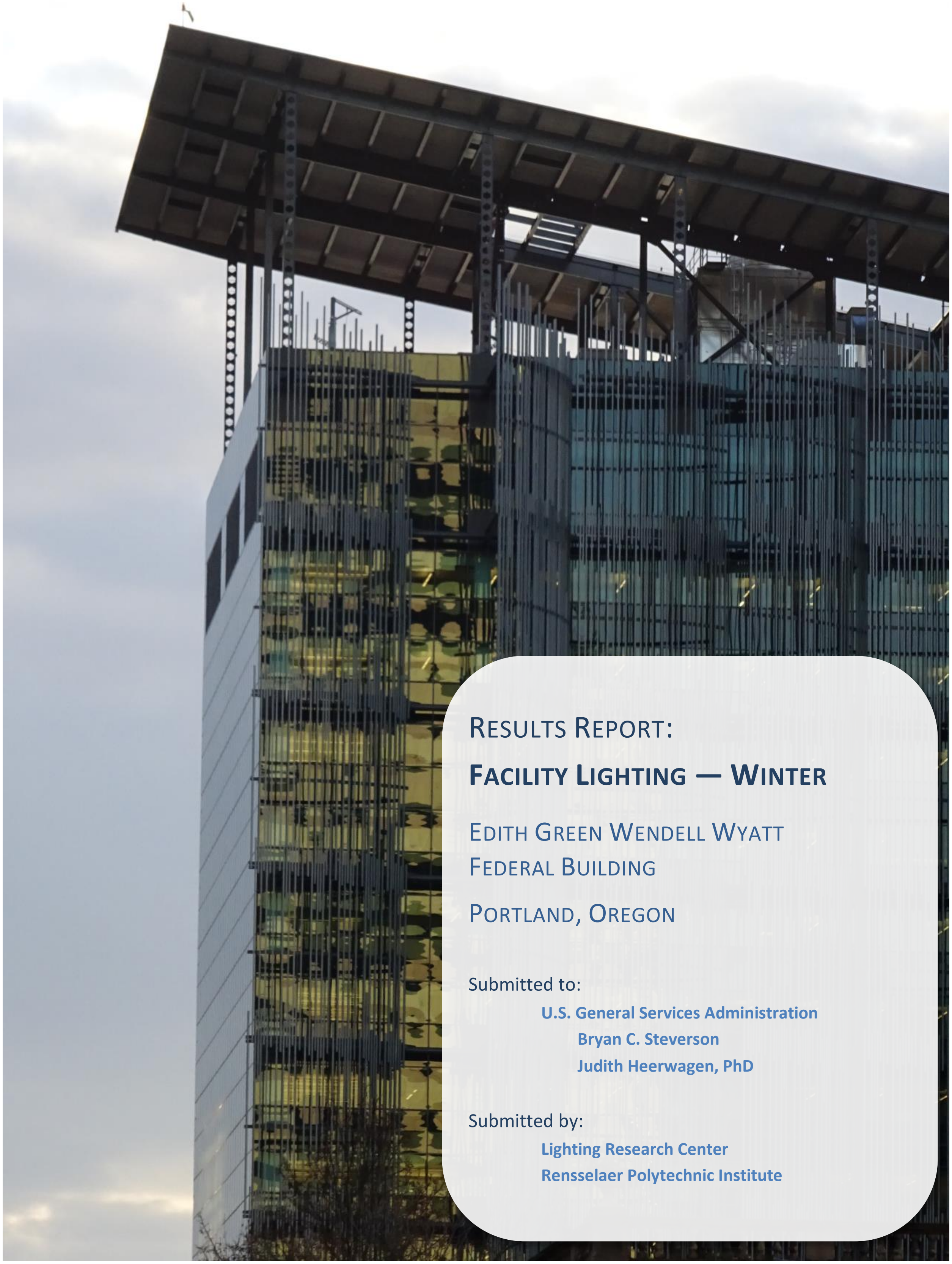

Results Report:

Facility Lighting — Winter

Edith Green Wendell Wyatt Federal Building

Portland, Oregon

Submitted to:

U.S. General Services Administration

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Lighting Research Center

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RESULTS REPORT: FACILITY LIGHTING — WINTER

EDITH GREEN WENDELL WYATT FEDERAL BUILDING PORTLAND, OREGON

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EXECUTIVE SUMMARY

The Edith Green Wendell Wyatt (EGWW) Federal Building is a 525,000 square foot high-rise office building in downtown Portland, Oregon. This 18-story building accommodates over 1200 workers from 16 federal agencies, and is managed by the U.S. General Services Administration (GSA). The building was originally constructed in 1974 and underwent a major renovation between 2009 and 2013. Today the building is a cornerstone of GSA's green building portfolio with all new mechanical, electrical, plumbing and data systems designed to make it one of the most energy efficient office buildings in the country.

In December 2014, researchers from the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute and GSA staff returned to the site to repeat the seasonal data collection originally performed in April 2014. LRC researchers made photometric measurements at the same open-plan deskspaces located on floors 4, 12, and 17. In addition to the field measurements, the LRC placed Daysimeter devices on the same deskspaces as the late spring visit to continously measure photopic lux and circadian light over the course of several days. Daysimeters measure continuous light exposures, allowing researchers to perform calculations of how much light that is effective for the circadian system may be reaching deskspaces (i.e., circadian stimulus, or CS).

Biological rhythms that repeat approximately every 24 hours are called circadian rhythms. Light is the main stimulus that helps the circadian clock, and thus circadian rhythms, synchronize with the 24-hour day. In other words, light tells our bodies to stay awake during the day and to sleep at night so that our sleep-wake cycle mirrors the earth's 24-hour cycle of night and day (dark and light). Light of the appropriate quantity, spectrum, timing, duration, and distribution can have a profound effect on sleep, alertness, and performance, along with overall wellbeing. Lack of synchrony between our internal clock and the local environment (such as what happens when travelling across multiple time zones) has been associated with a series of maladies such as diabetes, obesity, cardiovascular disease, and cancer.

Based on the LRC's previous work, it is hypothesized that CS values above or close to 0.3 should provide enough circadian stimulation to maintain entrainment of circadian rhythms to the local time on Earth. Due to availability of daylight and ease of access, research has continued[1] to focus on open-plan offices. While Daysimeters placed at deskspaces in the building may not be representative of workers' overall personal light exposures, they give an indication of how much circadian light is available in that part of the building. Another component of this research project, not discussed in this report, is the data collection of personal light exposures by building occupants.

The purpose of this report is to document measured photometric conditions as they relate to occupant visibility, comfort and circadian stimulus, as well as to document occupant behavior and acceptance of the lighting in their deskspaces. These winter data can be compared to the late spring data at the EGWW site. However, it is important to keep in mind that measurements on each seasonal visit were only made on one day with variable

[1] Previous LRC/GSA site evaluations also focused on open-plan offices with proximity to daylight.

weather. Photometric values will vary substantially in many spaces due to daily and seasonal changes in daylight.

Below are some of the main findings from the December site evaluation:

- Seasonal differences in circadian stimulation were as predicted, with less circadian stimulation during the winter months compared to the late spring months. One interesting observation was that CS values increased in winter months on the south and east façades, suggesting that occupants kept the shades up more often in winter months. On the other hand, CS values were much lower on the north façade, especially on the higher floors. This may be due to lower sun angles on the north façade, which is slightly tilted to the east; morning sun may have changed occupants' behavior during winter months.
- While deskspaces close to the windows often receive greater circadian stimulation than those away from the windows, the winter visit did not consistently show that lower level floors received less circadian stimulation than higher level floors, particularly on the north façade. Given that lower floors would not have direct sunlight as much as higher floors, it is expected that shades would be pulled down on higher floors if sunlight penetrates the space.
- On the winter visit, some of the deskspaces did not meet the target horizontal illuminance of 30 footcandles (approximately 300 lux). However, like the late spring visit, most workers reported the amount of light on their desks was neither too much nor too little. There was not a change in the percentage of workers that felt the need to use task lights.
- The use of shades to reduce discomfort glare on perimeter deskspaces may explain variation in vertical illuminances and circadian stimulation at these deskspaces, in particular on those located away from the windows. In winter months, opposite behavior than expected occurred: light availability on deskspaces facing south was greater in winter months, while light availability on deskspaces facing north was lower in winter months. It is hypothesized that changes in sun angles may have changed occupants' behavior.
- As in late spring, the use of architectural "reeds" on the west façade helped increase light levels on perimeter deskspaces compared to other buildings, because shades were found to be open. Seasonal variation in circadian stimulation was small in this façade, suggesting that occupants do not change shade positions too much, most likely because sunlight does not penetrate the space too much in either season.
- Unlike in late spring, the vertical illuminance measurements did not always show higher illuminance at Row A compared to Row B; the B desk on the north side of the 17^{th} floor had higher illuminances than other desks with that orientation. On the winter visit, the north side did not have the highest illuminances, but rather, the south side had several vertical measurements over 1000 lux. Vertical illuminances were not always higher on upper floors than lower floors, unlike in late spring; the 12^{th} floor had higher illuminances at several desks than the other floors. At many of the B desks, there was not much variation in vertical illuminance throughout the day, apart from a shaft of sun falling near the measurement point at midday on the south side, 12^{th} floor.

- Furniture layout at deskspaces located in the perimeter promotes circadian stimulation because workers are sitting in such a way that they are facing the window, increasing exposure to light. However, this setting may also increase discomfort glare on sides where there is direct sunlight, explaining why the deskspaces on the north façade did not receive enough circadian stimulation during the winter months.

Overview

The Edith Green Wendell Wyatt (EGWW) Federal Building is a 525,000 square foot high-rise office building in downtown Portland, Oregon, and is managed by the U.S. General Services Administration (GSA). The Lighting Research Center (LRC) collected photometric measurement data at a site visit December 15-17, 2014. This report is a winter-season repeat of the data reported from the late spring visit in April 2014.

Research Objectives

LRC researchers repeated photometric measurements at EGWW on December 15-17, 2014, at the same locations as in April 2014. The goal of the research was to compare seasonal photometric conditions as they relate to occupant comfort, productivity, and circadian health. Daylighting conditions were representative of winter, as the visit was after daylight savings, and winter solstice occurred five days after the visit. As in the April 2014 site visit, the LRC researchers included Dr. Mark Rea (LRC Director), Dr. Mariana Figueiro (LRC Light and Health Program Director), and Jennifer Brons (LRC DELTA Program Director[2]). The LRC team was escorted and assisted by Bryan Steverson of GSA, as well as on-site personnel Howard Schaffer and Annette Maddux.

Methods

On Day 1 (December 15), measurement locations were set up at the same locations as in April: two rows of desks on three floors with open-plan offices (floors 4, 12, and 17). Also on Day 1, battery-powered measurement equipment was installed and documented. Data collection started on the morning of Day 2 (December 16), continued until evening, then resumed on Day 3 (December 17). Each member of the research team was responsible for one aspect of data collection (detailed below). Two researchers collected illuminance and luminance measurements while one researcher performed spectral power distribution (SPD) measurements. Questionnaires were administered on Days 1-3.

Six types of measurements were repeated at EGWW:

Illuminance

Illuminance is a measure of the amount of light falling on a surface, in units of lux (lx [SI]) or footcandles (fc [in the U.S.]). Illuminance measurements are important because they are used conventionally as design criteria. The LRC measured illuminance multiple times over the measurement day, on horizontal and vertical surfaces, at desks on three floors, and at all window orientations. Two researchers collected these illuminance data using Cooke Hagner (model: E207 01X) and Gigahertz-Optik (model: X91) lux meters.

Luminance

Luminance is a measure of the amount of light emitted or reflected by a surface. Luminance relates to perceptions of brightness and glare. Luminance is measured in units of candela per square meter (cd/m^2), using a meter device that resembles the viewfinder of a camera aimed at luminous surfaces. Because viewing position impacts luminance,

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[2] The Demonstration and Evaluation of Lighting Technologies and Applications (DELTA) program is a case study program run by the LRC to design, evaluate, and publicize energy-efficient lighting solutions.

measurements were collected at the desk chair location when facing key surfaces, such as a computer monitor, and the nearest window. Two researchers collected luminance data using Minolta (models: LS-110 and LS-100) luminance meters.

Spectral power distribution

SPD is a measure of the wavelengths of light in the visible spectrum (380-770 nanometers [nm]). SPD will vary between light sources as well as time of day. SPD was measured at EGWW to allow researchers to calculate, using different response functions, measures such as brightness, glare, and circadian stimulus. SPD data were collected on the 4th, 12th and 17th floors at EGWW. A researcher collected these data at EGWW using a spectroradiometer system consisting of an Ocean Optics (model: USB650) spectrometer and a remote sensor, as well as a laptop. Raw SPD data were collected using the spectroradiometer system, and post-processed using Matlab version R2014a to generate curve functions.

Daysimeter photopic and circadian light exposure devices

Daysimeter devices collected continuous light exposures that allowed researchers to perform calculations of how much light that is effective for the circadian system was reaching deskspaces. Briefly, light sensing by the Daysimeter is performed with an integrated circuit (IC) sensor array (Hamamatsu model S11059-78HT) that includes optical filters for four measurement channels: red (R), green (G), blue (B), and infrared (IR). The R, G, B, and IR photo-elements have peak spectral responses at 615 nm, 530 nm, 460 nm, and 855 nm, respectively. The Daysimeter is calibrated in terms of orthodox photopic illuminance (lux) and of circadian illuminance (CL_A). CL_A calibration is based upon the spectral sensitivity of the human circadian system. From the recorded CL_A values it is then possible to determine the circadian stimulus (CS) magnitude, which represents the input-output operating characteristics of the human circadian system from threshold to saturation. These measurements are representative of light exposures one would receive while sitting at the desk working at a computer. However, it may not represent the person’s daily light exposures, such as exposure to outdoor lighting to and from work. Daysimeter devices were installed at 24 desks and 12 windows. These collected data for at least 7 days after the LRC visited the site. These were removed by personnel under direction of Mr. Schaffer after 2+ weeks on site, and were returned by mail to the LRC for read-out.

Luminaire activity

LRC researchers placed battery-powered light meters atop operating luminaires to confirm whether the lights were dimming in response to daylight. These devices were set to collect data for at least 10 days after the LRC visited the site. These were removed by personnel under direction of Mr. Schaffer after 2+ weeks on site, and were returned by mail to the LRC for read-out.

Questionnaires

The LRC administered questionnaires to 75 employees at EGWW. The questions were the same as the LRC used at EGWW in April 2014.

RESULTS

ILLUMINANCE RESULTS

The LRC measured photometric conditions (illuminance and luminance) at the locations shown in Figure 1 below, the same locations as in the April 2014 visit. Photometric data were organized by perimeter proximity, by perimeter window orientation, and by collection time. Data were collected for 24 desks: 8 per floor, on three floors. The skies were primarily cloudy, but there were occasional shafts of sun on the measurement day.

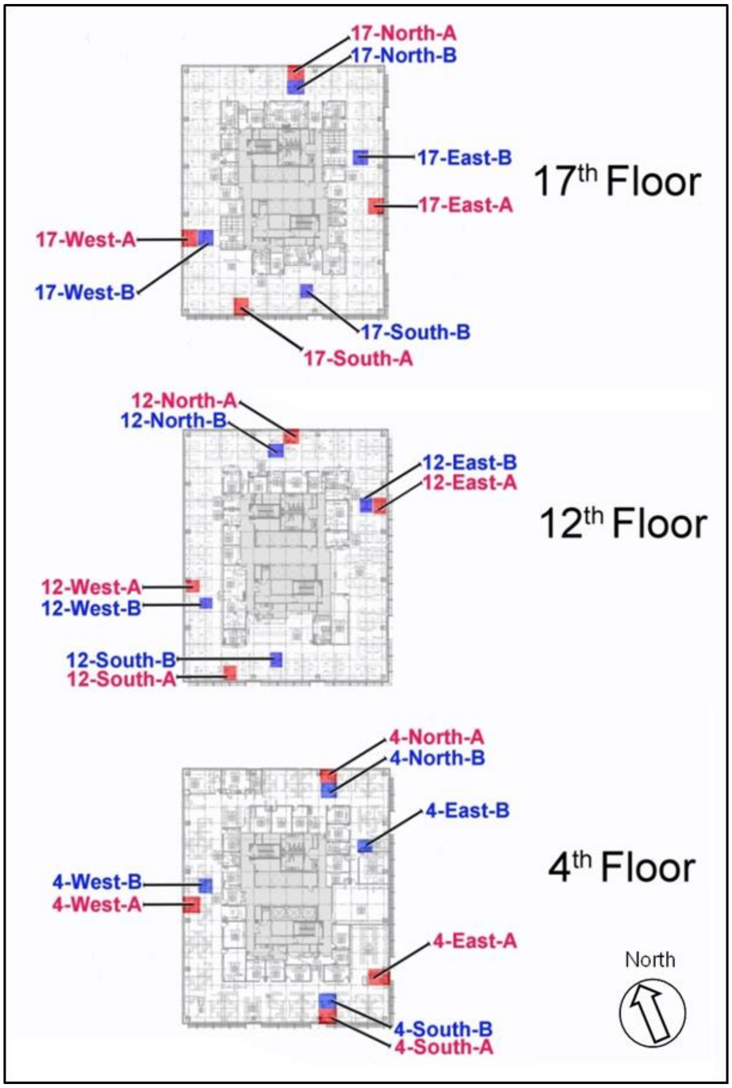

Figure 1. Locations of desks hosting repeated Illuminance and luminance measurements. Desks marked A are in Row A, nearest the windows, while desks marked B are in the adjacent row, Row B.

The resulting measurements are shown below, and in detail in Appendix A.

Figure 2 shows an example of typical horizontal and vertical illuminance measurement locations at the 24 desks. These were the same measurement locations as in LRC's April 2014 visit. Measurements occurred in the morning, midday, in the afternoon, and after dark. Measurements included additional daylight contribution, and reduction of electric lighting in response to daylight (see Luminaire Activity).

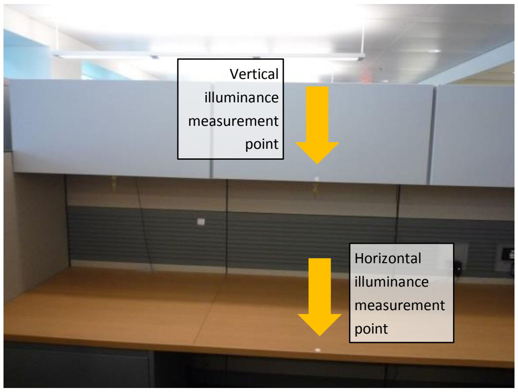

Figure 2. Typical horizontal and vertical illuminance measurement points.

Figure 3 below shows the results of horizontal illuminance measurements on the 24 desks. Unlike in the late spring measurements, the December data did not show that the horizontal illuminances on the north side of the building at the A desks were highest; peak horizontal illuminances were similar (~1000 lx) in all four orientations.

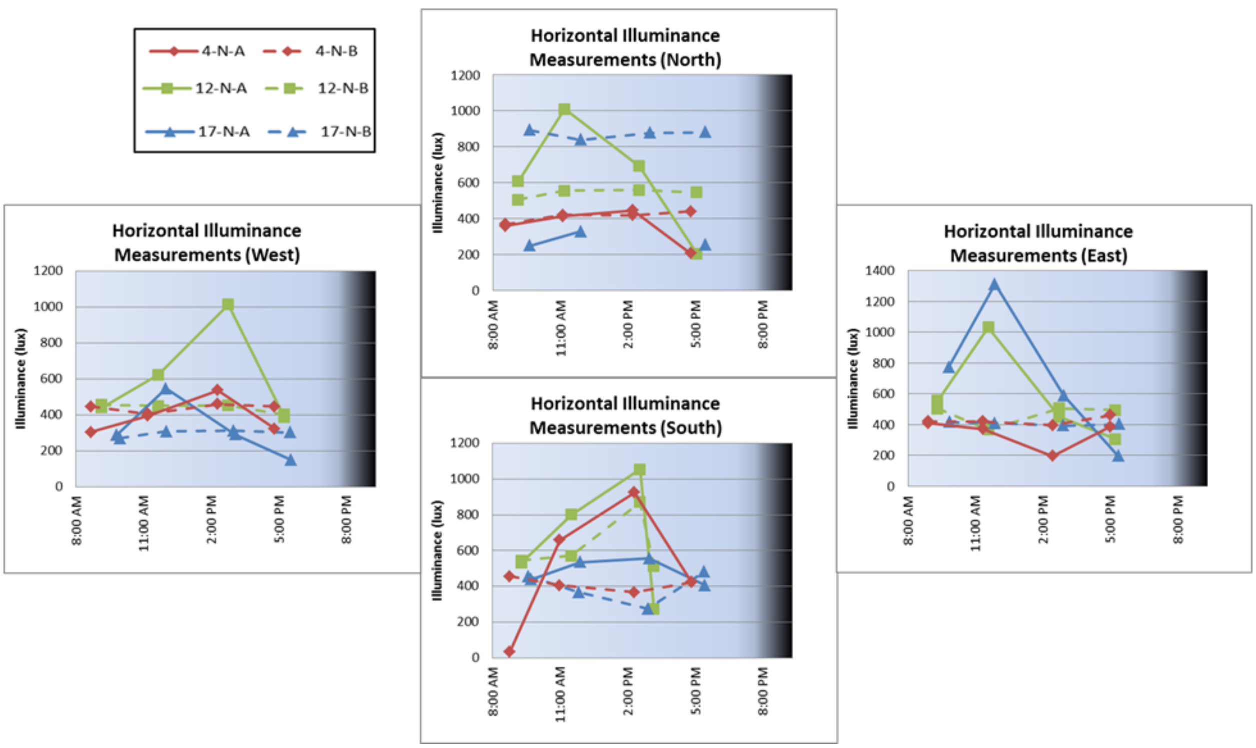

Figure 3. Horizontal illuminance measurements at 24 desks, during the day and in the evening.

In this winter visit, unlike the late spring visit, there were a few measurement times and locations that were below design illuminance target (323 lx, 30 fc).

Figure 4 below shows the results of vertical illuminance measurements on overhead desk shelving. Measurements occurred in the morning, midday, in the afternoon, and after dark. Measurements included additional daylight contribution, and reduction of electric lighting in response to daylight.

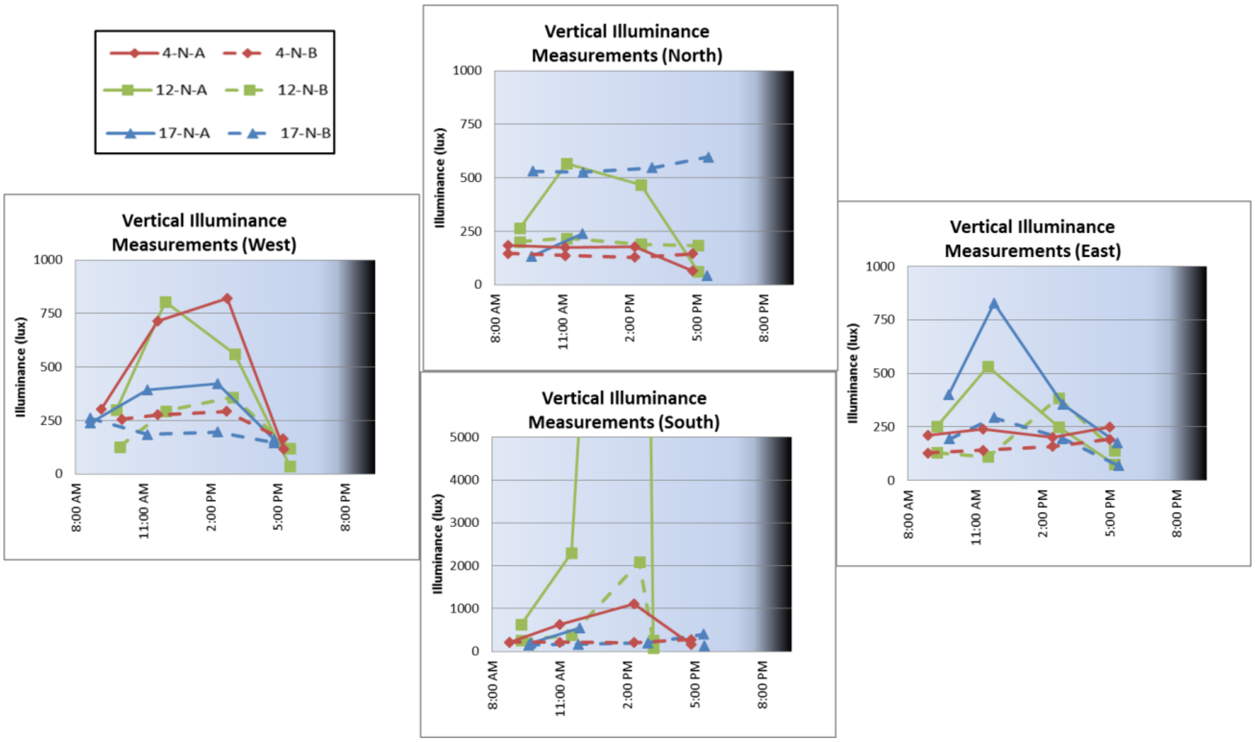

Figure 4. Vertical illuminance measurements at 24 desks, during the day and in the evening.

Unlike in late spring, the vertical illuminance measurements did not always show higher illuminance at Row A compared to Row B; the B desk on the north side of the 17th floor had higher illuminances than other desks with that orientation. On the winter visit, the north side did not have the highest illuminances, but rather, the south side had several vertical measurements over 1000 lx. Unlike late spring, vertical illuminances were not always higher on upper floors than lower floors; the 12th floor had higher illuminances at several desks than the other floors. At many of the B desks, there was not much variation in vertical illuminance throughout the day, apart from a shaft of sun falling near the measurement point at midday on the south side, 12th floor.

Luminance Results

The LRC measured luminance at the same time interval and desks locations used for illuminance measurements (see Figure 1). For each of the A desks and many of the B desks, the LRC measured luminance of the nearest window during the daytime measurements.

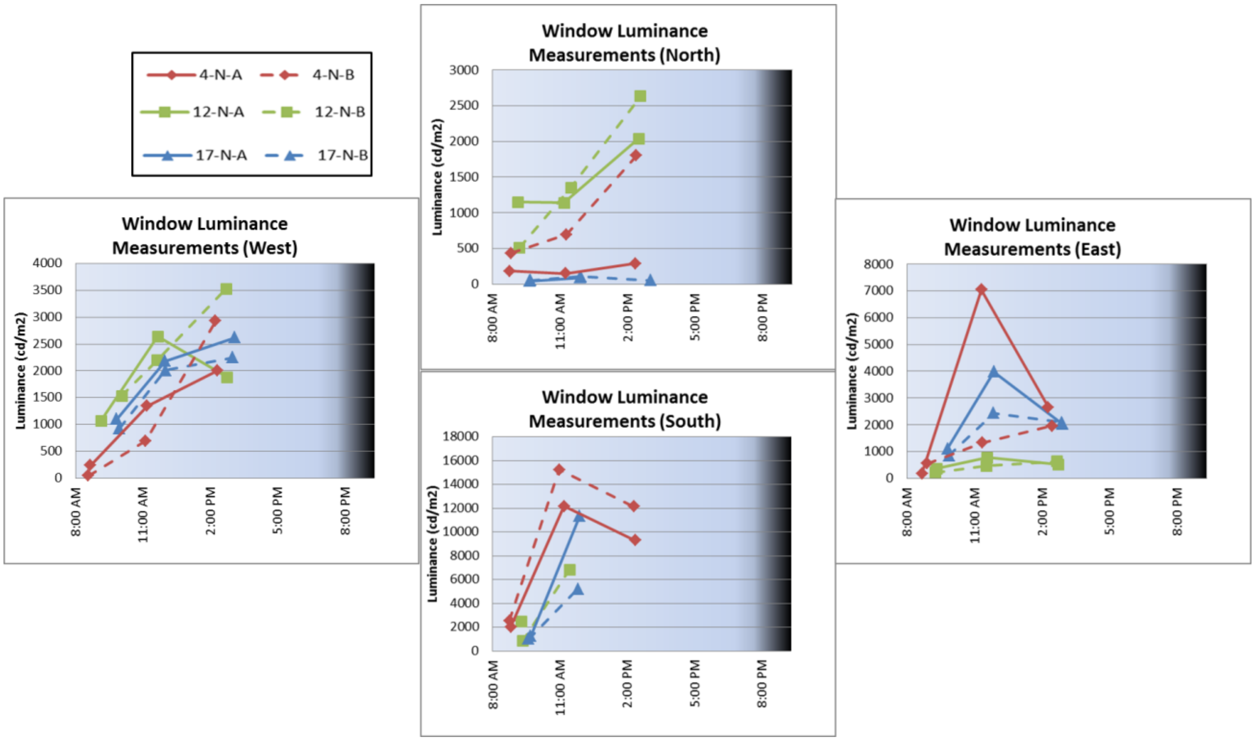

Figure 5. Window luminances during measurement day.

As shown in Figure 5, the highest luminance was the midday measurement at the south-facing window on the 4th floor (15,240 cd/m^2); this is a different orientation than on the late spring visit, in which the east side on the 17th floor had the highest window luminances. On this winter visit, window luminances were not always higher at A desks compared to B desks, unlike in the late spring measurements. As in late spring, floor elevation was not predictive of window luminance; upper floors did not consistently produce the highest window luminance.

The LRC also measured luminance of the key surfaces commonly viewed at the desk: on the desk and on the computer monitor bezel. As shown in Figures 6 and 7 below, in late spring, the desk typically has higher luminance than the computer bezel, because it is a more reflective (lighter) color. When the eye shifts from these lower luminance surfaces to the window, cubicle occupants may experience glare.

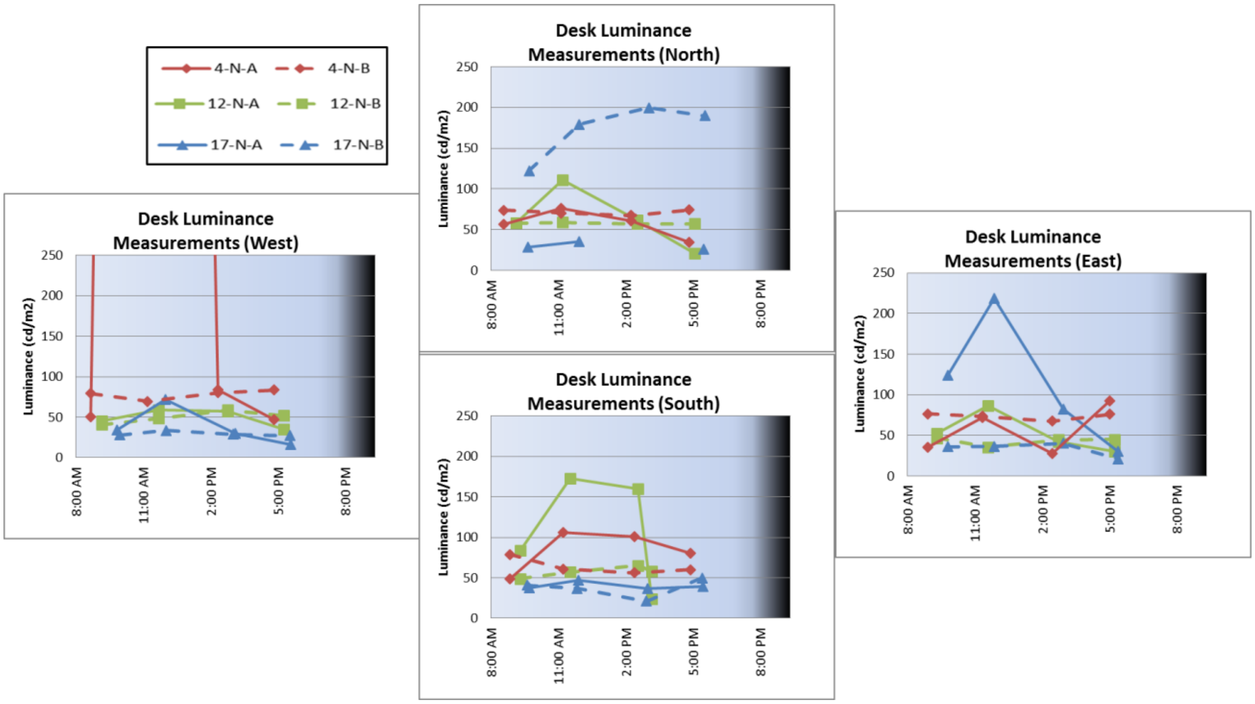

Figure 6. Desk luminances at different orientations.

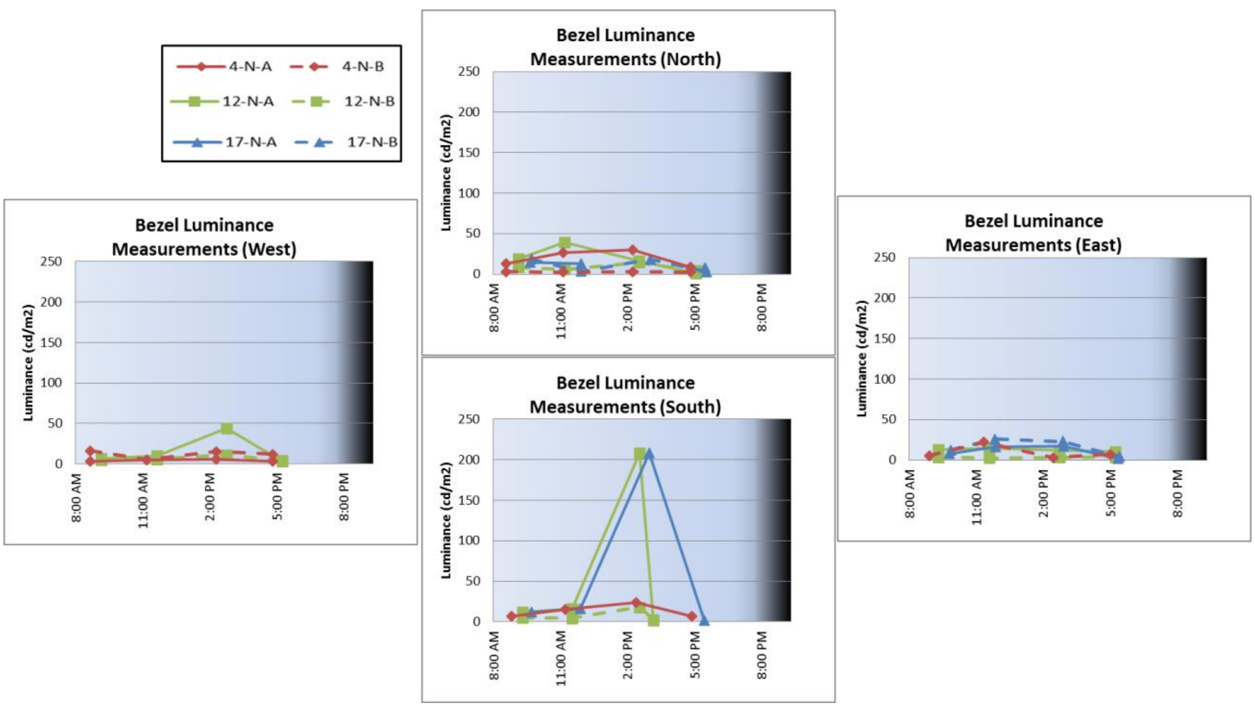

Figure 7. Computer monitor bezel luminances at four different orientations.

Luminaire Activity Results

LRC researchers placed 12 battery-powered light meters on top of operating luminaires to verify whether the lights were dimming in response to daylight (Figure 8). As in late spring, the devices were placed in luminaires located on floors 4, 12, and 17, in the same control zone as the desks where illuminance measurements took place.

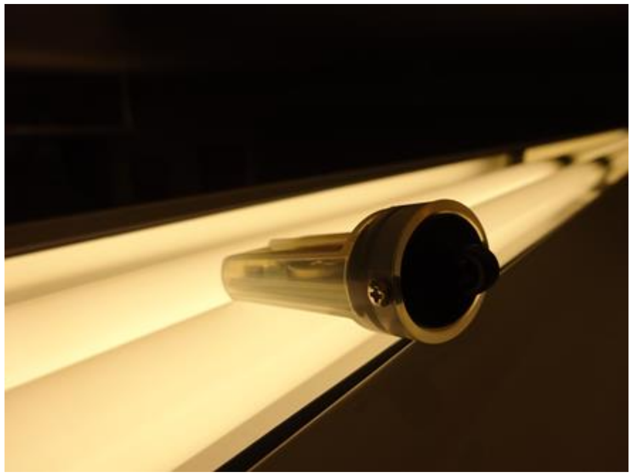

Figure 8. Battery-powered light meter in a luminaire during winter evaluation.

An example of a typical dimming profile is shown in Figure 9. The devices were set to record for at least seven days: four work days, a weekend, and another three work days before the holidays. As annotated, when the relative light output reduces in the middle of the day, this indicates that the luminaire is being dimmed by the photosensor. On the weekends, the luminaires were mostly off, thus monitoring devices measured less light.

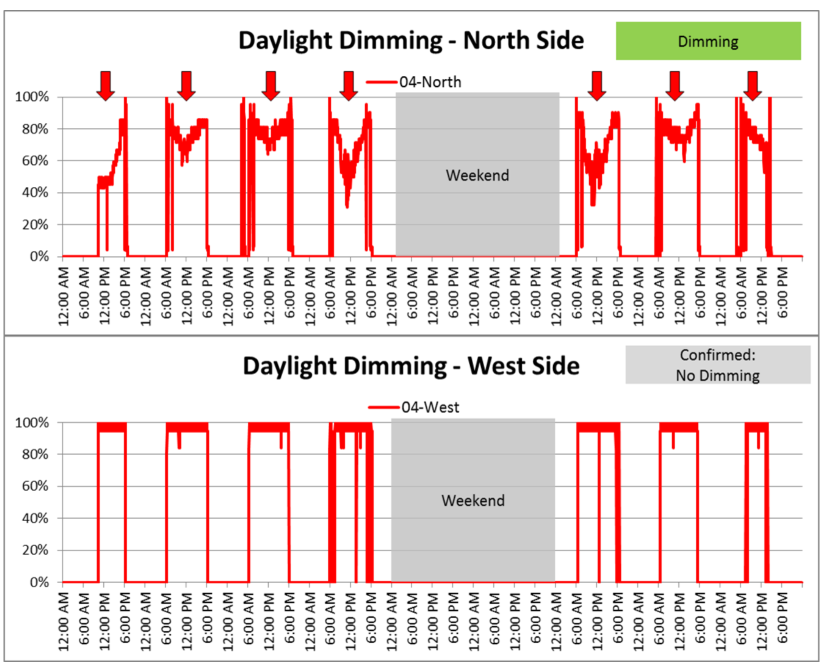

Figure 9. Dimming in EGWW. Winter monitoring showed that electric light output is reduced during the day on the north side (top), and not on the west side (bottom).

As shown in Appendix B, monitoring confirmed that dimming occurs at EGWW, but not in all areas, nor every day during this winter evaluation period.

Unlike results from April 2014, luminaires on the north side showed dimming (Figure 9). It is possible that the photosensor controls on the north side were recommissioned to save energy, per the LRC's recommendation after the late spring visit.

On the east side, dimming occurs on some mornings and afternoons on floors 4, 12 and 17. On the south side, dimming occurs on all three floors in the middle of the day, but not typically at the beginning and end of the day; this is sensible considering that the sun rises at about 7:45 a.m. and sets at about 4:30 p.m.

As expected, the lights on the west side do not dim in response to daylight. However, the data do reveal that the occupancy sensors in this area do sometimes turn off despite the space being occupied. The LRC received two more comments from occupants about lights turning off; sensors on the west and south side of the 17th floor may still need occupancy sensor adjustment.

Questionnaire Results

A brief questionnaire was administered to 75 people working in EGWW. Appendix C shows detailed questionnaire results. Where possible, the questionnaire data for EGWW were compared with results from other office case studies and the GSA evaluation site at Grand Junction, Colorado and late spring data from EGWW (see References).

Most respondents (65%) only work during the day, which was less than in late spring (84%).

Workers answered the questionnaire on all three days that the LRC evaluated the site. For much of that time, skies were cloudy and rainy; despite the weather, other data (see Appendix B) indicate that the electric lights were dimming in response to daylight when many of the people responded to the questionnaire.

Most workers were satisfied by the amount of light provided; 63% reported that the amount of light on their desk was neither too much nor too little (vs. 72% for late spring). Many commented that they love the amount of daylight ("natural light") they receive.

There was not an increase in task light use in winter; use of task lights at EGWW was reported by the same percentage of respondents (56%) in both seasons.

As in late spring, mesh window shades are often adjusted by EGWW's occupants, partly due to changes in weather, and partly due to time-of-day sun position. More respondents (44%) reported that they keep shades up all the time (vs. 28% in late spring). Again, workers reported adjusting shades due to cloudy weather (33%) or sunny (31%) weather (vs. 40% for both in late spring). In addition to weather and time of day, a few more commented that the glare from neighboring buildings motivated their use of mesh shades. One person commented that there is disagreement about blinds operation between people sitting at A desks vs. B desks. Another person commented that adjustment of shades is avoided due to affecting the co-worker.

Most respondents (73%) reported that the windows at EGWW are comfortable to look at (vs. 83% in late spring). Most (60%) also rated their luminaires as comfortable to look at (vs. 79% in late spring); this was similar to other LRC office lighting case studies.

Overall, compared to other offices, the lighting at EGWW was rated as "better" or "much better" by about half (49%) of the respondents (vs. 56% in late spring). Again, about a third (33%) considered the lighting to be "about the same" (vs. 32% in late spring). These results are similar to other office lighting case studies, as shown in Figure 10.

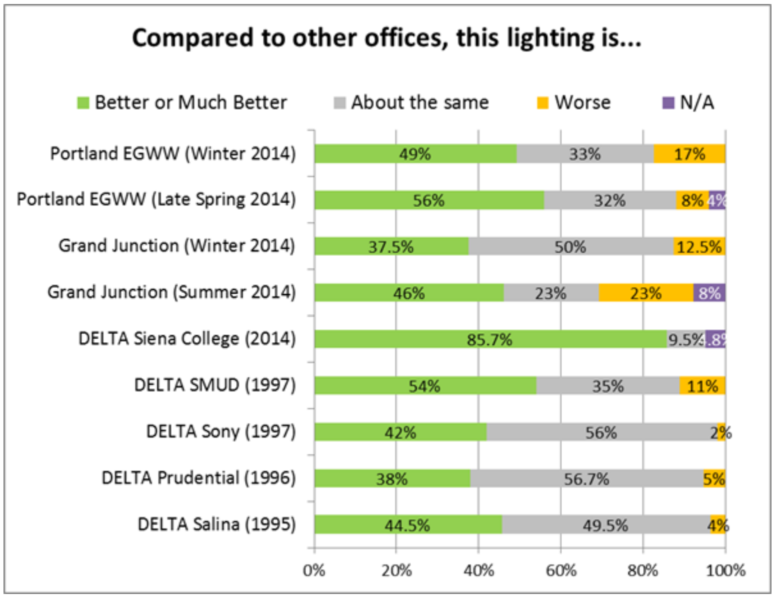

Figure 10. Overall questionnaire results at EGWW, compared with other office lighting evaluations by the LRC.

Spectral Power Distribution (SPD) Results

Shown below is a photo of the equipment used for measurement of spectral characteristics (Figure 11). The measurement probe was held at the eye and aimed at the computer screen to simulate the eye position of the person working at each desk. Measurements were collected three times during the day, as well as after dark, with only electric light and no daylight contribution.

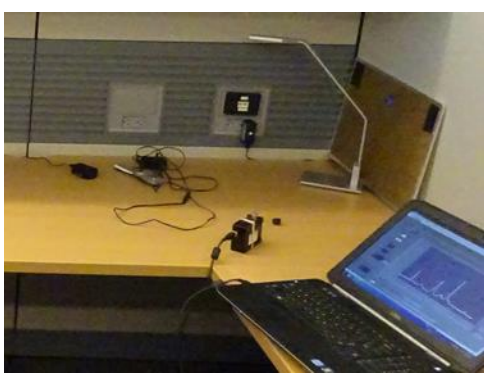

Figure 11. A spectroradiometer taking measurements at desk level.

As shown in Figure 12, SPDs were measured at the same desk locations as used for hosting other measurement equipment (see Daysimeter Stick and Window Results).

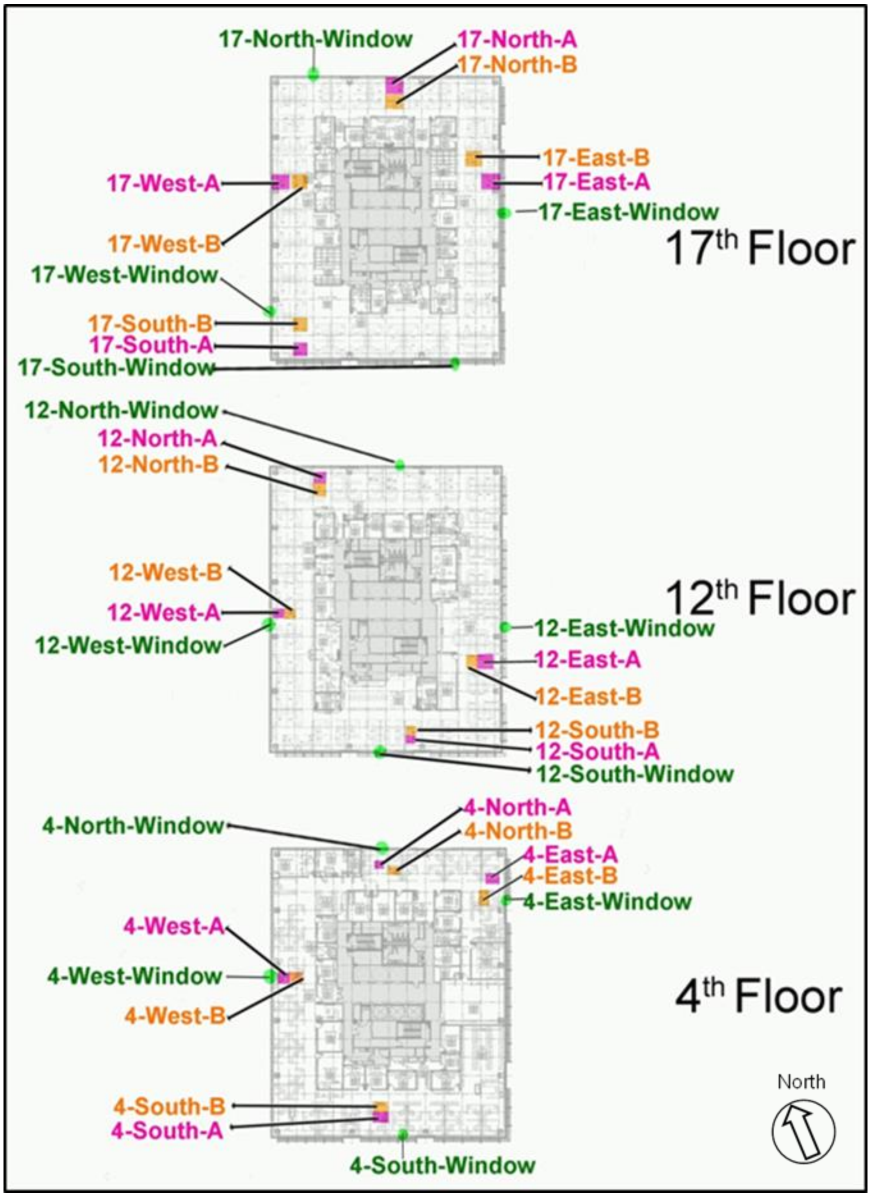

Figure 12. SPD measurements were collected at desks in Rows A and B on three floors; the same locations were used to host other measurement equipment.

The SPD measurements were later used to calculate the percentage of daylight and electric light in the space, as well as photopic lux and circadian stimulus.

Relative visual performance (RVP), or the speed and accuracy of reading, are high (RVP > 0.95) for all conditions, because the computer monitors provide high contrast/large font size, and any printed materials are illuminated to at least 30 fc (approximately 300 lx) on the desk surface (horizontal illuminance).

Detailed results are shown in Appendices D-G. Table 1 shows average results during the winter visit's daytime measurements (excluding evening measurements, since workers are not present after dark). For comparison, Table 2 shows the same results from the late spring visit.

Table 1: Winter average (except as indicated) daytime measurements using spectroradiometer

EXCLUDING Night Measurements

	Illum-inance	Approximate Contribution (+/- 10%)		Color Temp	Circadian Light		Circadian Stimulus (up to 0.7)	
Deskspace Locations	**Lux**	**Fluor %**	**Day %**	**CCT(K)**	**Average CL_A**	**Median CL_A**	**Average CS**	**Bright-ness**
A	678	33%	67%	5031	723	445	0.399	518
B	335	86%	14%	3296	320.3	319.6	0.323	192
Orientations								
E	456	62%	38%	4180	503	348	0.358	329
N	393	66%	34%	4012	381	332	0.335	261
S	766	50%	50%	4183	763	406	0.400	532
W	412	59%	41%	4279	439	334	0.350	298
Floors								
4	379	71%	29%	3685	329	292	0.305	243
12	571	50%	50%	4498	627	407	0.407	419
17	570	56.5%	43.5%	4308	609	379	0.371	403

Table 2: Late spring average (except as indicated) daytime measurements using spectroradiometer

Deskspace Locations	**Lux**	**Fluor %**	**Day %**	**CCT(K)**	**Average CL_A**	**Median CL_A**	**Average CS**	**Bright-ness**
A	865	30%	70%	5321	1178	617	0.446	709
B	344	81%	19%	3632	344	231	0.288	230
Orientations								
E	675	59%	41%	4272	836	303	0.360	514
N	1001	40%	60%	5017	1375	1057	0.490	812
S	302	65%	35%	4170	329	212	0.288	217
W	413	57%	43%	4396	462	256	0.324	313
Floors								
4	415	68%	32%	3968	439	247	0.328	292
12	487	63%	37%	4242	595	295	0.343	369
17	896	35%	65%	5175	1224	651	0.426	733

Like the spring data, the winter data show the impact of window proximity on light exposure. At many of the A desks, CS values were above 0.3, which is considered the lower end of the threshold boundary for circadian stimulation. In the winter measurements, some B deskspaces achieved CS values above the desired amount (Figure 13).

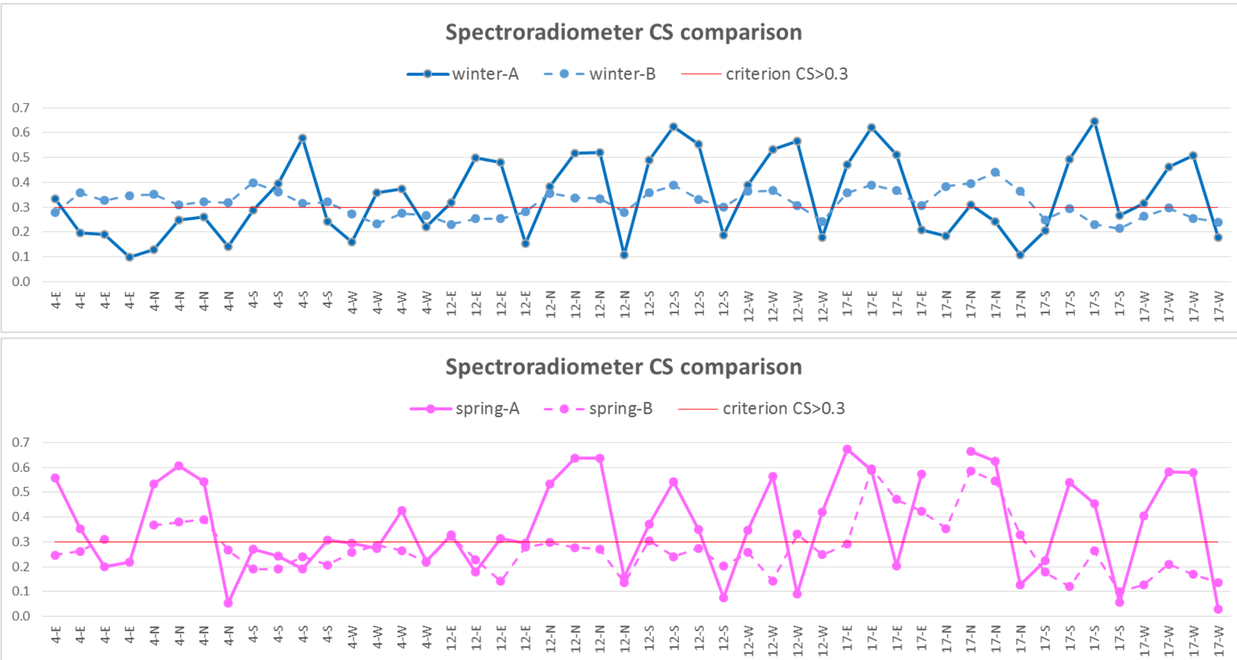

Figure 13. CS values on the site visit days, A vs. B desks, winter vs. late spring.

In late spring, workers on the north side of the building were exposed to higher light levels than the other sides of the building; however, on the winter visit, the south side desks measured higher CS values than other building orientations. On the day of the visit, workers on the 12th floor were exposed to higher light levels than on the 17th floors. These data are, however, snapshots of what the exposures are over the course of one working day. Weather changes may explain these unexpected results. Another possible explanation is that because the building is slightly tilted with respect to "true north," sun angles during winter months on the higher floors may have led users to pull the shades, as discussed below. Daysimeter measurements, discussed below, may be a better representation of the continuous light availability over the course of the working day.

Daysimeter Stick and Window Results

Appendices H-J show the hourly average from 8:00 a.m. to 5:00 p.m. of the CS values and the photopic lux values for each Daysimeter. For comparison, the winter and spring months data are plotted next to each other.

In general, the deskspaces located near the windows (Row A) had the highest potential for delivering the highest circadian stimulation to the employee, especially between 10:00 a.m. and 3:00 p.m. All deskspaces in Row A received desirable CS stimulation during the late spring months. There was, however, a seasonal change in the amount of CS measured during winter and late spring. CS values did not always reach the desired levels in winter months. The change in CS value between winter and late spring was less pronounced on the 4th floor than on the 12th and 17th floors at deskspaces located near the window. In Row B, where CS values did not increase in winter months compared to late spring months.

During the late spring, deskspaces located away from the windows (Row B) had CS values below the desired amount on the 4th floor; Row B desks on the 12th and 17th floor showed CS values at or above 0.4 on the north and east sides. The effect of season on CS values on deskspaces located farther from windows (Row B) was smaller.

As expected, the deskspaces located on the north façade tended to have the greatest CS values during the late spring, given that shades were up most of the time. CS values also tended to increase from the 4th to the 17th floor. In fact, all deskspaces facing north that were close to the window (Row A) had CS values above 0.3 in the late spring, the lower end of the threshold boundary for circadian stimulation. However, as expected, CS values in winter months were much higher in these deskspaces located in Row A and none of the CS values obtained in winter months were above the proposed threshold. These much lower CS values in the north façade may be explained by the fact that the building is slightly tilted with respect to true north. Therefore, the lower sun angle in winter months and the fact that the north façade may receive some east sun may explain why shades might have been drawn in the north façade during winter months.

Except for a few deskspaces located in the south and east façades that did not have the shades pulled down during the late spring measurements and, therefore, had vertical light levels above 1780 lx, all other deskspaces had light levels that are likely to be within the comfort range for glare. Some deskspaces had light levels that were bordering discomfort (between 900 lx and 1780 lx). In the winter months, only a few deskspaces located in the east façade had light level measurements slightly above the discomfort glare (DG) value. No other deskspaces reached the boundary for discomfort glare.

There was one interesting case on the 4th floor, where sun reflected from a building across the street hit the window sill of a deskspace in Row A and reflected light directly onto the worker's eyes, causing a very high rating of discomfort glare. The occupant covered the window sill with cloth and added a "personal shade" to her deskspace to mitigate the problem.

One difference noted in this building was that the deskspaces located close to the perimeter on the west façade had enough circadian stimulation because shades were generally up. This was because the architectural "reeds" on this side provided exterior shading and helped reduce sunlight penetration in the space, making it possible for workers to keep their shades up and still comfortably perform their computer and paper work.

Overall, while these measurements cannot be considered representative of the daily light exposure that office occupants are experiencing, it gives the researchers an idea of the potential for receiving enough circadian stimulation at these deskspaces. In summary, those located in the perimeter of the building on the north side and at higher floors are likely receiving the ideal dose of daily circadian light during the spring and summer months, but not during the winter months. Circadian stimulation increased during the winter months on the east and south façades and reduced on the north and west façades;

the reduction on the north façade was large, most likely due to some sunlight penetration during these months.

DISCUSSION

A summary of the findings is shown in Figure 14. Pink-shaded portions of the figure reflect areas likely to cause DG (above 1780 lx), or likely to provide low CS (below 175 lx), for a daylight source. The yellow-shaded boundary, between 940 lx and 1780 lx, is considered at or near threshold for evoking a discomfort glare response from occupants. The lower end of the threshold boundary for discomfort glare represents a DG rating of 4.5 whereas the upper boundary represents a DG rating of 4.0. The yellow-shaded boundary, between 175 lx and 300 lx, is considered to be at or near threshold for reliable stimulation of the human circadian system. The lower end of the threshold boundary for circadian stimulation represents a CS value of 0.3, whereas the upper boundary represents a CS value of 0.4.

The "ideal" vertical levels of photopic illuminance from daylight, lower than the discomfort glare threshold boundary and above the circadian stimulus threshold boundary, are between 300 lx and 940 lx. Except for one deskspace on the south side, all other deskspaces on the 17th floor were above the desired CS value. The fact that CS values are below 0.3 at night is actually desirable to help reduce circadian stimulation for those who might be working after normal working hours (e.g., evening hours). Perimeter deskspaces on the 12th floor achieved the desired circadian stimulus most of the time, as did north and east interior (Row B) offices. On the 4th floor most of the measurements met the criterion, except for the south side and the interior (Row B) desks.

Several caveats should be stressed, however:

- CS values are based upon melatonin suppression for a standard observer after 1 hour of light exposure. Longer exposures to light are probably sufficient to entrain subjects, but estimates of the trade-off between level and duration are not available. Functionally, CS levels as low as 0.1 may be sufficient for circadian entrainment for extended (i.e., 5-8 hours) exposures. More research is needed to determine the relationship between light level and exposure duration as it may affect the circadian system.
- Ideal conditions at work where high levels of CS are provided in the morning hours may be compromised by light exposure after work.
- DG ratings are highly variable among people and for different contexts.

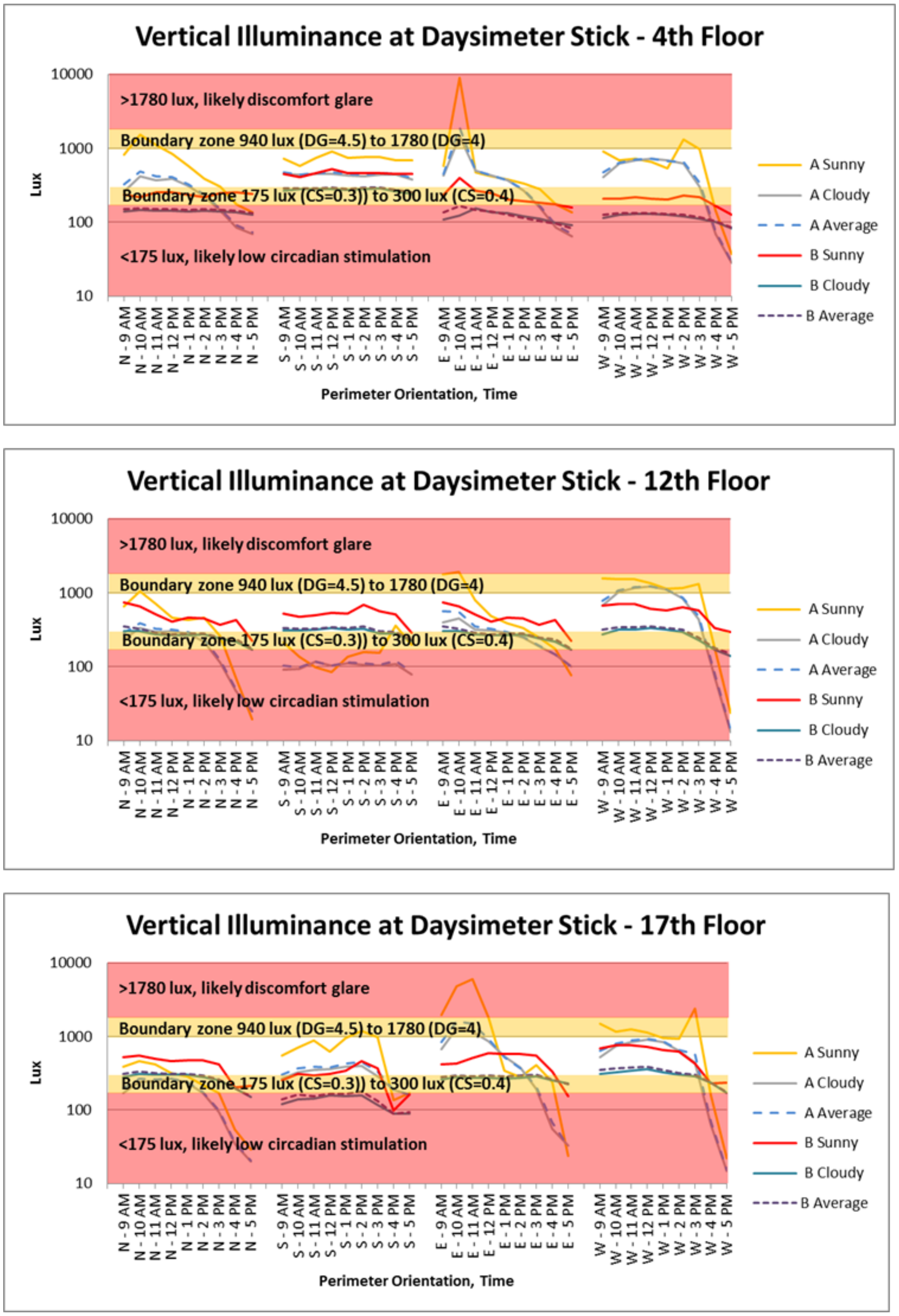

Figure 14. Vertical illuminance at the eye in different workstations at different times of day. The photopic sensor making measurements was oriented so that it faced the same direction as the occupant, at a common eye height.

The photometric measurements and the Daysimeter measurements provided some lessons learned that are consistent with other site evaluations performed by the LRC and other researchers (see References). Some of the lessons learned include:

- Deskspaces close to the windows receive greater circadian stimulation than those away from the windows. Lower level floors receive less circadian stimulation than higher level floors.
- Seasonal differences in circadian stimulation were as predicted, with less circadian stimulation during the winter months compared to late spring. One interesting observation was that CS values increased in winter months on the south and east façades, suggesting that occupants kept the shades up more often in winter months. On the other hand, CS values were much lower on the north façade, especially on the higher floors. This suggests that occupants pulled the shades down, perhaps due to lower sun angles or the fact that the north façade is slightly tilted to the east; morning sun may have changed occupants' behavior during winter months.
- Although all of the deskspaces measured met the target horizontal illuminance of 30 fc (approximately 300 lx), and most workers reported the amount of light on their desks was neither too much nor too little, some workers still felt the need to use task lights, while others complained about the space being "too bright" for computer use.
- The use of shades to reduce discomfort glare on perimeter deskspaces located on the east and south façades reduced vertical illuminances and circadian stimulation at these deskspaces, in particular on those located away from the windows. This effect was mostly observed in the late spring months and was not observed as much in winter months, as discussed above.
- The use of architectural "reeds" on the west façade helped increase light levels on perimeter deskspaces, because shades were found to be open. The CS values obtained in winter and late spring were satisfactory and very similar in both seasons.
- Furniture layout at deskspaces located in the perimeter promotes circadian stimulation because workers are sitting in such a way that they are facing the window, increasing exposure to light. However, this setting may also increase discomfort glare on sides where there is direct sunlight, explaining why the deskspaces on the south and east façades do not receive enough circadian stimulation during the late spring months. (This was not true during the winter months and on deskspaces located in Row B.) This could also explain why the deskspaces on the north façade did not receive enough circadian stimulation during the winter months.

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SERA Architects "Snapshot 5" Lighting Narrative, undated.

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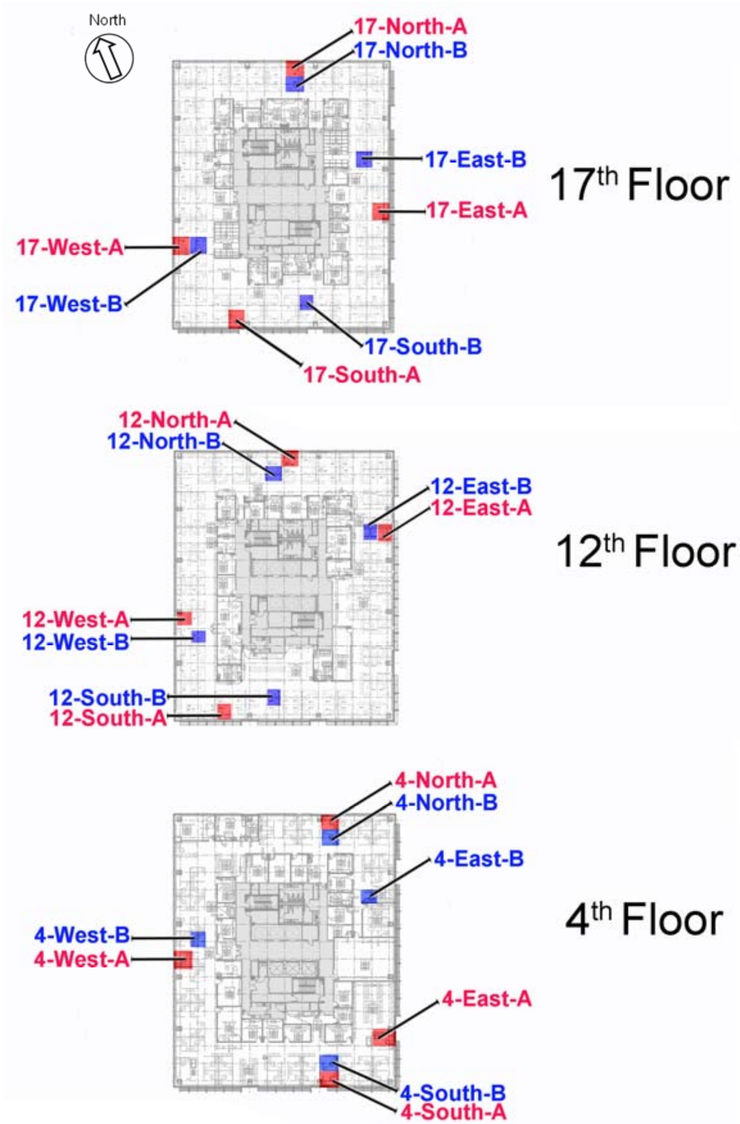
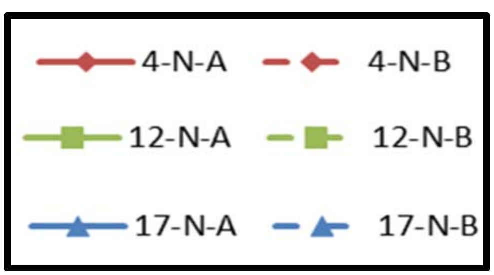
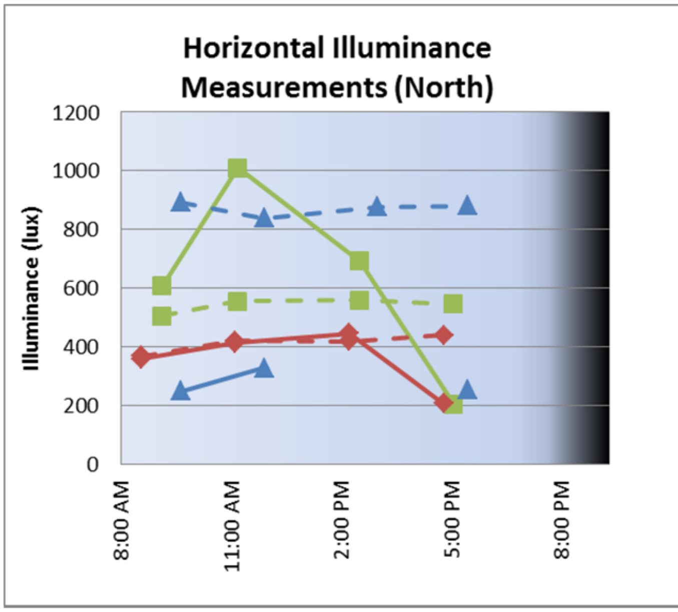
APPENDIX A: PHOTOMETRIC DATA (ILLUMINANCE AND LUMINANCE MEASUREMENTS)

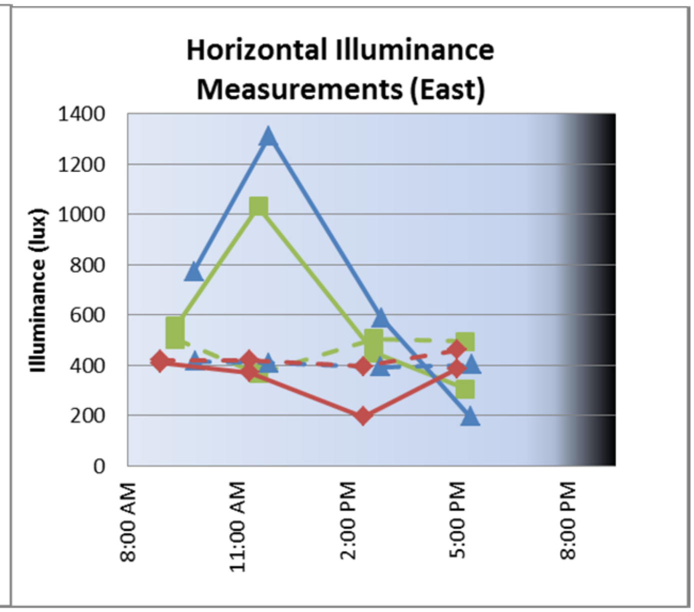


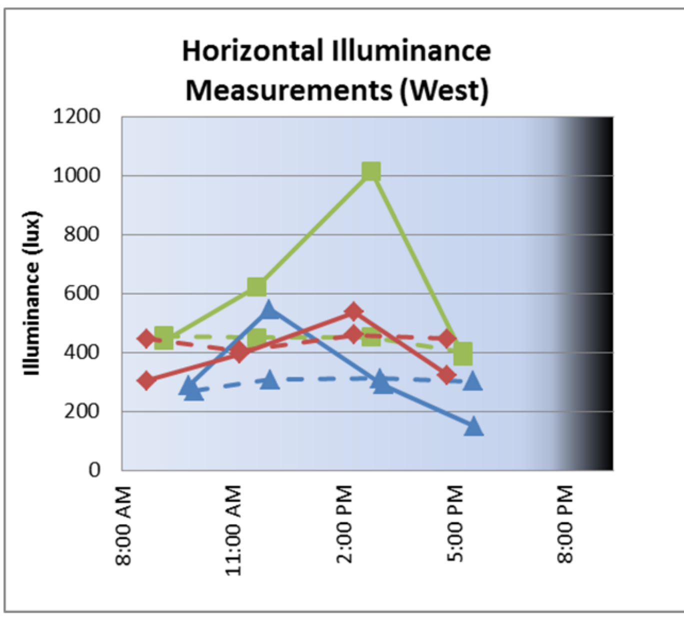
Desk measurement locations

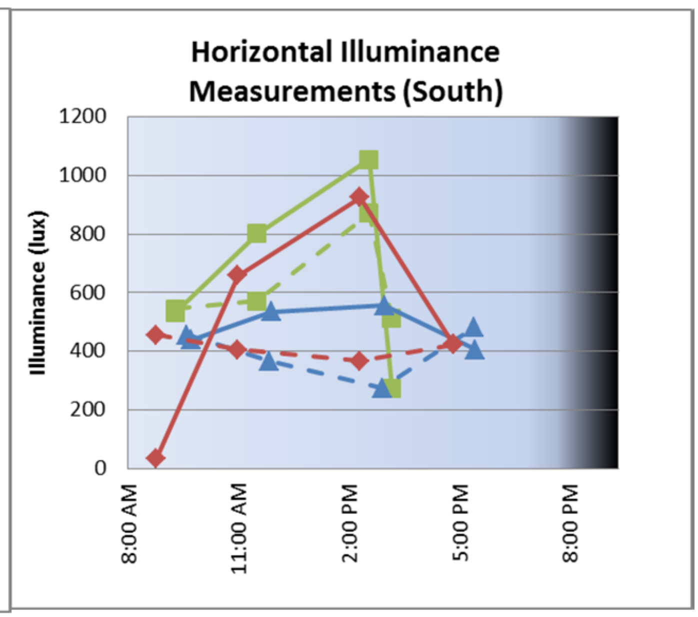


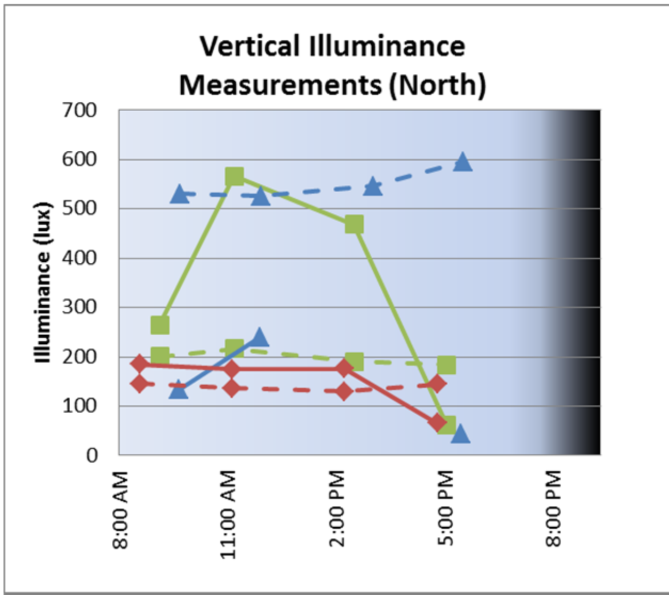
Legend for figures in this appendix

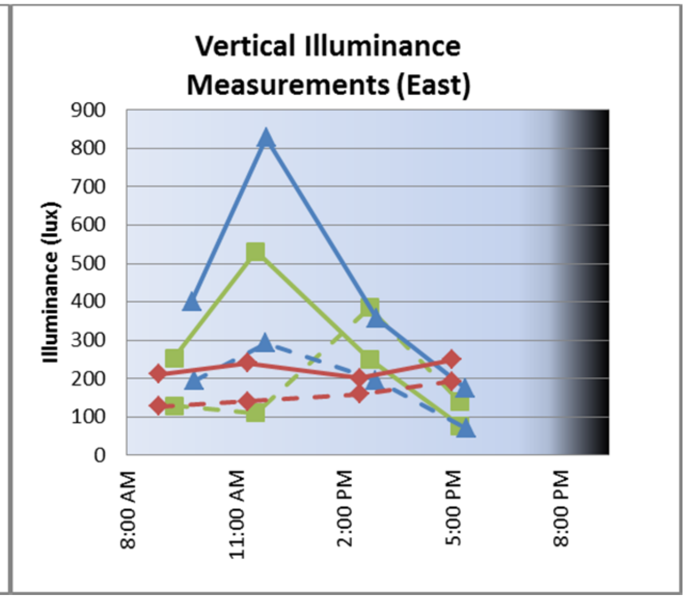

Horizontal Illuminance Measurements (North)
Illuminance (lux)
0
200
400
600
800
1000
1200
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

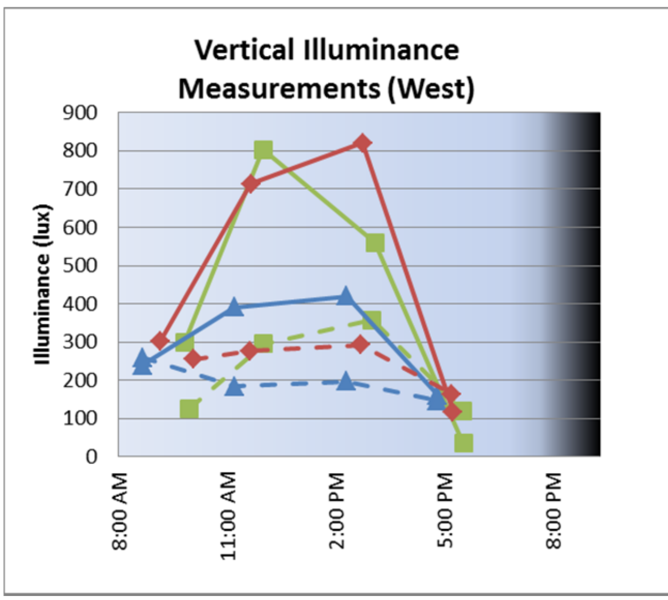

Horizontal Illuminance Measurements (East)
Illuminance (lux)
0
200
400
600
800
1000
1200
1400
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

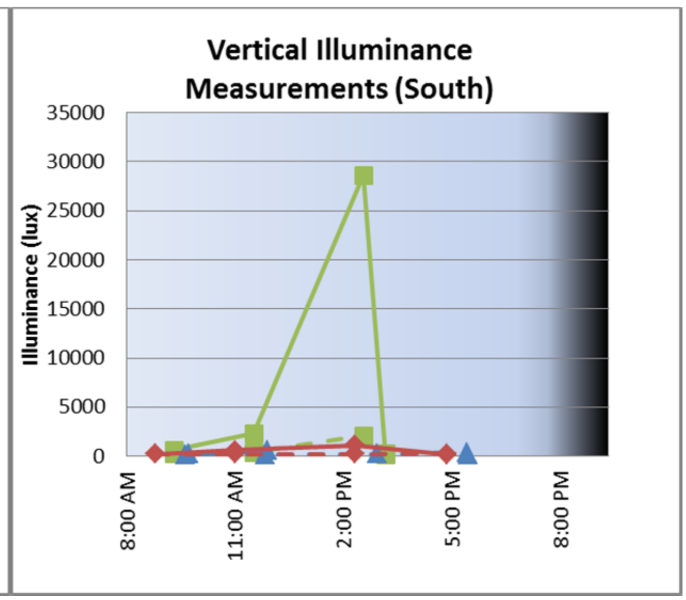

Horizontal Illuminance Measurements (West)
Illuminance (lux)
0
200
400
600
800
1000
1200
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

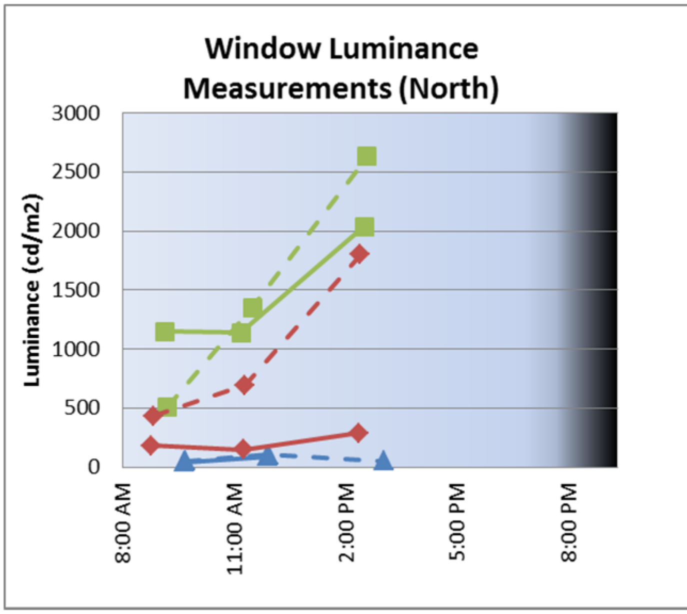

Horizontal Illuminance Measurements (South)
Illuminance (lux)
0
200
400
600
800
1000
1200
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

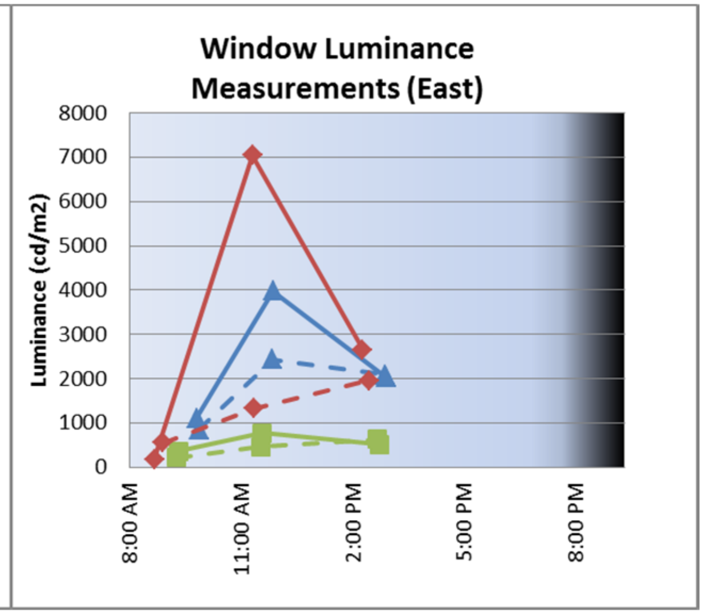

Vertical Illuminance Measurements (North)
Illuminance (lux)
700
600
500
400
300
200
100
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

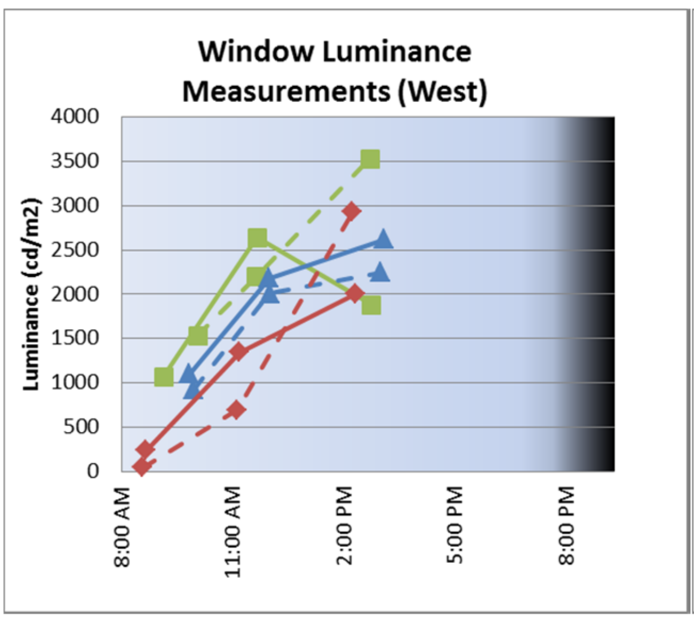

Vertical Illuminance Measurements (East)
Illuminance (lux)
900
800
700
600
500
400
300
200
100
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

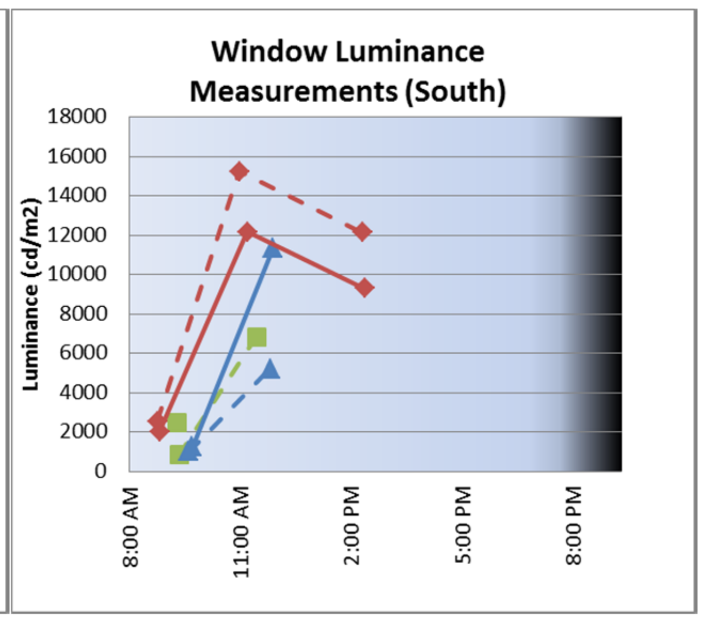

Vertical Illuminance Measurements (West)
Illuminance (lux)
900
800
700
600
500
400
300
200
100
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

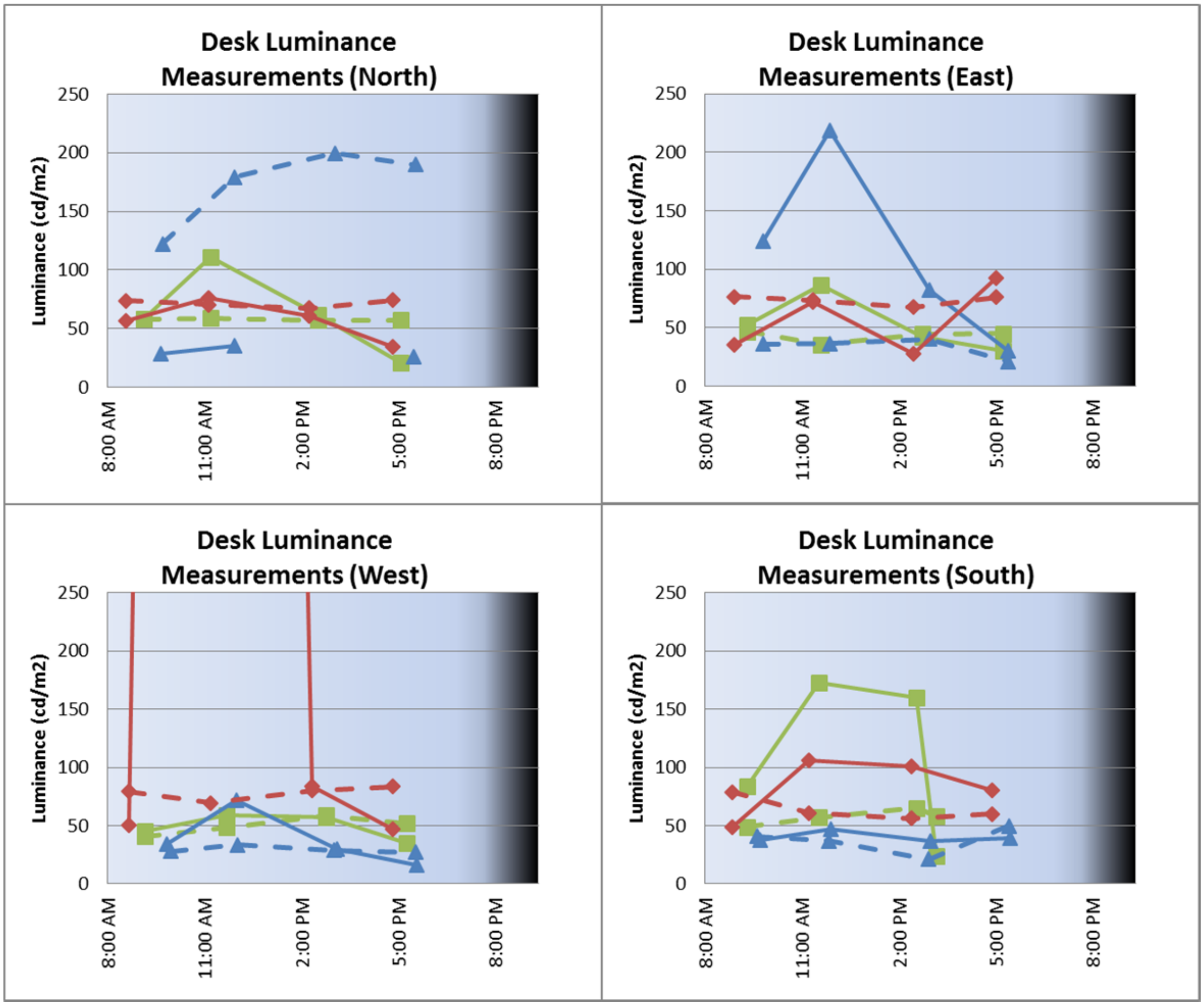

Vertical Illuminance Measurements (South)
Illuminance (lux)
35000
30000
25000
20000
15000
10000
5000
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

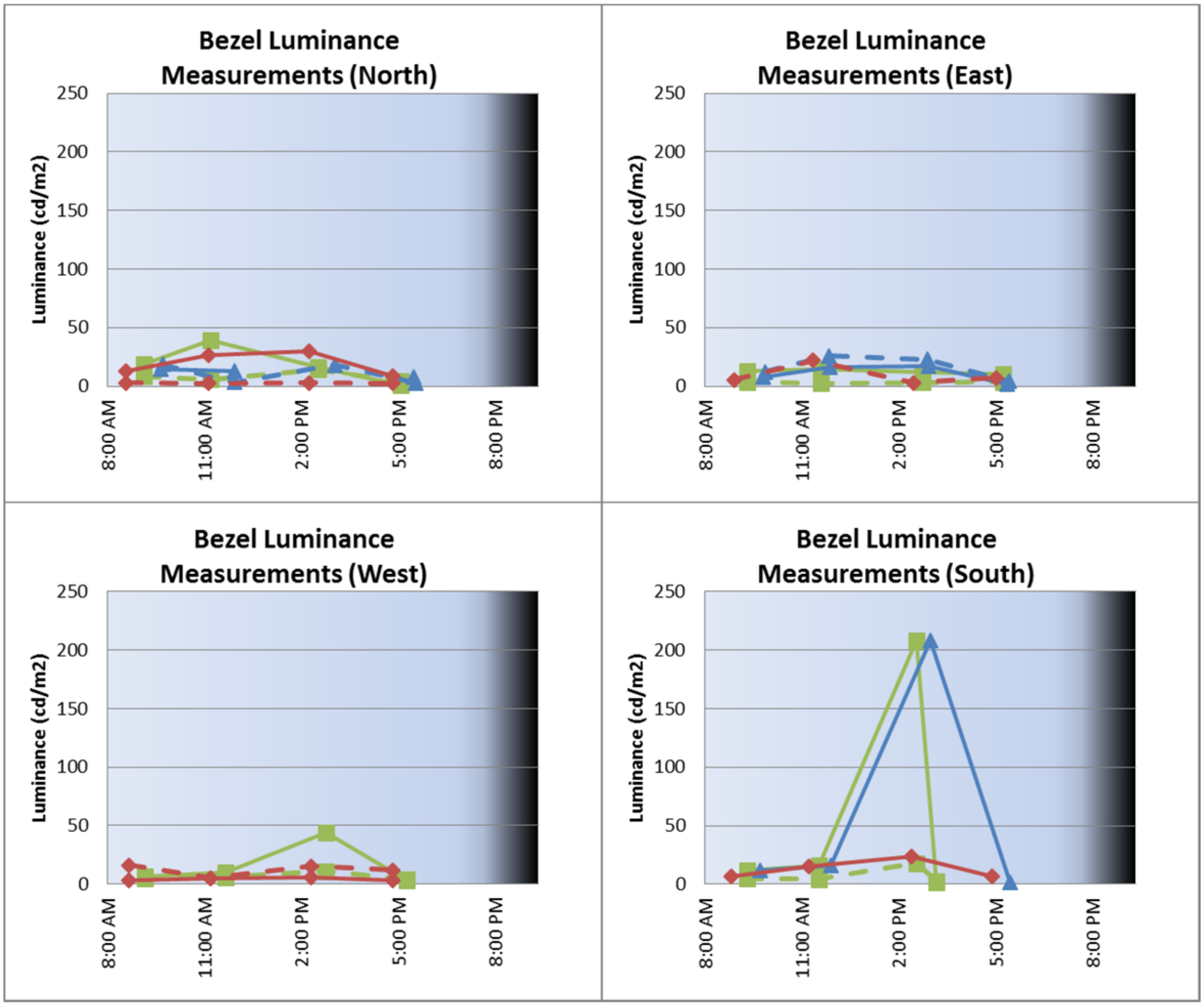

Window Luminance Measurements (North)
Luminance (cd/m2)
3000
2500
2000
1500
1000
500
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM


Window Luminance Measurements (East)
Luminance (cd/m2)
8000
7000
6000
5000
4000
3000
2000
1000
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

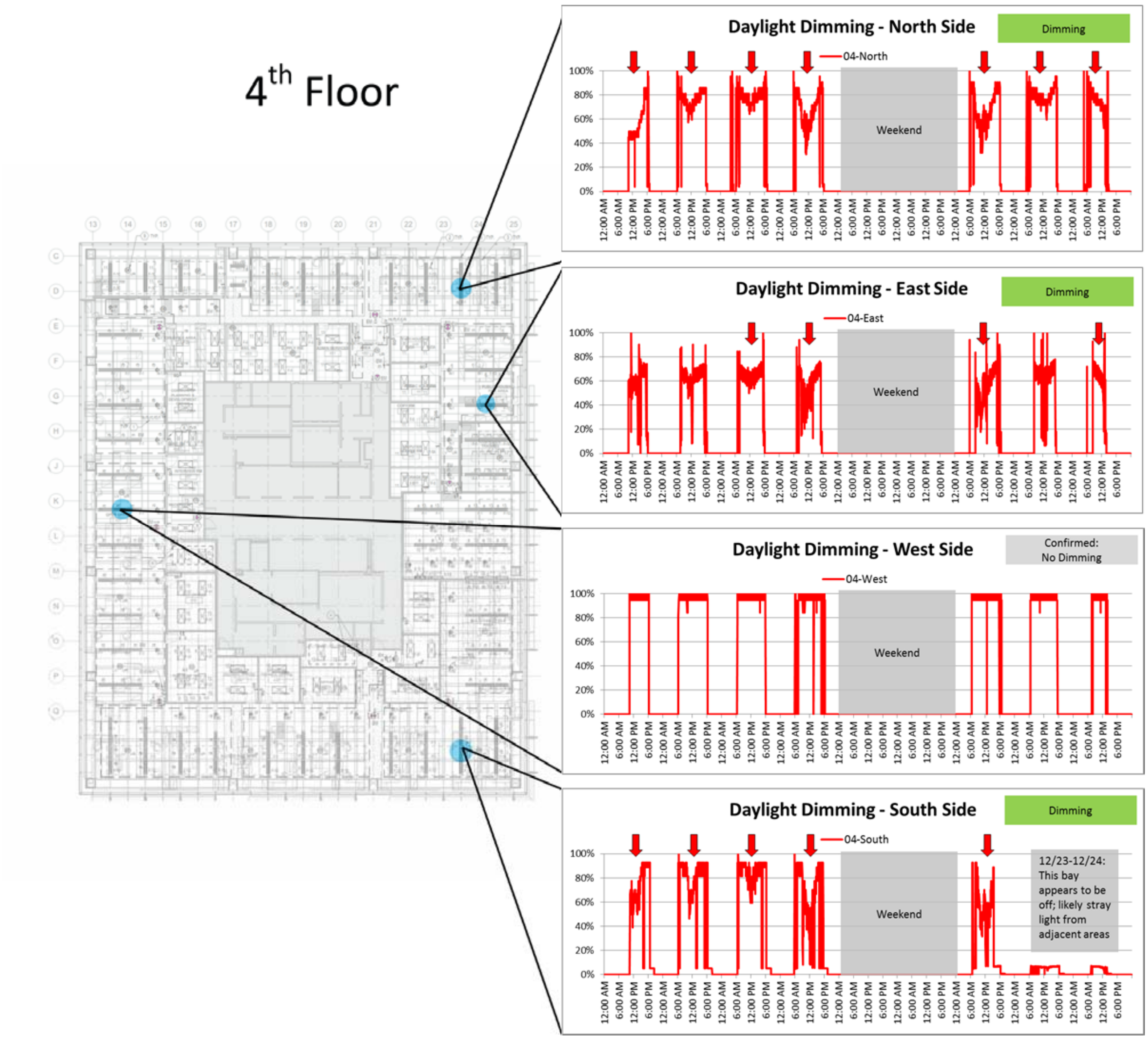

Window Luminance Measurements (West)
Luminance (cd/m2)
4000
3500
3000
2500
2000
1500
1000
500
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

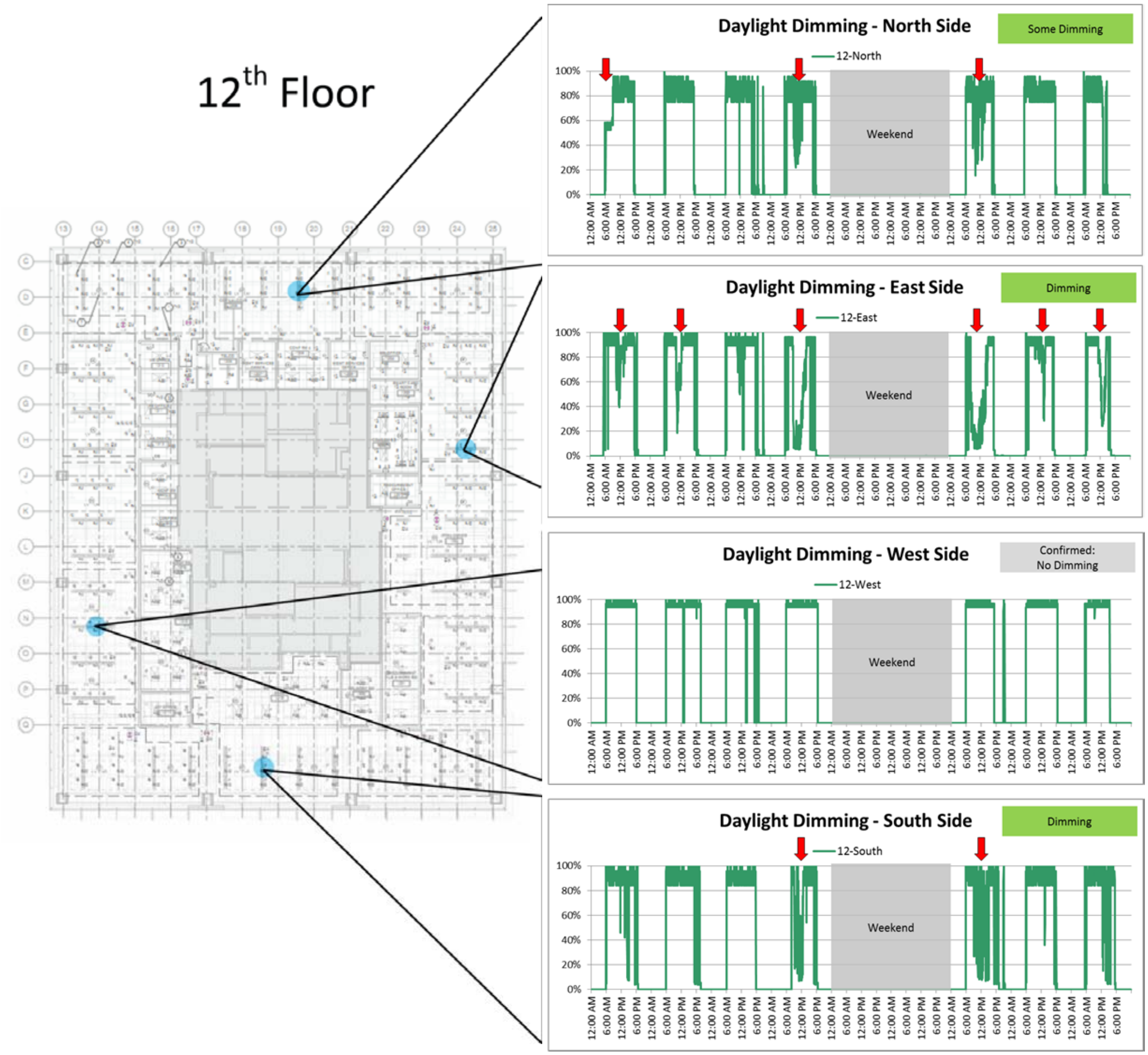

Window Luminance Measurements (South)
Luminance (cd/m2)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

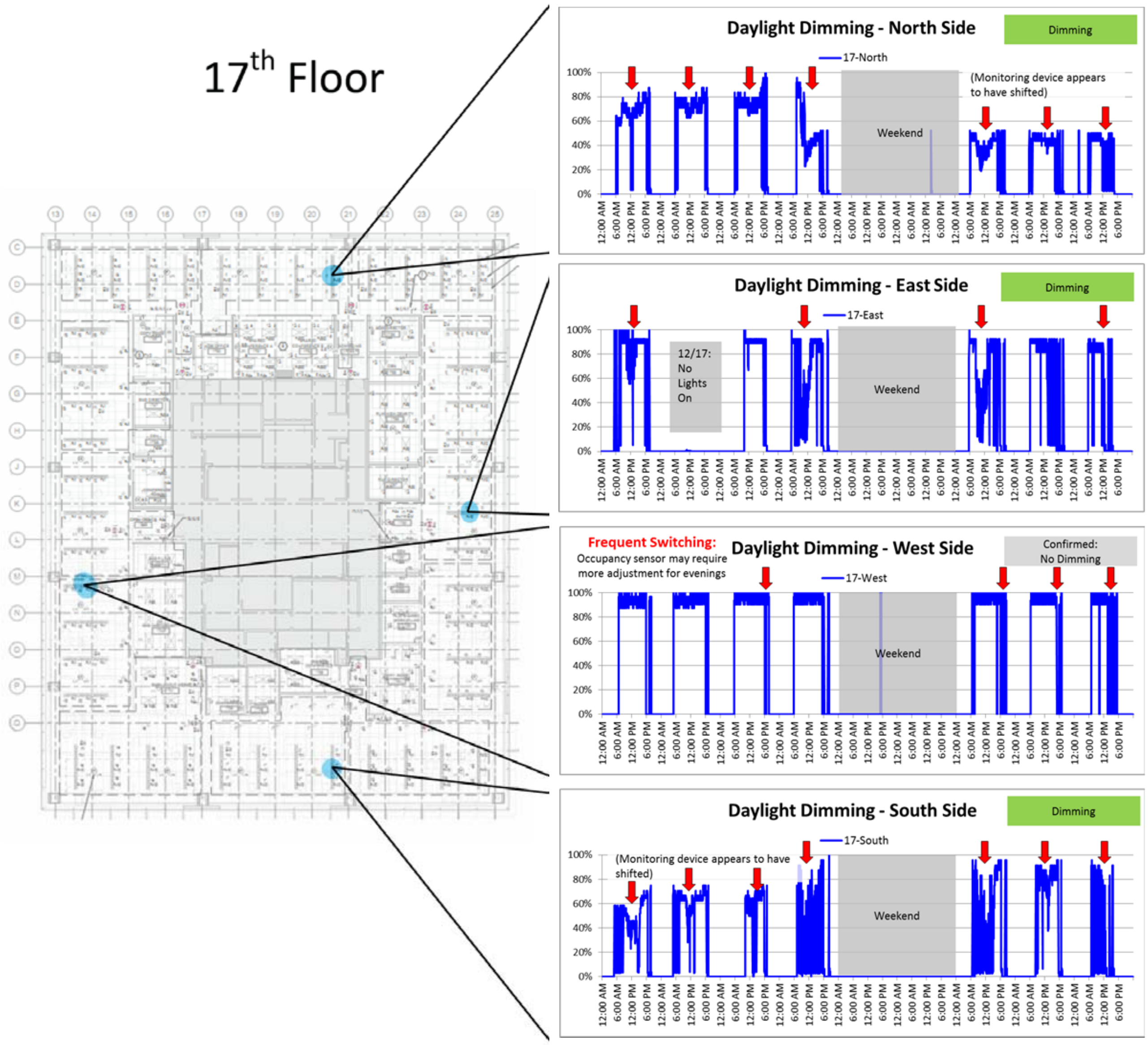

Desk Luminance Measurements (North)
Desk Luminance Measurements (East)
Desk Luminance Measurements (West)
Desk Luminance Measurements (South)
Luminance (cd/m2)
0
50
100
150
200
250
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM


Bezel Luminance Measurements (North)
Bezel Luminance Measurements (East)
Bezel Luminance Measurements (West)
Bezel Luminance Measurements (South)
Luminance (cd/m2)
0
50
100
150
200
250
8:00 AM
11:00 AM
2:00 PM
5:00 PM
8:00 PM

Appendix B: Luminaire Activity Results



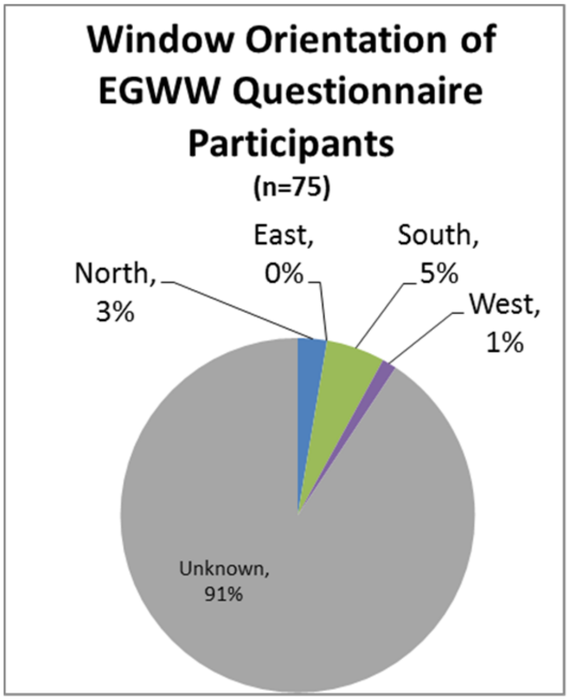

12th Floor
Daylight Dimming - North Side
Some Dimming
12-North
Weekend
Daylight Dimming - East Side
Dimming
12-East
Weekend
Daylight Dimming - West Side
Confirmed: No Dimming
12-West
Weekend
Daylight Dimming - South Side
Dimming
12-South
Weekend

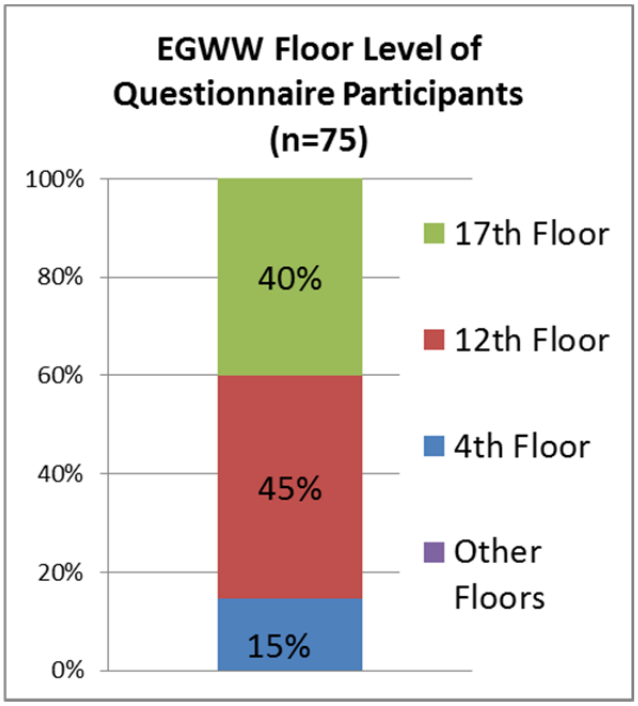

17th Floor
Daylight Dimming - North Side
Dimming
17-North
(Monitoring device appears to have shifted)
Weekend
Daylight Dimming - East Side
Dimming
17-East
12/17: No Lights On
Weekend
Frequent Switching:
Occupancy sensor may require more adjustment for evenings
Daylight Dimming - West Side
Confirmed: No Dimming
17-West
Weekend
Daylight Dimming - South Side
Dimming
17-South
(Monitoring device appears to have shifted)
Weekend

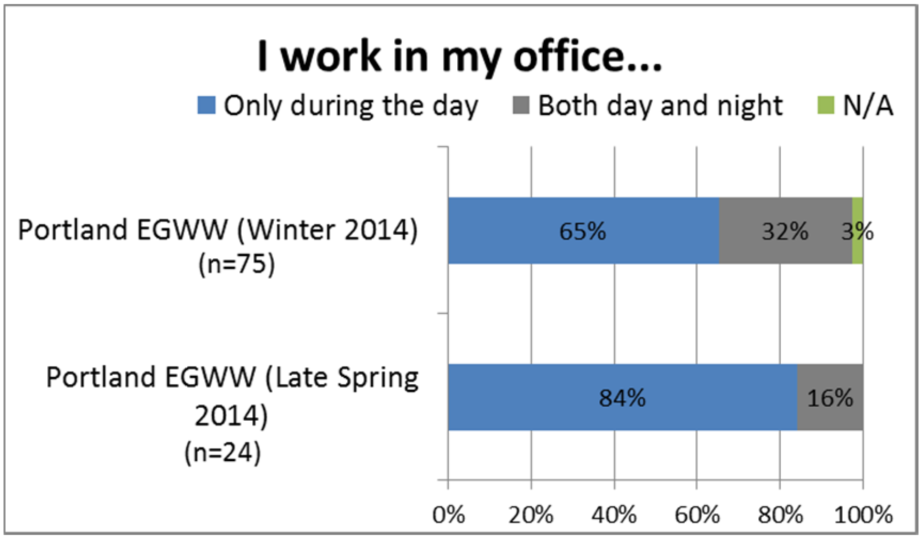
Appendix C: Questionnaire Results

On the winter visit, questionnaires were widely distributed, but less information was available in terms of building orientation, state of blinds use, and state of task light use.

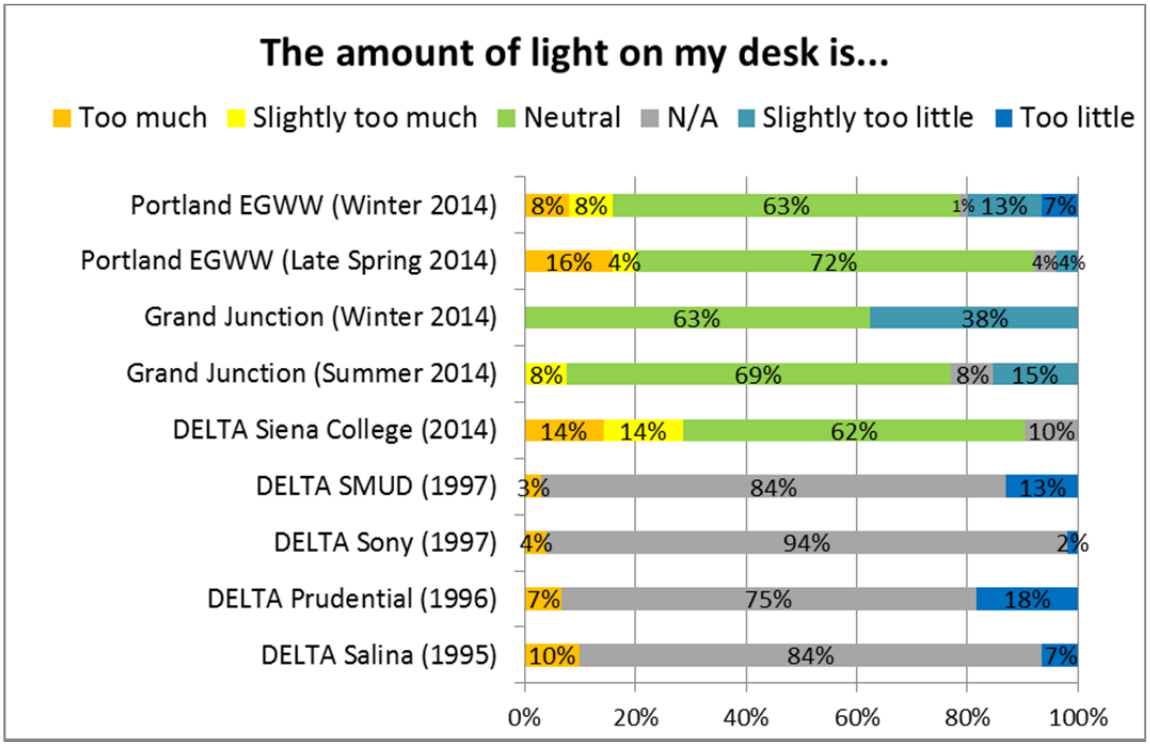
Questionnaire Demographics







Questionnaire Results (EGWW compared to other sites, as available)

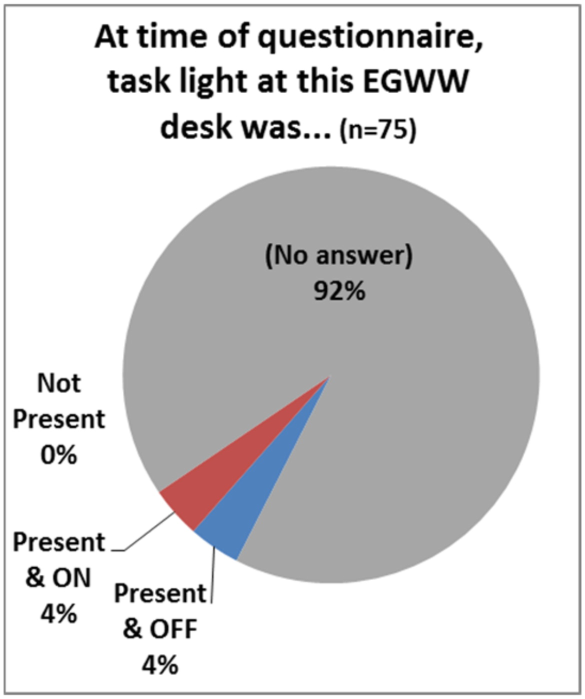


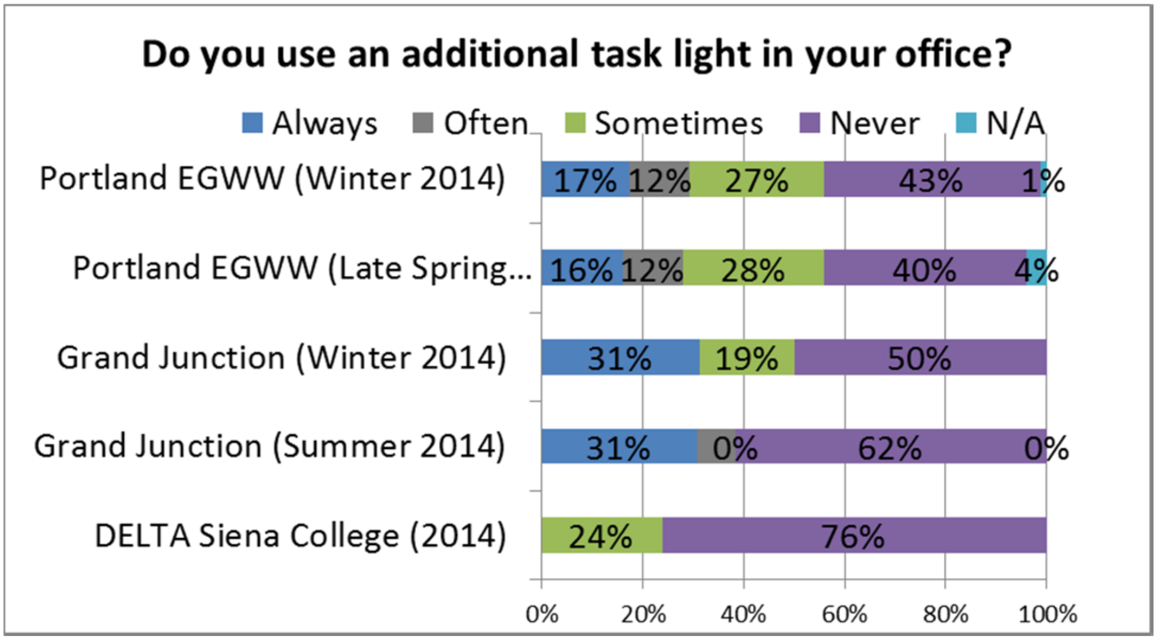
Other Comments (about amount of light on the EGWW desk)

- "Perfect lighting for me to review architectural plans."
- "Access to daylight is excellent. This is a wonderful office in terms of daylight."
- "I have to wear sunglasses when I work on my computer. It is too bright in here."
- "My eyes are sensitive to light so I prefer dim lighting."
- "I love all of the natural light!"
- "I love the natural window light!"
- "LOVE the natural light."
- "My office is in a corner, so I benefit from light through 2 sets of windows (Northwest corner)."
- "The building lights dim on their own frequently and there is often a battle with the shades because those that sit next to the window think there is too much natural light (glaring sun) and those that aren't next to the window prefer the natural light."

Other Comments (about lighting controls)

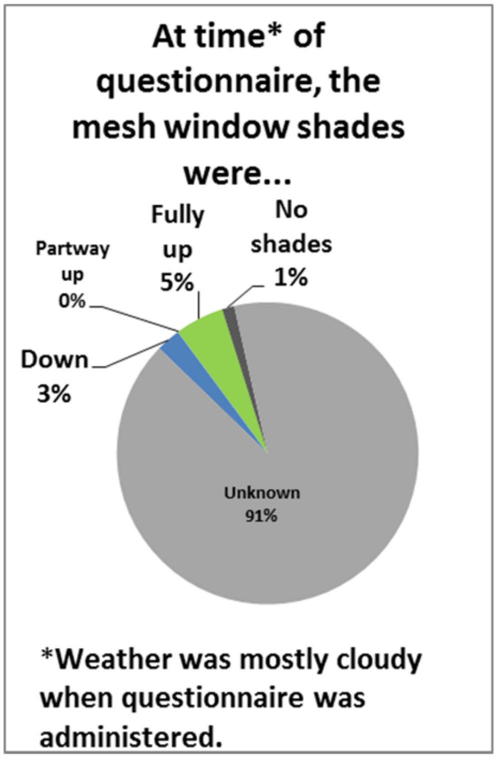
- "The lights over my desk go off even when it is dark outside."
- "I hate that the lights turn off if you don't move around; we sit at a computer not waving our arms."
- "I would really like the ability to turn off the panel above my desk without impacting the other lights on the switch."
- "There are products available to put in fixtures to change the intensity of the light over each cubicle."
- "There was an adjustment a while ago (maybe 6 months) and my overhead light behaves PERFECTLY."

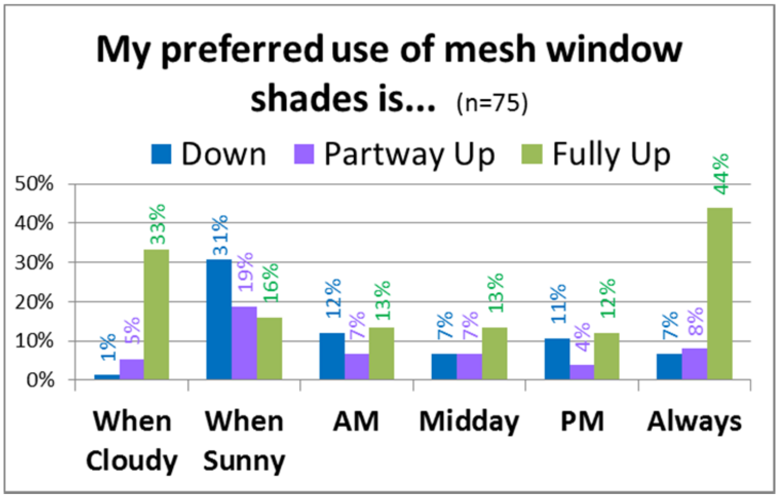




EGWW Task Light Comments

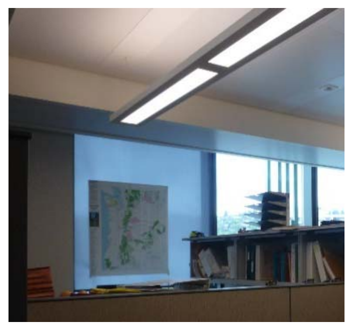
- "Love the task lights on these dark afternoons."
- "Too little" light because "No desk light; [it is] missing."
- "Will need a [task] lamp if lights are turned down."
- Uses task light always, "though it has [an electrical] short."

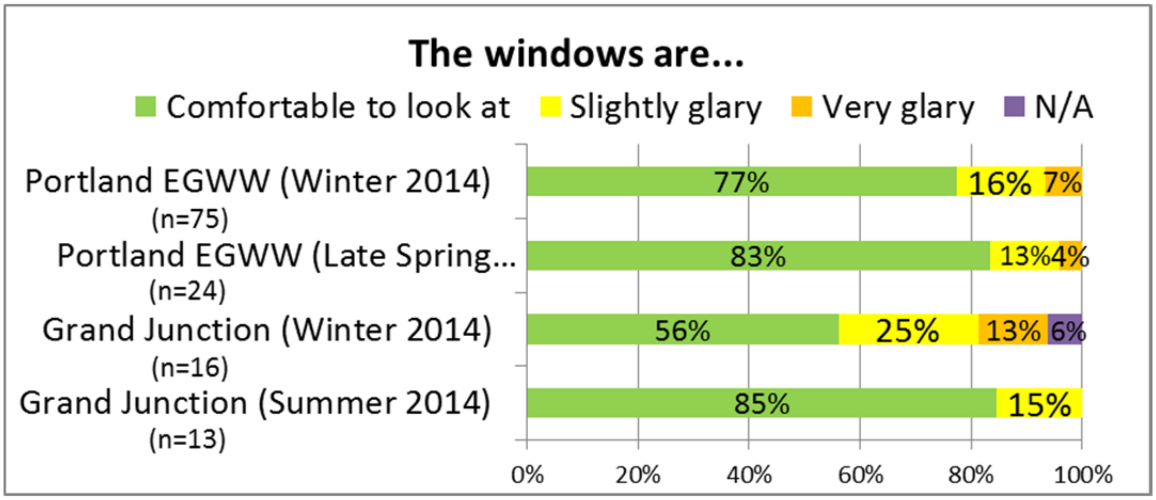

At time* of questionnaire, the mesh window shades were...
Fully up 5%
No shades 1%
Partway up 0%
Down 3%
Unknown 91%
*Weather was mostly cloudy when questionnaire was administered.


My preferred use of mesh window shades is... (n=75)
Down
Partway Up
Fully Up
50%
40%
30%
20%
10%
0%
1%
5%
33%
31%
19%
16%
12%
7%
13%
7%
7%
13%
11%
4%
12%
7%
8%
44%
When Cloudy
When Sunny
AM
Midday
PM
Always

EGWW Shades Comments

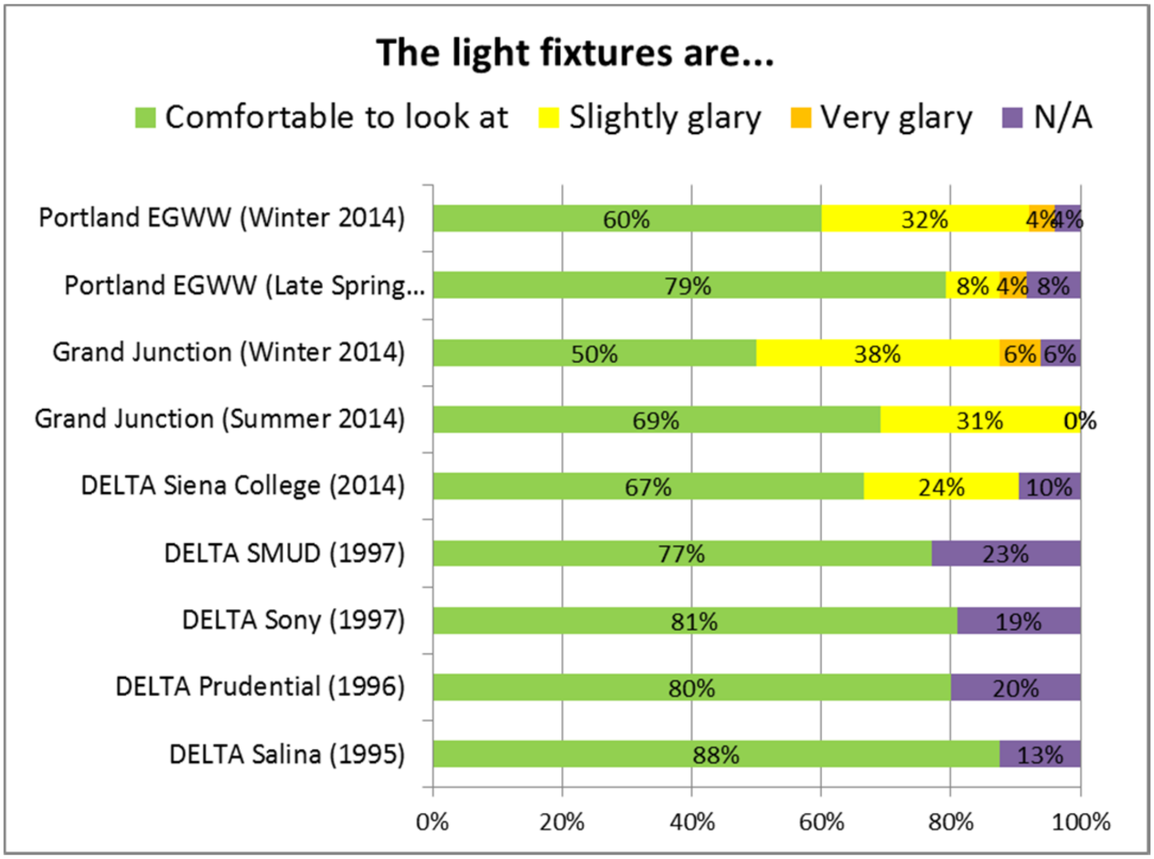
- "I use my shades all the time."
- "I always like shades up, but I need to lower them in sunny weather/afternoon to see monitor."
- "I only use the shade for a minimal amount of time when the sun is low on the horizon and directly in front of the window."
- Shades fully up "unless sun too glary; does not happen often."
- Puts the shades down "only when it's very bright."
- Adjusts the shades "daily if sunshine and no clouds."
- "I only adjust the shades when the sun is shining too bright (rarely)."
- "I never adjust shades because it affects co-worker."
- "[I] don't have access to window shades, light is clustered around my desk more than others." (In other words, subject has too much light)
- "Never" adjusts the shades because "not close to window."
- "I only adjust the shades in the summer when sunrays hit windows in building across from my view."
- "Very nice environment. Only issue is winter sun about 3:30 pm until sunset. Here shade needs adjusting. Summer sun, much higher, lets us keep mesh much higher. I adjust the shades twice a day in winter, almost never in summer."
- Shade use "depends on time of year and cloud cover."
- "Please make the shades quieter; they are too loud when people adjust them."
- "Window shades are too thin and do not block out the sun."
- "The building lights dim on their own frequently and there is often a battle with the shades because those that sit next to the window think there is too much natural light (glaring sun) and those that aren't next to the window prefer the natural light."
- "When it's sunny the glare becomes very bad even with shades down. Often giant maps are placed behind shades to block more of the sun." (See photo.)





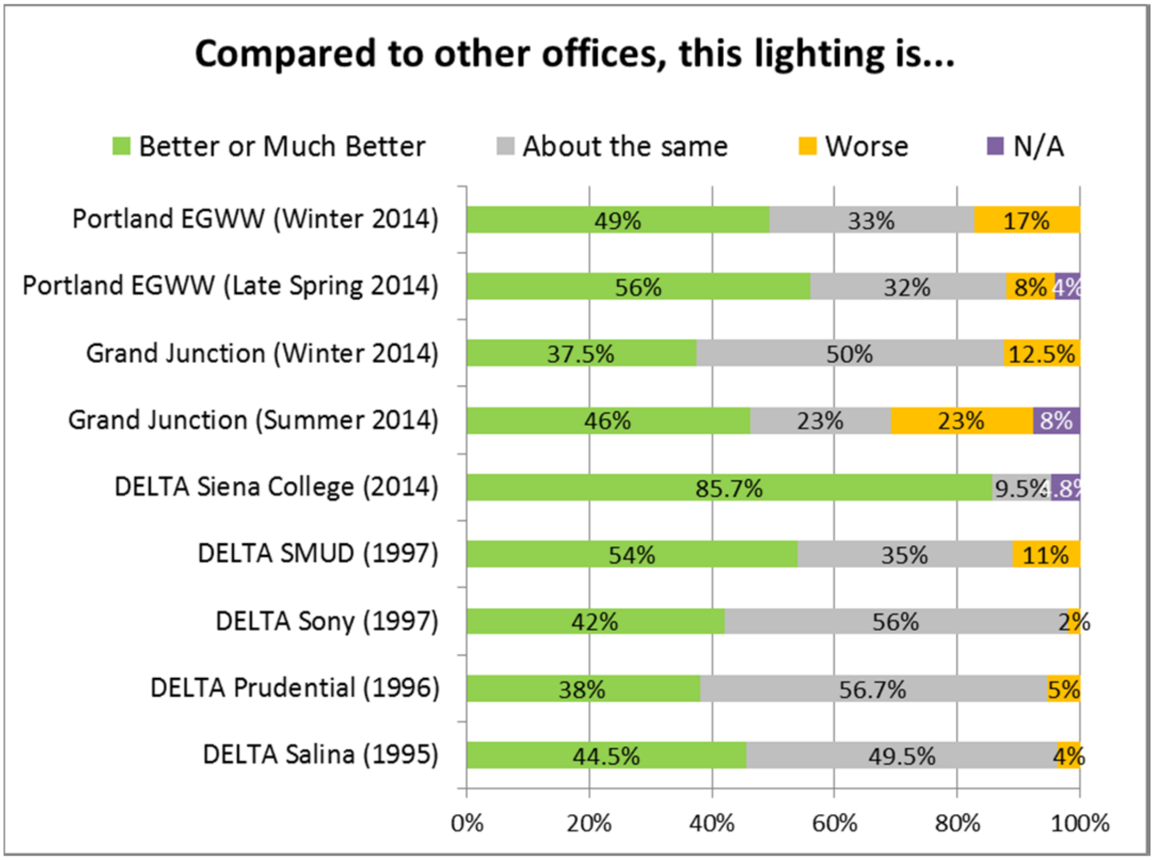
EGWW Window Glare Comments

- "If the windows weren't to my back I could see my computer screen with shades open."
- "Biggest Issue: My window faces south and during the winter the sun shines directly into my cube for most of the day. This backlights my computer and makes it a lot harder to work."
- "When it's sunny the glare becomes very bad even with shades down. Often giant maps are placed behind shades to block more of the sun."
- "Reflections of sunlight off other buildings on sunny mornings or late afternoons is when I have to put the shades down."
- "My east facing window is [affected] tremendously by the sun. It's not the task light or overhead that is a problem. I completely close the mesh screen. I don't look at the light fixtures. Windows are both comfortable to look at and very glary depending on the time of day."
- "Windows are comfortable, except when the sun is out, then very glary. I would prefer slightly darker tint on windows and not have to use shades since they cut out so much of the natural light."
- "Windows are very glary when sunny!"
- "Windows are 'slightly glary' when the sun shines."



EGWW Luminaire Glare Comments

- "My east facing window is [affected] tremendously by the sun. It's not the task light or overhead [light] that is a problem….I don't look at the light fixtures."

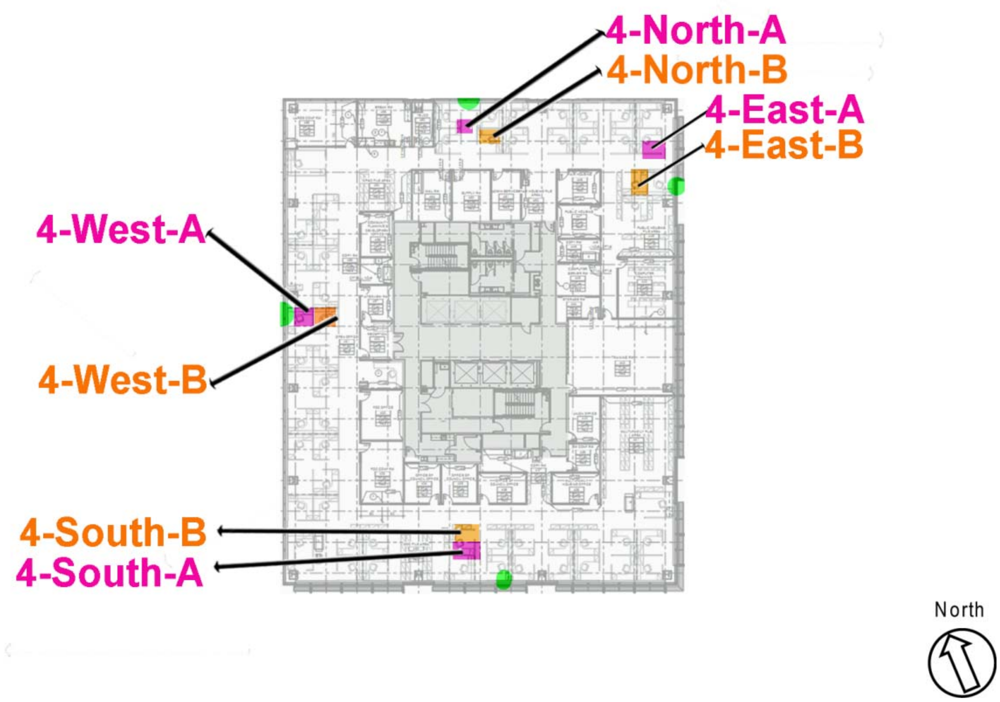


EGWW Overall Comments

- Rated this "much better" than other offices. "I work in (another agency unit) and that office has no natural light."
- Overall much better than other offices because "I have windows on two sides (corner cubicle)."
- Overall much better than other offices because "I like it brighter than most people."
- Overall worse because "I need light! Let there be light!"
- Only works during the day, "but in winter it's dark half the day!"

Appendix D: Spectral Photometric Data for 4th Floor Desks

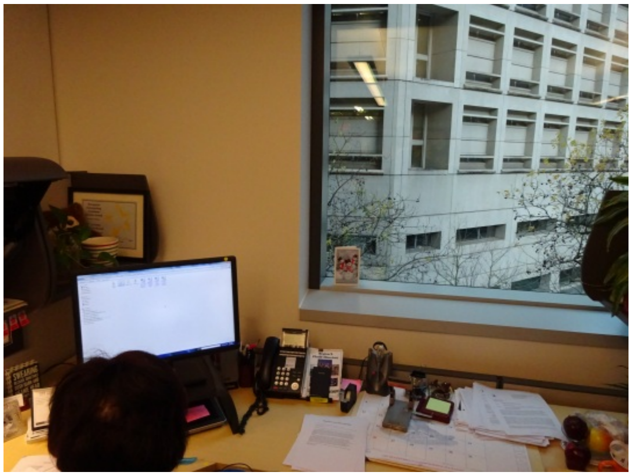
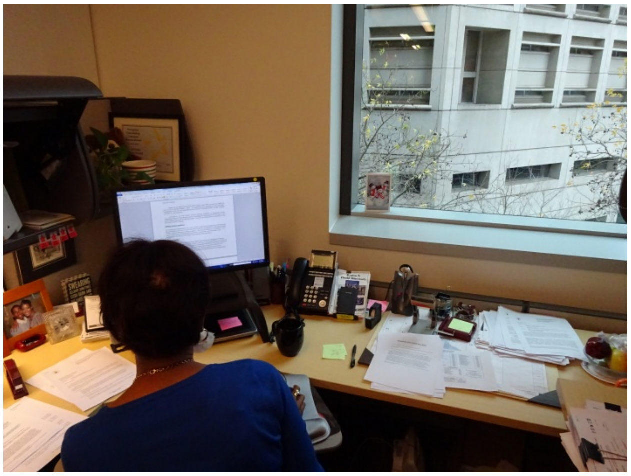
Spectral power distribution (SPD) was measured at 8 desks on the 4th floor at EGWW (see below) during the winter visit. These were the same desks that hosted other Daysimeter measurement equipment (see Appendix H) during the late spring measurements. SPDs were measured repeatedly over the day and after dark.



Desks on the 4th floor where SPD measurements were collected; windows are excluded from SPD measurements.

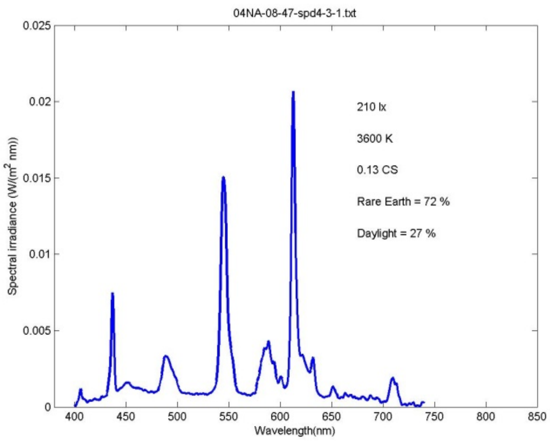
This appendix shows the results of repeated SPD measurements at 8 desks on the 4th floor. As shown below, the resulting SPD curves change as daylight contribution changes. For reference, a photograph is also presented for morning and midday measurement conditions, as this represents the scene that the occupant experienced at the time of measurement. Because measurements at the window are expected to remain consistently illuminated by daylight, SPD was not measured at the windows during the evaluation visit.

4-NORTH-A

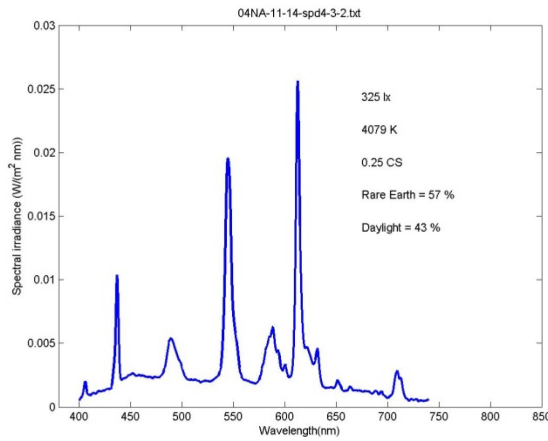
	
8:46 AM	***11:20 AM***

4-North-A

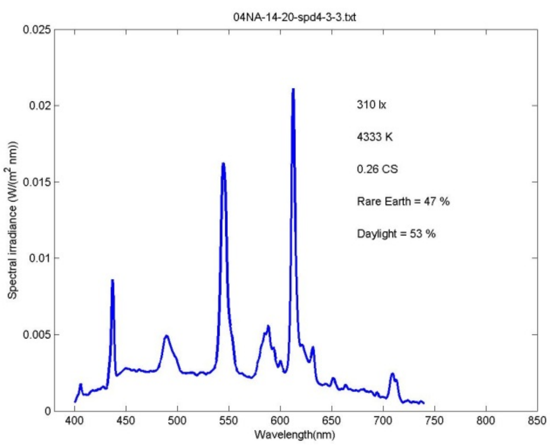
(Spectral Power Distribution)



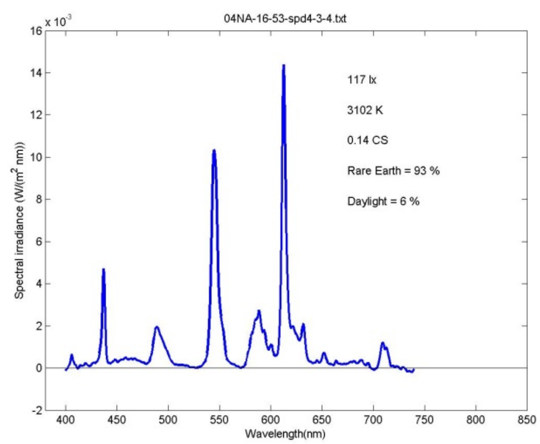
8:47 AM



11:14 AM



2:20 PM



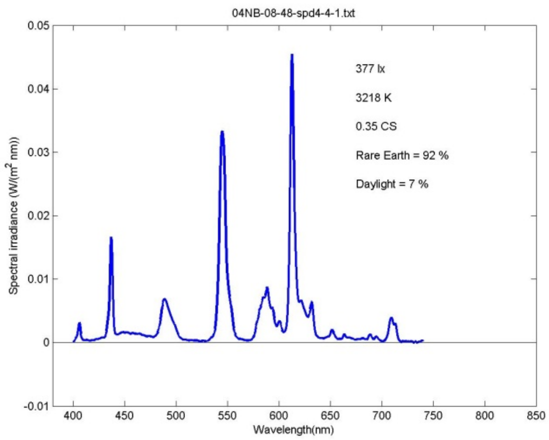
4:53 PM

4-North-B

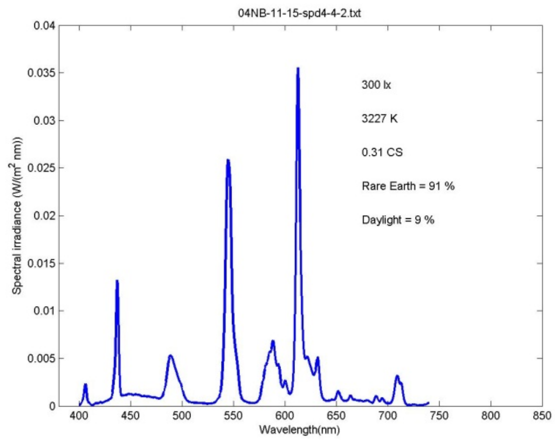
8:47 AM

11:13 AM

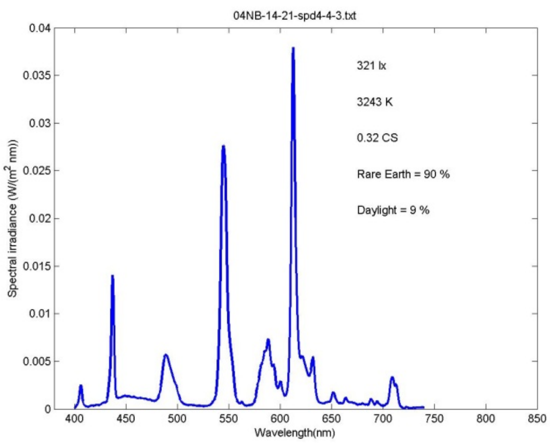
4-NORTH-B
(SPECTRAL POWER DISTRIBUTION)



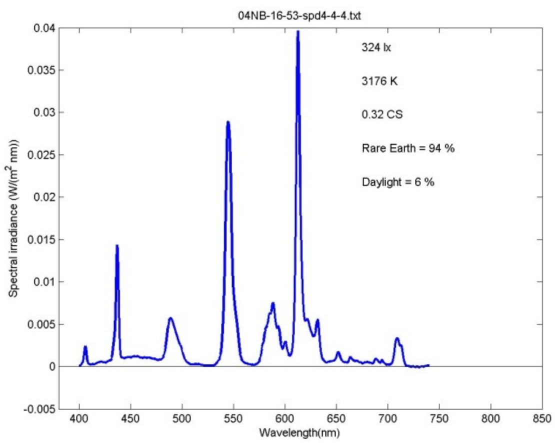
8:48 AM



11:15 AM

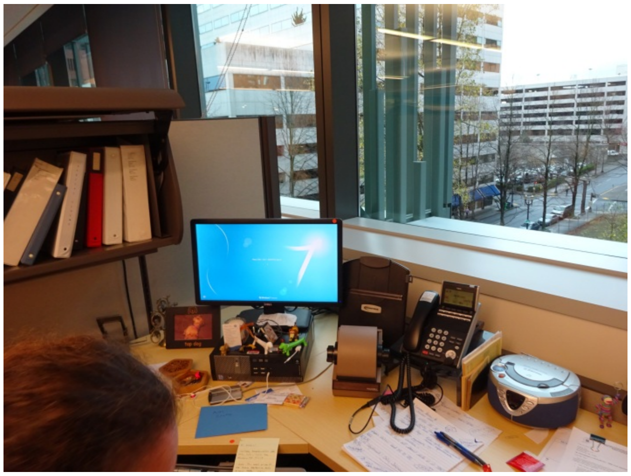


2:21 PM

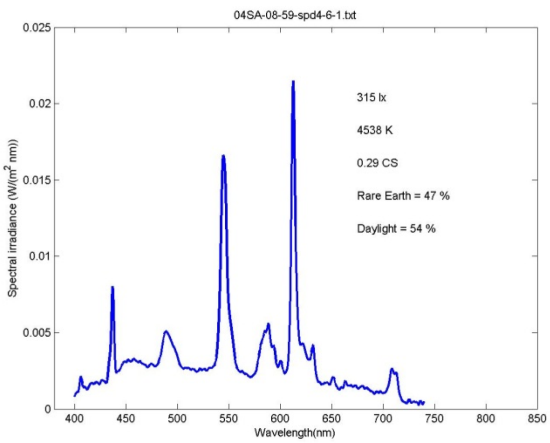


4:53 PM

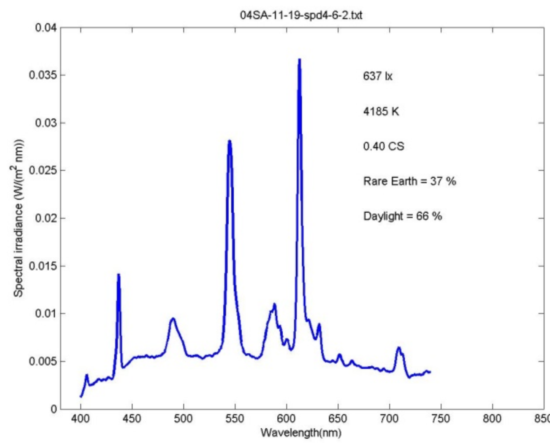
4-South-A

	
8:57 AM	***11:19 AM***

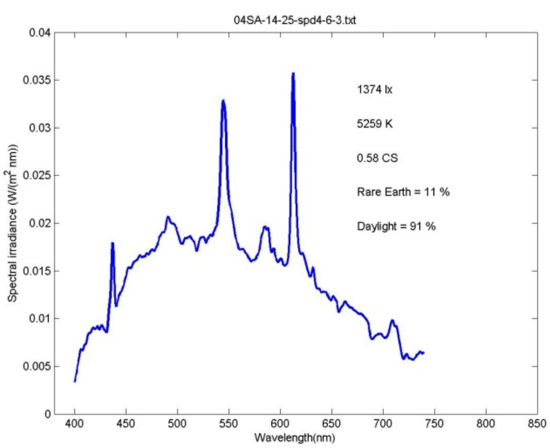
4-South-A
(Spectral Power Distribution)



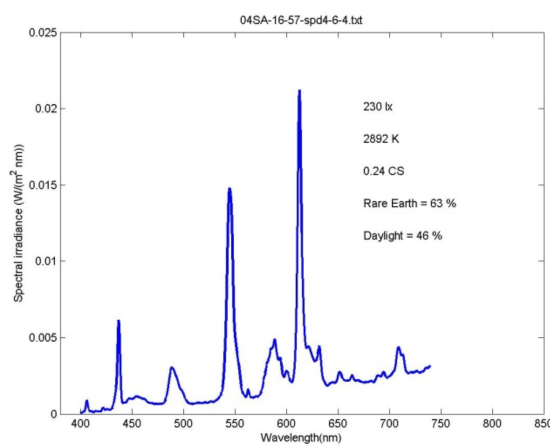
8:59 AM



11:19 AM



2:25 PM



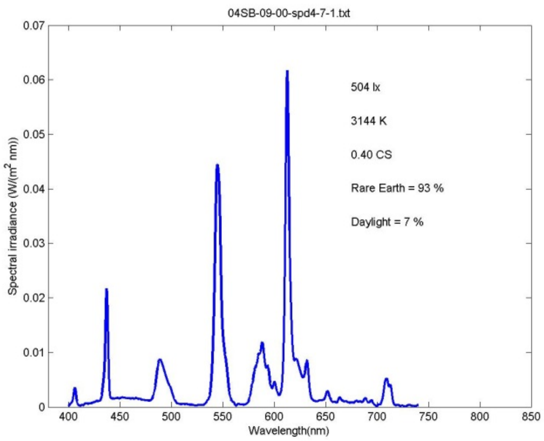
4:57 PM

4-South-B

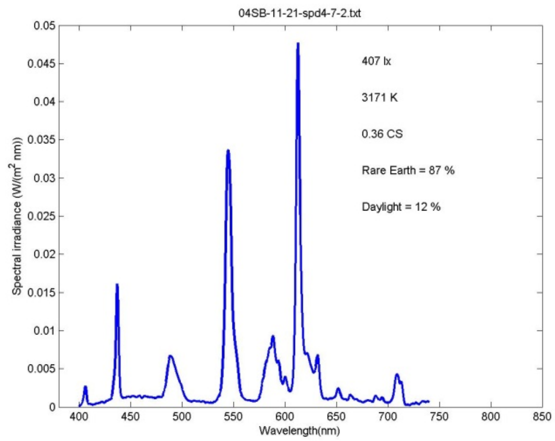
 ***8:59 AM***	 ***11:19 AM***

4-SOUTH-B

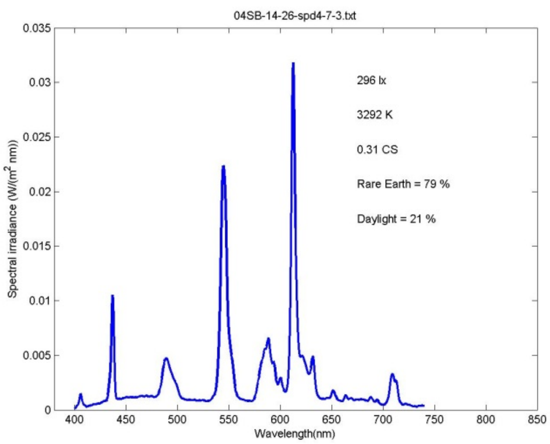
(SPECTRAL POWER DISTRIBUTION)



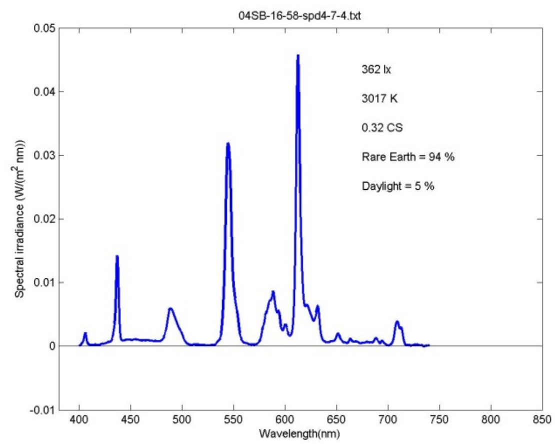
9:00 AM



11:21 AM



2:26 PM



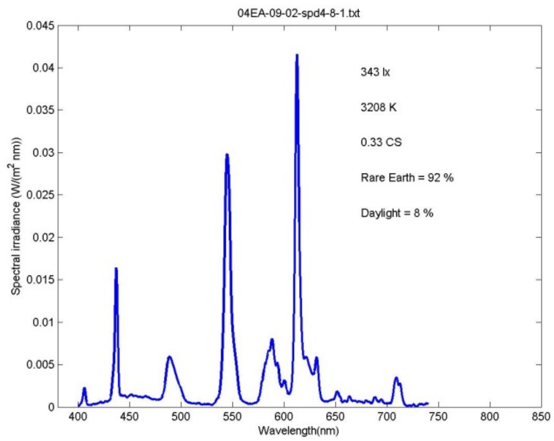
4:58 PM

4-EAST-A

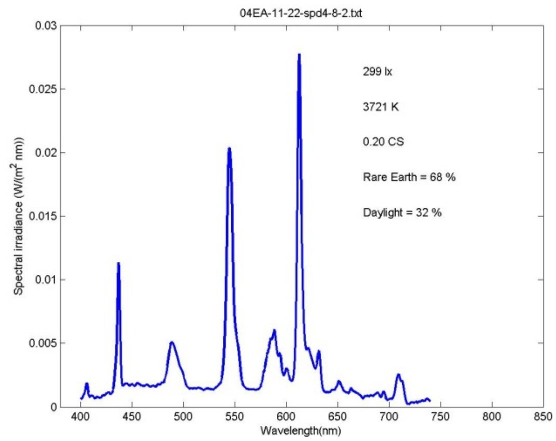
	
9:00 AM	***11:22 AM***

4-EAST-A

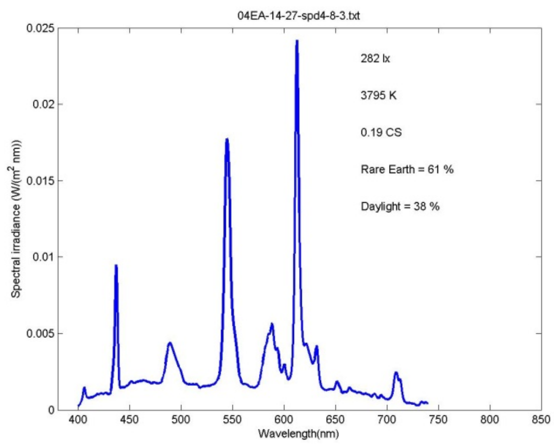
(SPECTRAL POWER DISTRIBUTION)



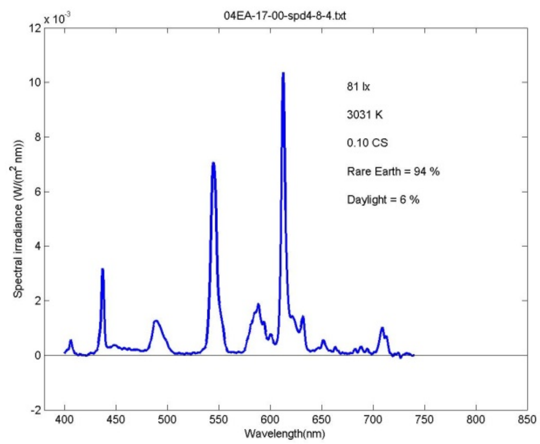
9:02 AM



11:22 AM

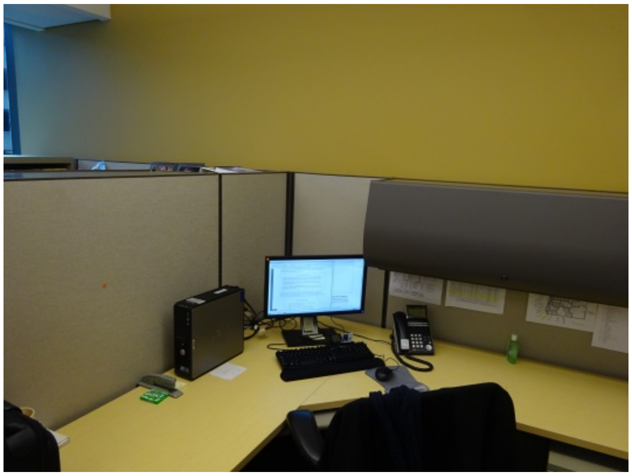


2:27 PM

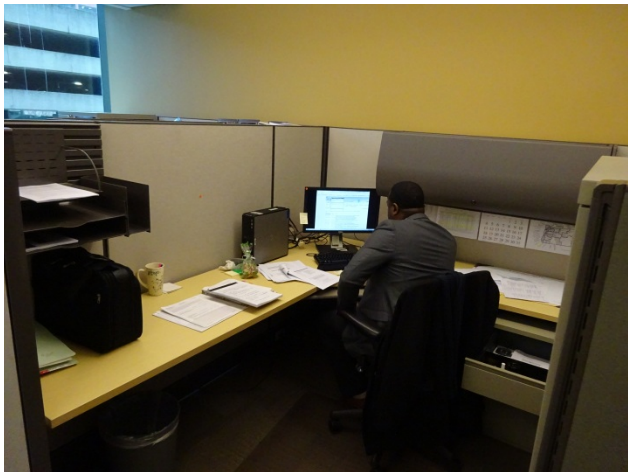


5:00 PM

4-EAST-B



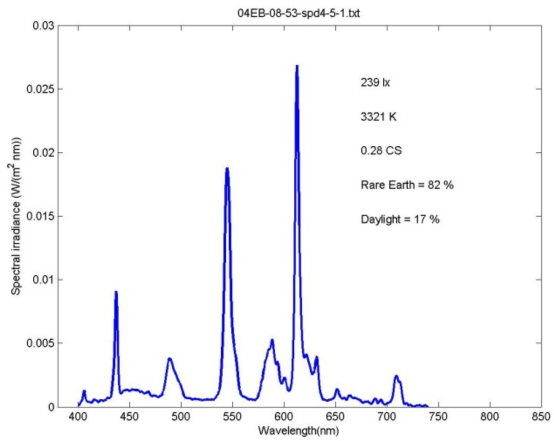
8:52 AM



11:16 AM

4-EAST-B

(SPECTRAL POWER DISTRIBUTION)



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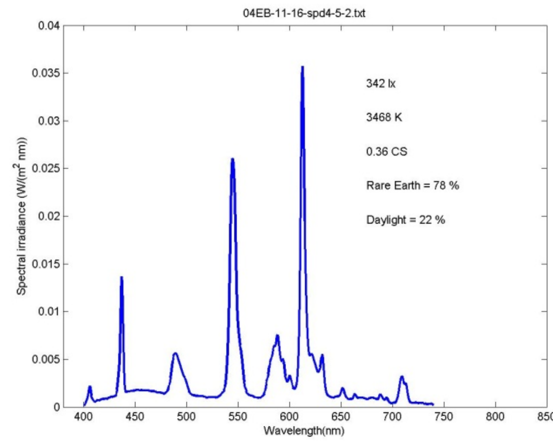

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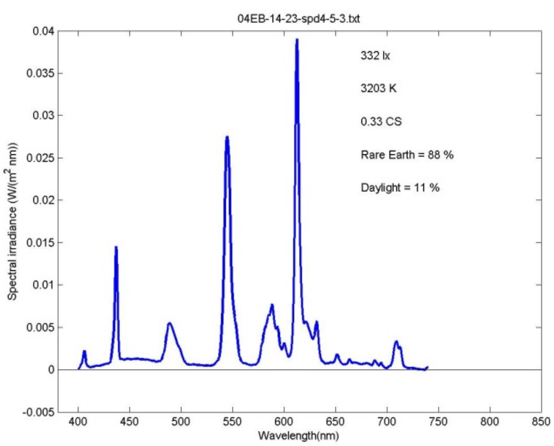
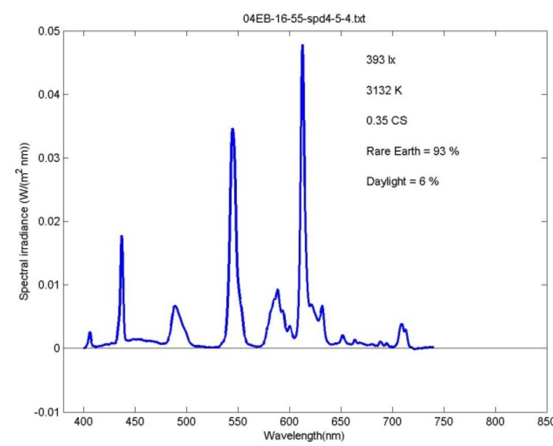
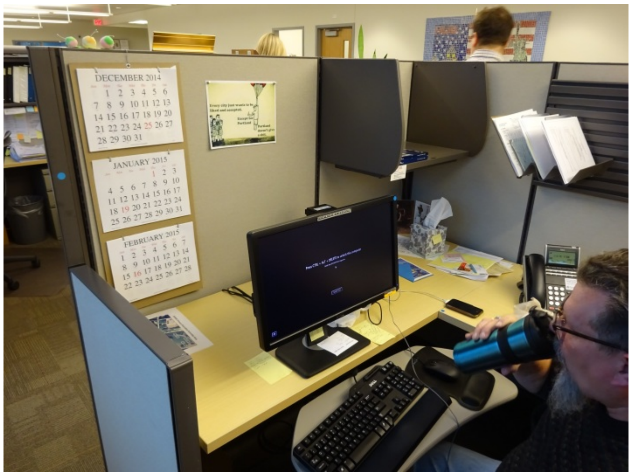
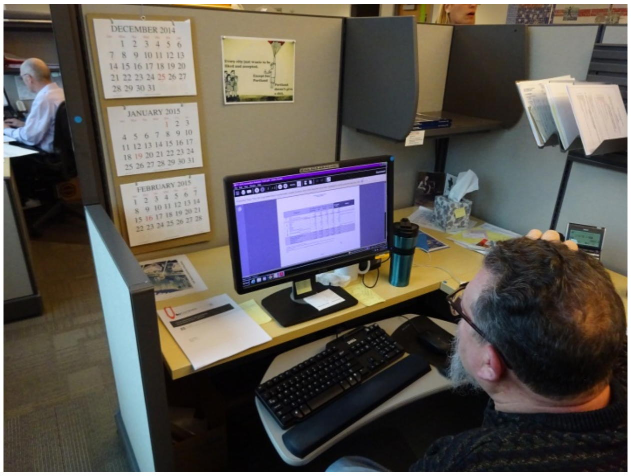


2:23 PM



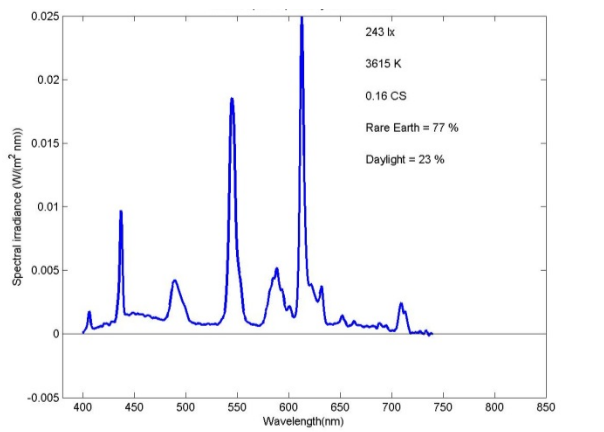
4:55 PM

4-West-A

 8:38 AM	 11:10 AM

4-WEST-A

(SPECTRAL POWER DISTRIBUTION)



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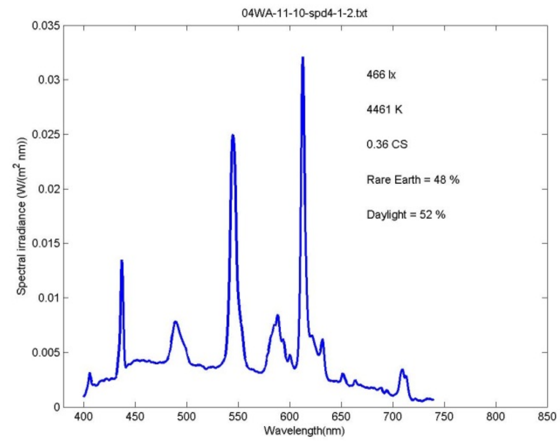
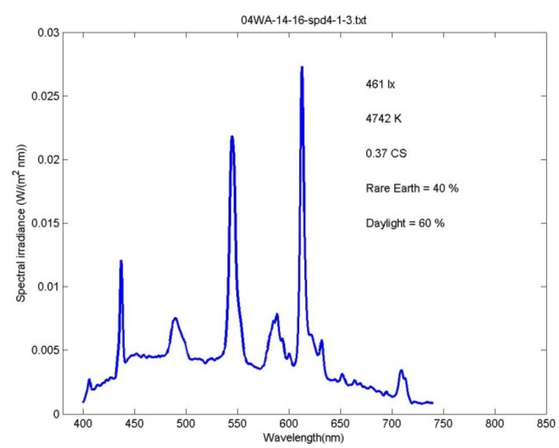
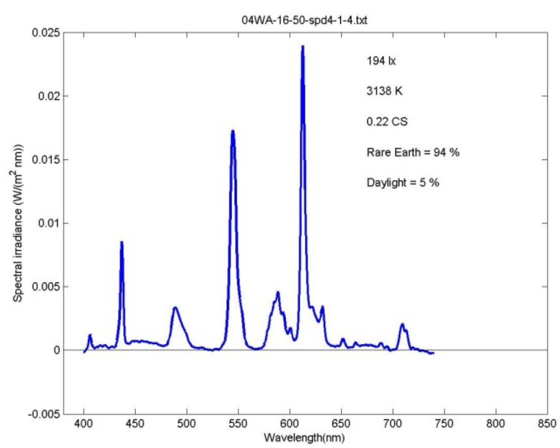


11:10 AM

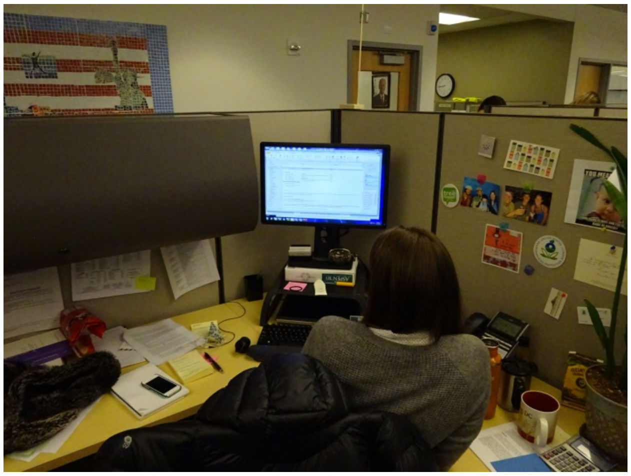
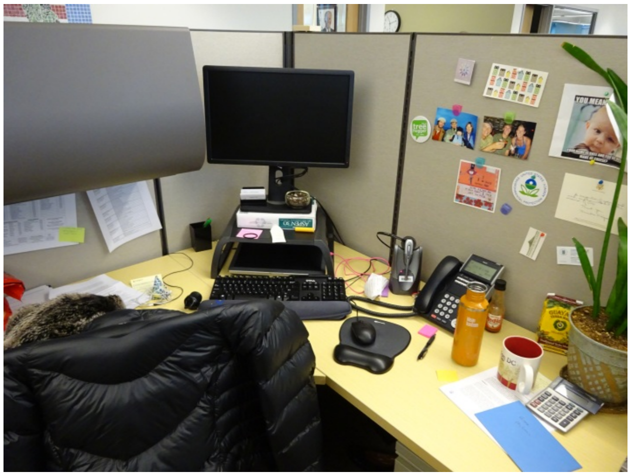


2:16 PM



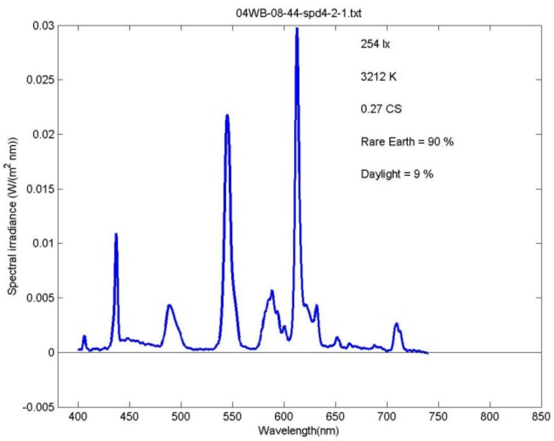
4:50 PM

4-West-B

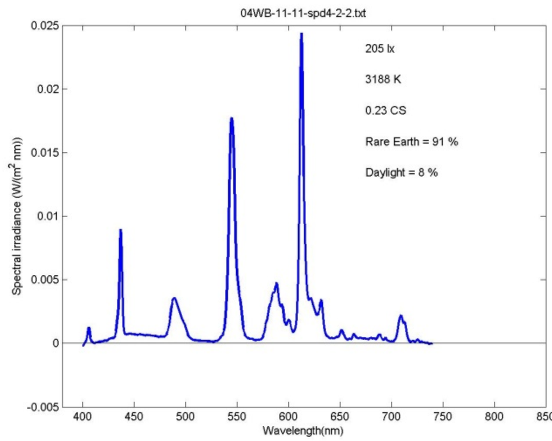
 8:43 AM	 11:11 AM

4-West-B

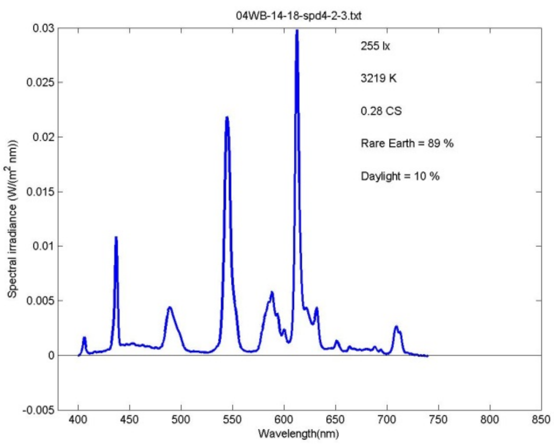
(Spectral Power Distribution)



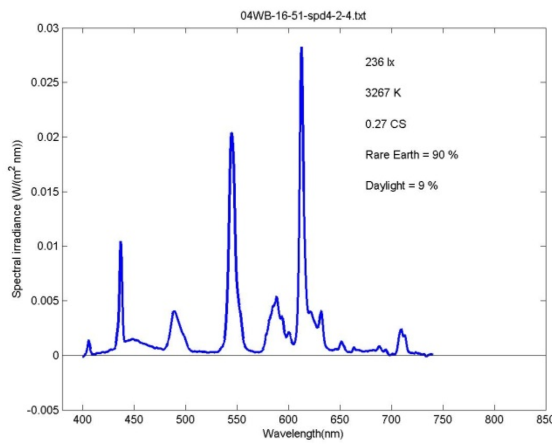
8:44 AM



11:11 AM



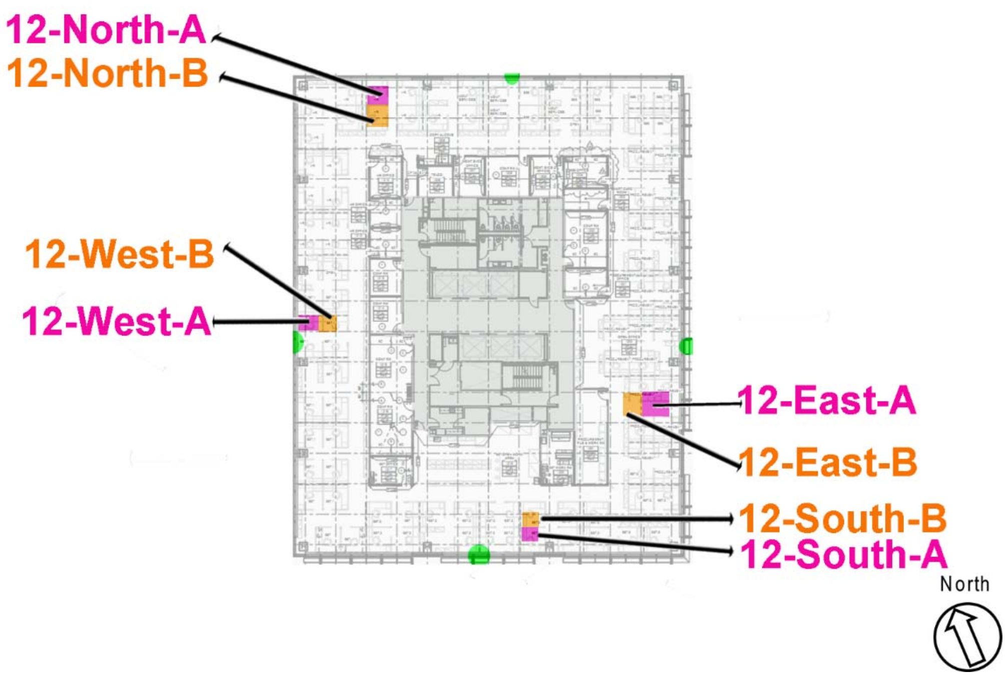
2:18 PM



4:51 PM

APPENDIX E: SPECTRAL PHOTOMETRIC DATA FOR 12TH FLOOR DESKS

Spectral power distribution (SPD) was measured at 8 desks on the 12th floor at EGWW (see below) during the winter visit. These were the same desks that hosted other Daysimeter measurement equipment (see Appendix H) during the late spring measurements. SPDs were measured repeatedly over the day and after dark.



Desks on the 12th floor where SPD measurements were collected; windows are excluded from SPD measurements.

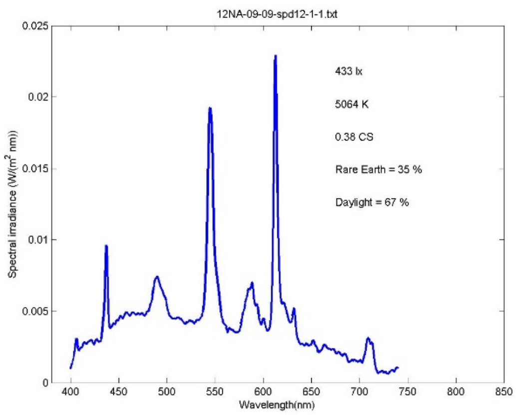
This appendix shows the results of repeated SPD measurements at 8 desks on the 12th floor. As shown below, the resulting SPD curves change as daylight contribution changes. For reference, a photograph is also presented for morning and midday measurement conditions, as this represents the scene that the occupant experienced at the time of measurement. Because measurements at the window are expected to remain consistently illuminated by daylight, SPD was not measured at the windows during the evaluation visit.

12-North-A

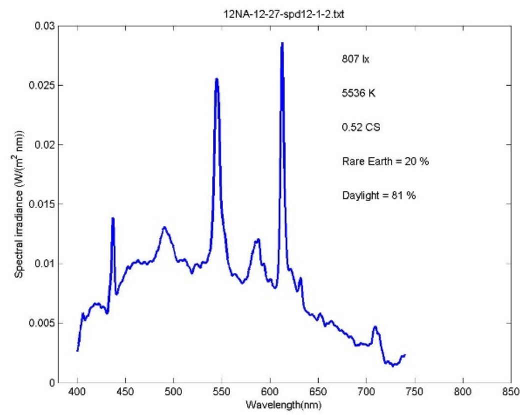
 ***9:09 AM***	 ***11:26 AM***

12-North-A

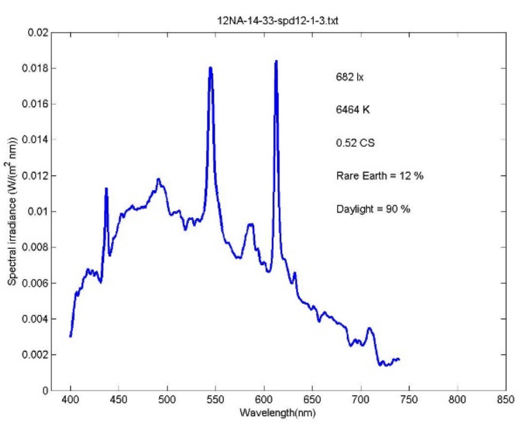
(Spectral Power Distribution)



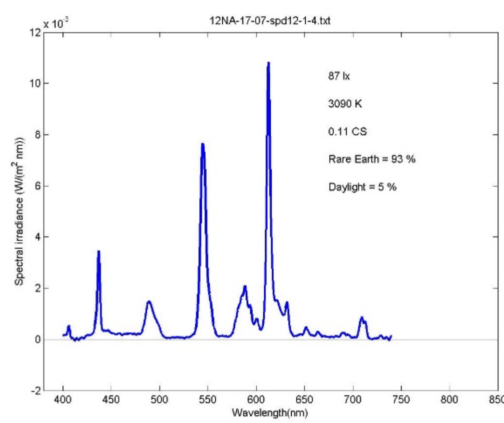
9:09 AM



12:27 AM

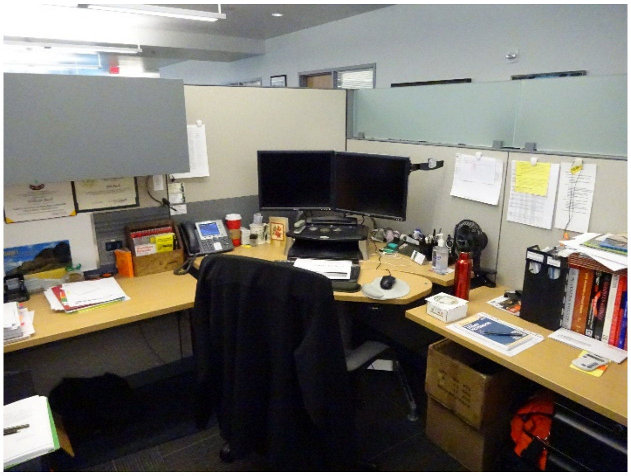
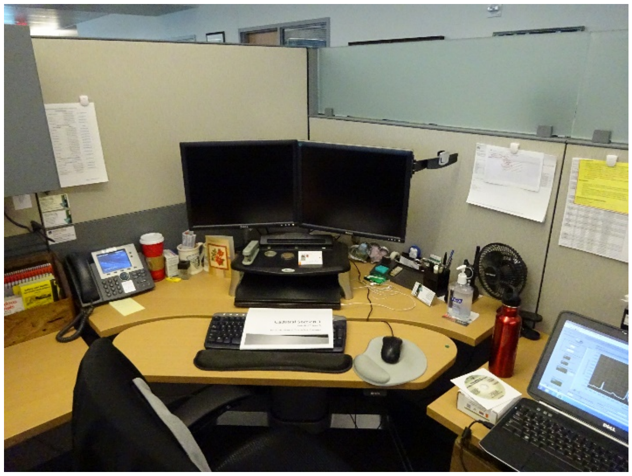


2:33 PM



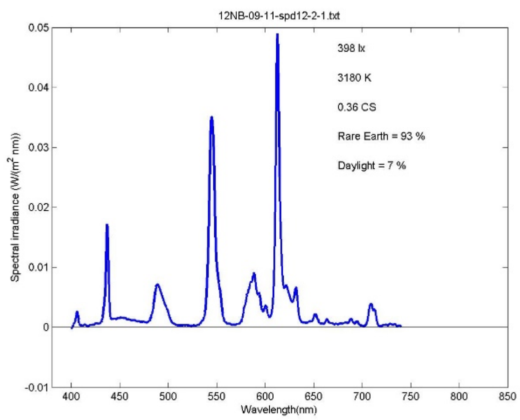
5:07 PM

12-NORTH-B

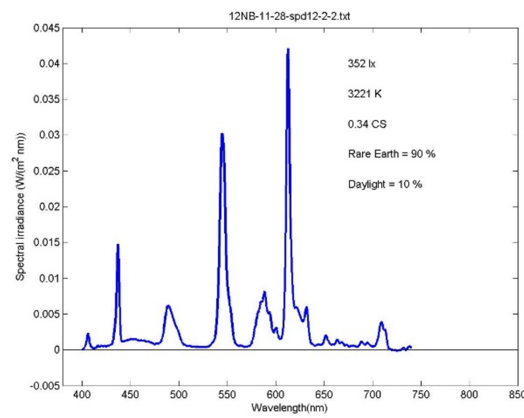
 9:11 AM	 11:28 AM

12-North-B

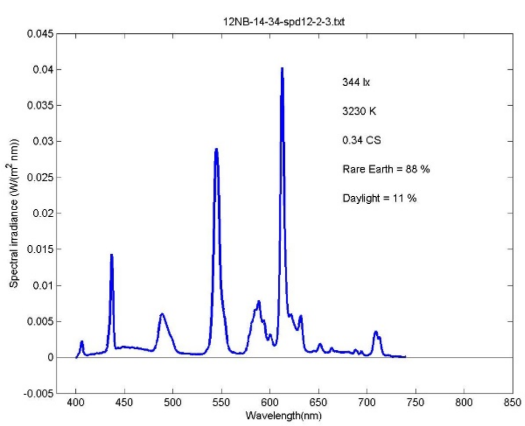
(Spectral Power Distribution)



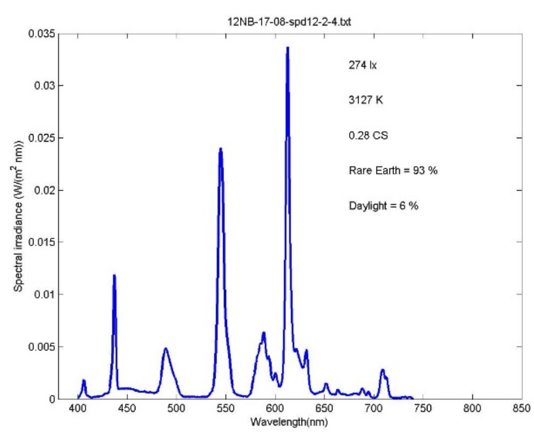
9:11 AM



11:28 AM



2:34 PM



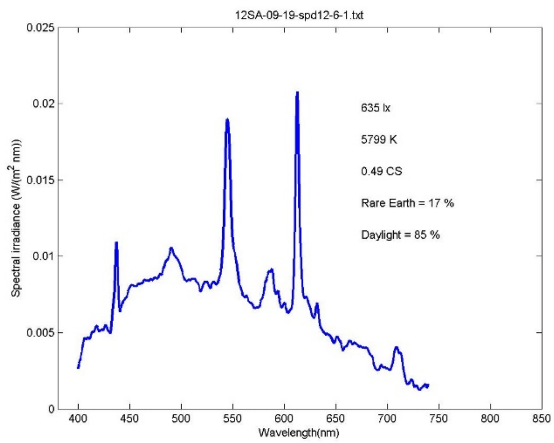
5:08 PM

12-South-A

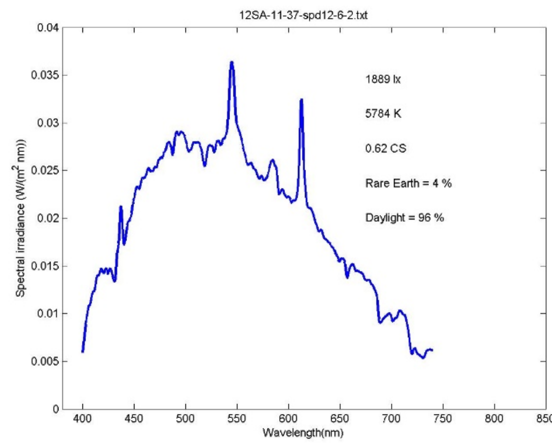
 **9:19 AM**	 **11:37 AM**

12-South-A

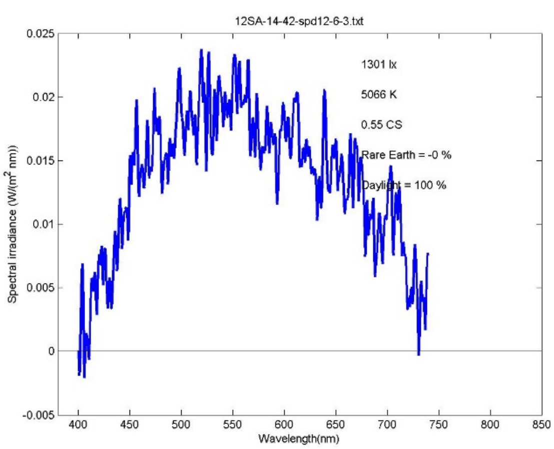
(Spectral Power Distribution)



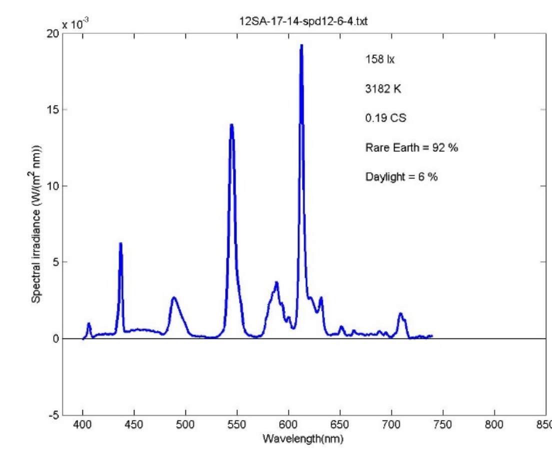
9:19 AM



11:37 AM

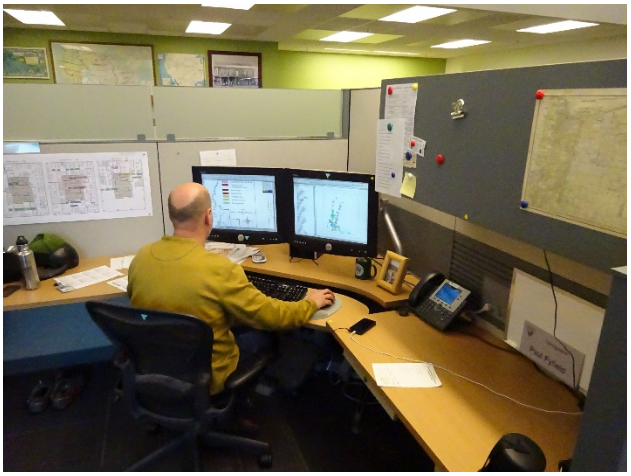
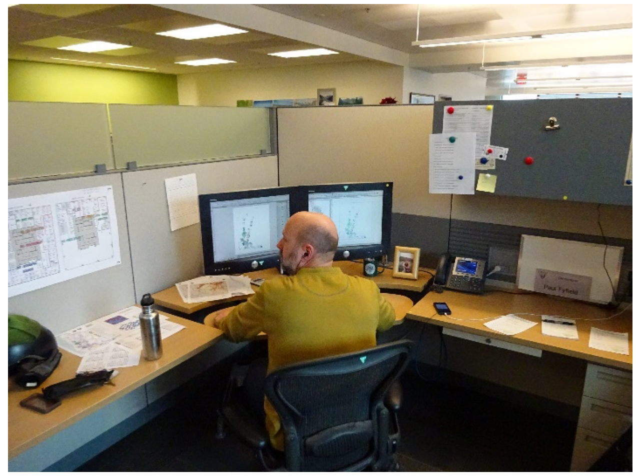


2:42 PM

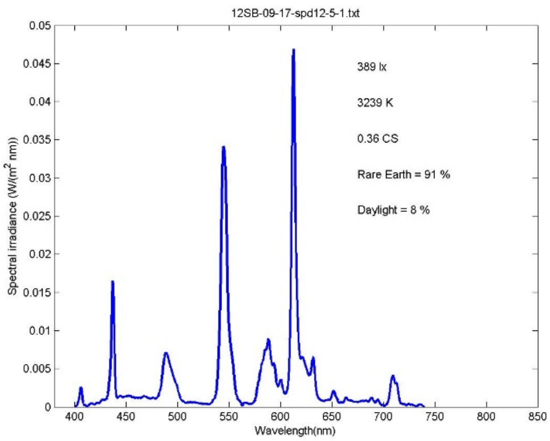


5:14 PM

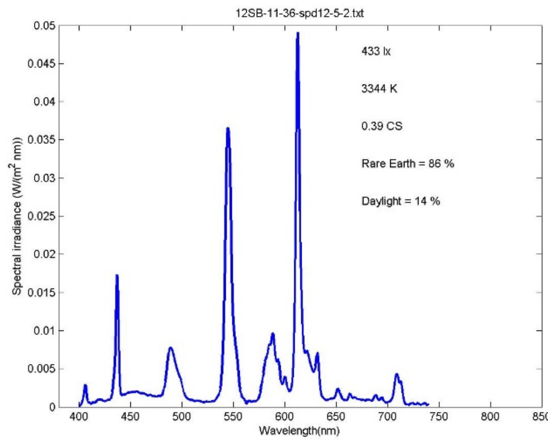
12-SOUTH-B

 ***9:17 AM***	 ***11:35 AM***

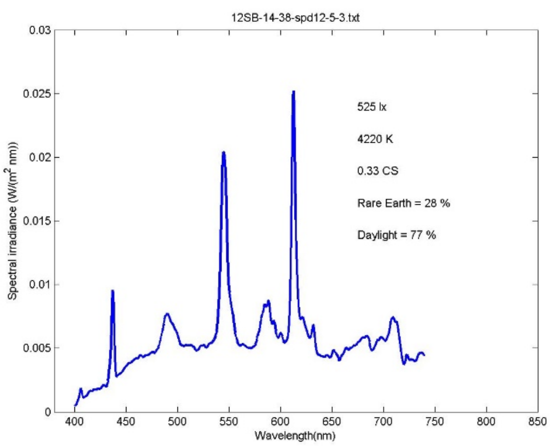
12-SOUTH-B
(SPECTRAL POWER DISTRIBUTION)



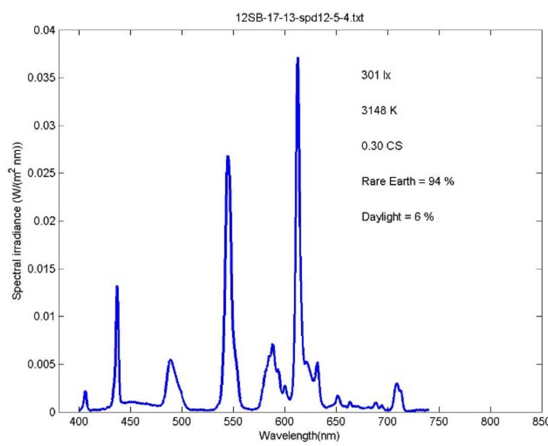
9:17 AM



11:36 AM



2:38 PM



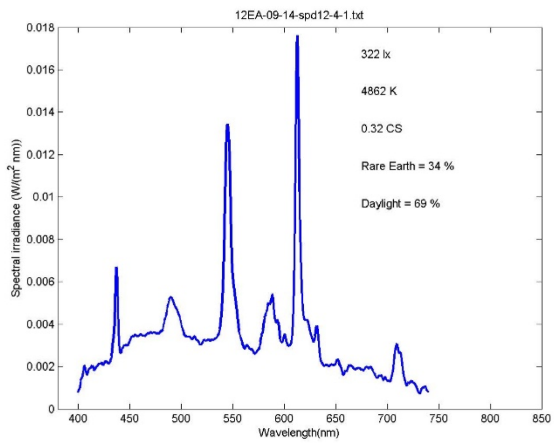
5:13 PM

12-East-A

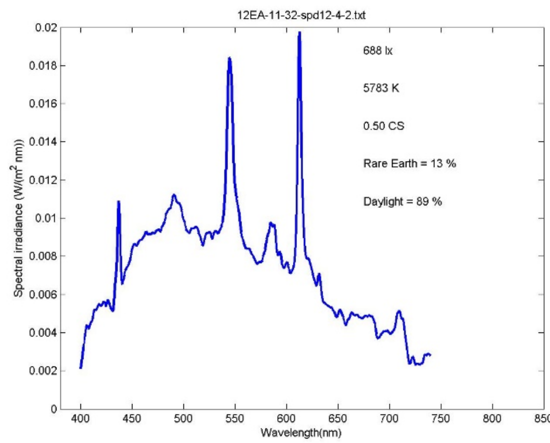
 ***9:14 AM***	 ***11:32 AM***

12-EAST-A

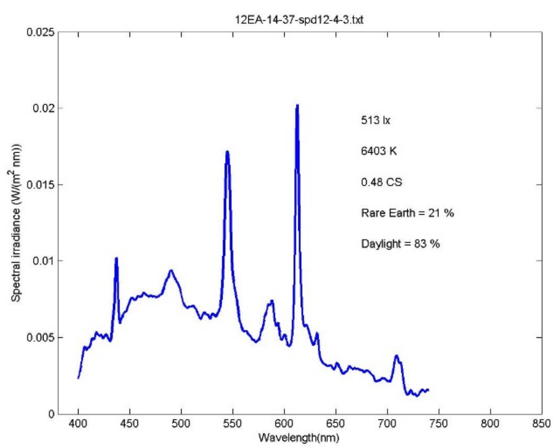
(SPECTRAL POWER DISTRIBUTION)



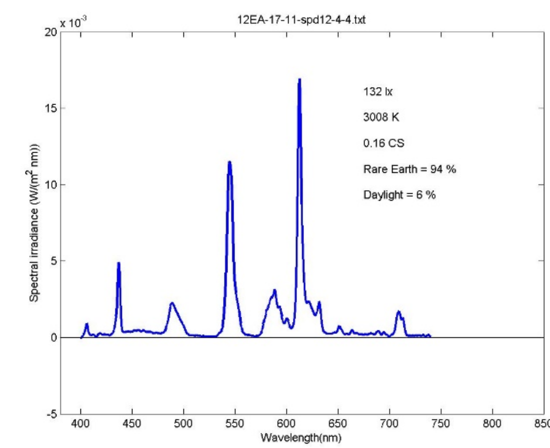
9:14 AM



11:32 AM

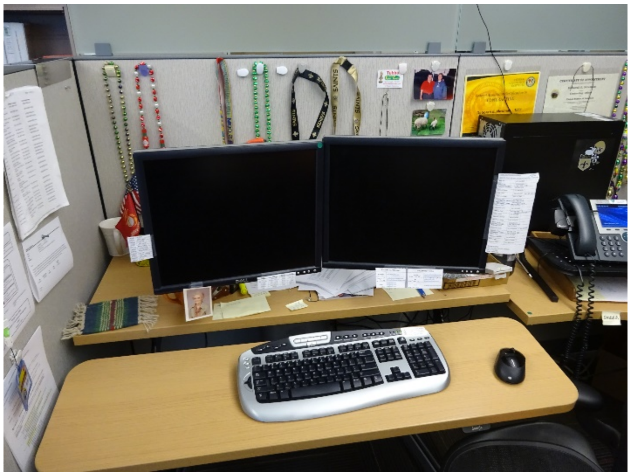
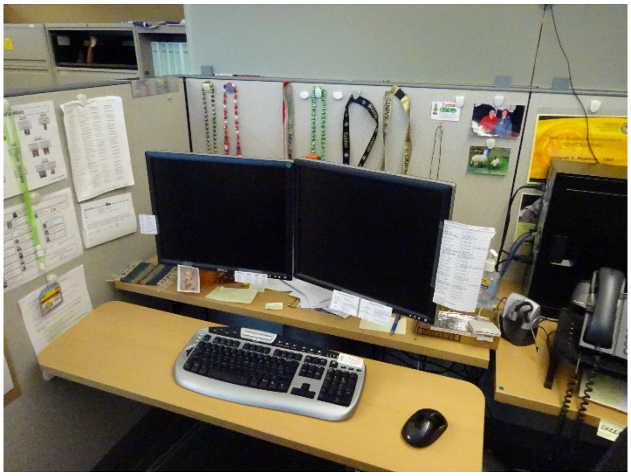


2:37 PM



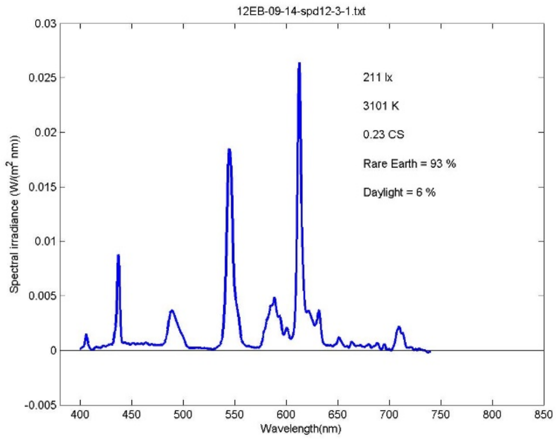
5:11 PM

12-EAST-B

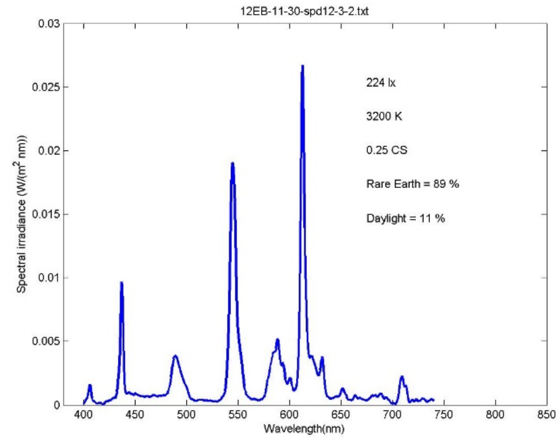
 *9:14 AM*	 *11:30 AM*

12-EAST-B

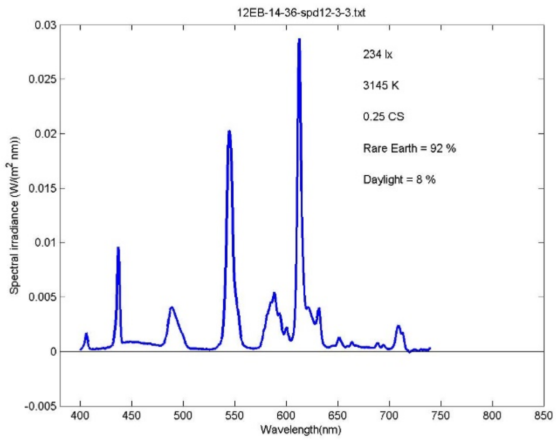
(SPECTRAL POWER DISTRIBUTION)



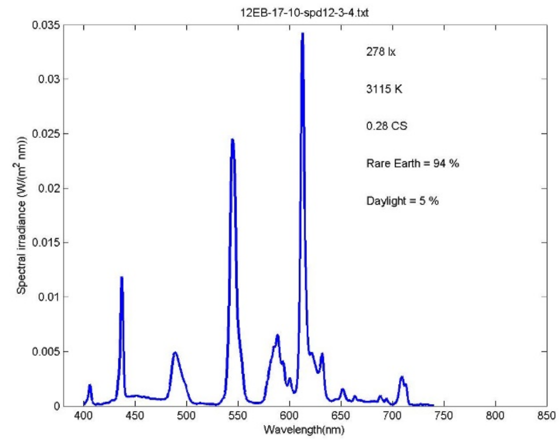
9:14 AM



11:30 AM

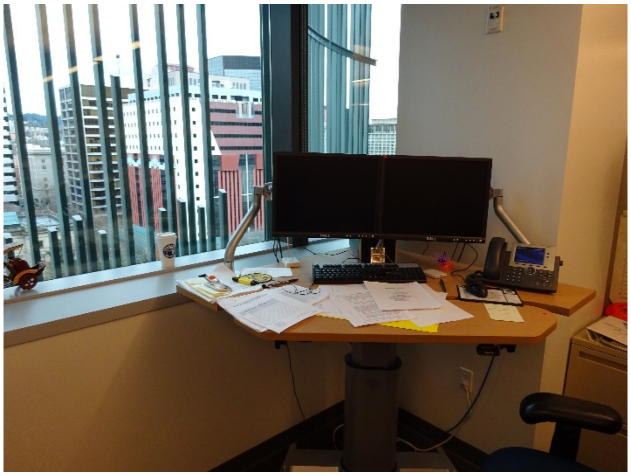


2:36 PM



5:10 PM

12-West-A

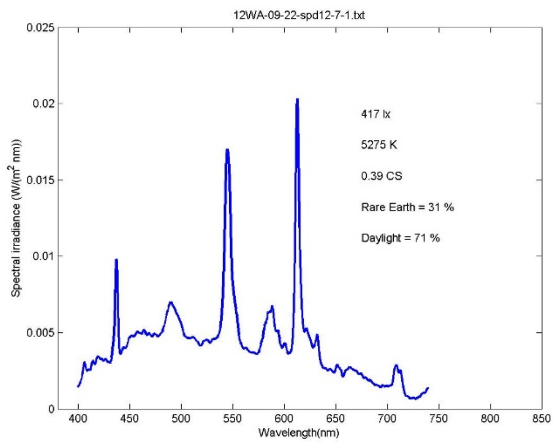


9:22 AM

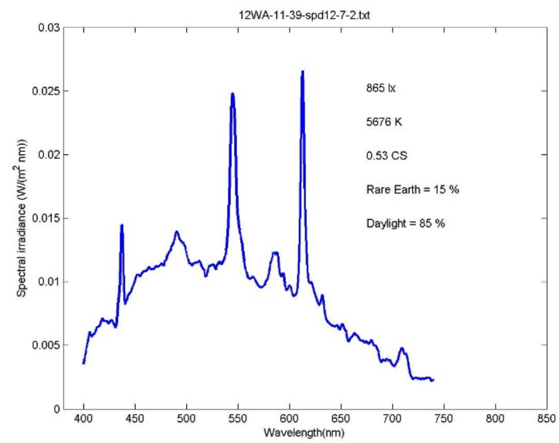
11:38 AM

12-West-A

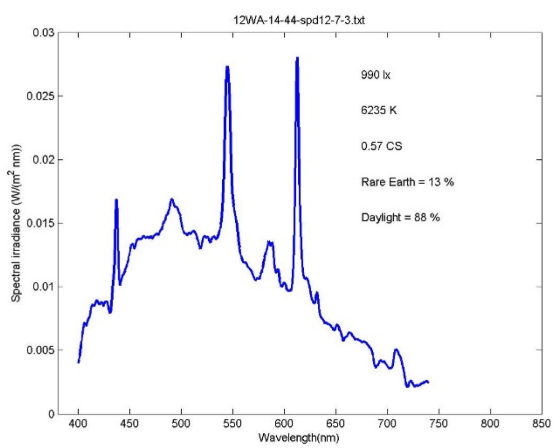
(Spectral Power Distribution)



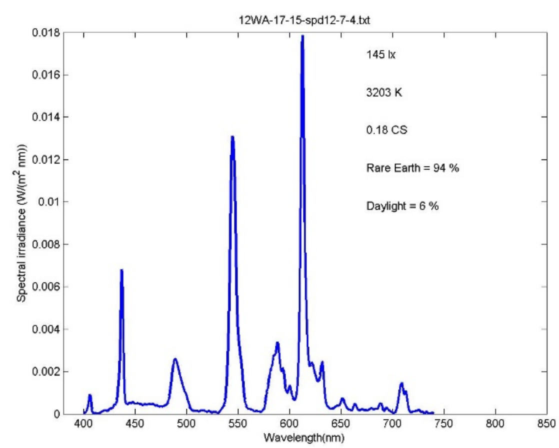
9:22 AM



11:39 AM

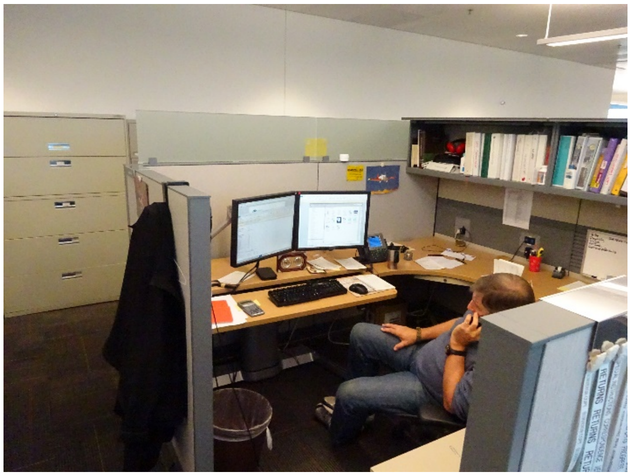


2:44 PM

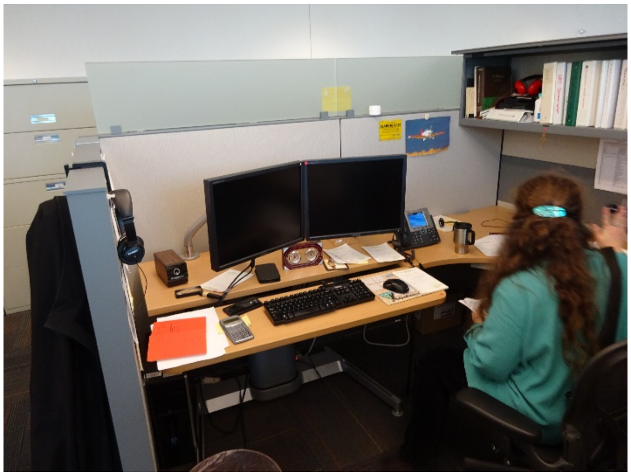


5:15 PM

12-West-B



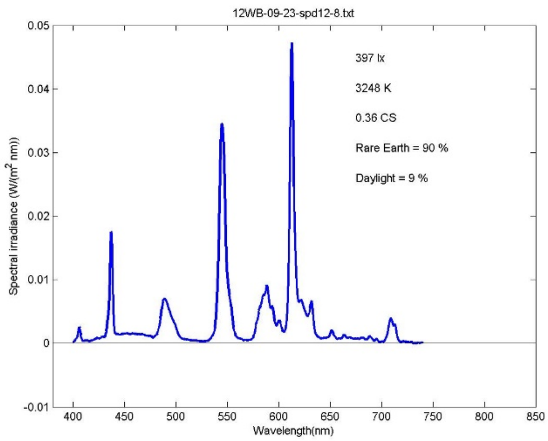
9:23 AM



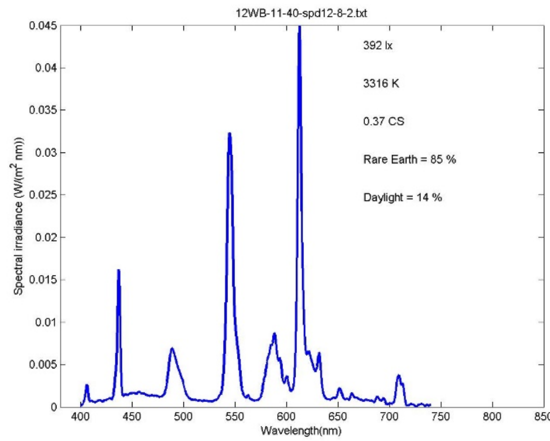
11:38 AM

12-West-B

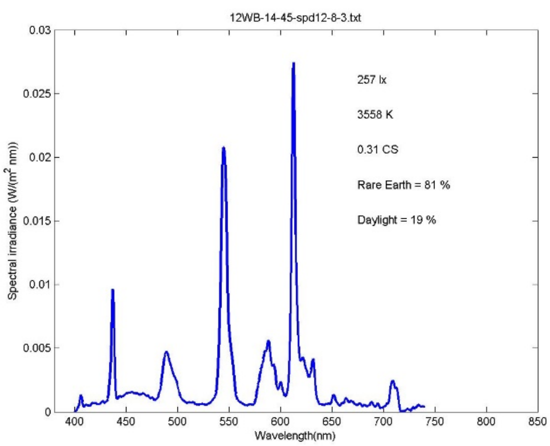
(Spectral Power Distribution)



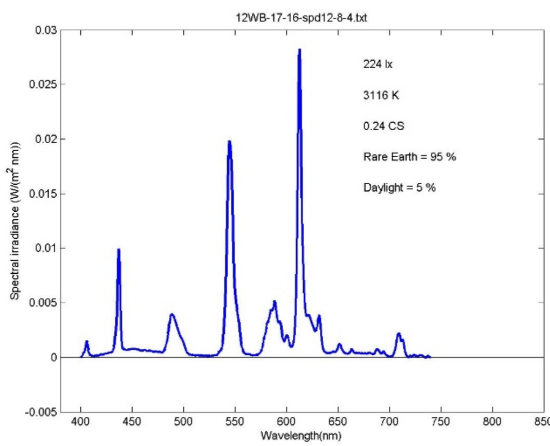
9:23 AM



11:40 AM



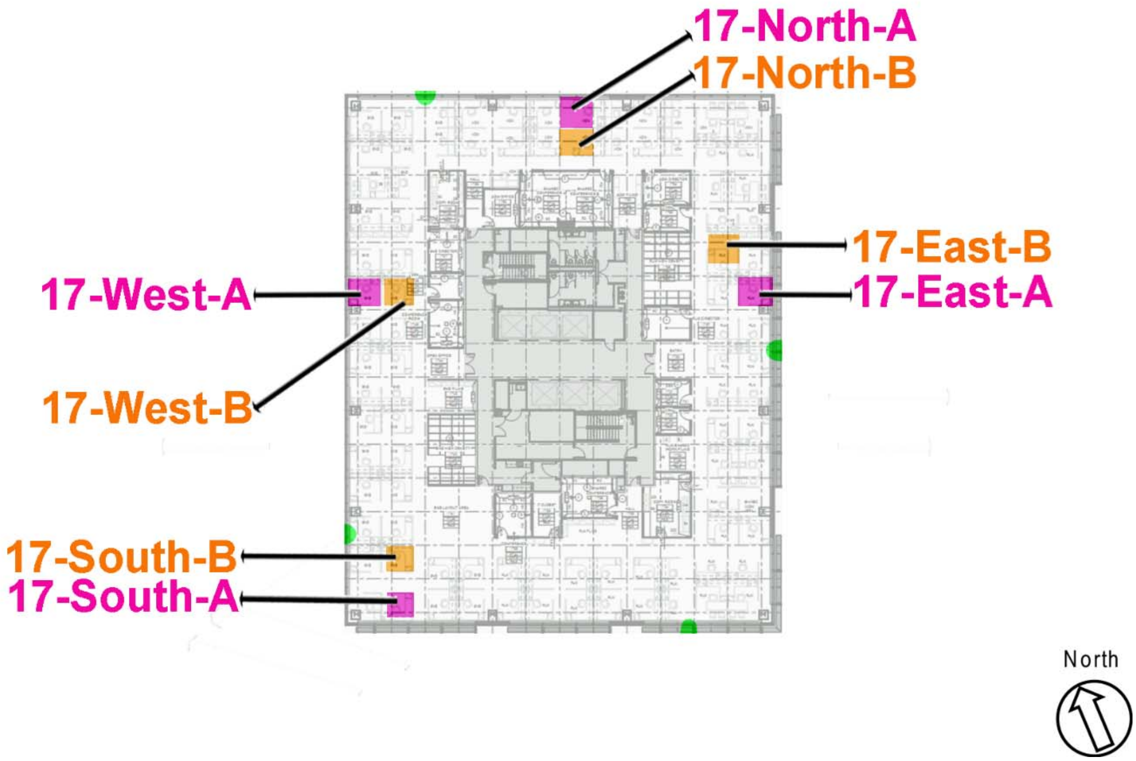
2:45 PM



5:16 PM

Appendix F: Spectral Photometric Data for 17th Floor Desks

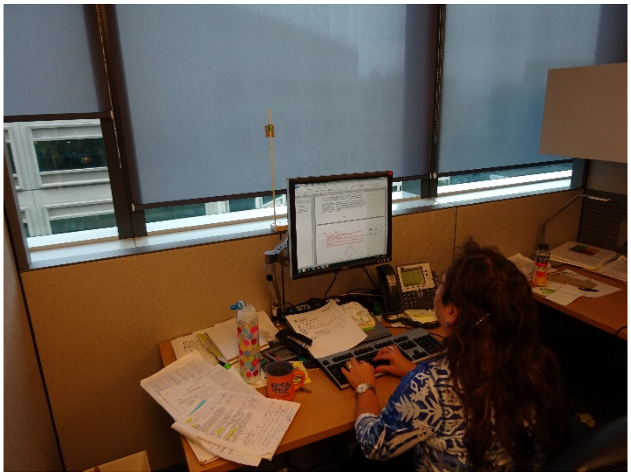
Spectral power distribution (SPD) was measured at 8 desks on the 17th floor at EGWW (see below) during the winter visit. These were the same desks that hosted other Daysimeter measurement equipment (see Appendix H) during the late spring measurements. SPDs were measured repeatedly over the day and after dark.



Desks on the 17th floor where SPD measurements were collected; windows are excluded from SPD measurements.

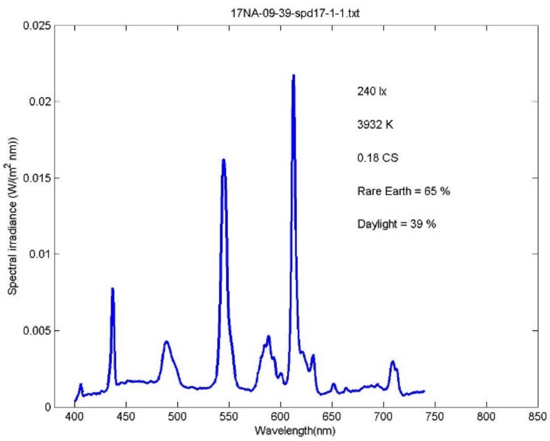
This appendix shows the results of repeated SPD measurements at 8 desks on the 17th floor. As shown below, the resulting SPD curves change as daylight contribution changes. For reference, a photograph is also presented for each measurement condition, as this represents the scene that the occupant experienced at the time of measurement. Because measurements at the window are expected to remain consistently illuminated by daylight, SPD was not measured at the windows during the evaluation visit.

17-NORTH-A

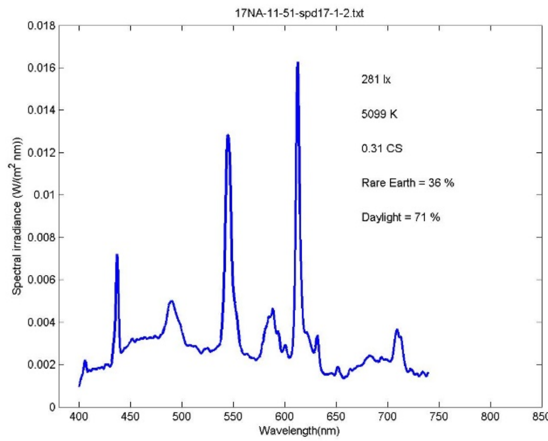
 ***9:38 AM***	 ***11:50 AM***

17-NORTH-A

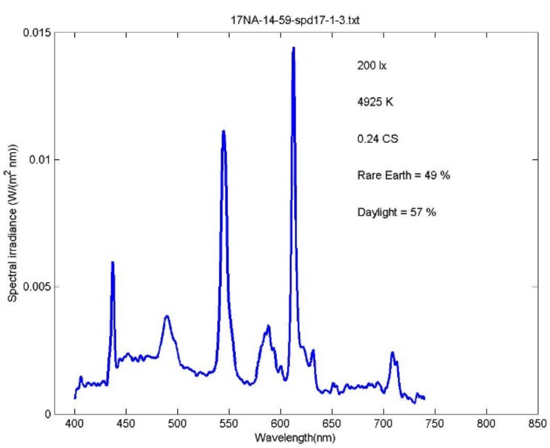
(SPECTRAL POWER DISTRIBUTION)



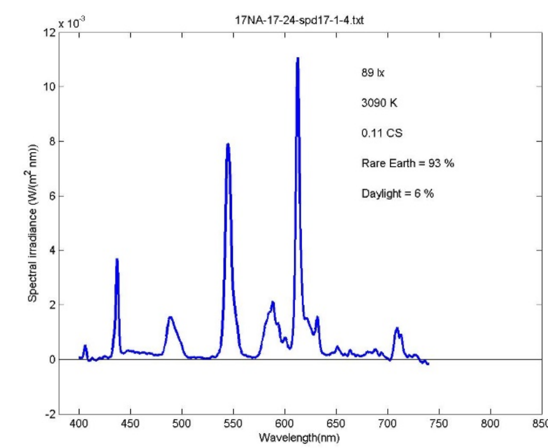
9:39 AM



11:51 AM



2:59 PM

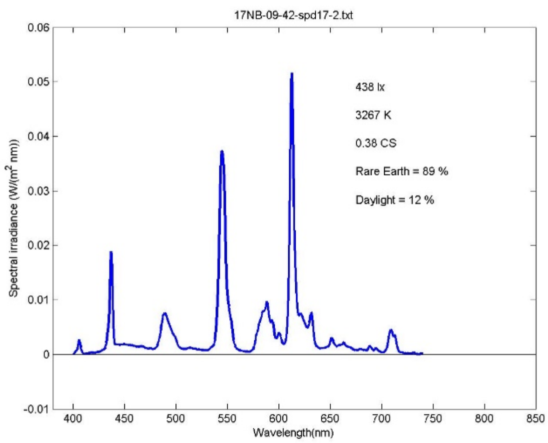


5:24 PM

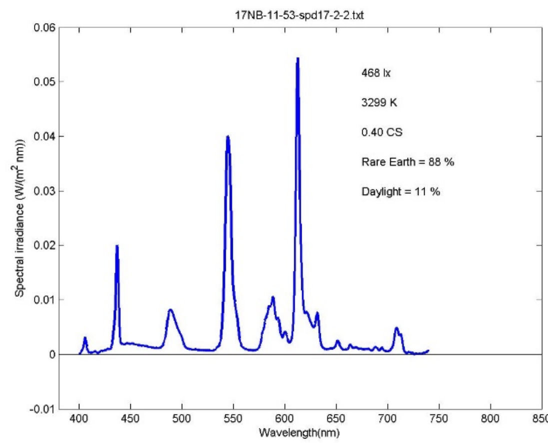
17-North-B

 9:38 AM	 11:51 AM

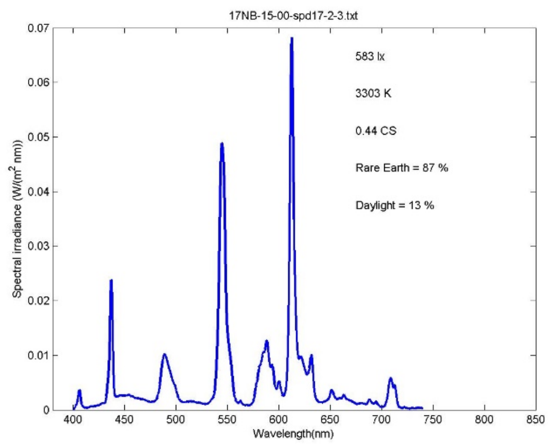
17-North-B
(Spectral Power Distribution)



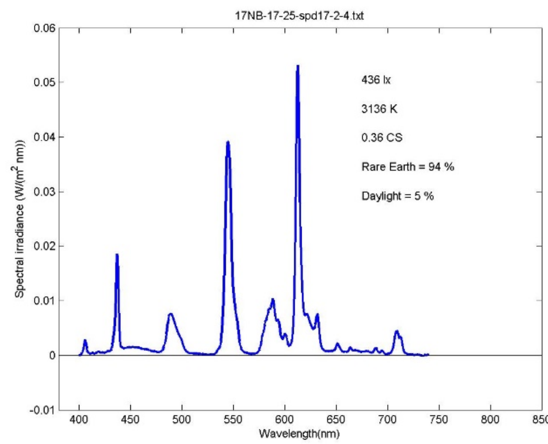
9:42 AM



11:53 AM

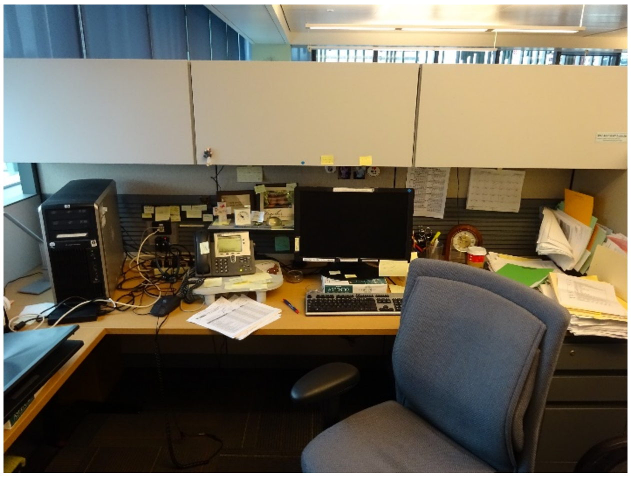


3:00 PM



5:25 PM

17-SOUTH-A

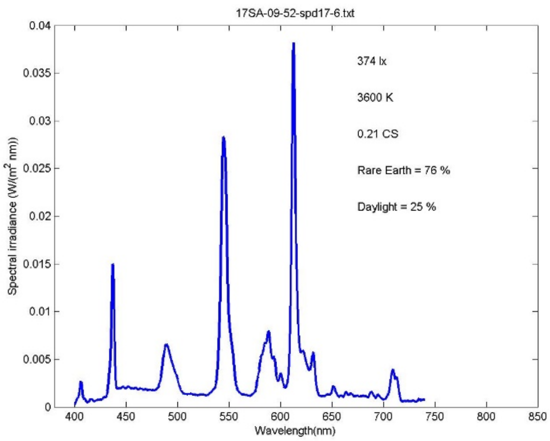


9:51 AM

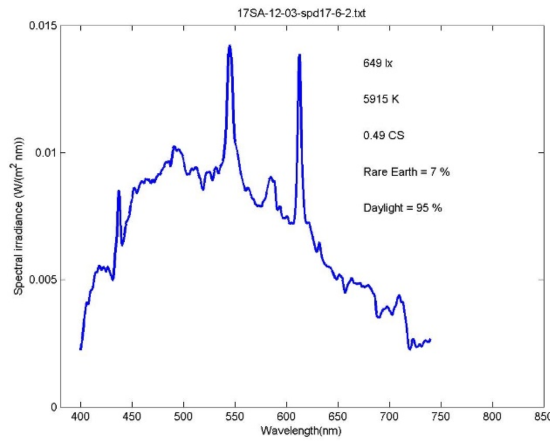
12:01 PM

17-South-A

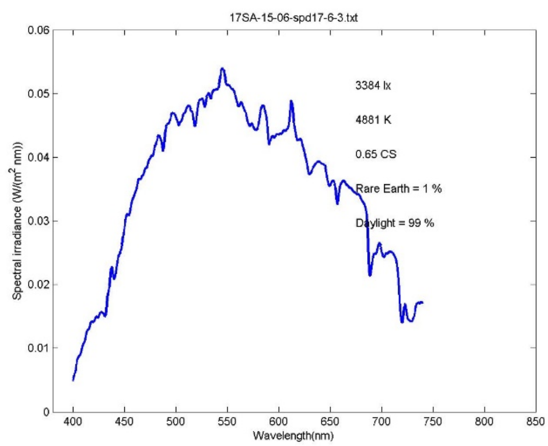
(Spectral Power Distribution)



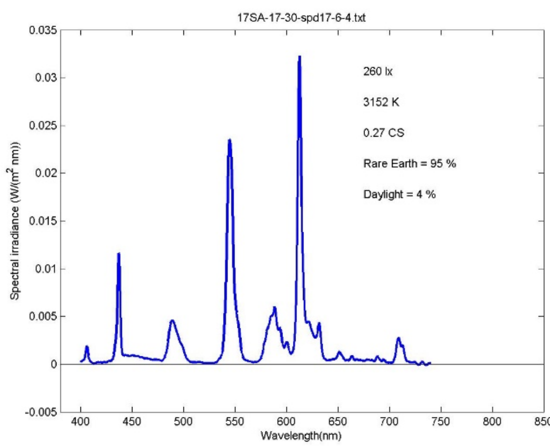
9:52 AM



12:03 PM

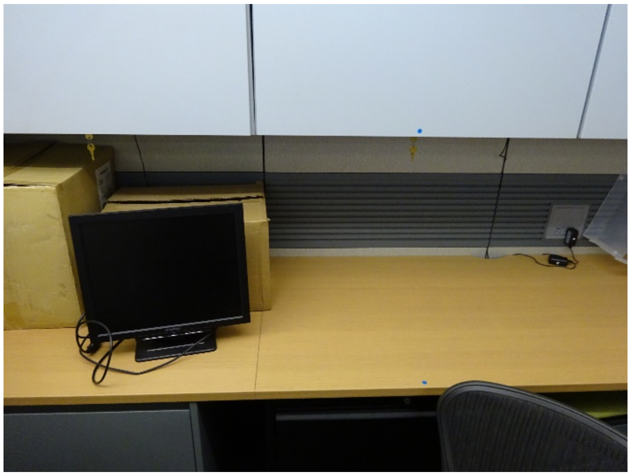
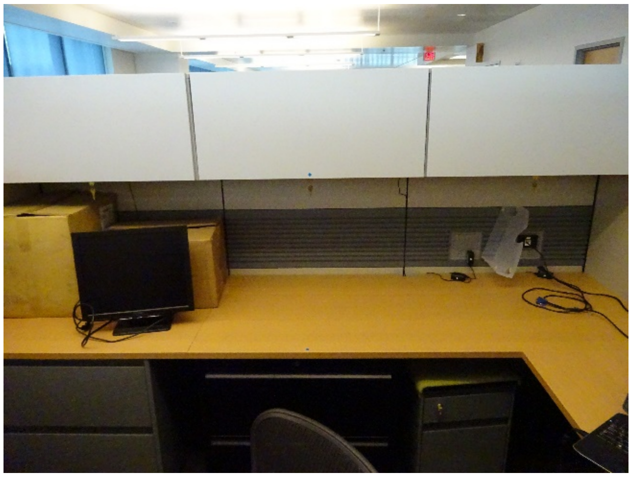


3:06 PM



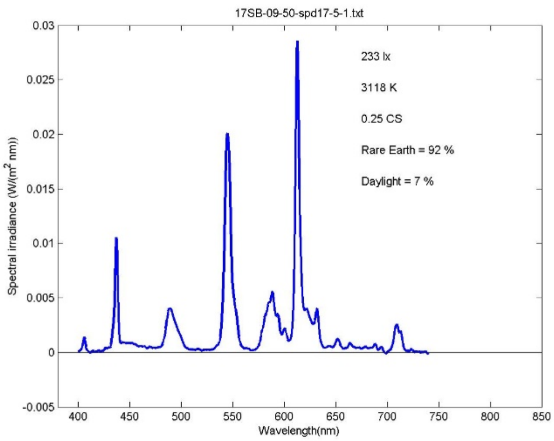
5:30 PM

17-South-B

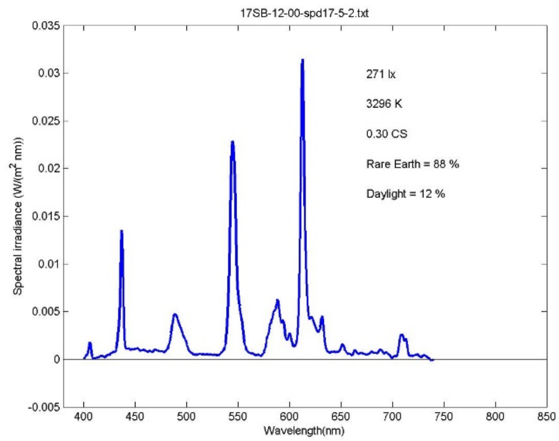
 *9:50 AM*	 *11:59 AM*

17-South-B

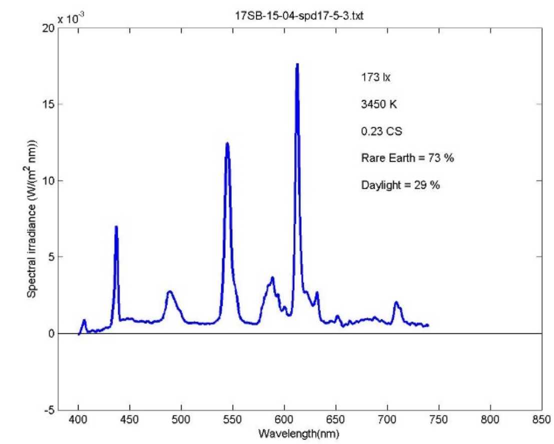
(Spectral Power Distribution)



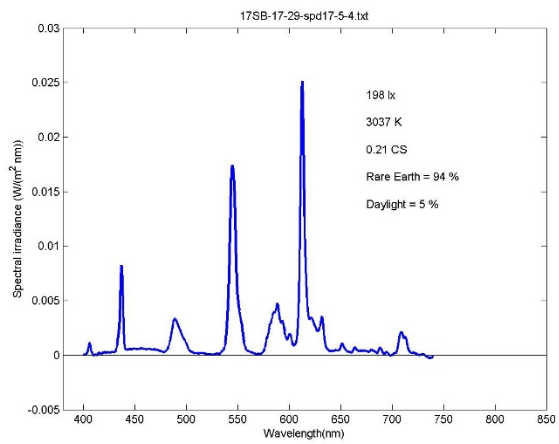
9:50 AM



12:00 PM

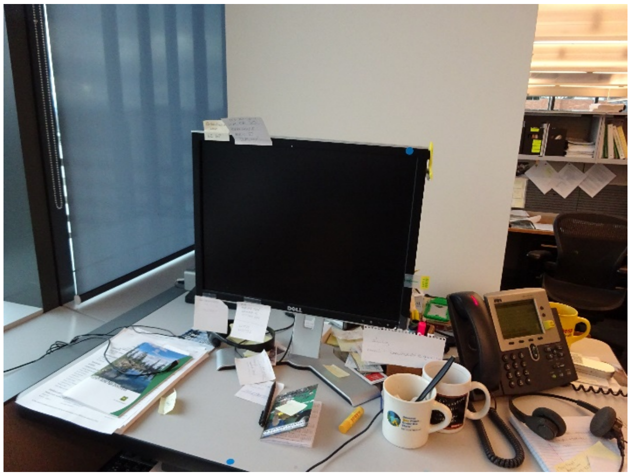
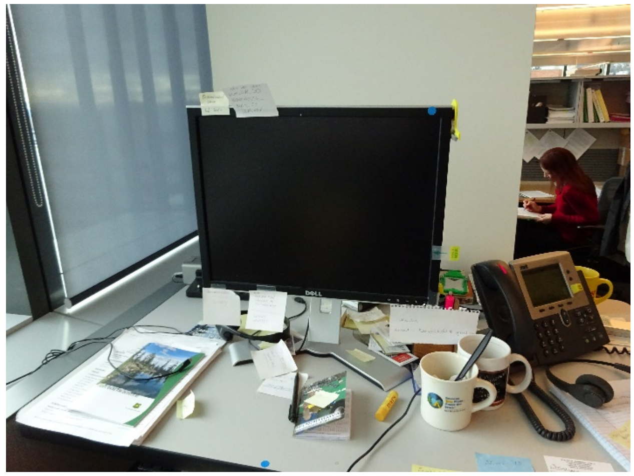


3:04 PM



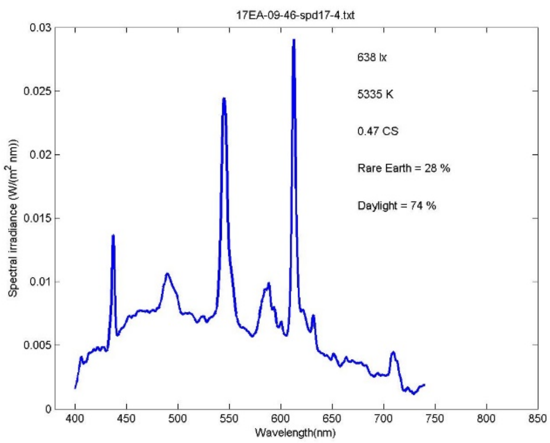
5:29 PM

17-EAST-A

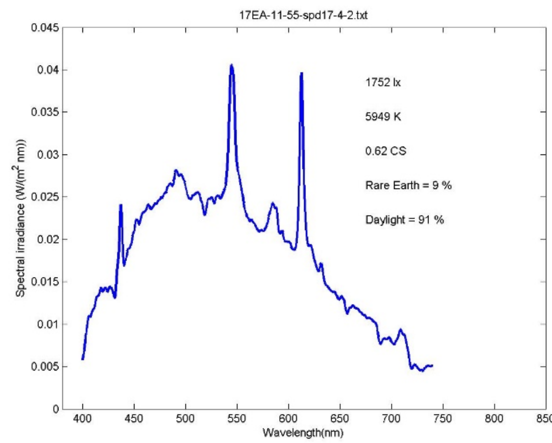
	
9:47 AM	***11:54 AM***

17-East-A

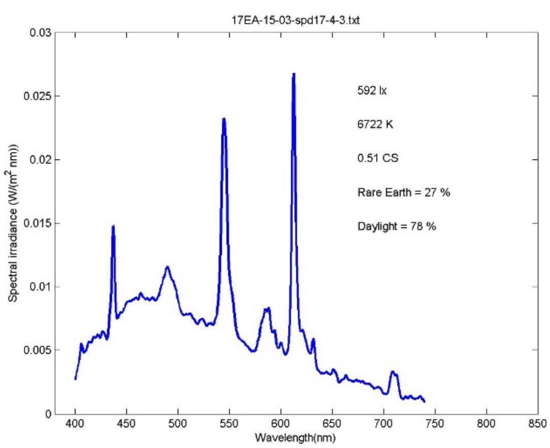
(Spectral Power Distribution)



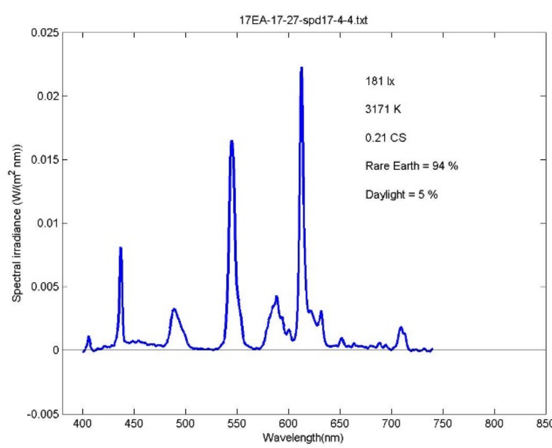
9:46 AM



11:55 AM

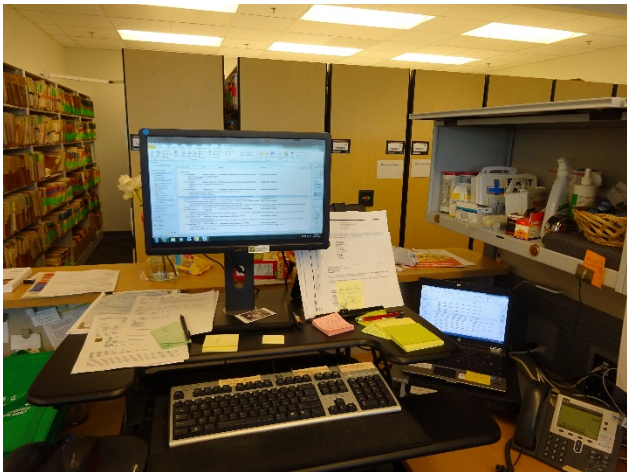


3:03 PM



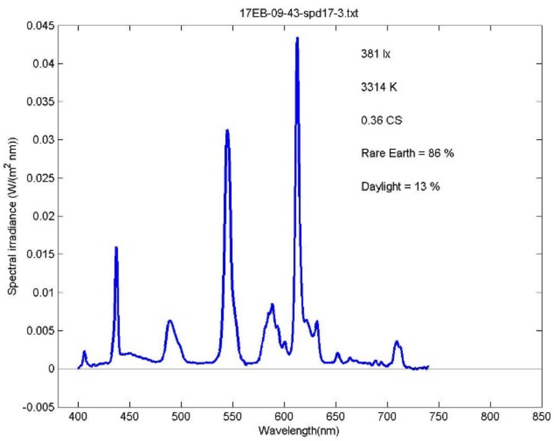
5:27 PM

17-East-B

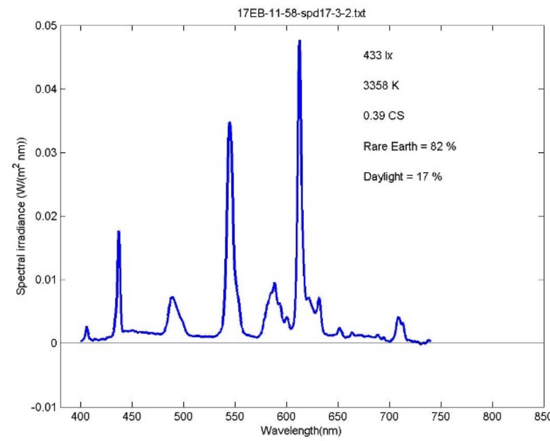
 9:43 AM	 11:57 AM

17-EAST-B

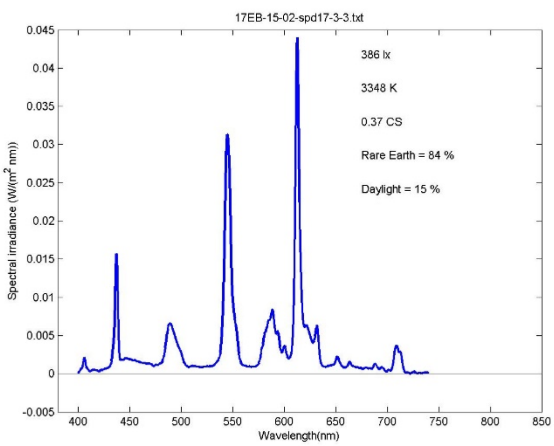
(SPECTRAL POWER DISTRIBUTION)



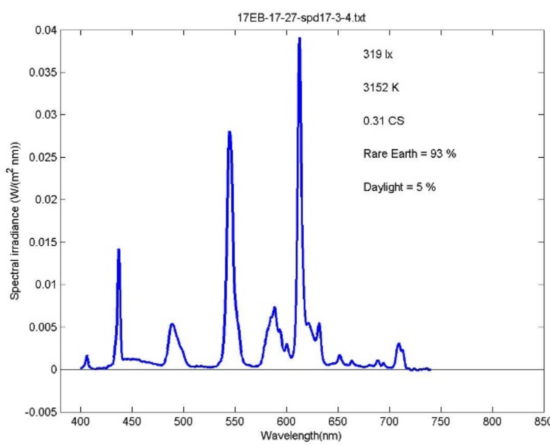
9:43 AM



11:58 AM



3:02 PM



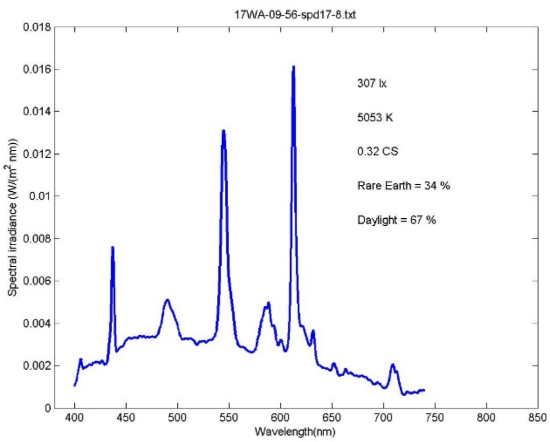
5:27 PM

17-West-A

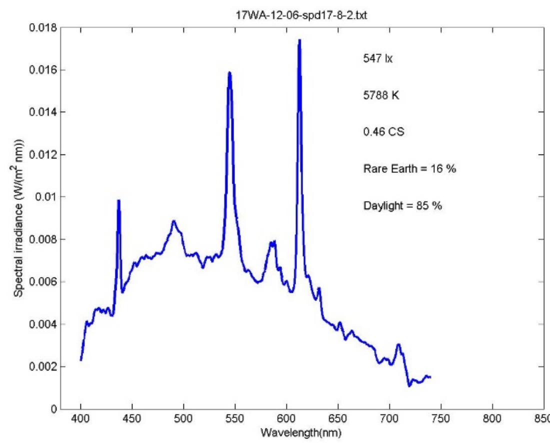
 ***9:53 AM***	 ***12:04 PM***

17-WEST-A

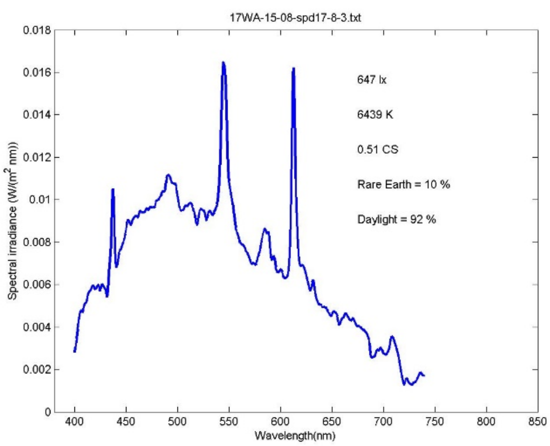
(SPECTRAL POWER DISTRIBUTION)



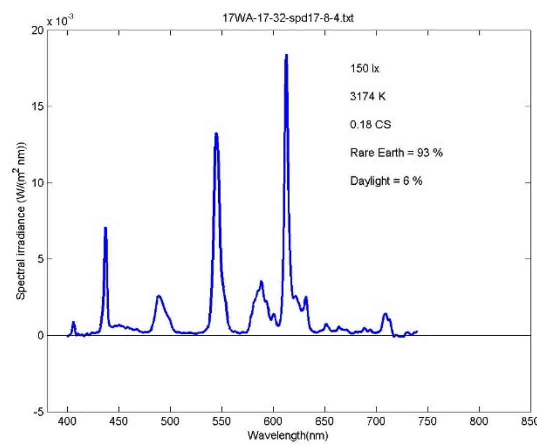
9:56 AM



12:06 PM



3:08 PM



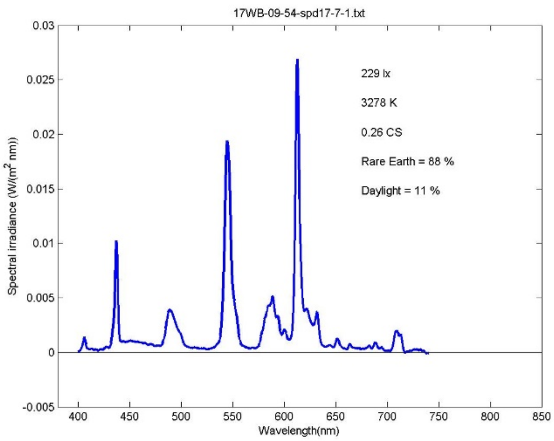
5:32 PM

17-West-B

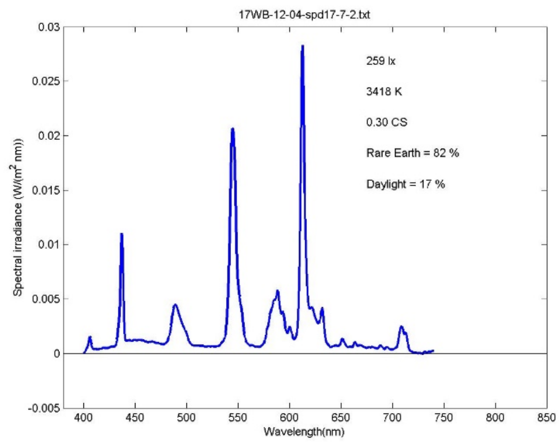
 ***9:53 AM***	 ***12:04 PM***

17-West-B

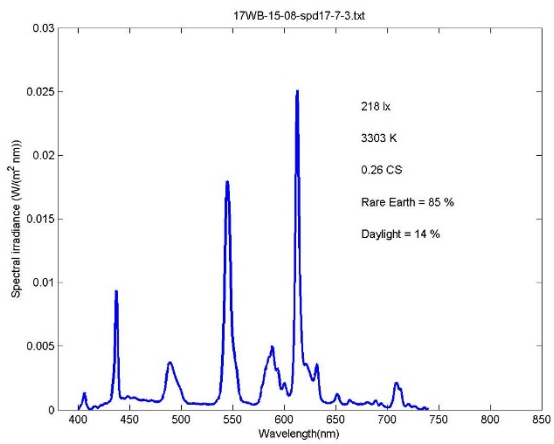
(Spectral Power Distribution)



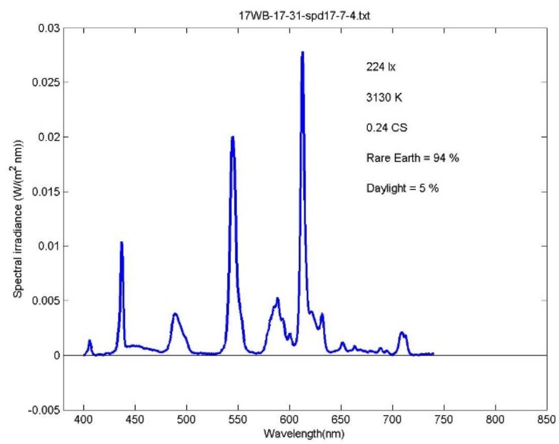
9:54 AM



12:04 PM



3:08 PM



5:31 PM

APPENDIX G: SPECTRORADIOMETRY RESULTS TABLE

				Illuminance	Approximate Contribution (+/- 10%)		Color Coordinates		Color Temp	Circadian Light	Circadian Stimulus (up to 0.7)	
Fl	Orientation	Row	Time	Lux	Fluor	Daylight	CIEx	CIEy	CCT(K)	CL_A	CS	Bright-ness
4	E	A	9:02	343	92%	8%	0.4235	0.4	3208	327	0.333	197
4	E	A	11:22	299	68%	32%	0.3958	0.391	3721	152	0.197	190
4	E	A	14:27	282	62%	38%	0.3932	0.393	3795	145	0.190	179
4	E	A	17:00	81	94%	6%	0.4377	0.409	3031	70	0.100	44
4	E	B	8:53	239	83%	17%	0.4161	0.396	3321	243	0.278	142
4	E	B	11:16	342	78%	22%	0.409	0.397	3468	369	0.357	207
4	E	B	14:23	332	89%	11%	0.4248	0.403	3203	316	0.327	189
4	E	B	16:55	393	94%	6%	0.4304	0.406	3132	352	0.348	217
4	N	A	8:47	210	73%	27%	0.4018	0.393	3600	93	0.130	131
4	N	A	11:14	325	57%	43%	0.3799	0.386	4079	206	0.247	218
4	N	A	14:20	310	47%	53%	0.3698	0.382	4333	222	0.261	215
4	N	A	16:53	117	94%	6%	0.4337	0.41	3102	104	0.143	63
4	N	B	8:48	377	93%	7%	0.4242	0.403	3218	357	0.351	215
4	N	B	11:15	300	91%	9%	0.4235	0.403	3227	288	0.309	171
4	N	B	14:21	321	90%	10%	0.4229	0.403	3243	309	0.323	183
4	N	B	16:53	324	94%	6%	0.4273	0.405	3176	301	0.318	182
4	S	A	8:59	315	46%	54%	0.3617	0.375	4538	255	0.287	228
4	S	A	11:19	637	34%	66%	0.3757	0.385	4185	451	0.396	433
4	S	A	14:25	1374	9%	91%	0.3396	0.376	5259	1470	0.579	1041
4	S	A	16:57	230	54%	46%	0.4462	0.409	2892	199	0.242	121
4	S	B	9:00	504	93%	7%	0.4302	0.408	3144	457	0.398	278
4	S	B	11:21	407	88%	12%	0.4292	0.409	3171	378	0.362	224
4	S	B	14:26	296	79%	21%	0.4219	0.407	3292	296	0.315	167
4	S	B	16:58	362	95%	5%	0.4402	0.413	3017	306	0.321	191
4	W	A	8:43	243	77%	23%	0.3992	0.388	3615	119	0.161	155
4	W	A	11:10	466	48%	52%	0.3644	0.377	4461	371	0.358	335
4	W	A	14:16	461	40%	60%	0.3549	0.373	4742	405	0.375	341
4	W	A	16:50	194	95%	5%	0.4306	0.408	3138	175	0.220	107
4	W	B	8:44	254	91%	9%	0.4247	0.403	3212	238	0.274	144
4	W	B	11:11	205	92%	8%	0.4276	0.407	3188	190	0.233	114
4	W	B	14:18	255	90%	10%	0.4253	0.406	3219	240	0.275	143
4	W	B	16:51	236	91%	9%	0.4187	0.396	3267	231	0.268	139

				Illuminance	Approximate Contribution (+/- 10%)		Color Coordinates		Color Temp	Circadian Light	Circadian Stimulus (up to 0.7)	
Fl	**Orientation**	**Row**	**Time**	**Lux**	**Fluor**	**Daylight**	**CIEx**	**CIEy**	**CCT(K)**	**CL_A**	**CS**	**Bright-ness**
12	E	A	9:14	322	31%	69%	0.3508	0.37	4862	302	0.318	244
12	E	A	11:32	688	11%	89%	0.3253	0.363	5783	816	0.500	561
12	E	A	14:37	513	17%	83%	0.3127	0.344	6403	723	0.480	460
12	E	A	17:11	132	94%	6%	0.4395	0.41	3008	114	0.155	70
12	E	B	9:14	211	94%	6%	0.4333	0.409	3101	188	0.231	115
12	E	B	11:30	224	89%	11%	0.4255	0.404	3200	213	0.254	127
12	E	B	14:36	234	92%	8%	0.43	0.407	3145	214	0.254	129
12	E	B	17:10	278	95%	5%	0.4328	0.409	3115	248	0.281	151
12	N	A	9:09	433	33%	67%	0.3448	0.369	5064	424	0.384	332
12	N	A	12:27	807	19%	81%	0.3317	0.366	5536	912	0.517	645
12	N	A	14:33	682	10%	90%	0.3105	0.351	6464	942	0.522	599
12	N	A	17:07	87	95%	5%	0.435	0.411	3090	76	0.108	47
12	N	B	9:11	398	93%	7%	0.4277	0.406	3180	369	0.357	221
12	N	B	11:28	352	90%	10%	0.4252	0.406	3221	334	0.338	198
12	N	B	14:34	344	89%	11%	0.424	0.404	3230	330	0.336	195
12	N	B	17:08	274	94%	6%	0.431	0.407	3127	246	0.280	151
12	S	A	9:19	635	15%	85%	0.3251	0.36	5799	766	0.490	525
12	S	A	11:37	1889	4%	96%	0.3251	0.369	5784	2378	0.623	1507
12	S	A	14:42	1301	0%	100%	0.3465	0.391	5066	1191	0.554	914
12	S	A	17:14	158	94%	6%	0.4297	0.411	3182	142	0.186	86
12	S	B	9:17	389	92%	8%	0.4248	0.407	3239	371	0.358	218
12	S	B	11:36	433	86%	14%	0.4181	0.404	3344	435	0.389	249
12	S	B	14:38	525	23%	77%	0.3778	0.399	4220	323	0.331	337
12	S	B	17:13	301	94%	6%	0.4308	0.409	3148	273	0.299	165
12	W	A	9:22	417	29%	71%	0.3386	0.364	5275	438	0.390	330
12	W	A	11:39	865	15%	85%	0.328	0.365	5676	1008	0.532	698
12	W	A	14:44	990	12%	88%	0.3147	0.359	6235	1306	0.565	838
12	W	A	17:15	145	94%	6%	0.4258	0.405	3203	134	0.178	81
12	W	B	9:23	397	91%	9%	0.4224	0.403	3248	383	0.364	227
12	W	B	11:40	392	86%	14%	0.4194	0.404	3316	389	0.367	225
12	W	B	14:45	257	81%	19%	0.4052	0.398	3558	285	0.307	156
12	W	B	17:16	224	95%	5%	0.4315	0.407	3116	201	0.243	123

				Illuminance	Approximate Contribution (+/- 10%)		Color Coordinates		Color Temp	Circadian Light	Circadian Stimulus (up to 0.7)	
Fl	**Orientation**	**Row**	**Time**	**Lux**	**Fluor**	**Daylight**	**CIEx**	**CIEy**	**CCT(K)**	**CL_A**	**CS**	**Bright-ness**
17	E	A	9:46	638	26%	74%	0.3371	0.366	5335	684	0.471	503
17	E	A	11:55	1752	9%	91%	0.3211	0.365	5949	2286	0.620	1432
17	E	A	15:03	592	22%	78%	0.3072	0.338	6722	886	0.513	548
17	E	A	17:27	181	95%	5%	0.4287	0.408	3171	164	0.209	100
17	E	B	9:43	381	87%	13%	0.4188	0.402	3314	371	0.358	220
17	E	B	11:58	433	83%	17%	0.4169	0.403	3358	437	0.390	250
17	E	B	15:02	386	85%	15%	0.4175	0.403	3348	387	0.366	222
17	E	B	17:27	319	95%	5%	0.4306	0.409	3152	282	0.305	174
17	N	A	9:39	240	61%	39%	0.3862	0.388	3932	140	0.184	157
17	N	A	11:51	281	29%	71%	0.3433	0.363	5099	289	0.310	222
17	N	A	14:59	200	43%	57%	0.348	0.361	4925	201	0.243	157
17	N	A	17:24	89	94%	6%	0.436	0.413	3090	77	0.110	47
17	N	B	9:42	438	88%	12%	0.4227	0.406	3267	422	0.383	247
17	N	B	11:53	468	89%	11%	0.4209	0.405	3299	453	0.396	266
17	N	B	15:00	583	87%	13%	0.4205	0.405	3303	574	0.440	332
17	N	B	17:25	436	95%	5%	0.4324	0.411	3136	382	0.364	236
17	S	A	9:52	374	75%	25%	0.4029	0.396	3600	162	0.207	229
17	S	A	12:03	649	5%	95%	0.3221	0.362	5915	787	0.494	535
17	S	A	15:06	3384	1%	99%	0.3532	0.397	4881	3354	0.646	2305
17	S	A	17:30	260	96%	4%	0.4316	0.412	3152	228	0.266	141
17	S	B	9:50	233	93%	7%	0.4314	0.407	3118	209	0.250	128
17	S	B	12:00	271	88%	12%	0.4185	0.399	3296	267	0.295	158
17	S	B	15:04	173	71%	29%	0.4104	0.398	3450	187	0.231	103
17	S	B	17:29	198	95%	5%	0.4383	0.412	3037	169	0.214	105
17	W	A	9:56	307	33%	67%	0.3451	0.369	5053	298	0.316	236
17	W	A	12:06	547	15%	85%	0.3253	0.361	5788	648	0.462	451
17	W	A	15:08	647	8%	92%	0.3104	0.356	6439	868	0.509	558
17	W	A	17:32	150	94%	6%	0.4283	0.407	3174	135	0.179	83
17	W	B	9:54	229	89%	11%	0.4201	0.401	3278	224	0.263	132
17	W	B	12:04	259	83%	17%	0.4127	0.4	3418	269	0.296	153
17	W	B	15:08	218	86%	14%	0.4193	0.402	3303	216	0.256	126
17	W	B	17:31	224	95%	5%	0.4312	0.408	3130	198	0.241	123

Average Spectroradiometry Results

The following table shows average results during the daytime measurements (excluding evening measurements, since workers are not present after dark).

EXCLUDING Night Measurements

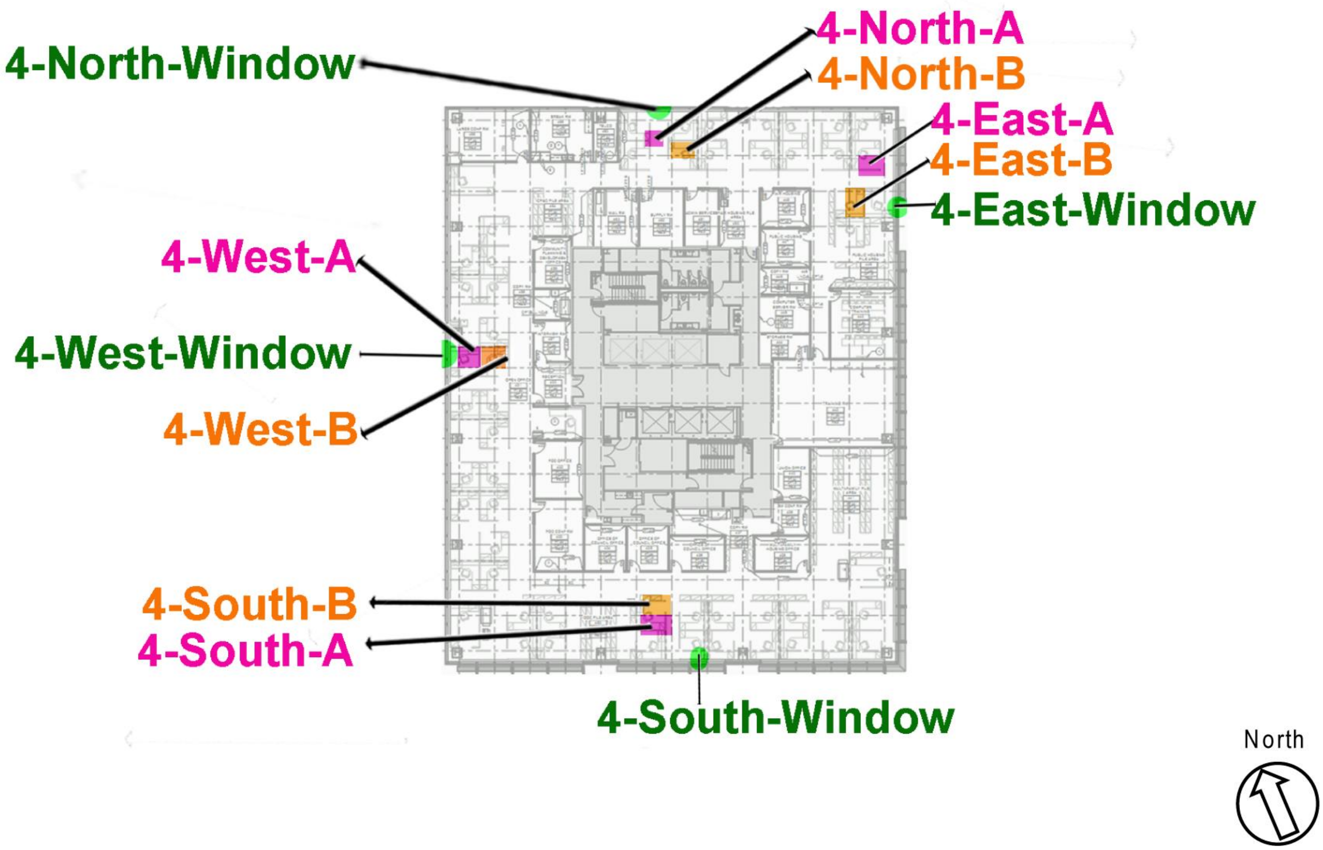
	Illum-inance	Approximate Contribution (+/- 10%)		Color Temp	Circadian Light	Circadian Stimulus (up to 0.7)	
Deskspace Locations	**Lux**	**Fluor %**	**Day %**	**CCT(K)**	**CL_A**	**CS**	**Bright-ness**
A	678	33%	67%	5031	723	0.399	518
B	335	86%	14%	3296	320	0.323	192
Orientations							
E	456	62%	38%	4180	503	0.358	329
N	393	66%	34%	4012	381	0.335	261
S	766	50%	50%	4183	763	0.400	532
W	412	59%	41%	4279	439	0.350	298
Floors							
4	379	71%	29%	3685	329	0.305	243
12	571	50%	50%	4498	627	0.407	419
17	570	56.5%	43.5%	4308	609	0.371	403

Uncertainty of Spectroradiometric Measurements

There are three main types of measurement uncertainty associated with the spectrometer used for the spectral measurements: 1) accuracy of the spectral calibration and maintaining it over time, 2) thermal noise due to the nature of the CCD detector employed in the device, and 3) a spatial response that deviates from an ideal cosine response. The accuracy of calibration is estimated to be ± 5% of the reading. The effect of thermal detector noise varies with wavelength and from an analysis of the resulting spectra is it estimated to be ± 0.004, ± 0.00018, and ± 0.007 W/(m^2 nm) for the spectral ranges $\lambda < 450$ nm; $450 < \lambda < 730$ nm; and $\lambda > 730$ nm, respectively. The corresponding uncertainty (1-sigma) in photopic illuminance is ± 3 lux. Combining these uncertainties leads to an uncertainty of ± (5% of reading + 3 lux).

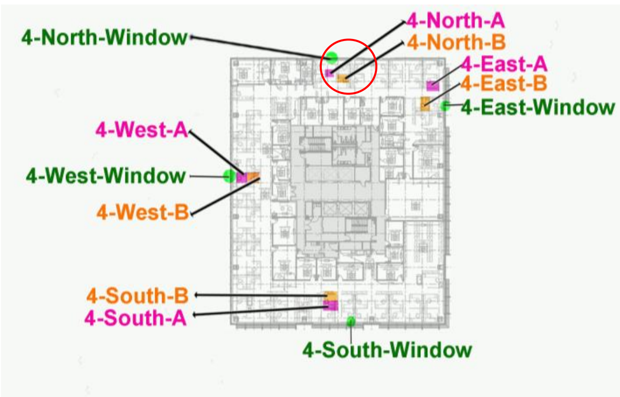
The spatial uncertainty depends greatly on the spatial distribution of light for each measurement; for light of normal incidence the error is near zero, but the error increases significantly, always underreporting the illuminance, for light incident at large angles. An estimate of the spatial uncertainty for the range of diffuse and direct illuminance commonly found in office environments for these measurements is +0, -5% of the reading.

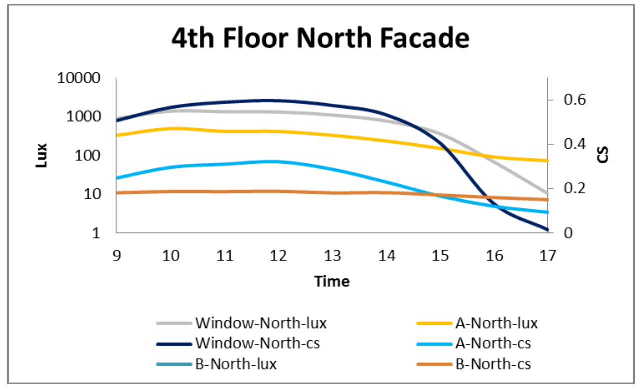
APPENDIX H: PHOTOMETRIC DATA FOR 4TH FLOOR STATIONARY DEVICES (MOUNTED ON STICKS AND IN WINDOWS)



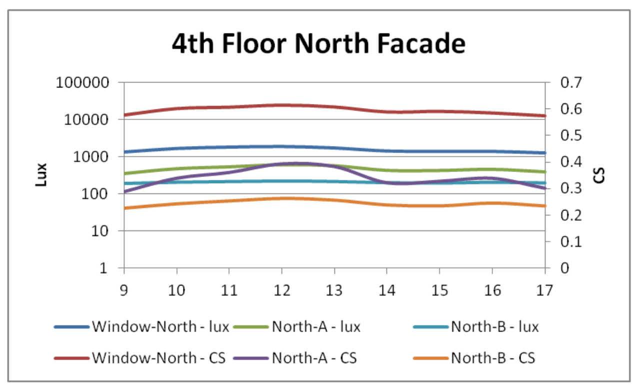
Location where measurements were collected.

4TH FLOOR NORTH FACADE



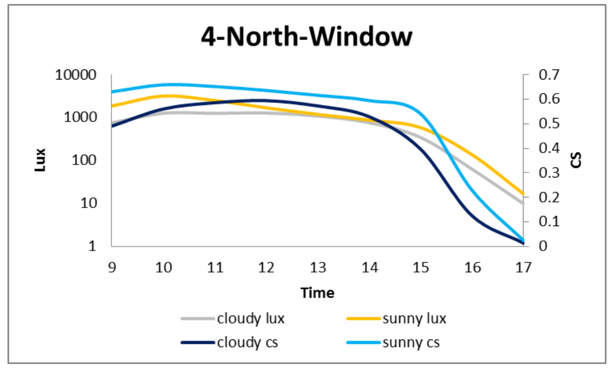


Average Lux and CS (Winter)



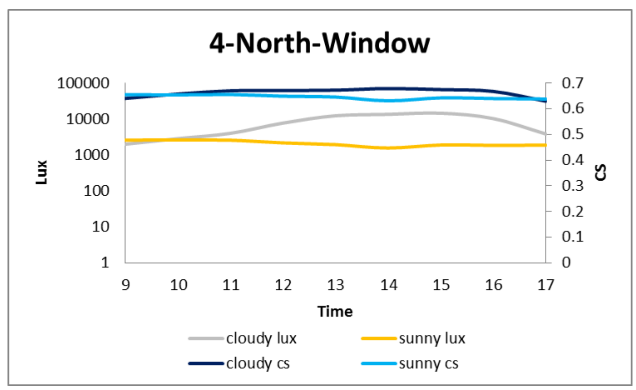
Average Lux and CS (Late Spring)

4-North-Window (Winter)



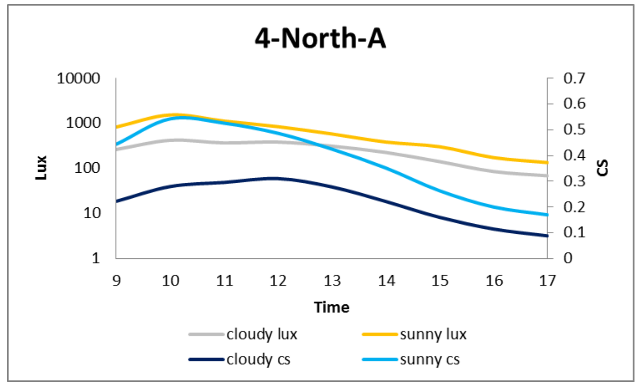
Daysimeter 107 – 4-North-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 762 ± 514 lux on cloudy days. The mean CS value was 0.43 ± 0.21 on cloudy days. On sunny days mean photopic light level during working hours was 1343 ± 1072 lux. The mean CS value was 0.51 ± 0.23 on sunny days.

4-North-Window (Late Spring)



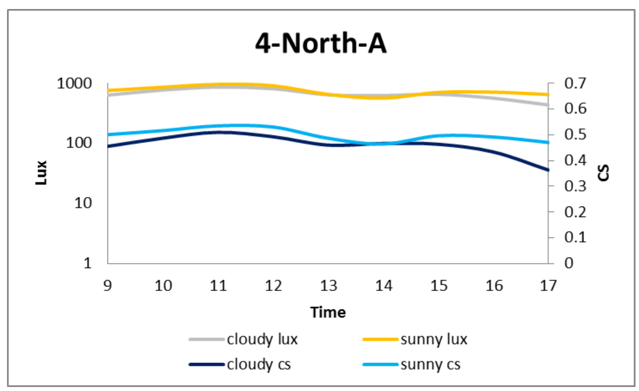
Daysimeter 134 – 4-North-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 7913 ± 4192 lux on cloudy days. The mean CS value on was 0.66 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 2129 ± 390 lux. The mean CS value on was 0.65 ± 0.01 on sunny days.

4-North-A (Winter)

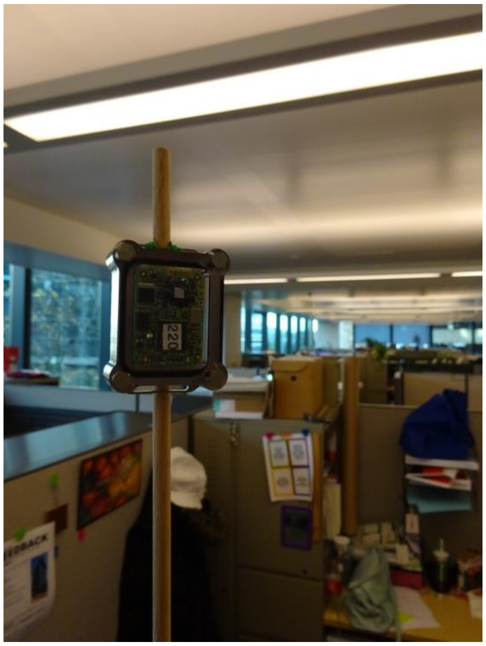


Daysimeter 221 – 4-North-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 253 ± 131 lux on cloudy days. The mean CS value was 0.22 ± 0.08 on cloudy days. On sunny days mean photopic light level during working hours was 658 ± 471 lux. The mean CS value was 0.38 ± 0.14 on sunny days.

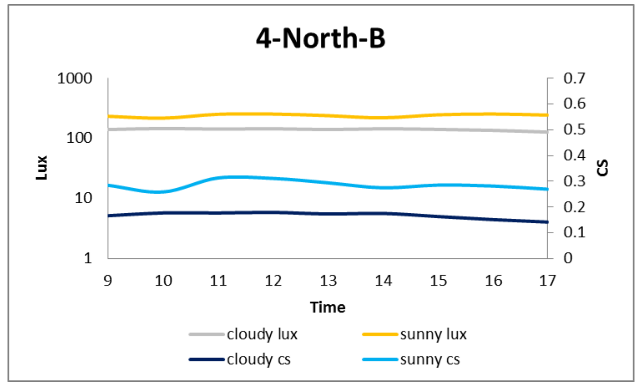
4-North-A (Late Spring)



Daysimeter 161 – 4-North-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 667 ± 131 lux on cloudy days. The mean CS value on was 0.46 ± 0.04 on cloudy days. On sunny days mean photopic light level during working hours was 753 ± 131 lux. The mean CS value on was 0.50 ± 0.02 on sunny days.

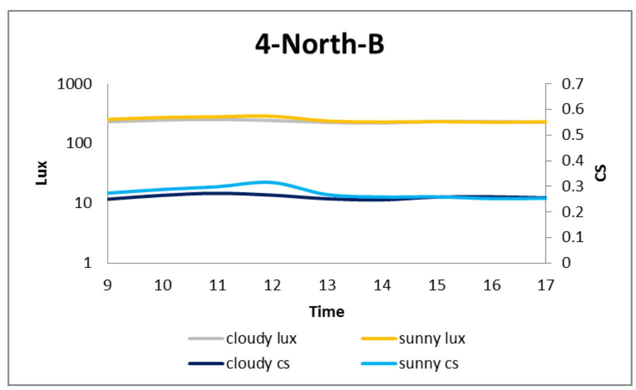


4-North-B (Winter)



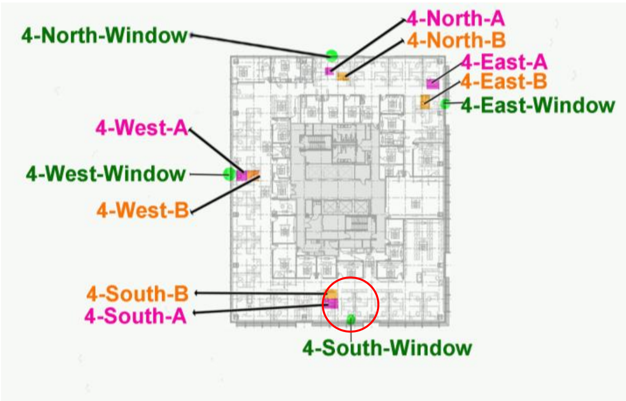
Daysimeter 220 – 4-North-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 141 ± 6 lux on cloudy days. The mean CS value was 0.17 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 240 ± 14 lux. The mean CS value was 0.29 ± 0.02 on sunny days.

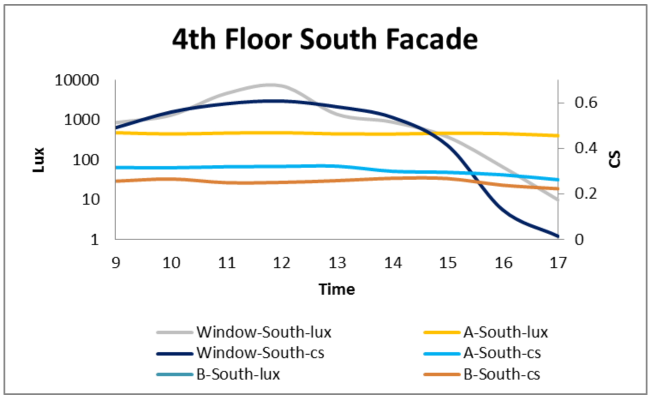
4-North-B (Late Spring)



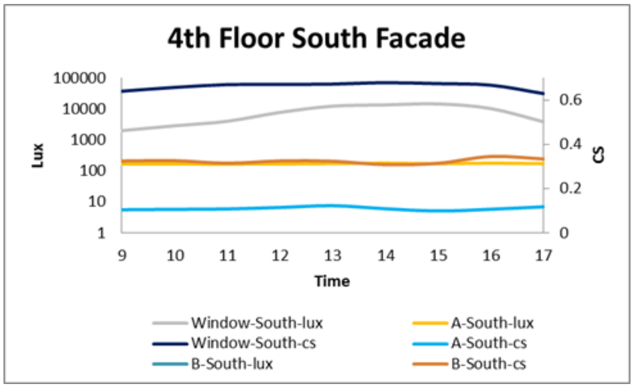
Daysimeter 164 – 4-North-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 236 ± 11 lux on cloudy days. The mean CS value on was 0.26 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 251 ± 24 lux. The mean CS value on was 0.27 ± 0.02 on sunny days.

4TH FLOOR SOUTH FACADE



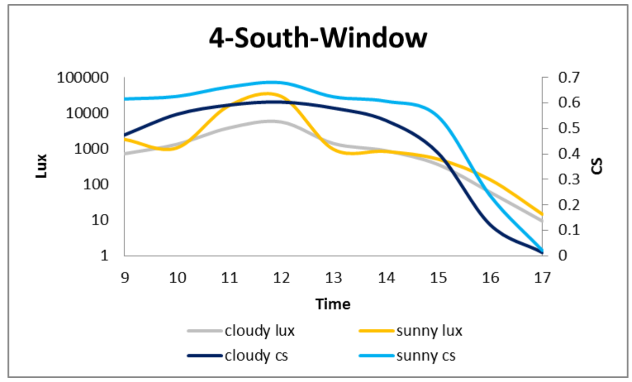


Average Lux and CS (Winter)



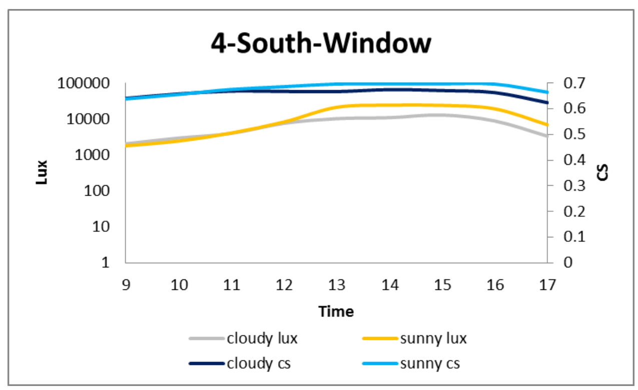
Average Lux and CS (Late Spring)

4-South-Window (Winter)

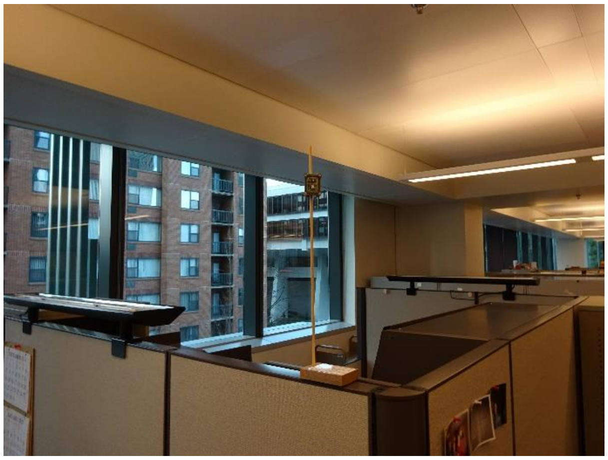


Daysimeter 113 – 4-South-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1596 ± 1923 lux on cloudy days. The mean CS value was 0.43 ± 0.22 on cloudy days. On sunny days mean photopic light level during working hours was 5673 ± 10308 lux. The mean CS value was 0.51 ± 0.23 on sunny days.

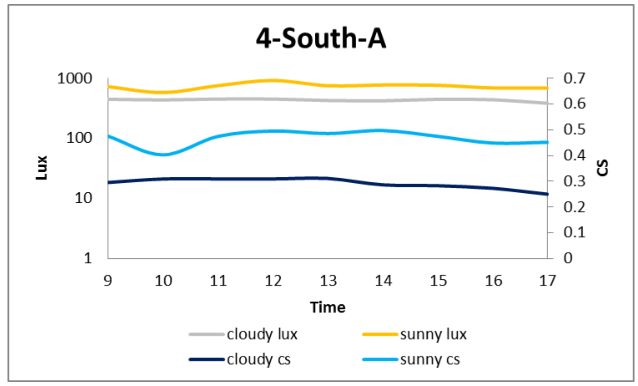
4-South-Window (Late Spring)



Daysimeter 138 - 4-South-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 6995 ± 4006 lux on cloudy days. The mean CS value on was 0.66 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 12487 ± 9556 lux. The mean CS value on was 0.68 ± 0.02 on sunny days.

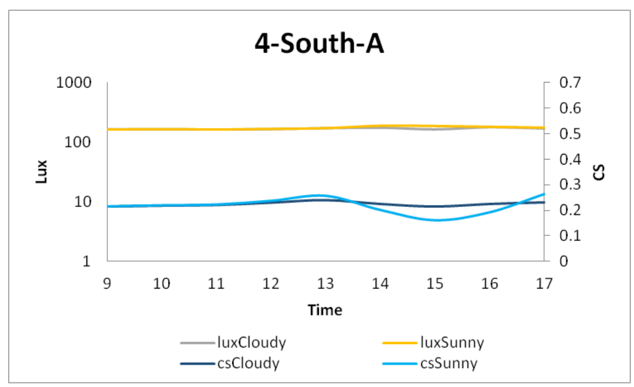


4-South-A (Winter)

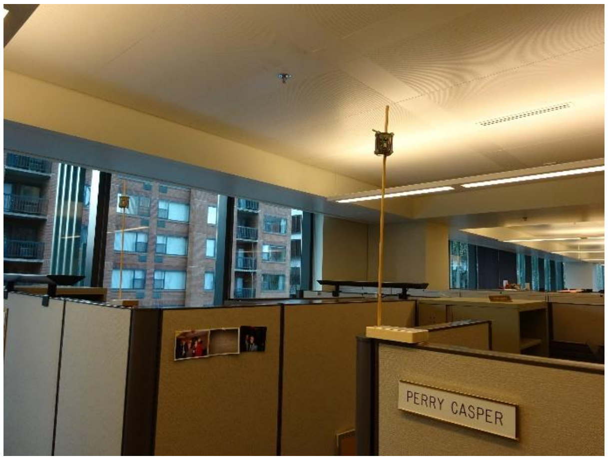


Daysimeter 217 – 4-South-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 434 ± 21 lux on cloudy days. The mean CS value was 0.29 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 739 ± 90 lux. The mean CS value was 0.47 ± 0.03 on sunny days.

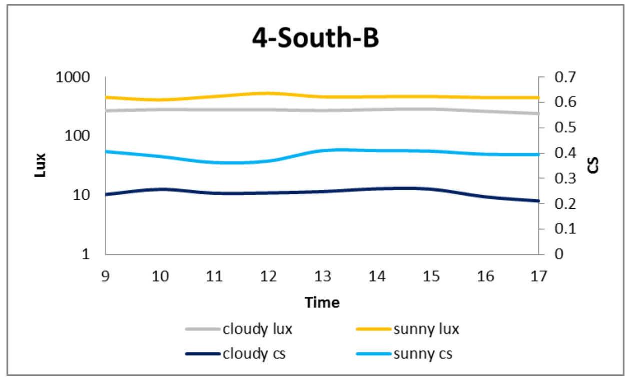
4-South-A (Late Spring)



Daysimeter 165 – 4-South-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 170 ± 4 lux on cloudy days. The mean CS value on was 0.22 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 177 ± 10 lux. The mean CS value on was 0.22 ± 0.03 on sunny days.

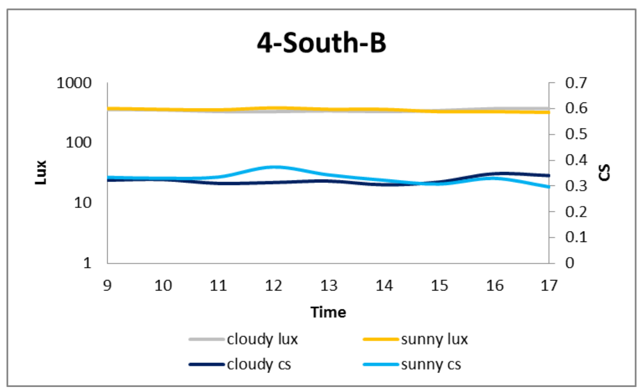


4-South-B (Winter)



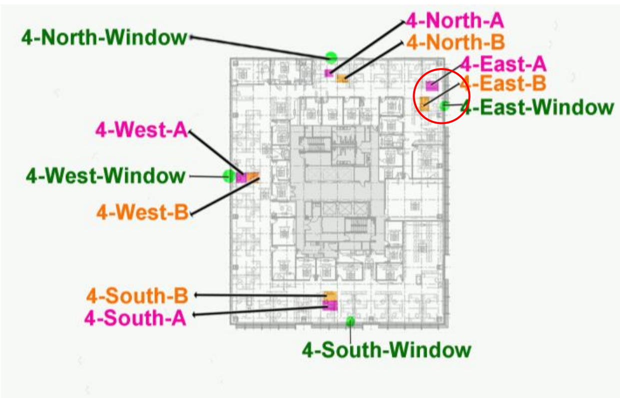
Daysimeter 193 – 4-South-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 279 ± 14 lux on cloudy days. The mean CS value was 0.24 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 463 ± 31 lux. The mean CS value was 0.39 ± 0.02 on sunny days.

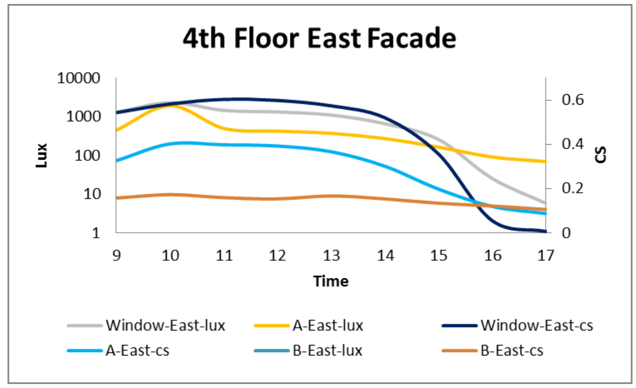
4-South-B (Late Spring)



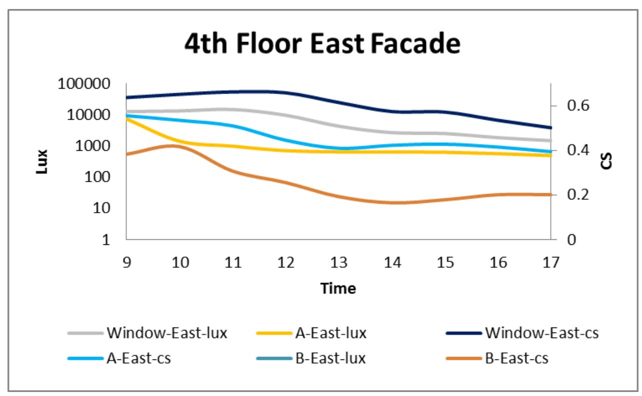
Daysimeter 162 – 4-South-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 350 ± 16 lux on cloudy days. The mean CS value on was 0.32 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 355 ± 21 lux. The mean CS value on was 0.33 ± 0.02 on sunny days.

4TH FLOOR EAST FACADE

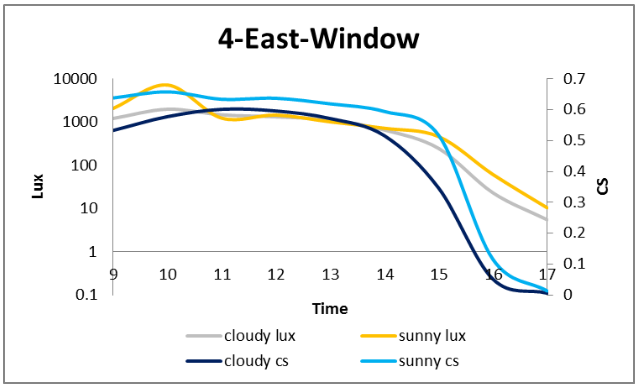
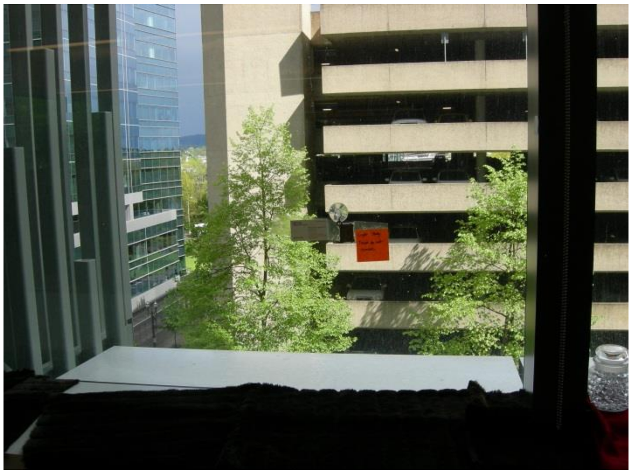
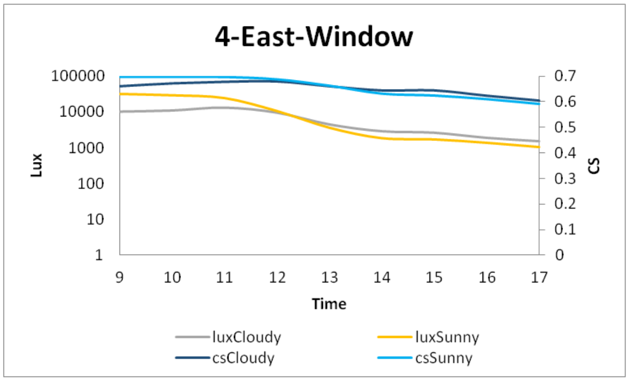




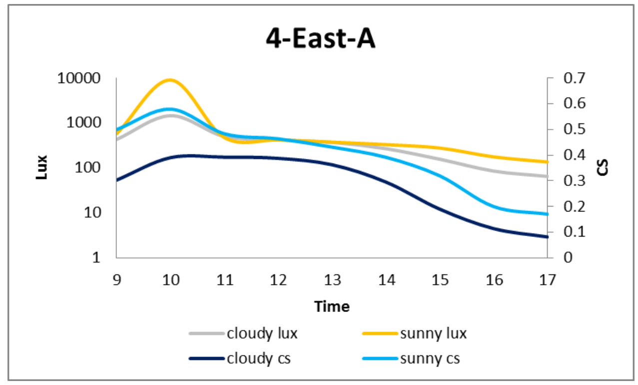
Average Lux and CS (Winter)



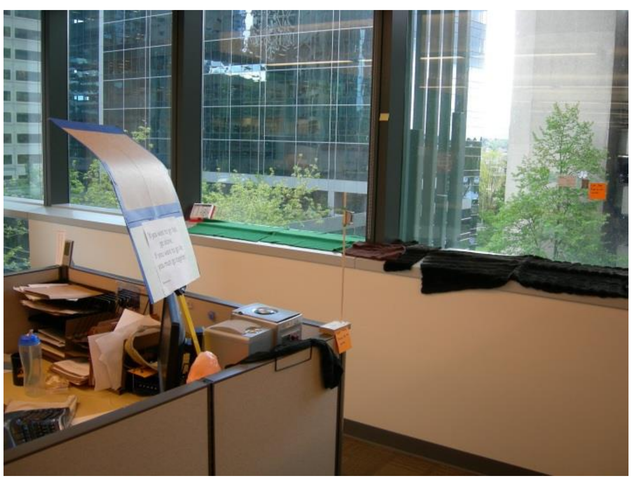
Average Lux and CS (Late Spring)

4-East-Window (No winter photo available)	 Daysimeter 101 – 4-East-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 892 ± 696 lux on cloudy days. The mean CS value was 0.42 ± 0.24 on cloudy days. On sunny days mean photopic light level during working hours was 1579 ± 2207 lux. The mean CS value was 0.49 ± 0.25 on sunny days.
 ***4-East-Window (Late Spring)***	 Daysimeter 144 – 4-East-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 6349 ± 4468 lux on cloudy days. The mean CS value on was 0.65 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 11897 ± 13192 lux. The mean CS value on was 0.66 ± 0.04 on sunny days.

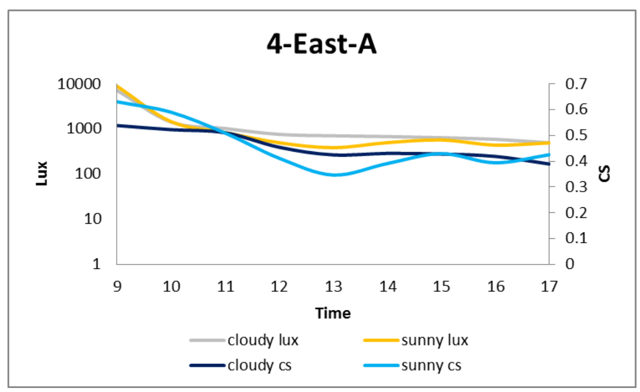
4-East-A (Winter)



Daysimeter 166 – 4-East-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 419 ± 421 lux on cloudy days. The mean CS value was 0.28 ± 0.12 on cloudy days. On sunny days mean photopic light level during working hours was 1314 ± 2905 lux. The mean CS value was 0.39 ± 0.14 on sunny days.

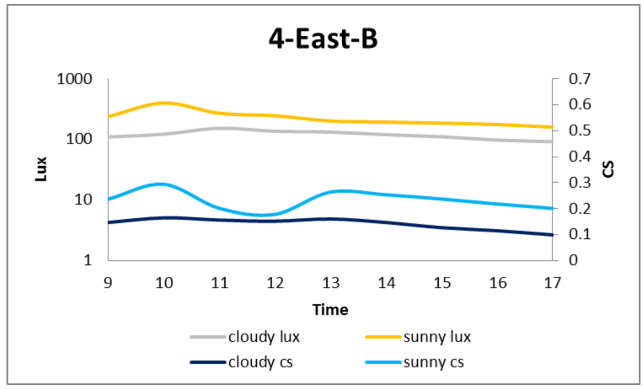


4-East-A (Late Spring)



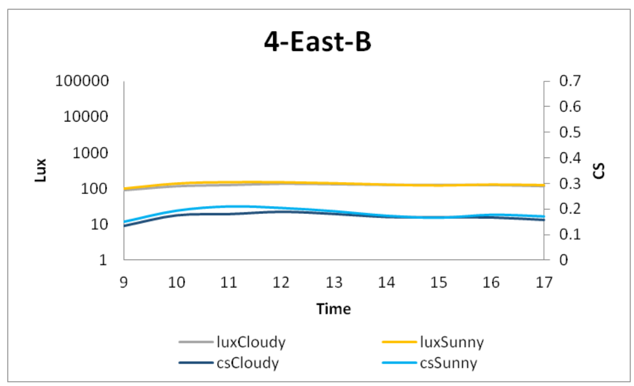
Daysimeter 166 – 4-East-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1499 ± 2136 lux on cloudy days. The mean CS value on was 0.46 ± 0.05 on cloudy days. On sunny days mean photopic light level during working hours was 1562 ± 2761 lux. The mean CS value on was 0.46 ± 0.10 on sunny days.

4-East-B (Winter)



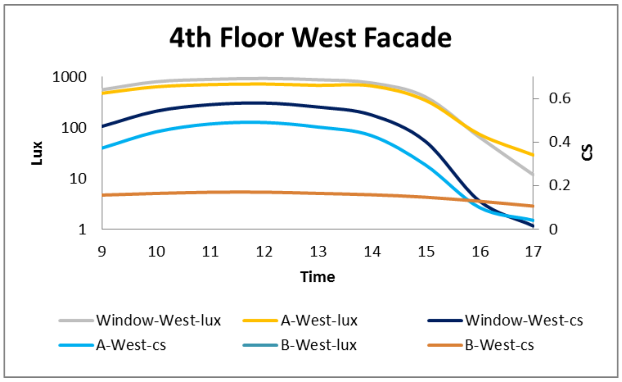
Daysimeter 138 – 4-East-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 120 ± 19 lux on cloudy days. The mean CS value was 0.14 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 230 ± 73 lux. The mean CS value was 0.23 ± 0.04 on sunny days.

4-East-B (Late Spring)

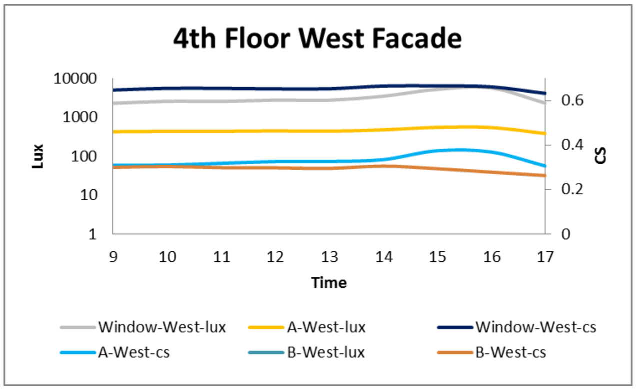


Daysimeter 152 – 4-East-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 120 ± 13 lux on cloudy days. The mean CS value on was 0.17 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 133 ± 15 lux. The mean CS value on was 0.18 ± 0.02 on sunny days.

4TH FLOOR WEST FACADE

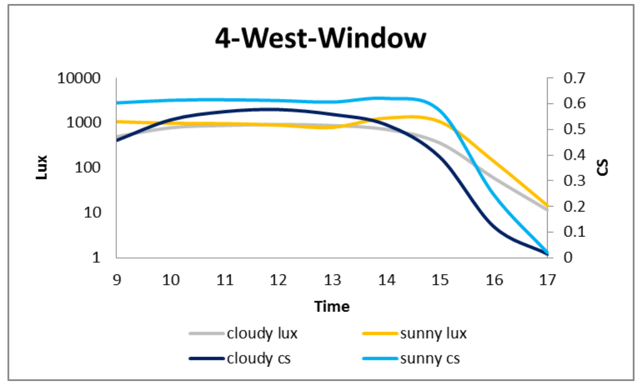


Average Lux and CS (Winter)



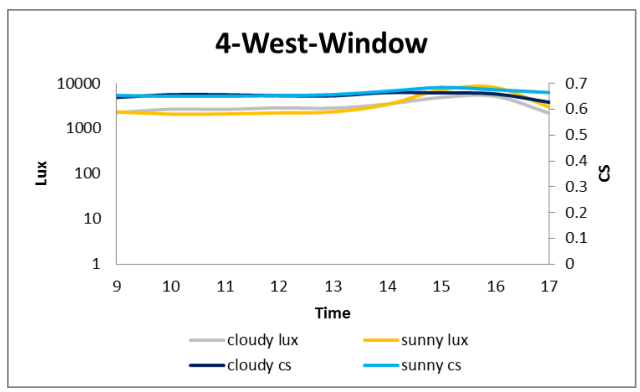
Average Lux and CS (Late Spring)

4-West-Window (No winter photo available)



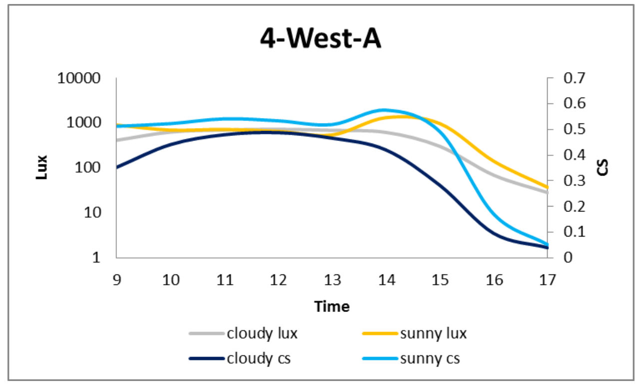
Daysimeter 97 – 4-West-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 571 ± 357 lux on cloudy days. The mean CS value was 0.42 ± 0.21 on cloudy days. On sunny days mean photopic light level during working hours was 806 ± 435 lux. The mean CS value was 0.50 ± 0.22 on sunny days.

4-West-Window (Late Spring)



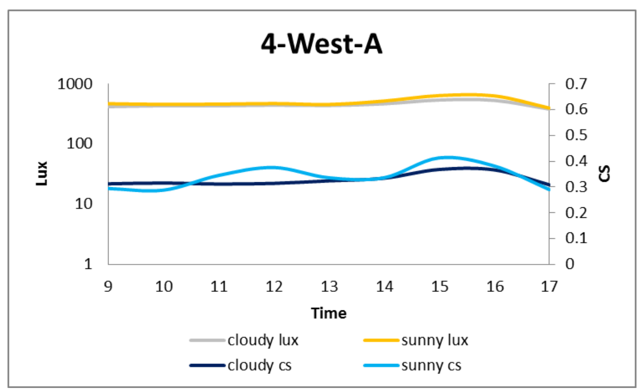
Daysimeter 133 – 4-West-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 3246 ± 1104 lux on cloudy days. The mean CS value on was 0.65 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 3663 ± 2333 lux. The mean CS value on was 0.66 ± 0.01 on sunny days.

4-West-A (Winter)



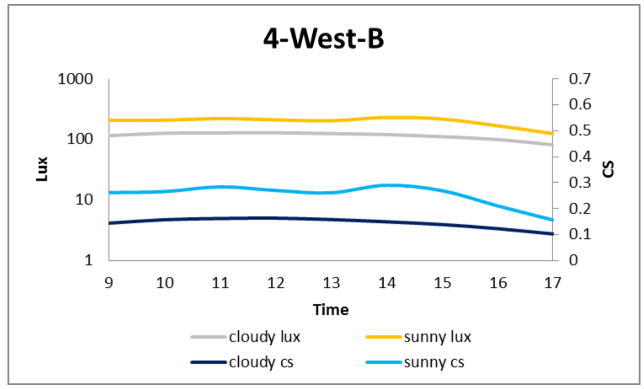
Daysimeter 214 – 4-West-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 496 ± 274 lux on cloudy days. The mean CS value was 0.34 ± 0.17 on cloudy days. On sunny days mean photopic light level during working hours was 666 ± 398 lux. The mean CS value was 0.44 ± 0.19 on sunny days.

4-West-A (Late Spring)



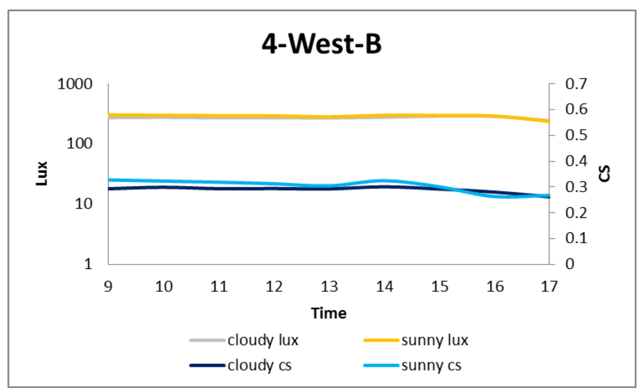
Daysimeter 163 – 4-West-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 454 ± 52 lux on cloudy days. The mean CS value on was 0.33 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 500 ± 83 lux. The mean CS value on was 0.34 ± 0.04 on sunny days.

4-West-B (Winter)



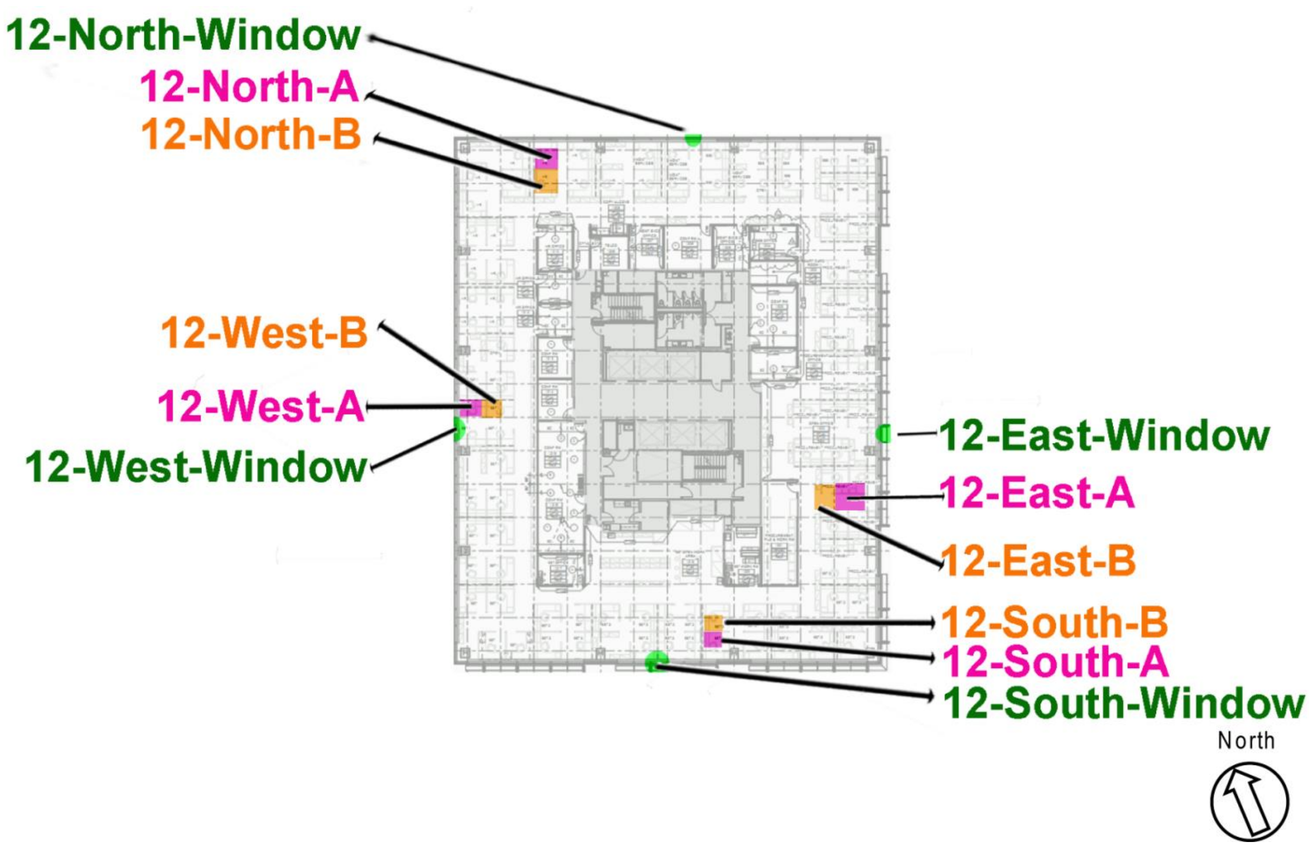
Daysimeter 159 – 4-West-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 115 ± 16 lux on cloudy days. The mean CS value was 0.14 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 199 ± 33 lux. The mean CS value was 0.25 ± 0.04 on sunny days.

4-West-B (Late Spring)



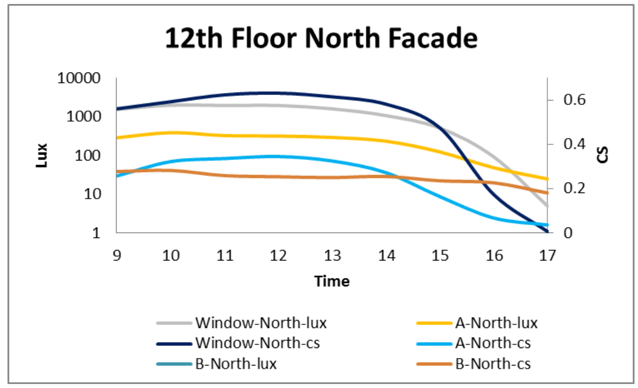
Daysimeter 155 – 4-West-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 275 ± 13 lux on cloudy days. The mean CS value on was 0.29 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 290 ± 21 lux. The mean CS value on was 0.31 ± 0.02 on sunny days.

APPENDIX I: PHOTOMETRIC DATA FOR 12TH FLOOR STATIONARY DEVICES (MOUNTED ON STICKS AND IN WINDOWS)

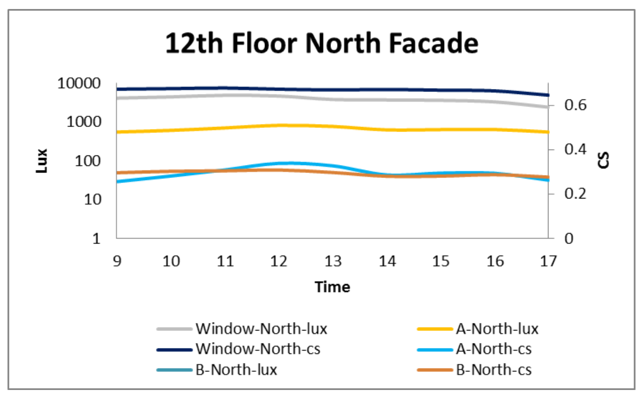


Location where measurements were collected.

12TH FLOOR NORTH FACADE

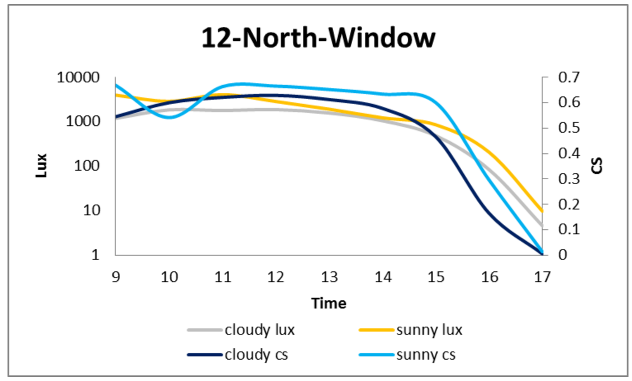


Average Lux and CS (Winter)

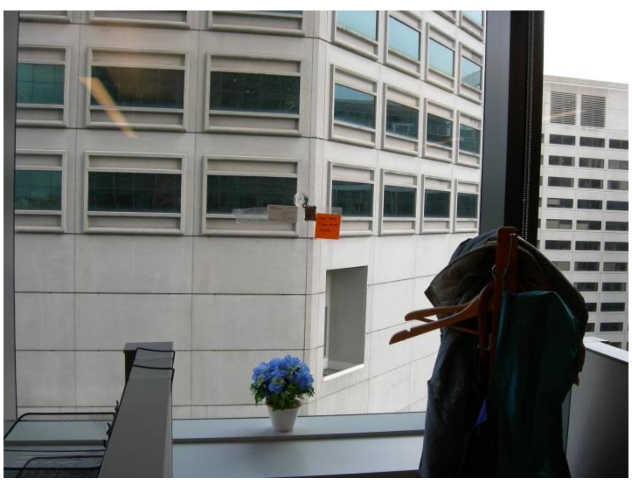


Average Lux and CS (Late Spring)

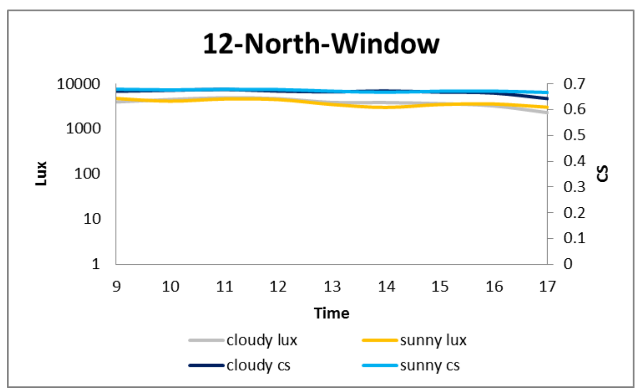
12-North-Window (Winter)



Daysimeter 20 – 12-North-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1104 ± 750 lux on cloudy days. The mean CS value was 0.47 ± 0.23 on cloudy days. On sunny days mean photopic light level during working hours was 2003 ± 1533 lux. The mean CS value was 0.53 ± 0.23 on sunny days.

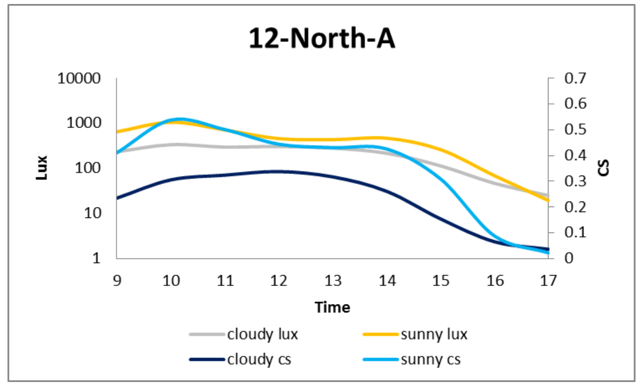


12-North-Window (Late Spring)



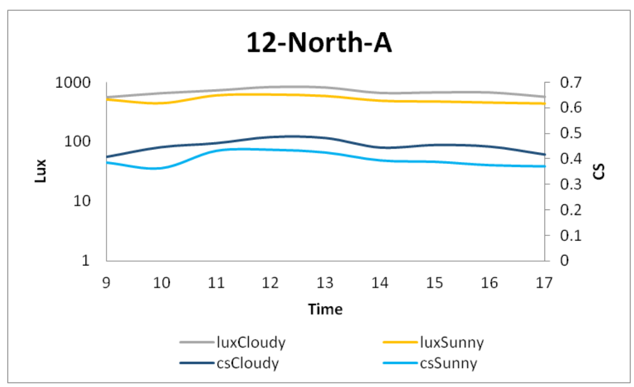
Daysimeter 141 - 12-North-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 3900 ± 800 lux on cloudy days. The mean CS value on was 0.67 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 3848 ± 670 lux. The mean CS value on was 0.67 ± 0.005 on sunny days.

12-North-A (Winter)

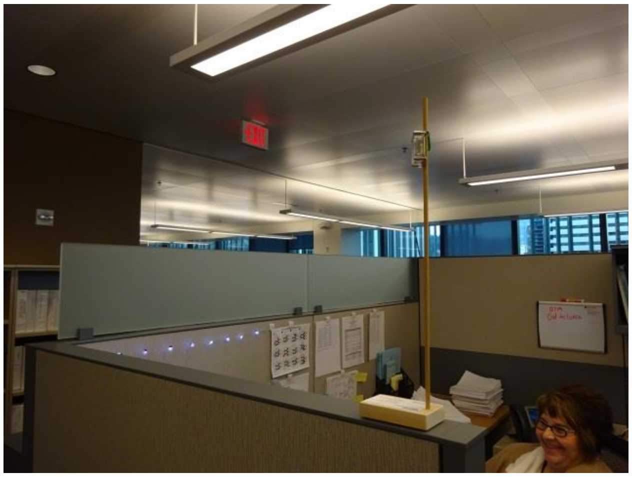


Daysimeter 213 – 12-North-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 207 ± 117 lux on cloudy days. The mean CS value was 0.23 ± 0.11 on cloudy days. On sunny days mean photopic light level during working hours was 460 ± 325 lux. The mean CS value was 0.35 ± 0.18 on sunny days.

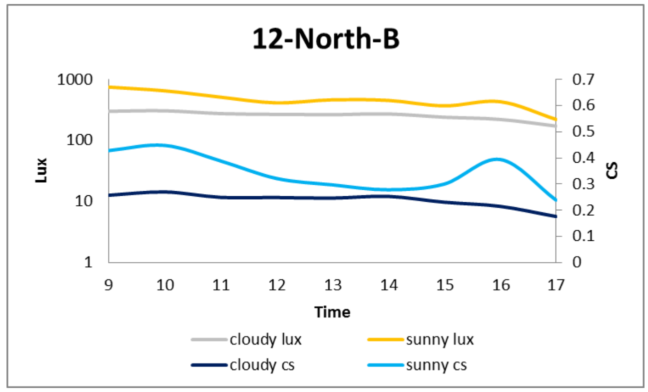
12-North-A (Late Spring)



Daysimeter 156 – 12-North-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 690 ± 95 lux on cloudy days. The mean CS value was 0.45 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 514 ± 73 lux. The mean CS value was 0.40 ± 0.03 on sunny days.

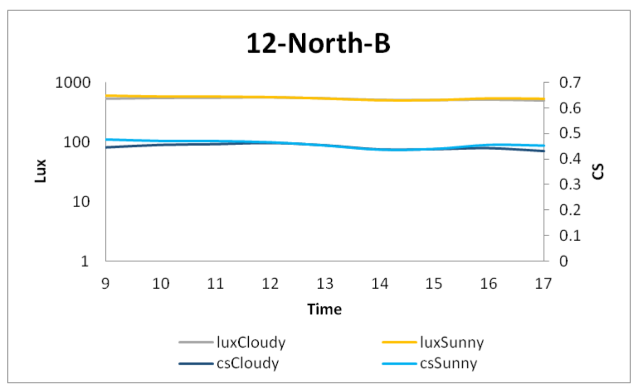


12-North-B (Winter)



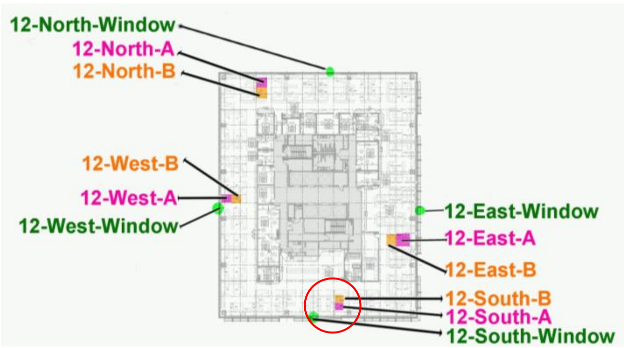
Daysimeter 194 – 12-North-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 258 ± 42 lux on cloudy days. The mean CS value was 0.24 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 475 ± 154 lux. The mean CS value was 0.34 ± 0.07 on sunny days.

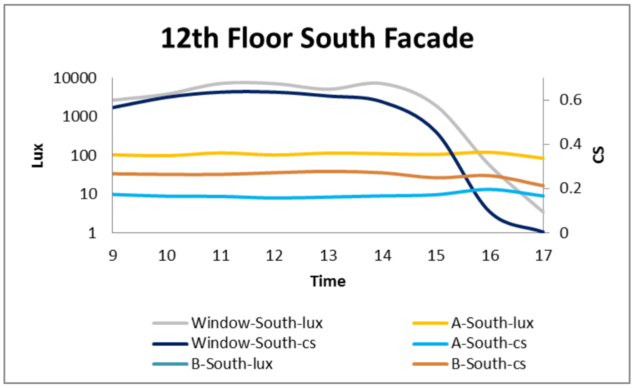
12-North-B (Late Spring)



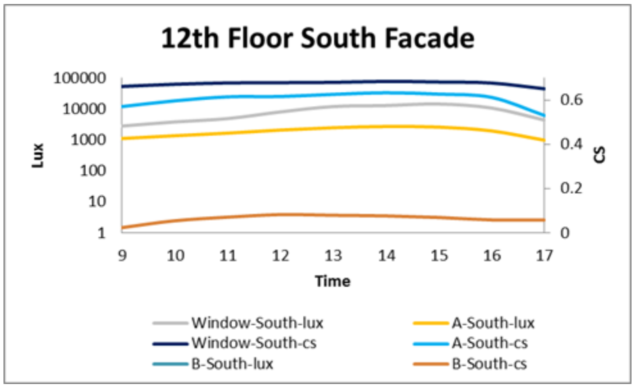
Daysimeter 160 – 12-North-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 533 ± 26 lux on cloudy days. The mean CS value was 0.45 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 554 ± 35 lux. The mean CS value was 0.46 ± 0.01 on sunny days.

12TH FLOOR SOUTH FACADE

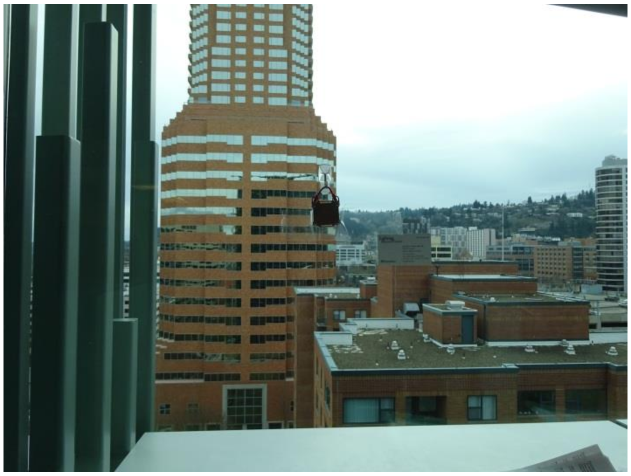




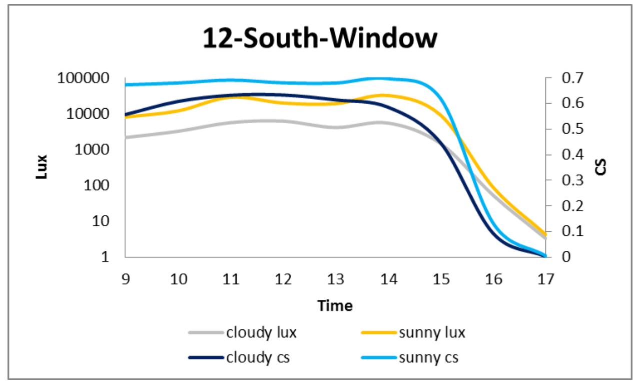
Average Lux and CS (Winter)



Average Lux and CS (Late Spring)

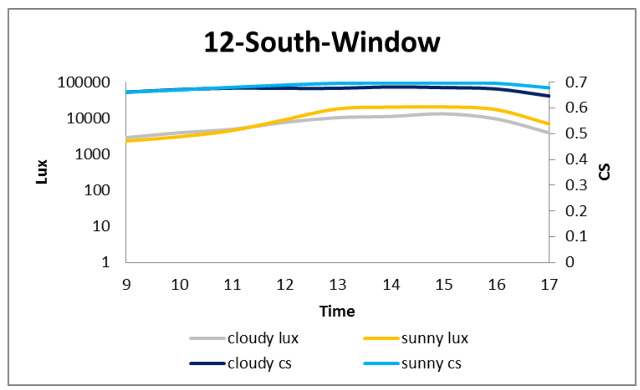


12-South-Window (Winter)

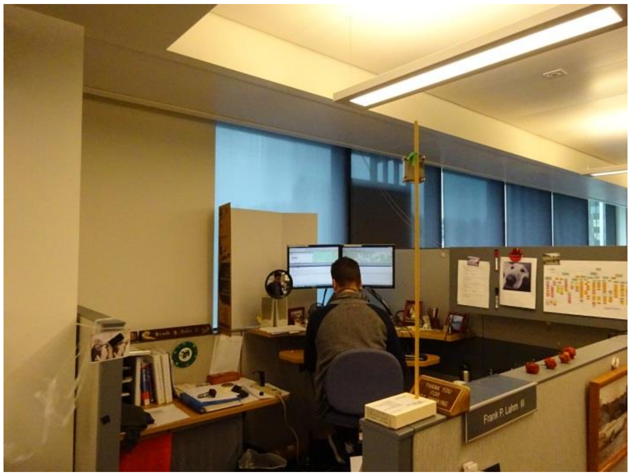


Daysimeter 134 – 12-South-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 3166 ± 2387 lux on cloudy days. The mean CS value was 0.46 ± 0.24 on cloudy days. On sunny days mean photopic light level during working hours was 14411 ± 11576 lux. The mean CS value was 0.54 ± 0.27 on sunny days.

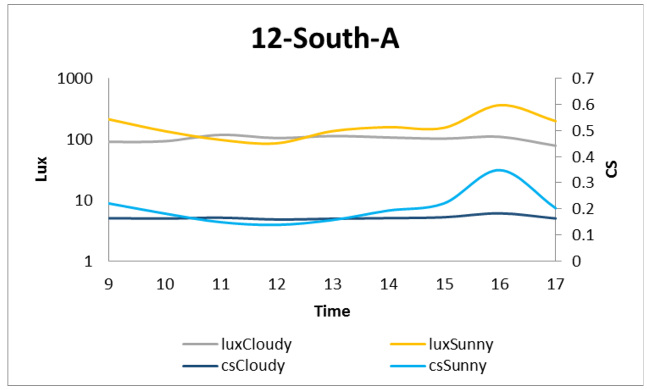
12-South-Window (Late Spring)



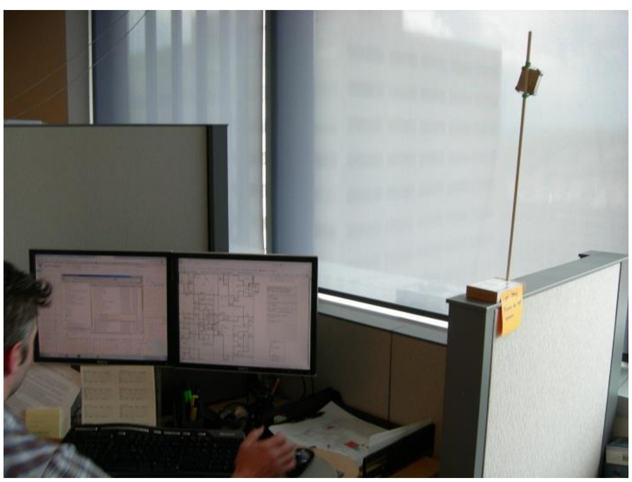
Daysimeter 137 - 12-South-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 7596 ± 3781 lux on cloudy days. The mean CS value on was 0.67 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 11471 ± 7724 lux. The mean CS value on was 0.68 ± 0.01 on sunny days.



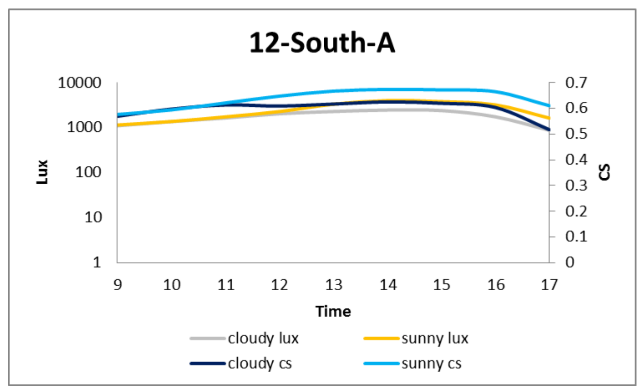
12-South-A (Winter)



Daysimeter 227 – 12-South-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 102 ± 12 lux on cloudy days. The mean CS value was 0.17 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 172 ± 83 lux. The mean CS value was 0.20 ± 0.06 on sunny days.

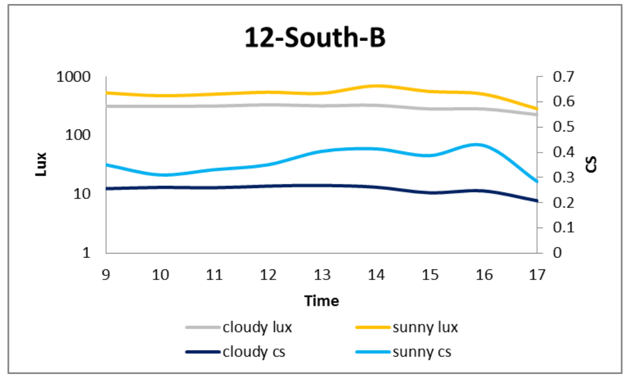


12-South-A (Late Spring)

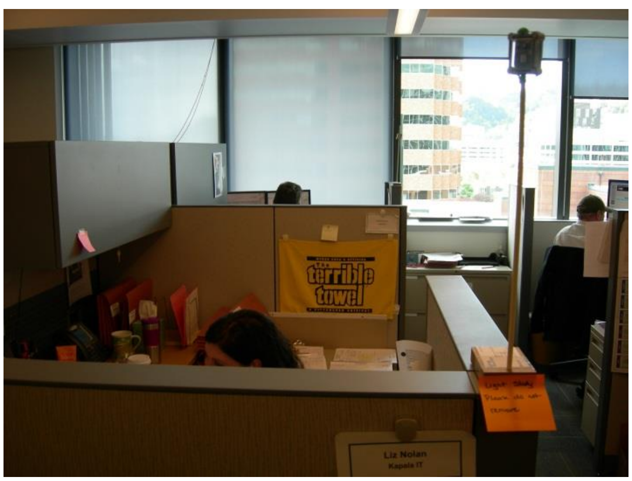


Daysimeter 142 – 12-South-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1771 ± 575 lux on cloudy days. The mean CS value on was 0.60 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 2502 ± 1094 lux. The mean CS value on was 0.64 ± 0.04 on sunny days.

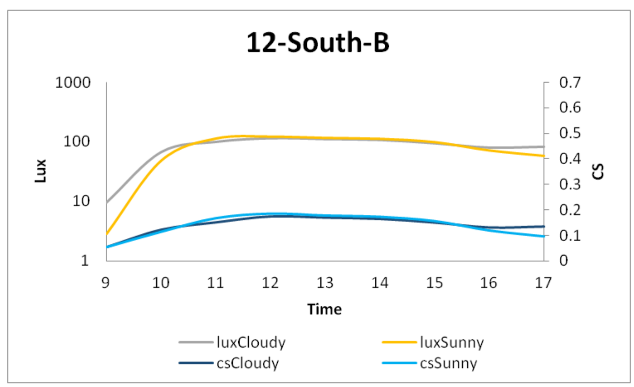
12-South-B (Winter)



Daysimeter 231 – 12-South-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 302 ± 33 lux on cloudy days. The mean CS value was 0.25 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 514 ± 107 lux. The mean CS value was 0.36 ± 0.05 on sunny days.

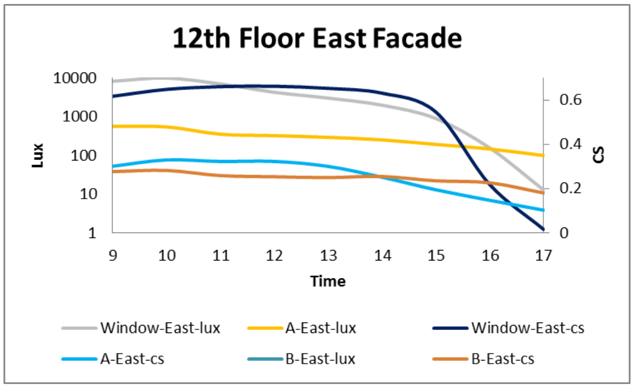


12-South-B (Late Spring)

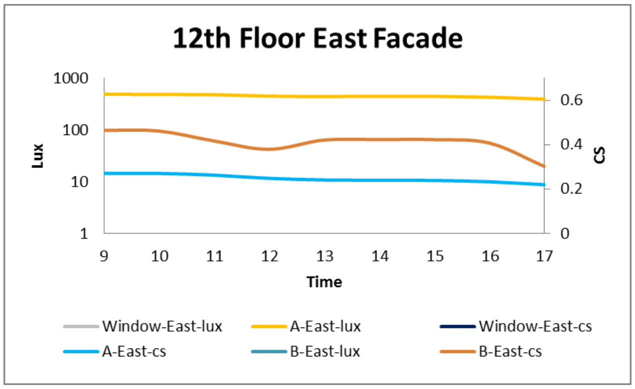


Daysimeter 143 – 12-South-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 86 ± 33 lux on cloudy days. The mean CS value was 0.14 ± 0.04 on cloudy days. On sunny days mean photopic light level during working hours was 84 ± 41 lux. The mean CS value was 0.14 ± 0.04 on sunny days.

12TH FLOOR EAST FACADE

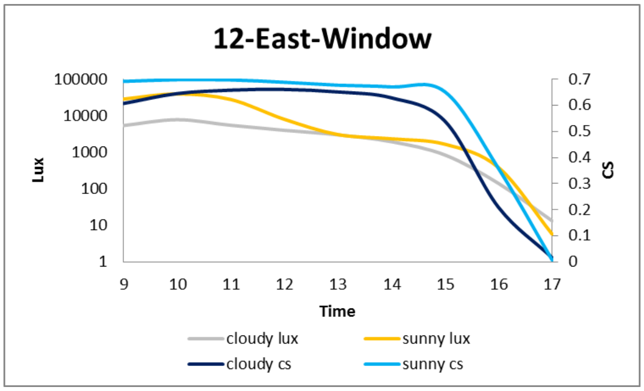


Average Lux and CS (Winter)



Average Lux and CS (Late Spring)

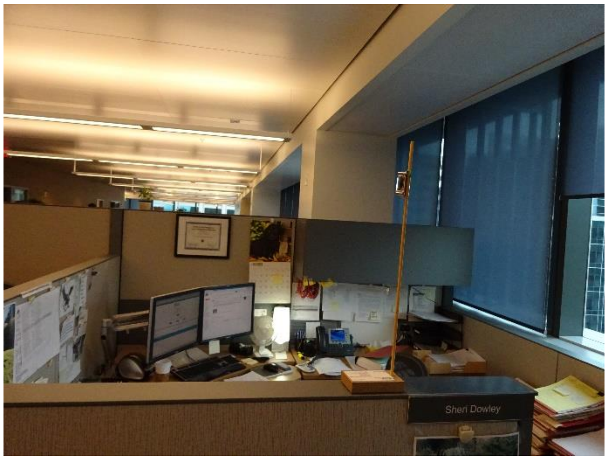
No photo available from December installation; this photo from Late Spring installation



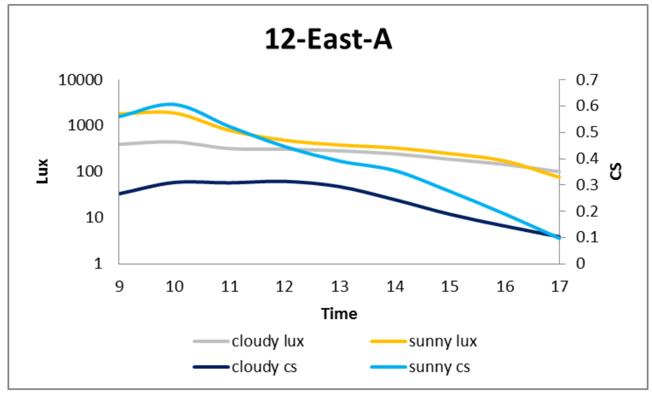
Daysimeter 15 – 12-East-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 3195 ± 2712 lux on cloudy days. The mean CS value was 0.51 ± 0.23 on cloudy days. On sunny days mean photopic light level during working hours was 12449 ± 15309 lux. The mean CS value was 0.57 ± 0.24 on sunny days.

12-East-Window (Late Spring)

Daysimeter 139 – 12-East-Window. Equipment Error. No Data Available.

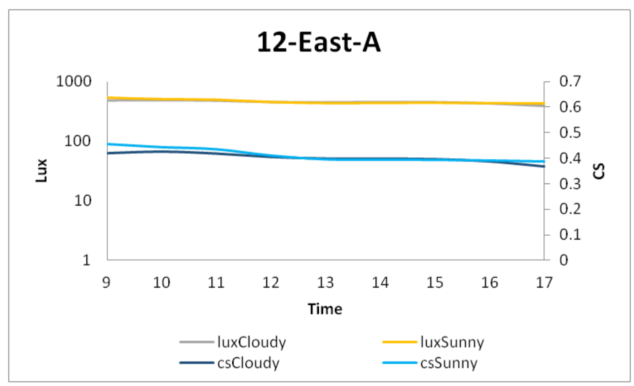


12-East-A (Winter)



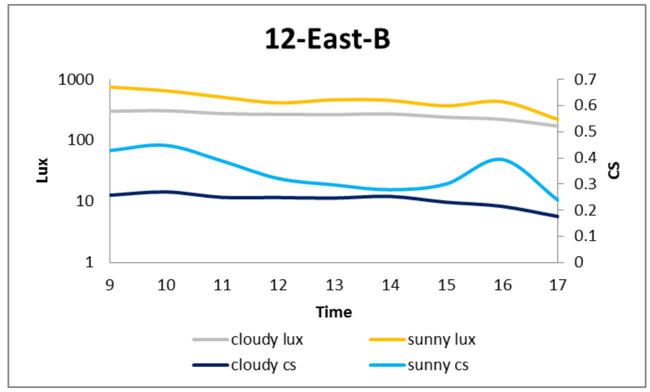
Daysimeter 232 – 12-East-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 273 ± 114 lux on cloudy days. The mean CS value was 0.24 ± 0.08 on cloudy days. On sunny days mean photopic light level during working hours was 692 ± 694 lux. The mean CS value was 0.38 ± 0.17 on sunny days.

12-East-A (Late Spring)



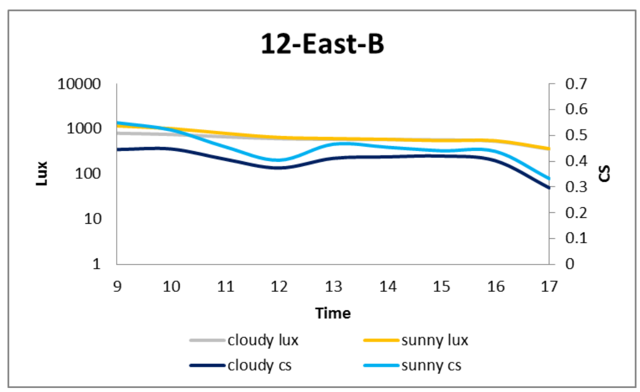
Daysimeter 147 – 12-East-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 449 ± 29 lux on cloudy days. The mean CS value was 0.40 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 467 ± 37 lux. The mean CS value was 0.41 ± 0.03 on sunny days.

12-East-B (Winter)



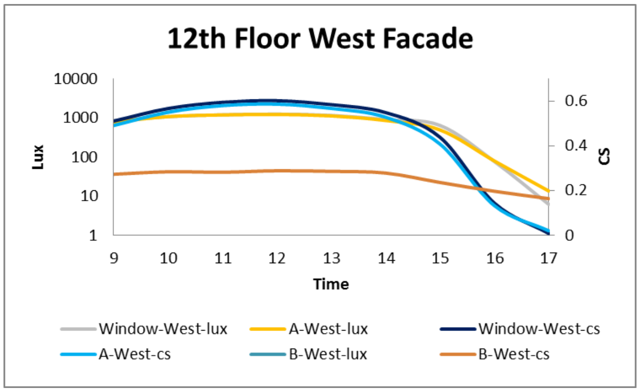
Daysimeter 194 – 12-East-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 258 ± 42 lux on cloudy days. The mean CS value was 0.24 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 475 ± 154 lux. The mean CS value was 0.34 ± 0.07 on sunny days.

12-East-B (Late Spring)

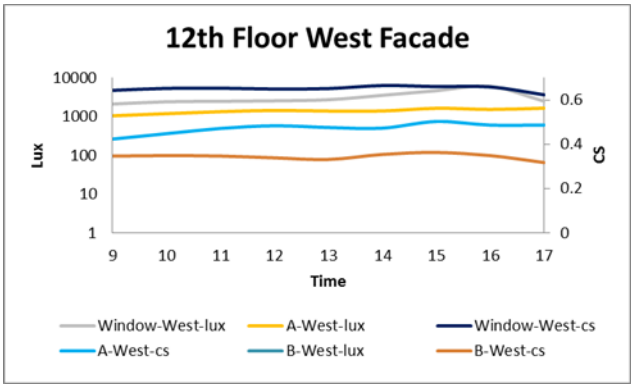


Daysimeter 148 – 12-East-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 611 ± 130 lux on cloudy days. The mean CS value on was 0.40 ± 0.05 on cloudy days. On sunny days mean photopic light level during working hours was 704 ± 254 lux. The mean CS value on was 0.45 ± 0.06 on sunny days.

12TH FLOOR WEST FACADE

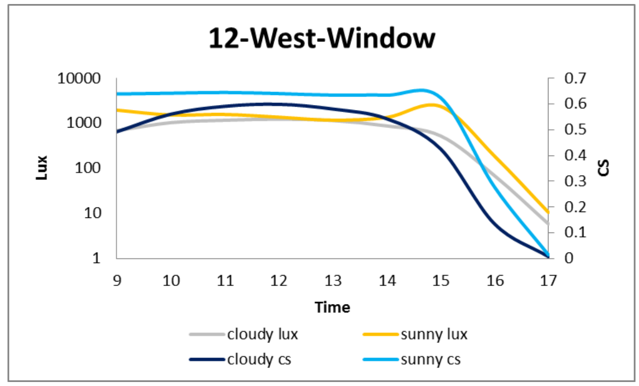


Average Lux and CS (Winter)

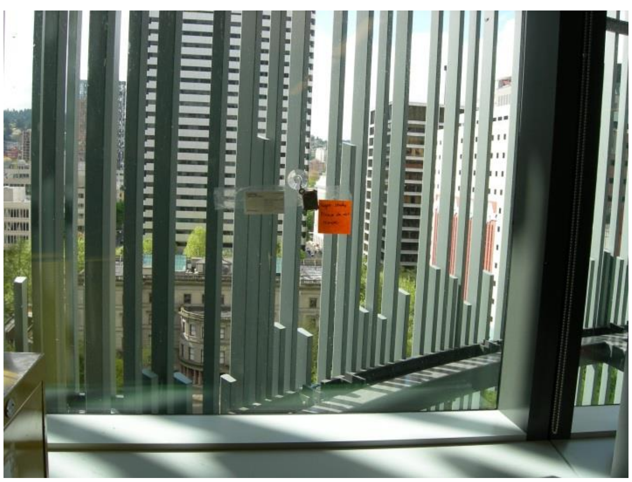


Average Lux and CS (Late Spring)

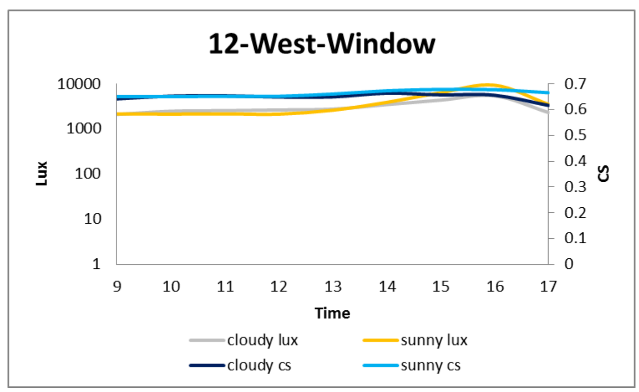
12-West-Window (Winter)



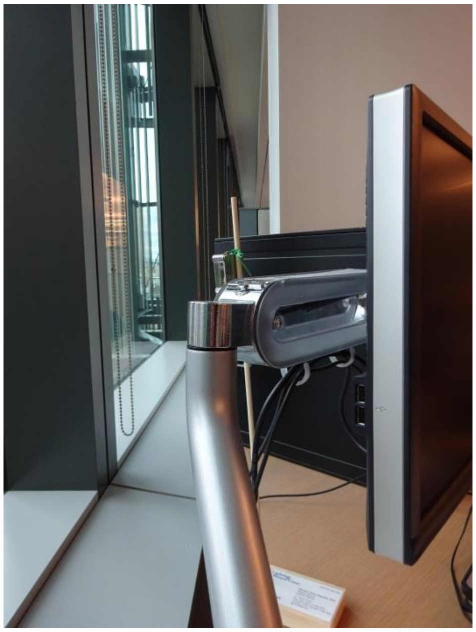
Daysimeter 122 – 12-West-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 754 ± 468 lux on cloudy days. The mean CS value was 0.44 ± 0.22 on cloudy days. On sunny days mean photopic light level during working hours was 1283 ± 762 lux. The mean CS value was 0.53 ± 0.23 on sunny days.



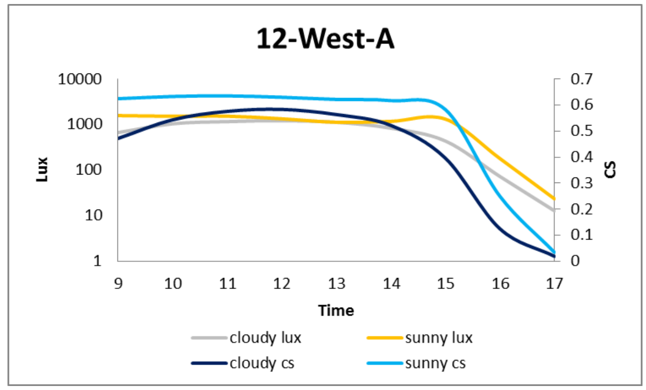
12-West-Window (Late Spring)



Daysimeter 140 - 12-West-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 3130 ± 1112 lux on cloudy days. The mean CS value on was 0.65 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 3818 ± 2496 lux. The mean CS value on was 0.66 ± 0.01 on sunny days.

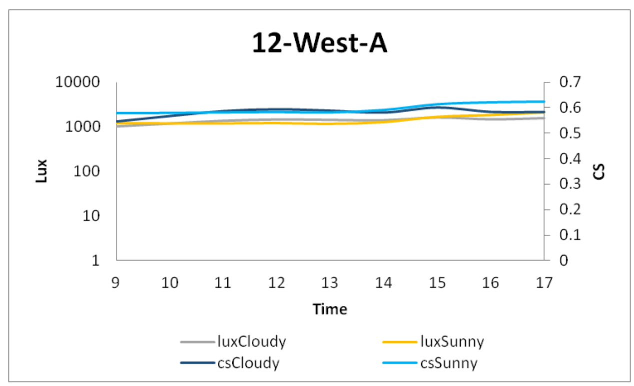


12-West-A (Winter)

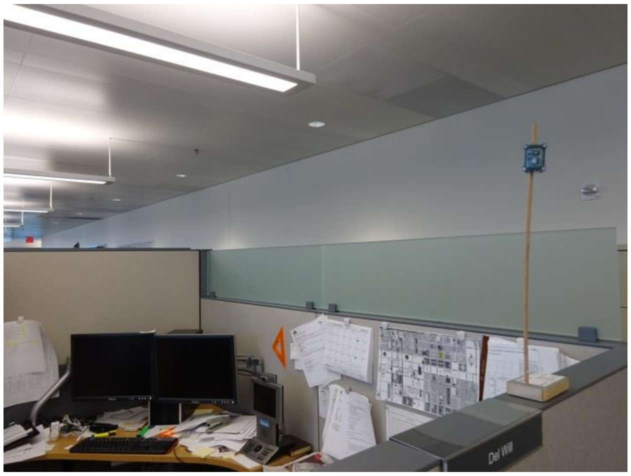


Daysimeter 230 – 12-West-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 732 ± 465 lux on cloudy days. The mean CS value was 0.42 ± 0.21 on cloudy days. On sunny days mean photopic light level during working hours was 1091 ± 583 lux. The mean CS value was 0.51 ± 0.22 on sunny days.

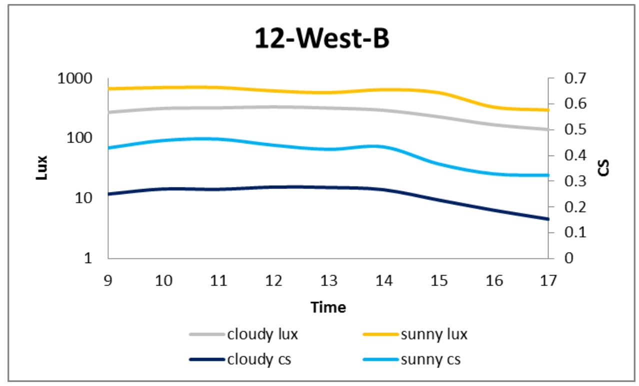
12-West-A (Late Spring)



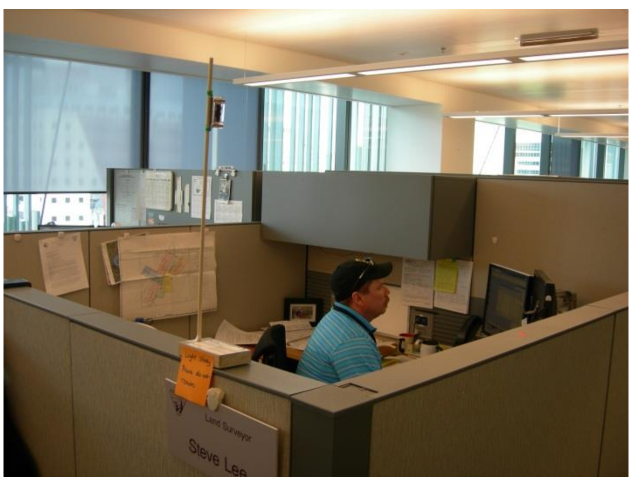
Daysimeter 150 – 12-West-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1406 ± 197 lux on cloudy days. The mean CS value was 0.58 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 1436 ± 344 lux. The mean CS value was 0.59 ± 0.02 on sunny days.



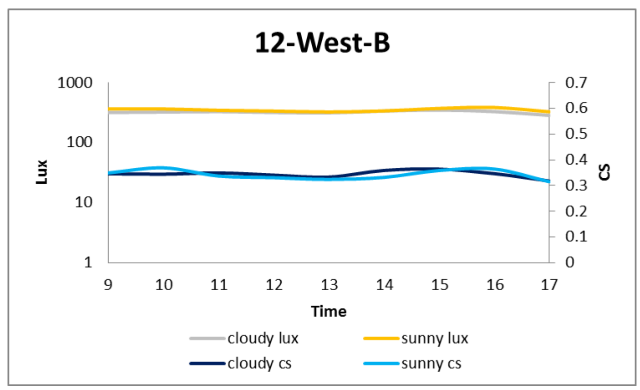
12-West-B (Winter)



Daysimeter 219 – 12-West-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 266 ± 71 lux on cloudy days. The mean CS value was 0.24 ± 0.04 on cloudy days. On sunny days mean photopic light level during working hours was 569 ± 152 lux. The mean CS value was 0.41 ± 0.05 on sunny days.

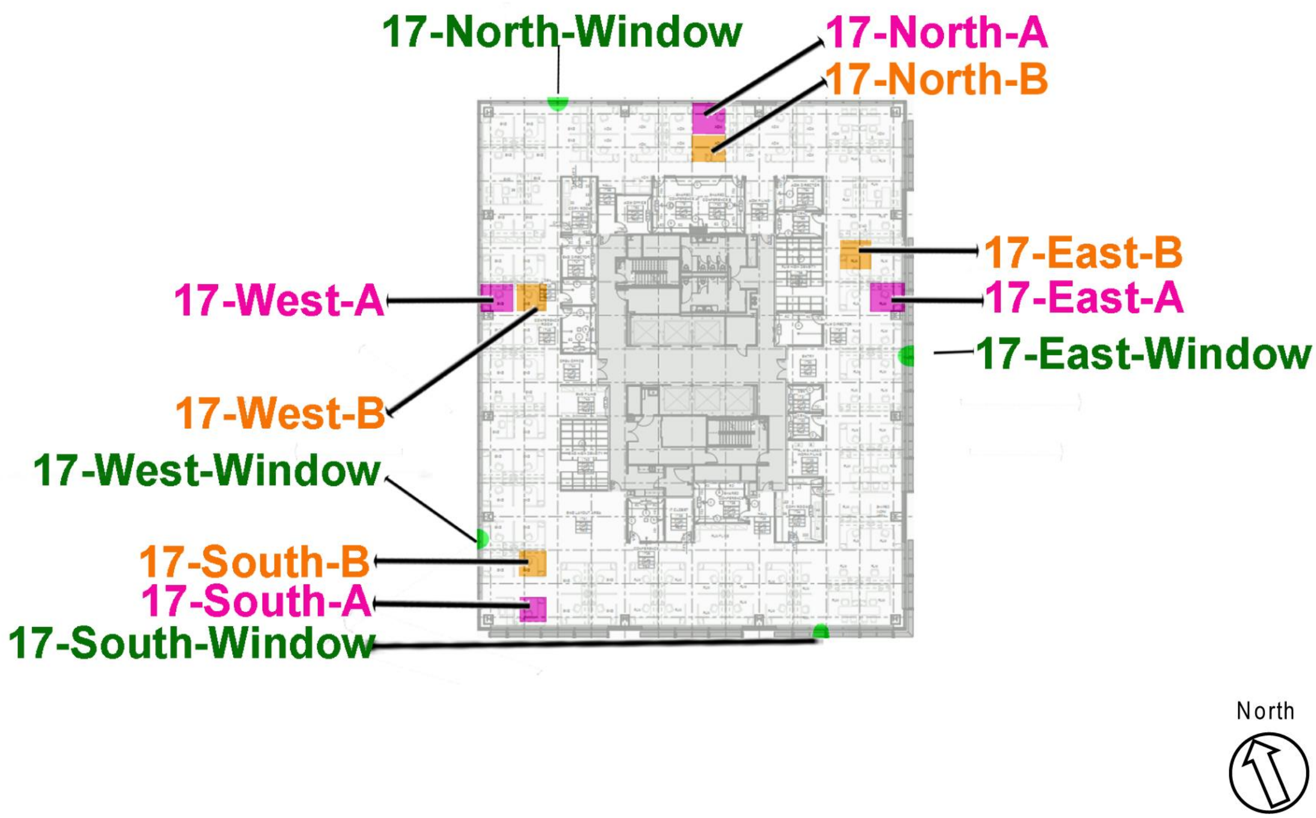


12-West-B (Late Spring)



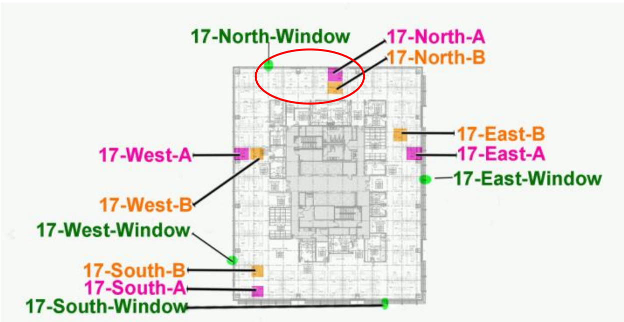
Daysimeter 153 – 12-West-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 323 ± 18 lux on cloudy days. The mean CS value on was 0.34 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 351 ± 22 lux. The mean CS value on was 0.34 ± 0.02 on sunny days.

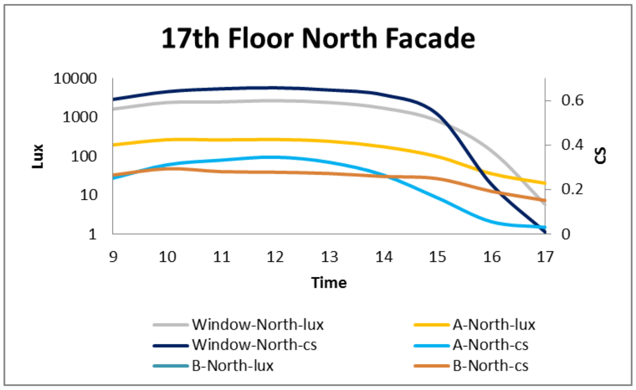
APPENDIX J: PHOTOMETRIC DATA FOR 17TH FLOOR STATIONARY DEVICES (MOUNTED ON STICKS AND IN WINDOWS)



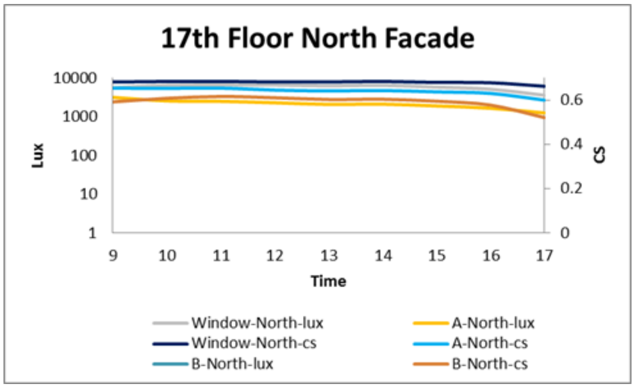
Locations where measurements were collected.

17TH FLOOR NORTH FACADE



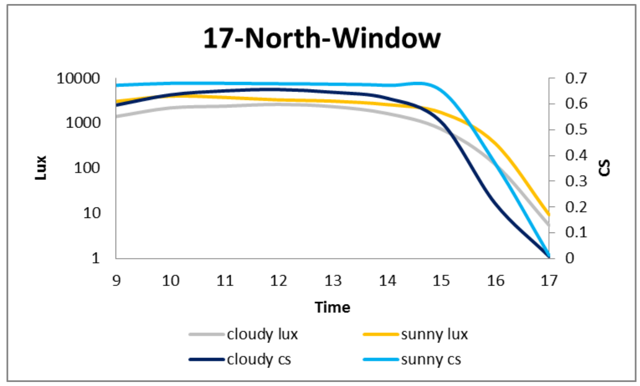


Average Lux and CS (Winter)



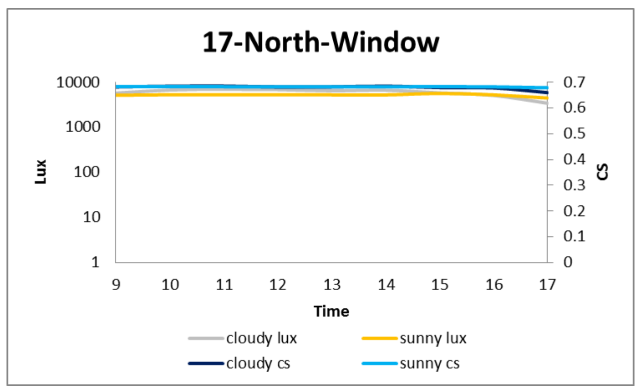
Average Lux and CS (Late Spring)

17-North-Window (Winter)



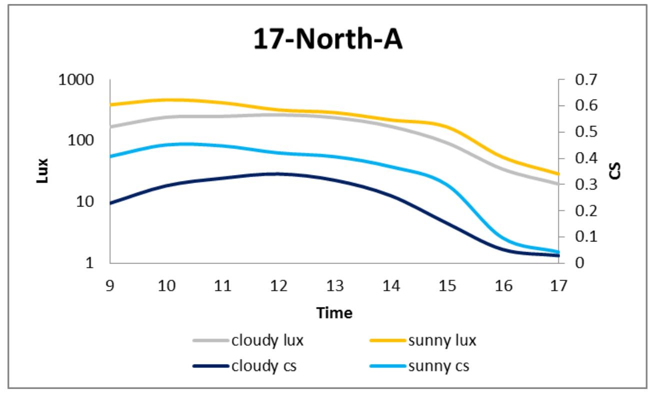
Daysimeter 31 – 17-North-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1507 ± 1002 lux on cloudy days. The mean CS value was 0.51 ± 0.23 on cloudy days. On sunny days mean photopic light level during working hours was 2446 ± 1440 lux. The mean CS value was 0.57 ± 0.23 on sunny days.

17-North-Window (Late Spring)



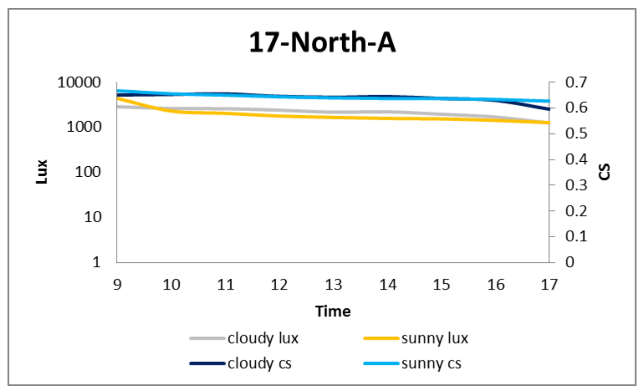
Daysimeter 136 - 17-North-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 5981 ± 1139 lux on cloudy days. The mean CS value on was 0.68 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 5211 ± 305 lux. The mean CS value on was 0.68 ± 0.001 on sunny days.

17-North-A (Winter)

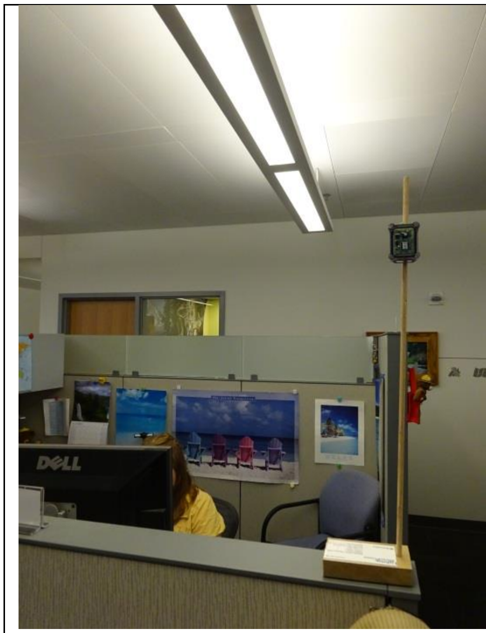


Daysimeter 222 – 17-North-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 166 ± 95 lux on cloudy days. The mean CS value was 0.22 ± 0.12 on cloudy days. On sunny days mean photopic light level during working hours was 262 ± 156 lux. The mean CS value was 0.33 ± 0.15 on sunny days.

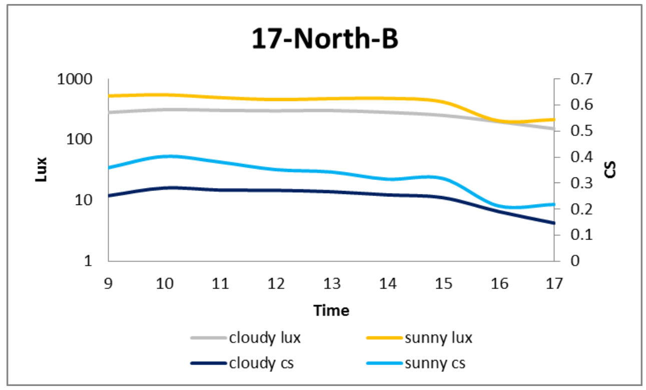
17-North-A (Late Spring)



Daysimeter 149 – 17-North-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 2197 ± 505 lux on cloudy days. The mean CS value on was 0.64 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 2004 ± 956 lux. The mean CS value on was 0.64 ± 0.01 on sunny days.

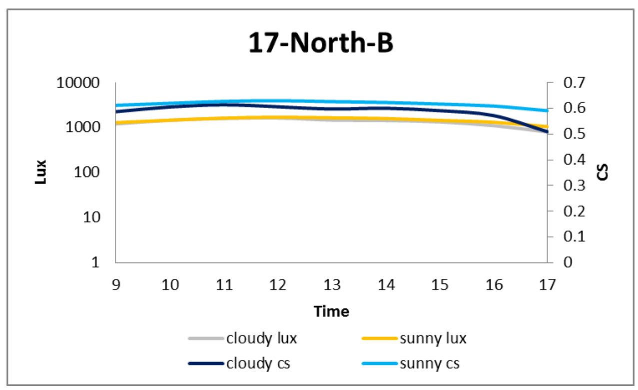


17-North-B (Winter)



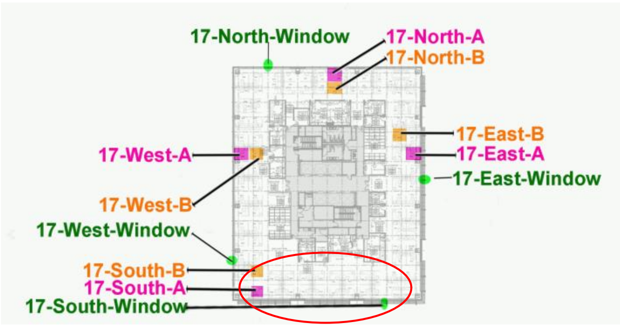
Daysimeter 233 – 17-North-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 266 ± 55 lux on cloudy days. The mean CS value was 0.24 ± 0.04 on cloudy days. On sunny days mean photopic light level during working hours was 426 ± 128 lux. The mean CS value was 0.32 ± 0.07 on sunny days.

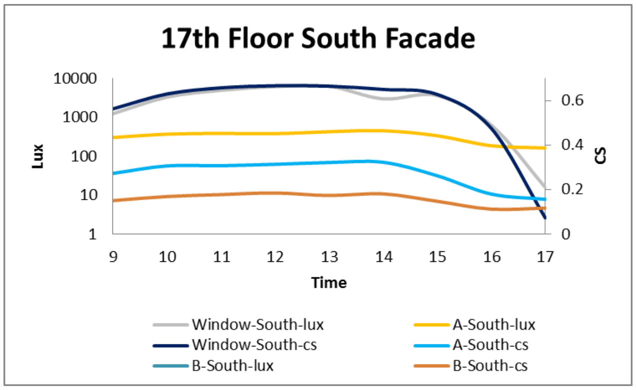
17-North-B (Late Spring)



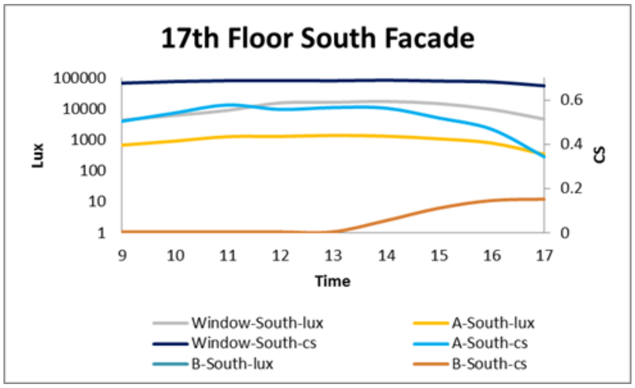
Daysimeter 157 – 17-North-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1346 ± 264 lux on cloudy days. The mean CS value on was 0.59 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 1468 ± 211 lux. The mean CS value on was 0.62 ± 0.01 on sunny days.

17TH FLOOR SOUTH FACADE



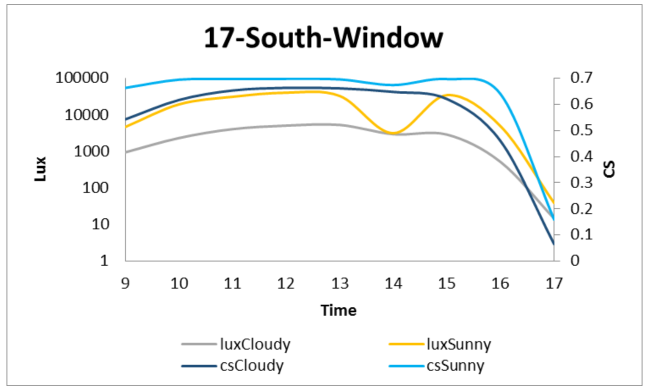


Average Lux and CS (Winter)



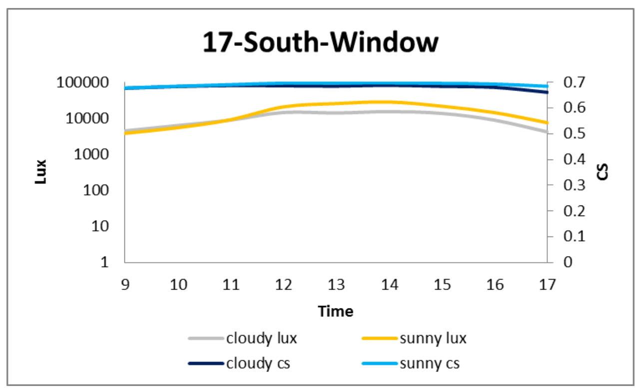
Average Lux and CS (Late Spring)

17-South-Window (Winter)



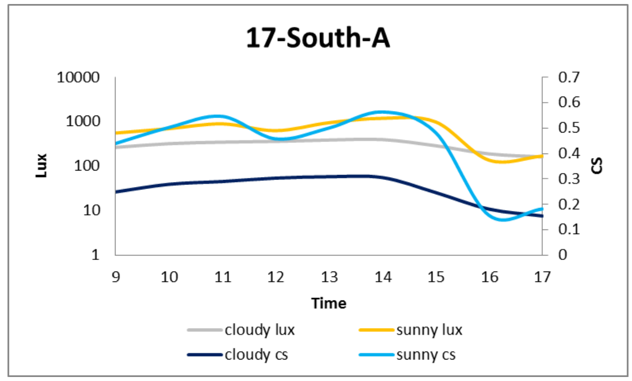
Daysimeter 75 – 17-South-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 2686 ± 1928 lux on cloudy days. The mean CS value was 0.55 ± 0.19 on cloudy days. On sunny days mean photopic light level during working hours was 19101 ± 16095 lux. The mean CS value was 0.62 ± 0.18 on sunny days.

17-South-Window (Late Spring)

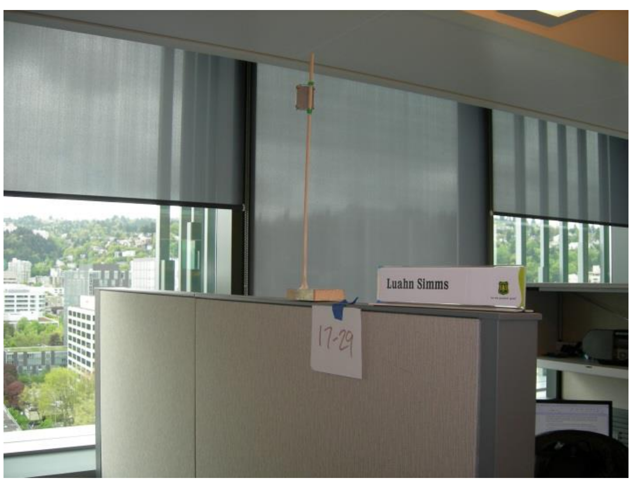


Daysimeter 131 - 17-South-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 10071 ± 4463 lux on cloudy days. The mean CS value on was 0.68 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 15229 ± 9194 lux. The mean CS value on was 0.69 ± 0.01 on sunny days.

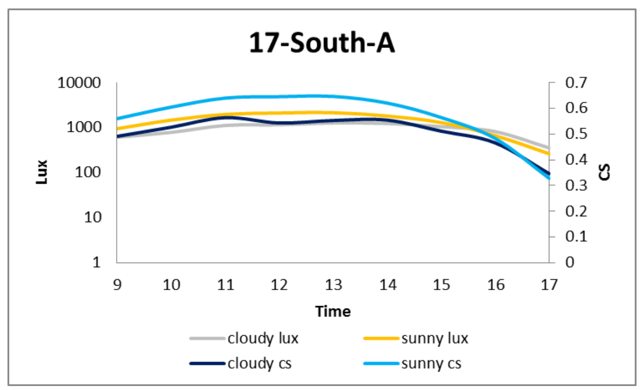
17-South-A (Winter)



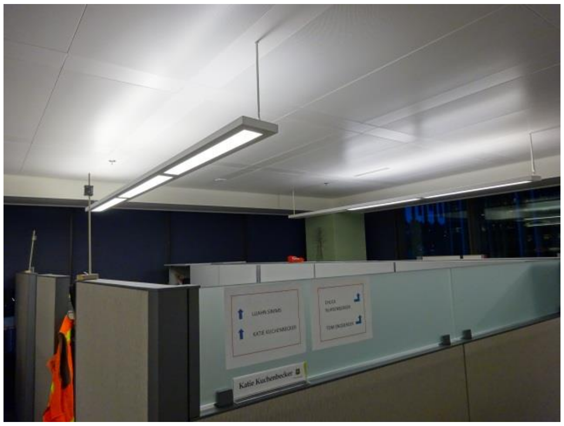
Daysimeter 234 – 17-South-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 304 ± 84 lux on cloudy days. The mean CS value was 0.26 ± 0.06 on cloudy days. On sunny days mean photopic light level during working hours was 694 ± 364 lux. The mean CS value was 0.43 ± 0.15 on sunny days.



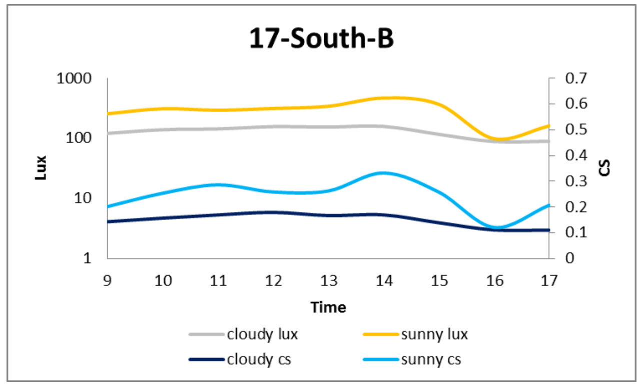
17-South-A (Late Spring)



Daysimeter 146 – 17-South-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 936 ± 312 lux on cloudy days. The mean CS value on was 0.51 ± 0.07 on cloudy days. On sunny days mean photopic light level during working hours was 1413 ± 674 lux. The mean CS value on was 0.57 ± 0.10 on sunny days.

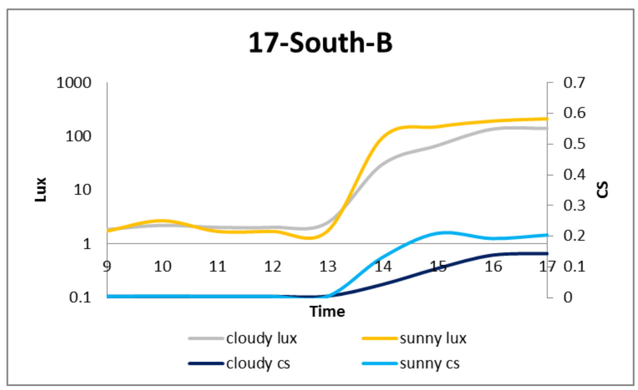


17-South-B (Winter)



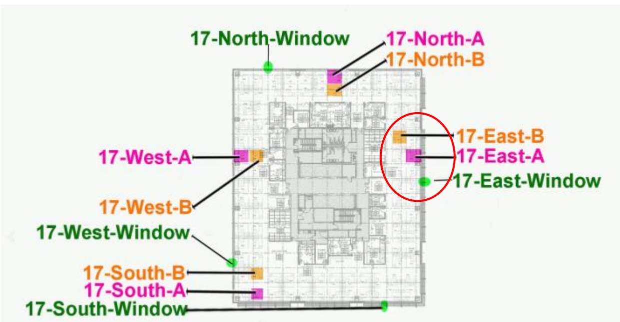
Daysimeter 226 – 17-South-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 130 ± 27 lux on cloudy days. The mean CS value was 0.15 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 291 ± 110 lux. The mean CS value was 0.24 ± 0.06 on sunny days.

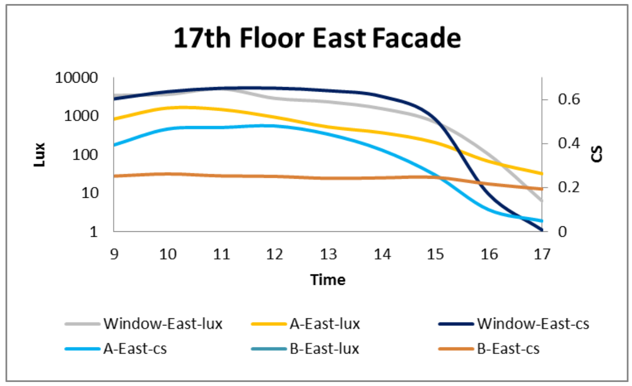
17-South-B (Late Spring)



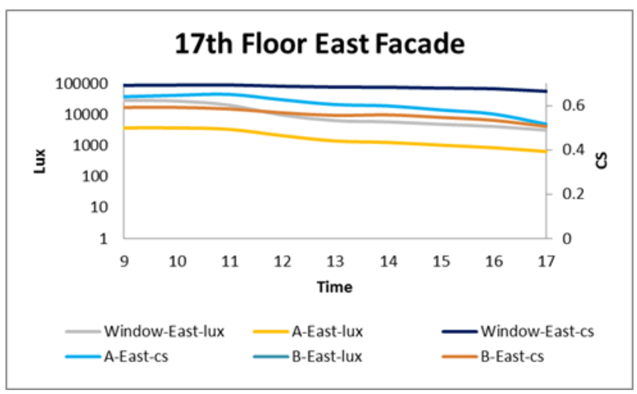
Daysimeter 151 – 17-South-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 43 ± 59 lux on cloudy days. The mean CS value on was 0.05 ± 0.06 on cloudy days. On sunny days mean photopic light level during working hours was 73 ± 91 lux. The mean CS value on was 0.08 ± 0.10 on sunny days.

17TH FLOOR EAST FACADE



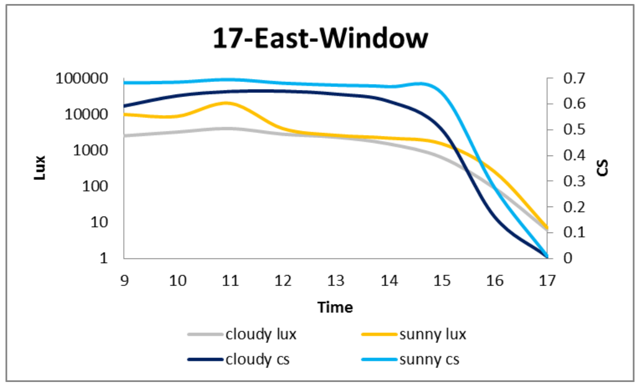


Average Lux and CS (Winter)



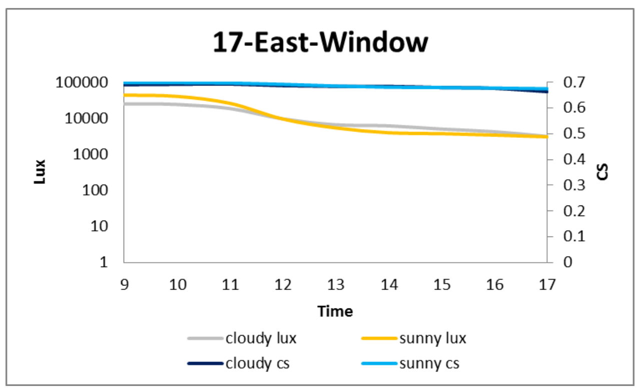
Average Lux and CS (Late Spring)

17-East-Window (Winter)



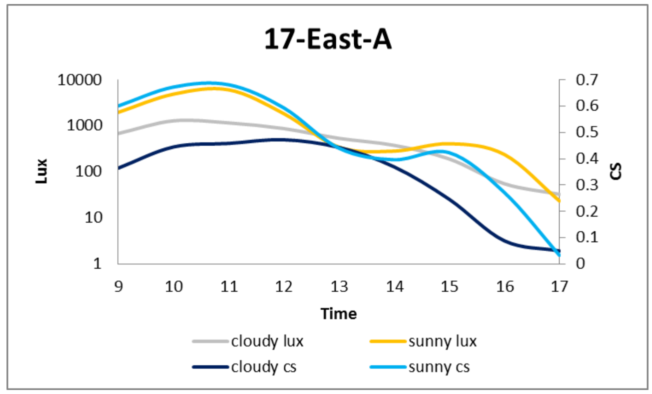
Daysimeter 121 – 17-East-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1915 ± 1431 lux on cloudy days. The mean CS value was 0.49 ± 0.24 on cloudy days. On sunny days mean photopic light level during working hours was 5518 ± 6548 lux. The mean CS value was 0.56 ± 0.24 on sunny days.

17-East-Window (Late Spring)



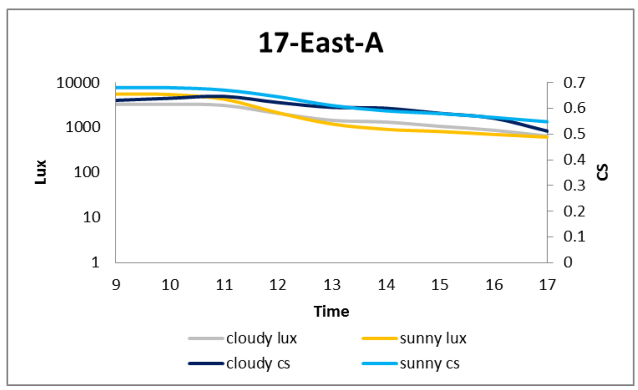
Daysimeter 132 – 17-East-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 11471 ± 8816 lux on cloudy days. The mean CS value on was 0.68 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 15596 ± 16861 lux. The mean CS value on was 0.69 ± 0.01 on sunny days.

17-East-A (Winter)

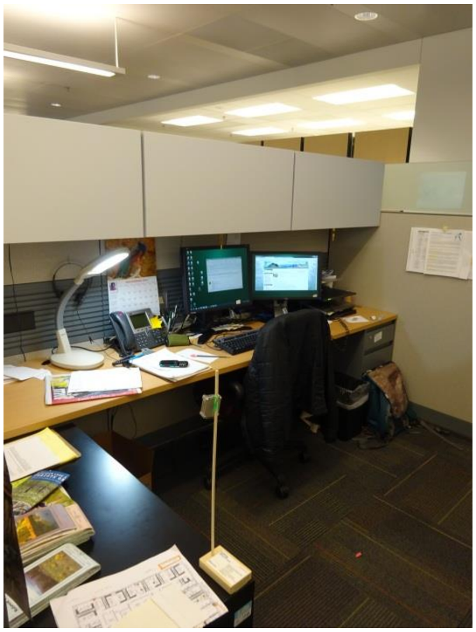


Daysimeter 212 – 17-East-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 579 ± 468 lux on cloudy days. The mean CS value was 0.33 ± 0.16 on cloudy days. On sunny days mean photopic light level during working hours was 1789 ± 2231 lux. The mean CS value was 0.46 ± 0.21 on sunny days.

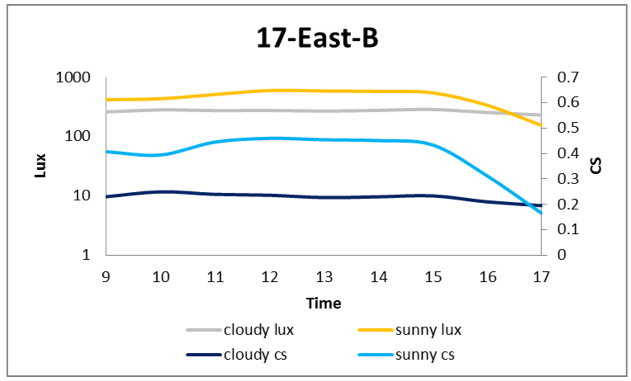
17-East-A (Late Spring)



Daysimeter 154 – 17-East-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1916 ± 1079 lux on cloudy days. The mean CS value on was 0.60 ± 0.04 on cloudy days. On sunny days mean photopic light level during working hours was 2419 ± 2097 lux. The mean CS value on was 0.62 ± 0.05 on sunny days.

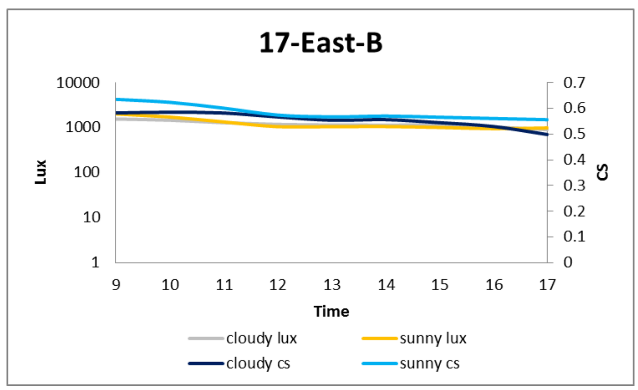


17-East-B (Winter)



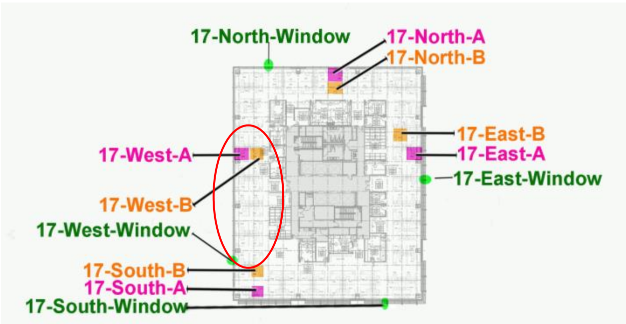
Daysimeter 216 – 17-East-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 268 ± 17 lux on cloudy days. The mean CS value was 0.23 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 464 ± 146 lux. The mean CS value was 0.39 ± 0.10 on sunny days.

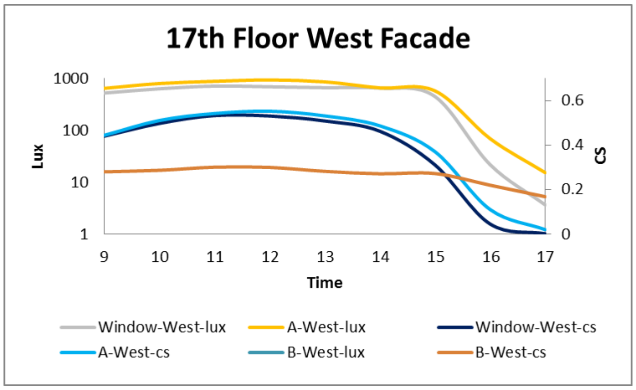
17-East-B (Late Spring)



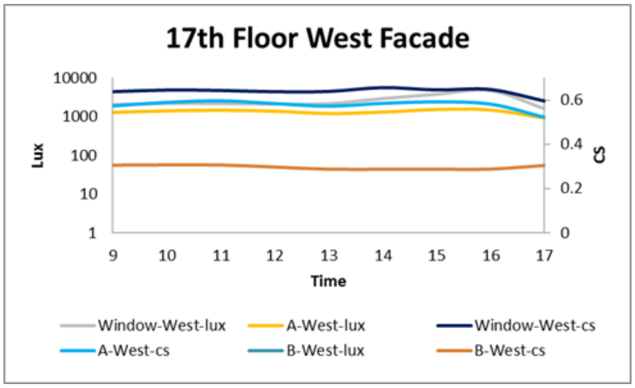
Daysimeter 159 – 17-East-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1208 ± 203 lux on cloudy days. The mean CS value on was 0.56 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 1245 ± 379 lux. The mean CS value on was 0.58 ± 0.03 on sunny days.

17TH FLOOR WEST FACADE



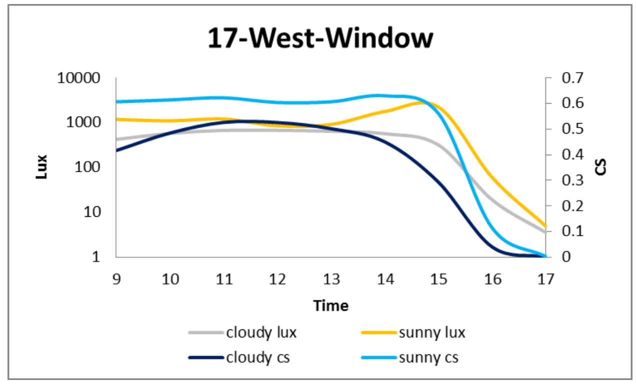


Average Lux and CS (Winter)



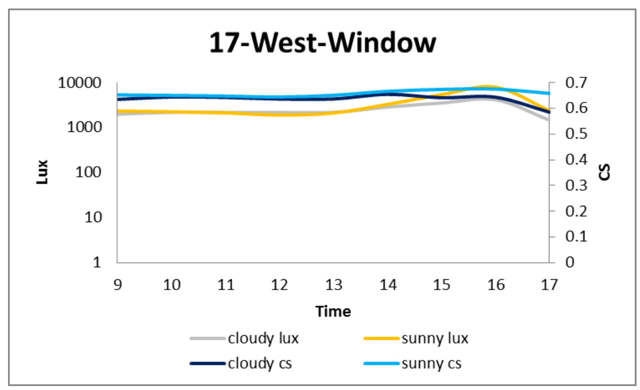
Average Lux and CS (Late Spring)

17-West-Window (Winter)

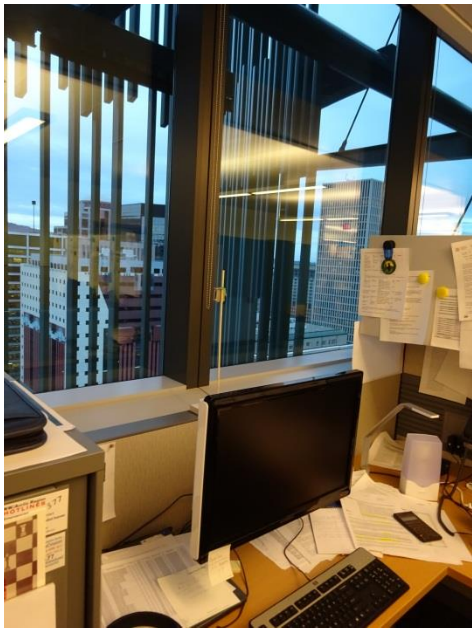


Daysimeter 29 – 17-West-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 435 ± 267 lux on cloudy days. The mean CS value was 0.36 ± 0.21 on cloudy days. On sunny days mean photopic light level during working hours was 1039 ± 716 lux. The mean CS value was 0.48 ± 0.24 on sunny days.

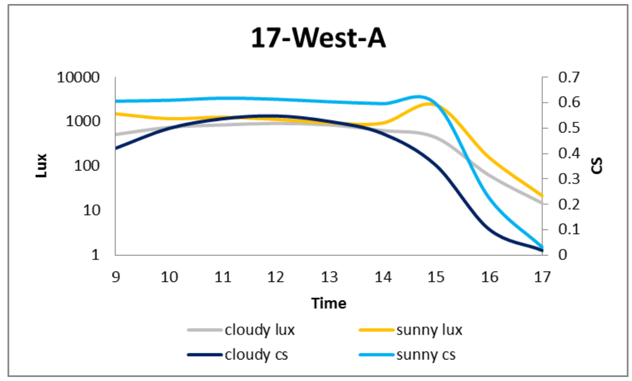
17-West-Window (Late Spring)



Daysimeter 135 – 17-West-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 2536 ± 844 lux on cloudy days. The mean CS value on was 0.64 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 3312 ± 2051 lux. The mean CS value on was 0.64 ± 0.02 on sunny days.

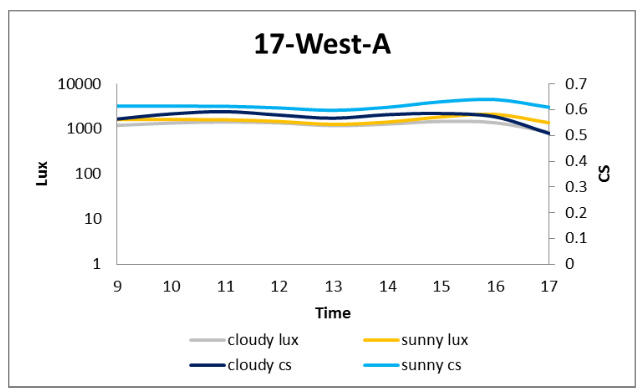


17-West-A (Winter)

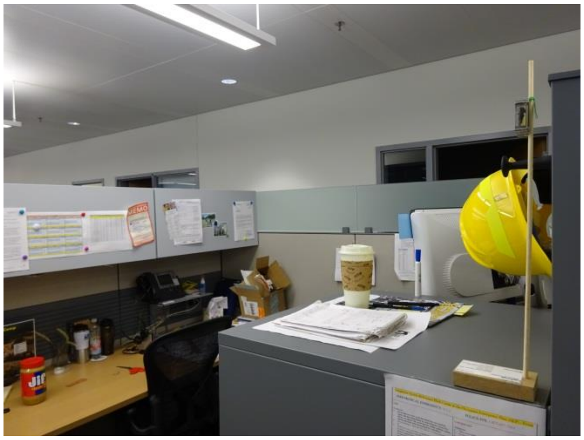


Daysimeter 223 – 17-West-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 561 ± 335 lux on cloudy days. The mean CS value was 0.39 ± 0.20 on cloudy days. On sunny days mean photopic light level during working hours was 1062 ± 705 lux. The mean CS value was 0.50 ± 0.22 on sunny days.

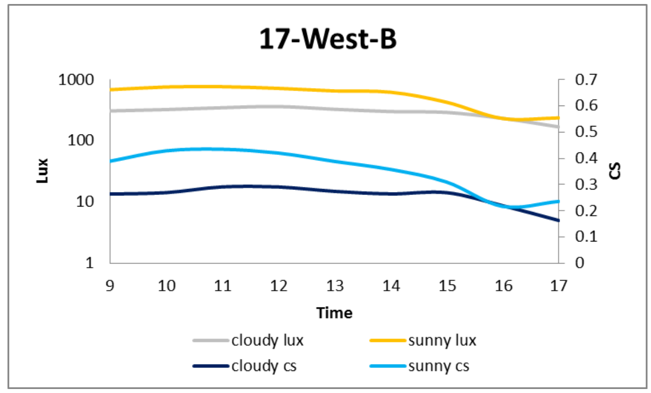
17-West-A (Late Spring)



Daysimeter 158 – 17-West-A. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 1289 ± 188 lux on cloudy days. The mean CS value on was 0.57 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 1602 ± 261 lux. The mean CS value on was 0.62 ± 0.01 on sunny days.

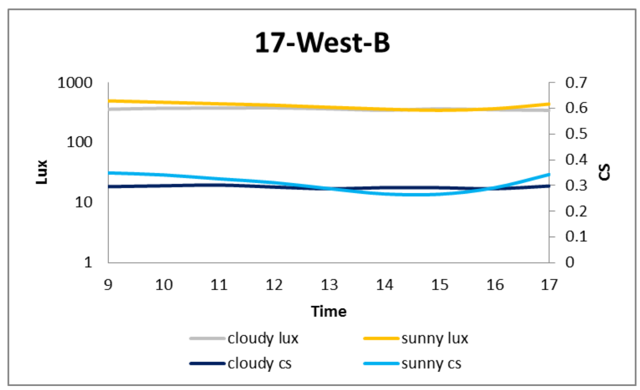


17-West-B (Winter)



Daysimeter 225 – 17-West-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 296 ± 60 lux on cloudy days. The mean CS value was 0.26 ± 0.04 on cloudy days. On sunny days mean photopic light level during working hours was 568 ± 214 lux. The mean CS value was 0.35 ± 0.08 on sunny days.

17-West-B (Late Spring)



Daysimeter 145 – 17-West-B. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 363 ± 12 lux on cloudy days. The mean CS value on was 0.29 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 416 ± 52 lux. The mean CS value on was 0.31 ± 0.03 on sunny days.