

# Household Appliance Replacement Program - Impact and Tradeoffs

***Peter Benenson, Cambridge Systematic, Inc.***

***Glen Weisbrod, HBRS, Inc.***

***Andre w Hub, Cambridge Systematics, Inc.***

***William Gavelis, Pacific Gas and Electric Company***

Low income households represent a group of special interest for broad public policy, as well as for evaluation of energy savings potential and DSM program impacts. For such households, new appliances can represent an opportunity for improvements in quality of life and social welfare, as well as an opportunity for saving money and increasing energy efficiency. Some of these effects have been measured through the evaluation of a large utility's low income appliance exchange program.

Through this program, qualified low income customers are offered new, high efficiency gas and electric appliances, at no cost, to replace older, less efficient equipment. These include refrigerators, gas furnaces, gas and electric water heaters, evaporative coolers, microwave ovens and compact fluorescent lamps. The impact evaluation for this project utilized on-site field-work as well as telephone surveys to document the use of the new appliances and what they had replaced.

The evaluation raised a variety of key issues confronting low income programs: Many of the participants had prior appliances which were no longer working. Many of the participants indicated that they had been living for a long time without the conveniences of heat, hot water and/or a refrigerator. This paper provides results of this evaluation to illustrate the magnitude of these issues, and to provide a basis for future public policy debate.

---

## Introduction

The Targeted Customer Appliance Program (TCAP) is designed to assist qualified low-income customers to conserve their residential energy use. The program is offered to Pacific Gas and Electric (PG&E) customers. Through the program, older less energy-efficient appliances are replaced with more efficient ones at no cost to the participants. The appliances provided through the program are refrigerators, evaporative coolers, gas furnaces, gas and electric water heaters, microwave ovens, and compact fluorescent lamps. The evaporative coolers are offered to owners of room air conditioners for use instead of the air conditioners during dry, hot weather. The other appliances are offered as direct replacements.

In addition, TCAP assists low-income households having a genuine need for an energy efficient appliance even though their existing appliance is not using energy. This is consistent with the objectives of state legislation mandating

utility low income programs. Not only does the customer benefit, but PG&E's actions also prevent subsequent installation of non-energy efficient equipment. These actions also help address PG&E's customer service and community relation goals.

## Market Segments and Evaluation Issues

In evaluating gross and net impacts of this low income program, it is useful to distinguish two very different groups of participants. The first group is the program's primary target market, low-income households with existing but inefficient working appliances. (Households with broken appliances that would have been repaired or replaced with used appliances are also placed in this group.) For these households, TCAP offers new, high efficiency replacement appliances intended to reduce energy consumption and lower energy bills. The extent to

which their overall household energy consumption actually drops, or is countered by the “take back” (or snapback) effect of increasing appliance use, can be measured via billing data analysis.

The other group of participants is the “non-replacement market,” low-income households for whom TCAP has provided working appliances where there was no existing working appliance. These include mostly cases where the household lacked heat and/or hot water, either because the existing appliance had been broken for some time or because there was no existing appliance. For these low-income households, the program has effectively provided new high efficiency appliances to enhance quality of life, while minimizing their purchase and operating costs. These results have positive social value, and they do provide energy savings compared to alternative appliances available. When viewed in terms of the traditional measurement of pre/post changes in energy consumption, however, these households are seen to have an increase rather than a decrease in energy use.

There can be a variety of viewpoints on how to evaluate and interpret these households that did not have a previously working appliance. If the household had an appliance that was broken and had planned to eventually repair or replace it with a used appliance, then the program did in fact save energy over “what would have occurred without it.” A traditional measurement of the pre/post energy bills, however, would still show an increase in energy use (i.e., negative savings) associated with installation of the program appliance. If the household had a previous appliance that was broken and had no Plans to repair it in the near future, then it could be argued that the broken appliance was still a “potential demand” on the PG&E system, since, in theory, it could have been fixed or replaced. By that same logic, it could be argued that replacing the non-working appliance actually requires no more generation or transmission and distribution capacity to be built, as the PG&E system was already able to accommodate the old appliance. In fact, since the TCAP appliance has a lower nameplate energy requirement than the old, previous non-working appliance, it could be argued that the TCAP replacement still represents a “potential energy savings.”

The extent to which any such potential would ever be realized is, in reality, speculative. It is a matter of the likelihood that the household would have fixed the old appliance (or replaced with an inefficient model) had the program not existed. There may also be time lags involved in any such repair. Some customers may have planned to eventually repair or replace their old appliance when they had the money to do so, or when they leased their housing unit to a new tenant, or when they sold the home. Without any such repair though, there would be an

increase (i.e., “negative savings”) in energy consumption with a positive social benefit associated in these situations.

The challenge for program impact evaluation, then, is to appropriately segmentize participants and properly identify impacts for these groups.

## Data Analysis

The general analysis approach for measuring gross energy savings for the TCAP evaluation was to rely on a combination of billing and survey analysis to establish “before-vs-after” changes in energy consumption, reflecting changes in levels of use or thermostat settings associated with installation of new appliances. The specific data collection plan was tailored to the types of end uses, since they differ in terms of measurability from bills or surveys. Billing analysis was used to measure impacts for gas furnaces, gas water heaters, electric refrigerators, and electric evaporative coolers. Survey-based updating of engineering calculations was used for compact fluorescent lamps and electric water heaters.

The analysis of net energy savings was based on a determination of what participants would have been expected to have done if the program had not existed. A series of questions was used to establish whether the household would be likely to have acquired a new appliance on its own without the program, and if so, whether that appliance would have been as energy-efficient as the appliance provided through the program. The survey also accounted for previous non-working appliances, fuel switchers and participants with no previous appliance.

A combination of telephone surveys and on-site visits were completed to ensure adequate coverage of low-income households regardless of telephone ownership. The survey was conducted in the Summer of 1993. Overall one-third of the households surveyed were found ineligible to complete the full survey on free ridership because they did not have a previous working appliance or because the participation decision had been made by the prior residents of that home.

## Survey Findings

Combined results of the telephone and on-site survey results were used to distinguish the net impact on the basis of a segmentation of participants. Their key factors used to segmentize the participants were:

- Condition of prior appliance
  - Was it in working condition?

- Condition of prior appliance
  - Was it in working condition?
- Plans for replacement of prior appliance without the program
  - Would it have been replaced without the program?
  - When would it have been replaced?
- Characteristics of replacement appliance without the program
  - Would it have been new or used?
  - Standard efficiency or high-efficiency?
  - Larger or smaller?

Survey results concerning these factors are as follows:

**Condition of Prior Appliance (Table 1).** Although the program was intended to replace existing working appliances with more efficient equipment, in fact 55 percent of the surveyed furnace installations and 22-24 percent of the surveyed refrigerator and water heater

installations had previous equipment that was not working. Evaporative coolers were intended to supplement existing air conditioners; the survey found that 20 percent of these sites had non-working units.

For those locations with non-working refrigerators or water heaters, most (66-76 percent) reported that appliance failure was a recent occurrence (within the last six months). For air conditioners and furnaces, a majority (75-81 percent) had not been working for over six months.

Households at a majority of the non-working furnace and air conditioner sites reported that they did not intend to replace the appliance within the year. In fact, only 32 percent of the sites with non-working furnaces and 13 percent with non-air conditioners intended to do so. In contrast, households at 55 percent of the sites with non-working refrigerators and 41 percent with non-working water heaters did intend to replace those appliances within the year.

**Table 1. Existence and Planned Replacement of Non-Working Appliances If TCAP Had Not Existed**

	Refrigerator	Gas Furnace	Evaporative Cooler/Air Conditioner	Gas/Elec. Water Heater
<b>A. Condition of old appliance</b>				
Working	74%	44%	79%	76%
Not Working	22%	55%	20%	24%
Not Present	4%	1%	1%	0%
<b>Total</b>	100%	100%	100%	100%
	(N=133)	(N=128)	(N=87)	(N=79)
<b>B. If old appliance was not working, how long has it been not working?</b>				
0-6 months	66%	19%	25%	76%
6-12 months	29%	45%	25%	12%
over 12 months	4%	36%	50%	12%
<b>Total</b>	100%	100%	100%	100%
	(N=24)	(N=56)	(N=16)	(N=17)
<b>C. If old appliance was not working, how long until it would have been replaced?</b>				
Same Time 0-3 month	42%	16%	13%	29%
Later 3-12 months	13%	16%	0%	12%
Later over 1 year	4%	36%	31%	29%
No Information (Never/Don't Know)	41%	32%	56%	30%
<b>Total</b>	100%	100%	100%	100%
	(N=24)	(N=56)	(N=16)	(N=17)

Source: Telephone and onsite surveys

Overall, these figures indicate that some participants would have gone on for a year or more continuing without heat, hot water or air conditioning. This underscores the social welfare value of the program.

**Replacement of Working Appliance (Table 2).** Participants with prior working appliances were asked whether they would have replaced their old appliance if they had not participated in the PG&E program. Overall, 60-63 percent of the refrigerator and water heater recipients and 36-42 percent of the furnace and evaporative cooler participants reported that they would have eventually purchased a replacement appliance. Of those intending to purchase a replacement appliance, a strong majority (64-83 percent) would have done so at a later time.

**Replacement Appliances (Table 3).** Both participants with prior working appliances and those with prior non-working appliances who reported that they would have purchased a replacement appliance were questioned about what kind of appliance would they have been mostly likely to purchase on their own, if the PG&E program had not been available. Interestingly, most of the refrigerator, furnace and water heater recipients claimed that they would have purchased a new unit, and one that was just as (or more) efficient as the TCAP appliance. The latter finding is surprising, since the TCAP appliances were more efficient than the standard efficiency for new appliances on the market. This survey result may in reality reflect the fact that not all of these survey respondents had been shopping to understand the range of available prices and efficiencies available, or their tradeoffs.

In terms of size, most survey respondents would have acquired the same size units. For refrigerators and furnaces, there were nearly equal proportions of respondents reporting that larger and smaller units would have been purchased. For air conditioning and water heating, there were larger proportions reporting that smaller units would have been purchased (than larger units).

**Decision Process.** Another useful means for assessing free ridership in appliance replacement is to obtain information on whether the household had already started thinking about or looking for replacement appliances prior to hearing about the PG&E program. Survey results showed that, for each type of appliance, roughly half of the respondents reported they had been in fact thinking about appliance replacement prior to hearing about the PG&E program. This is generally consistent with the reported intentions for appliance replacement.

### Net Impact Market Segments

Based on the proceeding results, we can define four basic groups, each of which have very different net impacts.

These “net impact groups” are:

1. Full Savings Impact Group
  - a. Target Market: TCAP replaced a prior appliance of same fuel type that was less efficient; and prior appliance was working (or would have been fixed or replaced with another used appliance within three months); AND

**Table 2. Replacement of Existing Working Appliance If TCAP Had Not Existed**

	Refrigerator	Gas Furnace	Evaporative Cooler/Air Conditioner	Gas/Elec. Water Heater
<b>A. Would have replaced existing working appliance</b>				
Yes	60%	42%	36%	63%
No	40%	58%	64%	37%
<b>Total</b>	100%	100%	100%	100%
	(N=88)	(N=51)	(N=61)	(N=59)
<b>B. If would have been replaced, when?</b>				
Same Time/Earlier	17%	35%	36%	31%
Later	83%	65%	64%	69%
<b>Total</b>	100%	100%	100%	100%
	(N=47)	(N=20)	(N=11)	(N=36)

Source: Telephone and onsite surveys

**Table 3. Type of Replacement Appliance If TCAP Was Not Available**

	Refrigerator	Gas Furnace	Evaporative Cooler/Air Conditioner	Gas/Elec. Water Heater
<b>A. Type</b>				
New	52%	71%	17%	80%
Used	48%	29%	83%	20%
<b>Total</b>	100%	100%	100%	100%
	(N=79)	(N=35)	(N=28)	(N=59)
<b>B. Efficiency</b>				
As or More Efficient	76%	81%	63%	62%
Less Efficient	24%	19%	37%	38%
<b>Total</b>	100%	100%	100%	100%
	(N=79)	(N=42)	(N=35)	(N=51)
<b>C. Size</b>				
Same size	55%	68%	61%	68%
Smaller	23%	17%	31%	20%
Larger	23%	15%	18%	12%
<b>Total</b>	100%	100%	100%	100%
	(N=71)	(N=40)	(N=36)	(N=59)

b. Without TCAP, customer would not have purchased a new appliance in next year.

been fixed within three months, or there was no prior appliance in place AND;

2. Partial Savings Impact Group

b. Without TCAP, customer would not have bought a new appliance.

a. Target Market, as above (1a); AND

b. Customer would have bought a new appliance with less efficiency than the TCAP appliance (or with equal efficiency but more than three months later.

A breakdown of the percentage of participants classified into each of these groups is shown, by appliance type, in Table 4.

The net energy savings for each of these groups are calculated as follows:

3. Free Rider Group

a. Either in Target Market (1a, above) or Non-Replacement Market (4a, below); AND

b. Without TCAP, customer would have bought a new appliance anyway, in same time period, with efficiency as high as TCAP appliance.

1. Full Savings Impact Group

Net Savings = Gross Savings, i.e., difference between old appliance efficiency and new TCAP appliance efficiency.

2. Partial Savings Impact Group

Net Savings = Gross Savings x (1 - Free Ridership Ratio), where free ridership ratio is the portion of gross savings which would have occurred without the program. This is determined based on: (1) probability of customer purchasing a new appliance without

4. Non-Replacement Impact Group

a. TCAP replaced prior appliance of different fuel type, or TCAP replaced prior appliance of same fuel type that was broken and would not have

**Table 4.** Percentage of Participants in Each Net Impact Group by Appliance

Group	Refrigerator	Gas Furnace	Evaporative Cooler/ Air Conditioner	Gas/Elect. Water Heater*	Compact Fluorescent
<b>Target Market (Appliance Replacement)</b>					
(1) Full Savings Impact Group	47%	29%	60%	48%	100%
(2) Partial Savings Impact Group	3%	6%	4%	18%	0%
(3) Free Rider Group	26%	11%	9%	20%	0%
<b>Non-Replacement Market</b>					
(3) Free Rider Group	4%	4%	2%	3%	0%
(4) Program Impact Group	20%	50%	25%	11%	0%
<b>Total</b>	100%	100%	100%	100%	100%

TCAP; (2) probability-weighted expected efficiency level of new appliance that would have been purchased without TCAP; and (3) probability-weighted expected timing delay in purchasing a new appliance without TCAP.

### 3. Free Ridership Group

Net Savings = 0

### 4. Non-Replacement Impact Group

Net Savings (compared to pre-program) = negative value, representing level of energy use for TCAP appliance.

Net Savings (compared to engineering estimate) = positive or negative value, depending on assumption about appliance replacement (see text below).

Note that the interpretation of the “net savings” and the net to gross ratio becomes complicated for the non-replacement market segment. For example, let us consider the case of those that had a non-working prior appliance, but reported that they would have repaired or replaced their broken appliance without TCAP. For all of these households, a pre/post analysis of energy bills would show that TCAP caused an increase in energy consumption. The net impact of the program, however, is actually zero or a decrease (savings) in energy use compared to the replacement equipment that would reportedly have been obtained. However, this net impact is still an increase in energy use compared to the pre-program situation, although we can discount that net increase to the extent that some of the

increase in energy use would have occurred anyway (when the non-working appliance was repaired or replaced). Thus, we can conclude that the net impact is either positive or negative, depending on the point of reference adopted for the gross savings calculation.

## Calculation of Net Impact Ratios

The full free ridership rate is the percentage of participants who were full free riders, i.e., who would have acquired a new appliance of similar efficiency at the same time without TCAP. That portion is shown as the full savings impact group in Table 4 (presented previously).

The overall free ridership ratio, on the other hand, is a probabilistic proportion which accounts for degrees of partial free riders. It represents an expected share of energy savings, for each appliance, which would have occurred without TCAP. This latter ratio is constructed on the basis of the following factors:

- **Likelihood** of purchasing a new appliance without TCAP;
- **Efficiency** of new appliance without TCAP; and
- **Timing** of new appliance without TCAP.

By definition, the free ridership rate is 100 percent for the “Free Rider Group,” who would have purchased a new appliance of the same efficiency at the same time without TCAP. The net-to-gross ratio for this group is thus zero percent.

Using similar logic, the free ridership rate is zero percent for the “Full Savings Impact Group,” who definitely would not have purchased any new appliance during the year, without TCAP. The net-to-gross ratio for this group is 100 percent.

The remaining group is the “Partial Savings Impact Group,” who are partial free riders. These participants reported that they would have purchased an appliance without TCAP, but it would have been less efficient and/or purchased later. For each of these participants, the free ridership rate may be any value from one percent to 99 percent. The net-to-gross ratio for each of these participants is calculated as (1 - Free Ridership Rate).

There is no perfect way to foretell what would have happened in the hypothetical situation where TCAP had not existed. The best that can be done, then, is to utilize a series of questions with consistency checks to assign individual values for the net-to-gross ratio for each individual participant in the group of partial free riders.

For this study, the net-to-gross assignments used the following rough assumptions about non-TCAP replacement appliances, based on survey responses:

- A **new** appliance that is less efficient than the TCAP appliance is of market standard efficiency, a value which varies by appliance type. (It provides from 40 percent of the TCAP appliance savings for gas water heaters to 85 percent of the TCAP savings for furnaces. This value thus depends on the appliance.)

- A **used** appliance that is purchased to replace the existing appliance will provide less (10-30) percent of the savings which the TCAP appliance provides over existing equipment.
- An appliance purchased **later** in the year will provide six months of savings rather than the 12 months of first-year savings assumed for the TCAP appliances.
- An appliance which is **larger** than the TCAP appliance will provide 20 percent less savings, and an appliance which is smaller than the TCAP appliance 20 percent more savings, than would otherwise be expected.

### Findings on Net Savings

The resulting net-to-gross ratios are shown, by appliance type and impact category, in Table 5. For the target market, the composite values of net-to-gross ratios for the “partial impact group” was .60 for water heaters, .69 for refrigerators, .77 for gas furnaces and .87 for evaporative coolers. The other corresponding net-to-gross ratios were, or course, 1.00 for the “full savings impact group” and 0.00 for the “free rider group.”

The net-to-gross ratio for compact fluorescent lamps was assumed to effectively be 100 percent. While this ratio was not constructed through the same battery of survey questions, free ridership was assumed to be non-existent

**Table 5. Percentage of Participants in Each Net Impact Group by Appliance**

Group	Refrigerator	Gas Furnace	Evaporative Cooler/ Air Conditioner	Gas/Elect. Water Heater*	Compact Fluorescent
<b>Target Market (Appliance Replacement)</b>					
(1) Full Savings Impact Group	1.00	1.00	1.00	1.00	1.00
(2) Partial Savings Impact Group	.69	.77	.87	.60	0.00
(3) Free Rider Group	0.00	0.00	0.00	0.00	0.00
<b>Non-Replacement Market</b>					
(3) Free Rider Group	0.00	0.00	0.00	0.00	0.00
(4) Program Impact Group	(A)	(A)	(A)	(A)	(A)
<b>Total</b>	.69	.84	.88	.70%	1.00

(A) Net-to-gross ratio for non-replacement group is + 1.00 (leading to energy consumption increases) insofar as no replacement would have occurred without TCAP, but flips to becoming negative (i.e., leading to energy savings) insofar as replacement with an appliance less efficient than the TCAP appliance would have occurred.

for compact fluorescent lamps in this program. The reason for this assumption was that most of these low-income customers were tenants rather than owner occupants and they had no knowledge that they were going to get a compact fluorescent, so they had no particular reason to be thinking about lighting measures.

For the non-replacement market, the net program impact on energy savings is negative, insofar as the household would not have otherwise repaired or replaced the prior non-working appliance. However, that net energy savings impact is positive for those cases where the household would have repaired the old appliance or replaced it with a new or used unit less efficient than the TCAP appliance.

## **Conclusions**

Low income program are often intended to address several different issues: energy efficiency objectives, concerns about the social equity of energy program benefits and social welfare (quality of life improvement) goals. The very existence of separate programs for low income customers is evidenced that these customers have their own special program needs. Higher rates of rental occu-

pancy and tenant turnover among properties, as well as prevalence of non-working appliances, are aspects which challenge efforts to achieve energy savings among low income customers.

At the same time, there are important social reasons not to ignore the plight of customers who are temporarily or permanently living without heat or hot water, because their current appliance is broken. For some of these households, the provision of new energy efficient appliances may be accelerating or improving appliance replacements which would otherwise eventually occur. For others, the benefits may be in terms of personal well being. For still others with working equipment, there may be immediate energy savings benefits.

Without analyzing the market segments separately, results of a billing analysis may show smaller overall savings than original engineering estimates. By segmenting the market, we can show that there may be larger energy savings for some groups and the appearance of “negative savings” for other groups who are receiving the social welfare benefits of the program. The challenge for program evaluation, then, is to recognize the existence of these different market segments and appropriately account for them in program impact evaluation.