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REPORT

FINAL REPORT

E3T Emerging Technology Assessment

Bi-Level Office Lighting with Occupancy Sensors

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Contents

Preface

This report is the result of a technology assessment project performed as a part of the Energy Efficiency Emerging Technologies (E3T) program administered by the Bonneville Power Administration (BPA). Through E3T, BPA seeks to lead the Pacific Northwest's identification, assessment and dissemination of innovative, highly-valued, energy-efficient emerging electrical end-use technologies and strategies in order to increase the scope, impact and stakeholder satisfaction with regional energy efficiency programs.

The Washington State University Extension Energy Program (WSU Energy Program), under contract to BPA, conducted an assessment of an emerging technology at a project host site, the County-City Building located in Tacoma, Washington. The purpose of this project is to assist BPA with the evaluation of bi-level switching of office lighting with occupancy sensor control in individual offices.

The WSU Energy Program prepared this report for BPA as a contractor under the E3T Program. The Project Manager for this project and author of this report is Mary Matteson Bryan, P.E., under contract to the WSU Energy Program. Jack Zeiger, Doug Koenen, and Cindy Wills of the WSU Energy Program coordinated and performed monitoring and data collection. Cori Jackson and Pedram Arani of the California Lighting Technology Center (CLTC) developed the experimental design and procedure and assisted in implementation of field monitoring. This report was reviewed for technical quality by Cori Jackson, as well as by Rob Penney and Jack Zeiger of the WSU Energy Program. The report was edited and produced by Shelley Kirk-Rudeen and graphics support was provided by Gerry Rasmussen, both of the WSU Energy Program.

Acknowledgements

The Washington State University Extension Energy Program gratefully acknowledges the Bonneville Power Administration for their direction and assistance, and Pierce County for their participation and support of this project.

Executive Summary

Background

This report summarizes an assessment project conducted to evaluate bi-level switching with occupancy sensors for lighting in individual offices. This emerging technology assessment study was designed to investigate the potential energy savings and economic performance of bi-level switching with occupancy sensors compared to the baseline single-level manual switching.

The facility selected for this assessment is the 11-story County-City building in Tacoma, Washington. The baseline for this study consisted of 30 individual offices with single-level manual switching of recessed T8 fluorescent office lighting. Each of the offices was retrofitted with bi-level switching with occupancy sensor control and bi-level ballasts.

The bi-level switches and occupancy sensors can be configured to provide various operational scenarios, each providing a different way for occupants to control the lights. This assessment investigated the energy savings potential of each of the following three scenarios:

1. Auto-on at 50%, auto-off: Lights are switched on automatically at the low level (50%) upon occupancy, the remaining lights can be switched on manually, all lights can be switched off manually, and lights are turned off automatically after the office is unoccupied for a period of time.
2. Auto-on at 100%, auto-off: Lights are switched on automatically at the high level (100%) upon occupancy, lights can be switched to a lower light level (50%) or all off manually, and lights are turned off automatically after the office is unoccupied for a period of time.
3. Manual-on, auto-off: Lights can be switched on and off manually at 50% or 100%, and lights are turned off automatically after the office is unoccupied for a period of time.

After monitoring existing lighting usage including task lighting for three weeks to establish a baseline, each office was retrofit with the new lighting systems and monitored for successive three-week periods in each of the three scenarios listed above. Data collected included the time of occupancy and the time the lighting level was on high (100%), low (50%), and off to determine which default setting resulted in the least energy usage.

Results

The assessment results demonstrate that lighting energy savings can be achieved through the use of bi-level switching. However, energy savings can vary depending on the operational setting for the occupancy sensors.

1. Auto-on at 50%, auto-off: energy savings were 37% in a retrofit case and 33% in a new construction case. Savings in new construction is lower because the baseline assumes new code-compliant single-level lighting with occupancy sensors.
2. Auto-on at 100%, auto-off: energy savings were 12% in a retrofit case and 5% in a new construction case.
3. Manual-on, auto-off: energy savings were 26% in a retrofit case and 13% in a new construction case.

Bi-level switching in individual offices can deliver significant savings compared to single-level switching. Of significant note, operation of the bi-level switches using the auto-on at 50% setting provides the highest level of savings. When promoting bi-level switching, it will be important to educate users that energy savings are highly dependent on the operational setting used. Use of the auto-on at 50% setting should be strongly encouraged, if not required.

The assessment results suggest that inertia plays a significant role in lighting operation for individual offices. When the bi-level switches are set to turn on the lights automatically, occupants most often leave the lights operating at the preset level, and do not make the effort to switch to a different level.

In general, occupants reported high satisfaction with the bi-level switches. They stated a clear preference for the auto-on at 50% setting, and this setting also provides the highest energy savings. Since most office workers now tend to work on computers a large proportion of the time, lower light levels are required than in the past. The post-assessment occupant survey indicated that a strong majority of the occupants preferred the lower light. In fact, 64% of the occupants chose the auto-on 50% scenario as their preferred default setting.

The maintenance staff reported that all of the equipment (wall switch sensors, ceiling sensors, and bi-level ballasts) was easy to install and commission. Staff reported that it was easy to set the occupancy sensors and bi-level switches for proper operation and that manuals and installation instructions were clear.

For this assessment, the payback periods for a new construction case are much shorter than for retrofit applications because of the relatively small incremental cost. Depending on the method of implementation used, the payback period can range from about nine years for a small office with a bi-level ballast included to about two years for a small office using bi-level wiring of fixtures or lamps and one year for large offices. As such, this technology may be of particular interest for inclusion in energy efficiency building codes.

The payback periods for retrofit to bi-level switching in individual offices are long, on the order of 30 to 40 years. However, the payback periods would be shorter where lighting hours are longer and installation costs are lower. As use of this technology becomes more common and as crews become more familiar with installation, material and labor costs are likely to decline. Available energy efficiency incentives and tax credits could also lower the installation cost. With favorable, but plausible, assumptions for longer lighting hours, lower installed costs, and factoring in the existing BPA incentive, the payback period could be on the order of 20 years. Utility incentives can help reduce payback periods further.

Project Background

The primary goal of BPA's Energy Efficiency Emerging Technologies (E3T) program is to engage in an ongoing collaborative effort to "fill the pipeline" of Northwest utility conservation program incentivized measures with innovative energy efficiency technologies and strategies that promise significant region-wide energy savings. Field assessments such as this report serve to measure, verify, analyze, and document the potential energy savings and electric demand reduction of specific technologies and strategies. In addition, field assessments examine market acceptance, potential obstacles, and application guidelines in different market segments.

The California Lighting Technology Center (CLTC) is a collaborative partner with the E3T program. The CLTC's mission is to stimulate the development and application of energy efficient lighting by conducting technology development and demonstrations, outreach and educational activities, in partnership with lighting manufacturers, lighting professionals, the electric utility community, and governmental agencies. The CLTC has long promoted the broad strategy of "adaptive lighting," in which unneeded lighting is minimized by utilizing bi-level lighting, occupancy sensors, and daylighting controls in applications with limited occupancy. The CLTC has been quite successful in assessing and promoting adaptive lighting in California, particularly to colleges and universities. By collaborating with the CLTC, the E3T program intends to build on their expertise and experience with emerging lighting technologies.

Project Overview

Office lighting has typically been controlled through the use of manual switches or occupancy sensors that switch on and off all of the lighting in the office. Incorporating bi-level switching with occupancy sensors would allow occupants to select from multiple levels of lighting (high, low, off).

Previous Study Results

Previous studies[1,2] by the CLTC and others have indicated that, with the option of bi-level switching, occupants often accept the lower light level. As a result of these choices, lighting energy use can be reduced. The CLTC study was conducted in eight private offices located at the University of California, Davis at the Office of Research. In this study, the reasons for choosing lower light levels reflected personal preference and included the availability of daylighting and a preference for less ambient light with the frequent use of computers. In addition, the study postulated that inertia may play a part. e.g., when entering an office with a 50% light level, the occupant may not bother turning on the additional lighting. The CLTC study found energy savings of 52% for the auto-on at 50% setting, 34% for the auto-on at 100% setting, and 46% for the manual-on setting.

[1] "Bi-Level Switching in Office Spaces," February 2010, California Lighting Technology Center

[2] "The Usefulness of Bi-Level Switching," Revised: August 1999, Building Technologies Department, Lawrence Berkeley National Laboratory

Technology and Market Overview

Mention of specific manufacturers in this report is not an endorsement of particular products. The type of control equipment analyzed in this field assessment is available from a number of different manufacturers and readers are advised to review various alternatives.

Bi-level lighting with occupancy sensing can be achieved through installation of a wall switch that provides both bi-level switching and occupancy sensing, such as the WattStopper DW-200. Other control system manufacturers such as Hubbell, Leviton, Lightolier, and Sensor Switch, provide similar products.

Figure 1. Examples of Bi-level Lighting Switches with Occupancy Sensors
From Left to Right: Leviton ODSOD-ID; Sensor Switch WSD PDT 2P Bi-level Wall Switch

In larger offices, a wall occupancy sensor might not provide adequate coverage to detect motion throughout the office. In these situations, a system that incorporates a ceiling-mounted occupancy sensor with a separate bi-level wall switch is needed. The control system manufacturers noted previously provide these systems.

The automatic bi-level wall switches turn lighting on and off based on occupancy. These switches contain two relays for controlling two independent lighting loads or circuits. This provides high/low switching where the occupant can choose the desired light level: low or high. After a period of time when no occupancy is detected, lighting automatically switches off. Occupants also have the option of manually switching the lights off or on.

Typically, these switches can be set to provide various operational scenarios, each providing a different way for occupants to control the lights. This assessment investigated the energy savings potential of each of the following three scenarios:

1. **Auto-on at 50%, auto-off:** Lights are switched on automatically at the low level (50%) upon occupancy, the remaining lights can be switched on manually, all lights can be switched off manually, and lights are turned off automatically after the office is unoccupied for a period of time.
2. **Auto-on at 100%, auto-off:** Lights are switched on automatically at the high level (100%) upon occupancy, lights can be switched to a lower light level (50%) or all off

manually, and lights are turned off automatically after the office is unoccupied for a period of time.

3. **Manual-on, auto-off:** Lights can be switched on and off manually at 50% or 100%, and lights are turned off automatically after the office is unoccupied for a period of time.

These three bi-level operating scenarios are referred to by the following shortened names throughout the remainder of the report.

1. Auto-on 50%
2. Auto-on 100%
3. Manual-on

A previous study[3] performed by the CLTC in offices on the University of California at Davis campus showed that lighting use varies depending on the operational scenario of the switches. The CLTC study indicated that lighting energy use is minimized, and energy savings maximized, with the switches adjusted for the auto-on at 50%. Lighting energy consumption was greatest with the auto-on at 100% setting. One of the goals of this assessment is to validate these findings.

When retrofitting an existing office from single-level switching to bi-level switching, rewiring is required. Retrofit of the ballasts is sometimes desired, but is not required. Typically, there are three alternatives to achieve bi-level lighting.

1. **Install new bi-level ballasts:** The bi-level switch can be wired to new bi-level ballasts in each luminaire. Bi-level ballasts are available that operate at 50% and 100% power levels. These ballasts have two line inputs that can be connected to the two relays of the bi-level switch. When one relay is engaged, the lights operate at 50% power. When both relays are engaged, the lamps operate at full power.
2. **Rewire existing ballasts, switch alternate luminaires:** The bi-level switch can be wired to existing ballasts so that one relay operates half of the luminaires in the office, while the second relay operates the remaining luminaires.
3. **Rewire existing ballasts, tandem wiring:** The bi-level switch can be wired to existing ballasts so that one relay operates half of the lamps in all of the luminaires in the office, while the second relay operates the remaining lamps in all of the luminaires.

The preferred method for a particular installation will depend on a number of factors, including the existing lighting configuration, desired lighting uniformity, and project cost. For instance, installing new bi-level ballasts will provide the same level of lighting uniformity as the existing lighting system, while rewiring the existing ballasts to switch alternate luminaires may result in less uniform lighting. In addition, the cost of each alternative will be different. While the bi-level ballast alternative will include the cost of a new ballast, it may be a simpler installation than the other options, requiring less labor cost.

Many of these switches have optional automatic daylighting control to further limit lighting use. The scope of this assessment included only potential savings from bi-level switching and occupancy sensors, so the daylighting control feature was not evaluated.

[3] "Bi-Level Switching in Office Spaces," February 2010, California Lighting Technology Center

Project Objectives

1. Quantify potential energy savings. This study incorporated on-site measurement to determine the level of energy savings available from replacing the baseline manual switching with bi-level switching and occupancy sensor control under various operational settings.

2. Develop an economic analysis. Using measured energy savings and actual incremental costs, the cost effectiveness of bi-level switching and occupancy sensor control was determined using an analysis of simple payback period.

3. Solicit occupant feedback regarding the project implementation and level of satisfaction with the new lighting system. A printed survey was developed and distributed to assess the occupants' satisfaction with the new lighting systems.

Methodology

Host Site Information

The facility selected for this assessment is the County-City building in Tacoma, Washington. The building is an 11-story office tower that houses City of Tacoma and Pierce County services and administrative functions such as courts, councils, and law enforcement (see Figure 2).

Thirty (30) individual offices were selected for the study. The offices were selected randomly to provide a mix of interior and exterior offices with various orientations and a mix of occupants, including executive, mid-level and support staff. The majority of the offices are approximately 120-130 square feet, with a few that are larger, up to 350 square feet. Many of the offices have significant window area and daylighting, while others have none. All have manual wall switches that are used to turn on or off all of the lighting. The existing lighting is typically provided by recessed two-lamp fixtures with 4-ft. T8 fluorescent lamps and electronic ballasts.

Figure 2. County-City Building

Experimental Design and Procedure

Bi-level lighting was achieved through installation of dual relay switches and new bi-level ballasts. These ballasts were installed to operate the fluorescent lamps in existing office fixtures and wired as needed to achieve bi-level operation at 50% and 100% power. In addition, occupancy sensors were incorporated to automatically switch the lights off after a period of time when no occupancy is detected.

In smaller offices, Wattstopper DW-200 integrated dual technology dual relay wall switch sensors were used, with the occupancy function integral to the wall switches (see Figure 3). In larger offices, a ceiling-mounted occupancy sensor and low voltage bi-level switch (WattStopper DLM system) were used (see Figure 4). The 7th floor offices included in the assessment were used low voltage wall switches; therefore, the low voltage DLM system was installed in all of these offices.

Figure 3. Wattstopper DW-200 Integrated Dual Technology Dual Relay Wall Switch Sensor

Figure 4. Wattstopper Digital Lighting Management (DLM) Controls

The switches and ballasts were installed to provide occupants with two levels of lighting operation, 50% on and 100% on. If one switch button is depressed, all luminaires are energized at 50% power, if both switch buttons are depressed, all luminaires are energized at 100% power. In addition, occupants have manual control to switch off the lights using the wall switches. The occupancy sensor time delay was set to turn off all the lights after 15 minutes without detecting occupancy.

The switches can be set to provide three operational scenarios.

1. **Auto-on at 50%, auto-off:** Lights are switched on automatically at the low level (50%) upon occupancy, the remaining lights can be switched on manually, all lights can be switched off manually, and lights are turned off automatically after the office is unoccupied for a period of time.
2. **Auto-on at 100%, auto-off:** Lights are switched on automatically at the high level (100%) upon occupancy, lights can be switched to a lower light level (50%) or all off manually, and lights are turned off automatically after the office is unoccupied for a period of time.
3. **Manual-on, auto-off:** Lights can be switched on and off manually at 50% or 100%, and lights are turned off automatically after the office is unoccupied for a period of time.

Prior to retrofit to bi-level lighting, baseline operation was monitored. The 30 offices selected for retrofit to bi-level lighting were monitored for a two-week period during the end of August and the beginning of September. This baseline-monitoring period occurred in the summer, when it was much sunnier than is typical for the Northwest. In an attempt to develop baseline lighting operation that is representative of typical annual skycover conditions, 15 additional offices were monitored. These offices were very similar in size, orientation, and lighting controls to the original 30 offices. Lighting operation was monitored in these offices during the post-retrofit weeks. All of this data was incorporated into calculation of baseline average annual lighting hours of operation.

Subsequently, each of the three operational scenarios was monitored for three-week periods. For the initial installation, the switch settings are adjusted for Scenario 1. After the initial three-week monitoring period, the switch settings were changed for Scenario 2. After the second three-week monitoring period, the switch settings were changed for Scenario 3.

To quantify lighting energy use, the following items were monitored.

Lighting Hours of Operation

For the baseline, lighting hours were recorded using Wattstopper IT-200 InteliTimer® Pro Loggers. Lighting-state changes were recorded as they occurred, with a one-minute accuracy.

For the post-retrofit case where two levels of lighting operation are possible, two monitoring devices were used. A Wattstopper IT-200 InteliTimer® Pro Logger was used to record total lighting hours of operation. In addition, operation of the lights on high (100%) was recorded using HOBO State Data Loggers with optional Split Core Adjustable Current Switches. The current switch was attached around the power source to the bi-level ballast. (The bi-level ballast operates such that the lights are at 50% power when either of the two switches are energized and at full power when both are energized.) The sensitivity of the current switch was adjusted so that it only recorded a positive state change when the current was at the level corresponding to 100% power. The monitor did not record state changes for lower current levels when the lights were at low power or off. Using information from both these devices, the hours of operation at the 50% level can be calculated.

Occupancy

Occupancy hours were recorded using the same Wattstopper IT-200 InteliTimer® Pro Loggers that recorded lighting hours. Occupancy-state changes were recorded using a five-minute time-out occupancy interval. The time-out interval is used to set the period of time that the logger waits to receive an "occupancy detected" message before it logs a state change to "vacant." If sometime during that period the logger receives an "occupancy detected" message, no state change is recorded. But if no occupancy is detected during the time-out period, the state changes to unoccupied at the end of the time-out interval.

Task Lighting Energy Use

Total energy consumption (kWh) for plug task lights was monitored using Brand Electronics energy meters.

Figure 5. Installation of the Wattstopper IT-200 InteliTimer® Pro Logger

Connected lighting load was developed based on accepted data as used in the BPA lighting calculator for the installed lamp and ballast combination. Lighting energy consumption was calculated by multiplying the measured hours of operation by the connected load.

A detailed Demonstration Test Plan is included in Appendix A.

Project Results

Electrical Energy Savings

<u>Lighting Hours of Operation</u>
A summary of lighting hours of operation for the baseline and each of the three bi-level switching scenarios is provided in Table 1 below.

Table 1: Average Annual Lighting Hours, All Offices

	Average Annual Hours Lights On	Percent of Lit Hours On at 100%	Percent of Lit Hours On @ 50%	Average Annual Hours Lights On @ 100%	Average Annual Hours Lights On @ 50%
Baseline	1924	100%	0%	1924	0
Auto-on 50%	1799	34%	66%	611	1188
Auto-on 100%	1793	90%	10%	1614	179
Manual-on	1655	73%	27%	1208	447

The average annual hours of lighting use in individual offices for the baseline condition was 1,924 hours per year. For a typical average occupancy of 241 days per year (assuming 2 weeks of vacation and 10 holidays), lights are operated an average of 8.0 hours per day.

For the three switching scenarios with bi-level switching and occupancy sensors, average annual lighting use dropped. For the two scenarios where lights were turned on automatically upon occupancy, the lighting use dropped by approximately 125 hours per year, or 6%. For Scenario 3, where the bi-level switches were set for manual-on operation, the average annual lighting use dropped by about 270 hours, as compared to the baseline, or 14%.

The operation of the lighting at high and low differed significantly between the three different bi-level switching scenarios, as illustrated in Figure 6. By far, the lights were operated at low most frequently under Scenario 1, auto-on at 50%. Under this scenario, lights were operated on low for 66% of the time and on high for 34% of the time. When the switches were set to operate with auto-on at 100% (Scenario 2), lights were operated on low for only 10% of the time and on high for 90% of the time. Similarly, for Scenario 3 with the switches set for manual on, the lights were operated on high most of the time, 73% of lit hours, and at low only 27% of the time. These results seem to indicate that inertia plays a significant role in lighting operation for these individual offices. When the bi-level switch turns on the lights automatically, occupants most frequently leave the lights operating at the preset level, and do not make the effort to switch to a different level.

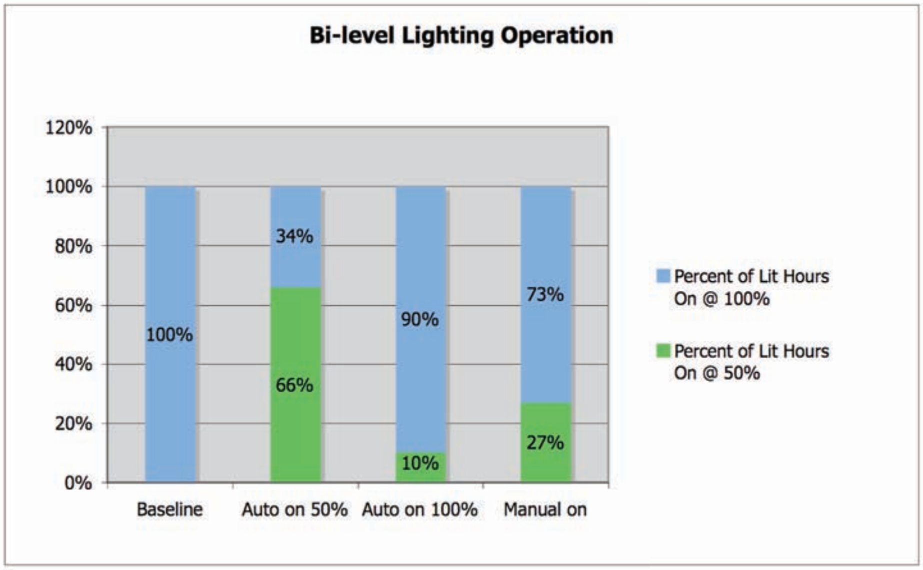

Figure 6: Bi-level Lighting Operation, All Offices

New Construction/Major Remodel Case

Under a new construction/major remodel case, incremental savings for the proposed bi-level switching operation are calculated as compared to the lighting control system that would otherwise have been installed. The baseline lighting control system for this analysis is the minimum code-compliant lighting system, which consists of a single-level occupancy sensor switch; that is, manual-on, auto-off. Conveniently, this is the same as our monitored Scenario 3. However, as the baseline assumes single-level switching, lights are assumed to be on at the 100% level for all of hours the lights are switched on (rather than sometimes at 50%).

For the proposed bi-level switching scenario, total annual average lighting hours do not change from the baseline hours, and incremental savings are calculated only from the upgrade from a single-level switch to a bi-level switch, with the associated operation at high and low lighting levels. Use of the bi-level switching is assumed to be the same as for the retrofit case, i.e. the hours that lights are operated at high or low are assumed to be the same as monitored for the retrofit case.

A summary of incremental electric energy savings for each of the three bi-level switching scenarios is provided in Table 2 below. The average percent operating hours at high and low lighting levels, as shown in Table 1, are calculated using data for all 30 offices and apply, on average, to all offices. However, savings are shown separately for the monitored small offices and for the monitored large offices, because installed lighting load and resulting total annual energy savings are different for the two offices sizes. Detailed calculations can be found in Appendix B.

Table 2: Average Annual Electric Energy Savings, New Construction

		Small Office		Large Office	
	Percent Savings	Average kWh/yr	Savings (kWh/yr)	Average kWh/yr	Savings (kWh/yr)
Baseline		195		586	
Auto-on 50%	33%	131	64	392	194
Auto-on 100%	5%	186	9	557	29
Manual-on	13%	169	26	507	79

The energy savings provided by each of the three different bi-level switching scenarios is illustrated in Figure 7. The greatest energy savings would be achieved under Scenario 1, auto-on at 50%. Under this scenario, energy use in a typical office would be reduced by 33%, or about 64 kWh/yr in a small office and 194 kWh/yr in a large office, as compared to the code-compliant case. With the switches set to operate with auto-on at 100% (Scenario 2), energy savings of 5% would be expected. Energy savings for the manual on setting would be approximately 13%.

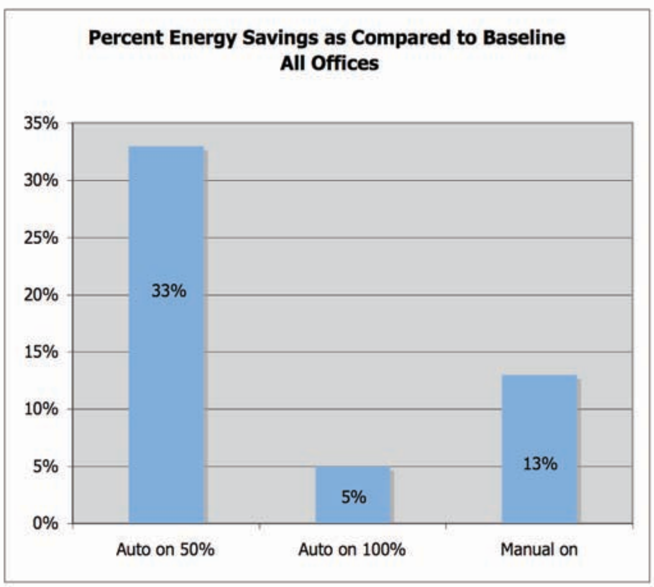

Figure 7: Percent Annual Electric Energy Savings, New Construction

<u>Retrofit Case</u>

In this case, the baseline condition is an existing individual office with a single-level manual switch operating all of the lights on or off. The office is converted to bi-level switching through installation of a bi-level switch with occupancy sensors, a bi-level ballast, and appropriate rewiring. Savings are calculated as the difference between the baseline condition and the bi-level switching condition. Detailed calculations can be found in Appendix B.

A summary of electric energy savings for each of the three bi-level switching scenarios is provided in Table 3 below.

Table 3: Average Annual Electric Energy Savings, Retrofit

		Small Office		Large Office	
	Percent Savings	Average kWh/yr	Savings (kWh/yr)	Average kWh/yr	Savings (kWh/yr)
Baseline		227		681	
Auto-on 50%	37%	142	85	427	254
Auto-on 100%	12%	201	26	603	78
Manual-on	26%	169	58	507	174

The energy savings provided by each of the three different bi-level switching scenarios is illustrated in Figure 8. The greatest energy savings was achieved under Scenario 1, auto-on at 50%. Under this scenario, energy use in a typical office was reduced by 37%, or about 85 kWh/yr in a small office and 254 kWh/yr in a large office. When the switches were set to operate with auto-on at 100% (Scenario 2), energy savings of 12% resulted. Energy savings for the manual-on setting were closer to the savings achieved by the auto-on at 50% setting, at about 26%.

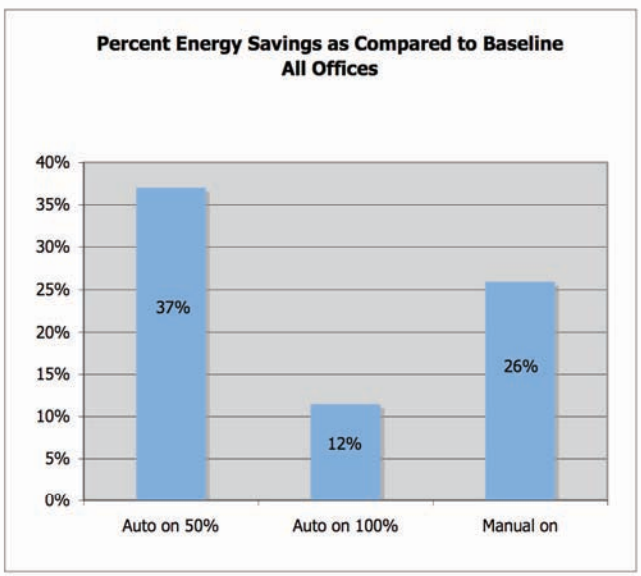

Figure 8: Percent Annual Electric Energy Savings, Retrofit

<u>Task Lighting Use</u>

Total energy consumption (kWh) for plug task lights was monitored for the baseline and for each of the three bi-level scenarios. Only eight of the monitored offices have task lighting and total installed task lighting load is approximately 0.45 kW, as compared to an installed lighting load for all the monitored offices of approximately 5.7 kW for the overhead lighting.

The change in use of task lighting is summarized in Table 4. The average daily energy use for the task lights was calculated for all 8 offices combined. These results indicate that task lighting use dropped for each of the bi-level scenarios as compared to the baseline. Intuitively, one might expect task lighting use to rise where bi-level switching was frequently set at the low lighting level, for instance during Scenario 1, auto-on at 50%. However, for this study, it appears that task lighting use is not directly related to use of overhead lighting. As a conservative analysis, the reduction in overall lighting energy consumption due to reduced task lighting use is not included in the energy savings calculations.

Table 4: Average Daily Energy Use of Task Lighting (kWh/day) as Compared to Baseline

	Auto-on 50%	Auto-on 100%	Manual-On
Baseline	0.16	0.16	0.16
Bi-level Switching	0.14	0.10	0.09
Percent Difference	-13%	-38%	-44%

BPA Analysis

The BPA currently offers incentives for standard occupancy sensors of $35 per sensor for controlled loads less than 200 W (small offices) and $60 per sensor for connected loads 200 W or greater (large offices). Figure 1 shows that, with bi-level switching, lighting is frequently operated at the low level, providing additional savings over a standard occupancy sensor. Given these additional savings, incentives for the combined strategy—bi-level switching with occupancy sensors—may be considered. For use by BPA program managers, savings and cost for the combined strategy are calculated using the following parameters:

- monitored data for operation at high and low lighting levels as shown in Figure 1
- current BPA assumption for baseline office lighting operation – 3,000 hr/yr
- current BPA assumption for standard occupancy sensor savings – 25%

The results of this analysis are shown in Table 5.

Table 5: Average Annual Electric Energy Savings – BPA Assumptions

Configuration	Baseline kWh/yr	Proposed kWh/yr	Savings kWh/yr	% Savings
Small Office <200W controlled	354	178	176	50%
Large Office >200W controlled	1,062	533	529	50%

Note that for the BPA analysis, new construction projects are evaluated differently than for the analyses included in the remainder of the report. For the BPA analysis, the baseline for new construction projects assumes a single level manual switch, since new construction projects are only eligible for incentives where building codes do not already require installation of occupancy sensors or bi-level switching. For the new construction analyses in the rest of the report, the baseline includes an occupancy sensor, as it is assumed that an occupancy sensor is required by code. The energy savings and incremental costs are calculated using appropriate parameters for each case, and therefore the savings and incremental costs will be different for the two different new construction analyses.

For the retrofit case, installed costs are estimated at approximately $303 for a small office and $698 for a large office. This includes the entire material and labor cost for a bi-level switch, occupancy sensor, and rewiring to bi-level operation (no bi-level ballast). For a new construction case, the installed costs are estimated at approximately $70 for a small office and $200 for a large office. This includes the incremental material costs of a bi-level switch and ballast and occupancy sensor above a standard manual single level switch. It is assumed that labor costs are the same for wiring a new office in either the baseline or bi-level switching configuration.

Economic Performance

Economic estimates are sensitive to site-specific variables such as lighting hours of operation, installation labor costs, utility incentives and energy costs. Economic calculations presented here are based on variables specific to this field assessment. Readers are advised to use their own cost estimates and assumptions when possible.

Economic performance was evaluated primarily by calculating the simple payback period of each scenario as compared to the baseline. Economic performance is calculated for both the retrofit case and the new construction/major remodel case. In addition, economic performance is calculated separately for a small office and a large office. As described previously, the energy savings will be different between a small and large office due to the different connected lighting load. Also, as described in the Experimental Design and Procedure section, ceiling mounted occupancy sensors are required for large offices, whereas wall mounted sensors and required for small offices. As a result, the installation cost is different.

Energy cost savings are calculated using an average electric rate of $0.09/kWh. This rate is the average rate for large commercial customers in Washington state as reported by the US Energy Information Administration, August 2010, and adjusted for taxes and fees. Equipment costs used in the analysis are actual end-user costs paid by the project for the materials used for the office retrofits. Pierce County maintenance staff who performed the installations were surveyed to obtain labor hours for installation and commissioning of the equipment. These hours were multiplied by an average labor rate from Means Construction Cost Estimating Guides to determine labor costs.

Detailed economic calculations can be found in Appendix B.

<u>New Construction/Major Remodel Case</u>
Under the new construction/major remodel case, the economic analysis is based on incremental cost and savings as compared to the baseline lighting control system that would have been installed. The baseline lighting control system for this analysis is the minimum code-compliant lighting system, which consists of a single-level occupancy sensor switch. The lighting control system is instead upgraded to bi-level switching through installation of a bi-level switch with

occupancy sensors and a bi-level ballast. Savings are calculated as the difference between the baseline condition and the bi-level switching condition.

For the new construction case, a summary of the economic performance for each of the three bi-level switching scenarios in both a small office and a large office is provided in Tables 6 and 7 below. The incremental costs used in the new construction case assume a base-case in which building codes require installation of an occupancy sensor, but not bi-level switching.

Table 6: Economic Performance – Small Office, New Construction

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Installed Cost ($)	Payback (yrs)
Auto-on 50%	64	$5.62	$50	9
Auto-on 100%	9	$0.79	$50	64
Manual-on	26	$2.28	$50	22

Table 7: Economic Performance – Large Office, New Construction

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Installed Cost ($)	Payback (yrs)
Auto-on 50%	194	$17.04	$110	6
Auto-on 100%	29	$2.55	$110	43
Manual-on	79	$6.94	$110	16

<u>Retrofit Case</u>

For the retrofit case, the economic analysis is based on cost and savings of replacing an existing single-level manual switch with a bi-level switch and occupancy sensor. A summary of the economic performance for each of the three bi-level switching scenarios in both a small office and a large office is provided in Tables 8 and 9 below. The installed costs used in the retrofit are for the full cost of installing the new bi-level switch, occupancy sensor, and rewiring the existing lighting to bi-level switching.

Table 8: Economic Performance – Small Office, Retrofit

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Installed Cost ($)	Payback (yrs)
Auto-on 50%	85	$7.47	$360	48
Auto-on 100%	26	$2.28	$360	158
Manual-on	58	$5.09	$360	71

Table 9: Economic Performance – Large Office, Retrofit

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Installed Cost ($)	Payback (yrs)
Auto-on 50%	254	$22.31	$870	39
Auto-on 100%	78	$6.85	$870	127
Manual-on	174	$15.28	$870	57

One of the main variables that influence payback calculations is installation cost. As discussed in the Technology and Market Overview, there are several different options for achieving bi-level switching, each with a different installation cost:

1. Install new bi-level ballasts
2. Rewire existing ballasts, switch alternate luminaires
3. Rewire existing ballasts, tandem wiring

The economic analysis presented in this report is based on the first option, installation of new bi-level ballasts. For options 2 and 3, the cost of a bi-level ballast would not be included. It is not known if labor costs would be higher or lower for options 2 and 3. However, for the retrofit case, the labor cost for rewiring to bi-level operation is a large percentage of the total cost, and this rewiring is required for all three options. The cost of the bi-level ballast (approximately $30) is a small percentage of the total cost and eliminating it will have relatively small impact on the payback period.

For the new construction case, it is assumed that there is no incremental labor cost for wiring an initial installation as bi-level switching over the labor required for wiring the baseline single-level switching. In this case, eliminating the incremental cost of the bi-level ballast can significantly reduce the total cost and the payback period.

Using the energy cost savings as recorded in this study for the auto-on at 50% scenario, the payback period is calculated as a function of installed cost and illustrated in Figure 9 below.

For small offices, installed costs would need to be lower than approximately $37 in a retrofit case and $28 (incremental) in a new construction case to achieve a simple payback period of 5 years. For large offices, installed costs would need to be lower than approximately $112 in a retrofit case and $85 (incremental) in a new construction case to achieve a simple payback period of 5 years.

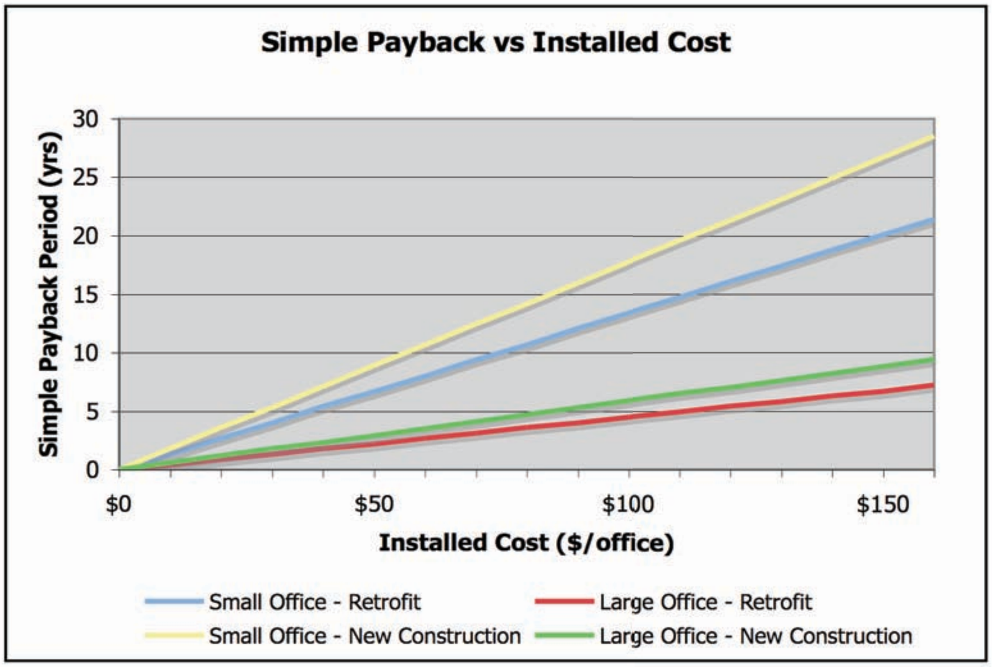

Figure 9: Simple Payback as a Function of Installed Cost

Another significant variable influencing payback period calculations is annual hours of lighting operation. Overall, it appears that the occupants of the County-City building have a high awareness of energy use and lighting operation. Average annual lighting hours of operation were measured at approximately 1,900 hours per year, or about 8 hours/day for a typical 241 occupied days. This is low compared to other references for office lighting use. The Department of Energy Building Energy Data Book[4] reports typical U.S. large office building lighting hours of 4,190 hours per year (over 17 hours/day for 241 occupied days). The BPA uses 3,000 hours per year (about 12 hours/day for 241 occupied days) for development of incentives for office lighting energy efficiency measures. A study commissioned by the California Energy Commission[5] found baseline lighting use in offices of approximately 3,100 hours per year (about 13 hours/day for 241 occupied days).

These data imply that occupants of the County-City building are conscientious about turning off lights when leaving their offices, while lights in typical US office buildings are often left on during evening and weekend hours. Another factor influencing the large difference in annual lighting hours of operation is the type lighting included in each data set. The data from the County-City building are limited to only individual offices with individual control of lighting operation. The DOE data likely include a significant percentage of office space with large open offices (typical of large office buildings) where individual control of lighting is not available, and longer hours of lighting operation would be expected. The BPA and California lighting

[4] http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.6.8
[5] Lighting Efficiency Technology Report, September 1999, California Energy Commission, Volume I, California Baseline

hours may be more representative for this geographical area where energy efficiency has been promoted for many years.

Assuming the percent energy savings as recorded in this study for the auto-on at 50% scenario, the payback period is calculated as a function of baseline lighting hours and illustrated in Figure 10 below.

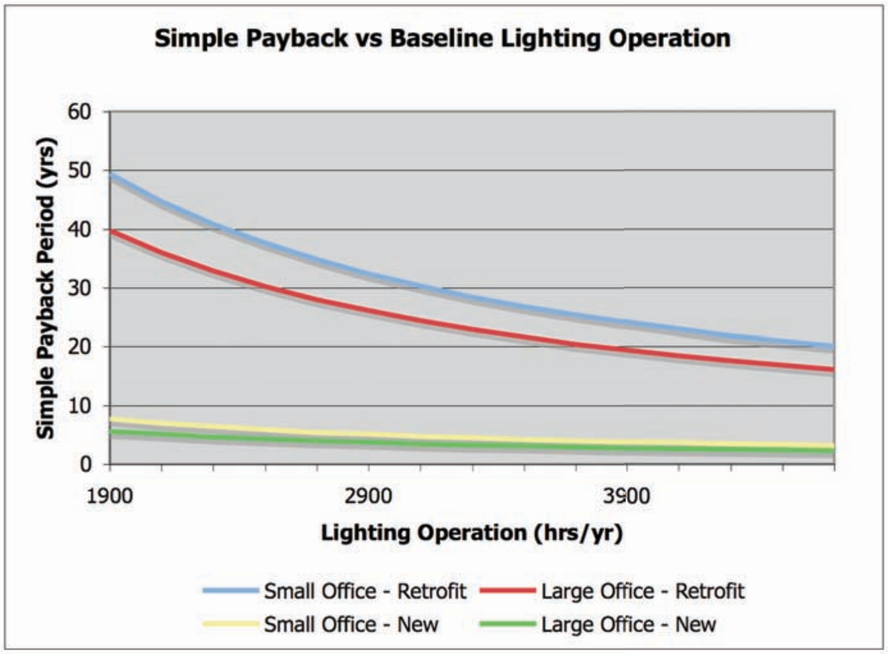

Figure 10: Simple Payback as a Function of Baseline Lighting Hours

As a point of reference, the economic performance for a hypothetical situation with more favorable lighting operation variables was calculated. The following assumptions were used in this analysis.

- monitored percent energy savings for bi-level switching with occupancy sensors as shown in Figures 11 and 12
- current BPA assumption for baseline office lighting operation – 3,000 hr/yr
- average electric rate – $0.09/kWh (average rate for large commercial customers in Washington state)
- lower installation costs without a bi-level ballast included
- available incentives of $35 per occupancy sensor for small offices and $60 per occupancy sensor for large offices for the retrofit case

The results of this analysis for a new construction and retrofit case are shown in Tables 10 and 11.

Table 10: Economic Performance – Favorable Assumptions, Retrofit

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Installed Cost ($)	Payback (yrs)
Small Office	131	$11.51	$303	23
Large Office	393	$34.52	$698	18

Table 11: Economic Performance – Favorable Assumptions, New Construction

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Installed Cost ($)	Payback (yrs)
Small Office	354	$10.26	$22	2
Large Office	1062	$30.78	$24	1

Customer Acceptance

One of the goals of the study was to gauge customer acceptance of the bi-level switching. A survey was developed to assess the occupants' satisfaction with the new lighting switches. Printed copies of the surveys were distributed to the occupants and they were asked to return the completed forms to the Pierce County maintenance personnel. A total of 14 completed surveys were returned. A copy of the survey is provided in Appendix C.

In general, the occupants had very favorable reactions to the bi-level switches and occupancy sensors. Over 78% of the respondents were either satisfied, somewhat satisfied or very satisfied when asked, "How satisfied are you with the new lighting switches as compared to the original?" Of the three respondents who were dissatisfied with the new switches as compared to the original, two were unhappy with occupancy sensors that switched lights off inadvertently. While these switching issues were resolved during the study period, initial problems apparently left lasting impressions.

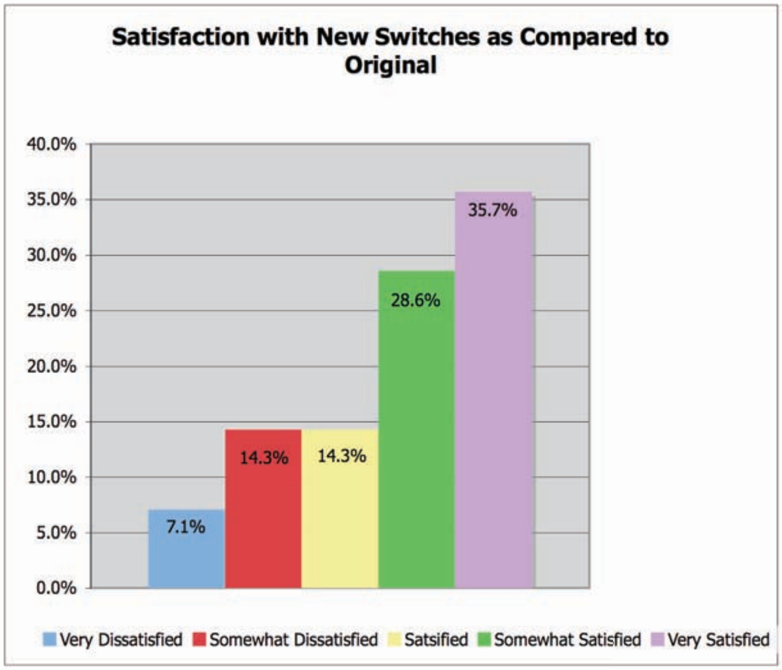

Figure 11: Occupant Satisfaction with Bi-level Switches

The occupants were asked which of the three operating settings they preferred: auto-on at 50%, auto-on at 100% or manual on. Respondents clearly favored the auto-on at 50% setting, with about 64% selecting this setting. About 29% of the respondents preferred the auto-on at 100% setting, with only 7% of the respondents preferring the manual on setting.

Detailed survey results are included in Appendix C.

Installation and Commissioning

Pierce County maintenance staff installed and commissioned the bi-level switches, occupancy sensors and bi-level ballasts. Prior to installation, copies of all installation manuals and product cut sheets were provided to the maintenance staff. In addition, the project manager and a representative from Wattstopper met in person with the maintenance staff for a hands-on installation demonstration of the Wattstopper controls that were used on this project. At that meeting, a detailed review of wiring and installation requirements was provided.

After installation, the maintenance staff was surveyed regarding installation and commissioning of the equipment and any issues that were encountered. The maintenance staff reported that, in general, all of the equipment was easy to install and commission. Installation instructions were reported as clear and it was easy to set the occupancy sensors and bi-level switches for proper operation. However, it was noted that the wall switches were sometimes a bit difficult to fit into some shallow existing single gang enclosures. Installation hours, as reported by the maintenance staff, were used in calculations of installation cost.

Discussion

This report documents an assessment project conducted to evaluate bi-level switching with occupancy sensors for lighting in individual offices. The assessment results demonstrate that lighting energy savings can be achieved through the use of bi-level switching. However, energy savings can vary depending on the operational setting for the occupancy sensors. Energy savings are greatest when occupancy sensors are set to automatically turn the lights on at the 50% level when occupants enter the space. For this operational scenario, resulting energy savings were 37% in a retrofit case and 33% in a new construction case. In comparison, energy savings were only 12% (retrofit) and 5% (new construction) for the auto-on at 100% scenario and 26% (retrofit) and 13% (new construction) for the manual-on scenario.

The assessment results suggest that inertia plays a significant role in lighting operation for individual offices. When the bi-level switches are set to turn on the lights automatically, occupants most frequently leave the lights operating at the preset level, and do not make the effort to switch to a different level. By far, the lights were most frequently operated on low when the switches were set for auto-on at 50%. Under this scenario, lights were operated on low for 66% of the time and on high for 34% of the time. When the switches were set to operate with auto-on at 100%, lights were operated on low for only 10% of the time and on high for 90% of the time. Interestingly, with the switches set for manual on, occupants chose to operate the lights on high most of the time, 73% of lit hours, and at low only 27% of the time.

Overall, it appears that the occupants of the County-City building have a high awareness of energy use and lighting operation. Average annual lighting hours of operation were measured at approximately 1,900 hours per year, or about 8 hours/day for a typical 241 occupied days. These data imply that occupants of the County-City building are conscientious about turning lights off when leaving their offices, providing limited savings potential from the addition of occupancy sensors. However, use of a more aggressive, shorter time-out period in these offices could increase these savings.

In general, occupants reported high satisfaction with the bi-level switches. A clear preference was stated for the auto-on at 50% setting, and this setting also provides the highest energy savings.

The maintenance staff reported that all of the equipment (wall switch sensors, ceiling sensors, and bi-level ballasts) was easy to install and commission. Staff reported that it was easy to set the occupancy sensors and bi-level switches for proper operation and that manuals and installation instructions were clear. Given this reported ease of installation, it is likely that crews can become proficient in installation, resulting in fewer hours for experienced installers.

For this assessment, retrofit of existing individual offices with manual, single-level switching to bi-level switching with occupancy sensors was found to have a long payback period, on the order of 30-40 years. For a new construction case, where bi-level switching is installed instead of code-compliant single-level switching, the payback period is lower, under 10 years.

Simple payback calculations are sensitive to many variables, in particular installation cost and hours of operation. Where installation costs can be lowered, either through use of less costly bi-level switching options or through the use of experienced crews, the payback period will be shorter. Similarly, where baseline hours of operation are long, energy savings will be greater and the payback period will be shorter. In addition, available energy efficiency incentives and tax credits could lower the installation cost. Using more favorable, but plausible, assumptions for each of these variables in the economic analysis, the payback period could be in the order of 20 years for the retrofit case and 2 years for the new construction case.

However, one of the main factors contributing to the long payback periods is the fact that baseline energy use and associated energy cost for lighting in individual offices is relatively low. For the County-City building, and many typical office buildings, the overhead lighting is provided by efficient T-8 fluorescent lamps and electronic ballasts. For this assessment, total baseline lighting energy cost for a small office is about $20 per year, and about $60 per year for a large office. Even a large percentage savings achieved through bi-level switching will not yield a large annual monetary savings.

Conclusions

Bi-level switching in individual offices can deliver significant savings as compared to single-level switching. Of significant note, operation of the bi-level switches in the auto-on at 50% provides the highest level of savings. It will be important when promoting bi-level switching to educate users that energy savings are highly dependent on the operational setting used. Use of the auto-on at 50% setting should be strongly encouraged, if not required.

In addition, bi-level switching provides high occupant satisfaction with the lighting system. A significant majority of occupants were either satisfied, somewhat satisfied or very satisfied when asked, "How satisfied are you with the new lighting switches as compared to the original?" This sense of improved occupant satisfaction could possibly provide non-energy benefits to building owners.

For this assessment, the payback periods for retrofit to bi-level switching in individual offices are long, on the order of 30-40 years. However, the payback periods would be shorter where lighting hours are longer and installation costs are lower; these payback periods use the measured lighting period of 1900 hours/year rather than the BPA assumed average of 3,000 hours/year, which would cut paybacks by a third. As use of this technology becomes more common and as crews become more familiar with installation, material and labor costs are likely to decline. In addition, available energy efficiency incentives and tax credits could lower the installation cost. With favorable, but plausible, assumptions for higher energy cost savings and lower installed costs, the payback period could be on the order of 20 years.

A limiting factor for cost effectiveness of this technology is the efficient baseline lighting systems, using high efficiency T8 lamps, electronic ballasts, and occupancy sensors, that are becoming more common in office buildings. With a relatively low total annual baseline energy use, and associated energy cost, for lighting in individual offices, savings are limited.

The payback periods for a new construction case are much shorter, because of the relatively small incremental cost. Depending on the method of implementation used, the payback period can range from about 9 years for a small office with a bi-level ballast included, to about 2 years for a small office using bi-level wiring of fixtures or lamps. As such, this technology may be of particular interest for inclusion in energy efficiency building codes. Utility incentives can help reduce payback periods further.

An ideal application for bi-level switching with occupancy sensor control would be new exterior offices where people work long days but are frequently out of their office and work mostly on computers, where utility rates and conservation incentives are both high, and where new construction standards don't require occupancy sensors.

Areas for Further Study

As noted in prior discussions in this report, one of the variables having a significant impact on the economic performance of bi-level lighting is installed cost. There are three options for implementing bi-level switching, each with a different installation cost. While this assessment evaluated one of these options, installation of a bi-level ballast, it is recommended that future studies evaluate implementation of bi-level lighting using the other two options, switching of alternate luminaires and tandem wiring (low-level lighting would light one lamp of two in each fixture, for instance). It will be useful to determine the actual installation costs for these options. It will also be important to investigate the resulting lighting performance and occupant satisfaction, as these installation methods could impact the uniformity of the office lighting.

This assessment evaluated the cost and savings associated with change from a single level manual switch to a bi-level switch with occupancy sensor. One of the main findings is that energy savings are maximized when the occupancy sensor is set for auto-on at the 50% lighting level. Another case recommended for evaluation is retrofit from an existing bi-level manual switch to a bi-level switch with occupancy sensor set for auto-on at 50%. In this case, the installation cost would be lower because rewiring from single level to bi-level switching would not be required. Energy savings might be achieved through the use of the auto-on at 50% setting, as compared to the existing manual bi-level switching situation.

This assessment identified high occupant satisfaction with the bi-level switching. Occupants reported preferring the bi-level switching with occupancy sensor control to the original manual, single-level switching, anecdotally citing the additional individual control provided by the bi-level switches. However, this assessment did not investigate the potential non-energy benefits that might result from this improved occupant satisfaction, such as improved worker productivity. The value of improved worker productivity could be significantly greater than the value of the energy savings from this technology. Further study of potential non-energy benefits is recommended.

Many of these bi-level switches have optional automatic daylighting control to further limit lighting use. While the scope of this assessment included only potential savings from bi-level switching and occupancy sensors, it is recommended that future studies investigate the potential additional savings provided by the use of the daylighting control feature.

Appendix A

Test and Monitoring Plan

Demonstration Test Plan

Dual-Relay Automatic Occupancy Sensor Wall Switches
in Commercial Offices

Introduction

The purpose of this test plan is to describe the data collection equipment and installation procedures required to determine and quantify energy savings resulting from the use of dual-relay automatic occupancy sensor wall switches. This procedure will serve to establish a baseline of lighting use and occupancy for select private offices in a commercial building. Following retrofit of existing manual switches with bi-level functionality, additional monitoring shall be completed to determine if energy savings results from installation of this technology. Energy savings may result from three lighting control scenarios, which are enabled through the use of the dual-relay automatic occupancy sensor wall switches.

The savings opportunities and diagrams contained in this test plan are generalized representations based on probable host site conditions. Savings, monitoring requirements and procedures may require amendment once the final host site has been selected.

Technology and Savings Opportunities

Dual-Relay Automatic Occupancy Sensor Wall Switch

These wall switch sensors can independently control two lighting loads. If required, private offices shall be rewired to create two lighting levels. Approximately, half the existing lighting will included in the first control level (50% level), and the remaining in the second (100% level). Each level will be controlled by the new wall switch sensor. This technology will enable various lighting control strategies, each with different savings opportunities.

Figure 1: Examples of dual-relay occupancy sensor wall switches

Savings Opportunities

Energy savings will be the result of three scenarios that are enabled through the use of the dual-relay automatic occupancy sensor wall switches.

1. Manual On/Auto Off: Lights can be switched on and off manually, and lights are turned off automatically after the office is vacant for a period of time.
2. Auto On at 50%/Auto Off: Lights are automatically switched on at the low level upon occupancy, the remaining lights can be switched on manually by office occupants, and lights are turned off automatically after the office is vacant for a period of time.
3. Auto On at 100%, Auto Off: Lights are switched on at the high level automatically upon occupancy, lights can be manually switched to a lower light level or extinguished completely, and lights are turned off automatically after the office is vacant for a period of time.

In the first scenario, the wall switch sensor shall be configured to require manual operation of the lights at both the 50% level and 100% level. With the option of two levels of lighting, occupants may choose to use the lower light level, resulting in energy savings. A second savings opportunity shall result from situations where office lights were normally left on at the 100% level, even when the office was vacant. In these situations, the new wall switch sensors will extinguish all the office lights during unoccupied periods.

In the second scenario, the wall switch sensor shall be configured to automatically turn on lights in the 50% level. It is hypothesized that some occupants will be satisfied with the lower light level, and will choose not to take the extra step of manually switching to the 100% level, resulting in 50% energy savings. A second savings opportunity shall result from situations where office lights were normally left on at the 100% level, even when the office was vacant. In these situations, the new wall switch sensors will extinguish all the office lights during unoccupied periods.

In the third scenario, the wall switch sensor shall be configured to automatically turn on all lights to the 100% level and automatically extinguish all lights during unoccupied periods. Savings shall result from situations where office lights were normally left on at the 100% level even when the office was vacant and from situations where the occupants choose to manually switch the lights down to the low level or completely off.

Host Site Conditions and Monitoring Requirements

Several states must be monitored to accurately establish light usage and office occupancy. For offices with single-level lighting and manual switching (Figure 2), the project team must independently monitor two distinct states: office occupancy (vacant/occupied) and light level (on/off). A single device is available, which can perform these activities. This device is the IT 200 Intelitimer® Pro Logger manufactured by the Wattstopper/Legrand. This device is described in the next section. This is the simplest baseline scenario to monitor and requires a single monitoring device.

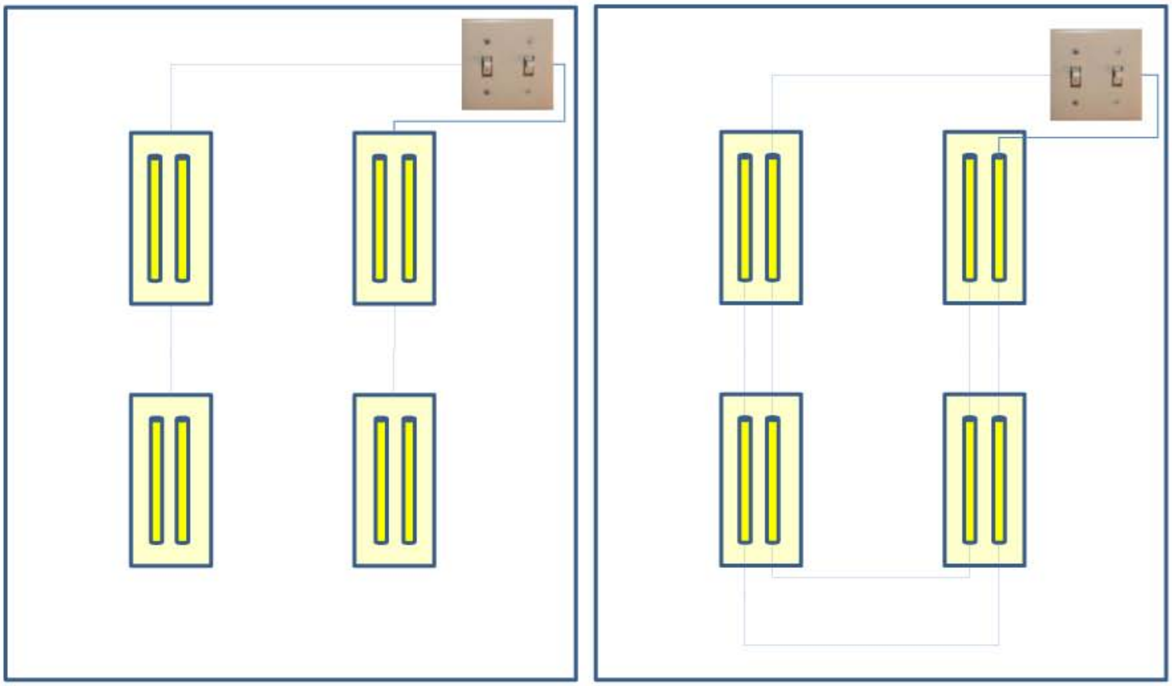

Figure 3: Lighting Scenario B - Bi-level lighting with half the luminaires controlled by each switch (left); Lighting Scenario C - bi-level lighting with half the lamps in each luminaire controlled by a each switch (right). Both scenarios provide 50% illumination when one switch is ON and 100% illumination when both switches are ON.

Monitoring Equipment

The IT-200 Intelitimer Pro Logger records a log entry every time there is a change in either the occupancy status or lighting status and stores a detailed history of these events for retrieval by PC. ITProSoft software, available for purchase from Wattstopper/Legrand, is required to retrieve data from this logger. This logger will allow the project team to determine the baseline usage and occupancy patterns, and quantify the potential cost savings from the automatic off feature included in the dual-relay automatic occupancy sensor wall switch. The IT-200 can be clipped to the T-bar ceiling, and should be mounted as close as possible to the monitored luminaire. For pendant luminaires, mount the logger with double sided adhesive. The occupancy timeout setting should be set to no less than 5 minutes. This technology is appropriate for baseline conditions similar to those shown in Figure 2 and Figure 3 (left).

The HOBO State Data Logger, manufactured by Onset Corporation, monitors state changes by monitoring contact closures or current flow of remote devices. To monitor current flow, the optional CSV-A8 adjustable current switch is required. This switch monitors current flow between 0.5 and 175 amps. HOBOware software must be used to retrieve data and is available for purchase from OnSet Corporation. These are small devices that can be installed at the junction box serving each office. This logger will allow the project team to determine the amount of time that Light Level 2 is used. It is appropriate for baseline conditions similar to those shown in Figure 3 (right). This logger must be used in combination with the IT-200 Intelitimer Pro Logger previously described. The IT-200 will monitor occupancy of the space and total time of lighting use (on/off). This combination of devices will provide data for all three required states.

Figure 4: IT-200 Intelitimer® Pro Logger (left), HOBO State Data Logger (middle) and optional current switch for HOBO logger (right)

Test Procedures

Lighting Scenario A

For lighting scenario A, a single IT-200 logger may be used. Select a luminaire for monitoring that is centrally positioned within the space so that office occupants can be easily detected. IT-200 loggers should be installed as near to the monitored luminaire as possible. The logger should be clipped to T-bar ceiling frame surrounding recessed luminaires or affixed to pendant luminaires with double-sided tape. Ensure the directional light pipe is pointing at the monitored luminaire. Depress the test button and switch the luminaire on and off. A red LED indicator should blink when motion is detected. A green LED indicator light should blink when the light level changes from on to off. Use the rotary pot to adjust the sensitivity of the logger if the LED indicator light does not recognize the light level change. Retest and continue to adjust the sensitivity until the logger recognizes the difference between lights on and lights off. For additional information, refer to the IT-200 Intelitimer Pro Logger specification sheet included with this test plan.

Lighting Scenario B

Lighting Scenario B requires two IT-200 data loggers. The first logger will monitor the state of Light Level 1 and the second the state of Light Level 2. For this first logger, follow the procedures detailed under Lighting Scenario A. The second logger should monitor a luminaire as far away from the first monitored luminaire as possible. This is to ensure the second IT-200 logger doesn't detect light from luminaires in Light Level 1, creating a false positive for Light Level 2 usage. Adjust the sensitivity, following the process detailed in Lighting Scenario A, so that second IT-200 logger only detects light when Light Level 2 in activated.

Lighting Scenario C

Lighting Scenario C requires one IT-200 data logger and one HOBO State Data Logger with optional Current Switch. Install and adjust the IT-200 logger as described under Lighting Scenario A. The IT-200 logger will collect occupancy and total lighting usage data. The HOBO State Data logger is used to monitor current flowing in both switch legs. Data collected by this device will provide the amount of time that Light Level 2 is used by office occupants. Install this logger only on unenergized circuits. This logger should be mounted at or near the junction box serving the office. The current switch should be attached around both conductors leaving the junction box. Connect the two current switch output leads to the HOBO State Data logger input cable (Cable 2.5 – Stereo provided with logger). Energize circuits serving the office, and turn on all lights. Adjust the sensitivity of the current switch according to directions contained in the CSV-A8 Installation Instructions included with this report. The sensitivity should be set such that the logger records an event only when the lights are at 100% power. Note, the CSV-A8 current switch cannot monitor current less than 0.5 amps. The time recorded by the state logger will provide the amount of time the lighting system operates at Light Level 2. This amount of time can then be subtracted from the amount time recorded by the IT-200 to determine the amount of time the lighting system operates at Light Level 1.

Task Light Monitoring

Plug load task lighting should be monitored along with general overhead lighting. All task lighting should be connected to a single power strip and this strip should be connected to a plug load data logger. Brand Electronics supplies a plug load data monitor that his appropriate for use in this study and specification sheets are included with this test plan. The Brand Electronics meter only records the absolute amount of time the task lighting is ON, and does not record on/off status with respect to time. It updates the total plug load time of use every 8 minutes. Task lighting that is hard-wired will require additional monitoring equipment similar to that described in Lighting Scenario B, but this task lighting scenario is unexpected and therefore, not addressed in this test plan.

Other Monitoring and Data Collection Procedures

All data loggers should be charged and memory cleared, if applicable. The occupancy timeout period should be set to no less than 5 minutes. Loggers should be coded with a unique identifier and logged along with the unique name of its installation site. The same equipment should be used for both pre (baseline) and post retrofit measurements, when possible.

A monitoring period of no less than two weeks is recommended for pre and post retrofit scenarios. This monitoring period should be sufficient to indicate general usage patterns over the course of several work periods. Short interviews should be conducted with each office occupant participating in the study, in order to determine any nonstandard occupancy or use patterns expected during the monitoring periods, such as those that would occur during vacations or other scheduled long-term absences. Longer monitoring periods are ideal to most accurately reflect average usage and occupancy patterns.

Logger data should be collected at the end of the pre-retrofit monitoring period, loggers cleared and reinstalled. If loggers are installed during installation of new dual-relay wall switches and rewiring of luminaires (if necessary), data collected during this time will need to be cleaned from the data file. For a host site going from Lighting Scenario A to Lighting Scenario B or C, installation of the current switch should be coordinated with the installation electrician.

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Appendix B

Energy Savings and Economic Performance Analyses

Project: **Bi-Level Office Lighting**
Facility: **Pierce County County-City Building** **Retrofit Case**

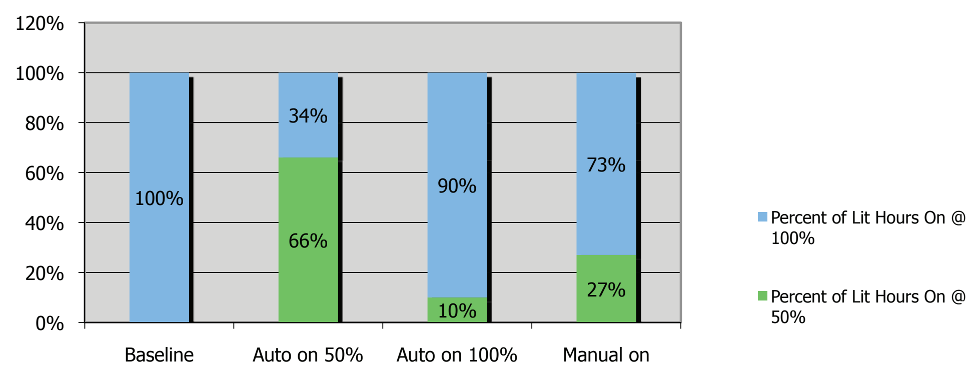
Scenario Descriptions

Baseline	Manual switch, single level, all on or all off.
Scenario 1	Auto on at 50%, auto off with occupancy sensor.
Scenario 2	Auto on at 50%, auto off with occupancy sensor.
Scenario 3	Manual on, bi-level: 50% or 100%, auto off with occupancy sensor.

Lighting Operation Summary

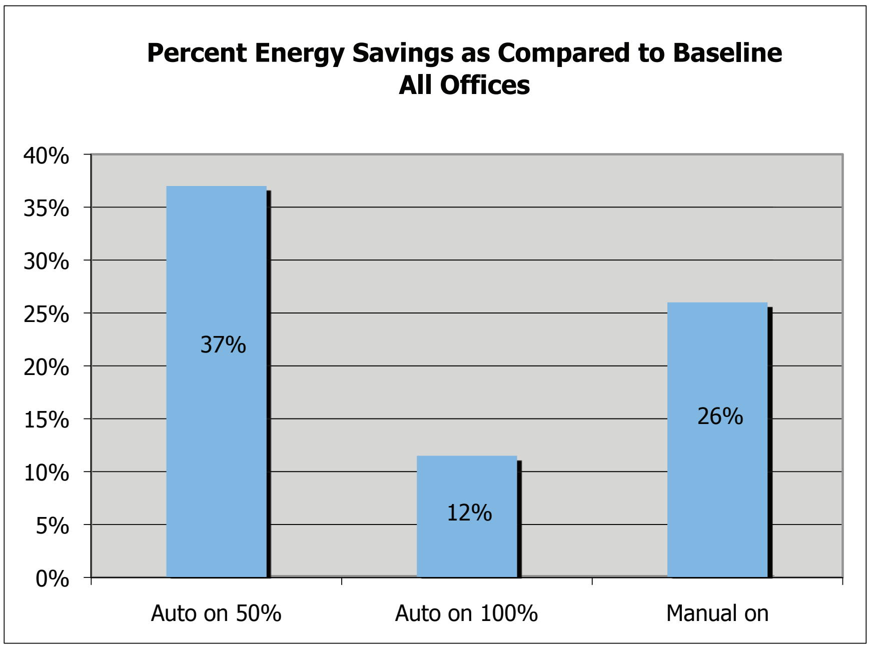
	Average Annual Hours Lights On	Percent of Lit Hours On @ 100%	Percent of Lit Hours On @ 50%	Average Annual Hours Lights On @ 100%	Average Annual Hours Lights On @ 50%
Baseline	1924	100%	0%	1924	0
Auto on 50%	1799	34%	66%	611	1188
Auto on 100%	1793	90%	10%	1614	179
Manual on	1655	73%	27%	1208	447

Bi-level Lighting Operation



Energy Savings

	Small Office			Large Office		
	Average kWh/yr	Savings (kWh/yr)	Percent Savings	Average kWh/yr	Savings (kWh/yr)	Percent Savings
Baseline	227			681		
Auto on 50%	142	85	37%	427	254	37%
Auto on 100%	201	26	12%	603	78	12%
Manual on	169	58	26%	507	174	26%



Bi Level Office Lighting
Savings Calculations

Retrofit Case

Individual offices in the Pierce County City-County building were converted from manual, single level switching to bi-level switching with occupancy sensors and bi level ballasts. Lighting operation for each scenario was monitored in numerous offices. Energy savings and simple payback period are calculated for the monitored scenarios listed below.

Basecase Scenario
Small office, Two fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%).

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	2	
Power per office	0.118	kW
Incentive per office:	$35	

Control Retrofit Scenarios - T8 lamps and electronic bi-level ballasts, wall occupancy sensors
1 Convert to bi-level switching with occ sensor, auto-on at 50%.
2 Convert to bi-level switching with occ sensor, auto-on at 100%.
3 Convert to bi-level switching with occ sensor, manual on.

	Savings		**Installed Cost**	**Payback**	**Installed Cost w Incentive**	**Payback w Incentive**
Scenario	**kWh/yr**	**$/yr**	**$**	**yrs**	**$**	**yrs**
1 Bi-level, auto on at 50%, auto off	85	$7.47	$360	48	$325	44
2 Bi-level, auto on at 100%, auto off	26	$2.28	$360	158	$325	142
3 Bi-level, manual on, auto off	58	$5.09	$360	71	$325	64

Scenario 1 - Manual, single pole switch to bi-level w occupancy sensor, auto-on 50%

Assumptions

Energy Rate	$0.09	Note 2
Basecase hours, manual	1924	hr/yr
Post retrofit hours	1799	hr/yr
Bilevel: % hours at low, auto-on 50%	66%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		1924	1924		227	$19.94
Proposed	0.118	0.059	1799	611	1188	142	$12.47
Savings						85	$7.47
% Savings						37%	

Estimated cost	$360	installed cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)
Simple payback	48 years	

Scenario 2 - Manual, single pole switch to bi-level w occupancy sensor, auto-on 100%

Assumptions

Energy Rate	$0.10	
Basecase hours, manual	1924	hr/yr
Post retrofit hours	1793	hr/yr
Bilevel: % hours at low, auto-on 100%	10%	

Bi Level Office Lighting
Savings Calculations Retrofit Case

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		1924	1924		227	$19.94
Proposed	0.118	0.059	1793	1614	179	201	$17.66
Savings						26	$2.28
% Savings						11%	

Estimated cost	$360	installed cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)
Simple payback	158 years	

Scenario 3 - Manual, single pole switch to bi-level w occupancy sensor, manual on

Assumptions

Energy Rate	$0.10
Basecase hours, manual	1924 hr/yr
Post retrofit hours	1655 hr/yr
Bilevel: % hours at low, manual on	27%

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		1924	1924		227	$19.94
Proposed	0.118	0.059	1655	1208	447	169	$14.84
Savings						58	$5.09
% Savings						26%	

Estimated cost	$360	installed cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)
Simple payback	71 years	

Note 1: Ref: BPA Ltg Calculator, Standard 4' T8 2L, 32 W 80+CRI with NLO ballast, (2-F32T8)
Note 2: Ref: US Energy Information Administration, Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, For Washington, commercial sector. August 2010. Tax and fee multiplier of 20% added.

Bi Level Office Lighting
Savings Calculations

Retrofit Case

Individual offices in the Pierce County City-County building were converted from manual, single level switching to bi-level switching with occupancy sensors and bi level ballasts. Lighting operation for each scenario was monitored in numerous offices. Energy savings and simple payback period are calculated for the monitored scenarios listed below.

Basecase Scenario
Large office, six fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%). Configuration for typical large office in study.

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	6	
Power per office	0.354	kW
Incentive per office:	$60	

Control Retrofit Scenarios - T8 lamps and electronic bi-level ballasts, ceiling occupancy sensors
1 Convert to bi-level switching with occ sensor, auto-on at 50%.
2 Convert to bi-level switching with occ sensor, auto-on at 100%.
3 Convert to bi-level switching with occ sensor, manual on.

	Savings		**Installed Cost**	**Payback**	**Installed Cost w Incentive**	**Payback w Incentive**
Scenario	**kWh/yr**	**$/yr**	**$**	**yrs**	**$**	**yrs**
1 Bi-level, auto on at 50%, auto off	254	$22.31	$870	39	$810	36
2 Bi-level, auto on at 100%, auto off	78	$6.85	$870	127	$810	118
3 Bi-level, manual on, auto off	174	$15.28	$870	57	$810	53

Scenario 1 - Manual, single pole switch to bi-level w occupancy sensor, auto-on 50%

Assumptions

Energy Rate	$0.09	
Basecase hours, manual	1924	hr/yr
Post retrofit hours	1799	hr/yr
Bilevel: % hours at low, auto-on 50%	66%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.354		1924	1924		681	$59.82
Proposed	0.354	0.177	1799	611	1188	427	$37.51
Savings						254	$22.31
% Savings						37%	

Estimated cost	$870	installed cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)
Simple payback	39 years	

Scenario 2 - Manual, single pole switch to bi-level w occupancy sensor, auto-on 100%

Assumptions

Energy Rate	$0.10	
Basecase hours, manual	1924	hr/yr
Post retrofit hours	1793	hr/yr
Bilevel: % hours at low, auto-on 100%	10%	

Bi Level Office Lighting
Savings Calculations Retrofit Case

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.354		1924	1924		681	$59.82
Proposed	0.354	0.177	1793	1614	179	603	$52.97
Savings						78	$6.85
% Savings						11%	

Estimated cost $870 installed cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)

Simple payback 127 years

Scenario 3 - Manual, single pole switch to bi-level w occupancy sensor, manual on

Assumptions

Energy Rate	$0.10	
Basecase hours, manual	1924	hr/yr
Post retrofit hours	1655	hr/yr
Bilevel: % hours at low, manual on	27%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.354		1924	1924		681	$59.82
Proposed	0.354	0.177	1655	1208	447	507	$44.53
Savings						174	$15.28
% Savings						26%	

Estimated cost $870 installed cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)

Simple payback 57 years

Note 1: Ref: BPA Ltg Calculator, Standard 4' T8 2L, 32 W 80+CRI with NLO ballast, (2-F32T8)
Note 2: Ref: US Energy Information Administration, Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, For Washington, commercial sector. August 2010. Tax and fee multiplier of 20% added.

Bi Level Office Lighting

Installation Costs Retrofit Scenario

Control Retrofit Scenarios

Small office: Add bi-level wall switch with occ sensor and bi-level ballasts.

Large office: Add bi-level wall switch, ceiling occ sensor and bi-level ballasts.

Means Data

	Rate incl O&P	
Electrician	$75.30	
Helper	$51.60	
Install Cost A(	90%	Avg for NW
Avg Rate	$57.11	Assume 1 Elec+1 Helper

INSTALLED COSTS

Small office: Add bi-level wall switch with occ sensor and bi-level ballasts.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	1	$10.00	$10.00	0.25	0.25	$57.11	$14.28	$24.28	estimate
2	Bi-level wall switch w occ sensor, dual technology, incl commissioning.	1	$107.12	$107.12	1	1	$57.11	$57.11	$164.23	See attached sheet: Material Costs
3	Bi-level ballast	2	$28.66	$57.32	1	2	$57.11	$114.22	$171.54	See attached sheet: Material Costs
	Subtotal			**$174.44**		**3.25**		**$185.61**	**$360.05**	
4	Misc						0%		$0.00	estimate
	TOTAL								**$360**	

Large office: Add bi-level wall switch, ceiling occ sensor and bi-level ballasts.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	1	$10.00	$10.00	0.25	0.25	$57.11	$14.28	$24.28	estimate
2	Bi-level ballast	6	$28.66	$171.96	0.5	3	$57.11	$171.33	$343.29	See attached sheet: Material Costs
3	BI-level wall switch	1	$36.73	$36.73	1	1	$57.11	$57.11	$93.84	See attached sheet: Material Costs
4	Ceiling occupancy sensor	1	$174.52	$174.52	1	1	$57.11	$57.11	$231.63	See attached sheet: Material Costs
5	Room Controller	1	$110.19	$110.19	0.5	0.5	$57.11	$28.56	$138.75	See attached sheet: Material Costs
6	Cable	2	$4.73	$9.46	0.25	0.5	$57.11	$28.56	$38.02	See attached sheet: Material Costs
	Subtotal			**$512.85**		**6.25**		**$356.95**	**$869.80**	
7	Misc						0%		0	
	TOTAL								**$870**	

Assume no bi-level ballast, same labor hours to rewire to alternate fixture switching or tandem lamp switching.

Small office: Add bi-level wall switch with occ sensor and rewire.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	1	$10.00	$10.00	0.25	0.25	$57.11	$14.28	$24.28	estimate
2	Bi-level wall switch w occ sensor, dual technology, incl commissioning.	1	$107.12	$107.12	1	1	$57.11	$57.11	$164.23	See attached sheet: Material Costs
3	Rewire luminaires	2	$0.00	$0.00	1	2	$57.11	$114.22	$114.22	See attached sheet: Material Costs
	Subtotal			**$117.12**		**3.25**		**$185.61**	**$302.73**	
4	Misc						0%		$0.00	estimate
	TOTAL								**$303**	

Large office: Add bi-level wall switch, ceiling occ sensor and rewire.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	1	$10.00	$10.00	0.25	0.25	$57.11	$14.28	$24.28	estimate
2	Rewire luminaires	6	$0.00	$0.00	0.5	3	$57.11	$171.33	$171.33	See attached sheet: Material Costs
3	BI-level wall switch	1	$36.73	$36.73	1	1	$57.11	$57.11	$93.84	See attached sheet: Material Costs
4	Ceiling occupancy sensor	1	$174.52	$174.52	1	1	$57.11	$57.11	$231.63	See attached sheet: Material Costs
5	Room Controller	1	$110.19	$110.19	0.5	0.5	$57.11	$28.56	$138.75	See attached sheet: Material Costs
6	Cable	2	$4.73	$9.46	0.25	0.5	$57.11	$28.56	$38.02	See attached sheet: Material Costs
	Subtotal			**$340.89**		**6.25**		**$356.95**	**$697.84**	
7	Misc						0%		0	
	TOTAL								**$698**	

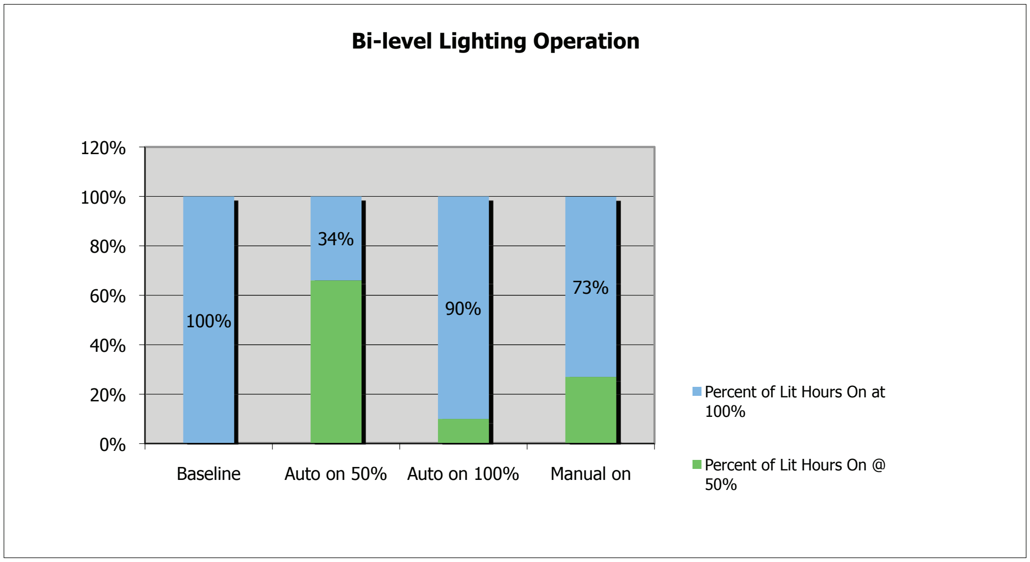
Project: **Bi-Level Office Lighting**
Facility: **Pierce County County-City Building** **New Construction**

Scenario Descriptions

Baseline	Single level occ sensor switch, set at manual on, auto off. (Use total hrs monitored for Scenario 3)
Scenario 1	Auto on at 50%, auto off with occupancy sensor.
Scenario 2	Auto on at 50%, auto off with occupancy sensor.
Scenario 3	Manual on, bi-level: 50% or 100%, auto off with occupancy sensor.

Lighting Operation Summary

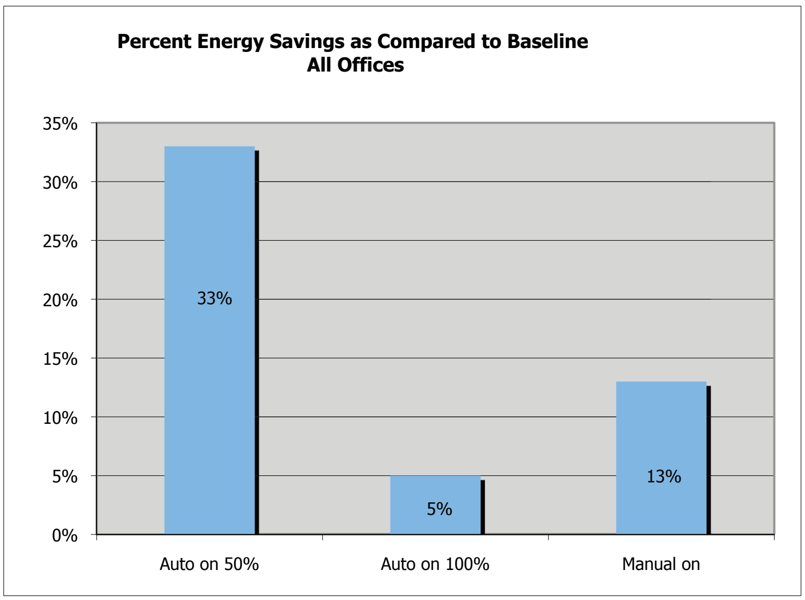
	Average Annual Hours Lights On	Percent of Lit Hours On at 100%	Percent of Lit Hours On @ 50%	Average Annual Hours Lights On @ 100%	Average Annual Hours Lights On @ 50%
Baseline	1655	100%	0%	1655	0
Auto on 50%	1655	34%	66%	562	1093
Auto on 100%	1655	90%	10%	1490	166
Manual on	1655	73%	27%	1208	447



Project: **Bi-Level Office Lighting**
Facility: **Pierce County County-City Building** **New Construction**

Energy Savings

	Small Office			Large Office		
	Average kWh/yr	Savings (kWh/yr)	Percent Savings	Average kWh/yr	Savings (kWh/yr)	Percent Savings
Baseline	195			586		
Auto on 50%	131	64	33%	392	194	33%
Auto on 100%	186	9	5%	557	29	5%
Manual on	169	26	13%	507	79	13%



Bi Level Office Lighting
Savings Calculations New Construction/Major Remodel

Under a new construction/major remodel scenario, the economic analysis is based on incremental cost and savings as compared to the lighting system that would have been installed. The basecase lighting system for this analysis is the minimum code-compliant lighting system.

Basecase hours are assumed as the annual hours monitored for the matching switch situation - single level manual on, auto off (Scenario 3).

Basecase Scenario - Code-compliant Retrofit
Small office, Two fixtures, each with 2, T8 lamps and electronic ballast. Single switch (0% or 100%) with occupancy sensor. Manual on/auto off.

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	2	
Power per office	0.118	kW

Control Retrofit Scenarios - T8 lamps and electronic bi-level ballasts, wall occupancy sensors
1 Upgrade to bi-level occ sensor, auto-on at 50%.
2 Uphrade to bi-level occ sensor, auto-on at 100%.
3 Upgrade to bi-level occ sensor, manual on.

	Savings		Installed Cost	Payback
Scenario	**kWh/yr**	**$/yr**	**$**	**yrs**
1 Bi-level, auto on at 50%, auto off	64	$5.62	$50	9
2 Bi-level, auto on at 100%, auto off	9	$0.79	$50	64
3 Bi-level, manual on, auto off	26	$2.28	$50	22

Scenario 1 - Manual on, single level switch w OS to bi-level switch w OS, auto-on 50%

Assumptions

Energy Rate	$0.09	
Basecase hours, manual	1655	hr/yr
Post retrofit hours	1655	hr/yr
Bilevel: % hours at low, auto-on 50%	66%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		1655	1655		195	$17.13
Proposed	0.118	0.059	1655	562	1093	131	$11.51
Savings						64	$5.62
% Savings						33%	

Estimated cost	$50	incremental cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)
Simple payback	9 years	

Scenario 2 - Manual on, single level switch w OS to bi-level switch w OS, auto-on 100%

Assumptions

Energy Rate	$0.10	
Basecase hours, manual	1655	hr/yr
Post retrofit hours	1655	hr/yr
Bilevel: % hours at low, auto-on 100%	10%	

Bi Level Office Lighting
Savings Calculations New Construction/Major Remodel

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		1655	1655		195	$17.13
Proposed	0.118	0.059	1655	1490	165	186	$16.34
Savings						9	$0.79
% Savings						5%	

Estimated cost	$50	incremental cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)
Simple payback	64 years	

Scenario 3 - Manual on, single level switch w OS to bi-level switch w OS, manual on

Assumptions

Energy Rate	$0.10
Basecase hours, manual	1655 hr/yr
Post retrofit hours	1655 hr/yr
Bilevel: % hours at low, manual on	27%

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		1655	1655		195	$17.13
Proposed	0.118	0.059	1655	1208	447	169	$14.84
Savings						26	$2.28
% Savings						13%	

Estimated cost	$50	incremental cost, switch & ballast plus rewiring to bilevel (See attached cost calculations)
Simple payback	22 years	

Note 1: Ref: BPA Ltg Calculator, Standard 4' T8 2L, 32 W 80+CRI with NLO ballast, (2-F32T8)
Note 2: Ref: US Energy Information Administration, Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, For Washington, commercial sector. August 2010. Tax and fee multiplier of 20% added.

Bi Level Office Lighting
Installation Costs New Construction/Major Remodel

Control Retrofit Scenarios
Small office: Upgrade from single level OS wall switch/sensor to bi-level wall switch/sensor and to bi-level ballasts.
Large office: Upgrade from single level wall switch to bi level wall switch and to bi-level ballasts.

Means Data

	Rate incl O&P	
Electrician	$75.30	
Helper	$51.60	
Install Cost A	90%	Avg for NW
Avg Rate	$57.11	Assume 1 Elec+1 Helper

CODE REQUIRES OCC SENSOR
Include bi-level ballast.
Small Office
Incremental cost of bi-level wall switch/sensor as compared to single level wall switch/sensor.
Incremental cost of bi-level ballast over single level ballast.
Incremental cost of labor is assumed to be zero. Installation of both systems should require roughly the same effort.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	0	$10.00	$0.00	0	0	$57.11	$0.00	$0.00	estimate
2	Bi-level wall switch w occ sensor, dual technology, incl commissioning.	1	$21.87	$21.87	0	0	$57.11	$0.00	$21.87	See attached sheet: Material Costs
3	Bi-level ballast	2	$14.19	$28.38	0	0	$57.11	$0.00	$28.38	See attached sheet: Material Costs
	Subtotal			**$50.25**		**0**		**$0.00**	**$50.25**	
4	Misc						0%		$0.00	estimate
	TOTAL								**$50**	

Large Office
Incremental cost of bi-level wall switch as compared to single level wall switch.
Incremental cost of bi-level ballast over single level ballast.
Incremental cost of dual relay room controller over single relay room controller.
Incremental cost of labor is assumed to be zero. Installation of both systems should require roughly the same effort.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	0	$10.00	$0.00	0	0	$57.11	$0.00	$0.00	estimate
2	Bi-level ballast	6	$14.19	$85.14	0	0	$57.11	$0.00	$85.14	See attached sheet: Material Costs
3	BI-level wall switch	1	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
4	Ceiling occupancy sensor	0	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
5	Room Controller	1	$24.49	$24.49	0	0	$57.11	$0.00	$24.49	See attached sheet: Material Costs
6	Cable	0	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
	Subtotal			**$109.63**		**0**		**$0.00**	**$109.63**	
7	Misc						0%		0	
	TOTAL								**$110**	

Assume no bi-level ballast, wire to alternate fixture switching or tandem lamp switching.

Small Office

Incremental cost of bi-level wall switch/sensor as compared to single level wall switch/sensor.

Incremental cost of labor is assumed to be zero. Installation of both systems should require roughly the same effort.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	0	$10.00	$0.00	0	0	$57.11	$0.00	$0.00	estimate
2	Bi-level wall switch w occ sensor, dual technology, incl commissioning.	1	$21.87	$21.87	0	0	$57.11	$0.00	$21.87	See attached sheet: Material Costs
3	Bi-level ballast	2	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
	Subtotal			**$21.87**		**0**		**$0.00**	**$21.87**	
4	Misc						0%		$0.00	estimate
	TOTAL								**$22**	

Large Office

Incremental cost of bi-level wall switch as compared to single level wall switch.

Incremental cost of dual relay room controller over single relay room controller.

Incremental cost of labor is assumed to be zero. Installation of both systems should require roughly the same effort.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	0	$10.00	$0.00	0	0	$57.11	$0.00	$0.00	estimate
2	Bi-level ballast	6	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
3	BI-level wall switch	1	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
4	Ceiling occupancy sensor	0	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
5	Room Controller	1	$24.49	$24.49	0	0	$57.11	$0.00	$24.49	See attached sheet: Material Costs
6	Cable	0	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
	Subtotal			**$24.49**		**0**		**$0.00**	**$24.49**	
7	Misc						0%		0	
	TOTAL								**$24**	

NO CODE REQUIREMENT FOR OCC SENSOR - USE FOR BPA INCENTIVE ANALYSIS

Assume no bi-level ballast, wire to alternate fixture switching or tandem lamp switching.

Small Office

Incremental cost of bi-level wall switch/sensor as compared to single level wall switch.

Incremental cost of labor is assumed to be zero. Installation of both systems should require roughly the same effort.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	0	$10.00	$0.00	0	0	$57.11	$0.00	$0.00	estimate
2	Bi-level wall switch w occ sensor, dual technology, incl commissioning.	1	$70.40	$70.40	0	0	$57.11	$0.00	$70.40	See attached sheet: Material Costs
3	Bi-level ballast	2	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
	Subtotal			**$70.40**		**0**		**$0.00**	**$70.40**	
4	Misc						0%		$0.00	estimate
	TOTAL								**$70**	

Large Office

Incremental cost of bi-level wall switch as compared to single level wall switch.

Incremental cost of a ceiling occupancy sensor.

Incremental cost of dual relay room controller over single relay room controller.

Incremental cost of labor is assumed to be zero. Installation of both systems should require roughly the same effort.

		Materials			Labor					
	Item	Qty	Cost/ea	Total	Hr/ unit	Total hr	Rate	Total	Total Matls + Labor	Note
1	Wire and misc materials.	0	$10.00	$0.00	0	0	$57.11	$0.00	$0.00	estimate
2	Bi-level ballast	6	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
3	BI-level wall switch	1	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
4	Ceiling occupancy sensor	1	$174.52	$174.52	0	0	$57.11	$0.00	$174.52	See attached sheet: Material Costs
5	Room Controller	1	$24.49	$24.49	0	0	$57.11	$0.00	$24.49	See attached sheet: Material Costs
6	Cable	0	$0.00	$0.00	0	0	$57.11	$0.00	$0.00	See attached sheet: Material Costs
	Subtotal			**$199.00**		**0**		**$0.00**	**$199.00**	
7	Misc						0%		0	
	TOTAL								**$199**	

Bi Level Office Lighting
Material Costs

Actual costs paid by project to local distributor, including tax and shipping.

Tacoma sales tax	9.3%
Estimate shipping adder	2.0%
Total adder	11.3%

Retrofit Case

Small Office	Cost each		Description
Bi-level ballast	$28.66		Sylvania Quicktronic Prostart T8 Quickstep Bi-level Dimming Ballast. Item number: 49157. Model number: QHES2x32T8/UNV PSN-SC
BI-level wall switch sensor	$107.12		Wattstopper DW-200 Dual Technology Dual Relay Wall Switch Sensor

Large Office	Cost each		Description
Bi-level ballast	$28.66		Sylvania Quicktronic Prostart T8 Quickstep Bi-level Dimming Ballast. Item number: 49157. Model number: QHES2x32T8/UNV PSN-SC
BI-level wall switch	$36.73		Wattstopper LMSW-102 Series Digital Wall Switches
Ceiling occupancy sensor	$174.52		Wattstopper LMDC-100 Digital Dual Technolgy Ceiling Mount Occupancy Sensor
Room Controller	$110.19		Wattstopper LMRC-102 Series Digital On/Off Room Controller
Cable	$4.73		Wattstopper LMRJ Series Per-Terminated Cales and Sement Network Wire

New Construction/Major Remodel Case

Small Office	Cost each	Incremental Cost	Description
Single level ballast	$14.47		Sylvania Quicktronic T8 electronic ballast, single level.
Bi-level ballast	$28.66	$14.19	Sylvania Quicktronic Prostart T8 Quickstep Bi-level Dimming Ballast. Item number: 49157. Model number: QHES2x32T8/UNV PSN-SC
Single level wall switch sensor.	$85.25		Wattstopper DW-100 Dual Technology Single Relay Wall Switch Sensor
BI-level wall switch sensor	$107.12	$21.87	Wattstopper DW-200 Dual Technology Dual Relay Wall Switch Sensor

Large Office	Cost each	Incremental Cost	Description
Single level ballast	$14.47		Sylvania Quicktronic T8 electronic ballast, single level.
Bi-level ballast	$28.66	$14.19	Sylvania Quicktronic Prostart T8 Quickstep Bi-level Dimming Ballast. Item number: 49157. Model number: QHES2x32T8/UNV PSN-SC
Single level wall switch	$36.73		Wattstopper LMSW-101 Series Digital Wall Switches
BI-level wall switch	$36.73	$0.00	Wattstopper LMSW-102 Series Digital Wall Switches
Single relay room controller	$85.70		Wattstopper LMRC-101 Series Digital On/Off Room Controller
Dual Relay Room Controller	$110.19	$24.49	Wattstopper LMRC-102 Series Digital On/Off Room Controller

Bi Level Office Lighting
Savings Calculations Favorable Lighting Operation Assumptions

Economic performance of bi-level lighting is impacted by a number of variables, such as baseline lighting hours of operation and installation cost. The economic performance for a hypothetical situation with favorable lighting operation variables was calculated to show "best case" economics.

The following assumptions were used in this analysis.
- monitored percent energy savings for bi-level switching with occupancy sensors as calculated for this study
- current BPA assumption for baseline office lighting operation – 3,000 hr/yr
- average electric rate – $0.09/kWh (average rate for large commercial customers in Washington state)
- lower installation costs without a bi-level ballast included
- available incentives of $35 per occupancy sensor for small offices and $60 per occupancy sensor for large offices

RETROFIT

Summary

	Basecase	Savings			Installed Cost[5]	Installed Cost w Incentive	Payback w Incentive
Option	**kWh/yr**	**kWh/yr**	**%**	**$/yr**	**$**	**$**	**yrs**
Small Office, Bi-level, auto on at 50%, rewire.	354	131	37%	$11.51	$303	$268	23
Large Office, Bi-level, auto on at 50%, rewire.	1062	393	37%	$34.52	$698	$638	18

Assumptions

Energy Rate[2]	$0.09	
Basecase hours, manual[3]	3000	hr/yr

Basecase Scenario Small Office

Small office, Two fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%).

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	2	
Power per office	0.118	kW
Incentive per office:	$35	
Bilevel: % energy savings, auto-on 50%	37%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		3000	3000		354	$31.10
Proposed						223	$19.59
Savings						131	$11.51
% Savings						37%	

Basecase Scenario Large Office

Large office, six fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%). Configuration for typical large office in study.

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	6	
Power per office	0.354	kW
Incentive per office:	$60	
Bilevel: % energy savings, auto-on 50%	37%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.354		3000	3000		1062	$93.29
Proposed						669	$58.77
Savings						393	$34.52
% Savings						37%	

NEW CONSTRUCTION

Under a new construction/major remodel scenario, the economic analysis is based on incremental cost and savings as compared to the lighting system that would have been installed. The basecase lighting system for this analysis is the minimum code-compliant lighting system.
Incentives are not available where code requires occupancy sensors.

Summary

	Basecase	Savings			Installed Cost[5]	Payback
Option	**kWh/yr**	**kWh/yr**	**%**	**$/yr**	**$**	**yrs**
Small Office, Bi-level, auto on at 50%, rewire.	354	117	33%	$10.26	$22	2
Large Office, Bi-level, auto on at 50%, rewire.	1062	350	33%	$30.78	$24	1

Assumptions

Energy Rate[2]	$0.09	
Basecase hours, OS[4]	2250	hr/yr

<u>Basecase Scenario Small Office</u>
Small office, Two fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%).

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	2	
Power per office	0.118	kW
Bilevel: % energy savings, auto-on 50%	33%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		3000	3000		354	$31.10
Proposed						237	$20.83
Savings						117	$10.26
% Savings						33%	

<u>Basecase Scenario Large Office</u>
Large office, six fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%). Configuration for typical large office in study.

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	6	
Power per office	0.354	kW
Bilevel: % energy savings, auto-on 50%	33%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.354		3000	3000		1062	$93.29
Proposed						712	$62.50
Savings						350	$30.78
% Savings						33%	

Note 1: Ref: BPA Ltg Calculator, Standard 4' T8 2L, 32 W 80+CRI with NLO ballast, (2-F32T8)
Note 2: Ref: US Energy Information Administration, Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, For Washington, commercial sector. August 2010. Tax and fee multiplier of 20% added.
Note 3: Ref: BPA Ltg Calculator, basecase office lighting hours, 12 hr/dy, 5 dy/wk, 50 wk/yr
Note 4: Assume lighting hours for code compliant basecase with OS. Use BPA assumption of 25% reduction from no OS baseline hours or 3000 hr/yr.
Note 5: See attached cost calculations

Bi Level Office Lighting
Savings Calculations BPA Incentive Program Case

The BPA currently offers incentives for standard occupancy sensors. Consideration of incentives for bi-level switching in combination with occupancy sensors requires information on savings and cost. Monitored data for operation at high and low lighting levels is combined with current BPA assumptions for standard occupancy savings to calculate savings and cost for the combined strategy - bi-level switching with occupancy sensors.

Basecase Scenario Small Office
Small office, Two fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%).

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	2	
Power per office	0.118	kW

Retrofit Options
1 Convert to bi-level switching with occ sensor, auto-on at 50%, bi-level ballast.
2 Convert to bi-level switching with occ sensor, auto-on at 50%, rewire luminaires or lamps.

	Basecase	Savings			Installed Cost[5]	Payback
Option	**kWh/yr**	**kWh/yr**	**%**	**$/yr**	**$**	**yrs**
1 Bi-level, auto on at 50%, bi-level ballast.	354	176	50%	$15.46	$360	23
2 Bi-level, auto on at 50%, rewire.	354	176	50%	$15.46	$303	20

Assumptions

Energy Rate[2]	$0.09	
Basecase hours, manual[3]	3000	hr/yr
Occ sensor savings[4]	25%	
Post retrofit hours	2250	hr/yr
Bilevel: % hours at low, auto-on 50%	66%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.118		3000	3000		354	$31.10
Proposed	0.118	0.059	2250	764	1486	178	$15.64
Savings						176	$15.46
% Savings						50%	

Basecase Scenario Large Office
Large office, six fixtures, each with 2, T8 lamps and electronic ballast. Single manual switch (0% or 100%). Configuration for typical large office in study.

Power per fixture: 2L, T8, EB [1]	0.059	kW/fix
Number of fixtures	6	
Power per office	0.354	kW

Retrofit Options
1 Convert to bi-level switching with occ sensor, auto-on at 50%, bi-level ballast.
2 Convert to bi-level switching with occ sensor, auto-on at 50%, rewire luminaires or lamps.

	Basecase	Savings			Installed Cost[5]	Payback
Option	**kWh/yr**	**kWh/yr**	**%**	**$/yr**	**$**	**yrs**
1 Bi-level, auto on at 50%, bi-level ballast.	1062	529	50%	$46.47	$870	19
2 Bi-level, auto on at 50%, rewire.	1062	529	50%	$46.47	$698	15

Assumptions

Energy Rate[2]	$0.09	
Basecase hours, manual[3]	3000	hr/yr
Occ sensor savings[4]	25%	
Post retrofit hours	2250	hr/yr
Bilevel: % hours at low, auto-on 50%	66%	

Savings

	kW high	kW low	Total Hrs	hr/yr high	hr/yr low	kWh/yr total	$/yr
Base case	0.354		3000	3000		1062	$93.29
Proposed	0.354	0.177	2250	764	1486	533	$46.82
Savings						529	$46.47
% Savings						50%	

Note 1: Ref: BPA Ltg Calculator, Standard 4' T8 2L, 32 W 80+CRI with NLO ballast, (2-F32T8)
Note 2: Ref: US Energy Information Administration, Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, For Washington, commercial sector. August 2010. Tax and fee multiplier of 20% added.
Note 3: Ref: BPA Ltg Calculator, basecase office lighting hours, 12 hr/dy, 5 dy/wk, 50 wk/yr
Note 4: Ref: BPA Ltg Calculator, assumed reduction in lighting hours for standard OS. 25%
Note 5: See attached cost calculations

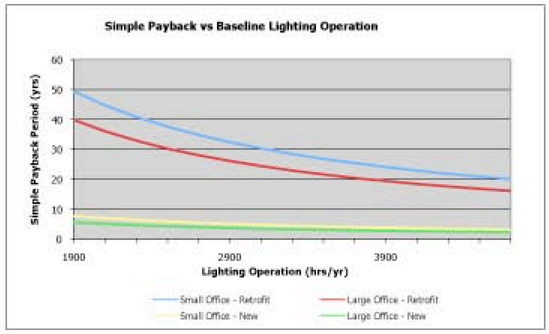
Project: Bi-Level Office Lighting
Facility: Pierce County City-County Building

Analysis
For the Auto-on at 50% scenario, which yields the highest savings, calculate the payback for different hours of operation

Installed Cost		$
Small Office - Retrofit		$360.05
Large Office - Retrofit		$869.80
Small Office - New Construction		$50.25
Large Office - New Construction		$109.63

Simple Payback (yrs) Small Office Retrofit

Baseline Hours/year	Baseline Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Small Office - Retrofit
1900	$19.69	$7.29	49.4
2100	$21.77	$8.05	44.7
2300	$23.84	$8.82	40.8
2500	$25.91	$9.59	37.6
2700	$27.99	$10.35	34.8
2900	$30.06	$11.12	32.4
3100	$32.13	$11.89	30.3
3300	$34.20	$12.66	28.4
3500	$36.28	$13.42	26.8
3700	$38.35	$14.19	25.4
3900	$40.42	$14.96	24.1
4100	$42.50	$15.72	22.9
4300	$44.57	$16.49	21.8
4500	$46.64	$17.26	20.9
4700	$48.72	$18.02	20



Simple Payback (yrs) Large Office Retrofit

Baseline Hours/year	Baseline Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Large Office - Retrofit
1900	$59.08	$21.86	39.8
2100	$65.30	$24.16	36.0
2300	$71.52	$26.46	32.9
2500	$77.74	$28.76	30.2
2700	$83.96	$31.06	28.0
2900	$90.18	$33.37	26.1
3100	$96.40	$35.67	24.4
3300	$102.61	$37.97	22.9
3500	$108.83	$40.27	21.6
3700	$115.05	$42.57	20.4
3900	$121.27	$44.87	19.4
4100	$127.49	$47.17	18.4
4300	$133.71	$49.47	17.6
4500	$139.93	$51.77	16.8
4700	$146.15	$54.07	16.1

Simple Payback (yrs) Small Office New Constr

Baseline Hours/year	Baseline Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Small Office - New
1900	$19.69	$6.50	7.7
2100	$21.77	$7.18	7.0
2300	$23.84	$7.87	6.4
2500	$25.91	$8.55	5.9
2700	$27.99	$9.24	5.4
2900	$30.06	$9.92	5.1
3100	$32.13	$10.60	4.7
3300	$34.20	$11.29	4.5
3500	$36.28	$11.97	4.2
3700	$38.35	$12.66	4.0
3900	$40.42	$13.34	3.8
4100	$42.50	$14.02	3.6
4300	$44.57	$14.71	3.4
4500	$46.64	$15.39	3.3
4700	$48.72	$16.08	3.1

k (yrs) Large Office New Constr

Baseline Hours/year	Baseline Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Large Office - New
1900	$59.08	$19.50	5.6
2100	$65.30	$21.55	5.1
2300	$71.52	$23.60	4.6
2500	$77.74	$25.65	4.3
2700	$83.96	$27.71	4.0
2900	$90.18	$29.76	3.7
3100	$96.40	$31.81	3.4
3300	$102.61	$33.86	3.2
3500	$108.83	$35.92	3.1
3700	$115.05	$37.97	2.9
3900	$121.27	$40.02	2.7
4100	$127.49	$42.07	2.6
4300	$133.71	$44.12	2.5
4500	$139.93	$46.18	2.4
4700	$146.15	$48.23	2.3

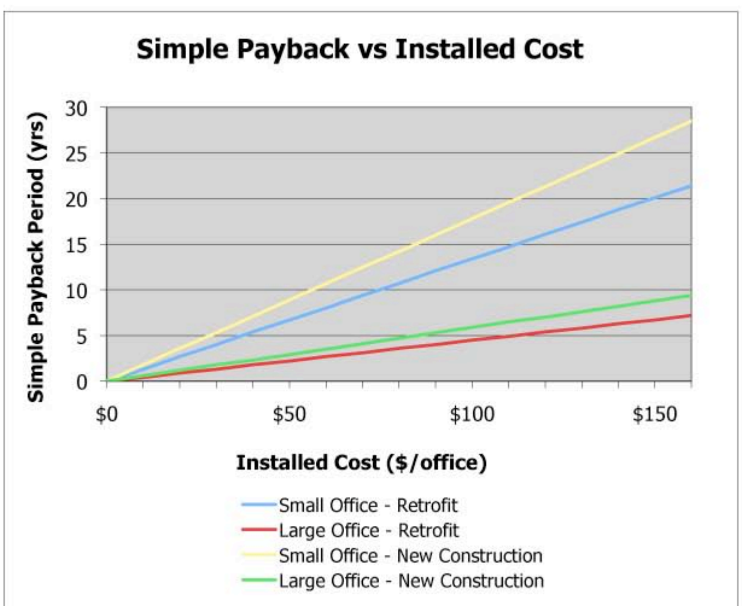
Project: **Bi-Level Office Lighting**
Facility: **Pierce County City-County Building**

Analysis
For the Auto-on at 50% scenario, which yields the highest savings, calculate the payback for different installed costs.

Energy Cost Savings		$/yr
Small Office - Retrofit		$7.47
Large Office - Retrofit		$22.31
Small Office - New Construction		$5.62
Large Office - New Construction		$17.04

Simple Payback (yrs)

Installed Cost ($/office)	Small Office - Retrofit	Large Office - Retrofit	Small Office - New Construction	Large Office - New Construction
$0	0	0	0	0
$10	1.3	0.4	1.8	0.6
$20	2.7	0.9	3.6	1.2
$30	4	1.3	5.3	1.8
$40	5.4	1.8	7.1	2.3
$50	6.7	2.2	8.9	2.9
$60	8	2.7	10.7	3.5
$70	9.4	3.1	12.5	4.1
$80	10.7	3.6	14.2	4.7
$90	12.1	4	16	5.3
$100	13.4	4.5	17.8	5.9
$110	14.7	4.9	19.6	6.5
$120	16.1	5.4	21.3	7
$130	17.4	5.8	23.1	7.6
$140	18.8	6.3	24.9	8.2
$150	20.1	6.7	26.7	8.8
$160	21.4	7.2	28.5	9.4
$170	22.8	7.6	30.2	10
$180	24.1	8.1	32	10.6
$190	25.4	8.5	33.8	11.1



Appendix C

Occupant Survey and Results

LIGHTING SURVEY
NEW LIGHTING SWITCHES

DEPARTMENT/POSITION ____________________________ DATE _____________

ROOM NO. ________ NAME (Optional) ____________________________________

Pierce County, in collaboration with the Washington State University (WSU) Energy Program and the Bonneville Power Administration (BPA) is conducting an assessment of different types of switches for office lighting. First, we monitored the use of the existing lighting switches in your office. Subsequently, the light switch in your office was replaced with a new light switch and we again monitored the use of the switches under three different operating scenarios.

As part of the study, we would like to assess your satisfaction with your NEW lighting switches. PLEASE COMPLETE AND RETURN BY DECEMBER 3.

For the questions below, circle the response most closely matching your answer. Comments are encouraged.

1. Does your office lighting provide the right amount of light for your needs?

Much Too Dim	Somewhat Too Dim	Just Right	Somewhat Too Bright	Much Too Bright
1	2	3	4	5

Comments:

____

____

2. Do your new lighting switches provide adequate flexibility for your needs?

No	Neutral	Yes
1	2	3

Comments:

____

____

3. In general, how satisfied are you with the light provided by your office lighting system?

Very Dissatisfied	Somewhat Dissatisfied	Satisfied	Somewhat Satisfied	Very Satisfied
1	2	3	4	5

Comments:

____

____

(More questions page 2)

4. In general, how satisfied are you with the new switches for your office lighting?

Very Dissatisfied	Somewhat Dissatisfied	Satisfied	Somewhat Satisfied	Very Satisfied
1	2	3	4	5

Comments:

____

____

5. How satisfied are you with the new lighting switches as compared to the original?

Very Dissatisfied	Somewhat Dissatisfied	Satisfied	Somewhat Satisfied	Very Satisfied
1	2	3	4	5

Comments:

____

____

6. Of the three operating scenarios tested for the new lighting switches, which do you prefer (listed in the order tested)? (please check one)

☐ 1. Auto On at 50%/Auto Off: Lights are switched on automatically at the low level upon occupancy, the remaining lights can be switched on manually or all off manually, and lights are turned off automatically after the office is unoccupied for a period of time.

☐ 2. Auto On at 100%, Auto Off: Lights are switched on at the high level automatically upon occupancy, lights can be switched to a lower light level or all off manually, and lights are turned off automatically after the office is unoccupied for a period of time.

☐ 3. Manual On/Auto Off: Lights can be switched on and off manually, and lights are turned off automatically after the office is unoccupied for a period of time.

Comments:

____

____

____

Thank you for completing this form. Please hold on to the form until December 3rd, when Pierce County maintenance staff and/or WSU engineers will pick it up.

Bi Level Office Lighting
Occupant Survey Results

1. Does your office lighting provide the right amount of light for your needs? Total number of answers 14

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	%
1	Much Too Dim																0	0.0%
2	Somewhat Too Dim												x				1	7.1%
3	Just Right		x	x	x	x	x	x	x	x	x	x		x	x		12	85.7%
4	Somewhat Too Bright																0	0.0%
5	Much Too Bright	x															1	7.1%

2. Do your new lighting switches provide adequate flexibility for your needs? Total number of answers 14

		1	2	3	4	5	6	7	8	9	9	11	12	13	14	15	Total	%
1	No												x				1	7.1%
2	Neutral		x				x										2	14.3%
3	Yes	x		x	x	x		x	x	x	x	x		x	x		11	78.6%

3. In general, how satisfied are you with the light provided by your office lighting system? Total number of answers 13

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	%
1	Very Dissatisfied																0	0.0%
2	Somewhat Dissatisfied		x		x												2	15.4%
3	Satsified			x			x	x				x	x	x			6	46.2%
4	Somewhat Satisfied																0	0.0%
5	Very Satisfied					x			x	x	x				x		5	38.5%

4. In general, how satisfied are you with the new switches for your office lighting? Total number of answers 14

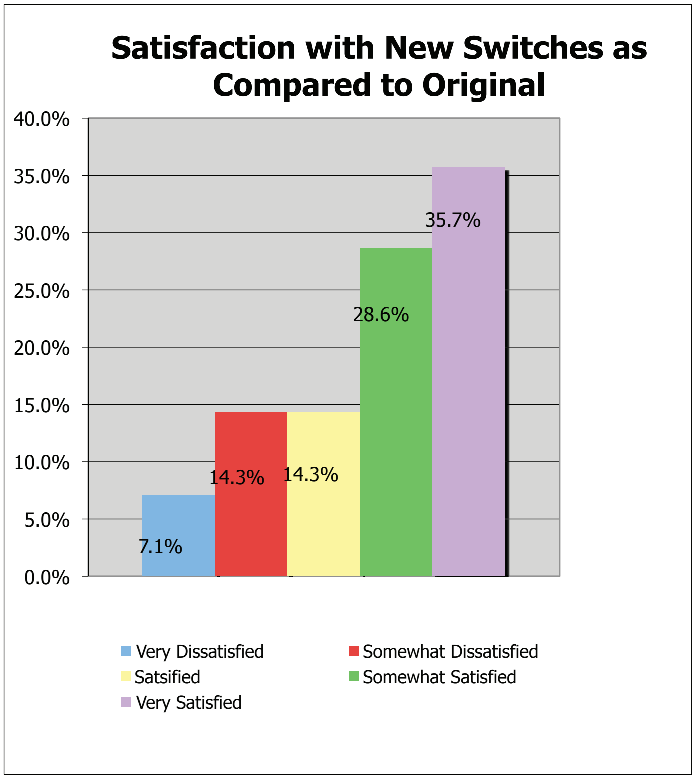
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	%
1	Very Dissatisfied																0	0.0%
2	Somewhat Dissatisfied		x		x										x		3	21.4%
3	Satsified	x										x					2	14.3%
4	Somewhat Satisfied			x			x	x					x	x			5	35.7%
5	Very Satisfied					x			x	x	x						4	28.6%

5. How satisfied are you with the new lighting switches as compared to the original? Total number of answers 14

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	%
1	Very Dissatisfied				x												1	7.1%
2	Somewhat Dissatisfied		x												x		2	14.3%
3	Satsified	x										x					2	14.3%
4	Somewhat Satisfied						x	x					x	x			4	28.6%
5	Very Satisfied			x		x			x	x	x						5	35.7%

6. Of the three operating scenarios tested for the new lighting switches, which do you prefer (listed in the order tested)? 14

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	%
1	Auto On at 50%/Auto Off			x	x	x	x	x	x		x	x		x			9	64.3%
2	Auto On at 100%, Auto Off		x							x			x		x		4	28.6%
3	Manual On/Auto Off	x															1	7.1%


Satisfaction with New Switches as Compared to Original
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
7.1%
14.3%
14.3%
28.6%
35.7%
Very Dissatisfied
Somewhat Dissatisfied
Satsified
Somewhat Satisfied
Very Satisfied

WASHINGTON STATE UNIVERSITY
EXTENSION ENERGY PROGRAM