Calculation Methodology for Sales-Weighted Unit Energy Consumption Estimates in the Retail Plug-Load Portfolio (RPP) Program

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1. Background and Justification for Developing a Methodology for Estimating Model-level Unit Energy Consumption (UEC)

Because plug loads represent a significant fraction of residential electricity consumption, reducing plug load energy consumption is a critical step on the path towards achieving California's residential Zero Net Energy (ZNE) goals. The 2012 ZNE Technical Feasibility Report stated that "…minimizing plug loads will be critical to meeting ZNE goals" (Arup 2012, Pg. 8), and recommended that utilities "continue equipment efficiency incentive programs" and "aggressively promote equipment efficiency regulations at the state and federal level" (Arup 2012, Pg. 51). While there is widespread recognition that plug load energy use constitutes a large portion of household electricity use and is critical to meeting energy reduction goals, developing cost-effective incentive program strategies is extremely challenging due to the distributed nature of the savings opportunities necessitating low per-unit incentives, and the frequent lack of available model-level energy consumption data for calculating energy savings.

The intent of the Retail Plug Load Portfolio (RPP) Program Trial is to generate residential electric energy savings by influencing retailers to sell more energy efficient models of home appliances and consumer electronics in targeted product categories. The intent is to influence the retailer by paying a per-unit incentive to the retailer for every program-qualified model that the retailer sells during the program period. Program-qualified models are typically ENERGY STAR models in each product category, which are more efficient than comparable non-qualifying models within a retailer's existing product category assortment. By increasing the sales of energy efficient models within the targeted product categories, the RPP Program Trial will generate energy savings. The broader RPP Trial strategy is discussed in detail in the PG&E document *Retail Plug-Load Portfolio Trial Plan.*

Most products incented within the RPP Program Trial, especially the smaller consumer electronics, have relatively low per-unit savings. Although the savings potential of these products is large in aggregate, their low individual savings limit the per-unit incentives that utilities can cost-effectively offer. Successfully scaling the RPP Program will require both large unit volumes and low per unit transaction costs. To achieve low per unit transaction costs, the RPP Program must use an efficient means of processing program data. Because there is an inherent tradeoff between highly accurate estimates and the cost required to obtain them, the success of the RPP Program is based on balancing an acceptable level of accuracy in model energy consumption with a rules-based, decision making approach that can be easily and systematically applied regardless of scale. The purpose of this document is to outline an approach for estimating robust unit energy consumption (UEC) values that strikes this balance. While this document focuses specifically on the six products in the 2014 RPP Trial, this UEC calculation approach can be easily tailored to incorporate the new product categories envisioned for a scaled up RPP Program.

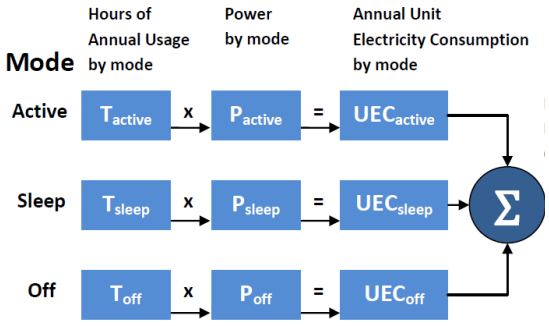
The mandated approach for California's investor-owned utilities is to use deemed values from the Database for Energy Efficient Resources (DEER). DEER is a comprehensive database for white goods, but there are no entries for most of the product categories under consideration for the RPP Program. A further shortcoming of DEER is that it assigns an *average* UEC value for each qualifying product within a

given measure code. Moreover, the current process for vetting and updating DEER values is cumbersome, contentious, and unlikely to be cost effective for product categories offering low per-unit energy savings such as those being pursued by the RPP Program. Consequently, as part of this effort, the RPP Program team is seeking the approval for new approaches to calculating ex ante per unit energy savings, all of which require obtaining UEC estimates for each program-qualifying and non-program-qualifying model. Such an approach means that there is no need to settle for an average value for each model, which, by definition, will be incorrect for any given model. This document does not explicitly discuss the merits of these various savings methods, but rather focuses on documenting the methods for developing robust UEC estimates, which will serve as the bases for calculating the ex ante savings that will be reported by the IOUs throughout the implementation of the program.

2. Overview of UEC Calculation Methods

The UEC estimates are determined by multiplying measured power in each operating mode by the corresponding annual hours of usage (HOU) for that mode. The summation of the UEC over all modes equals the total device UEC.[1] Figure 1 outlines the methodology for calculating model-level UEC estimates.[2]

Figure 1: Unit Energy Consumption (UEC) Calculation Methodology (Roth et al 2002)



Historically, workpapers have calculated UEC and energy savings by developing a 'baseline' and 'measure' case. UEC estimates for the measure case are based on 'qualifying' products, while baseline UEC estimates are based on 'non-qualifying' products. All qualifying products within the same measure code are assigned the same deemed energy savings values. The approach taken by the RPP Program provides a higher degree of resolution by determining UEC estimates by model when sufficient data are available. This improved resolution allows the program to calculate energy savings estimates with greater accuracy than the DEER database. Measuring model-level UECs by retailer could allow incentives

[1] Methodology for calculating UEC is described in further detail in Roth et al 2002 (Pg. 13). In this case, Active mode also includes standby mode power.

[2] For products with a single operating mode, the final UEC from Figure 1 simplifies to active mode HOU times active mode power.

and savings estimates (i.e., baseline case minus the measure case) to be customized for each retailer. In addition, tracking a retailer's sales-weighted UEC (SWUEC) over time could also help measure market transformation and change in overall energy consumption over time.

There are three different ways to determine UEC estimates, each with varying degrees of resolution: *model level, measure level*, and *product category level*.

Model Level: At the model level, each model has its own UEC value based on individual product testing. Model level data is available for all federally regulated products such as home appliances, as well as ENERGY STAR qualified models.

Measure Level: At the measure level, each model is assigned a UEC value based on its status as 'qualifying' or 'non-qualifying'. There may be multiple measures within a given product category (e.g., the 'Refrigerator' product category may have multiple measures for various size classes and feature sets). This is typically completed for product categories that have specific features that have a significant impact on energy consumption. DEER and the IOU workpapers typically use a measure level approach.

Product Category Level: Estimating UEC at the product category level provides a UEC for an entire class of products (e.g. the average UEC of all DVD Players). Product category level data is useful to estimate overall energy use and identify future efficiency opportunities, however, it does not differentiate between qualifying and non-qualifying energy use, and therefore cannot be used for developing energy savings estimates.

For the purposes of the RPP Program, the UEC for qualifying products is calculated at the model-level based on ENERGY STAR data, where possible. Federally regulated products require disclosure of energy consumption for all products in the Department of Energy's Certification Compliance Management System (CCMS); however, in practice, it is not always straightforward to identify energy consumption values in CCMS. For federally-regulated products, if model-level data cannot be obtained through ENERGY STAR or CCMS, unmatched models may warrant additional research to obtain UEC data, such as manually obtaining energy data from manufacturer websites depending on the fraction of total sales that the model represents. If data are unavailable and the model has a low sales volume, non-qualifying products will be assigned energy consumption values at the measure level. For federally-regulated products, the goal is to match a minimum of 80% of total sales or all models with 2% or more of total sales at the model level.[3]

In some cases, such as Audio / Video products, ENERGY STAR listed data does not translate into a straightforward UEC calculation and therefore a measure-level, rather than a model-level, approach is

[3] For the initial RPP Program Trial, our goal was to match 100% of qualifying products and 80% of non-qualifying products at a model level. For a broader rollout of the RPP Program, we are revisiting these ratios. Accuracy should be tied to level of program risk, which is related to incentive payments, which are derived from the product of per-unit energy savings and unit volume.

more appropriate.[4] For example, soundbars and HTIB products Table 1 provides an overview of how UEC is calculated for each product category.

Table 1: Unit Energy Consumption (UEC) Calculation

	Refrigerator	Freezer	Room A/C	air cleaner	HTIB / Soundbars	DVD/Blu-Ray Players
Qualifying	Model Level	Model Level	Model Level	Model Level	Measure Level	Measure Level
Non-Qualifying	Model-level when available, otherwise Measure Level	Model-level when available, otherwise Measure Level	Model-level when available, otherwise Measure Level	Model-level when available, otherwise Measure Level	Measure Level	Measure Level

Developing a UEC Estimate from Model-level Data

For some products, such as refrigerators and freezers, ENERGY STAR provides model-level UEC values. However, for many other products the ENERGY STAR specification has different qualification criteria, and having models on the ENERGY STAR qualifying list does not always readily translate into a UEC value. For example, while ENERGY STAR refrigerator and freezer qualification is based on meeting specific UEC levels, Room AC qualification is based on Energy Efficiency Ratio (EER) requirements (which is the ratio of cooling capacity to power input). Similarly, air cleaner qualification is based on an efficiency requirement and not attaining a specific UEC value. ENERGY STAR requirements for Audio / video products, including HTIB/soundbars and DVD/Blu-Ray Players, are most complex primarily because the category covers a wide range of products which have many different functions. Table 2 provides an overview of the primary metrics used to determine ENERGY STAR qualification. For these products that do not base ENERGY STAR qualification on UEC, additional data sources are required to develop the UEC calculation. Table 3 provides an overview of the data required to develop a UEC from model-level data. Hours of Usage, while required to determine model-level UEC, are applied uniformly to all products within a specific product category.

Table 2: Primary Metric used for ENERGY STAR Qualification

	Refrigerator	Freezer	Room A/C	Air Cleaner	HTIB / Soundbars	DVD/Blu-Ray Player
Metric for Qualifying	UEC	UEC	EER	Clean Air Delivery Rate (CADR) Efficiency	Amplifier Efficiency, Standby Power	Idle Power, Standby Power, Auto Power Down

[4] Many A/V qualification requirements have 'adders' for additional functionality, such as In-Use Networking with Wake Capability and HD 'Upconversion' for DVD Players. Reported values on the ENERGY STAR list do not include these adders, which makes difficult to create an apples-to-apples comparison between ENERGY STAR and non-qualifying data at the model-level.

Table 3: Data Requirements to estimate model-level energy consumption

Refrigerator	Freezer	Room A/C	Air Cleaner	HTIB	DVD/Blu-Ray Player
Model UEC	Model UEC	EER, Capacity, Hours of Usage	CADR Rate, Model CADR Efficiency, Hours of Usage	N/A	N/A

Developing a UEC Estimate for Measure-level Data

For products without model-level energy data, energy consumption is approximated based on the product's key features that impact energy consumption. If models do not have a minimal level of product data available, it is recommended that these sales be excluded from UEC calculations altogether. For example, without knowing whether a refrigerator models capacity is 2 ft^3 or 20 ft^3, it is impossible to determine an accurate energy consumption estimate. Table 4 provides an overview of product features required to estimate energy consumption.

Table 4: Product features required to estimate measure-level UEC

Refrigerator	Freezer	Room A/C	Air Cleaner	HTIB / Soundbar	DVD/Blu-Ray Player
Capacity, Configuration, Defrost Type*, Through the Door Ice*	Capacity, Configuration, Defrost Type*	Capacity, Louvered Sides*, Reverse Cycle*	CADR value	Product Type (HTIB or Soundbar)	Product Type (DVD or Blu-Ray Player)

(An asterisk denotes that if data is unavailable for the specific product, default assumptions can be used)

Based on these product features, a measure-level UEC can be assigned based on a generic efficiency assumption. For federally regulated products, this is the Maximum (or Minimum) value to required meet federal standards. For other products, it is an average efficiency assumption for that measure. For example, all non-ENERGY STAR air cleaners are assigned a default efficiency of 3.0 Watts per CADR. Similarly, all ENERGY STAR soundbars are assigned the same default modal power values. Table 5 provides an overview of the Default Efficiency Levels for calculating measure-level UECs.

Table 5: Default Efficiency Levels for calculating measure-level UECs

Refrigerator	Freezer	Room A/C	Air Cleaner	HTIB	DVD/Blu-Ray Player
Maximum UEC for similar product to meet federal standards	Maximum UEC for similar product to meet federal standards	Minimum EER for similar product to meet federal standards	Non-ENERGY STAR CADR Efficiency Assumption	Average ENERGY STAR/ Non-ENERGY STAR Product Modal Power	Average ENERGY STAR/ Non-ENERGY STAR Product Modal Power

3. Supplemental Data Sources for Estimating UEC Values

While UEC values for refrigerators and freezers can be directly obtained from the ENERGY STAR list, the other product categories require additional data sources to develop a UEC estimate.

Room AC: Room AC HOU varies by geographic location, and therefore location based on climate zone is required to determine UEC for Room ACs. HOU is estimated by determining the number of cooling load hours for a specific location. The DEER database does not have an HOU value for Room ACs, therefore the HOU estimate is based on the DEER HOU value for split system air conditioners for all of PG&E territory. Based on the availability of more granular runtime data, Room AC hours of operation can be refined based on the store ZIP code of purchase.

Air Cleaners: Air cleaners require estimates for HOU assumptions and the average efficiency of non-qualifying products (in units of Watts per CADR). Assumptions are based on EPA's Appliance Calculator,[5] which lists both operating hours and efficiency of non-qualified products. EPA's source for these assumptions is based on 'internal research', but is not explicitly cited.

DVD/Blu-Ray Players: Energy consumption for DVD/Blu-Ray players cannot be easily calculated using the data at the model level, and so a measure level approach is most appropriate to estimate power draw in each mode for both qualifying and non-qualifying products. Because Audio / Video products do not have an Energy Guide label, there are no standard hours of operation listed by DOE or ENERGY STAR. Hours of operation for all A/V products are based on best available published data. Existing HOU assumptions are based on a 2013 Lawrence Berkeley National Laboratory metering study in Northern California homes. A detailed discussion of source selection for consumer electronics is included in Appendix A –Product Category Level Power Draw and HOU Assumptions for Consumer Electronics.

[5] http://www.energystar.gov/buildings/sites/default/uploads/files/appliance_calculator.xlsx

Table 6 provides a summary of HOU data sources by product category. All products within a given product category have the same HOU assumptions.

Table 6: Source for HOU Assumptions by RPP Product Category

	Refrigerator	Standalone Freezer	Room A/C	Air Cleaner	HTIB / Soundbar	DVD / Blu-Ray Player
Data Source	HOU assumption, integrated into DOE test method	HOU assumption, integrated into DOE test method	DEER values for Split System Air Conditioners	ENERGY STAR Assumption	Fraunhofer 2014	LBNL 2013

Appendix A –Product Category Level Power Draw and HOU Assumptions for Consumer Electronics

This appendix provides power and HOU values for products calculated at the measure level (HTIB/soundbars and DVD/Blu-Ray players), as well as the methodology used for selecting the best available study as a source for the estimates. The specific studies are cited in the references section and links to the studies are provided as well.

DVD/Blu-Ray Player HOU Assumptions

DVD/Blu-Ray player HOU assumptions are based on a 2013 LBNL metering study. This is the most comprehensive metering study completed to data with the largest sample size (35 and 23 units for DVD & Blu-Ray players, respectively) over 42-day study duration. We selected this study due to its comparatively large sample size, significant monitoring duration, and its use of metering data. We believe metering data better reflects actual operating conditions that a user survey, since users may not pay attention to the various power states of small consumer electronics like DVD/Blu-Ray players and therefore have significant reporting bias. While the reported values for DVD and Blu-Ray Players were significantly different, we averaged the two values because the functionality and usage of DVD and Blu-Ray players is essentially the same.

Hours of Operation (All Products)						
	Active	Idle	Sleep	Off	Total	**Source**
DVD Player	686	1373	1848	4853	8760	LBNL 2013, cited in Kisch et al 2014
Blu-Ray Player	409	817	1191	6342	8760	LBNL 2013, cited in Kisch et al 2014
DVD/Blu-Ray Average	548	1095	1520	5598	8760	

DVD/Blu-Ray Modal Power Assumptions

Modal Power for DVD and Blu-Ray players was calculated using EPA's 2013 Consumer Electronics savings calculator. These modal power values were used because there measure level sources that differentiate between ENERGY STAR and non-ENERGY STAR products. Power draw for non-qualifying products is based on the non-qualifying products for the Version 2 Audio/Video ENERGY STAR specification. Power draw for qualifying models reflects maximum allowable requirements to meet ENERGY STAR, and therefore is considered a conservative estimate.

Conventional Power Consumption (W)					Conventional Energy Consumption (kWh/yr)	
	Active	Idle	Sleep	Off		**Source**
DVD Player	10.2	7.9	1.3	-	16.2	2013 EPA Consumer Electronics Savings Calculator
Blu-Ray Player	12.1	8.5	1.0	-	17.5	2013 EPA Consumer Electronics Savings Calculator

	Energy Star Power (W)				Energy Star Product Energy Consumption (kWh/yr)	Source
	Active	Idle	Sleep	Off		
DVD Player	6.0	5.0	1.0	-	10.3	2013 EPA Consumer Electronics Savings Calculator
Blu-Ray Player	10.5	5.0	1.0	-	12.7	2013 EPA Consumer Electronics Savings Calculator

HTIB / Soundbar HOU Assumptions

There are no metering studies for HTIB with a significant sample size (>10) or monitoring duration, and so the best estimate is based on a 2,000 person survey by Roth and McKenney in 2007. Because the usage patterns of soundbars are similar to HTIB, Fraunhofer 2014 estimates that they have similar hours of operation.

	Hours of Operation (All Products)					Source
	Active	Idle	Sleep	Off	Total	
HTIB	1580	730	6450	-	8760	Fraunhofer 2014 (based on Roth and McKenny 2007)
Soundbar	1580	730	6450	-	8760	Fraunhofer 2014 (based on Roth and McKenny 2007)

HTIB / Soundbar Power Draw Assumptions

Conventional Power consumption for HTIB is based on a 2007 metering study using instantaneous, in-store measurements from 13 models. Although there is not significant test data for soundbars, Fraunhofer 2014 assumes that power draw for soundbars is equal to mini-shelf stereo systems since their basic functionality and total system output power is similar.

	Conventional Power Consumption (W)				Conventional Energy Consumption (kWh/yr)	Source
	Active	Idle	Sleep	Off		
HTIB	37.0	33.0	1.3	-	90.9	Fraunhofer 2014 (based on Roth and McKenny 2007)
Soundbar	30.0	12.0	4.0	-	82.0	Fraunhofer 2014

ENERGY STAR power for HTIB and Soundbars is based on an internal analysis by EPA of ENERGY STAR Version 2 Qualified models. Note that while EPA's current analysis did not provide modal power values, they did provide estimated annual energy consumption. We hope to improve the HTIB value by receiving Modal Power data for ENERGY STAR HTIBs, which will provide a more transparent understanding of how values are derived.

	Energy Star Power (W)				Energy Star Product Energy Consumption (kWh/yr)	Source
	Active	Idle	Sleep	Off		
HTIB	-	-	-	-	53.0	EPA Internal Analysis of Energy Star Version 2 Qualified Models
Soundbar	20.2	3.5	0.5	-	37.5	EPA Internal Analysis of Energy Star Version 2 Qualified Models

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