Statewide Investor Owned Utility Ceiling Fan Study

Final Report

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Executive Summary

Introduction

This is the California Statewide Ceiling Fan Study final report. The California Statewide Ceiling Fan Study is the result of California's Investor Owned (IOU) utilities and other industry stakeholders' quest to understand the operational characteristics of residential ceiling fans. In particular, this project studied ceiling fan motor run time and ceiling fan lighting run time. This was accomplished through long term monitoring of ceiling fan motors and lighting using a representative sample of ceiling fans and extrapolating the results back to the statewide population.

Additional occupant operational aspects included in the study were fan speed usage, seasonal fan directional preferences, and the use of the ceiling fans in conjunction with air conditioning (when applicable).

In 1999-2000 RLW Analytics conducted the California Lighting and Appliance Saturation Study (CLASS) on behalf of SDG&E, the CEC and the other IOUs. For the CLASS study the RLW team completed 1,000 residential on-site surveys of both single and multi-family dwellings throughout California. While data was collected on all major home appliances, data was also collected on all household lighting fixtures and lamps. All participants for the California Statewide Ceiling Fan Study were recruited from the sub-population of CLASS study participants.

Methodology Overview

The evaluation of statewide ceiling fan usage was performed through primary data collection, and processing and analysis of the collected data.

A sample of 62 homes was drawn for occupant surveys and ceiling fan monitoring. The sample was drawn from the participant sample of RLW's California Lighting and Appliance Statewide Survey, a statewide survey of residences performed by RLW in 1999 and 2000. These homes were located within SDG&E, SCE and PG&E service territories.

RLW Analytics recruited the participants and performed on-site logger installations in PG&E's service territory, sub-contractor ASW Engineering handled these tasks in the SDG&E and SCE service territories.

Occupants were surveyed on ceiling fan motor and ceiling fan lighting operation during the first site visit. Lighting loggers and motor loggers were installed on all fans wherever feasible during the initial visit. If the ceiling fans could not be fitted with loggers, customer reported usage was used in place of monitored data. Customer reported usage was also used if the data logger failed or was lost.

A second site visit was conducted to specifically download data from the loggers. The loggers were removed during a third site visit and any missing data was collected at this point.

After the data collection was complete the sample data was used to extrapolate the results to the population. Since all of these homes had participated in the CLASS study, additional information was (and is) available on these homes for a more detailed analysis.

Findings

The data collection and analysis produced a statewide estimate of 897 hours of run-time per year for ceiling fan motors. The 897 hours equates to an "On Time" of 10.2%, meaning that the average fan is running 10.2% of the time over the course of the year. The average ceiling fan lighting usage is estimate at 360 hours per year, or 4.1% of the year. Annual run times by utility service territory are presented in Table 1. The definition of "statewide" as used throughout this report means across the California IOU service territories. Error bounds for these estimates are included in the Results section of this report.

Fan Motors	Run Time Hours	On-Time
Statewide	897	10.2%
PG&E	1508	17.2%
SCE	360	4.1%
SDG&E	828	9.4%

Table 1 Annual Ceiling Fan Run Time

The average fan motor load for the analysis was determined from the fan speeds used, as reported by the resident, and blade diameter. The statewide average fan load is 38 Watts. The statewide average ceiling fan lighting load is 132 Watts. Table 2 presents the average fan motor and lighting loads by utility service territory.

Load	Fan Motor (Watts)	Lighting (Watts)
Statewide	38	132
PG&E	38	125
SCE	37	135
SDG&E	44	155

Table 2 Average Ceiling Fan Loads by Utility Service Territory

Table 3 presents the estimates of annual energy usage by utility. The findings suggest that ceiling fans in SDG&E's service area use more energy than SCE or PG&E ceiling fans, approximately 100 kWh per year.

	Annual Energy Usage (kWh)		
	Motor	**Lighting**	**Fixture**
Statewide	32.8	43.4	76.3
PG&E	56.6	26.8	83.4
SCE	15.8	53.0	67.7
SDG&E	38.4	62.4	100.7

Table 3 Annual Ceiling Fan Energy Usage by Utility

The estimated savings from replacing the statewide average ceiling fan with an Energy Star ceiling fan are presented in Table 4. These estimates assume 60% savings on lighting energy and 20% savings on fan motor energy with an Energy Star replacement. Total fixture energy savings for standard to an Energy Star upgrade is estimated at 32.5 kWh per year.

		Load	Run Time	Annual Energy
Statewide		(Watts)	(Hours)	(kWh)
	Lighting	132	329	43.4
	Fans	38	897	32.8
Energy-Star				
	Lighting	53	329	17.4
	Fans	15	897	25.6
Savings				
	Lighting	79	329	26.1
	Fans	7	897	6.4

Table 4 Estimated Energy Star Ceiling Fan Replacement Savings

An average statewide ceiling fan with integrated lighting draws between 6 and 24 Watts on a summer weekday. An hour-by-hour "summer" weekday loadshape of an average ceiling fan is shown in Figure 1, with the breakdown of lighting and fan motor power draw.

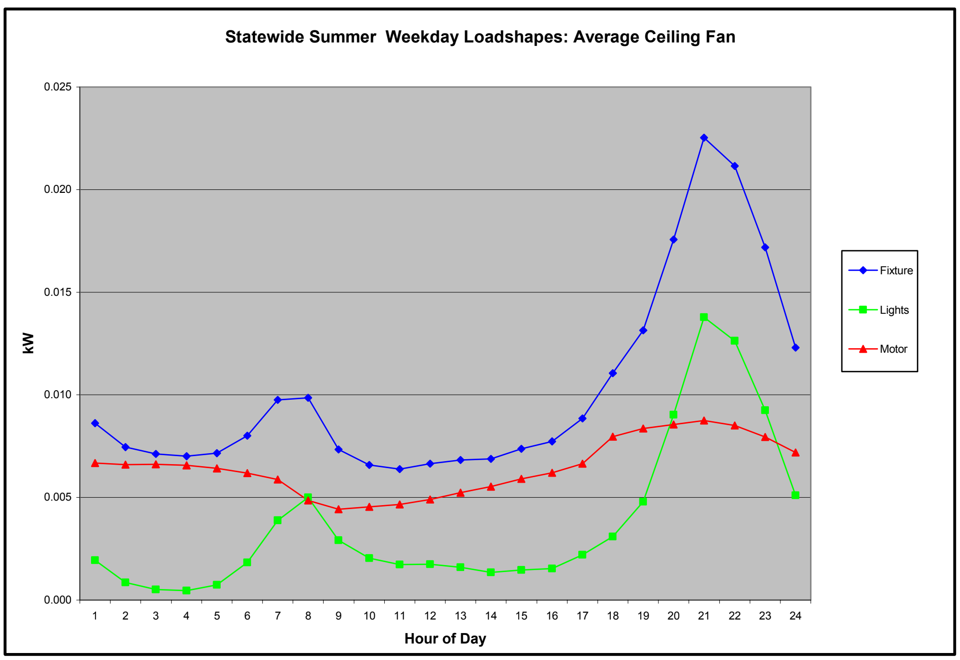

Figure 1 Average Weekday Statewide Summer Ceiling Fan Loadshapes

The estimated aggregate summer load of all ceiling fans in IOU service territories is shown in Figure 2. The total fixture peaks at over 200 MW at hour 21, or between 8 and 9 PM. Note that this is the load averaged over each utility's summer costing period, not a peak summer day.

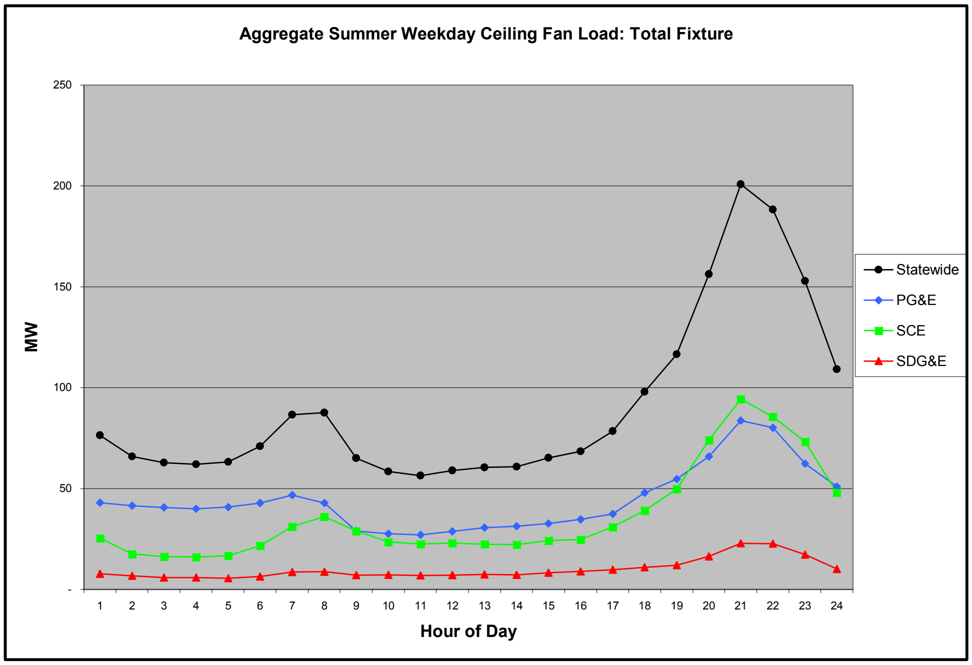

Figure 2 Summer Weekday Ceiling Fan Total Fixture System Load by Utility Service Territory

SMUD Ceiling Fan Study

Sacramento Municipal Utility District (SMUD), and RLW conducted a separate ceiling fan study concurrent with the Statewide Investor Owned Utility Ceiling Fan Study. Although the analysis RLW conducted for SMUD was nearly the same as the IOU scope of work, the SMUD ceiling fan study also sought to investigate the operational relationships of ceiling fans and air conditioning usage during the cooling season in recently constructed single family SMUD homes. Unfortunately the results of this study component were largely inconclusive. The report for the SMUD study has been included in Section 4 of this report.

Section 2 - Technical Discussion and Approach

Study Overview

In 1999-2000 the RLW/ASW team conducted the California Lighting and Appliance Saturation Study (CLASS) on behalf of SDG&E, the CEC and the other IOUs. For the CLASS study the RLW team completed 1,000 residential on-site surveys of both single and multi-family dwellings throughout California in the service territories of SCE, PG&E and SDG&E. While data was collected on all major home appliances, data was also collected on all household lighting fixtures and lamps.

RLW utilized the CLASS database to contact homeowners that own ceiling fans with lamps. The database has contact information for 472 homeowners and renters that have at least one ceiling fan present in their home. Using the appropriate case weights, the CLASS study also extrapolated study findings to the population of California's residential customers. This study used these same case weights to extrapolate to the population of ceiling fans.

Using the CLASS database, a sample of 62 ceiling fan customers were selected to be part of the Study. Customers having multiple fans were over sampled to increase the penetration of ceiling fans and stretch the field work budget. The sample of 62 customers resulted in the end-use monitoring of approximately 150 ceiling fan fixtures. Note that the sample design eliminated fans without integrated lighting, since they comprise only 5% of ceiling fans in California.[1]

Sample Design

The CLASS data includes 472 homes with one or more ceiling fans[2] from which to select the sample. About half of these homes have one or more ceiling fans, with a few homes having as many as seven and eight fans. Figure 3 shows the number of homes served by each utility, categorized according to the number of fans in the home.

[1] RLW CLASS Study, 1999-2000.

[2] Ceiling fans with light kits. It was decided that ceiling fans without lighting would be excluded from the study. Typically fans without lights account for approximately 5% of all ceiling fans found in homes.

# Fans with Bulbs	# of Homes			
	PG&E	SCE	SDG&E	Total
1	110	84	36	230
2	42	38	5	85
3	29	29	5	63
4	20	23	6	49
5	9	19		28
6	4	7		11
7	1	4		5
8		1		1
Total	215	205	52	472

Figure 3: CLASS Homes with one or more ceiling fans

Figure 4 shows the number of homes in each category, after we apply the weights from the CLASS study. These results show that PG&E serves nearly two million homes with ceiling fans, SCE serves 1.8 million homes and SDG&E serves almost one half million. Together these three utilities serve almost 4.2 million homes with ceiling fans.

# Fans with Bulbs	# of Homes			
	PG&E	SCE	SDG&E	Total
1	971,880	736,789	317,134	2,025,802
2	370,771	341,607	43,991	756,368
3	252,629	255,648	44,116	552,392
4	175,728	204,296	52,939	432,963
5	78,294	170,819		249,113
6	35,428	57,962		93,390
7	8,863	35,925		44,788
8		8,981		8,981
Total	1,893,592	1,812,026	458,179	4,163,797

Figure 4: Homes with Fans, Weighted to Population

Figure 5 shows the number of fans in each category of Figure 4. For example, Figure 4 shows that PG&E serves approximately 371 thousand homes with two fans. Together, these homes have about 741 thousand fans. Based on these CLASS results, we estimate that the homes served by PG&E have approximately 3.8 million fans, the homes served by SCE have almost 4.5 million fans, and the homes served by SDG&E have over seven hundred thousand fans, for a total of over 9.0 million fans.

# Fans with Bulbs	# of Fans			
	PG&E	SCE	SDG&E	Total
1	971,880	736,789	317,134	2,025,802
2	741,541	683,214	87,982	1,512,737
3	757,886	766,944	132,347	1,657,176
4	702,912	817,186	211,755	1,731,852
5	391,472	854,093		1,245,565
6	212,568	347,771		560,338
7	62,043	251,472		313,515
8		71,849		71,849
Total	3,840,301	4,457,467	749,217	9,046,985

Figure 5: Number of Fans in the Population

As discussed earlier, the sample of homes was selected from the sample of customers that participated in the CLASS study. During the project kickoff meeting it was decided that each IOU would get 20 sample points, or 20 on-sites, for a total of 60 on-site surveys. Figure 6 shows the planned sample by utility. The total planned sample size was 60 homes, with a total of 172 fans in the sample homes. Also shown in Figure 6 is the proportion of sampled homes with air-conditioning. The samples for both PG&E and SCE resulted in 50% of homes having air-conditioning, SDG&E had far less homes fall into the sample, with 15% of the primary sample of homes having air-conditioning.

Utility	# Homes	# Fans	% with AC
PG&E	20	60	50%
SCE	20	69	50%
SDG&E	20	43	15%
Total	**60**	**172**	

Figure 6: Original Sample

Though the sample had 172 fans, the project only budgeted enough equipment to study 150 of these fans. The surveyors were trained to select the appropriate fans to not monitor. This selection process is discussed in the monitoring plan section. As discussed in the section on data analysis, we used data imputation techniques to minimize the danger of bias from the missing data.

We stratified the sample by utility service territory and number of fans in the home. In order to provide more efficient data collection, we deliberately chose an increased sampling fraction in proportion to the number of fans in the home. Figure 7 shows the number of homes in the original sample in each stratum.

Count of Site ID	Utility			
Fans with bulbs	PG&E	SCE	SDG&E	Grand Total
1	5	4	10	19
2	4	4	2	10
3	4	3	3	10
4	3	3	5	11
5	2	3		5
6	1	1		2
7	1	1		2
8		1		1
Grand Total	20	20	20	60

Figure 7: Original Sample Size by Utility and Number of Fans

Figure 8 shows the final sample by utility. The final sample is comprised of 168 fans located at 62 homes throughout the state. The PG&E sample consists of 59 fans at 20 homes; Fifty-five percent of these 20 homes have air conditioning. The SCE sample includes 73 fans at 21 homes, 71% of which have air conditioning in the home. The 21 homes from SDG&E had 36 fans. The penetration of air conditioning was lower among the SDG&E sample than the samples from the other 2 utilities; only 29% of the SDG&E sample had air conditioning.

Utility	# Homes	# Fans	% Homes with AC
PG&E	20	59	55%
SCE	21	73	71%
SDG&E	21	36	29%
Total	**62**	**168**	

Figure 8: Final Sample

Figure 9 presents the final sample sizes by utility and number of fans.

# Fans with Bulbs	# of Homes			
	PG&E	SCE	SDG&E	Total
1	5	4	12	21
2	5	5	5	15
3	3	2	2	7
4	3	3	2	8
5	2	4		6
6	1	1		2
7	1	1		2
8		1		1
Total	**20**	**21**	**21**	**62**

Figure 9: Final Sample Size by Utility and Number of Fans

Case Weights

Each site in a given stratum has corresponding case weight that can be thought of as the number of sites in the population that the site is thought to represent. The following formula defines the stratum weight to be the ratio of the number of sites in the population in that stratum to the number of sites in the sample in that stratum. Each stratum will have a corresponding weight, and accordingly, each site within the stratum will be associated with that weight. These weights are used to expand the sample to the population. The following formula illustrates the calculation:

$$\mathbf{w_h = N_h / n_h},$$ where h is the stratum number.

The case weights were calculated for each stratum, the resulting case weights are shown in Figure 10. For each stratum, the associated case weight is calculated as the number of homes in California in the stratum divided by the number of sample homes in the stratum. For example, the weight associated with sample homes in PG&E's service territory that have one fan is calculated as 971,880 / 5 = 194, 376.

# Fans with Bulbs	PG&E			SCE			SDG&E		
	# Homes in Pop.	# Homes in Sample	Weight	# Homes in Pop.	# Homes in Sample	Weight	# Homes in Pop.	# Homes in Sample	Weight
1	971,880	5	194,376	736,789	4	184,197	317,134	12	26,428
2	370,771	5	74,154	341,607	5	68,321	43,991	5	8,798
3	252,629	3	84,210	255,648	2	127,824	44,116	2	22,058
4	175,728	3	58,576	204,296	3	68,099	52,939	2	26,469
5	78,294	2	39,147	170,819	4	42,705			
6	35,428	1	35,428	57,962	1	57,962			
7	8,863	1	8,863	35,925	1	35,925			
8				8,981	1	8,981			

Figure 10: Calculating the Case Weights

Recruiting Study Participants

Using the sample of customers described in the Sample Design section, RLW/ASW offered customers an incentive of $50 for agreeing to have one or more of their ceiling fans monitored for approximately one year. The brief recruiting instrument gathered key information that will qualified the customer as a house for the study. The recruiting instrument is attached as *Appendix B.*

The Recruiting Instrument

The recruiting instrument was brief and concise, with the focus to qualify customers for the study and recruit them. The recruiting instrument captured the following data:

- A check to ensure all fans in the home still exist,
- Fans are operational,
- Fans are used to some degree,
- Willingness to participate in the study,
- Not planning to move in the next 12 months, and

- Special fan characteristics (e.g., Height of ceiling fans)

Once the customer agreed to participate in the study, the recruiter then set the appointment for a time that was agreeable to the customer. The surveyor then contacted the customer one day before the scheduled appointment for a reminder and a confirmation of the time and date of the appointment.

Recruiting Procedure

RLW/ASW attempted to recruit the primary sample, however in some cases the backup sites were required to fill the sample. When customers/addresses in the primary sample were not qualified to participate or refused to participate, A backup sample of addresses was utilized to replace the primary sample. RLW/ASW made at minimum seven phone calls before moving to a backup address. Contact information obtained for the CLASS study was used to re-contact the customers.

In cases where the customer moved or the phone number was no longer valid a letter was sent to the address, explaining the study and asking that the customer contact RLW/ASW if they are interested in participating. Additionally, RLW/ASW recruiters used Internet resources to look up phone numbers by address. Every effort was made to retain as many addresses as possible from the primary sample. In some extreme cases ASW surveyors went to the door of the primary sample and asked the resident in person if they would like to participate. The final sample contained 29 homes from the primary sample and 33 that were randomly selected from the back-up sample.

The Monitoring Plan

Based on many hours of research and testing, RLW selected the following equipment to monitor the ceiling fan motor and associated lights.

- **Lighting** – HOBO H6 Lighting ON/OFF (event) loggers.

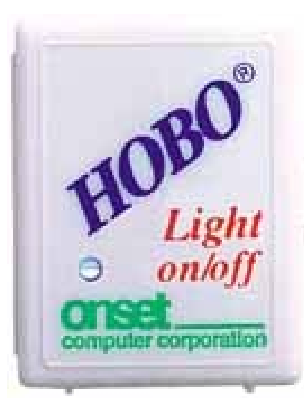

Figure 11: HOBO Lighting Logger Actual Size

- **Fan Motor** – HOBO H6 Motor ON/OFF Vibration Sensor

Figure 12: HOBO Motor Vibration Sensor

Logger Modifications

When tested without modification, the motor on/off loggers, when mounted on the ceiling fan motor housing, were not sensitive enough to determine when the fan motor was on. At the project kickoff meeting RLW demonstrated a motor logger modified with a small washer fixed to the vibration sensor to increase the sensitivity of the logger. However we found during the first of two pilot tests that the increased sensitivity was causing the logger register false events by picking up vibrations other than the fan motor, such as occupant merely walking across the home. Since the logger is only capable of storing 2,007 events this method quickly consumed the memory of the logger in addition to storing false data.

It was readily determined that a new logger modification would be needed following the first pilot test. Following extensive research and testing, a superior logger modification was developed. The chosen modification required attaching a short length of wired ribbon to vibration sensor. The logger was then mounted on the ceiling fan such that the ribbon was in the path of rotating parts of the ceiling fan. When the fans were turned on, the rotating parts of the fan, typically the arms that support the fan blades, would brush against the ribbon. The force against the ribbon was transmitted to the logger vibration sensor and the logger would register an "on" event. The ribbon that was used in the modification had small wire in both edges, adding rigidity to the ribbon and aiding the transmission of the force to the logger vibration sensor.

Figure 13: HOBO Vibration Logger Modified with Ribbon

The "ribbon modification" had several advantages over other methods tested. First, it captured all speeds at which the fans run. This was not true of other modifications tested, where low and high speeds introduced problems. Secondly, the ribbon method is nowhere near as vulnerable to false vibrations as was the logger modified with a washer. In the six fans pilot tested with the ribbon-modified loggers, only one logger picked up any false reads.

Although the ribbon modified loggers were more effective than other methods tested, they had some significant drawbacks of note. Regarding data collection, the primary drawback was that the installation of this logger type required much greater skill and subtlety than typical data logging procedures. The ribbon modified logger had to be installed in such a fashion that the fan rotation disturbed the ribbon to some degree, but did not jar the ribbon loose or cause excessive noise during fan operation. The effects of the many thousands of fan/ribbon collisions had to be taken under consideration. With the vast differences in ceiling fan design, a great deal of "on your feet" thinking, imagination, and occasionally on-site re-modification was required to achieve a quality installation. The majority of lost fan motor data was a result of the logger modification and/or installation being not robust enough to sustain many thousands of collisions.

The ribbon method has another problem that occurs when the fan is turned off. Depending on fan and the logger installation, when the fan is turned off and as the blades slows to a stop several false events are registered. This is a result of the fan blade traveling so slowly that the collisions occur less frequently that the sampling rate of the logger, one-half second. During this condition, the logger registers an off event since it hasn't been disturbed for a half-second, followed by an on event when the next collision occurs. This continues until the blades stop. At the onset of the study, we were very concerned that this situation would consume logger memory before sufficient data has been collected. Although some data loss was evidenced from slow traveling fan blades upon stopping, installation and modification quality was a much greater problem.

As discussed in the sample design section, the original sample included 62 homes with 168 fans. Since the study funded enough equipment for 150 fans, there was insufficient equipment to monitor all of the fans in the sample. Therefore a systematic approach to selecting which fans were not monitored was developed. There were three conditions where logger installs were not performed.

1. Amount of use – If the customer asserts the fan and fan light are not used, or are used very infrequently, the surveyor will determine whether or not to log that particular fan. For example, a customer we visited had 4 fans, one of which is in a guest bedroom that is used two weeks of the year. Instead of using loggers on the spare bedroom fan, we will ask detailed questions about when it is used, avoiding the need for logger installations. Alternatively, if a customer had only a single ceiling fan in the residence the motor and lighting were monitored even if it was used infrequently.
2. Tandem Usage – If a resident asserted that two ceiling fans were operated identically, either by switching or habit, then only one of the fans would be logged. The logger data in these cases were applied to both fans.
3. Quality of logger install – When surveyors encountered a ceiling fan where they could not configure a suitable installation, they were directed to not monitor the fan. This could be either the fan motor or fan light logging. Again, if the surveyor determines the installation may lead to unreliable data they will instead collect information from the customer to determine the hours of use.

Installation

Installation of the motor loggers required the surveyor to choose a location for the logger such that the ribbon extending from the logger would be disturbed by the movement of the fan. Whenever possible, the ribbon was placed on the fan assembly where the blades are mounted onto the rotating flange. This location provided collisions at a greater frequency than using the fan blades alone. Therefore, when the fan slows to a stop, the probability of false events was reduced

The HOBO data loggers have red and green LEDs that indicate whether or not the logger is sensing an “on” event or “off” event. The motor logger installation was checked by manually rotating the fan blades while observing the red and greed LED lights on the side of the logger. If the installation was deemed adequate, i.e. the green light flashes when the fan is rotating and the red light flashes when it is not, the logger was then re-launched in “stealth mode”. In stealth mode the red and green do not flash so as not to disturb the occupants or to draw attention to the loggers.

If the installation was not adequate, the logger was moved to a different location on the fan or perhaps replaced with a logger with a different ribbon length. Then the re-installation was performance checked.

Figure 14: Primary Motor Logger Mounting Location

The lighting logger installations required calibration or sensitivity adjustment of the logger photocell at the time of installation. The target of lighting logger calibration was to collect data on the fixture light source and not other light fixtures or daylight. The lighting loggers have a sensitivity adjustment that allows the light sensing photocell to be calibrated. After proper mounting, the loggers were calibrated to ensure accurate data collection.

Affixing the loggers to the ceiling fans was done using several techniques. The primary method utilized “sticky back” hook and loop fasteners with one side stuck to the logger and the other to the fixture. This method allowed for small adjustments to the logger placement, and temporary removal to download logger data or re-launch without compromising the adhesive. A secondary method utilizes a flat magnet that is adhered to the logger, and then the magnet side of the logger is placed on the metal housing of the ceiling fan. When hook and loop fasteners or magnets were not sufficient to secure the logger, nylon cable ties were used to strap the logger in place.

Most installations mounted the lighting logger on the outside or inside of the lamp cover, as seen in Figure 15

Figure 15: Data Loggers Mounted with Hook and Loop Fasteners

Each logger installed for this project used new batteries. All batteries were successful throughout the study and there were no data losses due to battery failure. The study did lose two loggers when they were destroyed from excessive heat. In these cases the customers were using a lamp with higher wattage than the fixture was rated. Figure 16 shows the damage incurred to the loggers as a result of heat from the lamps.

Figure 16 Damaged Lighting Loggers

Data Acquisition

A two-phase data acquisition plan was implemented for primary data collection. Phase one required a return visit to the residence after three to five months to verify operation, download stored data, and note fan settings. Phase two was the final trip to the residence, where loggers were collected and the final data was downloaded.

Pilot Testing the Monitoring Technique

RLW conducted two rounds of pilot testing. The pilot test was necessary to determine the best strategy for logging the fan motor, since the fan lights was a more straight forward application for the loggers. The first pilot test was sufficient to determine that vibration loggers modified with a small hex nut did not perform as desired. Subsequently, the RLW team worked hard to modify the vibration loggers in such a way that they accurately monitored the ceiling fan run time. Many applications were tested, ultimately the best modification was that of the wired ribbon, as described in the Monitoring Plan section.

The ribbon method was tested on a fan in Sonoma, then on six other fans in Santa Ana. During the training session each surveyor was taught how to install the loggers on a ceiling fan, the loggers were then left in place for approximately three days. The results from this test were encouraging and showed that the ribbon method worked well in most cases, however not entirely flawlessly. As discussed previously, in some circumstances (or installations) the method consumes logger events (false on/offs) when the fan is slowing to a stop. While this does not necessarily compromise the data, it did impact the duration the loggers were left in the field. Of the six loggers we left on fans the average number of events used when the fans were turned off was seven. This was more false events than we had previously had hoped, but was sufficient in the case of most fans.

Surveyor Training

A one-day training course was required for all surveyors. The training emphasized surveyor etiquette, the data to be collected, and explanation of the study to the customer as well as installation of monitoring equipment. Matt Brost and Eric Swan developed the training material and conducted the training session. The training was split between a classroom environment and an off site location that facilitated hands on installations in two homes that included six ceiling fans.

Etiquette

Both RLW and ASW staff have extensive experience surveying residential customer dwellings and interacting with such customers. The training reiterated the importance of making a good impression upon the customer.

Data Collection

The training session covered the data collection component of the on-site. The study design requires more than simply installing loggers and leaving the site, the surveyors also are required to record a series of observations that are included in the final analysis of the data. The training provided surveyors with a comprehensive understanding of what other data was to be collected, why it was needed and the protocols for collecting it. Surveyors were trained to gather the following data:

- Connected wattage of the lights installed in the fan (quantity and wattage)
- Approximate number of times in a day the ceiling fan lights and fan motor are switched on and off. (Critical to estimating when the logger memory will exceed its capacity).
- Fan Settings

  - Fan speeds available on each fixture
  - Speed at which fan is set (i.e., high, medium, low)
    - Customer behavior with this setting
  - Fan directional settings available on each ceiling fan
    - Customer behavior with this setting
- Fan size (diameter of fan blades)
- Multi-level lighting (some ceiling fan fixtures allow the occupant to select the amount of light using a pull chord. For example one pull turns on two of four lights, a second pull turns on all four lights, and a third pull turns off all four lights. This may either require two loggers, or placement of the lighting logger on the lights that are turned on during the first pull of the chord.)
- Thermostat settings

Use of Monitoring Equipment

The training covered in detail how the surveyor should deploy the monitoring equipment. For this study we were required to select equipment that is very easy to install, non-intrusive and time efficient. The surveyors were trained on logger setup, placement, configuration, and calibration while in the field. The following areas were covered in depth:

- **Orientation** – Surveyors will be trained on the features and specifications of each logger type.
- **Selection** – Surveyors were trained how to select the appropriate fans to monitor. For example, a fan rarely or never used would not be a monitored fan since the project did not budget to monitor all 172 fans.
- **Setup/Operation** – Surveyors were shown how the modified logger worked, how to modify loggers, and how to prepare the loggers for installation. Surveyors were also trained with the logger software, which is essential to setting up the loggers for use.
- **Placement** – Critical to the success of the data collection plan is the placement of the logger. Surveyors were trained to properly locate the logger such that it collects accurate data and is securely positioned on the fixture.
- **Deployment and Calibration** – Surveyors were shown how to properly deploy/activate the logger for data collection. Additionally, the training covered calibration of the logger to ensure the data being collected is in fact the fan light, not other artificial light or natural light sources.
- **Inventory** – Surveyors were trained to properly inventory each logger immediately after the installation has been completed. They were shown how to complete a worksheet that describes the logger model number, its location by house ID, room, and fixture.

- **Data Collection** – Surveyors were trained in the use of logger technologies for downloading and transporting data from the logger to a PC workstation.

Discussion with Customer

Before departing from the residence the surveyor were instructed to have a discussion with the customer. The surveyors were trained to discuss the following aspects of the study:

- **Location** – The surveyor will show the customer what logging equipment they have installed and where.
- **Problems with the equipment** –The customers were provided a number to call if they notice that the equipment became detached from its original location. Magnetized business cards were given to each customer by the surveyor to ensure contact information was easily accessible. Customers were asked to place the magnet on their refrigerator.
- **Behavior** – The surveyor reiterated the importance of not changing their behavior or operational practices of the ceiling fan fixture. In other words, the surveyor asked that they use the ceiling fan just as they had before the logging equipment was installed.
- **Moving** – The customer was asked to inform the RLW team if they intended to move from the location.
- **Data Acquisition** – The surveyor then reminded the customer of their intent to return to their home twice during the study, once to download the data and once to pick-up the loggers. Of course the customers were informed of this during the recruiting task.

Conducting the On-sites

The Customer Survey

Once at the site, the surveyor introduced himself to the customer, explained the nature of the study and implemented a customer survey. The following data was gathered, in addition to any other data the study team determines necessary:

- Approximate number of times in a day the ceiling fan lighting and fan motor are switched on and off. (Critical in estimating when the logger memory will exceed its capacity).
- Customer reported number of hours the fan motor and the fan lighting are used. The question was asked for each of the four seasons and weekday and weekend day types.
- Occupancy of the room the ceiling fan is installed in. Whether or not the room is occupied and what the room is commonly used for.
- Those that have air-conditioning were asked a series of behavioral questions regarding ceiling fan use with AC. For example, whether or not they adjust the AC thermostat setting when the fans are used.

- Use of ceiling fan controls. Which speed they use most often, whether it is changed often, and fan blade operational direction behavior.
- Occupancy information. Is the fan motor or fan lighting used when the rooms are unoccupied. Is the customer planning to move in the next 12 months?

Data Processing

After all data retrieval was completed, the data was processed through a series of steps

1. The log files were exported as text file.
2. The files were "trimmed" such that the file contained only information that was applicable to when the logger was installed on the fan. (The pre and post installation data was deleted.)
3. The text files were imported into RLW's Visualize-IT software.
4. A quality control check was performed by viewing the data in Visualize-IT. If less than two weeks of data were collected the data was not used, and the RLW Team collected self-report data from the customer. Using the Visualize-IT software and the HOBO software to review the data RLW was easily able to perform quality control on the metered data.
5. The connected load of the lights was then applied. Lighting connected load was simply the sum of lamp wattages installed on the fan fixture. If the fan fixture had multiple switching available, the most commonly used lighting level was input as the connected load.
6. The connected load of the fan motor was applied. The fan motor connected load was estimated from the fan blade diameter and fan speeds used from the resident survey. Customers reported for each fan in the home the speeds they used during the summer and the winter, proportional to the speeds available on the fan. For example a customer may have reported for the bedroom fan using it 75% on high and 25% on low during the summer, and 100% on low during the winter. A small database of ceiling fan motor connected load was used to derive connected load for each fan using the blade diameter and speed data.
7. Average weekend and weekday profiles were generated for each of the log files using RLW's Visualize-IT software.

Customer reported usage was gathered from survey responses that asked which specific hours the fan motor and lights were used on an individual basis. They were also asked how often they used the lights or fan, either never, occasionally, a few days per week or daily. The usage questions were also posed to residents that had successfully monitored ceiling fans. From a correlation of monitored data to survey responses, a numerical estimate of usage was assigned to each survey response. The customer reported loadshapes were generated by applying these usage estimates to hours that resident reported using the fan or lights and multiplied by the connected load.

Table 5 shows the quantities of customer reported and metered loadshapes obtained for analysis. Light logging was generally more successful than motor logging, due to the less problematic monitoring methodology. Less metered loadshapes were obtained in winter than in summer as the installations "fatigued", as loggers fell, went missing, or the residents moved away, among other reasons.

	Metered	Reported	Unavailable
Summer Lighting	127	36	2
Summer Motors	117	41	7
Winter Lighting	116	40	9
Winter Motors	90	68	7

Table 5: Breakdown of Metered and Reported Loadshapes

When data logging was unsuccessful and an accurate customer reported loadshapes was not obtainable, some residents were not capable of providing an accurate hourly usage profiles. We called these loadshapes unavailable. In these cases, a mean usage profile based on room type was substituted to complete the sample design.

Data Analysis

The key analysis goal for this study was to produce adequate information for each utility to run a cost effectiveness analysis. In order for the utilities to effectively do this they will require, for lights and fans, the annual hours of operation and utility costing period usage. These operating hours were developed by the appropriate costing periods for each IOU. The operating hours have been estimated separately for the fan motors and lights. In addition, we estimated the average hourly load profiles by season and weekday / weekend for each utility. RLW used the costing periods presented in Table 6 to provide the utilities with daily load shapes for ceiling fan motors and lights separately and combined.

Utility	Period	Dates	Days / Times
SCE	Summer On-peak	June 4 to first Friday in October (Oct 5th)	Weekdays 12:00 AM to 6:00 PM
	Summer Mid-peak	June 4 to first Friday in October (Oct 5th)	Weekdays 8:00 AM to 12:00 AM and 6:00 PM to 11:00 PM
	Summer off-peak	June 4 to first Friday in October (Oct 5th)	All other hours weekends and holidays
	Winter Mid-peak	October 7th – June 3rd (first Sunday in June)	Weekdays 8:00 AM to 9:00 PM
	Winter Off-peak	October 7th – June 3rd (first Sunday in June)	All other hours
PG&E[3]	Summer On-peak	May 1 to October 31	Weekdays 12:00 PM to 6:00 PM
	Summer Part-peak	May 1 to October 31	Weekdays 8:30 AM to 12:00 PM and 6:00 PM to 9:30 PM
	Summer off-peak	May 1 to October 31	Weekdays 9:30 PM to 8:30 AM. All day weekends and holidays
	Winter part-peak	November 1 to April 30	Weekdays 8:30 AM to 9:30 PM
	Winter Off-peak	November 1 to April 30	Weekdays 9:30 PM to 8:30 AM All day weekends and holidays.
SDG&E	Summer On-peak	May 1 – September 30	Weekdays 11:00 AM – 6:00 PM
	Summer Part-peak	May 1 – September 30	Weekdays 6:00 AM – 11:00 AM and 6:00 PM – 10:00 PM
	Summer off-peak	May 1 – September 30	Weekdays 10:00 PM – 6:00 PM and all Weekends and Holidays
	Winter on-peak	October 1 – April 30	Weekdays 5:00 PM – 8:00 PM
	Winter part-peak	October 1 – April 30	Weekdays 6:00 AM – 5:00 PM and 8:00 PM – 10:00 PM
	Winter Off-peak	October 1 – April 30	Weekends and Holidays

Table 6: Utility Costing Periods

[3] Compliance Application of Pacific Gas and Electric Company for Approval of Year 2001 Energy Efficiency Program in Compliance with Ordering Paragraph 93 of Decision 00-07-017, p. B-3 and the PG&E E-19 Rate Schedule

Section 3 - Results

Run Time

Table 7 presents the annual run time results for fan motors and lighting "statewide", and by utility service territory. Statewide is defined here as across the three California IOU service territories. The error bounds are at the 90% confidence level. The "On Time" is the portion of the time period considered that the device is operating. Statewide the average fan motor runs an estimated 897 hours per year, with an error bound of 342 hours at the 90% confidence level, the 897 hours equates to 10.2% of the year.

Fan Motors	Run Time Hours	Error Bound	On-Time
Statewide	897	342	10.2%
PG&E	1508	704	17.2%
SCE	360	176	4.1%
SDG&E	828	441	9.4%

Table 7 Ceiling Fan Motor and Lighting Annual Run-Times

Ceiling fan motor run times by utility service territory and costing period are shown in Table 8 along with their associated error bounds. The "On Time" percentage is the estimated fraction of each costing period that the average fan motor is operating throughout the service territory for the costing period indicated. Summer usage greatly exceeds winter usage in all cases as would be expected for ceiling fan motors.

	Summer Motors								
	PG&E			SCE			SDG&E		
Costing Period	Hours	Error Bound	On Time	Hours	Error Bound	On Time	Hours	Error Bound	On Time
All Periods	1057	390	23.9%	315	163	10.6%	591	325	16.1%
On Peak	164	60	3.7%	59	30	2.0%	56	37	5.8%
Mid Peak	218	73	24.1%	86	43	12.2%	234	127	31.3%
Off Peak	676	266	24.7%	171	92	9.8%	300	165	15.3%
	Winter Motors								
	PG&E			SCE			SDG&E		
	Hours	Error Bound	On Time	Hours	Error Bound	On Time	Hours	Error Bound	On Time
All Periods	451	391	10.4%	44	22	0.8%	237	217	4.7%
On Peak	-	-	-	-	-	-	23	20	5.2%
Mid Peak	143	123	8.9%	12	6	0.6%	77	69	4.0%
Off Peak	308	268	11.2%	32	17	1.8%	137	128	5.0%

Table 8 Seasonal Ceiling Fan Motor Run Time by Costing Periods

Ceiling fan lighting run times by utility service territory and costing period are shown in are shown in **Table 9** along with the associated error bounds. These results indicate that, on average, ceiling fan lighting is used infrequently.

	Summer Lighting								
	PG&E			SCE			SDG&E		
Costing Period	Hours	Error Bound	On Time	Hours	Error Bound	On Time	Hours	Error Bound	On Time
All Periods	87	41	2.0%	99	40	3.3%	126	57	3.4%
On Peak	8	6	0.2%	8	4	0.3%	12	7	1.2%
Mid Peak	26	14	2.9%	48	21	6.8%	56	25	7.5%
Off Peak	53	22	1.9%	43	18	2.5%	59	28	3.0%
	Winter Lighting								
	PG&E			SCE			SDG&E		
	Hours	Error Bound	On Time	Hours	Error Bound	On Time	Hours	Error Bound	On Time
All Periods	128	43	2.9%	304	143	5.3%	289	156	5.7%
On Peak	-	-	-	-	-	-	72	36	16.3%
Mid Peak	65	23	4.1%	140	60	6.5%	65	45	3.4%
Off Peak	62	21	2.3%	164	86	9.4%	152	79	5.6%

Table 9 Seasonal Ceiling Fan Lighting Run Time Results By Costing Period

Loads

Ceiling fan motor load was determined from the customer reported fan speeds used. The weighted average load of statewide ceiling fan motors is 38 Watts and average statewide lighting load is 132 Watts. Nearly all fans in the study were equipped with incandescent lamps. Table 10 shows calculated average ceiling fan loads by utility service territory. Fixture is defined here as simply the sum of motor and lighting loads.

	Average Load (Watts)		
	Motor	Lighting	Fixture
Statewide	38	132	170
PG&E	38	125	163
SCE	37	135	178
SDG&E	44	155	195

Table 10 Average Ceiling Fan Loads by Utility Service Territory

Energy Usage

Load and run time estimates were used to calculate energy usage estimates. Table 11 presents the estimates of annual energy usage by utility.

	Annual Energy Usage (kWh)		
	Motor	Lighting	Fixture
Statewide	32.8	43.4	76.3
PG&E	56.6	26.8	83.4
SCE	15.8	53.0	67.7
SDG&E	38.4	62.4	100.7

Table 11 Annual Ceiling Fan Energy Usage by Utility

Table 12 presents the energy usage estimates by utility costing season and costing periods. Both “seasons” and costing periods vary among the three utilities.

	(Summer)			(Winter)		
	On Peak	Mid Peak	Off Peak	On Peak	Mid Peak	Off Peak
Fan Motor Energy Usage (kWh)						
PG&E	6.3	7.5	26.8	-	5.1	10.9
SCE	3.3	4.7	6.4	-	0.3	1.1
SDGE	7.2	9.8	12.9	0.5	3.3	4.7
Fan Lighting Energy Usage (kWh)						
PG&E	1.0	3.1	6.7	-	8.1	7.8
SCE	1.7	9.4	5.8	-	14.1	22.1
SDGE	2.7	11.8	7.5	6.2	17.0	17.3
Total Fixture Energy Usage (kWh)						
PG&E	7.3	10.6	33.5	-	13.2	18.7
SCE	4.9	14.1	12.2	-	14.4	23.3
SDGE	9.9	21.6	20.4	6.7	20.2	22.0

Table 12 Ceiling Fan Energy Usage Breakdown by Costing Periods.

Energy Star Savings

The estimated savings if the statewide average fan were replaced with an Energy Star ceiling fan are presented in Table 13. The EPA has estimated that Energy Star fans provide the same air flow rate with 17 to 22 percent less energy usage than standard ceiling fans[4]. All fans in the study were standard ceiling fans. An assumed motor efficiency savings of 20% is shown below in Table 13. All Energy Star ceiling fans with lighting are equipped with compact fluorescent lamps with a maximum of 40 Watts of lighting power. Replacing 132 Watts of lighting with 40 Watts of lighting reduces lighting power by 70%. As a conservative energy savings estimate, we have used 60% lighting power reduction to estimate savings for Energy Star lighting. The results show that the average ceiling fan replaced with an Energy Star ceiling fan will reduce 26 kWh in lighting and 6 kWh in fan energy annually.

		Load	Run Time	Annual Energy
Statewide		(Watts)	(Hours)	(kWh)
	Lighting	132	329	**43**
	Fans	38	897	**34**
Energy-Star				
	Lighting	53	329	**17**
	Fans	30	897	**27**
Savings				
	Lighting	79	329	**26**
	Fans	8	897	**7**

Table 13 Estimated Energy Star Ceiling Fan Replacement Savings

[4]EPA webpages
http://yosemite1.epa.gov/estar/consumers.nsf/content/ceilingfan.htm

http://yosemite1.epa.gov/estar/consumers.nsf/content/ceilingfan.htm#what

Summer Hourly Results

Statewide Summer Loadshapes

The loadshapes below represent an average ceiling fan over the summer utility costing period. Note that each utility has different definition of “summer” as far as costing periods are concerned. All “statewide” seasonal loadshapes presented in this report are the weighted averages over each utility’s summer costing period.

The statewide summer loadshapes of an average ceiling fan for a weekday are shown in Figure 17. The total fixture loadshape for this, and all subsequent graphs, is simply the sum of lighting and fan motor loadshapes.

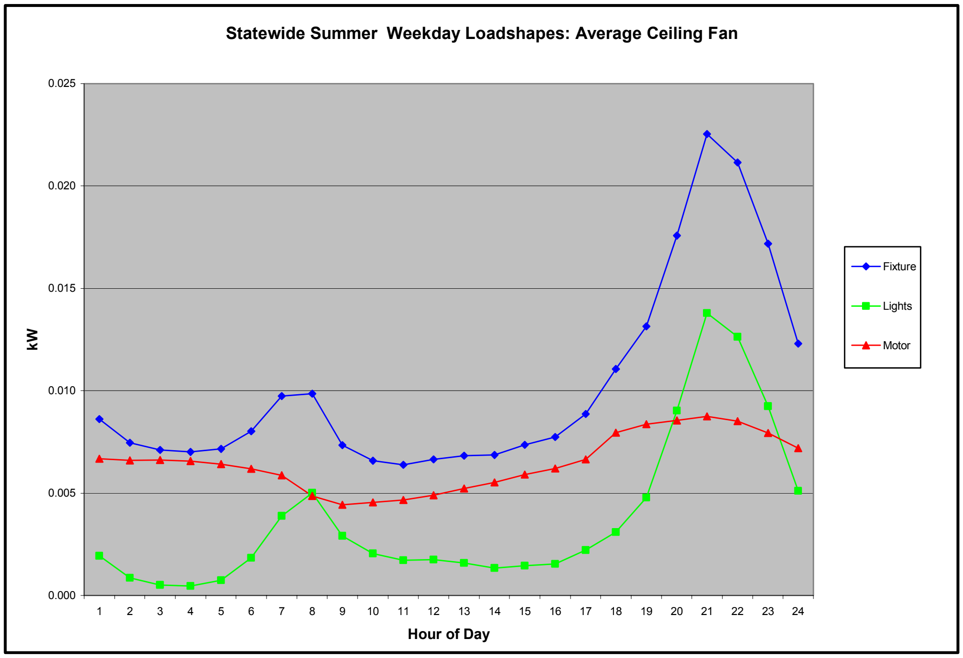

Figure 17 Statewide Summer Weekday Average Ceiling Fan Loadshapes

Figure 18 shows the statewide summer weekend loadshapes for an average ceiling fan. The most noticeable difference from the weekday loadshapes is the slightly reduced lighting usage in the evening.

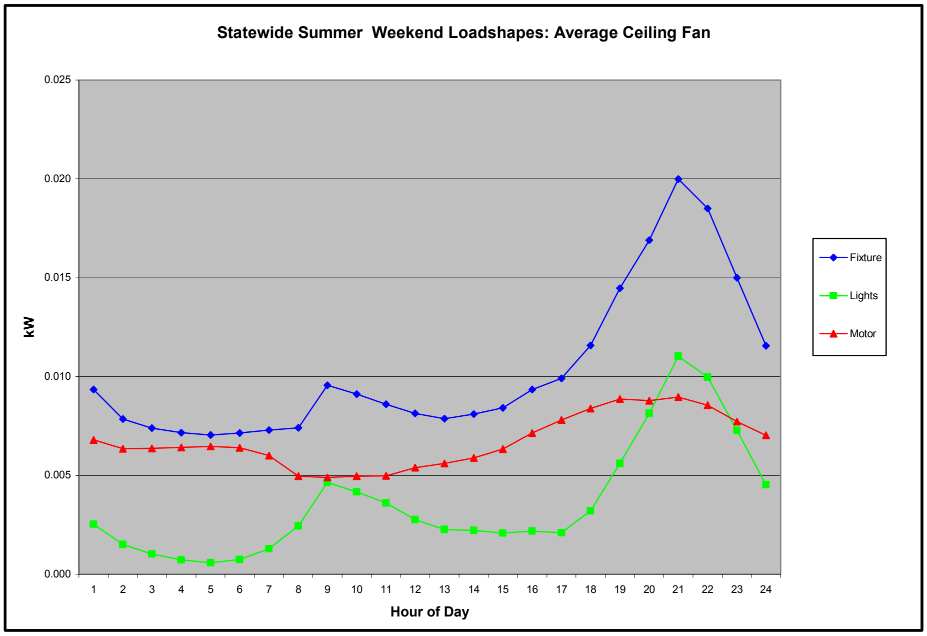

Figure 18 Statewide Summer Weekend Average Ceiling Fan Loadshapes

The average summer weekday ceiling fan usage in each of the three utility service territories are illustrated in three graphs below.

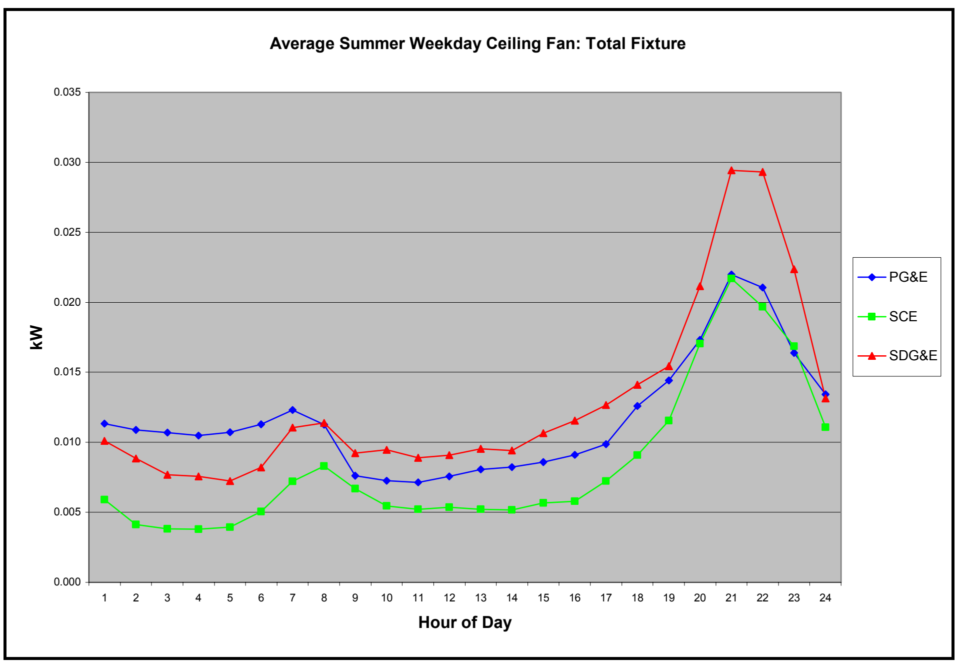

Figure 19 Summer Weekday Loadshapes of an Average Ceiling Fan Total Fixture Demand by Utility Service Territory

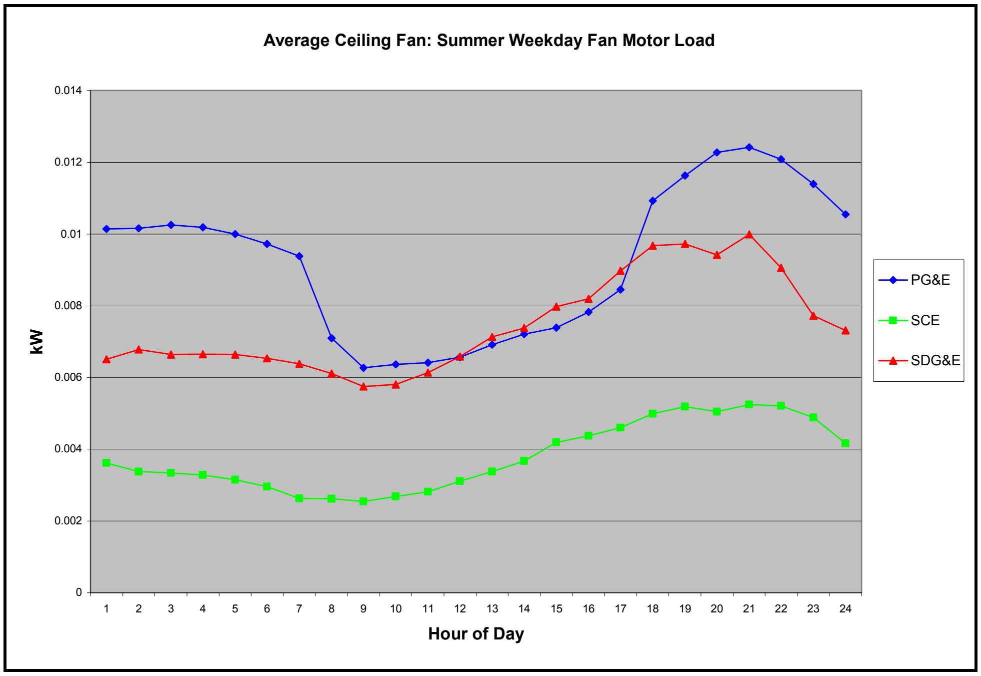

Figure 20 Summer Weekday Average Ceiling Fan Motor Loadshapes by Utility

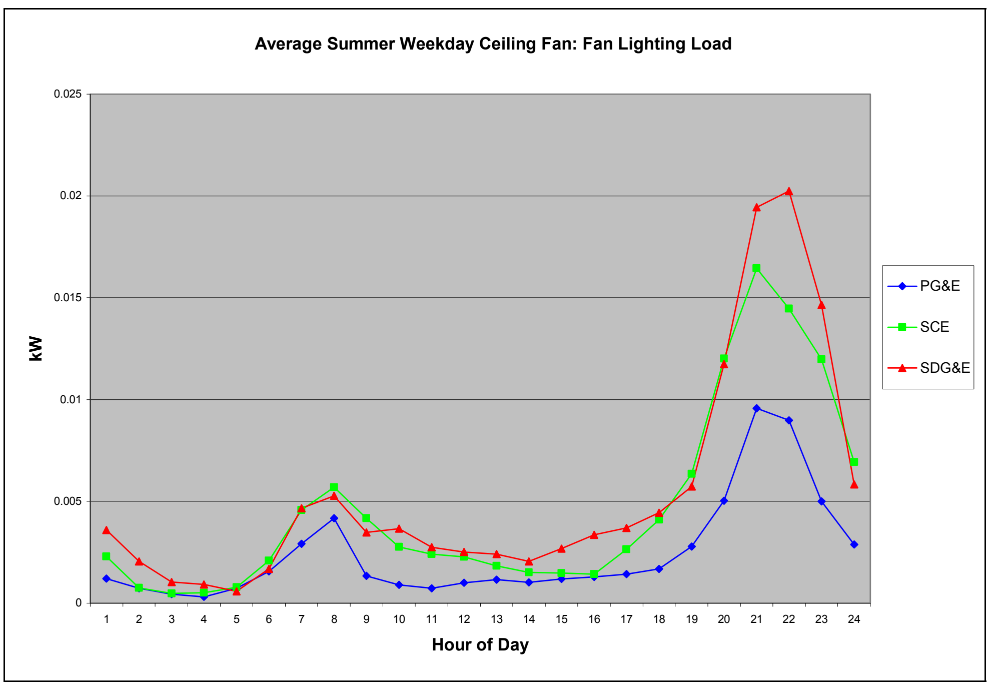

Figure 21 Summer Weekday Average Ceiling Fan Lighting Loadshapes by Utility

Summer System Hourly Load Results

The estimated aggregate loadshapes of all ceiling fans in three utility service territories are presented in the following graphs. The "statewide" loadshapes are simply the sum of the three utility service territory loadshapes. Figure 22 shows the system wide ceiling fan loadshapes for ceiling fan total fixture, the statewide loadshape shows a peak of slightly over 200 MW at hour 21, the hour between 8 and 9 PM.

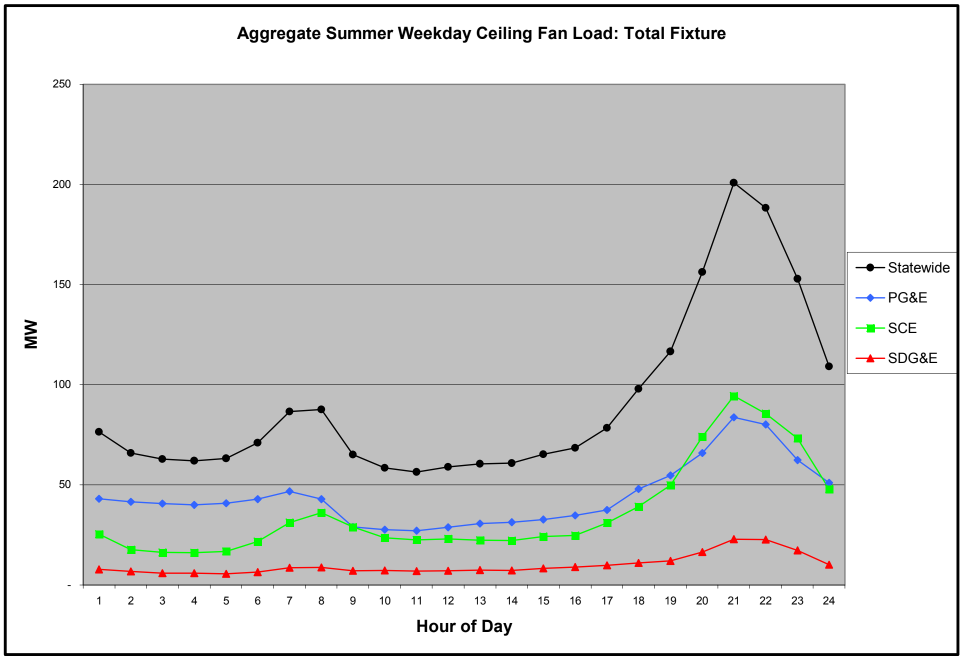

Figure 22 Summer Weekday Ceiling Fan Total Fixture System Load

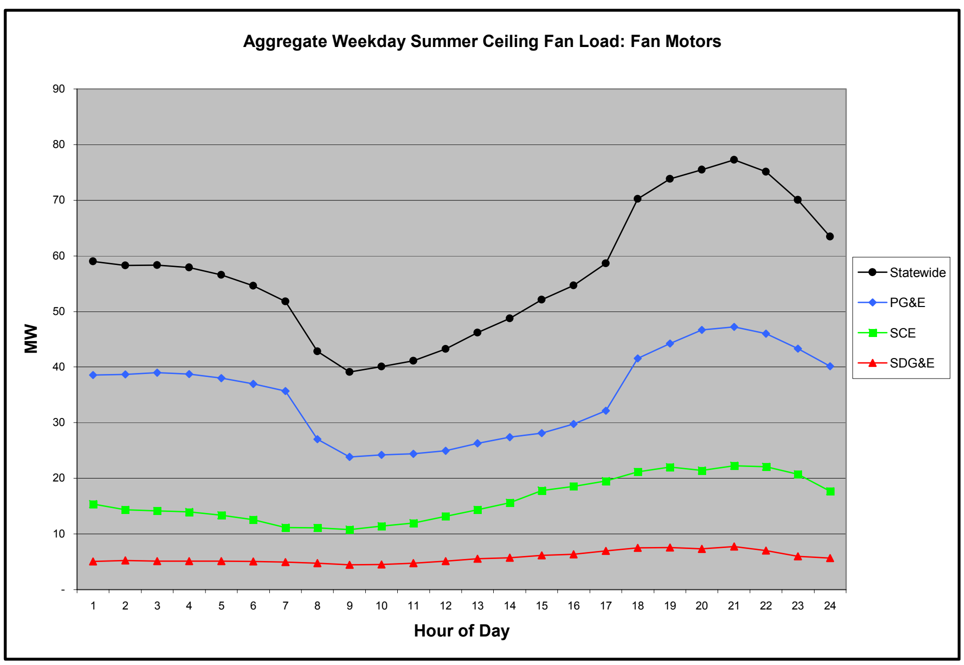

Figure 23 Summer Weekday Ceiling Fan Motor System Load

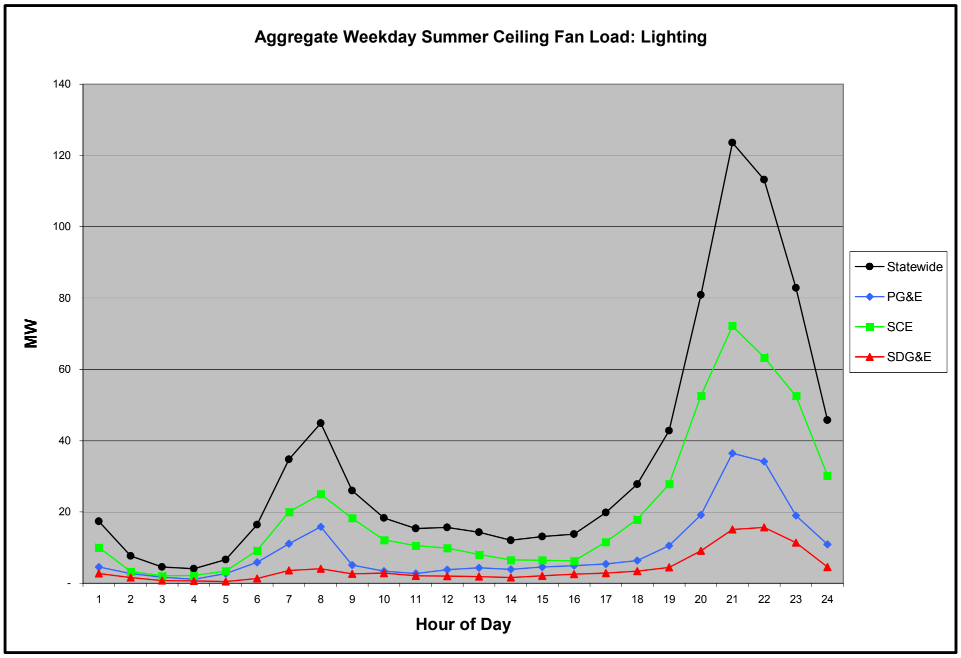

Figure 24 Summer Weekday Ceiling Fan Lighting System Load

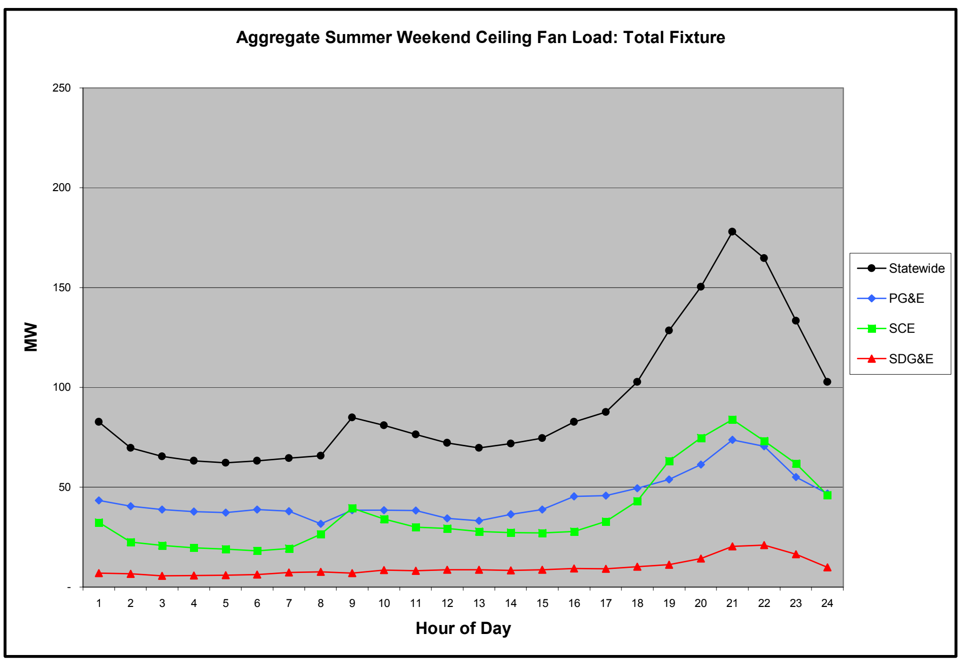

Figure 25 Summer Weekend Ceiling Fan Total Fixture System Load

Summer Cooled and Non-Cooled Hourly Results

The next the graphs show the breakdown of statewide ceiling fan system load between cooled and non-cooled residences.

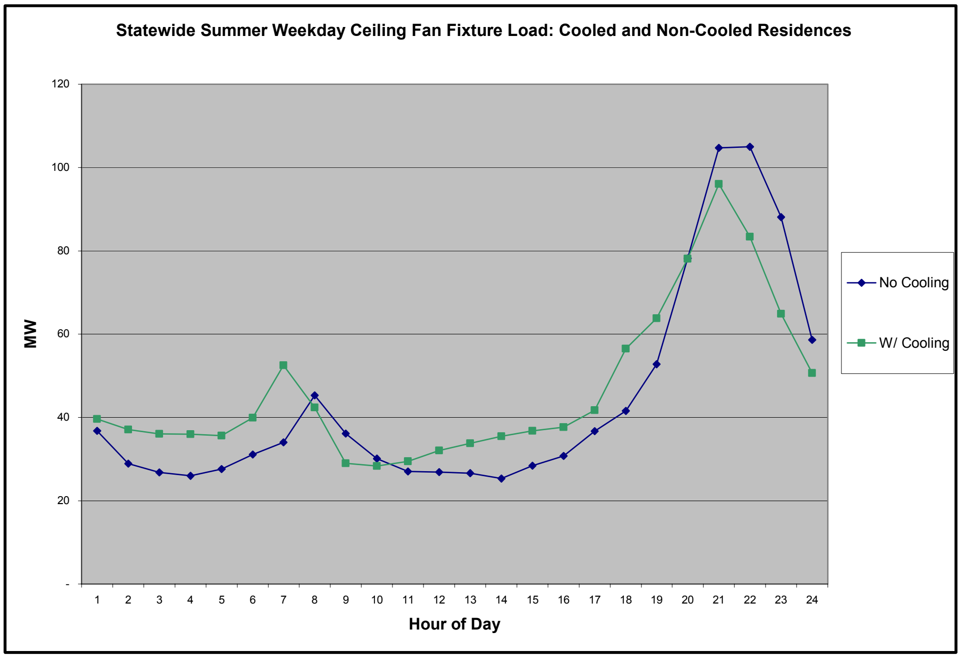

Figure 26 Statewide Ceiling Fan Total Fixture Summer Aggregate Load Breakdown between Cooled and Non-Cooled Residences

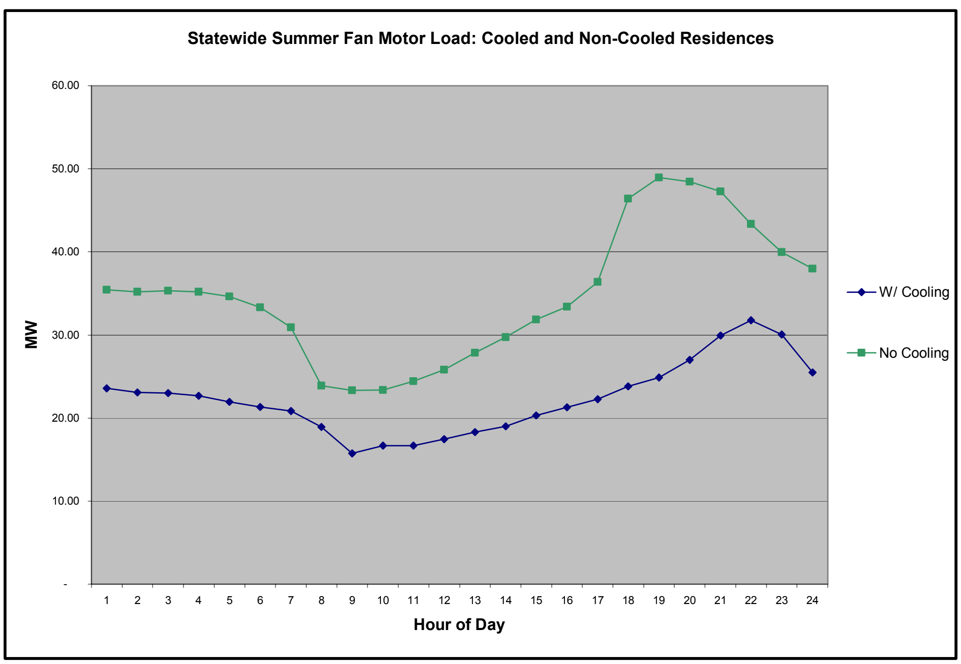

Figure 27 Summer Statewide Ceiling Fan Motor Aggregate Load Breakdown between Cooled and Non-Cooled Residences

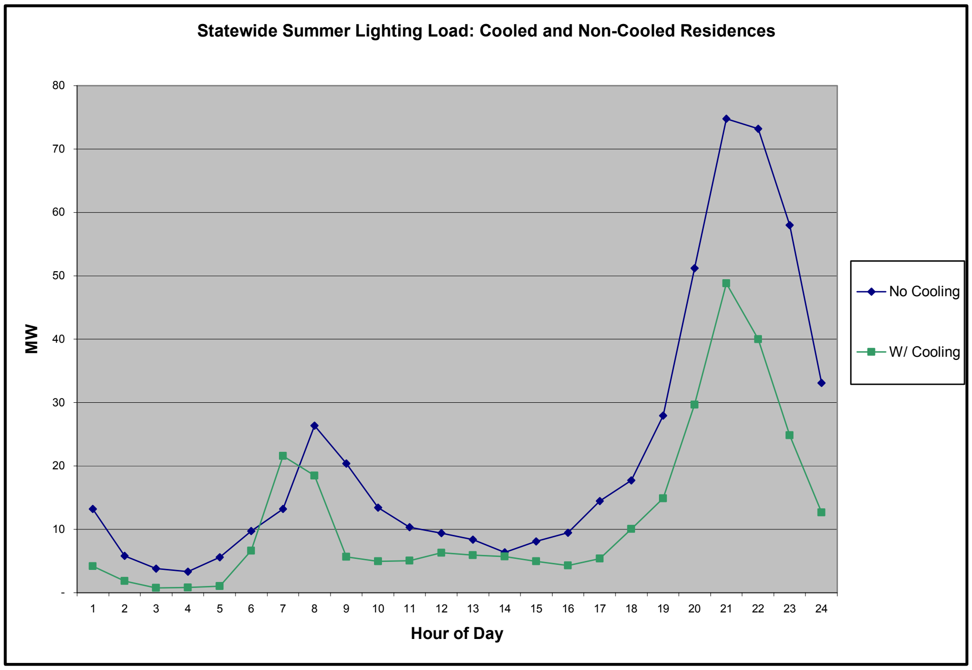

Figure 28 Summer Statewide Ceiling Fan Lighting Aggregate Load Breakdown between Cooled and Non-Cooled Residences

Winter Hourly Results

The same graphs as shown above for summer are all repeated with data for the winter utility costing periods.

Statewide Winter Loadshapes

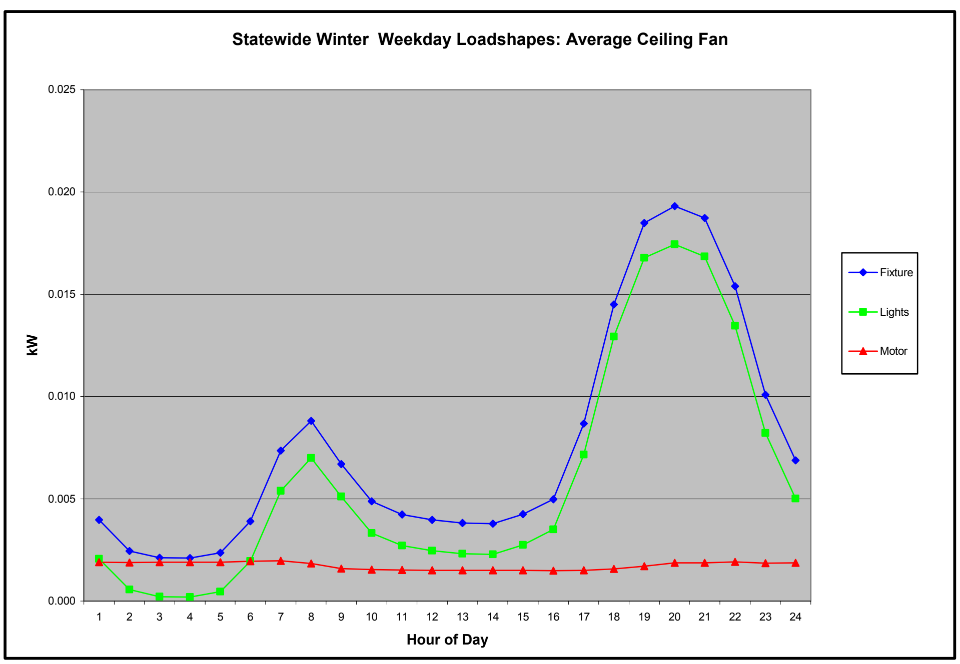

Figure 29 Statewide Winter Weekday Average Ceiling Fan Loadshapes

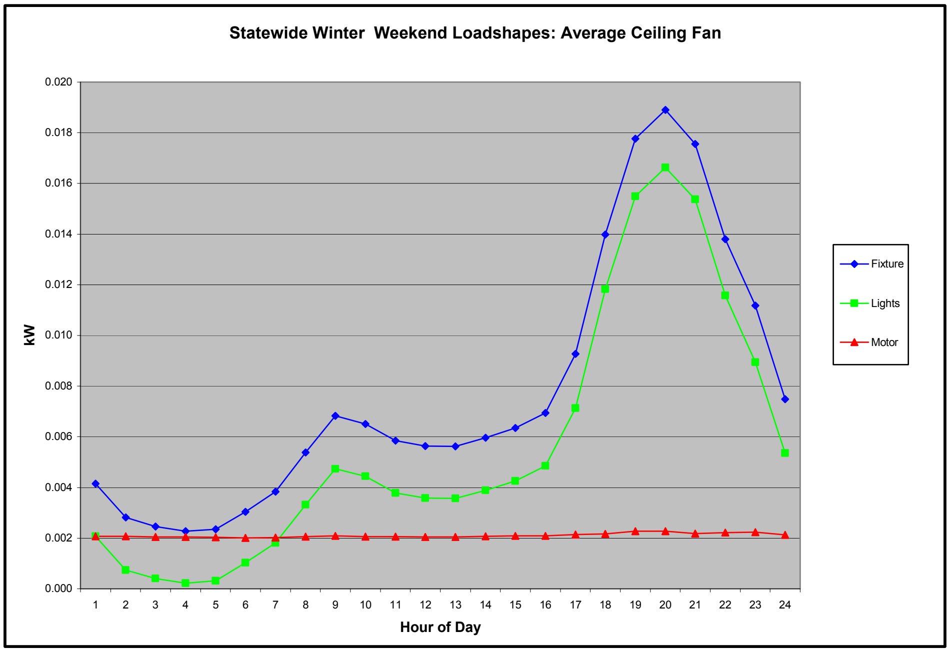

Figure 30 Statewide Winter Weekend Average Ceiling Fan Loadshapes

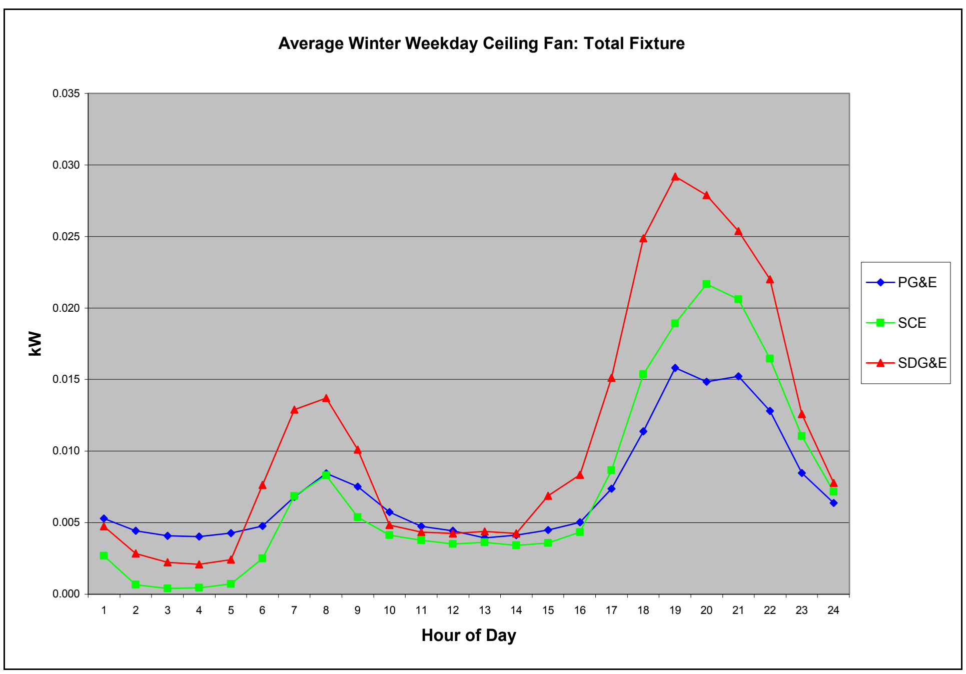

Figure 31 Winter Weekday Average Ceiling Fan Total Fixture Demand by Utility Service Territory

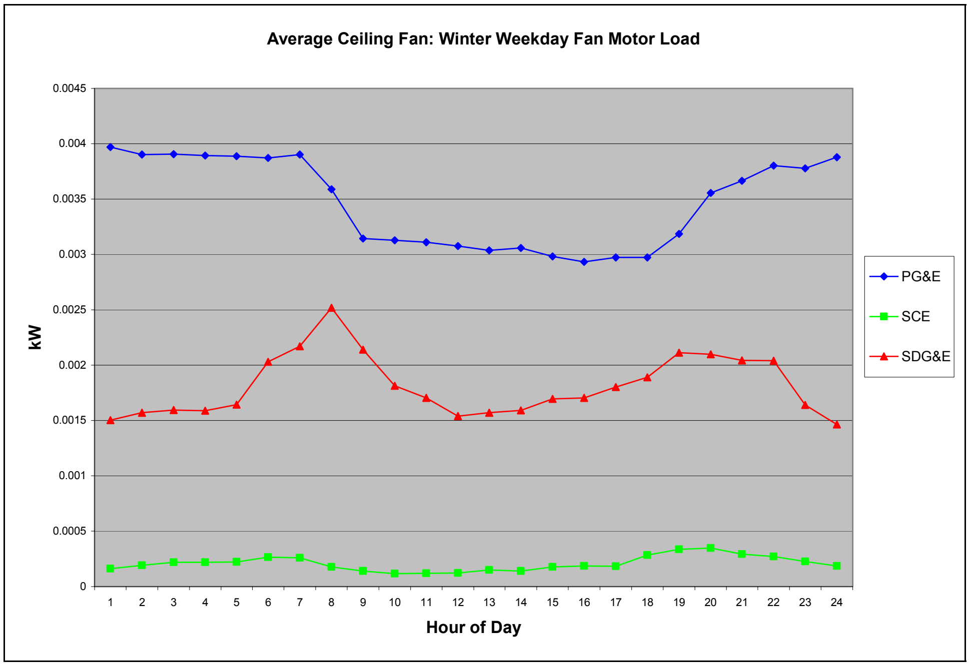

Figure 32 Winter Weekday Average Ceiling Fan Motor Loadshapes by Utility

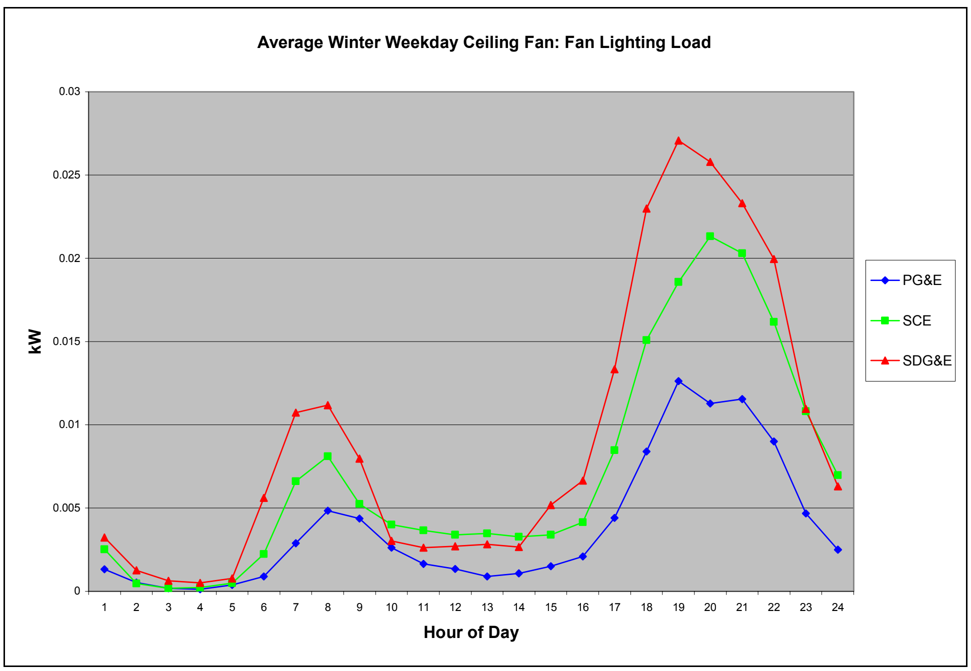

Figure 33 Winter Weekday Average Ceiling Fan Lighting Loadshapes by Utility

Winter System Load Hourly Results

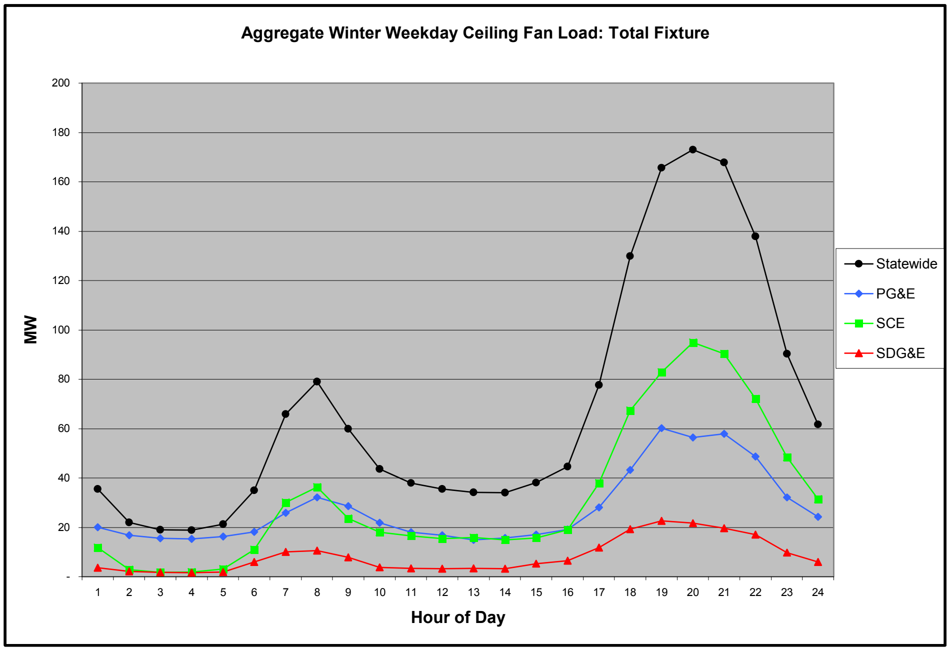

Figure 34 Winter Weekday Ceiling Fan Total Fixture System Load

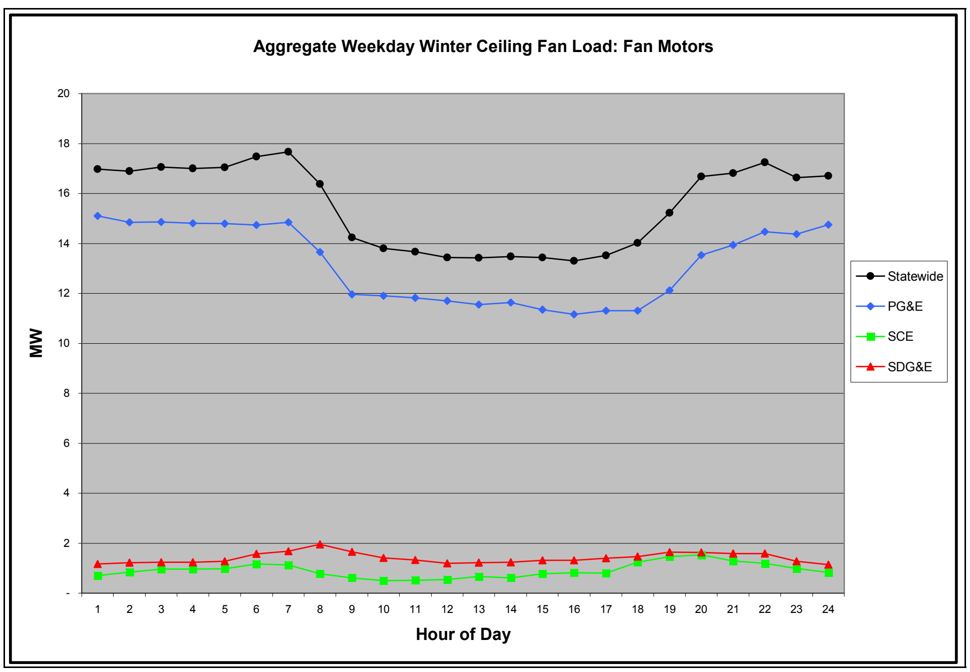

Figure 35 Winter Weekday Ceiling Fan Motor System Load

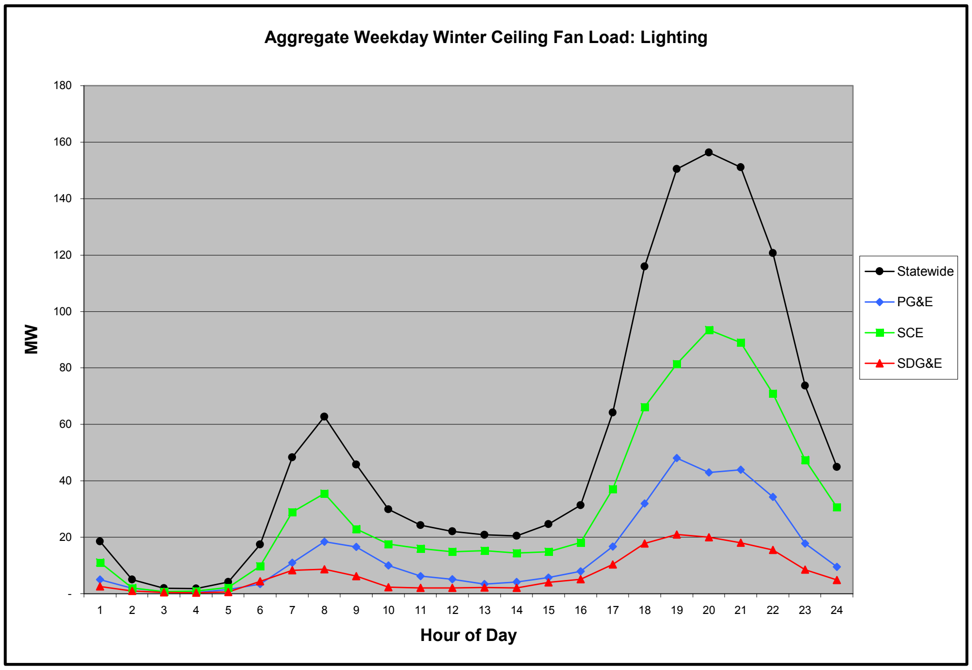

Figure 36 Winter Weekday Ceiling Fan Lighting System Load

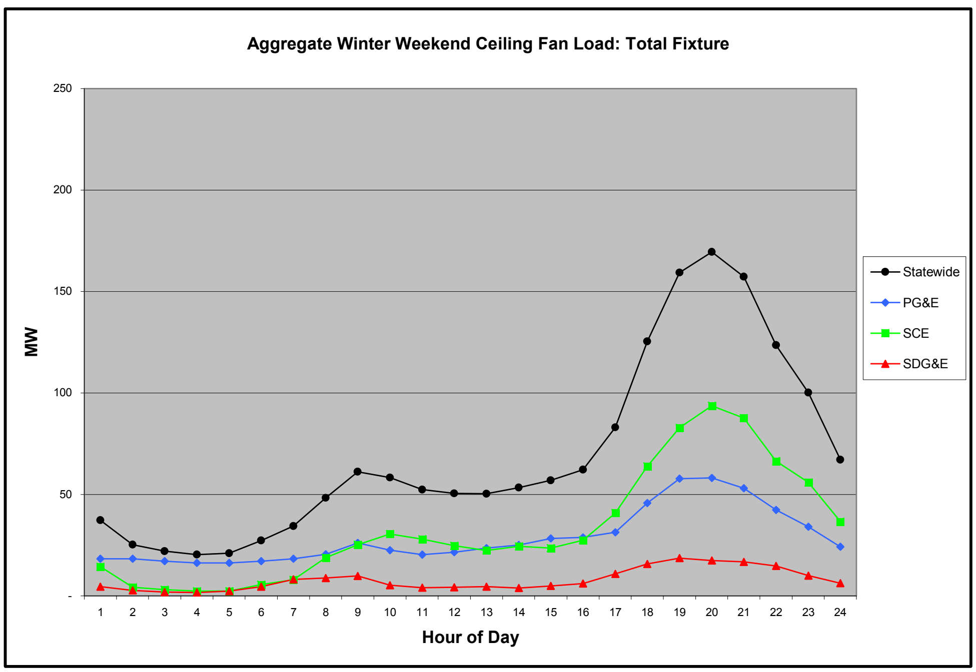

Figure 37 Winter Weekend Ceiling Fan Total Fixture System Load

Winter Cooled and Non-Cooled Hourly Results

The next three graphs show the breakdown of statewide ceiling fan system load between cooled and non-cooled residences during the winter costing season.

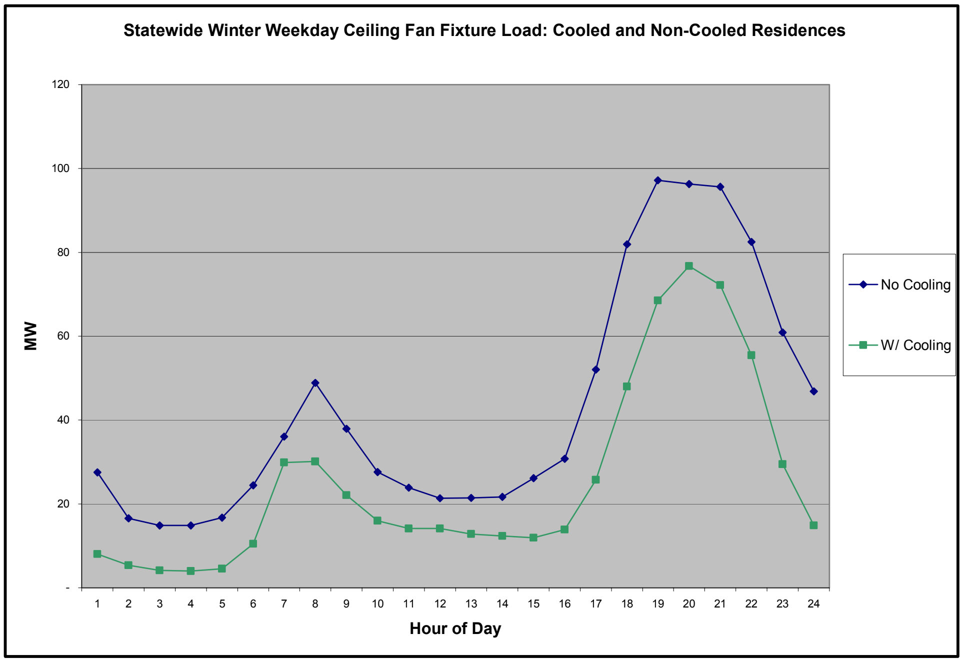

Figure 38 Statewide Ceiling Fan Total Fixture Winter Aggregate Load Breakdown between Cooled and Non-Cooled Residences

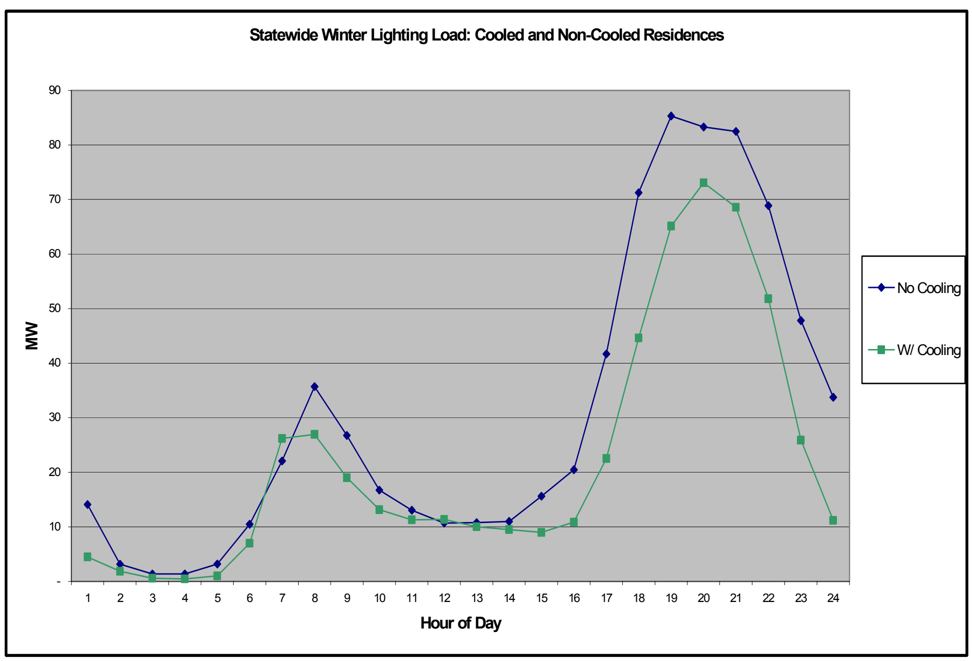

Figure 39 Winter Statewide Ceiling Fan Motor Aggregate Load Breakdown between Cooled and Non-Cooled Residences

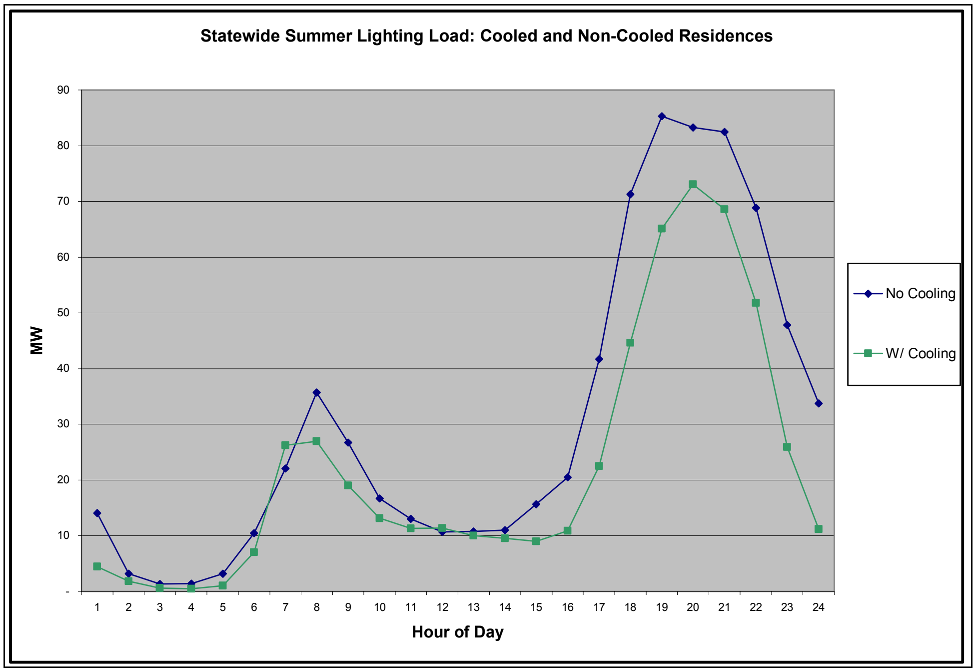

Figure 40 Winter Statewide Ceiling Fan Lighting Aggregate Load Breakdown between Cooled and Non-Cooled Residences

Customer Behavior

This section presents findings related to customer behavior with regard to operation of ceiling fans. The findings are based on survey data gathered during the initial site visit.

Fan Direction

Customers were asked if they were aware that the rotational direction of the fan could be changed. Eighty-two percent report to be aware of this fan option.

Awareness of Fan Direction	# Fans	Proportion
Aware	51	82%
Not Aware	11	18%

Figure 41: Awareness of Fan Directions

The customers who were aware that fan direction was adjustable, they were then asked if they practiced changing the direction on a seasonal basis. Figure 42 shows the results of this question, where 52% report never changing the direction, 30% change direction sometimes, and nearly 20% always change the direction. Those who are aware but do not change the direction are presumably those customers that are not using the fans during the winter months.

Seasonal Direction Change	# Fans	Proportion
Never	70	52%
Sometimes	40	30%
Always	25	19%

Figure 42: Seasonal Directional Change

Operation with Air-conditioning Systems

Customers with air-conditioning and programmable thermostats were asked if they raised the set-point of their thermostat during simultaneous operation of their ceiling fans and air-conditioners. Of the 36 customers with air-conditioning and programmable thermostats, 2% reported always raising the thermostat, 17% sometimes raise the temperature, and nearly three quarters of the sample never change the temperature.

Adjust Thermostat with Fan Use	#	Proportion
Always	2	6%
Sometimes	6	17%
Never	26	72%
No Response	2	6%

Figure 43: Change Cooling Set-point with Fan Operation

For those that responded "always" or "sometimes", the question was asked regarding how many degrees they usually set-up the thermostat. Figure 44 shows the responses to this question.

Degree Adjusted	Residents
1 or 2	3
3 or 4	0
5 or 6	3
More than 6	2

Figure 44: Number of Set-up Degrees

Section 4 - SMUD Ceiling Fan Study

SMUD Study Introduction

The SMUD Ceiling Fan Study final report studied ceiling fan motor operation in conjunction with the air conditioning (mechanical cooling) in recently constructed residences in SMUD's service territory. This was accomplished through short term monitoring of ceiling fan motor run time and indoor temperature along with ongoing long term monitoring of air conditioning usage previously installed.

Eighty-one ceiling fans in twenty-five new homes, all constructed in 1998, 1999, and 2000, were monitored for an average of 35 days in august, September and October of 2001. The data from the loggers were analyzed along with long-term air conditioner load and outdoor temperature for each residence.

The primary goal of the study was to determine whether the use of ceiling fans changes how air conditioners are operated in residences. Analyses were performed to quantify independent and concurrent usage of ceiling fans and air conditioners as well as identify operational and load patterns of ceiling fan use.

This SMUD study augments the Statewide Ceiling Fan Study, conducted concurrently by RLW. The comparisons are made throughout this report to findings in the "statewide" or IOU study. Please note that the findings of the "statewide" study are for the IOU service territories only and did not include data from SMUD or any other municipal utility in California.

The important distinction between these studies is that data were collected for the SMUD study during the cooling season only, whereas the "statewide" study also included winter data collection.

Another important distinction is that data collected for the IOU Ceiling Fan Study was collected from homes of varying vintages. One significant characteristic that separates newer homes in SMUD's service territory from most other older vintage homes is that these newer homes, on average, have a higher number of ceiling fans than older homes.

SMUD Study Methodology Overview

SMUD selected a sample of recently built homes with ceiling fans where instrumentation for collecting whole premise and air conditioning usage data was in place, for participation in the Ceiling Fan Study. Site visits were performed at all participating homes where modified motor loggers were installed on all ceiling fans. Temperature loggers were installed at the thermostats in the residence at the same time. After a period of time the loggers were removed and the data was downloaded from the loggers. Customer reported usage was used if any data logger failed or was lost.

SMUD staff processed the fan motor on/off event data into average weekday and weekend loadshapes using the same methodology RLW used for the IOU Ceiling Fan Study. SMUD sent the logger datasets to RLW as well as hourly whole premise load and hourly air conditioner load data for each residence in the study. Hourly outdoor air temperature was also provided from Sacramento's executive airport weather station.

Analysis of the data was directed at the average indoor and outdoor temperature conditions of the residence during ceiling fan, air conditioner and ceiling fan/air conditioning concurrent usage, and the run time proportions of ceiling fans and air conditioners. Additional analyses calculated outdoor lag temperatures prior to ceiling fan and/or air conditioner usage. Average fan loadshapes as well as population system load were also calculated.

Case Weights

Each residence has corresponding case weight that can be thought of as the number of sites in the population, the number of new single family homes erected in SMUD territory in 1998 through 2000, that the site is thought to represent. Since the sample of 25 homes was not stratified, each residence in the sample represented an equal proportion of homes in the population of 9840; the case weights for all residences were equal, 393.6

$$w = n / n_{,}$$

$$w = 9840 / 25$$

$$w = 393.6$$

SMUD Study Findings

Energy Usage

The average fan motor load for the analysis was determined from the predominant fan speed used, as reported by the resident, and blade diameter. The estimated average operating fan load for the study is 27 watts. Table 14 presents the average fan motor load and distribution of fan speeds used.

Average Fan Load	Fan Speed Distribution		
W	High	Medium	Low
27	5%	51%	44%

Table 14 Average Ceiling Fan Loads and Speed

Table 15 shows a comparison of operating fan motor load from the IOU Ceiling Fan Study. The estimate of 27 watts for this study is considerably less than the statewide study. The difference may be because SMUD customers indicated using predominately a single speed, whereas customers in the IOU study indicated proportional usage of the different fan speeds.

	Average Fan Load Watts
SMUD	27
Statewide Study Average	38
PG&E	38
SCE	37
SDG&E	44

Table 15 Comparison of Fan Motor Load

Table 3 presents estimates of ceiling fan energy usage. The analysis estimates weekly energy usage of 1.5 kWh per fan. Expanded to the population of 9,840 homes[5], the ceiling fan motor energy usage is estimated at nearly 48 MWh per week. The IOU study estimated less energy usage per fan, 1.1 kWh per week. Since on-time connected load is greater in the IOU study, this indicates that fans in SMUD's recently constructed homes are used considerably more often than the fans in the IOU study. Longer operating hours may be attributed to the warmer climate in SMUD's territory, compared to the IOU average.

	Average Weekday Energy Usage	Average Weekday Energy Usage	Average Weekly Energy Usage
SMUD Study	**kWh**	**kWh**	**kWh**
Average Fan	0.23	0.21	1.50
Average Residence	0.76	0.67	4.85
Study Population	7,438	6,572	47,738
"Statewide" Study	**kWh**	**kWh**	**kWh**
Average Fan	0.16	0.16	1.10
Average Residence	0.33	0.34	2.33
Study Population	1,368,667	1,421,421	9,686,177

Table 16 Weekly Ceiling Fan Motor Energy Usage

Loadshapes

Individual loadshape information was acquired for 77 of the 81 ceiling fans. Sixty fans had sufficient monitored data and the remaining 17 used customer reported data to generate loadshapes. Figure 45 shows the average ceiling fan loadshapes for the study by day type. Weekends show slightly more usage throughout most of the day, likely due to increased occupancy. Note that these loadshapes do not average to the 27 watt connected load but represent the diversity of usage of all fans during the monitoring period.

[5] The SMUD study population consists of new single-family homes constructed between January 1998 and June of 2000.

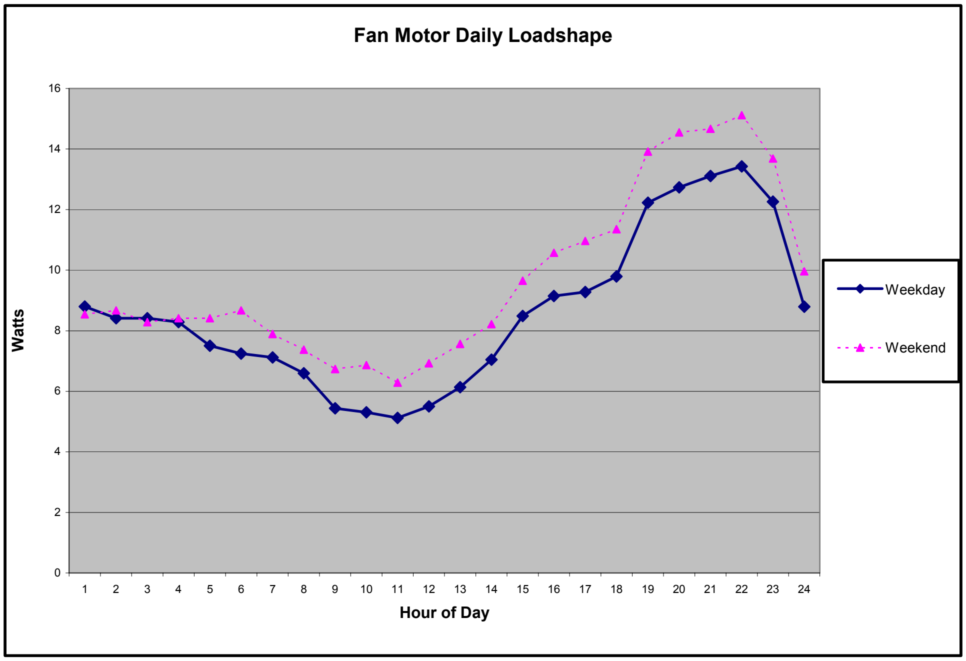

Figure 45 Average Fan Motor Loadshape

Although the average connected fan motor load is less than the estimates from the IOU Ceiling Fan Study, the comparison of fan motor loadshapes in Figure 46 shows that the average fan in this study uses more energy than the average fan in the IOU Ceiling Fan Study, for the summer season. Fans in SMUD's recently constructed homes are used considerably more, as evidenced by the SMUD fans lower average connected load and greater average energy use than fans in the IOU study.

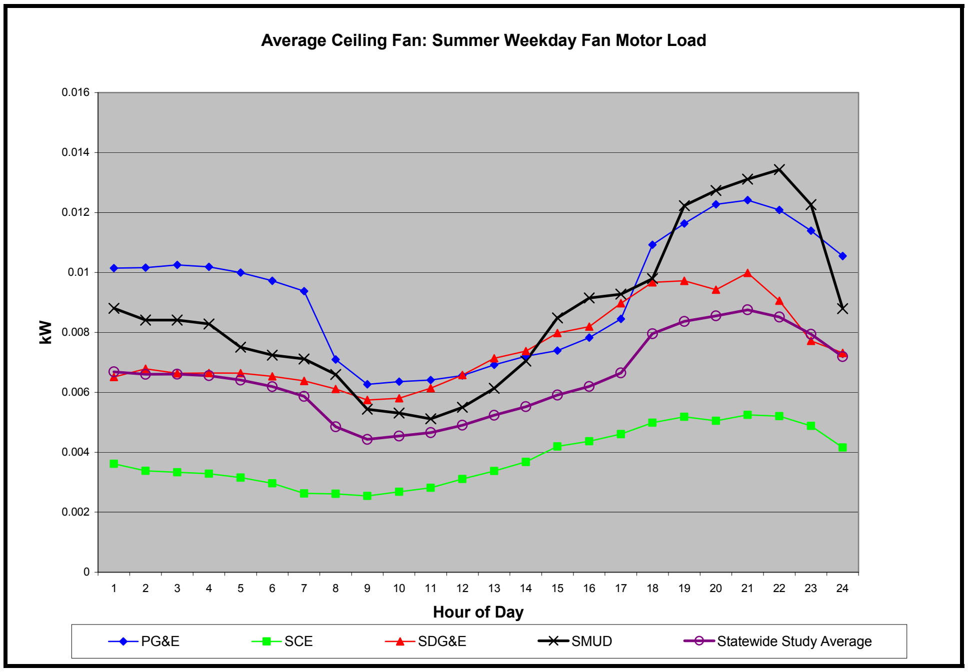

Figure 46 Summer Weekday Average Loadshapes

The aggregate system loadshapes, shown in Figure 47, represents the ceiling fan load for the population of 9,840 new homes. The population load is in direct proportion to the individual fan loadshapes as all residences were weighted equally for this study. The peak system load occurs at hour 22, or 9 to 10 pm, with a weekend peak of 502 kW and a weekday peak of 446 kW during the same hour.

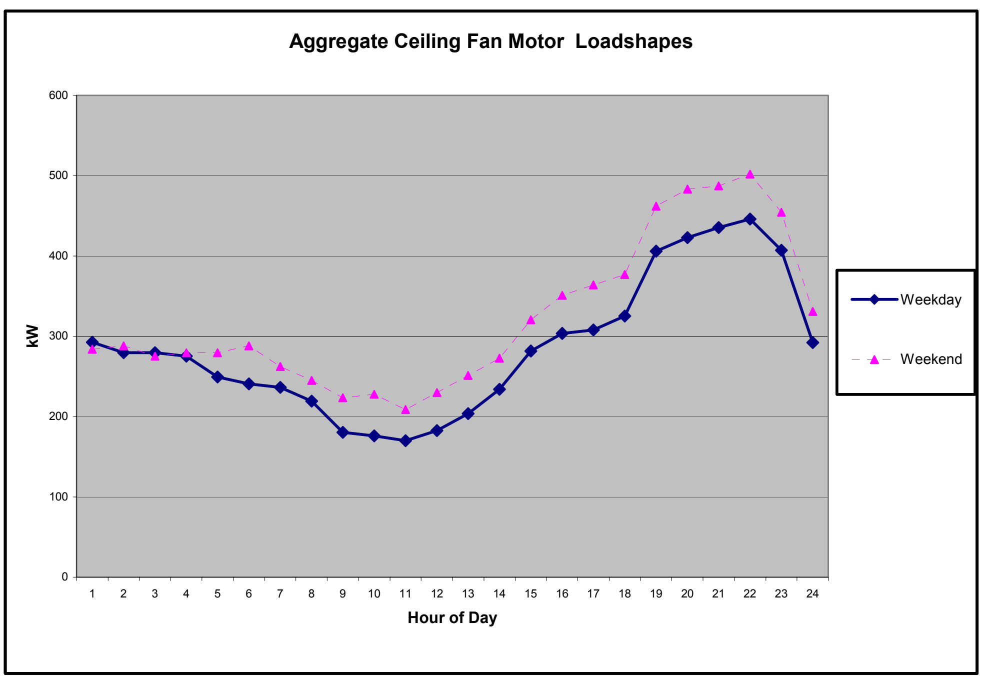

Figure 47 Ceiling Fan Population System Load

Usage Conditions

Table 1 shows proportional usage and temperature conditions during operation. These data represent the conditions of operation for 58 fans with complete data sets for ceiling fan usage, air conditioning usage, and indoor temperature. The fans that are used more frequently have a greater influence on the average temperature data than fans that are used infrequently. Indoor and outdoor dry bulb are simply the average temperatures during operation.

The outdoor dry bulb lag temperatures presented in Table 1 are for the outdoor average temperatures for each of the four previous hours prior to the given condition. Lag temperatures are presented here to provide a better indication of the heat load on the residence. Typically, high outdoor temperatures most profoundly affect indoor thermal comfort hours after they have occurred, as the heat works its way through the home. As the walls, windows and other surfaces heat up, the radiant heat transfer from these surfaces increases such that occupants feel "warmer" than they would even if the air temperature remains constant. "mean radiant temperature" which considers surface and air temperatures, is a better indicator of thermal comfort than air temperature alone. Therefore, though average indoor dry-bulb temperatures for "air conditioning on" and "ceiling fan only" are nearly the same, the significantly lower outdoor lag temperatures during the "ceiling fan only" condition have the same space feeling "cooler" to the occupants since surrounding surfaces are cooler.

All (n=58)	Operating Proportion	Indoor Dry-Bulb Temperature	Outdoor Dry-Bulb Temperature	Outdoor DB 1 Hour Lag Temperature	Outdoor DB 2 Hour Lag Temperature	Outdoor DB 3 Hour Lag Temperature	Outdoor DB 4 Hour Lag Temperature
Concurrent Usage	9.9%	78.4	78.6	80.2	81.3	81.8	81.0
Air Conditioning Only	10.9%	76.7	78.3	80.4	82.0	82.8	82.0
Ceiling Fan Only	22.7%	77.4	67.0	67.2	67.6	68.8	69.7
Neither	56.6%	75.5	67.7	66.9	66.3	65.6	65.5
Monitored Period	100.0%	76.3	69.8	-	-	-	-
Ceiling Fan On	32.5%	77.7	70.5	71.2	71.8	72.7	73.1
Air Conditioning On	20.7%	77.5	78.4	80.3	81.7	82.3	81.5

Table 17 Ceiling Fan and Air Conditioning Operating Conditions

The table shows that, overall, the ceiling fans were operated more often than air-conditioning, 32.5% to 20.7% on average, including concurrent usage. The average outdoor temperature is significantly greater when the air-conditioning is on than when the ceiling fan is on. The indoor temperature is nearly the same when the air conditioning is on and when the ceiling fan is in operation, however differences emerge when considering independent and concurrent usage.

During the periods where the air conditioning and ceiling fans are being used concurrently, the average indoor temperature, 78.4, is warmer than when air conditioning is being used alone, 76.7. This indicates that occupants were willing to tolerate higher indoor temperatures when ceiling fans were operating, and using higher set points while the fans were running. Alternatively, this concurrent usage could be occurring during a transitional phase, while the temperature of the home is being brought down into the comfort range, and ceiling fan or air conditioning is turned off after the air conditioning has "taken control of the load". However, the similar lag temperature profiles during concurrent and air conditioning only usage indicates it is more likely to be higher set points than a transitional phase.

During the monitored period the average indoor temperature was 76.3 F, while the average outdoor temperature was 69.8 F. The low overall outdoor temperatures are due to the wide daily swing in outdoor temperature, as shown in Figure 48.

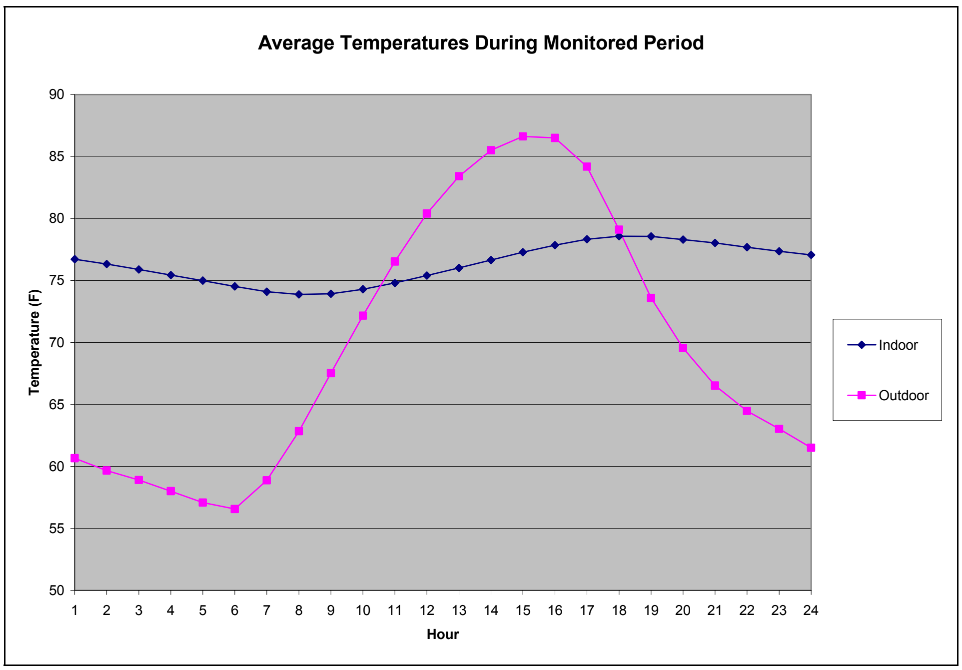

Figure 48 Hourly Average Temperatures During Monitored Period

Table 18 demonstrates the effects of the daily temperature swing during the monitored period. The peak period, 1 pm to 9pm had an average outdoor temperature of 78.9. However when broken into bins of 1 pm to 5 pm and 5 pm to 9 pm, the difference between the average indoor temperatures shows that the afternoons are warm, an average of 85.7 degrees, and the evenings are rather cool with an average of 72.2.

	1:00PM to 9:00PM	1:00PM to 5:00PM	5:00PM to 9:00PM
Outdoor Temp	78.9	85.7	72.2
Indoor Temp	77.9	77.5	78.4

Table 18 Average Temperatures Over Peak Periods

Table 19 shows the average usage conditions over the 5pm to 9pm peak period. Although the average outdoor temperatures are lower than the 1pm to 5pm period, ceiling fan and air conditioner usage is more frequent and the average indoor temperature is higher in the 5pm to 9pm peak period. Contrasted with Table 1, it shows that the outdoor lag temperatures are much higher for all usage conditions, and outdoor temperatures are lower. Considering that this period constitutes a high usage period, these data reinforce the concept that lag temperatures are a better indicator of thermal comfort and air conditioner usage of a residence than current outdoor temperature.

5PM to 9 PM Peak Period	Operating Proportion	Indoor Dry-Bulb Temperature	Outdoor Dry-Bulb Temperature	Outdoor DB 1 Hour Lag Temperature	Outdoor DB 2 Hour Lag Temperature	Outdoor DB 3 Hour Lag Temperature	Outdoor DB 4 Hour Lag Temperature
Concurrent Usage	21.7%	78.6	76.0	81.1	85.7	90.0	89.9
Air Conditioning Only	25.5%	76.8	75.3	80.3	84.8	89.0	88.9
Ceiling Fan Only	20.9%	80.5	69.7	73.7	77.8	83.0	83.7
Neither	31.9%	78.1	68.7	72.5	76.4	80.7	81.0
Monitored Period	100.0%	78.4	72.2	-	-	-	-
Ceiling Fan On	42.6%	79.5	72.9	77.5	81.8	86.6	86.9
Air Conditioning On	47.2%	77.6	75.7	80.7	85.2	89.5	89.3

Table 19 Average Usage Conditions During 5pm to 9pm Peak Period

Table 19 also shows the higher indoor temperature for concurrent ceiling fan, 78.6, than air conditioner only usage, 76.8, for the 5 pm to 9pm peak period, which is consistent with the overall findings in Table 1. Figure 49 illustrates the difference in indoor air temperature on an hourly basis for concurrent and air conditioning only usage during the hours where air-conditioning is most used.

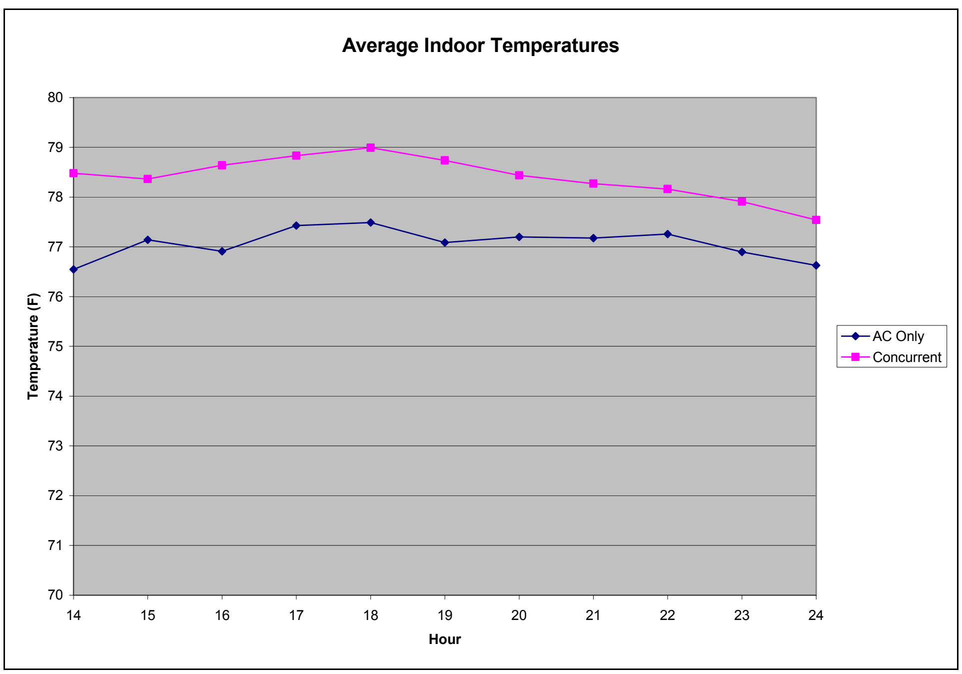

Figure 49 Comparison of Indoor Temperature During Air Conditioning Only and Air Conditioning In Conjunction with Ceiling Fan Usage

Differing Usage Patterns

On closer inspection of individual fan data, two divergent styles of ceiling fan operation can be observed. The two styles are ceiling fans that are operated habitually, sometimes constantly, and those that are operated less often, typically in response to thermal conditions.

Separating the fan data into two groups, fans that were used greater than 50% of the time during the monitored period and fans that were operated less than 50% of the time, illustrates the difference.

As Table 20 shows, the spaces where fans are frequently used, the air conditioning systems are also used more frequently. Overall these spaces have over 50% more air-conditioning usage than spaces where fans are used less frequently, 29.8% of the period as opposed to 17.6% of the period. Also interesting is that the overall indoor temperature for the spaces where the fans are frequently used, 77.2, is higher than spaces with lesser-used fans 76.0. This shows that the fans that are lesser used are occupied comparably to spaces where fans run frequently, since an unoccupied home with no air conditioner running would suffer from higher overall indoor temperatures, which are not in evidence.

Greater Usage (n=14)	Operating Proportion	Indoor Dry-Bulb Temperature	Outdoor Dry-Bulb Temperature	Outdoor DB 1 Hour Lag Temperature	Outdoor DB 2 Hour Lag Temperature	Outdoor DB 3 Hour Lag Temperature	Outdoor DB 4 Hour Lag Temperature
Concurrent Usage	25.3%	78.5	78.8	79.6	80.0	79.3	78.0
Air Conditioning Only	4.5%	77.2	78.8	80.2	80.9	80.6	79.0
Ceiling Fan Only	53.5%	77.2	65.8	65.6	65.7	66.6	67.5
Neither	16.7%	75.8	68.2	67.3	66.4	65.1	64.5
Ceiling Fan On	78.8%	77.6	70.0	70.1	70.3	70.6	70.9
Air Conditioning On	29.8%	78.3	78.8	79.7	80.1	79.5	78.2
Less Usage (n=44)	**Operating Proportion**	**Indoor Dry-Bulb Temperature**	**Outdoor Dry-Bulb Temperature**	**Outdoor DB 1 Hour Lag Temperature**	**Outdoor DB 2 Hour Lag Temperature**	**Outdoor DB 3 Hour Lag Temperature**	**Outdoor DB 4 Hour Lag Temperature**
Concurrent Usage	5.1%	78.4	78.7	81.6	84.0	86.3	86.1
Air Conditioning Only	13.3%	76.5	78.3	80.5	82.1	83.1	82.4
Ceiling Fan Only	12.5%	78.0	69.0	69.8	70.7	72.2	73.0
Neither	69.0%	75.4	67.6	66.8	66.2	65.5	65.5
Ceiling Fan On	17.6%	78.0	71.3	72.6	73.9	75.7	76.3
Air Conditioning On	17.6%	77.1	78.6	81.0	82.9	84.2	83.7

Table 20 Comparison of Operating Conditions of Ceiling Fans with Differing Usage Patterns

There are several possible reasons why even though the air-conditioning is used more often in spaces where fans are used frequently, they have higher indoor temperature than spaces where fans are used less frequently. Possible causes of why this may be occurring include differences in household ventilation practices during the cooler periods of the day, or the ratio of heat load to air conditioning capacity may be greater in the spaces where ceiling fans are used frequently.

In the spaces where fans are used less often, neither ceiling fan nor air conditioning is in operation a majority of the time. Ceiling fan alone is operated during periods with a mild outdoor temperature profile. For lesser-used fans, air-conditioning is typically used during periods with a much warmer outdoor temperature profile than ceiling fan only. Simultaneous operation of air conditioning and ceiling fan happens rarely and during periods with the warmest outdoor lag temperature profile.

Frequently used fans appear to be left on regardless of thermal conditions, as the outdoor temperature profile for ceiling fan only is very similar to “neither’ temperature profile. Less often used fans seem to be turned on to improve thermal comfort.

For frequently used fans, no significant difference can be seen between the air conditioning only and concurrent usage outdoor temperature and outdoor temperature lag profiles. However in both frequently and less frequently used fans, the concurrent usage indoor temperatures are higher for air conditioning only. Further illustrating that occupants seem to be willing to endure slightly higher indoor temperatures during concurrent operation than ac only operation.

In the IOU Ceiling Fan Study, occupants were asked if they turned up their cooling set points while operating their ceiling fans. Only a small fraction agreed that they did so, making it is possible that occupants are using higher cooling set points during ceiling fan operation without being aware of it. Commonly, residential set points are adjusted during the course of the day so that the occupants are comfortable. Therefore, the higher cooling set points may be the result of *not* being adjusted down just as easily as they are consciously being adjusted up.

One might also conclude that on the hottest days during simultaneous operation of fans and air-conditioners that the air-conditioning systems may be having a difficult time keeping up with the home’s thermal load. This would result in higher average indoor temperatures and would provide another explanation for the two degree separation between the two groups.

Conclusions

During the cooling season, the fans in SMUD’s new construction sample on average use more energy than the average statewide Ceiling Fan Study fan. That is because although the ceiling fans in this study had a lower average connected load, they had greater average run hours than the average fan in the IOU Ceiling Fan Study. This may be attributed to the climatic differences between a statewide average and SMUD’s warmer inland climate.

Upon examination of the indoor temperature and outdoor temperature lag profiles it appears that ceiling fans may be used to provide thermal relief in the home, however only up to a point. Typically, after the prolonged high outside temperatures have warmed up the home the air conditioning is turned on.

Average indoor temperatures are higher during concurrent usage of ceiling fans and air conditioner than when air conditioners are used without ceiling fans. From this fact, it appears that occupants are willing to endure warmer conditions if the ceiling fan is in operation. In spaces where ceiling fans and air conditioning is used concurrently the average indoor temperature was 1.8 degrees higher during the noon to 8 pm peak period than spaces where air conditioning was being used without ceiling fans. Therefore ceiling fans are responsible for some energy savings from increased cooling set-points in the population represented by this sample of SMUD recently constructed homes. Moreover, this does not appear to be part of conscious decision making process by the occupants.

Further Study

Close observation of the temperature data shows that very often the indoor temperatures are several degrees higher than outdoor temperatures. With the cool summer evenings in the Sacramento area, the opportunities for free cooling are abundant, but do not appear to be taken advantage of by this sample of homes. A possible question for further research is whether or not the installation of a whole house fan could facilitate free cooling during the evenings and early morning for these homes.

Another possible research question is whether the pre-cooling of homes could realize energy savings. Since air conditioning units work significantly more efficiently under cooler outside air temperatures, anticipating a cooling event and pre-cooling a well insulated home below set point before it occurs may result in lower overall energy usage. From the data it appears that pre-cooling would be beneficial, however as expected it is not practiced. Some units are only used during the warmest outdoor temperatures, when the efficiency of these units is the lowest.

Appendix

Appendix A – Project Initiation Meeting Minutes

Kickoff Meeting

SDG&E CA Statewide Ceiling Fan Monitoring Study

April 3, 2001

Present:

Noah Horowitz, Rob Rubin, Ed Hamzawi, Roger Wright, Matt Brost, Chris Baginski, Rich Pullium (by phone), Vic Sanchez

Absent:

Jim Green, Chris Ann Dickerson

Background

Noah described the work to develop an Energy Star spec –a performance spec on the fan and a pin based CF light package. Much of the work so far has been to develop a standard for testing the CFM per Watt of the fan. Hunter fan and King of Fans are the big producers. Both firms are supporting an Energy Star spec.

Once the Energy Star spec has been developed, we will know the energy savings in watts but we won't know the energy savings without the operating hours. This study is designed to determine hours of use so we can calculate energy savings and assess the cost effectiveness of programs.

SMUD has about 90 customers in a monitoring study. There are 40 Advantage homes and 50 non-Advantage homes. Ed is collecting 15-minute whole house load data and generally the compressor and AC fan. An audit will be done in the next month or so. Last winter, Ed sent out a hobo temperature logger and had the customer mail it back after a few weeks. Ed is interested in joining in the study if it can be worked out.

SMUD might be able to add 100 fans to the study. Ed will monitor the fan operating hours but probably not the lighting operating hours.

There is some possibility that a ceiling fan can reduce AC energy use by allowing a higher set point. But this is not the primary focus. Chances are the indirect savings would not be allowed in an estimate of energy savings for a utility sponsored program.

Study Objectives

The primary goals of the study are to:

1. Determine ceiling fan motor and ceiling fan lighting annual hours of operation,
2. Combine time of use data with existing engineering data to determine ceiling fan hourly load profiles for the population of CA ceiling fan owners,
3. Collect behavioral data regarding customer operation of ceiling fans, i.e. fan speeds, rotational direction, use of lights, etc.
4. Collect data on customer use of ceiling fans with air conditioning: especially set points and use while occupied vs. unoccupied.

The 4th point may be of lower priority than the first 3 points.

Sample Design

The key objective is to support cost effectiveness analysis by PG&E, SCE, and SDG&E. This suggests that the sample should be balanced across the three service areas. This will ensure an adequate sample for each of the three utilities. Therefore the sample will be 20 homes in each of the three utilities. We will use the data to test whether there are differences in operating hours between utilities. If not, we will develop pooled estimates of operating hours for each utility (by costing period), using the full sample. Otherwise we will develop the results using the sample specific to each utility.

Methodology

The methodology was reviewed, as presented in the proposal. The logger can store only 2,000 events. An issue is how many events will occur per day. Perhaps there will be more events for the lights than the fans. The lights are the larger savings relative to the fan. So we want good confidence on the lighting. If lights are not seasonal, the results should be ok even if we lose some data.

The fan hours of use will vary from fan to fan and home to home. We also need to estimate the fan speed. Since the loggers will not get fan speed, we will ask the occupants about what speed they usually use. The manufacturers report that low use is common, especially in the winter where people like the look of the slowly moving fan.

The target variable is the hours of use per fan – the ratio between total hours of use and total number of fans. Do we count fans that the homeowner reports as not being used? In the retrofit market, we might be able to justify ignoring fans that are not used. For new construction, we probably need to count all fans.

We will analyze the data both ways:

a) By dividing the hours of use by the total number of fans, including those not in use, and
b) By dividing the hours of use by the total number of fans, excluding those not in regular use.

The problem is determining a threshold between those in use and not in use.

The operational question is whether we monitor a fan that the customer says is not being used. We have assumed 10% of the fans are not being monitored. We will not monitor fans that the customer says are never used (both light and fan).

Monitoring Procedure

There are two ways to monitor the fan motor – a vibration sensor and an AC-field sensor. We have tested the sensors in 14 fans in five homes. The field sensor was found not to work in most of the cases that were tested. The vibration sensor was found to work after suitable calibration and modifications.

Matt set up a ceiling fan on the desk and ran a demonstration of how the monitoring would work. The demonstration showed that we could get false events in the vibration sensor – from stray vibrations while the fan is off. False events would probably be of short duration so that we think we will be able to eliminate them in the analysis. But they would eat up memory. We have planned to visit the site and retrieve the data after 4 to 6 months. If we want to avoid memory overflow after four - six months (120 - 180 days), we can only store 11- 17 events per day. This should work ok, unless we get a lot of false events.

There are several options for testing for or mitigating the impact of false events:

1. Test in 5-10 homes for a week
2. Use two loggers, one launched in 60 - 90 days, in order to lengthen the period of data collection,
3. Make the first site visit early, e.g., after 90 days instead of 120 - 180 days, in order to assess the rate of events; then plan the second site visit according, perhaps using a second logger.
4. Order a logger with added memory, RLW will determine whether this is feasible.
5. Calibrate the logger to medium or high speed, especially if the occupant reports never using low speed. This would underestimate true operating hours if low speed is common.

RLW will test the loggers in several homes for a week or so. Based on this test we will decide whether false events are likely to be a problem. If it looks like there may be a problem, one solution could be to install a second logger on the fan, with the second logger set to launch after 60-90 days. This would double the number of events we could handle, to about 22 – 34 events per day.

It may be that the false vibrations will only be a problem when there is occupied space above the ceiling fan, e.g. when the ceiling fan is in a first-floor room and there is an occupied room above it on the second floor. We could deploy the second logger in this type of situation.

If we use a second logger with a delayed launch, we will need to work out a way to calibrate the logger and then relaunch it with the delay. We may be able to accomplish this with two data shuttles, one set to launch a logger immediately and the second set to launch the logger in 90 days.

Schedule

The 60 homes will be installed by June 1 so that we are collecting data throughout the summer.

Analysis

The key analysis goal is the information needed for cost effectiveness analysis - for lights and fans, for each utility, annual hours operating time at different operating times, plus kW weighted consumption by coincident peak and utility costing period. We will also report operating hours by AC vs. non-AC, but not by type of room.

RLW will provide a preliminary estimate of hours of use, by costing period, after the first round of data collection.

Action Items

RLW will give Noah a list of info we need from the manufacturers.

RLW will order the loggers and send a bunch to Ed and Chris.

RLW will send out our notes.

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Appendix B – Recruiting Instrument

Introduction

Hello, may I speak with ***<<respondent>>***.

Hello, my name is <<interviewer>>, I'm calling from ASW or RLW. You may remember us, last <<date>> we conducted a survey of your home's lights and appliances as part of a statewide study sponsored by the CPUC. Do you recall meeting with someone for this purpose?

If no, is there someone else who may have met with us other than yourself?

We are re-contacting you because we would like you to participate in another study we are conducting. This time, we are offering a $50 dollar incentive for customers that agree to participate. The study we are conducting is a statewide study of ceiling fans and you have been selected because of the ***<<#fans>>*** ceiling fan(s) in your home. The intent of the study is to learn more about how many hours customers use their ceiling fan lights and fan motor throughout the year. To accomplish this we will be installing small data loggers that record the time of day the lights and fan motor are turned on and off. It is a very non-intrusive process that does not require anything more than sticking a logger directly on the fan motor and the fan lights. There are three parts to the study, they are:

1. Installation – An appointment will be made for a site surveyor to visit your home. Once at your home, the surveyor will ask you a few questions about the operation of each fan. They will then put on two loggers, one to meter the ceiling fan lights and one to meter the ceiling fan motor. Although the loggers are small, they will be noticeable to a small degree. The installations will take approximately 15-minutes per ceiling fan. At this time the surveyor will pay you $25 for participating. The surveyor will then leave, and the loggers will remain in place for approximately 3-6 months.

2. After 3-6 months have passed we will re-contact you and schedule another visit. This second visit will be very short. The visit is required simply to download the data from the logger and redeploy it. The visit should take 10-20 minutes, depending on the number of fans you have. The surveyor will leave, and the loggers will remain in place for another 3-6 months.

3. After another 3-6 months have passed we will contact you to schedule a final visit. During this final visit we will pick up the data loggers and pay you the final $25 for participating, for a

total of $50. Again, this will be a very brief visit that should take no longer than 10-15 minutes.

Do you have any questions about the study?

1. Would you be willing to participate in the study?
   - ❑ Yes
   - ❑ No

2. Are you planning on moving from this location in the next 12 months?
   - ❑ Definitely (Thank Customer and Terminate)
   - ❑ Possibly or Don’t Know
   - ❑ Definitely Not

3. Our records show that you have ***<<#Fans>>*** ceiling fans <u>with lights</u> in your home, is this correct?
   - ❑ Yes
   - ❑ No (explain, how many and in what rooms)

   Fan#1<<room>>____F
   an#2<<room>>____Fa
   n#3<<room>>____Fan
   #4<<room>>____Fan#
   5<<room>>____

4. Do all the fans in your home work?
   - ❑ Yes
   - ❑ No (explain, how many and in what rooms)

   Fan#1<<room>>____F
   an#2<<room
   Fan#3<<room>>____F
   an#4<<room>>____Fa
   n#5<<room>>____

5. Are all the fans in your home used to some degree during any part of the year?
   - ❑ Yes
   - ❑ No (explain, which fan(s))

   Fan#1<<room>>____F
   an#2<<room>>____Fa
   n#3<<room>>____Fan
   #4<<room>>____Fan#
   5<<room>>____

6. Can you think of any special characteristics we should know about any of these fans? Are all of these fans easily accessible, such as the height?

- ❑ Yes (explain, which fan(s))
- ❑ No

Fan#1<<room>>____F
an#2<<room>>____Fa
n#3<<room>>____Fan
#4<<room>>____Fan#
5<<room>>____

Appendix C – On-site Survey Instrument

<u>On-Site Interview</u>

During my visit I'll be asking a few questions about your home's ceiling fan(s). Then I will install some devices that are designed to tell us when you turn on and off your ceiling fan lights and fan motor. The information we collect will be used to better understand how often ceiling fans are used and to possibly inform a utility incentive program directed at residential ceiling fans. I have a few questions to ask you about each fan, then I will install the loggers. Once the installations are complete, I would like to show you where I have located the loggers and discuss any questions that you may have.

In a few months we will re-contact you for a second visit. This second visit will be very brief and is needed in order to download the logger data. Once we have downloaded the data we will leave the logger in its original location. After another 3-6 months we will re-contact you and make an appointment for a final visit. The final visit will also be very brief, we will return simply to collect the loggers. We will give you twenty-five dollar money order now and the remaining you twenty-five dollars when we return to gather the loggers. Do you have any questions regarding my visit?

General Information

7. Type of Residence?
   - ❑ Single Family, Unattached, One story
   - ❑ Single Family, Unattached, Two story
   - ❑ Single Family, Unattached, Three or more stories
   - ❑ Townhouse or Rowhouse
   - ❑ Duplex, Triplex, or Quadruplex
   - ❑ Apartment/Condo with more than 4 units (1 or 2 stories)
   - ❑ Apartment/Condo with more than 4 units (3 or more stories)

- ❑ Mobile Home, Single Wide
- ❑ Mobile Home, Double Wide
- ❑ Modular/prefabricated

8. Air Conditioning?
   - ❑ Central
   - ❑ Room
   - ❑ None

RLW ID#_________ Ceiling Fan #________Room Type___________

9. How often do you use this light and fan?

Summer					AVG # of times Switched On/Off per day	Avg. Total Hours per day
Lights	❑ Never	❑ Occasionally	❑ Few days a week	❑ Daily		
Fan	❑ Never	❑ Occasionally	❑ Few days a week	❑ Daily		
Winter						
Lights	❑ Never	❑ Occasionally	❑ Few days a week	❑ Daily		
Fan	❑ Never	❑ Occasionally	❑ Few days a week	❑ Daily		
Spring and Fall						
Lights	❑ Never	❑ Occasionally	❑ Few days a week	❑ Daily		
Fan	❑ Never	❑ Occasionally	❑ Few days a week	❑ Daily		

10. Is this room occupied?
    - ❑ Regularly
    - ❑ Sometimes
    - ❑ Never
    - ❑ Don't Know
11. Are you aware that you can change the rotational direction of the ceiling fan?
    - ❑ Yes
    - ❑ No
12. Do you change the direction of the fan depending on season?
    - ❑ Regularly
    - ❑ Sometimes
    - ❑ Never
    - ❑ Don't Know

13. Fan speeds commonly used? (percentage of operating time of each speed)
    - ❑ Winter %High_______ %2________ %3(Medium)_______ %4_______%Low______
    - ❑ Summer %High_______ %2________ %3(Medium)_______ %4_______%Low______
    - ❑ Fall/Spring %High_______ %2________ %3(Medium)_______ %4_______%Low______

If room is conditioned

14. Do you have a programmable thermostat for your air conditioner?

- ❑ Yes
- ❑ No

15. Do you adjust your cooling set-point temperature upward when running this ceiling fan
    - ❑ Always
    - ❑ Sometimes
    - ❑ No (Skip Q16)
16. How many degrees do you typically adjust your thermostat up?
    - ❑ 1-2
    - ❑ 2-4
    - ❑ 5-6
    - ❑ More

RLW ID#_________

Surveyor Data Form			
	Ceiling Fan #1	**Ceiling Fan #2**	**Ceiling Fan #3**
Room Type:			
Primary Lighting	Yes / No	Yes / No	Yes / No
Other Light Source	Yes / No	Yes / No	Yes / No
Mounting	Flush Hanging ___ft	Flush Hanging ___ft	Flush Hanging ___ft
Switch Config.	Code(s):	Code(s)::	Code(s):
Lighting Power	Total Watts I / CF / O	Total Watts I / CF / O	Total Watts I / CF / O
Install Date			
M Logger Serial #			
RLW M Logger #			
M Install Time	AM PM	AM PM	AM PM
L Logger Serial #			
RLW L Logger #			
L Install Time	AM PM	AM PM	AM PM
Fan Speed	L M H	L M H	L M H
Fan Direction/Flow	CW/CCW Up/Down	CW/CCW Up/Down	CW/CCW Up/Down
Fan Blade Diameter	Inches:	Inches:	Inches:
Room AC	Yes No NA	Yes No NA	Yes No NA
Remote Control	Yes No	Yes No	Yes No
Balanced?	Bad Poor Good	Bad Poor Good	Bad Poor Good

Complete only for fans that you do not monitor.
RLW ID#_________ Ceiling Fan #________Room Type___________

Summer - Weekday																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Fan																								
Light																								
Summer - Weekend																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Fan																								
Light																								
Fall/Spring - Weekday																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Fan																								
Light																								
Fall/Spring -Weekend																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Fan																								
Light																								
Winter - Weekday																								
	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2

										0	1	2	3	4	5	6	7	8	9	0	1	2	3	4
Fan																								
Light																								
Winter - Weekend																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Fan																								
Light																								

Block in the times the customer reports using the fan.

If the fan is used very infrequently, try to ascertain when the fan is used, i.e., summer, winter, both. And how much it is used. Record verbatim the customer's description of fan and light use if the tables above do not accurately gather the information. Use back of this sheet to record responses/description of use. Make sure to estimate the time of year.

Appendix D – Training/Final Test Pilot of Monitoring Equipment Memo

To: Rob Rubin, Noah Horowitz, Rich Pulliam, Jim Green, Chris Ann Dickerson, Chris Baginski, Vic Sanchez, Roger Wright, Ed Hamzowi

cc: Joni Bastian, Eric Swan

From: Matt Brost

Subject: Statewide Ceiling Fan Study Update

Date: 9/25/02

Greetings,

It has been about a month now since our kickoff meeting and there has been much progress since then. This memo is intended to update you all on these happenings and also on the project timeline. Since we last met we have come up with a new and improved way of monitoring the fan motor, training of all surveyors has taken place, a pilot test of the new methodology has been completed, the final sample has been selected and recruiting customers has begun. This memo will update you on each of these items and should answer most of the questions you may have. Once everyone has had a chance to read through this memo I would like to schedule a conference call to answer outstanding questions and to cover areas I may miss in this summary memo.

<u>Monitoring Methodology</u>

As you may recall we had originally planned on using a vibration logger modified with a small nut. This did not work well because in the first pilot test these modified loggers were far too sensitive to vibrations other than the ceiling fan motor. The idea was scrapped because the "nut method" used up far too many events on false activities. After this realization we spent many a night modifying vibration loggers in a plethora of ways before discovering the method we have selected to go with.

The HOBO Vibration loggers are now being modified with a short length of ribbon. The ribbon has small gauge wire in the edges that adds rigidity to the ribbon and also provides a way to transfer energy to the strain gauge of the logger. Common in all fans we have seen is a small cylinder that hangs directly below the fan motor, it is a standard size because this is where the light kit attaches (if one is installed). We place the modified logger on this cylinder in such a way that the top of the ribbon is touching the area where the fan blades are affixed to the motor housing. When the fan is turned on the fan blades cause the ribbon to "jump" around, while the wire in the ribbon puts strain on the strain gauge of the logger.

The "ribbon methodology" has a couple of benefits over other methods tried. First, we will definitely get all speeds at which the fans run. This was not true of other ideas tested, where low and high gave us problems. The ribbon picks up all of the speeds consistently. Secondly, the ribbon method is no where near as vulnerable to false vibrations as was the logger modified with a nut. In the six fans we pilot tested with the ribbon loggers, only one logger picked up false reads, there were about 8 over a three day period, while the others picked up no false reads. We should be able to eliminate false reads in most circumstances.

The only downfall of the ribbon method occurs when the fan is turned off, however not on all fans. Depending on the fan and the logger installation, when the fan is turned off and as the blade slows to a stop we lose a few events. This is a result of the fan blade traveling so slowly that the logger may sense it is off, then all of a sudden the ribbon is hit by a slow traveling fan blade, telling the logger the fan is on again. Worst case, a fan uses 8 to 10 events when it is turned off. Assuming in the worst case that a particular fan used 12 events each time it is turned on and off we would get 167 "on/offs". However, on average, I'm guessing this method will use 7 events every time the fan is turned on and off, for a total of 287 "on/offs". Assuming customers turn their fans on and off twice in a day this should result in about 4.5 months of data. Of course the number of times the fan is switched on and off is the key variable, along with the number of events used up as the fan slows to a stop.

I understand that this explanation may be confusing, we can discuss it verbally during a conference call if necessary.

Pilot Test

We tested the ribbon method on two homes, each having three fans apiece. We were very happy with the results from both the lighting and the motor logger installations and data. The motor loggers worked in all cases, the only problem being the one fan that picked up some "noise". The loggers used anywhere from one to seven events when the fans were turned off, and only one event in all cases when the fan was turned on (perfect). The lighting loggers were installed and calibrated for each of the fans. The lighting logger installations went very smoothly and were without problems.

Training

A total of six surveyors participated in the training session that was held in Southern California. A morning session was held in Tustin, where surveyors were trained on the survey instruments, data collection, logger software, on-site etiquette, and customer recruiting. The later half of the day surveyors experienced hands on training with the motor and lighting loggers and the software. Each surveyor installed at least one lighting logger and motor logger, calibrated the installations and operated the software. The training was well received by the surveyors and no problems were encountered.

Sample

The final sample was selected for each of the utilities. Each utility will have 20 sites monitored. The sample was stratified by number of fans in home, whereby those homes with more fans had a higher likelihood of being sampled than homes with fewer homes. This allows us to monitor more fans because travel costs are lower.

Table 21 shows the final sample. Each utility received a sample of 20 homes. Since the homes had a varying number of fans, the number of fans per utility varies. SCE has the most fans in the sample at 69, while SDG&E has the least at 43. Samples for PG&E and SCE have 50% air-conditioning vs. non air-conditioned homes. SDG&E has considerably less homes in the study with air-conditioning, with 15% of homes having AC.

Utility	# Homes	# Fans	% with AC
PG&E	20	60	50%
SCE	20	69	50%
SDG&E	20	43	15%
Total	**60**	**172**	

Table 21: Final Sample

The sample shows that a total of 172 fans were selected into the study, however the study only had enough funding for 150 loggers. Therefor only 150 of the 172 fans will be monitored. The RLW/ASW team will attempt to log the entire sample of SDG&E's fans, the remaining 22 fans not logged will be taken from SCE and PG&E's sample of fans. Of course as customers in the primary sample are replaced with backup customers the total number of fans will change to some degree. The goal is to end up with 150 fans monitored, which could result in less sites for PG&E and SCE, depending on how the installations go.

Recruiting

Recruiting customers began on 5-2-01. RLW has scheduled two customers, two customers have refused and two customers contact information is no longer valid. ASW has scheduled four sites, with no refusals, however they too have encountered problems with contact information being out of date. A more comprehensive recruiting update will be provided once more time has been invested in this task.

Appendix E – Database Documentation

MS Access Database Tables

Case Weights

Field Heading	Value	Comments
SiteID	RLW Site Identification Number	
Weight_Revised	Case Weight number of estimated number of residences that this site ID represents	
Have AC	Existence of mechanical cooling in the residence	
Utility	Electrical Provider of Residence	

Lighting Hours by Costing Period

Field Heading	Value	Comments
Utility	Applicable Service Territory	
season	Winter , Summer or both (Annual) Costing Seasons	
Have_AC	Existence of mechanical cooling in the segment	
hours_tot	Total hours of lighting operation for the indicated segment	
hours_on	On-Peak hours of lighting operation for the indicated segment	
hours_mid	Mid-Peak hours of lighting operation for the indicated segment	
hours_off	On-Peak hours of lighting operation for the indicated segment	

Motor Hours by Costing Period

Field Heading	Value	Comments
Utility	Applicable Service Territory	
season	Winter , Summer or both (Annual) Costing Seasons	
Have_AC	Existence of mechanical cooling in the segment	
hours_tot	Total hours of fan motor operation for the indicated segment	
hours_on	On-Peak hours of fan motor operation for the indicated segment	

hours_mid	Mid-Peak hours of fan motor operation for the indicated segment	
hours_off	On-Peak hours of fan motor operation for the indicated segment	

Lighting Hours MBSS

Field Heading	Value	Comments
samn	Number of Residences in Sample for indicated segment	
popn	Estimated number of residences in population	
utility	Electrical Service Provider Territory	
ac	Existence of mechanical cooling	
season	Winter , Summer or both (Annual) Costing Seasons	
FLHours	Total hours of fan lighting operation for the indicated segment	
ErrBbd	Error bound at the 90% confidence level for FL_Hours esstimate	
CostingPeriod	Applicable Costing Period of Segment	

Motor Hours MBSS

Field Heading	Value	Comments
samn	Number of Residences in Sample for indicated segment	
popn	Estimated number of residences in population	
utility	Electrical Service Provider Territory	
ac	Existence of mechanical cooling	
season	Winter , Summer or both (Annual) Costing Seasons	
FLHours	Total hours of fan motor operation for the indicated segment	
ErrBbd	Error bound at the 90% confidence level for FL_Hours esstimate	
CostingPeriod	Applicable Costing Period of Segment	

Lighting Profiles

Field Heading	**Value**	**Comments**
Have_AC	Existence in Mechanical Cooling	
Utility	Electrical Service Provider	
Daytype	Weekday or Weekend	
season	Costing Season	
ConL	Connect Load in kW	Total Residence Load (not by Fan)
load1	Total Residence Ceiling Fan Lighting Load in kW for Hour 1 (Midnight-1AM)	Total Residence Load (not by Fan)
load2	Total Residence Ceiling Fan Lighting Load in kW for Hour 2 (1 AM-2AM)	
load3	Total Residence Ceiling Fan Lighting Load in kW for Hour 3	
load4	Total Residence Ceiling Fan Lighting Load in kW for Hour 4	
load5	Total Residence Ceiling Fan Lighting Load in kW for Hour 5	
load6	Total Residence Ceiling Fan Lighting Load in kW for Hour 6	
load7	Total Residence Ceiling Fan Lighting Load in kW for Hour 7	
load8	Total Residence Ceiling Fan Lighting Load in kW for Hour 8	
load9	Total Residence Ceiling Fan Lighting Load in kW for Hour 9	
load10	Total Residence Ceiling Fan Lighting Load in kW for Hour 10	
load11	Total Residence Ceiling Fan Lighting Load in kW for Hour 11	
load12	Total Residence Ceiling Fan Lighting Load in kW for Hour 12	
load13	Total Residence Ceiling Fan Lighting Load in kW for Hour 13	
load14	Total Residence Ceiling Fan Lighting Load in kW for Hour 14	
load15	Total Residence Ceiling Fan Lighting Load in kW for Hour 15	

load16	Total Residence Ceiling Fan Lighting Load in kW for Hour 16	
load17	Total Residence Ceiling Fan Lighting Load in kW for Hour 17	
load18	Total Residence Ceiling Fan Lighting Load in kW for Hour 18	
load19	Total Residence Ceiling Fan Lighting Load in kW for Hour 19	
load20	Total Residence Ceiling Fan Lighting Load in kW for Hour 20	
load21	Total Residence Ceiling Fan Lighting Load in kW for Hour 21	
load22	Total Residence Ceiling Fan Lighting Load in kW for Hour 22	
load23	Total Residence Ceiling Fan Lighting Load in kW for Hour 23	
load24	Total Residence Ceiling Fan Lighting Load in kW for Hour 24	
fans	Average Number of Fans per Residence	
sites	Number of Sites in Sample	

Motor Profiles

Field Heading	Value	Comments
Have_AC	Existence in Mechanical Cooling	
Utility	Electrical Service Provider	
Daytype	Weekday or Weekend	
season	Costing Season	
ConL	Connect Load in kW	Total Residence Load (not by Fan, all fans)
load1	Total Residence Ceiling Fan Motor Load in kW for Hour 1 (Midnight-1AM)	Total Residence Load (not by Fan, all fans)
load2	Total Residence Ceiling Fan Motor Load in kW for Hour 2 (1 AM-2AM)	
load3	Total Residence Ceiling Fan Motor Load in kW for Hour 3	
load4	Total Residence Ceiling Fan Motor Load in kW for	

	Hour 4	
load5	Total Residence Ceiling Fan Motor Load in kW for Hour 5	
load6	Total Residence Ceiling Fan Motor Load in kW for Hour 6	
load7	Total Residence Ceiling Fan Motor Load in kW for Hour 7	
load8	Total Residence Ceiling Fan Motor Load in kW for Hour 8	
load9	Total Residence Ceiling Fan Motor Load in kW for Hour 9	
load10	Total Residence Ceiling Fan Motor Load in kW for Hour 10	
load11	Total Residence Ceiling Fan Motor Load in kW for Hour 11	
load12	Total Residence Ceiling Fan Motor Load in kW for Hour 12	
load13	Total Residence Ceiling Fan Motor Load in kW for Hour 13	
load14	Total Residence Ceiling Fan Motor Load in kW for Hour 14	
load15	Total Residence Ceiling Fan Motor Load in kW for Hour 15	
load16	Total Residence Ceiling Fan Motor Load in kW for Hour 16	
load17	Total Residence Ceiling Fan Motor Load in kW for Hour 17	
load18	Total Residence Ceiling Fan Motor Load in kW for Hour 18	
load19	Total Residence Ceiling Fan Motor Load in kW for Hour 19	
load20	Total Residence Ceiling Fan Motor Load in kW for Hour 20	
load21	Total Residence Ceiling Fan Motor Load in kW for Hour 21	
load22	Total Residence Ceiling Fan Motor Load in kW for Hour 22	
load23	Total Residence Ceiling Fan Motor Load in kW for Hour 23	
load24	Total Residence Ceiling Fan Motor Load in kW for	

	Hour 24	
fans	Average Number of Fans per Residence	
sites	Number of Sites in Sample	

Light Profiles MBSS

Field Heading	Value	Comments
ID	RLW Site Identification Number	
samn	Number of Homes in Sample	
daytype	Weekday or Weekend	
Season	Costing Season	
ac	Existence of Mechanical Cooling	
utility	Electrical Service Provider	
hour	Hour of Day (1-24)	
Load	Estimated Average Ceiling Fan Lighting Load in kW for hour indicated	
ErrBbd	Error Bound at 90%confidence level for Load	

Motor Profiles MBSS

Field Heading	Value	Comments
ID	RLW Site Identification Number	
samn	Number of Homes in Sample	
daytype	Weekday or Weekend	
Season	Costing Season	
ac	Existence of Mechanical Cooling	
utility	Electrical Service Provider	
hour	Hour of Day (1-24)	
Load	Estimated Average Ceiling Fan Motor Load in kW for hour indicated	
ErrBbd	Error Bound at 90%confidence level for Load	

Summer Lighting Data

Field Heading	Value	Comments

Datatype	Source of hourly data. Metered, self reported, or calculated	Some hourly loads were calculated based on other metered data when metered and self report were not available.
Utility	Electrical Service Provider	
AC	Existence of Mechanical Cooling	
SiteID	RLW Site Identification Number	
Fan	Fan number	Each fan in home was assigned a with a unique number.
ConL	Total connected load of fan lighting	
Description	Logger file name	
RoomType	Room type where fan is located	
Daytype	Weekday or Weekend	
load1	Average lighting (kW) load for hour 1	
load2	Average lighting (kW) load for hour 2	
load3	Average lighting (kW) load for hour 3	
load4	Average lighting (kW) load for hour 4	
load5	Average lighting (kW) load for hour 5	
load6	Average lighting (kW) load for hour 6	
load7	Average lighting (kW) load for hour 7	
load8	Average lighting (kW) load for hour 8	
load9	Average lighting (kW) load for hour 9	
load10	Average lighting (kW) load for hour 10	
load11	Average lighting (kW) load for hour 11	
load12	Average lighting (kW) load for hour 12	
load13	Average lighting (kW) load for hour 13	
load14	Average lighting (kW) load for hour 14	
load15	Average lighting (kW) load for hour 15	
load16	Average lighting (kW) load for hour 16	
load17	Average lighting (kW) load for hour 17	
load18	Average lighting (kW) load for hour 18	

load19	Average lighting (kW) load for hour 19	
load20	Average lighting (kW) load for hour 20	
load21	Average lighting (kW) load for hour 21	
load22	Average lighting (kW) load for hour 22	
load23	Average lighting (kW) load for hour 23	
load24	Average lighting (kW) load for hour 24	
Notes	Misc. notes	

Winter Lighting Data

Field Heading	**Value**	**Comments**
Datatype	Source of hourly data. Metered, self reported, or calculated	Some hourly loads were calculated based on other metered data when metered and self report were not available.
Utility	Electrical Service Provider	
AC	Existence of Mechanical Cooling	
SiteID	RLW Site Identification Number	
Fan	Fan number	Each fan in home was assigned a with a unique number.
ConL	Total connected load of fan lighting	
Description	Logger file name	
RoomType	Room type where fan is located	
Daytype	Weekday or Weekend	
load1	Average lighting (kW) load for hour 1	
load2	Average lighting (kW) load for hour 2	
load3	Average lighting (kW) load for hour 3	
load4	Average lighting (kW) load for hour 4	
load5	Average lighting (kW) load for hour 5	
load6	Average lighting (kW) load for hour 6	
load7	Average lighting (kW) load for hour 7	
load8	Average lighting (kW) load for hour 8	
load9	Average lighting (kW) load for hour 9	
load10	Average lighting (kW) load for hour 10	

load11	Average lighting (kW) load for hour 11	
load12	Average lighting (kW) load for hour 12	
load13	Average lighting (kW) load for hour 13	
load14	Average lighting (kW) load for hour 14	
load15	Average lighting (kW) load for hour 15	
load16	Average lighting (kW) load for hour 16	
load17	Average lighting (kW) load for hour 17	
load18	Average lighting (kW) load for hour 18	
load19	Average lighting (kW) load for hour 19	
load20	Average lighting (kW) load for hour 20	
load21	Average lighting (kW) load for hour 21	
load22	Average lighting (kW) load for hour 22	
load23	Average lighting (kW) load for hour 23	
load24	Average lighting (kW) load for hour 24	
Notes	Misc. notes	

Summer Motor Data

Field Heading	Value	Comments
Datatype	Source of hourly data. Metered, self reported, or calculated	Some hourly loads were calculated based on other metered data. (When metered and self-report were not available.)
Utility	Electrical Service Provider	
AC	Existence of Mechanical Cooling	
SiteID	RLW Site Identification Number	
Fan	Fan number	Each fan in home was assigned a with a unique number.
ConL	Total connected load of fan motor	
Description	Logger file name	
RoomType	Room type where fan is located	
Daytype	Weekday or Weekend	
load1	Average motor (kW) load for hour 1	
load2	Average motor (kW) load for hour 2	

load3	Average motor (kW) load for hour 3	
load4	Average motor (kW) load for hour 4	
load5	Average motor (kW) load for hour 5	
load6	Average motor (kW) load for hour 6	
load7	Average motor (kW) load for hour 7	
load8	Average motor (kW) load for hour 8	
load9	Average motor (kW) load for hour 9	
load10	Average motor (kW) load for hour 10	
load11	Average motor (kW) load for hour 11	
load12	Average motor (kW) load for hour 12	
load13	Average motor (kW) load for hour 13	
load14	Average motor (kW) load for hour 14	
load15	Average motor (kW) load for hour 15	
load16	Average motor (kW) load for hour 16	
load17	Average motor (kW) load for hour 17	
load18	Average motor (kW) load for hour 18	
load19	Average motor (kW) load for hour 19	
load20	Average motor (kW) load for hour 20	
load21	Average motor (kW) load for hour 21	
load22	Average motor (kW) load for hour 22	
load23	Average motor (kW) load for hour 23	
load24	Average motor (kW) load for hour 24	
Notes	Misc. notes	

Winter Motor Data

Field Heading	**Value**	**Comments**
Datatype	Source of hourly data. Metered, self reported, or calculated	Some hourly loads were calculated based on other metered data when metered and self report were not available.
Utility	Electrical Service Provider	
AC	Existence of Mechanical Cooling	
SiteID	RLW Site Identification Number	
Fan	Fan number	Each fan in home was

		assigned a with a unique number.
ConL	Total connected load of fan motor	
Description	Logger file name	
RoomType	Room type where fan is located	
Daytype	Weekday or Weekend	
load1	Average motor (kW) load for hour 1	
load2	Average motor (kW) load for hour 2	
load3	Average motor (kW) load for hour 3	
load4	Average motor (kW) load for hour 4	
load5	Average motor (kW) load for hour 5	
load6	Average motor (kW) load for hour 6	
load7	Average motor (kW) load for hour 7	
load8	Average motor (kW) load for hour 8	
load9	Average motor (kW) load for hour 9	
load10	Average motor (kW) load for hour 10	
load11	Average motor (kW) load for hour 11	
load12	Average motor (kW) load for hour 12	
load13	Average motor (kW) load for hour 13	
load14	Average motor (kW) load for hour 14	
load15	Average motor (kW) load for hour 15	
load16	Average motor (kW) load for hour 16	
load17	Average motor (kW) load for hour 17	
load18	Average motor (kW) load for hour 18	
load19	Average motor (kW) load for hour 19	
load20	Average motor (kW) load for hour 20	
load21	Average motor (kW) load for hour 21	
load22	Average motor (kW) load for hour 22	
load23	Average motor (kW) load for hour 23	
load24	Average motor (kW) load for hour 24	
Notes	Misc. notes	

Sample with contact info

The fields in these tables correspond to the numbered questions in the on-site survey instrument. The survey was implemented on site by the auditor, data was collected from the home owners and the ceiling fans to complete the survey. Use the survey instrument to define the fields in this table. The survey instrument can be found in the appendix of the final report.

Sample with contact info cont.

The fields in these tables correspond to the numbered questions in the on-site survey instrument. The survey was implemented on site by the auditor, data was collected from the home owners and the ceiling fans to complete the survey. Use the survey instrument to define the fields in this table. The survey instrument can be found in the appendix of the final report.

Sample with contact info cont.2

The fields in these tables correspond to the numbered questions in the on-site survey instrument. The survey was implemented on site by the auditor, data was collected from the home owners and the ceiling fans to complete the survey. Use the survey instrument to define the fields in this table. The survey instrument can be found in the appendix of the final report.