University of Washington Molecular Engineering & Sciences Building: Integrated Design for Natural Ventilation

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Association of Professional Energy Managers

3 | 16 | 2018

Project Context

> Unique aspects of this project: client, location, program

Problem

> Incorporating natural ventilation in offices of a laboratory building

> Design process

> Local climate

> Applicable standards and codes

Solution

> Building organization

> Load reduction

> Facade development

> Related mechanical systems

> Projecting performance

Conclusions

> Phase change material performance

> Occupant satisfaction

> Energy and carbon savings

> Cost impacts

UNIVERSITY of WASHINGTON

Sustainability Ratings

- GOLD rated campus (STARS)
- Rated in top 10 U.S. Universities in Sustainability (Sierra Cool Schools, 2016)

Sustainability Accomplishments

- Salmon Safe Campus
- 15% reduction in GHG since 2015

Sustainability Practices

- 31 UW LEED-Certified Projects
- 13 UW Registered Projects (certification pending)
- LEED Silver is mandated for all state-funded University of Washington major projects.

UW Carbon Initiatives & Building Stock

Signatory to the American College and University Presidents Climate Commitment in March 2007.

Performed an inventory of greenhouse gas emissions attributable to the University.

Developing a carbon reduction plan.

Operates over 20 million gross square feet of space.

Owns 527 buildings, leases 175 another at 3 campuses and numerous field facilities.

48% of the total square footage on the Seattle Campus is air-conditioned, with laboratories and classrooms commonly being air-conditioned.

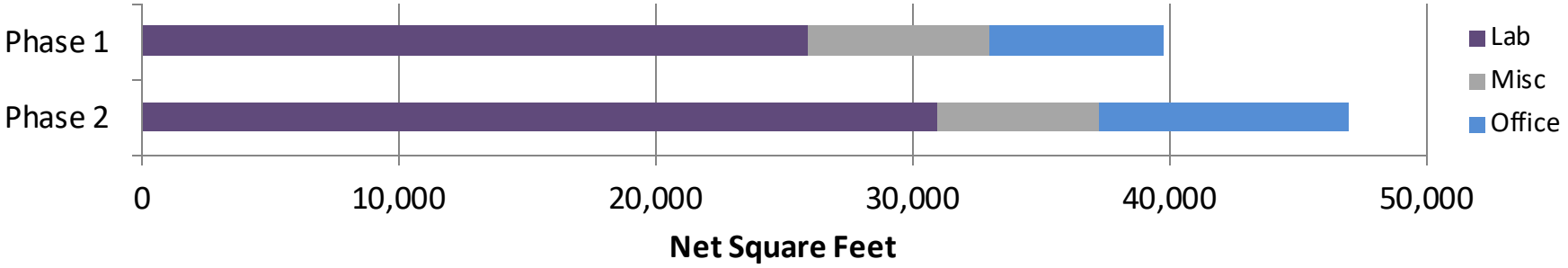
Office space is approximately 25% of all space on campus, and is the largest single category of space.

Project Goals

Provide instrumentation space to support future high sensitivity measurement in the rapidly evolving field of molecular engineering;

Address campus needs for modern lab space as research requirements for advanced labs have expanded faster than the current infrastructure can support;

House flexible research lab spaces designed to bring different fields together attracting eight new interdisciplinary faculty hires to join approximately 30 other faculty from bioengineering, chemical engineering, electrical engineering, materials science and engineering, biochemistry, chemistry, and microbiology.



LEED NC v 2.2 Checklist

UW MEB

5/10/2010

46	2	0	21				Total Project Points	Certified 26-32, Silver 33-38, Gold 39-51, Platinum 52+
Y	?Y	?N	N					
11	0	0	3				**SUSTAINABLE SITES**	
Y				c	KPFF	Prereq 1	Construction Activity Pollution Prevention	
1				d	UW	Credit 1	Site Selection	
1				d	UW	Credit 2	Development Density & Community Connectivity	
1				d	UW	Credit 3	Brownfield Redevelopment	
1				d	UW	Credit 4.1	Alternative Transportation: Public Transportation Access	
1				d	ZGF	Credit 4.2	Alternative Transportation: Bicycle Storage & Changing Rooms	
			1	d	ZGF	Credit 4.3	Alternative Transportation: Low-Emitting and Fuel-Efficient Vehicles	
1				d	ZGF	Credit 4.4	Alternative Transportation: Parking Capacity	
1				c	ZGF	Credit 5.1	Site Development: Protect or Restore Habitat	
1				d	ZGF	Credit 5.2	Site Development: Maximize Open Space	
			1	d	KPFF	Credit 6.1	Stormwater Design: Quantity Control	
			1	d	KPFF	Credit 6.2	Stormwater Design: Quality Control	
1				c	ZGF	Credit 7.1	Heat Island Effect: Non-Roof	
1				d	ZGF	Credit 7.2	Heat Island Effect: Roof	
1				d	Sparl	Credit 8	Light Pollution Reduction	

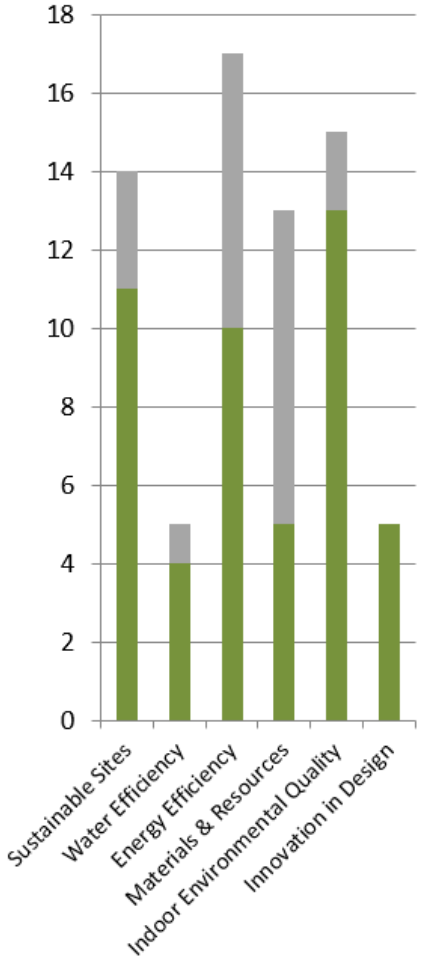
4	0	0	1				**WATER EFFICIENCY**
1				d	WM	Credit 1.1	Water Efficient Landscaping: Reduce by 50%
1				d		Credit 1.2	Water Efficient Landscaping: No Potable Water Use or No Irrigation
			1	d		Credit 2	Innovative Wastewater Technology
1				d	AEI	Credit 3.1	Water Use Reduction: 20% Reduction
1				d	AEI	Credit 3.2	Water Use Reduction: 30% Reduction

8	2	0	7				**ENERGY & ATMOSPHERE**
Y				c	UW	Prereq 1	Fundamental Commissioning of the Building Energy Systems
Y				d	Slrc	Prereq 2	Minimum Energy Performance
Y				d	AEI	Prereq 3	Fundamental Refrigerant Management
2				d	Slrc	Credit 1.1	Optimize Energy Performance: 14% new or 7% Existing (2 points)
2				d	Slrc	Credit 1.2	Optimize Energy Performance: 21% new or 14% Existing (2 points)
2				d	Slrc	Credit 1.3	Optimize Energy Performance: 28% new or 21% Existing (2 points)
	2			d	Slrc	Credit 1.4	Optimize Energy Performance: 35% new or 28% Existing (2 points)
			2	d	Slrc	Credit 1.5	Optimize Energy Performance: 42% new or 35% Existing (2 points)
			1	d		Credit 2.1	On-Site Renewable Energy: 2.5%
			1	d		Credit 2.2	On-Site Renewable Energy: 7.5%
			1	d		Credit 2.3	On-Site Renewable Energy: 12 %
1				c	UW	Credit 3	Enhanced Commissioning
1				d	AEI	Credit 4	Enhanced Refrigerant Management
			1	c	AEI	Credit 5	Measurement & Verification
			1	c	UW	Credit 6	Green Power

Y	?Y	?N	N				**MATERIALS & RESOURCES**
5	0	0	8				
Y				d	ZGF	Prereq 1	Storage and Collection of Recyclables
			1	d		Credit 1.1	Building Reuse: Maintain 75% of Existing Walls, Floors, & Roof
			1	d		Credit 1.2	Building Reuse: Maintain 95% of Existing Walls, Floors, & Roof
			1	d		Credit 1.3	Building Reuse: Maintain 50%% of Interior Non-Structural Elements
1				c	Hoff	Credit 2.1	Construction Waste Management: Divert 50% from Disposal
1				c	Hoff	Credit 2.2	Construction Waste Management: Divert 75% from Disposal
			1	c		Credit 3.1	Material Reuse: 5%
			1	c		Credit 3.2	Material Reuse: 10%
1				c	Hoff	Credit 4.1	Recycled Content: 10% (post-consumer + 1/2 pre-consumer)
1				c	Hoff	Credit 4.2	Recycled Content: 20% (post-consumer + 1/2 pre-consumer
			1	c	Hoff	Credit 5.1	Regional Materials: 10% Extracted, Processed, and Mfg Regionally
			1	c	Hoff	Credit 5.2	Regional Materials: 20% Extracted, Processed, and Mfg Regionally
			1	c	Hoff	Credit 6	Rapidly Renewable Materials
1				c	Hoff	Credit 7	Certified Wood

13	0	0	2				**INDOOR ENVIRONMENTAL QUALITY**
Y				d		Prereq 1	Minimum IAQ Performance
Y				d		Prereq 2	Environmental Tobacco Smoke (ETS) Control
			1	d	AEI	Credit 1	Outdoor Air Delivery Monitoring
			1	d	AEI	Credit 2	Increased Ventilation
1				c	Hoff	Credit 3.1	Construction IAQ Management Plan: During Construction
1				c	Hoff	Credit 3.2	Construction IAQ Management Plan: Before Occupancy
1				c	Hoff	Credit 4.1	Low-Emitting Materials: Adhesives & Sealants
1				c	Hoff	Credit 4.2	Low-Emitting Materials: Paints & Coatings
1				c	Hoff	Credit 4.3	Low-Emitting Materials: Carpet Systems
1				c	Hoff	Credit 4.4	Low-Emitting Materials: Composite Wood & Agrifiber Products
1				d	ZGF	Credit 5	Indoor Chemical and Pollutant Source Control
1				d	AEI	Credit 6.1	Controllability of Systems: Lighting
1				d	AEI	Credit 6.2	Controllability of Systems: Thermal Comfort
1				d	AEI	Credit 7.1	Thermal Comfort: Design
1				d	AEI	Credit 7.2	Thermal Comfort: Verification
1				d	ZGF	Credit 8.1	Daylight and Views: Daylight 75% of Spaces
1				d	ZGF	Credit 8.2	Daylight and Views: Views for 90% of Spaces

5	0	0	0				**INNOVATION IN DESIGN**
1				d	UW	Credit 1.1	Innovation in Design: Green Housekeeping
1				d	UW	Credit 1.2	Innovation in Design: Transportation Demand Mngt
1				c	ZGF	Credit 1.3	Innovation in Design: Green Education
1				d	AEI	Credit 1.4	Innovation in Design: 40% water use reduction, or 10% of process water
1				d	ZGF	Credit 2	LEED Accredited Professional



LEED Scorecard

CONTEXT

Energy Conservation Measures:

1. **Natural ventilation**

2. **Optimized laboratory/fume hood VAV System,** including:
   - reduced laboratory ACH rates
   - low flow VAV fume hoods
   - occupied/unoccupied controls
   - chilled beams where feasible

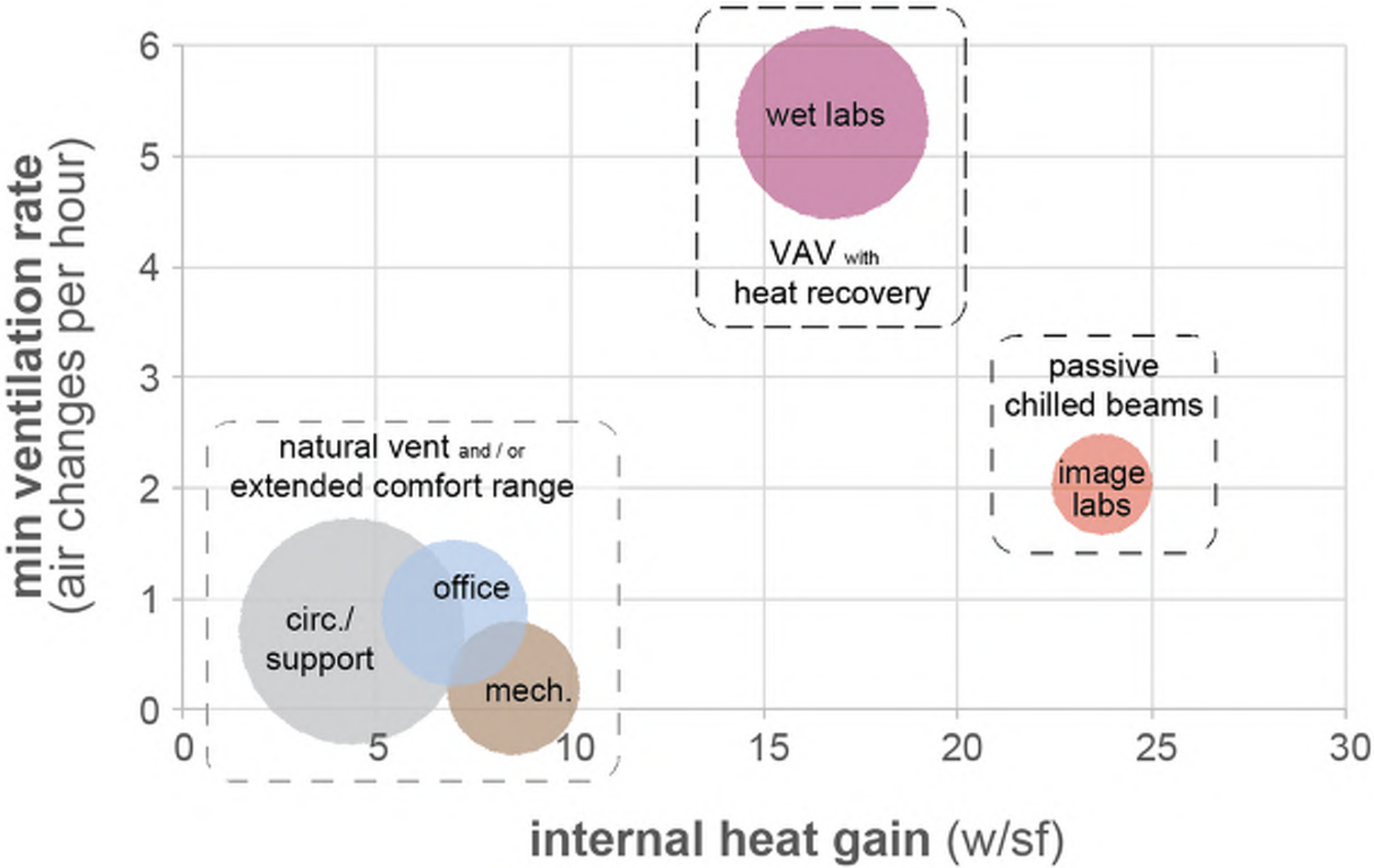
3. **High performance windows and optimized shading**

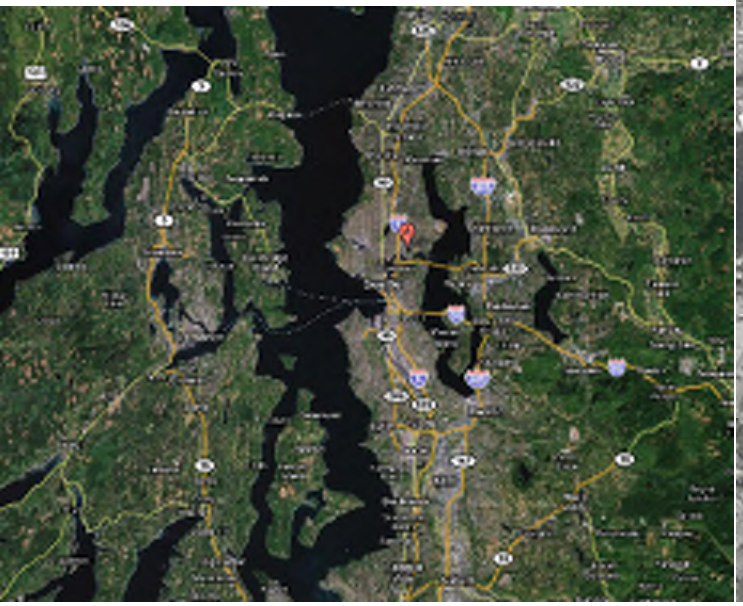
4. **Daylighting/efficient electric lighting**

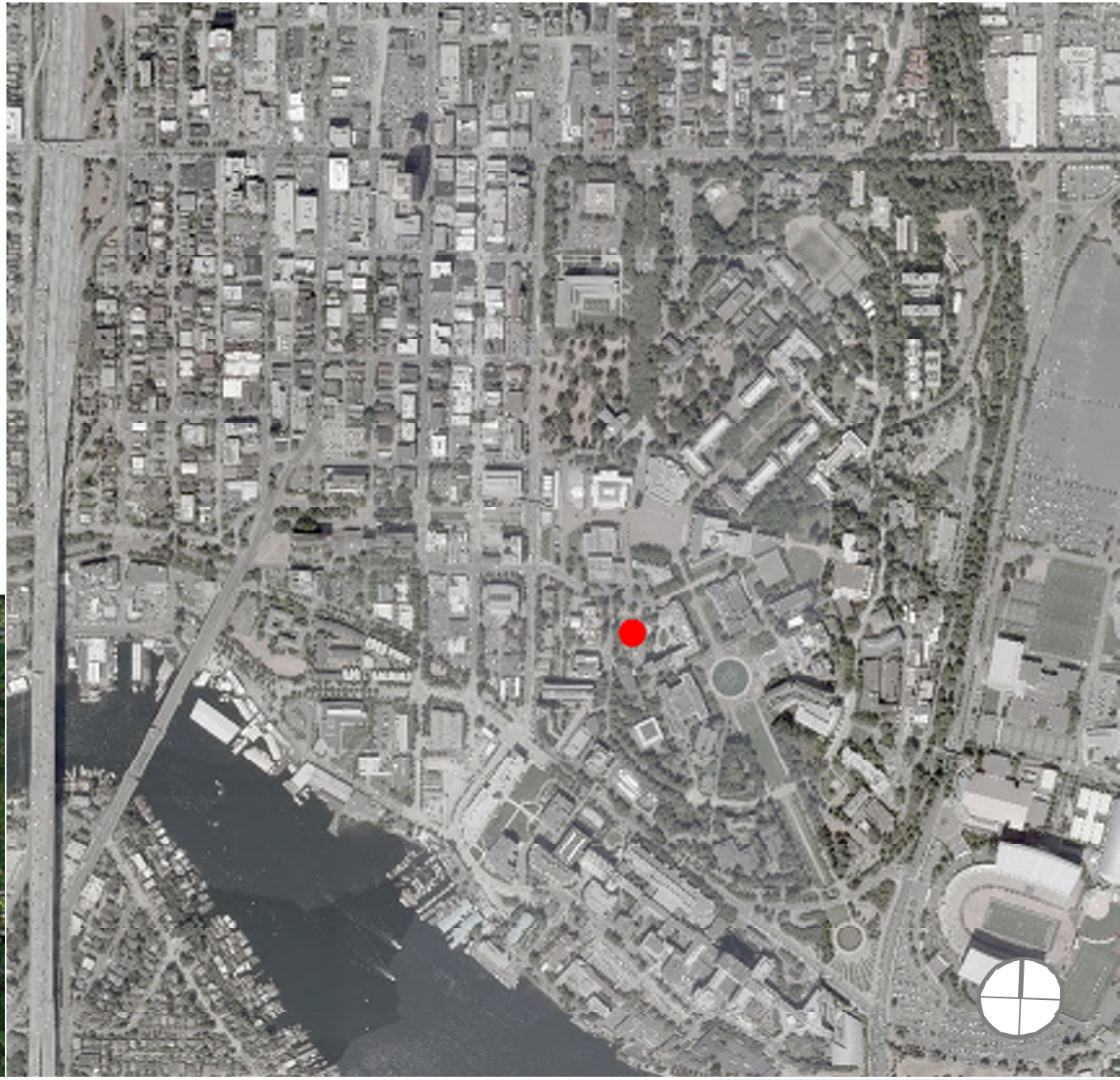
5. **Heat recovery from process chiller**

6. **Dynamic laboratory stack exhaust,** under study

7. **Maximum efficiency pumping,** with:
   - variable flow hydronic systems with pressure independent valves

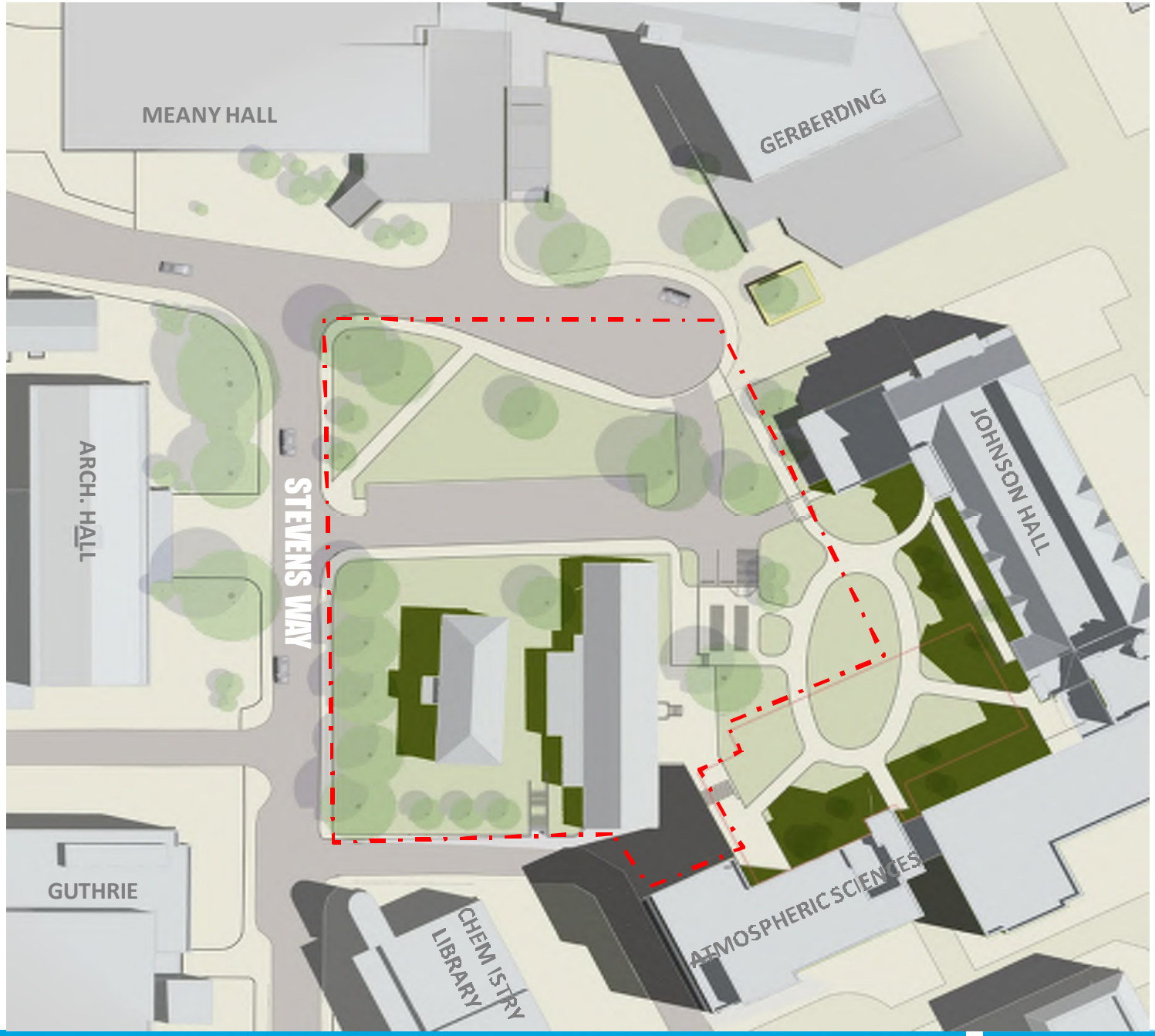

min ventilation rate
(air changes per hour)
6
5
4
3
2
1
0
0
5
10
15
20
25
30
internal heat gain (w/sf)
wet labs
VAV with
heat recovery
passive
chilled beams
image
labs
natural vent and / or
extended comfort range
office
circ./
support
mech.





Project Location

CONTEXT



Existing Site

CONTEXT

CONTEXT

Site Plan Phase One

CONTEXT

CONTEXT

Science Courtyard

CONTEXT

Weather

Building Structure

Lab/Office Program

Willing Client

Energy Intensive

Load Reduction Capable

Life Cycle Cost Driven Solutions

Lab Ventilation Energy Burden on Office System

Characteristics Related to Natural Ventilation

CONTEXT

Energy:	Reduced energy use
Costs:	Reduced operating costs Reduced construction costs
Reliability:	Reduced mechanical systems
Occupants:	Increased satisfaction and productivity of building occupants
Climate:	Opportunities presented by Pacific NW climate

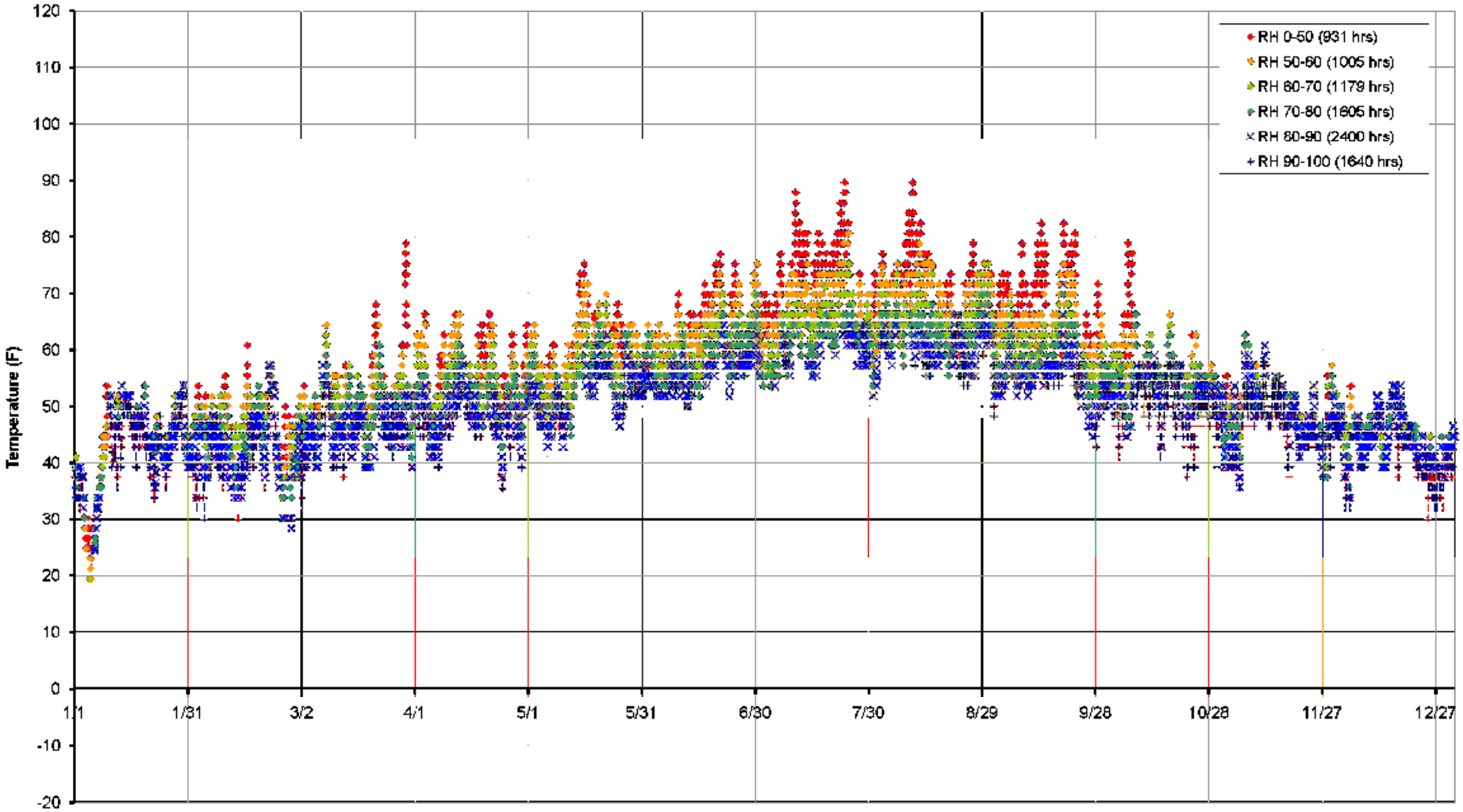
Potential Benefits of Natural Ventilation?

PROBLEM

	Schematic Design	Design Development	Construction Documents
Process	• Conceive natural ventilation approach • Apply experience to arrive at concept	• Define criteria for evaluation ASHRAE CIBSE • Educate the UW • Earn UW buy-in • Natural ventilation charrette • Establish impact to first cost	• Refine design: apertures, thermal mass, wind, solar, and mechanical assists • Determine energy savings • Life-cycle cost analysis
Tools	• Climate tools (temperature, wind)	• Energy model (define peak loads) • Single-zone bulk air flow model • Ecotect (facade insolation)	• CFD/multi-zone air flow model • Energy model (overall energy use) • Spreadsheets (cost analysis)

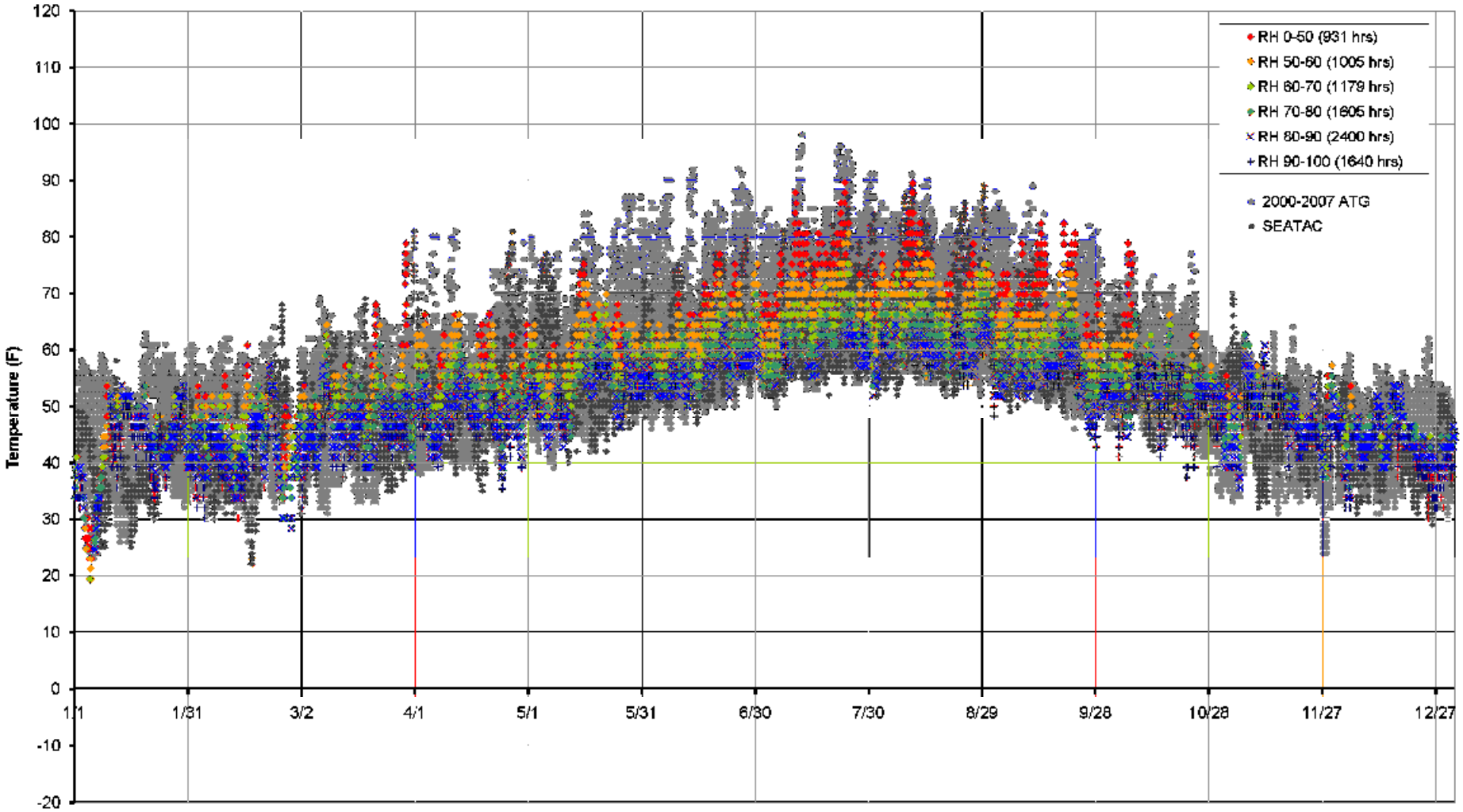
Process of Design

PROBLEM



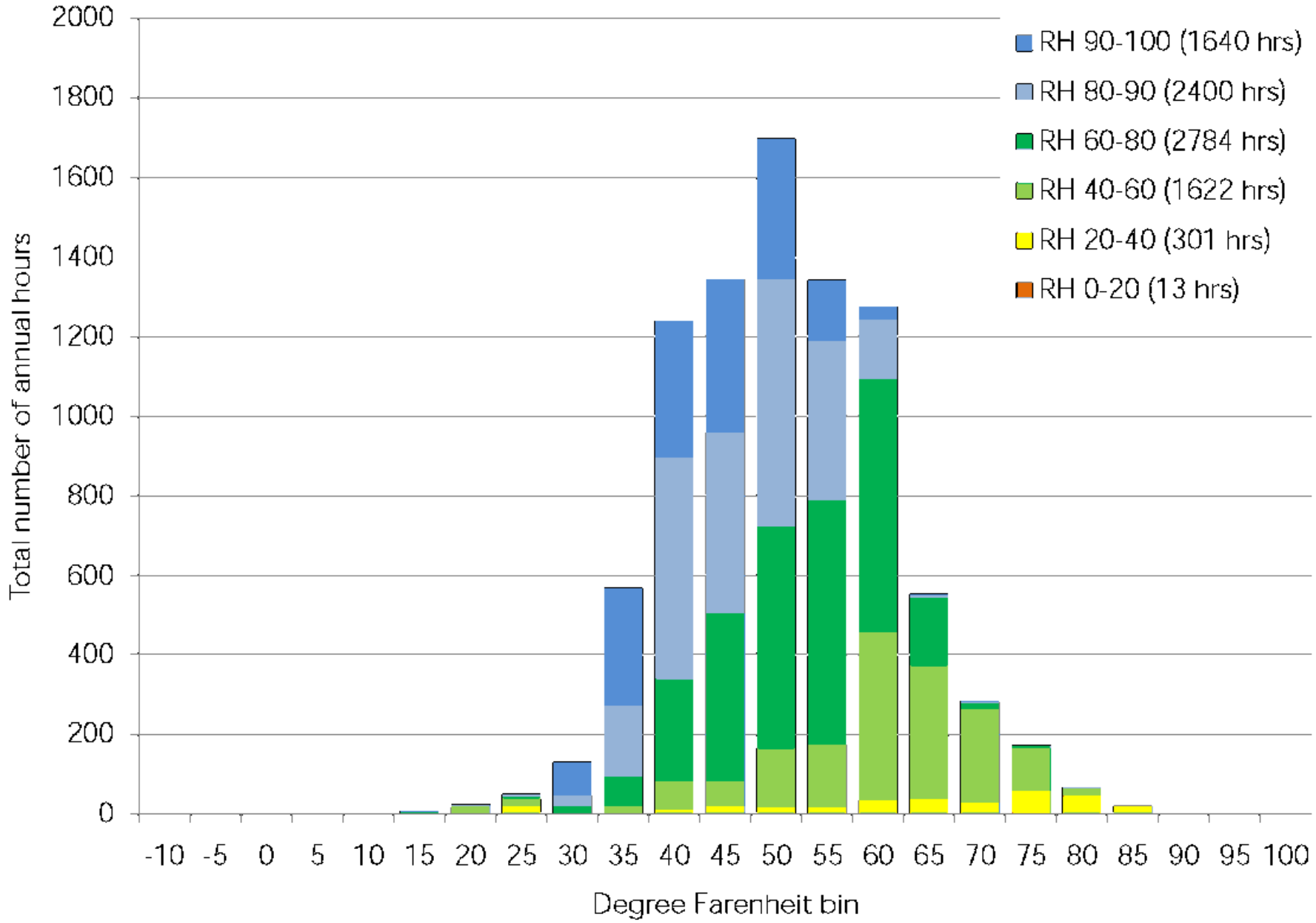
Annual Temperature – TMY3 Seattle Boeing

PROBLEM



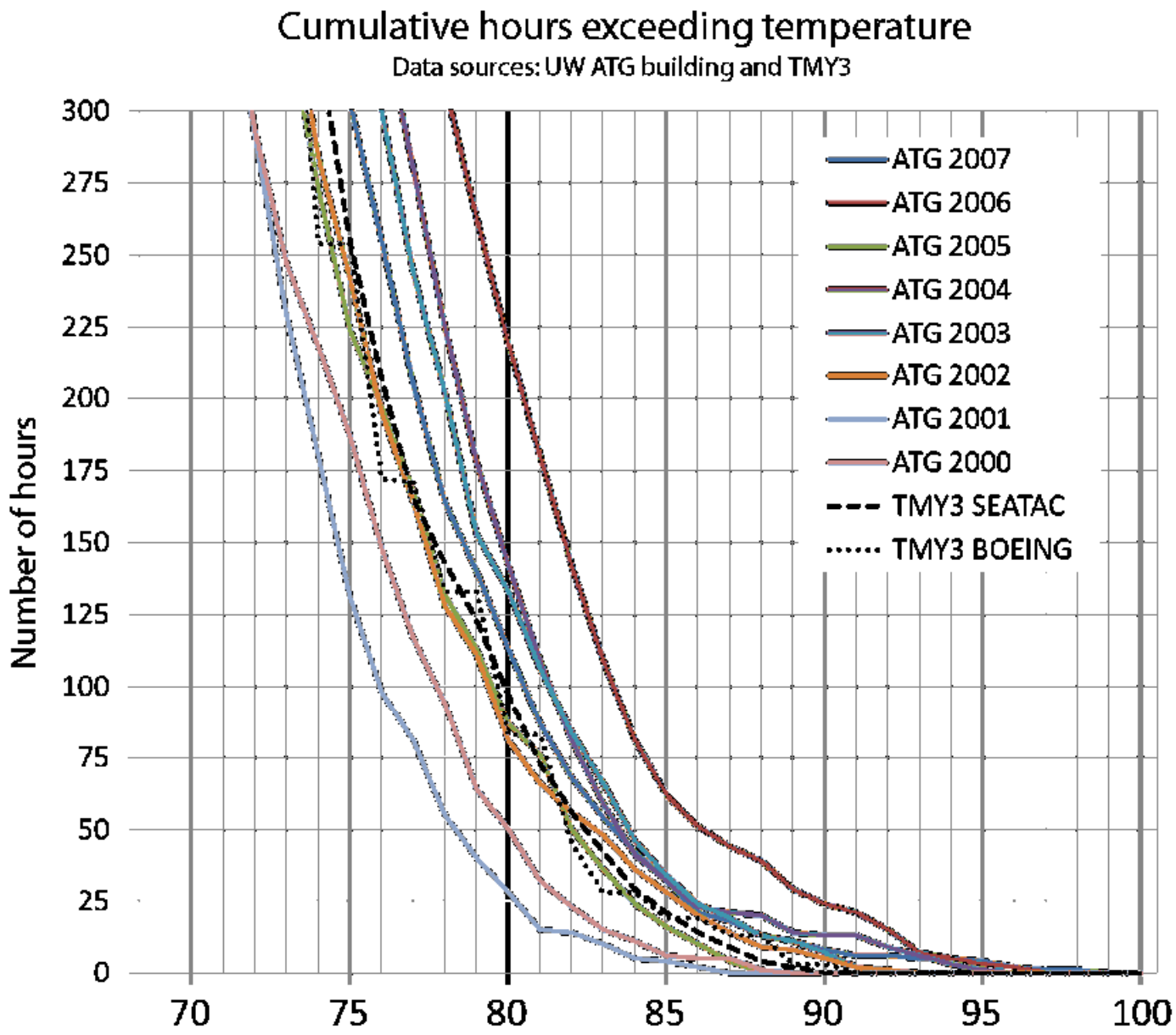
Annual Temperature – TMY3 & Campus ATG Building

PROBLEM



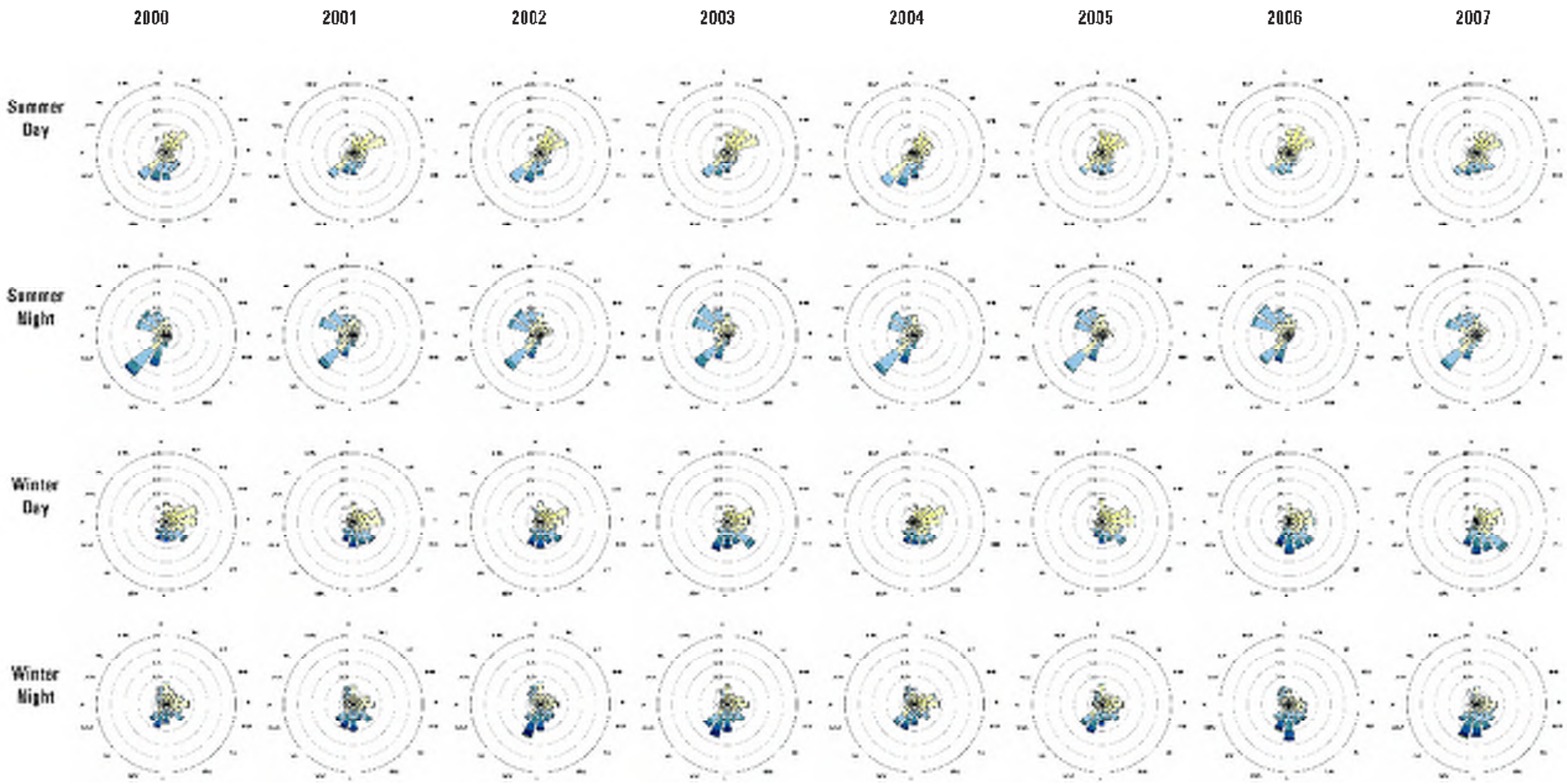
Annual Temperature Bins

PROBLEM



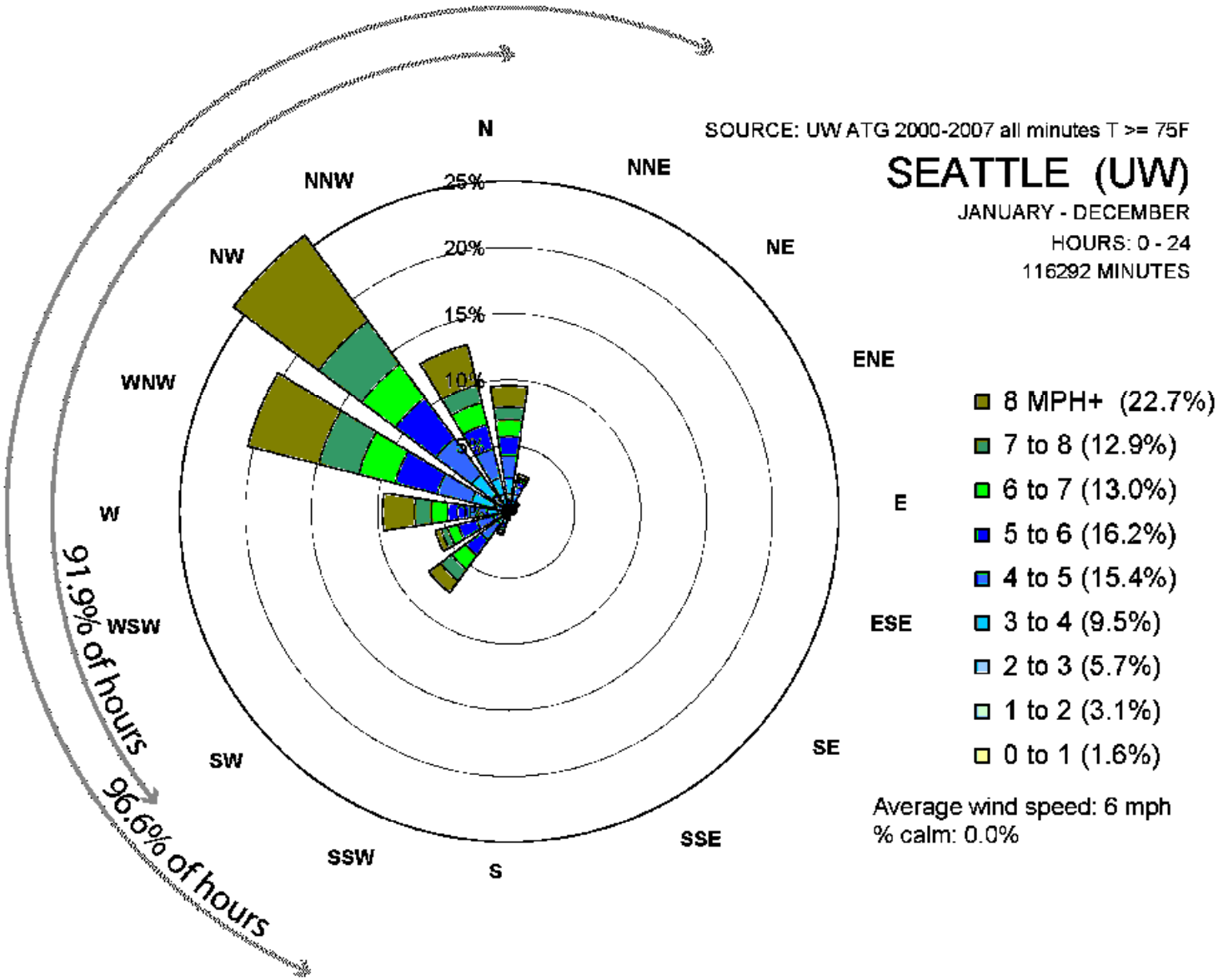
Annual Temperature – TMY3 & Campus ATG Building

PROBLEM



Local Wind Data

PROBLEM



Local Wind Data

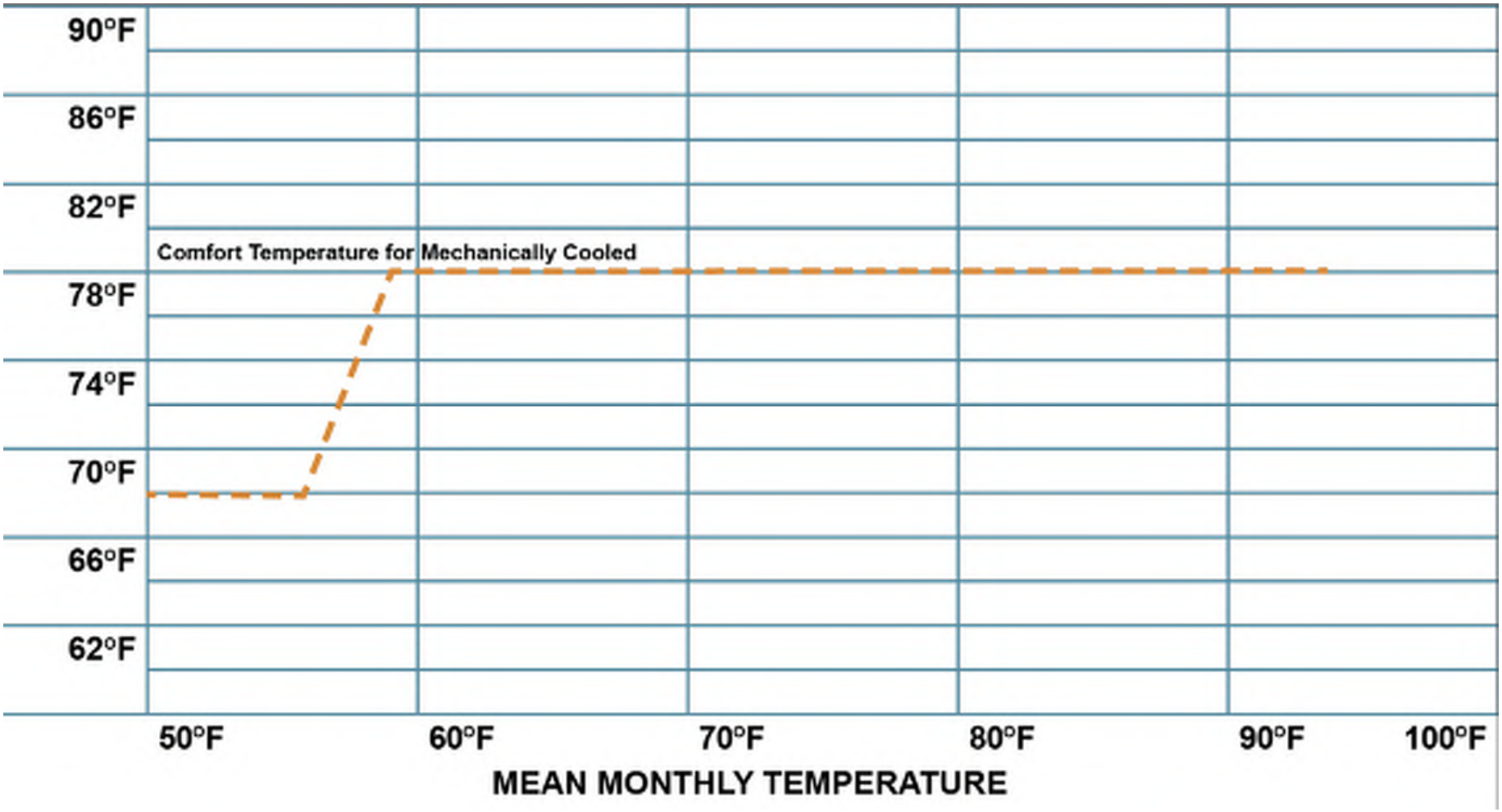
PROBLEM

FUNCTION	CRITERIA
1. Temperature control	(68°F-83°F)
2. Ventilation ASHRAE / Seattle Building Code LEED EQ C2	4% operable window area of zone floor area
3. Acoustical performance	Separation from vehicle noise
4. Lab/office separation	Containment control of lab air

Natural Ventilation Design Criteria

PROBLEM

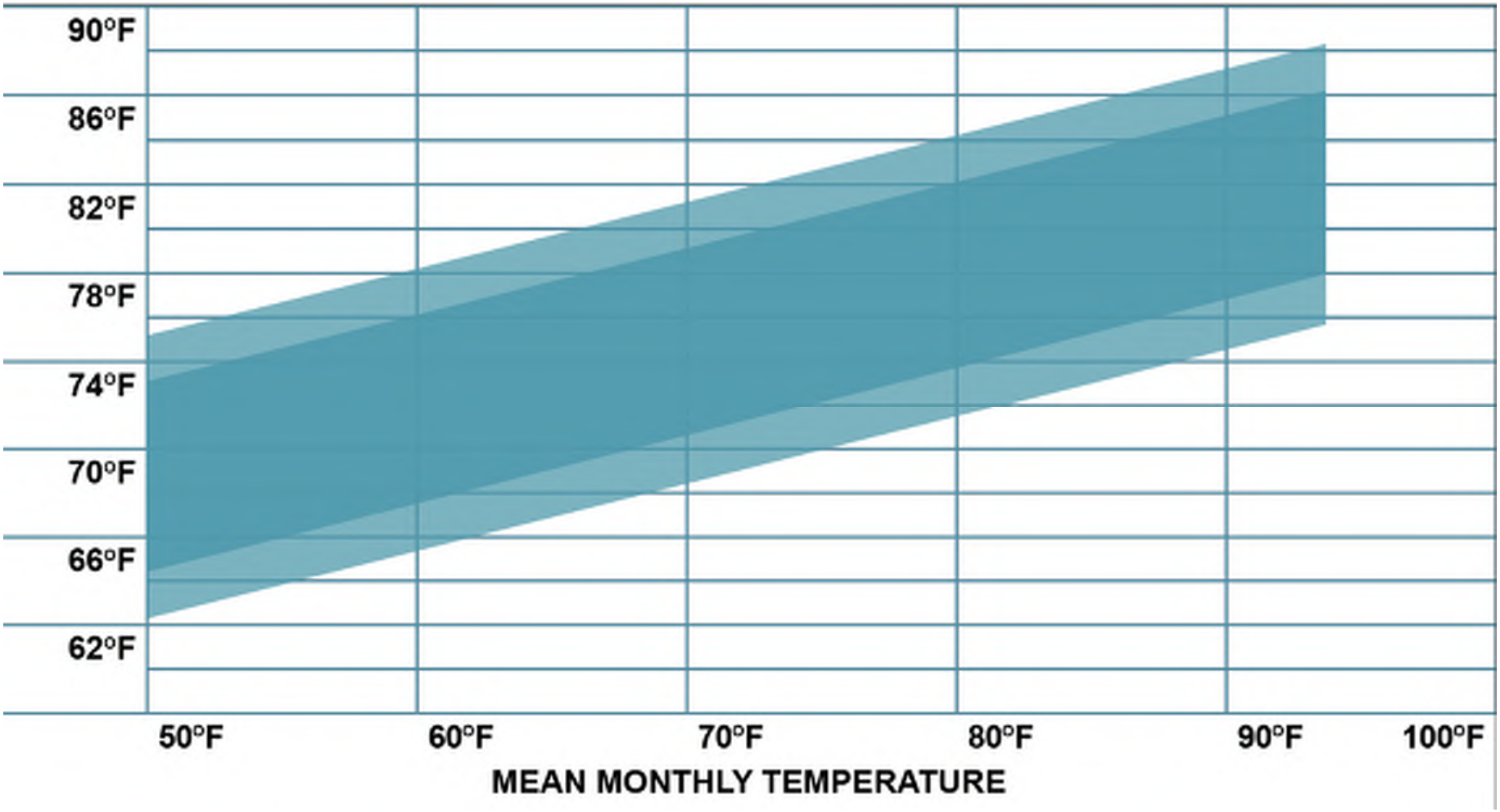
ASHRAE Comfort Range for Mechanically Cooled Spaces



Traditional Comfort Range

PROBLEM

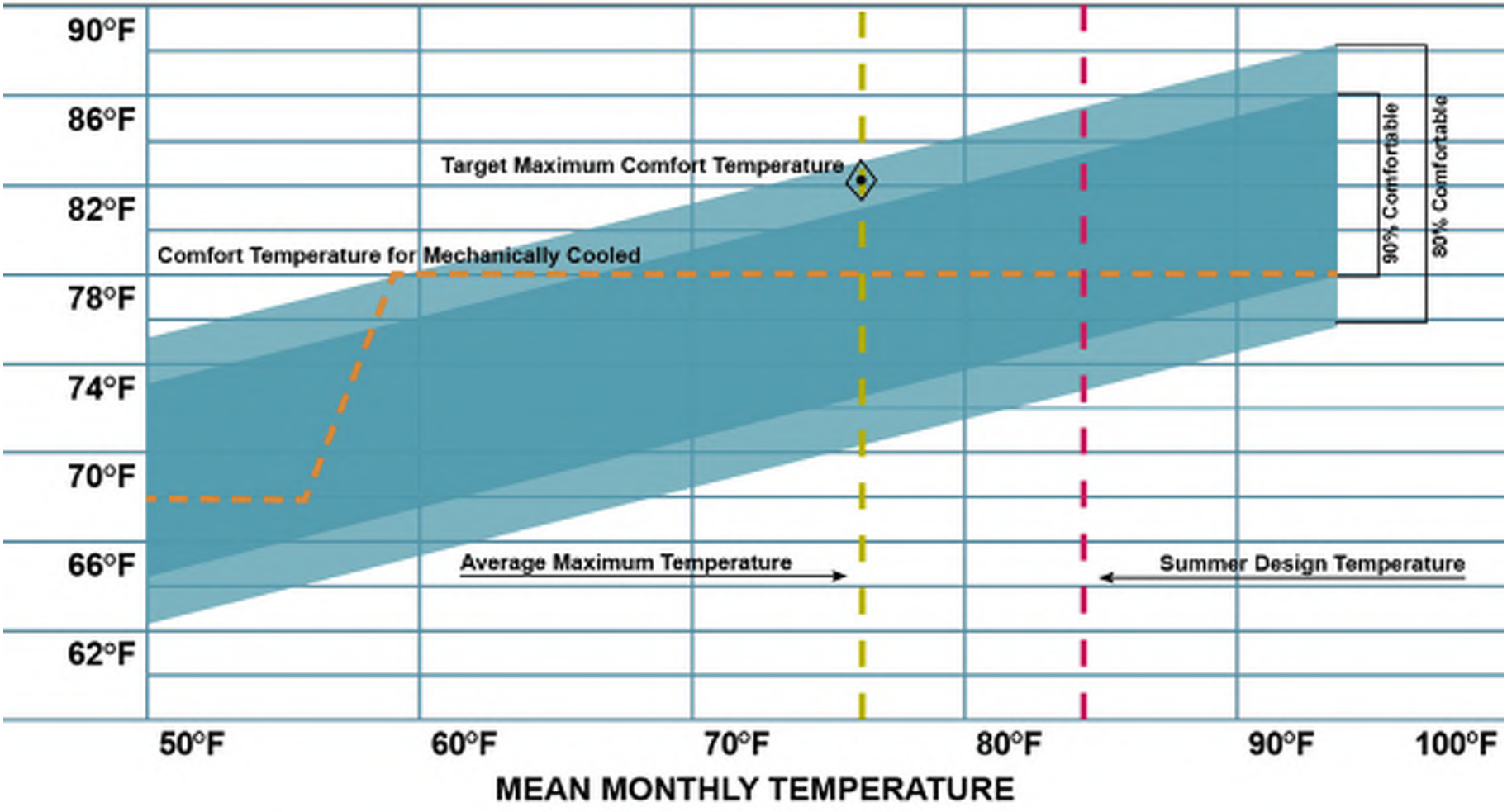
ASHRAE Comfort Range for Naturally Conditioned Spaces



Adaptive Comfort Range

PROBLEM

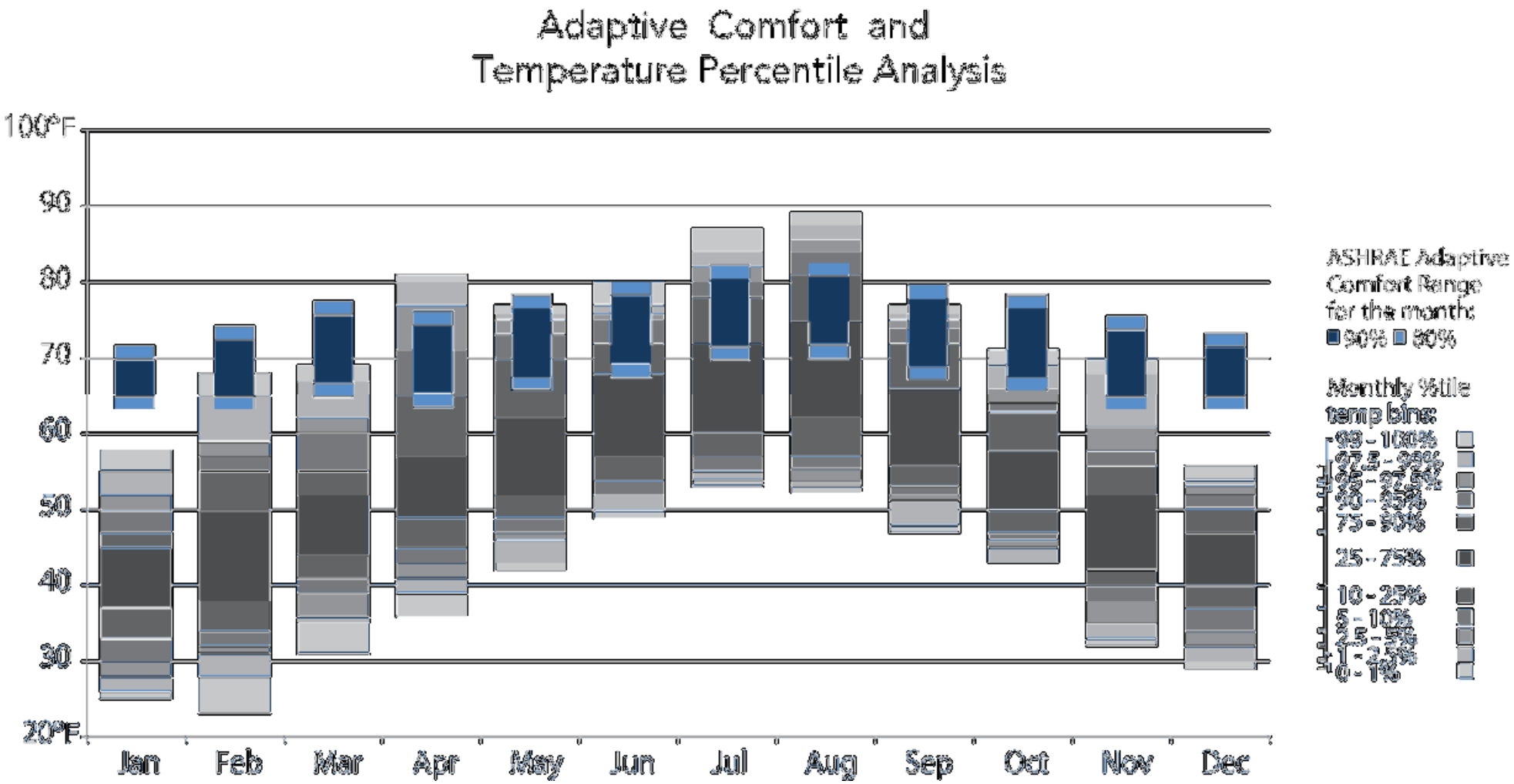
ASHRAE Comfort Range for Naturally Conditioned Spaces



Comfort Range Comparison

PROBLEM

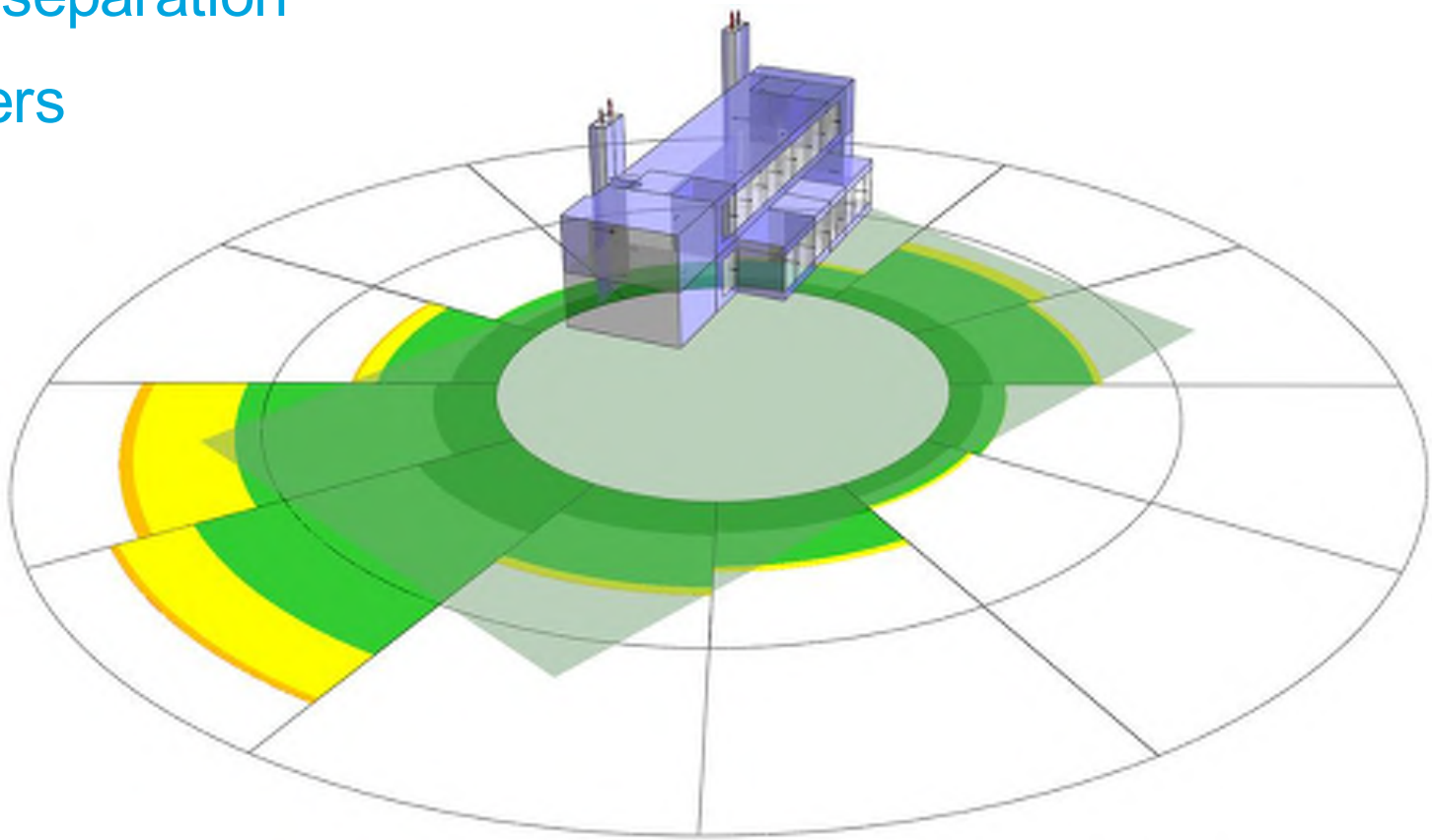
ASHRAE Comfort Range for Naturally Conditioned Spaces

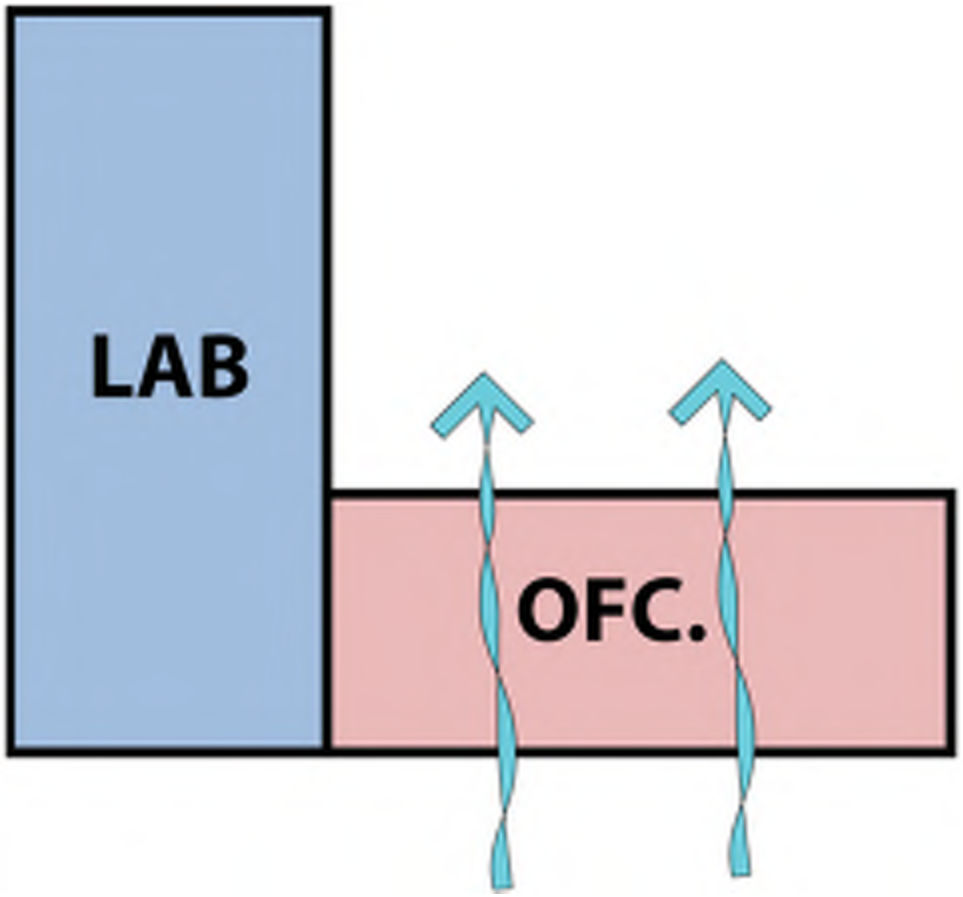


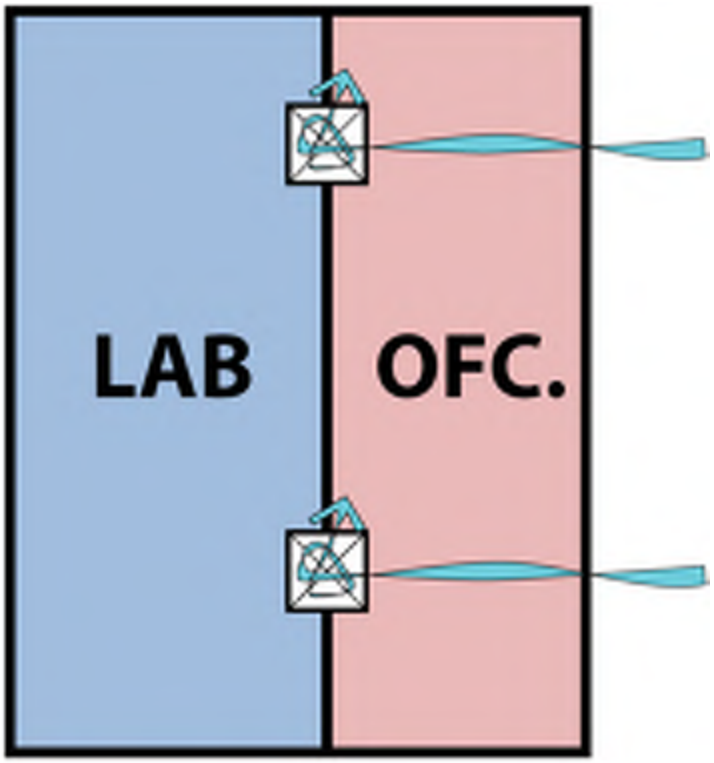
Adaptive Comfort Range

PROBLEM

1. Program orientation within building
2. Single sided vs. double-sided ventilation
3. Lab separation
4. Others







Lab – Office Morphologies

SOLUTION

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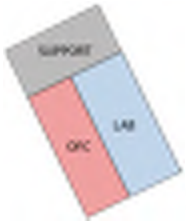
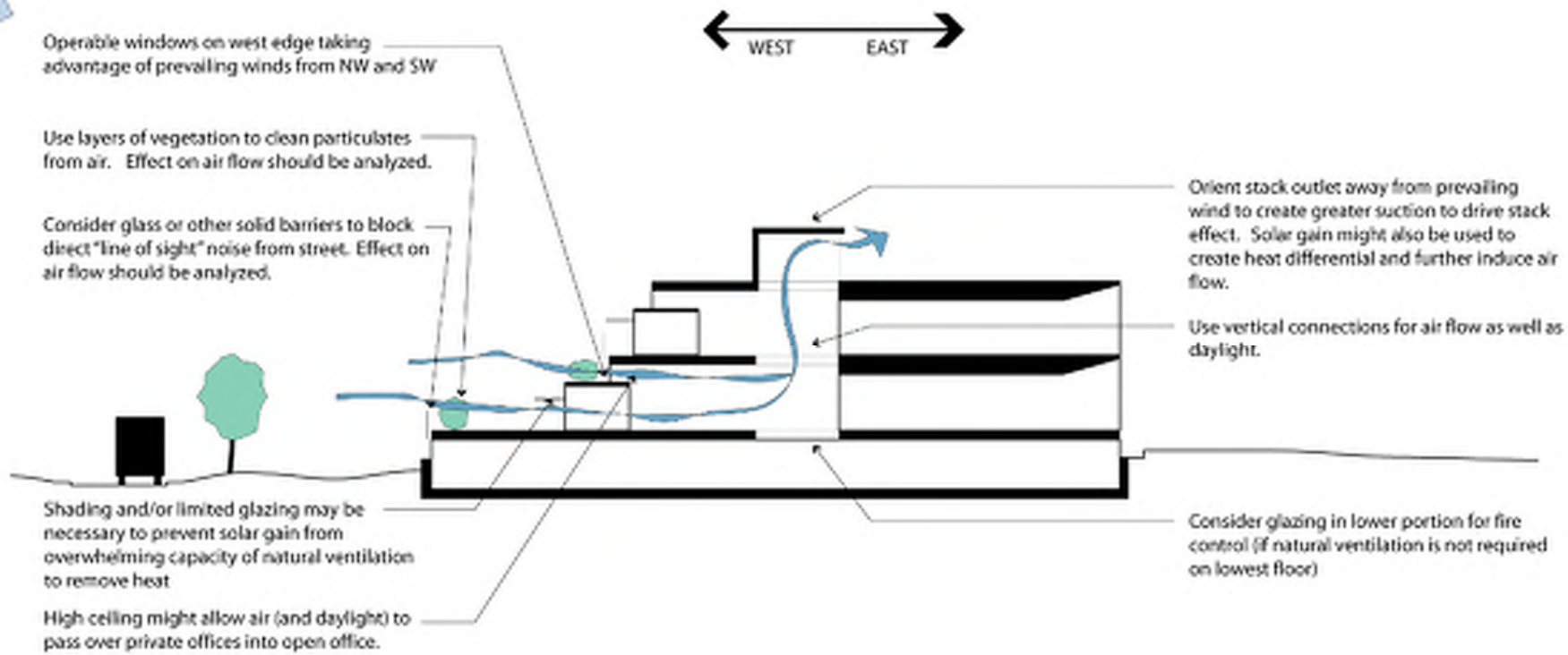
SOLUTION

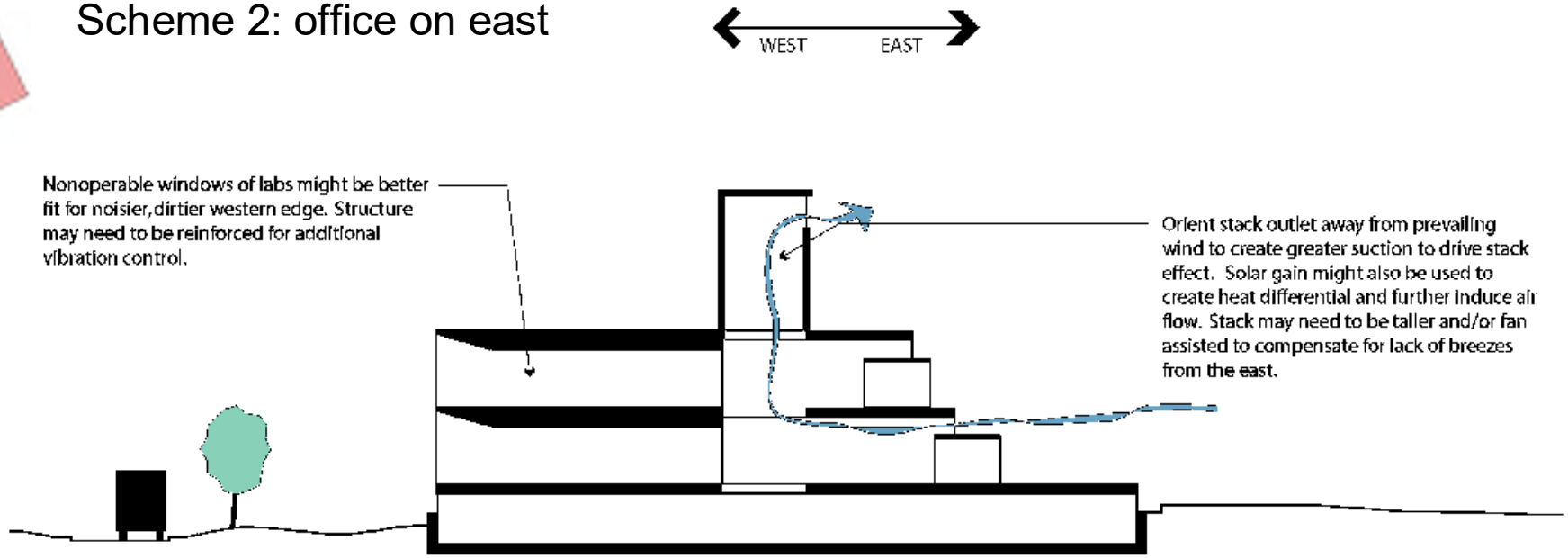


Scheme 1: office on west

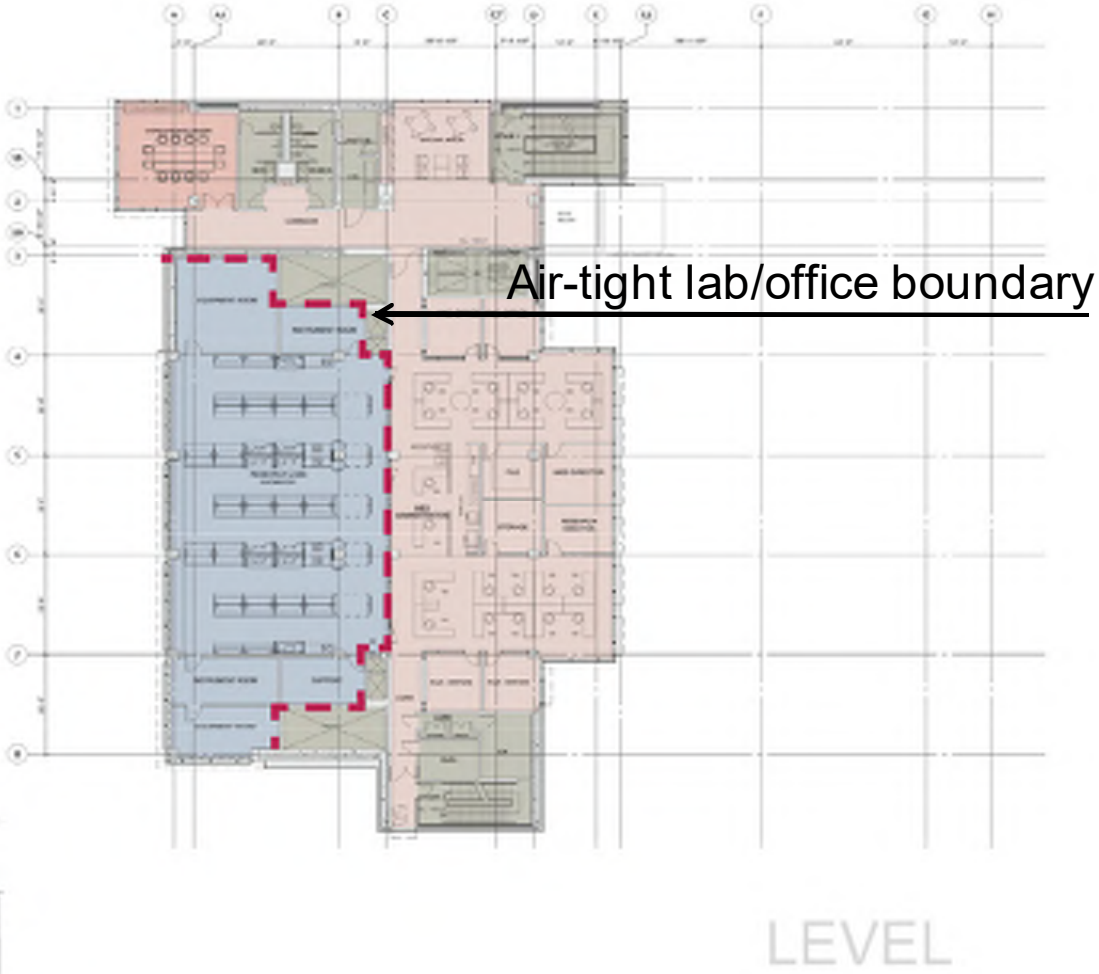


ADVANTAGES	DISADVANTAGES
+ Uses prevailing breezes from NW/SW to drive ventilation (greater airflow, greater capacity for cooling)	- Noise & dirt from busses may impact offices
+ Lab equipment less impacted from vibrations from buses	- Greater solar gain on W/SW orientations may work against natural ventilation

Scheme 2: office on east



ADVANTAGES	DISADVANTAGES
+ Offices more protected from noise and dirt of busses + E/NE orientation of offices reduces heat from solar gain	- E/NE orientation of offices reduces potential of using prevailing winds to drive natural ventilation (must rely on stack effect alone, opening sizes and/or stack height must be increased to compensate)



Lab – Office Boundary

SOLUTION

Developing System Components

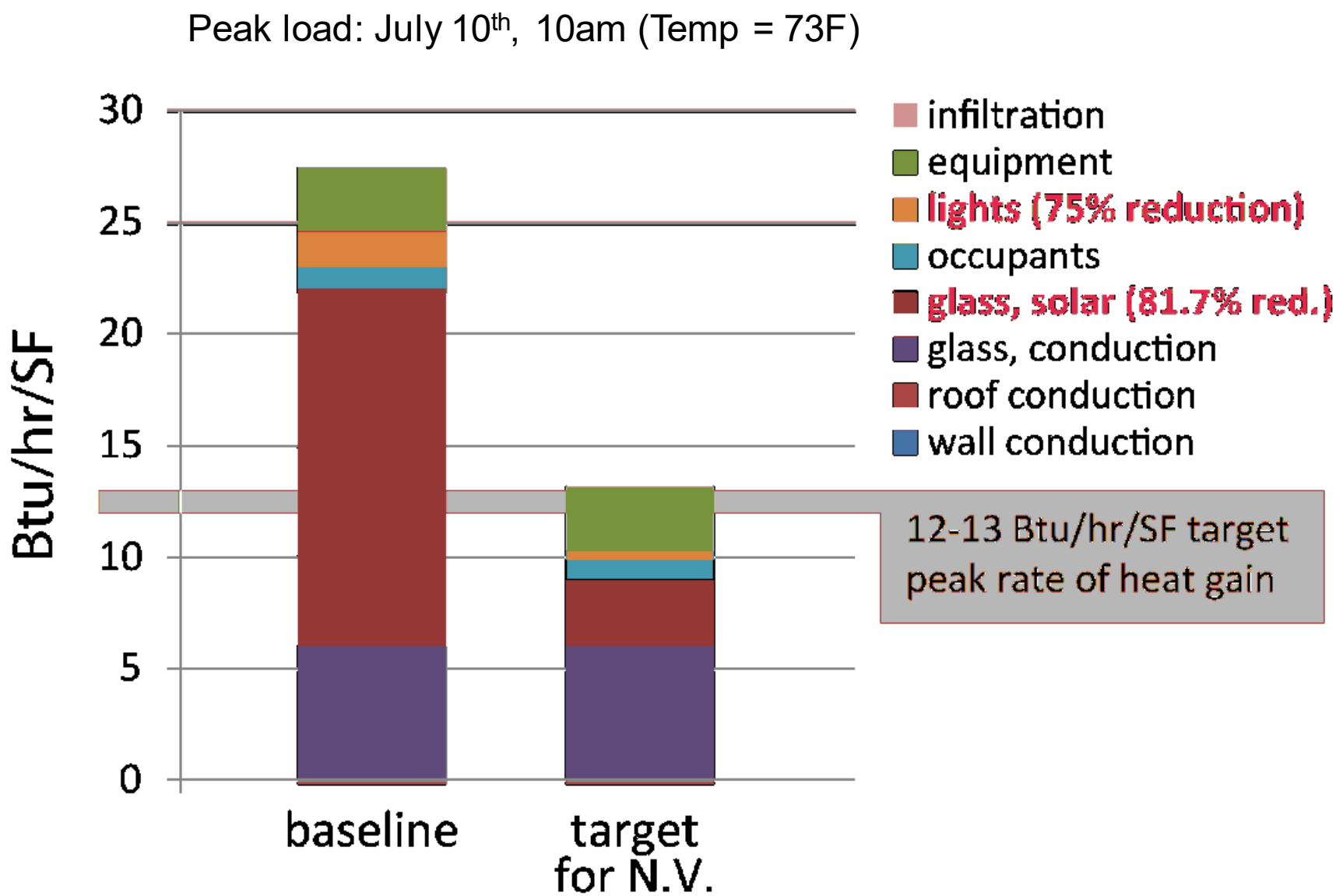
Load reduction

Facade development

Chimney configuration

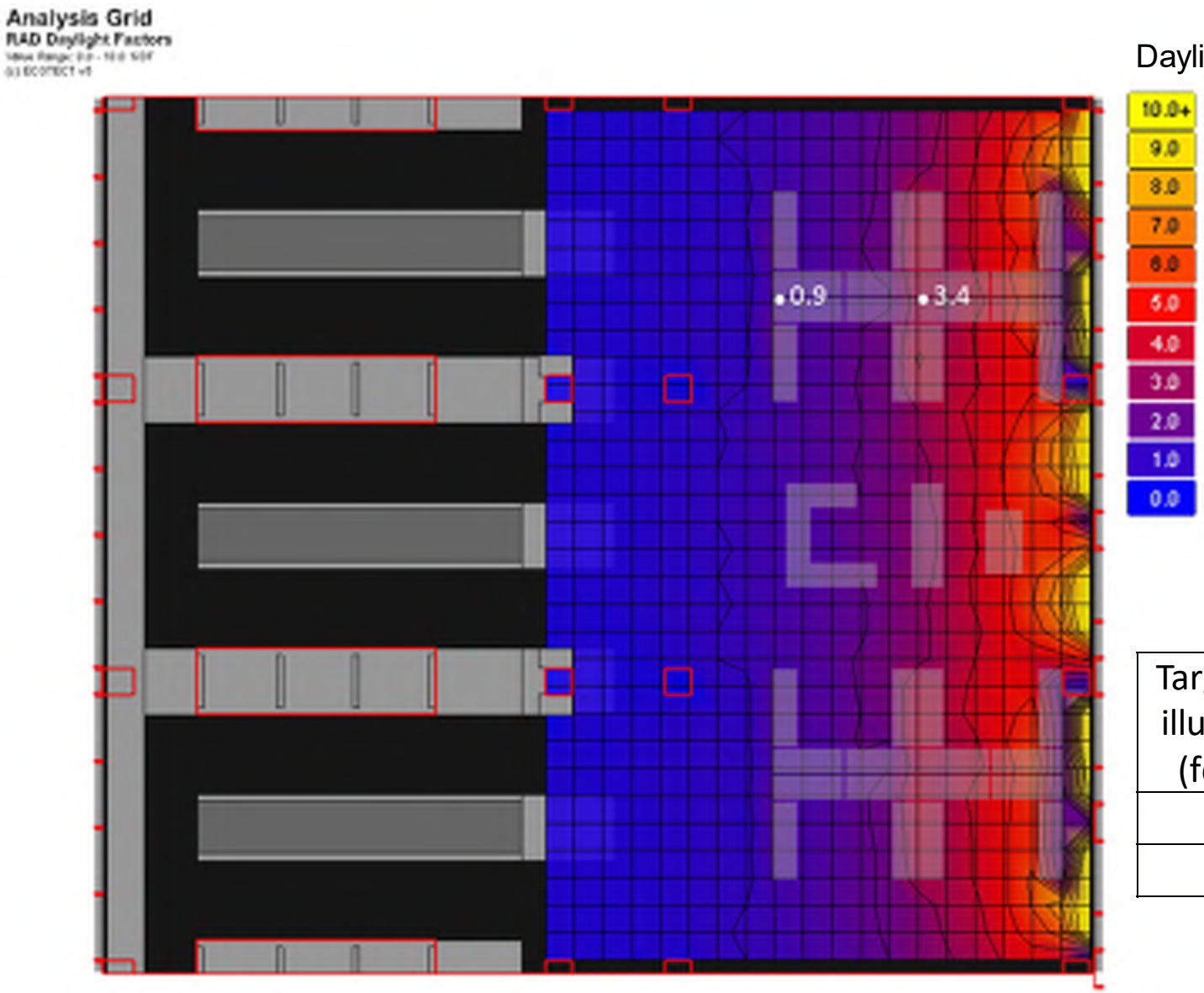
Aperture size

Exposing building mass (insulation of slab)



Load Reduction

SOLUTION

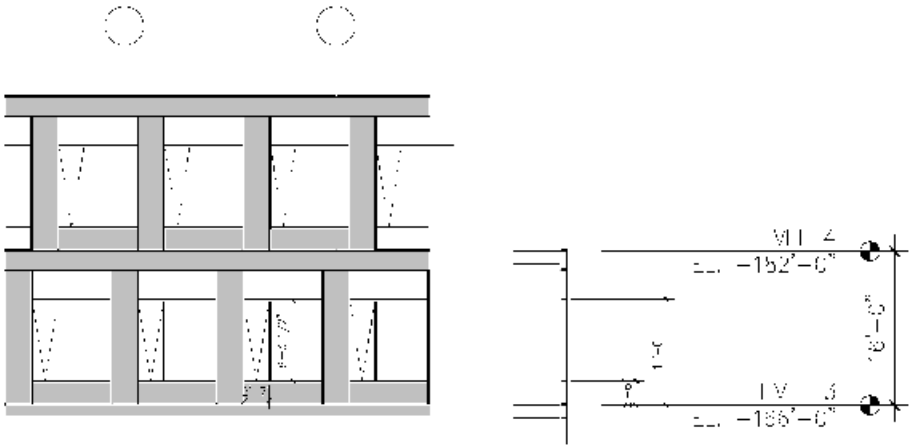


Target illum. (fc)	Daylight factor		Avg over space
	3.4	0.9	
30	75.9	26.9%	51.4%
20	87.9	40.3%	64.1%

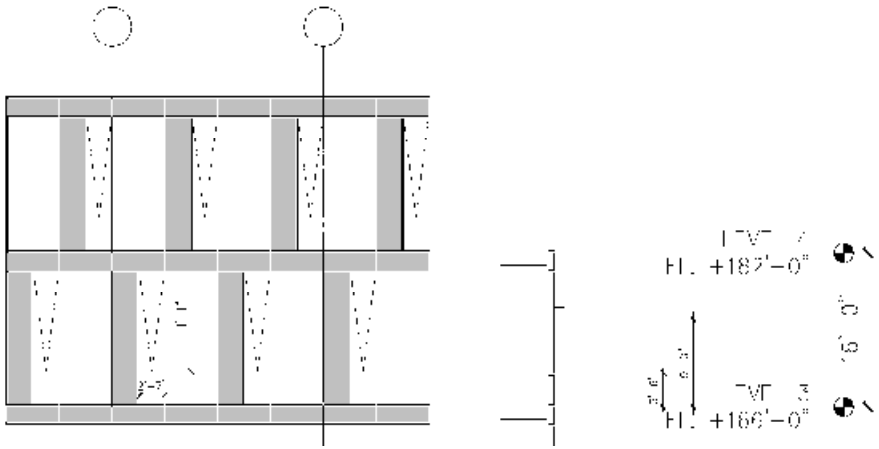
(vs. 75% goal)

Reducing Electric Light Usage Through Daylighting

SOLUTION

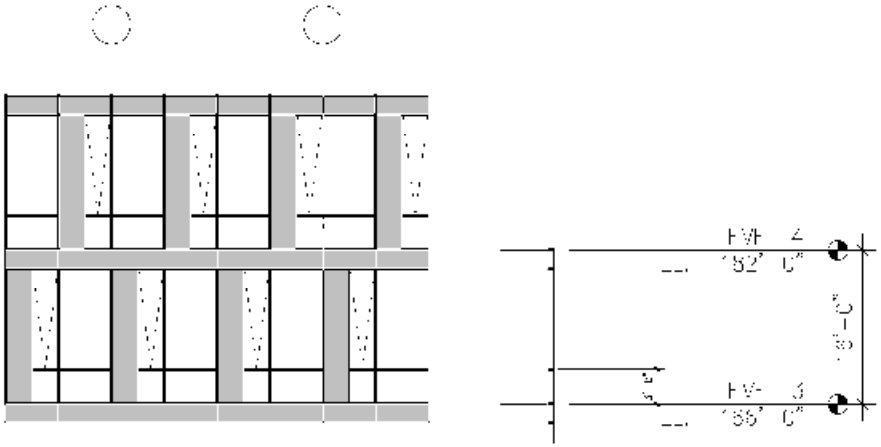


GLAZING AREA: 14' high, 41.6% opaque
EXTERNAL SHADING: none
OPERABLE WINDOW SIZE: 2' 7" x 8' 3 3/8"
(estimated 4.2 sf open area)



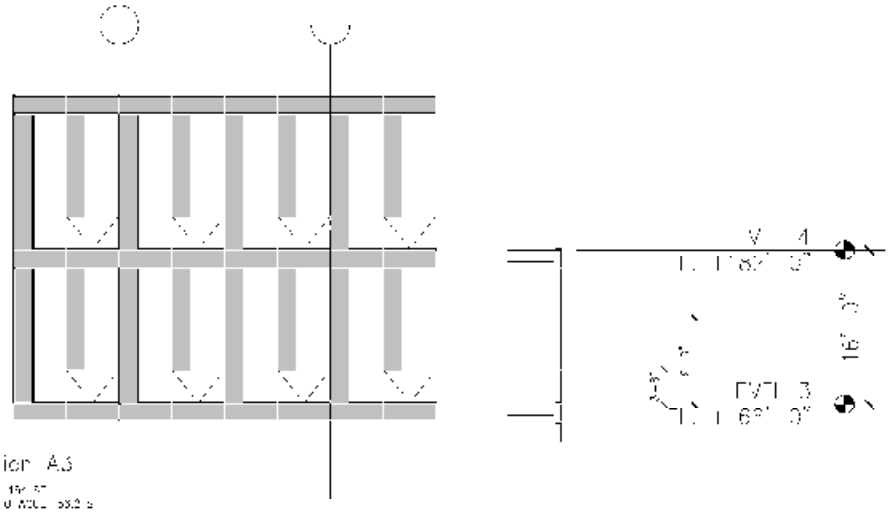
option A2
WITH SUNSHADES

GLAZING AREA: 14' high, 30% opaque
EXTERNAL SHADING: 3 1/2" horiz shades 18" apart
OPERABLE WINDOW SIZE: 2'-7" x 10'-4"
(estimated 5.3 sf open area)



option A2

GLAZING AREA: 14' high, 30% opaque
EXTERNAL SHADING: none
OPERABLE WINDOW SIZE: 2' 7" x 10' 4"
(estimated 5.3 sf open area)



option A3

GLAZING AREA: 14' high, 46.6% opaque
EXTERNAL SHADING: none
OPERABLE WINDOW SIZE: 5' 7" x 5' 5"
(estimated 3.4 sf open area)

Façade Development

SOLUTION

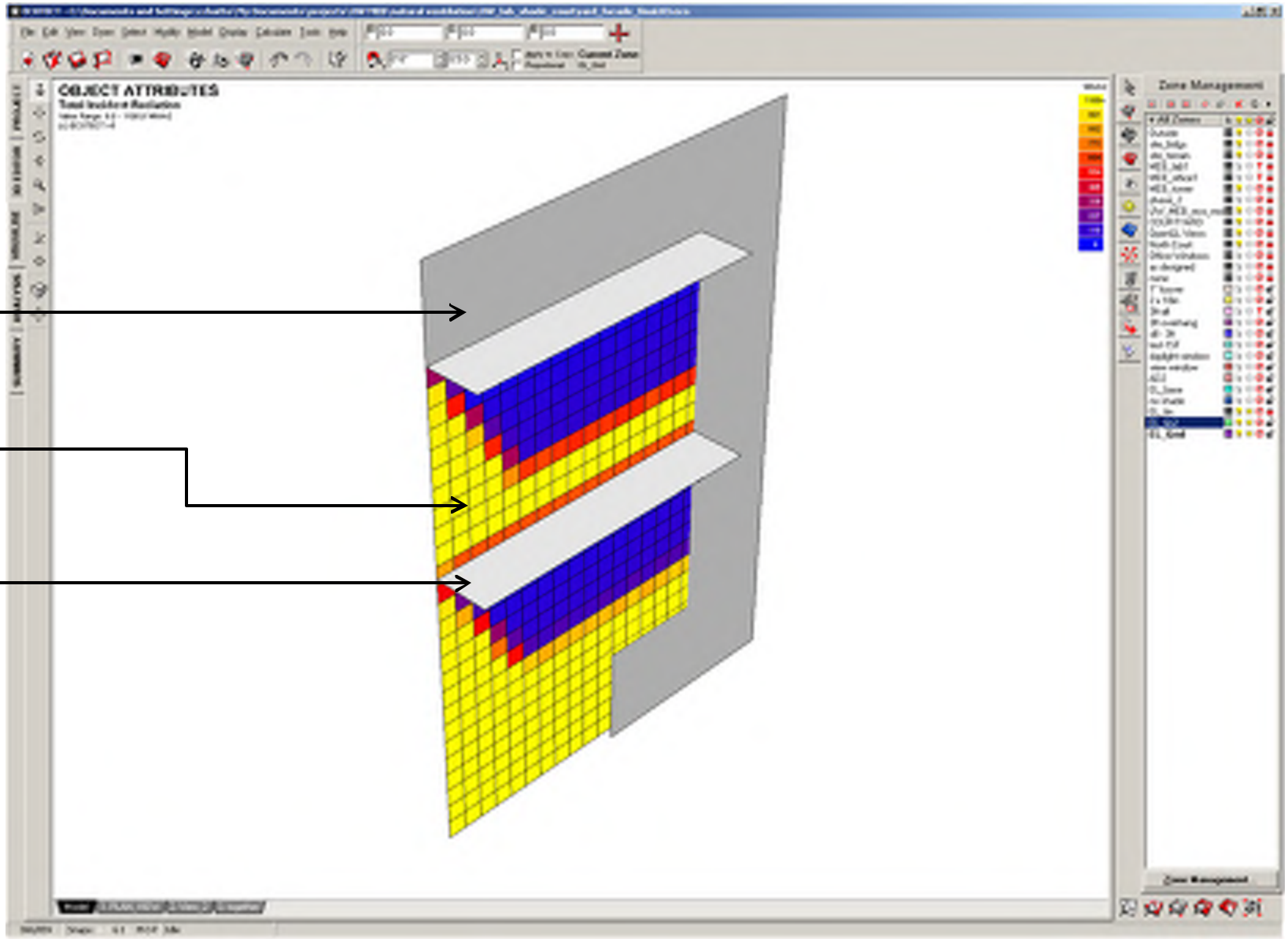
Facade opacity
40.8% red.

Glass type
34.1% red.

Overhangs
51.6% red.

Total
81.1% reduction

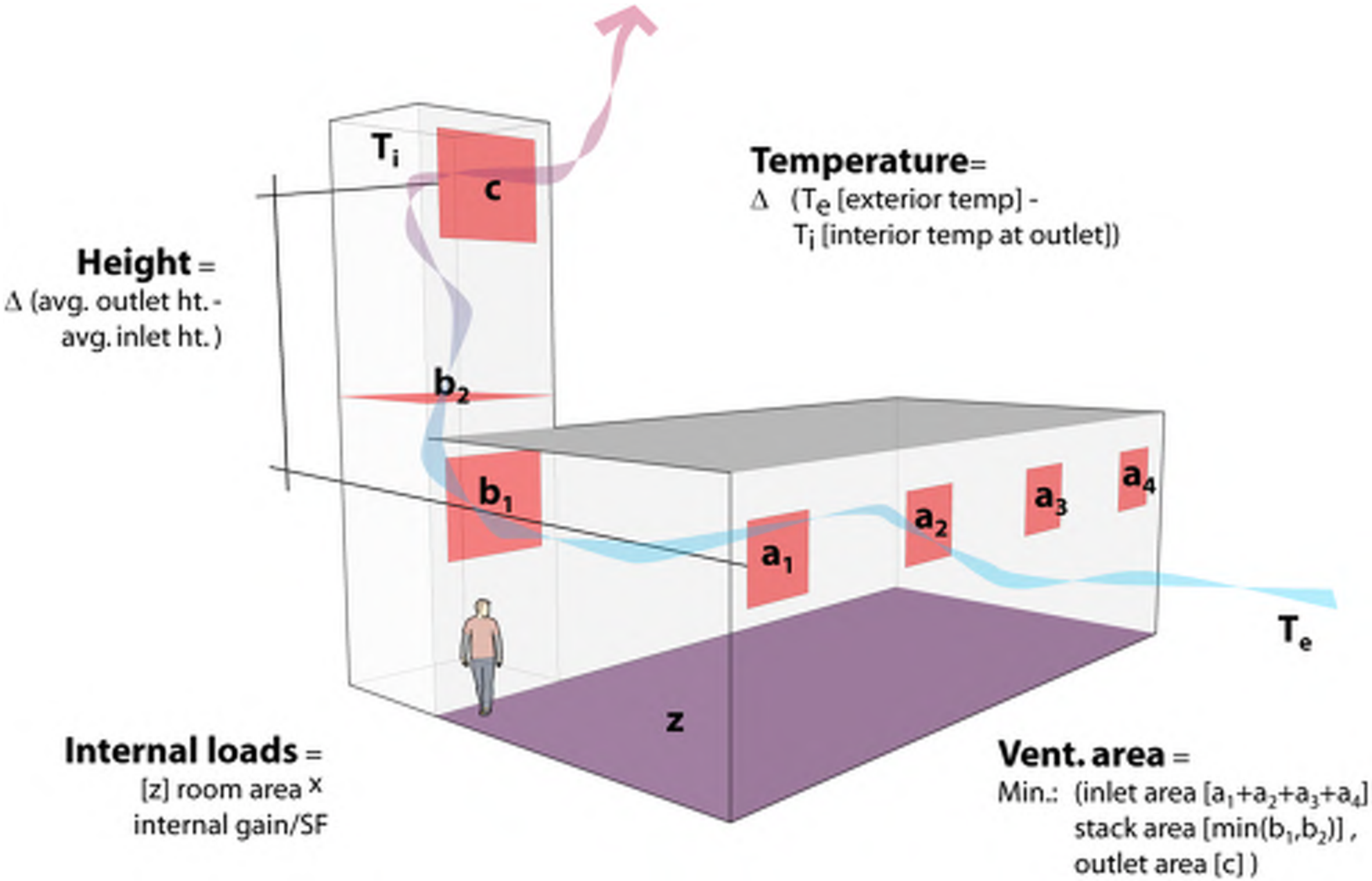
(vs. 81.7% goal)



Reducing Solar Gain

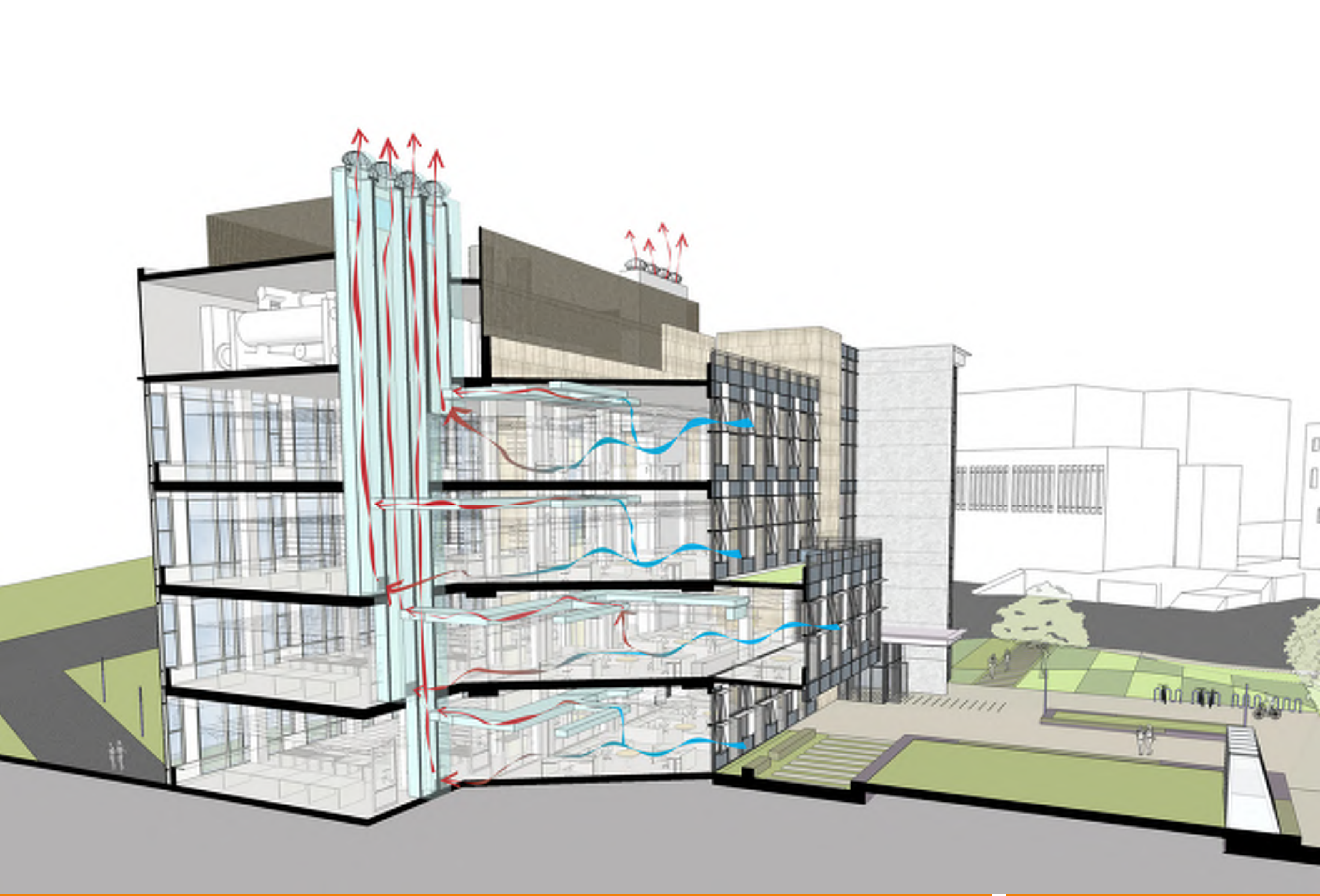
SOLUTION

SOLUTION



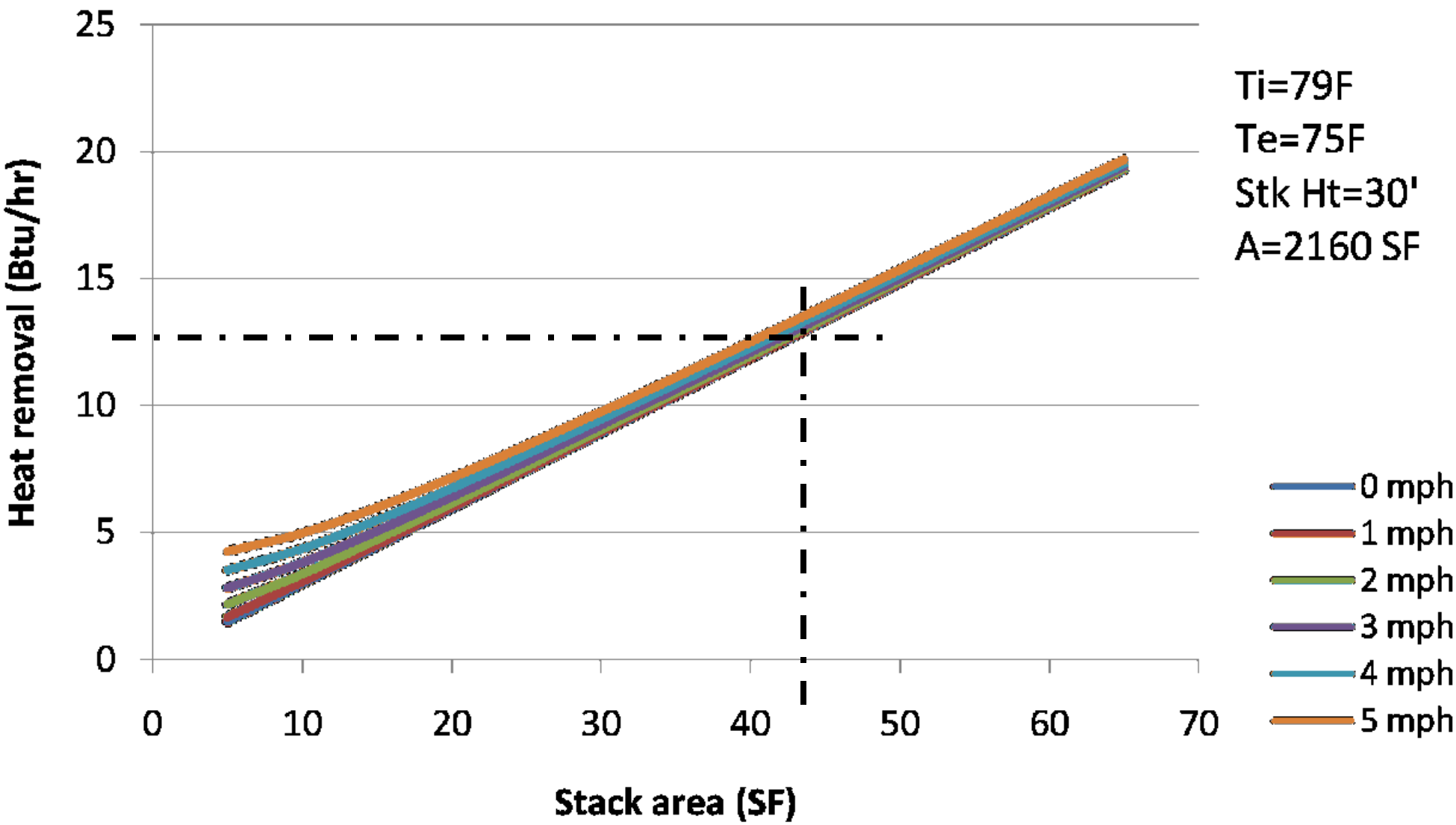
Stack Ventilation Variables

SOLUTION



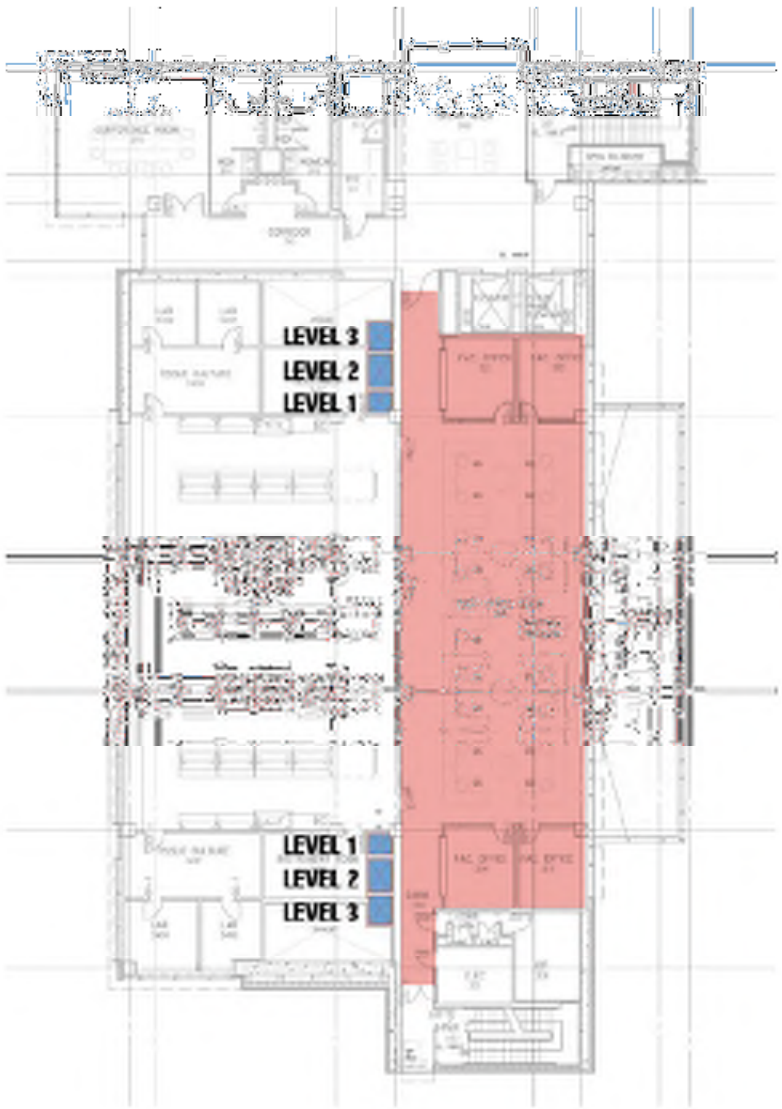
Stack Ventilation Scheme

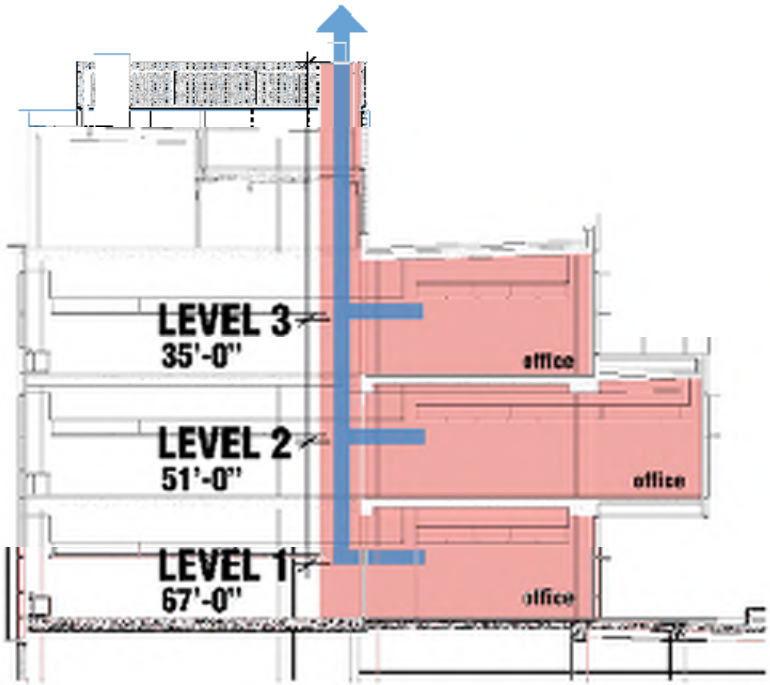
SOLUTION



Stack Performance: Single Zone Model

SOLUTION

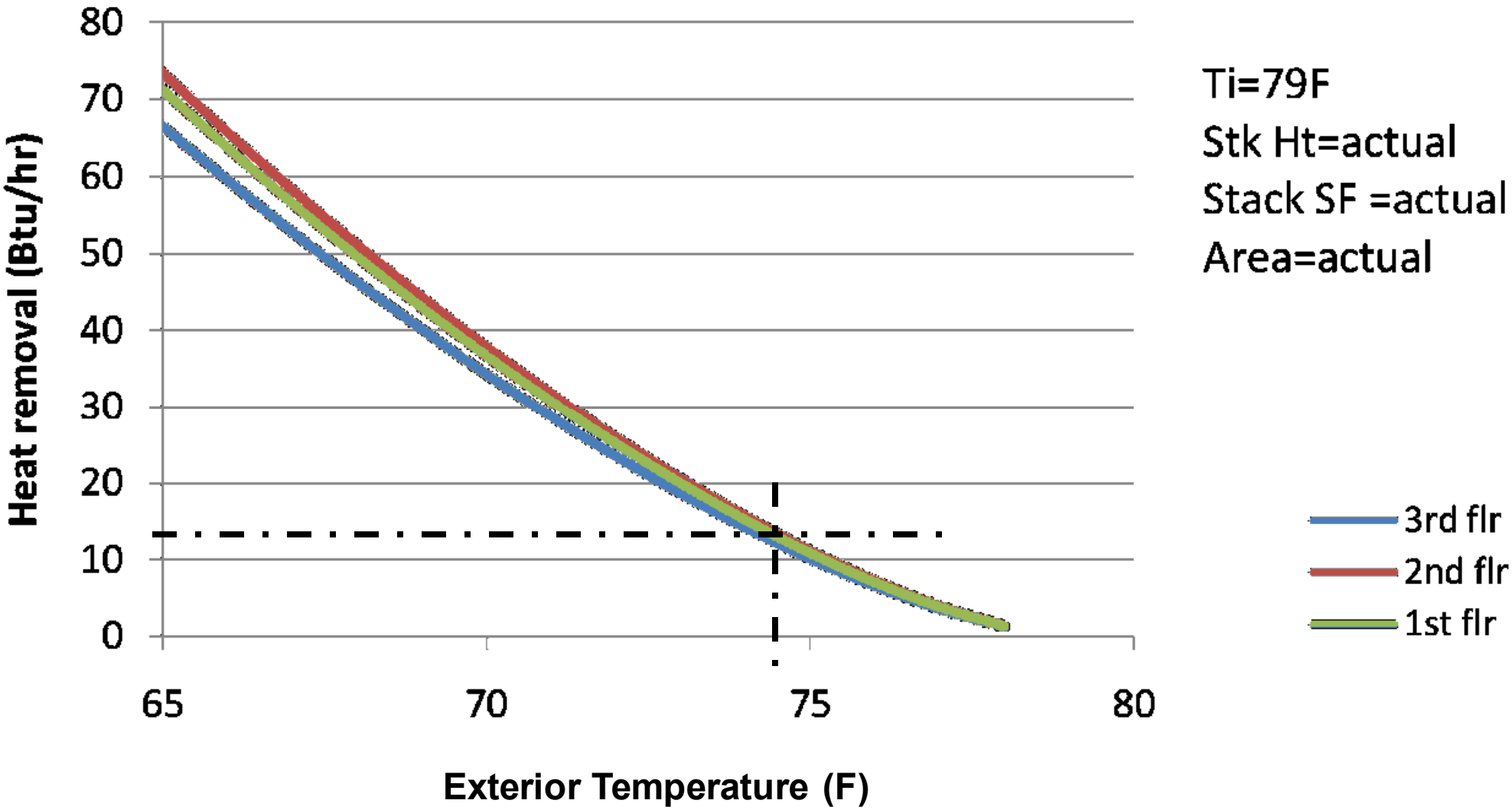




LEVEL 1	**AREA:**	**25.5 SF (12.75 x 2)**
	HEIGHT:	**62'-0"**
LEVEL 2	**AREA:**	**39.12 SF (19.56 x 2)**
	HEIGHT:	**46'-0"**
LEVEL 3	**AREA:**	**34.22 SF (17.11 x 2)**
	HEIGHT:	**30'-0"**

Actual Stack Areas and Heights

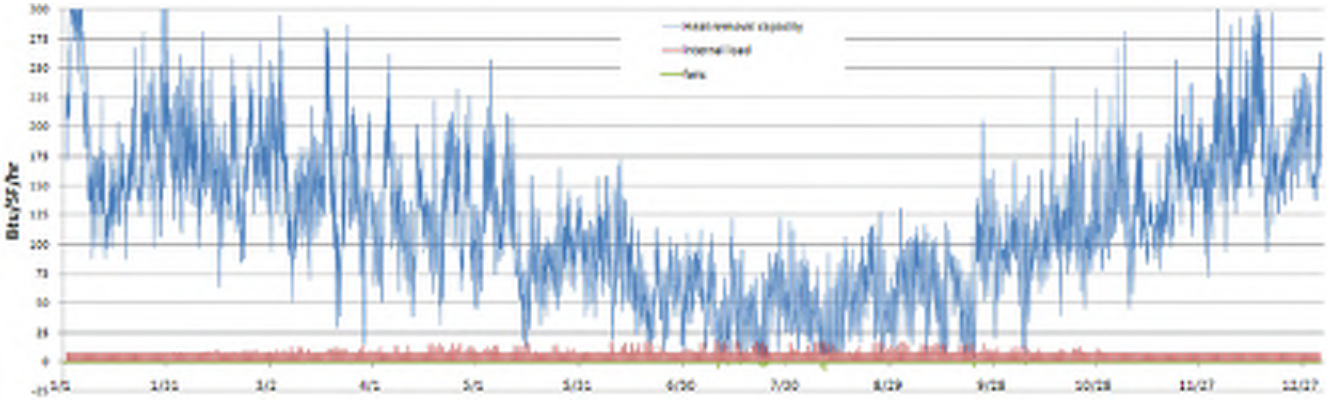
SOLUTION



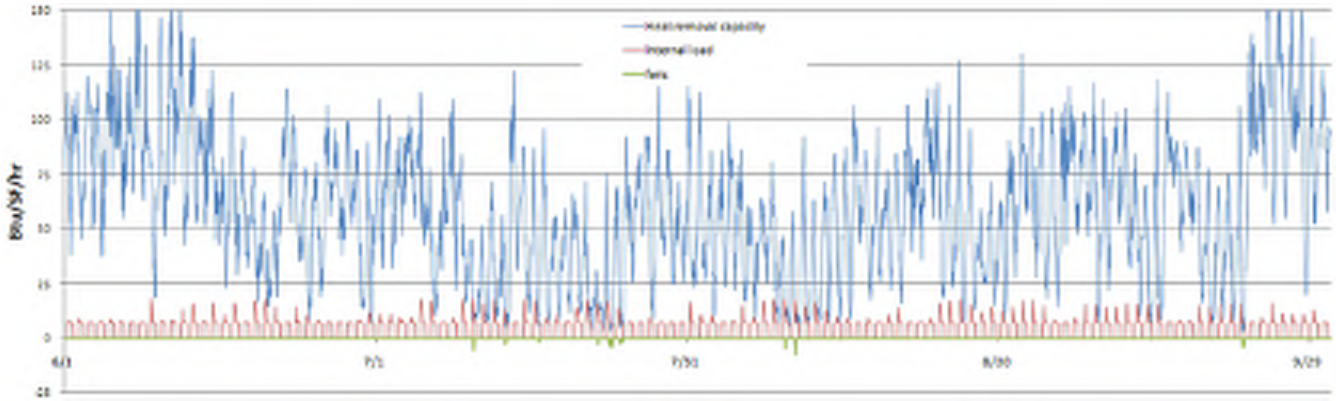
Stack Performance: Single Zone Model

SOLUTION

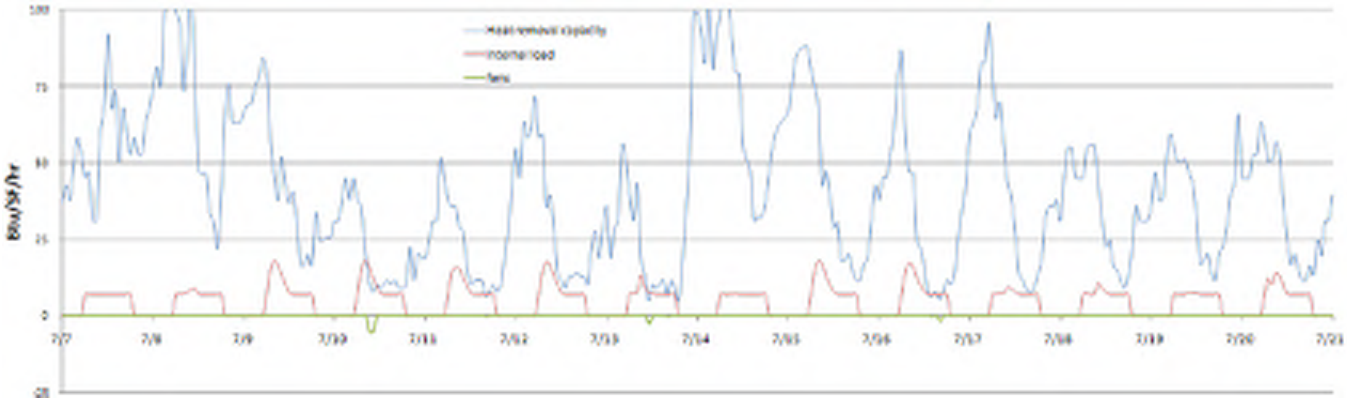
All year



Summer



Fortnight

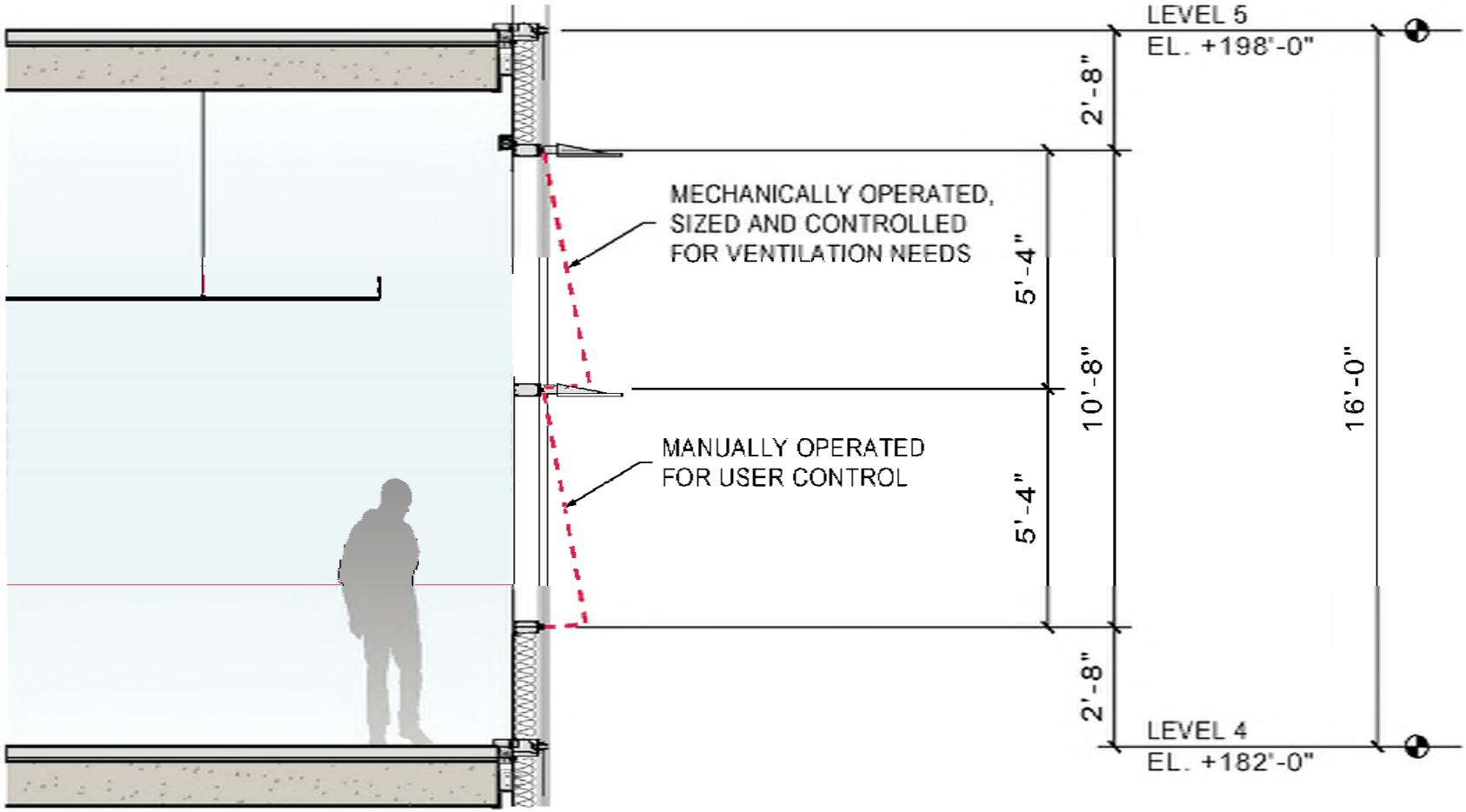


Predicted fan use:

Total hours: 33
Peak need: 7.3 btu/hr/F
Avg need: 2.1 btu/hr/SF

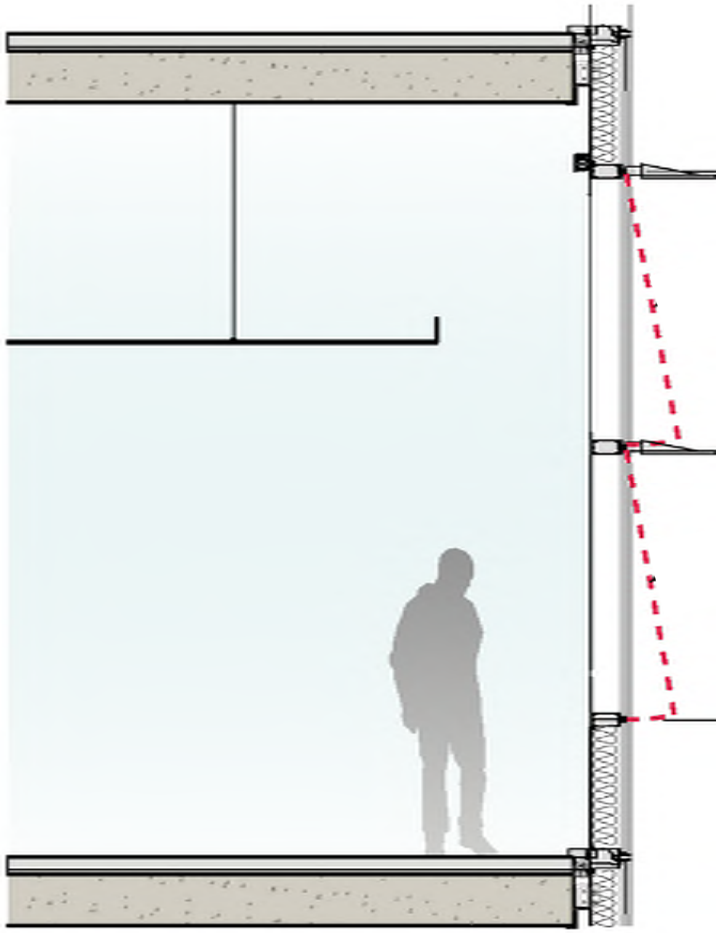
2nd Floor Single Zone Model

SOLUTION



Operable Window Strategy

SOLUTION



Operable Window Strategy

SOLUTION

Each floor has 16 windows:

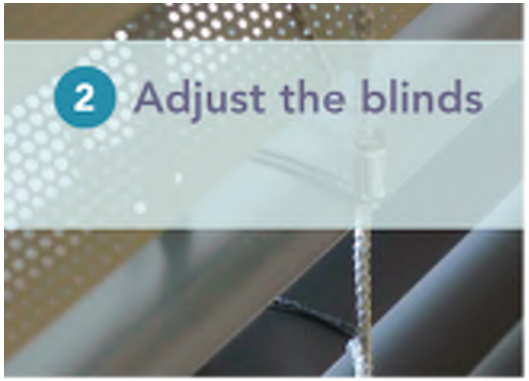
	# Windows	Effective SF
Mechanically actuated	8	40.6
Human operated	8	40.6

Facade

SOLUTION

1 Follow red + green lights

- The windows are user controlled and should only be opened when the **green** indicator light is illuminated.
- Closing the windows when the **red** light is illuminated will result in additional energy savings and increased thermal comfort.
- Close windows when you leave for the day.



2 Adjust the blinds

- Raise and lower the blinds, and rotate the blades in order to exclude direct sun.
- To maximize daylight and electric light dimming, open the blinds when the direct sun is no longer causing discomfort.

3 Utilize light + fan controls

- Electric lights are zoned to turn lights on only when needed and automatically dim or turn lights off in areas that are adequately daylit.
- To use the ceiling fans, hold the fan switch for 5 seconds, to allow building automation system and fan controls to communicate.

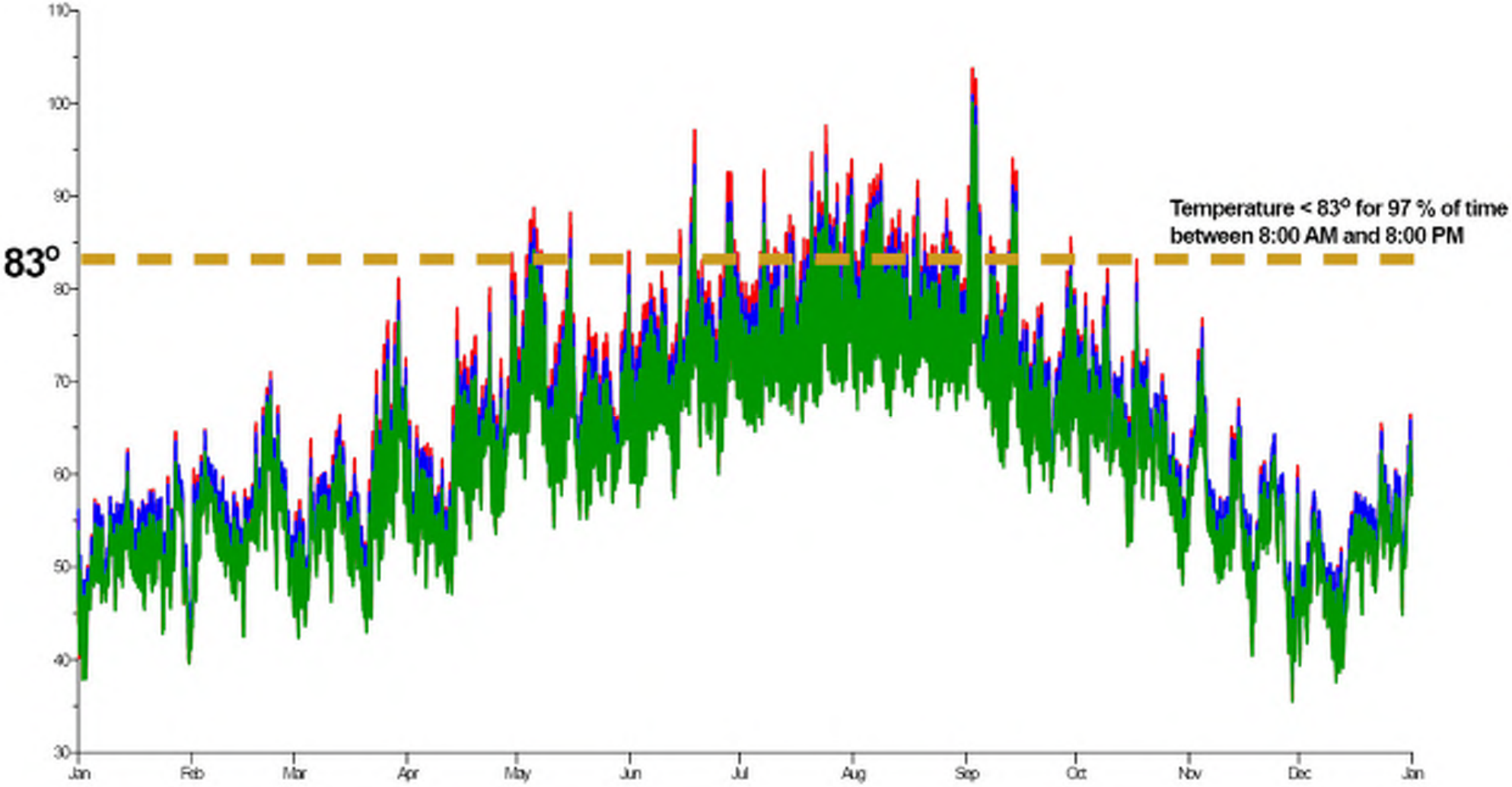
Occupant control strategies

SOLUTION

1. 500 CFM supply air from lab system
2. Thermal transfer through lab/office boundary
3. Mechanical assist for chimneys
4. Ceiling fans
5. Night flush of thermal mass

Additional Cooling Features

SOLUTION



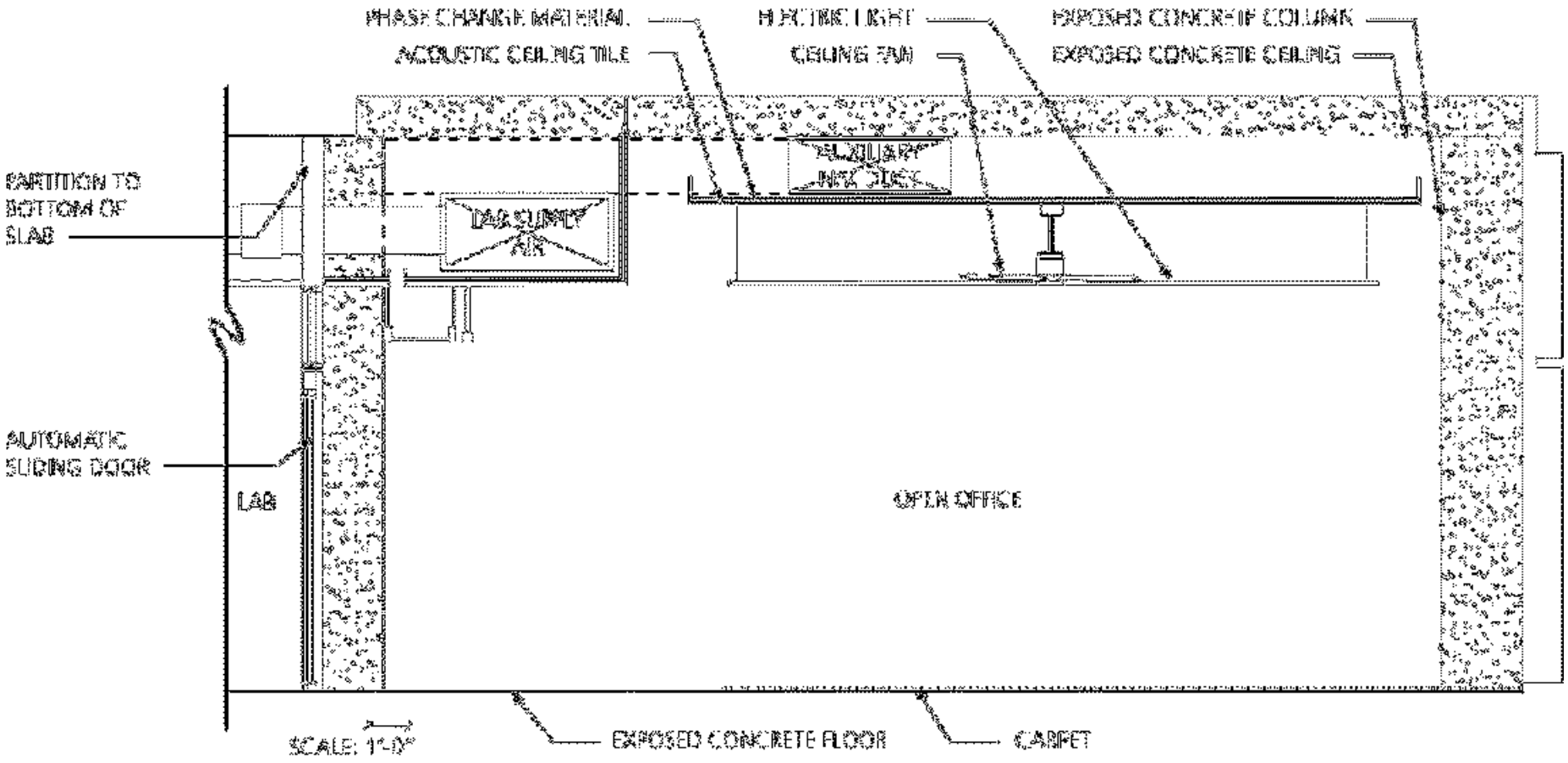
Baseline excludes mass and mechanical assist.

With mass Excludes mech. assist.

With mass With mechanical assist.

Preliminary Macro-Flow Interior Temp. Results

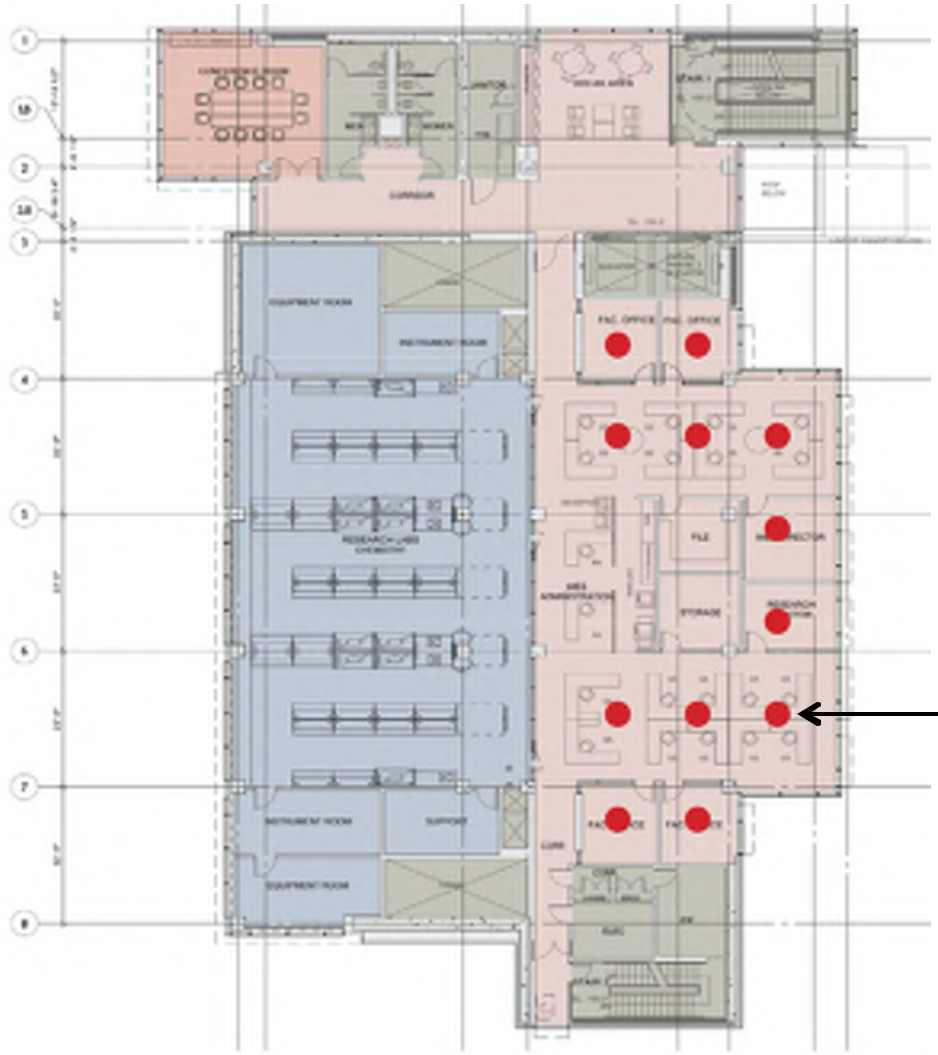
SOLUTION



Integrated components

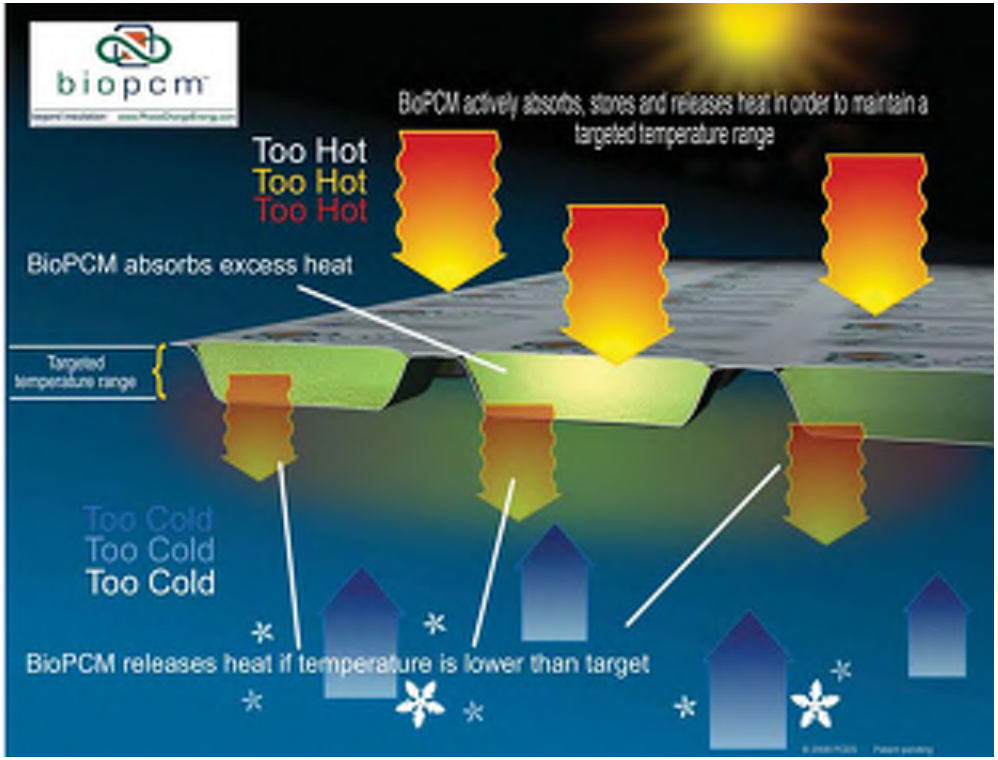
SOLUTION

ASHRAE Standard 55 predicts that air flow provided by cooling fans can reduce effective air temperature by 3°F.



Ceiling Fans

SOLUTION

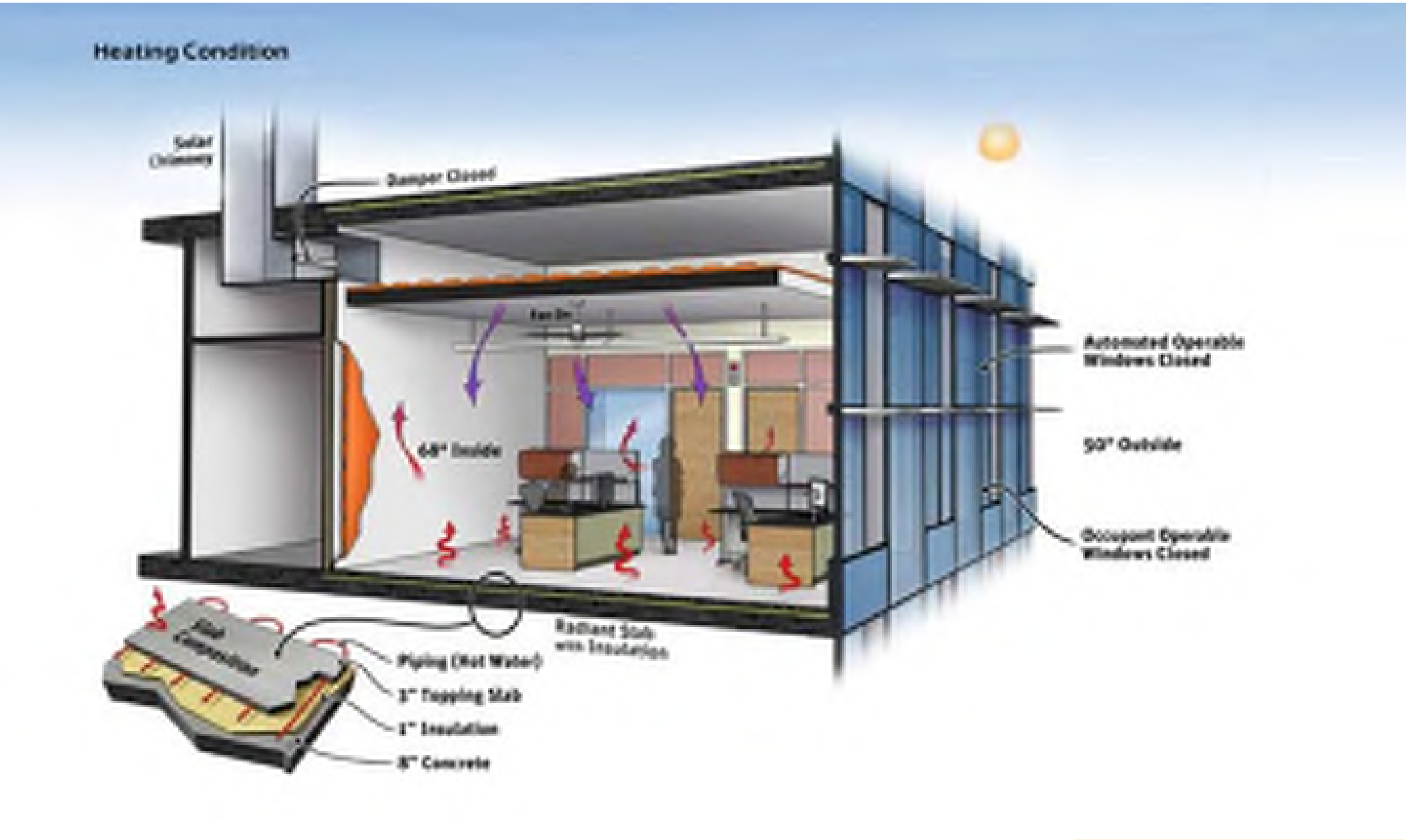


BioPCM™ phase change material

BioPCM™ Mats	Unit	23C/73F .56 lb/sq. ft.	23C/73F 1 lb/sq. ft.	23C/73F 2 lb/sq. ft.	27C/81F .56 lb/sq. ft.	27C/81F 1 lb/sq. ft.	27C/81F 2 lb/sq. ft.
Thickness	mm	14	14	14	14	14	14
Weight per square foot	lb	0.77	1.32	2.66	0.76	1.31	2.66
Total unit thickness	mm	.25-.35	.4-.5	1	.25-.35	.4-.5	1
Dimensions	mm/in	419.1/16.5	419.1/16.5	419.1/16.5	419.1/16.5	419.1/16.5	419.1/16.5
Energy Store values- Other temperature ranges are available							
PCM loading	%	73%	76%	75%	74%	76%	75%
Melt point*	°C/°F	23/73	23/73	23/73	27/81	27/81	27/81
Latent heat storage capacity	J/g >	209	209	209	219	219	219
Boiling Point	°C	>248.9	>248.9	>248.9	>248.9	>248.9	>248.9

Phase change material

SOLUTION

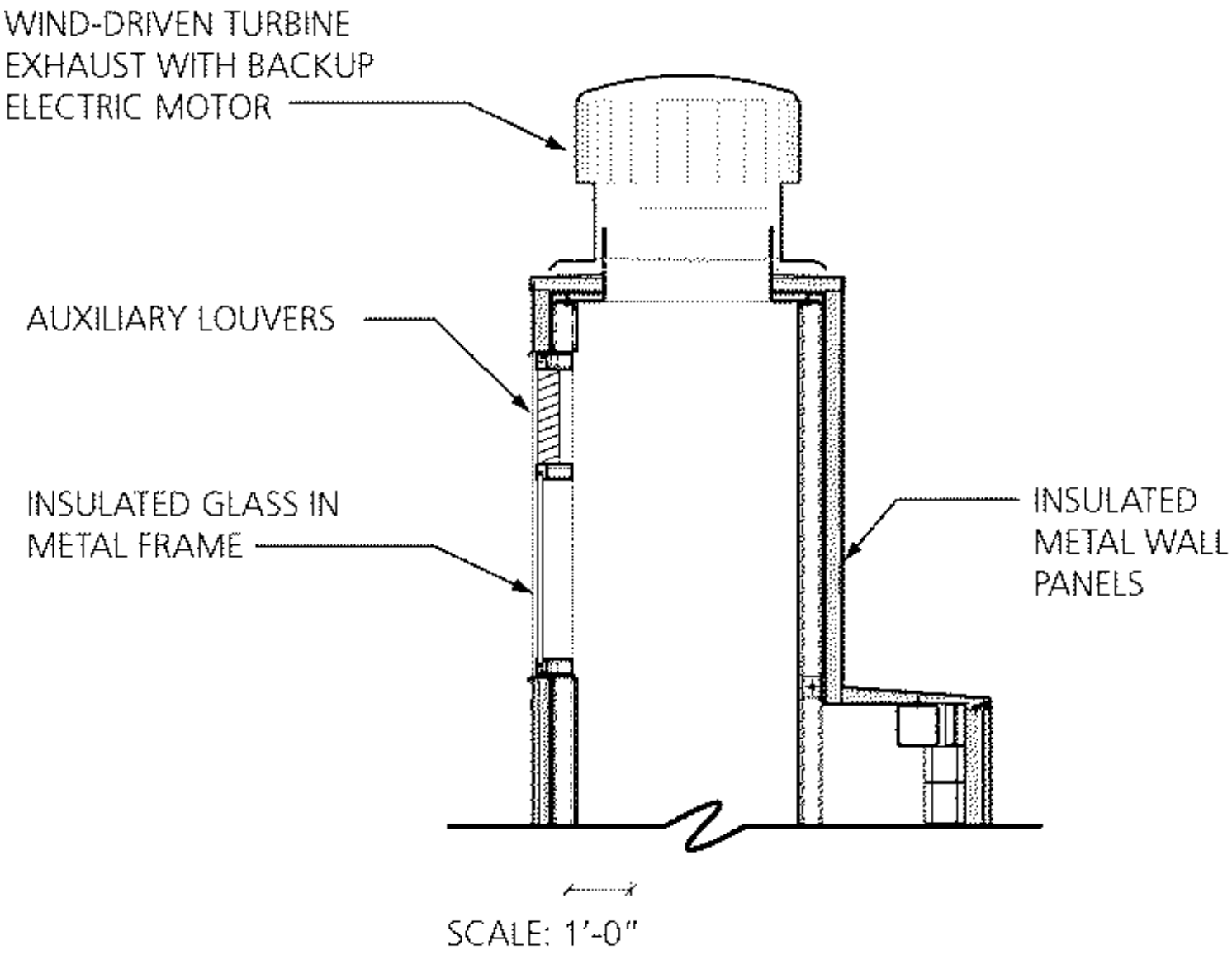


Phase change material

SOLUTION

Thermal mass

SOLUTION



Assists: Sun, Wind, Fan

SOLUTION

Assists: Sun, Wind, Fan

SOLUTION

> Phase change material

> Thermal comfort

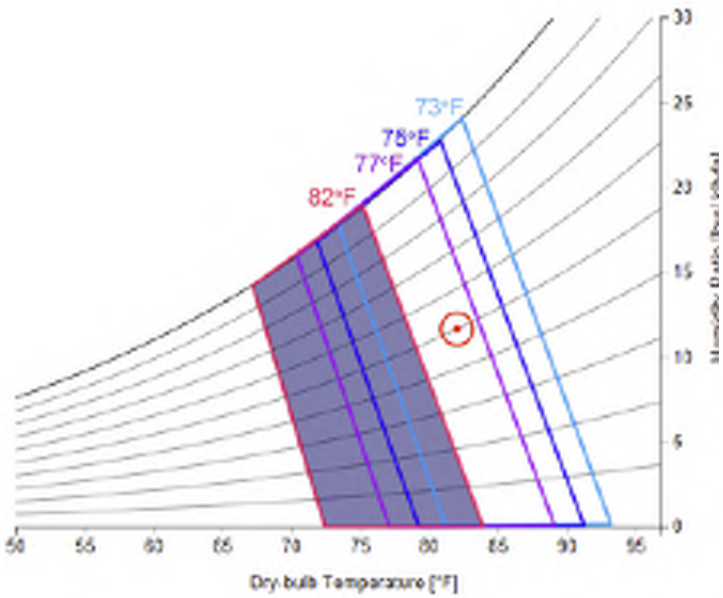
> Energy Savings

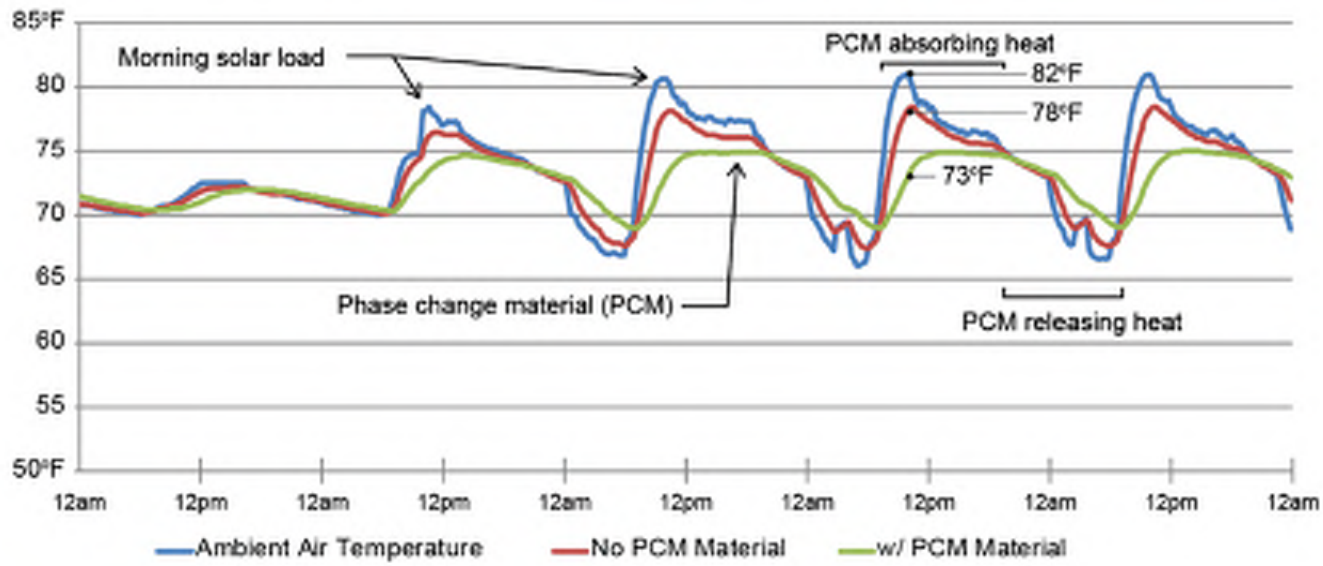
> Carbon Footprint Evaluation

> Cost

CONCLUSION

Jul 22	Jul 23	Jul 24	Jul 25	Jul 26
High 79°	High 88°	High 88°	High 88°	High 87°
Low 56°	Low 57°	Low 58°	Low 55°	Low 58°

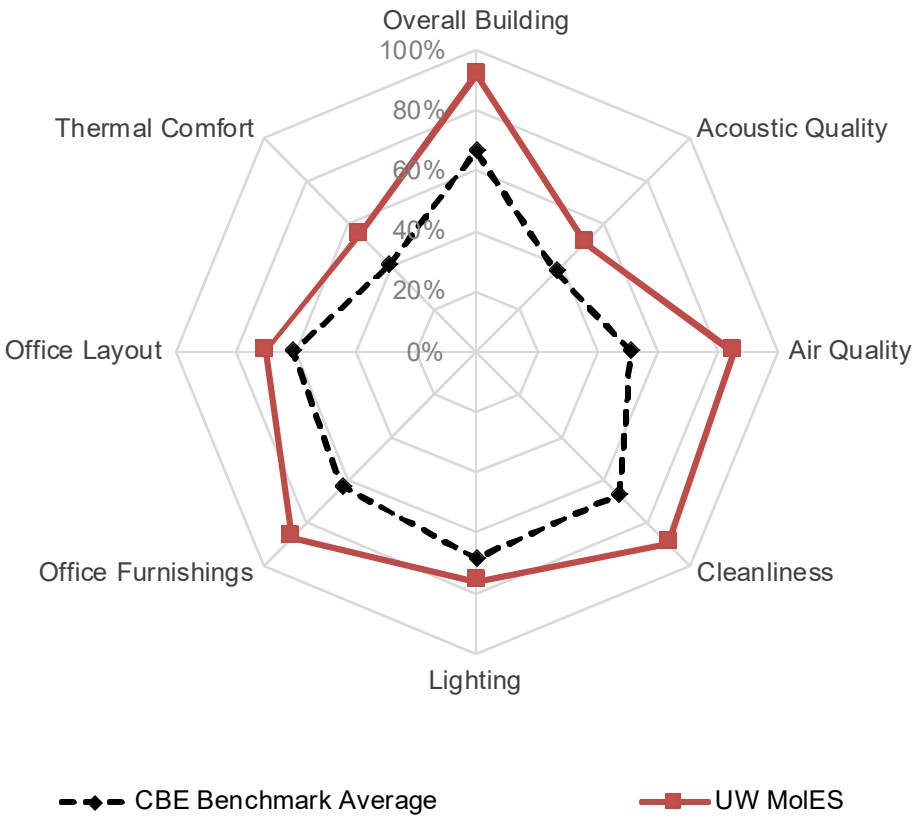




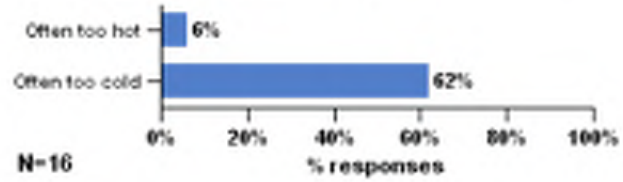
PCM effectiveness

CONCLUSION

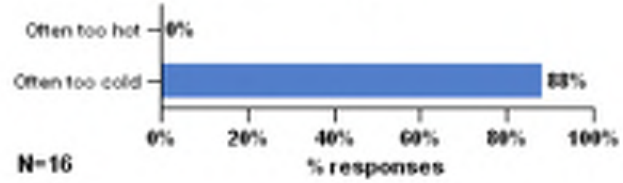
CBE Post Occupancy Survey Results (% occupants satisfied)



In warm/hot weather, the temperature in my workspace is: (check all that apply)



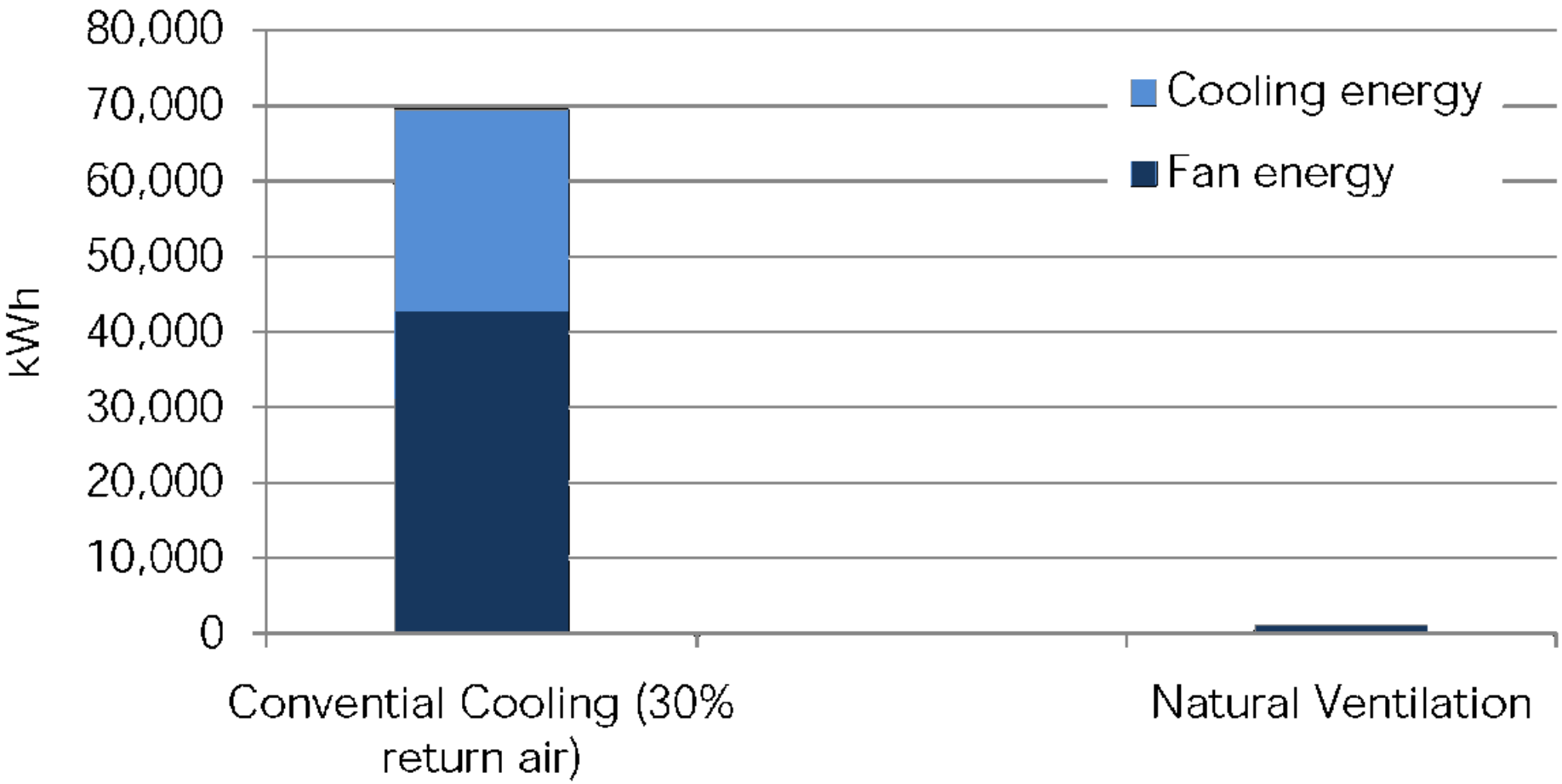
In cool/cold weather, the temperature in my workspace is: (check all that apply)



When is this most often a problem? (check all that apply)

Thermal comfort

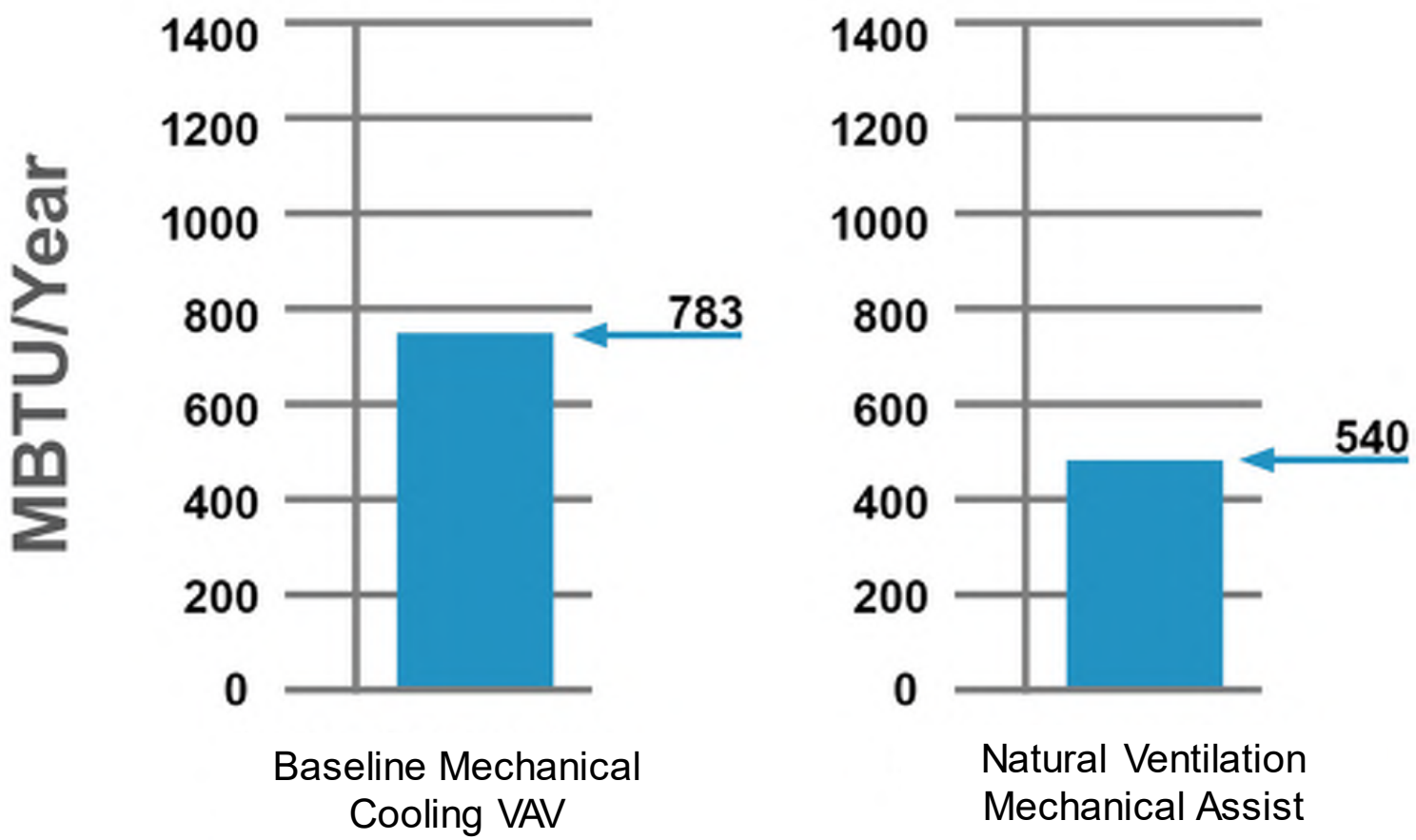
CONCLUSION



Energy Savings vs Typical

CONCLUSION

Estimated Office Natural Ventilation Savings



Energy Savings

CONCLUSION

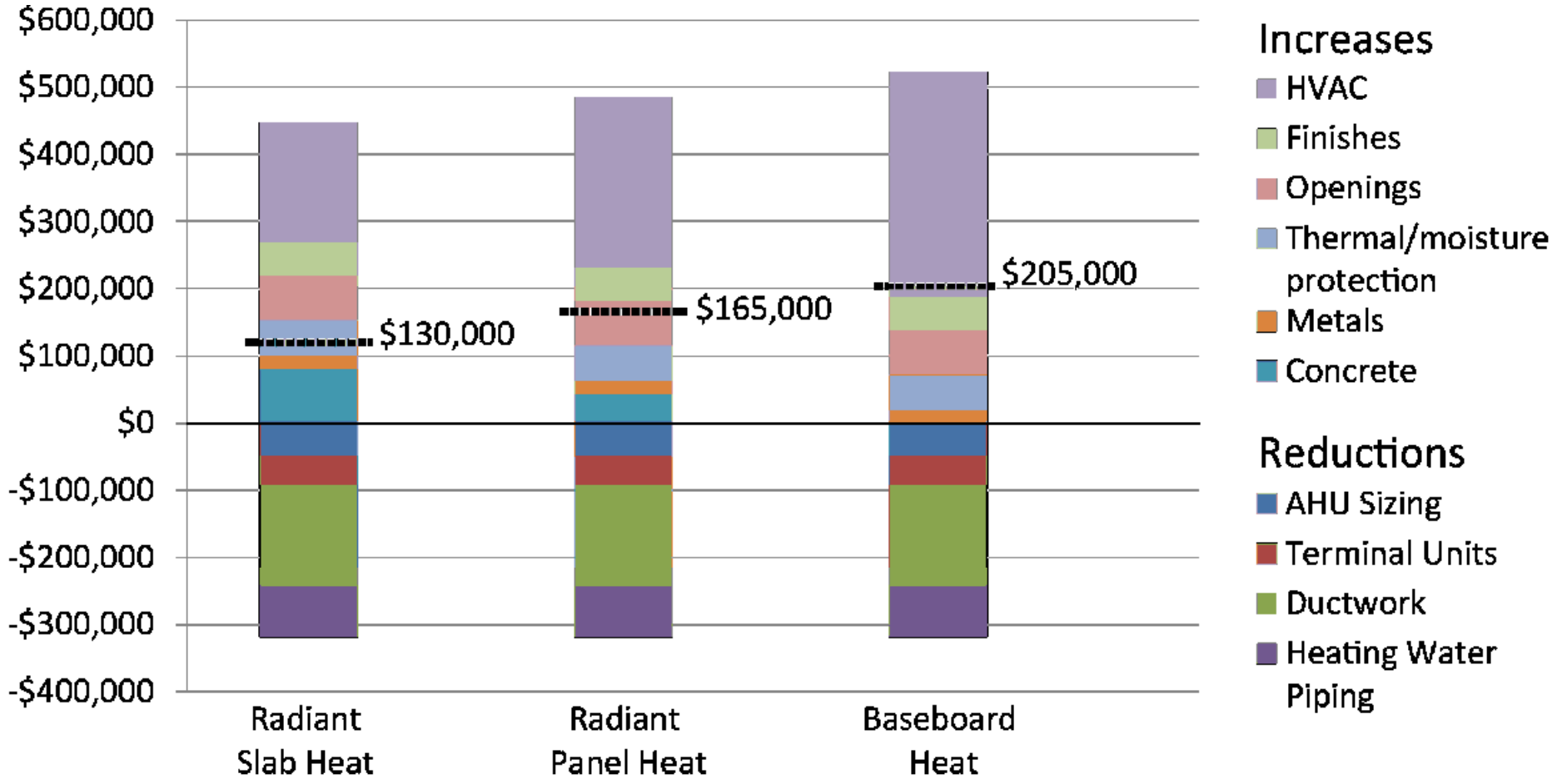
Natural Ventilation Reduces CO_2 by 44 Metric Tons

What does this mean?

103 barrels of oil burned per year ….or

8 cars on the road ….or

5,039 gallons of gasoline being consumed.



Cost Impacts & Net Effect of Natural Ventilation

CONCLUSION

Not Easy to Implement

Requires:

- Committed Team
- Integrated Design
- Aggressive Load Reduction
- Educated Occupants

Integrated Team:

ZGF Architects LLP

Affiliated Engineers, Inc.

University of Washington

SOLARC Architecture and Engineering
(Energy modeling & early natural ventilation concepts)

Seattle City Light
(local utility, helped fund energy model and provides energy conservation incentives)

Hoffman Construction
(contractor, provided cost estimation)

Chris Flint Chatto
ZGF Architects LLP
chris.chatto@zgf.com

CONCLUSION