The Post-occupancy Performance of Green Office Buildings
Evidence from the field

Guy Newsham, Ph.D. and colleagues
Introduction

• How do green buildings perform when occupied?
  – Indoor Environment Quality, Occupant Comfort and Well-being
  – Energy Use
• Fine-tuning of certification systems to ensure better performance
• A research consortium

Field study

- Green vs. conventional office buildings (N=24)
  - Matched pairs
  - Across Canada and northern US, public and private sector
  - Size: 1300 to 38500 m²
  - Age: 1956 to 2009
  - Green: mostly LEED at some level

“Do ‘green’ buildings have better indoor environments? New evidence”,
Building Research & Information: [http://dx.doi.org/10.1080/09613218.2013.789951](http://dx.doi.org/10.1080/09613218.2013.789951)
Field study

• Four sources of data from each building:
  – On-line questionnaire: environmental satisfaction, job satisfaction, health, absenteeism, environmental attitudes, commuting patterns (N=2545, response 39%)
  – On-site measurements of physical environment (N=974)
  – Interview with building manager: operational issues
  – Energy data: whole building utility bills (sub-systems & water, if available)
Measurements

- **Spot measurements**
  - Temperature, humidity, air speed, formaldehyde, particulates, TVOC, CO₂, light level, noise, SII

- **Longitudinal data**
  - Temperature, humidity, air speed, CO₂, light level, noise
Indoor Environment
Findings across Buildings

- 19 building “sites”
- Uses data at the site-average level
- Wilcoxon signed ranks tests (N=18)
  (9 matched pairs of green vs. conventional sites)
Wilcoxon Tests

Overall Environmental Satisfaction (average of 2 questions)

N = 160
AVE = 4.5
STDEV = 1.3

Building A

Percentage of respondents

Very unsatisfied

Very satisfied

Proceedings of the 13th International Conference for Enhanced Building Operations, Montreal, Quebec, October 8-11, 2013
Wilcoxon Tests
Green vs. Conventional (Questionnaire)

- Green buildings score more highly on:
  - Overall Environmental Satisfaction
    - Satisfaction with Aesthetic Appearance, View to the Outside, Size of Personal Workspace
  - Satisfaction with Ventilation & Temperature
    - Preferred Change in Thermal Conditions
    - Frequency of Thermal Adaptive Behaviours
  - Noise from HVAC systems
  - Workplace Image
  - Positive Mood
  - Visual and Physical Discomfort Frequency
  - Sleep Quality at Night
Green vs. Conventional (Physical Measurements)

• Green buildings perform better:
  – Lower air speed
  – Fewer airborne particulates

• Green buildings perform worse:
  – Speech Privacy Index in Private Offices
Green vs. Conventional (Physical Measurements)

• Acoustics solution!
All Buildings

- Linear regression (N=19, individual sites)
- Physical features associated with improved occupant outcomes:
  - lower articulation index (better speech privacy)
  - lower background noise levels
  - higher light levels
  - greater access to windows
  - lower predicted mean vote (better thermal comfort)
  - lower number of airborne particulates
Energy

• Re-analysis of data from 100 LEED-certified buildings, matched with 100 conventional buildings:
  – On average, LEED buildings used 25% less energy than conventional counterparts
  – But, about one-third of buildings used more
  – And, little correlation between energy credits and actual energy savings
Energy Case Study

Building B - conventional
(2010) 371 kWh/m²

Building A – LEED renovation
(2010) 290 kWh/m²
Conclusions

• Best research to date
• On average, green buildings had superior indoor environments
• Gained knowledge about key physical features affecting occupant outcomes in all buildings
• On average, LEED buildings had lower energy use
• Green building rating systems could be improved:
  – consideration of a LEED credit related to acoustic performance
  – a greater focus on reducing airborne particulates
  – enhanced support for the interdisciplinary design process
  – development of post-occupancy evaluation protocols, and their integration into on-going certification systems
• Complements research on real estate and business outcomes
Thank You

Questions?
Literature Review

- Little post-occupancy data available
- Tentative observed trends for IEQ:
  - Indoor Air Quality improved
  - Lighting about the same
  - Acoustics worse
<table>
<thead>
<tr>
<th>Module</th>
<th># Items</th>
<th>Description</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>35</td>
<td>Environmental and job satisfaction, demographics, job demands</td>
<td>2545</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>Organizational commitment, workplace image, internal communications</td>
<td>843</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>Acoustics</td>
<td>880</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>Thermal comfort</td>
<td>865</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>Chronotype, sleep quality, positive/negative feelings (affect)</td>
<td>876</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>Health</td>
<td>828</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>Commuting, environmental attitudes</td>
<td>798</td>
</tr>
</tbody>
</table>
Example results

![Graph showing SII (Susceptibility Index) for Building A. The graph displays the percentage of workstations across different SII values. The SII values are categorized as SII/OpenWS (N=16) and SII/ClosedWS (N=37). The average (AVE) and standard deviation (STDEV) are provided for each category.]

- SII/OpenWS (N=16):
  - N = 16
  - AVE = 0.49
  - STDEV = 0.24

- SII/ClosedWS (N=37):
  - N = 37
  - AVE = 0.21
  - STDEV = 0.12

Proceedings of the 13th International Conference for Enhanced Building Operations, Montreal, Quebec, October 8-11, 2013
Example results
Example results

![Graph showing CO2 levels over time for different pyramid models.](image-url)
Green vs. Conventional (Questionnaire)

- No statistically-significant difference on:
  - Environmental attitudes
  - Job demands
  - View quality (for occupants that had a view to the outside)
  - Commuting distance
  - Chronotype

- No biases in demographic profiles
- Suggests occupants of green buildings were not biased and samples were appropriately matched
Energy

- No effect of certification level
- Regression n.s. for:
  - offices only, and
  - % savings vs. model baseline
- No effect of additional commissioning and M&V credits
- Small sample, first year of operation, self-selection

EUI = -3.4•credits + 83.3
Introduction – Energy


• Source energy vs. site energy

• Weight results by building size
Construction costs comparison between ‘green’ and conventional office buildings

DOI: 10.1080/09613218.2013.769145

Michael Rehm & Rochelle Ade

pages 198-208