Measurement and Verification of Energy Savings at Small Commercial Facilities

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ABSTRACT

In 1997, a U.S. electric utility company initiated a three-year energy efficiency program to target small commercial customers in the service area with less than 18 kW of monthly demand. Traditionally, the target group is very difficult to reach with energy efficiency programs and is generally cash-constrained. This paper will discuss the measurement and verification (M&V) aspects of the program and the implementation of the M&V activities which meet the requirements of Options A and B of the IPMVP (International Performance Measurement and Verification Protocol, US DOE 1997). For Option A, monitoring of the energy savings involved the measurements of pre- and post-retrofit demand including demand diversity and use of agreed-upon or stipulated run hours. Option B is similar to Option A except the run hours were measured rather than stipulated. Several case studies of lighting retrofit projects are presented, including the statistical selection of customers, the difficulties encountered, the lessons learned, and the results achieved with the successful execution of the M&V plan. In all cases, the energy savings measured exceeded the projected energy savings by at least 11%. The information provided in this paper is intended to assist in developing more effective energy efficiency programs to reach smaller commercial customers in the future.

Introduction

This paper describes the M&V aspects of an energy efficiency program to target hard-to-reach small commercial customers in the transmission and generation constrained Laredo and the Rio Grande Valley areas of Texas. The program is offered by a U.S. electric utility company which serves 271,500 customers in the Laredo and Rio Grande Valley. Of those 271,500 customers, the program is focused on the 16,000 to 20,000 smaller commercial customers in the service area with less than 18 kW of monthly demand.

Traditionally, the target group is very difficult to reach with energy efficiency programs and is generally cash-constrained. Typical target customers include retail stores, small commercial office units, and certain doctor offices, such as dentists.

Although lighting retrofits are relatively commonplace in the U.S., the approach may be new to those in other countries where energy savings contracts are only now appearing. The results presented in this study are part of a U.S. utility-sponsored energy efficiency program to reduce energy consumption in small commercial facilities.

The calculation procedures for estimating the energy savings for lighting retrofits are fairly simple, consisting of factors for the connected loads before and after the retrofits, the number of operating hours, and a demand diversity factor (ASHRAE 1989; EPRI 1993). The pre- and post-retrofit connected loads can be determined with some reliability, but the demand diversity factors and run hours are often inaccurate. Taylor and Pratt (1990) as well as Scoops and Pratt (1990) addressed the above issue by conducting a study to evaluate a large utility DSM project in the Northwest.

In this study, two options for the measurements of energy savings are presented. For Option A, monitoring of the energy savings involved the measurements of pre- and post-retrofit demand including demand diversity and use of agreed-upon or stipulated run hours. Option B is similar to Option A except the run hours were measured rather than stipulated.

Methodology

1. Survey of Pertinent Characteristics of Lighting Equipment

The survey was carried out as part of the local utility's ongoing efforts to assist small commercial customers to achieve the best possible lighting efficiency and to minimize their operating costs. Customers were given an evaluation of the cost to upgrade or retrofit equipment for energy cost savings and the discount offered by the program. Discounts for implementing the energy efficiency measures were based on the demand reduction of the retrofit measures.

We conducted a walk-through lighting audit at each facility to determine the distribution of lighting equipment as well as the applicability of proposed electricity conservation measures. The major lighting systems in the facility were investigated to obtain the approximate number of each fixture type along with identification of the existing lamp and ballast combinations. Spot lighting levels were taken in areas identified as representative of the major lighting systems. Selected individual fixtures were visually inspected to determine light losses due to lens discoloration and dirt buildup.

2. Options for Lighting Energy Conservation and Peak Load Reduction at Small Commercial Facilities

Many small commercial facilities have antiquated lighting systems that are very inefficient in terms of lumens of light produced per kilowatt-hours of electricity consumed. Some very old facilities still use T-12 fluorescent lighting and incandescent lighting, which are extremely inefficient. T-8 fluorescent lighting with electronic ballast (ELIG) as well as compact fluorescent lighting can be used to replace these inefficient lighting. In addition, light emitting diode (LED) exit signs can be used to replace incandescent exit signs. High intensity discharge (HID) lighting is generally not used in small commercial facilities with demand load of less than 18 kW.

3. Measurement and Verification Plan

The objective of the measurement and verification plan is to quantify the energy savings and peak demand savings associated with the proposed lighting measures. The parameters that were measured included the lighting operating hours, time-of-use hours, and fixture kW draw before and after the retrofit. Metering was conducted on at least 10% of each type of fixture for at least 66 locations randomly selected from the Table of Random Numbers (Daniel and Terrell 1991). Instantaneous demand readings using a wattmeter were taken at the fixture or circuit prior to retrofit and after installation. Time-of use meters were installed on the same fixtures or circuits and were read once to capture the data during the months of June, July, August, and September. All monitoring instruments were pre-calibrated by the manufacturers. Options A and B of the IPMVP are outlined below. In addition, the statistical sampling selection of customers is also given although the sampling technique is not part of the IPMVP.

a) Statistical Random Selection of customer locations for measurement and verification

Assume that each customer location would yield about 0.8 kW of peak demand savings.
Total peak demand load to be achieved in the program = 1,410 kW
Therefore, number of customers to be reached to achieve the program goal
(population size)

= 1410/0.8
= 1,763

As such, each customer was assigned a number from 1 to 1763.

To determine the necessary sample size of customers to monitor, the following equation was used:

$$n^* = \frac{n}{1 + n/N}$$

where,

$$n = \frac{z^2 cv(y)^2}{p^2}$$

z = degree of confidence, for 90% confidence level, z = 1.645

cv(y) = coefficient of variation, used 0.5 for homogeneous usage group (Schiller Associates 1996)

p = precision level of 0.1

Using the Table of Random Numbers, 66 customers with the following assigned numbers were selected for the measurement and verification process:

Table 1. Customers with Assigned Numbers

No.	Assigned No.	No.	Assigned No.	No.	Assigned No.
1	8	23	535	45	1173
2	55	24	539	46	1196
3	61	25	567	47	1207
4	76	26	609	48	1245
5	87	27	691	49	1253
6	100	28	724	50	1263
7	184	29	738	51	1321
8	185	30	748	52	1333
9	189	31	768	53	1360
10	240	32	773	54	1431
11	256	33	854	55	1449
12	276	34	916	56	1450
13	286	35	940	57	1451
14	287	36	949	58	1456
15	344	37	1008	59	1481
16	348	38	1032	60	1535
17	378	39	1081	61	1547
18	391	40	1083	62	1552
19	423	41	1119	63	1594
20	429	42	1123	64	1598
21	439	43	1164	65	1616
22	447	44	1171	66	1645

The table below shows a partial list of participating customers with less than 18 kW of monthly demand.

Table 2. Partial List of Participating Customers

No.	Assigned No.	Customer
1	8	Menchaca Business Service (Notary Public)
2	55	Tommy Graham Body Shop
3	61	Security International
4	76	United Diesel & Lift
5	87	Brookshire Paint
6	100	77 Conoco
7	184	Riverview Apartment Office
8	185	Ace TV Service
9	189	Gulf Western Supply
10	240	Bobby's Auto Diesel

11	256	Ruben G. Valdez Insurance
12	276	Ben's Hair Style
13	286	Oralia Lerma Hair Style
14	287	Reynaldo Calderon Jewelery

b) Option A Metering

Monitoring of the energy savings involved the measurements of fixture kW before and after the retrofit including demand diversity and use of agreed-upon or stipulated run hours. Instantaneous demand metering using the rms watt meter was conducted on at least 10% of the fixtures, in accordance with the utility's measurement and verification protocol (CPL 1996). The 10% sample was selected across the entire variety of lamp, fixture, and operating schedule combinations; that is 10% of each combination of lamp, fixture and expected operating schedule was measured. Oftentimes, measurements of demand were made at the light switches.

In addition, time-of-use loggers were installed during the summer period on at least 10% of each type of fixture. Lighting load profiles for the buildings were also derived from the time-of-use measurements. The heating and cooling interactive effects due to the lighting efficiency measures were omitted because the utility did not allow additional credit for energy savings due to such interactive effects.

c) Option B Metering

Option B is similar to Option A except the run hours were measured rather than stipulated.

d) Data Analysis

The following procedures were used to estimate the annual energy savings:

A. Determine undiversified demand reduction (kW).

This involved simply summing the kW demand reductions reported on each of the measures.

B. Adjust for diversity.

The undiversified gross impacts were adjusted for demand diversity (the probability that the participating measure will be on-line during the peak demand period). The demand diversity factor was calculated as follows:

DDF, demand diversity factor = (total lighting operating hours during June, July, August, September between 1 pm to 7 pm, Mon - Friday)/utility peak demand period of 528 hours

C. Determine diversified demand reduction (kW)

Diversified demand reduction = undiversified demand reduction x DDF

D. Determine annual energy savings (kWh)

Annual energy savings = undiversified demand savings x annual lighting operating hours

Results and Discussion

Three case studies, namely an auto repair shop, a hair saloon, and a small commercial office are presented to compare the projected energy savings with the measured savings.

Case Studies

1. Auto repair shop

Case Study 1 is an auto repair shop that is about 2,000 sq ft without air conditioning. It typically operates from 9 am to 5 pm on weekdays and from 9 am to 1 pm on Saturdays. The existing stock of lighting at the auto repair shop consists of T-12 energy efficient (EE) lamps, energy efficient magnetic (EEMAG) ballasts, and incandescent (INC) lamps. Results of Option A and B metering are presented in Table 3. The results show that replacing all existing lighting with high efficiency lighting yielded annual energy savings of about 2,500 kWh, which is about 50% savings compared to the baseline lighting energy consumption. In addition, the measured energy savings is about 48% more than the projected energy savings. Option B metering shows that the average measured run hours of 4700 was significantly higher than the stipulated run hours of 2288, implying that the stipulated run hours provided by the shop manager were inaccurate or erroneous. A simple conmparison of the utility bills for several months before and after the retrofits show an average cost savings of $10 to $15 per month.

The current lighting load derived from the time-of-use measurements is 1.3 kW. The utility's diversified demand reduction is 0.7 kW, with a measured demand diversity of 0.93. The lighting load profile for a typical weekday in Figure 1 shows that the lights in the shop operated until 10 p.m. or later. Also, the customer's peak demand was reduced by about 58%. Detailed results of Option A time-of-use metering show that the two 1x8x2 light fixtures were often mistakenly left operating throughout the night. One suggestion was to install a timer to control the operation of those fixtures.

E = Existing, P = Proposed

ECM	*Existing Fixture Type*	*Proposed Fixture*	Fixture Qty		Projected Wattage		Measured Wattage		Projected hours	Measured hours	Projected kWh saved	Measured kWh saved
			E	P	E	P	E	P				
1	2L4' EE/EEMAG	2L4'T8/ELIG	2	2	76	59	76.1	56.1	2288	3273	78	131
2	2L8' EE/EEMAG	2L8'T8/ELIG	2	2	124	109	127.0	113.0	2288	6789	69	190
3	75W INC	15w Screw-in CFL	3	3	75	15	75.0	15.0	2288	3273	412	589
4	95W INC	23w Screw-in CFL	7	7	95	23	94.0	23.0	2288	3273	1,153	1,627
											1,711	2,537

Table 3. Projected and Measured Energy Savings and Lighting Operating Hours for Auto Repair Shop

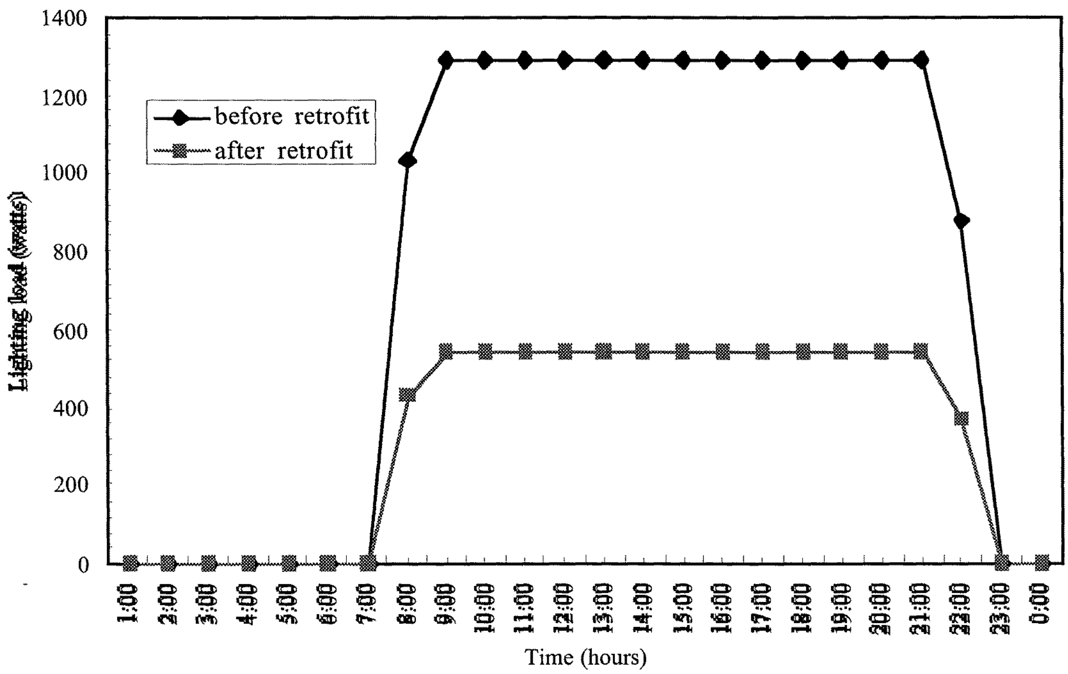

Figure 1. Lighting Load profile for a Typical Weekday in the Auto Shop

2. Hair Salon

Case Study 2 is a 1,500 sq ft. hair salon with space conditioning located in a strip shopping mall. It typically operates from 9 am to 6 pm on Tuesdays through Saturdays. The existing stock of lighting at the hair salon consists of a variety of T-12 fluorescent standard and energy efficient (EE) lamps and energy efficient magnetic (EEMAG) ballasts. Table 4 shows that replacing all existing lighting with high efficiency lighting yielded annual energy savings of about 2,900 kWh, which is about 47% savings compared to the baseline lighting energy consumption. Also, this measured energy savings is about 43% more than the projected energy savings. Option B metering shows that the average measured run hours of 3372 was significantly higher than the stipulated run hours of 2700, implying that the stipulated run hours provided by the owner were inaccurate or erroneous. Again, a simple conmparison of the utility bills for several months before and after the retrofits show an average cost savings of $30 to $40 per month including air conditioning savings.

The current lighting load derived from the time-of-use measurements is 2.3 kW. The utility's diversified demand reduction is 0.79 kW, with a measured demand diversity of 0.92. The lighting load profile for a typical weekday in Figure 2 shows that the customer's peak demand was reduced by about 34%. The profile also shows a slight drop in lighting demand at about 2 p.m. when the hair salon was closed briefly for a late lunch.

ECM	*Existing Fixture Type*	*Proposed Fixture*	Fixture Qty		Projected Wattage		Measured Wattage		Projected hours	Measured hours	Projected kWh saved	Measured kWh saved
			E	P	E	P	E	P				
1	4L4' STD/EEMAG	4L4'T8/ELIG/LOW	12	12	172	112	180.0	112.0	2288	3372	1,647	2,752
2	2L4' EE/EEMAG	2L4'T8/ELIG	2	2	76	59	71.0	47.3	2288	3372	78	160
											1,725	2,911

Table 4. Projected and Measured Energy Savings and Lighting Operating Hours for Hair Salon

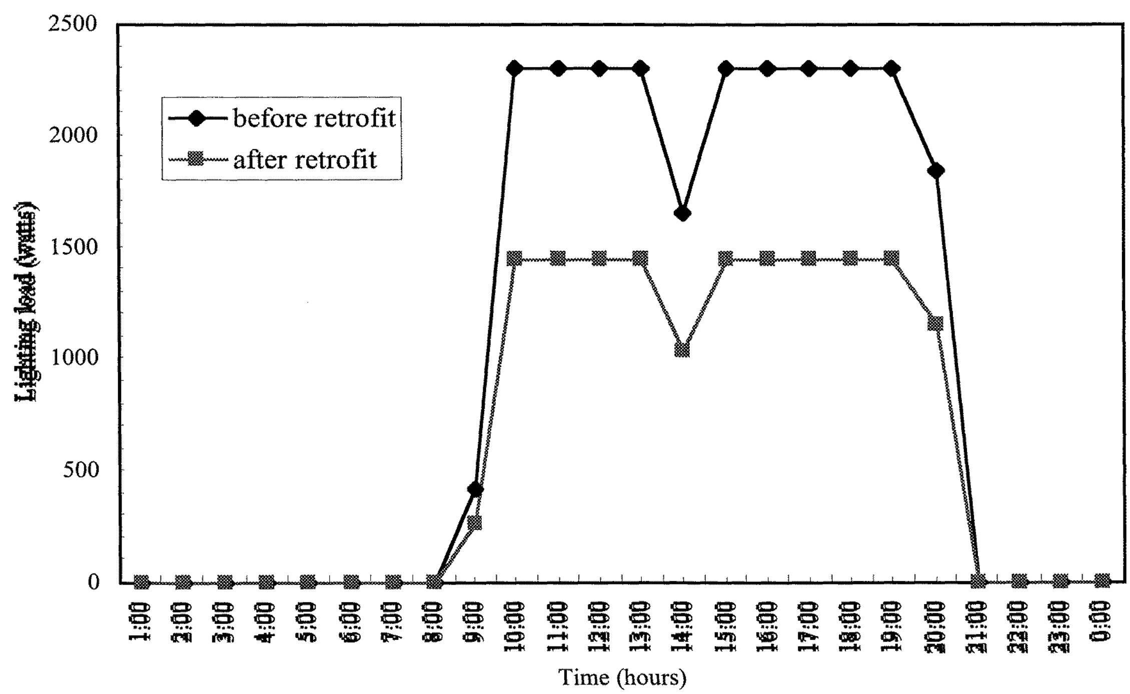

Figure 2. Lighting Load profile for a Typical Weekday in the Hair Salon

3. Small commercial office

Case Study 3 is a small commercial office unit that is 1,200 sq ft with space conditioning. It consists of a waiting area and two small office rooms. It typically operates from 8.30 am to 4.30 pm on weekdays . The existing stock of lighting at the office building consists of standard T-12 fluorescent (STD) lamps and standard magnetic (STD) ballasts. Results of Option A and B metering are presented in Table 5. The results shows that replacing all existing lighting with high efficiency lighting yielded annual energy savings of about 1,750 kWh, which is about 40% savings compared to the baseline lighting energy consumption. In addition, this measured savings is about 11% more than the projected energy savings. Option B metering shows that the average measured run hours of 2,333 was close to the stipulated run hours of 2,080. The current lighting load derived from the time-of-use measurements is 1.9 kW. A simple conmparison of the utility bills for several months before and after the retrofits show an average cost savings of $20 to $30 per month including air conditioning savings.

The utility's diversified demand reduction is 0.59 kW, with a measured demand diversity of 0.78. The lighting load profile for a typical weekday in Figure 3 shows that the customer's peak demand was reduced by about 31%. At about 1.30 p.m. each day, the manager leaves her office room for several hours to conduct outside customer calls. Her work pattern is reflected in the drop in lighting demand after 1.30 p.m.

	Existing Fixture Type	*Proposed Fixture*	Fixture Qty		Projected Wattage		Measured Wattage		Projected hours	Measured hours	Projected kWh saved	Measured kWh saved
ECM			E	P	E	P	E	P				
1	4L4' EE/STD	4L4' T8/ELIG/LOW	10	10	188	112	156.2	97.1	2080	2333	1,581	1,379
											1,581	1,379

Table 5. Projected and Measured Energy Savings and Lighting Operating Hours for Small Commercial Office

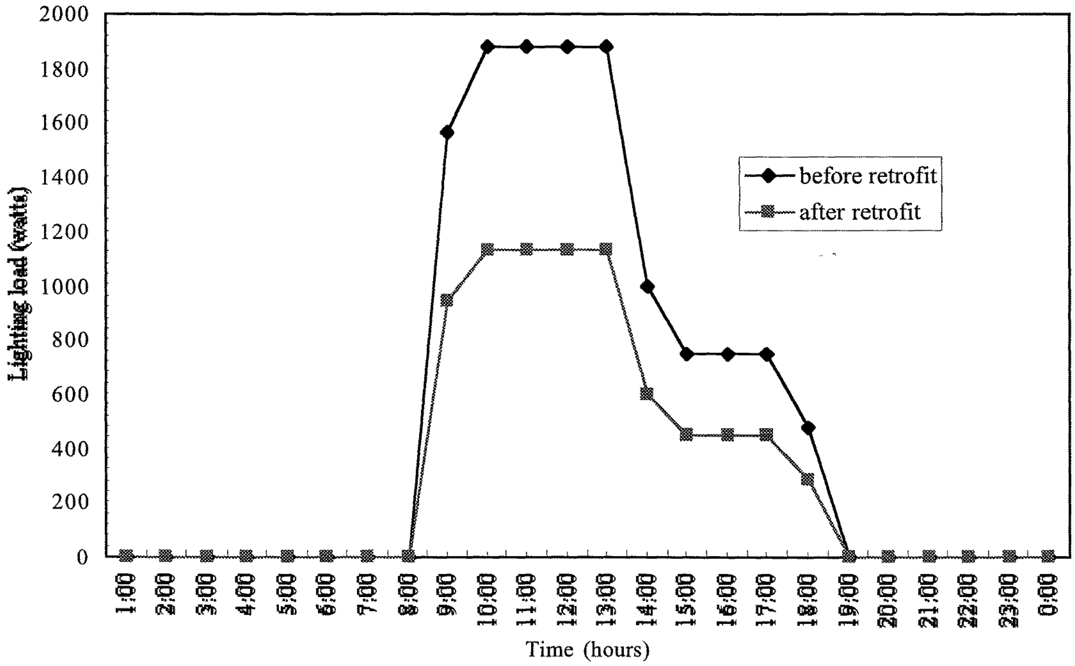

Figure 3. Lighting Load profile for a Typical Weekday in the Small Commercial Office

Conclusions and Lessons Learned

In this paper, we presented three case studies to verify the annual electrical energy savings associated with lighting retrofits using Options A and B monitoring. Option A monitoring is not reliable using stipulated run hours. Option B monitoring is more accurate with measured run hours. In all cases, the lighting retrofits achieved about 40-50% savings in each facility. Also, the energy savings measured exceeded the projected energy savings by 11-48%. These energy savings were reflected in the customers' utility bills with an average monthly cost savings of $10 to $40 per facility, including air conditioning savings.

Valuable lessons were learned through the projects that were implemented. One lesson was to install a timer to control the operation of lighting fixtures that are often mistakenly left operating throughout the night. Another lesson was to check the existence and proper operation of the loggers in the first week of logger installation. Any logger that is missing or malfunctioned can then be replaced immediately. In estimating the baseline run hours for these buildings, we interviewed the building managers or owners. Our results show that the actual run hours can differ significantly from the stipulated run hours provided by the building managers or owners. As such, we recommend installing lighting loggers and collecting the run time data after several weeks in order to establish the baseline run hours. A more accurate prediction of the energy savings can then be obtained. Finally, it was found that the measurements of lighting demand were more conveniently done at the light switches than at the light fixtures, particularly for small commercial facilities where a switch typically controls the same type of fixtures. It is hoped that the information provided in this paper will assist in developing more effective energy efficiency programs to reach smaller commercial customers in the future.

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