

Customer Advanced Technologies Program Technology Evaluation Report



Advanced Office Lighting Systems



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About the Customer Advanced Technologies Program

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use and evaluation of new or underutilized technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), indirect/direct evaporative cooling, non-chemical water treatment systems and a wide variety of other technologies.

For more program information, please visit: <http://www.smud.org/en/education-safety/cat/Pages/index.aspx>.

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Executive Summary

During this past year SMUD worked with customers to test state-of-the-art LED lighting fixtures and advanced wireless lighting controls. One question that has already been asked: “couldn’t similar savings have been achieved at a lower cost using dimmable fluorescents?” Absolutely, but cost effectiveness was not our primary objective.

Since the State of California has some of the toughest building energy codes in the nation, emerging technologies are becoming more important than ever for meeting aggressive energy efficiency goals. LED lighting and wireless lighting controls are rapidly advancing and appear to offer significant benefits. However, there are important factors that must be considered when implementing these technologies in the field.

The main purpose of this project was to determine the amount of achievable energy savings without being limited by the usual financial constraints (such as simple payback requirements). These projects provide valuable insights about what it takes to install new technologies in real world situations. This information is shared with manufacturers who often make changes to their products that enhance the performance and make implementation easier. This process often improves the overall cost effectiveness for future adopters.

This report summarizes the results of replacing conventional T8 fluorescent lighting with state-of-the-art LED lighting fixtures and wireless controls in a 2800 ft² office. Features of the new system included dimming and control of each individual light fixture (via hand-held remotes), occupancy sensors and energy tracking software.

Products selected for this project included:

- CREE LED LR24 troffers
- CREE LED LR6C recessed downlights
- Bruck LED wall washers
- Adura[®] wireless lighting controls

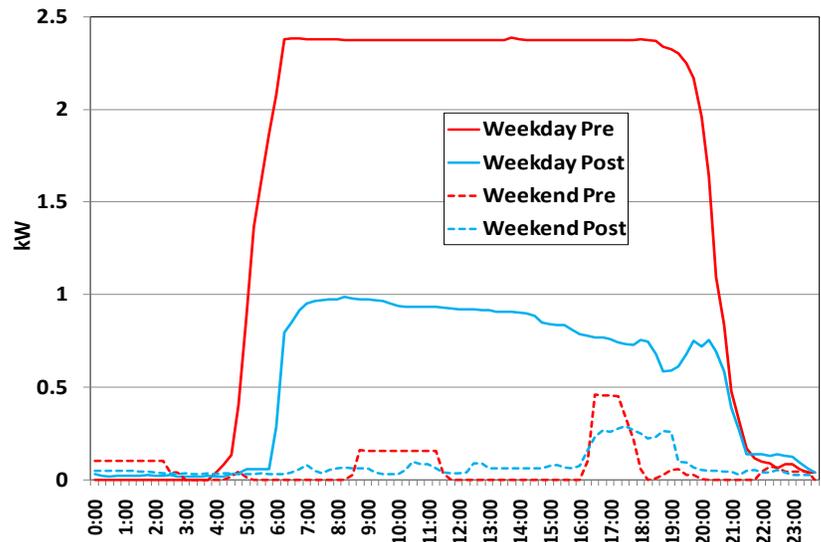


Figure 1: The new lighting system reduced energy consumption by over 60 percent, and operated at just 0.34 Watts / ft² – far below the maximum of 0.9 Watts / ft² allowed for office lighting under the 2008 Title 24 standards.

Savings Summary

SMUD hired ADM Associates Inc. (ADM) to determine the energy savings. ADM monitored the energy consumption of the original fluorescent lighting system as well as the new LED system for a period of over six months. The new system reduced energy consumption by over 60% (Figure 1). Further analysis of the monitoring data indicated that the LED lighting and controls operated at 0.34 Watts / ft² – 62% better than the maximum allowed for office lighting under the 2008 Title 24 standards. This is a truly remarkable achievement considering the system provided 50-60 fc of illumination on the desktops for employees who chose to run the system at the maximum available setting!

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Based upon ADM's monitoring data, the estimated savings for this project are:

Annual energy savings: 6,033 kWh (reduction of 62.5%)

Electrical demand reduction: 1.3 kW (reduction of 54%)

Annual utility bill savings: \$659

Annual maintenance savings (average): \$192

Total annual savings: \$851

Project cost

Cost for LED fixtures (self-installed):	\$11,855
<u>Cost for wireless controls:</u>	<u>\$8,277</u>
Total costs:	\$20,132

Simple payback: $\$20,132 \div \851 per year = 23.7 years*

* Since SMUD provided a research grant to cover all of the material and equipment costs, and AmerisourceBergen installed all of the lighting fixtures using in-house labor, the simple financial payback for AmerisourceBergen was significantly shorter than shown above.

Although the simple financial payback for this project was indeed very long, it should be noted that this project included only a very small office area (2800 ft²). This represents a worst case cost scenario for Acura Technologies (Acura) since the cost of the wireless gateway, software development and commissioning would have been nearly the same for a much larger project. Acura is also not dependent upon LED fixtures. Typical costs for wireless lighting controls in an equivalent fluorescent lighting system run \$1.50 to \$2.00 per square foot.

It is also important to note that the utility bill cost savings were based upon a rate of \$0.10 per kWh - customers in other parts of the country may pay considerably higher rates, particularly at peak times when the bulk of savings were realized.

While this technology provides many benefits, it is still not yet cost effective for most commercial customers. Significant cost reductions and utility incentives will be needed to encourage widespread adoption. Fortunately, steady improvements in LED and lighting controls technology and increased competition between manufacturers will help bring down costs in the near future.

SMUD intends to continue researching combinations of LED lighting fixtures and advanced lighting controls. In the meantime, SMUD offers customized energy efficiency incentives for LED fixtures that have been approved by Energy Star or the Design Lights Consortium (DLC). For a list of approved products, please call SMUD Commercial Services at 1-877-622-7683, visit www.smud.org, or check out the DLC website: <http://designlights.org/solidstate.about.php>.

Acknowledgments

SMUD wishes to acknowledge the management and staff members at AmerisourceBergen who made this project possible. Their pioneering spirit has provided key insights regarding the potential benefits and considerations of adopting new lighting technologies.

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Showcase Project

Project Location: AmerisourceBergen Drug Company
Sacramento, California

Background Information

AmerisourceBergen is one of the world's largest pharmaceutical service companies serving the United States, Canada and selected global markets with a focus on the pharmaceutical supply channel. Servicing pharmaceutical manufacturers and healthcare providers, the company provides drug distribution and related services designed to reduce costs and improve patient outcomes.

AmerisourceBergen has twenty-six pharmaceutical distribution centers and three specialty distribution centers strategically located throughout the United States; and nine distribution centers in Canada.

The Management and Staff at the Sacramento facility are passionate about new energy saving technologies and expressed interest to SMUD about upgrading their lighting and controls.

Test Site Description

- The section of the office chosen for the test serves as the customer contact center and includes approximately 2,800 ft² of space.
- The original lighting system consisted of thirty-six, 4 foot parabolic fixtures with three T8 fluorescent lamps and electronic ballasts (Figure 2). Maximum power consumption was 97 Watts per fixture with all three lamps turned on. Each fluorescent lamp was rated for 2,900 lumens.
- The original lighting controls consisted of manual wall switches located at the entrances to the office area. The switching offered four control options:
 - All three lamps on
 - Two lamps on and one lamp off
 - One lamp on and two lamps off
 - All three lamps off
- Based upon monitoring data, the employees preferred switching off the middle lamps during regular operating hours. The lights in this area typically operated from 6:00 a.m. to 10:00 p.m. daily during the work week.
- Illumination levels were measured on the desk top surfaces at strategic locations. The readings were 66 foot-candles (fc) with all three lamps on and 44fc with two lamps operating.



Figure 2: the original fluorescent lighting system

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New Lighting System

The Project Team implemented a very innovative lighting design that included the following elements:

- For general office lighting, one CREE LR24 fixture was installed above each workstation (Figure 3). The LR24 fixtures are designed to fit into a two foot by two foot suspended ceiling and are dimmable to 20% of maximum output. The LR24 has the following characteristics:
 - Light output: 3800 lumens @ 52 Watts
 - Efficacy: 73 lumens per Watt (LPW)
 - Color Rendering Index (CRI): 90
 - Correlated Color Temperature (CCT): 3500K
 - Rated life¹: 50,000 hours

¹ Unlike other light sources, the calculated life for LED fixtures is when the fixture loses 30% of its initial light output. This is commonly referred to as the L70 life.

- For the file cabinet area, a total of twelve CREE LR6C downlights (Figure 4) were installed. Both the LR24 and the LR6C fixtures use a combination of red and unsaturated yellow LEDs to produce warm, high-quality light (Figure 5). The output of the LEDs is balanced via patented controls to maintain consistent color and appearance.
- A total of eight Bruck LED wall wash fixtures (Figure 6) were installed to illuminate the artwork within the office. Each Bruck fixture consumes 6 Watts of power.
- The real key to the success of this project was the combination of the dimmable LED fixtures and Adura wireless lighting controls. Below are descriptions of the features and the control strategies implemented at this site:
 - Group control is accomplished via a wireless wall switch. Options include on / off and dimming.
 - Each fixture is individually controllable and programmable via a wireless ZigBee network and Adura software.
 - Individual fixture control is provided via hand-held remote controls. This enables the employees to adjust the light output of their fixture without affecting others. The fixtures used in this project may be dimmed down to 20% of maximum output and switched off.
 - Ceiling mounted motion sensors were used to turn off the lights after hours. The system is configured (via the software) to



Figure 3: CREE LR24. Photo credit: <http://creelighting.com>



Figure 4: CREE LR6C. Photo credit: <http://creelighting.com>

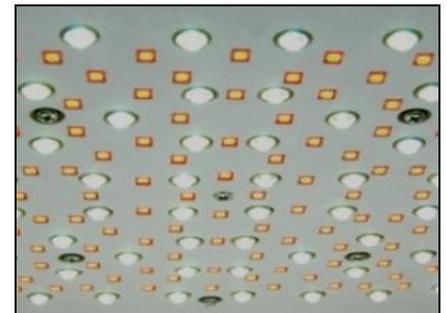


Figure 5: CREE uses red and unsaturated yellow LEDs to produce warm, high-quality light. Photo credit: <http://creelighting.com>



Figure 6: Bruck LEDRA Trio fixtures were installed to illuminate the art work within the office. Photo credit: <http://brucklighting.com>

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respond to the sensors only after closing hours. This feature prevents the system from accidentally turning off the lights during regular business hours.

- The software provides the ability to monitor the status and control each lighting fixture and motion sensor over the internet. The system is configured to update the status every 15 seconds.
- Adura controllers measure the energy consumption of the light fixtures that they control. This data is collected and may be used to display the energy savings on a Savings Dashboard in the Adura software (Figure 7). This feature provides valuable feedback and is a vital part of the commissioning process.

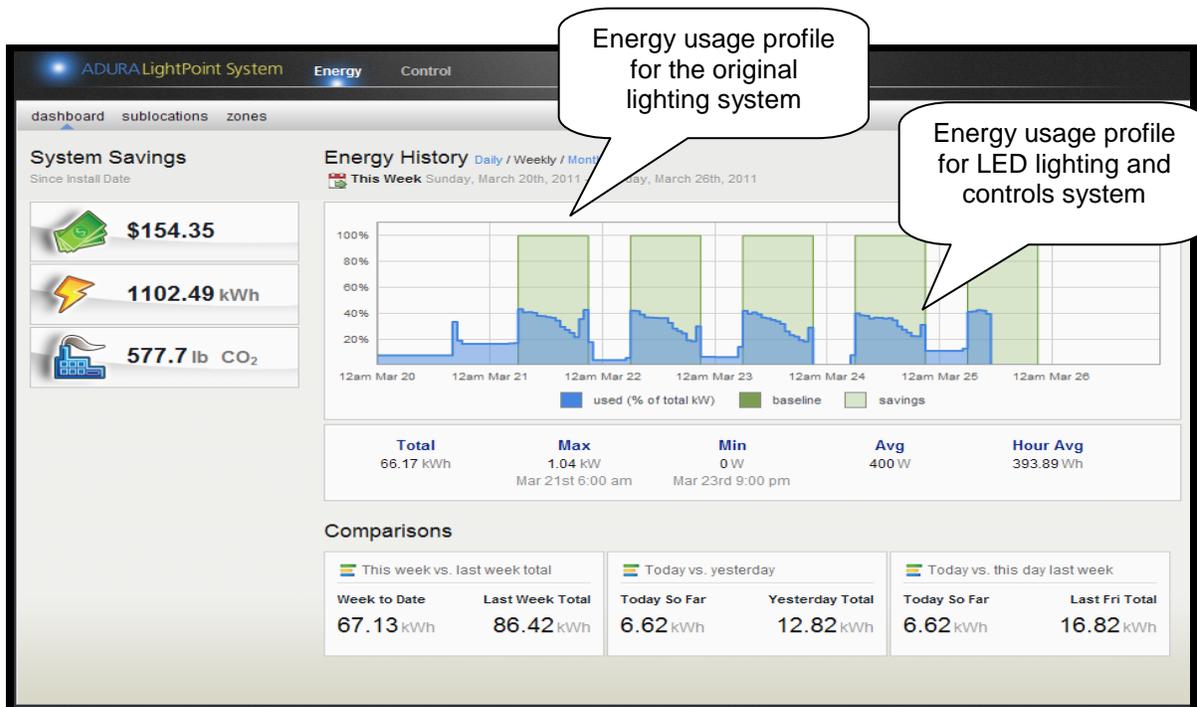


Figure 7: Adura controllers measure the energy consumption of the light fixtures that they control. This data is collected and may be used to display the energy savings on a Savings Dashboard in the Adura software. This feature provides valuable feedback and is a vital part of the commissioning process.

Summary of Results

The overall purpose of this project was to evaluate state-of-the-art LED lighting fixtures and wireless lighting controls. Specific objectives included determining:

- Annual energy savings (kWh)
- Peak electrical demand reduction (kW)
- Installation requirements
- Financial savings
- Customer satisfaction

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Energy and Demand Savings

SMUD hired ADM Associates Inc. (ADM) to monitor the office lighting systems before and after the lighting upgrade. The monitoring equipment was installed in March of 2010. Approximately four months of baseline and four months of post retrofit energy consumption data was acquired. The data was obtained via an Enernet K-20 multi-channel meter recorder and was recorded in 5-minute intervals.

For the purpose of this report, 12 weeks of baseline and 12 weeks of post retrofit energy consumption data were averaged into daily load profiles. The lighting profiles for weekdays and weekends are shown below in Figure 8. Based upon the monitoring data, the energy savings, electrical demand reduction and annual cost savings were calculated.

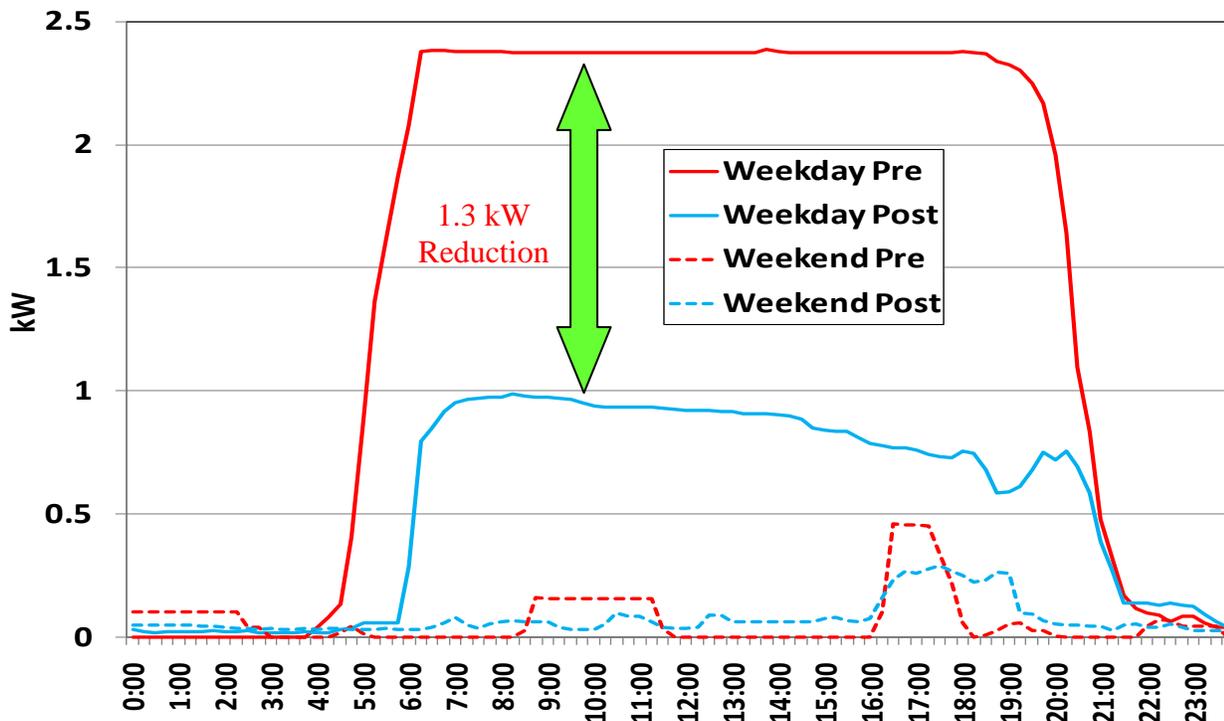


Figure 8: Monitoring of the lighting circuits reviewed an average demand reduction of 1.3 kW. Although the total connected load for the original lighting system was 3.9 kW, staff members who work in this area routinely chose to operate only two of the three fluorescent lamps. This explains why the measured electrical demand was only 2.4 kW.

Energy Savings

Baseline office lighting:	9,657 kWh per year
- <u>New lighting system & controls*:</u>	<u>3,625 kWh per year</u>
Estimated annual energy savings:	6,033 kWh per year

Total lighting energy savings of 62.5%

Annual cost savings @ \$0.10 per kWh: \$603 per year

*Since the Project Team chose to use higher lumen LED fixtures and limit the maximum output with controls, it would be very difficult to separate out the savings from the LED lights vs. the controls. Please see the Observations section of this report for more details.

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Electrical Demand Reduction

Baseline office lighting (measured):	2.4 kW
- <u>New lighting system (measured):</u>	<u>1.1 kW</u>
Estimated demand savings:	1.3 kW

Total lighting demand savings of 54%

Annual cost savings @ \$3.60 per kW / month: \$56 per year

Although the total connected load for the original lighting system was 3.9 kW, staff members who work in this area routinely chose to operate only two of the three fluorescent lamps, so the measured maximum electrical demand was only 2.4 kW.

Maintenance Savings

The estimated maintenance savings has been calculated based upon the following assumptions:

- Operating hours: 4,420 hours per year (17 hours per day, 260 days per year)
- Calculation period: 10 years (44,200 hours of operation)
- The new LED fixtures are rated for a minimum of 50,000 hours of operation at full output. Since the fixtures have been limited to 80% of full output, they may last considerably longer. Only time will tell if this assumption is correct. However, for the purpose of this calculation, it is assumed that no maintenance will be required during the calculated maintenance period.
- Original lighting system
 - 36 fluorescent fixtures
 - Each fixture had three T8 fluorescent lamps. However, only two lamps were operated. Therefore a total of 72 fluorescent lamps will be used for this calculation.
 - Rated life for T8 lamps: 24,000 hours of operation. Each fluorescent lamp will need to be replaced twice within the calculated period
 - Maintenance cost per 4 foot T8 lamp
 - Total cost = (cost of lamp) + (labor cost) + (disposal)
 - Total maintenance cost per lamp = (\$2.60) + (\$7.50) + (\$3.20)
 - Total maintenance cost per lamp = \$13.30
 - Assumed fluorescent ballast life: 45,000 hours
- Cost to maintain original lighting system for ten years:
 - Maintenance cost = (# lamps) x (two replacements) x (cost per lamp)
 - Maintenance cost = (72 lamps) x (two replacements) x (\$13.30 per lamp)
 - Maintenance cost = (144 lamps) x (\$13.30 per lamp)
 - Maintenance cost = \$1,915

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- Avoided Maintenance Costs (savings)
 - Average annual savings = cost to maintain original lighting system ÷ 10 years
 - Average annual savings = \$1,915 ÷ 10 years
 - Average annual savings = \$191.50 per year

Financial Savings

Annual energy savings: 6,033 kWh per year x \$0.10 / kWh =	\$603 per year
Demand savings: 1.3 kW x \$3.60 per kW / month x 12 months per year =	\$56 per year
<u>Maintenance savings:</u>	<u>\$192 per year</u>
Total estimated annual cost savings =	\$851 per year

Cost for LED fixtures (self-installed):	\$11,855
<u>Cost for wireless controls:</u>	<u>\$8,277</u>
Total costs:	\$20,132

Simple payback: \$20,132 ÷ \$851 per year = 23.7 years*

* Since SMUD provided a research grant to cover all of the material and equipment costs, and AmerisourceBergen installed all of the lighting fixtures and controls using in-house labor, the simple financial payback for AmerisourceBergen was significantly shorter than shown above.

Observations

The State of California has some of the toughest building energy standards in the country. 2008 Title 24 standards allow for a maximum of 0.9 Watts / ft² for office lighting. Analysis of the monitoring indicates the LED lighting and controls at AmerisourceBergen operated at only 0.34 Watts / ft.² This is a truly remarkable achievement considering the system provided 50-60 fc of illumination on the desktops for employees who chose to run the system at the maximum available setting! Key factors regarding the savings are presented below.

1. As mentioned previously, each employee was given the ability to control the light fixture above their work station via a hand-held remote control. It is very interesting that *although nobody asked these employees to save energy, several of them routinely dimmed or turned off their light fixtures during business hours* (see Figure 9, next page). It is important to note, however, that this office space is used as a customer contact center, where employees spend almost all of their time using their computers while talking to customers on the phone. It is unclear if this tendency to use the dimming feature would apply to people working in a more generalized office environment. More research may be needed to help answer this question.
2. The motion sensors reduced the operating time – primarily during the early hours of the morning. Employees who work in the distribution center tend to arrive before the office employees and use the break room to obtain coffee and snacks. Since the break room is adjacent to the office, the original office lights used to be turned on (and left on) by these employees. The new LED downlights installed in this area appear to provide sufficient light so the office lights are no longer needed during these periods.

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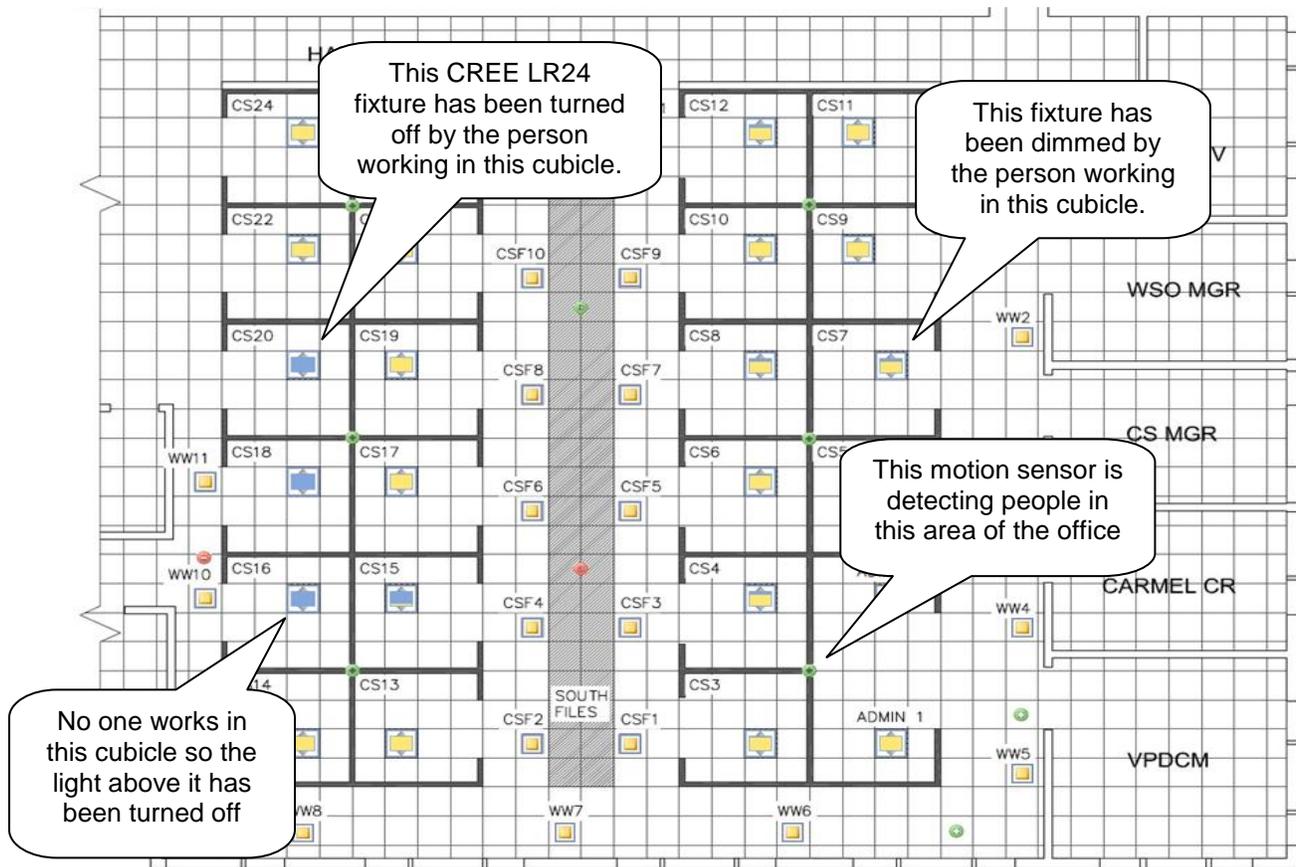


Figure 9: Although no one asked the employees to save energy, several of them routinely dimmed or turned off their light fixtures during business hours.

3. The lighting controls are also reducing peak demand. To allow for maximum flexibility, the project team chose to install LED fixtures that produce more light than required, and then limited the output to 80% of maximum via the Adura software. This approach provides several potential benefits including:
 - Like all other light sources, the output of the LED fixtures will diminish over time. Over sizing the fixtures and using dimming controls allows the system to be tuned during installation to meet the actual lighting requirements for each individual work station. Traditionally, standard industry practice has been to oversize fluorescent lighting systems to meet the illumination requirements after the lamps have depreciated (i.e. designing for maintained foot candles). While this approach is prudent, it results in wasted energy unless some form of dimming control is used.
 - Enables the Facility Manager to adjust the output to meet the needs for each employee. For example, if an employee requires more light, the maximum limit for their individual light fixture could be increased quickly and easily via a computer. This eliminates the need to replace lamps and ballasts or purchase supplemental task lights.

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Lessons Learned

One of the benefits of conducting field tests is the opportunity to learn about what is required to install and use emerging technologies. Although this project produced excellent results, there were several lessons waiting for us to learn along the way. Here are some helpful tips for those considering taking the plunge:

- LED lighting fixtures and wireless controls represent some of the latest innovations in office lighting. However, some LED fixtures, including the CREE LR24, have very small electrical junction boxes. Since the Adura LC1RD controller was originally designed to fit inside fluorescent fixtures, there was not enough room to fit it inside CREE's junction boxes. Consequently, new junction boxes had to be fabricated. This caused some considerable delays and increased the overall cost of the project. Make sure the electrical junction box of the lighting fixture has room to accommodate the controls you intend to use.
- Employees like the ability to turn fixtures completely off - not just dim them. Fortunately, we were able to make this change very easily via Adura's software.
- The new system provides excellent illumination on task surfaces yet the office appears darker (Figure 10). This is partly due to the directional nature of LEDs. To address this issue, the team installed Bruck LED wall wash fixtures to illuminate the perimeter walls.
- If you are installing Adura (or any other wireless lighting control system) in an occupied space, allow plenty of time to work through the concerns of the customer's Information Technology (IT) department. In this age of cyber attacks, IT Departments may be very reluctant to allow outside access to corporate computer networks. This may limit the functionality of the system and require additional hardware. SMUD encountered this challenge at **all** of our potential test sites. Ultimately, the project team addressed this issue by installing a separate wireless gateway and setting up a dedicated wireless phone account.
- The CREE LR24 fixture is designed for installation in a two foot by two foot suspended ceiling. Since the ceiling at AmerisourceBergen was configured as a two foot by four foot grid, a significant amount of effort was required to install the new LED fixtures. Since the inception of this project, several manufacturers have introduced products designed to fit into two foot by four foot grids.



Figure 10: Although the new lighting system provided excellent illumination on desk top surfaces, it created somewhat of a “cave” effect in some areas of the office

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Customer Feedback

“Since 2005 AmerisourceBergen’s Sacramento Distribution Center has benefitted from a strong working partnership with the Sacramento Municipal Utility District. In that six year period ABC had the privilege of working with a deep bench of highly professional SMUD subject matter experts in how to reduce energy consumption through lighting and capital equipment upgrades. We had access to SMUD professionals with a broad scope of knowledge on light fixtures, light design and layout for commercial office space, light installation, electricity consumption monitoring, data gathering and data synthesis. This report is the culmination of the most recent endeavor between ABC Sacramento and SMUD to beta test the efficacy of LED lighting attached to wireless controls in the Customer Service cubicles of the Sacramento office.

“By all measures the LED retrofit in the Customer Service office area is a resounding success. Associates love the individual control of their work space lighting and are actively engaged in saving energy by turning off and dimming the lights in their work space. The fixture selection placement and design gives the space a modern look worthy of a shot in Architectural Digest. SMUD also introduced us to the folks at Acura technologies, who have a revolutionary wireless control system that makes remote control of individual lights possible. We would like to thank Zach Gentry, Josh Mooney from the Acura Management team for delivering on their promise. Special kudos are in order for Sarah Diegnan, Mercy Ringelmann and Dennis Thompson, members of the Acura staff, for their ongoing support.

“Thank you to John DePietro the Sacramento Vice President Distribution Center Manager. He became an expert on LED technology by sheer determination and exhaustive research. Without him this project would not have been possible. He was committed to the use of LEDs early in the project and remained steadfast in his decision. His knowledge made the dialogue with SMUD on project details easy during concept and design work. Special recognition goes out to Robert Sorenson who did research on the Acura systems wireless controls and the potential effect on our wireless infrastructure. And finally a debt of gratitude to Steve Drake, David Broyles, Miguel Fuentes, Adwin Narayan, Kevin Narayan for removing the old lights and installing the new ones.



Figure 11: The lighting system and controls were installed by AmerisourceBergen employees.

“Just like the Rocky franchise there is going to be a sequel. We are going to expand the project to the remaining office areas on the first floor. We have also just completed replacing hundreds of T8 fluorescent fixtures in the warehouse with LED fixtures and controls. The installation phase has been completed and SMUD is monitoring consumption to gather data. Preliminary results show that this project will yield excellent energy and cost savings. SMUD expects to have a report completed later this year.”

Bill Presnell
MHE & APS Systems Manager
AmerisourceBergen Sacramento Division

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Final Thoughts

LED lighting fixtures and advanced lighting control systems continue to improve and may offer the following advantages:

- **Significant energy savings:** Analysis of the monitoring data indicates the LED lighting and controls at AmerisourceBergen operated at only 0.34 Watts / ft² – 62% better than the 2008 Title 24 maximum for office lighting. This is a truly remarkable achievement considering the system provided 50-60 fc of illumination on the desktops for employees who chose to run the system at the maximum available setting.
- **Reduced maintenance costs:** high quality LED luminaires are available with predicted life spans of over 50,000 hours. This is the equivalent of two standard T8 fluorescent lamp replacements. Since the calculated life for LED fixtures is when the fixture loses 30% of its initial light output, the fixture could be oversized and then dimmed via controls. This may significantly extend the useful life of the fixture well beyond 50,000 hours.
- **Improved employee satisfaction:** Although a formal written survey was not part of this project, AmerisourceBergen reports that most of their employees are very happy with the new system, especially with having the ability to control the lights above their individual workspace.

On the downside, this technology is clearly not yet cost effective for most commercial customers. Significant cost reductions and utility incentives will be needed to encourage widespread adoption, since commercial customers tend to shy away from projects with simple financial paybacks of longer than two years.

The cost of the controls, including labor and materials to modify the electrical junction boxes controls, accounted for approximately 41% of the project cost. LED fixture manufacturers should ensure that their electrical junction boxes are large enough to accommodate advanced lighting controls. Finally, the new LED fixtures that fit into two foot by four foot suspended ceiling grids may help speed up market adoption.

SMUD intends to continue researching combinations of LED lighting fixtures and advanced lighting controls. In the meantime, SMUD offers customized energy efficiency incentives for LED fixtures that have been approved by Energy Star or the Design Lights Consortium (DLC). For a list of approved products, please call SMUD Commercial Services at 1-877-622-7683, visit www.smud.org, or check out the DLC website: <http://designlights.org/solidstate.about.php>.

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