Final Report

Measurement and Evaluation Study of the 2002 SDG&E Residential Hard-to-Reach Lighting Program

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1. Executive Summary

This document is the final report for the Measurement and Evaluation Study of the 2002 SDG&E Local Residential Hard-to-Reach Lighting Program. This report contains verification of the number of lamps distributed and the number of lamps currently in use. Additionally, this report contains measures of program effectiveness resulting from a process evaluation.

The program allows Hard-to-Reach (HTR) residential customers to exchange inefficient halogen torchiere fixtures and incandescent bulbs for ENERGY STAR qualified torchiere fixtures and compact fluorescent lamps at no cost.

The primary objectives of the study are to:

1. Verify achieved levels of energy and peak demand savings through a program savings study, and
2. Measure indicators of program effectiveness through a process evaluation.

The evaluation is based on telephone surveys with 125 program participants. We attempted to contact a total of 218 participants to complete 125 surveys, resulting in a conversion rate of 57.3%[1]. Only 5 participants refused to complete the survey, which is a refusal rate of only 2.3%. The survey responses have been statistically extrapolated to the program population.

Savings Verification Results

Table 1 presents the estimated number of lamps distributed and in use now relative to the number of lamps distributed according to the program tracking system. For all program participants, the total number of lamps distributed was estimated to be 42,766 lamps representing a distribution realization rate of 100.0%. The distribution rate for torchieres was 107.1%[2] and for CFLs, the distribution rate was 99.6%. A total of 37,317 lamps are currently in use, representing an excellent usage realization rate of 87.3%.

	Program Tracking # Lamps Distributed	Estimated # Lamps Distributed	Distribution Realization Rate	Estimated # Lamps In Use Now	Usage Rate (Tracking)	Usage Rate (Distribution)
Torchieres	2,450	2,623	107.1%	2,485	101.4%	94.7%
CFLs	40,318	40,143	99.6%	34,832	86.4%	86.8%
Total	**42,768**	**42,766**	**100.0%**	**37,317**	**87.3%**	**87.3%**

Table 1: Lamp Distribution and Usage Rates by Lamp Type

Once the number of lamps distributed was estimated, we determined the program's peak demand reduction and energy savings, using IPMVP option A, stipulated energy savings. The stipulated values for the relevant parameters were combined with the verified lamp

[1] The conversion rate is defined as the ratio of successfully completed surveys to all attempted contacts.

[2] There were some respondents who stated they received more torchieres than recorded in the program tracking data, whereas there were no respondents who stated they received fewer torchieres than recorded in the program tracking data. This results in the estimated number of torchieres distributed exceeding the total recorded in the program tracking data, and consequently a torchiere distribution rate that exceeds 100%.

distributions[3]. Table 2 shows the results. Overall, the program is achieving a gross demand reduction of 460 kW and a net demand reduction of 368 kW. For energy savings, the program is achieving an annual gross energy savings of 2,924,008 kWh, an annual net energy savings of 2,339,206 kWh, a life cycle gross energy savings of 26,316 MWh, and a life cycle net energy savings[4] of 21,053 MWh.

	# Distributed	Total Annual Gross kW Demand Reduction	Total Annual Net kW Demand Reduction	Total Annual Gross kWh Savings	Total Annual Net kWh Savings	Life Cycle Gross kWh	Life Cycle Net kWh
14 W CFL	8,883	46	37	293,139	234,511	2,638,251	2,110,601
27 W CFL	31,261	300	240	1,906,921	1,525,537	17,162,289	13,729,831
Torchieres	2,623	113	91	723,948	579,158	6,515,532	5,212,426
Total	**42,767**	**460**	**368**	**2,924,008**	**2,339,206**	**26,316,072**	**21,052,858**

Table 2: Program Demand Reduction and Energy Savings

Table 3 compares the evaluated net kW demand reduction and net kWh energy savings to those recorded in the program's AEAP filing. The verified net demand reduction and energy savings just barely exceed those recorded in the program's AEAP filing and are also well above the CPUC targets. There is less than a 1.5% difference between both the verified net demand reduction and energy savings and the values filed by the program. This difference is likely explained by the respondent's inability to distinguish between the 14 Watt and 27 Watt CFLs, as footnoted below.

	CPUC Target	Program AEAP Filed	Verified
Net kW Demand Reduction	294	363	368
Net kWh Energy Savings	1,867,677	2,308,648	2,339,206

Table 3: Demand Reduction and Energy Savings Compared to AEAP Filing

[3] Respondents were unable to distinguish between 14-Watt CFLs and 27-Watt CFLs. Therefore, our evaluation estimates the total number of CFLs distributed. Since the stipulated parameters are different for the 2 types of CFL, it was necessary to also estimate the number of lamps distributed of each wattage. To do this, we multiplied the total number of CFLs distributed by the proportion of CFLs of that wattage, as determined from the program tracking data. For example, the program tracking data shows that 14-Watt CFLs accounted for 22.1% of all CLFs. We have verified that a total of 40,143 CFLs were distributed. So, we have estimated the number of 14-Watt CFLs distributed as (40,143 * 22.1%) = 8,883.

[4] We have calculated the life cycle energy savings as (first-year annual energy savings) * (effective useful life).

All participants who stated that they received lamps, but that they were not currently in use, were asked to indicate why. For torchieres not currently in use, the primary reason they are not currently in use is because the lamp burned out, and the participant cannot locate a replacement lamp. Table 4 presents the reasons why CFLs are not currently in use. Just over 40% of CFLs not currently being used are not in use because they did not fit in the fixtures[5]. Another 40% of the unused CFLs are not currently in use because the participant did not have enough fixtures to place all of the lamps they received.

	Estimated # CFLs	Error Bound	Relative Precision
Did Not Fit in My Light Fixture	2,202	1,290	58.6%
Not Bright Enough	182	312	171.4%
Burned Out	343	292	85.1%
Not Enough Fixtures	2,157	898	41.6%
Other	426	612	143.7%
Total	**5,311**	**1,490**	**28.1%**

Table 4: Reasons Why CFLs Are Not In Use

Table 5 shows the number of lamps not currently in use, but future use of the lamps is planned. For torchieres, none of the lamps not currently in use are planned for future use, likely a direct consequence of the fact that participants cannot locate replacement lamps. For CFLs, of the 5,311 lamps not currently is use, participants plan to use 4,382 in the future. Participants were asked to state how they planned to use the CFLs in the future. All participants that planned to use the CFLs in the future stated they will use the unused CFLs as replacements for burnouts.

	# Lamps Distributed	# Lamps In Use Now	# Lamps Future Use Planned	# Lamps Not In Use & No Planned Use
Torchieres	2,623	2,485	0	138
CFLs	40,143	34,832	4,382	929
Total	**42,766**	**37,317**	**4,382**	1,067

Table 5: Number of Lamps Not In Use Now But Future Use Planned

[5] SDG&E reports they have since learned that customers did not like the length of the 27 Watt CFL because they do not fit in all fixtures. Starting in November 2003, SDG&E has been supplying a 23 Watt CFL with a short length that should fit in all fixtures instead.

Process Evaluation Results

Table 6 displays the incidence of program participants telling others about the lamps they received through the program. Over 80% of participants report that they have told others about the lamps.

	% of Participants
Yes	81.7%
No	17.3%
Don't Know	1.0%

Table 6: Incidence of Telling Others about Lamps Received Through Program

Participants who told others about the lamps were asked how many people they told. Table 7 summarizes the responses. Nearly 20% of participants who told others about the lamps report telling 10 or more people, and about 50% of these participants told 4 to 9 people.

	% of Participants Who Told Others
I Told A Few People (1 to 3)	35.9%
I Told Some People (4 to 9)	46.5%
I Told A Lot of People (10 or More)	16.7%
Don't Know	0.8%

Table 7: Number of People Told about Lamps from Program Among Participants Who Told Others about Lamps

Participants who reported telling others about the lamps they received through the program were asked how good or bad the information was they mentioned to others. As shown in Table 8, over 95% of participants state that everything they mentioned to others was all good, indicating that participants are quite pleased with the program and the lamps they received through the program.

	% of Participants Who Told Others
All Bad	-
Some Bad and Some Good	2.1%
All Good	97.5%
Don't Know	0.5%

Table 8: Content of Information Mentioned about Lamps from Program Among Participants Who Told Others about Lamps

Table 9 presents the incidence of others purchasing the same type of lamps among participants who have told others. Nearly half of participants who have told others do not know if others

have purchased the same type of lamps. However, over 45% of participants who told others report that other people have purchased similar lamps.

	% of Participants Who Told Others
No, Nobody	6.0%
A Few People (1 to 3)	33.6%
Some People (4 to 9)	11.7%
A Lot of People (10 or More)	3.4%
Don't Know	45.3%

Table 9: Incidence of Others Purchasing Same Type of Lamps Among Participants Who Told Others about Lamps

Observations and Recommendations

Several observations were made about the 2002 Hard-to-Reach Lighting Program through the course of conducting this evaluation. Some of these observations have resulted in recommendations for the program. Detailed specifics for each observation are articulated in the chapter entitled "Observations and Recommendations". Our major observations are:

1. The evaluation results show excellent gross realization rates of lamp distribution and energy savings.
2. The evaluation results show excellent distribution and usage rates,
3. The WIC center connects with truly hard-to-reach customers,
4. Newspaper attracts marginally hard-to-reach customers,
5. Some participants don't meet program criteria (at least 1 respondent reported supplying her work address to the program and installed the bulbs at her office),
6. Participant networking with peers has resulted in non-participant procurement and usage of similar lamps, and
7. Customers are finings replacement lamps for torchieres difficult to locate and purchase.

2. Introduction

This is the final report for the Measurement and Evaluation Study of the 2002 SDG&E Local Residential Hard-to-Reach Lighting Program. In this chapter, we will describe the 2002 program as well as our general evaluation approach.

Program Overview

The SDG&E Local Residential Hard-to-Reach Lighting Turn-In Program targets hard-to-reach (HTR) residential customers, including seniors and lower and fixed income customers that may not have financial means or other resources to participate in energy efficiency programs. The program allows HTR residential customers to exchange inefficient halogen torchiere fixtures and incandescent bulbs for ENERGY STAR qualified torchiere fixtures and compact fluorescent lamps at no cost. Prior to August 2002, each HTR customer could exchange up to 2 halogen torchiere fixtures and up to 5 incandescent bulbs. Starting in August 2002, HTR residential customers could exchange up to 2 halogen torchiere fixtures and up to 10 incandescent bulbs. In 2002, according to the program tracking system, the program exchanged 40,318 compact fluorescent lamps and 2,450 torchiere lamps to 7,330 HTR customers.

Evaluation Overview

The primary objectives of the study are to:

1. Verify achieved levels of energy and peak demand savings through a program savings study, and
2. Measure indicators of program effectiveness through a process evaluation.

To verify the achieved levels of energy and peak demand savings, the study will determine the number of measure distributions achieved during the 2002 program year using telephone surveys. The same telephone survey will also be utilized to measure indicators of program effectiveness.

Using the SDG&E program tracking data as a sampling frame, we selected a statistically representative sample of 125 participants for the telephone survey. All results were extrapolated to the program participant population.

We used a telephone survey to serve two purposes: verifying the lamp distributions and assessing the effectiveness of the program approach in delivering customer satisfaction. For each participant in the sample, the survey verified the distributed lamps listed in the SDG&E tracking database. The survey also determined how participants heard of the program, reasons for participation, program satisfaction, and customer perceptions on how the program has helped them manage their energy bills.

For the savings verification component of the evaluation, the statistical analysis of the data consisted of extrapolating the verified lamp distributions in the sample to the program population to estimate the total number of lamp distributions achieved by the program. We calculated measure-specific distribution realization rates by comparing the tracking system data to the verified distributions. The total number of lamp distributions achieved in the program year was then used to verify the energy and peak demand savings achieved by the program using IPMVP option A, Stipulated Energy Savings, and the parameters assumed in the detailed cost-effectiveness workpapers. The verified energy and peak demand savings were then combined with actual program costs to calculate program cost effectiveness. For the process evaluation component of the study, the statistical analysis of the data will consist of weighted frequency

distributions, means, and cross-tabulations, where appropriate, to measure indicators of program effectiveness.

3. Results

Savings Verification Results

Verification of Number of Lamps Distributed

Table 10 presents the estimated number of lamps distributed and in use now relative to the number of lamps distributed according to the program tracking system. For all program participants, the total number of lamps distributed was estimated to be 42,766 lamps representing a distribution realization rate of 100.0%. The distribution rate for torchieres was 107.1%[6], and for CFLs, the distribution rate was 99.6%. A total of 37,317 lamps are currently in use, representing a usage realization rate of 87.3%.

	Program Tracking # Lamps Distributed	Estimated # Lamps Distributed	Distribution Realization Rate	Estimated # Lamps In Use Now	Usage Rate (Tracking)	Usage Rate (Distribution)
Torchieres	2,450	2,623	107.1%	2,485	101.4%	94.7%
CFLs	40,318	40,143	99.6%	34,832	86.4%	86.8%
Total	**42,768**	**42,766**	**100.0%**	**37,317**	**87.3%**	**87.3%**

Table 10: Lamp Distribution and Usage Rates by Lamp Type

Table 11 shows the estimated number of lamps distributed and error bound by lamp type as well as overall. The total number of lamps distributed was found to be 42,766, with an error bound of 693 lamps, yielding a 90% confidence interval of (42,073, 43,459) lamps.

	Estimated # Lamps Distributed	Error Bound	Relative Precision
Torchieres	2,623	163	6.2%
CFLs	40,143	674	1.7%
Total	**42,766**	**693**	**1.6%**

Table 11: Number of Lamps Distributed by Lamp Type

[6] There were some respondents who stated they received more torchieres than recorded in the program tracking data, whereas there were no respondents who stated they received fewer torchieres than recorded in the program tracking data. This results in the estimated number of torchieres distributed exceeding the total recorded in the program tracking data, and consequently a torchiere distribution rate that exceeds 100%.

Table 12 shows the estimated number of lamps in use now and error bound by lamp type as well as overall. The total number of lamps in use now is 37,317 lamps, with an error bound of 1,755 lamps, yielding a 90% confidence interval of (35,562, 39,072) lamps.

	Estimated # Lamps In Use Now	Error Bound	Relative Precision
Torchieres	2,485	202	8.1%
CFLs	34,832	1,743	5.0%
Total	**37,317**	**1,755**	**4.7%**

Table 12: Number of Lamps In Use Now by Lamp Type

All participants who stated received lamps were not currently in use were asked to indicate why. For torchieres not currently in use, the reason is that the bulb burned out and the participant cannot locate a replacement bulb. Table 13 presents the reasons why CFLs are not currently in use. Just over 40% of CFLs are not currently is use because they did not fit in the fixtures. Another 40% of CFLs are not currently in use because the participant did not have enough fixtures to place all of the lamps they received.

	Estimated # CFLs	Error Bound	Relative Precision
Did Not Fit in My Light Fixture	2,202	1,290	58.6%
Not Bright Enough	182	312	171.4%
Burned Out	343	292	85.1%
Not Enough Fixtures	2,157	898	41.6%
Other	426	612	143.7%
Total	**5,311**	**1,490**	**28.1%**

Table 13: Reasons Why CFLs Are Not In Use

Table 14 shows the number of lamps not currently in use but future use of the lamps is planned. For torchieres, none of the lamps not currently in use used are planned for future use. For CFLs, of the 5,311 lamps not currently is use, participants plan to use 4,382 in the future. Participants were asked to state how they planned to use the CFLs in the future. All participants that planned to use the CFLs in the future stated they would use the unused CFLs to replace other CFLs as they burn out.

	# Lamps Distributed	# Lamps In Use Now	# Lamps Future Use Planned	# Lamps Not In Use & No Planned Use
Torchieres	2,623	2,485	0	138
CFLs	40,143	34,832	4,382	929
Total	**42,766**	**37,317**	**4,382**	1,067

Table 14: Number of Lamps Not In Use Now But Future Use Planned

Verify Program Savings

Once the number of lamps distributed was estimated, we determined the program's peak demand reduction and energy savings, using IPMVP option A, stipulated energy savings. The stipulated values for the relevant parameters were combined with the verified lamp distributions[7]. Table 15 shows the results. Overall, the program is achieving a gross demand reduction of 460 kW and a net demand reduction of 368 kW. For energy savings, the program is achieving an annual gross energy savings of 2,924,008 kWh, an annual net energy savings of 2,339,206 kWh, a life cycle gross energy savings of 26,316 MWh, and a life cycle net energy savings of 21,053 MWh[8].

	# Distributed	Total Annual Gross kW Demand Reduction	Total Annual Net kW Demand Reduction	Total Annual Gross kWh Savings	Total Annual Net kWh Savings	Life Cycle Gross kWh	Life Cycle Net kWh
14 W CFL	8,883	46	37	293,139	234,511	2,638,251	2,110,601
27 W CFL	31,261	300	240	1,906,921	1,525,537	17,162,289	13,729,831
Torchieres	2,623	113	91	723,948	579,158	6,515,532	5,212,426
Total	**42,767**	**460**	**368**	**2,924,008**	**2,339,206**	**26,316,072**	**21,052,858**

Table 15: Program Demand Reduction and Energy Savings

Table 16 compares the evaluated net kW demand reduction and net kWh energy savings to those recorded in the program's AEAP filing. The verified net demand reduction and energy savings just barely exceed those recorded in the program's AEAP filing and are also well above the CPUC targets. There is less than a 1.5% difference between both the verified net demand reduction and energy savings and the values filed by the program. This difference is likely explained by the respondent's inability to distinguish between the 14 Watt and 27 Watt CFLs, as footnoted below.

	CPUC Target	Program AEAP Filed	Verified
Net kW Demand Reduction	294	363	368
Net kWh Energy Savings	1,867,677	2,308,648	2,339,206

Table 16: Demand Reduction and Energy Savings Compared to AEAP Filing

[7] Respondents were unable to distinguish between 14-Watt CFLs and 27-Watt CFLs. Therefore, our evaluation estimates the total number of CFLs distributed. Since the stipulated parameters are different for the 2 types of CFL, it was necessary to also estimate the number of lamps distributed of each wattage. To do this, we multiplied the total number of CFLs distributed by the proportion of CFLs of that wattage, as determined from the program tracking data. For example, the program tracking data shows that 14-Watt CFLs accounted for 22.1% of all CLFs. We have verified that a total of 40,143 CFLs were distributed. So, we have estimated the number of 14-Watt CFLs distributed as (40,143 * 22.1%) = 8,883.

[8] We have calculated the life cycle energy savings as (first-year annual energy savings) * (effective useful life).

Process Evaluation Results

Table 17 shows how participants first became aware of SDG&E's 2002 Residential Hard-to-Reach Lighting Program. Nearly one-fifth of participants became aware of the program through word-of-mouth. Approximately 10% of participants learned of through the program though each of flyers and newspapers. Approximately 10% of participants do not know how they learned of the program.

	% of Participants
Word of Mouth - Friend / Relative / Co-worker	18.6%
Newspaper	12.9%
Flyer	11.2%
Don't Know / Can't Remember	11.0%
Other	8.8%
Distribution Location	7.1%
WIC Center	6.0%
Fair	4.4%
Senior Center	4.4%
Bill Insert	4.1%
Letter or Mailing (Other Than Bill Insert)	3.4%
Church	3.0%
E-Mail	2.4%
Community Center	1.0%
Other Community Group or Organization	1.0%
Clinic or Hospital	0.7%

Table 17: Source of Awareness of Hard-to-Reach Lighting Program

Next, respondents were asked to provide the primary reason they participated in the program. Table 18 displays the responses. Over 70% of participants state their primary reason for participating in the program was to save energy or reduce their electricity bill.

	% of Participants
Energy Savings	78.5%
Free Benefit	31.3%
Other	19.7%
Environmental Concerns	3.7%
Safety	3.0%

Table 18: Primary Reason for Participating in Hard-to-Reach Lighting Program

Table 19 presents the incidence of participants noticing a change in their electricity bill since participating in the Hard-to-Reach Lighting Program. Nearly half of participants have noticed a change in their bill. Approximately another 20% of participants do not know if they have seen a change in their bill.

	% of Participants
Yes	47.1%
No	34.3%
Don't Know	18.6%

Table 19: Incidence of Noticing a Change in Electricity Bill

All participants who have noticed a change in their electricity bill were asked to compare the change to their expectations. As shown in Table 20, only about 10% of participants who have noticed a change are experiencing less energy savings than they expected, with nearly half of participants who have noticed a change saving about as much as they expected. Nearly 20% of participants who have noticed a change are saving even more than they expected.

	% of Participants With Change in Bill
Less Than Expected	12.4%
About As Much As Expected	50.3%
Even More Than Expected	18.1%
Don't Know	19.3%

Table 20: Change in Electricity Bill Compared to Participant Expectations Among Participants Who Noticed A Change in Bill

Table 21 displays the incidence of program participants telling others about the lamps they received through the program. Over 80% of participants report that they have told others about the lamps.

	% of Participants
Yes	81.7%
No	17.3%
Don't Know	1.0%

Table 21: Incidence of Telling Others about Lamps Received Through Program

Participants who told others about the lamps were asked how many people they told. Table 22 summarizes the responses. Nearly 20% of participants who told others about the lamps report telling 10 or more people, and about 50% of these participants told 4 to 9 people.

	% of Participants Who Told Others
I Told A Few People (1 to 3)	35.9%
I Told Some People (4 to 9)	46.5%
I Told A Lot of People (10 or More)	16.7%
Don't Know	0.8%

Table 22: Number of People Told about Lamps from Program Among Participants Who Told Others about Lamps

Participants who reported telling others about the lamps they received through the program were asked how good or bad the information was they mentioned to others. As shown in Table 23, over 95% of participants state that everything they mentioned to others was all good, indicating that participants are quite pleased with the program and the lamps they received through the program.

	% of Participants Who Told Others
All Bad	-
Some Bad and Some Good	2.1%
All Good	97.5%
Don't Know	0.5%

Table 23: Content of Information Mentioned about Lamps from Program Among Participants Who Told Others about Lamps

Table 24 presents the incidence of others purchasing the same type of lamps among participants who have told others. Nearly half of participants who have told others do not know if others have purchased the same type of lamps. Over 45% of participants who told others report that other people have purchased similar lamps.

	% of Participants Who Told Others
No, Nobody	6.0%
A Few People (1 to 3)	33.6%
Some People (4 to 9)	11.7%
A Lot of People (10 or More)	3.4%
Don't Know	45.3%

Table 24: Incidence of Others Purchasing Same Type of Lamps Among Participants Who Told Others about Lamps

Demographics

Table 25 presents the home ownership status of the Hard-to-Reach Lighting Program participants. Nearly 75% of participants own their homes. One telephone survey respondent reported turning-in lamps for her office, suggesting that a small percentage of the lamps distributed through the program were distributed to non-residential locations.

	% of Participants
Own	73.4%
Rent	25.6%
City of San Diego Office	1.0%

Table 25: Home Ownership Status

Table 26 shows the distribution of the number of people per household among program participants. Nearly 50% of participating households are occupied by one or two people. Another 30% of participating households contain either three or four people, and approximately 10% of participating households are occupied by six or more people.

	% of Participants
One	16.4%
Two	31.1%
Three	11.5%
Four	21.8%
Five	9.1%
Six	5.7%
Seven	0.7%
Eight	1.7%
Nine	1.0%
Not Applicable	1.0%

Table 26: Number of People in Household

Table 27 summarizes the distribution of the primary language spoken in participating households. Approximately 66% of participating households primarily speak English, and about 25% of participating households speak Spanish.

	% of Participants
English	67.9%
Spanish	24.6%
Other	4.7%
Chinese	1.4%
Not Applicable	1.0%
Vietnemese	0.4%

Table 27: Primary Language of Household

All respondents were asked the highest level of education they have completed. As shown in Table 28, just over 30% of participants are high school graduates or less, another 30% have completed some college, another 30% have a 4-year college degree, and about 10% have an advanced degree.

	% of Participants
High School Graduate or Less	31.1%
Some College	29.7%
4-Year College Degree	28.7%
Advanced Degree	10.4%

Table 28: Level of Education Completed

Table 29 presents the distribution of 2002 household income. Nearly 25% of participants had a 2002 household income of $23,000 or less. Approximately another 20% of participants had a 2002 household income between $23,001 and $32,500. One-third of participants had a 2002 household income of $43,501 or more.

	% of Participants
Less Than $23,000	24.0%
$23,001 - $27,000	13.4%
$27,001 - $32,500	7.8%
$32,501 - $38,000	4.5%
$38,001 - $43,500	4.8%
$43,501 or More	33.3%
Don't Know	6.5%
Refused	5.8%

Table 29: 2002 Household Income

Source of Awareness of Program Among Various Demographic Groups

Table 30 displays how participants first became aware of the program by home ownership status. Renters were significantly more likely to learn about the program either through word-of-mouth or the WIC Center, and owners were significantly more likely to learn about the program through the newspaper.

	% of Participants	
	Owners	**Renters**
Bill Insert	4.2%	3.9%
Letter or Mailing (Other Than Bill Insert)	3.8%	2.6%
Flyer	10.8%	12.8%
Word of Mouth - Friend / Relative / Co-worker	15.7%	27.6%
Senior Center	5.9%	-
Community Center	1.4%	-
Church	4.1%	-
Clinic or Hospital	0.9%	-
Other Community Group or Organization	1.4%	-
Fair	4.6%	3.9%
Newspaper	16.7%	2.6%
E-Mail	3.3%	-
WIC Center	0.9%	21.1%
Distribution Location	5.9%	6.6%
Other	9.2%	7.9%
Don't Know / Can't Remember	11.1%	11.0%

Table 30: Source of Awareness of Hard-to-Reach Lighting Program by Home Ownership Status

As shown in Table 31, participants whose household's primary language is Spanish were significantly more likely to learn about the program through flyers, word-of-mouth, or the WIC Center. Participants whose primary language is English were significantly more likely to learn about the program through the newspaper or not be able to recall how they became aware of the program.

	% of Participants	
	English	**Spanish**
Bill Insert	5.4%	-
Letter or Mailing (Other Than Bill Insert)	2.1%	5.4%
Flyer	10.4%	16.9%
Word of Mouth - Friend / Relative / Co-worker	13.0%	26.0%
Senior Center	6.4%	-
Community Center	1.5%	-
Church	3.0%	4.1%
Clinic or Hospital	-	2.7%
Other Community Group or Organization	1.5%	-
Fair	6.5%	-
Newspaper	18.1%	2.7%
E-Mail	2.0%	-
WIC Center	-	24.6%
Distribution Location	4.5%	8.0%
Other	10.9%	5.6%
Don't Know / Can't Remember	14.6%	4.1%

Table 31: Source of Awareness of Hard-to-Reach Lighting Program by Primary Language Spoken At Home

Table 32 presents how participants first became aware of the program by level of education completed. Participants who have completed high school or less were significantly more likely to learn about the program through the WIC Center. Participants who have at completed at least a 4-year college degree were significantly more likely to learn about the program through the newspaper, while participants who have completed an advanced degree were significantly more likely to learn about the program at the location of distribution of the lamps.

	% of Participants			
	High School or Less	**Some College**	**College Graduate**	**Advanced Degree**
Bill Insert	-	5.7%	8.4%	-
Letter or Mailing (Other Than Bill Insert)	4.3%	2.2%	5.1%	-
Flyer	17.3%	2.7%	15.1%	7.8%
Word of Mouth - Friend / Relative / Co-worker	14.2%	26.6%	16.6%	16.2%
Senior Center	3.3%	4.5%	7.1%	-
Community Center	3.3%	-	-	-
Church	3.3%	6.9%	-	-
Clinic or Hospital	2.1%	-	-	-
Other Community Group or Organization	-	3.4%	-	-
Fair	-	1.3%	10.7%	9.8%
Newspaper	7.6%	11.9%	19.1%	16.2%
E-Mail	3.3%	3.5%	1.3%	-
WIC Center	19.6%	-	-	-
Distribution Location	6.4%	4.7%	3.5%	16.2%
Other	8.7%	11.6%	7.1%	6.3%
Don't Know / Can't Remember	6.6%	15.0%	5.9%	27.3%

Table 32: Source of Awareness of Hard-to-Reach Lighting Program by Level of Education

Table 33 shows how participants learned of the program by 2002 household income. As shown in the table, participants in the lowest income categories were significantly more likely to learn about the program through the WIC Center or word-of-mouth, while participants in the higher income categories were more likely to learn about the program through the newspaper.

	% of Participants							
	<= $23,000	**$23,001 - $27,000**	**$27,001 - $32,500**	**$32,501 - $38,000**	**$38,001 - $43,500**	**$43,501 +**	**Don't Know**	**Refused**
Bill Insert	2.8%	-	14.4%	-	-	7.3%	-	-
Letter or Mailing (Other Than Bill Insert)	3.4%	4.9%	-	14.5%	13.9%	2.0%	-	-
Flyer	18.1%	8.7%	9.3%	14.5%	-	9.5%	10.3%	17.7%
Word of Mouth - Friend / Relative / Co-worker	23.0%	32.9%	9.3%	8.2%	-	20.5%	15.8%	-
Senior Center	-	15.3%	9.3%	-	-	3.1%	10.3%	-
Church	-	-	-	-	-	3.1%	31.8%	-
Fair	-	-	-	22.4%	-	10.4%	-	-
Newspaper	5.6%	-	9.3%	17.9%	21.4%	21.6%	-	55.0%
E-Mail	-	-	-	-	-	7.3%	-	-
WIC Center	18.4%	7.6%	-	-	-	-	10.3%	-
Distribution Location	12.6%	-	-	-	29.3%	2.0%	-	27.3%
Other	8.6%	15.3%	34.0%	-	13.9%	5.1%	-	-
Don't Know / Can't Remember	7.7%	15.3%	14.4%	22.4%	21.4%	8.2%	21.6%	-

Table 33: Source of Awareness of Hard-to-Reach Lighting Program by 2002 Household Income

4. Observations and Recommendations

This chapter presents observations made about the 2002 Hard-to-Reach Lighting Program through the course of conducting this evaluation. Recommendations to improve the program are also presented.

Excellent Distribution and Usage Rates

The program is experiencing high lamp distribution and lamp usage rates. Overall, the program achieved a distribution rate of 100.0%, demonstrating that the program kept excellent records of lamp distribution. Nearly 90% of all lamps distributed through the program are currently in use, and the majority of lamps not currently in use are intended for future use.

WIC Center as a Source of Program Awareness

The Women Infant and Children's (WIC) Center has proven to be a great source of connecting with the truly hard-to-reach residential market segment. Over 20% of renter participants, about 25% of Spanish-speaking participants, 20% of participants who have completed high school or less, and nearly 20% of participants whose 2002 household income was less than $23,000 first became aware of the program through the WIC Center.

Conversely, very few homeowners, no English-speakers, and no participants with at least some college heard about the program through the WIC Center. Furthermore, only participants with a 2002 household income of $27,000 or less became aware of the program through the WIC Center.

If possible, we recommend increasing, or at a minimum maintaining, the level of program promotional activities and number of distribution events taking place at the WIC Center. This will help to ensure that the program continues to connect with the truly hard-to-reach.

Newspaper as a Source of Program Awareness

Program promotions in newspapers seem to be attracting program participants that may not be the truly hard-to-reach residential segment. Only 2.6% of renter participants, 2.7% of Spanish-speaking participants, 7.6% of participants who have completed high school or less, and 5.6% of participants whose 2002 household income was less than $23,000 first became aware of the program through the newspaper.

Conversely, over 15% of homeowners, nearly 20% of English-speakers, approximately 15% of participants with at least some college, and over 20% of participants with a 2002 household income of $43,500 or more heard about the program through the newspaper.

Therefore, we recommend decreasing the level of program promotions in newspapers. This will help to ensure that the program's resources are directed towards residential customers that are truly hard-to-reach.

Validation of Participation Criteria

During the telephone survey data collection process, we encountered at least one participant who did not meet the criteria for program participation. This participant exchanged the lamps on behalf of her work location, where the lamps are currently in use. The participation address for this individual in the program tracking system matches that of her work location. Additionally, the participant's work location is the same as the location of distribution. Thus, we are confident that the lamps were in fact distributed to a non-residential customer and tracked as such by the

program. Since we only contacted approximately 200 participants out of a program of 7,330 participants and encountered such a situation, it seems quite plausible that there are other program participants that are non-residential.

Additionally, about 33% of program participants had a 2002 household income of $43,501 or greater. Conceivably, some, if not most, of these higher income participants do not actually meet the criteria to participate in a hard-to-reach program.

We recommend making the method of validating the customer participation criteria more stringent. At a minimum, the participant should be verified as a residential customer. Ideally, the program would also verify that the participant meets at least one hard-to-reach criterion.

Participant Networking With Non-Participant Peers

Program participants have networked with their peers about the program and the lamps received through the program. Over 80% of program participants state they have told others about the program and the lamps they received. Among participants who have told others, approximately 50% report that the peer networking has resulted in non-participants procuring and using similar lamps.

Replacement Lamps Difficult to Locate

Every respondent who exchanged a torchiere that is no longer in use stated the reason why is that the lamp burned out and they could not locate a replacement lamp in stores. We recommend providing participants with a list of retailers who supply the same type of lamps at the time of the exchange, so when lamps expire, it is easy for participants to replace them with similar lamps.

5. EM&V Methodology

To evaluate the number of lamps distributed through the Hard-to-Reach Lighting Program, RLW utilized telephone surveys with a statistically representative sample of program participants. We used the program tracking data to design a sample statistically representative of the program. For each program participant in the sample, we verified the number of lamps distributed listed in the program tracking data using a phone survey.

We also assessed the effectiveness of the program approach in delivering customer satisfaction using phone surveys. The process evaluation component was also designed to explore how participants first became aware of the program, reasons for participation, whether the participant networked with their peers about the program and the program measures, and whether the networking resulted in any non-program procurements and use of identical measures by those peers.

Sample Design

The selection of the sample homes was guided by a model-based statistical sampling plan. Model-based sampling methods were also used to analyze the data, i.e., to extrapolate the findings from the sample homes to the target population of all program participants and to evaluate the statistical precision of the results. We stratified the participant population by the number of lamps exchanged, as a way to maximize the number of lamps verified in the sample.

Theoretical Foundation

MBSS™ methodology was used to develop an efficient sample design and to assess the likely statistical precision associated the planned sample. The target variable of analysis, denoted *y*, is the number of lamps distributed through the program. The primary stratification variable, the program tracking number of lamps distributed, will be denoted *x*. A ratio model was formulated to describe the relationship between *y* and *x* for all units in the population, e.g., program participants.

The MBSS™ ratio model consists of two equations called the primary and secondary equations:

$$\begin{aligned} y_k &= \beta x_k + \varepsilon_k \\ \sigma_k &= sd(y_k) = \sigma_0 x_k^{\gamma} \end{aligned}$$

Here $x_k > 0$ is known throughout the population. *k* denotes the sampling unit, i.e., the participant. $\{\varepsilon_1, \ldots, \varepsilon_N\}$ are independent random variables with zero expected value, and β, σ_0, and γ (gamma) are parameters of the model. The primary equation can also be written as

$$\mu_k = \beta x_k$$

Under the MBSS ratio model, it is assumed that the expected value of *y* is a simple ratio or multiple of *x.*

Here, y_k is a random variable with expected value μ_k and standard deviation σ_k. Both the expected value and standard deviation generally vary from one unit to another depending on x_k, following the primary and secondary equations of the model. In statistical jargon, the ratio model is a (usually) heteroscedastic regression model with zero intercept.

One of the key parameters of the ratio model is the error ratio, denoted *er*. The error ratio is a measure of the strength of the association between *y* and *x*. The error ratio is suitable for measuring the strength of a heteroscedastic relationship and for choosing sample sizes. It is *not* equal to the correlation coefficient. It *is* somewhat analogous to a coefficient of variation except that it describes the association between two or more variables rather than the variation in a single variable.

Using the model discussed above, the error ratio, *er*, is defined to be:

$$er = \frac{\sum_{k=1}^{N} \sigma_k}{\sum_{k=1}^{N} \mu_k} = \frac{\frac{1}{N}\sum_{k=1}^{N} \sigma_k}{\frac{1}{N}\sum_{k=1}^{N} \mu_k}$$

Figure 1 gives some typical examples of ratio models with different error ratios. An error ratio of 0.2 represents a very strong association between *y* and *x*, whereas an error ratio of 0.8 represents a weak association.

As Figure 1 indicates, the error ratio is the principle determinant of the sample size required to satisfy the 90/10 criteria for estimating *y*. If the error ratio is small, then the required sample is correspondingly small.

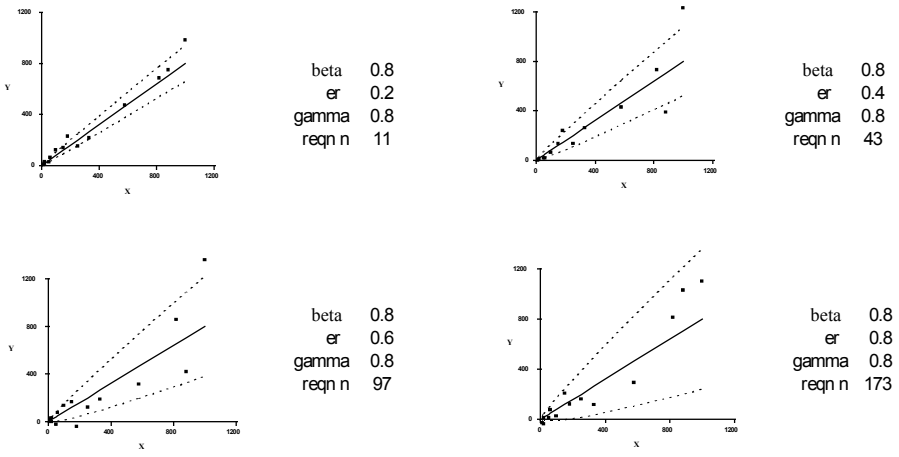

Figure 1: Examples of MBSS Ratio Models

Sampling Plan

At the planning stage of the M&V evaluation for the Residential Hard-to-Reach Lighting Program, we proposed a sample of 125 participants for the telephone survey effort. Based on our past experience with programs of this nature, we conservatively assumed an error ratio of 0.4 for the telephone survey sample design. The expected relative precision associated with our sampling plan was $\pm 6.0\%$. By selecting a conservative value for the error ratio, the expected relative precision associated with the planned sample can be considered an upper bound. Therefore, we expected the relative precision achieved with our sample would be less than or equal $\pm 6.0\%$.

We stratified the program population by program tracking number of lamps distributed. Table 34 shows our original sampling plan. Our sampling plan called for a sample of 125 participants for telephone survey data collection. This sample design was expected to yield a relative

precision of ±6.0% at the 90% level of confidence for the overall number of lamps distributed through the program.

Stratum	Max. # Lamps	Population Size	Population # Lamps	Sample Size
1	5	2,585	7,464	25
2	5	1,616	8,080	25
3	10	1,323	8,522	25
4	10	928	9,280	25
5	20	878	9,422	25
Total		**7,330**	**42,768**	**125**

Table 34: Original Hard-to-Reach Lighting Program Sample Design

Final Sample Design

The case weights were calculated using balanced post-stratification[9]. In this approach, the sample units are sorted by the stratification variable, program tracking number of lamps distributed, and then divided as equally as possible among the strata. Then the first stratum cutpoint is determined midway between the values of the stratification variable for the last sample case in the first stratum and the first sample case in the second stratum. The remaining strata cutpoints are determined in a similar fashion. Then the population sizes are tabulated within each stratum.

Table 35 shows the final sample design that was used to calculate the case weights. In this case, a sample of 125 participants has been divided among four strata[10] based on program tracking number of lamps distributed. Then the stratum cutpoints shown in column two were calculated from the distributed number of lamps of the sample participants according to the program tracking database. Next the population sizes shown in column three were calculated from the stratum cutpoints. The final step was to calculate the case weights shown in the last column. For example, the case weight for the 61 units in the first stratum is 4,538 / 61 = 74.393.

Stratum	Max. # Lamps	Population Size	Population # Lamps	Sample Size	Case Weight
1	5	4,538	17,229	61	74.393
2	6	410	2,460	7	58.571
3	10	1,931	17,927	40	48.275
4	12	451	5,152	17	26.529
Total		**7,330**	**42,768**	**125**	

Table 35: Final Hard-to-Reach Lighting Program Sample Design

[9] For a thorough discussion of balanced post-stratification, refer to the Case Weights Section later in this chapter.

[10] When calculating the case weights using balanced post-stratification, we considered either four or five strata. We have selected the four strata sample design because the relative precision achieved with our final sample was lower, or better, with the four strata design.

Telephone Survey Instrument Design

We developed a questionnaire for the evaluation with separate sections dedicated to the verification of distributed lamps and the process evaluation. The first section of the survey instrument is dedicated to verifying the distribution and usage of lamps recorded in the SDG&E program tracking database including:

- Verification of the number of lamps distributed,
- Verification of lamps in use now,
- If not in use now, reason why not,
- If not in use now, do they still have the lamp, are they planning on using it, and under what conditions would they do so,

The next section of the participant survey instrument was designed to obtain a variety of information for the process evaluation including:

- How participants heard of the lighting turn-in program,
- The reasons for program participation,
- Customer perceptions on how the program has helped them manage their energy bills,
- Participant satisfaction and recommended program improvements,
- Whether the participant networked with their peers about the program and the program measures, and
- Whether the networking resulted in any non-program procurements and use of identical measures by those peers.

The survey also contained a series of demographic questions. The following demographics were captured with the survey:

- Home ownership status,
- Number of people in household,
- Primary language of household,
- Level of education completed, and
- 2002 household income.

RLW submitted the survey instrument to the SDG&E project manager and other interested parties for a final review and ultimately approval.

Telephone Survey Data Collection

Using the survey instrument described above, telephone surveys were conducted from RLW's CA office. All telephone surveyors were provided instruction on program operation, proper etiquette for contacting participants, and how to interpret participant responses.

All survey calls will be tracked and any refusals or incomplete responses will be recorded. Upon completing each interview, the telephone survey manager reviewed the survey for accuracy and completeness and then entered the data into an electronic database designed specifically for this survey by the project analyst.

Data were validated automatically using imbedded database functionality. The entered data were also continuously reviewed by the telephone survey manager. Prior to analysis, the project analyst thoroughly performed a quality control check on the data, identifying and correcting any illogical or unreasonable responses.

Table 36 presents the dispositions of the telephone survey data collection effort. We attempted to contact a total of 218 participants. Of these 218 participants, 125 completed a telephone survey, corresponding to conversion rate of 57.3%[11]. Only 5 participants refused to complete the survey, which is a refusal rate of only 2.3%.

Disposition	# of Participants
Total	**218**
Left Message	26
Wrong Number	18
Disconnected	16
No Answer	12
Busy	5
Refusal	5
Callback	3
Cannot remember program.	3
No phone number/cannot locate #	3
Claims no participation in program.	1
Participant recently passed away.	1
Completed	**125**
Conversion Rate	**57.3%**

Table 36: Telephone Survey Dispositions

Lamp Verification Analysis

Model-Based Statistical Sampling or MBSS™ was used to extrapolate the sample results to the target population. The general idea behind model-based statistics is that there is a relationship between the variable of interest – in this case, number of lamps distributed – and a variable that is known for the entire population – in this case, the program tracking number of lamps distributed. Using this prior information allows for greater precision with a given sample size because the prior information eliminates some of the statistical uncertainty.

The estimate of the number of lamps distributed in the population is expressed as the ratio of the sample average number of lamps distributed to the sample average program tracking number of lamps distributed times the population total program tracking number of lamps distributed.

$$Y = y/x\ X$$

Where:

Y is the population total number of lamps distributed

[11] The conversion rate is defined as the ratio of successfully completed surveys to all attempted contacts.

y is the average number of lamps distributed in the sample

X is the population total program tracking number of lamps distributed

x is the average program tracking number of lamps distributed in the sample.

Lamp distribution and usage results for the overall program are calculated in the next chapter. Results are also disaggregated for torchieres versus CFLs.

Theoretical Background

The sample design discussion in the methodology section of this report described the sample designs used in this study. Therefore this section will describe in more detail the methods used to extrapolate the results to the target population. Three topics will be described:

- Case weights
- Balanced stratification to calculate case weights
- Stratified ratio estimation using case weights.

Case Weights

Background

Given observations of a variable *y* in a stratified sample, estimate the population total *Y*.

Note that the population total of *y* is the sum across the *H* strata of the subtotals of y in each stratum. Moreover each subtotal can be written as the number of cases in the stratum times the mean of *y* in the stratum. This gives the equation:

$$Y = \sum_{h=1}^{H} N_h \mu_h$$

Motivated by the preceding equation, we estimate the population mean in each stratum using the corresponding sample mean. This gives the conventional form of the stratified-sampling estimator, denoted $\hat{Y}$, of the population total *Y:*

$$\hat{Y} = \sum_{h=1}^{H} N_h \bar{y}_h$$

With a little algebra, the right-hand side of this equation can be rewritten in a different form:

$$\begin{aligned} \hat{Y} &= \sum_{h=1}^{H} N_h \bar{y}_h \\ &= \sum_{h=1}^{H} N_h \left(\frac{1}{n_h} \sum_{k \in s_h} y_k \right) \\ &= \sum_{k=1}^{n} \left(\frac{N_h}{n_h} \right) y_k \end{aligned}$$

Motivated by the last expression, we define the ***case weight*** of each unit in the sample to be $w_k = \frac{N_h}{n_h}$. Then the conventional estimate of the population total can be written as a simple weighted sum of the sample observations:

$$\hat{Y} = \sum_{k=1}^{n} w_k y_k$$

The case weight w_k can be thought of as the number of units in the population represented by unit *k* in the sample. The conventional sample estimate of the population total can be obtained by calculating the weighted sum of the values observed in the sample.

Calculating the Case Weights Using Balanced Post-Stratification

Balanced post-stratification was used to calculate the case weights associated with the final participant sample. In this approach, the sample units are sorted by the stratification variable, program tracking number of lamps distributed, and then divided as equally as possible among the strata. Then the first stratum cutpoint is determined midway between the values of the stratification variable for the last sample case in the first stratum and the first sample case in the second stratum. The remaining strata cutpoints are determined in a similar fashion. Then the population sizes are tabulated within each stratum. Finally the case weights are calculated in the usual way.

Table 37 shows an example, using the actual population and sample sizes for this study. In this example, the program population of participants has been stratified into four strata based on the number of lamps distributed as shown in the tracking system. For example, the first stratum consists of all participants that received less than or equal to 5 lamps. The maximum number of lamps in each stratum is called the stratum cut point. There are 4,538 participants in this stratum and they account for 17,229 lamps in the population. The estimate of the number of lamps distributed was obtained from the measured number of lamps distributed found in a total sample of 125 participants. Column 5 of Table 37 shows that the sample contains 61 sites from the first stratum. Each of these 61 projects can be given a case weight of 4,538/61 = 74.393.

Stratum	Max. # Lamps	Population Size	Population # Lamps	Sample Size	Case Weight
1	5	4,538	17,229	61	74.393
2	6	410	2,460	7	58.571
3	10	1,931	17,927	40	48.275
4	12	451	5,152	17	26.529
Total		**7,330**	**42,768**	**125**	

Table 37: Telephone Sample Case Weights

Stratified Ratio Estimation

Ratio estimation is used to estimate the population total *Y* of the target variable *y* taking advantage of the known population total *X* of a suitable explanatory variable *x*. The ratio estimate of the population total is denoted $\hat{Y}_{ra}$ to distinguish it from the ordinary stratified sampling estimate of the population total, which is denoted as $\hat{Y}$.

Motivated by the identity $Y = BX$, we estimate the population total *Y* by first estimating the population ratio *B* using the sample ratio $b = \bar{y}/\bar{x}$, and then estimating the population total as the product of the sample ratio and the known population total *X*. Here the sample means are calculated using the appropriate case weights. This procedure can be summarized as follows:

$$\begin{aligned}
\hat{Y}_{ra} &= b\,X \quad \text{where} \\
b &= \frac{\overline{y}}{\overline{x}} \\
\overline{y} &= \frac{1}{\hat{N}}\sum_{k=1}^{n} w_k\, y_k \\
\overline{x} &= \frac{1}{\hat{N}}\sum_{k=1}^{n} w_k\, x_k \\
\hat{N} &= \sum_{k=1}^{n} w_k
\end{aligned}$$

The conventional 90 percent confidence interval for the ratio estimate of the population total is usually written as

$$\begin{aligned}
\hat{Y}_{ra} &\pm 1.645\sqrt{V\left(\hat{Y}_{ra}\right)} \quad \text{where} \\
V\left(\hat{Y}_{ra}\right) &= \sum_{h=1}^{H} N_h^2\left(1-\frac{n_h}{N_h}\right)\frac{s_h^2(e)}{n_h} \\
s_h^2(e) &= \frac{1}{n_h-1}\sum_{k\in s_h}\left(e_k-\overline{e}_h\right)^2 \\
e_k &= y_k - b\,x_k
\end{aligned}$$

We can calculate the relative precision of the estimate $\hat{Y}_{ra}$ using the equation

$$rp = \frac{1.645\sqrt{V\left(\hat{Y}_{ra}\right)}}{\hat{Y}_{ra}}$$

MBSS theory has led to an alternative procedure to calculate confidence intervals for ratio estimation, called model-based domains estimation. This method yields the same estimate as the conventional approach described above, but gives slightly different error bounds. This approach has many advantages, especially for small samples, and has been used throughout this study.

Under model-based domains estimation, the ratio estimator of the population total is calculated as usual. However, the variance of the ratio estimator is estimated from the case weights using the equation

$$V\left(\hat{Y}_{ra}\right) = \sum_{k=1}^{n} w_k\left(w_k-1\right)e_k^2$$

Here w_k is the case weight discussed above and e_k is the sample residual $e_k = y_k - b\,x_k$. Then, as usual, the confidence interval is calculated as

$$\hat{Y}_{ra} \pm 1.645\sqrt{V\left(\hat{Y}_{ra}\right)}$$

and the achieved relative precision is calculated as

$$rp = \frac{1.645\sqrt{V\left(\hat{Y}_{ra}\right)}}{\hat{Y}_{ra}}$$

The model-based domains estimation approach is often much easier to calculate than the conventional approach since it is not necessary to group the sample into strata. In large samples, there is generally not much difference between the case-weight approach and the conventional approach. In small samples the case-weight approach seems to perform better. For consistency, we have come to use model-based domains estimation in most work.

This methodology generally gives error bounds similar to the conventional approach. Equally, the model-based domains estimation approach can be derived from the conventional approach by making the substitutions:

$$\begin{aligned} \bar{e}_h &\approx 0 \\ s_h^2(e) &\approx \frac{1}{n_h}\sum_{k\in s_h} e_k^2 \end{aligned}$$

In the first of these substitutions, we are assuming that the within-stratum mean of the residuals is close to zero in each stratum. In the second substitution, we have replaced the within-stratum variance of the sample residual ***e,*** calculated with $n_h - 1$ degrees of freedom, with the mean of the squared residuals, calculated with n_h degrees of freedom.

Model-based domains estimation is appropriate as long as the expected value of the residuals can be assumed to be close to zero. This assumption is checked by examining the scatter plot of *y* versus *x*. It is important to note that the assumption affects only the error bound, not the estimate itself. $\hat{Y}_{ra}$ will be essentially unbiased as long as the case weights are accurate.

Process Analysis

The project analyst analyzed the results of the telephone survey. The quantitative process survey analysis was carried out using SPSS, a commonly used statistical software package. RLW calculated weighted frequencies, means, and cross tabulations of data, where appropriate, to provide unbiased estimates of population characteristics. All statistical significance tests were conducted at the 90% level of confidence, and statistically significant differences are shaded in gray. These tests have been used to make comparisons among various demographic groups.