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## Indoor Environmental Quality (IEQ)

### Title

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# Measuring Indoor Environmental Quality: A Web-based Occupant Satisfaction Survey

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## 1. INTRODUCTION

High-performance green buildings are often promoted as offering higher quality, more productive environments for their occupants. Yet measuring how successful a building is at achieving this objective can be difficult. Post-occupancy studies are done infrequently and tend to be highly customized for specific applications. The Center for the Built Environment (CBE) at the University of California, Berkeley has developed a web-based occupant indoor environmental quality (IEQ) survey to inexpensively measure occupants' perception of the quality of their workplace environment. A set of core questions is used to assess occupant satisfaction and comfort with respect to many issues related to green building objectives including indoor air quality, thermal comfort, lighting and acoustics. Custom modules can be added to address issues not covered in the core questions, and the survey can be offered in multiple languages. Surveys assessing other aspects of building quality are also in use, including an operations and maintenance staff survey, and a design and construction process survey. Together this set of surveys provides a complete picture of the quality of the building process, from the planning phase through the occupancy phase. The CBE building quality surveys have been conducted in 45 buildings to date (including three LEED-rated buildings), including office buildings, laboratories, banks and courthouses in North America and Europe. The database of survey responses is growing rapidly and is increasing its utility for benchmarking performance.

## 2. SURVEY STRUCTURE

### 2.1 Development of the CBE Building Quality Surveys

The collection of web-based CBE building quality surveys began with the development of a core occupant IEQ survey. New modules and survey types have also been developed, facilitated by the flexibility of the survey infrastructure.

**2.1.1 The Occupant IEQ Survey.** Comprised of faculty and researchers at the University of California, and supported by the National Science Foundation and public- and private-sector industry partners, CBE works to inform the building industry about new building technologies and design techniques. A core tenet of CBE is that everyone in the building process benefits from learning how a building actually performs in practice. The occupant IEQ survey is a standardized survey instrument that can be applied widely to evaluate the performance of individual buildings as well as systematically compare the performance of groups of buildings. The survey grew out of earlier thermal comfort surveys conducted by CBE (Benton, 1994; de Dear, 1997; Schiller, 1988), but the focus has now shifted to a new audience – facility managers and building owners involved in acquiring, operating and improving their building portfolio. Working with several of our industry partners, the survey has evolved into a web-based tool that measures employees’ satisfaction with their workplace environment quickly and at a low cost.

The survey is comprised of a core survey and optional survey modules. Each organization using the survey has the option of using the core survey or customizing the survey to include additional modules that support their information needs. The core survey includes modules for office layout, office furnishings, thermal comfort, air quality, lighting, acoustics, and building cleanliness and maintenance. Examples of optional modules include wayfinding, operable windows, shading systems, floor diffusers, and washrooms. Core questions stay consistent from survey to survey to maintain data integrity for the purposes of benchmarking and trend analysis.

The survey has been extensively tested and refined, and facility managers and designers have evaluated the reporting format to determine the utility of various report designs. An established in-depth pre-testing method called cognitive interviewing was used by the Survey Research Center at UC Berkeley to assess how well respondents were able to comprehend and accurately report answers to survey questions (Eisenhower, 2000). Cognitive interviews allow researchers to examine the thought processes that affect the quality of answers provided to survey questions. The primary technique used was the “concurrent think aloud” whereby respondents were asked to comment out loud about anything crossing their mind as they read, interpreted and answered each question. This technique was supplemented by paraphrasing (asking the respondents to put something in their own words) and systematic probing. Seven people participated in this testing. Results were used to refine the survey organization, question text, graphic design of the scales, and the process required to access the survey website.

The time to completion has been monitored, and occupants have evaluated the length of each section of the survey. Approximate time to completion for the core survey is 5-12 minutes; time to completion varies depending on the number of branching questions and comments answered. This length of time has not been regarded as an impediment to completion in most (but not all) of the buildings surveyed to date. Surveys that include several customized modules in addition to the core survey have had completion times of up to 20 minutes. Organizations that choose to implement longer surveys are briefed regarding the potential negative effect that longer time to completion can have on response and completion rates.

**2.1.2 Customization and Continued Survey Development.** As mentioned above, survey customization is possible, and clients can add new or existing modules to the core survey to suit the needs of a particular project. Indeed, owing to the flexible infrastructure underlying the

survey, whole new surveys can be and have been developed. One CBE partner has commissioned a customized occupant IEQ survey, as well as the creation of two new building quality surveys: the operations and maintenance staff survey aims to determine how satisfied the staff is with the construction of the building and its affect on their ability to run and maintain the facility; and the design and construction process survey polls the design and construction teams for their satisfaction with the process of building the facility. Each of the three surveys is designed for a distinct population, and during the post-occupancy evaluation (POE), all three surveys are conducted in each building to learn how it is performing for its occupants and operators, and how the design team felt about the construction process.

**2.1.3 Multilingual Capabilities.** We have implemented the occupant IEQ survey in buildings across the United States and in Canada, and in Europe as well. The structure of the survey scripts enables us to offer the survey and accompanying reporting tools in any language. The first organization to implement the survey internationally did so in two buildings in Finland, and thus our initial translation is in Finnish. A Danish translation is also underway for a University in Denmark. The survey can be offered in multiple languages simultaneously, with respondents choosing the desired language at the time they access the survey web page. The foreign language questions have been mapped to the English ones so that comparisons of the data can be made regardless of the language in which the survey was taken.

## **2.2 Implementation**

The occupant IEQ survey implementation process typically begins with an email informing building occupants of the survey web site address, start date and end date. This email is drafted and sent either by CBE or the sponsoring agency. Subjects can open the survey at their convenience. After linking to the survey, respondents see a welcome screen informing them of the purpose of the survey. The welcome page also advises them of the amount of time it should take to complete the survey, and their rights as a research participant. Participation in the survey is voluntary and anonymous. Upon starting the survey, participants click through a series of questions asking them to evaluate their satisfaction with different aspects of their work environment. Satisfaction is rated on a 7-point scale ranging from “very satisfied” to “very dissatisfied,” with a neutral midpoint. In most cases, respondents who indicate dissatisfaction (the lowest three points on the scale) with a particular aspect of their work environment are branched to a follow-up screen probing them for more information about the nature of their dissatisfaction. Respondents who indicate neutrality or satisfaction (the upper four points on the scale) move directly to the next survey topic. Tailoring the survey to each respondent in this fashion enables diagnostic information to be gathered about potential problems in the building, and keeps questions relevant while making the survey as short as possible. When applicable, respondents are also asked to assess the impact of environmental factors on their effectiveness in getting their job done.

Occupant responses are collected via the Internet and recorded to a secure SQL Server database. A survey typically stays open for 1-2 weeks. The rate of participation is monitored; and if it is going slowly, reminder emails may be sent. Of the buildings surveyed to date, response rates have ranged from 27%-88%, with the majority of response rates between 45%-65%.

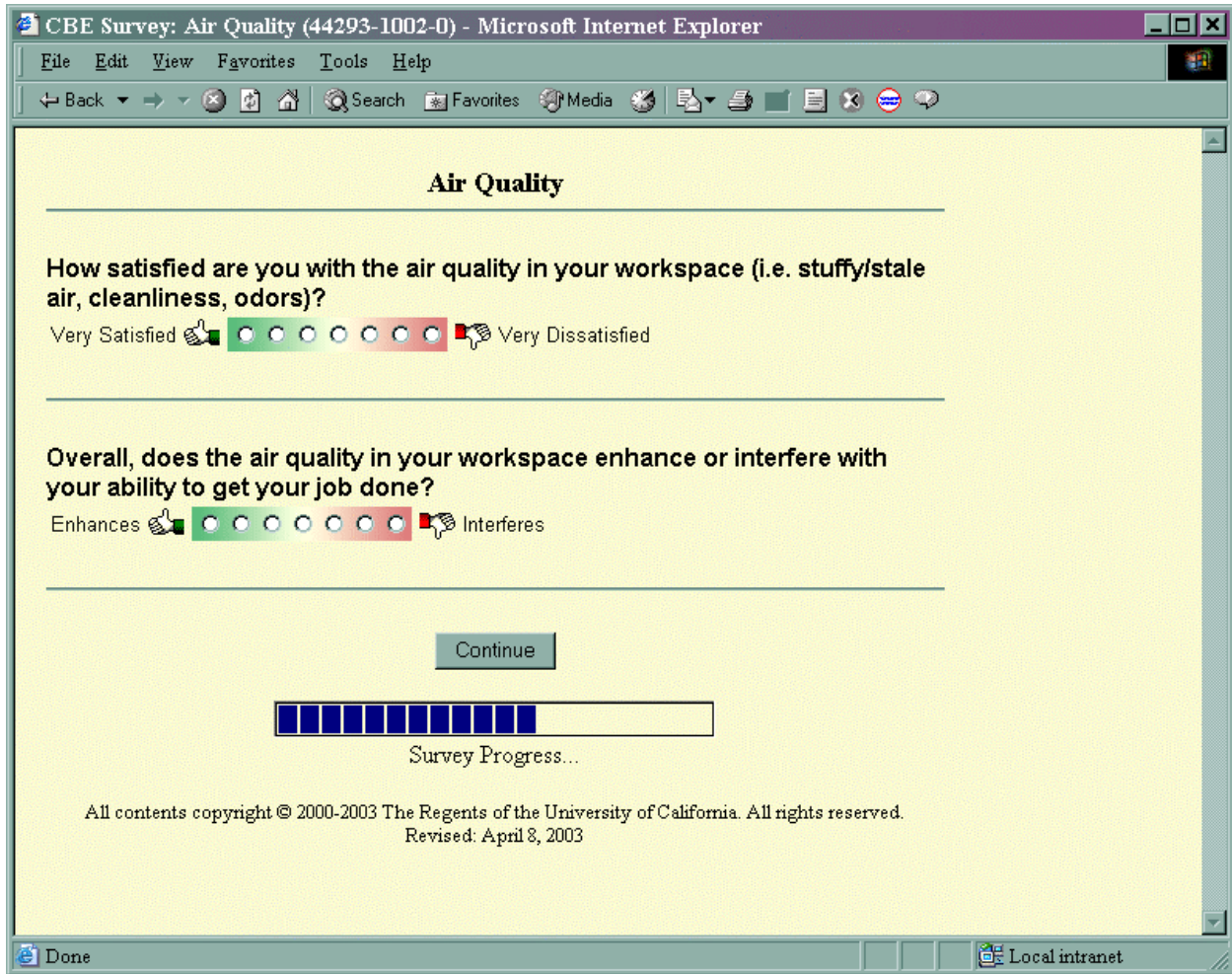


Figure 1 Sample occupant IEQ survey page (screen shot of web-based survey)

## 2.3 Reporting Results

**2.3.1 Individual Building Report.** Data is reported using a web-based reporting tool, and is quickly made available to clients after survey implementation, typically within a week following the survey close date. With the exception of some data cleaning, the report generation is entirely automated. The home page of the report summarizes the satisfaction ratings for each of the survey categories. Satisfaction ratings are tabulated for each point on the scale, and are also summarized into three bins: satisfied (top three points), neutral (middle point) and dissatisfied (bottom 3 points). This executive summary is particularly useful to managers that need to see a top-level overview of occupant feedback. The report's survey category pages provide charts representing the responses to each of the survey questions. Comments are also displayed for each question. We have learned that reviewers typically scan these comment lists right after looking at the executive summary page (Baughman, et al, 1995). To protect the confidentiality of participants, the online report contains only aggregated, anonymous results.

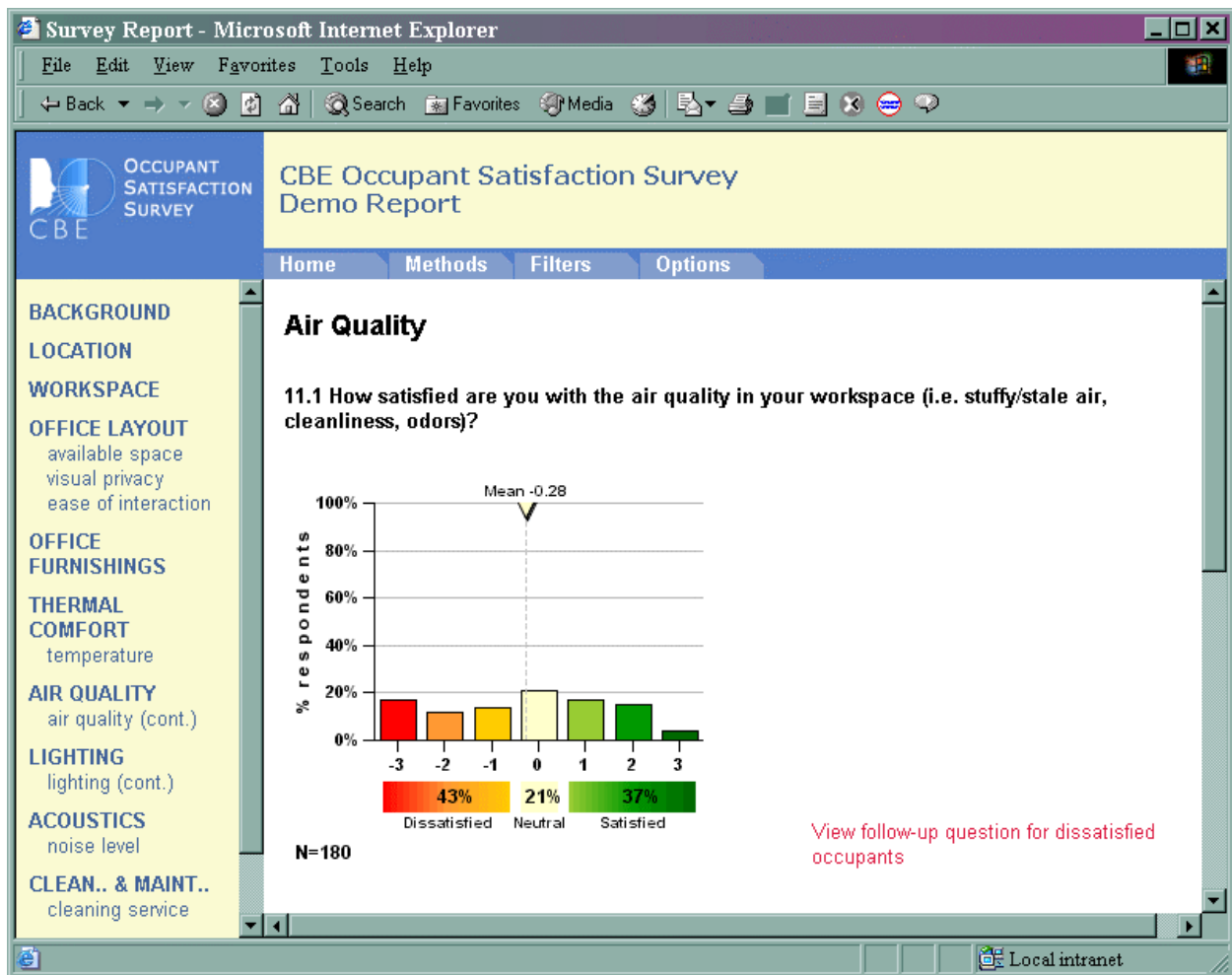


Figure 2 Sample individual building report page (screen shot of web-based report)

The report's filtering feature enables users to view relationships between questions. Using an intuitive interface, filtering criteria is set up that allows just a subset of the responses to be displayed in the charts. For example, perhaps data for occupants who sit near an exterior wall is of special interest: with this filter enabled, the report shows only the data for those respondents who indicated that they sit near an exterior wall. Several filters can be set up and strung together in a Boolean AND query, further defining the results viewed in the individual building report.

**2.3.2 Datamining Tool.** Currently in development, a Java-based software application will enable users to dynamically explore the data in the survey database, in order to investigate hypotheses and observe trends in building quality satisfaction with respect to various building technologies. The tool will first be made available to in-house researchers, then as layers of permissions are added will be made available to the wider audience of the external research groups, architects/designers, building owners/managers and operators who commission surveys. The tool has tiered security access, allowing participating organizations to view their own results in full but keep detailed comments and building identifier data confidential. CBE industry partners have the option of comparing the results for their building(s) against the entire CBE database. Non-partners can conduct comparisons only among the group of buildings they have surveyed.

**2.3.3 Raw Data.** A comma-separated values (CSV) file or Excel spreadsheet is made available to clients who wish to do further analysis in statistical software packages. This also allows the survey results to be analyzed in tandem with physical measurements data that is collected in the occupants' workspaces in some studies.

### **3. SURVEY UTILIZATION**

The CBE building quality surveys have been used to evaluate the performance of 45 buildings in North America and Europe including office buildings, laboratories, banks and courthouses. Survey clients are government and industry organizations at all stages of the building process, including researchers, operators, owners/managers, and designers.

#### **3.1 Post-Occupancy Evaluations**

The survey is often an important part of a POE process in which the design and construction of a new building or renovation is assessed. When studying a particular building technology, ideally two surveys are conducted for each building: one while occupants are in the old building or pre-renovated space, and the other six months after the occupants have moved into the new building or renovations have been completed. This waiting period allows occupants to become accustomed to the new space in order that the experience of change itself doesn't bias the results. Often, however, just one POE survey is conducted, and the data collected is extremely valuable for diagnostics, and to provide feedback to those involved in building process.

#### **3.2 Green Building Features**

To date, three LEED-rated buildings have been surveyed, as well as other buildings without LEED ratings that contain green features. Studies have included buildings with operable windows in comparison to sealed buildings, floor diffusers compared to overhead air distribution systems, and innovative bathroom fixtures such as composting toilets and waterless urinals. New survey modules for high-performance facades and other shading systems have also been written and those surveys are being conducted in summer 2003.

### **4. SURVEY DATABASE**

The individual building report described above is of great value to survey clients who wish to learn how a given building is performing, and receive feedback about areas in the building that could use improvement. Further, the database itself can provide valuable feedback to the research community, the green building community and the building industry at large. As the database of surveyed buildings continues to grow, we're increasingly able to explore this data for trends of importance with respect to various building technologies, such as floor diffusers, operable windows, and shading systems. We anticipate that the CBE building quality surveys, and the data they collect, will be useful tools in assessing how well buildings are meeting the goals of sustainability and indoor environmental quality.

#### **4.1 Analysis of the Survey Database**

The data collected by the surveys can be used to compare two or more buildings against one another, and also as a benchmarking tool. It is useful, for example, to examine how buildings with a certain feature compare to buildings without those features, or how LEED-rated buildings perform compared to non-LEED buildings. Below we explore both of these angles, and indicate

the kinds of comparisons that researchers and others in the building industry are likely to want to make with this dataset. While the results may not be statistically significant, these comparisons do highlight points of interest and indicate areas for further exploration. As the database grows, we'll be increasingly able to learn from it and find significant trends of interest to the green building community.

**4.1.1 Comparison Based on Building Features.** Two office buildings in the San Francisco Bay Area were surveyed at the same time during Summer 2002, using the occupant IEQ survey with a custom operable windows module. In one of the buildings, occupants had access to operable windows, and in the other building the windows were fixed. The purpose of the ongoing study is to ascertain how operable windows affect perceived occupant comfort. Occupants in the building with operable windows reported higher levels of satisfaction with thermal comfort and air quality than did those in the control group (without operable windows). Satisfaction with acoustics was lower in the building with operable windows, and the results were not statistically different between the two buildings for lighting and overall building satisfaction.

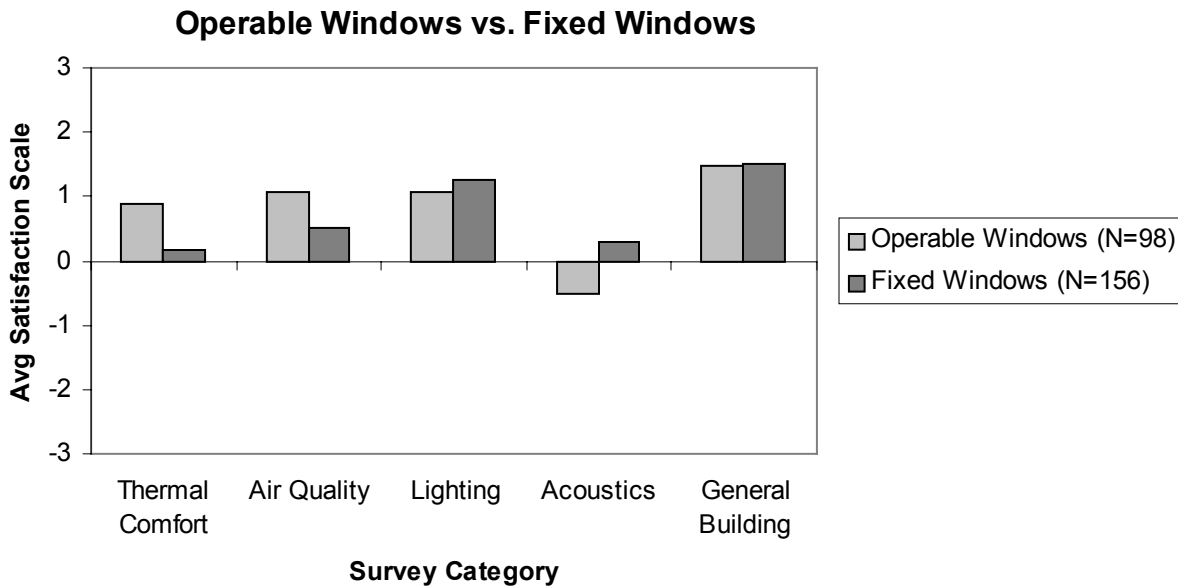


Figure 3 Chart illustrating comparison of survey data between two buildings, exploring the relationship between the presence of operable windows and occupant satisfaction

**4.1.2 Surveys as a Benchmarking Tool.** To date three LEED-rated buildings have been surveyed with the occupant IEQ survey. Figure 4 compares these three buildings, using the entire database as a benchmark. While the number of respondents in two of the three LEED-rated buildings is low and thus those results are not significant, the results do suggest that the green buildings received high marks for air quality in comparison to the benchmark.

This can be used to assess how well green buildings are performing in various areas in comparison to all other buildings in the database. Using the survey as a benchmarking tool is important to many of the clients who commission surveys. A single statistic (e.g., average air



quality satisfaction = 0.69), while it does tell us that the majority of the building occupants were satisfied with air quality, becomes far more meaningful when we compare the number against all buildings that have been surveyed, in which the average air quality satisfaction is 0.08, just above neutral.

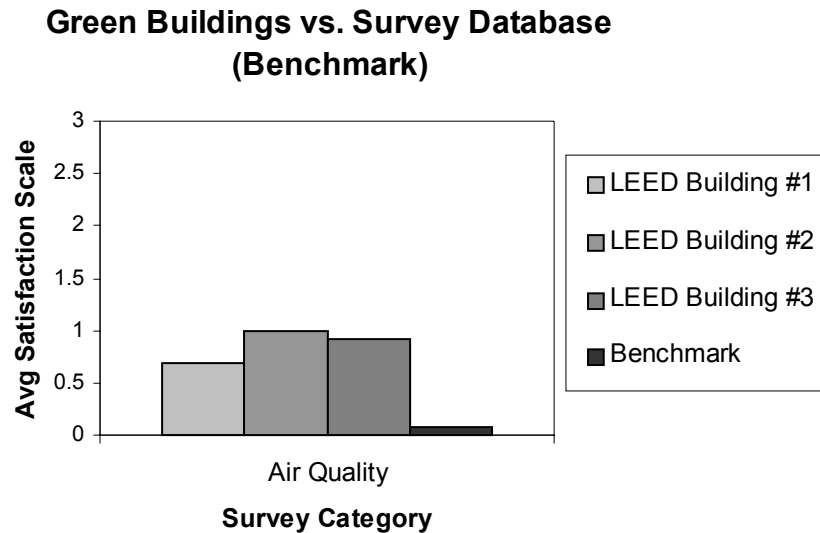


Figure 4 Chart illustrating comparison of air quality satisfaction for a set of buildings against benchmark data

## 5. CONCLUSION

The occupant IEQ survey is a tool that helps assess how well a building is performing from the viewpoint of its occupants. Together with the additional modules and other custom surveys that the CBE building quality survey infrastructure allows, a complete picture of a building's performance can be assembled. Our goal is to create a process that provides this feedback to the building industry so it can learn how various building features affect occupant comfort, satisfaction and productivity, as well as how the building performs from an operations and maintenance standpoint, and how the building process met the needs of the design and construction teams. By creating this feedback loop, we hope to help move the industry towards sustainable, healthy, comfortable workspaces. For more information, please visit [www.cbесurvey.org](http://www.cbесurvey.org).

## 6. ACKNOWLEDGEMENTS

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