LIGHTING RESEARCH PROGRAM

Project 6.2 Program Technology and Product Design Tools

FINAL REPORT

Consultant Report

SPOT

SENSOR PLACEMENT + ORIENTATION TOOL

Prepared For:

California Energy Commission

Public Interest Energy Research Program

Arnold Schwarzenegger, *Governor*

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PREFACE

The *Program Technology and Product Design Tools Final Report* is a part of the *PIER Lighting Research Program (LRP)*, a Public Interest Energy Research (PIER) program. The program was funded by California ratepayers through California's System Benefit Charges administered by the California Energy Commission (Commission) under PIER contract No. 500-01-041, and managed by the Architectural Energy Corporation. The 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.

The PIER LRP consisted of 6 elements; element 1 was administrative in nature, elements 2 through 5 each had three to five projects that developed an energy efficient lighting system, fixture, protocol, or controls product, and element 6 had three projects focused on market connection activities. The *Program Technology and Product Design Tools Final Report* shows the results of a two year effort under project 6.2 to develop new design tools and case studies to effectively link the lighting technologies and products developed through the PIER LRP to lighting design practice. These tools will enable quicker application and acceptance in the marketplace.

For more information about the PIER program, or to obtain the Final Report and other publications produced by this project, please visit www.energy.ca.gov/pier or contact the Commission's Publications Unit at 916-654-5200. All research products are also available through the PIER LRP website at http://www.archenergy.com/lrp.

ABSTRACT

The *Program Technology and Product Design Tools Final Report* is the result of a two year effort to develop new design tools and case studies to effectively link the lighting technologies and products developed through the PIER LRP to lighting design practice. These tools will enable quicker application and acceptance in the marketplace.

Under project 6.2, case studies were completed highlighting the installation and performance of three LRP products. Additionally, a software tool, SPOT™ (Sensor Placement, and Orientation Tool) was developed which includes two parts: a design tool and an analysis tool. SPOT™ is a relatively user-friendly software package intended to inform the design of photosensor electric lighting control systems, optimizing for lighting performance and energy savings in a single classroom or space. The design portion of the program provides recommendations for optimal photosensor placement, photosensor type, photosensor aiming, and electric lighting zoning. The analysis portion of the program performs simulations and provides annual energy savings and lighting performance information.

The case studies are brief, product specific summaries, to be used to support various market transformation efforts under the LRP. These are available for download at www.energy.ca.gov/pier and will also be distributed by members of the PIER Lighting Research Program to highlight product data or technology performance. SPOT™, which is owned by Architectural Energy Corporation, is freeware intended for wide-spread use in the lighting and design communities. The use of SPOT™ is continuing to grow as more lighting designers and energy consultants become aware of the availability of the software tool on a daily basis.

The ripple effect from the tools developed under this project will continue to compound and pay dividends to the citizens of California by supporting the effort to save energy using energy efficient lighting technologies and products.

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EXECUTIVE SUMMARY

The *Program Technology and Product Design Tools Final Report* is a part of the *PIER Lighting Research Program (LRP)*, a Public Interest Energy Research (PIER) program. The PIER LRP consisted of 6 elements; element 1 focused on administrative, advisory, meeting, and web site tasks, elements 2 through 5 each had three to five projects that developed an energy efficient lighting system, fixture, protocol, or controls product. Element 6 included three projects and coordinated the market connection activities for the program.

The *Program Technology and Product Design Tools Final Report* shows the results of the two-year effort under project 6.2 to develop new design tools and case studies to effectively link the lighting technologies and products developed through the LRP to lighting design practice. These tools will enable quicker application and acceptance of the technologies in the marketplace.

This report summarizes work performed for the key tasks under this project.

1. The Introduction to this report gives information about the goals of this project, a list of the key tasks, and background about this project.
2. The Project Approach section summarizes the AEC team, the general approach, and the contributions of various individuals.
3. The Project Outcomes section summarizes the key outcomes, both technical and market, achieved under this project.
4. The Conclusion section provides final thoughts about this project.
5. The appendices are an important part of this report, as they include the case studies and the SPOT™ (Sensor Placement + Orientation Tool) technical users manual. The SPOT™ software, which is owned by AEC, is available to the public at no cost and may be downloaded from the Internet. Reference www.archenergy.com/SPOT for more information.

INTRODUCTION

The goal of the California Energy Commission's PIER Lighting Research Program (LRP) is to create new lighting technology and products that can: save energy, reduce peak demand, and reduce pollution for the citizens of California.

The Lighting Research Program (LRP) is a two-year $5.2 million R&D program focused on developing and introducing new energy efficient lighting technologies into the marketplace. This unique program is funded by the California Energy Commission and is managed by Architectural Energy Corporation. The LRP includes fifteen research projects and spans both the residential and commercial sectors, as well as outdoor lighting associated with buildings. The current report is part of the efforts to develop new design tools and case studies to effectively link the lighting technologies and products developed through the LRP to lighting design practice.

Project Goals

The primary goal of this project was to develop new design tools that effectively link the lighting technologies and products developed through the PIER Program to lighting design practice. These design tools enable quicker application and integration of the proposed technologies into the marketplace.

This project meets the PIER goal of improving the energy cost/value of California's electricity by facilitating quicker adoption of energy efficient lighting technologies. The objectives of the project were to:

- Fully define the information requirements and information sources of lighting designers (and others) to promote acceptance of the new technologies and lighting products that are the focus of Program efforts.
- Ensure that information created by specific Program research efforts meets the information needs of lighting designers.
- Create simple, targeted design tools to demonstrate the value – performance, energy savings, maintenance savings, durability/ reliability, etc. as relevant -- from the technologies and products developed through the LRP.

Overview of the Tasks

This final report provides an overview of the following main tasks performed under Project 6.2 Program Technology and Product Design Tools.

- Select target program lighting technologies and products and identify information requirements and sources; coordinate with other project leads.
- Create design tools and case studies.
- Incorporate program lighting technology and product information into the existing market. Promote and make available the lighting design tool, SPOT™.
- Develop technology transfer strategies and a plan for product readiness.

Background

Many new technologies are slow to enter the market because lighting designers are unfamiliar or uncomfortable with the design and performance of the new technologies and, therefore, hesitate to apply them in professional practice. Lack of design precedent or positive case studies, make new technologies appear riskier than tried and true methods. Design tools assist and educate designers so they are able to best implement these technologies. An increased level of understanding leads to an increased level of comfort, which leads to wider market acceptance and more applications of new technologies in the lighting industry.

The anticipated market benefit of the developed design tools, therefore, is increased market penetration as designers are better prepared to implement the technologies in real world applications. Key measures focus on increased skill, knowledge base, and understanding regarding the technologies. The case studies include summaries of analysis, performance results, implementation criteria, cost evaluations, specifications or design details, i.e., any information that assists the designer to integrate the new technologies into professional practice. The software tool, SPOT™, is a software program which analyzes, evaluates and recommends photosensor electric lighting control system design to optimize daylight harvesting, annual energy savings, and lighting performance.

Extensive research exists regarding new-technology or technology transfer markets. A large number of design tools in the lighting or energy-related fields are available at no or low-cost, distributed by manufacturers, public interest groups, utility companies, or government institutions. Research, as well as direct experience, shows that design tools are successful at encouraging professionals to integrate new products into their work when the tools are user friendly, reliable and informative. There is much precedent for manufacturers providing AutoCAD files or in-house software tools to industry clients to increase sales. Architects have proven more likely to specify a product if sufficient and detailed information or boilerplate product specifications already exist. Designers are more comfortable with a product if design tools are available which predict performance. In other words, market penetration has proven greater when designers have the tools and information necessary to properly and efficiently design using a given product.

PROJECT APPROACH

Architectural Energy Corporation was charged with reviewing and identifying design tools and case studies to enhance the adoption and acceptance of the technologies and products developed under the LRP. The AEC team, lead by Caroline Clevenger, was comprised of the following design and software engineers: Zack Rogers, Halley Fitzpatrick, Galen Burrell, Rod Foth, Renee Temple, Michael Holtz, and Dave Roberts.

Various members of the team reviewed the LRP projects and discussed potential design tools and case studies. They identified the information requirements and sources that may be necessary to develop the potential tools and case studies. The team also talked with other LRP participants like Don Aumann with the CLTC, Karl Johnson with the CIEE, and Bret Logue with BKi to gain input from those individuals on the tools and case studies.

Advisory Group Inputs

The PIER LRP had two main advisory groups –

- The Program Advisory Committee (PAC) – the PAC members' role was to provide guidance to the overall development of the LRP products and facilitate generation of market connections.
- Technical Advisory Groups (TAG) – there was a separate TAG for each of the 6 elements within the LRP, and the TAG role was to provide detailed technical input on the products and recommendations.

Project 6.2 had a separate technical advisory group from Element 6 to provide input on the software tool developed under this project. The following individuals comprised the group and participated in various phone calls and web conferences conducted by AEC. Their input over the two-year period has contributed greatly to the technical and market success of the product.

Don Aumann, CLTC; Frances Rubinstein, LBNL; George Loisos, Loisos + Ubbelohde; Doug Paton, The Watt Stopper; Rick Mistrick, Penn State; Charles Ehrlich, Heschong Mahone Group; Charles Knuffke, The Watt Stopper; David Kaneda, Integrated Design Associates Inc.; Kostas Papamichael, CLTC.

PROJECT OUTCOMES

This section provides summaries of the findings from the key project tasks. Full reports are available on the PIER LRP website at www.archenergy.com/lrp.

Targeting LRP Lighting Technologies and Products

Design Tool Selection

The PIER LRP involved research of 15 products and technologies. Initial screening of all projects immediately eliminated four projects as unsuited for the development of design tools. These were Long Lifetime White LEDs (LRP Project 2.2), Portable Office Lighting Systems (LRP Project 4.4), Evaluation of Electronic Ballasts and Related Controls for HID Lighting Systems (LRP Project 5.2), and DALI Lighting Control Device Standard Development (LRP Project 5.4). Each of these projects would not primarily rely on a designer for their implementation, as they are either general research, variable in application (portable), or concerned with industry standards (DALI). The remaining project are listed below and were considered candidates for design tool development:

- LED lighting (LRP Projects 2.1 and 2.3)
- Demand Responsive Lighting (LRP Projects 3.1 and 3.2 and 3.3)
- Hotel and institutional bathroom fixtures (LRP Project 4.1)
- Energy Star table lamps (LRP Project 4.2)
- Downlight retrofit (LRP Project 4.3)
- Integrated classroom lighting (LRP Project 4.5)
- Bi-level stairwell lighting (LRP Project 5.1)
- Low glare outdoor luminaires (LRP Project 5.3)

Criteria were established using the following questions and were used to select the projects that warranted a design tool.

Which lighting technology will have the greatest impact on energy savings for California?

Energy savings are evaluated both in terms of energy use (kWh) and energy costs ($). Dis-aggregated end-use data should be provided for all of the lighting technologies. In general, comparing implementation of the proposed technology to a "base case" will be used to assess potential energy savings on an individual basis. These savings will be evaluated according to market share, so that the products with the greatest overall energy savings for the State will be given preference.

Which lighting technology involves a lighting designer in the specification / design process? Lighting technologies may be integrated into a project in a variety of ways. In order for a design tool to be useful, the design tool must influence the decision making process of the designer.

What lighting technologies do existing design tools currently address? Can these tools be modified to accommodate new lighting technologies? Some of the lighting technologies design tools already exist. Is it possible to provide performance data (photometric files etc.) for use in existing lighting simulation packages?

How much flexibility is there in the application of a given lighting technology? Priority will be given to versatile lighting technologies rather than are ones that are designed for unique applications.

What is the commercial viability of the product? Priority will be given to products considered more commercially viable. Manufacturers and experts will be consulted to determine commercial viability as it relates to technical viability, market projections, costs and ease of integration.

How complex is the lighting technology design process? Lighting technologies requiring complicated design and analysis are better candidates for design tools. If implementation is simple, unvarying analysis will be unnecessary and design tools ineffective.

Viability of creating a design tool? The complexity of the analysis required for a specific lighting technology application dictates the viability and level of effort required to create a useful design tool.

Design Tool Recommendations

The following is a list of the projects that were top candidates for the development of a design tool:

- LRP Project 3.3 Classroom Photosensor
- LRP Project 3.1 Retrofit Fluorescent Dimming
- LRP Project 3.2 Load-shedding Technology
- LRP Project 4.5 Integrated Classroom Lighting
- LRP Project 2.1 Exterior LED Luminaires
- LRP Project 2.3 Low Profile LEDs
- LRP Project 4.4 Portable Office Lighting

Multiple factors influenced whether or not a technology was a viable candidate. In general, characteristics deemed favorable to the development of design tools were:

Highly variable applications. Designs with a high degree of variability require numerous decisions on the part of the designer. In these cases, design tools can prove invaluable to select and to shape the technology as it is applied.

Performance Impact. The energy saving performance (and occupant satisfaction) of certain technologies is more dependent on their design and implementation than others. It is those technologies, which are highly affected by the design and resulting user interaction, where a design tool can be the most effective.

Preliminary characteristics of various LRP technologies noted that discouraged the creation of LRP design tools within the project term were:

Portability. The portability of task lights or portable lighting systems limits the control of the designer over performance and reduces the effectiveness of design tools.

Scheduling. In some cases, the project schedules were not conducive to this project's integrated development of design tools in coordination with product development.

Standardization. If product application is standard and highly specific, a design tool has little effectiveness in selecting whether or not and in what manner the technology should be applied.

Preliminary research identified the photosensor system technology of LRP 3.3 - classroom photosensor system as the leading candidate for the creation of a design tool. In addition, Projects 4.1, 4.5, 5.1 were selected for the creation of Case Studies to summarize the technologies as specified, installed and monitored during the LRP.

The goal of SPOT™, the software tool developed, is to assist in the proper implementation of photosensor electric lighting control systems by providing guidance and analysis for classroom specific photosensor system design. The potential and need for such a design tool was identified by the LRP 3.3 Project Team, the LRP 6.2 Project Team, and by numerous lighting design experts and professionals through surveys, interviews and industry trends. In particular, an initial survey prepared and distributed by the LRP 6.2 Project Team and completed by design professional, documented a strong sentiment in the industry that there is a real need for a design tool that could analyze lighting controls.

According to research being done by the LRP 3.3 Project Team, the use of photosensor controls appears to be quite limited in current classroom construction practices. In many of the schools in which daylight is being addressed, photosensor controls are often value-engineered out of the design near the end of the project. The ready acceptance of this value-engineering decision to eliminate the photosensors is due, in part, to the general perception of the industry that photosensors are difficult to successfully integrate into a project. Several generations of photosensors with spotty performance records along with poor photosensor system design have left many design professionals as well as building owners with little confidence in the effectiveness of these systems, and worse yet, with the feeling that the performance might be problematic for the occupants.

Recently, the industry has made significant strides to improve the reliability and effectiveness of photosensor performance. Current obstacles to their acceptance and application have more to do with the challenge of proper implementation (and cost) rather than unreliable performance. For this reason, a user-friendly tool to help diagnose and optimize photosensor selection and placement was identified as extremely valuable in furthering market acceptance.

The objective of Project 3.3 was to develop a photosensor lighting control system that is optimized for common classroom electric lighting solutions (recessed and pendant lighting) and daylighting configurations (side-lighting only, top-lighting only, side- and top-lighting). The optimization involves maximizing energy savings while ensuring adequate light levels are provided at all times. In addition, an optimized system is one that can be simply and easily commissioned and that effectively operates in conjunction with manual controls and occupancy sensors. Building on prior work by and in conjunction with Dr. Richard G. Mistrick, Associate Professor of Architectural Engineering, Pennsylvania State University and Dorene Maniccia, Manager, Market Segment Development, of The Watt Stopper, SPOT™ was developed to be an interactive analysis tool which could assist designers in designing a photosensor system for classrooms or a variety of design scenarios.

SPOT™ Development

Working with the PIER Lighting Research Program (LRP), AEC developed the Sensor Placement and Orientation Tool or SPOT™. The software, which is owned by AEC, is intended to assist designers in quantifying existing or intended electric lighting performance and annual daylight contribution for a given space and to establish the optimal photosensor placement relative to annual performance and annual energy savings.

The program consists of an Excel interface on top of a Radiance calculation engine and is available at no cost to the public. Although it was developed with classroom daylighting in mind, it can be used for a variety of space types. The tool handles top and side daylight sources and can

model the light distribution of any electric light fixture with an .IES file. The program is restricted geometrically to analyzing the lighting performance a single room at a time.

The goal of SPOT™ is to assist lighting designers develop proper design and implementation strategies for photosensor electric lighting control systems by providing feedback and analysis for classroom specific photosensor system design. It is organized into two main parts: a design tool and an analysis tool. Figure 1 shows a schematic flow diagram of the software program. The design portion of the program provides recommendations for optimal photosensor placement, photosensor type, photosensor aiming and electric lighting zoning. The analysis portion of the program performs simulations and provides annual energy savings and lighting performance information.

Figure 2 is from the design tool and shows a screen shot from a sample run indicating the photosensor placement locations. The photosensor scenarios are listed in the table and are shown graphically as black dots in the 3-D isometric of the space in the upper left corner and on a reflected ceiling plan in the upper right corner of the screen.

Figure 3 is from the analysis tool and shows the screen shot of the analysis page from the same example. The user can mix and match the various photosensor selections and layouts and have SPOT™ analyze how they will perform under a set of representative days and sky conditions. Correlations are presented characterizing the relationship of the available solar resource and the electric lighting response. Energy savings are then projected from the results. Figure 4 shows a screen shot with an example of the annual energy results table.

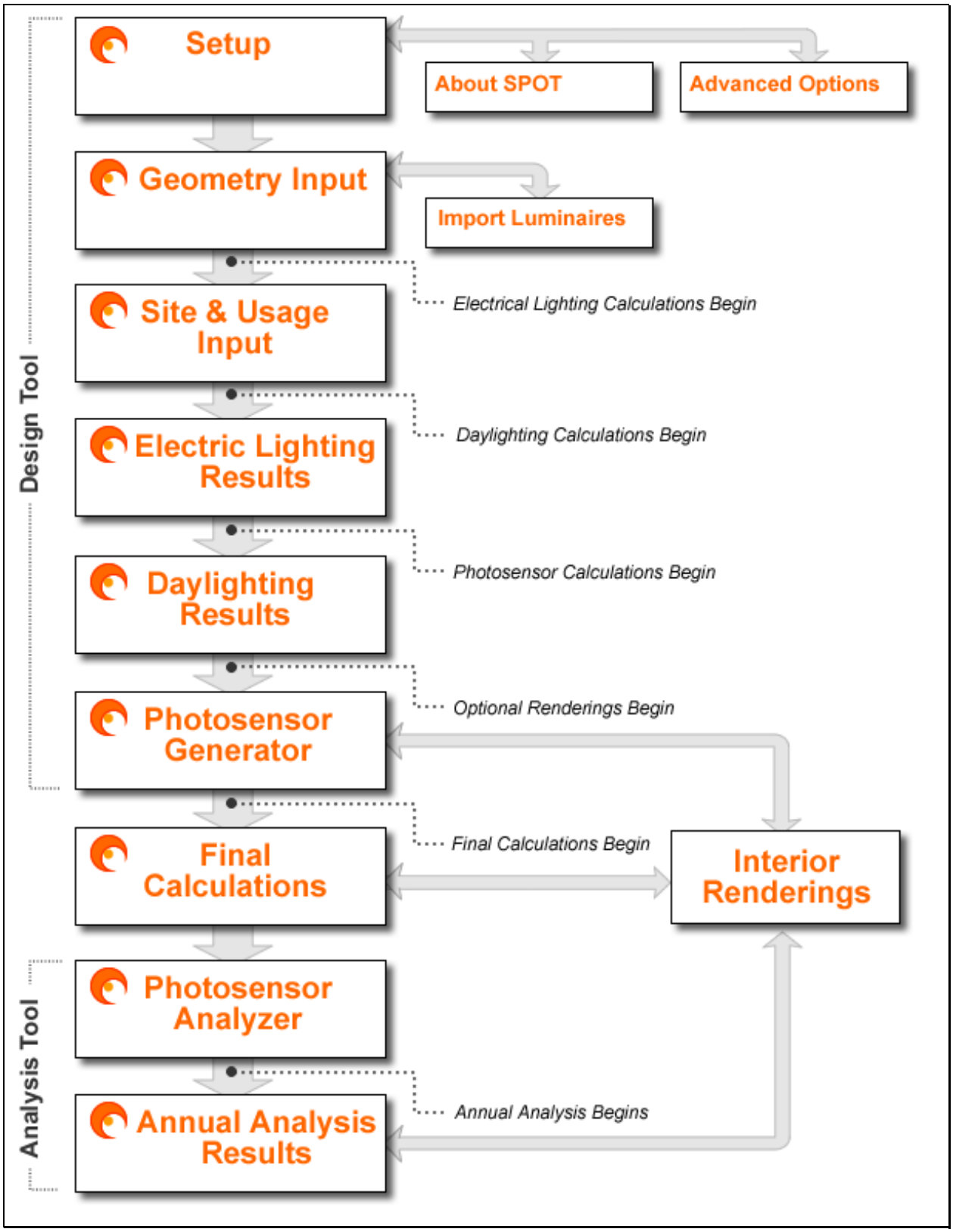
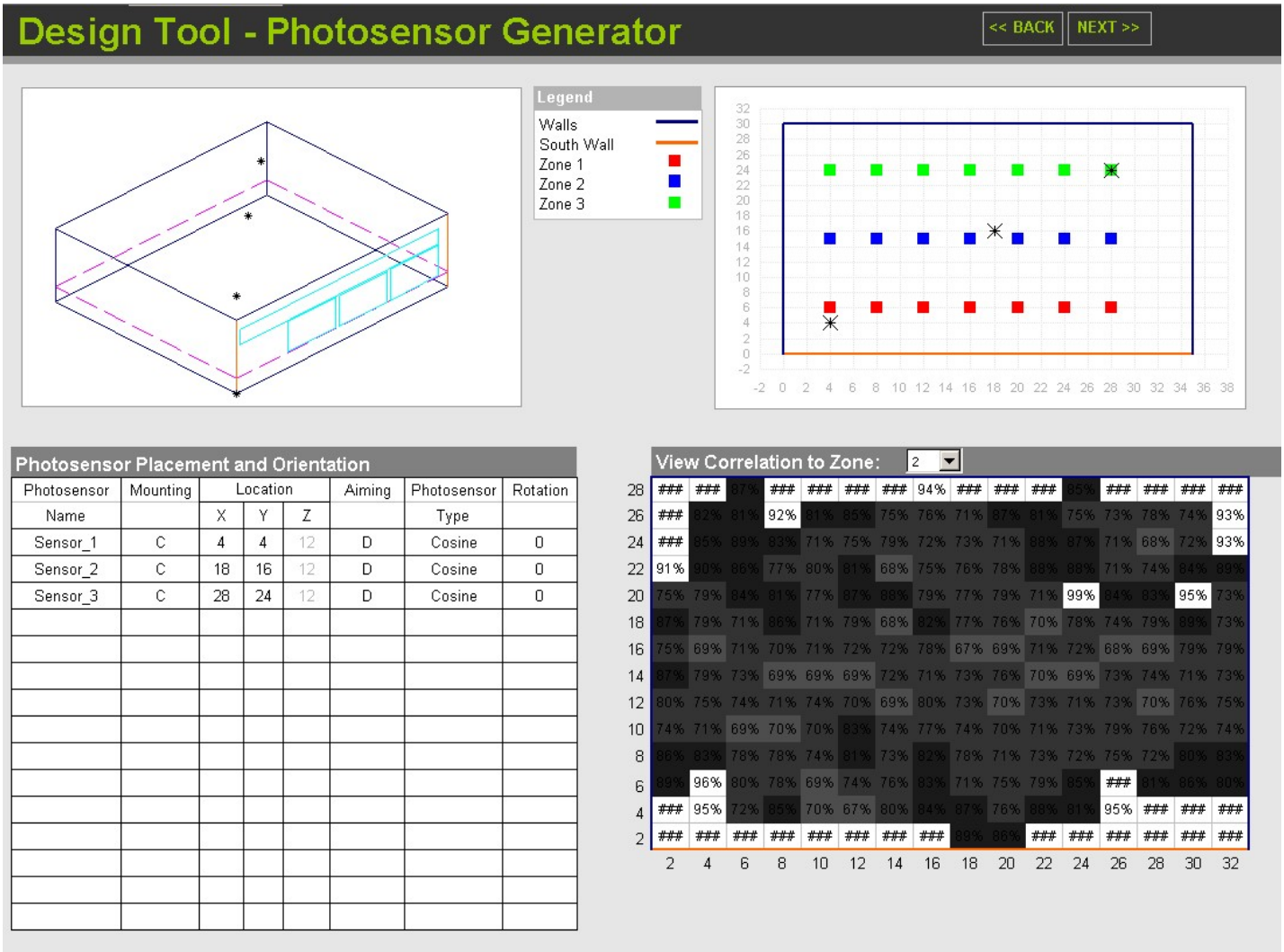


Figure 1: SPOT™ - flow diagram of software program



Photosensor Name	Mounting	Location X	Location Y	Location Z	Aiming	Photosensor Type	Rotation
Sensor_1	C	4	4	12	D	Cosine	0
Sensor_2	C	18	16	12	D	Cosine	0
Sensor_3	C	28	24	12	D	Cosine	0

	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
28	###	###	87%	###	###	###	###	94%	###	###	###	85%	###	###	###	###
26	###	82%	81%	92%	81%	85%	75%	76%	71%	87%	81%	75%	73%	78%	74%	93%
24	###	85%	89%	83%	71%	75%	79%	72%	73%	71%	88%	87%	71%	68%	72%	93%
22	91%	90%	86%	77%	80%	81%	68%	75%	76%	78%	88%	88%	71%	74%	84%	89%
20	75%	79%	84%	81%	77%	87%	88%	79%	77%	79%	71%	99%	84%	83%	95%	73%
18	87%	79%	71%	86%	71%	79%	68%	82%	77%	76%	70%	78%	74%	79%	88%	73%
16	75%	69%	71%	70%	71%	72%	72%	78%	67%	69%	71%	72%	68%	69%	79%	79%
14	87%	79%	73%	69%	69%	69%	72%	71%	73%	76%	70%	69%	73%	74%	71%	73%
12	80%	75%	74%	71%	74%	70%	69%	80%	73%	70%	73%	71%	73%	70%	76%	75%
10	74%	71%	69%	70%	70%	83%	74%	77%	74%	70%	71%	73%	79%	76%	72%	74%
8	86%	83%	78%	78%	74%	81%	73%	82%	78%	71%	73%	72%	75%	72%	80%	83%
6	89%	96%	80%	78%	69%	74%	76%	83%	71%	75%	79%	85%	###	81%	86%	80%
4	###	95%	72%	85%	70%	67%	80%	84%	87%	76%	88%	81%	95%	###	###	###
2	###	###	###	###	###	###	###	###	89%	86%	###	###	###	###	###	###

Figure 2: SPOT™ Design Tool – Screen shot shows the recommended photosensor locations

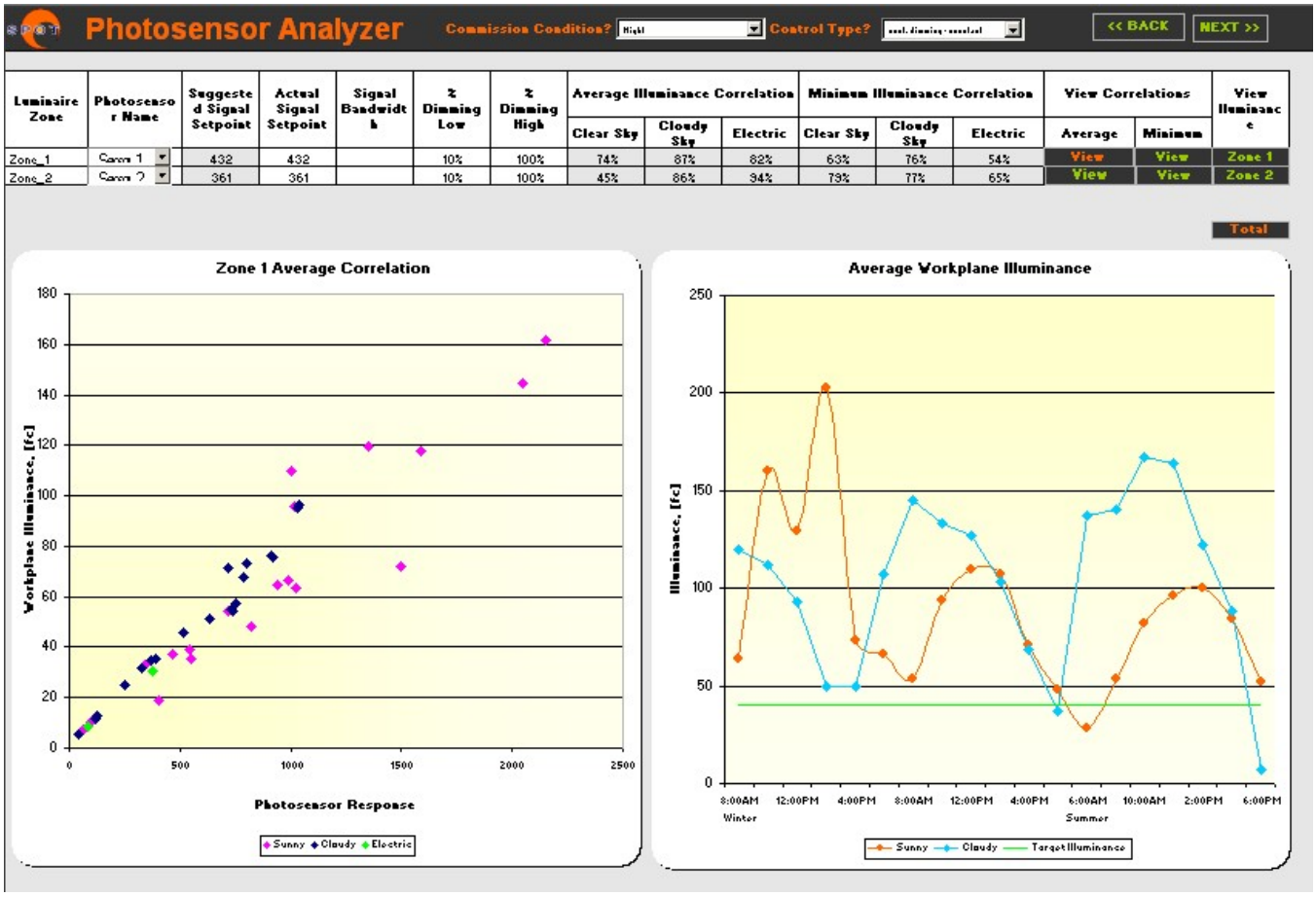


Figure 3: SPOT™ Analysis Tool – Screen shot shows the illuminance results

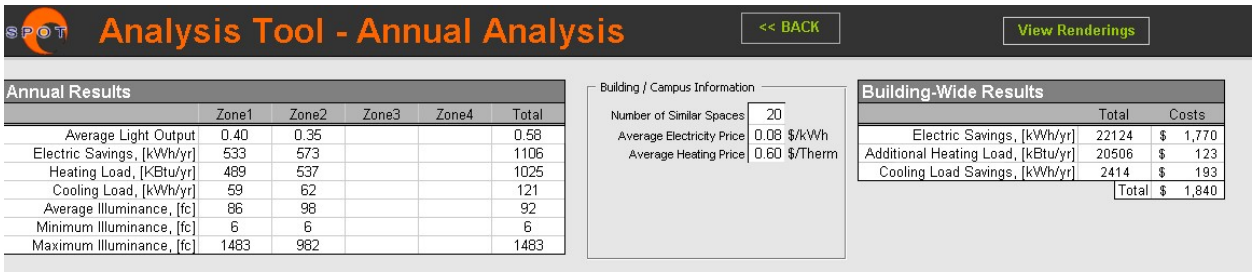


Figure 4: SPOT™ – Screen Shot of Annual Results Table

Current Status

SPOT™ has undergone thorough beta testing by several users and members of the technical advisory group and is now available at no cost to the public. Users may request either a CD-ROM or download the software install package from the Internet (reference www.archenergy.com/SPOT).

A detailed Users Manual is available to guide users through the application. A development report has also been prepared for advanced users to assist them in understanding the methodology behind the daylighting/electric lighting calculations and photosensor placement recommendations.

The SPOT™ software is packaged as a complete install package that users can install and use immediately. Although the software uses Radiance and Python, the user is not required to have either of those platforms installed previously on their computers. However, users should have administrative privileges. Questions regarding administrative privileges should be directed at the users' IT department. To successfully install SPOT™, users should have the following software/hardware requirements available on their computer systems.

- Windows 2000, Windows NT, or Windows XP
- Excel '97 (or higher)
- 400 MHz processor
- 128 MB available disk space

SPOT™ Marketing Plan

During development and beta testing, advanced (beta) copies of the SPOT™ software were released to software testers and other knowledgeable users for initial testing. In addition several conference calls were held with the Technical Advisory Group or TAG to present the software and allow the TAG to review and comment on program development. With the release of SPOT™ Beta version 1.15, AEC proposes to introduce SPOT™ to the general community of lighting designers and energy consultants in the California region and nationally.

SPOT™ is owned by AEC and currently available for download on the AEC SPOT™ website (www.archenergy.com/SPOT). The current marketing plan is to increase the software's visibly and availability by identifying addition organizations or companies involved with the lighting community that could potentially promote the use of SPOT™ software. Suggested groups included:

- Sustainable Buildings Industry Council
- Daylight Dividends Program
- U S Green Buildings Council (USGBC)
- Photosensor Manufacturers
- Energy Design Resources Program
- NYSERDA
- Lighting Control Association
- Radiance online users group

Currently, AEC has been working to find an organization or program to provide broad visibility, appeal, and support to SPOT™. Several organizations have been contacted and discussions pursued. The most promising at this point is the Energy Design Resources (EDR) Program, which already offers a valuable palette of energy design tools and resources to promote and assist with the design and construction of energy-efficient commercial and industrial buildings in California. EDR is funded by California utility customers and administered by Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison, and Southern California Gas under the auspices of the California Public Utilities Commission.

The goal of the EDR Program is to educate architects, engineers, lighting designers, and developers about techniques and technologies that contribute to energy efficient nonresidential new construction. Additionally, EDR already offers design tools like Skycalc, eVALUator, and eQuest that reduce the time energy consultants spend evaluating the energy use impact of design decisions. A long term vision for SPOT™ is to have it included as a qualified (approved) and appropriate software in established programs intended to rate sustainable design, lighting and / or energy saving performance in buildings such as the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) or the California utilities' Savings By Design program.

Recommendations for Future Enhancements

AEC recommends that additional work should be performed to further advance the analytical capabilities and robustness of the application of the software as well as to promote its standing among the suite of tools used by lighting design teams and energy consultants. Specifically, AEC design engineers suggests researching the various manufacturer photosensor system types

focusing on the control algorithms and spectral sensitivity functions for accuracy, and creating an extensive database for use within the software. AEC would also recommend researching current design, installation and commissioning practices of available photosensor products in real world applications to increase the usability and applicability of the tool's analytical capabilities.

Other work suggested includes:

- Refine IES global library with options to delete, rename, and group by type or manufacturer.
- Develop print and report functions for "images" and "annual analysis" results.
- Research light to power consumption curves. The software currently assumes linearity and probably needs to implement different curves.
- Research and implement manual shade usage patterns.
- Provide validation of SPOT™ results, using various test classrooms, and prepare documentation of the results.
- Provide customized results and printouts, if appropriate, for programs such as LEED and Savings By Design.

Finally, AEC remains committed to providing long-term support for SPOT™, which includes participating in validation studies and identifying and correcting newly identified flaws in the software.

Case Studies

In addition to the Design Tools, AEC was also responsible for writing several Case Studies to highlight and document the progress and outcomes of selected LRP lighting technologies. The goal of these Case Studies is to assist in promoting the LRP lighting technologies and products in specific market segments. The technologies of LRP elements are frequently designed to target specific market segments, such as K-12 schools, commercial outdoor lighting, office lighting, stairwells, and so on. AEC developed three application-oriented Case Studies, based on information provided by the LRP Project Teams, on the installation and performance of the LRP lighting technology and product.

The following projects were candidates for the development of case studies:

- LRP Project 2.3 – LED Low Profile Fixture
- LRP Project 4.1 – Bathroom Nightlight Study
- LRP Project 4.5 – Integrated Classroom Lighting System
- LRP Project 5.1 – Bi-Level Stairwell Fixture Performance
- LRP Project 5.4 – DALI Lighting Control Device Standard Development

Due to external circumstances, sample technologies were installed and monitored in only Projects 4.1, 4.5, 5.1 within the time frame required to develop the Case Studies. As a result, these were the projects selected for the creation of Case Studies. These projects are outlined below:

LRP Project 4.1- Hotel and Institutional Bathroom Lighting Project

The Lighting Control System (LCS) developed for project 4.1 was a wall switch occupancy sensor designed specifically for hotel bathrooms to save energy. The LCS has two key features. 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. The one-hour setpoint will presumably turn off the bathroom lights if the occupant has no need for the light while greatly minimizing the chances of generating "false offs" when the lights turn off while a guest is in the bathroom. The second key feature is a built-in LED nightlight that automatically turns on whenever the bathroom luminaire is turned off. During the LRP program, project researchers measured the lighting use in 15 guest bathrooms at the DoubleTree Hotel in Sacramento, California for four months. A Case Study was prepared summarizing the product specifications, performance, installation test results as well as outlining potential energy savings.

LRP Project 4.5- Integrated Classroom Lighting System

The product for LRP 4.5 is an integrated classroom lighting system that combines a high performance, direct – indirect light fixture with high efficiency, Super T8 lamps and electronic ballasts together with sensors, controls, and plug and play interconnection cables to provide excellent quality lighting, more teacher control of the lighting mode, and energy savings of 30 to 50 percent above current Title 24 levels. The lighting system proposed delivers 25 percent more light due to a new 96 percent reflective coating combined with Super T8 lamp and ballast technology.

The integrated classroom lighting systems were installed in 20 sites in Northern California, including a test classroom at Finelite and 14 additional classrooms at five other schools. Five classrooms at Heritage Oaks School were chosen and tested for energy savings, occupant comfort, and overall system performance. The results from this classroom monitoring, the results from an administered teacher survey, the product specifications, as well as the potential for energy savings in future installations were summarized in a Case Study for the project.

LRP Project 5.1- Bi-Level Stairwell Fixture Performance

Bi-level stairwell fixtures are two-lamp T8 fluorescent fixtures manufactured by LaMar Lighting. These fixtures use newly-developed dimmable ballasts capable of step-dimming the fixture from (nominal) 64W at full power to a 13 watt "standby" level, based on the response of the occupancy sensor built into each fixture. The occupancy sensors used are capable of detecting occupancy from floor to floor and allow energy savings through dimming when the stairways are unoccupied, while maintaining minimum light levels. Researchers replaced 23 2-lamp 40 W T12 fixtures with 2-lamp 32 W T8 bi-level lighting fixtures in one stairwell at Evans Hall on the UC Berkeley campus, which is a 10-story math building with multiple stairwells. Total energy savings for Evans Hall were calculated by recording the amount of time the fixtures were in standby mode (dimmed to 5%). A Case Study was prepared summarizing the product specifications, performance, installation test results as well as highlighting the potential for energy savings.

In conclusion, findings, lessons learned, monitored data, and calculated performance were summarized for these three projects in Case Studies prepared by AEC to more effectively link the lighting technologies and products developed through the LRP to lighting design practice. These Case Studies are referenced in Appendix A of this report.

CONCLUSION

The *Program Technology and Product Design Tools Final Report* is the result of a two year effort that developed new design tools and case studies to effectively link the lighting technologies and products developed through the PIER LRP to lighting design practice. These tools will enable quicker application and acceptance in the marketplace.

Under project 6.2, Case Studies were completed highlighting the installation and performance of three LRP products. Additionally, a software tool was developed which includes two parts: a design tool and an analysis tool. The design portion of the program provides recommendations for optimal photosensor placement, photosensor type, photosensor aiming and electric lighting zoning. The analysis portion of the program performs simulations and provides annual energy savings and lighting performance information.

The Case Studies have already and will continue to be used to support various market transformation efforts under the LRP. SPOT™ marks a true advancement for the lighting design industry. An innovative software tool, SPOT™ provides a level of detailed analysis for electric lighting and daylighting performance and their interaction previously unavailable in the industry with an unparalleled eased of modeling and input for the designer. The use of SPOT™ is and will continue to grow as more lighting designers and energy consultants become aware of its availability on a daily basis. The ripple effect from the tools developed under this project will continue to grow and pay dividends to the citizens of California by supporting the effort to save energy using energy efficient lighting technologies and products.

APPENDIX A: CASE STUDIES

To view case studies, visit www.archenergy.com/lrp/presentations.htm.

APPENDIX B: SPOT™ USERS MANUAL

To download SPOT™ software and view the user' manual, visit www.archenergy.com/SPOT.