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Responsive Lighting Solutions

Prepared for the General Services Administration

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The Green Proving Ground program leverages GSA's real estate portfolio to evaluate innovative sustainable building technologies and practices. Findings are used to support the development of GSA performance specifications and inform decision-making within GSA, other federal agencies, and the real estate industry. The program aims to drive innovation in environmental performance in federal buildings and help lead market transformation through deployment of new technologies.

Disclaimer

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1 Executive Summary

1.1 Background

Lighting accounts for 38% of the electricity used by commercial buildings in the United States and 39% of electricity use in office buildings, representing a large potential source of energy savings [1]. Responsive lighting controls are the most practical and economical means to dramatically reduce the energy footprint of commercial building lighting systems and make building electrical systems more responsive to times of grid stress. Controls also provide an opportunity to maximize efficiency while maintaining favorable lighting conditions when and where they are needed. Despite these advantages, key interested parties, ranging from building managers to large public and private owners, are unaware of how new control technologies have significantly improved the energy-efficiency of lighting systems. Efficient, highly-controlled lighting for open-plan office spaces has always been a challenge for facility designers. This work focuses on one emerging solution for responsive lighting – workstation-specific (WS) luminaires - that offers tremendous potential advantages in terms of energy efficiency and providing luminous conditions that reflect occupant needs in open-plan offices.

The General Services Administration (GSA) Public Building Service (PBS) owns or leases more than 9,600 assets and is responsible for managing an inventory of diverse Federal buildings, totaling more than 370 million square feet of building stock. Since the large majority of the GSA's buildings include office spaces, and GSA is mandated to meet ambitious energy targets by 2015 and greenhouse gas reductions by 2020, the Green Proving Ground identified cost-effective, energy-efficient lighting solutions as a priority focus area for its 2011 program.

This GPG study built upon earlier Lawrence Berkeley National Laboratory (LBNL) studies conducted on workstation specific (WS) lighting in the Phillip Burton Federal Building, San Francisco [2][3]. This study expanded on the previous studies by analyzing results for both a wider subset of GSA-operated buildings in California as well as a greater number of responsive lighting control strategies.

1.2 Study Design and Objectives

The technology evaluated in this study is characterized as "Responsive Lighting Solutions". Responsive Lighting Solutions technology represents a comprehensive lighting retrofit package that has the following characteristics:

- Workstation-specific (WS) luminaires (light fixtures centered over individual cubicles)
- Dimmable ballasts that allow WS luminaires to be provide preferred light levels for individual occupants

- Sensors that allow WS luminaires to be dimmed or turned off when an individual cubicle is vacant
- A Lighting Management Control System (LMCS) that coordinates sensor information and occupant input to control and monitor lighting output and energy use

This study was designed to evaluate the energy savings, photometric performance, and occupant satisfaction associated with Responsive Lighting Solutions by comparing the performance of the retrofitted lighting system to the systems in place prior to the retrofit. This study was conducted in seven sites located in five Federal Buildings in California selected to capture a diverse group of agencies, occupancy patterns, work styles, site conditions, and baseline conditions. Note that this report contains a subset of the data and sites that will be presented in a Final Report to the Commercial Buildings Partnership's (CBP) program. The current report summarizes the key findings from seven of the ten sites studied. The more detailed Final Report, which will discuss the results with greater depth and analysis will be released in November 2012.

This study focused on three key objectives:

- Quantifying and understanding the energy savings, light condition changes, and occupant satisfaction changes associated with each lighting retrofit
- Evaluating the costs and paybacks associated with the lighting retrofits
- Analyzing the results across sites to deliver a recommendation for future deployment of this technology across GSA's portfolio

1.3 Technology Description

The responsive lighting systems implemented in this study provide a high granularity of control by employing a variety of advanced design and control approaches to match light conditions to a building's set points and occupant needs. A basic schematic of the responsive lighting and control system measured for this study and its inputs can be seen in Figure 1 below.

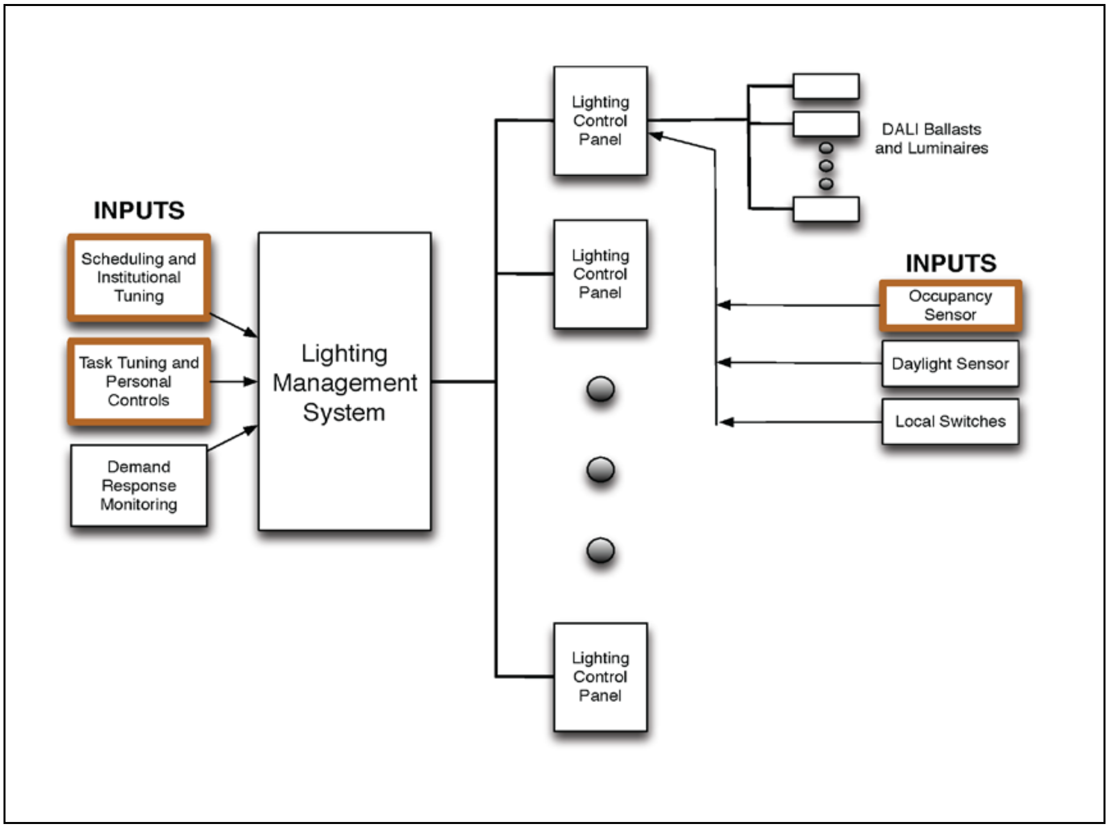


Figure 1: Schematic design of a workstation specific lighting management system. This study focused on the effects of the highlighted controls: scheduling and institutional tuning, task tuning and personal controls, and occupancy sensors.

Key technical attributes of system components are as follows:

- **Lighting management system:** The lighting management system is a Digital Addressable Lighting Interface (DALI)-based control system that offers operators individual ballast control and records sensor information and estimated power levels based on ballast settings.

- **Digital dimmable ballasts:** Digital ballasts (DALI ballasts in this study) allow operators to set light levels for individual ballasts, while continuous dimming provides a wide range of available light levels.

- **Workstation-specific (WS) luminaires with built-in occupancy sensors:** By aligning individual luminaires with individual cubicles, WS lighting enables granular control based on individual cubicle occupancy and light level control based on personal preferences.

Although responsive lighting systems can employ a multitude of control strategies, this study focused on institutional tuning and scheduling, personal control, and occupancy sensing. Institutional tuning allows building managers and tenants to decrease energy consumption by programming default light levels within the lighting management system that reflect sub-zone and/or building policies. Occupancy sensors reduce electrical demand by adjusting light levels or turning lights on or off at the workstation level in response to the presence or absence of an occupant. Finally, personal control allows occupants to adjust their individual light levels to suit their personal preferences.

1.4 Technology Deployment

Pre-retrofit overhead lighting and controls varied from site to site. In general, pre-retrofit lighting systems consisted of recessed luminaires that were regularly spaced in open areas and large rooms or distributed based on layout in private offices. Dimmable ballasts or photocells were not installed in any of the study areas prior to the retrofits, although some sites employed large zonal occupancy sensors. Although some occupancy sensors were located in private offices, this was not common practice. Several sites maintained scheduled shutoffs or sweeps in the evening to turn lights off after operating hours.

The retrofits consisted primarily of installing new fixtures, installing sensors, and running new communications wiring within the existing ceiling grid. Fixture and circuit layout were changed in open office areas to create a workstation-specific (WS) layout such that a fixture was centered above each cubicle in the open office plan. This change generally increased the lighting power density (LPD) significantly.

Each retrofit in this study used luminaires selected from a small suite of efficient options. To operate these luminaires, dimmable ballasts were controlled by a Lighting Management Control System (LMCS). Suspended, direct/indirect 4- or 8-foot long WS fixtures were installed above open office cubicles, while recessed 2x4 and 2x2 fixtures were installed in private offices, conference rooms, and other similar room types. The direct/indirect WS fixtures in open office areas provided both upward-directed (ambient) light and downward-directed (task) light; the up-light and down-light components had separate ballasts and were individually controllable. Open office WS fixtures also employed built-in occupancy sensors. Lights turned on to a preset level when an occupant entered their workspace, and with one exception, both up-lights and down-lights turned off in unoccupied cubicles after a timeout (typically 30 minutes).

1.5 Analysis Methods

In addition to characterizing the sites, occupants, and control system, a thorough assessment of the pre-retrofit and post-retrofit power metering, workspace light characterization, and occupant surveys were completed for each site.

1.5.1 Power Metering and Energy and Cost Analysis

Lighting branch circuits corresponding to either the entirety or a representative portion of the study area were metered for both pre- and post-retrofit periods at each site. Power data was converted to lighting power density (LPD) in watts per square foot over the course of each complete day of data. Days were separated into weekdays, weekends, and holidays, and the sorted LPDs were then converted to weekday, weekend, and holiday energy use intensity (EUI) in watt-hours per square foot per day. Finally, annual EUIs (in kilowatt-hours per square foot per year) were calculated for each site based on an assumed typical distribution of 251 weekdays, 104 weekend days, and 10 holidays per year. Pre-retrofit and post-retrofit annual EUIs were then compared to determine energy savings at each site. Since the WS lighting system installation generally raised the LPD at each of the sites, energy savings seen were assumed to be the result of the advanced lighting controls instead of the redesign. Greenhouse gas (GHG) emissions were also summarized by determining the global warming effect (GWE) for both pre- and post-retrofit operations based on both regional utility fuel mixes and national average fuel mixes.

A cost-effectiveness analysis was performed to determine whether the value of the future energy savings from the installation justified the expense of the investment. In the five buildings assessed in this study, the existing ceiling lighting systems were retired from service and replaced with an entirely different lighting system (the advanced lighting controls and WS lighting system). Therefore, this study considered the costs with the view that the installation was relighting the space, rather than simply retrofitting an existing system.

With this in mind, the cost-effectiveness analysis isolated the incremental cost of the lighting controls portion from the entire lighting replacement project cost for two scenarios. In the "GSA Standard" relighting scenario, we subtracted the cost of a lighting system meeting the minimum requirements of the 2010 Facility Standards for the Public Buildings Service (P-100) from the full project cost. Recognizing that similar controls could be applied to this base case system, and, alternatively, that upgraded lighting beyond this base case may be provided under a variety of circumstances, this study also identified payback for a second scenario, "Control System Cost Only" that subtracted from the full investment cost, the cost of a similar lighting system that did not include the advanced lighting controls, such as sensors, dimmable ballasts, or lighting controllers. Both of these scenarios assumed that GSA was planning on relighting the existing space and therefore subtracted the labor costs associated with reconfiguring the existing conditions. A further analysis was performed to determine sensitivity to pre-retrofit lighting energy consumption and electricity rates.

1.5.2 Photometric Characterization

Photometric characterizations were conducted for open office workspaces only. Desktop illuminance measurements were taken at the assumed primary work area, characterized as the front edge of the main desk's center section. The goal of these measurements was to characterize electric light levels; an effort was made to eliminate the effect of daylight by taking measurements at night or excluding measurements that deviated more than 25% when blind positions were modified. Task lights were typically turned off during measurements, but some measurements were taken with task lights turned on to approximate task light levels. The resulting median, quartile, minimum, and maximum pre-retrofit and post-retrofit light levels were compared. Post-retrofit workstations with non-default light level settings were separated from workstations with default levels for part of this comparison.

1.5.3 Occupant Surveys

Occupant surveys were administered before and after the lighting retrofit at each site. Occupants were asked to describe their workspace, lighting, and controls, and to respond to qualitative questions about their workspace and overall office light conditions. The survey was based on an earlier survey developed by Pacific Northwest National Laboratory (PNNL) in collaboration with the Light Right Consortium that was modified by PNNL in 2010 and 2011 with input from LBNL, among others. Surveys were administered online with the exception of two sites where paper surveys were distributed due to limited internet connection availability. In either case, responses were recorded anonymously. Survey response distributions were compiled and comparisons between pre-retrofit and post-retrofit responses were made using one-sided significance tests to determine satisfaction levels after the retrofits.

1.6 Results, Lessons Learned, and Recommendations

1.6.1 Results Summary

1.6.1.1Energy and Cost Analysis

Although the retrofits typically increased installed lighting power density (LPD), the installations still lowered energy consumption significantly through the use of advanced lighting controls. The retrofits generally achieved energy savings of around 1 kWh/SF/yr. From the calculated pre- and post-retrofit Energy Use Intensities (EUIs), reductions in greenhouse gas (GHG) emissions were calculated for both the regional utility fuel mix as well as the national average fuel mix. The regional utility fuel mix resulted in an average reduction of GHG emissions of 0.4 kg $CO_{2,eq}/ft^2$/year, while the national average fuel mix resulted in an average reduction of 0.6 kg $CO_{2,eq}/ft^2$/year across the sites.

Across all five buildings in the study, the shortest payback was achieved in the Roybal building (3.8 years calculated using the incremental “Control System Cost Only” scenario and 6.3 years for the ‘GSA Standard Cost’ scenario). This building was intensively occupied for 18 hours a day including over the weekends. This resulted in far larger initial lighting energy consumption at Roybal than at the other studied sites. After the retrofit, the use of responsive lighting at Roybal reduced the lighting energy cost by an impressive $0.49/ft^2/year while the other buildings, with their more modest pre-retrofit energy consumption, saw savings between $0.11 - $0.15/ft^2/year. These lower energy cost savings resulted in very long paybacks for two buildings especially (as high as 24 years when computed using the “Control System Cost Only” scenario and about 40 years when calculated the more stringent “Full Cost -GSA Standard Cost” scenario). For these buildings with low initial energy use, WS lighting would not be cost-effective based on avoided energy costs alone. However, it should be noted that WS lighting results in a higher quality illumination than the standard GSA solution and is highly customizable according to occupants' lighting needs. These potential non-energy benefits of WS lighting may result in their being adopted in some installations even though they are not cost-effective when evaluated entirely from the energy cost perspective.

Energy savings were largely attributable to the ability of fine-grained controls that enable lights to be controlled for vacancy at the cubicle level in intensively used space, as well as institutional tuning, and personal control. Site specific and workspace specific factors had a significant impact on both energy savings and cost effectiveness, with key factors including the nature of work being performed by the tenant, and whether or not the facility had unintentional after-hours lighting use.

1.6.1.2Photometric Characterization

The lighting retrofits were shown to provide light levels comparable to or higher than pre-retrofit conditions at the occupants' work surfaces. Of the measured workstation surfaces, 60% of the workstation-specific fixtures on default settings provided light levels higher than the acceptable Illuminating Engineering Society of North America (IESNA) level of 350 lux, compared to only 42% of the pre-retrofit fixtures. If measured light levels were included from WS fixtures with occupant-requested light settings changes, 56% of the measured workstation surfaces exceeded 350 lux. This suggested that given personal control over their overhead light, occupants would request a diverse range of light levels, often choosing lower light levels than the default settings. Although the chosen light levels may be lower than the acceptable IESNA level, they would result in improved occupant experience and greater energy savings.

1.6.1.3Occupant Satisfaction

The occupant surveys demonstrated that users were generally more satisfied with the retrofitted lighting system, although the survey also indicated that users wanted greater control over their overhead lights. Occupants typically found the new lighting system to provide better quality light with less glare. Occupants who worked in open office areas where the lighting layout switched from a regularly spaced grid to a WS layout typically preferred the location of the WS lighting over the pre-retrofit system. However, although the installed system allowed for individual control over overhead lights, GSA security restrictions during this study required occupants to contact the building O&M contractor to alter personal light levels. This restriction in personal control, combined with a lack of understanding on how to request changes in light level settings or lack of knowledge about the capabilities of the installed lighting system at some of the sites, appeared to be a source of occupant dissatisfaction. Additionally, a large number of free responses mentioned that the occupant sensors were not sensitive enough to small movements and would therefore sometimes turn off while the occupant was still present in the space.

Survey results also suggested that the timing of the survey distributions had an effect on occupant satisfaction results. Surveys that were administered a short period after an extended and complicated commissioning process resulted in less satisfied occupants than occupants who took the survey at a similar site but at a significantly later date after commissioning was completed. This suggests that although the retrofit may cause initial dissatisfaction due to the disruption of lighting usage habits, occupants will eventually acclimate to the new lighting system, especially when given greater knowledge and control of the system.

1.6.2 Key Lessons Learned and Recommendations

The study revealed a variety of lessons for responsive lighting control retrofits, including the following:

- Thorough commissioning that is both transparent and well-documented is essential to providing a control system that matches owner intent, operates effectively, and can be maintained over time. Additionally, a protocol for commissioning lighting controls systems should be reflected in contractual language to ensure the desired level and quality of commissioning.

- Advanced lighting control systems should be intuitive to operate with well-designed user interfaces and useful data presentation; in addition, appropriate training should be provided to operators in order to counter the steep learning curve and maintain investment in the commissioning process.

- Built-in diagnostics that provide clear feedback to operators would provide a major benefit and improve performance by reducing operational errors; in addition, a lack of diagnostics can result in large amounts of wasted energy.

- Direct and easily accessible control over workspace light levels would allow occupants to obtain the full benefits of personal control, which could result in increased energy savings, increased satisfaction, and improved performance.

1.7 Conclusions

As GSA strives to comply with mandated targets to reduce energy use intensity and Greenhouse Gas (GHG) emissions, and develop net-zero energy building designs, the demand to find innovative technologies that can deliver significant whole-building energy use reduction will grow. This study demonstrated that overall, responsive lighting systems have proven their ability to achieve deep energy savings while providing comparable or improved light levels and increased occupant satisfaction compared to existing GSA lighting systems.

For all sites except Roybal, this study has shown that responsive lighting controls can achieve energy savings of about 30% compared to measured baseline conditions. These savings resulted in an average energy use reduction of about 0.9 kWh/sf/yr. However, the average lighting energy use measured prior to all the retrofits (except Roybal) was only 2.6 kWh/sf/yr, which is 34% lower than the national average lighting energy use for offices (4 kWh/ft/yr). Because the measured baseline energy use without controls was already low in these buildings, the calculated paybacks for responsive lighting controls exceed 15 years using the lighting controls equipment costs that GSA paid at the time of the study. Lighting controls equipment costs and labor installation costs would need to drop substantially before workstation lighting could be considered cost-effective for retrofitting into the majority of GSA's building stock, which is already efficiently run.

The Roybal site was unique in that it was a call center lit 18 hours a day, 7 days a week. Because of its long hours of operation, Roybal's pre-retrofit lighting energy use was 6.5 kWh/sf/yr, which is 62% *higher* than the national office average. Applying responsive lighting at Roybal resulted in a 63% reduction in energy use and reduced the energy intensity by 4.1 kWh/sf/yr. For this building, the controls investment (calculated using the full cost – GSA retrofit cost) would be clearly life-cycle cost-effective, with a pay back of 6 years. Thus we conclude that for GSA buildings with higher-than-average energy use, responsive lighting controls will be life-cycle cost-effective, with a payback of under 10 years, for buildings with energy costs greater than or equal to $0.12/kWh.

As previously mentioned, the Occupant Responsive Lighting technology studied here focused primarily on workstation-specific lighting operating in tandem with occupancy sensing, and a lighting management control system that coordinated sensor input and tuning for user and institutional preference. In prioritizing deployment across GSA office spaces, Occupant Responsive Lighting technology would be most appropriate in spaces with extended operating hours and high levels of baseline illumination. In such spaces, the granular control capability of this technology will enable users to set individually preferable light levels that are likely to be lower, luminaires to be turned off when cubicles are vacant (e.g. during a swing shift) and institutional tuning strategies that turn off lights otherwise left on in unoccupied spaces (e.g., in infrequently used areas and/or after hours). More broadly, the underlying workstation-specific luminaire design works best in open offices with low and/or variable occupancy and larger cubicles.

Although energy savings will not be as high for spaces with lower baseline lighting power densities, and/or open offices with high levels of routine occupancy during a 12 hour/5 day work week, Occupant Responsive Lighting technology in a workstation-specific layout is highly customizable and enables occupants to work under desired light levels rather than institutionally set levels which may present other potential benefits to tenants, including improved occupant mood, satisfaction, and visual comfort, which could in turn increase productivity [4]. Finally, as responsive lighting controls become more widespread, costs will decrease as the technology moves to widespread production, and contractor knowledge of how to implement this technology becomes more commonplace.

The high granularity of control inherent in the advanced lighting controls system provides additional opportunities for energy savings not studied here. Occupancy data from occupancy sensors, particularly those associated with a workstation-specific lighting layout, could inform other systems such as HVAC on their heating and cooling loads. High levels of daylight availability could also increase the potential for energy savings associated with daylight harvesting. Since lighting accounts for 39% of electricity use in commercial buildings, control systems could also be programmed to adapt to demand response events or other increases in electricity rates [1].

2 Background

2.1 Assessment

Lighting accounts for 38% of the electricity used by commercial buildings in the United States and 39% of electricity use in office buildings, and therefore represents a large potential source of energy savings [1]. While energy savings have been achieved through the wide proliferation of efficient lamps and ballasts in the past several decades, advanced lighting controls have become a significant and largely untapped energy savings strategy. Despite the availability of advanced lighting controls, only 2% of commercial buildings in the U.S. employ daylighting sensors and only 1% have installed energy management and lighting control systems [5]. Many of the remaining buildings still utilize manual switches or simple lighting controls such as on-off time scheduling. Even where controls include more advanced options such as occupancy sensing, they generally monitor and control large areal zones within a building, rather than individual workstations. Consequently, there is considerable potential for advanced controls such as continuous dimming, daylight harvesting, fine-tuned occupancy sensing, institutional tuning, personal control, and individual ballast control to achieve deep energy savings. These control strategies also have the potential to improve occupant productivity and satisfaction by creating more flexibility within the lighting system to better cater to occupant preferences.

This GPG study sought to demonstrate that incorporating advanced responsive controls into lighting systems can be an essential strategy in decreasing energy consumption.

2.2 Opportunity

The General Services Administration (GSA) has an abiding interest in examining the technical performance and cost-effectiveness of different energy-efficient lighting technologies in their existing building portfolio as well as those currently proposed for construction. GSA's Public Building Service (PBS) owns or leases more than 9,600 assets and is responsible for managing an inventory of diverse Federal buildings totaling more than 370 million square feet of building stock. Since the large majority of the GSA's buildings include office spaces, identifying appropriate energy-efficient lighting solutions has been a high priority for the GSA, as well as for other United States federal agencies.

Several past studies have evaluated the impact of advanced lighting controls on energy use and occupants. A meta-analysis of energy savings in commercial buildings presented in current literature performed by Williams and others assessed the effect of lighting controls: occupancy sensing, daylight sensing, personal tuning, and institutional tuning. Employing each control technique independently produced an average percentage of energy savings within office spaces of 28% for daylighting, 24% for occupancy, 31% for personal tuning, 36% for institutional tuning, and 38% when control strategies were combined [5]. Galasiu and others[4] focused on a workstation specific (WS) lighting system, employing a 3-lamp direct-indirect luminaire combined with an integrated occupancy sensor, integrated light sensor, and an individual control represented as an on-screen slider on each occupant's computer. This study determined that combining the lighting controls resulted in 70% energy savings; if taken individually, occupancy sensing saved 35%, daylight sensing 20%, and individual dimming 11%. Although individual dimming had the smallest impact in reducing energy consumption, Galasiu and others noted that allowing for personal preference resulted in improved occupant mood, satisfaction, and visual comfort [4].

Two pilot studies were previously conducted on WS lighting by LBNL in the Phillip Burton Federal Building in San Francisco, CA, in 2007 and 2009-2010[2][3]. In these studies, the WS lighting system consisted of independently controllable overhead luminaires installed above each cubicle in an open-plan office. The pilot study in 2007 tested the energy savings from WS lighting in 15 cubicles and found that it reduced energy use by 53% compared to the baseline [3]. An expanded study of 86 cubicles in 2009-2010 found that WS lighting used 40% less energy than the baseline [2]. This study also brought up several lessons for future installations, including the strong impact occupancy patterns and standby power can have on results, the benefit of shorter timeouts after-hours, and the importance of reducing field assembly whenever possible.

This Green Proving Ground study expanded on the previous studies by analyzing both a wider subset of GSA-operated buildings in California as well as a greater number of responsive lighting control strategies. This study widened the scope of work further to incorporate alternate space types in addition to open offices, such as private offices, as well as pre-retrofit metered baselines, expanded monitoring periods, and an improved occupant survey. Furthermore, by applying the same system in a variety of sites, cross-site comparisons provided insight into where and how to implement advanced controls in order to achieve the deepest and most cost-effective energy savings, improve building operation, and satisfy diverse sets of occupants.

3 Project Overview

The GPG Responsive Lighting Solutions study evaluated the energy savings, photometric performance, and occupant satisfaction associated with responsive lighting and controls retrofits by comparing the performance of the workstation-specific (WS) lighting system to the systems in place prior to the retrofit. The study took place in five Federal Buildings in California and included a total of seven office areas, referred to as *sites* in this report. The seven sites were selected to capture a diverse group of agencies, occupancy patterns, work styles, site conditions, and baseline conditions. Note that this report contains a subset of the data and sites that will be presented in a Final Report to the Commercial Buildings Partnership's (CBP) program. The current report summarizes the key findings from seven of the ten sites studied. The more detailed

Final Report, which will discuss the results with greater depth and analysis will be released in November 2012.

This study focused on three key objectives:

- Quantifying and understanding the energy savings, light condition changes, and occupant satisfaction changes associated with each lighting retrofit
- Evaluating the costs and paybacks associated with the lighting retrofits
- Analyzing the results across sites to determine how site and occupant conditions affect a project's success

3.1 Technical Objectives Overview

This study assessed the performance of the workstation-specific (WS) lighting system compared to that of the lighting systems prior to the retrofit on three fronts: energy savings and cost-effectiveness, photometric performance, and occupant satisfaction. Definitions for the metrics used can be found in Table 1 below.

Table 1: Description of metrics used in assessment of technical performance for lighting systems

Analysis	Metric	Definition
Energy Savings	Lighting Power Density (LPD)	A metric for characterizing the lighting power in a space at a given time, defined as the lighting power divided by the corresponding floor area. LPD is usually calculated in watts per square foot.
Energy Savings	Energy Use Intensity (EUI)	A metric for characterizing energy use, defined as the amount of energy used in a space over a given time period divided by the area of the space and the time interval studied. In lighting, EUI is usually calculated in watt-hours per square foot per day or kilowatt-hours per square foot per year.
Energy Savings	Global Warming Effect (GWE)	A metric for characterizing greenhouse gas emissions by summing the product of instantaneous greenhouse gas emissions and their specific time-dependent global warming potential. In this study, GWE was calculated for each utility provider (g $CO_{2,eq}$ /kWh electricity generated) and also normalized by floor area and calculated based off of annual energy savings (kg $CO_{2,eq}/ft^2$/year).
Cost-effectiveness	Simple Payback Period (SPP)	A metric for characterizing the length of time required to recover the cost of an investment, defined as the cost of project over the energy savings at the site per year. SPP is usually calculated in years.

Analysis	Metric	Definition
Photometric Performance	Illuminance	The density of incident luminous flux on a surface. In less technical terms, a measure of the amount of incoming light reaching a surface. Recorded here using the unit lux.

3.1.1 Energy Savings and Cost-effectiveness

The purpose of performing an energy savings and cost-effectiveness analysis for any energy-conserving measure (ECM) is to determine whether the value of the future energy savings from the installation of the ECM justifies the expense of the investment. The primary challenges involved in performing the analyses for this study were ensuring relevancy of measured data both within the site and building, as well as across sites.

To ensure appropriate comparisons, energy savings were determined by metering a representative area for the site and building during both pre-retrofit and post-retrofit stages. Energy savings were presented in the form of Energy Use Intensities (EUIs) and were normalized by square foot in order to compare results across sites (See Table 1). Since the WS lighting system installation generally raised the LPD or reduced it marginally at each of the sites, energy savings seen can be assumed to be attributable to the advanced controls instead of the redesign. Greenhouse gas (GHG) emissions were also assessed by calculating the reduction in global warming effect (GWE) at each site to gain insight into the environmental impacts of implementing the responsive lighting controls.

The subsequent cost-effectiveness analysis determined simple payback periods (SPP, see Table 1) resultant from the energy savings. In the five buildings assessed in this study, the existing ceiling lighting systems were retired from service and replaced with an entirely different lighting system (the advanced lighting controls and WS lighting system). Therefore, this study considered the costs with the view that the installation was relighting the space, rather than simply retrofitting an existing system. That is, scenarios were chosen assuming that GSA was planning on relighting the existing space and the costs related to other possible relighting options were subtracted from the full investment cost to determine the cost-effectiveness of the controls investment alone. Additionally, labor costs associated with reconfiguring the existing system were excluded. More details on the chosen scenarios can be found in section 4.1 (p. 30).

3.1.2 Photometric Performance

In order to determine whether the WS lighting system supplied the necessary light levels, light levels provided by both the WS lighting system and the pre-retrofit existing lighting system were documented. Appropriate light levels were defined to be above 350 lux, the Illuminating Engineering Society of North America (IESNA) acceptable light level for an office space.

Challenges to measuring representative light levels included accounting for daylight effects and standardizing measurement location.

3.1.3 Occupant Satisfaction

For a lighting system to perform to its full potential, users must understand and accept the strategy tested. Therefore, occupant satisfaction was assessed through the administration of occupant surveys both pre- and post-retrofit. Surveys have an inherent degree of variation, and associated challenges included surveying a representative population to achieve statistical confidence. Therefore, the study attempted to survey the same population in both pre- and post-retrofit periods and attempting to meet a 40% response rate with at least 30 respondents. Additionally, anonymity was enforced and free response boxes were employed in order to encourage a more complete understanding of successes or issues the occupants experienced with the lighting systems.

3.2 Study Areas

This study defined a site as an agency-specific section of a building that extended throughout the entire floor or a large portion of the floor. Sites included open office areas, private offices, conference rooms, libraries, storage areas, bathrooms, transition spaces, and other miscellaneous end use spaces. Although the focus was on open and private office space, which makes up the majority of the study areas, other spaces were monitored as well. Sites were selected to capture the diversity of agencies and space types in Federal office buildings to the extent possible.

Table 2 summarizes key characteristics for each site. Agencies are not listed here due to security restrictions. More specifics can be found in the facility descriptions in the subsections below.

Table 2: Description of sites included in the study

Site	Site Abbreviation	Location	Approximate floor area (ft^2)	Description of work spaces
Chet Holifield FB, 2nd floor SE quadrant	CH2SE	Laguna Niguel, CA	46,500	Large, deep open office plan with a few private offices
Cottage Way FB, 2nd floor NE building	CW2NE	Sacramento, CA	21,000	Open office plan with a few private offices
Phillip Burton FB, 10th floor W half	PB10W	San Francisco, CA	23,500	Private offices
Ron Dellums FB, 8th floor N tower	RD8N	Oakland, CA	18,500	Open office plan with a few private offices
Ron Dellums FB, 13th floor N tower, all except SW quadrant	RD13N	Oakland, CA	15,000	Open office plan with a few private offices

Site	Site Abbreviation	Location	Approximate floor area (ft^2)	Description of work spaces
Ron Dellums FB, 14th floor S tower, W half of floor	RD14S	Oakland, CA	8,000	Open office plan with a few private offices
Roybal FB, 18th floor	R18	Los Angeles, CA	25,500	Combination of open office plan and private offices

3.2.1 Chet Holifield Federal Building 2nd Floor SE Quadrant

Built in the late 1960s in Laguna Niguel, CA, the monumental concrete Chet Holifield Federal Building was designed as a stepped pyramid with a deep footprint and each floor set back from the floor below it. The site located in the SE quadrant of Chet Holifield's 2nd floor (CH2SE) consisted of more than 400 open office workstations in a very deep, rectangular space. The overall site area was approximately 46,750 ft^2 in plan. With windows only along the east side, the vast majority of the site had negligible available daylight. Most workstations were single occupancy cubicles, but about 100 workstations were in cubicles with two workstations or cubicle clusters with four. Several high-walled, fully enclosed cubicles with doors stood near the site's central corridor. Occupants performed predominately desk and computer work.

3.2.2 Cottage Way Federal Building 2nd Floor East, North Building

The two-story Cottage Way Federal Building, located in Sacramento, CA, was built in the 1960s. Cottage Way is a concrete building that has two connected sections. The north-east section has a small and rectangular plan while the south-west section has a larger, square floor plan. The study area, located on the 2nd floor of Cottage Way's north-east section (CW2NE), consisted primarily of an open office area located along the perimeter of the building on three sides. This site contained 138 open offices, 8 private offices, as well as a few printer stations, break areas, and other miscellaneous rooms. The overall study area was approximately 21,075 ft^2 in plan. Most workstations were single occupancy cubicles with high partitions. There were several additional fully enclosed private offices with doors along the perimeter of this building. Because the study area followed the perimeter of the building, a significant portion of the offices had exposure to daylight from the tall windows common to this site. Occupants generally performed a lot of paperwork and computer-focused tasks within these spaces.

3.2.3 Phillip Burton Federal Building 10th Floor West

San Francisco's Phillip Burton Federal Building is a large, 21-story office building constructed in the late 1960s. It has a fairly deep, rectangular floor plan with the long direction running roughly east to west. Phillip Burton's façade is a typical concrete grid, providing large openings for windows. The study area consisted of the west section of Phillip Burton's 10th floor

(PB10W), covering slightly less than half of the floor's area. The office consisted of 54 private offices as well as storage rooms, conference rooms, a library, and other miscellaneous use rooms. For the purposes of this study, the site area, totaling approximately 25,500 ft^2, included the entire agency space except for a small interior section in the southwest portion of the site that included bathrooms, the custodial room, electrical closets, elevator shafts, and other non-work spaces. Occupants performed legal work that included a combination of desk work, phone calls, and meetings. Exterior offices had very high daylight availability, while interior spaces were exposed to little or no daylight.

3.2.4 Ronald Dellums Federal Building

The Ronald Dellums Federal Building consists of two 18-story towers with walkways between them at some levels and a central ground-level atrium. Constructed in the 1990s, the towers are oriented roughly on a north and south axis, each with an octagonal floor plan and circulation through elevators at the core. Large, regularly-spaced windows cover most exterior walls.

3.2.4.1Ronald Dellums Federal Building 8th Floor, North Tower

The approximately 18,650 ft^2 study area in the Ron Dellums Federal Building included the entire 8th floor of the north tower (RD8N), except for the core area and interior corridor to the west of the core and outside the tenant space. The core area extended to the south side of the tower, leaving three main sections of study area in the west, north, and east. The vast majority of the site contained open office cubicles (121 total), with a few private offices and conference rooms. Occupants spent a good deal of time collaborating in addition to working at their own desks.

3.2.4.2Ronald Dellums Federal Building 13th Floor North Tower

The approximately 15,000 ft^2 site covered the majority of the Ron Dellums' North Tower's 13th floor (RD13N). The central core and interior corridors were excluded, which extended to the south end of the floor. The southwest quadrant of the floor was also excluded because of abnormal occupancy during a renovation which continued for the entire baseline period. The site included 55 open office cubicles, approximately 13 private offices, and several conference rooms and other miscellaneous rooms. Occupants performed mostly computer work at their desks.

3.2.4.3Ronald Dellums Federal Building 14th Floor South Tower

The approximately 8,000 ft^2 study area covered the west half of the Ron Dellums' South Tower's 14th floor (RD14S), and had windows to the west, north, and south. It excluded core areas and a call center on the east half of the floor. The majority of the site was a large open office with 49 individual cubicles. Four large private offices occupied perimeter spaces. Occupants performed mostly computer and other desk work.

3.2.5 Roybal Federal Building 18th Floor

The Roybal Federal Building is 22 stories tall, with an elongated octagonal floor plan and a stately brick façade. Built in the early 1990s, it stands in downtown Los Angeles and overlooks a large courtyard to the west. The study area located on the 18th floor of the Roybal Federal Building (R18) included a mixture of open and private office spaces. The overall site area was approximately 25,700 ft^2. The open office was broken into three main groups: 20 small cubicles with 57”-66” partitions and a standard layout, 14 workstations located in open rooms with no partitions, and 69 cubicles with 60” partitions oriented mostly in groups of four in a call center with very long operating hours and multiple work shifts per cubicle. Private offices and other rooms are scattered throughout the site, and large windows line most of the perimeter.

3.3 Technology Description

3.3.1 Overview

In general, the advantage of responsive lighting and control systems over traditional lighting and control systems is the high granularity of control inherent to the system. Traditional lighting systems utilize manual switches or simple lighting controls such as basic on-off scheduling. Even where controls include more advanced options such as occupancy sensing, they generally monitor and control large areal zones within a building, rather than individual workstations. Responsive lighting systems employ a variety of advanced design and control approaches to match light conditions to building set points and occupant needs. Responsive systems reduce light when and where it is not needed, target light where it is required, and allow building managers and occupants to determine area and workspace light levels.

The sites studied here all incorporated the same ballasts and lighting control system in each retrofit. However, the luminaires installed at each site were selected from a small suite of efficient options. A basic schematic of the responsive lighting and control system studied and its’ inputs can be seen in Figure 2 below (p. 25). Major components of the system are described below. Details on both the existing lighting system and WS lighting system can be found in the Technology Evaluation section (Section 3.4, p. 27) and Detailed Technology Specifications Appendix (Section 8.2, p. 98).

- **Lighting management system:** The lighting management system installed is a Digital Addressable Lighting Interface (DALI)-based digital control system that offers operators individual ballast control and records sensor information and estimated power levels based on ballast settings. The lighting control configurations can be informed by schedules, institutional tuning and personal controls, as well as demand response. Some management systems also have the capability to alert operators to potential issues such as lamp burnouts.

- **Lighting control panel:** Lighting control panels are typically located on each floor and provide the juncture point for relays associated with the ballasts on that floor.
- **Digital dimmable ballasts:** Digital ballasts allow operators to set light levels for individual ballasts, while continuous dimming provides a wide range of available light levels. The digital dimmable ballasts used in the lighting retrofits studied are DALI ballasts.
- **Workstation-specific (WS) luminaires with built-in occupancy sensors:** WS luminaires allow for occupancy control based on individual cubicle occupancy. They also allow for occupants to set workspace light level settings to match personal preferences.
- **Occupancy sensors in private offices and other space types:** Occupancy sensors in private offices and other rooms disconnect power to lamps and ballasts in unoccupied spaces, reducing control system standby power to zero.

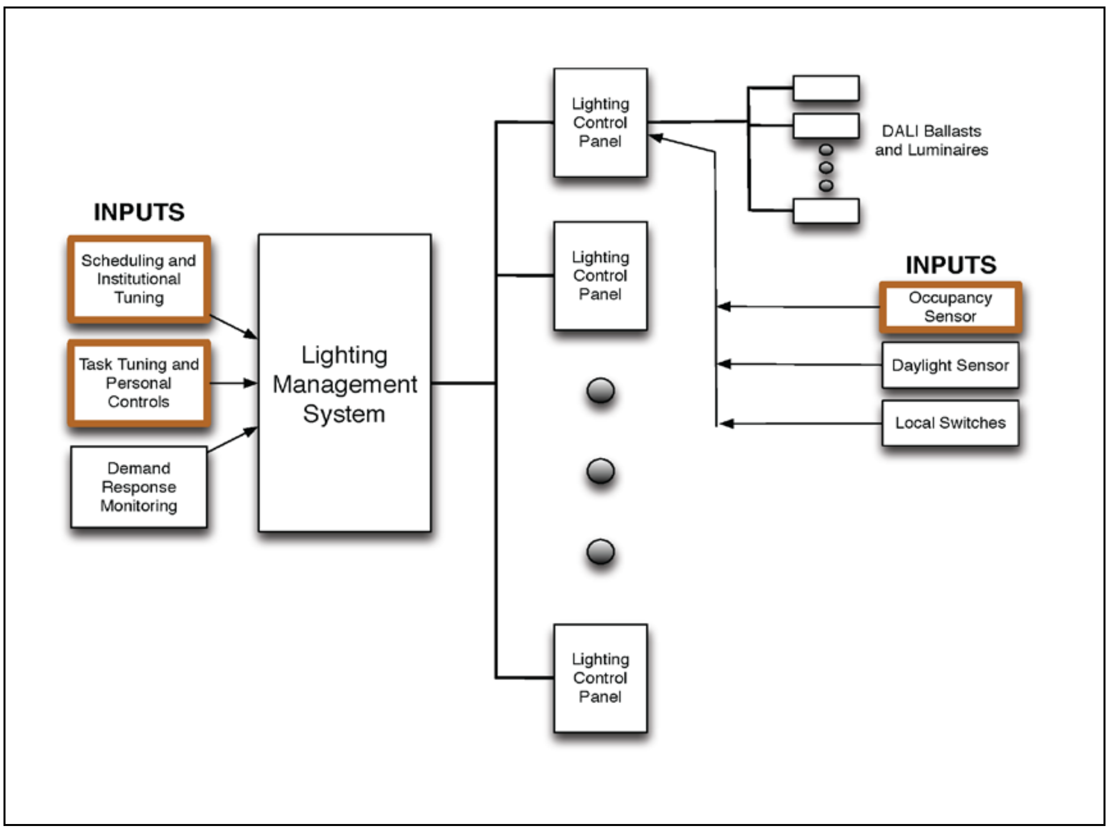


Figure 2: Schematic design of a workstation specific lighting management system. This study focused on the effects of the highlighted controls: scheduling and institutional tuning, task tuning and personal controls, and occupancy sensors.

Lighting management systems grew from the development of preliminary automated systems spurred by the energy crisis in the early 1970s, which initially focused on HVAC systems [6].

Since the 1970s, automated systems expanded to include data acquisition and management services that could be controlled from a central location instead of locally. With the addition of Digital Addressable Lighting Interface (DALI) controls, lighting systems have furthered their capabilities to include fine-grained control over individual ballasts. DALI control first became standardized in 2003 for linear fluorescent lamps, and has since expanded to include more lamp types and become an independent standard in 2009. Although concerns had been raised that DALI control separated lighting systems from a building's other automated systems, recent developments have allowed for lighting control systems to be connected to whole building systems, specifically becoming BACnet compatible for office building applications [7].

The lighting management and control system (LMCS) technology evaluated in this report is currently in Tech Level 4: Late Deployment, where savings have been proven and market transformation and penetration is needed. The LMCS was manufactured by Lumenergi, and consists of a central server with multiple controllers tied to ballasts controlling the fixtures with the capabilities of incorporating the following light control strategies: institutional tuning, occupancy sensing, daylighting, scheduling, personal light control, lumen maintenance, and load shedding/demand response. The Lumenergi LMCS is considered representative of comparable technologies provided by several other manufacturers. Industry claims for this technology are between 50-70% in energy cost savings when all available lighting strategies are implemented. For the strategies evaluated in this study, the studied LMCS system purports to produce savings of up to 20% for institutional tuning, 15% for occupancy sensing, and 10% for personal light control, depending on prior installations [8].

Despite the availability of advanced controls, only 2% of commercial buildings in the U.S. employ daylighting sensors and only 1% have installed energy management and lighting control systems [5]. Responsive lighting controls face barriers to adoption that are largely attributable to unfamiliarity with the technology and its capabilities, including high installation and equipment costs, and concerns with commissioning and performance. However, as responsive lighting systems become more widespread, increased and improved knowledge on responsive lighting controls should serve to mitigate these roadblocks. Barriers and enablers to adoption are discussed further in Section 7.2 (p. 95).

Although responsive lighting systems can employ a multitude of control strategies, this study focused on assessing the effects of institutional tuning and scheduling, personal control, and occupancy sensing. These control strategies are explored further below.

3.3.2 Institutional Tuning and Scheduling

Institutional tuning allows building managers and tenants to decrease energy consumption by programming default light levels within the lighting management system that reflect area and/or building policies. Scheduling informs institutional tuning by considering operating hours that reflect general occupancy patterns. Institutional tuning and scheduling aim for flexibility and ease of use by breaking down an area into several zone types and applying lighting configurations to each zone template separately. Since most offices change their layout on a regular basis, this system has an added benefit: reconfiguring the lighting to match the new lighting needs does not require rewiring. An example of the scheduling control strategy is scheduling all lights in an office to turn off during non-operating hours between 7 PM and 6 AM. An example of institutional tuning would then be tuning corridor lights to 35% power levels and work areas to 50% power levels when turned on during operating hours.

3.3.3 Occupancy Sensing

Occupancy sensors reduce electrical consumption by adjusting light levels or turning lights on or off in an area in response to the presence or absence of an occupant. Electrical demand is reduced by taking advantage of actual individual occupancy and the corresponding reduction of loads. The sensors used in this study detect occupancy by passive infrared. Other sensors found in the market utilize audio, ultrasonic, or optical signals to determine occupancy. The placement and shielding of sensors is important to ensure correct sensor performance. Additionally, false off events can be ameliorated by programming timeouts so that lights turn off a preset amount of time after the sensor detects an occupant's absence.

3.3.4 Personal Control

Personal control allows occupants to adjust their individual light levels to suit their individual preferences. While the system studied here was designed to give occupants direct control over light levels, GSA security restrictions prevented the implementation of direct occupant control. Several studies have found that occupants preferred direct control over their lighting and that people selected a wide range of light levels when given this control even when occupants performed similar tasks [9][10][11] [12]. Direct control over workspace light levels provides a major opportunity for improvement over the retrofits as implemented in this study, both in terms of energy savings and occupant satisfaction.

3.4 Technology Evaluation

3.4.1 Pre-retrofit Lighting Systems

Pre-retrofit overhead lighting and controls varied from site to site. In general, the existing pre-retrofit lighting systems consisted of recessed luminaires that were regularly spaced in open areas and large rooms or distributed based on layout in private offices. Dimmable ballasts or photocells were not installed in any of the study areas prior to the retrofits although some sites employed occupancy sensors. However, these occupancy sensors only referenced and controlled large open office zones and/or conference rooms. Although some occupancy sensors were located in private offices, this was not common practice. Several sites maintained scheduled shutoffs or sweeps in the evening to turn off lights after operating hours. Task lighting varied from site to site, and was not included in monitoring and analysis due to the difficulty of isolating task light loads on mixed-use plug load circuits. Task lighting did not change during any of the retrofits, therefore task lighting energy use was assumed to remain constant. For further site-specific details, please see Section 8.2.1 (p. 98).

3.4.2 Retrofit and Commissioning Process

The retrofit and commissioning schedule and timing varied extensively by site. Major tasks and the generalized order of tasks for the retrofit and commissioning process can be seen in Table 3. Further commissioning and system operation was an iterative process that continued after controls were transferred over to the O&M contractor.

Table 3: Key tasks during the retrofit and commissioning process

Phase	Key Tasks
Retrofit installation	• Install control system backbone and LMCS controllers • Install ceiling sensors in circulation spaces • Reconfigure existing circuits and run communications wiring • Install new fixtures
Commissioning	• Confirm IP addresses • Verify controls and fixtures • Verify settings • Refine light level settings according to personal preferences

The retrofits consisted primarily of installing new fixtures, installing sensors, and running new communications wiring (see Section 8.2.2, p.99). Fixture layouts were typically left unaltered in areas with the same fixture type pre-retrofit and post-retrofit (e.g. in private offices with recessed 2x4 fixtures), and circuit layouts were not modified in these cases. Fixture and circuit layouts were always changed in open office areas to create a workstation-specific layout so that a fixture was centered above each cubicle or open office. In general, these changes increased the installed LPD significantly due to ballasts with high ballast factors (BF=1.2) and the increase in fixture density. Dimmable ballasts controlled by the Lighting Management Control System (LMCS) were installed to operate all linear fluorescent lamps. Lighting control settings were accessible through a desktop computer and lighting controller located either on the same floor as the site or in a consolidated location for the building as a whole. For detailed technology specifications, please see Section 8.2 (p. 98).

In many cases, commissioning was not completed in the formal, traditional sense. An electrical contractor and the lighting manufacturer verified settings and operation, but did not provide formal documentation of this process. Clear objectives were usually documented informally, and the transition of control over operations to the O&M contractor control was often lengthy. Finally, operational settings were gradually checked after the retrofits were completed; in many cases the period of time that passed between the retrofit and the time when settings were considered stable was extensive. This issue will be discussed further in the Lessons Learned section (Section 6.2, p.91).

3.4.3 Post-retrofit Lighting Systems

Each retrofit used luminaires selected from a small suite of efficient options. Suspended, direct/indirect 4- or 8-foot long WS fixtures were installed above open office cubicles, while recessed 2x4 and 2x2 fixtures were installed in private offices, conference rooms, and other similar room types. Corridors and other transition spaces were lit by recessed 2x4, 2x2, or can fixtures, or by a combination. All luminaires were installed with F32T8 (32W) lamps except for the recessed can fixtures, which have 26W CFLs. Available luminaire types and the types selected for each site can be found in Section 8.2.2 (p. 99).

The direct/indirect WS fixtures in open office areas provided both upward directed (ambient) light and downward directed (task) light; the up-light and down-light components had separate ballasts and were individually controllable. Open office WS fixtures implemented built-in occupancy sensors, allowing for control based on individual workstation occupancy. Lights turned on to a preset level when an occupant entered their workspace, and with one exception, both up-lights and down-lights turned off in unoccupied cubicles after a timeout (typically 30 minutes). During the last 10 minutes of the timeout, lights were dimmed to a lower power level. Contrary to other sites, RD13N programmed the up-lights in their post-retrofit WS system to remain on, including in unoccupied cubicles, between 6AM and 6PM each day. This is discussed further in Section 5.1.5 (p. 43). Open office controls in the study areas did not include daylight harvesting, even in areas with high levels of available daylight. As mentioned previously, due to GSA security restrictions, open office occupants could not turn their lights off or adjust light levels without requesting assistance from a systems operator.

Private offices typically had manual wall switches, ceiling or wall-mounted occupancy sensors, and photosensors if appropriate (i.e., in daylit spaces). When triggered, the manual switches and occupancy sensors disconnected power to the ballasts, overriding the LMCS system. This reduced standby power to zero in these areas, which increased energy savings. Similar to private offices, corridor and transition space lighting were also typically controlled by overhead occupancy sensors that overrode the LMCS system. Although 2x4 and 2x2 fixtures in corridors and transition spaces were also typically dimmed and controlled by the LMCS system, the recessed can fixtures had no additional controls. Daylight harvesting did not occur in corridors and transition spaces.

In general, all lights were set to initial default levels below full power and light output (see Table 4 for typical defaults). After each retrofit, GSA attempted to solicit occupants' light level preferences. Their methods varied from site to site, but typically involved personal conversations with occupants followed by light level adjustments some time later. In some cases, follow up visits were conducted to see if occupants were content with their new light levels.

Table 4: Typical control system defaults

Space type	Typical control system defaults (details vary by site)
Open office cubicles	• Tuning (50% of installed power for downlights, 30% for uplights) • Workstation-specific occupancy sensing for both uplights and downlights • Indirect personal control
Perimeter private offices	• Tuning and daylight harvesting (50fc constrained to 30%-70% power) • Occupancy sensors that override the control system • Wall switches • Indirect personal dimming control
Interior private offices	• Tuning (50%) • Occupancy sensors that override the control system • Wall switches • Indirect personal dimming control
Perimeter conference rooms	• Tuning and daylight harvesting (50fc constrained to 30-70% power) • Occupancy sensors that override the control system • Wall switches with scene setting
Interior conference rooms	• Tuning (50%) • Occupancy sensors that override the control system • Wall switches with scene setting
Corridors and transition spaces	• Tuning (50%) for 2x4 and 2x2 fixtures only • Occupancy sensors that override the control system • Daylight harvesting in a few perimeter areas (50fc constrained to variable power ranges)

4 Measurement and Verification Evaluation Plan

Pre-retrofit and post-retrofit power metering, workspace light characterization, and occupant surveys were conducted for each site to analyze the effectiveness of the new lighting solutions. These tasks and the associated analyses are described in the following sections.

4.1 Power Metering and Energy and Cost Analysis

In order to assess the energy savings achieved at each site, selected circuits were metered and energy and cost analyses were performed at each site. Lighting branch circuits corresponding to either the entirety or a representative portion of the study area were metered for both pre- and post-retrofit periods at each site. In cases where metering the entire study area was not feasible, circuits were selected to provide a representative sample of the site and emphasized the site's most common work spaces. Circuits were traced or identified from as-built drawings both pre- and post-retrofit, and meters were moved to new circuits after the retrofit when necessary. Meters were left in place during the retrofit and commissioning periods, but data from these periods was not included in the final analysis.

The study used power meters that recorded true Root Mean Square (RMS) current, voltage, power factor, and power levels. Meters were set to record average values from the previous 5 minutes on a five minute interval. Power data was converted to lighting power density (LPD) in watts per square foot over the course of each complete day of data. Days were separated into weekdays, weekends, and holidays, and the sorted LPDs were then converted to weekday, weekend, and holiday energy use intensity (EUI) in watt-hours per square foot per day. Finally, annual EUIs (in kilowatt-hours per square foot per year) were calculated for each site based on an assumed typical distribution of 251 weekdays, 104 weekend days, and 10 holidays per year. Pre-retrofit and post-retrofit annual EUIs were then compared to determine energy savings at each site.

From the calculated annual EUIs, greenhouse gas (GHG) emission reductions were also determined for each site based on regional utility fuel mixes as well as national average fuel mixes. Please see Section 8.3.1 (p. 104) for details on fuel mixes. The global warming effect (GWE) of each regional utility provider as well as the national average can be seen in Table 5 below. GHG emission reductions were then calculated by multiplying the pre-retrofit and post-retrofit EUI by the GWE of the regional utility provider as well as the national average and then determining the difference.

Table 5: Global warming effect (GWE) per kWh electricity generated for regional utility fuel mixes and the national average fuel mix

Federal Building	Utility Provider	GWE, g CO2 eq/kWh
Chet Holifield Federal Building	Southern California Edison (SCE)	258.4
Cottage Way Federal Building	Sacramento Municipal Utility District (SMUD)	247.8
Phillip Burton Federal Building	Pacific Gas & Electric (PGE)	229.7
Ronald Dellums Federal Building	Pacific Gas & Electric (PGE)	229.7
Roybal Federal Building	Los Angeles Department of Water and Power (LADWP)	255.5
All	National Average	404.4

A cost-effectiveness analysis was then performed to determine whether the value of the future energy savings from the installation justified the expense of the investment. Fixture equipment costs and control systems costs were isolated. Control systems costs included material and labor costs from sensors, DALI scene controllers, control system and software, network backbone, and CAT5 cable. To account for the cost of DALI ballasts which were folded into the fixture package, the related cost was subtracted from the fixture costs and added to the incremental control systems cost. Based on communication with GSA, the DALI ballasts were assumed to cost $40 each. Each WS luminaire was controlled by two DALI ballasts, while all other DALI-controlled fixtures were each controlled by one DALI ballast. Fixture equipment costs included costs from fixtures, MC cables, and miscellaneous items such as ceiling tiles. Labor and material breakdowns were also applied where possible. Labor costs associated with control systems were assumed to be $0.30/SF when calculations resulted in lower pricing. This approach may have overestimated payback periods slightly, but it ensured that labor costs were reasonable. To account for possible regional variation in costs, electricity costs were determined for utility providers for each federal building, as seen in Table 6. Electricity rates shown in Table 6 assume Time-of-Use (TOU) rates appropriate for large commercial buildings.

Table 6: Electricity rates by provider

Federal Building	Electricity Provider	Electricity Rates ($/kWh)
Chet Holifield Federal Building	Southern California Edison (SCE)	$0.13
Cottage Way Federal Building	Sacramento Municipal Utility District (SMUD)	$0.13
Phillip Burton Federal Building	Pacific Gas & Electric (PGE)	$0.12
Ronald Dellums Federal Building	Pacific Gas & Electric (PGE)	$0.13
Roybal Federal Building	Los Angeles Department of Water and Power (LADWP)	$0.12

As mentioned above, this study considered associated costs with the view that the installation was relighting the space, rather than simply retrofitting an existing system. With this in mind, two incremental cost scenarios were considered for the cost-effectiveness analysis: a "Control System Cost Only" approach and a "GSA standard" relighting approach. In the "Control System Cost Only" scenario, we subtracted the cost of a WS lighting system but without any controls from the full project cost, referred to as the "Control System Cost Only" Case. In the GSA standard relighting scenario, we subtracted the cost of a code-compliant lighting system (referred to in this study as "GSA standard") from the full project cost. The GSA standard relighting system, "GSA standard", was considered to conform to GSA's P100-2005, typical of retrofits in the past five years. The material and labor costs associated with the GSA standard relighting were estimated to be $\$3/ft^2$ [13]. Both of these scenarios assumed that GSA was planning on relighting the existing space; therefore, labor costs associated with reconfiguring the existing system were excluded. The above scenarios subtracted out the costs related to other possible relighting options to determine the cost-effectiveness of the controls investment.

Additional sensitivity analyses to pre-retrofit LPD and energy costs were performed using the two incremental cost scenarios at each site. In order to determine viable sites for a responsive lighting retrofit, payback periods were calculated for pre-retrofit LPDs varying from 0.5 to 4 W/ft^2 while keeping energy costs constant. In the energy cost sensitivity analysis, payback periods were calculated while electricity costs varied from $0.05/kWh to $0.50/kWh and pre- and post-retrofit LPDs were held constant. Pre-retrofit LPDs and electricity rates which resulted in 15-, 10-, and 5-year payback periods were highlighted.

4.2 Photometric Characterization

Photometric characterizations were conducted for open office workspaces only in order to characterize electric light levels. Desktop illuminance measurements were taken at the assumed primary work area, characterized as the front edge of the main desk's center section. Objects directly obstructing the overhead lights were removed, but otherwise desktop objects and clutter were not modified. An effort was made to eliminate the effect of daylight by taking measurements at night or excluding measurements that deviated more than 25% when blind positions were modified. Task lights were typically turned off during measurements, but some measurements were taken with task lights turned on to approximate task light levels. The resulting median, quartile, minimum, and maximum pre-retrofit and post-retrofit light levels were compared. Post-retrofit workstations with non-default light level settings were separated from workstations with default levels for part of this comparison. An adjustment was made when applicable to both pre- and post-retrofit measurements to account for differences in calibration between the two illuminance meters (see Section 8.3.1).

4.3 Occupant Survey

Occupant surveys were administered before and after the lighting retrofit at each site. Occupants were asked to describe their workspace, lighting, and controls, and to respond to qualitative questions about their workspace and overall office light conditions. The survey was based on an earlier survey developed by Pacific Northwest National Laboratory (PNNL) in collaboration with the Light Right Consortium that was modified by PNNL in 2010 and 2011 with input from LBNL, among others. The survey was moved to a new server in the summer of 2011, which meant that two slightly different versions of the survey were administered. Both versions can be found in Section 8.3.3. Additionally, the post-retrofit survey at CH2SE was modified according to tenant requests to remove questions which were "too confusing." These modifications were not expected to have made a difference in occupant responses.

Surveys were administered online with the exception of two sites, where paper surveys were distributed due to limited internet connection availability. An email from LBNL explaining the survey and providing a link to the survey was sent to occupants, typically via an onsite tenant contact. Occupants could click the link to take the survey and responses were recorded anonymously online. If necessary, follow-up reminder emails were sent out to encourage more occupants to take the survey. The final version of the survey contained 40-44 multi-point rating and multiple choice type questions (some questions appear based on earlier responses), a comment box, and two free response questions at the end. Survey response distributions were compiled, and comparisons between pre-retrofit and post-retrofit responses were made using one-sided significance tests to determine satisfaction levels after the retrofits.

5 Results

The first section of this chapter analyzes the energy savings that resulted from the installation of responsive lighting controls in the seven studied sites. The second section examines whether the energy savings are sufficient to justify the cost of installing WS lighting at these sites.

5.1 Energy Results

Even though LPDs generally increased across sites, the lighting retrofits achieved energy savings of around 1 kWh/SF/yr, resulting in calculated annual savings by site ranging from 27% to 63% (Table 7 and Table 8). Energy savings were largely attributable to fine-grained occupancy zones, institutional tuning, and some personal control. The variation in energy savings was due to a range of site-specific factors, in particular, high energy baselines due to extensive unintentional after-hours lighting use during the pre-retrofit period. Sites that eliminated standby power in unoccupied rooms and after hours achieved deeper energy savings than other sites.

Table 7 presents the pre-retrofit and post-retrofit installed LPD estimates in metered areas and the percent change in LPD due to the retrofit. Sites with higher proportions of open office experienced the largest increases in LPD.

Table 7: Installed pre-retrofit and post-retrofit lighting power density (LPD) in metered areas and percent change

Site	Pre-retrofit installed LPD in metered area (W/ ft^2)	Post-retrofit installed LPD in metered area (W/ ft^2)	Percent change
CH2SE	0.96	1.44	50%
CW2NE	1.03	0.92	-11%
PB10W	1.22	0.97	-20%
RD8N	0.68	1.20	76%
RD13N	0.72	1.03	43%

Site	Pre-retrofit installed LPD in metered area (W/ ft^2)	Post-retrofit installed LPD in metered area (W/ ft^2)	Percent change
RD14S	0.67	1.17	75%
R18	1.09	1.11	2%

Energy results are summarized below in Table 8 while individual site details can be found in the following site sections, 5.1.1 through 5.1.7.

Table 8: Annual energy use intensity (EUI) and savings by site

Site	Pre-retrofit EUI (kWh/ft^2/yr)	Post-retrofit EUI (kWh/ft^2/yr)	EUI Savings (kWh/ft^2/yr)	Percent savings
CH2SE	2.92	2.11	0.81	28%
CW2NE	2.52	1.32	1.20	48%
PB10W	2.52	1.57	0.95	38%
RD8N	2.75	2.01	0.74	27%
RD13N	2.36	1.66	0.70	30%
RD14S	2.72	1.64	1.08	40%
R18	6.50	2.37	4.12	63%

As can be seen in Table 8, the calculated pre- and post-retrofit EUIs at all sites except for R18 are lower than the national average EUI, 4.1 kWh/ft^2/yr [14]. However, the national average EUI includes energy consumption from task lights which were not accounted for here. The scope of this study metered circuits for overhead fixtures only, while task lights were on plug load circuits and were therefore absent from both pre- and post-retrofit analyses. Since task lights did not change during the retrofit, the comparison between pre- and post-retrofit energy consumption is still valid. Please see Appendix 8.2.4 (p. 103) for site-specific task light details.

From the calculated EUIs, reductions in greenhouse gas (GHG) emissions were calculated for both the regional utility fuel mix as well as the national average fuel mix (see Table 9 and Figure 3). The regional utility fuel mix resulted in an average reduction of GHG emissions of 0.4 kg $CO_{2,eq}$/ft^2/year, while the national average fuel mix resulted in an average reduction of 0.6 kg $CO_{2,eq}$/ft^2/year across the sites.

Table 9. Greenhouse gas (GHG) emissions for regional utility fuel mixes as well as national average fuel mixes, in kg CO2,eq/ft2/year

Site	Pre-retrofit GHG Emissions, Regional Utility Fuel Mix	Post-retrofit GHG Emissions, Regional Utility Fuel Mix	Pre-retrofit GHG Emissions, National Average Fuel Mix	Post-retrofit GHG Emissions, National Average Fuel Mix
Chet Holifield	0.8	0.5	1.2	0.9
Cottage Way	0.6	0.3	1.0	0.5
Phillip Burton	0.6	0.4	1.0	0.6
Ron Dellums	0.6	0.4	1.1	0.7
Roybal	1.7	0.6	2.6	1.0

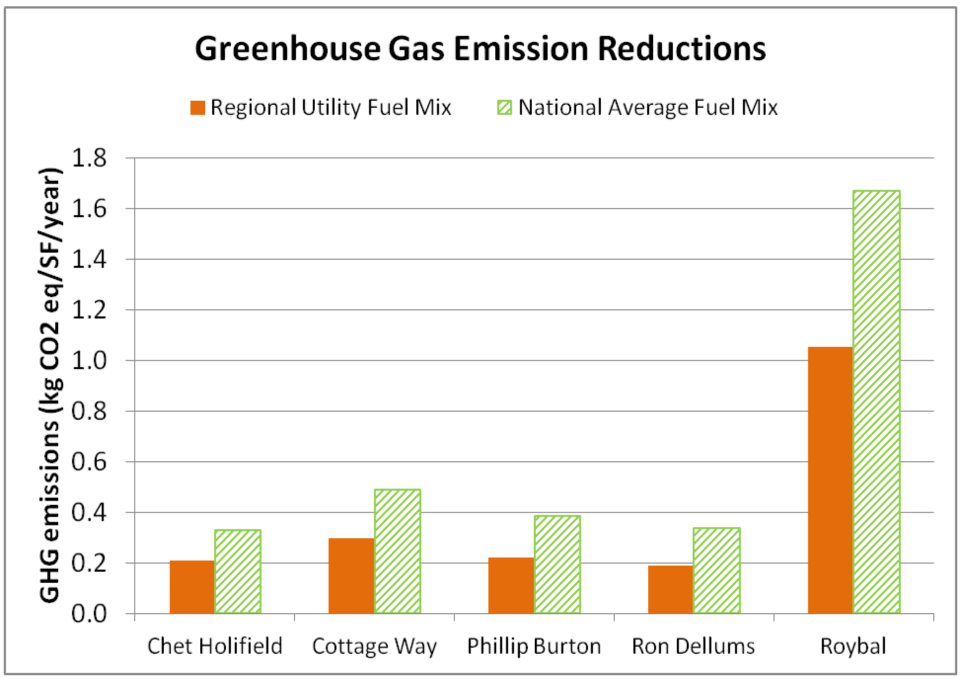


Figure 3: Results for greenhouse gas emission reductions as a result of the energy savings seen from the advanced controls and lighting installations at each site. Reductions were calculated for both the regional utility fuel mix and the national average fuel mix.

5.1.1 Chet Holifield Federal Building 2nd Floor SE Quadrant

The Chet Holifield Federal Building 2nd Floor SE (CH2SE) site consisted of a large, deep open office area with over 400 workstations. Pre-retrofit fixtures were spaced on a regular grid and were operated by a building scheduler that disengaged power to non-emergency lighting circuits outside of work hours. This scheduler continued to operate after the retrofit took place, overriding the lighting control system. The post-retrofit lighting system consisted of WS fixtures over cubicles that shut off in unoccupied areas after a 30 minute timeout.

Due to timing and logistical constraints, pre-retrofit metering took place during an extremely short period of time in early March 2011. This period included six complete weekdays and one complete weekend day. Post-retrofit metering took place from mid-September 2011 until the beginning of April 2012. This period included 117 weekdays, 50 weekend days and 7 holidays. Please note that the short pre-retrofit metering period only included one weekend day, during which lighting power remained at zero throughout the day, and no holidays. Therefore, annual energy use calculations for the pre-retrofit period were probably unrealistically low and result in an underestimate of baseline energy use. Lighting circuits individually covered comparably smaller number of fixtures than at other sites; therefore, only a portion of the site was metered, monitoring open offices and corridors.

Table 10 presents daily and annual EUI results, and Figure 4 displays the installed and average LPD for weekdays and weekends for each study period (pre-retrofit and post-retrofit).

Table 10: Chet Holifield 2nd Floor SE weekday, weekend, holiday, and annual energy use intensity (EUI). Pre-retrofit metering period included 6 weekdays, 1 weekend day, and no holidays. Post-retrofit metering period included 117 weekdays, 50 weekend days and 7 holidays.

Phase	Weekday EUI ($Wh/ft^2/day$)	Weekend EUI ($Wh/ft^2/day$)	Holiday EUI ($Wh/ft^2/day$)	Annual EUI ($kWh/ft^2/year$)
Pre-retrofit	11.63	0.00	N/A	2.92
Post-retrofit	7.75	1.28	3.23	2.11
Energy Savings	3.88	-1.28	N/A	0.81
% savings	33.4%	N/A	N/A	27.7%

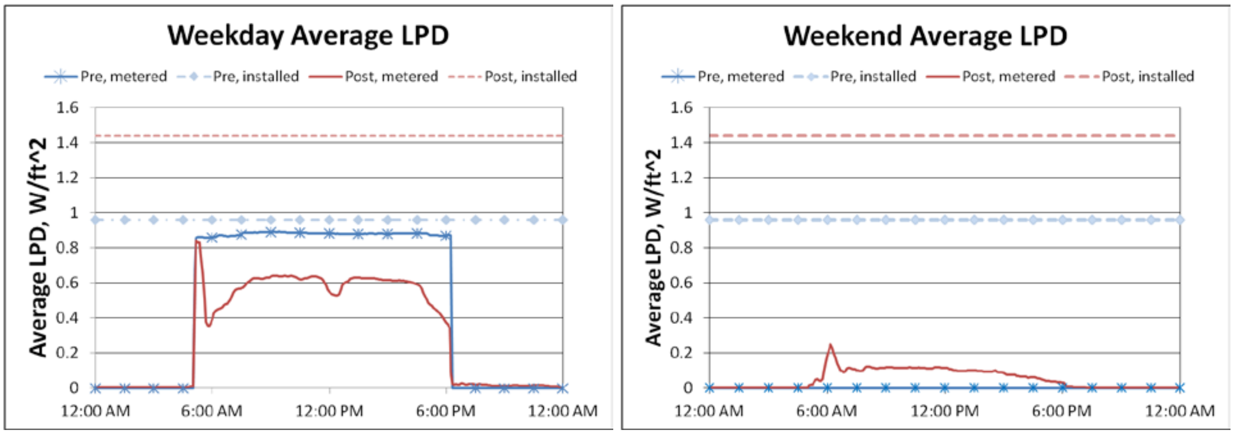


Figure 4: Chet Holifield 2nd Floor SE installed and average lighting power density (LPD) over the course of the day for weekdays and weekends. Pre-retrofit metering period included 6 weekdays, 1 weekend day, and no holidays. Post-retrofit metering period included 117 weekdays, 50 weekend days and 7 holidays.

Although the installed post-retrofit LPD was 50% greater than the pre-retrofit LPD, the CH2SE retrofit resulted in a calculated annual energy savings of 0.81 kWh/ft^2/year, or 28%. The lighting circuits operated almost exclusively on a set schedule with defined operating hours of 5:15 AM to 6:15 PM on the weekdays both pre- and post-retrofit. During weekday operating hours, pre-retrofit lighting use was around 0.9 W/ft^2, near the installed LPD of 0.96 W/ft^2. While pre-retrofit lighting power varied only slightly over the course of the day, post-retrofit WS lighting power changed throughout the day, reflecting occupancy patterns. With the exception of the power spike at the beginning of the workday, post-retrofit lighting use generally stayed around 0.6 W/ft^2, 58% below the post-retrofit installed LPD of 1.44 W/ft^2 and 33% below the peak pre-retrofit LPD.

The power spike occurred as a result of initially turning on the DALI ballasts at full power before dimming them to programmed settings in order to establish proper operating conditions within the fluorescent lamp. On several post-retrofit evenings, the scheduler did not successfully turn lights off due to a miscommunication with the LMCS control system, resulting in some after-hours energy use. No lighting use was seen over the weekends during the short pre-retrofit metering period, while post-retrofit weekend lighting use stayed below 0.2 W/ft^2.

5.1.2 Cottage Way Federal Building 2nd Floor East, North Building

The site located in the east side of Cottage Way Federal Building's 2nd floor north building (CW2NE) contained a large open office area with 138 open offices, as well as eight private offices located along three sides of the building. Regularly spaced pre-retrofit fixtures were turned off via a scheduler at 6 PM, although override buttons were located throughout the space, allowing for 30 minute overrides for fixtures switched on after the sweep. The post-retrofit lighting system shifted the lighting layout to WS fixtures over cubicles that shut off in unoccupied areas after a 30 minute timeout.

Pre-retrofit metering took place from May 2011 to August 2011, which included 60 complete weekdays, 24 weekend days, and 2 holidays. The post-retrofit metering period took place beginning from late September 2011 to the beginning of April 2012. This period included 116 weekdays, 49 weekend days, and 8 holidays. Due to equipment and logistical constraints, the metered area covered the northern half of the site which had a representative portion of space types including open office areas and corridors.

Table 11 presents daily and annual EUI results, and Figure 5 displays the installed and average LPD for weekdays and weekends for each study period (pre-retrofit and post-retrofit).

Table 11: Cottage Way 2nd Floor NE weekday, weekend, holiday, and annual energy use intensity (EUI). The pre-retrofit metering period included 60 weekdays, 24 weekend days, and 2 holidays. The post-retrofit period included 116 weekdays, 49 weekend days, and 8 holidays.

Phase	Weekday EUI ($Wh/ft^2/day$)	Weekend EUI ($Wh/ft^2/day$)	Holiday EUI ($Wh/ft^2/day$)	Annual EUI ($kWh/ft^2/year$)
Pre-retrofit	9.87	0.41	0.31	2.52
Post-retrofit	5.02	0.47	1.17	1.32
Savings	4.85	-0.06	-0.86	1.2
% savings	49.1%	-13.2%	-272.9%	47.6%

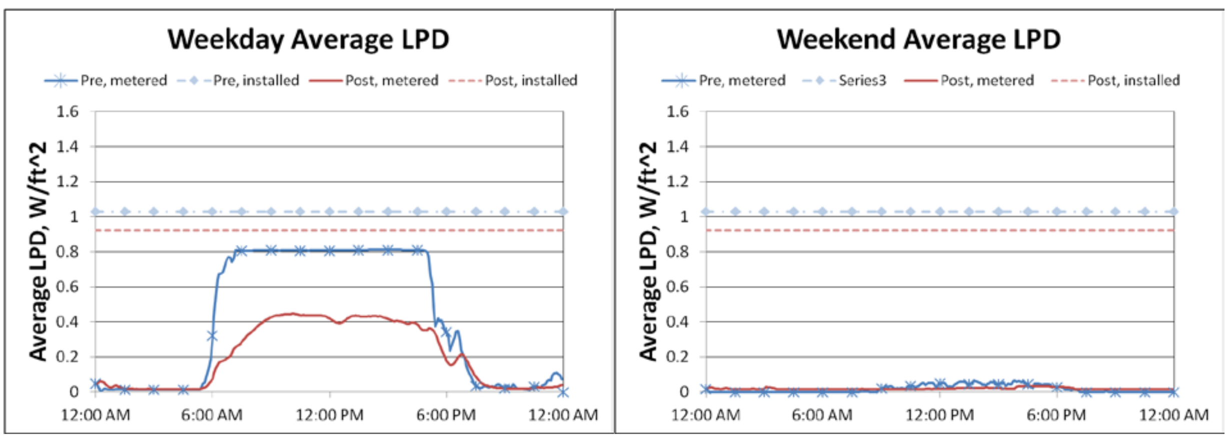


Figure 5: Cottage Way 2nd Floor NE installed and average lighting power density (LPD) over the course of the day for weekdays and weekends. The pre-retrofit metering period included 60 weekdays, 24 weekend days, and 2 holidays. The post-retrofit period included 116 weekdays, 49 weekend days, and 8 holidays.

The retrofit at CW2NE reduced the calculated annual energy consumption by 1.2 $kWh/ft^2/yr$, or 48%. Although there was a slight reduction of 11% in installed LPD from pre- to post-retrofit, energy savings seem generally attributable to the advanced controls rather than the lowered installed LPD. During weekday operating hours, the pre-retrofit average metered LPD was 0.8 W/ft^2, or 78% of the pre-retrofit installed LPD, while post-retrofit lighting use stayed below 49% of the post-retrofit installed LPD and 56% of the average peak pre-retrofit LPD with a peak of

0.45 W/ft^2. Weekend energy consumption due to lighting was considered negligible, with average LPDs peaking at 0.06 W/ft^2 and 0.04 W/ft^2 for pre-retrofit and post-retrofit conditions, respectively. Occupants at this site often engage in field work, so the reduced LPD reflects not only variable occupancy patterns throughout the day, but also intermittent occupancy through the week.

The difference between the installed and metered pre-retrofit LPD was a result of many of the pre-retrofit occupants finding their space to be over-lit. This resulted in requests for de-lamping (removing lamps from fixtures) or turning off lights in sections of the site. Additionally, in some cases requests were not made to replace burned out lamps because the spillover from the surrounding fixtures provided sufficient light levels. The slight peaks seen in both pre- and post-retrofit metered LPDs around 7 PM and 11 PM were attributable to cleaning crews.

5.1.3 Phillip Burton Federal Building 10th Floor West

The Phillip Burton Federal Building 10th Floor West (PB10W) study area included 54 private offices as well as storage rooms, conference rooms, a library, and other miscellaneous use rooms. Fixture locations were not changed during the retrofit because most of the work areas were private offices. Three-lamp (F32T8) recessed 2x4 fixtures were replaced with 2-lamp (F32T8) recessed 2x4 fixtures, reducing the installed LPD substantially from 1.22 W/ft^2 to 0.97 W/ft^2. Pre-retrofit rooms employed bi-level manual wall switches throughout. The post-retrofit control system maintained bi-level switching in most private offices, while also implementing daylight harvesting in perimeter areas and room-level occupancy sensors in most private offices. The occupancy sensors interrupted power to ballasts, circumventing the centralized control system.

Pre-retrofit metering took place between November 2010 and March 2011, including 68 complete weekdays, 30 weekend days, and 6 holidays. The post-retrofit metering period took place from mid-June 2011 until the beginning of April 2012. This period included 168 complete weekdays, 74 weekend days, and 9 holidays. The metered area encompassed the entire site, including private offices, corridors, and alternate end use rooms such as the library, filing room, and reception area.

Table 12 presents daily and annual EUI results, and Figure 6 displays the installed and average LPD for weekdays and weekends for each study period (pre-retrofit and post-retrofit).

Table 12: Phillip Burton 10th Floor W weekday, weekend, holiday, and annual energy use intensity (EUI). The pre-retrofit metering period included 68 weekdays, 30 weekend days, and 6 holidays. The post-retrofit metering period included 168 weekdays, 74 weekend days, and 9 holidays.

Phase	Weekday EUI (Wh/ft^2/day)	Weekend EUI (Wh/ft^2/day)	Holiday EUI (Wh/ft^2/day)	Annual EUI (kWh/ft^2/year)
Pre-retrofit	9.00	2.21	3.18	2.52
Post-retrofit	5.61	1.28	2.58	1.57

Phase	Weekday EUI ($Wh/ft^2/day$)	Weekend EUI ($Wh/ft^2/day$)	Holiday EUI ($Wh/ft^2/day$)	Annual EUI ($kWh/ft^2/year$)
Savings	3.39	0.93	0.60	0.95
% savings	37.6%	42.0%	18.9%	37.8%

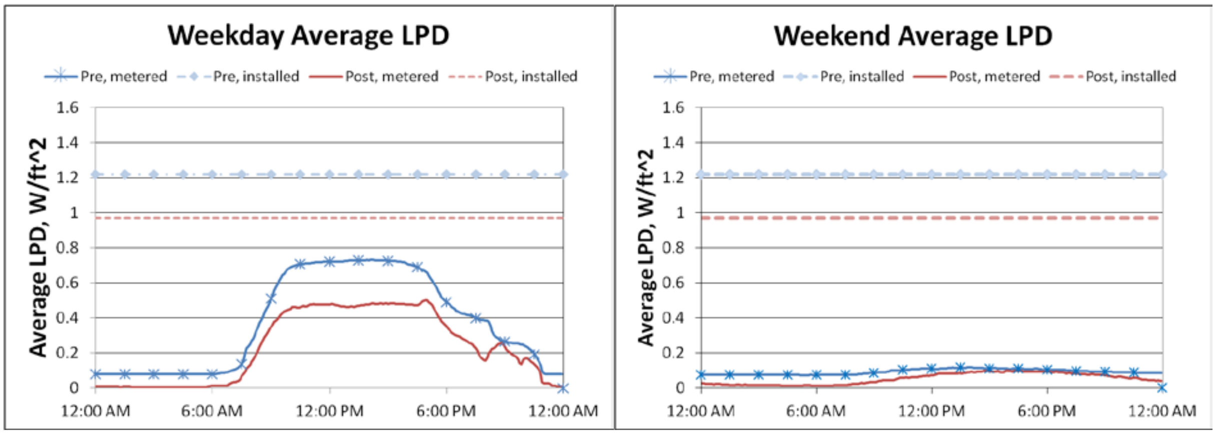


Figure 6: Phillip Burton 10th Floor W installed and average lighting power density (LPD) over the course of the day for weekdays and weekends. The pre-retrofit metering period included 68 weekdays, 30 weekend days, and 6 holidays. The post-retrofit metering period included 168 weekdays, 74 weekend days, and 9 holidays.

The PB10W retrofit achieved a calculated annual energy savings of 0.95 $kWh/ft^2/yr$, or 38%. Since the lighting system layout did not change during the retrofit, reductions in energy usage were largely due to institutional tuning and some occupancy and daylight related savings. Due to the prevalence of alternate use spaces and private offices in this study area combined with variable occupancy patterns throughout the day, neither pre-retrofit nor post-retrofit metered LPD exceeded 60% of their respective installed LPDs during the weekday. Workday lighting use plateaued at approximately 0.73 W/ft^2 during the pre-retrofit study period and 0.48 W/ft^2 during the post-retrofit study period. Weekend lighting use was considered negligible, as average LPDs peaked at around 0.1 W/ft^2 for both pre-retrofit and post-retrofit conditions.

Some lights frequently remained on overnight during the pre-retrofit metering period, resulting in after-hours energy consumption during both weekdays and weekends which can be seen in Figure 6. The post-retrofit lighting system successfully turned off lights after hours due to the occupancy sensors. The comparatively gradual decline in LPD at the end of the work day was probably due to lighting usage in alternate end use spaces: reception area, library, etc. Circuits controlling primarily private offices typically saw little energy consumption after 8 PM except for a peak shortly thereafter, which is attributable to the cleaning crews. However, circuits which controlled the library, filing room, etc., typically stayed above zero energy consumption until 11 PM, when presumably the cleaning crew turned the lights off.

5.1.4 Ron Dellums Federal Building 8th Floor, North Tower

The study area in Ron Dellums Federal Building's 8th Floor, North tower (RD8N) encompassed 121 open office cubicles with a few private offices and conference rooms outside the metered area. In almost half the site, cubicles were arranged into workgroups with low or nonexistent partitions within groups. The remainder of the site consisted of a more typical open office layout, with individual cubicles and partition sections between 42" and 66" high. The pre-retrofit lighting control system used manual switches and occupancy sensors covering large areas, with sweeps in the evening to prevent after hours lighting use. During the retrofit, recessed fixtures on a regularly spaced grid were replaced with suspended WS fixtures. Due to small cubicle sizes (8'x7' typical) installing a WS fixture at each cubicle increased the installed LPD by 76%, from 0.68 W/ft^2 to 1.2 W/ft^2.

The pre-retrofit metering period occurred from November 2010 until February 2011, including 60 complete weekdays, 24 weekend days, and 6 holidays. The post-retrofit metering period began in June 2011 and lasted until the beginning of April 2012. This period included 179 complete weekdays, 76 weekends, and 9 holidays. The metered area included only open office areas and corridors.

Table 13 presents daily and annual EUI results, and Figure 7 displays the installed and average LPD for weekdays and weekends for each study period (pre-retrofit and post-retrofit).

Table 13: Ron Dellums 8th Floor, North tower weekday, weekend, holiday, and annual energy use intensity (EUI). The pre-retrofit metering period included 60 weekdays, 24 weekend days, and 6 holidays. The post-retrofit mitering period included 179 weekdays, 76 weekend days, and 9 holidays.

Phase	Weekday EUI (Wh/ft^2/day)	Weekend EUI (Wh/ft^2/day)	Holiday EUI (Wh/ft^2/day)	Annual EUI (kWh/ft^2/year)
Pre-retrofit	10.13	1.56	4.45	2.75
Post-retrofit	7.39	1.33	2.05	2.01
Savings	2.74	0.23	2.40	0.74
% savings	27.1%	14.8%	53.9%	26.8%

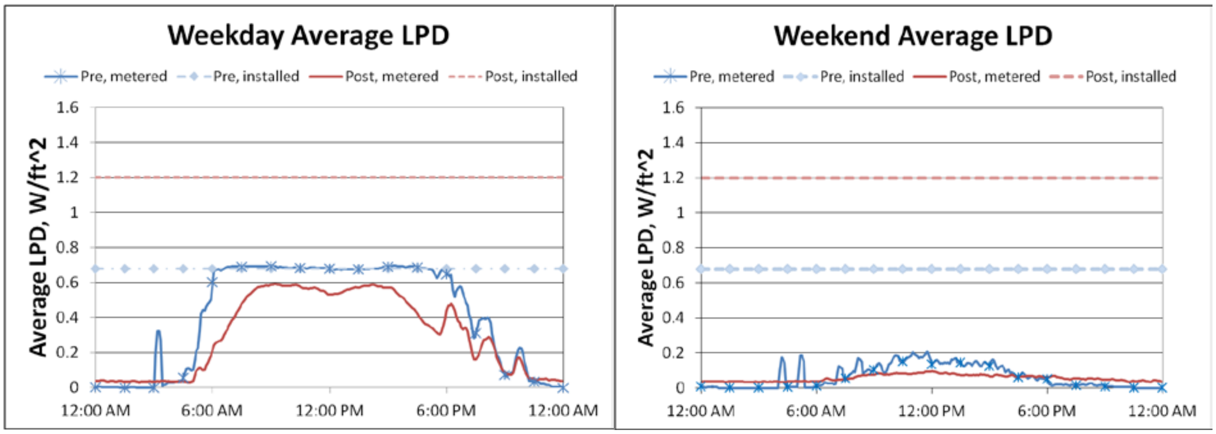


Figure 7: Ron Dellums 8th Floor, North tower installed and average lighting power density (LPD) over the course of the day for weekdays and weekends. The pre-retrofit metering period included 60 weekdays, 24 weekend days, and 6 holidays. The post-retrofit metering period included 179 weekdays, 76 weekend days, and 9 holidays.

As mentioned above, the significant increase in installed LPD for this predominantly high-density open office site during the retrofit is mostly due to the change from a regular grid layout of fixtures to a WS layout. Small cubicles also contributed to creating a denser fixture layout than prior to the retrofit. Despite this increase in installed LPD, the retrofit achieved substantial energy savings in the open office areas, reducing the calculated annual EUI by 0.74 kWh/ft^2/yr, or 27%. During the weekday, the pre-retrofit lighting use reached the installed LPD of 0.68 W/ft^2 between the operating hours of 6 AM and 6 PM, while post-retrofit lighting use plateaued at approximately 0.58 W/ft^2, 50% of the post-retrofit installed LPD. Due to the low pre-retrofit installed LPD, the difference between pre- and post-retrofit peak average LPDs is small (15%).

Small peaks in the weekday LPD after regular operating hours during both pre- and post-retrofit study periods correlated with RD8N's cleaning crew schedule. Standby power and a small contingency of lights that appeared to stay on over a number of nights due to communication issues with the control system during the post-retrofit study period resulted in after-hours energy consumption for both weekdays and weekends. However, energy savings of 15% were still seen during the weekend with peak average LPDs of 2.1 W/ft^2 and 0.09 W/ft^2 for pre- and post-retrofit study periods, respectively.

5.1.5 Ron Dellums Federal Building 13th Floor North Tower

The site located in the Ron Dellums Federal Building 13th Floor, North tower (RD13N) was composed of 55 open office cubicles, as well as several private offices and conference rooms outside the metered area. During the retrofit, recessed fixtures on a regular grid were replaced with suspended WS fixtures. The pre-retrofit lighting controls consisted of manual switches and occupancy sensors controlling large zones, with sweeps in the evening to prevent after hours lighting use. In contrast to other sites, up-lights in the post-retrofit WS system were programmed to remain on between 6am and 6pm each day, even in unoccupied cubicles. This was done in response to a tenant request following the retrofit focused on making the site appear less gloomy.

The pre-retrofit metering period took place from August 2010 to November 2010 and included 45 complete weekdays, 23 weekend days, and 2 holidays. The post-retrofit metering period began in June 2011 and lasted until beginning of April 2012, including 180 weekdays, 76 weekend days, and 9 holidays. The metered area included open office areas and corridors.

Table 14 presents daily and annual EUI results, and Figure 8 displays the installed and average LPD for weekdays and weekends for each study period (pre-retrofit and post-retrofit).

Table 14: Ron Dellums 13th Floor, North tower weekday, weekend, holiday, and annual energy use intensity (EUI). The pre-retrofit metering period included 45 weekdays, 23 weekend days, and 2 holidays. The post-retrofit metering period included 180 weekdays, 76 weekend days, and 9 holidays.

Phase	Weekday EUI ($Wh/ft^2/day$)	Weekend EUI ($Wh/ft^2/day$)	Holiday EUI ($Wh/ft^2/day$)	Annual EUI ($kWh/ft^2/year$)
Pre-retrofit	9.07	0.76	0.48	2.36
Post-retrofit	6.01	1.23	2.46	1.66
Savings	3.06	-0.47	-1.98	0.70
% savings	33.7%	-61.7%	-414.5%	29.6%

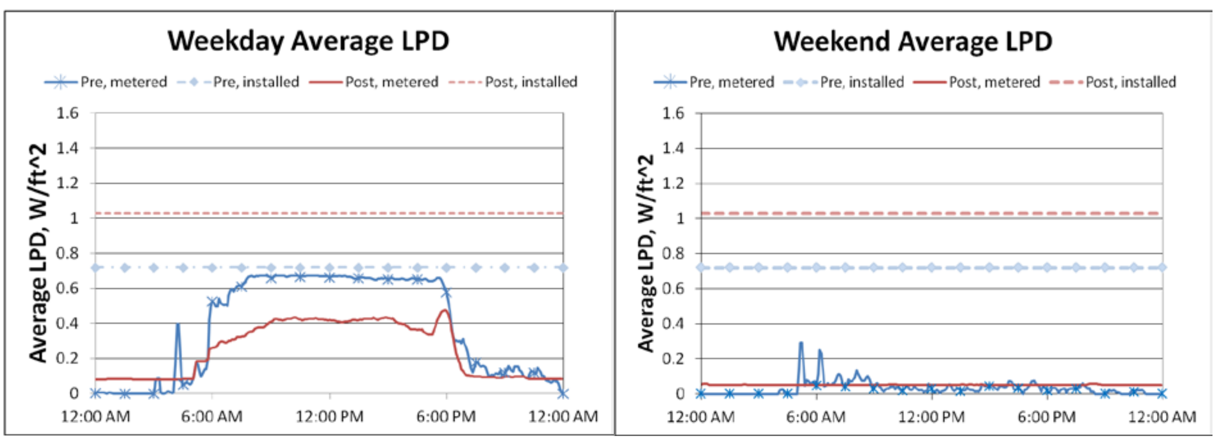


Figure 8: Ron Dellums 13th Floor, North tower installed and average lighting power density (LPD) over the course of the day for weekdays and weekends. The pre-retrofit metering period included 45 weekdays, 23 weekend days, and 2 holidays. The post-retrofit metering period included 180 weekdays, 76 weekend days, and 9 holidays.

The WS system achieved a calculated annual energy savings of 0.70 $kWh/ft^2/yr$, or 30%, despite a 43% increase in installed LPD, from 0.72 W/ft^2 to 1.03 W/ft^2. Lighting use during the pre-retrofit study period resulted in average metered LPDs peaking at 0.67 W/ft^2, or 94% of the pre-retrofit installed LPD, during operating hours between 6 AM and 6 PM during the weekday.

Post-retrofit lighting use peaked at 0.48 W/ft^2, approximately 46% of the post-retrofit installed LPD and 72% of the pre-retrofit average peak LPD. Several up-lights remained on 24 hours/day during a portion of the post-retrofit period, resulting in higher after-hours energy consumption during weekdays and weekends. Despite after-hours lighting power consumption, significant energy savings were still seen due to the high variability in occupancy patterns at RD13N. Site contacts indicated that some occupants telecommute on a regular basis and many occupants are on a reduced schedule due to the recession. The peak in the weekday LPD around 6 PM correlated with RD13N's cleaning crew schedule. Weekend lighting use was considered negligible, as average LPDs generally hovered around 0.06 W/ft^2 throughout the day for both pre- and post-retrofit study periods.

5.1.6 Ron Dellums Federal Building 14th Floor South Tower

The Ron Dellums Federal Building 14th Floor, South tower (RD14S) site covered the west half of the floor. The majority of the site consisted of a large open office area with 49 individual cubicles, with four large private offices along the perimeter. During the retrofit, recessed fixtures on a regular grid were replaced with suspended WS fixtures. The pre-retrofit lighting controls consisted of manual switches and occupancy sensors controlling large zones, with sweeps in the evening to prevent after hours lighting use.

The pre-retrofit metering period took place between October and November 2010, including 24 complete weekdays, 12 weekend days, and 2 holidays. Post-retrofit metering period ran from early June 2011 until April 2012 and included 189 weekdays, 78 weekend days, and 9 holidays. The metered area encompassed the majority of the site area, including open office areas, private offices, and corridors.

Table 15 presents daily and annual EUI results, and Figure 9 displays the installed and average LPD for weekdays and weekends for each study period (pre-retrofit and post-retrofit).

Table 15: Ron Dellums 14th Floor, South tower weekday, weekend, holiday, and annual energy use intensity (EUI). Pre-retrofit metering period included 24 weekdays, 12 weekend days, and 2 holidays. Post-retrofit metering period included 189 weekdays, 78 weekend days, and 9 holidays.

Phase	Weekday EUI (Wh/ft^2/day)	Weekend EUI (Wh/ft^2/day)	Holiday EUI (Wh/ft^2/day)	Annual EUI (kWh/ft^2/year)
Pre-retrofit	9.52	2.99	1.67	2.72
Post-retrofit	6.26	0.57	1.22	1.64
Savings	3.26	2.42	0.45	1.08
% savings	34.3%	81.1%	27.0%	39.6%

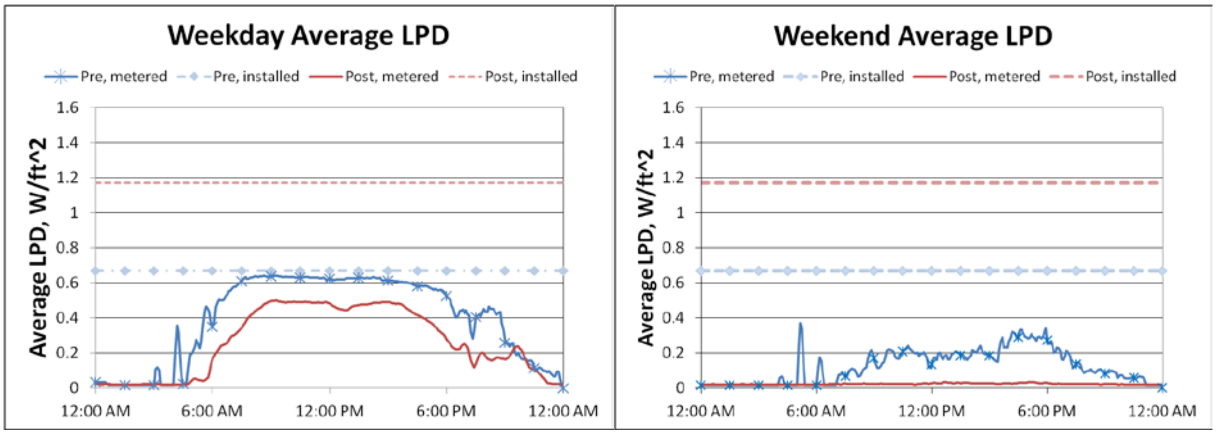


Figure 9: Ron Dellums 14th Floor, South tower installed and average lighting power density (LPD) over the course of the day for weekdays and weekends. Pre-retrofit metering period included 24 weekdays, 12 weekend days, and 2 holidays. Post-retrofit metering period included 189 weekdays, 78 weekend days, and 9 holidays.

Similar to RD8N, the significant increase in installed LPD at RD14S was a result of the change from regularly spaced fixtures to a WS layout in a densely packed open office area with WS fixtures that contained three F32T8 lamps each. Although the retrofit increased the installed LPD by 75% from 0.67 W/ft^2 to 1.17 W/ft^2, the lighting control system at this site reduced calculated annual lighting energy use by 1.08 kWh/ft^2/yr, or 40%. As can be seen in Figure 9, pre-retrofit lighting use during a typical weekday resulted in an average peak LPD of around 0.64 W/ft^2, 95% of the pre-retrofit installed LPD. During the post-retrofit metering period, however, the combination of institutional tuning, WS lighting, and occupancy sensing resulted in an average peak LPD of 0.50 W/ft^2, which comprised 43% of the post-retrofit installed LPD and 78% of the pre-retrofit average peak LPD. The peak in the weekday LPD around 6 PM correlated with RD13N's cleaning crew schedule. The RD14S retrofit significantly reduced weekend lighting use from the pre-retrofit metered lighting use of approximately 0.2 W/ft^2 between 10 AM and 6 PM with a peak of 0.37 W/ft^2, to a post-retrofit level of around 0.04 W/ft^2. Post-retrofit weekend LPDs seem to be largely due to standby power.

5.1.7 Roybal Federal Building 18th Floor

The site located on the 18th floor of the Roybal Federal Building (R18) included a mixture of open and private office spaces, including a call center with long operating hours and multiple work shifts per cubicle. The pre-retrofit lighting system consisted of recessed 2x4 fixtures, which were either replaced with suspended WS fixtures above cubicles or replaced in place with more efficient fixtures.

The pre-retrofit metering period took place from late January 2011 until mid-April 2011, and included 28 weekdays, 11 weekend days, and no holidays. The post-retrofit metering period ran from mid-September 2011 until April 2012. The post-retrofit metering period included 124 weekdays, 52 weekend days, and 8 holidays. The metered area covered the majority of the site area including the open office areas, call center, private offices, and corridors.

Table 16 presents daily and annual EUI results, and Figure 10 displays the installed and average LPD for weekdays and weekends for each study period (pre-retrofit and post-retrofit).

Table 16: Roybal 18th Floor weekday, weekend, holiday, and annual energy use intensity (EUI). The pre-retrofit metering period included 28 weekdays, 11 weekend days, and no holidays. The post-retrofit metering period included 124 weekdays, 52 weekend days, and 8 holidays.

Phase	Weekday EUI ($Wh/ft^2/day$)	Weekend EUI ($Wh/ft^2/day$)	Holiday EUI ($Wh/ft^2/day$)	Annual EUI ($kWh/ft^2/year$)
Pre-retrofit	17.88	17.63	N/A	6.50
Post-retrofit	7.31	4.71	4.91	2.37
Savings	10.57	12.92	N/A	4.13
% savings	59.1%	73.3%	N/A	63.5%

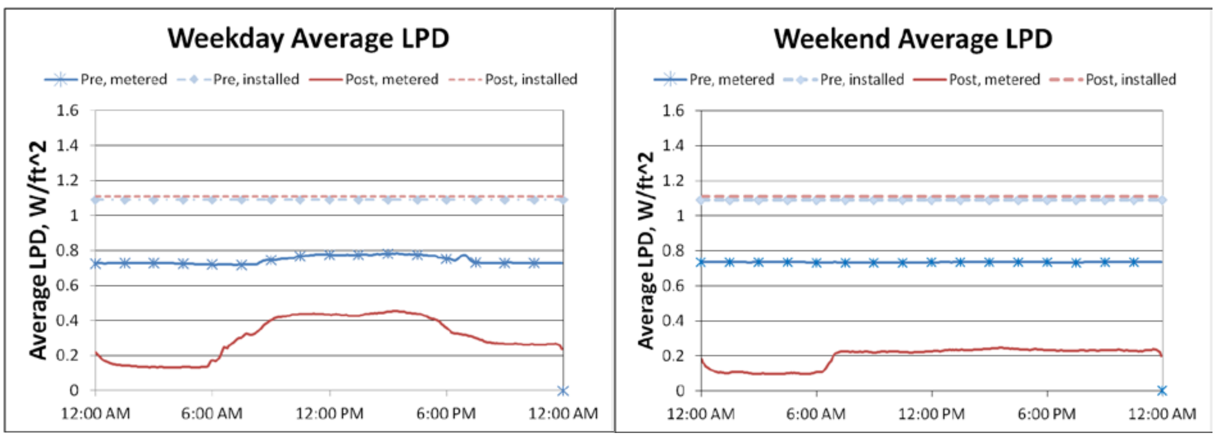


Figure 10: Roybal 18th Floor installed and average lighting power density (LPD) over the course of the day for weekdays and weekends. The pre-retrofit metering period included 28 weekdays, 11 weekend days, and no holidays. The post-retrofit metering period included 124 weekdays, 52 weekend days, and 8 holidays.

The R18 retrofit achieved very deep energy savings, reducing annual lighting energy use by 4.13 $kWh/ft^2/yr$, approximately 63%. The pre-retrofit lighting power usage varied very little during the study period, with a high weekday and weekend baseline use of 0.74 W/ft^2, due to long operating hours in the call center, from 6 AM to midnight. However, despite the study area's 24 hour/day lighting power usage, lights were never all on simultaneously; therefore, the pre-retrofit LPDs never reached the installed values.

Although the retrofit installed a similar LPD to pre-retrofit conditions, average metered LPD were reduced significantly; peak LPDs during the weekdays decreased 42%, from 0.78 W/ft^2

pre-retrofit to 0.45 W/ft^2, post-retrofit, while even greater reductions were seen outside of typical work hours. These deep savings were achieved largely as a result of the ability to shut or dim lights that had been unnecessarily left on in unoccupied spaces throughout the day. Post-retrofit LPDs were also greatly reduced during the weekend with a 66% difference between the pre-retrofit LPD of 0.74 W/ft^2 and post-retrofit LPD of 0.25 W/ft^2.

5.2 Cost-Effectiveness Analysis

The purpose of performing a cost-effectiveness analysis for any energy-conserving measure (ECM) is to determine whether the value of the future energy savings from the installation of the ECM justifies the expense of the investment. To account for possible regional variation in costs, electricity costs were determined for utility providers for the federal building in question, as seen in Table 6 (p. 32).

As stated earlier, fixture equipment costs and control systems costs were to highlight the incremental cost and the subsequent payback period of applying advanced control strategies: institutional tuning, occupancy sensing, and some personal control. Labor and material breakdowns were also applied where possible. Summary operating savings and full installation costs can be seen below in Table 17 and

Table 18. Building-specific breakdowns and discussions can be seen in the following sections.

Table 17: Summary of annual operating savings

Building	Pre-retrofit EUI, kWh/ft2/year	Post-retrofit EUI, kWh/ft2/year	Annual Operating Savings ($/ft2/year)
Chet Holifield	2.92	2.11	$0.11
Cottage Way	2.52	1.32	$0.15
Philip Burton	2.52	1.57	$0.11
Ronald Dellums	2.66	1.83	$0.11
Roybal	6.50	2.37	$0.49

Table 18: Summary of installation costs broken down by material and labor costs without costs associated with reconfiguring the existing system, in \$/ft^2

Building	Materials Cost	Labor Cost	Full Investment Cost
Chet Holifield	$5.39	$1.89	$7.28
Cottage Way	$4.71	$0.92	$5.64
Philip Burton	$3.61	$1.41	$5.02
Ron Dellums	$5.41	$1.77	$7.18
Roybal	$3.91	$2.19	$6.10

As described earlier, two incremental cost scenarios were considered: a standard GSA baseline retrofit and a controls system only approach (Table 19). In the control system cost only case, we subtracted the cost of a similar WS lighting system without any controls from the full project cost. The GSA standard relighting system, "GSA standard", was considered to conform to GSA's P100-2005, typical of retrofits in the past five years. The cost associated with the GSA standard relighting was calculated to be $3/ft^2$ [13]. The GSA standard relighting system incremental cost was calculated by subtracting the cost of the GSA standard retrofit from the full installment cost. Additionally, labor costs associated with reconfiguring the existing system were excluded.

Table 19: Summary of incremental cost payback periods using building-specific utility energy rates, in years

Building	Utility energy rates, $/kWh	Control System Cost only Payback Period, years	Full Cost - GSA Standard Cost Payback Period, years
Chet Holifield	$0.13	15.5	40.7
Cottage Way	$0.13	15.4	17.3
Philip Burton	$0.12	13.9	17.9
Ron Dellums	$0.13	23.7	38.4
Roybal	$0.12	3.8	6.3

5.2.1 Chet Holifield Federal Building

Chet Holifield Federal Building's retrofit was calculated to have payback periods of 16 years for the "Control System Only" and 41 years for the "GSA standard" incremental cost approaches. The calculated pre- and post-retrofit EUI at CH2SE resulted in energy savings of 0.81 kWH/ft^2/year and an annual operating savings of $0.11/ft^2/year. Although a total of 116,300 square feet of the Chet Holifield Federal Building was considered to be retrofitted, only 60,100 square feet of the "retrofitted area" completely decommissioned the existing lighting system and installed the workstation-specific lighting system with advanced controls. The remaining areas left the existing system in place while rewiring for large zonal occupancy sensors; therefore, costs associated with these remaining areas were excluded from this analysis. Finally, the control system labor cost was estimated to be $0.30/ft^2. Cost information and retrofitted area values were based on price proposals dated January 17, 2011, and as-built drawings dated November 15, 2011.

Table 20 lists Chet Holifield's incremental cost for the GSA standard and control systems only approaches while Figure 11 displays sensitivity analyses to varying pre-retrofit LPDs and energy costs. The "GSA standard" incremental cost is depicted by the solid red square markers while the "Control System Only" incremental cost is depicted by the solid green triangle markers.

Table 20: Chet Holifield Incremental Costs

Incremental Cost	$/ft^2
Control System Cost only	$1.63
Full Cost – GSA Standard Cost	$4.28

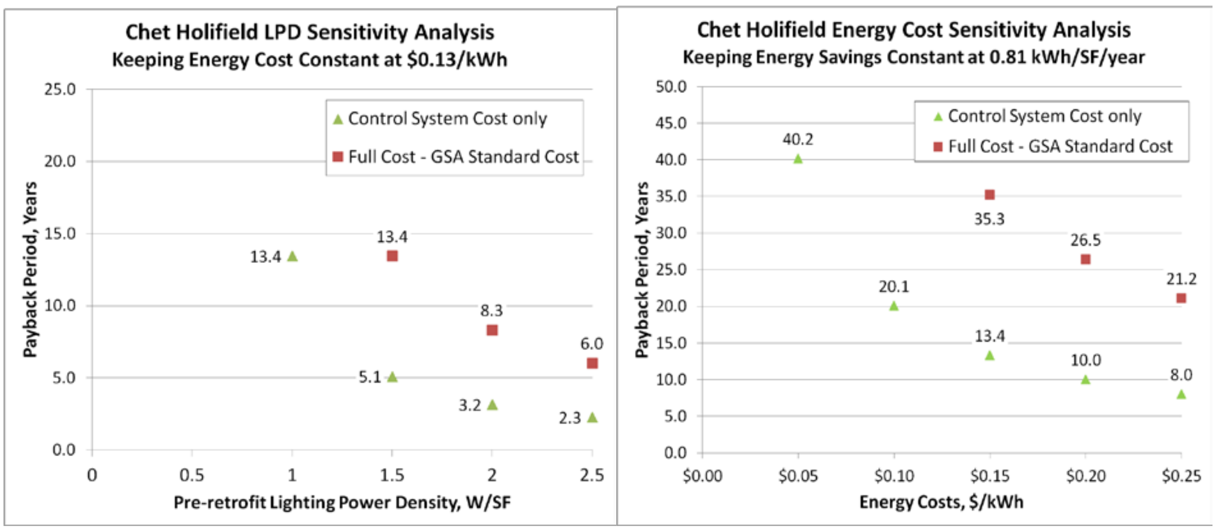


Figure 11: Chet Holifield sensitivity analyses to varying pre-retrofit lighting power density (LPD) and electricity rates

As can be seen in Figure 11, the Chet Holifield installation is not cost-effective (resulting in payback periods greater than 15 years) for pre-retrofit LPD less than 1.4 W/ft^2 under the "Full Cost – GSA Standard" scenario and 1.0 W/ft^2 under the "Control System Cost Only" Scenario Figure 11 also shows how the payback period varies as a function of the cost of electricity. If energy costs are greater than $0.13/kWh, then the control system cost scenario pays back in less than 15 years, although electricity rates would have to be greater than $0.35/kWh for this installation to be cost-effective under the "Full Cost – GSA Standard" scenario.

If energy costs were kept constant, in order to achieve payback periods of 10 years or less, pre-retrofit LPDs needed to be at least 1.1 W/ft^2 for the control system only approach or 1.8 W/ft^2 for the GSA standard approach. Similarly, when pre-retrofit LPDs were kept constant, a 10-year payback period would require energy costs exceeding $0.20/kWh or $0.53/kWh for the control system only and GSA standard approach, respectively.

5.2.2 Cottage Way Federal Building

The Cottage Way Federal Building retrofit was calculated to have payback periods of 15 years for the "Control System Only" and 17 years for the "GSA standard" incremental cost approaches. The calculated pre- and post-retrofit EUI at CW2NE resulted in energy savings of 1.20 kWh/ft^2/year and an annual operating savings of $0.15/ft^2/year. A total retrofit area of

95,000 square feet was considered and the control system labor cost was estimated to be $0.30/ft^2. Cost and retrofitted area values were based on communications with GSA on April 19, 2012, and price proposals dated August 15, 2011.

Table 21 lists Cottage Way's incremental cost for the GSA standard and control systems only approaches, while Figure 12 displays sensitivity analyses to varying pre-retrofit LPDs and energy costs. The "GSA standard" incremental cost is depicted by the solid red square markers while the "Control System Only" incremental cost is depicted by the solid green triangle markers.

Table 21: Cottage Way Incremental Costs

Incremental Cost	$/ft^2
Control System Cost only	$2.35
Full Cost – GSA Standard Cost	$2.64

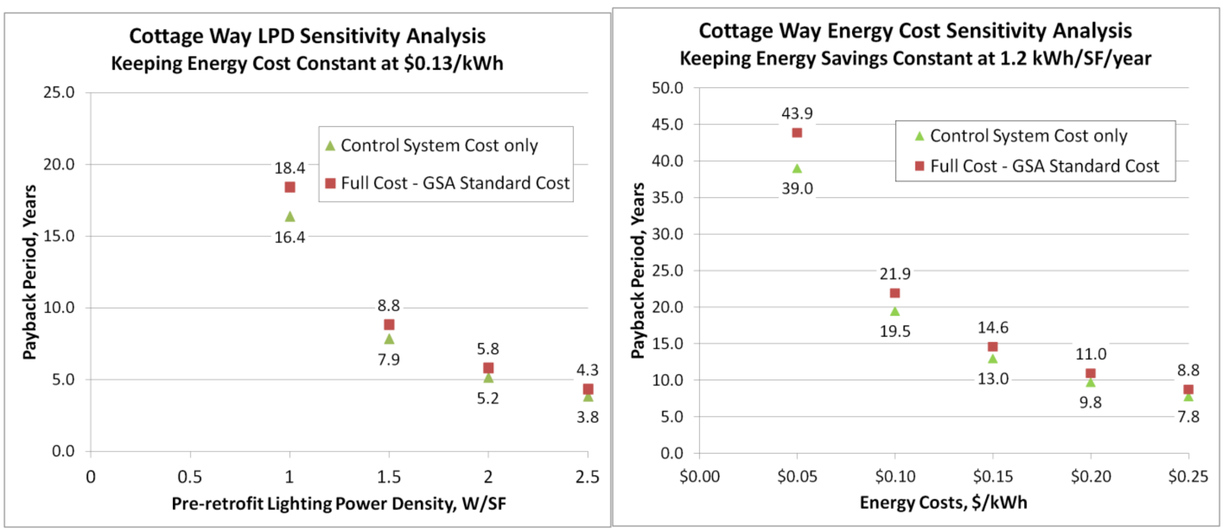


Figure 12: Cottage Way sensitivity analyses to varying pre-retrofit lighting power density (LPD) and energy costs

As can be seen in Figure 12, the Cottage Way installation is cost-effective for pre-retrofit LPDs greater than 1.1 W/ft^2 or electricity rates greater than $0.15/kWh for payback periods of 15 years or less under the "Full Cost – GSA Standard" scenario. Under the "Control System Cost Only" scenario, payback periods of 15 years or less would be achieved by pre-retrofit LPDs greater than 1.0 W/ft^2 or energy rates greater than $0.13/kWh. If energy costs were kept constant, in order to achieve payback periods of 10 years or less, pre-retrofit LPDs needed to be at least 1.3 W/ft^2 for the control system only approach or 1.4 W/ft^2, for the GSA standard approach. Similarly, when pre-retrofit LPDs were kept constant, a 10-year payback period would require energy costs exceeding $0.20/kWh or $0.22/kWh for the control system only and GSA standard approach, respectively.

5.2.3 Phillip Burton Federal Building

The Phillip Burton Federal Building retrofit resulted in payback periods of 14 years for the "Control System Only" and 18 years for the "GSA standard" incremental cost approaches (see Figure 13). The calculated pre- and post-retrofit EUI at PB10W resulted in energy savings of 0.95 kWH/ft^2/year and an annual operating savings of \$0.11/ft^2/year. A total retrofit area of 627,500 square feet was considered. Cost information and retrofitted area values were based on communications with GSA on November 23, 2011 and February 8, 2012, respectively.

Table 22 lists Phillip Burton's incremental cost for the GSA standard and control systems only approaches while Figure 13 displays sensitivity analyses to varying pre-retrofit LPDs and energy costs. The "GSA standard" incremental cost is depicted by the solid red square markers while the "Control System Only" incremental cost is depicted by the solid green triangle markers.

Table 22: Phillip Burton Incremental Costs

Incremental Cost	\$/ft^2
Control System Cost only	\$1.58
Full Cost – GSA Standard Cost	\$2.02

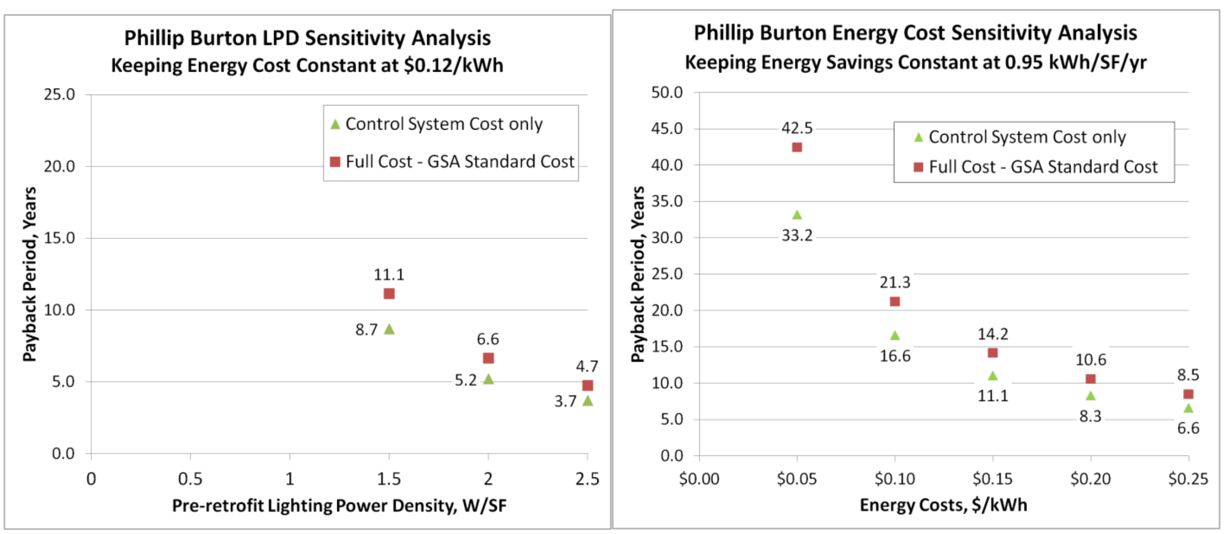


Figure 13: Phillip Burton sensitivity analyses to varying pre-retrofit lighting power density (LPD) and energy costs

As can be seen in Figure 13, the Phillip Burton installation is cost-effective for pre-retrofit LPDs greater than 1.3 W/ft^2 or electricity rates greater than \$0.14/kWh, resulting in payback periods of 15 years or less under the "Full Cost – GSA Standard" scenario. Under the "Control System Cost Only" scenario, pre-retrofit LPDs would have to be greater than 1.2 W/ft^2 or energy rates would have to be greater than \$0.11/kWh for payback periods of 15 years or less. If energy costs were kept constant, in order to achieve payback periods of 10 years or less, pre-retrofit LPDs needed to be at least 1.4 W/ft^2 for the control system only approach or 1.6 W/ft^2 for the GSA standard approach. Similarly, when pre-retrofit LPDs were kept constant, a 10-year payback period would require energy costs exceeding $0.17/kWh for the control system only approach or $0.21/kWh for the GSA standard approach.

One should keep in mind that PB10W's layout is comprised primarily of private offices, which effectually already simulated WS lighting layout. Therefore results should be largely attributed to institutional tuning and personal control with minor occupancy sensing effects.

5.2.4 Ron Dellums Federal Building

The Ron Dellums Federal Building retrofit resulted in payback periods of 24 years for the control system only and 38 years for the GSA standard incremental cost approaches (see Figure 14). Since three of the sites studied were located within the Ron Dellums Federal Building, a combined EUI was calculated by weighting the calculated EUI at RD8N, RD13N, and RD14S with their respective metered area. The combined calculated pre- and post-retrofit EUI resulted in an energy savings of 0.83 $kWh/ft^2/year$ and an annual operating savings of $\$0.11/ft^2/year$. A total retrofit area of 600,000 square feet was considered. Cost information and retrofitted area values were based on communications with GSA on May 25, 2012 and as-built drawings dated between August 18 and September 23, 2011, respectively.

Table 23 lists Ron Dellums' incremental cost for the GSA standard and control systems only approaches while Figure 14 displays sensitivity analyses to varying pre-retrofit LPDs and energy costs. The "GSA standard" incremental cost is depicted by the solid red square markers while the "Control System Only" incremental cost is depicted by the solid green triangle markers.

Table 23: Ron Dellums Incremental Costs

Incremental Cost	$\$/ft^2$
Control System Cost only	$2.58
Full Cost – GSA Standard Cost	$4.18

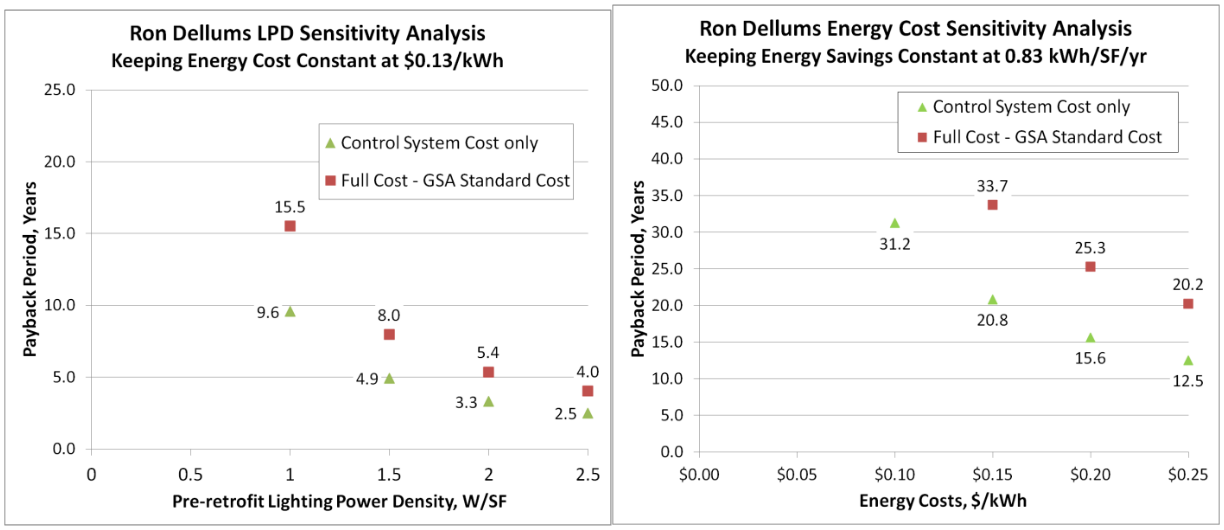


Figure 14: Ron Dellums sensitivity analyses to varying pre-retrofit lighting power density (LPD) and energy costs

As can be seen in Figure 14, the Ron Dellums sites result in payback periods less than 15 years, considered to be cost-effective, if the pre-retrofit LPD is greater than 1.0W/ft^2 or electricity rates are higher than $0.34/kWh under the “Full Cost – GSA Standard” scenario. When considering the “Control System Cost Only” scenario, pre-retrofit LPDs need to be greater than 0.8 W/ft^2 or energy rates need to be higher than $0.21/kWh for payback periods of 15 years or less. If energy costs were kept constant, in order to achieve payback periods of 10 years or less, pre-retrofit LPDs needed to be at least 1.0 W/ft^2 for the control system approach or 1.3 W/ft^2 for the GSA standard approach. Similarly, when pre-retrofit LPDs were kept constant, a 10-year payback period would require energy costs exceeding $0.31/kWh or $0.51/kWh for the control system only and GSA standard approach, respectively.

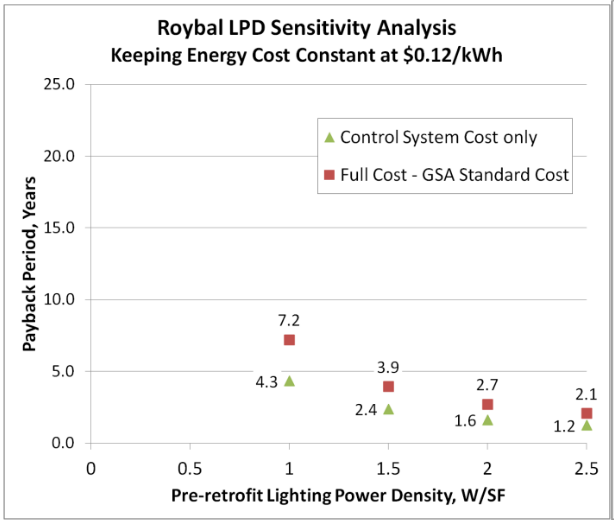
5.2.5 Roybal Federal Building

The Roybal Federal Building retrofit resulted in payback periods of 4 years for control systems and 6 years for GSA standard incremental cost approaches (see Figure 15). The calculated pre- and post-retrofit EUI at R18 resulted in an energy savings of 4.12 kWh/ft^2/year and an annual operating savings of $0.49/ft^2/year. A total retrofit area of 126,000 square feet was considered. Cost information was based on price proposals dated January 17, 2011, and retrofitted area values were based on as-built drawings dated September 2011.

Table 24 lists Roybal’s incremental cost for the “GSA standard” and “control systems only” approaches while Figure 15 displays sensitivity analyses to varying pre-retrofit LPDs and energy costs. The “GSA standard” incremental cost is depicted by the solid red square markers while the “Control System Only” incremental cost is depicted by the solid green triangle markers.

Table 24: Roybal Incremental Costs

Incremental Cost	$/ft²
Control System Cost only	$1.86
Full Cost – GSA Standard Cost	$3.10



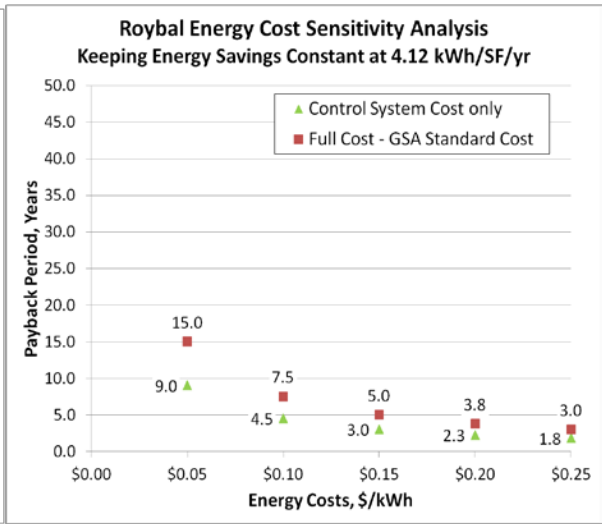


Figure 15: Roybal sensitivity analyses to varying pre-retrofit lighting power density (LPD) and energy costs

As can be seen in Figure 15, the Roybal installation is cost-effective, with a payback under 15 years, for pre-retrofit LPDs greater than 0.7 W/ft² or electricity rates higher than $0.05/kWh under the "Full Cost – GSA Standard" scenario. Under the "Control System Cost Only" scenario, payback periods of 15 years or less could be achieved if pre-retrofit LPDs were greater than 0.6 W/ft² or if energy rates were greater than $0.03/kWh. If energy costs were kept constant, in order to achieve payback periods of 10 years or less, pre-retrofit LPDs needed to be at least 0.7 W/ft² or 0.8 W/ft², while payback periods of 5 years required pre-retrofit LPDs to exceed 0.9 W/ft² or 1.3 W/ft² for the control system only and GSA standard approach, respectively. Similarly, when pre-retrofit LPDs were kept constant, a 10 year payback period would require energy costs exceeding $0.05/kWh for the control system only approach or $0.08/kWh for the GSA standard approach. Payback periods of 5 years or less would require energy costs of at least $0.09/kWh or $0.15/kWh for the control system only and GSA standard approach, respectively.

As mentioned previously, R18 maintains 24 hr/day operating hours due to its call center, which results in high energy use in this particular site as compared to others. As a result, the retrofit achieved deep energy savings, largely due to the combination of institutional tuning and occupancy sensing which decreased energy usage by 63%. This drastic reduction may not be representative of the entire building.

5.3 Photometric Results

In order to determine whether the WS lighting system supplied the necessary light levels, light levels provided by both the WS lighting system and the pre-retrofit existing lighting system were documented. Appropriate light levels were defined to be above 350 lux, the IESNA acceptable light level for an office space. A summary of average illuminances for the pre-retrofit existing lighting system, post-retrofit fixtures under default settings, and all post-retrofit fixtures can be seen in Table 25. Details on the range of illuminances can be found in the following site-specific sections.

Table 25: Average illuminances for pre-retrofit and post-retrofit lighting systems. Percent changes between pre- and post-retrofit conditions are also listed. Positive percent changes reflect higher post-retrofit illuminances while negative percent changes reflect lower post-retrofit illuminances.

Site	Pre-retrofit illuminances, lux	Post-retrofit, default settings illuminances, lux	Post-retrofit, default settings, % change	Post-retrofit, all fixtures illuminances, lux	Post-retrofit, all fixtures, % change
CH2SE	263	331	26%	359	37%
CW2NE	292	327	12%	335	15%
PB10W	616	428	-30%	414	-33%
RD8N	381	495	30%	476	25%
RD13N	481	430	-11%	449	-7%
RD14S	386	425	10%	409	6%
R18	328	514	57%	524	59%

5.3.1 Chet Holifield Federal Building 2nd Floor SE Quadrant

The WS lighting system in CH2SE generally provided higher light levels than the pre-retrofit system (Table 26 and Figure 16). Pre-retrofit illuminance measurements were taken on a sunny afternoon at 128 workstations. Due to high partitions at the site, daylight penetration was considered negligible at the interior workstations where measurements were taken. A total of 165 illuminance measurements were recorded at night during the post-retrofit site visit, 128 of which operated under default settings and 37 under occupant-requested settings. The WS fixture default settings were programmed to turn down-lights to 50% and up-lights to 20% as a default, with 30-minute timeouts.

Table 26: CH2SE photometric results, in lux. Pre-retrofit results were based on illuminances measured at 128 workstations. Post-retrofit results were based on illuminances measured at 165 workstations, 128 of which were operating under default settings.

	Pre-retrofit, Overhead lights only	Pre-retrofit, With task lights	Post-retrofit, Default settings only	Post, retrofit, Default with task lights	Post, retrofit, All user settings	Post-retrofit, All with task lights
Min	23	143	192	313	192	313
Quartile 1	205	326	285	405	289	409
Quartile 2	280	400	327	447	338	459
Quartile 3	315	436	357	478	389	510
Max	522	643	643	764	836	956
Mean	263	383	331	451	359	480

Figure 16 displays the range of illuminance measurements for pre- and post-retrofit light installations. Blue diamonds and adjacent values give the mean, rectangles represent the range between the 1^{st}, 2^{nd}, and 3^{rd} quartiles, and bars cover the entire range of data. Pre-retrofit results are in grey while post-retrofit results are in green.

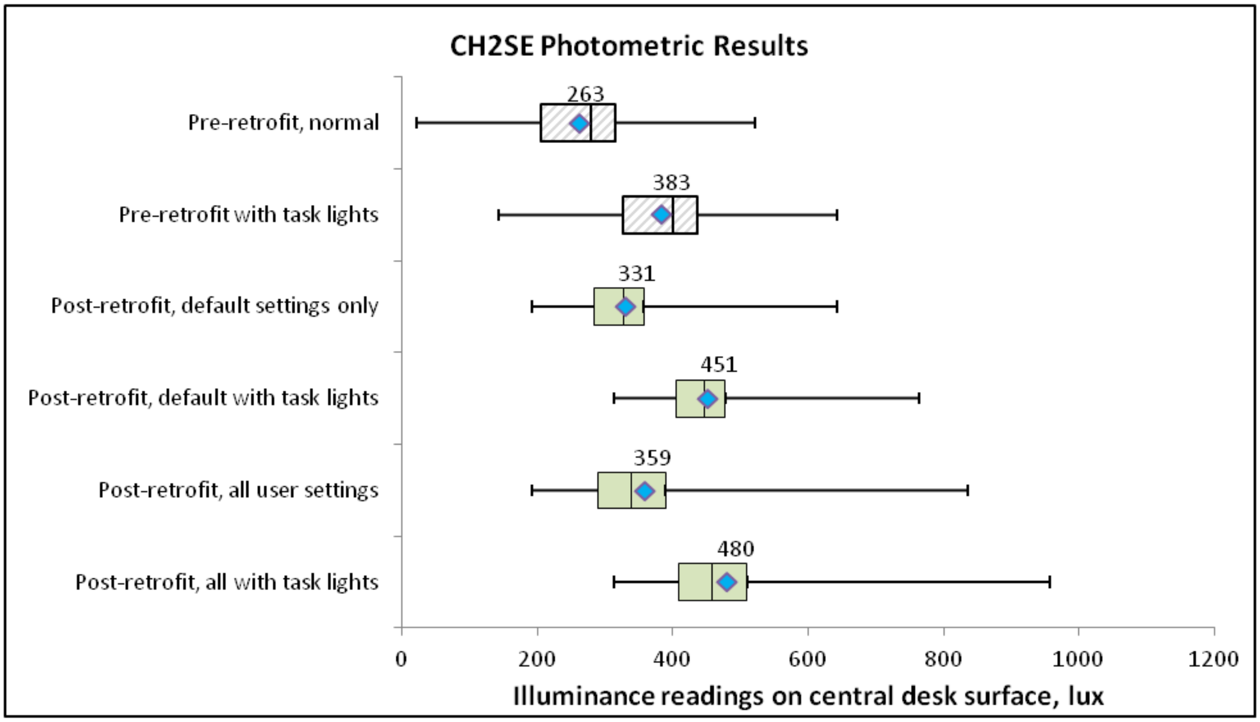


Figure 16: CH2SE metered illuminances at front edge of central desk area. Pre-retrofit results were based on illuminances measured at 128 workstations. Post-retrofit results were based on illuminances measured at 165 workstations, 128 of which were operating under default settings.

The pre-retrofit lighting system provided an average of 263 lux at the workstations, while the post-retrofit WS lighting system provided an average of 331 and 359 lux for the "default settings only" and "all user settings" case, respectively, without the under-cabinet task light. Of the measured pre-retrofit fixtures, 88% produced desktop illuminances below the IESNA acceptable light level of 350 lux. As for the post-retrofit system, 66% of the measured fixtures on default settings and 57% of all fixtures measured maintained light levels lower than 350 lux. The under-cabinet task lights were determined to produce an average of an additional 120 lux.

5.3.2 Cottage Way Federal Building 2nd Floor East, North Building

The WS lighting system in CW2NE provided comparable and sometimes higher light levels to the pre-retrofit system (Table 27 and Figure 17). Pre-retrofit illuminances were measured at 122 workstations. A total of 129 workstation light levels were measured during the post-retrofit site visit; 100 workstations of which were operating under default settings and the remaining 29 were operating under occupant-requested settings. Post-retrofit default settings turned down-lights on to 50% and up-lights to 20% levels. Daylight effects were not considered as both pre- and post-retrofit illuminances were recorded during the evening. Pre- and post-retrofit illuminance values are presented below with and without under-cabinet task lights, where the average under-cabinet task light reading of an additional 186 lux was used.

Table 27: CW2NE photometric results, in lux. Pre-retrofit results were based on illuminances measured at 122 workstations. Post-retrofit results were based on illuminances measured at 129 workstations, 100 of which were operating under default settings.

	Pre-retrofit, Overhead lights only	Pre-retrofit, With task lights	Post-retrofit, Default settings only	Post-retrofit, Default with task lights	Post-retrofit, All user settings	Post-retrofit, All with task lights
Min	41	227	128	313	41	227
Quartile 1	187	373	275	461	282	468
Quartile 2	305	490	320	505	330	515
Quartile 3	406	592	363	549	376	562
Max	736	922	553	738	554	739
Mean	292	478	327	512	335	521

Figure 17 shows illuminance measurements for pre- and post-retrofit light installations. Blue diamonds and adjacent values give the mean, rectangles represent range between the 1^{st}, 2^{nd}, and 3^{rd} quartiles, and bars cover the entire range of data. Pre-retrofit results are in grey while post-retrofit results are in green.

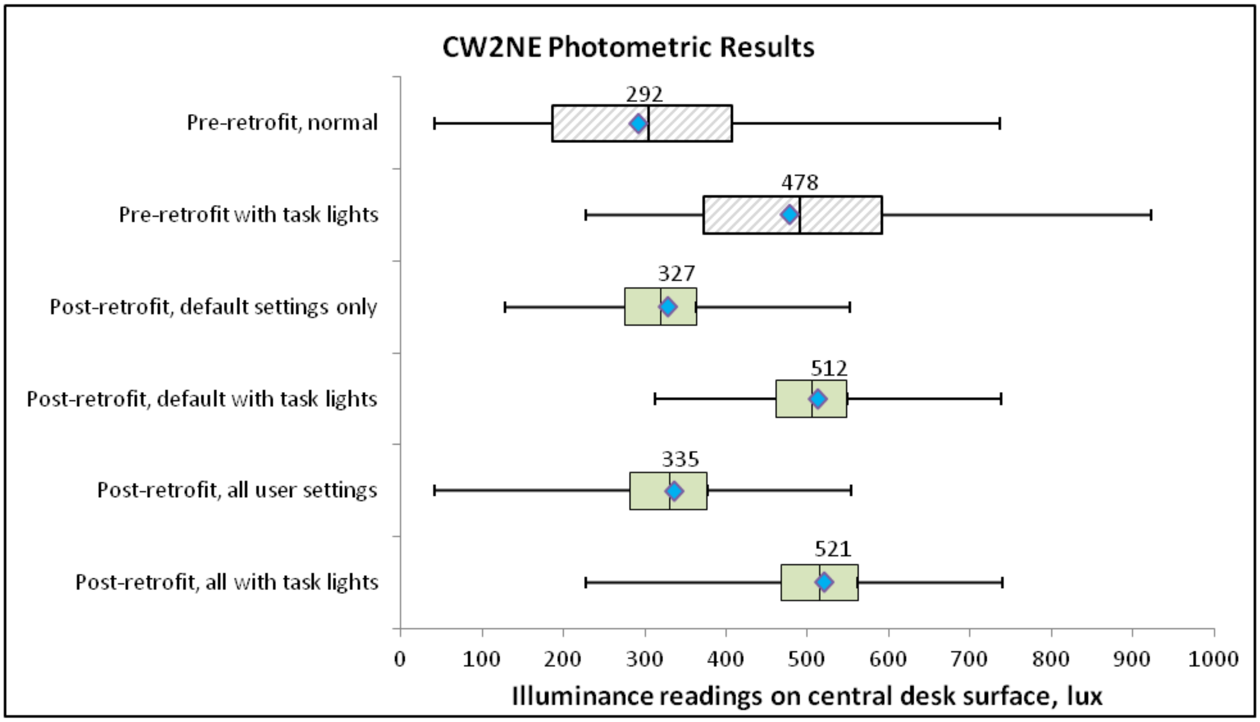


Figure 17: CW2NE metered illuminances at front edge of central desk area. Pre-retrofit results were based on illuminances measured at 122 workstations. Post-retrofit results were based on illuminances measured at 129 workstations, 100 of which were operating under default settings.

On average, the measured pre-retrofit luminaires provided 292 lux without the under-cabinet task light, where 65% of which fell below the IESNA acceptable light level of 350 lux. The post-retrofit WS lighting system provided an average of 327 lux when considering only fixtures at default settings and 335 lux for all measured fixtures, including those with occupant-requested setting changes. Of the measured fixtures, 65% of those on default settings and 61% of all measured fixtures produced light levels lower than 350 lux.

5.3.3 Phillip Burton Federal Building 10th Floor West

The results of the photometric characterization for PB10W demonstrated that the retrofitted lighting system generated appropriate desktop light levels (Table 28 and Figure 18). Pre-retrofit illuminances were recorded after dark for 50 private offices. Post-retrofit illuminances were measured for a total of 28 offices; however, four measurements were excluded due to high daylight sensitivity. Of the remaining 24 office illuminance measurements, 22 operated under default settings and 2 operated under occupant requested changes. Task lights were not considered at this site due to the high variability of task light type present in the private offices.

Table 28: PB10W photometric results, in lux. Pre-retrofit results were based on illuminances measured at 28 workstations. Post-retrofit results were based on illuminances measured at 24 workstations, 22 of which were operating under default settings.

	Pre-retrofit, Overhead lights only	Post-retrofit, Default settings only	Post-retrofit, All user settings
Min	275	290	214
Quartile 1	530	385	345
Quartile 2	591	429	422
Quartile 3	670	491	480
Max	1220	618	618
Mean	616	428	414

Figure 18 shows illuminance measurements for pre- and post-retrofit light installations. Blue diamonds and adjacent values give the mean, rectangles represent range between the 1st, 2nd, and 3rd quartiles, and bars cover the entire range of data. Pre-retrofit results are in grey while post-retrofit results are in green.

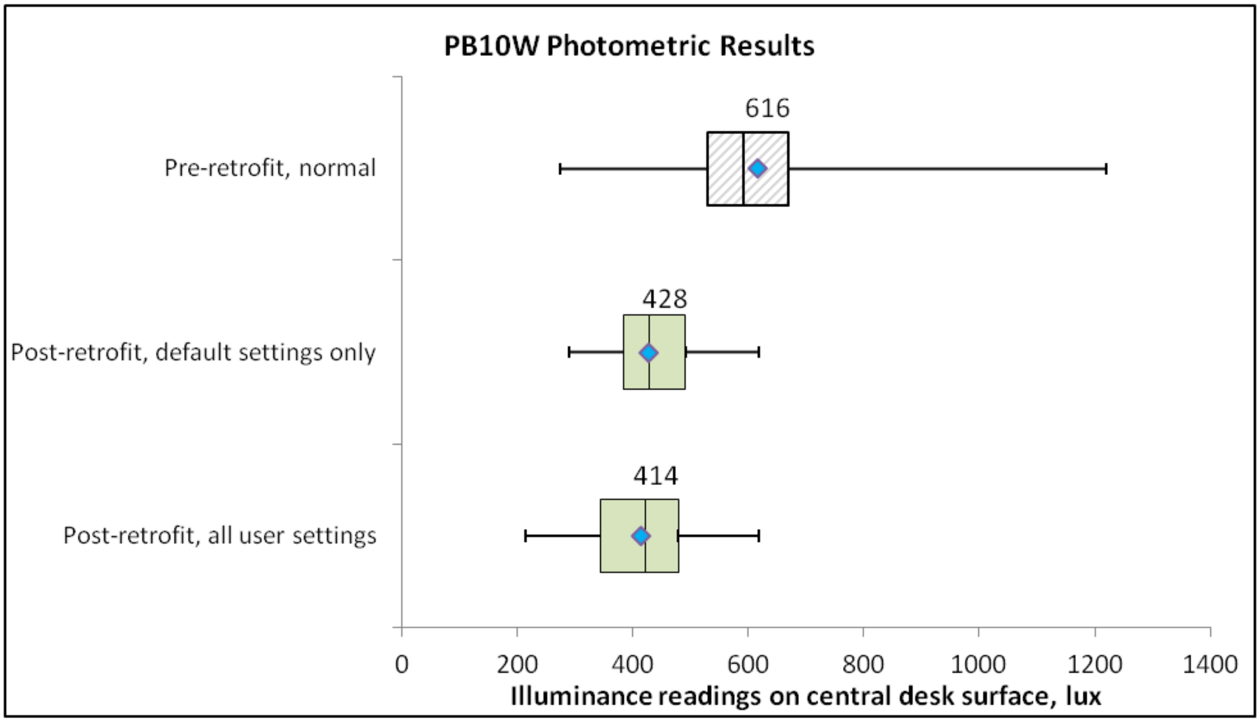


Figure 18: PB10W metered illuminances at front edge of central desk area. Pre-retrofit results were based on illuminances measured at 28 workstations. Post-retrofit results were based on illuminances measured at 24 workstations, 22 of which were operating under default settings.

On average, the pre-retrofit luminaires provided 616 lux. The post-retrofit WS lighting system provided an average of 428 and 414 lux for the “default settings only” and “all user settings” case, respectively. When checking whether light levels exceeded IESNA acceptable light levels, 6% of measured pre-retrofit fixtures, 18% of measured post-retrofit "default settings only" fixtures, and 21% of all measured post-retrofit fixtures produced desktop illuminances lower than 350 lux. The high pre-retrofit illuminance measurements suggest that the study area was over-lit.

5.3.4 Ron Dellums Federal Building 8th Floor, North Tower

The results of the photometric characterization for RD8N demonstrate that the workstation-specific luminaires generated comparable if not higher desktop light levels (Table 29 and Figure 19). A total of 60 workstations were measured during the pre-retrofit site visit, 20 of which were excluded due to daylight exposure. Post-retrofit illuminances were measured at 45 workstations, 12 of which were excluded due to daylight exposure. Of the remaining 33 measured workstations, 28 operated under default settings and 5 operated under occupant-requested changes. Post-retrofit default settings were programmed to turn down-lights on to 50% and up-lights on to 30%. Pre- and post-retrofit illuminance values are presented below with and without under-cabinet task lights, where the average under-cabinet task light reading of an additional 118 lux was used.

Table 29: RD8N photometric results, in lux. Pre-retrofit results were based on illuminances measured at 40 workstations. Post-retrofit results were based on illuminances measured at 33 workstations, 28 of which were operating under default settings.

	Pre-retrofit, Overhead lights only	Pre-retrofit, With task lights	Post-retrofit, Default settings only	Post-retrofit, Default with task lights	Post-retrofit, All user settings	Post-retrofit, All with task lights
Min	146	264	321	439	289	407
Quartile 1	298	416	452	570	427	545
Quartile 2	410	528	493	611	477	595
Quartile 3	469	588	557	676	549	667
Max	648	766	615	733	615	733
Mean	381	499	495	613	476	594

Figure 19 displays illuminance measurements for pre- and post-retrofit light installations. Blue diamonds and adjacent values give the mean, rectangles represent range between the 1st, 2nd, and 3rd quartiles, and bars cover the entire range of data. Pre-retrofit results are in grey while post-retrofit results are in green.

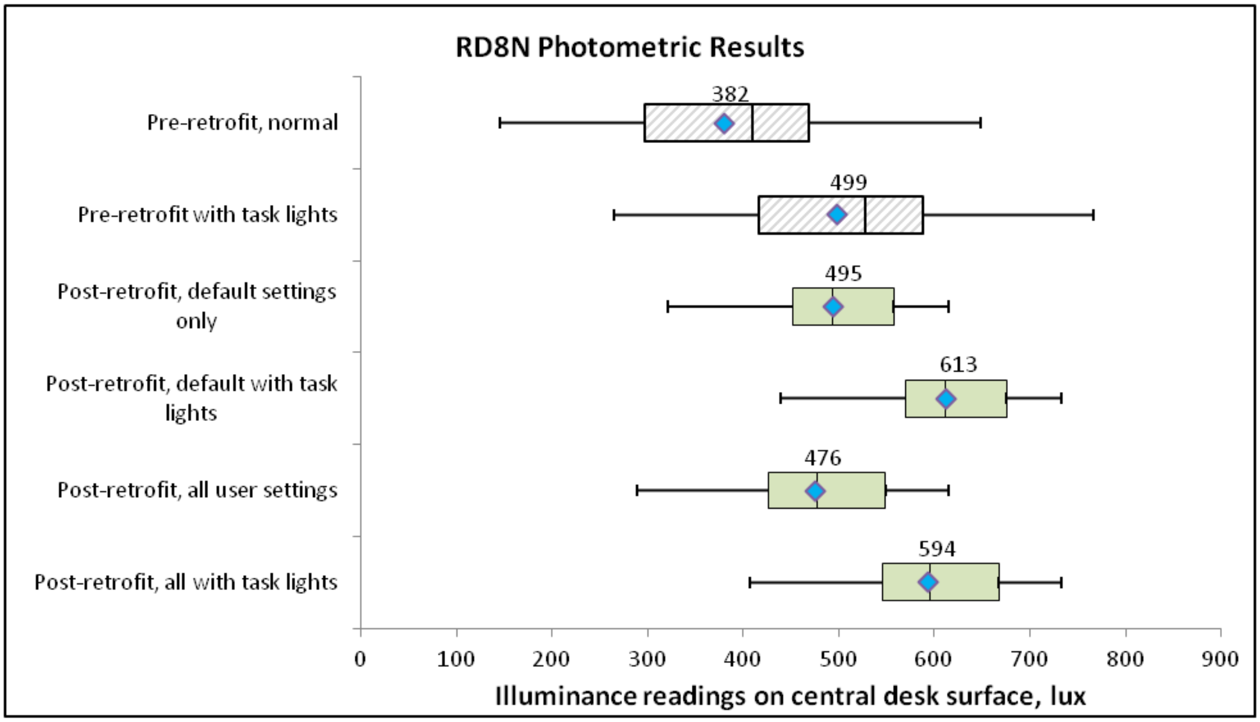


Figure 19: RD8N metered illuminances at front edge of central desk area. Pre-retrofit results were based on illuminances measured at 40 workstations. Post-retrofit results were based on illuminances measured at 33 workstations, 28 of which were operating under default settings.

On average, the pre-retrofit luminaires provided 381 lux without the under-cabinet task light, 38% of which produced less than the IESNA acceptable light level of 350 lux. The post-retrofit WS lighting system provided an average of 495 lux for fixtures operating under default settings and 476 lux for all measured fixtures. Of the measured post-retrofit fixtures, 11% of fixtures operating under default settings and 15% of all measured fixtures produced light levels lower than 350 lux.

5.3.5 Ron Dellums Federal Building 13th Floor, North Tower

This photometric analysis demonstrated that the WS lighting system provided comparable and acceptable light levels (Table 30 and Figure 20). A total of 54 workstations were measured during the pre-retrofit site visit, 27 of which were excluded due to daylight exposure. Post-retrofit illuminances were measured at 29 workstations, 9 of which were excluded due to daylight exposure. Of the remaining 20 measured workstations, 16 were operating under default settings. Changes in programmed light levels were requested by the occupants in the other four workstations. Post-retrofit default settings were programmed to turn down-lights on to 50% and up-lights on to 30%. Both pre-retrofit and post-retrofit illuminance values are represented below with and without under-cabinet task lights, where the average under-cabinet task light reading of an additional 50 lux was used.

Table 30: RD13N photometric results, in lux. Pre-retrofit results were based on illuminances measured at 27 workstations. Post-retrofit results were based on illuminances measured at 20 workstations, 16 of which were operating under default settings.

	Pre-retrofit, Overhead lights only	Pre-retrofit, With task lights	Post-retrofit, Default settings only	Post-retrofit, Default with task lights	Post-retrofit, All user settings	Post-retrofit, All with task lights
Min	279	329	285	335	285	335
Quartile 1	394	444	407	456	418	468
Quartile 2	473	523	434	483	456	506
Quartile 3	562	612	483	533	485	535
Max	686	736	517	567	553	603
Mean	481	531	430	479	449	498

Figure 20 shows illuminance measurements for pre- and post-retrofit light installations. Blue diamonds and adjacent values give the mean, rectangles represent range between the 1st, 2nd, and 3rd quartiles, and bars cover the entire range of data. Pre-retrofit results are in grey while post-retrofit results are in green.

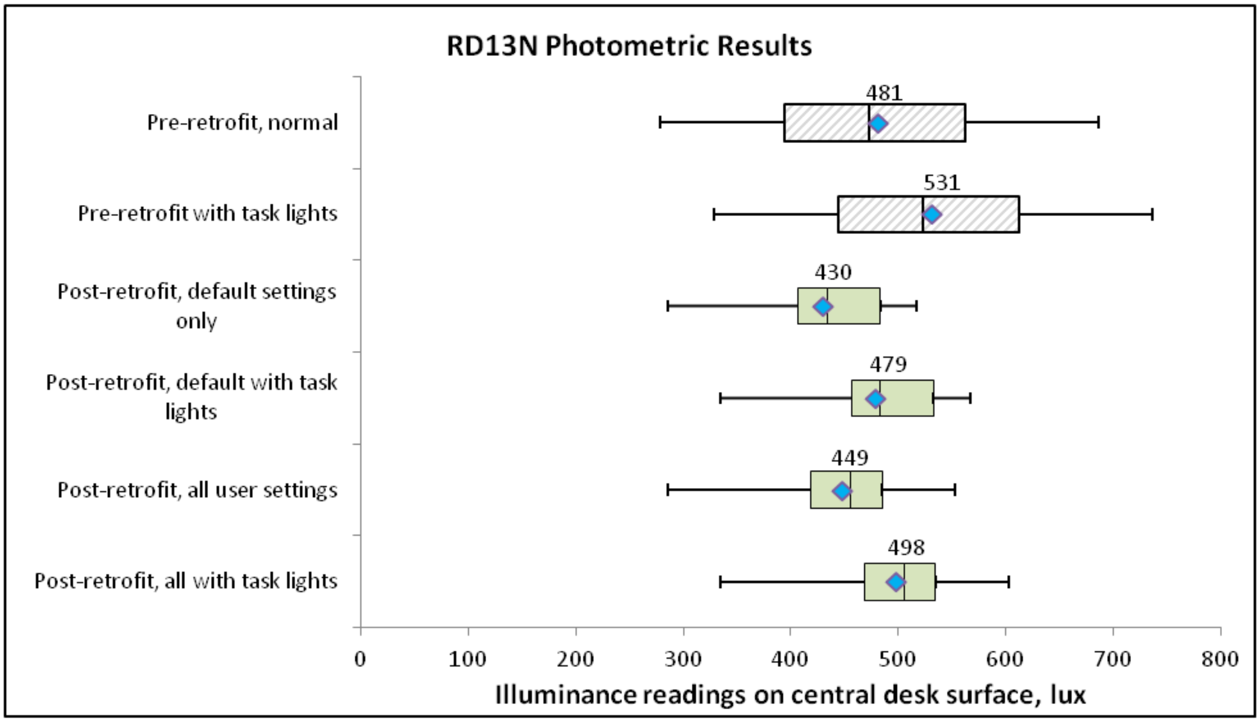


Figure 20: RD13N metered illuminances at front edge of central desk area. Pre-retrofit results were based on illuminances measured at 27 workstations. Post-retrofit results were based on illuminances measured at 20 workstations, 16 of which were operating under default settings.

On average, the pre-retrofit luminaires provided 481 lux without the under-cabinet task light, and only 7% of the pre-retrofit luminaires produced light levels lower than IESNA acceptable light level of 350 lux. Post-retrofit WS fixtures provided an average of 430 lux for fixtures operating under default and 449 lux settings for all measured fixtures. Of the measured post-retrofit luminaires, 13% of the fixtures with default settings and 10% of all measured post-retrofit fixtures fell below 350 lux. The high pre-retrofit illuminance measurements suggest that the study area was over-lit and that the WS retrofit allowed for reduced light levels by focusing the light within the workstation and culling the extremely high light levels.

5.3.6 Ron Dellums Federal Building 14th Floor, South Tower

The results of the RD14S photometric characterization demonstrated that the WS luminaires generated comparable desktop light levels (Table 31 and Figure 21). A total of 45 workstations were measured during the pre-retrofit site visit, 10 of which were excluded due to daylight exposure. Post-retrofit illuminances were measured during the evening at 45 workstations, 38 of which operated under default settings. Post-retrofit default settings were programmed to turn down-lights on to 50% and up-lights on to 30%. Pre- and post-retrofit illuminance values are presented below with and without under-cabinet task lights, where the average under-cabinet task light reading of an additional 44 lux was used.

Table 31: RD14S photometric results, in lux. Pre-retrofit results were based on illuminances measured at 35 workstations. Post-retrofit results were based on illuminances measured at 45 workstations, 38 of which were operating under default settings.

	Pre-retrofit, Overhead lights only	Pre-retrofit, With task lights	Post-retrofit, Default settings only	Post-retrofit, Default with task lights	Post-retrofit, All user settings	Post-retrofit, All with task lights
Min	202	246	271	315	98	142
Quartile 1	342	386	356	400	348	392
Quartile 2	402	446	399	443	385	429
Quartile 3	458	502	480	524	474	518
Max	507	551	671	715	741	785
Mean	386	431	425	469	409	453

Figure 21 shows illuminance measurements for pre- and post-retrofit light installations. Blue diamonds and adjacent values give the mean, rectangles represent range between the 1st, 2nd, and 3rd quartiles, and bars cover the entire range of data. Pre-retrofit results are in grey while post-retrofit results are in green.

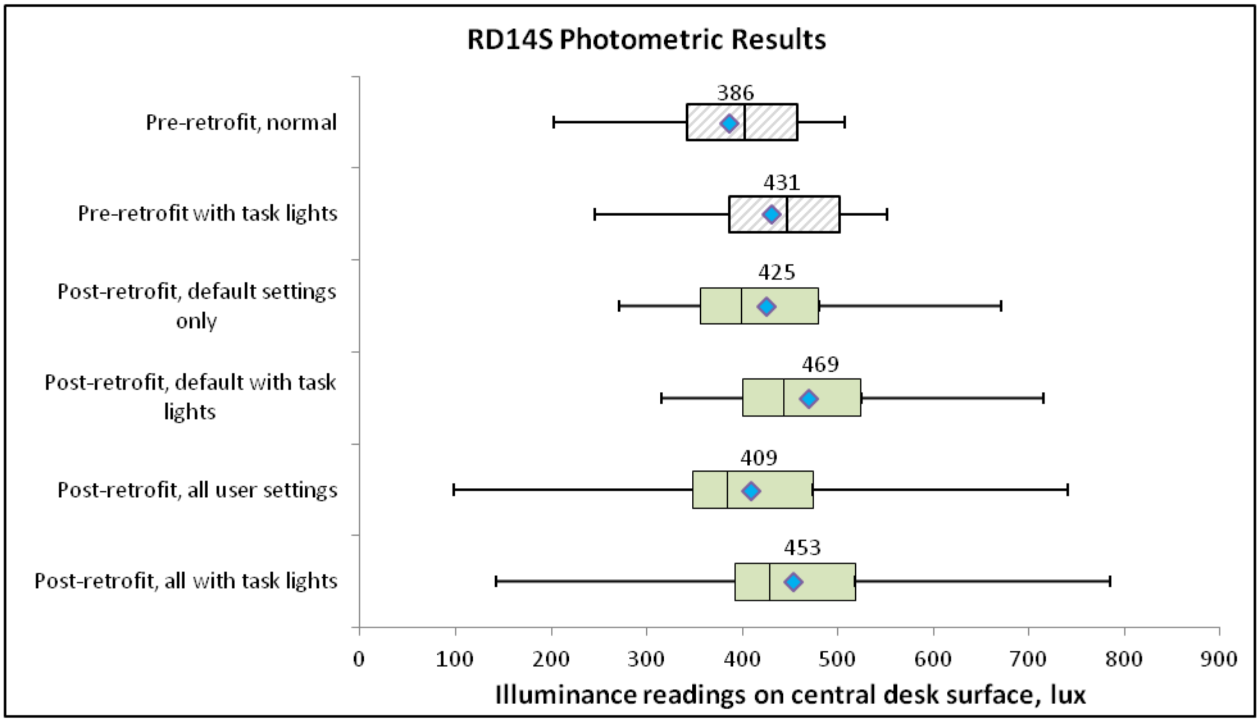


Figure 21: RD14S metered illuminances at front edge of central desk area. Pre-retrofit results were based on illuminances measured at 35 workstations. Post-retrofit results were based on illuminances measured at 45 workstations, 38 of which were operating under default settings.

On average, the pre-retrofit luminaires provided 386 lux without the under-cabinet task light. The post-retrofit WS lighting system provided an average of 425 and 409 lux for the "default settings only" and "all user settings" case, respectively. Of all measured fixtures, 29% of pre-retrofit fixtures, 21% of post-retrofit "default settings only" fixtures, and 29% of measured post-retrofit fixtures produced illuminances which fell below the IESNA acceptable level of 350 lux. Of note is the significant increase in the range of illuminances between the measured post-retrofit fixtures with default settings and those including all user settings.

5.3.7 Roybal Federal Building 18th Floor

The results of R18's photometric characterization demonstrated that WS luminaires generated comparable or higher desktop light levels (Table 32 and Figure 22). Pre-retrofit illuminance measurements were recorded during a sunny day. Daylight effects were minimal at most workstations; therefore, the results below were based upon 37 of the 41 measured illuminances. Post-retrofit illuminances were measured at a total of 42 workstations on an overcast day. Four measurements were excluded due to high daylight sensitivity. Default settings were assigned to 33 of the remaining 38 measured workstations; occupants requested changes in programmed light levels for the other five workstations. Pre- and post-retrofit illuminance values are presented below with and without under-cabinet task lights, where the average under-cabinet task light reading of an additional 113 lux was used.

Table 32: R18 photometric results, in lux. Pre-retrofit results were based on illuminances measured at 37 workstations. Post-retrofit results were based on illuminances measured at 38 workstations, 33 of which were operating under default settings.

	Pre-retrofit, Overhead lights only	Pre-retrofit, With task lights	Post-retrofit, Default settings only	Post-retrofit, Default with task lights	Post-retrofit, All user settings	Post-retrofit, All with task lights
Min	68	181	272	386	272	386
Quartile 1	225	338	454	567	443	556
Quartile 2	348	462	536	650	540	653
Quartile 3	427	540	576	690	605	719
Max	550	664	730	843	731	844
Mean	328	442	514	627	524	637

Figure 22 shows illuminance measurements for pre- and post-retrofit light installations. Blue diamonds and adjacent values give the mean, rectangles represent range between the 1st, 2nd, and 3rd quartiles, and bars cover the entire range of data. Pre-retrofit results are in grey while post-retrofit results are in green.

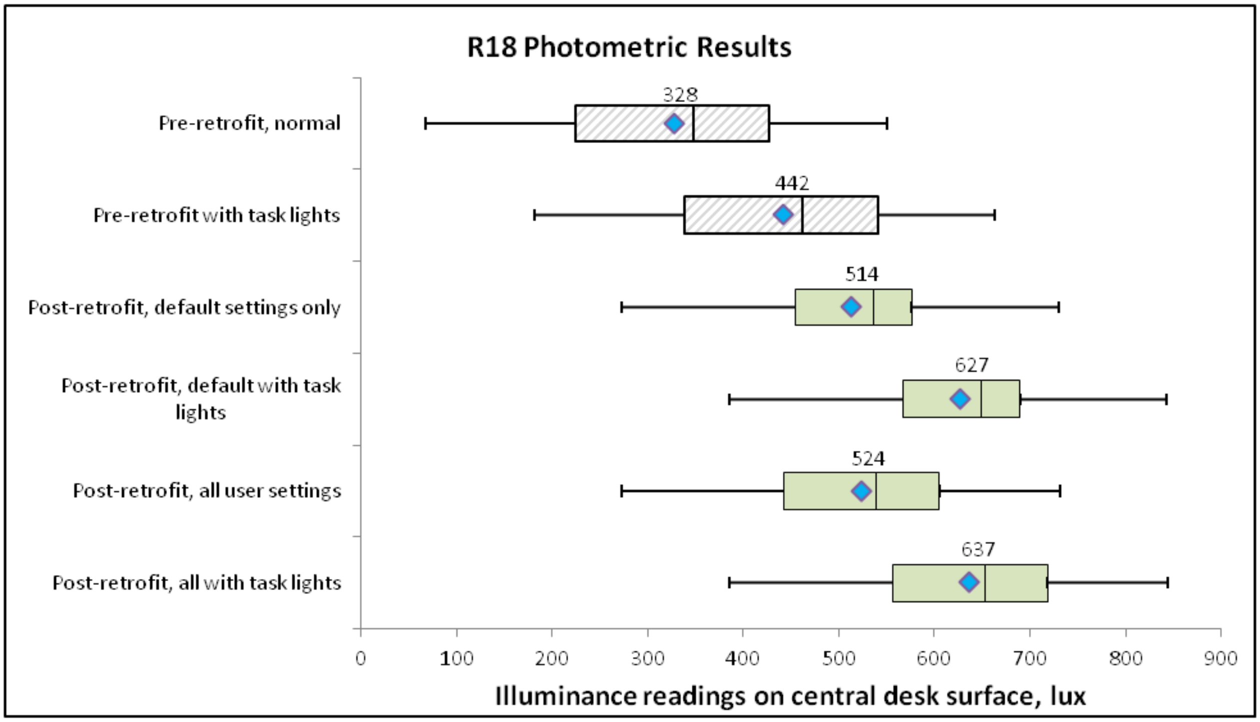


Figure 22: R18 metered illuminances at front edge of central desk area. Pre-retrofit results were based on illuminances measured at 37 workstations. Post-retrofit results were based on illuminances measured at 38 workstations, 33 of which were operating under default settings.

On average, the pre-retrofit luminaires provided 328 lux without the under-cabinet task light. Approximately half (51%) of the pre-retrofit luminaires produced desktop illuminances of less than IESNA acceptable light levels of 350 lux. The post-retrofit WS lighting system provided an average of 514 and 524 lux for the "default settings only" and "all user settings" case, respectively. Of all measured post-retrofit fixtures, 8% of those operating under default settings and 9% of all measured fixtures produced light levels lower than 350 lux.

5.4 Occupant Survey Results

For a lighting system to perform to its' full potential, users must understand and accept the strategy tested. Therefore, occupant satisfaction was assessed through the administration of occupant surveys both pre- and post-retrofit. Selected results relevant to WS lighting are presented and discussed below (see Section 8.3.3.2, p. 133 for complete results). Percentages are calculated out of the number of occupants who responded to a given question and may not sum to 100% due to rounding.

5.4.1 Chet Holifield Federal Building 2nd Floor SE Quadrant

The pre-retrofit survey link was emailed to 300 occupants; 102 occupants responded between March 28, 2011 and April 6, 2011 for a 34% response rate. A paper version of the post-retrofit survey was distributed to 200 occupants, 63 of whom responded between May 3, 2012 and May

23, 2012, for a 32% response rate. The response rates for both pre- and post-retrofit surveys were slightly lower than desired for statistical confidence, but due to the high number of respondents, results were still considered to be representative of the population. As mentioned previously, the post-retrofit survey was modified according to tenant requests. Questions which were deemed "too confusing" were eliminated, particularly with regard to individual control. Due to the eliminated questions, one chart was removed from this section that can be found in the following sections.

Complete results are included in Section 8.3.3.2.1 (p. 133) and selected results are presented below. Percentages were calculated out of the number of occupants who responded to a given question, and may not add to 100% due to rounding. Also note that responding to questions was voluntary; therefore, not all survey takers responded to every question.

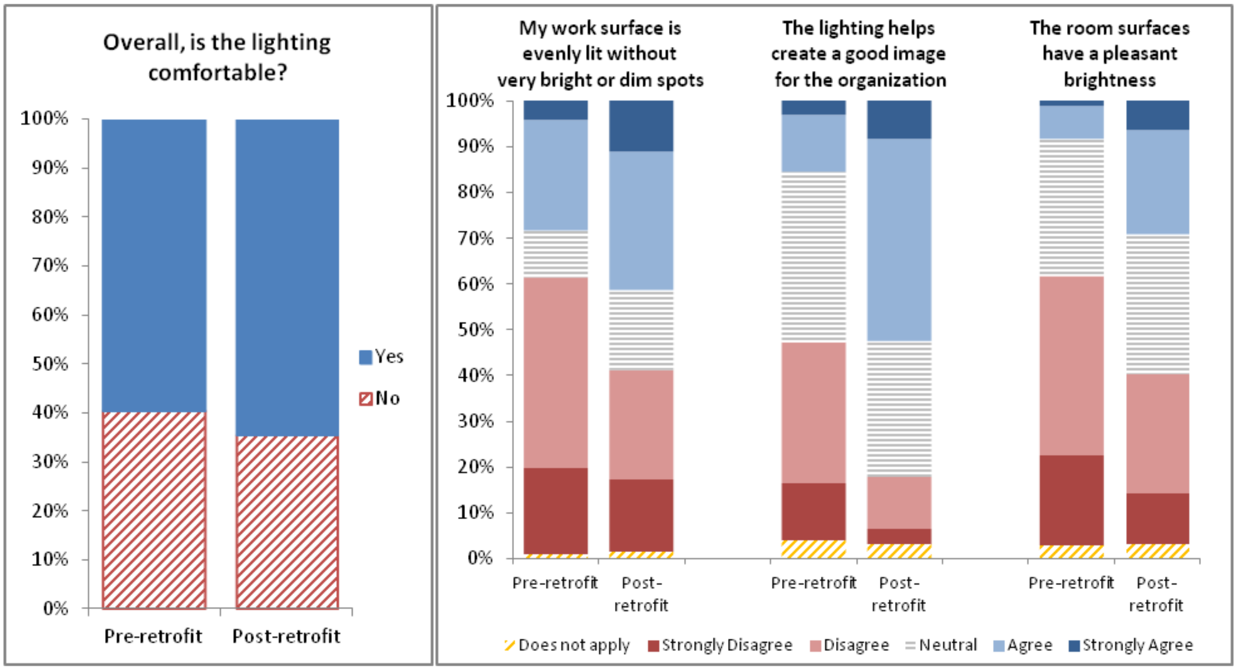


Figure 23: CH2SE responses to questions regarding overall satisfaction with general lighting. There were 101 pre-retrofit and 62 post-retrofit survey takers who responded to the overall lighting comfort question, while 96, 97, and 97 pre-retrofit and 63, 61, and 62 post-retrofit survey takers responded to the work surface, organization image, and room surface questions, respectively.

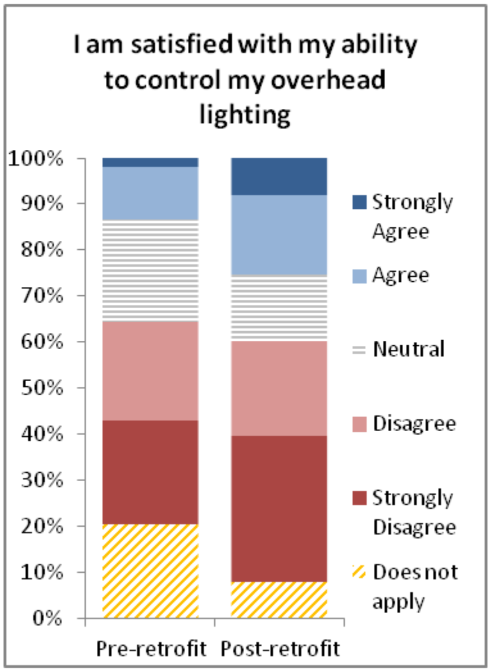


Figure 24: CH2SE response to question regarding satisfaction with lighting controls. There were 98 pre-retrofit and 63 post-retrofit survey takers who responded to this question.

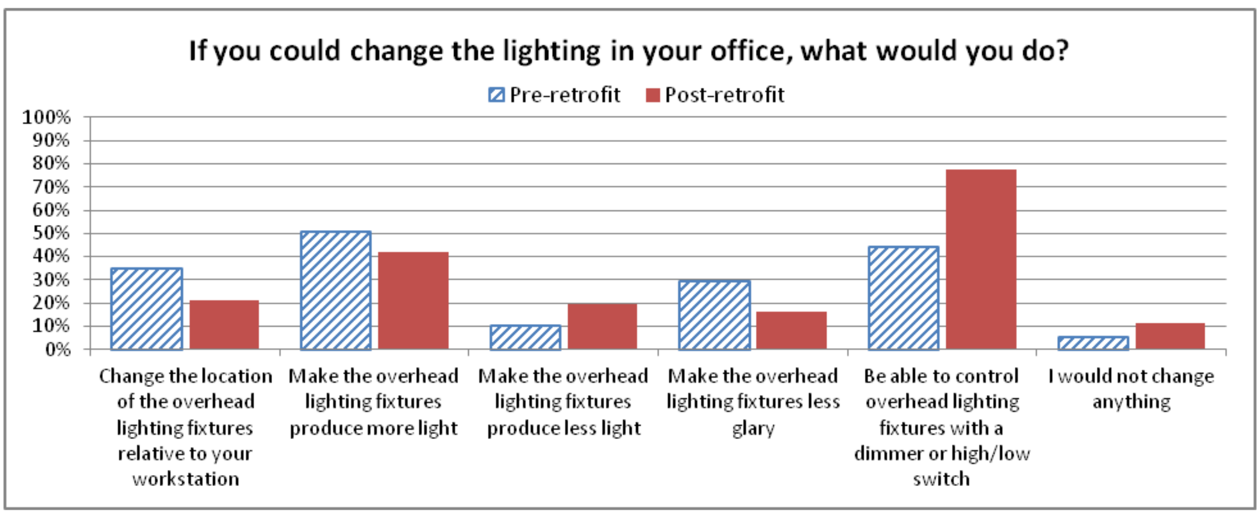


Figure 25: CH2SE responses to question regarding changes occupants would make to the lighting system. This question requested responses in a "check all that apply" format, therefore, percentages will not add up to 100%. There were 95 pre-retrofit and 62 post-retrofit survey takers who responded to this question.

Occupants at CH2SE seemed to be more satisfied overall with the retrofitted WS lighting when compared to the pre-retrofit lighting system. Furthermore, a significantly greater percentage of respondents found the post-retrofit lighting system to provide an evenly lit surface, help create a good image for the organization and provide a pleasing brightness on room surfaces when compared with the pre-retrofit lighting system (see Figure 23). However, two free responses stated that the fixtures were poorly placed and cast shadows on the occupants' work spaces, and two other free responses mentioned a desire for common areas, such as walkways, to be left on during the workday.

A comparable percentage of post-retrofit survey participants were satisfied with their overhead light controls (see Figure 24). However, of the 28 free responses given for the post-retrofit survey, 20 expressed frustrations with either poor sensor positioning or insufficient sensor sensitivity, resulting in the occupant having to continually move around to retrigger the occupancy sensor after a false off event.

Responses to a question regarding any changes occupants would like to make to the lighting system highlighted occupants' desire for greater control over their lighting fixtures where 77% of post-retrofit survey takers selected this option, compared to 44% pre-retrofit survey takers (see Figure 25). However, 11% of post-retrofit responders responded that they would not change anything about their lighting system compared to 5% of pre-retrofit responders; there was also a clear reduction in the percentage of responses opting for lighting fixtures which produced less glare. However, a significant percentage of post-retrofit survey takers still desired different light levels and changes in location of their overhead lighting.

5.4.2 Cottage Way Federal Building 2nd Floor East, North Building

The pre-retrofit survey link was emailed to 175 occupants, 79 of whom responded between July 25, 2011 and August 10, 2011, for a response rate of 45%. The post-retrofit survey was initially emailed to 180 occupants, 73 of whom responded between January 18, 2012 and February 16, 2012. However, this data was lost due to a server issue and a replacement survey had to be administered. The replacement survey was emailed to 180 occupants, but only 27 responded between April 26, 2012 and May 20, 2012, for a response rate of 15%. Although the pre-retrofit response rate was sufficient, the replacement post-retrofit survey did not obtain enough responses for statistical confidence and results may not be representative of the population. This is to be expected, though, since this was a repeat survey and the offer to provide incentives was declined at this site.

Complete results are included in Section 8.3.3.2.2 (p. 144) and selected results are presented below. Percentages are calculated out of the number of occupants who responded to a given question, and may not add to 100% due to rounding. Also note that responding to questions was voluntary; therefore, not all survey takers responded to every question.

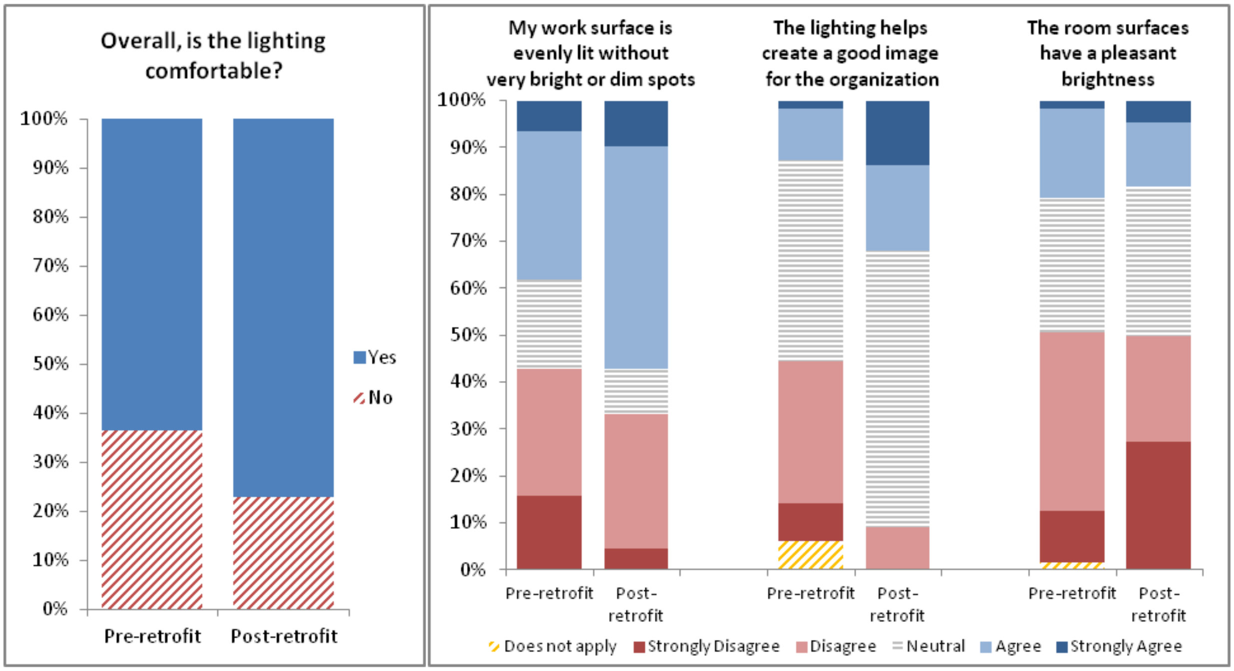


Figure 26: CW2NE responses to questions regarding overall satisfaction with general lighting. There were 74 pre-retrofit and 22 post-retrofit survey takers who responded to the overall lighting comfort question. For the remaining questions, 63 pre-retrofit survey takers responded to the remaining questions and 21, 22, and 22 post-retrofit survey takers responded to the work surface, organization image, and room surface questions, respectively.

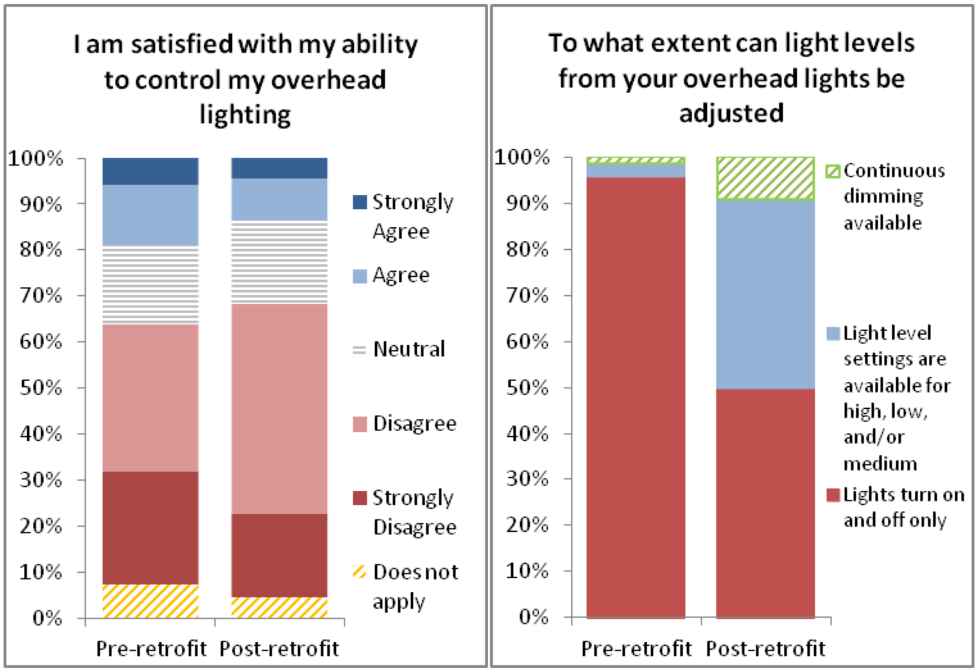


Figure 27: CW2NE responses to questions regarding lighting controls. There were 69 and 72 pre-retrofit and 22 post-retrofit survey takers who responded to the questions above.

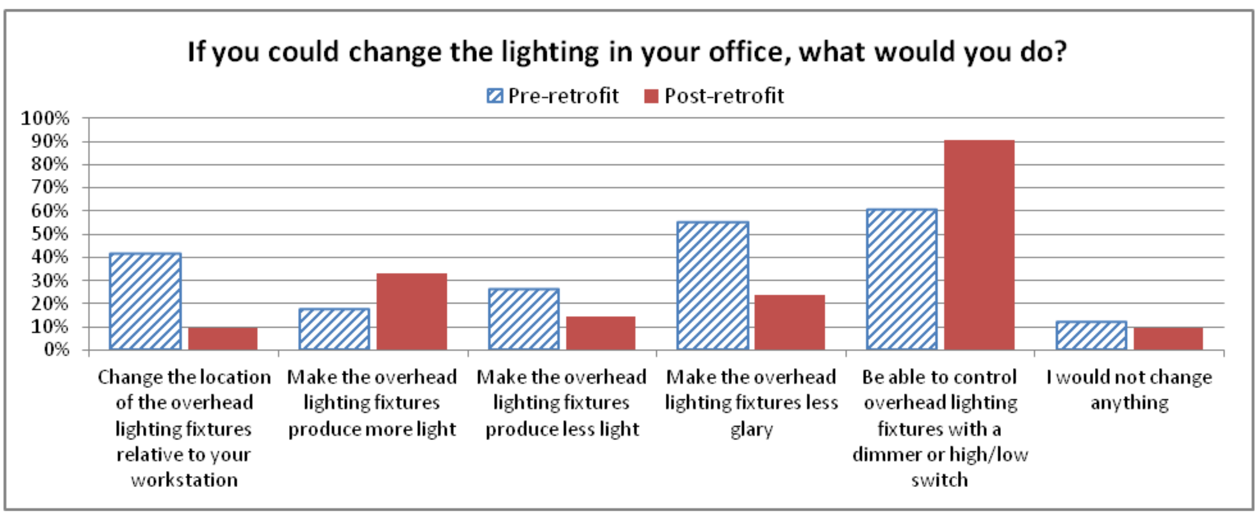


Figure 28: CW2NE responses to question regarding changes occupants would make to the lighting system. This question requested responses in a "check all that apply" format, therefore, percentages will not add up to 100%. There were 58 pre-retrofit and 24 post-retrofit survey takers who responded to this question.

Occupants at CW2NE seemed to be more satisfied overall with the retrofitted WS lighting when compared to the pre-retrofit lighting system. A greater percentage of respondents found the the post-retrofit lighting system was comfortable overall, provided an evenly lit surface, and helped create a good image for the organization when compared with the pre-retrofit lighting system (see Figure 26). A comparable percentage of respondents both pre- and post-retrofit agreed that the respective lighting system provided a pleasing brightness on room surfaces. However, of the 10 free responses given, three mentioned that the office looked "dark" or "gloomy" when the surrounding lights are not on due to their neighbors working in the field.

A comparable percentage of post-retrofit survey participants were satisfied with their overhead light controls (see Figure 27). Still, it is important to note that of the 10 free responses given, five commented on short timeouts and having to move around to retrigger the occupancy sensor after a false off event.

Responses to a question regarding any changes occupants would like to make to the lighting system also demonstrated an overall greater satisfaction with the post-retrofit lighting system, except for the issue of control over their overhead lights (see Figure 28). Although only 10% percent of post-retrofit responders checked that they would not change anything about their lighting system, compared to 12% of pre-retrofit responders, there was a reduction in percentages of responses opting for "less glary" and dimmer overhead lighting fixtures and changes in overhead fixture location. However, 90% of post-retrofit survey takers compared to 60% of pre-retrofit survey takers responded that they would like greater control over their overhead lights as well as greater light levels.

5.4.3 Phillip Burton Federal Building 10th Floor West

The pre-retrofit survey link was emailed to 54 occupants, 34 of whom responded between February 14, 2011 and March 4, 2011, for a response rate of 63%. The post-retrofit survey was emailed to 57 occupants, 30 of which responded between November 1, 2011 and December 31, 2011, for a response rate of 53%. Both pre- and post-retrofit survey response rates were sufficient to achieve statistical confidence.

Complete results are included in Section 8.3.3.2.3 (p. 155) and selected results are presented below. Percentages are calculated out of the number of occupants who responded to a given question, and may not add to 100% due to rounding. Also note that responding to questions was voluntary; therefore, not all survey takers responded to every question.

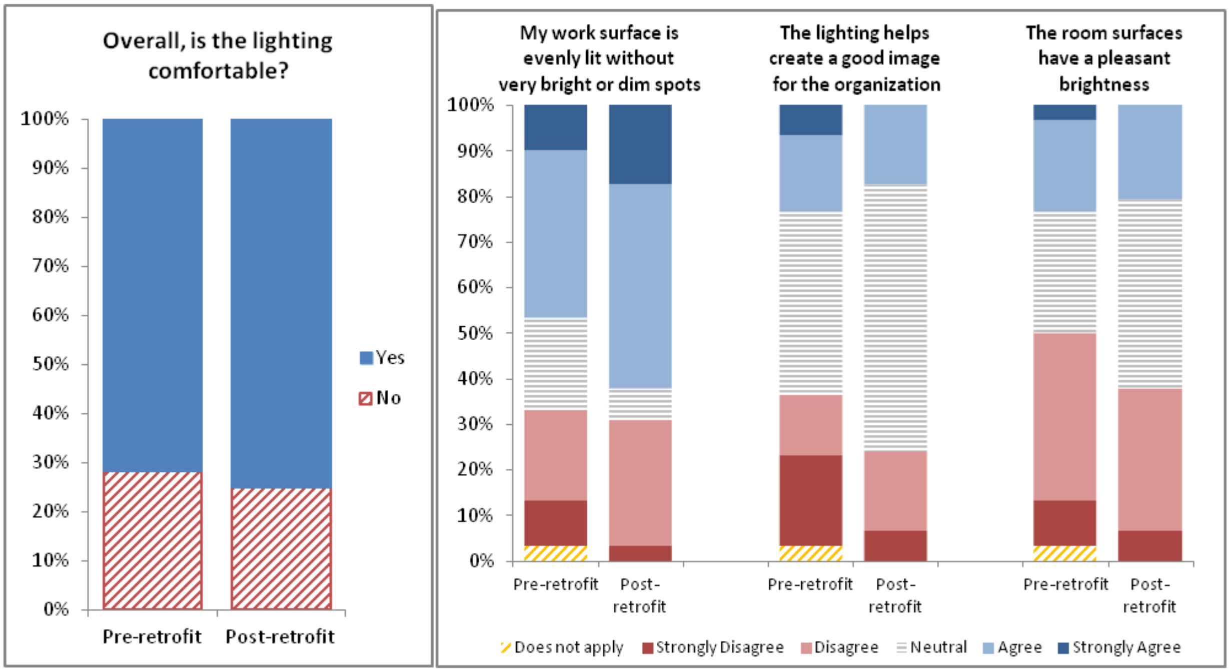


Figure 29: PB10W responses to questions regarding overall satisfaction with general lighting. There were 32 pre-retrofit and 28 post-retrofit survey takers who responded to the overall lighting comfort question, while 30 pre-retrofit and 29 post-retrofit survey takers responded to the remaining questions for this figure.

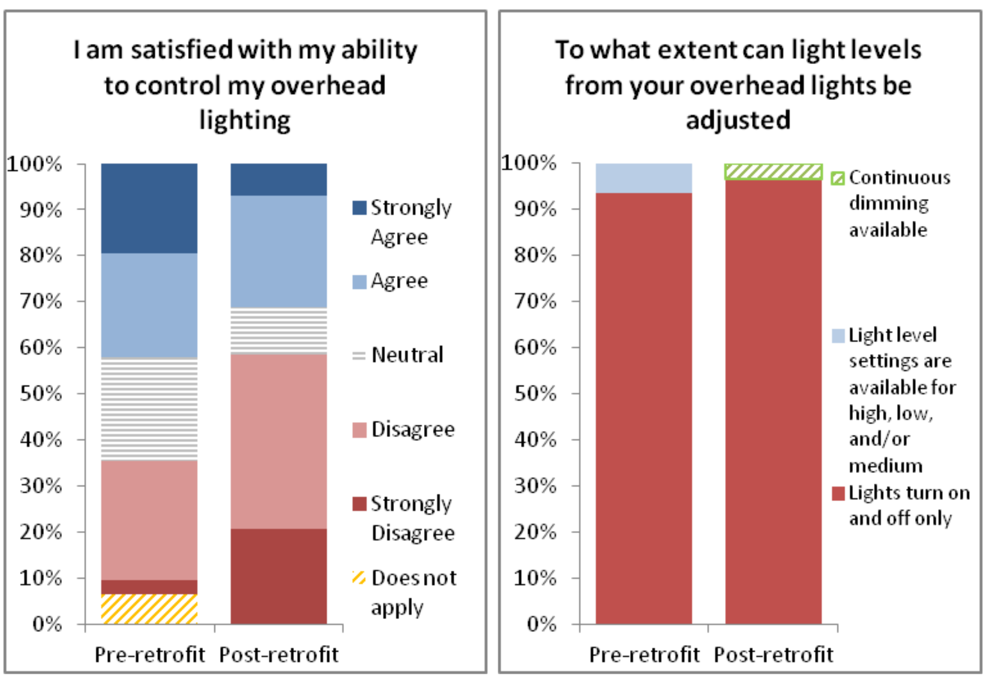


Figure 30: PB10W responses to questions regarding lighting controls. There were 31 pre-retrofit and 29 post-retrofit responses to these questions.

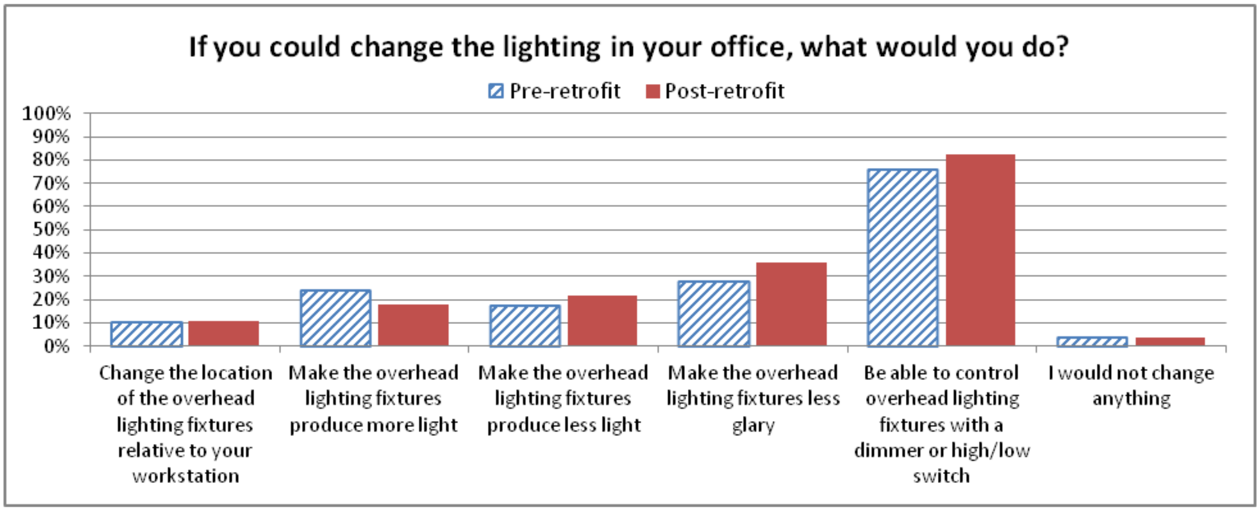


Figure 31: PB10W responses to question regarding changes occupants would make to the lighting system. This question requested responses in a "check all that apply" format, therefore, percentages will not add up to 100%. 29 pre-retrofit and 28 post-retrofit survey takers responded to this question.

A similar percentage of occupants found the lighting to be comfortable overall pre- and post-retrofit (see Figure 29). Although a greater percentage of occupants post-retrofit expressed that their work surface was evenly lit, the percentage of survey takers who found that the lighting helped create a good image for the organization and that room surfaces had a pleasant brightness decreased from 24% to 17% and from 23% to 21%, respectively. Post-retrofit survey participants also appeared to be less satisfied with their overhead light controls (see Figure 30). Prior to the retrofit, 42% of survey takers were satisfied with their overhead lighting control, which decreased to 31% post-retrofit. Additionally, an overwhelming 97% of post-retrofit survey takers stated that their lights could only turn on and off, even though the installation allowed for a wide range of light levels.

Occupants responded comparably pre- and post-retrofit to the question regarding changes to the lighting system (Figure 31). The two requested changes which resulted in the greatest difference between pre- and post-retrofit responses were reducing glare and gaining more control over overhead lighting fixtures.

Responses to the WS lighting system appeared to have had insignificant changes in most areas addressed by the survey. This could be attributed to PB10W's layout which was comprised primarily of private offices, effectually simulating WS lighting layout. This suggests that the difference between responses was due to the expansion of capabilities and controls in the shift to the new lighting system.

5.4.4 Ron Dellums Federal Building 8th Floor, North Tower

The pre-retrofit survey link was emailed to 75 occupants, 35 of whom responded between November 9, 2010 and November 19, 2010, for a response rate of 47%. The post-retrofit survey was initially emailed to 106 occupants, 61 of whom responded between January 24, 2012 and February 16, 2012. However, this data was lost due to a server issue and a replacement survey had to be administered. The replacement survey was emailed to 110 occupants, 51 of whom responded between April 26, 2012 and May 20, 2012, for a 46% response rate. Both pre- and post-retrofit response rates were sufficient to achieve statistical confidence. The high repeat survey response rate, compared to CW2NE, could be attributed to the use of incentives.

Complete results are included in Section 8.3.3.2.4 (p. 166) and pertinent results are presented below. Percentages were calculated out of the number of occupants who responded to a given question, and may not add to 100% due to rounding. Also note that responding to questions was voluntary; therefore, not all survey takers responded to every question.

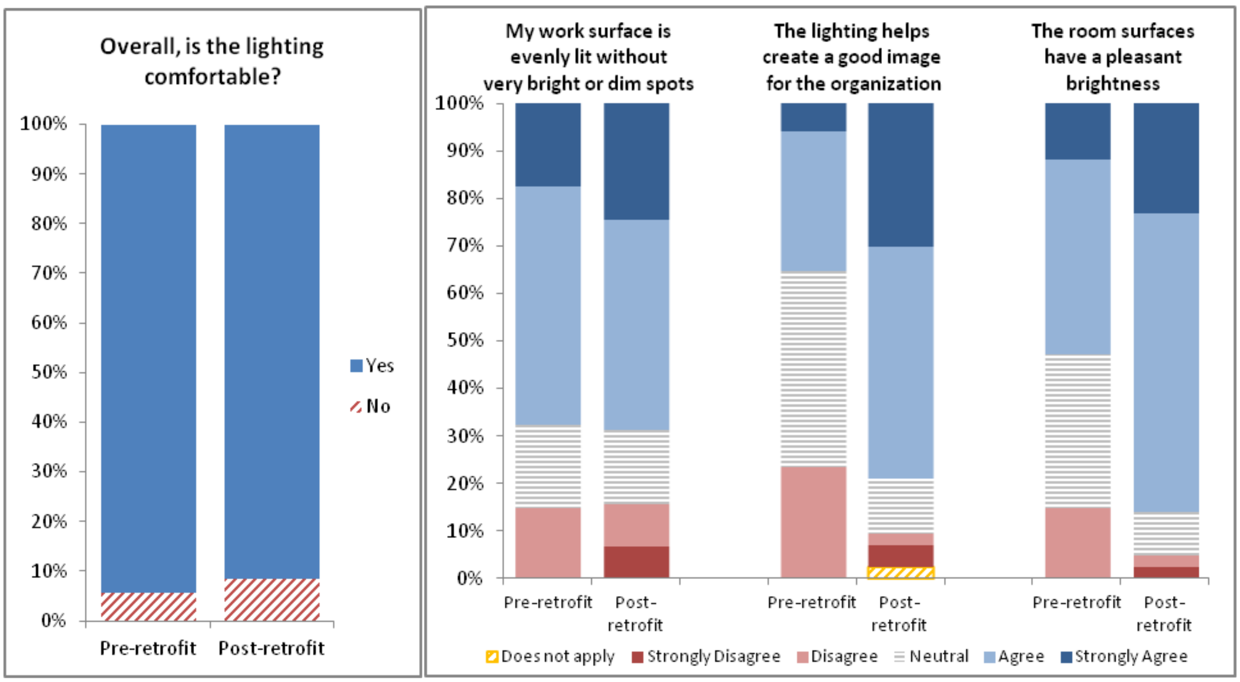


Figure 32: RD8N responses to questions regarding overall satisfaction with general lighting. There were 34 pre-retrofit and 47 post-retrofit survey takers who responded to the overall lighting comfort question. For the remaining questions, 34 pre-retrofit survey takers responded to the remaining questions and 45, 43, and 43 post-retrofit survey takers responded to the work surface, organization image, and room surface questions, respectively.

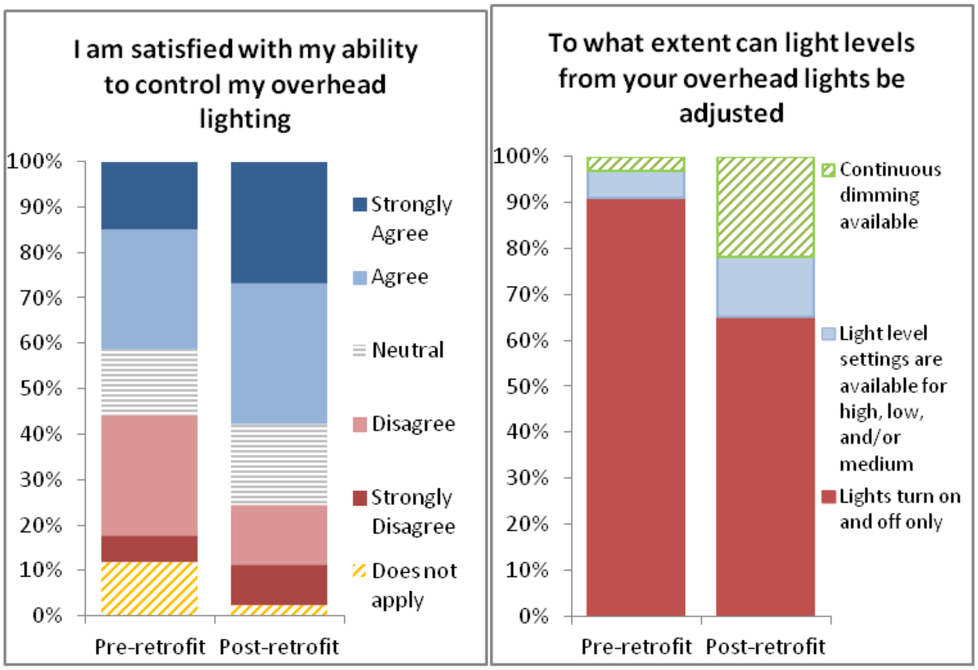


Figure 33: RD8N responses to questions about lighting controls. There were 34 pre-retrofit responses to both questions above and 46 and 45 post-retrofit responses to the control satisfaction and extent of control questions, respectively.

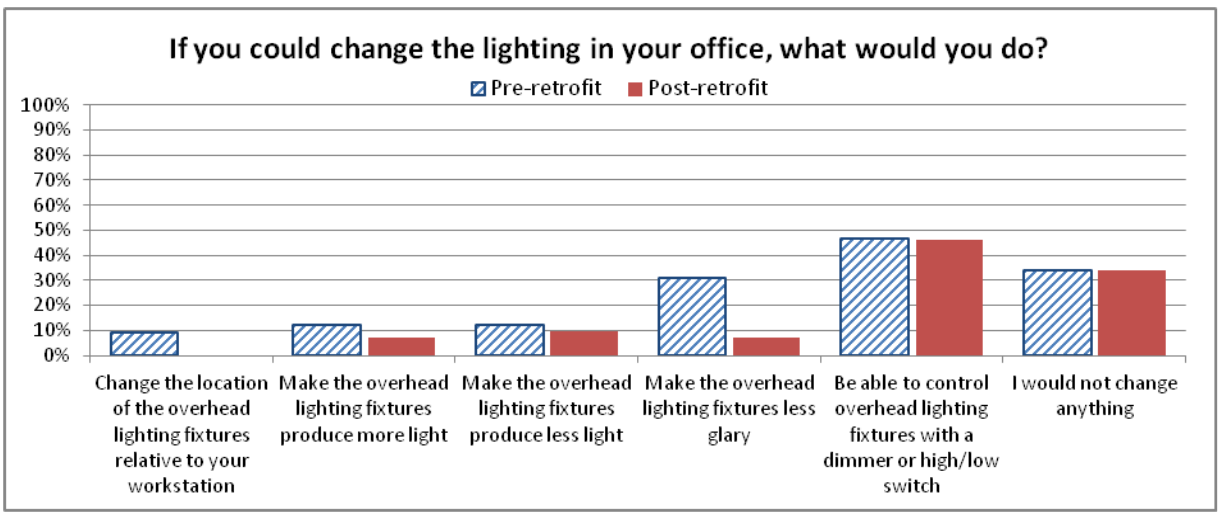


Figure 34: RD8N responses to question regarding changes occupants would make to the lighting system. This question requested responses in a "check all that apply" format, therefore, percentages will not add up to 100%. There were 32 pre-retrofit and 41 post-retrofit responses to this question.

Occupants at RD13N seemed generally more satisfied with the retrofitted WS lighting when compared to the pre-retrofit lighting system. A comparable percentage of respondents found the post-retrofit lighting system to be comfortable overall and that the post-retrofit lighting system provided an evenly lit surface when compared with the pre-retrofit lighting system (see Figure 32). A significantly higher percentage of respondents agreed that the post-retrofit lighting system helped create a good image for the organization, and provided a pleasing brightness on room surfaces.

Post-retrofit survey participants were also significantly more satisfied with their overhead light controls (see Figure 33). Before the retrofit, 41% of survey takers were satisfied with their lighting controls, compared to 58% of post-retrofit participants. However, it is important to note that of the 11 free responses given, six commented on short timeouts and having to move around to retrigger the occupancy sensor after a false off event. There was an additional comment from a private office occupant that mentioned a preference for greater control over their lighting by installing a dimmable wall switch.

Responses to a question regarding any changes occupants would like to make to the lighting system also demonstrated an overall greater satisfaction with the post-retrofit lighting system (see Figure 34). Although a lower percentage of post-retrofit responders responded that they would not change anything about their lighting system, in all other categories there was a reduction in percentages of responses opting for a specific change post-retrofit, most significantly in "less glary" overhead lighting fixtures. However, 47% of pre-retrofit and 46% of post-retrofit survey takers responded to the lighting control option, showing that having greater control over their lighting system still remained a major issue.

5.4.5 Ron Dellums Federal Building 13th Floor, North Tower

The pre-retrofit survey link was emailed to 53 occupants, 17 of whom responded between October 19, 2010 and October 25, 2010, for a 32% response rate. Similarly, 53 occupants were emailed the link to the post-retrofit survey, 22 of whom responded between November 1, 2011 and December 31, 2011, for a 42% response rate. Although response rates were reasonable, the number of respondents was lower than the desired 30. Therefore, results were not supported by statistical confidence but should be considered as part of the narrative. It should be noted that in addition to an insufficient number of survey respondents, results may also be skewed at RD13N due to timing and commissioning issues (see Section 6.1.3, p.90).

Complete results are included in Section 8.3.3.2.5 (p. 177) and pertinent results are presented below. Percentages were calculated out of the number of occupants who responded to a given question, and may not add to 100% due to rounding. Also note that responding to questions was voluntary; therefore, not all survey takers responded to every question.

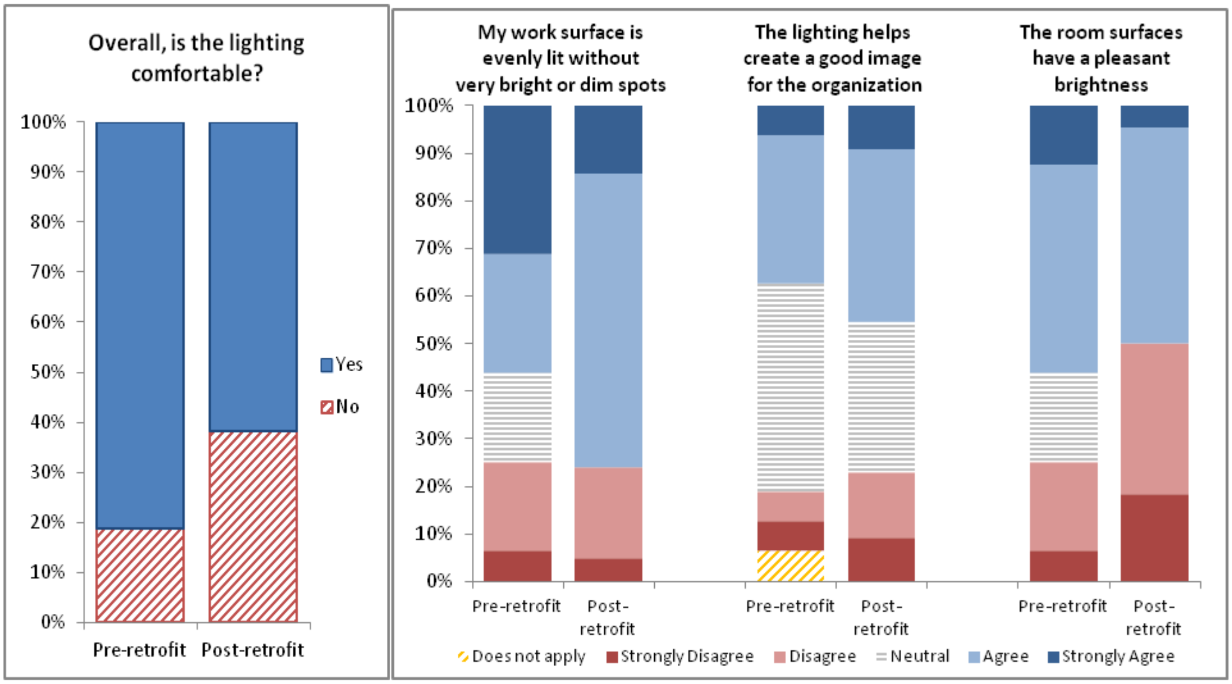


Figure 35: RD13N responses to questions regarding overall satisfaction with general lighting. There were 16 pre-retrofit and 21 post-retrofit responses to the overall lighting comfort question. There were 16 pre-retrofit responses to the remaining questions, while 21, 22, and 22 post-retrofit survey takers responded to the work surface, organization image, and room surface questions.

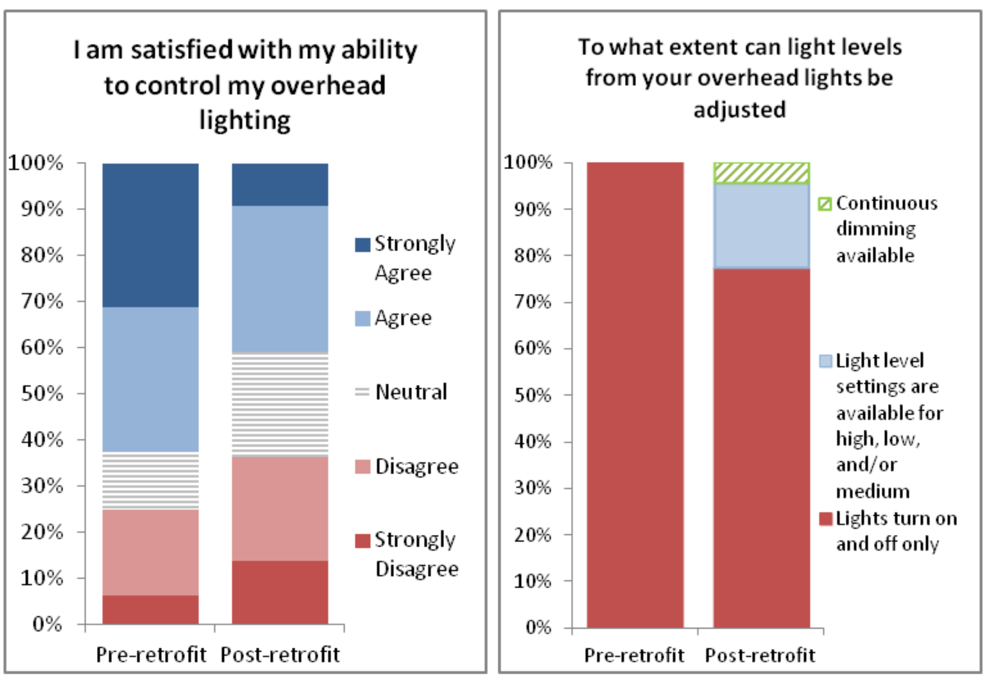


Figure 36: RD13N responses to questions about lighting controls. There were 14 and 16 pre-retrofit responses and 22 post-retrofit responses for the questions above.

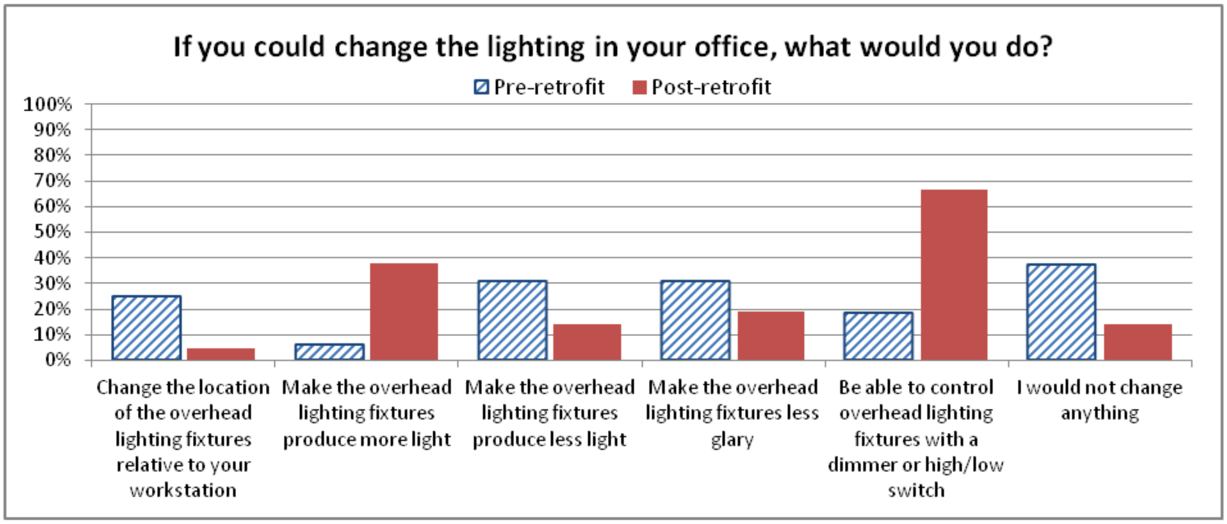


Figure 37: RD13N responses to question regarding changes occupants would make to the lighting system. This question requested responses in a "check all that apply" format, therefore, percentages will not add up to 100%. There were 16 pre-retrofit and 21 post-retrofit survey takers who responded to this question.

Occupants at RD13N were generally unsatisfied with the retrofitted WS lighting when compared to the pre-retrofit lighting system (see Figure 35). Although higher percentages of respondents agreed that their work surface was evenly lit, less people found the WS lighting system to be more comfortable overall. This sentiment was also reflected for the overall office area, where prior to the retrofit 57% of the respondents agreed that the room surfaces had a pleasant brightness, compared to 50% of the post-retrofit respondents. Post-retrofit survey participants also seem to be more dissatisfied with their overhead light controls (see Figure 36). Before the retrofit, 62% of survey takers were satisfied with their lighting controls, compared to only 41% of post-retrofit participants. It is notable that while 73% of post-retrofit respondents acknowledged that their overhead lighting was on an automated system or controlled by a building manager, 77% responded that their lights turned on and off only.

In response to a question regarding any alterations to the lighting, pre-retrofit and post-retrofit occupant takers focused on different issues (see Figure 37). Prior to the retrofit, although 38% of respondents would not change anything, a significant portion of survey takers wanted luminaires that produced lower light levels and less glare, and were located differently. After the retrofit, although more participants appreciated that the luminaires were located above their work space and that the fixtures produced less glare, a significant jump in survey takers felt that the lighting system was too dim post-retrofit. As addressed previously, lighting controls were an important issue at RD13N as well, where 67% of post-retrofit respondents wanted greater control over their overhead lights, compared to only 19% of pre-retrofit respondents.

5.4.6 Ron Dellums Federal Building 14th Floor South Tower

The pre-retrofit survey link was emailed to 52 occupants, but only 8 responded between November 2, 2010 and November 15, 2010, for a 15% response rate. Similarly, 42 occupants were emailed the link to the post-retrofit survey, 11 of whom responded between November 18, 2011 and December 31, 2011, for a 26% response rate. Both response rates and number of respondents were insufficient to achieve statistical confidence. Therefore, results may not be representative for this site. It should be noted that in addition to an insufficient number of survey respondents, results may also be skewed at RD14S due to timing and commissioning issues (see Section 6.1.3, p.90).

Complete results are included in Section 8.3.3.2.6 (p. 186) and pertinent results are presented below. Percentages were calculated out of the number of occupants who responded to a given question, and may not add to 100% due to rounding. Also note that responding to questions was voluntary; therefore, not all survey takers responded to every question.

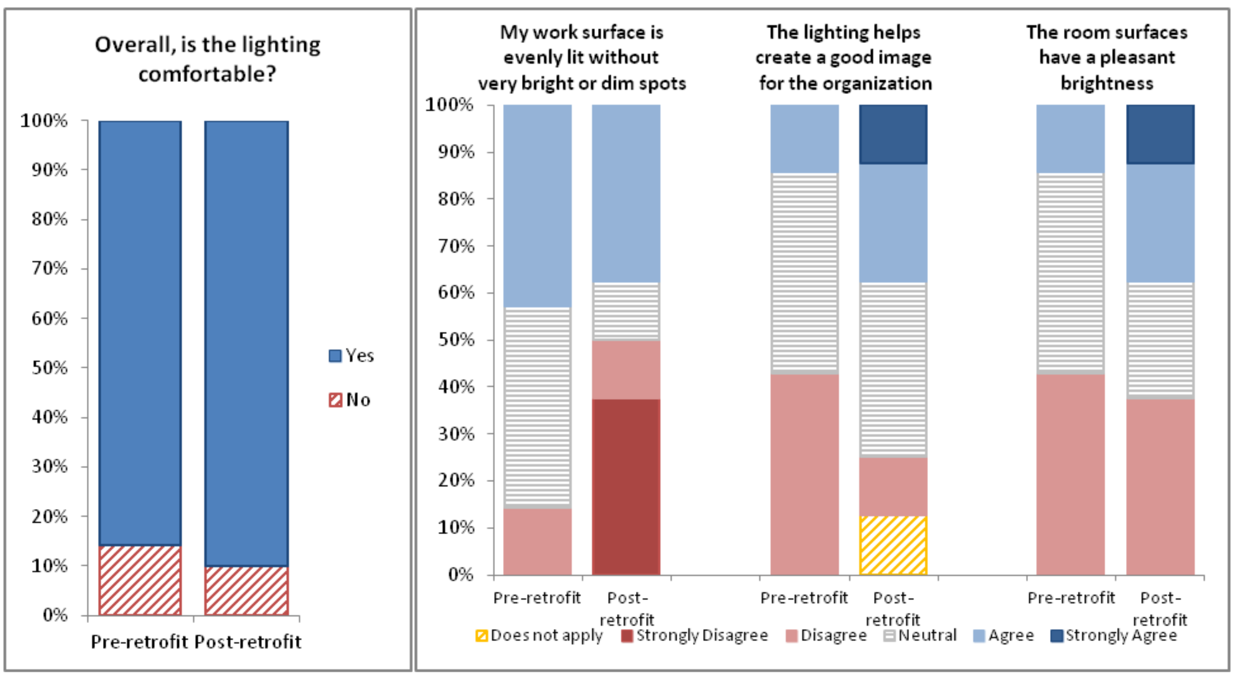


Figure 38: RD14S responses to questions regarding overall satisfaction with general lighting. There were 7 pre-retrofit and 10 post-retrofit responses to the overall lighting comfort question. There were 7 pre-retrofit and 8 post-retrofit responses to the remaining questions.

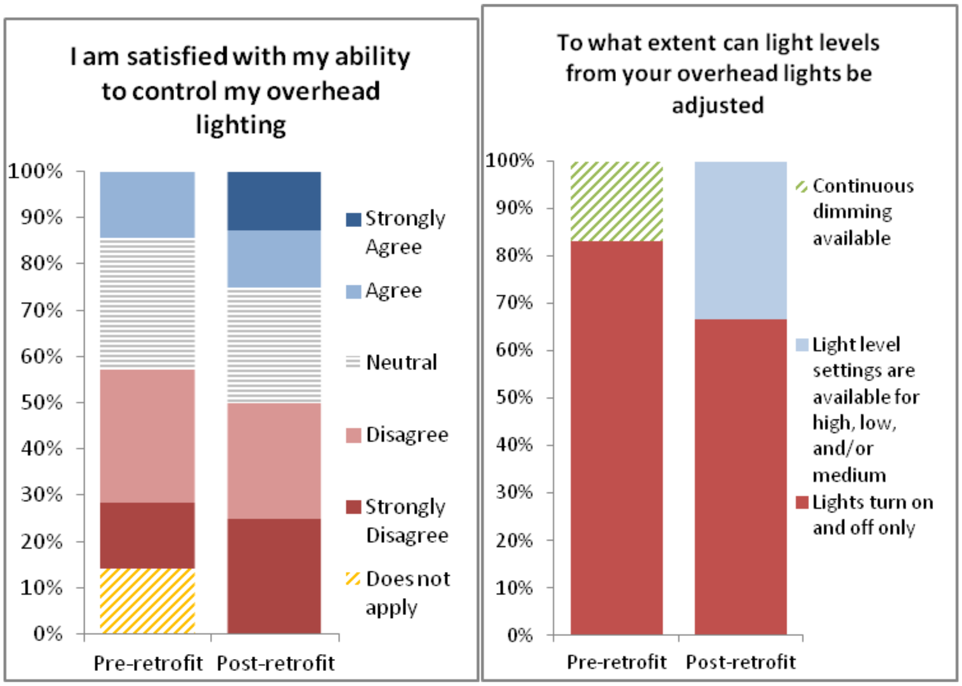


Figure 39: RD14S responses to questions about lighting controls. There were 6 and 7 pre-retrofit and 6 and 8 post-retrofit responses to the control satisfaction and extent of controls questions, respectively.

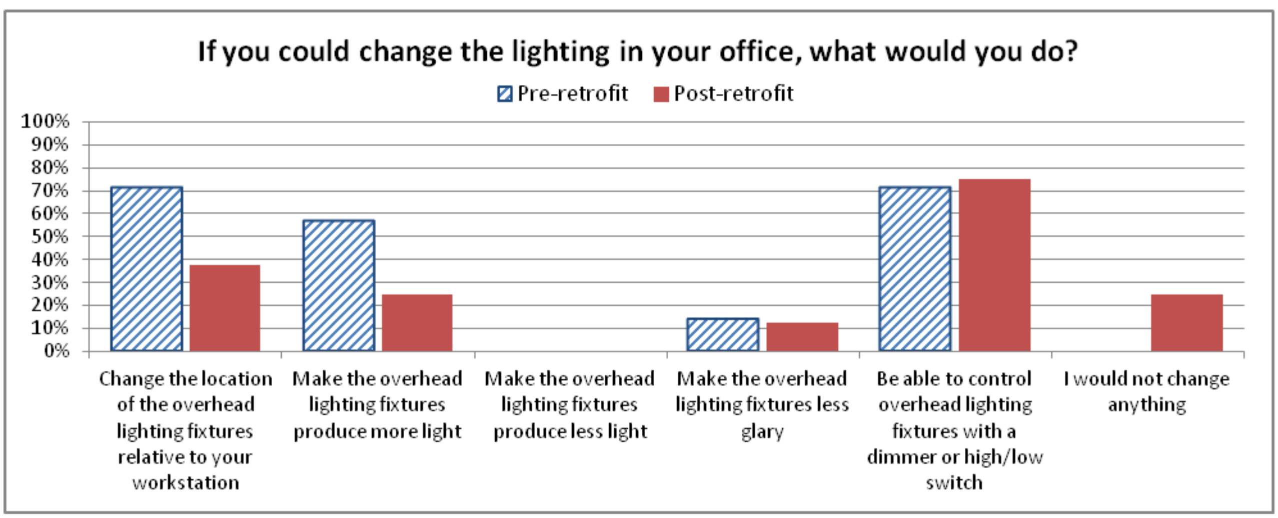


Figure 40: RD14S responses to question regarding changes occupants would make to the lighting system. This question requested responses in a "check all that apply" format, therefore, percentages will not add up to 100%. There were 7 pre-retrofit and 8 post-retrofit survey takers who responded to this question.

A similar percentage of occupants found the lighting to be comfortable overall in both pre- and post-retrofit cases (see Figure 38). A greater percentage of post-retrofit occupants also found that the retrofitted lighting system created a good image for the organization as well as provided a pleasant brightness on the room surfaces. However, there was a reduction of occupants who found their work surface to be evenly lit with the WS system.

Post-retrofit survey participants were also more satisfied with their overhead lighting controls (see Figure 39). However, although the system allowed for variable light levels, 67% responded that their lights turned on and off only in the post-retrofit survey.

Occupants also seemed less likely to change their lighting situation post-retrofit (see Figure 40). Fewer respondents wished to change the location or the light levels of their overhead lighting after the retrofit. Although more occupants were satisfied with their lighting controls, the survey demonstrated that control is still an important issue, as 75% of post-retrofit respondents still desired greater control over their overhead lights.

5.4.7 Roybal Federal Building 18th Floor

The pre-retrofit survey was printed out and distributed to 24 occupants, 11 of whom responded between April 13, 2011 and May 6, 2011, for a 46% response rate. Similarly, 36 occupants were given a paper version of the post-retrofit survey, 18 of whom responded between May 9, 2012, and June 1, 2012, for a 50% response rate. Although response rates were sufficiently high enough to achieve statistical confidence, the number of respondents was still low. Therefore, although results may be representative, the significance of the differences between pre- and post-retrofit results was not verifiable.

Complete results are included in Section 8.3.3.2.7 (p. 198) and pertinent results are presented below. Percentages were calculated out of the number of occupants who responded to a given question, and may not add to 100% due to rounding. Also note that responding to questions was voluntary; therefore, not all survey takers responded to every question.

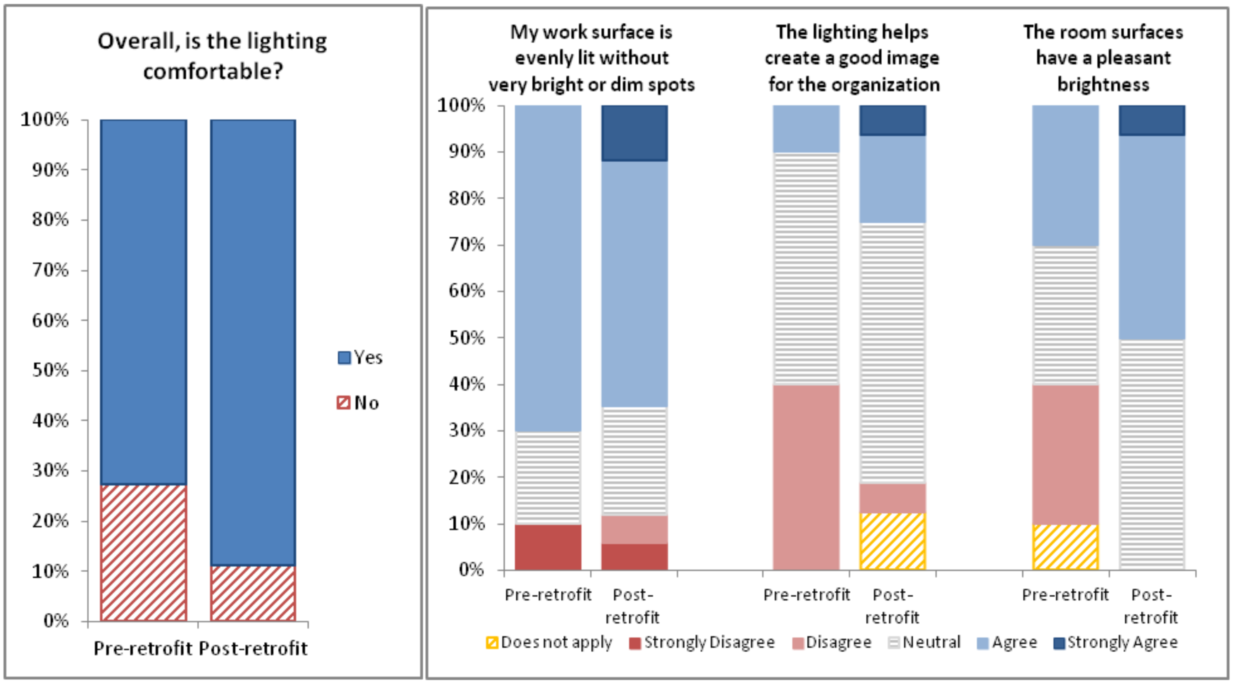


Figure 41: R18 responses to questions regarding overall satisfaction with general lighting. There were 11 pre-retrofit and 18 post-retrofit responses to the overall lighting comfort question. There were 10 pre-retrofit responses and 17, 16, and 16 post-retrofit responses to the work surface, organization image, and room surface questions, respectively.

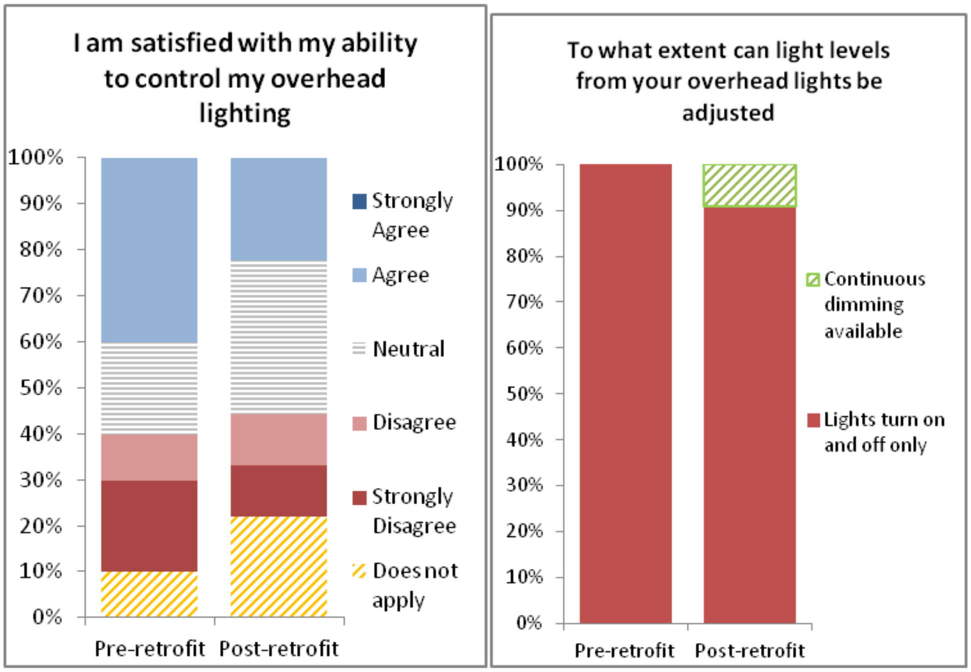


Figure 42: R18 responses to questions about lighting controls. There were 10 and 7 pre-retrofit and 18 and 11 post-retrofit responses to the lighting control satisfaction and extent of control questions, respectively.

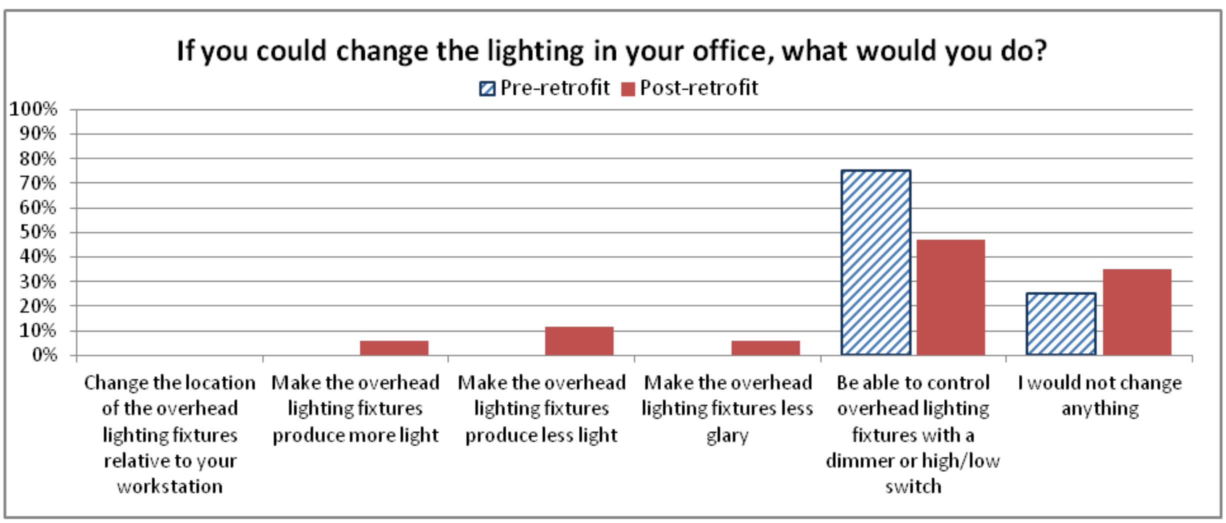


Figure 43: R18 responses to question regarding changes occupants would make to the lighting system. This question requested responses in a "check all that apply" format, therefore, percentages will not add up to 100%. There were 4 pre-retrofit and 17 post-retrofit survey takers who responded to this question.

A higher percentage of occupants found the lighting to be comfortable overall post-retrofit when compared to pre-retrofit conditions (see Figure 41). Additionally, while a comparable percentage of occupants found that the retrofit provided an evenly lit work surface, a greater percentage of occupants found the retrofit created a good image for the organization and provided a pleasing brightness on the room surfaces. However, one free response comment mentioned that the area became too dark once their neighbor's light turned off.

A lower percentage of post-retrofit survey participants seemed to be more satisfied with their overhead light controls (see Figure 42). Of interest is that although the system allowed for a range of light levels, 22% responded that having control over their overhead lights is not applicable to them and 91% responded that their lights turn on and off only in the post-retrofit survey. Additionally, of the four free response comments given, one mentioned a desire to have control over dimming of the lights to ameliorate glare. Another free response expressed frustration with the poor sensitivity of the occupant sensor, causing the occupant to continually move around to retrigger their lights.

Occupants were less likely to want to change their lighting situation post-retrofit (see Figure 43), where 35% of post-retrofit survey takers would not change anything compared to 25% of pre-retrofit survey takers. Furthermore, although a significant percentage of post-retrofit survey takers still desired greater control over their overhead lights, the percentage decreased from 75% to 47% after the WS lighting system was installed. However, compared to no responses from the pre-retrofit survey takers on any of the other categories, 6%, 12%, and 6% of post-retrofit survey takers selected that they would like to have higher light levels, lower light levels, and less glare, respectively.

6 Summary Findings

6.1 Overall Technology Assessment

6.1.1 Energy Savings and Costs

Although the retrofits typically increased installed lighting power density (LPD), the installations still lowered energy consumption significantly through the use of advanced lighting controls. The retrofits generally achieved energy savings of around 1 kWh/SF/yr, resulting in calculated annual savings by site ranging from 27% to 63%. From the calculated pre- and post-retrofit Energy Use Intensities (EUIs), reductions in greenhouse gas (GHG) emissions were calculated for both the regional utility fuel mix as well as the national average fuel mix. The regional utility fuel mix resulted in an average reduction of GHG emissions of 0.4 kg $CO_{2,eq}/ft^2$/year, while the national average fuel mix resulted in an average reduction of 0.6 kg $CO_{2,eq}/ft^2$/year across the sites.

Energy savings were largely attributable to fine-grained occupancy zones, institutional tuning, and some personal control. For example, CW2NE, a site composed primarily of open offices, obtained large energy savings by transitioning from manual switches that controlled large zones within the site to workstation-specific luminaires controlled by individual occupant sensors. Therefore, energy usage was automatically reduced by eliminating the demand from unoccupied zones while further energy savings were seen by reducing light levels at both the institutional (programmed default settings) and personal control level. The variation in energy savings was due to a range of site-specific factors, in particular, high energy baselines from extensive unintentional after-hours lighting use during the pre-retrofit period.

Additionally, sites that eliminated standby power in unoccupied rooms and after hours achieved deeper energy savings than other sites. This can be seen when comparing CH2SE with RD8N. Although RD8N's comparably low energy savings may be caused by a low pre-retrofit LPD, standby power and a small number of lights that appeared to stay on throughout a number of nights had an impact on energy use. CH2SE, on the other hand, employed a scheduler which forced operating LPD to zero after hours, thereby saving more energy. Due to a small percentage of measured spaces that were day-lit, daylight savings were minimal.

These energy savings resulted in an average payback period of 14 years when considering the "Control System Cost Only" scenario, where the cost of a WS lighting system without controls was subtracted from the full investment cost. When considering the 'Full cost – GSA Standard Cost' scenario, where the cost of a standard GSA code-compliant system was subtracted from the full investment cost, an average payback period of 26 years resulted. A closer look into the sensitivity of the cost-effectiveness analysis at each site to pre-retrofit lighting conditions and energy costs revealed that in order to obtain payback periods of 15 years or less under the "Full Cost – GSA Standard" scenario, a pre-retrofit installed LPD of at least 1.1 W/ft^2 or an electricity rate of at least $0.21/kWh was necessary, on average.

The high costs associated with the installations are in part due to the requirements of installing a workstation-specific (WS) system as well as low market penetration of the technologies involved. Implementing WS lighting requires installing a highly-controllable suspended fixture over each cubicle. Although strategically placing the luminaires in this manner will result in high quality illumination for the occupants, this lighting arrangement is considerably more expensive than installing recessed fixtures on a uniform grid. In addition, in order to allow the greatest amount of flexibility, two dimmable ballasts were used for each WS luminaire, one to control the uplight and the other for the downlight. This is an expensive solution given the current high cost of dimmable DALI ballasts. Researchers believe that costs could be significantly reduced without loss in functionality simply by using one dimmable ballast for both uplight and downlight components. Finally, due to low market penetration of WS lighting and advanced lighting controls, costs associated with the fixtures and the ballasts were still quite high. For this study, WS fixtures cost $400, which included the cost of two dimmable ballasts that cost $40 each. With greater market penetration these costs will decrease.

Although topics such as operational errors, site-specific variation in energy savings, and reducing installation costs could only be touched upon briefly in this report, the upcoming CBP report will delve deeper into these issues.

6.1.2 Photometric Performance

The lighting retrofits were shown to provide light levels comparable to or higher than pre-retrofit conditions at the occupants' work surfaces. Of the measured workstation surfaces, 60% of those lit by workstation-specific fixtures on default settings provided light levels higher than the acceptable IESNA level of 350 lux, compared to only 46% of those lit by pre-retrofit fixtures. If measured light levels were included from WS fixtures with occupant-requested light settings changes, 44% of the measured workstation surfaces would exceed 350 lux. The similar percentages suggested that given personal control over their overhead light, occupants requested a diverse range of light levels, both above and below 350 lux. Although these light levels were sometimes lower than the acceptable IESNA level, the occupant's experience with their lighting system likely improved and resulted in greater energy savings. Additionally, during the study period, 20% of occupants received workspace light level adjustments from the default settings. This fairly low number likely resulted from occupants having only indirect control over light levels, requiring them to request changes from the control system operator rather than implementing the changes in real time themselves.

6.1.3 Occupant satisfaction

The occupant surveys demonstrated that users were generally more satisfied with the retrofitted lighting system, although the survey also indicated that users wanted greater control over their overhead lights. Occupants typically found the new lighting system to provide better quality light with less glare. Occupants who worked in open office areas where the lighting layout switched from a regularly spaced grid to a WS layout typically preferred the location of the WS lighting over the pre-retrofit system.

During this study, however, although the installed system allowed for individual control over overhead lights, GSA security restrictions required occupants to contact the building O&M contractor to alter personal light levels. This restriction in personal control, combined with a lack of understanding on how to request changes in light level settings or lack of knowledge about the capabilities of the installed lighting system, became a source of occupant dissatisfaction. Additionally, a large number of free responses mentioned that the occupant sensors were not sensitive enough to small movements and would therefore sometimes turn off while the occupant was still present in the space. This may be solved in part by prolonging the timeouts; however, this may decrease energy savings and would also require sufficient knowledge of the process of changing default settings. Furthermore, as pointed out in a few free responses at CH2SE, some fixtures were located poorly, resulting in shadows cast across the occupant's workspace. This indicated an issue during the design of the lighting system, as workstation-specific fixtures should ideally be centered above a workstation so that this issue would not occur.

Survey results also suggested that the timing of the survey distributions had an effect on occupant satisfaction results. For instance, Ron Dellums Federal Building, which housed three sites: RD8N, RD13N, and RD14S, underwent an extended and complicated commissioning process. Post-retrofit occupant surveys were administered to RD13N and RD14S about 5 months after the retrofit occurred while RD8N received the survey 10 months afterwards. Although site-specific factors may have been involved, RD8N occupants seemed generally more satisfied with the installed system than those located in RD13N and RD14S. This suggests that although the retrofit may cause initial dissatisfaction due to the disruption of lighting usage habits, occupants will eventually acclimate to the new lighting system, especially when given greater knowledge and control of the system.

6.2 Lessons Learned and Recommendations

6.2.1 Installation and Commissioning

Installation

Earlier work emphasized the importance of reducing field assembly and simplifying installation whenever possible [2]. The retrofits studied here used pre-assembled luminaires, reducing a potential source of error. One project manager noted that the pre-retrofit circuitry often employed master-slave operation with bi-level switching, meaning that the ballasts in one fixture would control all the fixtures in the room. Therefore, line power was necessary only for the one fixture in the room with the controlling ballasts. The retrofits required line power to every fixture since each fixture is controlled individually by its' own DALI ballasts. This led to an unexpected and significant increase in installation costs.

A few free responses from the occupant survey at one of the sites mentioned that the workstation-specific luminaire was placed in such a way that the fixture cast shadows on the occupant's workspace. This also created issues with lighting quality as well as the probability of poor occupancy sensor placement, creating even more false-off events. Workstation-specific luminaires should ideally have been located directly above the workstation to appropriately light the workspace and promote accurate occupancy sensing.

We suggest that a thorough assessment of the existing workstation layout be completed before the design process in order to inform appropriate fixture placement. We also recommend that an in depth evaluation of both the technology and costs associated with retrofits should be undertaken when planning for a workstation-specific lighting system. This should help guard against unexpected costs and complications and serve to expedite the installation process.

Commissioning

For the most part, formal and well-documented commissioning did not occur in the study areas. Both project managers expressed frustration that the commissioning process was not more transparent and effective. Issues such as a lack of clarity regarding control settings, ballasts unintentionally set to hold lights on continuously, irregular occupancy sensor timeouts, and illogical operational sequences emerged in many of the retrofits. Additionally, when occupants were asked about their personal light level preferences once the installation had been in place for a few weeks, one project manager expressed a desire for a stronger commissioning agent presence during the period of initial commissioning. The commissioning agent's presence would have allowed for changes to be made and confirmed with the occupant in real time. These factors impeded performance and in some cases resulted in extended work to address occupant complaints and correct performance issues.

We recommend establishing a protocol for the commissioning of lighting controls systems that is reflected in contractual documents and language signed by the commissioning agent. These documents should emphasize the importance of following a clear, well-documented commissioning process.

6.2.2 Control System Operation

The control system studied here presented some challenges for post-commissioning operation and presented a steep learning curve for system operators. In particular, operators had difficulties identifying and viewing relevant information on the building floor plans, and layers of setting overrides complicated adjusting operational settings. One project manager mentioned the lack of accessible outputs such as a printer-friendly floor plan with control system zone numbers and tables that clearly specify operational settings, as well as a readable log of operational changes. The challenges with learning how to operate the control system as well as insufficient training may result in disinvested operators, which could potentially have an effect on energy savings.

Lighting control systems with a central controller had the potential to improve building operations and maintenance by notifying operators when lamps need to be replaced, providing feedback that allows operators to identify opportunities for future savings, and alerting operators to unusual behavior. However, these capabilities depended fundamentally on how the system gathered and presented data. Performance tracking needed to reflect real-world performance as closely as possible (i.e., the system must be doing what it says it is doing). Furthermore, in systems that did not include direct power measurements, estimates must be accurate in order to be useful. Power level estimates in the tested system were accurate in some cases but very inaccurate in others, making the information of little use without independent verification.

Finally, this study revealed operational issues in several sites, in particular lights that stayed on unintentionally after hours, which could have a large impact on results. There was also a recurring issue of programmed settings either losing the occupant-requested changes or all programmed settings, forcing all lights to turn to 100% whenever the control system software went through a major update. It is important to note that these issues were identified through a combination of continual evaluation of metered power and control system data performed for this study. However, this level of scrutiny would not be found in standard responsive lighting systems. Although this topic was only discussed briefly here, a more in-depth analysis will be undertaken for the upcoming CBP report.

We recommend that advanced lighting control systems should be intuitive to operate with well designed user interfaces and useful data presentation in order for operators to take advantage of opportunities for improving operations and maintenance. A clear, searchable record of operational setting changes and other control system changes would provide a major additional benefit to operators. Furthermore, diagnostics should be employed within control systems to identify and pinpoint errors to operators, including communications failures, after-hours lighting use, and other issues.

We also suggest that appropriate training should be provided to operators so that operators can control the lighting system effectively and maintain investment in the commissioning process. This obligation should be reflected in the contract with the designer and manufacturer installer.

6.2.3 User acceptance and personal preferences

User acceptance varied widely; while many occupants were happy with the new system, some resorted to tampering with WS occupancy sensors to prevent workspace lights from turning on. In addition, occupants generally had varying degrees of knowledge of the lighting system and its' capabilities. In an attempt to counter this, project managers emphasized the importance of repeated communications to occupants of upcoming changes and explanations of how the retrofit process would work.

As mentioned earlier, during the study period, fewer than 23% of occupants received workspace light level adjustments from the default settings. This fairly low number is likely due to the fact that occupants had only indirect control over light levels and were required to request changes to the control system operator rather than implementing them themselves. Anecdotal evidence during site visits and free responses from surveys indicated that the occupants generally desired greater control over their light levels and have found the process of requesting light level changes to be unknown or too cumbersome, thus preventing occupants from obtaining the full benefits of personal control. Additionally, free responses from surveys expressed frustration with the occupant sensor sensitivity or location across all sites.

Furthermore, while dimmable workspace lights generally allow occupants to select light levels based on the task they are working on, this potentially large benefit to occupants was not incorporated here. In general, light level adjustments were not performed in real time at most sites, meaning that light level changes requested by occupants were implemented at least day after the request was made. This means that occupants could not evaluate light level changes to select their preferred level. However, even a proactive occupant who requested a light level change through the facilities contractor was not able to adjust light levels throughout the day in accordance with daylight availability, task requirements, or other factors.

We recommend that occupants be provided with direct, easily accessible control over light levels and timeouts in real time in order to obtain the full benefits of personal control. Occupants should be able to turn workspace lights on and off and adjust both default levels and temporary levels within boundaries set by building management. To align personal preferences with institutional standards, building managers and system operators should be able to designate the extent of personal control available.

We also suggest that occupants be given sufficient information about the installation and commissioning process, such as providing a lighting system user manual in conjunction with the installation. Information should also explain how problems will be addressed and notify occupants of who they should contact with questions or to report problems.

7 Conclusions

7.1 Market Potential within GSA Portfolio

Responsive lighting controls could be applied to effectively deliver on GSA targets for energy savings and green house gas reduction in every GSA zone and region. Additionally, responsive lighting solutions were found to deliver improved light conditions and increased occupant satisfaction in all tested locations.

However, the results from this study suggest that the above benefits can only be achieved cost-effectively relative to a retrofit solution satisfying the current standards of the Facility Standards for the Public Buildings Service (P-100) in targeted deployments. Additionally, while responsive lighting is appropriate in a wide variety of building types, this study evaluated applications in office spaces only.

Within office spaces, responsive controls would cost effectively deliver energy and GHG savings, as well as improved lighting conditions and increased occupant satisfaction in spaces with large potential for granular reductions in *light levels* and/or *operating hours* through the advanced control strategies of institutional tuning and occupancy sensing. For example, offices that are broadly over-lit to satisfy the requirements of a relatively small subset of occupants or work areas present opportunities for savings associated with institutional tuning. Energy savings could be achieved by implementing building or zonal policies that specify default light levels of less than 100% while still providing an appropriate amount of light, and the ability to ramp up light levels in select areas. Lights that are globally left on in unoccupied spaces (e.g., in infrequently used areas and/or after standard work hours) also create a large potential for energy savings through the reduction of electrical demand achieved from occupancy sensing. Workstation-specific systems also present opportunities for significant savings in open offices with low and/or variable occupancy and larger cubicles, or open offices with denser levels of cubicles, long operating hours, and varying levels of occupancy such as call centers.

Although payback periods may be high for open office spaces with lower baseline lighting power densities, 12 hour weekday only operation, dense cubicle layouts and/or constant levels of cubicle occupancy throughout the workday, responsive lighting controls in a workstation-specific layout nonetheless deliver energy and GHG reductions that may be required to meet mandated targets, and offer the potential for occupants to work under desired light levels rather than institutionally set levels. Although direct occupant control was not implemented in the retrofits studied here, it presents a major potential benefit to occupants. In addition to saving energy, control over light levels could increase occupant satisfaction and productivity by adapting workspaces to occupant preferences.

High daylight availability could also increase the potential for energy savings associated with daylight harvesting; however, this control strategy was not studied here.

7.2 Barriers and Enablers to Adoption

Responsive lighting controls are an emerging technology with few installed locations. Higher first costs lack of contractor familiarity with correctly installing, commissioning and operating the technology represent the key barriers to adoption. However, as responsive lighting systems become more widespread, increased volume should decrease costs, while improved contractor knowledge about installation, commissioning and operation are likely to mitigate these roadblocks. Barriers and enablers to adoption are summarized in greater detail below.

Barriers to adoption include:

- High installation costs due to contractors’ unfamiliarity with advanced systems
- High equipment costs associated with specialized equipment, including dimmable ballasts and other control hardware
- Concerns about installing and commissioning complicated control systems
- Concerns with real world performance as energy savings are difficult to guarantee. Variation in tenant behavior (changes in nature of use and/or hours of occupancy), the potential for elements of the system, particularly sensors, to require higher than predicted standby (‘vampire load’) power, communication failures that compromise intended operation for extended periods all represent potential issues, particularly for installations financed through an Energy Savings Performance Contract (ESPC).

Enablers to adoption include:

- Greater familiarity with the installation process as responsive lighting systems become more widespread will help reduce installation and material costs
- Improvements to control systems are also being developed to allow for easier installation and greater flexibility
- Continuing studies verifying energy savings and unbiased predictive tools to estimate savings can help address performance uncertainty

Manufacturers must also make a concerted effort to improve real-world performance and diagnostics if responsive controls are to become widespread. This includes improving commissioning, making systems easy to operate, providing accurate energy use estimates, and giving operators sufficient instruction and support.

Finally, cost-effectiveness assessments typically result in long payback periods due to unfair comparisons between lighting systems that do not account for the additional benefits resultant of putting in responsive lighting controls. These long payback periods present a barrier to installing advanced lighting systems to many building owners and operators. However, the usage of incremental costs, such as in this study, is becoming more prevalent and should result in less "sticker shock" and a better assessment of the costs associated with these control strategies, thus engendering greater adoption. Additionally, as deeper market penetration of this technology occurs, the associated costs should decrease, thus reducing payback periods significantly.

7.3 Final Conclusions

As 'low hanging fruit' energy savings measures become exhausted, the demand to find alternate methods to reduce energy usage will grow in order to meet mandated federal targets for energy reduction, and to contain energy costs. This study demonstrated that overall, responsive lighting systems have proven their ability to achieve deep energy savings while providing comparable or improved light levels and increased occupant satisfaction relative to existing GSA lighting systems. However, it should be noted that payback periods of less than fifteen years can only be achieved in spaces that have long operating hours but variable density of occupancy. This study also assumed that the owner was already intending on replacing the lighting system. Additionally, for responsive lighting control systems to reach their full potential, they must be designed, installed, commissioned, and operated effectively.

The lighting system studied here focused primarily on workstation-specific lighting operating in tandem with institutional tuning and occupancy sensing. As mentioned previously, personal controls were implemented to a limited extent; employing them to a greater extent could reap greater energy savings. This would include allowing occupants to set and adjust light levels in real time within boundaries set by building policy.

The high granularity of control inherent in the advanced lighting controls system provides additional opportunities for energy savings not studied here. Future studies could look into the effectiveness of implementing advanced lighting controls for dimming light levels depending on daylight availability, potentially further decreasing energy use and reducing the payback period associated with this technology.

Further work might also look at using data from occupancy sensors, particularly those associated with a workstation-specific lighting layout, to improve the control of other systems such as HVAC to provide heating and cooling loads appropriate for occupancy/vacancy. Finally, future studies could look at the potential for the lighting controller to be programmed to adapt to demand response events or other increases in electricity rates [1].

8 Appendices

8.1 Complete Commercial Building Partnership Report to GSA

This study was partially funded by the Department of Energy's Commercial Building Partnership (CBP). A separate report prepared with funding from that program delves deeper into the energy implications of advanced controls as includes an expanded number of sites within its analysis. This report will be available as a separate document in December 2012.

8.2 Detailed Technology Specifications

8.2.1 Pre-retrofit Lighting Controls and Lamp and Luminaire Types

Site	Lighting Controls	Luminaire Type	Lamps
CH2SE	Lights controlled by scheduler with non-emergency lights typically staying on from 5:15 am – 6:15 pm on weekdays.	1. Recessed 2x4, 27 cell 2. Recessed 2x4, flat prism covers 3. Recessed 1x4	1. (3) F32T8 2. (3) F32T8 3. (1) F32T8
CW2NE	Scheduled sweep where lights go off at 6 pm, although override buttons existed for every zone. Otherwise, manual control over lights.	1. Recessed 1x4 with louvers 2. Recessed 2x4 with baffles	1. (2) F32T8 2. (3) F32T8
PB10W	Manual wall switches	1. Recessed 2x4, 18 cell, bi-level switch 2. Recessed 2x4, 24 cell, bi-level switch 3. Recessed can fixture	1. (3) F32T8 2. (4) F32T8 3. (2) 13W CFLs
RD8N	Open offices have distributed occupancy sensors. Private offices have built-in occupancy sensors and wall switches.	1. Recessed 2x4, 18 cell 2. Recessed 2x2, 9 cell	1. (2) F32T8 2. (2) F17T8

Site	Lighting Controls	Luminaire Type	Lamps
RD13N	Open offices have distributed occupancy sensors. Private offices have built-in occupancy sensors and wall switches.	1. Recessed 2x4, 18 cell 2. Recessed 2x2, 9 cell	1. (2) F32T8 2. (2) F17T8
RD14S	Open offices have distributed occupancy sensors. Private offices have built-in occupancy sensors and wall switches.	1. Recessed 2x4, 18 cell 2. Recessed 2x2, 9 cell	1. (2) F32T8 2. (2) F17T8
R18	Manual wall switches. Inactivated occupancy sensors.	1. Recessed 2x4, 18 cell	1. (3) F32T8

8.2.2 Post-retrofit Lamp and Luminaire Types

Name	Type	Lamps	Efficiency
Lightolier Energos (EC18HIB46WUGLBST and EC18HIB86WUGLBST)	Suspended, louvered, direct/indirect 4’ or 8’ fixture with a built-in occupancy/photo-sensor	4’ fixtures: (3) F32T8 lamps (1 uplight and 2 downlight) 8’ fixtures: (6) F32T8 lamps (2 uplight and 4 downlight)	4’ fixtures: LE=62.5 when used with F54T5HO lamps, no specs available for use with F32T8 lamps (custom for this project)
Lightolier Skyway (SKS2GPK232 and SKS2GPK217)	Recessed, tri-lens 2’x4’ or 2’x2’ fixture	2x4 fixtures: (2) F32T8 lamps 2x2 fixtures: (2) F17T8 lamps	2x4 fixtures: LE=75.3 2x2 fixtures: LE=70.7
Lightolier GO2 (GOS2G232 and GOS2G217)	Recessed, louvered, 2’x4’ or 2’x2’ fixture	2x4 fixtures: (2) F32T8 lamps 2x2 fixtures: (2) F17T8 lamps	2x4 fixtures: LE=85.0 2x2 fixtures: LE=80.5
Lightolier Lycaster (1101CD/1101F2642U)	Recessed CFL downlight with 6.75” open aperture	(1) 26W CFL triple	LE=65.4

Site	Luminaire types
CH2SE	4’ Energos, 8’ Energos, 2x4 Skyway, 2x2 Skyway, Lycaster
CW2NE	4’ Energos, 2x4 GO2, 2x2 GO2, Lycaster

Site	Luminaire types
PB10W	2x4 Skyway, 2x2 Skyway, Lycaster
RD8N	4’ Energos, 2x4 GO2, 2x2 GO2, Lycaster
RD13N	4’ Energos, 2x4 GO2, 2x2 GO2, Lycaster
RD14S	4’ Energos, 2x4 GO2, 2x2 GO2, Lycaster
R18	4’ Energos, 8’ Energos, 2x4 Skyway, 2x2 Skyway

8.2.3 Post-retrofit Ballast and Control System Specifications

8.2.3.1LumEnergi iB-100 Dimming Ballast Specifications

Number and Type of Lamps	Ballast Factor (BF)	Power Input (Watts, Max/Min)	System Efficacy (lm/W, Max/min)	Power Factor
(1) F28T5	1.2	36/8	102/46	0.92
(2) F28T5	1.2	69/12	105/60.25	0.95
(3) F28T5	1.2	103/20	106/55	0.97
(1) F32T8	1.2	40/8	90/45	0.92
(2) F32T8	1.2	77/15	93.5/48	0.95
(3) F32T8	1.2	115/23	94/47	0.98
(1) F54T5HO	0.85	49/9	87/41.2	0.92
(2) F54T5HO	0.85	95/13	87/63.3	0.95

8.2.3.2LumEnergi LMCS Controller and Remote Server Specifications

Name	Type	Specifications
LumEnergi LMCS Controller	Control panel	• Inputs: 32 LV switches, 32 photosensors • Outputs: 32 DALI streams, 32 industry standard 0-10VDC, 32 contactors – 12VDC • Supports 32 zones with 8 scenes per zone • Input voltage: 110-277V
LUMEnergi LMCS Remote Server	Control server	• Operating system: Win32 platforms, web browsers, mobile clients • Supports 32 LMCS controllers

8.2.3.3Control Programming

Chet Holifield 2nd Floor, SE (CH2SE)

Fixture Type	Default settings

Fixture Type	Default settings
Energos	• On power: 50% downlight, 20% uplight • On timeout: 20 minutes • Preliminary power: 20% downlight and uplight • Preliminary timeout: 10 minutes
2x4, 2x2 Skyway	• On power: 50% • On timeout: 20 minutes • Preliminary power: 20% • Preliminary timeout: 10 minutes

Cottage Way 2nd Floor North, East Building (CW2NE)

Fixture Type	Default settings
Energos	• On power: 50% downlight, 20% uplight • On timeout: 20 minutes • Preliminary power: 20% downlight and uplight • Preliminary timeout: 10 minutes
2x2 GO2, Lycaster	• On power: 50% • On timeout: 20 minutes • Preliminary power: 20% • Preliminary timeout: 10 minutes

Phillip Burton 10th Floor, West (PB10W)

Fixture Type	Default settings
Energos	• On power: 50% downlight, 20% uplight • On timeout: 20 minutes • Preliminary power: 20% downlight and uplight • Preliminary timeout: 10 minutes
2x2 GO2, Lycaster	• On power: 50% • On timeout: 20 minutes • Preliminary power: 20% • Preliminary timeout: 10 minutes

Ron Dellums 8th Floor, North Tower (RD8N)

Fixture Type	Default settings

Fixture Type	Default settings
Energos	• On power: 50% downlight, 30% uplight • On timeout: 20 minutes • Preliminary power: 30% downlight and uplight • Preliminary timeout: 10 minutes
2x2 and 2x4 GO2	• On power: 50% • No timeouts
2x4 GO2 fixtures in daylit private offices	• Maintain 50 fc • Min power: 20% • Max power: 35% • On timeout: 20 minutes • Preliminary power: 20% • Off timeout: 5 minutes

Ron Dellums 13th Floor, North Tower (RD13N)

Fixture Type	Default settings
Energos	• On power: 50% downlight, 30% uplight • On timeout: 20 minutes for downlight • Preliminary power: 30% downlight • Preliminary timeout: 10 minutes for downlight • No timeouts for uplights
2x2 and 2x4 GO2	• On power: 50% • No timeouts
2x4 GO2 fixtures in daylit private offices	• Maintain 50 fc • Min power: 20% • Max power: 35% • On timeout: 20 minutes • Preliminary power: 20% • Off timeout: 5 minutes

Ron Dellums 14th Floor, South Tower (RD14S)

Fixture Type	Default settings

Fixture Type	Default settings
Energos	• On power: 50% downlight, 30% uplight • On timeout: 20 minutes • Preliminary power: 30% downlight and uplight • Preliminary timeout: 10 minutes
2x2 and 2x4 GO2	• On power: 50% • No timeouts
2x4 GO2 fixtures in daylit private offices	• Maintain 50 fc • Min power: 20% • Max power: 35% • On timeout: 20 minutes • Preliminary power: 20% • Off timeout: 5 minutes

Roybal 18th Floor

Fixture Type	Default settings
Energos	• On power: 50% downlight, 20% uplight • On timeout: 20 minutes • Preliminary power: 20% downlight and uplight • Preliminary timeout: 10 minutes
2x4 Skyway	• On power: 50% • On timeout: 20 minutes • Preliminary power: 20% • Preliminary timeout: 10 minutes

8.2.4 Task Lighting Details

Site	Location and Size	Lamps
CH2SE	• Under-cabinet task light • 36" long • Typically two (2) at each cubicle	(1) F30T8
CW2NE	• Under-cabinet task light, built in • 36" long • Typically two (2) at each cubicle	(1) F30T8
PB10W	Variable	Variable
RD8N	• Round, surface-mounted, built in under-cabinet fixture • 11" diameter, extends 3.25" • Typically one (1) at each cubicle	(1) F13TT

Site	Location and Size	Lamps
RD13N	• Under-cabinet task light, built in • 3' x 9" • Typically (1) at each cubicle	(1) T8 or (1) T12
RD13N	• Under-cabinet task light, built in • 2' x 9" • Typically (1) at each cubicle	(1) F17T8
RD14S	• Under-cabinet task light, built in • 32" x 6" • Typically (1) at each cubicle	(1) F30T8
RD14S	• Under-cabinet task light, built in • 20" x 6" • Typically (1) at each cubicle	(1) F15T8
R18	• Under-cabinet task light, built in • 24" long • Typically (1) at each cubicle in east side of site	(1) F14T5
R18	• Under-cabinet task light, built in • 14" long • Typically (1) at each cubicle in east side of site	(1) F8T5
R18	• Under-cabinet task light, built in • 32" long • Typically (2) at each cubicle in northwest corner of site	(1) F17T8

8.3 Research Details

8.3.1 Global Warming Effect Calculations

Several LCA assessments were used to convert the energy from each source in each fuel mix into GWE (see following table). Utility and national average fuel mixes can be found in subsequent sections.

Technology	GWE (g CO2 eq/kWh electricity generation)	Source
Coal	680	[15]
Natural Gas	410	[15]
Nuclear	24	[16]
Large Hydroelectric	20	[15]
Biomass and Waste	3.1	[17]
Geothermal	26	[18]
Small Hydroelectric	20	[15]
Solar	24	[16]
Wind	5	[15]

8.3.1.1Los Angeles Department of Water and Power (LADWP)

LADWP's fuel mix was based off of 2010 data [19] and can be seen in the table below.

Source	**%**	**GWE (g CO2 eq/kWH electricity generation)**	**GWE (g CO2 eq/kWH PGE electricity generation)**
Natural Gas	22.0%	410	90.2
Nuclear	11.0%	24	2.6
Biomass and Waste	4.0%	3.1	0.1
Geothermal	1.0%	26	0.3
Wind	8.0%	5	0.4
Small Hydroelectric	7.0%	20	1.4
Solar	0.0%	24	0.0
Large Hydroelectric	3.0%	20	0.6
Coal	39.0%	410	159.9
Natural Gas	22.0%	410	90.2
		Total	**255.5**

8.3.1.2Pacific Gas and Electric (PGE)

PGE's fuel mix was based off of 2009 data and can be seen in the table below. The most recent fuel mix was not used because 23% was listed as unspecified sources [20].

Source	**%**	**GWE (g CO2 eq/kWH electricity generation)**	**GWE (g CO2 eq/kWH PGE electricity generation)**
Nuclear	23.0%	24	5.5
Coal	4.0%	680	27.2
Natural Gas	47.0%	410	192.7
Large Hydroelectric	13.0%	20	2.6
Biomass and Waste	4.1%	3.1	0.1
Geothermal	3.6%	26	0.9
Wind	1.8%	5	0.1
Small Hydroelectric	2.5%	20	0.5
Solar	0	24	0.0
		Total	**229.7**

8.3.1.3Sacramento Municipal Utility District (SMUD)

SCE's fuel mix was based off of 2009 data [21]and can be seen in the table below.

Source	%	GWE (g CO2 eq/kWH electricity generation)	GWE (g CO2 eq/kWH PGE electricity generation)
Natural Gas	56.0%	410	229.6
Nuclear	0.0%	24	0.0
Biomass and Waste	9.0%	3.1	0.3
Geothermal	2.0%	26	0.5
Wind	6.0%	5	0.3
Small Hydroelectric	3.0%	20	0.6
Solar	0.0%	24	0.0
Large Hydroelectric	21.0%	20	4.2
Coal	3.0%	410	12.3
		Total	**247.8**

8.3.1.4Southern California Edison (SCE)

SCE's fuel mix was based off of 2009 projections [22] and can be seen in the table below.

Source	%	GWE (g CO2 eq/kWH electricity generation)	GWE (g CO2 eq/kWH SCE electricity generation)
Natural Gas	51.0%	410	209.1
Nuclear	18.0%	24	4.3
Biomass and Waste	2.0%	3.1	0.1
Geothermal	9.0%	26	2.3
Wind	3.0%	5	0.2
Small Hydroelectric	1.0%	20	0.2
Solar	1.0%	24	0.2
Large Hydroelectric	5.0%	20	1.0
Coal	10.0%	410	41.0
		Total	**258.4**

8.3.1.5National Average

The national average fuel mix was based off of 2009 data from eGRID2012 and can be seen in the table below [23].

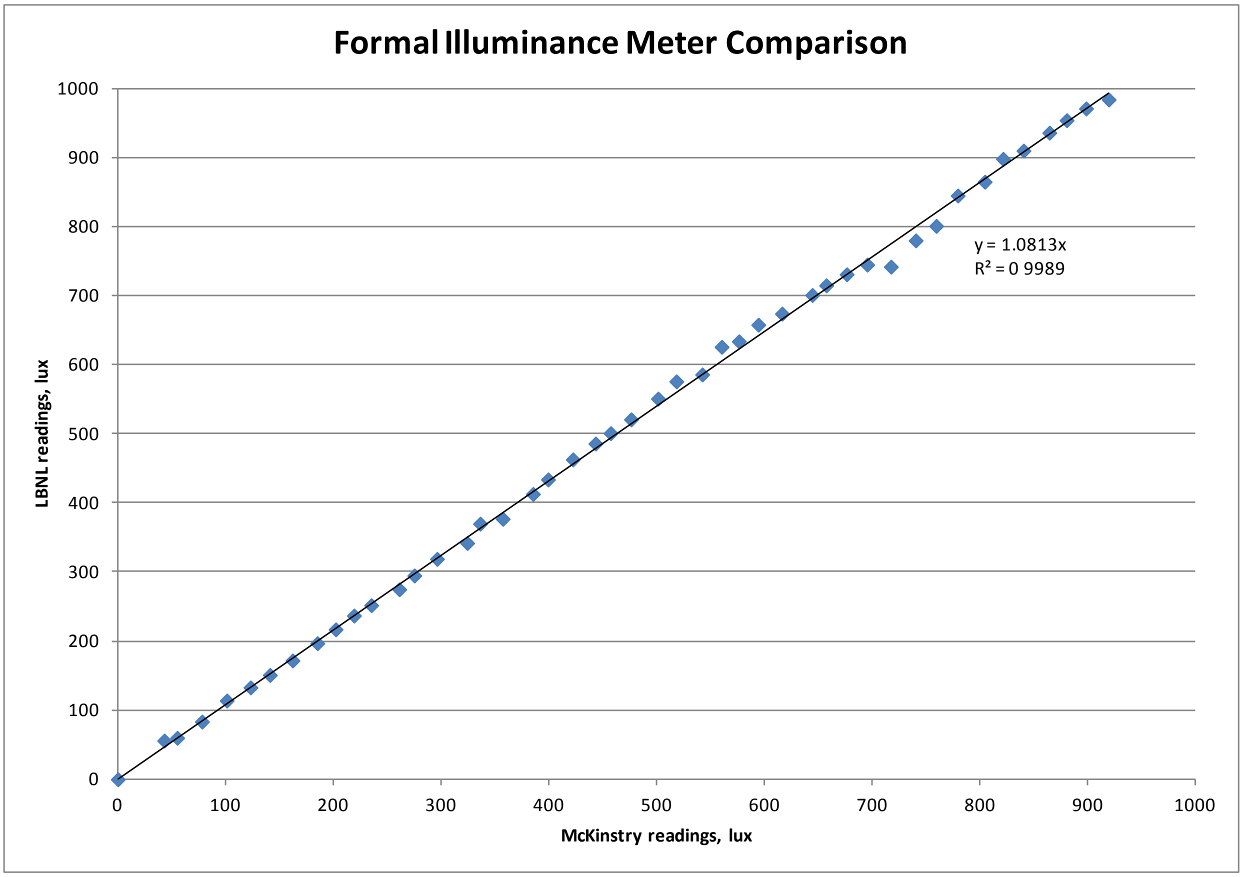
Source	%	GWE (g CO2 eq/kWH electricity generation)	GWE (g CO2 eq/kWH PGE electricity generation)
Coal	44.5%	680	302.4
Natural Gas	23.3%	410	95.6
Nuclear	20.2%	24	4.9
Large Hydroelectric	6.8%	20	1.4
Other fossil fuels	1.5%		
Biomass and Waste	1.4%	3.1	0.0
Geothermal	0.4%	26	0.1
Wind	1.9%	5	0.1
		Total	**404.4**

8.3.2 Illuminance Meter Comparison

Results are presented below from the formal comparison between LBNL (Minolta T1 206872) and McKinstry's (Extech Q134383) illuminance meters. This comparison was performed to account for differences in calibration between the two illuminance meters so that the illuminance data would be accurate and relatable Illuminance data across multiple sites. In order to accurately look at the relationship between the two Illuminance meters, readings were taken between 0-900 lux, generally in 10 lux increments. To obtain the different illuminance levels, a combination of task light (Sylvania Octron 25W T8) and overhead lights (Sylvania OCtron F32T8) was used.

LBNL meter (lux)	McKinstry meter (lux)
0	0
56	43
60	55
83.5	78
114	101
133	123
151	141
172	162
197	185
217	202
237	219
252	235
275	261
295	275
319	296
342	324

LBNL meter (lux)	McKinstry meter (lux)
370	336
377	357
413	385
434	399
463	422
486	443
501	457
521	476
551	501
576	518
586	542
626	560
634	576
658	594
674	616
701	644
715	657
731	676
742	717
745	695
780	740
801	759
845	779
865	804
898	821
910	840
936	864
954	880
971	898
984	919



8.3.3 Occupant Surveys

8.3.3.1Occupant Survey Details

The occupant satisfaction survey was sent via email link or in paper form to site occupants both pre-retrofit and post-retrofit (see table below).

Pre-retrofit Survey

Site	RD13N	RD14S	RD8N	PB10W	R18	CH2SE	CW2NE
Start date	10/19/10	11/2/10	11/9/10	2/14/11	4/13/11	3/28/11	7/25/11
Close date	10/25/10	11/15/10	11/19/10	3/4/11	5/6/11	4/6/11	8/10/11
# emailed	53	52	75	54	24	300	175
# respondents	17	8	35	34	11	102	79
response rate	32.1%	15.4%	46.7%	63.0%	45.8%	34.0%	45.1%

Post-retrofit Survey

Site	RD13N	RD14S	RD8N	PB10W	R18	CH2SE	CW2NE

Site	RD13N	RD14S	RD8N	PB10W	R18	CH2SE	CW2NE
Start date	11/1/11	11/8/11	4/26/12	11/1/11	5/9/12	5/3/12	4/17/12
Close date	12/31/11	12/31/11	5/20/12	12/31/11	6/1/12	5/23/12	5/25/12
# emailed	53	42	110	57	36	200	175
# respondents	22	11	51	30	18	63	27
response rate	41.5%	26.2%	15.4%	52.6%	50.0%	31.5%	15.4%

8.3.3.1.1 Occupant Survey Version 1

This version of the survey was used from 10/19/2010 to 8/15/2011 with the exception of Roybal's post-retrofit survey which used version 1 of the occupant survey between 5/9/2012 and 6/1/2012 because Roybal surveys could not be taken online.

Lighting Satisfaction Survey

The survey is being conducted by the General Service Administration and Lawrence Berkeley National Laboratory to determine occupant preferences about office lighting. Results will be used to help future lighting retrofits in federal buildings nationwide take occupant preferences and comfort into account.

About the survey:

- Responses are anonymous. Your name will not be recorded, and data will be stored by Lawrence Berkeley National Laboratory and will only be presented as aggregated group information.
- Participation is voluntary. You are free to choose at any time whether or not to provide responses to the survey or to individual questions.
- If you have questions about the survey or the lighting study, please contact Abby Enscoe (aienscoe@lbl.gov) or Susana Mercado (susana.mercado@gsa.gov).

Thanks so much for your candid feedback!

General Information

Date: ____________________

Which of the following best describes the type of work you do?

☐ People management, leadership, and/or training
☐ Computer aided design, engineering, or software development

- ☐ Combination of computer work, paper tasks, phone calls and meetings
- ☐ Facility management
- ☐ Other

Personal Workspace Information

Which of the following best describes your personal workspace?

- ☐ Enclosed private office
- ☐ Cubicles with partitions above standing eye level
- ☐ Cubicles with partitions below standing eye level
- ☐ Other (please specify)

If other, describe your workspace:

____

What type of computer screen do you have?

- ☐ Laptop
- ☐ Flat panel screen
- ☐ Traditional screen
- ☐ Other

If other, describe your computer screen:

____

On a typical day, how long are you in your personal workspace?

- ☐ More than 6 hours
- ☐ 4-6 hours
- ☐ 2-4 hours
- ☐ Less than 2 hours

Are you able to see out a window while sitting in your workspace?

- ☐ Yes
- ☐ No

If "yes", do you like the view?

- ☐ Yes
- ☐ No

Do you sit adjacent to a window?

- ☐ Yes
- ☐ No

Overhead Lighting

Which of the following most closely resembles the overhead lighting in your immediate workspace? (check all that apply)


☐


☐


☐

Other (picture not shown)
☐

If other, describe your overhead lighting:

____

Overall, is the lighting comfortable?

☐ Yes
☐ No

Task Lighting

Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?

☐ Undercabinet task light
☐ Desktop task light
☐ I do not have a task light

Wall Lighting

Which of the following most closely resembles the lighting on the walls in your general office area? (Check all that apply)

☐ Uniformly bright walls
☐ Uneven light distribution on walls
☐ Accent lighting on artwork only
☐ Walls are dim
☐ Other
☐ Do not know

Lighting and Shading Controls

Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?

☐ Yes
☐ No
☐ Do not know / does not apply

Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?

☐ Yes
☐ No
☐ Do not know / does not apply

If your lights turn off automatically, can you turn them back on from your immediate work area?

☐ Yes
☐ No
☐ Does not apply

Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?

☐ Yes
☐ No
☐ Does not apply

How are your overhead lights controlled? (Check all that apply)

☐ Switch at wall
☐ Handheld remote
☐ Interface at your computer
☐ Automated system / controlled by building management
☐ Other (please specify)
☐ Do not know / Does not apply

If other, describe your overhead lighting control:

____

To what extent can light levels from your overhead lights be adjusted?

☐ Lights turn on and off only
☐ Light level settings are available for high, low, and/or medium
☐ Continuous dimming available

What type of control do you have for your task lighting?

☐ On/off switch
☐ Dimmer switch
☐ Other (please specify)
☐ Does not apply

If other, describe your task lighting control:

____

What type of shading system do you have to control the amount of daylight entering your windows?

☐ Manual blinds (e.g. Venetian blinds)
☐ Manual window shades (e.g. roller shades)
☐ Automatic blinds or shades
☐ Other (please specify)
☐ No shading control
☐ I have no daylight in my workspace

If other, describe your daylight control:

____

Can you control the amount of daylight entering your windows without affecting other occupants?

☐ Yes
☐ No
☐ Does not apply

To what extent do you agree or disagree with the following statements about the lighting in your *personal* workspace?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
I am satisfied with my ability to control my overhead lighting.	☐	☐	☐	☐	☐	☐
I am satisfied with my ability to control my task lighting.	☐	☐	☐	☐	☐	☐
I am satisfied with my ability to control my window shades or blinds.	☐	☐	☐	☐	☐	☐

Lighting Quality

To what extent do you agree or disagree with the following statements about the lighting in your *personal* workspace?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
My work surface is evenly lighted without very bright or dim spots.	☐	☐	☐	☐	☐	☐

The lights flicker throughout the day.	☐	☐	☐	☐	☐	☐

To what extent do you agree or disagree with the following statements about the lighting in your *general* office area?

	Strongly disagree	Disagree	Neutral	Agree	Strongl y agree	Does not apply
The lighting fixtures in the general office area around my workspace are nice looking.	☐	☐	☐	☐	☐	☐
The lighting helps create a good image for the organization.	☐	☐	☐	☐	☐	☐
The room surfaces (walls, ceilings) have a pleasant brightness.	☐	☐	☐	☐	☐	☐

How would you rate the lighting in your workspace for each of the following tasks?

	Much too bright	Too bright	Just right	Too dim	Much too dim	Does not apply
Paper tasks (reading and writing)	☐	☐	☐	☐	☐	☐
Reading from a computer screen	☐	☐	☐	☐	☐	☐
Typing on a keyboard	☐	☐	☐	☐	☐	☐
Filing or locating papers	☐	☐	☐	☐	☐	☐
Face to face conversations	☐	☐	☐	☐	☐	☐

How often do you experience any of the following conditions when in your personal workspace during an average day? [For the purpose of answering these questions, consider the definition of glare to be unwanted light, e.g. loud noise is to sound as glare is to light.]

	Never	Rarely	Sometimes	Often	Always
Glare reflected from your work surface	☐	☐	☐	☐	☐
Glare from the light fixtures reflected	☐	☐	☐	☐	☐

on your computer screen					
Glare from the window reflected on your computer screen	☐	☐	☐	☐	☐
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	☐	☐	☐	☐	☐
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	☐	☐	☐	☐	☐
Glare from your task lighting	☐	☐	☐	☐	☐
Direct glare from a window	☐	☐	☐	☐	☐

Lighting comes in a range of colors, from a "warm" white to a "cool" white. "Warm" light is often described as slightly yellow in appearance, and "cool" light is often described as slightly blue in appearance. Please indicate:

	Very warm	Somewhat warm	Neutral	Somewhat cool	Very cool	Don't know
What is the color appearance of the lighting in your personal workspace?	☐	☐	☐	☐	☐	☐
What would you prefer for the color appearance of lighting in your personal workspace?	☐	☐	☐	☐	☐	☐

How often do you experience any of the following conditions when in your personal workspace?

	Never	Rarely	About once per month	About once per week	Every day
"Burning" or tired eyes after reading extensively	☐	☐	☐	☐	☐
"Burning" or tired eyes after using the computer extensively	☐	☐	☐	☐	☐
I have to take a break to let my eyes recover	☐	☐	☐	☐	☐
Headache that you think is caused by your lighting	☐	☐	☐	☐	☐

If you could change the lighting in your office, what would you do? Please check all that apply.

- ☐ Change the location of the overhead lighting fixtures relative to your workstation
- ☐ Make the overhead lighting fixtures produce more light
- ☐ Make the overhead lighting fixtures produce less light
- ☐ Make the overhead lighting fixtures less glary
- ☐ Change the aesthetic appearance of the lighting fixtures
- ☐ Change the color appearance of the lighting fixtures
- ☐ Add a task light
- ☐ Be able to control the brightness / light output of the overhead lighting fixtures with a dimmer or high/low switch
- ☐ Get better access to a window view
- ☐ Get better access to daylight
- ☐ Have light bulbs replaced faster when they burn out and fixtures repaired faster when they break
- ☐ I would not change anything

Please feel free to submit any other comments about your lighting below:

Please feel free to submit any other comments about this survey below:

8.3.3.1.2 Occupant Survey Version 1A

This version of the survey is a modified version 1 (version 1A) of the occupant survey and was used from 5/3/2012 to 5/23/2012 for Chet Holifield's post-retrofit survey. This occurred because both Chet Holifield and Roybal surveys could not be taken online.

Lighting Satisfaction Survey

Thank you for taking this survey! The survey is being conducted by the General Service Administration and Lawrence Berkeley National Laboratory to determine occupant preferences about office lighting. Results will be used to help future lighting retrofits in federal buildings nationwide take occupant preferences and comfort into account. We can't do this without candid feedback from you!

We know that your time is limited and that the survey looks long, but it should only take about 10 minutes to complete. Your office is one of only ten sites in our study, and occupant feedback is an essential component of our work. Thank you in advance for your help!

About the survey:

- Responses are anonymous. Your name will not be recorded, and data will be stored by Lawrence Berkeley National Laboratory and will only be presented as aggregated group information.

- Participation is voluntary. You are free to choose at any time whether or not to provide responses to the survey or to individual questions.
- If you have questions about the survey or the lighting study, please contact Joy Wei (jwwei@lbl.gov) or Susana Mercado (susana.mercado@gsa.gov).

Thanks so much for your candid feedback!

Lighting Satisfaction Survey

General Information

Date: ____________________

Which of the following best describes the type of work you do?

☐ People management, leadership, and/or training
☐ Computer aided design, engineering, or software development
☐ Combination of computer work, paper tasks, phone calls and meetings
☐ Facility management
☐ Other

Personal Workspace Information

Which of the following best describes your personal workspace?

☐ Enclosed private office
☐ Cubicles with partitions above standing eye level
☐ Cubicles with partitions below standing eye level
☐ Other (please specify)
If other, describe your workspace:

____

What type of computer screen do you have?

☐ Laptop
☐ Flat panel screen
☐ Traditional screen
☐ Other
If other, describe your computer screen:

____

On a typical day, how long are you in your personal workspace?

☐ More than 6 hours
☐ 4-6 hours
☐ 2-4 hours
☐ Less than 2 hours

Are you able to see out a window while sitting in your workspace?

☐ Yes
☐ No

If "yes", do you like the view?

☐ Yes
☐ No

Do you sit adjacent to a window?

☐ Yes
☐ No

Overhead Lighting

Which of the following most closely resembles the overhead lighting in your immediate workspace? (check all that apply)

 ☐

 ☐

 ☐

Other (picture not shown) ☐

If other, describe your overhead lighting:

____

Overall, is the lighting comfortable?

☐ Yes
☐ No

Task Lighting

Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?

☐ Undercabinet task light
☐ Desktop task light
☐ I do not have a task light

Wall Lighting

Which of the following most closely resembles the lighting on the walls in your general office area? (Check all that apply)

☐ Uniformly bright walls
☐ Uneven light distribution on walls
☐ Accent lighting on artwork only
☐ Walls are dim
☐ Other
☐ Do not know

Lighting and Shading Controls

Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?

☐ Yes
☐ No
☐ Do not know / does not apply

Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?

☐ Yes
☐ No
☐ Do not know / does not apply

If your lights turn off automatically, can you turn them back on from your immediate work area?

☐ Yes
☐ No
☐ Does not apply

Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?

☐ Yes
☐ No
☐ Does not apply

How are your overhead lights controlled? (Check all that apply)

☐ Switch at wall
☐ Handheld remote
☐ Interface at your computer
☐ Automated system / controlled by building management
☐ Other (please specify)
☐ Do not know / Does not apply

If other, describe your overhead lighting control:

____

To what extent can light levels from your overhead lights be adjusted?

☐ Lights turn on and off only
☐ Light level settings are available for high, low, and/or medium
☐ Continuous dimming available

What type of control do you have for your task lighting?

☐ On/off switch

☐ Dimmer switch
☐ Other (please specify)
☐ Does not apply
If other, describe your task lighting control:

____

What type of shading system do you have to control the amount of daylight entering your windows?

☐ Manual blinds (e.g. Venetian blinds)
☐ Manual window shades (e.g. roller shades)
☐ Automatic blinds or shades
☐ Other (please specify)
☐ No shading control
☐ I have no daylight in my workspace
If other, describe your daylight control:

____

Can you control the amount of daylight entering your windows without affecting other occupants?

☐ Yes
☐ No
☐ Does not apply

To what extent do you agree or disagree with the following statements about the lighting in your *personal* workspace?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
I am satisfied with my ability to control my overhead lighting.	☐	☐	☐	☐	☐	☐
I am satisfied with my ability to control my task lighting.	☐	☐	☐	☐	☐	☐
I am satisfied with my ability to control my window shades or blinds.	☐	☐	☐	☐	☐	☐

Lighting Quality

To what extent do you agree or disagree with the following statements about the lighting in your *personal* workspace?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
My work surface is evenly lighted without very bright or dim spots.	☐	☐	☐	☐	☐	☐
The lights flicker throughout the day.	☐	☐	☐	☐	☐	☐

To what extent do you agree or disagree with the following statements about the lighting in your *general* office area?

	Strongly disagree	Disagree	Neutral	Agree	Strongl y agree	Does not apply
The lighting fixtures in the general office area around my workspace are nice looking.	☐	☐	☐	☐	☐	☐
The lighting helps create a good image for the organization.	☐	☐	☐	☐	☐	☐
The room surfaces (walls, ceilings) have a pleasant brightness.	☐	☐	☐	☐	☐	☐

How would you rate the lighting in your workspace for each of the following tasks?

	Much too bright	Too bright	Just right	Too dim	Much too dim	Does not apply
Paper tasks (reading and writing)	☐	☐	☐	☐	☐	☐
Reading from a computer screen	☐	☐	☐	☐	☐	☐
Typing on a keyboard	☐	☐	☐	☐	☐	☐
Filing or locating papers	☐	☐	☐	☐	☐	☐
Face to face conversations	☐	☐	☐	☐	☐	☐

How often do you experience any of the following conditions when in your personal workspace during an average day? [For the purpose of answering these questions, consider the definition of glare to be unwanted light, e.g. loud noise is to sound as glare is to light.]

	Never	Rarely	Sometimes	Often	Always
Glare reflected from your work surface	☐	☐	☐	☐	☐
Glare from the light fixtures reflected on your computer screen	☐	☐	☐	☐	☐
Glare from the window reflected on your computer screen	☐	☐	☐	☐	☐
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	☐	☐	☐	☐	☐
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	☐	☐	☐	☐	☐
Glare from your task lighting	☐	☐	☐	☐	☐
Direct glare from a window	☐	☐	☐	☐	☐

Lighting comes in a range of colors, from a “warm” white to a “cool” white. “Warm” light is often described as slightly yellow in appearance, and “cool” light is often described as slightly blue in appearance. Please indicate:

	Very warm	Somewhat warm	Neutral	Somewhat cool	Very cool	Don’t know
What is the color appearance of the lighting in your personal workspace?	☐	☐	☐	☐	☐	☐
What would you prefer for the color appearance of lighting in your personal workspace?	☐	☐	☐	☐	☐	☐

How often do you experience any of the following conditions when in your personal workspace?

	Never	Rarely	About once per month	About once per week	Every day

"Burning" or tired eyes after reading extensively	☐	☐	☐	☐	☐
"Burning" or tired eyes after using the computer extensively	☐	☐	☐	☐	☐
I have to take a break to let my eyes recover	☐	☐	☐	☐	☐
Headache that you think is caused by your lighting	☐	☐	☐	☐	☐

If you could change the lighting in your office, what would you do? Please check all that apply.

☐ Change the location of the overhead lighting fixtures relative to your workstation
☐ Make the overhead lighting fixtures produce more light
☐ Make the overhead lighting fixtures produce less light
☐ Make the overhead lighting fixtures less glary
☐ Change the aesthetic appearance of the lighting fixtures
☐ Change the color appearance of the lighting fixtures
☐ Add a task light
☐ Be able to control the brightness / light output of the overhead lighting fixtures with a dimmer or high/low switch
☐ Get better access to a window view
☐ Get better access to daylight
☐ Have light bulbs replaced faster when they burn out and fixtures repaired faster when they break
☐ I would not change anything

Please feel free to submit any other comments about your lighting below:

Please feel free to submit any other comments about this survey below:

8.3.3.1.3 Occupant Survey Version 2

This version of the survey was used from 11/1/2011 to 5/25/2012 with the exception of Roybal and Chet Holifield. Roybal's post-retrofit survey used version 1 of the occupant survey and Chet Holifield's post-retrofit survey used a modified version 1 (version 1A) of the occupant survey. This occurred because both Chet Holifield and Roybal surveys could not be taken online.

Lighting Satisfaction Survey

Privacy statement:

This survey is being conducted to determine occupant preferences about office lighting. The information gathered may be used by employers or facility managers to make informed choices about lighting, and to improve the state of knowledge about lighting and worker satisfaction.

About this survey:

Responses are anonymous — Your responses to this on-line survey will be sent directly to the survey administration company server which is not associated with and cannot be accessed by your employer. This ensures that your specific responses will never be available to the organization or individuals that you work for. Your responses will only be available as aggregated group information. Participation is Voluntary — This survey is entirely voluntary, and you are free to choose at any time whether or not to provide responses to the survey or individual questions. Your Rights — If you have questions about your rights as a participant of this research survey or this website, please email the Institutional Review Board at Pacific Northwest National Laboratory. A research specialist will respond to your question promptly.

Introduction

Which of the following best describes the type of work you do?

☐ People management, leadership, and/or training
☐ Computer aided design, engineering, or software development
☐ Combination of computer work, paper tasks, phone calls and meetings
☐ Facility management
☐ Other

What is your age?

☐ 30 or under
☐ 31 - 40
☐ 41 - 50
☐ Over 50

What is your gender?

☐ Female
☐ Male

Personal Workspace Information

Which of the following best describes your personal workspace?

☐ Enclosed private office
☐ Cubicles with partitions above standing eye level
☐ Cubicles with partitions below standing eye level
☐ Other (please specify)

If other, describe your workspace:

____

What type of computer screen do you have?

☐ Laptop
☐ Flat panel screen

☐ Traditional screen
☐ Other
If other, describe your computer screen:

____

On a typical day, how long are you in your personal workspace?

☐ More than 6 hours
☐ 4-6 hours
☐ 2-4 hours
☐ Less than 2 hours

Are you able to see out a window while sitting in your workspace?

☐ Yes
☐ No

Do you like the view?

☐ Yes
☐ No

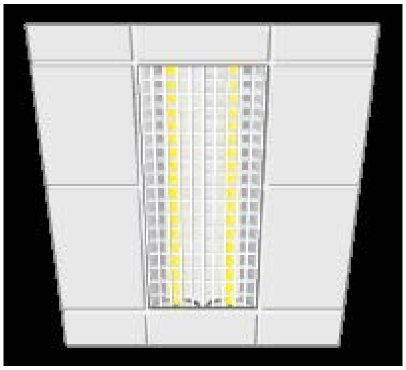
Do you sit adjacent to a window?

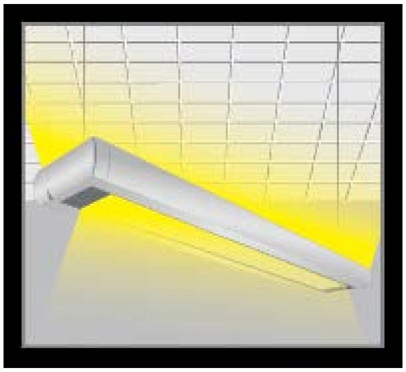
☐ Yes
☐ No

Overhead Lighting

Which of the following most closely resembles the overhead lighting in your immediate workspace?


☐


☐


☐

☐ I don't see my fixture here

Overall, is the lighting comfortable?

- [ ] Yes
- [ ] No

Task Lighting

Do you have task lighting?

- [ ] Yes
- [ ] No

Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?

- [ ] Undercabinet task light
- [ ] Desktop task light

What type of control do you have for your task lighting?

- [ ] On/Off switch
- [ ] Dimmer switch
- [ ] Other (please specify)
- [ ] Does not apply

Wall Lighting

Which of the following most closely resembles the lighting on the walls in your general office area?

- [ ] Uniformly bright walls
- [ ] Uneven light distribution on walls
- [ ] Accent lighting on artwork only
- [ ] Walls are dim
- [ ] Other
- [ ] Do not know

Lighting and Shading Controls

Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?

- [ ] Yes
- [ ] No
- [ ] Do not know / does not apply

Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?

- [ ] Yes
- [ ] No
- [ ] Do not know / does not apply

If your lights turn off automatically, can you turn them back on from your immediate work area?

- ☐ Yes
- ☐ No
- ☐ Does not apply

Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?

- ☐ Yes
- ☐ No
- ☐ Does not apply

How are your overhead lights controlled? (Check all that apply)

- ☐ Switch at wall
- ☐ Handheld remote
- ☐ Interface at your computer
- ☐ Automated system / controlled by building management
- ☐ Other (please specify)
- ☐ Do not know / Does not apply

If other, describe your overhead lighting control:

____

To what extent can light levels from your overhead lights be adjusted?

- ☐ Lights turn on and off only
- ☐ Light level settings are available for high, low, and/or medium
- ☐ Continuous dimming available

What type of shading system do you have to control the amount of daylight entering your windows?

- ☐ Manual blinds (e.g. Venetian blinds)
- ☐ Manual window shades (e.g. roller shades)
- ☐ Automatic blinds or shades
- ☐ Other (please specify)
- ☐ No shading control
- ☐ I have no daylight in my workspace

If other, describe your daylight control:

____

Can you control the amount of daylight entering your windows without affecting other occupants?

- ☐ Yes
- ☐ No

To what extent do you agree or disagree with the following statements about the lighting in your *personal* workspace?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
I am satisfied with my ability to control my overhead lighting.	☐	☐	☐	☐	☐	☐
I am satisfied with my ability to control my task lighting.	☐	☐	☐	☐	☐	☐
I am satisfied with my ability to control my window shades or blinds.	☐	☐	☐	☐	☐	☐

Lighting Quality

To what extent do you agree or disagree with the following statements about the lighting in your *personal* workspace?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
My work surface is evenly lighted without very bright or dim spots.	☐	☐	☐	☐	☐	☐
The lights flicker throughout the day.	☐	☐	☐	☐	☐	☐

To what extent do you agree or disagree with the following statements about the lighting in your *general* office area?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
The lighting fixtures in the general office area around my workspace are nice looking.	☐	☐	☐	☐	☐	☐
The lighting helps create a good image for the organization.	☐	☐	☐	☐	☐	☐

The room surfaces (walls, ceilings) have a pleasant brightness.	☐	☐	☐	☐	☐	☐

How would you rate the lighting in your workspace for each of the following tasks?

	Much too bright	Too bright	Just right	Too dim	Much too dim	Does not apply
Paper tasks (reading and writing)	☐	☐	☐	☐	☐	☐
Reading from a computer screen	☐	☐	☐	☐	☐	☐
Typing on a keyboard	☐	☐	☐	☐	☐	☐
Filing or locating papers	☐	☐	☐	☐	☐	☐
Face to face conversations	☐	☐	☐	☐	☐	☐

How often do you experience any of the following conditions when in your personal workspace during an average day? [For the purpose of answering these questions, consider the definition of glare to be unwanted light, e.g. loud noise is to sound as glare is to light.]

	Never	Rarely	Sometimes	Often	Always
Glare reflected from your work surface	☐	☐	☐	☐	☐
Glare from the light fixtures reflected on your computer screen	☐	☐	☐	☐	☐
Glare from the window reflected on your computer screen	☐	☐	☐	☐	☐
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	☐	☐	☐	☐	☐
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	☐	☐	☐	☐	☐
Glare from your task lighting	☐	☐	☐	☐	☐
Direct glare from a window	☐	☐	☐	☐	☐

Lighting comes in a range of colors, from a "warm" white to a "cool" white. "Warm" light is often described as slightly yellow in appearance, and "cool" light is often described as slightly blue in appearance. Please indicate:

	Very warm	Somewhat warm	Neutral	Somewhat cool	Very cool	Don't know
What is the color appearance of the lighting in your personal workspace?	☐	☐	☐	☐	☐	☐
What would you prefer for the color appearance of lighting in your personal workspace?	☐	☐	☐	☐	☐	☐

How often do you experience any of the following conditions when in your personal workspace?

	Never	Rarely	About once per month	About once per week	Every day
"Burning" or tired eyes after reading extensively	☐	☐	☐	☐	☐
"Burning" or tired eyes after using the computer extensively	☐	☐	☐	☐	☐
I have to take a break to let my eyes recover	☐	☐	☐	☐	☐
Headache that you think is caused by your lighting	☐	☐	☐	☐	☐

If you could change the lighting in your office, what would you do? Please check all that apply.

- ☐ Change the location of the overhead lighting fixtures relative to your workstation
- ☐ Make the overhead lighting fixtures produce more light
- ☐ Make the overhead lighting fixtures produce less light
- ☐ Make the overhead lighting fixtures less glary
- ☐ Change the aesthetic appearance of the lighting fixtures
- ☐ Change the color appearance of the lighting fixtures
- ☐ Add a task light
- ☐ Be able to control the brightness / light output of the overhead lighting fixtures with a dimmer or high/low switch
- ☐ Get better access to a window view
- ☐ Get better access to daylight
- ☐ Have light bulbs replaced faster when they burn out and fixtures repaired faster

when they break

☐ I would not change anything

Please feel free to submit any other comments about your lighting below:

Please feel free to submit any other comments about this survey below:

8.3.3.2Complete Occupant Survey Results

8.3.3.2.1 CH2SE Occupant Survey Results

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes the type of work you do?	People management, leadership, and/or training	9	10%	3	5%
	Computer aided design, engineering, or software development	0	0%	1	2%
	Combination of computer work, paper tasks, phone calls and meetings	81	90%	54	92%
	Facility Management	0	0%	0	0%
	Other	0	0%	1	2%
	Total	90	100%	59	100%
What is your age?	30 or under	23	23%	0	N/A
	31-40	24	24%	0	N/A
	41-50	15	15%	0	N/A
	over 50	40	39%	0	N/A
	Total	102	100%	0	N/A
What is your gender?	Female	49	48%	0	N/A
	Male	53	52%	0	N/A
	Total	102	100%	0	N/A

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes your personal workspace?	Enclosed private office	9	9%	4	6%
	Cubicles with Partitions above standing eye level	87	85%	52	83%
	Cubicles with partitions below standing eye level	6	6%	7	11%
	Other	0	0%	0	0%
	Total	102	100%	63	100%
What type of computer screen do you have?	Laptop	0	0%	0	N/A
	Flat Panel Screen	92	90%	0	N/A
	Traditional Screen	10	10%	0	N/A
	Other	0	0%	0	N/A
	Total	102	100%	0	N/A
On a typical day, how long are you in your personal workspace?	More than 6 hours	98	97%	62	98%
	4-6 hours	3	3%	0	0%
	2-4 hours	0	0%	1	2%
	Less than 2 hours	0	0%	0	0%
	Total	101	100%	63	100%
Are you able to see out a window while sitting in your workspace?	Yes	3	3%	3	5%
	No	98	97%	59	95%
	Total	101	100%	62	100%
If "Yes," do you like the view?	Yes	3	100%	2	67%
	No	0	0%	1	33%
	Total	3	100%	3	100%
Do you sit adjacent to a window?	Yes	2	67%	6	10%
	No	1	33%	56	90%
	Total	3	100%	62	100%
Which of the following most closely	Picture 1	16	16%	2	3%
	Picture 2	78	76%	4	6%
	Picture 3	1	1%	56	90%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
resembles the overhead lighting in your immediate work space?	Other	7	7%	0	0%
	Total	102	100%	62	100%
Overall, is the lighting comfortable?	Yes	60	59%	40	65%
	No	41	41%	22	35%
	Total	101	100%	62	100%
Do you have task lighting?	Yes	99	97%	57	92%
	No	3	3%	5	8%
	Total	102	100%	62	100%
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Under-cabinet Task light	91	96%	53	93%
	Desktop Task light	4	4%	4	7%
	Total	95	100%	57	100%
What type of control do you have for your task lighting?	On/Off switch	75	82%	0	N/A
	Dimmer switch	0	0%	0	N/A
	Other (please specify)	0	0%	0	N/A
	Does not apply	16	18%	0	N/A
	Total	91	100%	0	N/A
Which of the following most closely resembles the lighting on the walls in your general office area?	Uniformly bright walls	9	9%	9	15%
	Uneven light distribution on walls	16	16%	11	18%
	Accent Lighting on artwork only	1	1%	0	0%
	Walls are dim	26	26%	11	18%
	Other	5	5%	8	13%
	Do not know	44	44%	23	37%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Total	101		62	100%
Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	20	20%	0	N/A
	No	50	50%	0	N/A
	Do not know/ Does not apply	30	30%	0	N/A
	Total	100	100%	0	N/A
Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	11	11%	0	N/A
	No	56	56%	0	N/A
	Do not know/ Does not apply	33	33%	0	N/A
	Total	100	100%	0	N/A
If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	2	18%	0	N/A
	No	9	82%	0	N/A
	Do not know/ Does not apply	0	0%	0	N/A
	Total	11	100%	0	N/A
Can you control the	Yes	9	9%	0	N/A
	No	70	71%	0	N/A

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
overhead lights in your personal workspace without changing the lights in neighboring areas?	Do not know/ Does not apply	19	19%	0	N/A
	Total	98	100%	0	N/A
How are your overhead lights controlled (check all that apply)?	Switch at wall	28	28%	0	N/A
	Handheld remote	1	1%	0	N/A
	Interface at your computer	0	0%	0	N/A
	Automated system/controlled by building management	26	26%	0	N/A
	Other (Please specify)	3	3%	0	N/A
	Do not know/ Does not apply	46	46%	0	N/A
	Total	99		0	N/A
To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	90	95%	0	N/A
	Light level settings are available for high, low, and/or medium	3	3%	0	N/A
	Continuous dimming available	2	2%	0	N/A
	Total	95	100%	0	N/A
What type of shading system do you have to control the amount of daylight	Manual blinds (e.g., Venetian blinds)	12	12%	0	N/A
	Manual window shades(e.g., roller shades)	1	1%	0	N/A

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
entering your windows?	Automatic blinds or shades	0	0%	0	N/A
	Other (please specify)	0	0%	0	N/A
	No shading control	4	4%	0	N/A
	I have no daylight in my workspace	81	83%	0	N/A
	Total	98	100%	0	N/A
Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	3	23%	2	3%
	No	10	77%	18	29%
	Does not apply	0	0%	43	68%
	Total	13	100%	63	100%
I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	22	22%	20	32%
	Disagree	21	21%	13	21%
	Neutral	22	22%	9	14%
	Agree	11	11%	11	17%
	Strongly Agree	2	2%	5	8%
	Does not apply	20	20%	5	8%
	Total	98	100%	63	100%
I am satisfied with my ability to control my task lighting.	Strongly Disagree	10	10%	10	16%
	Disagree	17	17%	15	24%
	Neutral	26	27%	11	17%
	Agree	22	22%	19	30%
	Strongly Agree	16	16%	7	11%
	Does not apply	7	7%	1	2%
	Total	98	100%	63	100%
I am satisfied with my ability to	Strongly Agree	10	10%	0	N/A
	Disagree	6	6%	0	N/A
	Neutral	11	11%	0	N/A

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
control my window shades or blinds.	Agree	3	3%	0	N/A
	Strongly Agree	1	1%	0	N/A
	Does not apply	67	68%	0	N/A
	Total	98	100%	0	N/A
My work surface is evenly lighted without very bright or dim spots.	Strongly Disagree	18	19%	10	16%
	Disagree	40	42%	15	24%
	Neutral	10	10%	11	17%
	Agree	23	24%	19	30%
	Strongly Agree	4	4%	7	11%
	Does not apply	1	1%	1	2%
	Total	96	100%	63	100%
The lights flicker throughout the day.	Strongly Disagree	26	27%	14	23%
	Disagree	20	21%	14	23%
	Neutral	19	20%	7	11%
	Agree	14	15%	11	18%
	Strongly Agree	4	4%	10	16%
	Does not apply	12	13%	6	10%
	Total	95	100%	62	100%
My skin is an unnatural tone under the lighting.	Strongly Disagree	12	13%	0	N/A
	Disagree	13	14%	0	N/A
	Neutral	39	41%	0	N/A
	Agree	10	11%	0	N/A
	Strongly Agree	3	3%	0	N/A
	Does not apply	18	19%	0	N/A
	Total	95	100%	0	N/A
The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Disagree	14	15%	0	0%
	Disagree	32	33%	5	8%
	Neutral	35	36%	19	31%
	Agree	12	13%	30	49%
	Strongly Agree	1	1%	7	11%
	Does not apply	2	2%	0	0%
	Total	96	100%	61	100%
The lighting helps create a good image	Strongly Disagree	12	12%	2	3%
	Disagree	30	31%	7	11%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
for the organization.	Neutral	36	37%	18	30%
	Agree	12	12%	27	44%
	Strongly Agree	3	3%	5	8%
	Does not apply	4	4%	2	3%
	Total	97	100%	61	100%
The room surfaces (walls, ceilings) have a pleasant brightness.	Strongly Disagree	19	20%	7	11%
	Disagree	38	39%	16	26%
	Neutral	29	30%	19	31%
	Agree	7	7%	14	23%
	Strongly Agree	1	1%	4	6%
	Does not apply	3	3%	2	3%
	Total	97	100%	62	100%
Paper Tasks (reading and writing)	Much too Bright	0	0%	2	3%
	Too Bright	6	6%	1	2%
	Just Right	44	45%	29	48%
	Too Dim	36	37%	18	30%
	Much too Dim	12	12%	9	15%
	Does not apply	0	0%	1	2%
	Total	98	100%	60	100%
Reading from a computer screen	Much too Bright	0	0%	2	3%
	Too Bright	10	10%	2	3%
	Just Right	64	66%	41	66%
	Too Dim	16	16%	13	21%
	Much too Dim	7	7%	2	3%
	Does not apply	0	0%	2	3%
	Total	97	100%	62	100%
Typing on keyboard	Much too Bright	1	1%	3	5%
	Too Bright	5	5%	2	3%
	Just Right	70	72%	39	63%
	Too Dim	16	16%	14	23%
	Much too Dim	5	5%	3	5%
	Does not apply	0	0%	1	2%
	Total	97	100%	62	100%
Filing or locating	Much too Bright	0	0%	2	3%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
papers	Too Bright	3	3%	2	3%
	Just Right	55	57%	39	63%
	Too Dim	31	32%	14	23%
	Much too Dim	5	5%	4	6%
	Does not apply	3	3%	1	2%
	Total	97	100%	62	100%
Face to face conversations	Much too Bright	1	1%	2	3%
	Too Bright	2	2%	2	3%
	Just Right	72	75%	48	77%
	Too Dim	19	20%	7	11%
	Much too Dim	0	0%	2	3%
	Does not apply	2	2%	1	2%
	Total	96	100%	62	100%
Glare reflected from your work surface	Never	24	25%	21	34%
	Rarely	33	34%	22	36%
	Sometimes	28	29%	11	18%
	Often	9	9%	5	8%
	Always	3	3%	2	3%
	Total	97	100%	61	100%
Glare from the light fixtures reflected on your computer screen	Never	31	32%	26	43%
	Rarely	34	35%	27	45%
	Sometimes	21	22%	2	3%
	Often	5	5%	4	7%
	Always	6	6%	1	2%
	Total	97	100%	60	100%
Glare from the window reflected on your computer screen	Never	79	82%	50	85%
	Rarely	8	8%	8	14%
	Sometimes	4	4%	1	2%
	Often	2	2%	0	0%
	Always	3	3%	0	0%
	Total	96	100%	59	100%
Glare from the overhead lighting in your immediate	Never	38	39%	28	47%
	Rarely	30	31%	20	33%
	Sometimes	20	21%	5	8%
	Often	5	5%	2	3%
	Always	4	4%	5	8%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
workspace (usually experienced as discomfort)	Total	97	100%	60	100%
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	45	47%	36	59%
	Rarely	30	31%	17	28%
	Sometimes	16	17%	5	8%
	Often	3	3%	2	3%
	Always	2	2%	1	2%
	Total	96	100%	61	100%
Glare from your task lighting	Never	33	34%	29	48%
	Rarely	23	24%	17	28%
	Sometimes	25	26%	10	16%
	Often	9	9%	2	3%
	Always	7	7%	3	5%
	Total	97	100%	61	100%
Direct glare from a window	Never	77	82%	49	86%
	Rarely	6	6%	6	11%
	Sometimes	5	5%	2	4%
	Often	0	0%	0	0%
	Always	6	6%	0	0%
	Total	94	100%	57	100%
What is the color appearance of the lighting in your personal workspace?	Very Warm	7	7%	1	2%
	Somewhat Warm	18	19%	11	18%
	Neutral	33	34%	27	44%
	Somewhat Cool	22	23%	16	26%
	Very Cool	4	4%	3	5%
	Don't Know	12	13%	4	6%
	Total	96	100%	62	100%
What would you prefer for the color appearance	Very Warm	9	9%	3	5%
	Somewhat Warm	17	18%	16	26%
	Neutral	34	36%	24	39%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
of the lighting in your personal workspace?	Somewhat Cool	23	24%	8	13%
	Very Cool	2	2%	5	8%
	Don't Know	10	11%	6	10%
	Total	95	100%	62	100%
If you could change the lighting in your office, what would you do? Please check all that apply.	Change the location of the overhead lighting fixtures relative to your workstation	33	35%	13	21%
	Make the overhead lighting fixtures produce more light	48	51%	26	42%
	Make the overhead lighting fixtures produce less light	10	11%	12	19%
	Make the overhead lighting fixtures less glary	28	29%	10	16%
	Change the aesthetic appearance of the lighting fixtures	40	42%	4	6%
	Change the color appearance of the light produced by the lighting fixtures	36	38%	3	5%
	Add a task light	36	38%	22	35%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	42	44%	48	77%
	Get better access to a window view	56	59%	22	35%
	Get better access to daylight	63	66%	26	42%
	Have light bulbs replaced faster when they burn out and fixtures repaired faster when they break	25	26%	1	2%
	I would not change anything	5	5%	7	11%
	Total	95		62	

8.3.3.2.2 CW2NE Occupant Survey Results

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes the type of work	People management, leadership, and/or training	8	10%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
you do?	Computer aided design, engineering, or software development	3	4%	1	4%
	Combination of computer work, paper tasks, phone calls and meetings	65	82%	22	96%
	Facility Management	0	0%	0	0%
	Other	3	4%	0	0%
	Total	79	100%	23	100%
What is your age?	30 or under	7	9%	2	8%
	31-40	12	16%	6	25%
	41-50	19	25%	5	21%
	over 50	39	51%	11	46%
	Total	77	100%	24	100%
What is your gender?	Female	56	73%	17	74%
	Male	21	27%	6	26%
	Total	77	100%	23	100%
Which of the following best describes your personal workspace?	Enclosed private office	3	4%	0	0%
	Cubicles with Partitions above standing eye level	58	75%	21	88%
	Cubicles with partitions below standing eye level	15	19%	2	8%
	Other	1	1%	1	4%
	Total	77	100%	24	100%
What type of computer screen do you have?	Laptop	1	1%	0	0%
	Flat Panel Screen	75	96%	23	96%
	Traditional Screen	0	0%	1	4%
	Other	2	3%	0	0%
	Total	78	100%	24	100%
On a typical day, how long are you in your	More than 6 hours	71	91%	22	96%
	4-6 hours	7	9%	1	4%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
personal workspace?	2-4 hours	0	0%	0	0%
	Less than 2 hours	0	0%	0	0%
	Total	78	100%	23	100%
Are you able to see out a window while sitting in your workspace?	Yes	38	49%	9	39%
	No	40	51%	14	61%
	Total	78	100%	23	100%
If "Yes," do you like the view?	Yes	32	80%	8	89%
	No	8	20%	1	11%
	Total	40	100%	9	100%
Do you sit adjacent to a window?	Yes	28	36%	8	89%
	No	50	64%	1	11%
	Total	78	100%	9	100%
Which of the following most closely resembles the overhead lighting in your immediate work space?	Picture 1	52	71%	3	13%
	Picture 2	16	22%	5	22%
	Picture 3	2	3%	15	65%
	Other	3	4%	0	0%
	Total	73	100%	23	100%
Overall, is the lighting comfortable?	Yes	47	64%	17	77%
	No	27	36%	5	23%
	Total	74	100%	22	100%
Do you have task lighting?	Yes	75	100%	18	78%
	No	0	0%	5	22%
	Total	75	100%	23	100%
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Under-cabinet Task light	73	97%	18	100%
	Desktop Task light	2	3%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Total	75	100%	18	100%
What type of control do you have for your task lighting?	On/Off switch	67	96%	18	100%
	Dimmer switch	0	0%	0	0%
	Other (please specify)	1	1%	0	0%
	Does not apply	2	3%	0	0%
	Total	70	100%	18	100%
Which of the following most closely resembles the lighting on the walls in your general office area?	Uniformly bright walls	0	0%	4	17%
	Uneven light distribution on walls	28	36%	4	17%
	Accent Lighting on artwork only	0	0%	0	0%
	Walls are dim	14	18%	10	43%
	Other	6	8%	1	4%
	Do not know	29	38%	4	17%
	Total	77		23	100%
Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	44	61%	23	100%
	No	23	32%	0	0%
	Do not know/ Does not apply	5	7%	0	0%
	Total	72	100%	23	100%
Do the overhead lighting fixtures in your workspace turn off automatically (when you	Yes	47	66%	18	78%
	No	18	25%	4	17%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
leave the space, on a set schedule, or both)?	Do not know/ Does not apply	6	8%	1	4%
	Total	71	100%	23	100%
If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	25	36%	12	71%
	No	39	56%	4	24%
	Do not know/ Does not apply	6	9%	1	6%
	Total	70	100%	17	100%
Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	Yes	11	15%	11	50%
	No	59	83%	6	27%
	Do not know/ Does not apply	1	1%	5	23%
	Total	71	100%	22	100%
How are your overhead lights controlled (check all that apply)?	Switch at wall	61	85%	0	0%
	Handheld remote	0	0%	0	0%
	Interface at your computer	0	0%	0	0%
	Automated system/controlled by building management	42	58%	15	68%
	Other (Please specify)	1	1%	2	9%
	Do not know/ Does not apply	1	1%	7	32%
	Total	72		22	
To what extent can light levels	Lights turn on and off only	69	96%	11	50%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
from your overhead lights be adjusted?	Light level settings are available for high, low, and/or medium	2	3%	9	41%
	Continuous dimming available	1	1%	2	9%
	Total	72	100%	22	100%
What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	28	44%	9	41%
	Manual window shades(e.g., roller shades)	4	6%	0	0%
	Automatic blinds or shades	0	0%	0	0%
	Other (please specify)	1	2%	0	0%
	No shading control	2	3%	0	0%
	I have no daylight in my workspace	28	44%	13	59%
	Total	63	100%	22	100%
Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	20	29%	5	56%
	No	17	25%	4	44%
	Does not apply	32	46%	0	0%
	Total	69	100%	9	100%
I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	17	25%	4	18%
	Disagree	22	32%	10	45%
	Neutral	12	17%	4	18%
	Agree	9	13%	2	9%
	Strongly Agree	4	6%	1	5%
	Does not apply	5	7%	1	5%
	Total	69	100%	22	100%
I am satisfied	Strongly Disagree	2	3%	1	5%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
with my ability to control my task lighting.	Disagree	12	17%	6	29%
	Neutral	11	16%	2	10%
	Agree	23	33%	10	48%
	Strongly Agree	18	26%	2	10%
	Does not apply	3	4%	0	0%
	Total	69	100%	21	100%
I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	5	7%	1	5%
	Disagree	5	7%	0	0%
	Neutral	6	9%	5	23%
	Agree	13	19%	1	5%
	Strongly Agree	7	10%	3	14%
	Does not apply	33	48%	12	55%
	Total	69	100%	22	100%
My work surface is evenly lighted without very bright or dim spots.	Strongly Disagree	10	16%	1	5%
	Disagree	17	27%	6	29%
	Neutral	12	19%	2	10%
	Agree	20	32%	10	48%
	Strongly Agree	4	6%	2	10%
	Does not apply	0	0%	0	0%
	Total	63	100%	21	100%
The lights flicker throughout the day.	Strongly Disagree	8	13%	8	38%
	Disagree	22	35%	8	38%
	Neutral	16	26%	1	5%
	Agree	4	6%	1	5%
	Strongly Agree	6	10%	1	5%
	Does not apply	6	10%	2	10%
	Total	62	100%	21	100%
My skin is an unnatural tone under the lighting.	Strongly Disagree	10	16%	4	19%
	Disagree	15	24%	5	24%
	Neutral	25	40%	7	33%
	Agree	7	11%	2	10%
	Strongly Agree	1	2%	1	5%
	Does not apply	5	8%	2	10%
	Total	63	100%	21	100%
The lighting fixtures in the general office area around	Strongly Disagree	3	5%	0	0%
	Disagree	21	33%	2	9%
	Neutral	23	37%	11	50%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
my workspace are nice-looking.	Agree	12	19%	4	18%
	Strongly Agree	2	3%	5	23%
	Does not apply	2	3%	0	0%
	Total	63	100%	22	100%
The lighting helps create a good image for the organization.	Strongly Disagree	5	8%	0	0%
	Disagree	19	30%	2	9%
	Neutral	27	43%	13	59%
	Agree	7	11%	4	18%
	Strongly Agree	1	2%	3	14%
	Does not apply	4	6%	0	0%
	Total	63	100%	22	100%
The room surfaces (walls, ceilings) have a pleasant brightness.	Strongly Disagree	7	11%	6	27%
	Disagree	24	38%	5	23%
	Neutral	18	29%	7	32%
	Agree	12	19%	3	14%
	Strongly Agree	1	2%	1	5%
	Does not apply	1	2%	0	0%
	Total	63	100%	22	100%
Paper Tasks (reading and writing)	Much too Bright	3	5%	1	5%
	Too Bright	8	13%	1	5%
	Just Right	37	61%	13	59%
	Too Dim	11	18%	6	27%
	Much too Dim	2	3%	1	5%
	Does not apply	0	0%	0	0%
	Total	61	100%	22	100%
Reading from a computer screen	Much too Bright	4	7%	1	5%
	Too Bright	11	18%	3	14%
	Just Right	40	66%	14	64%
	Too Dim	6	10%	3	14%
	Much too Dim	0	0%	1	5%
	Does not apply	0	0%	0	0%
	Total	61	100%	22	100%
Typing on keyboard	Much too Bright	2	3%	0	0%
	Too Bright	8	13%	0	0%
	Just Right	44	72%	17	81%
	Too Dim	7	11%	3	14%
	Much too Dim	0	0%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Does not apply	0	0%	1	5%
	Total	61	100%	21	100%
Filing or locating papers	Much too Bright	1	2%	1	5%
	Too Bright	8	13%	1	5%
	Just Right	40	66%	13	59%
	Too Dim	10	16%	6	27%
	Much too Dim	1	2%	1	5%
	Does not apply	1	2%	0	0%
	Total	61	100%	22	100%
Face to face conversations	Much too Bright	1	2%	1	5%
	Too Bright	9	15%	0	0%
	Just Right	44	75%	19	90%
	Too Dim	3	5%	1	5%
	Much too Dim	1	2%	0	0%
	Does not apply	1	2%	0	0%
	Total	59	100%	21	100%
Glare reflected from your work surface	Never	11	18%	6	29%
	Rarely	20	33%	10	48%
	Sometimes	18	30%	5	24%
	Often	7	12%	0	0%
	Always	4	7%	0	0%
	Total	60	100%	21	100%
Glare from the light fixtures reflected on your computer screen	Never	16	27%	9	43%
	Rarely	18	30%	7	33%
	Sometimes	16	27%	4	19%
	Often	9	15%	1	5%
	Always	1	2%	0	0%
	Total	60	100%	21	100%
Glare from the window reflected on your computer screen	Never	35	60%	15	71%
	Rarely	10	17%	1	5%
	Sometimes	9	16%	4	19%
	Often	2	3%	0	0%
	Always	2	3%	1	5%
	Total	58	100%	21	100%
Glare from the overhead lighting in your immediate	Never	16	27%	10	48%
	Rarely	20	34%	6	29%
	Sometimes	12	20%	4	19%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
workspace (usually experienced as discomfort)	Often	6	10%	1	5%
	Always	5	8%	0	0%
	Total	59	100%	21	100%
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	23	39%	14	67%
	Rarely	20	34%	5	24%
	Sometimes	8	14%	1	5%
	Often	2	3%	1	5%
	Always	6	10%	0	0%
	Total	59	100%	21	100%
Glare from your task lighting	Never	16	28%	9	43%
	Rarely	16	28%	8	38%
	Sometimes	15	26%	2	10%
	Often	7	12%	2	10%
	Always	3	5%	0	0%
	Total	57	100%	21	100%
Direct glare from a window	Never	28	48%	11	55%
	Rarely	8	14%	2	10%
	Sometimes	14	24%	5	25%
	Often	4	7%	1	5%
	Always	4	7%	1	5%
	Total	58	100%	20	100%
What is the color appearance of the lighting in your personal workspace?	Very Warm	5	10%	1	5%
	Somewhat Warm	9	18%	5	25%
	Neutral	14	28%	5	25%
	Somewhat Cool	14	28%	4	20%
	Very Cool	8	16%	1	5%
	Don't Know	0	0%	4	20%
	Total	50	100%	20	100%
What would you prefer for the color appearance of	Very Warm	6	12%	1	5%
	Somewhat Warm	11	22%	0	0%
	Neutral	19	38%	6	30%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
the lighting in your personal workspace?	Somewhat Cool	13	26%	6	30%
	Very Cool	1	2%	1	5%
	Don't Know	0	0%	6	30%
	Total	50	100%	20	100%
If you could change the lighting in your office, what would you do? Please check all that apply.	Change the location of the overhead lighting fixtures relative to your workstation	24	41%	2	10%
	Make the overhead lighting fixtures produce more light	10	17%	7	33%
	Make the overhead lighting fixtures produce less light	15	26%	3	14%
	Make the overhead lighting fixtures less glary	32	55%	5	24%
	Change the aesthetic appearance of the lighting fixtures	20	34%	2	10%
	Change the color appearance of the light produced by the lighting fixtures	30	52%	3	14%
	Add a task light	12	21%	4	19%
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	35	60%	19	90%
	Get better access to a window view	16	28%	11	52%
	Get better access to daylight	22	38%	11	52%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Have light bulbs replaced faster when they burn out and fixtures repaired faster when they break	8	14%	1	5%
	I would not change anything	7	12%	2	10%
	Total	58		21	

8.3.3.2.3 PB10W Occupant Survey Results

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes the type of work you do?	People management, leadership, and/or training	1	4%	3	12%
	Computer aided design, engineering, or software development	1	4%	0	0%
	Combination of computer work, paper tasks, phone calls and meetings	23	92%	23	88%
	Facility Management	0	0%	0	0%
	Other	0	0%	0	0%
	Total	25	100%	26	100%
What is your age?	30 or under	7	21%	8	28%
	31-40	10	30%	3	10%
	41-50	9	27%	11	38%
	over 50	7	21%	7	24%
	Total	33	100%	29	100%
What is your gender?	Female	20	61%	20	69%
	Male	13	39%	9	31%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Total	33	100%	29	100%
Which of the following best describes your personal workspace?	Enclosed private office	31	97%	26	90%
	Cubicles with Partitions above standing eye level	0	0%	0	0%
	Cubicles with partitions below standing eye level	0	0%	0	0%
	Other	1	3%	3	10%
	Total	32	100%	29	100%
What type of computer screen do you have?	Laptop	0	0%	0	0%
	Flat Panel Screen	31	97%	25	86%
	Traditional Screen	0	0%	4	14%
	Other	1	3%	0	0%
	Total	32	100%	29	100%
On a typical day, how long are you in your personal workspace?	More than 6 hours	26	81%	21	72%
	4-6 hours	6	19%	8	28%
	2-4 hours	0	0%	0	0%
	Less than 2 hours	0	0%	0	0%
	Total	32	100%	29	100%
Are you able to see out a window while sitting in your workspace?	Yes	19	59%	10	34%
	No	13	41%	19	66%
	Total	32	100%	29	100%
If "Yes," do you like the view?	Yes	13	68%	7	70%
	No	6	32%	3	30%
	Total	19	100%	10	100%
Do you sit adjacent to a window?	Yes	19	100%	9	90%
	No	0	0%	1	10%
	Total	19	100%	10	100%
Which of the following most closely resembles the overhead	Picture 1	16	50%	11	38%
	Picture 2	15	47%	16	55%
	Picture 3	0	0%	0	0%
	Other	1	3%	2	7%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
lighting in your immediate work space?	Total	32	100%	29	100%
Overall, is the lighting comfortable?	Yes	23	72%	21	75%
	No	9	28%	7	25%
	Total	32	100%	28	100%
Do you have task lighting?	Yes	4	13%	5	18%
	No	28	88%	23	82%
	Total	32	100%	28	100%
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Undercabinet Task light	0	0%	0	0%
	Destop Task light	4	100%	5	100%
	Total	4	100%	5	100%
What type of control do you have for your task lighting?	On/Off switch	4	100%	4	80%
	Dimmer switch	0	0%	1	20%
	Other (please specify)	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	4	100%	5	100%
Which of the following most closely resembles the lighting on the walls in your general office area?	Uniformly bright walls	10	31%	10	34%
	Uneven light distribution on walls	8	25%	5	17%
	Accent Lighting on artwork only	1	3%	1	3%
	Walls are dim	2	6%	6	21%
	Other	0	0%	2	7%
	Do not know	11	34%	5	17%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Total	32		29	100%
Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	0	0%	24	83%
	No	32	100%	5	17%
	Do not know/ Does not apply	0	0%	0	0%
	Total	32	100%	29	100%
Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	0	0%	25	86%
	No	32	100%	4	14%
	Do not know/ Does not apply	0	0%	0	0%
	Total	32	100%	29	100%
If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	0	N/A	19	76%
	No	0	N/A	5	20%
	Do not know/ Does not apply	0	N/A	1	4%
	Total	0	N/A	25	100%
Can you control the overhead lights in your	Yes	24	75%	12	41%
	No	4	13%	14	48%
	Do not know/ Does not apply	4	13%	3	10%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
personal workspace without changing the lights in neighboring areas?	Total	32	100%	29	100%
How are your overhead lights controlled (check all that apply)?	Switch at wall	32	100%	23	79%
	Handheld remote	0	0%	0	0%
	Interface at your computer	0	0%	0	0%
	Automated system/controlled by building management	0	0%	9	31%
	Other (Please specify)	0	0%	0	0%
	Do not know/ Does not apply	0	0%	1	3%
	Total	32		29	
To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	29	94%	28	97%
	Light level settings are available for high, low, and/or medium	2	6%	0	0%
	Continuous dimming available	0	0%	1	3%
	Total	31	100%	29	100%
What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	17	55%	10	34%
	Manual windo shades(e.g.,roller shades)	1	3%	0	0%
	Automatic blinds or shades	0	0%	0	0%
	Other (please specify)	0	0%	0	0%
	No shading control	0	0%	2	7%
	I have no daylight in my workspace	13	42%	17	59%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Total	31	100%	29	100%
Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	18	100%	10	100%
	No	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	18	100%	10	100%
I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	1	3%	6	21%
	Disagree	8	26%	11	38%
	Neutral	7	23%	3	10%
	Agree	7	23%	7	24%
	Strongly Agree	6	19%	2	7%
	Does not apply	2	6%	0	0%
	Total	31	100%	29	100%
I am satisfied with my ability to control my task lighting.	Strongly Disagree	0	0%	1	3%
	Disagree	2	6%	8	28%
	Neutral	5	16%	2	7%
	Agree	1	3%	13	45%
	Strongly Agree	4	13%	5	17%
	Does not apply	19	61%	0	0%
	Total	31	100%	29	100%
I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	2	6%	0	0%
	Disagree	3	10%	2	7%
	Neutral	4	13%	0	0%
	Agree	5	16%	6	21%
	Strongly Agree	6	19%	5	17%
	Does not apply	11	35%	16	55%
	Total	31	100%	29	100%
My work surface is evenly lighted without very bright or dim spots.	Strongly Disagree	3	10%	1	3%
	Disagree	6	20%	8	28%
	Neutral	6	20%	2	7%
	Agree	11	37%	13	45%
	Strongly Agree	3	10%	5	17%
	Does not apply	1	3%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Total	30	100%	29	100%
The lights flicker throughout the day.	Strongly Disagree	10	33%	7	24%
	Disagree	12	40%	13	45%
	Neutral	3	10%	2	7%
	Agree	1	3%	2	7%
	Strongly Agree	0	0%	1	3%
	Does not apply	4	13%	4	14%
	Total	30	100%	29	100%
My skin is an unnatural tone under the lighting.	Strongly Disagree	4	13%	5	17%
	Disagree	5	17%	11	38%
	Neutral	12	40%	6	21%
	Agree	7	23%	3	10%
	Strongly Agree	0	0%	0	0%
	Does not apply	2	7%	4	14%
	Total	30	100%	29	100%
The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Disagree	3	10%	1	3%
	Disagree	9	31%	5	17%
	Neutral	10	34%	17	59%
	Agree	6	21%	6	21%
	Strongly Agree	0	0%	0	0%
	Does not apply	1	3%	0	0%
	Total	29	100%	29	100%
The lighting helps create a good image for the organization.	Strongly Disagree	6	20%	2	7%
	Disagree	4	13%	5	17%
	Neutral	12	40%	17	59%
	Agree	5	17%	5	17%
	Strongly Agree	2	7%	0	0%
	Does not apply	1	3%	0	0%
	Total	30	100%	29	100%
The room surfaces (walls, ceilings) have a pleasant brightness.	Strongly Disagree	3	10%	2	7%
	Disagree	11	37%	9	31%
	Neutral	8	27%	12	41%
	Agree	6	20%	6	21%
	Strongly Agree	1	3%	0	0%
	Does not apply	1	3%	0	0%
	Total	30	100%	29	100%
Paper Tasks	Much too Bright	0	0%	1	3%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
(reading and writing)	Too Bright	6	20%	6	21%
	Just Right	16	53%	17	59%
	Too Dim	8	27%	4	14%
	Much too Dim	0	0%	1	3%
	Does not apply	0	0%	0	0%
	Total	30	100%	29	100%
Reading from a computer screen	Much too Bright	0	0%	0	0%
	Too Bright	11	37%	12	41%
	Just Right	17	57%	14	48%
	Too Dim	2	7%	3	10%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	30	100%	29	100%
Typing on keyboard	Much too Bright	0	0%	0	0%
	Too Bright	5	17%	5	18%
	Just Right	22	73%	20	71%
	Too Dim	3	10%	3	11%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	30	100%	28	100%
Filing or locating papers	Much too Bright	0	0%	0	0%
	Too Bright	2	7%	4	14%
	Just Right	22	73%	20	71%
	Too Dim	5	17%	4	14%
	Much too Dim	0	0%	0	0%
	Does not apply	1	3%	0	0%
	Total	30	100%	28	100%
Face to face	Much too Bright	1	3%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
conversations	Too Bright	5	17%	7	25%
	Just Right	24	80%	17	61%
	Too Dim	0	0%	4	14%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	30	100%	28	100%
Glare reflected from your work surface	Never	6	20%	8	29%
	Rarely	11	37%	9	32%
	Sometimes	11	37%	8	29%
	Often	2	7%	3	11%
	Always	0	0%	0	0%
	Total	30	100%	28	100%
Glare from the light fixtures reflected on your computer screen	Never	9	30%	11	39%
	Rarely	11	37%	10	36%
	Sometimes	7	23%	6	21%
	Often	2	7%	1	4%
	Always	1	3%	0	0%
	Total	30	100%	28	100%
Glare from the window reflected on your computer screen	Never	9	30%	15	54%
	Rarely	6	20%	8	29%
	Sometimes	9	30%	1	4%
	Often	3	10%	2	7%
	Always	3	10%	2	7%
	Total	30	100%	28	100%
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	9	30%	7	25%
	Rarely	11	37%	13	46%
	Sometimes	7	23%	5	18%
	Often	2	7%	2	7%
	Always	1	3%	1	4%
	Total	30	100%	28	100%
Direct glare from the light fixtures beyond your immediate	Never	19	63%	14	50%
	Rarely	8	27%	11	39%
	Sometimes	1	3%	0	0%
	Often	2	7%	2	7%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
workspace (the light fixtures appear too bright)	Always	0	0%	1	4%
	Total	30	100%	28	100%
Glare from your task lighting	Never	19	66%	18	67%
	Rarely	4	14%	8	30%
	Sometimes	3	10%	1	4%
	Often	1	3%	0	0%
	Always	2	7%	0	0%
	Total	29	100%	27	100%
Direct glare from a window	Never	12	40%	15	54%
	Rarely	4	13%	6	21%
	Sometimes	8	27%	1	4%
	Often	4	13%	3	11%
	Always	2	7%	3	11%
	Total	30	100%	28	100%
What is the color appearance of the lighting in your personal workspace?	Very Warm	3	10%	0	0%
	Somewhat Warm	4	13%	6	21%
	Neutral	8	27%	8	29%
	Somewhat Cool	8	27%	7	25%
	Very Cool	1	3%	5	18%
	Don't Know	6	20%	2	7%
	Total	30	100%	28	100%
What would you prefer for the color appearance of the lighting in your personal workspace?	Very Warm	1	3%	1	4%
	Somewhat Warm	3	10%	18	64%
	Neutral	8	28%	4	14%
	Somewhat Cool	9	31%	3	11%
	Very Cool	0	0%	1	4%
	Don't Know	8	28%	1	4%
	Total	29	100%	28	100%
If you could change the lighting in your office, what would you do? Please check all that apply.	Change the location of the overhead lighting fixtures relative to your workstation	3	10%	3	11%
	Make the overhead lighting fixtures produce more light	7	24%	5	18%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Make the overhead lighting fixtures produce less light	5	17%	6	21%
	Make the overhead lighting fixtures less glary	8	28%	10	36%
	Change the aesthetic appearance of the lighting fixtures	12	41%	10	36%
	Change the color appearance of the light produced by the lighting fixtures	14	48%	16	57%
	Add a task light	16	55%	17	61%
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	22	76%	23	82%
	Get better access to a window view	8	28%	13	46%
	Get better acces to daylight	10	34%	13	46%
	Have lightbulbs replaced faster when they burn out and fixtures repaired faster when they break	0	0%	0	0%
	I would not change anything	1	3%	1	4%
	Total	29		28	

8.3.3.2.4 RD8N Occupant Survey Results

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes the type of work you do?	People management, leadership, and/or training	6	17%	6	13%
	Computer aided design, engineering, or software development	3	9%	3	7%
	Combination of computer work, paper tasks, phone calls and meetings	25	71%	37	80%
	Facility Management	1	3%	0	0%
	Other	0	0%	0	0%
	Total	35	100%	46	100%
What is your age?	30 or under	11	31%	10	21%
	31-40	7	20%	10	21%
	41-50	7	20%	12	25%
	over 50	10	29%	16	33%
	Total	35	100%	48	100%
What is your gender?	Female	4	11%	13	27%
	Male	31	89%	35	73%
	Total	35	100%	48	100%
Which of the following best describes your personal workspace?	Enclosed private office	2	6%	4	9%
	Cubicles with Partitions above standing eye level	9	26%	19	41%
	Cubicles with partitions below standing eye level	19	54%	22	48%
	Other	5	14%	1	2%
	Total	35	100%	46	100%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
What type of computer screen do you have?	Laptop	0	0%	0	0%
	Flat Panel Screen	30	88%	47	100%
	Traditional Screen	4	12%	0	0%
	Other	0	0%	0	0%
	Total	34	100%	47	100%
On a typical day, how long are you in your personal workspace?	More than 6 hours	27	77%	41	87%
	4-6 hours	8	23%	6	13%
	2-4 hours	0	0%	0	0%
	Less than 2 hours	0	0%	0	0%
	Total	35	100%	47	100%
Are you able to see out a window while sitting in your workspace?	Yes	21	60%	26	55%
	No	14	40%	21	45%
	Total	35	100%	47	100%
If "Yes," do you like the view?	Yes	17	85%	25	96%
	No	3	15%	1	4%
	Total	20	100%	26	100%
Do you sit adjacent to a window?	Yes	14	67%	19	73%
	No	7	33%	7	27%
	Total	21	100%	26	100%
Which of the following most closely resembles the overhead lighting in your immediate work space?	Picture 1	2	6%	8	17%
	Picture 2	32	94%	16	34%
	Picture 3	0	0%	23	49%
	Other	0	0%	0	0%
	Total	34	100%	47	100%
Overall, is the lighting comfortable?	Yes	32	94%	43	91%
	No	2	6%	4	9%
	Total	34	100%	47	100%
Do you have task lighting?	Yes	33	97%	40	89%
	No	1	3%	5	11%
	Total	34	100%	45	100%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Under-cabinet Task light	33	100%	38	97%
	Desktop Task light	0	0%	1	3%
	Total	33	100%	39	100%
What type of control do you have for your task lighting?	On/Off switch	27	82%	39	98%
	Dimmer switch	1	3%	0	0%
	Other (please specify)	0	0%	0	0%
	Does not apply	5	15%	1	3%
	Total	33	100%	40	100%
Which of the following most closely resembles the lighting on the walls in your general office area?	Uniformly bright walls	15	45%	13	28%
	Uneven light distribution on walls	6	18%	10	21%
	Accent Lighting on artwork only	0	0%	2	4%
	Walls are dim	2	6%	2	4%
	Other	1	3%	6	13%
	Do not know	9	27%	14	30%
	Total	33		47	100%
Do the overhead lighting fixtures in	Yes	26	76%	46	98%
	No	4	12%	0	0%
	Do not know/ Does not apply	4	12%	1	2%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Total	34	100%	47	100%
Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	23	68%	44	94%
	No	4	12%	2	4%
	Do not know/ Does not apply	7	21%	1	2%
	Total	34	100%	47	100%
If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	13	57%	36	82%
	No	10	43%	4	9%
	Do not know/ Does not apply	0	0%	4	9%
	Total	23	100%	44	100%
Can you control the overhead lights in your	Yes	6	18%	25	53%
	No	26	76%	16	34%
	Do not know/ Does not apply	2	6%	6	13%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
personal workspace without changing the lights in neighboring areas?	Total	34	100%	47	100%
How are your overhead lights controlled (check all that apply)?	Switch at wall	12	35%	4	9%
	Handheld remote	0	0%	0	0%
	Interface at your computer	0	0%	1	2%
	Automated system/controlled by building management	18	53%	34	72%
	Other (Please specify)	6	18%	5	11%
	Do not know/ Does not apply	10	29%	4	9%
	Total	34		47	
To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	31	91%	30	65%
	Light level settings are available for high, low, and/or medium	2	6%	6	13%
	Continuous dimming available	1	3%	10	22%
	Total	34	100%	46	100%
What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	27	79%	34	76%
	Manual window shades(e.g., roller shades)	3	9%	6	13%
	Automatic blinds or shades	0	0%	0	0%
	Other (please specify)	0	0%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	No shading control	0	0%	1	2%
	I have no daylight in my workspace	4	12%	4	9%
	Total	34	100%	45	100%
Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	5	17%	6	15%
	No	25	83%	34	85%
	Does not apply	0	0%	0	0%
	Total	30	100%	40	100%
I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	2	6%	4	9%
	Disagree	9	26%	6	13%
	Neutral	5	15%	8	18%
	Agree	9	26%	14	31%
	Strongly Agree	5	15%	12	27%
	Does not apply	4	12%	1	2%
	Total	34	100%	45	100%
I am satisfied with my ability to control my task lighting.	Strongly Disagree	0	0%	3	7%
	Disagree	2	6%	4	9%
	Neutral	9	26%	7	16%
	Agree	14	41%	20	44%
	Strongly Agree	7	21%	11	24%
	Does not apply	2	6%	0	0%
	Total	34	100%	45	100%
I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	3	9%	1	2%
	Disagree	7	21%	2	5%
	Neutral	7	21%	4	9%
	Agree	7	21%	18	41%
	Strongly Agree	5	15%	12	27%
	Does not apply	5	15%	7	16%
	Total	34	100%	44	100%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
My work surface is evenly lighted without very bright or dim spots.	Strongly Disagree	0	0%	3	7%
	Disagree	5	15%	4	9%
	Neutral	6	18%	7	16%
	Agree	17	50%	20	44%
	Strongly Agree	6	18%	11	24%
	Does not apply	0	0%	0	0%
	Total	34	100%	45	100%
The lights flicker throughout the day.	Strongly Disagree	12	35%	16	36%
	Disagree	11	32%	18	41%
	Neutral	6	18%	3	7%
	Agree	3	9%	2	5%
	Strongly Agree	0	0%	2	5%
	Does not apply	2	6%	3	7%
	Total	34	100%	44	100%
My skin is an unnatural tone under the lighting.	Strongly Disagree	9	26%	14	32%
	Disagree	12	35%	15	34%
	Neutral	6	18%	10	23%
	Agree	2	6%	2	5%
	Strongly Agree	0	0%	1	2%
	Does not apply	5	15%	2	5%
	Total	34	100%	44	100%
The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Disagree	0	0%	3	7%
	Disagree	4	12%	1	2%
	Neutral	16	47%	5	11%
	Agree	11	32%	23	52%
	Strongly Agree	3	9%	12	27%
	Does not apply	0	0%	0	0%
	Total	34	100%	44	100%
The lighting helps create a good image for the organization.	Strongly Disagree	0	0%	2	5%
	Disagree	8	24%	1	2%
	Neutral	14	41%	5	12%
	Agree	10	29%	21	49%
	Strongly Agree	2	6%	13	30%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Does not apply	0	0%	1	2%
	Total	34	100%	43	100%
The room surfaces (walls, ceilings) have a pleasant brightness.	Strongly Disagree	0	0%	1	2%
	Disagree	5	15%	1	2%
	Neutral	11	32%	4	9%
	Agree	14	41%	27	63%
	Strongly Agree	4	12%	10	23%
	Does not apply	0	0%	0	0%
	Total	34	100%	43	100%
Paper Tasks (reading and writing)	Much too Bright	0	0%	0	0%
	Too Bright	2	6%	2	5%
	Just Right	28	85%	40	91%
	Too Dim	2	6%	2	5%
	Much too Dim	0	0%	0	0%
	Does not apply	1	3%	0	0%
	Total	33	100%	44	100%
Reading from a computer screen	Much too Bright	1	3%	0	0%
	Too Bright	5	15%	5	11%
	Just Right	27	82%	39	87%
	Too Dim	0	0%	1	2%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	33	100%	45	100%
Typing on keyboard	Much too Bright	0	0%	0	0%
	Too Bright	4	12%	1	2%
	Just Right	29	88%	42	98%
	Too Dim	0	0%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	33	100%	43	100%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Filing or locating papers	Much too Bright	0	0%	0	0%
	Too Bright	0	0%	2	5%
	Just Right	32	97%	38	88%
	Too Dim	1	3%	3	7%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	33	100%	43	100%
Face to face conversations	Much too Bright	0	0%	0	0%
	Too Bright	2	6%	2	5%
	Just Right	31	94%	42	95%
	Too Dim	0	0%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	33	100%	44	100%
Glare reflected from your work surface	Never	7	22%	14	31%
	Rarely	13	41%	12	27%
	Sometimes	10	31%	18	40%
	Often	1	3%	1	2%
	Always	1	3%	0	0%
	Total	32	100%	45	100%
Glare from the light fixtures reflected on your computer screen	Never	9	27%	14	31%
	Rarely	9	27%	18	40%
	Sometimes	11	33%	12	27%
	Often	3	9%	1	2%
	Always	1	3%	0	0%
	Total	33	100%	45	100%
Glare from the window reflected on your computer	Never	9	27%	15	33%
	Rarely	6	18%	11	24%
	Sometimes	9	27%	14	31%
	Often	7	21%	5	11%
	Always	2	6%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
screen	Total	33	100%	45	100%
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	13	39%	15	33%
	Rarely	11	33%	22	49%
	Sometimes	6	18%	6	13%
	Often	2	6%	2	4%
	Always	1	3%	0	0%
	Total	33	100%	45	100%
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	15	45%	26	58%
	Rarely	8	24%	14	31%
	Sometimes	6	18%	4	9%
	Often	3	9%	1	2%
	Always	1	3%	0	0%
	Total	33	100%	45	100%
Glare from your task lighting	Never	16	48%	26	58%
	Rarely	11	33%	13	29%
	Sometimes	5	15%	6	13%
	Often	1	3%	0	0%
	Always	0	0%	0	0%
	Total	33	100%	45	100%
Direct glare from a window	Never	8	24%	17	40%
	Rarely	7	21%	13	30%
	Sometimes	9	27%	8	19%
	Often	7	21%	5	12%
	Always	2	6%	0	0%
	Total	33	100%	43	100%
What is the color appearance of the lighting in your personal workspace?	Very Warm	0	0%	1	2%
	Somewhat Warm	5	15%	17	38%
	Neutral	15	45%	20	44%
	Somewhat Cool	7	21%	6	13%
	Very Cool	2	6%	0	0%
	Don't Know	4	12%	1	2%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Total	33	100%	45	100%
What would you prefer for the color appearance of the lighting in your personal workspace?	Very Warm	0	0%	1	2%
	Somewhat Warm	2	6%	14	31%
	Neutral	18	55%	19	42%
	Somewhat Cool	6	18%	9	20%
	Very Cool	1	3%	0	0%
	Don't Know	6	18%	2	4%
	Total	33	100%	45	100%
If you could change the lighting in your office, what would you do? Please check all that apply.	Change the location of the overhead lighting fixtures relative to your workstation	3	9%	0	0%
	Make the overhead lighting fixtures produce more light	4	13%	3	7%
	Make the overhead lighting fixtures produce less light	4	13%	4	10%
	Make the overhead lighting fixtures less glary	10	31%	3	7%
	Change the aesthetic appearance of the lighting fixtures	5	16%	2	5%
	Change the color appearance of the light produced by the lighting fixtures	9	28%	3	7%
	Add a task light	2	6%	2	5%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	15	47%	19	46%
	Get better access to a window view	8	25%	9	22%
	Get better access to daylight	9	28%	7	17%
	Have light bulbs replaced faster when they burn out and fixtures repaired faster when they break	3	9%	1	2%
	I would not change anything	11	34%	14	34%
	Total	32		41	

8.3.3.2.5 RD13N Complete Occupant Survey Results

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes the type of work you do?	People management, leadership, and/or training	2	13%	2	9%
	Computer aided design, engineering, or software development	9	56%	10	45%
	Combination of computer work, paper tasks, phone calls and meetings	4	25%	9	41%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Facility Management	1	6%	1	5%
	Other	0	0%	0	0%
	Total	16	100%	22	100%
What is your age?	30 or under	0	0%	1	5%
	31-40	3	19%	0	0%
	41-50	4	25%	5	23%
	over 50	9	56%	16	73%
	Total	16	100%	22	100%
What is your gender?	Female	4	25%	6	27%
	Male	12	75%	16	73%
	Total	16	100%	22	100%
Which of the following best describes your personal workspace?	Enclosed private office	4	24%	10	45%
	Cubicles with Partitions above standing eye level	6	35%	7	32%
	Cubicles with partitions below standing eye level	6	35%	4	18%
	Other	1	6%	1	5%
	Total	17	100%	22	100%
What type of computer screen do you have?	Laptop	0	0%	0	0%
	Flat Panel Screen	15	94%	21	95%
	Traditional Screen	0	0%	0	0%
	Other	1	6%	1	5%
	Total	16	100%	22	100%
On a typical day, how long are you in your personal workspace?	More than 6 hours	15	94%	20	91%
	4-6 hours	1	6%	2	9%
	2-4 hours	0	0%	0	0%
	Less than 2 hours	0	0%	0	0%
	Total	16	100%	22	100%
Are you able to see out a window while sitting in your workspace?	Yes	9	56%	13	59%
	No	7	44%	9	41%
	Total	16	100%	22	100%
If "Yes," do you like the view?	Yes	7	88%	12	92%
	No	1	13%	1	8%
	Total	8	100%	13	100%
Do you sit adjacent	Yes	7	78%	8	62%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
to a window?	No	2	22%	5	38%
	Total	9	100%	13	100%
Which of the following most closely resembles the overhead lighting in your immediate work space?	Picture 1	1	6%	4	18%
	Picture 2	15	94%	14	64%
	Picture 3	0	0%	4	18%
	Other	0	0%	0	0%
	Total	16	100%	22	100%
Overall, is the lighting comfortable?	Yes	13	81%	13	62%
	No	3	19%	8	38%
	Total	16	100%	21	100%
Do you have task lighting?	Yes	10	63%	6	29%
	No	6	38%	15	71%
	Total	16	100%	21	100%
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Undercabinet Task light	9	90%	5	83%
	Destop Task light	1	10%	1	17%
	Total	10	100%	6	100%
What type of control do you have for your task lighting?	On/Off switch	6	60%	5	83%
	Dimmer switch	0	0%	1	17%
	Other (please specify)	1	10%	0	0%
	Does not apply	3	30%	0	0%
	Total	10	100%	6	100%
Which of the following most closely resembles the lighting on the walls in your general office area?	Uniformly bright walls	3	19%	5	24%
	Uneven light distribution on walls	6	38%	9	43%
	Accent Lighting on artwork only	0	0%	0	0%
	Walls are dim	3	19%	2	10%
	Other	2	13%	2	10%
	Do not know	2	13%	3	14%
	Total	16		21	100%
Do the overhead lighting fixtures in your workspace turn on	Yes	13	81%	20	91%
	No	3	19%	2	9%
	Do not know/ Does not apply	0	0%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
automatically (when you enter the space, on a set schedule, or both)?	Total	16	100%	22	100%
Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	15	94%	20	91%
	No	1	6%	2	9%
	Do not know/ Does not apply	0	0%	0	0%
	Total	16	100%	22	100%
If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	10	67%	17	85%
	No	5	33%	3	15%
	Do not know/ Does not apply	0	0%	0	0%
	Total	15	100%	20	100%
Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	Yes	5	33%	12	55%
	No	10	67%	8	36%
	Do not know/ Does not apply	0	0%	2	9%
	Total	15	100%	22	100%
How are your overhead lights controlled (check all that apply)?	Switch at wall	6	40%	7	32%
	Handheld remote	0	0%	0	0%
	Interface at your computer	0	0%	0	0%
	Automated system/controlled by building management	9	60%	16	73%
	Other (Please specify)	3	20%	2	9%
	Do not know/ Does not apply	2	13%	0	0%
	Total	15		22	
To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	14	100%	17	77%
	Light level settings are available for high, low, and/or medium	0	0%	4	18%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Continuous dimming available	0	0%	1	5%
	Total	14	100%	22	100%
What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	11	69%	13	59%
	Manual windo shades(e.g.,roller shades)	1	6%	2	9%
	Automatic blinds or shades	0	0%	0	0%
	Other (please specify)	1	6%	0	0%
	No shading control	1	6%	1	5%
	I have no daylight in my workspace	2	13%	6	27%
	Total	16	100%	22	100%
Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	4	31%	10	67%
	No	9	69%	5	33%
	Does not apply	0	0%	0	0%
	Total	13	100%	15	100%
I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	1	6%	3	14%
	Disagree	3	19%	5	23%
	Neutral	2	13%	5	23%
	Agree	5	31%	7	32%
	Strongly Agree	5	31%	2	9%
	Does not apply	0	0%	0	0%
	Total	16	100%	22	100%
I am satisfied with my ability to control my task lighting.	Strongly Disagree	1	6%	1	5%
	Disagree	1	6%	4	19%
	Neutral	2	13%	0	0%
	Agree	6	38%	13	62%
	Strongly Agree	4	25%	3	14%
	Does not apply	2	13%	0	0%
	Total	16	100%	21	100%
I am satisfied with my ability to	Strongly Agree	0	0%	0	0%
	Disagree	2	13%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
control my window shades or blinds.	Neutral	0	0%	1	5%
	Agree	5	31%	9	41%
	Strongly Agree	5	31%	5	23%
	Does not apply	4	25%	7	32%
	Total	16	100%	22	100%
My work surface is evenly lighted without very bright or dim spots.	Strongly Disagree	1	6%	1	5%
	Disagree	3	19%	4	19%
	Neutral	3	19%	0	0%
	Agree	4	25%	13	62%
	Strongly Agree	5	31%	3	14%
	Does not apply	0	0%	0	0%
	Total	16	100%	21	100%
The lights flicker throughout the day.	Strongly Disagree	6	38%	6	29%
	Disagree	9	56%	8	38%
	Neutral	1	6%	3	14%
	Agree	0	0%	3	14%
	Strongly Agree	0	0%	0	0%
	Does not apply	0	0%	1	5%
	Total	16	100%	21	100%
My skin is an unnatural tone under the lighting.	Strongly Disagree	6	38%	4	19%
	Disagree	7	44%	11	52%
	Neutral	2	13%	3	14%
	Agree	0	0%	0	0%
	Strongly Agree	1	6%	0	0%
	Does not apply	0	0%	3	14%
	Total	16	100%	21	100%
The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Disagree	2	13%	0	0%
	Disagree	0	0%	1	5%
	Neutral	8	50%	8	36%
	Agree	4	25%	12	55%
	Strongly Agree	1	6%	1	5%
	Does not apply	1	6%	0	0%
	Total	16	100%	22	100%
The lighting helps create a good image for the organization.	Strongly Disagree	1	6%	2	9%
	Disagree	1	6%	3	14%
	Neutral	7	44%	7	32%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Agree	5	31%	8	36%
	Strongly Agree	1	6%	2	9%
	Does not apply	1	6%	0	0%
	Total	16	100%	22	100%
The room surfaces (walls, ceilings) have a pleasant brightness.	Strongly Disagree	1	6%	4	18%
	Disagree	3	19%	7	32%
	Neutral	3	19%	0	0%
	Agree	7	44%	10	45%
	Strongly Agree	2	13%	1	5%
	Does not apply	0	0%	0	0%
	Total	16	100%	22	100%
Paper Tasks (reading and writing)	Much too Bright	0	0%	1	5%
	Too Bright	2	13%	1	5%
	Just Right	12	75%	8	36%
	Too Dim	2	13%	10	45%
	Much too Dim	0	0%	2	9%
	Does not apply	0	0%	0	0%
	Total	16	100%	22	100%
Reading from a computer screen	Much too Bright	0	0%	1	5%
	Too Bright	3	19%	2	9%
	Just Right	13	81%	14	64%
	Too Dim	0	0%	4	18%
	Much too Dim	0	0%	1	5%
	Does not apply	0	0%	0	0%
	Total	16	100%	22	100%
Typing on keyboard	Much too Bright	0	0%	1	5%
	Too Bright	2	13%	1	5%
	Just Right	13	81%	14	64%
	Too Dim	0	0%	4	18%
	Much too Dim	1	6%	1	5%
	Does not apply	0	0%	1	5%
	Total	16	100%	22	100%
Filing or locating papers	Much too Bright	0	0%	1	5%
	Too Bright	2	13%	1	5%
	Just Right	12	75%	9	41%
	Too Dim	1	6%	9	41%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Much too Dim	0	0%	1	5%
	Does not apply	1	6%	1	5%
	Total	16	100%	22	100%
Face to face conversations	Much too Bright	0	0%	1	5%
	Too Bright	2	13%	1	5%
	Just Right	13	81%	12	55%
	Too Dim	0	0%	6	27%
	Much too Dim	1	6%	0	0%
	Does not apply	0	0%	2	9%
	Total	16	100%	22	100%
Glare reflected from your work surface	Never	3	19%	7	32%
	Rarely	10	63%	9	41%
	Sometimes	2	13%	4	18%
	Often	0	0%	2	9%
	Always	1	6%	0	0%
	Total	16	100%	22	100%
Glare from the light fixtures reflected on your computer screen	Never	4	25%	10	45%
	Rarely	9	56%	9	41%
	Sometimes	1	6%	2	9%
	Often	1	6%	1	5%
	Always	1	6%	0	0%
	Total	16	100%	22	100%
Glare from the window reflected on your computer screen	Never	2	13%	6	27%
	Rarely	7	44%	4	18%
	Sometimes	6	38%	5	23%
	Often	1	6%	5	23%
	Always	0	0%	2	9%
	Total	16	100%	22	100%
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	5	31%	8	36%
	Rarely	6	38%	12	55%
	Sometimes	2	13%	1	5%
	Often	3	19%	0	0%
	Always	0	0%	1	5%
	Total	16	100%	22	100%
Direct glare from the light fixtures	Never	6	38%	11	50%
	Rarely	6	38%	10	45%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
beyond your immediate workspace (the light fixtures appear too bright)	Sometimes	2	13%	1	5%
	Often	2	13%	0	0%
	Always	0	0%	0	0%
	Total	16	100%	22	100%
Glare from your task lighting	Never	10	63%	13	62%
	Rarely	4	25%	3	14%
	Sometimes	1	6%	2	10%
	Often	1	6%	1	5%
	Always	0	0%	2	10%
	Total	16	100%	21	100%
Direct glare from a window	Never	3	19%	7	32%
	Rarely	8	50%	2	9%
	Sometimes	4	25%	5	23%
	Often	1	6%	5	23%
	Always	0	0%	3	14%
	Total	16	100%	22	100%
What is the color appearance of the lighting in your personal workspace?	Very Warm	1	6%	1	5%
	Somewhat Warm	6	38%	3	14%
	Neutral	4	25%	9	41%
	Somewhat Cool	2	13%	7	32%
	Very Cool	2	13%	0	0%
	Don't Know	1	6%	2	9%
	Total	16	100%	22	100%
What would you prefer for the color appearance of the lighting in your personal workspace?	Very Warm	1	6%	0	0%
	Somewhat Warm	2	13%	4	18%
	Neutral	4	25%	9	41%
	Somewhat Cool	7	44%	6	27%
	Very Cool	0	0%	0	0%
	Don't Know	2	13%	3	14%
	Total	16	100%	22	100%
If you could change the lighting in your office, what would you do? Please check all that apply.	Change the location of the overhead lighting fixtures relative to your workstation	4	25%	1	5%
	Make the overhead lighting fixtures produce more light	1	6%	8	38%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Make the overhead lighting fixtures produce less light	5	31%	3	14%
	Make the overhead lighting fixtures less glary	5	31%	4	19%
	Change the aesthetic appearance of the lighting fixtures	2	13%	1	5%
	Change the color appearance of the light produced by the lighting fixtures	5	31%	3	14%
	Add a task light	3	19%	7	33%
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	3	19%	14	67%
	Get better access to a window view	6	38%	5	24%
	Get better access to daylight	5	31%	4	19%
	Have lightbulbs replaced faster when they burn out and fixtures repaired faster when they break	1	6%	0	0%
	I would not change anything	6	38%	3	14%
	Total	16		21	

8.3.3.2.6 RD14S Complete Occupant Survey Results

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes the type of work you do?	People management, leadership, and/or training	3	43%	1	11%
	Computer aided design, engineering, or software development	0	0%	2	22%
	Combination of computer work, paper tasks, phone calls and meetings	4	57%	6	67%
	Facility Management	0	0%	0	0%
	Other	0	0%	0	0%
	Total	7	100%	9	100%
What is your age?	30 or under	0	0%	0	0%
	31-40	0	0%	0	0%
	41-50	1	13%	3	33%
	over 50	7	88%	6	67%
	Total	8	100%	9	100%
What is your gender?	Female	5	63%	8	80%
	Male	3	38%	2	20%
	Total	8	100%	10	100%
Which of the following best describes your personal workspace?	Enclosed private office	2	25%	0	0%
	Cubicles with Partitions above standing eye level	4	50%	7	70%
	Cubicles with partitions below standing eye level	1	13%	3	30%
	Other	1	13%	0	0%
	Total	8	100%	10	100%
What type of computer	Laptop	1	13%	4	40%
	Flat Panel Screen	6	75%	3	30%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
screen do you have?	Traditional Screen	1	13%	2	20%
	Other	0	0%	1	10%
	Total	8	100%	10	100%
On a typical day, how long are you in your personal workspace?	More than 6 hours	7	88%	10	100%
	4-6 hours	1	13%	0	0%
	2-4 hours	0	0%	0	0%
	Less than 2 hours	0	0%	0	0%
	Total	8	100%	10	100%
Are you able to see out a window while sitting in your workspace?	Yes	5	63%	2	20%
	No	3	38%	8	80%
	Total	8	100%	10	100%
If "Yes," do you like the view?	Yes	4	80%	2	100%
	No	1	20%	0	0%
	Total	5	100%	2	100%
Do you sit adjacent to a window?	Yes	4	80%	1	50%
	No	1	20%	1	50%
	Total	5	100%	2	100%
Which of the following most closely resembles the overhead lighting in your immediate work space?	Picture 1	0	0%	0	0%
	Picture 2	7	100%	2	25%
	Picture 3	0	0%	6	75%
	Other	0	0%	0	0%
	Total	7	100%	8	100%
Overall, is the lighting comfortable?	Yes	6	86%	9	90%
	No	1	14%	1	10%
	Total	7	100%	10	100%
Do you have task lighting?	Yes	7	100%	6	67%
	No	0	0%	3	33%
	Total	7	100%	9	100%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Undercabinet Task light	6	86%	4	80%
	Destop Task light	1	14%	1	20%
	Total	7	100%	5	100%
What type of control do you have for your task lighting?	On/Off switch	5	71%	5	83%
	Dimmer switch	0	0%	0	0%
	Other (please specify)	0	0%	0	0%
	Does not apply	2	29%	1	17%
	Total	7	100%	6	100%
Which of the following most closely resembles the lighting on the walls in your general office area?	Uniformly bright walls	1	17%	1	10%
	Uneven light distribution on walls	1	17%	2	20%
	Accent Lighting on artwork only	0	0%	0	0%
	Walls are dim	2	33%	1	10%
	Other	0	0%	1	10%
	Do not know	2	33%	5	50%
	Total	6		10	100%
Do the overhead lighting fixtures in	Yes	6	86%	6	86%
	No	0	0%	1	14%
	Do not know/ Does not apply	1	14%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Total	7	100%	7	100%
Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	6	86%	6	86%
	No	0	0%	0	0%
	Do not know/ Does not apply	1	14%	1	14%
	Total	7	100%	7	100%
If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	3	60%	5	83%
	No	2	40%	1	17%
	Do not know/ Does not apply	0	0%	0	0%
	Total	5	100%	6	100%
Can you control the overhead lights in your	Yes	0	0%	1	14%
	No	6	100%	5	71%
	Do not know/ Does not apply	0	0%	1	14%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
personal workspace without changing the lights in neighboring areas?	Total	6	100%	7	100%
How are your overhead lights controlled (check all that apply)?	Switch at wall	2	29%	1	13%
	Handheld remote	0	0%	1	13%
	Interface at your computer	0	0%	0	0%
	Automated system/controlled by building management	2	29%	3	38%
	Other (Please specify)	1	14%	1	13%
	Do not know/ Does not apply	4	57%	2	25%
	Total	7		8	
To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	5	83%	4	67%
	Light level settings are available for high, low, and/or medium	0	0%	2	33%
	Continuous dimming available	1	17%	0	0%
	Total	6	100%	6	100%
What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	4	57%	4	50%
	Manual windo shades(e.g.,roller shades)	1	14%	0	0%
	Automatic blinds or shades	0	0%	0	0%
	Other (please specify)	0	0%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	No shading control	1	14%	0	0%
	I have no daylight in my workspace	1	14%	4	50%
	Total	7	100%	8	100%
Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	2	40%	2	50%
	No	3	60%	2	50%
	Does not apply	0	0%	0	0%
	Total	5	100%	4	100%
I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	1	14%	2	25%
	Disagree	2	29%	2	25%
	Neutral	2	29%	2	25%
	Agree	1	14%	1	13%
	Strongly Agree	0	0%	1	13%
	Does not apply	1	14%	0	0%
	Total	7	100%	8	100%
I am satisfied with my ability to control my task lighting.	Strongly Disagree	0	0%	3	38%
	Disagree	1	14%	1	13%
	Neutral	1	14%	1	13%
	Agree	4	57%	3	38%
	Strongly Agree	1	14%	0	0%
	Does not apply	0	0%	0	0%
	Total	7	100%	8	100%
I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	1	14%	0	0%
	Disagree	2	29%	0	0%
	Neutral	0	0%	1	13%
	Agree	1	14%	1	13%
	Strongly Agree	2	29%	1	13%
	Does not apply	1	14%	5	63%
	Total	7	100%	8	100%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
My work surface is evenly lighted without very bright or dim spots.	Strongly Disagree	0	0%	3	38%
	Disagree	1	14%	1	13%
	Neutral	3	43%	1	13%
	Agree	3	43%	3	38%
	Strongly Agree	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	7	100%	8	100%
The lights flicker throughout the day.	Strongly Disagree	0	0%	1	13%
	Disagree	2	29%	3	38%
	Neutral	3	43%	2	25%
	Agree	2	29%	0	0%
	Strongly Agree	0	0%	0	0%
	Does not apply	0	0%	2	25%
	Total	7	100%	8	100%
My skin is an unnatural tone under the lighting.	Strongly Disagree	0	0%	0	0%
	Disagree	1	14%	1	14%
	Neutral	5	71%	4	57%
	Agree	1	14%	0	0%
	Strongly Agree	0	0%	1	14%
	Does not apply	0	0%	1	14%
	Total	7	100%	7	100%
The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Disagree	0	0%	0	0%
	Disagree	1	14%	1	13%
	Neutral	5	71%	2	25%
	Agree	1	14%	4	50%
	Strongly Agree	0	0%	1	13%
	Does not apply	0	0%	0	0%
	Total	7	100%	8	100%
The lighting helps create a good image for the organization.	Strongly Disagree	0	0%	0	0%
	Disagree	3	43%	1	13%
	Neutral	3	43%	3	38%
	Agree	1	14%	2	25%
	Strongly Agree	0	0%	1	13%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Does not apply	0	0%	1	13%
	Total	7	100%	8	100%
The room surfaces (walls, ceilings) have a pleasant brightness.	Strongly Disagree	0	0%	0	0%
	Disagree	3	43%	3	38%
	Neutral	3	43%	2	25%
	Agree	1	14%	2	25%
	Strongly Agree	0	0%	1	13%
	Does not apply	0	0%	0	0%
	Total	7	100%	8	100%
Paper Tasks (reading and writing)	Much too Bright	0	0%	0	0%
	Too Bright	0	0%	0	0%
	Just Right	4	57%	5	71%
	Too Dim	2	29%	1	14%
	Much too Dim	0	0%	1	14%
	Does not apply	1	14%	0	0%
	Total	7	100%	7	100%
Reading from a computer screen	Much too Bright	0	0%	0	0%
	Too Bright	0	0%	0	0%
	Just Right	4	57%	5	71%
	Too Dim	2	29%	1	14%
	Much too Dim	0	0%	1	14%
	Does not apply	1	14%	0	0%
	Total	7	100%	7	100%
Typing on keyboard	Much too Bright	0	0%	0	0%
	Too Bright	0	0%	0	0%
	Just Right	4	57%	6	86%
	Too Dim	2	29%	0	0%
	Much too Dim	0	0%	1	14%
	Does not apply	1	14%	0	0%
	Total	7	100%	7	100%
Filing or locating papers	Much too Bright	0	0%	0	0%
	Too Bright	0	0%	0	0%
	Just Right	5	71%	6	86%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Too Dim	1	14%	1	14%
	Much too Dim	0	0%	0	0%
	Does not apply	1	14%	0	0%
	Total	7	100%	7	100%
Face to face conversations	Much too Bright	0	0%	0	0%
	Too Bright	0	0%	0	0%
	Just Right	5	71%	7	100%
	Too Dim	0	0%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	2	29%	0	0%
	Total	7	100%	7	100%
Glare reflected from your work surface	Never	0	0%	1	13%
	Rarely	2	29%	6	75%
	Sometimes	3	43%	1	13%
	Often	2	29%	0	0%
	Always	0	0%	0	0%
	Total	7	100%	8	100%
Glare from the light fixtures reflected on your computer screen	Never	0	0%	0	0%
	Rarely	3	43%	5	63%
	Sometimes	4	57%	3	38%
	Often	0	0%	0	0%
	Always	0	0%	0	0%
	Total	7	100%	8	100%
Glare from the window reflected on your computer screen	Never	2	29%	3	38%
	Rarely	2	29%	3	38%
	Sometimes	2	29%	0	0%
	Often	1	14%	2	25%
	Always	0	0%	0	0%
	Total	7	100%	8	100%
Glare from the overhead	Never	0	0%	1	13%
	Rarely	4	57%	6	75%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
lighting in your immediate workspace (usually experienced as discomfort)	Sometimes	3	43%	1	13%
	Often	0	0%	0	0%
	Always	0	0%	0	0%
	Total	7	100%	8	100%
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	0	0%	3	38%
	Rarely	6	86%	5	63%
	Sometimes	1	14%	0	0%
	Often	0	0%	0	0%
	Always	0	0%	0	0%
	Total	7	100%	8	100%
Glare from your task lighting	Never	1	14%	2	25%
	Rarely	2	29%	5	63%
	Sometimes	4	57%	1	13%
	Often	0	0%	0	0%
	Always	0	0%	0	0%
	Total	7	100%	8	100%
Direct glare from a window	Never	2	29%	3	38%
	Rarely	2	29%	3	38%
	Sometimes	1	14%	1	13%
	Often	1	14%	1	13%
	Always	1	14%	0	0%
	Total	7	100%	8	100%
What is the color appearance of the lighting in your personal workspace?	Very Warm	2	29%	0	0%
	Somewhat Warm	0	0%	2	25%
	Neutral	2	29%	5	63%
	Somewhat Cool	1	14%	0	0%
	Very Cool	1	14%	0	0%
	Don't Know	1	14%	1	13%
	Total	7	100%	8	100%
What would you prefer for	Very Warm	0	0%	0	0%
	Somewhat Warm	1	14%	1	13%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
the color appearance of the lighting in your personal workspace?	Neutral	2	29%	5	63%
	Somewhat Cool	3	43%	1	13%
	Very Cool	0	0%	0	0%
	Don't Know	1	14%	1	13%
	Total	7	100%	8	100%
If you could change the lighting in your office, what would you do? Please check all that apply.	Change the location of the overhead lighting fixtures relative to your workstation	5	71%	3	38%
	Make the overhead lighting fixtures produce more light	4	57%	2	25%
	Make the overhead lighting fixtures produce less light	0	0%	0	0%
	Make the overhead lighting fixtures less glary	1	14%	1	13%
	Change the aesthetic appearance of the lighting fixtures	3	43%	0	0%
	Change the color appearance of the light produced by the lighting fixtures	3	43%	0	0%
	Add a task light	2	29%	2	25%
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	5	71%	6	75%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Get better access to a window view	2	29%	2	25%
	Get better acces to daylight	2	29%	2	25%
	Have lightbulbs replaced faster when they burn out and fixtures repaired faster when they break	1	14%	0	0%
	I would not change anything	0	0%	2	25%
	Total	7		8	

8.3.3.2.7 R18 Complete Occupant Survey Results

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following best describes the type of work you do?	People management, leadership, and/or training	0	0%	2	15%
	Computer aided design, engineering, or software development	0	0%	0	0%
	Combination of computer work, paper tasks, phone calls and meetings	7	78%	11	85%
	Facility Management	2	22%	0	0%
	Other	0	0%	0	0%
	Total	9	100%	13	100%
What is your age?	30 or under	1	33%	0	#DIV/0!
	31-40	0	0%	0	#DIV/0!

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	41-50	2	67%	0	#DIV/0!
	over 50	0	0%	0	#DIV/0!
	Total	3	100%	0	#DIV/0!
What is your gender?	Female	0	0%	0	#DIV/0!
	Male	2	100%	0	#DIV/0!
	Total	2	100%	0	#DIV/0!
Which of the following best describes your personal workspace?	Enclosed private office	2	18%	3	17%
	Cubicles with Partitions above standing eye level	4	36%	8	44%
	Cubicles with partitions below standing eye level	2	18%	2	11%
	Other	3	27%	5	28%
	Total	11	100%	18	100%
What type of computer screen do you have?	Laptop	3	27%	7	39%
	Flat Panel Screen	8	73%	10	56%
	Traditional Screen	0	0%	1	6%
	Other	0	0%	0	0%
	Total	11	100%	18	100%
On a typical day, how long are you in your personal workspace?	More than 6 hours	9	82%	9	50%
	4-6 hours	2	18%	7	39%
	2-4 hours	0	0%	2	11%
	Less than 2 hours	0	0%	0	0%
	Total	11	100%	18	100%
Are you able to see out a window while sitting in your workspace?	Yes	7	64%	11	61%
	No	4	36%	7	39%
	Total	11	100%	18	100%
If "Yes," do you like the view?	Yes	6	86%	9	82%
	No	1	14%	2	18%
	Total	7	100%	11	100%
Do you sit adjacent to a window?	Yes	6	86%	10	59%
	No	1	14%	7	41%
	Total	7	100%	17	100%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Which of the following most closely resembles the overhead lighting in your immediate work space?	Picture 1	6	55%	3	18%
	Picture 2	5	45%	6	35%
	Picture 3	0	0%	7	41%
	Other	0	0%	1	6%
	Total	11	100%	17	100%
Overall, is the lighting comfortable?	Yes	8	73%	16	89%
	No	3	27%	2	11%
	Total	11	100%	18	100%
Do you have task lighting?	Yes	9	82%	11	61%
	No	2	18%	7	39%
	Total	11	100%	18	100%
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Under-cabinet Task light	3	38%	10	91%
	Desktop Task light	5	63%	1	9%
	Total	8	100%	11	100%
What type of control do you have for your task lighting?	On/Off switch	6	67%	4	25%
	Dimmer switch	0	0%	0	0%
	Other (please specify)	2	22%	2	13%
	Does not apply	1	11%	10	63%
	Total	9	100%	16	100%
Which of the following most closely resembles the lighting on the walls in your general office	Uniformly bright walls	0	0%	7	47%
	Uneven light distribution on walls	4	36%	3	20%
	Accent Lighting on artwork only	2	18%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
area?	Walls are dim	0	0%	1	7%
	Other	1	9%	0	0%
	Do not know	4	36%	4	27%
	Total	11		15	100%
Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	2	20%	15	83%
	No	4	40%	1	6%
	Do not know/ Does not apply	4	40%	2	11%
	Total	10	100%	18	100%
Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	1	10%	13	72%
	No	6	60%	2	11%
	Do not know/ Does not apply	3	30%	3	17%
	Total	10	100%	18	100%
If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	1	100%	6	43%
	No	0	0%	7	50%
	Do not know/ Does not apply	0	0%	1	7%
	Total	1	100%	14	100%
Can you	Yes	0	0%	2	12%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
control the overhead lights in your personal workspace without changing the lights in neighboring areas?	No	6	60%	14	82%
	Do not know/ Does not apply	4	40%	1	6%
	Total	10	100%	17	100%
How are your overhead lights controlled (check all that apply)?	Switch at wall	4	40%	0	0%
	Handheld remote	0	0%	0	0%
	Interface at your computer	0	0%	0	0%
	Automated system/controlled by building management	3	30%	11	61%
	Other (Please specify)	0	0%	2	11%
	Do not know/ Does not apply	4	40%	5	28%
	Total	10		18	
To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	7	100%	10	91%
	Light level settings are available for high, low, and/or medium	0	0%	0	0%
	Continuous dimming available	0	0%	1	9%
	Total	7	100%	11	100%
What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	10	91%	11	61%
	Manual window shades(e.g., roller shades)	0	0%	0	0%
	Automatic blinds or shades	1	9%	0	0%
	Other (please specify)	0	0%	0	0%
	No shading control	0	0%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	I have no daylight in my workspace	0	0%	7	39%
	Total	11	100%	18	100%
Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	3	43%	4	22%
	No	4	57%	8	44%
	Does not apply	0	0%	6	33%
	Total	7	100%	18	100%
I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	2	20%	2	11%
	Disagree	1	10%	2	11%
	Neutral	2	20%	6	33%
	Agree	4	40%	4	22%
	Strongly Agree	0	0%	0	0%
	Does not apply	1	10%	4	22%
	Total	10	100%	18	100%
I am satisfied with my ability to control my task lighting.	Strongly Disagree	2	18%	1	6%
	Disagree	0	0%	1	6%
	Neutral	2	18%	4	24%
	Agree	4	36%	9	53%
	Strongly Agree	1	9%	2	12%
	Does not apply	2	18%	0	0%
	Total	11	100%	17	100%
I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	1	10%	0	0%
	Disagree	0	0%	2	11%
	Neutral	1	10%	4	22%
	Agree	4	40%	5	28%
	Strongly Agree	1	10%	3	17%
	Does not apply	3	30%	4	22%
	Total	10	100%	18	100%
My work surface is evenly lighted without very bright or dim	Strongly Disagree	1	10%	1	6%
	Disagree	0	0%	1	6%
	Neutral	2	20%	4	24%
	Agree	7	70%	9	53%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
spots.	Strongly Agree	0	0%	2	12%
	Does not apply	0	0%	0	0%
	Total	10	100%	17	100%
The lights flicker throughout the day.	Strongly Disagree	1	10%	3	21%
	Disagree	7	70%	8	57%
	Neutral	1	10%	3	21%
	Agree	1	10%	0	0%
	Strongly Agree	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	10	100%	14	100%
My skin is an unnatural tone under the lighting.	Strongly Disagree	1	25%	0	#DIV/0!
	Disagree	1	25%	0	#DIV/0!
	Neutral	1	25%	0	#DIV/0!
	Agree	0	0%	0	#DIV/0!
	Strongly Agree	0	0%	0	#DIV/0!
	Does not apply	1	25%	0	#DIV/0!
	Total	4	100%	0	#DIV/0!
The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Disagree	1	10%	0	0%
	Disagree	3	30%	1	6%
	Neutral	5	50%	6	38%
	Agree	1	10%	7	44%
	Strongly Agree	0	0%	1	6%
	Does not apply	0	0%	1	6%
	Total	10	100%	16	100%
The lighting helps create a good image for the organization.	Strongly Disagree	0	0%	0	0%
	Disagree	4	40%	1	6%
	Neutral	5	50%	9	56%
	Agree	1	10%	3	19%
	Strongly Agree	0	0%	1	6%
	Does not apply	0	0%	2	13%
	Total	10	100%	16	100%
The room surfaces (walls, ceilings) have a	Strongly Disagree	0	0%	0	0%
	Disagree	3	30%	0	0%
	Neutral	3	30%	8	50%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
pleasant brightness.	Agree	3	30%	7	44%
	Strongly Agree	0	0%	1	6%
	Does not apply	1	10%	0	0%
	Total	10	100%	16	100%
Paper Tasks (reading and writing)	Much too Bright	0	0%	1	6%
	Too Bright	0	0%	1	6%
	Just Right	5	50%	14	88%
	Too Dim	5	50%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	10	100%	16	100%
Reading from a computer screen	Much too Bright	0	0%	1	6%
	Too Bright	1	10%	1	6%
	Just Right	4	40%	14	88%
	Too Dim	5	50%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	10	100%	16	100%
Typing on keyboard	Much too Bright	0	0%	1	6%
	Too Bright	1	10%	1	6%
	Just Right	7	70%	14	88%
	Too Dim	2	20%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	10	100%	16	100%
Filing or locating papers	Much too Bright	0	0%	0	0%
	Too Bright	1	10%	1	6%
	Just Right	7	70%	14	88%
	Too Dim	2	20%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	1	6%
	Total	10	100%	16	100%
Face to face conversations	Much too Bright	0	0%	0	0%
	Too Bright	1	10%	2	13%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
	Just Right	7	70%	14	88%
	Too Dim	2	20%	0	0%
	Much too Dim	0	0%	0	0%
	Does not apply	0	0%	0	0%
	Total	10	100%	16	100%
Glare reflected from your work surface	Never	1	10%	4	25%
	Rarely	6	60%	6	38%
	Sometimes	3	30%	4	25%
	Often	0	0%	1	6%
	Always	0	0%	1	6%
	Total	10	100%	16	100%
Glare from the light fixtures reflected on your computer screen	Never	1	10%	3	19%
	Rarely	3	30%	6	38%
	Sometimes	4	40%	5	31%
	Often	2	20%	0	0%
	Always	0	0%	2	13%
	Total	10	100%	16	100%
Glare from the window reflected on your computer screen	Never	2	20%	1	8%
	Rarely	4	40%	4	31%
	Sometimes	2	20%	5	38%
	Often	2	20%	0	0%
	Always	0	0%	3	23%
	Total	10	100%	13	100%
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	1	10%	3	19%
	Rarely	7	70%	8	50%
	Sometimes	2	20%	3	19%
	Often	0	0%	1	6%
	Always	0	0%	1	6%
	Total	10	100%	16	100%
Direct glare from the light	Never	3	30%	7	44%
	Rarely	6	60%	6	38%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
fixtures beyond your immediate workspace (the light fixtures appear too bright)	Sometimes	1	10%	2	13%
	Often	0	0%	0	0%
	Always	0	0%	1	6%
	Total	10	100%	16	100%
Glare from your task lighting	Never	5	50%	8	53%
	Rarely	4	40%	5	33%
	Sometimes	1	10%	2	13%
	Often	0	0%	0	0%
	Always	0	0%	0	0%
	Total	10	100%	15	100%
Direct glare from a window	Never	3	30%	3	23%
	Rarely	3	30%	3	23%
	Sometimes	3	30%	5	38%
	Often	1	10%	0	0%
	Always	0	0%	2	15%
	Total	10	100%	13	100%
What is the color appearance of the lighting in your personal workspace?	Very Warm	1	10%	1	6%
	Somewhat Warm	1	10%	4	25%
	Neutral	3	30%	6	38%
	Somewhat Cool	4	40%	3	19%
	Very Cool	0	0%	1	6%
	Don't Know	1	10%	1	6%
	Total	10	100%	16	100%
What would you prefer for the color appearance of the lighting in your personal workspace?	Very Warm	1	10%	0	0%
	Somewhat Warm	2	20%	4	25%
	Neutral	3	30%	7	44%
	Somewhat Cool	3	30%	3	19%
	Very Cool	0	0%	0	0%
	Don't Know	1	10%	2	13%
	Total	10	100%	16	100%
If you could change the lighting in your office, what would you do?	Change the location of the overhead lighting fixtures relative to your workstation	0	0%	0	0%

Question	Answers	Pre-retrofit Number of respondents	Pre-retrofit Percentage of respondent	Post-retrofit Number of respondents	Post-retrofit Percentage of respondent
Please check all that apply.	Make the overhead lighting fixtures produce more light	0	0%	1	6%
	Make the overhead lighting fixtures produce less light	0	0%	2	12%
	Make the overhead lighting fixtures less glary	0	0%	1	6%
	Change the aesthetic appearance of the lighting fixtures	0	0%	1	6%
	Change the color appearance of the light produced by the lighting fixtures	0	0%	1	6%
	Add a task light	0	0%	2	12%
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	3	75%	8	47%
	Get better access to a window view	0	0%	2	12%
	Get better access to daylight	0	0%	3	18%
	Have light bulbs replaced faster when they burn out and fixtures repaired faster when they break	0	0%	0	0%
	I would not change anything	1	25%	6	35%
	Total	4		17	

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8.5 Glossary

Advanced lighting controls	*See Lighting controls.*
Areal/building policy	An area or building wide agreed upon course of action regarding certain behaviors. With respect to institutional tuning in lighting systems, these policies could involve setting default light levels and timeouts for different zones (eg. Corridors vs. open office area).
Ambient light	General indirect lighting that illuminates the whole volume of a room softly.
Ballast	A device that regulates the current and voltage supplied to a gaseous discharge lamp or lamps (e.g. a fluorescent lamp).
Ballast Factor (BF)	The ratio of lumen output of lamps operated on a ballast compared to the lumen output of lamps operated on the reference ballast.
Commissioning	A process by which an installed building system is verified that it functions according to design objectives and/or specifications.
Control strategy	A particular method of regulating the timing or quantity of light levels in a space. See *Lighting controls*.
Daylight harvesting	A control strategy that reduces electric light levels in the presence of available daylight, “harvesting” the daylight to save electrical lighting energy.
Diagnostics	A visual representation of a system (e.g. a lighting control system) that notifies the user of severe system faults, errors, or possible improvements.
DALI	DALI is short for Digital Addressable Lighting Interface; a two-way communication system which allows ballasts and control systems to “talk” to each other.
Dimmable ballast	A ballast that responds to external control signals by adjusting current flowing through the lamp(s), raising and lowering light output.

Energy Use Intensity (EUI)	A metric for characterizing energy use, defined as the amount of energy used in a space over a given time period divided by the area of the space and the time interval studied. In lighting, EUI is usually calculated in watt-hours per square foot per day or kilowatt-hours per square foot per year.
Fuel mix	The range of energy sources of a region, including both renewable and non-renewable sources. Also called an *energy mix*.
Global Warming Effect (GWE)	A metric for characterizing greenhouse gas emissions by summing the product of instantaneous greenhouse gas emissions and their specific time-dependent global warming potential. In this study, GWE was calculated for each utility provider (g $CO_{2,eq}$ /kWh electricity generated) and also normalized by floor area and calculated based off of annual energy savings (kg $CO_{2,eq}/ft^2$/year).
Greenhouse Gas (GHG)	A gas in the atmosphere that absorbs and emits radiation within the thermal infrared range, resulting in the greenhouse effect in our atmosphere.
Hard timeout	The time difference between when an occupancy sensor registers an unoccupied event and when that event is logged in the control system.
IESNA acceptable light level	Illuminating Engineering Society of North America (IESNA) sets standards for light levels in different environments. For this study, the acceptable light level for an office task lighting is 350 lux.
Illuminance	The density of incident luminous flux on a surface. In less technical terms, a measure of the amount of incoming light reaching a surface.
Institutional tuning	A control strategy which allows building managers and tenants to decrease energy consumption by programming default light levels with the lighting management system that reflect area and/or building policies.
Lamp	An electric light source. Also called a *bulb* or, in the case of linear fluorescent lamps, a *tube*.
Light sensor	*See Photocell.*

Lighting circuit	Wiring that provides power to light fixtures and ballasts.
Lighting controls	Systems that regulate the timing and quantity of light emitted by a light source. Advanced lighting controls include daylight harvesting, occupancy sensing, and institutional tuning.
Lighting Management Control System (LMCS)	A type of lighting control which allows operators control over a lighting system (either panel- or building-wide). Control configurations can be informed by schedules, institutional tuning, personal controls, as well as demand response.
Lighting Power Density (LPD)	A metric for characterizing the lighting power in a space at a given time, defined as the lighting power divided by the corresponding floor area. LPD is usually calculated in watts per square foot.
Luminaire	A complete lighting unit, including a light source, physical elements to distribute light, and the necessary electronics to power the light source.
Lux	The SI unit of illuminance, equal to one lumen per square meter.
Meta-analysis	A method of identifying patterns among multiple studies by comparing and combining results from the different studies.
Occupancy sensing	A control strategy in which lighting in a space is automatically turned on or off based on detected occupancy.
Occupancy sensor	A control device that detects the presence or absence of people.
Personal control	A control strategy that gives occupants direct control over light operation and light levels.
Photometric characterization	An analysis involving measured illuminances to assess the visible light performance of a lighting system.
Photocell/photosensor	A sensor that detects the amount of light falling on its lens. Also called a *light sensor*.
Power metering	A measurement strategy involving collecting power consumption data from various circuits.

Retrofit	An addition or substitution to the current system. As related to this study, could involve any combination of activities from changing out lamp types to reconfiguring the lighting system.
RMS current	The effective value of a current such that the heating effect is the same for equal values of alternating or direct current. RMS is an abbreviation for root mean square, a mathematical process of determining the effective value of an alternating current.
Standby power	The power a device or system requires while in an off state.
Task lighting	Directed lighting that focuses light output on a specific area within a workspace. Light location and levels depend on the tasks performed in the area.
Timeout	A specified time period during which an area must remain unoccupied before occupancy controls shut off lights in that area.
Tuning	A control strategy that caps light output below the maximum possible output.
Workstation-specific luminaire	An independently controllable luminaire that lights a single open-office workstation, typically with a built-in occupancy sensor for individual occupancy control.