

# Assessing Players, Products, and Perceptions of Home Energy Management

ET Project Number: ET15PGE8851



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**Issued: November 19, 2016**

*Cite as: Ford, R., Karlin, B., Sanguinetti, A., Nersesyan, A., & Pritoni, M. (2016). Assessing Players, Products, and Perceptions of Home Energy Management. San Francisco, CA: Pacific Gas and Electric.*

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## Acknowledgements

Pacific Gas and Electric Company's Emerging Technologies Program is responsible for this project. It was developed as part of Pacific Gas and Electric Company's Emerging Technology program under internal project numbers ET15PGE8851. SEE Change Institute conducted this technology evaluation for Pacific Gas and Electric Company with overall guidance and management from Jeff Beresini, Kari Binely and Oriana Tiell. For more information on this project, contact Pacific Gas and Electric Company at [ETInquiries@pge.com](mailto:ETInquiries@pge.com).

## Special Thanks

This project was truly a team effort and the authors would like to thank all those who contributed to making it a reality.

First, we'd like to acknowledge Pacific Gas and Electric (PG&E) for funding this research. Particular thanks go to Susan Norris for having the vision and foresight to make this project a reality and to Oriana Tiell, Kari Binley, and Jeff Beresini for continued support and feedback throughout the project.

Several partners also collaborated with our team on the various research streams and deserve acknowledgement. Thanks to Sears and Target who opened up their stores to us and worked hand in hand to develop our retail research streams from concept to execution. Thanks also to the PG&E Consumer Insights team, who were integral to the dissemination of our customer survey and to Livingston Energy Innovations (LEI), Northeast Energy Efficiency Partnerships (NEEP) and the New York State Energy Research and Development Authority (NYSERDA) for collaboration and data sharing on the stakeholder research stream.

We would also thank our amazing HEMS Advisory Committee – Joey Barr, Lara Bonn, Karen Herter, Emily Kemper, Adam Laskowitz, Claire Miziolek, and Jasmine Rivest – for invaluable advice on the research and feedback on previous versions of this report.

Finally, we are deeply grateful to our extended research team – Cassandra Squiers, Shannon Hall, Birgit Penzenstadler, Suhaila Sikand, Kelsea Dombrovski, Kiernan Salmon, Siva Gunda, and Ryan Taylor – for their contributions to the work presented in this report.

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## Abbreviations and Acronyms

API	Application Programming Interface
DR	Demand Response
EE	Energy Efficiency
EMT	Energy Management Technologies
HAN	Home Area Network
HEM	Home Energy Management
HEMS	Home Energy Management Systems
HVAC	Heating, Ventilation, and Air Conditioning
IFTTT	If This Then That
IoT	Internet of Things
LED	Light Emitting Diode
PV	Photovoltaic
SDK	Software Development Kit
TOU	Time of Use

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# Executive Summary

The technologies that make up Home Energy Management Systems (HEMS), providing users with information, feedback and/or control of household energy usage, are developing in a rapidly growing market within the broader smart home and Internet of Things (IoT) space. As developments create more and more energy saving products with increasing functionality, new strategies must be developed for engaging with end-users (both before adoption and after) in order to fully leverage these technologies for the energy reduction and load shifting capabilities they offer.

This report explores the potential role utilities may play in the emerging home energy management (HEM) marketplace and develops a roadmap to leverage, promote, and enable the use of these technologies for energy savings and grid load reduction. It takes a comprehensive view of HEMS by evaluating the evolving market in which they are developing, the technological capabilities of the products and systems, and the consumer attitudes and perceptions of these technologies. Each of these three lines of inquiry – the Industry Assessment, Technology Inventory, and Consumer Assessment – informs both immediate and longer-term recommendations for successful utility engagement with HEMS.

From an industry perspective, the potential of HEMS to deliver energy savings is acknowledged by stakeholders across the energy, smart home, and IoT landscapes, and supported by the literature (Karlin et al., 2015). Findings from the Industry Assessment suggest that utilities are perceived to be in a unique position to leverage HEM technologies for customer engagement on a continuous basis, to help educate them about how their decisions can impact energy consumption. While this has the potential to create behavioral changes that can support long-term grid sustainability, it was also recognized across the industry that HEM technologies also present risks due to the early stage of the market development. Poorly performing products may serve to decrease engagement, interoperability issues could lead to poor usability and confused customers, data ownership and privacy issues are yet to be resolved, and the value proposition of HEM technologies are not yet clear. Thus, while many actors and forces (including technology manufacturers and, in some cases, legislative mandates) are looking to the utility to help drive the HEMS market forward, there remain significant unanswered questions about how best to engage in such a new, rapidly evolving, and in some cases volatile, market.

From a technology perspective, understanding features and attributes of HEM technologies is vital, as they can influence both adoption and subsequent savings. Further, understanding the current marketplace is key to identifying the types and combinations of products available; the Technology Inventory explored 313 independent products (including load monitors, in home displays, smart appliances, smart lights, smart thermostats, smart plugs, smart switches, and hubs) and 41 software platforms on the market as of April 2016 to identify how they work independently and together to meet both consumer and utility goals. While one of the key values of HEM technologies is the energy savings they can deliver to users, the products themselves rarely highlight these benefits, many of which are unproven at scale. Further, while it seems clear that advantages can be gained through interacting with a whole home product ecosystem rather than with multiple HEM technologies independently, there are limitations around product integration and interoperability in the current market. While two products may use the same communications protocol (e.g. Zigbee, Z-Wave etc.) they may remain non-interoperable because the higher software layers are not compatible. This makes navigating the HEMS space non-trivial, suggesting a greater need to explore the interaction between consumers and HEM technologies.

To better understand consumer engagement with and adoption of HEM technology, the Consumer Assessment undertook a multi-faceted study including an online survey, in-store observations and interviews, and product reviews. Two key needs emerged for increased adoption and energy savings; education and marketing. While consumers are aware of some products, they were typically unaware of the extensive variety of products available, and were particularly confused by the more highly technical concepts of hubs, platforms and protocols. Education is required across the entire consumer journey to support their awareness and knowledge of the market, address motivations to purchase, support decision making processes during purchase, help customers install and set up products, and encourage them to use HEM technologies to deliver energy saving benefits. Such education may be delivered through the use of user scenarios, videos, demonstrations and hands on opportunities. From a marketing perspective, there is a clear opportunity to target both products and customer segments to increase adoption, particularly through leveraging more popular products that may already be in customers' homes. Some HEM technologies have a strong independent value proposition and could be bundled with less popular products (e.g. hubs) through the use of kits or partial incentives. In addition to segmenting, customers with solar or electric vehicles and large households are excellent prospects for future pilot studies of HEMS due to unique opportunities for energy management.

Findings from the industry, technology, and customer research suggest that HEMS have the potential to deliver significant benefits and opportunities to both users and utilities. However, caution must be taken in such a rapidly evolving market, and this work identified six main recommendations for how utilities might best engage with HEMS.

**1) Think Big:** The anticipated growth in the smart home and Internet of Things market suggest that the future of HEMS could be highly intertwined with the wider connected home. This means that thinking about individual savings from isolated products is no longer fit for purpose, and to fully leverage the potential of the larger smart home ecosystem utilities should shift their focus from individual products to interconnected systems. They should consider the potential benefits beyond first order savings that increased interoperability and access to big data sets can deliver.

**2) Explore Implications of Data:** Data plays a key role in supporting real-time demand flexibility, and interconnected HEM technologies offer the potential to optimize demand across the entire home. However, this raises questions around data access and privacy, both of which are unresolved issues in the smart home space. Utilities are well placed to engage customers in these concerns, and should explore their role as the trusted advisor in the smart home space.

**3) Revisit Benefits - Savings and Beyond:** While savings have been successfully tested and deemed for some products, the energy savings opportunities of HEM technologies and interconnected systems is harder to prove, particularly because it may vary as a function of user interaction. While behavioral pilots can help through the determination of ex-post savings, the characteristics of HEM technologies and systems challenges the traditional model due to entanglement of savings from multiple aspects of the technology or system. To inform this process and explore the wider reaching impact of HEMS, further research is needed to determine how best to collect, measure and leverage back end data, as well as promote the additional benefits HEMS may offer.

**4) Support the Customer Journey:** Many customers are largely unfamiliar with smart home technology; they struggle to understand how it works, do not always perceive its

value, and are relatively less interested in its energy management functionalities. Utilities should consider how programs might support customers through the entire journey, promoting HEMS and overcoming barriers at the knowledge, persuasion, decision, implementation and confirmation stages.

**5) Create and Test Use Cases:** While some HEM technologies have clear independent value propositions, many customers better appreciate their value than their function is illustrated through creative use cases or user scenarios. This is particularly true when scenarios implement storytelling to put HEMS into everyday contexts and support customers envision how HEMS might benefit their daily lives.

**6) Establish Cross-Sector Partnerships:** Utilities have a unique opportunity to partner with retailers to engage customers in the smart home space. Innovative retailers pioneering smart home demonstrations have been successful, and further opportunities exist in creating decision guides to support in store or on-line purchase. In addition, utilities should explore relationships with home improvement stores, as this is where many in-store HEM technology purchases have been made to date.

Finally, with legislation in California necessitating quick action, the following recommendations outline how utilities could proceed in the near to immediate term:

- Incentivize and promote the products, platforms, and systems that are most flexible in terms of interoperability and compatibility;
- Bundle products by value propositions in kits that help customers understand their usefulness;
- Create an education campaign to engage and upskill customers beyond just filling out a rebate form;
- Create training resources and guides for customer service employees and other staff to strengthen and highlight the utility's position as trusted energy advisor;
- Determine potential pathways to assist in the installation and deployment of products to help the customer along the entire user journey;
- Begin to develop pilots to test energy savings of products beyond the smart thermostat; and
- Evaluate the effectiveness of efforts through user research on statistically valid samples of customers.

Through engaging with HEMS today in a way that supports both the customer journey and the wider market development, utilities can help grow the potential of smart home technology, laying the foundations to leverage energy reduction and load shifting capabilities at scale in the smart grid of the future.



# Introduction

HEM technologies are defined as those that enable households to manage their energy consumption by providing information about how they use energy and/or by allowing them (or third parties) to control energy consumption in the home. They can also become a gateway for more detailed data collection of demand patterns (to better understand and predict demand) and enable smarter management of demand through both independent and user-driven control. Home Energy Management Systems (HEMS) include some combination of HEM hardware and software, linked through a network with controls accessible either remotely with a smartphone or web service, or based on a set of rules, which can be scheduled or optimized based on user behavior.

The Home Energy Management (HEM) market is rapidly evolving alongside the burgeoning smart home and Internet of Things space. Decreasing costs and increasing performance and prevalence of information and communications technology has supported the growth of “big data” in the residential setting. As more and more connected products and systems begin to emerge – combined with substantial infrastructure upgrades in the smart grid – wide-reaching opportunities are created for leveraging two-way communication between utility and customer, facilitating real-time data transmission, analytics, and control, and delivering energy savings and demand management.

The potential for energy savings and/or demand response associated with HEM technologies has been widely demonstrated. Such is especially the case for information-only products (load monitors, energy portals, and in-home displays; Allen & Janda, 2006; Harrigan, 1992; Hutton et al., 1986; Martinez & Geltz, 2005; Matsukawa, 2004; Mountain, 2007; Parker et al., 2008; Sexton, Johnson, & Konakayama, 1987; Sipe & Castor, 2009; Wood & Newborough, 2003; Dobson & Griffin, 1992; Haakana, Sillanpää, & Talsi, 1997; Mansouri, & Newborough, 1999; Wood & Newborough, 2003; Ueno et al., 2005; Ueno et al., 2006; Opower, 2014).

The evidence is also building regarding the energy savings potential of more recent HEM technologies that enable control, including smart plugs and switches, smart thermostats, smart lights, and smart appliances (Chua & Chou, 2010; SCE, 2012a, 2012b; Herter & Okuneva, 2014), as well as integrated solutions (HEMS; Strother & Lockhart, 2013; Williams and Matthews, 2007).

Beyond energy and cost savings, numerous consumer benefits of HEMS have been identified, both in this and other research particularly around protection. Surveys by Icontrol Networks and the Shelton Group (2015) found that 90% of homeowners deploy HEMS due to security concerns. Furthermore, the Chamberlain Group, Inc. (2016) determined that the three most commonly used smart home devices are garage door openers, smart door locks, and security cameras, all of which are security focused. Despite this, many smart home products do not include sufficient safeguards, making them vulnerable to hackers (Tsukayama, 2016).

A study by Kelton Global and Nest (Daws, 2016) found convenience to be customers' top priority (54%). While smart home technology may enable users to take greater remote control of devices, many may not make tasks more convenient to carry out. The same survey also found that 59% of Americans worry about their energy consumption. Another survey, by Coldwell Banker and CNET (2015), indicates that 42% of homeowners would consider the purchase of a smart home product if it could yield \$500 or more in yearly

savings. Given the lack of validated savings to date from smart home technologies, this may suggest a barrier to uptake. Additionally, some HEM technologies may provide entertainment and productivity benefits, and others may play into a consumer's tech-savvy or green sense of identity.

For utilities, HEMS hold great potential for delivering on energy efficiency mandates and demand-side management (DSM) goals, both of which can contribute to a reduction in power grid operating costs. Peak demand mitigation offers considerable savings for utilities since it flattens load. As such, it simultaneously reduces line losses and the amount of power generated by peaking power plants, which tend to have the highest cost (both financially and, in many areas, regarding carbon emissions) of operation per megawatt-hour. HEMS can also provide a higher degree of power grid visibility - particularly how consumption changes by the hour, where it is concentrated, and how it is distributed among different types of electrical devices - and create opportunities to enhance customer engagement. Thanks to this combination of factors, utilities, and other service providers are in an ideal position to drive forth the adoption of HEMS, leveraging their established business relationships with consumers.

## Evolution of HEMS

The HEMS, smart home, and Internet of Things markets are evolving rapidly, and the long-term viability of specific products and systems is still relatively unknown (Karlin et al., 2015). In 2011, feedback technologies were dominant, and control functionalities were only beginning to emerge. At this time prior work identified 208 HEM technologies on the global market, of which only 20% offered control functionality (Karlin et al., 2013).

A further review of HEM technologies (Karlin et al., 2015) revisited the 208 products, and found that just 3 years later only 49 were still active and available in the US; 31 were out of business, 50 had been retired, and 43 were not available in the US market. An additional 119 new products were also identified at that time, bringing the total to 168. Of these, almost all offered control functionality alongside energy feedback.

Over this time, the trend in the HEM space has evolved from independent products to systems, in which some combination of energy management software and hardware are linked together via a network to provide additional benefits beyond those provided by standalone products (Harvard Business Review, 2014). As increasing numbers of household devices begin to incorporate sensing, communication, and actuation components, additional value can be leveraged from multiple HEM technologies working in synergy and communicating with one another, as opposed to fragmented systems where each smart device operates in isolation (Ramsinghani, 2016).

Emerging industry alliances are facilitating the shift toward more integrated systems capable of leveraging data from individual products to enable increasingly autonomous operation. This has also been reflected in the market; 13 hubs and 19 smart home and web services platforms that enable devices to communicate with a home energy management system were identified in late 2014 (Karlin et al., 2015), and this number continues to grow.

This shift from independent products to whole home ecosystems is aligned with consumer preferences as well. One recent study (Daws, 2015) found 70% of homeowners prefer to work with a single provider for all HEMS needs, and another (Intel, 2015) determined that 83% of Americans expect smart home applications to be bundled with other services such as cable and Internet. Sixty percent of consumers say they would prefer HEMS to operate

behind-the-scenes via automated control capabilities (Icontrol Networks, 2015); however, consumers have also indicated they are unwilling to relinquish *total* control of the operation of their devices (Karlin et al. 2015). Thus, to truly leverage the capabilities of a “smart home”, devices should be able to communicate directly with other devices, share data, and create some degree of autonomy in demand management, while simultaneously engaging users and enabling them to interact (to some degree) with these increasingly complex technologies and the functionalities they offer.

The industry seems to be working hard to push HEM technologies to consumers. For example, Sears started to put Connected Solutions Shops in 200 Sears and 300 Kmart stores around the country (Sears, 2015), Target rolled out Connected Life departments in 1,800 stores in May (CNET, 2015), Wal-Mart now has a “Your Life. Connected: Home Automation” site (Walmart, 2016). It is evident that some smart home products have begun to generate attention and engagement. Many consumers are projecting a future with smart home technology; 31% of Americans believe a fully connected home will be achievable in the next year and 60% think it will happen within the next 5 years (Head, 2015). In another study, 68% of Americans claimed to believe smart homes would be as common as smartphones in 10 years (Intel, 2015).

Despite these high expectations, the market has yet to deliver. According to a smart home device forecast by Forrester (“Where the smart is,” 2016), 6% of American households currently own a smart home device, with that number projected to rise to 15% by 2021. This fact displays a sharp contrast from earlier projections of smart home devices growing exponentially in the coming years. In 2009, Smart Grid news predicted the market to be worth \$3 billion annually by 2012 (Berst, 2009). Meanwhile, in 2012 Navigant Research predicted that the HEM market would grow from \$300.7 million to \$1.8 billion by 2022 (Navigant, 2012), and in 2013 GTM Research predicted a market value of \$4.1 billion by 2017 (Bojanczyk, 2013).

There are many explanations for the less-than-enthusiastic reaction these products have received to date. There are conflicting perspectives on the status of consumer awareness and interest in this space. Some argue that consumer interest in and demand for smart home technologies is growing astronomically (Shelton Insights, Energy Pulse 2015). Meanwhile, other sources suggest many customers have low, or no, awareness of smart home technology. For example, in a recent survey over half of the respondents (64%) indicated they “don’t know much” about smart home technology (The Harris Poll #53, 2015). In another survey, just over half of the respondents (53%) knew what connected home technology does (“Americans do not totally ‘get’ smart home,” 2015).

Concerns about data security and privacy are also among the top obstacles to consumer adoption of HEM: one consumer survey found that 82% of respondents were concerned about keeping their personal information secure (Daws, 2016). With 70% of smart home devices using unencrypted network services, and 80% failing to demand a minimum password strength, consumers can feel that these devices make them more vulnerable instead of providing protection (IoT Tech, 2016). In fact, many people who had deployed HEMS have since abandoned them due to fears of being hacked (Tsukayama, 2016).

Lack of interoperability among products is another key barrier to adoption, creating customer confusion about the technology options available to them, a problem further compounded by the lack of comprehensive educational resources. Users expect smart home technologies to deliver simplicity with seamless installation and operation. Research by Intel (2015) found that 74% of respondents expected HEMS to be as simple to set up as a cable

TV connection, but interoperability issues across multiple devices being used by multiple users presents a barrier to this desired simplicity. Other major potential sources of dissatisfaction with smart home devices stem from product malfunctions (Intel, 2015), with survey respondents identifying product glitches (67%), connection failures (63%), system updates (46%) and system reboots (45%) as their top concerns.

Another barrier to adoption is cost. A recent poll found that 88% of respondents believe these smart devices are too expensive (The Harris Poll #53, 2015), and 66% of respondents in a survey by Honeywell (2015) cited the cost of HEMS as the reason they had not yet acquired any of these products. A similar survey, by Coldwell Banker & CNET (2015), found that 44% of respondents would consider purchasing smart home products on the condition that the price was lower.

## Limitations of Previous Research

As HEM technologies continue to evolve in terms of their information, control, and networking functionalities, understanding how they work independently and together as part of a fully connected system becomes increasingly important. There has been very limited work identifying the entire range of products on the market, their functionalities (including both similarities and differences), and their interoperability.

Much of the research to date has also tended to focus on the broader smart home and Internet of Things market. Although large market forecasting surveys conducted do provide some insights into consumer perceptions of smart home technology in general, including HEMS (e.g., King Brown Partners, 2011; Lowes, 2014; Navigant, 2013; Park Associates, 2014), they lack in-depth investigation into specific HEM technology categories, such as smart thermostats and smart lights.

While the HEMS market is continually evolving and every prediction is a moving target, further research to help better understand consumer uptake, behavior, and interaction with HEMS can assist in piecing together a more accurate forecast. It seems that many market predictions to-date have overshot the market potential, which may mean that the products are not as attractive to consumers as preliminary researchers and product developers think and further research focused on user perceptions and experiences could be fruitful.

Further, past research has rarely been conducted with naturalistic adopters of HEM technology in the residential sector. Savings estimates have been largely based on laboratory simulations and limited pilots (with inconsistent evaluation methodologies) with recruited participants. Particularly with regards to control-based HEM technologies, this has resulted in a limited understanding of their potential adoption and impact in real-world circumstances.

To fully address these limitations of previous research, a thorough study of the industry actors and forces that have a stake in the HEMS market, the capabilities of the technologies, as well the consumers who make the choice whether or not to adopt this technology is required. This is the foundation of the research presented in the following chapters.

## Assessment Objectives

The current study builds on findings from prior research and seeks to create a deep understanding of how HEMS stakeholders, technologies, and consumers interact to support energy savings and drive customer engagement. The goal of this research is to explore the role of the utility in the developing HEMS marketplace, examine the opportunities that may deliver the greatest impact in both the immediate and longer term, and develop a roadmap identifying the role of the utility in leveraging, promoting, and enabling the use of HEMS.

In particular, the study aims to answer the following questions:

1. (Industry) How might the HEMS market evolve, and what industry partnerships might help utilities to achieve their goals?
2. (Technology) What types and combinations of HEMS products exist and how may they work together to meet consumer and utility goals best?
3. (Consumers) What are the current perceptions of HEMS in the general population and how can utilities frame the costs and benefits of HEMS to increase adoption?

From an industry perspective, understanding key stakeholder perspectives is vital for understanding how they can work together. With the overall goal of defining the role of the utility, the industry assessment seeks to understand how the market might evolve and what industry partnerships could be most promising to help guide a successful evolution.

From a technology perspective, understanding features and attributes of these products and systems are vital, as technical features impact the ability to enable EE and DR savings, while other attributes (e.g., cost, skill required) can influence adoption. Building on past research, the technology inventory aims to identify the types and combinations of products that exist and understand how they may work together to form systems. It will review technologies to identify the market-ready opportunities (short-term) while keeping an eye on the horizon to consider evolving HEMS strategies (longer-term).

From a consumer perspective, estimates and projections of HEMS market penetration have conflated the variety of product types and have not dug deep into the experience of early adopters. Prior research has not been precise in distinguishing between different stages of consumer adoption, such as awareness, interest, and purchase. Using the Diffusion of Innovation Theory as a framework (Rogers, 1983), the consumer assessment investigates customer awareness of HEMS (knowledge stage), attitudes toward HEMS (persuasion stage), adoption rates (decision stage), user experience (implementation and confirmation stages), and communication channels for specific product categories in order to provide a comprehensive and precise analysis that can guide targeted and effective programs.

To answer these questions, we conducted primary research, and also tracked a variety of online, industry, and media sources to follow the evolution of the market as it developed. News articles, podcasts, and consumer research reports conducted by other interested parties provided considerable insight into many of the themes discussed in this report. These, coupled with the findings from our primary industry, technology, and consumer research, combine to inform a comprehensive roadmap for utility-led initiatives to help catalyze consumer interest in HEMS, drive product adoption and ultimately lead to energy savings and grid load reduction targets.



# Industry Assessment

Because HEMS are emerging within, and inextricably linked to, the larger smart home and IoT ecosystem, a variety of different actors – beyond just the utility, consumer, and product manufacturer – have an interest and stake in the development and success of this new technology. To realize fully the potential benefit HEMS may deliver, it is important to understand this larger landscape of stakeholders driving the development and adoption of HEMS. The first step in our research was to conduct a comprehensive stakeholder assessment, which analyzes perspectives and roles among key players across the HEMS ecosystem (including regulators, retailers, researchers, manufacturers, utilities, and a variety of industry organizations), seeks to understand the evolution of the HEMS market, identify the role of the utility within this rapidly changing space, and determine which partnerships may support consumer adoption of HEMS within the broader marketplace.

## Methods

This chapter synthesizes findings from 32 interviews and 15 survey responses from high-ranking individuals across leading organizations and companies in the energy and smart home space. It aims to answer the following questions:

1. What are the **opportunities** that stakeholders see in the HEMS / IoT space?
2. What **options** are they pursuing to work toward wide-scale adoption?
3. What are the **obstacles** to adoption and how can they best be overcome?

The first objective of this work was to explore the utility perspective on HEMS to understand if and how people in positions of leadership across these organizations saw HEMS technologies playing a role in future energy efficiency initiatives, as well as their expectations and hesitations in engaging with a still-evolving market. A total of 14 interviews were conducted with utility employees in California as well as regional utilities from New England, the Midwest, and the South.

The second objective was to explore the perspective of other key stakeholders in the HEMS market. For the second round of interviews, 133 individuals working in the HEMS and wider smart home/IoT space were identified, in part through referral sampling from a Delphi Study conducted in earlier research (Karlin et al., 2015), and in part through recommendations from personal contacts familiar with the industry.

These individuals represented perspectives across key stakeholders groups including regulators, retailers, researchers, manufacturers, utilities, and industry organizations. Thirty-four of the 133 individuals initially identified were considered to be “high priority” targets and invited to participate in an interview, of which 18 (representing government agencies, research labs, program administrators, energy efficiency non-profits, software and hardware technology companies, retail companies, energy industry consultants, and trade associations) agreed. This group, combined with the initial 14 utility interviews, resulted in a total of 32 interviews. Those stakeholders not selected for an interview<sup>1</sup> were invited to participate in an online survey, designed to capture similar information as the interviews from the wider stakeholder group. This chapter includes a synthesis of both interview and survey findings, and represents perspectives across 31 different companies and organizations in the space.

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<sup>1</sup> Time limitations prevented all 133 identified stakeholders from being interviewed.

Interviews were semi-structured and conducted virtually, either via phone or video conference, with at least two researchers present, one to conduct the interview and a second to take notes. They lasted from 45 minutes to an hour and were recorded for transcription purposes with permission from participants. Interviews were framed within the following themes and questions:

- **Opportunities:** What are your goals in this space? What opportunities do you see?
- **Options:** What are your current initiatives? What are your plans for the future?
- **Obstacles:** What are your main obstacles? How can they be overcome?

The full interview protocol is included as Appendix A. Probing questions were added based on responses.

The online survey was similarly structured around these themes and questions. The questions were largely open-ended and intended to elicit further qualitative information around the opportunities, options and obstacles in the HEMS and smart home space (see Appendix B for the full instrument). The survey was open for two weeks, during which time stakeholders received a reminder email to participate; of the 99 successful e-mail outreach efforts, 15 complete responses were gathered (15%). Survey respondents included representatives from academia, government agencies, technology companies, utilities, and industry organizations.

Qualitative data analysis began with open coding that revealed key concepts and categories identified through multiple close readings of preliminary interviews with utility staff, as well as through readings of media articles written on the subject of either HEMS specifically or the IoT and smart home space more broadly. Interviews and surveys were then compiled and coded both to validate those initial themes, as well as to determine further themes, categories, and subcategories across the data and infer the relationships between them. These themes are presented in detail below.

## Findings

### Opportunities

Key opportunities identified in the research included energy savings potential, automation, behavior change, and customer engagement.

#### Energy Savings Potential

There was a broad consensus across all stakeholder groups about the *potential* of Home Energy Management Systems (HEMS) to support grid load issues and provide energy savings. Beyond any obvious monetary incentives among for-profit companies, interviewees appeared to care deeply about the underlying environmental benefits of a more sustainable and energy efficient landscape and saw HEMS as playing a critical role in the realization of that goal.

Many, however, remained cautious about the actual savings proved thus far, and some research findings (e.g. where smart thermostat users end up using more energy than they were previously, citation?) presented “a big red flag” to some. On the other hand, the potential of HEM technologies to provide new ways of measuring

and verifying actual energy usage (and savings) data of households was seen to provide a whole host of new opportunities.

In addition to savings through energy efficient smart home products versus their non-smart counterparts, most interviewees acknowledged that, because of the control these products provide for both the consumer on a household level and third parties for more wide-scale efforts, the “biggest opportunities [exist] around demand response” (*industry organization*).

## Automation vs. Behavior Change

Where opinions diverged slightly, however, was whether the opportunities around HEMS were better positioned for automated or behavioral efforts (though of course, these are not mutually exclusive). One industry professional admitted that they saw the most potential in an automated shifting or decreasing of energy usage without the homeowner's involvement because they were “not sure homeowners are ever going to really change.” Another interviewee attributed the success of his technology company's smart home product to the fact that it “delivers results as unobtrusively as possible,” because “it is folly to consider a program that is going to be dependent on bringing energy to top of mind to people.”

Other stakeholders, however, saw the most potential in educating households regarding their energy usage and thereby driving behavior change. One technology company interviewed strongly attributed the success of their pilot programs to “behavioral science techniques” that use feedback and gamification to “save average households that are engaged between 7-10%, [and] save high energy use households who are also highly engaged between 14-15%.”

Another technology company credited their product's real-time visibility of consumption data with “driving behavior change” and leading to “10% and in some cases 15-20% savings” as opposed to the “1-2% from typical energy efficiency programs.” Another respondent, a government agency professional, described an alternative pathway taking into account customers' hesitation to be “too engaged” by pursuing “a balance [between] controls to initiate initial engagement [and] back[ing] off once the system learns what the consumer wants.”

## Customer Engagement

Regardless of the approach, the opportunities for utilities in particular to leverage behind-the-meter access to consumers (e.g. through third-party information and control portals provided by some HEM technologies) was seen to bring with it additional key benefits, particularly around customer engagement and trust. In fact, many utility interviewees noted that one of the greatest long-term strategic values of HEMS was building customer relationships and increasing customer satisfaction; as one utility employee explained, “people who engage in energy programs tend to be more satisfied with their utility. To the extent that our core business is by making money by investing in core infrastructure, your ability to continue as a successful utility depends on keeping customers happy.”

Other stakeholders also commonly cited customer engagement benefits for utilities. “[Utilities can use] HEMS, or connected thermostats, as a continuing touch on a customer, either through behavioral programs or through designing rates which reward consumers essentially for using their controls wisely,” said one government



employee, adding that “the value of those controls increase if you have either demand charges or time of use (TOU) rates.”

The particular value of this new model of customer engagement is multiplied when looking at the utility's historical relationship with customers, namely, as one technology professional stated, that it was “just a few years ago that [utilities] started calling people ‘customers’ and not ‘ratepayers.’” As more and more customers begin to be aware of and interested in these products, multiple stakeholders acknowledged that customers would likely look to their utility for information about the and their energy saving potential. As one industry advisor noted, “having the opportunity to present granular data and give customers a chance to do something about their energy usage is a huge opportunity to build trust with the customer base.”

## Obstacles

Despite benefits of HEMS - to both users and utilities - a number of obstacles to consumer adoption have been identified in prior work, including a lack of interoperability between technologies, difficulties in setting products up or attending to malfunctions, high costs, and security concerns.

When surveyed about some of the more common obstacles observed in the market to date, stakeholders shared their thoughts on the significance of each (Figure 1).

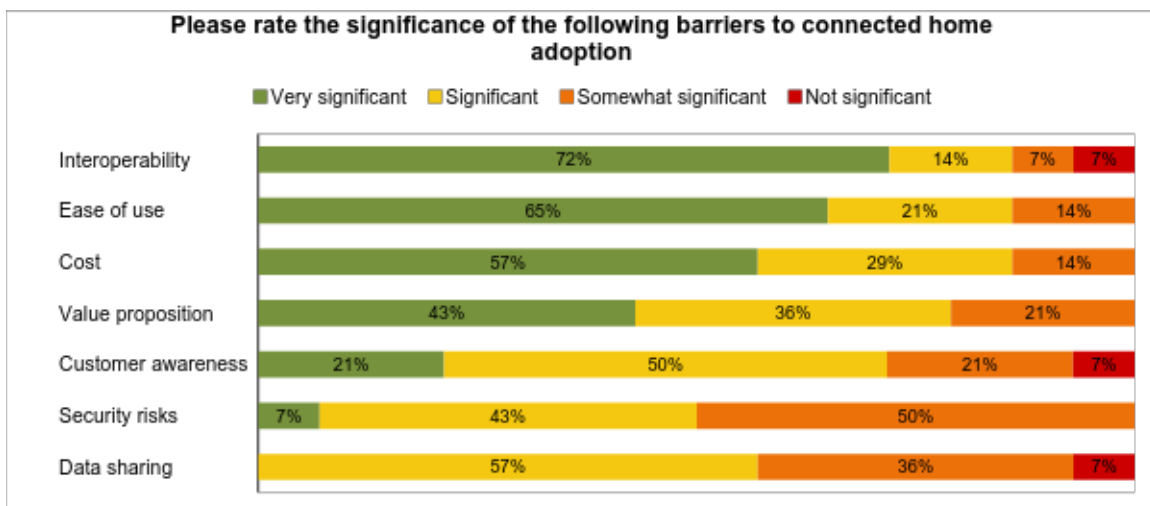


Figure 1: Stakeholder Survey Responses

### Interoperability

Overall, achieving a sufficient level of interoperability between different smart technologies was frequently cited as a common barrier to greater penetration of the market. One academic made an analogy relating to the standardization of cars: “Imagine some cars having the gas pedal on the right, and some on the left. Moreover, that is the situation we are often in with some of these products. So it is not surprising that two things happen: the first is that there’s many accidents, and the second is that a lot of people discard these devices or don’t use them the way

they're anticipated...So we have got this sort of house of Babel with several different smart home systems that are incapable of talking to each other and leading to not a smart home but a frustrated home."

Utilities and program administrators tasked with promoting these products for energy efficiency, in particular, were hesitant about moving forward with initiatives at this stage of market development in the face of such an obstacle. Because utilities have traditionally partnered with companies that manufacture these products, confusion about which products to adopt extends through to the utility. As one utility employee explained, "[F]or us, [interoperability] makes forming partnerships difficult. If we want to form partnerships now, it may force us to pick a narrower set of market participants, thus creating winners and losers. However, if we wait, it may take years for this industry to shake out."

As demonstrated in the survey, however, not all parties agreed about the significance of interoperability as a barrier. Some technology companies, for example, were much more confident in the ability of the market (and/or their own engineers) to solve the interoperability problem. While one representative from a technology company admitted that they could not "see the world coalescing in the next decade on a single standard," this respondent felt that achieving a single standard was not the appropriate goal to consider. Instead, they felt the future of the industry depended on products that can "play very nicely in a multi-mode world."

## Measurement of Savings

Another major barrier cited throughout stakeholder interviews relates to the lack of reliably demonstrated energy savings of HEM technologies. One interviewee from a non-profit worried about the lack of confidence that smart technology will necessarily lead to a defined percent of savings. There were also concerns that the use of HEM technologies could, in some cases, lead energy demand to increase depending on how they were used. As one industry organization employee explains: "If anyone proves that the products don't save energy, it's obviously going to change the entire course of the product category and possibly redirect it back to a point where the products need to be reevaluated as to why they're not saving energy and what needs to change before they are implemented in programs."

While industry organizations, utilities, and regulators all cited measurement and verification of energy savings as a critical roadblock to the proliferation and promotion of HEM technologies, most technology companies were confident in their ability to incur savings via additional data collected with the devices. As one smart thermostat manufacturer explains: "I think that in practice what you're able to see is the only thing that you really need to know to effectively measure savings related to heating and cooling with a fairly high degree of accuracy on an individual household level is the date to which a new measure was introduced...Utilities are already in an advantageous position of having all the meter data for a home...If they know when the measure was introduced and they know both what happened before and what happened after, and if they know what the weather was in the territory...to the extent that they're interested in evaluating homes on an individual basis, it's very easy to measure that pre-post analysis adjusting for weather."

## Data Sharing

The question of sharing data (both smart meter AMI data as well as consumer usage data) was widely cited as simultaneously a prerequisite and obstacle to adoption, as

well as being important to the measurement and verification of the impact of smart products, while also helping to enhance the offerings provided by these products (e.g., one mobile energy app is hoping to incorporate smart meter data in order to enhance the quality and potential of their own product).

One academic respondent described data sharing as the “starting point” for many useful analyses to support the proliferation of the smart home market, lamenting that currently data is “held very tightly to the chest of the utility.” Even more strongly, one respondent from a non-profit trade association declared the number of meters with electronic third party access is a “primary” metric of success. The importance of data sharing was reflected by many others; one consultant voiced a similar opinion that utilities and manufacturers “need to change their idea of sharing data to be a little more cooperative” to “get the backing” necessary “to get their products into home[s].”

It is clear, however, that successful and streamlined data sharing for maximum benefit requires equally optimized legal policies. One respondent from a non-profit discussed how laws are necessary to protect utilities as “the holder of...information.” This issue is the “lynchpin in so many states” on which the ability to share data is dependent. This same respondent described how in California, the commission “strongly and affirmatively eliminate[d] any kind of liability for the utility,” which is the only way that this organization obtained its desired data. Clearly, similar legal protections are necessary nation-wide to fully reap the potential benefits of more openly sharing data.

## Limitations to Customer Engagement

The realities of a continuously changing and thus unstable new technology, however, coupled with customer research on awareness, interest, and adoption of HEMS to date have cast doubts on the ability of HEMS to engage customers on a wide-scale. A common theme among those interviewed, especially those who had conducted their own customer research, was the issue of consumers likely not caring much about their energy use.

One respondent from an energy advisory organization maintained that energy is a relatively “niche” interest, one that “traditionally [has] not been an important consideration.” Another respondent, an academic, explained that “there are people who will only spend a few minutes a year on topics related to saving energy, so it is difficult to market these products and convince users to do something different if you have their ears for only those few minutes a year.”

Even more challenging is the fact that one of the most immediate and marketable customer benefits – monetary savings – is in some cases at such a small scale that it cannot fully be leveraged to encourage consumer interest in smart technology; consumers “may not care that much about saving \$5/month,” especially if there is an upfront cost to obtaining and installing smart products.

Further complicating the monetary savings angle to catalyze adoption is the fact that HEMS products today are still expensive and “prohibitive” (*technology company stakeholder*) for a large segment of the population. Coupled with the fact that some of these technologies do not always work as they are intended, due to either hardware, software, or connectivity issues, and you have, as one retail employee explained, “expensive products that don’t always work well.” As one utility employee

summed it up, "Customers will second guess why they are paying so much for 'cool' if products do not live up to savings." However, as the global energy landscape continues to shift to renewable and variable energy and power grids become more challenging to manage, the risk of blackouts and the incentives provided by time-of-use tariffs or demand charges may start to reshape energy and financial motivations to engage.

Fortunately, as one technology expert put it, "everyone cares about something." Among the larger ecosystem of the Internet of Things, there are ample value propositions to excite and engage interest in smart home technology despite cost and value barriers. Security, for example, was the most commonly cited value proposition for customers among the stakeholders surveyed and interviewed. However, while one technology expert felt that the "majority of people care" about security, they admitted that worst-case scenarios, like burglaries and robberies, "don't happen very often."

Instead, the success of their company's security offerings were due to expanding the value proposition of these products to include the ability to monitor the everyday health and safety of household members, like "mak[ing] sure that your kid came home from school on time, even though you are at work." This not only provides customers with a clear benefit to owning and engaging with a smart home product but also enables energy saving benefits to enter the home via a gateway.

As one academic explained, the best path to engaging customers around energy is to "create products that are cool and attractive for reasons other than energy savings, because energy savings is particularly unsexy; the technology or features have to get a free ride on something far more appealing to the consumer." A utility employee further elaborated: "I am dubious of any approach that attempts to make customers care about something they do not care about. So we need to understand that if it is security that customers are really after, we piggyback energy on that."

## Options

"Technically, consumers are not engaged with HEMS at all; they're engaged with certain components of HEMS that serve other purposes." (Industry org.)

The idea of energy savings getting 'a free ride' or 'piggybacking' on other products was a commonly cited pathway to engage customers with their household energy management. Despite the relatively low overall interest and adoption of primarily energy focused products, other smart products have enjoyed some notable success. Stakeholders across the space commonly noted that while some of these products may not necessarily be centered on saving energy, they can still be utilized to that effect. As one utility employee noted: "Customers are happy to be 'green' or help us have a more stable grid if it is a by-product."

One of the most referenced products across stakeholder surveys and interviews has few if any, explicitly energy focused functionalities marketed. The Amazon Echo was widely cited as having great potential to not only galvanize consumer interest and awareness in smart home technology but also leverage its popularity to encourage energy management on a household level. "When Amazon introduced that product, initially they thought it'd be used for things like people asking 'Alexa, what's the weather?' or 'What's the largest country in

the world?" one technology company explained; "they found rather quickly that people were using it to manage their devices and applications instead." Now, the Echo is "the number one" product in the space for consumers because it not only provides a clear value proposition but because of "how easy it is to use" (*technology company*).

The smart thermostat has also seen considerable customer attention, partly due to big market players like Google getting involved in the space. "Everybody is in love with the Nest...Nest made a thermostat sexy and interesting...They buy them because they have great, useful, futuristic features, and they just happen to save energy." One industry researcher attributed the popularity of smart thermostats like the Nest or ecobee to the fact that they are a "cool, shiny device you can show off," while one technology professional declared them now "mainstream." In fact, in their annual, Consumer Technology Ownership and Market Potential Study (2016), the Consumer Technology Association (CTA) determined that smart thermostats lead the IoT space in terms of household ownership of devices.

The energy industry at large has also coalesced on smart thermostats as providing the most potential for energy savings and demand side management, with utilities across the country engaging in pilot programs to measure and verify these savings. One respondent from a government agency noted how significant the potential energy savings could be just from reducing heating and cooling of unoccupied homes alone; as an additional benefit, they added, smart thermostats are also capable of "making people aware of how their choices regarding their thermostats affect their energy use." The most significant benefit to the proliferation of smart thermostats according to the same interviewee, however, is in their ability to provide data to help understand how people use these devices once they're in the home – data that has not traditionally been easy to come by and the absence of which has hindered many efforts to date of understanding how best to optimize for energy savings.

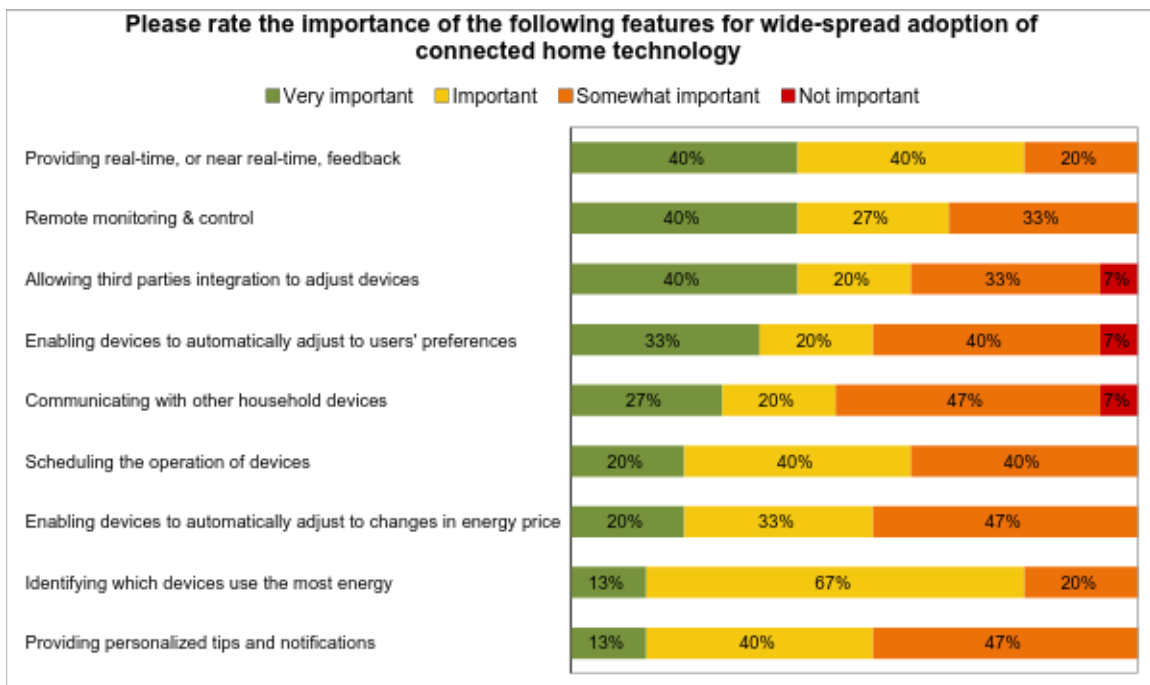


Figure 2: Stakeholder Survey Responses

It is important to note that the industry's current focus on smart thermostats is not without its critics. Most stakeholders interviewed expressed a general desire for expanded pilot programs to determine the potential savings available from other HEM technologies (particularly considering that smart thermostats are "one of the more expensive pieces of equipment") and others criticized the usefulness of smart thermostat pilots given their climate-dependence. "Energy management is a lot more than smart thermostats," stated one technology company leader, "particularly in [states like] California where you do not have the weather extremes."

The most useful pilots, according to one energy industry professional, are the ones "that can remove as many variables as possible...because [it is] always difficult to transfer one utility's study elsewhere." From a market perspective, one technology professional expressed concerns that the utility's "singular focus on thermostats without looking at what the rest of the world is trying to do...creates two separate entities trying to do the same thing in the home with a consumer base who's interested in more than just energy savings."

## Options for the Utility

Interviews with people in leadership positions across multiple utilities indicated a strong interest in HEMS to support energy efficiency and demand side management efforts. However, while the overwhelming message from non-utility stakeholders to utilities reads like a mandate to help lead and drive the market forward, there were higher levels of uncertainty and trepidation about engaging with the HEMS market among the utility sector than any other. Given certain constraints that utilities must operate under, many utility employees wondered how large a role they should play at such an early stage of the market and whether helping drive down the cost of adoption for consumers was enough. "Our core business is to sell energy. We are not in the IoT business," said one utility employee, before adding: "But we can leverage the IoT industry to enhance our core business."

Another utility leader explained further:

"[The] utility's role is to drive energy efficiency and demand response. We need to figure out how to get connected devices to lead to that outcome. However, it might not be the role of utilities to figure it all out. Maybe utilities are just a stakeholder. Moreover, once the devices are available and capable, the next issue for utilities to go after is put in place strategies that drive market adoption."

On one end of the spectrum, utility employees saw the utility's role in the market predominantly defined by (and limited to) their access to detailed energy data. Multiple interviewees cited the benefits of big data not only for the purpose of measurement and verification of energy savings but also to help educate customers on how they are using energy by providing them with more data than has been available to them before. On the other hand, other voices within the utility sector emerged to caution that they and their peers "need to get on this bandwagon now or they will be missing out."



Those with a more hands-on approach to utility engagement in the HEMS market commonly cited a need for utilities to help push for standard protocols, either directly with manufacturers or regulators. There were limitations to this perspective on the utility's ability to push innovation, however. As one utility leader explained: "While utilities need to push protocols, we do not have a place in pushing interoperability of different product ecosystems (Thread, Weave, AllSeen). That is something the market should figure out." The same employee added: "We do not care what wins in the market, we just want to be able to connect to the back end."

However, despite utility uncertainty about their level of engagement with the market, considerable research, both in this study and other research, has determined that customers not only *expect* their utilities to provide smart home technologies and services, but many *prefer* to engage with this market through their utility (Shelton Group, 2015). One interviewee from a smart technology company cited an internal study that found 82% of people surveyed would prefer to receive Home Energy Management technology from their local utility, whereas only about 19% of customers would prefer this technology to come from third-party companies. Though this sentiment may seem surprising, one respondent summed it up as follows: "People [may] hate their utilities, but they trust their utilities."

In fact, one of the most common sentiments expressed across stakeholder interviews and surveys was the widespread belief in the utilities' unique potential to help drive the smart home market forward. There were many perspectives as to how a utility could successfully do so. While rebates and incentive programs were the most commonly cited pathway to catalyze awareness and drive down costs, differences emerged in terms of what program specifics were most likely to help achieve this.

A clearly emerging pathway to implementation was considered to be through bring-your-own-device programs, where customers can receive rebates for acquiring any number of devices that fit a set of parameters. One respondent from an energy advising firm stated that the model of Bring Your Own Thermostat (BYOT) programs is particularly potent because these initiatives allow for utilities to clearly convey and communicate a need and present technology vendors with an opportunity to meet that need. In this manner, technology companies would be driven to innovate through competition, as opposed to a utility choosing a single vendor with which to work. Further, Bring Your Own Device (BYOD) programs establish a greater sense of consumer choice, which could further encourage customer trust of utilities.

Utilities could also help drive the market simply by capitalizing on their already wide customer reach. As one technology company employee explained, "the best way to get millions of people to use our technology is to sell it to companies with millions of people as their customers." The topic of "bundling," whether in reference to bundling products or services, was also a common theme.

One respondent from a technology company further elaborated on the potential significance of the utility leveraging its customer base through bundling by drawing an analogy to the successful adoption of Wi-Fi. Wi-Fi, they explained, was at first

relatively unpopular until cable companies began bundling it with other services. This respondent felt that utilities could serve the same purpose as the cable companies for smart home technologies, taking advantage of their already existing network of customers and services to push for more widespread adoption. In fact, external market research has determined that "83% of Americans expect smart home devices to be packaged with other services such as cable and Internet" (Intel, 2015).

Many respondents felt that there should be stronger collaborations between utilities and technology companies, particularly because utilities own information that would be useful for technology companies to develop their products appropriately. One respondent from a government agency stated:

"I think we all probably want a world in which the utility will work with the technology developers to provide real-time data and real-time electricity utilization; the more utilities engage with tech developers, the more actively tech development can happen."

Beyond integration of the products into more people's homes, some respondents saw a role for the utility to support technology research and development by more openly sharing data.

Collaborations with utilities are not without certain risks and precautions, however. One respondent from a technology company worried about utilities' ability to be an effective ambassador between consumers and smart technologies. This respondent stated, "if utilities are educating consumers, we have to be on the same page that there's a lot more than thermostats," worrying that an incomplete education initiative could skew the market and prevent consumers from fully taking advantage of the benefits that can come from a more integrated and systematic approach.

Additional concerns that respondents voiced at the involvement of utilities in the smart home market involved confidentiality and privacy (e.g. in potentially sharing data with technology firms), an overall unwillingness to share the most relevant data, a lack of appreciation of the benefits they might accrue, and the inevitable bureaucracy when working with utilities.

No matter the potential advantages and risks of utilities becoming more involved with the smart home market, however, there is a fundamental need for greater cooperation between utilities and smart products. One respondent, a consultant, felt that it was a "chicken and egg" situation, in that utilities, need proof of savings to implement a product into a program, and products need to be put in valid studies to be able to obtain sufficient proof of savings potential.

## Options for Other Stakeholders

While utilities were central to most respondents' recommendations for partnerships that could either help drive consumer adoption or mitigate market obstacles,



respondents also touted the benefits of many other types of partnerships towards these ends, including those that involve technology manufacturers, regulatory bodies, behavioral economists, usability designers, safety and data privacy stakeholders, and insurance companies. As one respondent nicely summarized, "there's a lot of stakeholders involved, so the opportunity for partnership and integrating lots of different systems is unique in the energy space."

One respondent described the importance of involving the private sector, in particular companies that are "developing both the hardware and the software," as it is these companies who are driving the market. The same respondent, a non-profit industry professional, added the caveat that it is first necessary for the HEMS community to "come together" and elaborate their needs so that manufacturers can meet those needs. Also, one respondent from a government agency highlighted the importance of partnerships and suggested connecting academics studying human behavior with both utilities and the companies designing the technologies to develop processes for iterative design.

Other proposed partnerships included those between technology companies, utilities, and the Environmental Protection Agency (EPA.) One respondent stated that EPA's ENERGY STAR had enormous potential to "successfully drive measurements of energy efficiency" from anonymized smart thermostat data. Additionally, other stakeholders identified the necessity of partnerships with companies working in data security and privacy; given that many of these smart products collect sensitive and highly private information, partnering with third-party experts in the field of data privacy could go a long way in appeasing customer concerns about potential security breaches or hacks.

What remains clear, however, is that interest in this market is far-reaching, and not just among entities with a seemingly obvious stake in energy; as one technology expert admitted, "[if utilities] choose to do nothing, Telcos will be selling HEMS." Another respondent, a retail employee, described "HEMS as one vertical" in the larger Internet of Things ecosystem – an ecosystem this retailer aims to "become a major player in" – and expanded their vision for partnerships in the space as follows: "A health or medical insurance company is likely to be interested in wearables. An auto insurance company is likely to be interested in ... smart car technology. All State is already incentivizing and discounting those products, so people put them in their cars, so if we could work with them to create a triangulated ecosystem in some way, that is beneficial to everybody."

## Implications

It is clear that most stakeholders see significant potential for HEMS to deliver values to both users and the utility through energy reductions, peak demand management, and customer engagement. However, in such an early stage market there are significant enough challenges to prompt utility actors to be wary of their level of engagement with the market; products may not work properly, may prove difficult to set up, or may not deliver the anticipated savings. Thus, the value in the short term is not entirely clear as load reduction and shifting potential has not yet been determined, nor customer engagement proved. In

fact, in such an early stage market, there is the potential for poorly performing products to decrease demand or disengage customers, highlighting the importance of supporting the appropriate selection of products.

Further, given the lack of interoperability between HEM technologies, product selection is of particular importance to prevent customers ending up with multiple "smart" products in their homes that are unable to communicate with one another. While there are risks associated with the formation of utility-technology partnerships to promote only specific products (e.g., forcing market winners and losers), there may be opportunities for the utility to support consumer choice through the provision of more guidance around interoperability.

Data emerged as a key issue requiring resolution, particularly around supporting technology development and validation of energy saving measures by making end-user data available to manufacturers. However, legal issues remain regarding data ownership and privacy to ensure both customers and the utility are protected.

Finally, it was recognized that HEMS may not have an independent value proposition to customers, but that there is an opportunity to piggyback on either existing and prevalent products (e.g. smart thermostats) or other strong value propositions (e.g. home security). However, it is important to understand both how different HEM technologies interact with other smart home devices, as well as understanding consumer perceptions and values in further detail. The following two chapters explore both of these in greater detail.

# Technology Inventory

The technological features and attributes of HEM technologies and systems can influence both adoption and subsequent savings. Understanding the current market is key to identifying the types and combinations of products available and how they work together to meet consumer and utility goals (and ultimately boost adoption and savings potential). The technology inventory has two components: a product inventory and system inventory. The product inventory aims to explore HEM technologies currently on the market, and evaluate how they vary according to a variety of technical specifications and product attributes, particularly those that may impact adoption, use and savings potential. Specifically, the technology product inventory will identify key features that: (1) distinguish between products, (2) may impact adoption, and (3) provide co-benefits to users.

The systems inventory aims to determine how different technologies work together to form a home energy management system to drive greater functionality and potentially leverage further savings. Understanding how these systems might be used to deliver advanced functionality to users, the implications in terms of communication protocols on both the networking and application layer and the opportunities for innovative forms of user interaction with systems are of particular interest. Specifically, the technology systems inventory will analyze how HEM technologies: (1) talk to other connected products, (2) integrate with different software platforms, and (3) deliver value to customers.

## Methods

The technology inventory used content and classification analysis to analyze data about HEM technologies, determine key differences within and between categories, and identify the formation and implementation of home energy management systems. Both analyses followed a series of key steps including (1) Identification of products/systems, (2) Development of coding guide, (3) Coding, and (4) Analysis.

## Product Inventory

The first step in the product inventory involved identifying the specific HEM technologies on the market. This built heavily on prior work, drawing from the list of products developed in Phase 1 of this project (Karlin et al., 2015) that were published (and added to) by NEEP (Northeast Energy Efficiency Partnerships, 2016).

Additional products were identified through: (1) review of websites across key actors including retailers (e.g. Lowes, Staples, Home Depot), service providers (e.g. Comcast, ADT), and product manufacturers (e.g. Honeywell, Emerson, Trane, Allure); (2) Internet search of online markets for smart home products (e.g. SmartHome, SmartHomeDB); (3) lists from personal contacts, and (4) review of key media sites and newsletters focused on smart home technologies, including GreenTechMedia, Mashable, Techcrunch, Gigaom, and CABA.

The second step involved creating a set of codes to systematically collect detailed data about each HEM technology, which also built heavily on a coding guide developed in prior work (Karlin et al., 2015). However, due to the evolution of HEM technology since that work was undertaken, additional codes were added to this

guide to ensure that all data relating to the hardware, software, and communication capabilities were collected.

Additionally, to distinguish between similar technologies, we reviewed the coding guide to ensure sufficient data related to the quality of HEM technologies were collected. The International Software and Systems Engineering Standards, ISO/IEC JTC1/SC7 N4522, were used to provide structure to the development of the coding guide. The coding guide was finalized following three rounds of iterative development (proposing initial codes, testing codes by coding a variety of products, reviewing and amending the codes, and working through the process again) resulting in a total of 96 attributes on which data were collected (see Appendix C for the full coding guide).

In the third step, data were collected about each HEM technology following the coding guide. Because the coding process can include some degree of subjectivity, inter-rater reliability was first established to ensure consistency in coding. Once data collection was complete, the lead coder systematically reviewed the data across variables to ensure accuracy and consistency. Despite this rigorous approach, data were not always available across every feature for each HEM technology; in some cases, it was not obtainable, and in others it was ambiguous. Under these circumstances, the data were reported as missing.

The final step involved analysis of the products. For each product category, data were analyzed across the key characteristics relating to hardware (including sensing and actuation capabilities), information (including feedback and prompts), control (both remote and automated), communication protocols, and benefits (energy savings and co-benefits). This was used to identify key differences between products within each category regarding both functionality and product quality. Additional features relating to software compatibility (including energy portals and HEM platforms) and utility interaction were used to support the systems analysis.

## System Inventory

While the product inventory focused on individual products, the system inventory focused on exploring home energy management systems (HEMS), in which some combination of HEM technologies are linked together by a network to provide an integrated solution for users to interact with. The communication and connections that enable such integrated solutions are typically provided by a hub and a software platform, and while data about hubs were collected in the product assessment, the systems assessment focused on collecting data on both user and utility facing software platforms.

The first step of the system inventory involved identifying a range of home energy management systems that enabled different energy management technologies to communicate in a single ecosystem for the interactive user capability. These were identified through review of key media sites and newsletters focused on smart home technologies, as well as via the product analysis, and particularly reviewing any “works with” labels included in the product marketing (which are often sold as additional benefits to the user).

The second step involved creating a set of codes to collect data to describe both utility facing and smart home platforms. An initial set of codes were developed to

address the key questions around how different products communicate within the system, and how they deliver value to both the user and utility. These codes were reviewed by an external group of sector experts, and revised as needed.

Coding (third step) was conducted primarily by the lead coder, with input and review from other members of the team to ensure objectivity and accuracy in interpretation. Analysis (fourth step) was largely inductive, based on key features, particularly around interoperability and system expansion.

## Findings

A total of 550 HEM products and platforms were identified between November 2015 and April 2016, of which 397 appeared to match the definition of HEMS and were available in the US. Upon further review in June 2016, 43 additional products/platforms were removed because: (1) they were no longer on the market, (2) they were concept ideas and had not been commercialized, (3) they were duplicates of other products, and (4) some of their features, discovered while coding, did not match the definition of HEMS. This left a total of 313 products and 41 platforms for coding (see Appendix D for full list).

While most of the products and platforms remained in line with the categorization proposed by Karlin et al. (2015), a new category of smart switch emerged, having grown out of the smart plug category. The assessment also resulted in collapsing smart home platforms and web services platforms into a single category; as the smart home and wider IoT market has continued to develop, the services both platforms provide users has increasingly overlapped. These changes are reflected in Figure 3.

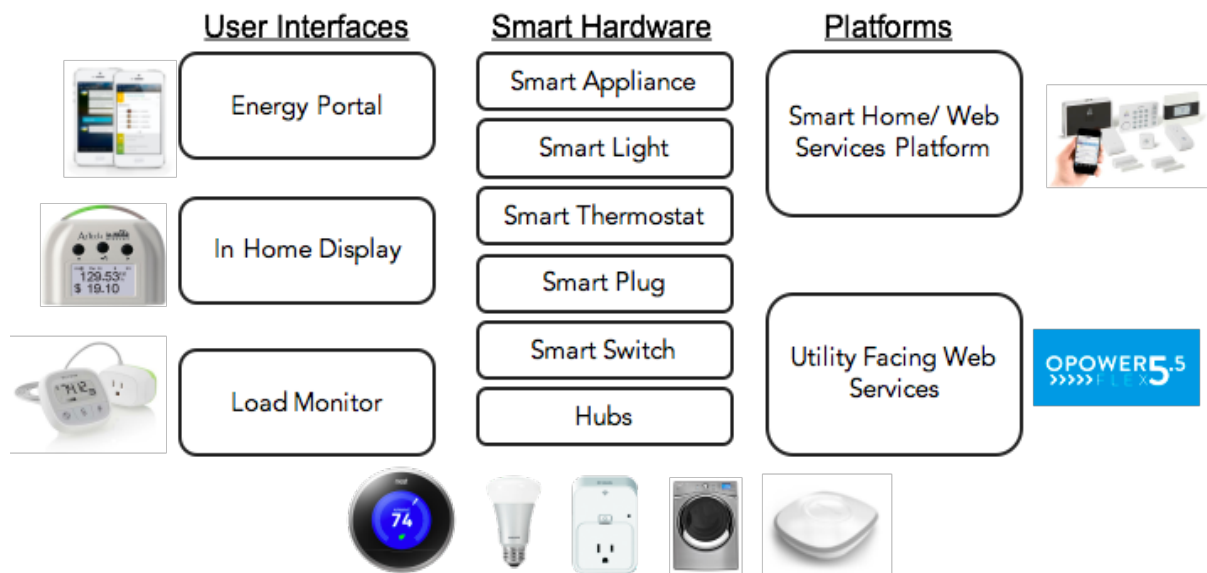


Figure 3: Categories of HEM technologies

## Home Energy Management Technologies

Home energy management technologies, defined as “those that enable households to more actively manage their energy consumption by providing information about how they use energy in the home or to prompt them to modify their consumption, and/or providing the household (or third parties) the ability to control energy-consuming processes in the home” (Karlin et al., 2015, pp 17), incorporate user interfaces and smart hardware, often connected together in a system via smart home platforms, or leveraged by utility facing web services to deliver additional benefits to the utility and/or grid.

Across the different product categories, load monitors and in-home displays have been on the market the longest, but more recent and rapid developments have been emerging in the smart hardware space (see Figure 4). Energy portals are a piece of software (typically an app or web-based interface) provided with most smart hardware, enabling users to view and/or control the hardware remotely. However, not all smart hardware comes with an energy portal; some manufacturers produce hardware-only solutions intended to be incorporated into a third-party home energy management system and use the corresponding third-party energy portal to connect to the device. Across the 313 products identified, 207 include an energy portal.

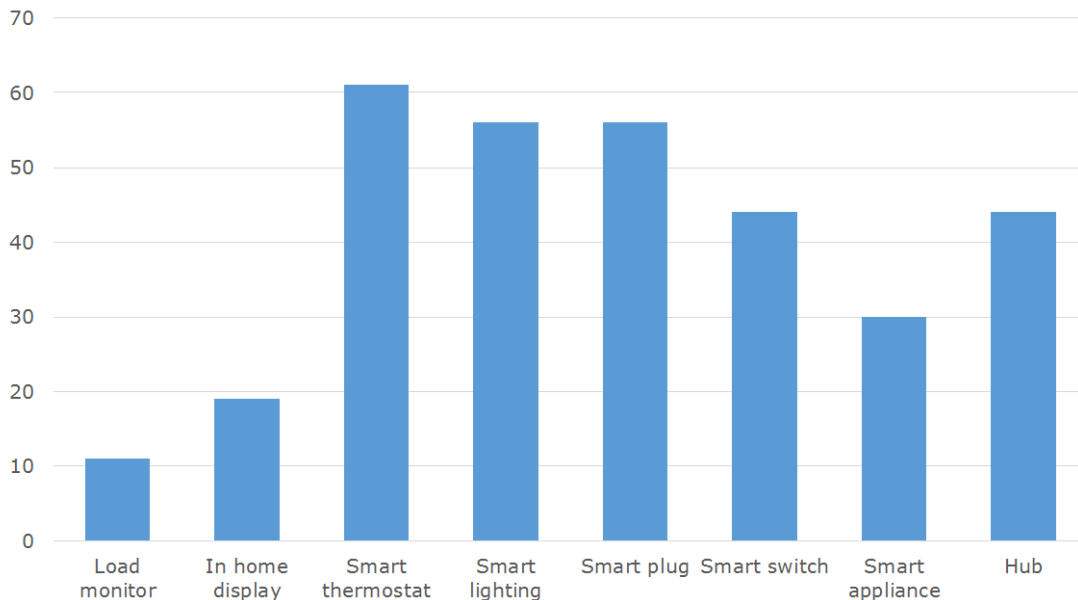


Figure 4: Number of different HEM technologies on the market

## Load Monitors

Load monitors are perhaps one of the simplest and oldest forms of home energy management devices on the market. They are hardware only and do not have a corresponding cloud-based platform or energy portal for users to view data. They serve as a proxy between an energy source and energy-consuming device (e.g. between the wall outlet and an appliance) and are composed of a socket (with sensors) and (typically) a screen that displays the energy consumption data of the

connected device. They are designed to be portable, such that users move the load monitor from appliance to appliance rather than track the use of one appliance over time. Information collected by load monitors remains on the device unless manually loaded onto a computer via a physical connection (e.g. SD card, USB key). In this way, information may be shared upstream, but the load monitor does not communicate across a home area network.

In total, 11 load monitors were reviewed, produced by 8 different manufacturers. While most of these monitors collect data at the individual plug level, one collects data from a power strip with 10 sockets. The key differentiating factor in terms of hardware relates to the sensors embedded in the device. While all the products measure the current consumed by the connected appliance, it appears that only four measure voltage to provide accurate power readings and power factors; the rest estimate power (and therefore energy consumption) based on the expected voltage level, which may not always be accurate.

Most products had a small screen embedded within the device, making the screen rather hard to view for sockets that are low to the floor or hidden behind appliances or furniture. Five products have cords such that the screen is more easily accessed, and one product communicates with the displays using a wireless (rather than wired) connection. Across the 11 products the following information was provided: power (n=9), energy (n=9), cost (n=9), carbon emissions (n=5), current (n=5), voltage (n=4), power factor (n=4), cumulative use/cost (n=7), predictive use/cost (n=3). One product had no display and indicated an approximate power demand via lights.

Because load monitors do not enable control (aside from one product that incorporated an in-built timer allowing users to manually preset a time for the load monitor to shut off – or turn on – power to the connected appliance) they are better suited to support users learn about the energy demands of different household appliances. In this way they may help users increase awareness of high usage appliances and identify ways to reduce demand through minimizing waste, changing operating conditions, or replacing the appliance. Because load monitors tend not to track use over time, they are less likely to support demand shifting or peak reduction.

## In-Home Displays

An in-home display collects data from other devices in the home, such as the meter, sensor, or other smart hardware, and provides energy use feedback and/or prompts (such as energy pricing signals) to users. These are provided via a standalone physical display (e.g. a table-top portable display or a wall-mounted display).

In total, 19 in-home displays were reviewed, produced by a total of 13 manufacturers. While the majority (n=10) connect directly to the smart meter, two connect to optical sensors reading traditional meters, five get data from current transformers that either connect to the main meter or to sub-circuits on the distribution board in the home, one gets data from other Insteon smart hardware via the home area network, and one get data from its corresponding load monitor. The most commonly used networking protocol is ZigBee (n=10). Seven devices use an unspecified proprietary protocol, one communicated via customer-provided WiFi, and one using Insteon.



All energy portals show real-time (or near to real-time) data about power demand and/or energy use, and many also provide cost and carbon comparisons. Seventeen provide historical use data, and 6 display predictive use. Nine products also provide prompts to users about DR events (n=7), target budgets being reached (n=4), or custom information as requested/set up by users (n=2). None enabled control.

In-home displays are not particularly common in today's smart-home market, where the prevalence of home area networks combined with the declining costs of embedding sensing and communication components into smart hardware has reduced the need for dedicated displays that collect data from retrofitted sensors. Instead, the past few years as seen the rise of energy portals that provide a similar functionality via existing media, particularly via software on increasingly pervasive smartphones and tablets.

## Energy Portals

This category describes remote interfaces that provide users with feedback about the use of connected devices and/or deliver energy saving prompts and/or enable them to remotely control or automate the use of connected electronic devices. Most energy portals connect to cloud-based infrastructure (e.g. utility platforms to capture Green button data, smart home platforms to collect data about or control connected smart hardware), although some applications can be run locally in a hub or other device (e.g. Apple HomeKit). They provide functionality through existing media, such as smartphone apps, websites, or computer software. Historically energy portals have been predominantly provided through websites and computer software, but are increasingly falling into the mobile app domain; of the 207 energy portals identified, 195 work with iOS and 191 of these are also Android compatible (of the remaining 12 most lacked sufficient information to determine compatibility).

The main information functionality provided by the energy portals is the visualization of energy feedback from either Green Button data<sup>2</sup> (or other utility side data), smart meter data obtained directly from the meter (often via a hub in the home to collect it), or data from connected smart hardware (e.g. whether the connected device is on or off, its power use, its runtime status). This is obtained via a connection to the data source, typically via a remote server in the cloud. In some cases, disaggregated energy feedback is provided to identify the appliances contributing to total energy consumption.

Typically, users are provided with information about how much energy each appliance is consuming, and may also be provided with tips for how to address or reduce consumption. In addition to the feedback, portals often provide projections about future energy use over a defined time period; prompts or notifications to

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<sup>2</sup> The Green Button initiative is an industry-led effort that responds to a White House call-to-action to provide utility customers with easy and secure access to their energy usage information in a consumer-friendly and computer-friendly format. Customers are able to securely download their own detailed energy usage with a simple click of a literal "Green Button" on electric utilities' websites.



users, often triggered by rules such as their pre-defined energy budgets being exceeded or their temperature rising too high; and comparisons with either peers, to previous usage, or against a goal.

The control capabilities of energy portals depend entirely on the connected hardware. In some cases, energy portals may connect to multiple different energy management technologies, and offer differing degrees of control for each. However, all allow users to switch connected devices on or off remotely, and some also enable users to set automation schedules or rules. Most commonly, the intelligence that sits behind control capabilities of energy portals resides in the corresponding software platform. Some portals also interact with third-party cloud-based solutions (using APIs) to provide additional capabilities (e.g. 60 of the energy portals interact with IFTTT, which allows users to establish rules for controlling connected smart hardware based on external conditions or data). However, some portals rely on intelligence embedded in products themselves or in the connected hub (e.g. SmartThings).

However, the functionality of the energy portal, which impacts on the savings potential that can be achieved by both behavior and automation strategies, depends entirely on what information is provided to users, as well as on the control opportunities for managing connected smart hardware; Figure 5 shows some of the different sorts of information provided to users.

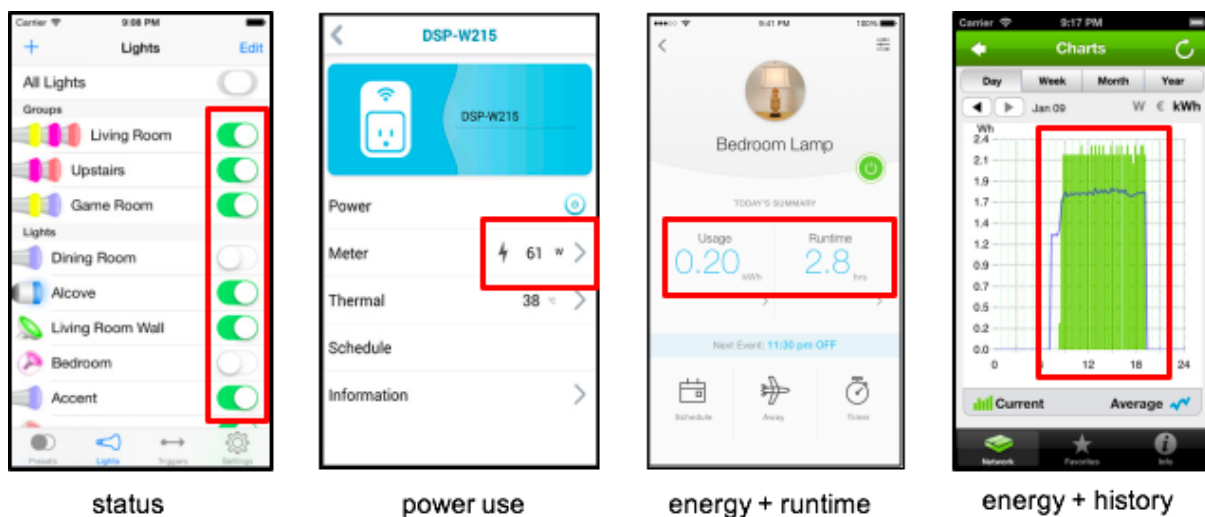


Figure 5: Types of information provided by energy portals.

## Smart Thermostats

A smart thermostat connects to the home area network to offer users remote (e.g. via an energy portal) and/or intelligent control to improve comfort and convenience and/or reduce energy consumption. Programmable thermostats (which pre-date smart thermostats and do not offer user remote control functionality) incorporate on-board schedules, whereby the user can set a variety of time points with different set-

point temperatures, enabling energy savings by reducing heating and cooling loads at times of the day when it is not needed.

Smart thermostats build on this capability, using some type of communications protocol (often WiFi) so that users can view and adjust their settings remotely via a compatible smartphone app or website. Smart thermostats often incorporate or communicate with additional sensors, such as occupancy, light level, or outdoor weather. These sensors can trigger a reaction in the thermostat; for instance, when the house is unoccupied the thermostat can revert to "away" mode, using energy-savings setpoints. Some smart thermostats also offer optimization of energy use through the use of machine learning algorithms that are either built into the device or reside in the cloud.

In total, 61 smart thermostats were reviewed, produced by 30 different manufacturers. While some manufacturers have only a single thermostat in their product range, most sell a variety; for example, 7 different Honeywell thermostats were coded, each with slightly different information, control, and communication capabilities. Across the products, three distinct subcategories emerged. The first, "communicating programmable thermostats" (n=3), is fundamentally an evolution of the programmable thermostat with additional communications to utility servers for demand response purposes. However, customers do not usually have remote access to these thermostats, and thus, from a consumer perspective, these thermostats offer little additional "smarts" beyond programmable thermostats.

The second subcategory, "hardware-only thermostats," corresponds to those products that are hardware-only solutions, sold to users as a component of a smart home platform rather than as a standalone product. Of the 61 products, 24 were hardware-only thermostats, costing between \$100 and \$250 (average \$160). The third subcategory, "standalone thermostats" are typically sold as stand-alone products that communicate using Wi-Fi directly to the router in the home (though some communicate using alternative protocols and require a hub to translate this for sending to the smart home platform). From here, data is sent to a native smart home platform and energy portal to allow users to see usage statistics and remote access control. Of the 61 products, 34 belong to this sub-group, which cost between \$150 and \$300 (average \$250).

In addition to temperature sensors (which all thermostats have), smart thermostats also collect data related to humidity (n=19), occupancy (n=3), light level (n=1), and outdoor weather (n=4). Some come with or connect to additional separate sensors in the home, typically placed in other rooms, enabling the thermostat to determine temperature and occupancy in multiple rooms or occupancy across the whole house.

All the thermostats coded provide users with real-time information for setpoint and HVAC status, but only a few store historical use data. The real power of the attached HVAC unit is never measured, but HVAC runtime is frequently reported as a proxy for energy use. Some predict energy use based on modeling around the selected setpoint, and others provide usage comparisons to peers to encourage energy management. A few send notifications if problems occur (e.g. temperature too high), while others provide energy advice.

While all thermostats in subgroups 2 and 3 enable users to remotely control their status and set scheduled operations via the energy portal, 11 do *not* allow scheduled temperature profiles to be set directly in the device (e.g. they can *only* do this via

the connected energy portal). Some portals also allow users to set rules to trigger actions based on an event (e.g., changing the temperature setpoint if rooms become unoccupied, if energy costs increase, or if people are coming home), while others include “intelligent” learning. These different features may enable different degrees of load shifting or saving, but because they are largely developed in the software layer, they can be modified and updated over time.

## Smart Lights

Smart lights are defined as those that incorporate sensors, microprocessors, and remotely controllable switches or relays to offer automated control functionality (e.g., scheduling, occupancy control, daylight harvesting) into traditional lights; eliminating over-illumination and unnecessary usage to reduce the lighting demand of a building. These systems may also enable communication such that users can view and adjust control settings or energy patterns of the lights remotely through turning them on or off, dimming, or changing the color setting.

In total, 56 unique lighting products were coded, produced by a total of 15 separate manufacturers. While the products were dominated by industry standard lamps (n=44) that could fit into existing plug sockets, 4 were light strips, 2 were strings with multiple small LED lamps for outdoor lighting purposes, 3 were portable lights comprising LED lamps and batteries housed in an aesthetically designed shaped for indoor and outdoor mood lighting, and 4 were mixed use products (e.g., lamps that house other products, such as audio speakers, cameras, Wi-Fi boosters etc.). Of the 56 products, 49 were sold as individual light sources (costing between \$15 and \$150) and 7 as starter kits (typically comprising 1-2 lamps and a hub, costing between \$50 and \$100), and all used LED technology.

While none of the lights measure actual power demand, they do provide information to users about the status of the connected light (on/off/dim level), which enables power demand to be approximated if the bulb type and power rating are known. All the lamps were able to be controlled remotely, either via the energy portal accompanying the product or, in the case of hardware only lighting solutions (e.g. those designed to work with other hubs and home energy management systems), via the energy portal corresponding to the compatible home energy management system.

The main difference between the products is around how they connect to the home area network. Of the 15 manufacturers, whose products were reviewed, four distinct communication approaches emerged. Most developed proprietary hubs (5), others produced bulbs that were compatible with a slew of platforms developed by other manufacturers (4). Two manufacturers produced bulbs that connect to the Wi-Fi router directly. Nine additional products did not need a hub and were directly controlled via Bluetooth using smartphones and tablets, but can only communicate in close proximity, prohibiting remote control from outside the home.

## Smart Plugs and Switches

Smart plugs and switches are both hardware that serves as a proxy between the energy source and energy-consuming device, which can control and/or provide feedback about the device. They receive control signals via the communication

network and respond (normally by turning on or off) to control the connected appliance. Many can additionally provide feedback about the energy consumption of connected appliances. They enable users to remotely control connected appliances via an energy portal, typically a mobile app. Some also respond to triggers from built-in sensors, networked sensors, or signals sent via a smart home platform.

In total, 100 smart plugs and switches were reviewed, produced by a total of 30 manufacturers. While some manufacturers have only a single product in their product range, many sell multiple products. These products tended to differ along two dimensions: (1) type of installation, and (2) type of control, as shown in Figure 6.

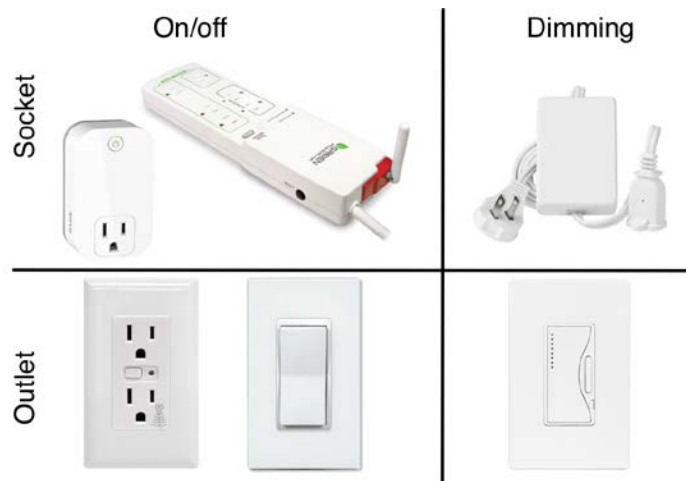


Figure 6: Types of Smart Plugs and Switches

In terms of installation, the key distinction is whether the technology takes the shape of a highly portable plug socket (e.g. a smart plug, including multi-socket plugs) that could be inserted into any traditional outlet, or whether it's a less portable wall outlet (e.g. a smart switch) intended to replace a traditional switch or outlet. In terms of control, the key distinction is whether it enables simple actuation (e.g. on/off toggling only) or whether more complex functionality such as dimming is also included (traditionally only provided for lighting solutions to enable a greater level of control).

Across the 60 smart plugs and 40 in-wall smart switches, all enabled simple on/off toggling, while 27 offered more complex dimming actuation (in addition to being able to turn off or fully on). The exact degree of control available depends on the platform, but almost all enable remote control. Some (63) allow users to schedule automation. Others provide rule-based control, for example, some smart plugs often use power sensing (or data sent from other sensors on the HAN or via the smart home platform) to manage the standby power autonomously. None offered optimization of demand through machine learning.

Many (particularly smart switches) only provided information about the connected appliance or light status (e.g. whether it is on or off, or what level the dimmer is set

to), enhancing controllability rather than directly motivating savings. However, many smart plugs do also show energy use, both in real-time as well as historical trends. Smart plugs also have a low barrier to entry; they are relatively inexpensive, simple and easy to install, and can retrofit “smarts” into a large number of traditional household appliances.

## Smart Appliances

Smart appliances describe those appliances that incorporate advanced or remote monitoring and control capabilities via the addition of sensors, software, and/or communication components. The embedded sensors and microprocessors may enable the smart appliance to collect information about its demand patterns, which can be transmitted across the home area network via a wireless connection for users to interact with remotely, typically via an energy portal. This data can also be used to optimize operation through algorithms that are either built into the appliance or the product cloud. Some also have the capacity to receive and respond to control commands from users or third parties and adjust operation accordingly.

Typically, the term smart appliance has been used to refer to large devices within the home (e.g. washers, dryers, refrigerators), but the decline in sensing, actuation, and communication module costs has led to smaller appliances and appliance components having “smarts” incorporated. Across the 30 products, three subcategories emerged; (1) large appliances, including fridges, ovens, dishwashers, clothes washers, and dryers; (2) small appliances, including coffee makers and other countertop kitchen appliances; and (3) HVAC appliances and components, including vents, room air conditioners, mini split air conditioners, and ceiling fans.

Of the 30 appliances coded, only 8 collected data on power consumption (limited to large appliances produced by LG and Whirlpool). Seven collected temperature data, 3 humidity, 1 motion, and 1 air pressure (all HVAC related). Additionally, a number of devices collected data on their own operation, including HVAC fan speed or status, filter life, rinse agent status, operation completion, internal moisture temperature or pressure.

Information is typically provided in real time, and very few provide historical trend data. More often information is provided to users via notifications, such as when the operation is finished or when problems occur (e.g., freezer door left open). In terms of feedback, most smart appliances only provide information to users about their status, making the information more suited to enhancing controllability of the appliance rather than directly inducing or motivating savings.

Users can remotely control smart appliances via a connected energy portal, turning them on or off, setting modes (e.g., selecting a cycle to run), and, in some instances; they can change parameters such as temperature setpoints. While some allow users to set schedules, most just allow a delay time to be applied to the start of the operation. Where rule-based automation is used it tends to be relatively simple, for example, using data about household occupancy (which may come from sensors embedded in the device itself, or may come from other connected HEM technologies) to create recipes using IFTTT.

## Hubs

Hubs enable and manage the interaction between existing smart hardware within the confines of a home, and a major part of their role is to create one or more networks to which other devices can join. Fundamentally a box of radios, a hub allows consumers to connect their existing smart hardware across a common network by integrating products that talk different protocols (e.g., Wi-Fi, ZigBee, Z-Wave). At their core, hubs are responsible for decoding a networking protocol, wrapping the information inside in another protocol, and sending it through the network, so that devices that speak different languages can communicate with each other. The two most common languages spoken by hubs (excluding Wi-Fi) are ZigBee (n=28) and Z-Wave (n=11).

Commonly hubs do not connect directly to the Internet but connect via the home's broadband router to send and receive data from cloud-based platforms. In the cloud, different software applications store the data and allow users to access the devices through the web and app-based portals, and to create control rules and schedules.

In total, 43 hubs produced by 36 different manufacturers, were reviewed. Across the products, two distinct subcategories emerged. The first, "network hubs," corresponds to 21 products that are primarily networking devices, enabling smart products to connect to a HAN by translating one protocol into another. Some network hubs speak only a single network protocol in addition to the wired (e.g. Ethernet) or wireless (e.g. Wi-Fi) protocols they used to connect to the home router and send data to the cloud. These hubs provide a HAN gateway for smart lights or smart meters and cost around \$50. Other hubs speak multiple protocols and have a wider remit regarding the type and variety of smart hardware they communicate with. They cost more, ranging from \$100 to \$150. Their hardware is akin to that of a wireless router.

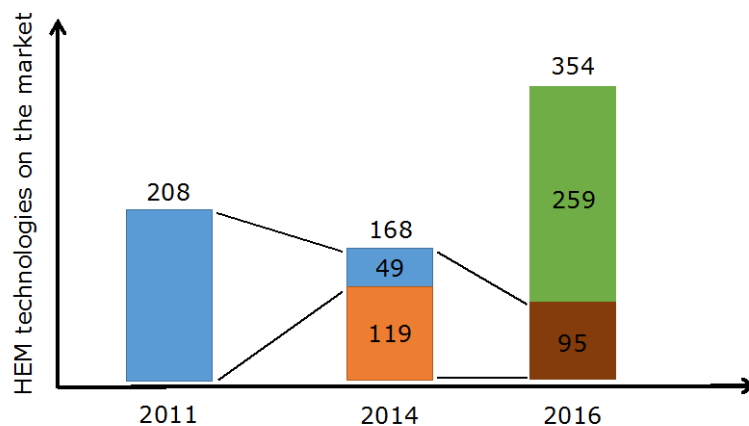
The second category, "intelligent hubs", includes 10 products that have a more powerful processor and memory; effectively acting as small computers – of the 1GHz, 1GB ram/HD scale – running an operating system such as Linux, Android or Windows (e.g. CastleOS; a full computer running Windows 10 and dedicated scripting language to write rules). Some intelligent hubs perform additional computation, enabling functionality, such as rule-based control, to be implemented locally. This can also allow energy portals to directly control devices in the home without having to communicate via the cloud, avoiding delays in communication.

While hubs are key to enabling smart home products to communicate with one another, their standalone value can be hard to demonstrate. However, because they act as a gateway product for many other HEM technologies, their stability in the market is key.

## HEM Technology Evolution

When considering the HEM technologies on the market, a particularly interesting point to note is the rate at which products are being developed into and removed from the market. Of 208 HEM technologies identified in 2011 (Karlin et al., 2013), only 49 remained as of November 2014. At this time an additional 119 products were identified, and of the 168 products reviewed at this point (Karlin et al., 2015), only 95 appear to have remained on the market as of April 2016 (see Figure 7). Further, of those remaining, many have evolved substantially during the 18 months.

Figure 7: HEM technology evolution



This volatility is to be somewhat expected in such a rapidly evolving market. However, some product removals have illustrated the potential issues that can emerge as HEM technologies become increasingly interconnected. When Nest bought and then shut down the Revolv hub servers and app (Pegorano, 2016), customers were left with an entire range of smart home products that would no longer work, demonstrating some key concerns as HEM technologies shift from independent products to products working together in home energy management systems.

## Home Energy Management Systems (HEMS)

One of the key findings across the technology analysis is the shift in how HEM technologies interact; almost half of the products identified in the HEM technology inventory (47%) are not sold as stand-alone products but as part of one or more ecosystems. This can support both marketability for the manufacturer and increased benefits for consumers, particularly in delivering greater functionality for controlling devices.



As an increasing number of devices proliferate the market and smart hardware becomes a commodity, the boundaries between home energy management and home automation more broadly begin to blur as HEM technologies interact with wider smart home and Internet of Things ecosystems. One of the most notable examples of this shift has been in terms of how consumers interact with HEMS. Traditionally, user interaction with home energy management technologies and systems has been via a dedicated energy portal, but increasingly diverse interaction channels are available. Amazon Echo and Google Home, for example, use voice interaction to provide users with many non-energy benefits such as playing music; answering questions; reading audiobooks; delivering news, traffic reports, and weather information; and so on.

Users who have HEM technologies (e.g. smart lights, smart plugs) that are compatible with these voice activated controllers are also able to control these connected devices using voice commands. While not primarily an energy management technology, voice-activated controllers like the Amazon Echo, Google Home or Apple Siri have the potential to play a very important role by providing a new form of interaction for users to engage with their home energy management system.

## Smart Home Platforms

A Smart Home Platform incorporates collections of software applications that allow multiple devices to interoperate. Whether situated in the cloud or locally on an intelligent hub, the smart home platform delivers a managed environment that provides core services to enable a standardized way for devices and appliances to interact and form a home energy management system. Users can interact with an integrated energy portal to remotely control multiple devices in the home. In some instances, they can implement an integrated scheduling feature across connected devices, as well as use a trigger-based control to switch one device on or off based on data received from another (e.g., if the thermostat switches to "Away" setting, turn off all smart lights and smart plugs).

## Interoperability

Despite the rapid evolution of the market and the trend of integrating products into these larger ecosystems, users still experience interoperability issues when they buy smart products. From a more in-depth analysis of seven of the more popular smart home platforms (Lowes Iris, Belkin Wemo, SmartThings, Nest, Wink, Insteon, and Apple HomeKit) it was found that each of these systems includes between 17-69 HEM technologies; a small fraction of the 397 products analyzed. In other words, each device is – on average – only compatible with 12% of other devices, narrowing customer choices after their first HEM technology purchase.

For instance, if a customer buys an ecobee thermostat, they will not be able to integrate it with smart plugs or other products from the Lowe's platform. Similarly, a smart light from SmartThings may not be controllable using Apple's HomeKit App. In fact, only about 20% of smart hardware are compatible with multiple systems (though not all systems). While customers can still buy and operate products belonging to incompatible platforms, the user experience may be poor as they may need to interact with each of these devices using separate energy portals, and may not be able to leverage all the benefits of interoperating products (e.g. rule-based automation, integrated scheduling). Furthermore, the different systems may require



different installation procedures and possibly additional hardware (up to one hub per platform).

Interoperability across devices is determined by both software and communication characteristics of the devices. For example, when a user controls a smart plug via an energy portal, a command is sent from the web-based application to its software platform, and from the software platform to the device via the home router. To reach the corrected device, the message is routed through different media (e.g., wires, radios) and networks (e.g., 3G, WiFi, ZigBee). Also, the command sent to the smart plug needs to be interpreted by its firmware and software. All these operations are invisible to the user, but they are fairly complex and require software and hardware compatibility at different levels.

The Open Systems Interconnection model ("Networking Tutorials," 2013), as depicted in Figure 8, provides an overview of the various layers and functions of a smart home platform. Layers one through four are fundamentally about providing a basic communications service to send data, and this is where hubs support communications through providing translation between different network protocols. Layers five through seven are concerned with being able to use the data for end-use applications, for example, switching smart plugs on/off remotely via an energy portal. Interoperability at the higher layers is achieved through the use of standard communication protocols (e.g., HTTP or MQTT for the application layer), exposure of APIs to access device functionalities and the definition of generic device types and capabilities. The latter feature allows software developers to write generic applications that do not depend on the specific device (e.g., writing a single app to manage different smart plugs that have the same functions).

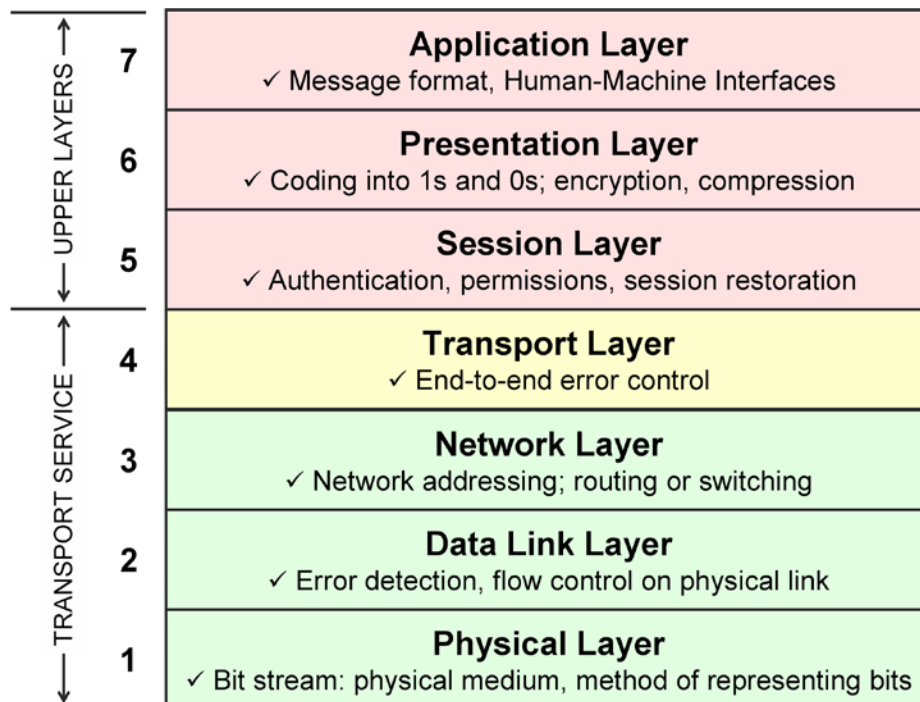


Figure 8: Open Systems Interconnection model

To integrate a new third-party device into an existing platform, the two companies have to work closely to make sure that the hardware (physical layer) and all the other software layers are compatible. The process is frequently regulated by a certification program to which the third-party manufacturer applies. Being compatible with a platform can offer marketing advantages, but also access to useful services (local interaction with devices, cloud access, cloud storage, security and software management tools). Software development kits (SDK) and APIs are also frequently provided to third-party programmers (not necessarily device manufacturers) who want to write applications using the platform.

The systems assessment identified important dimensions of smart home platforms including market strategy (business model, distribution channels and partnership with other manufacturers), platform architecture (availability of API, type of intelligence – local vs. cloud, platform hub), and platform ecosystem (compatible products). Three major archetypes emerged from this analysis.

### Archetype 1: Closed hardware and software platforms

Retailers and service providers (e.g., Lowe's Iris, AT&T Digital Life) tend to apply very tight control over the commercial distribution of their products as well as the partnership with other manufacturers. Smart products are branded and sold under their logo through controlled channels. These players frequently sell users a premium service for a fee to access the full potentiality of their platforms.

Due to the limited partnerships with other parties, the range of products available is small. APIs and other details to interact with their systems are not publicly available. Platform architectures vary, but hubs are often used to connect ZigBee or Z-Wave devices (as illustrated in Figure 9). While this type of system architecture is the most limiting in terms of product interoperability, it may provide some benefits in terms of simplicity; the tight control over products makes it very clear which products work together and may make it easier for users to install and set-up their system.

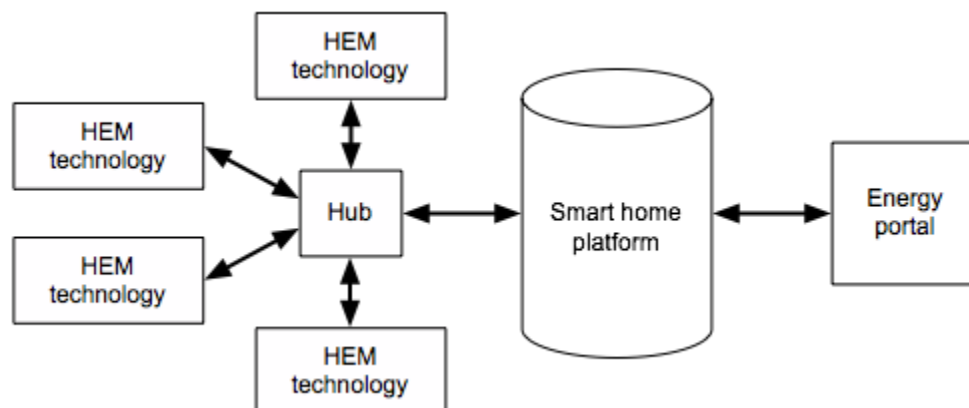


Figure 9: Software Platform Architectures

## Archetype 2: Open hardware and software platforms

Some companies, such as SmartThings and Wink have developed ecosystems that work with a larger number of devices in a more open fashion. APIs are publicly available; SDKs and other tools are available for software developers and hardware manufacturers. These companies offer third-parties different types of interactions with their products. Nest, for instance, allows other companies to use their cloud (using a cloud API or hosting some of the software), get data locally from their devices (e.g., get notified of when the house is unoccupied) or integrate with their energy portal. Compatible products are marketed and sold through the platform website, but third party manufacturers are free to sell them through other channels. Interoperability varies as “works with ...” can actually mean different things for different compatible products. Platform architecture can also take different forms. SmartThings and Wink use a dedicated hub while Nest’s products all have hub capabilities. Apple HomeKit, instead, allows users to control devices locally without a hub (using Bluetooth from an Apple device) but requires an AppleTV to work as a gateway for control outside the house. Figure 10 illustrates these different options for communication with the smart home platform.

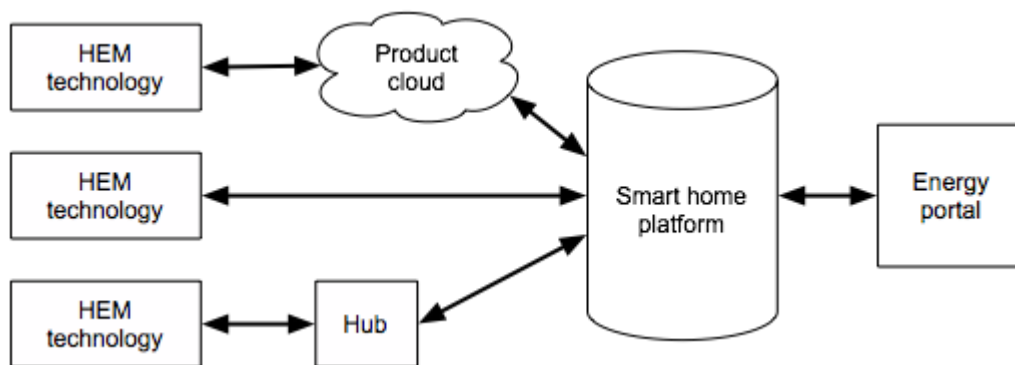


Figure 10: Communications Options for Smart Home Platform

## Archetype 3: Open software-only platforms

Some smart home platforms do not access the devices directly but use other platform’s APIs (including HEM technology product clouds as well as other smart home platforms) to provide additional services (as illustrated in Figure 11). For instance, IFTTT is a cloud framework that connects two devices or services via “recipes” such as “IF device 1 does THIS (trigger) THEN device 2 does THAT (reaction).” Other similar platforms are Yonomi and PEQ.

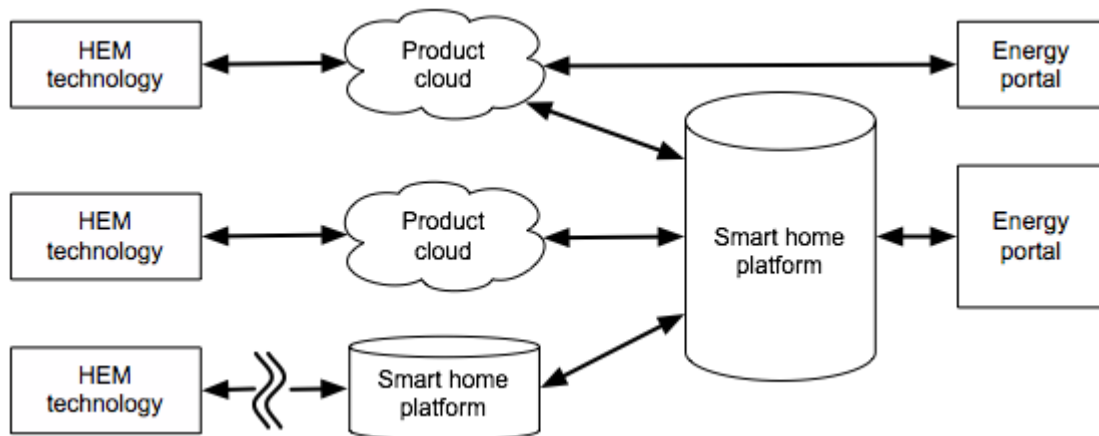


Figure 11: Open Software-Only Platforms

Even though the previous categories capture the typical characteristics of smart home platforms fairly well, collaboration within the industry is increasing. For example, ADT (a service provider with a closed system) that now “works with Nest” and Insteon, an open platform, recently added support for Nest and Apple Home kit (other platforms).

It should also be noted that all the smart home platforms analyzed across all three archetypes offered more than just home energy management. Some also integrate management of electric vehicle chargers or solar panels, and most include other smart home products (e.g., cameras, leak detectors, smart locks) and broader Internet of Things devices (e.g. wearables).

While some HEM technologies focus explicitly on managing energy demand, this isn’t always the focus of broader smart home platforms, and when it is, there is rarely a focus on delivering benefits to the grid or utility (e.g. whilst the platforms and products may enable users to reduce or shift demand, they often do not account focus on reducing demand to relieve grid stress or reduce the market cost of providing electricity). Delivering energy management benefits to the wider grid (as well as to individual homes) has instead been picked up by a number of companies offering HEMS services direct to utilities.

## Utility Facing Web Services

Utility-facing web services are software platforms, developed for utilities, which provide customer engagement, demand response, and data analytics services. The core of these systems run in the cloud on a cloud-based platform, but can receive data from physical devices through smart home platforms and can push data to energy portals. These solutions can be part of a larger portfolio (e.g., EE program design and management, EE program implementation, outreach, marketing, targeting, customer recruitment) or can be stand-alone services. Figure 12 illustrates the potential complexity of data flows in utility-facing web services.

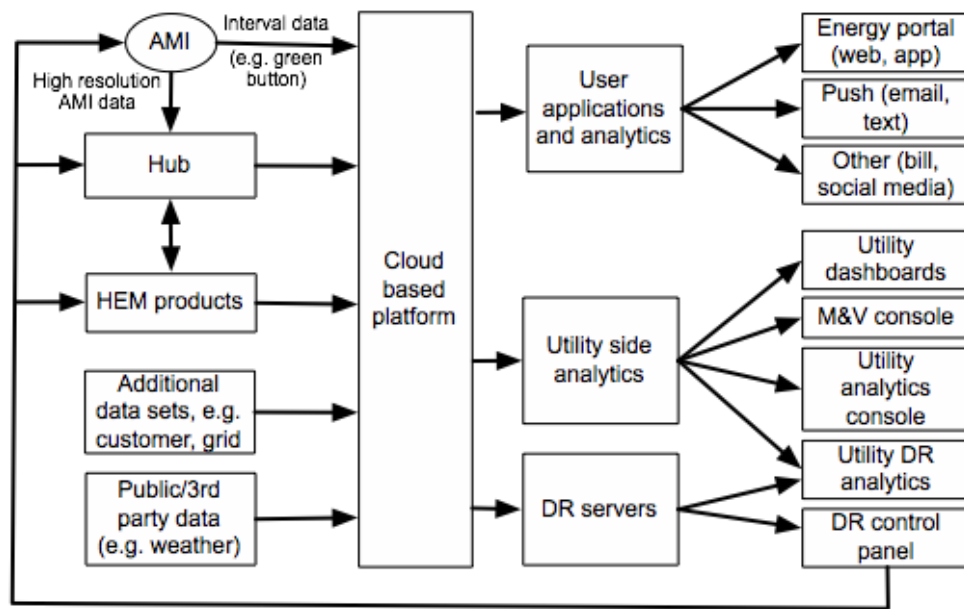


Figure 12: Utility-facing Web Services

These software platforms are marketed to the utility rather than the customer, providing end value direct to the utility, and sometimes to the customer *via* the utility. This may be in the form of improved customer engagement and support, cost reductions or revenue increases, or for compliance. Some platforms include connected and powerful computer servers to provide analysis of large volumes of data collected from existing smart hardware and/or utility meters. This can provide additional insights, for both the utility and customers, about energy use patterns. Others support data warehousing, data visualization, and web and mobile communication frameworks that are needed to build cloud-based energy management solutions, for example, to support behavioral demand-response programs.

However, the amount of information readily available pertaining to the capabilities of these solutions is limited; often solutions are tailored to particular customers, and as they are marketed direct to utility, further information about the specific platform (and any associated hardware and software) functionalities would need to be obtained through personal contact.

## Implications

Across the product and system assessments, a number of key challenges and implications around uptake and use of HEM technologies are identified, including (1) savings potential, (2) integration and interoperability, and (3) education.

## Energy Benefits

One of the key values that HEM technologies can deliver to both end users and utilities is around enabling both energy efficient operation of appliances and shifting

the time of use of appliances to reduce peak demand. In addition to the savings that may be obtained through improved energy feedback via load monitors, in-home displays, and energy portals (see Karlin et al., 2015), the different categories of HEM technologies offer distinct opportunities to leverage savings as summarized in Table 1 and expanded on in the sections below.

### Smart Thermostats

Smart thermostats offer a variety of savings opportunities to users. From an energy efficiency perspective, they may enable more effective heating and cooling. Products that include occupancy sensors can determine whether users are home and adjust set points accordingly, which can help reduce the unnecessary energy consumption associated with keeping an unoccupied home within a tight temperature range.

Further energy efficiency gains are possible through machine learning algorithms, which can identify users' heating and cooling preferences, and automatically adjust thermostat operation to accommodate these while optimized efficiency. Those systems that also collect third party data, such as weather forecasts, may be able to modify setpoints further, minimizing unnecessary use and increasing operational efficiency.

Table 1: Categories of HEMS Technologies & Opportunities for Savings

Category	Efficiency gains	Load shifting
Smart thermostats	Can improve heating and cooling demands through data-driven temperature management.	Pre-heating/cooling can shift load away from peak times.
Smart lights	Replacement of traditional bulb with LEDs drives savings. Reduction of waste through smarter control can leverage further efficiency gains.	Limited (some reduction potential through dimming).
Smart plugs	Can reduce waste and standby loads. Savings dependent on connected appliance.	Users can enable plugs to switch off during peak periods. Savings dependent on connected appliance.
Smart switches	Efficiency gains to be leveraged through smarter management of bulbs.	Typically used to control lighting so shifting potential is limited.
Smart appliances	Typically appliances are more efficient in operation than traditional counterparts.	Opportunities for load shifting, particularly wet appliances.

Furthermore, feedback to users about heating and cooling use, and notifications, prompts, and energy advice, may encourage users to change set-point preferences and increase operational efficiency. Pre-heating or cooling through demand-response

programs can help shift the time of operation, resulting in whole of system efficiency gains, and carbon and cost reductions.

## Smart Lights

One of the primary energy efficiency benefits of smart lighting is leveraged when these solutions are used to replace traditional, non-LED light sources. However, there is the potential for smart lights to facilitate additional savings through supporting users to reduce waste through smarter control. This could be by enabling households who are away from home to turn lights on remotely (or using rule-based control) for when they are required at night rather than leave them on the entire day, or by enabling lights to be more tightly controlled within and between rooms to match occupancy.

## Smart Plugs and Switches

Smart plugs and switches offer a variety of energy savings potential to users. One of their primary uses is to reduce waste by enabling users to stop power flowing to connected appliances that are unused, for example, if users plug in home media equipment that consumes energy throughout the day whether it is used or not. They can also help users reduce energy during operation (e.g., dimming lights when possible). Further energy savings may be achieved through participation in behavioral demand-response programs, or through users becoming increasingly educated and aware of the energy demand of particular appliances (and thus modifying their operation accordingly).

## Smart Appliances

Larger appliances (e.g. refrigerators, washers, dryers, etc.) tend to have a wider variety of features and operate more efficiently than their non-smart counterparts. These increases in operational efficiency are not always linked to the “smarts” (e.g., a refrigerator with an inverter on the compressor is more efficient than one without independently from the wireless connection/remote control capabilities also offered), and in some cases the additional control functionality may result in increased energy use (e.g. setting the oven to pre-heat before arriving home). However, many appliances do offer load reduction and shifting potential.

Dishwashers, washing machines, and dryers all offer energy saving potential through the use of energy-saving cycles. While this can be achieved with non-smart appliances, the increased information may provide additional incentives to users through real-time prompts or energy saving advice. Perhaps a bigger opportunity for these appliances is through load shifting potential via delayed or scheduled start times to tie in with time of use tariffs or demand-response events.

Users can reduce energy use in refrigerators by increasing temp setpoints, for example, during vacations when nobody is going to open the doors (letting warm air in) and when there is also less food in the fridge. Temperature setbacks can also be made for shorter time periods during demand-response events, and during these times defrosting operation can be avoided.



For HVAC appliances, the use of fans and humidifiers (in addition to smart heating/cooling) can support the distribution or quality of air in a room and remove the need for additional heating/cooling due to stratification. Vents can save energy by closing airflow in rooms that are not being used (or during demand-response events), though natural air mixing inside the house may limit this, as may reduced distribution efficiency due to back pressure in ducts (which were not designed for smart vents and may waste energy in functioning at restricted airflow).

However, one of the major opportunities for load shifting occurs with those appliances where power consumption and service provision can be decoupled. Water heating, whereby thermal storage enables this decoupling of power demand from user demand, offers significant demand response potential. However, the search for smart appliances did not reveal any consumer-facing smart water heating products; potentially a missing opportunity in this market.

## Hubs and Platforms

Hubs and platforms do not, on their own, offer energy savings potential to users. However, their presence facilitates a more fully interconnected and integrated home energy management eco-system, which seems to be positively related to overall savings potential (Karlin et al., 2015; Strother & Lockhart, 2013; Williams and Matthews, 2007).

While a single energy management product gives users advanced control over a single device, a fully integrated system allows products to communicate with each other to further reduce waste. For example, a smart thermostat that can determine when a home is occupied or not may be able to share that information with other products on the HAN, enabling them to change their operating conditions accordingly.

A more fully connected system may also enable more effective demand shifting in response to behavioral demand-response programs. Moreover, in a home with solar and storage, a smart home ecosystem could help optimize when appliances run, how energy from solar panels is used, and when the battery is charged. This will become increasingly more important as feed-in-tariff structures change, and time-use pricing is introduced. So while hubs and platforms, on their own, are not of particular interest in leveraging energy savings, their role in creating a home energy management system could be critical in leveraging greater savings across connected hardware.

## Integration and Interoperability

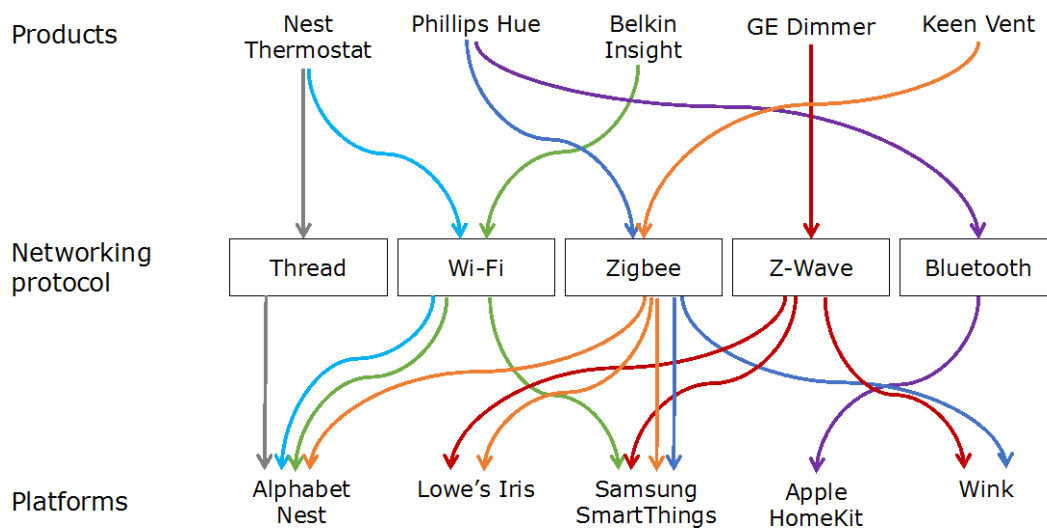
It seems clear that there are advantages to be gained from HEM technologies interacting within a home energy management system rather than users interacting with each independently, however, the specific functionality depends not just on the hardware, but also on the smart home platform and corresponding energy portal, which frequently updated by vendors, making HEMS features very dynamic. Understanding which products work together, how exactly they can work together (e.g. is their interaction limited to simply being accessed via the same energy portal, or are users able to set integrated schedules or rule-based control so events or data

from one HEM technology can be used to control another) is a moving target as the HEMS, smart home, and IoT industries are rapidly evolving.

Further confusion arises due to the lack of standardization of smart home network protocols (e.g., ZigBee vs. Z-Wave vs. Wi-Fi) and how this "protocol war" is confusing consumers and slowing down adoption (Wroclawski, 2014). Also, consumer media often confuses protocols (e.g., Bluetooth) with smart home platforms (e.g., Wink). The former strictly describes the type of network protocol the device uses, whereas multiple network protocols can still be integrated into a smart home platform, either using a hub to translate between them or via a system that can communicate across all of these protocols.

At the same time, two HEM technologies that speak the same network protocol could still be non-interoperable because the higher software layers are not compatible. This is illustrated in Figure 13, showing how HEM technologies (on top) use different wireless protocols (the middle) and are compatible with different smart home platforms (bottom).

Figure 13: Integration & Interoperability within HEMS technologies



Interoperability is thus used to describe: (1) HEM technologies that use the same communication protocol (e.g. to move data packets between devices), (2) the ability to access a device's API (e.g., the application can communicate/exchange information), and/or (3) the ability to develop "generic applications" that can be used to address multiple different devices. Navigating this space is non-trivial.

## Data and Education

In an increasingly "smart" and interconnected world, more and more data is being collected by sensors embedded in HEM technologies and other smart home and IoT devices. For products to be truly interoperable such that demand and other services

can be optimized across the entire home, energy management systems require data to be shared between different technologies. In this way, demand across an entire product ecosystem could be optimized; leveraging data from multiple sensors to support smarter and more dynamic management across the entire home.

However, even if the technical barriers could be overcome, a number of issues remain. Companies may not be willing to make this data available, as they may see commercial opportunities. It is also not clear who owns the data, and whether it belongs to the customer or the manufacturer. This is important to understand, particularly because the nature of the data could provide huge insights into when people are at home and what they are doing. Regulation and legislation to protect consumers in an increasingly data-driven world are lacking, and many consumers do not have the skills or knowledge required to engage in such a conversation.

Consequently, there is a need to better understand how customers both perceive and engage with smart home technology with regard to data, privacy, security, and instability issues that exist, as well as a more general understanding of which products can support the functionality they require, either independently or as part of a system, and how they may work together to deliver a smart home environment.

# Consumer Assessment

A multi-faceted assessment of consumers was undertaken to understand adoption of smart home technology better broadly, and HEM technology specifically. This broader view was taken in recognition of HEM as just one of a number of elements in the highly connected space of smart home technology. To address gaps in the existing literature, the consumer assessment investigates consumer perceptions of specific HEM product categories, as well as the characteristics and experiences of early adopters. The ultimate aim of the research was to suggest how utilities might engage consumers in the HEM space, for example, by framing costs and benefits to increase adoption and promoting associated energy savings and grid resilience.

## Methods

This study used Rogers' (2003) Diffusion of Innovation Theory as a framework to guide a comprehensive assessment of consumer adoption. Specifically, the work was guided by Rogers' concept of the innovation-decision process, which details how people adopt new technologies in a series of iterative stages. These five innovation-decision stages are as follows:

1. **Knowledge Stage:** Awareness and understanding of the technology
2. **Persuasion Stage:** Attitudes regarding the degree to which the technology aligns with one's needs and values
3. **Decision Stage:** The choice to purchase/acquire the technology or not
4. **Implementation Stage:** User experience after acquisition
5. **Confirmation Stage:** Mirrors the Persuasion Stage in that the customer can reassess the degree to which the technology aligns with their values and goals

The consumer assessment implemented three distinct methodologies, designed to converge on a holistic understanding of the process of consumer adoption of HEMS (Figure 14).

1. **Utility Customer Survey:** Online survey of 1,414 PG&E customers
2. **Retail Studies:** Observation and interviews of retail customers and employees
3. **Analysis of HEM Product Reviews:** Content analysis of customer reviews on Amazon.com

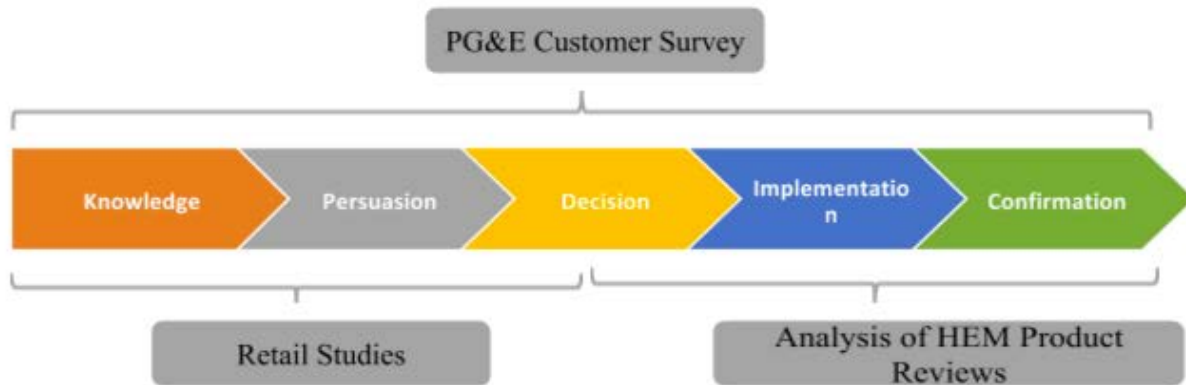


Fig 14: Consumer research methodologies correspond to innovation-decisions stages.

## Customer Survey

A survey was conducted to assess PG&E customers' awareness, attitudes, and adoption rates of HEM technologies. Questions were geared toward all five innovation-decision stages. Customers were asked about their familiarity and attitudes toward smart home technology in general. The terms "smart home" and "connected home" were split-test so that half of the sample received a version using each terminology. The purpose of this split-test was to determine which term was more popular in the vernacular and what their connotations were. See Appendix E for survey instrument.

The survey also asked about familiarity, attitudes, and ownership of four HEM technology categories: smart thermostats, smart (large) appliances, smart lights, and smart plugs. Those who indicated they owned a smart thermostat, appliance, light or plug were asked a series of follow-up questions about their experience with the product. A key aspect of the survey was the use of infographics to introduce customers to the concepts of smart home and each product category; these infographics were presented after questions inquiring about awareness, and before questions about attitudes toward the technology.

The survey was implemented using PG&E's Customer Voice Panel, a voluntary pool of more than 15,000 customers who agreed to be contacted for research recruitment. A stratified sampling methodology was used to increase the representativeness of the sample in terms of region (Northern, Central Valley, Central Coast, Bay Area), sex, age, income, and housing tenure (own or rent). The resultant sample consisted of 1,414 customers, described by the following average demographics: 50% female; 33% aged 45 – 64 years; 41% with annual income less than \$50,000; 72% White; 34% with four-year college degree; 53% employed full-time; and 72% homeowners.

## Retail Research

A partnership with two retailers who feature smart home demonstrations in their stores was created to further assess the customer experience of smart home, including HEM, technology. This research focused on the early stages of the innovation-decision process (Knowledge and Persuasion) as many customers in the retail spaces were just learning about the technology and products for the first time.

Passive observation was undertaken of around 250 customers in the smart home demo spaces, as well as 21 customer interviews and 6 employee interviews. Customer observation and interviews were conducted within and outside the context of employee-guided or self-guided tours of the smart home demo space. Participants of tours and interviews were provided with store gift cards. See Appendix F for the Employee Interview Protocol.

## Product Reviews

To understand the experience of early adopters of HEMS, a content analysis of customer reviews on Amazon.com was conducted for the following HEM technology categories: smart thermostats, smart lights, smart plugs and switches, hubs, in-home displays, and load monitors. The top three to five most-reviewed products within each of these categories were selected at two different time points (November 2015 and May 2016); the first time the top three most-reviewed products were selected, and the second time any products that had moved into the top three were added.

Only the most recent model was included if two models of the same product were in the top three. Ten reviews were collected for each product, sorted by most recent and proportionally representing each star rating based on the entire population of reviews (e.g., if half the reviews were 5-star reviews, we selected five 5-star reviews). Four to seven additional reviews were collected to supplement reviews with low word counts, providing a total of 14 to 17 reviews per HEM technology category. See Appendix G for sample details.

## Findings

The results presented here form a synthesized analysis of data from all three methods. They are organized according to themes that were constructed and organized both inductively based on the data and deductively based on the innovation-decision process. Wherever specific numbers, percentages, and statistical analyses are presented, the source is the online customer survey. Data from the retail studies and analysis of product reviews were analyzed qualitatively. Therefore they support themes via quotes and descriptions rather than quantifications.



## Knowledge Stage

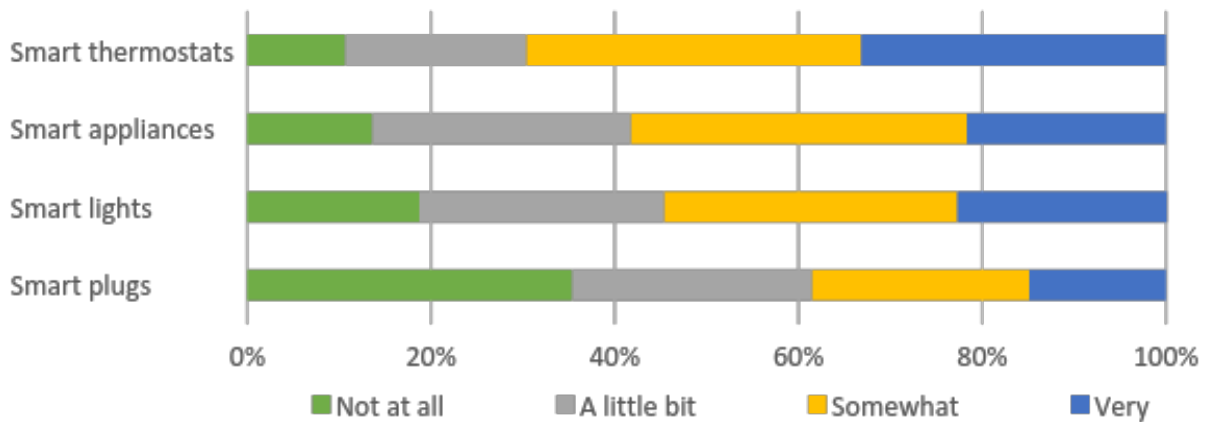
The data allow for assessment of customers' existing levels of knowledge regarding smart home technology, as well as what they do not know (e.g., knowledge gaps); and, moreover, what they are having trouble understanding (e.g., barriers at the knowledge stage). The survey also ascertained the sources by which customers are learning about smart home technology and customer characteristics that predict familiarity with smart home technology.

### Existing Knowledge

Customers ranged greatly in their levels of awareness of smart home technology. The split-test in the survey revealed that the term "smart home" was significantly more familiar to customers than the term "connected home"; 75% said they were "somewhat" or "very" familiar with "smart home" compared to only 50% "somewhat" or "very" familiar with "connected home". Customers associate the term "smart home" with "green" and "energy efficiency," whereas "connected home" brings to mind the concepts "Internet," "systems," and "communication"; both are associated with the ideas of remote control and monitoring.

The survey sample reported the most familiarity with smart thermostats and the least familiarity with smart plugs (Figure 15). This was consistent with findings from the retail studies. Nest, in particular, was found to be the most familiar product (Nest thermostat) and brand to participants at one retailer, although a customer at another retailer mistook the smart thermostat for a CD, highlighting that wide range of familiarity with HEM technology. Regardless of familiarity with products, customers were consistently surprised to learn about the possibilities for integrating multiple products. In several cases, customers who already owned a smart product (e.g., Nest thermostat) were unaware of its ability to integrate with other products.

Fig 15: Customer survey responses to the question, "How familiar are you with each of the following products?"



Survey respondents reported learning about smart/connected home technology through the following channels: mass media (64%), word of mouth (31%), and retail (8%). Predictors of greater familiarity with smart home technology included being male, living in the Bay Area, and having higher income and education, a larger home, more pervasive use of technology, and greater performance efficacy concerning energy management (e.g., feeling competent one has the skills to manage their energy use).

### Knowledge Gaps

Retail customers were quite curious to learn more about smart home technology. The data collected in the consumer assessment revealed six general types of questions customers had about smart home products and systems (Figure 16).



Fig 16: Themes emerging from customer questions and comments in our retail studies.

To begin with, customers were not always clear on the basic functions and features of products (e.g., “I don’t know what SmartThings is”), including interoperability. Customers also wanted to know how products work (e.g., how a water leak sensor detects leaks), with tech-savvy customers asking more “targeted” and “deep technical questions” about performance, storage, and cloud protection, according to retail employees. When retail displays highlighted a user scenario, or use case, that customers appreciated, they wanted to be sure they understood which products were involved.

For smart lights, in particular, customers wanted to know whether they would be compatible with their lighting fixtures (e.g., “You can put this (smart bulb) in a regular lamp?”); questions about compatibility were also raised about smart plugs, switches, and thermostats, as well as whether products could integrate with a home security service. Retail store employees noted that customers had many questions about how to install and set up a variety of products, especially smart thermostats, speakers, and door locks. Finally, customers had questions about how to interface with the products. One way customers new to smart home technology came to understand it was “everything by the phone”; comments like this were delivered in a tone suggesting comprehension (e.g., an “ah-hah” moment), with accompanying head nods and smiles.

## Knowledge Barriers

The utility customer survey revealed that only one-third of customers thought information on smart/connected home technology was readily available. Not only was information hard to find, but it was also hard to understand. Even with access to retail staff highly trained and experienced with respect to these technologies, many customers in the retail studies had difficulty grasping the abstract and technically complex aspects of this new technology. For example, at the end of a tour one customer summarized, “Very interesting. It was way over my head.”

Three concepts were especially difficult for customers to understand: hubs, platforms, and protocols. Customers struggled to understand the function of hubs (e.g., “Do I use it for Internet?”), why they are required or work for certain products but not others (“For the doorknob, do you need the hub?”; “Does the doorbell link to the hub?”), and whether the hub might replace the function of another product (“Do

I need the hub or the smart switch or both?”). Retail store employees mentioned that customers also struggle with the concept of platforms, reporting that it is helpful to explain them in terms of apps, with Yonomi being the easiest to introduce. Employees also reported that Nest is among the platforms customers more readily grasp, whereas SmartThings is more “advanced.” Few customers we interviewed mentioned protocols (e.g., “I am assuming everything is Bluetooth?”), but employees reported this is also something customers have difficulty understanding. For example, employees often have to explain the difference between Wi-Fi, Bluetooth, and ZigBee, and the implications of each for product functionality (e.g., a smart door lock using Bluetooth cannot be controlled from far away).

## Persuasion Stage

In terms of the Persuasion Stage, the data allowed an assessment of the degree to which the general concept of a smart/connected home appeals to customers, the relative appeal of specific products, and the perceived benefits and values underlying adoption. Themes emerged regarding the relative appeal of products in isolation versus in the context of a multi-product system, the perceived value of products on-the-shelf versus in the context of a user scenario, and barriers at the Persuasion Stage.

### Appeal of Smart/Connected Home

In response to the question, *How much does the idea of a (smart/connected) appeal to you?* Seventy-one percent of respondents answered “somewhat” or “very.” There was a significant difference again with the split-test, with the term “smart home” rated as more appealing (74%) than “connected home (68%) [ $t(1412) = 2.23, p = .026$ ].

When asked about agreement with the statement, *Most people I know would want to have a (smart/connected) home*, 33% answered “agree” or “strongly agree”, with those responding to the term “smart home” reporting greater agreement (38%) than those responding to the term “connected home” (29%) [ $t(1412) = 2.98, p = .003$ ].

Characteristics of survey respondents that predicted their attraction to the smart/connected home concept included: being younger and having more pervasive use of technology, greater social norms concerning energy conservation, and greater trust in their utility.

The majority of survey participants indicated interest in the following features of smart home technology: remote monitoring (66%), remote control (65%), scheduling (65%), learning (65%), tips and notifications (57%), and demand response for time-of-use energy prices (51%). Survey participants were also asked how they would prefer to interface with their smart home. Most participants reported interest in using their smartphone (78%) and computer (70%), followed by tablet (49%), in-home standalone display (42%), a display embedded in a product (41%),

and voice control (24%). Customers in the retail studies were also interested in motion sensors and automation that would preclude the need to use a digital device to interface with the products; some of these customers did not have a smartphone or Internet at home, or they lived with someone who did not have access to these technologies, which could present a major barrier to widespread adoption of HEMS.

## Appeal of Specific Products

Upon reviewing the infographics used in the survey, participants were asked how much each of the following product categories appealed to them: smart thermostats, smart appliances, smart lights, and smart plugs. Considering the proportion of respondents who found the product “somewhat” or “very” appealing, smart thermostats were most appealing (70%), followed by appliances and lights (both 61%), and plugs (58%). Retail studies revealed appealing products in the smart home space beyond HEMS; in general, customers were most interested in smart doorbells, garage door openers, door locks, and cameras.

An interesting theme that emerged from the retail studies was that some products seemed to provide a strong value proposition on their own, as a single product, whereas others were more valuable in multiples of the same product, and yet other were appreciated in the context of a system of different types of products. Similarly, and difficult to distinguish, some products could convey their value in a box on a shelf (conventional retail display), whereas customers were much more likely to perceive the value of other products when they were either displayed to illustrate a use case or an employee described a use case. Products that could stand alone on a shelf and attract attention included smart thermostats, doorbells, door locks, garage door openers, and cameras.

Products that were appealing in multiples or systems and attracted more attention in the context of a use case included smart lights, plugs, and switches, as well as smart buttons and sensors. Use cases suggested by employees that resonated with some customers revolved around forgetting something, highlighting the remote control feature of various products (smart plugs for curling iron or entertainment center; smart garage door control for forgetful mornings) and “coming home” use cases involving smart lights and thermostats.

A strong and consistent theme in the retail studies was customer appreciation of the integration of multiple products; for example, “The connection between all of them is neat”; “Being able to leave home and the practicality of everything being off”; “For the light stuff, how many lights could plug in?”; “I like the combination of products”; “I like the communication between devices.”

Despite this interest in whole-home solutions or systems, retail employees noted that customers often come in with one specific product in mind. Also, when customers are just discovering smart home technology, it usually takes one particular product that resonates with them before they warm up to the whole general idea; for example, “It’s usually a specific product that brings people around, and they say ‘I get this now’”; “One or two items will stick out to them; it’s very random which ones.” They

discussed how whole systems could be overwhelming at first; customers just want "one or two things to make life easier."

## Perceived Benefits and Values Underlying Adoption

The majority of survey participants expressed that smart home technology could benefit their household in the following ways: save money on energy bills (83%), reduce energy use (83%), enable better management of household energy use (67%), alert them when household equipment needs attention (64%), reduce negative environmental impact (56%); make their home more comfortable (50%). A different picture emerged from the retail studies regarding the values underlying smart home technology adoption.

When customers and employees were asked about the benefits of smart home technology, the most prevalent theme was convenience (e.g., "Simpler, faster, and easier"). However, convenience in itself was not necessarily a strong value proposition for customers (e.g., "Would be easier, but I do not see a big benefit right now"). Instead, it appeared that convenience was of greater importance when it related to achieving valued goals, such as making it convenient to monitor the safety of one's household. Some customers mentioned safety, energy savings, and comfort, but more commonly customers only implicitly suggested their underlying values by the way they responded to the products. Three sets of underlying values were identified in the retail studies: *Protect*, *Nurture*, and *Conserve*.

*Protect: Security, safety, and structure.* Values related to protecting the health and safety of one's household are implied by customer interest in the smart doorbell, door lock, camera, and water leak sensor. One customer remarked about the smart door lock, "If you hear a noise in the night, it is comforting for the nervous person." Another customer expressed a desire for a 911 call feature. Both customers and employees noted the appeal of some smart home products as a do-it-yourself replacement for a security service, eliminating the need for a monthly fee.

*Nurture: Comfort, care, cleanliness, and cooking.* A variety of positive customer reactions to smart home technology implied a set of values related to fostering a nurturing home environment. These values included comfort (e.g., "Do the lights come on when it gets dark?"; "I like to read in bed, and I don't like to get up to shut off the lights"); caregiving (e.g., "I like keeping track of the baby"; "Love that you can take care of a cat for a few days"), cleanliness (interest in robotic vacuum), and convenient cooking (e.g., "I like that you can brew coffee from bed").

*Conserve: Energy and money.* A small segment of customers named energy and/or its associated cost savings as a primary value of smart home technology (e.g., "I drag my feet at the idea of letting electronics control my house, but to save energy, I'm fine with that"; "It's all about saving money and saving energy."). More customers acknowledged savings as a benefit of smart thermostats in particular. While energy savings was not top-of-mind for most customers when asked about the benefits of smart home technology, it was universally appreciated as an added value

(e.g., "Would like it to be efficient, but not a deterrent"; "Prefer low energy"; "If it could achieve energy savings that'd be great"). Employees noted that questions about energy savings tend to come up later after customers become interested in the product for other reasons.

## Persuasion Barriers

Based on the retail studies, two main reasons smart home products did not appeal to customers emerged: (1) insufficient value proposition, or (2) not applicable to their household/lifestyle.

*Insufficient value proposition.* Customers who did not perceive sufficient value in some of the technology used terms like "overkill," "excessive," "luxury," "novelty," and "gimmicky." A common sentiment was just that it was unnecessary (e.g., "I understand it but seems like a lot, unneeded") or moreover an unnecessary encroachment of technology (e.g., "Too much technology... Way too much"). Along these same lines, 29% of the survey respondents agreed with the statement, *Smart home technology makes simple tasks unnecessarily complicated.*

The promise of convenience (e.g., saving time and effort) alone was a turn-off for some customers, who perceived certain products or use cases as promoting laziness or waste. For example, one customer noted that curtains should be opened for natural light in the morning rather than artificial lights coming on automatically. One customer sarcastically implied the wastefulness of adopting these new technologies to replace basic models that are still functional: "So your crock pot at home is useless."

*Not applicable.* Regardless of whether customers appreciated the value of certain products/systems/use cases, in some cases, their life situation was such that they would not personally benefit; "Security is not a big case for me, I live in a condo complex. Would be hard to break in and if someone goes through that much effort, they are welcome to my stuff... and good luck getting it out"; "The temperature thing is nice, but I am a San Francisco native so not a lot of hot days." This barrier was prevalent for the nursery, pet, and kitchen products.

## Decision Stage

Regarding the Decision Stage, the consumer assessment data provide insight into the rate of customer adoption of specific HEM technologies, as well as which products are popular within each category, where customers are buying the products, and characteristics of adopters. It also provided an insight into barriers to adoption at the Decision Stage.

## Product Ownership



Among survey respondents, 14% owned a smart thermostat, 10% owned a smart appliance, 7% owned a smart plug, and 5% owned a smart light. Smart thermostats and plugs were most frequently purchased online (34% and 48%, respectively). Amazon.com was the most popular online retailer for HEM purchases, followed by manufacturers, eBay, and Smarthome.com. Smart appliances and lights were most frequently purchased at retail stores. Home improvement stores, especially Lowe's and Home Depot, were most common, followed by electronics stores, Target, and Costco. Other sources of product purchase included service providers (e.g., ADT, Comcast) and contractors (supplied at the time of upgrade or repair). Customer characteristics that predicted ownership of a HEM product (smart thermostat, light, plug, or appliance) included: being male and a homeowner, having higher income and more pervasive technology use and owning solar panels and a plug-in electric vehicle.

The number of customer reviews on Amazon.com can serve as a proxy for product popularity. Table 2 shows the sample of most-reviewed products in each of the HEM technology categories analyzed in the study of customer reviews. It is important to note that other factors, such as date of product release, also affect a number of reviews.

Table 2: Most-reviewed HEM products sampled for analysis of reviews on Amazon.com.  
Note: Data collected July 2016; since then the # of reviews per product has increased.

<i><b>In-home Displays</b></i>	<i><b># of Reviews</b></i>
Black and Decker Energy Saver Series Power Monitor	209
Watt's Up RC Watt Meter	126
Efergy E2 Wireless Electricity Monitor	108
Wink Relay Smart Home Wall Controller	93
Current Cost EnviR Wireless Home Energy Savings Monitor	93

<b><i>Load Monitors</i></b>	<b><i># of Reviews</i></b>
Belkin Conserve Insight Energy Use Monitor	3,006
P3 International Kill A Watt EZ Electricity Usage Monitor	1,124
Plug Power Meter ... with Electricity Usage Monitor	283
<b><i>Smart Thermostats</i></b>	<b><i># of Reviews</i></b>
Honeywell Wi-Fi Smart Thermostat	1,924
Nest Learning Thermostat, 3 <sup>rd</sup> Generation	4,489
Sensi Wi-Fi Programmable Thermostat	1,677
Ecobee3 Smarter Wi-Fi Thermostat with Remote Sensor, 2 <sup>nd</sup> Generation	1,280
<b><i>Smart Plugs and Switches</i></b>	<b><i># of Reviews</i></b>
WeMo Switch	3,725
Etekcity Wireless Remote Control Electrical Outlet Switch	3,123
Ankuoo NEO Smart Switch	648
<b><i>Smart Lights</i></b>	<b><i># of Reviews</i></b>
Flux Bluetooth Smart LED Light Bulb	1,187
GE Link Wireless Smart Connected LED Light Bulb	953
MagicLight Bluetooth Smart LED Light Bulb	909
Philips Bulb Starter Kit 2 <sup>nd</sup> Generation	537
<b><i>Hubs</i></b>	<b><i># of Reviews</i></b>
Samsung SmartThings Hub 2 <sup>nd</sup> Generation	735
Wink Connected Home Hub	700
Lutron Caseta Wireless Smart Bridge	44

## Decision Barriers

Data from the retail studies and customer survey revealed nine barriers at the Decision Stage: prohibitive cost, concerns about privacy and security, effort required, concerns about performance, lack of knowledge, lack of foundational technology, redundancy with other products/services, structural incompatibility, and renting.

*Prohibitive cost.* In the survey, customers were asked to rate several barriers at the Decision Stage: cost, effort, privacy/security, and performance (Figure 17). Cost was the biggest differentiator when comparing owners of HEM products (smart thermostats, appliances, lights, or plugs) to non-owners; specifically, non-owners were significantly more likely to agree with the statement, *Smart home products are probably not worth the price* [ $t(1412) = 4.50, p < .001$ ].

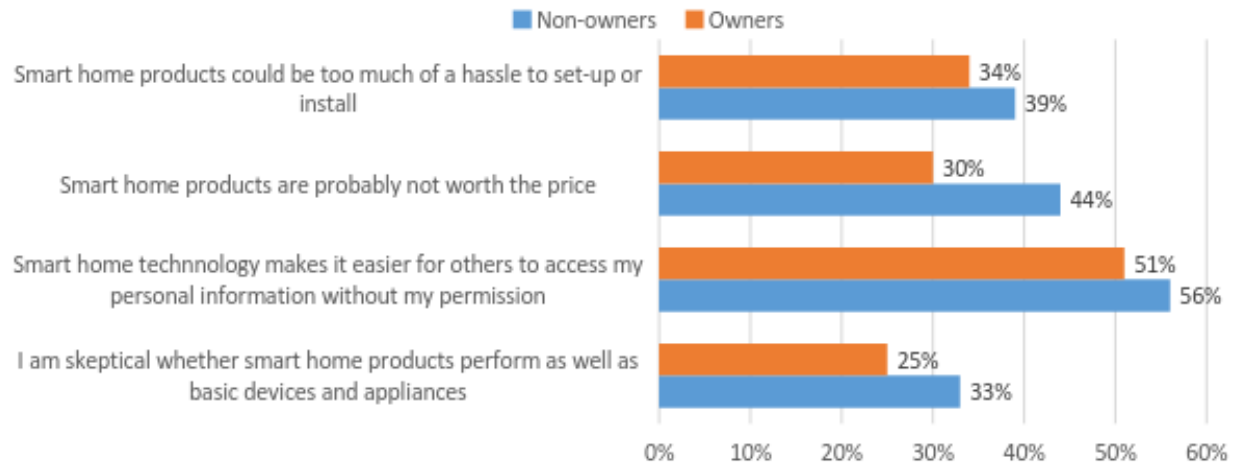


Figure 17: Barriers at the Decision Stage for HEM product owners versus non-owners.

This finding is also indicative of an insufficient value proposition (a barrier at the Persuasion Stage). Findings from the retail studies further support these ideas. For example, one customer was very interested in a water leak sensor that required a hub. The cost of the hub was much higher than the cost of the sensor. “Why do I need to buy this?” she remarked, perplexed about the need to buy the hub when, from her perspective, she just wanted the functionality of the sensor. Thus, there was an interaction between cost and lack of value proposition of the required hub forming a barrier to adoption.

Cost is also a likely culprit behind the tendency of an interested customer to buy one or two items with standalone functions rather than systems that include products with more abstract values (e.g., hubs). For example, a slightly sarcastic remark from one retail customer was, “Do you have to buy *everything* (to make it a smart area)?” This theme was also found specifically in discussions about smart lighting, for example, “Do I need to buy a switch for every lamp?” At the end of one tour, one customer remarked, “Wish I had the money to buy it all!”

*Concerns about privacy and security.* Of the barriers assessed in the survey, customers most frequently reported a concern regarding privacy and security (Figure 16). Retail studies were consistent with this finding. Interestingly, however, there was no significant difference between owners and non-owners in the survey in terms

of this concern [ $t(1412) = 1.58, p = .116$ ], suggesting that customers adopted smart home technology in spite of these concerns.

*Effort required.* A substantial proportion of customers in the survey indicated they would be concerned about the effort required to install and set-up smart home technology (Figure 16). This concern was more prevalent among non-owners than owners, but the difference was not statistically significant [ $t(1412) = 1.87, p = .062$ ]. In the retail studies, customers had particular anxieties about installing smart thermostats and setting up integrations of multiple products.

*Concerns about performance.* Of the barriers assessed in the survey, concern regarding whether smart home products would perform as well as basic devices were the least frequently cited. However, like cost, this barrier was significantly more prevalent among non-owners compared to owners [ $t(1412) = 2.89, p = .004$ ]. The retail studies provided evidence of this barrier as well (e.g., one customer's comment: "What if there is a power outage? Would I need a backup battery for my connected products?").

*Lack of knowledge.* Barriers at the decision stage pertain to customer lack of knowledge concerning smart home, including HEM, technology. For example, one-third of survey respondents indicated that they did not know where to buy smart/connected home products. When unaddressed, the knowledge gaps described earlier, for example, *How does it work? What products do I need? Is it compatible with what I have at home?* become barriers to the decision to purchase products. For example, one retail customer concluded, "I need more info before I buy this," and another, "(I) have to digest... See how my home fit... It is old version."

Also, customers often did not have enough information to differentiate between products. Retail customers who were seeking a particular product may have done their research on a particular brand and not be aware of other similar products and differentiating features. For example, the myriad of options for implementing smart lighting – smart bulbs versus smart switches versus smart plugs – within all of which there are multiple kinds, was difficult for customers to navigate. One couple came into a retail store with a coupon, intent to buy a product, but were unsure which to choose; they left without purchasing, conceding, "We have time to do more research" (before the coupon expired). Given that customers had difficulty differentiating between products within the same category, it is unsurprising that they were often overwhelmed by kits that contained multiple types of products and instead tended to purchase just one or two products with independent value propositions (per reports by retail employees).

*Lack of foundational technology.* Another barrier for some customers in the retail studies was the lack of technology either required for smart home products or perceived to be required, specifically no Internet at home or no smartphone. In some cases, customers were concerned about access for another person in their household (e.g., older parent). As previously mentioned, many customers began to form an understanding of the smart home revolving around the smartphone. Thus, there was

a distinct impression that not having a smartphone was an insurmountable barrier and many comments to this effect were made during discussions of HEM products in particular, for example, "I don't have a smartphone yet, so I don't understand how it works" (while discussing Belkin WeMo products); "What if my mom is home all day, and she wants to turn off the light? She does not have a smartphone" (regarding smart light). Along the same lines, an older woman interested in the security products was discouraged because she did not have a smartphone.

Structural incompatibility, redundancy, and renting. Several other barriers identified in the retail studies include structural incompatibility, for example, the customer did not believe the product would work with their home (e.g., lights would not fit light fixtures; old home has limited electrical outlets so would not be able to plug in products). Sometimes product functions were valued but redundant with products/services already owned, for example, "I have already switched all my lights to LED. Do I need new lights?"; "We would not replace our current alarm system." Finally, renting was perceived as a barrier to adoption, for example, "I rent and Nest is more permanent, not worth installing and uninstalling...What if I broke it?"

## Implementation Stage

"It is one thing for an individual to decide to adopt a new idea, quite a different thing to put the innovation to use, as problems in exactly how to use the innovation crop up at the implementation stage" (Rogers, 2003, p. 179). The customer survey and, to a larger extent, the analysis of Amazon.com customer reviews of HEM products revealed some of these problems "crept up" on HEM technology adopters, especially pertaining to product installation and setup, as well as insights into how early adopters are using these products (e.g., use cases), and desired features and interoperability.

### Installation and Setup

In the Amazon.com reviews, customers appreciated when product installation and setup was fast and simple (few steps), they could do it themselves, and it only needed to be done once. Some customers seemed pleasantly surprised at the ease of installation, perhaps especially with smart thermostats. Difficulties with installation and setup featured problems with connectivity, such as connecting the product to household Wi-Fi or to one's phone via Bluetooth. There were reports of wireless setup taking multiple tries and connections being unreliable throughout product use. There were also reports of poor or insufficient instructions and poor customer support. Some customers experienced difficulties or disappointments with software updates and hardware upgrades, including cases where products were no longer supported by manufacturers. Less frequently, customers experienced structural incompatibilities, such as needing extensive rewiring to install a smart thermostat.

## Confirmation Stage

Both the survey and analysis of HEM product reviews yielded insights into early adopters' experiences in the Confirmation Stage. In the survey, HEM product owners were asked about the impact of using the products on their energy consumption and their plans to continue or discontinue product use. Amazon.com reviews provided more context around customer satisfaction regarding favorite features and performance.

### Energy Savings and Continuation of Use

Reported impact of HEM products on energy consumption and customer continuation of product use are shown in Table 3. Of the four product categories, smart thermostats were most frequently reported to result in energy savings, but more than one-third of the owners of other products types also reported energy savings. Most HEM product owners reported intention to continue using their products, especially smart thermostat owners.

Table 3: Survey responses of HEM product adopters regarding energy impact and continuation

	Smart thermostats	Smart appliances	Smart lights	Smart plugs
Impact on energy consumption	51% decreased	37% decreased	35% decreased	35% decreased
	20% no change	32% no change	40% no change	44% no change
	6% increased	7% increased	3% increased	4% increased
Continuation of product use	95% yes	87% yes	89% yes	80% yes
	3% not sure	11% not sure	10% not sure	17% not sure
	2% no	2% no	1% no	3% no

### Satisfaction with Features

Remote control and monitoring capabilities were favorite features for all HEM product categories. The consumer research also revealed the desire for a balance between customer engagement with the technology (via remote control and monitoring, customization, tips, and notifications) and opportunities for automation (via presets, scheduling, learning, and demand-response). For example, adopters appreciate the high degree of customizability of some smart lights, but in the absence of presets that are easily implemented (e.g., off and on at dawn and dusk, respectively, and

the ability to extend a setting to multiple lights) options can be overwhelming. As one adopter lamented, "I now really wish I'd just stuck with inexpensive dimmers instead of a system that wants me to make a career out of lighting control."

As with the above example of presets for smart lights, some desired features were present in some by not all products within a given category, or present to varying degrees (e.g., differentiating features). Other differentiating features of smart lights included color-change, precise dimming control, ability to synchronize with music, and sound effects. Differentiating features of smart thermostats included preferred aesthetics of hardware design (preferences for design were relatively subjective), an indoor temperature indicator on the device, and the inclusion of remote sensors. General differentiating features across product categories included the degree of integration possible and the protocols used—e.g., remote control away from home was a valued feature only available for products or systems using Wi-Fi.

Favorite features of energy feedback were highlighted in reviews of load monitors, in-home displays, and hubs. These included a display of average consumption over time, disaggregation by end-uses/appliances, notifications when over a target level of consumption, and a balance between a simple, intuitive interface and options for deeper analytics. Other desired features for hubs included the ability to program with IFTTT commands, remote control away from home, and the ability to connect lots of devices. Regarding the latter, one hub reviewer remarked, "I wish these home automation companies would get on a standard. It is too confusing for consumers."

## Satisfaction with Performance

When adopters were satisfied with HEM product performance, they appreciated the ease of use (including intuitive software), accuracy, reliability, and of course the delivery of anticipated outcomes (e.g., increased comfort or energy savings). Most adopters who mentioned cost conveyed contentment with the value of the product, with the exception of some adopters of smart lights and plugs-switches who mentioned the cost was high for the value. Adopters of smart thermostats, load monitors, and in-home displays were also generally satisfied with their return on investment due to energy savings. Disappointments regarding performance features connectivity problems, causing unreliability; this was a pronounced and prevalent issue. There were also reports of poor quality hardware and poorly designed energy portals across multiple product categories.

Smart thermostat adopters were also generally satisfied with product performance in terms of the precision of programming and simplicity of scheduling. The intelligent learning function received mixed reviews. Some customers felt it was accurate in learning their preferences, whereas other complained about lags after adjustments and insufficient "smartness," one claiming there would be a negligible return on investment compared to programming a programmable-controllable thermostat. Other complaints included inaccuracies in temperature readings and erratic behavior.



Adopters of smart lights were sometimes disappointed in the flexibility of their products. Specifically, some smart lights can only be controlled remotely and not by conventional switches; this was problematic for some adopters and led to discontinued use. Adopters of some load monitors and in-home displays suspected inaccuracies in consumption information; for load monitors, the reported case pertained to a lack of ability to account for time-of-use rates when consumption was displayed in terms of cost. With in-home displays, there were also reports of delays in consumption information and limited usefulness (e.g., they did not directly identify opportunities to save energy/money).

## Implications

This comprehensive assessment of consumer adoption of HEMS yields important implications concerning potential roles for utilities in the future of the market. These implications can be discussed in terms of two general needs for increased consumer adoption and energy savings outcomes: education and marketing.

## Education

Consumer adoption of HEMS is lagging in part due to a lack of awareness of certain products (Figure 18). Even when consumers are aware of some products, they are usually unaware of the extensive variety of smart home products available and opportunities for product integration. Additionally, a few highly technical concepts (e.g., hubs, platforms, and protocols) are difficult for the average customer to grasp. A better understanding of all these things would help consumers navigate this space.

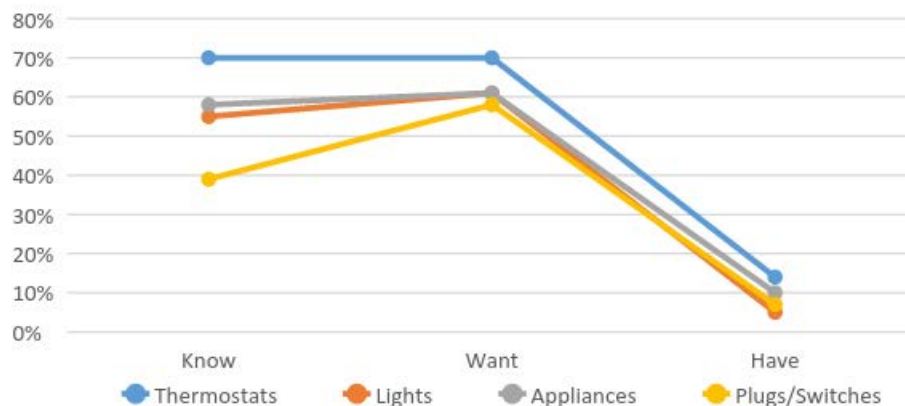


Figure 18: Survey responses regarding awareness, interest, and ownership of HEM products.

While some educational efforts should address the Knowledge Stage, introducing the technology to customers and filling those knowledge gaps identified in this research (e.g., *How does it work? Does it work with what I have at home?*), they should also address the Persuasion and Decision Stages, explaining differentiating features to help customers choose among products within a given category (e.g., via decisions

guides). Finally, to help get products into homes and to achieve energy-related benefits, education must continue after purchase into the Implementation Stage, supporting installation and setup, and informing customers about energy management use cases that will save energy (e.g., promoting "Leaving Home", "Vacation", or "Nighttime" scenarios that involve turning appliances off).

Other important considerations for educational communications include the use of user scenarios, videos, demonstrations, and hands-on opportunities. Visual communication is key to illustrate the complex relationships between products in a connected home. Videos can help demonstrate installation. Hands-on opportunities, including at demonstration sites and via product trials, can give customers confidence in their ability to successfully implement these new technologies.

## Use Cases

Use cases described in HEM product reviews on Amazon.com give insight into how early adopters are using these products, along with the implications for energy consumption. For example, smart thermostats were used: to help couple's compromise (or counter-control each other's behavior) with respect to managing their thermal comfort; to adjust the temperature remotely from bed; to monitor and control their home or second home while away or leasing it out, respectively; and to adjust the temperature before arriving home. Any of these use cases could result in increases or decreases in energy consumption depending on user behavior before adopting the smart thermostat.

Lighting was the predominant use case, not only for smart lights but also for smart plugs and switches. With plugs and switches the lighting uses were more utilitarian: easing access to inconveniently located switches/plugs; remote control away from home; scheduling on/off times in coordination with sunrise/sunset; and centralized control of multiple lights (and other devices). With smart lights, use cases were also about novelty, entertainment, and aesthetics: gift/fun for children; showing off to friends; and mood and decorative lighting. Use in the context of social relationships was featured for both plugs/switches and lights. Plugs and switches were used for taking care of pets, small children, teens, and older parents (monitoring their behavior and improving their comfort), whereas smart lights were used to entertain children and guests. Customers tended to use (or want) multiple smart plugs/switches or lights, not just one.

In-home displays and load monitors were most likely to be used explicitly for energy management purposes. For example, both were used to help determine sizing requirements for solar panels and a generator in one case). Customers also used them to monitor electricity production PV panels and consumption of electric vehicle charging and various other devices and appliances (including phantom power draw). Moreover, they harnessed this knowledge to curb energy use and save money on bills. Finally, hubs were touted for enabling whole home automation and one review highlighted the utility for persons with disabilities affecting their mobility.

## Interoperability

Product reviews revealed that customers wanted to integrate their HEM products with a variety of other products and platforms. The most frequently mentioned integration was with the Amazon Echo. Reviewers of the Belkin WeMo Switch were especially keen to integrate with the Echo, sometimes indicating this was a primary motivation for their smart plug purchase. Customers also wanted to use their smart thermostats and smart lights with the Echo. Wink was also popular; customers mentioned integrating (or wanting to integrate) smart thermostats, smart lights, and in-home displays into a Wink eco-system. Other desired integrations can be seen in Table 4.

Table 4: Desired Integrations with HEM Products

HEM Product	Desired Integrations
Smart Thermostats	Amazon Echo, HomeSeer, Wink, Comcast router, IFTTT
Smart Plugs/Switches	Amazon Echo
Smart Lights	Amazon Echo, Wink, Samsung SmartThings, other types of smart lights
Hubs	Blink camera, MyQ garage door opener, sensors, lights, Z-Wave, Nest, Siri, Harmony universal remote, Hunter Douglas blinds, Belkin outlets
In-home Displays	Z-Wave, ZigBee, Wink, multiple types of electricity meters

## Marketing

Findings from the consumer assessment have implications for which products should be marketed, how, and to whom in order to increase adoption of HEMS and associated energy savings. In terms of which products to market, there is potential to leverage more popular products in the smart home space to promote adoption of HEM products with more abstract value that tends to be more appreciated in the context of product integrations (e.g., hubs, smart plugs, switches, and lights). For example, HEM products that work with Nest or Amazon Echo may have a greater likelihood of uptake among the growing customer segment who already own these products.

In terms of how to market products, those products with a strong independent value proposition could be bundled with less popular/more abstract HEM products in a kit or via partial incentives (e.g., rebated hub and/or set of smart plugs/switches/lights with the purchase of a smart thermostat, doorbell, door lock, garage door opener, or security camera). Kits of multiple smart lights, switches, and/or plugs are also a promising approach per our findings that customers prefer more than one of these

products. It is crucial to frame products/offerings according to the three sets of consumer values identified in this research: protecting one's household; conserving resources; and nurturing one's family. Although energy savings was not paramount for most customers when considering smart home technology, it was of high importance to some, and it was virtually always appreciated as a secondary benefit.

Both the customer survey and retail studies suggest a variety of personal, housing, attitudinal and behavioral (e.g., technology adoption) characteristics that predict consumer awareness, interest, and ownership of HEM technology (Figure 19). By considering predictors of interest that do not also predict awareness or ownership (Figure 20), promising market segments are identified, for example, groups who were more interested in learning about HEMS in the survey but were no more (or perhaps even less) aware of and likely to own any of the following: smart thermostats, plugs, appliances or lights. For example, men were more aware of smart home technology and more likely to own, but no more interested than women. This suggests that current information outlets are accessed by men more than women, and educational strategies that address this gender knowledge gap could increase HEMS adoption among women (Shelton Group, 2015).

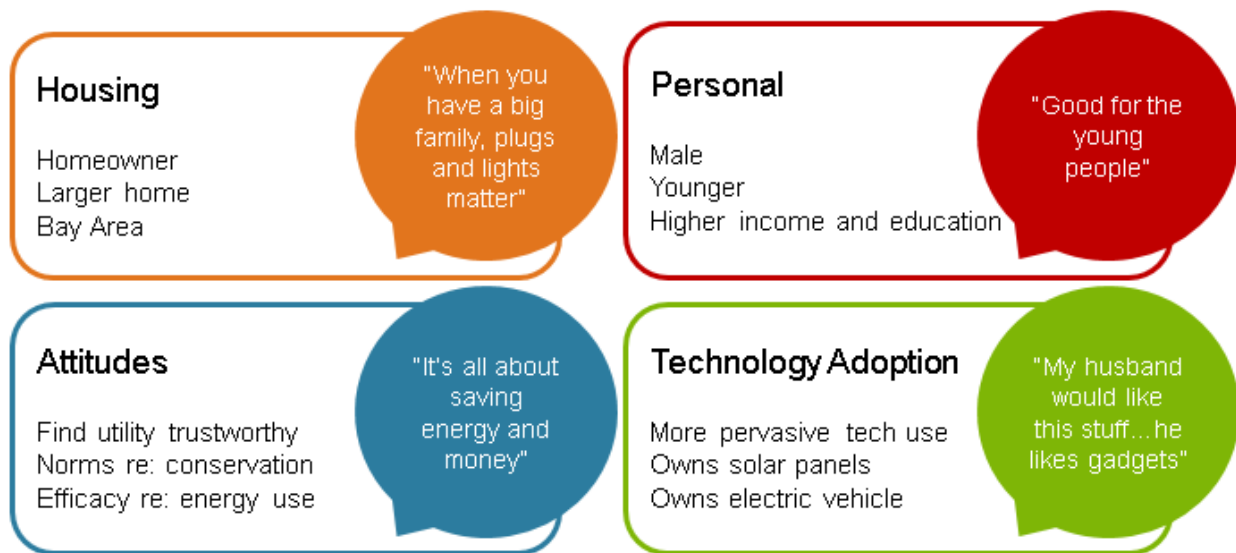


Figure 19: Customer characteristics identified in the survey that predict awareness, interest, and/or ownership, with supportive quotes from retail customers.

- **KNOWLEDGE:** *How familiar are you?*
  - Male
  - Higher income and education
  - Larger home
  - More pervasive tech use
  - Greater performance efficacy (feels competent to reduce/manage energy use)
- **PERSUASION:** *How much does the idea appeal to you?*
  - Younger
  - More pervasive tech use
  - Social norms about energy conservation
  - I find PG&E to be trustworthy
- **DECISION:** *Do you own a smart \_\_\_\_\_?*
  - Male
  - Homeowner
  - Higher income
  - More pervasive tech use; owns PV; owns PEV

Figure 20: Factors that differentially predict familiarity, appeal, and ownership of HEMS.

The home size was predictive of knowledge, but not persuasion or decision, indicating that barriers at the persuasion stage (e.g., insufficient value proposition) may be particularly important to address when marketing to large households. User scenarios that drive home the value of HEMS for large households could be leveraged in marketing efforts. The fact that customers with higher income are more knowledgeable and likely to own, but no less interested, drives home the gravity of cost as a barrier. Younger customers found HEMS more appealing, but they were no more likely to own, which may also imply the cost barrier.

Social norms of energy conservation and trust in the utility predicted persuasion but not a decision to adopt. These findings have interesting implications for the role of utilities in the future of HEMS. They suggest that involvement of the utility in customer-facing education and marketing, and increased marketing around energy management benefits of smart home technology, would promote adoption among some customer segments. In addition to segmenting for marketing purposes, customers with solar or electric vehicles and large households are excellent prospects for future pilot studies of HEMS due to unique opportunities for energy management.

## Recommendations

Home energy management (HEM) technologies have the potential to deliver a variety of benefits to both users and utilities. The products themselves can deliver demand reductions (e.g., through more efficient delivery of services such as heating, cooling, lighting, etc.), and can also support users to reduce or shift their load, saving both energy and money. Utility-facing services can support improved customer engagement, leverage demand-response opportunities, as well as drive cost reductions or revenue increases. Moreover, home energy management systems (HEMS) can provide further value to users in terms of protecting homes to make them safer and more secure, and fostering a more nurturing home environment through providing comfort, supporting caregiving, and facilitating cleanliness. Beyond this, HEMS also have the potential to educate consumers about how their decisions can impact their energy consumption and thus engender long-term behavioral changes that can positively impact energy use and grid stress. The benefits and opportunities HEMS offer are too great to ignore; it is therefore recommended that utilities should support the adoption and use of HEMS in their energy efficiency programs.

However, in an ever-evolving market, caution must be taken. Because consumers are being asked to invest in products and devices that they may not fully understand, do not fully trust, and which may not remain on the market in even a year's time, removing the potential risk for consumers should be a key consideration for developing HEMS program options. For example, should utilities choose to promote a product that becomes defunct, the damage to both the consumer-utility relationship and the success of the smart home market at large could potentially be irreparable. In order for utilities to maintain and elevate their position as a trusted energy advisor, therefore, simply promoting or selling products to customers will not suffice; new program models are needed to help mitigate the potential risk to customers, while helping educate them on how best to use these products to add value and savings both to themselves and the electricity grid at large.

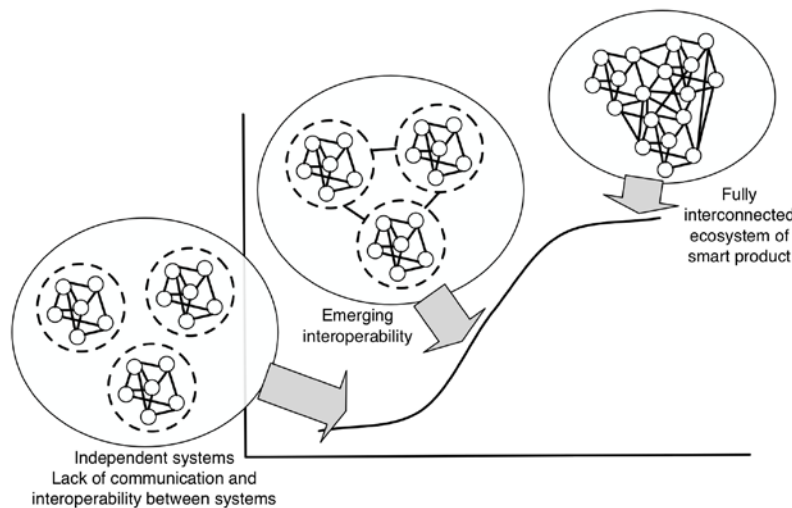
Key elements of potential new program models should include (1) leveraging the utility's large customer base and their position as a trusted advisor to educate or "upskill" consumers about HEMS, ultimately enabling them to participate in the IoT and smart home space successfully and helping to mitigate fears of data security; (2) deeming and promoting a set of criteria for HEM products and systems rather than promoting specific products themselves, ultimately enabling consumer choice while accounting for a rapidly changing market place; (3) including and promoting product replacement policies that account for the potential discontinuation of smart home products purchased for home energy management and used in demand side management, ultimately helping to mitigate customer risk.

While it is still somewhat unclear what the future might hold for HEM technologies and their adoption, this research gives rise to the following six recommendations around how best to engage with these technologies in the current market.

## Think Big

The research presented in this report as well as prior work (Karlin et al., 2013; 2015) is indicative of the emerging shift from independent products working separately to energy management systems incorporating multiple products working together. The anticipated growth in the smart home and Internet of Things market and the alliances already emerging whereby smart home platforms incorporate both HEM technologies, and non-energy related smart home devices suggest that the future of HEMS could be highly intertwined with the wider connected home.

The transition from independent products to a fully interconnected smart home is still underway. While interoperability challenges still exist today, there is action underway to support the development of standard protocols for addressing smart devices (e.g. the Hypercat consortium and standard driving secure and interoperable Internet of Things technologies), software solutions that can interoperate with multiple devices to analyze data from disparate sources (e.g. Autogrid systems who recently raised \$20m in venture capital financing to make sense of data coming from millions of devices (Lacey, 2015), and communication networks to allow Internet of Things technologies to connect to a wide range of other systems, networks, and data (e.g., the Samsung/SK Telecom roll out of a public Internet of Things network in South Korea (Irving, 2016)). These actions may help drive increased product-to-product communication, and shift the smart home market further along the curve toward fully interconnected product ecosystems (see Figure 21), a move that would align with customer desires for technologies in their home to work together



(Daws, 2016).

Figure 21: Curve of Interconnected Product Ecosystems

However, the evolution of an infrastructure backbone to deliver interoperability is not yet evident. While standardization would ensure that companies develop all their products and portfolios according to one common API, this process can take much time and require lengthy consortium discussions involving many different companies. Some companies are instead working to develop common APIs so that any product development company can



provide the software to plug a product into a common backbone, enabling it to communicate with a central smart home platform to share data and offer control. Other companies are taking a “first to market” approach, dictating a closed infrastructure and ensuring tight control over the products that can integrate into the smart home platform.

The resultant uncertainty around the specific direction that interoperability might take creates uncertainty in terms of what products, companies, and partnerships may prevail, and how these products will interact and share data in the near future. Traditional “widget” solutions become risky as product longevity is questioned, particularly as it relates to the software required to support its “smart” features.

This means that thinking about individual savings from isolated products is no longer fit for purpose; as smart devices, collecting granular data about use and enabling remote and rule-based control, are increasingly able to communicate with other smart devices, bigger opportunities for smarter whole home energy management (beyond just smart products) are becoming realistic.

Thus, to fully leverage the potential of the larger smart home ecosystem while taking into consideration the effects of this rapid market growth, utilities should shift their focus from individual products to interconnected systems. While at face value the cost-effectiveness of this will be hard to justify with uncertain energy benefits for many products, utilities can focus on products that do offer these benefits, deemphasize focus on those products that have no or negative impact on energy, and consider the potential benefits beyond first order savings that increased interoperability and access to big data sets can deliver.

## Explore Implications of Data

Data plays a key role in supporting real-time demand flexibility and optimization. While this has been explored for specific products delivering specific services such as frequency keeping (e.g., dynamic management of air handling units (University of East Anglia, 2015) and artificial intelligence to optimize heating and cooling in commercial (University of East Anglia, 2015) and residential applications (Nest, 2016) interconnected HEM technologies offer the potential to optimize demand across the entire system.

However, to optimize across, a system relies on data from each part of that system, which may sit in silos that are hard to access. Even within a single home, there may be a range of smart hardware developed by different manufacturers, and sharing this data may present challenges. Some manufacturers may not be willing to share their data with others, particularly if it delivers a revenue stream. Even if they could, interoperability issues may exist today due to a lack of standardization in how different devices store and manage data, and how they are addressed and process commands.

In addition to these challenges, there are questions about the availability of data; in some instances, data about energy demands may not even be collected (e.g., smart lights tend only provide status information), and in others, the data may be collected but not stored. Additionally, there are smart home products embedding intelligence within devices (rather

than cloud) making it unclear how much data will remain within customers homes (and be communicated between products directly) and how much will be sent to the cloud and available for others, outside of the home (e.g., remote access from users, access by utilities) to use.

Further questions arise related to ownership and access; the sort of data collected by HEM technologies could give rise to highly personal information about occupancy and activity patterns, and many people are not equipped with the skills or knowledge required to understand these new and complex privacy and agency issues. As the value of "smart" homes, workplaces, and cities increasingly depends on access to and use of personal data, there needs to be a greater consideration around how we manage this data and protect consumers in the emerging "smart" new era. However, the resolution of these issues and the ability to leverage highly granular data from across smart home systems could deliver a wide range of benefits to both users and utilities. Utilities are well placed to engage consumers around these issues and should consider their role as the trusted advisor in the smart home space.

## Revisit Benefits – Savings and Beyond

One of the most obvious benefits that can be leveraged from increased information and control is the ability to more efficiently manage demand to deliver energy (and cost) savings. In fact, the ability to demonstrate these savings is key to implementing programs to get HEM technologies into homes. Recent legislation in California (e.g., AB32, SB350, AB793) has created an environment in which regulated utilities are both mandated and incentivized to engage consumers in demand-side management. While the utilities have successfully tested and pre-calculated (or deemed) energy savings for products such as appliances and light bulbs, the energy savings that can be achieved through HEM technologies is more difficult to prove since savings vary as a function of user interaction.

For products in which deemed savings may not be possible, savings calculations can still be made ex-post through in-home behavioral pilots. To promote products (or a set of criteria for products) through deemed savings, testing of these products is required. While considerable measurement and verification efforts have been spent on piloting smart thermostats to determine their savings potential, other smart home products have received much less attention and scrutiny.

However, the characteristics of HEM technologies and systems present interesting challenges to this model of promotion. For example, smart lights may deliver savings resulting from both the shift in bulb technology (e.g. incandescent or halogen to LED) as well as savings from changes in operation stemming from the increased data and control functionalities they provide users; these will require disentangling to determine the true savings potential from smart lights. Other products, such as hubs, are enabling technologies, making it even more difficult to determine their unique contribution to savings outcomes.

As the market shifts from individual products to interconnected products and systems, serious consideration should be given to piloting around measured savings from product

*ecosystems*, or the set of connected and communicating products and systems that work in tandem for energy savings. Because determining energy savings for every variation of product connectivity (e.g., a smart hub plus smart thermostat, or smart lights plus smart appliances, etc.) is unfeasible, more research is required to determine the best way to define and measure savings from these connected products and systems. It may be worth utilities exploring opportunities to use data from HEM technologies to identify impacts at the individual household level over time, as well as determining the potential for data across a service territory to be used to claim savings for devices incentivized in a particular region.

To support and inform this process of calculating savings and exploring the wider reaching impact of HEMS, further research is needed into how best to collect, measure, and leverage the backend data (e.g., white-labeling, or leveraging backend data through a secure software platform), as well as a deeper look into data security and consumer trust issues at large (e.g., what's happening with all that data). The shift toward data-driven demand management and impact evaluation is relatively new, and further research would be required to explore the feasibility of connecting devices and sharing data, to address concerns about ownership and use of data, and to remove risks related to security.

Beyond delivering savings and providing additional measurement and verification opportunities, HEMS can be used to support the integration of renewable energy. The quantity of distributed solar photovoltaics (PV) has grown exponentially across many nations, in part due to the global push for renewable energy coupled with financial incentives such as feed-in tariffs. This growth, which by February 2016 equated to one million solar PV systems installed in the US to date, largely residential (Greentech Media, 2016), is set to continue due to economic considerations (e.g., PV prices dropping by 50% every 13 months and battery prices continuing to decrease as manufacturing volume increases), social incentives (e.g., the emerging desire among communities to enhance local resilience through ownership of local generation assets), and policy shifts (e.g., the recent legislation in San Francisco mandating all new homes to have solar pre-installed).

The ability to integrate distributed energy generation with HEMS would enable households to manage their demand to maximize the quantity of power generation consumed onsite. This would maximize the financial return of microgeneration systems, as well as reduce demands on the grid. The HEMS/PV space has already seen some partnerships emerging, such as SolarCity teaming up with Nest (Lacey, 2015) to explore the pairing of smart thermostats and PV, and SunPower investing \$20M in Tendril (Tweed, 2014) to link solar with home energy management to provide options to customer enabling them to set their systems to save more money, use more energy to align better with solar production, or a combination of the two.

HEMS also presents an opportunity for the utility to increase customer satisfaction and trust. Smart homes enable consumers to interact with energy and appliances in new and complex ways. Many customers are currently not equipped with the knowledge and skills necessary to engage with and benefit from this market. The utility, as a familiar entity and expert in this space, can come alongside the customer to support their journey toward the connected home of the future. Because the HEMS survey showed that consumer trust in their utility correlated with their interest in HEMS, and because key non-utility market stakeholders are looking to the utility to help catalyze awareness and adoption among their large customer

bases, utilities are in a unique position both to cement their position as a 'trusted energy advisor' and help lead and define a technological transformation. For the utility to harness this opportunity while also meeting their other goals, however, it is crucial to support customers at all stages of the innovation-decision process and to understand and promote use cases of HEMS that will mutually benefit the customer and the utility.

## Support the Customer Journey

The consumer research showed that many customers are largely unfamiliar with smart home technology. Once introduced, they struggle to understand how it works, do not always perceive its value, and are relatively less interested in its energy management functionalities. Even when convinced of the value of HEMS, customers face a myriad of barriers when it comes to the decision to adopt, including doubts about performance, high cost, and data security.

Those who adopt in the face of these barriers are often confronted with the realities of poor performance, unreliability, and lack of value derived. These hurdles on the path to widespread consumer adoption of HEMS, though challenging, are not impossible to overcome. Having identified the various obstacles along the customer journey (e.g., lack of awareness in the Knowledge Stage, lack of perceived value in Persuasion Stage, etc.), the utility can intervene to support customers each step of the way.

### Knowledge Stage

Obstacles at the Knowledge Stage include a void of adequate information available to consumers to help them navigate the smart home market. The utility is ideally situated to act as a clearinghouse of information to support consumers, increasing awareness and understanding of HEMS. As a trusted energy advisor, utilities should provide resources that address consumer knowledge gaps, including what HEMS can do, which products are required for particular services, how HEMS work, compatibility specs, how-to information on installation and setup. Resources should also strive to clarify the complex concepts of platforms, protocols, and hubs.

Manifestations of these recommendations include demonstration projects that provide customers with an experiential introduction to HEMS. Visual displays and opportunities for hands-on interactions are crucial to support customers in learning about the systematic relationships and complex concepts inherent in HEMS. In addition to physical spaces for HEMS education, which are necessarily limited in terms of customer reach, a virtual space that illustrates HEMS via graphics and videos and provides comprehensive and up-to-date information would be a valuable strategy to support customers at the Knowledge Stage and beyond. Finally, the utility should develop training programs regarding HEMS for employees who interact with customers.

### Persuasion Stage

Educating customers is only the first step in galvanizing adoption. The customer must then be persuaded of the value of HEMS for their household and lifestyle.

Effectively communicating these value propositions is key to supporting customers at the Persuasion Stage. Moreover, a strong enough value proposition can overcome some of the barriers to adoption (e.g., data privacy concerns).

Strong value propositions of smart home technology currently center on protecting one's household and nurturing one's family. When customers do not perceive these deeper values, they often see smart home products as unnecessary, excessive, gimmicky, and promoting laziness - an image currently promoted by marketing that over-emphasizes convenience for its sake. Greater emphasis on the practical values of energy conservation and independence, personal control, and financial responsibility could mitigate these negative perceptions and give HEMS a more prominent place in the smart home space.

Utilities can leverage use cases, systems, and products with a strong independent value proposition to convey the value of HEMS. Use cases illustrate the value of HEM products in a highly relatable way and convey the value of multiple integrated products and systems. For example, some HEM products are valued more in the context of multiple products of the same type (e.g., multiple smart lights, switches, or plugs) and some are valued more in the context of having multiple HEM product categories (e.g., hubs and in-home displays).

Highlighting the HEM functionalities of connected and potentially connected products enjoying relative popularity (e.g., Nest, Echo, Ring doorbell, solar panels, and electric vehicles) and/or the interoperability of those products with other HEM products is also a promising strategy for increasing HEMS adoption. Specific applications of these strategies include smart home demonstrations that focus on systems and use cases, targeting marketing to customers with smart home products, and product bundling and kits.

## Decision Stage

The biggest challenges to supporting customers while increasing HEMS adoption lie at the Decision Stage. The consumer research identified nine barriers at this stage: prohibitive cost, concerns about privacy and security, effort required, concerns about performance, lack of knowledge, lack of foundational technology, redundancy with other products/services, structural incompatibility, and renting. Educational strategies continue to be crucial at this stage; for example, to address anxieties about data security and effortful implementation, and help consumers differentiate among products and systems that deliver similar services. Hands-on demonstrations, opportunities to borrow HEM products from the utility, and an educational web portal are all applicable here.

Intervening at the point of purchase is key. The research indicates that many customers do not know where to purchase smart home products, to begin with. Early adopters who buy at retailers are typically going to home improvement stores, but these stores are not showcasing HEMS via the kind of innovative and interactive displays that this research suggests are most useful. Utilities should partner with

major home improvement retailers to leverage both organizations' relationships with customers. A number of utilities currently have a product marketplace to support consumers purchase household appliances. However, smart home products are not generally featured in the marketplace. This presents not only a missed opportunity, but also a sizeable challenge because the appropriate smart home product depends on relational features (e.g. how it interacts with other smart products already owned) in addition to the static features of cost or saving potential.

Two other strategies are particularly promising for increasing conversions at the Decision Stage: incentives and product bundling. The cost barrier to HEMS is huge for the majority of customers. Incentives will help address this issue, especially for hubs, a keystone HEM product that has no independent value proposition for customers yet carries a high price tag. Product bundling can also help subsidize HEM products with insufficient independent value propositions. For example, some companies provide kits of multiple smart lights, switches, or plugs, sometimes along with a hub, which is a promising approach per our findings that customers prefer more than one of these products. Product bundling around valued use cases makes it easier for customers to adopt systems because it takes some of the work out of the Decision Stage.

## Implementation and Confirmation Stages

Consumer research revealed that many HEM products are difficult (or perceived as difficult) to install, setup, and update and some are not delivering the value and performance that the adopters expected. Wireless connectivity, in particular, is problematic, requiring multiple attempts to install/setup and continued problems with unreliability. Furthermore, setting up a system of integrated, coordinating products is where the real opportunities for HEMS lie, but also the heaviest demand on customers when it comes to installation and setup. Utilities are uniquely placed to support customers in these later stages of adoption.

Strategies already mentioned are relevant here, including educating customers about installation and setup via hands-on demonstration sites, finding partnerships that can offer installation service or support, training utility customer service staff, and providing online resources. Utilities should also consider how they can mitigate the risks customers take when entering this emerging and rapidly changing market.

## Create and Test Use Cases

Although some smart home products have clear, independent value propositions, such that they are appealing as standalone products in a conventional retail display, this research suggests that many customers better appreciate the value of HEM technologies when their function is illustrated through creative demonstrations of use cases or user scenarios. This is especially the case for integrations of multiple products and products with abstract or ambiguous functions, such as hubs and smart lights and switches.



Developing user scenarios can be extremely useful in giving consumers a more accessible vision of what the future may look like with a home energy management product than descriptors of the technical specification of products and their features. For example, the technical description of the features of a thermostat are perfectly understandable to technology-affine people, but will not necessarily spark their motivation for installing one in their house.

Instead, seeing a scenario about how smart thermostats automatically increase the temperature in the morning from sleeping time temperature (cooler setting) to day activities temperature (warmer setting) so that the room is perfectly comfortable when the family gets out of bed, may trigger a memory of when the temperature was not at a comfortable level at a time the user had to go out of bed, for example during a cold winter. Using storytelling to put HEM technologies into an everyday context can help paint a picture for customers and enable them to envision using HEM products and services in a way that benefits their everyday lives while simultaneously delivering energy savings.

Consumer research has demonstrated that energy management is often perceived by customers as a secondary benefit of smart home technology that offers primary values related to protecting one's household and nurturing one's family. Therefore, the broader smart home ecosystem that includes products without any energy implications is important to consider in efforts to increase HEMS adoption. Products like smart cameras, doorbells, door locks and garage door openers have independent value propositions that customers easily understand and appreciate. Leveraging the popularity of these products and related mainstream values as a 'hook' for HEMS adoption is a significant opportunity.

One way to leverage mainstream values and popular products with a strong independent value proposition is by bundling products (and thereby bundling values). Less popular products with potentially important HEM functionalities could be combined with 'hook' products in kits or via partial incentives (e.g., rebated hub and/or HEMS kit with the purchase of 'hook' product). Product bundles can be framed according to values and user scenarios. For example, bundling home security and energy management technologies leverages popular values (e.g., protecting one's household), and many of the triggers and capabilities that enable security services can also be used for energy management (e.g., leaving home as a trigger for door locks, security cameras, and window/door sensors, as well as smart thermostats, lights, and plugs/switches). HEM use cases to be highlighted include leaving home, nighttime, and going on vacation. Hook products could include smart security cameras, doorbells, door locks, garage door openers.

"Smart Care Package" kits, leveraging the value of nurturing one's family, could feature efficient and convenient thermal comfort, cooking, cleaning, and/or caregiving. Hook products could include smart cooking and cleaning appliances, smart thermostats, and smart devices related to infants and pets. Relevant user scenarios include Off to work, Evening Routine, and Nighttime (see Appendix H for more details).



## Establish Cross-Sector Partnerships

In general, retailers are not currently engaging customers with smart home technology. For example, only 8% of the customer survey respondents had heard about smart home technology from retailers; most were exposed to the idea via mass media. This presents a huge opportunity for utilities to partner with retailers to leverage the unique relationship each has with customers.

Utilities should support retailers who are already innovating in this space. For example, retailers who are pioneering innovative smart home demonstrations are quite successful in terms of supporting customers at the Knowledge and Persuasion Stages of smart home adoption more broadly. Utilities partnering with these retailers can ensure energy management becomes a more prominent part of their education and marketing efforts, which is currently dominated by non-HEM related smart home technologies. Specifically, utilities can encourage retailers to emphasize systems over individual products in their displays and help them showcase use cases that feature energy and cost savings in addition to the values of protecting one's household and nurturing one's family. Utilities could also support retailers in developing decision guides that help customers determine which products would meet their HEM needs.

Partnering with home improvement stores would be particularly strategic in terms of supporting customers in the Decision, Implementation, and Confirmation Stages. In the utility customer survey, most early HEMS adopters who shopped at retailers (as opposed to online) purchased from home improvement stores. Large home improvement retailers also have the infrastructure to support customers after their purchase, with installation, setup, and on-going customer service.

# Conclusion

With legislation in California, and beyond, now necessitating that regulated utilities take quick action regarding HEMS in the very near term (and demonstrate quick wins), many utilities are not in a position to wait out the market until it's more fully developed before engaging with and promoting it. Given this consideration, the most pressing task at hand for many utilities is determining which products, platforms, and systems add the most value in the short term and establishing programs that can help drive their adoption while keeping in mind the long-term considerations and pathways outlined above. With that in mind, the following recommendations outline how utilities should proceed in the near to immediate term.

**Incentivize and promote** the products, platforms, and systems that are most flexible in terms of interoperability and compatibility. Once customers have a hub or a voice controller or discover IFTTT, they are looking (or open) to growing their system. Instead of 'picking a winner,' identify a set of criteria for rebate-eligible products to give customers a choice and support follow through via through platforms like an online marketplace.

**Bundle products by value propositions** in kits that help customers understand their usefulness. Key devices or systems can help get other products into the home, particularly those that only show their value when they are part of a system. User scenarios can be used both to determine the best groupings of products to bundle, and help educate customers on their value.

Create an **education campaign** to engage and upskill customers beyond just filling out a rebate form. Regardless of the product(s) or system(s) being deemed or promoted, there needs to exist a highly marketed platform that explains the smart home space and guide customers through it.

Create **training resources and guides** for customer service employees and other staff to strengthen and highlight the utility's position as trusted energy advisor.

Determine potential pathways to **assist in the installation and deployment** of products (currently identified through user research as a significant barrier) to help the customer along the entire user journey.

Begin to **develop pilots to test energy savings of products beyond the smart thermostat**, in particular, remote monitoring devices, plugs and switches, and integrated home energy management systems. Pilots should include how customers interact with these products as well as if and how their behavior changes.

**Evaluate** the effectiveness of efforts through user research on statistically valid samples of customers to determine what's working and what's not, as well as to inform the design of future programs and efforts.

In the longer term, there are further issues that will need to be addressed. The current approach for determining the energy savings potential of products may struggle in an environment where: (1) many similar products differ according to a number of features, which may drive differences in savings, and (2) where the true potential depends on a combination of technology and behavior. Utilities may need to go beyond just getting HEM technologies into the home and explore how occupants use them, and how this can be optimized to drive energy benefits.

Additionally, beyond the potential for household energy benefits, HEMS offer an opportunity to support dynamic demand management. However, most products do not focus on this potential or provide a way to integrate utility signals such as time-of-use or critical-peak pricing. As the smart home market develops and the grid need for dynamic demand grows, utilities would be well served to explore mechanisms to bring together home energy management with grid management.

Through engaging with HEMS today in a way that supports both the customer journey and the wider market development, utilities can help grow the potential of smart home technology, laying the foundations to leverage energy reduction and load shifting capabilities at scale in the smart grid of the future.

# Appendix A: Industry Interview Protocol

## Interview Protocol

The following questions will guide the semi-structured interview towards addressing the research goals outlined above. Follow-up questions will be asked accordingly.

### 1) Opportunities:

*What are your goals in this space? What opportunities do you see?*

- **Motivations:** What is the big problem your organization is looking to solve using HEMS?
- **Goals:** How can your Connected Home initiatives help solve this problem? What does success look like for these initiatives?
- **Consumer engagement:** How engaged are consumers with your (or the industry's) existing initiatives in this space?
- **External stakeholder roles:** Where does the utility fit into your goals and initiatives in this space? How important are the other stakeholders in the HEMS space to the evolution and success of the market?

### 2) Options:

*What are your current initiatives? What are your plans for the future?*

- **Current Initiatives:** What is your current go-to-market strategy? What is working well/not so well with this strategy?
- **Future plans:** What are your plans for advancing your initiatives in the next 3-5 years?
- **Partnerships:** How are your current partnerships in this space-faring? What other partnerships would help you achieve your goals?
- **External stakeholder roles:** Has your organization engaged with a utility (or any other external stakeholder) before in these or other initiatives? Was it successful?

### 3) Obstacles:

*What are your main obstacles in the market? How can these obstacles be overcome?*

- **Identifying obstacles:** What are some of your known obstacles, either on an organizational or industry level, for moving forward on your initiatives?
- **Efforts to overcome obstacles:** What efforts (if any) are you making to resolve some of those obstacles? Do you see any organizations working to overcome these obstacles in a promising way?
- **External stakeholder roles:** What role should the utility play in addressing these obstacles? What role should other stakeholders play?

# Appendix B: Industry Survey Protocol

## BENEFITS OF SMART HOME TECHNOLOGY

1. Please rate the importance of the following features for wide-spread adoption of smart home technology.  
(Randomized)
  - Remote monitoring and control
  - Scheduling the operation of devices
  - Enabling devices to automatically adjust based on habits and preferences
  - Enabling devices to automatically adjust their operation in response to changes in energy price
  - Allowing third parties to adjust devices in order to save energy or cut peak demand
  - Providing personalized tips and notifications
  - Providing real-time, or near real-time, energy feedback
  - Identifying which devices use the most energy
  - Communicating with other household devices
  - Other (Please Specify): \_\_\_\_\_
2. What do you see as the greatest benefit(s) of smart home technology for consumers?  
[Open ended]
3. What do you see as the greatest benefit(s) of smart home technology for society at large?  
[Open ended]

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## BARRIERS TO SMART HOME TECHNOLOGY

4. Please rate the significance of the following barriers to smart home adoption.  
[Not significant at all ; A little significant; Somewhat significant; Very significant]
  - Customer awareness
  - Cost
  - Interoperability
  - Value proposition
  - Security risks
  - Data sharing
  - Complexity
  - Usability
  - Other (please specify): \_\_\_\_\_
5. Please share any ideas you have to overcome these barriers.  
[Open ended]
  - Customer awareness
  - Cost

- Interoperability
- Value proposition
- Security risks
- Data sharing
- Complexity
- Usability
- Other (please specify): \_\_\_\_\_

---

## TRENDS AND INNOVATIONS IN SMART HOME TECHNOLOGY

6. What do you think the smart home market will look like in the next 3-5 years?  
[Open ended]
7. Who and what are the key products, players, and protocols in the smart home space?  
[Open ended]
  - Products (e.g., Nest, WeMo)
  - Players (e.g., Google, Tendril)
  - Protocols (e.g., Zigbee, ifft)

---

## PARTNERSHIPS & ROLE OF UTILITY

8. Please describe any partnerships your organization has established in the smart home space.  
[Open ended]
9. What further partnerships would your organization be interested in pursuing in the smart home space?  
[Open ended]
10. What role do you think utilities should play with regards to smart home technology?  
[Open ended]
11. Is there anything else you would like to share with us at this time?  
[Open ended]

---

## THANK YOU!

Thank you for your responses! As a reminder, no individual name or organization will be identified with their responses in our published report. However, we'd love to know more information about you so we can better situate your role within the space. If you're comfortable doing so, please list your organization and title below.

12. Your organization / company:

[Open end]

13. Your title:

[Open end]

14. Finally, we would like to include a list at the end of our report, thanking all of the organizations who participated. Do we have permission to include the name of your organization in this list?

☐ Yes

☐ No

☐ I would like to speak further about this. Please contact me at the following email address:

\_\_\_\_\_



## Appendix C: Product Coding Guide

<b>PRODUCT INFO</b>	<b>Purpose: to provide overarching information through which the product can be identified by future users of this information</b>
<i>Code</i>	<i>Overview</i>
Developer/Make	Name of company or organization that manufactures the HEM product (e.g., Belkin)
Model	Full name of HEM product (e.g., WeMo Insight switch)
Date Coded	Date that HEM product was coded
Cost	Cost to purchase the product. If there is a range, list the manufacturer's suggested retail price (MSRP)
Cost of Service	Cost of the service required to operate the product (e.g., \$10/month) Note: For some products, there may be no service cost
Functions lost with free service	If a free service is available, list the functions that are lost from the paid service to the free service
Version/Model number	Version of HEM product (e.g. first generation, second generation) or model number
Demographic - utility	Is the product's target market the utility - e.g. is the product being sold directly to utilities
Demographic - consumer	Is the product's target market the end user/consumer - e.g. is the product being sold directly to the public
<b>PRODUCT CATEGORY</b>	<b>Purpose: to identify the various smart hardware and user interface components that are included in the product/product package. Note that software platforms are not included here - those platforms to which particular HEM products/technologies connect are noted in the "Software" coding category.</b>
<i>Code</i>	<i>Overview</i>
Smart appliance	Does product include smart appliance?
Smart thermostat	Does product include a smart thermostat?
Smart lighting	Does product include smart lighting?
Smart plug	Does product include smart plug(s)?
Smart hub	Does product include a smart hub?
In home display	Does product include a separate home display?
Energy portal	Does product include an energy portal?
Load monitor	Does product include load monitor?
Embedded Display	Does the product have an embedded display?

<b>HARDWARE</b>	<b>Purpose: to define the hardware components of the HEM product that identify how it delivers functionality.</b>
<i>Code</i>	<i>Overview</i>
Traditional Features	Note down some of the product specifications that determine its quality
Sensors - Power	Does the device sense power consumption?
Sensors - Temperature	Does the device sense temperature?
Sensors - Humidity	Does the device sense humidity?
Sensors - Motion	Does the device sense motion/movement (e.g. to identify whether people are in a particular room in the home)?
Sensors - Light	Does the device sense ambient light?
Sensors - Other	Does the device sense something else not listed above? If so, what?
Detects - Occupancy	Does the device detect occupancy (e.g. whether or not the user is home or away)?
Detects - Location	Does the device detect how close/far the user is from the device?
Actuation - on/off	Does device have an on/off switch (e.g. does it enable the users to control the device by turning in on and off)
Actuation - dimming	Does the device have a dimmer switch (e.g. does it enable users to dim the device; appropriate for smart lights only)?
Actuation - setting specific mode	Does device have the ability to control for a particular mode (e.g. for smart thermostats can you select fan, heating, etc.)?
Actuation - setting specific mode - what	Describe how the device enables specific modes to be set/what those modes are
Power source	Describe how the device is powered

<b>COMMUNICATION</b>	<b>Purpose: to understand how the product communicates and how it connects into part of a larger HEM ecosystem</b>
<i>Code</i>	<i>Overview</i>
Product-system interaction	Provide an open-ended description of how product connects into the smart-home ecosystem
Additional Hub/gateway required	Does product require a hub to communicate (e.g. that ISN'T included as part of the product package being coded; e.g. Belkin WeMo Smart LED bulb requires the user to already have a WeMo Link)
Hub/gateway required - specify	If the product requires a hub (e.g. one that doesn't come with the product), specify which hub it requires
Home Wi-Fi network required	Can the product still provide functionality if there is no access to a home WiFi network and if so, are functionalities lost?
Protocol - Bluetooth	Does this device use Bluetooth as a communications protocol?
Protocol - Bluetooth low energy	Does this device use Bluetooth low energy as a communications protocol?
Protocol - Wi-Fi	Does this device use Wi-Fi as a communications protocol?
Protocol - ZigBee	Does this device use ZigBee as a communications protocol?
Protocol - Z-Wave	Does this device use Z-Wave as a communications protocol?
Protocol - Thread	Does this device use Thread as a communications protocol?
Protocol - Insteon	Does this device use Insteon as a communications protocol?
Protocol - X-10 (powerline)	Does this device use X-10 as a communications protocol?
Protocol - Ethernet	Does this device use Ethernet to communicate?
Protocol - Other	If the device uses a communications protocol not listed above, list it here

<b>SOFTWARE</b>	<b>Purpose: to identify which software platforms (smart home platforms and other supporting software platforms) the HEM product connects into to provide added functionality</b>
<i>Code</i>	<i>Overview</i>
Works with Nest	Does the device interact with this platform
WeMo	Does the device interact with this platform
SmartThings	Does the device interact with this platform
Wink/Quirky	Does the device interact with this platform
HomeKit	Does the device interact with this platform
Iris	Does the device interact with this platform
Other Platform	Does the device connect to a platform not listed above? If so, describe here
IFTTT Compatible	Is the device compatible with the IFTTT app/platform?
Yonomi Compatible	Is the device compatible with the Yonomi app/platform?
Energy portal - which ones	List all product's energy portals (apps and web interfaces)
Works with iOS	Does the product app work on iOS devices?
Works with Android	Does the product app work on Android devices?
Other OS - specify	Does the product app work on an OS not listed above? If so, list here
Local interaction	Describe whether there are any other opportunities to interact with system (e.g. physical button, voice control, via larger eco-system)

<b>INFORMATION - FEEDBACK</b>	<b>Purpose: to provide additional information about the information functionality of the HEM product (focus on feedback)</b>
<i>Code</i>	<i>Overview</i>
Feedback	Does the system provide feedback?
Feedback - what	What feedback is provided?
Feedback - where	Indicate what HEM product is getting data that is used to provide feedback
Real-time feedback	Is any real-time feedback (e.g. feedback at the actual time energy use/appliance use is taking place) provided?
Historic use	Describe what (if any) historical use data is provided, including the temporal granularity of the information?
Predictive use	Describe how the HEM product presents information about predictive use
Comparison	Does the HEM product/system present comparisons between user's information and some standard/baseline?
Comparison type	What standards/baseline are used and how are they established?
Electricity production	How does the HEM product/system present feedback about the user's electricity production, e.g. from their solar system?
<b>INFORMATION - PROMPTS</b>	<b>Purpose: to provide additional information about the information functionality of the HEM product (focus on non-feedback)</b>
<i>Code</i>	<i>Overview</i>
Prompts / notification	Does the HEM product push information to the user in the form of a prompt? (e.g. notifications)
Prompts / notification type	What information is provided and how is it provided to users?
Advice	Does the product provide users with advice?
Advice type	What and how does the HEM product present recommendations to the user?
Other information	Does it provide any other information to users
Other information - what	What other information is provided to users (e.g. information about the price of electricity)?
<b>CONTROL</b>	<b>Purpose: to identify how the HEM product provides control functionality to end users</b>
<i>Code</i>	<i>Overview</i>
Remote control	Does the HEM product enable the user to control devices remotely?
Remote control - how	How does the HEM product enable the user to control devices remotely?
Scheduled Automation	Does the product enable the user to schedule the energy use of the household device(s)?

Scheduled Automation - how	How does the product enable the user to schedule the energy use of the household device(s)?
Rule-Based Automation	Does the HEM product enables the user to create rules for automating?
Rule-Based Automation - how	If the product enables the user to create rules for automating household devices, what kind of rules can the user set?
Learning	Does product optimize appliance use in some way, e.g. by learning?
Learning - how	How does the product optimize the energy use of itself/ device(s)?

<b>UTILITY INTERACTION</b>	<b>Purpose: to explore how the utility can interact with the system</b>
<i>Code</i>	<i>Overview</i>
Utility partnerships	Describe any utility partnerships the product already has (e.g. who are the current utility clients for the product); the extent to which the product/app can be customized for the utility; and how utilities interact with the product
DR control	Does the HEM product enable the energy service provider to control the user's energy-consuming household devices during peak events?
<b>ADDITIONAL BENEFITS</b>	<b>Purpose: to identify whether the HEM product provides users with benefits in addition to energy management/cost savings</b>
<i>Code</i>	<i>Overview</i>
Fault detection	Does the HEM product/system have the ability to give the user more insight into problems with electrical devices/equipment?
Convenience	Does the HEM product/system have the ability to make household and personal tasks easier for the user to perform?
Comfort	Does the HEM product/system have the ability to make the user's home environment more comfortable
Safety/security	Does the HEM product/system have the ability to protect the user and the user's home from harm/intruders?
<b>USABILITY</b>	<b>Purpose: to explore how usable (plug and play) the product is</b>
<i>Code</i>	<i>Overview</i>
Installation	Whether the product is plug and play, or whether it needs professional installation, or somewhere in between.
Removal	Whether the product can be removed by householders, or whether it needs professional removal or somewhere in between.
Support	What type of support (e.g. tech support) is available for users

## Appendix D: HEM Product List

Developer / Make	Model	Cost (USD)	Category
2Gig	GC-TBZ48 Z-Wave Programmable Thermostat	\$145.30	Smart Thermostat
Aeon Labs / Aeotec	In-Wall Z-Wave Control Lighting	\$38.99	Smart Switch
Aeon Labs / Aeotec	In-Wall Z-Wave Control Switching	miss	Smart Switch
Aeon Labs / Aeotec	In-Wall Z-Wave Control Motors	miss	Smart Switch
Aeon Labs / Aeotec	Nano Dimmer	miss	Smart Plug
Aeon Labs / Aeotec	Smart Dimmer 6	\$34.99	Smart Plug
Aeon Labs / Aeotec	Smart Switch 6	\$49.95	Smart Plug
Aeon Labs / Aeotec	Z-Wave Smart Strip	\$78.98	Smart Plug
Aeon Labs / Aeotec	Z-Wave LED Lightbulb, Gen5	\$30.00	Smart Light
Aeon Labs / Aeotec	Z-Wave LED light strip	miss	Smart Light
Alarm.com	Smart thermostat	\$199.00	Smart Thermostat
Allure Energy	Eversense	\$249.00	Smart Thermostat
Ambient Devices	Energy Dash	\$100.00	In Home Display
Ambient Devices	Energy Joule	miss	In Home Display
Ambient Devices	Energy Orb	miss	In Home Display



Ankuoo	Neo WiFi Switch	\$21.99	Smart Plug
Ankuoo	Neo Pro	\$42.99	Smart Plug
Ankuoo	Nut	miss	Smart Plug
AzTech Associates	Aztech in-Home Display	\$149.99	In Home Display
AzTech Associates	Optio	miss	In Home Display
Bayit Home Automation	Bayit Switch Wi-Fi Socket	\$39.99	Smart Plug
Belkin	Crock-Pot Smart Slow Cooker with WeMo	\$129.99	Smart Appliance
Belkin	Mr. Coffee 10-Cup Smart Optimal Brew Coffeemaker with WeMo	\$149.99	Smart Appliance
Belkin	Holmes Smart Air Purifier with WeMo	\$199.99	Smart Appliance
Belkin	Holmes Smart Humidifier With WeMo	\$199.99	Smart Appliance
Belkin	Holmes Large Room Smart Heater with WeMo	\$149.99	Smart Appliance
Belkin	Holmes Extra-Large Room Smart Heater with WeMo	\$199.99	Smart Appliance
Belkin	Conserve Insight Monitor	\$29.99	Load Monitor
Belkin	WeMo OSRAM LIGHTIFY	\$29.99	Smart Light
Belkin	WeMo OSRAM LIGHTIFY Flex RGBW	\$64.99	Smart Light
Belkin	WeMo OSRAM LIGHTIFY Gardenspot Mini RGB	\$79.99	Smart Light
Belkin	Cree Connected LED Bulb - Daylight	\$15.00	Smart Light
Belkin	Sylvania Ultra iQ LED BR30 Bulb	\$19.99	Smart Light
Belkin	WeMo Insight Switch	\$49.99	Smart Plug
Belkin	WeMo Light Switch	\$49.99	Smart Plug
Belkin	WeMo Maker	\$79.99	Smart Switch
Belkin	WeMo LED Lighting Starter Set	\$49.99	Smart Light

Belkin	WeMo LED Bulb (F7C033)	\$24.99	Smart Light
Belkin	WeMo Switch	\$39.99	Smart Plug
Bidgely	Homebeat Energy Monitor	free	Hub
Big Ass Fans	Haiku Fan with SenseME (H series or I series)	\$895-995	Smart Appliance
BlueLine Innovations	PowerCost Monitor	\$100.00	In Home Display
Branto	Branto	\$300.00	Hub
Carrier	ComfortChoice Touch	miss	Smart Thermostat
Carrier	ComfortChoice Edge	miss	Smart Thermostat
Carrier	ComfortChoice Legacy	miss	Smart Thermostat
Carrier	COR	\$249	Smart Thermostat
CastleOS	CastleHub	499+199	Hub
Centralite	Pearl Thermostat	\$130.00	Smart Thermostat
Centralite	3-Series Lamp Module	\$55.99 - \$90.81	Smart Plug
Centralite	3-Series Appliance Module	\$55.99 - \$90.81	Smart Plug
Centralite	Azela Appliance Module	\$49.99	Smart Plug
Chai Energy	Chai Energy Pro	\$49.00	Hub
Control4	Control4 Wireless Thermostat by Aprilaire	miss	Smart Thermostat
Control4	Control4 HC-800 Controller (EA -5)	\$1,300.00	Hub
Control4	HC-250 Controller (EA-1)	miss	Hub
Control4	Wireless Outlet Switch	\$74.99	Smart Plug
Control4	Wireless Outlet Dimmer	\$79.99	Smart Switch
Cooper Industries - EATON	Programmable Communicating Thermostats	miss	Smart Thermostat

Cooper Industries - EATON	In-home Peak Indicator	miss	In Home Display
Cooper Industries - EATON	Load Control Switches	miss	Smart Switch
Cree	Connected LED Bulb	\$14.97	Smart Light
D-Link Systems	Smart Plug DSP-W110	\$39.99	Smart Plug
D-Link Systems	Smart Plug DSP-W215	\$39.99	Smart Plug
ecobee	ecobee3	\$249	Smart Thermostat
ecobee	Smart Si Thermostat	\$179.00	Smart Thermostat
EcoNet	EV100 Vent	\$113	Smart Appliance
Ecovent	Ecovent System (Vents + Sensors+HUB)	miss	Smart Appliance
Edimax	Edimax SP-2101	\$35.95	Smart Plug
Efergy	E2 Classic	\$140.00	In Home Display
Efergy	Elite Classic	\$120.00	In Home Display
Efergy	Elite IR	\$100.00	In Home Display
Efergy	Engage hub solo	\$79.95	Hub
Elgato	Eve Energy	\$49.95	Smart Plug
Elgato	Avea Bulb	\$39.95	Smart Light
Elgato	Avea Flare	\$99.95	Smart Light
Embertec	Emberplug AV+	\$69.99	Smart Plug
Embertec	Emberstrip 8AV+	\$79.99	Smart Plug
Embertec	Emberstrip PC+	\$79.95	Smart Plug
Embertec	Emberstrip 8PC+	\$79.95	Smart Plug
Embertec	Emberstrip 8AV+ Bluetooth Sensor	\$99.99	Smart Plug

Emerson	Sensi Wi-Fi Thermostat	\$139.99	Smart Thermostat
Emerson	Smart Energy Thermostat (EE542-1Z)	\$199.99	Smart Thermostat
Energate	Pioneer Smart Thermostat	\$294.00	Smart Thermostat
Energate	Energate HolHom (foundation thermostat and DR gateway)	\$344.00	Smart Thermostat
Energate	ZEV110 In Home Display	miss	In Home Display
Energate	HōIHōm Smart Plug	\$49.95	Smart Plug
Energate	Wired Load Control Switch	miss	Smart Switch
Energy Inc	TED 5000-C (one panel with display)	\$199.00	In Home Display
Energy Inc	TED Pro Home	\$299.95	In Home Display
Enerwave	Enerwave ZW15R	\$36.99	Smart Switch
Enerwave	Enerwave ZW20rm	\$34.99	Smart Switch
Enerwave	In-Wall Dimmer (ZW500D)	\$42.11	Smart Switch
Enerwave	On/Off Switch (ZW15S–15A)	miss	Smart Switch
Enerwave	ZW15SM Z-Wave Wireless In-wall Smart Meter On/Off Switch.	miss	Smart Switch
Enerwave	ZWN-323—PLUG-IN DIMMER MODULE	\$44.99	Smart Plug
Enerwave	ZWN-333—PLUG-IN APPLIANCE MODULE	miss	Smart Plug
Ensupra	Wireless Home Power Electric Monitor	\$130-\$250	In Home Display
Ensupra	Plug electricity use monitor	\$26.00	Load Monitor
Evolve	Glass Series T-100-H Thermostat	miss	Smart Thermostat
Evolve	Glass Series T-1500 Thermostat	miss	Smart Thermostat
Evolve	Glass Series TB-200 Thermostat/Temperature Sensor	miss	Smart Thermostat
Evolve	T-100-H Thermostat	miss	Smart Thermostat
Evolve	T-1500 Thermostat	miss	Smart Thermostat
Evolve	TB-200 Thermostat/Temperature	miss	Smart Thermostat

	Sensor		
Evolve	LOM-15 Wall Outlet	\$32.00	Smart Switch
Evolve	Wall Mounted Dimmer	\$30.00-\$49.79	Smart Switch
Evolve	Wall Mounted Binary Switch	\$40.00	Smart Switch
Evolve	Wall Mounted 3-Way Switch	miss	Smart Switch
Evolve	Plug-In Appliance Module	\$39.99	Smart Plug
Evolve	Plug-In Dimmer Module	\$28.20	Smart Plug
Evolve	Contact Fixture Module	\$44.95	Smart Switch
Eyedro	Home Electricity Monitoring + Cloud Platform	\$129-\$199	Hub
Fibaro	Home Center 2	\$749.00	Hub
Fidure	A1730 Thermostat	\$109.00	Smart Thermostat
First Alert	First Alert Onelink Thermostat	\$207.99	Smart Thermostat
Floureon	TS-836A	\$16.00	Load Monitor
Flux	Smart LED lightbulb	\$34.00	Smart Light
GE	Connected refrigerators	\$3,200-3,300	Smart Appliance
GE	Connected Oven and Ranges	\$3,000-4,000	Smart Appliance
GE	Connected Dishwashers	\$1,500	Smart Appliance
GE	Connected Washers	\$1,100-1,200	Smart Appliance
GE	Connected Dryers	\$1,100-1,300	Smart Appliance
GE	Connected GEOSPRING™ HYBRID WATER HEATER	\$1,400-1,900	Smart Appliance
GE	Connected WINDOW ROOM AIR CONDITIONER	\$350-440	Smart Appliance
GE	Plug-In Smart Switch (Z-Wave)	\$33.99	Smart Plug
GE	Plug-In Smart Dimmer (Z-Wave)	\$44.99	Smart Plug
GE	Plug-In Outdoor Smart Switch (Z-	\$44.99	Smart Plug

	Wave)		
GE	In-Wall Smart Dimmer (Z-Wave)	\$44.99	Smart Switch
GE	In-Wall Smart Switch (Z-Wave)	\$39.99	Smart Switch
GE	In-Wall Smart Fan Control (Z-Wave)	\$44.99	Smart Switch
GE	In-Wall Smart Outlet (Z-Wave)	\$39.99	Smart Switch
GE	On-Wall Smart Remote (Z-Wave)	\$44.99	Smart Switch
GE	Plug-In Smart Switch (ZigBee)	\$49.99	Smart Plug
GE	Plug-In Smart Dimmer (ZigBee)	\$54.99	Smart Plug
GE	In-Wall Smart Switch (ZigBee)	\$49.99	Smart Switch
GE	In-Wall Smart Dimmer (ZigBee)	\$54.99	Smart Switch
GE	Plug-In Smart Switch (Bluetooth)	\$34.99	Smart Plug
GE	Plug-In Smart Dimmer (Bluetooth)	\$39.99	Smart Plug
GE	Plug-In Outdoor Smart Switch (Bluetooth)	\$49.99	Smart Plug
GE	In-Wall Smart Switch (Bluetooth)	\$39.99	Smart Switch
GE	In-Wall Smart Dimmer (Bluetooth)	\$44.99	Smart Switch
GE	Link starter kit	\$49.97	Smart Light
GE	A19	\$14.75	Smart Light
GE	BR30	\$16.96	Smart Light
GE	PAR38	\$24.97	Smart Light
Honeywell	Lyric	\$250.00	Smart Thermostat
Honeywell	Thermostat (YTH8320ZW1007/U)	\$159.99	Smart Thermostat
Honeywell	Wi-Fi Smart Thermostat RTH9580WF	\$206.99	Smart Thermostat
Honeywell	Wi-Fi 7-Day Programmable Thermostat RTH6580WF	\$119.99	Smart Thermostat
Honeywell	Wi-Fi 7-Day Programmable Touchscreen Thermostat RTH8580WF	\$249.99	Smart Thermostat

Honeywell	Wi-Fi Smart Thermostat with Voice Control RTH9590WF	\$299.99	Smart Thermostat
Honeywell	VisionPRO Wi-Fi 7-Day Programmable Thermostat	\$278.79	Smart Thermostat
ilumi solutions	ilumi Smartbulb - a19 smart bulb	\$59.99	Smart Light
ilumi solutions	ilumi Smartbulb - br30 flood	\$59.99	Smart Light
ilumi solutions	ilumi Smartbulb - outdoor flood	\$69.99	Smart Light
Insteon	Smart Thermostats	\$79.99	Smart Thermostat
Insteon	Insteon Hub	\$79.00	Hub
Insteon	Insteon Hub - Pro	\$149.00	Hub
Insteon	Insteon Energy Display	\$29.99	In Home Display
Insteon	LED Bulb	\$29.99	Smart Light
Insteon	LED Bulb for Recessed Lights	\$49.99	Smart Light
Insteon	Plug-in-Devices - Dimmer Module	\$49.99	Smart Plug
Insteon	Plug-in-Devices - On/Off Module	\$49.99	Smart Plug
Insteon	Plug-in-Devices - Outdoor On/Off Module	\$49.99	Smart Plug
Insteon	Smart Wall Switches - Dimmer Switch	\$49.99	Smart Switch
Insteon	Smart Wall Switches - Dimmer Switch (1000W)	\$69.99	Smart Switch
Insteon	Smart Wall Switches - Dimmer Switch (2-Wire)	\$49.99	Smart Switch
Insteon	Smart Wall Switches - On/Off Switch	\$49.99	Smart Switch
Insteon	Smart Outlets - Insteon Dimmer Outlet	\$49.99	Smart Switch
Insteon	Smart Outlets - Insteon On/Off Outlet	\$59.99	Smart Switch
Insteon	Smart Wall Keypads - Dimmer Keypad 6-Button	\$79.99	Smart Switch
Insteon	Smart Wall Keypads - Dimmer Keypad 8-Button	\$79.99	Smart Switch



Insteon	Smart Wall Keypads - On/Off Keypad 6-Button	\$79.99	Smart Switch
Insteon	Smart Wall Keypads - On/Off Keypad 8-Button	miss	Smart Switch
Insteon	Insteon SynchroLinc - Power Synching Controller	miss	Smart Plug
Keen	Home Smart Vent	\$64-90	Smart Appliance
Leviton	Lumina RF Programmable Thermostat	\$406.62	Smart Thermostat
Leviton	Lumina Home Control System Hub	\$700.00	Hub
LG	ThinQ Super-Capacity French Door Refrigerator	\$3,799.99	Smart Appliance
LG	Smart ThinQ Washer	\$1,600.00	Smart Appliance
LG	Smart ThinQ Dryer	\$1,600.00	Smart Appliance
LG	Smart ThinQ Oven	\$1,259.99	Smart Appliance
LIFX	LIFX White 800	\$39.99	Smart Light
LIFX	LIFX Color 1000	\$59.99	Smart Light
LIFX	LIFX White 900 BR30	\$39.99	Smart Light
LIFX	LIFX Color 1000 BR30	\$59.99	Smart Light
Lockstate CONNECT	Ls 60i Smart Thermostat	\$250.99	Smart Thermostat
Lockstate CONNECT	Ls 90i Smart Thermostat	\$299.95	Smart Thermostat
Logitech	Harmony Home Hub	\$99	Hub
Lowe's	Iris Smart Thermostat	\$100.00	Smart Thermostat
Lowe's	Iris Smart Hub	\$49.99	Hub
Lowe's	Iris Smart Plug	\$34.99	Smart Plug
Lutron	Lutron smart Bridge	\$120	Hub
LUX	GEO 7-Day Wi-Fi Programmable Thermostat in White	\$179.99	Smart Thermostat

Nest	Nest Learning Thermostat	\$249	Smart Thermostat
Neurio	Neurio Home Energy Monitor	\$179.99	Hub
OSRAM	LIGHTIFY Gateway Home	\$30	Hub
OSRAM	LIGHTIFY CLASSIC A TW	\$22.79	Smart Light
OSRAM	LIGHTIFY CLASSIC A RGBW	\$39.99	Smart Light
OSRAM	LIGHTIFY CLASSIC A 60 WHITE	\$34.99	Smart Light
OSRAM	LIGHTIFY CLASSIC B 40 TW FR	miss	Smart Light
OSRAM	LIGHTIFY PAR16 50 RGBW	miss	Smart Light
OSRAM	LIGHTIFY PAR16 TW	\$80.00	Smart Light
OSRAM	LIGHTIFY Gardenspot Mini RGB	\$79.99	Smart Light
OSRAM	LIGHTIFY LED Flexible Strip RGBW	\$64.99	Smart Light
P3 International	Kill A Watt	\$22.99	Load Monitor
P3 International	Kill A Watt CO2 Wireless	\$79.95	In Home Display
P3 International	Kill A Watt PS-10 (P4330)	\$59.20 - \$88.19	Load Monitor
P3 International	Save A Watt Phantom Power Indicator	\$12.95	Load Monitor
Philips	Philips Hue Starter Kit	\$199.95	Smart Light
Philips	Philips Hue White E26 Starter Kit	\$79.95	Smart Light
Philips	Philips Hue White and Color GU10 spot	\$59.95	Smart Light
Philips	Philips Hue White and Color PAR16 spot	\$59.95	Smart Light
Philips	Philips Hue A19 bulb	\$59.95	Smart Light
Philips	Philips Hue White and Color BR30 bulb	\$59.95	Smart Light
Philips	Hue White E26 Light Bulb	\$14.95	Smart Light
Philips	Hue Bloom	\$59.95	Smart Light
Philips	Hue Go	\$99.95	Smart Light

Philips	Hue LightStrip	\$89.95	Smart Light
Plum	Lightpad Dimmer	\$99.00	Smart Switch
Powehouse Dynamics / SiteSage	SiteSage for homes	\$499.00 - \$899.00	Hub
Radio Thermostat of America	Thermostat CT 50 + Wi-Fi Module	\$99-125	Smart Thermostat
Radio Thermostat of America	Thermostat CT 32 + ZigBee module	\$139.95	Smart Thermostat
Radio Thermostat of America	Thermostat CT 32 + Z-Wave module	\$139.95	Smart Thermostat
Radio Thermostat of America	Thermostat CT 80 + WiFi module	\$199.99	Smart Thermostat
Radio Thermostat of America	Thermostat CT 80 + ZigBee module	\$199.99	Smart Thermostat
Radio Thermostat of America	Thermostat CT 80 + Z-Wave module	\$199.99	Smart Thermostat
Radio Thermostat of America	Thermostat CT 100	\$129.99	Smart Thermostat
Radio Thermostat of America	Thermostat CT 101	\$99.99	Smart Thermostat
Radio Thermostat of America	Thermostat CT 110	\$129.00	Smart Thermostat
Rainforest Automation	EAGLE Home Energy Gateway	\$100.00	Hub
Rainforest Automation	RAVE n / Personal Meter Reader	miss	Hub
Rainforest	EMU2	\$70.00	In Home Display

Automation			
RCS Technology	TZ 45 Thermostat	\$166-399.00	Smart Thermostat
RCS Technology	TZB 45 Thermostat	\$166-399.00	Smart Thermostat
RCS Technology	TE45 RDS Thermostat	\$166-399.00	Smart Thermostat
RCS Technology	TW 45 Thermostat	\$150.00	Smart Thermostat
RCS Technology	In-Home display	miss	In Home Display
Reliance Controls	AmWatt Appliance Load Tester	\$24.97	Load Monitor
Remotec	Dual mode Dimmer/Switch (ZDS-110)	miss	Smart Plug
Remotec	Configurable Dimmer and Switch Module (ZDS-200)	miss	Smart Plug
Remotec	Z-Wave Fixture Switch Module (ZFM-80)	miss	Smart Switch
Samsung	Family Hub Refrigerator	\$5,800-6,000	Smart Appliance
Samsung	Wi-Fi Range	\$2,400-3,000	Smart Appliance
Samsung	Smart Washer	\$1,400.00	Smart Appliance
Samsung	Smart Dryer	\$1,500.00	Smart Appliance
Samsung	Whisper Wi-Fi	miss	Smart Appliance
Savant	Savant Lamp Control	\$99.00	Smart Plug
Schneider Electric	Wiser Air Smart Thermostat	\$239.00	Smart Thermostat
Schneider Electric	Wiser In-Home Display	\$180.00	In Home Display
sengled	Pulse	\$149.99	Smart Light
sengled	Pulse-Solo	\$59.99	Smart Light
sengled	Element Touch	\$17.99	Smart Light

sengled	Snap	\$149.99	Smart Light
sengled	Boost	\$49.99	Smart Light
Smapppee	Smapppee Comfort Plug	\$39.95	Smart Plug
Smartenit	Harmony Gateway	\$100.00	Hub
Smartenit	Harmony Gateway G1 – Model # 6007D	\$99.99– \$149.99	Hub
Smartenit	HA Dual-Relay Controller ZBLC15 (4033A)	\$89.99	Smart Switch
Smartenit	HA Metering Dual-Load 30A Controller ZBMLC30 (4040B)	\$179.99	Smart Switch
Smartenit	HA Metering Single Load Controller ZBMLC15 (4034A)	\$89.99	Smart Switch
Smartenit	HA Metering Smart Plug ZBMPlug15 (5010Q)	\$59.99	Smart Plug
SmartThings	SmartThings Hub	\$99.00	Hub
SmartThings	SmartPower Outlet	\$54.99	Smart Switch
STACK	Stack classic starter kit	\$89.00	Smart Light
STACK	Stack classic bulb	\$28.00	Smart Light
STACK	Stack Downlight starter kit	\$99.00	Smart Light
STACK	Stack Downlight Bulb	\$45.00	Smart Light
Staples	D-Link Staples Connect Hub	\$50.00	Hub
Sylvania	iQ LED BR30 Bulb	\$29.98	Smart Light
TCP	Connected Smart LED Bulbs	Varied - 8 lamp options available	Smart Light
TCP	Starter kit	\$42.99	Smart Light
Tenrehte	PICOWatt	miss	Smart Plug
ThinkEco	Gateway	\$140.00	Hub
ThinkEco	ThinkEco Modlet Starter Kit	\$50.00	Smart Plug

ThinkEco	WiFi smartAC Kit	\$139.99	Smart Plug
ThinkEco	SmartAC Kit (For Gateway)	\$135.99	Smart Plug
ThinkEco	Modlet BN WiFi	\$80.00	Smart Plug
TRANE	ComfortLink™ II XL950	\$620.00	Smart Thermostat
TRANE	ComfortLink™ II XL850	miss	Smart Thermostat
TRANE	XL824	\$350.00	Smart Thermostat
TRANE	XL624	\$120.00	Smart Thermostat
Tri Cascade	Bright 700-10 - Thermostat	miss	Smart Thermostat
Tri Cascade	i-bright7	\$106.32	Smart Plug
Tri Cascade	Bright 20-10 Outlet - Plug	miss	Smart Switch
Tri Cascade	Bright 60-10 Switch - Light	miss	Smart Switch
TrickleStar	Plug-in Energy Monitor 890 EM-US-W	\$29.99	Load Monitor
TrickleStar	Plug-in Energy Monitor 891EM-US-W	\$26.99	Load Monitor
Universal Devices	isy994i-series	\$199-399	Hub
Vectorform	Powerley	miss	Hub
VENSTAR	ColorTouch	\$198.95	Smart Thermostat
VENSTAR	Voyager	\$100.00	Smart Thermostat
Vera	Smart Contorller	\$99-149	Hub
Visible Energy	UFO Power Center	\$127.49	Smart Plug
Vue	Single Socket	\$41.79 - \$53.79	Load Monitor
Watts Up?	Watts up? Plug Load Meters	\$130.95	Load Monitor
Wattvision	Wattvision 2 App + Gateway	\$249.00	Hub
WeBee	Smart Hub	\$179.00	Hub
Whirlpool	Smart Dryer	\$1,699	Smart Appliance

Whirlpool	Smart Washer	\$1,699	Smart Appliance
Whirlpool	Smart Dishwasher	\$950	Smart Appliance
Whirlpool	Smart Refrigerator	\$1,999	Smart Appliance
Wink	Connected Home Hub	\$50.00	Hub
Wittech WiTenergy	load monitoring smart plug	\$29.99	Smart Plug
York	York® Affinity™ Residential Communicating Control	\$475.00	Smart Thermostat
Zen	Thermostat	\$150-200	Smart Thermostat
Zuli	Zuli SmartPlug	\$59.99	Smart Plug
Chai Energy	Chai Energy App	free	Energy Portal
Curb	Curb Lite: For Apartment	free	Energy Portal
Bidgely	HomeBeat Web & Mobil App	free	Energy Portal
Meter Hero	Meter Hero	\$7.99- \$19.99/month	Energy Portal
WeatherBug	WeatherBug HOME	free	Energy Portal
Aclara	Behavioral Efficiency	NA	Utility Facing Web Service
Aclara	Customer Self Service	NA	Utility Facing Web Service
Aclara	Adaptive Consumer Engagement (ACLARA ACE™)	NA	Utility Facing Web Service
Aclara	TWACS® Technology – Communications for AMI, Networking and Distribution Management	NA	Utility Facing Web Service
Bidgely	Demand Management	NA	Utility Facing Web Service
Bidgely	HomeBeat Agent	NA	Utility Facing Web Service
C3 Energy	Residential Solution	NA	Utility Facing Web Service



Calico Energy Services	HomeSMART Energy Management	NA	Utility Facing Web Service
Comverge	SmartConsumer	NA	Utility Facing Web Service
Comverge	IntelliSOURCE	NA	Utility Facing Web Service
Energate	Energate Home Energy Management Suite	NA	Utility Facing Web Service
EnergySavvy	Optix Engage	NA	Utility Facing Web Service
EnergySavvy	Optix Manage	NA	Utility Facing Web Service
EnergySavvy	Optix Quantify	NA	Utility Facing Web Service
iFactor	iFactor Mobile	NA	Utility Facing Web Service
Opower	Bill Advisor	NA	Utility Facing Web Service
OPower	Demand Response Solution	NA	Utility Facing Web Service
OPower	Energy Efficiency Solution	NA	Utility Facing Web Service
Opower	Digital-Engagement	NA	Utility Facing Web Service
Schneider Electric	Schneider Wiser Home	NA	Utility Facing Web Service
Silver Spring Networks	CustomerIQ Energy Portal	NA	Utility Facing Web Service
Silver Spring Networks	Demand Side Management	NA	Utility Facing Web Service
Simple Energy	Engagement Platform	NA	Utility Facing Web Service
Tendril	Alerts & Notifications	NA	Utility Facing Web Service

Tendril	Energy Messaging	NA	Utility Facing Web Service
Tendril	Home Assessment	NA	Utility Facing Web Service
Tendril	Tendril Energize	NA	Utility Facing Web Service
Lowe's Iris	NA	NA	Smart Home Platform
Belkin WeMo	NA	NA	Smart Home Platform
SmartThings	NA	NA	Smart Home Platform
Nest	NA	NA	Smart Home Platform
Wink	NA	NA	Smart Home Platform
Insteon	NA	NA	Smart Home Platform
Apple HomeKit	NA	NA	Smart Home Platform
Vera	NA	NA	Smart Home Platform
IFTTT	NA	NA	Smart Home Platform
Yonomi	NA	NA	Smart Home Platform
PEQ	NA	NA	Smart Home Platform
Comcast Xfinity - EcoFactor	NA	NA	Smart Home Platform
ADT	NA	NA	Smart Home Platform
Icontrol	NA	NA	Smart Home Platform



## Appendix E: PG&E Customer Survey

### Welcome Text

We are interested in your opinions about new technologies that enable household occupants to control better and manage their energy use. Your feedback will help PG&E with the integration of new technologies into the home.

This survey may be a little longer than average. For most, it will take about 12 minutes. However, it could take 15 -20 minutes to complete for some, depending on your answers. But we think you'll find the topic very interesting!

We hope you will take the time to provide us with your opinions.

Thank you for participating!

(PAGE BREAK)

### Message to Mobile Device Users

Although the survey will be fitted for mobile devices (Smartphones and Tablets), because of its length and because there are several complex graphics, we strongly recommend that you conduct the survey on a Personal Computer. This will provide you with the most optimal experience for this survey.

### Section 1: Perceptions of General Concept of Smart/Connected Home

[SINGLE CHOICE GRID]				
Q1. How familiar are you with the concept of a [VERSION 1]: "smart home"/ [VERSION 2]: "connected home"?				
[RANDOMIZE]	Not At All	A Little	Somewhat	Very
	1	2	3	4

--	--	--	--	--	--

(PAGE BREAK)

[ASK Q2 IF Q1 > 1; ELSE SKIP TO Q3]
[OPEN END]
Q2. What do you think about when you hear the term [VERSION 1]: "smart home"/ [VERSION 2]: "connected home"?

(PAGE BREAK)

[SINGLE CHOICE GRID]					
Q3. How familiar are you with each of the following products?					
[RANDOMIZE]		Not At All	A Little Bit	Somewhat	Very
a	Smart appliances	1	2	3	4
b	Smart plugs	1	2	3	4
c	Smart lights	1	2	3	4
d	Smart thermostats	1	2	3	4

(PAGE BREAK)

[IF CODE 1 (NOT AT ALL FAMILIAR) FOR ALL ITEMS IN Q3, THEN SKIP TO Q5]
[MULTIPLE CHOICE]
Q4. Where did you learn about [VERSION 1]: smart home/ [VERSION 2]: connected home products? (Please Select All That Apply)

1	Store (e.g. home improvement, electronics, department or big box store)	
2	Service provider (e.g. cable, mobile phone, or security company)	
3	Word of mouth (e.g. friend, family, colleague)	
4	Media (e.g. TV, Internet, magazine, newspaper)	
5	Other (Please Specify): _____	
9	Not sure	

(PAGE BREAK)

[SHOW INFOGRAPHIC 1A and 1B FOR RANDOMLY SELECTED VERSION]	
Please review this infographic that describes the concept of a [VERSION 1]: smart home/ [VERSION 2]: connected home and answer the questions below.	
INFOGRAPHIC 1A	INFOGRAPHIC 1B
VERSION 1 Smart Home (image: smart home)	VERSION 2 Connected Home (image: connected home)

(PAGE BREAK)

[SINGLE CHOICE]		
Q5. How much does the idea of a [VERSION 1]: "smart home"/ [VERSION 2]: "connected home" appeal to you?		
1	Not at all	
2	A little	
3	Somewhat	
4	Very much	

(PAGE BREAK)

[MULTIPLE CHOICE]		
Q6. In which of the following ways, if any, might [VERSION 1]: smart home / [VERSION 2]: connected home products benefit your household? (Please Select All That Apply)		
01	Make my home more comfortable	
02	Make household chores easier	
03	Save time	
04	Save money on energy bills	
05	Reduce energy use	
06	Reduce negative environmental impact	
07	Enjoyable to have and/or use	
08	Improve home resale value	
09	Enable better management of household energy use	
10	Protect home from theft or vandalism	
11	Protect health of household members	
12	Alert me when household equipment needs attention	
13	Enable better care for children or elderly	
14	Enable better care for pets	
15	Other (Please Specify): _____	
99	None of these	

(PAGE BREAK)

[MULTIPLE CHOICE]
[RANDOMIZE 1 THRU 7]



Q7. Which of the following [VERSION 1]: smart home / [VERSION 2]: connected home capabilities appeal to you? (Please Select All That Apply)		
1	Allow me to monitor devices and appliances remotely via an app or website, e.g., see whether devices and appliances are on/off and track energy use.	(image: monitor)
2	Allow me to control devices and appliances remotely via an app or website, e.g., turn devices and appliances on/off or adjust settings.	(image: control)
3	Allow me to schedule the operation of devices and appliances, e.g., lights and music turn on at 8 a.m.	(image: schedule)
4	Enable devices and appliances to automatically adjust based on my habits and preferences, e.g., thermostat, adjusts settings based on my past settings and whether my home is occupied	(image: automation)
5	Enable devices and appliances to respond to changes in energy price, e.g. laundry cycle pauses when electricity prices are high	(image: cost)
6	Allow PG&E to adjust appliances to save energy or cut peak demand, e.g. turn appliances on/off for limited time periods with an incentive.	(image: PG&E)
7	Provide me with personalized tips and notifications, e.g., no one is home so turn down the thermostat, door unlocked when you are away, laundry is done.	(image: alarm clock)
8	Other (Please Specify): _____	
9	None of these	

(PAGE BREAK)

[MULTIPLE CHOICE]		
[RANDOMIZE 1 THRU 6]		
Q8. Which, if any, of the following, would you want to use to interact with [VERSION 1]: smart home / [VERSION 2]: connected home products? (Please Select All That Apply)		
1	A standalone display in my home	(image: IHD)
2	Laptop or desktop computer	(image: computer)

3	My tablet	(image: tablet)
4	My smartphone	(image: smartphone)
5	A display embedded in the smart/connected product itself	(image: embedded)
6	My voice (e.g. retrieve information or control products through spoken commands)	(image: voice)
7	Other (Please Specify): _____	
9	None of these	

(PAGE BREAK)

[SINGLE CHOICE GRID]						
Q9. Please indicate how much you agree or disagree with the following statements:						
[RANDOMIZE]		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a	Information about [VERSION 1]: smart / [VERSION 2]: connected home products is readily available	1	2	3	4	5
b	I know of at least one [VERSION 1]: smart / [VERSION 2]: connected home product that would benefit my life	1	2	3	4	5
c	I know where to buy [VERSION 1]: smart / [VERSION 2]: connected home products	1	2	3	4	5
d	I am interested in purchasing a [VERSION 1]: smart / [VERSION 2]: connected home product	1	2	3	4	5
e	Most people I know would want to have a [VERSION 1]: smart / [VERSION 2]: connected home	1	2	3	4	5

(PAGE BREAK)

[MULTIPLE CHOICE]		
[RANDOMIZE 1 THRU 5]		
Q10. Which, if any, of the following concerns, do you have with [VERSION 1]: smart home / [VERSION 2]: connected home technology? (Please Select All That Apply)		
1	I am skeptical whether [VERSION 1]: smart / [VERSION 2]: connected home products perform as well as basic devices and appliances	
2	[VERSION 1]: smart / [VERSION 2]: connected home technology makes it easier for others to access my personal information without my permission	
3	[VERSION 1]: smart / [VERSION 2]: connected home technology makes simple tasks unnecessarily complicated	
4	[VERSION 1]: smart / [VERSION 2]: connected home products are probably not worth the price	
5	[VERSION 1]: smart / [VERSION 2]: connected home products could be too much of a hassle to set-up/install	
6	Other (Please Specify): _____	
9	None of these	

## Section Two: Smart Products (Questions Repeat For Four Product Types)

BLOCK A	SMART APPLIANCES	QUESTIONS 11A THRU 11H
BLOCK B	SMART THERMOSTATS	QUESTIONS 12A THRU 12G
BLOCK C	SMART LIGHTS	QUESTIONS 13A THRU 13G
BLOCK D	SMART PLUGS	QUESTIONS 14A THRU 14G

[SHOW INFOGRAPHIC 2A_APPLIANCES]
Please review this infographic and answer the questions below.
SMART APPLIANCES

INFOGRAPHIC 2A (image: smart appliances)

BLOCK A: SMART APPLIANCES

[SINGLE CHOICE]		
Q11A. How much do <b>smart appliances</b> appeal to you?		
1	Not at all	
2	A little	
3	Somewhat	
4	Very Much	

[SINGLE CHOICE]		
Q11B. Do you own a <b>smart appliance</b> ?		
1	Yes	[GO TO Q11C]
2	No	[SKIP TO Q12A]
9	Not sure	[SKIP TO Q12A]

(PAGE BREAK)

[ASK Q11C IF Q11B = CODE 1 'YES'; ELSE SKIP TO Q12A]		
[MULTIPLE CHOICE]		
Q11C. Which, if any, of the following <b>smart appliances</b> , do you own? (Please Select All That Apply)		
1	Smart washing machine	
2	Smart dryer	

3	Smart dishwasher	
4	Smart refrigerator	
5	Smart oven	
6	Other (Please Specify): _____	
9	None of these / not sure	[SKIP TO Q12A]

(PAGE BREAK)

[MULTIPLE CHOICE]		
Q11D. Where did you acquire your <b>smart appliance(s)</b> ? (Please Select All That Apply)		
1	Store (Please Specify): _____	
2	Online (Please Specify): _____	
3	Gift from: (Please Specify): _____	
4	Borrowed from (Please Specify): _____	
5	Came with my home	
6	Other (Please Specify): _____	
9	None of these / not sure	

(PAGE BREAK)

[OPEN END]
Q11E. What, if anything, do you <b>LIKE</b> about your <b>smart appliance(s)</b> ?

## Appendix F: Employee Interview Protocol

I'm part of a research effort, funded by PG&E. I represent a company called SEE Change Institute, who PG&E has hired to conduct the research. The research is about Home Energy Management Technology. Part of this research is aimed at understanding customers' perceptions of smart home technology, particularly those products and features that enable home energy management. We'd like to interview you because your experience working at [retailer] involves a lot of customer interaction and you get to see first hand how customers are responding to these new technologies.

Before we begin, I'd like to have you read this consent form and sign at the bottom if you agree to the terms. Please let me know if you have any questions about the form.

[Wait for signature. Collect form. Keep separate from notes.]

OK, great! This interview will be about 30 minutes long. I will ask you a series of questions regarding your observations and experiences with customers.

First, can you tell me how long you have worked here?

Please tell me about some of the common or interesting reactions customers have to smart home technology.

[Possible prompts]

What do they like? Dislike? What are they surprised by?

What are some of the typical experiences of customers shopping here?

[Possible follow-up questions]

Is that typical for most customers or just particular types? Which types of customers?

Have you noticed changes in this response over the time you've been here?

What products or features are customers most interested in and why?

[Possible prompts]

What products are most popular?

What have customers said about why they like this product?

What have customers said about how they would use this product?

[Follow-up questions]

What, if anything, do customers find interesting about smart plugs? Smart lights? Hubs? Smart thermostats? Which particular product/features do they like?

[Possible follow-up questions]

Is that typical for most customers or just particular types? Which types of customers?

What products or features are customers least interested in and why?

[Possible prompts]

Which products get the least attention? Why do you think that is?

Which products do customers dislike? Why do you think that is?

[Follow-up questions]

What, if anything, do customers dislike about smart plugs?

Smart lights? Hubs? Smart thermostats?

Which particular product/features?

Why do you think that is?

[Possible follow-up questions]

Is that typical for most customers or just particular types? Which types of customers?

What aspects of the technology or products do customers have difficulty understanding?

[Possible prompts]

What are some common questions you get from customers?

[Possible follow-up questions]

Is that typical for most customers or just particular types? Which types of customers?

What can you tell me about customers' interest in energy use or saving energy?

[Possible prompts]

Do customers ever ask how much energy products use?

Do customers ever ask if products will save energy? Which products?

Does energy use or energy savings seem to influence customer purchases? If so, how?

[Possible follow-up questions]

Is that typical for most customers or just particular types?

Which types of customers?



## Appendix G: Amazon.com Reviews

Product Category	Product	Total Reviews	Reviews Sampled
Smart Plugs and Switches	WeMo Switch	3,725	17
	Etekcity Wireless Remote Control Electrical Outlet Switch	3,123	16
	Ankuoo NEO Smart Switch	648	14
Smart Thermostats	Nest Learning Thermostat, 3rd Generation	4,489	16
	Honeywell Wi-Fi Smart Touchscreen Thermostat	1,924	14
	Sensi Wi-Fi Programmable Thermostat	1,677	16
	EcoBee3, 2nd Generation	1,280	15
Smart Lights	GE Link, Wireless A19 Smart Connected LED Light Bulb	953	17
	MagicLight Bluetooth Smart LED Light Bulb	909	15
	Philips 456210 Hue White and Color Ambiance A19 Bulb Starter Kit 2nd Generation	537	15
	Flux Bluetooth Smart LED Light Bulb	1,187	31
In-home Displays	Black & Decker EM100B Energy Saver Series Power Monitor	209	16
	Current Cost EnviR Wireless Home Energy Savings Monitor	93	14
	Efergy E2 Wireless Electricity Monitor	108	16
	Wink Relay - Smart Home Wall Controller	93	13
	Watt's Up RC Watt Meter	126	16
Load Monitors	Belkin Conserve Insight Energy Use Monitor	3,006	15
	P3 International P4460 Kill A Watt EZ Electricity Usage Monitor	1,124	15

	TS-836A Plug Power Meter Energy Watt Voltage Amps Meter with Electricity Usage Monitor	283	17
Hubs	Samsung Smart things Hub 2nd Generation	735	18
	Wink Connected Home Hub	700	14
	Lutron L-BDG2-WH Caseta Wireless Smart Bridge	44	15

## Appendix H: User Scenarios

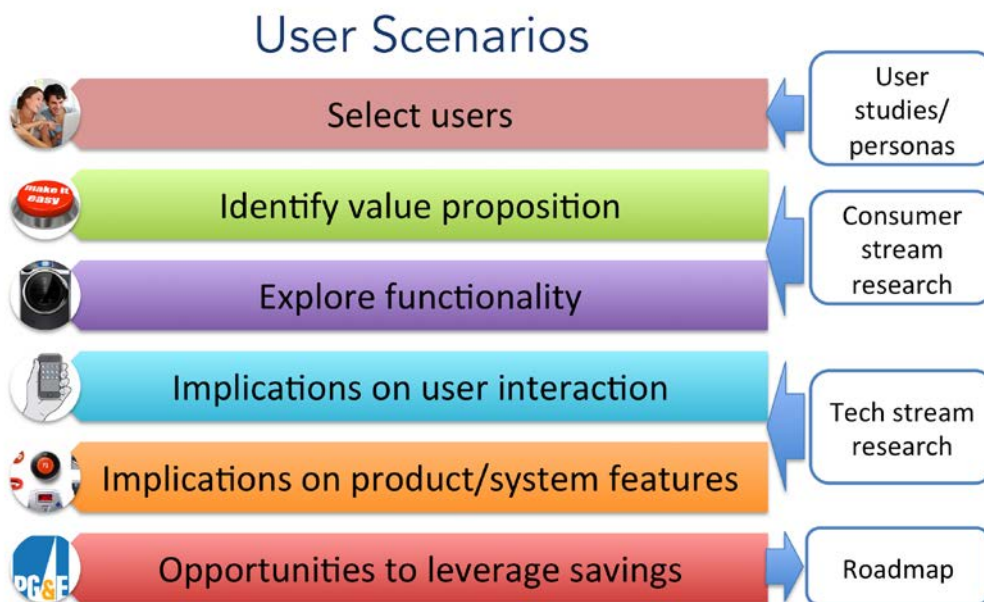
The user scenarios presented in this appendix support two points of the marketing plan of the roadmap:

- Emphasize the value proposition of HEMS through telling stories with user scenarios (e.g., coming home from work) that help customers envision their life with smart home technologies and understand: where the data are coming from, how it can be accessed and by who or what, and what this actually means for regular people in their daily lives.
- Communicate in a way that makes it easy to illustrate systematic relationships (e.g., with graphics more than words).

### The Representation of user scenarios

The representation of choice for the following user scenarios is derived from a mix of user stories and service descriptions, which we extended for the purpose at hand with opportunities to leverage savings. It is an easy-to-understand description for non-technical and technical readers alike. Accompanying graphical illustrations provide additional food for thought and discussion and can be used in workshops and focus groups for future development.

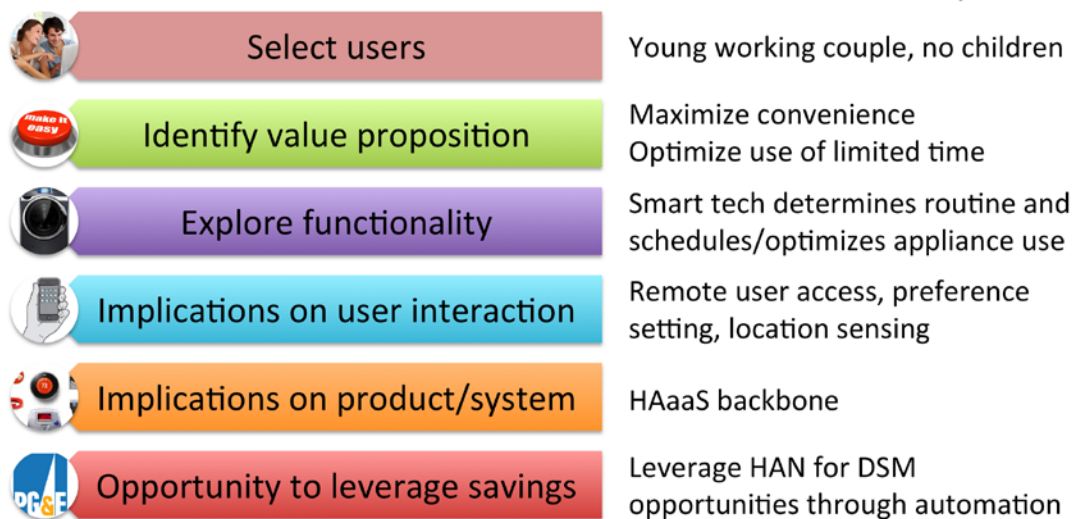
We use service descriptions to expand on details about the surrounding system and how it plugs into the operational environment. Fundamentally, five key questions must be answered when defining a service:



1. Select user group: for whom do we want to develop user scenarios – e.g. tech-savvy working couple who want maximum convenience
2. Identify value proposition: to users and to utility – e.g. home prepared when they come home, bill reductions, energy savings
3. Describe service delivery: work out what this means in terms of service delivery – e.g. tasks scheduled during their away-time
4. Identify user interaction: what is the kind of user interaction that is required? – e.g. previously defined protocol
5. Identify impacts/requirements: impacts of system and requirements to be able to provide this service - e.g. the need for a central control system that talks to all appliances

To these implications, we add the opportunities to leverage savings as further exploration, which is a part of the roadmap. The figure below shows an abbreviated and simplified example according to this scheme:

## User Scenarios - an example



## Categories for Future user scenarios

There are a few alternatives of how to group user scenarios, and each has a different set of overlaps and drawbacks. We can group according to:

- **User group / Personas**, e.g. gadget fans, eco-active people [REF PG&E REPORT].
  - Drawback: most scenarios are relevant for multiple personas.
- **User benefits**, e.g. convenience, cost savings, identity [REF OUR LIT SURVEY]
  - Drawback: many scenarios bring multiple benefits.
- **User characteristics**, e.g. energy perspective, omnipresent, individualized, social-centric, tech savvy, prosumer, interconnected, pay it forward, energy diverse

- Drawback: many scenarios assume multiple of these characteristics.
- **Product categories**, e.g. smart homes, mobility, wearables, and energy generation devices
  - Drawback: many scenarios include multiple product categories.
- **Location** where the service would be used, e.g. kitchen, driveway, bedroom, home office, front door, etc.
  - Drawback: some scenarios include various locations.

We used all four structuring mechanisms to come up with scenarios so we would not overlook anything, but didn't want to repeat them in four different ways. Therefore we decided on one coherent scheme and then provide references to overlapping categories.

Locations seem to have the least overlap, and at the same time, they allow us to put the scenarios into a larger structuring picture, for example, by walking through the day of a persona or individual.

From each of the categories we take **inputs** for the development of the scenarios:

**1) User groups:** Understanding of the relevant audiences as every user group will have a different set of requirements and need targeting.

**2) User benefits:** We infer discussion topics around the user benefits and in which context they apply to HEMS scenarios.

- **Safety & Security** - discussion of the ability to protect the user and the user's home from harm/intruders
- **Convenience** - discussion of the ability to make household and personal tasks easier for the user to perform
- **Comfort** - discussion of the ability to make the user's home environment more comfortable through automation and/or optimization of electronic devices in the home
- **Energy Savings** - the ability to lower the user's energy consumption
- **Cost Savings** - the ability to lower the user's utility bill
- **Identity** - discussion of consumers perceiving themselves or others as tech-savvy, progressive, or green.
- **Fault Detection** - discussion of the ability of HEMS to provide more insight into problems with equipment
- **Resilience** - discussion of the ability of HEMS to help manage energy balance in a home, e.g. by tapping into multiple resources to manage grid usage in the event of a power outage.
- **Entertainment** - discussion of the ability of HEMS to make it easier for users to enjoy music, movies, and web surfing, etc.
- **Productivity** - discussion of the ability of HEMS to facilitate greater productivity and help users better manage work-life balance
- **EV/DG Integration** - discussion of the ability of HEMS to help homeowners that generate their energy (e.g. rooftop solar) or own electric vehicles to better manage electricity generation and use

**3) User characteristics** help us understand which aspect of a user group is addressed by a user scenario and how it should be marketed.

**4) Product categories** are used in the scenarios to make the ideas more tangible and the scenarios as concrete to imagine as possible.

**5) Location** helps to structure the narrative and is important for the potential implementation and future deployment of the services.

### Development of User Scenarios

The overall value proposition of the following generic scenarios include convenience, comfort, savings, safety, and resilience. They were developed by looking at the product categorization and the product lists of the tech assessment, the literature review, the consumer assessment, the websites of many products, related magazine articles, and the conducted surveys. Specifically, the conducted surveys helped in identifying which scenarios would be relevant for which user groups and what the most important perceived benefits would be for them.

### Scenario Overview: A Day in the life...

The following bullet list is the overview of what might happen throughout a typical day in the life of a potential HEMS customer.

1. Waking up
2. Getting ready for the day
3. Breakfast time
4. Off to work and school
5. Home office
6. Mobile office
7. Gardening
8. Homework time
9. Household chores
10. Monitoring and billing
11. Dinner with friends
12. Entertaining guests
13. Going to bed

From this initial outline, five scenarios are detailed in the section below.

## Five Core Scenarios

For each of those scenarios, the following specifications add more details on:

Identifying value proposition: A description of the value proposition to both the users and the utility company.

- A. Describing service delivery: A description of what this scenario means in terms of service delivery, e.g. what exactly happens in that scenario.
- B. Identifying user interaction: A description of the options of the kind of user interaction that is required for this scenario.
- C. Identifying impacts/requirements: A description of the impacts of system and requirements to be able to provide this service

The user scenarios are meant to demonstrate energy savings, as well as their connection to other value propositions as our research in the user assessments, found that there are closely interrelated in the perception of the users. When they buy a thermostat, they don't only think of energy savings, but also of convenience, same as for other types of appliances or energy saving devices.

Although these core scenarios are relevant for all user groups, there may be varying choices of settings and combinations of devices according to specific user preferences and these scenarios can only serve as examples.

## Waking Up

The following scenario is just one example of how waking up in a smart, potentially interconnected environment could take place. User preferences may vary widely from what is chosen as a specific setting in this particular instance. For example, one user may like to be woken up by sunlight, having smart window shades rise with the sun. Other users may prefer ambient lighting to be woken up at a time different than sunrise and then have the smart shades go up after they had a chance to get dressed, because their bedroom window may face a street or another home.

Further variations are also possible in the user interaction with the devices, so there are different levels of automation or connectivity between the devices. This depends on the degree of individual interaction or automation that the user desires.

# WAKING UP



**Value proposition:** In this scenario, the main value propositions are comfort and energy savings, furthermore convenience. It is important to note that our consumer research stream [TARGET-REPORT] revealed that for some consumers, there is a negative connotation of convenience alone. It is more important to them to get at the underlying values of protecting and nurturing one's household. Convenience is only meaningful insofar as it is making achieving an important goal easier, so smart thermostats make achieving thermal comfort more convenient lots of products make security and monitoring your home more convenient. However, convenience alone is often perceived as wasteful, excessive, promoting laziness, or just unnecessary.

**Service delivery - what happens and how it works:** It is 6 am, and while the sun starts rising outside, in both the master bedroom and the kids' bedrooms, soft morning light is produced by the energy-efficient LED ambient lighting, and nature sounds help them to wake up gently. The parents prefer forest sounds while the kids love the jungle sounds.

In the kitchen, a smart plug switches on and the coffee machine starts brewing. The scent of fresh coffee starts to waft through the air and puts the parents in a good mood.

The thermostat adjusts to daytime setting and slowly raises the temperature in the room after the cooler setting for during the night (both for reasons of energy savings and a cool room providing for a better sleeping climate).

At the set time, the smart window shades go up as they have been triggered.

**User interaction/trigger options:** There are a couple of options here depending on how much automation the user prefers in their home and how well they want to connect all their devices.

Variant 1: User may have to interact with each physical device separately once, like the ambient light and the smart speakers to make them start on the desired time.

Variant 2: The settings can be adjusted by the physical display in the wall.



Variant 3: The user may use an app that connects to multiple devices, the lights, the speakers, and the shades, via wireless.

Variant 4: The user may not have to interact at all, which means that the devices would have light sensors outside for the actual sunrise (that users would get up year around with the actual sunrise is unlikely though)

**Impact and requirements:** There may be multiple levels of requirements for the home and the products, which break down from the preferred type of user interaction.

The system needs to know that the user wakes up, which could be either a preset (programmable) time or by a wearable (e.g. Fitbit). If a wearable detects that the user is waking up, the other appliances can be triggered by an IFTTT ("if this then that") service. Alternatively, the appliances could be linked via IFTTT and triggered initially by a simple timer.

The smart home platform needs to be able to talk to the lighting system, sound system, the thermostat, and the wearable (if included).

**Required products:** Smart lights, smart speakers, smart shades, and coffee machine with smart plug. As the scenario described a variety of options for user interaction, the installation of the required infrastructure cannot be described here in general but would have to be detailed for one specific set-up chosen by the user.

**Potential savings:** A single product can achieve change through some savings, but real savings could be achieved through changing the very nature of how people act with their home ecosystem. This is not possible with a single product. However, it is possible to do that with a series of connected products. Most importantly, we want to point out that the fully integrated smart home system can have benefits well over and above what a single smart product can do. In terms of demand-response, there is little savings potential in this particular scenario as the interactions are all immediate and set to a specific time unless batteries were charged at a cheaper rate and the energy was stored for this purpose. In terms of energy-efficiency, all the individual products save some energy, especially LED lights as opposed to incandescent bulbs, but even more via the automation potential that avoids wasting energy. In terms of behavioral savings, the choice of electric light in the morning versus shades going up depends more on the location of the bedroom in the house and the time that the users have to get up but adjusting thermostats and lights to default settings that don't waste energy is important.

## Off to Work/School

**Value proposition:** The value propositions of this scenario are safety, security, and energy savings. Furthermore, some of the services add convenience.

**Service delivery:** When Dad and daughter get into the car to leave for him to drop her off at school before work, the garage opener automatically opens the door and lets them proceed and then closes after the car, but stops for a few seconds when it senses the cat swooshing through.

Dad gets a notification on his phone flagging him that the lighthaaave been left on in the hallway and asks whether to turn them off - they are not turned off automatically in this case because he might have chosen to leave them on for security purposes

and they are sometimes used at night during vacation time to let the home appear occupied.

The lights are switched off automatically in the garage after a brief time-out to save energy.

The safety system automatically locks the front and back door after mom and son leave the house to walk him to kindergarten. Furthermore, the thermostat adjusts, the security system activates, further lights and appliances turn off, for example, the curling iron mom used earlier, the coffee pot that is still on in the kitchen, and the music in the kids' bedroom.

Monitoring while away, there are phone notifications with video when the kids get home, their friends come over, or packages are delivered. It is also possible to remotely view the status of lights, appliances, and doors for peace of mind. Furthermore, there is a potential for smart thermostats to help maximize use of solar by modifying the home cooling patterns in summer accordingly.

For flexibility in schedule, the security system can unlock the door when the kids get home, or the housekeeper arrives, and door and window sensors can activate an alarm sequence employing smart lights and speakers to ward off intruders and notify the user. This can possibly be integrated with security services to send help.

**User interaction:** Again, depending on how much automation the user prefers, many of these elements can be integrated into a service platform that the user accesses via their smartphone, or the interaction can be more individualized and less automated.

**Impact and requirements:** The system needs to know when specific users leave home via which mode and be made aware of whether there still are other users at home.

**Required products:** Smart plugs, energy-efficient appliances, security system, smart doors, smart lights, smart thermostat, and smartphones.

**Potential savings:** Again, there is potential for energy efficiency as per the individual appliances, there is very high automation potential if the services are integrated via a common backbone, and there are potential behavioral savings depending on how the user chooses the settings for 'monitoring while away.'

## Household Chores

**Value proposition:** Here the main value propositions are saving time and saving energy, as well as some added convenience.

**Service delivery:** Over the course of the day, there are a few household chores to be taken care of. Mom and Dad try to split the work up evenly and involve the kids in a few tasks as well.

The laundry was loaded in the morning and set to a mode where it automatically runs during low load times, using solar energy when available, and renewable energy from the grid otherwise. The laundry coordinates with energy prices and sources and then sends notifications when loads are done to preventing the need to re-wash or fluff dry.

Specifically, around the area of solar energy, smart appliances (washer, dryer, dishwasher) could be set so that they run when the solar is generating to get the

most use out of the solar system (leading to cost savings for family) and minimize grid constraints (good for the utility company).

In the kitchen, with regard to shopping trips, Mom can dictate her shopping lists to Echo or a similar service. If she is already on her way, she can check the refrigerator camera remotely to minimize trips and maximize productivity.

For cleaning, the little vacuuming robot zooms around the house during the morning hours twice per week - the only part it cannot handle (yet) are the stairs. It takes longer than manually vacuuming but it is also more energy-efficient and as it is done when no one is around, the duration of the task is not important.

The little dog has an automatic food dispenser that helps with the everyday pet care, but of course, everyone sneaks him a few favorite treats here and there.

For maintenance tasks, the house is equipped with two kinds of sensors that report back on issues that might need tending to Water leak sensors and energy drain sensors.

There are water leak sensors connected to inform the family of floods as well as slower water leaks which might cause mold in the long run. Especially as the parents remodeled an old house with smart devices, potential mold, and the related health risks are a concern they take seriously.

The other type of sensors are energy drain sensors, such that when one device continues to use lots of energy even though it has not been "used," it gets flagged and the parents can check on it. Finally, the energy portal prompts to clean light fixtures and refrigerator coils and oven on a regular basis.

**User interaction:** There are many different types of user interaction in this scenario as it includes a variety of appliances, e.g. the washing machine and dishwasher. Then there is a lot of automated tasks that require initial settings by the user, for example, the vacuuming robot and the automatic food dispenser.

**Impact and requirements:** If the appliances are run individually without a connecting backbone structure, then all appliances need to be aware of their own settings for delivering their services, e.g. in which time frame to vacuum and to then receive the according DR information to be activated at an appropriate point in time. If there is a connecting backbone system, that system needs to have all the information to be able to trigger the appliances according to their schedule, which requires fewer automation capabilities by the individual devices.

**Required products:** Smart plugs, washing machine, smart fridge, vacuuming robot, automatic food dispenser, water leak sensors, and energy drain sensors.

**Potential savings:** Demand response is mainly taken care of by the washing machine, energy efficiency, automation potential, behavioral savings.

## Monitoring and Billing

**Value proposition:** In this scenario, the main value propositions are saving energy, saving money, and some added on convenience.

**Service delivery:** The family gets their bills online, no more unnecessary printed statements. They want to improve their energy consumption monitoring and use the dashboard of the smart home app for keeping an overview of their energy use. The base case is an app that gets data from smart meter in home to give them better

information. On top of such a base case, there are several layers of how “smarts” can build on this.

The family has set conservation goals that they review together with the kids every month and make a fun little competition out of it. This also includes who takes the fastest showers, but Mom still checks whether the kids scrubbed properly behind their ears to make sure they do not cheat for the sake of the competition. For this, the app provides some disaggregation on the data and can add in user prompts if the usage gets above a certain point/goal, or with energy advice, tips, recommendations. It could also be imagined that the app that's disaggregating energy usage can then make product (smart product) recommendations to the user accordingly.

Their dashboard also provides demand-response timing information for energy needs that the user plans ahead of time, for example, to run the washing machine at low-cost times. That way, they can make optimal use of participation in smart grids. Also, the app could help pulling them into behavioral DR programs by advertising the right program for their usage patterns in its recommendations.

On a next layer, smart appliances can also be monitored by the platform/app. That means, the dashboard also features a report panel on savings and emissions where they can see how well the smart plugs and smart lights have paid off within only a short period. These could be used in: (1) making the advice the app gives about energy saving smarter and/or more accurate, help users save money if TOU tariffs are implemented, and (3) potentially enable automated DR. Obviously the smart devices and smart meter would need to communicate together in one platform for their information to be delivered to app/included in prompts, and for the user to be able to control them remotely from the app.

Another nice feature of the family's overall set-up is that they have solar panels in combination with being connected to a smart grid that already takes into account different renewable sources. With the demand-response service, they can feed unused energy back into the grid and make it available for others.

The monitoring panel for different energy sources that get integrated tells them that, during this month, they managed to produce 45% of their energy consumption by solar, they used 25% energy from wind power and 15% from water power. The remaining 15% are powered by traditional carbon. In the neighborhood high score for lowest energy use that the family decided to participate in a few months ago they are now in second rank.

**User interaction:** In this scenario, the user interaction is mainly in between the user and the energy dashboard app. The user can view the information in different perspectives, e.g. aggregated and broken down, read recommendations, set new savings goals, and follow up on new program information offered by their utility company.

**Impact and requirements:** The main reason when monitoring apps fail is because of insufficient usability. Therefore, the highest priority for the energy dashboard app is to present information in a very easily accessible way, with intuitive drill-down of the data. This could, for example, be visualized by tapping (touchscreen) on the individual rooms of the house for drilling down from the aggregated overall family consumption this month to the individual rooms and then appliances.

It requires a lot of context-sensitive menus so that the user can find linked information from different points in the app. For example, recommendations should be available in a context-sensitive menu from every room display as well as in a

general tab and from the monthly statement, each time ordered according to the user perspective that the user came from in that particular step. That means, when the user taps onto the kitchen drill-down of information and then uses the context-sensitive menu for recommendations, they will see recommendations that have to do with kitchen usage and appliances.

**Required products:** Energy dashboard app.

**Potential savings:** This scenario combined the different types of savings in the sense that the user gets an overview of them aggregated by the dashboard of the app and can also break down those savings to see how the appliances and smart devices individually contribute to that. This way of presenting information will trigger the user to further pursue their savings goals.

## Going to Bed

**Value proposition:** In this scenario, the main value propositions are safety, security, relaxation, mobility, and energy-saving.

Service delivery

Finally, after hosting a fun evening with friends and capping it off with a night cap, the guests are on their way home. The front door locks automatically and switches on the alarm system's night mode because it is after 10 pm. The alarm system connects a camera in front of the house and one in the back as well as the front and back door locks and the ground floor windows.

In this scenario, there are similar services engaged as when leaving home in terms of shutting things down and stopping phantom power draws. For example, the shades go down, the remaining ambient lighting in the house is dimmed down to facilitate relaxation until the parents go to bed, the smart thermostat adjusts for optimal sleeping conditions, the baby monitor switches on, the humidifier turns on, the smart plugs that are not needed in night mode switch off.

The little lights that the parents like to leave on at the door of the kids room to make them feel safe in case they wake up during the night are implemented as smart lights (LED) to help minimize those lighting demands at night (when solar is not generating).

Even though there is a storm warning for the night, the parents sleep well because they trust their lightning protection system that has a kill switch, a fuse with attached feedback mechanism that would switch off any electric system so that no damage would be caused.

The electric vehicle is charging in the garage at night from the solar batteries that were charged throughout the day so that the car is fully charged for the next day.

**User interaction:** In this scenario, the interaction happens predominantly when the user sets the system settings for automating tasks like activating the security system and adjusting the systems for the night, for example, the thermostat and the shades.

**Impact and requirements:** This scenario can be implemented with varying degrees of connectedness and automation to occur as described. The security system has connected subsystems, but the system may just have a night setting that gets activated by the user. The shades and thermostats and night lights might be

programmed individually or accessed within the same night setting on a joint app. The kill switch is an independent safety measure. The electric vehicle needs to be plugged at some point and then the recharge setting could be individual or included in a general smart home monitoring app.

**Required products:** smart alarm system, smart shades, smart thermostat, smart lights, smart plugs, kill switch, and electric vehicle.

**Potential savings:** This scenario can include demand-response savings (charging of the electric vehicle), energy efficiency (smart devices), automation potential (connection of the services and automated triggering of energy-saving modes), and behavioral savings (as the user has to program all the automation settings and prepare the car for charging).

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