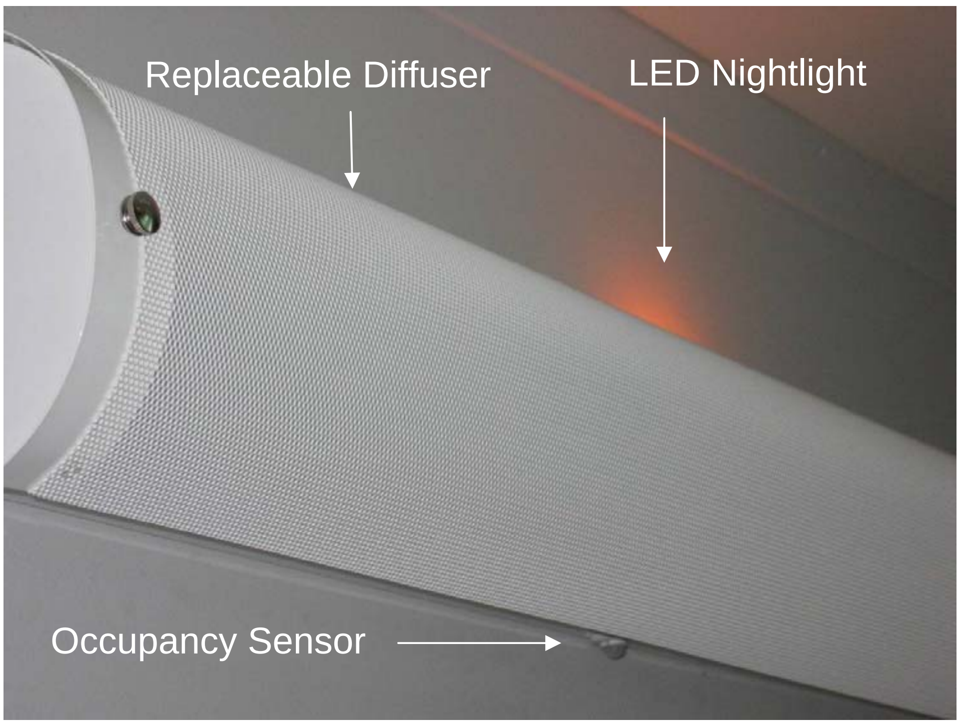
LIGHTING RESEARCH PROGRAM

Project 4.1 Hotel and Institutional Bathroom Lighting
FINAL REPORT



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California Energy Commission
Public Interest Energy Research Program

CONSULTANT REPORT

Arnold Schwarzenegger, *Governor*

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CALIFORNIA ENERGY COMMISSION

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Table of Contents

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

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

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

What follows is the final report for the Hotel and Institutional Bathroom Lighting Project, PIER Lighting Research Program Contract #500-01-041, conducted by the California Lighting Technology Center under contract to the Lawrence Berkeley National Laboratory and directed by Architectural Energy Corporation. The report is entitled Hotel and Institutional Bathroom Lighting. This project contributes to the Building End-Use Energy Efficiency program.

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

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

EXECUTIVE SUMMARY

There are unique energy savings opportunities in the United States' estimated 4 million hotel guestrooms, which includes approximately 365,000 rooms in California. One of the key opportunities relates to the lighting of the hotel guestroom bathrooms. The energy-saving opportunity is even larger considering the numerous related institutional applications such as dormitories, assisted living housing, etc.

The California Lighting Technology Center (CLTC) research team developed two energy-efficient bathroom lighting technologies that will save energy and improve safety in hotel bathrooms and related institutional applications. The first is a Motion Sensor Nightlight, targeted at retrofit applications. It is now a commercial product produced and distributed by The Watt Stopper as product WN-100. The second is a "Smart" Light Fixture (SLF), targeted at new construction or major renovations, to be produced and distributed by Speclight, a subsidiary of Lithonia Lighting. Both products reduce bathroom lighting energy use by about 50 to 75 percent.

The development of the Motion Sensor Nightlight (WN-100) technology involved collaboration among the PIER LRP, California Lighting Technology Center (CLTC), The Watt Stopper (TWS), Sacramento Municipal Utility District (SMUD), and Sacramento Doubletree Hotel. The WN-100 combines a motion-sensor with a low-power (less than one watt) LED nightlight into a wall switch unit that controls lighting based on occupancy. The LED nightlight remains on when lights are off, providing adequate nighttime illumination and energy savings from reduced usage of overhead lighting. A field study of the WN-100 at the Sacramento Doubletree hotel demonstrated an average of 50% energy savings with a 2–5 year simple payback. Most important, the WN-100 was perceived as an amenity by hotel room guests, rather than just an energy-saving device. A WN-100 demonstration project in assisted living housing is currently being planned by PG&E in collaboration with the CLTC.

The development of the Smart Lighting Fixture (SLF) involved collaboration among the PIER LRP, CLTC, SMUD, Speclight, and TWS. The SLF technology is based on the same strategy as the WN-100, i.e., combining occupancy-based switching with LED-based nightlight. However, the SLF consists of a lighting fixture that includes all of the features of the WN-100 technology, with the additional use of the LED nightlight as a safety light during power outage. The placement of the LED nightlight and the occupancy sensor at the lighting fixture offers even better nightlight illumination and occupancy sensing.

The CLTC explored the placement of LED nightlights and motion sensors, while SMUD addressed aesthetic issues related to the light diffuser and the overall fixture design. Several alternative combinations of LED nightlight and motion sensor placement were considered and tested in simulations and prototype fixtures at the CLTC. The iterative development, which involved a teamwork approach, resulted in a fixture design that is offered in three different lengths (two, three, and four feet) and provides a large selection of light diffusers to meet various aesthetic and financial needs and desires.

Using the same strategy and technology, the SLF is expected to offer the same 50% energy savings as the WN-100, with increased amenity, safety, and effectiveness of controls. Payback is expected to be 2–6 years. Moreover, the SLF offers significant first-cost savings, since it is a complete, out-of-the-box solution that replaces the traditional hotel bathroom renovation approach of custom-made fixtures constructed on site.

The final design of the SLF is currently being produced by Speclight, with TWS producing the motion sensor and LED drivers into one unit. Several demonstration projects are currently being planned in collaboration with SMUD at assisted living housing applications, and with the California Energy Commission at California college dormitories.

ABSTRACT

The California Lighting Technology Center (CLTC) research team developed two energy-efficient bathroom lighting technologies that will save energy and improve safety in hotel bathrooms and related institutional applications. The first is a Motion Sensor Nightlight, targeted at retrofit applications. It is now a commercial product produced and distributed by The Watt Stopper as product WN-100. The second is a "Smart" Light Fixture (SLF), targeted at new construction or major renovations, available from Speclight. Both units are expected to reduce energy use by about 50 to 75 percent energy with a 2–6 year simple payback.

Both units combine a motion-sensor with a low-power (less than one watt) LED nightlight into a wall switch unit that controls lighting based on occupancy. The LED nightlight remains on when lights are off, providing constant illumination and energy savings from reduced usage of overhead lighting.

The SLF consists of a lighting fixture that includes all of the features of the WN-100 technology, with the additional use of the LED nightlight as a safety light during power outage.

To speed product acceptance in the marketplace, CLTC staff will conduct several demonstration projects during 2005 for both technologies in assisted living and dormitory facilities through collaboration among the CLTC, SMUD, PG&E, California Energy Commission, and the University of California.

INTRODUCTION

Background

There are unique energy savings opportunities in the United States' estimated 4 million hotel guestrooms. One of the key opportunities relates to the lighting of the bathrooms in such guestrooms (Figure 1). The energy-saving opportunity is even larger considering the numerous related institutional applications such as dormitories, assisted living housing, etc.

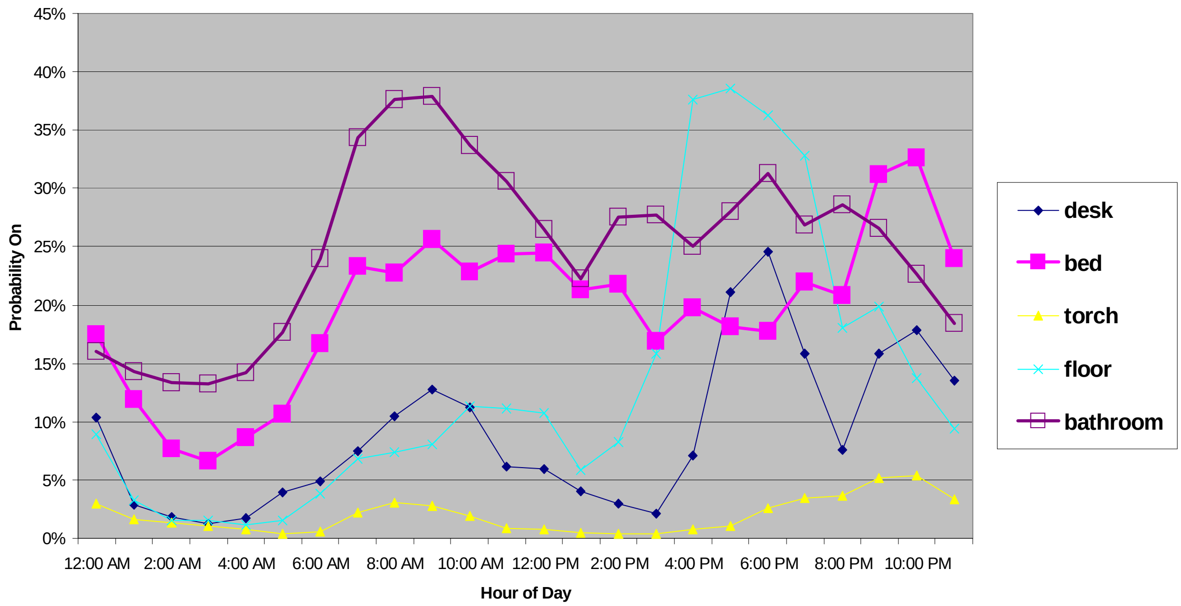


Figure 1: Usage patterns for hotel guestroom lighting as a function of time of day (Page and Siminovitch, 2000).

Prior research conducted by the CLTC staff has determined that the lighting energy in hotel bathrooms can be cut in half by using occupancy sensors, since bathroom lights seem to be left on for extended periods of time, because guests either forget to turn them off, or they leave the bathroom lights on deliberately, to serve as nightlights (Figure 2).

Hotel managers have traditionally been reluctant to utilize occupancy sensors in these applications due to concerns related to lights accidentally being turned off while the bathroom is occupied – for instance if someone is in the shower for a long period of time and out of the view of the occupancy sensor. The hotel managers that partnered with the CLTC were also accepting of the use of the bathroom light as a nightlight since it served their guests. They indicated that they would be very interested in energy savings, if these concerns related to "false-offs" and night lighting could be addressed.

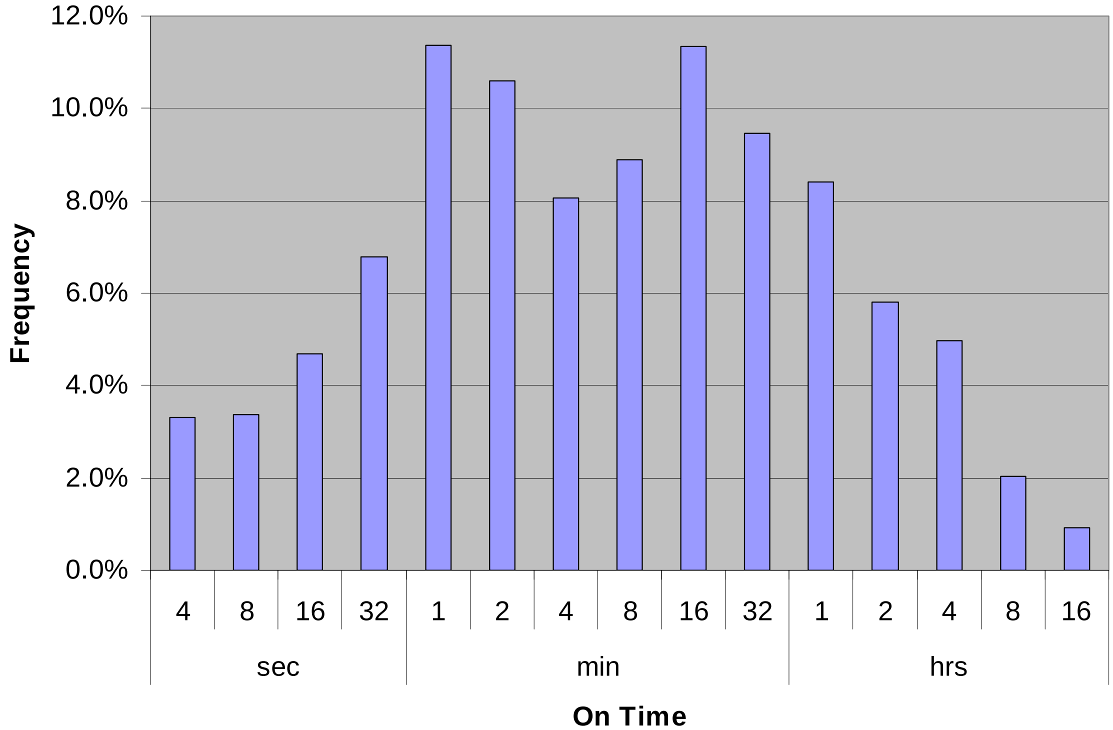


Figure 2: Frequency of hotel bathroom lights on-time (Page and Siminovitch, 2000).

Studying the total energy for the different durations of “on” status indicated that 75% of the bathroom lighting energy was consumed when the bathroom lights were left on for more than 1 hour (Figure 3). An occupancy sensor with a time delay of 1 or more hour would effectively reduce up to 75% of the energy used, while addressing the concerns related to false-offs. The integration of LED technology would effectively resolve the night lighting issue. These two ideas led to the formulation of this LRP project.

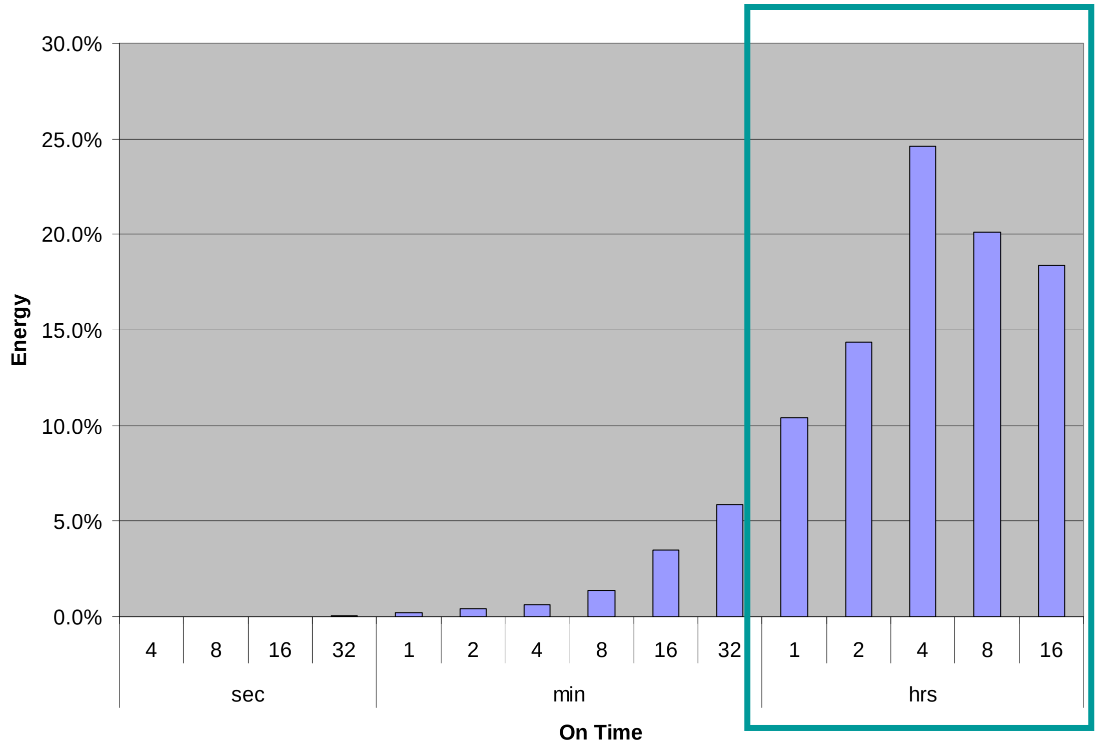


Figure 3: The total energy associated with the on-time of hotel bathroom lights. The highlighted box indicates the savings potential from using a one-hour occupancy sensor setpoint (Page and Siminovitch, 2000).

Project Objectives and Team

The goal of this project is to develop energy efficient bathroom lighting technologies that reduce energy use during unoccupied periods, through two key technical objectives:

1. Development of a retrofit Bathroom Lighting Control System
2. Development of a Smart Bathroom Lighting Fixture

The economic objective is to reduce energy use by 50 to 75 percent with a simple payback of three years or less. The project team includes:

- *California Lighting Technology Center (CLTC)*: project lead, develop technology[1]
- *The Watt Stopper*: work with CLTC to produce the Motion Sensor Nightlight Switch and the occupancy sensor and LED array controller for the Smart Bathroom Lighting Fixture
- *Speclight*: work with CLTC to produce prototype bathroom lighting fixtures
- *SMUD*: work with CLTC on the design and the esthetic appeal of the Smart Bathroom Lighting Fixture
- *Sacramento Doubletree*: hosted WN-100 field test and provided early feedback during development of Smart Bathroom Lighting Fixture

[1] LBNL staff began this project but the principal investigator left LBNL during the project to start the new CLTC so the project transitioned to CLTC.

MOTION SENSOR NIGHTLIGHT (WN-100)

Project Approach

The development of the WN-100 technology involved collaboration among the PIER Program, California Lighting Technology Center (CLTC), The Watt Stopper (TWS), the Sacramento Municipal Utility District (SMUD), and the Sacramento Doubletree Hotel. The WN-100 combines a motion-sensor with a low-power (less than one watt) LED nightlight into a wall switch unit that controls lighting based on occupancy (Figure 4). The LED nightlight remains on when lights are off, providing constant illumination and energy savings from reduced usage of overhead lighting.

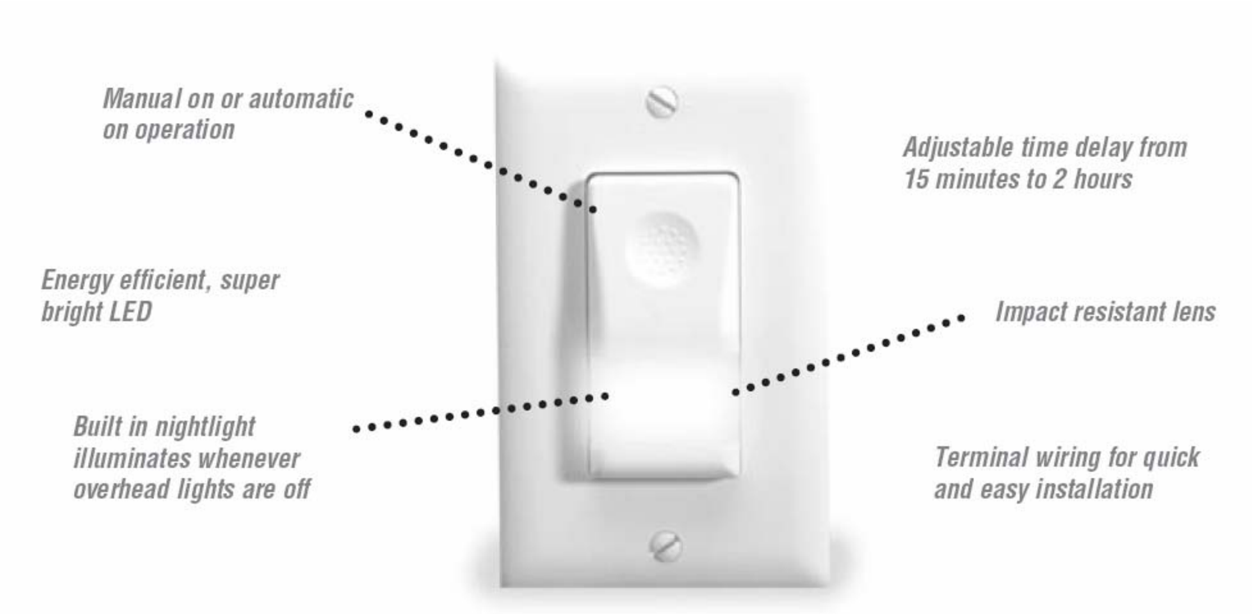


Figure 4: The WN-100 Motion Sensor Nightlight.

The nightlight uses a super-bright LED technology which consumes less than one Watt, providing a convenience to occupants who might otherwise leave lights on throughout the night.

Project Results

A field study of the WN-100 in 60 guest rooms of the Doubletree Hotel demonstrated that the one-hour time delay of the occupancy sensor successfully met its objectives (Figure 5) resulting in 50% energy savings (Figure 6). Most important, it was perceived as an amenity by hotel room guests.

The Lighting Control System (LCS) technology and field demonstration are described in detail in a 2003 PIER report (Deliverable 4.1.2b) and a 2004 ACEEE Conference paper (Appendix A).

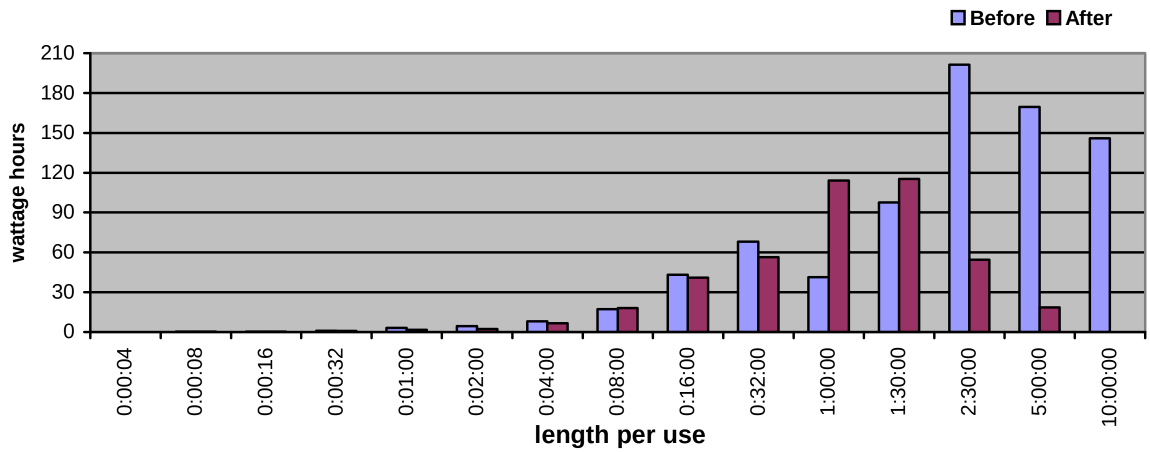


Figure 5: Bathroom lighting energy use as a function of on-time periods, before and after the installation of the WN-100 Motion Sensor Nightlight

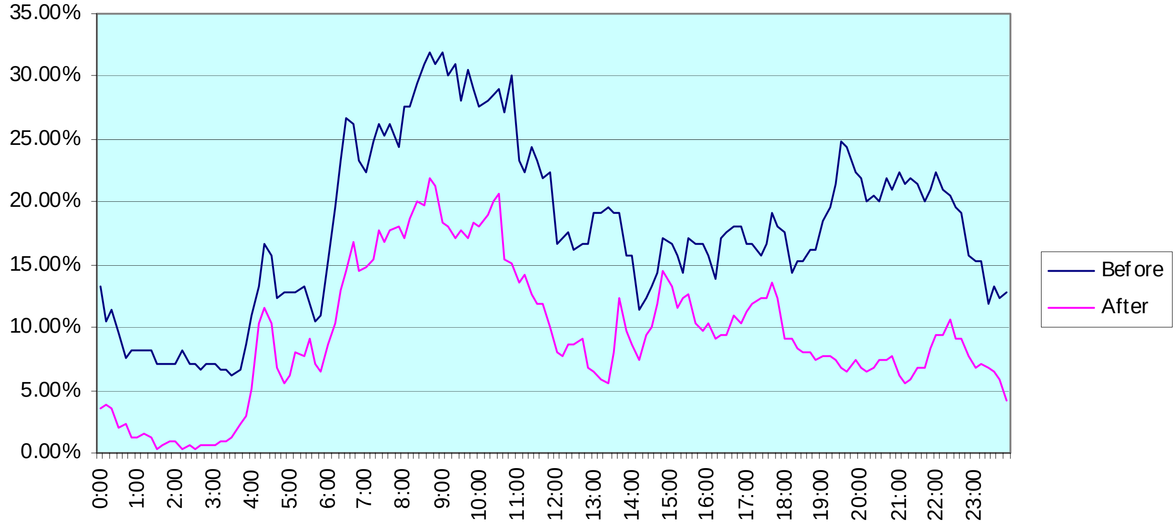


Figure 6: Average bathroom lighting energy before and after the installation of the WN-100 Motion Sensor Nightlight.

SMART BATHROOM LIGHTING FIXTURE

Project Approach

The development of the Smart Light Fixture (SLF) technology involved collaboration among the PIER Program, California Lighting Technology Center (CLTC), the Sacramento Municipal Utility District (SMUD), Speclight (subsidiary of Lithonia Lighting), and The Watt Stopper (TWS).

Original Specification

The SLF technology is based on the same strategy as LCS, i.e., combining occupancy-based switching with LED-based night lighting. While the LCS is marketed as a low-cost retrofit option with short payback, the SLF is marketed as a renovation option. The basic idea for the SLF was to integrate the LCS features into an existing product (Figure 7).

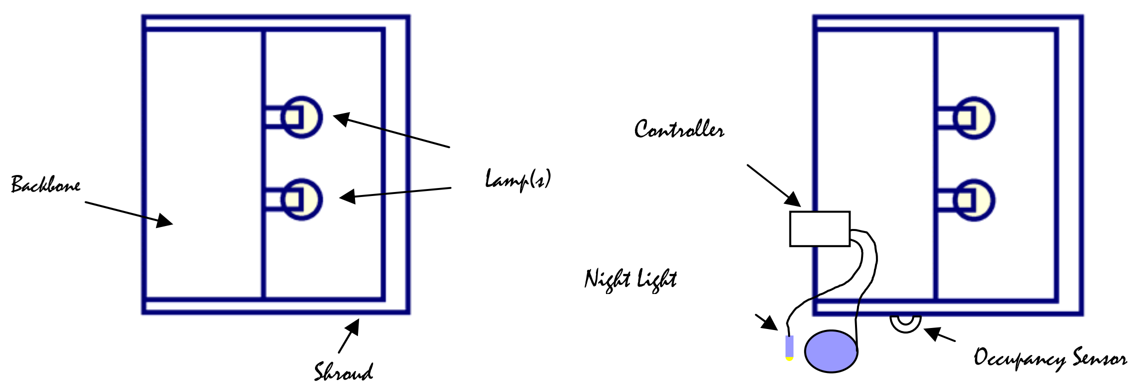


Figure 7: The SLF development strategy was based on taking an existing product and adding the LSC functionality with enhanced features.

The initial step in the development of the SLF technology involved detailed specification of performance characteristics, as well as consideration and discussion of available options. The performance characteristics of the SLF technology are summarized in a "wish" list, which served as the basis for the development of ideas:

- *Integrated occupancy sensor* — In order to capture the percent of energy savings that were verified during the WN-100 study, the luminaire must have an integrated occupancy sensor. This sensor should be integrated into the luminaire in a manner that allows for appropriate sensor coverage of the bathroom area for all potential application scenarios. The occupancy sensor should also be integrated into the luminaire in a manner that is transparent during installation (i.e., it should wire exactly like any other luminaire). It is important to emphasize that the amount of energy savings from the bathroom smart light fixture may be less than were shown in the WN-100 (wall switch LED-based nightlight with occupancy sensor) study. The reason is the

WN-100 is designed for use in retrofit applications, which include mostly inefficient incandescent lighting fixtures. The bathroom smart light fixture is designed for new construction applications and will use high efficient fluorescent lamps. However, the occupancy sensor should provide an equivalent percent of savings.

- *Integrated nightlight* — The LED nightlight will be integrated into the luminaire and function in a manner similar to the WN-100 unit. That is, the nightlight will be on whenever the general luminaire lighting is off and vice versa. The LEDs on the WN-100 draw approximately one Watt and it is felt that the WN-100 package provides an acceptable level of nighttime illumination; thus the LED package for the luminaire will likely be in the same range. Proper placement of the LEDs in the luminaire should yield a more uniform level of illumination than the illumination level provided by the WN-100.

- *Easy installation* — A key feature of the newly developed system is the need for its installation to be as easy or easier to install than current systems. Reducing the labor associated with the installation will make the system more desirable to hotel facility managers and help to justify the higher overall luminaire cost that the inclusion of the occupancy sensor and nightlight will require.

- *Broadly applicable* — The newly developed system needs to be broadly applicable to a wide variety of applications. The more flexible the luminaire is to both potential geometric and mounting constraints, as well as aesthetic considerations, the greater its potential appeal. It is conceivable that a universal “backbone” of a system can be developed that will fit in a wide cross-section of hotel and potentially dormitory bathroom applications. The universal backbone would allow for a large number of “faceplates” to be attached that would be appropriate to the specific geometric and aesthetic requirements of a wide variety of applications. Such an approach would have the additional potential benefit of allowing the hotel or dormitory to change the appearance of the luminaire relatively inexpensively during renovation by changing the faceplate while maintaining the backbone.

- *Power outage lighting* — Hospitality industry representatives revealed that it would be of great value to them if the luminaire had a function that operated the LEDs – either at their standard nightlight level or at an increased output level – during power outages. Typically hotels have emergency lighting in the hallways, but none in the guestrooms themselves. It was felt that this capability would be a safety feature they could tout when negotiating contracts with large customers, such as airlines.

- *Compatible with any wall switch* — It would be desirable if the newly developed luminaire could be fully functional regardless of what type of wall switch operated it, rather than requiring a special switch also to be installed with the luminaire. This would allow the luminaire to be an all-in-one solution for hotel facility managers, reducing both the material costs and the installation cost of the system. This specification may affect the ability to select control option #1, which toggled between the LED and fluorescent lamp.

- *Improved maintenance* — Due to the nature of their occupancy, hotels are unable to perform group relamping. In fact, when lamps fail, there is a critical need to perform an immediate spot replacement. This is an expensive, labor intensive process that also has obvious implications on guest comfort. It was determined that it would be desirable to have a luminaire that either significantly increased lamp life, or was still substantially functional after a lamp failed (for example, it switches to a "backup lamp" when the primary lamp fails) so it could be relamped during a convenient period of vacancy. A backup lamp and proper switching could be designed into the new product, though it would more than likely increase the overall cost.

Development Process

The development partners identified different fixture and control options and discussed in-depth the various options. Four basic physical fixture configurations were selected for development of concepts and prototypes:

- *Build-out box fixture* — This fixture incorporates the fluorescent and LED portions of the fixture into a dedicated box unit that is designed specifically for hotel guestroom applications.
- *Lens covered wall mount* — This fixture is similar to existing bathroom lighting fixtures that employ a fluorescent lamp covered by a diffusing lens.
- *Direct/indirect wall mount* — This type of fixture uses a front plate to redirect the fluorescent lamp flux upwards and downwards.
- *Dual wall sconce* — This fixture combo uses two wall sconces on either side of the mirror and, as such, is fundamentally different from the first three concepts.

The control options considered are as follows:

- *Switch only* — This approach uses only a switch to toggle between the LED nightlight and the fluorescent light. No occupancy sensing is performed.
- *Wall-based occupancy sensing* — This approach integrates an occupancy sensor into the wall mount switch. The sensor controls the LED/fluorescent functions.
- *Fixture-based occupancy sensing* — This approach places the occupancy sensor into the fixture. The wall mount switch is used to manually turn off the fluorescent.

These fixture and control options are described in more detail in a CLTC report (PIER LRP deliverable 4.1.3d, submitted on March 10, 2004).

The performance specifications and fixture/controls options formed the basis for the development of ideas and prototypes that were considered and discussed in a collaborative effort among the CLTC, SMUD, Speclight and TWS (Figure 8).

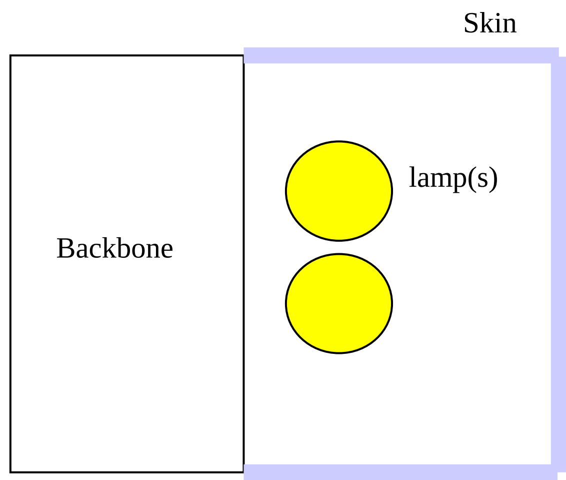
Figure 8: Prototypes installed and tested at LCTC during design development.

CLTC focused on technical issues, i.e., placement of sensors and controls, operation, etc. while SMUD focused on aesthetic issues, i.e., the shape and material of alternative diffusers, etc. Speclight focused on integrating the components into a product, while TWS focused on developing a new controller that integrates the occupancy sensor functionality with the driver for the LED sources into one system.

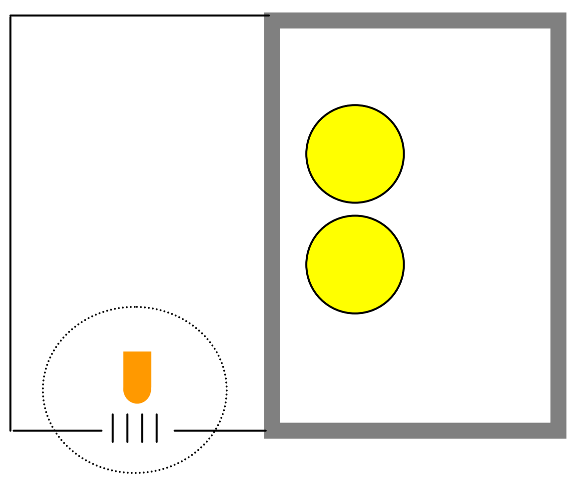
Nightlight and Motion Sensor Placement

Placement of the LED nightlights and the motion sensor at the fixture area is very effective for illuminating the whole bathroom area and detecting occupancy. Many options were considered, which are listed in Table 1 along with comments related to advantages and disadvantages. Most options were tested in bathroom spaces to understand light distribution and effectiveness.

Table 1: Alternative designs for LED and controls placement.



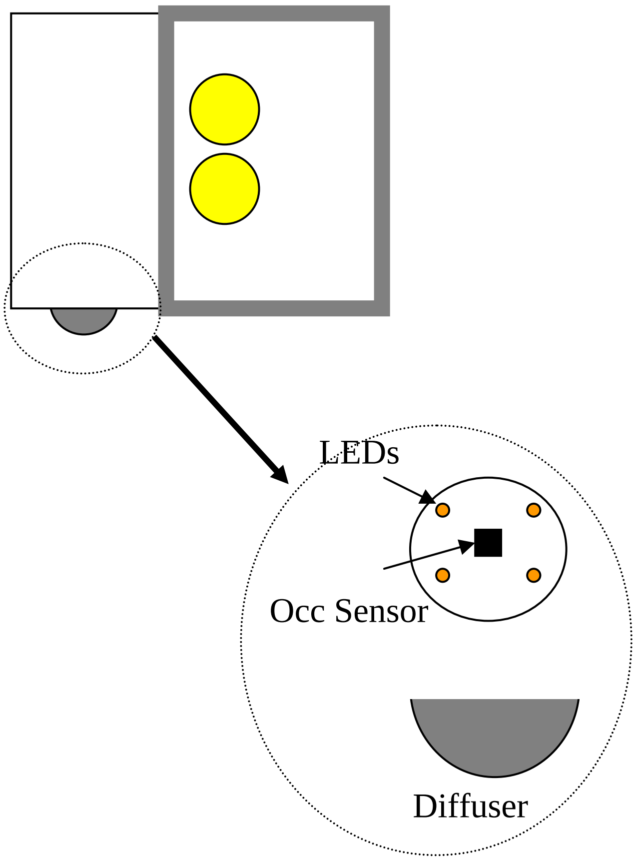
Basic Anatomy



Inside Fixture Backbone

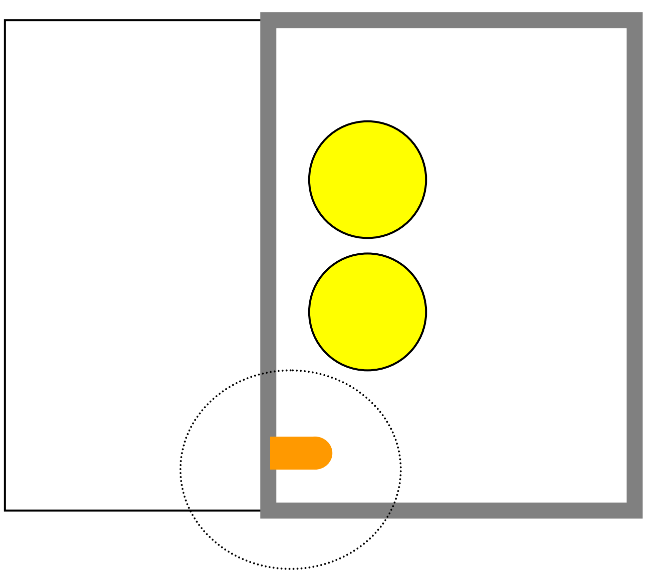
- LED lights mainly hidden
- Potential for high level of downward flux
- Potential for glare (direct or off mirror)
- Potentially complicated (costly) optical opening

Table 1: Alternative designs for LED and controls placement (continued)



Dome – Integral

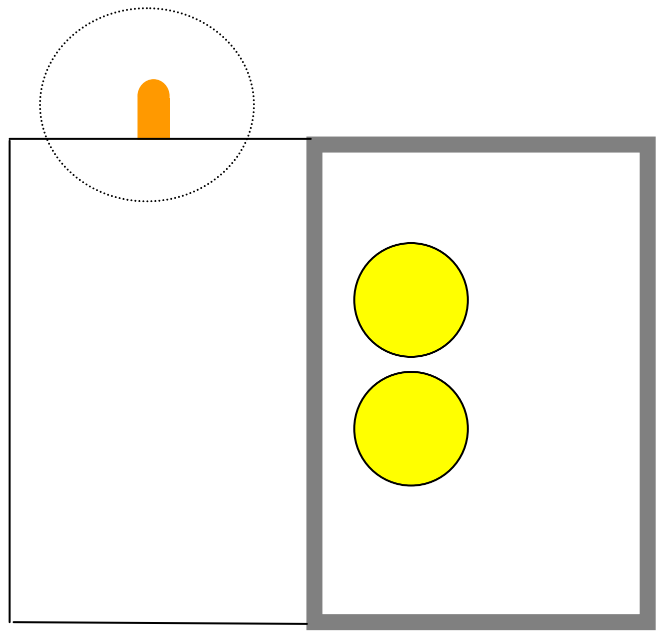
- LED lights & Occupancy Sensor integrated onto bottom of backbone
- Even, low-glare illumination
- Easily integrated



Inside Fixture Diffuser

- LED lights entirely hidden
- Fixture will have "soft glow" when in nightlight mode
- Might not work will all "skins"
- Might have low fixture efficiency

Table 1: Alternative designs for LED and controls placement (continued)



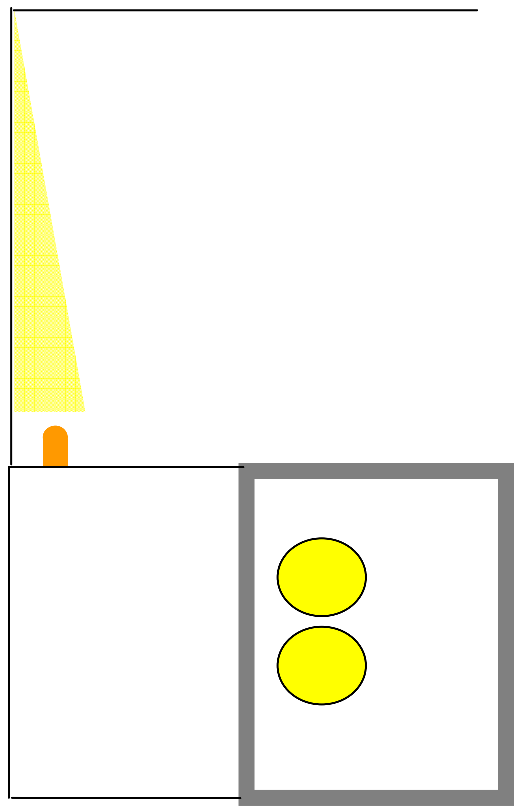
Inside Fixture Backbone – Up-light

- LED lights mainly hidden
- Low potential for glare (direct or off mirror)
- No need for diffuser, light guide, or baffles
- Might need more LEDs to get room bright enough

Grazing - Bottom of Backbone

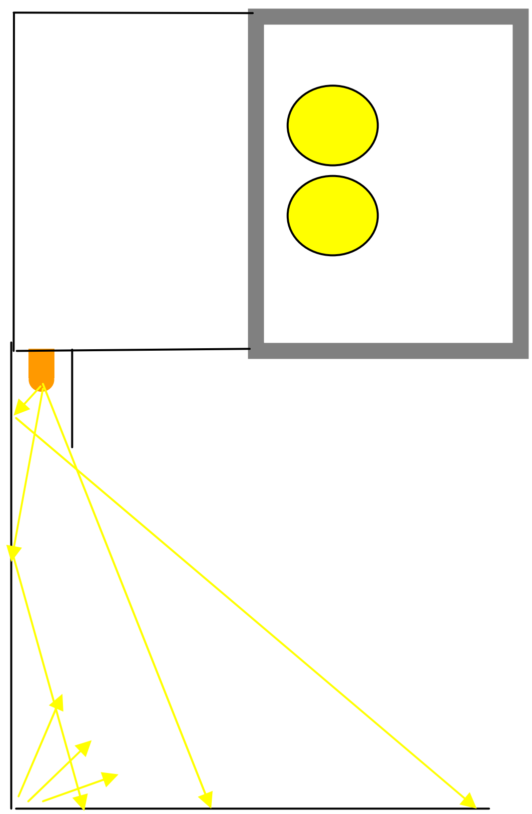
- LED lights widely used for grazing now
- Low likelihood of glare
- Aesthetically appealing effect
- Might be hard to integrate into backbone

Table 1: Alternative designs for LED and controls placement (continued)



Grazing - Wall or Ceiling

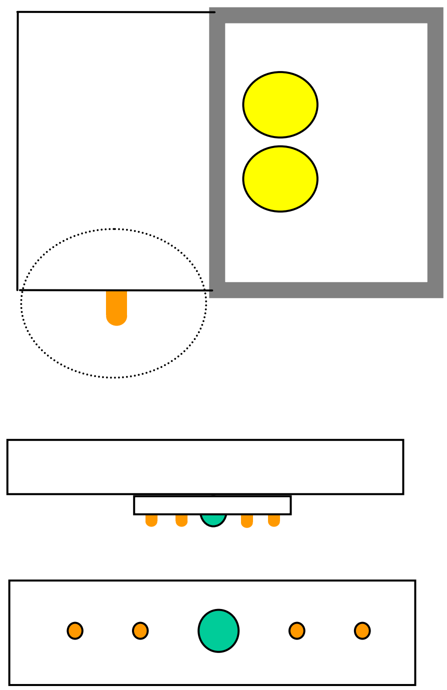
- Same as previous
- Less glare, less light as previous



Grazing - Mirror/Sink

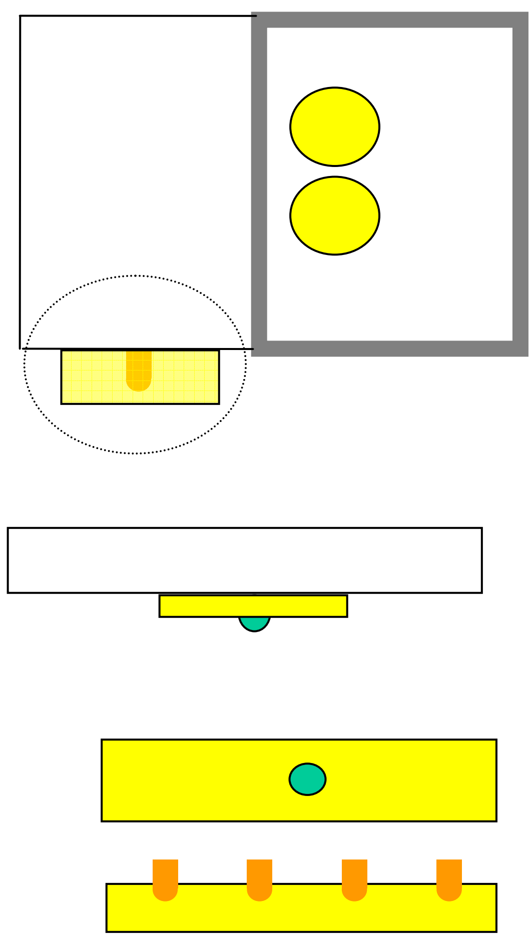
- Same as previous
- Optical element for glare protection

Table 1: Alternative designs for LED and controls placement (continued)



Simple Downlight Array (original idea)

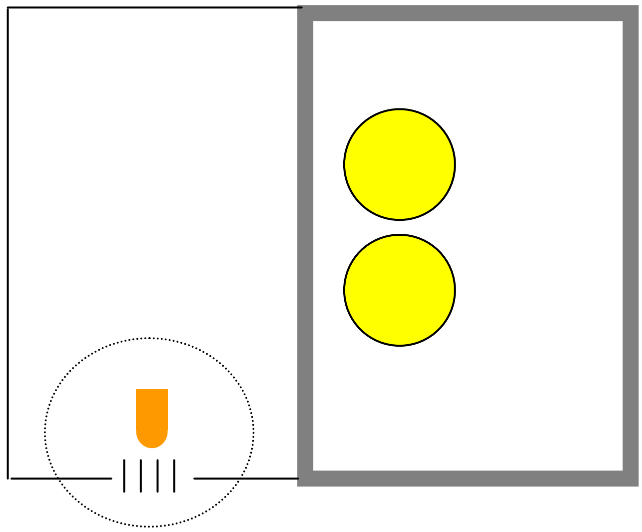
- Simple add-on to backbone
- LED lights not hidden
- High potential for glare (direct and off mirror)



Optically Designed Plastic Molding

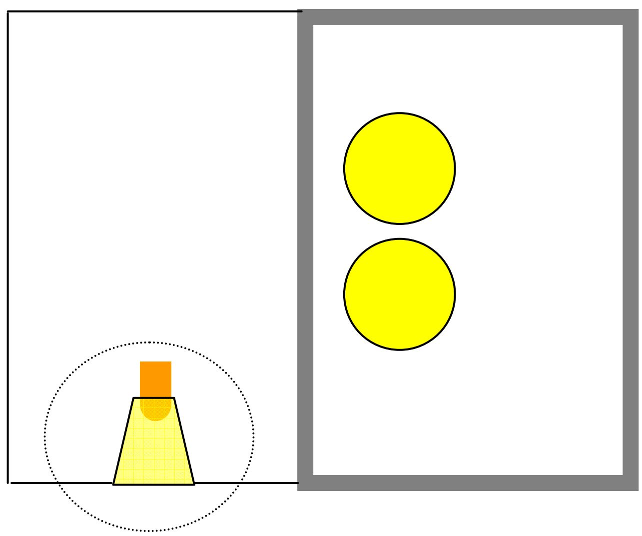
- LED lights hidden
- Even luminance from plastic piece
- Simple add-on to backbone
- Needs optical design work
- might not be possible

Table 1: Alternative designs for LED and controls placement (continued)



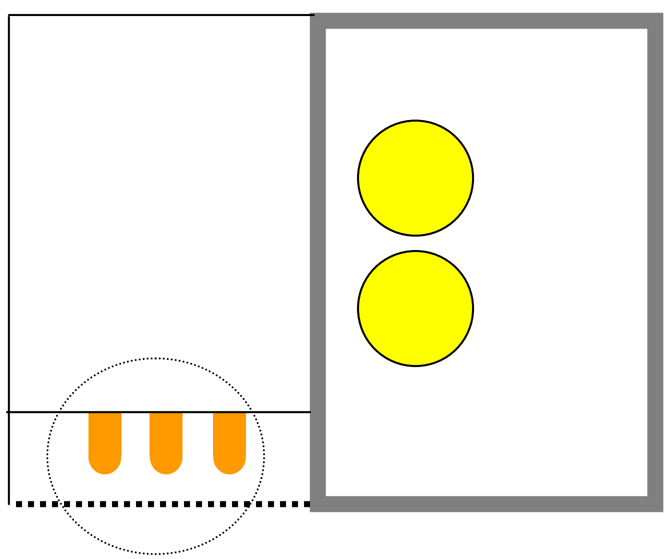
Inside Fixture Backbone

- LED lights mainly hidden
- Potential for high level of downward flux
- Potential for glare (direct or off mirror)
- Potentially complicated (costly) optical opening



Inside Fixture Backbone – Light guide

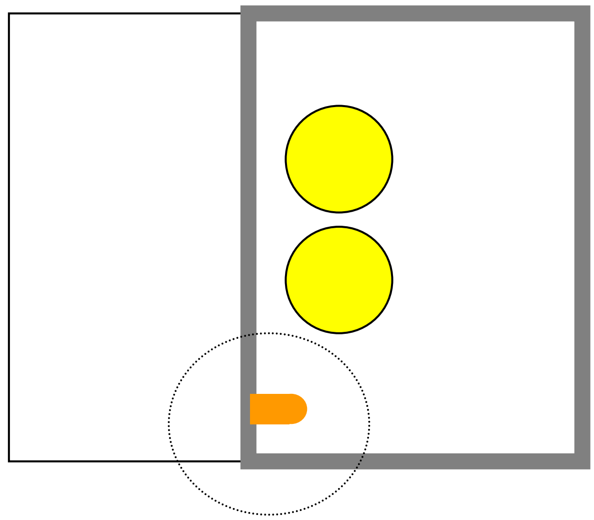
- LED lights mainly hidden
- Potential for high level of downward flux
- Less potential for glare (direct or off mirror)
- Potentially complicated (costly) optical opening



Inside Fixture Backbone - perf

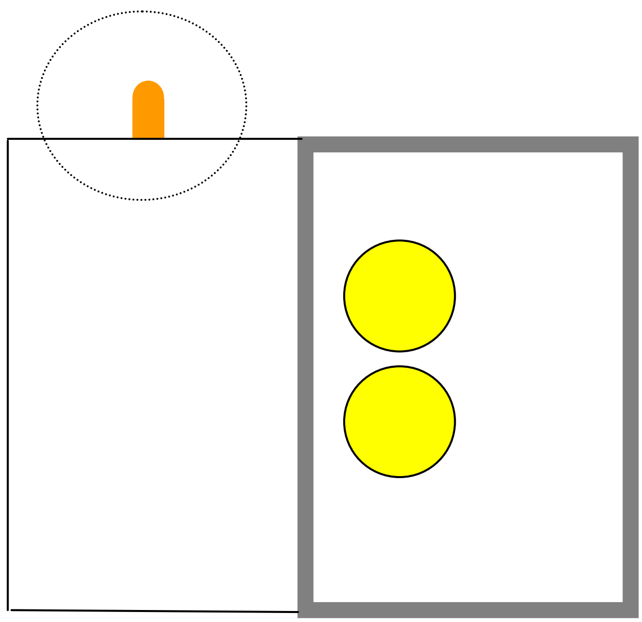
- LED lights mainly hidden
- Less potential for glare (direct or off mirror)
- Requires change to standard backbone
- May have low fixture efficiency

Table 1: Alternative designs for LED and controls placement (continued)



Inside Fixture Diffuser

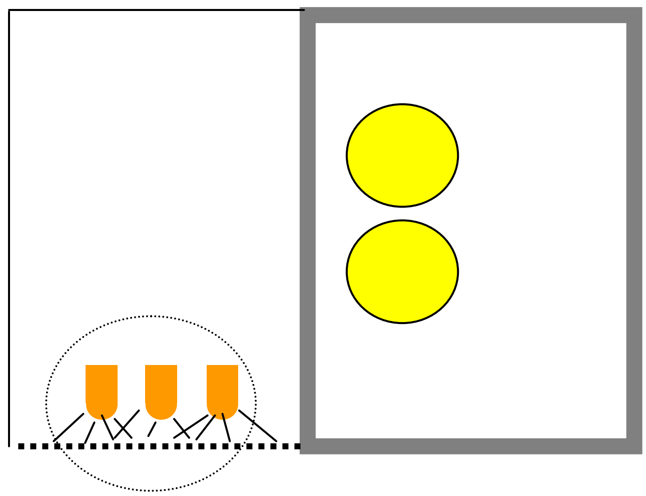
- LED lights entirely hidden
- Fixture will have "soft glow" when in nightlight mode
- Might not work will all "skins"
- Might have low fixture efficiency



Inside Fixture Backbone – Up light

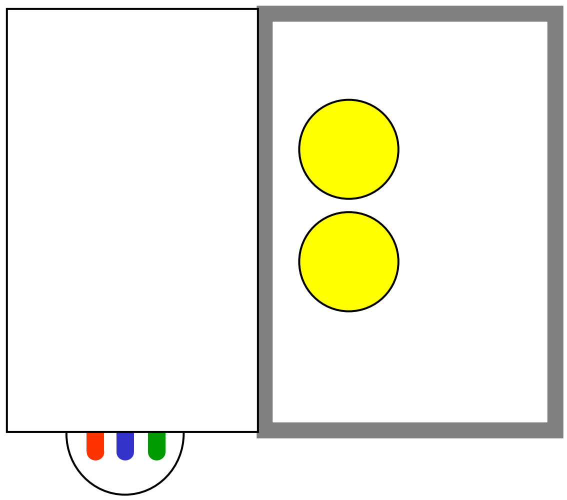
- LED lights mainly hidden
- Low potential for glare (direct or off mirror)
- No need for diffuser, light guide, or baffles
- Might need more LED lights to get room bright enough

Table 1: Alternative designs for LED and controls placement (continued)



Inside Fixture Backbone - Fiber Optics

- LED lights hidden
- "Starry Night" Effect
- Can cycle LED lights separately
- Low potential for glare (direct or off mirror)
- Requires change to standard backbone
- Expensive, complicated



Sun Brothers Approach

- R-B-G
- Variable color output
- Can go to "all on" for white in "emergency"
- Can work in many of the previous applications

Most of the above designs were prototyped and tested for evaluation, refinement and development of new ideas. Placement of the occupancy sensor at the bottom of the fixture gave the best results in sensing occupancy. Placement of an amber LED array at the top of the fixture provided the most effective nightlight distribution.

Control System

Two approaches were considered for the controls system. The first approach includes the LED array and motion sensor and can be used with ordinary wall switches (Figure 9).

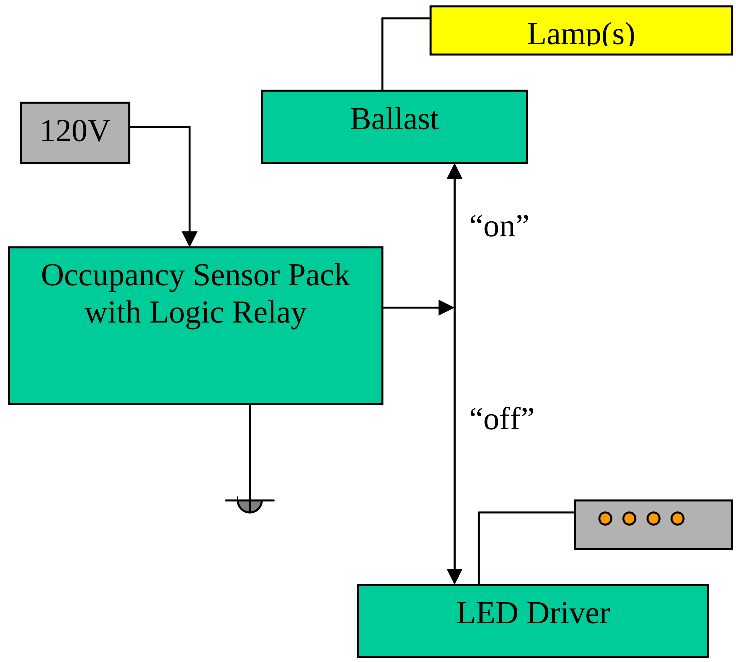


Figure 9: SLF controls schematic for basic configuration with LED nightlight and occupancy sensor.

The second approach for controls includes the additional feature of using the LED nightlight as a safety light as well, i.e., the LED nightlight is powered by a rechargeable battery and is turned on in the event of a power outage. This approach was selected for the final design, as hotel partners expressed strong interest in implementing the safety lighting (Figure 10).

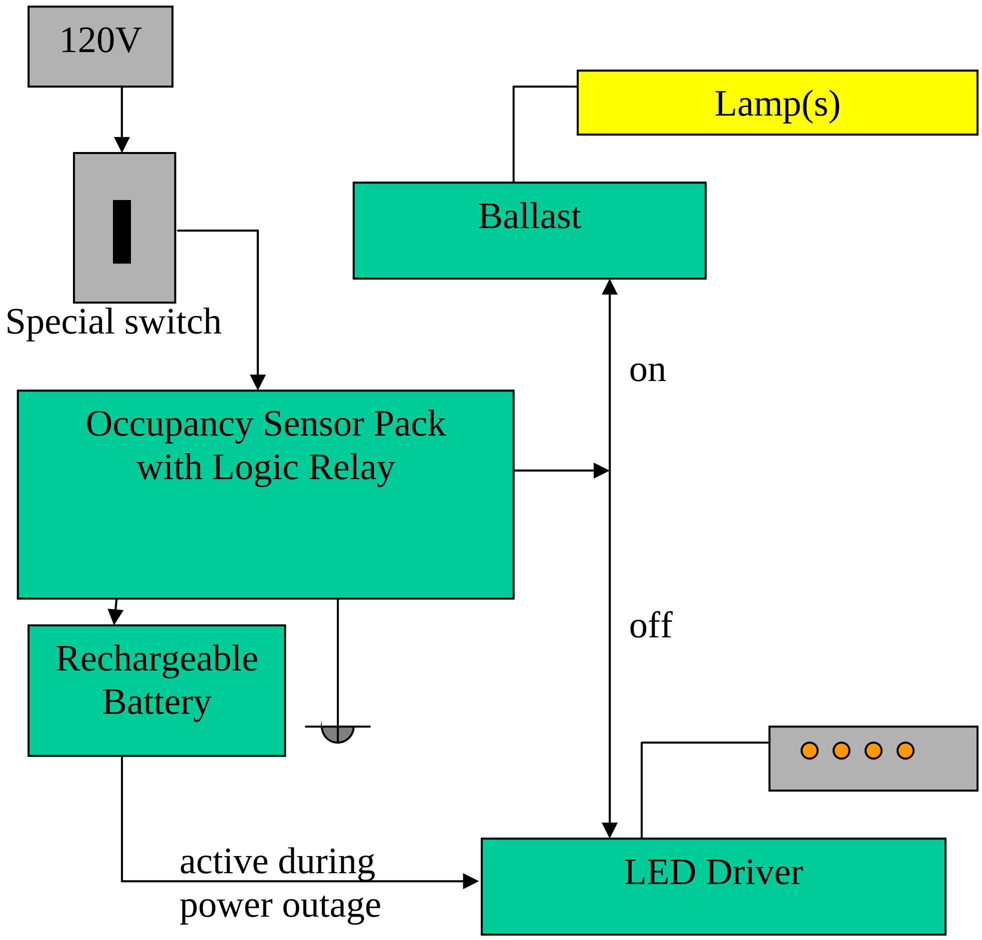


Figure 10: The control system for the final design allows activation of the LED nightlight by the occupancy sensor and at the event of a power outage.

The Watt Stopper is in the process of producing a new component that will integrate the motion sensor and LED light controls into one unit. The final design will be produced and distributed by Speclight in 2-, 3- and 4-foot lengths and a variety of diffusers with different aesthetic and optical characteristics and at different cost levels (Figure 11).

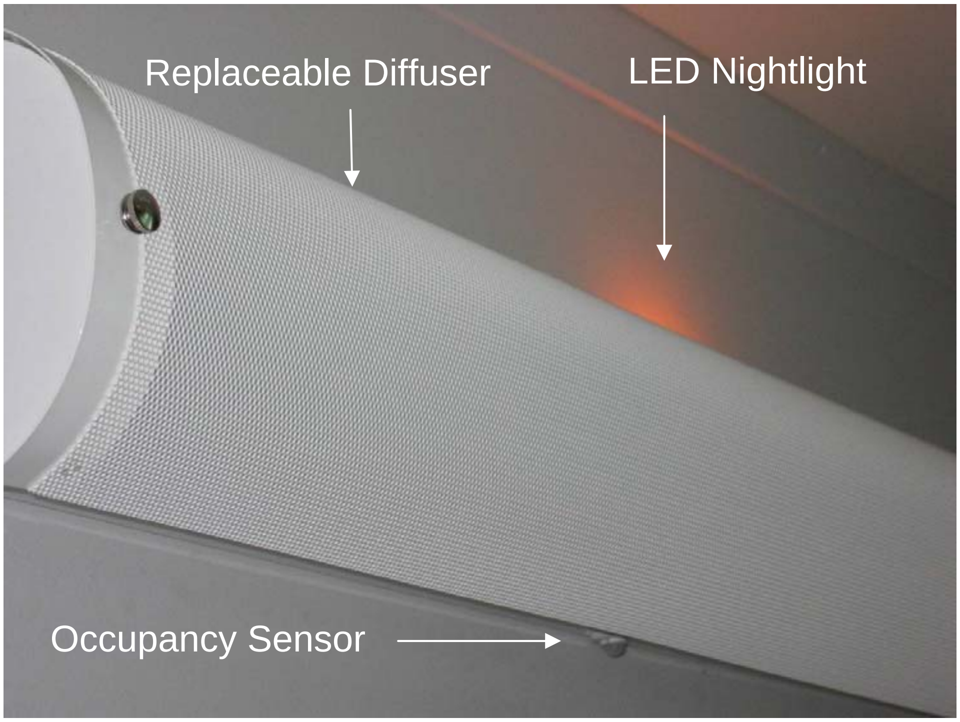


Figure 11: Prototype of the final design of the SLF technology.

Project Results

The SLF is currently being developed into a commercial product manufactured and distributed by Speclight. The CLTC staff coordinated with Speclight on a production run of about 200 units for installation in hotel and assisted living field-testing sites to demonstrate and refine the product line for wide-spread distribution. These demonstration efforts are supported by SMUD and are listed in Table 2.

Table 2: SMUD Demonstration Projects

Parent Company / affiliation	Demonstration Site Address	Quantity	Length	Trim description
Covenant Care California Inc 27071 Aliso Creek Road, Suite 100 Aliso Viejo, California 92656	**Emerald Gardens Nursing Center** 6821 24th Street Sacramento, CA 95822	**30**	**2-foot**	**White plastic/perf** **Combination**
Eskaton Inc. 8190 Arroyo Vista Drive Sacramento, CA 95823	**Regency Place** 8190 Arroyo Vista Drive Sacramento, CA 95823	**50**	**3-foot**	**Faux alabaster**
WestCoast Hospitality 201 W. North River Drive Spokane, Washington 99021	**Sacramento Red Lion Inn** 1401 Arden Way Sacramento CA. 95815	**52**	**4-foot**	**Faux alabaster**

Parent Company / affiliation	Demonstration Site Address	Quantity	Length	Trim description
McClellan Park 3140 Peacekeeper Way McClellan, CA 95652	**Lion's Gate Hotel** 3410 Westover Street McClellan, CA 95652	**50 to 60**	**2-foot**	**Faux alabaster**

In addition to the SMUD demonstration efforts, several PIER demonstration efforts are currently in planning stages, focusing on university applications, i.e. dormitories, at the University of California, Davis, and the Sonoma State University. These demonstration projectswill be focused on collecting and analyzing “before” and “after” performance data through monitoring, as well as eliciting user feedback through surveys and interviews with occupants and facility persons.

Commercialization Status

Speclight is currently taking orders and plans to deliver products to SMUD in January 2005. There is a patent pending for a bathroom lighting fixture with integrated occupancy sensor and LED nightlight with battery backup. Speclight and TWS are in communications with the UC Davis patent department for licensing of technologies.

MARKET POTENTIAL

Based on data from the American Hotel & Lodging Association's 2002 Lodging Industry Profile and the 1997 U.S. Economic Census, there are approximately 4.1 million hotel guest rooms in the United States with 365,000 rooms in California. The top fifty hotel companies manage fifty percent of hotel properties and seventy-five percent of all guestrooms in the United States.

Based on two studies performed by LBNL at two different hotels and subsequent conversations with hotel managers, hotel guests can be divided into two distinct types of energy users: vacationers and business travelers. This is consistent with how the industry subdivides its guests. The following summaries were taken from the American Hotel & Lodging Association's 2002 Lodging Industry Profile.

"The typical business room night is generated by a male (70%), age 35-54 (53%), employed in a professional or managerial position (53%), earning an average yearly household income of $76,394. Typically, these guests travel alone (62%), make reservations (92%), and pay $95 per room night."

"The typical leisure room night is generated by two adults (51%), ages 35-54 (46%), earning an average yearly household income of $69,147. The typical leisure traveler also travels by auto (74%), makes reservations (83%), and pays $87 per room night."

For leisure room nights, researchers have observed a greater per day use of bathroom lights (8 hrs per day) and a greater average reduction of use (63%) with the bathroom nightlight product. For business room nights, researchers found a per day use of bathroom lights to be less (4.5 hours per day) and a lower average reduction of bathroom light usage (44%).

The hotel user breakdown is as follows:

- 23.7% are on vacation
- 29.5% are transient business travelers
- 27.0% are attending a conference/group meeting
- 19.8% are traveling for other reasons (e.g., personal, family, special event)

Marketing these two new energy efficient technologies to the top hotel companies could have a significant impact on hotel bathroom energy usage in California and nation-wide. Over the past two years, the CLTC has provided numerous presentations to various hotel industry groups.

Significant non-energy benefits also exist. A WRA Research study found that two out of five travelers leave the bathroom light on at night to serve as a nightlight. An additional 16 percent of travelers bring their own nightlight to the hotel. According to Sunbeam Hospitality and Andis Company, about 45 percent of all hotel guests leave the bathroom light on while they sleep. And that's across all segments—economy to luxury, families and singles, men and women. The demand for a nightlight has not gone unnoticed by the industry. In one response, the American Automobile Association plans to list nightlights, or their equivalent, as a guideline for hotels receiving a rating of three Diamonds or above in its 2005 TourBook publications.

MARKET CONNECTIONS

Outreach

The research team delivered many presentations to various industry and utility groups to publicize the project results. The presentations included:

- Hawaiian Electric (hotel applications), 2004
- San Francisco Power Authority (senior/assisted living facilities), 2004
- American Hotel and Lodging Association , 2004
- BIRA meeting on lighting controls, 2004
- Group of Hotel General Managers and Directors of Operations brought together by the SF Department of the Environment and PG&E (2004).
- ACEEE Summer Study 2004

Flex Your Power Award

In recognition of the WN-100’s impact in reducing hotel bathroom lighting energy use the research team was awarded a “Flex Your Power” award in 2003.

Codes and Standards Implications

Despite being non-residential buildings, hotels and motels currently are granted an exception within Title 24 (in section 130(b)) such that they need only comply with the residential lighting requirements (section 150(k).

Section 3 of 150(k) requires that bathroom lighting must be high efficacy *or* must be controlled by a motion sensor with automatic off. Consequently, hotel builders may put fluorescent fixtures in bathrooms but may not be willing to support the additional cost of motion sensors. Guaranteed incentives, assured replacement contracts, or a comprehensive outreach program may help to persuade builders to install the fixtures developed by this project. Alternatively, cooperation with industry bodies such as the International Hotel and Restaurant Association or with specific hotel chains might be helpful. The IH-RA supports a program of seminars and provides a variety of publications to inform its members about useful technologies.

Section 150(k) requires that motion sensors comply with section 119(d), which requires that motion sensors “shall be capable of automatically turning off all the lights…no more than 30 minutes after the area has been vacated”. The research conducted for this project showed that a 30-minute delay would save only slightly more energy than a 60-minute delay, and it would run the risk of annoying occupants by switching the lights off while they’re taking a bath. So while the 60-minute setting is preferable, in order to make the fixture compliant with the letter of Title 24, it should have the option of being set to a 30-minute delay (note that the wording of section 119(d) requires only that the fixture be *capable* of having a 30-minute delay, not that a 30-minute delay must actually be used in practice). If it can be demonstrated that bathroom occupant sensors with time delays greater than 30 minutes and less than 60 minutes are significantly less likely to be disabled, this could form the basis of a code change proposal to Title 24.

The requirements for hotels could be amended for the 2008 edition of Title 24, or alternatively the exclusion for hotel lighting in 130(b) could be removed. As Title 24 becomes more detailed in its treatment of specific space, it may be worth incorporating a table showing preferred motion sensor time delays in various types of space.

CONCLUSIONS AND RECOMMENDATIONS

This project has successfully met its objective in developing lighting technologies that save 50 to 70 percent of the lighting energy used in hotel and institutional bathroom applications.

The project goals and scope have been exceeded with two technologies resulting in commercial products produced and distributed by the manufacturing partners of the project: a Motion Sensor Nightlight (WN-100) manufactured and distributed by The WattStopper and a "Smart" Lighting Fixture (SLF) manufactured and distributed by Speclight. The project has been completed on time and under budget.

The WN-100 was installed at the Sacramento Doubletree Hotel and resulted in 50% average savings. The SLF is currently in preparation for production. Several demonstration applications are being planned in hotel, dormitory, and assisted living facilities.

Successful outcome of demonstration projects should be followed by larger scale pilot projects where the WN-100 and SLF are demonstrated in multiple buildings and locations to become mainstream approaches and inspire development of more products that can save energy while providing comfort, safety, and amenity. Additionally, the Commission should work with additional manufacturers to stimulate wide-spread production of such technologies that integrate low-power LEDs with occupancy sensors.

APPENDIX A: 2004 ACEEE CONFERENCE PAPER ON THE WN-100 TECHNOLOGY

Performance Analysis of Hotel Lighting Control System

Erik Page and Michael Siminovitch; California Lighting Technology Center, Department of Environmental Design, University of California, Davis[2]

ABSTRACT

The Lighting Control System (LCS), a wall switch occupancy sensor, was designed with two key features to save energy while maintaining hotel guest acceptance of the system. First, based on a detailed analysis of user patterns, the LCS was programmed with a much longer timeout setpoint than traditionally used. Second, when the bathroom luminaire is turned off, the LCS provides an LED nightlight that is automatically activated. Researchers established detailed criteria to determine representative hotel rooms in the Sacramento area, and selected the Doubletree Hotel as its test site. Hobo light state loggers were installed in 15 rooms and collected data for at least two months. Data was downloaded from the loggers, LCSs were installed in the bathrooms, and the loggers continued to record use for an additional two months. The researchers planned to determine (1) the average burning hours per day before and after installation of the LCS; (2) the effect of the LCS on decreasing long burning periods; (3) the extent to which the reduction of long burning periods contributes to energy savings; and (4) how the LCS change the usage profile as a function of time of day. Analysis of the pre- and post-installation data allowed researchers to gain insight into bathroom luminaire usage patterns in the rooms, and to determine an energy savings of approximately 46 percent with the use of the LCS.

Introduction

Lawrence Berkeley National Laboratory (LBNL), the Sacramento Municipal Utility District (SMUD), Doubletree Hotels, and The Watt Stopper, Inc., formed a partnership to study a new energy-efficient lighting control system under the PIER Lighting Research Program. This report describes the details and results of this study, which had the objective of evaluating the performance of this new lighting control system.

The new Lighting Control System (LCS) is a wall switch occupancy sensor that has been designed specifically for hotel environments to save energy while providing users a higher level of lighting amenity. The LCS has two key features that make it ideally suited for placement in hotel guestroom bathrooms. The first feature is that the LCS is preprogrammed with a timeout setpoint that is significantly longer than what is typically used by occupancy sensors. Findings from prior research conducted by LBNL and The Watt Stopper, Inc. suggested that most of the energy used by hotel bathroom luminaires is from the relatively infrequent periods when they are left on for very long periods of time (i.e. greater than four hours). By utilizing longer timeout setpoints (one hour for the LCS), these long periods can be eliminated while greatly minimizing

[2] At the time of this study, the authors were staff researchers at the Lawrence Berkeley National Laboratory (LBNL). They have subsequently left LBNL to establish the California Lighting Technology Center at UC Davis.

the chances of generating "false offs" in which the lights turn off when there is a guest in the bathroom.

The second key feature of the LCS is a built-in LED nightlight that automatically turns on whenever the bathroom luminaire is turned off. Prior research also suggested that a small but significant amount of the extended period usage of the bathroom luminaires occurred during nighttime hours. It is thought that these periods represent the hotel guests purposely leaving the bathroom luminaire on as a nightlight when they retire for the evening. The nightlight feature of the LCS has the potential to provide adequate illumination for guests to navigate at night while using only a fraction of the energy of the bathroom luminaire.

LBNL researchers measured the lighting use in 15 guest bathrooms in the Doubletree Hotel in Sacramento, California, over an eight-month period, gathering a minimum of two months of pre-retrofit LCS (baseline) and two months of post-retrofit LCS data from each room. The average savings from the LCS measured from this study was found to be 46.5 percent, though this result was likely limited by a number of factors including the hotel's baseline condition and the occupancy rates of the rooms measured. A conservative estimate of expected savings from the LCS for the hotel industry as a whole is 50 percent. Overall, guests responded very favorably to the LCS, appreciating the effect of the nightlight.

Test Plan

The following section describes the steps taken to identify the practical advantages and disadvantages of using this system. This includes the selection of test rooms, data collection for the baseline condition, installation of the LCS devices, and data collection of the post-LCS condition.

Choose representative hotel rooms

It was considered critically important to the study to select test rooms that were both representative of the hotel as a whole, and also representative of "typical" hotel rooms. Part of the criteria for selecting the Doubletree Hotel in Sacramento as the test site was that it was considered to contain a wide variety of typical rooms. The hotel was built in the 1970s in several phases and, consequently, its bathroom layouts and fixtures vary widely throughout the hotel. It is mainly a business hotel, but 25 percent of the rooms are rented long term by an airline and are used for flight crews to rest. These factors may affect the test results in that (1) different layouts may affect the user's preference, and (2) flight crews have different schedules than ordinary travelers. Considering these factors, LBNL selected 15 rooms that cover different conditions (different bathroom layouts, and flight crew/no flight crew occupancy), so that the results of this study could be more widely applied.

Install data-logging equipment

LBNL researchers went to the Doubletree Hotel to initialize and install Hobo light state loggers. These loggers are installed close to the luminaires and record every time the lights are switched on or off. These loggers needed to be carefully installed and calibrated in order to be sensitive enough to register the switching of the bathroom luminaire, but not so sensitive as to register the usage of other lighting in the area, such as heat lamps that were present in many of the spaces. The loggers can hold a maximum of 2007 data points, which normally represents about four months of data. The data can then be downloaded into a text file to be analyzed. Table 1 shows a sample of the Hobo light state logger output data.

Table 1: Sample Output from Hobo Light State Loggers

Date	Time OFF (0) /	ON (1)
10/04/02	18:59:59.5 /	ON
10/04/02	19:24:43.5 /	OFF
10/04/02	22:10:25.0 /	ON
10/04/02	22:23:41.0 /	OFF
10/05/02	05:38:39.0 /	ON
10/05/02	08:23:17.5 /	OFF
10/05/02	13:10:01.0 /	ON

The majority of the rooms were fit with a single logger. However, in five rooms three loggers were installed. This was done to ensure the accuracy of the loggers by allowing for data crosschecking between the various loggers.

Baseline data collection

After the loggers were installed for at least two months, LBNL researchers went to the Doubletree Hotel to download the data from the loggers. These data represent the baseline data without the LCS. The loggers were then reinitialized and relaunched in anticipation of data collection of the post-LCS period. (For data logging periods in which the loggers recorded both baseline and post-LCS data, the data files were manually parsed at the end of the logging period based on the installation date of the LCS.)

Install Lighting Control System (LCS)

After downloading the baseline data, the LCSs were installed by the Doubletree Hotel engineering staff. The installation process involved removing the existing bathroom luminaire wall switch and wiring in the LCS in its place. These installations generally took about 15 minutes each. The LCSs were preprogrammed with the 1-hour timeout set point and thus needed no additional programming during installation.

Post-LCS data collection

After the loggers operated for an additional two months following installation of the LCS, LBNL researchers again went to the Doubletree Hotel to download the data from the loggers. This is the post-LCS data.

Performance Analysis

Five of the 15 original test rooms were logged with redundant loggers. These five rooms each had three loggers measuring the bathroom luminaires during testing, allowing for a cross comparison of data. While most of the data from the 10 rooms with single loggers appeared to be valid, some of them clearly had errors. This led to a decision to base the overall analysis of the LCS on data gathered from the five rooms with redundant loggers. This decision was based primarily on the facts that (1) it was very difficult to separate valid from invalid data in the single logger rooms with a high level of certainty, and (2) the data from the five redundant rooms provided a statistically significant data set. Therefore, the analysis presented below is based on data just from these five rooms. For the purposes of gathering as many data points as possible and to ensure uniformity between the test rooms during the study, these five rooms were kept at near 100 percent occupancy during the study.[3]

It should be stressed that while the analysis was limited to data from these five rooms, the overall data set is still very large. It is also important to note that monitoring hotel rooms is very different from monitoring other types of spaces because the occupants change so frequently. The real "sample" in this study is not the number of rooms but the number of room-days or occupant-days. Since all five of the rooms were monitored for at least two months in both baseline and post-LCS cases, data from these rooms represent over 300 room-days (5 rooms * 60 days) of data. Additionally, as the average stay in a business hotel is one to two days, the data collected represent the usage patterns of approximately 400 unique guests (or data points) over the duration of the test. To get a statistically significant sample, researchers like to typically get 30 to 60 independent data points.

The primary objective of this study was to answer the following questions.

- What are the average burning hours per day before and after installation of the LCS?
- To what extent does the LCS eliminate the long burning periods?
- To what extent does the reduction in long burning periods contribute to energy savings?
- How does the LCS change the usage profile as a function of time of day?

Answering these questions should give an initial indication of the effectiveness of the LCS and perhaps provide broader insights into the potential usefulness of the device.

Average burning hours per day

Table 2 shows the average usage data. The average burning hours per day for each of the five rooms were between four and five hours before installation of the LCS, while this number decreased to 1.5 to three hours after installing the LCS. In an "average" room, the luminaires were generally left on for 4.4 hours every day without the LCS, while this number decreased to about 2.4 hours with the LCS. The overall reduction is 46.5 percent.

Table 2: Average burning hours per day

Room #	**Average**	**210**	**215**	**242**	**588**	**616**
Hours – baseline	4:25:33	4:09:54	4:30:27	4:18:35	5:00:17	4:08:33
Hours – post-LCS	2:22:02	3:00:02	2:22:19	2:12:43	1:30:48	2:44:17
Reduction (%)	46.5	28.0	47.4	48.7	69.8	33.9

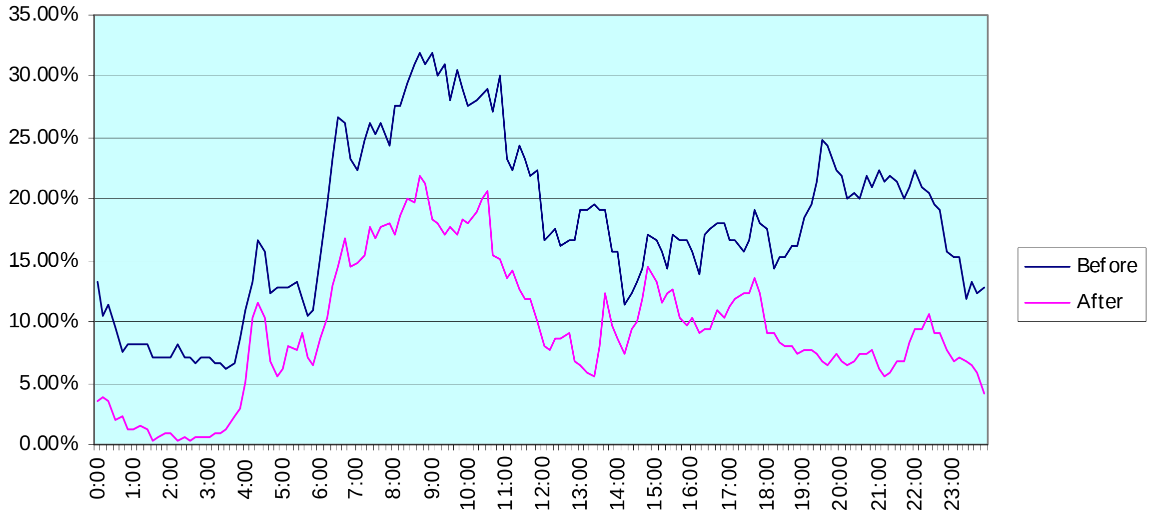
Usage profile as a function of time of day

Figure 1 looks at the same set of data and shows when, on average, the bathroom luminaires were operated during both the baseline and the post-LCS periods. Both cases experience peak usage in the morning, but the LCS reduced both the amplitude and duration of this peak. In the evening, the usages for the post-LCS are less than half of the baseline; after midnight the usages for the post-LCS cases were reduced even more, as they approached zero.

[3] The overall effect of occupancy rates on the energy savings of the LCS will be touched on further in the analysis later in this report.

During the peak load period, from noon to 6 p.m., an average of approximately 40 percent energy savings was obtained.

Figure 1. Usage profile as a function of the time of day



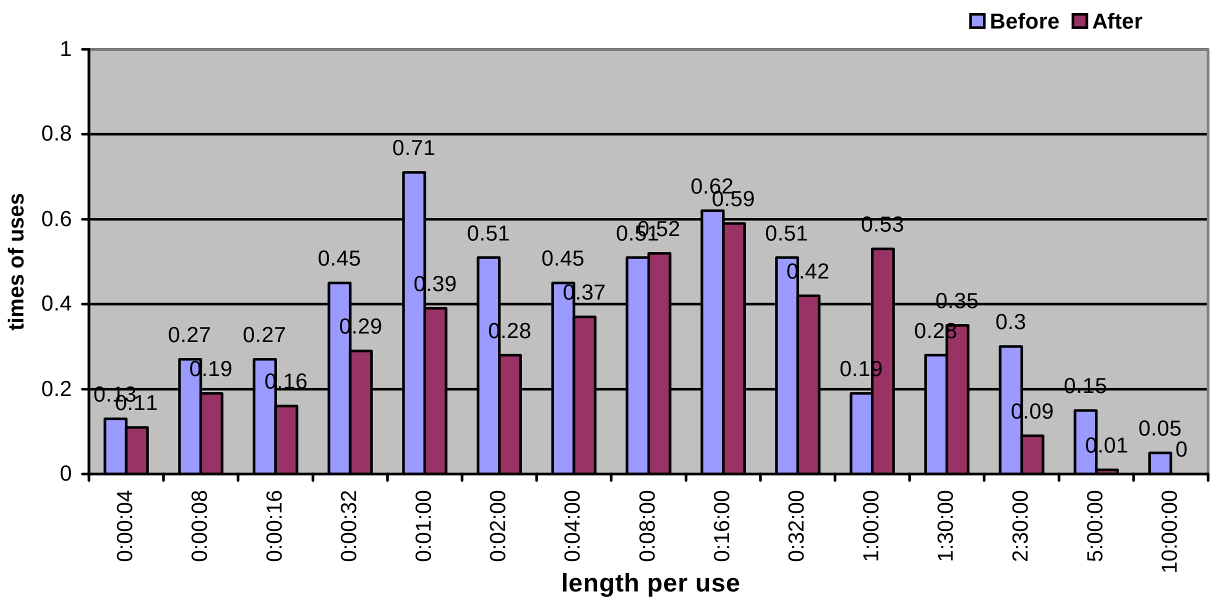
Reduction of long burning uses

The LCS saves energy by reducing the time of operation of the bathroom luminaires. With its preprogrammed timeout set to one hour, the LCS should eliminate most of the long-burning uses, which, though infrequent, consumed a significant amount of energy. Figure 2 presents a comparison of the usage pattern profile that demonstrates the length of burning for each use. It shows, on average, how frequently the luminaires were used for a given length of time each day. For example, the bars for 0:16:00 indicates that the luminaires on average are turned on greater than 16 minutes and less than 32 minutes for only 0.62 times per day. Interesting points demonstrated by Figure 2 are:

- Uses with burning lengths greater than 2.5 hours were reduced significantly by the LCS. Eighty percent of the uses falling in this interval were eliminated. The number of uses per day with durations greater than 2.5 hours was changed from 0.50 to 0.10, a reduction of 0.40.
- Uses with burning lengths between one hour and 2.5 hours increased. The number of uses in this interval was changed from 0.47 to 0.88, an increase of 0.41, which was approximately the reduction from 2.5+ hours. Intuitively, this is a direct effect of the LCS cutting the long burning uses into shorter ones.
- Uses with burning lengths up to one hour decreased slightly. This is an interesting finding because uses less than one hour should not have been affected by the occupancy sensors timeout of one hour. One possible explanation of this result is that the night light on the LCS provides enough light for some functions allowing the user, on average, to turn on the bathroom luminaire less frequently.
- The average number of uses per day can be found by adding up all the bins in Figure 2. This results in a finding that the baseline has an average of five uses a day while the LCS yields an average of four uses a day. This result goes against conventional wisdom that occupancy sensors tend to increase the number of switches encountered by a luminaire, but does seem consistent with the theory above that the presence of the nightlight may at times eliminate the

number of uses of the bathroom luminaire. Although this finding has little effect on the energy consumption, it shows an unexpected usage pattern change caused by the LCS, which may actually suggest a further maintenance advantage as a reduced number of switches a day should have a positive impact on lamp life.

Figure 2. Frequency on an average day



Energy saving benefit from reduction of long burning uses

Findings from prior research conducted by LBNL and The Watt Stopper, Inc. suggested that most of the energy used by hotel bathroom luminaires is from the relatively infrequent periods when the luminaires are left on for very long periods of time. This result was reinforced by the current data. Figure 3 shows the frequency and energy used for the given length of burning before installation of the LCS. The frequency has a similar meaning as in Figure 2, except Figure 3 data is presented as a percentage instead of an absolute number. The total time represents the percentage that the ON periods from each time interval contributed to the total operating time of the luminaire. The energy usage is directly related to the total time, as it is merely the product of the total time and the wattage of the luminaire. Figure 3 shows that while the bathroom lights are left on for longer than 2.5 hours only 9.5 percent of the time, these longer burning periods account for 65 percent of the fixture's energy consumption.

Figure 3. Frequency vs. Energy (Baseline)

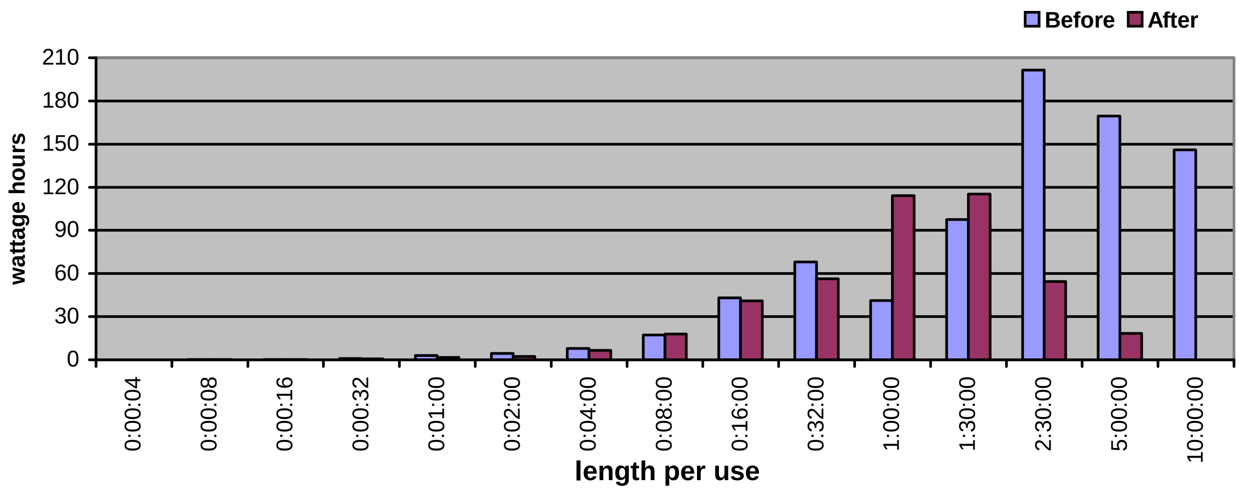


Figure 4. Energy on an average room-day

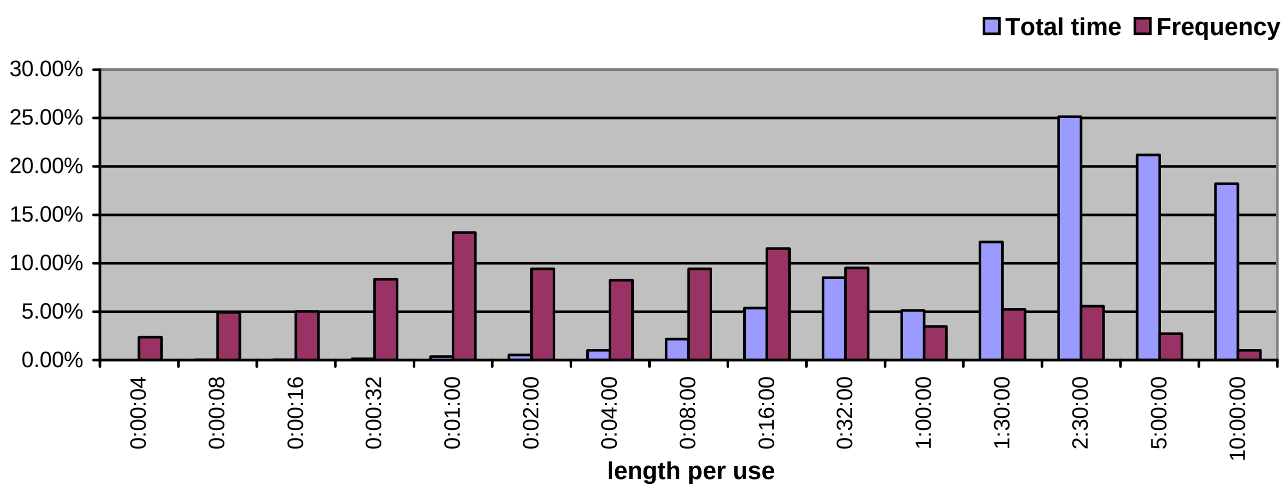


Figure 4 presents the overall energy savings generated by the LCS. Using the average luminaire power of 180W, Figure 4 shows average room-day energy consumption for both before and after installation of the LCS. For time durations greater than 2.5 hours, the energy savings were significant at 86 percent. The energy consumption between one hour and 2.5 hours increased about 56 percent. The total energy savings were 46.5 percent, which is consistent with the analysis of average burning hours per day.

Discussion

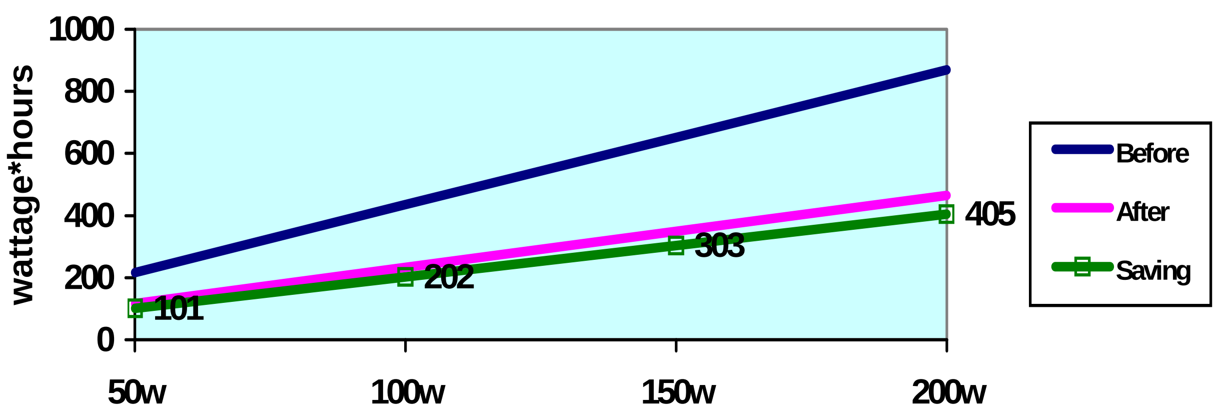
The analysis above provides a great deal of insight into the usage patterns and energy savings at the Sacramento Doubletree Hotel. The next step is to determine how these results relate to the hotel industry as a whole. There are many different types of hotels (business, vacation, conference, etc.) with a variety of baseline conditions that may affect the specific LCS savings at any given site. In this section several baseline factors, such as baseline usage and hotel occupancy rates, will be discussed. Finally, a brief discussion of customer feedback is included.

Baseline Conditions

Connected Load

The energy savings produced by the LCS are largely dependent on the load or watts (W) of the existing bathroom luminaire. This can range from under 50 W for a single fluorescent lamp to well over 200 W for an incandescent vanity luminaire. Figure 5 demonstrates what energy reduction is represented by a 46.5 percent reduction in operating hours for luminaires of various wattages. The average load in the rooms at the Doubletree was 180 W, yielding savings of approximately 360 W-hours per day per room. Obviously, larger loads would result in greater energy savings from the LCS, which would produce shorter paybacks for the cost of purchasing and installing the LCS.

Figure 5. Energy savings for different wattage luminaires



Baseline Hours of Operation

Another variable that has a substantial effect on the energy savings and payback for the LCS is the baseline hours of operation of the bathroom luminaire. The average of 4.4 hours per day found in this study is significantly lower than that of previous LBNL studies that had found up to eight hours per day at vacation hotels. Hotel industry sources have indicated that these findings are consistent with their experience. Vacation hotels tend to have more occupants spending more time in the hotel rooms than do business hotels. This leads to longer baseline hours of operation for the guestroom luminaires. This difference in baseline hours is significant, as a doubling of the baseline hours could result in cutting the payback for the LCS in half.

The most accurate method to document LCS energy savings potential in the hotel industry as a whole would be to monitor the usage patterns of many different hotels. Baseline data and post-LCS installation data from each site could be compared to gather averages and trends. As this was not practical for this study, LBNL performed an estimate of the LCS energy savings potential for vacation hotels based on a dataset obtained in a previous study. The discussion is presented below and is not intended to conclusively state what the expected savings in vacation hotels would be. However, it is meant to serve as an approximation of the potential savings at such sites.

Table 3 shows the process of the estimation. This table includes data from the bin analysis discussed previously in Figure 2, as well as “prior data” from the previous vacation hotel study. The savings potential (column 1) represents the energy savings that the LCS was found to generate for each use period at the Doubletree Hotel. By multiplying this savings potential (column 1) by the baseline energy consumption (column 2) that was found for each bin, the energy savings generated by the LCS can be calculated (column 4). If the assumption is then made that the savings potential (column 1) of the LCS is independent of hotel, then for any hotel in which a breakdown of baseline usage is available, the energy savings can be estimated.

Table 3: Energy savings estimate for vacation hotel baseline data set

Length per use		**Savings Potential**	**Energy consumption percentage before installing the LCS**		**Energy Savings**	
			Current data	**Prior data**	**Current data**	**Prior data**
		(1)	**(2)**	**(3)**	**(4)=(1)*(2)**	**(5)=(1)*(3)**
Sec	4	18.44%	0.00%	0.00%	0.00%	0.00%
	8	25.52%	0.02%	0.01%	0.00%	0.00%
	16	43.50%	0.04%	0.02%	0.02%	0.01%
	32	35.56%	0.13%	0.07%	0.05%	0.02%
Min	1	44.83%	0.38%	0.22%	0.17%	0.10%
	2	46.55%	0.55%	0.41%	0.26%	0.19%
	4	18.01%	1.00%	0.62%	0.18%	0.11%
	8	-4.74%	2.15%	1.37%	-0.10%	-0.07%
	16	4.55%	5.37%	3.51%	0.24%	0.16%
	32	17.29%	8.50%	5.86%	1.47%	1.01%
Hour	1	-96.40%	11.85%	10.41%	-11.42%	-10.03%
	2	41.26%	18.29%	14.38%	7.55%	5.93%
	4	92.27%	29.68%	24.62%	27.38%	22.72%
	8	88.00%	11.89%	20.14%	10.46%	17.72%
	16	100.00%	10.14%	18.35%	10.14%	18.35%
Overall					**46.40%**	**56.24%**

Essentially, this assumption allows for various hotels to have different usage profiles, but calculates the percentage reduction of each of the bins by the introduction of the LCS to match that found at the Doubletree. The energy savings estimate (column 5) of the prior data (column 3) can then be found by multiplying those data by the savings potential (column 1).

This analysis yields the overall result that the energy savings for the current data set is about 46 percent, while for the prior data set it is about 56 percent. This increase in savings is primarily due to the higher percentage of energy consumption by the prior dataset in the five and 10 hour usage bins. This result is noteworthy because not only does the absolute energy savings increase simply because the baseline is larger, but the savings percentage actually increases due to changes in the usage pattern.

LCS Timeout Delay

While the LCS can be programmed with various timeout delays, all of the units used in this study were set to one hour. The effective increase in energy savings from a shorter timeout delay, such as 30 minutes, would be useful to explore. Again, the more accurate method of determining this result would be to monitor a statistically significant number of rooms with shorter timeout delays and compare the results. Unfortunately, this also was not practical during the current study. The data from this study did allow for a first order approximation of increased savings from shorter timeout delays.

A detailed analysis of the data found that decreasing the setpoint to 30 minutes would have only a modest effect on the overall savings of the LCS. This analysis found that, depending on the assumptions made, dropping the setpoint from one hour to 30 minutes would only result in overall energy savings of an additional 1 to 4 percent. Based on this result, it certainly appears that the modest increase in energy savings would not justify the hotel guest complaints from increased "false offs" that would be the likely result of changing the LCS timeout delay from one hour to 30 minutes.

Occupancy Rates

The effect of the occupancy rate on the energy savings potential of the LCS was not studied directly. It was determined early in the study that the Doubletree Hotel could not provide LBNL with the desired information on the actual occupancy information for each test room during the test period. Thus, LBNL was required to make the assumption that on the days in which the bathroom light was never used the room was unoccupied. Because of the uncertainty of this method of estimating occupancy and the desire to maximize the number of data points, the hotel staff was asked to keep the study rooms at an occupancy rate of 100 percent for the duration of the study in order to maximize the number of data points.

The relationship between the occupancy rate and the LCS savings and usage patterns clearly would be useful to know. While the current data set does not contain enough information to fully characterize this relationship, it does provide some clues. Four of the study rooms were kept very near the 100 percent occupancy rate requested, but one of the rooms (#588) had an occupancy rate near 80 percent for both the baseline and post-LCS periods. Interestingly, room #588 was found to have a larger baseline and a smaller post-LCS period than any of the other four rooms, with energy savings of nearly 70 percent vs. 46.5 percent from the overall average (see Table 2). A closer look at the data from this room suggests that this result may not be a coincidence, but rather the effect of the room's increased vacancy. During the baseline period, the bathroom luminaire will remain in the state in which the guest or housekeeper left it until the room is visited again. Thus, a luminaire that is left on prior to a period of vacancy will generate a very long "on" period. Even if these occurrences are extremely rare, these "super-usages" will have a significant impact on the energy usage of the luminaire. But in the post-LCS period, the super-usages will never occur. This appears to be the difference in room #588. While there are not enough data to calculate the numerical effect of occupancy on the LCS energy savings, data from room #588 give a strong indication that there is such an effect. As the industry average occupancy rate is even lower than that of room #588 (65 percent vs. 80 percent), this remains a very important open question that merits further investigation.

Customer Feedback

The Doubletree Hotel staff collected informal user feedback on the LCS. Production, placement, collection, tabulation and analysis of a formal user survey placed in the guestrooms was determined to be impractical. Still, significant feedback was obtained from guest interactions with the hotel's customer service representatives and engineering staff. The initial response from hotel guestroom users has been almost uniformly very positive. This is noteworthy because typically the only feedback the hotel staff receives when making changes to the guestrooms is complaints. However, the staff has already received a number of complimentary comments regarding the unit's nightlight feature.

Report Conclusions

As a result of (1) the collaboration established between LBNL, The Watt Stopper Inc., SMUD and the Doubletree Hotel; (2) the LCS units and logging equipment installed at the hotel test site; and (3) the quantitative methodologies described in this report, the LCS was found to significantly reduce energy usage in hotel guestroom bathrooms. The average savings from the LCS measured from this study was found to be 46.5 percent, though this result was likely limited by a number of factors including the hotel's baseline condition and the occupancy rates of the rooms measured.

A conservative estimate of expected savings from the LCS for the hotel industry as a whole is 50 percent. Based on a hotel's current baseline (hours/day), the bathroom luminaire wattage, and the final cost of the LCS, a conservative payback based on 50 percent savings can be easily calculated. The LCS timeout delay of one hour was found to effectively limit long periods of operation without adversely effecting guest comfort. Decreasing the LCS timeout would only slightly increase energy savings, but may adversely affect guest comfort. Overall, guests responded very favorably to the LCS, appreciating the effect of the nightlight.

REFERENCES

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