
<td>557.12</td>
<td>0.6996</td>
</tr>
<tr>
<td>Pattern</td>
<td>High-2</td>
<td>463.66</td>
<td>440.44</td>
<td>0.3006</td>
</tr>
<tr>
<td>PM Low</td>
<td>1332.39</td>
<td>172.01</td>
<td>&lt;.0001</td>
<td>1332.39</td>
</tr>
<tr>
<td>Ref: PM</td>
<td>Moderate</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>PM High</td>
<td>-195.96</td>
<td>172.01</td>
<td>0.2628</td>
<td>-195.96</td>
</tr>
</tbody>
</table>

| Intercept    | 1258.18 | 190.51 | <.0001 | 1161.12 | 278.56 | 0.0002 | 944.21 | 121.63 | <.0001 | 717.95 | 95.05 | <.0001 |
| F            | 4.12 | 0.29 | 0.0002 | 46.75 | 67.11 | 0.0233 |
| p            | 0.0252 | 0.8829 | <.0001 |            |            |   |            |            |            |            |            | <.0001 |
| R²           | 0.200 | 0.036 | 0.739 |            |            |   |            |            |            | 0.952 | 0.952 | <.0001 |

*** = p < .001; ** = p < .01; * = p < .05
Percent of Variance Due to Each Aspect

* = p < .05
So, what does this tell us?

- **Quantification of the issue:** Combining results on the size and direction of the range with the proportion of that variance due to each aspect identifies problem areas for each type of device.
- **Examples:**
  - **Rice cooker**
    - Most profiles higher energy use than the standard
    - Pattern had the largest impact, more so than PM
    - Why? Fixed costs of one pot, regardless of amount of rice in that pot + low energy needed for keeping warm → focus on cook cycle (active state)
  - **Video game console**
    - Large range, much more higher than lower
    - PM had largest impact but active also significant
    - Standby state effective, but without settings or user input, game pauses indefinitely in “menu” mode, which uses almost as much energy as active game play → possible long idle?
Effects of Aspects

- Active use
  - Less impact than PM (but note selection of devices)
  - However, reducing energy use during active states would ameliorate PM problems too

- Pattern
  - Pattern should be affected by PM if enabled (sleep delays) or transition costs (although none have long warm up periods)
  - Any effect drowned out by PM for most devices
Effects of Aspects

- **Power Management**
  - Low-power states not saving energy (set-top box)
  - Low-power states not effectively used
    - Low-power states not enabled by default (pod coffee makers)
    - PM options limited (e.g., HDTV had no auto-off tied to user input, and shortest delay for auto-off in the 4KTV was 4 hours)
  - Dire consequences if PM settings are disabled and users fail to turn off devices (most devices) → user interface, better options
  - Devices stay fully functional during long idle periods (game console)
  - Missed opportunities for PM based on connected device input
Conclusions

- Approach: promising (quantified, systematic)
- Ranges: too large and high, except when they’re too small
- Aspects: big impact of power management, but also others

- Overall: It’s not enough to make sure devices are efficient under *ideal conditions*.

- Definitions of aspect levels rely on limited data and assumptions
  - Need more and better data on real-life usage
- Device use profiles show what *could be* but not what proportion of users/households would fall into each profile
  - However, the profile results are so skewed that we’d need multiple “do gooders” to make up for each “do badder”.

- Read the report for more!
Thank you!

Dr. Joy Pixley
jpixley@uci.edu

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California Institute for Telecommunications and Information Technology
University of California, Irvine