Arnold Schwarzenegger
Governor

LIGHTING RESEARCH PROGRAM PROJECT 5.1 BI-LEVEL STAIRWELL FIXTURE PERFORMANCE

PIER FINAL PROJECT REPORT

Prepared For:
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This report is dedicated to the memory of

the Energy Commission's Lighting Research Program Project Manager from 2002–2004

Don Aumann

June 17, 1959–March 9, 2007

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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 (Energy Commission), conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

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

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Lighting Research Program Project 5.1 Bi-Level Stairwell Fixture Performance is one of five final reports for the Lighting Performance Metrics, Codes, and Standards Element of the PIER Lighting Research Program (contract number 500-01-041). This project was conducted by International Facility Management Association and managed by Architectural Energy Corporation. This report is an appendix to the final report for the PIER Lighting Research Program conducted by Architectural Energy Corporation. The information from this project contributes to PIER's Building End-Use Energy Efficiency program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at 916-654-5164.

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Abstract

This report is an appendix to the final report developed under the Lighting Research Program, which supported the creation of new lighting technologies and products that can save energy, cut peak demand, and reduce air pollution for the residents of California. It comprised 15 research projects conducted in four major research areas and three market connection projects, and encompassed both residential and commercial sectors, as well as outdoor lighting associated with buildings.

This report describes a two-year study of a bi-level stairwell fixture—an occupancy-based standby lighting system developed specifically to save lighting energy in stairwells—co-funded with New York State Energy Research and Development The study field-tested the fixture in California to determine the energy savings, demand reduction, user satisfaction, and safety code acceptability of occupancy-based standby lighting in stairwells in California commercial buildings. The product studied has been commercialized by LaMar Lighting in its OccuSmart product line.

Field test results showed average energy savings from 40 to 60 percent at the four sites and high user satisfaction. Assuming a market of 1 million interior stairwell fixtures, at 1 percent market penetration, the bi-level stairwell fixture could save California approximately 4 megawatts per year. Assuming 6132 operating hours per year, 1 percent market penetration would save about 2453 megawatt-hours state-wide. These and other results were provided to potential users statewide through several live and webcast workshops.

The International Facility Management Association and Lawrence Berkeley National Laboratory acted as co-project managers for this project. Chiron, AT&T (formerly SBC), University of California, Berkeley, and Alameda County provided access to stairwells in their buildings for the field tests.

Keywords: energy efficient elevator lighting, energy efficient lighting, bi-level fixture, bi-level stairwell fixture, occupancy-based standby lighting, egress lighting, stairwell lighting, OccuSmart, LaMar Lighting

Executive Summary

Background

Recognizing that an adequate light level can be key to safe use of stairwells—particularly in emergencies—many building codes are calling for brighter stairwell lighting levels. Given that California could have as many as 1 million lighting fixtures in interior stairwells in commercial buildings, achieving these higher lighting levels could lead to a spike in energy use and costs. The bi-level stairwell fixture from LaMar Lighting (www.occusmart.com) maintains a dim light level when stairwells are empty and turns the light up as soon as occupants are sensed. It could provide an energy-saving and cost-effective way to achieve safe stairwell lighting. The New York Energy Research and Development Authority (NYSERDA) had tested the bi-level fixture's performance at stairwells in the state of New York. However, specific data on performance, costs, user acceptance, and code acceptability in California was not available.

Purpose

To help California commercial building owners determine if a new bi-level stairwell fixture could provide safe, economic, and energy-saving stairwell lighting by monitoring the performance of these fixtures in California buildings and assessing user satisfaction with the resulting light levels.

Objectives

The objectives of this project were as follows:

- Research the development of bi-level fixtures and gain applications data from the NYSERDA field test project.
- Identify suitable commercial buildings to serve as test facilities, working with International Facility Management Association (IFMA) members in California to optimize installation costs of bi-level fixtures for the field test program.
- Establish pre- and post-installation conditions at each test building and collect monitored performance data for baseline and post-installation conditions at each test building.
- Conduct user surveys to determine satisfaction with the bi-level stairwell fixture.
- Analyze the monitoring data to document performance of the bi-level fixtures for any safety code, building code or building energy code compliance issues, and report performance data to building owners and operators, code officials, and others in California.

Approach

The project team met with NYSERDA representatives to discuss their study of two sites featuring the bi-level stairwell fixture technology in the New York area. The project team then selected four buildings in California— based on stairwell use patterns — to participate in the current study. For each of these buildings, the team established baseline measurements before installation of the bi-level stairwell fixtures and monitored occupancy patterns and energy usage in stairwells after bi-level stairwell fixtures were placed in use.

The project team also conducted several user surveys on the four sites:

- A facility survey with seven building managers and safety engineers
- An occupant survey with 29 users
- A survey of the installing contractor and field investigator

In addition, the team analyzed the economics of the fixture and the California code requirements for lighting in commercial building stairwells.

Outcomes

In the four California buildings monitored, use of the bi-level stairwell fixtures saved building owners between 38 and 49 percent of lighting energy on work week days (24-hour basis), and between 47 and 67 percent on weekend days compared to the pre-installation baseline. Average energy savings at the four test sites ranged from 40 to 60 percent. The study also showed that stairwells were in dimmed mode 62 to 82 percent of the time during work week days and 85 to 97 percent on weekend days.

The study determined the economics of the new fixture for a given application will depend largely on three factors: electricity rates, whether the application is new or retrofit, and the types of fixtures are being replaced. Overall, the bi-level fixture faces the lowest incremental cost increase in new applications or new buildings. The best payback scenarios occur in new applications in the service territories of Investor Owned Utilities (IOUs), which tend to have higher electricity rates than do municipal utilities. Payback periods are very advantageous when the bi-level fixture replaces T12 lamps, and range from 2.5–5 years in IOU service areas when replacing T8 lamps.

The survey results showed overwhelming satisfaction with the new light levels, the response time of the occupancy sensor, and the energy savings. Some facility managers indicated they would be interested in using the technology in other facility areas, such as parking garages. Surveyed building occupants said that light levels seemed brighter.

The review of codes and standards showed that, while new code initiatives calling for higher lighting levels were highly likely in California, the bi-level fixture would be acceptable under such provisions.

Conclusions

Many emergency preparedness experts are questioning whether current minimum code requirements for light levels for life safety in commercial building stairwells 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 keep energy costs low by dimming to lower levels when stairwells are unoccupied.

Recommendations

More value engineering (including engineering to produce cheaper ballasts) and utility rebates are required if this technology is to achieve payback in 2–5 year or less in all common applications. In IOU areas, rebates should be approximately the amount achieved if one combined an efficient fixture rebate and an occupancy sensor rebate.

Benefits to California

The project team used the following assumptions to estimate market size:

- California has about 5.83 billion square feet of commercial space.
- Multi-story buildings with interior stairwells comprise approximately 50% of total commercial space in California.
- Stairwells account for roughly 2 per cent of multi-story commercial square footage.
- There is one fixture for every 58 square feet of stairwell.

Thus, approximately 1 million stairwell fixtures are installed in interior spaces in California—a figure that represents a reasonable market for the bi-level fixture.

Replacing a current fixture with a bi-level fixture creates an average energy savings of about 39 watts (W) per fixture. Based on current data, the statewide demand savings at 1 per cent market penetration would be approximately 400 kilowatt (kW) or 4 megawatts (MW) per year. Assuming 6132 operating hours per year, 1 per cent market penetration would save about 2453 megawatt-hours (MWh).

1.0 Introduction

1.1. Background

Building code sections that focus on commercial stairwells rely on bright lighting to ensure safe use everyday and in emergency exit events. Maintaining the code requirements for these high-brightness light levels in stairwells, however, could lead to increased energy use and costs if the luminaires are operated constantly at those levels.

The study's purpose was to test a new type of lighting technology, the bi-level stairwell fixture, in California to determine its energy savings, demand reduction, and acceptance among building code officials. This bi-level fixture uses a built-in ultrasonic occupant sensor that causes the luminaire to switch to high-level lighting when a stairwell is occupied. Then, after a period of time with no motion detected, the luminaire switches back to low-level, standby lighting. A line of bi-level products with these features has been commercialized by LarMar Lighting under the OccuSmart brand name (www.occusmart.com).

Technologies that reduce energy consumption can help building owners improve building performance and decrease utility costs. Accordingly, International Facility Management Association (IFMA) was commissioned to find commercial building owners in California 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 Lighting Research Program (LRP) technologies and products, to various California organizations. Finally, this report includes plans for moving the technology from its initial developmental state to the market while addressing issues regarding acceptance by the code and standards community.

This work built on previous research conducted in 2003 by the Lighting Research Center (LRC) from Rensselaer Polytechnic Institute (RPI) and funded by the New York State Energy Research and Development Authority (NYSERDA). In their study, the fixtures were installed in a high-rise residential complex located on New York City's 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 occupied infrequently due to security restrictions. The resulting energy savings were substantial, ranging from 53 to 60%.

1.2. Report Organization

Section 2.0 of this report discusses the NYSERDA study. Section 3.0 summarizes the experience in California, discussing the four test sites selected, the monitoring process, and the energy savings measurement and analysis. Section 4.0 provides information on the California user evaluations, and Section 5.0 discusses the economics of the project for

California, including energy and demand savings potential, payback, and non-energy benefits to consumers.

Section 6.0 highlights efforts to increase awareness of the product and its benefits to potential uses, and Section 7.0 contains an analysis of whether California will adopt lighting codes that increase stairwell lighting levels. Section 9.0 focuses on conclusions and potential benefits to California from use of the bi-level lighting fixture.

2.0 NYSERDA Bi-level Fixture Performance Study

2.1. Background

NYSERDA awarded the LaMar Lighting Company, Inc. (LaMar), of Farmingdale, New York, a research and development contract in early 2001 to develop and commercialize a lighting system that incorporates a two-lamp 32-watt (W) T8 electronic fixture, integral ultrasonic motion sensor, bi-level dimming ballast, and battery back-up for use in stairwells and corridors or other spaces where constant full illumination 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 website (www.occusmart.com) in support of the commercialized fixture, NYSERDA also funded a field test of the fixture that included full-scale monitoring by the Lighting Research Center (LRC) in New York. Extensive data were obtained from 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.

2.2. 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, in many applications, such as stairwells and corridors, building occupant comfort or building codes require that the area be at least partially lit when occupants enters the space. LaMar 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. Maintenance of this lower level of lighting allows the fixture to save energy while still meeting code requirements.

LaMar's Occu-smart® product line consists of luminaires with the bi-level dimming capability. These fixtures are available in 2'-, 3'- and 4'- lengths for both 120-volt (V) and 277-V applications, with both one- and two-lamp models. These luminaires can dim to 5 per cent, 10 per cent, or 33 per cent of normal, depending on voltage/ballast combinations. Battery packs can be added for emergency lighting applications. Vandal-proof options are also available.

NYSERDA's project used bi-level fixtures that dimmed to 33 per cent of normal. Due to extremely low occupancy in both NYSERDA test staircases (0.7–3.3%)—as measured by LRC, energy savings were significant for both sites (53–60%) compared to the baseline condition. NYSERDA rebates and the high electrical rates of New York City generated a payback period of about two and a half 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 5–10 per cent instead of 33 per cent. Both sites also showed increased illuminances.

NYSERDA documented the complete findings from the field test, which included a multi-family apartment building and an office building, as well as the two high-rise buildings in the New York City mentioned above.[1] For each field test location, the report provides the following:

- Luminaire characteristics
- Project (building) description and photographs
- 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
- Energy calculation sheets

LRC issues a publication series called *Delta Snapshots.* Each publication is a colorful, yet technical, summary of a lighting-related case study. A two-page *Delta Snapshot* was prepared for one of the buildings (the Rivercross building) from the field test report discussed above and is included in the NYSERDA report (see http://www.lrc.rpi.edu/publicationDetails.asp?id=894).

Below, in Table 1, is a summary of the two NYSERDA test sites as reported March 18, 2004.

[1] Brons, Jennifer, Field Test DELTA Evaluation: Occusmart Light Fixture, Project A70913 (Lighting Research Center, Troy, NY, March 2004)

Table 1. Before and After Performance Comparison for NYSERDA test sites

	RiverCross Building		Lexington Avenue Building	
	Before	**After**	**Before**	**After**
Fixtures				
	4'	4'	2'	2'
	2-lamp	2-lamp	1- and 2-lamp	2-lamp
	T12ES	T8	T12ES	T12
	Flat lens	Dropped Lens	Bare strip	Dropped lens
Energy Use				
	60 W	62 W occupied; 28 W unoccupied	28 W (1-lamp fixture) 53 W (2-lamp fixture)	62 W occupied
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 + Installation		$138.40		$187.50
Energy Savings				
		$26.04 (@$0.094/kWh)		$23.67 (@$0.131/kWh)
Simple Payback (Retrofit Application)				
Without Rebate:		5.3 years		7.9 years
With Rebate:		2.6 years		5.0 years

3.0 California Bi-level Fixture Performance Study

3.1. Introduction

Stairwells in non-residential buildings throughout the United States are typically lit 24 hours a day to allow emergency egress. This study examines the bi-level stairwell luminaires manufactured by LaMar (www.occusmart.com). LaMar's Occusmart fixtures are equipped with a built-in occupancy sensor that switches the bi-level ballast from high to standby mode depending on occupancy. By reducing light levels to the minimum code requirement when no occupants are present, the fixture uses 1/3 or less of normal power in standby mode. It therefore provides considerable energy savings while meeting code provisions for emergency egress lighting while still providing for full lighting when required. This work was supported by the PIER LRP and 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.

For this new technology to take hold in the marketplace, it must be acceptable to building officials. Building owners and facilities personnel also must be aware of its operational characteristics and potential benefits. Building on studies conducted by NYSERDA in multi-story residential buildings (see Section 2.0, above), the present study of four diverse buildings in California makes the results more accessible to building owners and operators in California. The purposes of the California tests were to examine and characterize a range of savings patterns due to different occupancy profiles, providing building owners and operators 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. Energy can be saved when stairwells are unoccupied. An occupancy-sensor controlled fixture responds to motion, so the key research variable was the stairwell's occupancy profile. A variety of factors influence the use of a stairwell:

- Number of floors
- Location of the stairwell within the building
- Likelihood of interaction between floors
- Proximity of amenities such as the parking garage or vending machines
- 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)

Four California test sites in the Oakland-Berkeley Area were recruited for their diversity of function and size, rather than for the sake of a statistically significant sample. For building owners, the salient information is the likelihood of savings a specific building with its specific occupancy pattern. Therefore, the goal of this study is to enable savings comparisons under a range of diverse occupancy patterns to help owners and managers characterize the potential savings in their own buildings.

3.2. Description of Sites

Some limited criteria were applied in selecting sites to minimize extraneous factors:

- Windowless sites were selected to avoid the influence of external events.
- Buildings with inadequate existing lighting were preferred to encourage the owners to participate.
- The buildings must have had the expectation of a variety of occupancy patterns.

The following buildings were used in this study:

- ***Evans Hall***. Evans Hall is the mathematics building at the University of California, Berkeley. It has several department offices on different floors, including the Mathematics Department office on the 10th floor and the statistics department office on the 4th floor. Large classrooms and a library are located on the first two floors and some classes are also on the upper floors. Professors' and graduate students' offices are located on the higher floors. The building has three stairwells, two in the southern half of the building flanking the main elevator lobby and the restrooms and one in the north half 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' T12 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 in use at the time of the retrofit. The project team replaced these fixtures with the bi-level fixture. Figure 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

- ***Chiron Building M***. Chiron Corporation has a complex of buildings in Emeryville, California, close to the eastern shore of San Francisco Bay. Chiron's Building M is an older building in the complex, measuring five stories high. It houses researchers' offices and laboratories, as well as 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 and very dirty circlines fluorescent lamps in round, discolored enclosures, with a four-foot parabolic troffer in two locations. There was one fixture per landing. Figures 2 and 3 show pre- and post-retrofit fixtures in the Chiron Building M middle stairwell.

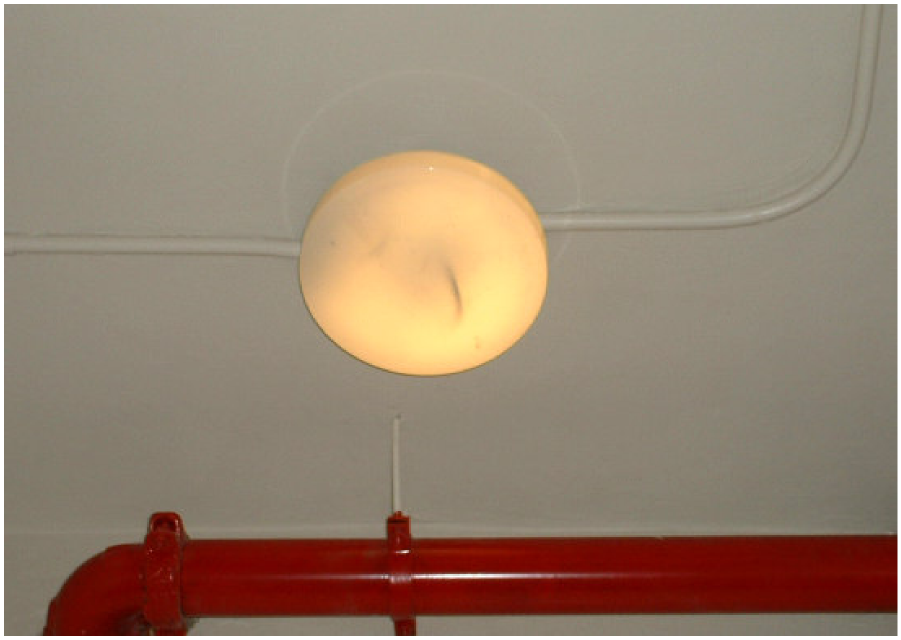


Figure 2. Old fixture at Chiron Building M, first floor

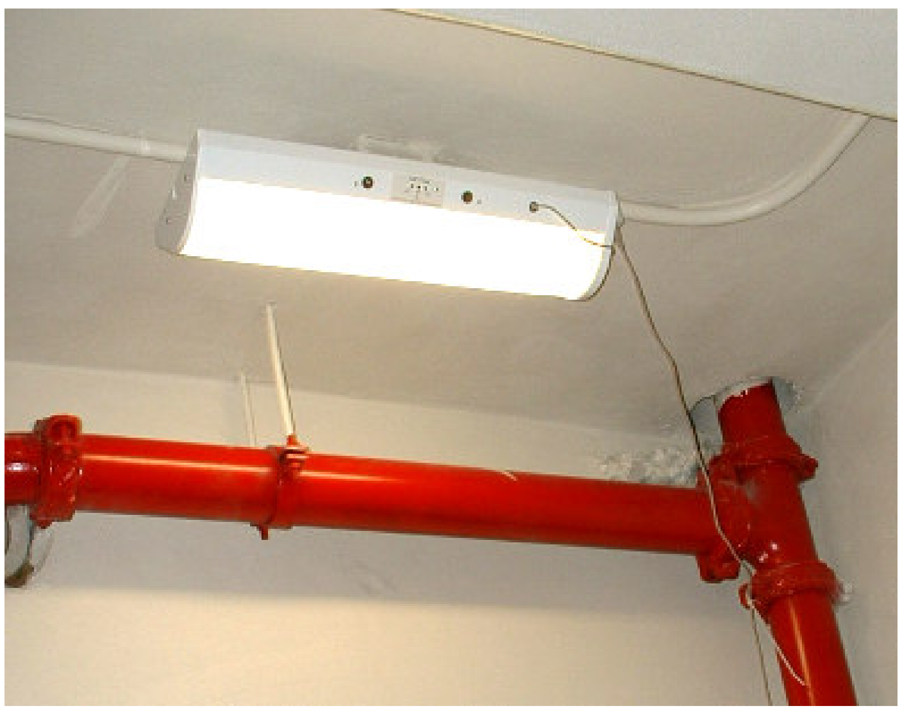


Figure 3. New fixture at Chiron Building M, first floor

- ***Alameda County General Services Administration (GSA) Building***. Located on Lakeside Drive across the street from Lake Merritt in Oakland, California, this 11-story building houses a variety of Alameda County GSA offices. It has two stairwells, one to the north and one to the 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, a few people had 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. Figure 4 shows pre-retrofit fixture in Alameda County GSA building south stairwell.

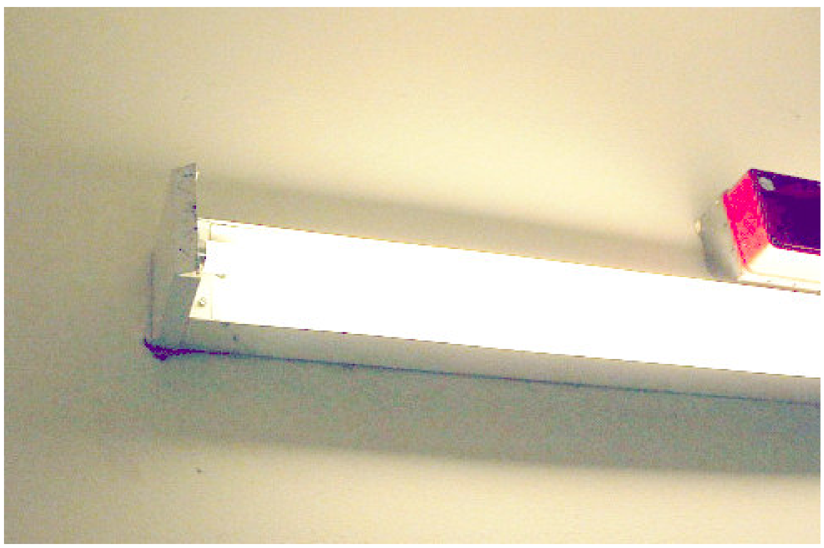


Figure 4. Old fixture at Alameda County GSA building (Lakeside)

- ***AT&T Building***. The AT&T building (called the SBC building at the time of this study) on Webster Street in Oakland, California, houses a variety of AT&T 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.

3.3. 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 2 summarizes salient characteristics of the four monitored stairwells.

Table 2. Building characteristics and monitoring description2

	Evans Hall	Chiron	Alameda County	AT&T
Location	UC Berkeley	Building M, Emeryville	Lakeside Dr., Oakland	Webster St., Oakland
No. of floors	10	5	11	10
Stairwell monitored	Northeast (1 of 3)	Middle (1 of 3)	South (1 of 2)	North (1 of 2)
Existing Fixture	2-lamp 40-W T12	Circlines and misc. on 7 landings; 2 landings had 4' 2-lamp T8s	1-lamp T8 each landing	2-lamp T8 each floor
New Fixture	2-lamp 32-W T8 100%/10% Voyager, each landing	1-lamp U-tube 32-W T8 100%/33% 2' 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 (W)]	1380	320	736	384
Power at Standby (W)	138	106	74	127
Baseline light level (fc) at handrail	0.8 fc–11 fc (delamped shielded 1960-era F40 2-lamp fixtures each landing)	.07 fc (lowest circline) to 24 fc (2-lamp parabolic T8)	2.9–6.8 fc (31–73 lux)	2.3 fc–7 fc

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

Specified standby % light output	10	33	10	33
New light level (fc) at handrail	3.5 fc low; 9.0 fc at full power	5.8–13.1 fc at full power	9.0–15.1 fc at full power	2.2–20.1 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 3 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

3.4. 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, it is difficult to argue that existing lighting not compliant with current electrical code creates a valid 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, assuming they are never dimmed. This strategy focuses the discussion on the savings due to the control technology, excluding other uncontrollable factors, such as inconsistencies in lighting design.

3.5. Energy Consumption Measurements

The ballast in the LaMar fixtures has two separate hot leads. One lead operates the ballast at the low power level and 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[3]) the full-power lead is switched off and the lamp power returns to the minimum or "standby", level.

To measure fixture 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[4]. 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[5] 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 10 minutes, so the maximum possible frequency of events (approximately one every 10+ minutes) would fill up the loggers in about two weeks. To minimize potential data losses from a logger failure, the site point of contact 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.

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 2. Sample data from a floor in the Evans Hall are illustrated in Figure 5.

[3] The time delay was set as closely as possible to 10 minutes.

[4] The number of passes through the current switch varied according to the nominal fixture wattage and the voltage of each stairwell's lighting circuit.

[5] Manufactured by Onset Computing Corporation.

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

3.6. Results

Daily occupancy patterns were fairly consistent over time, with variations primarily attributable to weekends and holidays. The results of the monitoring are summarized in Tables 3 and 4 for weekday and weekend average days. The average weekday time at full power (representing nominal "occupied" time) ranges from 18% at AT&T to 38% at Evans Hall. The overall statistics by test site are shown in Tables 5i-5iv.

Figures 6 to 10 show the amount of time the bi-level lighting fixtures are standby mode (the data refer to 24-hour weekdays and 24-hour weekend days). These percentages indicate the floor-by-floor variation in occupancy from building to building:

- At Chiron, the relatively low-rise building saw regular stairwell use on weekdays, but practically none on weekends.
- On weekdays, Evans Hall shows a great deal of activity on the first two floors, but relatively less on the upper floors. On weekends, all stairwell activity slows down, but the first two floors are still fairly busy. The stairwell configuration

stairwell likely 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 the second floor.

- The Alameda Country GSA building has very little activity on most of the upper floors. However, some interfloor communication is generated by workers who have keys to exit the stairwell, and there is activity on the 11th floor, where it is possible to exit without walking all the way to the bottom. Since floors 9 and 10 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 second 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 AT&T building operates every day, though with a reduced staff on weekends, hence its weekend patterns are close to those on the weekdays. The first floor exit, which leads to the street and is locked from the outside, 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 the elevators. Interfloor use of the stairwells is slightly greater on the lower floors, possibly influenced by the vending machine on the second floor. On upper floors, it may be due to the workers going up or down one floor to interact with other workers.

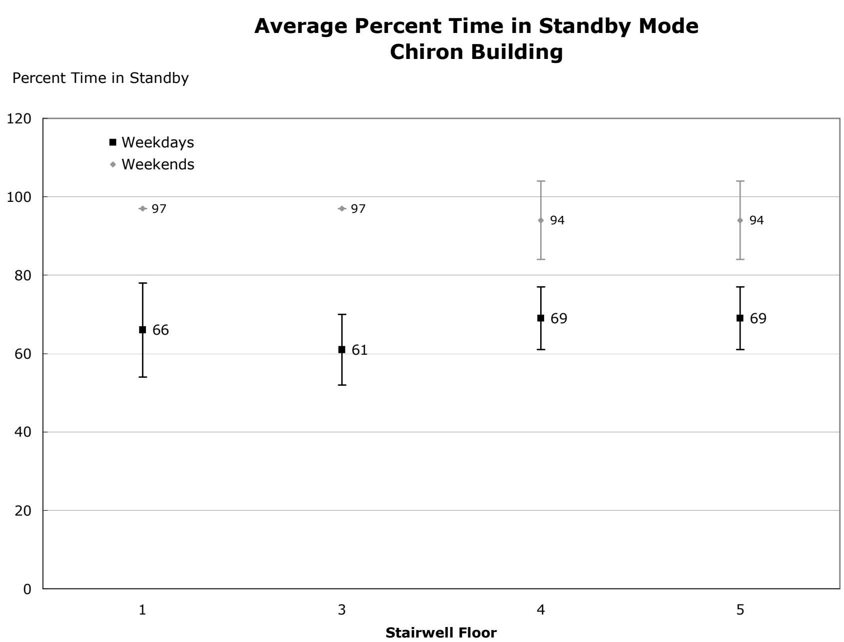


Figure 6. Bi-level fixture average percent time in standby mode, Chiron Building

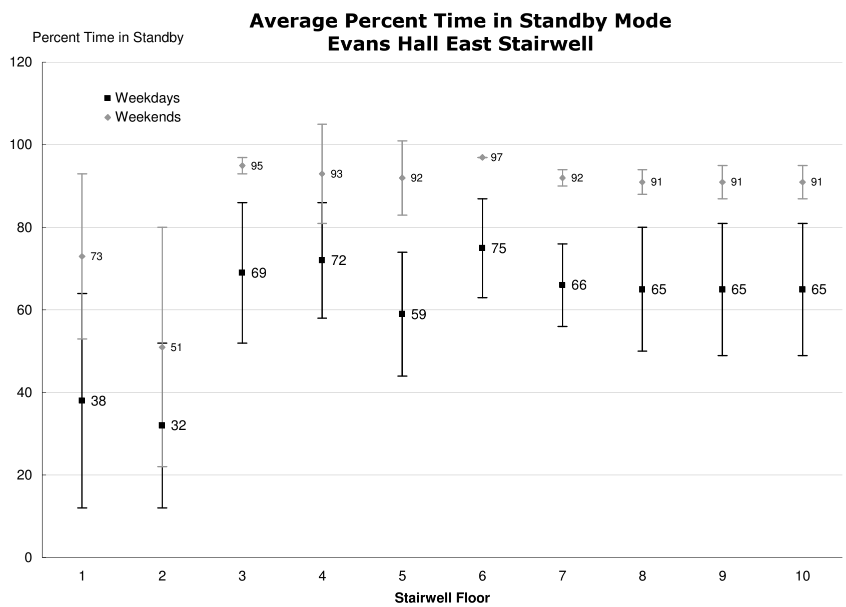


Figure 7. Bi-level fixture average percent time in standby mode, Evans Hall

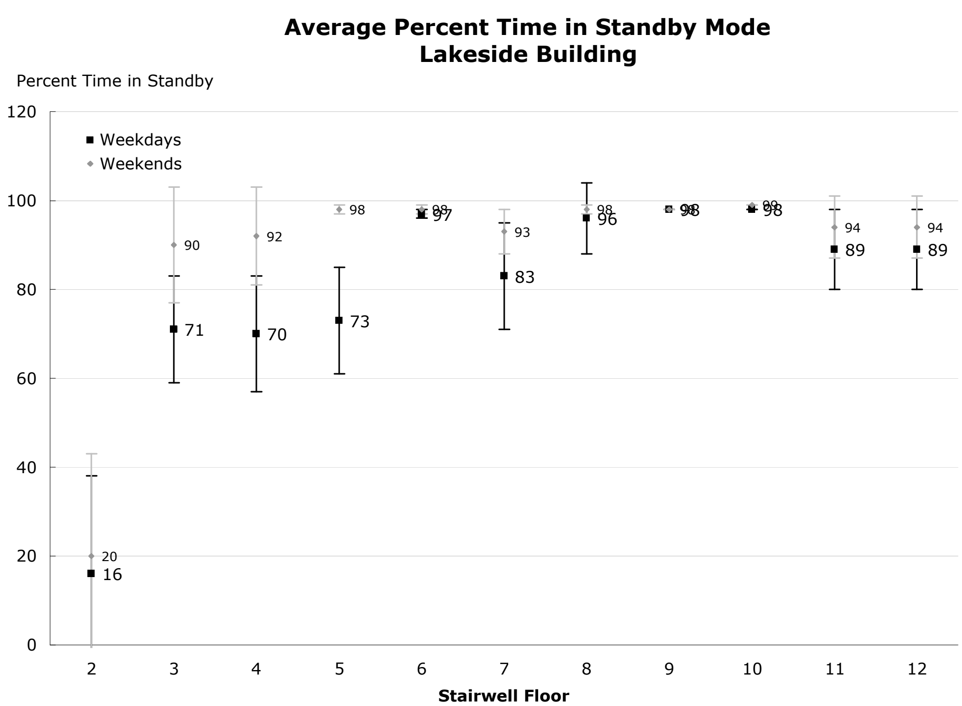


Figure 8. Bi-level fixture average percent time in standby mode, Alameda County GSA Building

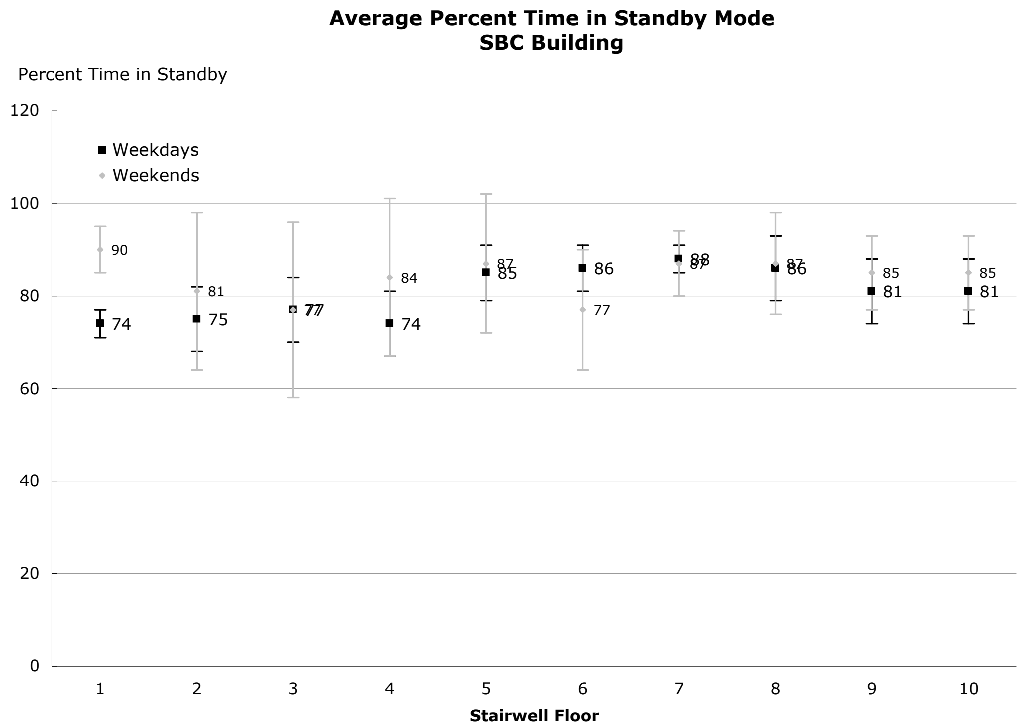
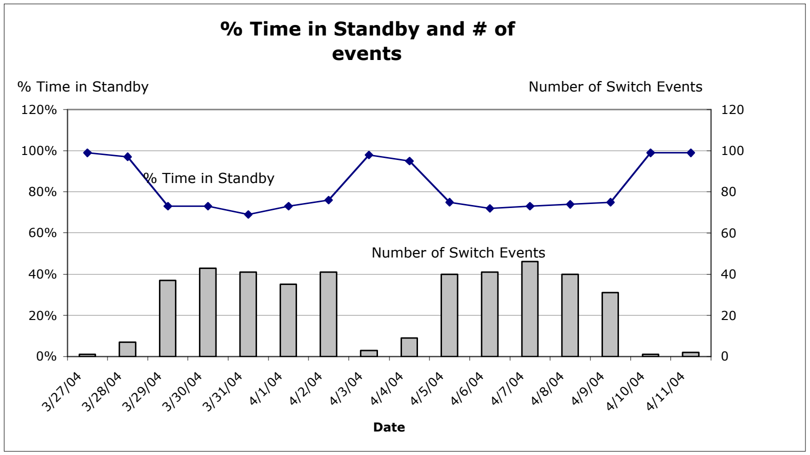
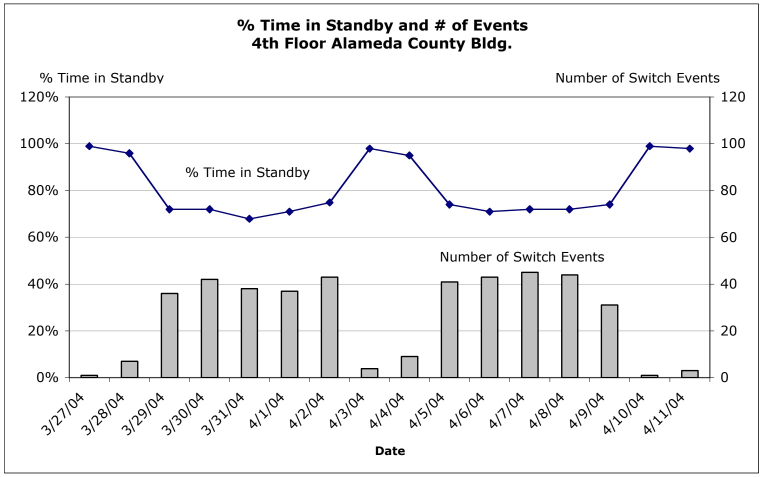


Figure 9. Bi-level fixture average percent time in standby mode, AT&T (formerly SBC) Building

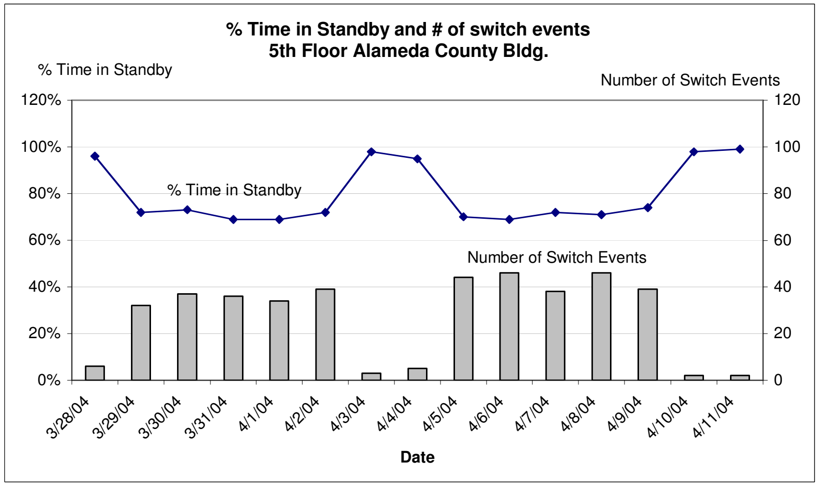
a.


% Time in Standby and # of events
% Time in Standby
Number of Switch Events
Date

b


% Time in Standby and # of Events
4th Floor Alameda County Bldg.
% Time in Standby
Number of Switch Events
Date

c.


% Time in Standby and # of switch events
5th Floor Alameda County Bldg.
% Time in Standby
Number of Switch Events
Date

d.

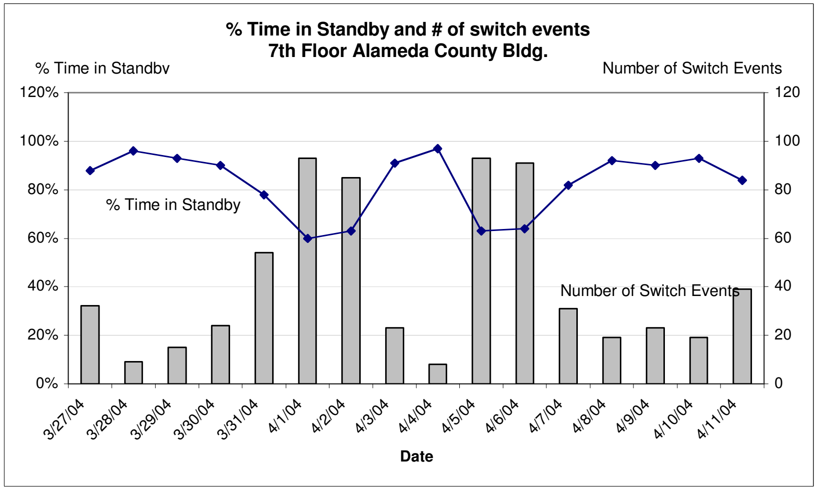

% Time in Standby and # of switch events
7th Floor Alameda County Bldg.
% Time in Standby
Number of Switch Events
Date

Figure 10a-d. Percent time lighting fixture is 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

Table 3. Weekday 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	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 4. 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%

Table 5i. Summary statistics for Chiron Building[6]

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 5ii. Summary Statistics for Evans Hall[7]

			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

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[6] LBNL reference: Chiron1f.xls

[7] LBNL reference: Evans2f-fc.xls

Table 5iii. Summary Statistics for Alameda County GSA Building (Lakeside)[8]

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

[8] LBNL reference: from Lakeside3.xls

Table 5iv. Summary Statistics for SBC Building[9]

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

[9] LBNL reference: From SBC4.xls

As mentioned, Tables 5i–5iv indicate the percent time in standby mode and corresponding number of daily switch events. It is important to note that 40 switch events are not uncommon on weekdays. One floor at one test site occasionally recorded 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 will frequently shorten lamp life considerably. To explore this effect further, LBNL plotted the likelihood of different ON cycles for the Evans Hall data. Findings are 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.

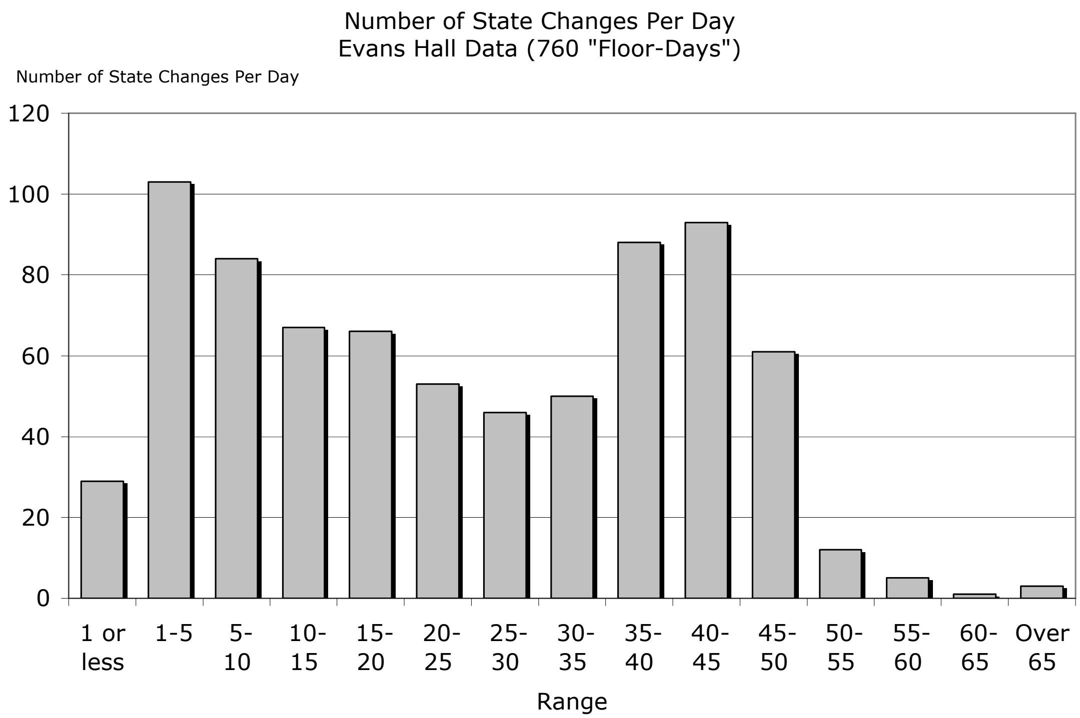


Figure 11. Number of "switch ON" events per day for 760 floor-days from the Evans Hall data.

3.7. 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% of the time. Factors that affect occupancy, and thus energy use, include the following:

- 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.

- Whether or not the stairwell is intended for interfloor use. For example, the Alameda County GSA building 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.

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. The project team concluded that the high apparent occupancy 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. However, possible savings depend on the timing, as well as the number, of occupancy events. 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 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 and 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.

3.8. Conclusions

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 U.S. buildings. As shown in Table 6, bi-level stairwell fixtures saved between 38–49% of lighting energy on 24-hour weekdays, and between 47–67% on weekend days in the four buildings studied. The percentage of time in dimmed mode ranged from 62–82% during weekdays and from 85–97% on weekends.

Table 6. Percentage of lighting fixture time in dimmed mode and corresponding energy savings

	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%
AT&T	74%	88%	50%	59%	77%	90%	52%	60%
Chiron	61%	69%	41%	46%	94%	97%	63%	65%

4.0 User Evaluations

4.1. Introduction

This project installed LaMar bi-level lighting fixtures with motion sensors in one stairwell of four buildings located in the Oakland-Berkeley-Emeryville area, as discussed in Section 3.0 PIER LRP Bi-level Fixture Performance Results.

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.

As part of this work, the project team conducted the following:

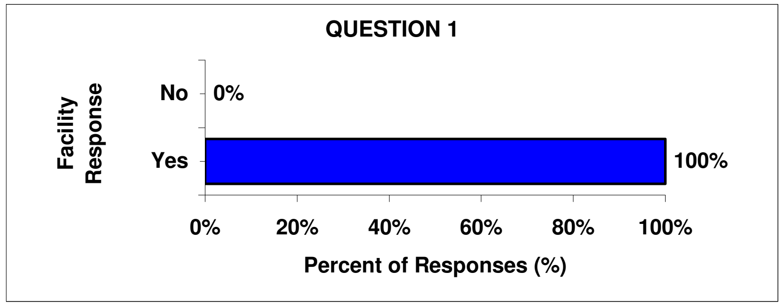
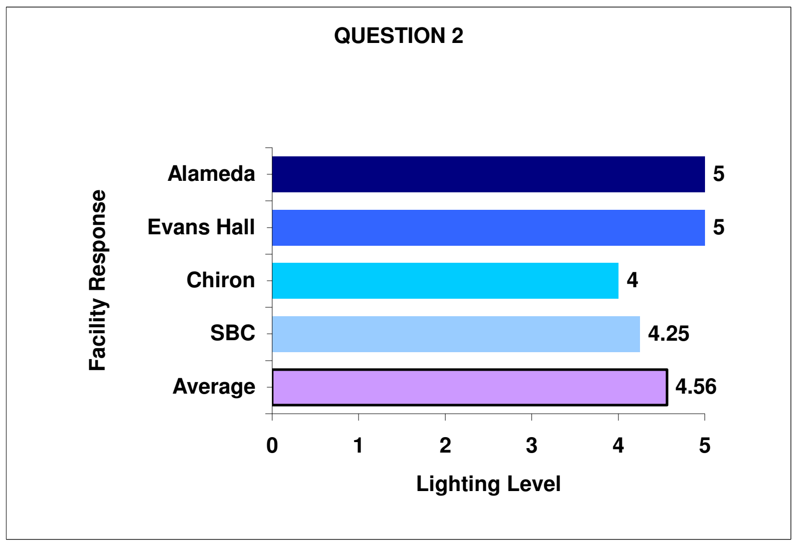
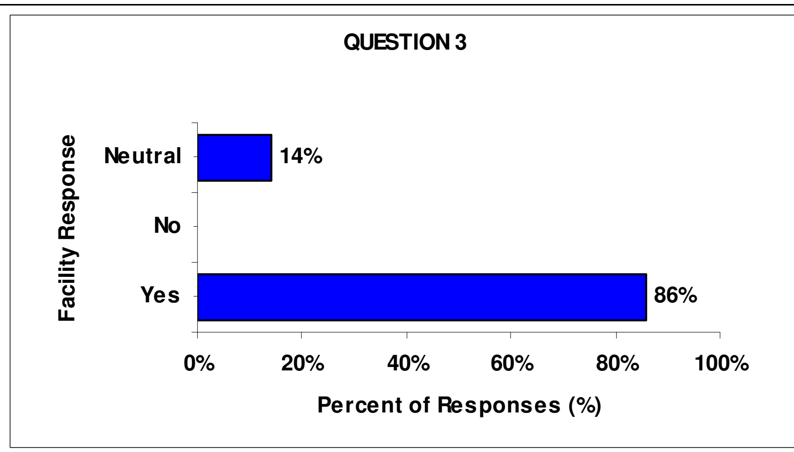
- A facility survey with seven building managers and safety engineers on the four project sites
- An occupant survey with 29 users of the four project stairwells
- A survey with the project installing contractor and field investigator

The results of the surveys, along with the site managers, users, contractors, and field investigator comments, are presented and summarized in this section.

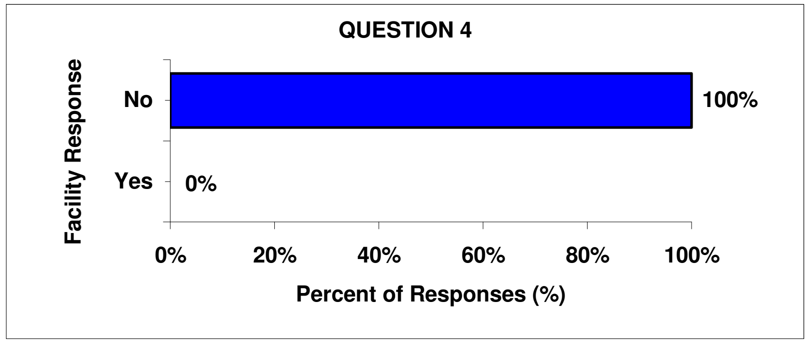
4.2. Facility Manager Survey Results

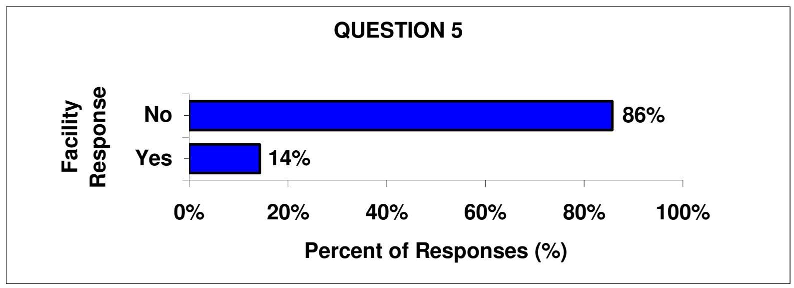
The results of the facility manager survey involving seven building managers and safety engineers on the four-project sites are summarized in Table 7.

Table 7. Facility manager survey results

<table>
<tr><th>Question</th><th>Response</th></tr>
<tr><td>Question 1. Was the overall appearance of the fixtures acceptable?</td><td>
</td></tr>
<tr><td>Question 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).</td><td>
</td></tr>
<tr><td>Question 3. Were the reaction times of the occupancy sensors, from low level to high level, sufficient?</td><td>

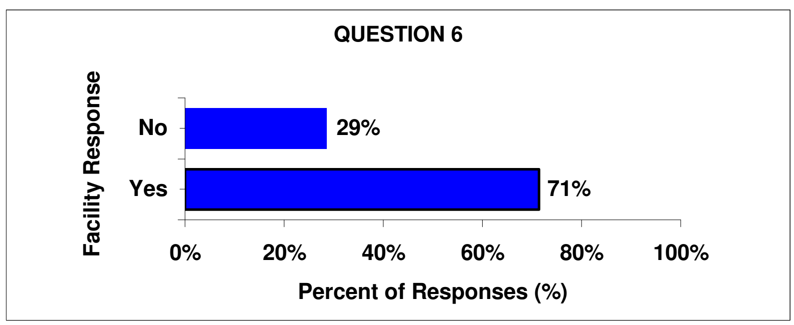
Facility manager comments:
Adjustments were needed.
Somewhat.</td></tr>
</table>

<table>
<tr>
<td>Question 4. Did the bi-level lighting keep you or anyone else from using the stairwell? If so, why?</td>
<td>


</td>
</tr>
<tr>
<td>Question 5. Were there any malfunctions of the fixtures lamps, ballasts, etc, that required repairs? If so, what were they?</td>
<td>


Facility manager comments:

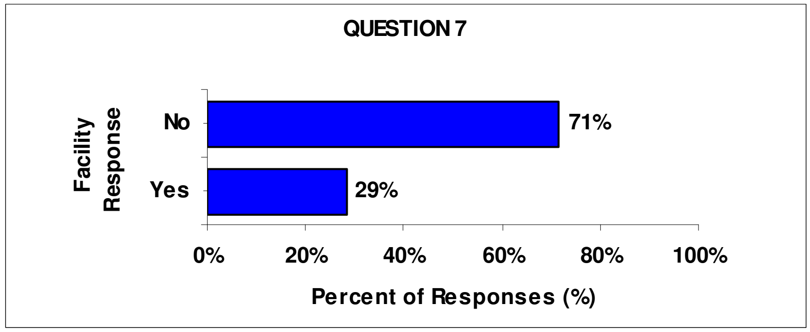
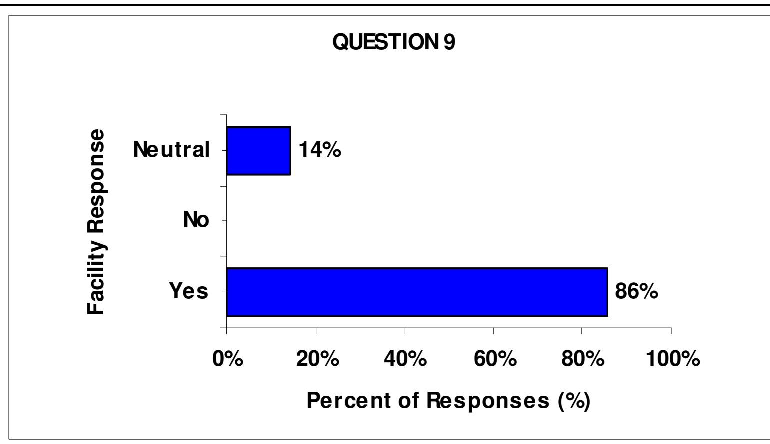
None after startup.
Time on High level had to be reset.

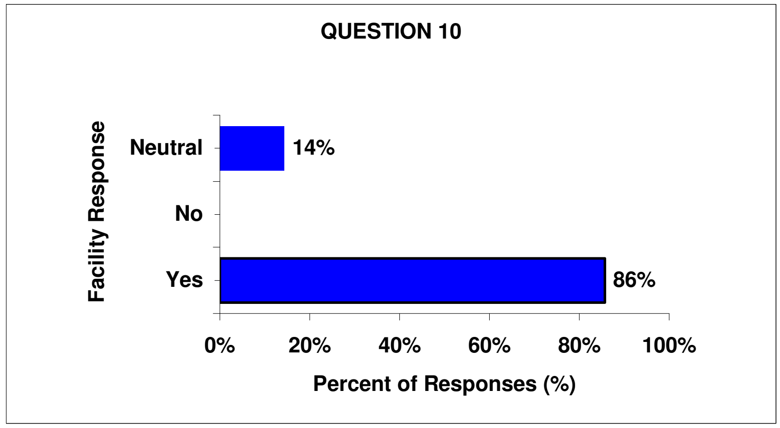
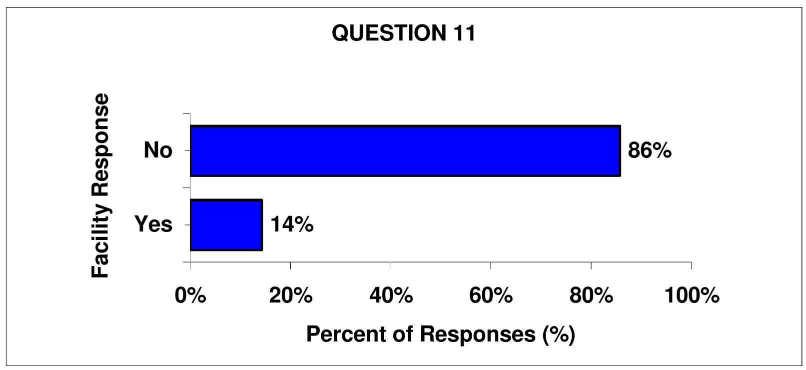
</td>
</tr>
<tr>
<td>Question 6. Were you able to observe the low level lighting? If so, what are your thoughts on the light levels provided?</td>
<td>


Facility manager comments:

Low-level lighting would be adequate if the sensor failed on one or two fixtures.
Low-level lighting was equivalent to the constant level lighting provided by original fixtures.
More energy savings could be achieved with lower setting on low-level.
Low-level lighting provided sufficient light.

</td>
</tr>
</table>

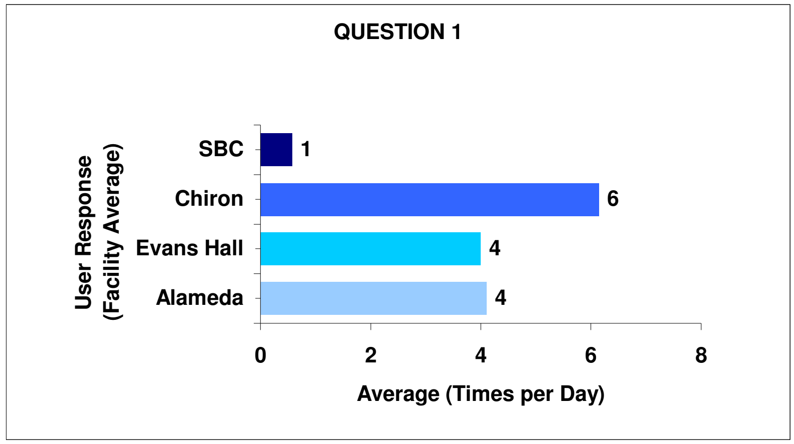
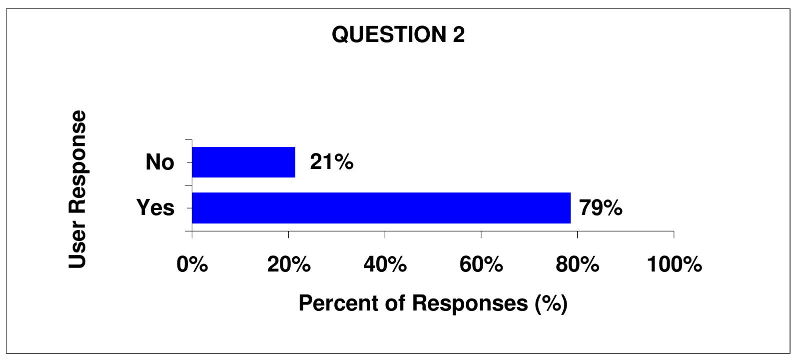
Question 7. Would you change anything about the installation, such as fixture appearance, fixture construction, occupancy sensor reaction times, etc? If yes, what would you change?	 Facility manager comments: • I would use a standard straight lamp in lieu of "U" type lamp installed on project. • I would suggest a brighter stairway.
Question 8. What is your overall opinion of the project and the potential for saving energy? Please elaborate.	Facility manager comments: • Very good. We would like to apply to our building underground garage. • Interesting project. We would like to see final energy analysis or research project. • A stairwell that was used less would benefit more. We could benefit even more by turning lights off when natural light is available through windowed stairwells. • Excellent plan to save money.
Question 9. Would you recommend bi-level lighting in other stairwells at your site or to other colleagues at their facilities?	 Facility manager comments: • I first would want to see the final energy analysis. • I would suggest it for new construction if it fit the style of the stairwell.

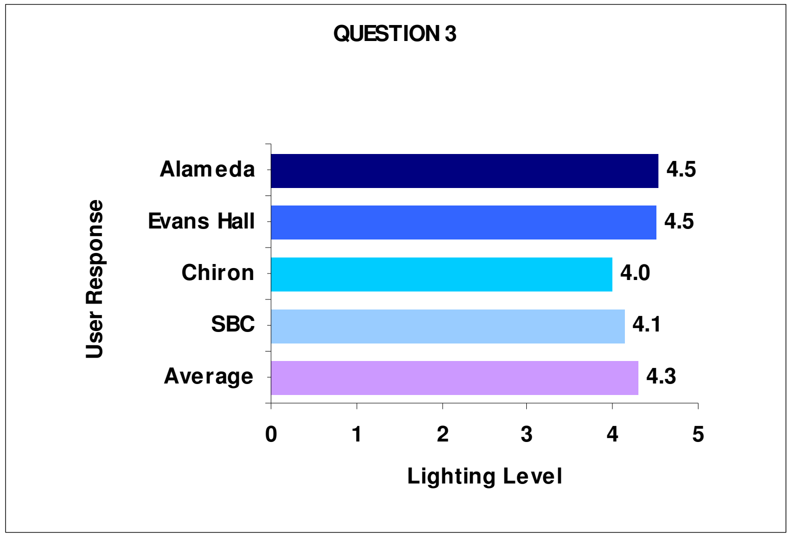
<table>
<tr><td>Question 10. Do you think by using bi-level stairwell lighting that energy can be saved?</td><td>
Facility manager comments:
• I first would want to see the final energy analysis.
• I think it would be a small amount.</td></tr>
<tr><td>Question 11. Do you have any other concerns about the bi-level stairwell lighting not mentioned above?</td><td>
Facility manager comments:
• I wonder about fixture components failure rate 2–5 years from now.</td></tr>
</table>

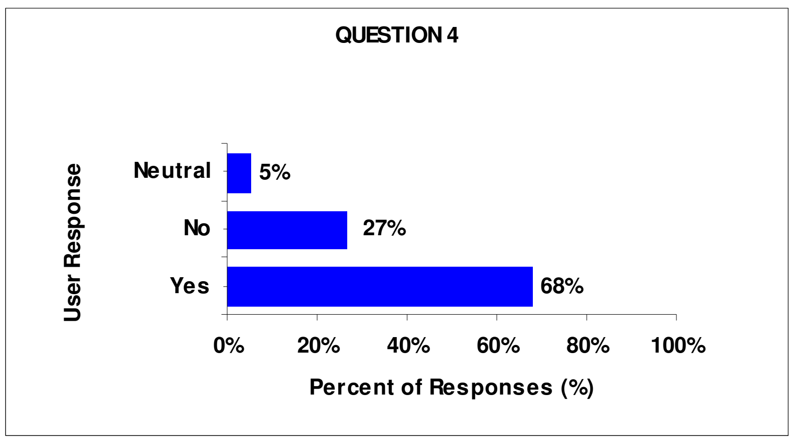
4.3. Building User Survey Results

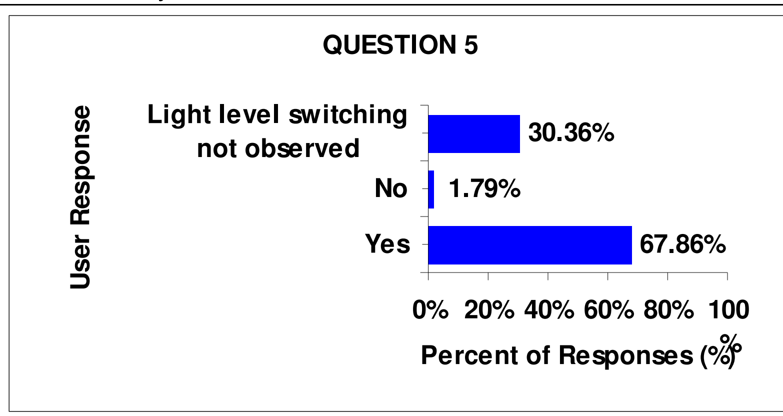
The results of the occupant survey, which was conducted with 29 users of the four project stairwells, is summarized in Table 8.

Table 8. Building user survey results

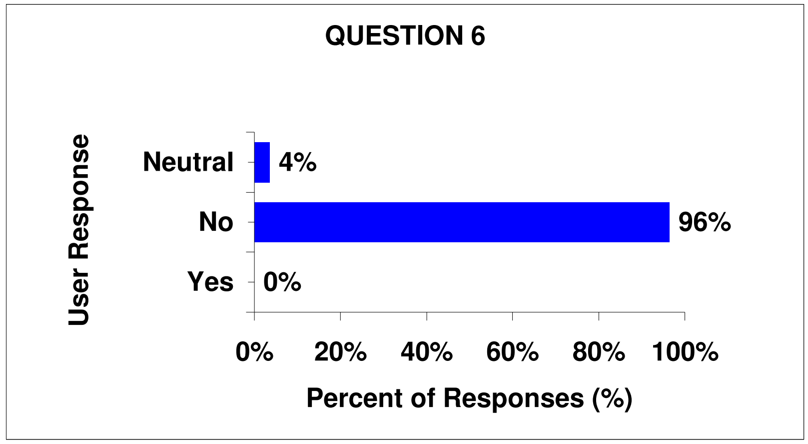
Question 1. Do you use the stairwells? If so, on average, how many times a day do you use them?	 Individual user comments: • Once every two weeks. • Few times per year. • Often. • One to three times per week.
Question 2. Have you noticed a change in the stairwell lighting?	 Individual user comments: • Stairwell was brighter. • Not much change.

<table>
<tr>
<td>Question 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).</td>
<td>


</td>
</tr>
<tr>
<td>Question 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?</td>
<td>


Individual user comments:
Not Sure.
Barely.
</td>
</tr>
<tr>
<td>Question 5. Were you satisfied with the speed at which the light levels were increased?</td>
<td>


Individual user comments:
Too slow.
</td>
</tr>
</table>

Question 6. Did the lighting keep you or anyone else from using the stairwell? If so, why	 Individual user comments: • Needs to be brighter.

4.4. Comments and Observations from Project Installer and Field Investigator

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

A number of steps were required prior to the installing the fixtures at the four sites:

- Identify whether the local building department would require permits for the lighting change-out. Only one of the four sites required a permit, and construction documents for that site were submitted to the local building department and approved.
- Establish a staging area 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 could commence.
- Reprogram the motion sensors prior to the start of the first installation and after the lighting fixtures were delivered to the first two sites (due to a problem discovered by the motion sensor manufacturers). The reprogramming of the motion sensors took place in the staging area of the first two sites, and the motion sensors for the remaining two sites were reprogrammed at the lighting manufacturer plant prior to delivery[10].

The first installation was done at Evans Hall on the campus of UC Berkeley. This first installation established the installation approach to be taken for the remaining three sites:

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

- Locating power and emergency lighting circuits
- Mounting the lighting fixtures and equipment
- Setting fixture motion sensor sensitivity

The average time to install a lighting fixture at this site was approximately 50 minutes, not including time needed to remove 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 that required adjustments to the motion sensors:

- 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-floor's 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.
- At the Alameda County and AT&T sites, the lighting level switched from low to high level when vibrations were sensed through the metal decking on the floor above.
- At the Alameda County site, one of the lighting fixtures did not switch from low level to high level in response to the opening of the stairwell door. 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 it sensed a person stepping into the stairwell.

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 County and AT&T 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.

5.0 Product Economics

5.1. The Product

LaMar Lighting's Occu-smart product line consists of unique bi-level fixtures from that operate at two levels:

- A low standby light level
- Full light output, achieved instantly 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 the following:

- High quality one- or two-lamp fixtures in 120 V or 277 V 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 W depending on fixture configuration.
- 100-hour lamp conditioning circuit to ensure 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 Underwriters Laboratories Inc.-(UL-) listed as "emergency lighting and power equipment" and can be used instead of the common "headlamp" emergency backup lights.
- Five-year factory warranty on all ballasts and sensor components.
- All fixtures are UL listed and made by the International Brotherhood of Electrical Workers Union.
- Easy two-wire installation.
- Multiple "knockout" openings to facilitate any new or retrofit application.

5.2. Product Configurations

This fixture is designed to be used in applications with infrequent occupancy where 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 in Table 9 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.

Table 9. Common configurations

Configuration			120 V		277 V	
			New	Retrofit	New	Retrofit
4'	1-Lamp	T12	n/a	**	n/a	**
		T8	**	**	**	**
4'	2-Lamp	T12	n/a	**	n/a	**
		T8	**	**	**	**
2'	1-Ulamp	T12	n/a	**	n/a	**
		T8	**	**	**	**
2'	2-Lamp	T12	n/a		n/a	
		T8				

**Economic analysis provided in this report.

5.3. Supplier's Product Costs and Price

LaMar 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 120 V and 277 V applications.

Table 10 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.

Table 10. Lamp/ballast/voltage combinations

Configuration		120 V			277 V		
		33%	10%	5%	33%	10%	5%
4'	1-Lamp	$163.45	**	$186.95	$163.45	**	$186.95
4'	2-Lamp	$163.45	$172.25	$186.95	$163.45	**	$186.95
2'	U-Lamp	$158.70	**	$180.60	$158.70	**	$180.60
2'	2 Lamp	**	**	$182.25	**	**	$182.25

**Not Available.

Note: Prices are for 40 fixtures or more in a single shipment.

5.4. Consumer's Installation-Related Costs

In retrofit applications, the total cost of installation includes 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 fixture 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.

5.5. Effects on Non-Energy Operations and Maintenance Cost

The step-down function used in the LaMar bi-level fixture differs significantly from simply turning on and off a fixture via 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 rather than restarting—an act 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.

5.6. 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. LaMar estimates that unoccupied periods in typical stairwells occur 95% of the time. This estimate was tested by LBNL during the monitoring portion of 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, an initial savings just for installing efficient T8 lamps in the new fixtures will accrue.

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 savings are significant. If an 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 (kilowatt [kW]) reductions and energy consumption (kilowatt-hour [kWh]) separately.

5.7. Non-Energy Benefits to Consumer

The importance of lighting stairwells for safe emergency egress under extreme conditions has received increased attention from both building owners and property insurance companies since 9/11. Many emergency preparedness experts are questioning whether current minimum light levels called for in life safety codes are truly sufficient for emergency egress situations, especially where smoke may be a factor. The bi-level stairwell fixture has the potential to significantly increase light levels in stairwells when needed, while 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 lessee 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. (Details are available from professional tax advisors.)

5.8. Payback Period and Return on Investment

A fixture with the ability to sense occupancy and control light levels 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 achievable in less than 5 years against better T8 fixtures.

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

The sections below provide more details on economic benefits.

5.8.1. Net Economic Benefit for a Customer within an Investor-Owned Utility District Paying 15.5¢kWh

Analysis

Table 11 shows the analysis of the net economic benefit of installing the bi-level fixture in a building served by in investor-owned utility (IOU) and paying 15.5¢/kWh for electricity.

Table 11. Net Economic Benefit: IOU district/15.5¢/kWh

Base Case Fixture	New or Retrofit Bi-Level Fixture	Base Cost: New Technology	Old Fixture (W)	New Fixture (W)	Level-2 (W)	Average (W)	Average kW Saved	kWh saved per year	Yearly Savings
Product 1: 10% Standby (120 V 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 (120 V or 277 V)									
(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 (120 V or 277 V)									
(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

The following assumptions were used in the economic benefit shown in Table 11:

- 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 per cent
- Time new fixture is on at minimum (stepped down) power: 95 per cent
- Total hours fixture is on per day: 24
- Total days per year fixture is on: 365

5.8.2. Payback and Avoided Cost for a Customer within an IOU District Paying 15.5¢kWh

Analysis

Table 12 shows results of the payback and avoided cost for a customer within an IOU district paying 15.5¢kWh.

Table 12. Payback and avoided cost: IOU district/15.5¢/kWh

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)
Product 1: 10% Standby (120 V 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 (120 V or 277 V)									
(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 (120 V or 277 V)									
(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

The payback and avoided cost analysis applied all of the assumptions used in the net economic benefit, as well as the following: :

- Net present value of a kWh: $0.70
- Optimal period for a direct payback: 2.5 years

5.8.3. Net Economic Benefit for a Customer within a Municipal Utility District paying10.5¢/kWh

Analysis

Table 13 shows the net economic benefit analysis for a customer within a municipal utility district paying 10.5¢/kWh for electricity.

Table 13. Net Economic Benefit: municipal utility district, 10.5¢/kWh

Base Case Fixture	New or Retrofit Bi-Level Fixture	Base Cost New Technology	Old Fixture (W)	New Fixture (W)	Level-2 W	Average W	Average kW Saved	kWh saved per year	Yearly Savings
Product 1: 10% Standby (120 V 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 (120 V or 277 V)									
(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 (120 V or 277 V)									
(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

The following assumptions were used in the net economic benefit analysis:

- 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

5.8.4. Payback and Avoided Costs for a Customer within a Municipal Utility District paying 10.5¢/kWh

Table 14 below shows the payback and avoided cost analysis for a customer within a municipal utility district paying 10.5¢/kWh.

Table 14. Payback and avoided cost: municipal utility district/10.5¢/kWh

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)
Product 1: 10% Standby (120 V 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 (120 V or 277 V)									
(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 (120 V or 277 V)									
(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

The payback and avoided cost analysis use all the assumptions from the net benefit analysis, as well as the following:

- Net present value of a kWh: $0.70
- Optimal period for a direct payback: 2.5 years
-

5.8.5. Key Findings from the Economic Analyses

The project team derived the following key findings from the economic analyses described above:

- A new alternative fixture such as the bi-level fixture faces the lowest incremental cost increase in new applications or new buildings.
- The best payback scenarios occur in new applications in IOU districts (which tend to have higher electricity rates than do municipal utilities.
- The toughest payback scenarios are retrofits in municipal utility districts.
- The current bi-level fixture line has great paybacks against any fixtures with T12 lamps.
- Against fixtures with T8 lamps, paybacks generally range from 2.5–5 years in IOU districts; ranges are higher in municipal utility districts.
- 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.

5.9. Energy Savings Volumes: Per Fixture Method

This section presents details on estimating market size in California. This estimate was based on the following assumptions:

- 5.83 billion square feet (ft^2) of commercial space in California
- 50% of total commercial space in California is in multi-story buildings with interior stairwells
- 2% of multi-story square footage is stairwells
- One fixture for every 58 ft^2 of stairwell
- **1 million stairwell fixtures in California** in interior spaces, a suitable market for this product

Using figures from the net economic benefit analyses shown in Tables 11 and 13 above, the average energy savings per fixture is shown in Table 15. Findings show that replacing an old fixture with a new bi-level fixture would create an average energy savings per fixture of about 39.0 W.

Thus, 1 million fixtures saving an average of 39 W per fixture would have a maximum potential to reduce peak electrical demand by **39 megawatts (MW)**.

Table 15. Average energy savings per fixture

Old Fixture (W)	New Fixture (W)	Level-2 (W)	Time at Full Power	Time at Min Power	Average New Fixture (W)	Average Energy Savings per Fixture (W)	Power Density of Old Fixtures at 58Wft²/fixture
90	62	13	5%	95%	15.5	74.5	1.55
50	62	13	5%	95%	15.5	34.5	0.86
62	62	13	5%	95%	15.5	46.5	1.07
32	62	13	5%	95%	15.5	16.5	0.55
90	62	28	5%	95%	29.7	60.3	1.55
50	32	14	5%	95%	14.9	35.1	0.86
56	32	14	5%	95%	14.9	41.1	0.97
62	62	28	5%	95%	29.7	32.3	1.07
32	32	14	5%	95%	14.9	17.1	0.55
34	32	14	5%	95%	14.9	19.1	0.59
90	62	13	5%	95%	15.5	74.5	1.55
50	32	8	5%	95%	9.2	40.8	0.86
56	32	8	5%	95%	9.2	46.8	0.97
62	62	13	5%	95%	15.5	46.5	1.07
32	32	8	5%	95%	9.2	22.8	0.55
34	32	8	5%	95%	9.2	24.8	0.59
56	36	9	5%	95%	10.4	45.6	0.97
34	36	9	5%	95%	10.4	23.6	0.59

5.10. Energy Savings Volumes: Power Density Method

The average power density in watts per square foot (W/ft^2) for all the commercial buildings in the data presented by LBNL is 1.574 W/ft^2. The average power density for stairwells from Table 15 above is about 0.93 W/ft^2. This difference is not surprising, given the typically lower light levels found in stairwells.

If half of the 5.83 billion ft^2 of commercial space in California has interior stairwells and these stairwells are 2% savings by dimming when the stairwells are unoccupied, the maximum potential to reduce peak electrical demand would be **52 MW.**

5.11. 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, would be:

- In an IOU district (15.5¢/kWh): **$68 million per year**
- In a municipal utility district (10.5¢/kWh): **$46 million per year.**

6.0 IFMA Workshops

From March to September, 2004, the International Facilities Management Association conducted three meetings to introduce new lighting technologies to its members. These meetings are discussed in the sections below.

6.1. California Radar: Shining Light on New Products and Regulations Workshop, March 2, 2004

The first meeting was a half-day workshop, *California Radar: Shining Light on New Products and Regulations*, held March 2, 2004 in a conference room at Chiron's headquarter facilities in Emeryville. 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. The following presentations were given:

- 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 at the time of the meeting, provided an overview of the Energy Commission and PIER. 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 LRP. 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 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.

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

Approximately 40 people attended the March 2004 workshop. Most were facility members in the San Francisco Bay Area. Three of the meeting participants 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.

About half of the meeting participants stayed for a 20-minute tour of the stairwell, which housed the bi-level light fixtures. While inspecting the stairwell, building occupants were using the stairwell, and the light fixtures were 'on' providing more than adequate lighting. 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.

6.2. IFMA Sacramento Chapter Meeting, June 20, 2004

The second meeting was a breakfast meeting IFMA Sacramento chapter held at Franklin Templeton Investments in Rancho Cordova on June 20, 2004. Don Aumann presented an hour-long presentation, *Using PIER Results to Improve Building Energy Performance.* He introduced the new lighting technologies from the PIER LRP to facility managers, potential users of these new technologies. Workshop participants also learned more about the 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. The presentation was followed by a 30-minute question and answer session.

Approximately 15 to 20 people attended the workshop. Most were engineers, energy consultants, or facility managers from the local area. Several members of the audience stayed after the one-hour 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.

6.3. California Radar: Shining Light on New Products and Regulations Webcast, September 21, 2004

The last meeting was not a physical meeting but rather a webcast, *California Radar: Shining Light on New Products and Regulations*, held on September 21, 2004. At this webcast, attended by IFMA members throughout California, speakers presented via telephone and web, and viewers listened and viewed the presentation using streaming audio. The webcast allowed viewers to submit questions, which presenters answered live and after the webcast. The following presentations were given.

- Kit Tuveson updated his March 2004 presentation 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 and Electric shared information about utility incentives for commercial building users, tailoring his presentation for all of California.

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

6.4. Conclusion

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.

7.0 Potential for Lighting Code Changes for California Stairwells

7.1. Introduction

This section assesses 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 as of 2004, it was likely that minimum lighting in stairwells would be increased to 10 footcandles (fc) (or 108 lux) during occupied periods. However, this requirement is not likely to take effect in new buildings until 2007.

7.2. 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. The subject is typically found in code 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 that has generated a respected body of published work. The horrific attack on the World Trade Center in New York in 2001 focused public attention on the importance of stairwells, which are typically out of sight and out of mind.

Three key factors ensure the safe use of stairs: visibility, geometry of steps, and handrails. Of these, 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—whether used or not—be lighted 24 hours every day. To date, energy costs for lighting have been modest because codes have required only 1 fc (or 10.8 lux) of lighting in exit stairs. However, code bodies have been reassessing this requirement, and several have already accepted proposals that require increasing exit stair lighting to 10 fc (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 1 fc (10.8 lux) during unoccupied periods.

This section first looks briefly at how the code making process works and identifies whether the provision increasing required lighting in stairwells had 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.

7.3. How Codes are Made and Adopted

A full discussion of the process for making and adopting building and fire codes is beyond the scope of this section. Code development is a mammoth undertaking, involving several national and international organizations, dozens of committees, and hundreds of volunteers. However, a simplified model is helpful to gain an understanding of code changes. The code process is roughly divided into four steps:

- Committee work: The beginning of the code-making process includes hundreds of committees that meet regularly to monitor existing codes, carefully consider proposals to modify existing codes, vote on proposed code changes, and revise model codes. These committees are made up of building or fire professionals, industry representatives, academics, and other experts. Non-government members can include the American National Standards Institute (ANSI), the International Code Council (ICC), the National Fire Protection Association (NFPA), and government members include the Access Board. This body was created by Congress to oversee design guidelines for the Architectural Barriers Act and the Americans with Disabilities Act (ADA). All of these organizations have easily accessed websites.
- Model code development: On a national basis, work of the expert committees is brought together in model codes, so called because they are examples 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. Model building codes include the International Building Code (IBC), the International Residential Code (IRC), and the new building code from the NFPA, NFPA 5000. Also relevant are the Life Safety Code (NFPA 101) and the Uniform Fire Code (NFPA 1). Although not a model code, but rather a federal law, the ADA Accessibility Guidelines (ADAAG) specifies design standards for the construction or alteration in the private and public sectors.
- State and local adoption: Model codes become law when they are adopted by a local jurisdiction, typically a city or county. There are more than 30,000 such jurisdictions in the United States. Each jurisdiction may accept the model code as is, or it may make amendments based on local conditions. Amendments may cause a new code provision to be added to the model code and then be removed by a different local jurisdiction. Thus, an organization that does not like a code provision but cannot get it removed at the national level can still remove it 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 ensure 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.

- Enforcement: Building codes are enforced by local city or county building inspectors. Fire codes are enforced by the "Authority Having Jurisdiction," which 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 in disagreement. This puts the building owner or contractor in an awkward position that can sometimes be difficult to resolve. In California, the BSC works to resolve these conflicts prior to code adoption to avoid presenting conflicting codes to the builder or developer.

In the case of the ADA standards, the Department of Justice has enforcement authority. If there is a problem, negotiations are required. If the problem cannot be resolved through negotiation, the Department of Justice files a lawsuit.

7.4. Status of the Proposed New Lighting Standard for Stairwells in the Model Codes as of 2004

A new standard has been proposed that will increase the required amount of light in stairwells, during occupancy, from the current standard 1 fc (or 10.8 lux) to 10 fc (or 108 lux) on the stair tread or landing. The codes or code-related organizations where this new lighting provision had been accepted as of 2004 are listed below with a brief discussion of each.

7.4.1. ANSI —Accepted

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 on November 26, 2003 (http://www.iccsafe.org/cs/standards/a117/index.html). The "Final Proofing Draft Z-3", published January 31, 2004, contained the following sections:

- **504 Stairways**
  - **504.8.1 Luminance Level**. Lighting facilities shall be capable of providing 10 fc (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.

7.4.2. 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 Spring 2003, the Technical Committee UFC-AAA of NFPA approved the 2003 Edition of the Uniform Fire Code™ (http://www.nfpa.org/Codes/index.asp). That code contained 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:
    - During conditions of stair use, the minimum illumination for new stairs shall be at least 10 fc (108 lux), measured at the walking surfaces.
    - The minimum illumination for floors and walking surfaces, other than new stairs, shall be to values of at least 1 fc (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 fc (2.2 lux) in any designated area.

7.4.3. NFPA 10 –Life Safety Code™—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 became part of the model code ((http://www.nfpa.org/Codes/index.asp):

  - **7.8.1.2.2** Automatic, motion sensor-type ....[same language as NFPA1, 14.12.1.2.2, above]
  - **7.8.1.3** The floors and other walking surfaces ….[same language as NFPA1, 14.12.1.3 above]
    - During conditions of stair use , the minimum illumination for new stairs shall be at least 10 fc (108 lux), measured at the walking surfaces.

7.4.4. NFPA 5000–Building Construction and Safety Code™—Pending/Unlikely

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 ICC. The Bi-Level Stairwell Fixture Performance project evaluated the 2002 edition of this code ,which was only its second cycle since inception (http://www.nfpa.org/Codes/index.asp). That code has yet to be accepted by any local jurisdiction. It was subsequently adopted for analysis in July 2003 by the California Building Standards Commission, but was not implemented.

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 fc. 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. It was anticipated that the new 10 fc and control references will be easily voted into the 2005 Edition of NFPA 5000.

California chose not to use NFPA in its revised code, adopted in summer 2007 and effective as of January 2008.

7.4.5. ADAA —Accepted

The Access Board, responsible for developing guidelines for implementing the ADA, 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. In July 2004, these new proposed guidelines were published in final form and did not address exit illumination. (http://www.access-board.gov/ada-aba/status.htm)

7.4.6. IBC

Prior to 1994, three separate U.S. organizations published 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 ICC. The ICC prepares and publishes both the IBC and the IRC.

The transition to create the ICC was slowed by a few delays. 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 fc standard was not moved into the ICC, IBC, and IRC processes. The ICC committee process determined to not include a 10 fc standard in its next (2007) round of code updates but the door remains open for future rounds (http://www.iccsafe.org/cs/codes).

7.4.7. Summary

In summary, the new 10 fc lighting standard has been accepted by both ANSI and NFPA, but was not included in the ADAAG or ICC process. Acceptance by both ANSI and NFPA gives the new lighting standard some deal of credibility. Whether or not the new model stairwell lighting standard will become law in California, however, has everything to do with the code adoption process unique to California, the subject of the next section.

7.5. The Code Adoption Process in California

In California, the BSC is "the boss" when it comes to building 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. Those adopted Codes 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 by the other jurisdictions (http://www.bsc.ca.gov/index.html).

7.5.1. California Uniform Fire Code

California's Office of the State Fire Marshal is the state agency responsible for developing fire and life safety policy and regulations for the California Fire Code. The BSC adopts the recommendations proposed by the Office of the State Fire Marshal for the California Fire Code. Office of the State Fire Marshal had suggested the 2003 Edition of NFPA 1 as the basis for the 2004 Annual Code Adoption Cycle for the California Fire Code. The deadline for submitting proposed code changes to the BSC was August 2004, but updates had been placed on hold in May 2004 due to the overarching discussions in California concerning whether to use the ICC or NFPA model code as the base document. The Office of the State Fire Marshal eventually developed a revised Building and Fire Code for California using the 2006 International Building Code (IBC) and the International Fire Code (IFC) as the base document. The objective has been to create an adoption package that will include model code language from the 2006 IBC and IFC, with current applicable California amendments for the 2007 California Building Standards Codes. (http://osfm.fire.ca.gov/CodeAdoptionProcess.html).

7.5.2. California Building Standards Code

Two major hurdles delayed a new draft of the California Building Code in 2004. First, because of a change of Governors and a moratorium by the new Governor on all new codes, the 2003 Annual Code Adoption Cycle was abandoned. As of May, 2004, all state agencies had withdrawn their proposed changes to the Building Code.

Second, California was in the midst of choosing between the model building codes proposed by the ICC and NFPA. After considerable deliberation, the BSC chose the 2003 Editions of the NFPA 5000 Building Code and NFPA 1 Uniform Fire Code. But that decision was highly controversial. As of March 1, 2003, the BSC issued a lengthy

Adoption Plan that deferred a new code until the summer of 2007. (http://www.bsc.ca.gov/documents/visio-NFPA5000&1_AdoptionPlan.pdf).

As of the date of this report, this debate has been resolved. The new code is proposing to rely on the ICC. If adopted on schedule, the new provisions will take effect in early 2008.

7.6. The Situation for Existing Buildings

All of the above discussion concerning codes affects only new buildings about to be built or existing buildings undergoing significant renovations. 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 already in place. If that system produces 1 fc 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 in 1998, more than 400,000 injuries associated with stairs or steps were treated in U.S. Hospital Emergency Departments. As noted in the opening paragraphs of this section, the three key environmental factors for safe stairs are visibility of stairs, geometry of steps, and handrails. Now that the new 10 fc standard has become accepted by three of the four most important model codes, it could become an issue in reviewing liability cases where visibility is a possible factor in the fall. To avoid future liability cases, building owners may wish to consider exit stair lighting upgrades even if the upgrades are not required by code.

8.0 Conclusions and Recommendations

8.1. Conclusions

At least three lighting fixtures are offered for sale in California that combine a fluorescent lighting fixture and an occupancy sensor to allow building owners to meet save energy by providing greater illumination during periods of occupancy and minimal illumination when there is no occupancy.

PIER LRP has supported development of one of these fixtures, now available from LaMar Lighting through the Occusmart product line, and is currently monitoring multiple installations of this fixture in California to be sure that it can meet all proposed code provisions. Initial findings indicate that this new technology can be installed with reasonable paybacks. Work is continuing to make this technology even more cost effective.

The following factors may influence whether that owners and developers of new buildings in California will or will not be subject to the new 10 fc standard for exit lighting.

- The public is highly sensitive to building exit safety.
- Visibility is a key element in exit stair safety.
- Three out of four model codes have adopted the 10 fc 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 BSC has rejected NFPA codes, which either include or soon will include the 10 fc standard, as the basis for the next California Building Code.
- Lighting technology exists that can cost effectively provide higher light levels only when needed so as to keep energy cost increases modest.

Given the current complexity of code adoption in California, the earliest any such new code provision could come into effect would be beyond January 2008. It is anticipated that some percentage of owners and managers of existing buildings may voluntarily choose to upgrade exit lighting as a hedge against future liability. Use of bi-level switching in stairwell luminaires can lead to improvements in public health and safety with only a very modest increase in energy cost.

8.2. Recommendations

In IOU districts, the most advantageous payback scenario, payback for the bi-level stairwell fixture can be 2.5–5 years. Decreasing the payback period will require value engineering (including engineering to produce cheaper ballasts) and utility rebates. In

IOU districts, rebates should be approximately the amount achieved if one combined an efficient fixture rebate and an occupancy sensor rebate.

8.3. Benefits to California

The project team used the following assumptions to estimate market size:

- California has about 5.83 billion ft^2 of commercial space.
- Multi-story buildings with interior stairwells comprise approximately 50% of total commercial space in California.
- Stairwells account for roughly 2% of multi-story square footage.
- There is one fixture for every 58 ft^2 of stairwell.

Thus, approximately 1 million stairwell fixtures are installed in interior spaces in California and represent a suitable market for this product.

Replacing a current always-on fixture with a bi-level fixture creates an average energy savings of about 39 W per fixture. Based on current data, the statewide demand savings at 1% market penetration would be approximately 400 kW or 4 MW per year. Assuming 6132 operating hours per year, 1 per cent market penetration would save about 2453 MWh.

9.0 Glossary

ADA	Americans with Disabilities Act
ADAAG	ADA Accessibility Guidelines
ANSI	American National Standards Institute
BOCA	Building Officials and Code Administrators International, Inc
BSC	Building Standards Commission
Energy Commission	California Energy Commission
fc	Foot-candle
ft^2	square feet
IBC	International Building Code
ICBO	International Conference of Building Officials, Inc
ICC	International Code Council
IFMA	International Facility Management Association
IOU	investor-owned utility
IRC	International Residential Code
kW	kilowatt
kWh	kilowatt-hour
LaMar	The LaMar Lighting Company, Inc.
LBNL	Lawrence Berkeley National Laboratory
LRC	Lighting Research Center
LRP	Lighting Research Program
MW	megawatt
MWh	megawatt-hour
NFPA	National Fire Protection Association
NYSERDA	New York State Energy Research and Development Authority
OMB	Office of Management and Budget
PAC	Professional Advisory Committee

PIER	Public Interest Energy Research
RD&D	research, development, and demonstration
RPI	Rensselaer Polytechnic Institute
SBCC	Southern Building Code Congress International, Inc.
UL	Underwriters Laboratories Inc.
V	volt
W	watt
WFCA	Western Fire Chiefs Association
W/ft^2	watts per square foot