Building Performance Evaluation (BPE) Project

Evaluation Report for Building "D"

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Building Performance Evaluation of Building D

Building performance evaluation (BPE) involves the inspection of buildings one to five years after their construction, and assessment of the extent to which a given building has met its design goals. The primary purpose of BPE is to improve design practice and ensure the continuous improvement of design methods, through the provision of feedback to designers on the effectiveness of their design choices. BPE is also useful to property managers, building operators, and building occupants, as its collation of detailed measurements and occupant feedback highlight which building features are operating optimally, and which features have the potential to be enhanced.

The office building assessed in this performance evaluation has been named Building D for the purpose of maintaining anonymity. Located in Greater Vancouver, this building is certified LEED® Gold by the U.S. Green Building Council, and includes many energy-efficient and sustainable features. The building performance evaluation for Building D was carried out in the summer of 2006.

Executive Summary

Building D is a prominent green building in British Columbia that obtained a LEED Gold certification. Constructed in 2003, this building showcases a number of sustainable features and renewable energy systems, in accordance with the goals set early in the design process.

The goal of energy reduction was pursued in the building design using a high performance envelope and solar shading. The mechanical systems used were underfloor air ventilation and radiant heating systems served by a combination of heat pumps and solar heat collectors with a backup boiler. A natural ventilation strategy using operable windows was designed for use throughout summer months, with some radiant cooling capacity installed in case of very extreme cooling requirements. Daylight sensors were installed for reduced lighting energy consumption. A photovoltaic system was also designed for the building. While the majority of these strategies functioned as intended in the occupied building, due to the absence of energy meters actual energy consumption data was unavailable. For this reason, no conclusions could be drawn about the energy performance of the designed features.

The goal of water conservation in the building was pursued using low-flow fixtures, waterless urinals and dual flush toilets, and by making use of captured stormwater for toilet flushing. Filters in the stormwater system clogged repeatedly due to the debris present in the raw storm water, leading to the shutdown of this system, yet water consumption in the building was still very close to the targets set during design.

The daylighting objective drove much of the architectural design of the building, with large windows and solar shading contributing to this goal. Most spaces in the building were completely daylit on the day “snapshot” lighting measurements were taken, although in some areas light levels were below benchmarks when task lights were not used.

Occupants in Building D tended to supplement the natural ventilation strategy by opening the print room door to induce airflow, and by bringing in personal fans. However, with the addition of these measures occupants appeared satisfied with the thermal conditions created by the natural ventilation strategy. This demonstrates the fact that these occupants are well informed about the operation of their building and empowered in their control over these features.

Acoustic conditions in most regularly occupied spaces were within benchmarks, with the exception of the lunchroom and meeting rooms which had higher noise and reverberation levels. Acoustic privacy was lower in open offices, as expected; occupant dissatisfaction with this demonstrates attitudes towards acoustic privacy that are difficult to change.

While air quality in the building was optimal for the most part, ultrafine particulate levels were higher than benchmarks, indicating vehicle exhaust from trucks idling outdoors was likely entering the building through operable windows. Due to the nature of the site on which Building D is located, the presence of idling trucks is common.

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1.0 Building Performance Evaluation Pilot Study

1.1 DEVELOPMENT OF THE PILOT STUDY

Building D was one of six buildings that participated in the Building Performance Evaluation (BPE) Pilot Study in 2006. In this Study, the EcoSmart Foundation applied a new protocol for post occupancy evaluation of buildings to diverse types of commercial and institutional green buildings. The protocol addresses the energy and water consumption, thermal comfort, acoustics, indoor air quality, and lighting in a building, with the Centre for the Built Environment (CBE) Indoor Environment Quality survey employed to gauge occupant satisfaction with each of these elements.

A list of funding partners of the Building Performance Evaluation Pilot Study is included in Appendix 3.5.

1.2 THE BUILDING PERFORMANCE EVALUATION PROTOCOL

The Building Performance Evaluation Protocol is a set of procedures for evaluating the actual performance of occupied buildings as compared to their design goals. The need for evaluation of occupied buildings is apparent to many designers, but this has not yet been built in to standard practice in the field of building design. The BPE Protocol was developed in order to provide a clear set of procedures to enable design firms or other proponents to evaluate occupied buildings using a focused method, asking the right questions and obtaining pertinent results.

It is important to make the distinction between a Building Performance Evaluation and a full building audit. While audits typically focus on one or two elements of a building's performance, for instance its mechanical and electrical systems, performing an exhaustive evaluation of each piece of equipment relating to those elements, a Building Performance Evaluation assesses a building's performance in a broad range of categories, from energy and water consumption to acoustic performance, thermal comfort, lighting, and air quality. A BPE also integrates these assessments with responses from building occupants about their satisfaction with each of these aspects.

While a Building Performance Evaluation may be combined with a full building audit to assess some elements of the building's performance in greater detail, a BPE is designed simply to provide an overview of how the building is performing in relation to its design goals.

A BPE does not involve use of a rating system to certify a building based on its performance. Certification using LEED for Existing Buildings is recommended for project teams interested in using such a rating system.

The following sections describe the elements that make up the BPE Protocol.

1.2.1 Interviews and Administration

A series of interviews were carried out during the Building Performance Evaluation, as shown in Table 1. These interviews were used to gather information essential to the BPE process.

Table 1: Interviews involved in the Building Performance Evaluation

Interviewee	Information Gathered
Building Owner	General building information, successes and opportunities for improvement in building operation
Design Team – Evaluation Kickoff Meeting	Design goals and strategies, building features, description of design process
Building Operator	Operational procedures, successes and difficulties in building operation
Occupants (random sample interviewed)	Satisfaction with various features in the building
Design Team – Evaluation Wrap-Up Meeting	Discuss results of evaluation, lessons learned by designers

1.2.2 The Occupant Satisfaction Survey

A Building Performance Evaluation involves a survey of building occupants to gauge their level of satisfaction with various aspects of the building. The Indoor Environment Quality web-based survey, developed and administered by the Center for the Built Environment (CBE) at the University of California at Berkeley, was used to gather this information from occupants. More information about the CBE's web-based Indoor Environmental Quality Survey is available at www.cbe.berkeley.edu.

The CBE survey gives occupants the opportunity to comment on their satisfaction with various elements of the building, such as spatial layout, office furnishings, office temperature, air quality, lighting, acoustic quality, and building maintenance. Each survey is customized to be specific to the building being evaluated. This is accomplished through discussion with the building owner, operator, and designers, and communication of required customization to the CBE's research staff. Customizations typically include a diagram to enable occupants to identify their location within the building, and a number of optional modules that question occupants about specific building features, such as exterior shading devices or operable windows.

A response rate of 50% is normally targeted for the occupant survey, however any dataset containing more than five responses may be used to gain insight into occupant satisfaction with a building, while maintaining the conditions of anonymity.

1.2.3 Empirical Measurements

Empirical measurements of acoustics, thermal comfort, indoor air quality and lighting are taken on one day during the performance evaluation period. These measurements are intended to complement the qualitative occupant feedback derived from the web-based survey. Results from the occupant satisfaction survey are used to select ten spaces within the building where measurements would be taken, with a balance of the most highly and poorly rated locations selected for measurement.

It is recognized that measurements taken over one or several days do not necessarily reflect the typical indoor environmental quality. It is thus important to examine this information collectively with the information from occupants, the building operator, and any recorded information available from the building's DDC system. The measurements are considered "snapshots" of the building in operation, and should not be viewed as definitive indicators of the overall indoor environment quality.

1.2.4 Analysis of Energy and Water Consumption

Energy and water consumption estimates, often calculated during the design of green buildings, are compared to actual annual energy and water consumption, metered for the building. More often than not, there are significant differences in occupancy, hours of operation, and building operation from what was anticipated during design, making a direct comparison of predicted and actual consumptions difficult. In such cases, an order of magnitude estimate of the degree to which these factors could impact original energy and water consumption estimates is given.

2.0 The Selected Building

2.1 OVERVIEW OF THE BUILDING

Building D is a small but prominent green building in BC's lower mainland, and was constructed in 2003. This two-storey building has a floor area of 600 square meters (6,550 square feet) and houses thirty-six workers, twenty of whom use the building for only a portion of each day. The building has a predominantly open office environment, with a few private offices and meeting rooms. Building D is located in a quiet residential area, close to public transit.

Building D was constructed on the existing foundations of a concrete tank from the sewage treatment plant previously on the site. The building's high performance envelope includes solar shading and showcases a green roof, photovoltaic panels, and evacuated tube solar collectors which provide hot water to the building.

The building employs a passive natural ventilation strategy using operable windows for much of the year. Radiant in-floor heating is the dominant source of heating, with an underfloor air distribution system in the office area providing ventilation air with some heating and cooling capacity. Water source heat pumps deliver energy from a pond on site, and together with the solar collectors and a backup boiler, provide the heating and cooling energy for the building systems.

Other sustainable features in the building include daylighting design, low-flow fixtures, and use of a stormwater catchment system for toilet flushing.

Because of the sustainable goals and features associated with this building, it was selected as an ideal candidate for the Building Performance Evaluation pilot project, which was carried out in 2006.

2.2 BUILDING DESIGN PROCESS

An integrated design process was implemented for the design of this building, with architects, engineers and owner's representatives consistently working together when making decisions regarding a building's design. This type of process is frequently used by the firms involved in this project. Bi-weekly design team meetings were held with the owner's engineer in attendance.

The target of LEED Gold was set for Building D early in the design process. This was the first LEED process carried out by the architectural team, who noted that the design of Building D was driven by their longstanding commitment to green building rather than by the desire to attain LEED credits.

2.2.1 Design Goals

The project's goal of producing an environmentally conscious "green building" began with the owner, and early IDP meetings led to the establishment of LEED Gold as a target.

The following six goals were identified by the project team for the building, and led to the implementation of the specific design strategies discussed in the next section.

Goal #1: Reduce Energy Consumption

While the building owner had mandated a LEED Gold building, no specific energy savings targets were established at the outset of the project. During design, however, an informal energy target of 50% energy savings over the American Society for Heating Refrigeration and Air Conditioning Engineers (ASHRAE) 90.1-1999 Standard was set, equivalent to roughly 85 kWh/m^2/year. Many energy conservation and renewable energy strategies were incorporated into the design to achieve this level of energy performance, as described in the next section.

Goal #2: Reduce Water Consumption

Goals for water consumption were set at 30% reduction based on LEED baseline calculations, and a number of strategies were implemented to achieve this goal, as described in Section 2.2.2.

Goal #3: Maximize Access to Daylight

The architectural design focused on daylighting, with natural light illuminating most spaces in the building on bright days. The goal of having 90% of workspaces within 8.5 metres of a window was targeted. The design strategies involved in achieving this goal are outlined in Section 2.2.2.

Goal #4: Achieve Thermal Comfort using Passive Systems

A passive system of natural ventilation, using operable windows and relying on solar shading, was designed for use in Building D through much of the year.The intent of the designers was to provide a thoroughly comfortable building using these passive strategies.

Goal #5: Create High-Quality Acoustic Environment

Although specific goals for acoustic quality were not set during the design phase, the building's acoustical design included several noise-reducing features described in Section 2.2.2.

Goal #6: Optimize Indoor Air Quality

ASHRAE 62 standards and LEED requirements were used to guide the design of systems to achieve optimal indoor air quality.

2.2.2 Key Design Strategies Implemented

The following strategies were developed during the design of Building D in order to achieve the goals expressed above. The results of each of these strategies in operation will be examined in Section 2.3.5.

Goal #1: Reduce Energy Consumption

The building's highly insulated envelope, designed with low-E glass and external shading, was intended to reduce heating and cooling loads in the building.

A natural ventilation strategy was designed for the building using operable windows, and was intended to provide cooling and ventilation for much of the year, conserving a large amount of energy. An underfloor ventilation system with heating and cooling capacity, coupled with radiant in-floor heating, was installed in the building for operation when climate conditions did not permit use of the natural ventilation strategy. Energy was provided to these efficient systems through a heat pump system and solar collectors, with a backup boiler to assist with the peak loads. Exhaust air heat recovery was also included in the design for preheating of ventilation air.

Daylight sensors were used to control electric lighting based on natural light levels in the building, serving to reduce electric lighting energy.

Photovoltaic panels were designed to provide electricity to the building, and evacuated tube solar collectors were used to provide hot water for space and domestic hot water heating within the building.

An energy model was created for the Canadian Building Incentive Program (CBIP) and LEED, and results indicated an energy savings of 56% below the CBIP Model National Energy Code for Buildings baseline. As such, an energy density of about 89.5 kWh/m^2 floorspace/year was estimated during design.

Goal #2: Reduce Water Consumption

The building's low-flow fixtures, waterless urinals and dual flush toilets were selected for reduced water consumption. In addition, a stormwater catchment system was designed, to be used for toilet flushing and washing of trucks on the building's site. These measures afforded a 37% water use reduction over the baseline used for LEED calculations, not including the process water used for truck washing. A LEED Innovation credit was also obtained for exemplary performance in water efficiency due to the use of stormwater for truck washing.

Goal #3: Maximize Access to Daylight

According to the designers interviewed during the BPE, the architectural design of the building was largely driven by the daylighting strategy. A long building shape was selected to allow 90% of workspaces to be within 8.5 metres of a window. Large glazed areas and high ceilings were designed, with blinds and external shading to control glare. Light shelves and reflective surfaces were selected to increase the effectiveness of the daylighting strategy.

The electric lighting in the building was designed for 9.7 Watts per square metre of floor area. Daylight sensors were designed to control electric lights based on daylight levels.

Goal #4: Achieve Thermal Comfort using Passive Systems

The natural ventilation strategy designed for the building, using operable windows and benefiting from the reduced solar loads made possible by solar shading, was intended to cool and ventilate the building during much of the year. Cooling capacity was available in the radiant floors and underfloor air systems for periods of extreme cooling demand when the natural ventilation scheme could not provide adequate cooling, and heating capacity was installed in these systems for winter use. The intent of designers was that the combination of these passive and active systems would maximize thermal comfort for occupants while minimizing energy use.

Goal #5: Create High-Quality Acoustic Environment

To improve acoustic quality in open plan office areas in Building D, sound-absorbing workspace partitions and carpets were installed. The designed mechanical systems were anticipated to be very quiet, and the mechanical room was designed beneath the building away from occupied areas, further reducing this source of background noise.

Due to the residential neighbourhood in which the building was located, outdoor noise was not expected to be a significant problem, although a moderate amount of noise from traffic on the building's site was anticipated.

Goal #6: Optimize Indoor Air Quality

According to the directives of the LEED credits pursued, the building's print room was isolated from the rest of the office space and exhausted separately. Carbon dioxide monitoring was installed and connected to the building's Direct Digital Control (DDC) system. Low volatile organic compound (VOC) materials were selected for the building's carpets, paint and finishes. A VOC consultant tested the air quality of the building prior to occupancy to ensure low VOC levels were achieved.

The results of all of the above strategies in operation will be examined in Section 2.3.5.

Another element that was not directly assessed by the BPE Protocol but that was important for Building D was the use of a green roof to reduce stormwater runoff and to mitigate the heat island effect.

2.3 RESULTS IN THE OCCUPIED BUILDING

2.3.1 Building Commissioning

As the LEED credit for additional commissioning was not pursued, a commissioning authority was not retained, and Building D followed the traditional commissioning process of involving a third-party contractor, hired by the mechanical contractor to commission the building's mechanical systems. It appears that no commissioning of electrical or enclosure systems was carried out for Building D.

It appears that mechanical commissioning procedures were well documented for Building D, and appropriate commissioning tasks were undertaken by the controls contractor, including training of the operator in use of the DDC system.

2.3.2 Building Operation

Building D is operated based on informal operational policies and priorities. Building operation is primarily driven by occupant requests, of which there are relatively few in this building due to the high level of occupant satisfaction.

The DDC system for the building is checked periodically by the operator, typically in response to occupant requests.

According to the operator, the building's natural ventilation system would have been optimized by a north-south axis instead of its actual orientation, which was decided on based on the desire to reuse the existing concrete tank walls from a sewage treatment plant previously on the site. Occupants are in the habit of propping the print room door open to increase air circulation when the natural ventilation scheme is in operation, which is not in accordance with the design intent. A number of occupants also use personal fans to assist in ventilation and cooling. However, the operator feels these measures lead to occupant satisfaction with thermal comfort conditions.

The operator has concerns with regards to the degradation of low-VOC paints and finishes in the building, and with regards to odours from the waterless urinals.

2.3.3 Disparity between Design and Occupied Building

No major changes to the building have been applied since building construction was completed in 2003. A problem of underheating in the building during the first winter was resolved with the replacement of a heat exchanger that was installed below its specification.

The stormwater reuse system experienced difficulties with clogging of filters and the buildup of algae, leading to the shutdown of this system. Thus, water for toilet flushing is now provided by the municipal water system. Water from the stormwater system continued to be used for truck washing for a time, but this also ceased when individuals observed the trucks were not being adequately cleaned by this system.

2.3.4 Occupant Satisfaction Survey

The evaluation of Building D included use of the Center for the Built Environment (CBE) Indoor Environmental Survey, as discussed in Section 1.2.2. The survey was customized to include the CBE's optional sections on window blinds.

Occupants working who responded to the survey were asked to locate themselves within one of four zones within the building, and also to specify on which floor their workspace was located, whether their work environment was open office, private office, or shared office. Together these responses allowed for significant sorting of results, and selection of areas in the building that had the most and least satisfactory ratings for lighting, acoustics, thermal comfort, and indoor air quality.

Seven people participated in the web-based occupant satisfaction survey, which was 19% of the invited responses in this small building. The majority of respondents (71%) had worked for more than three years in this building, and 57% of respondents spend more than 30 hours a week at their workstations. Seventy-one percent of respondents were male; 86% were over 30 years of age, and 43% described themselves as professional.

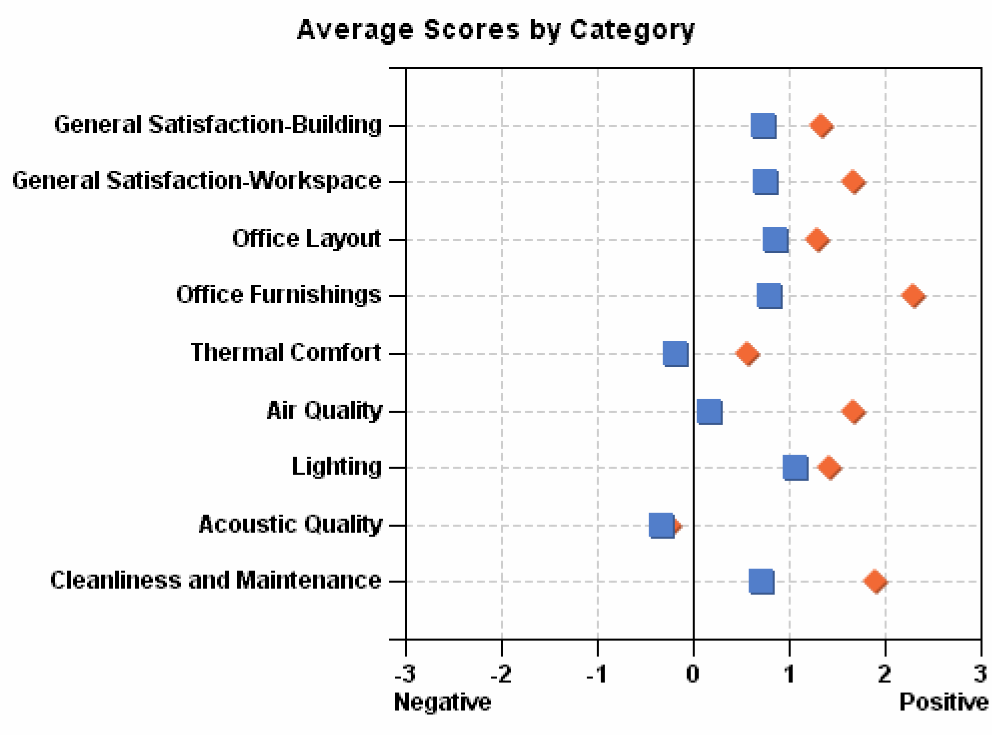


Figure 1: Survey Results for Building D

The above graph above shows the results generated from responses at Building D (diamond shapes), as well as results from the CBE's pooled data from over 31,000 occupant responses in 240 buildings (squares); the latter can be considered the average for office buildings.

As can be seen from the graph, the building rated above the CBE average in every category. Building D was rated most highly in the categories of office furnishings, cleanliness, workspace satisfaction, air quality, lighting, and office layout. The building scored well above the average for thermal comfort, but only slightly above the CBE average for acoustics.

The response rate targeted during the BPE for the occupant satisfaction survey was 50%, and only a 19% response rate was obtained, with seven occupants responding to the survey. Due to the very small sample of responses, the survey responses should not be viewed as representative of the views of all building occupants. In general with such surveys, it is conceivable that when offered the opportunity to complete the survey, occupants who were discontent with the building may have been more likely to take the time for this task than those who were satisfied with their experience in the building. However, according to the operator and others, occupant satisfaction in Building D is very high. Since the sample size exceeded the number of responses required to ensure anonymity, these results were used to give an indication of occupant responses from the building.

Survey responses pertaining to the results of key design strategies are included in Section 2.3.5 below. Results of the entire occupant survey can also be found in Appendix 3.2.

2.3.5 Results of Key Design Strategies

The Building Performance Evaluation of Building D assessed the post-occupancy performance of each of the design strategies outlined in Section 2.2.2. Occupant satisfaction survey responses, operation experiences, and empirical measurements relating to each of these strategies are outlined below.

Goal #1: Reduce Energy Consumption

The actual energy performance of Building D could not be ascertained, due to an absence of building-specific energy metering. For a building with such advanced energy targets as Building D, it is surprising that no monitoring of energy consumption has taken place. It is recommended by the BPE team that a power meter with datalogger be used in the building, or that periodic recordings of analog meter readings be undertaken, in order to gauge the actual energy performance of Building D.

It appears that most strategies employed in Building D for energy efficiency are now working as designed, though there were some initial underheating issues due to a problem with the backup boiler. Of course, due to the absence of energy metering, it is impossible to confirm the success of these strategies in reducing energy consumption in the building.

According to the building operator, the building uses natural ventilation for cooling even on hot summer days, thus reducing energy consumption as designed.

Energy from the building's photovoltaic panels was metered for the period of approximately one year; these panels provided 2,200 kWh of electricity to the building over that period. The anticipated electricity generation from these panels calculated during design was 2,140 kWh.

Goal #2: Reduce Water Consumption

The stormwater reuse system designed for the building met with some challenges, with filters clogging repeatedly, leading to the disabling of this system. The reason for this was believed to be the fact that raw storm water containing grass clippings and other debris was entering the system without prefiltration, and that the system filters were not robust enough for this debris. The stormwater was used for truck washing for a time, but this also ceased when it was felt that trucks were not being adequately cleaned. After disabling of the stormwater system, water from the municipal system could be used for both toilet flushing and truck washing without any additional cost, since the building is on a fixed water charge rate with this municipal system.

While the design team was aware of the issue of clogging filters, the problem of algae was not known to designers until the Building Performance Evaluation.

Water metering for the building exists, yet it includes the water used for truck washing, which was not included in original water consumption calculations.

Design predictions of water consumption based on LEED calculations estimated an annual water use of 261,000 litres. Actual metered water consumption, which includes water used for truck washing, shows an annual use of 263,000 litres of water, very close to the predicted amount, despite the fact that the predicted values assumed the use of stormwater for toilet flushing. The actual water consumption is equivalent to roughly 28 litres per occupant per day.

According to the building operator, there are some complaints from occupants relating to odours associated with the waterless urinals. However, on the whole, 84% of respondents to the CBE Indoor Environment Quality survey were satisfied with the washroom fixtures in the building.

Goal #3: Maximize Access to Daylight

The design strategies used to maximize daylighting in Building D were effective in introducing natural light into most workspaces.

Results of the CBE Indoor Environment Quality survey show that 83% of respondents were satisfied with the daylighting in the building, compared to the CBE database average of 85%. As mentioned in Section 2.3.4, the number of responses to the survey was very low in this small building, therefore it should be understood that these responses may not reflect the views of all building occupants.

On the sunny July day on which empirical lighting measurements were taken, electric lights were off and the building was fully daylit. Light levels in most spaces were within benchmarks, however in some areas light levels without electric lighting were low. Glare was noted in many workstations on the day of measurement, however blinds and shading trees appeared to be effective in reducing this glare.

Detailed lighting data from the day of measurement may be found in Appendix 3.3.4. It is important to note that these “snapshot” samples cannot definitively describe the overall lighting conditions in the building throughout the year.

Goal #4: Achieve Thermal Comfort using Passive Systems

According to the building operator, the building uses natural ventilation for cooling even on hot summer days, meaning no mechanical cooling is used. The operator feels the natural ventilation strategy would be more effective had the building been oriented north-south, however the fact that the building was constructed so as to reuse existing concrete tank walls precluded this. The operator stated that occupants have tended to prop the print room door open to increase ventilation for cooling, or to bring in their own fans. However, combined with these additional measures, the natural ventilation strategy appears to achieve adequate thermal comfort.

Of the respondents to the CBE survey, 71% were satisfied with thermal comfort conditions in their workspace, as compared to the CBE database average of 58%. These responses suggest that both the passive and active heating and cooling strategies used in Building D achieve an appropriate level of thermal comfort.

“Snapshot” empirical measurements of thermal conditions in Building D were carried out on a sunny August day. On the day of measurement, most spaces had air temperatures in the range of 22 - 24°C, with the exception of the two meeting rooms sampled, which both had temperatures between 24 - 25°C. These results demonstrate the successful operation of the natural ventilation strategy in general, and the challenge involved in conditioning high-load spaces such as meeting rooms with this passive strategy.

Detailed thermal measurement data may be found in Appendix 3.3.2. It is important to note that these “snapshot” samples do not definitively describe the overall thermal conditions in the building over a year.

Goal #5: Create High-Quality Acoustic Environment

“Snapshot” measurements of acoustics in the building indicated that noise levels and reverberation in private offices were within benchmark ranges. In the open plan office areas, noise levels were within benchmarks but speech privacy was somewhat low. Noise from outside the building occasionally raised background noise levels above benchmark levels. In the meeting rooms, noise levels were higher than benchmarks, and in the lunchroom high reverberation times were quite high.

Detailed data from the day of acoustic measurements is found in Appendix 3.3.3. It is important to note that these “snapshot” samples in a few locations do not definitively describe the overall acoustic quality in the building.

Of respondents to the CBE survey, 83% were satisfied with their acoustic environment, compared to the CBE database average of 62%. While acoustics was rated the lowest on the satisfaction scale compared to other aspects of the building's performance, it is important to note that this building exceeded the average CBE database rating for acoustics.

Goal #6: Optimize Indoor Air Quality

"Snapshot" measurements of air quality in the building were taken on a July day. These samples showed very low volatile organic compound (VOC) levels compared to benchmarks, indicating the success of the low VOC finishes, paints and carpet in optimizing air quality. As well, CO_2 levels were on the low end of benchmark ranges, indicating the successful operation of the passive and active ventilation systems, and of the carbon dioxide monitoring systems.

However, ultrafine particulate concentrations, which arise from products of combustion such as smoke or vehicle exhaust, were higher than benchmarks in all areas assessed. Trucks that periodically idle outside the building when operable windows are open are likely the source of these high levels.

Results of the CBE occupant survey indicated that all the seven respondents were satisfied with air quality, compared to the CBE database average of 67%.

2.3.6 Resource Use Analysis

2.3.6.1 Energy Use

An energy model was produced during the design of Building D for the Canadian Building Incentive Program (CBIP), and results of this model were compared to a benchmark building meeting the Model National Energy Code for Buildings (MNECB). Based on this model, the predicted energy use of the building was 56% lower than the MNECB baseline, at 89.5 kWh/m^2/year. As use of standardized schedules of operation and equipment loads is the common procedure for CBIP analysis, and as the selection of systems is somewhat limited, CBIP model results should not be expected to represent predictions of the actual energy performance of a building. Instead, they provide a comparison between the designed and baseline building based on a standard set of conditions.

As explained above in Section 2.3.5, no actual energy use data was available to the BPE team for comparison to the energy model results, or to the average energy consumption of existing office buildings in BC from the *Commercial and Institutional Building Energy Use Survey of 2000* (CIBEUS)[1], which is 378 kWh/m^2/year.

The electricity generation by the photovoltaic panels on the building, which was calculated during design at 2,140 kWh, was metered at 2,200 kWh.

[1] Commercial and Institutional Building Energy Use Survey 2000, December 2002, conducted by Statistics Canada on behalf of the Office of Energy Efficiency of National Resources Canada.

2.3.6.2 Water Use

The water conservation strategies followed in Building D, including the use of stormwater for toilet flushing, led to the design prediction of 37% reduction in water use over the benchmark developed for LEED calculations. The predicted annual water use based on these calculations was 261,000 litres.

Actual water use metered for the building, which included water used for truck washing, was 263,000 litres per year. This consumption was very close to the predicted amount, despite the fact that stormwater was not used for toilet flushing or truck washing, as was anticipated during design.

The water use in the building was equivalent to roughly 28 litres/occupant/day. This compares very favorably with the American Society of Plumbing Engineers (ASPE) baseline estimated water requirement of 76 L/occupant/day (20 gallons per capita per day).[2]

2.4 DESIGN LESSONS LEARNED

The final stage of the Building Performance Evaluation was a wrap-up meeting with the design team, during which the post-occupancy results of the key design strategies were discussed. What follows are the design lessons expressed by design team members based on these results. Where no lesson was explicitly stated by designers relating to a significant result, lessons felt to be apparent to the Building Performance Evaluation team were deduced.

Goal #1: Reduce Energy Consumption

While most of the designed strategies for energy conservation appear to be operating as intended in Building D, it is impossible to learn lessons about the actual energy use associated with these strategies in the building due to the absence of energy metering.

An important lesson learned by the project team for Building D during this BPE is about the importance of using building-specific energy metering to monitor the actual energy performance of green buildings. In order to learn from occupied green buildings in a way that can inform future energy-efficient design, energy metering is essential.

Goal #2: Reduce Water Consumption

Despite the fact that the stormwater reuse system was disabled, the water use in Building D was considerably lower than benchmarks, and was equivalent to the predictions calculated during design.

A lesson learned by the designers relating to the stormwater system was that systems accessing raw storm water from drains should be designed with pre-filters to remove larger

[2] Steele, Alfred. Advanced Plumbing Technology. Elmhurst: Construction Industry Press, 1984, p 155.

debris prior to storage. In cases where use of pre-filters is not possible, more robust filters should be used to prevent plugging of the system.

Members of the design team noted that the issue of algae in this system was not known to them until the Building Performance Evaluation, indicating the benefit of such evaluations for feeding information back to designers to inform future designs.

The problems experienced with the odours from the waterless urinals in the building may be attributable to a number of factors. Timely cartridge replacement is essential for these urinals, however even when this occurs many occupants still have concerns about odours. These problems may also be due to poor design of these particular urinals given that they were an early iteration of this technology, or simply to occupant reservations about this unfamiliar technology.

Goal #3: Maximize Access to Daylight

Overall, the daylighting strategy in Building D was effective in bringing natural light into the majority of workspaces. While "snapshot" measurements indicated some spaces were more dimly lit without electric lighting, appropriate use of task lights in the building to supplement natural light could resolve this issue without the use of overhead lights. Some members of the design team felt that the dark surface of the reused wood on the office ceiling may have the effect of reducing light levels, and that use of a lighter finish would be beneficial.

The fact that light levels in most spaces were within benchmarks demonstrates the success of the solar shading strategies implemented in the building.

Also, it appears that occupants were in the habit of using internal blinds to control glare, as many blinds were in use on the day of measurement. The lesson apparent from this observation relates again to the sense of ownership and empowerment felt by occupants over the operation of this building. Part of this potentially relates to the small size of Building D, however much of this is no doubt due to the occupant education carried out with respect to the green features in this building.

Goal #4: Achieve Thermal Comfort using Passive Systems

As described above, occupants of Building D implemented their own measures to supplement the cooling achieved by natural ventilation in summer months. As noted by the operator and also by the results of the occupant satisfaction survey, with the addition of these supplemental cooling measures, occupants appeared quite satisfied with the thermal conditions in the building.

The lesson for the design team with regards to this goal was that in this building, occupants are aware of how design strategies such as natural ventilation are intended to operate. This appears to have given them tolerance for a wider range of temperatures, and a sense of empowerment with respect to their control over thermal conditions.

A lesson regarding the effectiveness of the natural ventilation strategy is that building orientation options should be investigated based on the natural ventilation, daylighting and solar shading opportunities they present. However, in this building, the priority of reusing the existing concrete tank walls also influenced the decision regarding building orientation.

Goal #5: Create High-Quality Acoustic Environment

While the acoustic conditions of most workspaces in Building D were within benchmarks, low speech privacy was found in the open plan office areas, as is often expected in open office environments, and also high reverberation times existed in the lunchroom. It is common for building occupants in open plan office areas to be dissatisfied with low speech privacy; this dissatisfaction appears to be more moderate than average in Building D. In general, occupant attitudes towards acoustic privacy in open plan areas do not change easily, particularly in occupants who are accustomed to working in private offices. In the lunchroom, the presence of hard surfaces led to increased reverberation; designers may add sound absorbing finishes in communal spaces to avoid this.

Goal #6: Optimize Indoor Air Quality

Evidence gathered during the BPE suggests that the low-VOC finishes, paints and carpet in the building succeed in greatly reducing VOC concentrations in the building. Also, low CO_2 levels indicate that the passive and active ventilation strategies are functioning effectively, and also that the carbon dioxide monitoring in the building is operating as intended.

The presence of idling trucks outside the building, combined with the operable windows which were open on the day of measurement, is the most likely explanation for the high ultrafine particulate concentrations found in the building. While operable windows are essential to the natural ventilation strategy in this building and are effective at maintaining appropriate CO_2 levels, due to the activities carried out around the building they allow increased ultrafine particulate levels.

The Building Performance Evaluation matrix in Appendix 3.1 summarizes the key design goals for Building D, the strategies implemented to achieve these goals, and the results of these strategies found during the BPE.

3.0 Appendices

3.1 BUILDING PERFORMANCE EVALUATION MATRIX

Appendix 3.1: Building Performance Evaluation Matrix for Building D

LEED CATEGORY	COMPONENT	GOAL	STANDARD PRACTICE GOAL	STRATEGY	STANDARD PRACTICE STRATEGY	PREDICTED VALUES	MEASURED VALUES	BENCHMARKS	COMMENTS / DIFFERENCES BETWEEN DESIGN AND OCCUPIED BUILDING	OCCUPANT SATISFACTION SURVEY * (see footnote)	TRADEOFFS OR SYNERGIES	DESIGN LESSONS LEARNED
Sustainable Sites	**Stormwater management**	Reduce stormwater runoff	-	Partial green roof, permeable paving and native landscaping	-	-	-	-	-	-	-	Building Performance Evaluation pilot study did not directly evaluate this topic
Water Efficiency	**Domestic water consumption**	30% water savings based on LEED	Approximately meeting LEED baseline calculations	Stormwater reuse for toilet flushing and truck washing	-	37% water savings based on LEED calculations [28 L/occupant/day prediced] not including truck washing	28 L/occupant/day [including irrigation and truck washing]	76 L/occupant/day [ASPE standard water use estimate]	Stormwater system filters frequently clogged due to grass clippings and debris in raw storm water, and presence of algae, system disabled	-	-	More robust filtration, and preferably prefiltration, should be used on stormwater systems.
				Waterless urinals, dual flush toilets, low flow fixtures	Standard flow fixtures				-	84% of respondents satisfied with washroom fixtures in the building	Waterless urinals conserve water, however they are associated with some odour concerns in this building	-
Energy and Atmosphere	**Energy consumption**	50% below ASHRAE 90.1	Approximately meeting ASHRAE 90.1 - 1999	High performance low-E glass, solar shading	-	56% below MNECB based on CBIP energy model [89.5 kWh/m^2/year]	**Data unavailable** No building-specific energy metering	Energy intensity of 378 kWh/m^2/year [CIBEUS, Office Buildings, BC]	-	-	-	Significant energy savings are expected with this strategy but cannot be confirmed due to absence of building-specific metering.
				Natural ventilation	-				Occasional high summer temperatures have led some occupants to prop print room door open for additional ventilation, and to use personal fans to assist natural ventilation strategy. Mechanical cooling not used.	71% of respondents satisfied with temperatures, CBE database average is 58% satisfaction with temperatures	-	Occupants in this building are aware of how to use the building and feel empowered to control their thermal environment, leading to a higher than average thermal comfort satisfaction rating. In this building, occupant education about green building strategies has been successful.
				Radiant floor heating and cooling	Air-side heating and cooling						-	
				Underfloor air ventilation with heating and cooling	-						-	
				Daylight sensors controlling electric lighting					-	83% of respondents satisfied with lighting, CBE database average is 85% satisfaction with lighting		Significant energy savings are expected with these strategies but cannot be confirmed due to absence of building-specific metering. Building-specific metering is essential in occupied green buildings if lessons about energy use are to inform future designs.
				Exhaust air heat recovery	-				-	-	-	
				Heat exchange with pond water via heat pumps, with backup boiler	-				Problems with underheating led to replacement of heat exchanger after first winter	-	-	
				Solar hot water collectors	-				-	-	-	
				Photovoltaic panels	-	2,140 kWh per year expected from panels	2,200 kWh delivered from panels in one year	-	-	-	-	Photovoltaic energy generated was very close to design calculations.
Materials and Resources	**Building Reuse**	Reuse of existing building components	-	Reuse existing concrete walls from a tank previously on the site	-	-	-	-	-	-	Reuse of existing concrete walls predetermined a buildng orientation which was not the ideal one for natural ventilation	Building Performance Evaluation pilot study did not directly evaluate this topic
Indoor Environmental Quality	**Lighting**	Achieve illuminance levels of 540 lux (50 footcandles) at work surfaces using 9.7 Watts/m^2 electric lighting power	Illuminance levels of 540 lux (50 footcandles) at 15 Watts/m^2 electric lighting power	Efficient lighting and task lighting (see also Daylighting section below)	-	Illuminance levels of 540 lux (50 footcandles) at work surfaces	"Snapshot" measurements of lighting conditions were mostly within benchmark range, with some excursions both above and below benchmarks in certain areas	Illuminance levels of 200 - 500 lux based on tasks	Many occupants use task lighting	83% of respondents satisfied with lighting, CBE database average is 85% satisfaction with lighting	Reduced lighting energy consumption is expected with this strategy, but cannot be confirmed due to absence of energy data	-
	Thermal Comfort	Increased occupant control over thermal comfort	-	Operable windows	Sealed windows	-	"Snapshot" measurements of thermal conditions on a sunny August day when natural ventilation strategy in use indicated most temperatures in the range of 22°C 24°C.	Typical air temperature setpoints of 21°C in winter, 23°C in summer	-	100% of respondents satisfied with operable windows	Exhaust from idling trucks near operable windows can reduce indoor air quality.	Operable windows are enjoyed by occupants, who use them effectively to control their thermal environment.
		Achieve thermal comfort via natural ventilation in shoulder seasons	Full mechanical heating and cooling year-round	Natural ventilation used for much of the year with radiant cooling capacity installed in case of extreme cooling demands, radiant heating and underfloor air supply used the remainder of the year	Full air-side heating and cooling year-round				Occasional high summer temperatures have led some occupants to prop print room door open for additional ventilation, and to use personal fans to assist cooling strategy	71% of respondents satisfied with temperatures, CBE database average is 58% satisfaction with temperatures	Energy savings are anticipated with this strategy, but cannot be confirmed due to absence of energy data	Occupants are aware of how to use the building and feel empowered to control their thermal environment, leading to a higher than average thermal comfort satisfaction rating. Acceptance of the building's environmental goals has created tolerance for a wider temperature range. In this building, occupant education relating to green features has been successful.

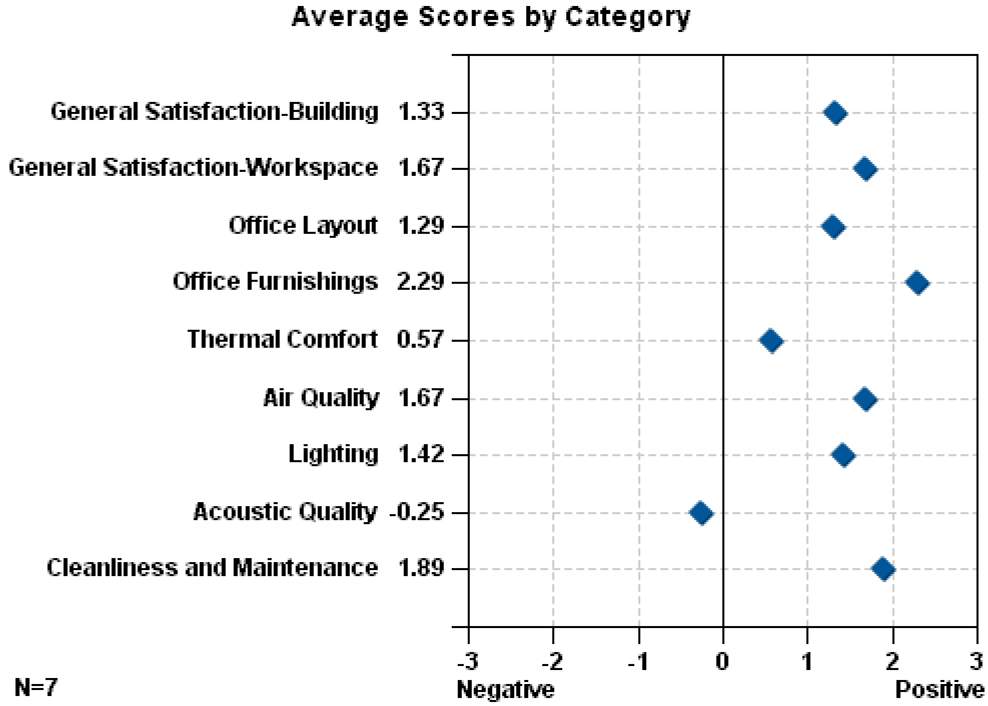
Appendix 3.1: Building Performance Evaluation Matrix for Building D

LEED CATEGORY	COMPONENT	GOAL	STANDARD PRACTICE GOAL	STRATEGY	STANDARD PRACTICE STRATEGY	PREDICTED VALUES	MEASURED VALUES	BENCHMARKS	COMMENTS / DIFFERENCES BETWEEN DESIGN AND OCCUPIED BUILDING	OCCUPANT SATISFACTION SURVEY * (see footnote)	TRADEOFFS OR SYNERGIES	DESIGN LESSONS LEARNED
Indoor Environmental Quality (cont'd)	**Daylight and Views**	Maximize daylighting	-	Most workspaces near windows	-	-	"Snapshot" measurements of lighting conditions were mostly within benchmark range, with some excursions both above and below benchmarks in certain areas, see report	Illuminance levels of 200 - 500 lux based on tasks	Blinds and exterior shading trees reduce glare in many areas	83% of respondents satisfied with lighting, CBE database average is 85% satisfaction with lighting	Reduced lighting energy consumption is expected with this strategy, but cannot be confirmed due to absence of energy data	Occupants use blinds to control glare to their satisfaction, indicating that occupants are aware of how to control their lighting conditions and are empowered to do so.
				High ceilings	-	-						
				Light shelves and reflective surfaces	-	-						
	Indoor air quality	Meet ASHRAE 62 requirements for indoor air quality using designed systems	Meet ASHRAE 62 requirements	Underfloor air supply	Air supplied at ceiling	-	"Snapshot" measurements of air quality indicate VOC and CO2 levels were low; ultrafine particulate levels were high, close to those of outdoors	Air quality measurements of CO2:600-1000ppm VOC < 300ppb ultrafine partic: 0.2	-	100% of respondents satisfied with air quality, CBE database average is 67% satisfaction with air quality	Energy savings are anticipated with these strategies, but cannot be confirmed due to absence of energy data	Evidence from the BPE suggests that ventilation systems and low VOC components have increased air quality in the building. However, use of operable windows near areas where trucks idle have led to elevated ultrafine particulate concentrations.
				CO_2 monitoring	-				-			
		Pollutant source control	-	Print room at negative presure with dedicated exhaust	-				Occupants tend to prop open the print room door to induce airflow during natural ventilation operation		-	
				Low VOC paints, finishes and carpets	-				Degredation of some low VOC paints and finishes was noted by operator		-	
	Acoustic quality	Achieve high quality acoustic environment	-	Sound-absorbing workspace partions and carpet	-	-	"Snapshot" acoustic measurements indicated most areas within benchmark ranges, with the exception of lunch and meeting rooms, speech privacy in open plan areas	Acoustic measurements of NC30-40 dB RT<0.75 s SII:0.2-0.7 NIC30-40 dB	-	83% of respondents satisfied with acoustics, CBE database average is 62% satisfaction with acoustics	-	Perdominantly hard surfaces in lunchroom have led to increased reverberation. Speech privacy in open plan areas is typically a concern in buildings, however satisfaction with acoustics in survey respondents is considerably higher than the CBE average.
Design Process	**Integrated Design Process**	Integrated design process	Traditional design process	Biweekly meetings of entire design team to make design decisions	Segregation of design tasks and decisions between disciplines	-	-	-	The LEED process was learned by design team members. The design process included involvement of occupant representatives.	-	-	Occupants of the building appear to take pride in their building and know how to use its features to control their environment. Occupant education relating to green features has been successful in this building.

*** Occupant Satisfaction Survey achieved a response rate of 19%, whereas 50% was targeted. Due to the small size of this building, sample size was only seven people. See text for discussion on significance of results.**

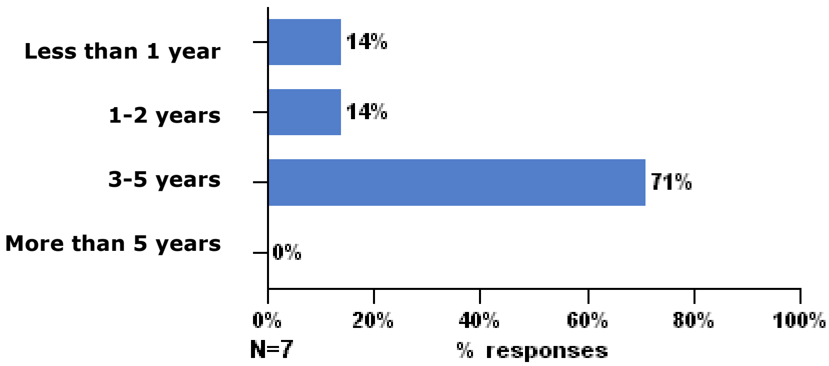
3.2 OCCUPANT SATISFACTION SURVEY RESULTS

Summary

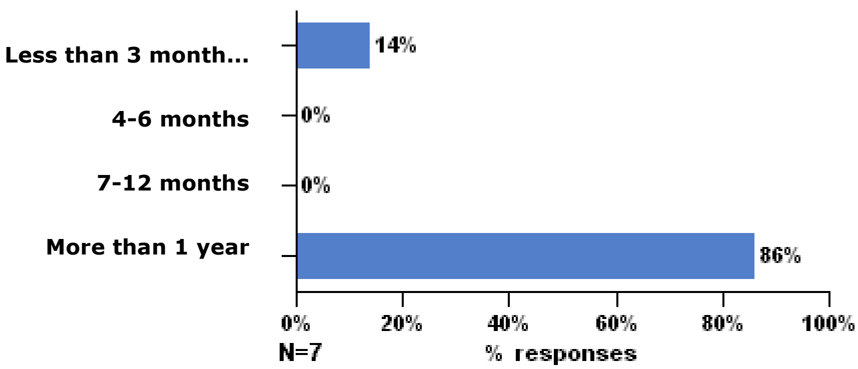

Average Scores by Category
General Satisfaction-Building 1.33
General Satisfaction-Workspace 1.67
Office Layout 1.29
Office Furnishings 2.29
Thermal Comfort 0.57
Air Quality 1.67
Lighting 1.42
Acoustic Quality -0.25
Cleanliness and Maintenance 1.89
-3 -2 -1 0 1 2 3
Negative
Positive
N=7

Background

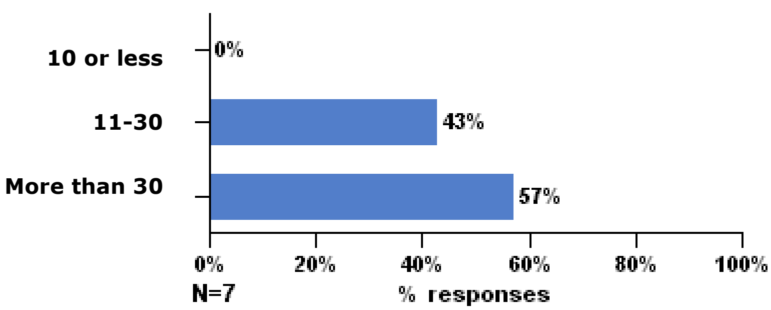
1.1) How many years have you worked in this building?



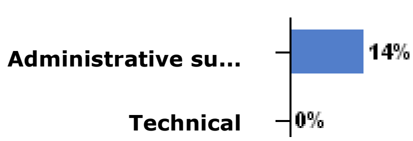
1.2) How long have you been working at your present workspace?

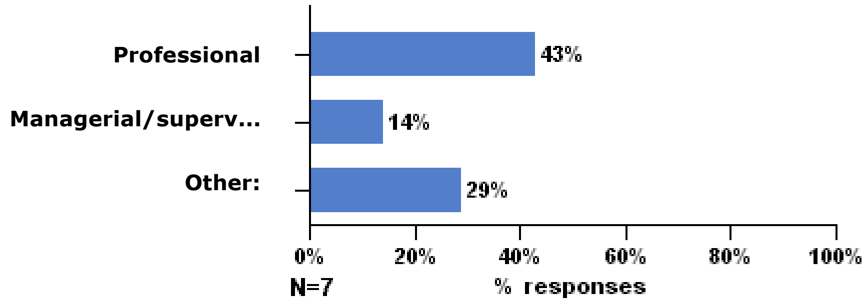


1.3) In a typical week, how many hours do you spend in your workspace?

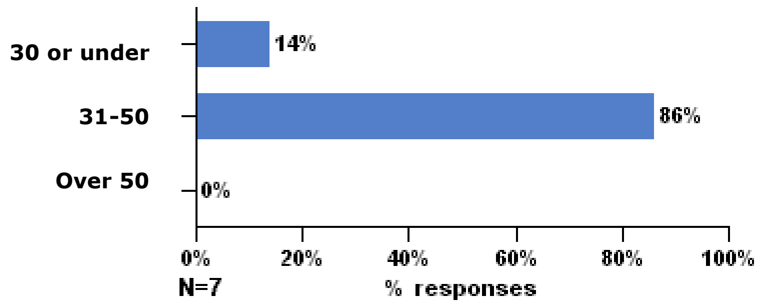


1.4) How would you describe the work you do? *("N" for this question is calculated based on the number of users who answered the question.)*

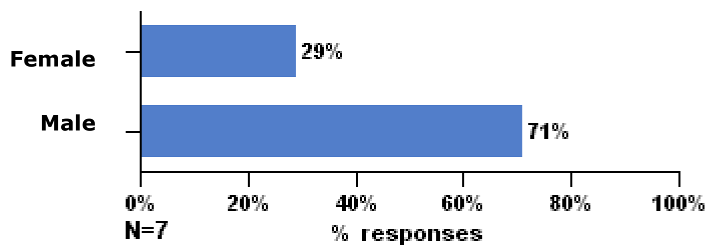




1.5) What is your age?

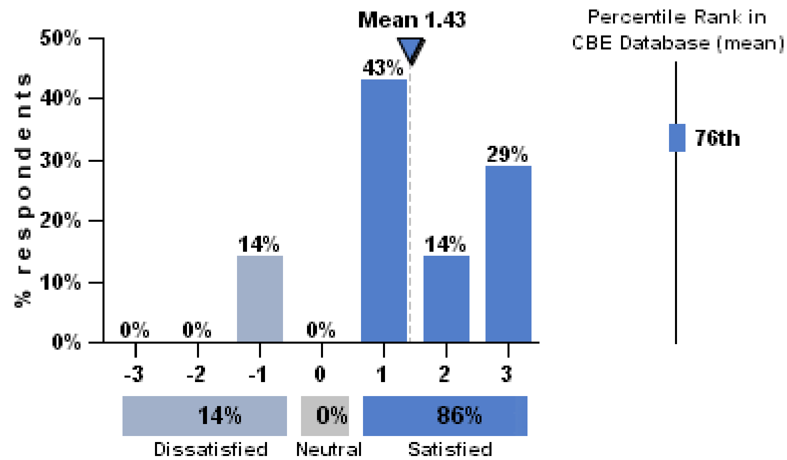


1.6) What is your gender?



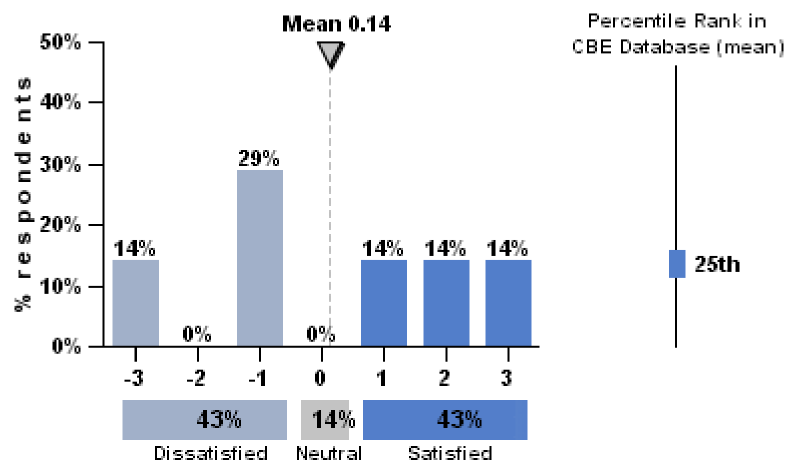
Office Layout

4.1) How satisfied are you with the amount of space available for individual work and s



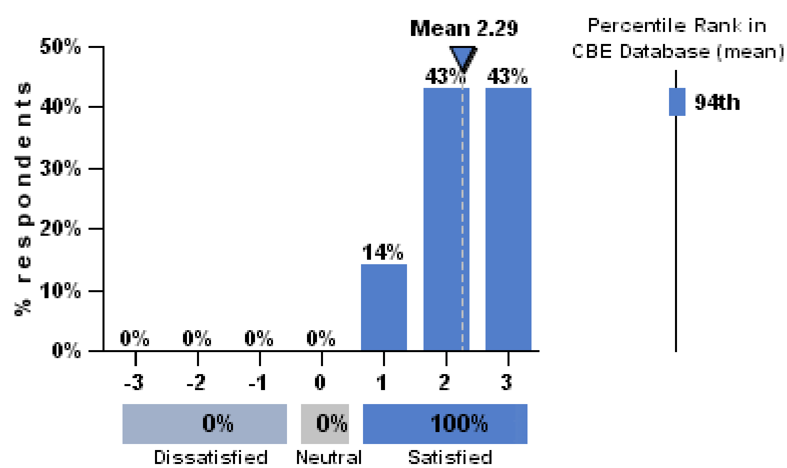
N=7

4.2) How satisfied are you with the level of visual privacy?



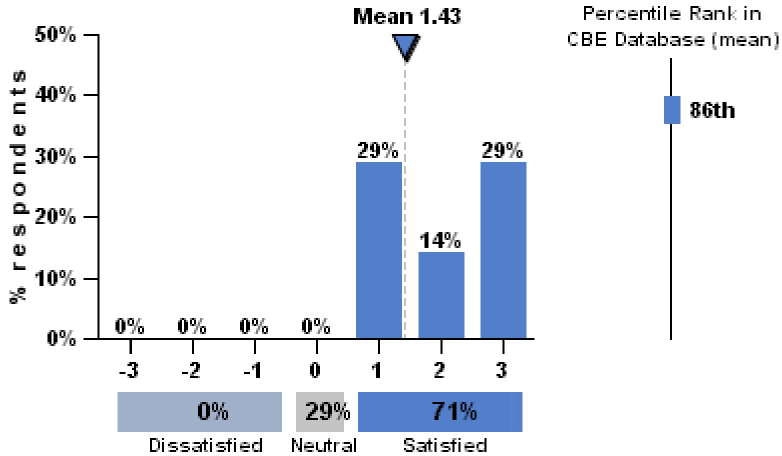
N=7

4.3) How satisfied are you with ease of interaction with co-workers?



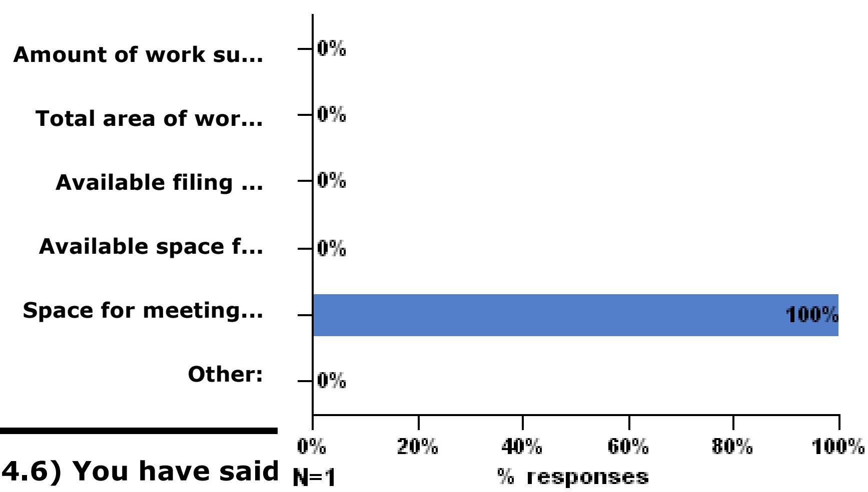
N=7

4.4) Overall, does the office layout enhance or interfere with your ability to get your jo



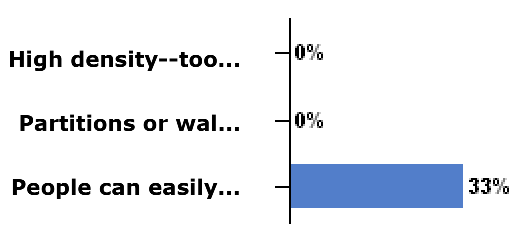
N=7

4.5) You have said that you are dissatisfied with the amount of space available for indi contribute to your dissatisfaction? *("N" for this question is calculated based on the nur*

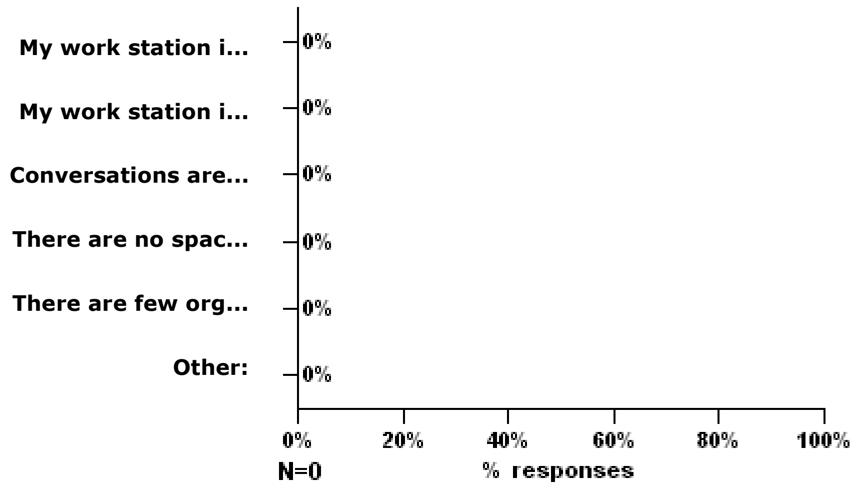


N=1

4.6) You have said ... of visual privacy. Which of th *("N" for this question is calculated based on the number of users who answered the qu*

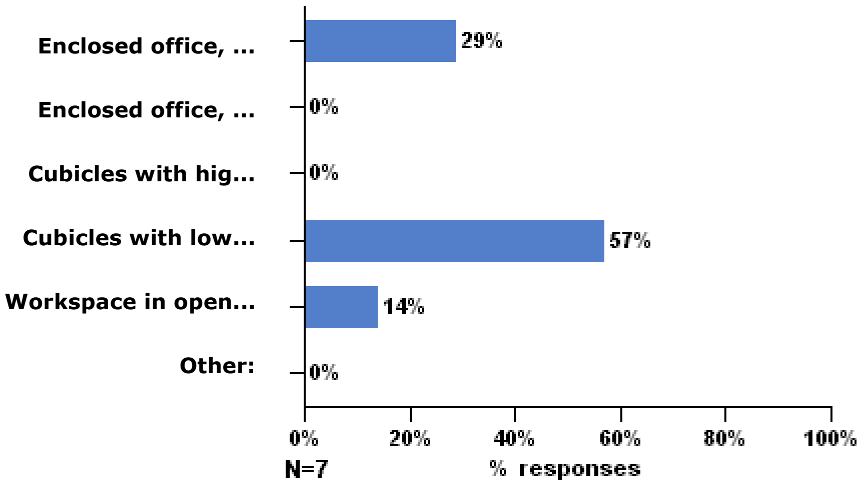


4.7) You have said that you are dissatisfied with the ease of interaction with co-worke dissatisfaction? ***("N" for this question is calculated based on the number of users who***



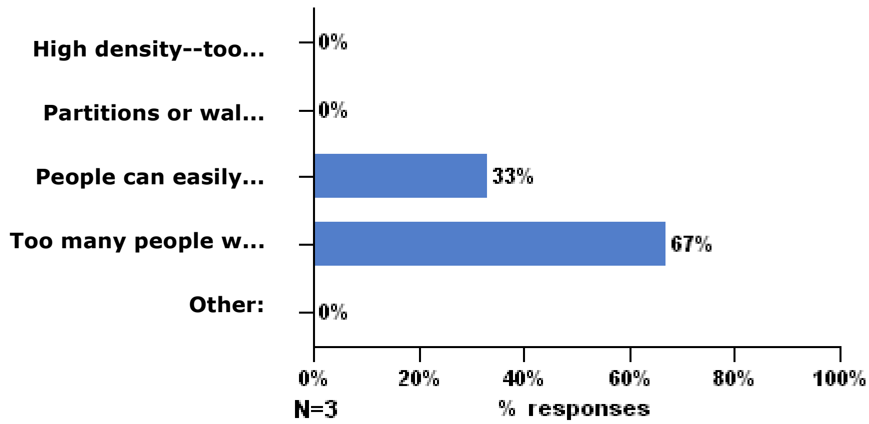
Personal Workspace Description

3.1) Which of the following best describes your personal workspace?



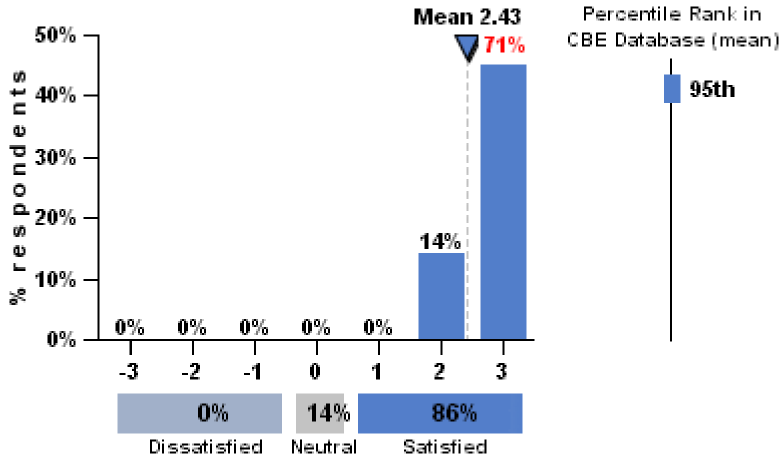
Visual Privacy

6.1) You have said that you are dissatisfied with the level of visual privacy. Which of the following contribute to your dissatisfaction? *("N" for this question is calculated based on the number of users who answered the question.)*



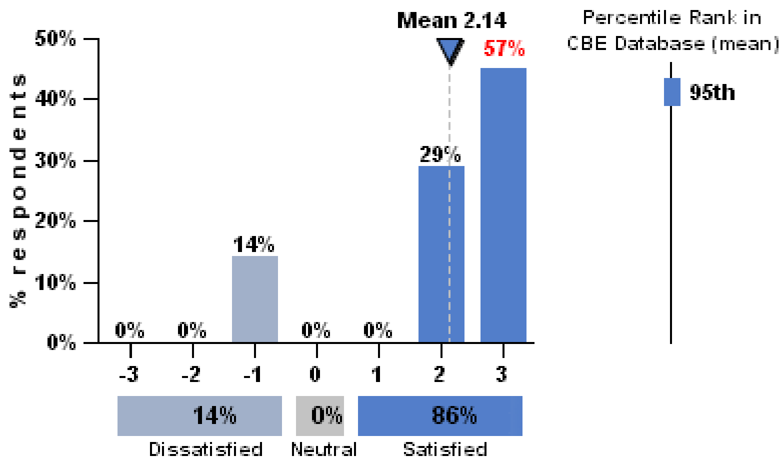
Office Furnishings

8.1) How satisfied are you with the comfort of your office furnishings (chair, desk, computer, equipment, etc.)?



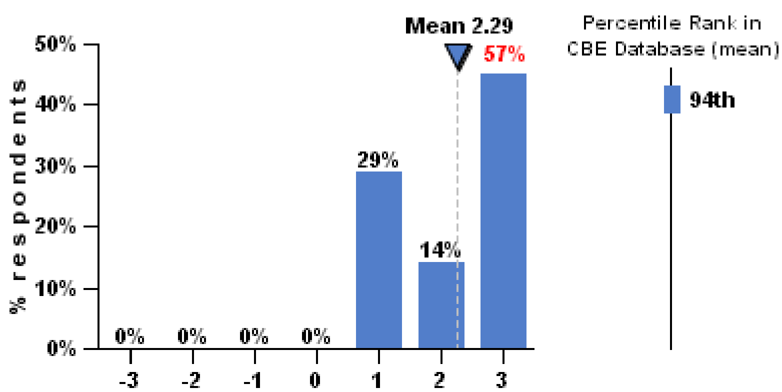
N=7

8.2) How satisfied are you with your ability to adjust your furniture to meet your needs?



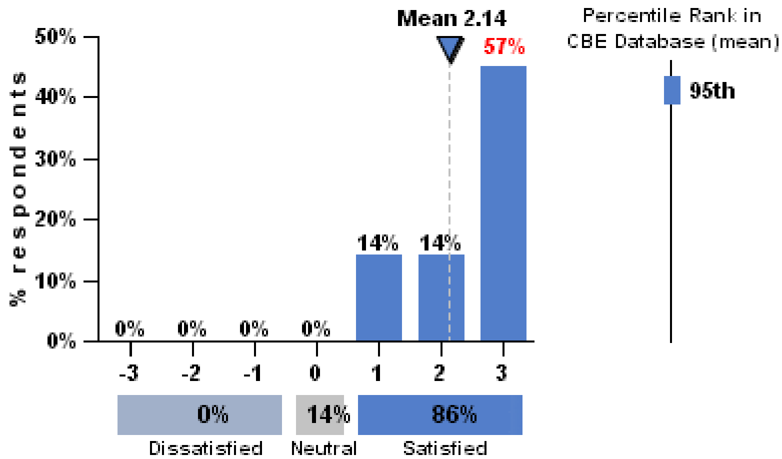
N=7

8.3) How satisfied are you with the colors and textures of flooring, furniture and surface finishes?



N=7

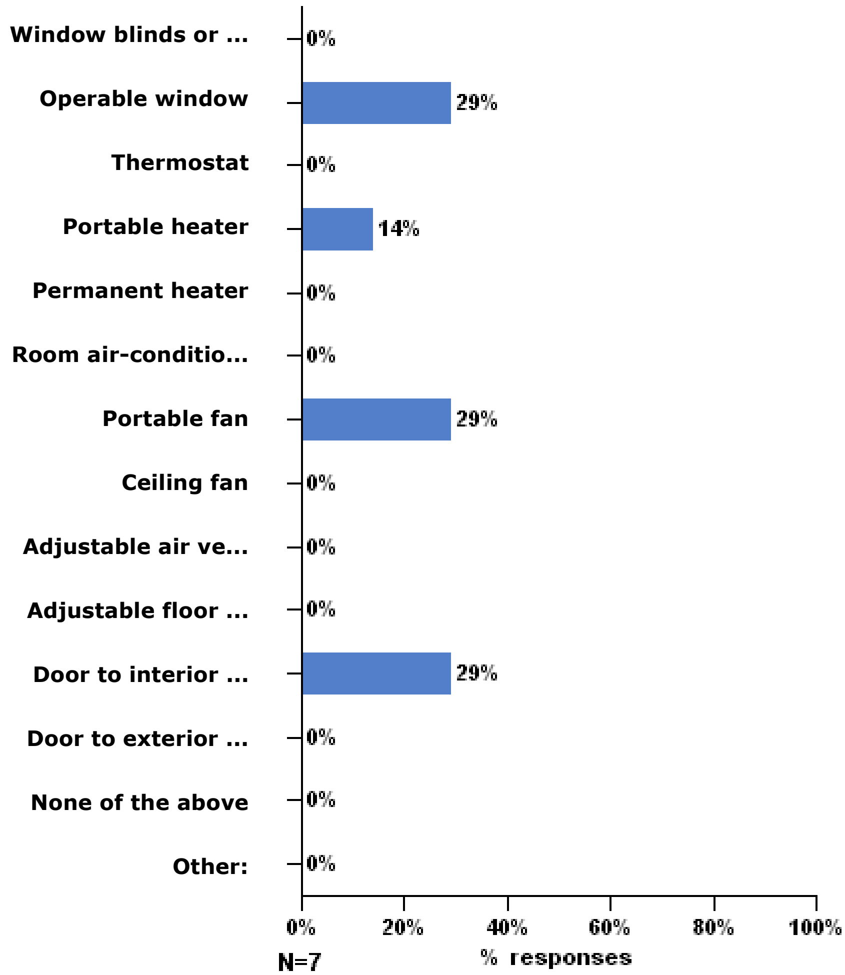
8.4) Do your office furnishings enhance or interfere with your ability to get your job done?



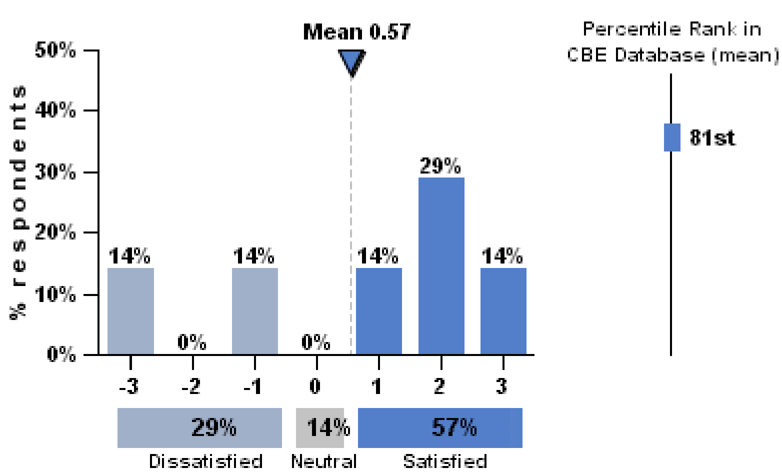
N=7

Thermal Comfort

9.1) Which of the following do you personally adjust or control in your workspace? *("N number of users who answered the question.)*

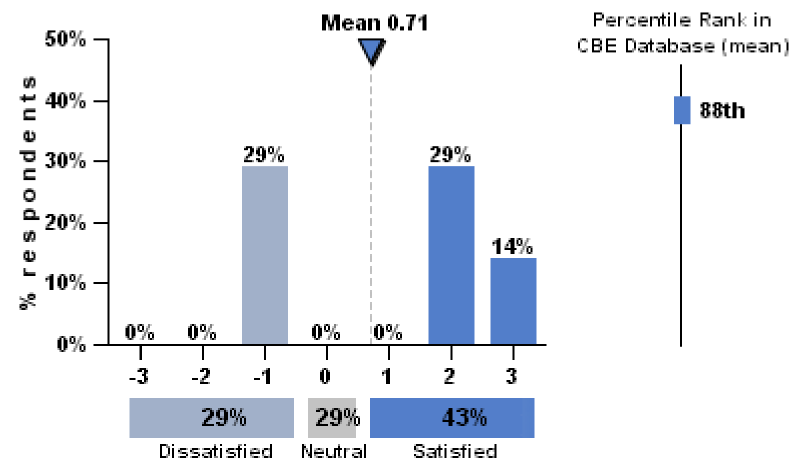


9.2) How satisfied are you with the temperature in your workspace?



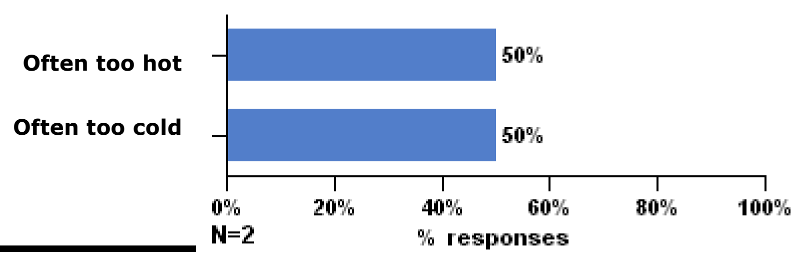
N=7

9.3) Overall, does your thermal comfort in your workspace enhance or interfere with y



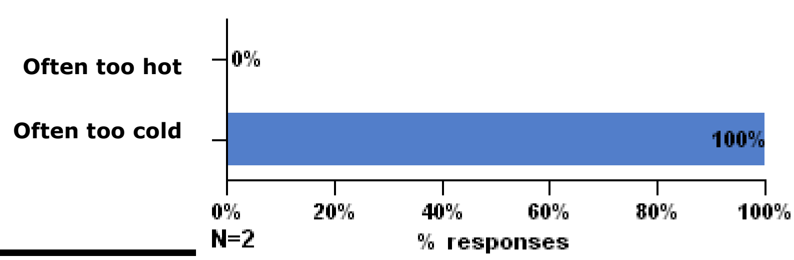
N=7

9.4) In warm/hot weather, the temperature in my workspace is: ***("N" for this question answered the question.)***



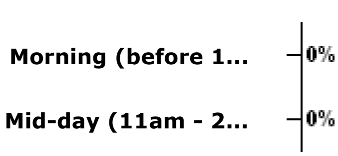
N=2

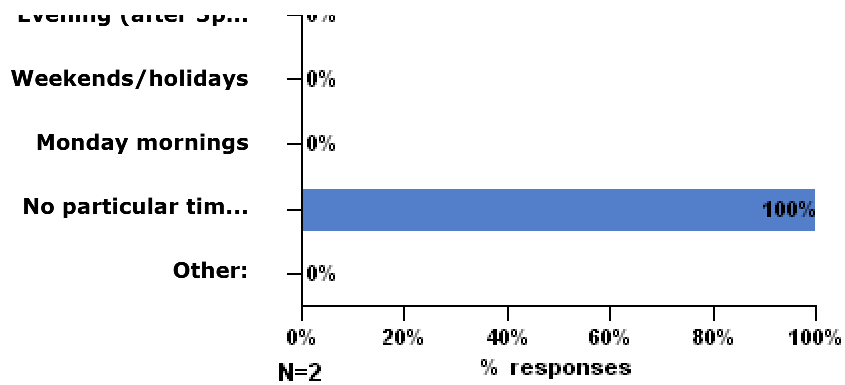
9.5) In cool/cold weather, the temperature in my workspace is: ***("N" for this question answered the question.)***



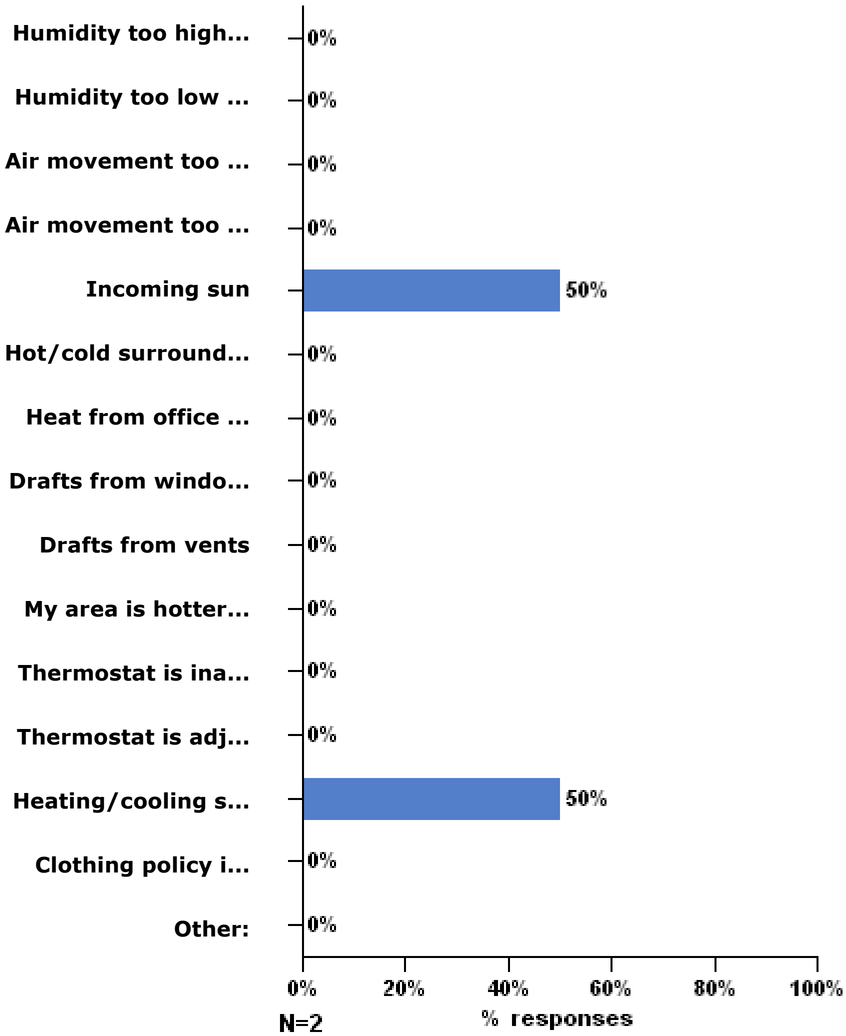
N=2

9.6) When is this most often a problem? ***("N" for this question is calculated based on t***



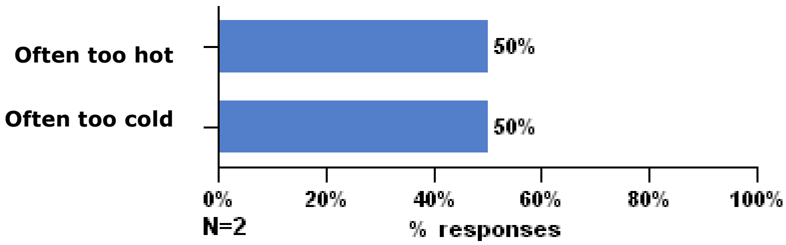


9.7) How would you best describe the source of this discomfort? *("N" for this question answered the question.)*

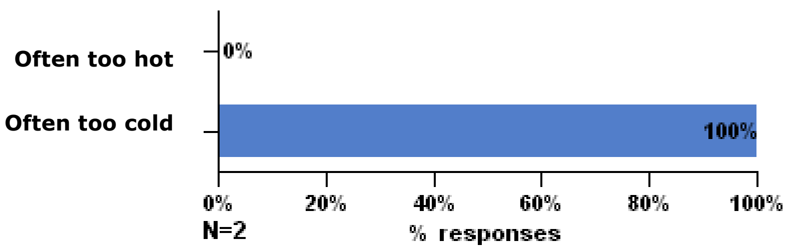


Temperature

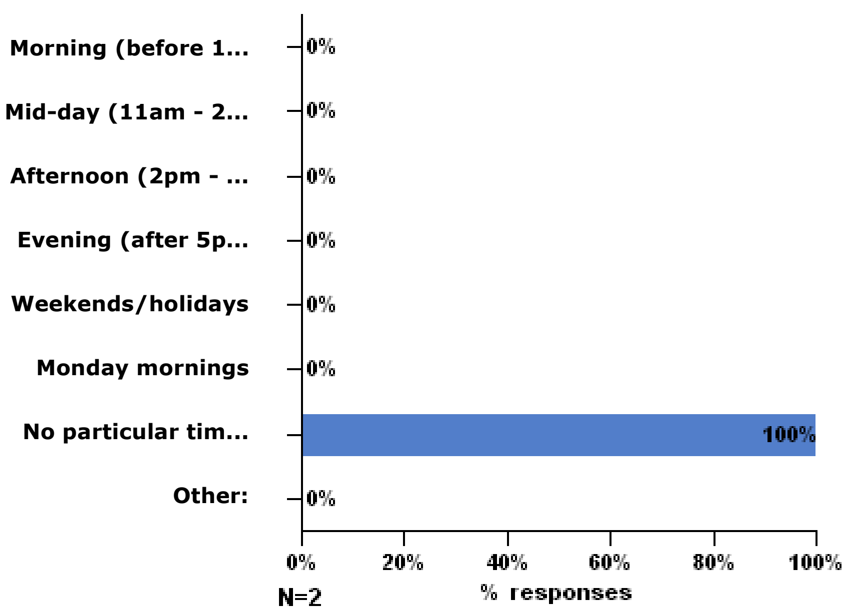
10.1) In warm/hot weather, the temperature in my workspace is: ***("N" for this question is calculated based on the number of users who answered the question.)***



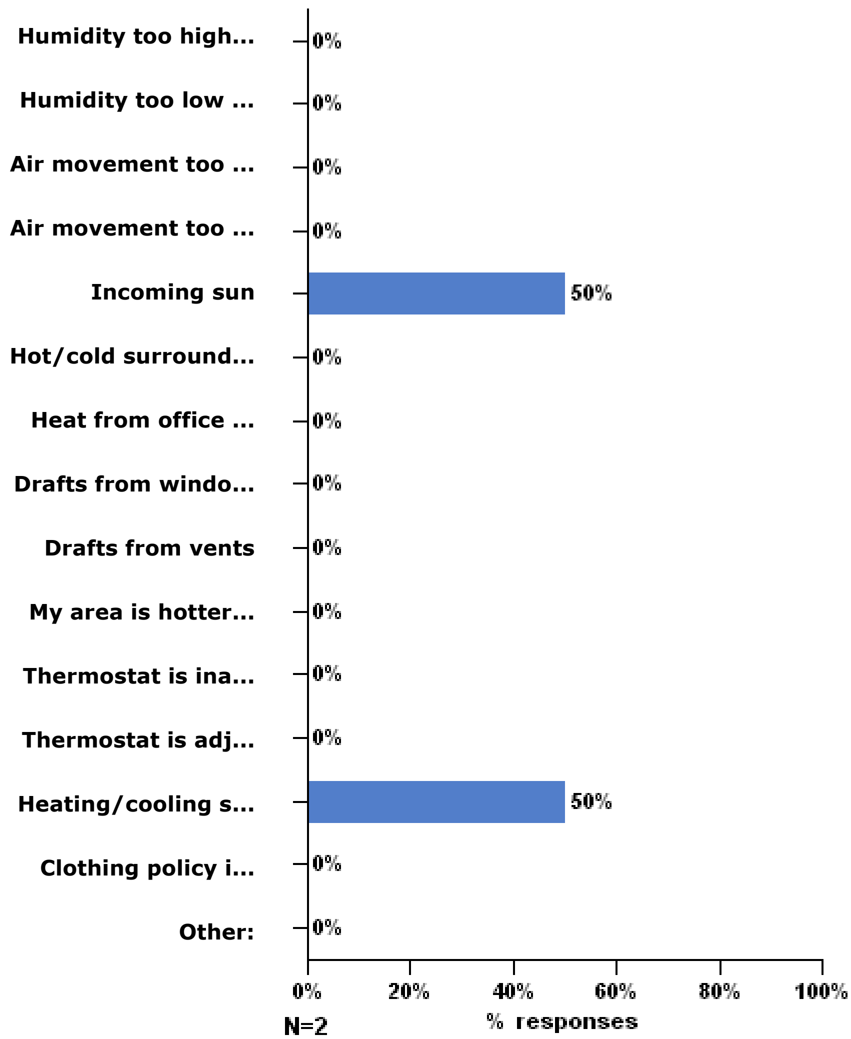
10.2) In cool/cold weather, the temperature in my workspace is: ***("N" for this question is calculated based on the number of users who answered the question.)***



10.3) When is this most often a problem? ***("N" for this question is calculated based on the number of users who answered the question.)***

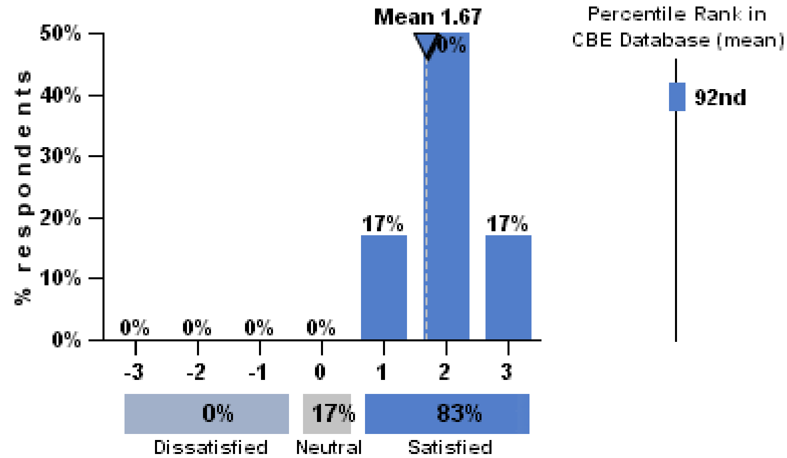


10.4) How would you best describe the source of this discomfort? ***("N" for this question is calculated based on the number of users who answered the question.)***


Humidity too high...
Humidity too low ...
Air movement too ...
Air movement too ...
Incoming sun
Hot/cold surround...
Heat from office ...
Drafts from windo...
Drafts from vents
My area is hotter...
Thermostat is ina...
Thermostat is adj...
Heating/cooling s...
Clothing policy i...
Other:
0%
0%
0%
0%
50%
0%
0%
0%
0%
0%
0%
0%
50%
0%
0%
0%
20%
40%
60%
80%
100%
N=2
% responses

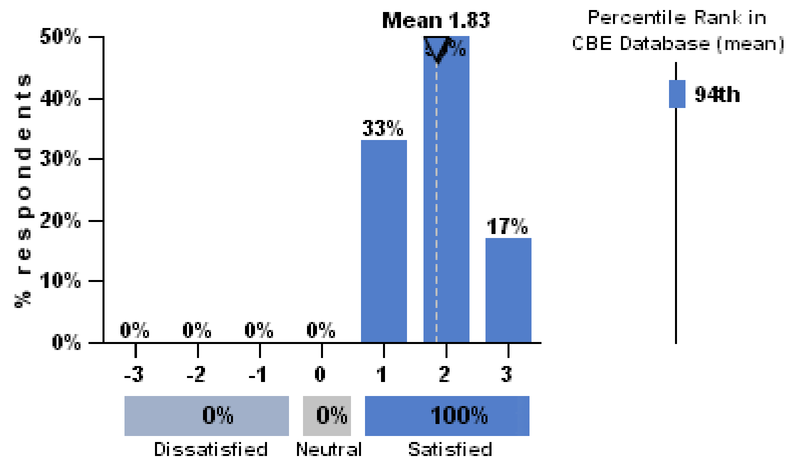
Air Quality

11.1) How satisfied are you with the air quality in your workspace (i.e. stuffy/stale air,



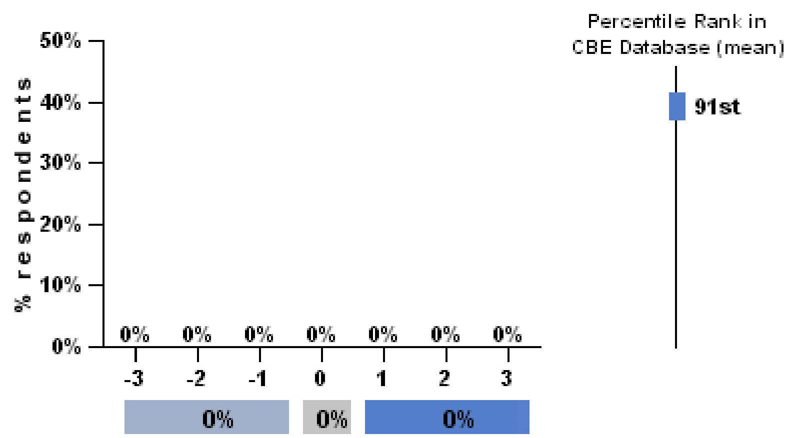
N=6

11.2) Overall, does the air quality in your workspace enhance or interfere with your ab



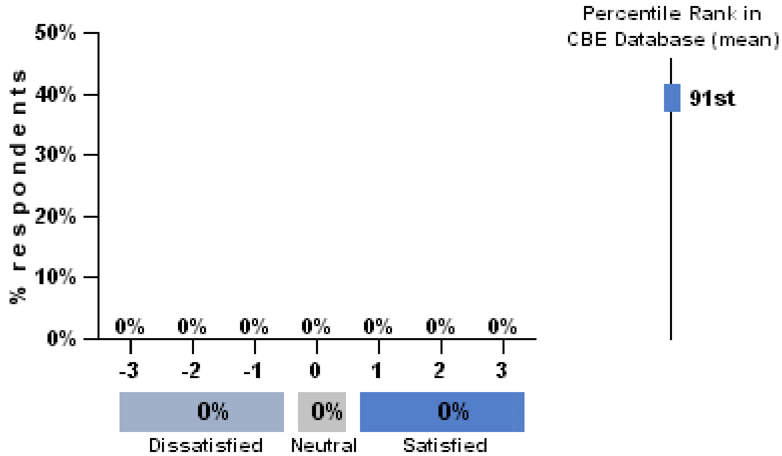
N=6

11.3) Air is stuffy/stale



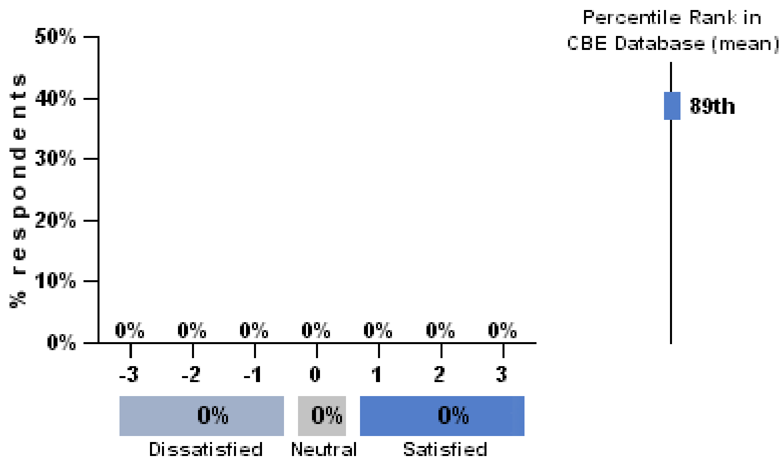
N=0

11.4) Air is not clean



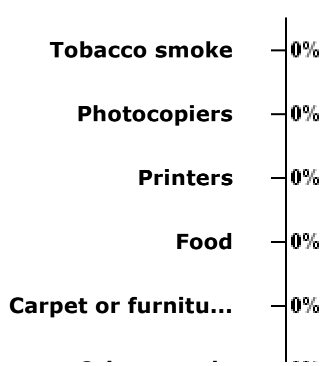
N=0

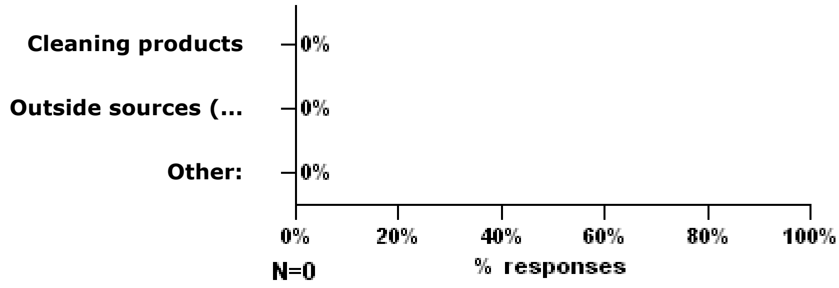
11.5) Air smells bad (odors)



N=0

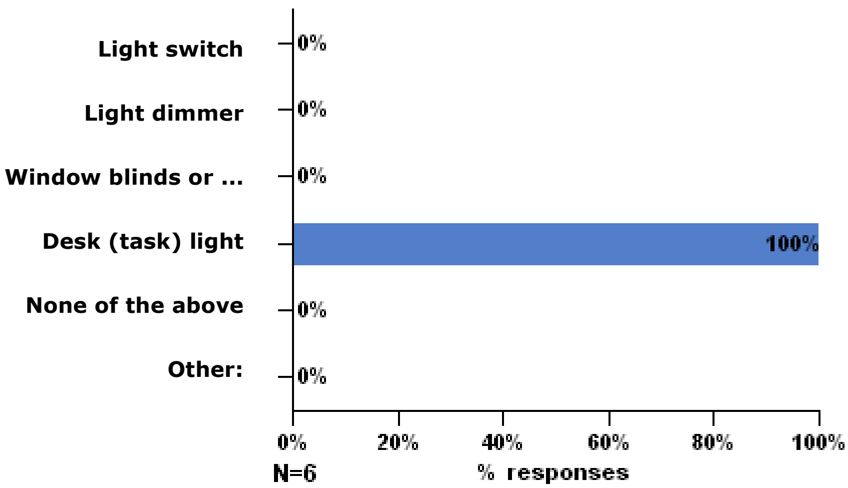
11.6) If there is an odor problem, which of the following contribute to this problem? *(" number of users who answered the question.)*



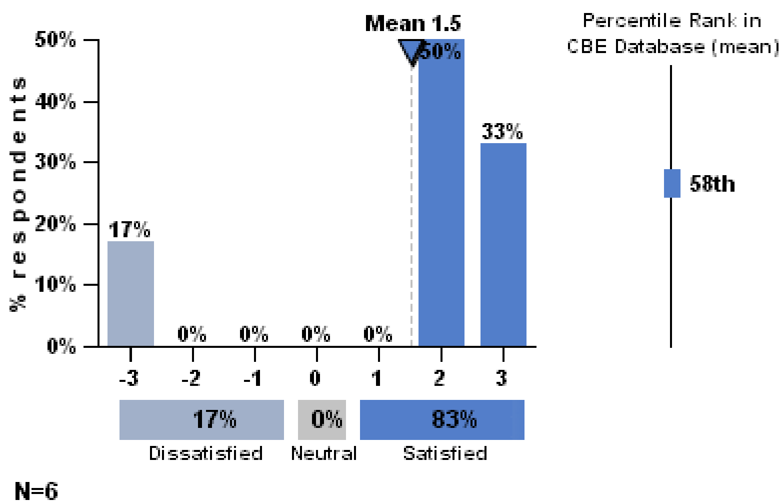

Cleaning products
0%
Outside sources (...
0%
Other:
0%
0%
20%
40%
60%
80%
100%
N=0
% responses

Lighting

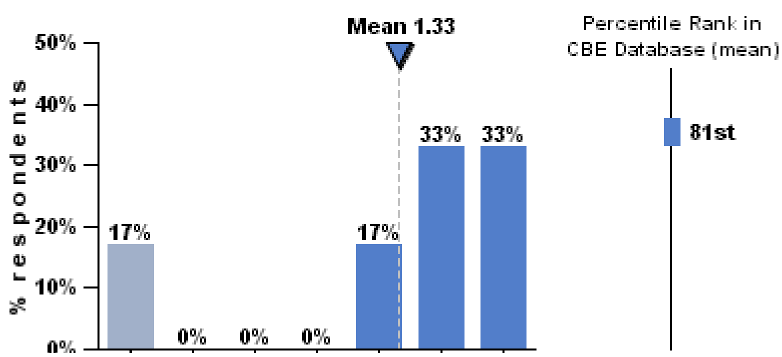
13.1) Which of the following controls do you have over the lighting in your workspace? *("N" for this question is calculated based on the number of users who answered the question.)*

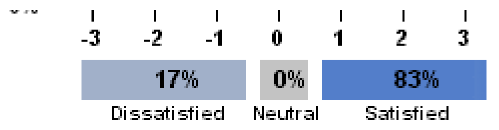


13.2) How satisfied are you with the amount of light in your workspace?



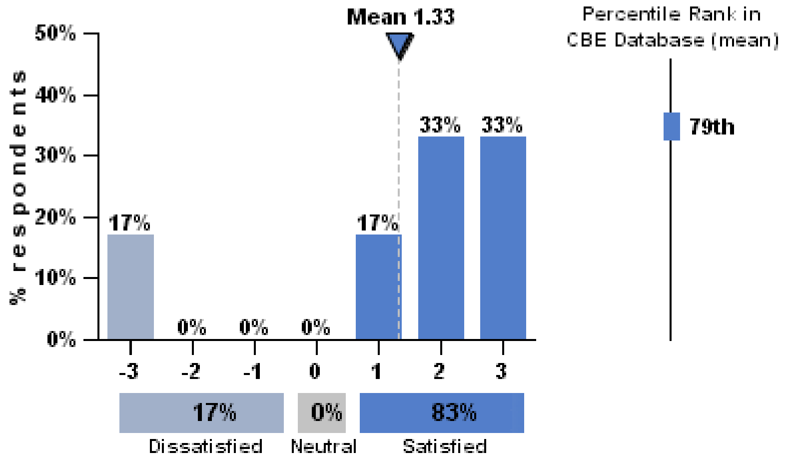
13.3) How satisfied are you with the visual comfort of the lighting (e.g., glare, reflections, contrast)?





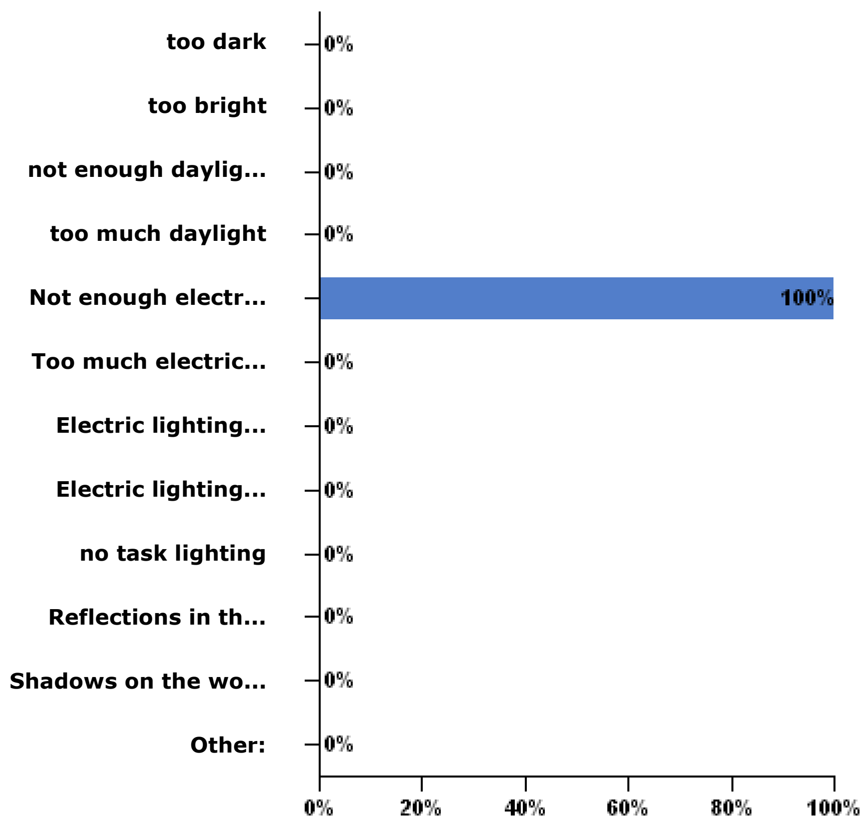
N=6

13.4) Overall, does the lighting quality enhance or interfere with your ability to get your job done?



N=6

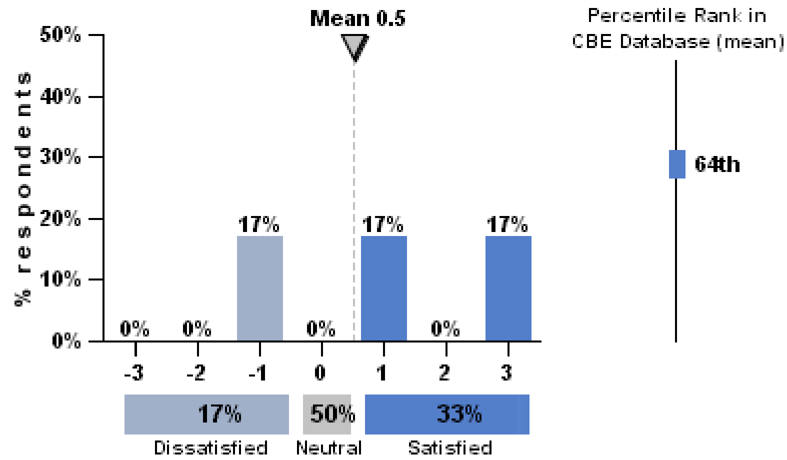
13.5) You have said that you are dissatisfied with the lighting in your workspace. Which of the following contribute to your dissatisfaction? *("N" for this question is calculated based on the number of users who answered the question.)*



N=1 % responses

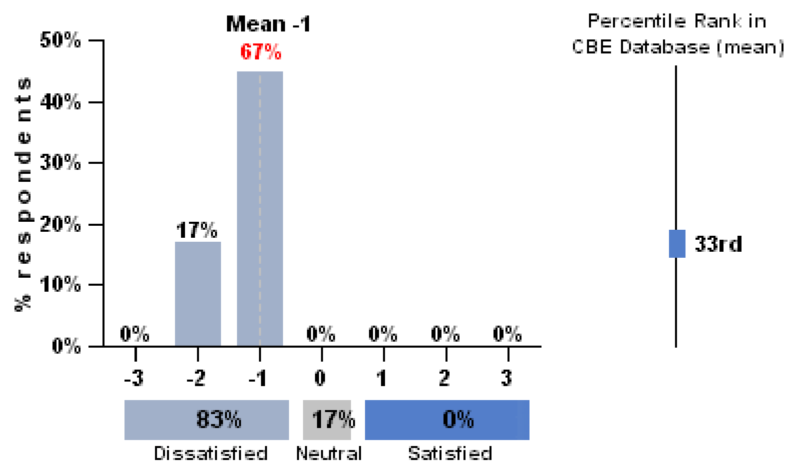
Acoustic Quality

15.1) How satisfied are you with the noise level in your workspace?



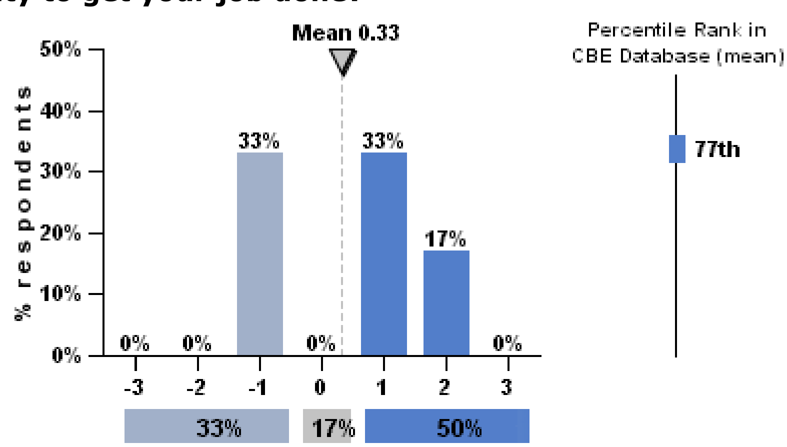
N=6

15.2) How satisfied are you with the sound privacy in your workspace (ability to have conversations without your neighbors overhearing and vice versa)?



N=6

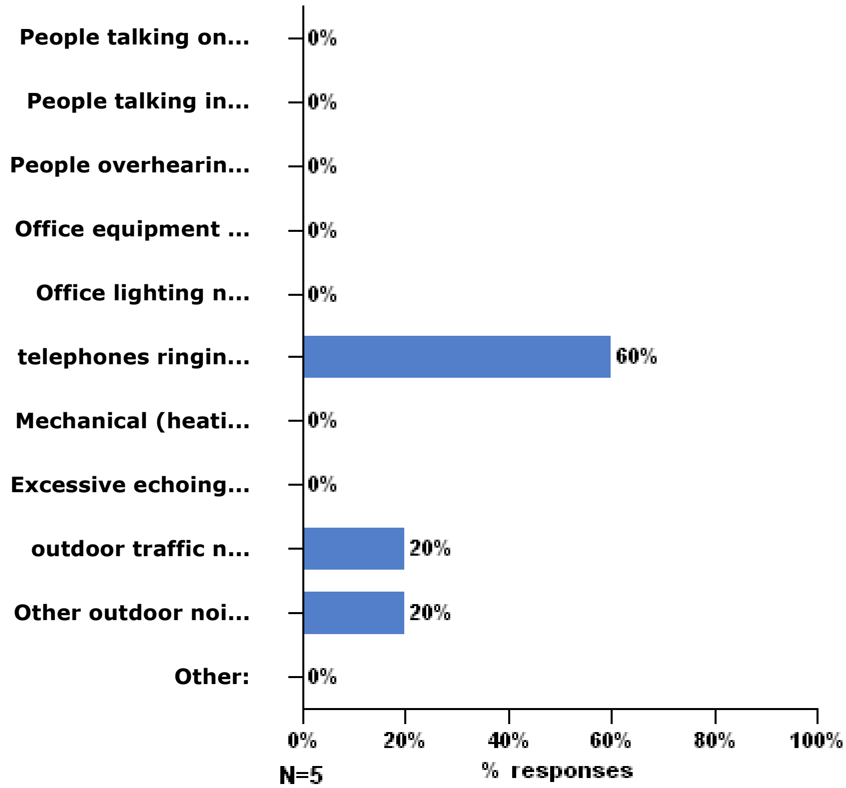
15.3) Overall, does the acoustic quality in your workspace enhance or interfere with your ability to get your job done?



Dissatisfied Neutral Satisfied

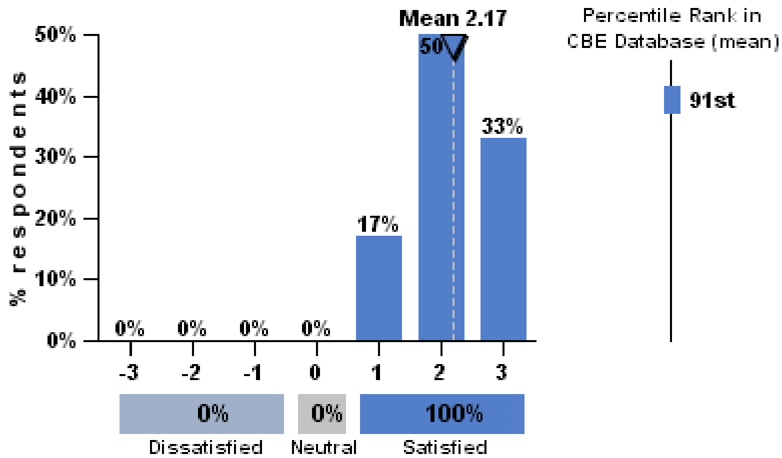
N=6

15.4) You have said you are dissatisfied with the acoustics in your workspace. Which of the following contribute to this problem? *("N" for this question is calculated based on the number of users who answered the question.)*



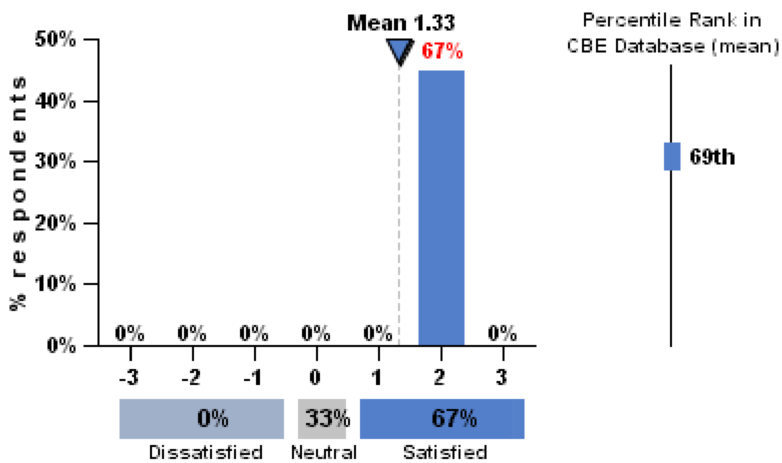
Cleanliness and Maintenance

19.1) How satisfied are you with general cleanliness of the overall building?



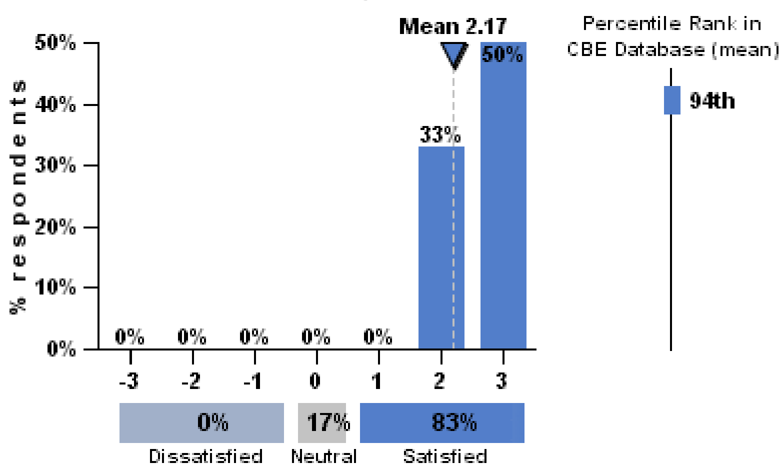
N=6

19.2) How satisfied are you with cleaning service provided for your workspace?



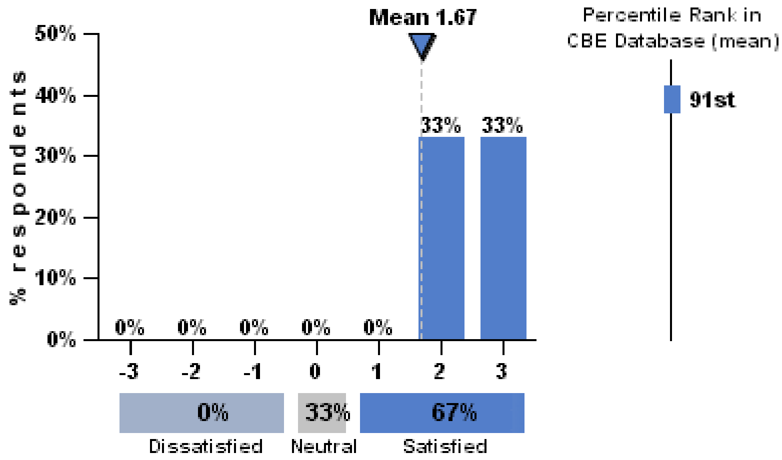
N=6

19.3) How satisfied are you with general maintenance of the building?



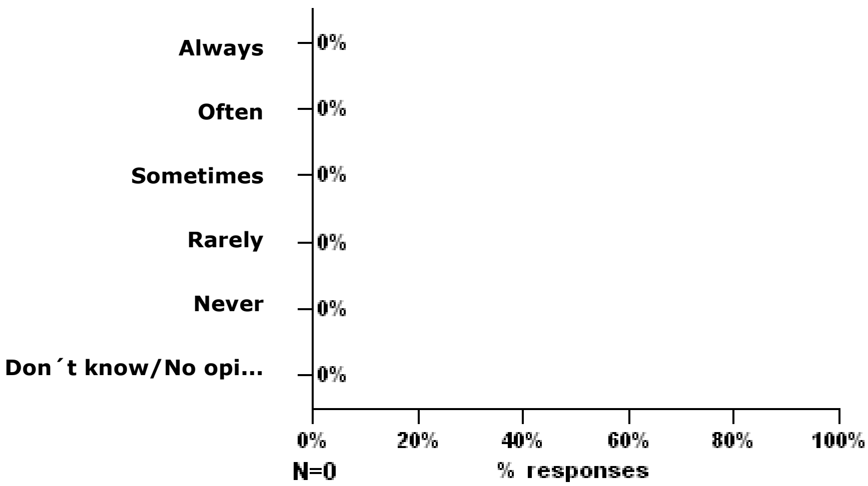
N=6

19.4) Does the cleanliness and maintenance of this building enhance or interfere with your ability to get your job done?

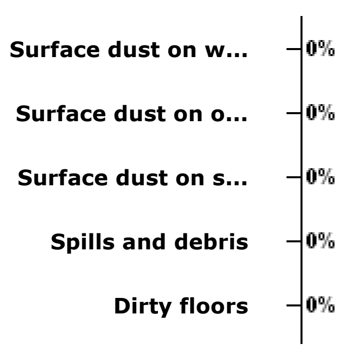


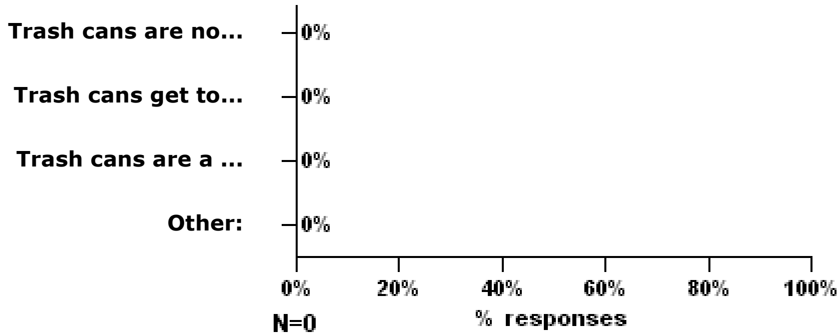
N=6

19.5) You have told us that you are dissatisfied with the cleaning service provided for your workspace. How often do you have significant problems?



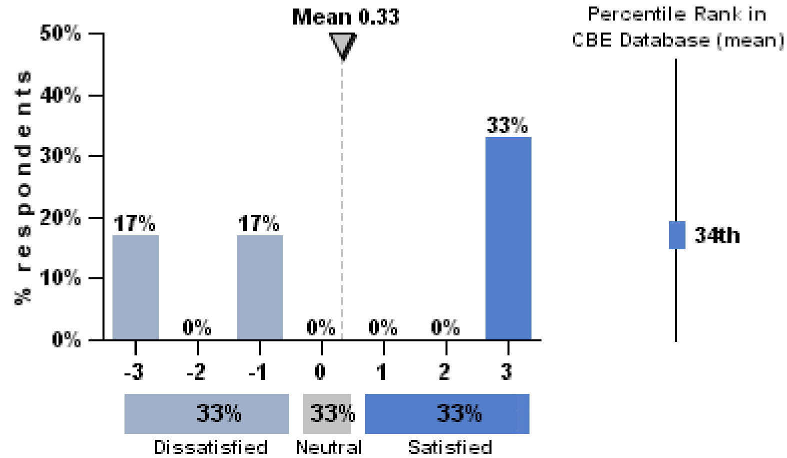
19.6) Which of the following contribute to this dissatisfaction? *("N" for this question is calculated based on the number of users who answered the question.)*




Trash cans are no...
Trash cans get to...
Trash cans are a ...
Other:
0%
0%
0%
0%
0%
20%
40%
60%
80%
100%
N=0
% responses

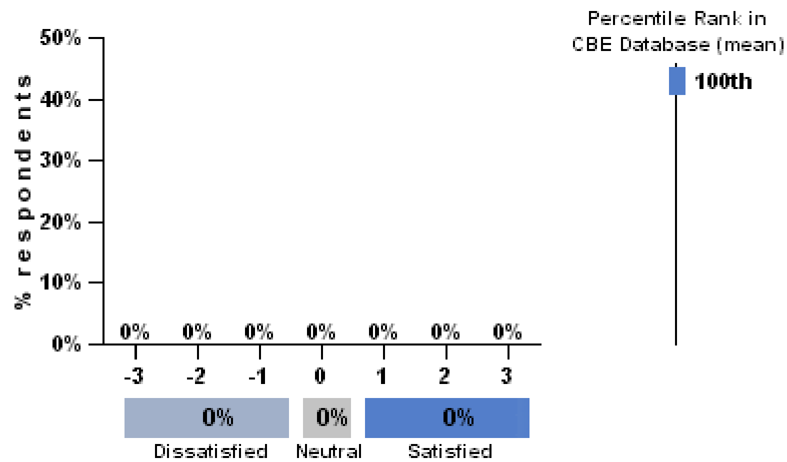
Building Features

19.1) Considering energy use, how efficiently is this building performing in your opinio



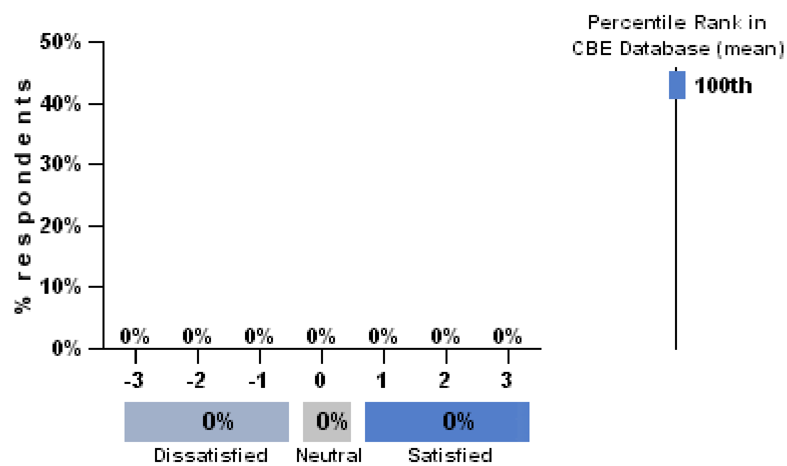
N=6

19.2) Floor air vents



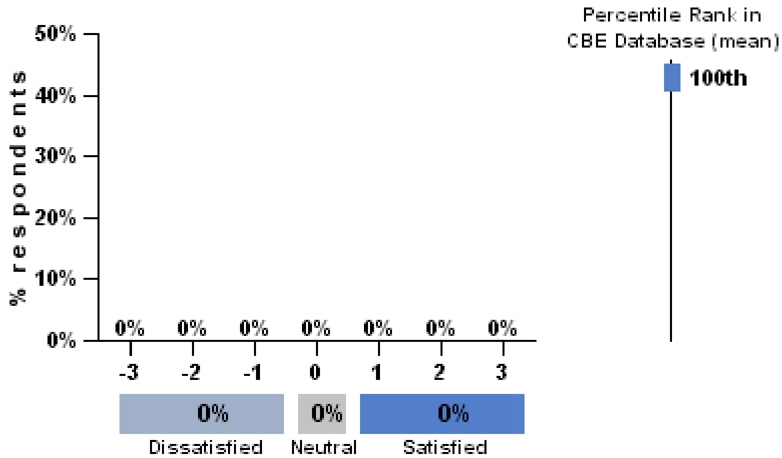
N=0

19.3) Thermostats



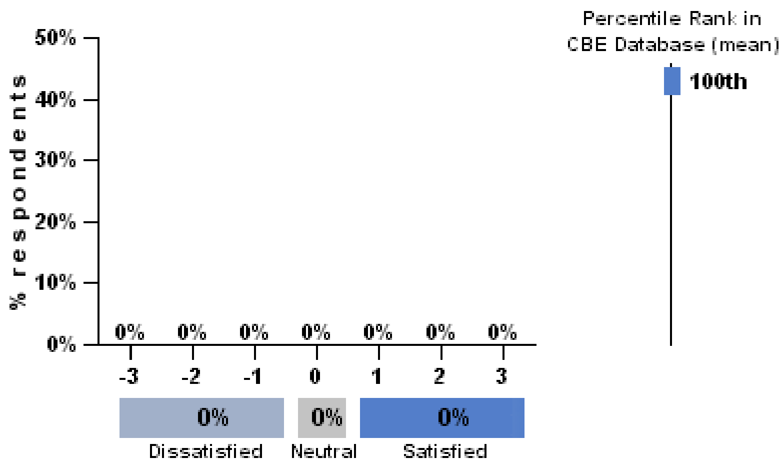
N=0

19.4) Light switches



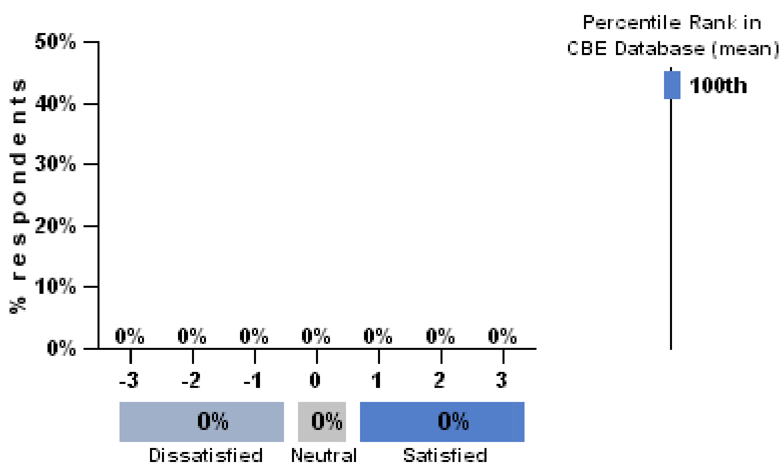
N=0

19.5) Automatic daylight controls



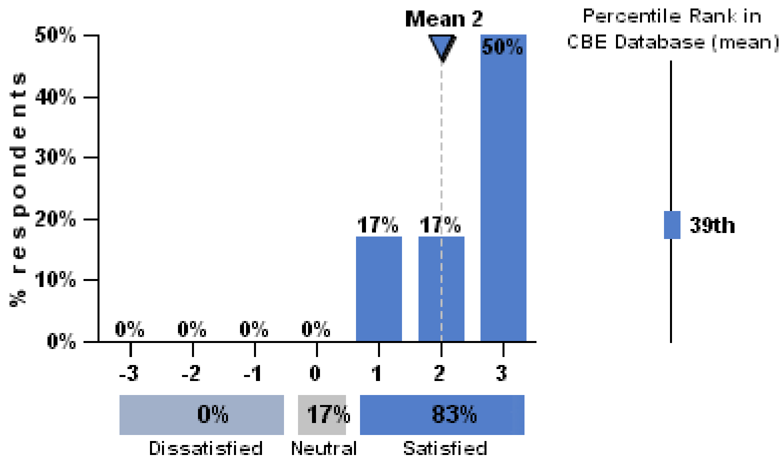
N=0

19.6) Occupancy sensors for lighting



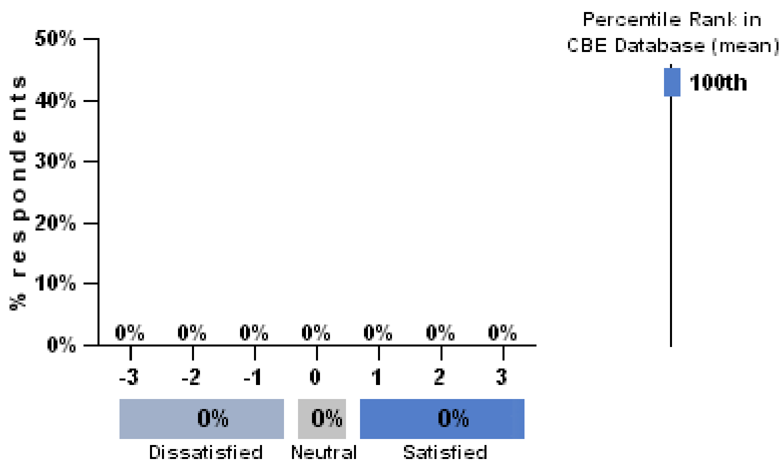
N=0

19.7) Window blinds



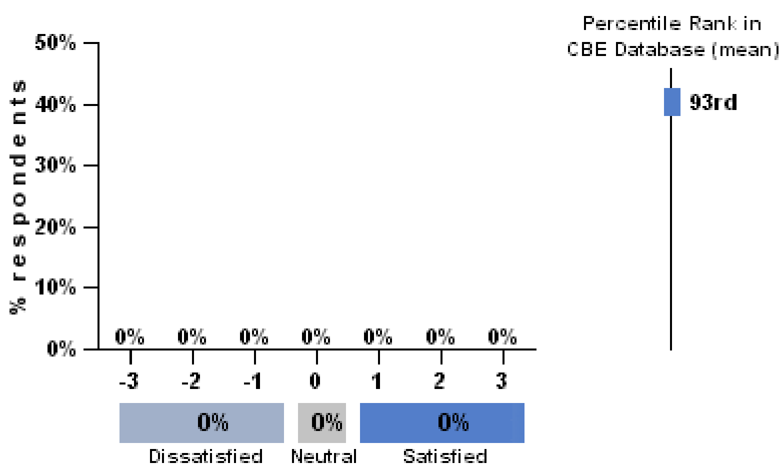
N=6

19.8) Roller shades



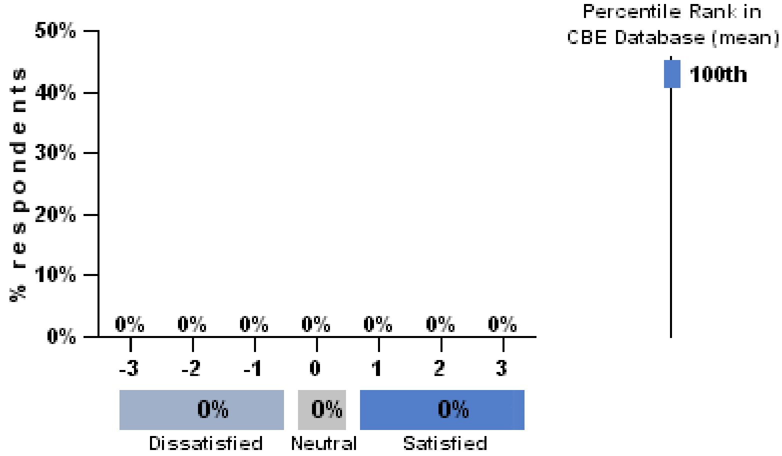
N=0

19.9) Exterior shades



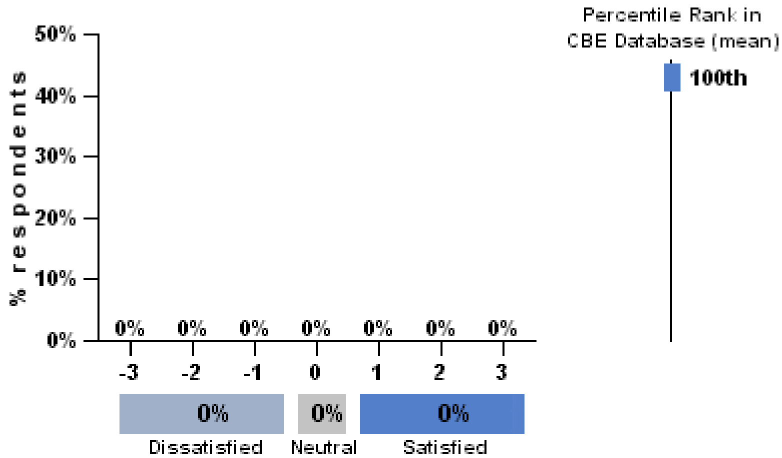
N=0

19.10) Low flow faucets



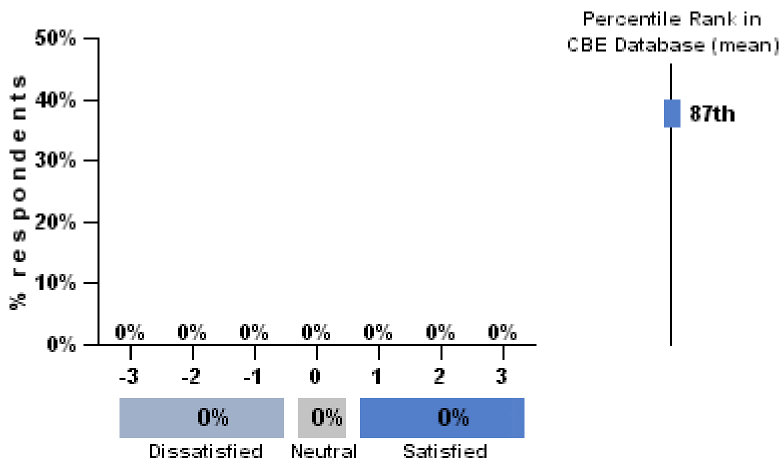
N=0

19.11) Private meeting rooms



N=0

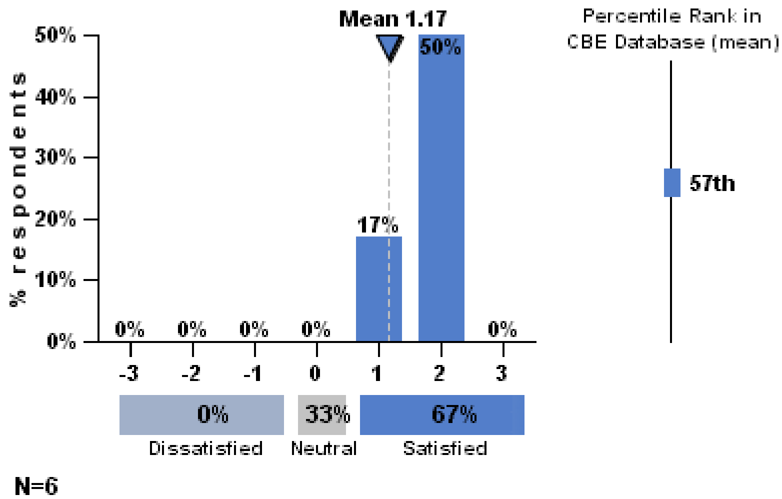
19.12) Security system



N=0

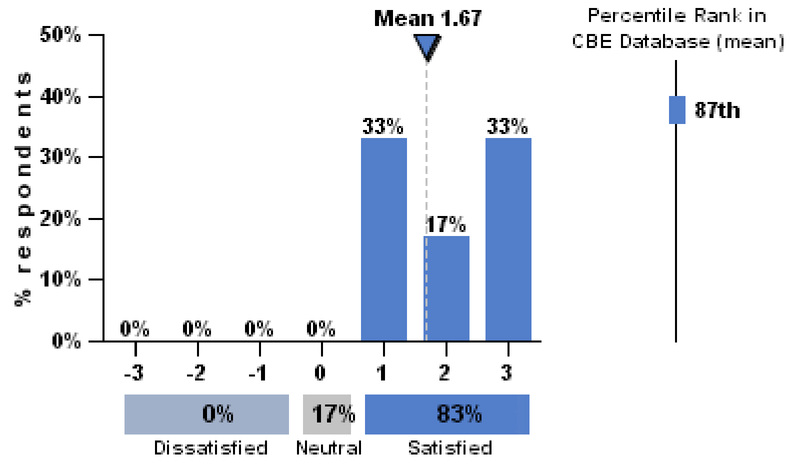
19.13) How well informed do you feel about using the above mentioned features in thi

19.13) How well informed do you feel about using the above mentioned features in thi



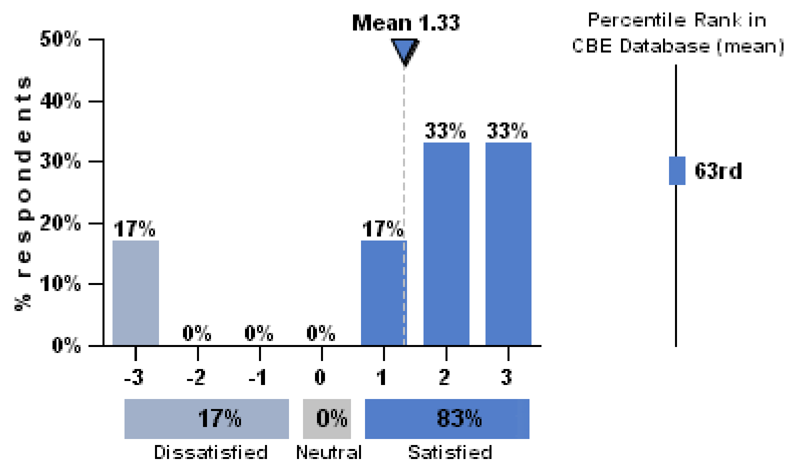
General Comments

20.1) All things considered, how satisfied are you with your personal workspace?



N=6

20.2) How satisfied are you with the building overall?



N=6

3.3 EMPIRICAL DATA

3.3.1 Indoor Air Quality Measurements

Ten sites were selected for air quality sampling on in Building D. Carbon dioxide, carbon monoxide, ultrafine particulate and composite volatile organic compounds (VOC) were evaluated in the morning and afternoon of July 17th, 2006, to assess variability over the day. Passive monitors for aldehydes were exposed for approximately 24 hours to collect integrated samples.

Results from sampling locations on each floor are shown in the following Tables. Optimal values in the rightmost column represent benchmark ranges for each measured variable.

Detailed results for each sampling location are included on the pages following the Tables.

Table 1: Selected indoor air quality parameters for private and open plan offices

Samples = 8	**unit**	**1st sample (9:00 – 10:00 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	< 1 - 99	< 1 - 120	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	1.1 – 3.4	1.1 – 1.2	0.2
Aldehydes				
CO_2 (range)	ppm	480 – 800	460 – 590	410 – 1000

Table 2: Selected indoor air quality parameters for photocopy and first aid rooms.

Samples = 2	**unit**	**1st sample (9:00 – 10:00 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	95 - 130	< 1 - 160	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	1.3 – 4.5	1.0 – 1.3	0.2
Aldehydes				
CO_2 (range)	ppm	480 – 650	530 – 690	410 – 1000

Building Performance Evaluation: IAQ

Date: 17-Jul-06

Building: Building D

Position:

Sample 1	Photocopy room
Sample 2	Private office near photocopy room
Sample 3	2nd private office
Sample 4	3rd private office
Sample 5	4th private office (windows on south and west)
Sample 6	South end of building, open plan office
Sample 7	Open office
Sample 8	Open office behind receptionist work area (SE side)
Sample 9	Receptionist work area (behind reception counter)
Sample 10	First aid room

Notes:

Morning	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Time:	9:11	9:25	9:36	9:37	9:44	9:40	9:40	9:52	9:56	10:00
weather:	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	NA
ppbRAE	130	60	75	50	99	<1	10	32	2	95
P-Track	5020	4440	5230	4750	5990	5580	6660	8130	13400	18000
CO2	647	480	580	530	685	800	555	545	530	480
CO	<1	<1	<1	<1	<1	<1	<1	<1	1	1
Temperature	25.3	24	24.3	24.2	23.9	23.4	24.4	25.1	27.7	25.1
%RH	42.7	41.9	41.3	42.4	43.2	43.3	42.4	41.7	39.3	38.6

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor <1

P-track (pt/cc) 3980

CO2 (ppm) outdoor 410 21.4oC 42.7% RH

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
I:O VOC	130	60	75	50	99	0	10	32	2	95
I:O P-track	1.3	1.1	1.3	1.2	1.5	1.4	1.7	2.0	3.4	4.5

Afternoon	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Time:	3:10	3:15	3:18	3:20	3:23	3:26	3:28	3:31	3:32	3:34
weather:	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	NA
ppbRAE	160	100	10	50	120	<1	<1	<1	<1	<1
P-Track	11600	13500	13200	12800	13500	14100	13800	14000	15000	15900
CO2	685	480	483	560	522	460	590	497	483	529
CO	1	1	1	1	1	1	1	1	1	1
Temperature	27.1	26.3	25.9	25.8	25.8	24.6	25.2	25.1	24.8	25.1
%RH	38.1	37.7	38.3	39.3	39.6	38.9	40.5	40.1	40.1	41.7

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor <1

P-track (pt/cc) 12100

CO2 (ppm) outdoor 428 28.2oC 37.9%RH

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
I:O VOC	160	100	10	50	120	0	0	0	0	0
I:O P-track	1.0	1.1	1.1	1.0	1.1	1.2	1.1	1.2	1.2	1.3

3.3.2 Thermal Comfort Measurements

Ten sites were selected for thermal measurement based on the results of the web-based occupant satisfaction survey, in locations of high and low satisfaction. Both internal rooms and spaces near windows were selected for thermal measurement.

The following Table shows thermal results for the ten sample locations, taken three times during the day on July 11, 2006 to assess variability over the day. The dry bulb temperature in the fourth column indicates the air temperature in each space, and the setpoint temperature in the fifth column indicates the temperature to which each space is to be conditioned by the building's heating and cooling systems.

Building D – Thermal Measurements, July 11, 2006

Time (morn)	Weather	Location	Air Temp	Setpoint	BMS	BMS	Air velocity	Description
10:13	cloudy	1	23.8	20	23	23.3	0.01	Open office, perimeter
10:20	cloudy	2	23.6	25	23.8	24.3	0.08	Copy room
10:27	cloudy	3	24.5	25	24.9	25.3	0.01	Private office, perim
10:07	cloudy	4	24.9	23	24.9	25.1	0.01	Lunch/meeting room
10:50	cloudy	5	22	20	22.2	23.1	0.13	Lunchroom
10:40	cloudy	6	22.4	20	23	23.1	0.00	Mud room
11:10	cloudy	7	25.9	25	25.4	25.8	0.00	Meeting room, upper
11:03	sun+cloud	8	22.8	25	24.2	24.2	0.01	Open area, upper
10:56	sun+cloud	9	21.2	19	22.8	22.2	0.09	Outside mech room
10:33	cloudy	10	20.6	none			0.06	Washroom
11:25	sun+cloud	Outside	20.9					
Time (mid)	Weather	Location	Air Temp	Setpoint	BMS	BMS	Air velocity	Description
11:50	sun+cloud	1	24	20	23.3	23.5	0.00	Open office, perimeter
11:56	cloudy	2	23.2	25	24.1	24.1	0.12	Copy room
12:03	cloudy	3	23.7	25	25	24.9	0.01	Private office, perim
11:39	sun+cloud	4	24.6	23	25	25.1	0.01	Lunch/meeting room
12:24	sun+cloud	5	22.2	20	23.2	22.3	0.00	Lunchroom
12:17	cloudy	6	23	20	23.3	23.5	0.00	Mud room
12:56	cloudy	7	25.5	25	25.9	26	0.20	Meeting room, upper
12:46	cloudy	8	22.1	25	23.9	23.7	0.00	Open area, upper
12:32	cloudy	9	21.4	19	21.9	21.6	0.08	Outside mech room
12:10	cloudy	10	22	none			0.05	Washroom
1:08	cloudy	Outside	21.8					
Time (aft)	Weather	Location	Air Temp	Setpoint	BMS	BMS	Air velocity	Description
1:55	cloudy	1	24.3	20	23.7	23.9	0.01	Open office, perimeter
2:02	cloudy	2	24.1	25	24.2	24.7	0.09	Copy room
2:09	cloudy	3	24	25	25.2	25.6	0.01	Private office, perim
2:45	cloudy	4	24.7	23	25.1	25.3	0.00	Lunch/meeting room
2:22	sun+cloud	5	23	20	23.7	22.8	0.05	Lunchroom
2:15	sun+cloud	6	23.2	20	23.7	23.9	0.00	Mud room
2:54	sun+cloud	7	25.8	25	25.9	25.9	0.08	Meeting room, upper
2:37	cloudy	8	22.2	25	23.8	24	0.04	Open area, upper
2:29	cloudy	9	22.8	19	22.3	23	0.00	Outside mech room
1:22	cloudy	10	22	none			0.08	Washroom
3:10	cloudy	Outside	24.5					

note: s=sun, c=cloud, r=rain, w=wind, f=fog

note: morn=morning, mid=midday, aft=afternoon

3.3.3 Acoustic Measurements

Based on a walk-through acoustical survey and on information from the web-based survey, acoustic measurements were made in the following locations, expected to be of particular interest acoustically, under various conditions:

- R1 – Southwest private office
- R2 – Private office near reception
- R3 – Reception area
- R4 – Office equipment room
- R5 – Lunch room
- R6 – First floor meeting room
- R7 – South open office cubicle
- R8 – First aid room

The following variables were measured at each sample location, as appropriate. Benchmark ranges for each variable are shown in the following Table.

Table 2: Acoustic measured variables and benchmark ranges

Measured Variable	Benchmark Ranges
Background-noise level, BN in dB	NC30-35 in meeting and conference rooms, NC35-40 in workspaces
Mid-frequency Reverberation time, RT in s	RT < 0.75 s for a comfortable environment and easy verbal communication
Speech Intelligibility Index, SII	Speech intelligibility requires SII > 0.7, Speech privacy requires SII < 0.2
Noise Isolation Class, NIC in dB	NIC35-40 dB for private offices and conference rooms, NIC30-35 dB for open offices and meeting rooms

Measurements were made under relevant operational and environmental conditions – for example, windows open and closed, office doors open and closed.

Results for each sampling location are found in the following Table.

Building D - Acoustics Measurements

Location	*Background Noise (dB)*	*Reverberation Time (sec)*	*Speech Intelligibility (SII)*	*Noise Isolation (NIC dB)*
R1	NC26 unoccupied, window/door closed NC36 occupied, window/door open	0.5	0.77 across desk, unoccupied, casual voice 0.56 from adjacent office, door open, casual voice	-
R2	NC30 window/door closed NC39 window/door open	-	-	38 from adjacent room, doors closed 35 from adjacent room, doors open
R3	NC41 unoccupied building NC48 occupied building, windows closed	0.6	0.03-0.10 from nearby cubicles, casual voice	29 from adjacent room, door closed 13 from adjacent room, door open
R4	NC60, equipment operating	-	-	-
R5	NC50 unoccupied, door closed NC47 occupied, door closed	0.8	-	-
R6	NC48 unoccupied, door closed NC55 occupied, door open	0.7	0.67 across table, doors closed, normal voice	29 doors closed 19 doors open
R7	NC38-41 unoccupied, windows closed NC48 occupied, windows closed NC49 unoccupied, truck passing, windows open	0.6	-	-
R8	NC15 door closed	-	-	33 from lunchroom, door closed

3.3.4 Lighting Measurements

Ten sites in Building D were selected for lighting measurements. Sites were sampled in the morning and in the afternoon of July 17th, 2006, to assess light level variability over the day.

Detailed results for sampling locations in each quadrant are shown in the following Tables. Optimal values in the rightmost column represent benchmark ranges for each measured variable.

Detailed results for each sampling location are included on the pages following the Tables.

Table 1: Light measurements taken from private offices (west-facing windows)

Private offices (n=4)	**unit**	**1st sample (9:00 – 10:00 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	4	4	NA
Blinds closed or greater than 50% closed	n	0	0	
Glare:				
Yes, veiling glare on work surface	n	4	4	NA
No glare	n	0	0	
Overhead lighting				
Lights "ON"	n	1	0	NA
Lights "OFF"	n	3	4	
Incident light				
Measured range	lux	440 – 770	295 – 770	200 – 500
Comfort ratios				
Incident light to background	range	0.3 – 5.5	0.5 – 2.8	0.3 – 3
Computer to background		0.2 – 1.4	0.3 – 1.7	0.1 – 10
Morning to afternoon incident light ratio	range	0.6 – 2.4		NA

Table 2: Light measurements taken from open plan offices (east/south-facing windows)

Work areas in open plan areas (n=4)	**unit**	**1st sample (9:00 – 10:00 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	1	1	NA
Blinds closed or greater than 50% closed	n	3	3	
Glare:				
Yes, veiling glare on work surface	n	3	3	NA
No glare	n	1	1	
Overhead lighting				
Lights "ON"	n	0	0	NA
Lights "OFF"	n	4	4	
Incident light				
Measured range	lux	80 – 1750	51 – 250	200 – 500
Comfort ratios				
Incident light to background	ratio	0.1 – 2.4	0.1 – 0.9	0.3 – 3
Computer to background		0.1 – 6.1	0.1 – 0.8	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	1.3 – 7.0		NA

Table 3: Light measurements taken from printer room and first aid room

Specialty rooms (n=2)	**unit**	**1st sample (9:00 – 10:00 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Glare:				
Yes, veiling glare on work surface	n	1	1	NA
No glare	n	1	1	
Overhead lighting				
Lights "ON"	n	2	2	NA
Lights "OFF"	n	0	0	
Incident light				
Measured range	lux	357 – 490	445 – 487	300 – 500
Comfort ratios				
Incident light to back-ground (range)	ratio	2.3 – 4.0	1.9 – 4.6	0.3 – 3
Morning to afternoon incident light ratio	ratio	0.8 – 1.0		NA

Building Performance Evaluation: Lighting

Date: 17-Jul-06

Building: Building D

Position:

Sample 1	Photocopy room
Sample 2	Private office near photocopy room
Sample 3	2nd private office
Sample 4	3rd private office
Sample 5	4th private office (windows on south and west)
Sample 6	South end of building, open plan office
Sample 7	Open office
Sample 8	Open office behind receptionist work area (SE side)
Sample 9	Receptionist work area (behind reception counter)
Sample 10	First aid room

Notes:

Morning	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Time:	9:11	9:25	9:36	9:37	9:44	9:40	9:40	9:52	9:56	10:00
weather:	NA	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	NA
fenestration:	NA	open	open	open	open	75% closed	closed	closed	open	NA
Incident (lux)	490	770	450	440	450	200	80	1750	140	357
Task lighting	No	No	No	No	No	No	No	No	No	No
Overhead lgt	On	Yes	Off	Off	Off	Off	Off	Off	Off	On
Glare (Y/N)	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

Contast:

Comp:bkg	NA	1.4	2.0	1.3	0.2	0.1	6.1	0.1	0.6	NA
Incident:bkg	2.3	5.5	4.4	2.9	0.3	0.1	2.4	1.2	0.3	4.0

Notes:

Afternoon	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Time:	3:10	3:15	3:18	3:20	3:23	3:26	3:28	3:31	3:32	3:34
weather:	NA	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	NA
fenestration:	NA	open	open	open	open	closed	50% closed	open	75% closed	NA
Incident (lux)	487	318	420	295	770	72	62	250	51	445
Task lighting	No	No	No	No	No	No	No	No	No	No
Overhead lgt	On	Off	Off	Off	Off	Off	Off	Off	Off	On
Glare (Y/N)	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

Contast:

Comp:bkg	NA	1.7	1.3	0.7	0.3	0.1	0.3	0.6	0.8	NA
Incident:bkg	1.9	2.7	2.8	1.9	0.5	0.0	0.2	0.6	0.9	4.6
AM:PM	1.0	2.4	1.1	1.5	0.6	2.8	1.3	7.0	2.7	0.8

Notes:

3.4 LIST OF FUNDING ORGANIZATIONS

The following organizations participated in the funding of this Building Performance Evaluation:

- Western Economic Diversification
- Real Estate Foundation
- Industry Canada
- Terasen Gas
- BC Hydro
- Clivus Multrum
- Public Works and General Services Canada
- Greater Vancouver Regional District
- Building D Owner
- Building D Architect
- Building D Mechanical Engineer