Building Performance Evaluation (BPE) Project

Evaluation Report for Building "C"

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Building Performance Evaluation of Building C

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 C for the purpose of maintaining anonymity. Located in Greater Vancouver, this building is certified LEED® Gold by the Canada Green Building Council, and includes many energy-efficient and sustainable features.

Executive Summary

Building C is a prominent green building in British Columbia that was certified LEED Gold. Constructed in 2004, 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, solar shading, displacement ventilation systems and radiant heating and cooling served by a geo-exchange system. Daylighting and occupancy sensors were installed for reduced lighting energy consumption, and carbon dioxide monitoring was used to control ventilation. The building systems were not designed for full cooling, and operable windows were designed to supplement occupants' control over ventilation and cooling in their workspaces. A photovoltaic system was also designed for the building. While the majority of these strategies functioned as intended in the occupied building, no recording of readings from the analog energy meters in the building was undertaken, so energy consumption data was unavailable. Thus 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 using rainwater captured in an existing cistern on site for toilet flushing. Although these strategies certainly conserve large amounts of water, absence of a building-specific water meter made it impossible to determine the actual water consumption in the building. Occupant satisfaction with the waterless urinals and dual flush toilets was quite low; concerns about odours from the urinals and plugging of the toilets were expressed.

The daylighting objective drove much of the architectural design of the building, with large windows and solar shading contributing to this goal. Internal blinds were intended to be used by occupants to control glare, but evidence gathered during the BPE suggests these blinds are often unused, thus glare is present on sunny days.

Although full cooling capacity was not designed for the building, occupant control over cooling was sought using operable windows. While these windows were often used and well liked, occupants were concerned about temperature swings and high summer temperatures, and personal fans and heaters were brought in to the building to compensate for this. Use of blinds for control over solar loads would have mitigated these concerns.

Acoustic conditions in most regularly occupied spaces were within benchmarks, but noise from outside led to higher noise levels inside the building, particularly when operable windows were open. High reverberation times due to hard surfaces in transition spaces caused noise propagation through the building.

While air quality in the building was optimal for the most part, ultrafine particulate levels were higher than benchmarks, indicating vehicle exhaust was likely entering the building through operable windows.

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1.0 Building Performance Evaluation Pilot Study

1.1 DEVELOPMENT OF THE PILOT STUDY

Building C 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 3.4.

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 C is a prominent green building in BC's lower mainland, constructed in 2004. This two-storey building has a floor area of 3,700 square meters (39,800 square feet) and houses approximately 70 full-time workers in a predominantly office environment, plus 180 transient workers who periodically use other facilities in the building.

The building makes use of efficient mechanical systems such as ground source heat pumps, underfloor displacement ventilation, and radiant hydronic panels for heating and cooling. The building envelope was designed for energy efficiency, with exterior solar shading, operable windows, and a green roof. Daylighting was a factor in guiding the architectural design of the building.

Water fixtures in the building are low-flow, with waterless urinals and dual flush toilets used. Stormwater is used in the building for toilet flushing, and the landscaping on the site is drought-tolerant. A photovoltaic system was also designed for the building.

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.

2.2 BUILDING DESIGN PROCESS

An integrated design process was implemented for the design of this building, with architects and engineers consistently working together when making decisions regarding a building's design. This type of process is frequently used by the firms involved in this building design. The design process began with a BC Hydro design assistance program which was used to select a set of building systems with a low life-cycle cost. These systems were then developed into design schematics as the design proceeded.

The design process for Building C was quite protracted, primarily because this was the first LEED project for all parties involved, which was noted by all to be a considerable learning process. Also, as the owner's engineer was very involved in the project, decisions required the approval of both the design team and the owner's engineer, thus requiring more time.

A considerable amount of research was required at the beginning of the project to gather information about the many design features considered for inclusion in the building's design. The client was open to the use of innovative design features, and both the ground source heat pump system and photovoltaic system were extensively researched prior to their inclusion in the design.

2.2.1 Design Goals

The project's goal of producing an environmentally conscious "green building" began with the owner, who set LEED as a goal for the project. However, the design team took the design a step further to include the innovative systems used in Building C.

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.

<u>Goal #1: Reduce Energy Consumption</u>

The owner's intent for the building was for greatly reduced energy use as compared to a standard building, resulting in lower greenhouse gas emissions and a smaller ecological footprint.

Results from the BC Hydro design assistance program used during design of Building C indicated that an energy savings of 40% over the ASHRAE 90.1-1999 standard was possible using the selected systems. Later in the design process, an energy use model of the building was created for the Canadian Building Incentive Program (CBIP), and its result indicated that building energy consumption was expected to be 60% below the Model National Energy Code for Buildings. The design strategies implemented to achieve this reduced energy consumption are discussed in Section 2.2.2.

<u>Goal #2: Reduce Water Consumption</u>

Goals for water consumption were largely directed by LEED; design calculations based on the LEED template indicated a predicted water use of 75% below average using the numerous water strategies outlined in the following section.

<u>Goal #3: Maximize Access to Daylight</u>

The architectural design focused on daylighting, with daylight being the predominant light source in over 75% of spaces on bright days, and views being present for 90% of spaces. The design strategies involved in achieving this goal are outlined in Section 2.2.2.

<u>Goal #4: Achieve Occupant Satisfaction with Thermal Comfort</u>

Associated with the goal of energy reduction was the intent not to design to full cooling capacity in the building. Despite this, designers aimed for a level of occupant satisfaction with the temperatures achieved by the designed systems, and pursued occupants' understanding about the reasons behind this design decision.

<u>Goal #5: Create High-Quality Acoustic Environment</u>

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

The design for indoor air quality was determined mainly by LEED requirements to achieve the credits pursued, as described in the following section.

2.2.2 Key Design Strategies Implemented

The following strategies were developed during the design of Building C 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 insulative envelope, designed with external shading and internal blinds, was intended to reduce heating and cooling loads in the building.

The displacement ventilation system designed in the building was known to be energy-efficient, as it provides air close to occupant level and relies on the natural stratification of air rather than forced air mixing. The radiant hydronic ceiling panels were intended to provide heating and cooling for the building while consuming less energy than standard air heating and cooling systems.

A geo-exchange system was installed in the grounds of the building to provide heating and cooling energy via ground source heat pumps. This system makes use of renewable energy, greatly reducing gas consumption in the building.

The decision was made not to install full cooling capacity to meet the building's peak cooling loads. This was a decision that was agreed to as acceptable by the owner, given their energy goals. Operable windows were installed in the building, so as to allow some additional cooling control to occupants with ventilation from outdoors. This measure partners well with the radiant cooling from the ceiling panels. Also, the air handling systems' ability to be run on 100% outdoor air affords "free cooling" when ambient weather conditions permit.

The daylighting design in the building makes use of daylight sensors to control electric lighting in response to natural light levels. This strategy was intended to reduce lighting energy consumption.

Photovoltaic panels were also designed for the building, to provide renewable electric energy.

Goal #2: Reduce Water Consumption

The building's low-flow fixtures, waterless urinals and dual flush toilets were selected for reduced water consumption as per LEED. In addition, an existing cistern on the site was used to capture rainwater for use in toilet flushing. Together, these measures afforded a 75% water use reduction over the baseline used for LEED calculations.

Goal #3: Maximize Access to Daylight

According to the designers interviewed during the BPE, the architectural design of the building focused on daylighting. Large glazed areas with blinds and external shading to control glare, allowed 75% of workspaces in the building to be daylit based on the design.

The electric lighting in the building was designed for 1 Watt per square foot of floor area (10.7 W/m^2). Occupancy sensors were installed in some spaces such as meeting rooms, washrooms, and private offices.

Goal #4: Achieve Occupant Satisfaction with Thermal Comfort

As described above, Building C was not designed with full cooling capacity to meet the peak cooling demands on the hottest summer days. However, radiant cooling capacity was installed, and operable windows were intended to afford occupants some control over their summer thermal environment, allowing for additional cooling from outdoor air. The ability of the air handling systems to run on 100% outdoor air also enables “free cooling” when outside temperature conditions permit.

According to the building operator, occupants were advised that the building would not be fully cooled.

Goal #5: Create High-Quality Acoustic Environment

While noise was not a major concern for the client, the ventilation, heating and cooling systems designed for the building are by their nature very quiet. The hydronic heating and cooling panels and the displacement ventilation system made even more quiet by insulation above the panels and around air distribution ducts.

Acoustic materials used in workspaces were predominantly limited to carpets. A roof deck with increased sound absorbance was presented as an option to the client during design, but was not selected.

Tasks carried out in some workspaces on the ground floor of the building were expected to produce noise. Due to the building’s location, outdoor sources of noise were also anticipated.

Goal #6: Optimize Indoor Air Quality

The design of Building C incorporated many strategies to optimize indoor air quality, as delineated in LEED. Low-emitting materials were selected for finishes, paints and carpets, aimed at reducing the concentrations of volatile organic compounds (VOC) in the building. Carbon dioxide monitoring was used to control the flow of outdoor air in order to maintain optimal air quality. The air handling systems’ capability of running on 100% outdoor air also improved the indoor air quality when in use. Areas in the building where pollutant sources existed were designed to be at negative pressure to prevent these pollutants from reaching other areas.

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 C was the use of a partial 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

Because this was a LEED building, a Commissioning Authority was hired by the owner to oversee the multi-discipline LEED commissioning process.

A high quality demonstration process from Portland Energy Conservation Inc. (PECI), referenced by LEED, allowed for effective communication in training the building owner and operator. By means of this process, documentation for each system type was presented to the owner by the Commissioning Authority.

Enclosure commissioning was not considered for this project, though this is now becoming more standard with LEED projects.

A DDC expert was not available during the design and construction period of this project. Involvement of a DDC expert starting six months prior to handover would have been beneficial to the commissioning process.

2.3.2 Building Operation

The building operator uses his general experience to operate the building so as to maximize occupant satisfaction and productivity, and to maintain the property so that it retains its value.

The DDC system enables monitoring and control of the building, and generally the system is altered in response to phone requests from occupants. The building is highly automatic, with lighting and temperature controlled via sensors and thermostats.

According to the operator, occupants are very happy with the appearance of the building, and are most concerned with temperature control and washroom fixtures. These concerns are described in Section 2.3.5.

2.3.3 Disparity between Design and Occupied Building

No major changes to the building have been applied since building construction was completed in 2004. Minor changes include the use of personal fans by some occupants for additional cooling.

2.3.4 Occupant Satisfaction Survey

The evaluation of Building C 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 operable windows, floor diffusers, window blinds, and waterless urinals.

Occupants working who responded to the survey were asked to locate themselves within one of two zones, North or South, 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.

Thirty-seven people participated in the web-based occupant satisfaction survey, which was 53% of the invited responses. The majority of respondents (89%) had worked for more than one year in this building, and 76% of respondents spend more than 30 hours a week at their workstations. Sixty-two percent of respondents were male; 81% were over 30 years of age, 35% described themselves as administrative employees and 41% described themselves as managerial employees.

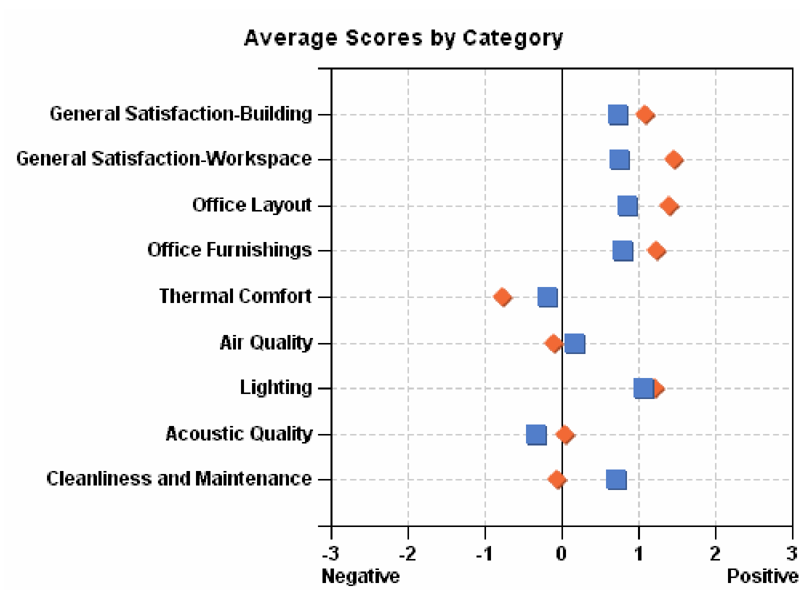


Figure 1: Survey Results for Building C

The above graph above shows the results generated from responses at Building C (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 most categories. Building C was rated most highly in the categories workspace satisfaction, office layout, office furnishings, lighting, and general satisfaction with the building. The building received a neutral rating for acoustics which was still higher than the CBE average for acoustics. Air quality and cleanliness were rated slightly below the scale midpoint by occupants; both ratings were below the CBE average. Thermal comfort received the lowest rating for the building, and was also below the CBE benchmark.

The response rate targeted during the BPE for the occupant satisfaction survey was 50%, and a 53% response rate was obtained. While the target response rate was achieved, the survey responses should not be viewed as representative of all building occupants. 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.

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 C 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.

<u>Goal #1: Reduce Energy Consumption</u>

The actual energy performance of Building C could not be ascertained, as energy metering for the building was analog rather than digital, and recording of analog readings had not occurred during the building's occupancy. For a building with such advanced energy targets as Building C, 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 C.

While it appears that most strategies employed in Building C for energy efficiency are working as designed, it is impossible to confirm the success of these strategies in reducing energy consumption in the building.

According to the operator, solar heat gain inside the building was common at low sun angles, when the solar shading projections no longer blocked direct sun.

The photovoltaic panels designed for the building had not yet been connected and therefore were not providing renewable electrical energy to the building at the time of the Building Performance Evaluation.

Goal #2: Reduce Water Consumption

Absence of building-specific water metering in Building C has made it impossible to determine the actual water consumption in the building. While water meters exist for the site on which Building C is located, other buildings and activities on site are responsible for a majority of the water use recorded by this meter. As stated above, it is surprising that a building with the advanced water savings targets of Building C does not have a building-specific water meter. It is recommended by the BPE team that installation of a digital flow meter with datalogger be carried out in Building C, to gauge its actual water consumption.

According to the building operator, there are many complaints relating to odours associated with the waterless urinals. In addition, the cost of maintenance and cartridge replacement for these urinals is felt to be excessive. The dual flush toilets in the building have had problems with plugging, an issue which has recently been substantially resolved according to the operator.

Of respondents to the CBE Indoor Environment Quality survey, 44% were satisfied with the washroom fixtures in the building. Of male respondents, only 20% were satisfied with the waterless urinals.

Use of the existing cistern on the site for rainwater catchment and reuse is reportedly operating as intended, though no confirmation of this system's impact on water conservation could be obtained during the BPE due to the absence of a building-specific water meter.

Goal #3: Maximize Access to Daylight

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

Results of the CBE Indoor Environment Quality survey show that 94% of respondents were satisfied with the daylighting in the building, and that 92% of respondents were satisfied with lighting overall. As well, 94% of respondents were satisfied with the operation of window blinds.

"Snapshot" measurements of light levels taken during the BPE on a sunny day in June showed that the majority of spaces assessed had light levels higher than benchmarks, particularly in open plan office areas. On the day measurements were taken, blinds remained open in many areas, and glare was present.

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 Occupant Satisfaction with Thermal Comfort

While occupants were advised that the building would not be fully cooled, many occupants are dissatisfied with the high summer temperatures inside the building. According to the building operator, cold temperatures in winter were also a concern to some occupants. Perceived swings between high and low temperatures in winter were also a concern; these swings may be attributable to a slower response time from the radiant panels. Personal fans and heaters are used in some workstations to provide increased personal control over thermal comfort. As well, use of operable windows is common during summer months for cooling control.

Of the respondents to the CBE survey, 44% were satisfied with thermal comfort conditions in their workspace, as compared to the CBE database average of 58%. When asked whether they were satisfied with the operable windows in the building, 97% of respondents indicated satisfaction with this feature.

“Snapshot” empirical measurements of thermal conditions in Building C were carried out on two warm, overcast June days. On both days of measurement, many operable windows were open on all sides of the building’s second floor. Measurements indicate that temperatures were quite consistent throughout the building, with no significant excursions from benchmarks. The highest temperatures, in the 24 - 25°C range, recorded in the south end of the open office area on the second floor and in the southwest corner office. As the day of measurement was overcast, it is conceivable that temperatures would be higher than this when direct sun entered these areas.

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.

<u>Goal #5: Create High-Quality Acoustic Environment</u>

“Snapshot” measurements of acoustics in the building taken on a June day showed that noise from the ventilation systems was very low. In most areas, noise levels were within benchmark ranges, however some open plan areas had low speech privacy. Background noise levels from noise sources outside the building were higher than benchmarks at times, depending on the activities occurring outdoors, even with operable windows closed. In some open office locations where acoustic measurements were taken, the BPE acoustical consultant felt the low reverberation times measured might be attributable to the profiled ceiling diffusing sound. In the corridors and lunch room, high noise reverberation makes these spaces louder than benchmarks, and this noise is audible in other areas of the building.

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, 64% were satisfied with their acoustic environment, compared to the CBE database average of 62%. The main concern for those respondents who were dissatisfied was the outdoor noise that was audible inside the building, particularly when operable windows were open.

<u>Goal #6: Optimize Indoor Air Quality</u>

“Snapshot” measurements of air quality in the building were taken on a June 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 very low, indicating the successful operation of the ventilation and 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. Some operable windows were open on the day of assessment and the building is close to an area where trucks idle; this may explain the high ultrafine particulate concentrations.

According to the building operator, outdoor sources of air pollution are a concern for occupants as they can enter the building via operable windows. The operator has noticed black dust on desks which is thought to originate from this outdoor pollutant source.

Results of the CBE occupant survey indicated that 51% of respondents were satisfied with air quality, compared to the CBE database average of 67%. For those respondents who were dissatisfied with air quality, stale air and odours from outside the building were of concern.

2.3.6 Resource Use Analysis

2.3.6.1 Energy Use

An energy model was produced during the design of Building C, 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 60% lower than the MNECB baseline. It is important to note that for CBIP analysis, use of standardized schedules of operation and equipment loads is the common procedure, and also that the selection of systems is somewhat limited, so CBIP model results should usually not be viewed as accurate predictions of a building's actual energy performance. 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.

2.3.6.2 Water Use

The water conservation strategies followed in Building C, including the use of rainwater from a cistern on site, led to the design prediction of 75% reduction in water use over the benchmark developed for LEED calculations.

[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.

As mentioned above, absence of a building-specific water meter made it impossible to compare actual water use results to these predictions, or to a benchmark water consumption for typical office buildings.

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 C, it is impossible to learn lessons about the actual energy use associated with these strategies in the building due to the absence of energy meter records.

However, much was learned by the design team about the strategies implemented in the building during design, with research into the geo-exchange and photovoltaic technology carried out. While the photovoltaic array had not yet been connected at the time of the BPE, the geo-exchange system appeared to be operating as designed.

The design approach of providing less than full cooling capacity in the building met with concern from some occupants about high temperatures in summer, despite information provided to occupants on the reasons for this approach. The lesson to designers was that although occupant education about design decisions related to sustainability is essential, it may not change occupant attitudes about thermal comfort.

Use of operable windows is widespread, indicating the success of this measure in providing additional occupant control of cooling and ventilation conditions. A number of occupants also make use of personal fans to supplement their control of airflow for cooling.

Goal #2: Reduce Water Consumption

While it is assumed that much less water is used in Building C than in typical office buildings, no firm conclusions could be drawn as to the actual amount of water conserved in the building since actual water consumption data for Building C was not available.

Evidence gathered during the BPE suggests that the use of rainwater from the catchment cistern for toilet flushing is operating as designed.

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 these is no evidence to suggest this is not occurring in Building C. However, it is possible that cleaning schedules are not timed optimally for the large group of workers who use the building only in the morning and late afternoon, which could lead to the buildup of odours. Alternatively, the odour problems may be due to poor design of these particular urinals, or simply to occupant reservations about this unfamiliar technology.

According to the operator, it is possible that the problems with plugging of dual flush toilets were due to flushing of paper towel, or that they arose from the low-flow technology. Design of plumbing systems must be appropriate for low-flow toilets; as yet there is no standard for low-flow plumbing design, but these systems should be conservatively designed for lower flows than standard.

Goal #3: Maximize Access to Daylight

It is clear from the results of the Building Performance Evaluation that the presence of daylight in workspaces is very important to occupants in this building, and that they are very satisfied overall with the daylighting strategies implemented in the building.

However, the blinds included in the design to control glare and solar loads appeared to be infrequently used by occupants, thus glare was noted in most locations where empirical measurements were carried out. While occupants are certainly aware of their ability to control glare using these blinds, it appears for the most part that they consider natural light a priority over glare control.

Two lessons may be learned from this. Firstly, occupants should be encouraged to make use of blinds to eliminate glare and reduce eye strain. It is possible that occupants require more empowerment regarding their control over this feature. It is also possible that the opaque blind material used reduces daylight levels to such an extent that occupants choose not to make use of it, preferring daylight at the cost of glare. Mesh blinds exist that inhibit glare and reduce solar gains while still allowing some daylight and visibility across the material.

Goal #4: Achieve Occupant Satisfaction with Thermal Comfort

Although “snapshot” measurements on the day of thermal measurement showed most space temperatures were appropriate, comments made by occupants indicate that the systems in the building have relatively slow response times, resulting in perceived swings between hot and cold temperatures. Part of the reason for this is likely the high solar load entering the building at low sun angles, when the solar shading projections no longer block direct sun. This sudden solar load must be met by the radiant panel system. As mentioned above, more widespread use of internal blinds by occupants to control this solar load would help control internal temperature swings.

The fact that the installed cooling capacity in the building was not designed to meet peak cooling demands indicates that use of blinds to control solar gains on hot summer days is of high importance. As it appears that occupants are not in the habit of using the blinds for this purpose, it may be that more occupant education to this effect would be helpful, or that the material selected for the blinds should be evaluated. It is possible that mesh blinds that allow for some visibility and daylighting would be used more by occupants.

The operable windows in the building appear to be effective for occupant control over ventilation and cooling in their workspaces, and are associated with a high level of occupant satisfaction.

<u>Goal #5: Create High-Quality Acoustic Environment</u>

The majority of regularly occupied workspaces in the building had noise levels within benchmarks, with the profiled ceiling in the open plan office space is thought to contribute to reduced noise reverberation.

However, noise from outdoors increased noise levels in the building. While outside noise sources were anticipated during design due to the location of Building C, the effect of this noise inside the building may have been underestimated, or conditions may have worsened. In either case, when operable windows were open with these outdoor sources of noise present, noise levels were above benchmarks. While occupants were very satisfied with operable windows in the building because of their contribution to ventilation, cooling control, and connection with outdoors, these windows also amplified this acoustic problem.

High levels of noise reverberation in the corridors and lunchroom on the ground floor were also of concern in this building due to an absence of sound-absorbing materials.

Despite these acoustic issues, occupant survey results indicated that this building was rated higher than the CBE database average with respect to acoustics.

<u>Goal #6: Optimize Indoor Air Quality</u>

“Snapshot” empirical measurements of air quality in Building C demonstrate 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 underfloor displacement ventilation system is functioning effectively, and also that the carbon dioxide monitoring in the building is operating as intended.

However, high ultrafine particulate concentrations were found during sampling, indicating products of combustion such as vehicle exhaust were present in higher than benchmark concentrations. 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 these measurements. As stated above, though operable windows are enjoyed by occupants and contribute to thermal comfort and control, use of operable windows in this location appears to negatively impact indoor air quality because of the activities occurring outside Building C.

The Building Performance Evaluation matrix in Appendix 3.1 summarizes the key design goals for Building C, 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 C

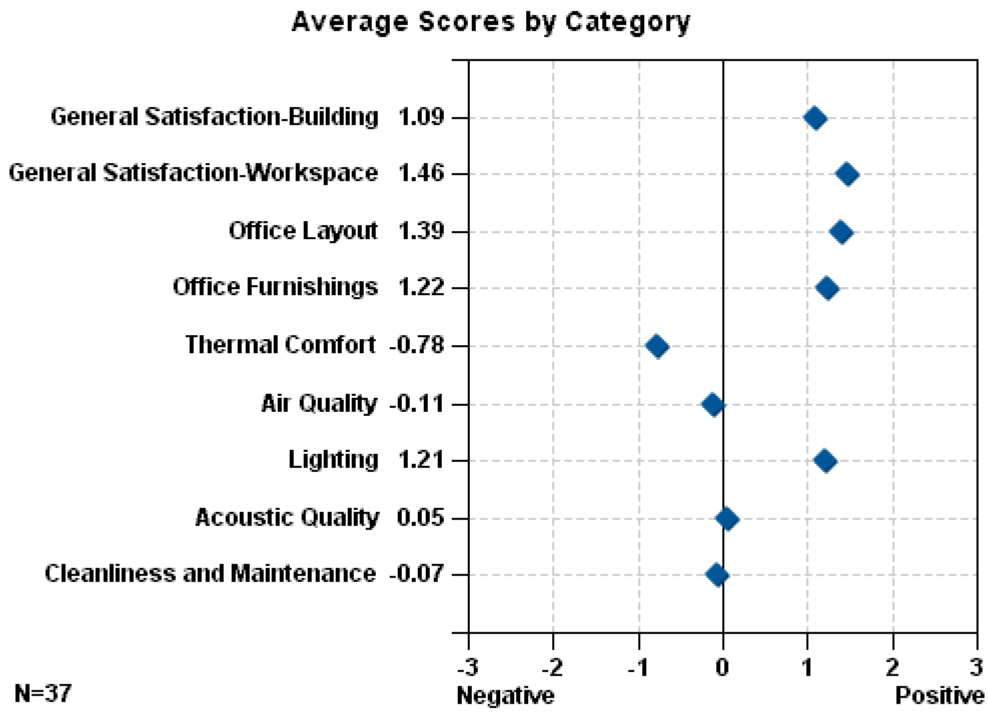
LEED CATEGORY	COMPONENT	GOAL	STANDARD PRACTICE GOAL	STRATEGY	STANDARD PRACTICE STRATEGY	PREDICTED VALUES	MEASURED VALUES	BENCHMARKS	COMMENTS / DIFFERENCES BETWEEN DESIGN AND OCCUPIED BUILDING	OCCUPANT SATISFACTION SURVEY	TRADEOFFS OR SYNERGIES	DESIGN LESSONS LEARNED
Sustainable Sites	**Stormwater management**	Reduce stormwater runoff	-	Green roof	-	-	-	-	-	-	-	Building Performance Evaluation pilot study did not directly evaluate this topic
Water Efficiency	**Domestic water consumption**	75% reduction in potable water consumption based on LEED calculations	Approximately meeting LEED baseline calculations	Low-flow fixtures, waterless urinals, rainwater capture for toilet flushing	Standard fixtures	75% reduction in potable water consumption based on LEED calculations	**Data unavailable** No building-specific water meter	76 L/occupant/day [ASPE standard water use estimate]	-	44% of respondents satisfied with washroom fixtures; 20% of male respondents satisfied with waterless urinals	Reduction in water use is expected, however in this building there are concerns about odours and cost of maintenance of waterless urinals, as well as plugging of dual-flush toilets	A number of factors may contribute to occupant disatisfaction with waterless urinals: infrequent cartridge replacement, poor urinal design, and occupant reservations about unfamiliar technology.
Energy and Atmosphere	**Energy consumption**	40% below ASHRAE 90.1	Approximately meeting ASHRAE 90.1	Highly insulative envelope	Standard envelope insulation	60% below MNECB based on energy model	**Data unavailable** Building-specific energy meters are analog and data is not recorded	Energy intensity of 378 kWh/m^2/year [CIBEUS, Office Buildings, BC]	-	-	-	-
				Ground source heat pumps for heating and cooling, with boiler backup	Boiler / Chiller				Ground source heat pump technology was highly researched before inclusion in design.	-	-	
				Hydronic heating and cooling, displacement ventilation	Forced air heating, cooling, and ventilation				-	-	Very quiet system operation is positive for noise levels but may be negative for speech privacy in open plan areas (absense of "white noise")	
				Demand controlled ventilation (CO_2 monitoring)	-				-	51% of respondents satisfied with air quality, CBE database average is 67% satisfaction with air quality; stale air and outdoor odours a concern	-	
				Daylighting and occupancy sensors for lighting control	-				-	92% of respondents satisfied with lighting, CBE database average is 85% satisfaction with lighting; glare a concern	-	
				Systems not designed for full cooling capacity	Systems designed to peak cooling loads				More use of internal blinds to reduce solar loads would improve thermal conditions.	44% of respondents satisfied with temperatures, CBE database average is 58% satisfaction with temperatures; hot summer temperatures a concern	-	Occupant education about design decisions relating to sustainability is essential but does not ensure occupant satisfaction. Evidence gathered during BPE suggests more use of blinds would likely improve thermal comfort.
				Photovoltaics	-				PV system is not yet connected	-	-	-
Materials and Resources	-	-	-	-	-	-	-	-	-	-	-	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 10.7 Watts/m^2 electric lighting power	Illuminance levels of 540 lux (50 footcandles) at 15 Watts/m^2 electric lighting power	Efficient electric lighting, see also Daylighting section	-	-	"Snapshot" measurements of lighting conditions indicated very high illuminance levels in many open areas, see text	Illuminance levels of 200 - 500 lux based on tasks	Blinds are in place to control glare and excessive illuminance levels, however in many cases these are not employed by occupants.	92% of respondents satisfied with lighting, CBE database average is 85% satisfaction with lighting; glare a concern	Reduced lighting energy consumption is expected (cannot be confirmed due to absence of energy data)	Daylighting strategy provides ample natural light. More use of blinds by occupants would reduce glare and excessive light levels.
	Thermal Comfort	Increased occupant control over thermal comfort	-	Operable windows	Sealed windows	-	"Snapshot" measurements of thermal conditions on a cloudy summer day indicated no excursions. No temperature measurements taken on a very hot day.	Typical air temperature setpoints of 21°C in winter, 23°C in summer	-	97% of respondents satisfied with operable windows	Benefit of operable windows trades off with concerns about odours/noise from outside activities	Operable windows are enjoyed by occupants, however location of operable windows should take into account external conditions.
		Reduce energy consumption and plant size by designing for less than full cooling capacity	Design with capacity to meet peak cooling load	Cooling capacity less than 100% of peak load	Cooling capacity determined by peak load	-			During the day of "snapshot" measurements, blinds were seldom used to control solar gains.	44% of respondents satisfied with temperatures, CBE database average is 58% satisfaction with temperatures; hot summer temperatures a concern	-	Occupant education about design decisions relating to sustainability is essential but does not ensure occupant satisfaction. Evidence gathered during BPE suggests more use of blinds would likely improve thermal comfort.
		Provide thermal comfort by means of radiant systems	-	Radiant systems and displacement ventilation	Air-side systems	-			Occupant concerns regarding swings in temperature are likely due to influence of solar gains; more use of blinds would be beneficial.		-	

Appendix 3.1: Building Performance Evaluation Matrix for Building C

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	TRADEOFFS OR SYNERGIES	DESIGN LESSONS LEARNED
Indoor Environmental Quality (cont'd)	**Daylight and Views**	75% of workspaces to be daylit	-	Large glazed areas	-	-	"Snapshot" measurements of lighting conditions indicated very high illuminance levels in many open areas, see text	200 - 540 lux based on tasks	Blinds are in place to control glare and excessive illuminance levels, however in many cases these are not employed by occupants.	92% of respondents satisfied with lighting, CBE database average is 85% satisfaction with lighting; glare a concern	Large windows are effective for daylighting but also lead to increased heating and cooling loads	Daylighting strategy provides ample natural light and leads to occupant satisfaction. More use of blinds would reduce glare and prevent excessive light levels; occupants should be encouraged to use blinds. Alternately, mesh blind material that permits daylighting when blinds are drawn may be preferred by occupants.
				Daylight sensors control lights	-	-				94% of respondents satisfied with daylighting	Reduced lighting energy consumption is expected (cannot be confirmed due to absence of energy data)	
	Indoor air quality	Increased ventilation effectiveness	-	Displacement ventilation	Air supplied at ceiling	-	"Snapshot" measurements of air quality indicate VOC and CO2 levels were low; ultrafine particulate levels were close to those of outdoors	Air quality measurements of CO2:600-1000ppm VOC < 300ppb	-	51% of respondents satisfied with air quality, CBE database average is 67% satisfaction with air quality; stale air and outdoor odours a concern	Reduced energy consumption is expected (cannot be confirmed due to absence of energy data)	Design of operable windows should take into account any anticipated activities in the viscinity of the building that create air contaminants.
				Operable windows	-				Outdoor contaminants from vehicle exhaust enter the building through operable windows.			
				CO_2 monitoring	-				-			
		Low-emitting materials	-	Low VOC materials	-				-		-	
	Acoustic quality	No specific goals; HVAC systems designed to be very quiet	-	Insulation of ducts and radiant panels	-	-	"Snapshot" acoustic measurements indicated some excursions, see text	Acoustic measurements of NC30-40 dB RT<0.75 s SII:0.2-0.7 NIC30-40 dB	Some interior acoustical finishes were cut from the design due to value engineering. External sources of noise on site were anticipated in the design but may have been under-estimated or actual conditions may have worsened.	64% of respondents satisfied with acoustics, CBE database average is 62% satisfaction with acoustics; outside noise a concern	Reduced "white noise" from HVAC systems lead to lessened speech privacy. Noise external to site impacts use of operable windows.	Quiet HVAC systems may lead to decreased speech privacy. Locations of operable windows should take into account outside noise sources. In open-plan offices, profiled ceiling may have mitigated some acoustical issues.
Design Process	**Integrated Design Process**	Integrated design process	Traditional design process	Regular meetings of entire design team to make design decisions	Segregation of design tasks and decisions between disciplines	-	-	-	-	-	-	LEED certification process was learned by design team.

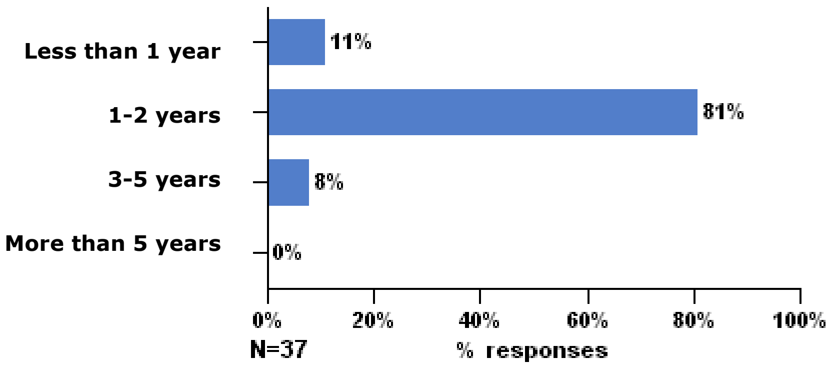
3.2 OCCUPANT SATISFACTION SURVEY RESULTS

Summary

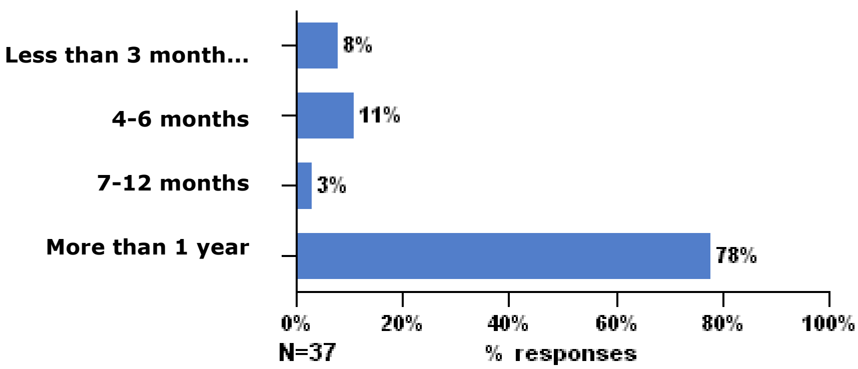

Average Scores by Category
General Satisfaction-Building 1.09
General Satisfaction-Workspace 1.46
Office Layout 1.39
Office Furnishings 1.22
Thermal Comfort -0.78
Air Quality -0.11
Lighting 1.21
Acoustic Quality 0.05
Cleanliness and Maintenance -0.07
-3 -2 -1 0 1 2 3
Negative
Positive
N=37

Background

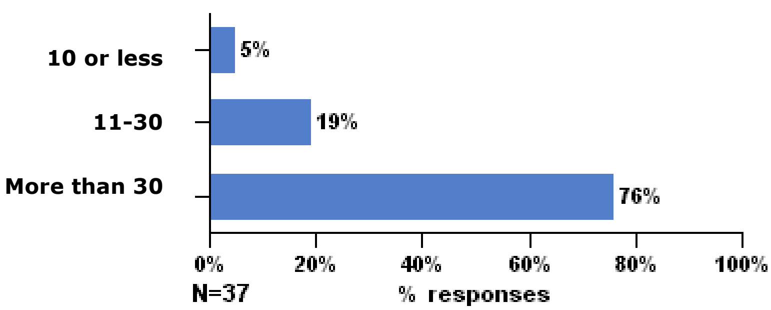
1.1) How many years have you worked in this building?



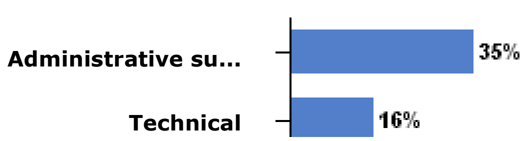
1.2) How long have you been working at your present workspace?

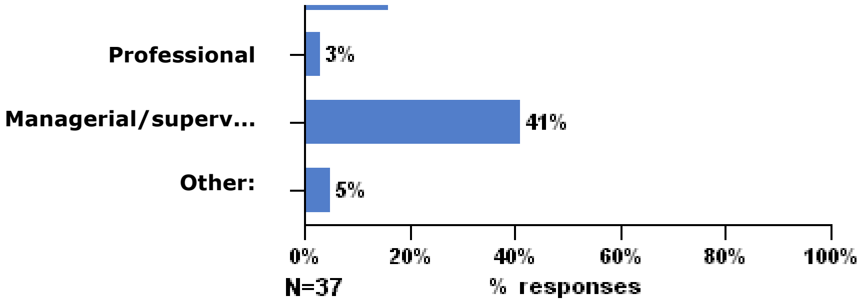


1.3) In a typical week, how many hours do you spend in your workspace?

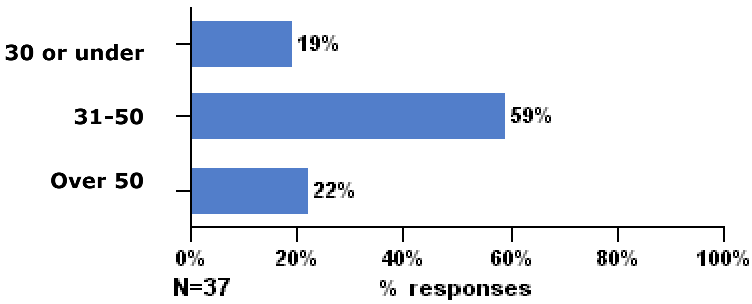


1.4) How would you describe the work you do? *("N" for this question is calculated based on the number of users who answered the question.)*

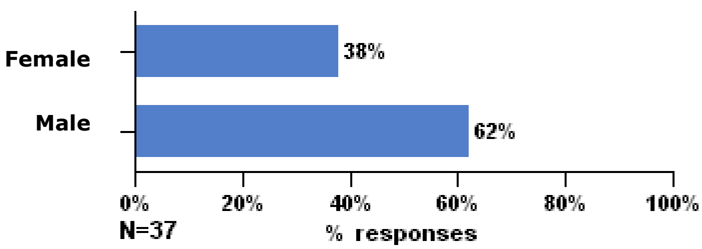




1.5) What is your age?

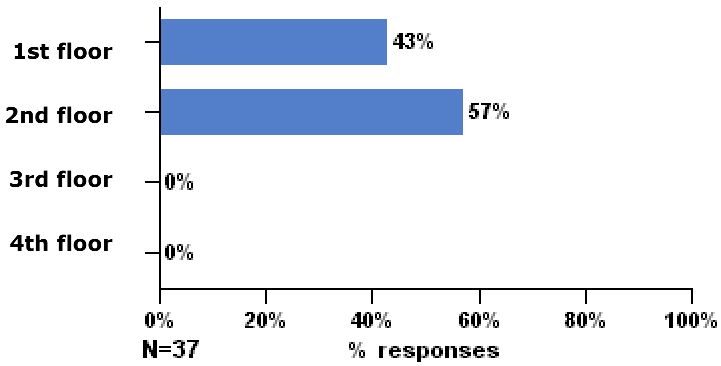


1.6) What is your gender?

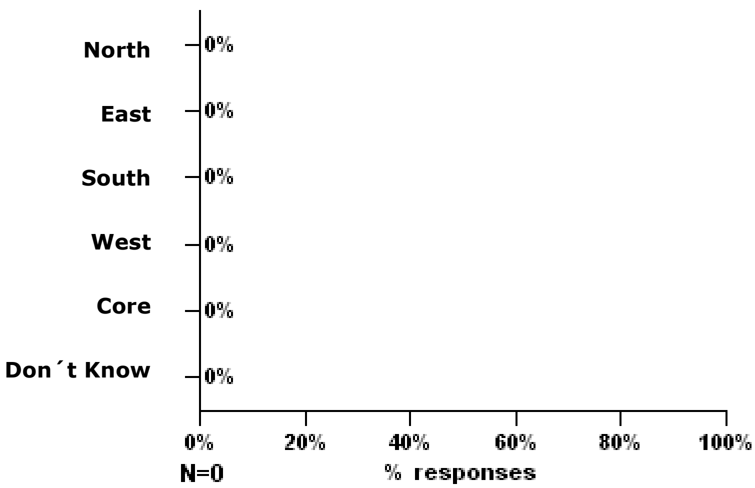


Personal Workspace Location

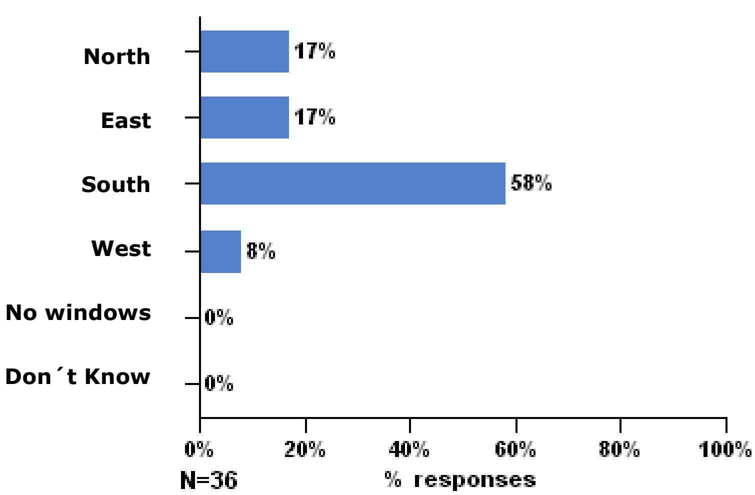
2.1) On which floor is your workspace located?



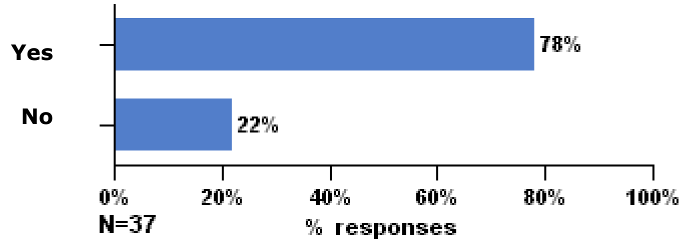
2.2) In which area of the building is your workspace located?



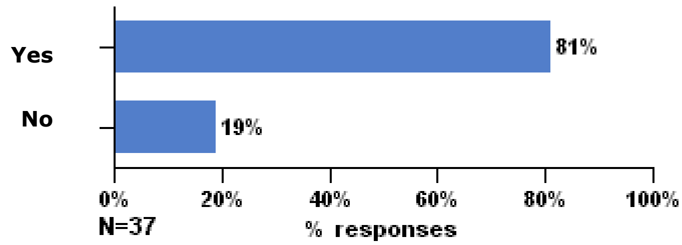
2.3) To which direction do the windows closest to your workspace face?



2.4) Are you near an exterior wall (within 15 feet)?

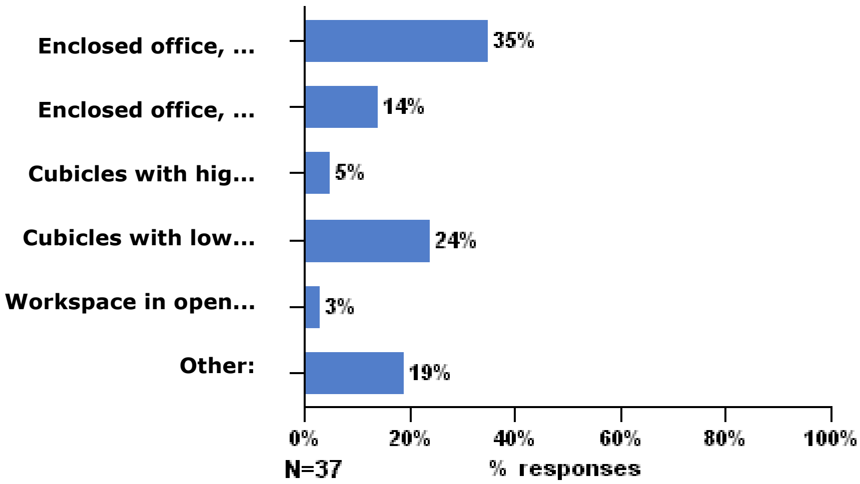


2.5) Are you near a window (within 15 feet)?



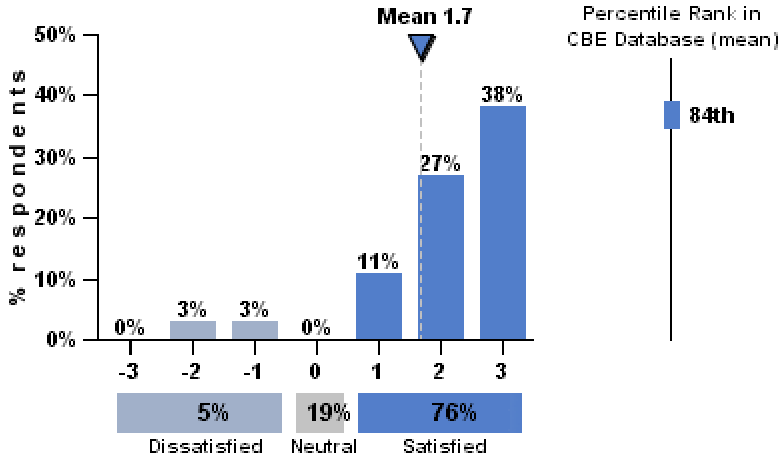
Personal Workspace Description

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



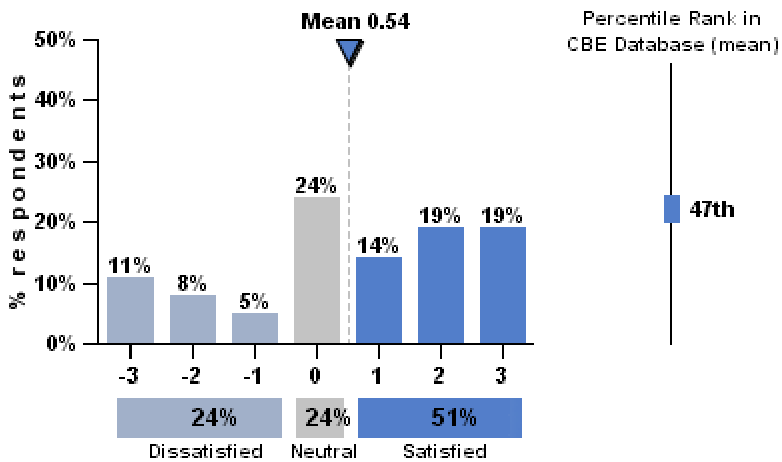
Office Layout

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



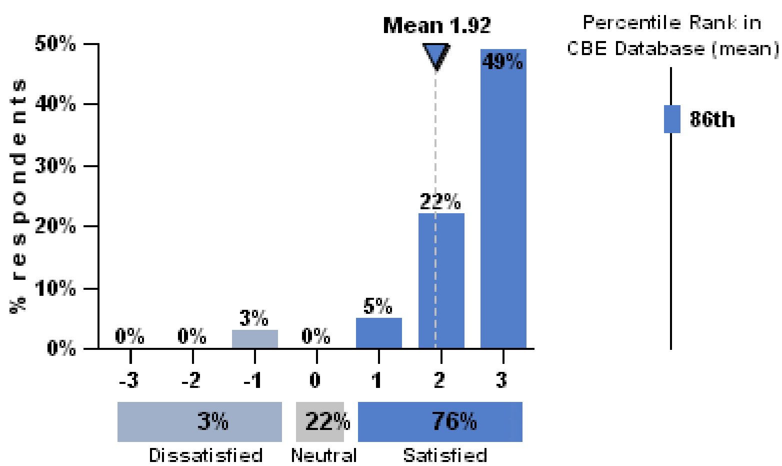
N=37

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



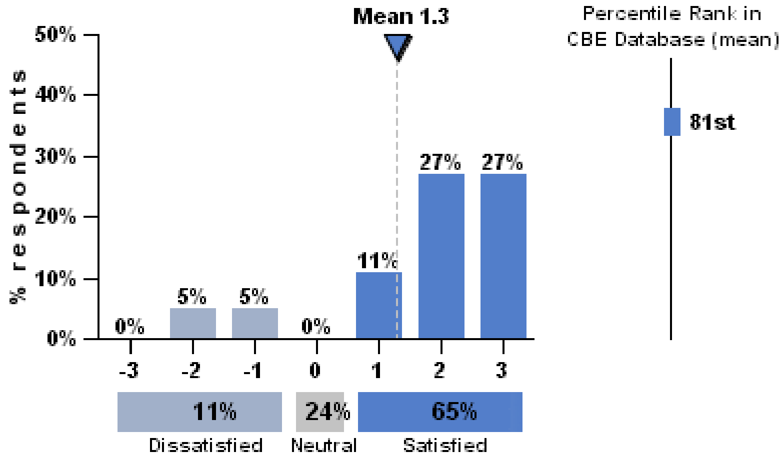
N=37

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



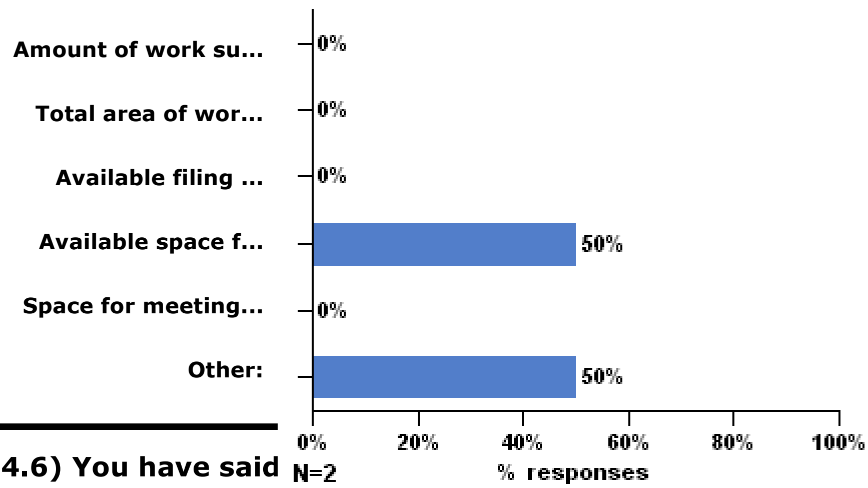
N=37

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

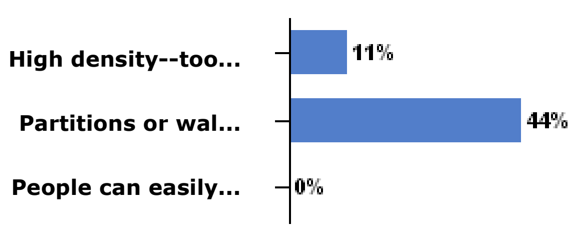


N=37

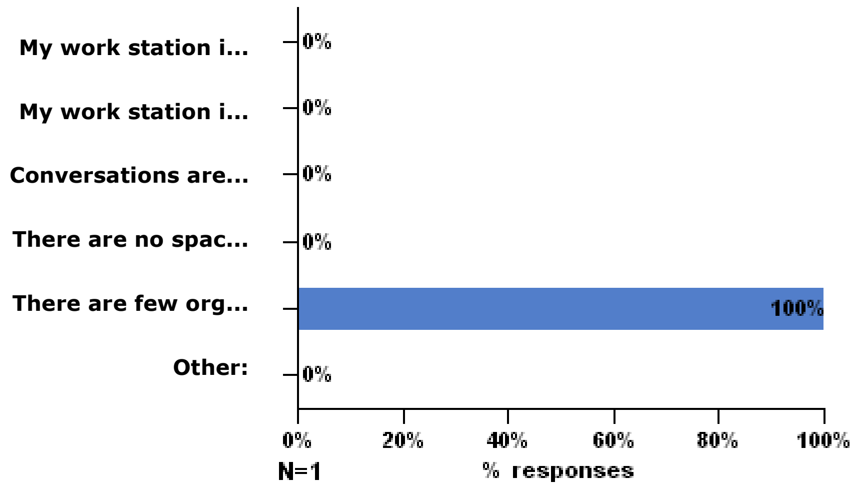
4.5) You have said that you are dissatisfied with the amount of space available for indi contribute to your dissatisfaction? *("N" for this question is calculated based on the nur*



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*

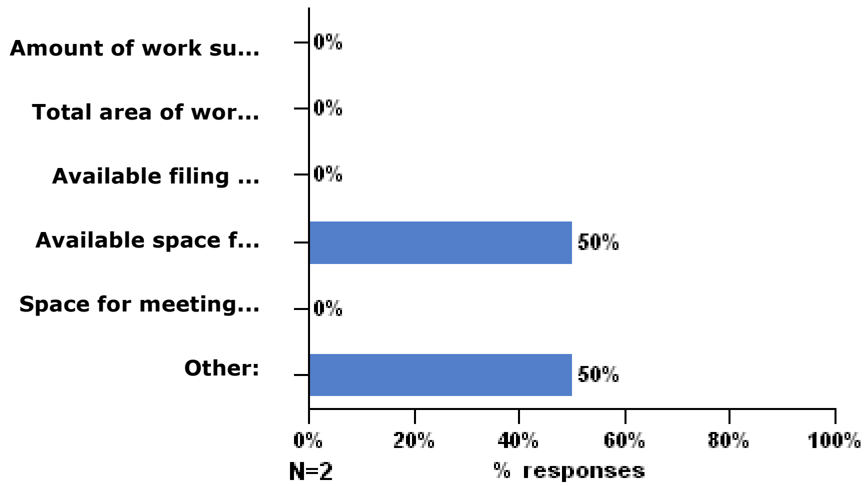


4.7) You have said that you are dissatisfied with the ease of interaction with co-worke dissatisfaction? ***("N" for this question is calculated based on the number of users who***



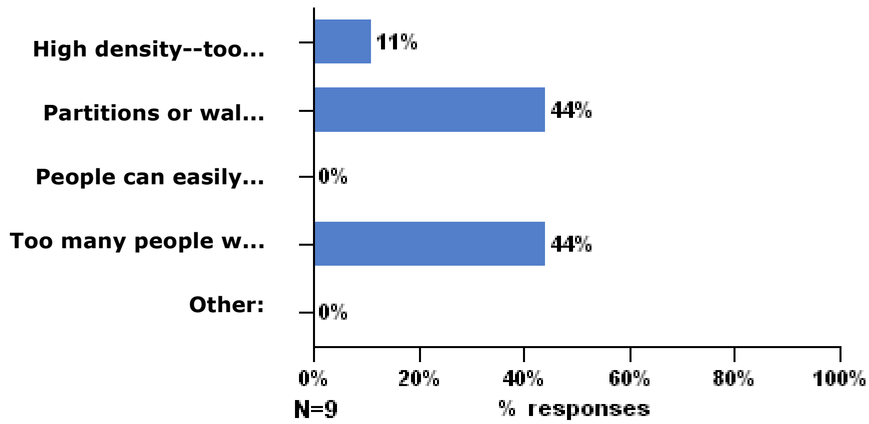
Available Space

5.1) You have said that you are dissatisfied with the amount of space available for individual work and storage. Which of the following contribute to your dissatisfaction? ***("N" for this question is calculated based on the number of users who answered the question.)***



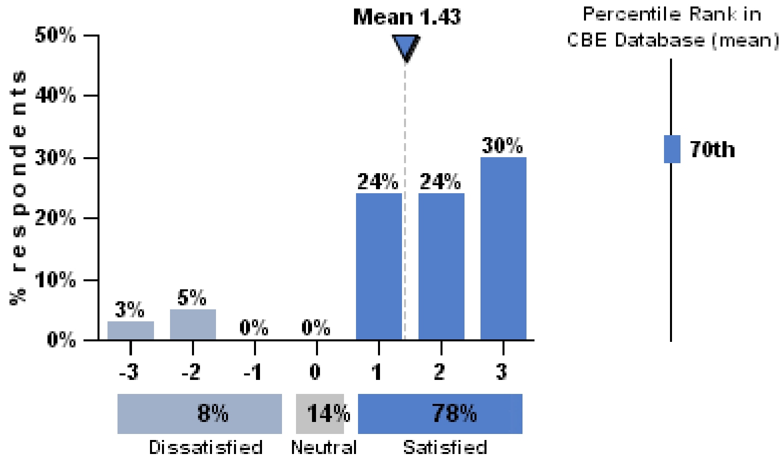
Visual Privacy

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.)*



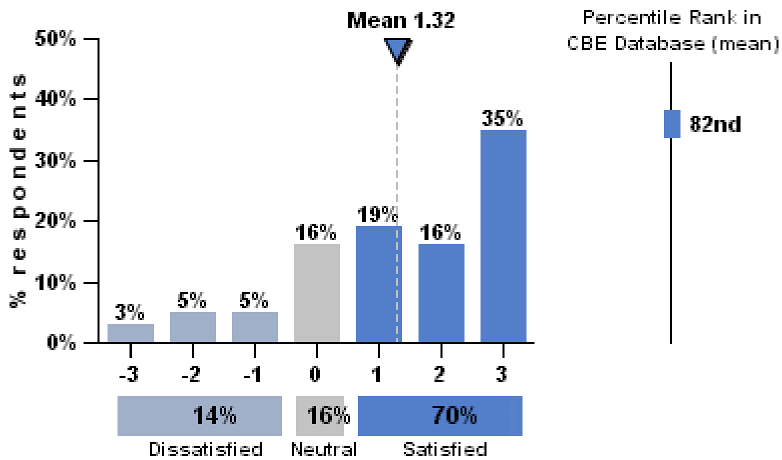
Office Furnishings

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



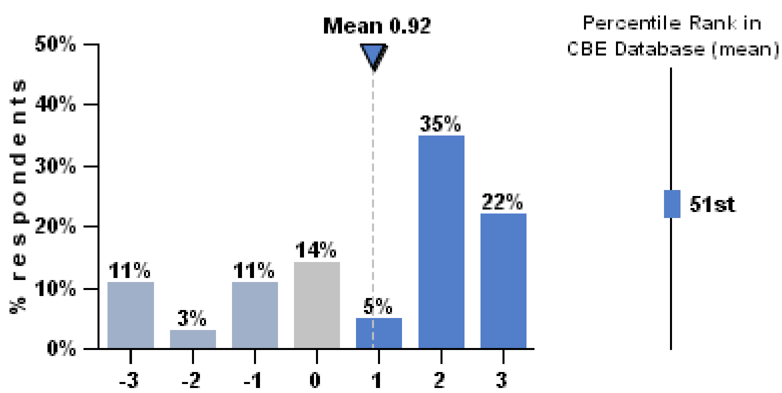
N=37

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



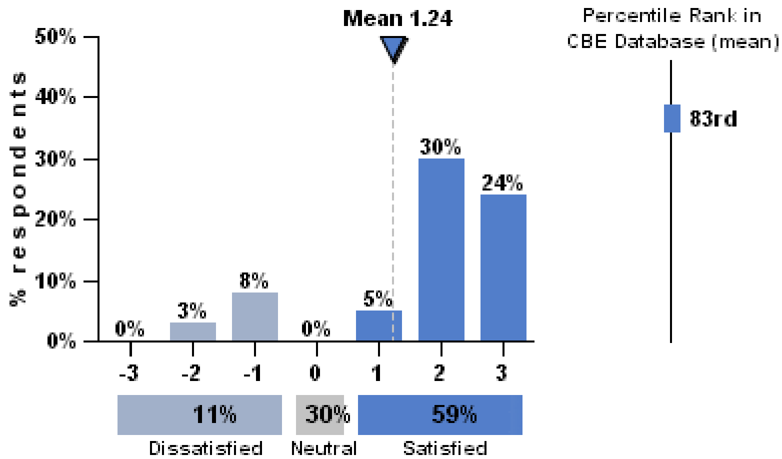
N=37

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



N=37

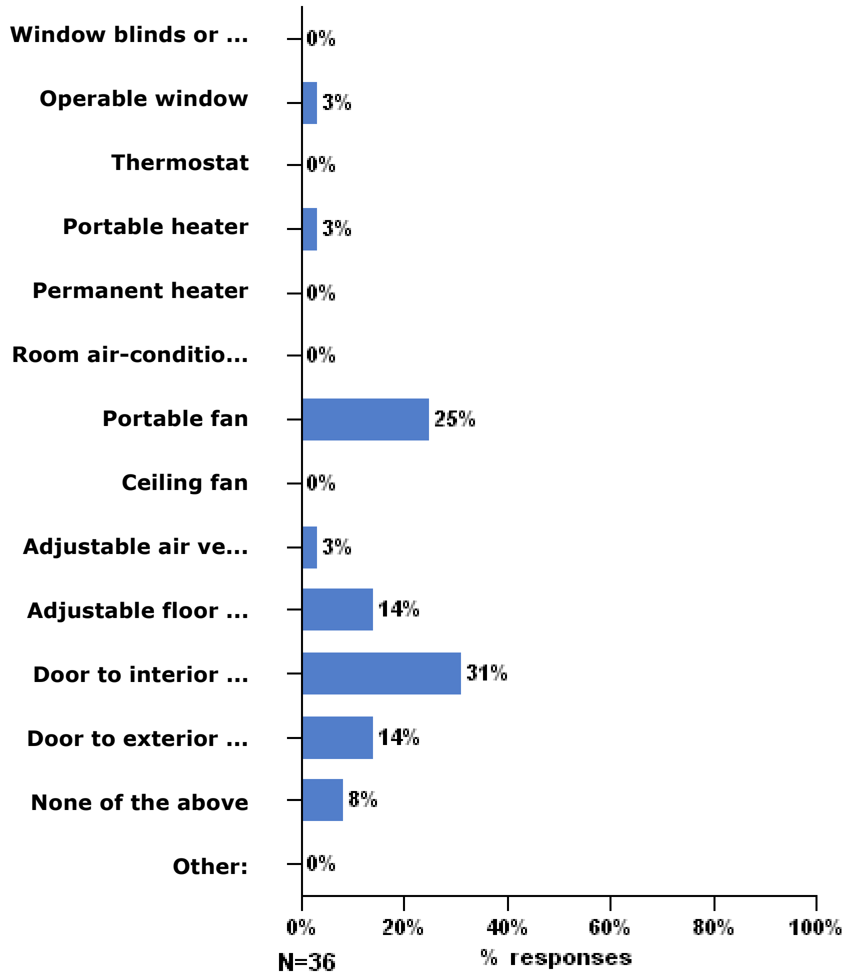
8.4) Do your office furnishings enhance or interfere with your ability to get your job done?



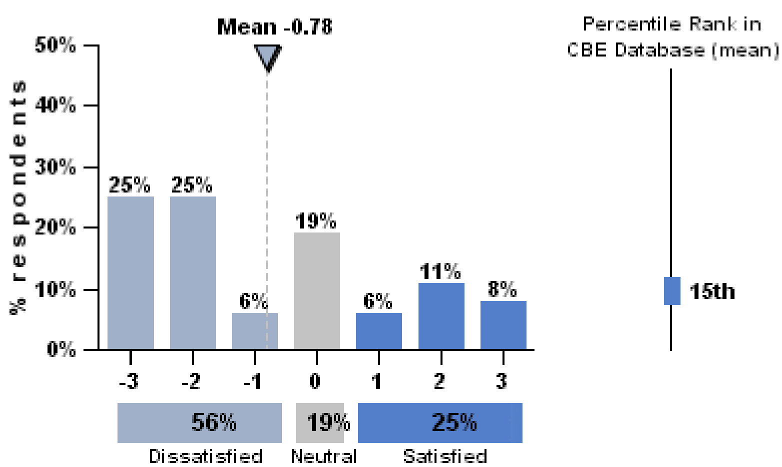
N=37

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.)*

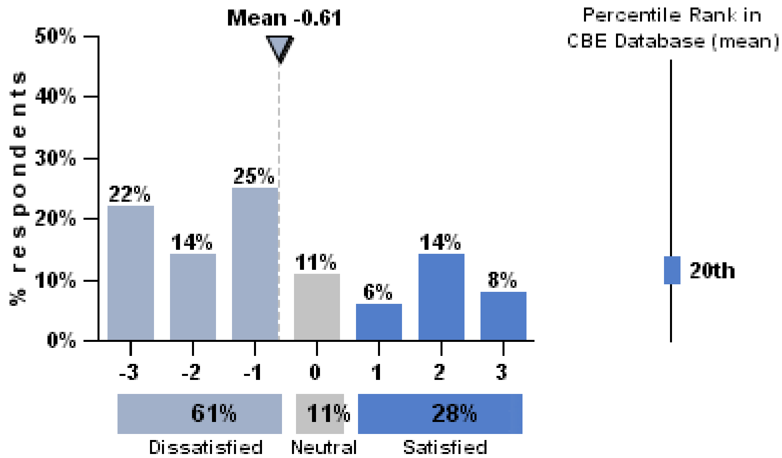


9.2) How satisfied are you with the temperature in your workspace?



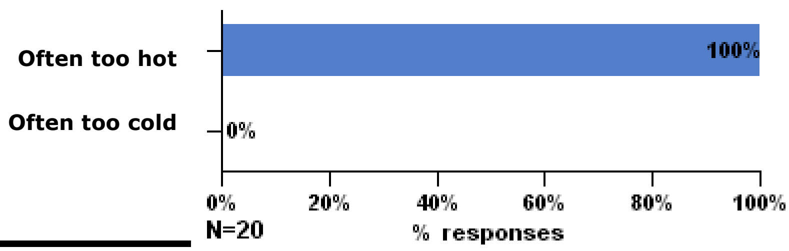
N=36

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



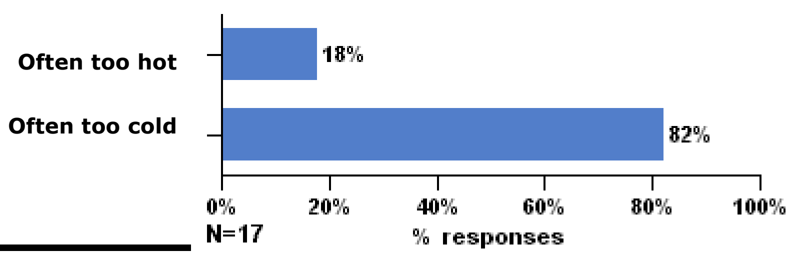
N=36

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



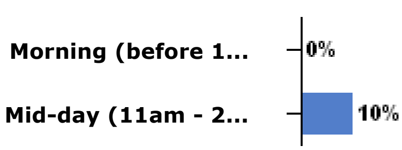
N=20

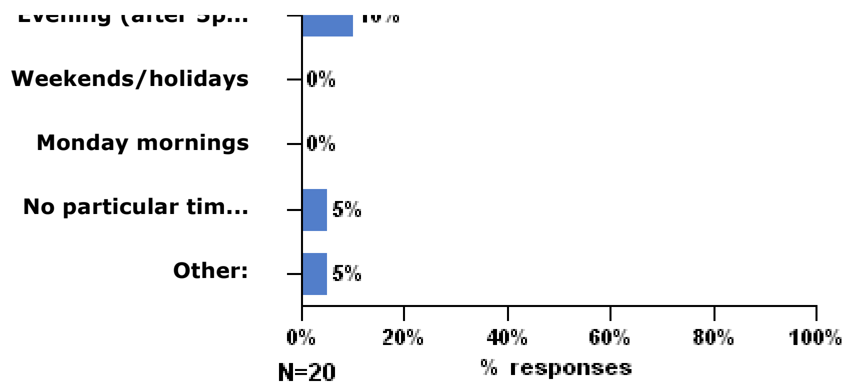
9.5) In cool/cold weather, the temperature in my workspace is: ***("N" for this question answered the question.)***



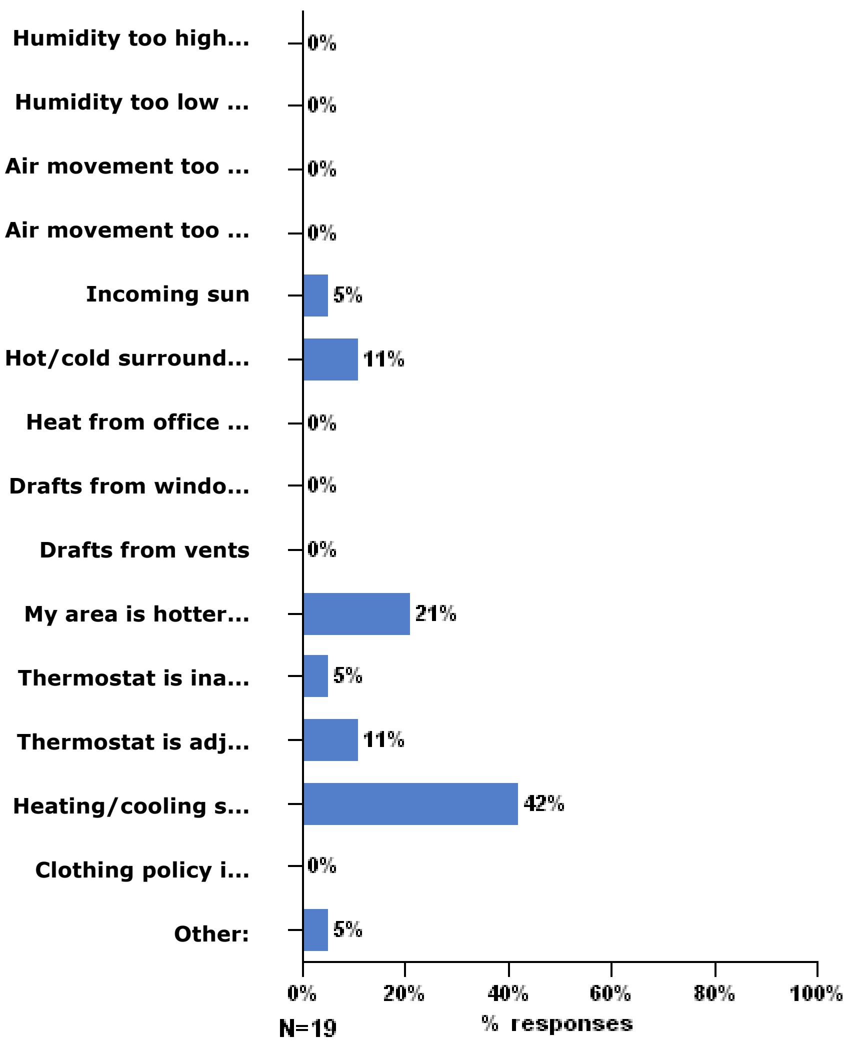
N=17

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



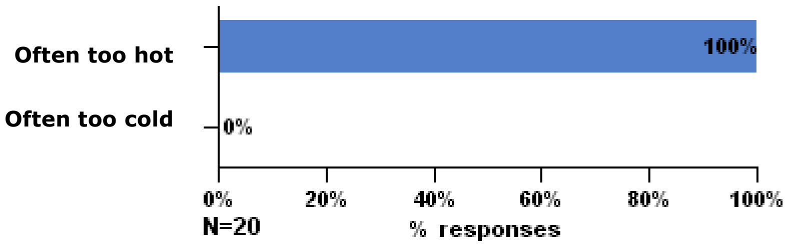


9.7) How would you best describe the source of this discomfort? ***("N" for this question answered the question.)***

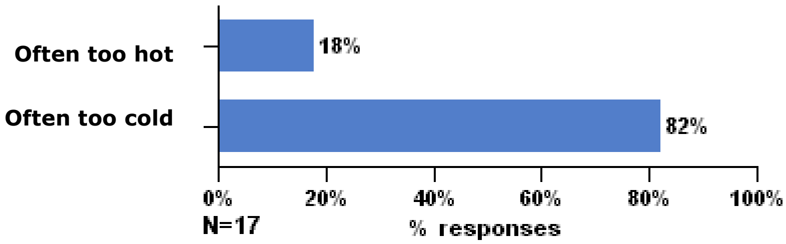


Temperature

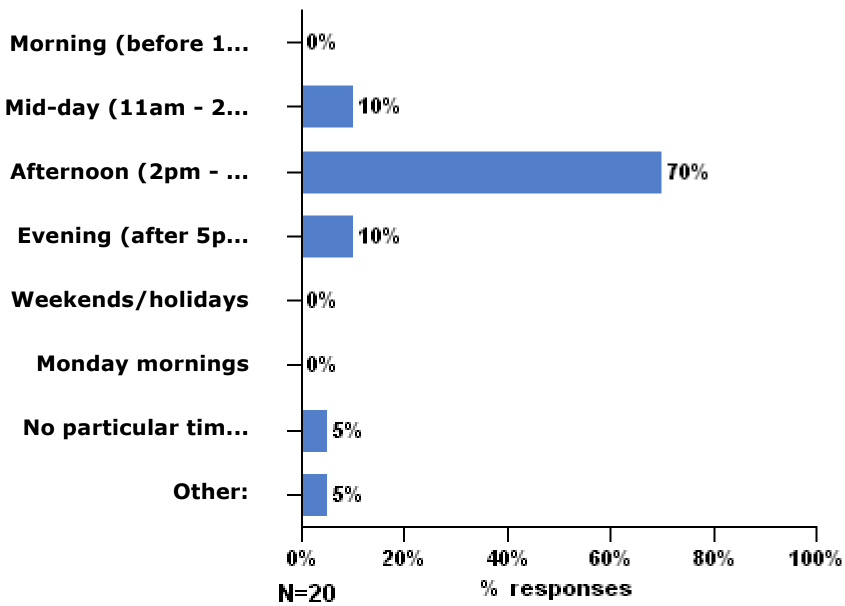
10.1) In warm/hot weather, the temperature in my workspace is: ***("N" for this question is calculated based on the number of users who answered the question.)***



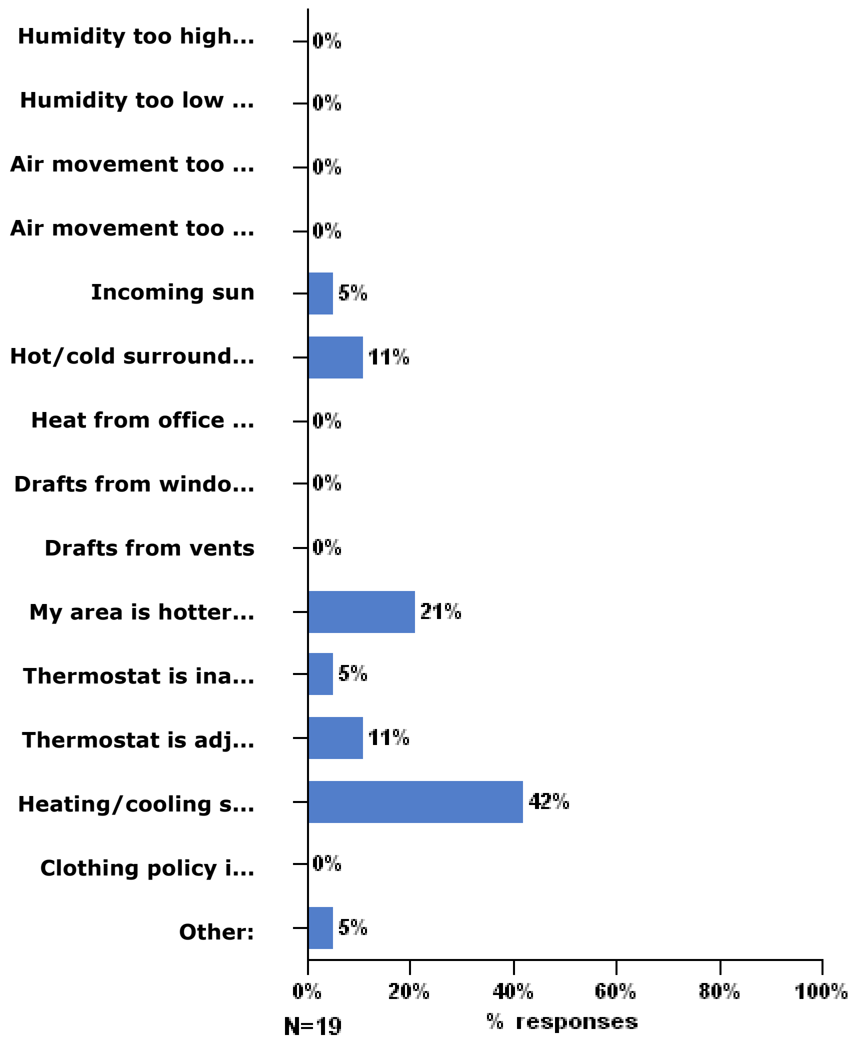
10.2) In cool/cold weather, the temperature in my workspace is: ***("N" for this question is calculated based on the number of users who answered the question.)***



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.)***

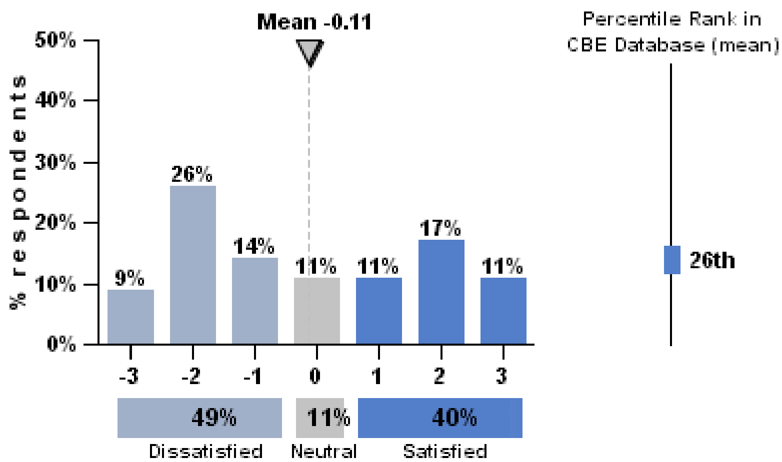


10.4) How would you best describe the source of this discomfort? ***("N" for this question is calculated based on the number of users who answered the question.)***


Humidity too high...
0%
Humidity too low ...
0%
Air movement too ...
0%
Air movement too ...
0%
Incoming sun
5%
Hot/cold surround...
11%
Heat from office ...
0%
Drafts from windo...
0%
Drafts from vents
0%
My area is hotter...
21%
Thermostat is ina...
5%
Thermostat is adj...
11%
Heating/cooling s...
42%
Clothing policy i...
0%
Other:
5%
0%
20%
40%
60%
80%
100%
N=19
% responses

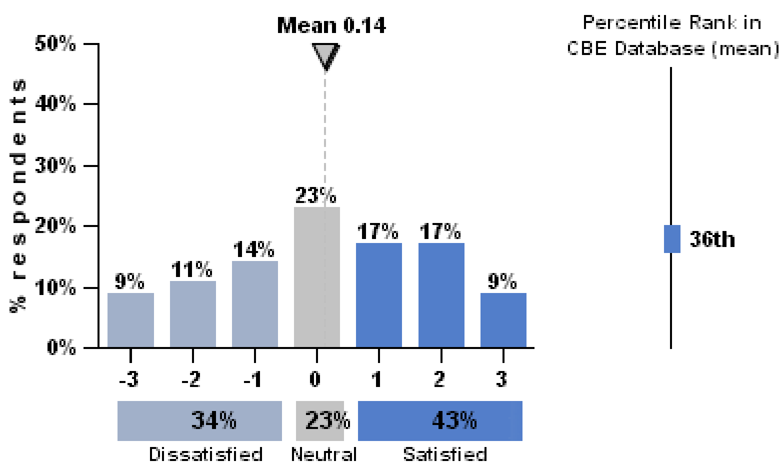
Air Quality

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



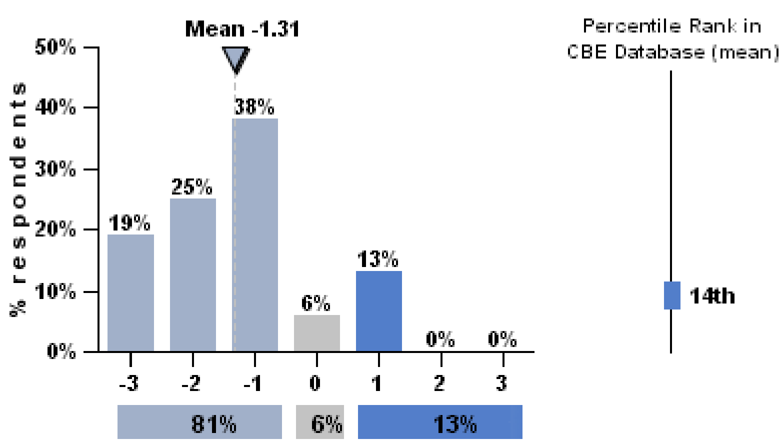
N=35

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



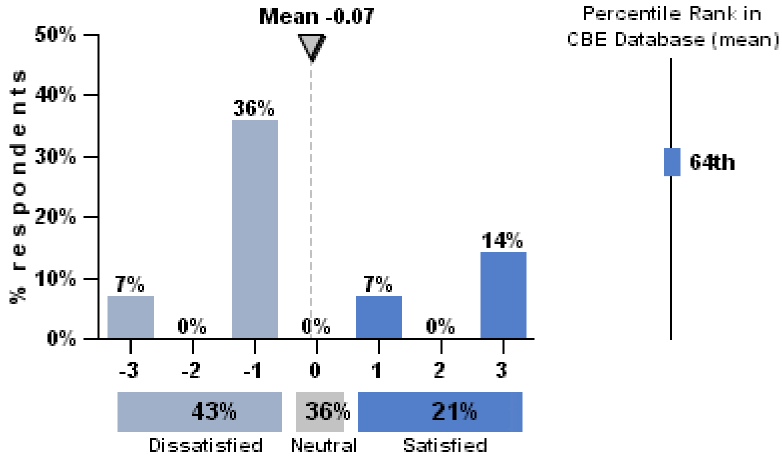
N=35

11.3) Air is stuffy/stale



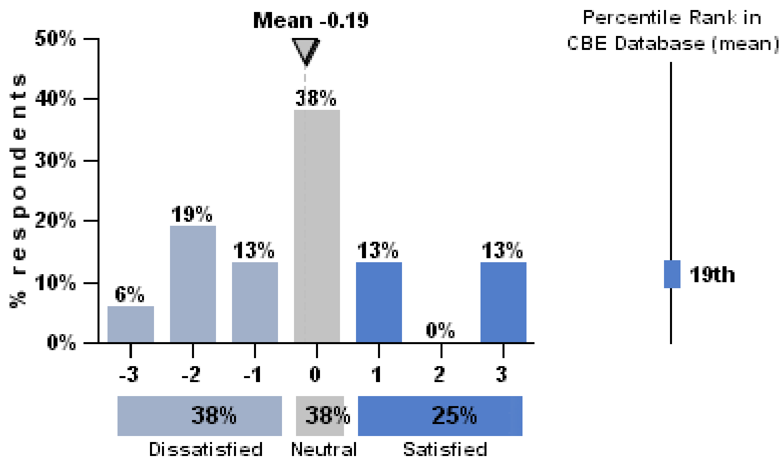
N=16 N/A=1

11.4) Air is not clean



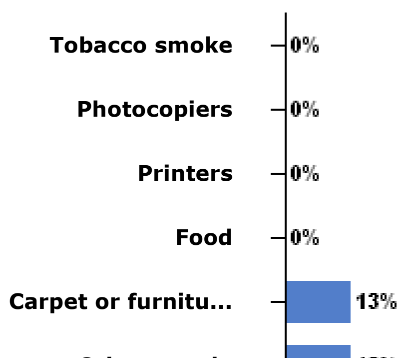
N=14 N/A=3

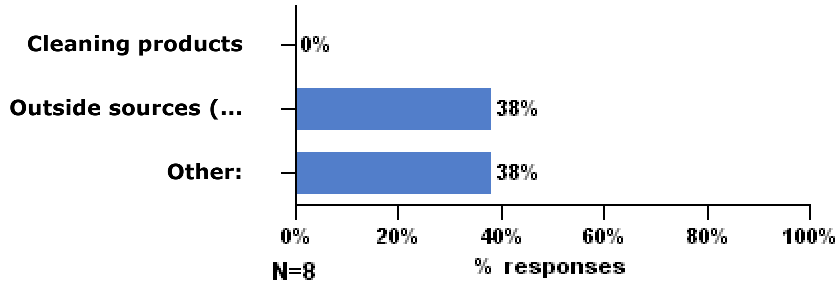
11.5) Air smells bad (odors)



N=16 N/A=1

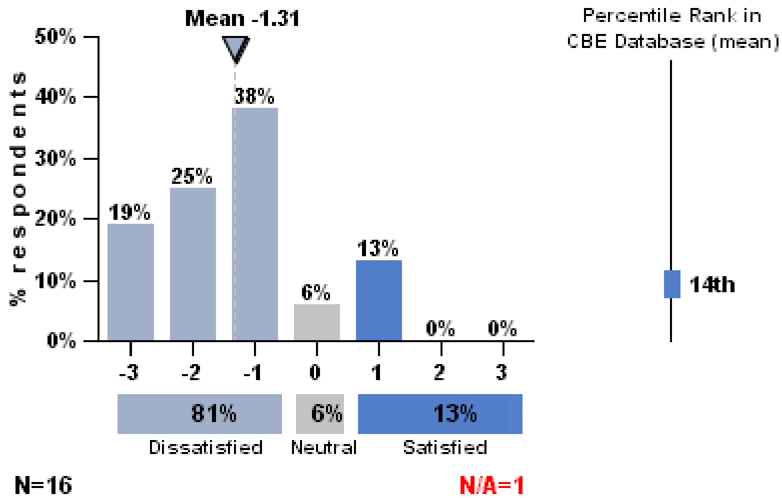
11.6) If there is an odor problem, which of the following contribute to this problem? (" ***number of users who answered the question.)***



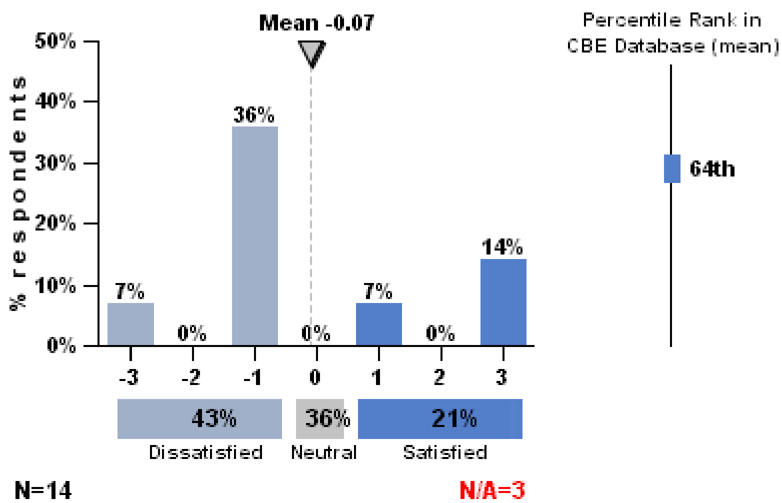

Cleaning products
Outside sources (...
Other:
0%
38%
38%
0%
20%
40%
60%
80%
100%
N=8
% responses

Air Quality (continued)

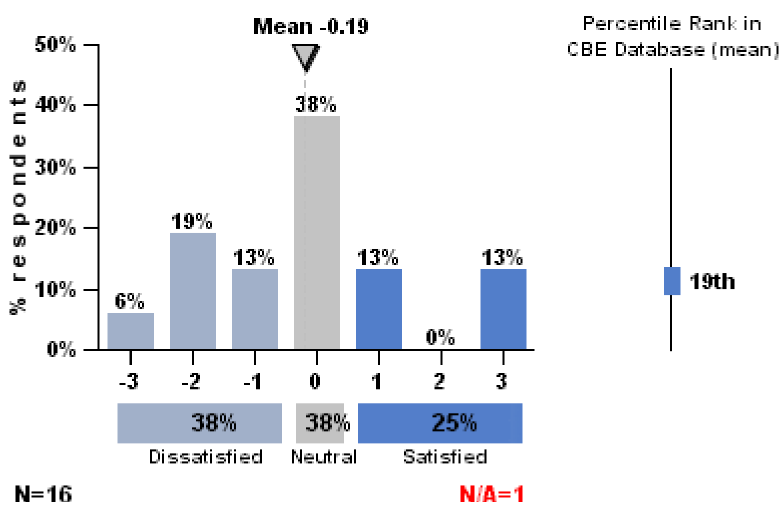
12.1) Air is stuffy/stale



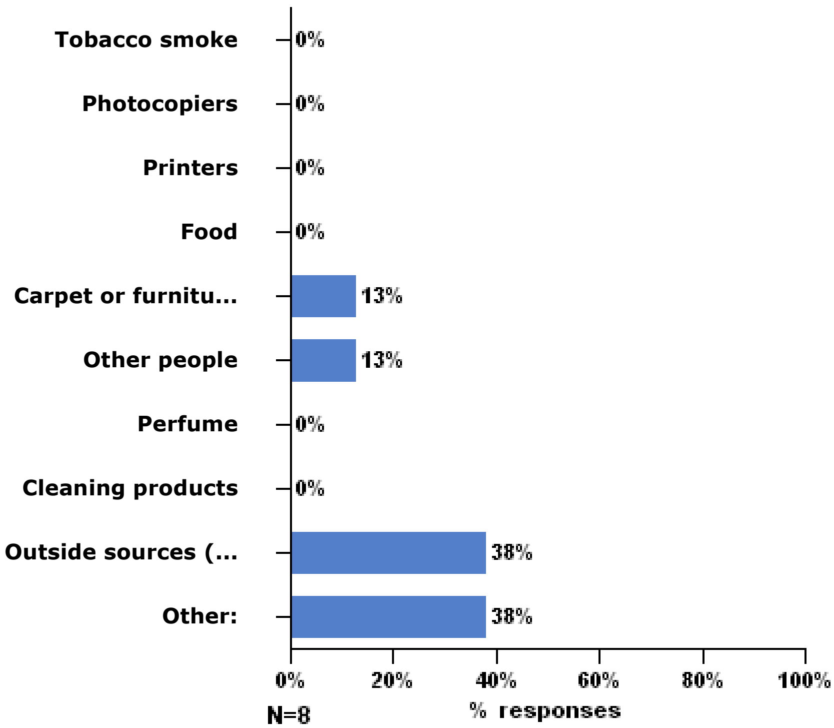
12.2) Air is not clean



12.3) Air smells bad (odors)

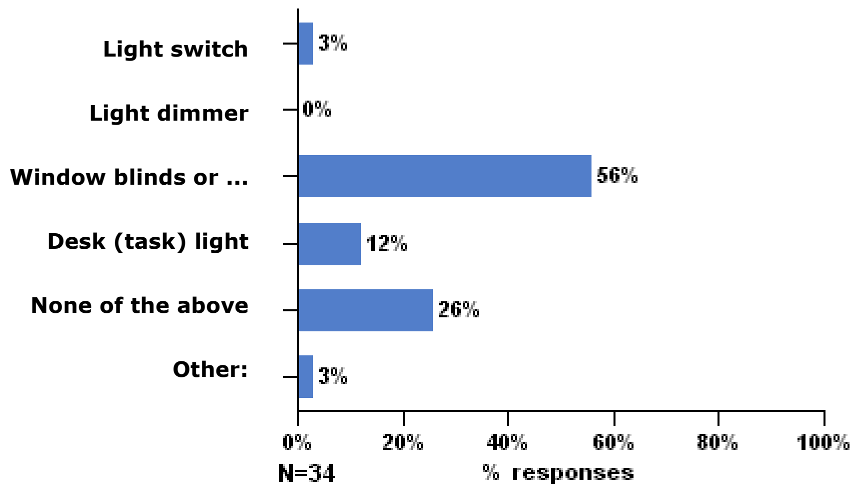


12.4) If there is an odor problem, which of the following contribute to this problem? ***("N" for this question is calculated based on the number of users who answered the question.)***

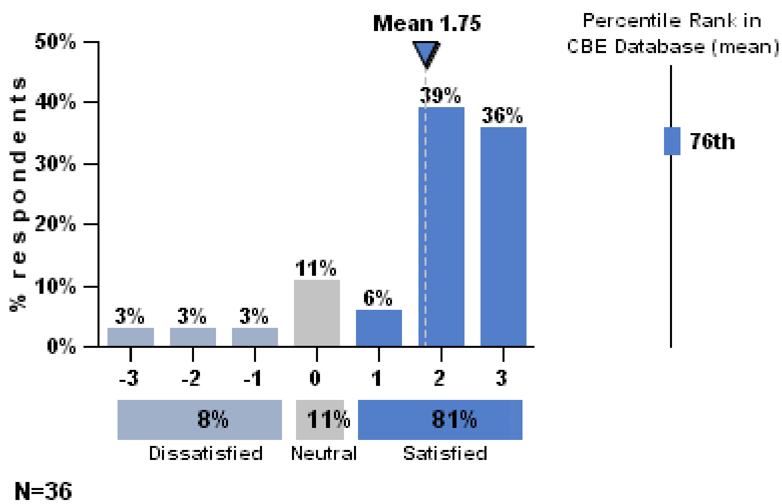


Lighting

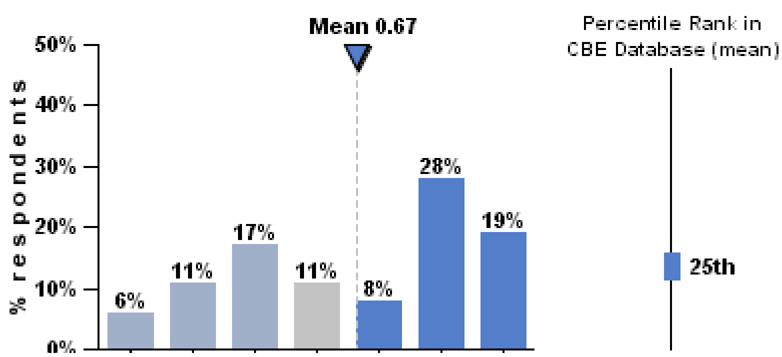
13.1) Which of the following controls do you have over the lighting in your workspace? *("N" for this question is calculated based on the number of users who answered the question.)*

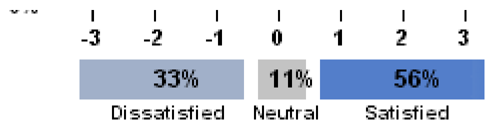


13.2) How satisfied are you with the amount of light in your workspace?



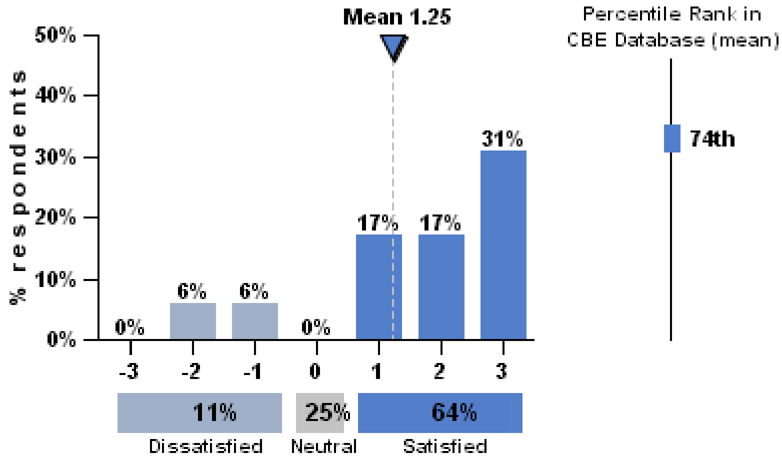
13.3) How satisfied are you with the visual comfort of the lighting (e.g., glare, reflections, contrast)?





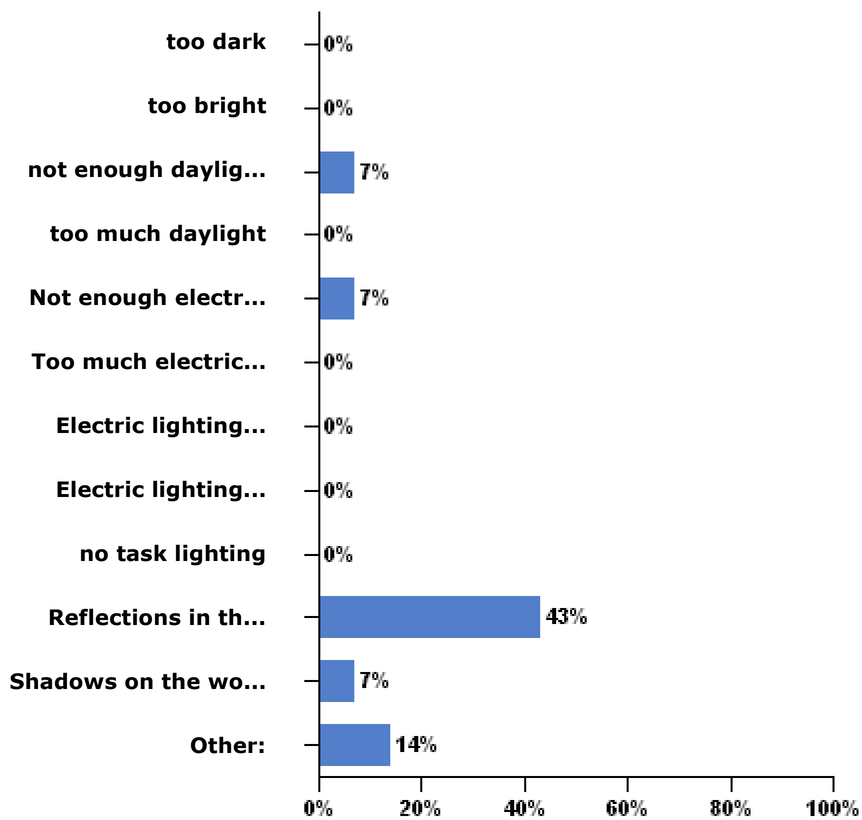
N=36

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



N=36

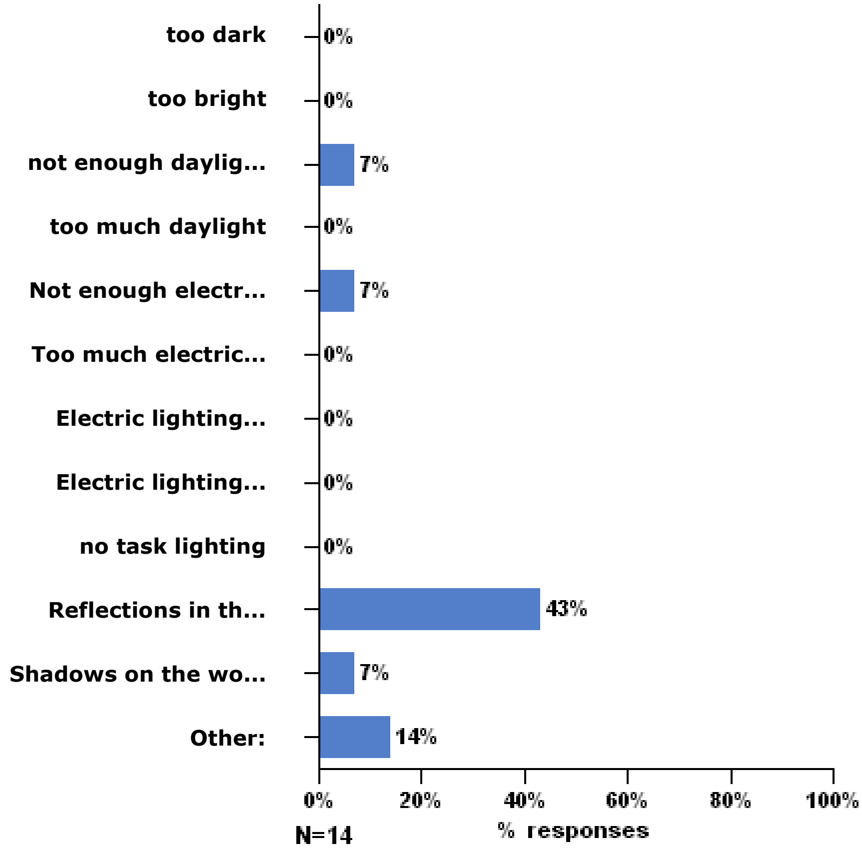
13.5) You have said that you are dissatisfied with the lighting in your workspace. Which of the following contribute to your dissatisfaction? *("N" for this question is calculated based on the number of users who answered the question.)*



N=14 % responses

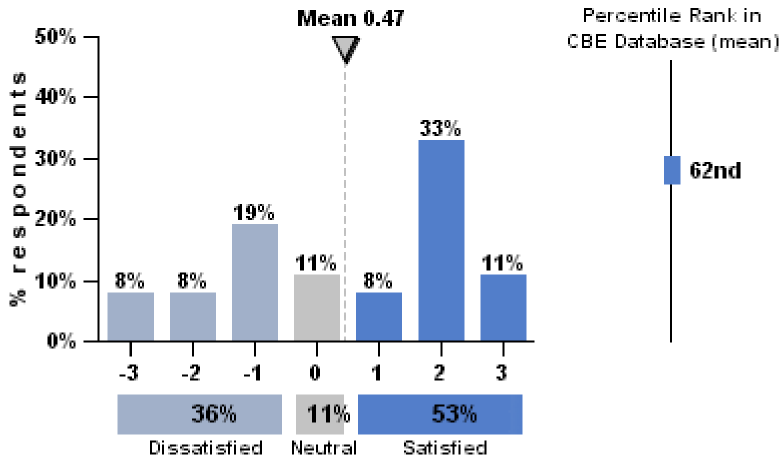
Lighting (continued)

14.1) 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.)*



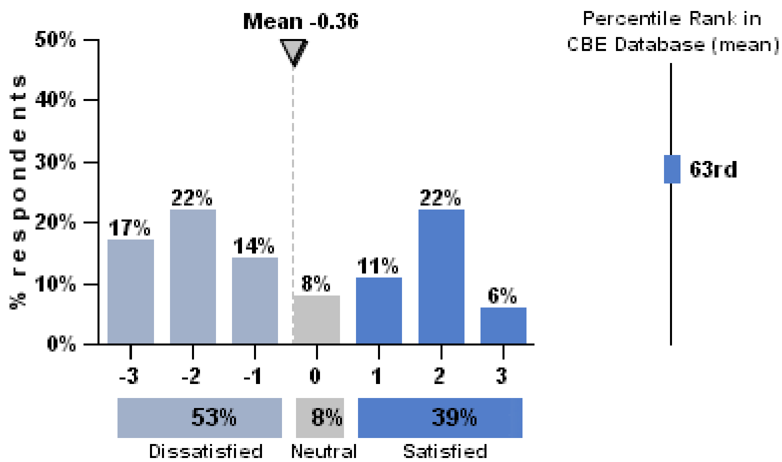
Acoustic Quality

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



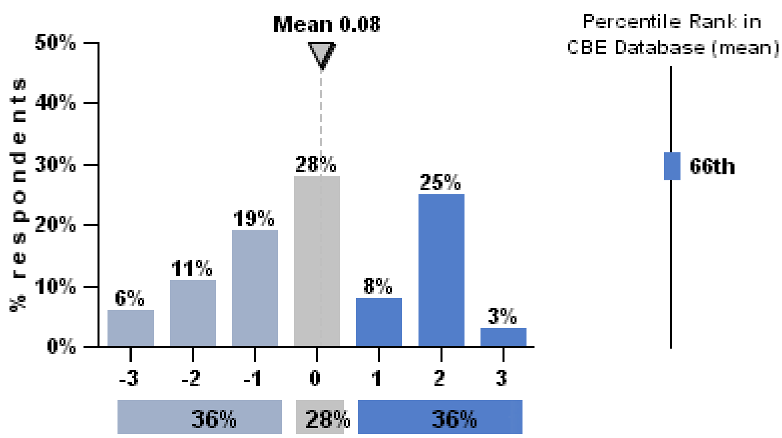
N=36

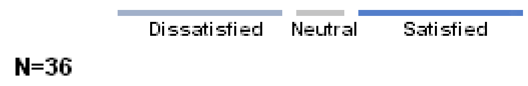
15.2) How satisfied are you with the sound privacy in your workspace (ability to have conversations without your neighbors overhearing and vice versa)?



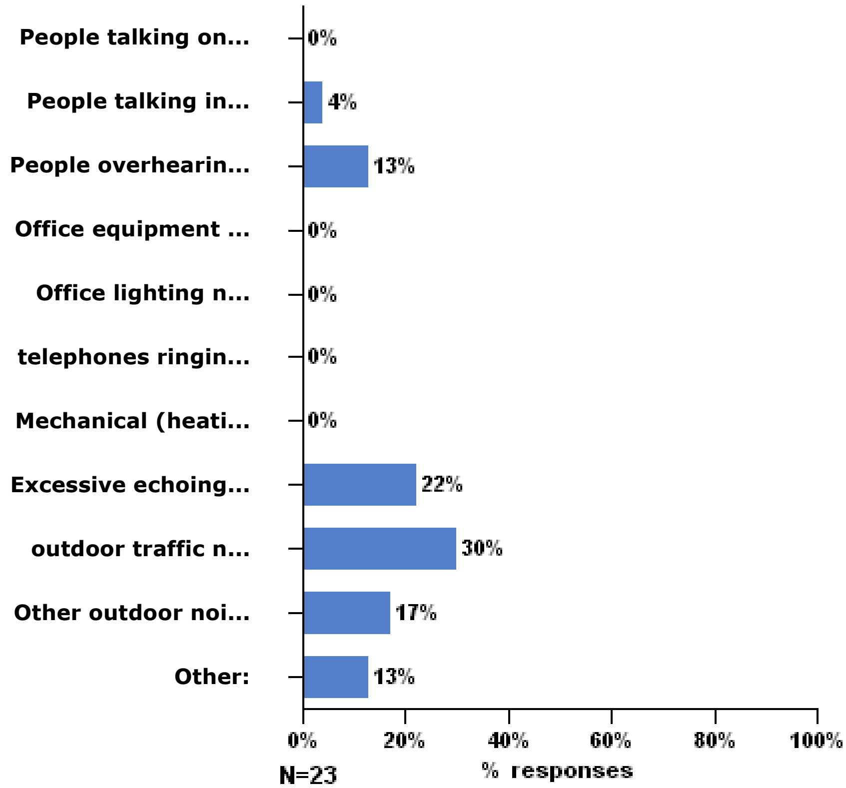
N=36

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



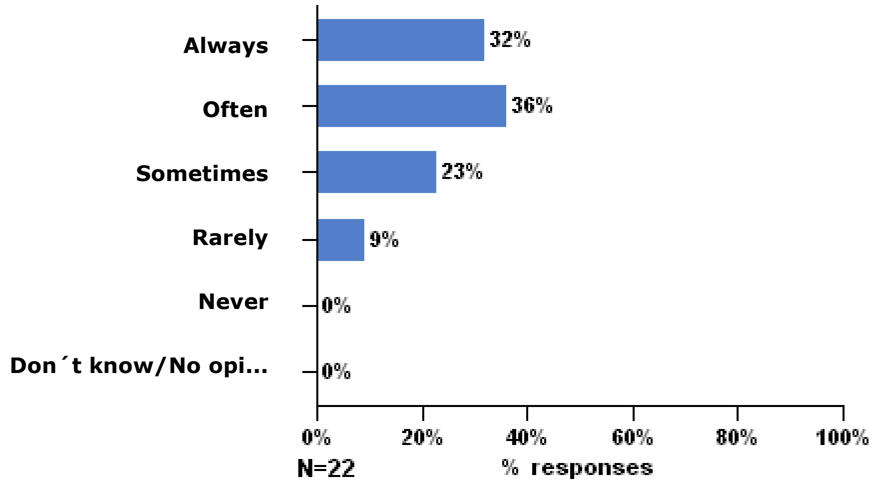


15.4) You have said you are dissatisfied with the acoustics in your workspace. Which of the following contribute to this problem? ***("N" for this question is calculated based on the number of users who answered the question.)***

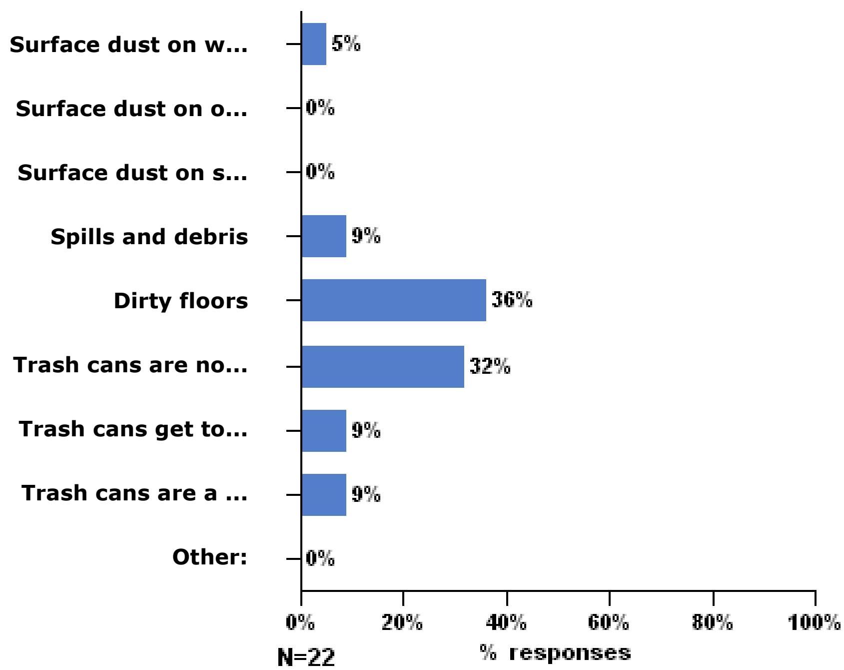


Cleaning Service

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

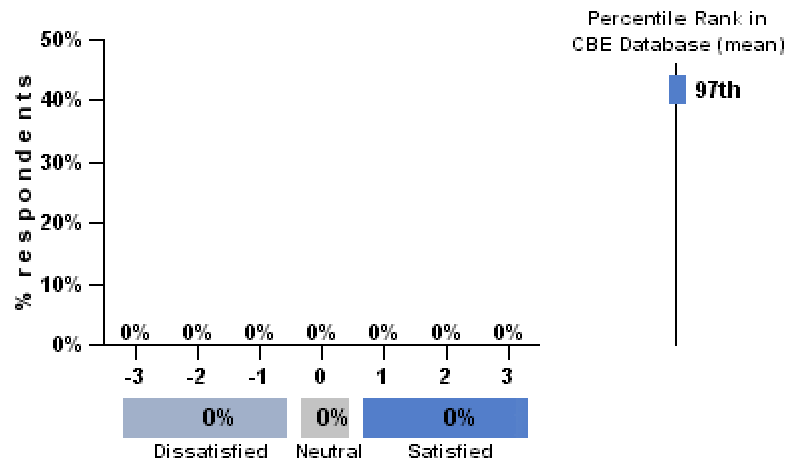


18.2) Which of the following contribute to this dissatisfaction? ***("N" for this question is calculated based on the number of users who answered the question.)***



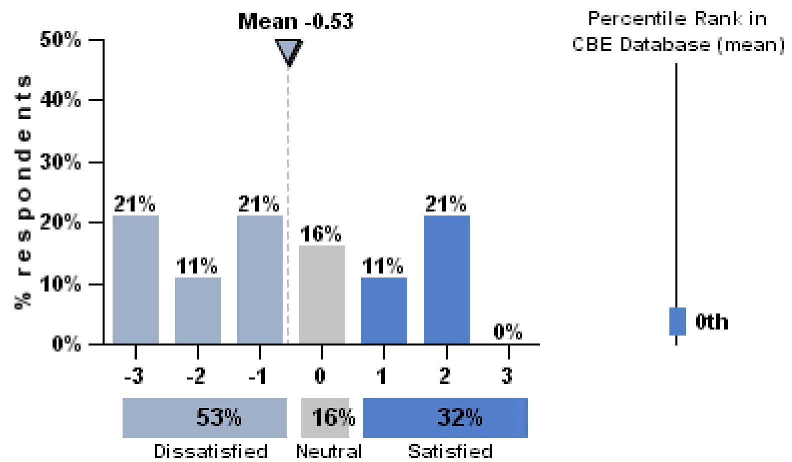
Building Features

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



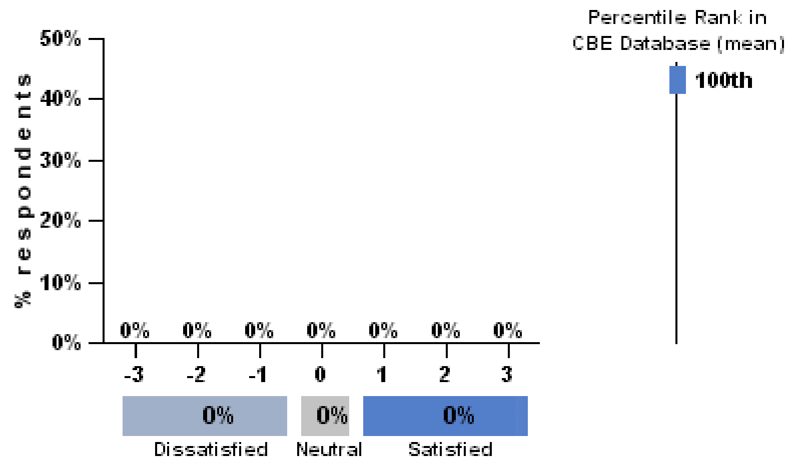
N=0

19.2) Floor air vents



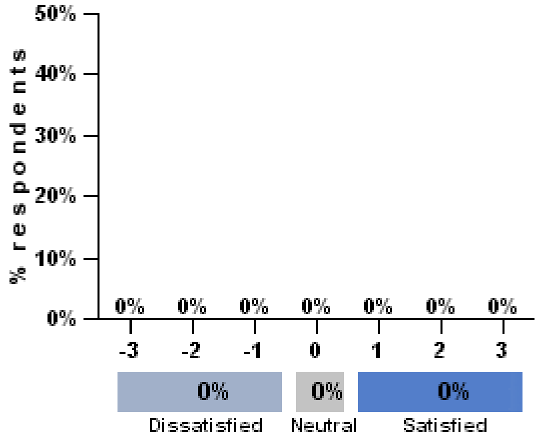
N=19 N/A=17

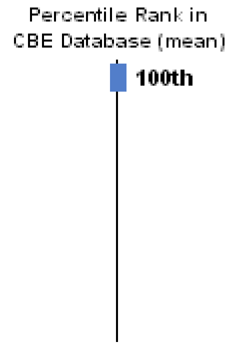
19.3) Thermostats



N=0

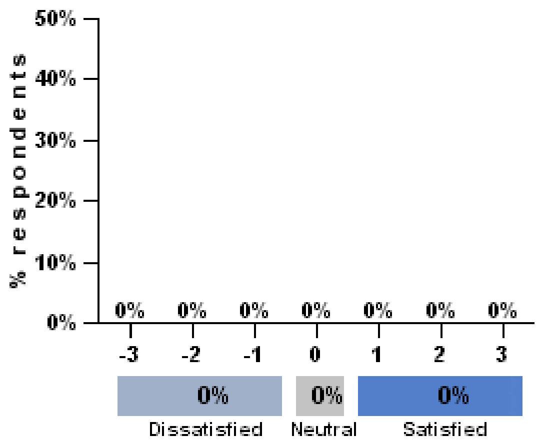
19.4) Light switches

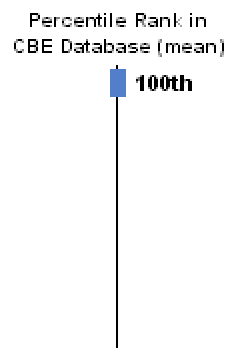




N=0

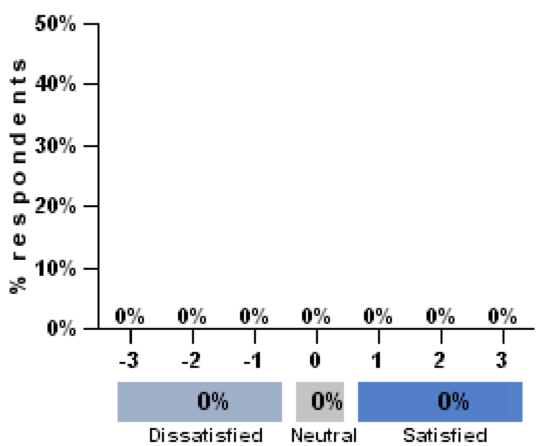
19.5) Automatic daylight controls

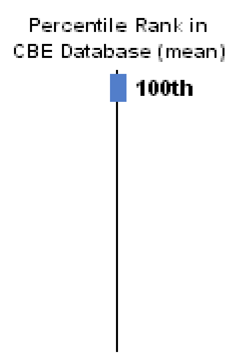




N=0

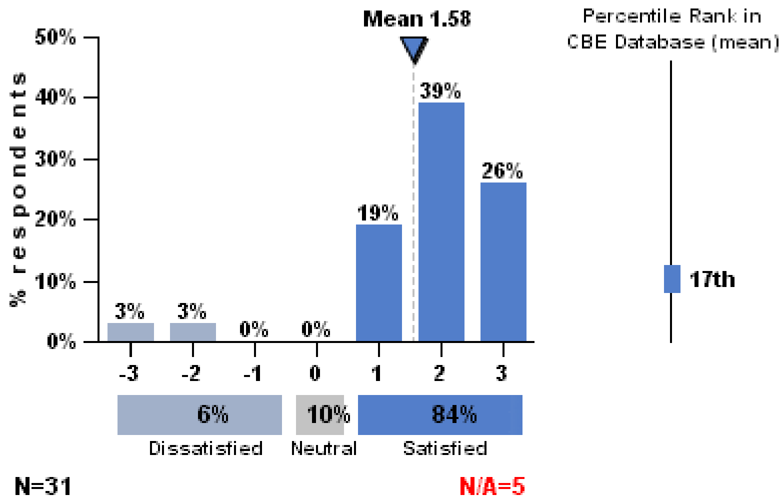
19.6) Occupancy sensors for lighting



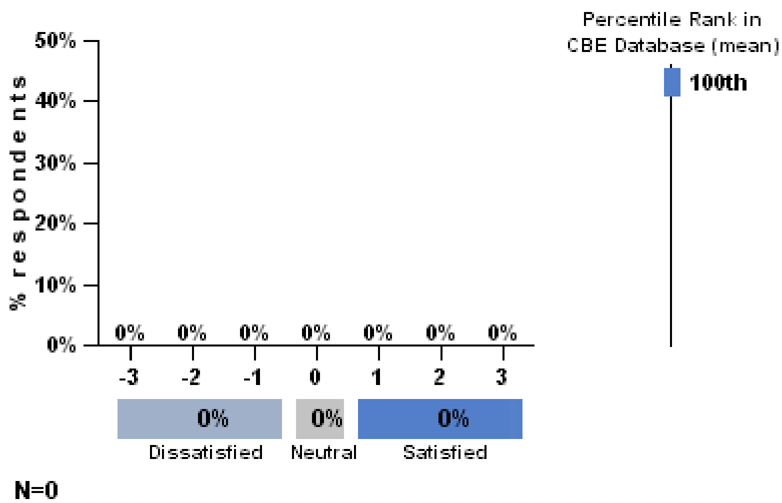


N=0

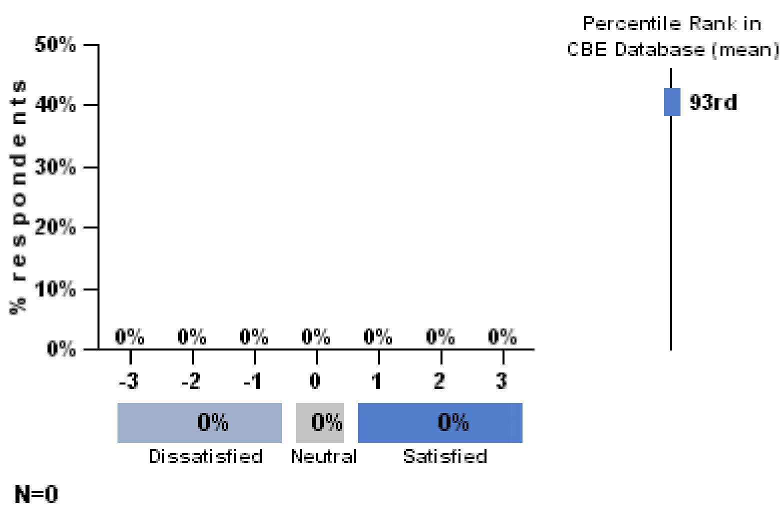
19.7) Window blinds



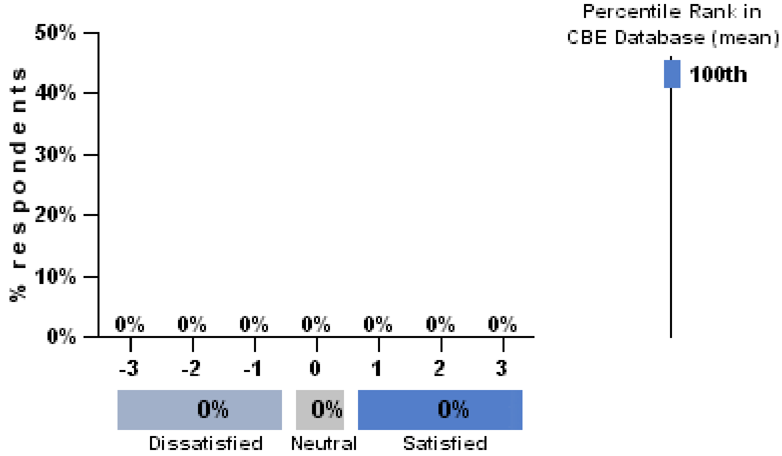
19.8) Roller shades



19.9) Exterior shades

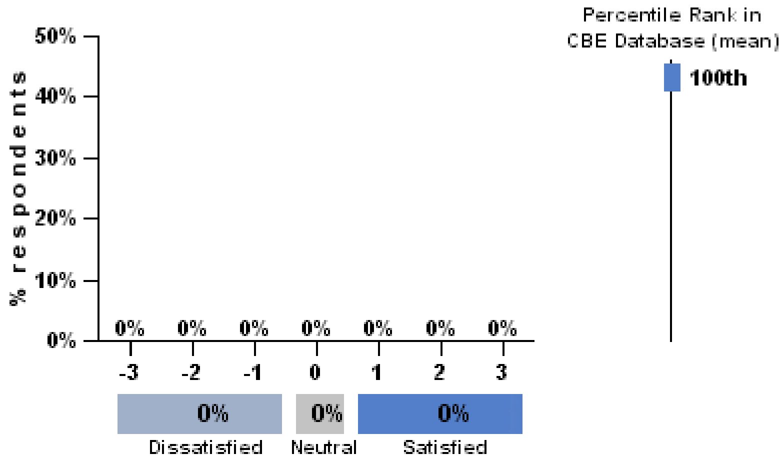


19.10) Low flow faucets



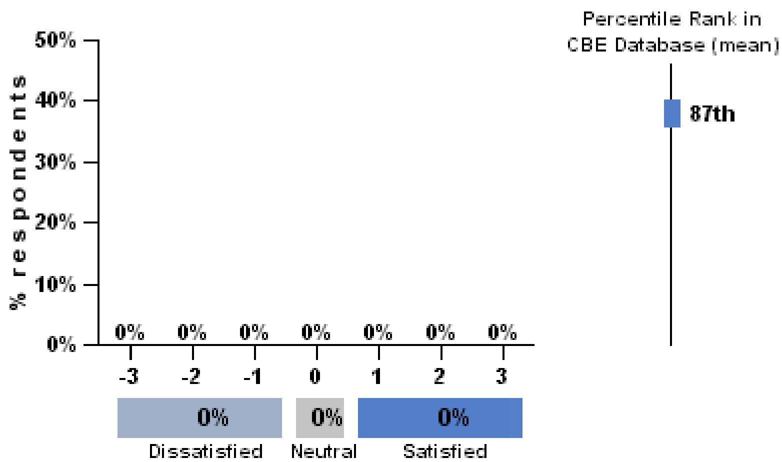
N=0

19.11) Private meeting rooms



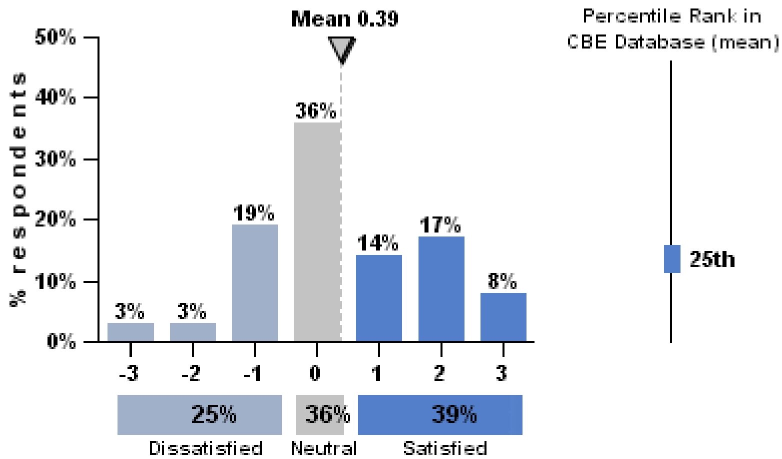
N=0

19.12) Security system



N=0

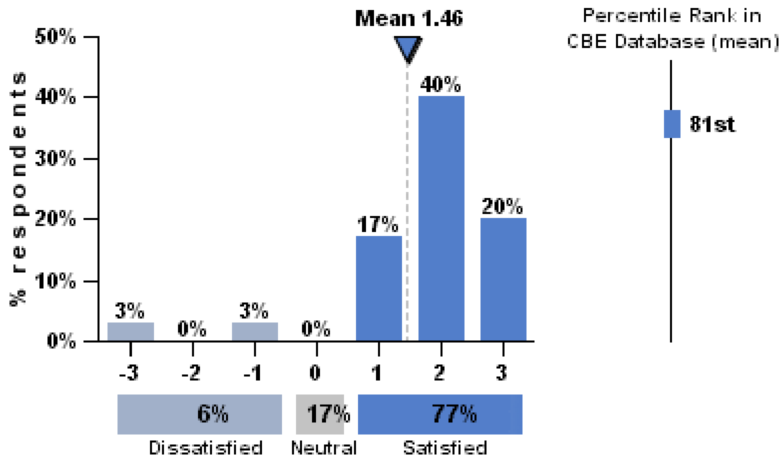
19.13) How well informed do you feel about using the above mentioned features in this


Mean 0.39
Percentile Rank in
CBE Database (mean)
50%
40%
30%
20%
10%
0%
% respondents
3%
3%
19%
36%
14%
17%
8%
-3
-2
-1
0
1
2
3
25%
36%
39%
Dissatisfied
Neutral
Satisfied
25th

N=36

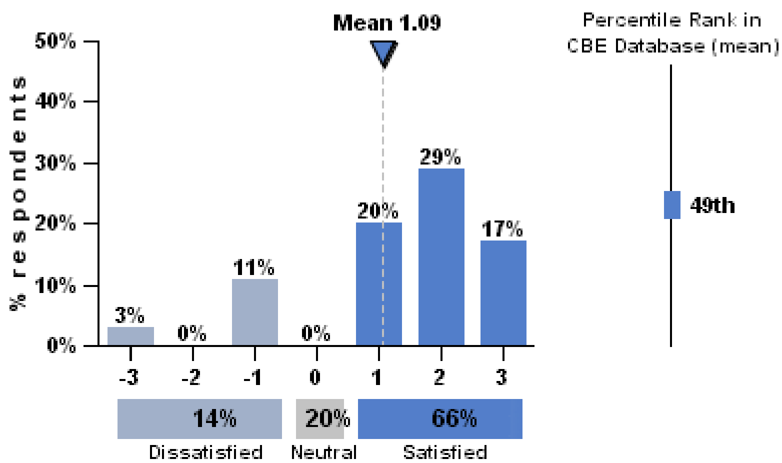
General Comments

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



N=35

20.2) How satisfied are you with the building overall?



N=35

3.3 EMPIRICAL DATA

3.3.1 Indoor Air Quality Measurements

Ten sites were selected for air quality sampling on in Building C, consisting of office spaces. Carbon dioxide, carbon monoxide, ultrafine particulate and composite volatile organic compounds (VOC) were evaluated in the morning and afternoon of June 21st, 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: Measurements taken from first floor private offices.

Private offices (n = 2)	**unit**	**1st sample (9:20 – 9:30 am)**	**2nd sample (2:45 – 3:00 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	< 1 – 10	1 – 6	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	1.8 – 2.0	3.5 – 4.4	0.2
Aldehydes (additive ratios, 24 hr sample, n=2)	ratio	< 1		< 1
CO_2 (range)	ppm	464 – 869	Not taken	410 – 1000

Table 2: Measurements taken from second floor private offices

Private offices (n = 3)	**unit**	**1st sample (9:50 – 10:30 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	6 – 24	< 1	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	1.7 – 2.0	1.2– 1.6	0.2
Aldehydes (additive ratios, 24 hr sample, n=3)	ratio	< 1		< 1
CO_2 (range)	ppm	Not taken	410 – 743	410 – 1000

Table 3: Measurements taken from second floor open plan offices

Open plan offices (n = 5)	**unit**	**1st sample (9:40 – 10:30 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	25– 50	< 1 – 19	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	1.6 – 1.9	2.1 – 6.8	0.2
Aldehydes (additive ratios, 24 hr sample, n=2)	ratio	< 1		< 1
CO_2 (range)	ppm	Not taken	410 – 743	410 – 1000

Building Performance Evaluation: IAQ

Date: 21-Jun-06

Building: Building C

Position:

Sample 1	Ground floor supervisor's private office (west desk)
Sample 2	Ground floor supervisor's private office (south side desk by window)
Sample 3	2nd Floor Superintendent's area (open, central reception area desk)
Sample 4	2nd Floor corner private office (SW corner)
Sample 5	2nd Floor Open office workspace, central
Sample 6	2nd Floor Open office workspace, central
Sample 7	2nd Floor Open office workspace, central
Sample 8	2nd Floor Open office workspace, central
Sample 9	2nd Floor Private office
Sample 10	2nd Floor Private office (south facing)

Notes:

Building C

Morning	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Time:	9:20	9:28	9:40	9:50	10:00	10:05	10:13	10:18	10:24	10:30
weather:	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c
ppbRAE	10	<1	50	24	32	25	60	45	24	6
P-Track	26800	30000	26700	30000	23000	24400	26100	28400	24400	24300
CO2	547 (range 464 - 869)									
CO	<1 (range 0 - 1)									
Temperature	24.8 (range 22.7 - 25.3)									
%RH	39.2 (range 37.5 - 46.1)									

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor	<1	CO	<1
P-track (pt/cc)	14700	Temp oC	17.8
CO2 (ppm) outdoor	463	% RH	46.5

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
I:O VOC	10	1	50	24	32	25	60	45	24	6
I:O P-track	1.8	2.0	1.8	2.0	1.6	1.7	1.8	1.9	1.7	1.7

Building C

Afternoon	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Time:	2:45	2:50	2:53	2:56	3:00	3:05	3:08	3:12	3:17	3:21
weather:	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c	sunny p/c
ppbRAE	6	1	<1	<1	<1	<1	<1	19	<1	<1
P-Track	19900	15900	9300	5510	12600	12100	23000	30600	NT	7060
CO2	NT		442	440 (range 410 - 743)						NT
CO	NT		1	<1 (range 0 - 1)						NT
Temperature	NT		25	24.7 (range 24.0 - 25.9)						NT
%RH	NT		37	37.6 (34.2 - 41.2)						NT

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor	<1	CO	<1
P-track (pt/cc)	4530	Temp oC	29.7
CO2 (ppm) outdoor	417	% RH	35.2

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
I:O VOC	6	1	1	1	1	1	1	19	1	1
I:O P-track	4.4	3.5	2.1	1.2	2.8	2.7	5.1	6.8	NT	1.6

3.3.2 Thermal Comfort Measurements

Eleven 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 11 sample locations, taken three times during the day to assess variability. The dry bulb temperature in the fourth column indicates the air temperature in each space.

Date: 13/06/06 Building C

time (morn)	weather	location	dry bulb	rad temp	air velocity	windows and environmental factors
7:48	c+r	1	22.5	23.1	0.000	0/2 wo, do
no access		2				
8:13	c	3	24.6	24.5	0.000	do, no windows
8:04	c	4	23.6	23.8	0.010	3/5 wo
8:40	c	5	23.2	23.9	0.000	2/2 wo
8:25	c	6	22.8	23.9	0.102	2/4 wo
8:32	c	7	23.6	23.8	0.305	FAN ON, 2/2 wo, do
8:49	c	8	22.2	23.5	0.112	1/1 wo
9:08	c	9	21.8	23.4	0.010	do (to outside) dc (to inside)
9:00	c	10	24.0	24.0	0.051	no windows, dc
9:17	c	11	22.8	22.9	0.000	no wo, dc
9:25	c	outside	17.4	19.2	gusty	

time (mid)	weather	location	air temp	rad temp	air velocity	windows and environmental factors
no access		1			0.003	
12:40	c	2	22.6	23.8	0.000	2/2 wc
1:22	c	3	23.8	24.6	0.003	do (only me present)
12:50	c	4	24.0	24.2	0.000	wc
12:58	c	5	23.6	24.2	0.013	do, wo, shade closed
1:07	c	6	23.0	23.8	0.081	2/4 wo, shades half closed
1:14	c	7	24.2	24.3	0.000	FAN ON, 1/2 wo
1:30	c	8	22.1	23.5	0.071	do (to outside) dc (to inside)
1:50	c	9	23.0	23.8	0.000	wc
1:57	c	10	24.2	24.2	0.000	no windows, dc
1:37	c	11	22.8	23.2	0.000	wc, dc
2:06	c	outside	19.4	23.3	gusty	

time (aft)	weather	location	air temp	rad temp	air velocity	windows and environmental factors
3:02	c+s	1	22.2	25.2	0.102	2/2 wo, 4/4 shades closed
no access		2			0.000	
no access		3			0.000	
3:12	c+s	4	24.5	24.9	0.051	3/5 wo
3:19	c+s	5	24.1	24.9	0.025	1/1 wo, do, blinds closed
3:26	c+s	6	22.9	24.7	0.076	1/2 wo, 2 blinds half closed
3:33	s	7	25.7	26.0	0.178	2/2 wo, do, 2/4 blinds half closed
3:47	c+s	8	23.9	24.7	0.102	1/1 wo
no access		9			0.000	
4:10	s	10	24.6	25.0	0.056	no windows, dc
4:16	c+s	11	23.6	24.7	0.178	wc, dc, 2/5 blinds closed
3:52	s	outside	25.7	36.9	gusty	

	s= sun c= cloud	degrees C	degrees C	degrees C	M/sec	w= window, c= closed, d= door o= open, b= blinds

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 – 2nd floor south, private office
- R2 – 1st floor south, shared office
- R3 – 2nd floor south, open office cubicle
- R4 – 1st floor lunch room
- R5 – 1st floor hallway
- R6 – 2nd floor hallway
- R7 – 2nd floor centre, open office cubicle
- R8 – Meeting room
- R9 – Locker 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.

3.3.4 Lighting Measurements

Ten sites in Building C were selected for lighting measurements. Sites were sampled in the morning and in the afternoon of June 21, 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 first floor private offices.

Private offices (n=2)	**unit**	**1st sample (9:20 – 9:30 am)**	**2nd sample (2:45 – 3:00 pm)**	**Optimal**
Use of blinds:				
Not applicable	n	1	1	NA
Blinds open	n	1	1	
Glare:				
Yes, veiling glare on work surface	n	1	1	NA
No glare	n	1	1	
Incident light				
Measured range	lux	300 – 800	280 – 1400	200 – 500
Comfort ratios				
Incident light to background	ratio	1.3 – 6.7	1.0 – 7.7	0.3 – 3
Computer to background		0.3 – 5.7	0.2 – 7.2	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	0.6 – 1.1		NA

Table 2: Light measurements taken from second floor private offices.

Private offices (n=3)	**unit**	**1st sample (9:30 – 10:30 am)**	**2nd sample (3:00 – 3:30 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	2	1	NA
Blinds closed or greater than 50% closed	n	1	2	
Glare:				
Yes, veiling glare on work surface	n	2	2	NA
No glare	n	1	1	
Incident light				
Measured range	lux	600 – 1800	600 – 2300	200 – 500
Comfort ratios				
Incident light to background	ratio	0.2 – 3.0	0.2 – 3.5	0.3 – 3
Computer to background		0.03 – 0.8	0.1 – 0.5	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	0.7 - 1.0		NA

Table 3: Light measurements taken from second floor open plan offices.

Open plan workspaces (n=5)	**unit**	**1st sample (9:40 – 10:30 am)**	**2nd sample (2:50 – 3:30 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	5	5	NA
Blinds closed or greater Than 50 % closed	n	0	0	
Glare:				
Yes, veiling glare on work surface	n	5	5	NA
No glare	n	0	0	
Incident light	lux			
Measured range		1050 – 1750	1000 – 3700	300 – 500
Comfort ratios				
Incident light to background	ratio	3.7 – 9.6	2.5 – 7.0	0.3 – 3
Computer to background		0.3 – 1.1	0.4 – 0.9	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	0.4 – 1.0		NA

Building Performance Evaluation: Lighting

Date: 21-Jun-06

Building: Building C

Position:

Sample 1	Ground floor supervisor's private office (west desk)
Sample 2	Ground floor supervisor's private office (south side desk by window)
Sample 3	2nd Floor Superintendent's area (open, central reception area desk)
Sample 4	2nd Floor corner private office (SW corner)
Sample 5	2nd Floor Open office workspace, central
Sample 6	2nd Floor Open office workspace, central
Sample 7	2nd Floor Open office workspace, central
Sample 8	2nd Floor Open office workspace, central
Sample 9	2nd Floor Private office
Sample 10	2nd Floor Private office (south facing)

Notes:

Building C

Morning	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Time:	9:20	9:28	9:40	9:50	10:00	10:05	10:13	10:18	10:24	10:30
weather:	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c
fenestration:	NA	open	90% open	90% open	90% open	90% open	90% open	90% open	open	50% closed
Incident (lux)	302	810	1360	1800	1480	1050	1743	1170	612	1062
Glare (Y/N)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Contast:

Comp:bkg	5.7	0.3	1.1	0.2	0.3	0.3	0.6	0.9	0.8	0.03
Incident:bkg	6.7	1.3	9.6	0.9	3.8	3.1	5.6	3.7	3.0	0.2

Notes:

Building C

Afternoon	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Time:	2:45	2:50	2:53	2:56	3:00	3:05	3:08	3:12	3:17	3:21
weather:	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c	sunny, p/c
fenestration:	NA	open	open	open	open	open	open	open	closed	50% closed
Incident (lux)	276	1395	3660	2300	2330	1001	3700	2160	610	1450
Glare (Y/N)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Contast:

Comp:bkg	7.2	0.2	0.9	0.1	0.5	0.6	0.5	0.4	0.5	0.1
Incident:bkg	7.7	1.0	7.0	0.6	6.4	3.3	4.5	2.5	3.5	0.2
AM:PM	1.1	0.6	0.4	0.8	0.6	1.0	0.5	0.5	1.0	0.7

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
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- Clivus Multrum
- Public Works and General Services Canada
- Greater Vancouver Regional District
- Building C Owner
- Building C Architect
- Building C Mechanical Engineer