

## *Energy Technologies as Social Innovations: Organizational Use Structures & Implications for Cultural Change*



Jennifer Senick, Ph.D.  
Executive Director, Rutgers Center for Green Building  
Rutgers, The State University of New Jersey, USA  
IAPS 2016, Sweden

# Framing the Issue

- Commercial building owners introduce energy-saving technologies based on *relative advantage*
  - This means that they expect that it costs less (incremental and/or life cycle costs), functions better and provides an overall benefit to the building portfolio (e.g., more attractive to tenants, other)
- Building owners assume that the technology is *compatible* with organizational functions

**WITH MANY ENERGY SAVINGS TECHNOLOGIES  
THIS MAY NOT BE THE CASE!!!**

Rogers' Innovation Diffusion Concepts	Operational Definition
Relative Advantage	How improved an innovation is over the previous generation.
Compatibility	The level of compatibility that an innovation has to be assimilated into an individual's /organization's life.
Complexity or Simplicity	If the innovation is too difficult to use an individual/organization will not likely adopt it.
Triability	How easily an innovation may be experimented with as it is being adopted. If a user has a hard time using and trying an innovation the user will be less likely to adopt it.
Observability	The extent that an innovation is visible to others. An innovation that is more visible will drive communication among peers and networks and will in turn create more positive or negative reactions.

Source: Rogers, E. (1962). *Diffusion of innovations*. Glencoe: Free Press.

# This Research

***Research Q: How do organizational use structures influence energy technology outcomes in tenanted office buildings in the US?***

Multi-tenanted buildings are a challenging case

- varied and changeable space needs
- split economic incentive (owner pays for building investments like energy saving technologies; tenant reaps the rewards)
- for typical office tenants energy is not a significant cost of doing business
- environmental values/interests of tenants and employees unknown
- communication channels owner-tenant-employee not necessarily unbroken and intended messaging may not be realized

# Method: Comparative POE\*



\*Source: Wener, R. E. (1989). Advances in evaluation of the built environment .In E. H. Zube& G. T. Moore (Eds.), *Advances in environment, behavior, and design, Vol 2* (pp. 287-313).

# Roadmap of POE and Data Collection Activities

Building	Retrofit Phase	Building Owner Pre-retrofit Survey 2011	Pre-retrofit Site Visit* 2012	Post-retrofit Site Visit 2012	Baseline (pre-load shedding) Survey 2012	Daily Load Shedding Surveys 2012	Follow-up Survey 2012	Post-retrofit Site Visit 2013	Baseline (pre-load shedding) Survey 2013	Daily Load Shedding Surveys 2013
1	1	X		X	X	X	X	X	X	X
2	1	X						X	X	X
3	2	X	X	X					X	X
4	2	X	X	X					X	X
5	2							X	X	X
6	2							X	X	X
7	3	X						X	X	X
8	3	X						X	X	X
9	3	X						X	X	X

\* Most site visits were accompanied by standardized environmental measurements (ANSI/ASHRAE Standard 55-2010 and IESNA guidelines) and behavioral observations.

More data points were collected in Building 1 than any other building. In Buildings 3 and 4, five different measurement points were realized, whereas in the remaining buildings longitudinal collection consisted of 3-4 points during the same year.



# Energy Technologies Evaluated through this Framework

- Advanced Lighting Controls with fully dimmable IP addressable ballasts
- Web Accessible Energy Management System/Smart Metering (Smart Grid, Load Shedding)
- Retro-commissioning of HVAC

*\*Energy saving objective of bundled ECMS: 20-30% per building. Load shedding subject to occupant comfort (SGIG, 2009).*

# In Quality of Use Terms

(Bevan and MacCleod, 1994)

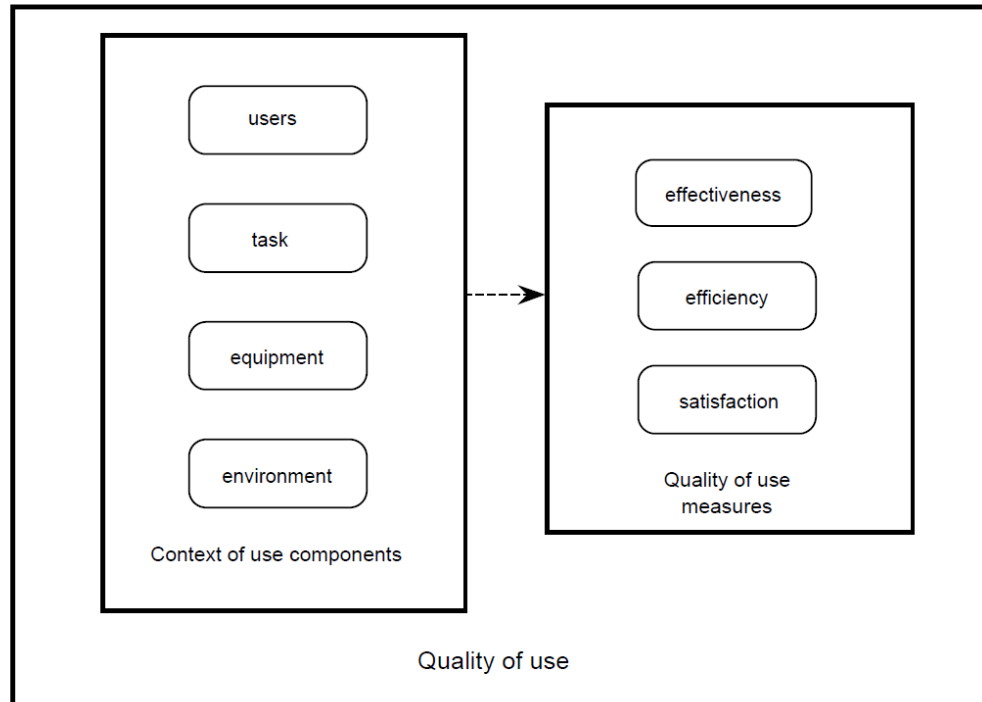


Figure 1 - Usability Factors

**Quality of Use: “....effectiveness, efficiency and satisfaction with which a specified set of users can achieve a specified set of tasks in a particular environment” (ISO 9241-11).**



# Synthesis: Quality of Use Predictions for Energy Conservation Retrofits + Roger's Innovation Concepts

	<b>Relative Advantage</b>	<b>Trialability</b>	<b>Observability</b>	<b>Complexity/ Simplicity</b>	<b>Compatibility</b>
<b>Advanced lighting controls</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>
Eliminate wasted energy	+Effectiveness				
Three methods of control	+ Satisfaction	+ Satisfaction		+ Satisfaction	+ Satisfaction
Improved worker productivity	+ Efficiency	+Satisfaction + Efficiency			+ Efficiency
Seamlessly integrates and deploys technologies	+Efficiency			+Efficiency	+Efficiency
Dynamically adjusts to uses	+Effectiveness	+ Satisfaction		+Efficiency	+Efficiency + Satisfaction
Integrated with smart metering, monitoring	+Efficiency +Effectiveness		+Efficiency	+Efficiency	

# Synthesis: Quality of Use Predictions for Energy Conservation Retrofits + Roger's Innovation Concepts

	<b>Relative Advantage</b>	<b>Trialability</b>	<b>Observability</b>	<b>Complexity/ Simplicity</b>	<b>Compatibility</b>
<b>Web-accessible, open EMS/Smart Metering</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>
Seamlessly accessible by building occupants through an IP protected address	+Efficiency +Satisfaction		+ Satisfaction	+Satisfaction	+Satisfaction
Near real time monitoring and data capture			+Efficiency	+Efficiency	+Efficiency
Dash-board profiles; formatted data for future usage			+Efficiency	+Efficiency	+Efficiency
<b>Retro-commissioning HVAC</b>	<b>X</b>	<b>X</b>	<b>N/A resulting changes should be invisible to the building occupant</b>	<b>N/A, depends on existing HVAC technology</b>	<b>N/A, depends on existing HVAC technology</b>
Better energy performance, reduced op expenses, fewer callbacks	+Efficiency +Effectiveness				
Improved occupant comfort and productivity	+ Satisfaction +Efficiency	+ Satisfaction +Efficiency			

# Results and Discussion

# Result 1: Energy and Cost Savings for the Buildings Evaluated

The retrofit buildings generally under-performed energy savings expectations of 20- 30%; most by a large measure. Not an effective or efficient outcome from perspective of building owner.

Building	Bldg sq. ft.	Fuel Type	Overall Energy Savings						
			Energy Savings		Predicted Total Energy Consumption for Post-Retrofit Period		% Energy Savings	Cost Savings	Savings per sq. ft.
			kWh	kBtu	kWh	kBtu			
Building 1	76,692	all-electric	141,721		1,509,680		9.4%	\$13,506	\$0.18
Building 2	103,024	all-electric	150,380		2,093,244		7.2%	\$15,540	\$0.15
Building 3	56,535	electric and gas		68,755		1,470,535	4.7%	\$2,141	\$0.04
Building 5	48,331	all-electric	144,224		880,238		16.4%	\$13,283	\$0.27
Building 6	103,500	all-electric	140,613		2,587,083		5.4%	\$14,108	\$0.14
Building 7	108,675	all-electric	240,540		971,155		24.8%	\$27,958	\$0.26
Building 8	89,165	all-electric			<b>Savings were not significant</b>				
Building 9	58,835	electric and gas		404,293		4,230,698	9.6%	\$11,420	\$0.19

Source: Adapted from Wagner et al, 2014. Note: Buildings 4 and 10 were not part of this analysis.

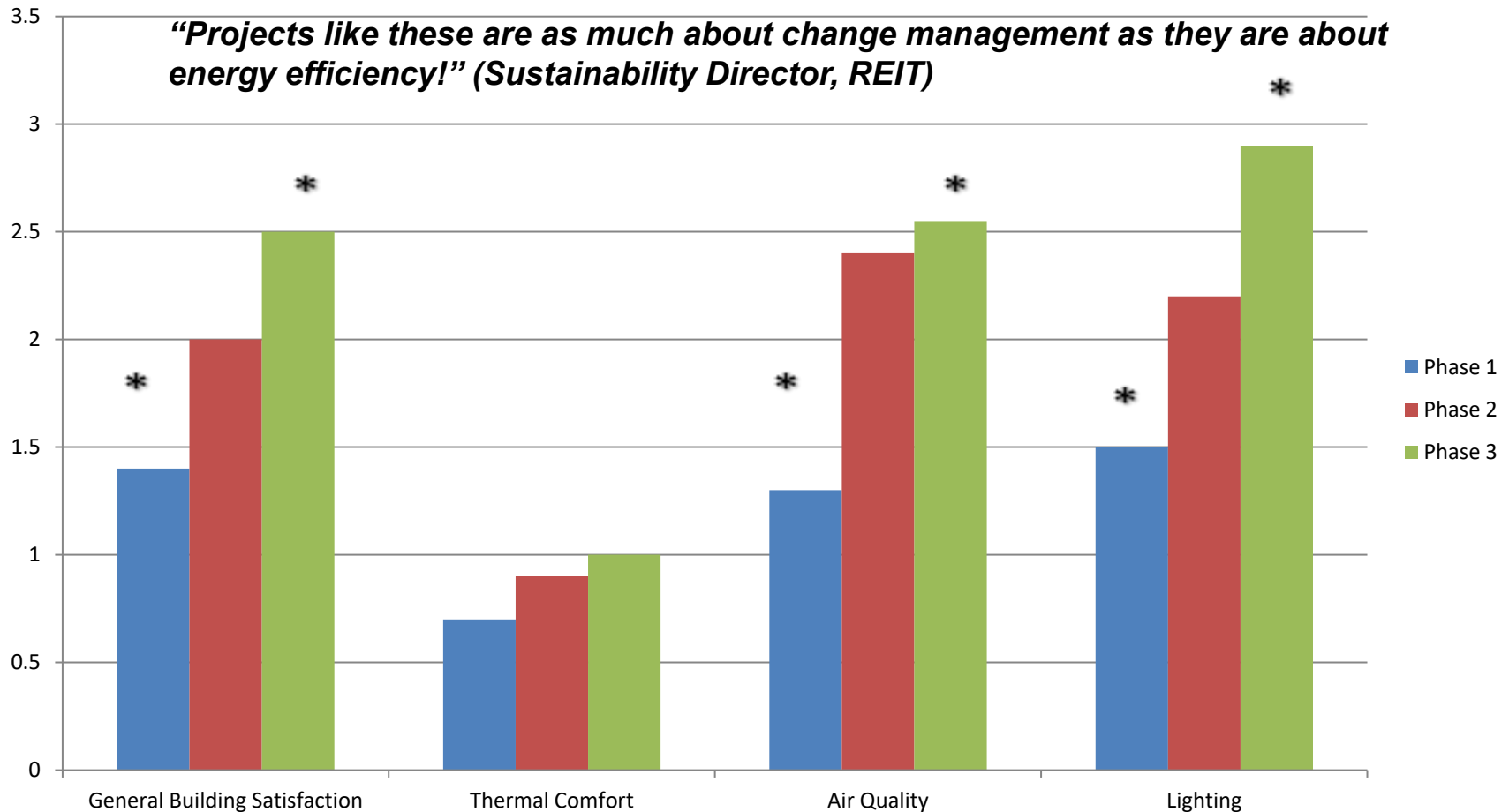
# Result 2: Organizational Characteristics Appear to Matter: Roles of Communication, Collaboration, Programming...?

Building	Year Built (1970s-early 2000s)	SF (50-100k)	Number of Tenants/ Occupancy % (2011)*	Pre- Retrofit Energy Star Score (2/11)**	Work Phase/Property Mgr	Energy Savings(%)
Building 1	2004	76,692	1 (prev. 2) 87.6%	71	1/A	9.4%
Building 2	2005	100,000	6 99.54%	76	1/B	7.2%
Building 3	1982	54,623	9 78.08%	74	2/C	4.7%
Building 4	1985	60,645	10 35%	64	2/B	Not calc.
Building 5	1983	46,697	3 100%	51	2/ D	16.4%
Building 6	1971	100,000	5 100%	58	2/ E	5.4%
Building 7	2000	108,675	9 86.63%	65	3/D	24.8%
Building 8	2001	89,165	4 68.22%	79	3/ E	Savings not sign.
Building 9	1977	58,835	4 75.86%	53	3/D	9.6%
Building 10	1988	49,526	vacant	--	3	Not calc.



# Result 3: Occupant Satisfaction Across Phases (2012-2013)

## Evidence Organizational Learning



Baseline survey data for all buildings. Likert Scale - averages. <sup>1</sup>n ranges from 42-45 between the variables; <sup>2</sup>n ranges from 8 to 9; <sup>3</sup>n ranges from 21 to 25. \*Denotes significance at the 5% level.

Chart: Rutgers Center for Green Building

# Result 4: Quality of Use Outcomes of the POE -Lighting

	Relative Advantage	Trialability	Observability	Complexity/ Simplicity	Compatibility
<b>Advanced lighting controls</b>					
Eliminate wasted energy	Effectiveness <b>(-) Very Limited</b>				
Three methods of control ( <i>or the fact that somebody is in charge?</i> )	Satisfaction <b>+ Improvement across phases ,although not fully realized</b>	Satisfaction <b>+ Some people</b>		Satisfaction <b>+ Some cases</b>	Satisfaction <b>+ Some cases</b>
Improved worker productivity	Efficiency <b>(-) Improvement across phases,</b>	Satisfaction, Efficiency <b>(+) Some people</b>			Efficiency <b>(+) Some workspaces; Improvement across phases</b>
Seamlessly integrates and deploys technologies ( <i>although many change orders, some light switches reinstalled</i> )	Efficiency <b>+ Mostly</b>			Efficiency <b>+Mostly</b>	Efficiency <b>+ Mostly</b>
Dynamically adjusts to uses	Effectiveness <b>+ Better, but uneven</b>	Satisfaction <b>(-)Not generally</b>		Efficiency <b>(-)Not generally, but in some instances better</b>	Efficiency, Satisfaction <b>+ Improvement across phases</b>
Integrated with smart metering, monitoring	<b>+Efficiency +Effectiveness</b>		Efficiency <b>+ Mostly</b>	Efficiency <b>+Improved</b>	

Legend: Red equals relatively poor outcome, yellow more mixed, green relatively positive.



# Result 5: Quality of Use Outcomes

## EMS, Retro-commissioning

	Relative Advantage	Trialability	Observability	Complexity/ Simplicity	Compatibility
Web-accessible, open EMS/Smart Metering (IP accessible, near real time monitoring, data capture, dashboard profiles)	+Efficiency, +Effectiveness	+ Effective, Efficient	(building occupants unaware and without access to dashboards, when aware = supportive)		
Retro-commissioning (energy performance, reduced op expenses, improved comfort and productivity)	Efficiency, <b>Effectiveness</b> , Satisfaction + In some cases	Some Satisfaction and Efficiency gains resulting	<b>Pre-existing challenges not resolved by the retrofit</b>	<b>Pre-existing challenges not resolved by the retrofit</b>	<b>Pre-existing challenges not resolved by the retrofit</b>

Legend: Red equals relative poor outcome, yellow more mixed, green relatively positive, orange not directly applicable.

# Dim and Overly Bright Conditions, Incompatibility in Lighting and Workspace Design



Overly dark hallways were said by occupants to feel “unsafe” and “unwelcoming” (dissatisfaction)



Inefficient lighting arrangement.



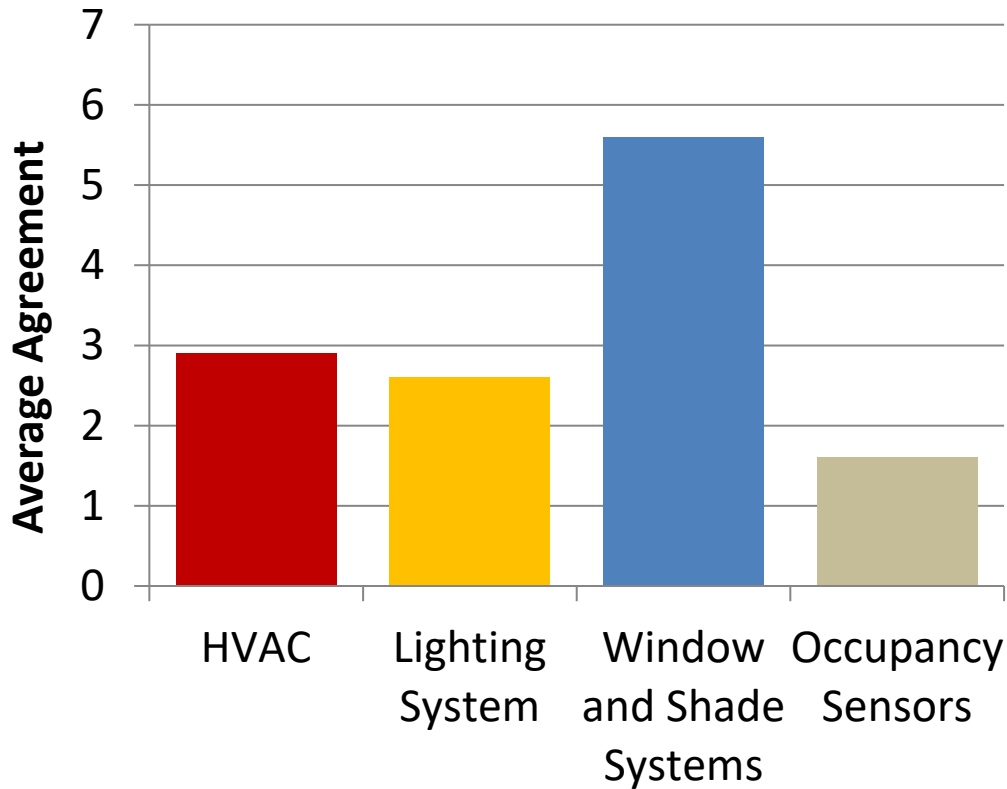
Misalignment of High Cubicles and Lighting Fixtures: ineffective from the standpoint of the user and may result in decreased satisfaction.



Wayfinding Challenge Compromises Daylight Strategy: increased energy usage (decreased efficiency).

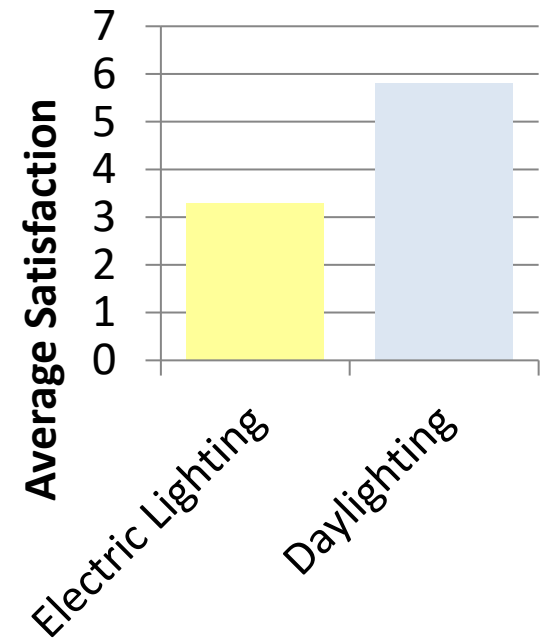
# Year 1 of the POE, Dissatisfaction with Ability to Adjust Environment (2012, 3 buildings)

## Is It Easy to Adjust?



1 = Very Strongly Disagree to  
7 = Very Strongly Agree

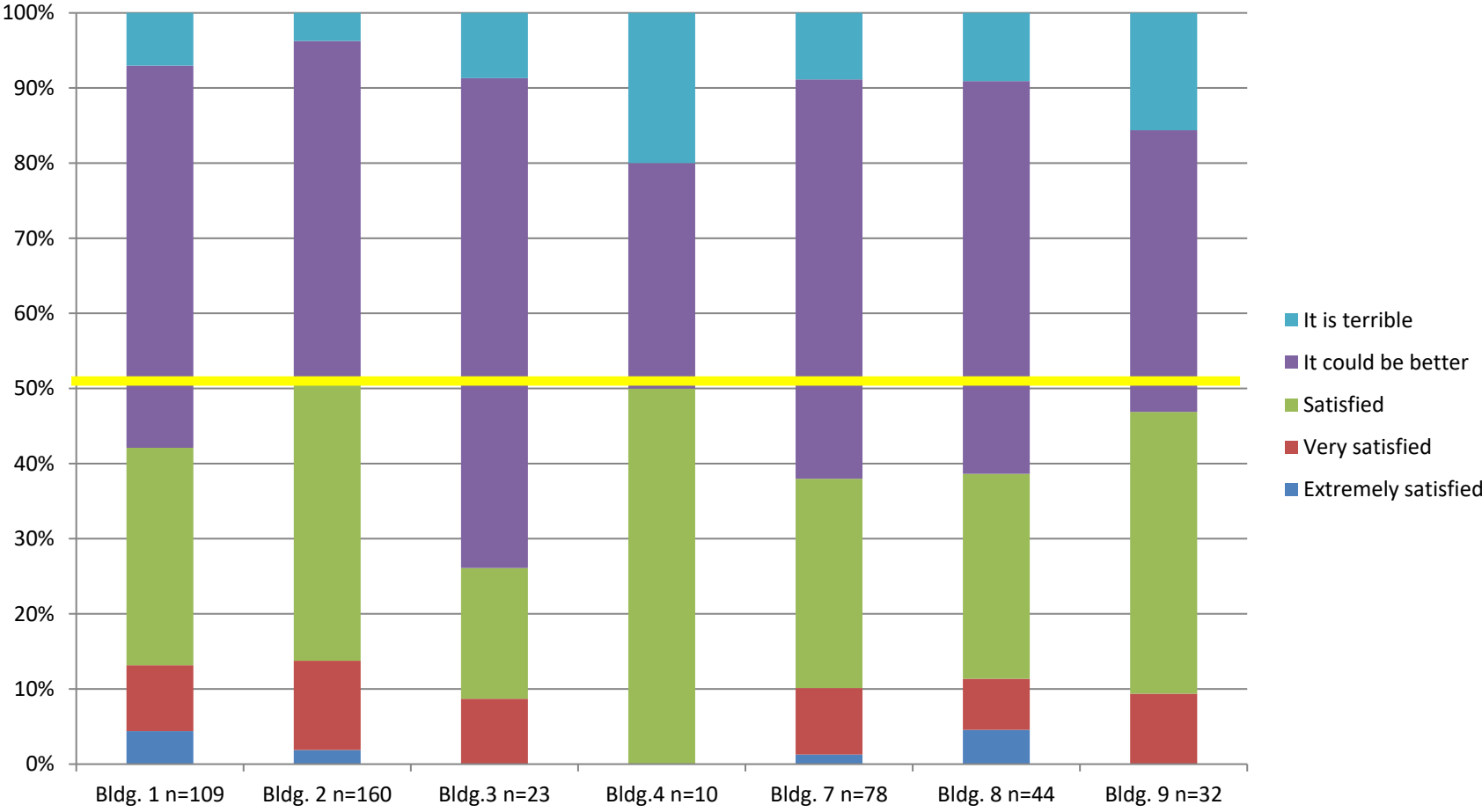
## Satisfaction with Ability to Adjust...



1 = Very Dissatisfied to  
7 = Very Satisfied

Baseline Survey (Building 1): n ranges from 37-41. "Satisfaction with ability to adjust electric lighting, n=25; daylighting, n=26. Source: Senick, J.A., R.E. Wener, I. Feygina, M. Sorensen Allacci, and C.J. Andrews. 2013b. *Occupant Behavior in Response to Energy-Saving Retrofits and Operations*. Prepared by the Center for Green Building at Rutgers University for the Energy Efficient Buildings Hub, Philadelphia, PA

# Comparison of 7 Buildings Thermal (Dis)Satisfaction



In all buildings, at least half of respondents are dissatisfied. Source: REIT Pre-retrofit survey.

# Control Complexity and Social Interaction - Lighting

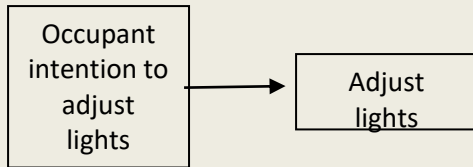
- “Motion activated lights in office cannot be controlled - very bad for employee satisfaction, loss of a simple control of an environmental factor, loss of the ability to turn off lights and use natural daylight, loss of the ability to lower lighting and use task lighting, not well suited to personal office space.” “Lack of control of my individual office lighting was a major mistake. I always turned off my lights when exiting the building and the cleaning crew always did the same. Any cost savings are far outweighed by employee dissatisfaction, feeling of lack of control. The automated lighting system is appropriate for common and high traffic areas, or low-traffic storage spaces - but not [appropriate] for individual private offices.” “T[h]e override buttons for the lighting in the conference rooms is not intuitive (e.g., push and wait) so most people just push a lot of buttons quickly and mess up the system. Why can't there just be a regular switch so that you can turn on the lights when [y]ou are in there and turn them off when you are done? There was a whole page instruction sheet on how to override the lights! That means it's too complicated.” “The workplace environment definitely affects work productivity. It would be nice to have some control over some of the settings, so that these can [be]adjusted as per individual needs.”

# Control Complexity and Social Interaction - HVAC

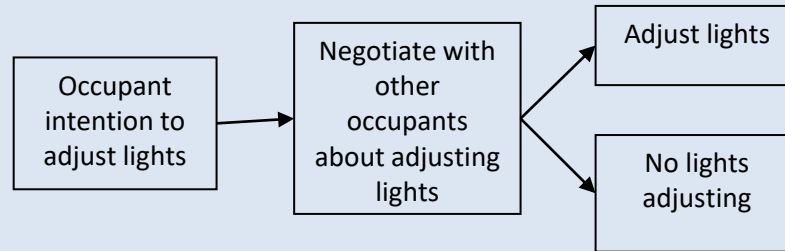
- “The thermometers always read higher than it feels.” “Too much air flow – overloads air conditioning coils.” “I was told that if the thermostats were left at 75 then the system would adjust the temperature as necessary and everyone should be comfortable but I have found the thermostat turned down to 55 a few times.” “The AC is often too cold. There is some control in the enclosed conference rooms (but not all conference areas have doors). The thermostat that controls my office is in the next office over and my supervisor sets it at what’s comfortable for him.” “The inability to override temperature and ventilation features causes a decrease in work productivity. This is very apparent during off-hours i.e. working on weekends. Overriding the climate controls in off-hours is non-existent.”

# Energy Technologies are Social Innovations

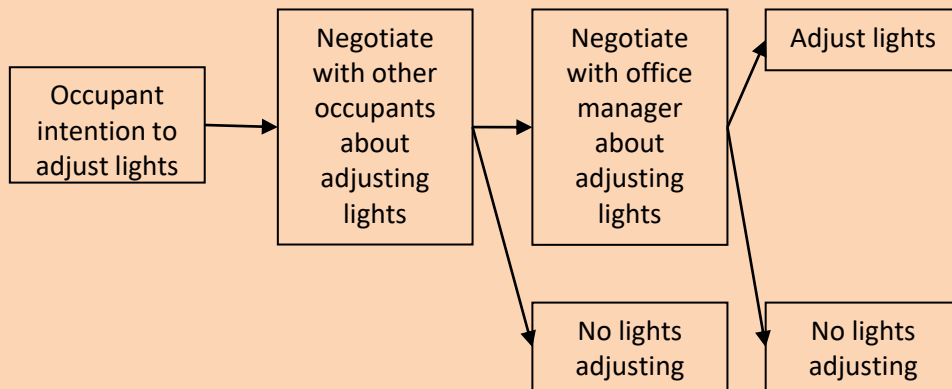
**Situation 1: Occupant has 100% locus of control over conventional switched lights**



**Situation 2: Occupant has shared locus of control with other occupants e.g. coworkers**



**Situation 3: Occupant has shared locus of control with other occupants and office manager**



As control is stripped away from the individual user, the negotiated nature of energy technologies becomes more apparent.



# Implications of Results/Discussion

# Use Structures and Organizational Contexts Influence Outcomes (effectiveness, efficiency and user satisfaction)

Accentuated in multi-tenanted buildings....conventional and LEED, existing and new

- ❖ Difficulty in design, fit-out and building operation for a diverse, changeable tenant base (compatibility, role of communication)
- ❖ Control over building operation (local vs centralized lighting/HVAC) highly variable and at times confusing (relative complexity-simplicity, in a context, affordances and conceptual models)
- ❖ Split incentives of stakeholders, including disinterest by building owner in losing a tenant (**the trial of these 10 buildings has not been extended to the REIT's 700+ buildings...**)
- ❖ Role of tenant motivation: may be lacking due to relatively low cost of energy as a percentage of business costs –**not a great case for cultural change**
- ❖ Trends in workspace organization entail greater social interaction; are energy technologies up to the task? Are there features of energy technologies that potentially could help lead towards environmentally supportive cultural change?
- ❖ There is on-going tension in **centralized vs decentralized approaches** to energy management

## Thank you!

Contact Info: Jennifer Senick, PhD

[jsenick@rutgers.edu](mailto:jsenick@rutgers.edu)

<http://www.greenbuilding.rutgers.edu>