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Navigating the Natural Ventilation Design Strategy in ZNE Buildings

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Paul Schwer, P. E., PAE
Kasper Hoejmark Ravn, Windowmaster Control Systems, Inc.

18 APRIL 2018

Learning Objectives

Understand how to reduce energy use through Natural Ventilation paired with “Smart” integrated controls.

Learn common mistakes and real-world experiences in the application of Natural Ventilation in several Zero-Net-Energy buildings.

Understand the design approach, resources available, control system features necessary and hardware specifications for natural ventilation.

Understand the issues involved in user-control of natural ventilation versus automatic controls and the advantages of a "smart" hybrid system.

Contents

Introduction

1

Large Potential of Natural Ventilation as a ZNE Design Strategy

The Impact of “Smart Building Technologies”

Automatic Operation or User Control

How Successful Designs Point the Way — ZNE Case Study Building and Their Design Lessons

Speaker Introduction

ED DEAN
BERNHEIM + DEAN, INC.

Building specialist, design coach, and experienced large-project architect.

PAUL SCHWER, PE
PAE

President of PAE, leading over 200 engineers in designing high performance buildings.

KASPER HOEJMARK RAVN
WINDOWMASTER

Building performance specialist specializing in natural ventilation design.

ZNE Case Studies: What Went Wrong

Edward Dean + Bernheim + Dean, Inc

IBEW-NECA Joint Apprenticeship Training Facility (San Leandro, CA)

J. Craig Venter Institute Laboratory (La Jolla, CA)

West Berkeley Branch Library (Berkeley, CA)

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ZNE Case Study Building: IBEW-NECA Joint Apprenticeship Training Facility

ZNE Case Study Building: IBEW-NECA Joint Apprenticeship Training Facility

LOCATION (CLIMATE): San Leandro (Warm, Coastal)

BUILDING TYPE: Educational, Office

RENOVATION

Summary Data:

Floor Area: 45,000 gsf

Occupied: June, 2013

Installed Renewable Energy System:
- 154 kW (DC) Solar PV—flat panel,
- 12 kW (DC) Solar PV—tracking,
- 12 kW (DC) Wind Turbines

Modeled EUI: 18.0

Measured EUI: 16.3 (2014)

On-Site Energy Production: 20.3 (kBtu/sf-year),

267,500 kWhr/year

ZNE Case Study Building:
IBEW-NECA Joint Apprenticeship Training Facility

VICINITY MAP

ZNE Case Study Building:
IBEW-NECA Joint Apprenticeship Training Facility

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IBEW-NECA Joint Apprenticeship Training Facility

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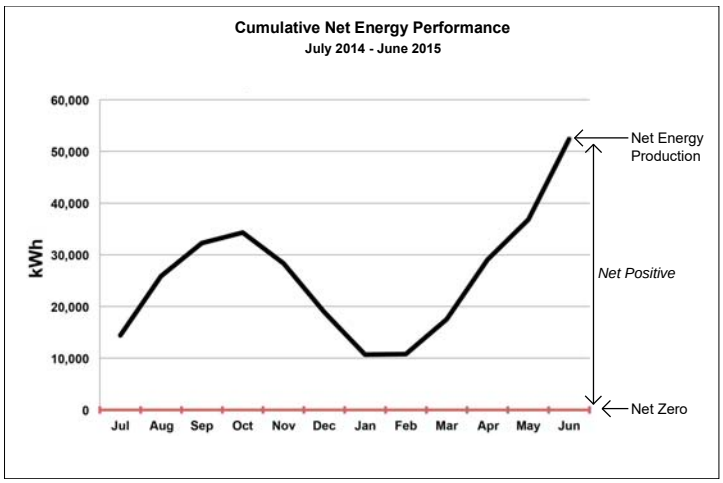
IBEW-NECA Joint Apprenticeship Training Facility



ZNE Case Study Building: IBEW-NECA Joint Apprenticeship Training Facility

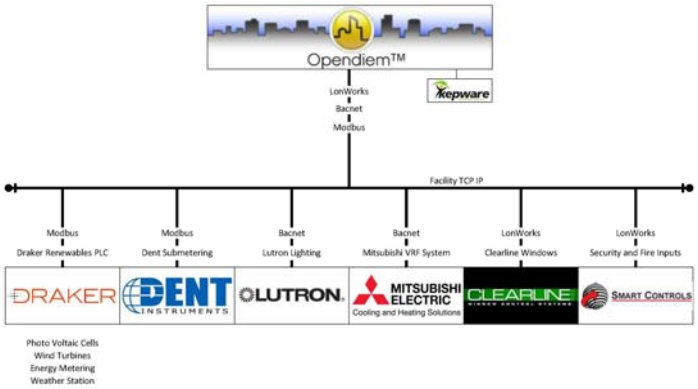
Natural Ventilation Design Strategy

- Simple automatically-operable windows with air outlets at roof monitors
- For internal spaces, air transfer grilles to perimeter rooms
- Night Ventilation utilized in swing seasons

ZNE Case Study Building: IBEW-NECA Joint Apprenticeship Training Facility

Natural Ventilation Design Strategy

Integration of automatically-operating windows with other "smart" energy systems



ZNE Case Study Building: IBEW-NECA Joint Apprenticeship Training Facility

What Went Wrong:

- Hardware was inadequate to the task: continuous, fine adjustment not possible and very noisy when operated
- Result: Instructors shut down *Natural Ventilation* system because of noticeably noisy operation
- "Master system integrator" was essential to the design and operation, but was special consultant role and involved many hours of work

ZNE Case Study Building: J. Craig Venter Institute Laboratory

ZNE Case Study Building: J. Craig Venter Institute Laboratory

LOCATION (CLIMATE): La Jolla (Moderate, Coastal)

BUILDING TYPE: Laboratory

NEW BUILDING

Summary Data:

Floor Area: 44,607 gsf

Occupied: 2013

Installed PV system: 500 kW (DC)

Modeled EUI (Site): 53.3 (kBtu/sf-year)

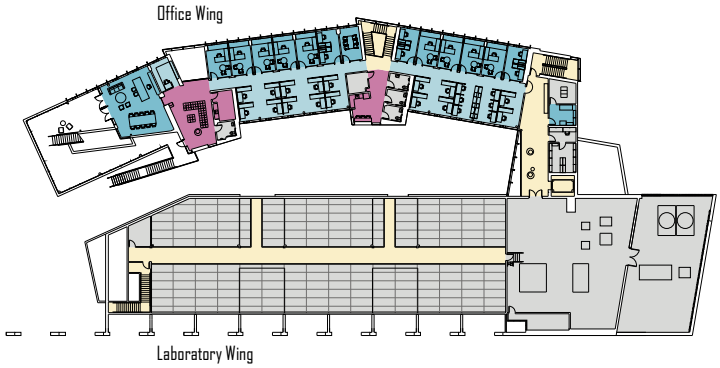
Measured EUI (Site): 73.7 (2014)

On-Site Energy Production: 65.0 (kBtu/sf-year), 850,000 kWhr/year

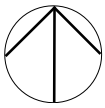
ZNE Case Study Building: J. Craig Venter Institute Laboratory

VICINITY MAP

ZNE Case Study Building:
J. Craig Venter Institute Laboratory



Level Two Plan



ZNE Case Study Building:
J. Craig Venter Institute Laboratory

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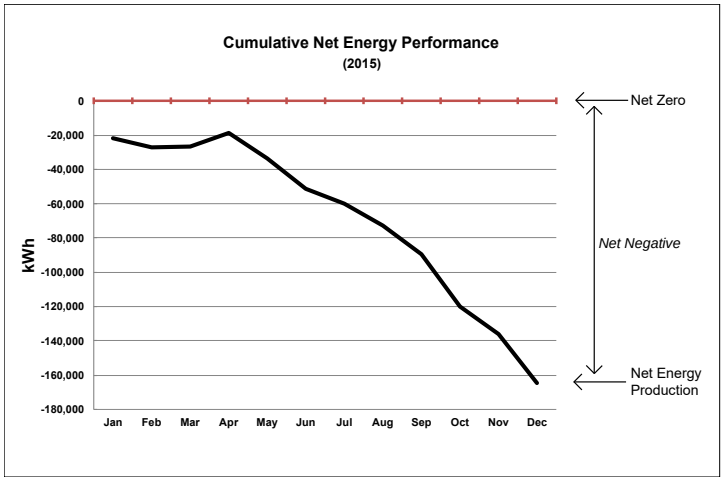
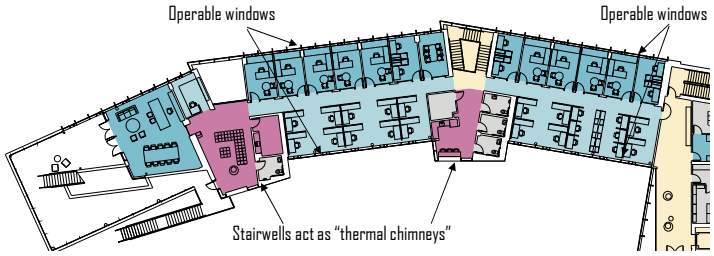


ZNE Case Study Building: J. Craig Venter Institute Laboratory

Natural Ventilation Design Strategy



- User-controlled operable windows (only) with "red-green" indicator lights in office space
- No night ventilation strategy possible

ZNE Case Study Building: J. Craig Venter Institute Laboratory

What Went Wrong:

- Users often failed to respond to "green light" to operate windows. Sometimes they were in the Lab.
- Insufficient air flow developed to provide enough cooling: either air inlet was inadequate, air outlet at top of stair tower was not large enough, or height of "thermal chimney" was not enough to create enough drafting effect
- Use of chilled beams in the office space actually limited time when natural ventilation mode can be used. High relative humidity of ocean fog prevalent in the morning hours created condensation when switching from natural ventilation to the chilled beams for cooling.

ZNE Case Study Building: West Berkeley Branch Library

ZNE Case Study Building: West Berkeley Branch Library

LOCATION (CLIMATE): Berkeley (Cool, Coastal)

BUILDING TYPE: Civic (Library)

NEW BUILDING

Summary Data:

Floor Area: 9,300 gsf

Occupied: 2014

Installed PV system: 52 kW (DC)

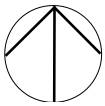
Modeled EUI (Site): 15.0 (kBtu/sf-year)

Measured EUI (Site): 23.1 (2014)

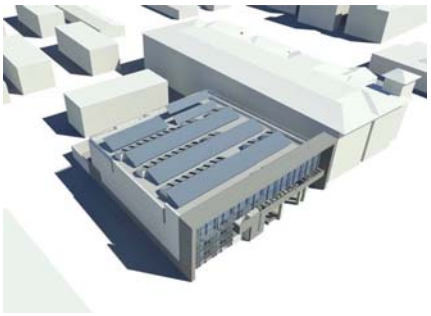
On-Site Energy Production: 27.7 (kBtu/sf-year), 75,350 kWhr/year

ZNE Case Study Building: West Berkeley Branch Library

VICINITY MAP



ZNE Case Study Building: West Berkeley Branch Library



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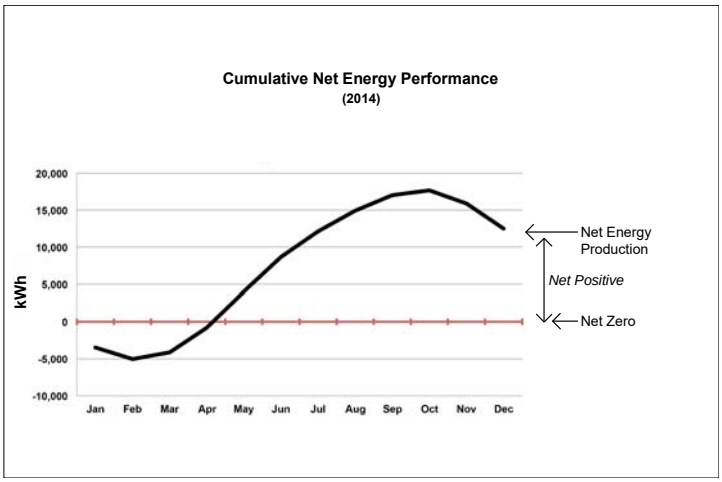
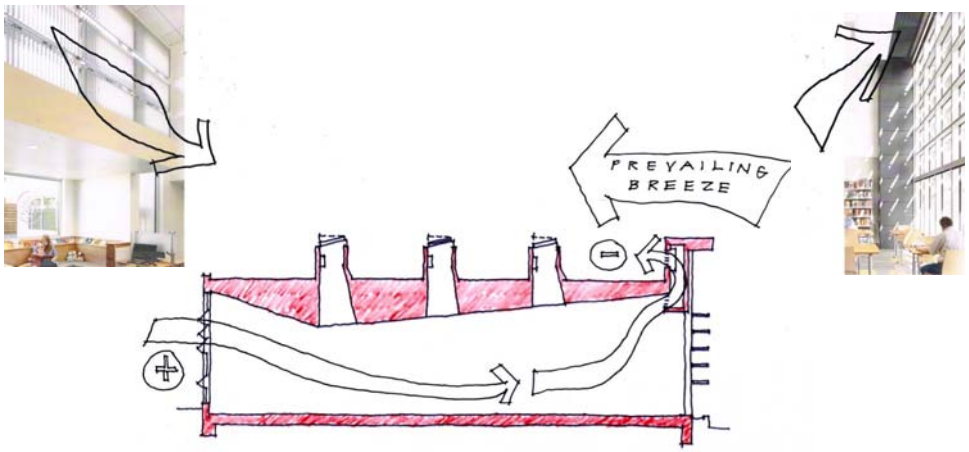


ZNE Case Study Building: West Berkeley Branch Library

Natural Ventilation Design Strategy



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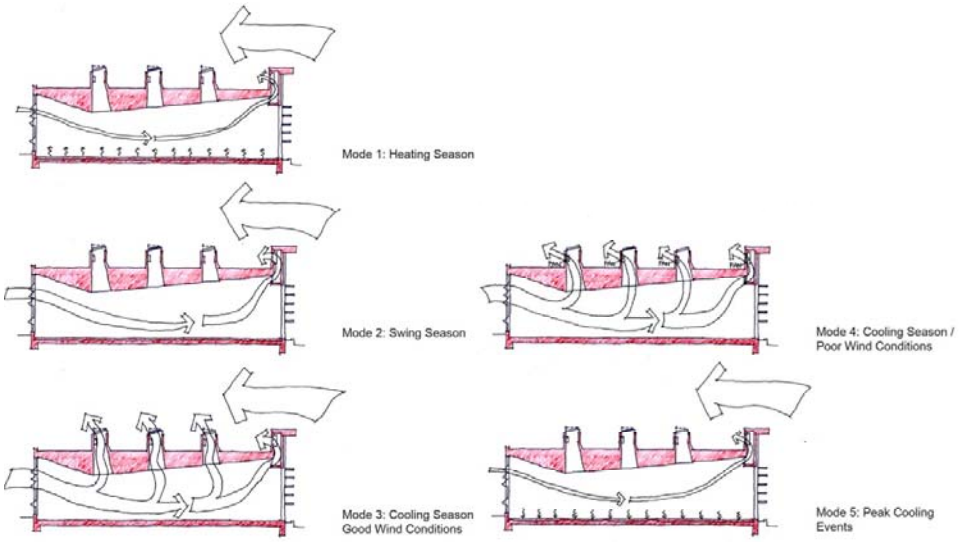

ZNE Case Study Building: West Berkeley Branch Library

What Went Wrong:

- Control system poorly integrated: no *master system integrator*.
- Hardware was inadequate to the task: windows could open to only four set positions. Continuous, fine adjustment not possible
- System would close the windows rather than go to minimal setting for fresh air.
- No *User Education*: resulted in one instance of broken actuator when window was forced open.

ZNE Case Studies: What Went Wrong

Questions?

ZNE Case Studies: What Went Right

Paul Scl
Rocky Mountain Institute Innovation Center
The Bullitt Center

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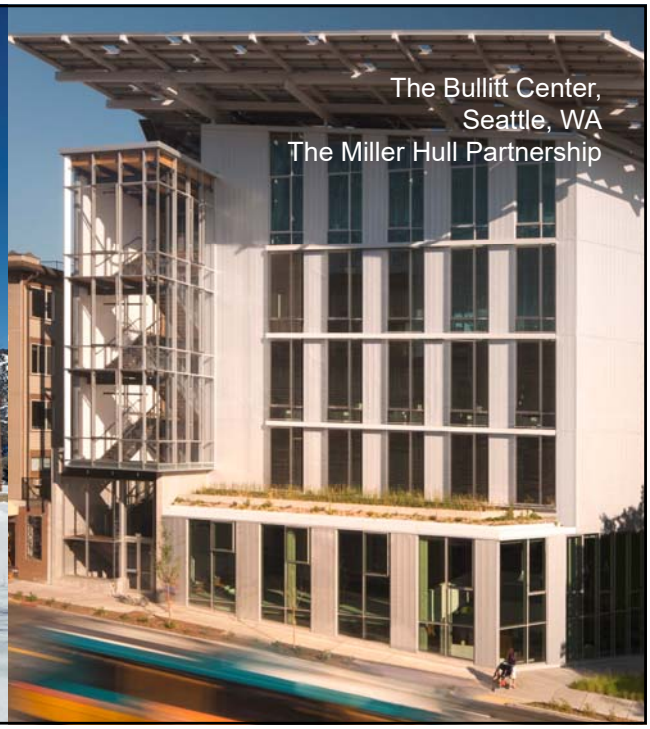
Rocky Mountain Institute Innovation Center
Basalt, CO
ZGF Architects



The Bullitt Center,
Seattle, WA
The Miller Hull Partnership

RMI's Vision

ROCKY MOUNTAIN INSTITUTE®

RMI's vision is a world thriving, verdant, and secure, for all, for ever.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Salt Lake City
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Tooele
Sandy
Provo
Routt National Forest
Greeley
Sterling
Longmont
McCook
Boulder
Denver
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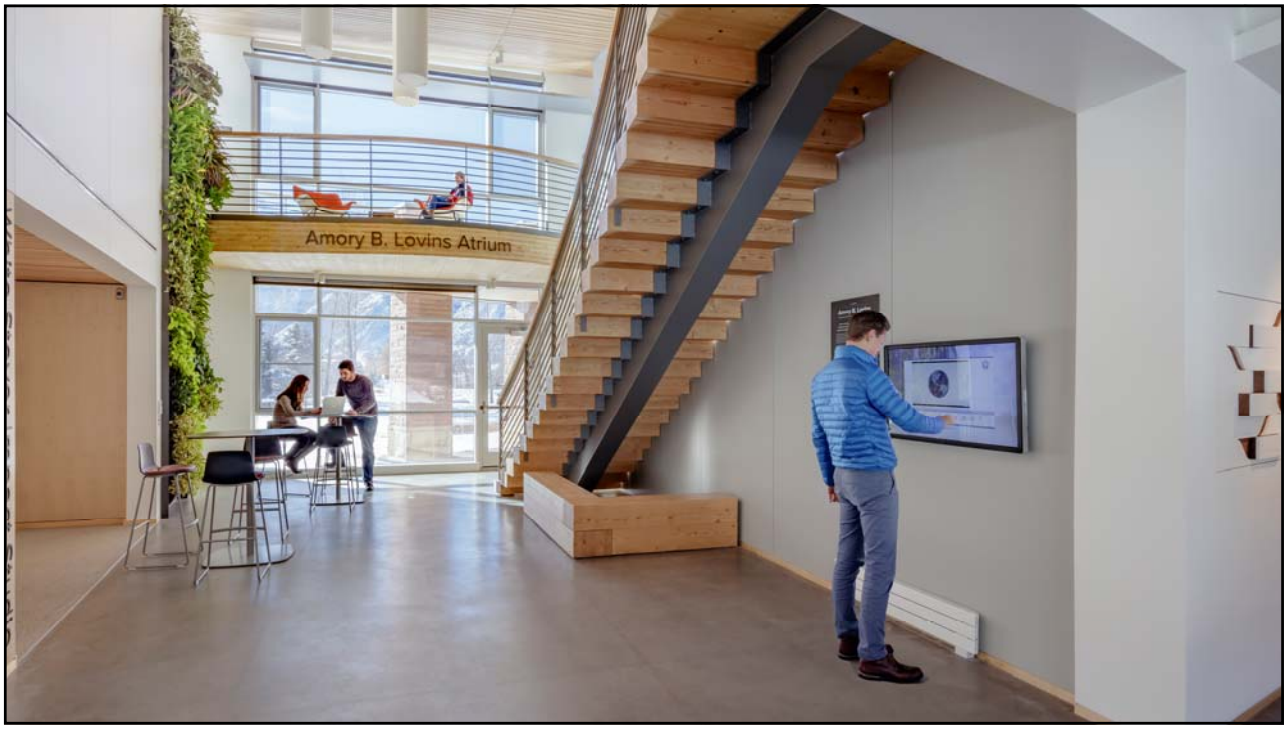
Glenwood Springs
Centennial
Castle Rock
Colorado
Utah
Grand Junction
Grand Mesa National Forest
Colorado Springs
Fountain Valley
Fishlake National Forest
Cañon City


Amory B. Lovins Atrium

Thermal Comfort in the News

The New York Times

Chilly at Work? Office Formula Was Devised for Men

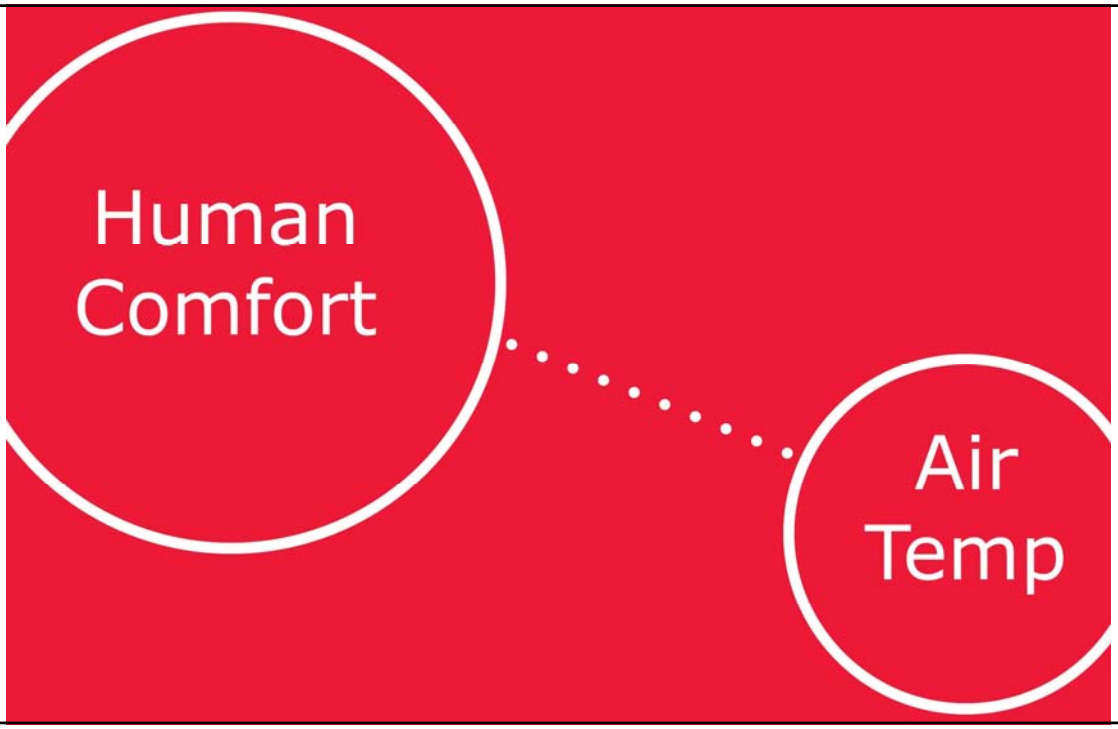
ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

Building standards aren't to blame for chilly offices

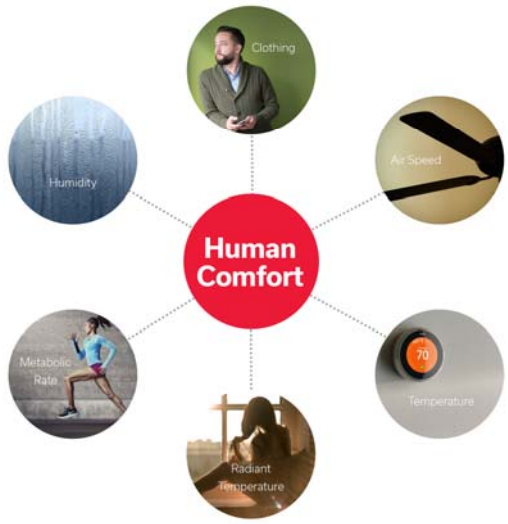
npr

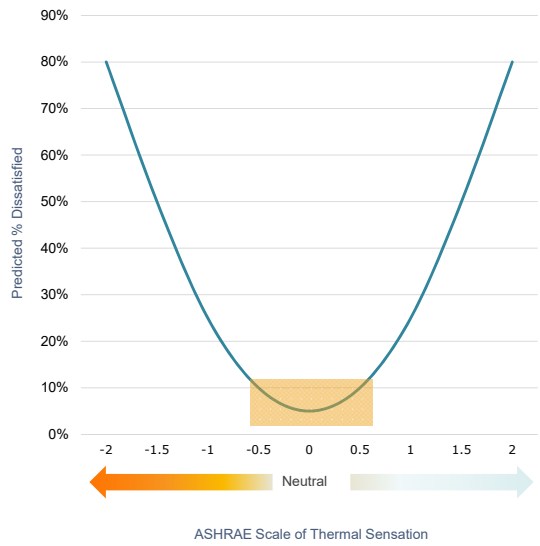
Women, There's A Reason Why You're Shivering In The Office

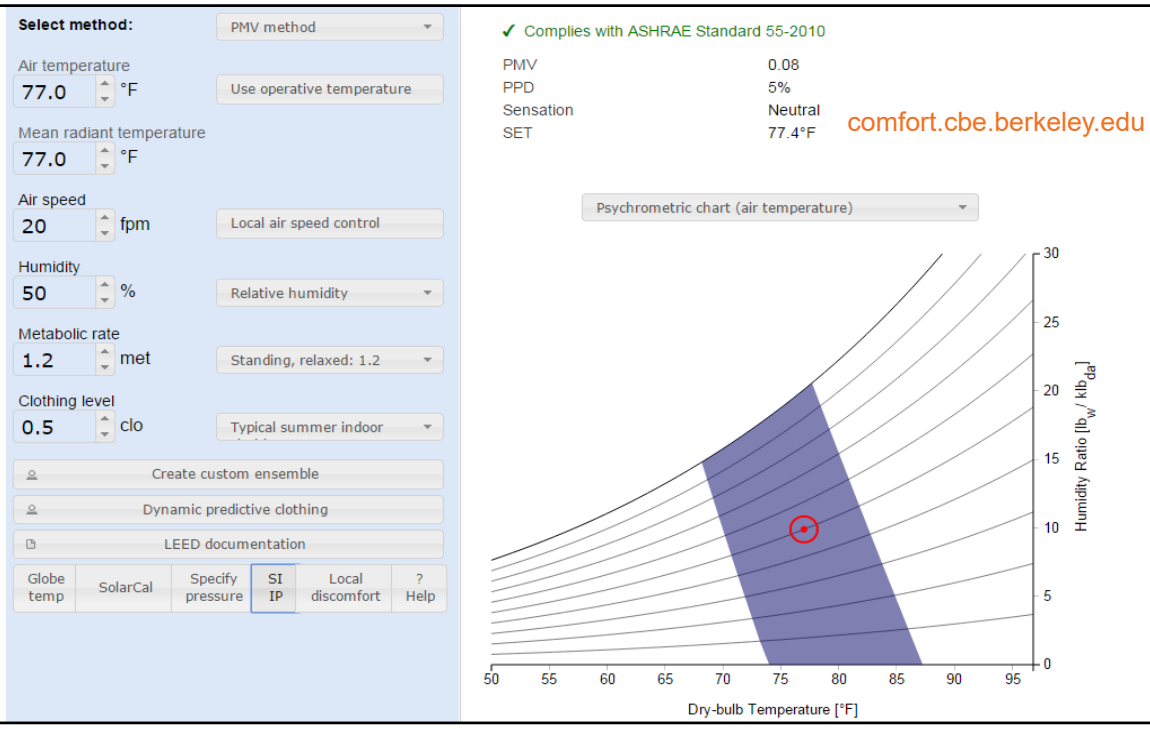
Thermal Comfort

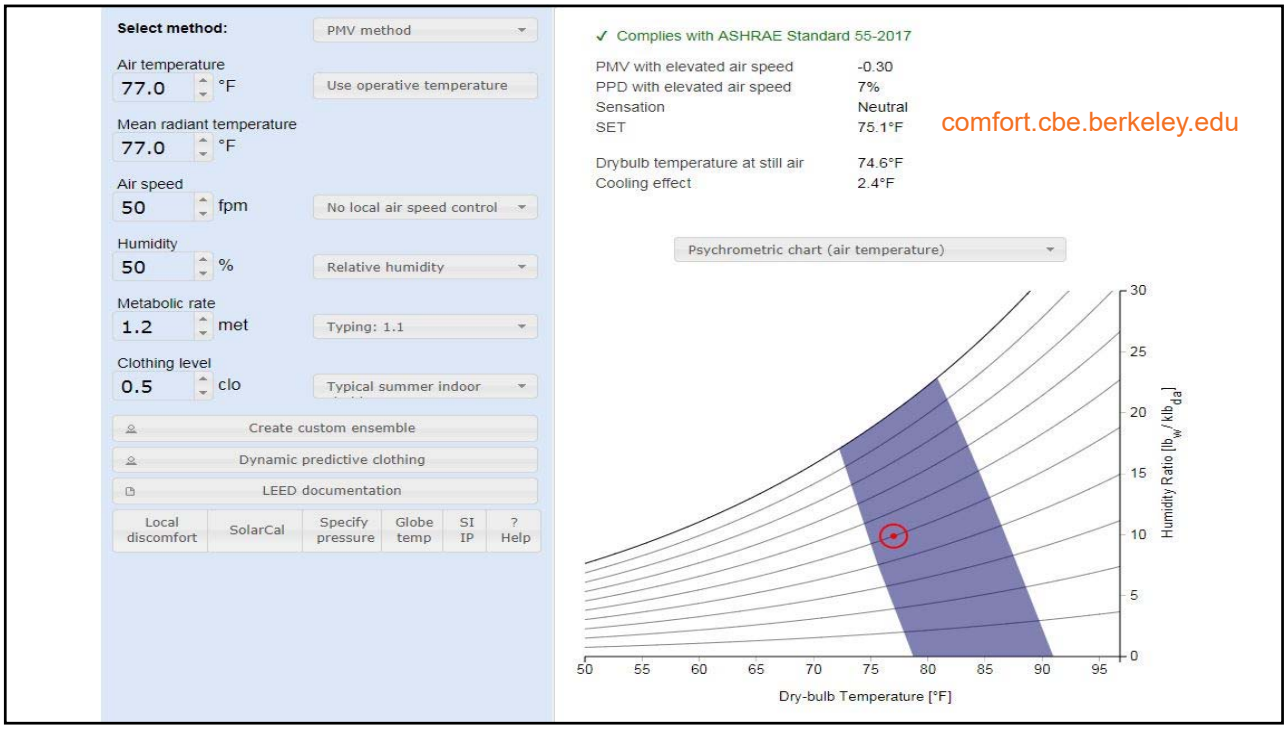

Human
Comfort
Air
Temp

Thermal Comfort Predictive Mean Vote (PMV)



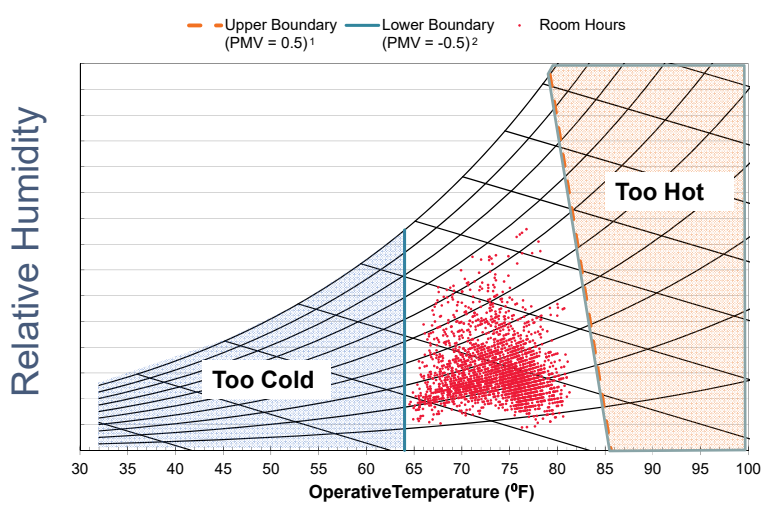






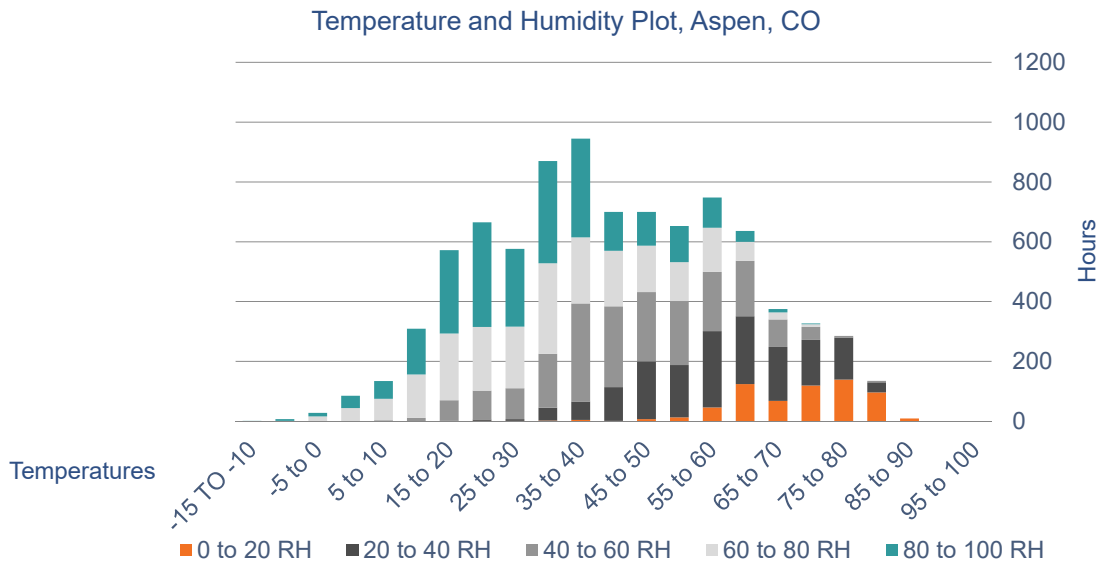
As Designed

Room Thermal Comfort Performance

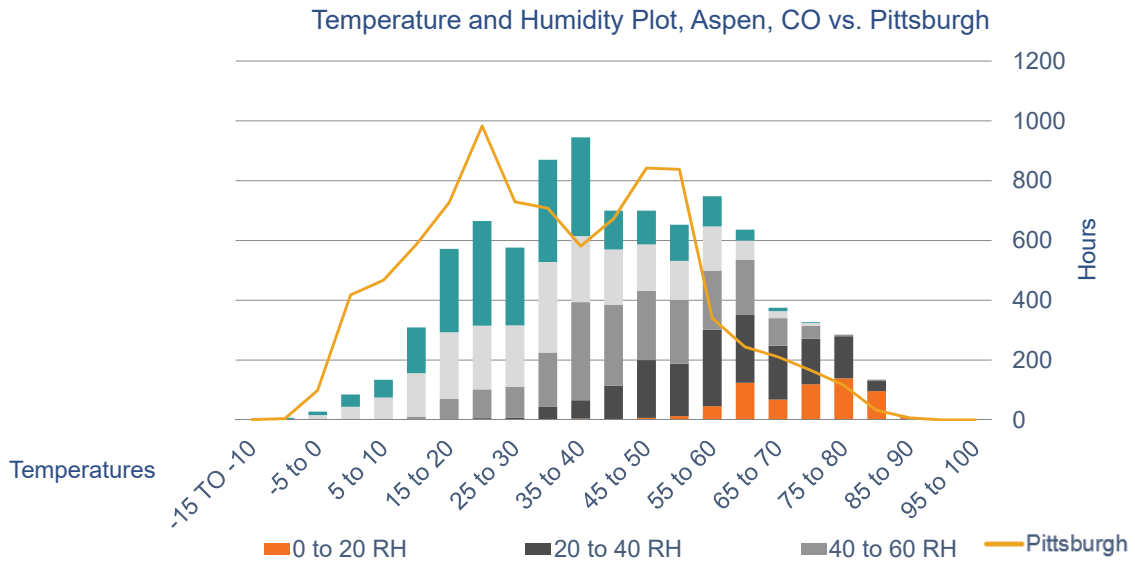


1. Upper boundary is based on the Elevated Air Speed Model, ASHRAE Standard 55-2013 Appendix G
2. Lower boundary is based on implementation of the CBE Personal Comfort System

Climate



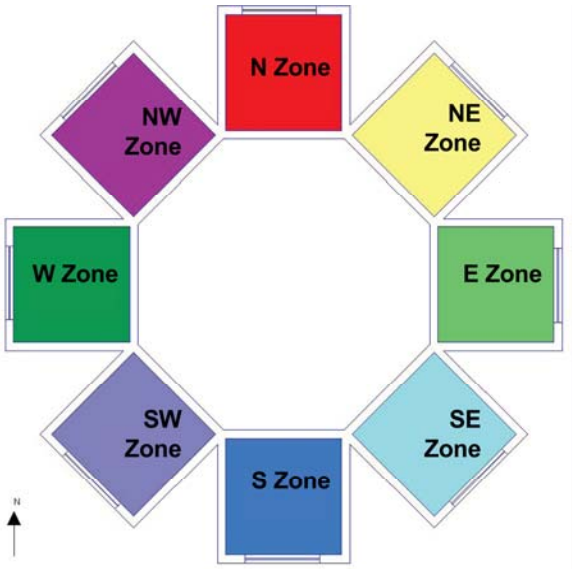
Climate



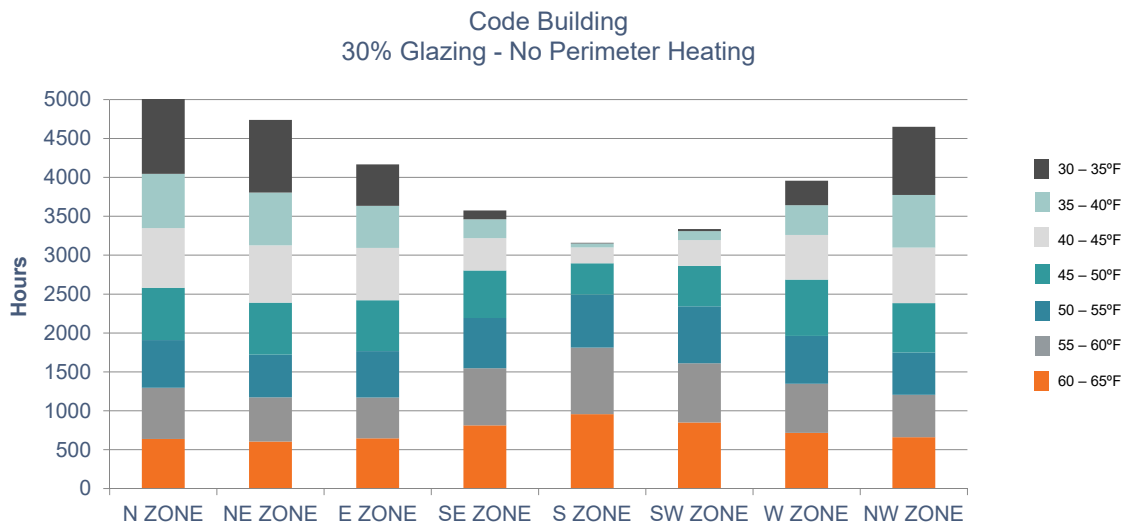
Earliest Modeling – Octagon Model

Simplified model to examine:

- Energy Use
- Peak Loads
- Comfort



Heating



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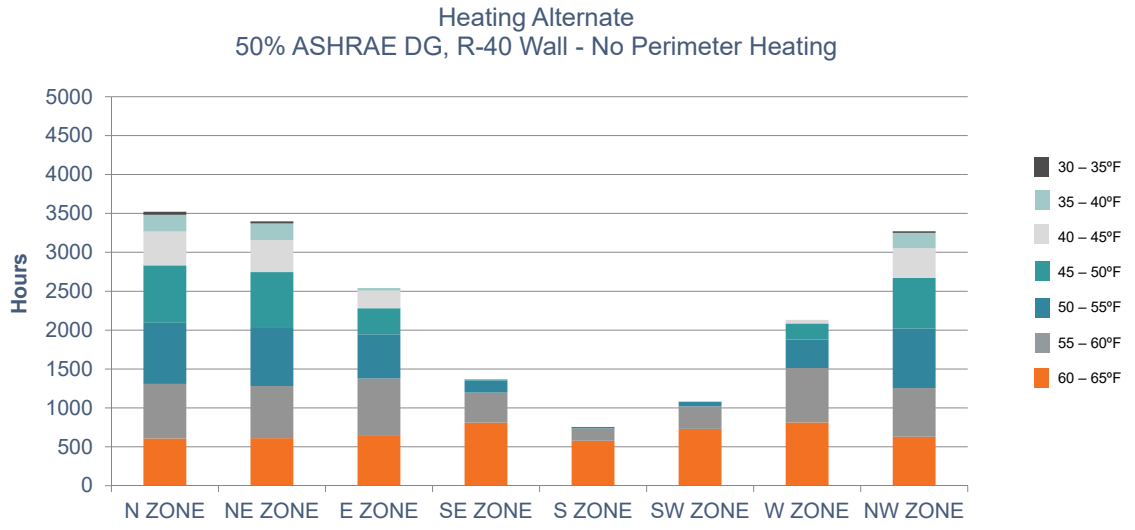
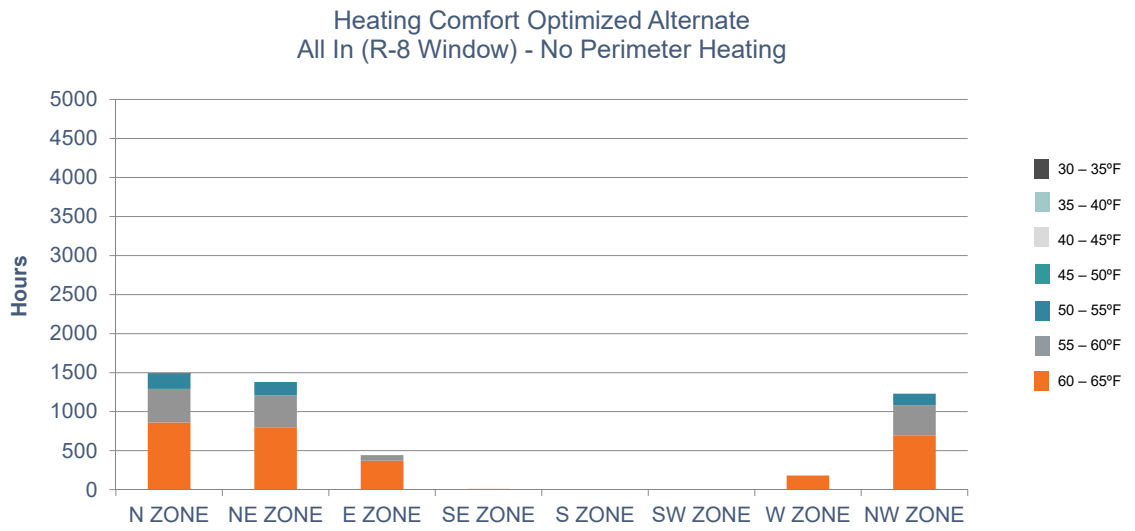
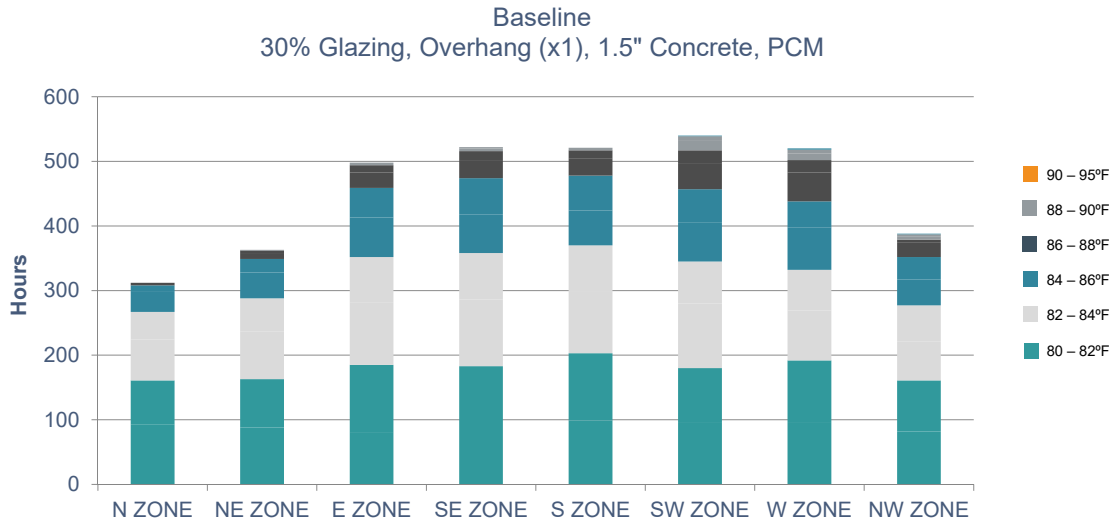


Heating



Cooling



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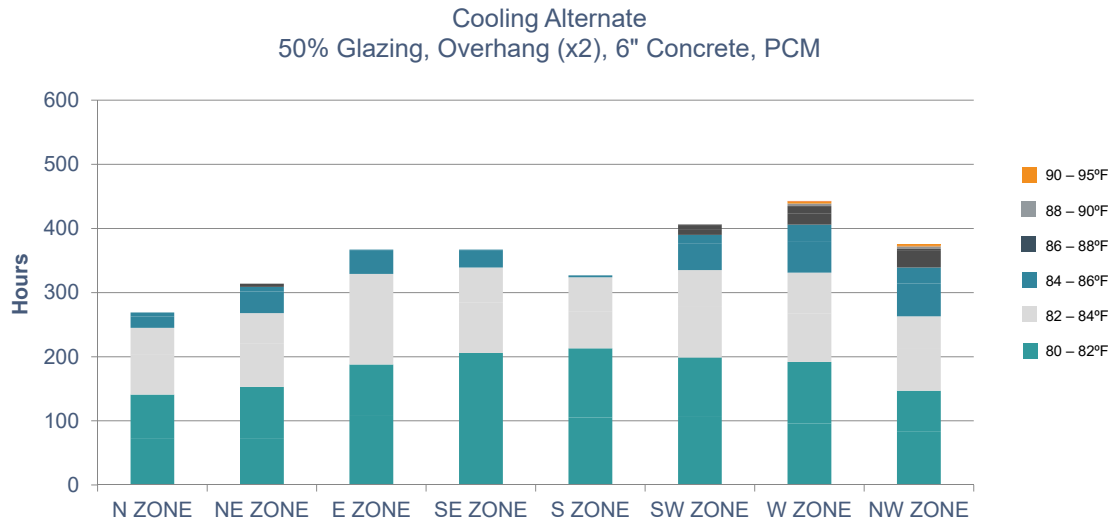
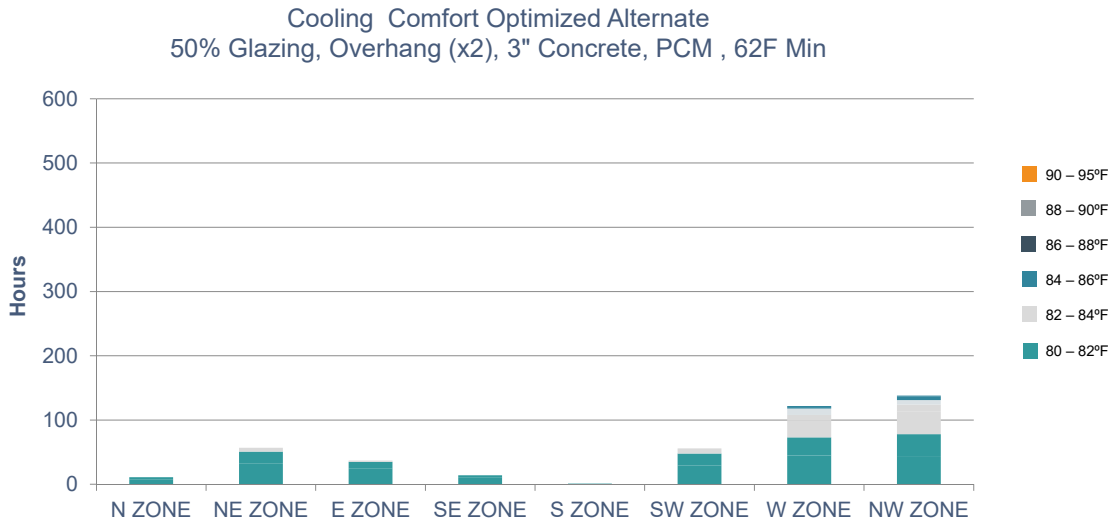
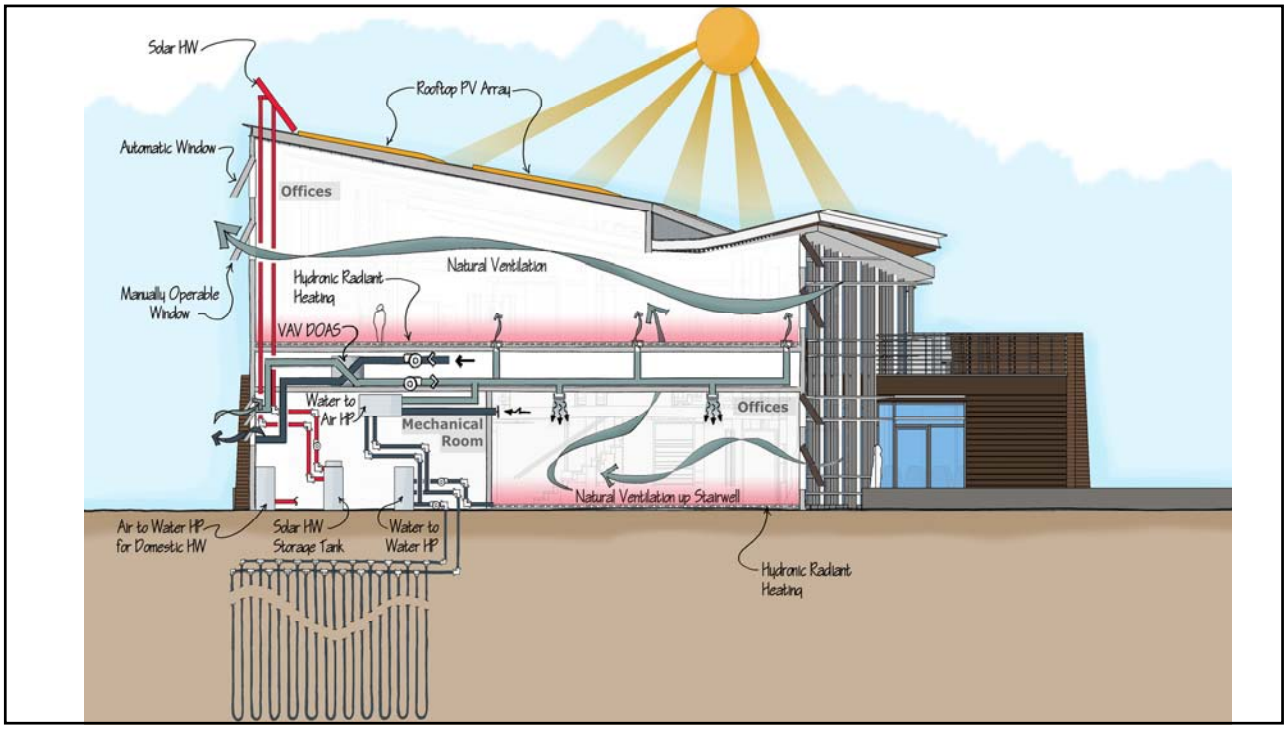
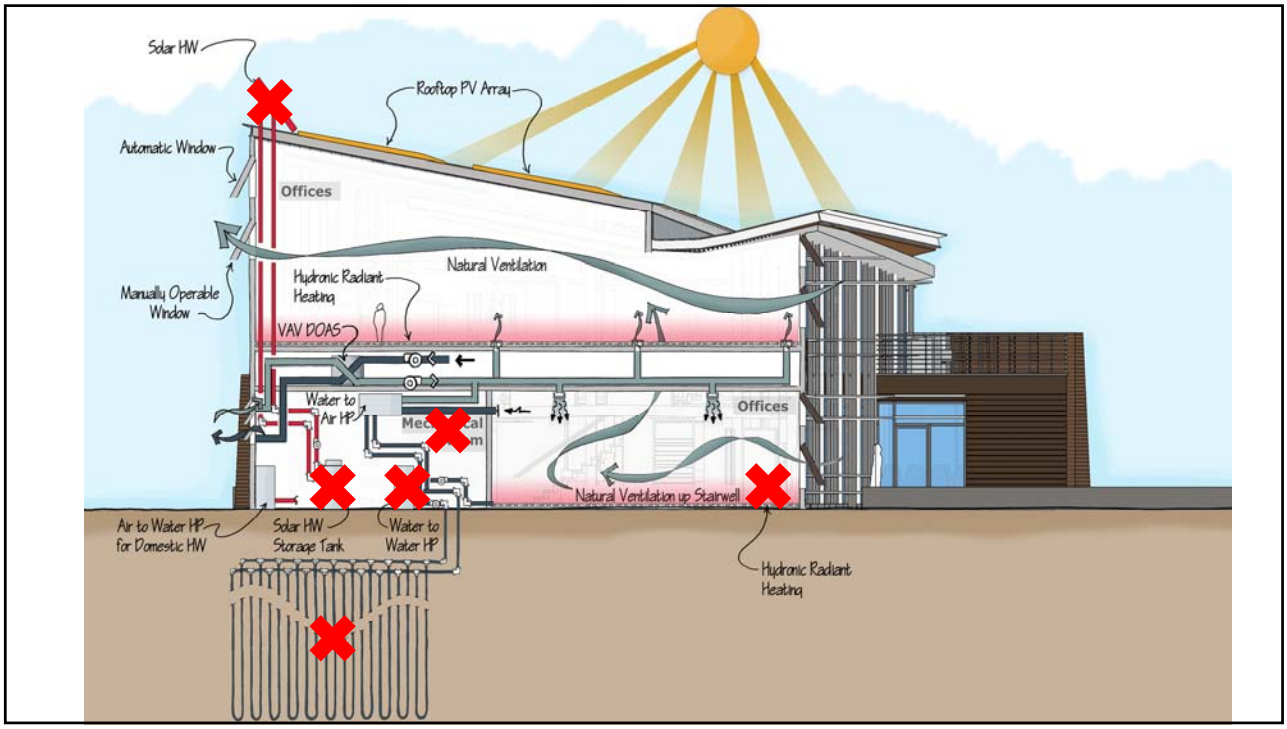


Cooling



Capture the Heat


Solar HW
Rooftop PV Array
Automatic Window
Offices
Natural Ventilation
Hydronic Radiant Heating
Manually Operable Window
VAV DOAS
Water to Air HP
Mechanical Room
Offices
Natural Ventilation up Stairwell
Air to Water HP for Domestic HW
Solar HW Storage Tank
Water to Water HP
Hydronic Radiant Heating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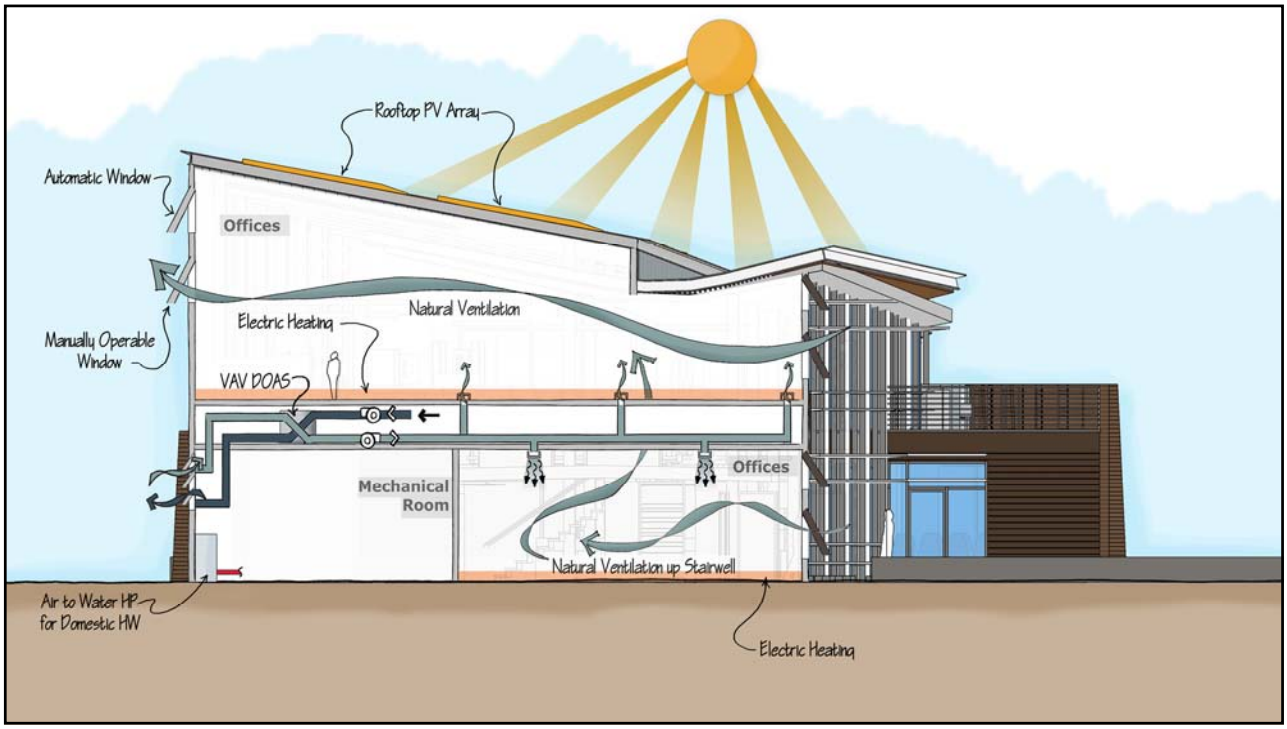
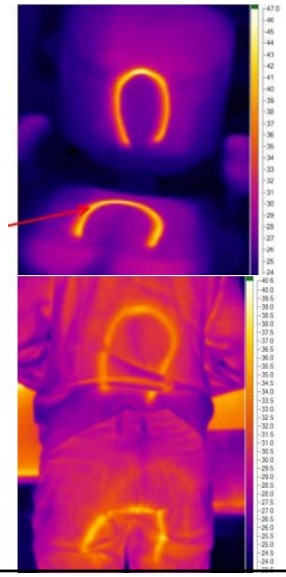
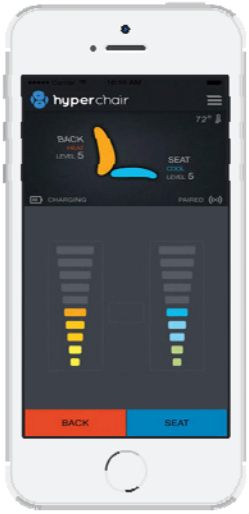


Personal Comfort – Hyperchair





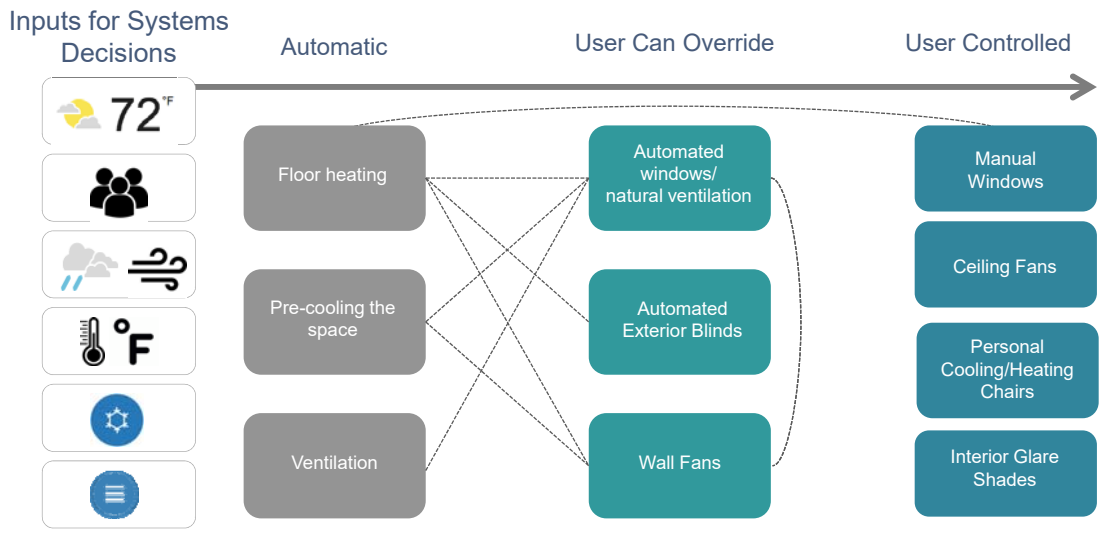
Personal Comfort

Controls

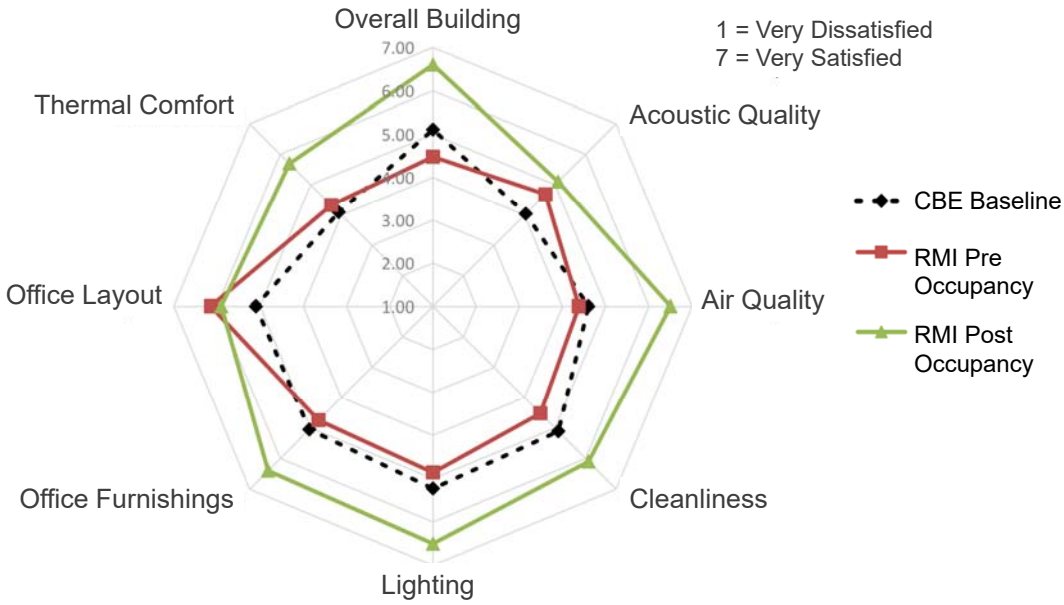
What we thought we had

What we actually had

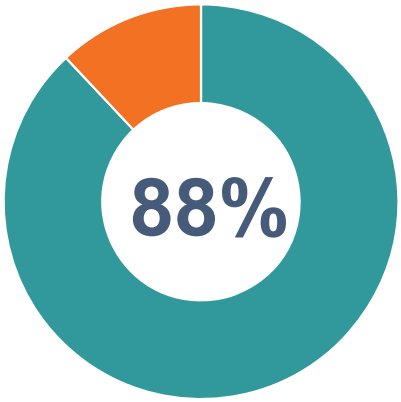
Simple Concepts, Complex System Interplays



CBE Post Occupancy Survey Results



Key RMI Findings – Occupant Surveys



'Very Satisfied, 'Satisfied' or 'Somewhat Satisfied' with space temperature

What We Learned

System limitations impact response time
Long cloudy periods = too cold
Incoming sun = too hot

Where We Succeeded

Lighting – positive feedback on the light, views and air movement within the building

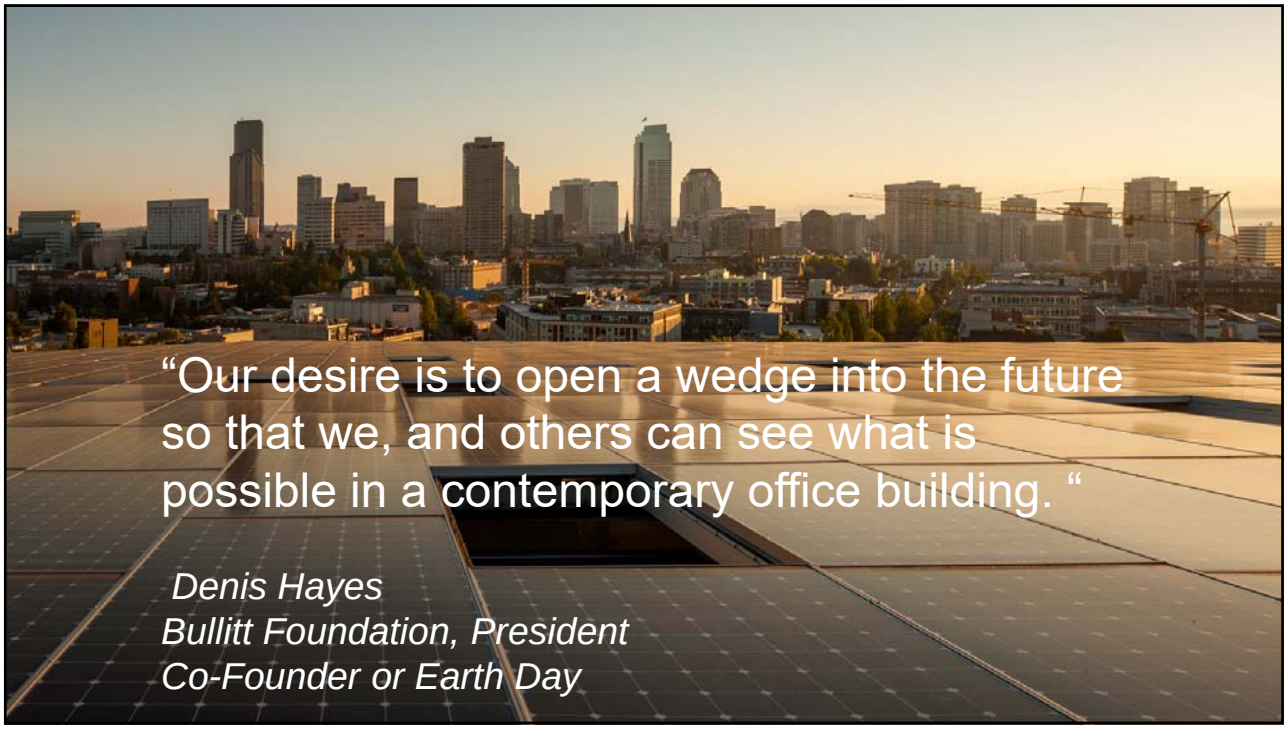
RMI Performance

Net **positive** building two years running

Actual operating **EUI 15.9**

Predicted EUI of 17.2


The Bullitt Center


"Our desire is to open a wedge into the future so that we, and others can see what is possible in a contemporary office building. "
Denis Hayes
Bullitt Foundation, President
Co-Founder or Earth Day

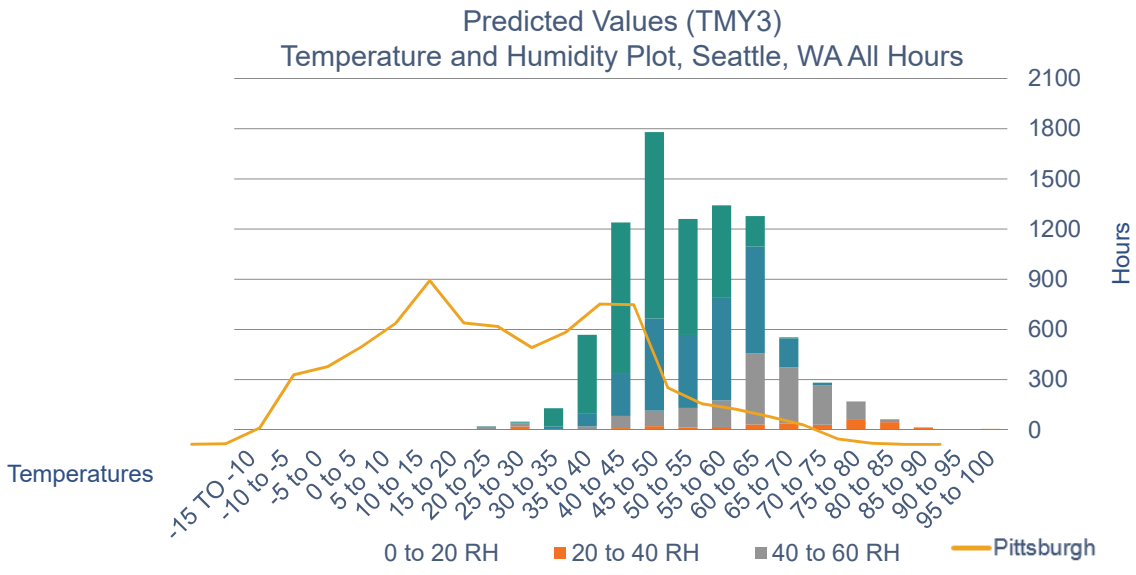
Bullitt Center Performance

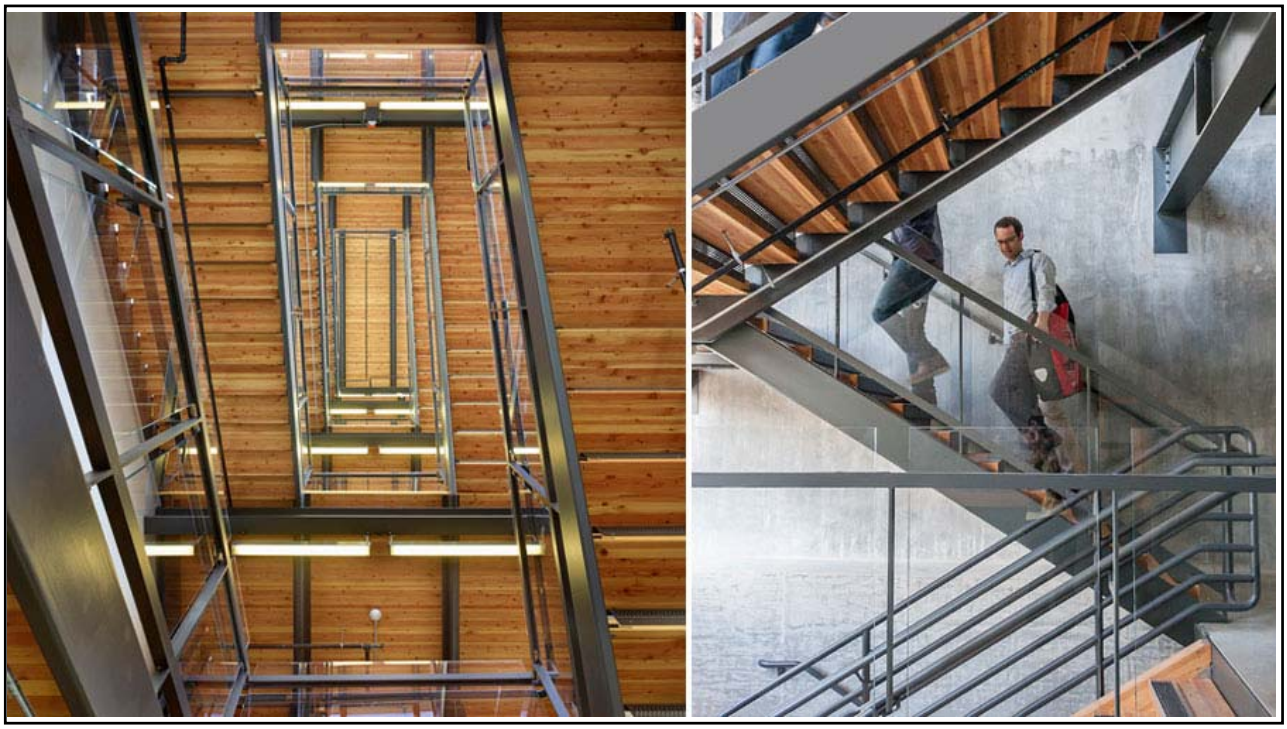
Net **positive** building five years running

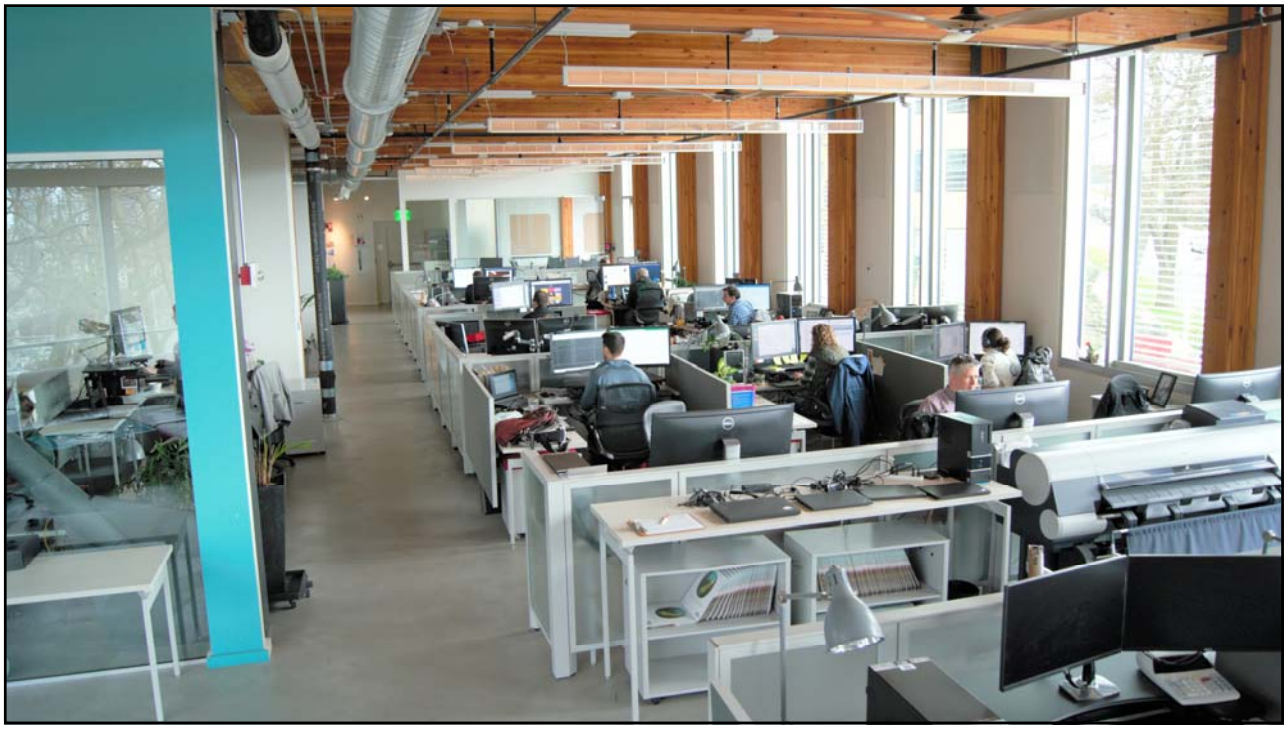
Actual operating EUI **~14**

Predicted EUI of 16

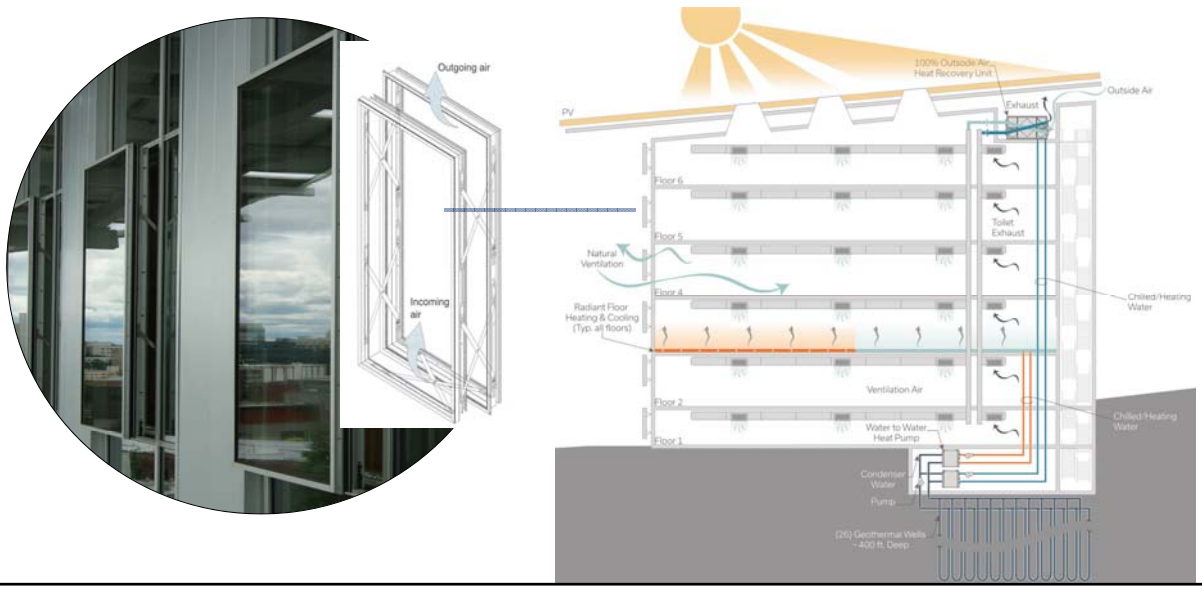
Climate



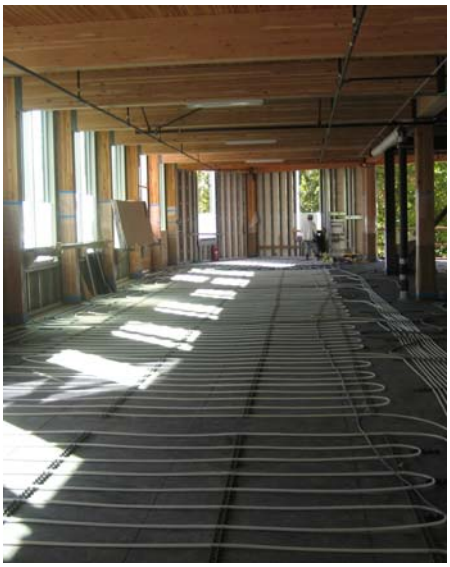


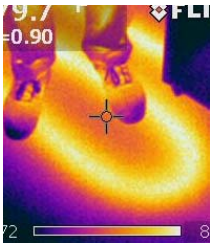


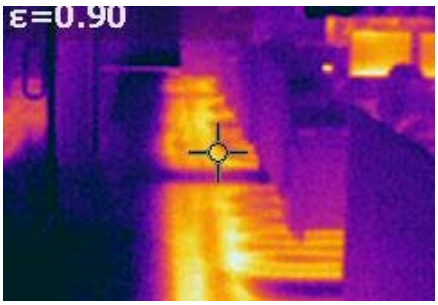
Net Zero Energy – Mixed Mode HVAC



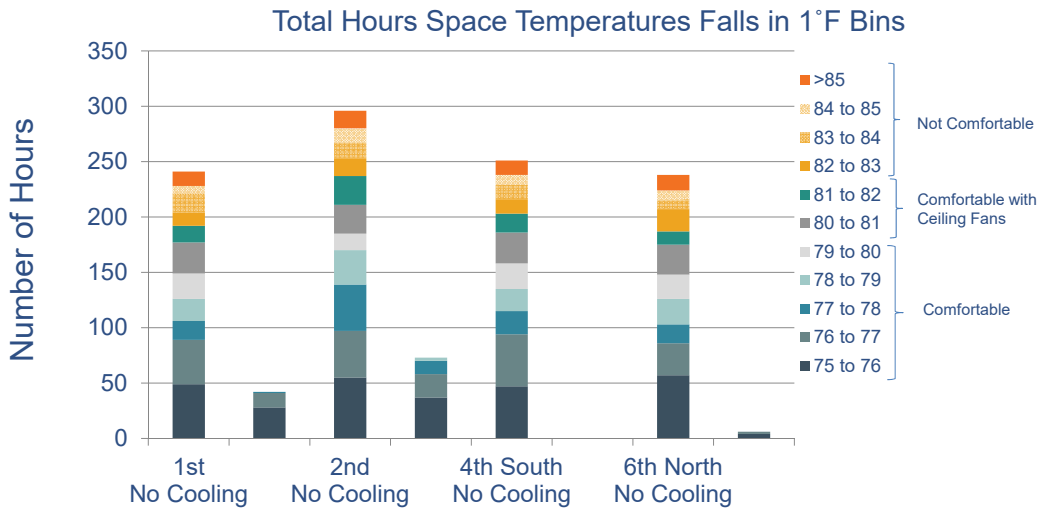
Radiant Floor



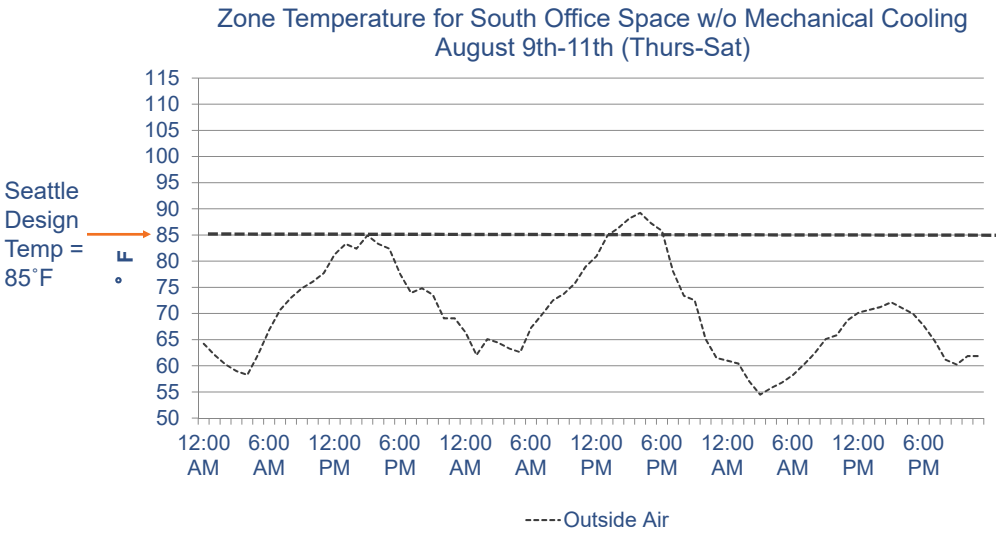




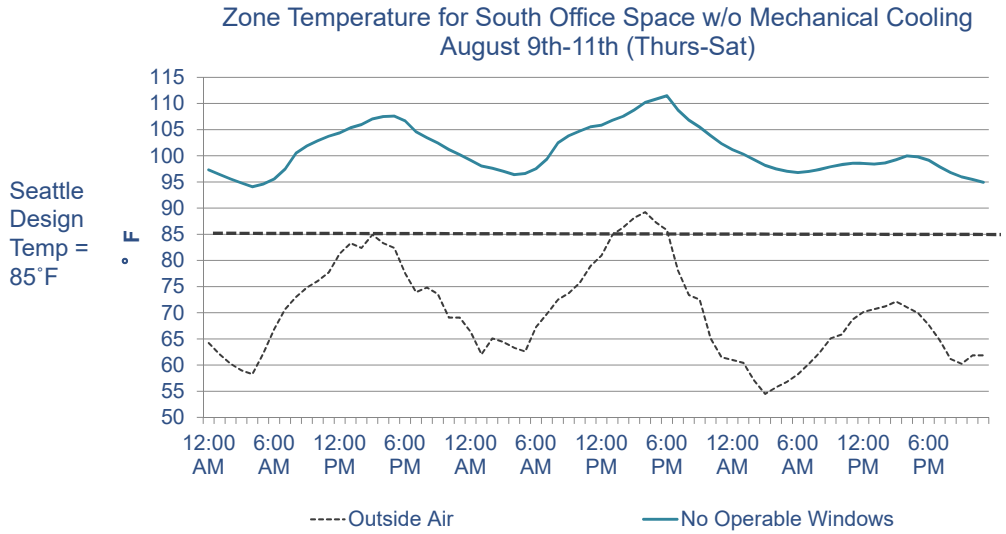
Bullitt Center Comfort Study



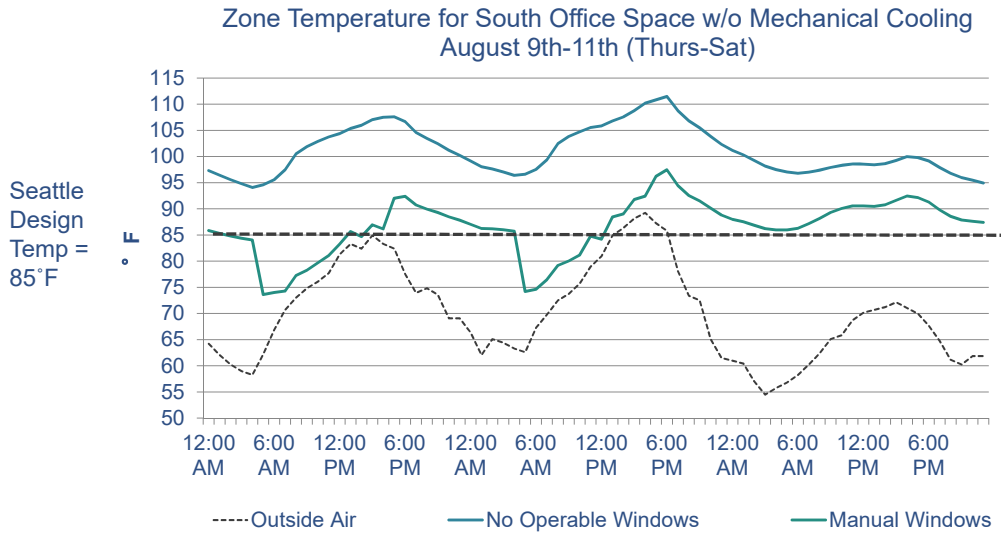
Passive Cooling



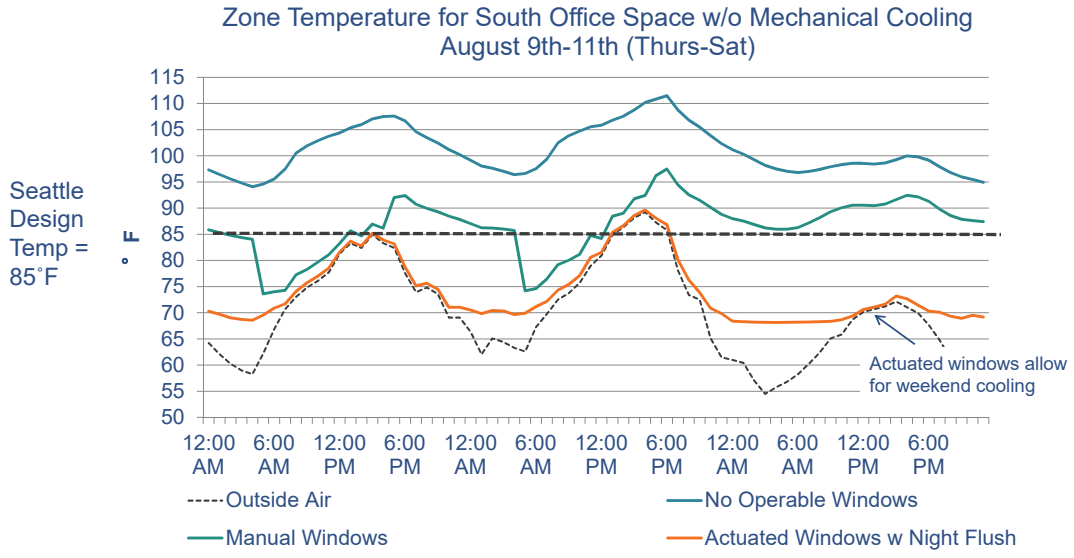
Passive Cooling



Passive Cooling



Passive Cooling



ZNE Case Studies: What Went Right

Questions?

Lessons Learned: Hardware and Control Systems

Kasper Hoejmark Ravn — WindowMaster

Design tools

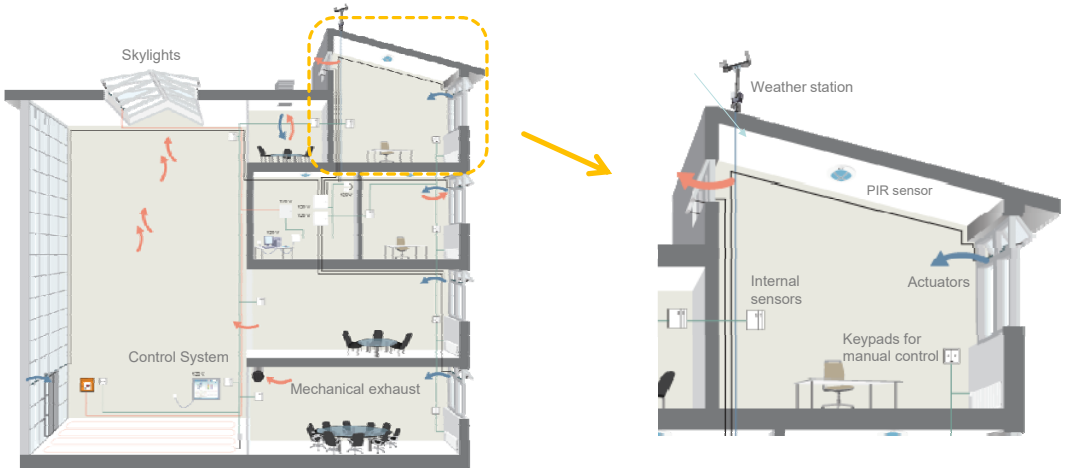
System communication

Motor control

System example

4

General Hardware in a Natural Ventilation System



Lessons Learned from Ed's Case Studies

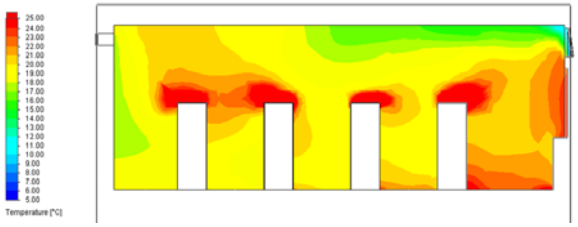
1. Lack of fine adjustment
2. Noisy actuators
3. "Green light" system
4. User behavior
5. System integration
6. Insufficient air flow
7. Condensation problems

Features of the Actuators

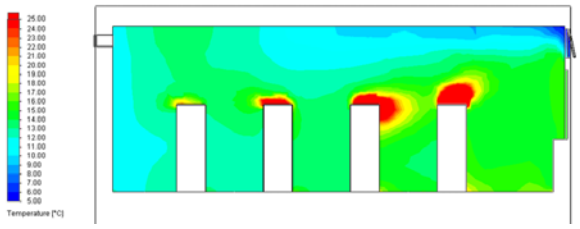
- Millimeter precise position control and actuator feedback
- Three speed actuator operation for noise and function control
- Genuine synchronisation between multiple actuators on the same window
- Pressure safety function reducing the risk of entrapment when closing
- Reversing function to protect weather seals
- Fault indication
- Online parameter set-up



Features of the Actuators



Optimal position
= 8 degree of opening



Non optimal position
= 12 degree of opening

Actuator Communication Protocol

Actuator

MotorController

BMS systems

MotorLink®

Interface between BMS systems and window actuators

Features

- Position control and feedback
- Three speed operation
- Reversing function
- Genuine synchronization
- Reducing the risk of entrapment
- Online parameter
- Etc.

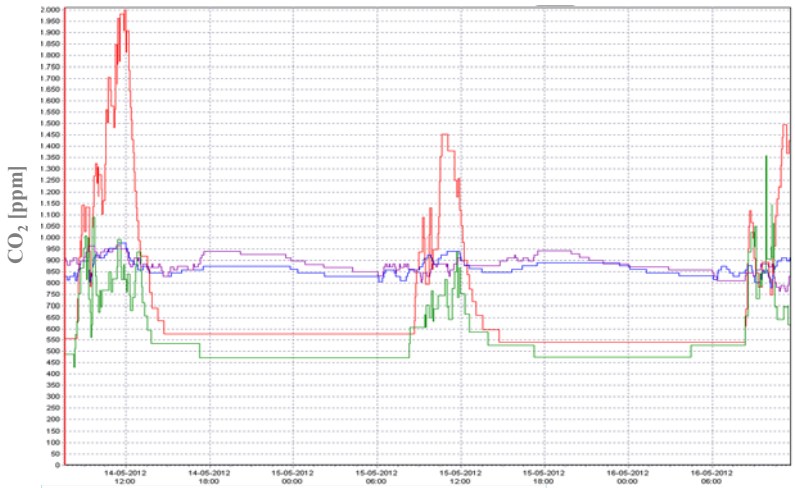
Open bus communication

- BACnet
- KNX
- LON
- Modbus

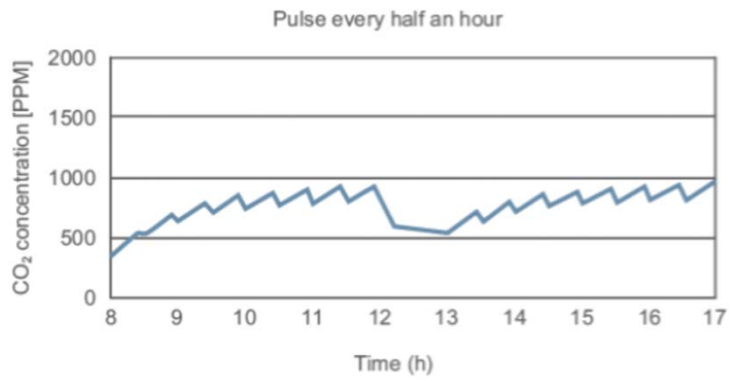
Lessons Learned from Ed's Case Studies

1. Lack of fine adjustment
2. Noisy actuators
3. "Green light" system
4. User behavior
5. System integration
6. Condensation problems
7. Insufficient air flow

User Control vs. Automatic Control



Ventilation Strategies

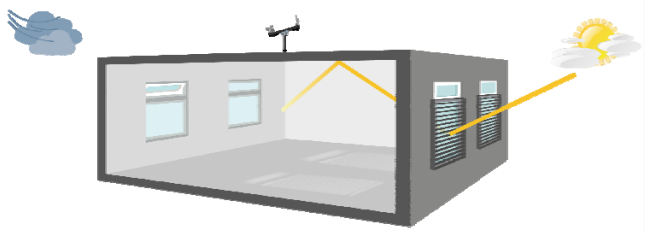


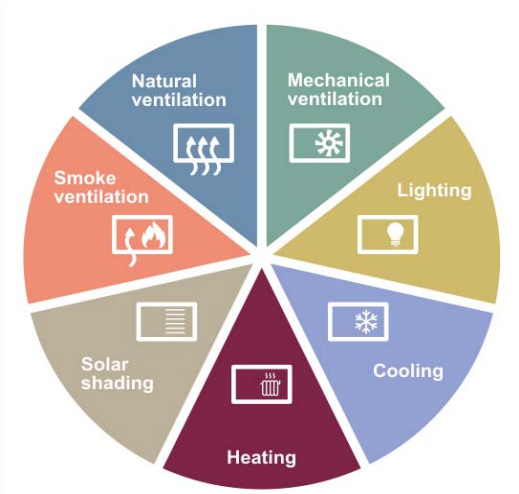
Example of the estimated CO_2 levels in a room with natural ventilation (winter mode)

Lessons Learned from Ed's Case Studies

1. Lack of fine adjustment
2. Noisy actuators
3. "Green light" system
4. User behavior
5. System integration
6. Condensation problems
7. Insufficient air flow

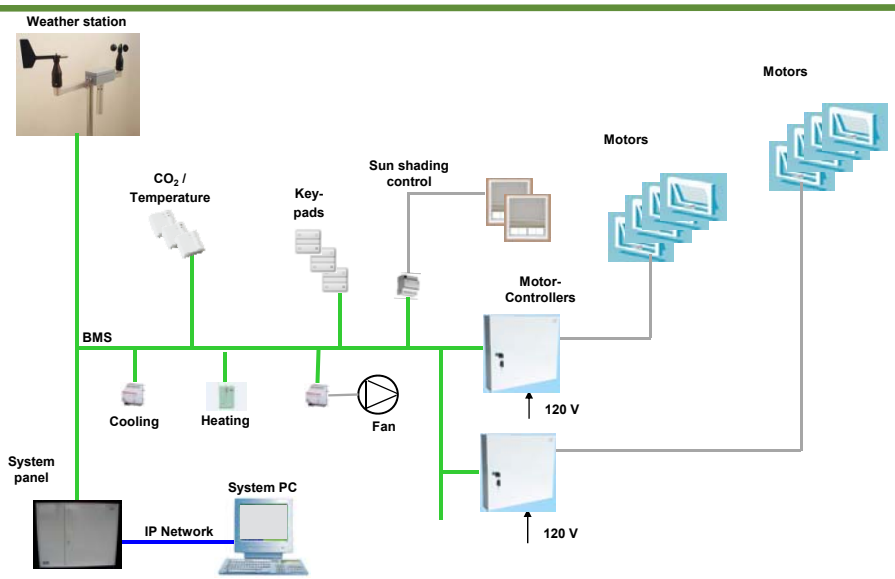
System Communication



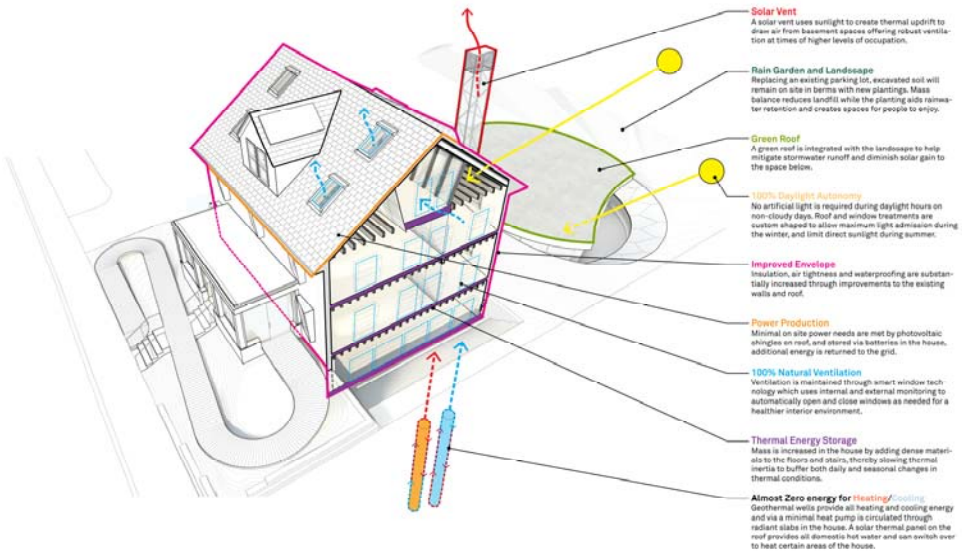


One control system – integrated seamlessly with other solutions

System Example



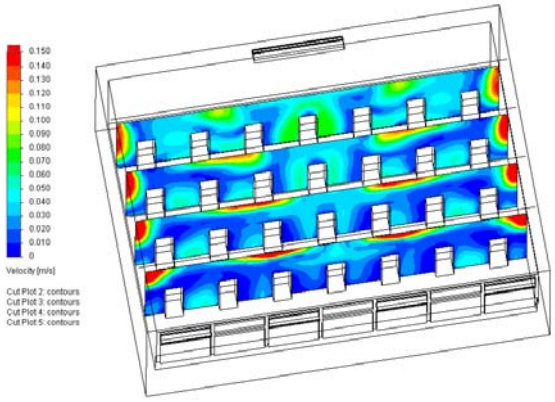
HouseZero

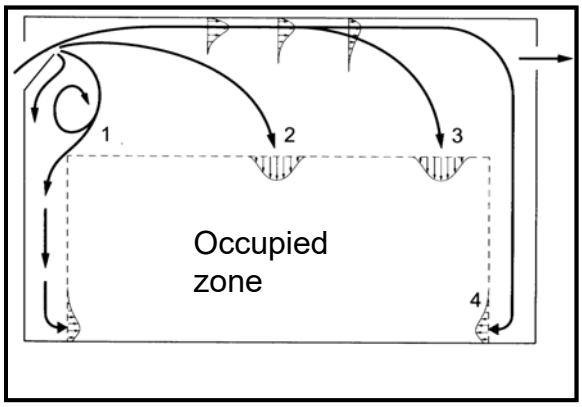


Lessons Learned from Ed's Case Studies

1. Lack of fine adjustment
2. Noisy actuators
3. "Green light" system
4. User education
5. System integration
6. Condensation problems
7. Insufficient air flow

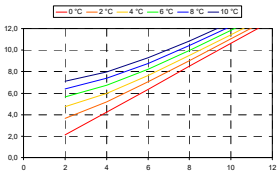
Air Flow





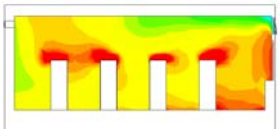
Predictive Design Tools

Basic hand calculations

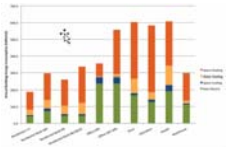


Dynamic simulations

CFD – internal

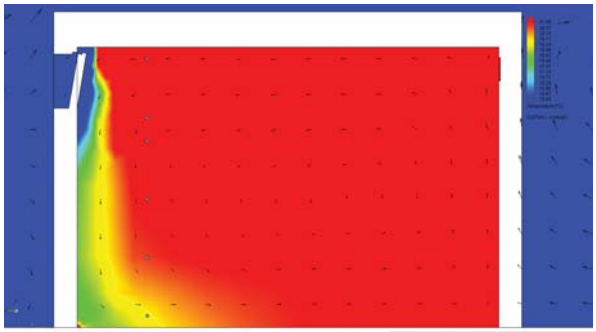


Energy calculations

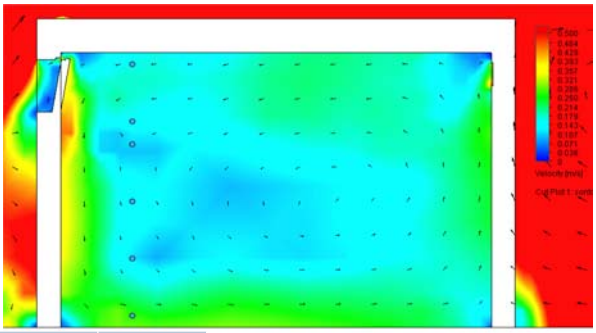


Predictive Design Tools

Temperature plot



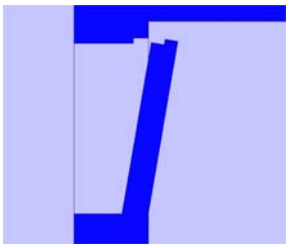
Velocity plot



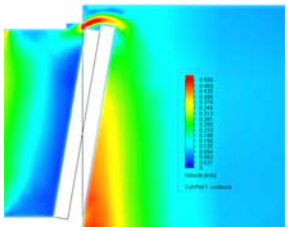
Height [m]	Temperature [ºC]	Air speed [m/s]	DR [%]
0,1	19,6	0,15	14,7
0,6	20,7	0,07	4,3
1,1	21,2	0,08	5,4
1,6	21,5	0,05	0
1,8	21,6	0,08	5,3
2,3	21,8	0,14	11,4

Predictive Design Tools

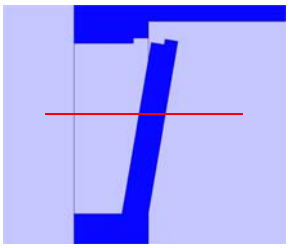
Cross section of window



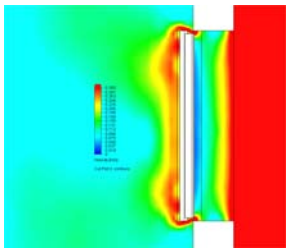
Respective air flow



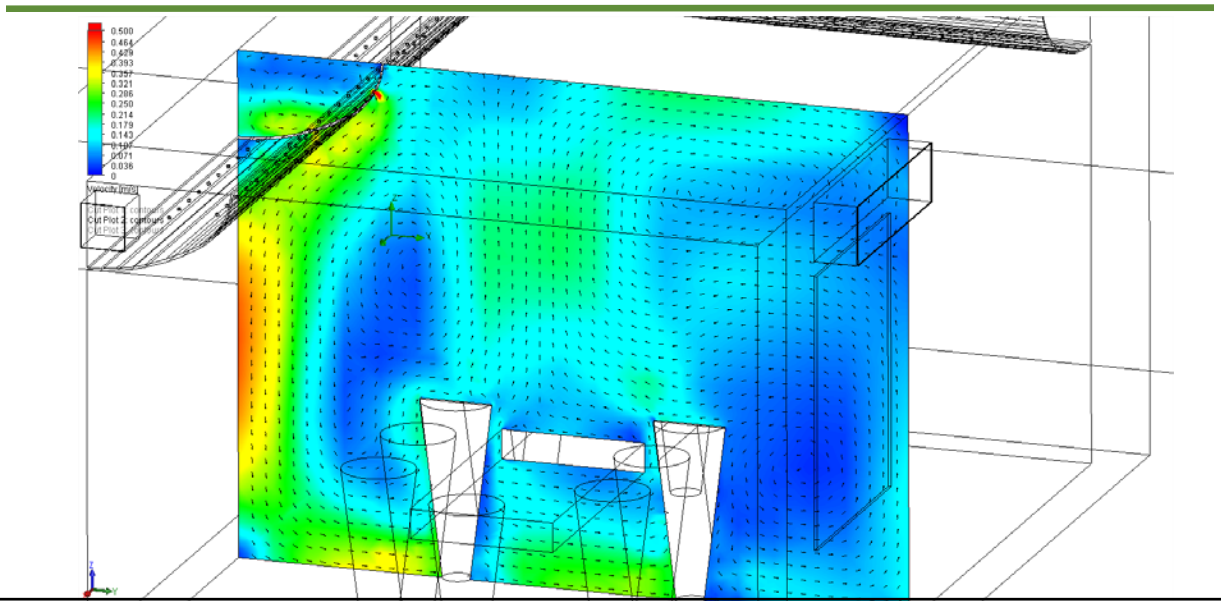
Cross section (red line)



Respective air flow



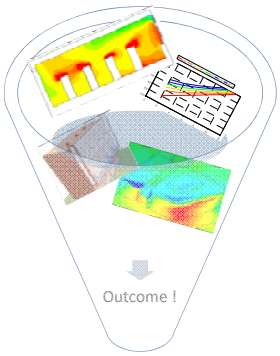
Predictive Design Tools



From Calculations to Reality

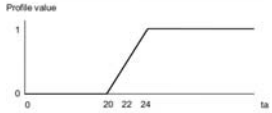
Calculations

- Design calculations (all parameters included)



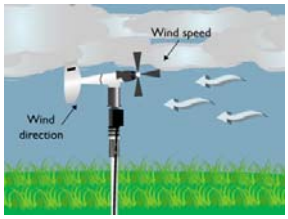
How it is controlled

- Temperature
- CO_2
- (RH)



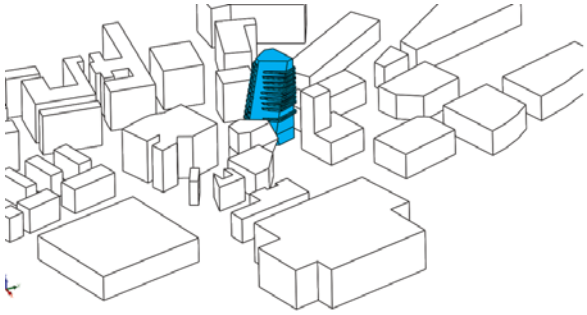
Missing link?

- One of the main driving forces for NV – wind (pressure)!

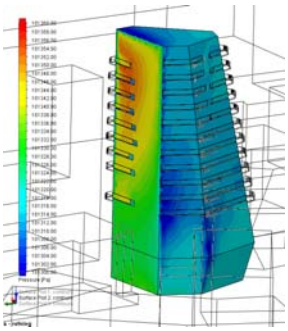


External CFD

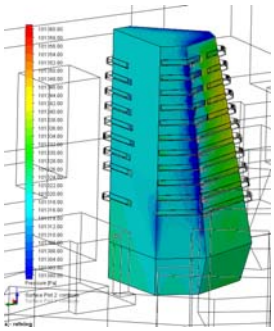
Model



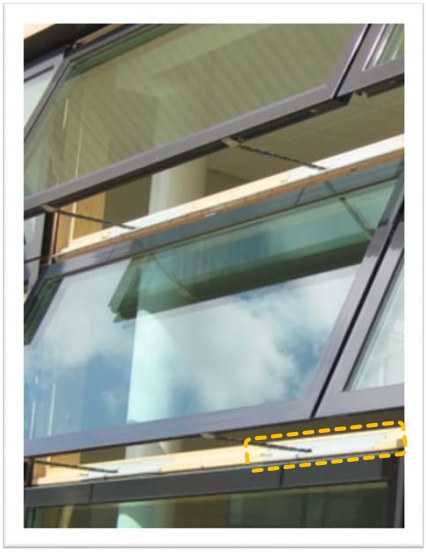
Wind direction north



Wind direction south

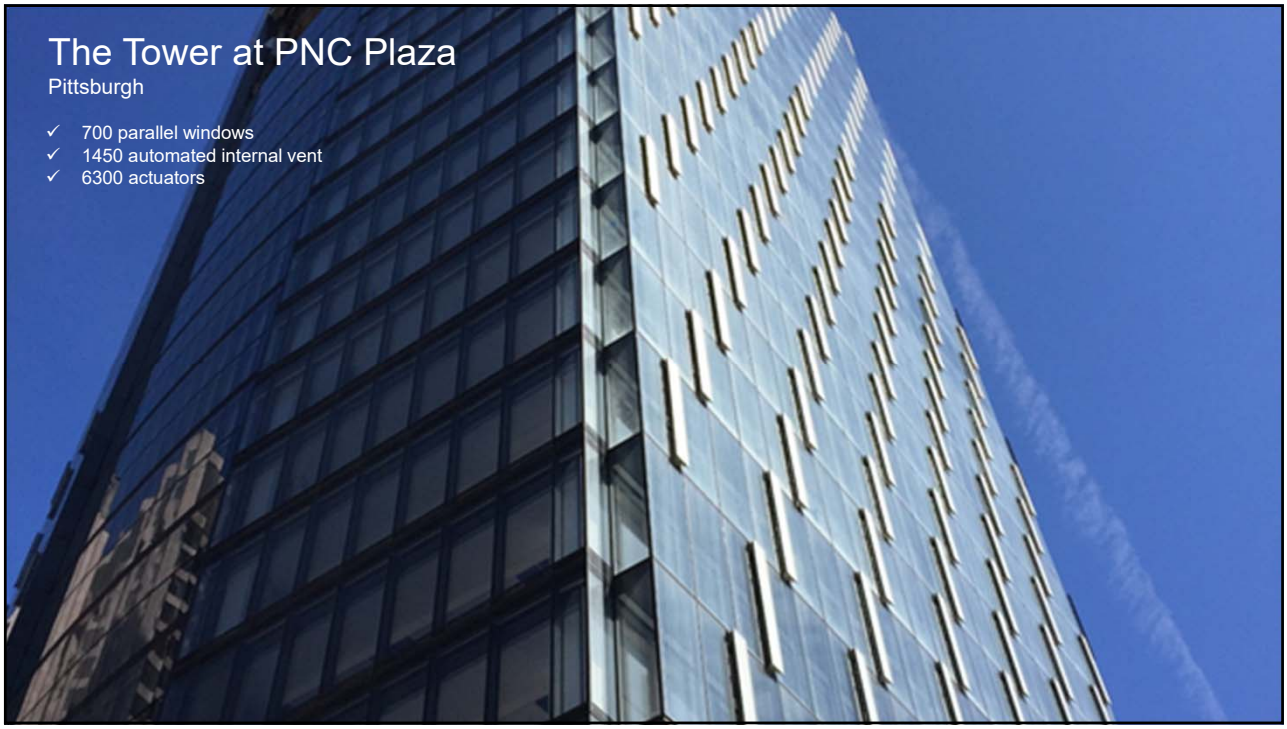


Actuators



Retrofits



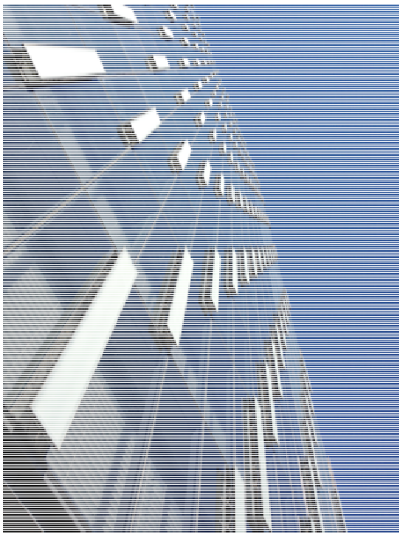


The Tower at PNC Plaza

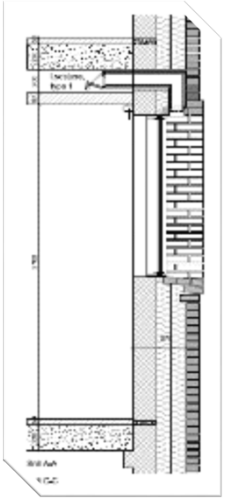
Pittsburgh

- ✓ 700 parallel windows
- ✓ 1450 automated internal vent
- ✓ 6300 actuators

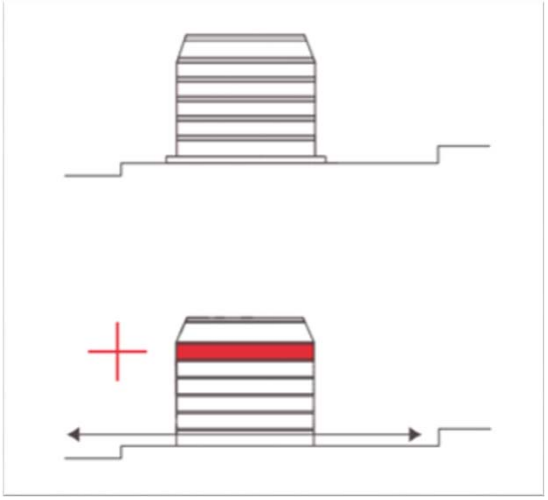
The Tower at PNC Plaza



Copenhagen Pakhuset



Copenhagen Pakhuset



Lessons Learned: Hardware and Control Systems

Questions?

Bernheim + Dean, Inc.
Sustainable Building Consultants

PAE

Window Master®
Fresh Air. Fresh People.

General Discussion and Q&A

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Sustainable Building Consultants

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