EVALUATION
OF YEAR 2001
SUMMER INITIATIVES
POOL PUMP PROGRAM

Program Effects
Assessment Report

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Prepared for:

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

EXECUTIVE SUMMARY

This report provides a baseline characterization of current equipment in the residential swimming pool markets and assesses the impacts of the 2001 timer and pump and motor rebate programs offered by three California utilities. These programs were authorized by the California Public Utilities Commission as part of its Summer Initiative (SI) aimed at reducing peak load in the summer of 2001. The objective of this report is to provide the reader with a description of how these programs have impacted summer peak load and what factors determine the magnitude of that impact.

The SI Pools Programs implemented by Pacific Gas & Electric Company (PG&E), Southern California Edison Company (SCE), and San Diego Gas & Electric Company (SDG&E) had two major components.

- The Timer Switch component of each program involves offering pool owners an incentive to change the operating hours for their pool pump from on-peak to off-peak hours. Pool pumps, which generally range in size between 1/2 and 2 horsepower, are often controlled by a manually adjusted clock switch that is part of the pool pumping and filtering control system. Since these pumps do not need to run all day to keep a pool clean, running the pool pump during a utility's system peak hours contributes unnecessarily to the peak demand. The pool pump scheduling strategy involves setting (or resetting) a pump’s control timer to prevent the pump from running during the system peak hours.
- The second component of the programs involves providing rebates or incentives to pool owners to replace existing pool pumps and motors with more efficient pumps and motors. For SCE and SDG&E, customers could receive rebates for replacing a single-speed pump/motor with a higher efficiency pump/motor. For PG&E, customers could receive a rebate for converting a single-speed pump/motor to a two-speed pump/motor. (Although SCE also offered rebates for two-speed pump/motors, their program was not targeted at this type of replacement. Fewer than five customers received rebates from SCE for two-speed pump/motors.)

The data for performing the evaluation of the Pool Pump Programs were collected through on-site audit verification visits that were made in the fall of 2001 to 300 households with pools who participated in a utility’s pool pump program. The visits were used to confirm and verify changes that program participants had made in pool pump operation as a result of participating in the SI Pools Program during the summer of 2001.

Participation in the pool programs during 2001 was as follows:

- For PG&E, 30,500 customers participated in the timer component of PG&E's program and 53 participated in the two-speed pump/motor replacement component.[1]
- For SCE, 47,044 customers participated in the program's timer component and 8,200 participated in the pump/motor replacement component.
- For SDG&E, 14,639 customers participated in the program's timer component and 4,984 participated in the pump/motor replacement component.

Analysis of data collected regarding the scheduling of pool pump operation for customers who participated in the timer components of the programs revealed that these participants operated their pool pumps an average of 3.51 hours in PG&E's service area; 4.26 hours in SCE's service area; and 3.77 hours in SDG&E's service area. Participants in the timer components also shifted their use of pool pumps away from the peak period of noon to 6:00 p.m. While the baseline study had shown that between 30 to 50 percent of pool owners operated their pool pumps during the peak period (depending on hour and utility service area), the post assessment study has shown that less than 5 percent of the program participants operated their pool pumps during these peak hours.

Under the pump/motor replacement components of the programs of the three utilities, customers who purchased a qualifying energy-efficient pool pump/motor were eligible for a rebate. Assuming that the pool filtration system is operated 365 days per year, the aggregate kWh savings and reductions in aggregate demand from the pump/motor replacement component of the PY 2001 programs were estimated as follows:

- For SCE's program, kWh savings were estimated at 7.65 GWh.[2] The connected kW load of pool pumps/motors was reduced by 2.94 MW for SCE.
- For SDG&E's program, kWh savings were estimated at 6.60 GWh. The connected kW load of pool pumps/motors was reduced by 1.64 MW for SDG&E.
- For PG&E's program, kWh savings were estimated at 41.60 MWh. There were only 53 participants in PG&E's program during PY 2001. However, the initial results from the analysis of PG&E's program suggest that substantial

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[1] The relatively smaller number of customers participating in PG&E's pump/motor replacement component is a consequence of that component of the program not being fielded until late summer 2001.

[2] The procedure used to estimate savings for SCE may overstate savings, but by no more than 15 percent.

savings might be realized by operating a pump/motor at low speed for perhaps somewhat longer hours than has been the norm.

Analysis of the daily savings from each program’s pump/motor component focused on the effects of several factors: higher efficiency equipment; equipment downsizing; and changes in hours of use.

- With respect to the effects of higher efficiency equipment, measurements made during this study showed that kW demand for single-speed motors of a given horsepower appeared to be higher for the pool pumps/motors installed by customers participating in the programs of SCE and SDG&E than was measured for motors during the baseline study. On a component-only basis, improving the efficiency of a pump motor would be expected to decrease kW demand. However, the motors changed out during these programs were installed for existing pool filtration systems, and the effects of the improved motor efficiency could be masked by the interaction of the pump/motor with other components that increased kW demand.
- Analysis of the savings indicated that downsizing the pump/motor equipment was a significant factor in providing savings for the SCE and SDG&E programs. Equipment downsizing and changing out both the pump and motor was explicitly required for participation in SDG&E’s program. Information from pool service companies and program participants indicated that downsizing was often offered as an option to participants in SCE’s program by pool service contractors. Most (over 90 percent) of SCE program participants also changed out both the pump and motor.
- Reducing hours of use per day was also shown to be an important factor in providing savings for pump/motor replacement programs. (This was an explicit requirement in SDG&E’s program.)
- Analysis of data pertaining to PG&E’s program for replacing single-speed pump motors with two-speed motors indicated that such replacement could afford noticeable savings, particularly for the case where the two-speed motor was run at low speed (albeit for somewhat longer hours) to provide the needed filtration. These savings are realized even without requiring a reduction in motor size, although there would be additional savings if the program were enhanced to include a motor size reduction element (where applicable). Because there was only a small number of participants in PG&E’s program during 2001, extensive data are not available on how customers would choose to operate their two-speed motors. However, it is clear that substantial savings would be realized if customers were comfortable in operating the pump/motor at low speed for perhaps somewhat longer hours than has been their norm.

1. INTRODUCTION

In Decision 00-07-017, the California Public Utilities Commission adopted the Summer 2000 Energy Efficiency Initiative and requested proposals for funding under that initiative. Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E) each submitted a proposal to initiate a program targeted toward reducing the peak load from residential swimming pool pumps. (In certain areas of California such as the Central Valley and southern California, the filtration and pumping of a residential swimming pool can be second only to central air conditioning in terms of demand load between the peak hours of 12 noon and 6:00 p.m. during the week.) These programs were approved by the CPUC in the August 21, 2000 Ruling of Assigned Commissioners and Administrative Law Judge on Summer 2000 Energy Efficiency Initiative. Each utility then developed a program for its service territory to assist homeowners in reducing the peak load resulting from the filtration and water flow management of in-ground swimming pools.

Another key component of this initiative was to conduct a statewide study that 1) assessed the statewide market for residential swimming pool pumps and water management systems, 2) developed a baseline study that characterizes current practices of residential pool owners, and 3) measured and evaluated the impact of the utility programs on summer peak load for 2001. Under contract with Pacific Gas and Electric Company (PG&E), ADM Associates, Inc. (ADM) conducted the aforementioned studies for a statewide committee consisting of the three utilities.

1.1 PURPOSE OF THIS REPORT

The purpose of this report is to provide the final baseline estimates and impact analysis for the 2001 Summer Initiatives Pool Pump Program. Included in this report are the following:

- Brief descriptions of the SI Pools program in each IOU;
- Program results for each IOU and statewide in terms of peak demand reduction and overall demand reduction when compared to baseline conditions and technical potential;
- Analysis of which aspects of each IOU's program impacted pool owners and contractors behavior and if there were other factors that affected the program's outcome;
- Discussion of options for program improvement for each IOU in terms of implementation of current program elements and other additional elements that could improve long-term energy savings potential in terms of peak kW, off-peak kWh and on-peak kWh.

1.2 STUDY METHODOLOGY

The data collection and analysis procedures used for the assessment evaluation are summarized in this section. A fuller discussion of the methodology is provided in the report on the baseline study.[1]

The data for performing the evaluation of the Pool Pump Programs were collected through on-site audit verification visits that were made in the fall of 2001 to 300 households with pools who participated in a utility's pool pump program. The visits were used to confirm and verify changes that program participants had made in pool pump operation as a result of participating in the SI Pools Program during the summer of 2001.

The data collected were analyzed using standard statistical methods, including calculation of means, standard deviations, and correlations. Where appropriate, regression analysis was used to determine relationships among different variables.

1.3 SUMMARY OF MAJOR FINDINGS

Participation in the pool programs during 2001 was as follows:

- For PG&E, 30,500 customers participated in the timer component of PG&E's program and 53 participated in the two-speed pump/motor replacement component.
- For SCE, 47,044 customers participated in the program's timer component and 8,200 participated in the pump/motor replacement component.
- For SDG&E, 14,639 customers participated in the program's timer component and 4,984 participated in the pump/motor replacement component.

Analysis of data collected regarding the scheduling of pool pump operation for customers who participated in the timer components of the programs revealed that these participants operated their pool pumps an average of 3.51 hours in PG&E's service area; 4.26 hours in SCE's service area; and 3.77 hours in SDG&E's service area. Participants in the timer components also shifted their use of pool pumps away from the peak period of noon to 6:00 p.m. Less than 5 percent of the program participants operated their pool pumps during these peak hours.

Under the pump/motor replacement components of the programs of both SCE and SDG&E, customers who purchased a qualifying energy efficient pool single-speed pump/motor were eligible for a rebate. PG&E offered a two-speed pump/motor

[1] ADM Associates, Inc., *Evaluation of Year 2001 SI Pool Pump Program: Baseline and Market Characterization Report*, March 2002.

replacement program that focused on the conversion of single-speed pump/motor units with two-speed pump/motor units that were qualified as eligible for a rebate. Analysis of the aggregate daily savings from each program's pump/motor component focused on the effects of several major factors: higher efficiency equipment; equipment downsizing; and changes in hours of use.

1.4 ORGANIZATION OF REPORT

In addition to this introductory chapter, this report includes the following chapters.

- Chapter 2 briefly describes the utility programs being evaluated and provides summary statistics on program participation.
- Chapter 3 provides information on the characteristics of the pool filtration systems for customers who participated in the pools programs during 2001.
- Chapter 4 provides an analysis of hours of operation for pool pumps for program participants.
- Chapter 5 provides an assessment of demand reductions for the timer switch components of the programs.
- Chapter 6 provides an assessment of energy savings and demand reductions for the pump/motor replacement components of the programs.
- Chapter 7 provides a summary of results as they pertain to program design.
- Appendix A provides a discussion regarding the validation of a savings estimation procedure for the pump/motor replacement component of SCE's program.

2. PROGRAM DESCRIPTIONS AND PARTICIPATION RATES

This chapter provides brief descriptions of the Pools Programs implemented by the different utilities and summarizes the participation rates for the programs.

2.1 PROGRAM DESCRIPTIONS

The SI Pools Programs implemented by PG&E, SCE, and SDG&E had two major components: a timer switch component and a pump replacement component.

The Timer Switch component of each program involved offering pool owners an incentive to change the operating hours for their pool pump from on-peak to off-peak hours. Pool pumps, which generally range in size between 1/2 and 2 horsepower, are often controlled by a manually adjusted clock switch that is part of the pool pumping and filtering control system. Since these pumps do not need to run all day to keep a pool clean, running the pool pump during a utility's system peak hours contributes unnecessarily to the peak demand. The pool pump scheduling strategy involved setting (or resetting) a pump’s control timer to prevent the pump from running during the system peak hours.

Each utility provided incentives to customers who changed the settings on their pool pump timers to ensure that the pump motors did not run during peak hours.

- PG&E paid a $20 incentive to participants who set their swimming pool timer switch to operate during the off-peak period between 8 p.m. and 10 a.m. PG&E offered the program only to its residential electric customers with an in-ground swimming pool. The customers could not be on the time-of-use rate or have an operational solar heat pump system. PG&E had offered this same program in their Pilot study in the Summer of 2000 to 48,000 pool owners identified through the Home energy surveys, which resulted in 16,000 participants. Customers eligible for the 2000 program did not qualify for the 2001 program incentive.
- SCE offered incentives to customers who agreed to run their pool pumps anytime between 6:00 p.m. and 12 noon from June 1 through September 30, 2001. Customers enrolling in the program by April 30, 2001, received a $40 incentive, while customers enrolling thereafter received a $20 incentive.
- SDG&E offered an incentive of $20.00 to customers for shifting pool filtering hours from on peak to off peak hours. To be eligible for participating in SDG&E’s program, a customer had to have been filtering his/her pool at least two (2) hours during peak hours (12:00 noon - 6:00 p.m., Monday – Friday). To receive the incentive, a customer agreed to set the pool pump timer system to filter during off-peak hours only (anytime before 12:00 noon or after 6:00 p.m.).

The second component of the programs involved providing rebates or incentives to pool owners to convert existing pool pumps and/or motors to more efficient pumps or motors.

- For PG&E, customers could receive a $250 rebate for replacing a single-phase/single-speed pool pump and motor with an energy-efficient-rated, two-speed pool pump and motor. This component of PG&E's pool pump efficiency program was implemented from September 1, 2001 through December 31, 2001.
- For SCE, customers who purchased a qualifying energy efficiency pool pump between January 1, 2001, and September 30, 2001, were eligible for a rebate of up to $100. Customers replacing only a motor were eligible for rebates of $50. (Although SCE also offered rebates for two-speed pump/motors, their program was not targeted at this type of replacement. Fewer than five customers received rebates from SCE for two-speed pump/motors.) Customers had to reserve their rebate funds before purchasing the new motor. The pump had to be purchased within 30 days of the rebate reservation or by September 30, 2001. Rebate reservations were not accepted after September 30, 2001.
- For SDG&E, a customer could receive a rebate of $200 for replacing his/her existing pool motor and pump assembly with an energy efficient motor and pump assembly from a list of qualifying models that SDG&E had approved. The new assembly had to be half the horsepower of the existing assembly. (If the existing assembly was 1 horsepower, the replacement motor and pump assembly could be ¾ horsepower.)

2.2 PROGRAM PARTICIPATION

Participation in the different components of the utility pool pump programs by the end of 2001 is shown in Table 2-1.

Table 2-1. Number of Participants in Utility Pool Pump Programs

Program Component	***Utility Service Area***		
	PG&E	***SCE***	***SDG&E***
Timer component	30,500	47,044	14,639
Pump/motor replacement component	53	8,200	4,984

3. CHARACTERISTICS OF POOLS AND PUMP MOTORS FOR PROGRAM PARTICIPANTS

This chapter provides information on the characteristics of the pools and pump motors for customers who participated in the pools programs.

3.1 CHARACTERISTICS OF FILTRATION PUMP MOTORS

Nameplate information on the horsepower of motors for pool filtration pumps was collected during on-site visits to 293 households in the service areas of PG&E, SCE, and SDG&E who participated in a pool pump program during 2001. Table 3-1 reports on the average nameplate horsepower of filtration pump motors for the three areas. The numbers of pools visited in each service area and the percentages of pools with filtration pump motors of different horsepower are reported for the three utility service areas in Table 3-2.

Table 3-1. Average Horsepower of Filtration Pump Motors by IOU Service Area

IOU Service Area	Number of Pump Motors	Horsepower of Pump Motor	
		Average	Standard Deviation
PG&E	100	1.170	0.425
SCE	118	1.500	0.466
SDG&E	81	1.225	0.464

Table 3-2. Percentage Distributions of Filtration Pump Motors by Pump Motor Horsepower by IOU Service Area

	Utility Service Area		
	PG&E	SCE	SDG&E
Number of pool sites surveyed	100	118	81
Percent with ½ hp motors	5.0%	1.7%	1.2%
Percent with ¾ hp motors	20.0%	8.5%	30.9%
Percent with 1 hp motors	38.0%	22.0%	23.5%
Percent with 1.5 hp motors	25.0%	29.7%	27.2%
Percent with 2 hp motors	12.0%	38.1%	17.3%
Total	100.0%	100.0%	100.0%

3.2 KW DEMAND PER HORSEPOWER FOR FILTRATION PUMP MOTORS

For 55 pools inspected during the post-program on-site visits, the kW demand of the filtration pump motor was measured. These 55 pools were for participants in the utility programs and were chosen as a sample from among program participants that was independent of the sample used for the baseline measurements. That is, the baseline and post-program samples are independent samples, not a pre-post sample where measurements would be taken on the same customers at two points in time. As with the baseline measurements, a true RMS wattmeter (AEMC Model 3910 TRMS Power Meter) was used to make the post-program measurements.

Data gathered for the baseline study showed that the average measured kW demands for filtration pump motors of a given size are fairly similar across IOU service areas. Accordingly, the data on measured kW that were collected during the post-program visits were combined for analysis. The average values for kW demand for motors of different horsepower are reported in Table 3-3.

Table 3-3. kW demand for Filtration Pump Motors by Pump Motor Horsepower for Combined Service Areas

Pump Motor Horsepower	Baseline Data			Post-Program Data		
	Number of Motors Measured	Average Measured kW Usage	Standard Deviation of kW Usage	Number of Motors Measured	Average Measured kW Usage	Standard Deviation of kW Usage
½ hp motors	2	0.857	0.081	2	1.120	
¾ hp motors	32	1.106	0.205	17	1.249	0.123
1 hp motors	90	1.223	0.281	15	1.305	0.242
1 ½ hp motors	47	1.440	0.327	11	1.736	0.177
2 hp motors	47	1.728	0.349	2	1.785	0.573
All motors	218	1.359	0.371	47	1.398	0.292

4. ANALYSIS OF HOURS OF OPERATION FOR POOL PUMPS

Data about the hours that pool pumps are operated were gathered through the on-site inspection of pool pumps for households that participated in the Year 2001 Summer Initiatives Pool Pump Programs sponsored by PG&E, SCE, and SDG&E. The information collected was analyzed to determine (1) average hours of operation for pool pumps in the program and (2) profiles showing the percentage of pool pumps on during different hours of the day. The results of that analysis are presented in this chapter.

4.1 HOURS OF POOL PUMP OPERATION FROM SURVEY DATA

Information was used to verify the hours of pool pump operation for households participating in the Year 2001 Summer Initiative Pool Pump Programs that was obtained through on-site inspections of pool pump timer settings for samples of participating households served by PG&E, SCE, or SDG&E. Table 4-1 shows the average hours of operation for pool pumps in the different service territories developed from the data collected through the on-site inspections.

Table 4-1. Comparison of Baseline and Program Hours of Pool Pump Operation by Utility Service Area

	Utility Service Area		
	PG&E	***SCE***	***SDG&E***
Baseline			
Number of Pools	131	165	127
Average Hours On	4.115	4.525	3.862
Standard Deviation, Hours On	2.009	2.599	1.763
Program			
Number of Pools	96	116	81
Average Hours On	3.505	4.260	3.772
Standard Deviation, Hours On	1.815	1.997	1.275

Table 4-1 shows some differences among service areas with respect to changes in average operating hours for pool pumps between the baseline and program periods. A series of t-tests was used to test whether differences between the two periods were statistically significant for the three service areas. The results of these t-tests are reported in Table 4-2. The change in average hours between the baseline and program periods is statistically significant for PG&E, but not for SCE and SDG&E.

Table 4-2. Results of t-tests for Differences in Hours of Pump Operation between Baseline and Program Periods by Utility Service Area

Sites Reported for	Hours Operated per Baseline			Hours Operated per Program			T statistic	Probability
	N	Mean	Standard Deviation	N	Mean	Standard Deviation		
All sites	423	4.199	2.208	293	3.878	1.787	2.066	0.0392
PG&E	131	4.115	2.009	96	3.505	1.815	2.350	0.0196
SCE	165	4.525	2.599	116	4.260	1.997	0.924	0.3561
SDG&E	127	3.862	1.763	81	3.772	1.275	0.400	0.6893

4.2 HOURLY PROFILES FOR PERCENTAGE OF PUMPS ON

For purposes of evaluating the effects of the pool pump programs, it is important to determine changes in the profile for the percentage of pumps that are on at any hour of the day. Accordingly, pump operating profiles were developed from data that were collected during the post-program field inspections regarding the starting and stopping times for the pool pumps. The profiles developed show the percentage of pool pumps that are operating for the various hours of the day.

The data for the percentage-on profiles developed from the on-site inspection data for the various areas are shown in Tables 4-3, 4-4, and 4-5. Graphical comparisons of various profiles are made in Figures 4-1, 4-2, and 4-3.

Inspection of the data and the graphical profiles clearly shows that customers participating in the pool pump programs for all three utilities shifted the operation of their pool pump motors away from the peak hours of noon through 6:00 p.m.

Table 4-3. Percentages of Pumps On during Given Hour of Day for Baseline and Program Periods for PG&E Service Area

Hour of Day	Percentages of Pumps On			Hour of Day	Percentages of Pumps On		
	Baseline Interview	Baseline On-Site	Program On-Site		Baseline Interview	Baseline On-Site	Program On-Site
1	5.6%	7.6%	17.0%	13	31.5%	28.8%	2.0%
2	5.6%	7.6%	12.0%	14	25.9%	24.2%	1.0%
3	10.2%	16.7%	17.0%	15	18.5%	19.7%	1.0%
4	15.7%	19.7%	18.0%	16	16.7%	19.7%	0.0%
5	20.4%	25.8%	23.0%	17	10.2%	13.6%	0.0%
6	24.1%	27.3%	29.0%	18	4.6%	9.1%	1.0%
7	33.3%	30.3%	36.0%	19	2.8%	7.6%	2.0%
8	29.6%	27.3%	33.0%	20	0.9%	4.5%	5.0%
9	33.1%	33.3%	30.0%	21	2.8%	6.1%	25.0%
10	35.2%	33.3%	22.0%	22	2.8%	6.1%	29.0%
11	41.0%	39.4%	5.0%	23	3.7%	6.1%	29.0%
12	38.9%	39.4%	2.0%	24	3.2%	6.1%	22.0%

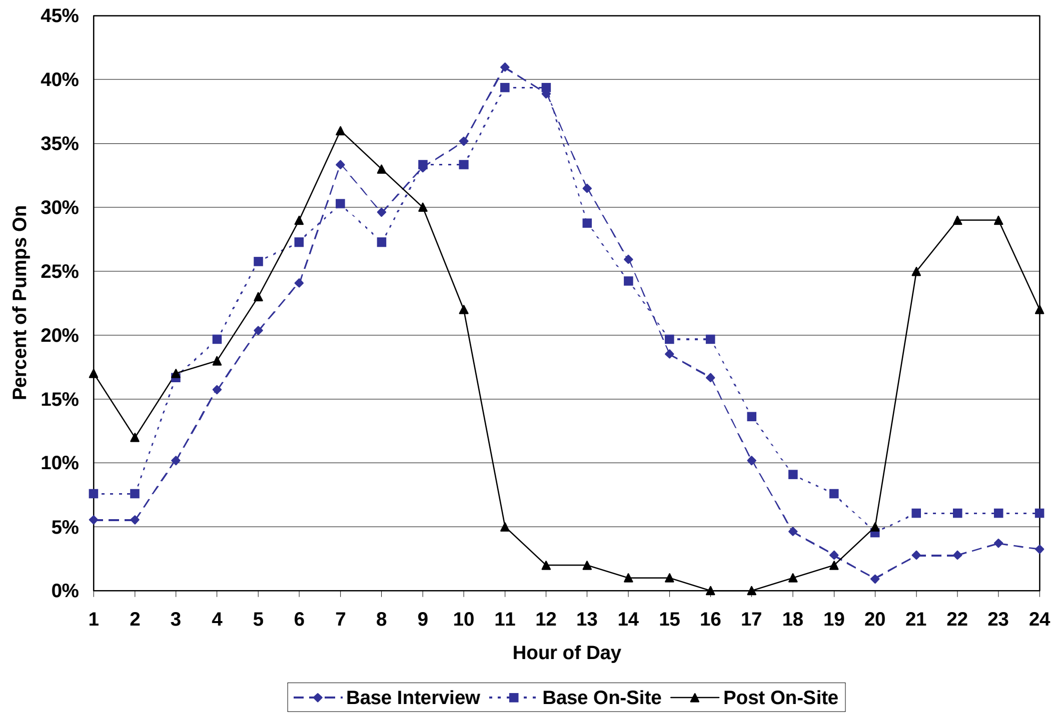

Figure 4-1. Comparison of Baseline versus Program Percentage-On Profiles for PG&E

Table 4-4. Percentages of Pumps On during Given Hour of Day for Baseline and Program Periods for SCE Service Area

Hour of Day	Percentages of Pumps On			Hour of Day	Percentages of Pumps On		
	Baseline Interview	Baseline On-Site	Program On-Site		Baseline Interview	Baseline On-Site	Program On-Site
1	5.2%	8.5%	11.8%	13	48.1%	53.7%	5.0%
2	8.2%	8.5%	10.1%	14	42.2%	46.3%	5.0%
3	11.2%	9.8%	10.1%	15	28.0%	37.8%	5.0%
4	11.6%	11.0%	10.9%	16	20.1%	26.8%	5.0%
5	9.7%	7.3%	10.1%	17	11.6%	17.1%	5.0%
6	10.4%	9.8%	13.4%	18	9.0%	7.3%	5.9%
7	17.4%	19.5%	22.7%	19	7.5%	11.0%	15.1%
8	23.1%	20.7%	31.1%	20	6.0%	14.6%	19.3%
9	37.3%	35.4%	35.3%	21	6.0%	15.9%	21.8%
10	42.7%	40.2%	33.6%	22	3.7%	14.6%	21.8%
11	49.3%	46.3%	27.7%	23	4.5%	13.4%	13.4%
12	50.0%	53.7%	11.8%	24	3.4%	11.0%	10.9%

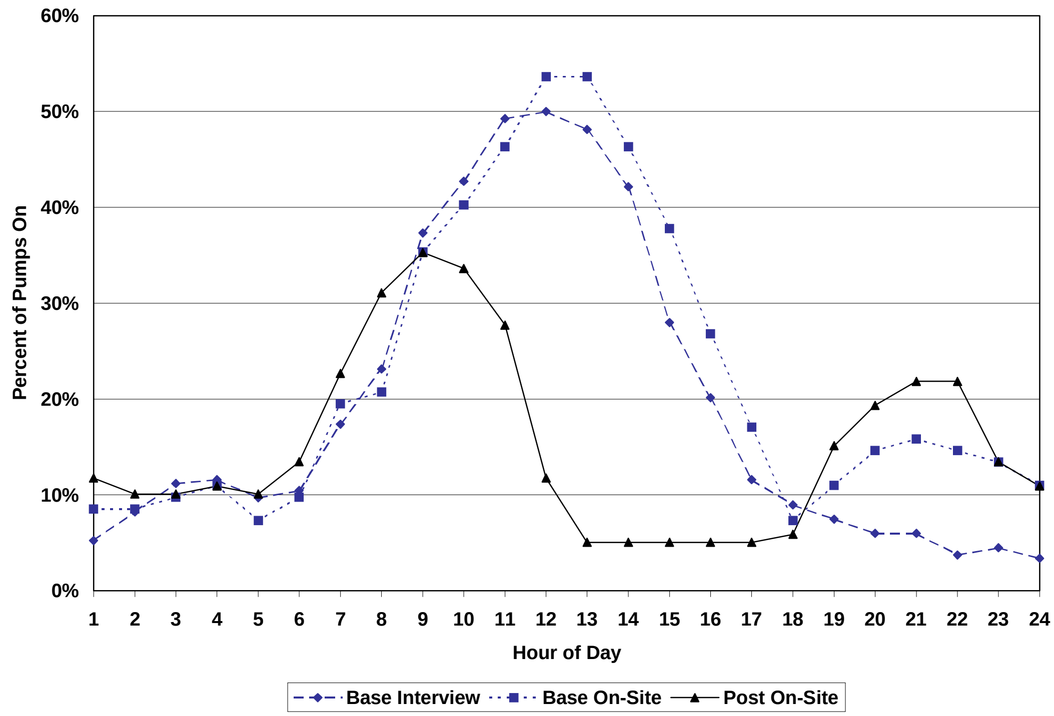

Figure 4-2. Comparison of Baseline versus Program Percentage-On Profiles for SCE

Table 4-5. Percentages of Pumps On during Given Hour of Day for Baseline and Program Periods for SDG&E Service Area

Hour of Day	Percentages of Pumps On			Hour of Day	Percentages of Pumps On		
	Baseline Interview	Baseline On-Site	Program On-Site		Baseline Interview	Baseline On-Site	Program On-Site
1	1.8%	1.4%	2.5%	13	34.5%	24.3%	1.2%
2	2.7%	1.4%	2.5%	14	27.9%	21.4%	0.0%
3	2.7%	1.4%	3.7%	15	19.9%	18.6%	0.0%
4	1.8%	2.9%	6.2%	16	18.1%	15.7%	0.0%
5	8.8%	8.6%	8.6%	17	7.1%	7.1%	1.2%
6	13.3%	12.9%	12.3%	18	3.5%	2.9%	1.2%
7	22.6%	28.6%	22.2%	19	2.7%	5.7%	12.3%
8	31.6%	34.3%	42.0%	20	1.8%	2.9%	16.0%
9	35.4%	40.0%	60.5%	21	0.9%	1.4%	16.0%
10	39.4%	42.9%	66.7%	22	0.9%	1.4%	13.6%
11	53.1%	50.0%	61.7%	23	1.8%	2.9%	9.9%
12	44.2%	42.9%	35.8%	24	1.3%	2.9%	3.7%

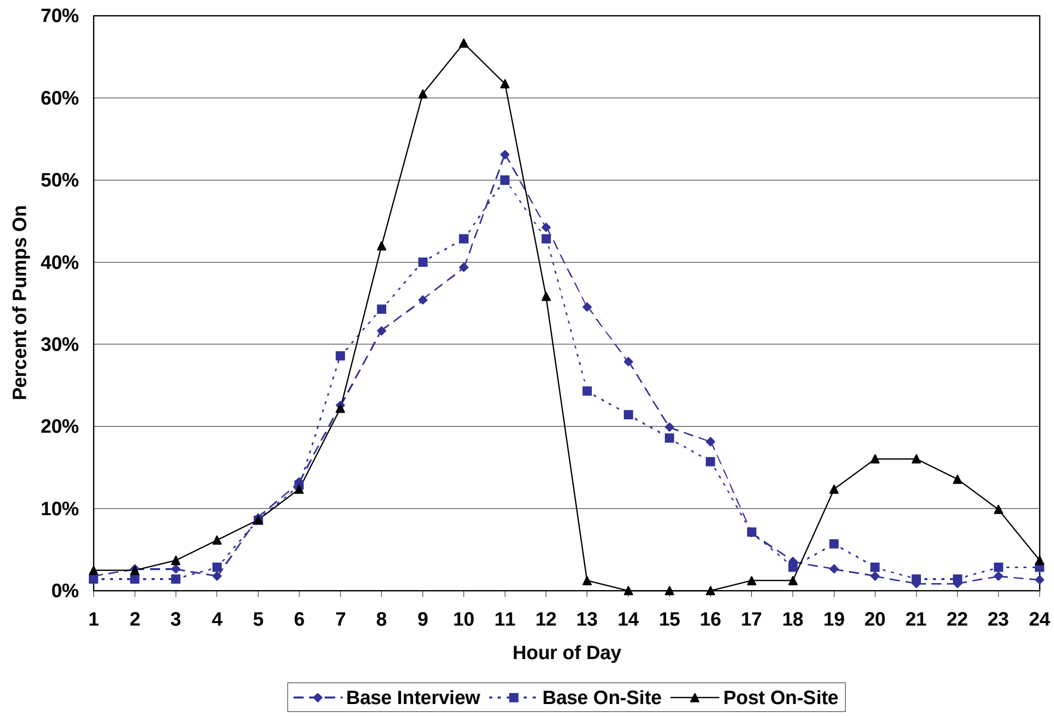

Figure 4-3. Comparison of Baseline versus Program Percentage-On Profiles for SDG&E

4.3 HOURLY PROFILES FOR AVERAGE PUMP KW

The kW data collected during the on-site inspections allow development of hourly profiles in terms of average kW per hour for the three IOU service areas for both the baseline period and the program period. That is, for each hour of the day the kW demand when a pool pump is on is averaged across all pumps. The average kW per hour for the baseline and program periods are reported in Table 4-6 for the three IOUs. These data are then plotted in Figure 4-4 for PG&E, in Figure 4-5 for SCE, and in Figure 4-6 for SDG&E.

Table 4-6. Average Hourly kW Profiles for Baseline and Program Periods for Different Utility Service Areas

Hour of Day	PG&E		SCE		SDG&E	
	Baseline	Program	Baseline	Program	Baseline	Program
1	0.118	0.208	0.117	0.217	0.015	0.036
2	0.123	0.149	0.106	0.173	0.028	0.028
3	0.229	0.192	0.124	0.178	0.028	0.051
4	0.289	0.196	0.136	0.186	0.043	0.073
5	0.385	0.252	0.077	0.170	0.121	0.102
6	0.403	0.342	0.120	0.229	0.210	0.165
7	0.473	0.444	0.224	0.394	0.408	0.306
8	0.442	0.412	0.270	0.538	0.493	0.553
9	0.576	0.376	0.470	0.656	0.571	0.782
10	0.652	0.249	0.546	0.615	0.585	0.900
11	0.783	0.047	0.654	0.501	0.688	0.784
12	0.789	0.024	0.729	0.195	0.592	0.393
13	0.562	0.018	0.735	0.090	0.342	0.008
14	0.452	0.012	0.674	0.056	0.287	0.000
15	0.369	0.012	0.546	0.081	0.254	0.000
16	0.362	0.000	0.379	0.081	0.226	0.000
17	0.227	0.000	0.223	0.082	0.102	0.018
18	0.139	0.014	0.073	0.092	0.044	0.018
19	0.110	0.020	0.128	0.273	0.077	0.136
20	0.057	0.049	0.196	0.349	0.037	0.215
21	0.118	0.302	0.201	0.399	0.019	0.202
22	0.118	0.361	0.192	0.382	0.019	0.165
23	0.110	0.376	0.186	0.208	0.036	0.104
24	0.076	0.269	0.132	0.187	0.025	0.043

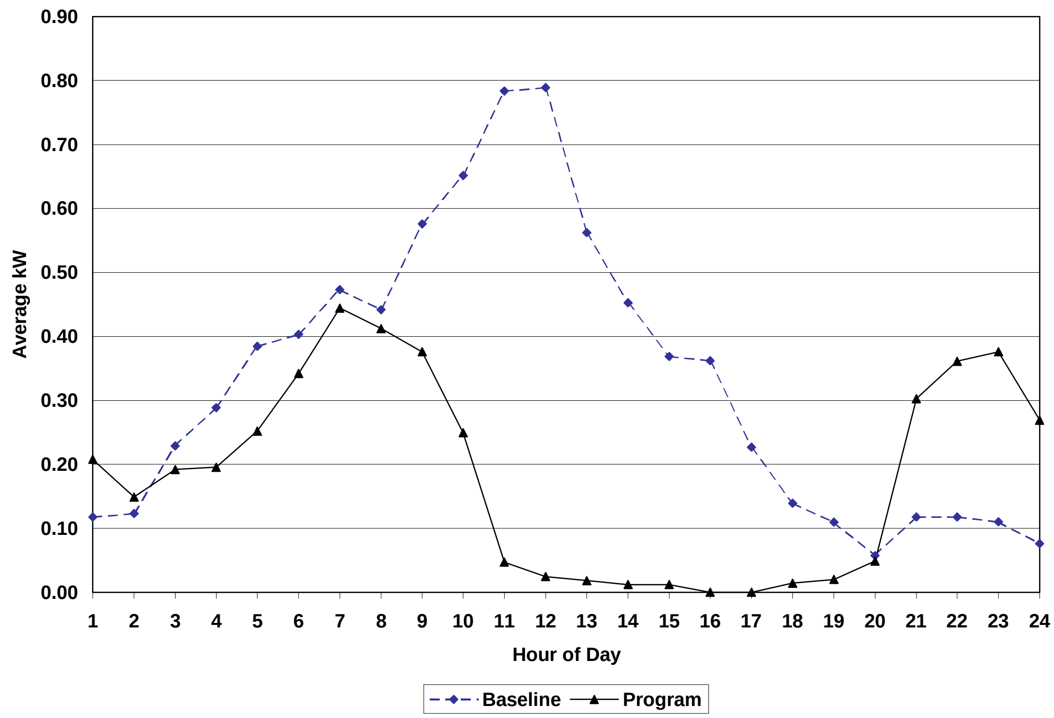

Figure 4-4. Comparison of Hourly Average kW Profiles for Baseline and Program Periods for PG&E

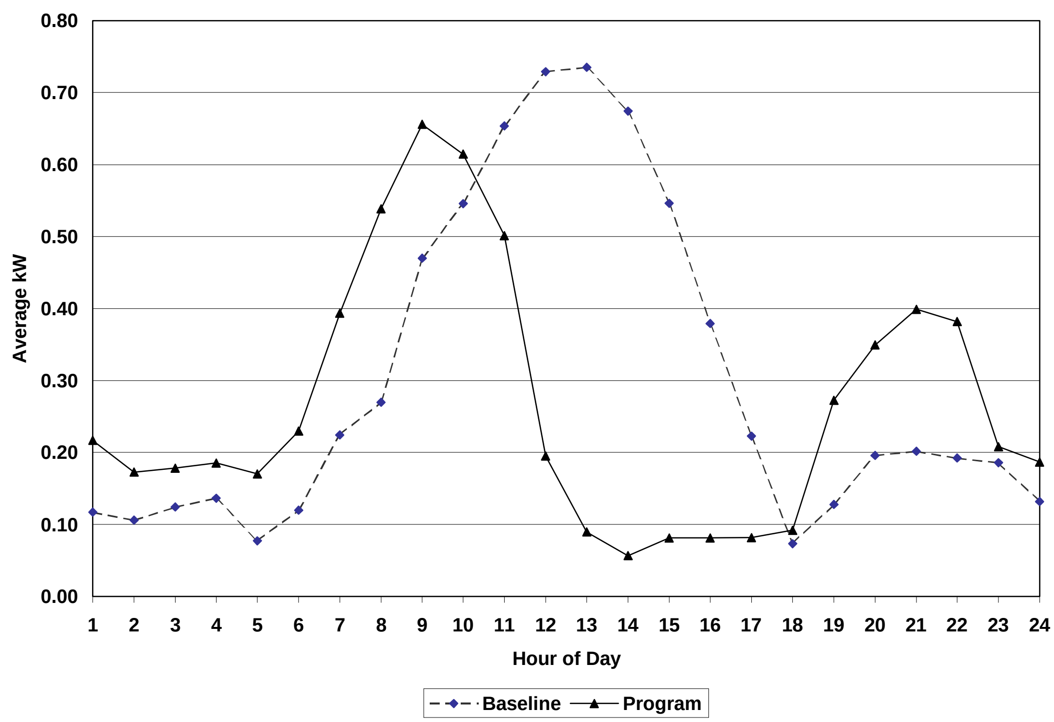

Figure 4-5. Comparison of Hourly Average kW Profiles for Baseline and Program Periods for SCE

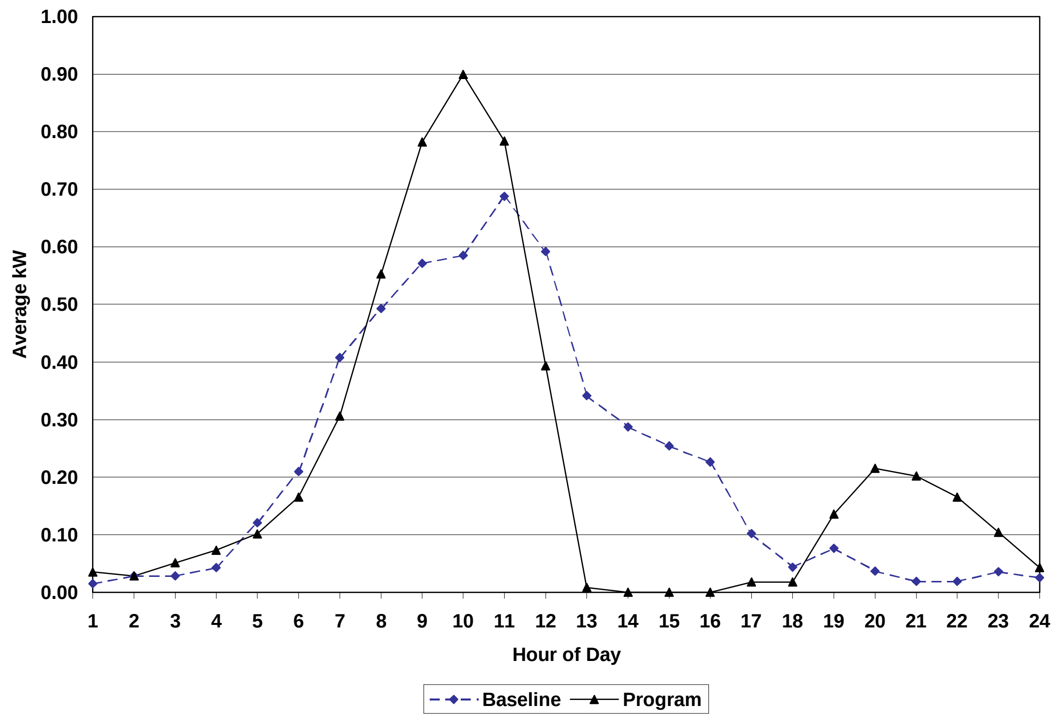

Figure 4-6. Comparison of Hourly Average kW Profiles for Baseline and Program Periods for SDG&E

5. ASSESSMENT OF DEMAND REDUCTION FROM TIMER COMPONENT OF PROGRAMS

One component of the pool pump programs was the timer switch component to encourage customers to shift operation of their pool pumps from on-peak to off-peak hours. To assess the demand reductions associated with this program component, changes in the load resulting from the operation of the pool pumps by participants in the programs needs to be determined.

The aggregate load at any hour of the day that is associated with pool pumps being operated can be estimated as the product of three factors:

- Number of pool pumps operated by participants in the programs;
- Percentage of pool pumps in place that are being operated during a given hour; and
- Estimated kW demand by a pool pump when it is operating.

Data on these factors were developed as follows:

- The numbers of pools for participants in the timer component of the programs were reported in Chapter 2.
- Estimated percentages of pools in place that operate during a given hour were reported in Chapter 4 for both baseline conditions and for program participants.
- Estimated kW demand by a pool pump when it is operating were reported in the baseline report.

Table 5-1 reports the numbers of pools for participants in the timer component of the programs and the average estimated kW per pool pump for the three IOU service areas.

Table 5-1. Number of Pools Participating in Timer Component and Estimated Average kW per Pool by IOU Service Area

	Utility Service Area		
	PG&E	***SCE***	***SDG&E***
Number of pools participating in timer component	30,500	47,044	14,639
Average kW per pool pump	1.718	1.374	1.417

The estimated loads associated with pool pump operation for program participants at different hours of the day under baseline conditions and under program participation conditions are shown in Table 5-2 for PG&E, Table 5-3 for SCE, and Table 5-4 for SDG&E. The baseline and program load profiles are compared graphically in Figure 5-1 for PG&E, Figure 5-2 for SCE, and Figure 5-3 for SDG&E.

Note that the data for SDG&E are presented to provide a consistent comparison against the other two utilities. In fact, SDG&E required that participants in the timer switch component of their program be operating their pool filtering equipment for at least two hours during the peak period. In effect, this requirement redefines the baseline for SDG&E in that the comparison is not against the general population of pool owners (as represented by the baseline study) but rather is the subset of pool owners who have been operating their pool equipment primarily during peak hours. Redefining the baseline conditions increases the baseline load significantly and hence the load reduction.

Table 5-2. Aggregate Electric Load from Swimming Pool Pumps by Hour of Day under Baseline and Program Conditions for PG&E Service Area

Hour of Day	Baseline Conditions		Program Conditions		Load Reduction (mW)
	Percent On	Load (mW)	Percent On	Load (mW)	
1	7.6%	4.0	17.0%	8.9	-4.9
2	7.6%	4.0	12.0%	6.3	-2.3
3	16.7%	8.8	17.0%	8.9	-0.2
4	19.7%	10.3	18.0%	9.4	0.9
5	25.8%	13.5	23.0%	12.1	1.5
6	27.3%	14.3	29.0%	15.2	-0.9
7	30.3%	15.9	36.0%	18.9	-3.0
8	27.3%	14.3	33.0%	17.3	-3.0
9	33.3%	17.4	30.0%	15.7	1.7
10	33.3%	17.4	22.0%	11.5	5.9
11	39.4%	20.6	5.0%	2.6	18.0
12	39.4%	20.6	2.0%	1.0	19.6
13	28.8%	15.1	2.0%	1.0	14.0
14	24.2%	12.7	1.0%	0.5	12.2
15	19.7%	10.3	1.0%	0.5	9.8
16	19.7%	10.3	0.0%	0.0	10.3
17	13.6%	7.1	0.0%	0.0	7.1
18	9.1%	4.8	1.0%	0.5	4.2
19	7.6%	4.0	2.0%	1.0	2.9
20	4.5%	2.4	5.0%	2.6	-0.3
21	6.1%	3.2	25.0%	13.1	-9.9
22	6.1%	3.2	29.0%	15.2	-12.0
23	6.1%	3.2	29.0%	15.2	-12.0
24	6.1%	3.2	22.0%	11.5	-8.3

Table 5-3. Aggregate Electric Load from Swimming Pool Pumps by Hour of Day under Baseline and Program Conditions for SCE Service Area

Hour of Day	Baseline Conditions		Program Conditions		Load Reduction (mW)
	Percent On	Load (mW)	Percent On	Load (mW)	
1	8.5%	5.5	11.8%	6.2	-0.7
2	8.5%	5.5	10.1%	5.3	0.2
3	9.8%	6.3	10.1%	5.3	1.0
4	11.0%	7.1	10.9%	5.7	1.4
5	7.3%	4.7	10.1%	5.3	-0.6
6	9.8%	6.3	13.4%	7.0	-0.7
7	19.5%	12.6	22.7%	11.9	0.7
8	20.7%	13.4	31.1%	16.3	-2.9
9	35.4%	22.9	35.3%	18.5	4.4
10	40.2%	26.0	33.6%	17.6	8.4
11	46.3%	29.9	27.7%	14.5	15.4
12	53.7%	34.7	11.8%	6.2	28.5
13	53.7%	34.7	5.0%	2.6	32.1
14	46.3%	29.9	5.0%	2.6	27.3
15	37.8%	24.4	5.0%	2.6	21.8
16	26.8%	17.3	5.0%	2.6	14.7
17	17.1%	11.1	5.0%	2.6	8.4
18	7.3%	4.7	5.9%	3.1	1.6
19	11.0%	7.1	15.1%	7.9	-0.8
20	14.6%	9.4	19.3%	10.1	-0.7
21	15.9%	10.3	21.8%	11.4	-1.1
22	14.6%	9.4	21.8%	11.4	-2.0
23	13.4%	8.7	13.4%	7.0	1.6
24	11.0%	7.1	10.9%	5.7	1.4

Table 5-4. Aggregate Electric Load from Swimming Pool Pumps by Hour of Day under Baseline and Program Conditions for SDG&E Service Area

Hour of Day	Baseline Conditions		Program Conditions		Load Reduction (mW)
	Percent On	Load (mW)	Percent On	Load (mW)	
1	1.4%	0.3	2.5%	1.3	-1.0
2	1.4%	0.3	2.5%	1.3	-1.0
3	1.4%	0.3	3.7%	1.9	-1.6
4	2.9%	0.6	6.2%	3.2	-2.6
5	8.6%	1.8	8.6%	4.4	-2.6
6	12.9%	2.7	12.3%	6.3	-3.6
7	28.6%	5.9	22.2%	11.3	-5.4
8	34.3%	7.1	42.0%	21.4	-14.3
9	40.0%	8.3	60.5%	30.9	-22.6
10	42.9%	8.9	66.7%	34.0	-25.1
11	50.0%	10.4	61.7%	31.5	-21.1
12	42.9%	8.9	35.8%	18.3	-9.4
13	24.3%	5.0	1.2%	0.6	4.4
14	21.4%	4.4	0.0%	0.0	4.4
15	18.6%	3.9	0.0%	0.0	3.9
16	15.7%	3.3	0.0%	0.0	3.3
17	7.1%	1.5	1.2%	0.6	0.9
18	2.9%	0.6	1.2%	0.6	0.0
19	5.7%	1.2	12.3%	6.3	-5.1
20	2.9%	0.6	16.0%	8.2	-7.6
21	1.4%	0.3	16.0%	8.2	-7.9
22	1.4%	0.3	13.6%	6.9	-6.6
23	2.9%	0.6	9.9%	5.0	-4.4
24	2.9%	0.6	3.7%	1.9	-1.3

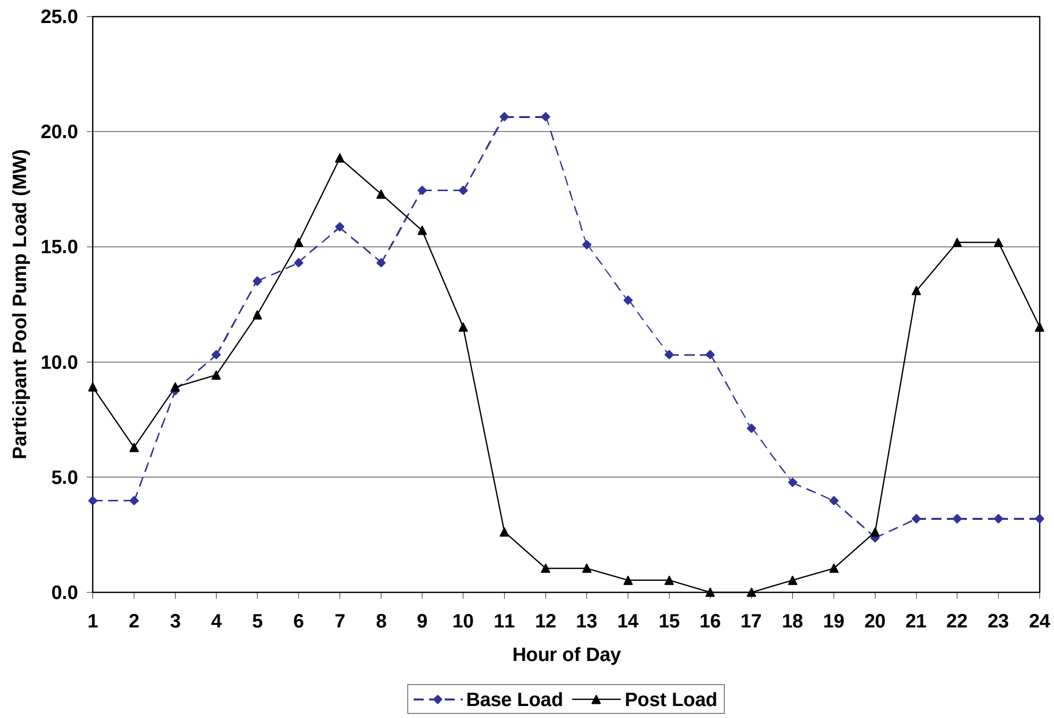

Figure 5-1. Comparison of Aggregate Load Profiles under Baseline and Program Conditions for Participants in Timer Component of PG&E Pool Pump Program

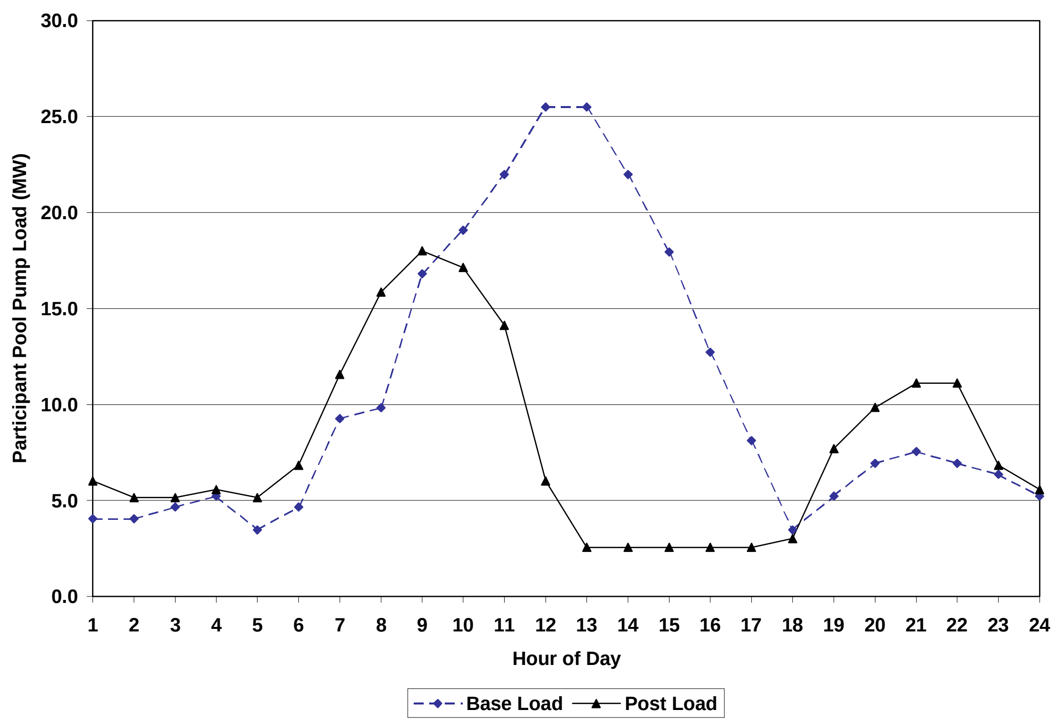

Figure 5-2. Comparison of Aggregate Load Profiles under Baseline and Program Conditions for Participants in Timer Component of SCE Pool Pump Program

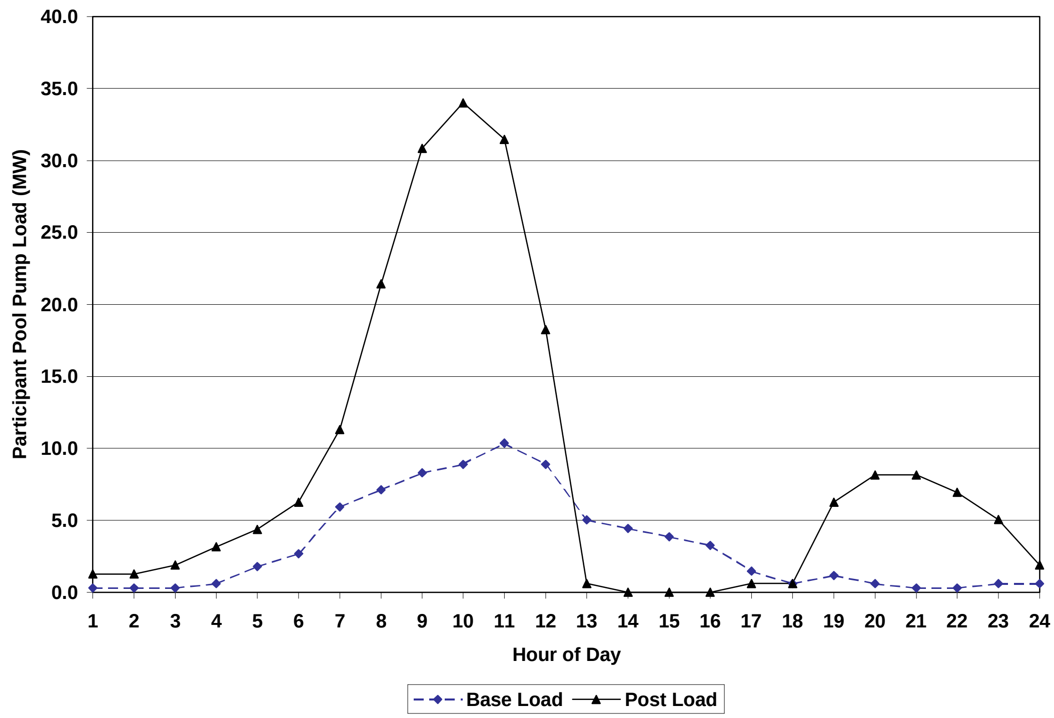

Figure 5-3. Comparison of Aggregate Load Profiles under Baseline and Program Conditions for Participants in Timer Component of SDG&E Pool Pump Program

6. ASSESSMENT OF ENERGY SAVINGS FROM PUMP/MOTOR REPLACEMENT COMPONENT OF PROGRAMS

Each utility's program included a component that involved providing rebates or incentives to pool owners to replace existing pool pumps and/or motors with more efficient pumps or motors. However, as described in Chapter 2, this component of the programs differed somewhat among the utilities.

- For SDG&E, a customer could receive a rebate for replacing his/her existing pool motor and pump assembly with an energy efficient motor and pump assembly from a list of qualifying models that SDG&E had approved. The new assembly had to be half the horsepower of the existing assembly. (If the existing assembly was 1 horsepower, the replacement motor and pump assembly could be ¾ horsepower.)
- For SCE, customers who purchased a qualifying energy efficient pool pump were eligible for a rebate.
- For PG&E, customers could receive a rebate for replacing a single-phase/single-speed pool pump and motor with an energy-efficient-rated, two-speed pool pump and motor.

Because of these differences in the programs and because the availability of data differed across the utilities, the savings from each utility's replacement component are examined individually.

6.1 EVALUATION OF SAVINGS FOR SDG&E REPLACEMENT COMPONENT

Program-level savings for the pump/motor replacement component of SDG&E's program can be defined as the difference in kWh usage for pool pumping for program participants before and after the pump/motor replacement. This would be a straightforward arithmetic calculation if before and after measurements of pool pump/motor kW demand and hours of use were available for each participant in the program.

Data were provided by SDG&E that allowed a close approximation of this calculation procedure. SDG&E provided data on the nameplate horsepower of the old and new motors for 4,910 participants in its program who received a $200 rebate for replacing their pump/motor. (There were an additional 76 customers who received a $100 rebate for the pump/motor replacement, but for whom data were not provided.)

The data for the customers receiving the $200 rebate were tabulated to show the replacement patterns in terms of horsepower. The resulting transition matrix is shown in Table 6-1. For customers who had an old motor of a given horsepower (i.e., each row in Table 6-1), Table 6-1 shows the number of customers who replaced that motor with one of a different size. For example, 83 customers had old motors of ¾ horsepower. Of these 83, 53 replaced the motor with one of ½ horsepower, 29 replaced the old ¾ hp motor with a new ¾ hp motor, and 1 replaced the old motor with a 1 hp motor. The average nameplate horsepower was 1.74 horsepower for old motors and 0.86 horsepower for new motors.

Table 6-1. Replacement Patterns for Old Motors to New for SDG&E Pump/Motor Replacement Program

Horsepower of Old Motor	***Horsepower of New Motor***						***Totals***
	0.50	***0.75***	***1.00***	***1.20***	***1.50***	***2.00***	
0.50	1						1
0.75	53	29	1				83
1.00	331	522	1		2		856
1.35		1					1
1.50	122	1,090	41				1,253
1.75	1	8					9
2.00	64	424	1,868		19		2,375
2.25			2				2
2.50	1	7	46		32		86
2.75			2				2
3.00	2	10	25	1	186	2	226
3.25			1				1
3.50			1		3		4
4.00			1		3	4	8
4.20					1		1
4.50		1					1
8.00		1					1
Totals	575	2,093	1,989	1	246	6	4,910

In effect, Table 6-1 shows that there were 4,910 combinations of old motor/new motor. For these combinations, the measured kW demand data that had been developed during the baseline and the post assessment studies were used to assign kW demands to the old and new motors. kW demands were assigned to the old motors using the baseline kW data and to the new motors using the post assessment data. (For some cases, kW demand had not been measured for motors of that horsepower. In those cases, the ratios of kW demand to horsepower for the nearest size motor were used to impute kW demand.)

Table 6-2 shows the kW demands for old and new motors that were assigned through this process. For the 4,910 customers, the total kW demands were estimated to be 7,900 kW for the old motors and 6,296 kW for the new motors.

Table 6-2. kW Demands for Old and New Pump/Motors

HP for Old Motor	HP for New Motor	Number of Pumps / Motors	kW for Old Motor	KW for New Motor
0.50	0.50	1	0.857	1.120
0.75	0.50	53	1.106	1.120
0.75	0.75	29	1.106	1.249
0.75	1.00	1	1.106	1.305
1.00	0.50	331	1.223	1.120
1.00	0.75	522	1.223	1.249
1.00	1.00	1	1.223	1.305
1.00	1.50	2	1.223	1.736
1.35	0.75	1	1.323	1.249
1.50	0.50	122	1.440	1.120
1.50	0.75	1,090	1.440	1.249
1.50	1.00	41	1.440	1.305
1.75	0.50	1	1.512	1.120
1.75	0.75	8	1.512	1.249
2.00	0.50	64	1.728	1.120
2.00	0.75	424	1.728	1.249
2.00	1.00	1,868	1.728	1.305
2.00	1.50	19	1.728	1.736
2.25	1.00	2	1.944	1.305
2.50	0.50	1	2.160	1.120
2.50	0.75	7	2.160	1.249
2.50	1.00	46	2.160	1.305
2.50	1.50	32	2.160	1.736
2.75	1.00	2	2.376	1.305
3.00	0.50	2	2.592	1.120
3.00	0.75	10	2.592	1.249
3.00	1.00	25	2.592	1.305
3.00	1.20	1	2.592	1.566
3.00	1.50	186	2.592	1.736
3.00	2.00	2	2.592	2.315
3.25	1.00	1	2.808	1.305
3.50	1.00	1	3.024	1.305
3.50	1.50	3	3.024	1.736
4.00	1.00	1	3.456	1.305
4.00	1.50	3	3.456	1.736
4.00	2.00	4	3.456	2.315
4.20	1.50	1	3.629	1.736
4.50	0.75	1	3.888	1.249
8.00	0.75	1	6.912	1.249

To calculate kWh savings, the hours for which a pump/motor is used per day are needed. These hours were available for three cases.

- For Case 1, the hours of use were 3.64 hours of operation per day for the old motors (as determined for SDG&E pool owners from the baseline study) and 4.11 hours for the new motor (as determined from the post assessment on-site visits).
- For Case 2, the hours of use are those determined from self-reports by participants in SDG&E's program. These were 5.53 hours of operation per day for the old motors and 3.65 hours per day for the new motors.
- For Case 3, the hours of use are those determined by SDG&E for the old motors and the hours of use determined from the post assessment on-site visits. These are 5.53 hours of operation per day for the old motors and 4.11 hours of use per day for the new motors.

Using these estimates of hours of use and the kW demands determined from Table 6-2, the savings for SDG&E's pump/motor replacement program could be estimated. These estimates are shown in Table 6-3 for the 4,910 customers who received the $200 rebates and in Table 6-4 projected to the entire program population of 4,984 customers. Assuming that the pool filtration system is operated 365 days per year, the aggregate savings from the pump/motor replacement component of the SDG&E program for PY 2001 are 6.60 GWh (per Case 3). SDG&E's pump/motor replacement components also resulted in reductions in aggregate kW demand attributable to pool pumps/motors. The connected kW load of participants' pumps/motors was reduced from 8.02 MW to 6.38 MW, a reduction of 1.64 MW.

Table 6-3. Estimated Savings under Different Assumptions Regarding Hours of Use (For Customers Receiving $200 Rebates)

	kW Demand	***Hours of Use***	***kWh Use and Savings per day***	***kWh Use and Savings per year***
		Case 1:		
Old motors	7,900	3.64	28,756	10,495,896
New motors	6,296	4.11	25,878	9,445,412
Savings			2,878	1,050,484
Savings per customer			0.59	214
		Case 2:		
Old motors	7,900	5.53	43,687	15,945,688
New motors	6,296	3.65	22,982	8,388,262
Savings			20,705	7,557,426
Savings per customer			4.22	1,539
		Case 3:		
Old motors	7,900	5.53	43,687	15,945,688
New motors	6,296	4.11	25,878	9,445,412
Savings			17,809	6,500,276
Savings per customer			3.63	1,324

Table 6-4. Projected Program-Level Savings for All Program Participants

	KWh Savings per day	***kWh Savings per year***
Case 1	2,921	1,066,316
Case 2	21,017	7,671,326
Case 3	18,077	6,598,243

Both hours of use and the size of the motors for participants in SDG&E's PY 2001 program were relatively high when compared to the average pool owner, as determined from the baseline study.

- As noted above, PY 2001 participants ran their pool pumps for significantly longer periods of time than the average customer. Other data collected and reported in the baseline study suggest that only about 10 to 15 percent of pool owners run their pumps/motors more than six hours a day, with most pool owners running their pool pumps for less than six hours a day.
- PY 2001 participants had larger motors than the average customer. In the baseline study, only 17.3 percent of SDG&E's customers had motors with 2 horsepower. However, nearly 55 percent of the PY 2001 participants had motors rated at 2 or more horsepower. Replacing larger motors will result in greater kWh savings than replacing small motors.

For these reasons, the energy savings achieved by participants in SDG&E's PY 2001 pump/motor replacement program are probably higher than the energy savings that the average pool pump user would achieve. However, there is not yet sufficient experience with the replacement of average pool pumps to determine program impacts on both the number of hours of pool pump use and energy savings.

The assumptions made about hours of use have a major impact on the estimated savings. The assumptions for Case 1 were that the program participants would have hours of use similar to those determined for the population of pool owners from the baseline study. However, it appears that SDG&E's requirement to reduce pumping time probably led to a self-selection where customers pumping longer hours were more likely to participate in the program. Cases 2 and 3 assume similar hours of use for old motors, based on the data program participants reported to SDG&E about the hours they used the old pump/motor. Although these data are self-reported, the number of customers reporting is large.

6.2 EVALUATION OF SAVINGS FOR SCE REPLACEMENT COMPONENT

Under the pump/motor replacement components of SCE's program, customers who purchased a qualifying energy efficient pool pump/motor were eligible for a rebate. However, SCE did not collect information regarding the nameplate horsepower of the old and new motors. Accordingly, a methodology to calculate program savings was needed that was different than the one used to estimate savings for SDG&E's program.

The methodology that was used for calculating savings is based on the observation that the aggregate daily savings from SCE's pump/motor component depend on five elements:

- kW demand per nominal (nameplate) horsepower;
- Nameplate gallons per minute per nominal horsepower;
- Hours of use per day;
- Nameplate gallons per minute per pool; and
- Number of pools.

The methodology was verified by applying it to SDG&E's program as well; this provided information as to how close the savings estimated with the methodology compared to the savings calculated when more complete information was available. This comparison (which is provided in Appendix A) shows that the methodology used for calculating estimates of savings for SCE's pump/motor replacement program provides estimates reasonably close to those that would be derived using more complete information.

For the analysis, aggregate savings result primarily because of program-induced changes in the following elements.[1]

- Changes in kW demand per nominal horsepower reflect primarily the impacts of the energy efficiency improvements that occur from installing a new, higher efficiency pump/motor.
- Changes in nameplate gallons per minute per nominal horsepower reflect primarily the impacts of downsizing the pump/motor in terms of horsepower for a given pool system. As noted above, such downsizing was explicitly required in SDG&E's program. For SCE, discussions with pool service companies and with SCE customers who replaced pumps/motors under the

[1] The last two elements (i.e., nameplate gallons per minute per pool and number of pools) do not change because of program effects.

program indicated that downsizing, while not required in the program, did occur for some percentage of the pools where a pump/motor was replaced.

- Changes in hours of use per day reflect primarily changes in operation. SDG&E explicitly required that customers who replaced a pool pump and motor assembly also reduce filtering time by one hour a day. This was not required in SCE's program.

Each of these elements is examined in turn to determine how they changed.

Consider first changes in kW demand per nominal horsepower. *Ceteris paribus*, energy savings would be expected when a new pump and/or motor is installed because it would be more efficient than the equipment replaced. In practice, however, exchanging an older pump/motor with a new pump/motor can produce changes that mask the energy savings that are being realized.

To illustrate, consider the data reported in Table 6-5 that compares the kW draw measured for different pump motors on pools of SCE and SDG&E customers who replaced pumps/motors. The baseline measurements were made on a sample of pump motors under the baseline study, while kW demand for program sites was measured as part of the on-site verification visits. As can be seen for each category of motor horsepower, the average kW draw for the program sites is greater than the average kW draw as measured for the baseline sites (except for 1 horsepower motors for SDG&E). In other words, kW demand per nominal horsepower had increased for the program sites over what was observed for the baseline sites.

Table 6-5. Comparison of kW Demand for Pump Motors of Different Nameplate Horsepower for Baseline and Program Sites for SCE and SDG&E

Motor Nameplate Horsepower	Baseline Sites			Program Sites		
	N	Average kW	Standard Deviation kW	N	Average kW	Standard Deviation kW
SCE						
¾ hp motors	9	1.011	0.240	4	1.255	0.142
1 hp motors	29	1.154	0.283	7	1.346	0.252
1.5 hp motors	18	1.379	0.356	7	1.780	0.066
2 hp motors	26	1.727	0.344	2	1.785	0.573
SDG&E						
¾ hp motors	11	1.185	0.151	13	1.247	0.124
1 hp motors	35	1.336	0.266	7	1.302	0.247
1.5 hp motors	9	1.461	0.335	1	2.000	

Why the kW demand increased for pump motors of given nominal horsepower was not studied, although there are several alternative explanations that could be explored.

- One possible explanation considers the other changes that occur when a new, more efficient pump/motor replaces an older pump/motor. With an existing pump/motor, the performance of the pump impeller may degrade over time, which would be reflected in lowering of flow rates and lower pressure in the filtration system. When a new pump/motor is installed, however, the impeller of the new pump will be working at peak performance. This will be reflected in a higher flow rate and higher pressure in the filtration system. With higher pressure at the filter, the kW demand for a motor of a given nominal horsepower also increases.
- Another possible explanation for the increase in kW demand is that replacing an existing pump/motor with one of lower nominal horsepower may cause the new pump/motor to work harder. That is, with the reduction in pump size, it may be possible that the pump/motor is undersized, resulting in an increase in load and lower efficiency.[2] Moreover, with a new pump/motor being undersized, pumping time may also have to increase to allow the new pump/motor to accomplish the work of the previous pump/motor.

The second element that can produce savings for pump/motor replacement is downsizing of the equipment for a given size pool. Nameplate gallons per minute per nominal horsepower is used here as an indicator of the effect of such downsizing. That is, nameplate gallons per minute is taken as a design feature of the pool that does not change. However, with higher efficiency pump/motor equipment, the size of the equipment can be reduced.

Evidence on the magnitude of the downsizing for the customers who replaced pumps/motors is provided in Table 6-6. To develop the data in Table 6-6, the customers in the on-site verification sample were separated between those who participated in the pump/motor replacement component of the pool programs and those who participated only in the timer component. It was determined through customer interviews that some customers in SCE's program voluntarily downsized pumps, based on evaluations and suggestions by the customers' pool service providers.

[2] For example, a situation such as this occurred with the ACT[2] Stockton Residential Site. See Eley Associates, *ACT[2] Stockton Residential Site EEM Impact Analysis,* Report prepared for PG&E, 1996, p. 5-5.

Table 6-6. Differences in Nameplate GPM per Nominal Horsepower between Customers Who Did or Did Not Replace Pump/Motor

	Utility	
	SCE	***SDG&E***
For Program Participants Not Replacing Pumps/Motors		
Number of Customers	95	53
Average Nameplate GPM	45.47	50.04
Average Motor Nominal Horsepower	1.57	1.36
Nameplate GPM per Nominal HP	29.02	36.67
For Customers Replacing Pumps/Motors		
Number of Customers	19	19
Average Nameplate GPM	57.26	56.89
Average Motor Nominal Horsepower	1.19	0.85
Nameplate GPM per Nominal HP	48.10	66.76

Inspection of the data in Table 6-6 shows the following.

- Comparison of the average nameplate GPM between those who replaced a pump/motor and those who did not indicates that those who chose to replace had somewhat larger pools when measured by nameplate GPM.
- For both SCE and SDG&E, the nameplate GPM per nominal nameplate horsepower for those who replaced a pump/motor was considerably higher than for those who did not replace such equipment. This is the measure of the effect of downsizing: more gallons per minute for a given nominal horsepower.
- As noted above, SDG&E explicitly required participants in its pump/motor replacement component to downsize, while SCE did not. The effect of this requirement can be seen by comparing nameplate GPM per nominal horsepower between the two sets of customers within each utility. For SCE, nameplate GPM per nominal horsepower for those replacing a pump/motor is 66 percent higher than for those not replacing a pump/motor. For SDG&E, nameplate GPM per nominal horsepower for those replacing a pump/motor is 82 percent higher than for those not replacing a pump/motor. This results because downsizing was optional for participants in SCE's program, but was mandatory for participants in SDG&E's program.

The third element that can produce savings for pump/motor replacement is reductions in the hours that a pump/motor is operated. As noted above, SDG&E explicitly required that participants in its program who replaced a pump/motor with a more efficient model also reduce their filtering time by one hour. However, SCE did not have this requirement for participation in their program.

Evidence on the changes in hours of operation associated with replacing a pump/motor is provided in Table 6-7. Data for three sets of customers were used to develop the estimates presented in Table 6-7.

- One set of customers includes SCE customers for which data on the hours that the pool filtration system were collected in the baseline study.
- A second set includes those customers in the on-site verification sample who participated only in the timer component of a utility's program.
- A third set includes those customers who participated in the pump/motor replacement component of the pool programs.

Table 6-7. Hours of Filtration System Use for Different Sets of SCE Customers

Customer Set	***Number of Customers***	***Average Hours of Use***
Customers in Baseline Study	165	4.53
Program Participants not replacing pumps/motors	95	4.40
Customers replacing pumps/motors	21	3.62

The pattern for hours of filtration system use shown in Table 6-7 for SCE is consistent with expectations. Customers who participated in the timer component of the pool program would be expected to have somewhat lower hours of use than customers in the baseline sample. Customers who replaced a pump/motor would be expected to have lower hours of use than customers in the other two groups.

Having examined one-by-one the various elements that determine the aggregate savings from pump/motor replacement, the next step is to bring these elements together to actually develop estimates of aggregate savings for the pump/motor replacement component of SCE's program. This estimate is shown in Table 6-8, where kWh use per day (Column 7) is the product of Columns 2 through 6.

Table 6-8. Estimation of Savings for SCE Pump/Motor Replacement Program

	kW Demand per Horsepower	***Horsepower per GPM***	***GPM per Pool***	***Number of Participant Pools***	***Hours of Use per Day***	***kWh Use per Day***
Pre-participation	0.9817	0.03446	47.439	8,200	4.40	57,927
Post-participation	1.2633	0.02079	47.439	8,200	3.62	36,974
Aggregate kWh savings per day:						20,953
kWh savings per participant per day:						2.56

This estimate of program savings accounts for all changes in major factors (i.e., kW demand per horsepower, gallons per minute per nominal horsepower, and hours of filtration system use) that result from program participation. However, it should be noted that this estimate is assuming that customers' pumps have been reduced in size properly and that the reduced run times have not sacrificed water quality or increased load.

Assuming that the pool filtration system is operated 365 days per year, the aggregate savings from the pump/motor replacement component of the SCE program are estimated to be 7.65 GWh. However, the discussion regarding the validation of the methodology in Appendix A suggests that the estimation procedure may overstate savings, albeit by less than 15 percent. If a 15 percent adjustment were made, the aggregate annual savings estimate would be lowered to 6.50 GWh. More extensive data on the horsepower of old and new motors would be needed to refine this estimate.

SCE's pump/motor replacement components also resulted in reductions in aggregate kW demand attributable to pool pumps/motors. For SCE, the connected kW load of pumps/motors was reduced from 13.16 MW to 10.22 MW, a reduction of 2.94 MW.

6.3 EVALUATION OF SAVINGS FOR PG&E REPLACEMENT COMPONENT

PG&E began a program in the fall of 2001 whereby customers could receive a rebate for replacing a single-phase/single-speed pool pump and motor with an energy-efficient-rated, two-speed pool pump and motor. As of the end of 2001, 53 customers had participated in PG&E's two-speed program. The savings being realized by these program participants were evaluated using both measurements made on a sample of 12 two-speed pump/motor systems that were among the participants in PG&E's program and data previously collected during the baseline study.

The sample size for taking kW demand measurements for the two-speed field study was somewhat smaller than the sample sizes used for field measurements of kW demand for the SCE and SDG&E single-speed motors. However, the figures should be statistically representative of the projected savings of the application of a two-speed pump/motor versus the application of a single-speed motor.

Savings from installing a two-speed motor on a pool filtration system are achieved because the motor can be run at different speeds, depending on the filtration needs. With a two-speed pump/motor, the high speed mode is only used when there are heavy filtration needs or when vacuuming or running an automatic pool sweep. The operation time for this is limited to a few hours a week in most applications, with a minimal impact to the overall energy consumption for the high use periods. The low-speed mode can be used for a majority of the filtration conditions. While a single-speed motor runs at high speed for the duration of the filtration time, the two-speed motor runs at the low speed for almost all of the filtration period in most applications.

Under these assumptions, the savings from using a two-speed motor can be estimated by comparing the energy use of a single-speed motor running at its single speed to the energy use that results from operating a two-speed motor under its two speeds for different lengths of time.

Data on the kW demand per horsepower for single-speed motors used on pool filtration systems were developed during the baseline study. These data also show the energy draw for a two-speed motor when operating at high speed. (That is, the energy draw of a two-speed pump/motor at high speed is equal to the energy draw of a single-speed pump/motor of the same horsepower.) To provide data on the kW demand of two-speed motors when operating at the low speeds, measurements were made for a sample of 12 two-speed motors, chosen from among the participants in PG&E's two-speed motor program. A true RMS wattmeter (AEMC Model 3910 TRMS Power Meter) was used to make the measurements. There were three different high/low configurations: 1 HP/0.17 HP; 1.5 HP/.25 HP; and 2.5 HP/.33 HP. The numbers of motors measured for each high-speed/low-speed characteristic and the average kW demands at high and low speed are shown in Table 6-9.

Table 6-9. High-Speed/Low-Speed Characteristics of Two-Speed Motors for Which Measurements Were Made

High-Speed Horsepower	***Low-Speed Horsepower***	***Number of Motors Measured***	***Average kW Demand at High Speed***	***Average kW Demand at Low Speed***
1.0 HP	0.17 HP	5	1.148	0.2903
1.5 HP	0.25 HP	5	1.485	0.3120
2.5 HP	0.33 HP	2	2.096	0.3775
		Averages		
1.46	0.23	12	1.445	0.3175

Data on hours of filtration use for a single-speed motor were available from the baseline study. The data collected for the baseline study showed that the average number of hours per day that a pool filtration system is used by PG&E customers is 4.11 hours.

When pool filtration is accomplished using a two-speed motor, the hours of operation are altered. As noted above, the pump needs to be operated at high speed only a short period of time each day in order to meet high filtration demands or to drive the vacuuming or pool sweeping equipment. The pump can then be operated at low speed to accomplish the filtering. However, because running the pump at low speed also lowers the flow rate through the filtration system, the hours of operation at low speed need to be increased to be able to filter the same amount of water.

The number of hours that the pump needs to operate when at low speed can be calculated as follows.[3] From the pump affinity laws, reducing the speed of the pump to 1/2 theoretically cuts the power demand to 1/8 and the flow rate to 1/2. When the pump is connected to the pool's filtration and piping system, the flow rate is not independent of pressure. While theoretically the flow would be cut in half, it actually turns out to be less than that because at 1/2 speed, the head pressure is reduced to 1/4. With 1/8 the power pumping against 1/4 the head pressure, the pump is unable to quite maintain 1/2 the flow rate. The actual flow rate would be approximately 42 percent. According to this calculation, to restore flow to pre-half-speed conditions, pumping would need to continue for 2.38 times the previous time (1/.42 = 2.38).

This analysis implies that if a single-speed pump operating at 4.11 hours per day is replaced with a two-speed pump that operates one hour at high speed, the hours of remaining pumping time need to be increased above 3.11 hours. Using the relationship just established, it takes 7.4 hours for a pump operating at low speed to have a flow rate and turnover for the volume of water in the pool that is equivalent to a single-speed pump operating at 3.11 hours.

On these assumptions, the average daily energy use for the two types of motors are as follows.

Single-speed motor: kWh per day = 1.4450 kW x 4.11 hours = 5.94

Two-speed motor: kWh per day = 1.4450 kW x 1 hour + 0.3175 kW x 7.4 hours = 3.79

The average savings per day from using a two-speed motor therefore are 2.15 kWh. Average annual energy savings are 785 kWh (i.e., = 2.15 kWh x 365 days per year). For the 2001 program, total savings from PG&E’s two-speed pump/motor replacement program would be 41,605 kWh (i.e., = 785 kWh per pool per year x 53 pools).

A two-speed pool pump also achieves average kW reductions during peak hours relative to a single-speed pump. Consider a period of 8.4 hours that would be required for a two-speed pump to provide the same filtering as a single-speed pump.

[3] This analysis is derived from work by Richard Pulliam at SCE and Gary Fernstrom at PG&E.

- For a single-speed pump, the average kW demand for the period is 0.71 kW [= (1.445 kW x 4.11 hours + 0 kW x 4 hours)/8.4]. That is, the single-speed operates only 4.11 hours of the period.
- For a two-speed pump, the average kW demand over the period is .45 kW [= (1.4450 kW x 1 hr + .3175 kW x 7.4 hrs) / 8.4 hrs = .45 kW.

Thus, the two-speed pump provides an average kW reduction of .26 kW over the entire period (i.e., .71 - .45). There are differences within the period.

- For one hour of the period, there is no difference in the kW demand of the two types of pumps.
- For 3.11 hours, the two-speed pump provides kW reductions of 1.13 kW (i.e., 1.445 kW - .3175 kW.)
- For 4 hours of the period (when the single-speed pump would be off), the two-speed pump increases kW demand by 0.3175 kW.

7. SUMMARY AND RECOMMENDATIONS FOR PROGRAM DESIGN

Analysis of data collected regarding the scheduling of pool pump operation for customers who participated in the timer components of the programs revealed that these participants responded by shifting their use of pool pumps away from the peak period of noon to 6:00 p.m. Less than 5 percent of the program participants operated their pool pumps during these peak hours.

However, because the California Public Utilities Commission has emphasized the need to reduce electricity use in the future, timer switch programs that primarily shift the load are not included in utilities' future planning. Instead, more emphasis is now directed at pump/motor replacement. Both SCE and SDG&E, offered programs during 2001 through which customers who purchased a qualifying energy efficient single-speed pool pump/motor were eligible for a rebate, while PG&E offered a program for two-speed motors.

Analysis of the daily savings from pump/motor replacement components of the SCE and SDG&E programs highlighted three factors that were of major importance in determining energy savings for those programs:

- Higher efficiency equipment;
- Equipment downsizing; and
- Changes in hours of use.

With respect to the effects of higher efficiency equipment, measurements made during this study showed that kW demand for motors of a given horsepower appeared to be higher for the pool pumps/motors installed by customers participating in the programs of PG&E, SCE and SDG&E than for motors that were measured during the baseline study. Pressure measurements made for a sample of sites where the pump/motor had been changed provided some empirical evidence that the change in pump/motors was associated with increases in pressure. However, further data and analysis would be required to evaluate whether the increased pressure increased or decreased filtration performance. For purposes of designing future programs, further data collection and analysis are warranted to determine whether the increased kW demand per horsepower identified during this study can be confirmed and substantiated.

Analysis of the savings indicated that downsizing the pump/motor equipment was an important factor in providing savings for the SCE and SDG&E programs. Equipment downsizing was explicitly required for participation in SDG&E's program, and information from pool service companies and program participants indicated that downsizing was often offered as an option by pool service contractors to participants in SCE's program. However, further study is needed to confirm whether downsizing provides all of the load reduction outcomes that are expected.

Reducing hours of use per day was also an important factor in providing savings for the SCE and SDG&E pump/motor replacement programs. Further data and analysis would be useful here to determine the extent to which pool run times can be reduced when a more efficient pump/motor is installed. There is an argument for requiring customers who install more efficient equipment to also reduce the number of hours that they filter their pools if they are pumping longer than required to maintain proper water quality. (As noted, this is an explicit requirement in SDG&E's program.) On the other hand, reducing pumping time may not be feasible for a significant number of customers. Pool turnover rates implied by data in the baseline study are already at 60 to 70 percent of the industry requirements for the average pool sizes found in the baseline data. Further reductions in pumping time might compromise water quality for the pools.

Analysis of the PG&E two-speed pump replacement program indicated that sizable energy savings could be realized by replacing a single-speed motor with a two-speed motor and performing the filtration pumping at lower speed, albeit for somewhat longer hours. These savings are realized even without requiring a reduction in motor size. There would be additional savings if the program were enhanced to include a motor size reduction element (where applicable). Because there was only a small number of participants in PG&E's program during 2001, extensive data are not yet available on how customers would choose to operate their two-speed motors. However, it is clear that substantial savings would be realized by operating the pump/motor at low speed but at somewhat longer hours than has been the norm.

APPENDIX A: VALIDATION OF METHODOLOGY USED TO CALCULATE SAVINGS FOR SCE PUMP/MOTOR REPLACEMENT COMPONENT

This appendix explains the rationale for the approach used to develop the savings estimates for the pump/motor replacement component of SCE's program.

Program-level savings for the pump/motor replacement components of the program are defined as the difference in kWh usage for pool pumping for program participants before and after the pump/motor replacement. This would be a straightforward arithmetic calculation if before and after measurements of pool pump/motor kW demand and hours of use were available for each participant in the program. In practice, such measured data were not available for participants in SCE's program. Accordingly, savings had to be estimated by using data for a sample of participants and then extrapolating the results from the sample of participants to represent the full population of participants.

The extrapolation procedure that was used is an application of the ratio estimation approach commonly used in survey statistics to project the results for a sample to represent results for the population from which the sample is drawn. For the pump/motor replacement programs, kWh usage needed to be estimated for program participants both before and after the replacement occurred.

For the estimation of before- and after-replacement energy use, the ideal ratio estimation procedure would have involved estimating kW demand per nameplate horsepower for a sample of program participants and multiplying this ratio by the total nameplate horsepower of all program participants and the hours of pump use for these participants. However, while SDG&E had data on the nameplate horsepower of the new pump/motors, SCE did not. An estimation procedure was therefore needed that could approximate the amount of horsepower being installed by program participants.

Another consideration in arriving at the estimation procedure was that there were no "before" measurements for program participants. Rather, data on kW demand per nameplate horsepower from the baseline analysis were available to be used in estimating the before-replacement energy use of program participants. During the analysis of the sample data that was collected, however, it became apparent that the program participants differed in some respects from the general population of pool owners represented in the baseline data set. For example, it appeared that the program participants for SCE had somewhat larger pools then was the case for the general population of pool owners. Using the baseline data without correcting for this difference in size would lead to misleading estimates of savings.

Factors for nominal horsepower per nameplate gallons per minute (gpm) and for nameplate gpm per pool were used in the savings estimation to allow these corrections to be made. Note, first, that the horsepower and gpm that were used for the calculation are nameplate values that could be read from the nameplates for the pump and motor during on-site visits. That is, as nameplate values the horsepower and gpm values that were used in the calculation are used as a way to characterize the population of pumps/motors for program participants. They are not values that represent changes as the operation of a given pump/motor changes.

It was assumed that nameplate gpm was a useful proxy to the capacity required for a pool pump/motor. The original design of a pool and its filtration system implies a required pumping capacity to ensure proper filtration. It was assumed that even with a pump/motor replacement that the required filtration capacity would not change and that the nameplate gpm was a reasonable measure of this required capacity. Moreover, by using the value for nameplate gpm per pool for program participants in calculating before energy use with baseline study values for kW demand per nameplate horsepower and nameplate horsepower per (nameplate) gpm, it was possible to correct for the possible difference in pool capacities between program participants and customers analyzed in the baseline study.

The nameplate horsepower per nameplate gpm was used as a factor because it provided a separate metric for the effect of pump/motor downsizing. Essentially, (nameplate) horsepower per nameplate gpm would be expected to decrease when the pump/motor was replaced.

Multiplying together the three factors of nameplate horsepower per nameplate gpm, (nameplate) gpm per pool and number of pools provides an estimate of the total horsepower of pump motors for the population of program participants being studied. Multiplying this product by the kW demand per nameplate horsepower and the hours of use gives the estimate of energy use for pool pumping.

The calculation of savings for SDG&E's pump/motor replacement programs provided data with which to assess the relative accuracy of this method to calculate savings for SCE's pump/motor replacement component. The data that SDG&E provided on horsepower for old and new motors permitted the assignment of kW demands to a substantial number of the customers who participated in SDG&E's program during 2001. Using the data reported in Table 6-2, the average kW demands were 1.61 kW for the old motors and 1.28 kW for the new motors. On the other hand, the procedure to be applied in preparing the savings estimates for SCE's program implied average kW demands of 1.62 for old motors and of 1.18 kW for new motors. (The calculation of the averages through this procedure is illustrated in Table A-1.) Thus, by and large, this procedure to estimate average kW demand provided estimates that are close to those that are derived with more complete data. The average kW demand estimated through the procedure was 92.2 percent of that estimated from the more detailed data provided by SDG&E.

Table A-1. Average kW Demands for Old and New Motors in SDG&E Program Calculated per Procedure Used to Estimate SCE Savings

	KW Demand per Horsepower	Horsepower per GPM	GPM per Pool	Implied Average kW Demand per pool
Old motors	1.1433	0.02727	51.847	1.62
New motors	1.5169	0.01498	51.847	1.18

A comparison of the program-level savings as determined through the two procedures is provided in Table A-2. Taking annual program-level savings, the approximation calculation procedure estimates savings that are about 12.8 percent higher than are calculated using the more detailed data that SDG&E could provide. The difference is primarily attributable to the procedure showing a lower average kW demand for new motors.

Table A-2. Comparison of Savings Estimates for SDG&E Program

	Average kW Demand	Hours of Use	Number of Participants	kWh Use and Savings per day	kWh Use and Savings per year
Calculated Using SDG&E Supplied Data on Horsepower					
Old motors	1.61	5.53	4,984	44,374	16,196,527
New motors	1.28	4.11	4,984	26,220	9,570,237
Savings				18,154	6,626,290
Savings per customer				3.64	1,330
Calculated Using Approximation Calculation Procedure					
Old motors	1.62	5.53	4,984	44,650	16,297,127
New motors	1.18	4.11	4,984	24,171	8,822,562
Savings				20,478	7,474,565
Savings per customer				4.11	1,500