Bundling energy savings with consumer interest in smart homes

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ABSTRACT

The swift adoption of IoT products presents opportunities to save households meaningful energy through increased information and control, even though it may also lead to increased stand-by loads. Meanwhile, purpose-built home energy management systems that excite consumers have not emerged. ENERGY STAR has now codified recognition of bundles of IoT devices and services that can save energy. The identified system combines smart home devices consumers are already adopting with services to optimize energy use, allowing efficiency programs to address smart home systems similarly to other consumer products, by advising consumers about which service options are most likely to generate energy savings.

The criteria for recognition were developed over 18 months of discussion with a wide variety of stakeholders, including smart home service providers, IoT device manufacturers, utilities, NGOs, and researchers. The criteria require a bundle of specific devices, specific services, and availability of additional services. To participate, service providers, such as cable providers or home security companies, must submit a well-defined set of aggregated field data capturing installations using this bundle of devices and services. The data confirm that the service provider is delivering the defined bundle to their users and will also be a basis for developing a future metric demonstrating energy savings across a variety of specific individual installations. The criteria were finalized in September 2019, and the first certifications are expected in 2020.

Introduction

The US revenue from the sale of devices marketed as "smart" grew thirty-six percent between 2017 and 2018 (Cassagnol 2018). Based on consumer interest in the novelty and convenience features of these devices, this trend is expected to continue. Left unchecked, the energy consumption of these devices could add significantly to the already growing category of "miscellaneous" energy use in U.S. homes, begging the question, "Is it smart, if it's not energy efficient?"

EPA and participating ENERGY STAR stakeholders saw an opportunity to mitigate growing consumption and bring a focus on energy savings to the smart home market through development of ENERGY STAR certification criteria. The strategy: leverage the powerful ENERGY STAR brand and partnership to guide smart home systems toward readily achievable energy savings in the near term, while working toward the future of a smart home ecosystem that can act as a single touchpoint to manage energy consumption. Working closely with stakeholders, EPA identified energy savings enabled by occupancy detection, standby power, interoperability, and user amenity as focal areas for the initial specification. As the first large-scale national program to recognize the energy performance of smart home systems, the ENERGY STAR Smart Home Energy Management Systems (SHEMS) program will be a primary platform for diverse stakeholders to collaborate towards realizing the potential of this technology to advance sustainability and resiliency through energy savings, grid services, and integrating distributed energy resources (DERs).

The ENERGY STAR program provides recognition to a bundle of smart home devices and the services that control the devices to save energy based on automatic detection of home occupancy and user-defined schedules and rules. The program is designed to meet the market where it is today by leveraging top selling device types, while providing a framework to build towards a more fully integrated whole home energy management system. Energy savings from the initial specification will be realized through automated control plus measurement and reporting of home heating, cooling, lighting, and plug loads. The program encourages smart home providers to maximize the energy savings and grid management potential of their systems through compatibility with additional devices such as water heater control, automated window attachments, battery storage systems, EV chargers, and solar inverters.

Over time, aggregated statistical data from service providers' platforms will inform the development of a performance metric that reflects the energy savings performance of SHEMS installations. EPA anticipates that including a performance metric in future versions of the specification will enhance the value of ENERGY STAR certified SHEMS for both consumers and utilities and further incentivize increases in SHEMS adoption.

Background

According to the U.S. Energy Information Administration, the residential sector accounts for approximately 20% of U.S. total energy consumption (2020). Within the residential sector, smart home technology is expected to grow dramatically in the coming years, with the Consumer Technology Association (CTA) projecting 16% growth in 2019 and McKinsey & Company noting a 31% compound annual growth rate in the number of connected homes in the U.S. (29 million in 2017) from 2015 to 2017 (Cassagnol 2019; Ahuja and Patel 2017).

Increasing adoption and use of smart home technology has the potential for energy savings and greenhouse gas emissions reductions. A study by CTA indicates that if used to save energy, widespread adoption of home automation products such as temperature, circuit and lighting control could collectively avoid up to 100 million tons of CO_2 emissions and reduce total residential primary energy consumption by as much as 10%. CTA's study suggests the overall U.S. technical energy savings potential from several individual approaches ranges from 0.3 to 1.1 quadrillion BTUs (quads) of primary energy consumption, or from 1% to 5% of total residential primary energy consumption (Urban, Roth, and Harbor 2016). The study highlights several areas where home automation could deliver energy savings, including connected thermostats, HVAC zoning, and control of window shades, circuits and lighting.

Previous efforts to deploy purposely designed HEMS, largely led to by utilities, have saved energy but have struggled to demonstrate persistent savings or market success. Other efforts have missed the mark in maintaining consumer attention and interaction with the system. For example, some utilities have piloted programs with in-home displays providing energy information to generate savings through behavioral change. As summarized by Northeast Energy Efficiency Partnerships (NEEP), Cape Light Compact ran a smart home energy monitoring pilot (SHEMP) project with cohorts in 2010 (Legacy) and 2013 (Energize) with a total of about 600 participants. While these projects did find some energy savings, savings were not necessarily persistent for a given user and were highly sensitive to consumer experience; whereas the Legacy cohort achieved savings approaching 9%, the Energize cohort only achieved 1.49-1.99% energy savings, likely due to differences in how participants were selected and engaged during device installation (Kemper et al. 2015). Similarly, a Pacific Gas and Electric (PG&E) meta-analysis found that savings from energy feedback was highly variable, depending on the length of the study (those that ranged from 3-12 months were less effective) and the informational strategy (Karlin, Zinger, and Ford 2015). This variability makes it difficult for utilities to justify behavioral programs based on energy monitoring and feedback. EPA's approach is consistent with one conclusion of the PG&E meta-analysis, which postulated that "integrated solutions" that include both energy feedback and control could achieve more consistent and higher savings.

Other projects, such as the Ecobee Massachusetts 2011 smart thermostat pilot, have focused on smart controls for energy savings. These programs generally find savings of 5-15% but have only included smart thermostats and fail to realize the potential of a truly integrated solution (Kemper et al. 2015). More recent utility efforts aim to make it easier to act on load shifting and money savings opportunities but require some extra work, like setting up IFTTT (If This Then That) Applets to be notified of price schedule changes or procuring devices through an online marketplace. The ENERGY STAR program was created in the hopes of recognizing solutions that make energy savings simple, effective, and long-lasting.

Specific Market Activity That Led to the ENERGY STAR SHEMS Program

Independent of utility actions, smart home automation technology is becoming increasingly popular, and accelerating even more through the rapid growth in voice assistants on mobile phones and smart speakers. The market growth of sophisticated controls offers new opportunities for sustainability through energy savings and grid services, but to capture them will require a compelling business case and clear choices for consumers.

The ENERGY STAR program began defining connected criteria in product specifications in 2013. EPA focuses on product categories where connectivity allows for some combination of greater energy savings, grid benefits, and diagnostics to improve performance or maintenance.

Consumer value is always the key element to adoption. As shown in Figure 1, consumers frequently purchase smart devices in order to save money. Given that utility bills are in most cases the best opportunities for cost savings from smart devices, this in turn suggests that energy management can be a major purchase driver. However, even products marketed for energy management often fail to fully realize the potential for occupancy-based savings. For example, a smart thermostat may sense occupancy and modify the thermostat setback schedule accordingly but not coordinate amongst other devices. The ENERGY STAR SHEMS program will help consumers identify systems that deliver the energy savings and central control they desire.

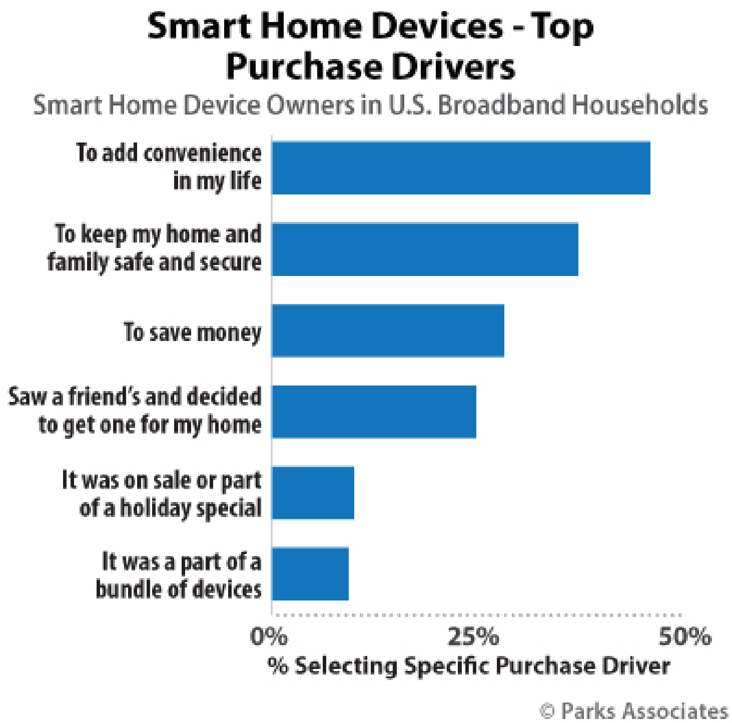

Figure 1: Rankings of smart home device purchase motivations among U.S. broadband households. *Source:* Parks Associates, 2018. http://www.parksassociates.com/blog/article/cus-2018-pr10.

Utility interest in leveraging connected home systems for integrated demand-side management is growing, especially within service territories with high renewables penetration or capacity constraints. In parallel, residential customers have more access to and are increasingly enrolling in time of use rate structures. Recent Parks Associates research reveals 11% of US broadband households participate in a time-of-use program (2020a); according to the Energy Information Administration, over 5.2 million residential utility customers were enrolled in time of use rates nationwide in 2018, an increase of 10% from 2017 (EIA 2018). More than 75 percent of residential customers in Maryland are enrolled in time-differentiated rates, and the 22.5 million residential customers of the California Investor-Owned Utilities (IOUs) will transition to default time of use rates in 2019 and 2020 (Miziolek 2019). In this context, the ability of a smart home system to automatically align various loads with low rates is becoming increasingly valuable to both consumers and to utilities.

The success of smart thermostats, with the farthest-reaching adoption among smart home energy related device to date (an estimated 13% adoption in 2017 for U.S. broadband customers), has opened the door to opportunities to bring more smart energy savings into more homes (Parks Associates 2018). Consumers are also showing more interest in automated energy programs, as 42% of current smart thermostat owners would allow a utility to adjust their device in order to save energy (Parks Associates 2020b).

Since 2017 when the first ENERGY STAR smart thermostat was certified, the program has grown quickly, with most popular smart thermostats participating and more than 34 million households in utility territories that offer rebates for certified thermostats. At least 207 utilities ran a smart thermostat program in 2019 with an average incentive of $68 (EPA 2019).

The success of ENERGY STAR smart thermostats was important to development of the SHEMS specification in two ways. First, it pioneered the principle of using field data to demonstrate savings, which applies to other controls such as SHEMS. Second, since most smart homes include a smart thermostat, requiring the use of an ENERGY STAR certified model guarantees at least those savings for the homeowner.

The Home Energy Management Systems (HEMS) working group co-chaired by the Building Performance Association (BPA) and Northeast Energy Efficiency Partnerships (NEEP) engages utilities, device manufacturers, and service providers to share market developments and best practices. This group was essential to the creation of the ENERGY STAR SHEMS program. The ENERGY STAR SHEMS program built on these efforts with EPA-organized targeted stakeholder engagement in dedicated work groups co-chaired by market experts to inform the creation of the program.

Role of ENERGY STAR as a National Labeling Program

The ENERGY STAR program recognizes savers among products already in the market, rather than specifying the design of new ones, to leverage the power of the market to drive savings. Because it is a voluntary program, ENERGY STAR relies on recognizing (and thereby rewarding) existing market differentiation in order to drive the adoption and innovation of energy efficient products. The program has historically recognized products representing the most energy efficient options on the market, with an expectation of maintaining similar or better performance as assessed under standardized test conditions.

Smart home automation systems that manage energy use face many of the same barriers to adoption as other energy-efficient products. By allowing consumers to easily recognize smart home systems that can save energy, the ENERGY STAR program addresses one of the biggest common challenges: visibility. Having garnered significant consumer recognition and trust in the past 28 years, the ENERGY STAR label is well positioned to provide the same customer visibility and marketing advantages for smart home energy management systems that it does for other products. By introducing standardized capabilities at a national scale and associating smart home systems with the trusted and powerful ENERGY STAR mark, the ENERGY STAR SHEMS specification is well-positioned to guide popular smart home offerings toward energy efficiency and energy management best practices.

Program Elements

As defined by EPA in the Version 1.0 Program Requirements, Smart Home Energy Management System(s) (SHEMS) refers to a package of smart home devices connected to a central service that enables user amenity and energy savings through scheduling, remote device control by the user, and automated device control based on occupancy detection. To be certified as an ENERGY STAR SHEMS, the package must meet minimum device requirements and service capabilities. As shown in Figure 2, the SHEMS certification mark only applies to the combination of devices and services and does not apply to the devices or services individually.

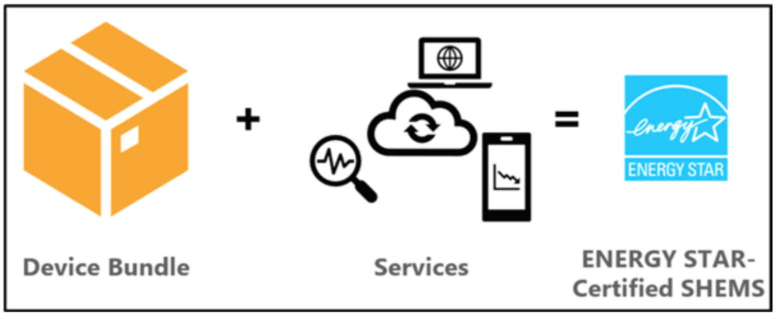

Figure 2: An ENERGY STAR SHEMS must combine devices and services.

Approach: Occupancy Based Automation

Hypothesis: Using occupancy information to help optimize smart home devices will deliver more energy savings than devices that are not tied to occupancy information.

Smart home energy management technology is hypothesized to offer a potential for energy savings and grid services. As mentioned above, a pilot study comprising 50 homes implemented by the New York State Energy Research and Development Agency (NYSERDA) indicated an average HEMS energy savings potential of 16% of annual energy use and 0.2kW peak demand savings per home (Piper et al. 2017). The studied HEMS used data from geofencing and occupancy sensors to control a thermostat, smart lighting, and smart plugs. The study noted that additional savings are possible, though difficult to quantify, through behavior change linked to the data reporting capabilities of HEMS.

EPA expects that occupancy-based automation will be the largest driver of energy savings. Therefore, homes with periods of low occupancy will see the greatest savings, whereas homes that are occupied constantly will save less energy. In addition, since HVAC control provides a large proportion of the savings, climate, home envelope, and efficiency of HVAC equipment will have a strong influence.

Interoperability

Interoperability is a key barrier for consumer adoption, satisfaction, and use. In the context of energy savings, interoperability issues prevalent today pose challenges not just to basic connectivity but also to the ability of a system to monitor and control energy use of connected devices. EPA designed the first SHEMS program specifically to address these challenges by focusing the criteria on a single service provider who manages the smart home network for the end user and ensures the devices within the home work together and can be managed, at least on a basic level, through a single platform. The focus on service providers will leverage existing market mechanisms to encourage interoperability. Adapting this program to systems that are do-it-yourself (and do not rely on a service provider) would be challenging for interoperability and other reasons, but it may be possible in the future as the market matures.

EPA is also encouraging interoperability by:

- Encouraging and reporting the use of open standards (e.g., Wi-Fi, SEP, Bluetooth)
- Mandating that required devices be automatically detected and that consumers can set them up through the SHEMS app (i.e., customer user interface).

- Encouraging additional compatible devices such as solar inverters, connected electric vehicle chargers, and connected appliances.
- Requiring that for devices to be considered compatible, they must share energy consumption and occupancy information with the SHEMS.

Security and Privacy

EPA recognizes that concerns about data privacy and cybersecurity are significant barriers to consumer adoption. Although the ENERGY STAR program, which focuses on energy efficiency, is not positioned to develop standards in these areas, several components of the program are intended to recognize or incentivize systems that protect consumers. First, the ENERGY STAR program recognizes single service providers, which are the logical entity to assess and manage risk and security of devices that come from multiple manufacturers and have strong incentives to do so. Service providers are also required to report any data privacy and cybersecurity standards they adhere to when certifying new products. EPA may make this information available as part of the certified product list.

As mentioned previously, EPA only receives aggregated statistical information about each service provider's offering and will not have access to any personally identifiable information. Energy efficiency programs that have direct data sharing agreements with SHEMS providers should consult with their legal and corporate communications departments to determine the best way to communicate data privacy issues with their customers.

Device Criteria

An ENERGY STAR SHEMS package includes the following devices and must meet the maximum standby power requirements specified in Table 1 below.

Table 1: ENERGY STAR SHEMS device requirements and standby power limits

Device Category (Minimum number)	Device Requirements	Maximum Allowable Standby Power Consumption
Connected Thermostat (1)	ENERGY STAR Certified Thermostat Must be automated based on occupancy detection.	3.0 watts
Connected Lighting (2)	At least one ENERGY STAR Certified Connected Bulb or Fixture; second device may be a smart light switch. Must be automated based on occupancy detection. Must be capable of reporting energy consumption and responding to vacation and safety modes.	0.5 – 1.5 watts for ENERGY STAR lighting; 0.5 watts for smart light switches
Connected Plug Load Device (1)	Includes smart plugs, smart power strips, and home energy monitors; must be capable of reporting power or energy consumption. Smart plugs and outlets must be automated based on occupancy detection.	1.0 watt

Device Category (Minimum number)	Device Requirements	Maximum Allowable Standby Power Consumption
Occupancy Sensor (1)	Permanently located in the home. Service provider must recommend installation in high traffic area. May be incorporated in one of the other devices (e.g. connected thermostat with an integrated sensor).	N/A
Optional Devices	Some systems may use a Hub to provide connectivity to other devices. Other optional devices, such as ENERGY STAR certified appliances with connected functionality, are encouraged.	Standby consumption must be reported for the Hub.

Required Interface and Service Capabilities

All ENERGY STAR-certified SHEMS must include an interface that provides user control of required and optional devices from outside the home, receipt and response to occupancy data, information on the energy consumption of SHEMS-connected devices; and that enables the energy saving device control actions below. Figure 3 illustrates how users may experience energy saving actions through their mobile device.

- Facilitating user-established rules and schedules or event-triggered actions (e.g., arming alarm panel triggers 'away' setting)
- Suggesting energy saving actions to the user based on device usage patterns, room occupancy, or home occupancy
- Automatically controlling smart home devices based on device usage patterns, room occupancy, or home occupancy. (There also must be user opt-out options for this feature.)

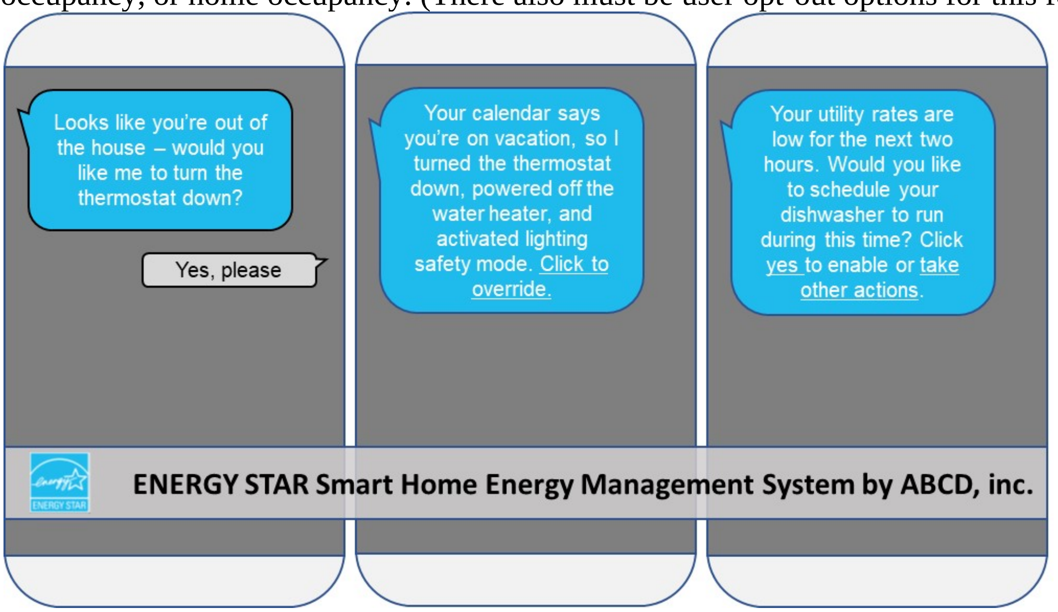

Figure 3: Sample screenshots of required energy-saving actions for ENERGY STAR SHEMS.

In addition, the SHEMS platform must be capable of the following:

- Automatically detecting devices through the SHEMS app/user interface
- Providing a vacation or nighttime safety mode that automates lighting when activated and consumes no more than 0.03kWh/day.
- Connecting to and controlling a water heater (i.e., water heater controller or ENERGY STAR-certified water heater).
- Enabling signal receipt and response to a demand response (DR) event. For instance, this could include enabling a DR request to shed load through an ENERGY STAR connected thermostat or to adjust water heater operation in response to an OpenADR request. (DR functionality is not activated unless the customer has agreed to participate in a demand response program or initiative.)
- Controlling devices based on time-of-use energy prices provided by the customer or via integration with a utility program.

Additional details about these criteria can be found in the ENERGY STAR Product Specification for Smart Home Energy Management Systems.

Opportunities for Utilities and Incentive Programs

Utilities are looking for ways to help manage demand, distributed energy resources and evolve energy efficiency program models. Utilities and other interested energy efficiency program sponsors are likely to first introduce ENERGY STAR-certified SHEMS on a pilot program basis and/or evolve existing pilots to align with ENERGY STAR criteria. EPA recommends that energy efficiency program sponsors encourage service providers to submit optional data in SHEMS pilots to better assist with understanding of systems and energy management potential.

Behavioral Programs

Given that program costs and breadth of reach are what drives what goes into a portfolio of programs, behavior programs are considered the next best thing to lighting in the residential sector. The main challenge with behavior programs from a utility planning perspective is how long the energy saving behaviors will persist. Most commissions limit the lifetime to 3 years or less. Therefore, a utility needs to constantly reacquire the savings from the same or different customers, which limits their usefulness in avoiding investment in another resource (e.g., supply).

ENERGY STAR SHEMS will make it simple for users to leverage technology to help change their behavior – and cement behavior through rules, schedules, and machine learning automation that can serve end users energy savings without a lot of effort. An installed SHEMS package can also be tapped for future DR—possibly with additional investment, but less than direct load control, and with better customer amenity.

Demand Response

ENERGY STAR SHEMS must be able to work with utility demand response programs by implementing a demand response signal to at least one device in the package, but there are no specific required responses. The functions need not be in use in every installation for ENERGY STAR certification. Providers are encouraged to use open standards to meet this criterion (e.g., by offering an OpenADR virtual end node). Standardization in this case was limited by the variety of utility DR programs available now and the variety of smart home business models.

Time of Use Pricing

Opt-out time of use rates and other time dependent variable rate structures are growing rapidly in the consumer market, and utilities are eager to offer consumers tools to make managing for cost savings easier. This reflects the increasing importance of the time of energy use to utilities. Depending on user preference and rate structure, there are several capability requirements in the ENERGY STAR SHEMS criteria that can help customers to respond to time-based rates. The most direct option is to allow device control based on time-of-use energy prices provided by the customer or via integration with a utility program. Additionally, the scheduling feature of an ENERGY STAR-certified SHEMS could be used by the customer to prioritize energy consumption based on rate schedules and other user-defined considerations. The interface enabling user control of devices from outside the home may further facilitate customer participation in periodic peak-time reward events.

Energy Savings

As previously referenced, a pilot study comprising 50 homes implemented by the New York State Energy Research and Development Agency (NYSERDA) indicated an average HEMS energy savings potential of 16% of annual energy use and 0.2kW peak demand savings per home (Piper et al. 2017). Other studies show a small system (thermostat, plug load and lighting for example) achieving savings of up to 22% (inclusive of the thermostat savings that represents roughly 14%).

Evaluation Method

To assess energy savings, program partners will commit to regularly submit aggregated statistical data on how their products are used by their customers. Controls save energy through a complex interaction between their technical features and user behaviors, so there is no way to evaluate their ability to save energy without considering how users interact with them. Because of this and to account for possible changes due to software updates, EPA asks for a well-defined set of data to be submitted at the time of third-party certification and every six months thereafter.

In deciding which data to collect, EPA concentrated on three categories: data that confirm that the installations meet the requirements of the SHEMS specification; data that we anticipate will help us develop a technology-agnostic savings metric; and data that reveal market developments toward integration with utilities and additional products.

The data rely on information EPA expects the SHEMS service provider partner to have access to. Notably, we don’t expect this to typically include data from utility meters. Based on our experience with smart thermostats, it is surprisingly hard to arrange to have both meter data and smart home data on the same home. That’s because both utilities and smart home service providers have an obligation to protect their customers’ privacy, which generally includes not giving customer names and addresses to the other company. For SHEMS, as for smart thermostats, EPA has a legal partnership with the service provider, and that is the entity that is obligated to meet the terms of the partnership and specification, including sharing data. Neither EPA nor the service provider have any way to compel utilities to share their customers’ data, nor do either have appropriate controls on data privacy that compare to what utility commissions require.

Based on the hypothesis that savings will be based on occupancy-based automation, data elements referring to average away time per week are required and will inform the metric. The optional data elements of average power used during non-away time and percent reduction in average power during away time will characterize the depth of savings. Actual savings will reflect both – a shallower energy reduction for a long time will save as much as a deeper reduction for a shorter time. This will only account for energy used by devices integrated into the SHEMS. Some installations may also have access to whole home energy use, either through a software solution like Green Button or through a hardware solution such as a power submetering system or optical meter reader. Depending on the proportion of installations with such access, whole home data may be useful to calibrate whatever metric we eventually propose.

We have deliberately been vague about what "away" time means. Some systems will have and use room-level occupancy to save energy; others will only have occupancy data about the whole home. The data collection is structured for the Partner (SHEMS service provider) to define "away" for themselves. This may muddy the results, but EPA was not in a position to predict which strategies were most effective, and in fact they may vary from home to home.

Standby Power Limits

A significant tradeoff for SHEMS, as with many connected devices, is between the potential for energy savings due to intelligent control and the additional standby power required to support connected functionality. In order to address this tradeoff for SHEMS, EPA has set standby power limits for all required devices. For required devices with separate ENERGY STAR specifications, such as connected thermostats and lighting, the relevant standby power limits are set by those specifications. For required devices not covered by a separate ENERGY STAR specification, the specification sets standby power limits. In this first version, the limits are intended to be achievable by a wide variety of devices on the market. EPA intends to revisit the standby power requirements in future specifications based on data collected and market developments. EPA believes that limiting standby power in combination with the requirements for device control and automation capabilities will maximize the potential for energy savings.

Next Steps and Vision

Starting from a place that is both practical for today's market and carefully managed by a service provider will allow for early and easy implementation of energy saving focused smart home systems that might otherwise be lost due to individual device focused approaches. In the future this platform can be used to expand the range of services both utilities and service providers can offer customers to better manage their energy use including managing demand response events, integration with time of use energy pricing, and leveraging a variety of distributed energy resources. In the short term, EPA anticipates developing a metric reflecting energy saved by SHEMS as used in homes, which can be relied on for future SHEMS specifications and utility program evaluation efforts. In the long term, SHEMS may grow into a single touchpoint for energy management in homes, optimizing for any of the many goals consumers and utilities may have for energy use.

This first version of the SHEMS specification is prescriptive in terms of both devices and services that must be included. One advantage of the energy saving metric that EPA intends to develop is to confirm that energy is saved while specifying as little as possible about how. Such a savings metric should eventually allow EPA to recognize SHEMS based on energy savings, allowing SHEMS providers maximum flexibility to differentiate themselves and innovate.

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