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Post-occupancy evaluation of green buildings: are they as green as we thought?

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Post-occupancy Evaluation of Green Buildings

Are they as green as we thought?

Guy Newsham, Ph.D. and colleagues



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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

<http://archive.nrc-cnrc.gc.ca/eng/projects/irc/post-occupancy.html>

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Roadmap

- Review of prior work
- Indoor Environment Quality, Occupant Comfort and Well-being
 - Original field study in 24 buildings
- Energy Use
 - Re-analysis of existing data from 100 buildings
 - Example from our field study

Literature Review

- Little post-occupancy data available
- Tentative observed trends for IEQ:
 - Indoor Air Quality improved
 - Lighting about the same
 - Acoustics worse



POST-OCCUPANCY EVALUATION OF ENERGY AND INDOOR ENVIRONMENT QUALITY IN
GREEN BUILDINGS: A REVIEW

<http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=20374714&article=10&fd=pdf>

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://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=20857897&article=0&fd=pdf>

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)

Questionnaire

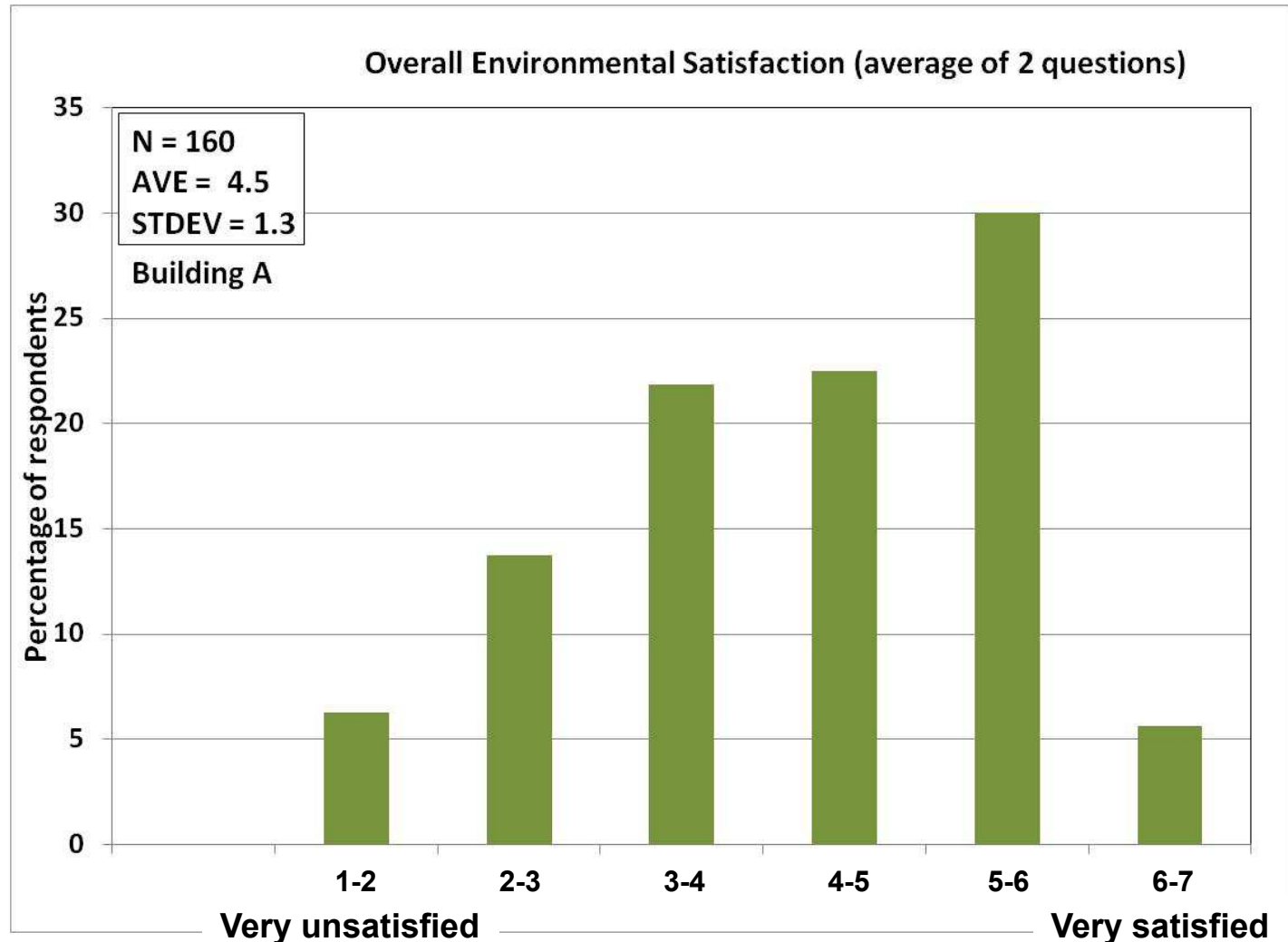
Module	# Items	Description	N
Core	35	Environmental and job satisfaction, demographics, job demands	2545
1	16	Organizational commitment, workplace image, internal communications	843
2	11	Acoustics	880
3	14	Thermal comfort	865
4	34	Chronotype, sleep quality, positive/negative feelings (affect)	876
5	13	Health	828
6	25	Commuting, environmental attitudes	798

Measurements

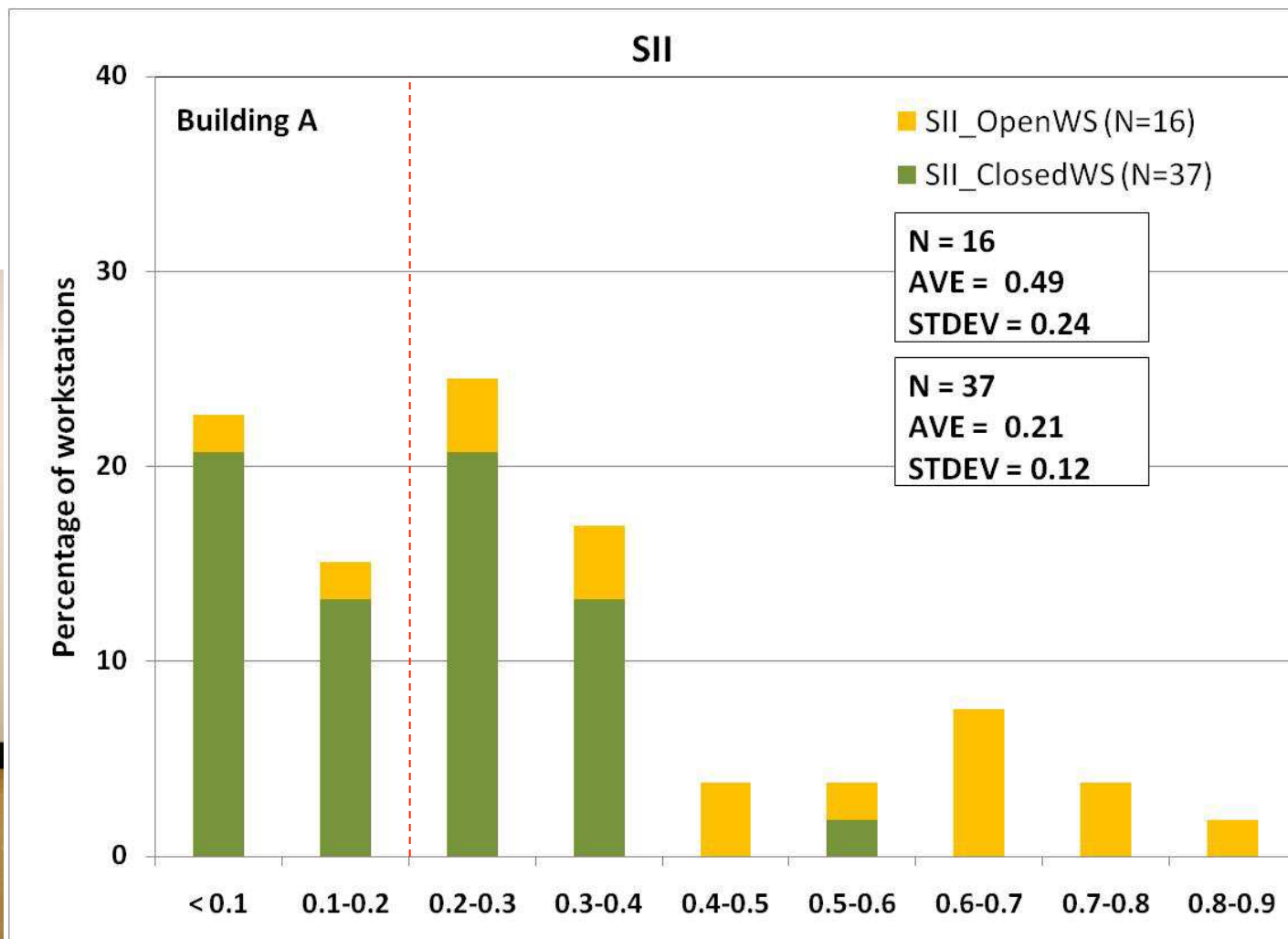
- Spot measurements
 - Temperature, humidity, air speed, formaldehyde, particulates, TVOC, CO₂, light level, noise, SII
- Longitudinal data
 - Temperature, humidity, air speed, CO₂, light level, noise



Example results



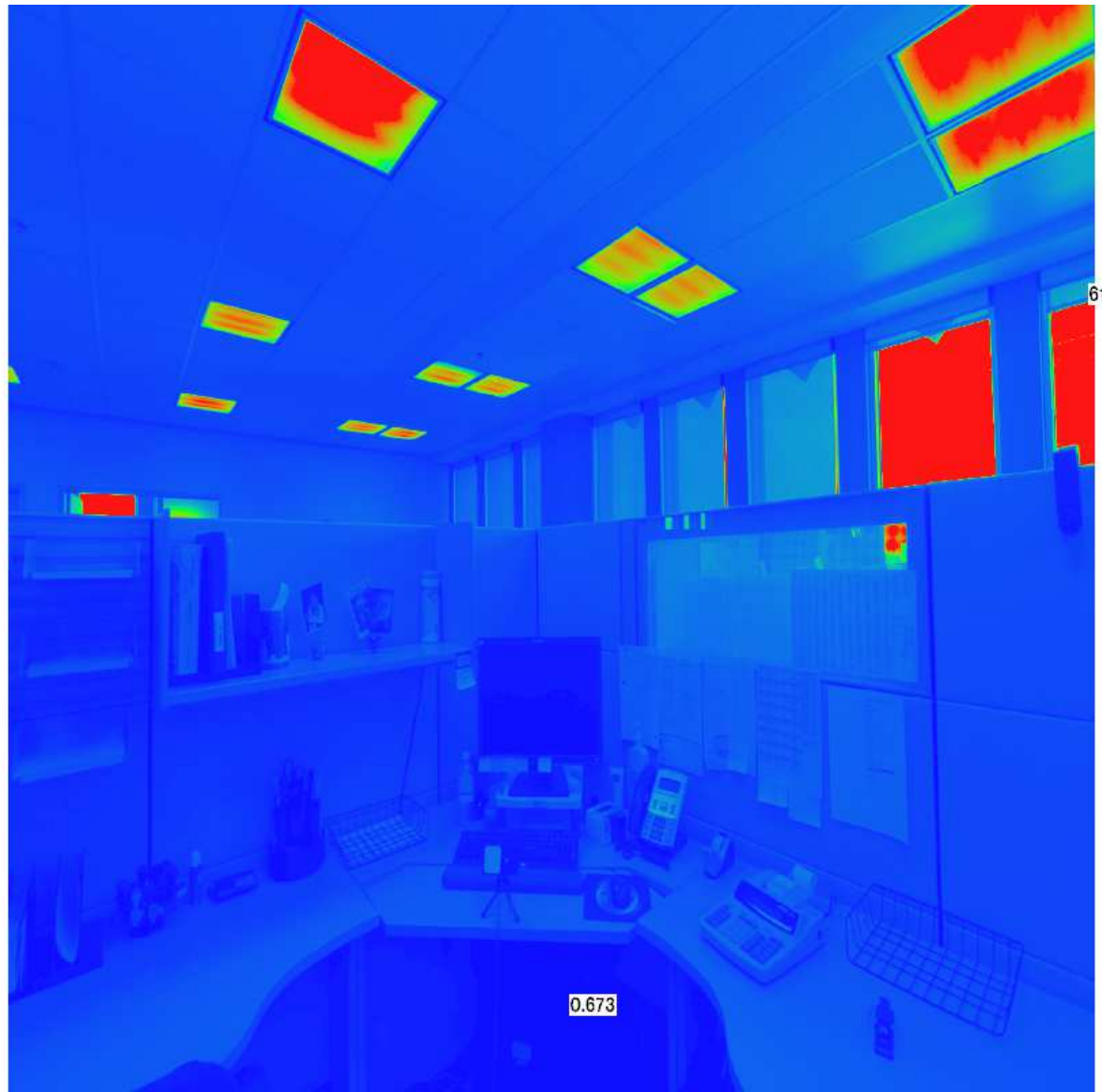
Example results



Example results



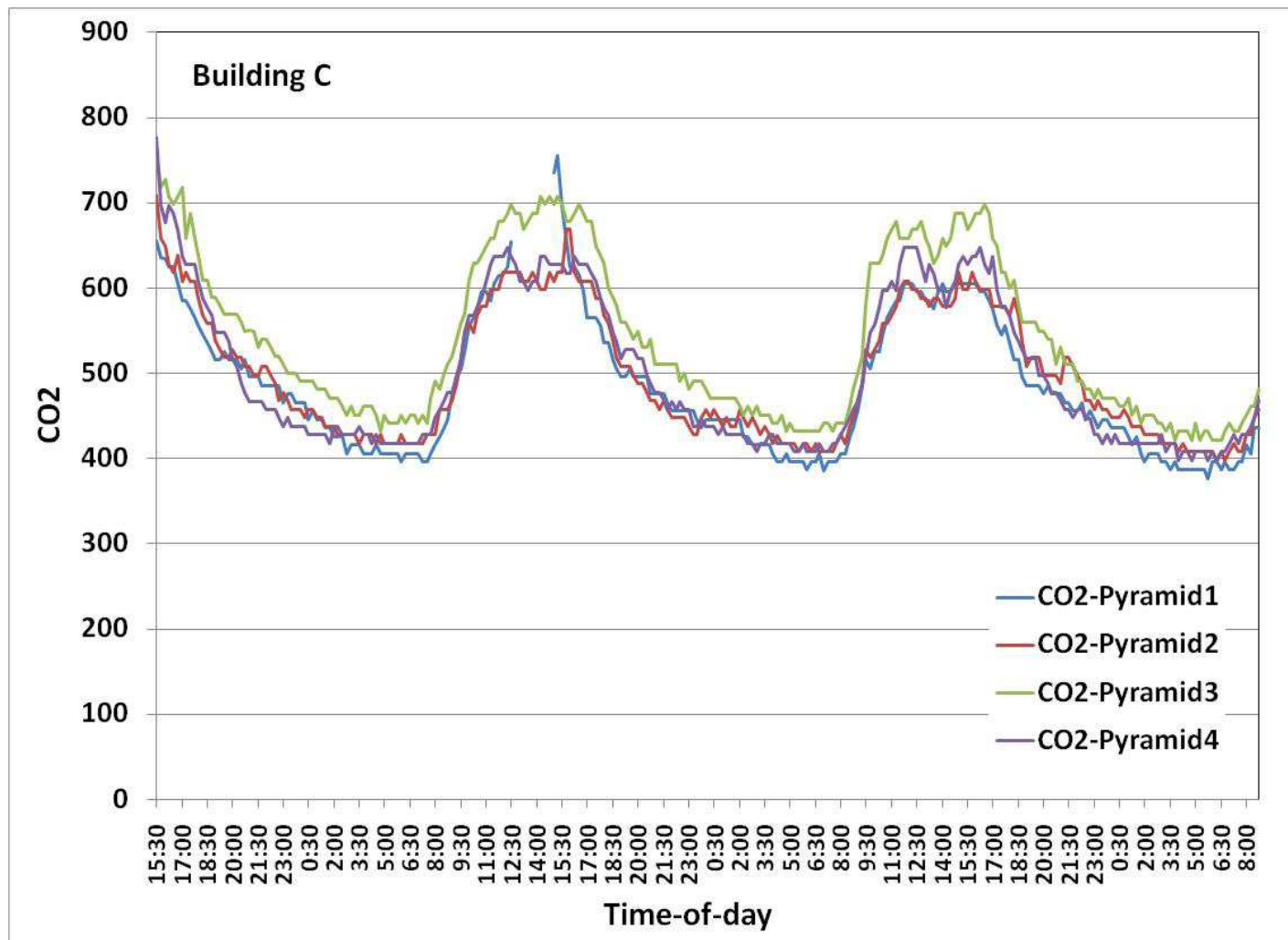
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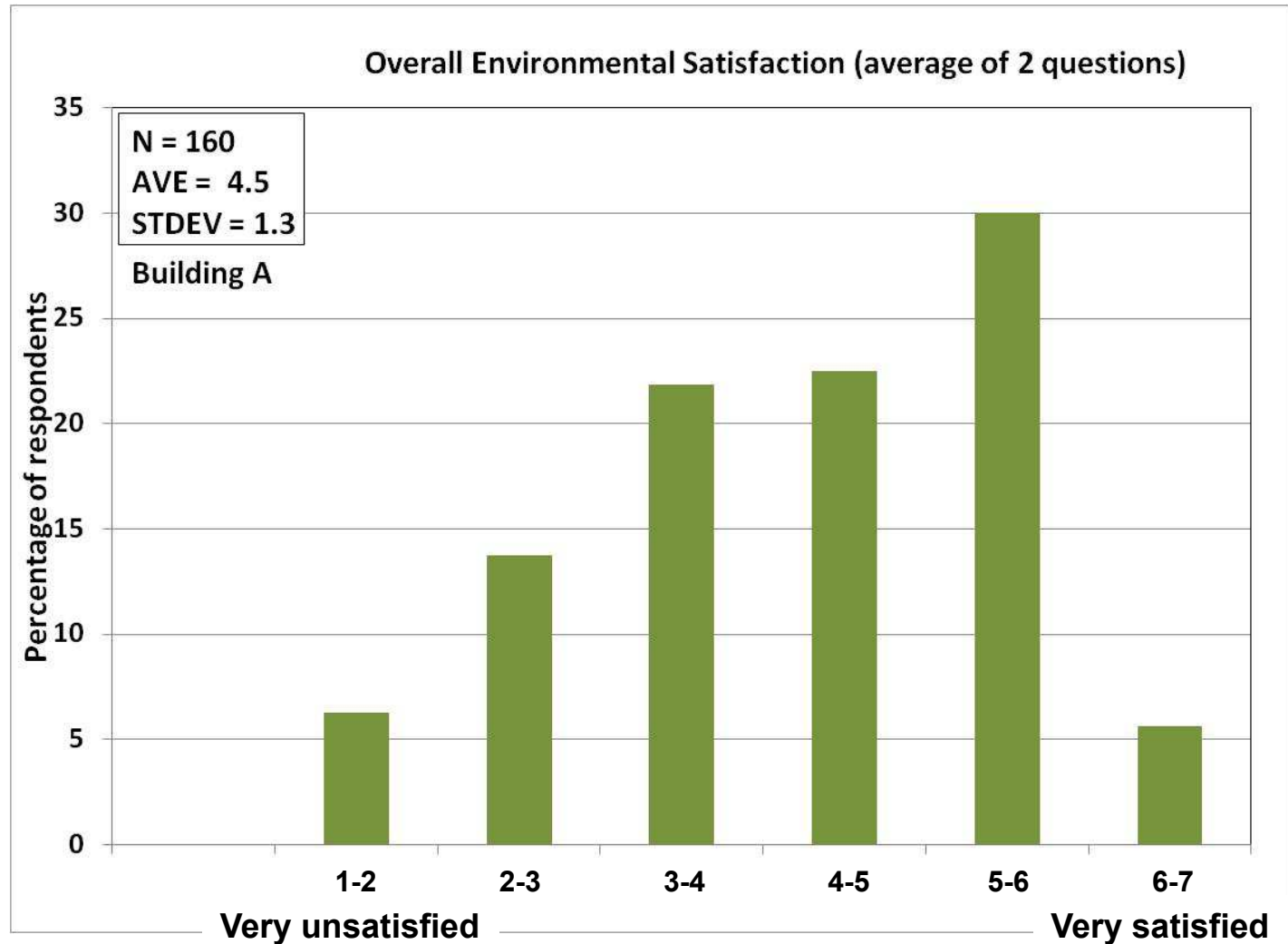
Example results



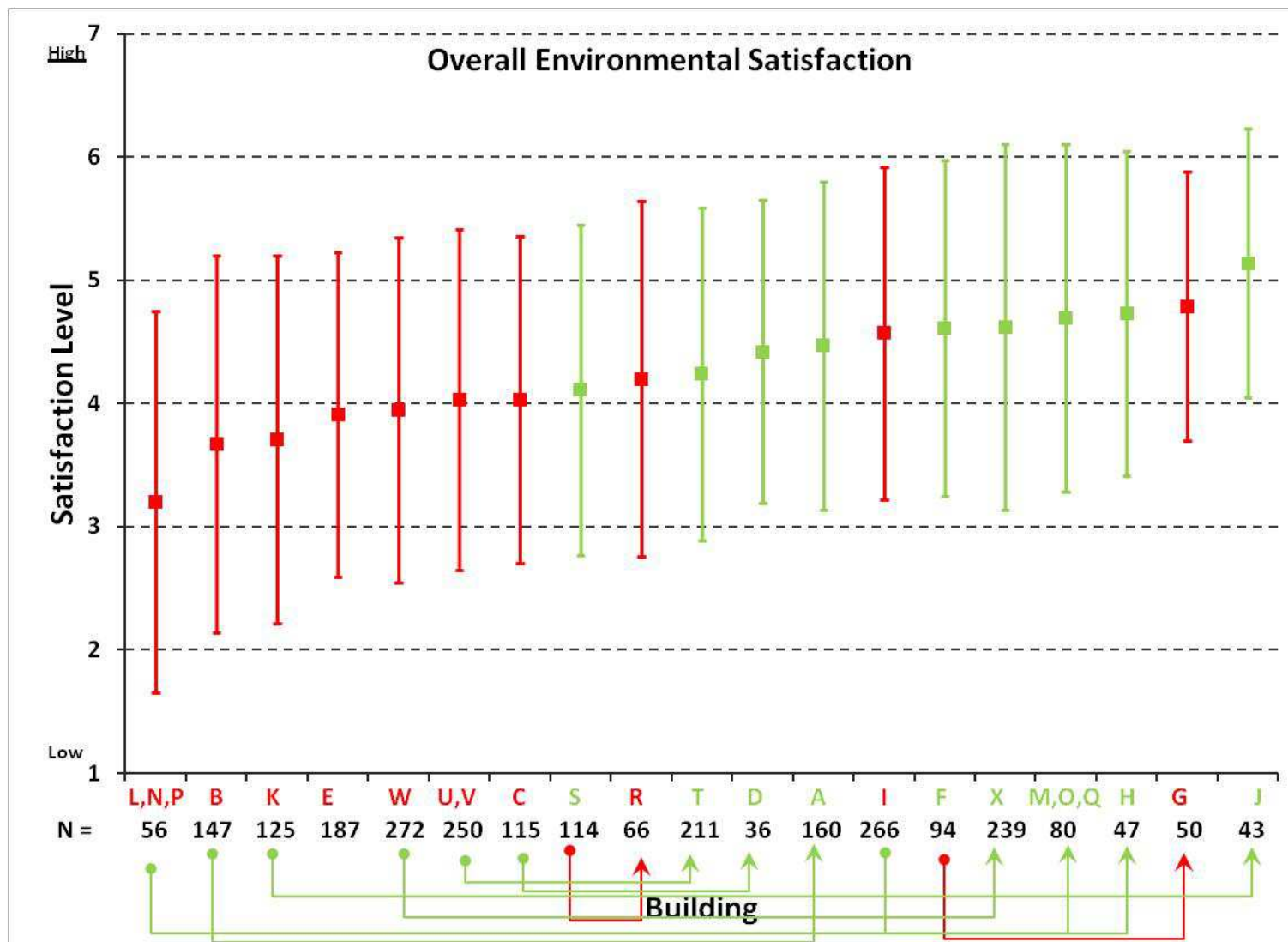
Indoor Environment Findings across Buildings

- 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



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 (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

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



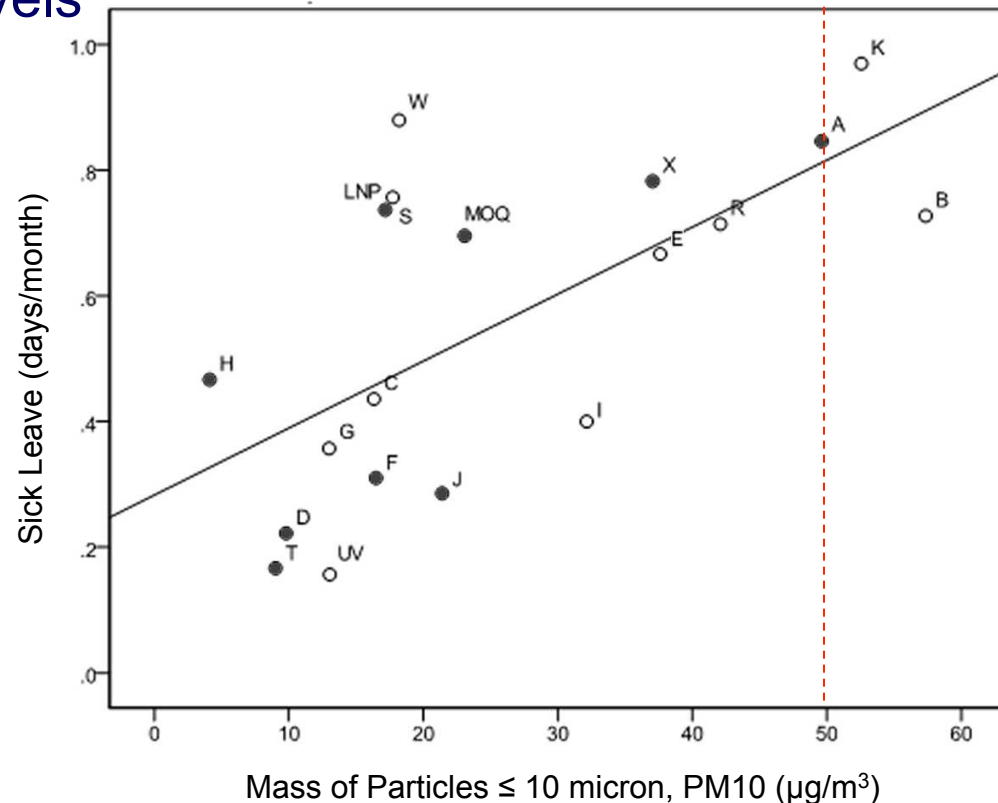
Green vs. Conventional (Physical Measurements)

- 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 and Buildings 41 (2009) 897–905

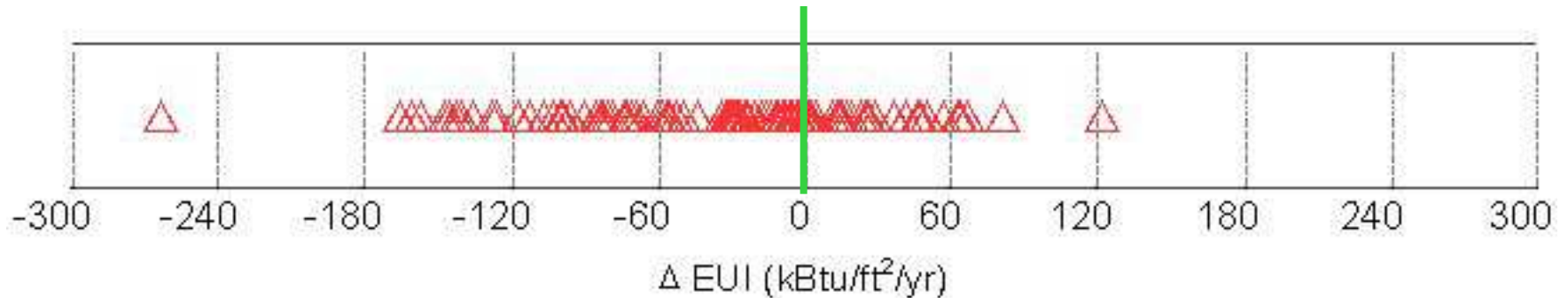


Do LEED-certified buildings save energy? Yes, but...

<http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=20373975&article=1&fd=pdf>

Energy

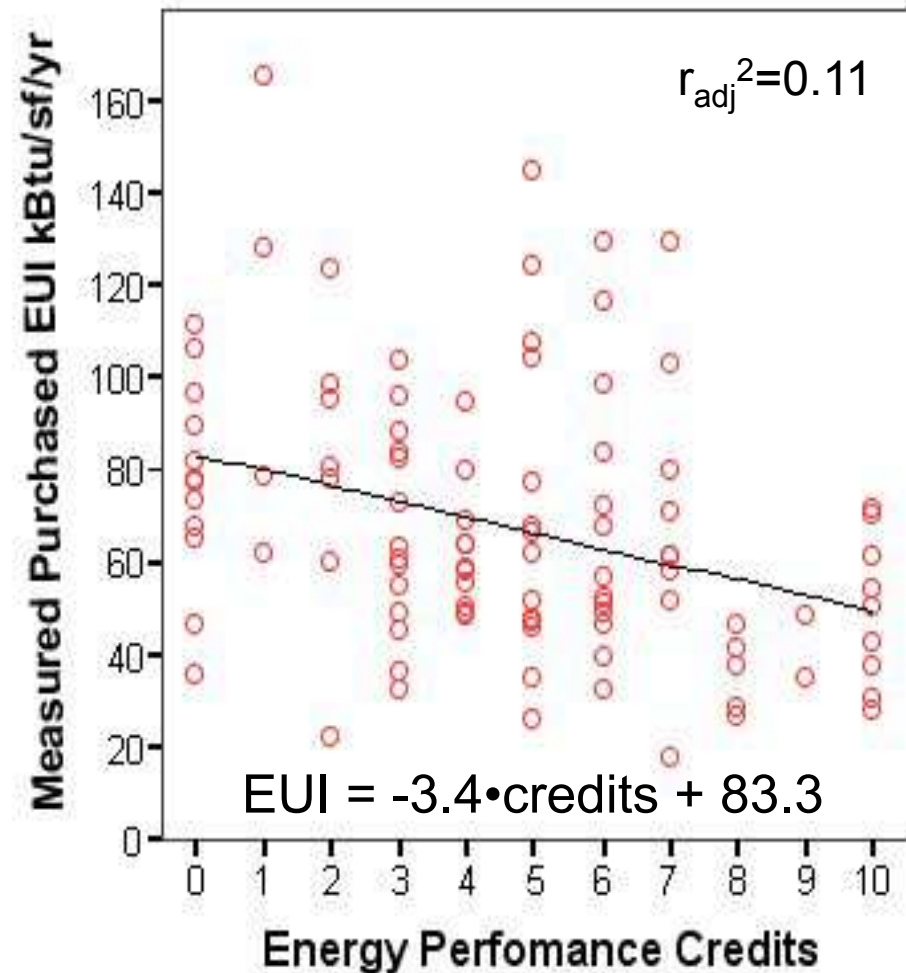
- about one-third of buildings used more ...



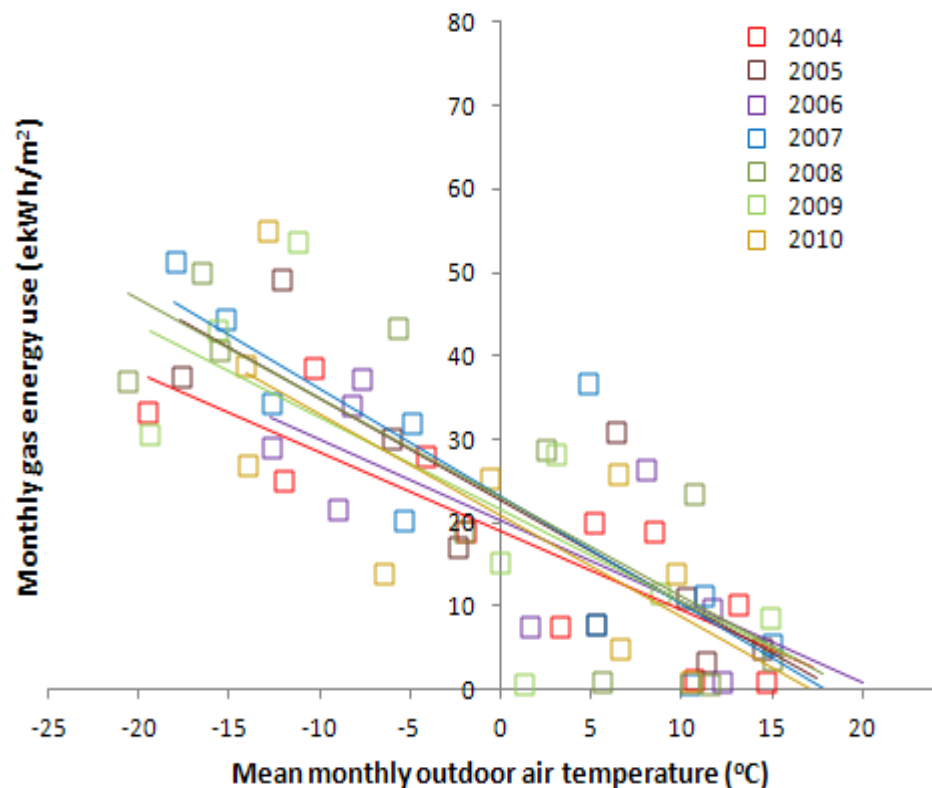
- Many unknown operational issues

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

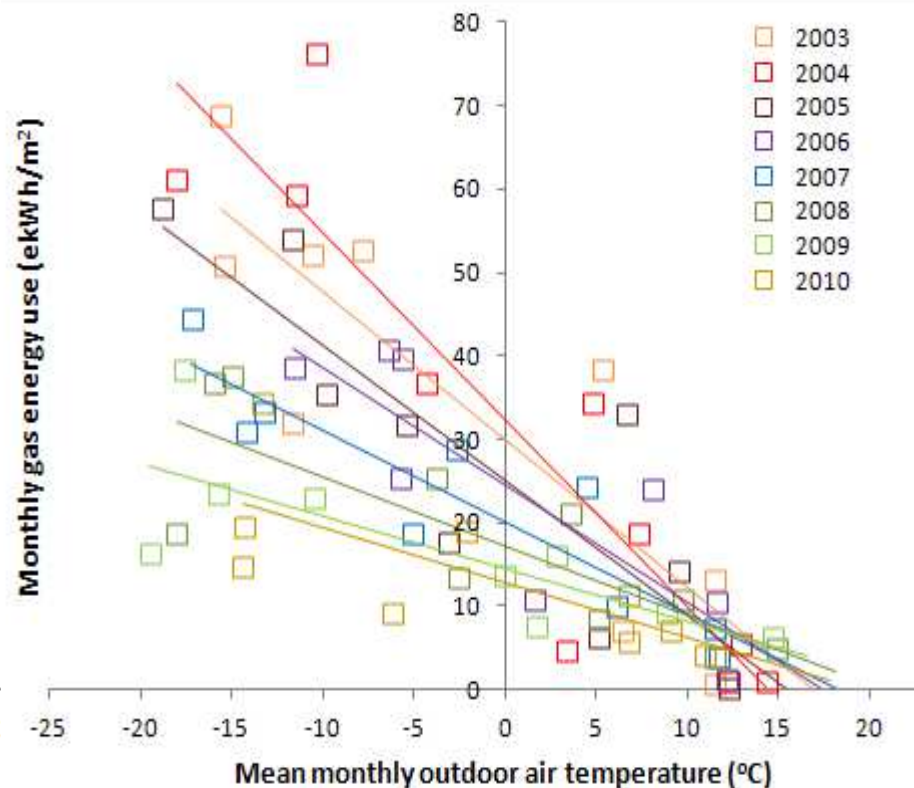


Energy Case Study



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



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Thank You

Questions?



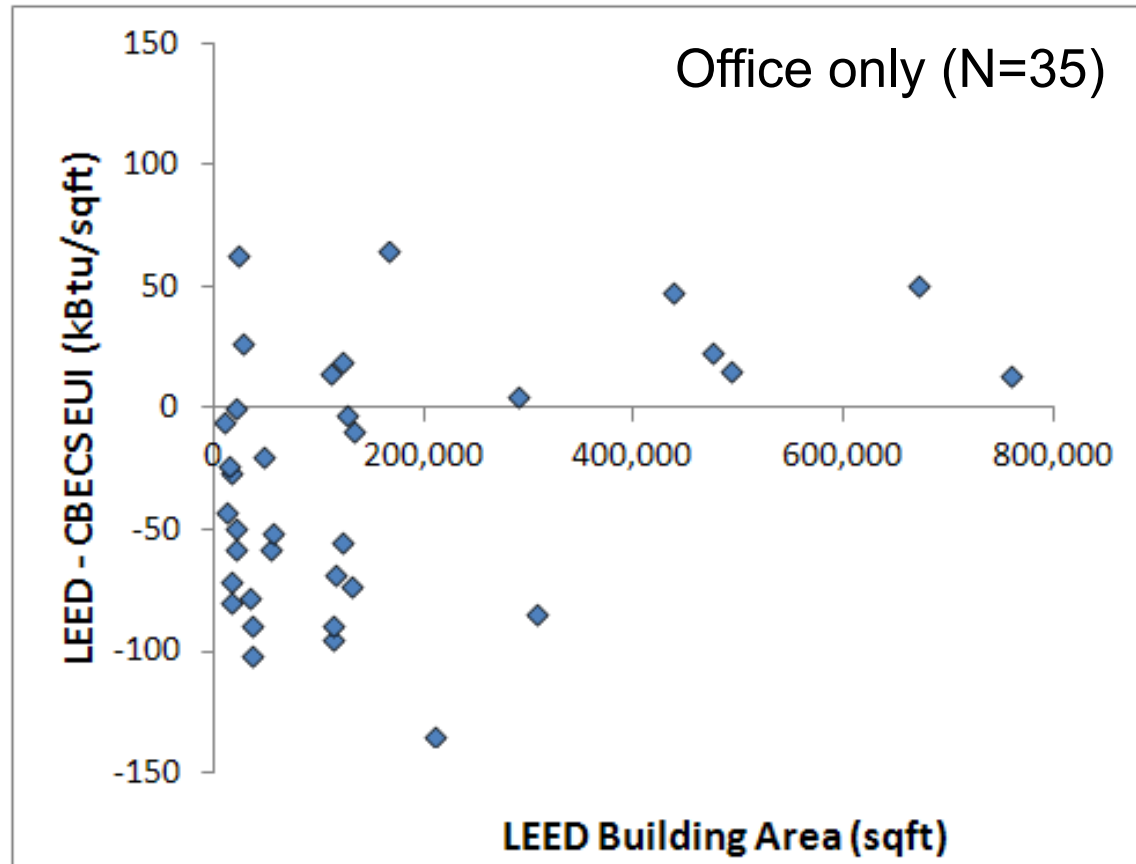
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Introduction – Energy

- Scofield, JH. 2009. “Do LEED-certified buildings save energy? Not really...” *Energy and Buildings*, 41 (12), 2009, 1386-1390
- Source energy vs. site energy
- Weight results by building size



Construction Costs

Building Research & Information

Volume 41, Issue 2, 2013



Construction costs comparison between 'green' and conventional office buildings

DOI: 10.1080/09613218.2013.769145

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pages 198-208