

Why Buy? How Longitudinal Survey Data Tracks Appliance Purchase Motivations, Trends, and More

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ABSTRACT

This research follows an existing pool of customers recruited for a rigorous home energy use study for which engineers collected on-site data from 1,000 homes and recorded details about the home construction and equipment characteristics (e.g., model number, age) for all visible end uses. These on-site surveys included an occupant interview to gain an understanding of household attributes such as primary language spoken in the home, household income, home ownership, and other demographics.

In addition to this robust cross-sectional database, every quarter since the third quarter of 2017, a subset of 50 participants has responded to a web survey asking about new purchases and changes in the home that may impact their energy use. We have also been actively monitoring most electric end uses in these homes in one-minute intervals since 2017, which allows us to cross-reference metered usage data with survey responses and provide more context to analyze.

This paper presents the findings from this new longitudinal data including which new appliances and electronics have been purchased in each home, what motivated the purchases, and how these purchases have impacted the households' energy use. Harnessing responses over the last 12 quarters (three years) provides a unique perspective into the homes and allows us to answer additional questions surrounding purchasing trends and motivations over time, seasonality and bundling of purchases, and other factors related to energy use and residential purchasing behaviors.

Introduction

Continued investment in energy market characterization research is an integral part of collecting data to inform California Energy Commission (CEC) and the U.S. Department of Energy (DOE) decisions surrounding the adoption of more stringent codes and standards. Ideally, the development of codes and standards is based on current and robust data that show what appliances are being purchased, how frequently they are being replaced, and how they are being used. Currently, there are sources that help address some of those questions, but there are gaps that can be filled with new data collection efforts.

The California Residential Appliance Saturation Study (RASS) collects comprehensive, self-reported data from around 40,000 households, with a sample that is designed to be representative of the broader California state population. This effort is extremely valuable in understanding saturations of different appliances at a point in time, however, there is value in obtaining additional information.

To address questions surrounding consumer behavior and household-level trends, Pacific Gas and Electric Company (PG&E) developed and sponsored the Home Energy Use Study (HEUS). The HEUS aims to collect data to inform questions surrounding the complex impact of customer behavior, including the seasonality of purchasing, habits surrounding appliance replacement on burnout or early replacement, and the bundling of purchases.

The HEUS covers the residential sector and includes both an on-site saturation survey of 1,000 homes (conducted between October 2015 and April 2016) and a nested sample of end-use equipment metering at 150 homes (starting in 2017). The HEUS involved recruiting a representative sample of homes

and collecting detailed information on appliance and equipment holdings. The study is a critical source of data for PG&E to provide more rigorous data to both the CEC and the DOE that reflects timely trends of real households in California.

This paper briefly describes the study effort and illustrates one of many uses for these data: combining longitudinal survey data with onsite and demographic data to pursue in-depth analysis about household motivations and purchasing trends. The authors present illustrative findings from original analysis conducted by Evergreen Economics using data collected as part of the original HEUS on-site survey and then layering on the survey responses collected from the subset of 50 metered homes over the next four years.

Home Energy Use On-Site Survey

Evergreen developed the on-site survey sample frame using PG&E’s customer information system data, with stratification based on home type, income, and region (see Table 1)¹. We oversampled customers living outside the more populous and denser Bay Area region and multifamily homes to capture significant results from the smaller groups.

Table 1. HEUS residential survey sample frame

Home Type	CARE ² Status	Bay Area	Non-Bay Area	Total	
Single Family	CARE	40	104	144	615
	Non-CARE	233	238	471	
Multifamily	CARE	80	51	131	385
	Non-CARE	222	32	254	
Total		575	425	1,000	

Field surveyors from kW Engineering and Michaels Energy used an electronic data collection tool to record information, adhering to protocols and quality control standards. The team collected comprehensive data at each household, including a customer interview as well as a detailed inventory of building characteristics, appliances, electric cars, photovoltaic systems, electronics, and lighting. For all equipment for which we could find the information, we collected 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).

Quarterly Web Survey Description

After field surveyors completed all on-site surveys, a nested subset of fifty households was separately recruited for end use metering and to receive longitudinal web surveys every quarter³. Evergreen Economics developed a web survey that is distributed every three months, beginning three months after the on-site visits conducted in 2017. The survey asks about any changes made to the home or household, including any new appliances purchased and energy efficiency upgrades made. Due to the frequency and ease of deployment for the survey, seasonal questions are also added in response to

¹ The HEUS was developed in collaboration with Northwest Energy Efficiency Alliance (NEEA) after their Residential Building Stock Assessment (RBSA) with the dual intention of reducing set up costs and providing a robust, compatible addition to NEEA’s research. In combination, data from the HEUS and the RBSA cover a significant portion of the United States.

² CARE is the California Alternate Rates for Energy program, which provides energy bill discounts to qualifying low-income households.

³ The HEUS planned to recruit 150 households into the metering and quarterly survey efforts, but recruitment plans were stalled due to COVID-19 effects.

specific data requests. Table 2 details the appliances and energy changes directly asked about in each survey. Respondents are asked if they purchased one any of the listed appliances in the last three months, the make and model of the appliance, whether the purchase replaced anything in the home or was an additional purchase, and what they did with the replaced item.

Table 2. Appliances in Quarterly Survey

Appliances	
Central air conditioner	Clothes dryer
Window, wall, or room air conditioner	Dishwasher
Furnace	Television
Space heater	Gaming system
Other heating equipment	Desktop computer
Water heaters (solar, tankless, and electric)	Laptop computer
Refrigerator	Router or modem
Stand-alone freezer	Set top/cable box/TV tuner
Clothes washer	

To ensure data accuracy and prevent attrition, survey respondents are incentivized with \$50 for each completed survey. The sample size gradually increased as homes completed the onsite survey and then decreased as participants moved away⁴; response rates also vary by quarter. The average response rate since 2017 has been 75%. Table 3 displays the response rate over time.

Table 3. Distribution Summary

Quarter	Surveys Sent	Completed Surveys	Response Rate
Q3 2017	8	5	63%
Q4 2017	5	4	80%
Q1 2018	11	19	91%
Q2 2018	51	29	56%
Q3 2018	22	19	86%
Q4 2018	41	31	76%
Q1 2019	40	34	85%
Q2 2019	40	33	83%
Q3 2019	40	34	85%
Q4 2019	49	33	67%
Q1 2020	45	37	82%
Q2 2020	45	34	75%
Q3 2020	45	33	73%
Q4 2020	45	31	69%
Q1 2021	45	29	64%
Q2 2021	45	26	58%

Purchase Trends

First, Evergreen identified frequencies of new appliances purchased since 2017. On average, 38 percent of all surveyed households purchase at least one new appliance each quarter. Looking over time, Figure 1 shows the percent of households that purchase a new appliance each quarter, split out by

⁴ Respondents were identified as moved away when they responded to a survey question asking if they plan to move in the next three months, then stop responding to the survey. Metering equipment is also removed from their homes upon their departure. Respondents who marked that they plan to move in 2021 Q2 have not yet been removed from the distribution list

appliance type. Electronics includes purchases of a television, gaming system, desktop or laptop computer, computer monitor, router or modem, or a set top cable box. Home essentials are categorized as purchases of a water heater, refrigerator, clothes washer, clothes dryer, freezer, or dishwasher. Finally, all purchases of central air conditioning systems, window, wall, or room air conditioning units, furnaces, space heaters, or other heating equipment is labeled as an HVAC purchase.

The figure is color-coded by quarter to help visualize any seasonality in purchases. This analysis suggests that electronics are consistently purchased more frequently than home essentials or HVAC equipment.

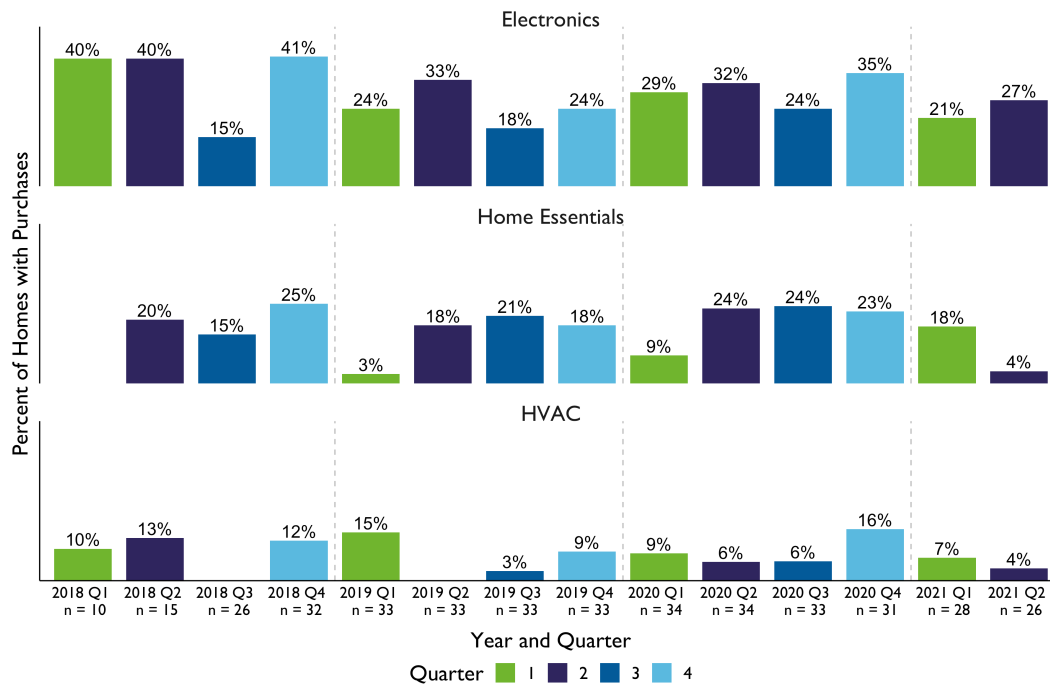


Figure 1: Percent of Households with at Least One Purchase Each Quarter, by Appliance Type

Since electronics are purchased most frequently, Evergreen pulled out specific appliances to observe seasonal changes within the group. Figure 2 shows that the percent of households that purchased at least one office electronic (desktop or laptop computer, computer monitor, or a router or modem) is highest in the second quarter of each year (deep purple line in the figure). Noticeably, in the fourth quarter of 2020, there was an uncharacteristic spike in households that purchased an office electronic. This trend could be due to the increase in occupants working from home during the COVID-19 pandemic. Additional income from government stimulus packages could also attribute to this spike.

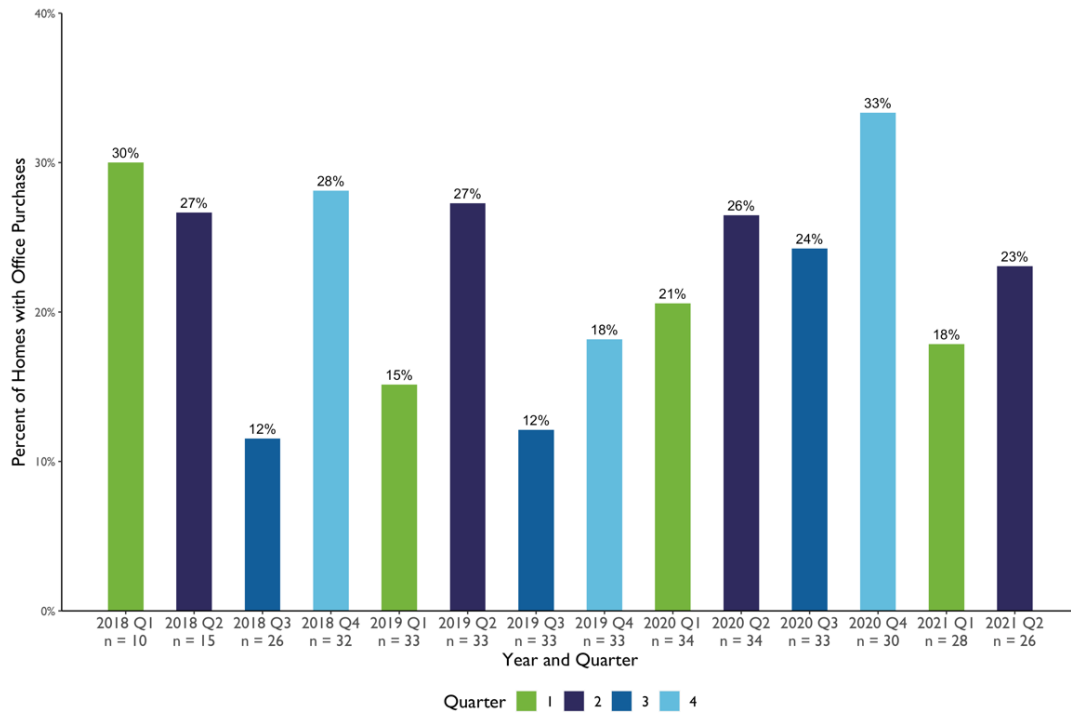


Figure 2: Percent of Households with at Least One Office Electronic Purchase by Quarter

Another group that displays a strong seasonality in purchases is plug-in HVAC systems. These purchases include window, wall, or room air conditioning units or space heaters. Figure 3 shows that the percent of households that purchases a plug-in HVAC system spikes in colder months, the first and fourth quarter of each year. Like electronics, more participants than usual reported purchasing these items in the fourth quarter of 2020.

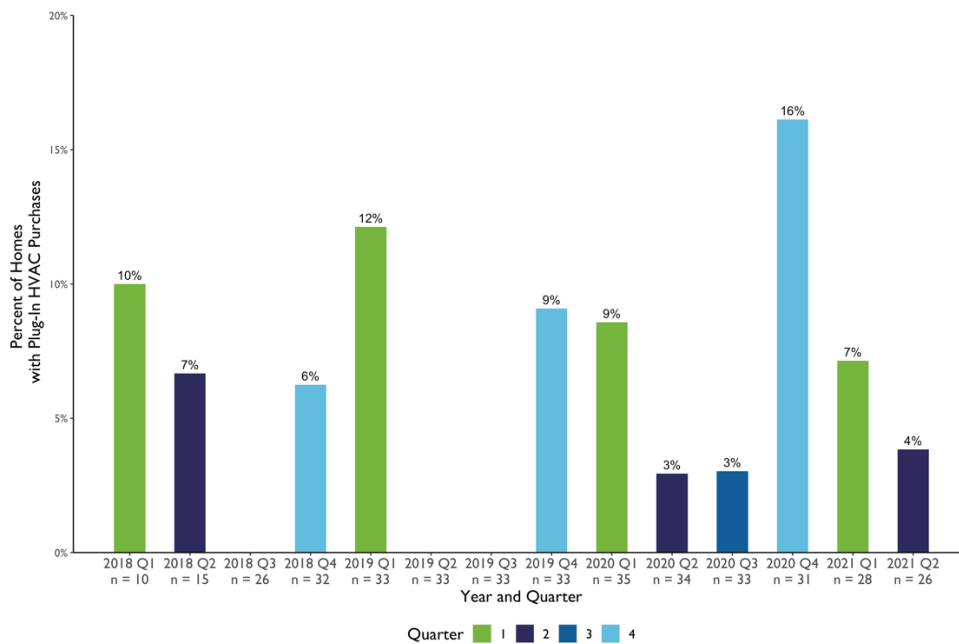


Figure 3: Percent of Households with at Least One Plug-in HVAC Purchase by Quarter

Purchase Bundling Rates

The value of following the same group of participants and analyzing their purchase behaviors is the ability to associate all purchases to the same household. Bundling of home essentials may be due to a desire to have appliances that appear aesthetically consistent (e.g., matching washer and dryer), planned home renovation projects, or marketing messages and discounts in stores that encourage customers to purchase related home essentials together. For example, many retailers campaign to encourage customers to purchase a washer and dryer together as a set. The desire or need to purchase a washer may lead some to also buy a dryer.

Evergreen analyzed all purchases within households and quarters to create bundles of purchases. A bundle is defined by one or more appliances purchased by a single household within the same quarter. Bundling rates are displayed as tiles in Figure 4 and are calculated by dividing the total number of times we observe appliance 1 and appliance 2 bundled together from the total number of appliance 1 purchases.

Tiles within the figure are read as the percentage of appliance 1 purchases observed to be purchased with appliance 2. For example, 100 percent of clothes dryer purchases were accompanied by the purchase of a clothes washer within the same household in the same quarter.

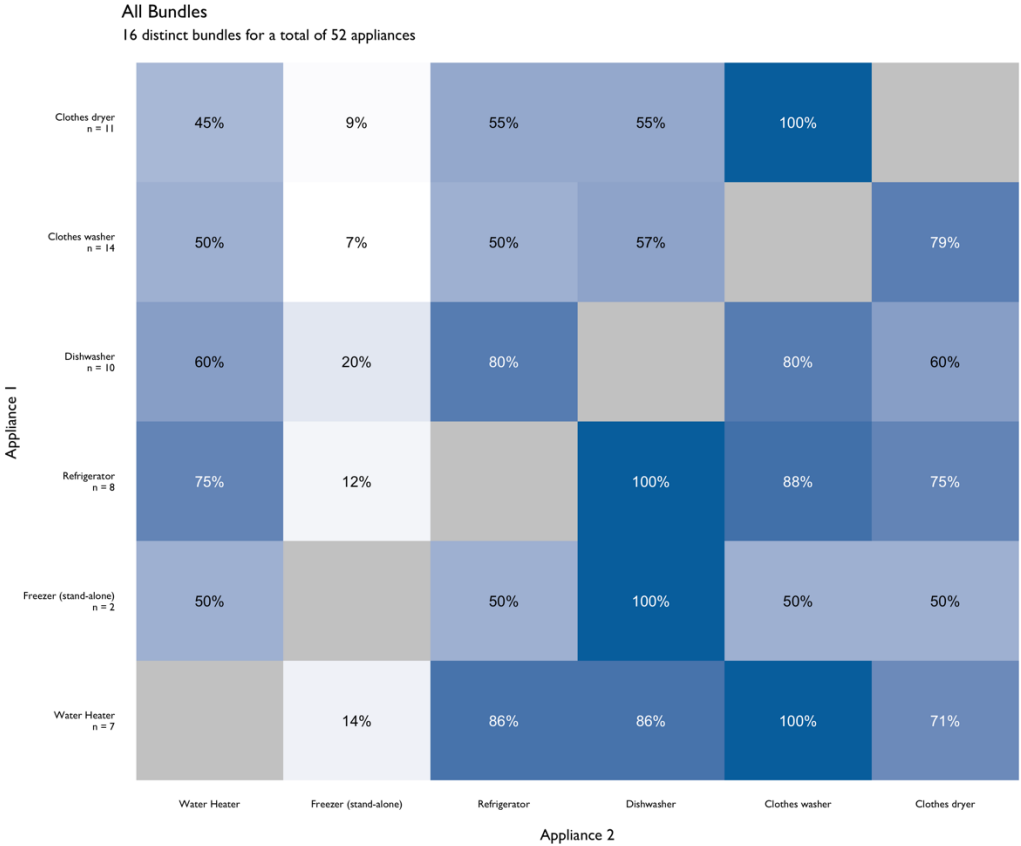


Figure 4: Bundling Rates of Home Essential Appliance Purchased Since 2017

Evergreen also analyzed the difference in bundling by purchase reason. In addition to what appliances respondents are purchasing, the quarterly survey also asks whether they are making the

purchase to replace a broken item, replace a working item, if the item is an additional unit, or if the item is brand-new (i.e., they never had the appliance previously).

When home essential appliances were purchased to replace something that broke (replaced on burnout), rather than to proactively replace a working appliance (early replacement), bundling rates were much lower. This suggests that planned purchases lead to more bundling, and forced purchases were more often made as individual purchases. The bundling rates of early replacement purchases are displayed in Figure 5, and bundles purchased due to a burnout are displayed in Figure 6.

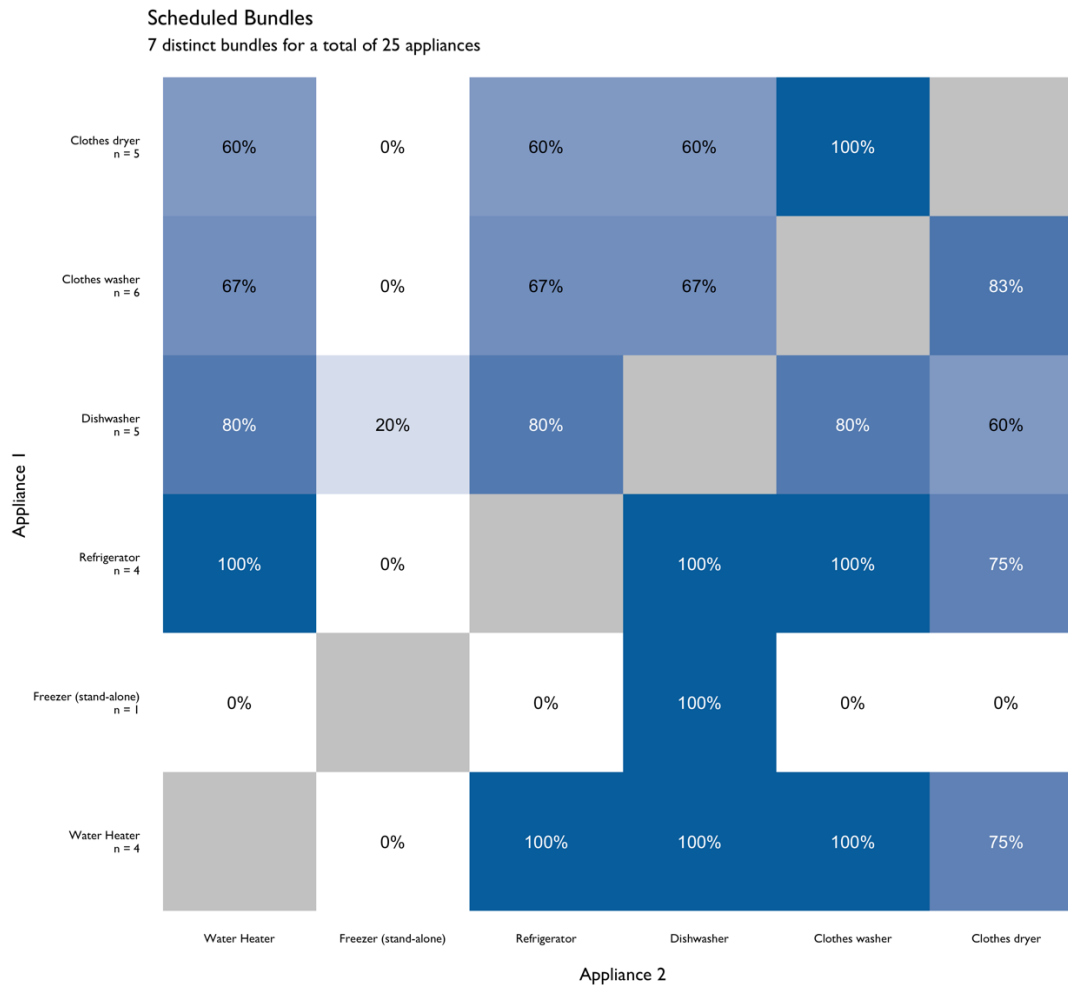


Figure 5: Bundling Rates of Home Essential Appliance Purchases, Early Replacement

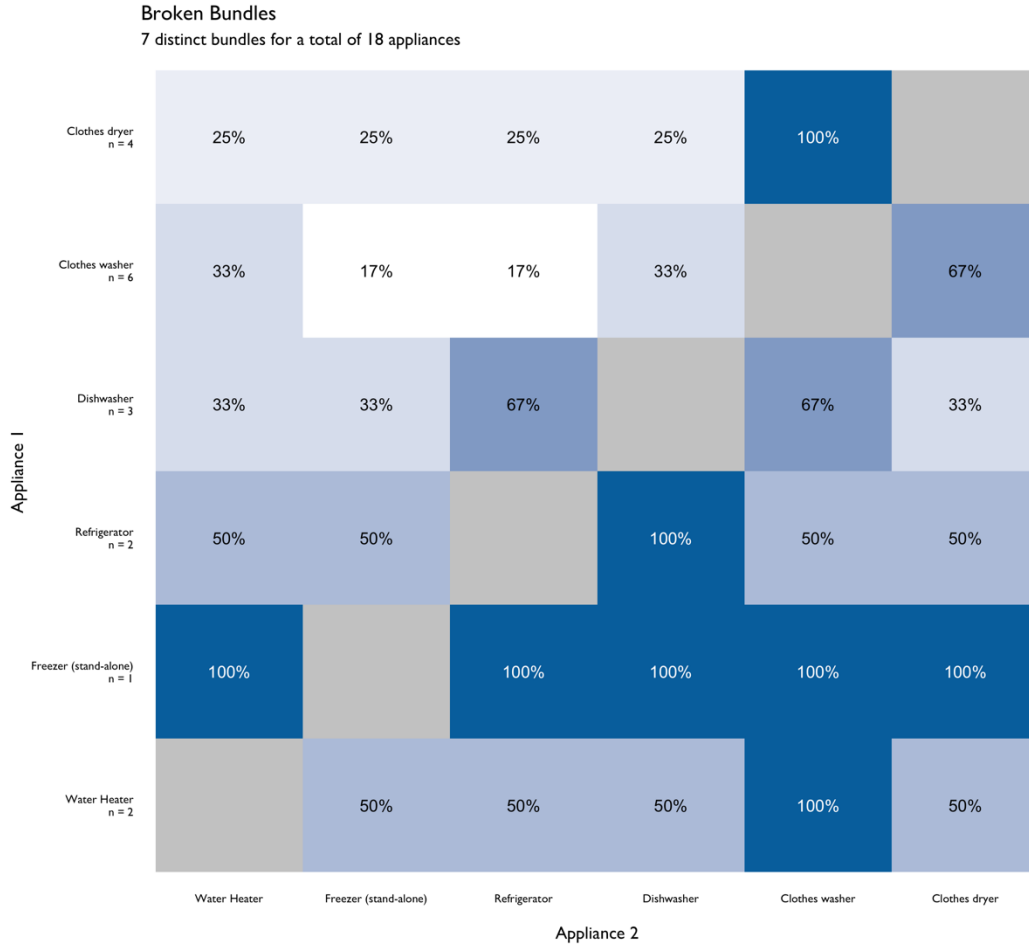


Figure 6: Bundling Rates of Home Essential Appliance Purchases, Burnout

Another way to analyze the bundling data is to compare two commonly purchased home essential appliances. Figure 7 below displays the type of purchase by bundling types for clothes washers and refrigerators. Clothes washers are equally purchased as an early replacement (46% of purchases), meaning they are purchased to replace another clothes washer that was still working, and as part of a forced bundle (i.e., they were purchased with another appliance that was purchased due to burnout; 46%). They are rarely (8%) purchased on their own. Compared to refrigerators, which are purchased most often as a single appliance (68% of purchases), but when bundled, are more likely to be part of a scheduled bundle (21% vs. 11%).

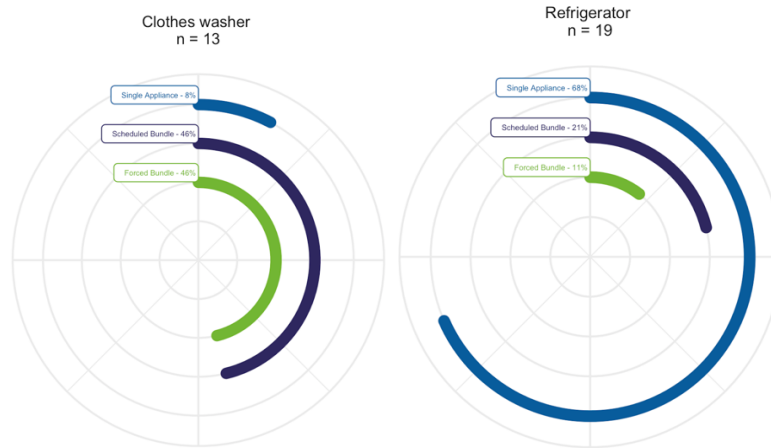


Figure 7: Purchases by Bundling Type, Clothes Washers and Refrigerators

In this sample, there were no clear patterns in bundling purchases of electronics or HVAC equipment. Electronics purchased in the same quarter do not appear as bundling and appear more random, therefore we could not infer causality.

Purchase Motivations

In addition to bundling trends, Evergreen analyzed the purchase motivations for individual appliances. As shown in Figure 8, office electronics (laptops, desktops, monitors) are more often replaced while they are still working (47% of purchases), whereas HVAC purchases are mostly new, not replacements for previously existing equipment (45% of purchases). Water heaters have the highest rate of purchases made to replace a broken unit (44%). These trends could be related to the useful life of office electronics versus HVAC systems, or the cost of replacing home essentials and adding HVAC systems.

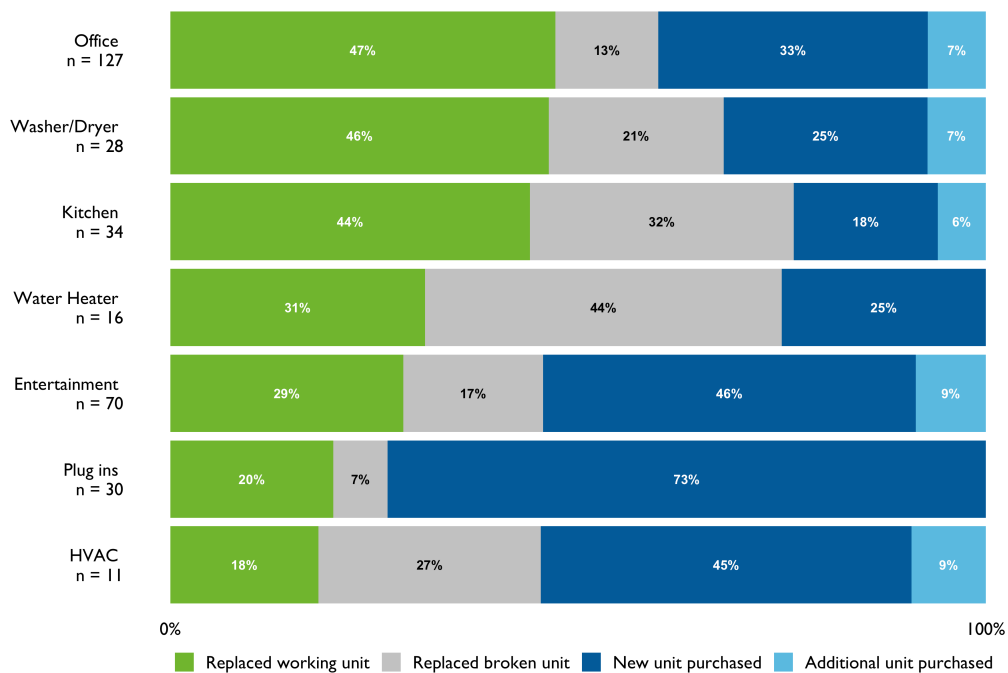


Figure 8: Purchase Motivations for Appliances by Category

An examination of purchases that were replacements of older appliances (i.e., not a brand-new or additional unit purchased) suggests that more expensive purchases are more often made to replace a broken unit respectively), rather than to replace ahead of burnout. As shown in Figure 9, HVAC and water heaters are most often replaced due to burnout, while office equipment is most often replaced early.

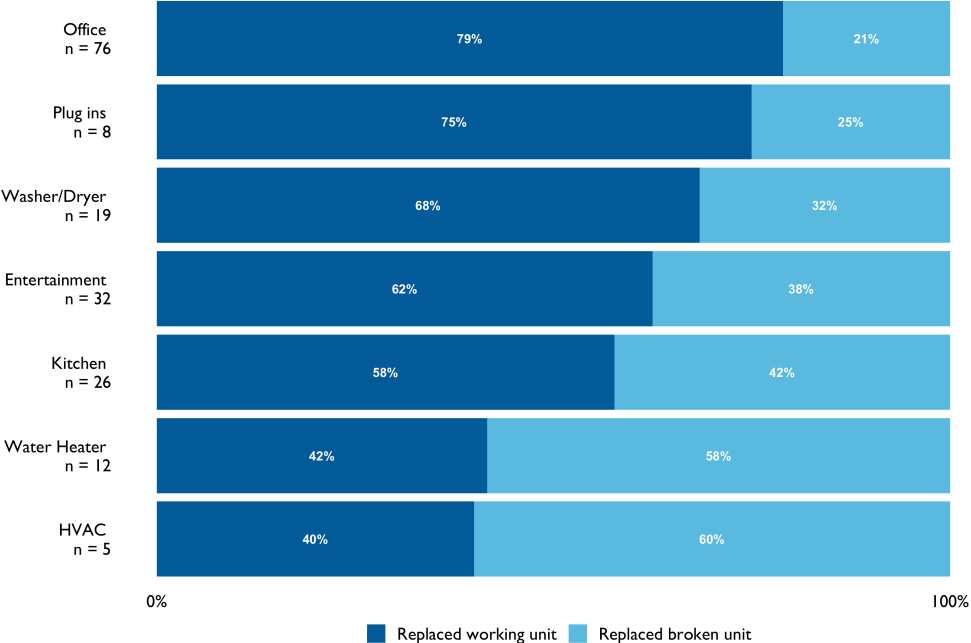


Figure 9: Replacement Reasons for Appliances by Category

Other Applications

In addition to new appliances purchased, the quarterly survey reports on other changes in the household that may affect energy use. Respondents report on other changes made in the quarter. These responses can be categorized into three main groups: some behavior change that would decrease energy use, some behavior change that would increase energy use, and behavior changes that occurred due to COVID-19.

For behavior that would decrease energy, responses included households using their HVAC systems less to conserve energy, hanging up laundry rather than using a dryer in the summer, and using their dishwasher after nine p.m. on weeknights to avoid peak electricity hours. For behaviors that would lead to an increase in energy use, respondents listed that they decorated their home with lights for Christmas and are using their space heater more often. COVID-19 related responses all mentioned that being home more led to an increase in their energy use, including additional people moving in, more people home during the day, and not leaving the house as often generally. Of all the responses since 2017, most (81%) have been changes that would decrease a home’s energy use.

Conclusion

In summary, the Home Energy Use Study includes an in-depth on-site survey of 1,000 homes in California (conducted between 2015 and 2016), end-use metering data from a nested subset of 50 homes (beginning in 2017 and ongoing) with an average of 27 end-use meters installed per site, and a quarterly survey dataset, which was the focus of this report. Other efforts using this dataset have answered

questions about annual replacement rates by demographics, appliance age, and energy use load shapes for different appliances, households, and seasons.

Early analysis of this rich data source provides insights into decision-making surrounding energy use at a household level. By collecting data quarterly for these fifty homes, we can follow a broader range of choices that provide insight on *when* and *why* these households are purchasing new appliances or making other changes that affect energy usage. The bundling analysis informs research on replacement on burnout versus early replacement and what drives those purchase decisions, and the analysis on seasonality of purchases builds on existing literature that helps contextualize electrification efforts and changes in energy demand, as well as changes in response to non-routine events, such as COVID-19.

PG&E's Codes and Standards Program's investment in the HEUS project will continue to provide a wealth of information for program planners, evaluators, regulators, and other agencies focused on meeting the challenges of climate change through energy efficiency. Similar longitudinal studies across different regions would provide even more representative data that could be used to strengthen code and standards recommendations and codify meaningful change.

Acknowledgements

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