# LIGHTING RESEARCH PROGRAM

## Project 5.1 Bi-level Stairwell Fixture Performance
## FINAL REPORT

*Prepared For:*
**California Energy Commission**
Public Interest Energy Research Program

CONSULTANT REPORT

Arnold Schwarzenegger, *Governor*

October 2005
CEC-500-2005-141-A16

# CALIFORNIA ENERGY COMMISSION

***Prepared By:***
*International Facility Management Association*
Shari Epstein
*Lawrence Berkeley National Laboratory*
Francis Rubinstein

***Managed By:***
*Architectural Energy Corporation*
Judie Porter
***Program Director***
Boulder, CO
CEC Contract # 500-01-041

***Prepared For:***
Michael Seaman
***Contract Manager***

Ann Peterson
***PIER Buildings Program Manager***

Nancy Jenkins
***Office Manager***
**ENERGY EFFICIENCY RESEARCH OFFICE**

Martha Krebs, Ph.D.
***Deputy Director***
**ENERGY RESEARCH AND DEVELOPMENT DIVISION**

B. B. Blevins
***Executive Director***

# Table of Contents



Contact Information:

Project Managers:
Shari F. Epstein
International Facility Management Association
1 E. Greenway Plaza, Suite 1100
Houston, Texas 77046
713-623-4362
shari.epstein@ifma.org

Francis Rubinstein
Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 90-3111
Berkeley, California 94720
510-486-4096
FMRubinstein@lbl.gov

Program Director:
Judie Porter
Architectural Energy Corporation
2540 Frontier Avenue
Boulder, CO 80301
303-444-4149
jporter@archenergy.com

Cover photo courtesy of Lighting Research Center and NYSERDA.

# ACKNOWLEDGEMENTS

The products and outcomes presented in this report are a result of funding provided by the California Energy Commission's Public Interest Energy Research (PIER) program on behalf of the citizens of California. Architectural Energy Corporation would like to thank the International Facility Management Association (IFMA) and the Lawrence Berkeley National Laboratory (LBNL) for their work on this project and the four organizations, Chiron, SBC, UC Berkeley, and Alameda County, which provided building sites for the demonstrations.

Architectural Energy Corporation would also like to acknowledge the support and contributions of the individuals below:

Project Directors: Shari Epstein, IFMA, and Francis Rubinstein, LBNL

Technical Manager: Judith Jennings, LBNL

Technical and Market Assistance: G. Kimball Hart, Hart McMurphy & Parks; Jeff Goldstein, LaMar Lighting; Bret Logue, BKi, Jon Martens, JEMCOR

Field Support: Nate Tyler; Net Electric; Lanny Ross, Newport Design; Alex Norton, SDV-ACCI

Demonstration Sites: David Grasseschi, Chiron; Don Lucas, Alameda County GSA; Jeffrey Kessel, P.E., UC Berkeley, Linda Pettie, SBC

Review and Advisory Assistance: Dave Weigand, New Buildings Institute, and the LRP Element 5 TAG members.

Program Advisory Committee: Ron Lewis, Department of Energy; Jerry Mills, Easy Lite; Gregg Ander, SCE; Bill Daiber, WFD Associates; James Bryan, Arden Realty; Neall Digert, Solatube; Jim Benya, Benya Lighting; Dennis Tiede, Sempra Utilities; Noah Horowitz, NRDC; Amy Cortese, Northwest Energy Efficiency Alliance; Pekka Hakkarainen, Lutron; Peter Turnbull, PG&E; Michael Waxer, Carmel Development Co; Kit Tuveson, Tuveson & Associates; David Kaneda, Integrated Design Associates, Inc; Connie Buchan, SMUD.

Program and Contract Management: Nancy Jenkins, California Energy Commission; Karl Johnson, CIEE; Eric Stubee, SAIC; Judie Porter, Architectural Energy Corporation; Don Aumann, CLTC.

# PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission, annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

What follows is The Bi-level Stairwell Fixture Performance Final Report for Project 5.1 under the Lighting Research Program, Contract #500-01-041. This project contributes to the PIER Lighting Research Program.

The key deliverables for each project, in the form of guidelines and technical reports, are attachments to this report and are listed and described at the start of the attachment section. Due to market dynamics and the normal passage of time between the completion of research and the publication of research results, products anticipated for market delivery in this report may not necessarily reflect the actual array of products as delivered, or planned for delivery, by manufacturers. Therefore, the reader is advised to contact the lighting product manufacturers directly to ascertain the current status of products.

For more information on the PIER Program, please visit the Commission's web site at www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at (916) 654-5200.

# ABSTRACT

The PIER LRP Bi-level Stairwell Fixture Performance Final Report is the result of a two-year research effort under the California Energy Commission PIER Lighting Research Program. The goals of this project were to co-fund the development of bi-level stairwell fixtures with NYSERDA and to determine the energy savings, demand reduction, and safety code acceptability of occupancy-based standby lighting in California.

The report describes the objectives, tasks, and outcomes of the research, which involved the installation and monitoring of the bi-level fixture technology in stairwells at four California test sites. Workshops were also presented to various California organizations highlighting the bi-level technology along with other LRP technologies and products. Code and standard issues regarding egress lighting in stairwells were also investigated. Results from the NYSERDA research were reviewed.

The International Facility Management Association and Lawrence Berkeley National Laboratory acted as co-project managers for this project. Chiron, SBC, University of California at Berkeley, and Alameda County provided building stairwells for the installation and monitoring work. Energy savings ranged from 40 to 60 percent at the four sites.

# EXECUTIVE SUMMARY

To address the desire for more light when needed and less light when not needed, a new energy-saving, bi-level stairwell lighting fixture has been developed. The fixture meets code minimums when stairwells are not occupied and can increase light levels automatically when controls sense that occupants are entering the stairwell.

The project team met with NYSERDA representatives and discussed a study by NYSERDA of two sites featuring the bi-level stairwell fixture technology in the New York area. Four buildings in California were then selected to participate in the PIER LRP 2004 study in which occupancy patterns and energy usage in stairwells were monitored.

The buildings were selected based on how often the stairwells were used by occupants. Baseline measurements were taken prior to the installation of the bi-level stairwell fixtures. In these four buildings, building owners saved between 38 and 49 percent of lighting energy on 24-hour weekdays, and between 47 and 67 percent on weekend days. The percentage of time in dimmed mode ranged from 62 to 82 percent during weekdays, and from 85 to 97 percent on weekends. The energy savings from the application of bi-level technologies to stairwells at the four test sites ranged from 40 to 60 percent.

Resulting information from this project along with other LRP technologies and products has been presented to various California business owners and organizations. Code and standard issues have been reviewed.

This project along with the results of the NYSERDA research provides empirical evidence that cost and energy savings exist, the technology can be introduced into the market, and codes and standards issues are not barriers to acceptance by California building owners.

# INTRODUCTION

The purpose of this study is to test a new type of lighting technology, bi-level stairwell fixtures, in California to determine energy savings, demand reduction, and its acceptance among code-making officials. The bi-level fixtures use a built-in ultrasonic occupant sensor that causes the light to switch to high-level lighting when a stairwell is occupied. After a period of time with no motion detected, the light fixture switches back to low-level, standby lighting.

Previous research, funded by the New York State Energy Research and Development Authority (NYSERDA), was conducted in 2003 by the Lighting Research Center from Rensselaer Polytechnic Institute (RPI.) The fixtures were installed in a high-rise residential complex located on Roosevelt Island just east of Manhattan and a high-rise office building located on Lexington Avenue in New York City. In both cases, the stairwells were not used frequently due to security restrictions. The resulting energy savings were substantial, 53 to 60 percent, when compared to the existing lighting fixtures. Findings from this NYSERDA study are included in this report.

Like New York, Californians experience some of the highest energy costs in the country. Introducing technologies that reduce energy consumption can help building owners improve building performance and decrease utility costs. The International Facility Management Association (IFMA) was commissioned to find commercial building owners in California who would be willing to install bi-level fixtures in their stairwells and allow researchers from Lawrence Berkeley National Laboratory (LBNL) to monitor occupancy patterns and lighting energy consumption. This report documents the performance of these fixtures and the building owners’ reaction to the fixtures. It also documents the presentations of the bi-level technology along with other LRP technologies and products to various California organizations. Finally, this report includes plans for introducing the technology from its current developmental state to the market and issues regarding acceptance by the code and standards community.

# NYSERDA BI-LEVEL FIXTURE PERFORMANCE STUDY

## Background

Early in 2001, LaMar Lighting was awarded a research and development contract from the New York State Energy Research and Development Authority (NYSERDA) "to develop and commercialize a lighting system that incorporates a 2-lamp 32W T8 electronic fixture, an integral ultrasonic motion sensor, bi-level dimming ballast, and battery back-up for use in stairwells and corridors or other spaces where full and no-light motion sensors are impractical."

This section contains a summary of the information produced by the NYSERDA project. In addition to product literature and a web site (www.occusmart.com) in support of the commercialized fixture, NYSERDA also funded a field test of the fixture including full-scale monitoring by the Lighting Research Center (LRC) from Rensselaer Polytechnic Institute (RPI) in New York. Extensive data is presented on two field test sites: a high-rise residential complex located on Roosevelt Island just east of Manhattan and a high-rise office building located on Lexington Avenue in New York City.

## Technology and Results

The concept of using an occupancy sensor to turn off lights and save energy was developed long before the NYSERDA project. However, there are many applications, like stairwells and corridors, where building occupant comfort or building codes require that the area not be entirely dark when occupants enters the space. The LaMar Lighting Company, Inc., of Farmingdale, NY, developed a new type of fluorescent lighting fixture that used an externally mounted, ultra-sonic motion sensor to detect motion in stairwells and corridors, and solid state controls in order to dim fixtures to lower light levels—and lower energy use—when stairs and corridors are not occupied.

All LaMar dimming fixtures are contained in the Occu-smart® product line. Fixtures come in 2', 3' and 4' lengths for both 120V and 277V applications. Both 1-lamp and 2-lamp models are available. Models are available to dim to 5%, 10%, or 33% of normal, depending on voltage/ballast combinations. Battery packs can be added for emergency lighting applications. Vandal-proof options are also available.

Due to extremely low occupancy in both staircases (0.7-3.3 percent)—as measured by RPI, energy savings were significant for both projects (53-60 percent) compared to the existing lighting. NYSERDA rebates and high electrical rates in New York City generated a payback period of about 2.5 years (excluding the cost of emergency battery packs which are not part of bi-level performance). Energy savings would have increased even further and paybacks would have been even shorter had the project chosen to dim to 5 or 10 percent instead of the 33 percent that was chosen. Both sites also showed increased illuminances.

A 32-page report is available from NYSERDA presenting the complete findings from the field test including two high-rise buildings in the New York City area, a multi-family apartment building and an office building. For each field test location, LRC provides:

- Luminaire Characteristics,
- Project (building) Description and Photographs, and

- Photometric Measurements (by staircase).
- Summary of Energy Savings,
- Laboratory Tests of Ballast Wattage,
- Project contact Information,
- Code Implications,
- Energy Calculation Methodology,
- Typical Light Logger Calculation Example,
- Occupancy percentage Sheets, and
- Energy Calculation Sheets.

RPI is well known for its series called the “Delta Snapshots.” Each is a colorful and yet technical summary of a lighting-related case study. A Snapshot has been prepared for the Rivercross building, from the field test report discussed above. The 2-page Delta Snapshot is provided in the NYSERDA report. Below is a summary of the two NYSERDA test sites as reported March 18, 2004.

**Before and After Performance Comparison**

| | **Rivercross** | | **Lexington Ave** | |
|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** |
| **Fixtures:** | 4’<br>2-lamp<br>T12ES<br>Flat lens | 4’<br>2-lamp<br>T8<br>Dropped Lens | 2’<br>1-lamp and 2-lamp<br>T12ES<br>Bare strip | 2’<br>2-lamp<br>T12<br>Dropped Lens |
| **Energy Use:** | 60W | 62W Occ.<br>28W UnOcc. | 28W (1 lamp)<br>53W (2 lamp) | 62W Occ.<br>13W UnOcc. |
| **Illuminance** (lux): | | | | |
| Entry Landing | 139 | 245 | 40 | 127 |
| Mid-First Flight | 9 | 52 | 24 | 90 |
| Middle Landing | 109 | 251 | 29 | 107 |
| Mid-Second Flight | 8 | 65 | 22 | 77 |
| **Installed Cost:** | | | | |
| Fixture + Install | | $138.40 | | $187.50 |
| **Energy Savings:** | (@$0.094/kWh) | $26.04 | (@$0.131/kWh) | $23.67 |
| **Simple Payback (Retrofit Application):** | | | | |
| Without Rebate: | | 5.3 years | | 7.9 years |
| With Rebate: | | 2.6 years | | 5.0 years |

# PIER LRP BI-LEVEL FIXTURE PERFORMANCE RESULTS

## Introduction

Stairwells in non-residential buildings throughout the US are typically lit 24 hours a day for purpose of emergency egress. This work is a study of a new fixture that uses an occupancy sensor to reduce light levels to the minimum code requirement when there are no occupants present. The fixture is equipped with a built-in occupancy sensor that switches the bi-level ballast from high to standby mode depending on occupancy. Since the fixture uses 1/3 power or less when in standby, considerable energy savings can accrue while providing for full lighting when required.

For a new technology to gain acceptance in the marketplace, it must be acceptable to building officials, while owners and facilities personnel must be aware of its operation and potential benefits. The present study builds on and extends studies conducted by NYSERDA in multi-story residential buildings. The present study of four diverse buildings in California broadens the scope, making the results more accessible to building owners and operators in this state. The goal was to examine and characterize a range of savings patterns due to different occupancy profiles, so that building owners and operators would have a means to estimate their own savings potential.

Lighting energy use in interior stairwells is typically unaffected by climate or location, because the lights are generally required to be on 24 hours per day. An occupancy-sensor controlled fixture can only respond to motion (typically due to occupancy), so the key research variable is the stairwell's occupancy profile. A variety of factors influence the use of a stairwell. These include the number of floors, the location of the stairwell within the building, the likelihood of interaction between floors, the proximity of amenities such as the parking garage or vending machines, and whether or not the stairwell is locked from the inside to prevent inter-floor access (as in the case of a stairwell meant only for emergency egress).

The four California test sites were recruited for their diversity of function and size, rather than for the sake of a statistically significant sample. The sites were in the Oakland-Berkeley Area. For a building owner, the salient information is the likelihood of savings in his or her specific building with its specific occupancy pattern, so the goal is to be able to compare savings under a range of diverse occupancy patterns in order to help owners and managers characterize the potential savings in their own buildings.

## Description of Sites

Some limited criteria were applied for the sake of minimizing extraneous factors. Each site was windowless to avoid the influence of external events. Buildings with inadequate existing lighting were preferred where possible to encourage the owners to participate. The buildings had to have the expectation of a variety of occupancy patterns.

***Evans Hall***. Evans Hall is the mathematics building at University of California at Berkeley. It has several department offices on different floors including the Mathematics Department office on the tenth floor and the statistics department office on the $4^{th}$ floor. Large classrooms and the library are located on the first two floors and to a lesser extent on upper floors. Professor and graduate student offices are located on the higher floors.

There are three stairwells in this building, two in the southern half of the building flanking the main elevator lobby and the restrooms, and one in the north close to the north elevator lobby. Because of the location of an airshaft, there is a short passageway from the elevator lobby to the stairwell door on each floor. The exit from the ground floor of the north stairwell opens directly to the outdoors without connection to the elevator lobby. On all other floors, the stairwell doors lead to the elevator lobby.

The original stairwell lighting consisted of 1960s-era 4-foot T-12 fixtures on each landing with anodized aluminum shields to create a wall-washing effect, directing light up and down. The fixtures had been delamped for energy conservation so that only one lamp was present at the time of the retrofit. Figures 1 shows the post-retrofit fixture in Evans Hall north stairwell.

**Figure 1.** New fixture at Evans 3rd floor, showing doorway logger and new fixture.[1]

***Chiron Building M***. Chiron Corporation has a complex of buildings in Emeryville, California, located between Oakland and Berkeley near the bay. Building M is an older building that is five stories high, housing researchers' offices and laboratories as well as some related offices. There are two elevators, one on the south end of the building and one near the middle, and three stairwells, one on the south, one in the middle, close but not adjacent to the elevator, and one on the north end. The south and north stairwells had some daylight access, so the middle stairwell was chosen for monitoring.

Original fixtures were a hodgepodge of old very dirty circlines in round discolored enclosures, with a four-foot parabolic replacement in two locations. There was one fixture per landing. Figures 2 and 3 show pre- and post-retrofit fixtures in Chiron Building M middle stairwell.

[1] LBNL ref. Evans doorway3noflash_1.jpg

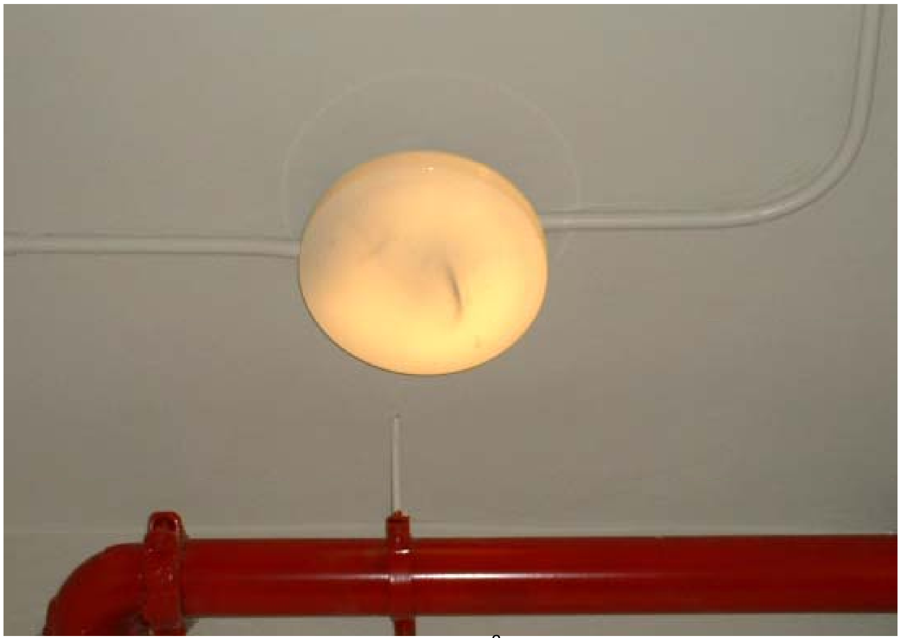


**Figure 2.** Old fixture at Chiron Building M[2], first floor.

**Figure 3.** New fixture at Chiron Building M, first floor[3]

***Alameda County General Services Administration Building***. Located on Lakeside Drive across the street from Lake Merritt, this eleven-story building houses a variety of Alameda County GSA offices. It has two stairwells, one to the north and one to the

[2] LBNL ref. Chiron1_1.jpg
[3] LBNL ref. Chironnew1stfloor_1.jpg

south. The north stairwell can be used fairly easily for interfloor communication, but the south stairwell's doors were locked from the inside, so the intended use of this stairwell was egress only. As it happened, there were a few people with keys, so there was noticeable interfloor activity on some of the upper level floors. At the bottom, the stairwell ended on the 2nd floor in close proximity to another short stairwell ending in the parking garage.

Original fixtures in this building were one-lamp F32T8s in a simple fixture with square cross-section, mounted on the wall on each landing. Just before installation of the replacement fixtures, an emergency lighting system was added just above or below the existing fixtures according to available space. Figures 4 show pre-retrofit fixture in Alameda County GSA building (Lakeside) south stairwell.

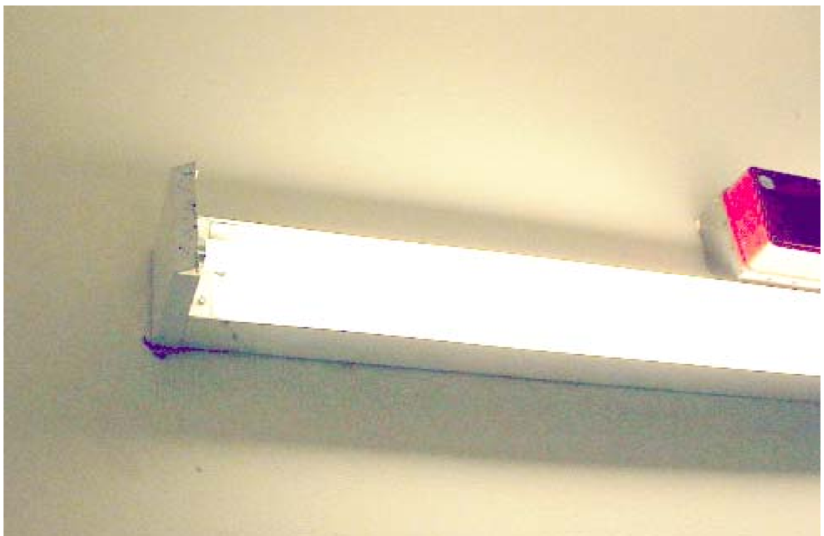


**Figure 4.** Old fixture at Alameda County GSA building (Lakeside)[4]

***SBC Building***. The SBC building on Webster Street in Oakland houses a variety of SBC offices on different floors. There are two main stairwells, one near the north and one closer to the interior in the southern part of the building. The north stairwell was chosen because it is closer to the main elevator lobby, and has an accessible vending machine area on the second floor. There is no communication between this stairwell and the main elevator lobby on the first floor, but on upper floors the stairwell door is a short distance from the elevators. The ground floor exit from the stairwell opens directly onto the street, so is used primarily when workers leave at the end of the day or at lunch. There is no entrance to the building from this door. Existing fixtures were 2-lamp F32T8s, mounted on the ceiling close to the stairwell doors. There were no intermediate landing fixtures in this building.

## Methods

One light fixture was monitored per floor in each building. Three of the stairwells also had a light fixture at the intermediate landing between floors that were not monitored. Table 1 summarizes salient characteristics of the four monitored stairwells.

[4] LBNL ref. Alacounty_oldfixt1.jpg

**Table 1. Building Characteristics and Monitoring Description**[5]

| Building | Evans Hall | Chiron | Alameda County | SBC |
|---|---|---|---|---|
| **Location** | University of California, Berkeley CA | Building M, Emeryville, CA | Lakeside Dr., Oakland, CA | Webster St., Oakland, CA |
| **No. of floors** | 10 | 5 | 11 | 10 |
| **Stairwell** | Northeast (1 of 3) | Middle (1 of 3) | South (1 of 2) | North (1 of 2 |
| **Existing Fixture** | 2-lamp 40W T12 | circlines and miscellaneous on 7 landings; two landings had 4' 2-lamp T8s | 1-lamp T8 each landing | 2-lamp T8 each floor |
| **New Fixture** | 2-lamp 32W T8 100%/10% Voyager, each landing | 1-lamp U-tube 32W T8 100%/33% 2-ft. Voyager, each landing | 1-lamp T8 100%/33% Cordelia, each landing | 2-lamp T8 100%/33% Cordelia, each floor |
| **No. of new fixtures** | 23 | 10 | 23 | 12 |
| **Power at full** | 1380 | 320 | 736 | 384 |
| **Power at Standby** | 138 | 106 | 74 | 127 |
| **Baseline light level (fc) at handrail** | 0.8 fc to 11 fc (delamped shielded 1960 era F40 2-lamp fixtures each landing) | .07 fc (lowest circline) to 24 fc (2-lamp parabolic T8) | from 2.9 to 6.8 fc (31 to 73 lux) | 2.3 fc to 17 fc |
| **Specified standby percent light output** | 10 | 33 | 10 | 33 |
| **New light level (fc) at handrail** | 3.5 FC low, 9.0 fc at full power | 5.8 to 13.1 fc at full power | 9.0 to 15.1 fc at full power | 2.2 to 20.1 fc at full power |
| **No. of Hobos installed** | 37 | 21 | 11 | 12 |
| **Hobo locations** | All fixtures NE stairwell; all doorways all stairwells | 5 fixtures in central stairwell; all doors on each of three stairwells. | All landings of south stairwell from 2nd to roof door. | Doorway landing on each floor from 2 to roof; floor 1 logger on intermediate landing below 2nd floor. |
| **Date installed** | Doorway loggers: 10/01/03. Fixture loggers: rewired 12/22/03 | Doorway loggers: 8/31/03. Fixture loggers: rewired 2/04/04 | 2/17/04 | 3/24/04 |
| **Monitoring period analyzed** | fixtures: 12/22/03 to 4/27/04 analyzed to date. | 2/12/04 to 6/23/04 analyzed. | 3/27/04 to 4/8/04 analyzed to date (to be completed) | 4/22/04 to 5/27/04 analyzed to date (to be completed) |

[5] From bldg_matrix_091004.xls, Table 1, jdj

## Baseline

Establishing the baseline is a key part of the energy savings calculation for any conservation project. Sometimes the lighting in place prior to the retrofit best represents the baseline. However, if the existing lighting is not compliant with current electrical code, it is hard to argue that it is valid baseline. For stairwells whose fixtures do meet code and are not at the end of their lifetime, the existing fixtures' energy usage can be used as a baseline.

The most straightforward baseline for a 24-hour stairwell is fairly simple: it is the energy consumption of a fixture that meets code, times the number of fixtures required, running 24 hours per day. If the existing fixtures are still serviceable and meet or exceed the code requirement, their energy consumption can be used as an alternate baseline.

For consistency among the four buildings, the primary baseline for this project is the energy consumption of the retrofit fixtures at their full light output, i.e. assuming they are never dimmed. This focuses the discussion on the savings due to the control technology, excluding other uncontrollable factors such as inconsistencies in lighting design.

## Energy Consumption Measurements

The ballast in the LaMar fixtures has two separate hot leads. One lead operates the ballast at the low power level. This lead is always energized. The other lead switches the ballast to full power only when commanded by the occupant sensor. If no occupant is sensed after the installer-selected time period (10 minutes[6]) the full-power lead is switched off and the lamp power returns to the minimum or "standby", level.

To measure the fixtures' state, a small current switch donut was preinstalled at the factory with the sensor-controlled power leg of the ballast wrapped two to four times through it[7]. A serial cable provided by Onset Computing was attached to the leads from the current switch with wire nuts, and its jack was left extending from a small knockout on the face of the fixture. Once the fixtures were installed, a Hobo[8] H6 state logger was connected to serial cable jack, and attached to the metal surface of the fixture with a supplied magnet. Each time the Hobo detects a change of state (on=full power, off=low power), it records the state, time and date.

The Hobo H6 loggers are capable of logging 2000 records at a stint, with a resolution of 0.5 seconds. The occupancy sensors were set with a time delay of ten minutes, so the maximum possible frequency of events (approximately one every ten+ minutes) would fill up the loggers in about two weeks. To minimize potential data losses from a logger failure, the site point of contact (POC) was requested to read the data each week for the first few weeks of the monitoring period and report the data to the LBNL project manager via email. After an initial "settling in" period, data were collected less frequently, according to the actual amount of time it took to fill up the loggers.

[6] The time delay was set as closely as possible to ten minutes.
[7] The number of passes through the current switch varied according to the nominal fixture wattage and the voltage of each stairwell's lighting circuit.
[8] Manufactured by Onset Computing Corporation.

Data were collected from the monitored fixtures for varying periods, depending on when it was possible to complete each installation. The monitoring periods analyzed for each building are given in Table 1. Sample data from a floor in the Evans Hall is illustrated in Figure 5.

| Date/Time | OPEN (0) / |
|---|---|
| 03/30/04 16:05:07.0 | CLOSED |
| 03/30/04 16:18:19.5 | OPEN |
| 03/30/04 16:18:52.5 | CLOSED |
| 03/30/04 16:24:03.0 | OPEN |
| 03/30/04 16:24:17.5 | CLOSED |
| 03/30/04 16:40:02.5 | OPEN |
| 03/30/04 16:40:08.0 | CLOSED |
| 03/30/04 16:45:27.0 | OPEN |
| 03/30/04 16:50:07.5 | CLOSED |
| 03/30/04 17:08:37.5 | OPEN |
| 03/30/04 17:10:10.5 | CLOSED |
| 03/30/04 17:18:55.0 | OPEN |
| 03/30/04 17:19:35.5 | CLOSED |
| 03/30/04 17:28:55.0 | OPEN |
| 03/30/04 17:30:57.0 | CLOSED |
| 03/30/04 17:40:10.0 | OPEN |
| 03/30/04 17:42:17.0 | CLOSED |
| 03/30/04 17:49:52.5 | OPEN |
| 03/30/04 17:59:01.5 | CLOSED |
| 03/30/04 18:04:11.0 | OPEN |
| 03/30/04 18:04:22.5 | CLOSED |
| 03/30/04 18:11:26.0 | OPEN |
| 03/30/04 18:12:29.5 | CLOSED |
| 03/30/04 18:19:10.0 | OPEN |
| 03/30/04 18:25:33.0 | CLOSED |
| 03/30/04 18:30:48.5 | OPEN |
| 03/30/04 18:31:13.5 | CLOSED |
| 03/30/04 18:37:02.5 | OPEN |
| 03/30/04 18:45:46.0 | CLOSED |

**Figure 5.** Sample Hobo Data from Evans Hall

## Results

Daily occupancy patterns were seen to be fairly consistent over time, with variations primarily because of weekends and holidays. The results of the monitoring are summarized in Tables 2 and 3 for weekday and weekend average days. The average weekday time at full power (representing nominal “occupied” time) ranges from 18 percent at SBC to 38 percent at Evans Hall. The overall statistics by test site are shown in Tables 4i-4iv.

The floor-by-floor variation in occupancy is illustrated in Figures 6 to 10. Note that the data refer to 24-hour weekdays and 24-hour weekend days. At Chiron, the relatively low-rise building saw regular stairwell use on weekdays, but practically none on weekends.

Evans Hall shows a great deal of activity on the first two floors, but relatively less on the upper floors on weekdays. On weekends, all stairwell activity slows down, but the first two floors are still fairly busy. The configuration of the stairwell probably contributes to this situation: the bottom floor door is an exterior door not connected to the elevator lobby; the doors to the first floor elevator lobby are locked on weekends, and there is no direct access to the elevators from this side of the building without walking up to floor 2.

The Lakeside building has very little activity on most of the upper floors, but in some cases there is interfloor communication by workers who have keys to exit the stairwell, or on the 11th floor where it is possible to exit without walking all the way to the bottom. Since floors 9 and 10 seem to have almost no stairwell use, the activity on floors 11 and 12 are most likely interfloor interactions. Few workers are likely to choose to walk down from these floors all the way to the bottom. The lowest floor in this stairwell is the 2nd floor, which exits into a corridor from which exiting workers take another short stairwell down into the parking garage below the building to go home.

The SBC building is in operation on all days, though with a reduced staff on weekends, hence its weekend patterns are closer to those on the weekdays. The 1st floor exit is an exit to the street that is locked from the outside, so it is used to leave the building at the end of the shift or to go to lunch. Entrance is via the main lobby, where the only access to the upper floors is via the elevators. Interfloor use of the stairwells is slightly greater on the lower floors, possibly influenced by the vending machine on floor 2. On upper floors, it may be due workers going up or down one floor to interact with other workers.

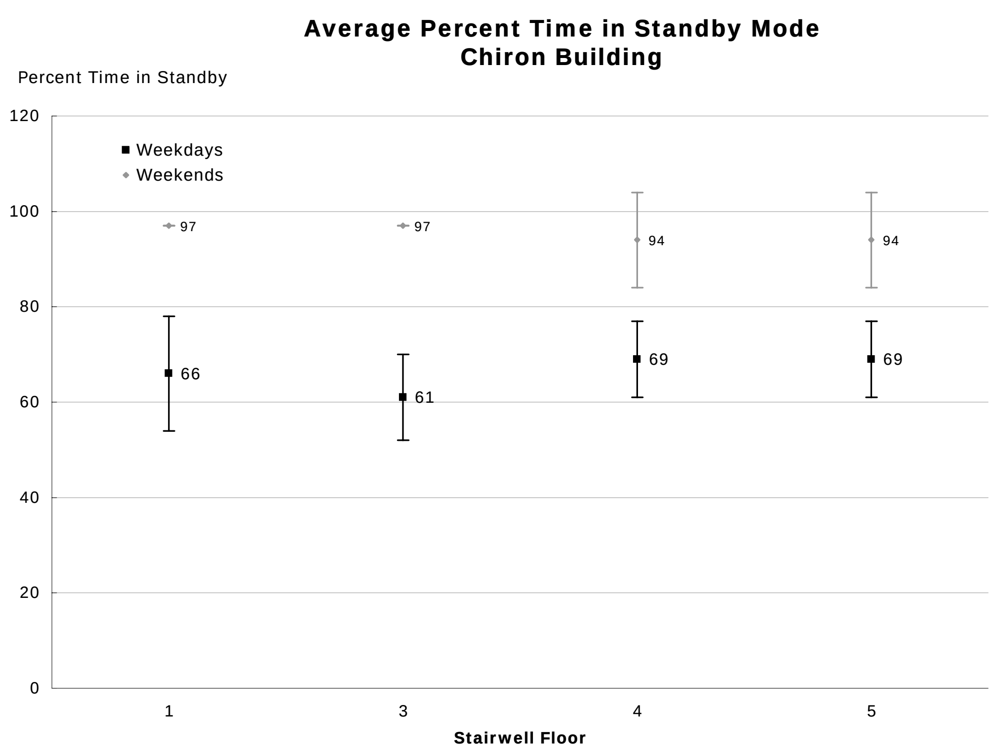



**Figure 6.** Average Percent Time in Standby Mode, Chiron Building

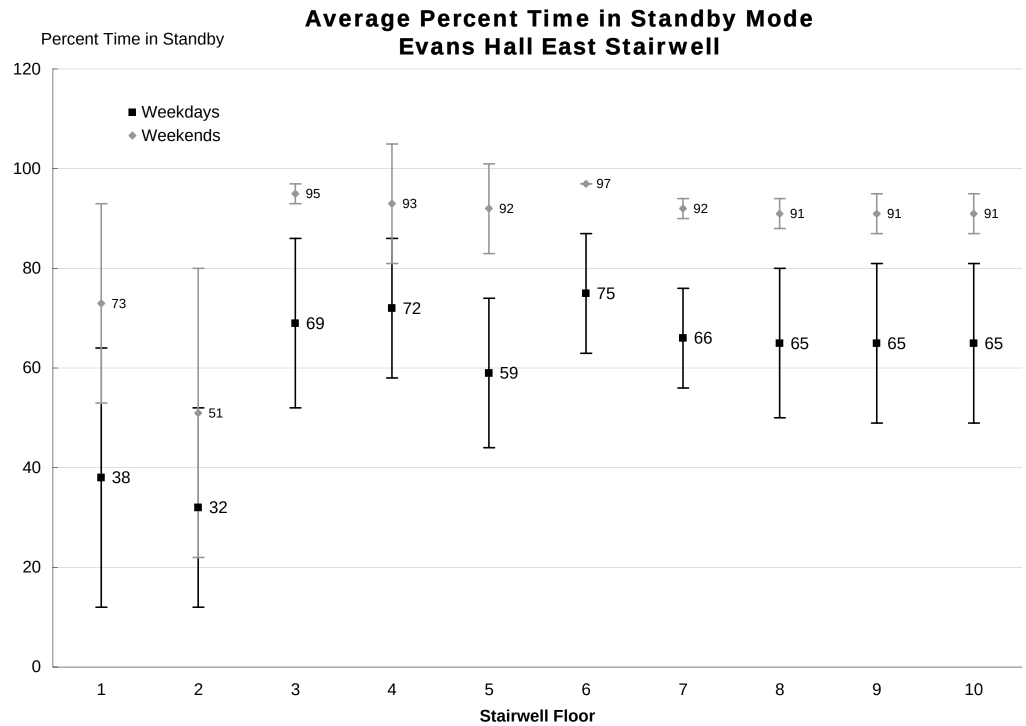



**Figure 7.** Average Percent Time in Standby Mode, Evans Hall

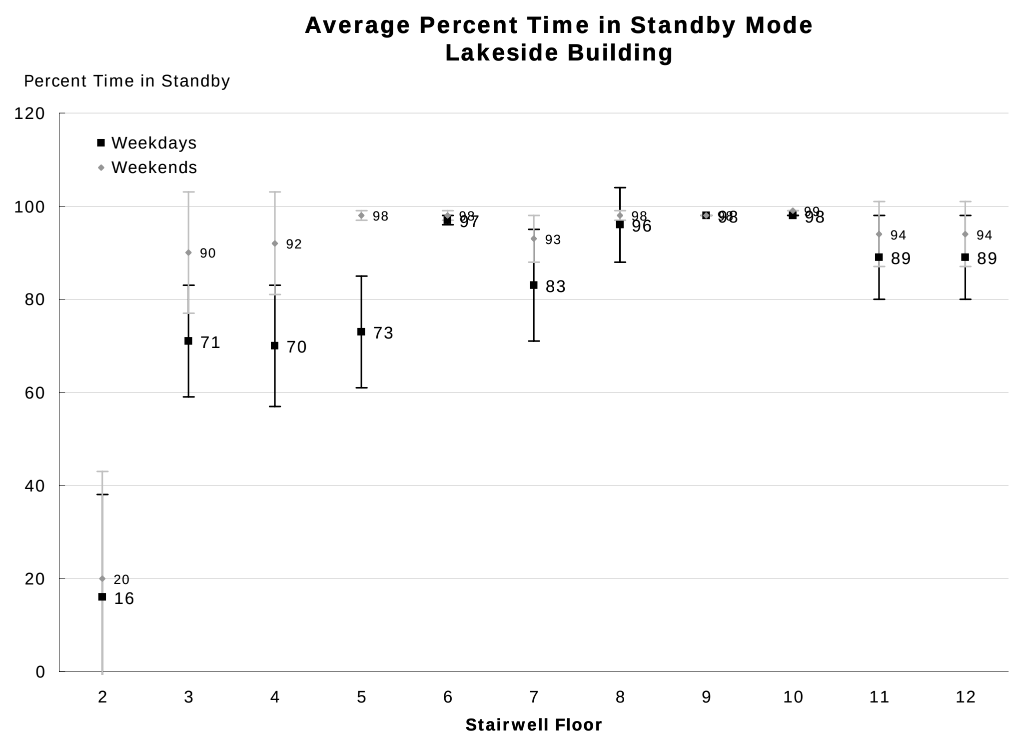



**Figure 8.** Average Percent Time in Standby Mode, Alameda County GSA (Lakeside)

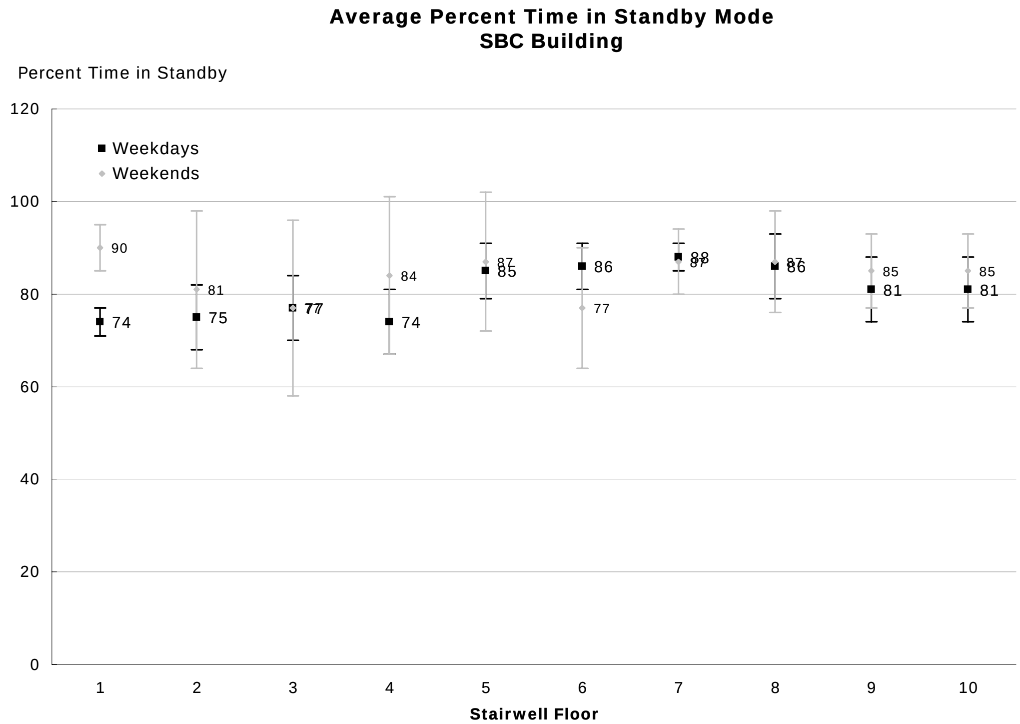



**Figure 9.** Average Percent Time in Standby Mode, SBC Building

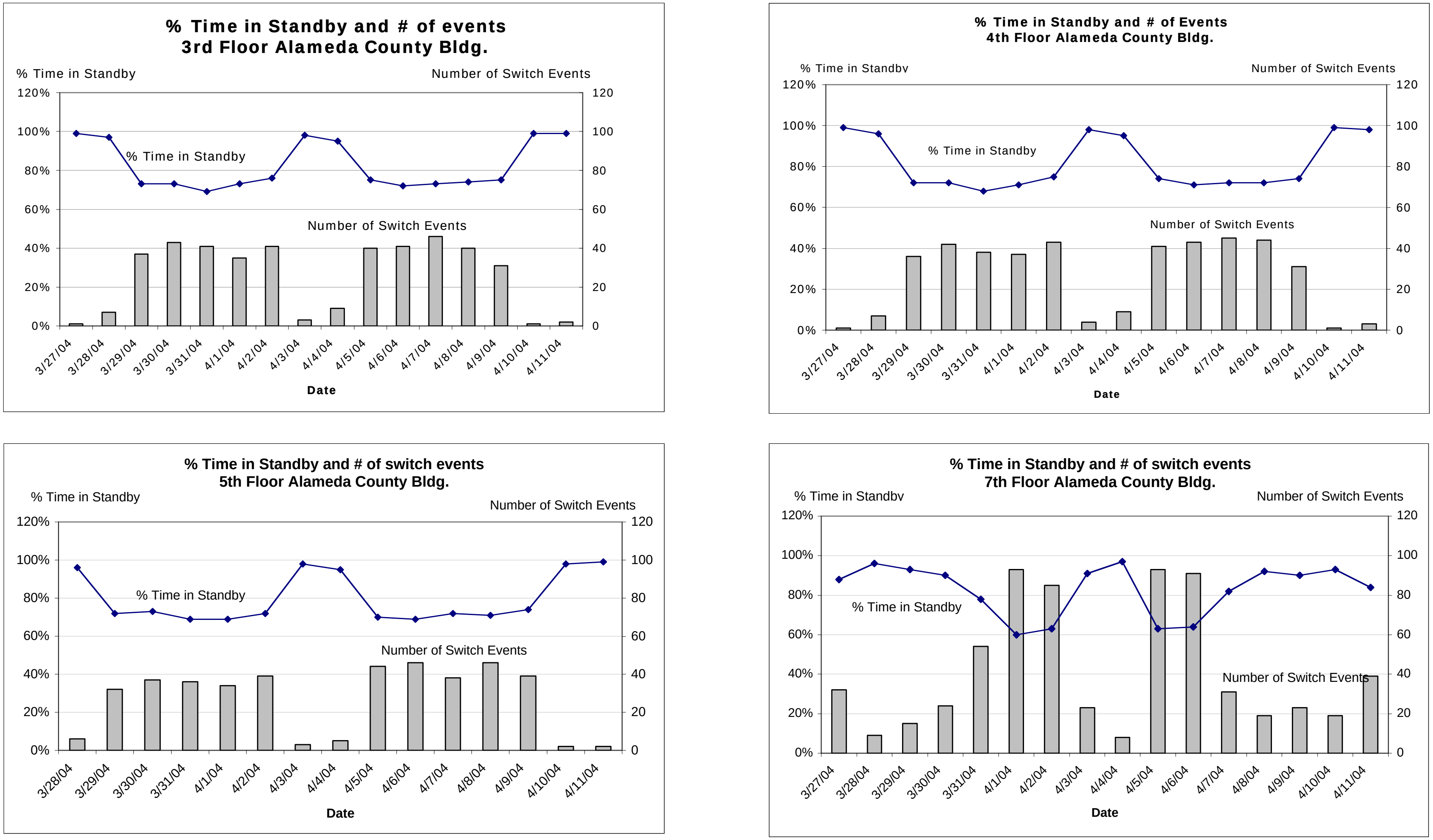



**Figure 10a-d.** Percent time in standby mode and corresponding number of daily switch events for two weeks interval at the Alameda County Building for the (a) 3rd floor, (b) 4th floor, (c) 5th floor and (d) 7th floors.

| | Number of Fixtures | Fixture Wattage (W) | Dimmed light level (%) | Dimmed power level (W) | time at full (minutes) | time dimmed (minutes) | time at full (%) | time dimmed (%) | energy without dimming (kWh) | actual energy (kWh) | daily savings (kWh) | savings per fixture (kWh) | savings (%) | max possible savings (zero occupancy) (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chiron** | 10 | 32 | 33% | 14 | 474 | 964 | 33% | 67% | 0.77 | 0.48 | 0.29 | 0.03 | 38% | 67% |
| **Evans** | 23 | 62 | 10% | 13 | 551 | 887 | 38% | 62% | 1.49 | 0.76 | 0.72 | 0.03 | 49% | 90% |
| **Lakeside** | 23 | 32 | 33% | 14 | 270 | 1168 | 19% | 81% | 0.77 | 0.42 | 0.35 | 0.02 | 46% | 67% |
| **SBC** | 12 | 62 | 33% | 28 | 262 | 1176 | 18% | 82% | 1.49 | 0.82 | 0.67 | 0.06 | 45% | 67% |

***Table 2. Weekday daily average energy usage and savings***

**Table 3. Weekend daily average energy usage and savings**

| | Number of Fixtures | Fixture Wattage (W) | Dimmed light level (%) | Dimmed power level (W) | time at full (minutes) | time dimmed (minutes) | time at full (%) | time dimmed (%) | energy without dimming (kWh) | actual energy (kWh) | daily savings (kWh) | savings per fixture (kWh) | savings (%) | max possible savings (zero occupancy) (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chiron** | 10 | 32 | 33% | 14 | 44 | 1394 | 3% | 97% | 0.77 | 0.35 | 0.42 | 0.04 | 55% | 67% |
| **Evans** | 23 | 62 | 10% | 13 | 221 | 1261 | 15% | 85% | 1.53 | 0.50 | 1.03 | 0.04 | 67% | 90% |
| **Lakeside** | 23 | 32 | 33% | 14 | 149 | 1289 | 10% | 90% | 0.77 | 0.38 | 0.39 | 0.02 | 50% | 67% |
| **SBC** | 12 | 62 | 33% | 28 | 215 | 1223 | 15% | 85% | 1.49 | 0.79 | 0.69 | 0.06 | 47% | 67% |

| floor | daytype | N | Closures Per Day | | | | time (minutes per day) | | | | Per Day | | | | (minutes per day) | | | | % Time in Standby Mode | | | | (minutes/cycle) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | STDev | Max | Min | Mean | v | Max | Min | Mean | STDev | Max | Min | Mean | v | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min |
| ch1L | Weekday | 16 | 36 | 12 | 55 | 6 | 479 | 184 | 645 | 34 | 36 | 12 | 56 | 6 | 959 | 184 | 1405 | 794 | 66 | 12 | 97 | 55 | 12 | 3 | 17 | 5 |
| ch1L | Weekend | 5 | 4 | 1 | 6 | 2 | 23 | 10 | 35 | 10 | 4 | 1 | 6 | 2 | 1415 | 10 | 1429 | 1404 | 97 | 0 | 99 | 97 | 5 | 0 | 7 | 5 |
| ch3L | Weekday | 31 | 33 | 8 | 49 | 7 | 550 | 139 | 655 | 42 | 33 | 8 | 49 | 7 | 888 | 139 | 1397 | 784 | 61 | 9 | 97 | 54 | 15 | 3 | 21 | 5 |
| ch3L | Weekend | 12 | 4 | 2 | 9 | 2 | 26 | 13 | 56 | 10 | 4 | 2 | 9 | 2 | 1412 | 13 | 1429 | 1383 | 97 | 0 | 99 | 96 | 5 | 0 | 6 | 5 |
| ch4L | Weekday | 30 | 40 | 10 | 53 | 7 | 434 | 120 | 562 | 36 | 40 | 10 | 54 | 7 | 1004 | 120 | 1404 | 877 | 69 | 8 | 97 | 60 | 10 | 1 | 14 | 5 |
| ch4L | Weekend | 10 | 7 | 14 | 48 | 1 | 64 | 147 | 481 | 5 | 7 | 14 | 48 | 1 | 1374 | 147 | 1434 | 958 | 94 | 10 | 99 | 66 | 5 | 1 | 10 | 5 |
| ch5L | Weekday | 22 | 40 | 10 | 53 | 7 | 434 | 120 | 562 | 36 | 40 | 10 | 54 | 7 | 1004 | 120 | 1404 | 877 | 69 | 8 | 97 | 60 | 10 | 1 | 14 | 5 |
| ch5L | Weekend | 9 | 7 | 14 | 48 | 1 | 64 | 147 | 481 | 5 | 7 | 14 | 48 | 1 | 1374 | 147 | 1434 | 958 | 94 | 10 | 99 | 66 | 5 | 1 | 10 | 5 |

## Table 4i. Summary Statistics for Chiron Building[9]

| | | | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENE01L | Weekday | 38 | 14 | 15 | 57 | 1 | 873 | 381 | 1438 | 10 | 14 | 15 | 57 | 0 | 565 | 381 | 1429 | 1 | 38 | 26 | 99 | 0 | 220 | 369 | 1438 | 5 |
| ENE01L | Weekend | 16 | 7 | 4 | 18 | 1 | 376 | 301 | 968 | 5 | 7 | 4 | 18 | 1 | 1062 | 301 | 1434 | 471 | 73 | 20 | 99 | 32 | 74 | 87 | 294 | 5 |
| ENE02L | Weekday | 61 | 21 | 14 | 58 | 1 | 957 | 297 | 1393 | 42 | 21 | 15 | 58 | 0 | 481 | 297 | 1397 | 46 | 32 | 20 | 97 | 3 | 116 | 186 | 1027 | 10 |
| ENE02L | Weekend | 23 | 7 | 5 | 18 | 1 | 685 | 420 | 1408 | 82 | 7 | 5 | 18 | 0 | 753 | 420 | 1357 | 31 | 51 | 29 | 94 | 2 | 304 | 457 | 1408 | 5 |
| ENE03L | Weekday | 42 | 30 | 15 | 50 | 1 | 433 | 251 | 1145 | 15 | 30 | 15 | 50 | 0 | 1005 | 251 | 1424 | 294 | 69 | 17 | 98 | 20 | 28 | 100 | 660 | 5 |
| ENE03L | Weekend | 15 | 11 | 5 | 20 | 2 | 63 | 34 | 114 | 10 | 11 | 5 | 20 | 2 | 1375 | 34 | 1429 | 1325 | 95 | 2 | 99 | 92 | 5 | 0 | 6 | 5 |
| ENE04L | Weekday | 61 | 36 | 16 | 56 | 1 | 391 | 209 | 1120 | 15 | 36 | 16 | 56 | 0 | 1047 | 209 | 1424 | 319 | 72 | 14 | 98 | 22 | 22 | 84 | 660 | 5 |
| ENE04L | Weekend | 21 | 9 | 5 | 23 | 1 | 87 | 179 | 865 | 5 | 9 | 5 | 22 | 1 | 1351 | 179 | 1434 | 574 | 93 | 12 | 99 | 39 | 6 | 6 | 37 | 5 |
| ENE05L | Weekday | 52 | 15 | 6 | 26 | 1 | 579 | 227 | 1439 | 10 | 15 | 6 | 26 | 1 | 859 | 227 | 1429 | 0 | 59 | 15 | 99 | 0 | 87 | 229 | 1439 | 10 |
| ENE05L | Weekend | 21 | 4 | 2 | 11 | 1 | 103 | 141 | 589 | 20 | 4 | 2 | 11 | 1 | 1335 | 141 | 1419 | 850 | 92 | 9 | 98 | 59 | 45 | 127 | 589 | 10 |
| ENE06L | Weekday | 59 | 34 | 13 | 48 | 1 | 347 | 180 | 1074 | 5 | 34 | 13 | 48 | 1 | 1091 | 180 | 1434 | 365 | 75 | 12 | 99 | 25 | 15 | 45 | 358 | 5 |
| ENE06L | Weekend | 24 | 4 | 2 | 11 | 1 | 23 | 12 | 62 | 5 | 4 | 2 | 11 | 1 | 1415 | 12 | 1434 | 1378 | 97 | 0 | 99 | 95 | 5 | 0 | 9 | 5 |
| ENE07L | Weekday | 48 | 42 | 9 | 60 | 9 | 475 | 144 | 1105 | 152 | 42 | 9 | 60 | 10 | 963 | 144 | 1287 | 334 | 66 | 10 | 89 | 23 | 12 | 16 | 122 | 6 |
| ENE07L | Weekend | 20 | 16 | 5 | 27 | 10 | 98 | 34 | 176 | 51 | 16 | 5 | 26 | 10 | 1340 | 34 | 1388 | 1263 | 92 | 2 | 96 | 87 | 5 | 0 | 6 | 5 |
| ENE08L | Weekday | 64 | 32 | 12 | 49 | 1 | 485 | 228 | 1129 | 5 | 32 | 12 | 49 | 1 | 953 | 228 | 1434 | 310 | 65 | 15 | 99 | 21 | 15 | 13 | 112 | 5 |
| ENE08L | Weekend | 24 | 17 | 8 | 31 | 1 | 108 | 58 | 221 | 5 | 17 | 8 | 31 | 1 | 1330 | 58 | 1434 | 1218 | 91 | 3 | 99 | 84 | 5 | 0 | 8 | 5 |
| ENE09L | Weekday | 54 | 31 | 12 | 49 | 2 | 487 | 231 | 1122 | 10 | 31 | 12 | 49 | 2 | 951 | 231 | 1429 | 317 | 65 | 16 | 99 | 22 | 15 | 13 | 102 | 5 |
| ENE09L | Weekend | 21 | 17 | 9 | 31 | 1 | 115 | 65 | 221 | 5 | 17 | 9 | 31 | 1 | 1322 | 65 | 1434 | 1218 | 91 | 4 | 99 | 84 | 5 | 0 | 7 | 5 |
| ENE10L | Weekday | 64 | 31 | 12 | 49 | 2 | 487 | 231 | 1122 | 10 | 31 | 12 | 49 | 2 | 951 | 231 | 1429 | 317 | 65 | 16 | 99 | 22 | 15 | 13 | 102 | 5 |
| ENE10L | Weekend | 23 | 17 | 9 | 31 | 1 | 115 | 65 | 221 | 5 | 17 | 9 | 31 | 1 | 1322 | 65 | 1434 | 1218 | 91 | 4 | 99 | 84 | 5 | 0 | 7 | 5 |

## Table 4ii. Summary Statistics for Evans Hall[10]

[9] LBNL reference: Chiron1f.xls
[10] LBNL reference: Evans2f-fc.xls

| floor | daytype | N | Day | | | | (minutes per day) | | | | Day | | | | (minutes per day) | | | | % Time in Standby Mode | | | | (minutes/cycle) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min |
| Lake02 | Weekday | 23 | 38 | 17 | 69 | 1 | 1189 | 329 | 1415 | 40 | 38 | 17 | 69 | 0 | 249 | 329 | 1399 | 24 | 16 | 22 | 97 | 1 | 41 | 37 | 190 | 11 |
| Lake02 | Weekend | 11 | 12 | 16 | 49 | 1 | 1140 | 338 | 1439 | 537 | 12 | 16 | 49 | 1 | 298 | 338 | 902 | 0 | 20 | 23 | 62 | 0 | 407 | 461 | 1418 | 27 |
| Lake03 | Weekday | 34 | 38 | 36 | 171 | 1 | 399 | 185 | 594 | 12 | 38 | 36 | 171 | 1 | 1039 | 185 | 1427 | 845 | 71 | 12 | 99 | 58 | 19 | 13 | 57 | 0 |
| Lake03 | Weekend | 15 | 14 | 29 | 116 | 1 | 123 | 195 | 515 | 0 | 14 | 29 | 116 | 1 | 1316 | 195 | 1439 | 924 | 90 | 13 | 99 | 64 | 9 | 8 | 28 | 0 |
| Lake04 | Weekday | 34 | 37 | 34 | 134 | 1 | 415 | 192 | 605 | 12 | 36 | 34 | 134 | 1 | 1023 | 192 | 1427 | 834 | 70 | 13 | 99 | 57 | 20 | 14 | 53 | 0 |
| Lake04 | Weekend | 14 | 14 | 33 | 129 | 1 | 97 | 172 | 503 | 0 | 14 | 33 | 129 | 1 | 1341 | 172 | 1439 | 936 | 92 | 11 | 99 | 65 | 9 | 8 | 31 | 0 |
| Lake05 | Weekday | 37 | 51 | 33 | 193 | 5 | 372 | 177 | 738 | 21 | 51 | 33 | 193 | 5 | 1066 | 177 | 1418 | 701 | 73 | 12 | 98 | 48 | 12 | 20 | 129 | 0 |
| Lake05 | Weekend | 12 | 2 | 1 | 6 | 1 | 19 | 20 | 66 | 0 | 2 | 1 | 6 | 1 | 1419 | 20 | 1439 | 1373 | 98 | 1 | 99 | 95 | 6 | 3 | 13 | 0 |
| Lake06 | Weekday | 30 | 12 | 7 | 31 | 3 | 26 | 27 | 83 | 0 | 12 | 7 | 31 | 3 | 1412 | 27 | 1439 | 1356 | 97 | 1 | 99 | 94 | 3 | 2 | 7 | 0 |
| Lake06 | Weekend | 9 | 8 | 6 | 22 | 1 | 19 | 21 | 50 | 0 | 8 | 6 | 22 | 1 | 1419 | 21 | 1439 | 1389 | 98 | 1 | 99 | 96 | 3 | 3 | 8 | 0 |
| Lake07 | Weekday | 32 | 38 | 29 | 93 | 8 | 224 | 185 | 589 | 7 | 38 | 29 | 93 | 8 | 1214 | 185 | 1432 | 850 | 83 | 12 | 99 | 59 | 8 | 9 | 51 | 0 |
| Lake07 | Weekend | 16 | 14 | 11 | 39 | 2 | 79 | 85 | 297 | 0 | 14 | 11 | 39 | 2 | 1359 | 85 | 1439 | 1142 | 93 | 5 | 99 | 79 | 6 | 4 | 21 | 0 |
| Lake08 | Weekday | 16 | 2 | 3 | 11 | 1 | 39 | 125 | 506 | 0 | 2 | 3 | 12 | 1 | 1399 | 125 | 1439 | 933 | 96 | 8 | 99 | 64 | 7 | 10 | 46 | 0 |
| Lake08 | Weekend | 6 | 3 | 3 | 11 | 1 | 14 | 26 | 68 | 0 | 3 | 3 | 11 | 1 | 1424 | 26 | 1439 | 1371 | 98 | 1 | 99 | 95 | 3 | 3 | 9 | 0 |
| Lake09 | Weekday | 14 | 2 | 3 | 14 | 1 | 6 | 5 | 20 | 0 | 2 | 3 | 14 | 1 | 1432 | 5 | 1439 | 1419 | 98 | 0 | 99 | 98 | 4 | 2 | 7 | 0 |
| Lake09 | Weekend | 6 | 3 | 1 | 6 | 1 | 6 | 5 | 15 | 0 | 3 | 1 | 6 | 1 | 1432 | 5 | 1439 | 1424 | 98 | 0 | 99 | 98 | 2 | 2 | 5 | 0 |
| Lake10 | Weekday | 21 | 7 | 8 | 35 | 1 | 6 | 8 | 28 | 0 | 7 | 8 | 35 | 1 | 1432 | 8 | 1439 | 1411 | 98 | 0 | 99 | 98 | 2 | 2 | 7 | 0 |
| Lake10 | Weekend | 8 | 4 | 7 | 23 | 1 | 4 | 3 | 9 | 0 | 4 | 7 | 23 | 1 | 1434 | 3 | 1439 | 1430 | 99 | 0 | 99 | 99 | 2 | 3 | 7 | 0 |
| Lake11 | Weekday | 31 | 23 | 16 | 54 | 1 | 146 | 142 | 500 | 0 | 23 | 16 | 54 | 1 | 1292 | 142 | 1439 | 939 | 89 | 9 | 99 | 65 | 4 | 5 | 29 | 0 |
| Lake11 | Weekend | 10 | 12 | 14 | 42 | 1 | 70 | 103 | 268 | 0 | 12 | 14 | 42 | 1 | 1368 | 103 | 1439 | 1171 | 94 | 7 | 99 | 81 | 4 | 2 | 8 | 0 |
| Lake12 | Weekday | 23 | 23 | 16 | 54 | 1 | 146 | 142 | 500 | 0 | 23 | 16 | 54 | 1 | 1292 | 142 | 1439 | 939 | 89 | 9 | 99 | 65 | 4 | 5 | 29 | 0 |
| Lake12 | Weekend | 7 | 12 | 14 | 42 | 1 | 70 | 103 | 268 | 0 | 12 | 14 | 42 | 1 | 1368 | 103 | 1439 | 1171 | 94 | 7 | 99 | 81 | 4 | 2 | 8 | 0 |

**Table 4iii. Summary Statistics for Alameda County GSA Building (Lakeside)[11]**

[11] LBNL reference: from Lakeside3.xls

| floor | daytype | N | Number of Switch Closures Per Day | | | | Accumulated CLOSED time (minutes per day) | | | | Number of Switch OPENs Per Day | | | | Accumulated OPEN time (minutes per day) | | | | % Time in Standby Mode | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min | Mean | STDev | Max | Min |
| SBC01 | Weekday | 9 | 41 | 6 | 51 | 34 | 352 | 52 | 433 | 282 | 41 | 6 | 51 | 34 | 1086 | 52 | 1157 | 1006 | 74 | 3 | 80 | 69 |
| SBC01 | Weekend | 6 | 18 | 10 | 29 | 1 | 128 | 78 | 222 | 6 | 18 | 10 | 30 | 1 | 1310 | 78 | 1433 | 1217 | 90 | 5 | 99 | 84 |
| SBC02 | Weekday | 20 | 35 | 5 | 46 | 26 | 342 | 101 | 656 | 241 | 35 | 5 | 46 | 26 | 1096 | 101 | 1198 | 783 | 75 | 7 | 83 | 54 |
| SBC02 | Weekend | 8 | 21 | 14 | 42 | 1 | 262 | 257 | 675 | 5 | 21 | 14 | 42 | 1 | 1176 | 257 | 1434 | 764 | 81 | 17 | 99 | 53 |
| SBC03 | Weekday | 22 | 31 | 5 | 43 | 15 | 312 | 101 | 630 | 128 | 31 | 5 | 43 | 15 | 1126 | 101 | 1311 | 809 | 77 | 7 | 91 | 56 |
| SBC03 | Weekend | 5 | 19 | 11 | 34 | 3 | 317 | 284 | 637 | 29 | 19 | 11 | 34 | 3 | 1121 | 284 | 1410 | 802 | 77 | 19 | 97 | 55 |
| SBC04 | Weekday | 18 | 36 | 9 | 57 | 14 | 359 | 109 | 647 | 138 | 36 | 9 | 57 | 14 | 1079 | 109 | 1301 | 792 | 74 | 7 | 90 | 55 |
| SBC04 | Weekend | 9 | 17 | 12 | 33 | 1 | 217 | 251 | 645 | 5 | 17 | 12 | 33 | 1 | 1222 | 251 | 1434 | 794 | 84 | 17 | 99 | 55 |
| SBC05 | Weekday | 20 | 28 | 7 | 45 | 10 | 207 | 91 | 494 | 72 | 28 | 7 | 45 | 10 | 1231 | 91 | 1367 | 945 | 85 | 6 | 94 | 65 |
| SBC05 | Weekend | 7 | 16 | 17 | 45 | 1 | 169 | 222 | 533 | 5 | 16 | 17 | 45 | 1 | 1269 | 222 | 1434 | 906 | 87 | 15 | 99 | 62 |
| SBC06 | Weekday | 22 | 26 | 7 | 44 | 9 | 194 | 85 | 470 | 65 | 26 | 7 | 44 | 9 | 1244 | 85 | 1374 | 969 | 86 | 5 | 95 | 67 |
| SBC06 | Weekend | 4 | 31 | 13 | 48 | 15 | 316 | 191 | 512 | 104 | 31 | 13 | 48 | 15 | 1122 | 191 | 1335 | 927 | 77 | 13 | 92 | 64 |
| SBC07 | Weekday | 19 | 23 | 6 | 33 | 9 | 160 | 51 | 247 | 55 | 23 | 6 | 33 | 9 | 1278 | 51 | 1384 | 1192 | 88 | 3 | 96 | 82 |
| SBC07 | Weekend | 6 | 23 | 14 | 46 | 6 | 168 | 111 | 339 | 35 | 23 | 14 | 46 | 6 | 1271 | 111 | 1404 | 1100 | 87 | 7 | 97 | 76 |
| SBC08 | Weekday | 19 | 23 | 13 | 73 | 5 | 180 | 113 | 544 | 27 | 23 | 13 | 72 | 5 | 1258 | 113 | 1412 | 895 | 86 | 7 | 98 | 62 |
| SBC08 | Weekend | 8 | 20 | 17 | 55 | 1 | 172 | 166 | 539 | 14 | 20 | 17 | 55 | 1 | 1266 | 166 | 1425 | 900 | 87 | 11 | 99 | 62 |
| SBC09 | Weekday | 19 | 45 | 22 | 87 | 14 | 255 | 115 | 456 | 89 | 45 | 22 | 87 | 14 | 1183 | 115 | 1350 | 983 | 81 | 7 | 93 | 68 |
| SBC09 | Weekend | 8 | 37 | 22 | 78 | 16 | 200 | 119 | 409 | 84 | 37 | 22 | 78 | 16 | 1238 | 119 | 1355 | 1030 | 85 | 8 | 94 | 71 |
| SBC10 | Weekday | 16 | 45 | 22 | 87 | 14 | 255 | 115 | 456 | 89 | 45 | 22 | 87 | 14 | 1183 | 115 | 1350 | 983 | 81 | 7 | 93 | 68 |
| SBC10 | Weekend | 8 | 37 | 22 | 78 | 16 | 200 | 119 | 409 | 84 | 37 | 22 | 78 | 16 | 1238 | 119 | 1355 | 1030 | 85 | 8 | 94 | 71 |

**Table 4iv. Summary Statistics for SBC Building[12]**

[12] LBNL reference: From SBC4.xls

As mentioned, Figures 4i-iv indicate the percent time in standby mode and corresponding number of daily switch events. It is important to note that 40 switch events is not uncommon on weekdays with one floor at one test site occasionally at 80 events per day.

These results are important to manufacturers of lighting equipment, since they show that rapid cycling is to be expected for these types of applications. Stairwell fixtures that turn a fluorescent lamp ON (rather than up to full from a dimmed level) when switched frequently will shorten lamp life considerably. To explore this effect further, LBNL plotted the likelihood of different ON cycles for the Evan Hall data. This data is plotted in Figure 11. It shows that while the number of cycles per day is often 5-10, 40 switch events a day are commonplace.

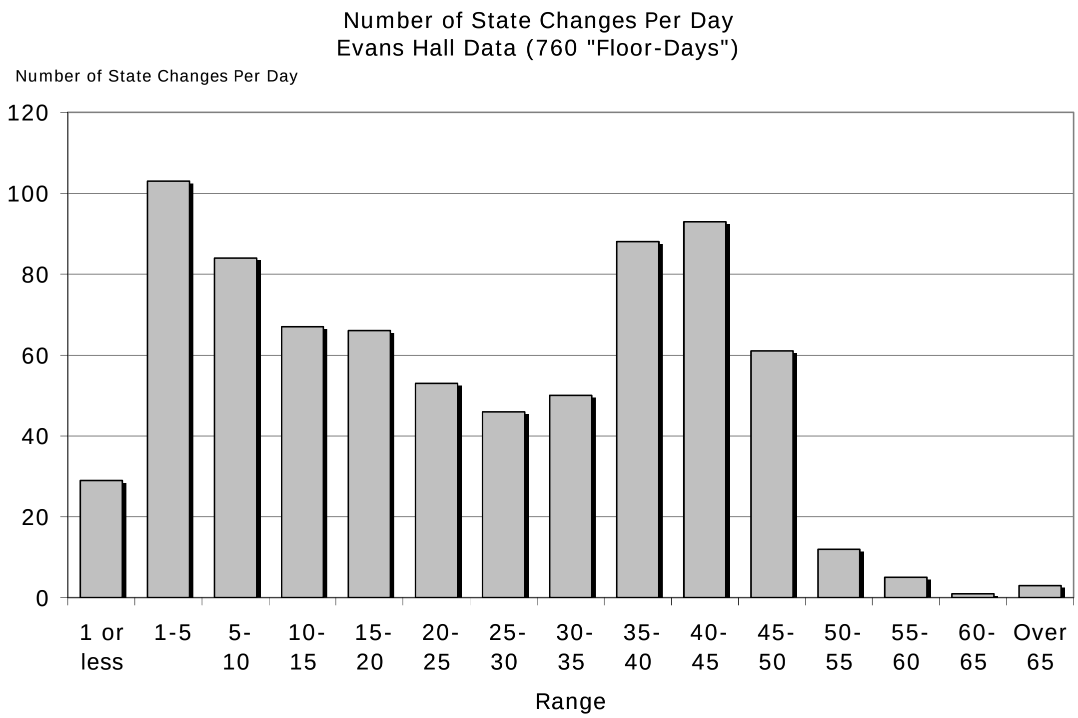



**Figure 11.** Number of “switch ON” events per day for 760 floor-days from the Evans Hall data.

## Discussion

The possible energy savings from bi-level fixtures is bounded by the standby level of the fixture chosen. If occupancy is zero, the lighting will stay at the standby level 100 percent of the time. Factors that affect occupancy, and thus energy use, include the building schedule (after-hours and weekend usage are lower in buildings that are unoccupied during these times), proximity of working groups that need to communicate between floors, and whether or not the stairwell is intended for interfloor use (the Alameda County stairwell was locked from the inside for security reasons, leaving occupants to use the elevator or the other stairwell). The proximity to amenities such as vending machines or other services can also affect local interfloor use.

In order to achieve savings from occupancy sensors, proper adjustment of the sensitivities and time delays is critical. If the sensitivity is too high, the sensors may pick up extraneous activities, and if the time delay is too short, the fixtures may cycle too quickly. One anomaly occurred in a building where a large fan was located adjacent to the upper floor of the stairwell. We believe the high apparent occupancy that was recorded was really just a measure of the constant fan vibrations. At the end of the project, the sensitivity of the sensors on the upper two floors of this building was set on the minimum level to compensate for this influence.

As noted in the introduction, lighting energy use in interior stairwells is typically unaffected by climate or location. Therefore, once the standby level is chosen, the occupancy pattern of a particular stairwell determines how much energy can be saved. Stairwells that see greater usage generally have less potential for savings from bi-level fixtures, but this depends on the timing of occupancy events as well as their actual number. When the usage is concentrated in short periods at the beginning of the day or at lunchtime, the total full-light period may be far less long than if the same number of occupants are spread out evenly throughout the day, because of the overlap of the occupant sensor time delay periods. Using the energy savings along with the electrical rate for the building, including any time-of-use scheduling, allows a building owner or operator to assess the value of an investment in this energy-saving technology.

## Conclusions

Bi-level stairwell fixtures saved between 38 and 49 percent of lighting energy on 24-hour weekdays, and between 47 and 67 percent on weekend days in the four buildings studied. The percentage of time in dimmed mode ranged from 62 to 82 percent during weekdays, and from 85 to 97 percent on weekends. The potential for energy savings from application of bi-level technologies to stairwells is in proportion to the very large number of stairwells in commercial US buildings.

| | Weekdays | | | | Weekends | | | |
|---|---|---|---|---|---|---|---|---|
| | % Time in Standby | | Energy Savings | | % Time in Standby | | Energy Savings | |
| | Low | High | Low | High | Low | High | Low | High |
| Evans | 32% | 72% | 21% | 48% | 51% | 97% | 34% | 65% |
| Lakeside | 70% | 98% | 47% | 66% | 90% | 98% | 60% | 66% |
| SBC | 74% | 88% | 50% | 59% | 77% | 90% | 52% | 60% |
| Chiron | 61% | 69% | 41% | 46% | 94% | 97% | 63% | 65% |

## Acknowledgements

This work was supported by the PIER LRP. This work was also supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

# USER EVAULATIONS

## Introduction

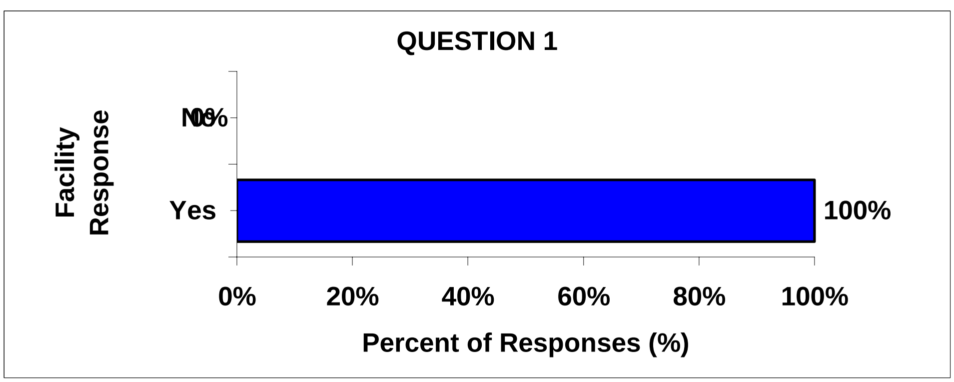
The Bi-level Stairwell Fixture Performance Project consisted of the installation of bi-level lighting fixtures with motion sensors in one stairwell of four buildings located in the Oakland-Berkeley-Emeryville area. The four buildings included a five-story research facility (Chiron), a ten-story classroom building (UC Berkeley - Evans Hall), an eleven-story office building (Alameda County) and a ten-story office building (SBC). The bi-level light fixtures replaced the existing fixtures located in the landings of the stairwells selected. The bi-level light fixture is normally on low-level at a reduced wattage but switches to high-level lighting whenever motion is detected in the stairwell. The high-level fixture switches back to low-level when no motion is detected after a predetermined set time period.

A facility survey was conducted with seven building managers and safety engineers on the four-project sites. An occupant survey was conducted with 29 users of the four project stairwells. A third survey was conducted was conducted with the project installing contractor and field investigator. The results of the surveys, along with the site managers, users, contractors and field investigator comments, are presented and summarized in this section.

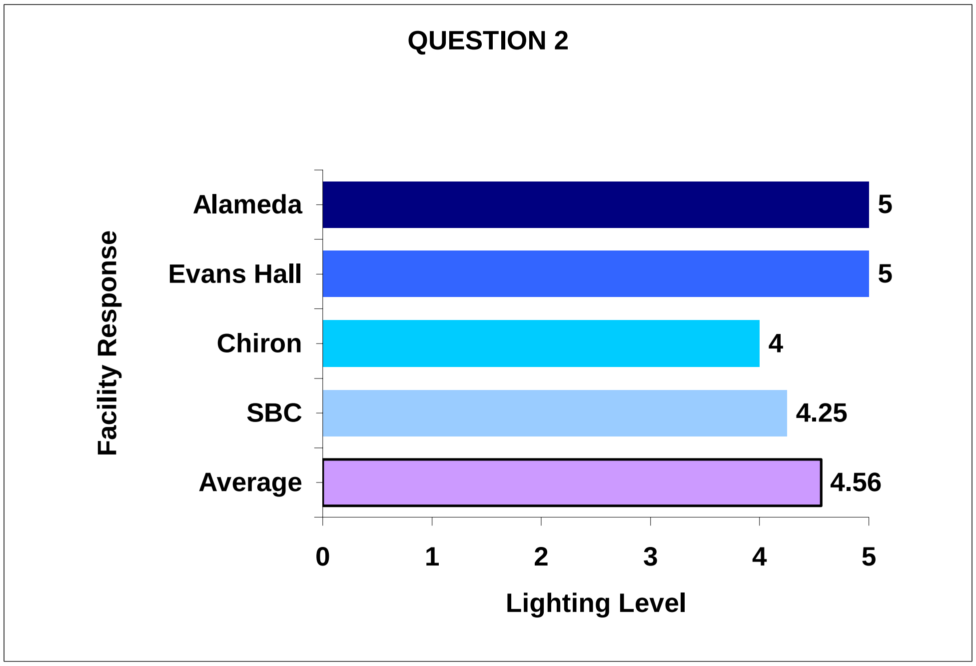
## Facility Manager Survey Results

The results of the facility manager survey involving seven building managers and safety engineers on the four-project sites are summarized in the following graphics.

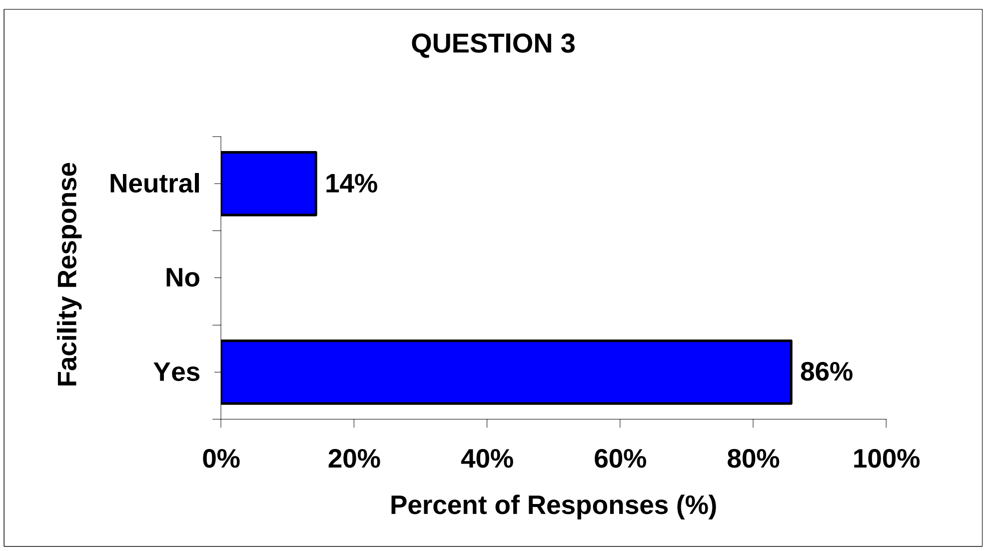
**1. Was the overall appearance of the fixtures acceptable?**




**2. Were the lighting levels sufficient in the stairwell? Please rate on a scale of 1-5 (with 1 being very poor lighting and 5 being very good lighting).**



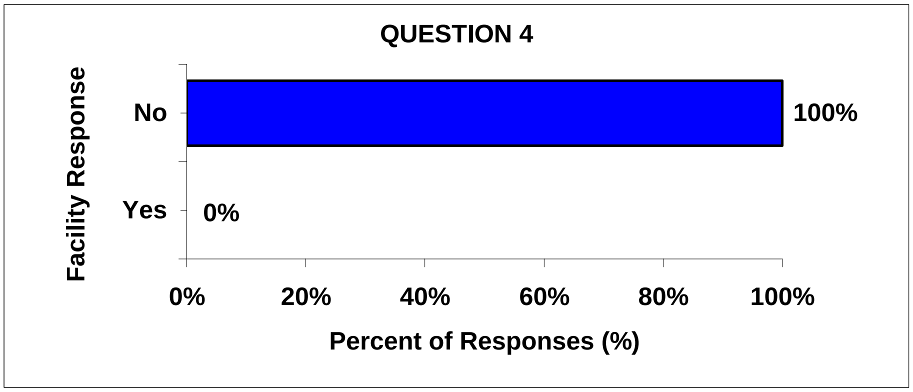

**3. Were the reaction times of the occupancy sensors, from low level to high level, sufficient?**



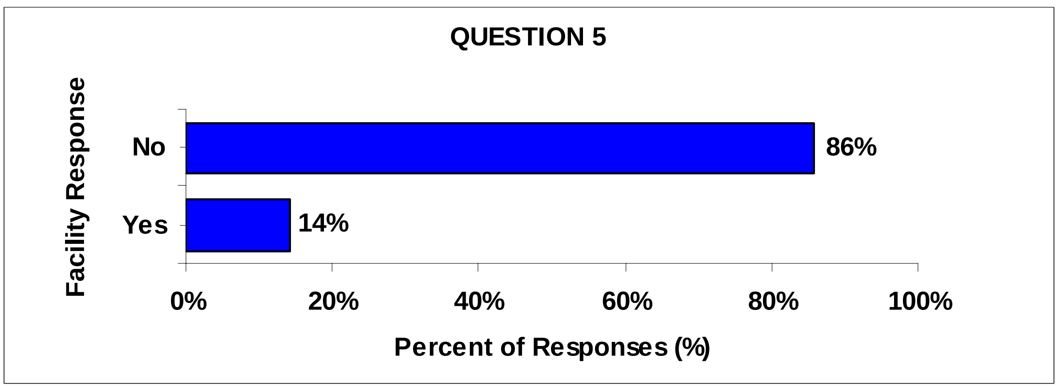

Facility manager comments:

1. Adjustments were needed.
2. Somewhat.

**4. Did the bi-level lighting keep you or anyone else from using the stairwell? If so, why?**



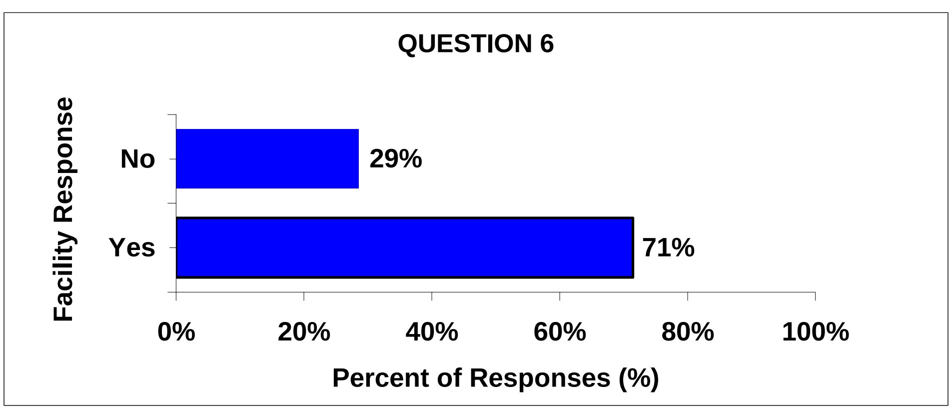

**5. Were there any malfunctions of the fixtures lamps, ballasts, etc, that required repairs? If so, what were they?**




Facility manager comments:

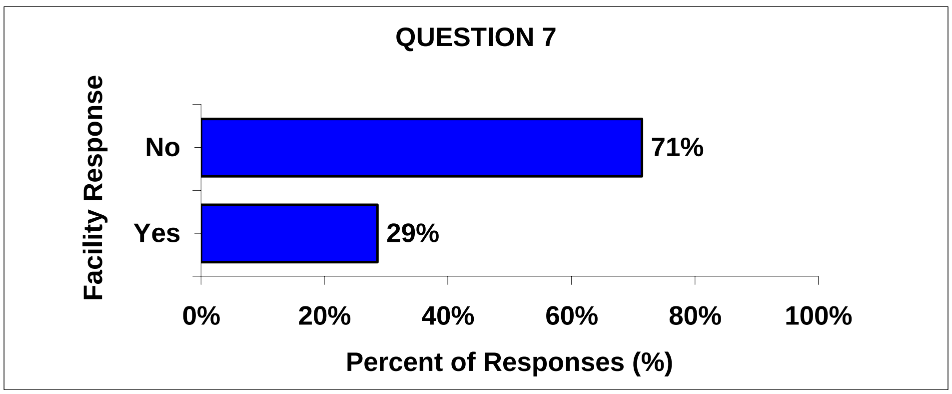
1. None after startup.
2. Time on High level had to be reset.

**6. Were you able to observe the low level lighting? If so, what are your thoughts on the light levels provided?**



Facility manager comments:
1. The low-level lighting would be adequate if the sensor failed on one or two fixtures.
2. Low-level lighting was equivalent to the constant level lighting provided by original fixtures.
3. More energy savings could be achieved with lower setting on low-level.
4. Low-level lighting provided sufficient light.

**7. Would you change anything about the installation, such as fixture appearance, fixture construction, occupancy sensor reaction times, etc? If yes, what would you change?**

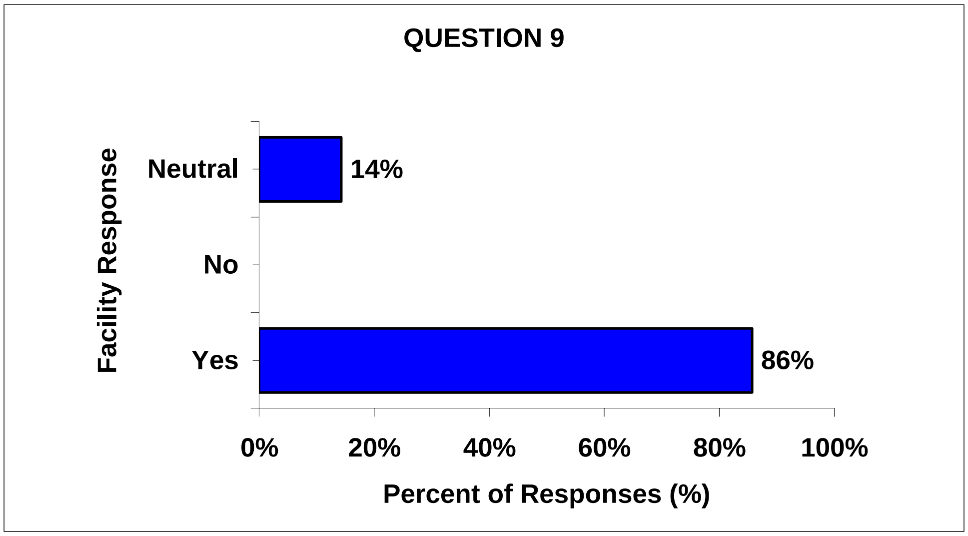



Facility manager comments:
1. I would use a standard straight lamp in lieu of “U” type lamp installed on project.
2. Brighter stairway.

**8. What is your overall opinion of the project and the potential for saving energy? Please elaborate.**

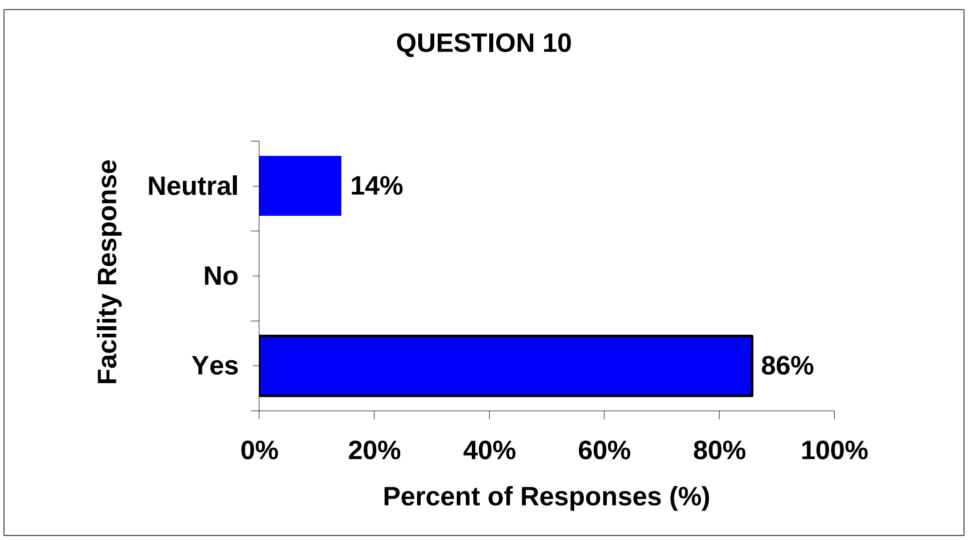
Facility manager comments:
1. Very Good. We would like to apply to our building underground garage.
2. Interesting project. Would like to see final energy analysis or research project.
3. A stairwell that was used less would benefit more. Could benefit even more by turning lights off when natural light is available through windowed stairwells.
4. Excellent plan to save money.

**9. Would you recommend bi-level lighting in other stairwells at your site or to other colleagues at their facilities?**



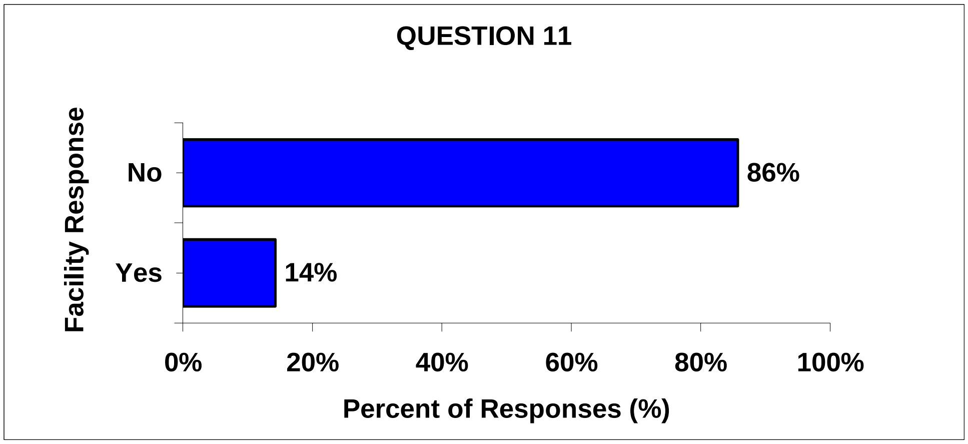

Facility manager comments:
1. I first would want to see the final energy analysis.
2. I would suggest it for new construction, if it fit the style of the stairwell.

**10. Do you think, by using bi-level stairwell lighting energy can be saved?**




Facility manager comments:
1. I first would want to see the final energy analysis.
2. Small amount.

**11. Do you have any other concerns about the bi-level stairwell lighting not mentioned above?**



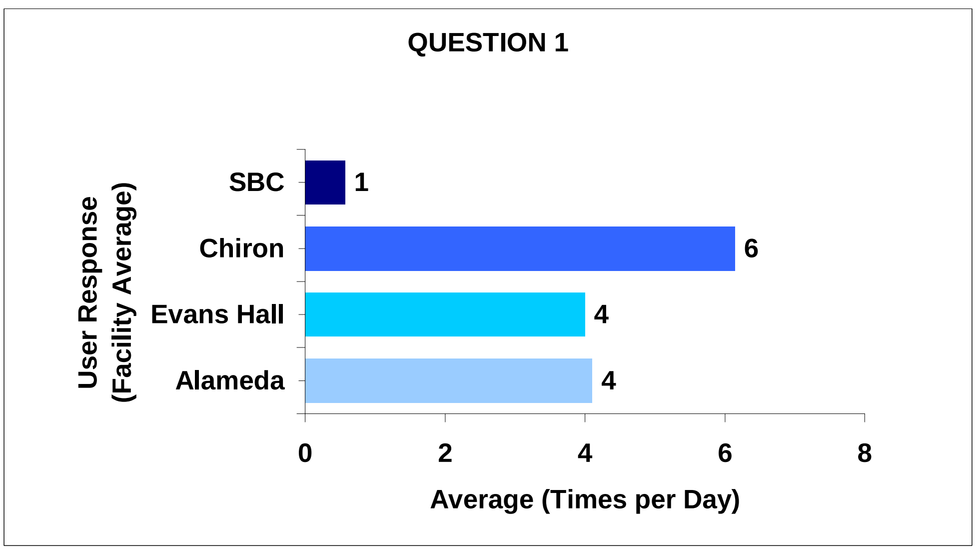

Facility manager comments:

1. I wonder about fixture components failure rate 2-3-5 years from now.

## Building User Survey Results

The results of the occupant survey, which was conducted with 29 users of the four project stairwells, is summarized in the following graphics.

**1. Do you use the stairwells? If so, on average, how many times a day do you use them?**

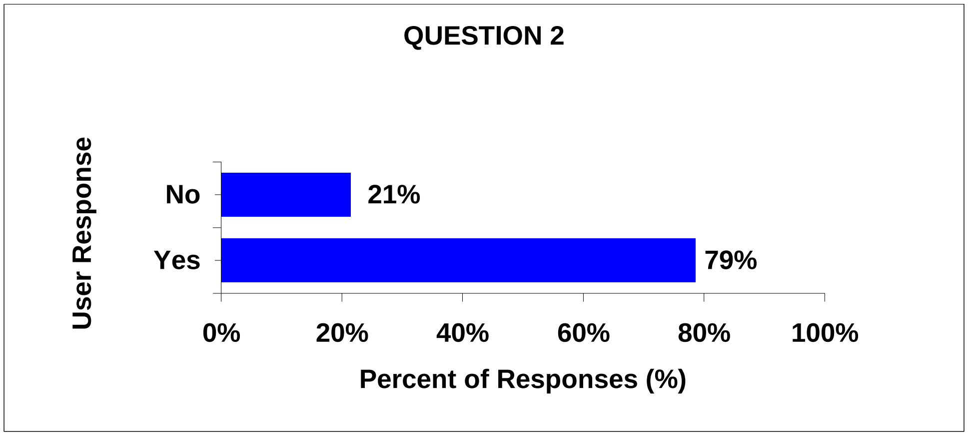



Individual user comments:

1. Once every two weeks.

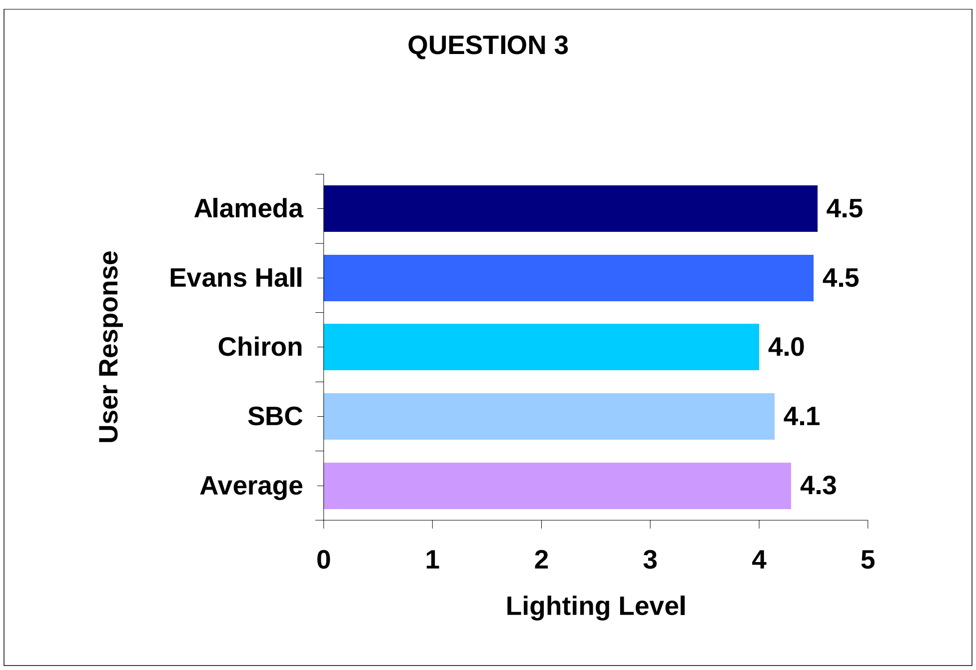
2. Few times per year.
3. Often.
4. One to three times per week.

**2. Have you noticed a change in the stairwell lighting?**

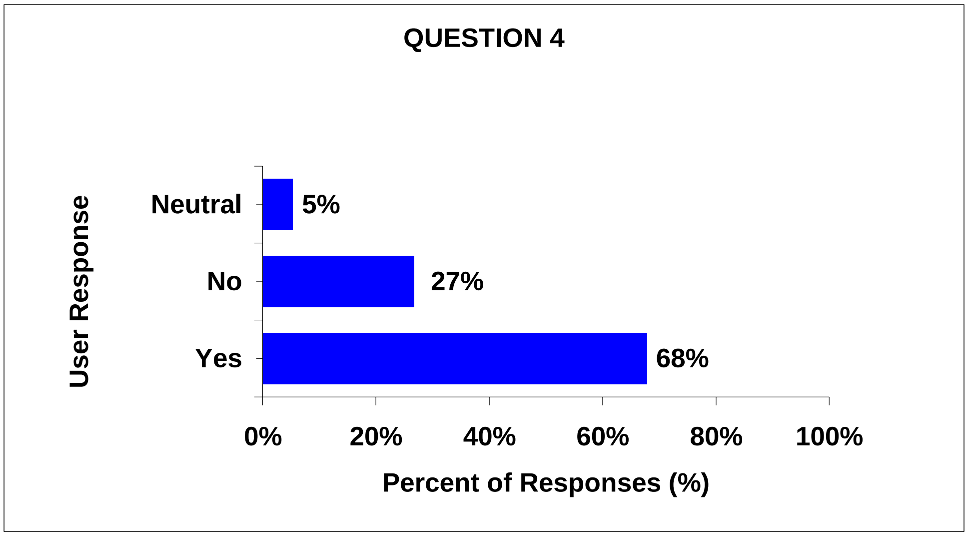



Individual user comments:
1. Stairwell was brighter.
2. Not much change.

**3. Were the lighting levels sufficient in the stairwell? Please rate on a scale of 1-5 (with 1 being very poor lighting and 5 being very good lighting).**

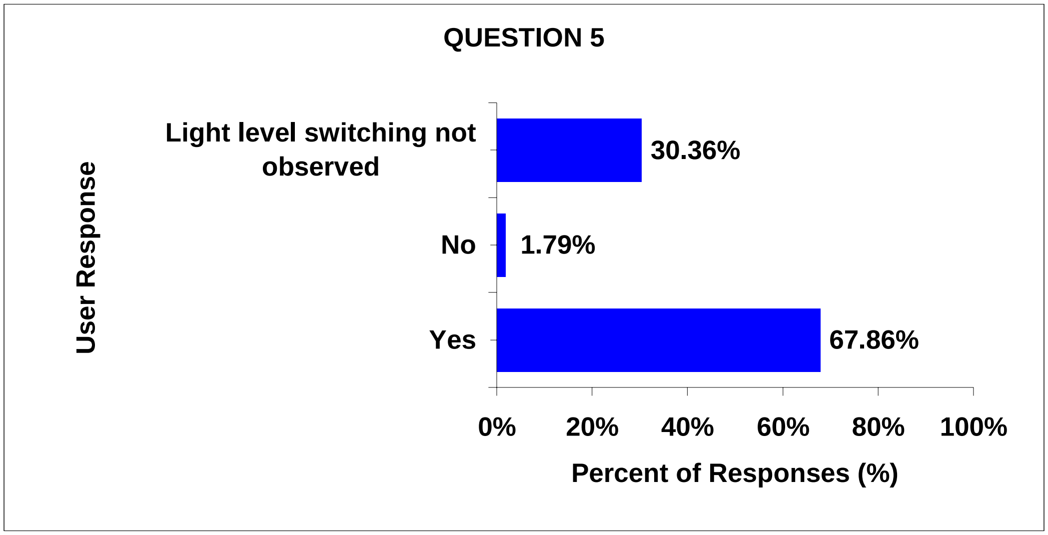


**4. The stairwell lighting level switches from low level to high level automatically whenever someone enters a stairwell. Did you notice the switching from low level to high level upon entering the stairwell?**



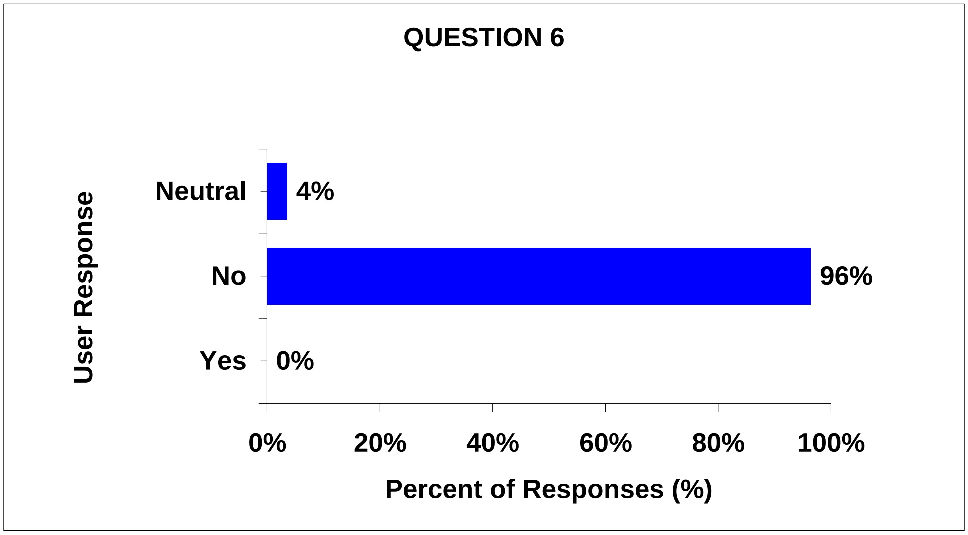

Individual user comments:
1. Not Sure.
2. Barely.
3. No Response.

5. **WERE YOU SATISFIED WITH THE SPEED AT WHICH THE LIGHT LEVELS WERE INCREASED?**




Individual user comments:
1. Too slow.
2. Question not Applicable based on “No” answer to question number 4.

6. **DID THE LIGHTING KEEP YOU OR ANYONE ELSE FROM USING THE STAIRWELL? IF SO, WHY?**




Individual user comments:
1. Needs to be brighter.

### Comments and Observations from Project Installer and Field Investigator

A third survey was conducted was conducted with the project installing contractor and field investigator. Comments are summarized below.

Prior to the installation at the four sites, a determination on whether building permits for the lighting change-out by the local building department was required. Only one of the four sites required a permit for which construction documents were submitted to the local building department and approved. Secondly, a staging area needed to be established at each site for delivery of the lighting fixtures as well as a common place from which to assemble equipment. Once a site staging area was determined and the lighting fixtures and equipment were delivered to the staging area, the installation by the contractor for each site would commence. The motion sensor manufacturers discovered a problem that required reprogramming of the motion sensors prior to the start of the first installation and after the lighting fixtures were delivered to the first two sites. The reprogramming of the motion sensors took place in the staging area of the first two sites, while the motion sensors for the remaining two sites were reprogrammed at the lighting manufacturer plant prior to delivery[13].

The first installation was done at Evans Hall on the campus of UC Berkeley. This first installation set up the installation approach to be taken for the remaining three sites, which included locating power and emergency lighting circuits, mounting of the lighting fixtures and equipment, and setting the fixtures' motion sensor sensitivity. The average

[13] NDC Field Reports 01 8-26-03 and 02 0-8-03, Newport Design Company

time to install a lighting fixture at this site was approximately 50 minutes, not including the removal of the old lighting fixture. A few minor problems with noise occurred during the installation at Evans Hall because classes were in session. A stealth approach was initiated during this installation. The installations at the remaining three sites were straightforward with no problems and an install time of 30-35 minutes per lighting fixture.

The following site observations were made:

1. The sensitivity on some of the motion sensors at the Evans Hall site did not switch from low to high level until midway between the floor landing and the between floors intermediate landing. Although light levels were good at low-level on the intermediate landing the motion sensor should have switched from low-level to high-level when motion was sensed on the floor landing.

2. At the Alameda and SBC sites, the lighting level switched from low to high level when vibrations were sensed through the metal decking on the floor above.

3. At the Alameda site, one of the lighting fixtures, upon entrance to the stairwell, did not switch from low-level to high-level by motion of the stairwell door opening. The motion of the door opening should have been sensed and triggered the low-high switching. This fixture did not switch from low-level to high-level until sensed by a person stepping into the stairwell.

In the observations indicated above, adjustments to the motion sensors were required.

After initial calibration, motion sensors were recalibrated by The Watt Stopper (motion sensor manufacturer) at the Chiron and Evans Hall locations and by research staff at the Alameda and SBC installations on some floors. The installer gained experience as he installed more fixtures, and the later installations went more smoothly than the earlier ones. Better markings to indicate time delay and sensitivity on the two trim pots would make it easier for first-time installers to complete a successful installation.

# PRODUCT ECONOMICS

## The Product

Occu-Smart is a product line of unique bi-level fixtures that operate either at a low standby light level or instantly go to full light output when occupancy is detected by an integral ultra-sonic motion sensor.

This product is ideal for stairwells, restrooms, laundry rooms or other areas where codes, building user preferences, safety, or security call for minimal light levels during unoccupied periods and full light output during occasional occupied periods. These fixtures provide maximum illumination when needed but conserve significant amounts of energy by dimming when not needed.

Product features include:

- High quality1-lamp or 2-lamp fixtures in 120V or 277V models.
- Linear ribbed acrylic lenses or prismatic lenses with linear reflective sides.
- Watt Stopper high frequency, extremely sensitive ultra-sonic motion sensor mounted internally.
- Bi-level, step-down ballasts to 5%, 10%, or 33% of full light output, reducing power at standby to 7-14 Watts depending on fixture configuration.
- 100-hour lamp conditioning circuit to assure long lamp life.
- Adjustable dwell time at full-on from 15 seconds to 30 minutes.
- Options available for vandal resistance or emergency operations. Fixtures with battery packs are UL listed as “emergency lighting and power equipment” and can be used instead of the common “headlamp” emergency backup lights.
- 5-year factory warranty on all ballasts and sensor components.
- All fixtures are U.L. listed and IBEW union made.
- Easy 2-wire installation.
- Multiple “knockout” openings to facilitate any new or retrofit application.

## Product Configurations

This fixture is designed to be used in applications where occupancy is infrequent but minimum light levels are desired so that occupants will feel comfortable entering the space. For this analysis, we will focus on stairwell applications.

The chart below indicates the most common configurations of fixtures, voltages, lamp sizes, and lamp types. The new bi-level fixture is also appropriate for both new and retrofit applications. Because T12 lamps are being phased out by law, they are not considered a viable base case alternative for new buildings. However, there are many old buildings where these fixtures have been used.

| Configuration | | | 120 Volt | | 277 Volt | |
|---|---|---|---|---|---|---|
| | | | New | Retrofit | New | Retrofit |
| **4 foot** | **1-Lamp** | T12 | NA | ** | NA | ** |
| | | T8 | ** | ** | ** | ** |
| **4 foot** | **2-Lamp** | T12 | NA | ** | NA | ** |
| | | T8 | ** | ** | ** | ** |
| **2 Foot** | **1-Ulamp** | T12 | NA | ** | NA | ** |
| | | T8 | ** | ** | ** | ** |
| **2 Foot** | **2-Lamp** | T12 | NA | | NA | |
| | | T8 | | | | |

**Economic analysis provided in this report.

### Supplier's Product Costs and Price

LaMar lighting is currently manufacturing a limited line of bi-level stairwell fixtures. The line is limited because multi-level ballasts are not currently available for all step-down percentages desired and are not always available for both 120V and 277V applications.

The following table illustrates the fixture/lamp/ballast/voltage combinations that are available and the manufacturer's list price as of September 15, 2003. These list prices are, of course, subject to change over time. Prices shown include estimates for dealer/distributor markup. It should be noted that a notice of price increases by LaMar was received in late October 2004.

| Configuration | | 120 Volts | | | 277 Volts | | |
|---|---|---|---|---|---|---|---|
| | | **33%** | **10%** | **5%** | **33%** | **10%** | **5%** |
| **4 Foot** | **1-Lamp** | $163.45 | ** | $186.95 | $163.45 | ** | $186.95 |

| Configuration | | 120 Volts | | | 277 Volts | | |
|---|---|---|---|---|---|---|---|
| | | 33% | 10% | 5% | 33% | 10% | 5% |
| 4 Foot | 2-Lamp | $163.45 | $172.25 | $186.95 | $163.45 | ** | $186.95 |
| 2 Foot | U-Lamp | $158.70 | ** | $180.60 | $158.70 | ** | $180.60 |
| 2 Foot | 2 Lamp | ** | ** | $182.25 | ** | ** | $182.25 |

**Not Available  Note: Prices are for 40 fixtures or more in a single shipment.

### Consumer's Installation-Related Costs

In retrofit applications the total cost of installation must include the full cost of the replacement fixture, the cost of removing the old fixtures and installing the new one, and the cost of disposing of the old fixture.

In a new application, the cost of the "old" fixture that would have been used is replaced by the cost of the new fixture. There is only a small incremental increase in cost. The cost of labor to install either is basically the same. There is also no disposal cost for a replaced fixture. Thus, new applications are more cost effective and have a faster payback than retrofit applications because one can take full credit for the fixture not used.

### Effects on Non-Energy Operations & Maintenance Cost

There is an important difference between the step-down function used in the LaMar bi-level fixture and fixtures that are simply turned off and on by a motion sensor. In the LaMar fixture, lamps are dimmed but power is not turned completely off. Therefore, when stairwell occupancy calls for full light output from the fixture, the ballast simply steps back up to full power. Note: it does not restart. It is starting that shortens lamp life. LaMar estimates that keeping lamps on full time can extend lamp life by as much as one- third.

It will be several years before actual field experience can confirm these estimates of extended lamp life. However, it is safe to say that bi-level fixtures are unlikely to have a negative impact on lighting maintenance by decreasing lamp life. In fact, it may have a significant positive benefit. In the analysis that follows, no credit is taken for extended lamp life at this time.

### Energy and Demand Savings Potential

Bi-level fixtures save energy by stepping down power during the many hours of a day when the space is unoccupied. It is estimated by LaMar Lighting that unoccupied periods in typical stairwells are about 95% of the time. This estimate will be tested by LBNL in the monitoring they are doing for this project.

The analysis presented at the end of this section looks carefully at all three wattages of interest:

- Wattage per hour for the “old” fixture being replaced.
- Wattage per hour for the “new” bi-level fixture at full power when the stairwell is occupied.
- Wattage per hour when the bi-level fixture steps-down during unoccupied periods.

It is also important to track energy use by lamp type. If the retrofit fixture being replaced is using old T12 lamps with high energy use, there will be an initial savings just for installing efficient T8 lamps in the new fixtures. Then add energy savings due to stepping down power for lighting during unoccupied periods.

Remember that these bi-level fixtures reduce both peak energy demand and energy consumption. Because these fixtures are on 24 hours per day, both types of energy saving are significant. If your energy supplier puts a particular premium on either type of electricity use, it may be beneficial to redo this cost benefit analysis by calculating demand(kW) reductions and energy consumption(kWh) separately.

### Non-Energy Benefits to Consumer

Because of the very unfortunate events of 9/11/01, the importance of lighting stairwells for safe emergency egress under extreme conditions has gotten increased attention from both building owners and property insurance companies. Many emergency preparedness experts are questioning whether current minimum light levels called for in life safety codes are really sufficient for emergency egress situations—especially where smoke may be a factor. This bi-level stairwell fixture has the potential to significantly increase light levels in stairwells when needed, yet keeping energy costs low.

Other possible non-energy benefits include the ability to avoid a scheduled group relamping or the opportunity to take rapid depreciation on a capital improvement. If a leasee pays for a fixture replacement of this type, it is possible to argue that the period of depreciation cannot be longer than the remaining lease period. (For details, be sure to ask you’re professional tax advisor.)

### Payback Period and Return on Investment

A fixture with a “brain”—the ability to sense occupancy and control light levels as a result—will always cost more than a standard construction-grade fixture. At present, the Occu-smart fixture is roughly three times more expensive than a standard fixture. In spite of the relative high cost, energy savings are so great that paybacks can be instantaneous against old T12 fixtures and under 5 years against better T8 fixtures.

If by further product improvements, value engineering, and the advent of cheaper multi-step ballasts, the cost of this bi-level fixture can be reduced to just double the cost of a "non-smart" conventional fixture, payback periods would be cut about in half and the bi-level fixture would be the obvious choice in virtually every building.

***The Bottom Line: Net Economic Benefit-Investor Owned Utility District-15.5¢/kWh***

| Base Case Fixture | New or Retrofit Bi-Level Fixture | Base Cost New Technology | Old Fixture Watts | New Fixture Watts | Level-2 Watts | Average Watts | Average kW Saved | kWhr saved per year | Yearly Savings |
|---|---|---|---|---|---|---|---|---|---|
| **Investor Owned Utility Districts $.155/kWh** | | | | | | | | | |
| **Product 1: 10% Standby (120V only)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8 (4ft)10% | $172.25 | 90 | 62 | 13 | 15.5 | 0.075 | 653.058 | $101.22 |
| (1) F40T12 (4ft) | (2)F32T8(4ft)10% | $172.25 | 50 | 62 | 13 | 15.5 | 0.035 | 302.658 | $46.91 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)10% | $172.25 | 62 | 62 | 13 | 15.5 | 0.047 | 407.778 | $63.21 |
| (1) F32T8 (4ft) | (2)F32T8(4ft)10% | $172.25 | 32 | 62 | 13 | 15.5 | 0.017 | 144.978 | $22.47 |
| **Product 2: 33% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)33% | $163.45 | 90 | 62 | 28 | 29.7 | 0.060 | 528.228 | $81.88 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)33% | $163.45 | 50 | 32 | 14 | 14.9 | 0.035 | 307.476 | $47.66 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)33% | $158.70 | 56 | 32 | 14 | 14.9 | 0.041 | 360.036 | $55.81 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)33% | $163.45 | 62 | 62 | 28 | 29.7 | 0.032 | 282.948 | $43.86 |
| (2) F32T8 (4ft) | (1) F32T8 (4ft)33% | $163.45 | 62 | 32 | 14 | 14.9 | 0.047 | 412.596 | $63.95 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)33% | $163.45 | 32 | 32 | 14 | 14.9 | 0.017 | 149.796 | $23.22 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)33% | $158.70 | 34 | 32 | 14 | 14.9 | 0.019 | 167.316 | $25.93 |
| **Product 3: 5% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)5% | $186.95 | 90 | 62 | 13 | 15.5 | 0.075 | 653.058 | $101.22 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)5% | $186.95 | 50 | 32 | 8 | 9.2 | 0.041 | 357.408 | $55.40 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)5% | $182.25 | 56 | 32 | 8 | 9.2 | 0.047 | 409.968 | $63.55 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)5% | $186.95 | 62 | 62 | 13 | 15.5 | 0.047 | 407.778 | $63.21 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)5% | $186.95 | 32 | 32 | 8 | 9.2 | 0.023 | 199.728 | $30.96 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)5% | $182.25 | 34 | 32 | 8 | 9.2 | 0.025 | 217.248 | $33.67 |

***Assumptions used in the "Net Economic Benefit" table above:***

- Base cost of the standard technology (construction grade fixture): $60.00.
- Expected life of the new bi-level fixture: 15 years.
- Labor cost for the retrofit application (remove and replace): $50.00.
- Rebate or other incentive payment: none.
- Average electricity rate (demand and consumption): **15.5¢/kWh**.
- Time new fixture is on at full power: 5%.
- Time new fixture is on at minimum (stepped down) power: 95%.
- Total hours fixture is on per day: 24.
- Total days per year fixture is on: 365.

***Payback and Avoided Cost—Investor Owned Utility District***

| Base Case Fixture | New or Retrofit Bi-Level Fixture | Avoided Costs | Direct Payback (New) | Direct Payback (Retrofit) | Optimal Direct Payback | Optimal Cost (New) | Cost Gap (New) | Optimal Cost (Retrofit) | Cost Gap (Retrofit) |
|---|---|---|---|---|---|---|---|---|---|
| **Investor Owned Utility Districts $.155/kWh** | | | | | | | | | |
| **Product 1: 10% Standby (120V only)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8 (4ft)10% | $457.35 | N/A | 2.20 | 2.5 | N/A | N/A | $203.06 | -$30.81 |
| (1) F40T12 (4ft) | (2)F32T8(4ft)10% | $211.96 | N/A | 4.74 | 2.5 | N/A | N/A | $67.28 | $104.97 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)10% | $285.57 | 1.78 | 3.52 | 2.5 | $218.01 | -$45.76 | $108.01 | $64.24 |
| (1) F32T8 (4ft) | (2)F32T8(4ft)10% | $101.53 | 5.00 | 9.89 | 2.5 | $116.18 | $56.07 | $6.18 | $166.07 |
| **Product 2: 33% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)33% | $369.93 | N/A | 2.61 | 2.5 | N/A | N/A | $154.69 | $8.76 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)33% | $215.33 | N/A | 4.48 | 2.5 | N/A | N/A | $69.15 | $94.30 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)33% | $252.14 | N/A | 3.74 | 2.5 | N/A | N/A | $89.51 | $69.19 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)33% | $198.15 | 2.36 | 4.87 | 2.5 | $169.64 | -$6.19 | $59.64 | $103.81 |
| (2) F32T8 (4ft) | (1) F32T8 (4ft)33% | $288.95 | 1.62 | 3.34 | 2.5 | $219.88 | -$56.43 | $109.88 | $53.57 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)33% | $104.90 | 4.46 | 9.19 | 2.5 | $118.05 | $45.40 | $8.05 | $155.40 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)33% | $117.17 | 3.81 | 8.05 | 2.5 | $124.83 | $33.87 | $14.83 | $143.87 |
| **Product 3: 5% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)5% | $457.35 | N/A | 2.34 | 2.5 | N/A | N/A | $203.06 | -$16.11 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)5% | $250.30 | N/A | 4.28 | 2.5 | N/A | N/A | $88.50 | $98.45 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)5% | $287.11 | N/A | 3.65 | 2.5 | N/A | N/A | $108.86 | $73.39 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)5% | $285.57 | 2.01 | 3.75 | 2.5 | $218.01 | -$31.06 | $108.01 | $78.94 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)5% | $139.87 | 4.10 | 7.65 | 2.5 | $137.39 | $49.56 | $27.39 | $159.56 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)5% | $152.14 | 3.63 | 6.90 | 2.5 | $144.18 | $38.07 | $34.18 | $148.07 |

***Assumptions used in the "Payback and Avoided Cost" table above:***

- All assumptions from the previous table (Net Economic Benefit) apply here.
- Net present value of a kWh: $0.70.
- Optimal period for a direct payback: 2.5 years.

***The Bottom Line: Net Economic Benefit--Municipal Utility District-10.5¢/kWh***

| Base Case Fixture | New or Retrofit Bi-Level Fixture | Base Cost New Technology | Old Fixture Watts | New Fixture Watts | Level-2 Watts | Average Watts | Average kW Saved | kWhr saved per year | Yearly Savings |
|---|---|---|---|---|---|---|---|---|---|
| **Municipal Utility Districts $.105/kWh** | | | | | | | | | |
| **Product 1: 10% Standby (120V only)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8 (4ft)10% | $172.25 | 90 | 62 | 13 | 15.5 | 0.075 | 653.058 | $68.57 |
| (1) F40T12 (4ft) | (2)F32T8(4ft)10% | $172.25 | 50 | 62 | 13 | 15.5 | 0.035 | 302.658 | $31.78 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)10% | $172.25 | 62 | 62 | 13 | 15.5 | 0.047 | 407.778 | $42.82 |
| (1) F32T8 (4ft) | (2)F32T8(4ft)10% | $172.25 | 32 | 62 | 13 | 15.5 | 0.017 | 144.978 | $15.22 |
| **Product 2: 33% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)33% | $163.45 | 90 | 62 | 28 | 29.7 | 0.060 | 528.228 | $55.46 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)33% | $163.45 | 50 | 32 | 14 | 14.9 | 0.035 | 307.476 | $32.28 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)33% | $158.70 | 56 | 32 | 14 | 14.9 | 0.041 | 360.036 | $37.80 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)33% | $163.45 | 62 | 62 | 28 | 29.7 | 0.032 | 282.948 | $29.71 |
| (2) F32T8 (4ft) | (1) F32T8 (4ft)33% | $163.45 | 62 | 32 | 14 | 14.9 | 0.047 | 412.596 | $63.95 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)33% | $163.45 | 32 | 32 | 14 | 14.9 | 0.017 | 149.796 | $15.73 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)33% | $158.70 | 34 | 32 | 14 | 14.9 | 0.019 | 167.316 | $25.93 |
| **Product 3: 5% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)5% | $186.95 | 90 | 62 | 13 | 15.5 | 0.075 | 653.058 | $68.57 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)5% | $186.95 | 50 | 32 | 8 | 9.2 | 0.041 | 357.408 | $37.53 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)5% | $182.25 | 56 | 32 | 8 | 9.2 | 0.047 | 409.968 | $43.05 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)5% | $186.95 | 62 | 62 | 13 | 15.5 | 0.047 | 407.778 | $42.82 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)5% | $186.95 | 32 | 32 | 8 | 9.2 | 0.023 | 199.728 | $20.97 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)5% | $182.25 | 34 | 32 | 8 | 9.2 | 0.025 | 217.248 | $33.67 |

***Assumptions used in the "Net Economic Benefit" table above:***

- Base cost of the standard technology (construction grade fixture): $60.00.
- Expected life of the new bi-level fixture: 15 years.
- Labor cost for the retrofit application (remove and replace): $50.00.
- Rebate or other incentive payment: none.
- Average electricity rate (demand and consumption): **10.5¢/kWh.**
- Time new fixture is on at full power: 5%.
- Time new fixture is on at minimum (stepped down) power: 95%.
- Total hours fixture is on per day: 24.
- Total days per year fixture is on: 365.

***Payback and Avoided Cost—Municipal Utility District***

| Base Case Fixture | New or Retrofit Bi-Level Fixture | Avoided Costs | Direct Payback (New) | Direct Payback (Retrofit) | Optimal Direct Payback | Optimal Cost (New) | Cost Gap (New) | Optimal Cost (Retrofit) | Cost Gap (Retrofit) |
|---|---|---|---|---|---|---|---|---|---|
| **Municipal Utility Districts $.105/kWh** | | | | | | | | | |
| **Product 1: 10% Standby (120V only)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8 (4ft)10% | $457.35 | N/A | 3.24 | 2.5 | N/A | N/A | $121.43 | $50.82 |
| (1) F40T12 (4ft) | (2)F32T8(4ft)10% | $211.96 | N/A | 6.99 | 2.5 | N/A | N/A | $29.45 | $142.80 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)10% | $285.57 | 2.62 | 5.19 | 2.5 | $167.04 | $5.21 | $57.04 | $115.21 |
| (1) F32T8 (4ft) | (2)F32T8(4ft)10% | $101.53 | 7.37 | 14.60 | 2.5 | $98.06 | $74.19 | -$11.94 | $184.19 |
| **Product 2: 33% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)33% | $369.93 | N/A | 3.85 | 2.5 | N/A | N/A | $88.66 | $74.79 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)33% | $215.33 | N/A | 6.61 | 2.5 | N/A | N/A | $30.71 | $132.74 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)33% | $252.14 | N/A | 5.52 | 2.5 | N/A | N/A | $44.51 | $114.19 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)33% | $198.15 | 3.48 | 7.18 | 2.5 | $134.27 | $29.18 | $24.27 | $139.18 |
| (2) F32T8 (4ft) | (1) F32T8 (4ft)33% | $288.95 | 1.62 | 3.34 | 2.5 | $219.88 | -$56.43 | $109.88 | $53.57 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)33% | $104.90 | 6.58 | 13.57 | 2.5 | $99.32 | $64.13 | -$10.68 | $174.13 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)33% | $117.17 | 3.81 | 8.05 | 2.5 | $124.83 | $33.87 | $14.83 | $143.87 |
| **Product 3: 5% Standby (120V or 277V)** | | | | | | | | | |
| (2) F40T12 (4ft) | (2)F32T8(4ft)5% | $457.35 | N/A | 3.46 | 2.5 | N/A | N/A | $121.43 | $65.52 |
| (1) F40T12 (4ft) | (1)F32T8(4ft)5% | $250.30 | N/A | 6.31 | 2.5 | N/A | N/A | $43.82 | $143.13 |
| (2) F20T12 (2ft) | 1T8Ulamp(2ft)5% | $287.11 | N/A | 5.40 | 2.5 | N/A | N/A | $57.62 | $124.63 |
| (2) F32T8 (4ft) | (2)F32T8(4ft)5% | $285.57 | 2.96 | 5.53 | 2.5 | $167.04 | $19.91 | $57.04 | $129.91 |
| (1) F32T8 (4ft) | (1)F32T8(4ft)5% | $139.87 | 6.05 | 11.30 | 2.5 | $112.43 | $74.52 | $2.43 | $184.52 |
| (2) F17T8 (2ft) | 1T8Ulamp(2ft)5% | $152.14 | 3.63 | 6.90 | 2.5 | $144.18 | $38.07 | $34.18 | $148.07 |

***Assumptions used in the "Payback and Avoided Cost" table above:***

- All assumptions from the previous table (Net Economic Benefit) apply here.
- Net present value of a kWh: $0.70.
- Optimal period for a direct payback: 2.5 years.

***Key Findings from Savings and Payback Analysis (above):***

- A new, alternative fixture—like the bi-level fixture—faces the lowest incremental cost increase in new applications or new buildings.
- Investor Owned Utilities typically have higher electric rates.
- Best Payback Scenarios: New applications in Investor Owned utility districts.
- Toughest Payback Scenarios: Retrofits in Municipal utility districts.
- Current bi-level fixture line has great paybacks against any fixtures with T12 lamps. (Too bad they are being phased out.)
- Against fixtures with T8 lamps, paybacks generally range from 2.5 to 5 years in IOU districts and higher in MUDs.
- More value engineering (including cheaper ballasts) and utility rebates are required if this technology is to achieve 2-5 year paybacks or less in all common applications.
- Needed rebates, at least in IOU districts, are close to the amount achieved if one combined an efficient fixture rebate and an occupancy sensor rebate.

### Energy Savings Volumes—Per Fixture Method

The next section of this report presents the details on estimating market size in California. There you will find an explanation for the following assumptions:

- 5.83 billion square feet of commercial space in California.
- We estimate that about 50% of total commercial space in California is in multi-story buildings with interior stairwells.
- Roughly 2% of multi-story square footage is stairwells.
- There is one fixture for every 58 square feet of stairwell.
- Thus, we estimate there to be about **1,000,000 stairwell fixtures in California** that are in interior spaces and are a suitable market for this product.

Using figures from the "Net Economic Benefit" table above, the average energy savings per fixture by installing a bi-level fixture would be about 39.0 Watts, computed as follows:

| Old Fixture Watts | New Fixture Watts | Level-2 Watts | Time at Full Power | Time at Min Power | Average New Fixture Watts | Average Watts Saved per Fixture | Power Density of Old Fixtures at 58SF/fix. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| 90 | 62 | 13 | 5% | 95% | 15.5 | 74.5 | 1.55 |
| 50 | 62 | 13 | 5% | 95% | 15.5 | 34.5 | .86 |
| 62 | 62 | 13 | 5% | 95% | 15.5 | 46.5 | 1.07 |
| 32 | 62 | 13 | 5% | 95% | 15.5 | 16.5 | .55 |
| | | | | | | | |
| 90 | 62 | 28 | 5% | 95% | 29.7 | 60.3 | 1.55 |
| 50 | 32 | 14 | 5% | 95% | 14.9 | 35.1 | .86 |
| 56 | 32 | 14 | 5% | 95% | 14.9 | 41.1 | .97 |
| 62 | 62 | 28 | 5% | 95% | 29.7 | 32.3 | 1.07 |
| 32 | 32 | 14 | 5% | 95% | 14.9 | 17.1 | .55 |
| 34 | 32 | 14 | 5% | 95% | 14.9 | 19.1 | .59 |
| | | | | | | | |
| 90 | 62 | 13 | 5% | 95% | 15.5 | 74.5 | 1.55 |
| 50 | 32 | 8 | 5% | 95% | 9.2 | 40.8 | .86 |
| 56 | 32 | 8 | 5% | 95% | 9.2 | 46.8 | .97 |
| 62 | 62 | 13 | 5% | 95% | 15.5 | 46.5 | 1.07 |
| 32 | 32 | 8 | 5% | 95% | 9.2 | 22.8 | .55 |
| 34 | 32 | 8 | 5% | 95% | 9.2 | 24.8 | .59 |
| | | | | | | | |
| 56 | 36 | 9 | 5% | 95% | 10.4 | 45.6 | .97 |
| 34 | 36 | 9 | 5% | 95% | 10.4 | 23.6 | .59 |

Simple Average Watts Saved per Fixture: 39.0

Simple Average Power Density per "Old" Stairwell fixture: 0.93

Thus, 1,000,000 fixtures saving an average of 39 Watts per fixture would have a maximum potential to reduce peak electrical demand by **39 megawatts**.

### Energy Savings Volumes—Power Density Method

The average power density in Watts per square foot (W/sf) for all the commercial buildings in the data presented by LBNL is 1.574. The average power density for stairwells from the chart above is about .93W/sf. This is not surprising given the typically lower light levels found in stairwells.

If half of the 5.83 billion square feet of commercial space in California has interior stairwells and these stairwells are 2% of total square footage with an average power density of .93W/sf, assuming 95% savings by dimming when the stairwells are unoccupied, the maximum potential to reduce peak electrical demand would be **52 megawatts.**

### Energy Savings

Recalling that stairwell fixtures are on 24 hours per day and 365 days per year (8760 hours), maximum dollar savings to building owners, using the average utility rates presented above, for 50 megawatts saved would be:

In a Municipal Utility District (10.5¢/kWh): **$46 million per year.**

In an Investor Owned Utility District (15.5¢/kWh): **$68 million per year.**

# IFMA WORKSHOPS

## Background

From March to September, 2004, IFMA conducted three meetings to introduce new lighting technologies to its members.

- The first meeting, held March 2, 2004, was a half-day workshop called California Radar: Shining Light on New Products and Regulations.
- On June 30, Don Aumann addressed members of the IFMA Sacramento chapter and shared PIER and CEC information.
- The last meeting was a webcast, also called California Radar: Shining Light on New Products and Regulations. The webcast was attended by IFMA members from around the state. This September 21 webcast featured several of the same presenters from the March workshop and a utility representative and PAC member, Tony Coonce.

## Meeting Sites

The first meeting, the March 2 workshop, was held in a conference room at Chiron's headquarter facilities in Emeryville, California. Chiron is a global biopharmaceutical company that produces vaccines and blood tests. The site was chosen because it is a test site for the bi-level technology, and it would allow attendees to see the light fixture in operation. In addition, Chiron's site is easily accessible by both car and mass transit. Because Chiron's activities are of a confidential nature, the site maintains a high-level of security. Arrangements were made prior to the workshop to guarantee admittance for those who had registered. Shari Epstein, Associate Director of Research for IFMA, was instrumental in organizing the event.

The second meeting was a June 30 breakfast chapter meeting held at Franklin Templeton Investments in Rancho Cordova, California. Don Aumann presented an hour-long presentation titled, "Using PIER Results to Improve Building Energy Performance." He provided an overview of the PIER program areas and emphasized the building programs. The presentation was followed by a 30-minute question and answer session.

The last meeting was not a physical meeting but rather a webcast sent live to IFMA members throughout California. The speakers presented via telephone and web. Viewers listened and viewed the presentation using streaming audio. The webcast allowed viewers to submit questions, for which presenters answered live and after the webcast.

## Presentations

***March 2, 2004***
Kit Tuveson, Tuveson Associates principal and a PIER LRP PAC member, delivered the opening address. He touched on a number of key issues for facility managers such as economics (nation and state), political, global, insurance, outsourcing, energy and sustainability. He challenged the audience regarding their business continuity planning.

Don Aumann, Commission Contract Manager, provided an overview of the California Energy Commission (Commission) and PIER. He shared that investor-owned utility companies fund the PIER program. He devoted the balance of his presentation on PIER research related to buildings such as daylight and its impact on productivity, skylights, lighting controls, and HVAC diagnostics.

Judie Porter with Architectural Energy Corporation provided an overview of PIER's Lighting Research Program. Ms. Porter devoted the most time to the bi-level stairwell fixture with occupancy sensor, demonstrating the economics of the fixtures for both new construction and retrofits. She also emphasized that LaMar is offering the fixture at a reduced price in California. Other LRP products discussed included the bathroom lighting control system, integrated lighting systems for classrooms and training facilities, and the retrofit fluorescent downlighting system.

Peter Turnbull, Pacific Gas & Electric manager and a PIER LRP PAC member, shared a wealth of information including information on commercial utility incentives for new building construction and equipment rebates.

Tom Kelly of the Environmental Protection Agency, Region 9, discussed environmental management systems and green buildings.

***June 30, 2004***

Don Aumann was the sole presenter for this meeting. He introduced the new lighting technologies from the PIER Lighting Research Program to facility managers, potential users of these new technologies. Workshop participants also learned more about the California Energy Commission, their policy objectives and PIER funded projects. He spent a considerable amount of time discussing the bi-level stairwell fixtures, lighting control systems, integrated high-efficiency lighting systems, retrofit energy efficient downlights and hybrid LED entry lights.

***September 21, 2004***

Kit Tuveson updated his March 2 presentation and spoke for about 20 minutes. He moderated the balance of the webcast and introduced the other speakers.

Don Aumann provided an overview of the PIER program. He discussed hot topics for facility managers including lighting (skylighting, lighting controls, outdoor/entry lighting and the effects of daylight on productivity) and HVAC diagnostics.

Judie Porter provided an update to her March presentation by describing bi-level stairwell fixtures, integrated lighting systems and exterior LED fixtures. She discussed the benefits and economics of the various lighting technologies.

PAC member Tony Coonce of San Diego Gas & Electric used his 20 minutes to share information about utility incentives for commercial building users. He tailored his presentation for all of California, as there were people listening from all over state.

## Material and Attendees

Material for the March workshop was provided to the Commission under separate cover as part of the January 2004 deliverables. The packet included the power point presentation for the five speakers and information, i.e. cut sheets, brochures, and case studies, for the four PIER LRP products presented to the group.

Approximately 40 people attended the March workshop. Most were facility members in the Bay area. Three of the meeting participants who are involved with the bi-level test site project, David Grassechi of Chiron, Linda Pettie of SBC and Jon Martens, were introduced during the presentation. Chiron staff was also well represented at the workshop.

Approximately 15 to 20 people attended the June 30 workshop. Most were engineers, energy consultants, or facility managers from the local area. The presentation lasted approximately one hour and several members of the audience stayed after the session to talk with Mr. Aumann. Shari Epstein with IFMA coordinated this presentation with Scott Hillis, who is with Carter & Burgess and represents the Sacramento IFMA Chapter, and Don Aumann.

More than 70 people signed up for the September webcast; however, only 45 made it to the actual broadcast. However, all 70 received the handouts prior to the webcast. The handout matched the four Power Point presentations that were shared during the 90-minute session. An online evaluation was conducted soon after the webcast concluded.

### Tour

During the March workshop, about half of the meeting participants stayed for the tour of the stairwell, which housed the bi-level light fixtures. The test stairwell is located in a different building, so the group split into two groups to facilitate movement to the other building. While inspecting the stairwell, the light fixtures were ‘on’ providing more than adequate lighting. There were building occupants using the stairwell during the 20-minute tour. The Chiron facility manager had posted signs in the stairwell with information about the fixtures and an acknowledgement that Chiron was participating in the PIER LRP test project.

In conclusion, IFMA was able to reach more than 100 members and as well as some non-members from around California at three different times during 2004. Each meeting had different audience profiles and presentations; however, each one featured a significant amount of information on the PIER LRP and resulting technologies. The audiences showed great interest in the PIER LRP information.

# POTENTIAL FOR LIGHTING CODE CHANGES FOR CALIFORNIA STAIRWELLS

## Introduction

This section assesses, in layman's terms, the potential that owners and developers of commercial buildings in California might become subject to new building or fire codes that would require more light in exit stairwells. It concludes that, given current activity in five different code processes, it is likely that minimum lighting in stairwells will be increased to ten foot-candles (10FC or 108 lux) during occupied periods. However, this requirement is not likely to take effect in new buildings until 2007.

## Background

Stairwell safety has been a public health issue, a building code issue, and a fire code issue for decades, certainly as long as modern building codes have been in effect. It is typically found in codes under the sections dealing with "paths of egress" from buildings, especially during emergencies. For at least the last 25 years, stairwell safety has been the subject of detailed, scientific research for which there is a respected body of published work. Recently, however, because of two horrific attacks on the World Trade Center in New York and a disastrous fire in a nightclub in Rhode Island, public attention has again been focused on the importance of stairwells that are typically out of sight and out of mind.

According to the literature, there are three key factors to the safe use of stairs: visibility, geometry of steps, and handrails. However, only visibility has an ongoing cost impact because building and fire codes demand that paths of egress for most commercial and large, multi-story residential buildings must be lighted 24 hours every day—whether used or not. To date, energy costs for lighting have been modest because codes have required that exit stairs be lighted to only one foot-candle (1FC or 10.8 lux). Code bodies have been reassessing this requirement and several have already accepted proposals that require lighting for exit stairs be increased to 10FC (108 lux) during occupancy. To mitigate the large jump in energy costs that would accompany such a requirement, these codes are also allowing the use of new lighting control technology that will reduce stairwell light levels back to 1FC (10.8 lux) during unoccupied periods.

This section will look briefly at how the code making process works and will assess the extent to which the new code provision, increasing required lighting in stairwells, has been adopted—or not—in six relevant codes. The State of California is reviewed in particular so that an "educated guess" can be made about the possibility that this code change will ultimately affect building owners and developers in the state.

### How Codes are Made and Adopted

A full discussion of the process for making and adopting building and fire codes is vastly beyond the scope of this section. It is a mammoth undertaking concerning several national and international organizations, dozens of committees, and hundreds of volunteers. However, to begin to understand where a code change is in the process, at least a simplified model of the process is helpful. The code process is roughly divided into four steps:

1) Committee Work

This is a catchall phrase to cover the beginning of the code-making process that includes hundreds of committees that meet regularly to monitor existing codes, to carefully consider proposals to modify existing codes, to vote on proposed code changes, and to revise model codes. These committees are made up of building or fire professionals, industry representatives, academics, and other experts. In Figure 1, this category includes the American National Standards Institute (ANSI), the International Code Council (ICC), the National Fire Protection Association (NFPA) in the non-governmental (NGO) sector and the Access Board in the Federal sector. The Access Board was created by Congress to oversee design guidelines for the Architectural Barriers Act (ABA) and the Americans with Disabilities Act (ADA). All of these organizations have websites that can be easily accessed using the acronym-of-the-organization.org.

2) Model Codes

On a national basis, work of the expert committees is brought together in "model" codes, so called because they are models that can be referenced as needed. These model codes are typically highly detailed, technical, and can easily be of book length. They are published by sponsoring organizations and their content is protected by copyright. Figure 1 illustrates three building codes: International Building Code (IBC), the International Residential Code (IRC), and the new building code from the National Fire Protection Association, NFPA 5000. There are also the Life Safety Code (NFPA 101) and the Uniform Fire Code (NFPA 1). Although not a model code (it is actually Federal law), the ADA Accessibility Guidelines (ADAAG) is similar in that it specifies design standards that must be met for the construction or alteration in the private sector (places of public accommodation and commercial facilities) and the public sector (state and local government facilities).

3) State and Local Adoption

Model codes become law when they are adopted by a local jurisdiction, typically a city or county. There are over 30,000 such jurisdictions in the US. Each jurisdiction may accept the model code "as is" or it may make amendments based on local conditions. It is possible for a new code provision to be added to the model code and then be removed by a local jurisdiction before becoming local ordinance. An organization that doesn't like a code provision but can't get it "killed" at the national level can still get it removed at the local level.

In California the Building Standards Commission (BSC) is responsible for codifying and publishing approved building standards, approving model codes and standards for state buildings (including both California university systems), and working to make highly consistent building standards throughout California. In the case of the fire code, the BSC takes recommendations from the Western Fire Chiefs Association. The BSC publishes the California Building Code and the California Fire Code.

4) Enforcement

In the case of the building codes, enforcement is by local city or county building inspectors. For the fire code, enforcement is by the "Authority Having Jurisdiction" (AHJ) that in most cases is the Fire Marshal. Because codes are revised and adopted in various cycles (every few years), it is possible for the building code and the fire code to be out of sync and disagree. This puts the building owner or contractor in a truly awkward position that can sometimes be difficult to resolve. In California, the Building Standards Commission works to resolve these conflicts prior to adoption so that there will not be conflicting codes presented to the builder or developer. In the case of the ADA standards, they are enforced by the Department of Justice. If there is a problem, negotiations are required. If the problem cannot be resolved through negotiation, the Department of Justice files a lawsuit.

### Status of the Proposed New Lighting Standard for Stairwells in the Model Codes

A new standard has been proposed that will increase the required amount of light in stairwells, during occupancy, from the current standard of one foot-candle (1FC or 10.8 lux) to 10FC (or 108 lux) on the stair tread or landing. The codes or code related organizations where this new lighting provision has been accepted are listed below with a brief discussion of each.

American National Standards Institute (ANSI) -- Accepted
On November 26, 2003, the Accredited Standards Committee A117 on Architectural Features and site Design of Public Buildings and Residential Structures for Persons with Disabilities approved American National Standard A117.1-2003 Accessible and Usable Buildings and Facilities. The "Final Proofing Draft Z-3" was published January 31, 2004 and the First Printing is scheduled for May 2004. This standard contains the following sections:

**504 Stairways**

> **504.8.1 Luminance Level.** Lighting facilities shall be capable of providing 10 foot-candles (108 lux) of luminance measured at the center of tread surfaces and on landing surfaces within 24 inches (610mm) of step nosing.
> **504.8.2 Lighting Controls.** If provided, occupancy-sensing automatic controls shall activate the stairway lighting so the luminance level required by Section 504.8.1 is provided on the entrance landing, each stair flight adjacent to the entrance landing, and on the landings above and below the entrance landing prior to any step being used.
>
> http://www.iccsafe.org/cs/standards/a117/index.html

NFPA 1: Uniform Fire Code™, 2003 Edition -- Accepted
This code covers "the prevention of fire and explosion through the regulation of conditions that could cause fire or explosion and panic resulting therefrom." In the spring of 2003, Technical Committee UFC-AAA of NFPA approved the 2003 Edition of the Uniform Fire Code™. That code, which is updated every-other year, now contains the following sections:

> **14.12 Illumination of Means of Egress**
> **14.12.1.2.2** Automatic, motion sensor-type lighting switches shall be permitted within the means of egress, provided that the switch controllers are equipped for fail-safe operation, the illumination timers are set for a minimum 15-minute duration, and the motion sensor is activated by any occupant movement in the area served by the lighting unit.

**14.12.1.3** The floors and other walking surfaces within an exit and within the portions of the exit access and exit discharge designated in 14.12.1.1 shall be illuminated as follows:

**(1)** During conditions of stair use, the minimum illumination for new stairs shall be at least 10 Ft-candles (108 lux), measured at the walking surfaces.

**(2)** The minimum illumination for floors and walking surfaces, other than new stairs, shall be to values of at least 1 Ft-candle (10.8 lux) measured at the floor.

**14.12.1.4** Required illumination shall be arranged so that the failure of any single lighting unit does not result in an illumination level of less than 0.2 Ft-candles (2.2 lux) in any designated area.

http://www.nfpa.org/Codes/index.asp
A no-cost registration is required to view this code on line.

NFPA 101- Life Safety Code^tm -- Accepted
This code deals with "safety from fire and like emergencies. It covers construction, protection and occupancy features to minimize danger to life from fires, smoke, fumes, or panic before buildings are vacated." In the same 2003 adoption cycle as NFPA 1, the Technical Committee for Assembly Occupancies and Membrane Structures (ASF-AXM) approved the following provisions which are now part of this model code:

**7.8.1.2.2** Automatic, motion sensor-type ....[exact same language as above]

**7.8.1.3** The floors and other walking surfaces ….[same as above]

**(1)** During conditions of stair use….10 Ft-candles….[same as above].

[Same website as NFPA 1 above.]

NFPA 5000 – Building Construction and Safety Code^tm -- Pending/Likely
The purpose of this code is to "provide minimum design regulations to safeguard life and limb, health, property, and public welfare by regulating and controlling the permitting, design, construction, quality of materials, use and occupancy, location, and maintenance of all buildings and structures within the jurisdiction and certain equipment specifically regulated herein." This is a new building code, written in competition to building codes written by the International Code Council (ICC). The current edition of this code is 2002 and is only its second cycle since inception. This code has yet to be accepted by any local jurisdiction.

Section 11.8.1.3 of NFPA 5000, which covers Illumination of Means of Egress, still references the illumination of surfaces in exits to be 1 Ft-candle. This cycle of NFPA 5000 is a year behind the cycles for NFPA 1 and NFPA 101 discussed above. To bring NFPA 5000 in line with these other two codes, a Committee Proposal was submitted in the current cycle of proposals to revise NFPA 5000. This proposal has been non-controversial and it is anticipated that the new 10 Ft-candle and control references will be easily voted into the 2005 Edition of NFPA 5000.

[Same website as NFPA 1 above.]

ADA Accessibility Guidelines (ADAAG) -- Pending
The Access Board, responsible for developing guidelines for implementing the Americans with Disabilities Act, is nearing completion of a very large, multi-year effort to update the guidelines and create a common set of technical criteria that the federal government will use to monitor compliance with ADA requirements. As of January, 2004, these new proposed guidelines were at the Office of Management and Budget (OMB) for approval. The old guidelines (Section 409.2 Exit Stairways-1996) did not address exit illumination. However, the committee responsible for this update is well aware of the recent work by ANSI and its approval of the new 10 Ft-candle standard. It is "rumored" that the 10 Ft-candle standard *may* be in the new ADAAG. This will be clear when the ADAAG is released from OMB within the next 2-3 months.

http://www.access-board.gov/ada-aba/status.htm

International Building Code (IBC)
Prior to 1994, there were three separate organizations in the US publishing model building codes: the Building Officials and Code Administrators International, Inc (BOCA); the International Conference of Building Officials, Inc. (ICBO); and the Southern Building Code Congress International, Inc. (SBCC). In 1994, the three organizations collaborated to form the International Code Council (ICC). The ICC prepares and publishes both the International Building Code (IBC) and the International Residential Code (IRC). There were a few delays in this transition to create the ICC. During this time, NFPA decided to create NFPA 5000 in competition with the ICC. The work of the ANSI A117 committee informs both the NFPA and the ICC code making processes. Given the very recent acceptance of ANSI A117.1-2003 (above) it is not surprising that the 10 Ft-candle standard has not yet moved into the ICC, IBC, and IRC processes. When it does, it still may be in for some "tough sledding" according to those familiar with the process. The ICC committee process is substantially different from the NFPA committee process and so far has been less inclined to accept the 10 Ft-candle standard.

http://www.iccsafe.org/cs/codes

In summary, concerning the current status of the new 10 Ft-candle lighting standard in the model codes, it has been accepted by both ANSI and NFPA. We don't yet know the outcome in the ADA Accessibility Guidelines, and there appears to be "tough sledding" in the ICC process. To have been accepted by both ANSI and NFPA gives the new lighting standard a lot of credibility. Whether or not the new model stairwell lighting standard will become law in California, however, has everything to do with code the adoption process unique to California, the subject of the next section.

## The Code Adoption Process in California

In California, the Building Standards Commission (BSC) is "the boss" when it comes to codes. This independent commission is appointed by the Governor and confirmed by the State Senate. The commission takes what it wishes from the national model codes, listens to advice from organizations and professionals, resolves conflicts or makes clarifications, and then publishes the California Building Code and the California Fire Code. These apply to state owned buildings and the university systems. They are the basis for adoption by other state agencies. However, they must still be adopted by local jurisdictions before becoming local law. The BSC seeks to write uniform codes for California that will be adopted with the fewest possible amendments.

http://www.bsc.ca.gov/index.html

California Uniform Fire Code

When it comes to the California Fire Code, the Building Standards Commission relies heavily on input and recommendations from the Western Fire Chiefs Association (WFCA), a division of the International Association of Fire Chiefs, which includes the ten most western states. The WFCA has adopted the 2003 Edition of NFPA 1 and has recommended that it be the basis for the 2004 Annual Code Adoption Cycle for the California Fire Code. Unless special action is taken by the Building Standards Commission to remove the 10 Ft-candle standard for exit stairs, which is unlikely, the new standard will become part of the 2004 California Fire Code. The deadline for submitting proposed code changes to the BSC is August 2, 2004. Accounting for review, comment, and BSC administrative work, it is anticipated that the 2004 Fire Code will be published late in 2005 and will be adopted by local jurisdictions starting in early 2006. As shown on Figure 1, the 10 Ft-candle standard is pending, though fairly likely, to be part of the 2004 California fire code and to be within the jurisdiction of local Fire Marshals by 2006.

http://www.wfca.com

California Building Standards Code

There have been two major problems in getting to a new draft of the California Building Code. First, because of a change of Governors and a moratorium by the new Governor on all new codes, the 2003 Annual Code Adoption Cycle had to be abandoned. As of May, 2004, all state agencies have withdrawn their proposed changes to the Building Code.

Secondly, California is facing head on the difficulty of choosing between the model building codes proposed by the ICC and NFPA. After considerable deliberation, the Building Standards Commission chose the 2003 Editions of the NFPA 5000 Building Code and NFPA 1 Uniform Fire Code. But that decision remains highly controversial. As of March 1, 2003, the BSC issued a lengthy Adoption Plan that will not lead to a new code until 2007 (Figure 2).

http://www.bsc.ca.gov/documents/visio-NFPA5000&1_AdoptionPlan.pdf

It is far too early to see how this debate will be resolved. If NFPA 5000 is the “winner” it is highly likely that the BSC will rule in favor of including the 10 Ft-candle standard for exit lighting. It is already included in NFPA 1 and it is in process for being included in NFPA 5000. If the ICC is the “winner” the BSC will have to resolve the fact that NFPA 1 includes this standard and the IBC does not. Given the input already in hand from the Western Fire Chiefs Association that they are fully supportive of NFPA 1, there is a strong probability that the new 10 Ft-candle rule will be included in the new California codes but will not go into effect locally until 2007 or 2008.

### The Situation for Existing Buildings

All of the above discussion concerning codes affects only new buildings about to be built or existing buildings undergoing such significant renovations as to force them to fall under new code provisions. But new buildings represent only a small percentage of the building stock in any one year. What about existing buildings?

Under the letter of the law, existing buildings can keep the exit lighting system they have. If that system produces one foot-candle on exit stair landings and treads, it will be sufficient under the code when it was built. One caution is due here. Some light fixtures commonly used in stairwells, like the old Circline fluorescent fixture, can degrade over time and produce less light than when they were installed. Building owners may want to check their existing fixtures to be sure they are still covered even under their "grandfathered" code.

However, liability is an issue that should be taken into consideration when reviewing existing exit lighting. According to the Consumer Product Safety Commission (CPSC) in 1998, there were over 400,000 injuries treated in U.S. Hospital Emergency Departments associated with stairs or steps. Recall from the opening paragraphs of this section that the three key environmental factors for safe stairs are: visibility of stairs, geometry of steps, and handrails. Now that the new 10 Ft-candle standard has become accepted by three of the four most important model codes, it is highly likely that it will become an issue in reviewing liability cases where visibility is a possible factor in the fall. Building owners wishing to avoid future liability cases may wish to consider exit stair lighting upgrades even if they are not required by code.

### Technology Exists to Mitigate the Energy Costs of More Exit Lighting

At least three lighting fixtures are now in production and offered for sale in California that combine a fluorescent lighting fixture and an occupancy sensor so that it is possible to meet provisions of the new lighting code that call for exit stair fixtures to provide 10 Ft-candles of light during periods of occupancy and to drop back to 1 Ft-candle when there is no occupancy. The PIER Lighting Research Program has supported development of one of these fixtures and is currently monitoring multiple installations of this fixture in California to be sure that it can meet all proposed code provisions. Initial findings are that this new technology can be installed with reasonable paybacks. Work is continuing to make this technology even more cost effective.

### Summary

Given that:

- The public is currently highly sensitive to building exit safety,
- Visibility is a key element in exit stair safety,
- Three out of four model codes (and possibly the new ADA Guidelines) have adopted the 10 Ft-candle standard for exit stairs,
- The Western Fire Chiefs Association has recommended NFPA 1 as the basis for the new fire code in California,
- The California Building Standards Commission has initially chosen NFPA codes, that either include or soon will include the 10 Ft-candle standard, as the basis for the next California Building Code, and

- That lighting technology exists that can cost effectively provide higher light levels only when needed so as to keep energy cost increases modest.

This concludes that it is highly likely, in the range of 80-90% likely, that owners and developers of new buildings in California will be subject to the new 10 Ft-candle standard for exit lighting. However, given the current complexity of code adoption in California, this new code will probably not come into effect before 2006 at the earliest and it may be 2007. It is anticipated that some percentage of owners and managers of existing buildings will also want to upgrade exit lighting to these standards as a matter of employee or tenant safety and as a hedge against future liability. The combine effect of these adoptions will be a substantial improvement in public health and safety with only a very modest increase in energy cost.