Blue Diamond Growers Lighting Controls Project (Phase 2)

ET12SMUD1025

Submitted to:

Sacramento Municipal Utility District

SMUD™

July 30, 2013

Prepared by:

Nexant

9245 Laguna Springs Drive, Suite 380
Elk Grove, CA 94105
(916) 478-0051

Acknowledgement: “This material is based upon work supported by the Department of Energy under Award Number OE0000214.”

CONTENTS

FIGURES AND TABLES

Figures

Tables

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

Earlier this year, Nexant evaluated an LED lighting system with advanced controls at a Blue Diamond Growers cold storage facility. Since that project was very successful, Blue Diamond decided to replace the lighting in their refrigerated distribution centers (DC). This project involved replacing two hundred and ninety eight (298) 250-Watt metal halide (MH) fixtures with 160-Watt dimmable LED fixtures with motion sensors. 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 552,161 kWh per year (72%) and may be broken down as follows:

Savings from LEDs:	362,342 kWh per year
Task tuning savings:	90,202 kWh per year
Motion sensor savings:	99,617 kWh per year
Total energy savings:	**552,161 kWh per year**

- Average savings per fixture: 1,853 kWh per year (with controls)
- Overall peak electrical demand was reduced by 52.2 kW (59%).

Financial Summary

Project Cost: $257,000

Estimated Utility bill reduction: $50,805

Simple payback: 5.1 yrs.

SMUD rebate: $165,648

Net project cost: $91,351

Simple payback with rebate: 1.8 yrs.

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.

Measurements taken at different locations show that the illumination levels increased at all locations under post-retrofit case with and without activating the task tuning. In some locations the measured light levels increased with the task tuning activated compared to the LED fixtures at full output. This was due to the removal of some pallets during the measurements (decreased light obstruction).

Feedback from Blue Diamond staff and the installation contractor regarding the new lighting system was positive.

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, Waqar Mustafa 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. Lighting controls can automatically turn on, off, or dim fixtures 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.

Advanced lighting control systems include some or all of the following:

- on/off and dimming controls
- occupancy sensors to detect whether rooms are occupied
- photosensors to detect illumination levels provided by natural and/or electric light
- scheduling that turns on, off, and dim lighting fixtures 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). Software 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).

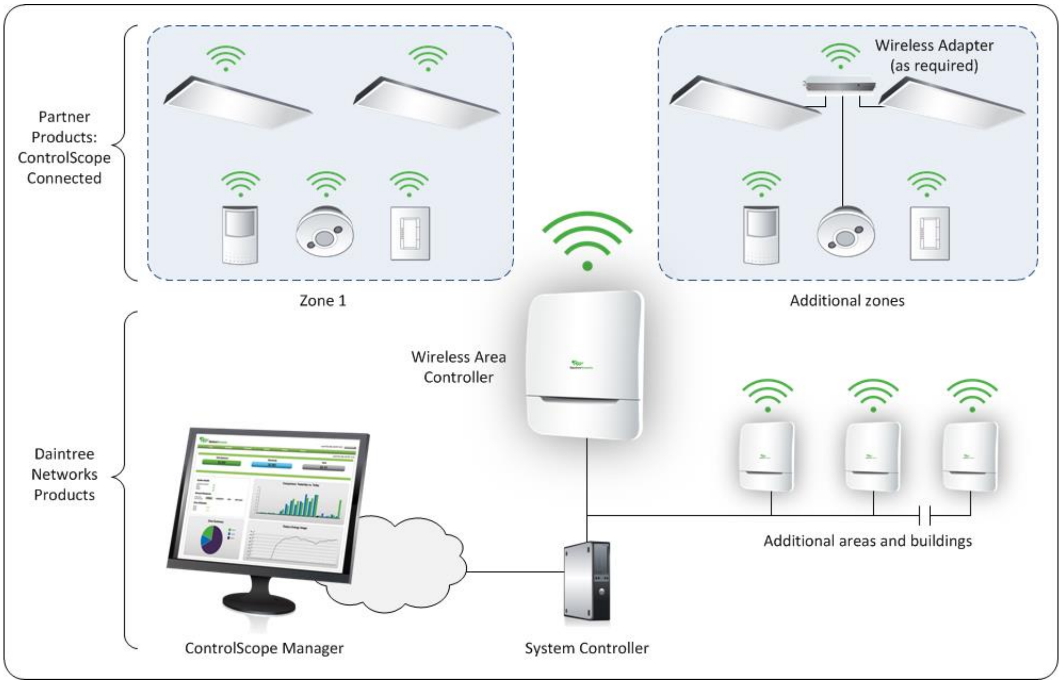

Figure 2-2: The intelligent lighting controls solution by Daintree

The control system offers the following capabilities:

- Task Tuning: Allows the users to adjust the lighting levels according to their needs and avoid having unneeded, over-lit areas. Task Tuning typically saves 20-30% electricity.
- Daylight Harvesting: Makes use of the available ambient light and reduces electric 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 suit 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 Distribution Center
1802 C Street, Sacramento, CA 95814

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.

Blue Diamond participated in SMUD's Advanced Lighting Controls program in 2012. Based upon the success of the first project, Blue Diamond decided to upgrade the lighting in their Distribution Center. This project involved replacing two hundred and ninety eight (298) 250-Watt metal halide (MH) fixtures with 160-Watt dimmable LED fixtures (shown in Figure 2-3).

The Distribution Center is divided into four sections; DC-1, DC-2, DC-3 and the Dock (shown in Figure 2-4 and **Error! Reference ource not found.**). 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.

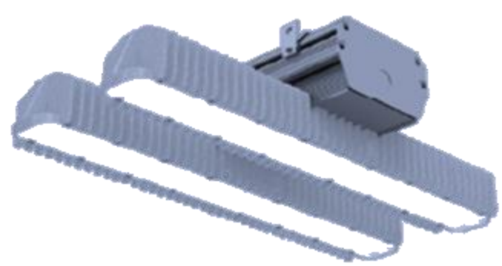

Figure 2-3: Albeo LED Fixture Installed at Blue Diamond Growers

Figure 2-4: Distribution Center interior view

Figure 2-5: Distribution Center exterior view

Original Lighting System

During November 2012 Nexant visited the Blue Diamond facility and met with 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 Distribution Center to examine the lighting systems and electrical panels for the proposed monitoring activities. The findings were as follows:

Figure 2-6: Distribution Center Original Lighting

- The original lighting system for three distribution centers and a dock consisted of two hundred and ninety eight (298) 250-Watt metal halide fixtures (shown in :).
- The lighting was too concentrated and bright in some areas, while poor in others. The illumination levels were not uniform throughout the Distribution Centers. 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 (4 days per year) when the lights were manually turned off. This was due to the lack of controls to effectively and efficiently operate the system and the re-strike time requirements associated with using metal halide lamps.

New Lighting System

The new lighting system included the following:

- Two hundred and ninety eight (298) 160-Watt dimmable LED fixtures (shown in Figure 2-7 on the following page).
- The new Albeo H-Series LED fixtures are equipped with an upper limit thermal control designed to provide consistent light output without sacrificing life.

- The new LED fixtures consume approximately 59% less power (without task tuning) than the original 250-Watt metal halide fixtures and also offer better color rendering.

The LED fixtures are 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, since there are no windows or skylights in this facility, the controls installed at the Blue Diamond Distribution Center are programmed for motion sensors and task tuning only.

Figure 2-7: Distribution Center with new LED lighting system

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 is 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 large, Nexant performed monitoring on a sample of 25 of the total 41 circuits (133 of 298 total fixtures), which meets the 90/10 confidence and precision criteria, according to the International Performance Measurement and Verification Protocol (IPMVP) and California Energy Efficiency Evaluation protocols.

Nexant initiated the monitoring activities on November 13, 2012 and took spot measurements to measure the following parameters:

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

Nexant also installed current transformers (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 two weeks (November 13, 2012 to November 29, 2012) period for baseline case. Figure 3-1 shows the Hobo logger and current transformers. 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.

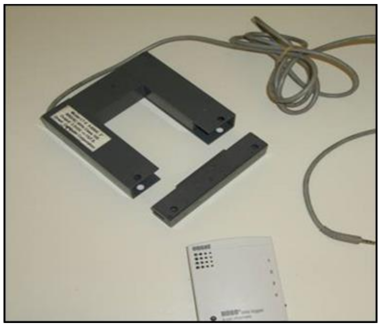

Figure 3-1: Hobo Logger and current transformer (CT)

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 control software trend data. The monitoring was performed in four phases:

1. Pre-retrofit baseline, with existing (original) 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 task tuning controls activated (lights dimmed 10%), as described in the following subsections.

4. Post-installation, with new lighting fixtures in place and with the task tuning (lights dimmed 10%) and occupancy controls activated, as described in the subsections below.

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

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

ID	Task Name	Start Date	End Date
1	Logger Installation/Spot Measurements (pre-installation)	11/13/2012	11/13/2012
2	Continuous Monitoring (pre-installation)	11/13/2012	11/29/2012
3	Logger Removal	11/29/2012	11/29/2012
4	Logger Installation/Spot Measurements (post-installation)	01/31/2013	01/31/2013
5	Continuous Monitoring (post-installation – new lighting)	01/31/2013	02/07/2013
6	Continuous Monitoring (post-installation – new lighting & activated task tuning)	02/11/2013	02/19/2013
7	Continuous Monitoring (post-installation – new lighting, activated task tuning & occupancy controls)	02/19/2013	03/07/2013
8	Logger Removal	03/07/2013	03/07/2013

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	25 (Pre) & 26 (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 November 13, 2012 to November 29, 2012 and January 31, 2013 to March 7, 2013. One Time Power Measurements (OTPM) were performed to determine voltage and power factor. The continuous monitoring was performed: pre-retrofit baseline, post-retrofit new lighting baseline, post-retrofit new lighting with task tuning, and post-retrofit new lighting with task tuning and 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 two weeks to monitor the baseline power consumption when the original metal halide 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 the facility is closed on national holidays. The total annual operating hours were estimated to be 8,664 and annual electricity consumption was estimated at 771,510 kWh. The average hourly profile is 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 4-1 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 89 kW to about 47 kW. The new lighting baseline annual energy consumption, based on the monitored data, is estimated to be about 409,168 kWh. The calculated annual electricity savings are 362,342 kWh, for replacing the metal halide fixtures with the LEDs only (no task tuning or motion sensor savings).

4.1.3 Post-Installation New Lighting with Task Tuning

The monitoring for post-retrofit case was continued, but now with the task tuning feature activated (lights dimmed 10%). The task tuning was activated in the first week of February (February 7, 2013) and monitored for one week to calculate the energy reduction. Figure 4-1 shows a comparison of lighting load profiles for the post-retrofit new lighting baseline and with the task tuning feature activated. A considerable amount of electricity savings can be seen due to dimming the lights 10%. The lighting load dropped from an average of 47 kW to an average of about 36.8 kW. The annual energy consumption with task tuning is estimated to be about 318,966 kWh based on the monitored data. The calculated annual electricity savings from the task tuning are 90,202 kWh.

4.1.4 Post-Installation New Lighting with Motion Sensors

The monitoring for post-retrofit case was continued, but now with both the motion sensor and task tuning features activated.

Figure 4-1 shows a comparison of lighting load profiles for the post- retrofit new lighting baseline, task tuning 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 36.8 kW to an average of about 25.3 kW. The annual energy consumption with motion sensors is estimated to be about 219,349 kWh based on the monitored data. The calculated annual electricity savings from using the motion sensors are 99,617 kWh.

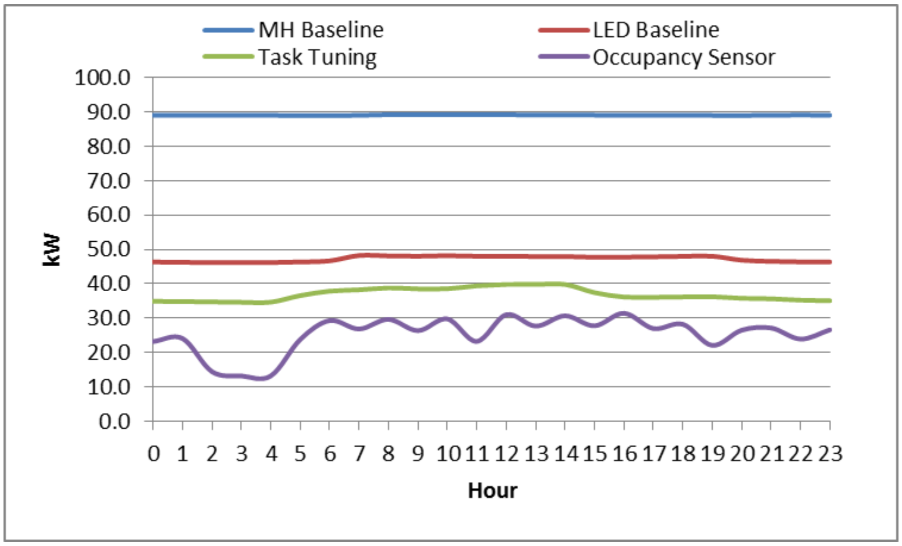

Figure 4-1: Lighting load profiles for pre retrofit baseline, new lighting baseline, task tuning and with motion sensors

The motion sensors were activated in the third week of February (February 19, 2013) and monitored for two weeks to calculate the energy reduction. We observed that the consumption was lower when the motion sensors were activated versus when the sensors were turned off, as shown in Figure 4-1. Thus, the calculated annual energy consumption is 219,349 kWh while the motion sensors are activated. The annual energy savings (with activated occupancy sensors) are 99,617 kWh from the task tuning, 189,819 kWh from the LED baseline, and 552,161 kWh from the MH baseline.

The total savings are estimated to be 552,161 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 4-2

.

Table 4-1: Annual energy consumption and savings summary

Description	Average Demand	Energy Consumption	Demand Savings	Energy Savings	Comments
	kW	kWh/year	kW	kWh/year	
MH Baseline	89	771,510	-	-	-
LED Baseline	47	409,168	42	362,342	LED Savings from MH Baseline
Task Tuning	37	318,966	10	90,202	Task Tuning Savings from LED Baseline
Occupancy Sensors	25	219,349	-	99,617	Occupancy Sensors Savings from Task Tuning Baseline
Total Savings	**-**	**-**	**52**	**552,161**	**Total Savings from MH Baseline**

Table 4-2: Control Software trend data electric energy usage and savings summary

Description	Average Demand	Energy Consumption	Demand Savings	Energy Savings	Comments
	kW	kWh/year	kW	kWh/year	
MH Baseline	89.0	771,510	-	-	-
LED Baseline	47.0	406,896	42.1	364,614	LED Savings from MH Baseline
Task Tuning	36.8	319,176	10.1	87,720	Task Tuning Savings from LED Baseline
Occupancy Sensors	20.5	177,822	-	141,354	Occupancy Sensors Savings from Task Tuning Baseline
Total Savings	**-**	**-**	**52.21**	**593,688**	Total Savings from MH Baseline

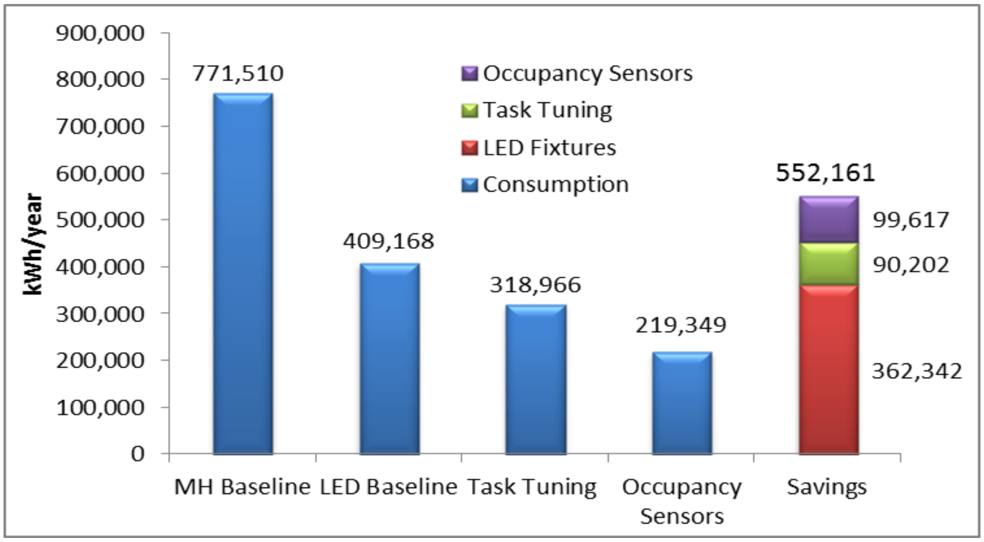

Figure 4-2: Calculated energy consumption and savings

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:

New Lighting

Wattage of Original Metal Halide Fixtures:	295 Watts
Wattage of New LED Fixtures:	164 Watts
Fixture Quantity:	298
Existing Lighting Operational Hours:	8,760 hours per year
Demand of Existing (Original) Lighting:	298 x 295 / 1,000 = 87.91 kW
Demand of New Lighting:	298 x 164 / 1,000 = 48.87 kW
Demand Savings:	87.91 – 48.87 = 39.04 kW
Energy Savings:	39.04 x 8,760 = 341,973 kWh per year

Task Tuning

Wattage of New LED Fixtures:	164 Watts
Fixture Quantity:	298
Lighting Operational Hours:	8,760 hours per year
Dimming Wattage:	0.90 x 164 = 147.6 Watts (assumed 90% of maximum power)
New Demand:	147.6 x 298 = 43.98 kW
Energy Savings:	(48.87 – 43.98) x 8,760 = 42,813 kWh per year

Motion Sensors

Wattage of New LED Fixtures:	147.6 Watts (with task tuning)
Fixture Quantity:	298 (282 for DC1-DC3, 16 for Dock area)
Existing Lighting Operational Hours:	8,760 hours per year
New Lighting Operational Hours:	3,504 (assumed 60% reduction due to motion sensors for DC-1, DC-2 and DC-3)
New Lighting Operational Hours:	6,132 (assumed 30% reduction due to motion sensors for Dock area)
New Demand:	298 x 147.6 / 1,000 = 43.98 kW
Energy Savings:	282 x 147.6 x 0.001 x (8,760 – 3,504) + 16 x 147.6 x 0.001 x (8,760 – 6,132) = 224,977 kWh per year
Total Annual Energy Savings:	**341,973 + 42,813 + 224,977 = 609,763 kWh**

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".

The control system also has capability to trend the history of energy consumption. Upon Nexant's request, the trend data for the post-installation phase was provided by the facility for the three cases, i.e. new lighting, task tuning and with motion sensor feature activated. Table 4-2 shows the trend data energy usage and savings summary.

Table **4-3** below shows the daily average energy usage and savings values.

Table 4-3: Trend data from control software showing energy usage and savings

Date	Daily Average Energy Usage	Daily Average Energy Savings
	kWh/ day	kWh/ day
New Lighting		
1/31/2013	1,127.14	1,010.01
2/1/2013	1,127.14	1,010.01
2/2/2013	1,127.14	1,010.01
2/3/2013	1,127.14	1,010.01
2/4/2013	1,127.14	1,010.01
2/5/2013	1,127.14	1,010.01
2/6/2013	1,127.14	1,010.01
Average	**1,127.14**	**1,010.01**
New Lighting & Task Tuning (Cumulative)		
2/11/2013	1,027.37	99.77
2/12/2013	1,014.38	112.75
2/13/2013	1,014.38	112.75
2/14/2013	1,014.38	112.75
2/15/2013	1,014.38	112.75
2/16/2013	1,014.41	112.73
2/17/2013	947.40	179.74
2/18/2013	369.46	757.68
2/19/2013	541.13	586.01
Average	**884.14**	**242.99**

New Lighting, Task Tuning, & Occupancy Sensors (Cumulative)		
2/20/2013	439.75	444.39
2/21/2013	440.11	444.03
2/22/2013	490.82	393.32
2/23/2013	289.63	594.51
2/24/2013	161.59	722.55
2/25/2013	459.60	424.54
2/26/2013	499.08	385.06
2/27/2013	456.77	427.38
2/28/2013	521.28	362.86
3/1/2013	647.09	237.06
3/2/2013	500.93	383.22
3/3/2013	437.76	446.38
3/4/2013	605.66	278.48
3/5/2013	639.67	244.47
3/6/2013	652.61	231.54
3/7/2013	638.95	245.19
Average	**492.58**	**391.56**

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

New Lighting

Demand of original MH fixtures from monitored data:	89 kW
Demand of new LED fixtures from trend data:	47 kW
Annual lighting operating hours:	8,664 (4 holidays per year)
Annual original lighting energy consumption:	89 x 8,664 = 771,510 kWh per year
Annual new lighting energy consumption:	47 x 8,664 = 406,896 kWh per year

Annual energy savings: 771,510 – 406,896 = 364,614 kWh per year

New Lighting and Task Tuning (cumulative)

Demand of new LED fixtures from trend data:	47.0 kW
Demand of new LED fixtures with task tuning:	36.8 kW
Annual lighting operating hours:	8,664 (4 holidays per year)

Annual energy savings: (47.0 – 36.8) x 8,664 = 87,720 kWh per year.

New Lighting, Task Tuning and Occupancy Sensors (cumulative)

Demand of new LED fixtures with task tuning:	36.8 kW
Demand of new LED fixtures with occ. sensors:	20.5 kW
Annual lighting operating hours:	8,664 (4 holidays per year)

Annual energy savings: (36.8 – 20.5) x 8,664 = 141,354 kWh per year

Total Annual energy Savings: 364,614 + 87,720 + 141,354 = 593,688 kWh

Table 4-4 shows a comparison of results among the calculation methodologies. It is evident that the savings obtained by the monitored data were most conservative. The savings calculated by the control software are 3% less than the spreadsheet savings, the spreadsheet calculation assumes higher savings by occupancy sensors. The savings calculated by the control software are about 8% higher than the savings from monitored data, which is mostly due to calculating the higher savings for occupancy sensors.

Table 4-4: 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	Energy Savings	Energy Consumption	Energy Savings	Energy Consumption	Energy Savings
	kWh/year	kWh/year	kWh/year	kWh/year	kWh/year	kWh/year
Baseline	770,092	-	771,510	-	771,510	-
New Lighting	428,119	341,973	406,896	364,614	409,168	362,342
Task Tuning	385,306	42,813	319,176	87,720	318,966	90,202
Occupancy Sensors	160,329	224,977	177,822	141,354	219,349	99,617
Total Savings	**-**	**609,763**	**-**	**593,688**	**-**	**552,161**

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 4-5 presents the illumination readings under the pre and post installation. In some cases, the differences between pre and post readings are noticeable, due to the increase in the lighting level with the LEDs. The overall lighting levels increased in the post-installation case.

Figure 4-3: Distribution Center with LED Lights

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

No.	Baseline Fixtures (Fc)	LED Fixtures (Fc)	Task Tuning 90% (Fc)
1	4.3	15	10
2	8.7	13	12.4
3	9	13	12.9
4	4.3	12	10.4
5	6	12	8.1
6	4.7	11	10.2
7	6.8	11	10.7
8	10	12	9
9	10	16	14.5
10	6.4	13	11.4
11	10.9	13	12.1
12	13.7	14	17.9
13	15.3	17	15.4
14	8	15	12.1
15	10.8	16	14.8
16	8.4	17	10.3
17	11.2	14	16.8
18	5.2	18	17.9
19	9.5	15	14.4
20	7.6	13	15.2
21	9.2	15	15.4
22	8.4	16	13.2
23	10.6	10	15.7
24	12.2	19	14.9
25	12.4	13	12.5
26	16.8	19	19
27	6.6	18	16.8
28	6.2	19	14.4
29	12	19	16.4
30	10.5	16	14.5
31	12.2	15	13.6
32	19	15	18
33	13	17	16.8
Average	**9.7**	**14.9**	**13.9**

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 distribution centers in the pre- and post-installation phases 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 MH lights with LEDs and use of task tuning and motion sensors reduced the electric energy consumption by 552,161 kWh per year based on the monitored data. The LEDs also reduced the electrical demand by 52 kW (the demand reduction does not include motion sensor effects).
- The LED lights alone (without controls) reduced the energy consumption by 362,342 kWh per year based on the monitored data.
- Activation of the task tuning reduced the electric energy consumption by an additional 90,202 kWh per year (this reduction is based on subtracting LED consumption with activated task tuning from the LED consumption with deactivated controls).
- Activation of the motion sensors reduced the electric energy consumption by an additional 99,617 kWh a year (this reduction is based on subtracting LED consumption with activated motion sensors from the LED consumption with activated task tuning).
- The Daintree Networks (control software) trend data shows the energy savings of 593,688 kWh a year by replacing MH lights to LEDs with task tuning and motion sensor control.
- The lighting levels are increased in the post-installation case due to new LEDs with better light distribution.
- The electricity savings obtained by spreadsheet calculation (609,763 kWh/year), were higher than control software and monitored data, due to an assumption of higher savings from the occupancy sensors. The spreadsheet savings were 3% and 10% higher than control software and monitored data, respectively.

6 BEHAVIORAL ASPECT STUDY

Blue Diamond Growers installed advanced lighting controls (ALC) in their Distribution Center located in Sacramento, which is divided into four sections: DC-1, DC-2, DC-3 and docking area. Surveys were conducted immediately after the technology was installed. This section summarizes the findings of the follow-up surveys.

6.1 BUILDING OCCUPANT SURVEY

The building occupant survey was designed to gather occupant satisfaction and general feedback on the advanced lighting control technology and software. Three occupants were available to be interviewed, and all identified themselves as staff employees. Two respondents described their workspace as an open warehouse space with no safety hazards, and one described his space as a shared enclosed office with safety hazards (defined as trip hazards, electrical hazards, fall hazards, etc.). None of the respondents spend more than half of their time working on a computer, and one spends a quarter or more of his 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 original 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. All three respondents rated the new lighting system at a 4, and said they noticed a positive change in lighting quality, including the system being brighter than the previous system. 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 6-1 illustrates their 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)
Original Lighting System					
The overhead lighting made it difficult for me to read				3	
The overhead lighting was acceptable		2		1	
The overhead lighting was too dim for the work I do			2	1	
The overhead lighting was too bright for the work I do	2		1		
Current (New) Lighting System					
The overhead lighting is set at my preferred level for the work I do			1	1	1
The overhead lighting makes it difficult for me to read	2		1		
The overhead lighting is acceptable			1		2
The overhead lighting is too dim for the work I do	2		1		
The overhead lighting is too bright for the work I do	2	1			
The overhead lighting is pleasant to work under				2	1

In addition to the overall positive ratings regarding the new lighting system, two respondents rated their overall satisfaction with the new lighting system at a 4 and 5 on a scale of 1 (very unsatisfactory) to 5 (very satisfactory). The respondent who works in the enclosed office noted that the lighting system is dimmer than he would prefer. He rated the new lighting system 3 out of 5.

6.2 INSTALLER

The interviewed ALC installer is part of a 150-person company with a local office near SMUD's service territory.

6.2.1 Technology

The installer was in the process of completing the California Advanced Lighting Controls Training Program at the time of the interview, and 40% of their business nationwide involves advanced lighting control technology.

The installer has a direct relationship with the manufacturer of the technologies used in this project. The manufacturer provided a limited degree of support on the design or installation of the system. The specific technology was chosen based on customer needs and cost, as well as the facility's hours of operation and light level requirements. The installer mentioned improved productivity as a non-energy benefit associated with the ALC technology.

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 considered during the design process. The system design was completed by the installer with input from the client. Blue Diamond Growers' Information Technology department provided appropriate network specifications. The installer indicated that if they were to do anything differently, they would change the mapping of the system. In this context "mapping" refers to the conceptual connectivity and architecture of the control scheme.

6.2.3 Installation

The installer was asked about the ease of the installation of the system, and he indicated it was not difficult. The manufacturer provided installation guidance, and it was helpful to the installer. The installation process met the planned schedule and additional installation training was not necessary.

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.

6.2.4 Assessment Results and Next Steps

According to the respondent, there are no roadblocks to the implementation of the ALC technology. He expects costs to change as more customers and suppliers become aware of the technology. He considers the technology to be ready for utility program implementation, and that hospitals, offices, food processing, and manufacturing are markets that might be ripe for advanced lighting controls.

6.3 INFORMATION TECHNOLOGY (IT) STAFF

The interviewed IT staff person was not previously aware of advanced lighting control technology. In his limited experience, irregular operating hours contribute to the success of the advanced lighting technology in his facility. The IT staff is not aware of any competing technologies in advanced lighting controls.

According to IT, Blue Diamond's engineering department initiated the advanced lighting control project, and the Maintenance and Receiving departments were also involved in the project installation. The IT staff was involved in the installation and planning before the network design was finalized. Prior to finalizing the design, IT had concerns with the security of the ALC system. These concerns were resolved by choosing the design with the least security risk, with input from the contractor, IT, and engineering. Aside from security, no IT barriers had to be overcome before the network design was finalized.

6.3.1 Installation

The IT staff person was involved in the project during the installation process and he mostly worked with the installer on project management. There was a concern during the installation about system integration, but this concern was resolved by the end of installation, and no other IT barriers had to be overcome. The respondent said that it was very important that he be involved in the project during installation.

6.3.2 Operation or Maintenance

The IT staff person is involved in operation and maintenance of the system, including setting lighting schedules, checking controls daily, and coordinating repairs. There are no concerns or barriers regarding the operation and maintenance, and the respondent believes it is very important for him to be involved because he is the most knowledgeable about the equipment and the ALC technology.

6.3.3 Hardware and Software

The IT respondent said there are no concerns regarding the network cabling or Wi-Fi enabled devices integrated into the advanced lighting control system. He was involved in commissioning the system, which took approximately one week.

The IT staff person was provided with training on ALC system software and on the graphical user interface. He is involved in providing user support for the software and interface, and mentioned that the system manufacturers will provide updates and product support moving forward. He has no security concerns with the AutoDR functionality creating a portal to external networks.

6.3.4 Assessment Results and Next Steps

According to IT, a related non-energy benefit with the technology is the integration capability for other applications. He believes there are no roadblocks to implementation of the advanced lighting technology, aside from initial security concerns, and the product is ready for the market.

6.4 CONCLUSIONS

According to occupants, the installer, and the information technology staff, the advanced lighting control system design and installation was a success. There have been very few complaints from occupants and the installer encountered very limited difficulties. All respondents agree that the ALC technology is ready for the market.