Energy Trust New Buildings

Occupant Cx: Learning from Occupants to Improve Building Designs

August 6th, 2015

EnergyTrust of Oregon

New Buildings Events

- Allies for Efficiency Training Series (AFE)
  - Trainings on high-performance design and construction
  - Takes place 3 times per year
  - Registration priority for New Buildings Trade and Design Allies
- Building Energy Simulation Forum (BESF)
  - Advance energy modeling presentations
  - Takes place every other month

Upcoming BESF

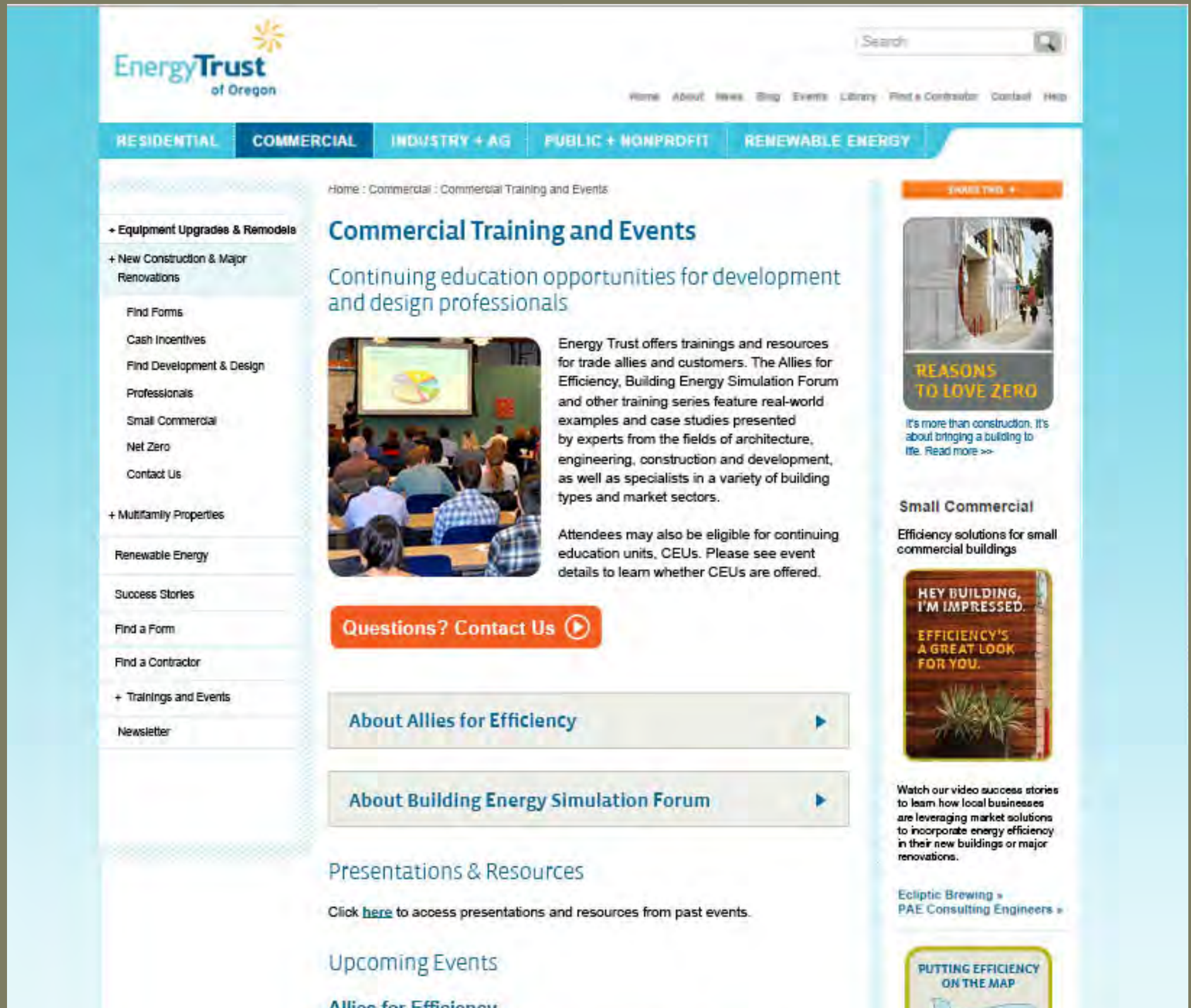
- August 19th – Energy and Comfort Modeling for the Net Zero Rocky Mountain Institute Headquarters

- October 21st – Energy Savings for Occupancy-Based Control (OBC) of Variable-Air-Volume (VAV) Systems

- December 16th – Revisiting the OHSU Data Dome

BESF takes place at the Ecotrust Building at noon

Training & Education



Today’s Agenda

- 2:40pm to 3:40pm: Research Overview
- 3:40pm to 3:50pm: Break
- 3:50pm to 4:50pm: Lessons Learned
- 4:50pm to 5:00pm: Program Wrap-up
- 5:00pm to 6:00pm: Networking Reception

OCCUPANT COMMISSIONING (Cx): LEARNING FROM OCCUPANTS TO IMPROVE BUILDING DESIGNS

JULIA K. DAY, PHD, IDEC, LEED AP, NCIDQ
KANSAS STATE UNIVERSITY
AUGUST 6, 2015

JULIAKDAY@KSU.EDU

ABOUT ME

my life's work summed up in logos…

BA interior design
minor, construction management
IDL | inland northwest

retail design

CALLISON

MA interior design
teaching
IDL | inland northwest

research
IDL | boise

PHD: architecture, design, education
teaching

Kansas State University | EBBEL
Energy, Behavior, and the Built Environment Laboratory

Ozzy and Zeppelin

PRESENTATION OBJECTIVES

1. **Understand key research** that demonstrates how **occupants play an integral role in building energy use** outcomes

2. **Identify factors** of building occupation that may negatively impact overall building energy use reduction goals

3. Understand the importance of an **integrated design process, post occupancy evaluation**, and **feedback loops**

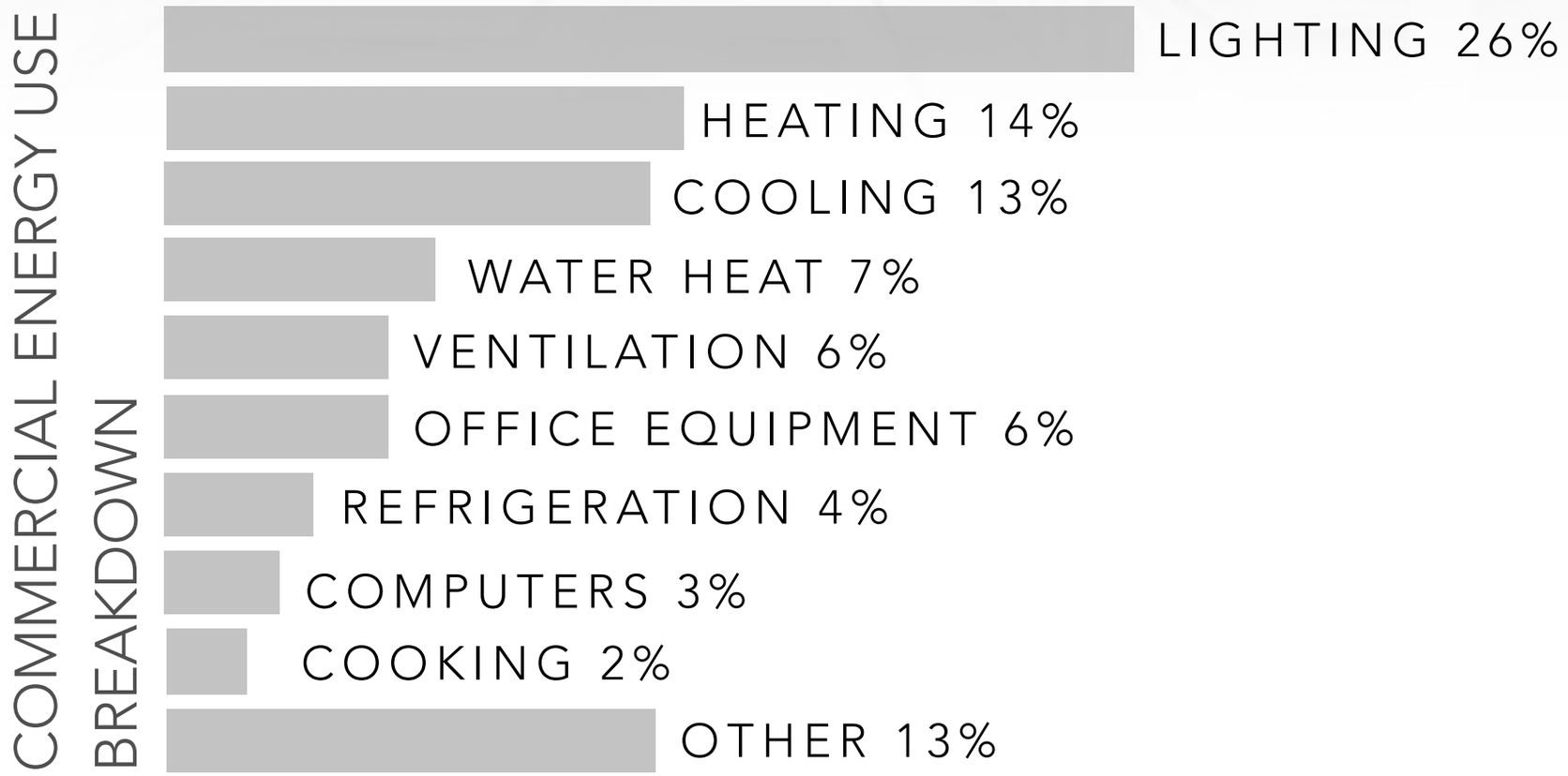
4. **Identify and learn techniques for effectively educating occupants** about high performance building strategies to maximize both comfort and energy efficiency

Terry Thomas Building, Seattle, WA
http://www.building.am/pagegal.php?id=359

BACKGROUND

IN 2010, COMMERCIAL & RESIDENTIAL BUILDINGS COMPRISED NEARLY 42% OF THE TOTAL ENERGY USE IN THE U.S. ...

DEPARTMENT OF ENERGY. HTTP://ENERGY.GOV/BETTER-BUILDINGS



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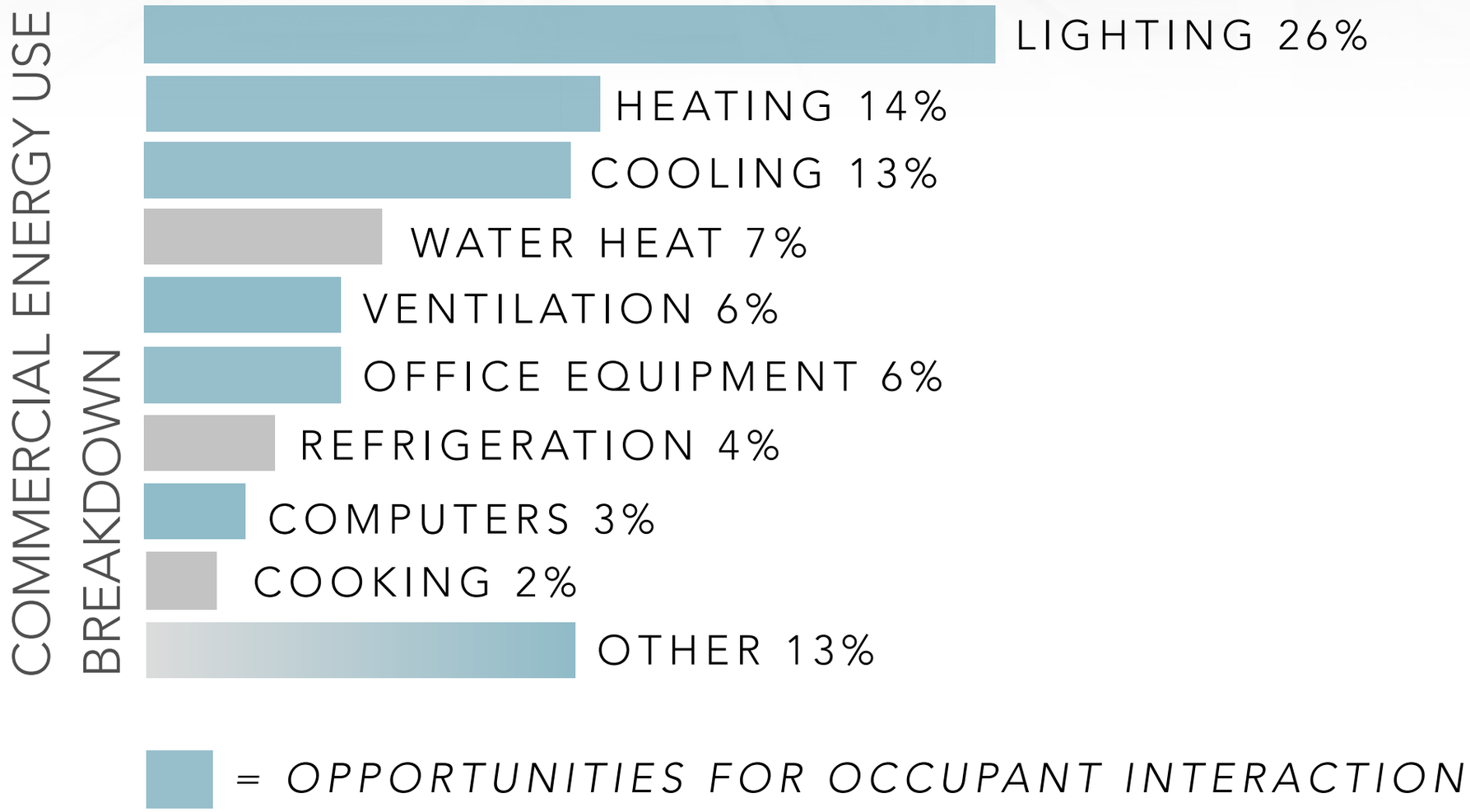
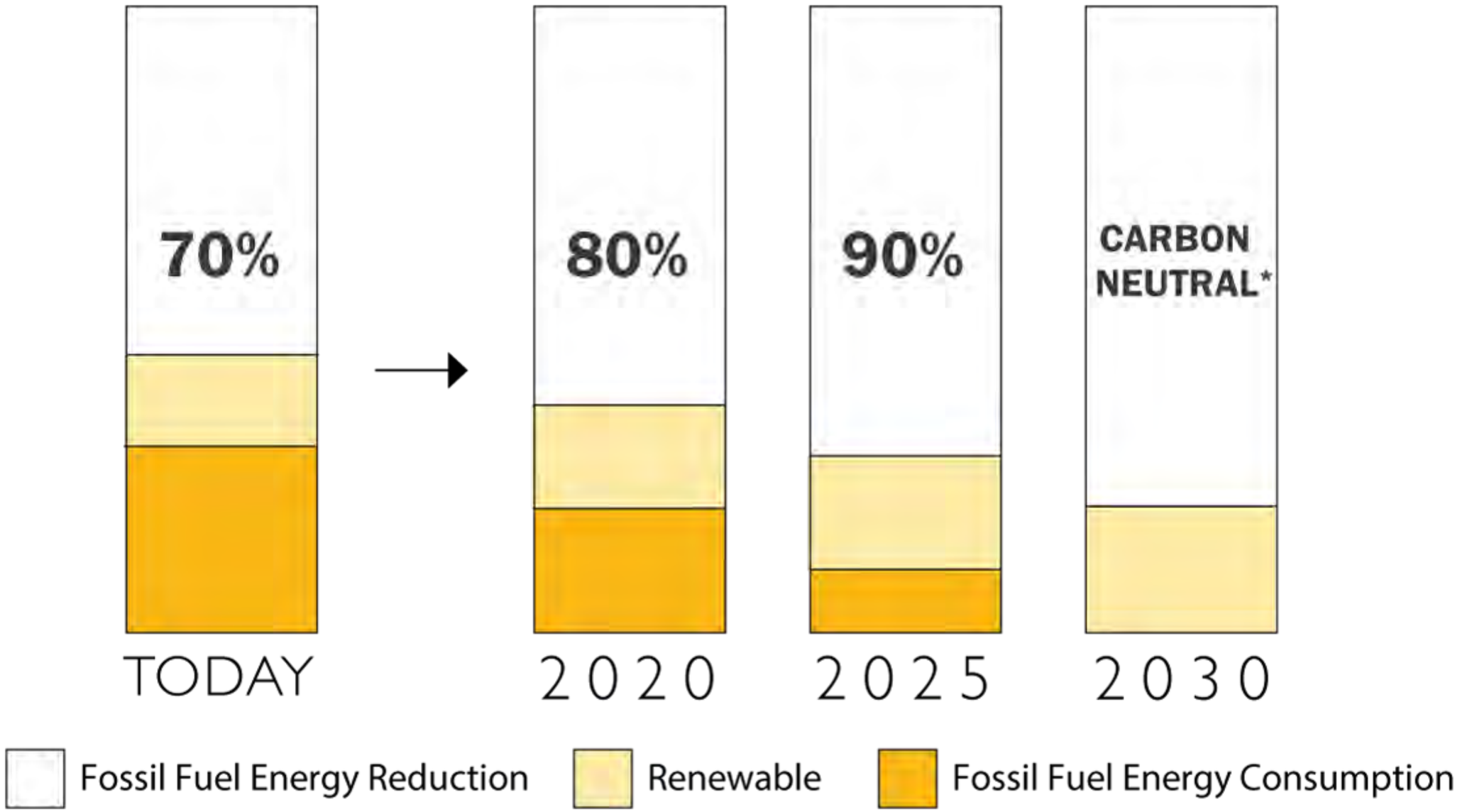


ARCHITECTURE 2030 | THE 2030 CHALLENGE

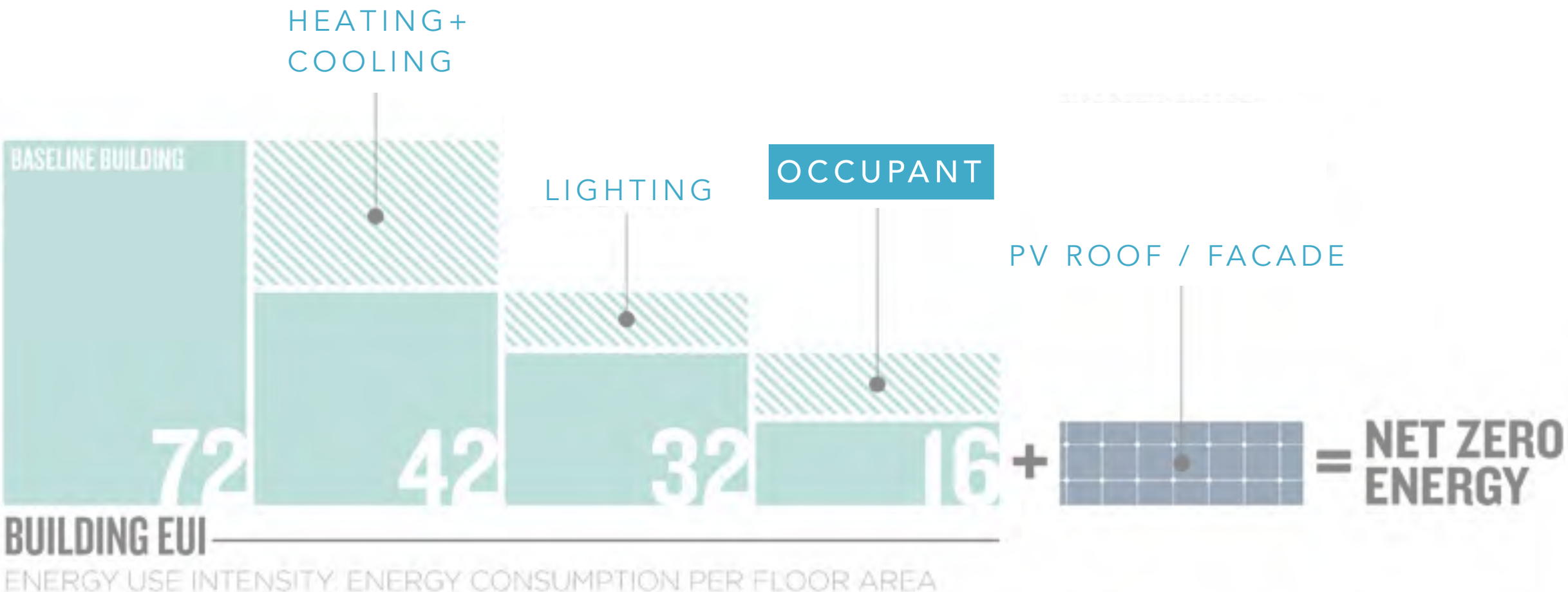


The 2030 Challenge

**Using no fossil fuel GHG-emitting energy to operate.*

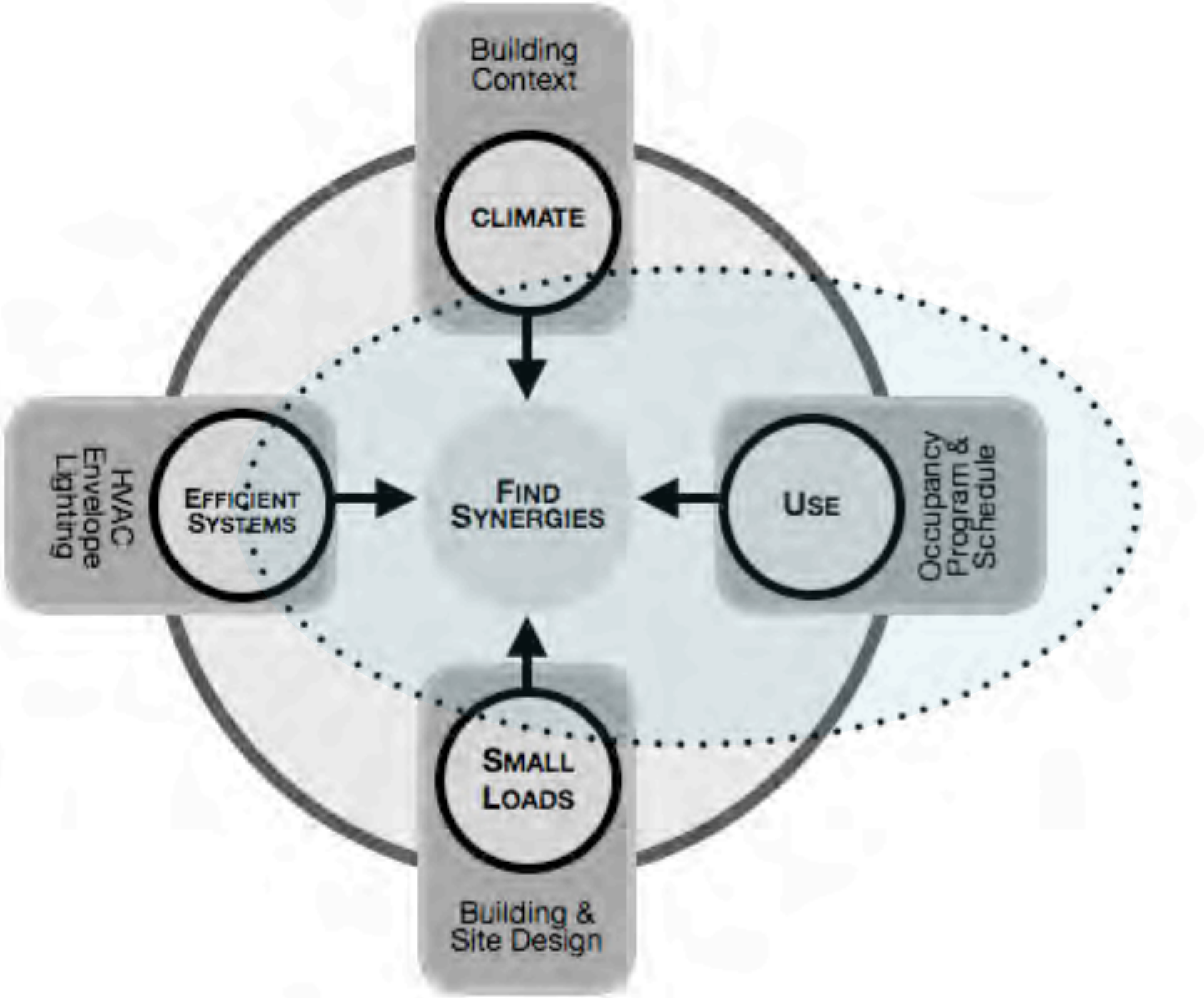
retrieved from: http://architecture2030.org/2030_challenges/2030-challenge/

THE PATH TO NET ZERO ENERGY USE



Adapted from an info-graphic by the Miller Hull Partnership of the Bullitt Center, a Net Zero Energy office building in Seattle, WA.

THE INTEGRATED ENERGY DESIGN



Adaption of Integrated Energy Design diagram
(Brown, G.Z. & Cole, J., 2008) Source: Betterbricks Educational Materials

HIGH-PERFORMANCE BUILDING | **DEFINED**

> “A HIGH-PERFORMANCE BUILDING IS **ENERGY EFFICIENT**, DURABLE, INTENTIONALLY **OPTIMIZES** ALL INSTALLED SYSTEMS, AND **PROMOTES HEALTH AND PRODUCTIVITY** FOR ITS OCCUPANTS.”

www.nibs.org/?page=hpbc, 2005

Terry Thomas Building, Seattle, WA
image retrieved from http://www.building.am/pagegal.php?id=359

THE PROBLEM...

image retrieved from googleimages

CONVENTIONAL OFFICE BUILDING

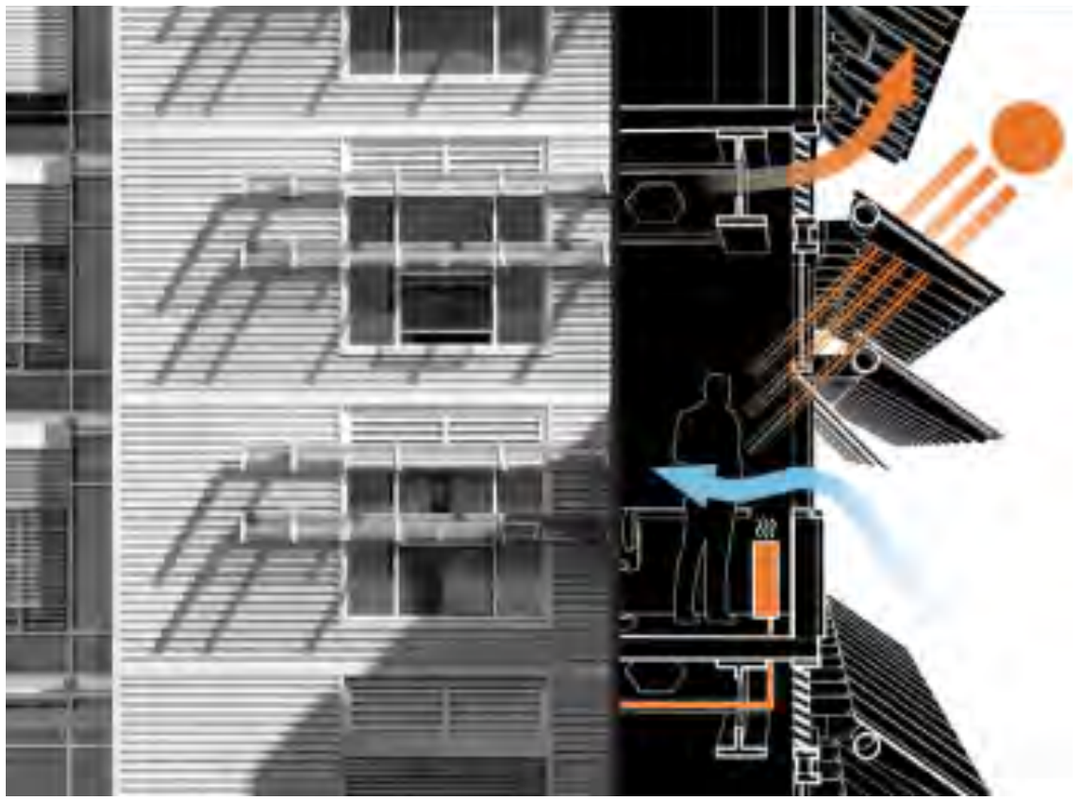
Terry Thomas Building, Seattle, WA

Photo Credit: Integrated Design Lab Puget Sound / C. M

HIGH PERFORMANCE OFFICE BUILDING

OCCUPANT COMMISSIONING (Cx)

THEREFORE...

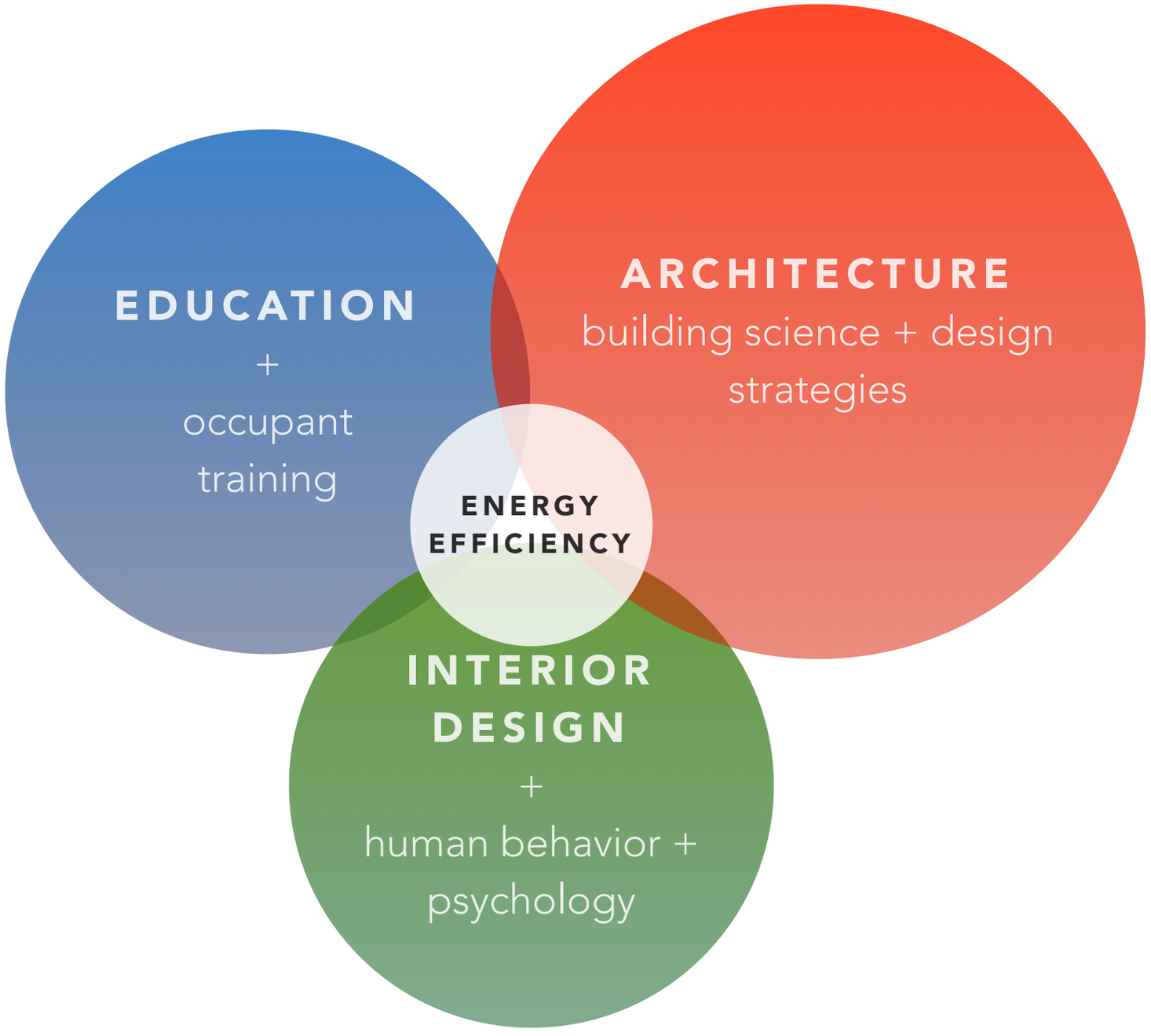


http://www.buildinggreen.com/hpb/energy.cfm?ProjectID=1292

> *It is necessary to educate occupants on the differences between using a green building versus a conventional building in order to secure the green building's success. (p. 175)*
>
> –STEINBERG, PATCHAN, SCHUNN, & LANDIS (2009)

INTERDISCIPLINARY PERSPECTIVE

"**interdisciplinary** studies is a **process** of answering a question, solving a problem, or addressing a **topic** that is **too broad or complex** to be dealt with adequately **by a single discipline** and draws on **disciplinary perspectives** and **integrates their insights to produce a more comprehensive understanding** or cognitive advancement." (Repko, 2008, p. 12)

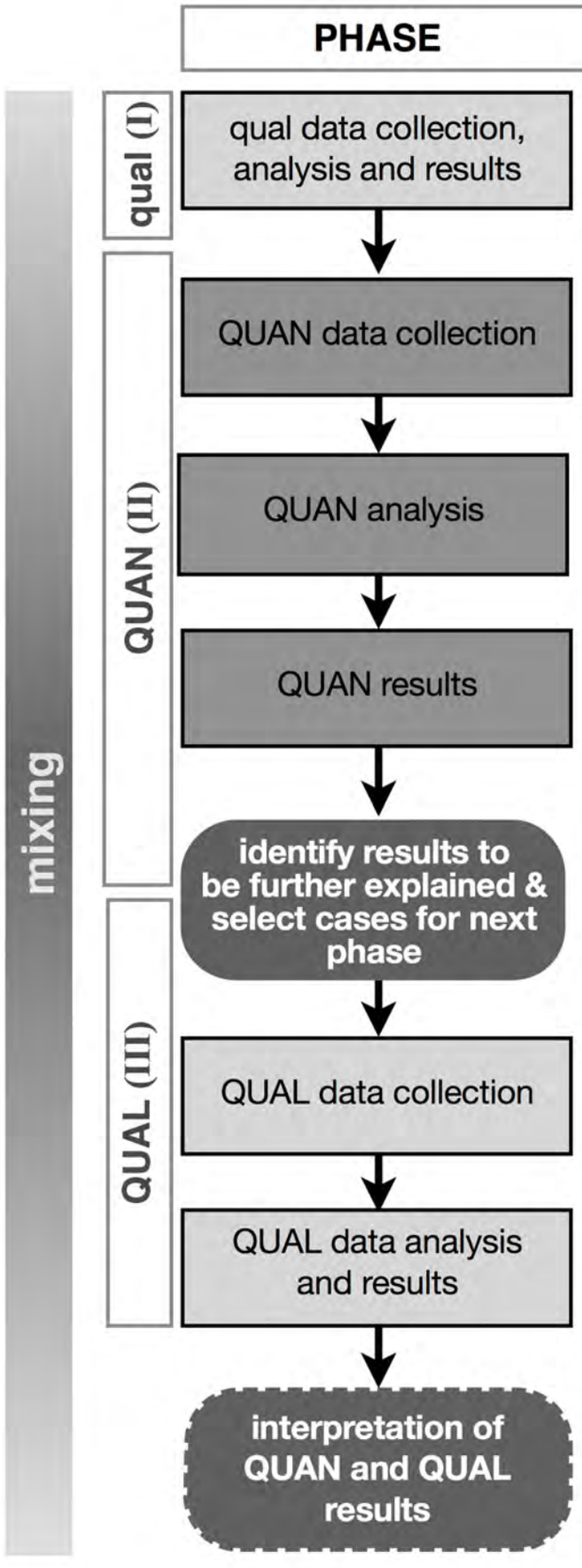


IDENTIFIED RESEARCH GAP

Many studies link passive design strategies and energy use and / or environmental satisfaction. However, there is a lack of research that successfully links passive design strategies with an occupant's **knowledge** of building systems, resulting **behaviors** and the corresponding relationship to **environmental satisfaction** and a building's **energy** use.

– DAY & GUNDERSON (2014) P.117

METHOD & SAMPLE



PHASE	PROCEDURE	PRODUCT
qual data collection, analysis and results	**open ended interviews** with experts in the field, examination of records, databases and literature	interviews with experts in the field (***n*=3**); coded and complied **database of high performance buildings (*N*=8045)**
QUAN data collection	implement **web based survey** [sent to ten buildings total; 154 total responses]	numeric data and open ended responses from **survey (*n*=118)**
QUAN analysis	clean data for missing values and incomplete entries [*n*=118 after data cleaning], **data analysis with R and SPSS**	frequencies, descriptive stats, inferential stats including t-tests, chi-square, Pearson r, one and two-way ANOVA results
QUAN results	**code open ended responses**; compile matrix of significant statistical findings	matrix of results/completed QUAN data analysis; QUAN results for each research question
identify results to be further explained & select cases for next phase	**identify themes** to pursue in next phase based on matrix; **purposefully select sample** population from survey responses	sample identified for QUAL phase; compiled list of potential interview questions
QUAL data collection	**conduct** individual email and phone **interviews**; **collect documents/artifacts/images**; transcribe taped interviews	text data (transcribed **interviews (*n*=41)**, documents, emails); image data (photographs, building plans + drawings for selected buildings)
QUAL data analysis and results	**open and axial coding**, allow themes to emerge with **NVivo 10;** categorize collected documentation	codes and emergent themes; similar and different themes; use results to answer each research question
interpretation of QUAN and QUAL results	**explanation of quantitative results and interpretation of qualitative results** identify similarities/differences between each phase	compared results, answer research questions & hypothesis, recommendations for further research

METHOD & SAMPLE

qual phase I

← experts in the field

n = 3

METHOD & SAMPLE

qual phase I continued

N=8045 “high-performance” building database

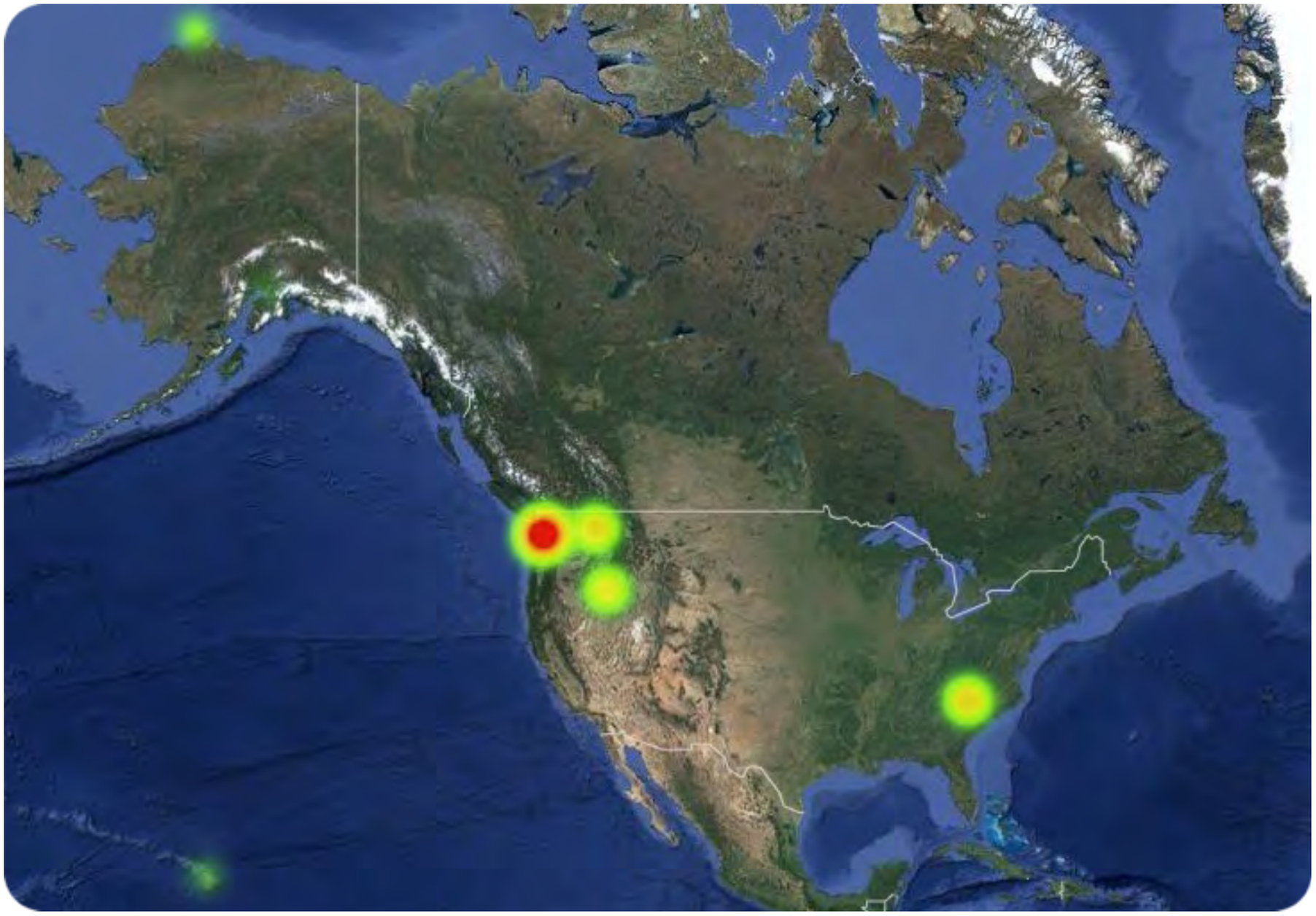
METHOD & SAMPLE

QUAN+QUAL data collection

data collected from 56 buildings

METHOD & SAMPLE

QUAN | survey responses



n=154 (*n*=118 after data cleaning)

survey responses from 13 buildings

METHOD & SAMPLE

QUAN | the survey tool

IN TOTAL, THERE WERE 51 QUESTIONS & FIVE PRIMARY CATEGORIES:

(1) OFFICE ATTRIBUTES,
(2) THE PRESENCE AND TYPE OF TRAINING FOR
    (A) MANUAL BLINDS,
    (B) AUTOMATIC BLINDS,
    (C) NATURAL VENTILATION,
    (D) TEMPERATURE CONTROLS, AND
    (E) ELECTRIC LIGHTING,
(3) SATISFACTION WITH THE OFFICE ENVIRONMENT,
(4) LEARNING STYLES, AND
(5) DEMOGRAPHICS.

BOTH **OPEN-ENDED AND CLOSED-ENDED QUESTIONS** WERE INCLUDED ON THE SURVEY.

SATISFACTION RESPONSES WERE ASSESSED THROUGH A SEVEN POINT LIKERT SCALE, WHICH RANGED FROM **"STRONGLY DISAGREE" (1) TO "STRONGLY AGREE" (7).**

A FIVE-POINT SCALE, FROM **"NEVER" (0) TO "ALWAYS" (4), WAS USED FOR FREQUENCY RATINGS** UNDER THE LEARNING STYLE SECTION. MULTIPLE CHOICE AND YES/NO RESPONSES WERE USED THROUGHOUT THE SURVEY.

METHOD & SAMPLE

QUAN | the survey tool | references

Day J, Theodorson J, Van Den Wymelenberg KG. Understanding controls, behaviors and satisfaction in the daylit perimeter office: a daylight design case study. J Interior Des 2012;31(1):17e34.

Lee YS, Guerin DA. Indoor environmental quality related to occupant satisfaction and performance in LEED-certified buildings. Indoor Built Environ 2009;18(4):293e300. http://dx.doi.org/10.1177/1420326X09105455.

Newsham G, Veitch J, Arsenault C, Duval C. Effect of dimming control on office worker satisfaction and performance. Canada: Institute for Research in Construction, National Research Council; 2004.

Stokols D, Scharf F. Developing standardised tools for assessing employees' ratings of facility performance. In: Davis G, Ventre FT, editors. Performance of buildings and serviceability of facilities. Philadelphia, PA: American Society for Testing and Materials; 1990. p. 55e68.

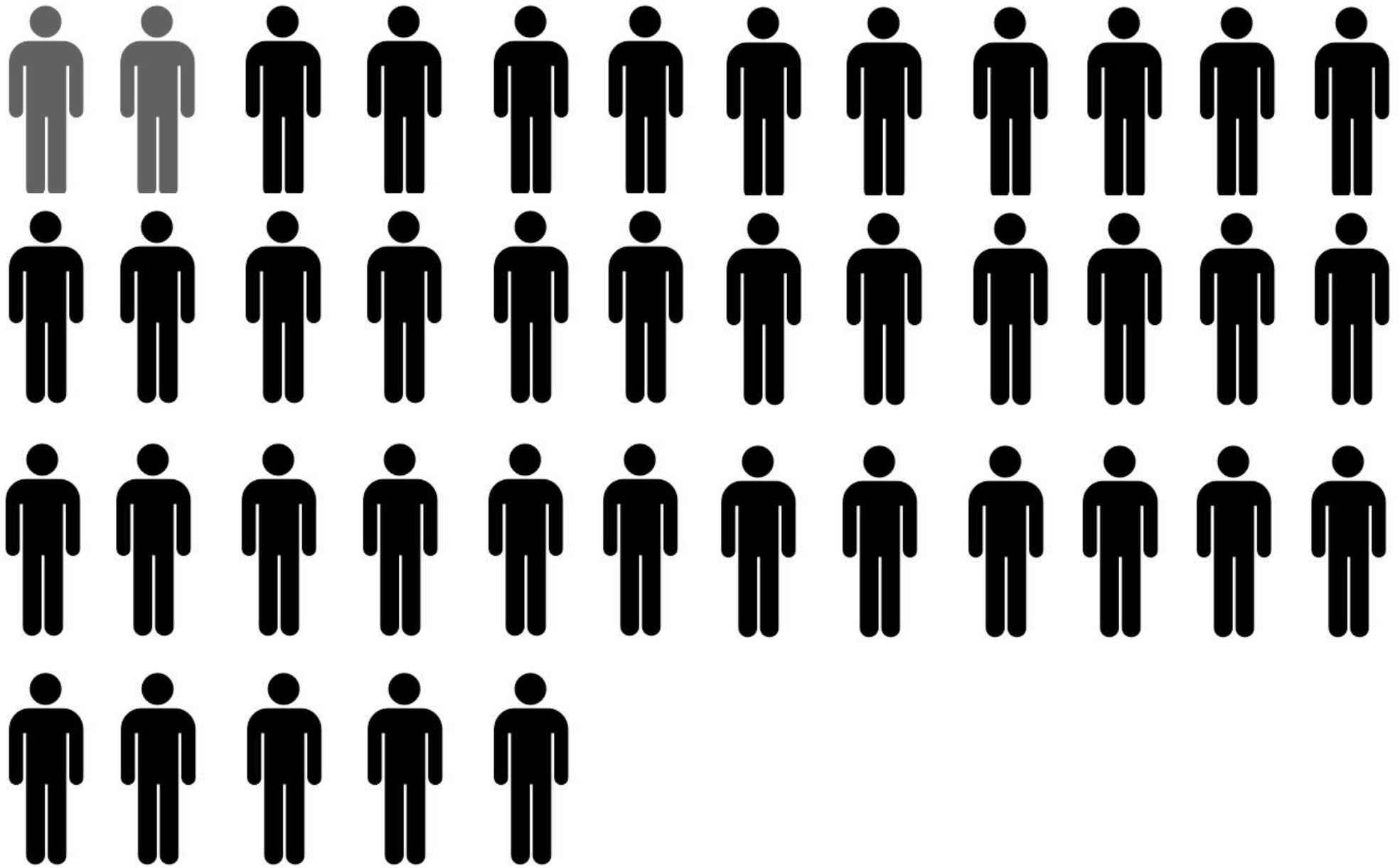
Theodorson J, Day J. Occupant perceptions of daylit classrooms: a comparison of north and south orientation. In: Proceedings from IDEC conference. Atlanta, GA; 2010.

Veitch JA, Newsham GR. Lighting quality and energy-efficiency effects on task performance. In: IESNA Conference Proceedings: lighting quality and Energy- Efficiency. Seattle, WA; 1997.

Learning style survey. (n.d.). Informally published manuscript, Center for Advanced Research on Language Acquisition at the University of Minnesota, University of Minnesota, Minneapolis, MN, Retrieved from http://www.carla.umn.edu/maxsa/documents/LearningStyleSurvey_MAXSA_IG.pdf.

METHOD & SAMPLE

QUAL phase II | interviews



n=41 interview responses

HYPOTHESIS

H1: **OCCUPANTS WHO RECEIVED TRAINING FOR HIGH PERFORMANCE BUILDING STRATEGIES** (SUCH AS BLINDS, NATURAL VENTILATION, THERMAL CONTROLS, OR ELECTRIC LIGHTING), **WILL DEMONSTRATE AN INCREASED LEVEL OF REPORTED ENVIRONMENTAL SATISFACTION WHEN COMPARED TO INDIVIDUALS WHO DID NOT RECEIVE ANY KIND OF TRAINING.**

RESEARCH QUESTIONS: TRAINING & LEARNING

RQ1 Did building occupants receive any training or education surrounding high performance building systems?

RQ2 Do occupants understand how to effectively control, change or override the building controls?

RQ3 What are the types of delivery methods for occupant training, and which were most effective?

RQ4 Were trainings delivered one time, continuously, or intermittently?

RQ5 How do individuals best learn a new concept?

RQ6 Is there a difference between an occupant's reported learning style and the assessment of the effectiveness of the training they received?

RQ7 Is there a difference between the building size and effectiveness of training?

RESEARCH QUESTIONS: ENVIRONMENTAL SATISFACTION

RQ8 In general, what were the most common high performance building complaints and appraisals?

RQ9 Is there a difference between the climate type and thermal satisfaction or visual satisfaction?

RQ10 Are individuals who reported health issues more or less satisfied with their office environment?

RQ11 How did satisfaction appraisals differ among groups?

RESEARCH QUESTIONS: BEHAVIOR

RQ12 Why do occupants interact with the blinds, electric lighting or thermal controls?

RQ13 For what reasons do occupants choose *not* to interact with high performance building features?

RQ14 How often do occupants interact with, change or override the blinds?

HYPOTHESIS

H1: **OCCUPANTS WHO RECEIVED TRAINING FOR HIGH PERFORMANCE BUILDING STRATEGIES** (SUCH AS BLINDS, NATURAL VENTILATION, THERMAL CONTROLS, OR ELECTRIC LIGHTING), **WILL DEMONSTRATE AN INCREASED LEVEL OF REPORTED ENVIRONMENTAL SATISFACTION WHEN COMPARED TO INDIVIDUALS WHO DID NOT RECEIVE ANY KIND OF TRAINING.**

RESULTS

HYPOTHESIS

Effectiveness of training and environmental satisfaction were tested using both a Pearson chi-square test and an independent *t*-test. A significant difference ($p < .05$) was found between groups for both tests. Therefore, the null hypothesis was rejected. **Occupants who received training for high performance building strategies** (such as blinds, natural ventilation, thermal controls, or electric lighting) **demonstrated an increased level of reported environmental satisfaction** when compared to individuals who did not receive any kind of training.

"I didn't actually receive any training because I am a part time employee... I guess...but I do think that understanding the big concepts of the building envelope, windows and daylight, how the toilet and the water system works ... ***understanding all of those things*** *might make people* ***more actively participate*** *and also* ***figure out ways to change the building to suit their needs***."

RESULTS

ENVIRONMENTAL SATISFACTION DESCRIPTIVE STATISTICS

J.K. Day, D.E. Gunderson / Building and Environment 84 (2015) 114–124

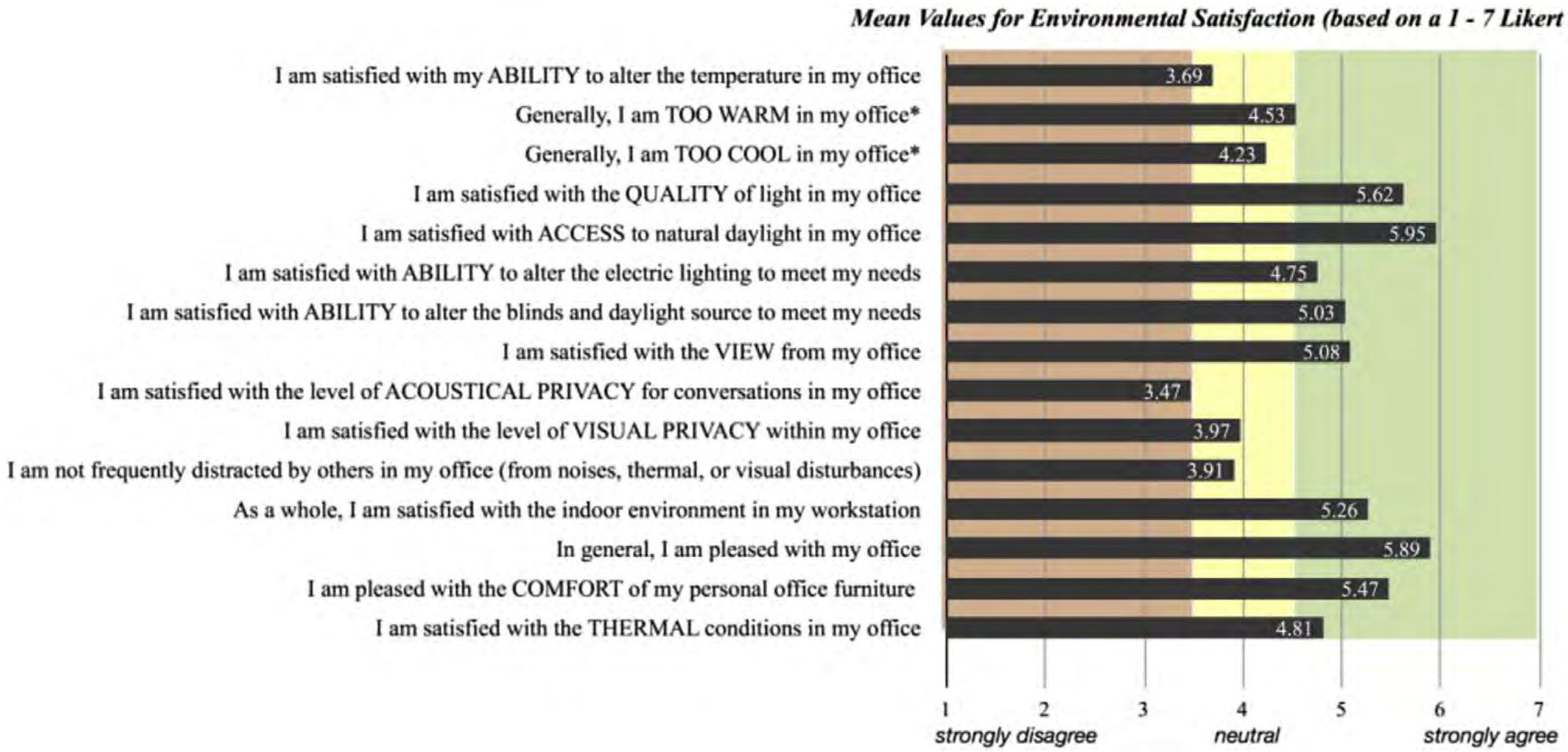


Fig. 2. Mean values for environmental satisfaction section, in response to: “please rank the following for your office”.

Table 3
Independent *t*-test: environmental satisfaction* effectiveness of training.

	Training	*N*	Mean	Std. deviation	Std. error mean	*d* (Cohen's *d*)	*r* (effect size)
Environmental Satisfaction (all)	no training reported, or reported that training was not helpful	87	4.56	1.059	.114	0.87	−0.39
	training was helpful	31	5.38	.810	.146		
Environmental Satisfaction (thermal)	no training reported, or reported that training was not helpful	87	4.08	1.133	.121	−0.72	−0.34
	training was helpful	31	4.97	1.316	.236		
Environmental Satisfaction (general)	no training reported, or reported that training was not helpful	87	5.35	1.518	.163	−0.57	−0.27
	training was helpful	31	6.06	.921	.165		
Environmental Satisfaction (visual)	no training reported, or reported that training was not helpful	87	5.21	1.459	.156	−0.77	−0.36
	training was helpful	31	6.15	.939	.169		

Independent samples test		Levene's test for equality of variances		*t*-test for equality of means						
		F	Sig.	*t*	d*f*	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
Environmental Satisfaction (all)	Equal variances assumed	4.750	.031	−3.940	116	.001*	−.825	.209	−1.239	−.410
Environmental Satisfaction (thermal)	Equal variances not assumed			−3.339	46.783	.002*	−.887	.266	−1.422	−.353
Environmental Satisfaction (general)	Equal variances assumed	6.135	.015	−2.452	116	.016*	−.712	.290	−1.287	−.137
Environmental Satisfaction (visual)	Equal variances assumed	10.714	.001	−3.325	116	.001*	−.935	.281	−1.491	−.378

Note: *significant difference found.

The table above shows that **respondents who received training were significantly more likely to be satisfied with their environment than those who did not receive training (or helpful training) for all environmental satisfaction categories tested** (environmental satisfaction as a whole ($p < .001$), thermal satisfaction ($p < .002$), visual satisfaction ($p < .001$), and the remaining satisfaction questions ($p < .016$).

RESULTS

SURVEYED OCCUPANTS

effective training

MORE SATISFIED

increased productivity $$$
fewer sick days
increased health
thermal/visual comfort

ineffective or no training

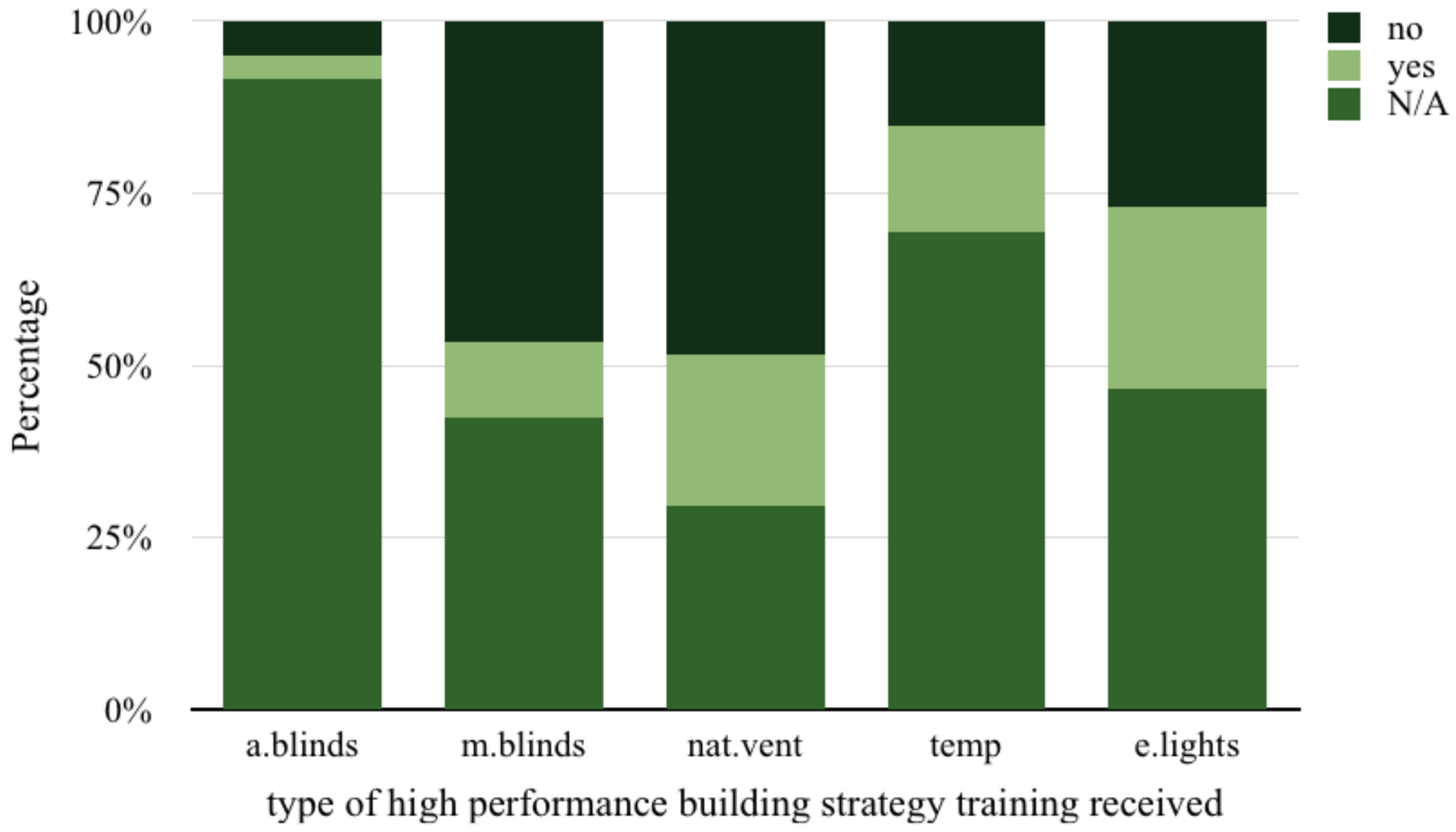
LESS SATISFIED

lower productivity
absenteeism
headaches, migraines, etc.
physical discomfort…

RESEARCH QUESTION

WHAT ARE THE DIFFERENT TYPES OF DELIVERY METHODS FOR OCCUPANT TRAINING OF HIGH PERFORMANCE BUILDING FEATURES, AND WHICH METHODS ARE MOST EFFECTIVE?

RESULTS



DID YOU RECEIVE TRAINING FOR ANY OF THE FOLLOWING BUILDING FEATURES?

RESULTS

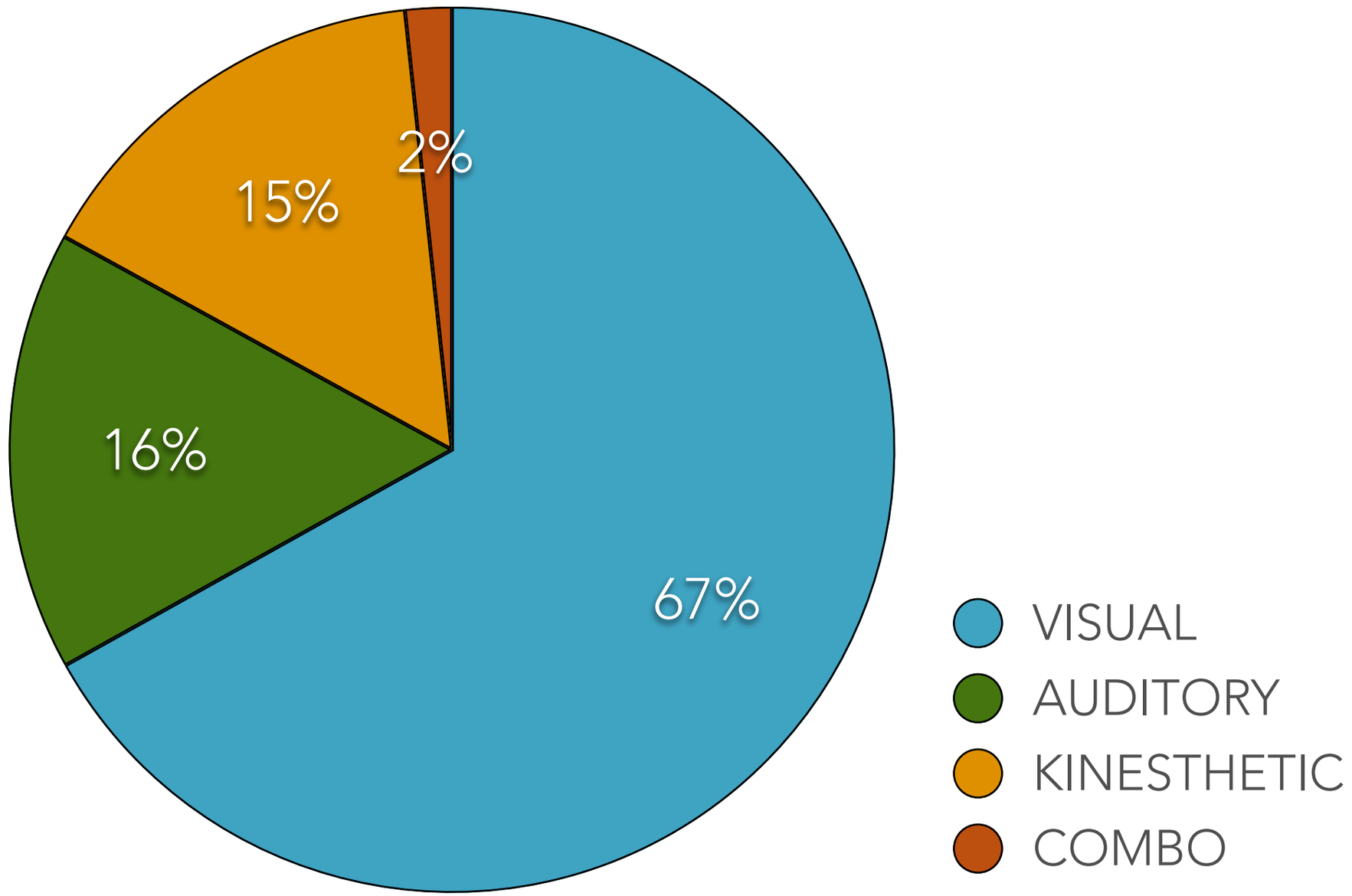
What kind of training did you receive (n=118)?

	verbally	meeting	memo	PP	formal training	informal training	email	workshop	document
automatic blinds	3	0	0	0	0	2	1	0	0
manual blinds	10	1	0	0	0	1	1	0	0
natural ventilation	20	12	1	1	0	2	7	0	2
thermal controls	15	4	0	0	0	0	1	0	1
electric lights	25	10	2	0	0	6	0	0	1

There were **49 participants** who **reported** having some kind of **training** on one or more of the five building features included on the survey (n=118). Of those, **31 participants rated the training they had received as (4) helpful, or (5) very helpful (63%)**. The remaining 18 participants **(37%) did not think the training they received was helpful or effective** in teaching them about the particular building strategy for which they had received training.

RESULTS

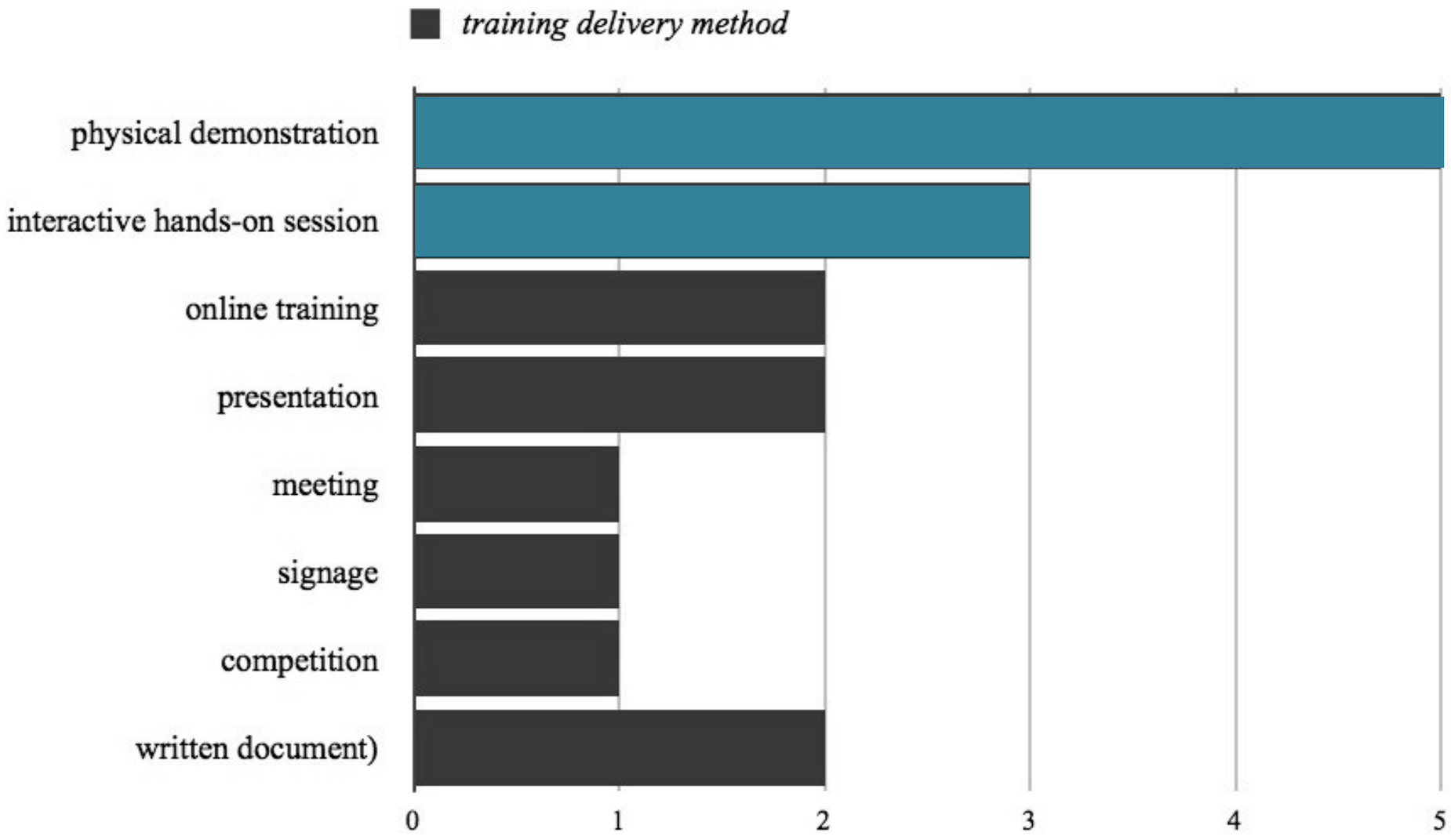
"HOW I USE MY PHYSICAL SENSES…"



HOW DID INDIVIDUALS BEST LEARN A NEW CONCEPT?

RESULTS

WHAT KIND OF TRAINING WOULD YOU LIKE TO RECEIVE IN YOUR BUILDING? WHAT WOULD BE MOST EFFECTIVE?



"…… maybe a **combo** of an **interactive** kind of session with some kind of **online training** that actually teaches you about the **systems** and their **functions** and the **rationale behind it**."

"……"I do think sometimes it's easier to have it **both verbally and** then also **written**, especially when you can **refer back to it as things change**."

RESULTS

IS THERE A DIFFERENCE BETWEEN THE BUILDING SIZE AND EFFECTIVENESS OF TRAINING?

QUAN

Quantitative results (Pearson chi-square statistic) showed that the reported **effectiveness of training was significantly different** between the two categories of building size [<25k SF and >25k SF] ($x^2 = 17.504$, $df = 1$, $N = 118$, $p \leq .000$).

OCCUPANTS IN SMALLER BUILDINGS (51.4%) WERE MORE LIKELY TO REPORT EFFECTIVE TRAINING THAN THOSE IN LARGER BUILDINGS (14.8%).

QUAL

All of the interviewed individuals who were interviewed **from smaller buildings had received some type of training**, although, the level of effectiveness cannot necessarily be interpreted from the responses. However, **none of the individuals interviewed in buildings over 25,000 SF reported any training.** Two individuals, who were interviewed from a larger building, knew about systems only because they had helped design the building.

SO... ARE THERE WAYS TO USE DESIGN AS A TOOL TO EDUCATE OCCUPANTS ABOUT THEIR BUILDINGS?

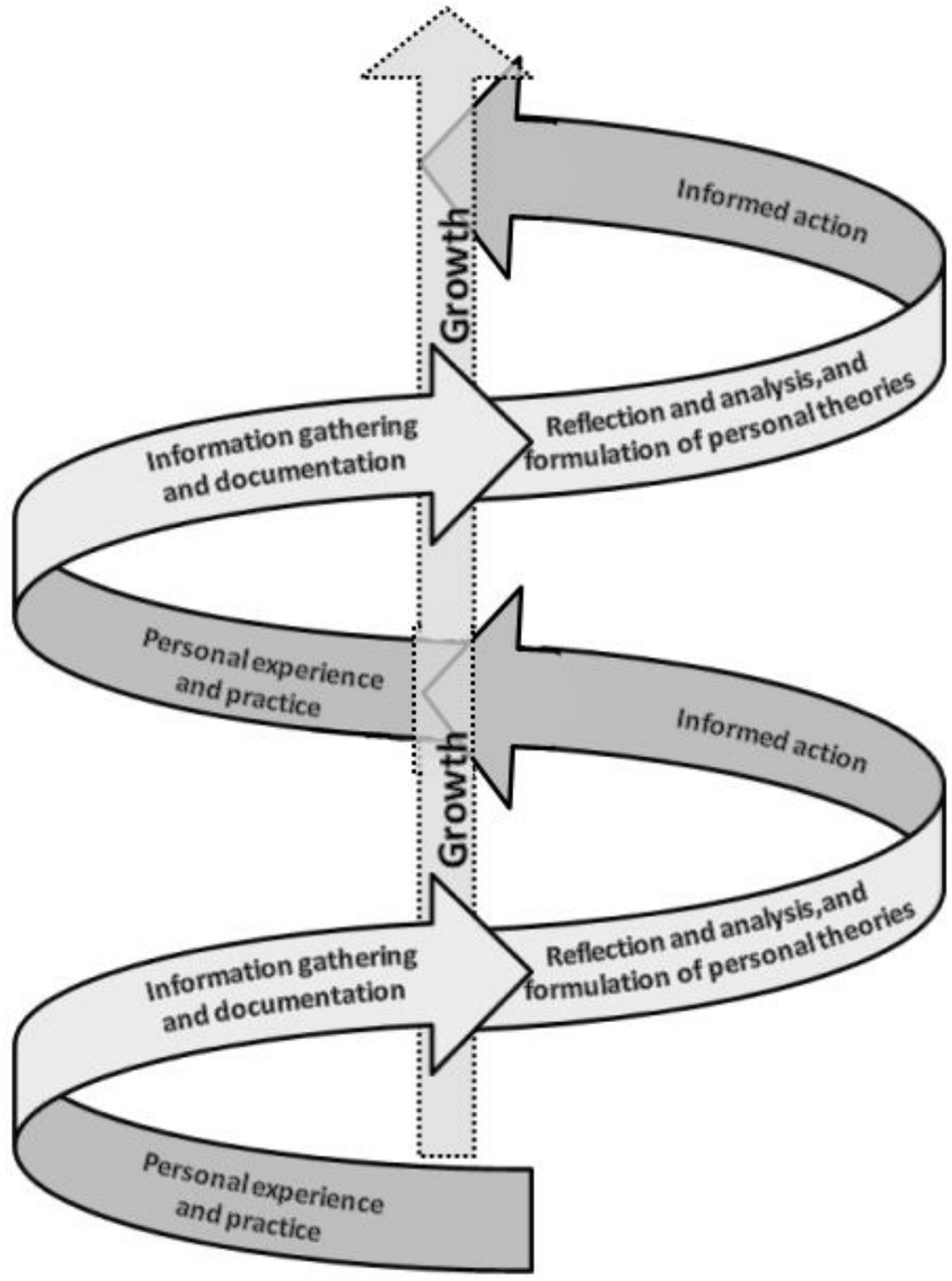
LITERATURE REVIEW
THE DESIGN PROCESS & THE LEARNING PROCESS

The **learning process is reflective**, **enhanced through re-representation, and builds upon existing knowledge and experience.**

> Mezirow (2000) defines learning as "the process of using a prior interpretation to construe a new or a revised interpretation of the meaning of one's experience in order to guide future action" (p. 5).

The learning process is **similar to the design process as it is enhanced through "re-representation"** (Schön, 1983).

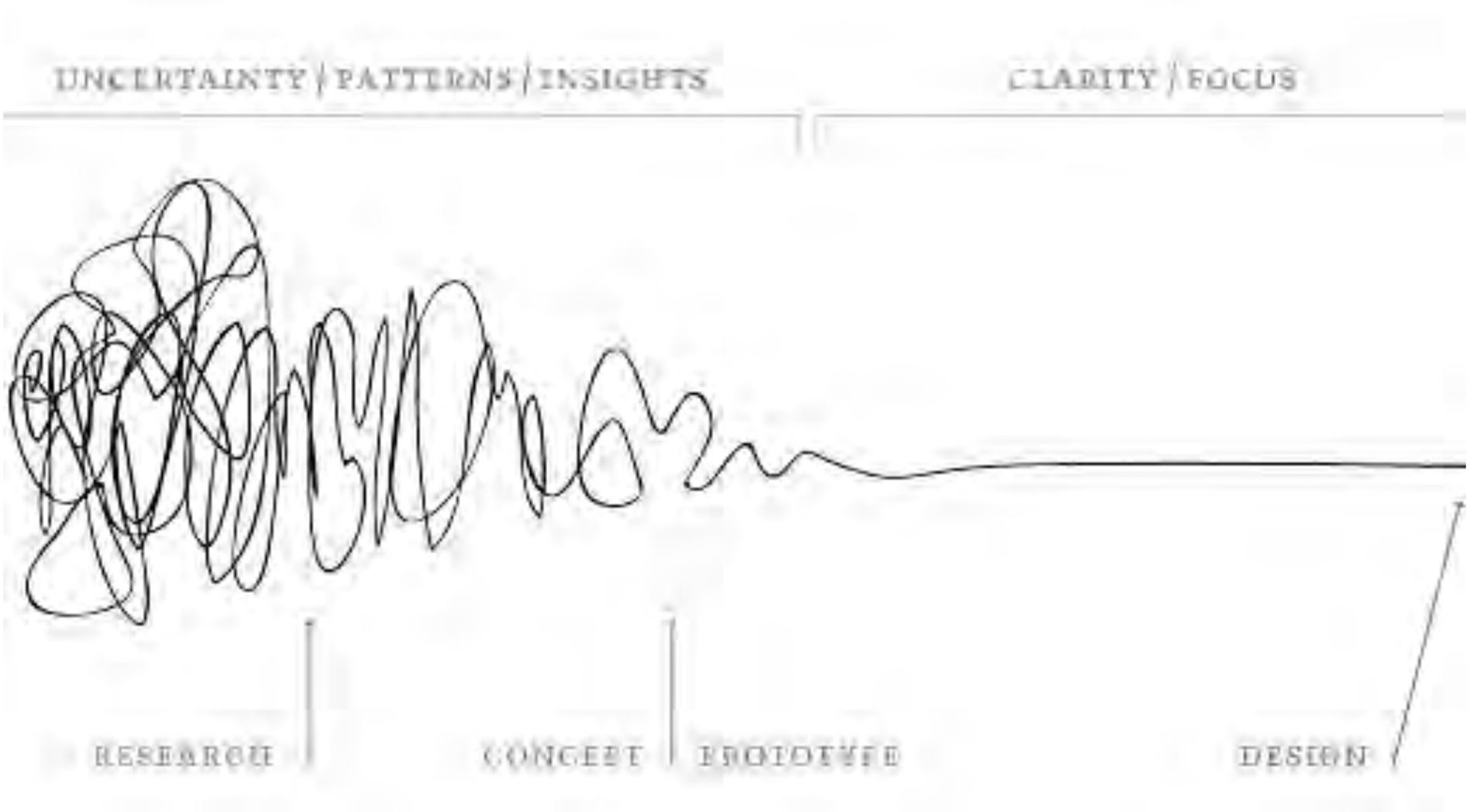
> In design, re-representational structures, such as sketching, are integral to the design process. Learning can also be enhanced in a similar manner.



Cyclical process of learning. Compton & Davis, 2010, p.316 (based on the model illustrated in Knowles & Cole, 1996).

LITERATURE REVIEW

THE DESIGN PROCESS & THE LEARNING PROCESS



http://www.designsojourn.com/category/design-process/

LITERATURE REVIEW
MODELS AND THEORIES OF ADULT LEARNING

Models and Theories of Adult Learning

Theory and Creator	*Identify why training/ learning is needed (how will it benefit them)*	*Focus on real world issues that involve solving an actual problem*	*Allow the learner to challenge ideas and make decisions*	*Training should relate and build upon past experiences*	*Respect individual differences, cultural backgrounds, etc*	*Learning should be action oriented so that adults can be actively engaged*
Andragogy (Knowles, 1980)	X	X	X	X	X	X
Thiagi's laws of learning (Zemke, 2002)	X	X	X	X	X	X
Three dimensions of learning model (Illeris, 2002)		X		X		X
Self-directed learning (Knowles, 1975)		X		X	X	X
Adult basic education principles (Imel, 1998)				X		X
Model of the learning process (Jarvis, 2006)				X		X

Note: Table modified and adapted from Bryan, Kreuter and Brownson, 2009, p.558

LITERATURE REVIEW
LEARNING IN AND FROM THE BUILT ENVIRONMENT

To truly maximize energy savings, occupants **should understand specific strategies and corresponding behaviours as they relate to the building they inhabit** (Cole & Brown, 2009; Janda, 2011).

Delivering a singular training session does not ensure that occupants will actually learn. However, **targeted training sessions can be paired with experiences and interactions** within the designed environment to elevate the learning process.

Learning can take place in multiple ways within the built environment (Orr, 1993).

Learning can be **enhanced through interactive behaviours and experiences** as "...knowledge is continuously derived from and tested out in the experiences of the learner" (Kolb, 1984, p. 27).

> *"... education about building performance needs to go beyond energy meters and monitors. If the goal [is] to prepare people to accept more responsibility for their role in the built environment, education should be much more comprehensive, integrated, hands-on, and iterative. (Janda, 2011, p. 19)"*

A FEW CASE STUDY EXAMPLES

There are a few exemplar buildings that have successfully integrated both **function** (energy efficiency and building systems) and **form** (building design and aesthetics) in a way that peaks occupants' interests surrounding the natural elements and high-performance strategies within the building.

CASE STUDIES

GENZYME CENTER: CAMBRIDGE, MA.

The unique aesthetics and designed elements in the space motivate occupants to learn about energy-saving features in the building. For instance, there are large mirrors on the roof (heliostats) that move around throughout the day to reflect the sun onto fixed mirrors and then into the atrium.

http://inhabitat.com/genzyme-center/

CASE STUDIES

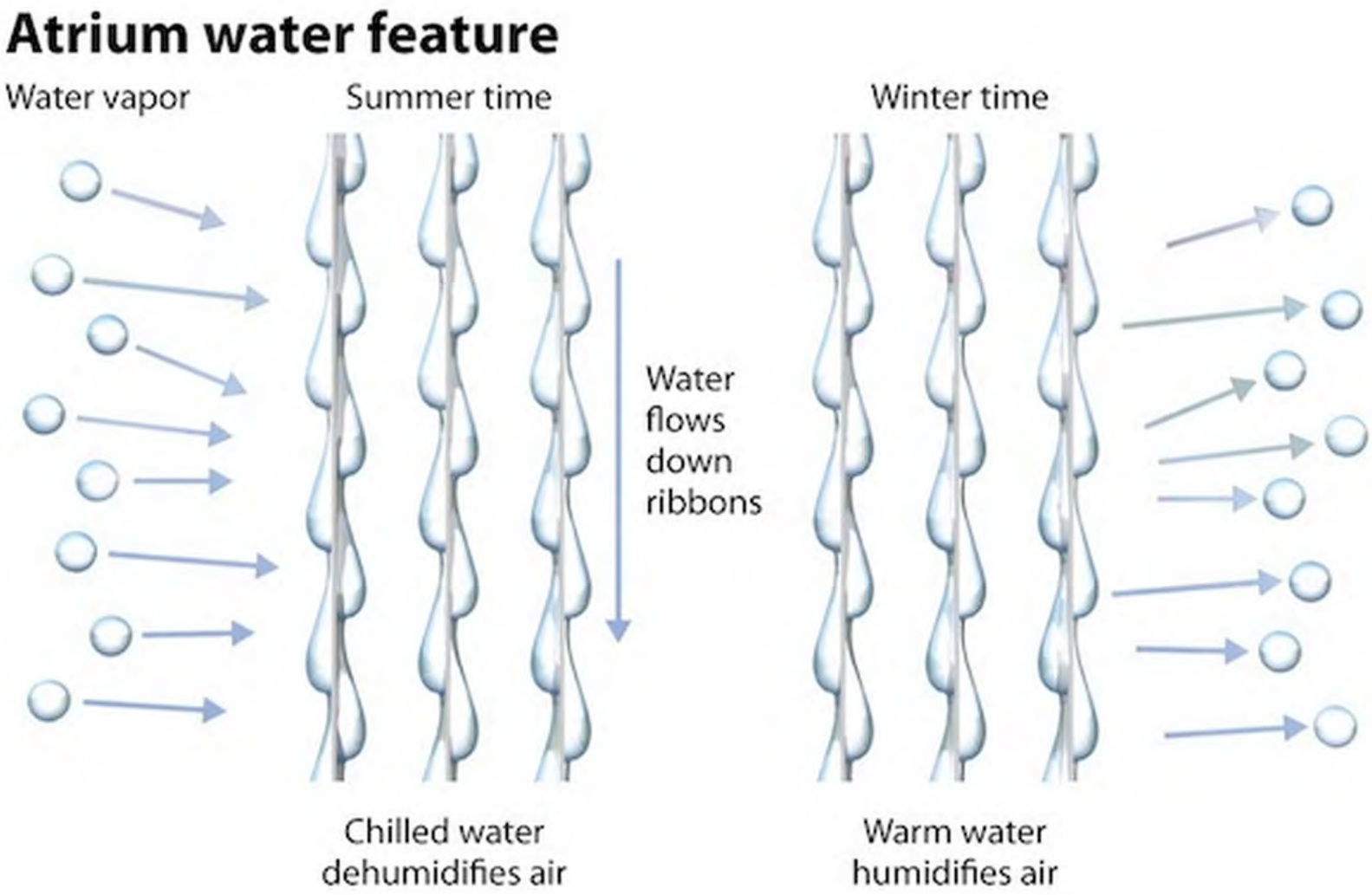
MANITOBA HYDRO PLACE: WINNIPEG, MANITOBA.

The water feature is six stories high and serves to humidify and dehumidify incoming air before it is distributed to other interior spaces. "During warmer, moist weather, water running down the water feature is cooled...[and] moisture in the air is absorbed into the water feature.... In the winter, the process is reversed" (KPMB Architects, 2009).

http://manitobahydroplace.com/Integrated-Elements/Water-Features/

CASE STUDIES

MANITOBA HYDRO PLACE: WINNIPEG, MANITOBA.



http://manitobahydroplace.com/Integrated-Elements/Water-Features/

CASE STUDY EXAMPLES CONTINUED

Although the examples above illustrate the use of **design elements as learning moments,** they are somewhat lacking in terms of **active engagement.**

There are several buildings that have truly aimed to **integrate the building design as an educational tool**.

CASE STUDIES

MANASSAS PARK ELEMENTARY SCHOOL: MANASSAS PARK, VA

...green lights signal it's time to open the windows. A gage on a cistern shows the rain water level. A bioretention area doubles as an outdoor classroom. Even the pipes of the HVAC system are painted red and blue to mimic illustrations of veins and arteries in human bodies. (Knox & Davis, 2010, p.37)

STUDENTS AS ACTIVE PARTICIPANTS IN CONSERVATION

Natural ventilation in the classrooms is encouraged by a 'green light' system. When the green light comes on, students know that windows may be opened in order to substitute natural ventilation for mechanical conditioning. Compressors in the heat pumps turn off, and natural convection currents circulate fresh air through the room. When the light turns off, students are quick to remind the teacher that any open windows need to be shut tightly once again.

http://www.vmdo.com/docs/Manassas_Park_case_study_1.pdf

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0CAcQjRw&url=http%3A%2F%2Fwww.aiatopten.org%2Fnode%2F103&ei=Gl4bVdHyPMmxggTCqISQBg&bvm=bv.89744112,d.eXY&psig=AFQjCNGYAVPtIlifxVIoXoop0adfmrcvFw&ust=1427943261524697

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

PRINCIPLE 1: IDENTIFY WHY TRAINING/LEARNING IS NEEDED.

PRINCIPLE 2: FOCUS ON REAL WORLD ISSUES.

PRINCIPLE 3: ALLOW THE LEARNER TO MAKE DECISIONS.

PRINCIPLE 4: RELATE TRAINING TO EXPERIENCE.

PRINCIPLE 5: RESPECT INDIVIDUAL DIFFERENCES.

PRINCIPLE 6: LEARNING SHOULD BE ACTION ORIENTED.

(CARLISLE ET AL., 2011; PRESS ET AL., 2011).

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

- Occupants were informed about the aggressive energy goals prior to moving in to the building.
- Goals and strategies were communicated to occupants in a variety of ways through employee newsletters, posts on the internal RSF web page, a brown bag lunch series, workstation prototype tours, an open house, YouTube videos, E-training, and blog polls.

(CARLISLE ET AL., 2011; PRESS ET AL., 2011).

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

- As an energy research laboratory, NREL considered training for energy efficiency very important for sustainability at a global and organizational level — *energy budgets were enforced*
- Occupants were well informed about the energy objectives of the company, and leaders at NREL and the Department of Energy (DOE) enforced these objectives.

(CARLISLE ET AL., 2011; PRESS ET AL., 2011).

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

- Each employee has access to an interactive computer program that allows him or her to report general concerns surrounding their environment (i.e. too cold, too hot, too bright, etc.).
- This provides valuable data to the building operators regarding occupant comfort so building systems can be altered if necessary, and it also allows employees to play an active role in thermal and visual comfort decisions.

(CARLISLE ET AL., 2011; PRESS ET AL., 2011).

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

- Before occupying the new building, employees were informed of behavioral and operational changes that were to take place in the new building.

- In some instances, it was explicitly stated that behaviors would have to change to accommodate the aggressive energy goals in the new facility — employees were taught how and why some of their past experiences and interactions in other buildings were no longer applicable to the new building.

(CARLISLE ET AL., 2011; PRESS ET AL., 2011).

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

- One way NREL was able to respect and respond to individual differences was through the implementation of "ask.rsf@nrel.gov."
- Employees were able to express concerns before and after move-in to the facility. Many employees were worried about issues surrounding privacy, noise, lights and health issues. The website allowed employees to ask a question and receive immediate feedback.

(CARLISLE ET AL., 2011; PRESS ET AL., 2011).

PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

- Design elements, such as red and green lights, daylighting systems, and operable windows, work in tandem with building technologies to create a feedback loop and signal system to occupants. When the outside air temperature is conducive to energy savings, a green light signals to occupants that they may open the windows for natural ventilation.

- Technology has been integrated within the design to encourage interaction, support occupant feedback, and to further occupants' understanding of the building systems.

(CARLISLE ET AL., 2011; PRESS ET AL., 2011).

ACHIEVING NET-ZERO THROUGH INTEGRATED LEARNING & DESIGN

Q&A

BREAK

PART B: LESSONS LEARNED (AND DESIGN MISSTEPS) FOR THE A&E COMMUNITY

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AUGUST 6, 2015

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RESEARCH QUESTION

FOR WHAT REASONS DO OCCUPANTS CHOOSE *NOT* TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE *NOT* TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

- **Social / cultural concerns** (occupants did not want to affect others) and/or the culture in the office was not conducive to changing thermal or visual conditions

"…normally in my own house I would certainly go ahead and *do it [change the blinds]. But here, I'll change my own position so it doesn't affect 20 other people usually ….If the sun is only in my eyes, you know, no big deal."*

RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE *NOT* TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

- **"Not my dime"** / **thermal comfort** (in reference to why they do *not care* about saving energy)

"… it feels like if you had some individual control [of the thermostat] you actually would end up with energy saved, because I've had my window open wasting heat a number of times … I had a father who taught me not to waste energy in the seventies, but the number of times that I have wasted energy here… it's because its not my dime, right? I do what I want because I'm uncomfortable."

RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE *NOT* TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

- **Occupants did not understand how to effectively control the building features**

"I have a problem remembering which way to tilt the blinds so they maximize daylight and reduce glare and heat gain so having a reference for blind positions at the controls or access to a building operation manual would be useful."

http://www.getreligion.org/getreligion/2012/02/someones-confused-about-santorum

RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE *NOT* TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

- **Lack of control or *perceived* control** *(or asked not to touch it by someone)*

**Example of weather station and automated light system (lack of control) — *need for an integrated design process.*

RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE *NOT* TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

They had disabled the control or building feature...

SO, WHY CAN'T WE JUST MAKE BUILDINGS COMPLETELY AUTOMATED SO THAT PEOPLE DON'T HAVE TO CONTROL ANYTHING?

PEOPLE WANT CONTROL!

"...the windows are annoying because it's all automated... so you can't control it."

SO WHAT CAN DESIGNERS AND OWNERS DO TO HELP REDUCE OVERALL BUILDING ENERGY USE & TO ENSURE THE BUILDING — AND THE OCCUPANTS — ARE REALLY PERFORMING AT THE DESIRED LEVEL???

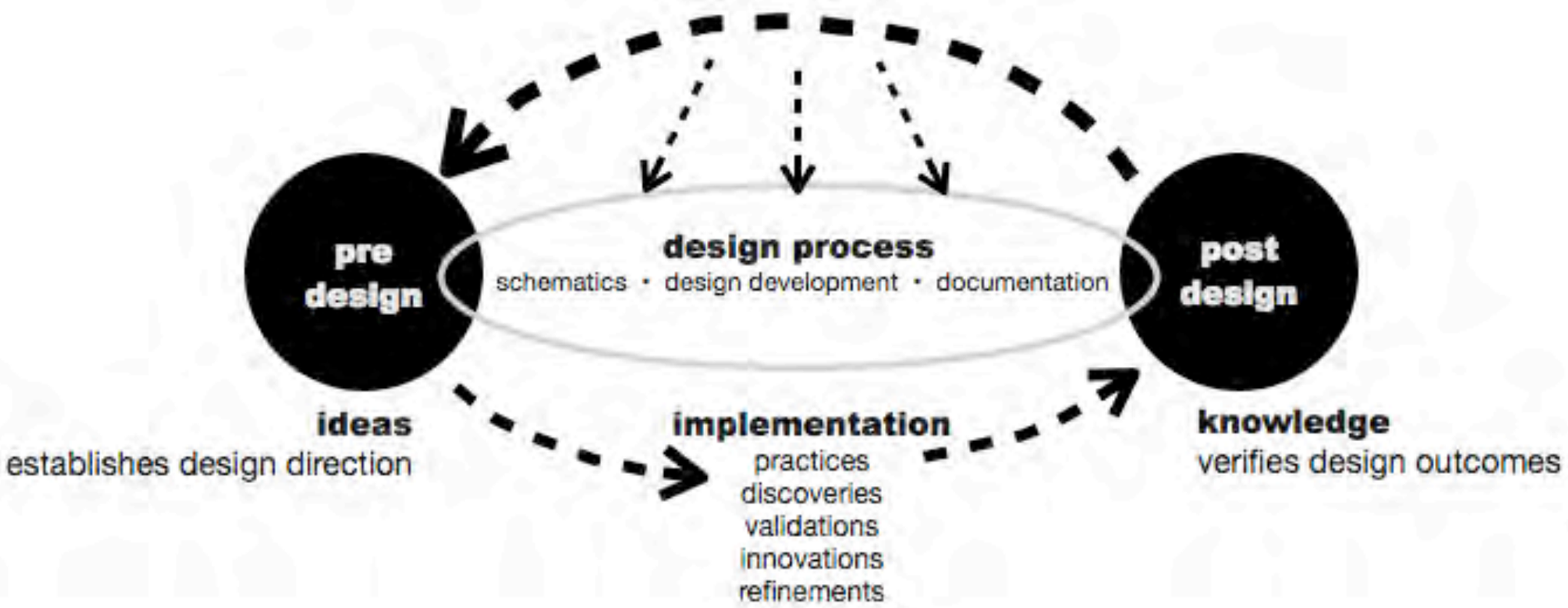
1.THROUGH AN INTEGRATED DESIGN APPROACH

2. REMOVE BARRIERS

3. EDUCATE OCCUPANTS

4. IMPLEMENT EFFECTIVE BEHAVIORAL CHANGE APPROACHES...

INTEGRATED DESIGN PROCESS + FEEDBACK LOOP



Integrated Design Process and Feedback Loop: pre- and post- design identified as critical areas for intervention
(Theodorson, 2014)

INTERIORS AND HUMAN-CENTERED ENERGY DETERMINANTS THROUGHOUT DESIGN PROCESS

DESIGN PHASE	DESIGN ACTIVITY	Interiors + Human Centered ENERGY DETERMINANTS	Interiors + Human Centered DAYLIGHTING DETERMINANTS
PRE-DESIGN	Eco-design charrette	• initiate team building, inclusive of occupant • establish importance of occupant in energy profile • influence leadership toward eco-design perspectives • discussion of automation vs. autonomy • set measurable energy goals, considering human-behavioral inputs	• present research on human benefits related to daylighting and resulting economic benefit • consider socio-cultural influences relative to the provision of daylight and views • rank daylight and views in preferred building attributes • establish 'daylight priority' • set daylighting performance goals relative to user inputs
	Programming	• align occupancy patterns with energy requirements • align spatial organization with climate resources • review comfort criteria in consideration of personal adaptation • passive buildings = active occupant	• align building schedules with daylight resource • prioritize daylight resource for areas of critical visual tasks and prolonged human occupation • set luminous environment requirements • consider concept of autonomy vs automation relative to daylight harvesting
	Form and siting	•align human functions with climate and microclimate resources	• consider qualities of daylight source relative to building / spatial orientation • provide "bright spaces" for circadian entrainment • maximize view
DESIGN	Space planning, fittings and finishes	• consideration of systemic inhabitant-architecture interactions relative to energy conservation strategies.	•shape interior space to modify and distribute natural light source, ie: interior light shelves, ceiling surfaces • select surface finishes to benefit daylight distribution • interior arrangements (furniture, computers, projection surfaces, etc) consistent with daylight controls and qualities • consider color of daylight relative to material color selections
	Interior Systems	• consider human-technology interfaces • provide multiple adaptive controls for thermal and luminous comfort provisioning	• review programming requirements and human interface in developing daylight controls
OCCUPANCY	Commissioning	• consider human-technology interfaces • provide multiple adaptive controls for thermal and luminous comfort provisioning • fine-tune behaviors	• occupant education • commission daylight harvesting systems (electric lighting) and daylight controls (blinds)
	Post occupancy evaluations	• verify performance with occupancy • increase understanding of inhabitant-architecture interactions	• collect data on user preferences, behaviors, controls • develop human-factors daylighting argument

Interiors and Human-Centered Energy Determinants throughout design process
(Theodorson, 2014)

EDUCATE OCCUPANTS

Based on the literature review, the results from this study, and a few case examples, a successful occupant education program should:

(1) incorporate multiple types of delivery methods to **support differing learning styles**,
(2) provide opportunities for **experiential learning** through an **interactive approach within the building context**,
(3) encourage learning through techniques that **facilitate motivation, reinforcement, retention, and transference of knowledge** such as *feedback, goal setting and competition*, and
(4) **explain the rationale behind the need for training** and how it will benefit the occupants. **Occupants need to understand** the building owners have aggressive **energy reduction goals** and their actions directly affect the energy use of the building and their personal comfort.

APPROACHES TO EE AND BEHAVIORAL CHANGE

Approach	*Why It Works*
Normative influence	It is a consistent finding that people tend to align their behavior with the perceived norm
Goal-setting/Pledges	Commitment is a powerful motivator -- especially when it's public.
Consistency Cues	Relates to goal-setting above; people tend to have a drive to be consistent with their internalized value system, stated commitments, or past behavior. Prompts that remind people of their commitments, or point out ways in which they could better align with them, can drive behavior change.
Competition	Competition can increase performance on familiar tasks, especially when a person is competing with those who are relevant or of similar ability. In the case of energy efficiency, competing with friends, similar households, and coworkers is likely to be more effective at inducing behavior change than competing with leaders in sustainability.
Remove Barriers	Behavior change often comes down to identifying and removing barriers to more desirable ways of acting. In the case of energy efficiency, providing individualized tips on how to save energy or shift load may help drive energy savings.
Provide Direct Feedback	Often, people persist in less desirable behaviors merely because they aren't aware of how much they do them, how impactful they are, or how easy it would be to change. Giving people access to their real-time energy use information can make wasteful behaviors more salient. In the case of energy efficiency, providing individualized, hour-by-hour reports through live feedback (computers, energy kiosk, etc.) can make people aware of opportunities throughout the day where they can save energy without sacrificing comfort.
Provide Indirect Feedback	Providing indirect feedback (via billing statements) can help people save energy by inducing them to "compete" with their own past performance and set goals.

Behavior based energy efficiency approaches around the northwest. Retrieved from https://conduitnw.org/pages/file.aspx?rid=1653
(Goodwin, 2013)

COMPETITION

KILOWATT CRACKDOWN

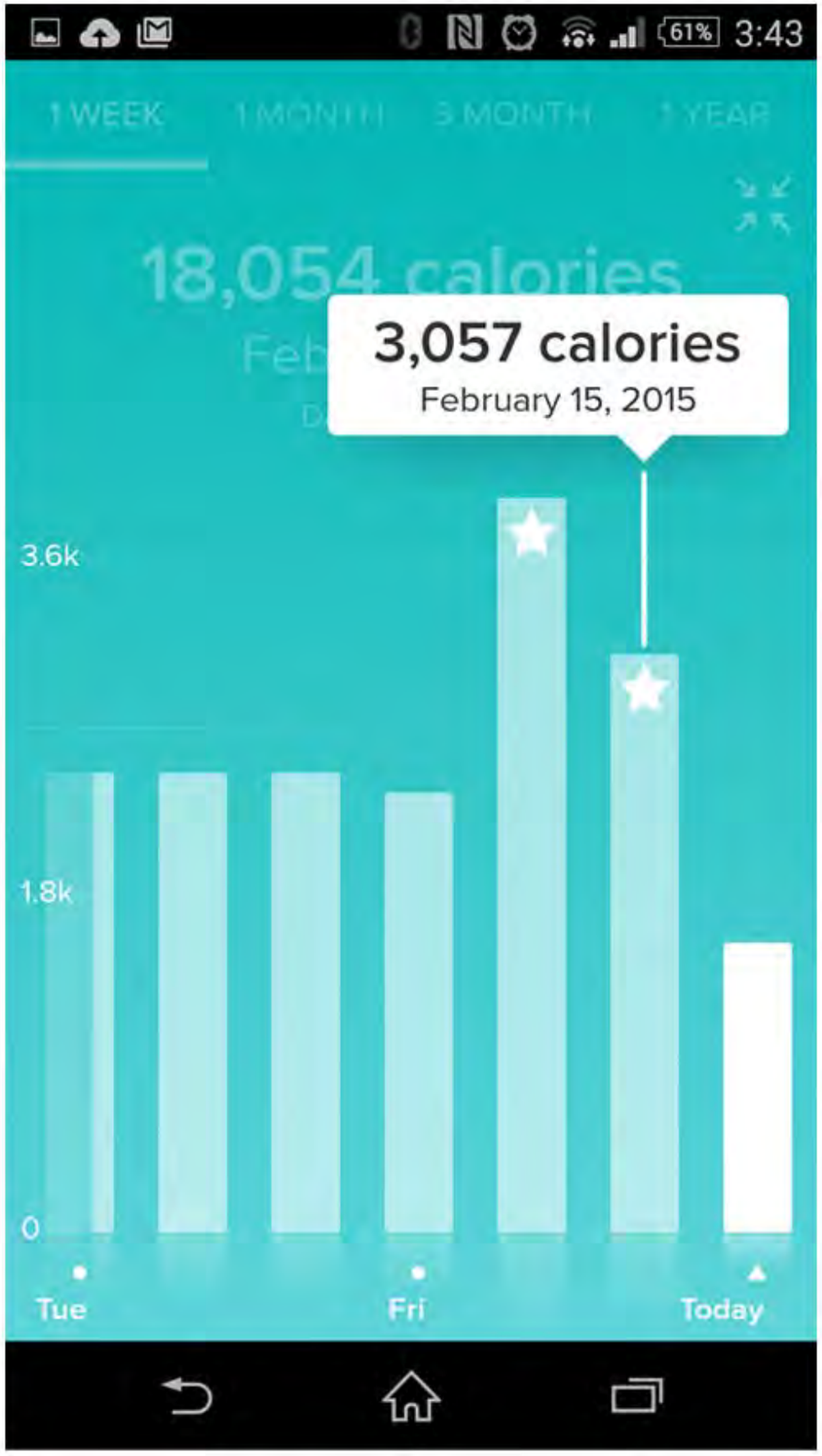
THE BUILDING PERFORMANCE PARTNERSHIP | KILOWATT CRACKDOWN

Kilowatt Crackdown is the energy-saving competition that helps everybuilding win.

Portland Metro **Boise Metro**

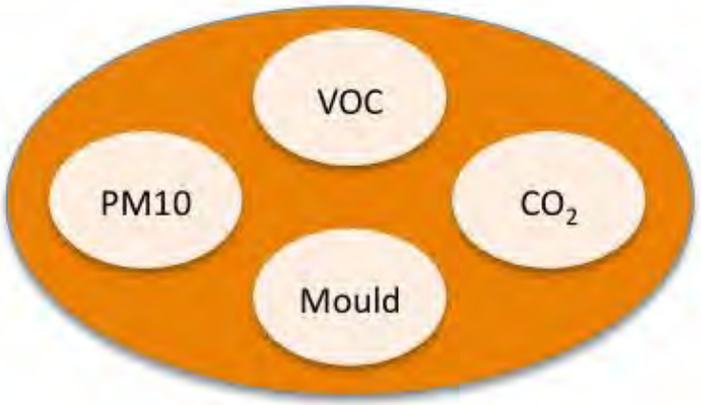
HTTP://WWW.KILOWATT-CRACKDOWN.COM/

GOAL SETTING



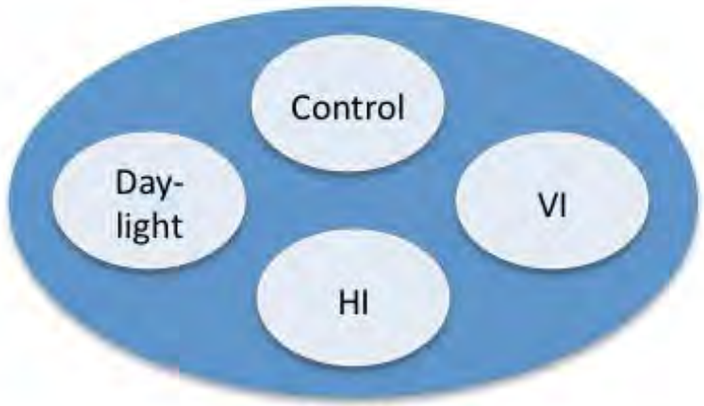
PROVIDE FEEDBACK (TO OCCUPANTS)

PROVIDE FEEDBACK (TO DESIGNERS) | POE



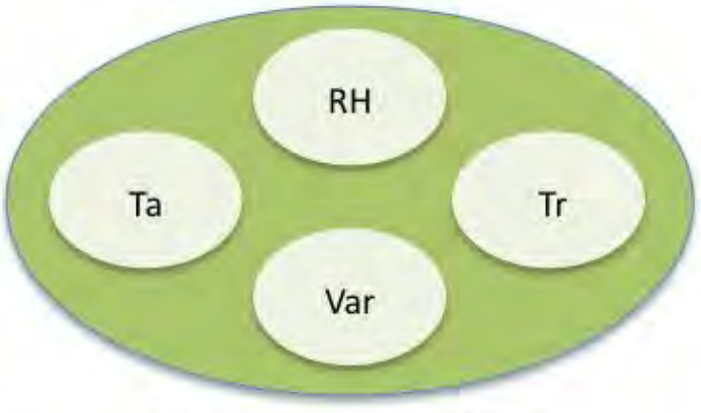
Air Quality

VOC = Volatile Organic Compound
PM10 = Particulate Matter
Mold = Microbial organisms
CO2 = Carbon dioxide



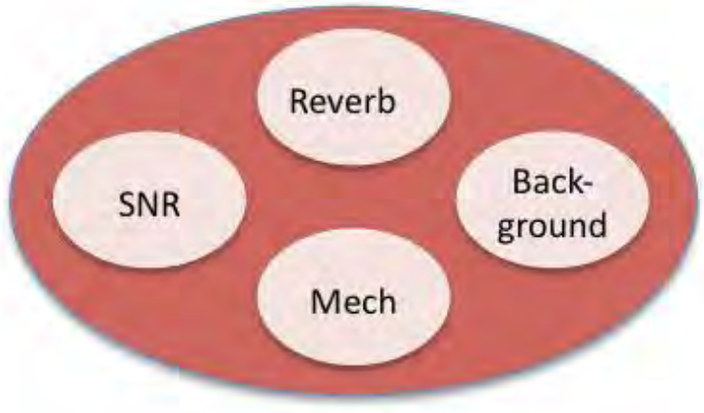
Light

Control = Light controllability
Daylight = Access to daylight
VI = Vertical Illumination
HI = Horizontal Illumination



Thermal Comfort

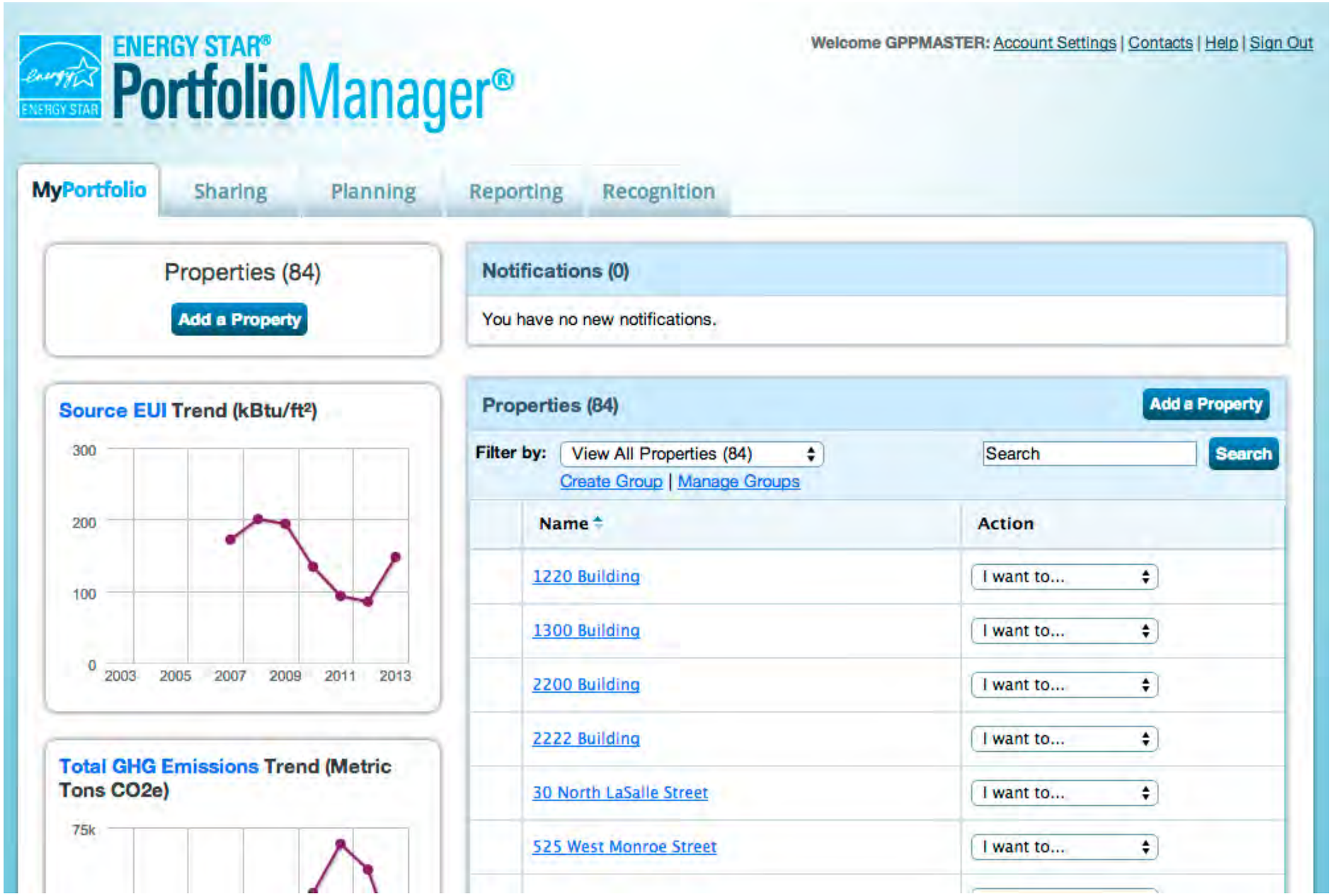
RH = Relative Humidity
Ta = Ambient Temperature
Var = Air Velocity
Tr = Radiant Temperature



Acoustics

Reverb = Reverberation times
SNR = Signal to Noise Ratio
Mech = Mechanical noise
Background = Background noise

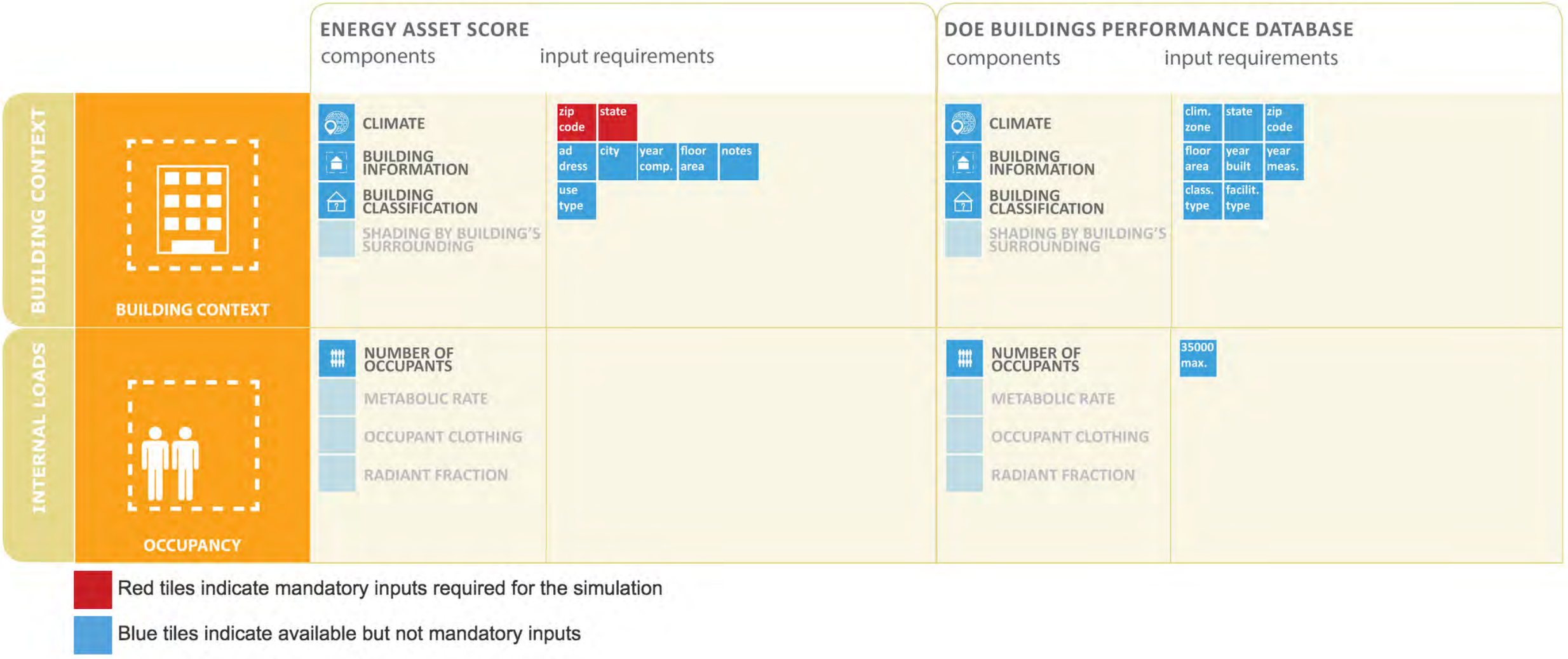
PROVIDE FEEDBACK (TO OWNERS)



TOOLS FOR DESIGNERS...COMING SOON

U.S. DEPARTMENT OF ENERGY | CBEI CONSORTIUM for BUILDING ENERGY INNOVATION | Carnegie Mellon University

DOE TOOL SELECTION



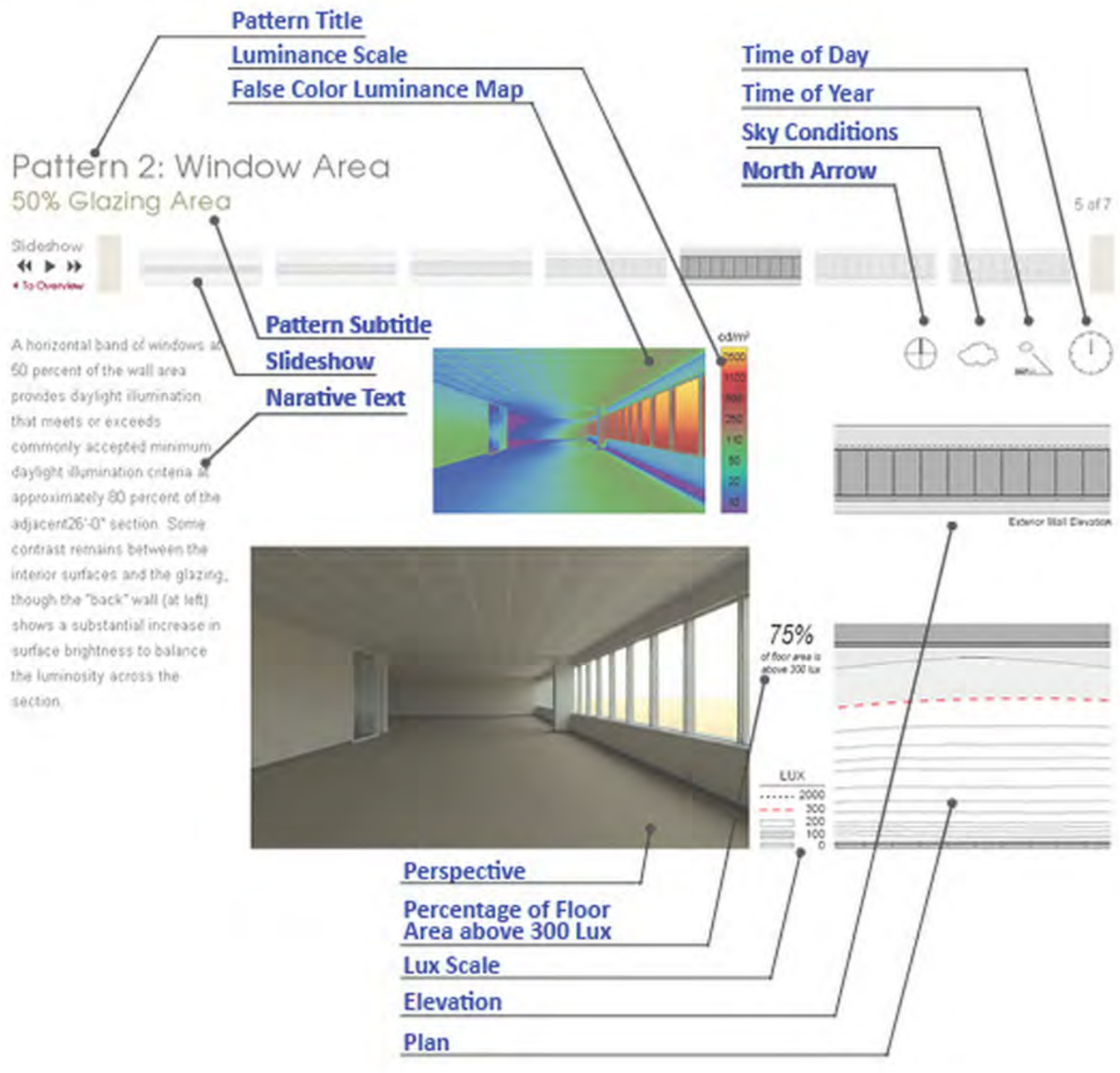
Red tiles indicate mandatory inputs required for the simulation

Blue tiles indicate available but not mandatory inputs

DOE TOOL SELECTION

TOOLS FOR DESIGNERS

DAYLIGHT PATTERN GUIDE



nbi new buildings institute

INTEGRATED idl DESIGN LAB
boise + puget sound

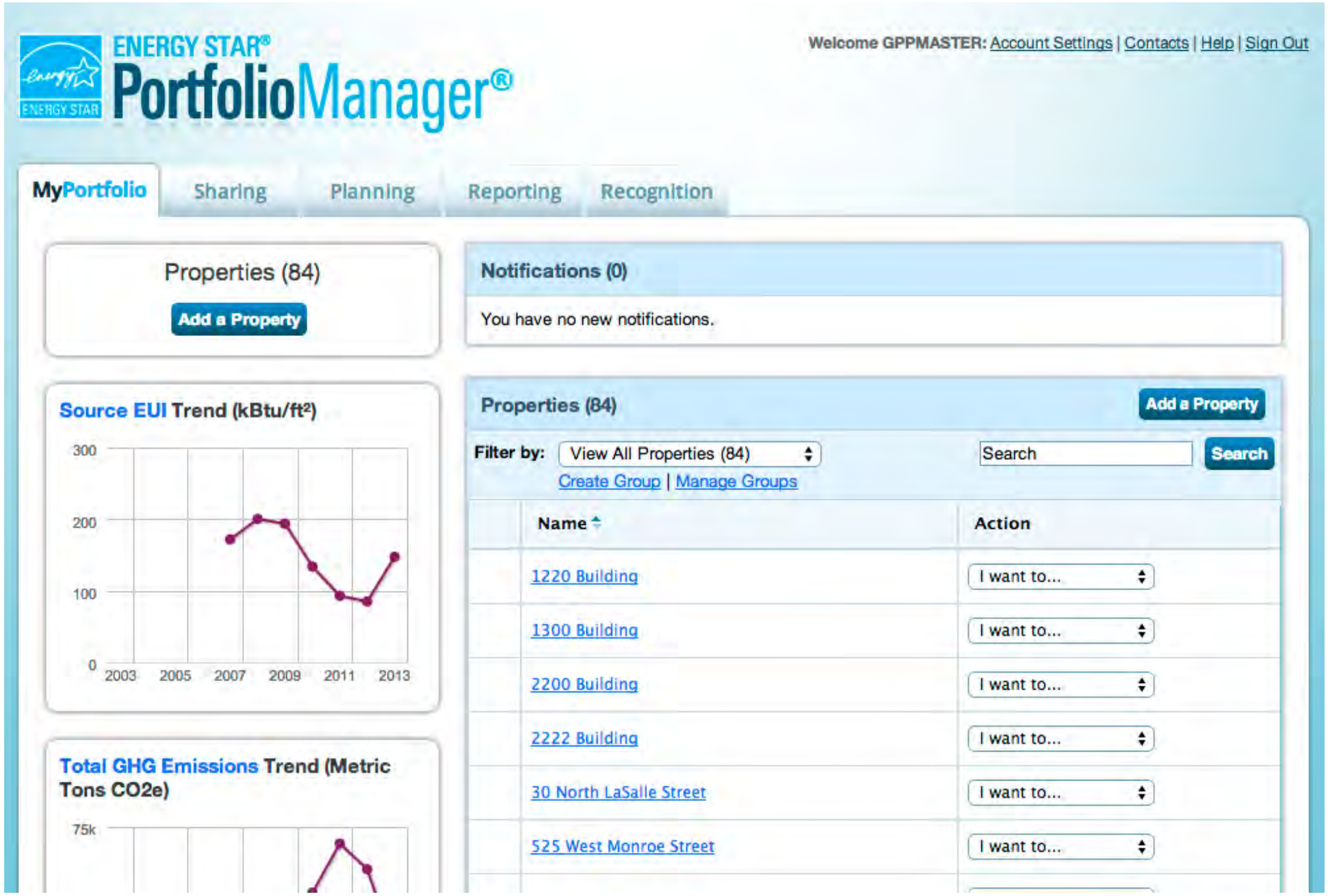
University of Idaho
College of Art and Architecture

BE COLLEGE OF BUILT ENVIRONMENTS

HTTP://PATTERNGUIDE.ADVANCEDBUILDINGS.NET/

EXISTING PROGRAMS / INITIATIVES - OWNERS

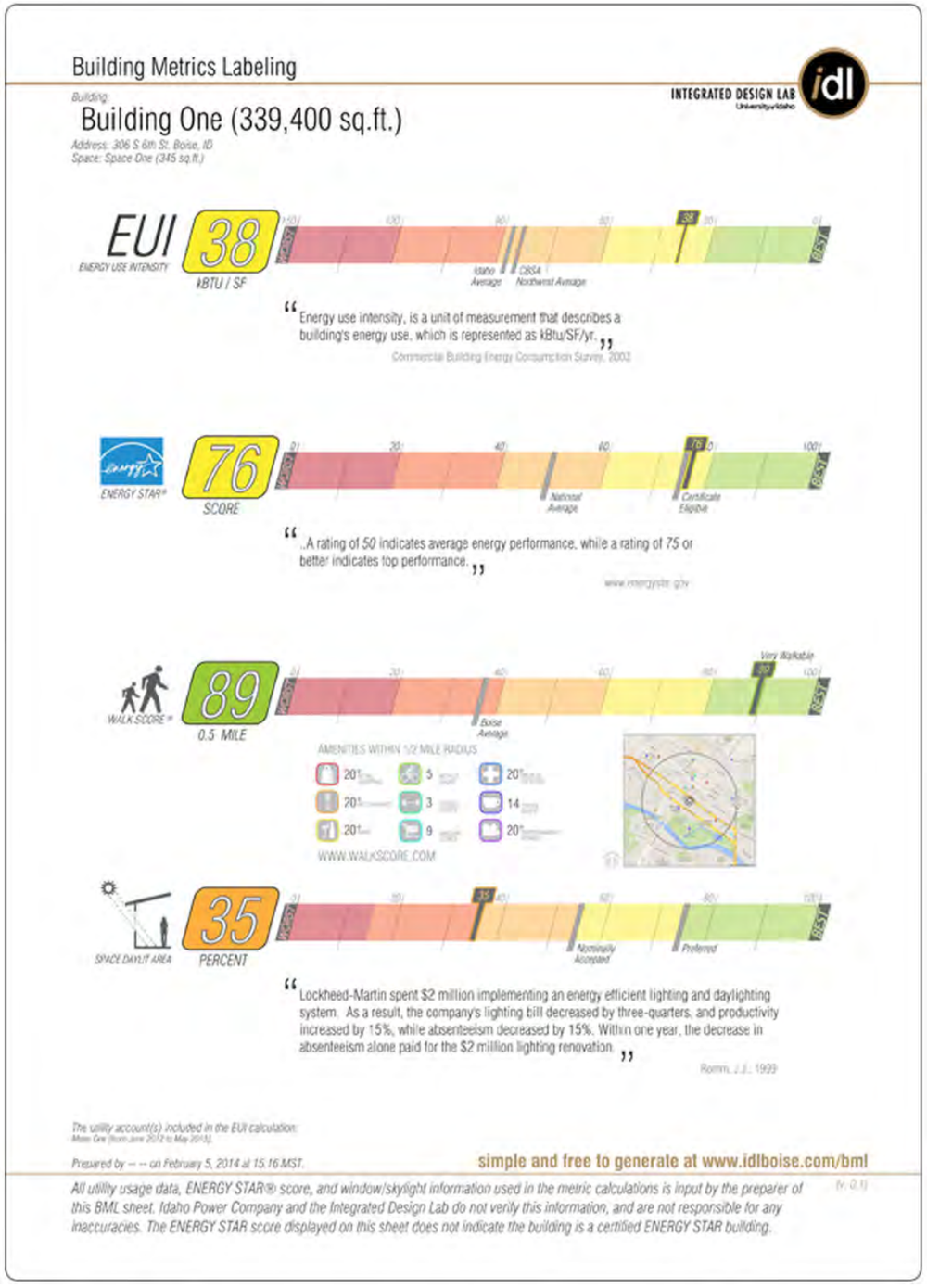
PORTFOLIO MANAGER



HTTPS://PORTFOLIOMANAGER.ENERGYSTAR.GOV/

EXISTING PROGRAMS / INITIATIVES - OWNERS

BUILDING METRIC LABELING



HTTP://WWW.IDLBOISE.COM/BML

SO, TO RECAP ..

HOW CAN WE ENCOURAGE ENERGY EFFICIENT OCCUPANT BEHAVIORS IN HIGH-PERFORMANCE BUILDINGS?

1.THROUGH AN INTEGRATED DESIGN APPROACH

2. REMOVE BARRIERS

3. EDUCATE OCCUPANTS

4. IMPLEMENT EFFECTIVE BEHAVIORAL CHANGE APPROACHES...

CONCLUSIONS

http://www.evolo.us/architecture/nouvels-glittering-new-apartment-building-on-eleventh avenue/

Ultimately, better **occupant education** initiatives may lead to **increased environmental satisfaction** for occupants and unrealized **energy and cost savings** in high-performance buildings.

ABBREVIATED REFERENCE LIST

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THANK YOU!!

DISCUSSION & QUESTIONS

Q&A

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Thank You

Occupant Cx: Learning from Occupants to Improve Building Designs

August 6th, 2015

EnergyTrust of Oregon