

Customer Acceptance and Use of Compact Fluorescents: Results from a Comprehensive Evaluation of PG&E's Program

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This paper presents the results of an evaluation of PG&E's residential compact fluorescent program and compares the findings with findings from several programs conducted by other utilities. The evaluation estimated the installation rates, hours of operation, and performance of the compact fluorescents sold under the program. It also examined the physical constraints to installing compact fluorescent bulbs in existing fixtures and other barriers to adoption. This was accomplished through a combination of customer surveys, on-site inspections, and direct metering. A telephone survey of program participants asked about the installation rates of compact fluorescents sold under the program, their utilization, retention, and customer satisfaction with their performance. A survey of nonparticipants was administered to estimate free ridership.

A follow-up, on-site inspection of a separate sample of participants verified the installation patterns and took direct measurements of lamp performance (lumens, watts, and power factor) and usage. The inspection included a detailed inventory of the lighting fixtures in each house to determine whether compact fluorescent bulbs would fit with and without some modification to the fixture. The project metered a selected number of compact fluorescent fixtures to estimate their average hours of operation per day.

Introduction

Description of the Program

PG&E has offered compact fluorescent bulbs to its residential customers through several channels since 1990. These include direct sales to customers and employees through a mail-order contractor, direct installations under PG&E's low-income and Energy Savings Plan Programs, and direct rebates to customers and lighting retailers. The mail-order portion of the program, which is the object of the survey summarized in this report, offers two models of compact fluorescent bulbs. The first is an 18-watt bulb with an electronic ballast that is intended to replace a 75-watt incandescent bulb. The second is a 27-watt bulb that is designed to replace a 100-watt incandescent.

Under the mail-order portion of its program, PG&E has offered these models through two offers. The first offer was a coupon that accompanied an article in PG&E newsletter *Progress* (March 1991 issue). The *Progress* newsletter is regularly included with PG&E's bills. The second offer was a direct mail offer that PG&E sent to selected lists of its residential customer during the summer of 1991. The customer lists were drawn from other PG&E programs (for example, residential time-of-use participants and the Energy Savings Plan participants) as well as lists

purchased from private vendors. Both offers sold the bulbs by return mail with UPS delivery. Recipients of the direct mail offer could order the bulbs through a toll-free telephone number.

The Objectives of the Study

The primary objective of the study was to determine the installation, utilization, and satisfaction with the bulbs purchased under the program. This information will be used to validate PG&E's estimates of the energy savings directly attributable to the sales of compact fluorescent bulbs under the program and to address several other impact parameters. The results of the study will also identify customer satisfaction with the technology performance and program delivery; this information will be used to improve the effectiveness of the promotion of compact fluorescent bulbs by PG&E. The information collected under the study includes:

- Installation rates and other disposition of bulbs;
- Changes in fixture wattage;
- Use of the compact fluorescent fixtures;

- Removal rates of compact fluorescent bulbs;
- Technical potential for compact fluorescents in residential applications;
- Customer satisfaction with the compact fluorescent bulbs and with PG&E's program services; and
- Characteristics of program participants and nonparticipants.

Description of the Study

Three surveys and a metering project were administered to achieve the study objectives. The first survey was administered by telephone to the direct mail program participants. The second was also a telephone survey of a random sample of PG&E residential customers to obtain baseline estimates of lighting equipment purchase patterns, customer characteristics, and satisfaction with PG&E. These telephone surveys were conducted during October and November of 1991. The third was an on-site survey and inspection of lighting fixtures to confirm installation rates and to take an inventory of fixtures to determine the number of fixtures that could accommodate compact fluorescents. This was conducted during January and February of 1992. The final study component was a metering project in which lighting loggers were used to determine the actual hours of use of compact fluorescents sold under the program. The meters were installed in conjunction with the on-site survey.

The participant survey asked respondents about the disposition of the compact fluorescents they had purchased under the program. For each installed bulb, respondents were asked what kind of bulb they had replaced, how much they used the new bulb, and their satisfaction with its performance. For bulbs that were removed or never installed, customers were asked their reasons for not installing them and any plans to use the bulbs in the future.

The participant survey was drawn at random from the program files that PG&E's mail-order contractor maintains to track orders and shipments. Separate samples were drawn from the databases for the sales from the *Progress* newsletter and for sales under the direct mail component. For the nonparticipant survey, PG&E provided a random sample of its residential customers from its customer information system.

The on-site survey and inspections were conducted on a separate random sample of program participants in the greater San Francisco Bay Area. The on-site survey

confirmed the installations of compact fluorescent lamps through direct inspection and also took an inventory of all of the lighting fixtures in the dwelling. The inventory determined the suitability of each fixture for compact fluorescent lamps in a range of sizes. The inventory was used to calculate the changes in wattage that could be achieved by replacing incandescents with compact fluorescents in all feasible applications.

The last component of the study was a metering project to measure the hours of operation of compact fluorescents installed under the program. Lighting loggers were installed on a random sample of fixtures with compact fluorescents. These were read periodically to determine the cumulative hours of operation.

Purchase and Installation of Compact Fluorescent Bulbs

The average number of compact fluorescent bulbs sold under PG&E's Direct Sales Program in 1991 to participant survey respondents was 3.9. Of these, 56% (an average of 2.2 per customer) were the 18-watt model, and 44% (an average of 1.7 per customer) were the 27-watt model. Survey respondents indicated they purchased the 18-watt model at a higher rate based on the light output that it provided.

The disposition of the bulbs that were purchased is summarized in Figure 1. According to the survey, over 56% of the bulbs purchased under the program are currently installed (an average of 2.2 per customer). Virtually all of these (98.5%) are installed in fixtures within PG&E's service territory. The respondents still have most of the remaining bulbs, and they stated their intentions to install the majority of these in the future (82% of the "never installed" category or an average of 1.2 bulbs per respondent). For the remainder (18% or 0.6 bulbs average), the respondents had either disposed of the bulb in one of several ways or did not indicate their intentions.

The installation patterns vary only moderately between the two models; installation rates by model are shown in Table 1. Slightly higher percentages of 27-watt models are either currently installed or were installed and later removed. The compacts are installed most frequently in permanent ceiling or wall fixtures. The most popular location for both models is the living or family room area.

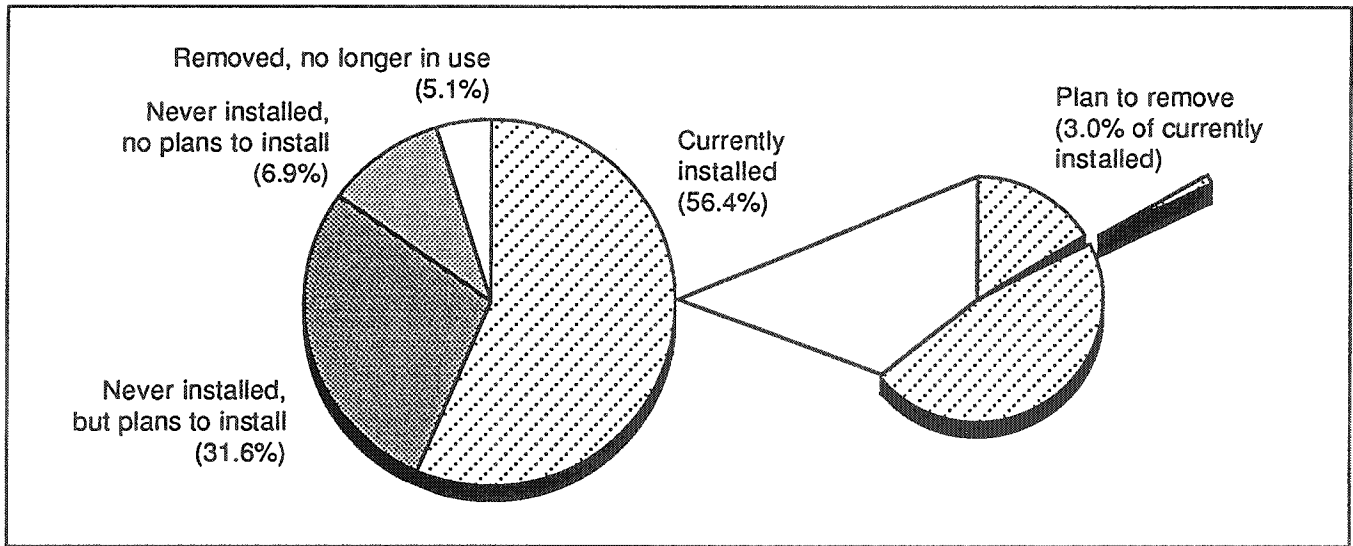


Figure 1. Disposition of Compact Fluorescent Bulbs

Table 1. Installation Rates of Compact Fluorescent Bulbs by Model Type

Action	Compact Fluorescent Model Type		
	18-watt	27-watt	Total
Installed	54.6%	58.6%	56.4%
Removed, no longer in use	4.2%	6.3%	5.1%
Never installed, but plan to install	33.8%	28.8%	31.6%
No plan to install	7.4%	6.3%	6.9%
Total	100%	100%	100%

Table 2. Wattage of Compact Fluorescent Bulbs by Incandescent Bulbs Replaced

Wattage of Replaced Incandescent Bulb	Compact Fluorescent Model Type		
	18-watt	27-watt	Total
40-watt	6.4%	1.0%	3.7%
60-watt	32.8%	18.9%	26.0%
75-watt	24.7%	16.4%	20.7%
100-watt	19.7%	43.4%	31.2%
Other	16.4%	20.3%	12.0%
Total	100%	100%	100%

What Compact Fluorescents Replaced

Table 2 shows the compact fluorescent (CF) wattage installed versus the wattage of the incandescent bulbs they replaced. Among customers who indicated the wattage of the incandescent bulb replaced, the average reduction in wattage by installing a compact fluorescent was 55.6 for the 18-watt CF and 61 for the 27-watt CF. While the 18-watt bulb is designed to replace a 75-watt incandescent bulb, respondents said that it was used to replace a 100-watt bulb almost 20% of the time. By the same token, the 27-watt model was often used to replace much smaller incandescent bulbs than recommended based on its lumen rating.

Compact Fluorescent Bulb Usage

The survey asked respondents about their usage patterns for the compact fluorescents. The average responses for each model by season and day type are summarized in Table 3. Assuming there are six months to the winter and six months to the summer, the overall average daily usage of the compact fluorescent bulbs is 3.8 hours. The average daily usage rate is slightly higher for 27-watt models (3.9 hours per day) and lower for the 18-watt bulbs (3.6 hours per day). The table shows that there is considerable variation in average daily usage by season but little difference between weekdays and weekends.

Table 3. Average Daily Hours of Operation of Compact Fluorescent Bulbs by Model Type

Season/Day	Compact Fluorescent Model Type		
	18-watt	27-watt	Total
Winter/Weekday	3.9	4.2	4.1
Winter/Weekend	4.0	4.3	4.1
Summer/Weekday	3.2	3.6	3.4
Summer/Weekend	3.3	3.7	3.5
Average	3.6	3.9	3.8

Usage by Time of Day

The survey asked respondents to indicate whether each installed bulb is "usually turned on at any time" during different daily time periods. The percentage of positive responses by time period for winter and summer are shown in Figures 2 and 3. Based on the responses, the compact fluorescent bulbs are used frequently during day time hours, including the summer peak period.

Rebound Effect

Almost 10% of the respondents said that they used the compact bulb more than the incandescent previously installed in the same fixture; 1.4% said they used it less. The average change in daily usage for all respondents who indicated either increased or decreased levels is +1.7 hours per day. This represents a 4.7% rebound for all installed bulbs. The most often cited reason for the increased use was the cost of operating the bulb (53%). The light output was mentioned by almost a quarter of the respondents who had changed their usage.

Persistence

Table 4 summarizes the removal rates of bulbs by wattage. The respondents indicated that 5.1% of the purchased bulbs have already been removed. They also indicated their intentions to remove another 5.4% of the installed bulbs in the near future, representing another 3% of all bulbs that were sold under the program. In almost 60% of the cases where respondents said they planned to remove the currently installed bulb, the stated reason was the brightness of the bulbs. The survey did not ask whether they planned to use the bulb in another fixture or dispose of it.

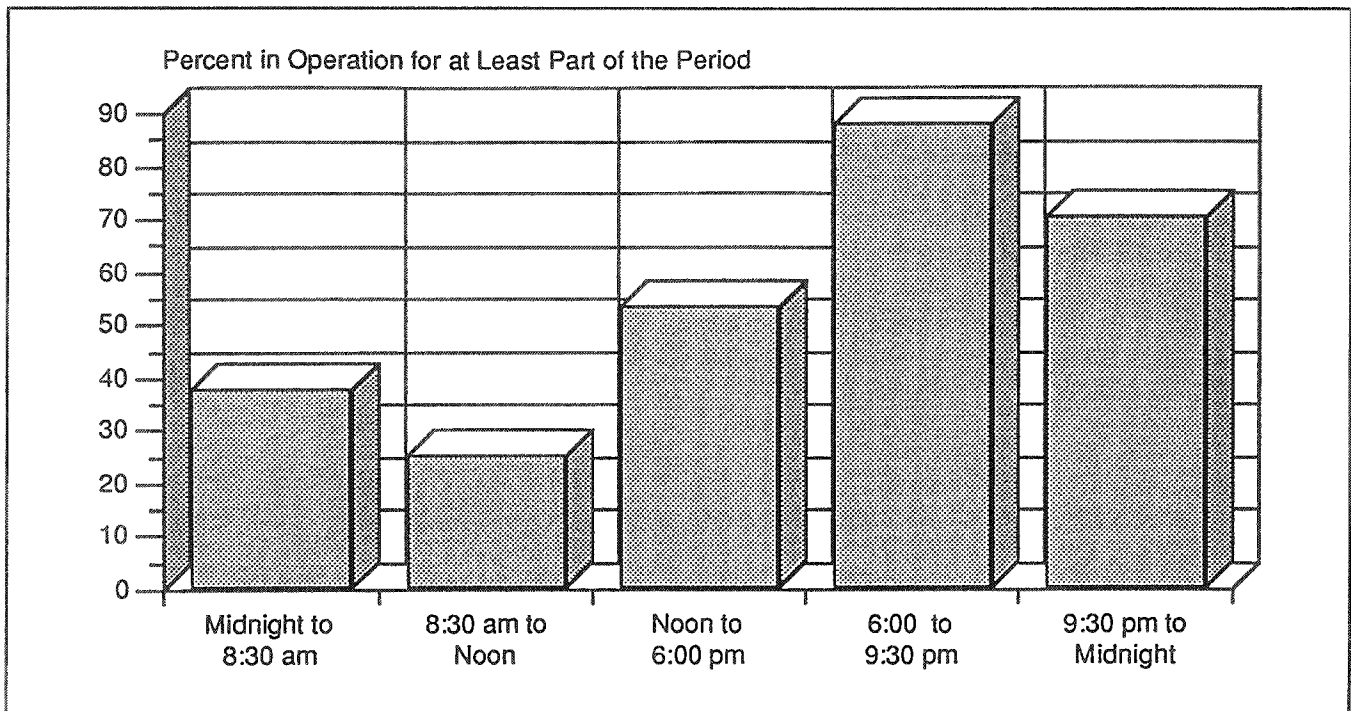


Figure 2. Time-of-Day Usage of Compact Fluorescent Bulbs - Winter Season

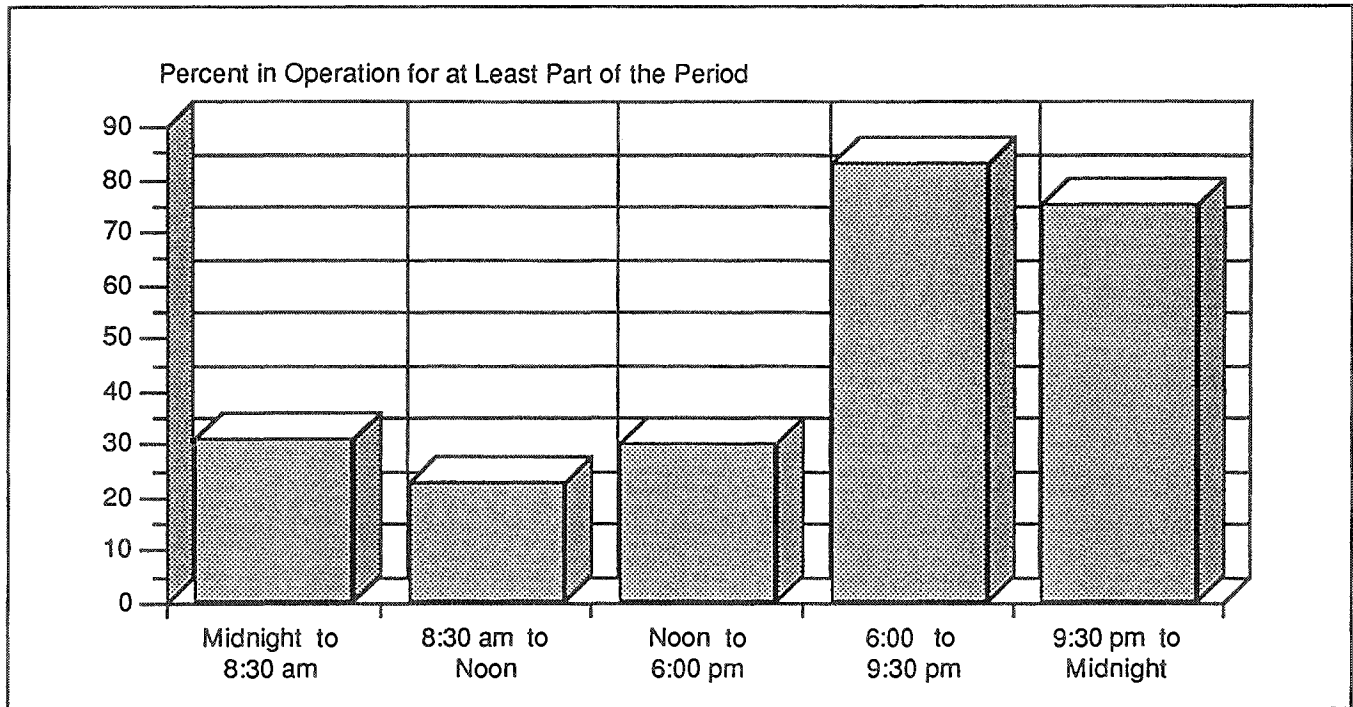


Figure 3. Time-of-Day Usage of Compact Fluorescent Bulbs - Summer Season

Table 4. Removal Rate of Compact Fluorescent Bulbs by Model Type

Intention	Compact Fluorescent Model Type		
	18-watt	27-watt	Total
Have removed	4.2%	6.3%	5.1%
Plan to remove	2.8%	3.3%	3.0%
Never plan to install	6.9%	5.7%	6.9%
Total	13.9%	15.3%	15%

Respondents said that they had installed, removed, and were no longer using 5.1% (0.2 average per respondent) of the bulbs that had been purchased under the program. The majority of the bulbs that were removed (57%) are 27-watt models. As a percentage of the number purchased by wattage, the removal rate for 27-watt models was higher than that for 18-watt bulbs (6.3% versus 4.2%).

The reasons given by respondents for removing the different CF models are summarized in Figure 4. The most commonly given reason for removing the 27-watt bulbs was that it was not bright enough (47%). For the 18-watt model the most frequently cited single reason was

that it "didn't fit properly/awkward to operate" (32%). Almost 10% (for both bulb wattages) said that the bulb had failed. Most of the bulbs that had been removed (83.5%) were still in the possession of the respondents. The survey did not ask what respondents planned to do with these.

According to the respondents, almost 40% (an average of 1.5 per household) of the bulbs had not been installed to date. Respondents gave a wide range of reasons for this. These are summarized in Figure 5. The most commonly stated reason was that the bulbs did not fit. The survey allowed for various reasons for not fitting--"too tall," "too wide," etc. In the aggregate these reasons were given for almost 50% of the cases. Next in significance were various behavioral responses: 15% said that they "hadn't gotten around to it or forgot"; 14.7% said that they would use the CF's as "a replacement."

The disposition of the "never installed" bulbs is shown in Figure 6. The respondents still own most of them and plan to install almost 76% of them in the future. 12% of the bulbs are still in respondents' possession, but there were no stated plans to install them. The remainder of the bulbs have either been returned for a refund or have been given away.

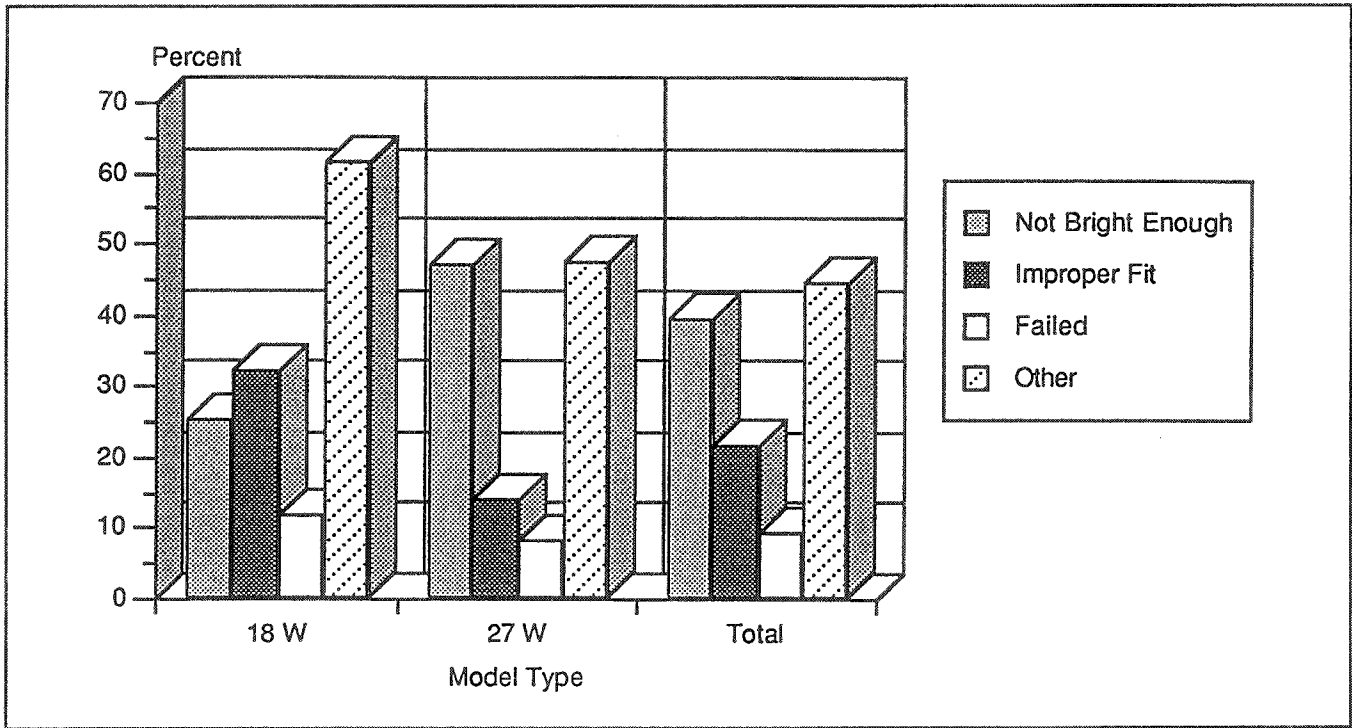


Figure 4. Reasons for Removing Compact Fluorescent Bulbs by Model Type

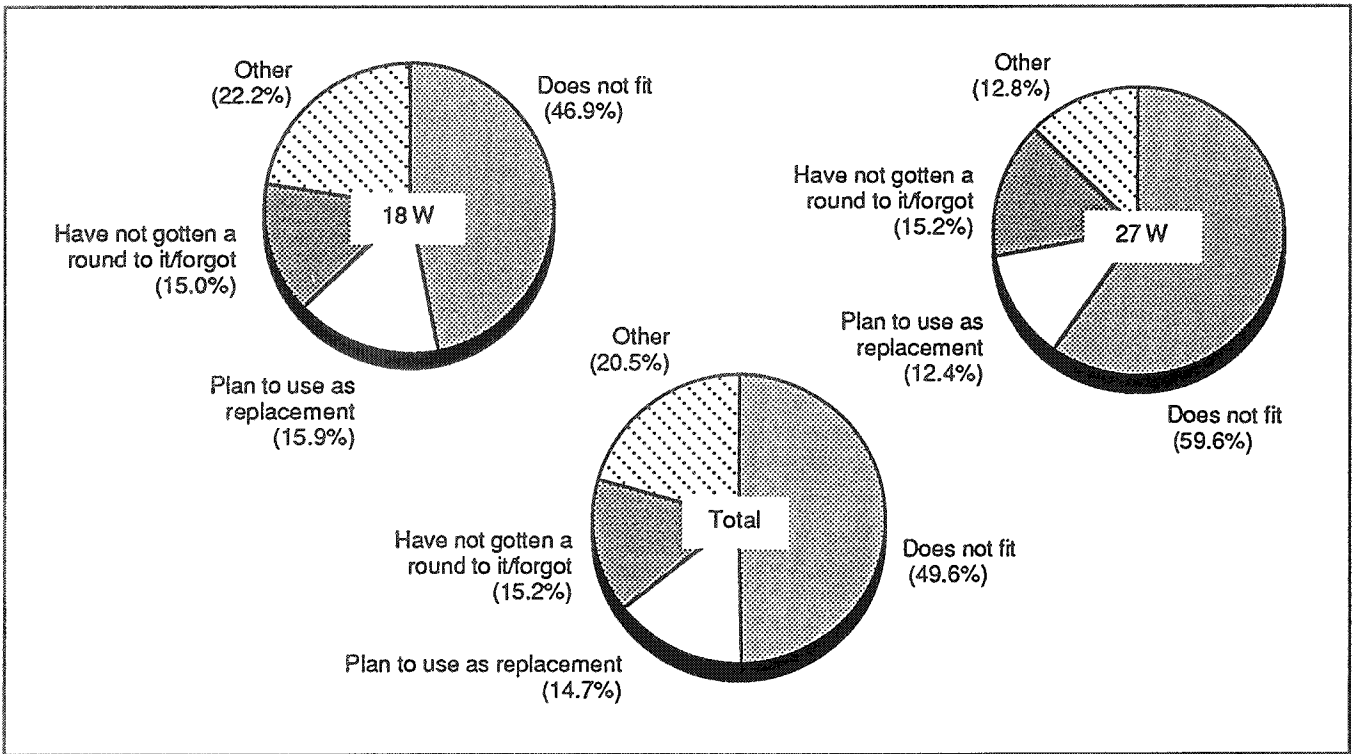


Figure 5. Reasons for Never Installing Compact Fluorescent Bulbs by Model Type

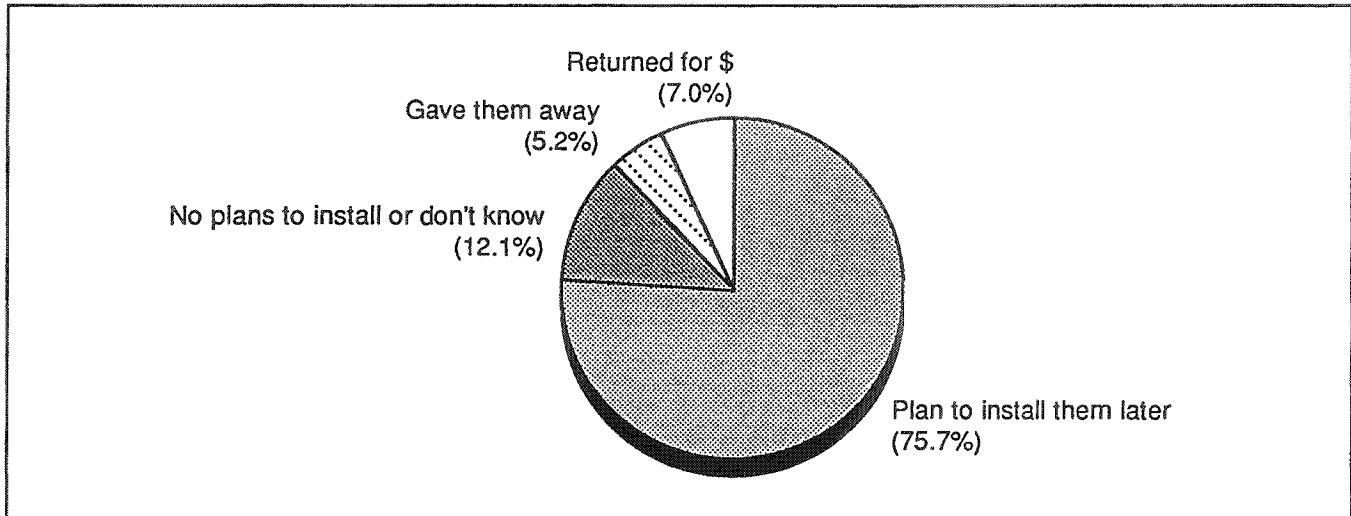


Figure 6. Disposition of "Never Installed" Bulbs

Net-to-Gross Effects

Through various strategies, the survey attempted to identify the net effect of the program on the decisions to buy compact fluorescent bulbs. The issue is complex and difficult to resolve for several reasons. One survey strategy would be to compare the purchases of participants to a control group of customers who were ineligible for the program. However, no true control group is available against which to compare the purchase patterns of participants, because the mail order offer was made to all of PG&E's residential customers. Using nonparticipants as a proxy for a true control group is probably biased because there is significant self-selection into the program and, as a result, nonparticipant behavior is not representative of what participants would have done in the absence of the program. Nonparticipants may also be influenced by other PG&E promotions (such as the dealer rebates) that have affected their purchases without their knowledge.

A second survey strategy would be to ask participants directly what they would have done without the program. This method assumes, implicitly, that compact fluorescent bulbs would have been available at comparable prices outside the program, which is very unlikely. Without utility subsidies, compact fluorescent bulbs typically sell through retail outlets for over twice the price of PG&E's offer. Finally, the PG&E program probably has a strong, albeit subtle, influence on increasing customer awareness and availability of compact fluorescent bulbs. These effects cannot be easily identified through customer survey methods.

Recognizing the limitations inherent in the alternative approaches to estimating net-to-gross impacts, the study approached the issue in several different ways in an attempt to "bound" its magnitude.

The random survey asked nonparticipant respondents about their recent purchases of compact fluorescent bulbs. Respondents who had not participated in PG&E's lighting program said that they had bought 0.5 bulbs on average, compared with the 3.9 bulbs bought by participants through the program. If these purchasers are considered free riders, then free-ridership is 13% (i.e., 0.5/3.9), giving a net-to-gross impact of 87%. Because of self-selection, this could be considered a liberal (i.e., high) estimate.

A more conservative estimate of net-to-gross was made by asking participants whether they would have bought compact fluorescent bulbs without the program. 72.7% said they would not have purchased the fluorescents without the program. The remaining 27.3% said that they probably would have purchased them at the same time without PG&E's offer. These respondents said that the average number that they would have bought was 3.1 bulbs. This compares to the 3.9 average that these respondents actually bought under the program. Thus, for these customers, the program had a net impact of 0.7 bulbs. If all 27.3% were considered free riders and only the net increase in their purchases were attributed to the program, then the net program impact would be an average of 3.0 per participant (i.e., .273*0.7 + .727*3.9) versus the 3.9 gross average sales. A conservative estimate, then, of free-ridership would be 23%, giving a net-to-gross impact of only 77% (i.e., 3.0/3.9).

It should be noted that one impact of PG&E's program will be to "move the market" by increasing the general availability of compact fluorescents and customer awareness about them. Neither of the above net-to-gross estimates takes this impact into account.

In addition to the respondents who said they would have purchased bulbs at the same time without the PG&E offer, another 22% said that they would have bought some bulbs within a year after the offer. The survey did not ask these respondents how many they would have bought.

The survey also attempted to assess the stimulative effect of the program on purchases outside of the program. A quarter of all participant respondents said that they had purchased compact bulbs from someone other than PG&E in addition to the bulbs they bought through the program. In fact, 6.7% of *all* program participants said that PG&E's program probably had some impact on their decision to buy bulbs outside the program. Among those customers who said that the PG&E program had influenced their purchases, the average number of compact bulbs bought outside the program was 4.3. This gives some indication of the effect of PG&E's program in stimulating other purchases.

Satisfaction with Compact Fluorescents

The survey asked several questions about the program participants' satisfaction with the compact fluorescent bulbs and with program services. Participants generally seemed highly satisfied with the quality of the program services such as the information about the bulbs, the order forms, and instructions for installation. Only the types of bulbs offered through the program scored low relative to the other program features.

Satisfaction levels were generally lower with respect to the characteristics of the bulbs themselves. The degree of satisfaction with various characteristics was expressed on a scale of 0 to 10; average scores are presented in Table 5. A large percent of the customers (22.1%) were dissatisfied with the way the bulbs fit in the fixtures. The average satisfaction score for this feature was the lowest of all those mentioned. Customers also gave the appearance of the bulb and the amount of light they provided relatively low scores.

Comparison of Participants and Nonparticipants

The program participants and a separate random sample taken of nonparticipants from PG&E's general residential customer population were asked about their demographic

Table 5. Satisfaction With Selected Bulb Characteristics: Mean Score on a Scale of 0 to 10

Bulb Characteristic	Score
Way bulb fits in fixtures	5.5
Time it takes bulb to light	7.5
Appearance of bulb	6.5
Amount of light from bulb	7.0

characteristics to identify any significant differences between the two groups. The results are summarized in Table 6. The results show that the program participants are significantly different from PG&E's average residential household. They tend to be older, more highly educated, and more affluent. A significantly higher percentage of them live in single-family residences and own their houses. The participants indicated a slightly higher overall level of satisfaction with PG&E.

On-Site Inventory and End-Use Metering of Lighting Fixtures

The on-site survey was designed and administered to gather information in three ways. First, as in the telephone survey, participants were asked about their household characteristics and about each of the compact fluorescent bulbs they purchased and installed in their homes. For each installed bulb, respondents were asked about the bulb they had replaced, how much they use it, and their satisfaction with its performance. Second, the lighting fixtures in each participant household were inspected to determine the wattage in each fixture and whether the fixtures would be suitable for compact fluorescent bulbs. Third, a metering device was installed on selected fixtures where compact fluorescent bulbs had already been installed to log the number of hours the bulbs were in use.

PG&E sold an average of 4.7 compact fluorescent bulbs under its Direct Sales Program in 1991 to the on-site survey respondents. Of these bulbs, 55% (an average of 2.6 per customer) were the 18-watt model, and 45% (an average of 2.1 per customer) were the 27-watt model.

Installation Rates

Physical inspection of respondents' homes showed that, of the bulbs purchased, over 51% (an average of 2.4 per customer) are currently installed. The installation rate for

Table 6. Selected Household Characteristics of Participants and Nonparticipants

Characteristic	Participants	Nonparticipants
Satisfaction with PG&E ^(a)	8.3	7.9
Percent who live in a single-family home	83.5%	70.8%
Average number of rooms in residence	6.4	5.5
Percent who own residence	89.2%	61.5%
Number of people who live in residence full time	2.5	2.7
Percent of households with a member:		
Under 6 years	9.4%	18.5%
Between 25 and 34 years	15.3%	29.5%
65 years or older	40.8%	18.5%
Percent whose head of household:		
Completed some college	85.0%	67.9%
Is a college graduate	63.5%	42.6%
Percent with total annual household income is:		
Greater than \$50,000	40.9%	29.8%
Greater than \$100,000	10.3%	5.6%

(a) Mean score on a scale of 0 to 10.

the 18-watt bulb is 50% (an average of 1.3 per customer), and for the 27-watt bulb it is 52% (an average of 1.2 per customer).

The self-reported installation rate from the same survey is 55% (an average of 2.6 per customer). This figure is not statistically different (at the 95% confidence level) from the value obtained by inspection.

Respondents in the telephone survey reported an average installation rate of 56%. This figure is also not statistically different from the installation rate derived by inspection in the on-site survey. The comparability of each of the above installation rates suggests that self-reported values with regard to installation are fairly reliable.

Metered Results

The on-site survey tracked usage through meters attached to fixtures where compact fluorescent lamps had been installed. These metering devices were attached to one or two fixtures per household and logged the total number of hours the bulbs were turned on during the study period. The metered results were then compared with the self-reported results to verify the survey participants' appraisal of their own usage patterns.

The meters installed in on-site survey homes logged a mean daily usage of 3.1 hours per compact fluorescent bulb over the period January 17 to March 17, 1992. Metered results varied only slightly by wattage.

The self-reported winter season mean over the same sample was 3.1 hours. This is not statistically different (at the 95% confidence level) from the logged mean. It appears, then, that the self-reported hours of operation appear to be reasonably accurate.

Lighting Inventory

The lighting fixtures in each respondent's home were visually inspected to confirm installation, location, and wattage of compact fluorescents, and to determine the wattage and usage of incandescent bulbs. In addition, the inspection ascertained whether the fixtures could accommodate various types of compact fluorescent bulbs, and whether they could do so with or without some modification. Results from the lighting fixture inventory are as follows.

The data from the lighting fixture inventory help establish the potential energy savings that could be realized by replacing incandescent bulbs with compact fluorescent bulbs. Each household in the on-site survey has an

average of 28.8 fixtures, totaling 2,134 watts. Average household lighting energy usage is 3.6 kWh per day.

On average, 43.9% of each household's lighting fixtures could accommodate compact fluorescents without any modification. If the incandescent bulbs in these fixtures were replaced, mean energy savings would total 0.9 kWh per day. In addition, compact fluorescents could fit in 8.3% of the fixtures with some modification. If each of these fixtures were converted, there would be further energy savings of 0.2 kWh per day. The maximum total energy savings per day that could be realized from replacing incandescent bulbs with compact fluorescent bulbs, then, is 1.1 kWh per day.

Implications for the Program

The results of the survey suggest some issues that PG&E should address in its promotion of compact fluorescent bulbs. These include the suitability of compact fluorescent bulbs in many fixtures, methods for adapting fixtures to accommodate compact fluorescent bulbs, the brightness of the fluorescents, and methods for targeting the program to attract a broader range of PG&E customers.

The primary obstacles to achieving higher installation rates of the compact fluorescents sold under the program appear to be their fit in existing fixtures and their brightness. The inability to fit the compact fluorescent tubes in many fixtures significantly limits their applications. Other studies have shown that many fixtures can be modified with larger lamp harps, socket extenders, and other low-cost devices to accommodate compact fluorescent bulbs. Barakat and Chamberlin is currently conducting a study to

estimate the potential of compact fluorescent bulbs in PG&E's service territory with such modifications. PG&E should probably investigate methods for informing program participants about these modifications and promoting the devices in conjunction with the sale of the bulbs.

The second major obstacle to installations seems to be the brightness of the bulbs. While the models that PG&E promotes under its program are advertized as replacements for 75- and 100-watt incandescents, it appears that their respective lumen outputs are somewhat lower. PG&E may wish to consider modifying its advertizing to promote these models as replacements for lower watt incandescent bulbs and to offer more models with a wider range of lumen outputs. Promotional literature might also emphasize the improvements in performance from keeping fixtures clean and adding reflectors where appropriate.

The third area concerns the demographic characteristics of participants. The PG&E direct mail program has been extremely successful in achieving high response rates to the offer. At this stage of the program, it is probably appropriate to continue this strategy. The market for compact fluorescent is still developing, and customer awareness about the technology is low. At some point, however, PG&E needs to broaden its promotional strategies to reach a broader customer group than current participants. Some of these strategies, such as direct installations in conjunction with the low-income program, are already in place. Other strategies, such as promotion through service organizations, need to be developed so that they can be implemented in the future.