

Airco Mechanical Advanced Lighting Controls Project

ET12SMUD1028

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Sacramento Municipal Utility District



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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, daylighting and a variety of other technologies.

For more program information, please visit:

<https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm>

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1 EXECUTIVE SUMMARY

The newest lighting control technologies offer unprecedented flexibility for customers to customize the lighting to suit their business style and needs. Over the past three years, SMUD customers completed research projects that resulted in energy savings of 50% to 90%. However, even though the results were impressive, high implementation costs and long financial return periods were identified as roadblocks to widespread acceptance.

To circumvent these roadblocks and encourage adoption of these technologies, SMUD developed the Advanced Lighting Controls (ALC) Program using funding from the U.S. Department of Energy (DOE) Smart Grid Investment Grant. The ALC Program offered incentives to help SMUD's commercial customers install advanced lighting systems. Potential benefits of installing advanced lighting systems include:

- Energy savings of 50-90%.
- Flexibility in scheduling lighting operation.
- Improved lighting quality and increased employee satisfaction.
- Ability to track energy costs and savings in real-time.
- Ability to control lighting on-site or remotely from Internet-based interfaces, such as smart phones or wireless computers.
- Automated demand response capability.

Lighting Systems and Controls

Airco Mechanical installed T8 fluorescent lighting systems equipped with advanced controls in the workshop of their facility in Sacramento, California. The project included:

- Removing thirty nine (39) 192-Watt 6-lamp T8 fluorescent fixtures and one hundred eighty (182) 465-Watt metal halide fixtures.
- Installing ninety six (96) 184-Watt 6-lamp T8 fluorescent fixtures. The new lighting fixtures included dimmable ballasts, motion sensors and daylight harvesting capabilities.

Results

SMUD hired Nexant to evaluate this project and determine the energy savings. The energy consumption of the lighting circuits was monitored before and after the retrofit, and energy savings were calculated. The summary of results is as follows:

- Total estimated annual energy savings: 194,783 kWh per year (77%)
- Savings from fixture replacement: 186,046 kWh per year
- Savings from controls: 8,737 kWh per year
- Overall peak electrical demand reduction: 75.5 kW
- Estimated energy cost savings: \$21,005 per year

Airco's objective for installing the new lighting system was to reduce energy and maintenance costs, improve control capabilities and improve lighting quality. Illumination measurements taken at different locations show that the lighting levels were lower after the project was completed. However, the illumination levels met Airco's requirements and were more uniform throughout the workshop than before.

Financial Summary

Project Cost: \$111,971

Estimated utility bill reduction: \$21,005

Simple payback: 5.3 yrs.

SMUD incentive: \$70,097

Net project cost: \$41,874

Simple payback with incentive: 2.0 yrs.

Conclusion

The results of this project were favorable with significant energy savings and a simple payback period of 2.0 years. The majority of savings (186,046 kWh per year) resulted from the installation of the T8 fluorescent fixtures. Surprisingly, the energy savings from the controls were very minimal (3.4% overall). Further investigation revealed two main causes:

1. The new lighting system provided adequate and uniform illumination levels. However since there were no overlit areas, there was no opportunity to use task tuning.
2. Some of the new fixtures were mounted at 23 feet above a dark concrete floor. Unfortunately, the daylight harvesting and motion sensors did not operate reliably. The installation contractor attempted to compensate by installing steel plates below the fixtures (Figure 1-1). Although this somewhat improved the situation, Airco opted to only use the daylight harvesting in a few selected areas, so the overall savings from the controls were minimal.



Figure 1-1: Steel plates installed below the sensor

Obviously some improvements are needed in order for this system to work more reliably in applications with high ceilings and dark floors. Fortunately, the lessons learned from projects like this one provide manufacturers with information to help them improve their products.

Although advanced lighting systems and controls show great promise, there are relatively expensive to install. Since most commercial customers continue to base many of their decisions on financial benefits, significant incentives from utilities will be needed to keep these technologies moving forward in the short-term future.

Acknowledgements

While many people contributed to the success of this project, we particularly appreciate the cooperation and help from the following individuals:

- Jeff Tuttle and Paul Chapling (Airco)
- Vance Ang (Acuity Brands)
- Safdar Chaudhry and Amandeep Singh (Nexant)
- Dave Bisbee (SMUD)

2 INTRODUCTION

This section provides more information about the controls, project details and the overall objectives of this study.

2.1 Technology Description

Airco chose to install nLIGHT wireless networking technology and T8 fluorescent fixtures. This new lighting system offers the following capabilities:

- **Task Tuning:** Allows end users to adjust the lighting levels according to their needs and to avoid having over-lit areas. Task Tuning typically saves 10-30%.
- **Daylight Harvesting:** Makes use of the available ambient daylight and adjusts the electric lighting to maintain illumination at a desired level; this may save an additional 5-10% in areas with readily available daylight.
- **Occupancy Control:** Turns off lights via motion sensors when an area has been unoccupied for a certain amount of time; typically saves an additional 30-60% depending on the level of occupancy within the controlled zone.
- **Lumen Maintenance:** Adjusts the light levels according to the age of the fixture; this may save as much as 10% over the life of the equipment.
- **Scheduling:** Allows the users to set lighting schedules to suit their needs. The energy savings depend upon how aggressively the lights are turned off when not needed.
- **Auto-DR (Demand Response) Readiness:** Provides the capability to automatically dim or turn off lights in pre-selected areas during demand response events.

The lighting control system (nLIGHT) at Airco utilizes wireless network technology to communicate commands between endpoints; i.e., occupancy sensors, photocells, power/relay packs, switches, and the T8 ballasts. nLIGHT's GreenScreen software allows facility managers and users to manage the system and change settings via laptop computers, desktop computers, smart phones or other Internet enabled devices.

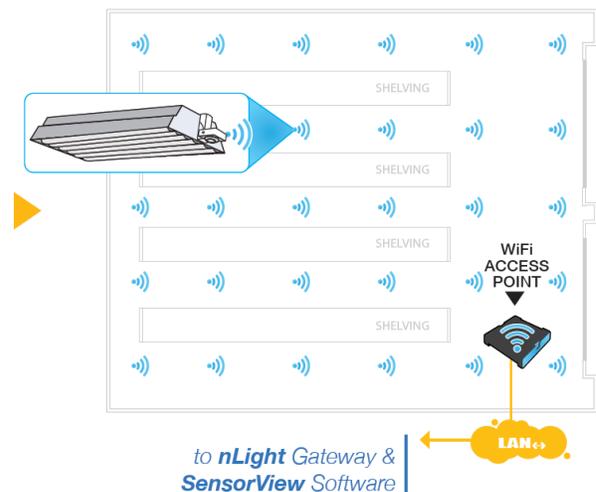


Figure 2-1: nLIGHT Wireless Lighting Controls

Source: http://nlightcontrols.com/wpcontent/uploads/nwifi_brochure.pdf

2.2 Project Description

Project Location and History

Airco Mechanical, Inc.
8210 Demetre Ave.
Sacramento, CA 95828

Airco Mechanical, Inc. has been in business since 1974 and is a leading design and build mechanical contractor. They specialize in designing, manufacturing, and installing heating, air conditioning, ventilation, plumbing, process related piping, and environmental control systems. Airco also provides mechanical systems for small, medium and major commercial, industrial and institutional projects throughout the region. Airco participated in SMUD's Advanced Lighting Controls program in 2012. The project involved replacing fluorescent fixtures and metal halide fixtures with T8 fluorescent fixtures in the workshop.

Original Lighting System

Nexant and SMUD met with Airco Mechanical staff at the project site to assess the existing lighting system and discuss the project. The discussion was followed by a walkthrough of the workshop area to examine the lighting systems and electrical panels for the proposed monitoring activities. Findings are presented below:

- The original lighting system consisted of:
 - One hundred eighty two (182) 465-Watt (400 Nominal Watts/Lamp) metal halide fixtures.
 - Thirty nine (39) 192-Watt 6-lamp T8 fluorescent fixtures.
- The lighting was too concentrated and bright in some areas, while poor in others. The illumination levels ranged between 9 and 48 foot-candles and were not uniform throughout the workshop.
- All of the lights were operating approximately 10 hours a day, five days a week. Since the metal halide lamps required a significant amount of time to turn back on and warm up after being turned off, the lights were left on continuously during business hours.

New Lighting System

The new lighting system included the following:

- Ninety six (96) 184-Watt 6-lamp T8 fluorescent fixtures controlled by motion and daylight harvesting sensors. The nLIGHT technology offers task tuning, motion sensor, daylight harvesting, scheduling, and auto-DR capabilities. However, most of the controls installed at the Airco facility are programmed for motion sensors only; the daylighting controls are programmed for a few selected areas (center drive through, sheet metal fabrication West corner, and piping South East corner). Figure 2-2 shows the new lighting system.



Figure 2-2: New T8 Fluorescent Lighting System

2.3 Study Objectives

The primary objective of this study was to determine energy and demand savings resulting from the installation of T8 fluorescent fixtures and advanced lighting control technologies at the Airco facility. A secondary objective was to validate various methodologies, energy saving algorithms, and calculations performed in the SMUD spreadsheet and by nLIGHT's GreenScreen software. To meet these objectives, the following research questions were addressed during this study:

- What were the energy, demand, and cost savings resulting from these lighting controls?
- What were the illumination levels under baseline and retrofit conditions?
- What was the project cost and simple payback?
- How was the energy savings calculated and reported for each system?
- How accurate were the various methodologies compared to end-use monitored data?

To answer these questions, a detailed research plan was prepared and shared with SMUD's program manager. During early discussions with the facility staff, preliminary information on the existing lighting fixtures at the Airco facility was obtained. Complete records of the fixture types, wattages, quantities, and control types of each lighting fixture for both baseline and post-retrofit conditions were prepared and maintained. A Measurement and Verification (M&V) plan was prepared and discussed with SMUD and Airco personnel. M&V activities included:

- Continuous monitoring (amperage) of the lighting fixtures (via data loggers) for several weeks before and after the installation. These data were combined with one-time power

measurements (voltage and power factor) to calculate the baseline energy consumption and energy savings. Monitoring details are given in Appendix A.

- Illumination measurements using a hand-held light meter, before and after the installations at the same locations to make comparisons of lighting levels. Details regarding the illumination measurements and the equipment used are presented in Appendix A.
- Obtaining post-installation trend data from the GreenScreen software to determine the energy savings from the different control strategies.
- Comparing the savings calculations from SMUD's spreadsheet and the GreenScreen software against the monitoring data.

3 RESULTS

This section includes monitoring results as well as comparisons of the energy savings based on monitoring data, SMUD’s spreadsheet calculations, and nLIGHT’s software data.

3.1 Energy Comparisons

As described earlier, this project included a pre-installation baseline period and a post-installation period with new T8 fluorescent fixtures and activated control strategies. A combination of continuous monitoring and one-time power measurements was used to calculate the baseline consumption and energy savings associated with each phase. Figure 3-1 shows average lighting load profiles for the pre-retrofit baseline, the new lighting baseline, and with all the control features activated. The pre-retrofit power curve (kW) is adjusted to account for the burned-out fixtures. As evident from this figure, the electricity savings is mainly due to fixture changes. There are additional, but relatively much less energy savings due to lighting controls.

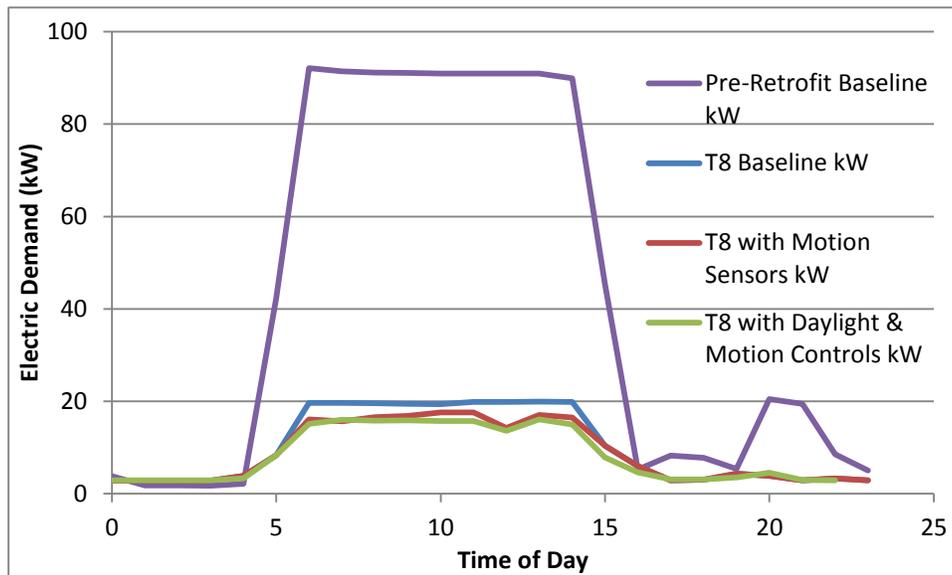


Figure 3-1: Lighting Load Profiles for Pre-Retrofit Baseline, New T8 Baseline, and T8 with Controls

3.1.1 Pre-Installation Baseline

The data loggers were installed on the lighting circuits for three weeks to monitor the baseline power consumption. The power drawn in kW was calculated using the continuous amperage data and one-time power measurement data (voltage and power factor), recorded for various circuits. Once the total electricity consumption for the monitored period was calculated, the annual baseline energy consumption was estimated using the annual lighting operating hours. Monitoring data showed the lighting fixtures were on continuously during business hours. Based upon Airco’s business calendar, the total annual operating hours were estimated to be 2,515. The total annual electricity consumption was estimated to be 253,591 kWh.

3.1.2 Post-Installation New T8 Fluorescent Lighting

The same types of data loggers were installed again on the lighting circuits to monitor the post-installation power consumption of T8 lights for a week. These measurements provided a new baseline for the T8 fluorescent fixtures.

As evident from the results presented in the Figure 3-2 below, the lighting load dropped from an average of 91.0 kW for the original lights to about 19.7 kW for the new T8 lights. Based on the monitored data, the new lighting baseline annual energy consumption is estimated to be about 67,545 kWh. The calculated annual electricity savings are 186,046 kWh for replacing the metal halide and fluorescent fixtures, with the T8 fixtures (with no control features activated), as shown in Figures 3-2 and 3-3.

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost (\$/year)
Baseline Consumption	253,591	91.0	\$27,347
New T8 Baseline Consumption	67,545	19.7	\$7,284
Fixture Replacement Savings	186,046	71.3	\$20,063

Figure 3-2: Energy Consumption and Savings Summary with T8 Fixtures

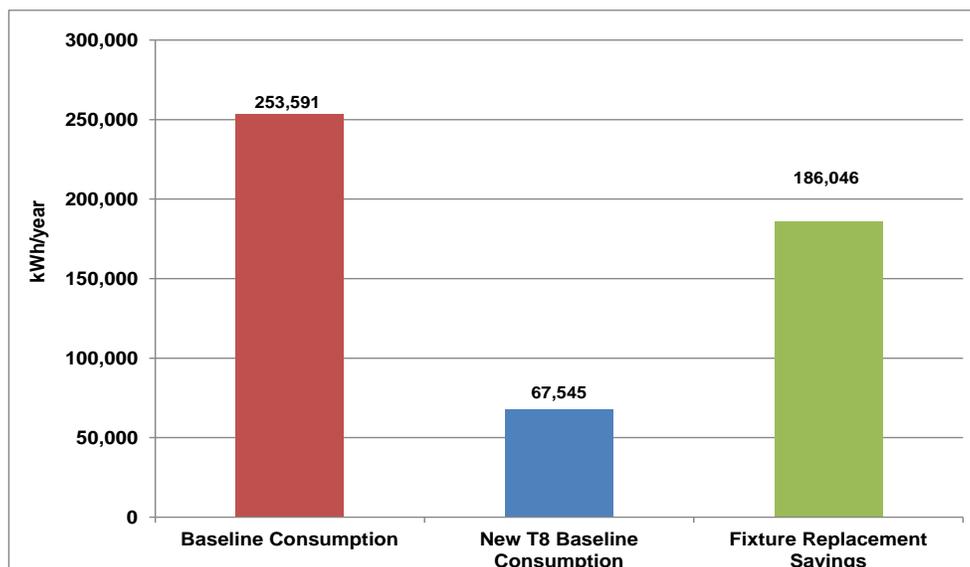


Figure 3-3: Monitored Energy Consumption and Savings with New T8 Fixtures

3.1.3 Post-Installation New T8 Lighting with Occupancy Control Features Activated

The monitoring for post-installation case was performed for a week with the occupancy control feature activated; Figure 3-4 shows energy consumption for the post-retrofit new lighting baseline and electricity savings with the occupancy control feature activated. Activating the occupancy control feature reduced the lighting system load from an average of 19.7 kW to an average of about 16.5 kW -- a 16% reduction.

The annual energy savings from activating the occupancy control features are 6,117 kWh/yr. (Figures 3-4 and 3-5).

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost (\$/year)
Baseline Consumption	253,591	91.0	\$27,347
New T8 Baseline Consumption	67,545	19.7	\$7,284
New T8 with Occupancy Controls Consumption	61,428	16.5	\$6,624
Occupancy Controls Savings	6,117	3.2	\$660

Figure 3-4: Energy Consumption and Savings Summary with Occupancy Controls

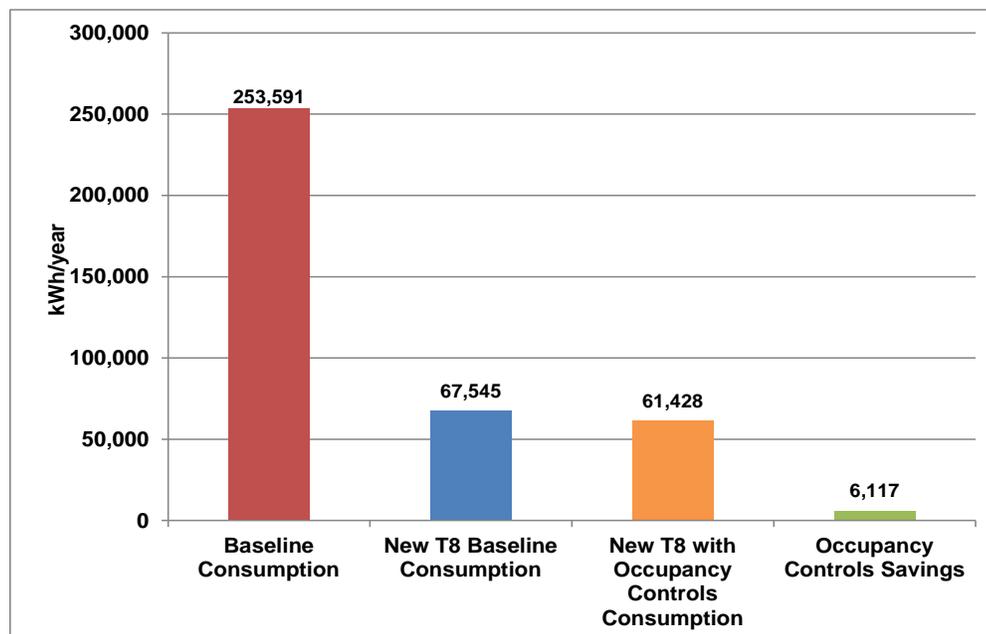


Figure 3-5: Monitored Energy Consumption and Savings with Activated Occupancy Controls

3.1.4 Post-Installation New T8 Lighting with Daylight Harvesting Control Feature Activated

The monitoring for post-retrofit case was continued for another two weeks with daylight harvesting control feature activated in addition to occupancy sensors. Activating the daylight harvesting control feature further reduced the lighting system load from an average of 16.5 kW to an average of about 15.5 kW -- a 6% reduction. As noted earlier, there were several problems with the daylight harvesting sensors used in this project.

Based on the monitored data and typical mean year (TMY) Global Horizontal Illuminance (GHI) data for Sacramento, the annual energy consumption with all the features activated is estimated to be about 58,808 kWh. The monitored kW reduction values due to daylight harvesting feature were compared with TMY GHI during the monitoring period and then extrapolated to whole year based on the TMY GHI data for Sacramento, California. The calculated annual electricity savings from activating daylight harvesting are 2,620 kWh, as shown in Figures 3-6 and 3-7.

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost (\$/year)
Baseline Consumption	253,591	91.0	\$27,347
New T8 Baseline Consumption	67,545	19.7	\$7,284
New T8 with Occupancy Controls Consumption	61,428	16.5	\$6,624
New T8 with all Controls Activated Consumption	58,808	15.5	\$6,342
Daylight Harvesting Savings	2,620	1.0	\$283

Figure 3-6: Energy Consumption and Savings Summary with Daylight Harvesting

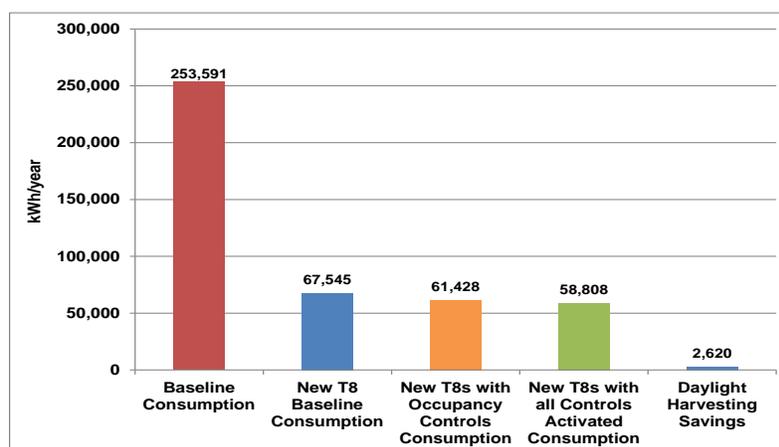


Figure 3-7: Monitored Energy Consumption and Savings with Daylight Harvesting Activated

The total calculated annual electricity savings from replacing fixtures and activating all of the control features are estimated to be 194,783 kWh, as shown in Figures 3-8 and 3-9.

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost (\$/year)
Baseline Consumption	253,591	91.0	\$27,347
New T8 Baseline Consumption	67,545	19.7	\$7,284
New T8s with Occupancy Controls Consumption	61,428	16.5	\$6,624
New T8s with all Controls Activated Consumption	58,808	15.5	\$6,342
Total Savings	194,783	75.5	\$21,005

Figure 3-8: Energy Consumption and Total Savings Summary with for the new lighting system and controls

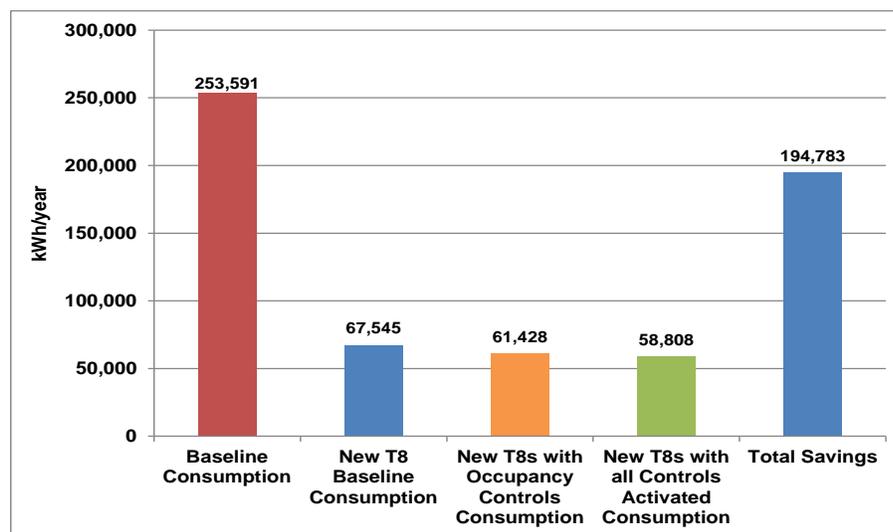


Figure 3-9: Monitored Energy Consumption and Total Savings for the new lighting system and controls

The total calculated annual energy savings are 194,783 kWh when all the control features were activated. These energy savings include 186,046 kWh savings associated with the fixture replacement, 6,117 kWh with the occupancy control feature, and 2,620 kWh with the daylight harvesting control feature. A summary of electricity savings resulting from new lighting systems and controls, along with the payback periods without and with SMUD incentives, is shown in Figure 3-10. Note that the project cost was \$111,971 and SMUD's financial incentives were \$70,097 for this project.

Period	Savings			Payback Period	
	kWh/year	%	Energy Cost	Simple	With Rebate
New T8	186,046	73%	\$20,063	5.3	2.0
T8 with Occupancy Controls	6,117	9%	\$660		
T8 with Daylight Controls	2,620	4%	\$283		
Total Savings	194,783	77%	\$21,005		

Figure 3-10: Summary of Electricity Savings Resulting from New Lighting Systems and Controls

3.1.5 Control Software Calculations

nLIGHT's GreenScreen software has the capability to track real-time status of every lighting fixture controlled by the system (on, off, dimmed and dimming level). The system can also detect whether areas are occupied or unoccupied via the motion sensors, and calculate the energy consumption of each lighting fixture. GreenScreen calculates energy consumption by using trend data, the history of power demand and disaggregate savings produced by different control strategies (i.e., task tuning, motion sensors, and daylight harvesting).

Although nLIGHT's system works well for tracking the performance of the new lighting system, information regarding the original lighting system must be manually entered into the software to calculate energy and costs savings. Obviously, if the information entered is incomplete or inaccurate, the savings calculations will not be reliable.

Based on the trend data provided by nLIGHT for the post-installation phase, the energy savings are presented in Figure 3-11 and 3-12. The data also showed that all the energy savings associated with the controls were due to motion sensors and none from daylight harvesting.

Savings		
Fixture Replacement (kWh/year)	Controls (kWh/year)	Total (kWh/year)
193,802	13,914	207,716

Figure 3-11: Disaggregated Energy Savings from nLIGHT's GreenScreen Software

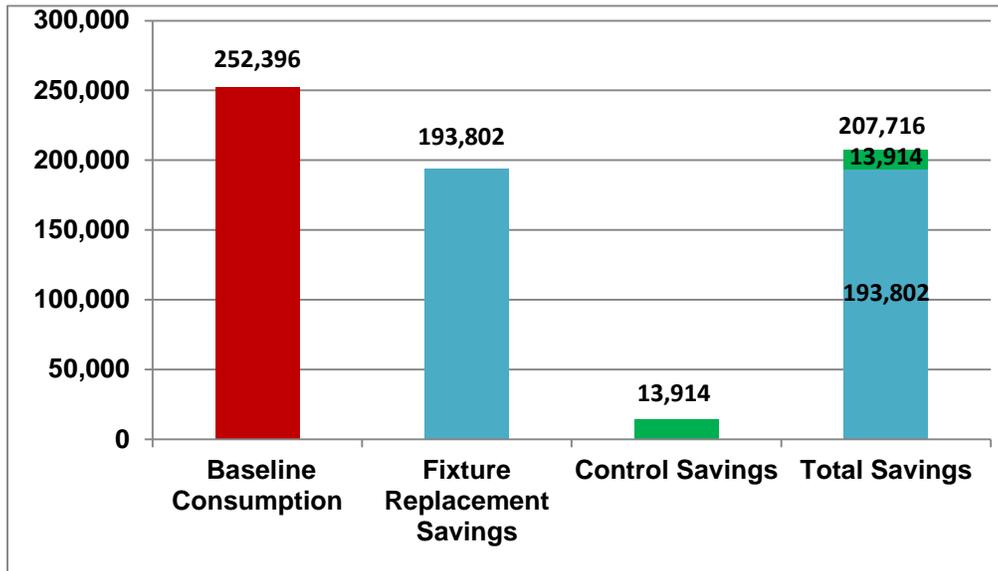


Figure 3-12: Disaggregated Energy Savings from nLIGHT's GreenScreen Software

3.1.6 Methodology Comparison Results

This section presents the energy savings estimated by different calculation methodologies; i.e. based on monitored data, spreadsheet calculations, and nLIGHT software. The detailed calculations are given in Appendix B of this report.

Figure 3-13 shows a comparison of results among the three calculation methodologies. The savings calculated by the monitored data is 17% lower than the calculated spreadsheet savings. This result was primarily due to the fact that the higher power reduction factors for controls used in the spreadsheet calculations (e.g. task tuning) compared to what the monitored data showed. The final project also included six additional new light fixtures that were not included in the spreadsheet calculations. The savings calculated by the GreenScreen software are 11% lower than the spreadsheet calculations.

The savings calculated by nLIGHT's software are comparable with the results obtained from the independently monitored data. This result is encouraging since SMUD and other utilities are considering using software capabilities for future energy efficiency incentive programs.

Period	Baseline Consumption and Energy Savings (kWh/year)		
	Monitored Data	Spreadsheet	nLIGHT Data
Baseline Consumption	253,591	252,396	252,396
Post -Retrofit Savings	194,783	233,568	207,716

Figure 3-13: Energy Savings Comparisons for Different Methodologies

3.2 Illumination Results

The illumination levels were measured before and after the lighting upgrade. These readings were taken at the “floor level”, with an EXTECH model # 401027 light meter. The meter was calibrated on August 13, 2012. Measurement locations were noted to repeat the readings at the same locations before and after the lighting system upgrades. Individual illumination readings for the pre and post conditions are shown in Figure 5-5 (Appendix A).

Observations include:

- Original Lighting System (Pre-Retrofit): Average illumination level was 27.2 fc.
- New T8 Lighting System (Post-Retrofit): Average illumination level was 22.2 fc.
- Under baseline case, the lighting was too concentrated and bright in some areas, while poor in others (illumination levels ranged between 9 and 48 fc). In other words, the illumination levels were not uniform throughout the workshop.
- Overall, the lighting levels decreased in most areas under post-installation case, mainly due to reduction in number of fixtures (221 fixtures were replaced with 96 fixtures). However, the new lighting levels met the customer’s needs and were more uniform than before.

4 SUMMARY OF FINDINGS

A combination of continuous monitoring and instantaneous measurements was used to evaluate the energy and cost savings for Airco's advanced lighting controls project. In addition to these measurements, SMUD's spreadsheet calculations and nLIGHT's energy tracking capabilities were reviewed and compared to the monitoring data. Key findings are presented below.

4.1 Energy Monitoring and Illumination Measurement Results

The following observations are drawn from this study:

- The total estimated savings for this project is 194,783 kWh per year – a 77% reduction in lighting energy consumption!
 - Replacing the original lighting systems with 6-lamp T8 fluorescent fixtures saved an estimated 186,046 kWh per year and reduced peak electrical demand by 71.3 kW
 - Activating the advanced lighting control system features (daylight harvesting and motion sensors) saved an additional 8,737 kWh per year and reduced peak electrical demand by 4.2 kW. The savings produced by the controls for this project were surprisingly small.
- The average lighting levels decreased, mainly due to an aggressive reduction in the number of fixtures (221 fixtures were replaced with 96 fixtures). However, the illumination levels provided by the new lighting system were more uniform throughout the workshop.

4.2 nLIGHT's Software / SMUD Spreadsheet Calculations

- The calculated energy savings from SMUD's spreadsheet were 17% and 11% higher than the monitoring data and nLIGHT's software, respectively. This was primarily due to the higher savings assumptions used for controls (i.e. task tuning) and the installation of six new fixtures that were not included in the spreadsheet calculations.
- Savings calculated by nLIGHT's software are comparable with results obtained from monitored data. This is very good news since SMUD and other utilities are considering using the control software energy tracking capabilities for future energy efficiency incentive programs.

4.3 Financial Summary

- Project Cost: \$111,971
- SMUD Incentive: \$70,097
- Net project cost: \$41,874
- Estimated annual bill reduction: \$21,005
- Simple payback: 2.0 years

4.4 Conclusion

Although this project resulted in significant energy savings and positive feedback, the costs for lighting fixtures and controls were high. Since potential economic benefits continue to be a major decision factor for most commercial customers, retrofitting existing buildings with advanced lighting controls may be difficult to sell without significant rebates or financial incentives from electric utilities.

5 APPENDIX A: MONITORING

5.1 Monitoring Details

After visiting the project site, Nexant prepared and maintained complete records of the fixture types, wattages, quantities, and control types for both the baseline and post-retrofit conditions. This information was used to prepare and implement a Measurement and Verification plan, which included the following:

- After careful review of the lighting systems, circuit diagrams and panel schedules, all the fixtures were selected for monitoring. Since the number of lighting branch circuits was relatively small, all of them were monitored. This provided a confidence level of 90/10 according to the International Performance Measurement and Verification Protocol (IPMVP) and California Energy Efficiency Evaluation protocols, ensuring our methodology provided accurate results and a good understanding of the overall savings.
- Current Transducers (CTs) were installed on the selected circuits, and the equipment connected to each circuit was documented. The CTs were connected to Hobo model U12-006 4 channel data loggers (Figure 5-1) to record data for about three weeks before and four weeks after the lighting upgrade. The data was downloaded from the loggers and analyzed to calculate the baseline energy consumption and savings.
- During the baseline monitoring period, approximately fifty percent of the metal halide fixtures were burned out. According to Airco's staff, these fixtures were intentionally not replaced due to the planned lighting upgrades. Consequently, adjustments were made to the baseline data to reflect the site conditions.
- Post-installation trend data was obtained from the nLIGHT software and compared to the information gathered from the data loggers.
- One Time Power Measurements were made before and after installation. Measurements included total power (Watts), service voltage, single phase amps, single phase power, and power factor.
- Nexant performed illumination measurements using a hand-held light meter (EXTECH model # 401027). Measurements were taken before and after the lighting upgrade in the same locations to compare lighting levels.



Figure 5-1: Hobo Logger and Current Transducer (CT)

The monitoring objective was to collect enough data to establish the baseline energy consumption and energy savings, and then compare those savings with the software trend data. Monitoring included a three-week pre-installation period and four-week post installation period.

The dates for each monitoring period are presented in the Figure 5-2 and monitoring parameters and equipment are presented in Figure 5-3. Monitoring was completed for each of the following scenarios:

1. **Baseline:** Old lighting fixtures without dimming drivers and occupancy sensors.
2. **Post-installation:** New T8 lighting fixtures and nLIGHT control system activated with the following settings:
 - Occupancy sensors activated
 - Daylight harvesting feature activated (only for a few selected areas, center drive, sheet metal fabrication West corner, and piping South East corner)

ID	Task Name	Start Date	End Date
1	Logger Installation/Spot Measurements (pre-installation)	05/31/2012	05/31/2012
2	Continuous Monitoring (pre-installation)	05/31/2012	06/20/2012
3	Logger Removal	06/20/2012	06/20/2012
4	Logger Installation (post-installation)	01/15/2014	01/15/2014
5	Continuous Monitoring (post-installation)	01/15/2014	02/20/2014
8	Logger Removal//Spot Measurements	02/20/2014	02/20/2014

Figure 5-2: Dates for Pre and Post Installation Monitoring Periods

Point#	Equipment	Quantity	Logger Type	Measurements	Units
1	Lighting Circuits	1	Power Sight Meter	Amps, volts and power factor	A, V
2	Lighting Phases/Circuits	3 (Pre) & 12 (Post)	Hobo 4 ext. channel logger with CTs	Amps	A
3	Lights	1	Foot-Candle Meter	Foot-candles	Fc

Figure 5-3: Monitoring Parameters and Equipment

5.2 The Power Curve

A test was performed to develop a power curve by dimming lights from 100% to 10% in five steps (the lights were dimmed by 20% in each step except for the first 10%), and by measuring voltage, current, and power factor (for Circuits 2, 4, 14, 16, 18, 20, 22, and 24 only) with a Power Sight meter. As shown in Figure 5-4, the power consumption and light output reduction relationship is not linear. The top twenty percent of the power curve was noticeably flat.

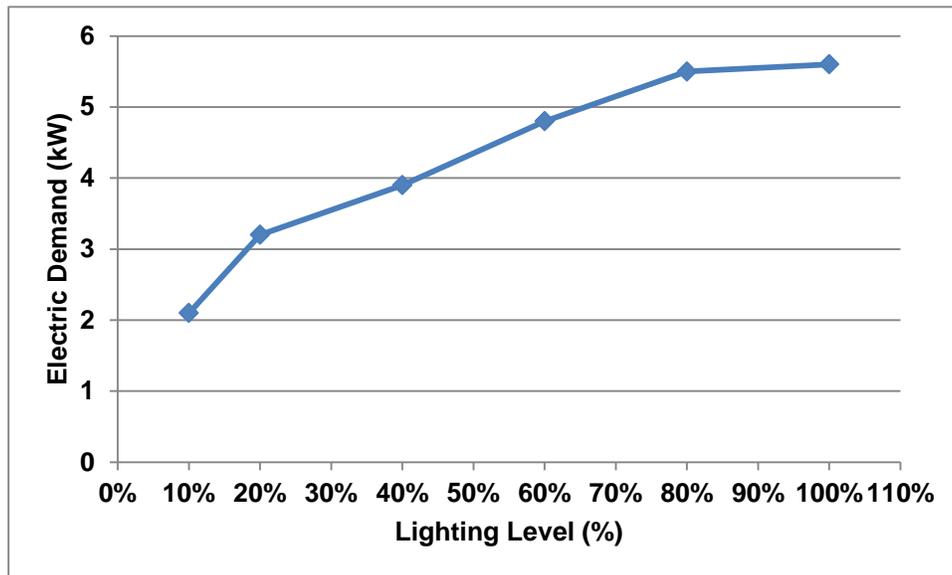


Figure 5-4: Electrical Demand at Various Dimming Levels

5.3 Illumination Readings

No.	Baseline Fixtures (Fc)	T8 Fixtures (Fc)
1	38	25
2	47.6	28.4
3	28	25.9
4	32	20.9
5	38	23
6	21	29.4
7	35	24
8	16	14.1
9	26	19.6
10	26	23.3
11	27	20.2
12	35	25
13	10	16.5
14	9	17.4
15	26	21.9
16	25	14.6
17	23	19.8
18	18	18.3
19	36	34.5
Average	27.2	22.2

Figure 5-5: Illumination Readings (Foot-Candles)

6 APPENDIX B: CALCULATIONS

6.1 Comparison of Different Energy Saving Methodologies with End-Use Monitored Data Results

SMUD's ALC Program provided energy efficiency incentives based upon calculated savings. The savings were calculated by using an Excel spreadsheet developed in-house by SMUD staff. Information regarding the fixture quantities, wattages, and operating hours were estimated based upon discussions between SMUD and Airco. The scope of this evaluation report included a comparison of the calculated spreadsheet savings, the end-use monitored data, and nLIGHT's software.

6.1.1 Spreadsheet Calculations

The following assumptions were used for calculating savings with the spreadsheet method:

Existing Lighting System

Wattage of Original Metal Halide Fixtures:	465 Watts
Fixture Quantity of Metal Halide Fixtures:	182
Wattage of Original 6-Lamp T8 Fixtures:	192 Watts
Fixture Quantity of 6-Lamp T8 Fixtures:	39

New Lighting

Wattage of New 6-Lamp T8 Fixtures:	184 Watts
Fixture Quantity of 6-Lamp T8 Fixtures:	90

6.1.1.1 Lighting System Savings

T8 Savings

Existing 132 MH Fixtures Operational Hours:	2,600 hours per year
Existing 50 MH Fixtures Operational Hours:	3,120 hours per year
Existing 31 T8 Fixtures Operational Hours:	2,600 hours per year
Existing 8 T8 Fixtures Operational Hours:	3,120 hours per year
Demand of Existing Lighting:	$(465 \times 182 + 192 \times 39) / 1,000$ = 92.12 kW
Demand of New Lighting:	$(184 \times 90) / 1,000 = 16.56$ kW

Demand Savings:	$92.12 - 16.56 = 75.56 \text{ kW}$
Pre-Retrofit Lighting Energy Consumption:	$465 \times (132 \times 2,600 + 50 \times 3,120)/1000 + 192 (31 \times 2,600 + 8 \times 3,120)/1000 = 252,396 \text{ kWh/year}$
Post-Retrofit Lighting Consumption:	$184 \times (73 \times 2,600 + 17 \times 3,120)/1000 = 44,683 \text{ kWh/year}$
Energy Savings:	$252,396 - 44,683 = 207,713 \text{ kWh/year}$
<i>Task Tuning Savings</i>	
Percent Power Drawn:	80%
Savings with Task Tuning:	$184 \times (1 - 0.80) \times (73 \times 2,600 + 17 \times 3,120)/1000 = 8,937 \text{ kWh/year}$
<i>Motion Sensors & Daylight Harvest Savings</i>	
Estimated Savings:	30% to 80%
Energy Savings:	$184 \times 0.80 \times ((0.80 \times 8 \times 2,600 + 0.60 \times 21 \times 2,600 + 0.60 \times 17 \times 3,120 + 0.30 \times 44 \times 2,600)/1000 = 17,008 \text{ kWh/year}$
Total Annual Energy Savings:	$207,713 + 8,937 + 17,008 = 233,658 \text{ kWh/year}$
<i>Financial Summary</i>	
Project Cost:	\$111,971
SMUD Incentive:	\$70,097
Energy Cost Savings:	\$25,198
Simple Payback:	1.66 years

6.1.2 Software Calculations

Pre-Retrofit Energy Consumption:	252,396 kWh/year
Weekly New T8 Baseline Consumption from Trend Data:	1,159.3 kWh/week
Lighting Operation Hours in a Week:	$10 \times 5 = 50 \text{ hours/week}$

Annual Operating Hours:	$10 \times 5 \times 365/7 - 10 \times 8$ $= 2,527.14 \text{ hours/year}$
Annual New T8 Baseline Consumption	$1,159.3 \times 2,527.14/50$ $= 58,594 \text{ kWh/year}$
Fixture Replacement Savings:	$252,396 - 58,594$ $= 193,802 \text{ kWh/year}$
Weekly Controls Savings from Trend Data:	275.3 kWh/year
Annual Control Savings:	$275.3 \times 2,527.14/50$ $= 13,914 \text{ kWh/year}$
Total Annual Energy Savings:	$193,802 + 13,914$ $= 207,716 \text{ kWh/year}$