Home Energy Management (HEM) STC

Lead by the Fraunhofer Building America Team

Chair: Kurt Roth, Olga Sachs
Outline

- Home Energy Management (HEM) Overview
- Priority Gaps that will be filled by end of 2011/2012
- Priority Gaps to be partially filled by end of 2011/2012
- Priority Gaps not significantly addressed by end of 2012
- Conclusions
What is Home Energy Management?

- STC agreed upon a broad, inclusive definition: Any device or system in the home used to:
  1. Control an energy-consuming device
  2. Identify or diagnose energy saving opportunities
  3. Provide information to occupants to influence how they consume energy

- Emerging product category

- Interaction between inhabitants and technology often lies at the center of HEM effectiveness
Home Energy Management Taxonomy

1. Control Devices
2. User Interfaces
3. Enabling Technologies

*Hybrids exist – devices and systems may belong to one or more category.*
# Home Energy Management: Control Devices

<table>
<thead>
<tr>
<th>Control Level</th>
<th>Description</th>
<th>Examples</th>
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</table>
| Centralized   | • Communicates with multiple control devices in the home and allows the user to manage them from a single location  
• Often multiple inputs | • Home automation (HA) systems  
• Whole-home lighting control systems  
• May build on security systems |
| Device-Level  | • User controls a single device or function  
• Standalone control | • Lighting control with motion sensors, dimmers, remotes, scheduling  
• Thermostats  
• Smart plugs  
• Smart power strips |
| On-Board      | • Control functionality integrated in the device | • Smart appliances, e.g., that respond to grid instability  
• Office equipment power management  
• Smart light bulb |
1. Raw Data UIs (aka direct feedback): Provide more basic information
   - Examples: Real-time and or historic energy data (kWh, $/hr, watts/hr, etc.)

2. Processed Data UIs (aka indirect feedback):
   - Potential to give users a better sense of the personal significance of raw usage data and how to act upon that information
   - Examples: energy consumption by end use, circuit, or device (disaggregation); historical comparisons / trends; personalized; targeted recommendations, and goal setting.

Display medium is another important attribute.
HEM Product Examples

1. Smart Power Strip
   - Smart power strip, Z-wave USB stick, Z-wave remote control

2. Smart Thermostat:
   - WiFi-enabled with touchscreen, web portal, iPhone app

3. HED, Processed Data – Phone App.
   - People Power mobile phone app.
State of the HEM Market

- Emerging market – very limited market penetration
  - One projection: 6 million households will have at least one HEM product circa 2015 (GTM 2011)
  - Positive technology trends

- Market entrants from a range of different industries
  - Many companies see significant opportunity
  - Widespread market experimentation ongoing

- No “killer app” yet found
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## Barriers Identified by STC

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<tr>
<th>Barrier</th>
<th>Fraction of Voters [%]</th>
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<tbody>
<tr>
<td>Unclear energy savings / ROI</td>
<td>50%</td>
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<tr>
<td>Lack of consumer awareness of and interest in HEM systems</td>
<td>44%</td>
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<tr>
<td>Low interest in saving energy / Lack of reasons to purchase HEM system beyond saving energy</td>
<td>44%</td>
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<tr>
<td>Complexity of HEM use and deployment</td>
<td>39%</td>
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<tr>
<td>Design, quality, functionality and individual preferences</td>
<td>28%</td>
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<tr>
<td>Lack of interoperability standards / different manufacturers for different appliances and controllers</td>
<td>22%</td>
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<td>For Controllers, need to “smarten” existent appliances/outlets or purchase smart appliances</td>
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<td>Potential conflict with utilities</td>
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<tr>
<td>Information provided is not actionable</td>
<td>11%</td>
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<tr>
<td>Too many controls already in household - confusion, info overload</td>
<td>6%</td>
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<tr>
<td>For Controllers, only partial solutions (e.g., HEM for lighting only) are available</td>
<td>6%</td>
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Key Research Needs Identified

- Highest Priority: Field tests to validate energy savings and ROI for different HEM approaches
- Other Important Themes:
  - Automation vs. Human-in-the-loop
  - Information customization / segmentation
  - Dynamic pricing
  - Interoperability standards (particularly whole-home)
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## Priority Gaps to be partially filled by end of 2011/2012

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<th>Project Title(s)</th>
<th>Organization(s)</th>
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<tr>
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<td>In Home Displays; Programmable Thermostat; Tools to Adopt Smart Power Strips; Phased Deep Retrofits; Energy Monitoring &amp; Control Systems Integration</td>
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HEM Project: In-Home Energy Displays - Consumer Adoption and Response

The Opportunity:
HEDs make energy visible and encourage energy savings through feedback and behavioral change by inhabitants

The Challenge:
Current HEDs fail to engage consumers and maintain their interest in the longer term, compromising their energy savings

Questions to Address:
What do users want from home energy displays?
How does HED feedback design influence user engagement?
Can more engaging HEDs achieve persistent energy savings?

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**HEM Project: Field evaluation of programmable thermostats: Usability, comfort and energy savings**

- **Research goal**: Identify impact of usability of programmable thermostats on energy consumption and comfort in the field

- **Duration**: 6 months heating season

- Install thermostats, HVAC state sensors, non-intrusive temperature and humidity sensors

- Collect energy consumption data

- Monitor changes in the thermostat program by home occupants

- Compare treatment group (high usability t-stats) and control group (conventional t-stats)
  - **Difference in nighttime setback use**

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HEM Project: Tools to Adopt Smart Power Strips

*The Opportunity:* Greater adoption of power strips can save energy consumed by miscellaneous electric loads (MELs)

*The Challenge:* Actual energy savings depend on occupant behavior—an unpredictable factor

- Market assessment of existing power strips
- Focus groups to study behavioral barriers to adoption
- Tailor a deployment strategy to work with existing human behavior instead of trying to change it
- Field evaluation of energy savings

*Outcome:* A list of effective strategies to increase adoption and energy savings of power strips

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HEM Project: Natural Gas Feedback

Research goals

- What is the current state of the art for residential energy feedback devices?
- What commercially available residential feedback devices are capable of monitoring either gas use or both gas and electric use within the residence?
- What are “lessons learned” from residential electricity use feedback, and how can they inform the design, efficacy, and potential for gas feedback?
- Why is there a lack of development of gas usage monitoring?
- What low-cost solutions are there for incorporating gas consumption feedback?
- Select three high priority gas feedback options for further RD&D
- How can high-efficiency gas end use equipment be effectively paired with feedback?
- What are alternate methods for gathering usage information beyond actual gas flow?
- Can incorporating automation and/or controls increase energy savings?

Team: PIRC

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HEM Project: Energy Monitoring and Control Systems Integration

- **Research goal**: Evaluate the value of HEM systems bring to utilities (particularly through demand response services) and renewable energy/distributed generation applications (optimal integration of on-site generation and storage).
- Determine the extent that these values can reduce or eliminate the cost to homeowners because of value to utilities
- **Ideal**: HEM user feedback and continuous auditing services a "free" benefit

*Team*: NELC

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**HEM Project: AHEM to Improve Audit Process**

- **Research goal**: Use modeling and system identification tools to extract dynamic system model parameters from HEM data.
  - Effective thermal mass, effective envelop resistance and HVAC system heat rate
  - Apply stochastic algorithms to obtain information from noisy signals
  - I've got some experience with them from an inertial navigation project I worked on many years ago during my time at Penn State.

- **Application**: Information for auditing practices, screening for specific upgrades, validation of energy models, verification of upgrade effectiveness and continuous auditing.

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**Team**: NELC
HEM Project: Phased Deep Retrofits

- Power strips and HEDs included as a measure as part of audits and shallow retrofits consisting of simple, “pass through” measures in 60 homes.
- Will conduct utility bill analysis and pre/post monitoring.
- Data from simple retrofit will inform design of follow-on deep retrofit in 6 of the 60 homes.
- HEM not focus of – but is part of – task

Team: PIRC

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Priority Gaps not addressed by end of 2012 – Priority 1

• Priority 1 – Unclear energy savings / ROI

• **Centralized Home Automation** – Existing systems are costly and complex
  – What are non-energy benefits that can enable some portion of HA to achieve appreciable impact?

• **Device-level Control** – Unproven ROI for plug-based control systems
Priority Gaps not addressed by end of 2012 – Priority 2

- Priority 2 – Lack of consumer awareness of and interest in HEM systems

- **HEDs**: Evaluate real-world energy savings in field tests of non-energy system with HED functionality incorporated to that of stand-alone HEDs

- **Smart Phones**: Evaluate potential non-energy benefits / features of HEM apps to increase HEM awareness throughout population

- **Smart Thermostats**:
  - What features/functionality keep costs low and interest high
  - What non-energy functionality can increase HEM interest and awareness
Priority Gaps not addressed by end of 2012 – Priority 3

- Priority 3 – Low interest in saving energy / Lack of reasons to purchase HEM system beyond saving energy

- What kind of feedback / information generates a sustained increase in energy savings over time?
  - Value of segmentation / customization
Priority Gaps not addressed by end of 2012 – Priority 4

• **Priority 4 – Complexity of HEM use and deployment**
  
  – *Overarching question:* To what extent do consumers want to be – or should they be involved in HEM?
    
    • Degree of human-in-the-loop preferred by occupants and its impact on cost effectiveness and realized energy savings
    
    • Particularly for controllable HEM systems
    
    • Avoiding inconvenience, discomfort key
  
  – Evaluate incremental, persistent energy savings from customized recommendations to residents based on their home, personal, and energy consumption characteristics
  
  – Field evaluation of effectiveness of non-intrusive load monitoring (NILM) products/systems that can be used to provide context-specific information and recommendations to households
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- Extensive experimentation in HEM by wide range of players
- Much experimentation – HEM is an emerging technology
  - Killer App not yet clear
- Very limited current BA research in this area
- HEM has the potential to increase awareness of energy consumption

Priority Needs:
- Highest and Immediate: Field validation of ROI/Energy Savings of sufficiently mature HEM technologies
  - Persistence of energy savings crucial
  - Help drive utility deployment
- Evaluate acceptable degree of human-in-the-loop for controls
- Ability of non-energy benefits to drive effective HEM deployment
- Value of customized recommendations