What's your UEC? Baselining Sales-Weighted Unit Energy Consumption for Plug Load Products at the Retailer Level

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ABSTRACT

According to the US Energy Information Administration (EIA), more than twenty percent of residential electricity load comes from "plug load" devices including home appliances and consumer electronics. A key challenge to traditional program designs that target many plug load devices is small unit energy consumption (UEC) that prevents these program designs from being cost-effective. Pacific Gas and Electric Company (PG&E) and Sacramento Municipal Utility District (SMUD) are piloting a new program design that overcomes this barrier by consolidating small per-unit savings across total sales of home appliance and consumer electronics sold at retail to improve program cost-effectiveness. However, past attempts to test similar designs have encountered trouble validating energy savings.

This paper describes the development of a new baseline approach for a retailer-focused program trial that seeks to overcome these past challenges. This approach combines retailer sales data with model-specific UEC data to track the sales-weighted UEC of seven home appliance and consumer electronics products sold by a major retailer. By tracking sales-weighted UECs, utilities can track preprogram trends and assess multiple evaluation approaches including multiple quasi-experimental designs to estimate program impact. This paper discusses barriers to acquiring sales and model-level UEC data, determining "proxy" UEC values where known energy use values are not readily available, and analysis techniques for understanding market trends and forecasting changes in product UECs. Ultimately, this paper argues that access to model-level UEC values for products may be necessary to develop and execute next generation retail-focused programs to address plug-load energy use.

Introduction

Plug loads are becoming an increasingly significant portion of residential energy use as lighting, HVAC equipment, building envelopes and other equipment becomes more energy-efficient. Though the efficiency of many plug load devices is also improving over time, the number of devices installed is also increasing, thereby driving up the overall consumption of energy use attributable to plug load devices (Kwatra, Amann, and Sachs 2013). Table 1 shows that the EIA now attributes over 28% of residential electricity use to home appliances and consumer electronics.

Table 1. EIA breakdown of estimated U.S. residential electricity consumption by end-use, 2011

Category	**Uses Covered**	**Billion kWh**	**Share of Total Households**
Heating and Cooling	Space cooling, water heating, space heating, furnace fans and boiler circulation pumps	522	37%
Plug Loads	Refrigerators, color televisions, set-top boxes, clothes dryers, personal computers and related equipment, cooking, dishwashers, freezers)	402	28%
Other	Small electric devices, heating elements, and motors not included above	313	22%
Lighting	Lighting	186	13%
Total		1,424	100%

Source: EIA 2013

Developing new programs to address plug loads has become an important focus for California IOUs. This is a result of the increased attention on this issue by regulators in the state. Plug loads were an important focus of the 2008 California Long-Term Energy Efficiency Strategic Plan. In addition, the 2011 California Potential Study, which is used to derive energy efficiency program goals for California Investor-Owned Utilities (IOUs), indicates that the future incremental market potential for plug loads grows to over 30% of the total by 2021 (CPUC 2011).

To address the growth of plug load energy use PG&E and SMUD partnered to develop the Retail Plug-load Portfolio (RPP) program trial in 2012. This program trial intends to influence retailers to assort, stock, and market more energy-efficient plug load products by offering retailers per-unit incentives for every energy-efficient unit they sell. A midstream incentive was chosen because per-unit savings are too low to develop cost-effective downstream incentives that are sufficiently large to influence end customers' decision to purchase these products.

While small incentives may not be able to influence the end consumer, according to the RPP program theory, small incentives will influence retailers as the incentives represent a meaningful increase to the small margins they earn on these products. Retailers will also aggregate these small incentives over thousands of unit sales, so that all the small incentives add up to a meaningfully large incentive to the retailer. A midstream incentive such as this should increase program cost-effectiveness because it allows for small per-unit incentives and keeps per-unit implementation costs low for the IOUs.

For the RPP program trial, incentives are being offered for seven product categories including DVD/Blu-ray Players, home-theater-in-a-box (HTIB), compact audio, stereo docks, air cleaners, room air conditioners, refrigerators and freezers. There is one retailer participating in the trial with stores in both the PG&E and SMUD service territories. This retailer is not participating in other California IOU energy efficiency programs, which helps eliminate overlap with other programs such as the refrigerator rebate program.

The RPP program trial is not the first retail-focused incentive program in California, and seeks to improve on what was learned through implementation of the 2009 -2012 Business and Consumer Electronics (BCE) program. The BCE program offered retailers incentives to sell more energy-efficient televisions. The purpose of the RPP program trial is to further test the midstream intervention strategy and to develop more effective evaluation protocols than used for BCE for this type of intervention.

This program trial is being designed and implemented through a collaborative effort between PG&E staff, program design consultants, evaluation consultants and CPUC Staff. The purpose of this collaborative approach is to get feedback from evaluators early in the trial to ensure the program model is designed to maximize evaluation outcomes. It has been especially important to engage regulators early in the process to get their buy-in on the novel program and evaluation designs. This is especially important because there is a lack of established evaluation protocols for this type of program intervention. This effort at collaboration will include striving to reach agreement over estimates of product energy consumption.

The proposed evaluation approach for this innovative new program approach involves measuring the Sales Weighted Unit Energy Consumption (SWUEC) for each of the seven product categories covered under the trial program. The SWUEC baseline is determined by combining past sales data from the retailer with model-specific UEC data for each model. Energy savings will be determined by measuring changes in the SWUEC over time.

Measuring and tracking SWUEC allows the evaluation team to test the practicality of a number of innovative evaluation approaches to measure the impact of the program. These include:

- Quasi-Experimental (Pre-Post) Participant-Only Segmented Regression
- Quasi-Experimental (Pre-Post) Participant-Only Forecasted Baseline
- Analysis of Non-Participant Comparison Stores within California

This paper focuses on the development of the SWUEC baseline and the specific challenge of the lack of robust estimates of model-level UEC data for different products.

Development of a SWUEC Baseline for Plug Load Products

An important element of the RPP program trial is testing the viability of developing SWUEC baselines for each product category for the participating retailer. Baseline development requires two main inputs: 1) retailer sales data, and 2) UEC values by model. This section discusses how data was collected for these inputs and how it was analyzed to assess the program trial baseline.

Securing Retailer Sales Data

Sales data comes directly from the retailer, but is still difficult to secure because it is very sensitive data for retailers. To overcome this barrier PG&E presented the retailer with the following information:

- The data required for participation in the program and the proposed use of that data.
- Benefits to the retailer in participating in the program, including the size and scope of the program and the alignment of the program with the business strategy of the retailer.
- The program's data management plan for receiving, storing, securing and destroying electronic data.

Once the retailer committed to the trial program, data requirements, data processes and data governance procedures were included in the contractual agreement between PG&E and the retailer. As a result, PG&E and the retailer agreed to data sharing processes that protect sensitive data from public disclosure. Sales data are transmitted to a secure site and are accessed by third parties who validate the data, create incentive invoices, analyze energy efficiency trends, and prepare reports for PG&E.

Under agreement, the retailer is making the following data accessible for products in the trial portfolio:

- Product category and model number
- Total sales by model, date of sale and transaction number
- Store zip code

The retailer is providing data for sales of products included in the program trial during the program period, as well as historical sales covering the preprogram sales period from January 2012 through the program launch date in October 2013. The retailer is providing this data for the stores participating in the program trial, as well as data for nonparticipant comparison stores.

While the retailer sales data were eventually secured, there were a number of challenges and lessons learned in collecting these data. These challenges included:

- **Costs to retailers in providing data.** Collecting, formatting, and delivering the data are costs to the retailers, as this requires IT and labor resources. Information systems are not set up to deliver the necessary information in the required formats outside of the retailer organization. The trial program includes a budget to compensate the retailer for extraneous costs associated with developing special reports, accessing historical data, and making necessary IT system upgrades to accommodate program needs. Because of the difficulties and costs associated with acquiring historical data, the trial team learned that historical data was limited to less than two years of past sales.
- **Establishing data needs early in the process.** It is important to understand data availability and to estimate data acquisition costs as early as possible and communicate this information to retailers. Ideally, all data needs should be clearly stated in the contract with the retailer prior to program launch. Trial results are expected to help define the requirements for historical and comparison data for programs of this type.

Determining UEC Values by Model

Product UEC data must come from secondary sources because it is not universally available from the retailers or product manufacturers. While data for some products is readily available from DOE or the EPA ENERGY STAR® program, UEC data on many products are not available from these sources and the UEC must be estimated.

Model-level UEC is typically calculated by multiplying measured power in each operating mode by estimates of hours of annual usage in each mode (Roth et al 2002). The summation of the energy consumption over all modes equals the total device UEC. There are three primary methods the trial program team used to estimate model-level UEC, ranked from most to least accurate:

- Source UEC based on robust existing data sources such as EPA's ENERGY STAR program, DOE's Energy Guide label or the California Energy Commission's (CEC) Title 20 efficiency standards
- Estimate UEC based on specific product attributes (e.g., for refrigerators, total capacity, through-the-door ice, and defrost configuration)
- Estimate UEC based on average estimates for an entire product category (e.g., Blu-ray players)

From a data quality perspective, it is preferred that all UEC estimates come directly from a robust data source. Given the limited availability of existing model-level energy data for some product categories, this is not always realistic. While federally regulated appliance products, such as refrigerators and room air conditioners, may have model-level energy data available for most models, smaller consumer electronics, such as compact audio or Blu-ray players, often have little or no model-level energy data available. This data is available for energy-efficient products qualified for ENERGY STAR, but not for the inefficient models that do not qualify. Therefore, alternate approaches must be used to estimate UEC values for these models.

Data sources for robust estimates of model-level UEC. There are three primary sources for robust model-level UEC data:

- EPA ENERGY STAR Qualified Product Lists (QPL)
- DOE Energy Guide label
- CEC Title 20 appliance efficiency standards

These sources are considered robust because EPA, DOE, and CEC require laboratory testing of each model based on specified test methods to measure power draw in various operating modes. These federal and state agencies typically adopt identical test methods to minimize the testing burden on manufacturers and to ensure uniform testing results.

Some of these data sources directly provide UEC values for some products, while others only provide power use measurements by mode. For product categories where UEC values are not directly provided, UEC is determined by multiplying power in each mode by assumptions of hours of use (HOU). HOU are assumed to be equivalent for all products within a given product category, unless explicitly noted otherwise.

ENERGY STAR's QPL covers all products that qualify for ENERGY STAR qualification, and so does not include data on inefficient models in the product category. ENERGY STAR often provides UEC values directly, but some specifications, such as the audio/video specification, only covers specific operating modes (such as sleep mode).

The Energy Guide label is a government-mandated labeling program jointly administered by the DOE and the FTC. The Energy Guide label covers primarily white good appliances, water heaters, televisions, room air conditioners, and other HVAC equipment. This source typically provides UEC estimates for each product on the market.

The CEC Title 20 appliance efficiency standards are California-mandated standards and therefore provide data on all applicable products sold in California. These standards cover a wide range of products that are not already pre-empted by federal legislation. This includes an audio/video (AV) specification. However, this standard only covers standby mode, and therefore has limited application to determining model-level UEC since it does not cover active power use.

These three data sources have varying degrees of data available for the seven product categories covered by the RPP program trial, as shown in Table 2. HTIB and compact audio do not have an existing data source that provides model-level active power use, and therefore UEC for these products must be estimated using generic power data estimates for the entire product category.

Table 2. Operating modes covered by existing data sources for rpp product categories

	Energy Guide	ENERGY STAR	CEC Title 20
Refrigerator	UEC	UEC	*N/A*
Freezer	UEC	UEC	*N/A*
Room A/C	Active	Active	*N/A*
Air Cleaner	*N/A*	Active	*N/A*
HTIB	*N/A*	Sleep	Standby
DVD/Blu-ray Players	*N/A*	Sleep, Idle	*N/A*
Compact Audio	*N/A*	Standby	Standby

Based on the sources and assumptions outlined above, Figure 1 describes the decision path for determining the best source for UEC estimates from the available data sources.

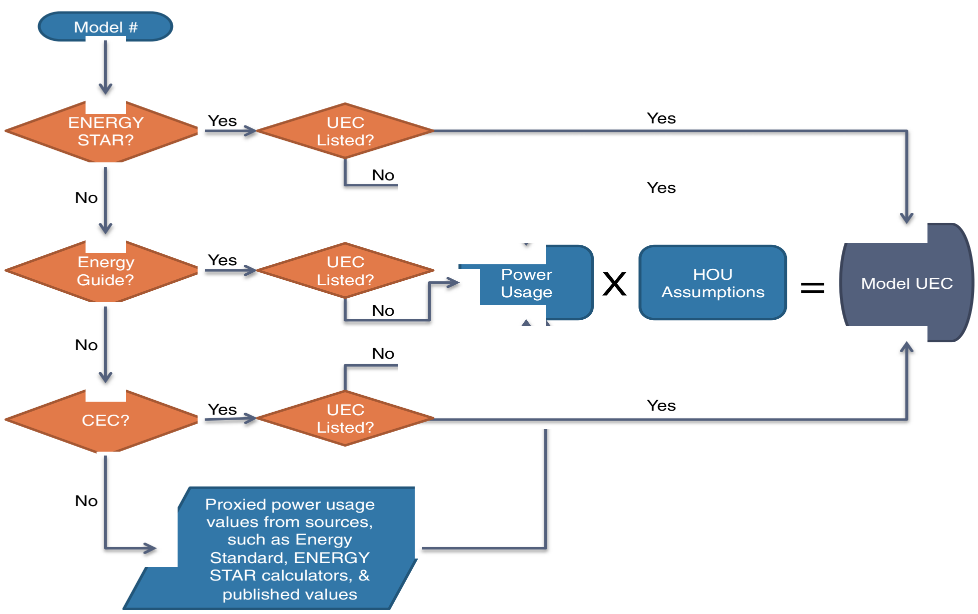


Figure 1. Process diagram for estimating model-level uec *Source:* EMI 2013.

Estimating UEC based on specific product attributes. If there are no UEC data available for a specific model, the next most accurate method of estimating UEC is to proxy the energy estimate based on specific product attributes that influence energy consumption. For example, key drivers for room air conditioner energy use are cooling capacity (in BTU) and whether or not a model has louvered sides. It is important to note that for some products, such as HTIB and compact audio, this is not applicable because there is no single product attribute that can easily distinguish model energy consumption.

Estimating UEC for an entire product category. For product categories that do not have sufficient product attributes to determine UEC, such as HTIB, DVD/Blu-ray players, and compact audio, UEC is estimated for the entire product category using best available study data for power draw and HOU in each operating mode. The data sources used for this analysis include:

- Consumer Electronics Association (CEA) *12th Annual Household CE Ownership and Market Potential* (2010)
- CEA *Energy Consumption of Consumer Electronics in U.S. Homes in 2010* (2010)
- CEA *Energy Consumption by Consumer Electronics in U.S. Residences* (2007)
- CEA *Ownership and Market Potential Study* (2005)
- Energy Center of Wisconsin *Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes: A Technical and Behavioral Field Assessment* (2010)
- LBNL *National Energy Use of Consumer Electronics in 1999* (1999)

Baseline Analysis

The baseline analysis consists of developing a SWUEC baseline by month for each product, attempting to forecast these data into the future as a "dynamic" counterfactual baseline, and performing other analyses of the data to help inform the program design. This paper only discusses the preprogram baseline analysis. During the program trial the SWUEC will be measured on an ongoing basis to observe trends in the SWUEC over time and to attempt to measure energy savings by comparing it to the counterfactual baseline or non-participant comparison stores.

Development of the sales-weighted UEC baseline. The RPP program baseline itself is an estimate of the average per-unit energy consumption across a whole product category at a retailer. The SWUEC is weighted based on the overall sales of each model for that month. The SWUEC is calculated across all stores participating in the trial, as well as for the non-participant comparison stores. The SWUEC is calculated for the months preceding the program intervention to understand the preprogram SWUEC and trends. Ideally the baseline would be based on multiple years (three or greater) of product sales data from the retailer to best understand the long-term trends and seasonal aspects of product assortment and sales. Unfortunately, as discussed previously, only less than two years of past sales data were available.

Figure 2 shows the monthly SWUEC for the seven products covered by the RPP trial program for 12 months prior to the program intervention. Months where sales were less than 20 units are excluded from analysis. For most products the SWUEC is relatively stable for the 12-month period. Some products display some seasonality for the UEC and some show modest trends up or down over the year (represented by the dotted lines within the figure).

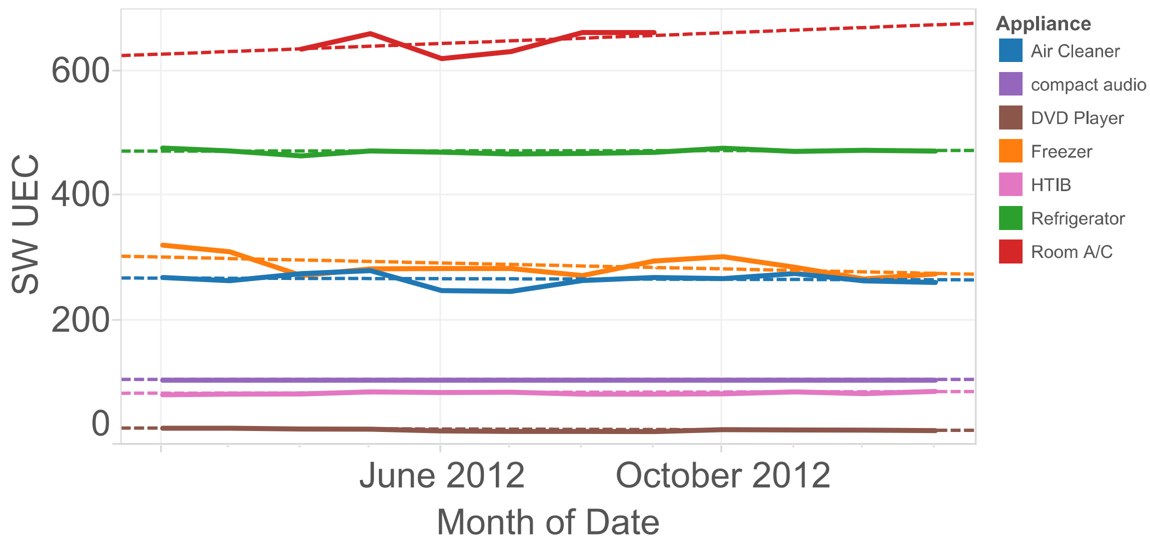
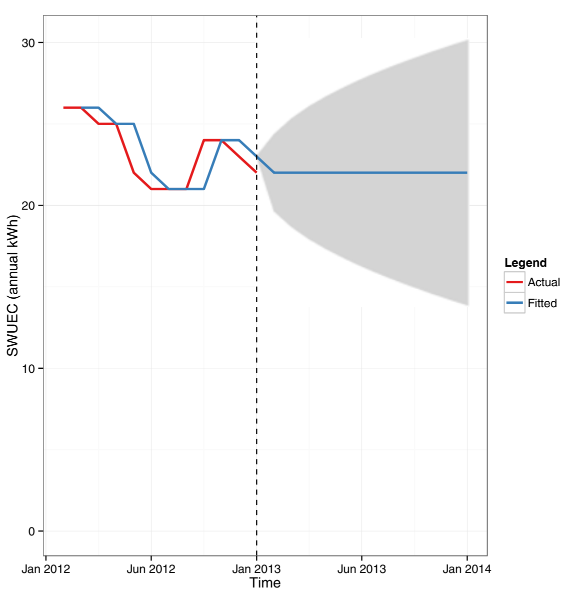


Figure 2. SWUEC baseline for 12 months of preprogram data for seven products.

Developing forecasted SWUEC based on historical sales data. To create a forward-looking counterfactual baseline, the historical data were used in statistical models to forecast the SWUEC, as shown in Figure 3.



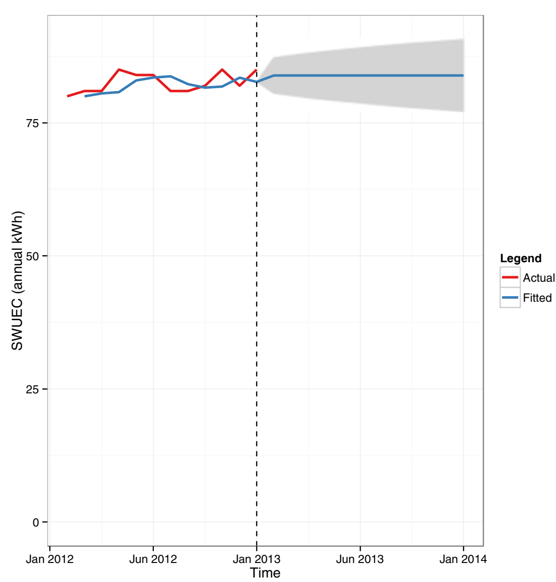


Figure 3. Forecasted SWUEC baseline results with uncertainty bounds for DVD players (left) and home theater in a box (right).

These simple forecasts show high uncertainty (represented by the shaded grey area) because of a limited amount of historical data (12 months in this case) and the high variability in monthly sales and UECs for some products. This variation is often driven by the seasonality of sales for some products. As the trial program progresses, the evaluation team will be looking to refine the forecasting methodology to decrease the uncertainty so these forecasted baselines might be used as a potential impact evaluation methodology.

This simple forecast approach does not account for other market forces that would disturb prevailing trends such as the introduction of new efficiency standards in the market. As a result, these forecasted baselines may need to account for the introduction of these standards. Future attempts to do this could be informed by SWUEC information collected and analyzed during the introduction of new efficiency standards during this program trial.

Other baseline analyses. The baseline data and model-level UEC estimates were also used to perform other analyses to help understand trends in the data that could be used to help inform the trial program development and evaluation. Figure 4 shows three examples of other analyses that were performed to better understand the preprogram baseline for the RPP trial. These included:

- Analysis of the sales of energy-efficient (ENERGY STAR-qualified) versus standard models looking at: 1) the UEC of the model, 2) unit size/capacity, 3) total unit sales, and 4) ENERGY STAR qualification status.
- The geographical sales distribution for products where sales can vary based on climate zone or regional demographics.
- Variation in sales by month and ENERGY STAR qualification for products with seasonal fluctuations.

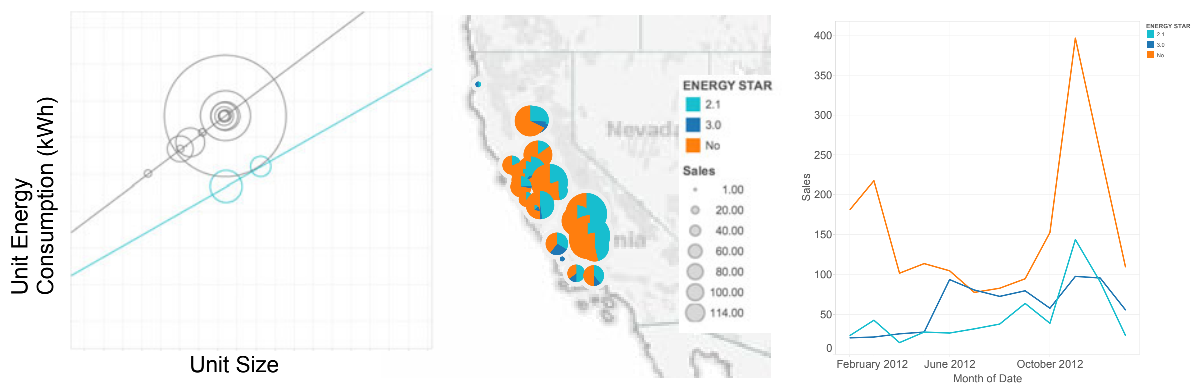


Figure 4. Examples of additional baseline analyses.

These data were used to help inform program development, such as efficiency criteria for incentives for different products and the seasonal fluctuations in sales. These data also provided a preprogram snapshot of the number and type of energy-efficient products sold at the retailer. By comparing these data to information collected during the trial period, the trial team can understand how changes to the mix of models affect the SWUEC of products in the program.

Lack of Availability of Model-Level UEC Data

As indicated above, a major challenge to this program design is the lack of availability of model-level UEC data for many products. Situations where UEC estimates were not available for particular models are summarized below.

- Models not covered by a federal standard and not ENERGY STAR-qualified, such as air cleaners and consumer electronics.
- Models where national/state standards and ENERGY STAR only cover operational mode data and do not give UEC estimates, such as room A/C and consumer electronics. For these products additional assumptions such as hours of use by operating mode must be made to determine the UEC estimate.
- Consumer electronics covered by ENERGY STAR often lack estimates of power use for every operating mode (on, sleep and standby). Therefore, additional assumptions must be made for the power use in these modes to estimate a UEC value.
- Models that do not list product attributes, such as a refrigerator model that does not list its capacity or configuration, has highly uncertain UEC values.

The lack of the availability of model-specific UEC data increases the uncertainty of baseline SWUEC estimates. This is especially true for the product categories which are not covered by the federal standard and where the rate of ENERGY STAR qualification is low, such as many of the consumer electronics products. For these products a large majority of products have UEC values developed by proxy or using averages for the whole product category, as shown in Table 3. Estimates from these two methods are less accurate and can ignore the wide variation of UEC within product categories. Using this less accurate data could have the result of making it more difficult to accurately measure the true impact of these program approaches.

Table 3. Sales weighted by UEC estimation method for each RPP category

Product Category	**UEC Based on Existing Data Source***	**UEC Based on Product Attributes**	**UEC Based on Average of Entire Product Category**
Refrigerator	91%	9%	0%
Freezer	95%	5%	0%
Room AC	95%	5%	0%
DVD/Blu-ray Player	37%	0%	63%
HTIB	14%	0%	86%
Air Cleaner	0%	100%	0%
Compact Audio	0%	0%	100%

* For Audio/Video products, this includes models that match to a data source for standby mode but not active mode.

Conclusion

This paper discusses the use of model-level UEC information to develop a baseline for an innovative program design to address plug load energy use through incentives to retailers. One of the barriers to the development of innovative programs of this type is the lack of availability of these data for many products not covered by state or federal efficiency standards or the EPA's ENERGY STAR program. Greater availability of model-level UEC data for plug load products available on the market would greatly enhance the ability of energy efficiency advocates to measure changes in the market by combining sales data with energy consumption to understand how the energy use of new products is changing over time. Access to model-level energy use data could also drive energy efficiency through greater energy transparency. This could be especially effective and important for dynamic markets where it is difficult to set federal standards.

To increase access to these data, a model-level UEC reporting requirement could be implemented by either the DOE, which carries out similar activities for products covered by federal standards or FTC labels, or by certification bodies such as UL that implement product safety testing but have not done testing for energy use.

An important requirement of any testing and reporting requirement is that the products covered must have solid product definitions and established and industry-accepted test procedures. Many products covered by ENERGY STAR already have established test procedures, but public data on these products is only available for models that meet the ENERGY STAR qualification criteria. For this reason, any requirement could initially focus on products already covered by ENERGY STAR. However, some test procedures may have to be updated to ensure they cover power use of all modes of operation.

Another important piece of data to make publically available would be updated HOU information for the different modes of operation of these products. This is necessary because many ENERGY STAR test procedures only test power use in different modes, and these must be converted to energy use by applying assumptions about HOU information for each mode. To ensure the accuracy of the energy use values, periodic studies could be undertaken to update these hours of use assumptions. To maximize the value to regional utilities, these estimates could be made on a regional level where usage assumptions might vary based on weather zone or demographics. Providing such data could greatly reduce the burden and cost for utility program evaluations by reducing the need to collect onsite metering data to meet state-mandated requirements. This reduced evaluation burden would result in the more cost-effective implementation of these programs.

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