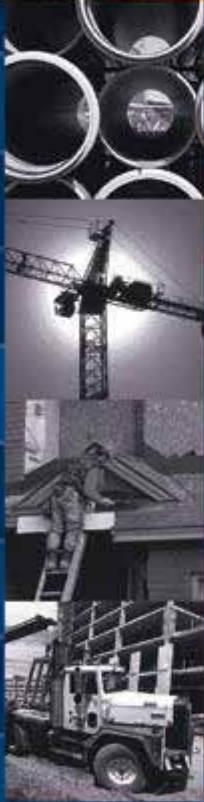


January 2005

Efficient Electric Lighting & Evaluating Satisfaction

Dr. Guy Newsham
Institute for Research in Construction
National Research Council Canada



National Research
Council Canada

Institute for
Research in
Construction

Conseil national
de recherches Canada

Institut de
recherche en
construction

NRC-CNRC
Construction

Overview of the Lecture

- **Focus on Office Buildings**
North American bias
- **Electric Lighting Energy Efficiency**
 - Good lighting for offices
 - Techniques
 - Examples
- **Occupant Satisfaction and “Sustainability”**
 - Techniques
 - Examples

Lighting Energy Use

- **US numbers (1995):**
 - 23 % of commercial energy
 - 46 % of commercial electricity
 - 9 % of residential energy
 - $\frac{1}{6}$ of all electricity is for lighting, worth \$40bn annually
- **Worldwide (1997):**
 - 2000 TWh (\equiv 1000 400 MW power plants, and 1775 Mt CO₂), worth \$185bn annually

US Energy Info. Admin; 1995 Commercial; 1993 Residential
Mills "Why we're here" Right Light 5, 2002



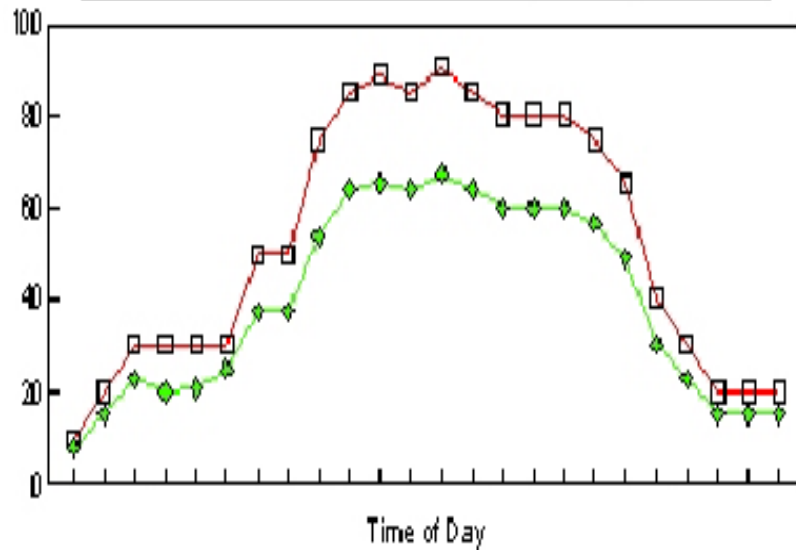
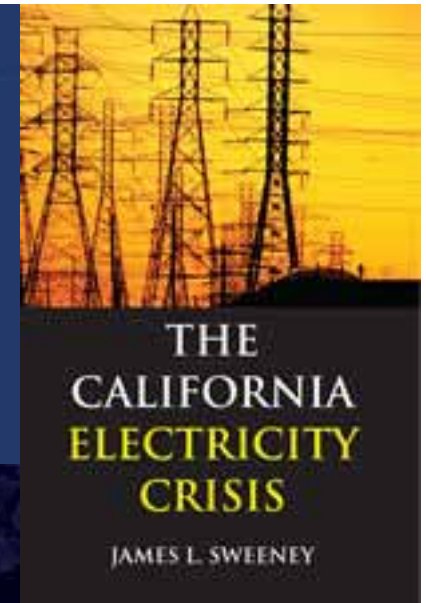
Thermal Energy Benefits

- **Lighting energy becomes heat**
- **Reducing lighting load lowers cooling load and increases heating load**
- **Even in Canada, in large office buildings, savings in cooling costs dominate**
- **Additional savings are 10-80% of lighting savings, depending on climate (Edmonton-Houston)**

*“Energy-efficient lighting options ...”, Newsham & Veitch,
Proceedings of CLIMA 2000, Brussels, 1997*

Reducing Load

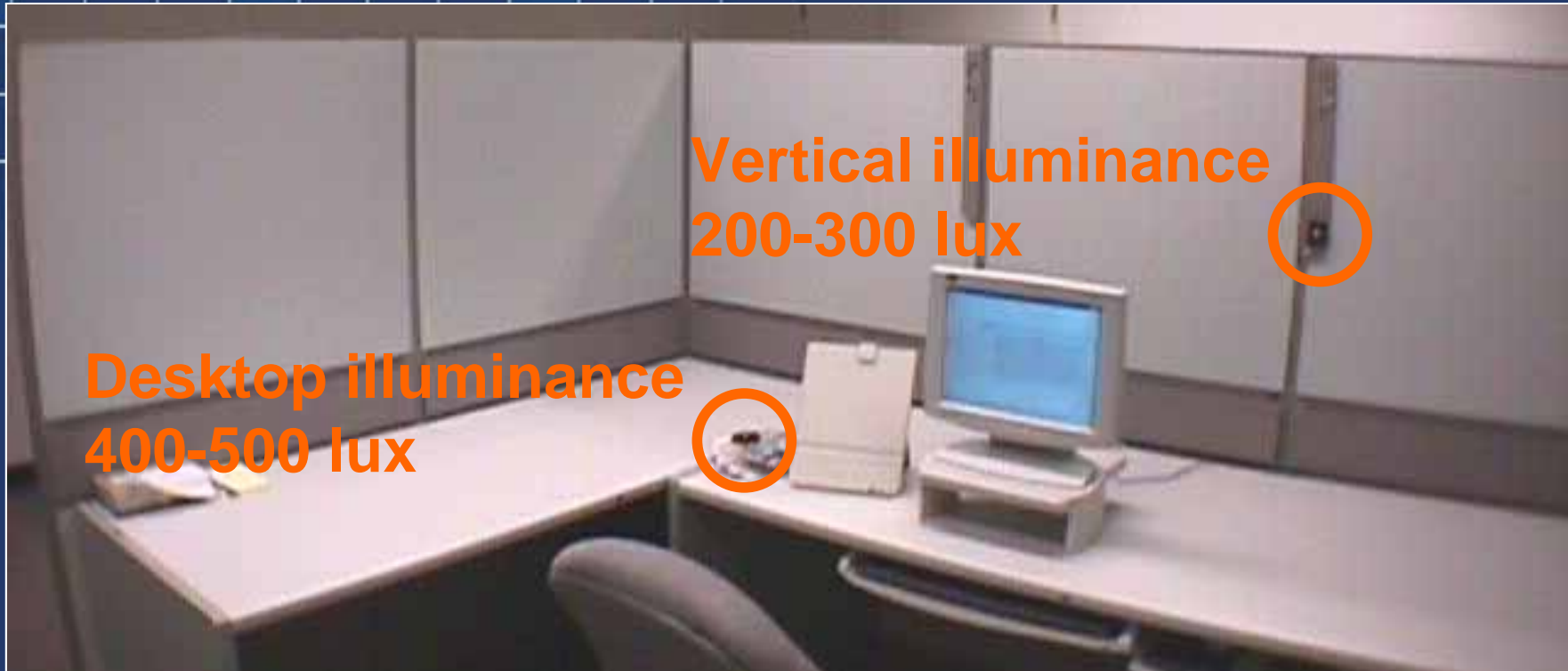
- Demand profiles and charges



Key to Reducing Lighting Energy

- **Right amount,
where it's needed,
when it's needed**
- **What's the right amount of light for office
work?**

Illuminance Selection



- **Illuminance reduced by:**
 - Higher panels
 - Smaller workstations
 - Darker surfaces

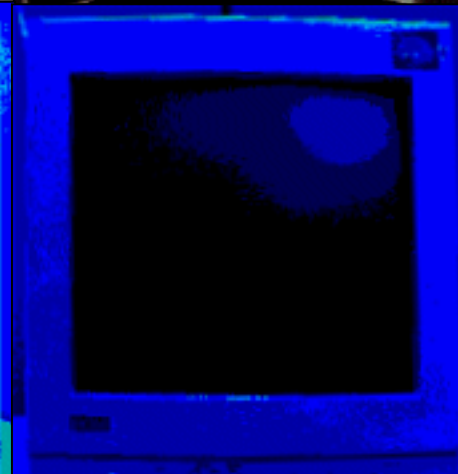
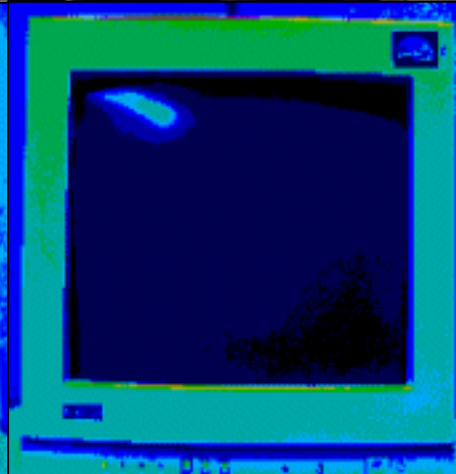
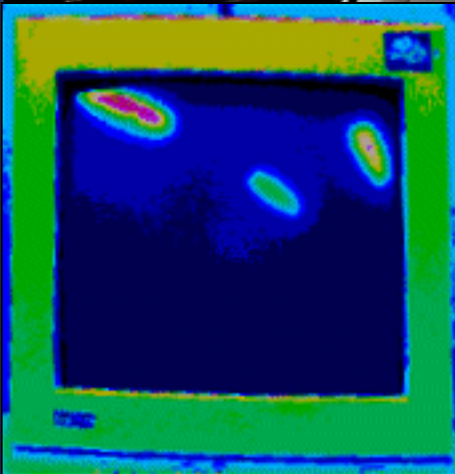
Lighting Design

Prismatic

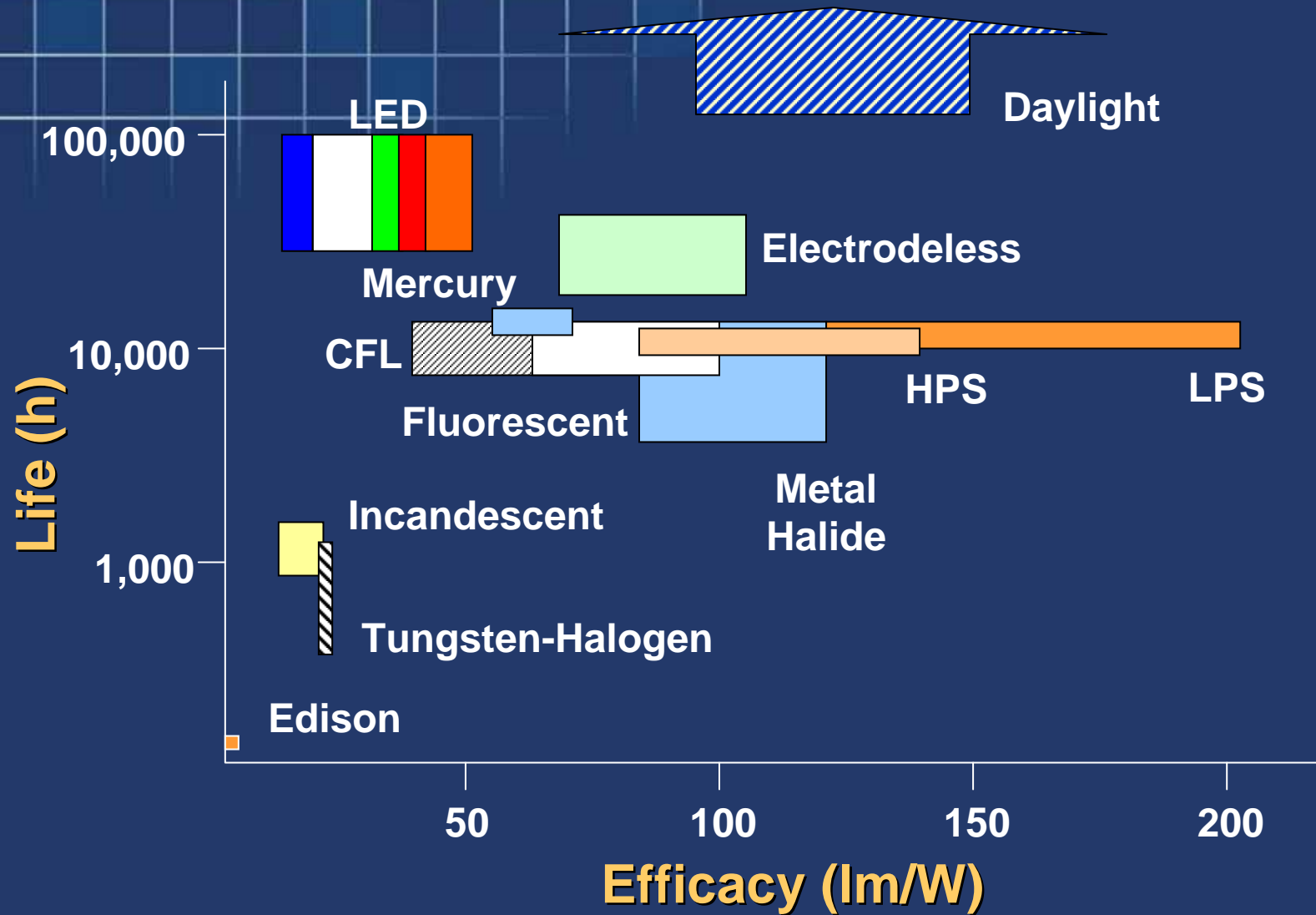
Parabolic

**Indirect
(good)**

**Indirect
(bad)**



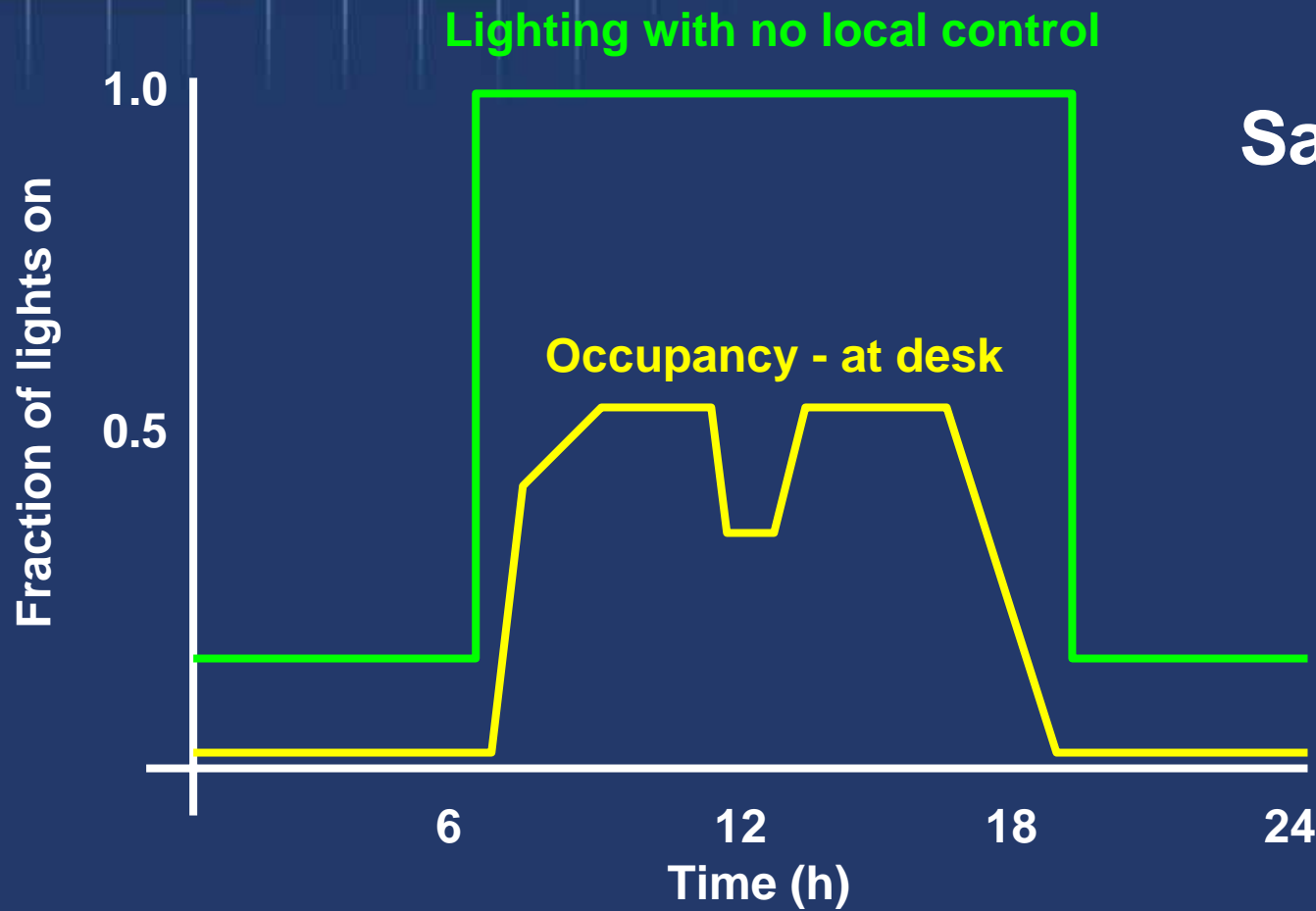
Higher Efficacy Sources





Controls (where and when)

Occupancy Sensors

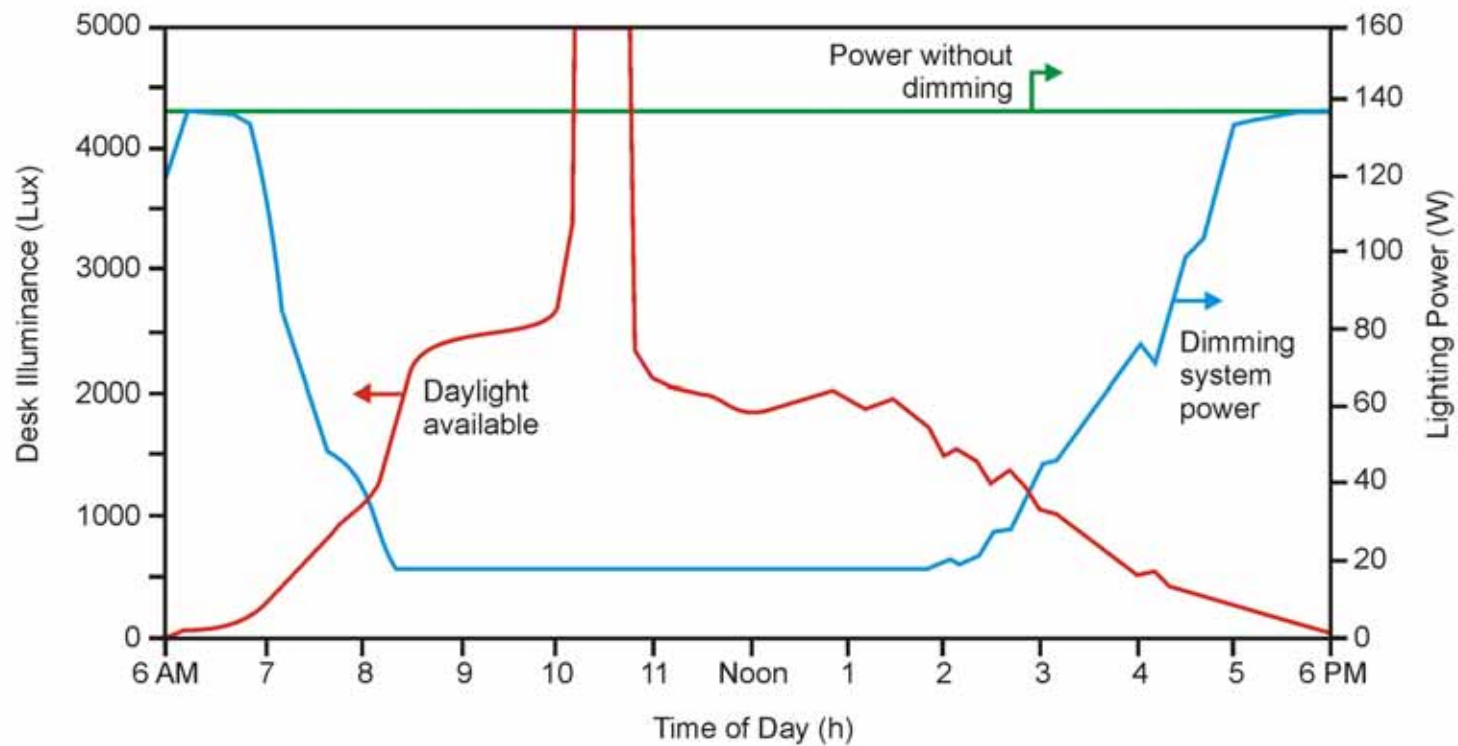


Savings: 25-40%

“Occupancy sensors: are there reliable estimates of the energy savings?”,
Figueiro, M., LD+A (2004)

Daylight Harvesting

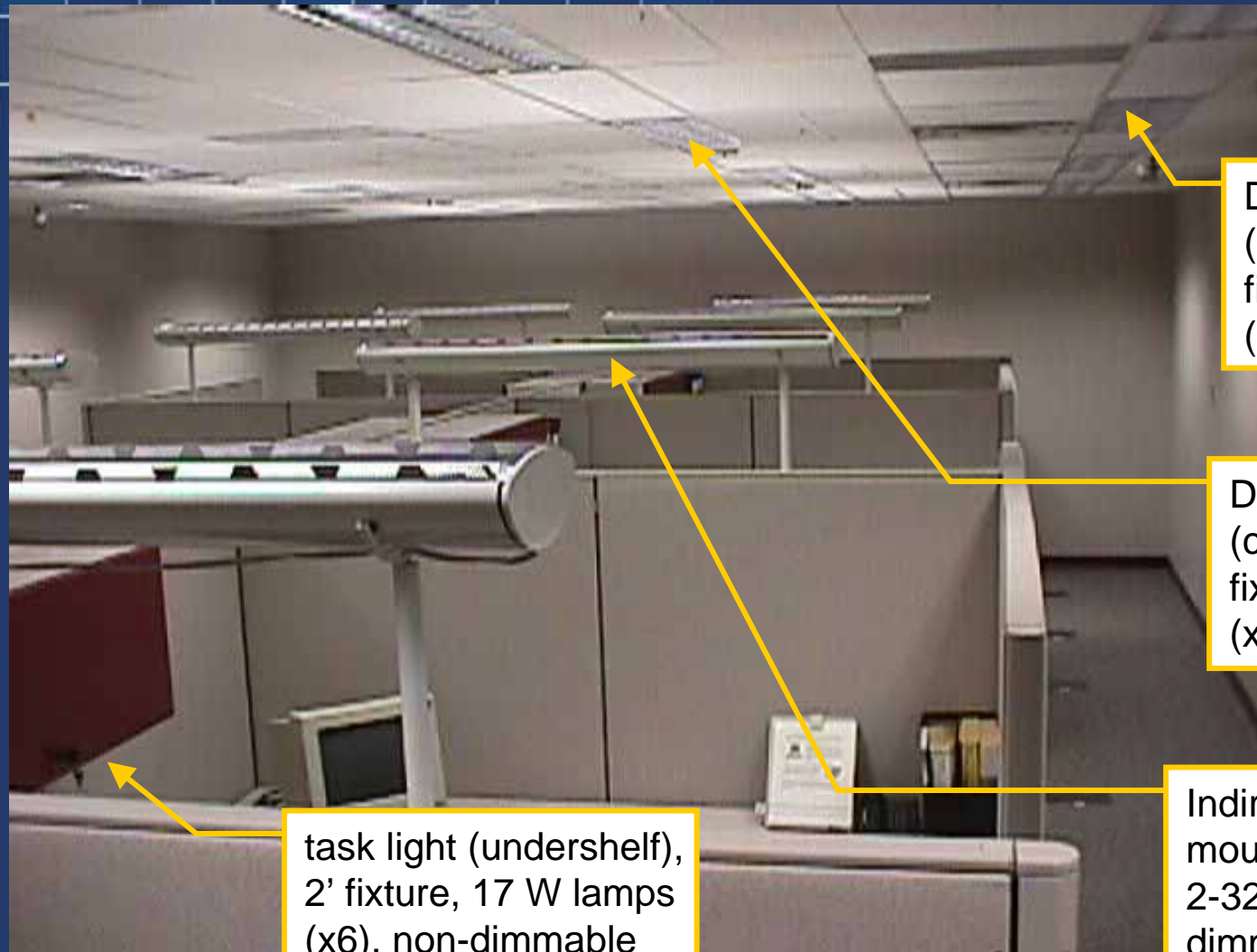
- Energy savings 25-60%



Individual Controls



Lighting System in the Mock-up Office



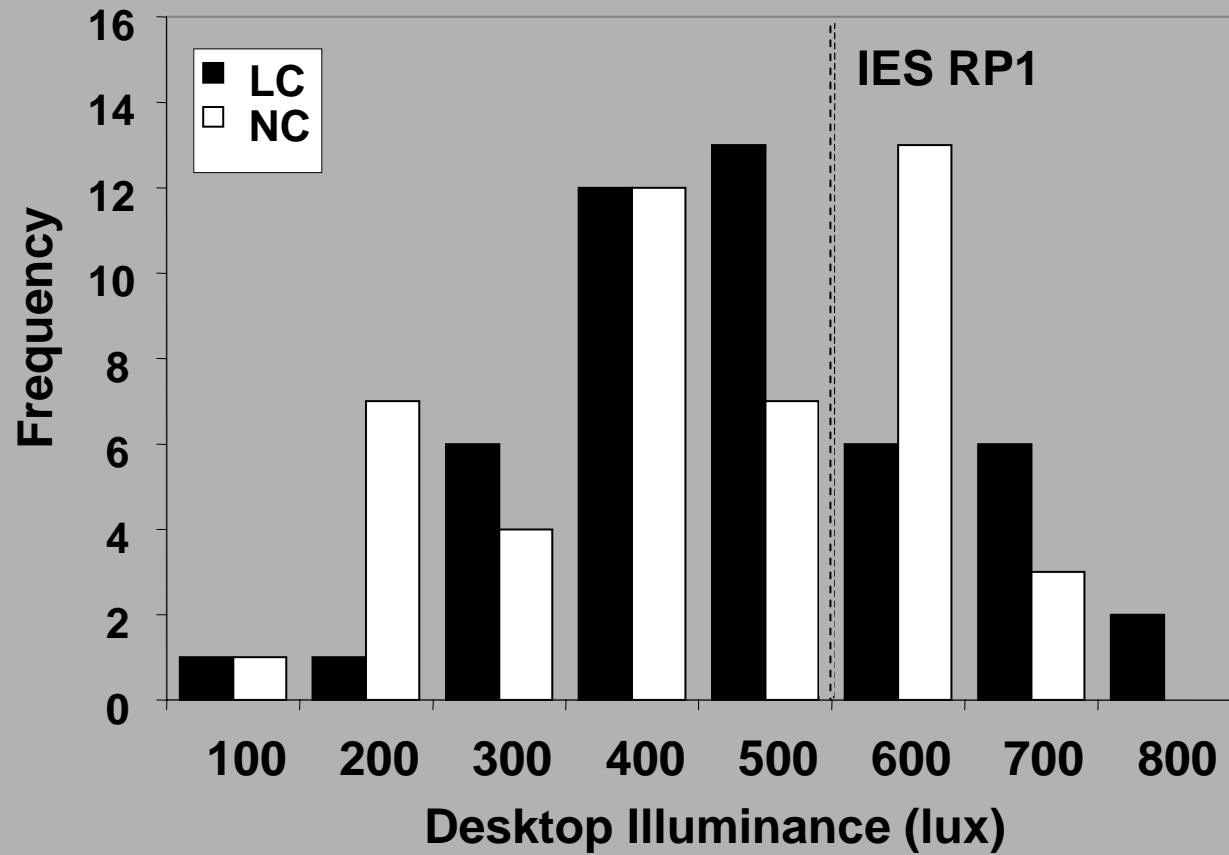
Direct Parabolic
(ceiling perimeter), 4'
fixture, 2-32 W lamps
(x10), dimmable

Direct Parabolic
(ceiling centre), 4'
fixture, 2-32 W lamps
(x10), dimmable

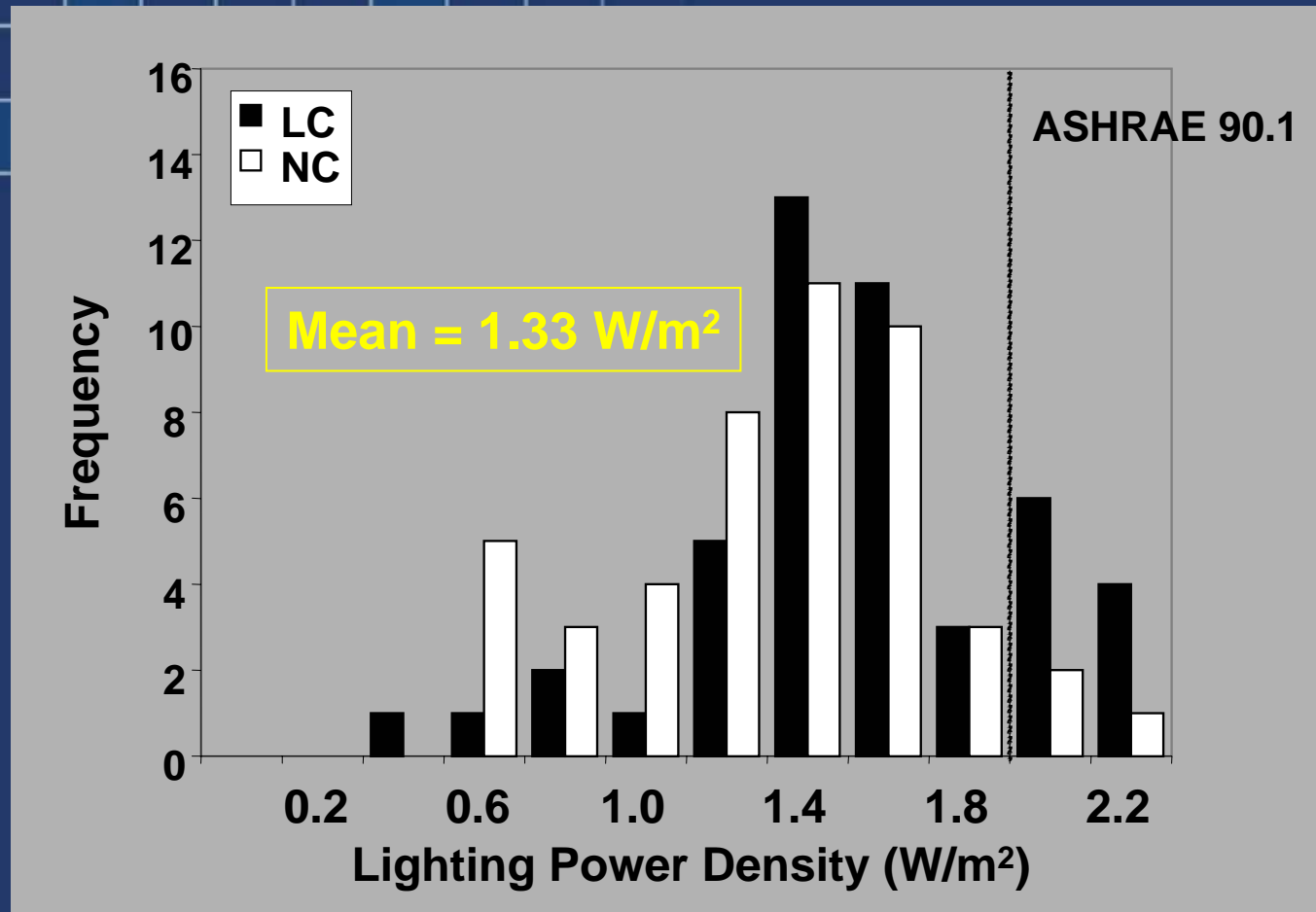
task light (undershelf),
2' fixture, 17 W lamps
(x6), non-dimmable

Indirect (partition-
mounted), 4' fixture,
2-32 W lamps (x8),
dimmable

Lighting Choices



Lighting Choices



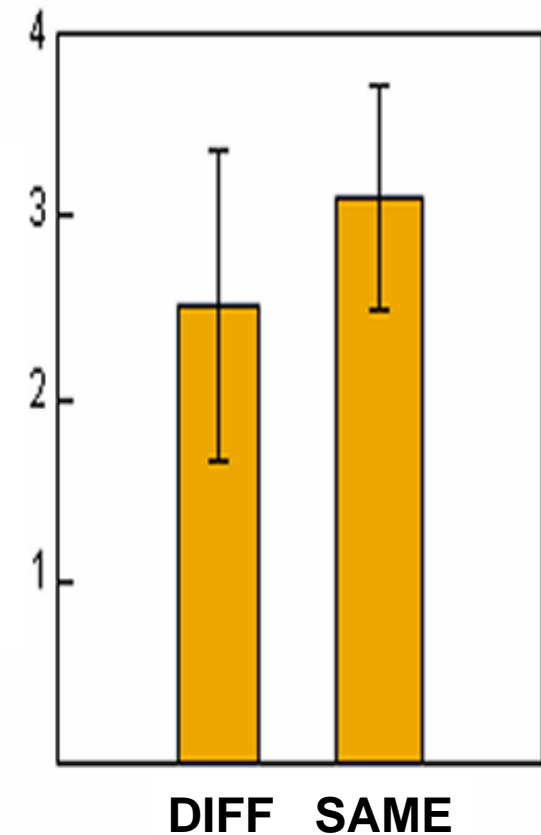
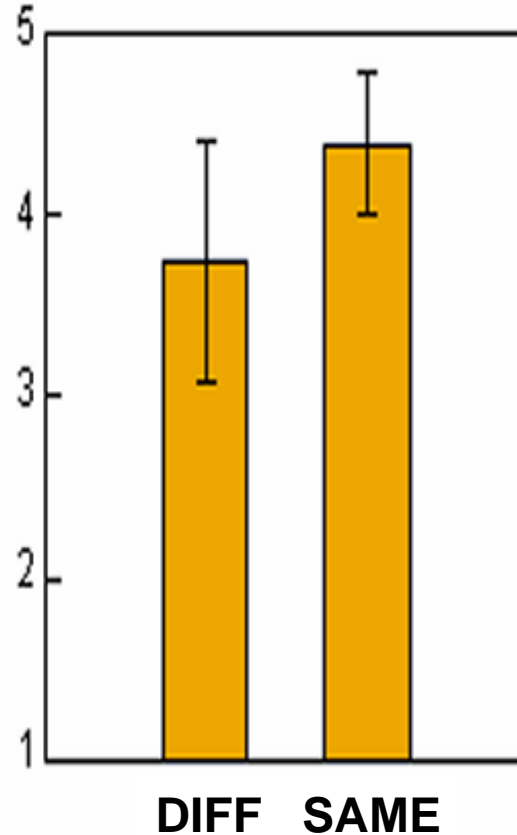
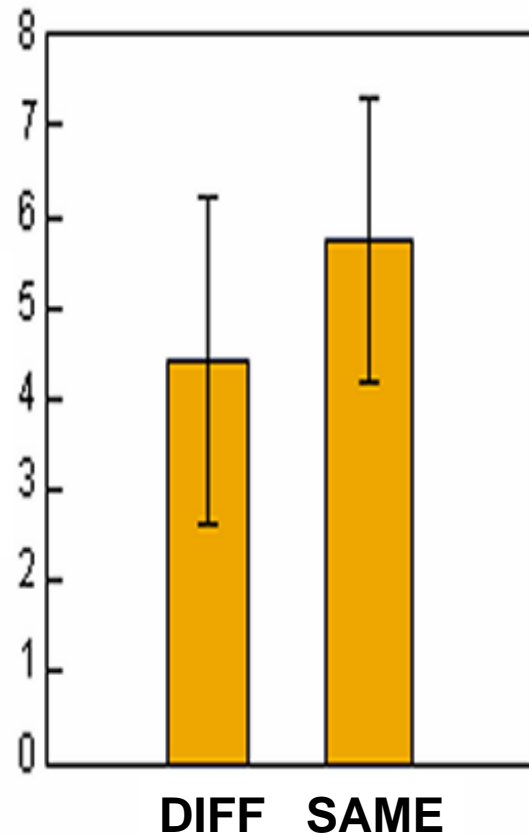
- Also manual occupancy switching ...
- ... and manual daylight harvesting

Positive Affect Hypothesis

PLEASURE

LIGHTING QUAL.

ENV. SATIS.



- Later research at NRC demonstrated the benefits of individual control on satisfaction, mood, and comfort



If people don't like the building,
it's not sustainable

Green Building Assessment

- **CEPAS also available soon**



HK-BEAM

- **Points in various categories:**
 - Site Aspects (23)
 - Materials Aspects (22)
 - Energy Use (46)
includes Demand/Load credits
 - Water Use (9)
 - **Indoor Environment Quality (37)**
 - Innovations & Performance Enhancements (5)

Why is Satisfaction Important?

- People cost a lot more than buildings



Staff
82%



**Equipment &
Training 10%**

3%
**Maintenance &
Operations**

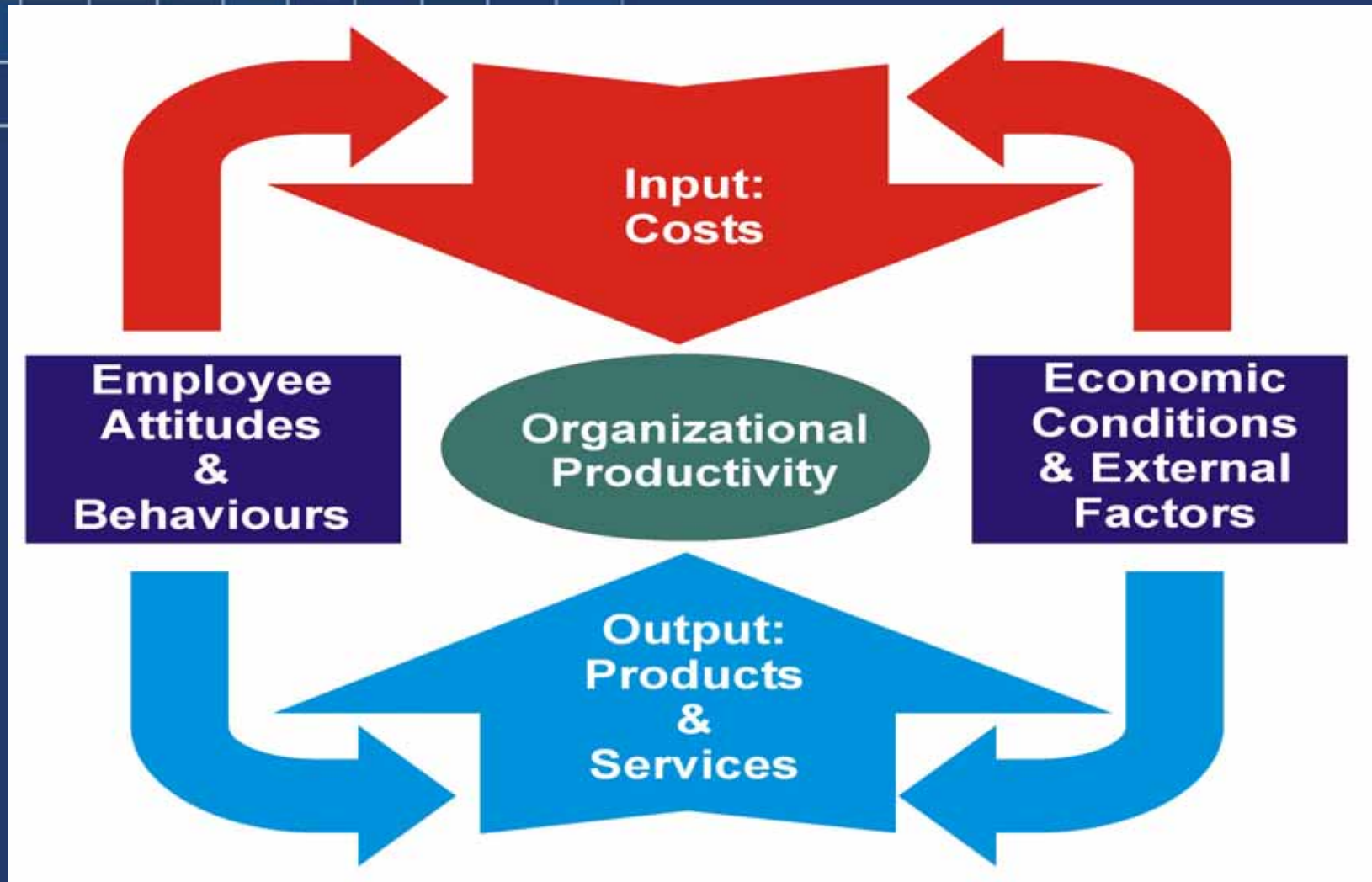


5%
Building & Furnishings

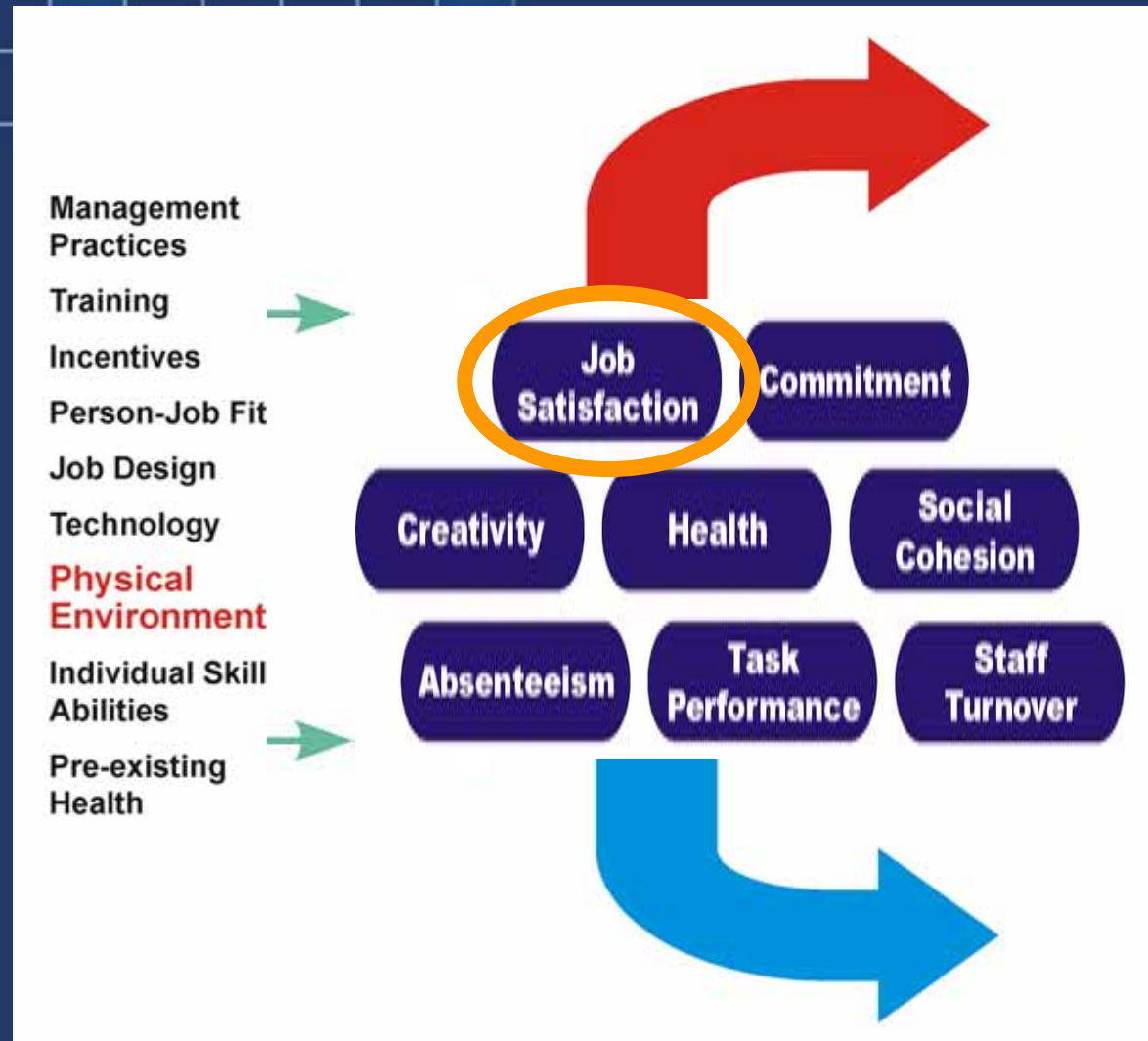


Source: Brill, M., Weidemann, S., & BOSTI Associates. (2001). *Disproving myths about workplace design*. Jasper, IN: Kimball International.

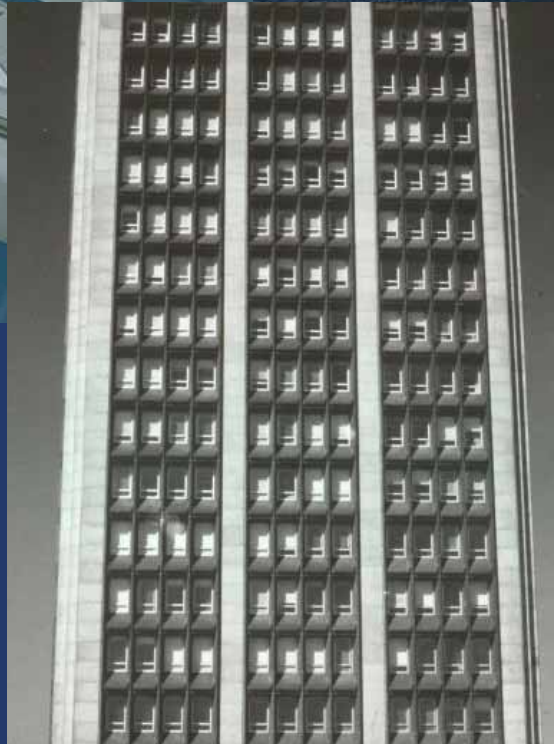
Model of Org. Productivity



Attitudes and Behaviours



Behaviour and building performance



Photos: Bill Bordass

Evaluating What People Think

- **Pre-construction**
 - Find out what people want
- **Post-construction**
 - Find out if you've achieved your goals
 - Find out if you've met needs

Pre-construction Renderings

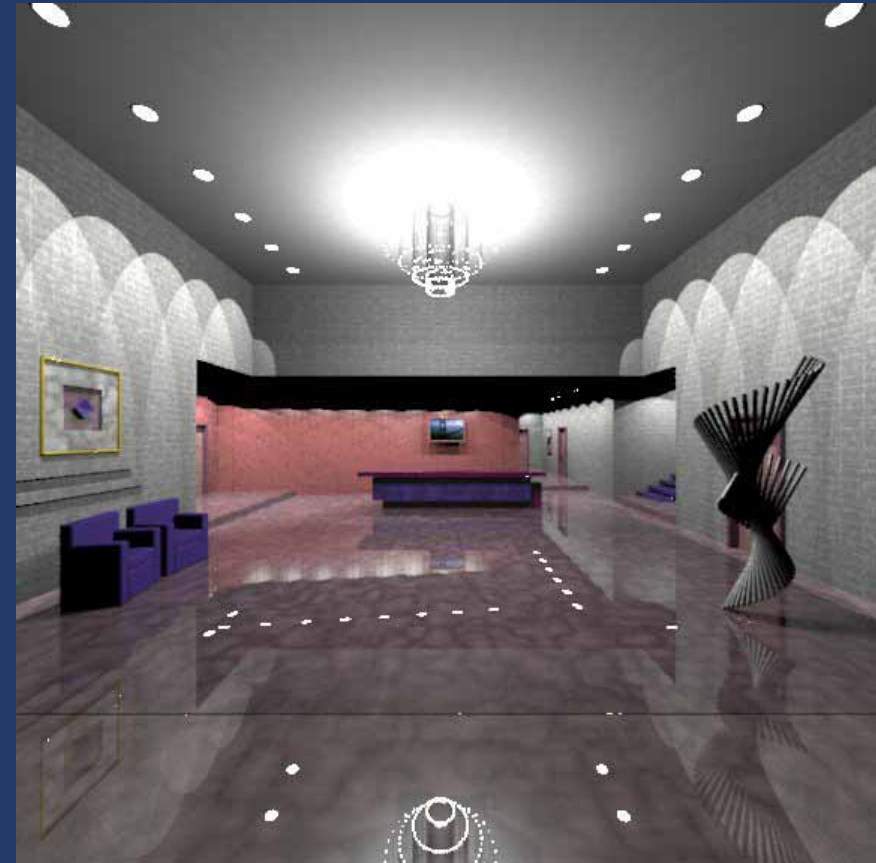
- **Ask the client:
What do you think of this?**

<http://www.archnewsnow.com/features/Feature17.htm>

Slide 26



Pre-construction Renderings



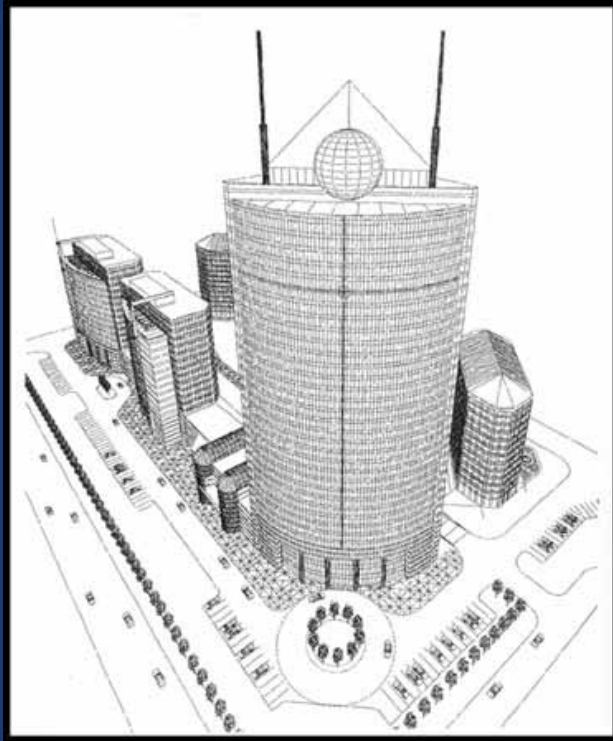
© 1994 by Martin Moeck, Siemens Lighting
<http://radsite.lbl.gov/radiance/gallery/electric.html>

Renderings are reality - right?

- **Assumption that responses to images are similar to responses to the real space**
- **Generally supported by research**
 - Rank ordering of options
 - Based on aesthetics
 - More detailed renderings are rated closer to reality

Effect of Rendering Type

- Don't mix rendering formats for comparisons



<http://studio4d.net/p22.htm>



http://www.cummings.com/international_appeal.htm

Post-construction Surveys

- **What questions to ask?**
- **Choice Guided by:**
 - Your specific goals
 - e.g. *“How satisfied are you with access to daylight and views”*
 - Informal or formal open-ended feedback from some occupants
 - Other similar studies

Parasuraman, A. (1986). *Marketing Research: Chapter 10*

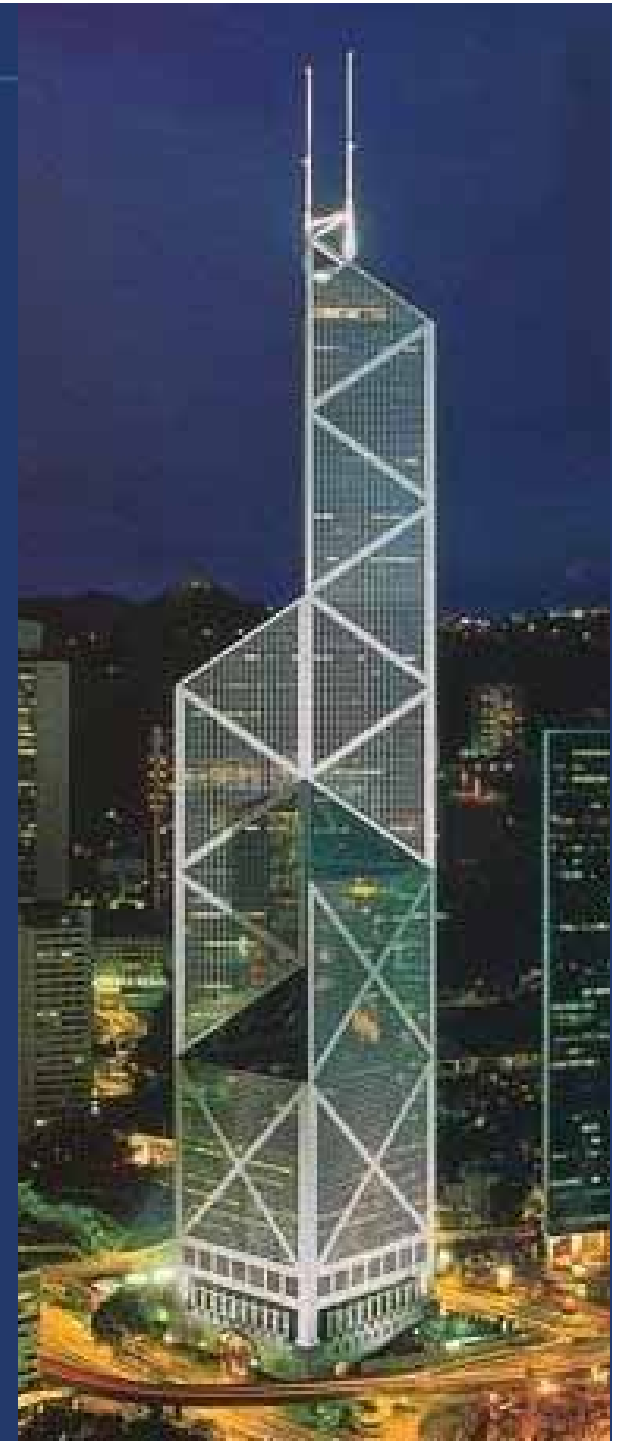
Questionnaire Design

- **What features do you like most?**

- Views from the windows
- Daylight at my desk
- Dimmable lighting controls
- Fast elevators
- Great cafeteria
- Large file storage
- Vibrant colours
- Flexible dress code
- Other _____

Questionnaire Design

- **Avoid uninformed data**
- **Who owns this building?**
 - Hong Kong-Shanghai Bank
 - Government of Hong Kong
 - Bank of China
 - Hilton Hotels
 - I don't know



Questionnaire Design

- **Avoid Double-barrelled questions:**
- **Do you think this company cares about its employees and customers?**
- **Split into two questions**
 - Do you think this company cares about its employees?
 - Do you think this company cares about its customers?

Questionnaire Design

- **Avoid Leading questions:**
- **Do you think land reclamation is bad for the environment because it destroys natural habitats?**
- **Do you think land reclamation is good for the environment because it relieves stress on natural habitats elsewhere?**
- **Word neutrally**
What is your opinion about the environmental effect of land reclamation?
 - Good for the environment
 - No effect on the environment
 - Bad for the environment

Questionnaire Design

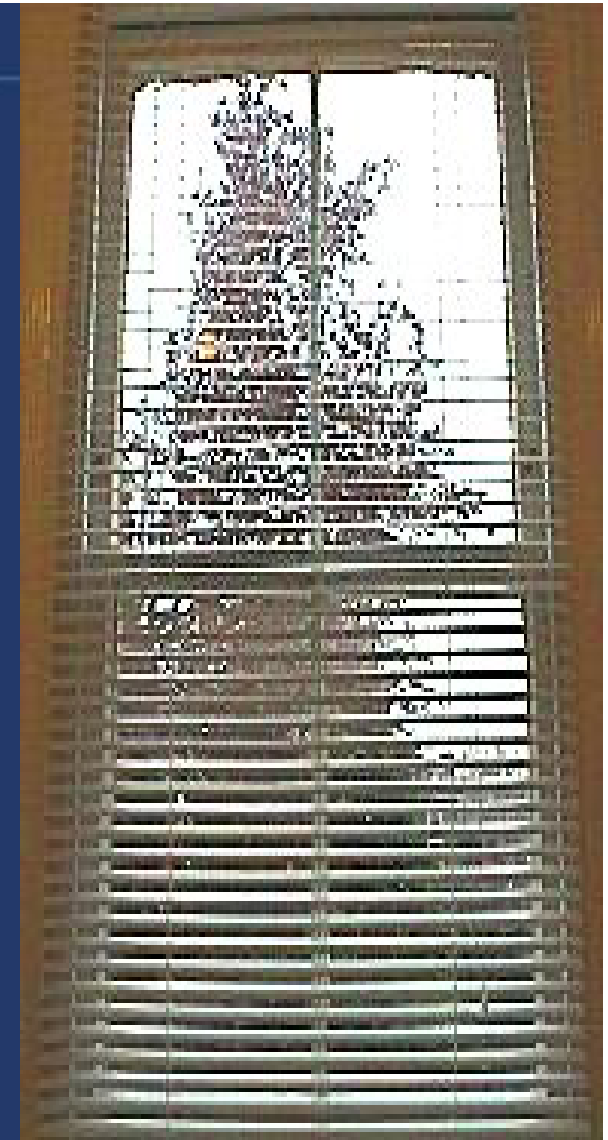
- **Avoid One-sided/Unbalanced questions:**
- **How important is first cost in your project?**
 - More important than anything else
 - Extremely important
 - Very important
 - Somewhat important
 - Unimportant
- **Word neutrally**
 - How important is first cost in your project?**
 - Very important
 - Somewhat important
 - Neither important nor unimportant
 - Somewhat unimportant
 - Very unimportant

Questionnaire Design

- **Avoid Unclear Meanings:**
- **How often do you get to work on the bus?**
 - Frequently
 - Occasionally
 - Rarely
 - Never
- **Be specific**
 - How often do you get to work on the bus?**
 - Every day
 - 3 or 4 times per week
 - 1 or 2 times per week
 - Never

Questionnaire Design

- **Avoid “Impossible” questions:**
How many times have you adjusted the window blinds in the past year?
- **Reasonable expectations**
How many times have you adjusted the window blinds...
... this week?
... today?
... in the last hour?



Questionnaire Design

- **Open-ended section**
 - Is there anything else you would like to comment on?
- **Demographics at the end**
 - Age
 - Education ...
 - Anything else sensitive

Questionnaire Design

- **Do a pre-test**

How often do you get to work on the bus?

- 5 or 6 times per week
- 3 or 4 times per week
- 1 or 2 times per week
- Never

- **Sample size**

- Representative
- More is better

Questionnaire Design

- **Permission**
 - Ethics
 - Confidentiality
- **Timing**
 - Avoid novelty effects
- **Interpreting the results, what's good?**
 - Absolute values *I want 80% satisfied*
 - Benchmarking *I want to be better than Building X*

Plaza bench study

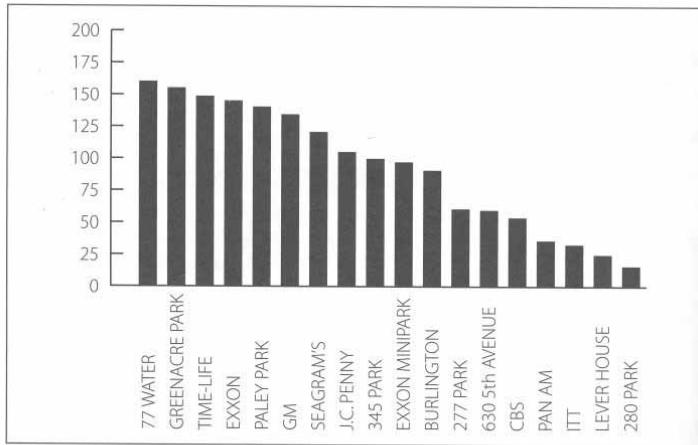


Figure 8.1 Plaza use: average number of people sitting at lunchtime in good weather. Courtesy of Project for Public Spaces, New York, New York.

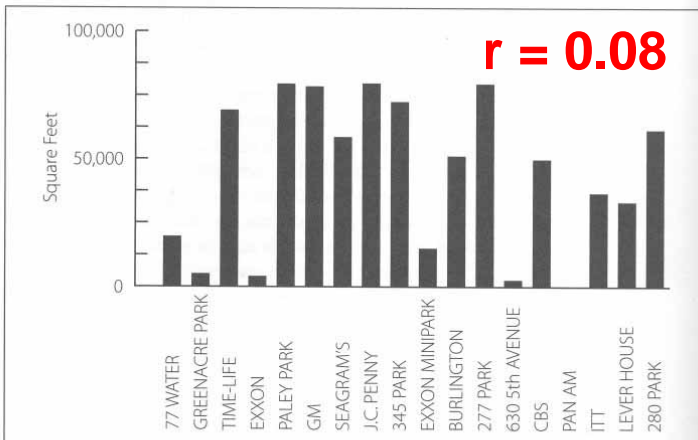


Figure 8.2 Amount of open space by square feet. Courtesy of Project for Public Spaces, New York, New York.

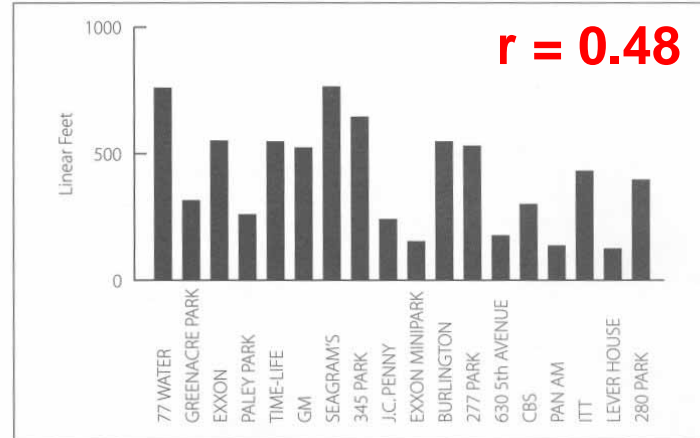



Figure 8.3 Amount of sittable space by linear feet. Courtesy of Project for Public Spaces, New York, New York.



Figure 8.4 Sittable space at 345 Park Avenue. Photo courtesy of Project for Public Spaces, New York, New York.

Study by Whyte in Groat L & Wang D (2002). *Architectural Research Methods*: 203-205



NRC study on office environment
satisfaction
(lab and field, questionnaire)

<http://irc.nrc-cnrc.gc.ca/ie/cope/>

Image: The Corporation © Big Picture Media Corporation

COPE Field Study

- **Sound Level, Temperature, Humidity, Air speed, Light Level, Air Quality**



- **Questionnaire**

Questionnaire

- 15 minutes per office
- 18 questions on office environment

Please read the statement below, and click on the button that best describes your degree of satisfaction with that characteristic of your workplace. When you have finished, click on Next to go to the next question. If you wish to skip this question, click on Skip and your response will not be recorded.

	Extremely poor	Very poor	Poor	Fair	Good	Very good	Excellent
2. Overall air quality in your work area.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Next

Skip

Questionnaire

- Relating environmental satisfaction to job satisfaction

Please click on the button to indicate your degree of agreement or disagreement with the following question. When you have finished, click on Next to move to the next question. If you wish not to respond to the question, please click on Skip and your answer will not be recorded.

	Very strongly disagree	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Very strongly agree
24. My department/agency is a good place to work.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Next

Skip

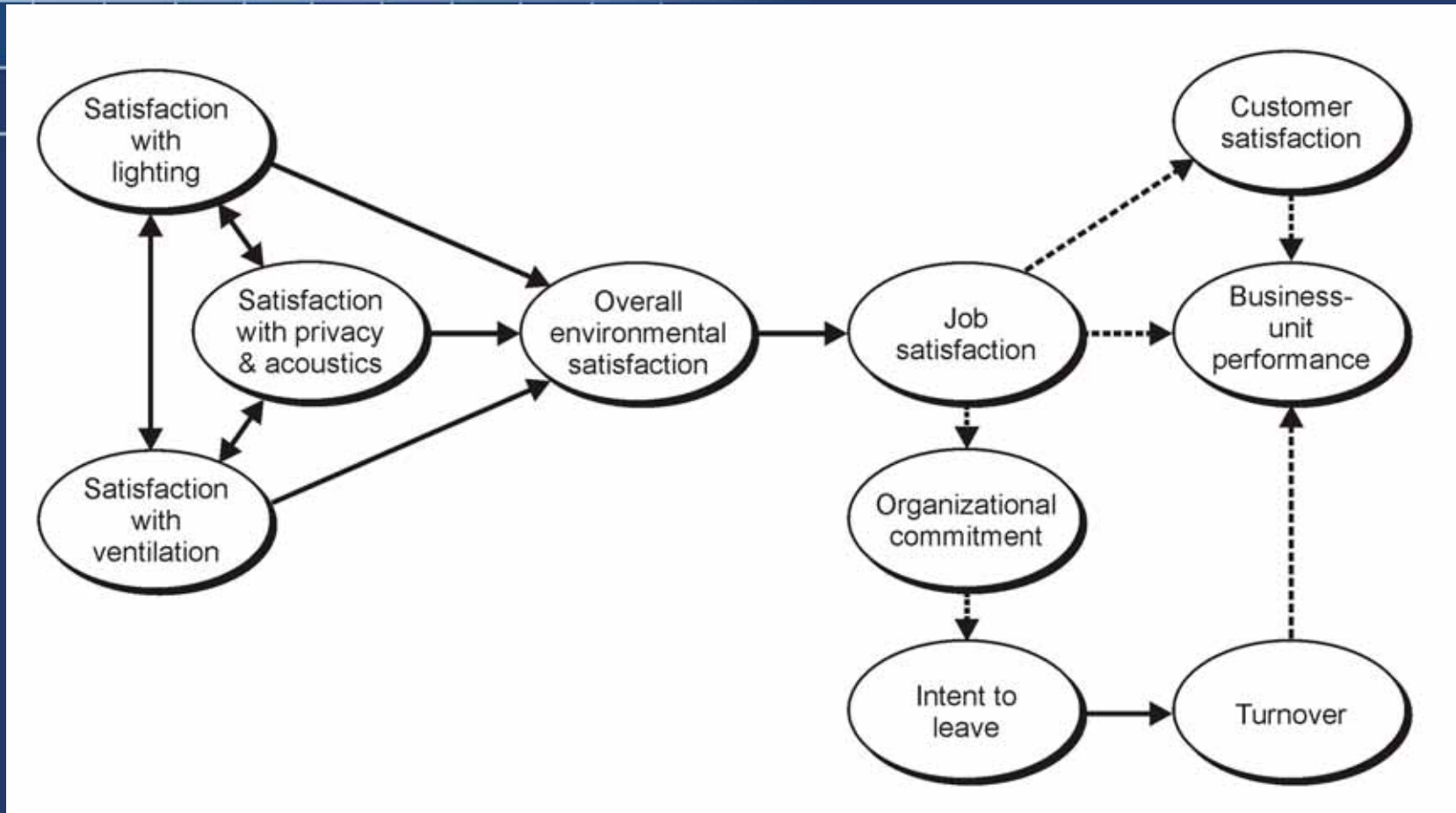
Please click on the button to indicate your degree of agreement or disagreement with the following question. When you have finished, click on Next to move to the next question. If you wish not to respond to the question, please click on Skip and your answer will not be recorded.

	Very strongly disagree	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Very strongly agree
25. I am satisfied with my job.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Next

Skip

One Result ... and my Conclusion



Veitch, J.A., Charles, K.E., & Newsham, G.R. (2004). *Workstation design for the open-plan office* (Construction Technology Update No. 61). Ottawa, ON: National Research Council Canada, Institute for Research in Construction.