LIGHTING CONTROLS EFFECTIVENESS ASSESSMENT

Final Report
on Task Lighting Study
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1. INTRODUCTION

Energy managers have long known that using task lighting as a supplement to general lighting in open office environments can contribute to energy efficiency. The use of task lighting allows the lighting designer to use lower ambient light levels, while allowing occupants to achieve high illuminance levels on their task surfaces. Because these areas are small compared to the area of general illumination, the overall system can be more efficient. Task lighting, however, is subject to the control of individuals, so the overall energy consumption is dependent on individual behavior. Little is known about this behavior and its effects on energy and demand. Increased attention to task lighting in the California Title 24 energy code and in the publicly funded energy efficiency programs has prompted the need for more field data on occupant behavior related to task lighting.

Under a contract with Southern California Edison Company (SCE) and Pacific Gas and Electric Company, ADM Associates, Inc. (ADM) has conducted a study to examine the use of permanently installed task lighting for open office spaces in office buildings. The purpose of this study of task lighting was to determine the operating patterns of such lighting. This document is the final report on this study of task lighting.[1]

The objectives for this study of task lighting included the following:

- Conduct a field survey of installed LPD for task and for ambient lighting in offices;
- Conduct a lighting logger study to estimate task lighting hours of operation;
- Estimate energy usage and demand (including observed diversity of load); and
- Observe occupant behavior (unnecessary usage of lighting) and recommend methods for improvement.

The results from achieving these objectives are expected to support several broader objectives. These broader objective include:

- Estimating the portion of office space that has permanently installed task lighting;
- Estimating savings potentials for both demand and energy from improved design and/or control of task lighting systems;

[1] This task lighting study was part of an overall study that also included collecting and analyzing data on bi-level lighting. The results of the bi-level lighting study are reported in ADM Associates, Inc. *Lighting Controls Effectiveness Assessment: Final Report on Bi-Level Lighting Study*, Report prepared under contract with Southern California Edison, June 2002.

- Developing code change proposals and justification for revisions to Title 24 lighting requirements; and
- Recommending changes in program design for utility sponsored nonresidential new construction programs.

Two types of data were collected for the study of task lighting.

- Measured data on use of task lighting were collected and analyzed for a sample of open office spaces where task lighting is commonly used. Although loggers were installed at 160 spaces in 30 office buildings, there were problems with the logger installations at some of the first sites that prevented data from being collected. As a result, monitored data were actually collected for 144 open office spaces in the office buildings. To facilitate analysis of the monitored data, data regarding the characteristics of the monitored spaces were collected.
- Information on operating practices for task lighting were collected from occupants of open office spaces. Questionnaires on the use of task lighting were administered to the occupants of the 160 spaces for which monitoring of task lighting was attempted and for another 218 occupants of spaces where task lighting was not monitored.

The data collected were used to analyze the operating patterns for task lighting and to develop estimates of the electricity use associated with task lighting.

This report on the study of task lighting is organized as follows.

- Chapter 2 provides an overview of the methodology used for the study.
- Chapter 3 presents results of the analysis of the survey data on operating practices for task lighting.
- Chapter 4 presents results pertaining to electricity use for task lighting.
- Chapter 5 summarizes the study findings.
- Appendix A contains a discussion of the study methodology.
- Appendix B contains copies of data collection instruments.

2. OVERVIEW OF METHODOLGY

This chapter provides an overview of the methodology used for the study of task lighting. A more detailed description of the methodology is provided in Appendix A.

Because this study of task lighting was conducted in conjunction with a study of bi-level lighting[2], recruitment of sites for the monitoring of task lighting was coordinated with the recruitment of the sites used for monitoring of bi-level switching. The target number of sites for the task lighting monitoring was 30, with nine of these sites being used as well for monitoring of bi-level switching. The spaces monitored for task lighting could be in the same buildings where monitoring of bi-level switching was being conducted, but could not be spaces where bi-level switching was being monitored.

Within the buildings selected for the monitoring of task lighting, spaces considered for the monitoring were only those open office spaces that had permanently mounted task lighting at each work station that would allow plug-in loggers to be installed. This could include movable/removable task lighting that was standard issue and universally available for workstations within the building. However, task lighting by individual-provided table lamps was not considered for the monitoring.

The following types of spaces were also excluded from selection for the monitoring of task lighting:

- Areas with occupancy sensors;
- Areas with daylighting controls;
- Areas with dimming controls; and
- Areas monitored for bi-level switching.

Upon arrival at a site selected for monitoring, our field installers determined the number of spaces suitable for monitoring task lighting. A random selection of the spaces within the building that were suitable for monitoring task lighting was made while on site. Up to eight areas in each building could be selected by the field staff for monitoring. As with the monitoring of bi-level lighting, spaces that had physical or other constraints were not considered for the monitoring.

There were 30 sites where monitoring was conducted, with loggers to monitor the task lighting being installed at 160 open office spaces at these sites. However, there were problems with the logger installations at some of the first sites that

[2] Ibid.

prevented data from being collected. (The low wattages associated with task lighting complicated the adjustments needed to set the loggers to detect when task lighting was turned on.) As a result, monitored data were actually collected for 144 open office spaces.[3] The installed loggers collected data in 5-minute intervals as to whether the task lighting was on. The monitoring of each space extended over a two-week period.

To facilitate analysis of the monitored data, data regarding the characteristics of the monitored spaces were collected. Such data included size of workplace, lighting power densities (i.e., watts per square foot) for both task lighting and ambient overhead lighting, amount of daylighting, etc. (The form used for this data collection is provided in Appendix B.) In addition, occupants of the monitored spaces were also interviewed about how they used task lighting. (The form used for the interviewing is also provided in Appendix B.)

Data on the amount of time the task lighting was used as well as data on the installed wattage for the task lighting were used to develop estimates of annual electricity use for the 144 spaces. Estimates of hourly electricity use for task lighting were developed for the spaces for a typical weekday and a typical weekend day. These estimates were then extrapolated to an annual basis according to the number of weekdays and weekend days in a year.

[3] Data collected for one additional space were found to be anomalous during the verification, and this space was therefore excluded from the analysis data set.

3. SURVEY RESULTS ON USE OF TASK LIGHTING

Interviews were conducted with users of task lighting in open office spaces to determine how they used their task lighting. Two groups of users were interviewed:

- One group consisted of those occupying the spaces where monitored equipment was installed. There were 160 interviewees in this group.
- The second group consisted of occupants of similar spaces that were not being monitored. There were 218 interviewees in this group.

Somewhat different interview questionnaires were used for the two groups. Copies of these questionnaires are provided in Appendix B. Not all of the questions asked of the first group were asked of the second group. Accordingly, the tabulations presented in this chapter are sometimes for only the first group and sometimes for the two groups. For each tabulation, the number interviewed is identified to indicate whether it includes one or both groups.

Occupants of the spaces that were monitored were asked whether they used task lighting only to perform certain tasks (e.g., reading, writing, working on a computer). Of the 160 interviewees asked this question, 118 (73.8 percent) indicated that they did. The reasons given for using task lighting are shown in Table 3-1. Some reasons pertained to performing specific tasks, while other reasons were more generic. (Because multiple responses were allowed, the response percentages total more than 100 percent.)

Table 3-1. Reasons for Using Task Lighting by Occupants of Monitored Spaces (Number Interviewed = 160)

Reason	***Number Giving As Reason***	***Percent of Those Interviewed***
To read printed materials	99	61.9%
To do computer work	67	41.9%
To compensate for daylight	59	36.9%
To create a comfortable work atmosphere	56	35.0%
To save energy	8	5.0%
Other	7	4.4%

As can be seen in Table 3-1, the reasons cited most often for using task lighting were related to performing specific tasks. The reason given most often was "to read printed material", which was given by nearly 62 percent of all interviewees. About 42 percent of the interviewees cited "to do computer work" as a reason for using task lighting. Of those interviewees citing these specific tasks as reasons

for using task lighting, about 53 percent) cited both reasons, about 39 percent cited only to do reading, and about 8 percent cited only to do computer work

Table 3-1 also shows that some of the interviewees indicated that they used task lighting for more generic reasons, such as to compensate for low daylight or to create a more comfortable work atmosphere. As will be discussed below, some occupants of open office spaces receive little or no daylight. An analysis of electricity use for task lighting for groups with different amounts of daylighting suggested that interviewees with limited access to daylight used task lighting to increase the amount of lighting in their spaces beyond that provided by overhead lighting.

Table 3-2 tabulates the responses from interviewees when they were asked how frequently they used task lighting during the workday.

Table 3-2. Frequency with Which Task Lighting Is Used during Workday

Frequency in Using Task Lighting	***All Spaces***	
	Number Citing	***Percent of Those Interviewed***
Always use	160	42.3%
Use most of the time	71	18.8%
Use sometimes	97	25.7%
Never use	46	12.2%
Not answered	4	1.1%
Totals	378	100.0%

When occupants of monitored spaces were asked whether they ever leave the task lighting off in their space during the workday, 72 of the 160 interviewees (45 percent) said that they did. Reasons given for leaving task lighting off included the following:

- *Usually when I am away from my desk, or when I'm using my computer*
- *When I am working on my computer*
- *When I am not at my work station*
- *On sunny summer days and when only doing computer work*
- *Always*
- *On extremely sunny days*
- *If eyes do not feel strained; if there is no need to do heavy reading or small print*
- *Do not use it*

- *If away for an extended period*
- *If I am doing work away from my desk for an extended time*
- *Most conditions - I use it only when reading material is difficult*
- *Leave off most all of the time*
- *After finished reading printed materials*
- *When working on computer*
- *When I am not reading*
- *Most of day*
- *When it is not needed*
- *Normal overhead light condition*
- *At all times when overhead lights are on*
- *I never use my task lights*
- *After house lights have been activated*
- *Only when I remember to turn it off*
- *During lunch, when going home*
- *If the blinds are open and its fairly light outside*
- *When sunny on desk, when at lunch or away*
- *If I forget to turn it on*
- *If I remember*
- *If not working in that area*
- *Turn off at lunch and turn back on when come back*
- *If I will be away from my desk for an extended period*
- *When forget to turn it on*
- *During break and lunch times, meetings, at the end of the day*
- *When office gets too hot*
- *Turn off during lunch*
- *When I go home or on clear sky day*
- *When I don't think about it*
- *When have enough overhead fluorescent lighting during normal work day*
- *If I leave my desk*
- *Whenever I'm not reading anything*
- *When I leave for lunch*
- *At lunch and when I go home*
- *When at lunch*
- *When no one is at desk*

- *When doing computer work and when I am not here*
- *When I am at a meeting or am out to lunch*
- *If I don't need to read*
- *Only if I'm gone for long periods*

Both groups of occupants (i.e., of monitored spaces and of spaces not monitored) were asked if overhead lighting affected their use of task lighting. The numbers of interviewees who indicated that overhead lighting did affect their use of task lighting are shown in Table 3-3. Overall, about a third of those interviewed indicated that overhead lighting affected their use of task lighting. Although the interviewees were not asked directly how overhead lighting affected their use of task lighting, additional information gathered through the monitoring of task lighting allowed some analysis of how task lighting use differed between those interviewees who said overhead lighting did affect their use of task lighting and those who said it did not. This analysis is discussed below in Section 4.5.

Table 3-3. Interviewees for Which Overhead Lighting Affected Use of Task Lighting

Type of Space	***Number Affected***	***Percent of Those Interviewed***
Spaces monitored	47 of 160	29.4%
Spaces not monitored	75 of 218	34.4%
All spaces	122 of 378	32.3%

When occupants of the monitored spaces were asked if the amount of daylight affected how they used their task lighting, 38 of 160 (23.8 percent) said that the amount of daylight did affect their use of task lighting. Descriptions of how daylighting affected the use of task lighting included the following:

- *Due to walls, cubicle has insufficient daylight, making me use the task light*
- *The task lights achieve a brighter work area*
- *Have lots of light from windows and overhead; will not turn on task lights*
- *Ultra-early in the morning only a few people are in the building; is a waste if use overhead light*
- *Use task lighting in morning and when no house/are lights are on*
- *Use it [task lighting] more when its darker outside*
- *Good natural lighting encourages turning off electrical lighting (though glare is strong)*
- *On a clear day, I turn off my desk light*
- *If it seems grayer, I use task lighting*
- *Located next to window, so I don't usually use task light*

- *If there is enough daylight, I'll turn task or any light off*

Occupants of monitored spaces and of spaces not monitored were asked about the frequency with which they turn off task lighting at the end of the work day. Table 3-4 tabulates the responses from interviewees regarding the frequency with which they turn task lighting off at the end of the day.

Table 3-4. Frequency with Which Task Lighting Is Turned Off at End of Workday

Frequency in Turning Off Task Lighting	***All Spaces***	
	Number Citing	***Percent of Those Interviewed***
Always turn off	299	79.1%
Turn off most of time	25	6.6%
Turn off sometimes	22	5.8%
Never turn off	18	4.8%
Not answered	14	3.7%
Totals	378	100.0%

Occupants of monitored spaces and of spaces not monitored were asked whether they used task lighting differently between summer and winter. Table 3-5 shows the distribution of responses to this question. Overall, about 13 percent of those interviewed indicated that their use of task lighting differs between summer and winter.

Table 3-5. Interviewees for Which Use of Task Lighting Differs between Summer and Winter

Type of Space	***Number Who Said Seasonal Use Differs***	***Percent of Those Interviewed***
Spaces monitored	16 of 160	10.0%
Spaces not monitored	34 of 218	15.6%
All spaces	50 of 378	13.2%

Occupants of monitored spaces were asked whether their use of task lighting had changed any in response to the electricity crisis in California over the past year. Out of the 160 individuals interviewed, 36 (22.5 percent) indicated that their use of task lighting had changed in response to the electricity crisis. Descriptions as to how use of task lighting had changed were as follows:

- *During level 3 emergency I would turn it off.*

- *I am more conscientious [about use of task lighting].*
- *I seldom use my desk light now.*
- *I turn it off when I'm away for extended periods.*
- *I turn lights off when I leave for the day.*
- *I make sure I shut it off before I leave for the day.*
- *I use a lot less.*
- *I turn unused light off.*
- *I turn on light only when I need to use it, and make sure to turn off light at end of day.*
- *I use task light early in the mornings or weekends, rather than turning on building overhead lights.*
- *I try to use it only when necessary.*
- *I make sure all additional lighting is turned off. Use lower wattage bulb.*
- *I am more aware of turning off the light.*
- *I make sure it's off at night.*
- *I turn them off more when I am away from my desk.*
- *I only use the light on one side of the cubicle, not both, as before*
- *I use it less.*
- *I turn on 2 task lights instead of 4.*
- *We were instructed not to use our task lights during the peak energy crisis.*
- *Yes, I make sure when I go to lunch or leave for the day that I turn them off. Before, I would only turn off when I left for the day.*
- *I am more conscious of turning my lights off when I'm not using them.*
- *I leave one off and only use the remaining two.*
- *I don't use it if not necessary.*
- *I'm more careful with turning it off at the end of the day.*
- *I shut it off at night.*

4. ANALYSIS OF ELECTRICITY USE FOR TASK LIGHTING

This chapter presents the results from analyzing the monitored data on the use of task lighting.

4.1 CHARACTERISTICS OF MONITORED SPACES

The analysis of the use of task lighting is based on monitored data for 144 open office spaces in 30 office buildings. All of the spaces where task lighting was monitored were cubicles within the open office areas. The characteristics of the spaces where task lighting was monitored are summarized in Table 4-1. The cited square footage is for the cubicle space, which was determined when the monitoring equipment was installed. The watts of installed task lighting were determined from the wattages for the types of lamps and ballasts observed in the spaces. The average lighting power density for task lighting was estimated to be 0.52 Watts per square foot.

Table 4-1. Characteristics of Spaces Where Task Lighting Was Monitored (n=144)

Characteristics of Space	***Minimum***	***Median***	***Mean***	***Standard Deviation***	***Maximum***
Square footage	25 sf	64 sf	66.3 sf	23.6 sf	250 sf
Watts of task lighting per space	17 Watts	28 Watts	31.2 Watts	11.3 Watts	75 Watts
Watts per square foot	0.10 W/sf	0.44 W/sf	0.52 W/sf	0.28 W/sf	1.53 W/sf
Percent of area daylit	0 %	21.50 %	29.2 %	31.5 %	100 %

The lighting power densities for overhead lighting in the open office spaces of the 30 buildings where task lighting was monitored were also determined using data collected on the number of lighting fixtures in open office spaces and their wattages. Summary statistics for the lighting power densities for overhead lighting for the 30 buildings are reported in Table 4-2. The average lighting power density for overhead lighting in open office areas was estimated to be 1.27 Watts per square foot. By comparison, estimates of installed overhead lighting were determined in the companion study of bi-level switching. From that study, the average connected overhead lighting load for open office areas was estimated to be 1.105 Watts per square foot.

Table 4-2. Summary Statistics for Lighting Power Densities for Overhead Lighting in Open Office Spaces in Monitored Buildings (n=30)

Overhead Lighting	***Minimum***	***Median***	***Mean***	***Standard Deviation***	***Maximum***
Watts per square foot	0.61 W/sf	1.17 W/sf	1.27 W/sf	0.45 W/sf	2.81 W/sf

The data on task lighting for the spaces that were monitored in each building were averaged to get building-level estimates of the lighting power densities for task lighting that could be compared to the building-level estimates of lighting power densities for overhead lighting in open office spaces. The task lighting and overhead lighting power densities for the monitored buildings are compared in Figure 4-1. There is little correlation between the two types of lighting power densities, with a calculated correlation coefficient of 0.04.

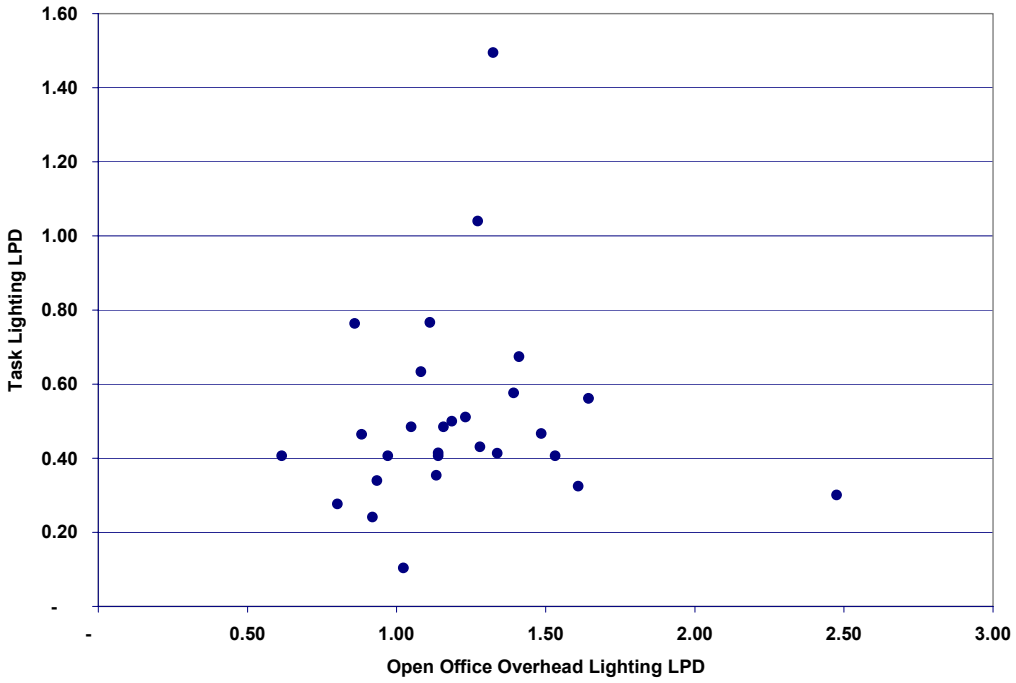

Figure 4-1. Comparison of Task Lighting LPDs and Open Office Overhead Lighting LPDs for Monitored Buildings

The percent of area daylit is an estimate of the percentage of the space in a monitored cubicle that was daylit; these percentages were estimated by the field personnel installing the monitoring equipment. Figure 4-1 shows the relationship between installed watts of task lighting per square foot for the monitored spaces and the percent of the space that is daylit. The correlation between installed watts and percent of space daylit is about 0.19, indicating that installed task lighitng watts is generally independent of the percent of the space that is daylit.

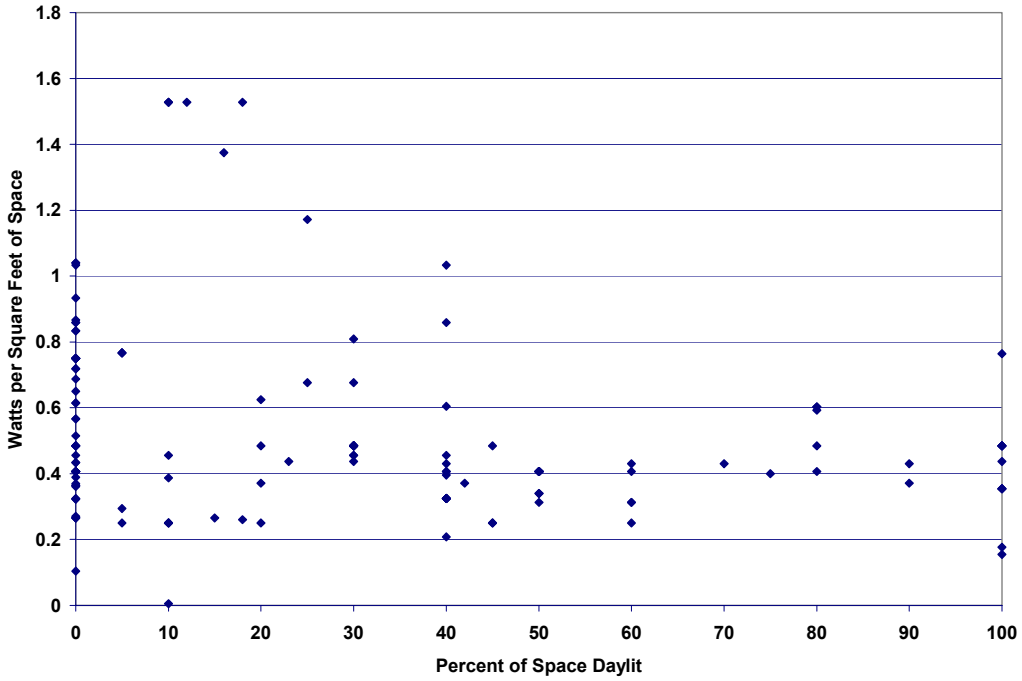

Figure 4-2. Watts of Task Lighting per Square Foot versus Percent of Area Daylit for Monitored Spaces

4.2 PERCENTAGE OF TIME TASK LIGHTING IS USED

Figure 4-3 depicts how the percentage of time that task lighting is on varies over a weekday and a weekend day.[4]

- The profile for a weekday shows that task lighting is used mostly during usual office hours, from roughly 6 AM to 7 PM. During other hours, task lighting is on about 10 percent of the time.
- The weekend profile for task lighting is flat, with task lighting being on just under 10 percent of the time.

For purposes of comparison, Figure 4-4 (which is taken from the companion report on bi-level lighting) depicts how the percentage of time that bi-level switching in open office areas is in an "on" state varies over a weekday. During working hours, one or both of the bi-level switches are on nearly 90 percent of the time. However, Figure 4-4 also shows that some overhead lighting is "on" between 15 and 20 percent of the time during usual non-working hours.

[4] The hourly percentages are calculated using the monitored data for the number of 5-minute intervals during an hour in which task lighting is on. That is, the percentage of time task lighting is on is calculated by dividing the number of intervals for which the lighting is on by the total number of intervals in the monitoring period. The calculation is made across all spaces monitored.

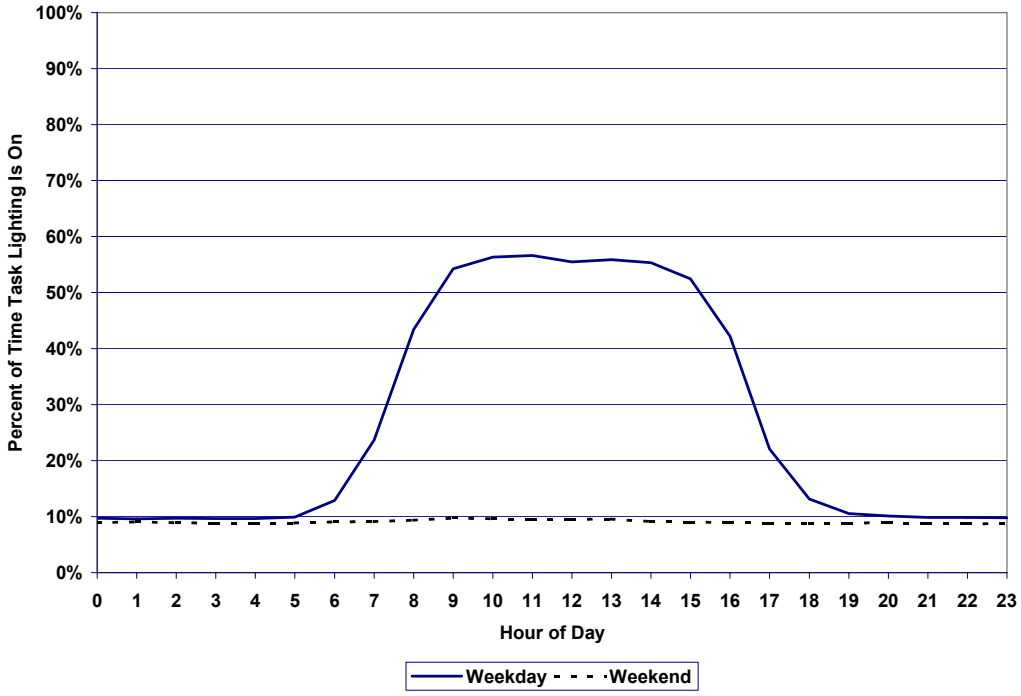

Figure 4-3. Percent of Time Task Lighting Is On throughout a Weekday and a Weekend Day

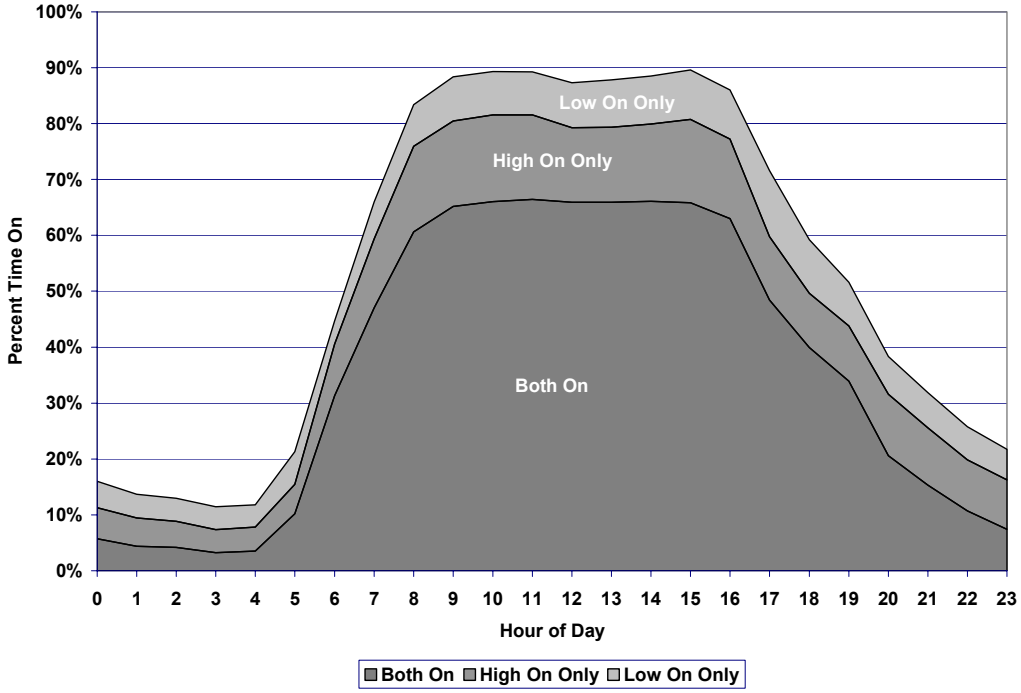

Figure 4-4. Percent of Time Bi-Level Switches in Open Office Areas Are in Different "On" States throughout a Weekday

4.3 ANNUAL ELECTRICITY USE FOR TASK LIGHTING

Data on the installed wattage for task lighting and on the hours of use collected through the monitoring were used to develop estimates of annual electricity use for the 144 spaces with task lighting that were monitored. Figure 4-5 plots the estimates of annual electricity use against the square footages of the spaces monitored.

Except for a few outlying points, Figure 4-5 indicates that the annual energy use for task lighting is independent of the area of the workspace. This is not unexpected, as the task area for which task lighting is used is generally more correlated to the task surface than to the overall area of the workspace.

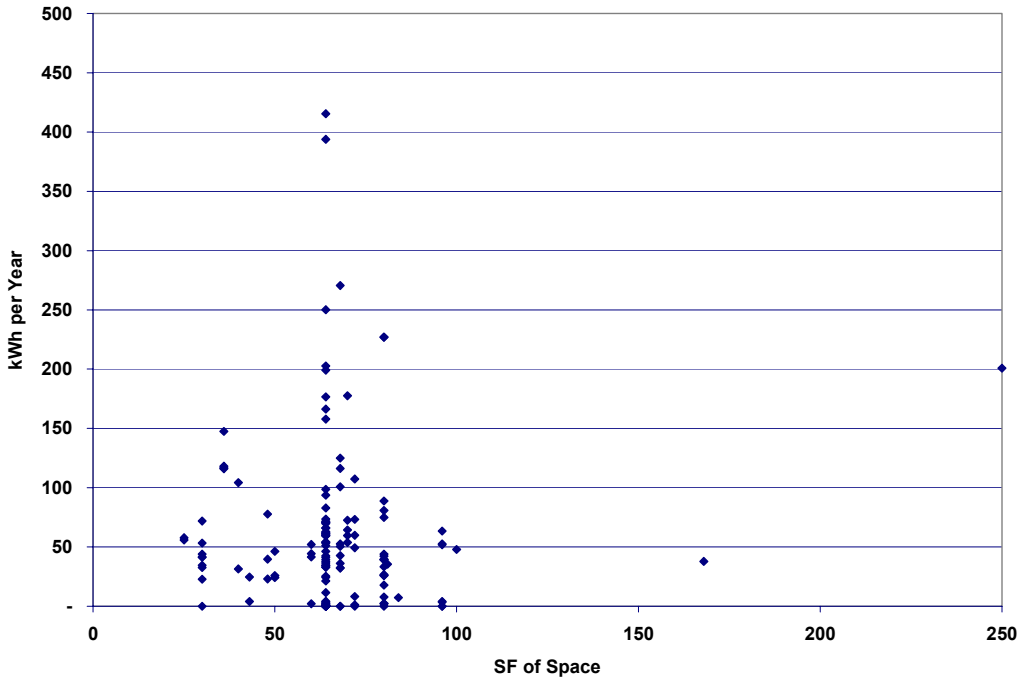

Figure 4-5. Estimates of Annual Electricity Use for Task Lighting for Monitored Spaces versus Square Footage of Spaces

Out of the 144 spaces, there were 13 (9 percent) for which the task lighting was not used during the period of the monitoring. Estimates of average annual electricity use for task lighting were therefore calculated for two sets of spaces:

- For all 144 spaces; and
- For 132 spaces for which the monitoring showed that task lighting was being used.

The mean estimates of annual electricity use for task lighting calculated for the two sets of spaces are shown in Table 4-3.

Table 4-3. Estimates of Average Annual Task Lighting Electricity Use for Monitored Spaces

	Minimum kWh per Year	***Median kWh per Year***	***Mean kWh per Year***	***Standard Deviation***	***Maximum kWh per Year***
For all 144 spaces monitored	-	42.3	58.9	68.4	415.6
For 131 spaces where task lighting was used	0.1	46.4	64.7	69.0	415.6

4.4 EFFECTS OF DAYLIGHTING ON USE OF TASK LIGHTING

As noted in Section 3.1, about 24 percent of the occupants of open office areas reported that the amount of daylight did affect how they used task lighting. To further examine the effects of daylight on the use of task lighting in open office areas, the spaces monitored were divided into five groups, based on how much of the space was daylit.[5] The five groups were defined as follows:

- Group 1 included spaces with no daylit area.
- Group 2 included spaces where from 1 to 33 percent of the space was daylit.
- Group 3 included spaces where from 34 to 66 percent of the space was daylit.
- Group 4 included spaces where from 67 to 99 percent of the space was daylit.
- Group 5 included spaces where all of the space was daylit.

Table 4-4 shows the estimates of average annual electricity use for task lighting for monitored spaces in the five groups. Comparison of these estimates suggests that the amount of daylight does influence the use of task lighting. There is a monotonic ranking, with areas with more and more daylight using less electricity for task lighting. As noted above, this suggests that occupants of spaces where daylight is limited use task lighting to compensate for that limitation.

[5] The percent of area daylit is an estimate of the percentage of the space in a monitored cubicle that was daylit; these percentages were estimated by the field personnel installing the monitoring equipment.

Table 4-4. Estimates of Average Annual Task Lighting Electricity Use for Monitored Spaces with Different Amounts of Daylighting

Daylit Group	Number of Spaces	Mean kWh per Year	Standard Deviation
1	51	69.2	85.3
2	37	64.9	60.3
3	36	51.8	62.8
4	9	40.7	25.5
5	11	28.5	29.0
All spaces	144	58.9	68.4

To adjust for the square footage of the spaces, estimates of average annual electricity use per square foot were also calculated. These estimates are shown in Table 4-5. The monotonic ranking seen in Table 4-4 is also seen in Table 4-5; spaces with more daylight use less electricity for task lighting.

Table 4-5. Estimates of Average Annual Task Lighting Electricity Use per Square Foot for Monitored Spaces with Different Amounts of Daylighting

Daylit Group	Number of Spaces	Mean kWh per SF per Year	Standard Deviation
1	51	1.12	1.32
2	37	1.21	1.20
3	36	0.79	0.91
4	9	0.61	0.39
5	11	0.48	0.55
All spaces	144	0.98	1.12

4.5 EFFECTS OF OVERHEAD LIGHTING ON USE OF TASK LIGHTING

Occupants of monitored spaces were asked whether overhead lighting affected their use of task lighting. As reported in Table 3-3, about 29 percent of the occupants said that overhead lighting did affect their use of task lighting. Although interviewees were not asked specifically how overhead lighting affected their use of task lighting, an analysis was made of how data on lighting power densities and on electricity usage for task lighting differed between those interviewees indicating that overhead lighting affected their use of task lighting and those indicating no effects.

A first comparison was made between the lighting power densities for overhead lighting and for task lighting for the two groups. These comparisons are reported in Table 4-6. The t-tests for differences in the means showed that the differences

between the mean values for the lighting power densities for the two groups were not statistically different from zero for either overhead lighting or task lighting.

Table 4-6. Comparison of Lighting Power Densities for Overhead Lighting and for Task Lighting for Interviewees Who Reported Their Use of Task Lighting Is Affected or Is Not Affected by Overhead Lighting

	Task Lighting Not Affected	*Task Lighting Affected*
Overhead Lighting LPD Comparison		
Mean Overhead Lighting LPD	1.25	1.21
Standard deviation of LPD	0.39	0.36
Number of Observations	113	47
Degrees of Freedom = 158 T stat = 0.71 Critical t = 1.98		
Task Lighting LPD Comparison		
Mean Task Lighting LPD	0.53	0.53
Standard deviation of LPD	0.25	0.30
Number of Observations	112	47
Degrees of Freedom = 157 T stat = 0.07 Critical t = 1.98		

A second line of analysis used the data on electricity use for task lighting. A first aspect of this analysis was to compare estimated electricity use for task lighting (measured as kWh per square foot) against the lighting power density for open office overhead lighting. This comparison, which was made on a building-level basis, is shown in Figure 4-6. There is no correlation between the intensity of task lighting use and overhead lighting power density for this set of monitored buildings (i.e., correlation coefficient = - 0.008).

A second aspect of the analysis of the effects of overhead lighting on task lighting electricity use was to compare space-level estimates of average annual task lighting electricity use between those who said overhead lighting did affect their use of task lighting and those who said it did not. The estimates of average annual electricity use for task lighting for the two groups are shown in Table 4-7. As can be seen, the mean kWh used per year for task lighting is almost the same for the two groups.

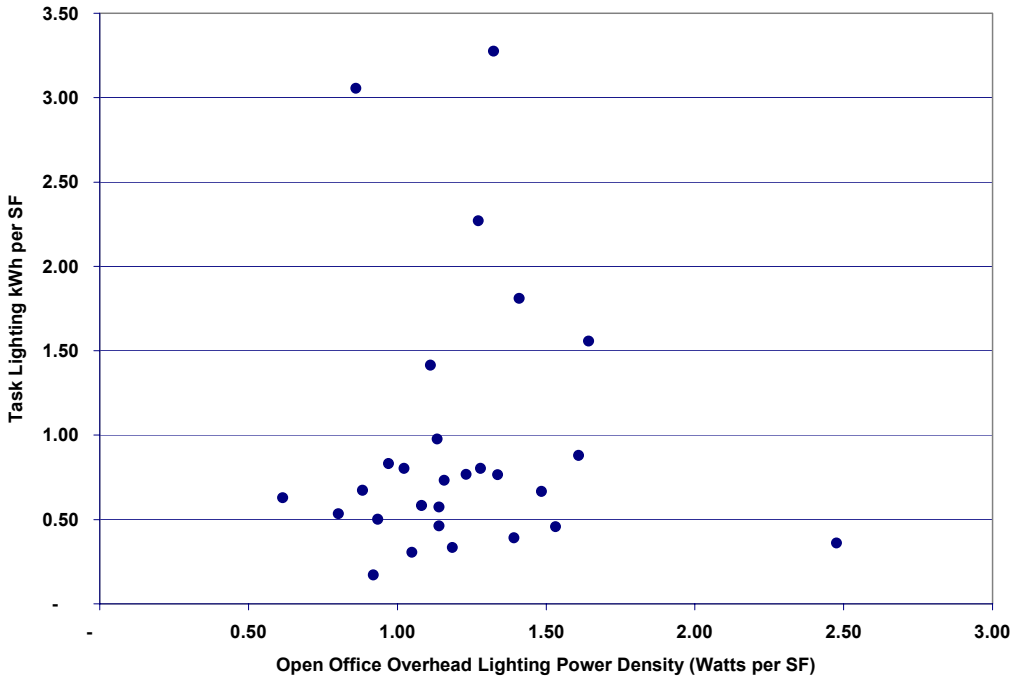

Figure 4-6. Comparison of Task Lighting Electricity Use per Square Foot against Open Office Overhead Lighting Power Density

Table 4-7. Estimates of Average Annual Task Lighting Electricity Use per Square Foot for Monitored Spaces Classified by Whether Overhead Lighting Affects Use of Task Lighting

Does Overhead Lighting Affect Use of Task Lighting?	***Number of Spaces***	***Mean kWh per Year***	***Standard Deviation***
Yes	36	58.6	71.5
No	97	59.0	66.6

5. FINDINGS AND CONCLUSIONS

This report has presented the results of a study of task lighting in open office spaces. Interview data, lighting and space characteristics data, and monitored data were used to examine operating practices for task lighting. Major findings from the analysis of the data collected are summarized here.

The average installed Watts per square foot for task lighting was 0.52 Watts per square foot in the spaces where task lighting was monitored. For the 30 buildings where spaces with task lighting were monitored, the average lighting power density for overhead lighting in open office areas was estimated to be 1.27 Watts per square foot. Thus, the installed Watts per square foot for task lighting in open office spaces is about half the Watts per square foot for overhead lighting.

A survey of 378 occupants of spaces where task lighting has been installed showed that over 60 percent of the occupants used their task lighting either most of the time (about 19 percent) or all of the time (42 percent). About a fourth of the interviewees (25.7 percent) indicated that they use task lighting sometimes. About 12 percent indicated that they never used the task lighting installed in their workspaces.

About a third of those interviewed indicated that overhead lighting affected their use of task lighting. The interviewees were not asked specifically in what way the overhead lighting affected their use of task lighting. However, various analyses of lighting power densities and data on electricity use for task lighting showed little difference between those who said overhead lighting did affect their use of task lighting and those who said it did not. For example, the mean kWh used per year for task lighting is almost the same for the two groups.

When occupants of spaces where the use of task lighting was monitored were asked if the amount of daylight affected how they used their task lighting, 38 of 160 (23.8 percent) said that the amount of daylight did affect their use of task lighting. Analysis of the estimates of task lighting electricity use developed from the monitoried data confirmed this in that it indicated that the use of electricity for task lighting was lower in spaces with more daylight.

Out of the 144 spaces for monitored data on the use of task lighting were collected, there were 13 (9 percent) for which the task lighting was not used during the period of the monitoring. Estimates of average annual electricity use for task lighting were therefore calculated for two sets of spaces:

- For all 144 spaces; and

- For 132 spaces for which the monitoring showed that task lighting was being used.

The mean estimates of annual electricity use for task lighting calculated for the two sets of spaces were 58.5 kWh per year when all spaces are included and 64.2 kWh per year when only spaces where task lighting was actually used are included.

Given that the amount of electricity used for task lighting in a given space during a year is relatively small, the total savings potential from improved design and/or control of task lighting systems will depend on the portion of office space that has permanently installed task lighting. However, the sample of 30 buildings that was used in this study to develop data on the operation of task lighting is too small to develop reliable estimates of the portion of office space that has permanently installed task lighting. Estimates of the portion of office space that has task lighting may be better derived from the data being collected in the Commercial Energy Use Survey (CEUS) that the California Energy Commission has fielded. As part of their collection of data for indoor lighting, CEUS surveyors are to determine the use type for the lighting, where task lighting is one of the uses. These data from CEUS, which is expected to be completed during 2003, could support estimation of the portion of office space that has task lighting.

APPENDIX A: METHODOLOGY

This appendix describes the methodology used to conduct the study of task lighting.

A.1 SAMPLE DESIGN

The sample of sites for which task lighting was monitored was selected in conjunction with the sample selection for a concurrent study of bi-level lighting.

Initial specifications for the sampling design included the following:

- The total sample for the data collection was to be 75 occupied nonresidential buildings that have been built since 1992.
- The types of buildings at which data were to be collected include office buildings, schools, public assembly, and retail.
- Within a building, different types of spaces were to be monitored, including private offices, open offices, conference rooms, classrooms, retail sales areas, and storage/stock rooms. The actual number of spaces surveyed might vary across buildings.
- On-site data collection was to be concentrated in two major regions: northern California (e.g., San Francisco Bay area, Sacramento) and southern California (e.g., Los Angeles, San Diego).

Subsequent discussion during the kick-off meeting modified or added to these specifications.

- Because monitoring of task lighting was included in the project, the sampling plan was expanded to include the monitoring of task lighting at 30 sites. However, these sites could overlap with the sites monitored for bi-level switching.
- The types of buildings for which data were to be collected was narrowed to include office buildings, retail stores, and schools.

A.1.1. Sampling Frame

Developing the sampling plan required a sampling frame that contained information on the nonresidential facilities that were candidates for the monitoring. The amount of information that was available in the database that was used to develop the frame determined the degree to which stratification and other sampling features could be incorporated into the sampling design.

Several existing databases that contain information on new and/or remodeled nonresidential buildings were reviewed as to their potential as sampling frames for this study.

- The California Statewide NRNC database is a collection of buildings statistically selected to represent the majority of statewide NRNC activity. Most of the data in this database come from on-site surveys conducted by RLW Analytics during impact evaluation studies of the SCE and PG&E 1994 and 1996 NRNC energy efficiency programs. These data were supplemented with thirty audits from the impact evaluation of the 1995 SDG&E NRNC program and some additional on-site surveys. Participants in utility energy-efficiency programs are included, but are weighted according to their general representation in the population. The population was defined using a listing of new construction projects obtained from F. W. Dodge. The data include renovations and expansions as well as entirely new buildings. There are 990 sites in the complete database.
- As part of the Nonresidential Remodeling and Renovation study conducted for the CEC, ADM had developed a database of information for a sample of 300 nonresidential buildings that underwent remodeling or renovation during 2000.

Together, these two databases provided a list of new or remodeled nonresidential buildings that could be used to prepare the sampling frame from which to develop the sampling design for this study. There were several advantages to using these databases as the sampling frames.

- First, the databases represent samples already drawn from the overall population of new and recently remodeled/renovated nonresidential buildings. Accordingly, there were pre-existing weights whereby information developed for buildings sampled for this study could be expanded back to represent the population of new and/or remodeled nonresidential buildings.
- Second, as noted above, the databases contain information identifying the space types within each building.

Upon inspection of the two data bases, it was determined that the level of detail available in the NRNC database considerably exceeded that in the remodeling/renovation database. Merging the two databases to create one sampling frame would create considerable disparity between sites in the frame. Accordingly, the NRNC database was chosen as the main vehicle for preparing the sampling frame. It had more sites for the building types of interest and more detailed information regarding those sites.

A.1.2 Sample Size and Allocation

For the study of bi-level switching, the total sample size was determined initially to be 75 sites to allow for examination of manual switching. With the added study of task lighting, monitoring of task lighting was expected to be conducted at 30 sites, but with 20 of these sites being sites where bi-level switching was also

being studied. Based on this, an additional 10 sites needed to be added to the overall study to be able to meet the desired ends. Thus, for sampling design purposes a total sample of 85 sites was used.

Given the total sample size of 85, the next question to be resolved was how to allocate these sample points across the three building types (i.e., offices, retail stores, schools) that were to be studied. Based on a review of different factors affecting sample allocations, it was determined to allocate the total sample of 85 sites to building types as follows:

- Office buildings 40 sites (30 for bi-level and 10 for task)
- Retail stores 20 sites
- Schools 25 sites

Only office buildings were used for the study of task lighting.

A.2 PROTOCOL FOR RECRUITING SITES

A protocol for recruiting buildings to participate in the study. A copy of this recruitment protocol is provided in Appendix B.

The recruitment protocol had several components. To begin with, the sample sites were screened to identify those with occupancy sensors and possible task lighting. Because the sample sites had been selected from the NRNC database, fairly detailed information was available on the types of lighting in different areas of the selected sites. These data were reviewed to determine the prevalence and location of occupancy sensors, dimming controls, and other lighting controls at the sample sites.

The NRNC database also includes the name of a contact person for each site. An introductory letter was sent to the contact person for each facility selected for the sample. This letter explained the purpose of the study and indicated that they would be contacted by telephone to arrange their participation in the study.

After the letters had been sent, telephone calls were begun to the contact persons to recruit their buildings to participate in the survey. Recruitment and scheduling of visits was handled by an ADM staff member who has considerable experience in this area. These customer contacts were handled according to a screening and recruitment script that we prepare. An example of this recruiting script is provided in Appendix B.

- The first part of the script was used to confirm that the buildings contacted are suitable for the study. That is, because of the detailed information on lighting that is contained in the NRNC database for each building, there was good information as to whether the building has had various types of lighting

controls installed. The screening was used mainly to confirm the information on the type and location of the building in the NRNC database and to determine whether daylighting controls, occupancy sensors, or task lighting beyond that specified in the NRNC database had been added to the building.

- For buildings that passed the screening questions, the recruiter proceeded in recruiting the building for the study. He/she explained the purposes of the study, indicated the types of data that would be collected, and described the amount of time for the on-site visits during which the monitoring equipment would be installed and then removed. This script also provided the scheduler with appropriate responses to questions that customers might ask.

If a building owner/operator agreed to participate in the study, our scheduler arranged a mutually acceptable time for installing the monitoring equipment, based on the convenience of the owner/operator and on the travel schedule of the field staff. As the dates for installations were scheduled, they were entered into a timetable. Particulars were also entered into a tracking database, including the names of the buildings to be surveyed and their locations, the contact persons at the buildings and their telephone numbers, and the dates and times planned for the visits. This information was used to administer and manage the data collection effort. Complete and accurate records of all attempts to contact a building's owner/operator and of the final disposition of the attempts to schedule a visit were kept in a status file on this tracking and reporting system.

A.3 APPROACH TO MONITORING TASK LIGHTING

Within the buildings selected for the monitoring of task lighting, spaces considered for the monitoring were only those open office spaces that had permanently mounted task lighting at each work station that would allow plug-in loggers to be installed. This could include movable/removable task lighting that was standard issue and universally available for workstations within the building. However, task lighting provided by individual table lamps was not considered for the monitoring.

The following types of spaces were also excluded from selection for the monitoring of task lighting:

- Areas with occupancy sensors;
- Areas with daylighting controls;
- Areas with dimming controls; and
- Areas monitored for bi-level switching.

Upon arrival at a site selected for monitoring, our field installers determined the number of spaces suitable for monitoring task lighting. A random selection of the

spaces within the building that were suitable for monitoring task lighting was made while on site. Up to eight areas in each building could be selected by the field staff for monitoring. As with the monitoring of bi-level lighting, spaces that had physical or other constraints were not considered for the monitoring.

Two types of loggers were used for the monitoring of task lighting: one type to monitor lighting on/off status and the other type to monitor lighting current load. Both logger types were installed at the task lighting electrical plug.

- Onset Computer Hobo Motor On/Off loggers were be fitted into an electrical receptacle outlet box with a plug pigtail. The Onset computer Hobo External loggers were connected to a 20 Amp CT (2.5Vdc) that were placed on one leg of a split extension cord.
- The Hobo External loggers and CT were placed inside a box with the short pigtails of the extension cord protruding.

All equipment was tested prior to initial deployment, and batteries were replaced as necessary.

A.4 QUESTIONNAIRES ON OPERATION OF TASK LIGHTING

On-site survey instruments were developed that could be used by the field staff in collecting data on the characteristics and operation of task lighting. Copies of the data collection instruments are provided in Appendix B. The on-site survey instrument for monitoring of task lighting had two major parts.

A first part of the survey instrument provided a form for entering information about the characteristics of the task lighting equipment found in the spaces to be monitored. The information collected with this form included a count of the task lighting fixtures and a characterization of the type of fixture, type of lamp, and type of ballast.

The field personnel also used the form to record the estimated area of the space with task lighting and the percent of this area that was daylit. As per Title-24, an area that was 15 feet back from a window and two feet on either side of the window was considered to be daylit. For open office areas, the selected area referred to the cubicle where the task lighting was monitored.

Field personnel also estimated the percent of the building that had lighting of the same type. The use of the space and its normal hours of operation were characterized and recorded on the survey form.

A second part of the survey instrument pertained to the interview of occupants to collect information regarding how they operate their task lighting.

A.5 PREPARATION OF STUDY DATABASE

All of the data collected or developed during the study were entered into computerized databases. These data included the building and lighting equipment characteristics data collected during the site visits and the results of the building-specific data logging.

To ensure that the data are accessible and transferable, documentation on the data base was prepared, including its contents and formats. This documentation includes the following:

- Sample disposition report;
- Copies of all sample contact logs, indicating the results of each attempt to collect data;
- Original hard copies of survey instruments;
- *Access* database;
- Codebook for database; and
- Data dictionary listing all variables contained in the database. The dictionary will provide a clear description of every database and variable and show a clear correspondence between the variable and any instruments.

A.6 DATA ANALYSIS PROCEDURES

Before beginning the analysis of the monitored data, a number of checks of the data were made. This verification effort included automated as well as manual checks. These checks were applied to ensure good data quality and to minimize the errors attributable to mis-coding, mis-judgments, or incorrect responses.

Additional checks were made of the logger data.

- Logger data were checked for evidence of "flickering". If the lamps in a fixture on a circuit being monitored flickered during the monitoring period, there might be a large number of cycles with very short duration in the logger data. Any transition less than 5 minutes was taken as an indicator that the lamps were flickering and that such episodes could be ignored in the analysis.
- There might also be episodes in the logger data that reflect "box time", which refers to the time a logger spends in a box as opposed to monitoring a fixture. There are two kinds of "box time": before a logger starts logging and after the logger is removed. The first type is the period between logger initialization and logger installation. Once a logger is initialized, it records "Light Off" until the sensor is properly installed. The second type is the period between logger removal and data downloading. The logger records "Off" when the logger is waiting for data to be downloaded.

APPENDIX B: DATA COLLECTION FORMS

Forms for recruitment and to document lighting characteristics and logger installation are provided in this appendix. The form used in interviewing occupants of open office spaces where task lighting is used is also provided.

RECRUITMENT SCRIPT

Hello, I am [_____]. I'm calling from ADM Associates, on behalf of [SCE / PG&E / SDG&E].

We recently sent you a letter describing a study that [SCE / PG&E / SDG&E] are conducting to determine how customers are using the manual lighting switches in buildings constructed during the last 10 years. The purpose of the study is to evaluate the actual operation of the type of light switches that have been required by building standards since 1990. This evaluation will provide customers like you and [SCE / PG&E / SDG&E] with the energy savings associated with these new switches. This study will identify ways to reduce your energy consumption.

First, can you confirm that your electricity is supplied by {SCE/PG&E/SDG&E]?

No Who supplies your electricity? _____
Yes

Our records showed that your building was built within the last 10 years and is therefore a good candidate for participating in the study. However, we do need to check whether the lighting in your building is of the type that we are studying. In particular:

Does your building have automatic occupancy sensors to control lighting?

No
Yes What percent of the building's lighting is controlled by automatic occupancy sensors? _____%

Does your building have non-ceiling lighting that is provided as a standard part of your work area to provide task lighting (such as workstation lighting installed as part of cubicle furniture/partitions, but not an individual's self-supplied desk lamp)?

No
Yes Where is this task lighting installed?
Private offices
Open offices

[If percent of lighting controlled by occupancy sensors is less than 25 percent and task lighting has been installed, continue recruitment. Otherwise, thank customer and end call.]

Continue recruitment:
In order to conduct this study, we need to install lighting monitors in a few selected areas in your building. This installation will take less than an hour. We will remove the equipment in two weeks.

[*If customer agrees to participate*] [_____] will be the person installing the equipment. He will have a badge identifying himself as an ADM employee.

[*If customer does not agrees to participate –* ***thank the customer and end the call.***]

If you have questions about this study, you may call the program manager.

(*at SCE*) His name is Richard Pulliam, and his phone number is (626) 302-8289.
(*at PG&E*) His name is Patrick Eilert, and his phone number is (530) 757-5261.

If you need to re-schedule the visit, please call ADM at (800) 556-2123.

Thank you for your cooperation.

Commercial Lighting Control Effectiveness Monitoring Form

SCE/PG&E/SDG&E /ADM - Project# 0119

Date Installed _____ Time _____

Date Removed _____ Time _____

TASK LIGHTING – Open Offices in Office Buildings

Business Name: _____ Contact Person: _____ Site ID: _____

Address: _____ City: _____ , CA ZIP: _____

Total Bldg Sq.Ft _____

PLUG-IN LOGGERS:

Item	Loggers SN	Logger Type	Location of Logger	Lamps on Switch	Initial Condition
1					
2					

FIXTURES:

Item	Fixture Count	Lamp Type, Ballast Type	Fixture Type
1			
2			

SPACE DESCRIPTION:

% Area Daylit	Area Sq.ft.	% of Bldg with this Lighting Type	% of Bldg with this Space Type

Space Use: _____

Estimated number of task lighting like this in building _____

Normal hours of operation (circle): M T W T F S S _____ to _____ and/or S S _____ to _____

Notes: _____ _____ _____ _____

_____ _____ _____ _____ _____

_____ _____ _____ _____ _____

INTERVIEW QUESTIONS: TASK LIGHTING

Site ID _____ Date _____

Task Monitoring Location _____ Logger SN _____

1. During the normal workday do you use your task lighting only to perform certain tasks such as reading, writing or working on a computer?
   ❑ No ❑ Yes
   If Yes, is it to:
   ❑ (A) To do computer work
   ❑ (B) To compensate for lack of daylight
   ❑ (C) To read printed materials
   ❑ (D) To create a comfortable work atmosphere
   ❑ (E) To save energy
   ❑ (F) Other (describe) _____

2. How frequently do you use your task lighting during the workday?
   ❑ Never ❑ Sometimes ❑ Most of the time ❑ Always

3. Do you ever leave the task lighting off in this space during the workday?
   ❑ No ❑ Yes Under what conditions do you leave the task lighting off?

   _____

4. Does the overhead lighting affect the use of your task lighting?
   ❑ No ❑ Yes

5. Does the amount of daylight affect how you use your task lighting?
   ❑ No ❑ Yes How does the amount of daylight affect how you set the light switches?

   _____

6. How frequently do you turn off your task lighting at the end of the work day?
   ❑ Never ❑ Sometimes ❑ Most of the time ❑ Always

7. Do you use your task lighting differently between summer and winter?
   ❑ No ❑ Yes How does your use of task lighting differ between summer and winter?

   _____

8. Has your use of task lighting changed any in response to the electricity crisis of the past year?
   ❑ No ❑ Yes How has your use of task lighting changed?

   _____

Other Comments: _____

_____