Intel Advanced Lighting Controls Project

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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

Although lighting controls have been around for several decades, a recent wave of new technologies offer a whole new level of potential energy savings. Several SMUD research projects resulted in savings levels of 50% to 90% using advanced control strategies and dimmable LED lighting fixtures. However, even though the results were impressive, high implementation costs and long financial return periods were identified as roadblocks to widespread acceptance.

In order to encourage adoption of these technologies, SMUD developed the Advanced Lighting Controls Program using funding from the U.S. Department of Energy (DOE) Smart Grid Investment Grant. The Advanced Lighting Controls (ALC) program offered incentives of up to $100,000 to help SMUD's commercial customers install advanced lighting systems.

Although SMUD's previous research efforts were predominately based upon using LED lighting and controls, the ALC program was designed to accommodate different lighting technologies (e.g. fluorescent, metal-halide, halogen), as long as they met the dimming requirements. 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, like smart phones or wireless computers
- Automated demand response capability

In 2012, the Intel Corporation installed advanced lighting controls on the second floor of one of their buildings in Folsom, California. The project included the installation of dimming ballasts, motion sensors and ambient light sensors (i.e. daylight harvesting) for 1,048 fluorescent lighting fixtures. After the installation was completed, Intel implemented three different phases of control strategies. SMUD hired Nexant Inc. to monitor the energy consumption and calculate the savings for each control phase. The following section includes descriptions of the strategies and results for all three phases of implementation.

Phase 1

Control Strategies:

- Task tuning level set at 80% of maximum output (i.e. reduced by 20%)
- Occupancy sensors activated with delay timers set for 5 minutes for all time periods
- Daylight harvesting feature deactivated

Figure 1-1: Office Lighting Fixtures

Results:

- Total estimated annual energy savings: 80,561 kWh per year (34%)
- Average savings per fixture: 77 kWh per year
- Peak electric demand reduction: 10.7 kW (16%)
- Estimated cost savings: $7,130 per year

Phase 2

Control Strategies:

- Task tuning level set at 70% of maximum output (i.e. reduced 30%)
- Occupancy sensors activated with delay timers set for 5 minutes for all periods
- Daylight harvesting feature deactivated

Results:

- Total estimated annual energy savings: 86,255 kWh per year (37%)
- Average savings per fixture: 82 kWh per year
- Peak electric demand reduction: 12.3 kW (19%)
- Estimated cost savings: $7,634 per year

Phase 3

Control Strategies:

- Task tuning level set at 60% of maximum output (i.e. reduced 40%)
- Occupancy sensors activated with active motion window of 7 minutes during regular working hours and 5 minutes for all other periods
- Daylight harvesting activated for all zones

Financial Summary (Phase 3)

Project Cost: $150,949

SMUD Rebate: $51,490

Net project cost: $99,459

Estimated bill reduction: $10,218

Simple payback: 9.7 yrs.

Results:

- Total estimated annual energy savings: 115,453 kWh per year (49%)
- Average savings per fixture: 110 kWh per year
- Peak electric demand reduction: 20.9 kW (32%)
- Estimated cost savings: $10,218 per year

During the second phase of testing, the savings were lower than expected. After a lot of investigating, the Project Team discovered that the culprit was not the lighting controls – it was the “tried and true” fluorescent ballasts. For years dimming fluorescent ballasts have been used as an effective means to achieve energy savings. Generally speaking, the energy consumption is roughly proportional to the amount of the light produced throughout most of the operating range. However, the ballasts used in this project have a very unusual operating characteristic: they consume about 5% more energy operating at 70% of full output than at 76% (Figure 1-2). This is due to the manufacturer’s method of heating the lamp cathodes while dimming. While at first glance 5% may not seem to be significant, there were over 1,000 ballasts installed at this project site set to operate at 70% of

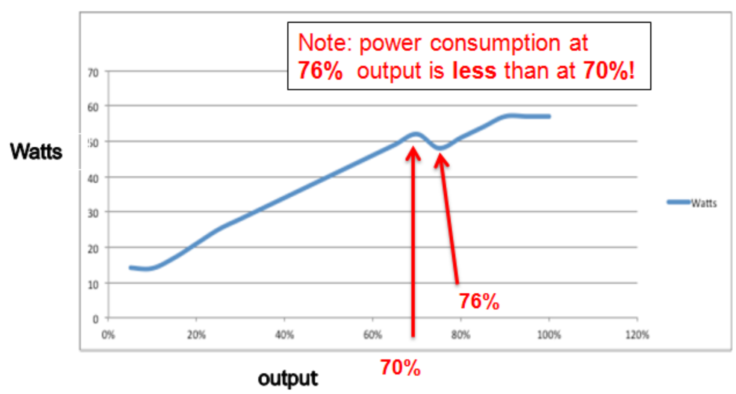

Figure 1-2: Dimming Ballast Performance Curve

maximum output, so a 5% difference translated to a significant amount of lost financial savings. This discovery led to some thought provoking questions: what about other dimming fluorescent ballasts? Do they also have quirks? Since California's newest version of Title 24 Building Energy Efficiency Standards (effective January 2014) will require the majority of new commercial interior lighting systems to be dimmable, SMUD hired a consultant to conduct a market survey of the most prominent dimming ballasts designed to operate 4 foot T8 fluorescent lamps. The findings, which are available via the Customer Advanced Technologies Program web page, should serve as a wake-up call for electrical contractors and the rest of the lighting controls industry, to pay close attention to the performance curves for dimmable fluorescent ballasts. The Dimming Ballast report may be downloaded at https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm.

Conclusion

Overall the results of this project were favorable with significant energy savings. However, since the original lighting system was already relatively energy efficient, the financial payback was long (9.7 years). This will most likely be unacceptable for most commercial customers in areas with low electric rates (e.g. SMUD's service territory). For now, the most promising applications for advanced lighting controls appear to be in manufacturing, data centers and warehouses.

Acknowledgements

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

- Susan Kortick (Intel)
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- Amandeep Singh (Nexant)
- Connie Samla (SMUD)
- Mike Moreno (SMUD)
- Dave Bisbee (SMUD)

2 INTRODUCTION

2.1 TECHNOLOGY DESCRIPTION

Intel chose to install Enlighted's digital networking technology and dimmable fluorescent ballasts. This new system offers the following capabilities:

- Task Tuning: Allows end users to adjust the lighting levels according to their needs and 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 lamp and ballast; 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.

Enlighted's system consists of multifunction sensors, controllers, servers (aka Energy Manager), gateways and user friendly software. The sensors are connected to the lighting controllers within each light fixture via a low voltage cable (Figure 2-1), and are used to detect occupancy, ambient light, and temperature. The sensors also collect energy consumption data and communicate via wireless technology to the Enlighted Gateways.

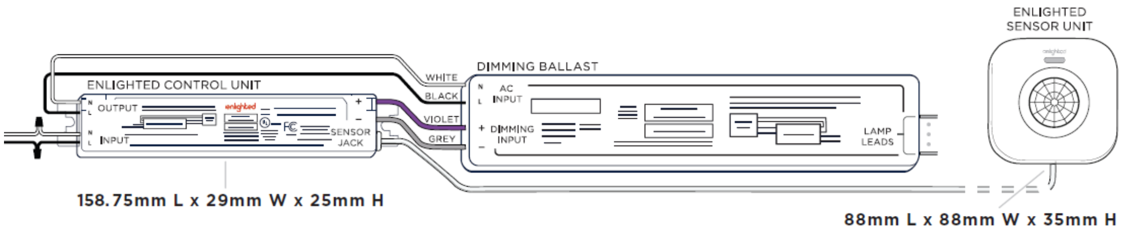


Figure 2-1: Wiring Diagram for an Enlighted Sensor Connected to a Dimming Fluorescent Ballast. Source: www.enlightedinc.com

Finally, the Enlighted Gateways (Figure 2-2) relay this information to a server-type device called the Enlighted Energy Manager (Figure 2-3). The entire system is controlled by user friendly software which enables end users to adjust schedules, task tuning levels and motion sensor settings from any Web enabled device (e.g. smart phones, tablets, laptops, desktop computers). A diagram showing a typical commercial building installation is shown in Figure 2-4 below.

Figure 2-2: Enlighted Gateway

Source: www.enlightedinc.com

Figure 2-3: Enlighted Energy Manager

Source: www.enlightedinc.com

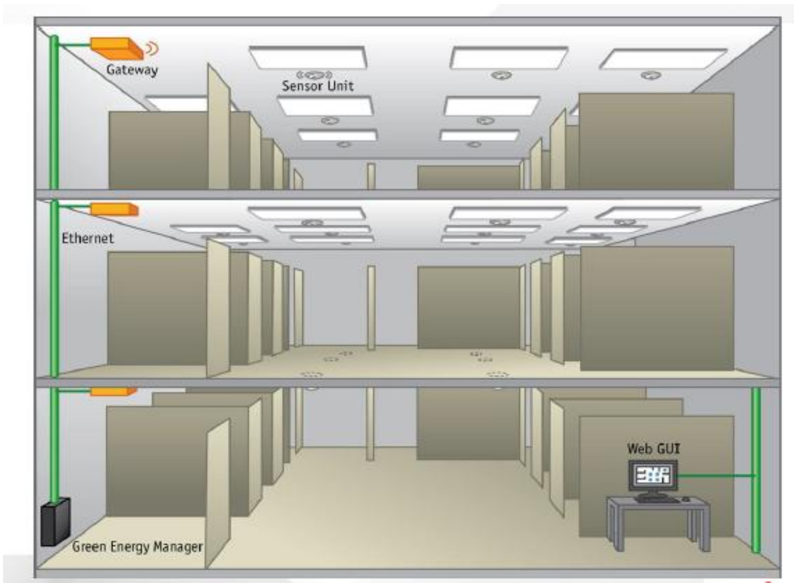


Figure 2-4: Typical Enlighted Installation for a Commercial Building. Source: www.enlightedinc.com

2.2 PROJECT DESCRIPTION

Project Location: Intel Corporation, Folsom Campus
1900 Prairie City Rd.
Folsom, CA 95630

Intel was founded in 1968 and is now the world's largest semiconductor chip maker. Their sprawling facility in Folsom includes over 1.6 million square feet of office and manufacturing space. In 2012, Intel decided to participate in SMUD's Advanced Lighting Controls Program. The project included installation of Enlighted's lighting control system and dimming ballasts on the second floor of Building FM3. The area chosen for the project consisted of 80,000 square feet of open office space (Figures 2-5 and 2-6 below).

Figure 2-5: Intel FM3 Building, Second Floor

Figure 2-6: Intel FM3 Building, Exterior View

Original Lighting System

The original lighting system for the second floor of FM3 consisted of two-lamp, 32-Watt, T8 fluorescent parabolic lighting fixtures for the open offices (Figure 2-7); CFLs for common areas, collaboration rooms, and phone booths; and three-lamp, 32-Watt, T8 fluorescent fixtures for conference and training rooms. Only the two-lamp fixtures in the open office area were included in this project (total of 1,048 fixtures). The open office lights were controlled by a sweep timer; there were no occupancy or daylight harvesting controls.

Figure 2-7: Two-Lamp, T8 Fluorescent Parabolic Lighting Fixture

New Lighting System

The new lighting system included the following:

- Full range dimming fluorescent ballasts (100 - 3%) designed to work with 0-10V controllers.
- New four-foot T8 fluorescent lamps and lamp holders (aka tombstones).
- Enlighted digital network technology with a Web enabled Graphical User Interface to remotely control the lights and track lighting system energy consumption.
- Installation of multi-function Enlighted sensors, lighting controllers, gateways and an Enlighted Energy Manager.
- Multiple control strategies including task tuning, scheduling, occupancy sensors and daylight harvesting. Please see Section 3: Monitoring for more information.

2.3 STUDY OBJECTIVES

The primary objective of this study was to determine energy and demand savings resulting from the installation of advanced lighting control technologies at Intel's FM3 building. A secondary objective was to validate various methodologies, energy saving algorithms, and calculations performed in the SMUD spreadsheet. 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?

3 MONITORING

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

- After careful review of the lighting systems, circuit diagrams and panel schedules, fixtures were selected for monitoring. Since the number of lighting branch circuits was relatively small, all of them were monitored. This provided a confidence level of 90/10 according to the International Performance Measurement and Verification Protocol (IPMVP) and California Energy Efficiency Evaluation protocols. This 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 3-1) to record data at five-minute intervals for about two weeks before and after the lighting upgrade. The data was downloaded from the loggers and analyzed to calculate the baseline energy consumption and savings.

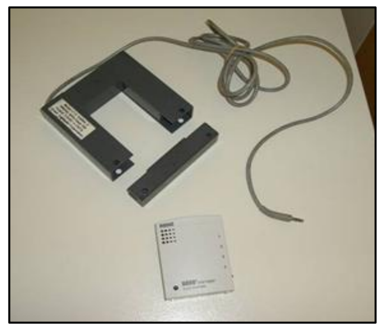


Figure 3-1: Hobo Logger and Current Transducer (CT)

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

- Illumination measurements were performed 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.

- On/off light loggers (Hobo model H06-002-02) were installed to determine the lighting operating hours for approximately three weeks.

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 three post installation periods (aka phases) with different control settings. The dates for each monitoring period are presented in the Appendix section of this report (Figure 6-1). Monitoring was completed for each of the following scenarios:

1. Baseline: lighting fixtures without dimming ballasts and occupancy sensors

2. Post-installation Phase 1: Enlighted control system activated with the following settings:

    - Task tuning set at 80% (lights dimmed by 20%)
    - Occupancy sensors activated with delay timers set for 5 minutes during all periods
    - Daylight harvesting feature deactivated

3. Post-installation Phase 2: Enlighted control system activated with the following settings:

    - Task tuning at 70% (lights dimmed by 30%)
    - Occupancy sensors activated with delay timers set for 5 minutes during all periods
    - Daylight harvesting feature deactivated

4. Post-installation Phase 3: Enlighted control system activated with the following settings:

    - Task tuning at 60% (lights dimmed by 40%)
    - Occupancy sensors activated with delay timers set for 7 minutes during working hours and 5 minutes for all other periods
    - Daylight harvesting activated for all zones

The monitoring parameters, logger type, type of measurements, and measurement units are presented in the Appendix section of this report (Figure 6-2).

4 RESULTS

4.1 RESULTS

As described earlier, this project included a pre-installation baseline period and three distinct phases of implemented control strategies. A combination of continuous monitoring and spot power measurements was used to evaluate the results for each phase.

This section also includes illumination measurements taken before and after the lighting upgrade, and a comparison of the monitoring data verses SMUD's spreadsheet calculations and Enlighted's software trend data.

4.1.1 Pre-Installation Baseline

Four external channel and current transformers 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. The majority of the lighting fixtures in FM3 were found to be on from 7 am to 7 pm and off during weekends and holidays. Total annual operating hours were estimated to be 3,259 hours per year. The annual lighting energy consumption was estimated at 234,300 kWh per year.

4.1.2 Post-Installation New Lighting Controls in Phase 1

After the dimming ballasts and lighting controls were installed, the motion sensor feature was activated with a time delay of 5 minutes for all periods. The task tuning level was set for 80% of maximum output (i.e. dimmed by 20%) and the daylight harvesting feature was not activated. The average weekday lighting load profiles for the baseline and all three phases are shown in Figure 4-1. Implementation of the Phase 1 control strategies reduced the lighting load by 10.7 kW (16%) and resulted in estimated annual electricity savings of 80,561 kWh (34%) as shown in Figure 4-2 and Figure 4-3.

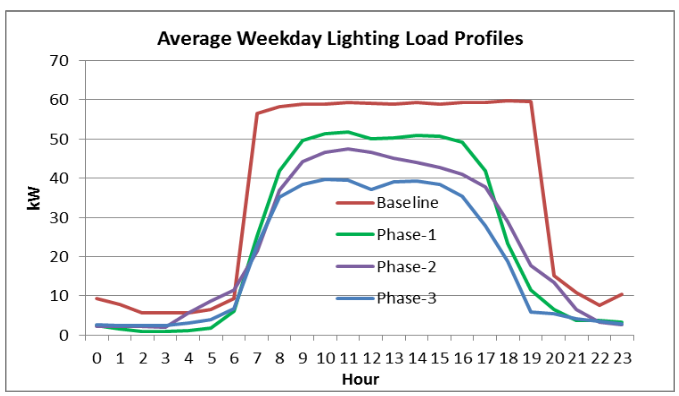
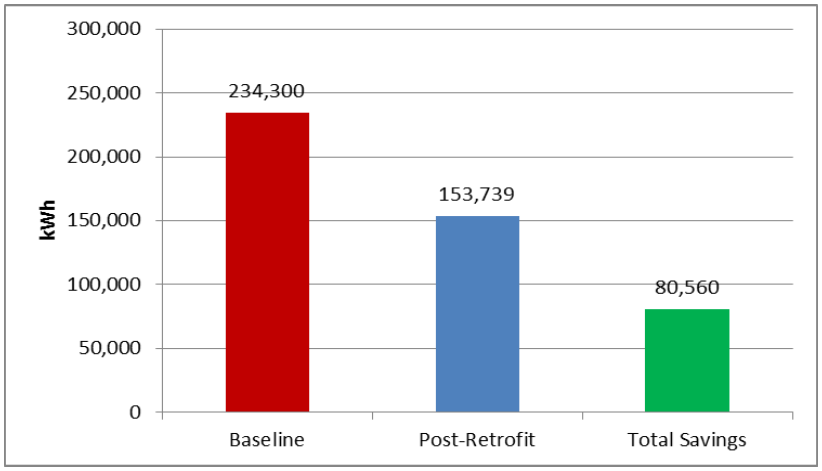


Figure 4-1: Average Weekday Lighting Load Profiles

Figure 4-2: Phase 1 Energy Consumption and Savings Summary

Period	Energy Consumption (kWh / year)	Max Demand (kW)	Energy Cost ($ per Year)
Baseline	234,300	65.5	$20,736
Post-Retrofit	153,739	54.8	$13,606
Total Savings	80,561	10.7	$7,130

Figure 4-3: Monitored Energy Consumption and Savings for Phase 1



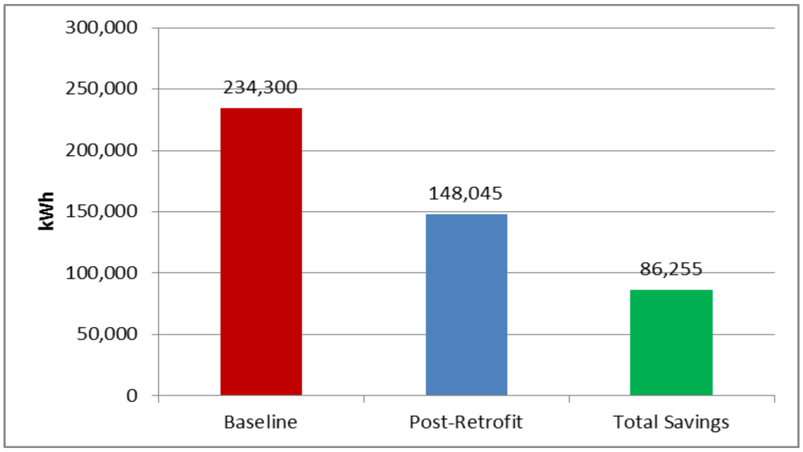
4.1.3 Post-Installation New Lighting Controls in Phase 2

During Phase 2, the task tuning levels were reduced to 70% (10% lower than Phase 1) and the motion sensors were activated with a five minute time delay for all periods. The daylight harvesting feature was deactivated. Based on the monitored data, this control strategy reduced the lighting load by 12.3 kW (19%) and saved an estimated 86,255 kWh per year (37%). The calculated annual energy consumption and savings for Phase 2 are shown in Figure 4-4 and Figure 4-5.

Period	Energy Consumption (kWh / year)	Max Demand (kW)	Energy Cost ($ per Year)
Baseline	234,300	65.5	$20,736
Post-Retrofit	148,045	53.2	$13,102
Total Savings	86,255	12.3	$7,634

Figure 4-4: Phase 2 Energy Consumption and Savings Summary

Figure 4-5: Monitored Energy Consumption and Savings for Phase 2



Although the task tuning levels for Phase 2 were 10% lower than Phase 1 (70% vs. 80%) the result was only a 3% increase in savings. These results were unexpected and disappointing. A subsequent investigation by the project team discovered the cause was the performance of the ballast used for this project. When the control strategy for Phase 2 was developed, the team was unaware of the performance curve of these particular dimming ballasts. As illustrated in Figure 4-6, this ballast consumes nearly the same amount of power at the 70% level as the 80% level, due to the heating of fluorescent lamp cathodes. In order for fluorescent lamps to operate properly while being dimmed, the lamp cathodes must be heated. While some ballast manufacturers choose to use a continuous heating strategy, this ballast switches from a low heating mode to a high mode at approximately 70% of maximum output. This is what caused the lower than expected savings during Phase 2.

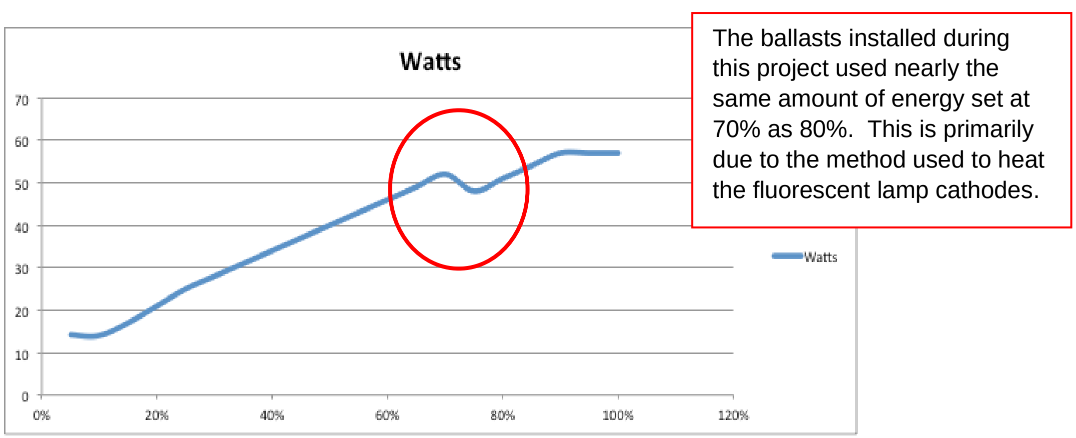


Figure 4-6: Performance Curve for 0-10V Dimming Ballast Used in Project

4.1.4 Post-Installation New Lighting Controls in Phase 3

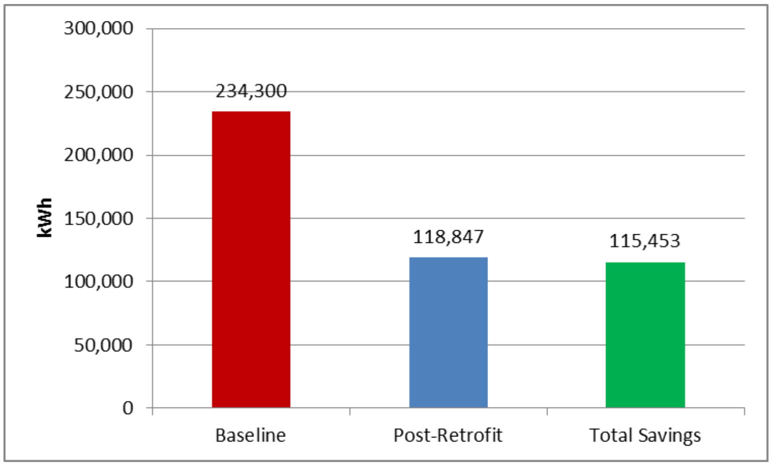
During Phase 3, the task tuning levels were set at 60% (dimmed by 40%) and the motion sensors were activated with time delay settings of 7 minutes during regular working hours and 5 minutes for all other periods. The daylight harvesting feature was also activated. Based on the monitored data, these settings reduced the lighting load by 20.9 kW (32%) and saved an estimated 115,453 kWh per year (49%).

A summary of annual energy consumption and savings for Phase 3 are shown in Figure 4-7 and Figure 4-8. The daylight harvesting feature did not really contribute to the savings since the aggressive task tuning settings had already dimmed the fixtures to the lowest acceptable illumination levels. Although the average illumination levels were reduced by approximately 33%, surveyed employees preferred the lower light levels.

Figure 4-7: Phase 3 Energy Consumption and Savings Summary

Period	Energy Consumption (kWh / year)	Max Demand (kW)	Energy Cost ($ per Year)
Baseline	234,300	65.5	$20,736
Post-Retrofit	118,847	44.6	$10,518
Total Savings	115,453	20.9	$10,218

Figure 4-8: Monitored Energy Consumption and Savings for Phase 3



A comparison of energy savings for all three phases is shown below in Figure 4-9. Please note: although three scenarios are shown, the project cost was $150,949 and the SMUD incentive (a.k.a. rebate) was $51,490.

Figure 4-9: Savings Summary Based Upon Monitoring Data

Phase	Savings			Payback Period	
	kWh/year	%	Energy Cost	Simple	With Rebate
Phase 1	80,561	34%	$7,130	21.2	13.9
Phase 2	86,255	37%	$7,634	19.8	13.0
Phase 3	115,453	49%	$10,218	14.8	9.7

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

SMUD's Advanced Lighting Controls 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 provided by the installation contractor and reviewed by SMUD's ALC Program Manager. The scope of this evaluation report included a comparison of the calculated spreadsheet savings, the end-use monitored data and Enlighted's software.

4.2.1 Spreadsheet Calculations

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

Existing Lighting System

Wattage of 2-lamp T8 fixtures: 62 Watts

Fixture Quantity: 1,048 fixtures

Existing Lighting Operational Hours: 4,500 hours per year

Demand of Existing Lighting: (1,048 x 62 Watts) ÷ 1,000 Watts / kW = 64.976 kW

Annual Energy Consumption: 64.976 kW x 4,500 hrs/year = 292,392 kWh/year

Lighting System Savings

Task Tuning

Electrical Demand[1]: (1,048 fixtures x 62W x 0.70) ÷ 1,000 W / kW = 45.483 kW

Electrical Demand Savings: 64.976 kW - 45.483 kW = 19.493 kW

Energy Savings: 19.493 kW x 4,500 hrs/year = 87,719 kWh/year

(1) Task tuning assumption: 30% power reduction at 70% set point

Task Tuning + Occupancy Sensors[2]

Energy Consumption: $\frac{(1{,}048 \text{ fixtures} \times 62\text{W} \times 0.70 \times 0.59 \times 4{,}500 \text{ hrs})}{1{,}000 \text{ Watts / kW}} = 120{,}758 \text{ kWh}$

Energy Savings: 292,392 kWh/year - 120,758 kWh/year = 171,634 kWh/year

Financial Summary

Project Cost:	$150,949
SMUD Incentive:	$51,490
Energy Cost Savings:	$16,151
Simple Payback:	6.2 years

4.2.2 Control Software Calculations

Enlighted's software has the capability of tracking the real-time status of every lighting fixture controlled by the system; whether the lights are on, off, or dimmed (and if dimmed, the dimming level). The system can also detect whether areas are occupied or unoccupied via the motion sensors, and measure the energy consumption of each lighting fixture using a power measurement computer chip embedded in Enlighted's controllers.

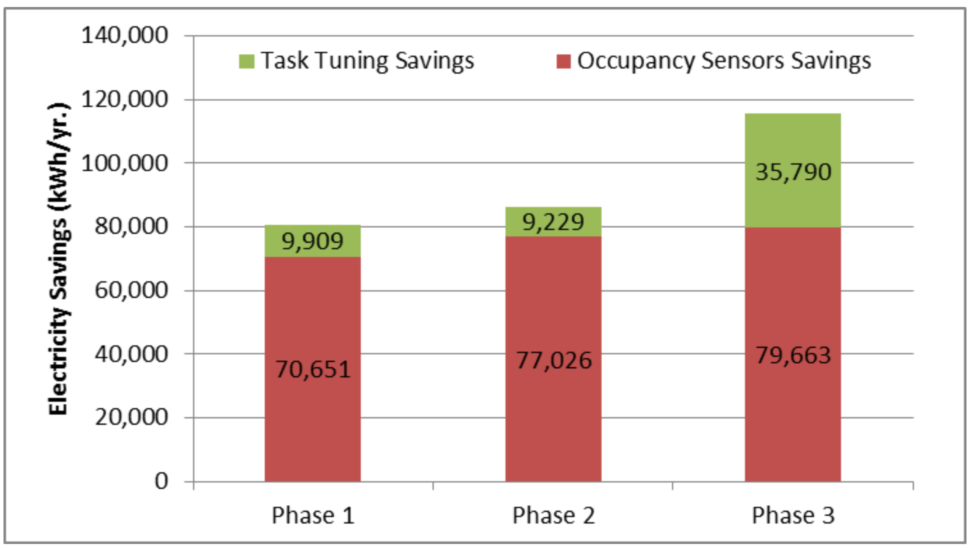
Enlighted's system also has capability to trend the history of power demand and disaggregate savings produced by different control strategies (i.e. task tuning, motion sensors, and daylight harvesting). Enlighted Inc. provided trend data for all three post-installation phases.

Although Enlighted'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 in order to calculate energy and costs savings. Since all of the original lighting fixtures in this project were the same type and operated under the same schedule, establishing the baseline was a relatively simple task. The data provided by Enlighted was used to calculate the disaggregated energy savings shown in Figure 4-10 and Figure 4-11.

Figure 4-10: Disaggregated Energy Savings for All Three Phases

Phase	Task Tuning (%)	Occupancy Sensors (%)	Task Tuning (kWh/year)	Occupancy Sensors (kWh/year)	Total Savings (kWh/year)
Phase 1	12.3%	87.7%	9,909	70,651	80,560
Phase 2	10.7%	89.3%	9,229	77,026	86,255
Phase 3	31.0%	69.0%	35,790	79,663	115,453

Figure 4-11: Bar Graph of Disaggregated Energy Savings for All Three Phases



4.2.3 Methodology Comparison Results

Figure 4-12 shows a comparison of results among the calculation methodologies. The savings calculated by the control software are about 33% less than the calculated spreadsheet savings. This was primarily due to the fact that the operating hours used in the spreadsheet were higher than the actual hours.

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

Figure 4-12: Energy Savings Comparison for Various Methodologies

Period	Baseline Consumption and Energy Savings (kWh/year)		
	Monitored Data	Enlighted	Spreadsheet
Baseline	234,300	234,300	292,392
Phase 1	80,561 (34%)	82,523 (35%)	N/A
Phase 2	86,255 (36%)	86,672 (37%)	N/A
Phase 3*	115,453 (49%)	116,320 (50%)	171,634 (59%)**

* Expected savings resulting from task tuning, motion sensor, and daylight harvesting features

** Calculations were based on task tuning, motion sensor, and daylight harvesting features

4.3 ILLUMINATION RESULTS

The illumination levels were measured before the lighting upgrade and during each phase of the project. These readings were taken at the desk level (approximately 30 inches above the floor) with an EXTECH model # 401027 light meter (Figure 4-13). The meter was calibrated on August 13, 2012. Each of the measurement locations were marked to ensure consistency. Some observations:

- Phase 1: Task tuning level set for 80%. Average illumination level: 42.8 fc (7.6% lower than the pre-installation baseline).

- Phase 2: Task tuning level set for 70%. Average illumination level: 40.8 fc (11.9% lower than the pre-installation baseline).

- Phase 3: Task tuning level set for 60%. Average illumination level: 31.1 fc (32.8% lower than the pre-installation baseline).

Although the illumination levels under Phase 3 were noticeably lower than the baseline, surveyed employees in these work areas preferred the new light levels. This makes sense considering these employees spend the majority of their time working on desktop computers and many people do not like the intensity or lighting quality produced by parabolic fluorescent troffers similar to the fixtures used in Intel's FM3 building.

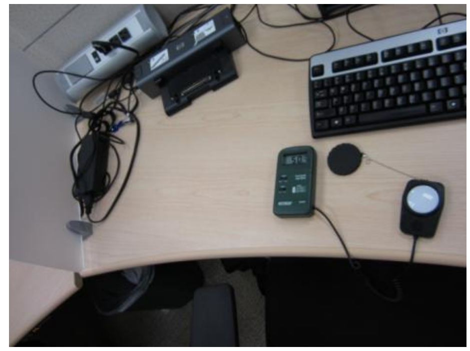


Figure 4-13: EXTECH Light Meter

5 SUMMARY OF FINDINGS

5.1 SUMMARY OF FINDINGS

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

5.1.1 Monitoring Results

Figure 5-1 below shows the energy savings (kWh), electrical demand savings (kW) and the average illumination levels for the pre-installation baseline and all three control phases for this project. Comments:

- Energy and demand savings for Phase 2 were lower than expected due to the performance characteristics of the dimming fluorescent ballasts used in this project. According to information provided by the ballast manufacturer, this particular model consumes as much power at 70% dim level as it does at 80%, due to the method used to heat the fluorescent lamp cathodes during dimming.

- During Phase 3, the average Illumination level was 31.1 fc (32.8% lower than the pre-installation baseline). However, employees indicated that the new illumination levels were preferable to the original levels.

Figure 5-1: Summary of Monitoring Results

Period	Electrical Energy			Electrical Demand			Lighting Levels	
	Consumption (kWh/year)	Savings (kWh / year)	% savings	kW	kW Savings	% savings	Avg. Illumination level (fc)	% Change
Baseline	234,300	n/a	n/a	65.5	n/a	n/a	46.3	n/a
Phase 1	153,739	80,561	34.4%	54.8	10.7	16.3%	42.8	-7.6%
Phase 2	148,045	86,255	36.8%	53.2	12.3	18.8%	40.8	-11.9%
Phase 3	118,847	115,453	49.3%	44.6	20.9	31.9%	31.1	-32.8%

5.1.2 Enlighted Software / SMUD Spreadsheet Calculations

- The calculated energy savings from SMUD's spreadsheet were 33% higher than the monitoring data and Enlighted's software. This was primarily due to the assumed baseline operating hours used in the spreadsheet, which were longer than the actual.
- Savings calculated by Enlighted's software are comparable with results obtained from monitored data. This is very good news since SMUD and other utilities are considering using the energy tracking capabilities of Enlighted and other advanced lighting control systems for future energy efficiency incentive programs.

5.1.3 Financial Summary

- Project Cost: $150,949
- SMUD Rebate: $51,490
- Net project cost: $99,459
- Estimated annual bill reduction: $10,218
- Simple payback: 9.7 years

5.1.4 Conclusion

Overall the results of this project were favorable with significant energy savings. However, since the original lighting system (T8 fluorescent lamps, electronic ballasts, sweep timer controls) was already fairly energy efficient, the simple financial payback was rather long (9.7 years). Since potential economic benefits continue to be a major decision factor for most commercial customers, retrofitting existing office buildings with advanced lighting controls may be a tough sell. For now, the most promising applications may be manufacturing, data centers, warehouses and new commercial office buildings.

6 APPENDIX

Figure 6-1: Dates for Pre and Post Installation Monitoring Periods

ID	Task Name	Start Date	End Date
1	Logger Installation/Spot Measurements (pre-installation)	5/30/2012	5/30/2012
2	Continuous Monitoring (pre-installation)	5/30/2012	6/14/2012
3	Logger Removal	6/14/2012	6/14/2012
4	Logger Installation/Spot Measurements (post-installation)	10/18/2012	10/18/2012
5	Continuous Monitoring (post-installation –Phase 1)	10/25/2012	11/08/2012
5	Continuous Monitoring (post-installation – Phase 2)	11/09/2012	1/10/2013
6	Continuous Monitoring (new baseline)	1/14/2013	1/21/2013
7	Logger Removal	1/21/2013	1/21/2013
8	Logger Installation/Spot Measurements (phase 3)	06/20/2013	06/20/2013
9	Continuous Monitoring (post-installation – Phase 3)	06/20/2013	07/16/2013
10	Logger Removal	07/16/2013	07/16/2013

Figure 6-2: 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) & 13 (Post)	Hobo 4 ext. channel logger with CTs	Amps	A
3	Lights	1	EXOTECH Light Meter	Footcandles	fc
4	Lights	24	Hobo Intensity Loggers	Lumens	lm
5	Lights	22	Hobo Light On/Off Loggers	Status	On/Off