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**Berkeley Lamp Applications Study
FINAL REPORT**



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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 (CEC), 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 Berkeley Lamp Applications Study, California Energy Commission Contract #74, conducted by the California Lighting Technology Center. This project contributes to the Building End-Use Energy Efficiency program.

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

The purpose of the Berkeley Lamp Application Study project was to conduct a field study to determine user satisfaction and identify their product improvement suggestions that would improve market acceptance. Two secondary goals were to give California State agencies experience with the technology and to confirm energy savings compared with standard overhead lighting.

The following sites were selected for the Berkeley Lamp Applications Study:

- California Environmental Protection Agency (CalEPA)
- Department of General Services (DGS)

Site selection was based on the following considerations:

- Influential in selecting lighting technology and dedicated to energy efficient lighting.
- Able to use new technology and spread the new technology to mainstream office buildings in California.
- Have up to date lighting technology installed to prove that the Berkeley Lamp will have greater energy savings than current lighting technology.
- Have 20 to 40 participants willing to use the lamp exclusively for 3 to 6 months.
- Be able to place the Berkeley Lamps in single, closed offices so we may obtain accurate power consumption of the Berkeley Lamp and prior overhead lighting.
- Participants must be willing to complete a web based user satisfaction survey.

Survey Results

The research team collected user feedback with a web based survey, with 26 of 80 users completing the survey. The key results include:

- 96% rated their overall impression the Berkeley Lamp as positive or very positive.
- 96% rated the Berkeley Lamp lighting quality as good or excellent.
- 54% never or rarely used their overhead lights after receiving the Berkeley Lamp.
- 89% preferred the Berkeley Lamp's warm lamp color compared with the typical cool-colored lamps.

The only significant design suggestions revolved around the Berkeley Lamp's form factor:

- 31% would prefer a floor lamp version instead of the current desktop version
- 92% like the looks of the current Berkeley Lamp and there were no new suggestions for design improvements.
- A few users requested a smaller shade to facilitate use on their crowded desktops.

LightCorp will consider these suggestions if they revise this product, but at this time they are not planning any design changes since this product is not a big seller.

Partially as a result of this project the Berkeley Lamp is now included the State's Boise (now OfficeMax) ordering system, with a product announcement faxed to all State agencies.

Energy Savings Results

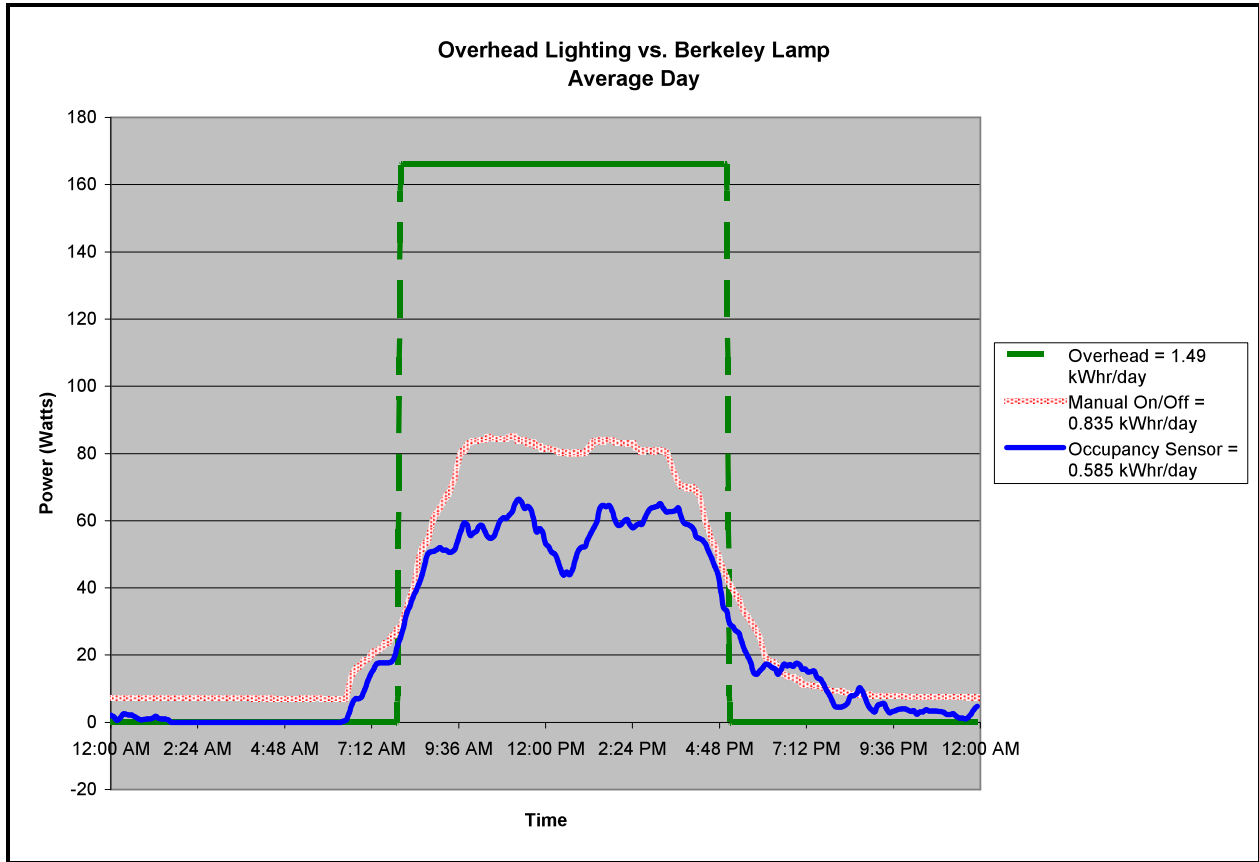
Half of the Berkeley Lamps deployed were set up with an occupancy sensor to determine if the sensors produced additional energy savings and user satisfaction. Eight weeks of data collection are summarized below in Table 1.

Table 1: Detailed Energy Analysis

Site	Control Option	Energy Use (kWh/day)		Energy Savings		Dollar Savings (Per year)	
		Base Case	Berkeley Lamp	Vs. overhead	Vs. BL manual	Vs. overhead	Vs. BL manual
DGS	Manual	1.49 kWh	0.835 kWh	43.96 %	Base	24.56	Base
	Occupancy	1.49 kWh	0.585 kWh	60.74 %	29.94 %	33.94	9.38
EPA	Manual	1.49 kWh	0.87 kWh	41.61 %	Base	23.25	Base
	Occupancy	1.49 kWh	0.665 kWh	55.37 %	23.56 %	30.94	7.69
Average	Manual	1.49 kWh	0.853 kWh	42.79 %	Base	23.91	Base
	Occupancy	1.49 kWh	0.625 kWh	58.06 %	26.75 %	32.44	8.53

Figure 1 on the following page shows the Berkeley Lamp energy results from the average day at DGS. The graph shows that the average usage of the Berkeley Lamp manual switch never actually reaches zero Watts. This happens because a few people accidentally left there light on overnight a couple of times. This brings the average usage up. You will notice that the Occupancy sensor results show some usage between the times of 5PM and 2AM. This is from the Janitorial staff entering to clean the office. The occupancy sensor results also show the small decline in usage at 12 o'clock pm. This proves that people often leave their lights on when they retreat for lunch. In this graph I have made the conservative assumption that the overhead lights will not be turned on between the hours of 5PM and 8AM. Knowing that some lights will have to be turned on by the Janitorial staff every night, this is low estimate of energy usage per day and still the Berkeley Lamp saves 42 to 58 percent energy.

Figure 1: Daily Energy Use Comparison Plot



Additional Manufacturer Pursues New Product

Near the end of this project, another company licensed the Berkeley Lamp technology from Lawrence Berkeley National Laboratory (LBNL) and plans to introduce a new product in late 2005 using a “full-spectrum” lamp.

Abstract

The purpose of the Berkeley Lamp Application Study project was to conduct a field study to determine user satisfaction and identify their product improvement suggestions that would improve market acceptance. Two secondary goals were to give California State agencies experience with the technology and to confirm energy savings compared with standard overhead lighting. Approximately 43% savings were accrued from the use of the Berkeley Lamp when compared to standard overhead lighting. The installation of the occupancy sensors on the lamps added an additional 27% savings.

The primary objective of the Berkeley Lamp application study was to use the results from the web based survey to give design improvement ideas to LightCorp. The key results include:

- 96% of users rated their overall impression the Berkeley Lamp as positive or very positive;
- 96% rated the Berkeley Lamp lighting quality as good or excellent;
- 54% never or rarely used their overhead lights after receiving the Berkeley Lamp;
- 89% preferred the Berkeley Lamp's warm lamp color compared with the typical cool-colored overhead lamps.

The only significant design suggestions revolved around the Berkeley Lamp's form factor. Data from the survey showed that 31% of users would prefer a floor lamp version to the current desktop version, although 92% liked the looks of the current Berkeley Lamp. There were no added suggestions for design improvements. LightCorp will consider these suggestions if they revise this product. Currently the product can be purchased through Office Max, the official office supply supplier to the state.

Introduction

The purpose of this project was to conduct a field study of Berkeley Lamps developed by Lawrence Berkeley National Laboratory (LBNL) that will identify what design issues need to be met to make the Berkeley Lamp a bigger success in the market. A series of lamps were installed at CalEPA and DGS with the objective of gaining an understanding of how the lamps perform in terms of energy savings under different operating conditions. The project also gathered an understanding of how people operate the lamps and measure their overall acceptance. The work authorization resulted in recommendations for future technology development activities, identified user satisfaction, product improvements, and documented, with engineering calculations, the energy savings. A web based survey was used to document user satisfaction as well as to receive design improvement ideas.

Project Objectives were to:

- Measure the energy usage after the installation of the Berkeley Lamp in each office to show energy savings compared to energy usage prior to Berkeley Lamp installation.
- Determine how users use the dimming and switching control features.
- Determine the user satisfaction with the Berkeley Lamp as well as receive user recommendations for design improvements.
- Present results of energy savings and user recommendations to LightCorp.

Project Approach

The California Lighting Technology Center (CLTC) staff sought office buildings where personnel were interested in participating in a study of the Berkeley Lamp. CLTC staff coordinated efforts with LightCorp and with key personnel at the Department of General Services (DGS) to determine appropriate locations for the study. CLTC staff used digital power meters to accurately measure the energy used by each Berkeley Lamp. An estimate of energy consumption was done prior to Berkeley Lamp installation to show actual energy savings obtained by Berkeley Lamp. A web based survey was developed to determine user satisfaction of the lamp. Included in the survey was a section for design improvement ideas. CLTC organized the survey results and design ideas to present to LightCorp for possible future improvements on the Berkeley Lamp.

Project Outcomes

Outcome #1—Characterize Energy Use

One project objective was to measure the energy usage after the installation of the Berkeley Lamp in each office to show energy savings and compare it to energy usage prior to Berkeley Lamp installation. CLTC staff coordinated efforts with DGS to decide which sites should be used for the study. Sites and participants were chosen based on the following considerations:

- Locations should be influential in lighting technology and dedicated to energy efficient lighting.
- Locations should be able to use new technology and spread the new technology to mainstream office buildings in California.
- Locations should have up-to-date lighting technology installed to prove that the Berkeley Lamp will have greater energy savings than current lighting fixtures.

- Locations should have 20 to 40 participants willing to use the lamp exclusively for 3 to 6 months.
- Locations should be able to place the Berkeley Lamps in single, closed offices so we could obtain accurate power readings of the Berkeley Lamp. Cubicles were not considered to be appropriate placement sites as they might get light from other sources and might not need the Berkeley Lamp as much as a closed office.
- Participants should be willing to complete a user survey to determine their likes and dislikes with the use of the Berkeley Lamp.

CLTC staff coordinated efforts with LightCorp and with personnel at the Department of General Services (DGS) to determine appropriate locations for the study. We placed 40 lamps at DGS, 40 lamps at the California Environmental Protection Agency (CalEPA), and 20 lamps at the Division of State Architects (DSA). LightCorp agreed to develop and donate 100 lamps to CLTC to distribute to CalEPA, DGS and DSA. CLTC staff notified the California Energy Commission by email of the sites selected for the study.

After receiving 100 Berkeley Lamps from LightCorp, CLTC staff coordinated with personnel at DGS and CalEPA to determine office placement for the Berkeley Lamps. CLTC staff worked with Dan Burgoyne from DGS and Jeff Castner from CalEPA to determine how to distribute 40 lamps at each location. Shannon Gillgrass assisted with the placement of 20 lamps at DSA.

Digital power meters were used to monitor the power consumed by selected Berkeley Lamps. The digital power meter is a black box that plugs into a wall socket and the Berkeley Lamp is plugged into the box. Every five minutes the digital meter recorded the average power used by the Berkeley Lamp during the previous five minutes. The digital power meter recorded data in text format with the date and time. Digital power meters were set for four week record time, at which point CLTC staff uploaded the text files with power readings and set the meters to run for another four weeks. A total of eight weeks of Berkeley Lamp energy usage was monitored.

The baseline energy report was computed with reference to the ‘Advanced Lighting Guidelines:1993.’ On page 3-19 the ‘Advance Lighting Guidelines: 1993’ shows that a recess static closed, F32T8 Lamp fixture with 3 lamps and a electronic standard rapid start ballast will run 83 Watts of power per fixture. 2 Fixtures are currently installed in each office, producing 166 Watts of power. Based on a 9 hr work schedule, 1.49 kWhrs of energy will be used each day in each office.

The records from the digital power meters were gathered, averaged and compared to the estimated energy use prior to Berkeley Lamp installation. Added energy savings were obtained by using an occupancy sensor to turn off Berkeley Lamps when people were not present. Results of energy savings of the Berkeley Lamp and occupancy sensor savings are shown in Table 2 and Figure 2. Table 2 shows the average daily usage of kilowatt-hours per day at DGS and CalEPA, compared to an average daily usage of the estimated overhead lighting. The manual results relate to turning the Berkeley Lamp on and off manually with the switch. The occupancy results relate to having an occupancy sensor hooked up to the Berkeley Lamp to turn the lamp on and off automatically when someone enters or leaves the room. The average kilowatt-hours (kWhr) used per day with use of the Berkeley Lamp is 0.835 kWhr at DGS and 0.87 kWhr at CalEPA. Compared to the overhead lighting kWhr usage per day of 1.49 kWhr, the Berkeley Lamp produced savings of 0.655 kWhr at DGS and 0.62 kWhr at CalEPA. This resulted in a 43 percent savings with use of the Berkeley Lamp as an alternative to overhead lighting. The use of an occupancy sensor saved an additional 0.25 kWhr per day at DGS and 0.205 kWhr per day at

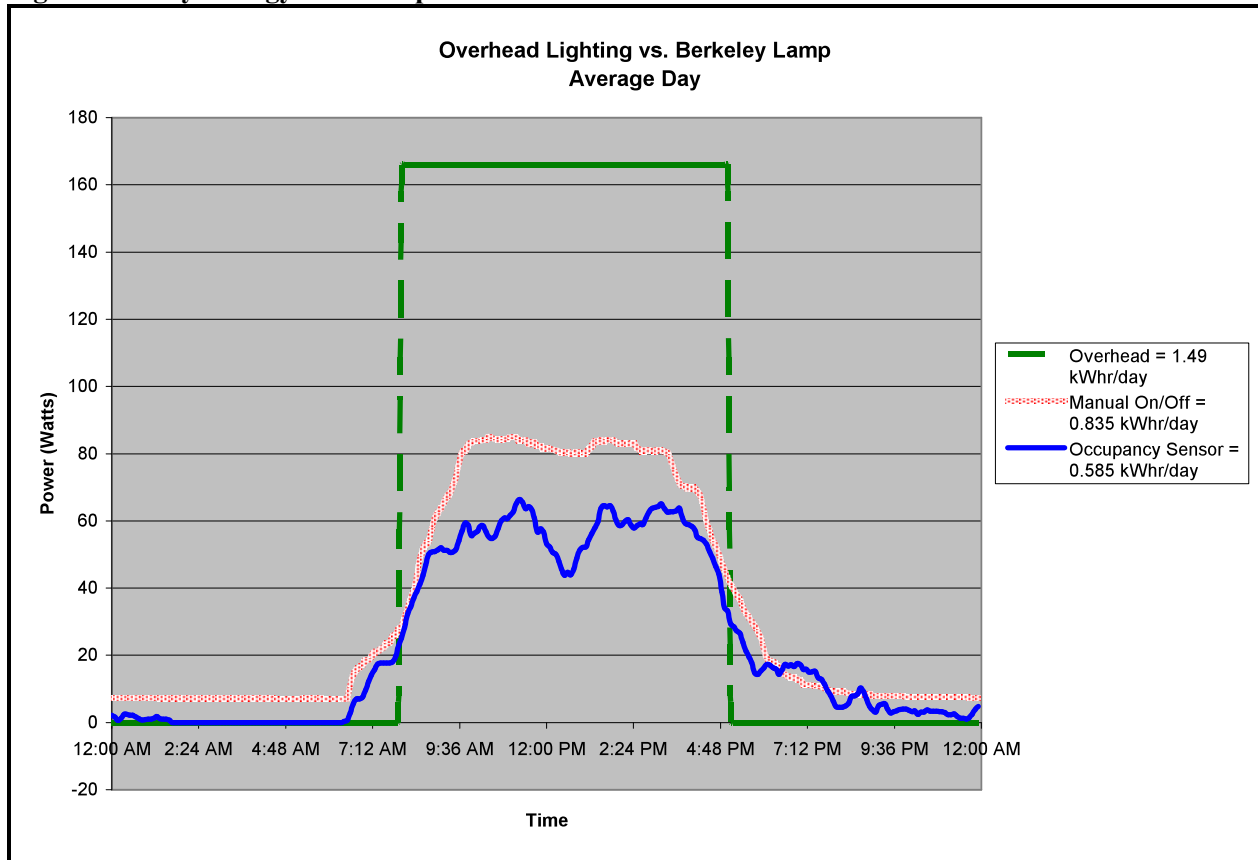
CalEPA over the standard manual switch. This resulted in 27 percent additional savings with use of an occupancy savings over the manual switch.

Table 2: Detailed Energy Analysis

Site	Control Option	Energy Use (kWh/day)		Energy Savings		Dollar Savings (Per year)	
		Base Case	Berkeley Lamp	Vs. overhead	Vs. BL manual	Vs. overhead	Vs. BL manual
DGS	Manual	1.49 kWh	0.835 kWh	43.96 %	Base	24.56	Base
	Occupancy	1.49 kWh	0.585 kWh	60.74 %	29.94 %	33.94	9.38
EPA	Manual	1.49 kWh	0.87 kWh	41.61 %	Base	23.25	Base
	Occupancy	1.49 kWh	0.665 kWh	55.37 %	23.56 %	30.94	7.69
Average	Manual	1.49 kWh	0.853 kWh	42.79 %	Base	23.91	Base
	Occupancy	1.49 kWh	0.625 kWh	58.06 %	26.75 %	32.44	8.53

Figure 2 shows the average daily usage pattern for three different test cases: (1) prior to the Berkeley Lamp installation, (2) Berkeley Lamps without occupancy sensors, and (3) Berkeley Lamps with occupancy sensors. This indicates the amount of energy that could be saved by using the Berkeley Lamp as a replacement to overhead lighting, as well as the added savings with use of an occupancy sensor.

Figure 2: Daily Energy Use Comparison Plot



Outcome #2—Characterize Satisfaction and Identify Design Improvements

The second project objective was to determine the user satisfaction with the Berkeley Lamp, as well as receive user recommendations for design improvements. A web-based survey was developed to determine user satisfaction. The survey included 20 multiple choice questions that enabled CLTC staff to understand how the lamp was used and whether participants felt that standard overhead lighting was still needed with the Berkeley Lamp. The survey also included a section in which participants could include anonymous comments about the Berkeley Lamp. We anticipated that Comments would include improvement ideas for the lamp. The survey was emailed to participants on September 29th, 2004. A copy of the survey with all results can be found in the appendices.

Of the responses received to this survey, 50% were from females and 50% were from males, with an average age of 40 to 49 years old. 73% of people using the lamp had an office smaller than 125 square feet, while only 15% of people using the lamp had an office larger than 150 square feet. Only 31% of users had an office with a window or other daylighting source.

The results from the survey show the majority of the people with a Berkeley Lamp (96%) enjoyed using it. 65% of Berkeley Lamp users found the lighting in their office to be fair, poor, or terrible prior to installing the lamp. After installation of the lamp, 96% of users found the lighting in their office to be good or excellent. This showed an obvious improvement in lighting quality for employees. In fact, 35% of users felt that the reduction in eye strain and glare in the office was greatly reduced, and 46% of users felt glare was somewhat reduced. Many of the respondents (42%) found that with the use of the Berkeley Lamp they never needed overhead lighting. Prior to the Berkeley Lamp, 81% of people always had their over head lighting on and

100% of people used it periodically. With the Berkeley Lamp, 42% of people turned their overhead lighting off and never turned it on again. Of the people who did use their overhead lighting, only 20% felt the need to have 6 or more 32Watt florescent tubes turned on.

The ability to dim the Berkeley Lamp was another added energy saver. 50% of users said they used the dimming feature of the lamp. 69% of people who received a lamp also received an occupancy sensor. Of the people who received an occupancy sensor 77% thought it was a positive or very positive feature for the lamp. 6% found the occupancy sensor to be a negative aspect to the lamp. 62% even felt the lamp should have an occupancy sensor built into the lamp. The Berkeley Lamp is built to use 2700K lamps and those received positive feedback from most users. 89% of users felt the warm color temperature is positive or very positive, while 12% found the light to be negative and would prefer a cooler color temperature. The people who do not like the 2700K generally have bad eyes and need the cooler light to see better.

The design of the Berkeley Lamp is very unique and 92% of users like the style of the lamp. 69% of users like the table lamp while 31% of users would prefer a floor lamp model to free up space of the desk. The people who like the table lamp also liked the convenience of the plug at the base of the lamp.

The only significant design suggestions revolved around the Berkeley Lamp's form factor:

- 31% would prefer a floor lamp version to the current desktop version
- 92% liked the looks of the current Berkeley Lamp and there were no new suggestions for design improvements.
- A few users requested a smaller shade to facilitate use on their crowded desktops, but that is the only design improvements mentioned.

Outcome #3—Determine How Users Use The Dimming And Switching Control Features.

An added energy saving tool that the Berkeley Lamp is built with is the ability to dim. Both task and ambient light can be turned on and off and dimmed individually. The Lamp can run at any combination between 22 Watts to 123 Watts, giving a maximum reduction of 82.1 percent. Unfortunately only 50 percent of users actually took advantage of the dimming and control feature of the Berkeley Lamp. The users who did not use the dimming feature used the lamp exclusively and needed all the flux that the lamp produces to light up the entire office. The 50 percent of people who did use the control and dimming feature often did not use the Berkeley Lamp exclusively. Some people used the Berkeley as a task light only. These users felt that low level ambient light was optimal with the standard overhead lighting. The overhead lighting was not run at full power at the few instances where this occurred. In general the overhead lighting that was left on was reduced to 30 percent maximum power.

Dimming proves to be an added energy saving component to the Berkeley Lamp. The ability to turn off 60 to 70 percent of the overhead light and only use the task lighting aspect of the Berkeley lamp you will still save around 60 Watts of energy. This accumulates to 0.54 kWhrs a day, assuming a 9 hour work day and 6 overhead T8 lamps are the standard. CLTC staff were unable to determine whether users used the task lighting or ambient lighting specifically, but found dimming to be relatively common.

Outcome #4—Impact Design Changes

The final project objective was to present results of energy savings and user recommendations to LightCorp, the product manufacturer. CLTC staff presented the preliminary survey results to

LightCorp staff in person at CLTC on August 4, 2004 and also sent draft written results on December 23, 2004 and this final draft report on March ??, 2005. Their staff was pleased to receive the results, though surprised to find no suggestions for design changes, except to produce a floor lamp model or smaller shade. LightCorp will consider the survey results if they revise this product, but they are not planning for any design changes.

Conclusions and Recommendations

Energy savings with use of a Berkeley Lamp, as opposed to standard overhead lighting, are approximately 50 percent, with an additional 25 percent savings with an occupancy sensor. These energy-saving estimates assume that overhead lighting is turned off entirely and the Berkeley Lamp is used exclusively. The finding that the Berkeley Lamp saved approximately 50% is consistent with prior metered studies of the Berkeley Lamp. The finding that the occupancy sensor saved an additional 25% is new information that will be utilized by LightCorp in determining if it would be practical for Berkeley Lamps to include integrated occupancy sensors.

A few issues that came up in the comment area of the web based survey include references to the color temperature and the brightness level. Remembering that only 12% of people did not like the 2700K lamps; one person who still uses very cool florescent tubes felt the warm color was too great of a contrast for him/her. This individual did note that they had bad eyes and kept both the overhead florescent tubes and the Berkeley Lamp on. Another person stated that with their bad eyes more light was needed, but they wanted more light with 2700K florescent tubes. A comment was made that they did not have enough light to read documents, but when working at the computer the Berkeley Lamp was all that was needed. So the use of a low powered task light is all that was needed in addition to the Berkeley Lamp, and it was only needed when reading documents. One user felt the lamp had the ideal amount of light and perfect color temperature for after-hours work. This person felt the contrast between the Berkeley Lamp and the standard overhead lighting during the day was too great and caused a little bit of glare on their eyes. Most of the user improvement ideas had to do with the color temperature and the addition of a floor model.

Many people do not have enough room on their desk for a large fixture; and this caused a few people to not want the standard Berkeley Lamp at work. Other table lamp problems occurred because of the size of the lamp shade; some felt it is too large. But that did not deter one person from making the comment that they would love to buy a couple of lamps for their home. A smaller shade option or a floor lamp version could help fix these concerns from the users.

While most users like the idea of an occupancy sensor; some showed concerns about the location of the sensor. The suggestion was made to locate the sensor as high up the lamp as possible to prevent objects from obstructing the view of the sensor. Any location that does not easily get blocked by miscellaneous desktop objects and has a clear line of site to the user is an adequate location.

The users overall impression of the lamp is that it is great and well liked by almost everyone using it, with 96% giving it a positive or very positive rating. The only significant design suggestions revolved around the Berkeley Lamp's form factor:

- 31% would prefer a floor lamp version to the current desktop version

- 92% liked the looks of the current Berkeley Lamp and there were no new suggestions for design improvements.
- A few users requested a smaller shade to facilitate easier use on their crowded desktops.

LightCorp will consider these suggestions if they revise this product, but they are not planning for any design changes since this product is not a big seller.

Currently there are two locations that the Berkeley Lamp can be purchased from. State agencies can purchase the product from Office Max, the official office supply supplier to the state. If you are a small California, certified business then you can order directly from Sierra Lake Group, Inc.

References

- Advanced Lighting Guidelines: 1993 (Revision1) its referenced on page – 11. Is this the correct reference format?)

Appendices (insert into this document)

- Raw Data (ENERGY USE AND SURVEY)
- SURVEY FORM