

LEED™ Post-Occupancy Evaluation: Taking Responsibility for the Occupants



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Better Bricks,
USGBC/CGBC Cascadia Chapter
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CENTER FOR THE BUILT ENVIRONMENT – UC BERKELEY

Today's talk

- About the Center for the Built Environment (CBE)
- Tour of the Occupant Indoor Environmental Quality (IEQ) Satisfaction Survey
- Recent analysis and findings
 - Acoustics
 - Thermal comfort and air quality
 - LEED IEQ
- Case studies
- Examples of POE studies using the survey
- Update on LEED and surveys
- Wrap-up & discussion

Center for the Built Environment (CBE)

Our Mission: To improve the design, operation, and environmental quality of buildings by providing timely, unbiased information on building technologies and design techniques



CBE Industry Partners

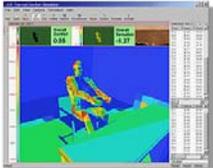
Armstrong World Industries
Arup*
California Energy Commission
Charles M. Salter Associates
CPP Inc.
Flack + Kurtz
HOK
Pacific Gas & Electric Co.
Price Industries
RTKL
Skidmore Owings and Merrill
Stantec
Steelcase

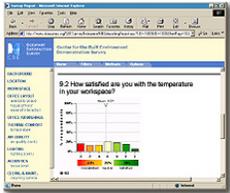
Syska Hennessy Group
Tate Access Floors*
Taylor Engineering Team:
• Taylor Engineering
• CTG Energetics
• Guttman & Blaevoet
• Southland Industries
• Swinerton Builders
Trane
U.S. Department of Energy (DOE)*
U.S. General Services Administration (GSA)*
Webcor*
York International Corporation

*founding partner

CBE research programs

- Indoor Environmental Quality
- Envelope and Facade Systems
- HVAC Systems
- Controls and Information Technology





CBE feedback loop

- Finding ways to “take the pulse” of buildings in operation
- Helping industry to make better buildings

CBE Design Tools and Resources

- HVAC Systems
- Envelope Systems
- Building Information Technology
- Indoor

Building Process

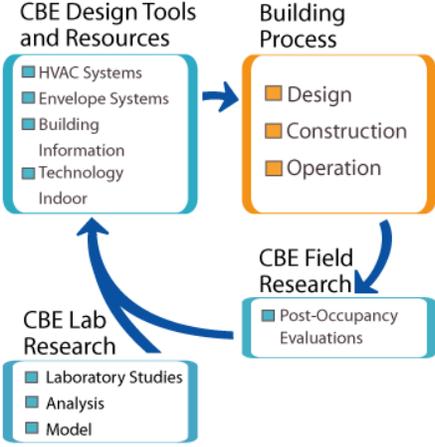
- Design
- Construction
- Operation

CBE Field Research

- Post-Occupancy Evaluations

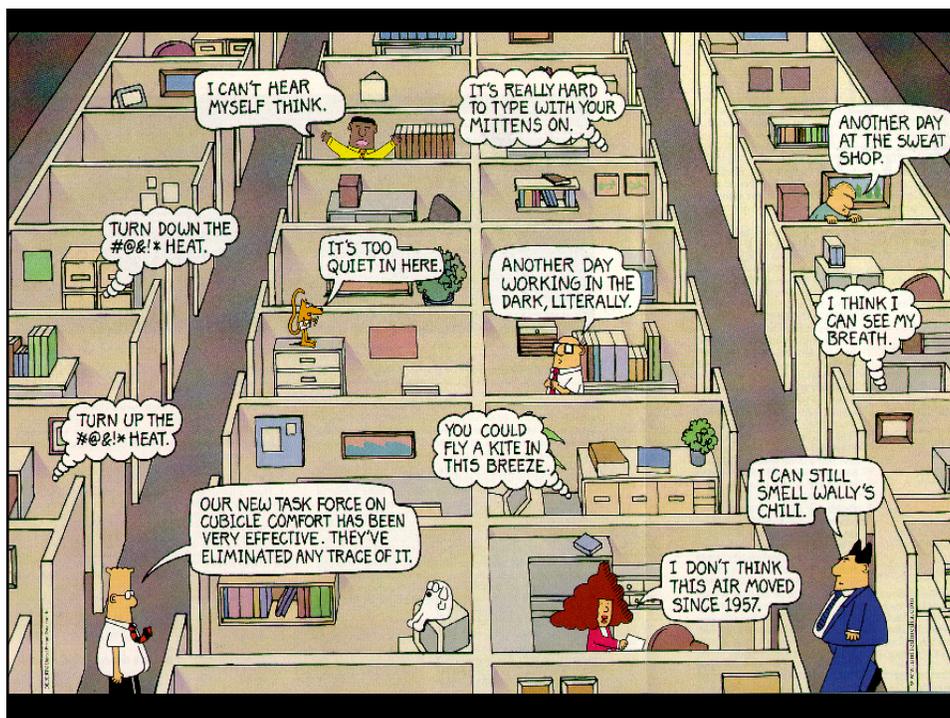
CBE Lab Research

- Laboratory Studies
- Analysis
- Model



Post occupancy evaluation (POE) process

- POEs rarely done by design teams
- POEs may include:
 - Surveys of building occupants
 - Observations and/or interviews with building users
 - Performance in terms of energy and/or water consumption
 - Physical measurements (temperature, humidity, acoustical, lighting, daylighting)
- When to do a POE
 - Part of commissioning plan – 6 months
 - Post commissioning – at least 12 months



Occupant IEQ survey

- Standardized methodology for studying building performance from occupants' point of view
- Provide feedback to building designers, owners, and operators
- Helps us understand how buildings perform in practice
- Web format is inexpensive, fast, allows for branching questionos, automatic reporting, data mining
- Results can be used for:
 - Diagnostics
 - Benchmarking




Survey history

- late 80's
 - ASHRAE Thermal Comfort Studies
- early 90's
 - Johnson Controls
 - Tablet-based survey
 - LAN-based survey
- mid 90's
 - First Web-based Survey
 - Research projects evaluating effectiveness of various building attributes
- 1999
 - U.S. General Services Administration
 - Developed current core survey, and special-purpose modules

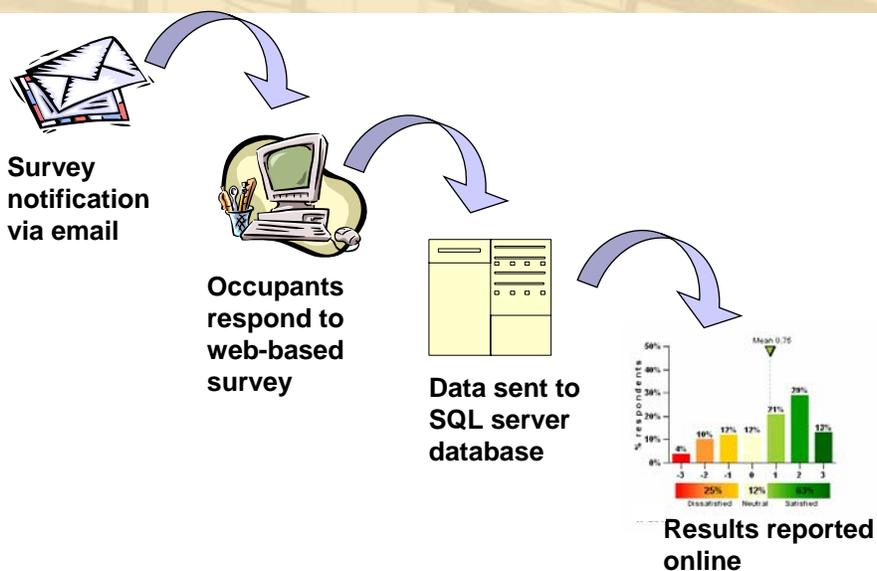


Usability testing

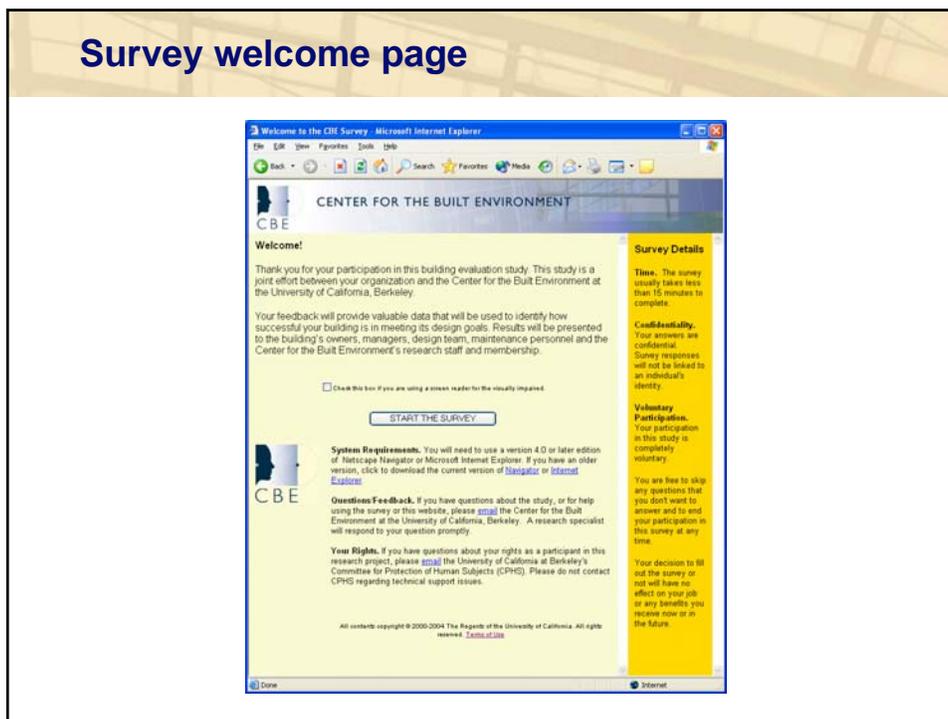
- UCB Survey Research Center
 - Focus groups
 - Cognitive interviewing
- Assessed
 - Comprehension of survey wording
 - Scale size and aesthetics
 - Survey length
- Core survey now highly standardized for accurate benchmarking



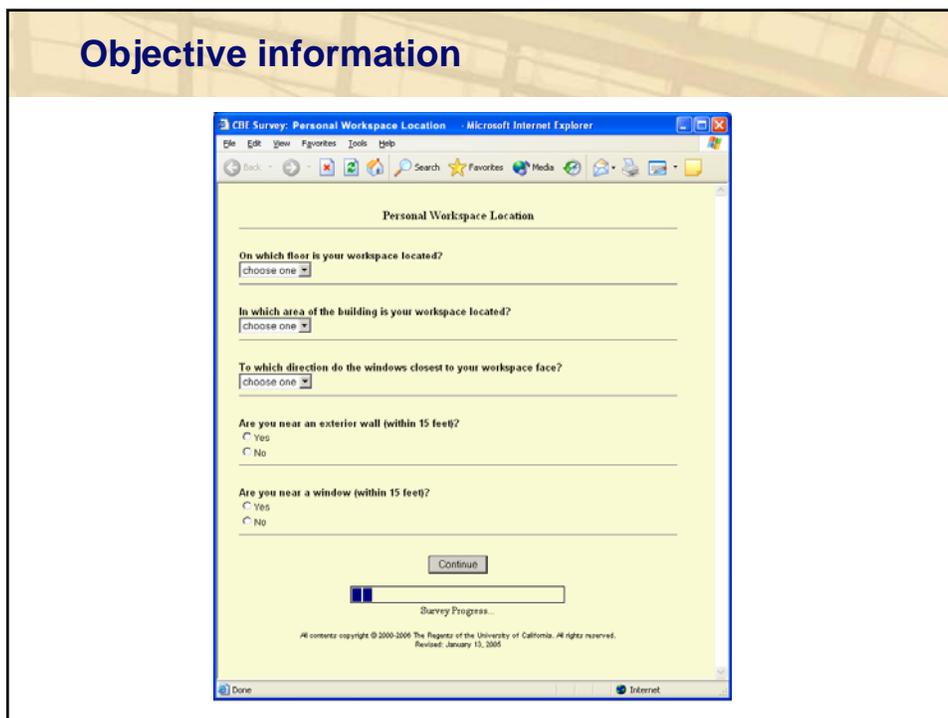
Survey implementation



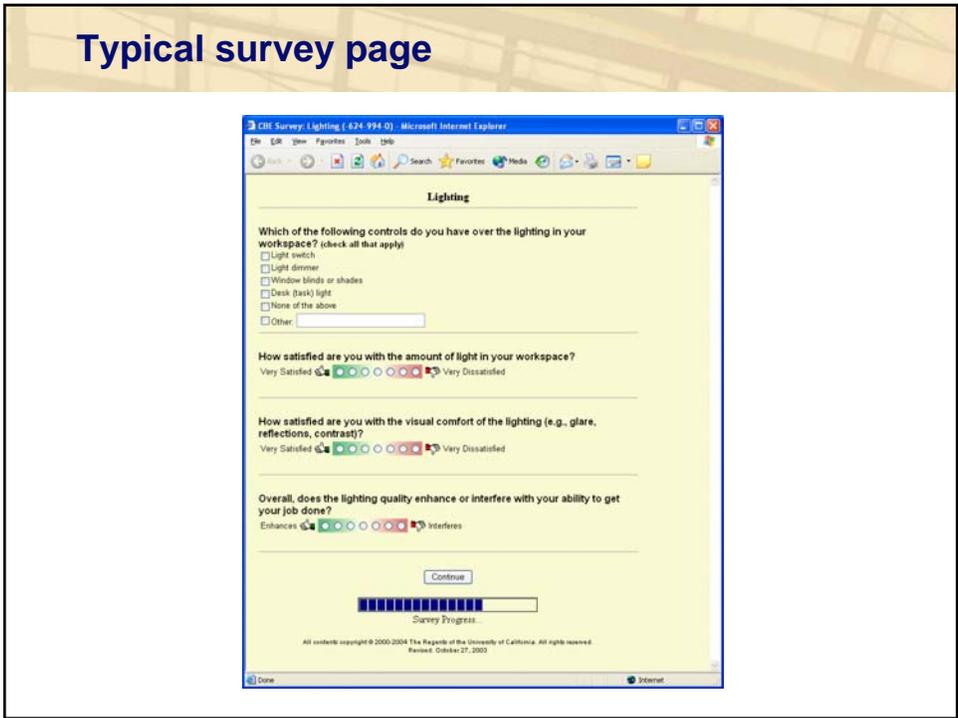
Survey welcome page



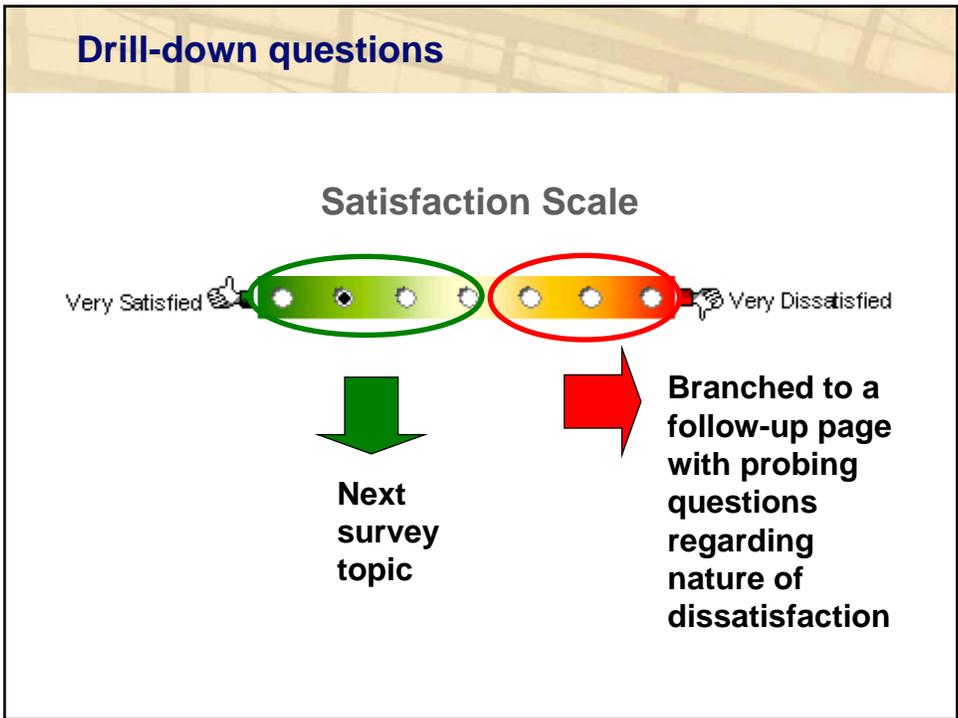
Objective information

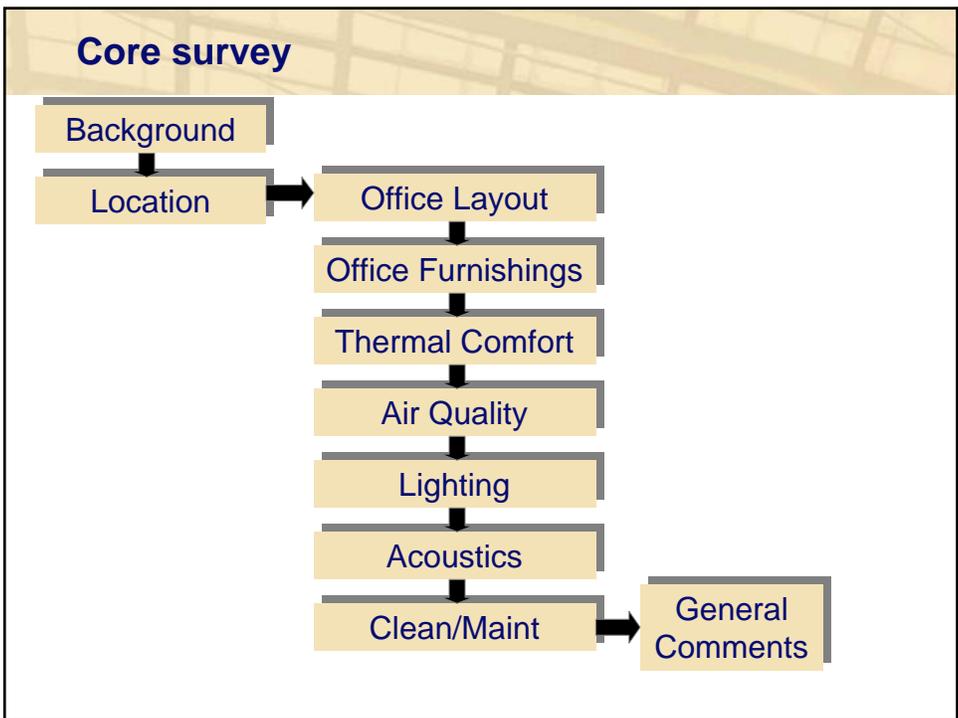
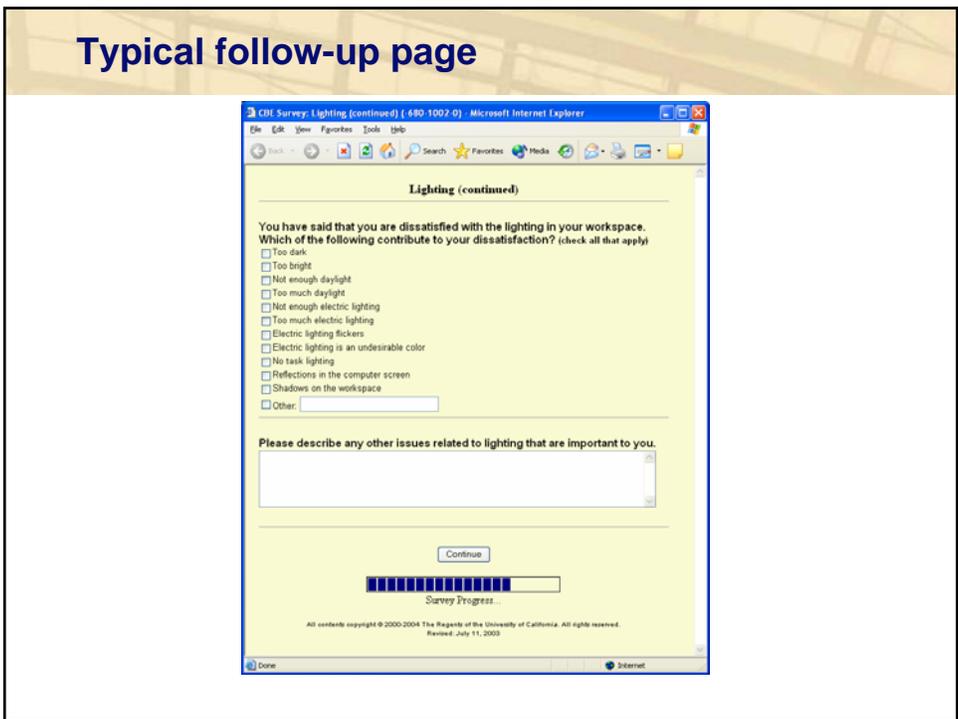


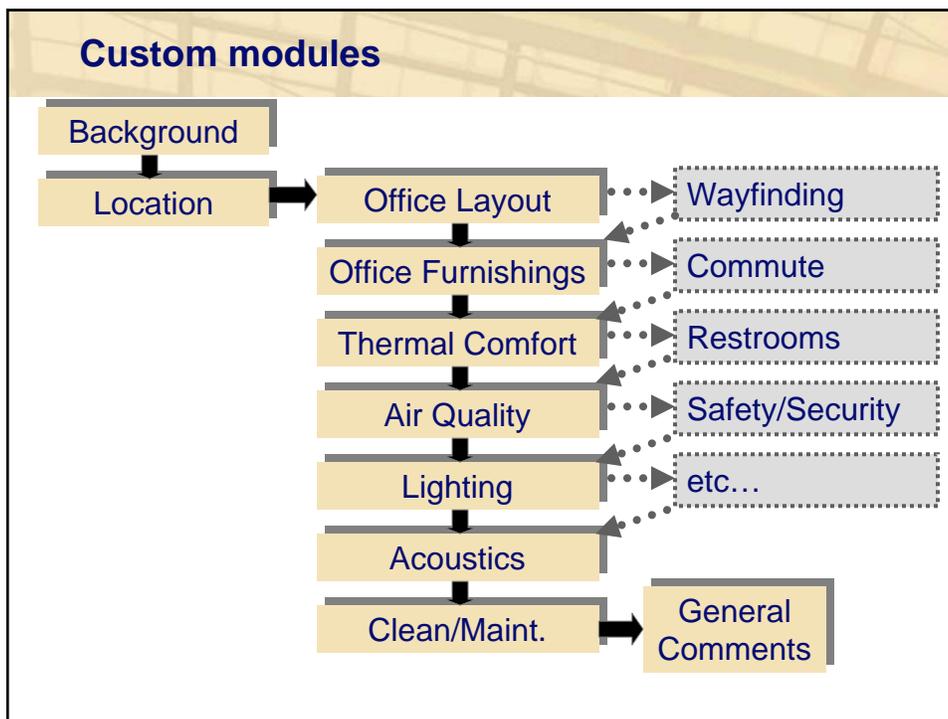
Typical survey page



Drill-down questions





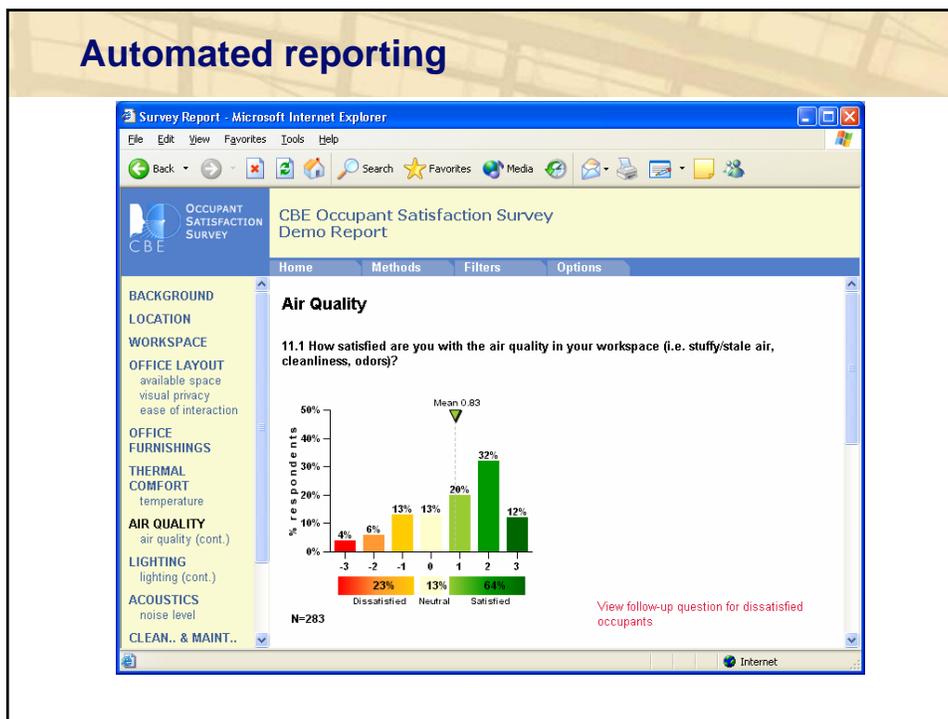


Custom modules

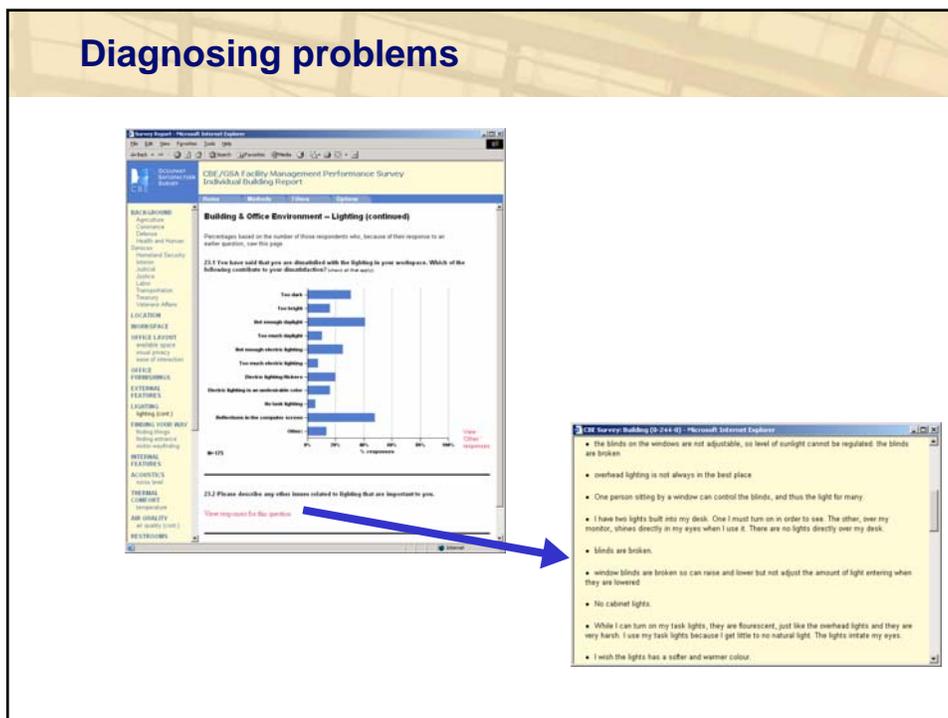
- Accessibility
- Building and Grounds
- Maintenance Service
- Commute
- Conference and Training Rooms
- Court Work
- Daylighting
- Laboratories
- Office Support Equipment
- Operable Windows
- Raised Floor and Floor Diffusers
- Restrooms
- Safety and Security
- Wayfinding

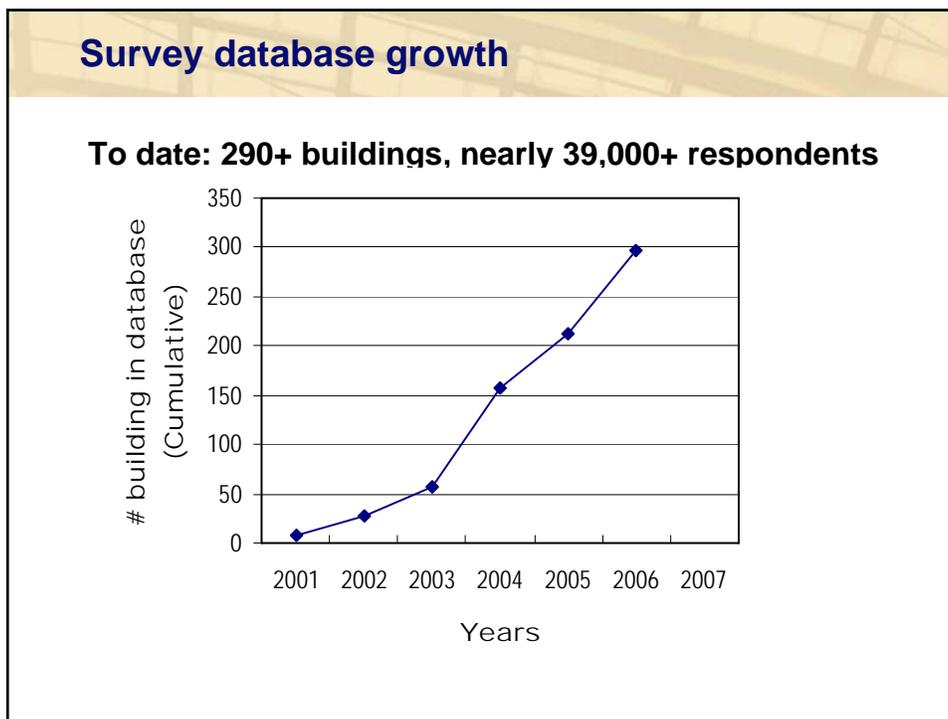
The top photograph shows a meeting in progress in a conference room. Several people are seated around a table, and one person is standing near a whiteboard, possibly presenting. The room has large windows and modern decor. The bottom photograph shows a wide-angle view of a modern office space. It features several desks with computers, ergonomic chairs, and large windows that provide ample natural light. The office is clean and organized.

Automated reporting



Diagnosing problems





Collecting building characteristics

Physical Features

Predominant exterior wall material:

Window glass (% of wall area):

Design Features

LEED Product:

LEED Version:

LEED Rating:

None
 Certified
 Silver
 Gold
 Platinum

Lighting and Daylighting (check all that apply):

Daylighting
 Daylighting controls
 Occupancy sensors
 Fixed exterior shading
 Automated exterior shading
 Manual exterior shading

Predominantly:

Indirect lighting
 Direct lighting

HVAC and Indoor Air Quality (check all that apply):

Air conditioning
 Window air conditioners
 Evaporative cooling systems
 Heat pumps
 Underfloor air distribution
 VAV air distribution
 Radiant heating system
 Natural ventilation
 Demand controlled ventilation
 Energy management system (e.g. EMCS, BAS, EMS, EIBS)
 Individual HVAC control

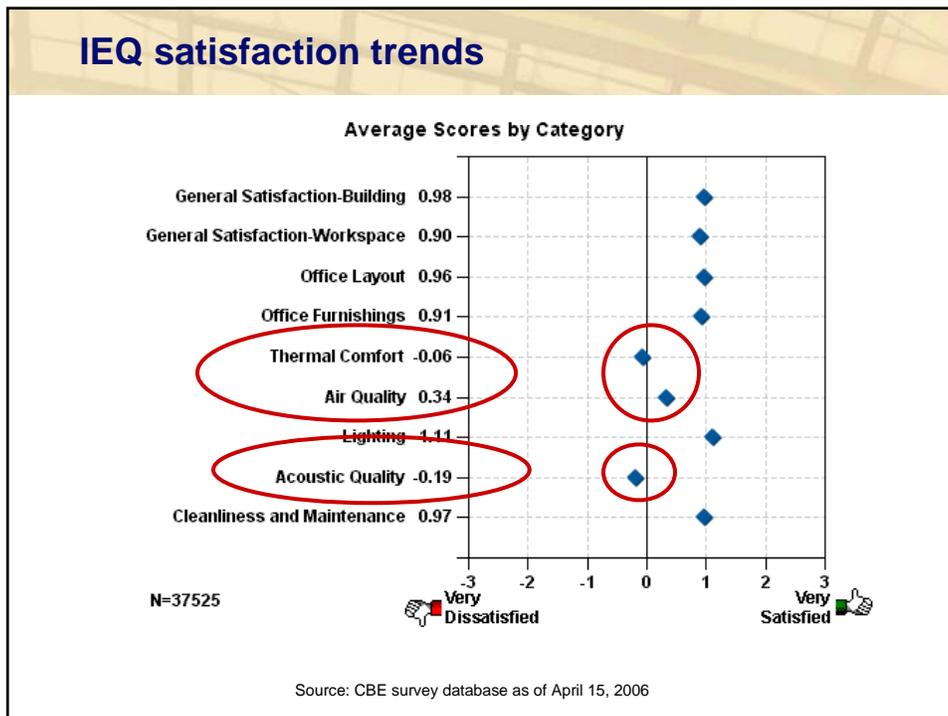
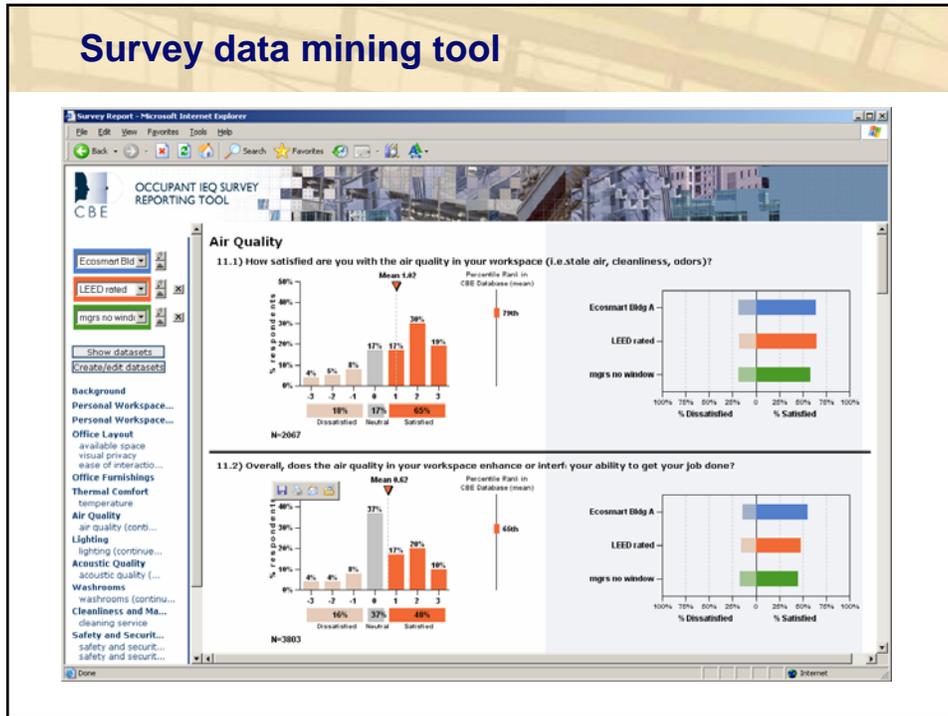
Building Envelope (check all that apply):

Insulating glass (i.e. 2 or more panes)
 Tinted glass
 Reflective glass
 High performance glass
 Exterior window shading
 Interior window blinds
 Operable windows

Acoustics (check all that apply):

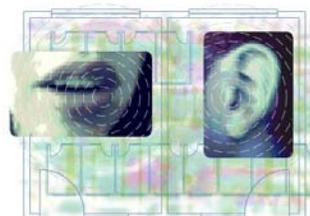
Electronic sound masking

Excerpt from building profile form

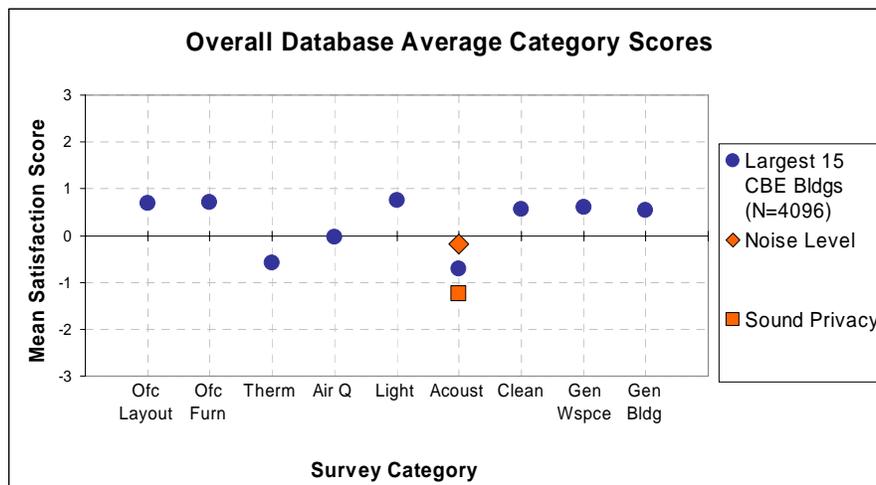


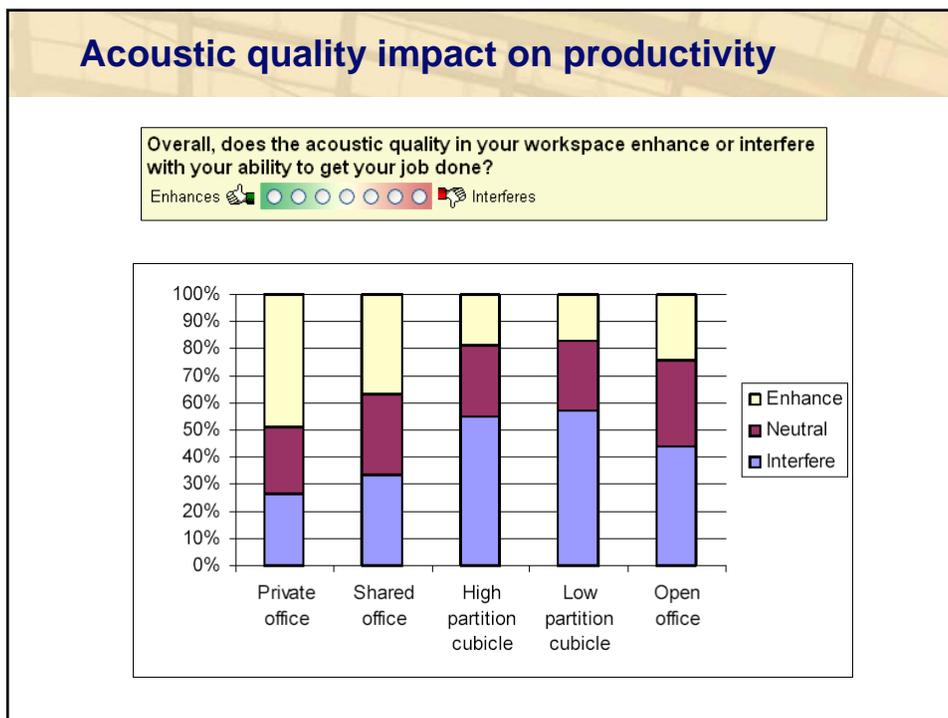
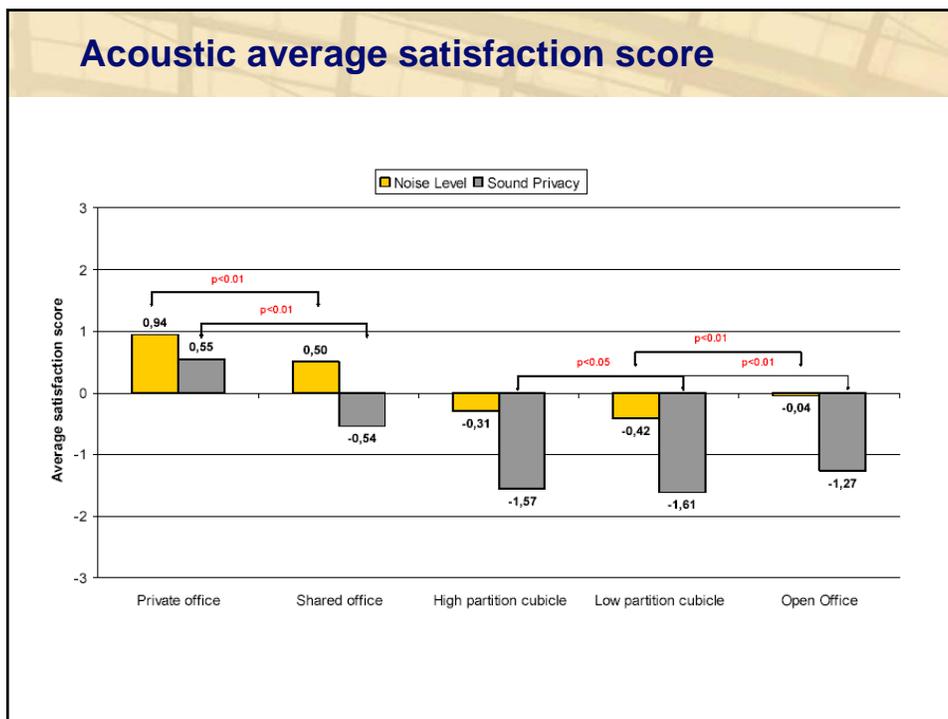
Acoustics analysis

- “Acoustic Quality in Office Workstations, as Assessed by Occupant Surveys,”
Jensen, K., E. Arens, and L. Zagreus, 2005
Proceedings, Indoor Air 2005, Sept. 4-9, Beijing, China.
- Studied satisfaction with acoustics in office environments
- Acoustical satisfaction lowest category
- Analyzed data from
 - 142 buildings
 - 23,450 occupants



Sound privacy vs. noise level





Top sources of dissatisfaction

Of those expressing dissatisfaction with acoustics...

Rank	Source of dissatisfaction	Private office	Shared office	Cubicles with high partitions	Cubicles with low partitions
1	People talking on the phone	21%	50%	70%	83%
2	People overhearing private conversations	25%	40%	65%	71%
3	People talking in surrounding offices	15%	21%	45%	54%
4	People talking in the corridor	6%	12%	25%	27%
5	Telephones ringing	2.5%	8%	23%	31%
6	Office equipment	4%	5%	13%	14%

Key findings

- Over 50% of occupants in cubicles think acoustics interfere with their ability to get their job done
- Acoustic satisfaction will not be improved much by making cubicles higher
- Occupants in open office more satisfied with acoustics than occupants in cubicles
- Of the 9 core survey categories, acoustics causes the greatest dissatisfaction

Potential solutions

- Acoustical consideration during design, using consultants or “Speech Privacy Predictor” (SPP)
- Focus on improving conditions for cube-dwellers
 - Sound masking, improved sound absorption
 - Lower telephone ringing volume, visual ring
 - Provide varied workspace options



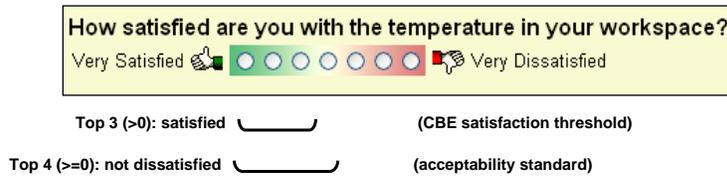
Thermal comfort and air quality analysis

- “Air Quality and Thermal Comfort in Office Buildings: Results of a Large Indoor Environmental Quality Survey,” Huizenga, C., S. Abbaszadeh, L. Zagreus and E. Arens, 2006. *Proceedings, Healthy Buildings 2006*, June 4-8, Lisbon, Vol. III, 393-397.
- Studied satisfaction with thermal comfort, air quality, compared to existing standards
- Analyzed data from
 - 215 buildings
 - 34,169 occupants



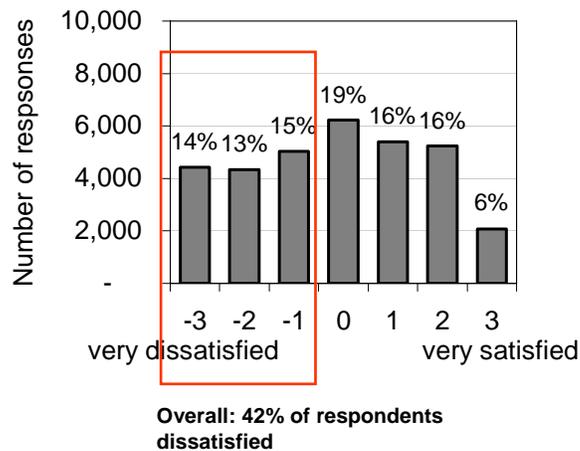
Thermal comfort & air quality standards

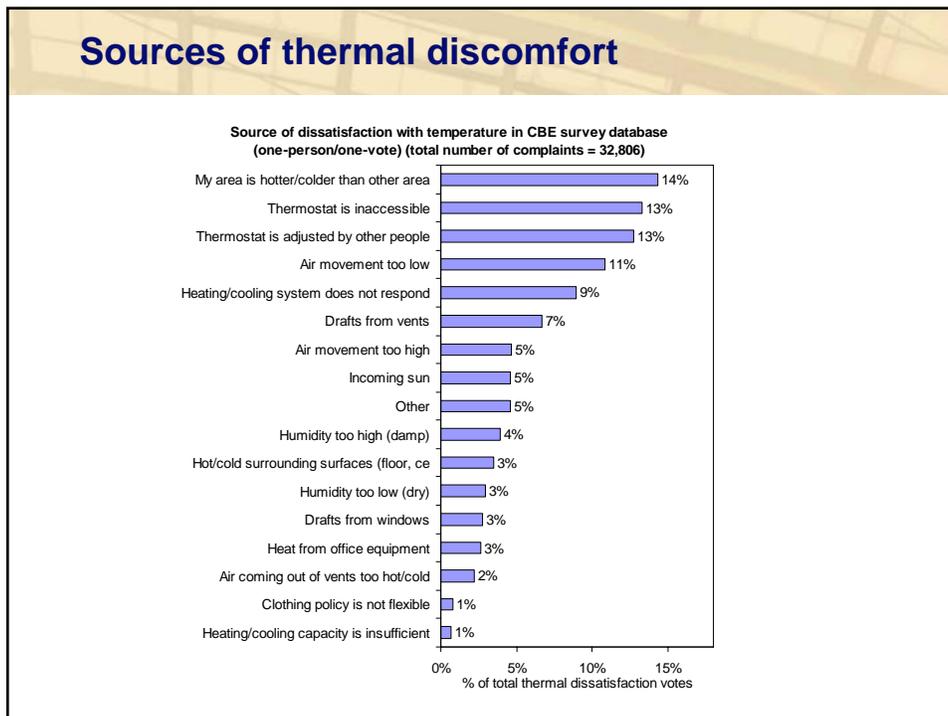
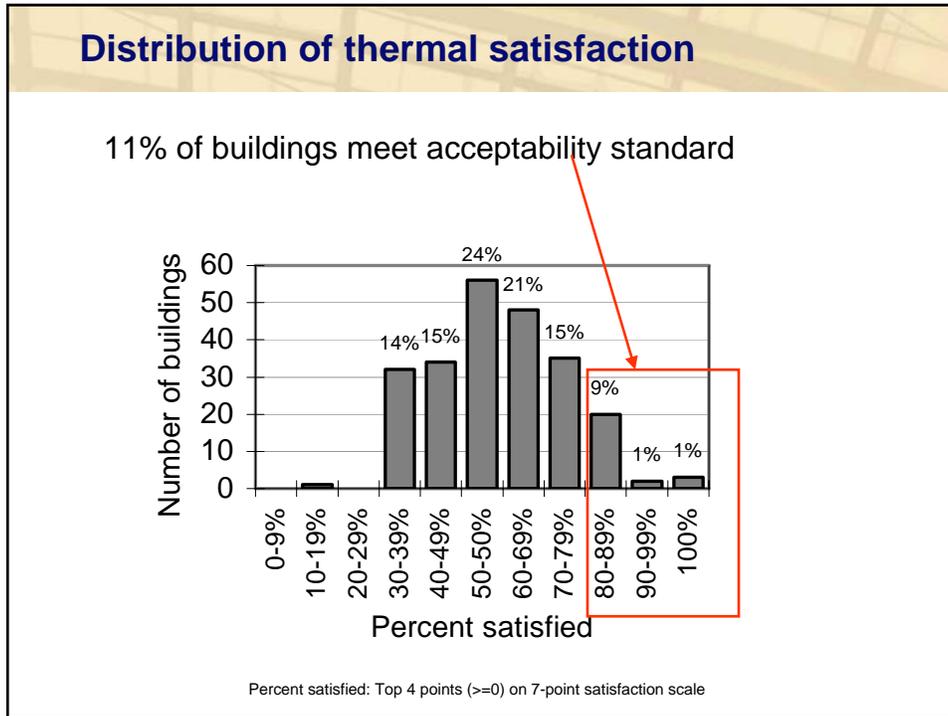
- Standards define acceptable indoor environment:
“Conditions in which more than 80% of people do not express dissatisfaction”
 - ASHRAE Standard 55-2004 (Thermal comfort)
 - ASHRAE Standard 62.1-2004 (Air quality)
- And others even more restrictive! (90% threshold)
 - ISO Standard 7730:1994 (Thermal comfort)

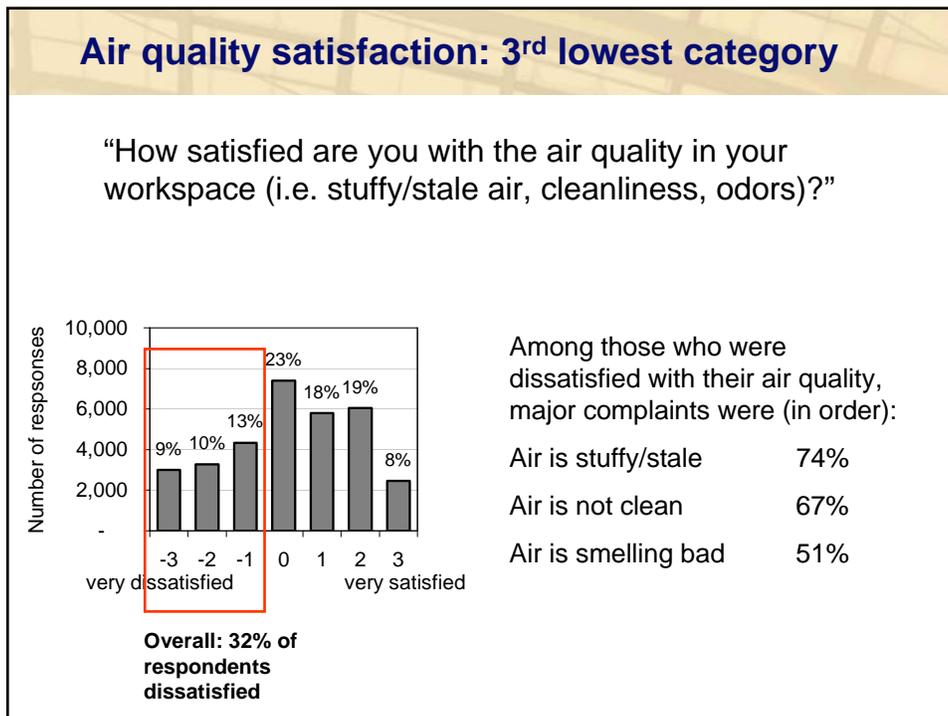
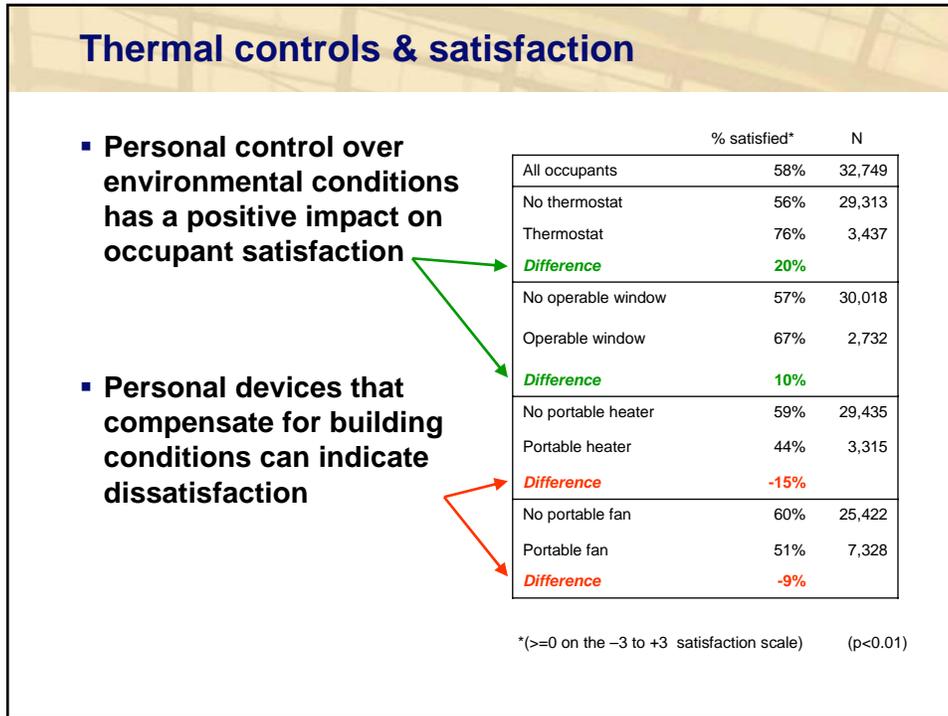


Thermal satisfaction: 2nd lowest category

“How satisfied are you with the temperature in your workspace?”

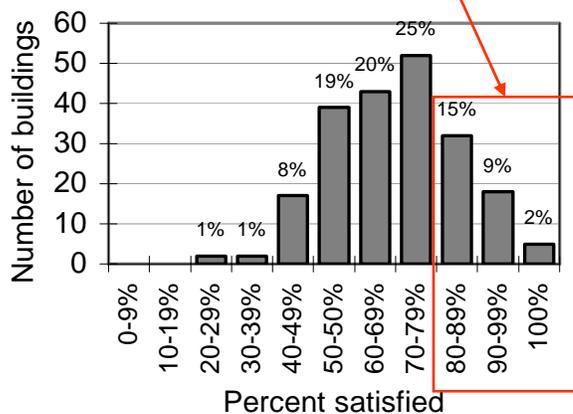






Distribution of air quality satisfaction

26% of buildings meet acceptability standard



Percent satisfied: Top 4 points (>=0) on 7-point satisfaction scale

LEED IEQ analysis

- “Occupant Satisfaction with Indoor Environmental Quality in Green Buildings.” Abbaszadeh Fard, S., L. Zagreus, D. Lehrer and C. Huizenga, 2006. *Proceedings, Healthy Buildings 2006*, June 4-8, Lisbon, Vol. III, 365-370.
- Compared occupant satisfaction in 21 green or LEED-certified buildings with 160 non-green buildings
- Analyzed data from
 - 181 buildings
 - 33,285 occupants



What is “Green” Design?

Design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas:

- Sustainable site planning
- Safeguarding water and water efficiency
- Energy efficiency and renewable energy
- Conservation of materials and resources
- Indoor environmental quality

Source: Introduction to USGBC and LEED Green Rating System, 3/18/2004

Research opportunity: LEED IEQ analysis

- Do LEED-rated / green buildings in fact have better indoor environmental quality?

Free Web-Based Occupant Survey Offer Available

For a limited time,
the Center for the Built
Environment (CBE) will
implement its Occupant Survey
in LEED™ certified buildings,
free of charge.

[See details below.](#)



Left: Chesapeake Bay Foundation, LEED™ Platinum © 2001 P. Patel
Right: Whitehead Biomedical Research Bldg, LEED™ Silver © 2004 HOK

LEED-rated / green buildings in database

15 LEED-rated and 6 self-nominated buildings
160 other buildings in CBE database

NC 2 platinum	1		
NC 2 gold	2		
NC 2 silver	3		
NC 2.1	2		
NC 2 certified	1		
NC 1 platinum	2		
EB pilot	1		
CI pilot	3		

NC=New Construction; EB=Existing Buildings; CI=Commercial Interiors

Self-nominated green buildings

- 6 buildings identified by building design team or owner:
 - 2 received national AIA Top 10 Green Building Awards
 - 2 received *Environmental Design & Construction* awards
 - 1 received Savings by Design award
 - 1 received local awards



Carnegie Center for Global Ecology



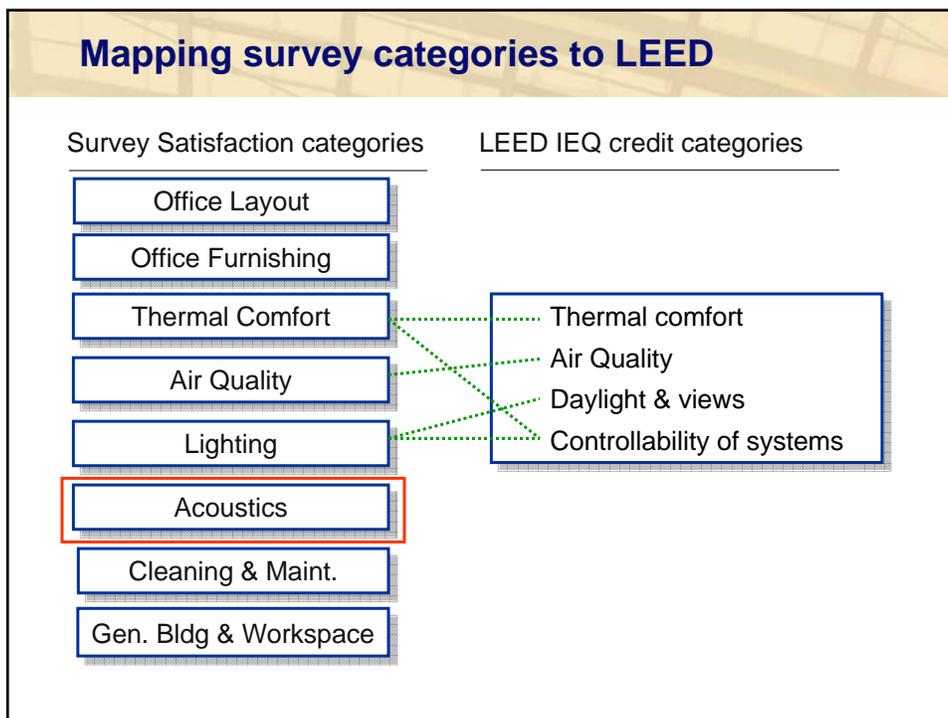
National Wildlife Federation

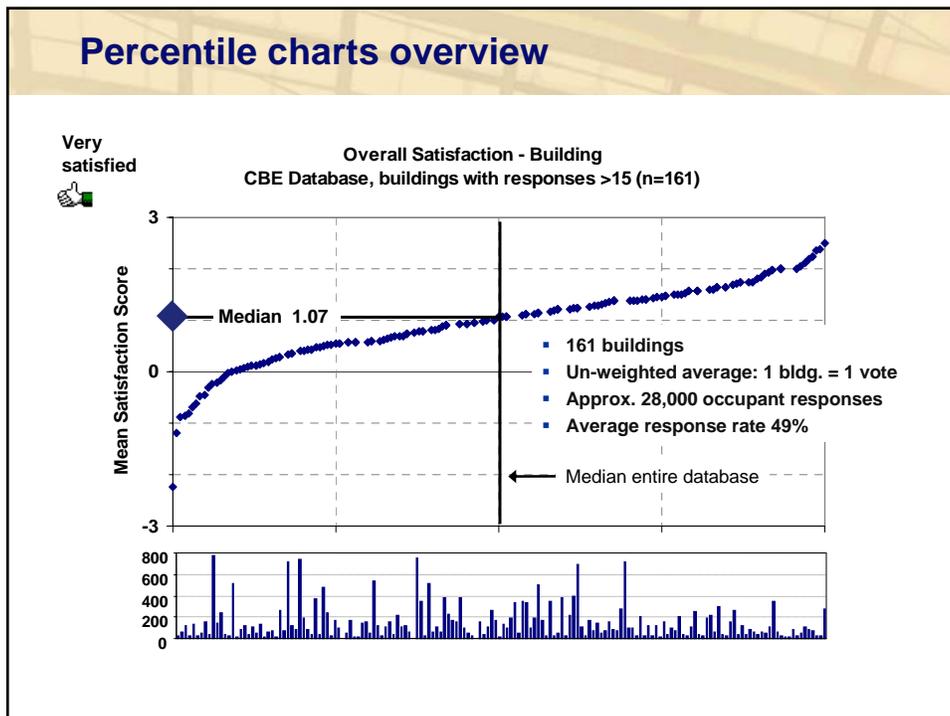
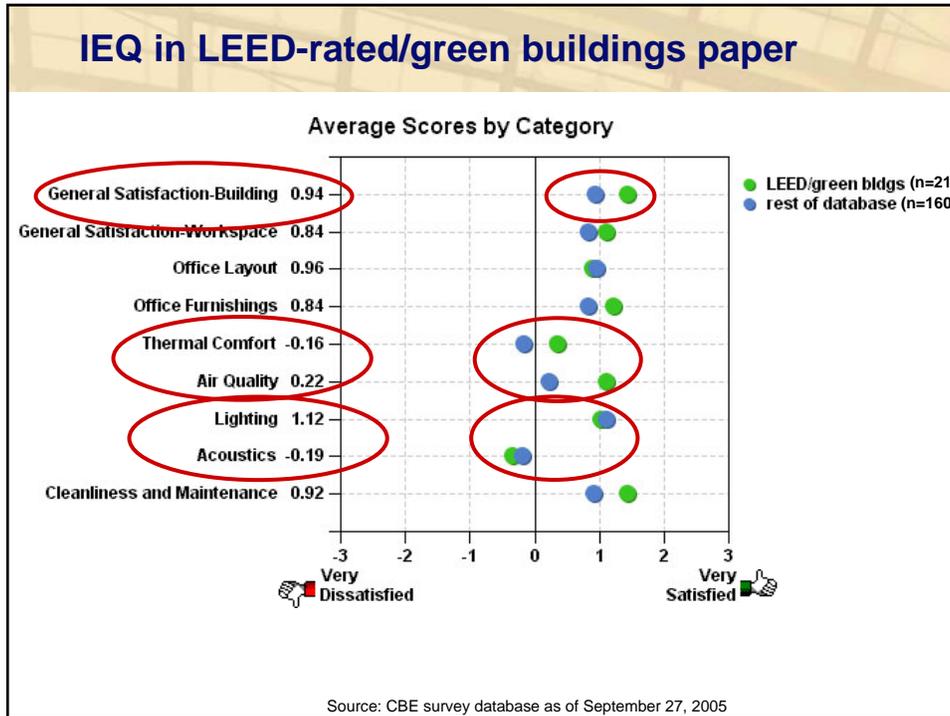


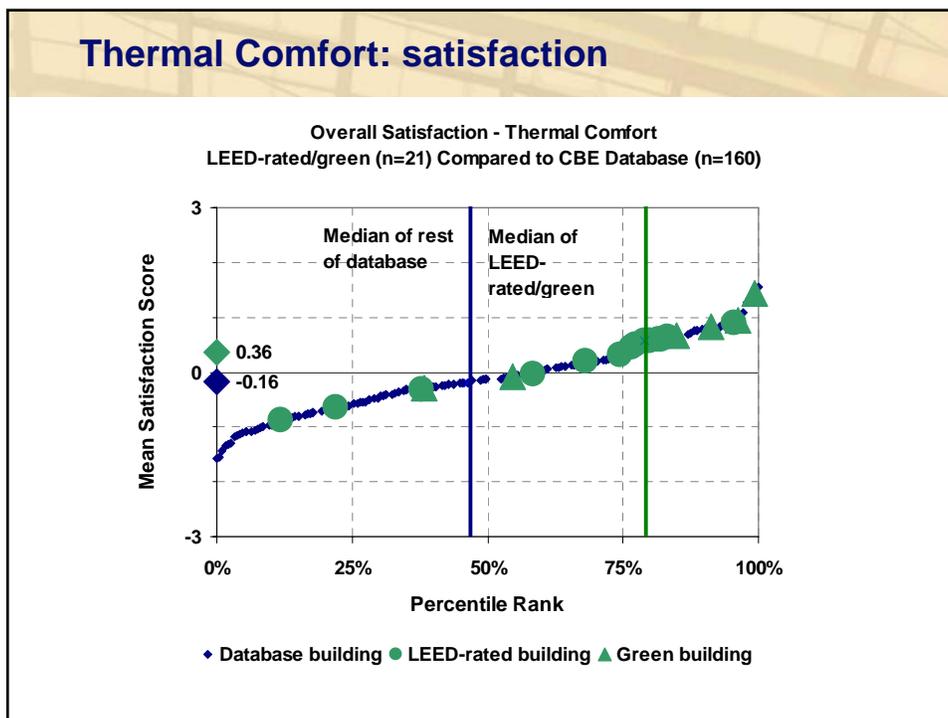
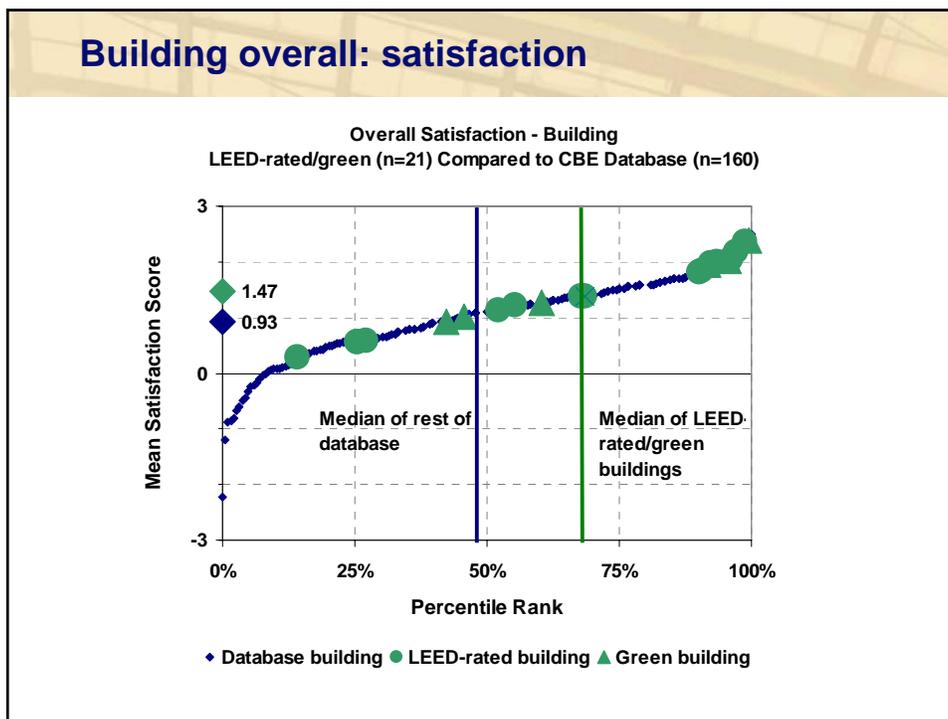
World Resources Institute

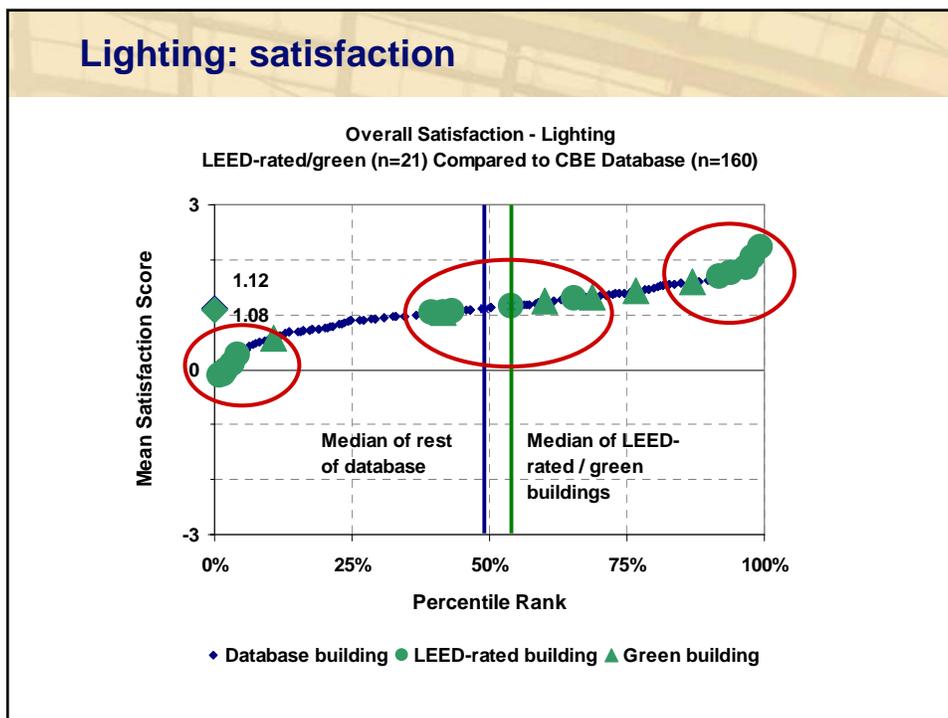
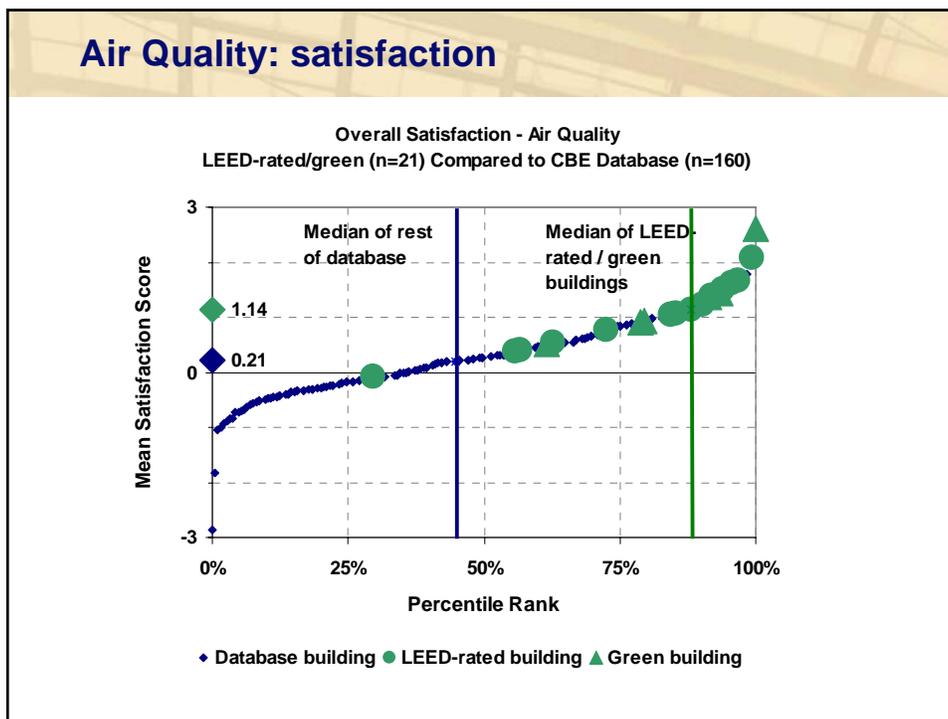
Categories in LEED – NC 2.1 & EB 2.0

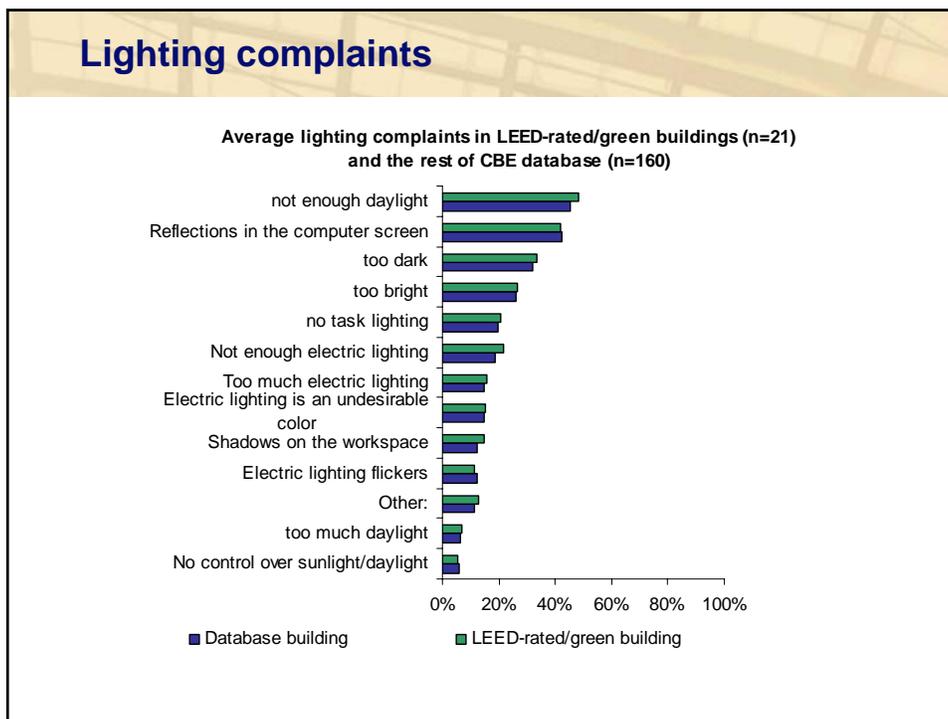
	LEED - NC	LEED - EB
Sustainable Sites	14	14
Water Efficiency	5	5
Energy & Atmosphere	17	23
Materials & Resources	13	16
Indoor Environmental Quality	15	22
Innovation & Design Process	5	5
Total	69	85
% of IEQ credit points	22%	26%



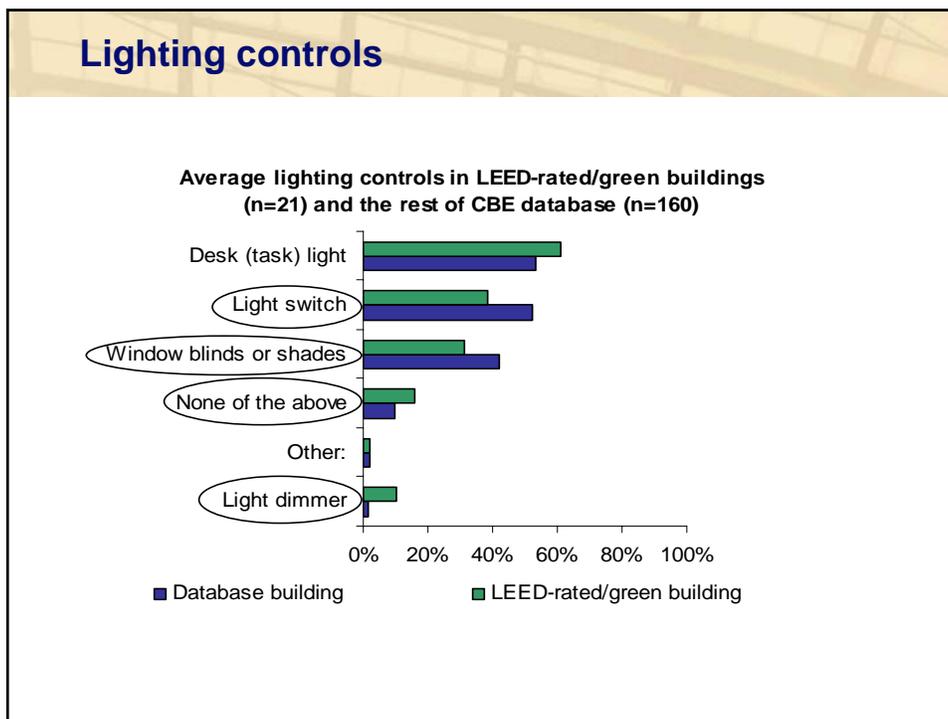




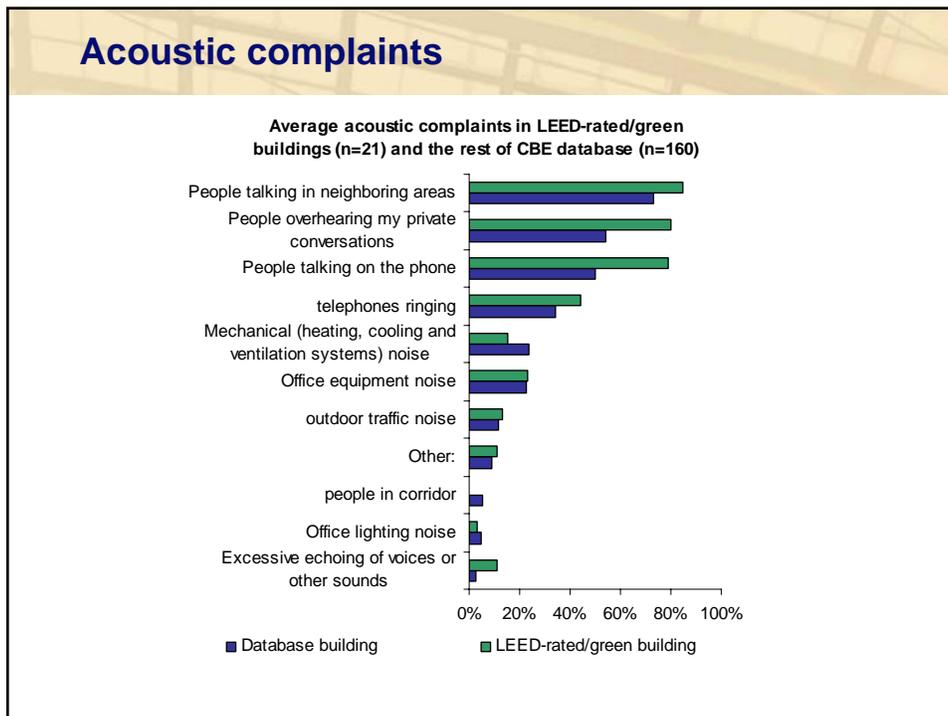
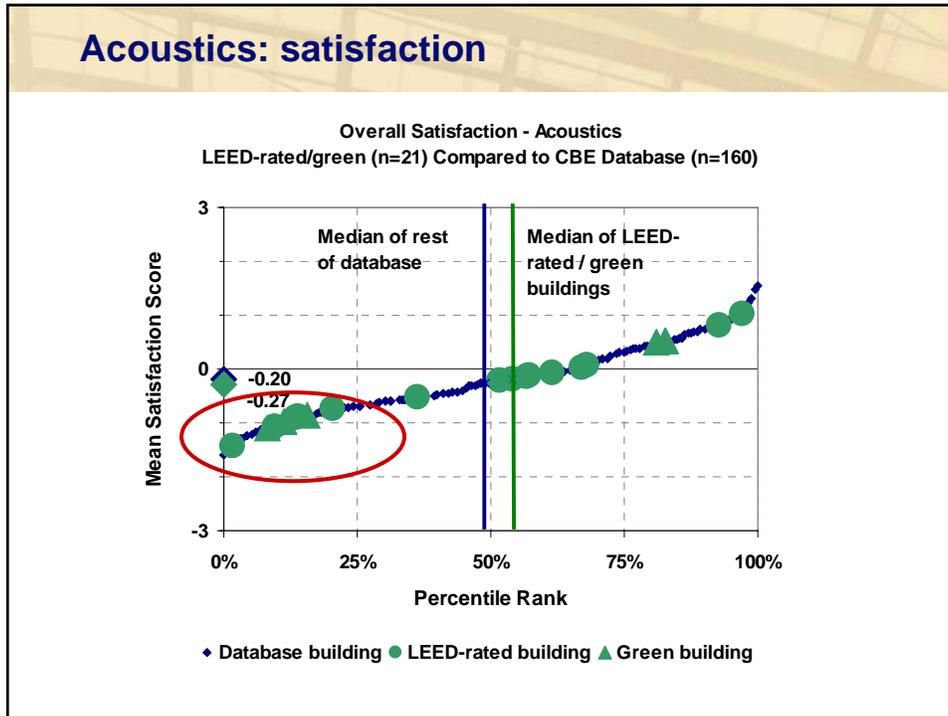


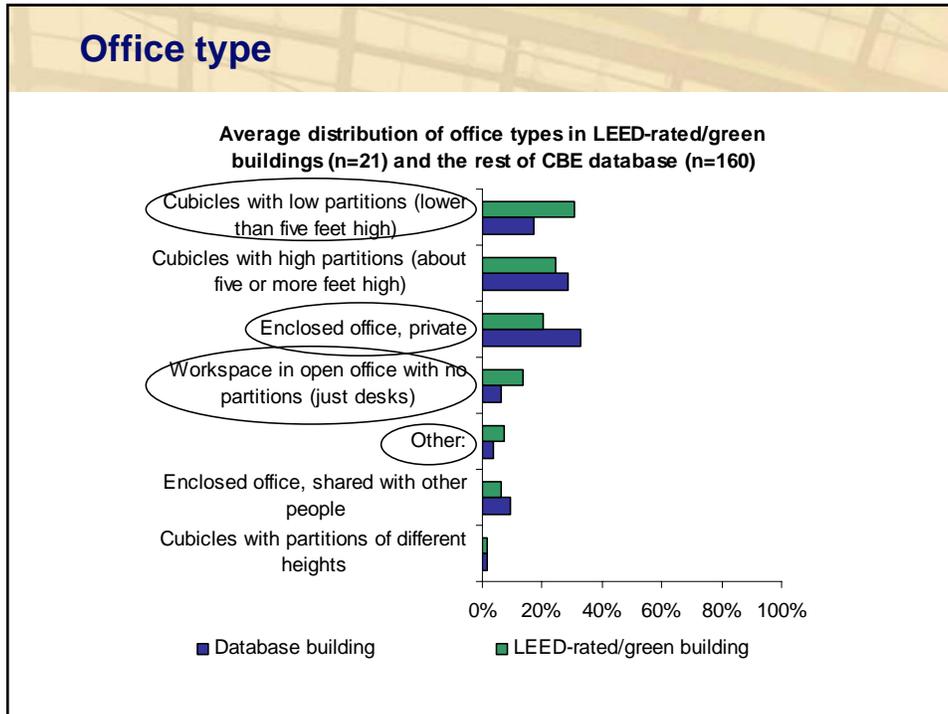


- ### Lighting dissatisfaction comments
- Building A**
- “task lights don’t work”
 - “...the only light is above the light shelf, I had to bring in my own lamp..”
- Building B**
- “Too bright in some places, too dark in others, and not enough task lighting...”
 - “The light sensors need to be adjusted... to come on sooner.”
 - “Task light mounted on wrong side of workstation.”
- Building C**
- “The lighting in my cube was woefully inadequate from day one. The task lighting does not shine where I do my reading and writing. Another light...lights the space behind my computer monitor and over my telephone...”



- ### Sustainable design strategies – Lighting
- Common strategies include
 - Provide lower levels of ambient electric lighting
 - Rely more on daylight to conserve energy and enhance IEQ
 - Can result in
 - Thermal discomfort
 - Glare/reflections
 - Workspace too dark/bright
 - Lessons learned
 - Provide effective controls to occupants such as task lighting, blinds and shades
 - Commission automated systems such as occupancy/daylight sensors and shading systems





Acoustics dissatisfaction comments

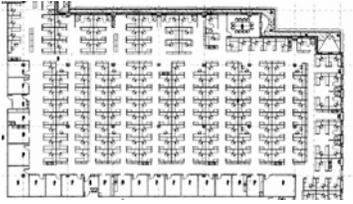
Building A (96% open office, n=703)

- “Desks too close...everyone can hear everything. Even a tiny sneeze.”
- “You can hear noises emanating 20 to 25 feet away. There is no sound deadening effect from the cubicle walls and the floor always sounds like a herd of elephants is doing a ballet.”



Building B (97% open office, n=173)

- “...obnoxious neighbors who think they are the only ones on the block.”
- “No one can ever hear my radio even though I think it's turned up loud.”
- ... I'm a loud talker and I'm sure I disturb other people...”

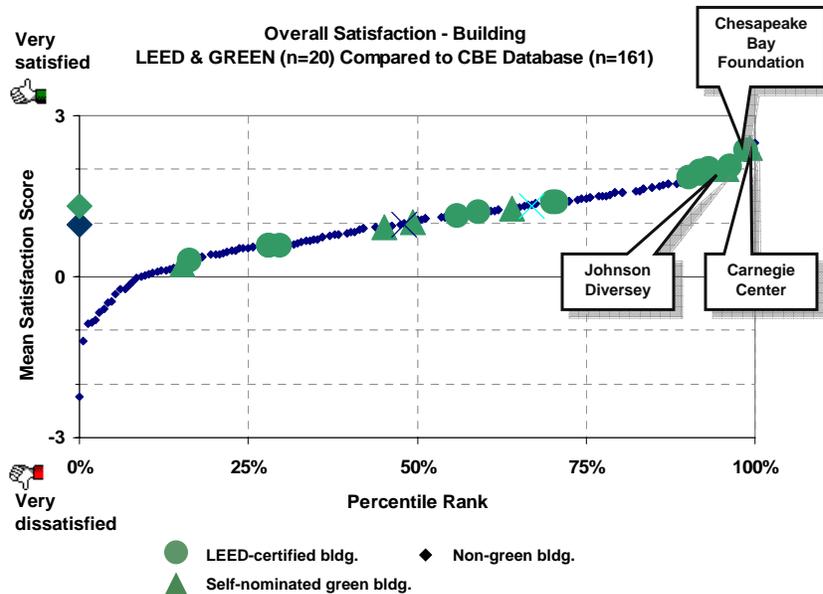


Conclusions: LEED IEQ analysis

- LEED-rated / green buildings had significantly higher satisfaction scores in:
 - building overall
 - indoor air quality
 - thermal comfort
- LEED-rated / green buildings did not have higher scores in:
 - lighting
 - acoustics
- No clear relationship found between LEED credit points and occupant satisfaction with IEQ
- LEED rating by itself does not *guarantee* better IEQ



Case studies



Case study: Chesapeake Bay Foundation

- First LEED-certified Platinum (version 1.0), completed in 2001
- 5 of 7 possible IEQ points (36 of 52 total possible points)
- Numerous sustainable features
- DOE-sponsored field study conducted by Judith Heerwagen, used extended version of occupant survey, interviews and observations



Heerwagen, J. and L. Zagreus, "The Human Factors of Sustainability: A Post Occupancy Evaluation of the Philip Merrill Environmental Center." April 2005

Case study: Chesapeake Bay Foundation

Average Scores by Category



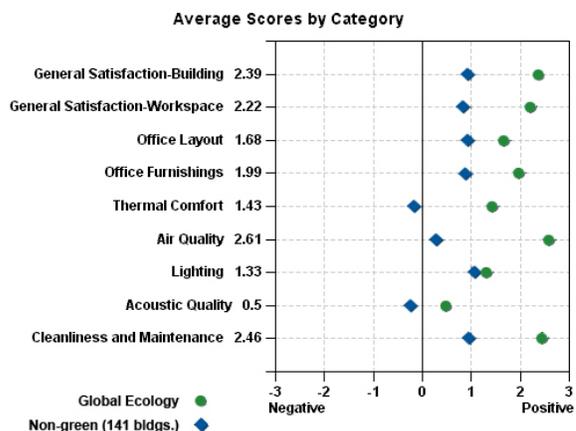
Case study: Carnegie Center for Global Ecology

- Stanford campus, Palo Alto, CA
- Clients understood green building priorities, did not rely on LEED
- Selected design team with extensive green building experience
- Designed to beat California energy code by 57%
- IEQ features include daylighting, radiant heating and cooling, natural ventilation with operable windows



Case study: Carnegie Center for Global Ecology

- High marks overall
- Acoustical score puts building in top quartile
- 83% in open office, no partitions



Case study: JohnsonDiversey

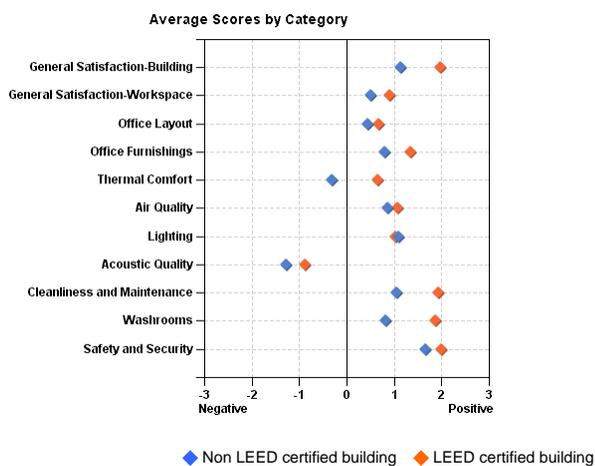
- Survey client: JohnsonDiversey
- 2 buildings surveyed
 - One LEED-EB certified
 - The other not LEED certified
- Core survey plus washrooms and security modules



JohnsonDiversey Headquarters – LEED-EB pilot (gold)

JohnsonDiversey survey results

Certified building performed significantly better than the non-certified building in nearly every category



JohnsonDiversey survey results, cont'd

Operational applications resulting from the study

- Certified building
 - Continue IAQ and other management programs
- Non-certified building
 - Instituted new cleaning and lighting programs to align with LEED standard
 - Plans improvements to HVAC, lighting and acoustics
- Both buildings
 - Numerous “low hanging fruit” fixes
 - Comments a rich source of information

POE Applications: HOK

- HOK Process
 1. CBE occupant satisfaction survey
 2. Energy evaluation
 3. Interviews
- Customized survey questions
 - Solar control
 - Automated lighting controls
 - Occupancy sensors
 - Building recycling program
- 9 buildings included



Images: HOK

POE Applications: HOK

Green Building Confessions...

World Resources Institute
Washington DC

Overall Building:	Very High (++)
Workplace:	Very High (++)
Lighting:	Low (-)
Air Quality:	Very High (++)
Thermal Comfort:	Very High (++)
Acoustics:	Very High (++)
Response Rate:	54%

* Comparison to CBE database of projects



Source: Sandra Mendler, AIA, HOK

POE Applications: HOK

- Summary of POEs identified:
 - Workplace
 - Conservation of resources
 - Placemaking & values
- What's working
- Room for improvement

Occupant comments:

"There's not a day that goes by that I take these working conditions for granted..."

"I feel like a rat in a cage,...
Otherwise everything's fine.
Thank you for asking my opinion."

Green Building Confessions...

Summary of Results: Values

- **Greatest success and largest driver**

GOAL: To be a model sustainable design that would express WRI's mission in physical terms... to "walk the talk" of strategic environmental and business management.

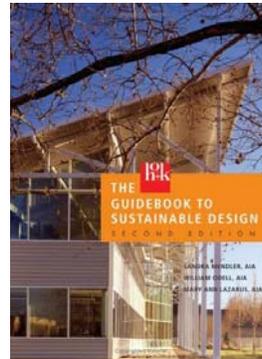



RESULT: "Our sustainable office is the first topic of conversation every time I meet and greets someone coming to the office... It is an extremely positive reflection of our values... The perimeter corridor with identical size offices really impresses people, they know that we value everyone here equally."

Source: Sandra Mendler, AIA, HOK

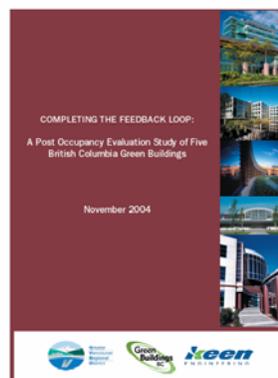
HOK POE outcomes

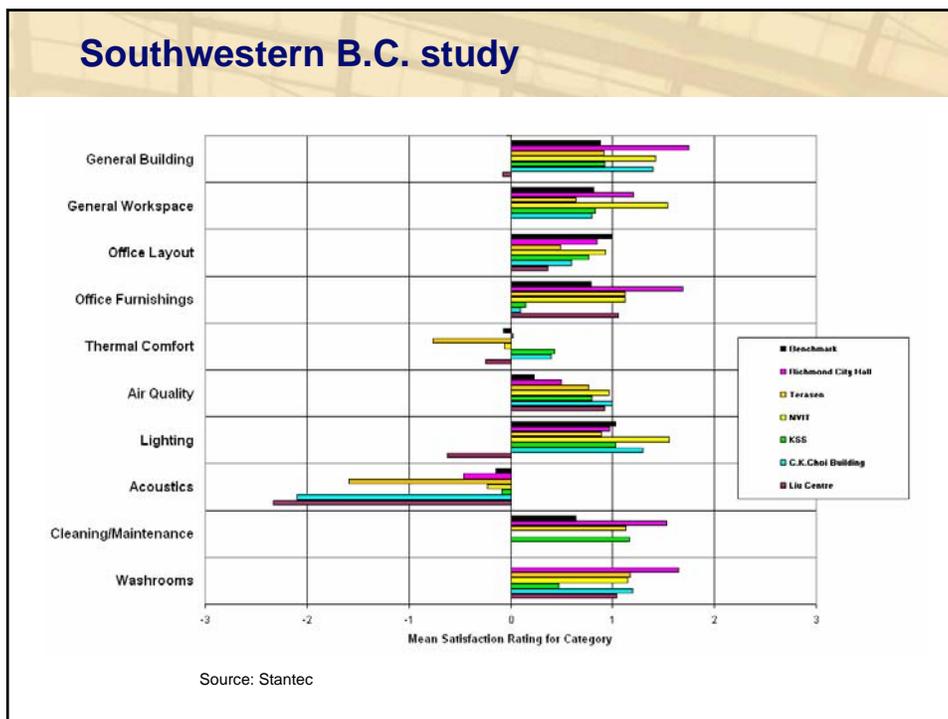
- Disseminated findings in guidebook
- Presentations to AIA membership, *Green building confessions*
- Motivate industry to conduct POEs
 - Assist design of future projects
 - Fosters closer relationship with clients
 - Raise awareness of need to focus on issues like daylighting
 - Study anticipated vs. actual energy use
 - Show importance of building commissioning



Southwestern B.C. study

- Detailed studies of five green buildings in SW British Columbia
- Led by Greater Vancouver Regional District, Green Buildings BC, and Stantec (Keen)
- Completed Nov. 2004
- Project led to the development of building performance evaluation (BPE) protocol now in development with Stantec and the EcoSmart Foundation





LEED – NC 2.2 updates thermal comfort credits

Previous version LEED – NC 2.1

- Credit 7.1 (Comply w/ ASHRAE 55-1992)
- Credit 7.2 (Permanent monitoring system)

New version LEED – NC 2.2 (November 2005)

- Credit 7.1 (Comply w/ ASHRAE 55-2004)
- Credit 7.2 (Verification)

IEQ Credit 7.2 Thermal Comfort: Verification

“Agree to implement a thermal comfort survey of building occupants within a period of six to 18 months after occupancy.

This survey should collect anonymous responses about thermal comfort in the building including an assessment of overall satisfaction with thermal performance and identification of thermal comfort-related problems.

Agree to develop a plan for corrective action if the survey results indicate that more than 20% of occupants are dissatisfied...”

Additional resources

- CBE Publications Page:
<http://www.cbe.berkeley.edu/research/publications.htm>
- Environmental Building News, Volume 12, Number 9, September 2003
(available free from BuildingGreen.com)
- Federal Facilities Council, Technical Report 145, “Learning from our buildings: a state-of-the-practice summary of post-occupancy evaluation” (2001)
- Mendler, S., W. Odell, M. A. Lazarus
“The HOK Guidebook to Sustainable Design” (2006)

Questions/discussion

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Survey demo

<http://www.cbesurvey.org>

Center for the Built Environment

<http://www.cbe.berkeley.edu>

Survey researcher wanted!

<http://www.cbe.berkeley.edu/jobs>

