Navigating the Natural Ventilation Design Strategy in ZNE Buildings

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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

1. Introduction
2. ZNE Case Studies: What Went Wrong
3. ZNE Case Studies: What Went Right
4. Lessons Learned: Natural Ventilation Hardware and Control Systems
5. General Discussion and Q&A

Introduction

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
ZNE Case Studies: What Went Wrong

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

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

West Berkeley Branch Library (Berkeley, CA)
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

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

Cumulative Net Energy Performance
July 2014 - June 2015

- Net Zero
- Net Positive
- Net Energy Production
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
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:
IBEW-NECA Joint Apprenticeship Training Facility

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

Office Wing
Laboratory Wing

Level Two Plan

ZNE Case Study Building:
J. Craig Venter Institute Laboratory
ZNE Case Study Building: J. Craig Venter Institute Laboratory


- Net Zero
- Net Negative
- Net Energy Production

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
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)

Modelled 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

Heavy Traffic Noise

ZNE Case Study Building: West Berkeley Branch Library
ZNE Case Study Building: West Berkeley Branch Library

Cumulative Net Energy Performance (2014)

Net Energy Production
Net Positive
Net Zero

ZNE Case Study Building: West Berkeley Branch Library

Natural Ventilation Design Strategy
**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 Schwer
Rocky Mountain Institute Innovation Center
The Bullitt Center
RMI’s Vision

RMI’s vision is a world thriving, verdant, and secure, for all, for ever.
Thermal Comfort in the News

The New York Times

Chilly at Work? Office Formula Was Designed for Men

ScienceNews

Building standards aren't to blame for chilly offices

npr

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

WELCOME TO TEMPERATURE COURT.

ONE OF YOU HAS FROZEN APPENDAGES AND ONE OF YOU IS BURNING UP. BUT ONLY ONE TEMPERATURE CAN RULE THE OFFICE.

I RULE THAT THE THERMOSTAT MUST BE SET AT EXACTLY 72 DEGREES.

NOOOO!!! SHOOT ME!
Thermal Comfort Predictive Mean Vote (PMV)

ASHRAE Scale of Thermal Sensation

Select method:
PMV method

Air temperature
77.0°F

Mean radiant temperature
77.0°F

Air speed
20 ft/min

Humidity
50%

Metabolic rate
1.2 met

Clothing level
0.5 clo

PMV
0.06

PPD
0%

Sensation
Neutral

SET
77.4°F

Psychrometric chart (air-temperature)
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

Temperature and Humidity Plot, Aspen, CO

Climate

Temperature and Humidity Plot, Aspen, CO vs. Pittsburgh
Earliest Modeling – Octagon Model

Simplified model to examine:
− Energy Use
− Peak Loads
− Comfort

Heating

Code Building
30% Glazing - No Perimeter Heating
Heating

Heating Alternate
50% ASHRAE DG, R-40 Wall - No Perimeter Heating

Heating Comfort Optimized Alternate
All In (R-8 Window) - No Perimeter Heating
Cooling

Cooling Comfort Optimized Alternate
50% Glazing, Overhang (x2), 3” Concrete, PCM, 62F Min

Capture the Heat
Personal Comfort – Hyperchair
Personal Comfort

What we thought we had

What we actually had

Controls

What we thought we had

What we actually had
Simple Concepts, Complex System Interplays

Inputs for Systems Decisions

- 72°F
- Person
- Pre-cooling the space
- Ventilation

Automatic
- Floor heating
- Pre-cooling the space
- Ventilation

User Can Override
- Automated windows/natural ventilation
- Automated Exterior Blinds
- Wall Fans

User Controlled
- Manual Windows
- Ceiling Fans
- Personal Cooling/Heating Chairs
- Interior Glare Shades

CBE Post Occupancy Survey Results

Overall Building
1 = Very Dissatisfied
7 = Very Satisfied

Thermal Comfort
Acoustic Quality
Office Layout
Air Quality
Office Furnishings
Cleanliness
Lighting

CBE Baseline
RMI Pre Occupancy
RMI Post Occupancy
Key RMI Findings – Occupant Surveys

88%

‘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

Predicted Values (TMY3)
Temperature and Humidity Plot, Seattle, WA All Hours

Temperatures

0 to 20 RH  20 to 40 RH  40 to 60 RH  Pittsburgh
Net Zero Energy – Mixed Mode HVAC

Radiant Floor
Bullitt Center Comfort Study

Total Hours Space Temperatures Falls in 1°F Bins

- 1st No Cooling
- 2nd No Cooling
- 4th South No Cooling
- 6th North No Cooling

Not Comfortable
Comfortable with Ceiling Fans
Comfortable

Number of Hours

Passive Cooling

Zone Temperature for South Office Space w/o Mechanical Cooling August 9th-11th (Thurs-Sat)

Seattle Design Temp = 85°F

Outside Air
Passive Cooling

Zone Temperature for South Office Space w/o Mechanical Cooling
August 9th-11th (Thurs-Sat)

Seattle Design Temp = 85°F

Outside Air
No Operable Windows

Passive Cooling

Zone Temperature for South Office Space w/o Mechanical Cooling
August 9th-11th (Thurs-Sat)

Seattle Design Temp = 85°F

Outside Air
No Operable Windows
Manual Windows
Passive Cooling

Zone Temperature for South Office Space w/o Mechanical Cooling
August 9th-11th (Thurs-Sat)

Seattle Design Temp = 85°F

Actuated windows allow for weekend cooling

---Outside Air
---No Operable Windows
---Manual Windows
---Actuated Windows w Night Flush

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

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

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

Red is the manually controlled classroom (CO2)
Green is automated (CO2)
Ventilation Strategies

Example of the estimated CO₂ 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
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

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<th>Height (m)</th>
<th>Temperature (°C)</th>
<th>Air speed (m/s)</th>
<th>DR (%)</th>
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<td>0,14</td>
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</tbody>
</table>

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
- CO₂
- (RH)

Missing link?
- One of the main driving forces for NV – wind (pressure)
External CFD

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?
General Discussion and Q&A

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