Customer Advanced Technologies Program
Project Evaluation Report

SMUD
Powering forward. Together.

Advanced Lighting Controls at Blue Diamond Growers




Prepared for:

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

1 EXECUTIVE SUMMARY

Nexant currently provides technical services to the Sacramento Municipal Utility District (SMUD), under a three-year Emerging Technology Evaluation Program that started January 2011. This program focuses on 1) the practical application of new and emerging technologies to overcome existing market barriers and 2) on educating potential consumers in new technology use. This approach brings producers and consumers together to solve problems of market entry, enabling manufacturers to make improvements to their products, and enabling customers to make informed decisions about applying those products. As a result, the program reduces the risk of testing and improving new technologies by using credible test methodologies in both laboratory settings and in venues familiar to end users.

Under SMUD's Customer Advanced Technologies Program, Nexant is evaluating several projects involving energy efficient lighting fixtures (e.g. LED fixtures) and advanced lighting controls, which have been retrofitted in existing facilities through the Advanced Lighting Controls (ALC) program. SMUD's Advanced Lighting Controls program offered incentives of up to $100,000 to help owners of medium and large-sized buildings install advanced lighting control systems. This program is funded in part by SMUD's "Smart Grid Investment Grant", in association with the United States Department of Energy. The ALC program started in February 2012 and will end December 1, 2013. Benefits of installing advanced lighting controls 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, like smart phones or wireless computers
- Automated demand response capability

Nexant evaluated an LED lighting system with advanced controls at a Blue Diamond Growers refrigerated warehouse (Cold 3). The project involved replacing seventy-seven (77) 400-Watt High Pressure Sodium (HPS) fixtures with 160-Watt LED fixtures and installing 33 motion sensors on the newly installed fixtures. SMUD contracted Nexant, Inc., to monitor the energy consumption of the lighting circuits before and after the retrofit. The summary of results is as follows:

- The total estimated energy savings is 236,477 kWh per year (79%).
- Average savings per fixture is 3,071 kWh per year.

It is important to note that Blue Diamond's objective for installing the new LED fixtures and advanced lighting controls was not only to save energy and cost but also improve lighting quality and control capabilities. The replacement of lighting fixtures contributed 180,785 kWh per year in electricity savings and the controls added another 55,692 kWh per year. Moreover, overall peak electrical demand was reduced by 21 kW (60%).

Financial Summary

Project Cost: $94,763

Estimated Utility bill reduction: $21,755

Simple payback: 4.3 yrs.

SMUD rebate: $57,728

Net project cost: $37,035

Simple payback with rebate: 1.7 yrs.

Illumination readings taken at different locations show that the lighting levels increased at some locations under post-retrofit case, but decreased at others. This was mainly caused by variations in the pattern of stacking merchandise in the warehouse. For example: sometimes stacks of large boxes obstructed the lighting, thereby reducing the illumination levels. However, overall average illumination levels remained the same before and after the new lighting systems were installed.

Feedback from the Blue Diamond staff was positive. Blue Diamond is currently in a process of retrofitting several additional warehouses and production facilities.

Acknowledgements

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

- Geoff Pyka (Blue Diamond Growers)
- Brooklyn Stewart (SmartWatt Energy)
- Safdar Chaudhry and Amandeep Singh (Nexant)
- Leah Pertl (SMUD)
- Dave Bisbee (SMUD)

2 INTRODUCTION

2.1 TECHNOLOGY DESCRIPTION

Lighting control systems use automated intelligence to deliver the required amount of light, where and when needed. Luminaires can automatically turn on, off, or dim at set times or under set conditions. Users have control over their own illumination levels to provide an optimal working environment while preventing energy waste caused by over-illumination.

Lighting control systems include some or all of the following:

- on/off and dimming controls
- occupancy sensors to detect whether rooms are occupied
- photo sensors to detect the current illumination levels provided by natural and/or electric light
- scheduling that turns on, off, and dims luminaires at preset times
- a centralized control system interface (such as a wall panel or computer software) to manage all of the above
- a method of communication between the lighting equipment and control system
- a method of measuring, displaying, and responding to lighting energy usage

Lighting control systems vary widely in complexity and cost according to the technologies they rely on. Historically, the more system-wide controls and advanced strategies are used, the greater the complexity, which often makes these solutions difficult or even impossible to implement across large-scale environments.

The Blue Diamond project uses wireless control technology by Daintree Networks. Wireless lighting control systems utilize wireless technology to communicate commands between endpoints – sensors, switches, and the ballasts or LED drivers connected to lights. While traditional lighting control systems utilize a controller that is hard-wired to each device (often with copper wiring), a wireless system uses a controller with an antenna that communicates wirelessly between a set of devices.

In Wireless Lighting Control systems, each endpoint is wirelessly enabled, either directly by the device manufacturer or with an external wireless adapter (shown in Figure 2-1). A software system provides facilities managers or individual users with access 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. In other words, each device in the network can communicate with a controller through at least two pathways, and can relay messages for its neighbors. 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: **An external wireless adapter for wireless control of lighting fixture**

The mesh network is self-healing, in that if any disruption occurs within the network (such as a device failing), data is automatically re-routed. The built-in redundancy of multiple pathways ensures the mesh network is both robust and reliable. Figure 2-2 shows ControlScope, which is 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 intelligence, while other partners provide compatible lighting control devices, including switches, sensors, ballasts, and LED drivers (using ZigBee standard).

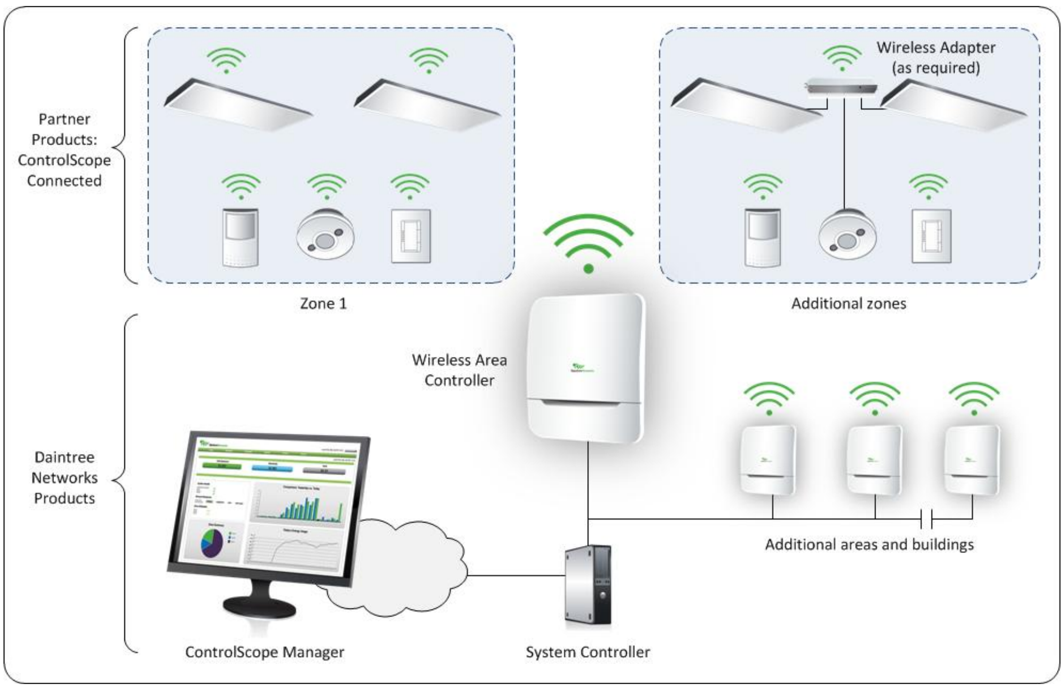

Figure 2-2: **The intelligent lighting controls solution by Daintree**

The control system offers the following capabilities:

- Task Tuning: Allows users to adjust the lighting levels according to their needs and avoid having unneeded, over-lit areas. The controls stop over-lighting and allows task tuning, which saves 20-30% electricity.
- Daylight Harvesting: Makes use of the available ambient light and reduces artificial lighting to maintain the lumens at a desired level; this could save 5-10% more electricity.
- Occupancy Control: Turns off lights via the motion sensor when the area has been unoccupied for certain time; this saves an additional 30-60% in electricity.
- Lumen Maintenance: Sets the light level according to the age of the lamp and ballast; this can save as much as 10% over the life of the equipment.
- Scheduling: Allows the users to set lighting schedules to meet their needs. The electricity 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 certain areas when a demand response event is called.

2.2 PROJECT DESCRIPTION

Project Location: Blue Diamond Growers
1802 C Street, Sacramento, CA 95814

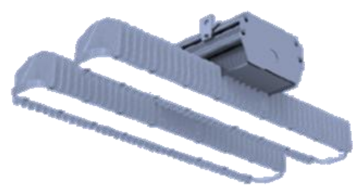

Figure 2-3: Albeo LED fixture installed in Blue Diamond's Cold 3 warehouse

Blue Diamond participated in SMUD's Advanced Lighting Controls program in 2012. Blue Diamond Growers is the world's largest almond processing and marketing company. It was founded in 1910 and produces over 80 percent of the world's almond supply. The California almond crop is marketed to all 50 states and more than 90 foreign countries, making almonds California's largest food export.

The project involved replacing of seventy-seven (77) 400-Watt High Pressure Sodium (HPS) fixtures with 160-Watt LED fixtures (shown in Figure 2-3) in a 62,000 square foot refrigerated warehouse (shown in Figures 2-4 and 2-5). The LED fixtures were equipped with motion sensors to turn off the lighting during unoccupied periods via remotely controlled Daintree networking technology. The Daintree lighting control system is a wireless mesh networking technology, coupled with intuitive software management tools.

Figure 2-4: Refrigerated warehouse (Cold 3) interior view

Figure 2-5: Refrigerated warehouse (Cold 3) exterior view

Original Lighting System

During May 2012, a project team consisting of a representative from SmartWatt Energy (installation contractor) and Nexant personnel visited the Blue Diamond facility and met with the Blue Diamond staff. The purpose 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 to examine the lighting systems and electrical panels for the proposed monitoring activities. The findings were as follows:

Figure 2-6: Warehouse with old lighting

- The lighting system for the warehouse (Cold 3) consisted of seventy-seven (77) 400-Watt High Pressure Sodium fixtures (shown in Figure 2-6).
- The lighting was too concentrated and bright in some areas, while poor in others. The illumination levels were not uniform throughout the warehouse. The situation was even worse in some areas where stacks of merchandise were stored.
- All of the lights were operating 24 hours a day and seven days a week. The only exception was during national holidays when the lights were manually turned off. This was due to the lack of controls to effectively and efficiently operate the system and lamp re-strike time requirements

associated with using high pressure sodium fixtures. The warehouse is lightly occupied. It was observed during site visits that two forklifts were in use. Only the entrance (East side) was used often for moving loads by the forklifts. The farthest side from the entrance (West side) was only occasionally used.

New Lighting System

The new lighting system proposed for the warehouse included the following:

- Seventy seven (77) 160-W LED fixtures (shown in Figure 2-7).
- The new LED fixtures are H-Series by Albeo Technologies. Each LED module is equipped with an upper limit thermal control designed to provide consistent light output without sacrificing life.
- The new fixtures use approximately 65% less power than the existing 400-Watt high pressure sodium fixtures and also offer better color rendering.

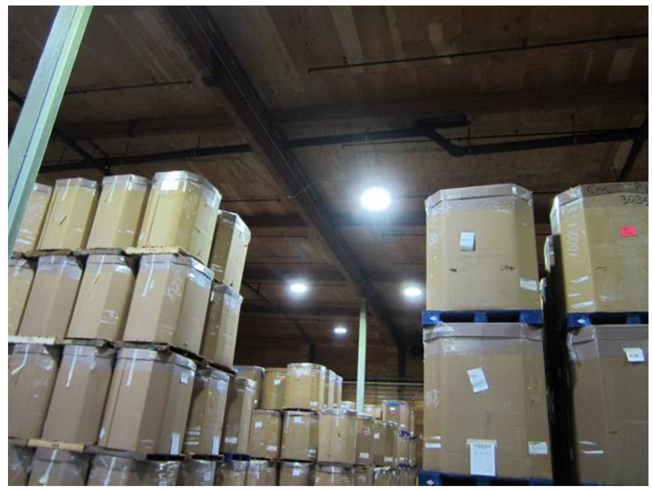

Figure 2-7: Warehouse with new lighting

- The LED fixtures were also equipped with motion sensors to 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. However, the controls installed at Blue Diamond Cold 3 warehouse are programmed for motion sensors only since there were no windows or skylights.

2.3 STUDY OBJECTIVES

This study's primary objective is to determine energy and demand savings resulting from the installation of advanced lighting control technologies at customer locations. A secondary objective is to validate various methodologies, energy saving algorithms, and calculations performed in the SMUD spreadsheet. To meet the objectives of this evaluation study, the following research questions are addressed:

- What are the energy, demand, and cost savings resulting from these lighting controls?
- What are the illumination levels under baseline and retrofit conditions and how well do these levels compare with each other?
- What is the project cost and simple payback?
- How are the energy savings calculated and reported for each system?
- How accurate are the various methodologies (compared to end-use monitored data)?
- How accurate were the energy saving algorithms?

To answer these questions, Nexant prepared a detailed research plan and shared it with SMUD's program manager. A sample was drawn to monitor selected fixtures throughout the warehouse and a Measurement and Verification plan was prepared then discussed. Current transformers and lighting loggers were installed to perform the necessary measurements. Illumination readings for pre and post cases were also taken. The details of sampling and monitoring are given in the following section.

Nexant prepared and maintained complete records of the fixture types, wattages, quantities, and control types of each lighting fixture for both baseline and post-retrofit conditions. During early discussions with the vendor and facility staff, Nexant obtained preliminary information on the existing lighting fixtures at the Blue Diamond facility.

Nexant performed One Time Power Measurements before and after installation. The continuous monitoring was also performed before and after the installation for several weeks to calculate the baseline energy consumption and energy savings. The post-installation trend data was also obtained from the facility to compare the energy savings. The illumination readings were performed using a hand held Extech Foot-candle light meter (shown in Figure 2-8), before and after the installations at same locations to make a comparison of lighting levels.

Figure 2-8: **Extech Foot-candle light meter**

3 MONITORING

3.1 MONITORING DETAILS

Nexant prepared a Measurement and Verification plan and finalized it after having a discussion with SMUD's program manager. Nexant, after careful review of the lighting systems, circuit diagrams and panel schedules, performed sampling to select the fixtures for monitoring. Since the number of branch circuits was relatively small, Nexant measured a census (100%) for branch circuits, which is 90/10 according to the International Performance Measurement and Verification Protocol (IPMVP) and California Energy Efficiency Evaluation protocols. This was useful, because it provides very accurate results and a good understanding of the overall savings.

Nexant initiated the monitoring activities on June 22, 2012 and took spot measurements to measure the following parameters:

- Service Voltage
- Single Phase Amps
- Single Phase Power
- Power Factor

Nexant also installed Current Transducers (CTs) on the selected circuits and documented each circuit's equipment. The CTs were connected to HOBO model U12-006 4 channel data loggers to record data at five-minute intervals for about three-weeks (June 22 – July 12, 2012) period for baseline case. Figure 3-1 shows the Hobo logger and Current Transducer (CT). Nexant downloaded the data from loggers and processed it for analysis and graphing. Nexant performed the measurements and continuous monitoring under the baseline and post retrofit.

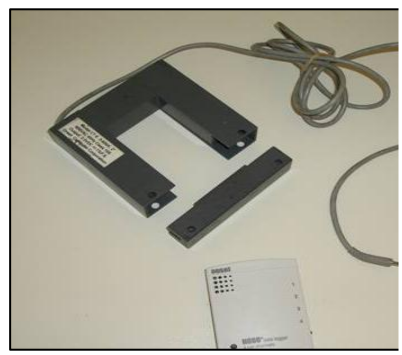

Figure 3-1: Hobo Logger and Current Transducer (CT)

The monitoring objective was to collect data in order to determine the baseline energy consumption and energy savings, and then compare those savings with the trend data. The monitoring was performed in three phases:

1. Pre-retrofit baseline, with old lighting fixtures in place
2. Post-retrofit baseline, with new lighting fixtures in place and without activating the controls
3. Post-installation, with new lighting fixtures in place and with the controls activated, conditions as described in the subsections below.

The monitoring dates of all three phases are presented in Table 3-1 below.

Table 3-1: Dates for pre and post installation monitoring

ID	Task Name	Start Date	End Date
1	Logger Installation/Spot Measurements (pre-installation)	6/22/2012	6/22/2012
2	Continuous Monitoring (pre-installation)	6/22/2012	7/12/2012
3	Logger Removal	7/12/2012	7/12/2012
4	Logger Installation/Spot Measurements (post-installation)	10/04/2012	10/04/2012
5	Continuous Monitoring (post-installation – new lighting)	10/04/2012	10/10/2012
5	Continuous Monitoring (post-installation – new lighting & controls)	10/12/2012	10/26/2012
6	Logger Removal	10/26/2012	10/26/2012

3.2 MONITORING PARAMETERS

The details of monitoring parameters, logger type, type of measurements, and measurement units are presented in Table 3-2.

Table 3-2: Monitoring parameters and equipment

Point#	Equipment	Quantity	Logger Type	Measurements	Units
1	Lighting Circuits	1	Power Sight Meter	Amps, volts and power factor	A, V
2	Lighting Circuits	7 (Pre) & 12 (Post)	Hobo 4 ext. channel logger with CTs	Amps	A
3	Lights	1	Foot Candle Meter	Foot-candles	Fc

4 RESULTS

4.1 RESULTS

This section presents the analysis results obtained from the data for the periods between June 6, 2012 to July 12, 2012 and October 4, 2012 to October 26, 2012. One Time Power Measurements (OTPM) were performed to determine voltage and power factor. The continuous monitoring was performed in three phases: pre-retrofit baseline, post-retrofit new lighting baseline, and post-retrofit new lighting with motion sensors, as described in the following sections. This section also presents a comparison of different saving calculation methodologies.

4.1.1 Pre-Installation Baseline

The four external channel and current transformers were installed on the lighting circuits for three weeks to monitor the baseline power consumption when the old high pressure sodium fixtures were still in place and operating. The power drawn in kW was calculated using the continuous amperage data one time power measurements data of voltage and power factor recorded for various circuits. Once the total electricity consumption for the monitored period was calculated, the annual baseline electricity consumption was estimated using the annual lighting operational hours. The lighting fixtures were found to be on all the time. However, the facility staff informed Nexant that lighting is completely shut down when facility is closed on national holidays. The total annual operating hours were estimated to be 8,568 and annual electricity consumption was estimated at 299,023 kWh. The average weekly profiles are shown in Figure 4-1.

4.1.2 Post-Installation New Lighting Baseline

The same four external channel and current transformers were installed again on the lighting circuits to monitor the power consumption of LED lights, while the control features were not activated yet. Figure 4-2 below shows lighting load profiles for the pre-retrofit baseline and with new lighting. As evident from this chart, the lighting load dropped significantly, i.e. from an average of 34 kW to about 14 kW. The new lighting baseline annual energy consumption, based on the monitored data, is estimated to be about 118,238 kWh. The calculated annual electricity savings are 180,785 kWh, only for replacing the high pressure sodium fixtures with the LEDs (no motion sensor savings).

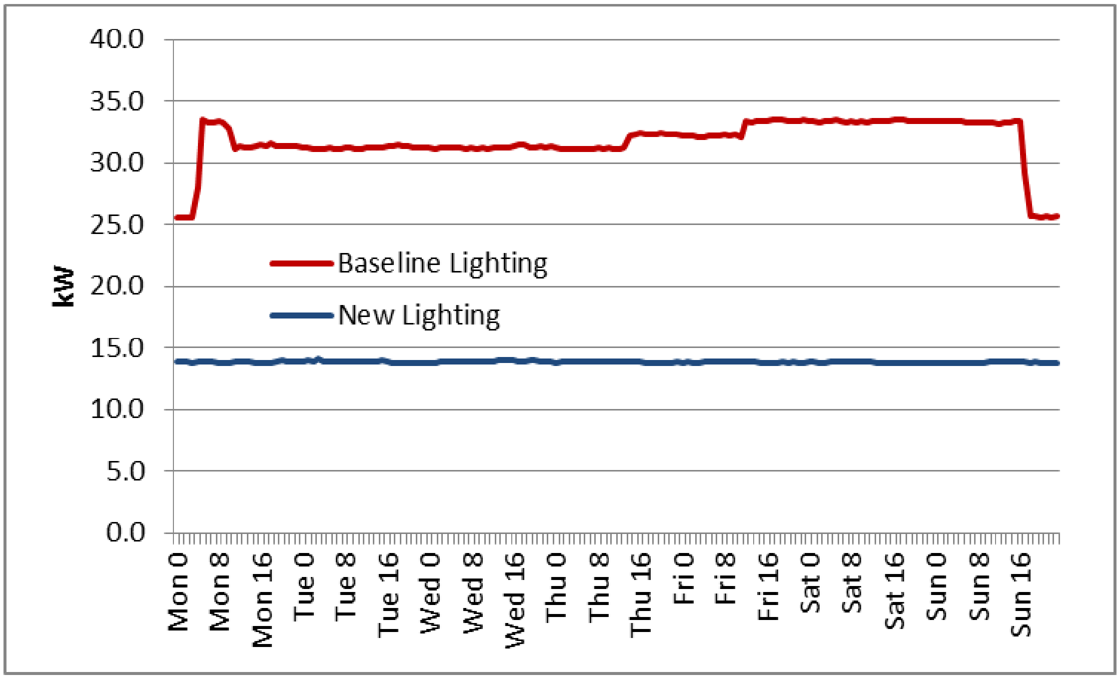

Figure 4-1: Lighting load profiles for the pre-retrofit baseline and new lighting

4.1.3 Post-Installation New Lighting with Motion Sensors

The monitoring for post-retrofit case was continued, but now with the motion sensor feature activated. Figure 4-2 below shows a comparison of lighting load profiles for the post- retrofit new lighting baseline and with the motion sensor feature activated. A considerable amount of electricity savings can be seen due to the use of motion sensors. The lighting load dropped from an average of 13.8 kW to an average of about 7.4 kW. The annual energy consumption with motion sensors is estimated to be about 62,546 kWh based on the monitored data. The calculated annual electricity savings are 55,692 kWh.

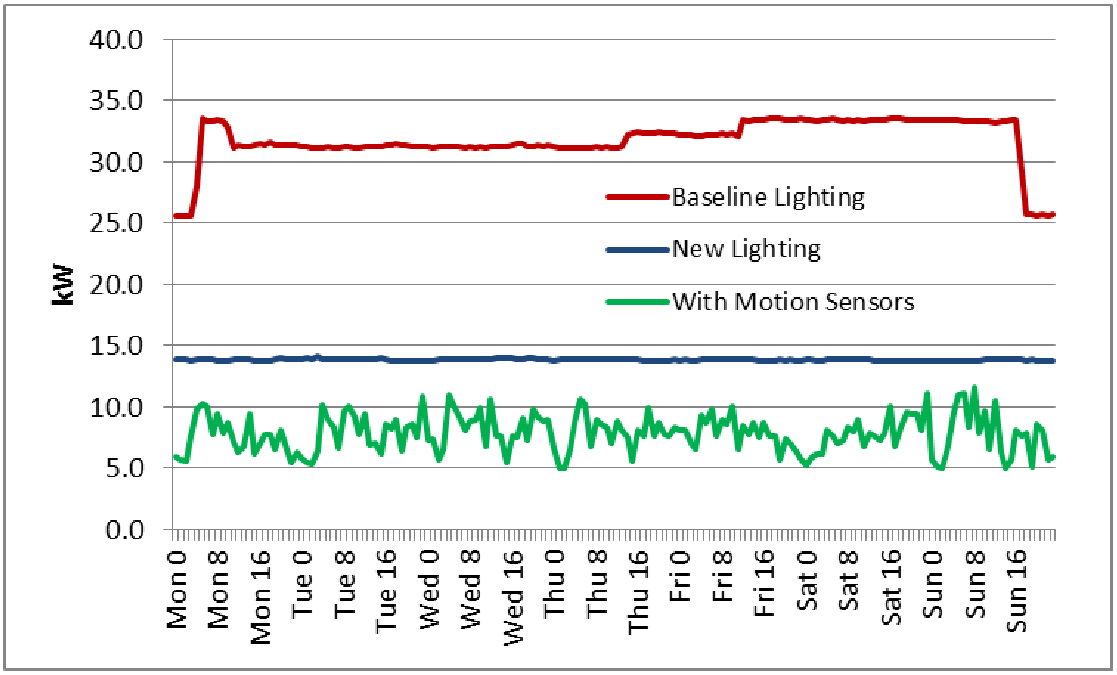

Figure 4-2: **Lighting load profiles for pre retrofit baseline, new lighting baseline, and with motion sensors**

The motion sensors were activated in the second week (October 11, 2012) and monitored for two weeks to calculate the energy reduction. We observed that the consumption was lower when the motion sensors were on versus when the sensors were off, as shown in Figure 4-2, and that the average power drawn was about 7 kW. Thus, the calculated annual energy consumption is 62,546 kWh while the motion sensors are activated. The annual energy savings are 55,692 kWh from the LED baseline and 236,477 kWh from the HPS baseline.

The total savings are estimated to be 236,477 kWh based on the monitored data. The summary of annual energy consumption and savings of the monitored warehouse is presented in Table 4-1. The energy savings are also illustrated graphically in Figure 4-3.

Table 4-1: Annual energy consumption and savings summary

Description	Energy Consumption	Average Demand	Energy Savings	Demand Savings	Comments
	kWh/year	kW	kWh/year	kW	
HPS Baseline	299,023	35	-	-	-
LED Baseline	118,238	14	180,785	21	LEDs Savings from HPS Baseline
LEDs with Motion Sensors	62,546	7	55,692	-	Motion Sensor Savings from LEDs Baseline
Total Savings	**-**	**21**	**236,477**	**21**	Total Savings from HPS Baseline

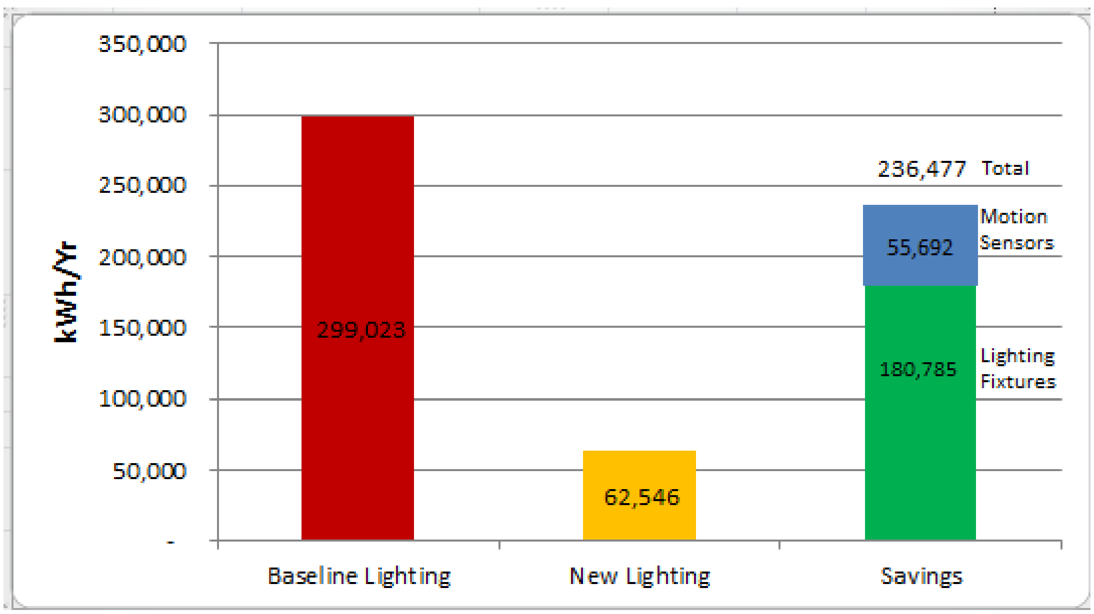

Figure 4-3: Calculated energy consumption and savings for Cold 3 warehouse

4.2 COMPARISON OF DIFFERENT ENERGY SAVING METHODOLOGIES WITH END-USE MONITORED DATA RESULTS

In this section results from two energy savings methodologies are compared with the end-use monitored data. These are:

1. Spreadsheet calculations based upon estimated lighting load and operation hours
2. Calculations performed by the control software

4.2.1 Spreadsheet Calculations

The following assumptions were used while calculating savings with spreadsheet method:

<u>New Lighting</u>

Wattage of High Pressure Sodium Fixtures:	465 Watts
Wattage of New LED Fixture:	164 Watts
Fixture Quantity:	77
Existing Lighting Operational Hours:	6,257 hours per year
Demand of Existing Lighting:	77 x 465 / 1,000 = 35.805 kW
Demand of New Lighting:	77 x 164 / 1,000 = 12.628 kW
Demand Savings:	35.805 – 12.628 = 23.177 kW
Energy Savings:	23.177 x 6,257 = 145,019 kWh per year

<u>Motion Sensors</u>

Wattage of New LED Fixture:	164 Watts
Fixture Quantity:	77
Existing Lighting Operational Hours:	6,257 hours per year
New Lighting Operational Hours:	2,503 (assumed 60% reduction due to motion sensors)
New Demand:	77 x 164/ 1,000 = 12.628 kW
Energy Savings:	12.628 x (6,257 – 2,503) = 47,408 kWh per year

Total Annual Energy Savings:	**145,019 + 47,408 = 192,427 kWh per year**

4.2.2 Control Software Calculations

The control software has the capability of tracking the state of every fixture in the system, whether the lights are on, off or dimmed (and if dimmed, the dimming level), on a real-time basis. The software also tracks how long each of the fixtures are in each of these states. To facilitate the energy savings calculation, each fixture is assigned a "maximum wattage" figure or better still, a "ballast curve", which is a function of how much power a ballast consumes at different dimming levels. If only "maximum wattage" is provided, then a linear curve (off or 0% dim means zero power consumed, 100% means 100% of maximum wattage consumed). Obviously, the calculations based on "maximum wattage" are less accurate than calculations based on the "ballast curve". Since in the case of Blue Diamond Cold 3 project, no dimming is performed, the “maximum wattage” method is used. Therefore, by inputting maximum wattage of each fixture and using the information from the control software about how long each of the fixtures was on during a specific interval, the calculations are performed.

The control system also has capability to trending the history of energy consumption. Upon Nexant’s request, the trend data for the post-installation phase was provided by the facility for the two cases, i.e. new lighting and with motion sensor feature activated. Table 4-2 below shows the trend data for energy usage and savings, which has been rolled over to per day figures.

Table 4-2: Trend data from control software showing energy usage and savings

Date	Energy Usage kWh/ day	Energy Savings kWh/ day
New Lighting		
10/04/12	177.600	681.720
10/05/12	177.597	681.723
10/06/12	177.600	681.720
10/07/12	177.598	681.722
10/08/12	177.597	681.723
10/09/12	177.598	681.722
10/10/12	177.600	681.720
Average	**177.599**	**681.721**
New Lighting & Motion Sensors (Cumulative)		
10/12/12	84.618	774.702
10/13/12	83.213	776.107
10/14/12	78.887	780.433
10/15/12	77.082	782.238
10/16/12	84.842	774.478
10/17/12	89.168	770.152
10/18/12	81.853	777.467
10/19/12	82.117	777.203
10/20/12	66.452	792.868
10/21/12	48.002	811.318
10/22/12	71.703	787.617
10/23/12	78.892	780.428
Average*	**77.814**	**781.506**

* Weighted average to account for weekdays and weekend operation separately

The annual energy consumption and savings from these data can be estimated as follows:

New Lighting

Average daily new lighting energy consumption:	177.599 kWh/day
Average daily energy savings:	681.721 kWh/day
Annual lighting operating days:	357
Annual new lighting energy consumption:	177.599 x 357 = 63,403 kWh per year
Annual energy savings:	681.721 x 357 = 243,375 kWh per year.

New Lighting and Motion Sensors (cumulative)

Average daily new lighting energy consumption:	77.814 kWh/day
Average daily energy savings:	781.506 kWh/day
Annual lighting operating days:	357
Annual new lighting energy consumption:	77.814 x 357 = 27,780 kWh per year
Annual energy savings:	781.506 x 357 = 278,998 kWh per year
Total Annual energy Savings:	**278,998 kWh per year**

Table 4-3 shows a comparison of results among the calculation methodologies. It is evident that the savings obtained by spreadsheet calculation were most conservative, due to less number of annual lighting operating hours assumed. Additional observations:

- Savings calculated by the control software are 45% higher than the spreadsheet savings and the savings calculated from monitored data are 23% higher than the spreadsheet savings.
- Savings calculated by the control software are about 18% higher than savings from monitored data, which is mostly due to calculating the higher savings for new lighting.
- When Daintree reviewed the above figures, they realized some mistakes must have been made during the process of setting up the software, resulting in inaccurate savings estimates. These mistakes were identified and corrected. The updated numbers, after the set up mistakes were corrected, are presented in Table 4-4.

Table 4-3: Comparisons of energy consumption and savings results based on spreadsheet method, control software, and monitored data

Description	Spreadsheet Calculations		Control Software		Monitored Data	
	Energy Consumption kWh/year	Energy Savings kWh/year	Energy Consumption kWh/year	Energy Savings kWh/year	Energy Consumption kWh/year	Energy Savings kWh/year
Baseline	224,032	-	306,777	-	299,023	-
New Lighting	79,013	145,019	63,403	243,375	118,238	180,785
With Motion Sensors	31,605	47,408	27,780	35,623	62,546	55,692
Total Savings	**-**	**192,427**	**-**	**278,998**	**-**	**236,477**

Table 4-4: Comparisons of energy consumption and savings results based on spreadsheet method, control software, and monitored data (after correcting software set up mistakes)

Description	Spreadsheet Calculations		Control Software		Monitored Data	
	Energy Consumption	Energy Savings	Energy Consumption	Energy Savings	Energy Consumption	Energy Savings
	kWh/year	kWh/year	kWh/year	kWh/year	kWh/year	kWh/year
Baseline	224,032	-	305,371	-	299,023	-
New Lighting	79,013	145,019	108,196	197,175	118,238	180,785
With Motion Sensors	31,605	47,408	41,017	67,179	62,546	55,692
Total Savings	**-**	**192,427**	**-**	**264,354**	**-**	**236,477**

4.3 ILLUMINATION RESULTS

The illumination readings (foot-candles) were taken with an EXTECH Light Meter for the pre- and post-installation cases. Measurement locations were marked with duct tape to repeat the readings at the same spots before and after the lighting system upgrade. Table 4-4 presents the illumination readings under the pre and post installation. In some cases, the differences between pre and post readings are noticeable, due to variations in the pattern of stacking merchandise in the warehouse. For example, a stack of large boxes blocked the lighting (shown above in Figure 4-4), thereby reducing the illumination levels. Although some readings varied, the overall average is surprisingly the same.

Figure 4-4: In some locations stacks of boxes blocked the lighting

Table 4-5: Illumination readings (foot-candles)

Tag	Pre-Installation	Post-Installation
	Foot-candles	Foot-candles
1	15.6	15.9
2	9.5	9.8
3	9.0	9.8
4	11.5	14.6
5	7.5	12.2
6	12.0	12.9
7	12.0	11.3
8	22.0	15.4
9	13.0	10.3
10	8.0	7.0
11	17.5	10.0
12	7.5	3.8
13	18.0	13.0
14	13.0	12.6
15	6.0	5.9
16	6.0	9.5
17	6.5	16.1
18	11.0	15.4
Average	**11.4**	**11.4**

5 SUMMARY OF FINDINGS

This section presents a summary of findings of Nexant's evaluation of the advanced lighting system at Blue Diamond Growers.

5.1 SUMMARY OF FINDINGS

Nexant monitored the lighting circuit of warehouse Cold 3 in the pre- and post-installation phases for three weeks each to determine the overall impact of the LED lights and motion sensors on the electric energy consumption. Our analysis findings are as follows:

- The replacement of the HPS lights with LEDs and installation of motion sensors reduced the electric energy consumption by 236,477 kWh a year based on the monitored data. The LEDs also reduced the demand by 21 kW (demand reduction does not include motion sensor effects).
- The LED lights alone (deactivated motion sensors) reduced the energy consumption by 180,785 kWh a year based on the monitored data.
- Activation of the motion sensors reduced the electric energy consumption by an additional 55,692 kWh a year (this reduction is based on subtracting LED consumption with activated motion sensors from the LED consumption with deactivated motion sensors).
- Initially the software data showed energy savings of 278,998 kWh a year by replacing HPS lights to LEDs with motion sensors control, which is different from the monitored data. This is mostly due to calculating the higher savings for fixture replacement. When Daintree went back and reviewed the data, they discovered some mistakes made during set up. After the mistakes were corrected, the revised savings were 264,354 kWh per year.
- Most of the pre and post installation illumination measurements are within close range. However, some of the post-installation readings are lower due to more stacks of finished product being in the warehouse at the time of the measurements; the stacks obstructed light from adjacent fixtures.
- The electricity savings obtained by spreadsheet calculation (192,427 kWh/year), were most conservative, due to an assumption of less annual lighting operating hours. The savings based upon monitoring data were 23% higher.
- Initially the savings calculated by the control software were 45% higher than the spreadsheet and 18% higher than the monitored data. After the mistakes made during set up were corrected, the savings calculated by the control software were 37% higher than the spreadsheet and 12% higher than the monitored data.

- The illumination readings taken at different locations show that the lighting levels increased at some spots under post-retrofit case, but decreased at others. This differentiation was mainly caused by variations in the pattern of stacking merchandise in the warehouse. For example, a stack of large boxes blocked the lighting, thereby reducing the illumination levels. However, the overall average illumination levels were the same for both cases.

6 BEHAVIORAL ASPECT STUDY

Blue Diamond installed advanced lighting controls in their manufacturing facility in Sacramento. Because this building is a warehouse, an Information Technology (IT) staff person is not located on-site.

6.1 BUILDING OCCUPANT SURVEY

The building occupant survey was designed to gather occupant satisfaction and general feedback on the newly installed advanced lighting control technology and software. Two occupants were available to be interviewed. In future projects, for larger facilities with more occupants, an online survey distributed to occupants and information technology staff would be helpful to gather satisfaction data and feedback.

One occupant interviewed is in management with Blue Diamond, and the other is an environmental engineer. They both described their workspace as an open warehouse space with no safety hazards. The engineer spends half or more of his time working on a computer and both respondents spend a quarter or more of their time performing manual tasks (characterized as visual work not on a computer).

6.1.1 Satisfaction

The occupants were asked to rate the new lighting system as compared to the old system on a scale of 1 (much worse) to 5 (much better) and to describe any changes in quality after the new controls were installed. The engineer responded by saying that the lighting was much better (5) and he noticed the lighting is "much brighter and whiter" than the previous system. The manager rated the new lighting system a 2, saying that the lighting flickers in his workspace. The occupants were then asked to rate statements regarding the previous lighting system and the new lighting system on a scale of 1 (strongly disagree) to 5 (strongly agree). Table 1 illustrates the responses.

Table 6-1: Statement Ratings Regarding Previous and Current (New) Lighting Systems

	1 (Strongly Disagree)	2 (Disagree)	3 (Neutral)	4 (Agree)	5 (Strongly Agree)
Previous Lighting System					
The overhead lighting made it difficult for me to read	✓			✓	
The overhead lighting was acceptable	✓	✓			
The overhead lighting was too dim for the work I do			✓✓		
The overhead lighting was too bright for the work I do	✓		✓		
Current (New) Lighting System					
The overhead lighting is set at my preferred level for the work I do				✓	✓
The overhead lighting makes it difficult for me to read	✓✓				
The overhead lighting is acceptable					✓✓
The overhead lighting is too dim for the work I do	✓✓				
The overhead lighting is too bright for the work I do	✓	✓			
The overhead lighting is pleasant to work under					✓✓

The engineer stated that, in his opinion, brightness and energy use are important lighting issues. In addition to the positive ratings regarding the new light system, the engineer rated his overall satisfaction with the new lighting system at a 4 on a scale of 1 (very unsatisfactory) to 5 (very satisfactory). While the manager has noticed some lighting quality issues with the new lighting, prompting a score of 2 when compared to the old system, overall he is satisfied with the new lighting system.)

6.1.2 Lighting Control Technology

Between six and ten people rely on the same lighting controls in the warehouse workspace. The interviewed engineer has the ability to control the overhead lighting with computer software, and he’s been instructed on how to operate the new lighting system. He said he likes having the ability to change the lighting level and believes the lighting controls are easy to use, though he indicated he never utilizes the computer software to adjust lighting levels during the day because he doesn’t need a change in lighting based on the type of work he does.

Though the installation process impacted work for the occupants, there have been no complaints about the lighting since the installation, and the occupants do not perceive the maintenance of the new lighting system to be difficult.

6.1.3 Software

The interviewed engineer has access to the software that controls the entire advanced lighting control system and he uses it once a day to make sure the functionality is working and to review the energy savings. He said the software user interface is easy and intuitive and there are no perceived barriers to using the software.

6.2 INSTALLER

The interviewed ALC installer is part of a 125-person company with a local office near SMUD service territory.

6.2.1 Technology

The installer was not previously familiar with the California Advanced Lighting Controls Training Program, though he has previous experience with advanced lighting controls through custom integrated lighting solutions. Twenty percent of their business involves advanced lighting control technology. Previous jobs have included lighting control strategies such as daylight harvesting and motion sensors.

The installer has a direct relationship with the manufacturer of the technologies used in this project. The manufacturer did not provide any support on the design or installation of the system. The manufacturer was chosen because "they have wireless systems, they are familiar with the [ALC] system, and they provide a good product."

6.2.2 Design

There was no existing building management system installed before the ALC, and the utilization of existing information technology networks in the building was not considered during the design process. The system design was conducted by the installer with input from the client, and the installer indicated there was nothing they would have done differently in the design of the system.

6.2.3 Installation

The installer was asked about the ease of the installation of the system, and he indicated it was somewhat difficult. A challenge faced by the installer was the labeling and matching of the fixtures during the installation process. Despite the difficulty, the installer said that the installation process met the planned schedule and additional installation training would not have been necessary. The commissioning process took two days, which was slightly longer than expected due to delays caused by the installation of the DSL line.

The installer did not encounter any unexpected difficulties in meeting SMUD program requirements. There is nothing he would have changed and they did not receive any comments or complaints from occupants after the system was installed.

6.3 CONCLUSIONS

According to both the occupants and the installer, the advanced lighting control system design and installation was a success. There have been no complaints from occupants and the installer encountered very limited difficulties. The few difficulties mentioned may have been avoided if the installer had more extensive training from the controls manufacturer.