Tri Tool Advanced Lighting Controls Project

ET12SMUD1027

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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

A recent wave of new lighting control technologies offers greater energy savings than ever before. Thanks to the use of advanced control strategies and dimmable LED lighting fixtures, several SMUD research projects have resulted in 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 financial incentives and technical expertise to help SMUD's commercial customers install advanced lighting systems. Potential benefits of installing advanced lighting systems include:

- Electricity 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

Tri Tool installed LED lighting systems equipped with advanced controls in the warehouse and office areas of their facility in Rancho Cordova, California. The project included:

- Replacing seventy eight (78) 455-Watt (400 Nominal Watts/Lamp) and six (6) 320-Watt (300 Nominal Watts/Lamp) metal halide fixtures in the warehouse with LED highbay fixtures. The LED fixtures include dimmable drivers and motion sensor controls.

- Replacing all fluorescent fixtures with dimmable LED fixtures in the office areas, bathrooms and hallways. Lighting control strategies included task tuning, occupancy sensors and daylight harvesting in the perimeter office areas.

Results

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

- Total estimated annual energy savings: 191,316 kWh per year (86%)
- Savings from LEDs: 137,110 kWh per year
- Savings from controls: 54,206 kWh per year
- Overall peak electrical demand reduction: 39 kW
- Estimated energy cost savings: $21,699 per year

Financial Summary

Project Cost: $189,774

Estimated utility bill reduction: $21,699

Simple payback: 8.7 yrs.

SMUD incentive: $125,126

Net project cost: $64,648

Simple payback with incentive: 3.0 yrs.

Tri Tool's objectives for installing the new lighting system were 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 better and more uniform after the project was completed.

Conclusion

The results of this project were favorable with significant energy savings and a simple payback period of 3.0 years. The majority of savings (137,110 kWh/year) resulted from the installation of LED fixtures. Additional, but relatively smaller savings (54,206 kWh/year) resulted from the installation of lighting controls. The controls offered Tri Tool employees a lot of flexibility and greatly increased their satisfaction with the new lighting system – especially in the office areas.

Although this project resulted in significant energy savings and positive feedback, the costs for LED fixtures and controls were high. Since potential economic benefits continue to be a major decision factor for most commercial customers, retrofitting existing offices with advanced lighting controls may be a tough sell without significant rebates or financial incentives from electric utilities. On the other hand, warehouse and industrial areas show great promise and should be combined with adjacent office areas whenever possible.

Acknowledgements

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

- Joel Walton (Tri Tool Inc.)
- Walter Pazik (Controlled Lighting Corporation)
- Tony Garcia (Controlled Lighting Corporation)
- Safdar Chaudhry (Nexant)
- Amandeep Singh (Nexant)
- Dave Bisbee, Leah Pertl and Connie Samla (SMUD)

2 INTRODUCTION

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

2.1 Technology Description

Tri Tool chose to install Daintree's wireless networking technology and LED 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 lamps or LEDs; 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 at Tri Tool utilizes wireless technology to communicate commands between endpoints; i.e., sensors, switches, and the LED drivers connected to lights. Whereas traditional lighting control systems use controllers that are hard-wired to each device (often with copper wiring), wireless systems use controllers with antennas that communicate wirelessly between devices. Software allows facility managers or individual users to manage the system and change settings, which are then routed through a controller to the individual endpoints. Wireless systems are often organized using "mesh" architecture. Data passes through the wireless network from device to device using the most reliable communication links and most efficient path until the destination is reached.

Figure 2-1 shows ControlScope, an intelligent lighting controls solution by Daintree that uses wireless communications for networked building control. Daintree provides the wireless network communications and lighting controls software, while other partners provide compatible lighting control devices, such as switches, sensors, ballasts, and LED drivers (using ZigBee standard).

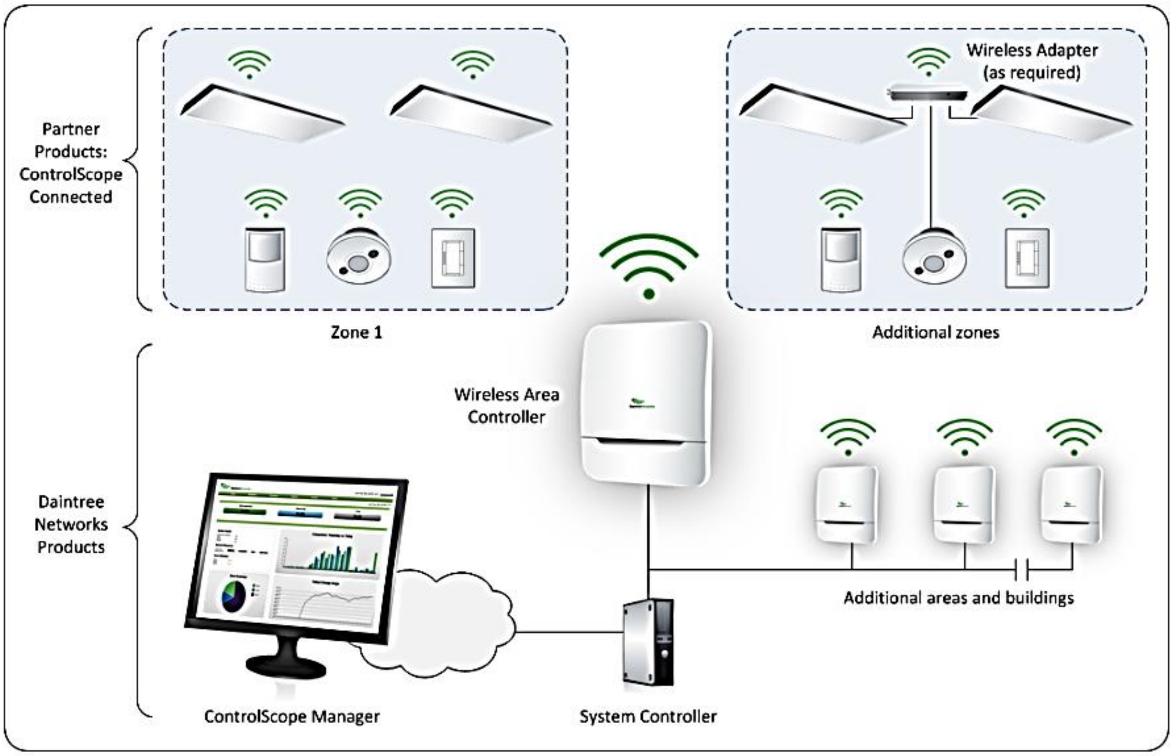

Figure 2-1: The Intelligent Lighting Controls Solution by Daintree

Source: www.daintree.net

2.2 Project Description

Project Location and History

Tri Tool Inc.
3041 Sunrise Blvd.
Rancho Cordova, CA 95742

Tri Tool Inc. has been the world's leading designer and manufacturer of precision portable machine tools for pipe beveling, tube squaring and severing equipment. It was founded in 1972 and moved to the Rancho Cordova facility in 2007. Tri Tool participated in SMUD's Advanced Lighting Controls program in 2012. The project involved replacing the fluorescent fixtures in the office areas and the metal halide fixtures in the warehouse area with new LED fixtures and advanced lighting controls.

Original Lighting System

During June 2012, Nexant and SMUD met with Tri Tool staff at the project site. The purpose of the visit was to assess the existing lighting system and discuss the scope of work, timeline, and data collection requirements of the evaluation project. The discussion was followed by a walkthrough of the warehouse and office areas to examine the lighting systems and electrical panels for the proposed monitoring activities. Findings were as follows:

- The original lighting system for the warehouse consisted of seventy eight (78) 455-Watt (400 Nominal Watts/Lamp) and six (6) 320-Watt (300 Nominal Watts/Lamp) metal halide fixtures.
- The illumination levels were not uniform throughout the warehouse; the lighting was too concentrated and bright in some areas, while poor in other areas. The situation was even worse in areas where large stacks of merchandise were stored.
- All of the warehouse lights were operating approximately 12 hours per day, 5 days per week. Since the metal halide lights 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.
- The original lighting system for the office areas consisted of:
  - Two hundred ninety seven (297) 3-lamp, 4-foot fixtures with 34-Watt, T12 fluorescent lamps
  - Eighteen (18) 2-lamp, 2-foot fixtures with 34-Watt, T12 U-tube fluorescent lamps
  - Four (4) 4-lamp, 4-foot fixtures with 34-Watt, T12 fluorescent lamps
  - Two (2) 2-lamp 4-foot fixtures with 30-Watt, T12 fluorescent lamps
- All of the office area lights were operating approximately 11 hours per day, 5 days per week.

New Lighting System

The new lighting system included the following:

- Forty (40) 164-Watt and ten (10) 246-Watt LED fixtures for the warehouse. The warehouse LED fixtures are controlled by motion sensors.
- The office area includes fully dimmable LED fixtures controlled by motion sensors and daylighting sensors. The daylighting controls are only used in the perimeter offices. The new fixtures include:
  - Forty six (46) 17-Watt, LED fixtures
  - Nineteen (19) 34-Watt, LED fixtures
  - One hundred seventy eight (178) 35-Watt, LED fixtures
  - Fifty three (53) 37-Watt, LED fixtures

The LED fixtures are controlled by motion sensors and turn off the lighting during unoccupied periods via remotely controlled Daintree networking technology. The technology offers task tuning, motion sensor, daylight harvesting, scheduling, and auto-DR capabilities. Most of the controls installed at the Tri Tool facility are programmed for motion sensors and task tuning only; the daylighting controls are programmed for the perimeter offices only. Figures 2-2 and 2-3 show the new lighting in the warehouse and an office, respectively.

Figure 2-2: New Office Lighting

Figures 2-3: New Warehouse Lighting

2.3 Study Objectives

The primary objective of this study was to determine energy and electrical demand savings resulting from the installation of LEDs and advanced lighting control technologies at Tri Tool. A secondary objective was to validate and compare various methodologies, energy saving algorithms, and calculations performed in the SMUD spreadsheet and by Daintree's ControlScope 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 Tri Tool's facility staff, preliminary information on the existing lighting fixtures 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 Tri Tool personnel. M&V activities included:

- Continuous monitoring (amperage) of the warehouse and office fixtures (via data loggers) for several weeks before and after the installation. This data was 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 ControlScope software to determine the energy savings from the different control strategies.
- Comparing the savings calculations from SMUD's spreadsheet and the ControlScope 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 Daintree'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 LED 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. Figures 3-1 and 3-2 show average lighting load profiles for the pre-retrofit baseline, the new LED lighting baseline, and the new LED lighting system with all control features activated. As evident from these figures, the energy savings in the warehouse are considerably higher than the offices.

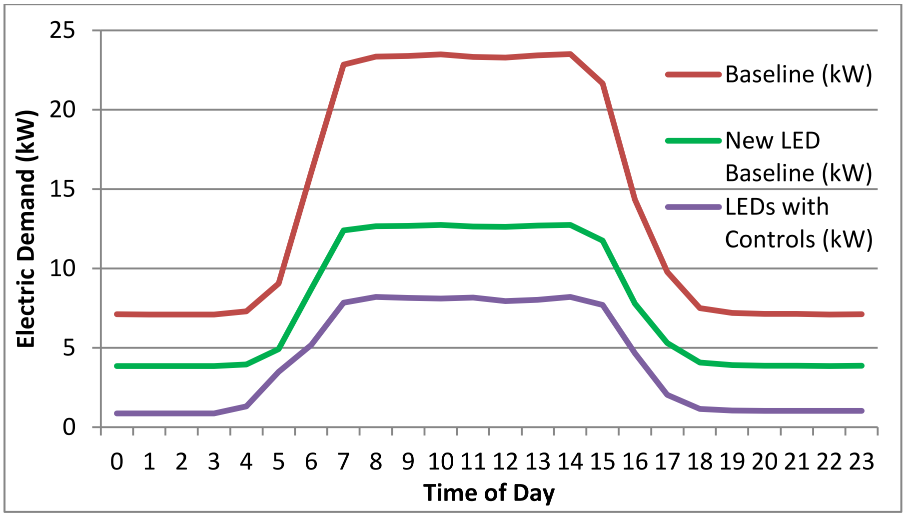

Figure 3-1: Lighting Load Profiles for Baseline, New LEDs, and LEDs with Controls (Office Areas)

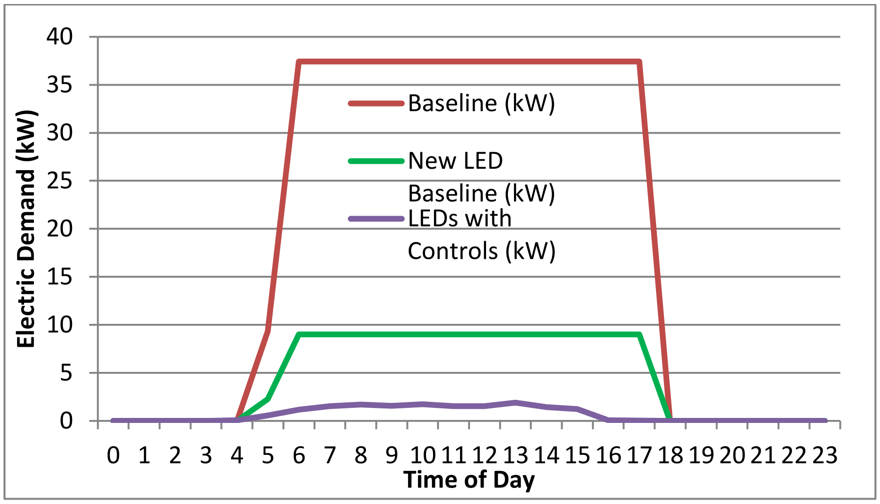

Figure 3-2: Lighting Load Profiles for Baseline, New LEDs, and LEDs with Controls (Warehouse)

3.1.1 Pre-Installation Baseline

The data loggers were installed on the lighting circuits for two 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 Tri Tool's business calendar, the baseline operating hours were estimated to be 3,096 hours per year for the warehouse and 2,812 hours per year for the office areas. The total annual electricity consumption for both areas was estimated to be 223,382 kWh.

3.1.2 Post-Installation New LED Lighting

The same types of data loggers were installed again on the lighting circuits to monitor the power consumption of the LED lights. A one-time power measurement test was also performed with lighting at 100%, while the control features were not activated. These measurements provided a new baseline for the LED fixtures.

As evident from the results presented in Figure 3-3, the lighting load dropped from an average of 60.54 kW for the original lights to about 21.57 kW for the new LED lights. Based on the monitored data, the baseline annual energy consumption for the new lighting is estimated to be 86,272 kWh. The calculated annual electricity savings for replacing the warehouse and office area fixtures with LED lighting (with no control features activated) are 137,110 kWh per year, as shown in Figures 3-3 and 3-4.

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost ($/year)
Baseline Consumption	223,382	60.5	$25,336
New LED Baseline Consumption	86,272	21.5	$9,785
Fixture Replacement Savings	137,110	39.0	$15,551

Figure 3-3: Energy Consumption and Savings Summary for LED Fixtures

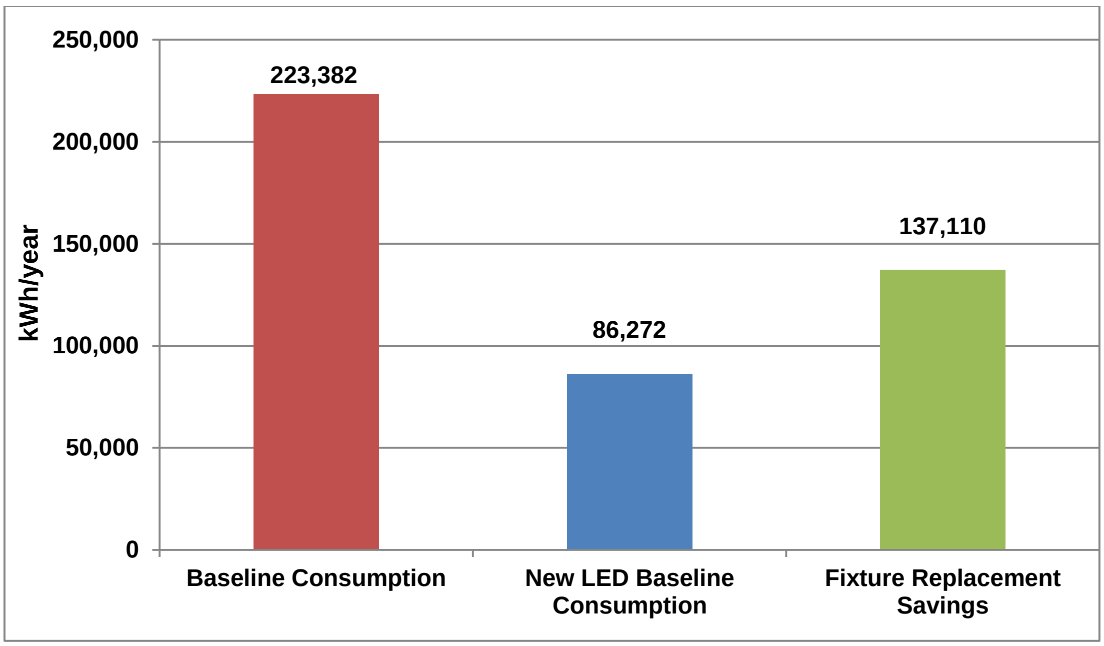

Figure 3-4: Monitored Energy Consumption and Savings for New LED Fixtures

3.1.3 Post-Installation New LED Lighting with All Control Features Activated

The monitoring for post-retrofit case was performed for a week with all control features activated (task tuning, motion sensors, and daylight harvesting). Figure 3-5 shows the energy consumption for the original lighting system, the new LED lighting system without controls, and the new LED system with all control features activated. Activating the controls reduced the LED lighting system load from an average of 21.5 kW to an average of about 9.6 kW -- a 55% reduction!

The calculated annual electricity savings from activating the control features are 54,206 kWh (Figures 3-5 and 3-6). The breakdown of savings associated with the lighting controls for the offices and warehouse are presented in Figures 3-7 and 3-8.

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost ($/year)
Baseline	223,382	60.54	$25,336
New LED Baseline	86,272	21.57	$9,785
New LEDs with Controls	32,066	9.61	$3,637
Controls Savings	54,206	11.95	$6,148

Figure 3-5: Energy Consumption and Savings Summary (All Areas)

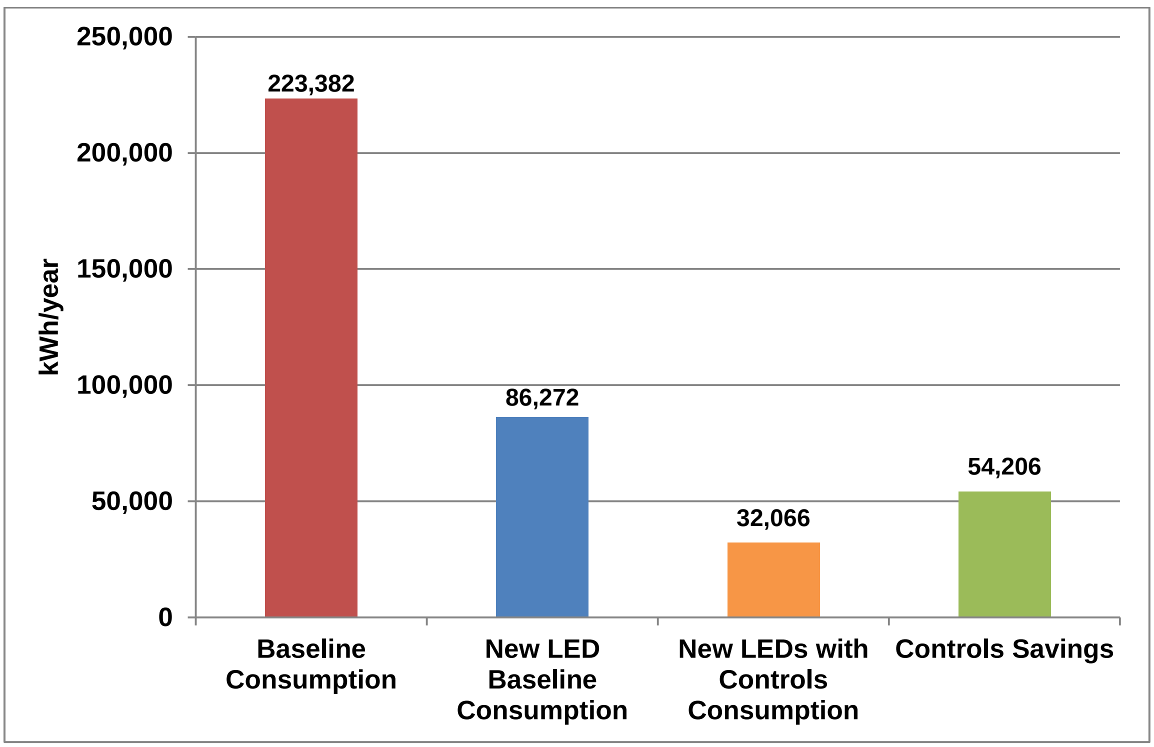

Figure 3-6: Monitored Energy Consumption and Savings (All Areas)

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost ($/year)
Baseline Consumption	107,570	37.41	$12,201
New LED Baseline Consumption	58,348	12.55	$6,618
New LEDs with Controls Consumption	27,992	8.03	$3,175
Controls Savings	30,356	4.51	$3,443

Figure 3-7: Energy Consumption and Savings Summary (Office Areas)

Period	Energy Consumption (kWh/year)	Max Demand (kW)	Energy Cost ($/year)
Baseline Consumption	115,812	37.41	$13,135
New LED Baseline Consumption	27,924	9.02	$3,167
New LEDs with Controls Consumption	4,074	1.58	$462
Controls Savings	23,850	7.44	$2,705

Figure 3-8: Energy Consumption and Savings Summary (Warehouse)

A summary of energy savings resulting from the new lighting systems and controls, along with the payback periods, without and with SMUD incentives, are shown below in Figure 3-9. The project cost was $189,774. SMUD's financial incentives were $125,126 for this project.

Period	Savings			Payback Period	
	kWh/year	%	Energy Cost	Simple	With Rebate
New LEDs	137,110	61%	$15,551	8.7	3.0
LEDs with Controls	54,206	63%	$6,148		
Total Savings	191,316	86%	$21,699		

Figure 3-9: Energy and Cost Savings Summary (All Areas)

3.1.4 Control Software Calculations

Daintree's ControlScope 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. ControlScope 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 Daintree'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 the energy and cost savings. Obviously if the information entered is incomplete or inaccurate, the savings calculations will not be reliable.

Since Daintree provided trend data only for the office area fixtures, the calculated energy savings presented in Figures 3-10 and 3-11 do not include the warehouse areas.

Area	Savings		
	LED Retrofit (kWh/year)	Controls (kWh/year)	Total (kWh/year)
Office Area	76,158	12,009	88,167

Figure 3-10: Disaggregated Energy Savings from Daintree Software (Office Areas)

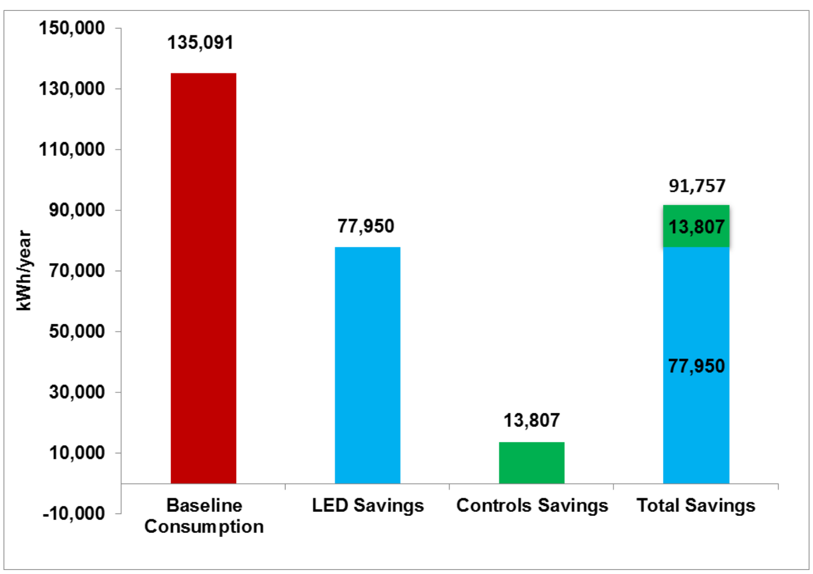

Figure 3-11: Disaggregated Energy Savings from Daintree's Software (Office Areas)

3.1.5 Methodology Comparison Results

This section presents the energy savings estimated by different calculation methodologies; i.e. based on monitored data, spreadsheet calculations, and ControlScope (Daintree) data. Detailed calculations are given in Appendix B of this report.

Figure 3-12 shows a comparison of office area results among the three calculation methodologies. The savings based upon the monitored data is about 17% lower than the calculated spreadsheet savings. This result was primarily due to the fact that longer operating hours were used in the spreadsheet calculations compared to what the monitored data showed. The savings calculated by the Daintree's software are 15% higher than the savings calculated from monitored data.

Figure 3-13 shows a comparison of warehouse results among the spreadsheet calculation and measured data calculation. Daintree's software comparisons were not included because the data was not available. The energy savings calculated by the monitored data is 66% less than the calculated spreadsheet savings. This result was primarily due to the fact that higher operating hours (8,760 hours) were used in the spreadsheet calculation. Based upon monitoring data, the actual operating hours were much less: 3,096 hours per year. Consequently, the baseline consumption and energy savings significantly lower than the spreadsheet calculations.

Period	Baseline Consumption and Energy Savings (kWh/year)		
	Monitored Data	Spreadsheet	Daintree Data
Baseline Consumption	107,570	111,898	135,091
Post-Retrofit Office Savings	79,578	92,945	91,757

Figure 3-12: Office Areas Energy Savings Comparisons for Different Methodologies

Period	Baseline Consumption and Energy Savings (kWh/year)		
	Monitored Data	Spreadsheet	Daintree Data
Baseline Consumption	115,812	334,807	N/A
Post -Retrofit Warehouse Savings	111,738	324,140	N/A

Figure 3-13: Warehouse Energy Savings Comparison for Different Methodologies

3.2 Illumination Results

The illumination levels were measured before and after the lighting upgrade. These readings were taken at the "desk level" for offices and at "floor level" for warehouse and hallways, 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 spots before and after the lighting system upgrades. Figures 5-5 and 5-6, included in Appendix A, present illumination readings under the pre and post conditions for the office areas and the warehouse. Observations include:

- Original Lighting System (Pre-Retrofit): Average illumination was 25.6 fc for the office areas and 11.8 fc for the warehouse.
- New LED Lighting System (Post-Retrofit): Average illumination was 24.8 fc for office areas and 19.1 fc for warehouse. These measurements were taken with the controls activated.
- Overall, the lighting levels increased for the warehouse and remained approximately the same for office areas. However, it is worth noting that in the office areas, the lighting levels increased in the office spaces, but were reduced in hallways (which were originally over lit). This scenario is highly desired from a good lighting design perspective.

4 Summary of Findings

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

4.1 Energy Monitoring and Illumination Measurement Results

- Replacing the original lighting systems with LED fixtures saved an estimated 137,110 kWh per year and reduced peak electrical demand by 39 kW. Activating the advanced lighting control system features (task tuning, daylight harvesting and motion sensors) saved an additional 54,206 kWh per year. The total estimated savings for this project is 191,316 kWh per year – an 85.6% reduction in lighting energy consumption!

- Average lighting levels in the warehouse increased because the new LED fixtures were re-aligned to fit the aisle ways. In office areas, the average lighting levels with the new LED lighting are about the same as pre-retrofit; however, the lighting levels are better in the office spaces, but reduced in hallways, which were originally over lit. This scenario is highly desired from a good lighting design point of view.

4.2 Daintree Software / SMUD Spreadsheet Calculations

- The calculated energy savings from SMUD's spreadsheet were 14% higher than the monitoring data for the office areas, and 66% higher for the warehouse. This was primarily due to higher power reduction factors and longer operating hours assumed in the spreadsheet calculations.

- The savings calculated by the Daintree's ControlScope software for the office areas are 13% higher than the savings calculated from the monitored data. Daintree data for the warehouse area was unavailable.

4.3 Financial Summary

- Project Cost: $189,774
- SMUD Incentive: $125,126
- Net project cost: $64,648
- Estimated annual bill reduction: $21,699
- Simple payback: 3.0 years

4.4 Conclusion

Although this project resulted in significant energy savings and positive feedback, the costs for LED fixtures and controls were high. Since potential economic benefits continue to be a major decision factor for most commercial customers, retrofitting existing offices with advanced lighting controls may be a tough sell without significant rebates or financial incentives from electric utilities. On the other hand, warehouse and industrial areas show great promise and should be combined with adjacent office areas whenever possible. For now, the most promising applications for advanced lighting controls may be manufacturing, data centers, warehouses, and new commercial office buildings.

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 carefully reviewing the lighting systems, circuit diagrams and panel schedules, Nexant decided to monitor all of the lighting branch circuits since there were relatively few of them. 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 the 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 at five-minute intervals for about two weeks before and a week 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 six percent (6%) of the fluorescent lamps and twelve (12) of the 455 Watt (400 Nominal Watts/Lamp) metal halide fixtures were burned out. According to Tri Tool's Facility Manager, these lamps were intentionally not replaced due to the planned lighting upgrades. Consequently, adjustments were made to the baseline data to reflect the site conditions.

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

- Post-installation trend data was obtained from the Daintree 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.

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 two-week baseline period and a week for post installation.

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 ballasts and occupancy sensors

2. **Post-installation:** New LED lighting fixtures and Daintree control system activated with the following settings:

   - Task tuning
   - Occupancy sensors activated
   - Daylight harvesting feature (only for perimeter offices) activated

ID	Task Name	Start Date	End Date
1	Logger Installation/Spot Measurements (pre-installation)	07/11/2012	07/11/2012
2	Continuous Monitoring (pre-installation)	07/11/2012	07/26/2012
3	Logger Removal	07/26/2012	07/26/2012
4	Logger Installation (post-installation)	10/09/2013	10/09/2013
5	Continuous Monitoring (post-installation – new lighting with activated controls)	10/09/2013	10/16/2013
8	Logger Removal//Spot Measurements	10/16/2013	10/16/2013

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

Point #	Equipment	Quantity	Logger Type	Measurem ents	Units
1	Lighting Circuits	1	Power Sight Meter	Amps, volts and power factor	A, V
2	Lighting Circuits	18 (Pre) & 18 (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 office area lights from 100% to 0% in four steps (the office area LED lights were dimmed by 25% in each step), and by measuring voltage, current, and power factor with a Power Sight meter. As shown in Figure 5-4, the relationship between power consumption and light output is not linear.

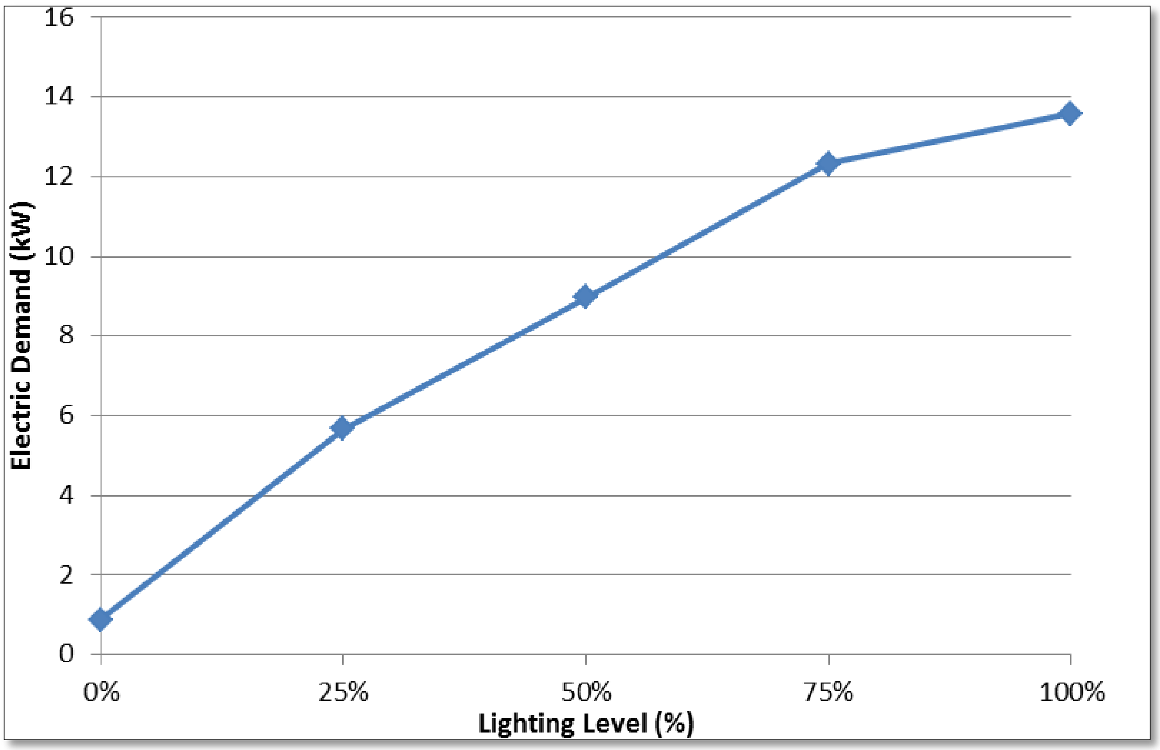

Figure 5-4: Electrical Demand at Various Dimming Levels

5.3 Illumination Readings

No.	Location	Baseline Fixtures (Fc)	LED Fixtures (Fc)
1	Hallway	22.1	18.5
2	Hallway	17.1	17.1
3	Hallway	23.8	16
4	Hallway	15.2	14.7
5	Lobby	28.2	23
6	Hallway	15.7	12.5
7	Hallway	29.3	19.6
8	Hallway	21.2	16.8
9	Hallway	25	18.7
10	Hallway	15.1	15.5
11	Lunch Room	20.8	30.54
12	Marketing Office	41.7	42.5
13	Production Office	40.6	45.8
14	International Sales Office	25.5	38.1
15	Engineering	21.9	26.1
16	Conference Room	46.6	41.7
Average	**Office Areas**	**25.6**	**24.8**

Figure 5-5: Illumination Readings for the Office Areas (Foot-Candles)

No.	Location	Baseline Fixtures (Fc)	LED Fixtures (Fc)
1	Warehouse	10.4	14.9
2	Warehouse	10.2	18.4
3	Warehouse	17.4	16.1
4	Warehouse	8.5	14.6
5	Warehouse	18.5	24.2
6	Warehouse	8.4	17.4
7	Warehouse	11.5	17.9
8	Warehouse	14.3	16.2
9	Warehouse	6.8	13.8
10	Warehouse	12.2	16.6
11	Warehouse	23.7	13
12	Warehouse	15.1	32.5
13	Warehouse	4.6	24.5
14	Warehouse	7.9	25.8
15	Warehouse	11.4	13.8
16	Warehouse	9	22.4
17	Warehouse	11.5	21.8
Average	**Warehouse**	**11.8**	**19.1**

Figure 5-6: Illumination Readings for the Warehouse (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 Tri Tool. The scope of this evaluation report included a comparison of the calculated spreadsheet savings, the end-use monitored data, and Daintree's software.

6.1.1 Spreadsheet Calculations

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

Existing Lighting System

Warehouse:

Wattage of Original Metal Halide Fixtures:	455 Watts
Fixture Quantity of Metal Halide Fixtures:	84 fixtures

Office Areas:

Wattage of Original 3-Lamp T12 Fixtures:	103 Watts
Fixture Quantity of 3-Lamp T12 Fixtures:	304 fixtures
Wattage of Original 2-Lamp T12 Fixtures:	70 Watts
Fixture Quantity of 2-Lamp T12 Fixtures:	11 fixtures
Wattage of Original 1-Lamp T12 Fixtures:	43 Watts
Fixture Quantity of 1-Lamp T12 Fixtures:	22 fixtures
Wattage of Original 1-Lamp CFL Fixtures:	26 Watts
Fixture Quantity of 1-Lamp CFL Fixtures:	3 fixtures

New Lighting

Warehouse:

Wattage of New LED Fixtures:	164 Watts
Quantity of 164W LED Fixtures:	40 fixtures
Wattage of New LED Fixtures:	246 Watts
Quantity of 246W LED Fixtures:	10 fixtures

Office Areas:

Wattage of New LED Fixtures:	17 Watts
Quantity of 17W LED Fixtures:	46 fixtures
Wattage of New LED Fixtures:	34 Watts
Quantity of 34W LED Fixtures:	19 fixtures
Wattage of New LED Fixtures:	35 Watts
Quantity of 35W LED Fixtures:	178 fixtures
Wattage of New LED Fixtures:	37 Watts
Quantity of 37W LED Fixtures:	53 fixtures

LED Lighting System Savings

Warehouse:

Existing MH Fixtures Operational Hours:	8,760 hours per year
Demand of Existing MH Lighting:	(455 x 84) / 1,000 = 38.22 kW
Demand of New Lighting:	(164 x 40 + 246 x 10) / 1,000 = 9.02 kW
Demand Savings:	38.22 – 9.02 = 28.6 kW
Energy Savings:	28.6 x 8,760 = 255,795 kWh/year

Office Areas:

Existing T12 Lamp Fixtures Operational Hours: 3,380 hours per year

Demand of Existing (Original) Lighting: $\frac{(103 \times 304) + (70 \times 11) + (43 \times 22) + (26 \times 3)}{1{,}000W / kW} = 33.106\ kW$

Demand of New Lighting: $\frac{(17 \times 46) + (34 \times 19) + (35 \times 178) + (37 \times 53)}{1{,}000W / kW} = 9.62\ kW$

Demand Savings:	33.106 – 9.62 = 23.49 kW
Energy Savings:	23.49 x 3,380 = 79,398 kWh/year
Total LED Energy Savings:	255,795 + 79,398 = 335,193 kWh/year

Task Tuning Savings

Percent Power Drawn (Office Area):	80%
Percent Power Drawn (Warehouse):	90%
Savings of Office LEDs with Task Tuning:	9.62 x (1 - 0.80) x 3,380 = 6,505 kWh/year
Savings of Warehouse LEDs with Task Tuning:	9.02 x (1 - 0.90) x 8,760 = 7,903 kWh/year

Motion Sensors & Daylight Harvesting Savings

<u>Office Area:</u>

Daylight Controlled Lights Demand (Open Office):	0.44 kW
Daylight Controlled Lights Demand (Private Office):	1.46 kW
Energy Savings:	(0.44(1 - 0.590) + 1.46 (1 - 0.616)) x 3,380 = 2,507 kWh per year
Occupancy Controlled Lights Demand (Open Office)	2.31 kW
Occupancy Controlled Lights Demand (Private Office)	3.52 kW
Energy Savings	(2.31(1 - 0.720) + 3.52 (1 – 0.792)) x 3,380 = 4,663 kWh per year

<u>Warehouse:</u>

Occupancy Controlled Lights Demand (Warehouse)	9.0 kW
Occupancy Sensor Savings	85%
Energy Savings	9.0 x 0.90 x 0.85 x 8,760 = 60,315 kWh per year
Total Controls Energy Savings:	6,505 + 7,903 + 2,507 + 4,663 + 60,315 = **81,893 kWh per year**
Total Annual Energy Savings:	**335,193 + 81,893 = 417,086 kWh**

Financial Summary

Project Cost:	$189,774
SMUD Incentive:	$125,126
Energy Cost Savings:	$47,036
Simple Payback:	1.37 years

6.1.2 Software Calculations

Office Areas Existing Lighting System

Wattage of Original 3-Lamp T12 Fixtures:	103 Watts
Fixture Quantity of 3-Lamp T12 Fixtures:	304 Fixtures
Wattage of Original 2-Lamp T12 Fixtures:	70 Watts
Fixture Quantity of 2-Lamp T12 Fixtures:	11 Fixtures
Wattage of Original 1-Lamp T12 Fixtures:	43 Watts
Fixture Quantity of 1-Lamp T12 Fixtures:	22 Fixtures
Wattage of Original 1-Lamp CFL Fixtures:	26 Watts
Fixture Quantity of 1-Lamp CFL Fixtures:	3 Fixtures

Office Areas Existing Lighting System Energy Consumption

Occupied Operational Hours: 2,780 hours per year

Demand of Existing (Original) Lighting - Occupied:

$$\frac{(103 \times 304) + (70 \times 11) + (43 \times 22) + (26 \times 3)}{1{,}000\text{W / kW}} = 33.1 \text{ kW}$$

Demand of Existing (Original) Lighting - Unoccupied: 7.2 kW

Unoccupied Period Operational Hours: 5,980 hours per year

Energy Consumption: 2,812 x 33.106 + 5,948 x 7.2 = 135,920 kWh/year

Office Areas New Lighting

<u>LED Lights without Activating Controls</u>

Occupied LED Baseline Demand from ControlScope:	12.81 kW
Occupied Period Operational Hours:	2,812 hours per year
Unoccupied LED Baseline Demand from ControlScope:	3.69 kW
Unoccupied Period Operational Hours:	5,948 hours per year
Energy Consumption:	(2,812 x 12.81) + (5,948 x 3.69) = 57,970 kWh/year
Energy Savings without Controls:	135,920– 57,970 = 77,950 kWh/yr.

LED Lights (with Activated Controls-Occupied LED with Controls Demand from ControlScope):	7.90 kW
Occupied Period Operational Hours:	2,812 hours per year
Unoccupied LED (with Controls Demand from ControlScope):	3.69 kW
Unoccupied Period Operational Hours:	5,948 hours per year
Energy Consumption:	2,812 x 7.90 + 5,948 x 3.69 = 44,163 kWh/year
Energy Savings with Controls:	57,970 – 44,163 = 13,807 kWh/yr.
Total Savings:	77,950 +13,807 = 91,757 kWh/yr.