Lighting Hours of Operation: Building Type versus Space Use Characteristics for the Commercial Sector

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Estimates of energy impacts for commercial lighting retrofit programs are highly dependent on the number of hours the lighting systems are operated. Many utilities have utilized standardized hours of operation based on building type and assumed operating schedules. These standardized hours of operation typically do not vary from customer to customer within a given building type. Others have used an approach based on customer-reported schedules, where a customer representative provides estimated hours based on their knowledge of building operations. Often, these schedules reflect the hours the establishment is open for customers and do not account for normal operations such as custodial or stocking activities. In addition, these hours of operation are typically applied to the entire building, regardless of the varying activities at the site.

This paper presents the results of a study conducted by San Diego Gas & Electric which examined the hours of operation used for evaluating load impacts for its Commercial Lighting Retrofit Program. While improving the values for hours of operation improves the estimates of program impacts, the specific interest of this paper is the finding that there appears to be different usage patterns of lighting within a building that is dependent on the manner in which the space is utilized. We found that there was significant variation in the hours of operation for various space uses within buildings. The metered hours of operation data were, on average, over eight percent greater than customer reported hours.

The data suggest that the program impacts may be enhanced through the incorporation of metered hours of operation in evaluating the program and in implementing the program. Lighting retrofit programs may increase effectiveness by targeting areas of buildings with high hours of operation.

Introduction

Commercial lighting retrofit programs have been implemented widely in utility DSM programs, due in part to the reliable energy and demand benefits that are achievable. The accurate estimation of load impacts is dependent on several factors, including the original and retrofit fixture-Iamp-ballast combinations and the number of hours the fixtures are operated. An assessment of the hours of operation used in the evaluation of the energy impacts of the San Diego Gas & Electric's (SDG&E) Commercial Lighting Retrofit Program (CLRP) was conducted to determine whether improvements can be made in the hours of operation that would improve the impact estimates of the program.

SDG&E has conducted a systematic evaluation of the impacts of the CLRP. This process has examined the *ex ante* assumptions of base case lighting equipment stock (Sickels, 1991a) and compared *ex ante* hours of operation and customer-reported hours of operation (Sickels, 199 lb). These studies indicate that: (1) actual base case equipment stock is more efficient than assumed in the *ex ante* assumptions; and (2) the customer-reported hours of operation were generally lower than the *ex ante* assumptions.

Next, an econometric model utilizing simplified conditional demand analysis (S-CDA) was used to estimate the load impacts of the CLRP. In addition to other parameters, the S-CDA model incorporated reported hours of operation (reported hours) as a key input.

To improve the load impact estimates of the CLRP, we conducted an in-field metering study to gather more precise hours of operation data. This study utilized

lighting schedule loggers to collect data on the hours of operation (metered hours) from over 88 participants in the CLRP. While the project was designed to develop information on lighting usage within the targeted buildings, a key factor examined in the study was the relationship of lighting use, as defined by hours of operation, and the manner in which the area was used, a parameter termed space use. This paper discusses the methodology and results of the study. We focus on the hours of operation associated with various types of space usage and the implications of these findings.

Methodology

The study methodology included the following steps: (1) developing the list of potential study participants; (2) soliciting participation; (3) conducting the on-site data collection, including logger installation and removal; and (4) data management and analysis.

Study Participants

Target study participants were drawn from 180 sites which were retrofit as part of the CLRP during 1991. These 180 sites were included in an impact evaluation utilizing S-CDA (Schiffman, et al., 1993a). A total of 96 sites were targeted. Most of these sites were either Small Office or Small Retail. Several Medical and Primary Education sites were also included.

Of the 96 sites targeted, 88 were metered, a completion rate of 92 percent. Site participation was solicited primarily by telephone. Data provided from the CLRP tracking system contained site contact and telephone numbers. While over half of the contacts had changed during the period between implementation and solicitation, a new contact was usually available. In a few cases, where the phone number was no longer in service, the property manager or building manager was contacted directly on-site. Table 1 shows the distribution of the participants by building type.

Table 1. Distribution of Study Participants by Building Type

Building Type	Frequency
Medical	6
Office	74
Retail	6
School	2

On-Site Data Collection

The total retrofitted area was audited and divided into space use categories. Square footage was measured and fixtures configurations verified and counted. The data suggest strongly that the manner in which the space is utilized has an effect on the number of hours of operation within the space. Whether the space is used for private office, open office, conference room, lobby, or hallway has a measurable impact on the hours of operation. To capture the effect of space use on lighting, the lighting retrofit was decomposed into lighting zones which were homogeneous from the pre-post fixture composition and the space use characteristics perspectives.

Homogeneous Lighting Zones. A hierarchy was developed which related lighting fixtures *as installed* (fixture groups) and as *identified by space usage characteristics* (zones) within a fixture group.

Typically, a lighting retrofit job is implemented at a site as one or more fixture groups. A fixture group is homogeneous with respect to: (1) pre-retrofit lamp-ballast combination; (2) post-retrofit lamp-ballast combination; and (3) hours of operation. Thus, a fixture group defines the primary components used in the S-CDA impact estimation, pre-post lamp-ballast combinations and associated hours of operation. By and large, the pre- and post-retrofit lamp-ballast combinations are known from the CLRP tracking system. Generally, a single value for the hours of operation is assumed for a given a building, regardless of how space within is actually used. There were a total of 149 fixture groups at the 96 targeted sites. The number of fixtures per fixture group ranged from 12 fixtures to greater than 1,000 fixtures. The average number of fixtures per fixture group was 185.

The hypothesis we tested is that a fixture group is not truly homogeneous with respect to the hours of operation, and that the lack of homogeneity is due to the individual control afforded by switches located throughout a facility. To test this hypothesis it was necessary to decompose each fixture group into smaller units called zones. A zone is defined as a sub-group of fixtures within a fixture group which are controlled by a single switch or lighting control.

To facilitate subsequent analyses and to operationalize the definition of zones in the field a space use code system was developed which would capture the bulk of major activities in the commercial sector. Table 2 shows the eight space use codes developed for the project. The space

Table 2. Space Use Categories

Space Use Category	Description
Conference Room	Conference room
Hall	Halls
	Stairs
Private Office	Private office
Open Office	Open office
Lobby	Lobby
Sales	Sales and display floor
Storage	Storage room
	Stock room
Other	Classroom
	Medical Exam
	Patient Rooms
	Dining/Lunch
	Lounge
	Restroom
	Other unclassified

use codes provided the ability to further identify homogeneous zones based on space use and lighting control characteristics.

Figure 1 illustrates the relationship of fixture groups, zones and space use codes by showing a floorplan of a hypothetical building. In the example, one fixture group was retrofit across the entire building. Within the building, a number of individual areas are found, each with its own space use code, such as the supervisor's office, which is given a space use code of private office.

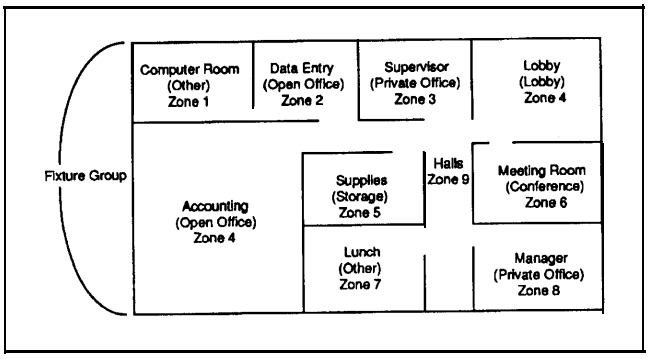

Figure 1. Relationship of Fixture Group and Lighting Zones

Key Data. Data were collected on-site on a room-by-room basis. While in a room, data on fixture and lamp types installed, number of fixtures, space usage, and square footage were collected. It should be noted that the scope of the project was to examine those areas which were retrofit through the CLRP. Thus, not all fixtures in a facility were counted at each site. Data were collected for over 3,900 individual zones across the 88 sites in the study.

Logger Installation and Removal. After the initial data gathering step, where data on fixture and lamp types installed, number of fixtures, space usage, and square footage were collected, the data for the site were reviewed in the field. The following steps were followed to identify monitoring points: (1) data were aggregated by space usage codes; (2) dominant space uses were identified on the basis of the number of fixtures throughout the facility; and (3) dominant space uses were prioritized and selected for monitoring. Referring to Figure 1, Table 3 shows how the nine zones in this building would be aggregated. Due to limited numbers of loggers available for the project, a maximum of five or six loggers per site were installed.

Loggers were installed for approximately four weeks. In most cases the loggers were installed for exactly four weeks, to facilitate annualizing the data. The date and time of installation and removal were recorded.

Table 3. Example of the Aggregation of Zones By Space Use Codes (Refer to Figure 1)

Space Use Code	Zone Number	Room Name
Open Office	2	Data Entry
	4	Accounting
Private Office	3	Supervisor
	8	Manager
Lobby	4	Lobby
Storage	5	Supplies
Conference	6	Meeting Room
Halls	9	Halls
Other	1	Computer Room
	7	Lunch Room

Data Management and Preparation

Data management and analysis followed a multi-step process. First, the data were input into a database on a room-by-room basis. The data were subject to several quality control steps to ensure data integrity. Hours of operation were annualized for each logger. Each record was matched to a logger based on the space use codes within a building. Finally, the fixture counts and square footage were aggregated by fixture group and space use code within each building.

The final dataset provided a variety of information, including:

- Pre- and post-retrofit equipment,
- Fixture counts,
- Space use codes,
- Measured square footage,
- Reported hours of operation, and
- Metered hours of operation.

Results and Discussion

Because of the method used to select study participants, the data presented in this paper should be used with some caution. The participants were selected to aid in improving the impact evaluation on a case by case basis, and thus, the results cannot be extrapolated to the program population. In addition a limited number of building types were metered, primarily office and retail facilities. The results do, however, provide insight on variations in lighting behavior in commercial buildings.

Hours of Operation by Space Use Characteristics

Figure 2 shows the average metered hours of operation and reported hours of operation for the space use codes addressed in the study. The metered hours are greater than reported hours for some space uses and less others.

In Figure 3 the ratio of metered hours to reported hours versus the reported hours are plotted. Table 4 shows the average metered and reported hours, and the ratio of metered to reported hours by space use. These results show that, on average, the unweighed metered hours of operation are 8.5 percent greater than the reported hours, and that there is a great deal of variation among the space use areas. Areas which are constantly in use such as halls, lobbies and sales areas have hours of operation which are consistently greater than reported hours. On the other hand, areas which are used somewhat intermittently, such as private offices, storage rooms and conference rooms have hours which tend to be less than the reported hours.

These findings at the space use level are not surprising as varying usage of lighting would be expected for different areas. Particularly interesting is the difference in hours for open and private offices, where there is a difference of 1,500 hours in the average metered values for the two space types, and virtually no difference in the reported hours. These results indicate a difference in the manner in which lighting is used in private and open offices. The results indicate that where possible, people tend to turn off the lights when a room is not occupied or used. Areas such as halls, lobbies, sales floors, and even open offices

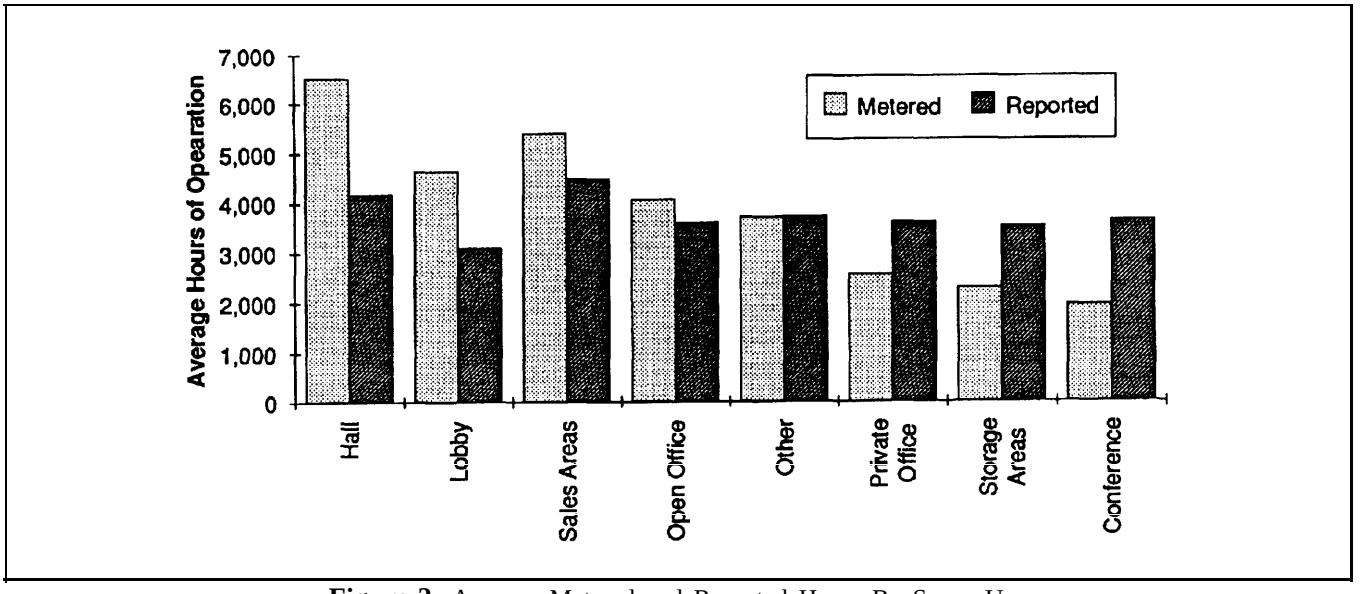

Figure 2. Average Metered and Reported Hours By Space Use

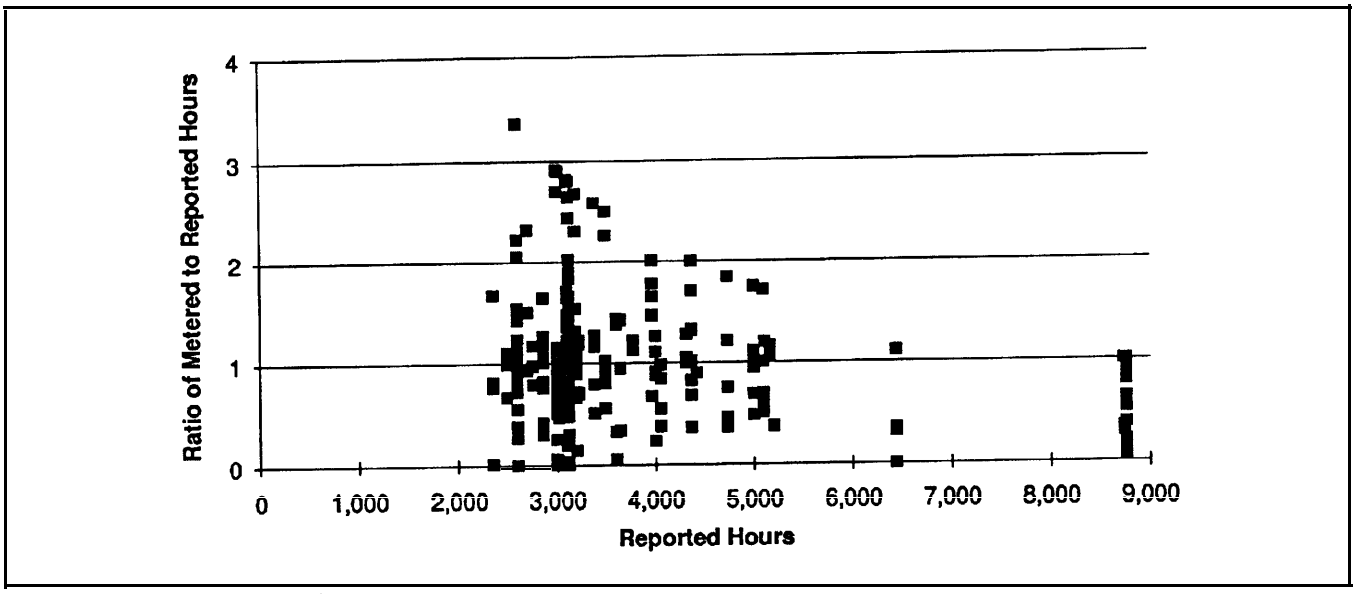

Figure 3. Ratio of Metered Hours to Reported Hours at Zone Level

Table 4. Averaged Metered Hours to Reported Hours and Average Ratio of Metered to Reported Hours by Space Usage

Space Use	Metered	Reported	Ratio
Hall	6,522	4,183	1.724
Lobby	4,645	3,089	1.507
Sales Areas	5,388	4,479	1.280
Open Office	4,067	3,600	1.180
Other	3,706	3,715	1.002
Private Office	2,551	3,596	0.738
Storage Areas	2,282	3,510	0.680
Conference	1,946	3,636	0.583
Overall	-	-	1.085

have hours of operation greater than areas where there is more discretionary use, such as private offices and conference rooms.

Hours of Operation by Building Type

Figure 4 shows the average hours of operation for metered, customer reported, and *ex ante* assumptions in 1994 for building types addressed in the study. Alternate weighting schemes were examined by SDG&E to incorporate metered data into the S-CDA framework (Schiffman, et al., 1993b). In this study, the metered data were weighted by square footage by zone, as well as by fixture counts per zone. The two weighting approaches yielded similar results. In the impact analysis, the metered data are weighted based on measured square footage by zone to represent each fixture group. Table 5 shows the average ratio of metered hours of operation to reported hours of operation by building type.

These results indicate that office and retail sites have metered hours which are greater than the reported hours and *ex ante* hours. As shown in Table 5, the ratio of metered hours of operation to reported hours of operation for Office and Retail indicates that the metered hours are 17.9 percent and 23.4 percent greater than reported hours. Metered hours are 1.6 percent and 16.1 percent lower than reported hours for medical buildings and schools, respectively, although there were limited sample points for these building types.

Conclusions

These findings suggest that the hours of operation used in planning and evaluation of the CLRP may be improved through metered data. Already, the inclusion of these data into an econometric impact evaluation of the CLRP have resulted in improved levels of precision of the impact estimates (Schiffman et all., 1993b). Adjustments have been made to *ex ante* hours of operation based on these metered data.

The data suggest that there are meaningful differences in the manner in which lighting is used in various space use types of commercial establishments. One approach for optimizing the impact of the CLRP is to intelligently apply the information on hours of operation by space use. This may be accomplished by targeting areas with high usage

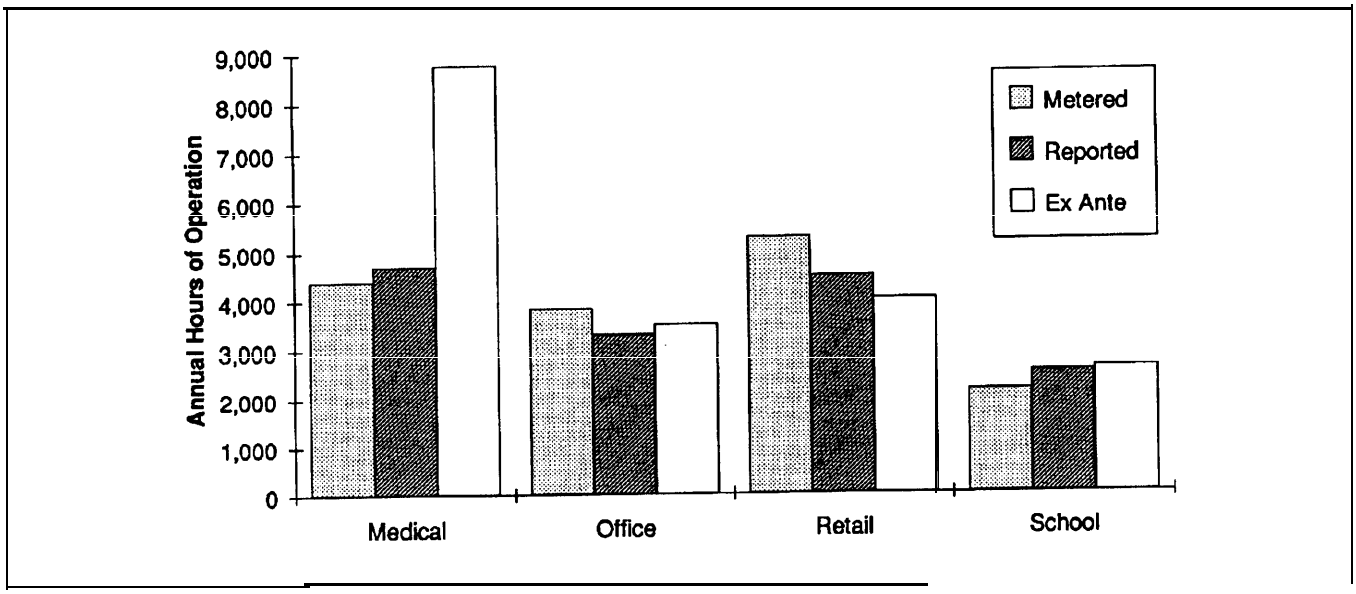

Figure 4. Average Metered and Reported Hours and Ex Ante Hours by Building Type

Table 5. Average Ratios of Metered Hours to Reported Hours, by Building Type

Building Type	Ratio
Office	1.179
Retail	1.234
Medical	0.984
School	0.839
Overall	1.158

areas, resulting in higher values for hours of operation. Another method would be to systematically update *ex ante* estimates of hours of operation by building type through a weighting scheme based on square footage or fixture counts by space uses.

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