Is The Customer Always Right? A Cost-Effective Method for Estimating Lighting Usage in Commercial Buildings

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ABSTRACT

The California Public Utilities Commission recently released the *Small Commercial Contract Group Direct Impact Evaluation Report*. This evaluation included the largest lighting end use monitoring study of its kind, with the installation of nearly 7,000 lighting loggers in over 1,200 commercial buildings throughout California. As part of the on-site visit for this study, participants were asked to estimate their lighting usage by activity area within their building, as well as provide their business operating hours. Lighting loggers were then installed on rebated CFLs and linear fluorescent fixtures. This allowed for a comparison of participants' actual lighting usage to both their self-reported lighting usage and their business operating hours.

This paper establishes a method for estimating lighting usage in commercial buildings without the cost of installing on-site metering equipment. The method leverages on-site monitoring data from the *Small Commercial Report* by using business operating hours as a predictor to estimate daily lighting usage profiles by building type and activity area. As a secondary approach, the usage estimates can be further refined using site-level self-reported usage data, if available.

Introduction

How does one estimate lighting usage profiles for commercial buildings? Ideally, lighting logger equipment can be installed to monitor the usage, but this is an expensive approach. A less costly option may be to ask customers to estimate their own lighting usage. But, how accurate are these self-reported usage values? Do customers tend to over- or under-estimate their usage? Do these trends vary by building type and activity area?[1] Are there certain times of the day that customers are simply unable to accurately estimate their own usage?

Another option may be to use business hours as a proxy for lighting usage. In its simplest form, this method would assume that all lights in a business were ON when the business was open, and OFF when the business was closed. However, some lights are left ON after businesses have closed, and not all lights are turned ON during open hours.

The purpose of this study was to develop a method for estimating lighting usage in commercial buildings that leverages existing monitoring data from the *Small Commercial Contract Group Direct Impact Evaluation Report*. The method developed requires only a building's business hours to develop accurate usage profiles. As a secondary approach, self-reported lighting usage information can also be used to further refine the estimation during times that businesses are open.

The primary results of this study are presented as lighting usage *rates*[2] that allow for the

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1 Activity areas are defined as areas at the premise that have different activity types (e.g., office, dining room, and kitchen).

2 In this context, a lighting usage *rate* is a percentage that can be thought of as a probability. For example, if the usage rate for a lamp is 50% in a certain period, then there is a 50% chance that the lamp will be on at any given time within that period.

development of simple 8760 lighting use shapes based on business open, closed, and shoulder hours[3] specific to building type and activity area. We refer to these primary results as the *business hour rates.* They are meant to be used to estimate lighting usage across an entire market segment or building type (such as Office buildings or Restaurants). To apply the business hour rates, a sample of sites and their business hours must be obtained (or assumed). Then, the rates are used to develop lighting usage profiles for each site in the sample based on their individual business hours. Finally, individual profiles are then averaged together to make an estimated usage profile for the entire sector.

As mentioned above, this paper also provides secondary results that use self-reported lighting usage to refine the business hour estimation. We refer to these secondary results as the *self-report adjustment factors,* since they are used to adjust self-reported usage to make it more accurate. Each self-report adjustment factor is the ratio of actual monitored lighting usage over self-reported usage. Although we began this study with the intention of presenting self-report adjustment factors as the primary method for estimating lighting usage, we found that customers too often self-reported zero or very little use during the times that the business was not open, making the ratios undefined or unreasonably large. Therefore, we present the self-report adjustment factors as a way to adjust self-reported usage during open times only.

Background

The analysis for this study was completed using data collected for the recently released *2006-2008 Small Commercial Contract Group Direct Impact Evaluation Report* (Small Com Report),[4] prepared by Itron, Inc., for the California Public Utilities Commission. The primary purpose of the Small Com Report was to provide an evaluation of the California investor owned utilities' claimed energy efficient accomplishments in the commercial sector for the 2006-2008 program cycle.[5] The majority of these claimed savings came by way of efficient lighting retrofit projects. Hence, an extensive statewide on-site survey and time-of-use data collection effort was undertaken by Itron to gather the lighting usage information needed to calculate the energy savings.

Data Collection

The three main components of the on-site survey utilized in this analysis were the site's business hours, the self-reported lighting usage, and the lighting logger data.

The business hours were collected over the phone during the initial telephone recruitment survey and then confirmed by the surveyor on-site. These business hours were recorded as the opening time and closing time for each day of the week. If a business kept a separate set of business hours for seasonal operation, that information was recorded as well.

The self-reported operating hours were collected as a percent of time on per hour for each hour in each day of the week. On-site surveyors collected these self-report estimates for each different lighting usage schedule within the building. Typically, different activity areas within a building had different lighting usage schedules.

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[3] As described in further detail below, the shoulder periods are defined as the two hours before opening and the two hours after closing.

[4] The Small Com Report can be found at www.CALMAC.org. Study ID: CPU0019.01.

[5] The scope of the Small Com Report included the evaluation of claimed lighting savings from all non-residential programs, *excluding* the custom programs. These non-custom programs were typically directed toward small- and medium-sized customers, while the custom programs typically served large customers. For this reasons, the Report was named "Small Commercial" even though the participants were not exclusively "small."

The time-of-use data were obtained through the installation of lighting loggers. A technical description of the lighting loggers and the installation/extraction procedures can be found in the Small Com Report, Appendix G. Once on-site, surveyors attempted to log every representative activity area where rebated CFLs and linear fluorescent lamps were installed.

Data Processing

After extraction, the lighting logger data were processed into a percent-ON-per-hour format. This allowed for a comparison of the actual lighting usage data with the business hours and secondarily with the self-reported hours of usage. Figure 1 demonstrates this comparison for an office area. The data shown represent CFL usage at an office activity area within a particular office building on an average Friday. The vertical axis represents the usage rate (i.e., percent ON for each hour of the day) for the self-reported and actual usage values. For the business hours, a value of 1 on the vertical axis means the business was open, and a value of 0 means the business was closed.

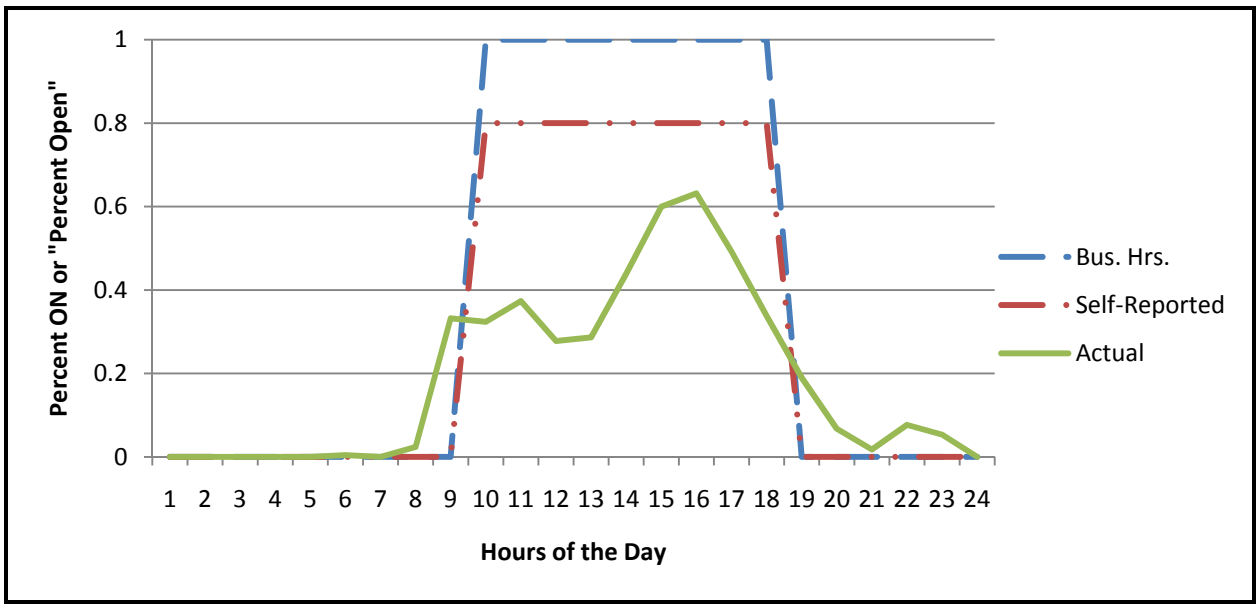

Figure 1: Example of Actual and Self-Reported Lighting Usage and Business Hours

This analysis was motivated by a desire to utilize these business hour and usage shapes to help estimate lighting usage in future studies. Understanding that buildings in future studies may have different business operating schedules, or self-reported usage, we provide our results at a level of granularity that allows future researchers to take those differences into account.

The next step in processing of the data was to identify each hour at each site as being in one of the following four periods (relative to business hours): Open, Opening Shoulder, Closing Shoulder, or Closed. The Open period was defined as all hours of the day for which the business was open. The Opening Shoulder and Closing Shoulder periods were defined as the two hours before opening and after closing, respectively. The Closed period was defined as all hours for which the business was closed and not in one of the two shoulder periods.

Once these periods were identified, the actual and self-reported usage rates were calculated for each period and each activity area at each site. The aggregation from individual loggers to activity areas

was done based on the number of lamps each logger was monitoring. The final calculation of the results is described in the Results section below.

Results

As mentioned in the Introduction, the primary results are the business hour rates. These results can be applied simply by knowing the business operating hours, building type, and activity areas. In case the activity area distributions within the buildings are not known, aggregated building type results are also provided.

The secondary results are the self-report adjustment factors. In order to apply these factors, one must also obtain self-reported usage rates during open times by activity area for the sample of buildings. The self-reported usage rates used in this analysis were collected on-site. We believe that the on-site visit is necessary to gather reliable self-report information and to properly label activity areas. Thus, we recommend that self-reported values used for future estimations also be collected on-site.

Business Hour Rates

The business hour rates represent the percent usage during each period of the day (Open, Closed, and the Shoulder periods). The dataset for the business hour rates included data from the seasonal business operation schedules and holidays. The usage rates for each logger were weighted by the total number of lamps represented and the total hours elapsed in each period.

Table 1 and Table 2 presented below contain the business hour rates by building type and activity area. Table 3 and Table 4 contain the business hour rates aggregated to the building type level. We chose to provide these building level estimation figures in addition to the activity area figures to offer additional flexibility to future evaluators.

Self-Report Adjustment Factors

As mentioned above, the original intent of this analysis was to produce adjustment factors (i.e., multipliers) that could be applied to self-reported usage for each of the four periods in the day. An adjustment factor is defined as actual metered usage divided by self-reported use. However, we found that many sites self-reported that they had zero or very little usage during the shoulder or closed periods. Since the denominator in the multiplier was zero or nearly zero, this made the adjustment factors either undefined or extremely large. Therefore, adjusting self-reported usage is not a good way to estimate lighting use during the closed and shoulder periods. For those periods, we recommend using the business hour rates as presented in the previous section.

Table 5 and Table 6 contain the self-report adjustment factors that can be applied to self-reported usage during the Open period. The results are presented by building type and activity area, separately for CFL and linear fluorescent lighting. The building level figures were not provided for the self-report factors because we assume that future evaluators will gather self-report usage information at the activity area detailed level.

Table 1: Business Hour Rates - CFL

Building Type	Activity Area	Num Sites	Closed		Opening Shoulder		Open		Closing Shoulder	
			Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.
Assembly	Assembly	32	0.03	(0.02, 0.05)[6]	0.04	(0.02, 0.06)	0.14	(0.11, 0.17)	0.09	(0.05, 0.13)
	HallwayLobby	54	0.13	(0.08, 0.17)	0.22	(0.13, 0.31)	0.43	(0.32, 0.54)	0.20	(0.13, 0.28)
	Kitchen/Break	12	0.04	(0.01, 0.07)	0.03	(0.01, 0.04)	0.12	(0.06, 0.18)	0.10	(0.02, 0.18)
	Office	23	0.04	(0.01, 0.07)	0.07	(0.02, 0.12)	0.30	(0.19, 0.41)	0.16	(0.09, 0.22)
	OtherMisc	35	0.03	(0.02, 0.04)	0.08	(0.04, 0.11)	0.43	(0.31, 0.55)	0.12	(0.08, 0.16)
	Restrooms	43	0.08	(0.04, 0.13)	0.12	(0.05, 0.18)	0.31	(0.2, 0.42)	0.17	(0.09, 0.26)
	Storage	31	0.04	(0.01, 0.07)	0.05	(0, 0.1)	0.16	(0.05, 0.27)	0.07	(0.01, 0.12)
Health/ Medical - Clinic	HallwayLobby	40	0.18	(0.05, 0.31)	0.32	(0.17, 0.47)	0.63	(0.47, 0.8)	0.38	(0.2, 0.55)
	Office	24	0.03	(0.02, 0.05)	0.12	(0.08, 0.16)	0.43	(0.25, 0.62)	0.21	(0.11, 0.31)
	OtherMisc	26	0.04	(0, 0.08)	0.09	(0, 0.2)	0.15	(0.1, 0.21)	0.21	(0, 0.44)
	Restrooms	24	0.01	(0, 0.01)	0.02	(0, 0.05)	0.16	(0.04, 0.27)	0.05	(0.02, 0.08)
Lodging	Guest Rooms	91	0.07	(0.04, 0.11)	0.10	(0.06, 0.15)	0.08	(0.07, 0.09)	0.05	(0.02, 0.08)
	HallwayLobby	54	0.25	(0.16, 0.33)	0.21	(0.13, 0.29)	0.64	(0.56, 0.73)	0.19	(0.13, 0.26)
	Kitchen/Break	12	0.13	(0, 0.38)	0.40	(0, 0.92)	0.34	(0.12, 0.57)	0.27	(0, 0.66)
	Mechanical/Elec. Room	16	0.01	(0, 0.01)	0.05	(0.02, 0.07)	0.31	(0.11, 0.51)	0.01	(0, 0.04)
	Office	13	0.07	(0, 0.18)	0.05	(0, 0.11)	0.32	(0.22, 0.42)	0.09	(0, 0.17)
	OtherMisc	18	0.08	(0, 0.19)	0.05	(0, 0.1)	0.61	(0.5, 0.72)	0.13	(0.07, 0.19)
	Restrooms	39	0.09	(0.03, 0.15)	0.16	(0.03, 0.3)	0.07	(0.06, 0.09)	0.15	(0.01, 0.29)
	Storage	13	0.14	(0, 0.48)	0.43	(0, 1.16)	0.18	(0.06, 0.3)	0.22	(0, 0.65)
Office - Small	HallwayLobby	46	0.29	(0.15, 0.44)	0.39	(0.25, 0.53)	0.64	(0.53, 0.76)	0.40	(0.28, 0.53)
	Office	32	0.04	(0.02, 0.06)	0.14	(0.08, 0.2)	0.57	(0.48, 0.67)	0.16	(0.11, 0.22)
	OtherMisc	23	0.04	(0.01, 0.07)	0.05	(0.02, 0.07)	0.32	(0.18, 0.46)	0.14	(0.08, 0.21)
	Restrooms	72	0.04	(0.01, 0.07)	0.06	(0.02, 0.1)	0.15	(0.08, 0.21)	0.09	(0.03, 0.14)
	Storage	20	0.06	(0, 0.11)	0.14	(0.06, 0.22)	0.20	(0.06, 0.33)	0.15	(0.06, 0.25)
Other	HallwayLobby	31	0.25	(0.17, 0.33)	0.11	(0.02, 0.2)	0.61	(0.42, 0.81)	0.57	(0.26, 0.88)
	Office	20	0.17	(0.03, 0.31)	0.23	(0.1, 0.36)	0.51	(0.42, 0.6)	0.31	(0.11, 0.52)
	OtherMisc	32	0.13	(0.11, 0.16)	0.08	(0.04, 0.13)	0.14	(0, 0.33)	0.04	(0, 0.09)
	Restrooms	62	0.08	(0.05, 0.11)	0.18	(0.09, 0.27)	0.45	(0.3, 0.6)	0.25	(0.12, 0.38)
	Storage	29	0.19	(0, 0.4)	0.22	(0, 0.46)	0.52	(0.28, 0.76)	0.27	(0.05, 0.5)
Restaurant	Dining	67	0.06	(0.03, 0.1)	0.23	(0.17, 0.3)	0.78	(0.71, 0.85)	0.30	(0.24, 0.35)
	HallwayLobby	36	0.33	(0.17, 0.49)	0.42	(0.23, 0.6)	0.64	(0.38, 0.9)	0.42	(0.23, 0.61)
	Kitchen/Break	26	0.13	(0.04, 0.22)	0.54	(0.4, 0.68)	0.84	(0.72, 0.96)	0.36	(0.23, 0.49)
	Office	14	0.10	(0.04, 0.16)	0.27	(0.14, 0.4)	0.40	(0.28, 0.53)	0.26	(0.13, 0.38)
	OtherMisc	8	0.23	(0.02, 0.45)	0.47	(0.22, 0.72)	0.70	(0.56, 0.84)	0.41	(0.25, 0.58)
	Restrooms	52	0.16	(0.09, 0.24)	0.31	(0.23, 0.4)	0.52	(0.42, 0.62)	0.32	(0.2, 0.43)
	Storage	42	0.09	(0.05, 0.14)	0.30	(0.2, 0.39)	0.45	(0.31, 0.6)	0.19	(0.11, 0.26)
Retail - Small	HallwayLobby	21	0.17	(0.06, 0.28)	0.31	(0.19, 0.43)	0.59	(0.43, 0.75)	0.28	(0.17, 0.4)
	Office	27	0.31	(0.08, 0.54)	0.44	(0.25, 0.62)	0.75	(0.57, 0.92)	0.36	(0.15, 0.57)
	OtherMisc	26	0.04	(0.01, 0.07)	0.18	(0.08, 0.28)	0.54	(0.33, 0.76)	0.13	(0.08, 0.18)
	Restrooms	104	0.03	(0.02, 0.04)	0.05	(0.03, 0.08)	0.17	(0.12, 0.22)	0.07	(0.04, 0.1)
	RetailSales	59	0.22	(0.08, 0.36)	0.29	(0.18, 0.4)	0.81	(0.74, 0.87)	0.31	(0.21, 0.42)
	Storage	31	0.04	(0, 0.1)	0.14	(0.05, 0.24)	0.37	(0.13, 0.62)	0.07	(0.01, 0.13)

[6] The lower confidence limits for all confidence intervals in this paper have been restricted to a minimum value of zero.

Table 2: Business Hour Rates- Linear Fluorescent

Building Type	Activity Area	Num Sites	Closed		Opening Shoulder		Open		Closing Shoulder	
			Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.
Assembly	Assembly	16	0.03	(0.02, 0.04)	0.06	(0.01, 0.11)	0.28	(0.13, 0.42)	0.08	(0.05, 0.12)
	HallwayLobby	9	0.13	(0.09, 0.17)	0.12	(0, 0.27)	0.24	(0.04, 0.44)	0.21	(0.05, 0.37)
	Kitchen/Break	10	0.06	(0.03, 0.09)	0.16	(0.03, 0.29)	0.37	(0.23, 0.52)	0.18	(0.08, 0.28)
	Office	14	0.03	(0.02, 0.04)	0.14	(0.07, 0.2)	0.44	(0.39, 0.5)	0.11	(0.06, 0.15)
	OtherMisc	20	0.04	(0.02, 0.05)	0.12	(0.07, 0.16)	0.27	(0.17, 0.37)	0.11	(0.06, 0.16)
Health/ Medical - Clinic	Comm/Ind Work	10	0.04	(0.01, 0.07)	0.06	(0.01, 0.12)	0.64	(0.3, 0.99)	0.30	(0.13, 0.47)
	HallwayLobby	27	0.20	(0.1, 0.29)	0.26	(0.15, 0.36)	0.81	(0.75, 0.88)	0.47	(0.36, 0.58)
	Kitchen/Break	12	0.03	(0, 0.07)	0.17	(0.06, 0.28)	0.61	(0.51, 0.7)	0.30	(0.18, 0.42)
	Office	25	0.07	(0.03, 0.11)	0.18	(0.11, 0.25)	0.64	(0.51, 0.76)	0.29	(0.22, 0.36)
	OtherMisc	16	0.01	(0, 0.02)	0.04	(0, 0.08)	0.41	(0.33, 0.49)	0.28	(0.15, 0.4)
	Patient Rooms	10	0.02	(0, 0.05)	0.06	(0.02, 0.1)	0.30	(0.13, 0.47)	0.20	(0.07, 0.34)
	Storage	10	0.01	(0, 0.02)	0.02	(0, 0.04)	0.45	(0, 0.92)	0.03	(0, 0.06)
Grocery	OtherMisc	6	0.18	(0.03, 0.33)	0.29	(0, 0.64)	0.69	(0.43, 0.95)	0.23	(0.07, 0.39)
	RetailSales	10	0.17	(0.03, 0.31)	0.57	(0.17, 0.96)	0.95	(0.88, 1.02)	0.32	(0.18, 0.46)
Office - Small	Comm/Ind Work	25	0.22	(0.04, 0.4)	0.37	(0.14, 0.61)	0.65	(0.56, 0.75)	0.41	(0.22, 0.6)
	Conference Room	23	0.02	(0.01, 0.04)	0.12	(0, 0.27)	0.35	(0.18, 0.52)	0.15	(0.05, 0.25)
	HallwayLobby	47	0.14	(0.06, 0.22)	0.27	(0.13, 0.42)	0.78	(0.71, 0.86)	0.41	(0.28, 0.55)
	Kitchen/Break	34	0.16	(0, 0.31)	0.31	(0.07, 0.56)	0.52	(0.31, 0.73)	0.31	(0.08, 0.55)
	Office	88	0.10	(0.01, 0.19)	0.23	(0.12, 0.35)	0.68	(0.61, 0.75)	0.33	(0.21, 0.46)
	OtherMisc	12	0.05	(0.01, 0.08)	0.21	(0, 0.46)	0.42	(0.22, 0.62)	0.15	(0.05, 0.25)
	Restrooms	9	0.04	(0.01, 0.08)	0.04	(0, 0.08)	0.34	(0.08, 0.61)	0.14	(0.02, 0.27)
	Storage	31	0.01	(0, 0.02)	0.05	(0.02, 0.09)	0.30	(0.16, 0.43)	0.07	(0.03, 0.11)
Other	Comm/Ind Work	30	0.09	(0.02, 0.16)	0.20	(0.11, 0.29)	0.67	(0.59, 0.74)	0.27	(0.11, 0.43)
	HallwayLobby	30	0.21	(0.08, 0.33)	0.41	(0.26, 0.56)	0.85	(0.82, 0.87)	0.49	(0.32, 0.66)
	Office	47	0.04	(0.02, 0.06)	0.11	(0.06, 0.16)	0.55	(0.42, 0.67)	0.19	(0.14, 0.24)
	OtherMisc	47	0.02	(0.02, 0.03)	0.11	(0.03, 0.19)	0.39	(0.25, 0.53)	0.13	(0.09, 0.16)
	Restrooms	13	0.03	(0.01, 0.04)	0.12	(0.05, 0.2)	0.27	(0, 0.62)	0.19	(0.03, 0.36)
	Storage	24	0.07	(0, 0.15)	0.14	(0, 0.27)	0.52	(0.37, 0.67)	0.19	(0.04, 0.34)
Retail - Small	Auto Repair Workshop	27	0.02	(0.01, 0.04)	0.12	(0.06, 0.18)	0.75	(0.63, 0.86)	0.31	(0.2, 0.42)
	Comm/Ind Work	33	0.06	(0.02, 0.11)	0.27	(0.13, 0.41)	0.83	(0.73, 0.92)	0.31	(0.22, 0.4)
	HallwayLobby	31	0.05	(0, 0.1)	0.16	(0.06, 0.26)	0.77	(0.65, 0.88)	0.22	(0.14, 0.3)
	Kitchen/Break	24	0.04	(0, 0.09)	0.11	(0.02, 0.19)	0.39	(0.24, 0.54)	0.18	(0.08, 0.28)
	Office	67	0.01	(0.01, 0.02)	0.09	(0.05, 0.13)	0.67	(0.59, 0.76)	0.15	(0.11, 0.2)
	OtherMisc	18	0.07	(0, 0.15)	0.17	(0.06, 0.29)	0.76	(0.6, 0.92)	0.30	(0, 0.61)
	Restrooms	15	0.02	(0.01, 0.03)	0.05	(0.01, 0.08)	0.26	(0.11, 0.4)	0.12	(0.04, 0.21)
	RetailSales	102	0.03	(0.02, 0.04)	0.15	(0.11, 0.18)	0.92	(0.9, 0.94)	0.14	(0.11, 0.17)
	Storage	62	0.04	(0.01, 0.06)	0.12	(0.07, 0.17)	0.72	(0.64, 0.79)	0.16	(0.08, 0.25)
Restaurant	Dining	12	0.03	(0, 0.07)	0.08	(0, 0.16)	0.58	(0.43, 0.74)	0.17	(0, 0.34)
	Kitchen/Break	13	0.28	(0.05, 0.51)	0.63	(0.35, 0.92)	0.80	(0.59, 1.01)	0.58	(0.34, 0.82)
	OtherMisc	8	0.01	(0, 0.03)	0.35	(0.26, 0.43)	0.83	(0.58, 1.07)	0.19	(0.14, 0.23)
Warehouse	Office	18	0.06	(0.02, 0.1)	0.20	(0.12, 0.28)	0.61	(0.56, 0.66)	0.13	(0.05, 0.2)
	OtherMisc	16	0.02	(0.01, 0.03)	0.18	(0.06, 0.29)	0.43	(0.28, 0.57)	0.05	(0.02, 0.07)
	Storage	14	0.10	(0, 0.22)	0.14	(0.02, 0.25)	0.48	(0.3, 0.65)	0.13	(0, 0.26)

Table 3: Business Hour Rates. Overall Building Type - CFLs

Building Type	Num Sites	Closed		Opening Shoulder		Open		Closing Shoulder	
		Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.
Assembly	230	0.06	(0.04, 0.07)	0.09	(0.07, 0.12)	0.31	(0.26, 0.37)	0.13	(0.11, 0.15)
Health/Medical - Clinic	114	0.11	(0.04, 0.19)	0.23	(0.12, 0.33)	0.21	(0.14, 0.28)	0.29	(0.17, 0.41)
Lodging	256	0.08	(0.06, 0.11)	0.11	(0.08, 0.14)	0.14	(0.11, 0.17)	0.08	(0.05, 0.11)
Office - Small	193	0.13	(0.07, 0.19)	0.19	(0.14, 0.25)	0.43	(0.36, 0.49)	0.22	(0.17, 0.28)
Other	174	0.15	(0.13, 0.17)	0.12	(0.06, 0.17)	0.30	(0.07, 0.53)	0.16	(0, 0.31)
Restaurant	245	0.11	(0.08, 0.15)	0.30	(0.25, 0.35)	0.72	(0.66, 0.77)	0.32	(0.27, 0.36)
Retail - Small	268	0.16	(0.08, 0.23)	0.24	(0.18, 0.31)	0.63	(0.56, 0.69)	0.24	(0.18, 0.3)

Table 4: Business Hour Rates. Overall Building Type - Linear Fluorescent

Building Type	Num Sites	Closed		Opening Shoulder		Open		Closing Shoulder	
		Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.	Usage Rate	90% C.I.
Assembly	69	0.04	(0.03, 0.05)	0.10	(0.07, 0.13)	0.30	(0.24, 0.37)	0.11	(0.09, 0.13)
Grocery	16	0.17	(0.06, 0.28)	0.51	(0.18, 0.85)	0.90	(0.81, 1)	0.30	(0.19, 0.41)
Health/Medical - Clinic	110	0.08	(0.05, 0.12)	0.16	(0.1, 0.21)	0.53	(0.41, 0.66)	0.33	(0.27, 0.38)
Office - Small	269	0.12	(0.06, 0.18)	0.25	(0.17, 0.33)	0.64	(0.59, 0.69)	0.33	(0.25, 0.41)
Other	191	0.06	(0.04, 0.09)	0.16	(0.11, 0.2)	0.54	(0.4, 0.68)	0.21	(0.16, 0.27)
Restaurant	33	0.10	(0.01, 0.18)	0.30	(0.14, 0.45)	0.70	(0.56, 0.83)	0.29	(0.15, 0.44)
Retail - Small	379	0.03	(0.02, 0.04)	0.14	(0.12, 0.17)	0.81	(0.78, 0.84)	0.18	(0.15, 0.21)
Warehouse	48	0.06	(0.02, 0.09)	0.18	(0.12, 0.24)	0.52	(0.46, 0.59)	0.11	(0.06, 0.15)

Table 5: Self-Report Adjustment Factor for Usage during Business Open Hours - CFLs

Building Type	Activity Area	Num Sites	Self-Reported Usage	Self-Report Adjustment Factor	90% C.I. for the Adj. Factor
Assembly	Assembly	32	28%	0.55	(0.37, 0.74)
	HallwayLobby	54	54%	0.83	(0.64, 1.02)
	Kitchen/Break Room	12	23%	0.45	(0.09, 0.8)
	Office	23	63%	0.53	(0.34, 0.71)
	OtherMisc	35	55%	0.70	(0.51, 0.89)
	Restrooms	43	34%	0.88	(0.66, 1.11)
	Storage	31	23%	0.58	(0.34, 0.81)
Health/Medical - Clinic	HallwayLobby	38	74%	0.80	(0.67, 0.92)
	Office	23	82%	0.63	(0.38, 0.89)
	OtherMisc	23	65%	0.22	(0, 0.44)
	Restrooms	22	16%	1.35	(0.29, 2.42)
Lodging	Guest Rooms	82	33%	0.22	(0.16, 0.27)
	HallwayLobby	46	84%	0.86	(0.77, 0.95)
	Kitchen/Break Room	12	55%	0.65	(0.36, 0.95)
	Mechanical/Electrical Room	14	32%	0.76	(0.4, 1.12)
	Office	10	80%	0.41	(0.25, 0.58)
	OtherMisc	17	57%	0.91	(0.73, 1.09)
	Restrooms	34	25%	0.30	(0.18, 0.42)
	Storage	12	26%	0.61	(0.21, 1.01)
Office - Small	HallwayLobby	45	74%	0.83	(0.72, 0.94)
	Office	31	75%	0.75	(0.66, 0.83)
	OtherMisc	23	43%	0.80	(0.63, 0.96)
	Restrooms	68	19%	0.76	(0.55, 0.96)
	Storage	20	34%	0.45	(0.16, 0.74)
Other	HallwayLobby	30	77%	0.72	(0.56, 0.87)
	Office	18	80%	0.60	(0.54, 0.67)
	OtherMisc	31	9%	0.97	(0.84, 1.1)
	Restrooms	61	28%	1.29	(0.83, 1.75)
	Storage	27	54%	0.86	(0.66, 1.06)
Restaurant	Dining	66	87%	0.88	(0.8, 0.97)
	HallwayLobby	35	81%	0.83	(0.69, 0.97)
	Kitchen/Break Room	25	91%	0.91	(0.83, 0.99)
	Office	13	34%	1.18	(0.65, 1.71)
	OtherMisc	8	72%	0.91	(0.68, 1.14)
	Restrooms	49	51%	1.02	(0.87, 1.17)
	Storage	40	44%	1.14	(0.88, 1.39)
Retail - Small	HallwayLobby	19	85%	0.62	(0.42, 0.82)
	Office	27	64%	1.11	(0.74, 1.48)
	OtherMisc	25	65%	0.70	(0.47, 0.93)
	Restrooms	99	14%	1.36	(0.85, 1.87)
	RetailSales	58	80%	1.02	(0.88, 1.17)
	Storage	29	59%	0.84	(0.68, 1.01)

Table 6: Self-Report Adjustment Factor for Usage during Business Open Hours - Linear Fluorescent

Building Type	Activity Area	Num Sites	Self-Reported Usage	Self-Report Adjustment Factor	90% C.I. for the Adj. Factor
Assembly	Assembly	16	53%	0.35	(0.08, 0.62)
	HallwayLobby	8	54%	0.43	(0.2, 0.66)
	Kitchen/Break Room	10	43%	0.92	(0.29, 1.55)
	Office	13	55%	0.78	(0.55, 1)
	OtherMisc	20	54%	0.49	(0.41, 0.58)
Grocery	OtherMisc	6	70%	0.97	(0.71, 1.24)
	RetailSales	10	95%	0.97	(0.86, 1.08)
Health/Medical - Clinic	Comm/Ind Work	9	77%	0.87	(0.55, 1.19)
	HallwayLobby	26	89%	0.89	(0.81, 0.98)
	Kitchen/Break Room	12	70%	0.91	(0.67, 1.14)
	Office	24	75%	0.77	(0.56, 0.99)
	OtherMisc	16	55%	0.80	(0.63, 0.98)
	Patient Rooms	10	73%	0.45	(0.35, 0.54)
	Storage	10	45%	1.05	(0, 2.14)
Office - Small	Comm/Ind Work	25	83%	0.78	(0.71, 0.85)
	Conference Room	23	45%	0.85	(0.47, 1.23)
	HallwayLobby	47	93%	0.83	(0.76, 0.9)
	Kitchen/Break Room	33	70%	0.80	(0.63, 0.97)
	Office	87	82%	0.81	(0.74, 0.87)
	OtherMisc	12	69%	0.73	(0.49, 0.97)
	Restrooms	9	43%	0.82	(0.49, 1.15)
	Storage	30	44%	0.70	(0.54, 0.87)
Other	Comm/Ind Work	29	69%	1.00	(0.84, 1.17)
	HallwayLobby	29	60%	1.47	(0.61, 2.33)
	Office	46	61%	0.88	(0.74, 1.01)
	OtherMisc	46	40%	1.06	(0.83, 1.29)
	Restrooms	12	22%	1.69	(0, 4.35)
	Storage	24	51%	1.02	(0.66, 1.39)
Restaurant	Dining	12	73%	0.83	(0.7, 0.95)
	Kitchen/Break Room	13	82%	0.96	(0.8, 1.13)
	OtherMisc	7	80%	0.86	(0.57, 1.15)
Retail - Small	Auto Repair Workshop	26	87%	0.88	(0.78, 0.98)
	Comm/Ind Work	33	93%	0.85	(0.75, 0.95)
	HallwayLobby	29	82%	0.96	(0.86, 1.05)
	Kitchen/Break Room	21	60%	0.69	(0.48, 0.9)
	Office	65	74%	0.91	(0.82, 0.99)
	OtherMisc	17	81%	0.93	(0.87, 0.99)
	Restrooms	15	34%	0.87	(0.49, 1.24)
	RetailSales	100	94%	0.98	(0.95, 1.02)
	Storage	59	72%	0.98	(0.9, 1.05)
Warehouse	Office	15	88%	0.71	(0.64, 0.79)
	OtherMisc	15	73%	0.73	(0.64, 0.81)
	Storage	12	50%	0.95	(0.78, 1.13)

Application of Results

In this section, we provide an example to give guidance on the application of the results. We apply the two methods to our own data to estimate CFL usage at office activity areas within office buildings. We start with an application of the business hour rates and then show how the self-report factors can offer an additional refinement. It is important to note that the estimation techniques presented in this paper are meant to be applied to a large survey sample; they are not meant to accurately predict usage at a single site. Since the estimation techniques are sensitive to business hours at the individual sites, they must first be applied to each site in the sample and then aggregated to represent the desired population-wide lighting usage.

Application of Business Hour Rates

For each site in the sample, apply the business hour rates to each appropriate business hour period. The dotted line in Figure 2 is an example of this application to a single site. The dashed line shows the business's opening and closing times.

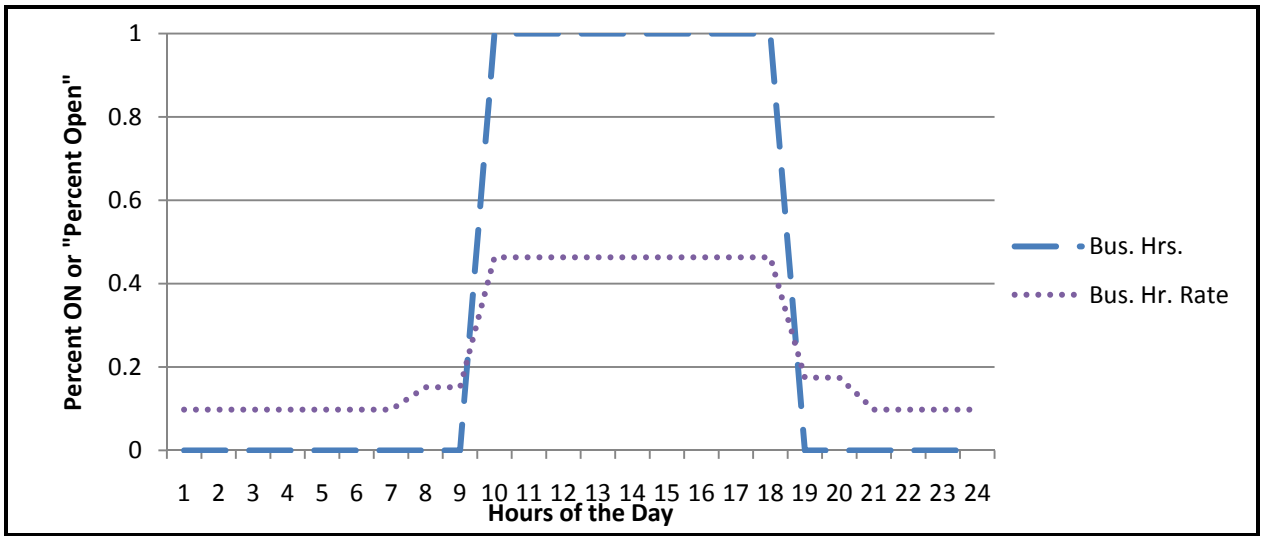

Figure 2: Application of the Business Hour Rates to a Single Site

Once the business hour rate estimates have been applied individually to all sites in the sample, the estimated usage profiles should be aggregated to create the desired population-wide lighting usage estimate. This population-wide estimation is shown in Figure 3. The Actual usage is also shown on Figure 3 to allow for a comparison with the estimate.

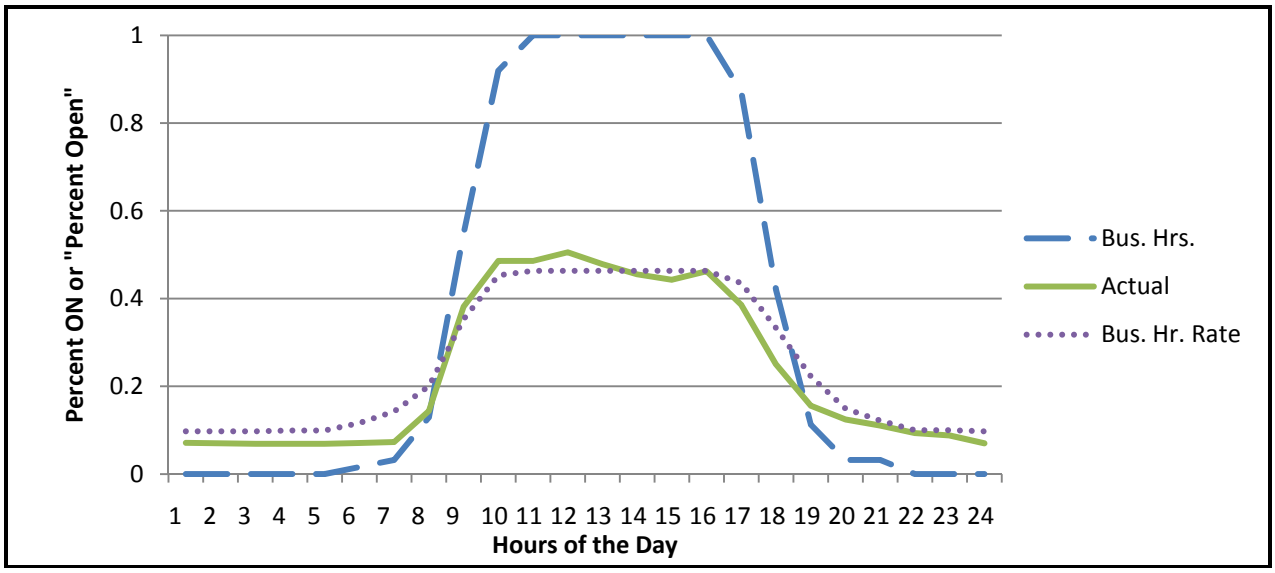

Figure 3: Population-Wide Actual Usage, Business Hours, and the Business Hour Rate Estimate

Application of Self-Report Adjustment Factors

As discussed in the Results section of this paper, the self-report adjustment factors can only be applied to self-reported usage during Open periods. In Figure 1, we saw a self-reported usage rate of 80% during the Open period. Table 6 tells us that this usage rate should be multiplied by a factor of 0.68. Thus, the estimated usage at this particular site during the Open period would be 54%. The estimates for the Closed and Shoulder periods are the same as the business hour rates.

Once these estimates have been applied individually to each site in the sample, they should be aggregated together to produce the desired population-wide estimate. This is shown in Figure 4.

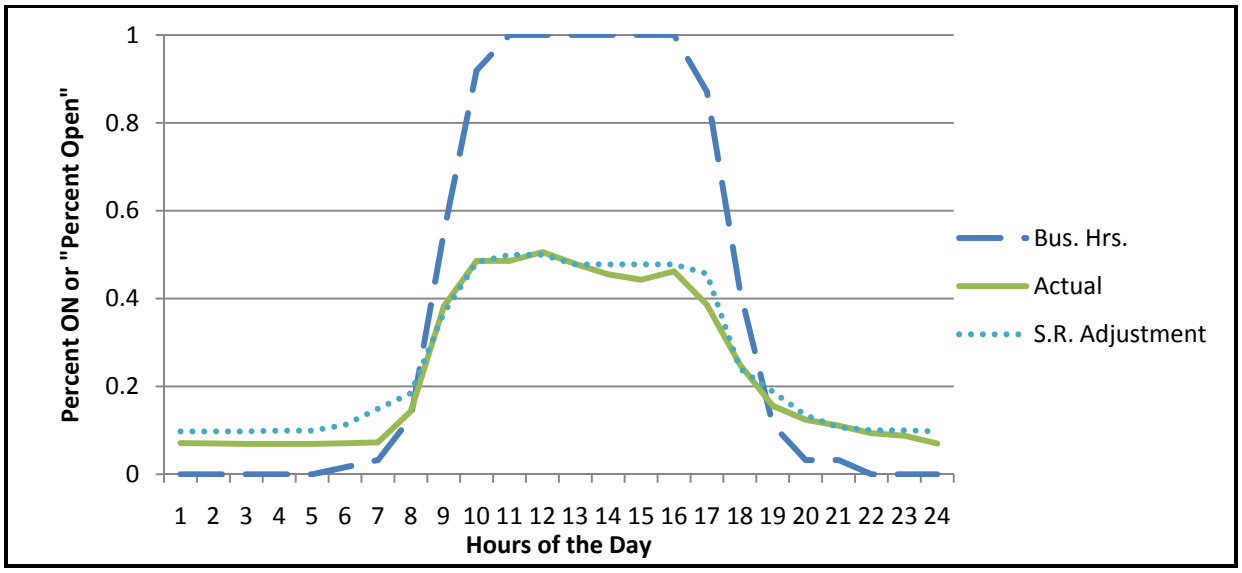

Figure 4: Population-Wide Actual Usage, Business Hours, and the Self-Report Adjustment Estimate

Conclusion

This paper provides evaluators with a cost-effective method for obtaining accurate lighting usage estimates in commercial buildings. With the business hour rates, evaluators can leverage simple business operating hours into reliable estimates of lighting use shapes. With the self-report method, evaluators can further refine their estimates to contour their lighting load shapes to the unique characteristics of the buildings under their study. Because these results are provided at a detailed level, evaluators have the flexibility to apply them based on the specific building type, activity area, and business hour characteristics of the population under their study.

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