Home Energy Management

Standing Technical Committee

Strategic Plan, v2011b – October 2011

Committee Chair:

2011	Kurt Roth	Fraunhofer

Prioritization of Gaps, Barriers and Needs

Summary Table

Number	Description	Value	Cost
1	Unclear Energy Saving / ROI	H	H
2	Complexity of HEM Products’	H	M
3	Lack of Consumer Awareness	M	M
4	Low Interest in Energy Saving	H	M

Introduction

Ongoing technology trends, including decreased sensor, computation, and display costs, more pervasive integration of device-level information processing capability and networking/communications, an increased interest in electric demand response, and the roll-out of smart utility meters have greatly increased the opportunities for home energy management (HEM) and enhanced their potential viability. HEM technologies have significant energy savings potential, e.g., a meta review by Erhardt-Martinez et al. (2010) an energy savings potential of up to 12 percent from enhanced energy feedback *alone*, i.e., not taking into account energy savings from home automation (HA).

To exploit those opportunities, a growing number of new HEM products and companies have emerged over the past decade, ranging from basic energy displays to whole-home control systems and smart phone apps. The great diversity of HEM product features, designs, and types points to the emerging state of the HEM industry, an industry that currently has relatively low market penetration. For example, Greentech Media (2011) estimates that approximately 6 million U.S. households will have some type of HEM device by 2015; this equals about 5 percent of households.

Put another way, the "killer app" of HEM has yet to surface.

What is HEM: A HEM Taxonomy and Product Summary

The Fraunhofer Center for Sustainable Energy Systems (CSE) leads the Building America HEM Standing Technical Committee. To help guide the STC's discussions of HEM market opportunities, barriers to achieving energy savings at scale, and research needs, CSE crafted a taxonomy of current HEM products, as well as a list of HEM products and their functionalities and prices; see ***Appendix D***. All information is current as of September, 2011, and we further seek to update some of the information provided by Herter et al. (2010). While we made an effort to be all-inclusive, many products that have been announced publicly have yet to become available for purchase. In addition, potential industry leaders such as Google and Microsoft are shifting product focus, reflecting the dynamic and emerging nature of the HEM market.

To summarize Appendix D and provide context for the Strategic Plan, the three basic categories of HEM are:

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

These categories are not mutually exclusive, but are meant to capture the key aspects of typical HEM devices.

Control devices allow the consumer or utility to actively control energy use, with varying degrees of automation / human-in-the-loop. Table 1 summarizes different levels of control and provides representative examples.

Table 1: HEM control levels – descriptions and examples.

Control Level	Description	Examples
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

User interfaces(UI) provide energy feedback to consumers. ***Raw* UIs**, also referred to as direct feedback, provide more basic information with limited processing to inhabitants, such real-time and or historic data on energy consumption (in kWh, $/hr, watts/hr, etc.). In contrast, UI's with ***processed data***, also referred to as indirect feedback, have the potential give users a better sense of the personal significance of raw usage data and how to act upon that information (Erhardt-Martinez et al. 2010). Examples of processed information include: energy consumption by end use, circuit, or device (disaggregation); historical comparisons / trends; personalized; targeted recommendations, and goal setting.

Another important attribute of UIs is the information *display medium*:

a. *Home Energy Display*: Stand-alone in-home display; often portable.
b. *Web Dashboard/Portal*
c. *Smartphone Application*: Current products typically pull information from an HED and generated processed data (but may also provide raw data).
d. Other (e.g., TV)

Enabling technologies are the underlying framework that supports *obtaining, processing,* and *communicating* information about energy usage (see Table 2). Enabling technologies are not home energy management systems per se, but are integral to their function.

Table 2: Summary of enabling technology taxonomy

Enabling Technology	Description	Examples
Sensing	Acquisition of dynamic variables within the home environment	• Smart meters • Temperature sensors • Occupancy sensors • Time of day
Communications	Physical devices necessary to support the network	• Gateways • Range extenders • Home area networks
Communication Protocols	Standards that allow individual nodes within a network to communicate	• X10 • UPB • Insteon • Z-wave • ZigBee

Prioritization of Barriers

The HEM STC collectively identified these numerous barriers to achieving widespread energy savings from HEM technologies. We combined similar barriers together, discussed the barriers in a webinar, and prepared and posted on-line a Google form where each STC member could select the (up to) three barriers s(he) believes are most important. The STC selected the four top barriers shown in Table 3 as the priority barriers for inclusion in the Strategic Plan and further analysis.

Table 3: Voting results priority barriers selected by the HEM STC for further evaluation

Barrier	Fraction of Voters [%]
Unclear energy savings / ROI	50%
Lack of consumer awareness of and interest in HEM systems	44%
Low interest in saving energy / Lack of reasons to purchase HEM system beyond saving energy	44%
Complexity of HEM use and deployment	39%
Design, quality, functionality and individual preferences	28%
Lack of interoperability standards / different manufacturers for different appliances and controllers	22%
For Controllers, need to “smarten” existent appliances/outlets or purchase smart appliances	17%
Lack of dynamic electricity pricing (flat rate limits HEM advantages for utilities)	17%
Potential conflict with utilities	17%
Information provided is not actionable	11%
Too many controls already in household - confusion, info overload	6%
For Controllers, only partial solutions (e.g., HEM for lighting only) are available	6%

The remainder of this document focuses on the STC’s evaluation of the priority barriers. While reading this document, please note that the STC decided in August to focus on one priority barrier per month from September through December. Thus, the assessment of Barrier 1, “Unclear Energy Savings / ROI“, is more refined than that for the other barriers when this Draft Strategic Plan was composed (early October, 2011).

Priority Barriers

We present summaries of the four priority barriers, followed by a discussion of general themes to address these barriers.

1. *Unclear energy savings / ROI*: People can use HEM to reduce energy consumption and costs, but need reasonably predictable energy cost savings to make a cost-benefit calculation; more rigorous assessments are required for utilities to incorporate HEM into their energy efficiency programs. For many HEM product classes, rigorous studies of their energy savings potential are lacking, particularly longer term studies that evaluate energy savings for more than just a few months.
2. *Complexity of HEM use and deployment*: The complexity of HEM systems themselves and/or their installation and use impedes their acceptance and effective use by consumers due to: 1) Deployment complexity, 2) Complexity of use, and 3) Complexity of information presented.

3. *Lack of consumer awareness of and interest in HEM systems*: A large portion of consumers are not aware that HEM exists; most are probably not aware of the full range of HEM available (see Appendix D). The relatively immature state of the HEM market and relatively common "vaporware" create market confusion for interested consumers. In general, the STC views this as a less important barrier than the first two barriers, since addressing those two should lead to appreciable market uptake, e.g., through utility programs
4. *Low interest in saving energy*: A large portion of households have a very limited interest in reducing and/or managing energy costs. This is a pervasive problem for Building America that is not restricted to HEM. On the other hand, by making intangible home energy use data visible, HEM technology has the potential to transform households' awareness of and interest in reducing energy costs and consumption. HEM technology that provides relevant, personalized, and actionable information can help bridge this gap.

General Solutions

The STC has noted several common themes related to the type of research needed to increase uptake of HEM: products and systems. Solutions to specific barriers are discussed in the barrier-specific sections.

Field Studies to Evaluate What Persistently Saves Energy and What Does Not: Rigorous field studies with sufficient sample sizes, including control groups, are essential to demonstrating the cost effectiveness of HEM products and systems. Such studies decrease the risk of deploying cost-effective systems and are essential to their inclusion in utility demand response and energy efficiency programs.

Consumer Engagement: HEM has the potential to increase consumers' engagement with energy costs/consumption. Key focus opportunities include leveraging existing functions valued by consumers (security systems, entertainment, life safety, communications) and enhancing user interface / design, ideally customized to individual households (see "Information Customization"). In particular, the STC notes smart phones as a promising medium, with the potential to leverage models used in other successful apps.

Information Customization: It appears that many households cannot effectively act upon information provided by HEM, either they are not clear what to do or are not motivated to act. Providing information, ideally specific actions, that households can take to reduce energy costs that are tailored to each household's context (segmentation) has the potential to significantly increase realized energy savings and its persistence. Understanding what, how, and how often to communicate is integral.

Automation versus Human-in-the-Loop: Typically, people need to feel in control of their homes, but often neglect to exploit energy saving opportunities due to a relative lack of interest in and inability to effectively manage energy costs. Automation of tasks has the potential to achieve significant energy cost savings potential conveniently for households, but needs to be done in ways that, foremost, do not inconvenience inhabitants (e.g., inadvertently shutting down devices still in use, diagnosing false positives), ideally offer significant non-energy functionality, and are cost effective.

Dynamic Pricing: Dynamic electricity prices would be a key enabling technology to create an economic incentive for households to take a more active role in managing energy cost. In turn, this would tend to increase households' awareness of energy consumption and energy saving opportunities.

Interoperability Standards: Most whole-home home automation (HA) solutions depend upon readily shared information among devices from multiple vendors; this will require the development of interoperability standards for key components of HA.

1: Unclear Energy Savings / ROI

Check all that apply:

BA Enclosures		**BA Hot Water**	
Walls		Test Standards	
Roof/Ceiling	**X**	Distribution	
Foundations	**X**	Condensing/Tankless	
Moisture		Heat Pump Water Heater	
Windows	**X**	Combined Space and DHW Heating	
Other: __________________		Other:__________________	
BA Space Conditioning		**BA Miscellaneous Loads**	
Heating	X	Home Energy Management	X
Cooling	X	Lighting	X
Dehumidification		Large MELs (pools, etc.)	X
Distribution	X	Small MELs (TVs, VCRs, etc.)	X
Ventilation	X	Other: __________________	
Other: __________________			
Testing Methods/Protocols		**BA Implementation**	
House Simulation Protocol		Quality Control / Quality Assurance	
Lab Test Methods		Training	
Field Test Methods		Documentation / Resources	
Analysis Methods/Tools		Needs Evaluation / Identification	
Analysis Tools		Other: __________________	
Strategic Analysis			
Other: __________________			

House Type	
New	**X**
Existing	**X**
Single Family	**X**
Multi-Family	**x**
DOE Emerging Technologies	
Walls and Windows	
Efficient Appliances	
Advanced Heating and Cooling Fluids	
Solar Heating and Cooling	
Geothermal Heat Pumps	
Solid State Lighting	
Bulk Purchase	
Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
DOE Deployment	
Labeling/Rating	
Codes	
Standards	
Large Scale Retrofit (Better Buildings)	

Problem Statement:

People can use HEM to reduce energy consumption and costs, but need reasonably predictable energy cost savings to make a cost-benefit calculation; more rigorous assessments are required for utilities to incorporate HEM into their energy efficiency programs. For many HEM product classes, rigorous studies of their energy savings potential are lacking, particularly longer term studies that evaluate energy savings for more than just a few months. Closing this gap would reduce the investment risk for households; a well-quantified ROI would enable more utilities to justify the inclusion of HEM technologies in their energy efficiency programs.
The STC identified three priority HEM technologies for which this barrier is most important to address:

1. User Interface (UI), Processed data, smartphone applications: The attributes and features, including non-energy "hooks", that attain *persistent* energy savings are not known or validated.
2. Device-level HEM, smart thermostats: Large fractions of the population disable or circumvent energy-saving features, so a large portion of potential savings is not realized in practice.
3. Control, centralized, sensor-based automation: Current systems are costly and complex, and do not include energy diagnostics.

Key Customers and Stakeholders:

Residents, utilities' energy efficiency and demand response programs, HEM manufacturers.

Background Knowledge:

Erhardt-Martinez et al. (2010): Meta review of energy savings from different types of feedback, including home energy displays, finding a range of electricity consumption reductions of 4 to 12%, depending on sophistication.
Parker et al. (2010): Two-year case study of 20 homes in FL using low-cost energy monitors. Initial savings of 7% through second year, then a follow-up 3 years later showed very little persistence"

O'Neil et al.: In-home field tests of smart power strips (SPS) suggested that behavior has a major impact on realized energy savings; significant savings variability due to consumer behavior and range of devices deployed.

Dam et al. (2010): Field study found that initial energy savings from home energy displays of 7.8% after 4 month not sustained after 15 months.

Peffer et al. (2011): Summary of how thermostats are used.

System Considerations:

Different HEM technologies can be used to reduce energy consumption by different end uses. One promising model for HEM is for it primarily to be deployed to perform non-HEM functions, i.e., the savings are an added bonus on top of what consumers are willing to pay for.

Planned or Ongoing Research:

SMUD, TXU, and National Grid running smart thermostat projects.

Fraunhofer team researching: 1) incremental energy savings from high-usability programmable thermostats relative to conventional programmable thermostats; 2) if high-usability energy displays show greater persistence in energy savings relative to conventional displays.

PARR team researching potential ways to reduce natural gas consumption using feedback.

NREL team researching ways to leverage HEM/smart grid for automated/assisted home energy audits.

"Closing the Gap":

Well-designed studies with sufficient sample sizes, durations, and control groups are crucial to obtaining meaningful results. Device-specific actions include:

<u>UI, Processed Data – Smartphone Applications</u>: Field testing based upon focus group research:

- Evaluate the influence of the following factors on energy savings and its persistence:
    - Usability, User Interface – Ease of use, design, info. communicated, info. format (alpha-numeric, visual, graph, etc.).
    - Customization of information proffered, interface based on demographics and/or motivation level of households (awareness of energy, attitude toward technology, use of other apps), etc.
    - Leveraging non-energy factors that people care about; take advantage of "hooks" identified from other fields, e.g., health (medication compliance research)
- What end-uses to focus upon? Most "bang-for-buck"?
- Value of apps focusing on tactical (e.g., thermostat set-back) vs. strategic (retrofits) energy behaviors

<u>Smart Thermostats</u>: Field and laboratory testing evaluating the influence of several factors on energy savings including persistence and greater, effective use of temperature set-up/set-back:

- Usability, User Interface
- Ease of use, design, info. communicated, communication format (alpha-numeric, visual, graph, etc.)
- Potential value of coupling with household-specific recommendations based on information gleaned from smart thermostat
- User acceptance of automated thermostat functionality (e.g., based on inferring state of house)
- Incremental cost and energy savings potential

<u>Control, centralized, sensor-based automation:</u>

- Basic cost and deployment issues are not well understood – Technology assessment study
- What end-use(s) to focus upon? Most "bang-for-buck"? User acceptance? – Tech assessment
- User acceptance, how much automation vs. human in-the-loop, including frequency and significance of information presented to occupants? – Field study, focus groups
- Additional value for utilities relative to stand-alone DR? – Technology assessment study
- Evaluate energy savings of occupancy-based control of major end uses – Field study to evaluate energy savings potential from eliminating energy wasted in unoccupied spaces

Timeline:
TBD.

Cost-Value:

Table 4: Cost-Value Matrix for Barrier 1

Value \ Cost	L	M	H
H			X
M			
L			

van Dam, S.S., Bakker, C.A., van Hal, J.D.M. (2010). Home energy monitors: impact over the medium-term. Building Research & Information 38(5), 458-469.

O'Neil, Braman, Hardy. 2010. "Out of Control: Barriers to Smart Power Strip Implementation."*Proc ACEEE Summer Study on Energy Efficiency of Buildings*.

Parker, Hoak, Cummings. 2010. "Pilot Evaluation of Energy Savings and Persistence from Residential Energy Demand Feedback Devices in a Hot Climate." Proc. ACEEE Summer Study on Energy Efficiency of Buildings.

Therese Peffer, Marco Pritoni, Alan Meier, Cecilia Aragon, Daniel Perry. 2011. "How people use thermostats in homes: A review". Building and Environment, Volume 46, Issue 12, December 2011, pp. 2529-2541

2: Complexity of HEM Products

Check all that apply:

BA Enclosures		**BA Hot Water**	
Walls		Test Standards	
Roof/Ceiling	**X**	Distribution	
Foundations	**X**	Condensing/Tankless	
Moisture		Heat Pump Water Heater	
Windows	**X**	Combined Space and DHW Heating	
Other: __________________		Other:__________________	
BA Space Conditioning		**BA Miscellaneous Loads**	
Heating	X	Home Energy Management	X
Cooling	X	Lighting	X
Dehumidification		Large MELs (pools, etc.)	X
Distribution	X	Small MELs (TVs, VCRs, etc.)	X
Ventilation	X	Other: __________________	
Other: __________________			
Testing Methods/Protocols		**BA Implementation**	
House Simulation Protocol		Quality Control / Quality Assurance	
Lab Test Methods		Training	
Field Test Methods		Documentation / Resources	
Analysis Methods/Tools		Needs Evaluation / Identification	
Analysis Tools		Other: __________________	
Strategic Analysis			
Other: __________________			

House Type	
New	**X**
Existing	**X**
Single Family	**X**
Multi-Family	**x**
DOE Emerging Technologies	
Walls and Windows	
Efficient Appliances	
Advanced Heating and Cooling Fluids	
Solar Heating and Cooling	
Geothermal Heat Pumps	
Solid State Lighting	
Bulk Purchase	
Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
DOE Deployment	
Labeling/Rating	
Codes	
Standards	
Large Scale Retrofit (Better Buildings)	

Problem Statement:
The complexity of HEM systems themselves and/or their installation and use impedes their acceptance and effective use by consumers in multiple ways:
1) Deployment complexity. Some HEM systems, particularly home automation systems, require professional installation, increasing cost.
2) Complexity of use. Centralized HEM systems require programming, as do thermostats. Effective actions based on home energy displays requires a level of understanding that many consumers lack, i.e., many consumers likely cannot make effective decisions based on energy consumption graphs or displays alone.
3) Complexity of information presented. Home energy displays may present extraneous information that confuses some consumers instead of enabling consumers.

An overarching question related to complexity of use and information presented is to what extent do consumers want to be – or should they be involved in HEM? Put another way, minimizing households' interaction with / involvement in HEM could greatly reduce these factors as barriers.

Key Customers and Stakeholders:
Residents, utilities' energy efficiency and demand response programs, HEM manufacturers.

Background Knowledge:
Perry et al. (2011): Usability metrics for thermostats.
Zeifman and Roth (2011): Summary of non-intrusive load monitoring research (NILM) to obtain device-specific energy consumption data that could be used to provide enhanced feedback to residents.
System Considerations:

This barrier is related to Barrier 1, Unclear Energy Savings/ROI. Savings that depend on residents' actions can be thwarted by complexity, costs increased for professional deployment (e.g., electrician).

Planned or Ongoing Research:

Some companies, e.g., Tendril, have started offering home energy information systems that leverage smart meters to present more context-specific, actionable information, although it is not clear how effective it is. Multiple thermostat manufacturers have or are planning to launch products to simplify thermostats with greater functionality.[1]

Several organizations performing NILM research and development, working to commercialize NILM. Fraunhofer BA team is researching: 1) incremental energy savings from high-usability programmable thermostats relative to conventional programmable thermostats; 2) if high-usability energy displays show greater persistence in energy savings relative to conventional displays.

"Closing the Gap":

Device-specific research recommendations include:

Home Energy Displays (HED):

1. Development of HEDs that do not require professional installation (i.e., no electrician), significant user effort (e.g., turning on-off devices for NILM set-up)
2. Evaluation of what displays and display attributes are understandable for technology-naive users, leading to specifications (e.g., for EnergyStar, utility energy efficiency programs): Field testing prepared by laboratory usability testing and focus groups.
3. Evaluation of the incremental, persistent energy savings from providing customized recommendations to residents based on their home, personal, and energy consumption characteristics: Field testing of savings based on development of relevant segmentation of residents.
4. Field evaluation of effectiveness of NILM products/systems that can be used to provide context-specific information and recommendations to households.

Controllable HEM Systems:

1. Field evaluation of installations that can be done by naïve users ("plug and play") and automatic control of appliances with optional manual intervention to understand if this yields greater acceptance and effective use (i.e., real-world energy savings). Prioritization of specific controllable HEM systems to be refined by STC in Fall 2011.
2. How can the smart meter infrastructure installed for demand response and/or real-time pricing be readily leveraged for in-home control (centralized, device, or on-board)? Technology assessment, field tests of systems based on smart meter infrastructure.
3. Field evaluation of effectiveness of NILM products/systems that can be used to provide context-specific information and recommendations to households; research to evaluate the degree of human-in-the-loop preferred by occupants and its impact on the cost effectiveness and realized energy savings of controllable HEM systems.

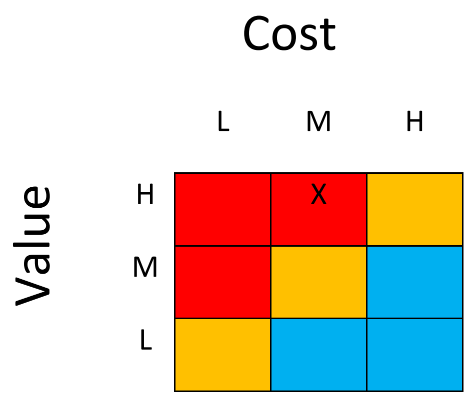
Timeline:

TBD.

[1] See: http://www.greentechmedia.com/articles/read/energyhub-teams-up-with-radio-thermostat-of-america/, http://www.greentechmedia.com/articles/read/ecofactor-cuts-house-power-by-17-percent-ibm-launches-its-buildings-effort/ .

Cost-Value:

Table 5: Cost-Value Matrix for Barrier 2



Perry, D., Aragon, C., Meier, A., Peffer, T. & Pritoni, M. 2011. "Making energy savings easier: Usability metrics for thermostats." PJournal of Usability Studies, 6 (4), 226-244.

M. Zeifman and K. Roth. 2011. “Nonintrusive Appliance Load Monitoring: Review and Outlook”. *IEEE Transactions on Consumer Electronics*, February.

3: Lack of Consumer Awareness of HEM Products

Check all that apply:

BA Enclosures		**BA Hot Water**	
Walls		Test Standards	
Roof/Ceiling	**X**	Distribution	
Foundations	**X**	Condensing/Tankless	
Moisture		Heat Pump Water Heater	
Windows	**X**	Combined Space and DHW Heating	
Other: __________________		Other:__________________	
BA Space Conditioning		**BA Miscellaneous Loads**	
Heating	X	Home Energy Management	X
Cooling	X	Lighting	X
Dehumidification		Large MELs (pools, etc.)	X
Distribution	X	Small MELs (TVs, VCRs, etc.)	X
Ventilation	X	Other: __________________	
Other: __________________			
Testing Methods/Protocols		**BA Implementation**	
House Simulation Protocol		Quality Control / Quality Assurance	
Lab Test Methods		Training	
Field Test Methods		Documentation / Resources	
Analysis Methods/Tools		Needs Evaluation / Identification	
Analysis Tools		Other: __________________	
Strategic Analysis			
Other: __________________			

House Type	
New	**X**
Existing	**X**
Single Family	**X**
Multi-Family	**x**
DOE Emerging Technologies	
Walls and Windows	
Efficient Appliances	
Advanced Heating and Cooling Fluids	
Solar Heating and Cooling	
Geothermal Heat Pumps	
Solid State Lighting	
Bulk Purchase	
Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
DOE Deployment	
Labeling/Rating	
Codes	
Standards	
Large Scale Retrofit (Better Buildings)	

Problem Statement:
A large portion of consumers are not aware that HEM exists; most are probably not aware of the full range of HEM available (see Taxonomy in Summary). The relatively immature state of the HEM market and relatively common "vaporware" create market confusion for interested consumers. With this gap addressed, the market for HEM products could grow several-fold and the quality of OTS HEM products would also improve, because greater uptake/market demand would drive innovation.

In general, the STC views this as a less important barrier than the first two barriers, since addressing those two should lead to appreciable market uptake, e.g., through utility programs

Key Customers and Stakeholders:
Residents, utilities' energy efficiency and demand response programs, HEM manufacturers.

Background Knowledge:
Dam et al. (2010): Their 15-month study of home energy displays (HEDs) deployed in 304 households in the Netherlands found an initial overall energy savings of 7.8% among their sample (after 4 months). Critically, these savings were not sustained at the end of the study (after 15 months). They concluded that HEDs "drift into the background of people's attention" after a successful short period of savings and interaction with the device. Importantly, they stress the need for longitudinal research that leverages insights from interaction design research. This could help to create more habitual use of the product over the long term.

System Considerations:
A strong potential exists to increase interest from incorporating HEM functionality into other systems that homeowners are already willing to pay for, such as security, life safety, entertainment, communications.

Planned or Ongoing Research:
Utility pilots of HEM technology have the potential to increase awareness of HEM, although the STC is not aware of general efforts made to quantify this awareness.

"Closing the Gap":
A strong potential exists to increase interest from incorporating HEM functionality into other systems that homeowners are already willing to pay for, such as smart phones, security, life safety, entertainment.

1. Field studies could be performed to evaluate the real-world energy savings from such systems, including to what extent households realize energy savings from HEM functionality embedded in orthogonal systems. Such research needs to be designed to ensure that its findings are not too system-specific, i.e., that they can be reasonably generalized to similar systems.
2. Technology assessment and focus group study to evaluate the energy savings potential and approximate cost effectiveness of potential HEM systems that leverage infrastructure installed for other systems.

In particular, smart phone apps have the potential to achieve significant market penetration very rapidly. Field studies could be performed to evaluate the real-world energy savings from such systems.

Publicly available data on the sales and penetration of HEM were not readily available; they could be used to determine when deployment of different HEM technologies has reached different levels.

Evaluation of different pilot deployment program to increase consumer awareness and uptake of HEM technologies, e.g., utility programs (traditional DR and efficiency programs, community-scale energy monitoring tolls such as OPower), integration of HEM functionality in systems consumers already use (TV, smartphone, graphical interface probably important), etc.

To a large extent, device effectiveness relates to how engaging the device is for consumers. This is directly related to user-centered design research related to the human-technology interface. Field evaluations of HEM technologies can be used to establish market guidelines that reflect user preferences; these will, in turn, help to optimize selling and functionality of HEM in the future. For Building America, this research needs to be very clearly tied to how it increases real-world energy savings as an energy efficiency measure.

Timeline:
TBD.

Cost-Value:

Table 6: Cost-Value Matrix for Barrier 3

Value \ Cost	L	M	H
H			
M		X	
L			

4: Low Interest in Energy Saving

Check all that apply:

BA Enclosures		BA Hot Water	
Walls		Test Standards	
Roof/Ceiling	X	Distribution	
Foundations	X	Condensing/Tankless	
Moisture		Heat Pump Water Heater	
Windows	X	Combined Space and DHW Heating	
Other: ___________________		Other:___________________	
BA Space Conditioning		**BA Miscellaneous Loads**	
Heating	X	Home Energy Management	X
Cooling	X	Lighting	X
Dehumidification		Large MELs (pools, etc.)	X
Distribution	X	Small MELs (TVs, VCRs, etc.)	X
Ventilation	X	Other: ___________________	
Other: ___________________			
Testing Methods/Protocols		**BA Implementation**	
House Simulation Protocol		Quality Control / Quality Assurance	
Lab Test Methods		Training	
Field Test Methods		Documentation / Resources	
Analysis Methods/Tools		Needs Evaluation / Identification	
Analysis Tools		Other: ___________________	
Strategic Analysis			
Other: ___________________			

House Type	
New	X
Existing	X
Single Family	X
Multi-Family	x
DOE Emerging Technologies	
Walls and Windows	
Efficient Appliances	
Advanced Heating and Cooling Fluids	
Solar Heating and Cooling	
Geothermal Heat Pumps	
Solid State Lighting	
Bulk Purchase	
Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
DOE Deployment	
Labeling/Rating	
Codes	
Standards	
Large Scale Retrofit (Better Buildings)	

Problem Statement:

A large portion of households have a very limited interest in reducing and/or managing energy costs. This lack of interest reflects that home energy costs are a relatively small portion of most home-owning households' annual budgets and that renters suffer from the agent problem and, in many cases, very limited capital. This is a pervasive problem for BA that is not restricted to HEM.

On the other hand, by making intangible home energy use data visible, HEM technology has the potential to transform households' awareness of and interest in reducing energy costs and consumption. HEM technology that provides relevant, personalized, and actionable information can help bridge this gap.

Key Customers and Stakeholders:

Residents, utilities' energy efficiency and demand response programs, HEM manufacturers, manufacturers of potential synergistic systems such as: security, health, entertainment, communications.

Background Knowledge:

Dam et al. (2010): Field study found that initial energy savings from home energy displays of 7.8% after 4 month not sustained after 15 months. Lack of persistence in energy savings attributed to lack of persistence in households' interest in engaging with display.

Utility programs by OPower have achieved marginal savings (up to a few percent on average), although it is not clear if they have significantly altered households' interest in reducing energy costs and consumption.

System Considerations:

This barrier is related to Barriers 1 (Unclear Savings/ROI) and 3 (Lack of Consumer Awareness).

Planned or Ongoing Research:
Fraunhofer BA team is researching if high-usability energy displays show greater persistence in energy savings relative to conventional displays.

"Closing the Gap":
The key to addressing this gap is to find the "killer app" for HEM technologies, foremost approaches that leverage potent non-energy drivers that consumers value, such as security, entertainment, life safety, and health. Thus, potential research projects should focus on evaluating how infrastructure installed for those purposes can be cost-effectively leveraged in a way that will be readily accepted by consumers to enable energy-saving HEM. Initially, Technology Assessment, followed by field studies to evaluate real-world energy savings of most promising approaches.

Additional research needs include:

1. Evaluation of what kind of feedback / information that HEM could provide that generates increased interest in energy savings over time. One promising approach is to pursue segmentation to provide more relevant information and recommendations based on households' current interest in reducing energy costs and consumption and their readiness to change: Field study combined with surveys (to measure interest). This could lead to a specification for presenting information via HEMs that could be adapted by EnergyStar and utility demand response and/or energy efficiency programs.
2. Understand what level of energy cost savings is sufficient to grab customers' attention – research should preferentially focus on HEM measures that exceed that threshold. The answer to this question likely lies in the energy efficiency literature.

Timeline:
TBD.

Cost-Value:

Table 7: Cost-Value Matrix for Barrier 4

Cost

Value	L	M	H
H		X	
M			
L			

Appendix A:
Change Log

Record of additions and modifications to the summary sheets.

Date	Version of Plan (updated version #)	Title of Gap/Barrier/Need	Description of Change
10/5/2011	Strategic Plan, v2011b	All	All gap/barrier/needs updated

Appendix B:
Past Research – Resolved Gaps, Barriers and Needs

None to date.

Appendix C:
Contributors

The following people participated actively in STC discussions, contributed input to the STC, and/or were on the STC mailing list.

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Appendix D:
Home Energy Management Products & Trends

HEM Taxonomy

We have devised the following classification system for all types of HEM products available in the residential market (see GreenTech Media 2011 for a HEM vendor taxonomy). The three basic categories are:

4. Control Devices
5. User Interfaces
6. Enabling Technologies.

These categories are not mutually exclusive, but are meant to capture the key aspects of typical HEM devices. Individual products may fit into multiple categories. For example, the TED 5000-C package reads usage data using current transfomers, provides data via a display as well as through a web portal or stand-alone software, and uses its own gateway device that communicates using ZigBee. The HEM market today consists of a range of hardware and software solutions that sometimes work with smart meters that are only provided through utilities.

Control devices allow the consumer or utility to actively control energy use, with varying degrees of automation / human-in-the-loop. Table 8 summarizes the different levels of control and representative examples.

Table 8: HEM control levels – descriptions and examples.

Control Level	Description	Examples
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

User interfaces(UI) provide energy feedback to consumers. *Raw* UIs, also referred to as direct feedback, provide more basic information with limited processing to inhabitants, such real-time and or historic data on energy consumption (in kWh, $/hr, watts/hr, etc.). In contrast, UI's with *processed data*, also referred to as indirect feedback, have the potential give users a better sense of the personal significance of raw usage data and how to act upon that information (Erhardt-Martinez et al. 2010). Examples of processed information include: energy consumption by end use, circuit, or device (disaggregation); historical comparisons / trends; personalized; targeted recommendations, and goal setting.

Another important attribute of UIs is the information display medium:

e. *Home Energy Display*: Stand-alone in-home display; often portable.
f. *Web Dashboard/Portal*
g. *Smartphone Application*: Current products typically pull information from an HED and generated processed data (but may also provide raw data).
h. Other (e.g., TV)

Enabling technologies are the underlying framework that supports *obtaining, processing,* and *communicating* information about energy usage (see Table 9). Enabling technologies are not home energy management systems per se, but are integral to their function. Examples of enabling technologies are sensors, data acquisition devices, and communications.

Table 9: Summary of enabling technology taxonomy

Enabling Technology	Description	Examples
Sensing	Acquisition of dynamic variables within the home environment	• Smart meters • Temperature sensors • Occupancy sensors • Time of day
Communications	Physical devices necessary to support the network	• Gateways • Range extenders • Home area networks
Communication Protocols	Standards that allow individual nodes within a network to communicate	• X10 • UPB • Insteon • Z-wave • ZigBee

Sensing data involves acquiring information, often integrated into HEM systems, about dynamic variables related to HEM. Smart meters gather temporal data on electricity usage. Temperature sensors and occupancy sensors characterize the home environment. Information about electrical usage, temperature and occupancy, combined with external information, such as time of day and weather data, can be used to customize energy management for an individual home. Landis+Gyr and Elster are examples of companies that specialize in smart meters. Many companies, including Digi and Ecobee, offer temperature and/or occupancy sensors.

Communications protocols and standards facilitate communications and may support the home network. Gateways are devices that connect the HAN to the Internet. Range extenders amplify signals to expand the area covered by a single network. Many companies manufacture their own gateways and/or range extenders to be compatible with their HEM systems. Communication protocols standardize and facilitate communications.

CONTROL

Figure 1shows several HEM control products available on the market today that don't require a smart meter, categorized by functionality. HEM products can allow the user to monitor energy usage, remotely manage energy usage (such as adjusting the thermostat while away from home), and automate energy savings, either with sensors or via user-programmed schedules.

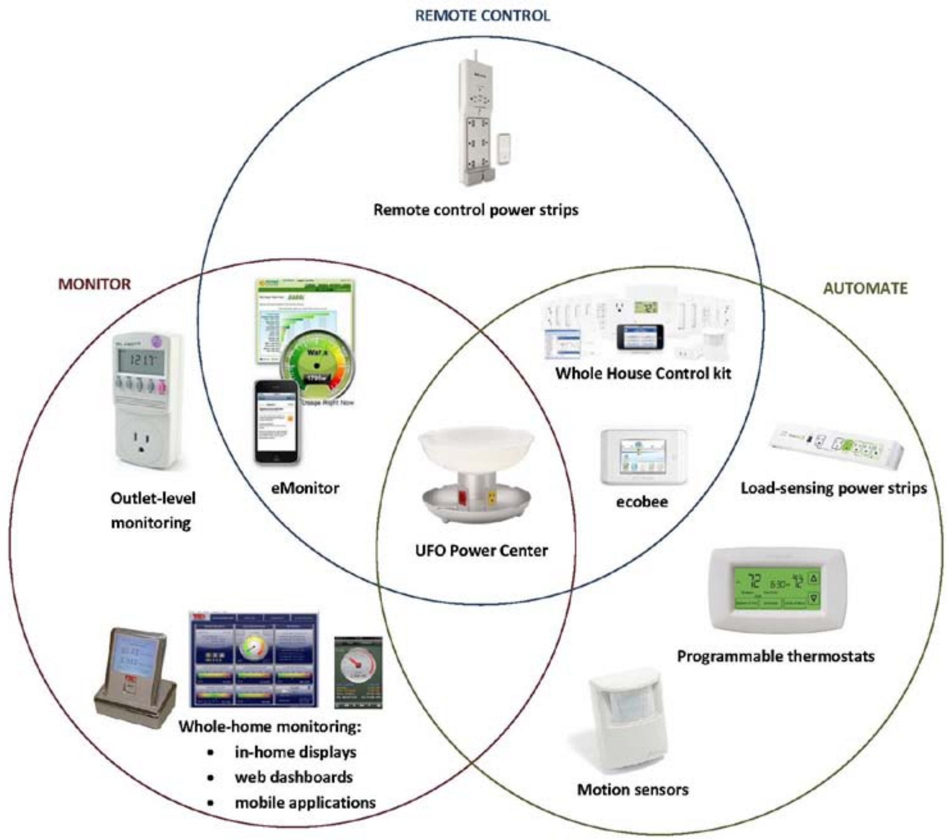


Figure 1: Available HEM products that do not require a smart meter, categorized by user functionality.

For instance, smartplugs, such as the Kill-A-Watt by P3 International, analyze and display energy usage at the outlet level. Whole-home systems usually use some combination of current transformers (CTs) to measure electricity usage at the circuit level, along with a wireless network to communicate the data to a home energy display (HED), such as The Energy Detective. Further, some monitoring systems like the eMonitor also provide software or a web application to view aggregate data on a personal computer or online.

Centralized Control

Ongoing Development in Home Automation (HA)

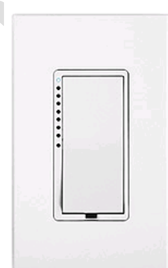
Because of its potential to manage electricity consumption and demand for multiple end uses, HA is an integralHEM subsector. Although several companies sell HA products, many of these products are still being developed and not always and readily available for purchase.

Erhardt-Martinez et al. (2010) argues that the future of HEM is likely to involve a complex network of wireless, consumer-controlled, HA “set and forget” systems. It also lists several companies currently developing consumer HEM systems, including Control 4, Energate, EnergyHub, and Tendril.
Other companies and ongoing developments can be found as part of our larger review in the Appendix.

Lighting

Advanced lighting controls allow homeowners to dim lights to lower energy use and turn lights off via occupancy sensors, timers, schedules, or remote control. Lighting control can be at both the centralized and device levels.

Table 10: Advanced lighting control companies & products.

Company	Areas of interest	Product on market?	Product list
Lutron	HA, lighting	Yes 	Dimmers, timers, occupancy sensors
Control4	HA, lighting, HVAC	Available through dealers 	Wireless dimmers, wireless switches for controlling remotely
HAI	HA, lighting, HVAC	Yes 	Home control system can incorporate lighting control (motion sensors, dimmers, remote control, scheduling), thermostats, load control modules, and appliance modules
Smarthome	HA, lighting, HVAC	Yes 	Remote control dimmers (INSTEON), appliance control, thermostats

Device-Level Control

Thermostat

With space heating and cooling comprising more than half of residential energy consumption (http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx), smart thermostats are an important element of a home energy management system. A smart thermostat is a thermostat that can communicate with other devices (either with a smart meter or over a home network). This differs from a programmable thermostat that can only be programmed to automatically reach different temperatures at different times. The most advanced of these products can be controlled and monitored remotely. The price range of programmable/smart thermostat products can be anywhere from $100 to $500. These products tend to have more HA capabilities than other HEM products on the market today.

In recent news, Honeywell has partnered with Opower to develop HVAC feedback capabilities, including energy analysis at the thermostat display level (http://news.cnet.com/8301-11128_3-20105529-54/smart-thermostats-to-get-smart-cloud-software/).

Table 11: Thermostat HEM products

Company	Relevant End Uses	Product on Market?	Product list	Notes:
Control4	HVAC, HA	Available through dealers 	Wireless thermostat can be programmed remotely with energy controller (gateway, IHD)	
ecobee	HVAC	Yes 	WiFi-enabled smart thermostat with touchscreen, web portal, iPhone app	Available through contractors; $338 on Amazon.com
EnergyHub	HVAC, HA, MELs[2], FB[3]	Yes 	Wireless thermostat, functions with home base for monitoring and control; smart socket; smart strip	$99 thermostat; $299 home base and thermostat bundle
Honeywell	HVAC	Yes 	Programmable thermostat with touchscreen	Requires professional installation; $248 on Amazon.com
Tendril	HVAC, DR, HA, MELs, FB	Only available through utilities 	Smart thermostat; smart outlet; in-home display; load control switch; gateway	

[2] MELs = Miscellaneous and electronic loads.
[3] FB = Feedback.

Smartplugs/strips

Plug-level solutions offer monitoring, control, and even automation at the level of individual sockets. The price range typically ranges from $20 to over $200. A smart power strip generally has one or more “always-on” plug(s) for the T.V. control box, and five or so plugs that (manually or automatically) turn off the other entertainment devices when not in use. A more expensive smart power strip, such as the Belkin Conserve, will also have a “control” appliance that automatically turns off all of the other plugged-in devices when the control appliance is turned off (ACEEE, 2010).

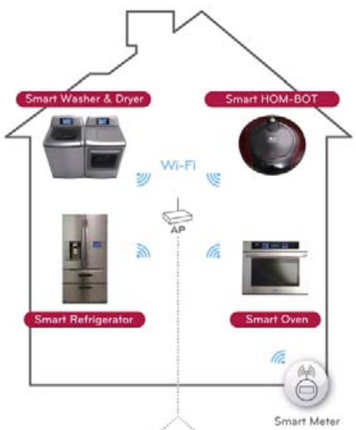
Table 12: Smartplug companies & products

Company	Products	Product image	Pricing
Belkin	Conserve series: plug monitoring, smart power strip, remote, timer		$30 outlet monitor, $30 smart strip, $10 timed outlet
EnergyHub	EnergyHub starter kit: smart socket, smart strip, home base		$325 starter kit; $40 socket, $90 strip when sold separately; monitoring and control
P3 International	Kill A Watt series: outlet level monitoring with wireless display available, power strip, timer (automation)		$99 for wireless display, $99 for each wireless plug (monitoring only)
PlugWise	Plugwise Home Basic (8 smart outlets, USB stick for wireless communication, software)		$299 for 8-plug monitoring, control, and automation
ThinkEco	Energy-saving modlet starter kit (5 2-plug sockets, USB receiver, monitoring/control software)		$355 for 10-plug monitoring, control, and automation
TrickleStar	Smart power strip, Z-wave USB stick, Z-wave remote control		$35 smart strip, $35 USB stick, $40 remote (energy monitor available through utilities?)
Visible Energy	UFO Power Center (four-outlet, smart power strip with iPhone app)		$99 for four-socket monitoring, control, and automation

On-Board Control

These companies are working to enable home appliances to communicate with smart meters, although companies like Whirlpool are developing appliances that do not need a smart meter.

Table 13: On-board companies & products

Company	Product on market?	Product list	Notes
GE	No; “widely available 2011” 	Network-communicating appliance suite: dishwasher, double-oven range, front-load washer & dryer, refrigerator; programmable thermostat, energy display, smart phone app, web portal	Automatically delays appliance use until off-peak hours; requires AMI Zigbee smart meter
Google	No; Android-controllable LED light bulb expected by end of 2011 	Android@Home protocol for controlling home appliances and thermostats with Android devices; Android-controllable LED light bulb in development with Lighting Science Group	
LG	No 	THINQ smart appliances display energy consumption and can be scheduled to run at off-peak hours: washing machine, dryer, oven, refrigerator	Supports WiFi and Zigbee to communicate with smart meter and smartphones
Whirlpool	Yes 	Energy-efficient refrigerator with built-in sensors to automatically adjust cooling; oven with energy save mode; washers and dryers with eco monitors that provide feedback on the eco-friendliness of the user’s choice of cycles.	

USER INTERFACE

Raw Data–HEDs

Many HEDs provide real-time electricity monitoring of the entire home in current kW, $/hr, or daily kWh. Currently available models tend to be similar in the general types of information and visualization they present to the user, and do not provide household controls. Installation for these models typically involves current clamps on a home's circuit panel (thus, does not interact with a smart meter).

Table 14: **HED companies & products**

COMPANY	PRODUCT	COST	IMAGE
2 Save Energy	**The Owl Micro** Battery-powered wireless display. 90-foot range. Breaker panel installation.	$77.25	
	The Owl Battery-powered wireless display. 90-foot range. Stores 2 years historical data. Breaker panel installation.	$139.95	
AlertMe	**Energy Monitoring Start Kit**	starting at £50	
Black and Decker	**Home Power Monitor** Battery-powered wireless display. 60-foot range from meter. Access data remotely with upgrade accessory ($159, $114 Amazon). Electricity meter sensor.	$99.99 ($24.99 Amazon)	
BlueLine Innovations	**PowerCost Monitor** Battery-powered wireless display. Access data remotely with upgrade accessory ($159, $114 Amazon). Electricity meter sensor.	$109.00 ($72.00 Amazon)	
Brultech	**ECM-1240**	$170-600	
CurrentCost Ltd	**ENVI** Tabletop display with power supply. Access data remotely with upgrade accessory ($69). Stores 7 years historical data. Breaker panel installation.	$129.00	

	EnviR	£30-50 (UK)	
DIY Kyoto	**Wattson display + Holmes software**	£100 (UK)	
Eco-eye	**Elite 200**	£90 (UK)	
	Eco-Eye Mini	£90 (UK)	
Efergy	**Elite** Battery-powered wireless display. 230-foot range. Breaker panel installation.	$123.76 ($109.87 Amazon)	
	E2 Battery-powered wireless display. 230-foot range. View data on computer with software. Breaker panel installation.	$138.05	
eGauge	**eGuage Kit**	$752	
Energy, Inc.	**TED 1000 Series** Stationary display. View data on computer with software. Stores 2 months historical data. Breaker panel installation.	$164.95	
	TED 5000 Series Wireless display with charger stand. Access data remotely from computer or mobile. Export data as .csv file. Stores 10 years historical data. Breaker panel installation.	$239.95	

WattVision	**SaveOmeter**	£80	
	WattVision	$250	

Processed Data

Table 12 summarizes User Interfaces that present processed data.

Table 15: Feature comparison chart for web and phone based energy applications

	Appliance Breakdown	Suggestions/Tips	Email alerts	Social comparison	Social media
MyEragy		✓	✓		
Wattvision			✓	✓	✓
PlotWatt	✓	✓	*		
MyEnerSave	✓	✓			
People Power		✓		✓	✓
TED-O-Meter					

*** Plotwatt supports email alerts for issues with the power sensor, but not energy usage alerts like Wattvision and MyEragy. MyEragy also supports SMS alerts.**

Processed Data – Web Medium

In some cases, displays and supplemental web software packages provide additional information, including household baseline energy use information, energy use trends, projections, alarms, social comparisons, and goal tracking (ACEEE, 2010). Some HED companies develop these capabilities themselves (e.g. EMonitor by PowerHouse Dynamics, $950).

Figure 2: The EMonitor monitors at the circuit level and provides processed data for home energy users.

Other third party freeware options are able to connect to HEDs like the TED or PowerCost Monitor (which has an open platform). This is generally done through a host URL or port forwarding method.
Dashboards allow HEM/HED users to view their energy use from anywhere that they have web access, whether on a computer, tablet, or smart phone. Until recently, Google PowerMeter and Microsoft Hohm were the two major competitors in this area. Currently, early adopters must find a replacement to continue to monitor their home energy use on the web. A number of new freeware options have been reviewed below (for a study of device-specific interfaces see LaMarche & Sachs, 2011). While some of these services claim to offer advanced features that go beyond what Microsoft and Google had, such as appliance-level breakdown of energy use, they
are predominately still in beta testing phase.

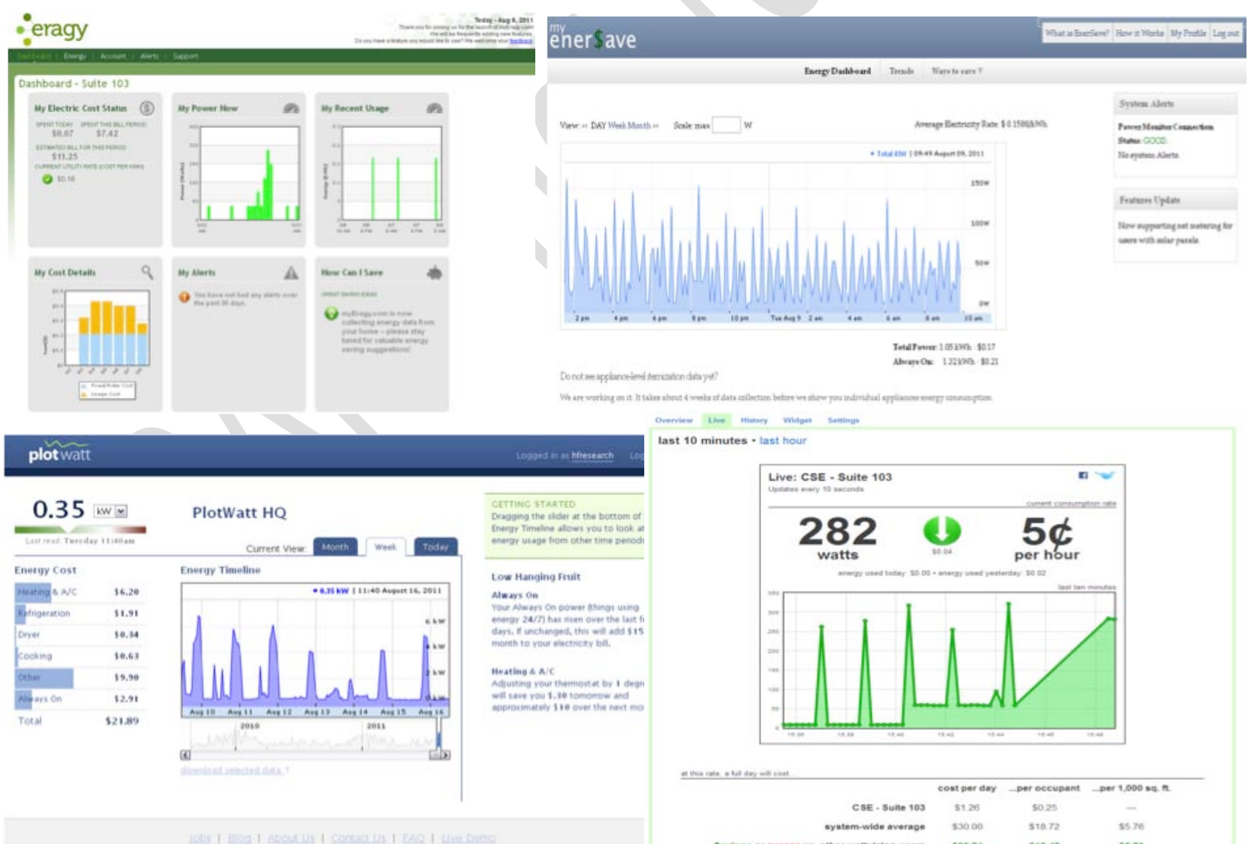


Figure 3: Screen captures of the four free energy dashboards, clockwise from left: MyEragy, EnerSave, Wattvision, and Plotwatt.

Freeware Capabilities

- MyEragy offers energy and cost breakdowns and allows the user to request email or SMS alerts when usage exceeds a threshold set by the user. MyEragy also promises custom energy-savings tips, although like PlotWatt and EnerSave, it must collect data for a certain period of time before these are available. It does not disaggregate energy consumption by appliance.
- EnerSave is one of the two dashboards that promise appliance-level breakdown of energy use data, a feature that would make it easy for consumers to understand howmuch energy different devices in their homes consume. The drawback is that three to four weeks of data collection is required before that level of feedback becomes available. Until then, the user can only see a chart of total power use viewed by day, week, or month. The risk of this long waiting period before the dashboard becomes more interactive and useful is that the consumer may lose interest.
- Wattvision offers a social component that gives it a unique advantage when compared to the other dashboards. Users can browse other Wattvision-enabled houses by location, view data from houses that choose to share publicly, and see rankings for the houses that used the least energy per occupant the day before. Wattvision also compares the user's estimated energy cost per day to the system-wide average. However, Wattvision does not provide any tips or suggestions for how the user might save on energy use. Additionally, to collect data continuously from the TED, the user must constantly have a program running on a computer, which puts Wattvision at a significant disadvantage to the other dashboards (and consumes additional energy!).
- PlotWatt, like EnerSave, promises the ability to break down energy data into use by individual appliances. However, also like EnerSave, it takes at least a week of data collection before this information (and customized tips based on it) is available. Of the two, PlotWatt has the more pleasing interface, but has the same risk that usersmay lose interest during the initial data collection period when there is not much to play around with on the dashboard.

Processed Data – Phone Medium

While most web dashboards can also be accessed through the web browser on a user's smart phone, applications have also been developed specifically for mobile phone use. And, if the current market is any indication, mobile solutions for both monitoring and controlling could be the next big branch in HEM. In fact, recent survey work (LaMarche et al., *in preparation*) has shown that early adopters prefer and are more likely to adopt smartphone applications over web dashboards or HEDs.

Two of the most well-knownmobile phone solutions for home energy monitoring are People Power and TED-O-Meter. People Power is available for both iPhones and Android phones and is compatible with both the TED 5000 and the Blue Line PowerCost Monitor. TED-O-Meter is only available on iPhones and only compatible with the TED 5000.

The People Power has been reviewed in Itunes as having a "better UI than web dashboard energy products," which may be true now that Hohm and Google PowerMeter are out of the picture. During our preliminary testing we did find that People Power does have more functionality than many of the freeware options tested above. Further, People Power allows users to set energy budgets, compare their usage to state and national averages, and view recommendations to cut energy bills, and take energy efficiency quizzes or post scores to Facebook.

Figure 4: People Power mobile phone app.

The TED-O-Meter provides the user with basic power use feedback without many bells and whistles. It shows low, average, and peak power use and also allows the user to view energy consumption in dollars spent or pounds of carbon dioxide emissions produced. What distinguishes it from most of the other available apps is its fairly pleasant user interface. One missing feature of the TED-O-Meter is the ability to view energy history, which users find very helpful.

Figure 5: Figure 6: TED-O Meter phone app.

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HEM Products

This appendix shows companies that have HEM offerings on the market today, including information about the kind(s) of HEM products they offer and their availability, as well as their target customers.

Company		Home Automation			Monitor				Display Type		Other		
Name, Location		Thermo-stat	Power-strip	Outlet	Physical Smart Meter	Meter Reader	Circuit Reader	Outlet Reader	IHD	Other User Interface	Proto-col	Target Market	Availability
2 Save Energy	*UK*	X	UK only	RC	X	X	Y	X	OWL CM119, OWL Micro	Software	ZB***	R	do not ship to US, but available on Amazon
4Home	CA	?	?	?	?	?	?	?	?	?	ZW	SP	currently in trial version by Verizon
AlertMe	*UK*	X	X	RC	X	Y	Y	Y	Y	Web, mobile	ZB**	R	only available in UK
Ambient Devices	MA	X	X	X	X	X	X	X	Energy Orb, Energy Joule	X	Power-line	U	only available through Consumer Powerline
AzTech	*CA*	X	X	X	X	X	X	X	Aztech Display	X	ZB***	U	requires special request through utility company
Belkin	CA	X	RC	RC	X	X	X	Y	X	X	ZB**	R	pre-order on Amazon
Black and Decker	*US*	X	X	X	X	Y	X	X	Home Power Monitor	X	ZW*	R	Y
Blueline Innovations	*CA*	X	X	X	X	Y	X	X	PowerCost Monitor	PlottWatt, web, mobile	WiFi	R	Y
Brultech	*CA*	X	X	X	X	Y	Y	X	ECM-1240	Software	ZB	R	Y
Control4	UT	Y	X	X	X	X	X	X	EC-100 Energy Controller	Y	ZB**	R	available through special dealers
Current Cost Ltd	*UK*	X	X	X	Y	X	Y	IAMs	ENVI, EnviR, TREC, Classic	Software, web, mobile	ZW**, ZB***	R	Y
Digi	MN	X	Y	X	Y	X	X	X	X	X	ZB**	R	Y
DIY KYOTO	*UK*	X	X	X	X	X	Y	X	Watson display	Holmes		R	not available in US
Eco-eye	*UK*	X	X	X	X	X	Y	Plug-in	Elite, Elite 200, Eco-Eye Mini	X		R	not available in US
Ecobee	*CA*	Y	X	X	X	X	X	X	X	Web	ZB**	U	custom installation
EcoDog Inc	CA	X	X	X	X	X	Y	X	FIDO Home Energy Monitoring	Y		R	custom-fit for each home
Efergy	*UK*	X	RC	RC	X	X	Y	Y	Elite, E2	Y		R	IHD available in US market; other products only available in UK
eGauge	*US*	X	X	X	X	X	Y	X	eGauge Kit	Web	Home-Plug	R	Y
Energate	*CA*	Y	Y	X	Y	X	X	X	Energate Companion	Mobile	ZB**	U, SP	not available to residents
Energy Inc	*US*	X	X	X	X	X	Y	X	TED 5000, TED 1000	FootPrints software	ZB	R	Y
EnergyHub	NY	Y	Y	Y	X	X	X	Y	Y	Y	ZB***	R	Y
GE	*US*	Y	X	X	Y	S	X	X	Y	Software, mobile	ZB**	R	currently only available to utilities, in pilot testing
Green Energy Options	*UK*	X	X	X	X	S	X	X	(wide selection)	Web	ZB	U, C	not available to residents
HAI	LA	Y	X	Y	X	X	X	X	X	Web, mobile	ZB	R	Y

Company		Home Automation			Monitor				Display Type		Other		
Name, Location		Thermo-stat	Power-strip	Outlet	Physical Smart Meter	Meter Reader	Circuit Reader	Outlet Reader	IHD	Other User Interface	Proto-col	Target Market	Availability
iControl	CA	Y	X	X	Y	X	X	X	Y	OpenHome software	ZW*, ZB**	SP, U	not available to residents
Landis + Gyr	*CH*	X	X	X	Y	S	X	X	ecoMeter	X	ZB*	SP	not available to residents
Onzo	*UK*	X	X	X	X	X	Y	X	Onzo Wireless	Web	ZB**	R, U	only available in UK
P3 International	NY	X	X	Y	X	X	X	Kill-a-Watt	Kill-A-Watt wireless display	X		R	Y
PeoplePower	CA	X	RC	X	X	X	X	X	X	Software, mobile		R	notyet available
Plugwise	*NL*	X	X	Y	X	X	X	Circles	X	Software	ZB	R	Y
PowerHouse Dynamics	MA	Y	X	Y	X	X	Y	Y	eMonitor	Web, mobile	ZB	R	Y
Tendril	CO	Y	X	Y	Y	Y	X	Volt	Insight	Energize application suite	ZB*	U	not available to residents
Tenrehte	NY	X	X	X	X	X	X	PicoWatt	X	Web, mobile		R	not yet available
ThinkEco	NY	X	X	RC	X	X	X	Modlet	X	Web, mobile	ZB**	R	Y
TrickleStar	DE	X	Y	X	X	X	Y	X	Y	X	ZW	U	not available to residents
Visible Energy, Inc	CA	X	Y	Y	X	X	X	Y	UFO Power Center	Mobile		R	Y
Vivint	UT	Y	X	Y	X	X	X	X	Go!Control Panel	Web, mobile	ZW	R	not directly available, and requires monthly subscription
WattsUp?	CO	X	X	X	X	X	Y	Y	Y	Software, web		R, U	Y
WattVision	*US*	X	X	X	X	Y	X	X	X	Web	WiFi	R	Y

KEY
Green - denotes availability
Orange - denotes not immediately available to residential market
X - Not available
? - Availability unknown
Bold – listed in previous report
Italics – country abbreviation (not US state)
C = commercial
R = residential
RC = remote-controlled
S = smart meter required
SP = service providers
U = utilities
ZB = Zigbee
ZW = Z-Wave
*, **, *** = Alliance levels 1, 2 and 3 respectively, where “Alliance” refers to either the Z-Wave or Zigbee Alliance