Neighbor Comparison Reports Save Energy, but What Drives Savings?

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ABSTRACT

This report describes the methodology used to estimate savings resulting from mail-based reports that feature neighbor comparisons of energy use ("Home Energy Reports" or "HERs") and the results of home inventories and face-to-face surveys to identify savings drivers and to avoid double-counting of savings from HERs that could be claimed by other measures. The effects from three large-scale experiments of HERs are estimated using Randomized Control Trials ("RCTs"). For the experiment in the field for the largest time (17 months) targeted at high-usage households, estimated annual electric savings are 1.5% and gas savings are 0.9%. A home inventory task was completed with 512 households to identify the behaviors driving energy savings and to estimate energy savings potentially claimed by upstream energy efficiency ("EE") measures. The inventories found that treatment households have one more compact fluorescent lamp ("CFL") installed compared to controls, on average. The extra CFL accounts for about one-third of the estimated electric savings from HERs so a reduction of 12% was made to avoid double-counting of CFL savings potentially claimed by the Upstream Lighting Program. An analysis of rebate records found minimal differences between treatment and control households in the uptake of downstream measures. to estimate the portion of energy savings potentially claimed by downstream EE measures found negligible risk of double-counting energy savings. The only reliable predictor of energy savings uncovered by the research is prior energy usage: those who used more energy tended to save more as a result of exposure to HERs.

Introduction

Pacific Gas and Electric and Company (PG&E) contracted with the firm Opower to produce and mail customized reports to residential customers. These "Home Energy Reports" (HERs) provide comparisons of household energy use to households with similar characteristics (i.e., homes of similar size and proximity). While the use of reports featuring neighbor comparisons of energy usage is a relatively new idea for EE, the "normative comparisons" technique for triggering behavior change is well grounded in social science theory.[1]

HERs have been subjected to numerous rigorous Randomized Control Trials (RCTs) that demonstrate they result in modest savings rates at the individual household level. Because of the large scale at which these programs can be deployed, HERs lead to significant societal reductions in energy consumption.[2] Savings estimates for HERs experiments using RCTs vary across utilities and customer segments by reasons that are not well understood–except that impacts vary with energy consumption. That is, the greater the energy consumption of the target households, the greater the energy savings resulting from exposure to HERs, both in absolute terms and on a percentage basis.

HER programs are designed to cause customers to lower their energy use by changing behavior related to household energy use. There are two classes of behavior that might be affected by the HER stimulus. First, exposure to the HERs may cause consumers to change the ways in which they use the appliances in their home–either by reducing hours of operation (e.g., turning off lights or setting back

[1] For example see Schultz, W. et al. 2007. *The Constructive, Destructive, and Reconstructive Power of Social Norms*. Psychological Science 18 (5), pp. 429-434.
[2] For a meta-analysis of the estimated impact of HER programs run by utilities throughout the U.S., see Davis, M. 2011. *Behavior and Energy Savings: Evidence from a Series of Experimental Interventions.* Environmental Defense Fund.

thermostats when not at home) or by changing the intensiveness of energy use (e.g., using more efficient settings such as unheated drying settings for dishwashers or using a cold water wash). Second, HERs may cause changes in purchasing behavior of energy-efficient appliances and building envelope-related products (that may or may not be eligible for a utility EE rebate). These are considered *behavioral* and *equipment* savings, respectively.

PG&E traditionally provides rebates for customer installation of energy-efficient appliances and building envelope-related products, so it is possible that some of the energy savings observed in the HER treatment groups have been counted by other programs (for example, if HER recipients are more likely to receive appliance rebates then some of the savings estimated for HER may have been reported by appliance measures). To avoid this possibility, research was undertaken to estimate the extent of possible double-counting. These attribution issues are the key focus of this paper.

Research Design

The HER program was implemented in an initial pretest and three large-scale experiments[3] as detailed in Table 1. The pretest ("Alpha Wave") involved PG&E employees and retirees (N=2,000) was designed to assess the information systems required to generate the HERs accurately and the back office systems needed to support larger-scale program operations. The Alpha Wave was designed to be a "friendly" test of likely customer reactions to receiving the reports. The sample frames and goals for the ensuing three experiments have the following characteristics:

- The *Beta Wave* was the first at-scale rollout and targeted customers with high energy use (i.e., highest usage quartile) living in relatively hot Central Valley and East Bay (San Francisco Bay Area) communities. The purpose of the Beta Wave was to gauge the level of call center and other back office support required to scale the program and to understand reactions of relatively friendly customers.
- The *Gamma* wave was designed to provide information needed to target successive program rollouts cost effectively. This larger experiment includes customers in all usage quartiles located in most geographical areas in the PG&E service territory. The sample frame was stratified by usage quartile, baseline territory (akin to climate zone), and commodity (i.e., customers who receive either electric or gas service from PG&E, or both ("dual fuel")).
- *Wave 1* was the largest of the three waves. This wave was targeted at the top three usage quartiles, and was stratified by usage quartile and baseline territory.

All three experiments utilized RCTs in which customers who were deemed eligible to receive HERs were randomly assigned to treatment and control groups within the sampling strata. In the parlance of experimental design, these experiments are known as randomized block designs: customers within sampling strata are randomly assigned to treatment or control conditions. This design ensures that, at the outset of the experiment, households in experimental treatments within strata are statistically equivalent to control subjects within the same strata with respect to prior household energy usage, key demographic characteristics of the occupants, and building characteristics including size, age, and presence of pools and spas. The control group in each stratum is used to estimate the energy consumption that would have occurred in the absence of the HER treatment. Comparison of these characteristics after random selection ensures that the treatment and control groups are essentially equal on these characteristics.

[3] More detailed information is available in the *Evaluation of Pacific Gas and Electric Company's Home Energy Report Initiative* for the 2010–2012. 2013. Report is available on the CALMAC website or through the authors of this paper.

Study Wave	Sampling Strata	Study Population		Exposure Months	Participants Sampled For Home Inventories		Home Inventories Completed	
		Treatment	Control		Treatment	Control	Treatment	Control
Beta	Top Usage Quartile. Climate Zones R S X.	60,000	60,000	18	86	72	50	52
Gamma*	All Usage Quartiles. Climate Zones R S T W X.	205,000	205,000	14	77	76	39	48
Wave 1	Top 3 Usage Quartiles. All Climate Zones	400,000	89,997	12	467	481	264	248

Table 1. Characteristics of the three HER RCT experiments

Net Impact Measurement

The simplest way to estimate the impact of the HER treatment on energy consumption is by using utility monthly billing data to calculate a "difference in differences" between usage billed to the treatment and control groups. A more sophisticated way to estimate the impact is by using a linear fixed effects regression ("LFER") model including variation in weather conditions and prior energy usage as control variables. Both estimation approaches lead to similar estimates of program impacts, though the LFER model is probably more precise and therefore the results reported in this paper are based on the LFER model.

Adjusting for Impacts of Measure-Based Programs

PG&E offers measure-based EE programs at three levels in the market: *upstream* (incentives paid to manufacturers of energy efficient products to buy-down the wholesale price so that retailers reduce the prices paid by consumers), *midstream* (incentives paid to retailers for selling energy efficient products) and *downstream* (incentives paid directly to consumers for purchasing energy efficient products). It is relatively simple to compare the uptake of downstream savings claims in the treatment and control groups by observing the differences in rebate submittal rates between the treatment and control groups in utility records. Any excess in EE measure adoption observed in the treatment group beyond levels observed in the control group is attributable to exposure to the HERs. The energy savings from this excess can either be deducted from the savings attributed to the measures or it can be deducted from the energy savings attributable to the HERs. For simplicity's sake PG&E has elected to deduct the excess savings attributable to measure adoption from the HER savings claims even though the evaluation protocols used[4] provide for the option of splitting of the estimated savings between HER and other utility measures.

In contrast to downstream programs, estimating whether households receiving HERs are more likely to adopt EE measures incented by midstream and upstream programs is more difficult. These programs intervene at the retailer or manufacturer level and there are no utility records that can be traced down to the household level. The principal measures of interest are compact fluorescent lamps (CFLs) and televisions. These products represent PG&E's largest residential EE measures. The possibility of double-counting the energy savings attributable to increased use of CFLs is of particular concern because consumers can easily substitute CFLs for incandescent bulbs. Rebates that PG&E pays for energy efficient televisions are also of concern because of the large number of TVs that PG&E has rebated in this program cycle.

[4] Todd, A. et al. 2012. *Evaluation, Measurement and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations.* State and Local Energy Efficiency Action Network.

Using In-Home Inventories to Ensure No Double-Counting of Savings

Combined, the lamps rebated to retailers and manufacturers through the California Upstream Lighting Program (ULP) accounted for over half (56%) of the expected net kWh savings in the total statewide IOU portfolio in the 2006-2008 cycle.[5] Because PG&E depends on ULP savings to achieve its EE savings goals, it is critical that the HER evaluation minimizes the risk of double-counting ULP savings.

The average annual savings from households receiving HERs is about 150 kWh per year, and replacing a typical incandescent lamp with a comparable CFL will produce an annual energy savings of about 44 kWh per year. Consequently a relatively small difference in the average counts of CFLs in use in treatment vs. control households could drive a substantial proportion of the savings observed in treatment households.

From prior research we know that consumers cannot be relied upon to reliably count and report lighting installations in telephone interviews[6]. Moreover, response rates to telephone surveying have fallen to historically low levels and it has been shown that the demographic characteristics of those who respond to telephone surveys are significantly different from those of the general population in very important respects (i.e., age, home ownership, building type, time in residence and presence of children).

Although it has not been documented, there is no reason to believe that self-reported counts of CFLs in use obtained through any other survey mode (such as through an online or mailed survey) would provide more reliable measurements. There is reason to be concerned about the representativeness of survey samples obtained through other means, such as through internet panels and—to a lesser extent—mixed mode surveys involving internet and mail surveying. Internet panels have unknown but potentially very large demographic biases. The use of mixed mode (internet and mail) surveying has recently been shown in some cases to produce reasonably high response rates (> 50%) in general population surveys with demographic characteristic that are comparable along most dimensions to the general population of households[7] but we concluded that consumers simply do not have the training required to distinguish between CFLs and other lighting technologies; nor are they likely to apply a standard counting protocol with sufficient rigor to allow us to have any confidence that the measurements that are reported from one household to another are valid and reliable. Moreover, using self-report methodologies to estimate whether households in the treatment groups are more likely to have purchased efficient TVs rebated by PG&E is also problematic as it requires accurately recording long model serial numbers found on the back of the TV sets.

Given these concerns, it was decided that the count of CFLs and TVs in treatment and control households would be performed on site by a trained observers. In-home inventories would offer the most reliable estimate of differences in counts of CFLs in use, and differences in counts of TVs that are likely to have been subjected to midstream rebates and would justify a deduction from the savings claim for the HER program. By contrast, if the in-home inventories result in no observed differences in the average number of installed CFLs or energy efficient televisions between the treatment and control groups, then it is reasonable to conclude that the HER treatment had no statistically significant effect on the purchase of CFLs or televisions and that there is no need to adjust the HER energy savings observed in the treatment groups.

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[5] Kema. 2010. *Final Evaluation Report: Upstream Lighting.* California Public Utilities Commission.

[6] For example, see The Cadmus Group et al. 2010. *Compact Fluorescent Lamps Market Effects Final Report.* California Public Utilities Commission.

[7] Dillman, D. et al. 2009. *Response rate and measurement differences in mixed-mode surveys using mail, telephone, interactive voice response (IVR) and the Internet.* Social Science Research.

Sample design for the in-home inventories

Sampling was done within the aggregated treatment and control groups of the Beta, Gamma and Wave One populations in order to produce results that could apply to all three populations. Two-stage cluster sampling was done so as to produce a random sample of households that could be visited relatively efficiently, thereby reducing fielding time and expense. In the first stage of the two-stage cluster sampling effort, 26 zip codes were randomly chosen from among the zip codes in which HER recipients and control group members lived. Zip codes were sampled with replacements, so that some were selected multiple times. Next, 30 treatment and 30 control households were selected within each zip code, with zip codes selected multiple times having more than one group of 30 treatment and 30 control customers selected. At the zip code selection stage, zip codes were sampled in proportion to the recipient and control households' aggregate energy usage; and within zip codes, households were sampled in proportion to their average energy usage. So a zip code with twice the total usage among resident HER households as another would have been twice as likely to be sampled; similarly, a household with twice the energy usage as another would have been twice as likely to be sampled. Because the Wave One treatment group was four times bigger than the control group, Wave One control group customers were over-sampled by a factor of four. This made the overall treatment sample comparable to the overall control sample.

A total of 1,259 customers were selected for the survey (630 treatment and 629 controls). The survey was actually carried out in 21 randomly-selected geographical clusters (ZIP Codes), each containing 30 treatment and 30 control customers. A total of 512 home inventories were completed for the analyses presented here. Statistical comparisons of prior energy use and demographic characteristics between treatment and control conditions demonstrate that they were virtually identical. For example, there was no statistical difference between the groups in the average number of sockets and TVs in the households or the number of residents or children living in the homes. It is reasonable to conclude that the households responding to surveys from the treatment and control groups were similar enough to conclude that any difference in the number of observed CFLs and TVs was a result of the HER treatment.

Results

As expected, exposure to HERs resulted in significant, but relatively modest, reductions in energy use in the households in the experiments. The monthly savings estimated are in the range of 1-1.5% for electricity (depending on wave) and 0.5-1.0% for natural gas. Figure 1 displays the estimated reduction in electricity consumption by month and study wave for all discrete samples under study. The figure expresses electricity savings as a percentage of monthly electric usage by wave over time elapsed since the initial treatment and the evaluation by wave. As the figure makes clear, energy savings, on average, increase over time the experiment is in field. Based on HER experiments conducted in other jurisdictions, we can expect the savings rates to grow over time. This figure further illustrates the important fact that actual savings from exposure to the HERs varies significantly with the waves under study; possible explanations for these differences include:

- Since the Beta wave is comprised exclusively of customers in the highest usage quartile in relatively hot climates, it follows that average household electricity savings estimates are almost twice the magnitude of electricity savings from customers in other waves.
- The Gamma wave is comprised of a representative sample of customers in most of the utility's service territory, so it contains a large proportion of customers with relatively low usage. Given its composition, it is not surprising that the average monthly savings per customer are about half of those found for the Beta wave. The difference in savings has obvious and powerful implications for the cost effectiveness of the program, as the cost of the program increases in a roughly linear fashion with the size of the target population.

- The savings from the electric-only Gamma sample are remarkable in two ways. First, the savings are significantly larger than those observed for the dual-fuel customers. Second, the savings for the electric-only sample appear to be greater in winter than they are in summer. Some of this effect may be due to electric space heating.
- The Wave 1 population is similar to Gamma in that it is stratified by usage and contains the top three usage strata. As in the case of the Gamma sample, that the average usage per household per month is significantly lower than for the Beta wave is not surprising.

Table 2 displays the estimated aggregate electricity and gas savings for each of the study waves. The total estimated savings over all waves is estimated to be approximately 57 GWh (+/- 8 GWh with a 90% degree of confidence). In aggregate, these savings represent well over half of PG&E's residential savings claims for the 2010-2012 program cycle. These aggregate savings estimates raise two important questions:

- How much of the energy savings from HERs correspond with savings produced by the uptake of utility sponsored EE measures (already claimed) in the HER population for which savings have already been claimed?
- What actions—related to both behavioral and equipment—are driving the observed savings in HER treatment households?

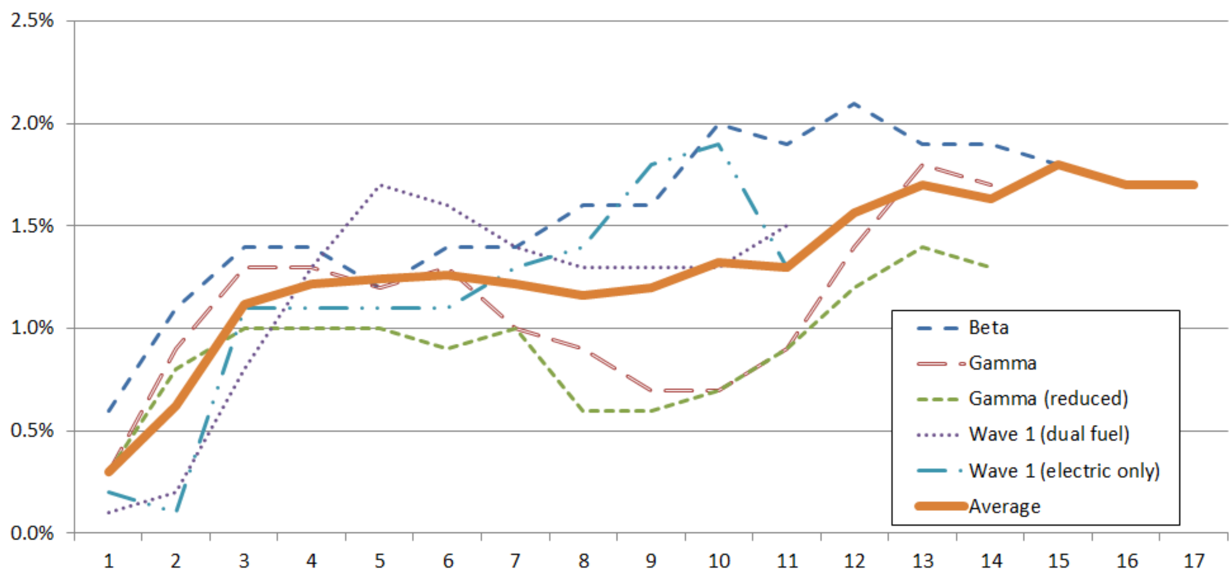

Figure 1. Average monthly percentage of electricity savings observed by treatment groups shown by months receiving treatment

Aggregate Savings	Beta	Gamma				Wave One		Total	Reduction for Upstream Programs	Reduct-ion for Down-stream Programs	Adj. Total
		Dual		Electric Only	Gas Only	Dual	Electric Only				
		Standard	Reduced								
Electric (in GWh)	12.7	5.8	4.8	4.4	NA	25.9	3.1	56.7	-6.6	-0.2	49.9
Standard Error	(0.9)	(0.6)	(0.6)	(0.5)	NA	(1.6)	(0.7)	(4.9)	–	–	(4.9)
Gas (in ,000 Therms)	538	224	232	–	13	461	-	1,469	–	–	1,469
Standard Error	(68)	(42)	(42)	–	NA*	(125)	-	(278)	–	–	(278)

Table 2. A summary of the savings claim for HER with adjustments to avoid double-counting of savings with other energy efficiency programs

Differences in Downstream Measure Adoption

PG&E has a variety of EE measures through which customers receive a rebate directly from PG&E for making an energy-saving purchase (such as installing a variable speed pool pump or purchasing a highly efficient refrigerator). The details of those programs are not discussed here, but the possibility that some part of the estimated HER savings could be attributable to increased uptake of measures rebated and claimed elsewhere by PG&E is analyzed below. As explained above, it is possible to directly observe the number of downstream EE measures that are adopted by customers and counted toward PG&E's EE savings goals in the treatment and control groups because PG&E pays downstream rebates directly to residential customers and keeps thorough records of these transactions.

Table 3 displays a comparison of the number of downstream EE measures adopted by customers and rebated by PG&E in the treatment and control conditions of the Beta wave over 19 months prior to the beginning of the experiment and after the first 17 months of HER treatment. Given the modest differences in the uptake of downstream rebates between treatment and control households prior to treatment, we conclude that the treatment and control groups are essentially equal. Given the modest differences in the uptake of downstream rebates between the two groups of households after 17 months of HER treatment, we conclude that energy savings attributable to an increase in the uptake of downstream measures in the HER population is exceedingly small and does not merit a reduction in the HER savings claim to avoid double-counting.[8]

The frequency counts of downstream rebates paid presented above were chosen as an example of the impact of HERs to drive energy savings observed in the treatment groups because the Beta wave has been in field the longest, but the calculations shown above were also made for all other waves. In total, the savings from all the HER waves attributable to increased adoption of downstream measures was less than one percent of the savings observed in the treatment groups vs. the controls. While savings from the adoption of downstream measures is only a small fraction of savings from HERs, it appears that removals of second refrigerators and second freezers, and installations of variable speed pool pumps, were significantly increased as a result of exposure to the HERs. Even though the differences between treatment and control households in the uptake of these measures are significant, the overall uptake of these measures is relatively

[8] Uptake by households in the HER treatment conditions may increase over time as they are exposed to more reports.

small compared to the size of the treatment population, so their contribution to the overall kWh saved by the HER program are modest.

Rebated Activity	Rebates Paid Prior to Treatment			Rebates Paid Post-Treatment		
	Control	Treatment	Difference	Control	Treatment	Difference
A/C Improvements	16	20	4	13	10	-3
AFUE Gas Furnace	229	205	-24	171	197	26
Cool Roof	0	2	2	3	1	-2
Efficient Clothes Washer	2,550	2,659	109	2,924	2,816	-108
Efficient Dishwasher	774	754	-20	766	836	70
Efficient Fridge	0	0	0	47	53	6
Efficient Water Heater	27	29	2	34	42	8
Improve Insulation	93	96	3	100	122	22
Low Flow Shower Head	1	0	-1	0	0	0
Remove Second Freezer	27	27	0	59	87	28
Remove Second Fridge	627	537	-90	882	1,196	314
Replace Second Freezer	54	53	-1	102	111	9
Test Ducts/Seals	5	0	-5	0	0	0
Variable Speed Pool Pump	181	181	0	367	419	52
Whole House Retrofit	57	86	29	258	263	5
Total	**4,641**	**4,649**	**8**	**5,726**	**6,153**	**427**

Table 3. Summary of downstream measures for which participant households in the Beta wave treatment and control households received rebates

Changes in Upstream Measure Adoption

Adoption of the key upstream measures of interest in this study (i.e., CFLs and energy efficient TVs) was accomplished by counting the numbers of CFLs installed in sockets and in storage, and counting of recently-purchased TVs. In-home inventories were carried out in person by trained observers in the selected households and the response rate to the survey was approximately 60% in both the treatment and control groups. Once the respondent had answered basic questions about their appliance stock and recent purchases, the interviewer did a walk-through of all of the rooms in the home and the outside areas and counted the numbers of different kinds of lamps installed in sockets. The model numbers for any recently-purchased television sets were also noted during the walk through.

Table 4 displays the distribution of CFLs installed and in storage in the treatment and control households. It is evident in the table that there are more CFLs—both installed and in storage—in the treatment group than there are in the control group. Although the observed difference is not large and the measurement is statistically imprecise given the modest number of homes inventories (in fact, zero is within the confidence interval in these estimates), it is reasonable to adjust the savings from the HER program under the assumption that the point estimates (averages) for the installed and in storage units are the best available data. To avoid a situation that a third-party evaluator would conclude that PG&E is over-estimating savings for HER by double-counting savings resulting from CFLs that may have already been claimed by the ULP, it was decided to reduce the estimate of energy savings by using the estimate that one additional CFL was installed in treatment compared to control households.

CFLS Counted during Home Inventory	Control	Treatment	Difference in CFL Count	Standard Error of the Difference	95% Confidence Interval	
					Lower Bound	Upper Bound
CFLs Not in Storage	12.99	13.94	0.95	0.98	-0.96	2.87
CFLS in Storage	2.95	3.55	0.60	0.43	-0.25	1.44

Table 4. Average household CFL counts found in home inventory, weighted by average annual energy use so as to be representative of the households participating in the three HER experimental groups

The estimated savings from the HER program attributable to an increased use of CFLs in treatment households is calculated using a procedure that incorporates information from the above-described survey results and estimated energy savings associated with CFL installations found in two evaluation documents pertaining to the 2006-2008 evaluation cycle in California.[9]

The home inventory described above has produced an estimated difference in the number of installed CFLs between HER treatment and control customers. As Figure 2 illustrates, only CFLs that are installed jointly due to HERs and the ULP cause double-counted savings. This difference between treatment and control customers is assumed to lead to energy savings and is at least partially attributable to HERs.[10] Some of the electric savings is also solely attributable to the ULP and will be claimed as such. It is assumed that methods used to calculate energy savings from CFLs are valid; and that they yield an accurate estimate of the ULP claimed savings. The implication is that only a modest proportion of the savings resulting from an increased uptake of CFLs in treatment households would have been claimed the PG&E's ULP. While evaluators may differ in the precise calculations used to estimate the energy savings observed in the treatment groups attributable to the increased uptake of CFLs, the procedure outlined below was used because it is very conservative: it is highly unlikely to result in underestimates of electricity savings that were claimed by other PG&E EE measures.

A three-step procedure is used to calculate the quantity of savings in the HER program that should be deducted as double counted; the process is illustrated in the equation below:

1. Estimate the aggregate expected number of installed CFLs in treatment homes as compared to the expected number in absence of HERs (referred to as excess CFLs) and the expected duration that those excess CFLs had been installed in years. This is the number of CFL-years at least partially attributable to HERs.
2. Estimate the fraction of the excess CFLs that are partially attributable to the ULP.
3. Estimate the expected total energy savings per year from the typical installed excess CFL, as compared to the baseline of an installed incandescent lamp.

$$
\begin{aligned}
&kWh\ attributable\ to\ both\ programs \\
&\qquad = (CFLs\ installed\ due\ to\ HERs) \times (years\ CFLs\ have\ been\ installed) \\
&\qquad \times \left(\frac{rebated\ CFLs}{total\ CFLs}\right) \times \left(\frac{CFLs\ attributable\ to\ ULP}{rebated\ CFLs}\right) \times (CFL\ savings\ per\ year)
\end{aligned}
$$

[9] KEMA and Cadmus. 2010. *Final Evaluation Report: Upstream Lighting Program* and *Compact Fluorescent Lamps Market Effects Final Report*.

[10] In the ULP evaluation, installations that occur in a given year are assumed to provide savings for the entire year, which is a standard assumption in EE calculations. We do not consider that a rationale for using the same assumption here because the HER program is not claiming savings for any time prior to the onset of each wave. Therefore, the savings being claimed by the ULP for the time period prior to actual installation are not potentially double-counted. They are not counted here; they are an inaccuracy in the ULP method due to a simplifying assumption, which should not lead to a deduction from the HER savings claim.

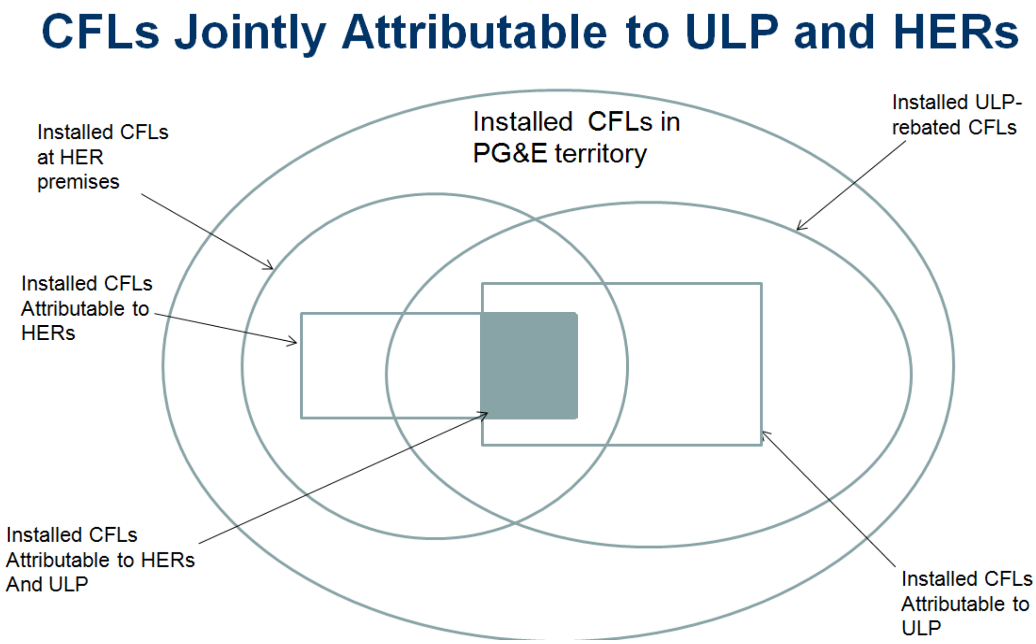

Figure 2. Venn diagram illustrating the subset of CFLs potentially double-counted by the HERs savings analysis.

Items 2 and 3 above are taken from the two ULP evaluation documents, in order to make the calculations consistent with those used to support the ULP savings claim. The first value is determined partially through the above-described home inventory, and partially through assumptions about CFL installation timing. The energy savings from the excess CFLs observed in the treatment group is a function of the number of excess CFLs and the length of time they were installed during the study period. We don't know from the survey when the additional CFLs were installed, but it is reasonable to assume that they were installed over the course of exposure to the HERs–approximately in proportion to the amount of time the households were exposed to the HERs. This means that in the Beta wave, the average excess CFL had been installed for a total of 9.5 months; for Gamma, the average excess CFL has been installed for 7.5 months; and for Wave 1 the average excess CFL has been installed for 4.5 months. These values must be multiplied by the average number of electric-service treatment group customers in each wave over this period, which is 55,000 for Beta, 172,000 for Gamma and 377,000 for Wave 1. This yields a total of 4.26 million customer-months of excess CFL installation or 355,250 customer-years. As reported above, 0.95 excess installed CFLs were found per HER recipient. So, the estimated number of excess CFL years for the first step above is 337,488 CFL-years at least partially attributable to HERs.

The fraction of excess CFLs that are partially attributed to the ULP was determined based on two values in the ULP evaluation reports–the fraction of CFLs that received rebates through the ULP (.74); and the fraction of rebated CFLs that are attributable to the ULP. This is the net-to-gross ratio (NTGR). The Final Evaluation Report of the ULP estimates and uses an NTGR of 0.49 for PG&E. Combining these two values indicates that the fraction of excess CFL years associated with the ULP is .33.

Finally, the third bulleted value is calculated based on values reported in the Final Evaluation Report of the ULP. That report uses values from California's Database for Energy Efficiency Resources (DEER): the typical ULP CFL in PG&E's territory is in use for 1.9 hours per day and uses 44.3 fewer Watts than the incandescent lamp that is assumed to have been installed otherwise. Therefore, the third value is 1.9 (hours per day) * 365 (days per year) * 44.3/1000 (savings per lamp) = 30.7 kWh per year per excess CFL observed. Multiplying these values together gives us 337,488 (excess CFLs in treatment vs. control households) * 0.74 (fraction of CFLs receiving rebates) * 0.49 (NTGR for CFLs for PG&E) * 30.7 = 3.8 GWh of potentially double-counted upstream savings. The authors acknowledge that these estimates are highly uncertain, but they are the best estimates possible using the data that were available.

The process for removing savings associated with energy efficient TV sets is in concept similar. However, there were only trivial differences in the uptake of rebated TVs between treatment and control customers and consequently no adjustment was made in for upstream TV savings (see Table 5).

TV Rebate Status	Control	Treatment
No Rebated TV	92%	93%
Rebated TV	8%	7%

Table 5. Potentially rebated televisions observed in the treatment and control households in the home inventories

Taken together, the double-counted savings in the HER savings estimated from upstream, midstream and downstream utility programs is 6.8 GWh or approximately 12% of annual energy savings. This estimate of potential double-counting is imprecise, but it was the best estimate possible given the data available to conduct the analyses.

Conclusions

This carefully-constructed research only deepens the mystery about how the bulk of the savings effects of the HERs materialize. Identifying the specific drivers of energy savings remains elusive. That said, this research has revealed the following savings drivers resulting from HERs:

- The lion's share of the savings attributable to the HERs stimulus results from a myriad of modest behavioral changes that were not detectable through self-report surveys conducted as part of the in-home inventories. Survey responses from adults living in treatment and control households offer little indication of the specific behavioral actions undertaken by households in the treatment groups that drive energy savings. The lack of any significant differences in reported energy-related behavior between treatment and control householders is likely due to these factors:
    - Single individuals responding to the surveys are not able to reliably report on the energy-savings behaviors undertaken by other members of their households.
    - The types of energy-savings behaviors resulting from exposure to home energy reports varies considerably by household and cannot be measured reliably via self-report due to the limited statistical power of the 512 completed in-home inventories.
    - Social desirability biases may drive householders in the control conditions to over-report energy savings actions undertaken in their households.
- A small proportion of the savings observed in the treatment groups is attributable to a modest uptick in the number of CFLs installed compared to control households.
- Relatively little of the energy savings observed in treatment households is attributable to increased uptake of PG&E's downstream rebate programs.
- The single predictor of whether a household will save energy as a result of exposure to a HERs experiment is prior use of energy. Households using the most energy prior to report exposure tended to reduce their energy more than other households, both on a percentage basis and on an absolute basis.

Given that these three large-scale experiments are ongoing, and that the savings analyses presented in this paper were conducted after the longest-running of the experiments was in the field for 17 months and the shortest wave for less than one year, it is too soon to estimate the full potential of energy savings resulting from HERs in the PG&E service territory. The greater savings observed in households using more energy prior to the experiments highlights the need for careful targeting of HER experiments to cost effectiveness of future HER experiments; households in the lowest quartile of energy use may simply not have many energy-use behaviors remaining to drive energy savings. Since the HERs do not seem to change important energy use-related behaviors reported by respondents (such as selection of thermostat settings, lighting use and the use of other energy using appliances), there may be considerable potential for improvement in the effectiveness of the HERs by more directly targeting these behaviors for change.

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