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WHOLE BUILDING
HOME ENERGY REPORTS
SWWB004-02

CONTENTS

MEASURE NAME

Home Energy Reports

STATEWIDE MEASURE ID

SWWB004-02

TECHNOLOGY SUMMARY

Home Energy Reports (HER) is a residential information-based measure that provides customers with comparisons of their household energy usage to similar residences and recommendations for no- and low-cost changes that householders can make to save energy. This information is provided via printed reports mailed to residential customers and similar information is provided via electronic mail.

The HER program employs experimental design, also referred to as randomized control trials (RCTs), whereby homogeneous groups of residential customers (stratified by key usage and climactic characteristics) are randomly assigned to either receive the information (the treatment group) or not (the control group) for each trial (the experiment, or sampling wave).[1] Random assignment ensures that the treatment and control groups are equivalent from a statistical standpoint, and the experimental design can test the null hypothesis that the reports do not lead to energy savings and peak demand reduction in the treatment group.

The measure is implemented through a series of discrete RCTs over time whereby a subset of the eligible customer population, defined by multiple eligibility criteria, is randomly assigned either to receive reports ("treatment condition") or not ("control conditions"). Each experiment is typically referred to as a "wave." From a definitional perspective, a customer is defined as having been "treated" when one or more reports have been mailed to the customer. Consequently, if a customer receives a single report and chooses to opt-out by requesting that no more reports be sent, such a customer is retained in the treatment group for analysis purposes.

Due to the unique composition of each RCT, savings for this measure must be estimated for each experimental wave separately using the associated control group as the Base Case energy consumption (acting as counterfactual or baseline), after a measurement period has ended (typically at the end of each calendar year, even though the treatment may have continued). Since savings are estimated by comparing usage between treatment and control conditions for each experiment separately, there is not a single numerical Base Case. Control groups evidence unique characteristics and are a function of wave-specific definitions of the sample frame. However, each control group is representative of its corresponding treatment group and is assumed to predict what would have been the energy usage and demand for the treatment group had they not be subjected to the treatment. As such, the control groups serve as counterfactuals to assess the treatment effect, defined as savings impact.

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[1] Decision 09-09-047 authorized the California investor-owned utilities (IOUs) to submit savings claims for interventions that use a "neighbor comparison" approach and an RCT design.
California Public Utilities Commission (CPUC). 2009. *Decision 09-09-047 in the Application of Southern California Edison Company (U338E) for Approval of its 2009-2011Energy Efficiency Program Plans and Associated Public Goods Charge (PGC) and Procurement Funding Requests.* Issued October 1. Page 304.

The objective of the HER program is to reduce energy consumption by motivating no-cost energy conservation actions and self-installation of low-cost energy efficient measures. No/ low-cost investments might include adjusting thermostats, replacing furnace filters and air-drying laundry. From a social science perspective, HERs activate social norming: when report recipients learn how their energy use compares to that of similar neighbors, they tend to align their behaviors in both conscious and unconscious ways to align with the ideal social norm. The relevant and easy-to-adopt energy savings tips provided in the reports improve customers' sense of self-efficacy, the belief in their ability to change their behaviors to succeed in changing their energy use.[2]

Many independent evaluations of comparative usage programs around the country provide evidence of their effectiveness in reducing energy use and peak demand.[3] A meta-analysis of HER programs conducted by Environmental Defense Fund (EDF) estimates that the typical effect size of experiments of HER is a reduction of 1.8% of electric use, with the effectiveness of individual programs ranging from 0.9% to 2.9%.[4] DNV GL has conducted numerous evaluations of HER programs administered by the California IOUs under contract for the Energy Division of the CPUC. Its most recent HER impact evaluations for the IOUs have been statewide and are consistent with EDF's effect size range.[5]

The difference in energy use between the treatment and control conditions yields an estimate of net savings. Because customers in the treatment conditions are sent the reports without being asked whether they wish to receive them (this is called an "opt-out" design), there is no concern about self-selection bias as there is when customers elect to participate in programs (these are called "opt-in" program designs). A more thorough explanation of RCT design best practices and research techniques can be found by Neenan and Robinson (EPRI)[6] and State and Local Energy Efficiency Action Network (SEE Action).[7]

Random selection for HER experiments is conducted at the customer account level rather than at the meter level. Consequently, there are two sources of attrition that need to be addressed when conducting HER analysis to ensure that the treatment and control groups remain balanced over time:

1. *Households requesting not to receive the reports ("opt-outs"):* The HER program experiments are opt-out. In practice, this means that customers are randomly-assigned to either treatment or

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[2] Ignelzi, P., J. Peters, K. Randazzo, A. Dougherty, L. Dethman, and L. Lutzenhiser. 2013. *Paving the Way for a Richer Mix of Residential Behavior Programs.* Prepared for Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), and Southern California Gas Company (SCG). CALMAC ID SCE0334.01. © EnerNOC, Inc. May 13.

[3] Decision 10-04-029 established the evaluation, measurement, and verification (EM&V) processes for savings claims of behavior-based programs based on experimental design.
California Public Utilities Commission (CPUC). 2010. *Decision 10-04-029 in the Application of Southern California Edison Company (U338E) for Approval of its 2009-2011 Energy Efficiency Program Plans and Associated Public Goods Charge (PGC) and Procurement Funding Requests.* Issued April 21. Pages 40-42 and O.P. 13.

[4] Davis, M. (Environmental Defense Fund). 2011. Behavior and Energy Savings Evidence from a Series of Experimental Interventions.

[5] DNV GL. 2019. *Home Energy Reports – Residential Program Year 2016.* DNV GL. Study ID: CPU0190.02.
DNV GL. 2019. *Home Energy Reports – Residential Program Year 2017.* DNV GL. Study ID: CPU0194.01.

[6] Electric Power Research Institute (EPRI). 2010. *Guidelines for Designing Effective Energy Information Feedback Pilots: Research Protocols.* Prepared by Freeman, Sullivan & Co. Palo Alto (CA): Electric Power Research Institute.

[7] State and Local Energy Efficiency Action Network. 2012. *Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*. Prepared by A. Todd, E. Stuart, S. Schiller, and C. Goldman, Lawrence Berkeley National Laboratory. DOE/EE-0734.

control conditions without their prior knowledge or approval. Reports are mailed to all households in the treatment condition. As of February 2017, about 0.5% of treatment households have requested to not receive additional reports after having received at least one report. Since households opting out of the program have received at least one report, they are considered to have been treated. Therefore, they are retained in the experiment and are included for the *ex-post* billing analysis.

2. *General attrition:* Attrition represents the households that move out of their residences (e.g., moving, change of utility billing address). The observed annual attrition rate of the treatment group in the PG&E HER experiments was 7% to 13% per year.[8] The attrition rate depends on the sample frame definition (that is, the customer energy usage and location characteristics) of each experiment. Experiments that have targeted electric-only customers reveal a higher attrition rate when compared with experiments that have targeted dual-fuel households. This difference in attrition rate may be explained by the greater proportion of renters in the electric-only customer segment. Attrited accounts are retained in the experiment until the end of the billing cycle during which the customer billing for that meter is "stopped" at account closing. Existing studies have shown that receipt of the reports do not cause attrition, and that control and treatment groups keep similar attrition rates over time.

Due to the unique composition of each RCT, savings for each experiment must be calculated independently and after the conclusion of the period of interest (this is still considered to be an e*x-ante* calculation when it is done to inform a savings claim). The determination of energy savings is done via billing analysis that compares energy use between the treatment and control groups using a difference-of-differences analysis whereby the pre/post difference of energy use of the treatment group is subtracted from the pre/post difference of energy use of the control group to yield the net impact of the program.

When HER savings are calculated, they will include savings already claimed by other (non-HER) programs in IOU residential portfolios ("joint savings"). To avoid double counting, joint savings need to be removed from the HER savings estimate. It is the increase in other program activity in the treatment group, relative to the control group, that represents HER-motivated overlap in other IOU program activity. A recent impact evaluation of the HER programs run by California IOUs conducted by DNV-GL summarizes the methodologies for correcting HER savings estimates for potential double-counting of savings.[9] In general terms:

- For downstream measures, rebate records for each measure must be examined so that the proportion of customers in treatment and control groups receiving rebates can be compared. If the proportion of customers in the treatment groups receiving downstream rebates is greater than the proportion of customers receiving rebates in the control groups, then an adjustment should be made to the HER claim to eliminate this uplift in other program activity.
- For upstream measures, the largest measure group of concern has been the IOU Upstream Lighting Program (ULP). Different approaches have been used over the past impact evaluations to adjust HER savings estimates downward to ensure that double-counting of savings does not occur, but in more recent years, customers in both treatment and control groups have been

[8] These results are consistent with the U.S. Census Department data.

[9] DNV GL. 2019. *Home Energy Reports – Residential Program Year 2017.* DNV GL. Study ID: CPU0194.01.

surveyed to assess differences in the installation and purchase of efficient lamps. If a greater number of efficient lamps is reported by customers treated by HER, then an adjustment should be made to the HER claim in proportion to the estimated proportion of efficient lamps sold that are subsidized by IOU programs.

Savings Determination

Impacts of comparative energy usage programs can be assessed using experimental design whereby a target group of similar households is randomly assigned to receive the reports ("treatment") or not ("control"). The random assignment ensures that the treatment and control groups are equivalent from a statistical standpoint such that the experimental design establishes whether the desired effects are more likely to occur in the intervention (or treatment) group due to the program. Households in the treatment and control groups are treated in the same fashion with respect to utility interactions outside of this intervention (such as exposure to marketing programs and recruitment to demand response programs).

The impacts of home energy reports have been tested in several jurisdictions across the nation by independent evaluators. These findings evaluation findings are based on the results of randomized controlled trial (RCT) experiments which are considered as the most effective way to establish causality between a treatment and its effect. This experimental design isolates the unique impact of the comparative usage. To reduce sampling error and thereby improve the representativeness of the sample of each of these experiments, each IOU utilizes stratified sample frames.

Savings from the HER program results from a myriad of actions that vary from household to household. They may be divided into three types of actions:

1. Behavioral changes or practices that affect equipment use (e.g., switching off lights, unplugging unused appliances, and adjusting thermostat settings to limit heating and cooling);
2. Behavioral changes in the purchase and installation of primarily low-cost equipment not rebated by IOU energy efficiency incentives programs (e.g., timers, replacement lamps, low-flow faucet aerators); and
3. Behavioral changes in the purchase and installation of energy efficient equipment rebated by IOU energy efficiency incentive programs (e.g., smart thermostats).

Since households have exhibit large variations in energy usage and savings are small (between 1.0% and 3.0% for electricity and between 0.5% and 1.5% for natural gas), large treatment and control groups are necessary to produce an un-biased savings estimate with a high level of statistical precision. Because the set of household's characteristics for each experiment is unique, savings is calculated on an ex-post basis using billing analysis and demand response impact assessment. Regression models are based on the "difference-of-differences" (DID) approach, whereby the average change in energy consumption between pre- and post-periods among the treatment group is subtracted from the average change in energy consumption between the pre- and post-periods among the control group. The difference between these two pre/post differences yield the impact of the program.

MEASURE CASE DESCRIPTION

The measure case is defined as a customer household that receives one or more Home Energy Reports and is assumed to take actions during the time (and after) the utility provides the reports to the customer.

BASE CASE DESCRIPTION

The base case for this measure is defined as a customer that is assigned to the control condition for any given experiment ("wave") in which a customer assigned to the treatment condition for that wave is provided one or more reports for the duration of the analysis period. The base case energy consumption is the average of each residential customers' energy consumption assigned to the control condition for a given experiment for the duration of the analysis period. Since savings are calculated by comparing usage between treatment and control conditions for each wave separately for the duration of the analysis period, there is not a fixed base case.

CODE REQUIREMENTS

The Home Energy Report measure represents a set of measures based on altered customer behavior through a periodic reporting system rather than savings from the installation of specific equipment, control system or building feature. Consequently, there are no state or federal code requirements for this measure.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	None.	n/a
CA Building Energy Efficiency Standards – Title 24	None.	n/a
Federal Standards	None.	n/a

NORMALIZING UNIT

The normalizing unit for this measure is per household.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation. Each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
BRO-Behavioral (BRO-Bhv)	DnDeemed	Residential

Eligible Products

Home Energy Reports is an "opt-out" program: households in the treatment condition receive custom reports without explicitly requesting them. Since the household characteristics that define the sample frame for each experiment (e.g., climate zone, fuel type, energy usage, time since account was established, etc.) are unique, each experiment requires a wave-specific analysis of energy savings and demand reduction.

Eligible Building Types and Vintages

This measure is applicable for single- and multi-family residential building types of any vintage.

Eligible Climate Zones

This measure is applicable in all California climate zones.

Savings Reporting

The IOUs will report quarterly ex-ante estimated savings, year-end ex-ante savings, and ex-post savings for the aggregated impact of the experiments in the program as single line items comprising the sum of savings from all participants. To the extent possible, reporting will align with rules established by the CPUC staff guidance for savings reporting for Population NMEC Programs. Specifically, savings for HER will be reported as follows:

- Ex-ante savings claims for electric and gas (kWh and therms) will be made on a quarterly basis using a running total of the best estimates of full-year savings for the entire customer population in the treatment groups as of the Claim Yr_Qtr. These ex-ante savings claims may include a holdback as discussed below.
- As data on program savings increase throughout the year, estimates of annual electric and gas savings (kWh and therms) will be updated on a quarterly basis using the most recent forecast information then available. These ex-ante savings claims may include a holdback as discussed below.
- The fourth quarter ex-ante savings claims will be the values to be reported to the Commission for publication in its annual report. These ex-ante savings claims may include a holdback as discussed in the example below.
    - *Example: The final ex-ante estimate of 2020 savings will be the values to be reported to the Commission for the publication in the 2020 Energy Efficiency Annual Report, which would be expected to be published in May 2021.*
- Provided an ex-post update for a prior year's ex-ante claim is available, it will be reported to the Commission in CEDARS for publication as a subsequent year Annual True-up Report that provides the positive or negative difference between the post-M&V values, if available, and the original ex-ante claims as discussed in the example below.
    - *Example: The May 2022 Annual True-up report will include the final ex-ante claim for the 2021 program year that incorporates a holdback calculated as discussed below. Provided an ex-post update for the 2020 program year claim is available, it will be included as well.*

Ex-ante savings estimates are based on savings forecasts from the third-party program implementer. These estimates may include a holdback for electric, demand and gas savings.

Before describing the concept of a holdback, it is important to define terms to ensure a common understanding of those used to describe HER savings.

> ***Unadjusted savings*** is the aggregate impact of an HER program on the average household energy consumption and demand. Unadjusted energy and demand savings reflect the overall program savings before applying any adjustment for joint savings achieved in conjunction with other IOU programs.
>
> ***Adjusted savings*** is the aggregate impact of an HER program on household energy consumption and demand after applying adjustments for joint savings achieved in conjunction with other IOU programs.
>
> ***Joint savings*** are energy and demand savings observed in an HER experiment that are the result of the increased uptake of other IOU programs and must be considered separately from savings attributable solely to an HER experiment. Joint savings may originate from two unique sources:
>
> > ***Downstream joint savings*** occur due to increased participation by the HER treatment group as compared to participation by the HER control group.
> >
> > ***Upstream joint savings*** occur due to increased purchases of PA-supported upstream program measures as compared to participation by the HER control group.
>
> ***Holdback*** is an estimate of ex-ante savings that are withheld from ex-ante savings claims to avoid the potential of double-counting savings (i.e., the risk of reporting savings that may have been included in ex-ante claims for other IOU measures).

Given the move to a third-party program implementer model, the IOUs will have discretion to decide how to apply holdbacks for ex-ante savings claims. The decision can be based on how each IOU contracts with its third-party program implementer to deliver HER and report savings to the IOU. The choice is as follows:

1. If the IOU contract with the third-party program implementer provides for the program implementer to provide an accounting of adjusted savings by the time the IOU must report ex-ante savings claims for the program year, then the IOU can report ex-ante savings claims based on the savings forecasts provided by the IOU's third-party program implementer.
2. If the IOU contract with the third-party program implementer does not provide for the program implementer to provide an accounting of adjusted savings, then the IOU can apply holdbacks to mitigate the risk of double-counting savings. When an IOU decides to apply holdbacks to its ex-ante savings claims, then the IOU will use the methodology of Holdback Rates as described below.

To determine holdbacks, Holdback Rates (HR) will be calculated independently for electric (kWh), demand (kW), and gas (therms) savings, respectively, for each program year. An HR is modeled, in concept, after the Gross Realization Rate (GRR) as defined in the Energy Efficiency Policy Manual Version 5 (2013)[10]. Within the context of HER, an HR will be defined as follows:

> ***Holdback Rate*** is a multiplier that attempts to take into account the likelihood that ex-ante savings claims from HER may include savings potentially claimed by other IOU programs (i.e., joint

[10] R.09-11-014. Energy Efficiency Policy Manual Version 5 (2013)

savings). An HR value will be applied as a retrospective value to account for the difference between adjusted and unadjusted savings. An HR will be based on the ratio of adjusted and unadjusted savings, as reported by the most recently available third-party evaluation, which is either:

- an impact evaluation commissioned by the CPUC, or
- an Early M&V study commissioned by an IOU.

The adjusted and unadjusted savings values from the most recent prior period for which a third-party evaluation is available will be used as inputs to calculate HRs as follows:

$$Holdback\ Rate\ (HR) = \frac{Adjusted\ Savings}{Unadjusted\ Savings}$$

For example, if the most recent third-party evaluation available is from the 2018 program year (i.e., the DNV GL impact evaluation[11]), then both the adjusted and unadjusted savings values from that impact evaluation will be used as inputs to calculate the HRs.

Once calculated, HRs are applied to the ex-ante unadjusted savings estimates, as reported by the third-party program implementer, to inform the program administrator ex-ante savings claims for the current program year. This calculation will result in the Reported Ex Ante Savings Claims. That is,

$$Reported\ ExAnte\ Savings\ Claim\ = Ex\ Ante\ Unadjusted\ Savings * Holdback\ Rate$$

IOUs shall be provided the discretion to adjust holdbacks to account for substantial changes in their residential measures that may affect the potential of double counting. For example, on December 31, 2019, the residential Upstream Lighting Program (ULP) was discontinued. Therefore, the IOUs could eventually eliminate the holdback for potentially double-counted upstream programs as no new lamps were subject to IOU rebates after that date. The IOUs would continue to account for potentially double-counted upstream measures until measures installed through 2019 reach the end of their effective useful lifetimes (EULs), at which point the upstream joint savings adjustment is eliminated and would no longer be reflected in the adjusted savings values used in the HR equation. The upstream joint savings adjustment can also take into account the attrition of HER-treated customers, which may include a rate at which households change premises and persistence of measures installed. The amount of joint savings attributed to upstream programs may be estimated as part of on-going Early M&V commissioned by an IOU or as a statewide effort. Ongoing third-party evaluation allows for updated adjusted savings values and therefore more accurate HRs.

[11] DNV GL Impact Evaluation. 2018. Impact Evaluation of Home Energy Reports: Residential Sector – Program Year 2018. CALMAC ID: CPUC0206.01

By contrast, should a program administrator launch a new upstream, midstream, or downstream program, the IOUs could elect to add holdbacks to ex-ante savings claims to mitigate the potential of double-counting savings from the new program until such time that ex-post evaluation data are available.

PROGRAM EXCLUSIONS

This measure excludes master-metered multi-family and all nonresidential facilities and residential buildings for which the vendor is unable to identify a sufficient number of comparable buildings (roughly 30) to generate the neighbor energy use comparisons that are used as a primary driver of savings in the reports. This measure excludes customers lacking at least nine months of energy usage history at the same address.

DATA COLLECTION REQUIREMENTS

Data requirements and timeline for gathering data. If additional data is needed to improve confidence of measure energy and demand impact estimates, it may be approved on an "interim" basis so in situ data can be gathered.

USE CATEGORY

Behavior

ELECTRIC SAVINGS (KWH)

The electric and gas savings from Home Energy Reports are determined after the end of a program period, typically a calendar year, using an econometric model to compare consumption using billing data of customers in the control and treatment groups for each experiment.[12] Data analysis requires the following assumptions:

1. The determination of energy savings is done via billing analysis that compares energy use between the treatment and control groups using a difference-of-differences analysis whereby the pre/post difference of energy use of the treatment group is subtracted from the pre/post difference of energy use of the control group to yield the net impact of the program. This is accomplished using a panel-based regression analysis to determine the mean value of the difference in energy consumption between the groups.
2. The number of participants constituting the control and treatment groups is defined as the average numbers of participants in each group throughout the test period.

[12] If the model is run as Early M&V to inform an IOU savings claim, this analysis is an *ex ante* analysis. If the model is run to verify a savings claim, this model is an *ex post* analysis.

3. "Opt-outs" continue to be counted in the treatment group. "Move-outs" are excluded as of the end of the final month of billing data.
4. Estimating joint savings requires assessing the uplift in treatment vs. controls using utility tracking records for downstream measures and survey data (or other similar sources of information as agreed upon with regulators) for upstream measures.

The methodology used to estimate electric and gas savings resulting from the HER program is based on a fixed-effects panel regression model in which monthly energy consumption for treatment and control group customers is estimated using an indicator variable for month of the study, a treatment month indicator variable and a customer-level indicator variable. Such a model is the standard for evaluating behavioral programs.[13] It produces a "difference-in-difference" calculation by comparing the pre- to post-treatment difference for the treatment group to the pre- to post-treatment difference for the control group.

The change that occurs in the average, per customer differences between treatment and control in post period *t* is adjusted to reflect any change that occurred in the control group to isolate changes attributable to the program. The fixed-effects equation is represented by Equation 1 below.

Equation 1. Fixed-Effects

$$E_{i,t} = \mu_i + \lambda_t + \beta P_{i,t} + \varepsilon_{i,t}$$

where:

E_{it} = *Average daily energy consumption for account i during month t*

P_{it} = *Binary variable equal to 1 for households in the treatment group in the post period month t, 0 otherwise*

λ_t = *Binary variable: one for a specific month/year, zero otherwise*

μ_i = *Account level fixed effect*

ε_{it} = *Regression residual*

This model produces estimates of average monthly savings using Equation 2.

Equation 2. Average Monthly Savings

$$\bar{S}_t = \widehat{\beta_t}$$

where:

$\bar{S}_t$ = *Average per-customer savings during month t*

$\hat{\beta}_t$ = *Estimated parameter measuring the average, per-customer difference between treatment and control in the post period month t*

The model also includes site-specific and month/year fixed effects. The site-specific effects control for average, per customer differences between the treatment and control groups that do not change over

[13] A lagged-dependent variable model is also valid, but a single approach is offered for simplicity and consistency.

time. The month/year fixed effects control for change over time that is common to both treatment and control groups. The monthly post-program dummy variables pick up the average monthly effects of the treatment. The total savings equal the sum of the monthly average savings combined with the count of households still eligible for the program in that month.

This approach to estimate the savings accounts for the effects of opt-outs, "move-outs," and other statistical variances during the treatment period. Because the analysis utilizes billing data for randomly selected user quartiles and weather areas, seasonal weather variations, as well as interactive effects are already accounted for in the statistical model. The further analysis of rebate records, home inventories, and online surveys accounts for the participation in rebate programs and prevent double counting savings.

This model is consistent with best practices as delineated in State and Local Energy Efficiency Action Network (SEEAction) Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations.[14]

The HER program may increase rebate activity in other energy efficiency programs. To ensure that the energy and peak demand impacts claimed for the HER program is not duplicative of the impacts claimed by other rebate programs, it is necessary to estimate the savings overlaps and subtract the overlapping or "joint-savings" from the HER savings to avoid double counting.

Two analyses were undertaken to estimate joint savings and calculate adjusted savings.[15] The resultant estimates were verified by the CPUC-managed impact evaluator and values from them were incorporated as inputs into the impact evaluations beginning with the 2015 program year.[16]

1. Assessment of HER-Related Increase in Downstream Rebate Program Participation in the Treatment Group. Downstream rebate program uplift among HER participants is estimated using rebate program tracking databases to determine the extent to which the HER program increased participation rates in each treatment group relative to its control group. Ideally, joint savings are estimated by transforming the downstream program deemed annual savings values into realistic day-to-day savings values based upon the installation dates of each measure. The daily share of annual savings is determined by 2011 Database for Energy Efficiency Resources (DEER)[17] hourly load shapes. These load shapes indicate when a measure is used during the year and, by proxy, when efficiency savings would occur.
2. Assessment of HER-Related Increase in Upstream Rebate Program Participation in the Treatment Group. The primary residential sector upstream program is the Upstream Lighting Program (ULP), which rebates compact fluorescent lamps (CFLs) and lamps with light emitting diodes (LEDs).

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[14] State and Local Energy Efficiency Action Network. 2012. *Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations.* Prepared by A. Todd, E. Stuart, S. Schiller, and C. Goldman, Lawrence Berkeley National Laboratory. DOE/EE-0734.

[15] 'Adjusted savings' are defined as 'unadjusted savings' (estimated by statistical analysis) minus 'joint-savings' (savings that have been claimed by other energy efficiency programs).

[16] For a detailed explanation of the methodology for assessing potential double-counting of HER savings with other IOU programs, see DNV GL. 2019. *Impact Evaluation Report: Home Energy Reports—Residential Program Year 2017.* CALMAC ID CPU0194.0.

[17] Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission.

Multiple data sources have been used to assess the increase in participation in the ULP in customers in HER treatment groups relative to customers in associated control groups. Beginning in 2015, DNV GL, the CPUC's impact evaluator of HER, began to survey HER treatment and control customers to measure the difference in reported purchase and installation of CFLs and LEDs. Respondents to the online surveys reported on both purchase and installation of CFLs and LEDs for the prior year. The results are used to estimate the *savings uplift* in installed CLFs and LEDs attributable to exposure to HER treatment for a given year. The last administration of the survey was in 2017. Not all the extra lamps reported by respondents in HER-treated households may have been rebated through the ULP, however. The *rebated sales fraction* term is used to adjust the uplift to the rebated proportion of excess lamps. It is assumed that excess lamps were installed evenly throughout the year. Therefore, the average fraction of months that a lamp is installed out of a year is referred to as the *installed proportion* of a given year. The *installation rate* term is taken from the impact evaluation of the 2013-2014 Upstream Lighting Program.[18] The uplift reported in households treated by HERs, relative to controls, is used as the basis for calculating the annual electric savings (kWh) and gas interactive effects using Equation 3.[19]

Equation 3. Upstream Joint Savings Equation Used for Calculating the Annual Electric Savings and Gas Interactive Effects

$$\begin{aligned} &Joint\ savings\ per\ household \\ &\quad = Excess\ lamps\ due\ to\ HER \times Rebated\ sales\ fraction\ \times NTG \times Installation\ Rate \\ &\quad \times Installed\ proportion\ of\ year's\ lamps\ X\ Savings\ per\ lamp \end{aligned}$$

GAS SAVINGS (THERMS)

The gas energy savings for Home Energy Reports were developed with the same approach as the electric savings except gas billing data was used in the analysis rather than electric billing data. See Electric Savings section for more detail.

PEAK ELECTRIC DEMAND REDUCTION (KW)

Starting January 1, 2020, reductions in peak demand as a result of HER program participation are estimated using the DEER definition as the average demand impact as would be "seen" at the electric grid level for a measure averaged across 15 hours from 4 p.m. to 9 p.m.[20] during the three consecutive weekday period containing the highest algebraic sum of: the average temperature over the three-day period, the average temperature from noon to 6 p.m. over the three-day period, and the peak temperature within the three-day period.[21] This definition represents a shift to evening from afternoon

[18] DNV GL. 2016. *Impact Evaluation of 2013-14 Upstream and Residential Downstream Lighting Programs.* CALMAC Study ID CPU0122.01.

[19] Table 3-1 in DNV GL 2019 describes each upstream lighting joint savings input and lists the sources that are used for lamps installed between 2011 and 2017.

[20] O.P. 1, Resolution E-4952, issued October 12, 2018.

[21] Resolution E-4867, issued August 24, 2017, ordered the IOUs to establish a working group to propose adjustments to the definition of the Peak Period. This working group produced a report on May 4, 2018. The recommendation in the working group

hours and replaces the 2011 Database of Energy Efficient Resources (DEER) definition used previously.[22] For both the new and the prior peak definitions, the average temperature, average afternoon temperature, and maximum temperature over the course of three-day heatwave candidates are taken into account. Each candidate is a combination of three consecutive, non-holiday weekdays between June 1 and September 30. Using this definition, the optimal heatwave (HW) for each climate zone is selected by choosing the single candidate three-day-period with the highest peak score ($Score_k$) among all possible candidates.

The mathematical expressions are provided in Equations 4 – 6 below.

Equation 4. Optimal Heatwave

$$HW = \max_{1 \le k \le K} (Score_k)$$

Equation 5. Peak Score

$$Score_k = \max_{1 \le d \le 3} (temp_{d,k}) + \frac{1}{d}\sum_{d=1}^{3}(daily\_mean_{d,k}) + \frac{1}{d}\sum_{d=1}^{3}(afternoon\_avg_{d,k})$$

where:

$HW =$ *Zone-specific set of three consecutive non-holiday weekdays that has the highest value of* $Score_k$ *for heat wave candidate k across all possible candidates K*

$Score_k =$ *The summation of maximum temperature, average daily, and afternoon average temperature*

$temp_{d,} =$ *The hourly temperature value across all hours on day d, for heat wave candidate k*

$daily\_mean_{d,} =$ *The average hourly temperature across all hours on day d, for heat wave candidate k*

$afternoon\_avg_{d,} =$ *The average hourly temperature between 12 noon and 6 p.m. on day d, for heat wave candidate*

Statistical differences in demand between treatment and control groups can be derived from 15-minute and 60-minute interval meter data, and consumption during the hours of 4:00 p.m. and 9:00 p.m. of the most common heat wave.

Since the HER program model is an RCT, the simplest approach is to calculate the difference in average hourly load between treatment and control households during peak periods using interval data. This is referred to as a "post-only" framework as it only utilizes interval data that is observed after the launch date of the program and does not make use of any pre-program period data.

The general equation for the post-only approach is represented in Equation 6.

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report were considered along with comments on the report and additional considerations as noted in the Resolution E-4952, Ordering Paragraph 1, effective January 1, 2020.

See http://www.deeresources.com/index.php/23-deer-versions#PkPeriod for more information.

[22] Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission.

Equation 6. Post-Only

$\overline{kW}$ savings = $\overline{post\_kW_C}$ - $\overline{post\_kW_T}$

where:

$\overline{kW}$ *savings* = *Average demand reductions during the peak period*

$\overline{kW_C}$ = *Average hourly load of the control group during the peak period in the post period being evaluated*

$\overline{kW_T}$ = *Average hourly load of the treatment group during the peak period in the post period being evaluated*

Another methodology is more suitable when pre-existing differences exist between average treatment and control load. A difference-in-differences approach would then be a more appropriate method for controlling the differences in demand from pre- to post-period to avoid biased estimates of demand reduction.

Load Shapes

A load shape indicates the distribution of a measure's energy savings over one year. As is the case with other key savings parameters, the CPUC establishes the values for load shapes that must be used for energy efficiency measures and provides them in DEER. When a load shape for a specific measure does not exist in DEER, as is the case with HER, implementers are permitted to calculate a weighted blend of DEER load shapes based on metered data.

The CPUC has commissioned research to replace the weighted blend of DEER load shapes currently being used for the HER measure that is described in this section. Because HER waves (experiments) have unique characteristics, multiple DEER load shapes may be developed that are up-to-date and wave- and/or IOU-specific. Load shapes should be estimated on a weather-normalized basis to reflect typical meteorological conditions. As these improvements are made, the associated DEER savings load shapes should be applied consistently across HER programs.

Until HER load shapes are published in DEER, the HER measure is using a weighted blend of DEER load shapes that was created using HER measure load shape data provided by HER vendor Opower from four PG&E HER waves comprised of approximately 1.2 million customers in treatment conditions as the input and a Proxy Tool developed by Energy + Environmental Economics (E3), developer of an avoided cost calculation methodology used by California IOUs to compute the cost-effectiveness of energy efficiency programs.. The remainder of this section describes the development of the weighted load shape employed for HER in general terms. A more detailed presentation of the development of the weighted blend of DEER load shapes being used for the HER measure, including the raw data used as input and the Proxy Tool itself, is provided as a supplement to this workpaper and is entitled *Avoided Energy Use for Home Energy Reports: Description of Methodology Used for Creation of Blended Load Shape*.

The Proxy Tool is an Excel-based spreadsheet that calculates a weighted average of two DEER savings load shapes that can be used to equal the avoided cost benefits that would have been attributed to the measure if that measure impact shape were a selectable DEER load shape. The Proxy Tool calculates the present value avoided cost benefits for a user-input hourly impact shape. This calculation is done using the same hourly avoided cost inputs that are used for the DEER shape "pre-processing", and the same

weighted average cost of capital (WACC) discount rate used in the E3 Calculator.[23] The tool then compares the avoided cost benefits of the user-input impact shape to the avoided cost benefits for the official DEER shapes and calculates allocation factors for any pair of DEER shapes. By splitting the measure's annual kWh across the pair of DEER shapes using these allocation factors, the E3 Calculator will attribute present value avoided cost benefits to the measure that match what the measure would have received if its actual shape were included among the official DEER shapes.

The Proxy Tool can calculate allocation factors for any pair of DEER measures. The choice of DEER measures to use will not affect the result, as the allocation factors will always result in the correct avoided costs, and will always sum to 100%, so the tracking of total annual kWh savings is not distorted. Certain pairings, however, will likely have more appeal from a pure optics perspective, and for this optics reason, one should probably try to avoid pairings that result in a negative share and a greater than 100% share (unless one is modeling a storage or load shifting measure).

At its core, the E3 Calculator is a cost-effectiveness tool that determines the present value of lifecycle avoided cost benefits and lifecycle costs. When one assigns a DEER shape to a measure, that DEER shape determines the avoided cost benefits that will be attributed to the measure. The Proxy Tool simply calculates a weighted average of two DEER shapes that can be used to equal the avoided cost benefits that would have been attributed to the measure if that measure's impact shape were a selectable shape.

For example, assume measure A saves 600 kWh per year, has an EUL of 10 years, and has present value avoided cost benefits of $1000 per annual kWh. Further assume that we have DEER shape 1 with present value avoided cost benefits of $1400/annual kWh and DEER Shape 2 with $900/annual kWh. The standard approach would be to enter measure A as saving 600 kWh per year and mapped to DEER Shape 2. The resulting benefits would be $540,000 (600 * 900) which is less than the actual $600,000 (600 * 1000). The Proxy Tool method would enter measure A as saving 480 kWh per year using DEER Shape 2 and 120 kWh per year using DEER Shape 1. By modeling measure A and using a blend of two existing DEER shapes, one can obtain the correct avoided cost benefits of $600,000 (480 * 900 + 120 * 1400).

The Proxy Tool can calculate allocation factors for any pair of DEER measures. The choice of DEER measures to use will not affect the result, as the allocation factors will always result in the correct avoided costs, and will always sum to 100%, so the tracking of total annual kWh savings is not distorted. Certain pairings, however, will likely have more appeal from a purely optics perspective, and for this optics reason, one should probably try to avoid pairings that result in a negative share and a greater than 100% share (unless one is modeling a storage or load shifting measure).

The allocation shares are calculated assuming the measures are installed at the beginning of the user-entered calendar year, and that EUL is integer years. While the E3 Calculator tracks installation quarters

[23] The E3 Calculator, previously published as an Excel spreadsheet, has subsequently been replaced by a SQL tool referred to as the Cost Effectiveness Tool (CET). The CET has the same functionality as the E3 calculator used to evaluate the cost effectiveness of energy efficiency measures for the three California electric IOUs. The E3 Calculator was first developed in 2004 with a focus on simplifying the program submission and review process by using a limited set of pre-determined EE impact shapes. 19 DEER-based impact shapes currently included in the E3 Calculator were selected to fit over 80 percent of the expected EE program savings. However, for those measures that were not a good fit with the pre-determined shapes, the user was generally left with the chore of selecting the least bad fit.

and fractional EUL years, we do not believe that level of detail is necessary for determining allocation factors, as we do not expect the factors would change significantly with those modifications.

As of the summer of 2016, most customers assigned to HER treatment groups had been treated for two years or more. For those experiments, the growth in average household savings had decelerated and grew marginally over time (as seen in most HER programs). Given this arrival to a near-steady state in savings, and given that the HER program was being rolled out in a largely homogeneous manner (that is, territory-wide to the top three quartiles of customers in terms of energy use), it was an appropriate time to calculate the actual load shape of avoided energy use by comparing the average usage of treated customers to that of control customers and generate the avoided cost load shape for the PG&E HER program. After this process was adopted by PG&E, the other electric IOUs adopted it for developing load shapes specific to its customers.

The initial process to generate this avoided cost load shape consisted of two steps:

1. Create hourly avoided energy use load shape for 2015
2. Match this load shape to approved DEER residential load shapes using an Excel-based tool provided to PG&E by E3.

Hourly-level electric usage data from HER treatment and control customers was used to derive the shape of avoided energy use ("HER load shape") for the then-most recent calendar year available (2015). Given that about two years of HER treatment are required to reach near-maximum household savings rates, usage data from treatment and control customers from the following HER experimental waves were included in this analysis:

- Beta Wave (launched in August 2011 with approximately 60,000 customers from the top quartile of energy users in treatment)
- Gamma Wave (launched in November 2011 with approximately 210,000 customers from all quartiles in treatment)
- Wave One (launched in February 2012 with approximately 400,000 customers from the top three quartiles of energy users in treatment, and
- Wave Two (launched in February 2013 with approximately 400,000 customers from the top three quartiles in treatment.

Using the E3 Excel tool provided by E3 and a savings load shape provided by OPOWER from the experimental waves listed above, PG&E engineering staff allocated the HER program annual kWh saved to a pair of DEER shapes. These load shapes are *Res:DEER:RefgFrzr_HighEff* and *Res:DEER:HVAC_Eff_AC*. This combination of two load shapes enables the E3 Calculator to attribute present value avoided cost benefits to the HER program that matches what the measure would have received if its actual shape were included among the official DEER shapes.

EFFECTIVE USEFUL LIFE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The intent of comparative usage programs is to affect behavioral change, and studies in multiple jurisdictions have confirmed that savings continues for as long as comparative usage reports are provided to households.[24] Some recent studies indicate that there are residual effects from these programs that continue after cessation of report deliveries.[25]

The EUL and RUL specified for the HER measure are presented below. The EUL is set to one year for each experiment from the start of report deliveries. The program measure life may be longer because of evidence of savings persistence.

Effective Useful Life and Remaining Useful Life

Parameter	Home Energy Report	Source
EUL (yrs)	1.00	Rulemaking 13-11-005 filed November 13, 2015 (Assigned Commissioner and Administrative Law Judge's Ruling Regarding High Opportunity Programs or Projects, commonly referred to as "the HOPPs Ruling") and as reaffirmed in Resolution E-4592 filed October 11, 2018 (Approval of the Database for Energy-Efficient Resources updates for 2020 and revised version 2019 in Compliance with D.15-10-028, D.16-08-019, and Resolution E-4818).
RUL (yrs)	n/a	--

BASE CASE MATERIAL COST ($/UNIT)

The base case assumes that no action is taken, and therefore the base case cost is equal to $0.00.

MEASURE CASE MATERIAL COST ($/UNIT)

The actions taken by customers in response to Home Energy Reports are primarily behavioral, and the cost associated with these actions is assumed to equal $0.00. Estimated savings overlaps with other portfolio measures—when they exist—are subtracted from the HER savings claims to avoid double counting in the energy efficiency portfolios.

BASE CASE LABOR COST ($/UNIT)

The actions taken by customers in response to Home Energy Reports are primarily behavioral, and the labor cost associated with these actions is assumed to equal $0.00.

[24] Allcott, H. and T. Rogers. 2012. *The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation*. Cambridge (MA): National Bureau of Economic Research.

[25] Nexant. *PG&E HER 2016 Energy and Demand Savings Early M&V*. 2018. CALMAC Study ID PGE0424.01 and Navigant. *Home Energy Report Opower Program Decay Rate and Persistence Study. 2016.*

Navigant. *Behavioral Energy Savings Programs: Home Energy Reports Persistence Study Part 2-April 2015 to September 2015.* 2016. Prepared for Nicor Gas.

MEASURE CASE LABOR COST ($/UNIT)

The actions taken by customers in response to Home Energy Reports are primarily behavioral, and the labor cost associated with these actions is assumed to equal $0.

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. Behavioral changes in practices and equipment installations only resulting from the treatment are reported without additional NTG adjustment. Because households are randomly assigned to either the treatment or control groups, differences between the two groups are eliminated, thus the estimated impacts represent "net" impacts.[26] Moreover, the savings of equipment purchases that have been rebated through another utility program are excluded from the HER savings, so any NTG adjustments are applied to the savings for those measures, rather than to the savings for the HER program.

Net-to-Gross Ratios

Parameter	Home Energy Reports	Source
RCT-Default	1.0	California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. P. A-45.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. Home Energy Reports uses RCTs to determine energy savings. Because this method randomly assigns households to either the treatment or control groups, differences between the two groups are eliminated. [27]

Gross Savings Installation Rate

Parameter	Home Energy Reports	Source
GSIA	1.0	n/a

[26] Violette, D. and P. Rathbun. 2017. Chapter 21: Estimating Net Savings: Common Practices: *Methods for Determining Energy Efficiency Savings for Specific Measures*. Golden (CO): National Renewable Energy Laboratory. NREL/SR-7A40-68578.

Stewart, J. and A. Todd. 2015. Chapter 17: Residential Behavior Protocol: The Uniform Methods Project: *Methods for Determining Energy Efficiency Savings for Specific Measures*. Golden (CO): National Renewable Energy Laboratory. NREL/SF-7A40-62497.

[27] Violette, D. and P. Rathbun. 2017. Chapter 21: Estimating Net Savings: Common Practices: *Methods for Determining Energy Efficiency Savings for Specific Measures*. Golden (CO): National Renewable Energy Laboratory. NREL/SR-7A40-68578.

Stewart, J. and A. Todd. 2015. Chapter 17: Residential Behavior Protocol: The Uniform Methods Project: *Methods for Determining Energy Efficiency Savings for Specific Measures*. Golden (CO): National Renewable Energy Laboratory. NREL/SF-7A40-62497.

NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	No
DEER Operating Hours	No
DEER eQUEST Prototypes	No
DEER Version	DEER 2017, READI v2.4.7
Reason for Deviation from DEER	DEER does not contain this measure
DEER Measure IDs Used	n/a
NTG	NTG ID: The NTG value of 1.0 is associated with NTG ID: *RCT-Default*
GSIA	GSIA ID: The GSIA value of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	EUL ID: The EUL value of 1 year is associated with EUL ID: *Res-Behavioral*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	11/5/2019	Jennifer Barnes, Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: – Workpaper PGECOALL107 Revision 1 (March 6, 2017) – Consensus reached among Cal TF members.
01	11/15/2019	Brian Smith and Henry Liu, PG&E	Updated workpaper with a statewide approach
01	12/18/2019	Brian Arthur Smith, PG&E	Updated workpaper to address comments from the CPUC submitted to PG&E on December 10, 2019, including the addition of a supplementary file describing the methodology used for the development of the weighted blend of DEER load shapes entitled *Home Energy Reports blended savings load shape methodology 12182019*.
01	02/06/2020	Brian Arthur Smith, PG&E	Updated workpaper to address comments from the CPUC submitted to PG&E on January 30, 2020
02	12/21/2020	Lester Sapitula, PG&E	Updated workpaper to clarify savings reporting process and address holdback language within Savings Reporting section; modified peak period hours within Peak Electric Demand Reduction section to align with Resolution E-4952
02	02/08/2021	Lester Sapitula, PG&E	Updated workpaper to clarify that savings holdbacks should continue through the effective useful life of the measure after it is discontinued. Updated EUL/RUL comment within DEER Difference Summary table.