To ZNE and Beyond! Building a Dynamic Energy Data Resource

Kevin Price and Tami Rasmussen, Evergreen Economics
Mary Anderson, Pacific Gas and Electric Company (PG&E)

ABSTRACT

California seeks to meet aggressive goals in the residential sector, including a zero net energy performance standard for all new homes and implementation of all cost-effective efficiency measures in existing homes by 2020. PG&E's Codes and Standards (C&S) Program is one key strategy to help meet the state's goals. To meet the goals, the program requires current and robust data on equipment saturations, efficiency levels, vintages, and operating hours. Much of this data is difficult to obtain and has not been updated in years, but a new study, the PG&E Home Energy Use Study, will provide this essential data.

The study's first phase involves drawing a representative sample of PG&E customer homes for conducting a detailed in-home survey designed to collect a breadth of information on appliance and equipment holdings. In phase two, a nested sample of surveyed homes will be selected to undergo full-scale metering to measure energy usage at the end use level. Meters will be installed for the long term in order to capture usage trends over time. The on-site surveys were conducted from October 2015 to April 2016, with meter installations set to begin in the summer of 2016. This study will provide an important resource for the state with residential metering data and data on household energy use and appliance holdings.

This paper shares findings from implementing this important field study. The paper also provides information on how the data can be used for C&S advocacy efforts at the utility, state, and federal levels.

Introduction

This paper presents results from the Home Energy Use Study being conducted by Evergreen Economics for Pacific Gas and Electric Company (PG&E), which covers the residential sector and includes both an on-site saturation survey of 1,000 homes and a nested sample of equipment metering at 250 homes.

PG&E's Codes and Standards (C&S) Program requires current and robust data on equipment saturations and efficiency levels, vintages, and operating hours. The Northwest Energy Efficiency Alliance (NEEA) recently completed large scale, robust field and measurement studies in both the residential and commercial sectors, including the Residential Building Stock Assessment (RBSA). The NEEA studies and related equipment inventories and metered data are publicly available and considered to be an extensive and highly reliable resource. Moreover, these studies provide a unique opportunity for PG&E to leverage the NEEA approach to deploy similar studies in its service territory with the benefits of reduced risk and cost. A California study modeled after NEEA's extensive studies will also provide a robust dataset covering a significant portion of the United States that could be used to serve many state and federal codes and standards development needs, including U.S. Department of Energy (DOE) rulemaking procedures.

Using the NEEA RBSA study as a guide, the PG&E residential study involves recruiting a representative sample of homes and collecting detailed information on appliance and

equipment holdings as well as energy usage at the end use level. To accomplish this, the residential study includes two large-scale, multi-year data collection efforts: 1) on-site surveys and 2) full-scale end use metering at a nested sample of surveyed homes.

The on-site surveys were conducted during the October 2015 – April 2016 period, with meter installation beginning in the summer of 2016. The plan is to keep the meters installed for several years in order to capture usage trends over time. The data will be analyzed and reported on via a comprehensive written report and a publicly available searchable database.

Background

For nearly 20 years, California's Investor-Owned Utilities (IOUs) have played a significant role in supporting building code updates and appliance, electronics, and lighting efficiency standards through the statewide utility Codes and Standards Program. The Building Codes and Appliances Standards advocacy subprograms[1] comprise the vast majority of both funding and program savings[2] (Cadmus 2014). The IOUs' advocacy efforts are aimed at both California building codes and appliance standards (Title 20 and Title 24, respectively) and, since 2010, at federal appliance standards. Products covered by appliance standards advocacy broadly range from televisions and general purpose lighting to commercial refrigeration equipment and air conditioners.

Through the advocacy programs, the IOUs seek to identify energy efficiency technologies and strategies with savings potential, and to document the technical feasibility, cost-effectiveness, and market feasibility in Codes and Standards Enhancement (CASE) reports. The IOUs provide this technical analysis to the California Energy Commission (CEC) and the DOE to support utility advocacy efforts for codes and standards adoption.

Title 24 advocacy focuses on regulatory changes to both strengthen and expand building standards found in California's Building Standards Code[3] through new codes and additions to existing codes. Similarly, the IOUs provide CASE studies to provide support for new regulations and for broadening the scope of existing standards to support more stringent California Title 20 appliance standards. Federal appliance standards advocacy efforts seek to increase the stringency of federal efficiency regulations, either through advocating for standards already in place or pushing for adoption of California standards at the federal level (including encouraging early adoption of California standards set to take effect federally at a later date). IOU program staff members conduct market research, identify energy saving products and technologies, attend and offer comments at proceedings, and assist with the negotiation process with industry (Cadmus 2012).

Furthermore, PG&E studies the code readiness of measures and to do so, requires data outside of the scope of data collection for typical energy efficiency program evaluations. This study does not intend to verify or quantify energy savings, but rather gather equipment data indiscriminately across end uses, vintages, and efficiencies, whether or not the household received incentives for any of its equipment—the data will represent all PG&E customers.

As such, the Home Energy Use Study will be a critical source of data for PG&E to provide more rigorous data to both the CEC and the DOE to inform consideration of more

[1] The other subprograms are Compliance Enhancement and Reach Codes.
[2] Since 2006, the California Public Utilities Commission has authorized the IOUs to count energy and gas savings and demand reduction from the C&S Program towards their portfolio achievement goals.
[3] Title 24, Part 6 of California's Building Standards Code.

stringent codes and standards. Without such a current and robust data source, the program has had to rely on small datasets, old data, and/or data from other regions to try to supports its claims. With this dataset, which may be combined with NEEA's RBSA to cover a significant portion of the country, the program will be better able to robustly support its advocacy, leading to informed codes and standards updates through which PG&E may generate energy savings both in-state and across the nation.

Research Approach

Evergreen Economics is leading this study for PG&E, with engineering support for fieldwork and metering equipment selection and installation provided by kW Engineering and Michaels Energy. Evergreen developed the on-site survey sample frame using PG&E's customer information system data,[4] with stratification based on home type, income, and region (groups of counties). The project team oversampled customers living outside the more populous and dense Bay Area region, multi-family homes, and customers living in one of the DOE climate zones not represented by NEEA's RBSA. The metering study sample is a nested sample within the on-site survey sample.

The project team developed the on-site survey instrument, working from NEEA's RBSA instrument. The team is collecting a very complete set of data at each household, including information gleaned from a customer interview as well as a detailed inventory of building characteristics, appliances, electronics, and lighting. The data include information on building foundation, building envelope (including insulation), and orientation information, as well as major appliances (including HVAC and water heating equipment), kitchen appliances, electronics, lighting, windows, and pool equipment. For most of the equipment, the team is collecting product attribute data such as equipment subtypes (specifying the type of furnace, for example), manufacturer, model number, date of manufacture, and efficiency characteristics (e.g., Energy Factor, rated wattage, etc.). The data are either collected for the whole house (e.g., foundation type or types), or on a room-by-room basis to aid in the data collection process and to provide additional granularity beyond NEEA's RBSA, that PG&E can use if needed (e.g., to answer questions such as "what is the saturation of televisions in bedrooms?"). Field surveyors used an electronic data collection tool to record information, adhering to protocols and quality control standards. The project team conducted a pre-test with live customers before finalizing the instrument and data collection and customer recruitment procedures.

Customers were provided with an incentive for participating in the on-site survey, which typically took between four and eight hours. The team will also offer customers an incentive to participate in the metering study, along with additional retention incentives for staying in the study and responding to periodic surveys and home visits.

Data is being collected and recorded in an electronic relational database, and will be available online for public use. In addition to extensive training on data collection procedures, the team has multiple levels of quality control checks and procedures for filling in missing information and making corrections to invalid information.

For the metering study, Evergreen and kW Engineering have developed a custom suite of monitoring equipment and communication devices in order to monitor equipment usage and consumption for the majority of study homes' appliances and electronics. The team plans to

[4] The sample frame is individually metered accounts with electric service, excluding the very remote portions of the territory (less than 2% of the electric service territory).

collect five-minute interval data for all major end uses and a sample of plug loads and electronics. The end-use monitor is a “modlet” that plugs into an existing electrical receptacle (outlet) and communicates usage data wirelessly to a central system. The team will also employ wireless and wired current transducer (CT) clips for major appliances (depending on whether these are on dedicated circuits or not). Lastly, the team plans to deploy interior and exterior temperature sensors for monitoring conditioned and ambient air temperatures, and temperature probes for gas fireplace and gas water heater monitoring (and potentially for gas furnace monitoring). All of the devices will transmit collected data at regular intervals to the centralized data acquisition system. Data will then be transmitted to Evergreen’s servers daily for quality control, cleaning, processing, and analyzing.

Interim Results

While data from this study will feed a report and data visualizations for a website, the key outputs of the study are the datasets. The broad study does not intend to answer specific research questions, but rather to provide a background for supporting codes and standards advocacy decisions. To illustrate the range of data we are collecting and the array of applications covered, the project team provides a series of interim results covering most of PG&E’s service territory.

Lamp Type Saturations

The residential lighting market has changed significantly in the past decade and even in the past four years. Figure 1 shows saturations of common lamp types in homes in PG&E’s service territory. As shown, incandescent lamps and CFLs still fill many sockets, with both halogens and LEDs filling about six sockets each, on average. The California Lighting Appliance and Saturation Study (CLASS) estimated homes in PG&E’s territory in 2012 had less than one LED on average (0.676 LEDs per home) (KEMA 2014). In comparison, this study found a nearly tenfold increase in LED prevalence (6.5 LEDs per home).

This type of time series data shows the impact of many simultaneous market interventions, including large-scale utility upstream rebate programs and standards programs advocacy efforts—CFL saturation increased between the 2005 CLASS and the 2012 CLASS, but LED saturation remained very low even in 2012. These new data show that LED saturation has increased during recent years—with concurrent programs and codes and standards advocacy efforts from PG&E. Saturation tracking studies like this one are a key component of tracking impacts of PG&E’s efforts—both those that have already occurred and those that will in the future.

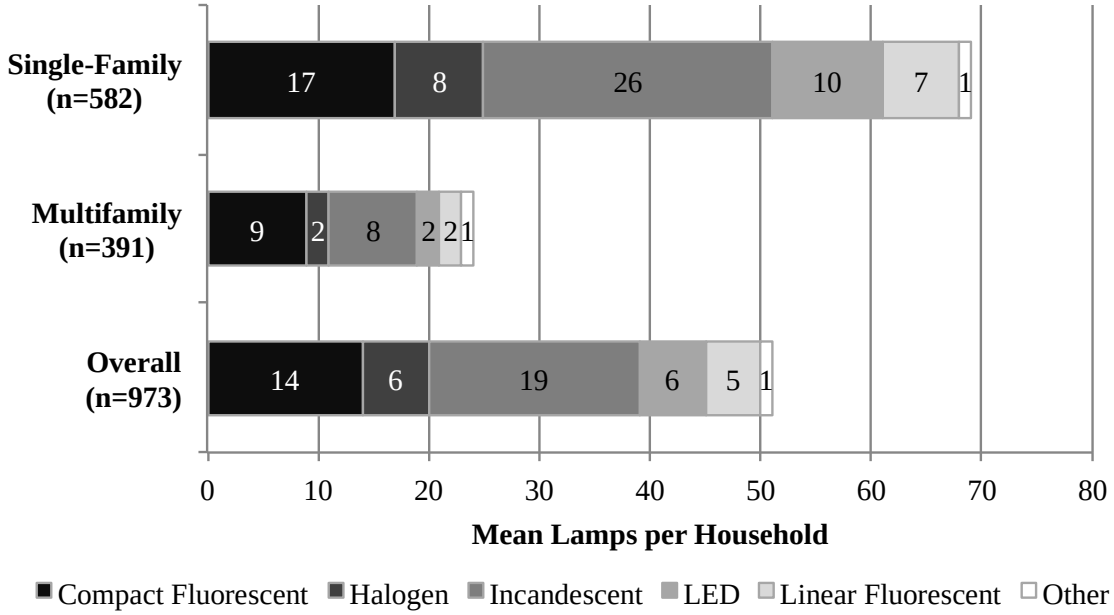


Figure 1. Preliminary lamp type saturations by home type and overall. *Source*: Analysis by Evergreen Economics.

The lighting data are useful for many different types of analysis. For instance, Figure 2 shows the percentages of surveyed lamps that are compliant, non-compliant, or exempt from the Energy Independence and Security Act of 2007 (EISA). As shown, 38 percent of lamps installed in homes in PG&E's service territory are not EISA-compliant, representing important data for code compliance programs and for estimates of potential energy savings in the residential sector.

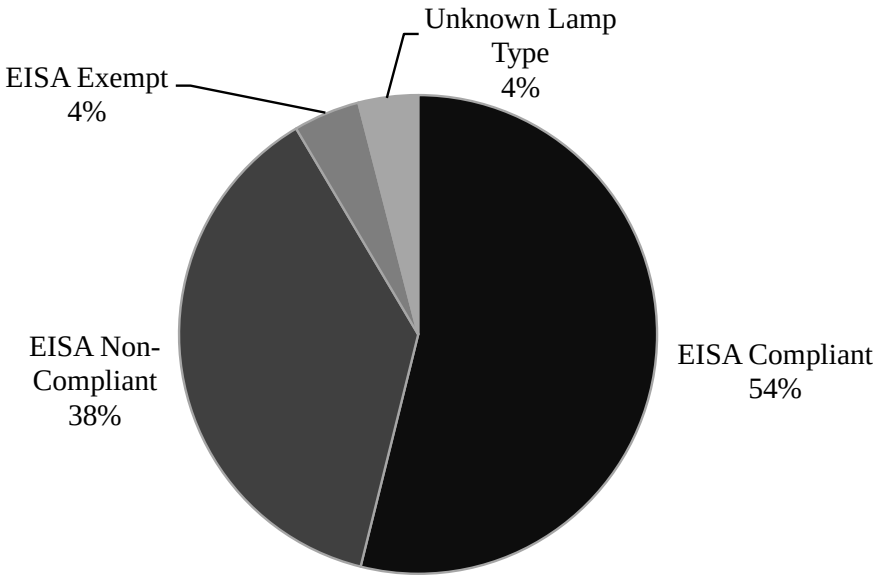
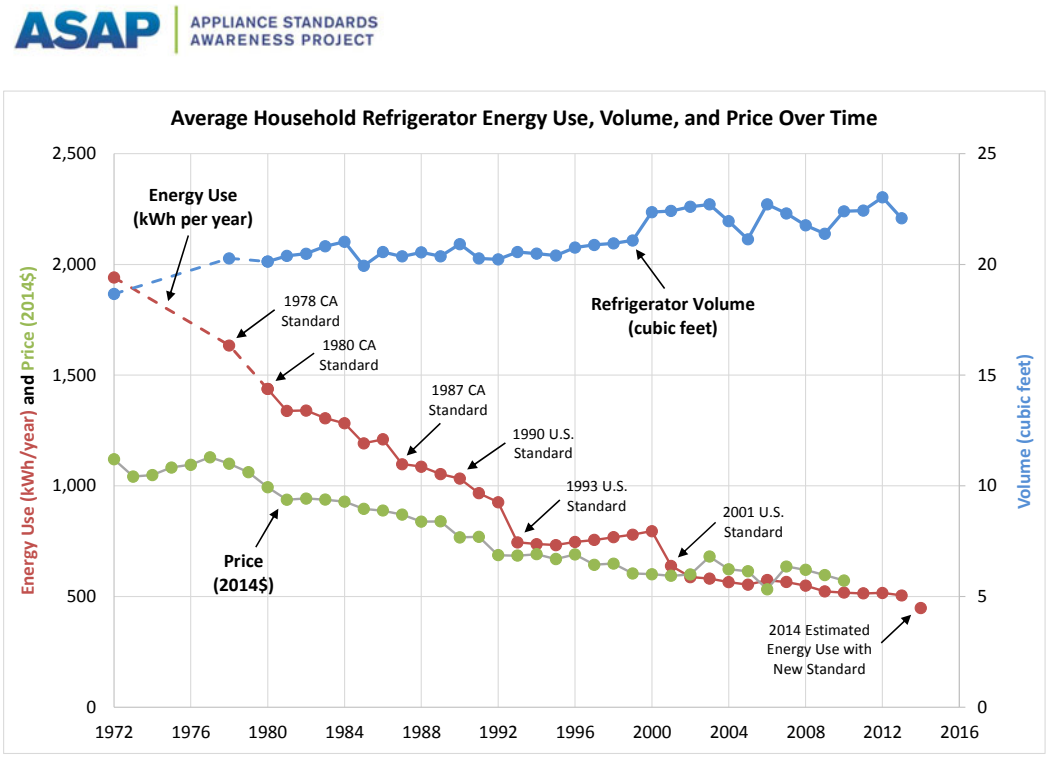


Figure 2. Preliminary analysis of surveyed lamps by EISA compliance status. *Source*: Analysis by Evergreen Economics.

Analysis by EISA compliance illustrates a particular way in which this new dataset can be used to better understand the impacts of standards advocacy efforts, and how to forecast the effects of future efforts.

Refrigerator Type Saturations

Refrigerator standards often are identified as a barometer of success for appliance standards, and California paved the way for current federal standards through numerous state standards in the 1970s and 1980s. Figure 3 shows the history of refrigerator efficiency standards over time, as well as refrigerator price and volume. While price and volume have increased over time, standards have driven efficiency gains.



Sources: Association of Home Appliance Manufacturers (AHAM) for energy consumption and volume; U.S. Census Bureau for price.

Notes: a. Data includes standard-size and compact refrigerators.
b. Energy consumption and volume data reflect the DOE test procedure published in 2010.
c. Volume is adjusted volume, which is equal to fresh food volume + 1.76 * freezer volume.
d. Prices represent the manufacturer selling price (e.g. excluding retailer markups) and reflect products manufactured in the U.S.

Figure 3. Average household refrigerator energy use, volume, and price over time. *Source*: Appliance Standards Awareness Project 2015.

This study provides additional insight to add to our collective understanding of residential refrigeration efficiency. Figure 4 shows refrigerator efficiency data gathered while onsite—with more coming as the study team processes the data and adds in information not observed while onsite (i.e., efficiency levels from CEC appliance databases, which is appended via model number lookups). The data collected thus far indicate that, on average, refrigerators in PG&E's service territory are rated to use just over 500 kWh per year, on par with the 2013 energy use

previously shown in Figure 3, but not quite as efficient as was anticipated for 2014 and beyond. These data may be used to update forecasts for refrigerator efficiency and volume in California, as an input into a national estimate for 2015/2016.

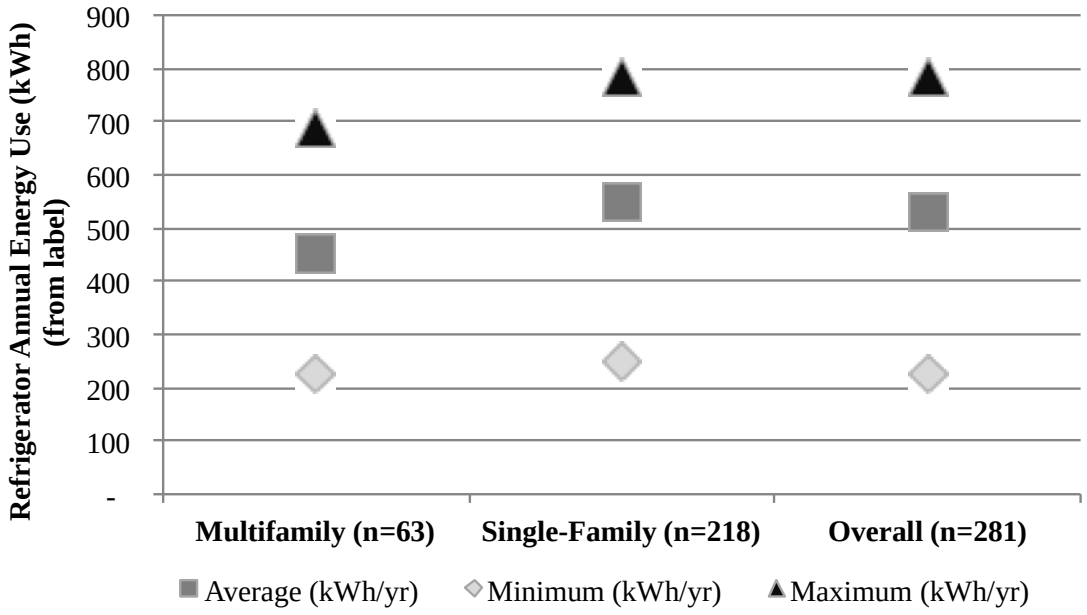


Figure 4. Preliminary refrigeration annual energy use (from energy label), by home type and overall. *Source*: Analysis by Evergreen Economics.

Television Type Saturations

Homes in PG&E's service territory each have 2.0 televisions on average. Figure 5 shows that the majority are LCD televisions (60%), while very few are plasma (5%). This is an important distinction because LCD (and LED) models are more efficient than similar plasma television models, and PG&E's energy efficiency programs support manufacturers and retailers in making and selling highly efficient televisions.

One goal of PG&E was to have a positive impact on the adoption of future television standards. The CEC adopted a new standard in 2009. As the data from our survey show, when compared to the 2012 CLASS, the percentage of televisions that are LCD or LED has increased since 2012. The CLASS study found that 57 percent of televisions were either LCD or LED in 2012 (KEMA 2014), compared to 70 percent currently.

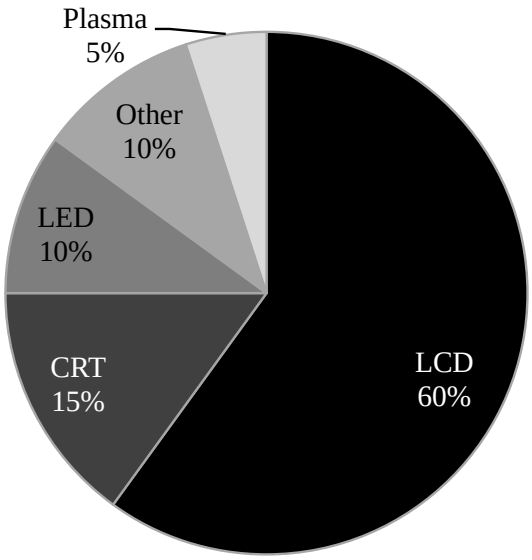


Figure 5. Preliminary television type saturations. *Source*: Analysis by Evergreen Economics.

Prevalence of Gaming Systems

This study also shows there is currently a higher prevalence of gaming systems than in 2012 across PG&E's territory. The 2012 CLASS study found an average of 0.4 gaming systems per household (KEMA 2014), compared to 0.6 game systems per household presently (Figure 6).

Gaming systems present a significant opportunity for energy savings, according to the Natural Resources Defense Council (NRDC) (Delforge and Horowitz 2014). In particular, standby mode power demand has increased with each iteration of the primary gaming systems available on the market (Sony's PlayStation product line, Microsoft's Xbox product line, and Nintendo's product line, including Wii models). The NRDC determined the number of Xbox One's sold before the end of 2013 consume the equivalent of the annual electricity output of a 750-megawatt power plant while in standby mode, which accounts for approximately half of their total energy use. The data collected in this study, particularly metering data, will inform updates to these types of calculations specific to PG&E customers, and thereby will inform the energy savings potential of various gaming system standards approaches and metrics, including considerations such as maximum standby power demand.

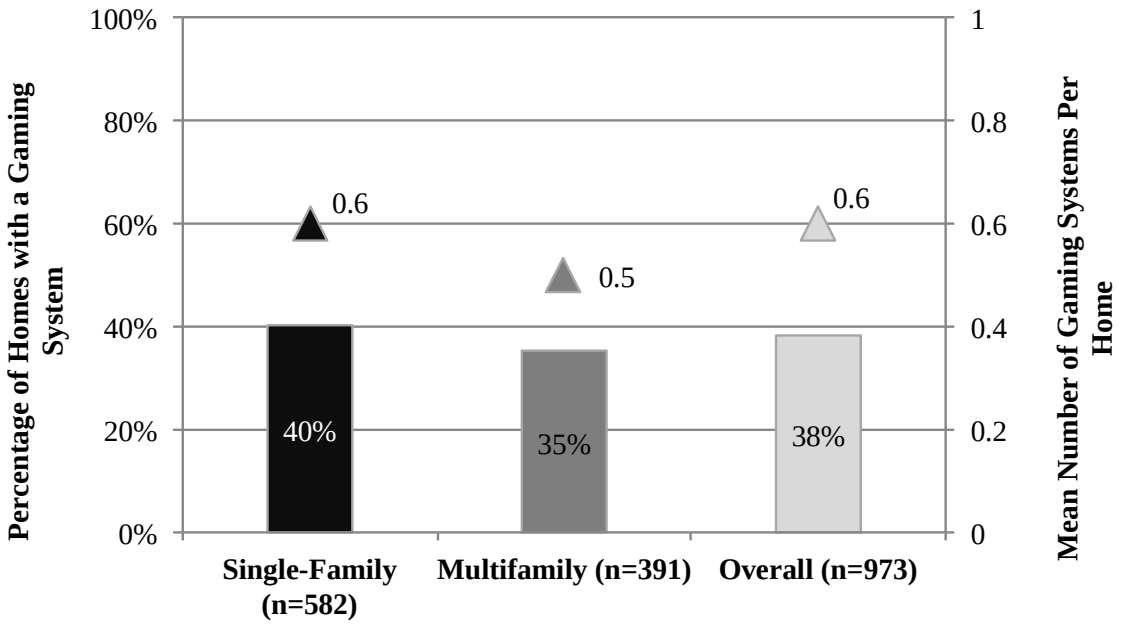


Figure 6. Preliminary gaming system saturations and mean number per household, by home type. *Source*: Analysis by Evergreen Economics.

Clothes Washer Saturations

This study found that 44 percent of single-family homes and 40 percent of all homes in PG&E's service territory have front-loading clothes washers (Figure 7), compared to 27 percent of single-family homes in 2009, according to the 2009 Residential Appliance Saturation Study (RASS) (KEMA 2010). Front-loaders are typically more energy efficient than top-loading clothes washers in terms of energy consumed by the appliance (including the energy used by the dryer), and these use less water and tend to have lower integrated water factors (IWF).

In 2007, the CEC petitioned the DOE to reconsider superseding California's statewide clothes washer standards. The DOE claimed that the low IWF in the CEC's standard would effectively eliminate top-loading clothes washers from the market altogether (the lower the IWF, the less water the clothes washer uses) (California Energy Commission v. Department of Energy 2009). However, the CEC prevailed, and manufacturers selling clothes washers in California had to comply with California's standards. There have since been additional updates to the standards at the state and national level, as well as even more stringent IWF requirements for ENERGY STAR labeling. The data presented below, along with IWF data also collected as part of this study, could inform an assessment of the success of CEC's petitioning for California-specific water factor standards for clothes washers, as well as provide updated saturations by clothes washer type and efficiency level for future standards advocacy efforts.

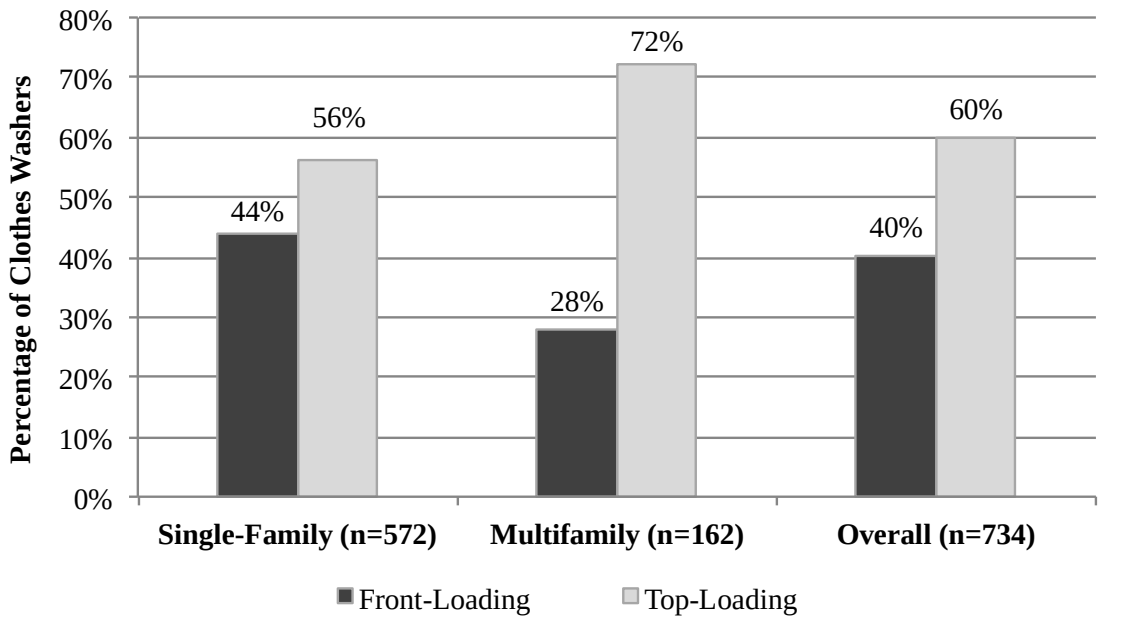


Figure 7. Preliminary findings for clothes washer types, by home type. *Source*: Analysis by Evergreen Economics.

Cooling System Saturations

Approximately 33 percent of single-family homes in PG&E's service territory do not have any air conditioning system in place. The most prevalent type of air conditioning is central air (53%). Figure 8 shows a breakdown of cooling system saturations for single-family homes in PG&E's service territory.

©2016 ACEEE Summer Study on Energy Efficiency in Buildings

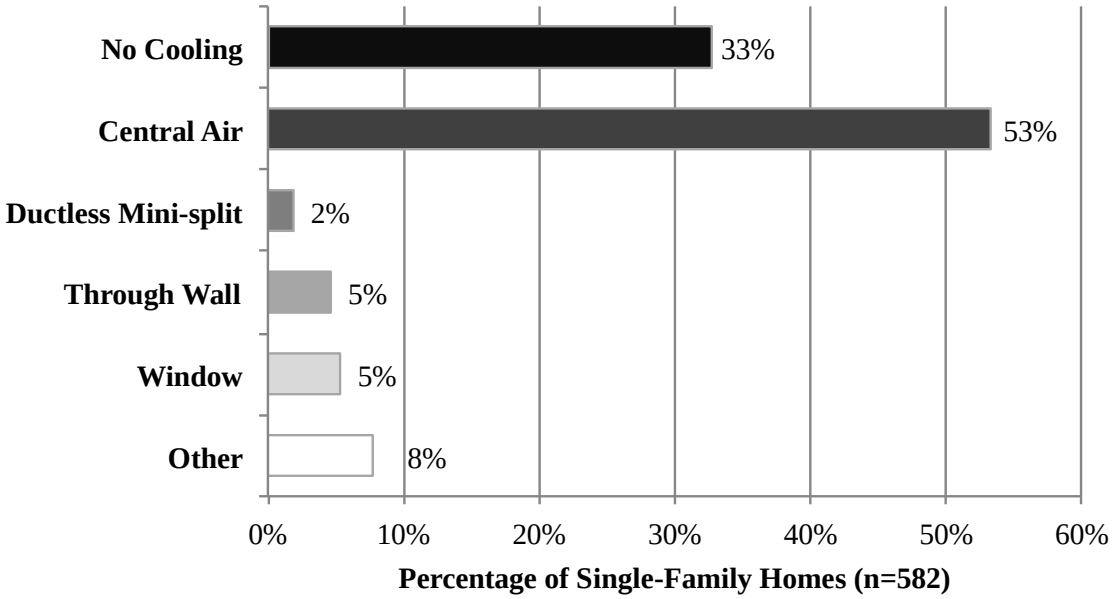


Figure 8. Preliminary air conditioning saturations by air conditioning system type. Multi-family centralized building air conditioning that serves individual units are included in the "other" category. *Source*: Analysis by Evergreen Economics.

Implications

The data collected as part of this study will allow PG&E to support its Codes and Standards Program and subprograms. The data provide a reliable, up-to-date backdrop for all advocacy efforts, including CASE reports and letters in support of or in opposition to federal or state standards rulemaking.

In this paper, we have demonstrated how these data can be used in conjunction with prior studies to show time-series changes in saturations of key energy efficiency equipment types. Tracking of such trends is useful for codes and standards programs, and energy efficiency programs in general, to understand how programs have impacted saturations and how much savings potential exists. Furthermore, as new technologies reach the consumer market, it is important to track their adoption and, in particular, the adoption of the leading edge efficient models within the product class.

This study will provide updated saturations by product type and subtypes, as well as efficiency levels and other supporting information to assist PG&E in its efforts at the state level. Conducting similar studies across the country would benefit each locale, but also could be aggregated to inform broader, national codes and standards advocacy efforts. Lastly, the participating metering sites comprise a panel dataset that can be queried for high priority study areas (such as add-on behavior studies), and the project team will be able to revisit sites—either in person or via surveys—to update saturations and efficiency levels over time.

References

Appliance Standards Awareness Project. *Average Household Refrigerator Energy Use, Volume, and Price Over Time*. November 9, 2015. http://www.appliance-standards.org/sites/default/files/Refrigerator_Graph_Nov_2015.pdf

Cadmus. 2012. *2010-2012 California Statewide Codes and Standards Program Process Evaluation Final Report.* Prepared for Southern California Edison and Pacific Gas and Electric. http://www.calmac.org/publications/SCE-PG%26E_C%26S_Process_Evaluation_FINAL_5-28-12.pdf

Cadmus. 2014. *Statewide Codes and Standards Program Impact Evaluation For Program Years 2010-2012*. Prepared for the California Public Utilities Commission. http://www.calmac.org/publications/CS_Evaluation_Report_FINAL_10052014-2.pdf

California Energy Commission v. Department of Energy. No. 07-71576. DOE No. EE-RM-PET-100 (9th Cir. 2009). http://www.energy.ca.gov/appliances/clotheswashers/2009-10-28_Ninth_Circuit_Opinion.pdf

Delforge, P., and N. Horowitz. 2014. *The Latest-Generation Video Game Consoles: How Much Energy Do They Waste When You're Not Playing?* June 10. New York City: Natural Resources Defense Council. https://www.nrdc.org/resources/latest-generation-video-game-consoles-how-much-energy-do-they-waste-when-youre-not-playing

KEMA. 2010. *2009 California Residential Appliance Saturation Study Volume 2: Results*. Prepared for the California Energy Commission. http://www.calmac.org/publications/2009_RASS_Volume_2_FINAL_101310.pdf

KEMA. 2014. *WO21: Residential On-site Study: California Lighting Appliance Saturation Study (CLASS 2012)*. Prepared for the California Public Utilities Commission, Energy Division. http://www.calmac.org/publications/2014.11_24_WO21_CLASS_Final_Report_Clean.pdf