The Feasibility of Natural Ventilation

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ASHRAE San Joaquin Chapter

Learning Objectives

- Apply the appropriate codes and standards when considering natural ventilation
- Identify key steps in evaluating outdoor conditions for supporting natural ventilation
- Evaluate internal and external heat gains to determine whether natural ventilation can provide sufficient cooling

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Session Summary

- This session will describe process of early phase analysis that a design team can to test whether natural ventilation is a feasible comfort-conditioning system for a given climate and building configuration. The speaker will build on her “Natural Ventilation Top 10 Feasibility Questions” from an ASHRAE Journal article to cover compliance with ASHRAE Standards 55 and 62.1 and a discussion of the impact of climate change.

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Mixed Mode Ventilation

Finding the Right Mix

By Erin McConahey, P.E., Member ASHRAE

With the rising cost of energy, the drive towards improved indoor air quality, and the industry's adoption of an adaptive comfort model for naturally conditioned spaces, interest is growing among HVAC engineers to explore how natural ventilation might best be reapplied in the building industry. This article presents an overview of ASHRAE standards applicable to spaces using natural ventilation, suggests an early-phase design decision-making methodology, and then compares a collection of recent mixed mode projects that have applied some level of natural ventilation within the San Francisco Bay area.

Starting From the Beginning

Natural ventilation is not a new concept. Indeed, it was the primary method of ventilation and cooling for many centuries. From the wind-catching towers of Iran to the termite mounds of Zimbabwe, humans and animals have harnessed nature's wind power and air's buoyancy effects to drive flows of air through internal spaces. However, since the introduction of air-conditioning by Willis Carrier's 1906 patent, a half-dozen generations of Americans have become accustomed to mechanical conditioning of indoor spaces, especially for large commercial buildings. Therefore, the reapplication of natural ventilation into modern buildings requires care, intentionality, involvement of the client parties, and in particular, a full understanding of the most recent ASHRAE standards: ANSI/ASHRAE Standard 62.1-2007, *Ventilation for Acceptable Indoor Air Quality* and ANSI/ASHRAE Standard 55-2004, *Thermal Environmental Conditions for Human Occupancy*. *Table 1* provides some key definitions related to natural ventilation, as found primarily in these standards.

About the Author

Erin McConahey, P.E., is an associate principal in mechanical engineering at the Los Angeles office of Arup, a global multidisciplinary design and consulting firm.

- ASHRAE Journal September 2008
- Table 4 Natural Ventilation Top 10 Feasibility Questions
- These were rules of thumb

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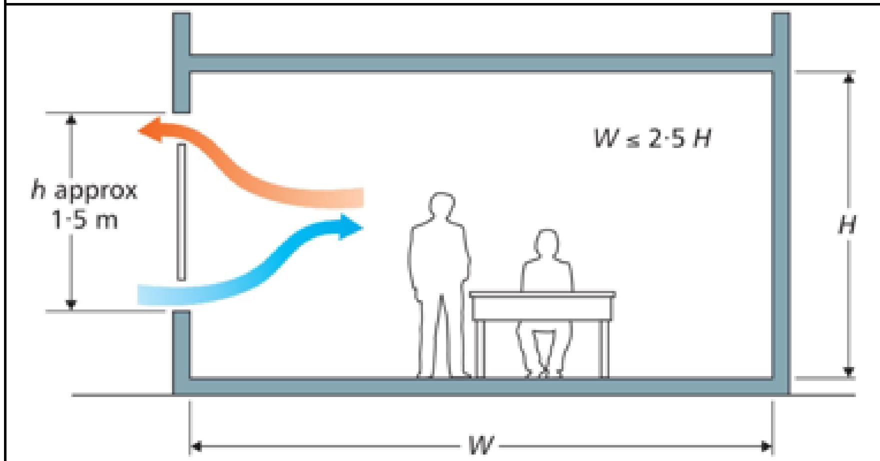
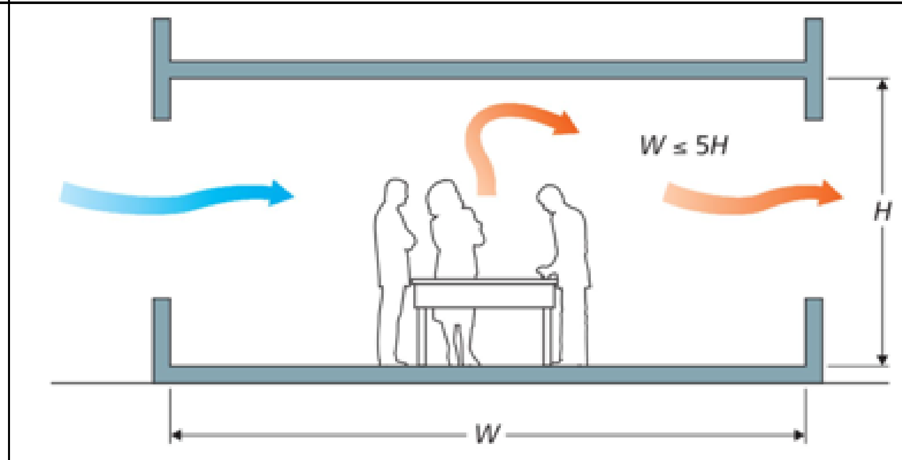
Mechanisms of Natural Ventilation

Buoyancy-Driven Natural Ventilation, also known as "Stack Effect"	Wind-Driven Natural Ventilation
	

Though obvious, the following basic natural ventilation principles bear repeating:

1. Natural ventilation only works if there are at least two openings (or a very tall opening that acts as a two-way opening).
2. The amount of airflow is controlled by the size of the smallest opening.
3. Air will always follow the path of least resistance.

Images courtesy of CIBSE

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Natural Ventilation vs Natural Conditioning

Natural Ventilation	Natural Conditioning
Per ASHRAE 62.1-2016 (ASHRAE 2016b) the definition of Natural Ventilation is "ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building." **Essentially, direct air intake from Outdoors into the occupied space to support only the Indoor Air Quality requirements.**	Per ASHRAE 55-2017 (ASHRAE 2017a) page 3, the definition of Occupant-controlled Naturally Conditioned spaces is "those spaces where the thermal conditions of the space are regulated primarily by occupant-controlled openings in the envelope." Essentially, direct air intake from Outdoors into the occupied space supports absorption of heat gains. This can occur via -direct cooling of occupants -removal of air heated from computers or lights -cooling of surfaces that then causes indirect cooling of occupants through radiative heat exchange.

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Natural Ventilation Codes & Standards

Standard/ Manual Name	Key chapters/clauses pertaining to natural ventilation and natural conditioning
ANSI/ASHRAE Standard 62.1-2016. Ventilation for Acceptable Indoor Air Quality	Section 6.4 with backup mechanical ventilation systems design per Section 6.2 and/or 6.3.
ANSI/ASHRAE Standard 55-2017. Thermal Environmental Conditions for Human Occupancy	Section 5.4
2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings for the 2016 Building Energy Efficiency Standards: Title 24, Part 6	Section 120.1.(b).1
2015 IMC International Mechanical Code	Section 402
2016 California Mechanical Code, California Code of Regulations Title 24, Part 4 based on 2015 Uniform Mechanical Code®	Section 402.2, essentially replicates ASHRAE Standard 62.1

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Other Applicable Guidance

Standard/ Manual Name	Key chapters/clauses pertaining to natural ventilation and natural conditioning
Leadership in Energy and Environmental Design (LEED®) Reference Guide for Building Design and Construction v4.	Minimum Energy Performance Prerequisite p. 357, Optimize Energy Credit (relies on calculation in previously named Prerequisite), Minimum Indoor Air Quality Performance Prerequisite pp.605-622, Enhanced Indoor Air Quality Strategies Credit pp.645-656, and Thermal Comfort Credit p 695-710. (note that this standard references ASHRAE Standard 62.1-2010 and ASHRAE Standard 90.1-2010.)
Natural ventilation in non-domestic buildings, CIBSE Applications Manual AM10	Entire document
Mixed mode ventilation, CIBSE Applications Manual AM13:2000.	Document addresses mixed mode or hybrid ventilation, within which natural ventilation is discussed as one of the modes available

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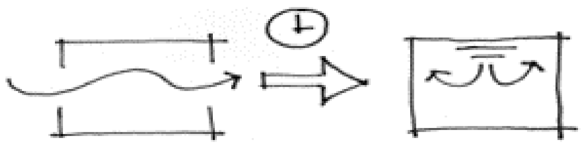
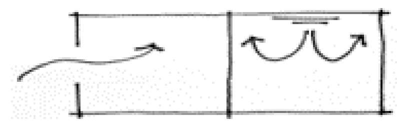
Natural Ventilation vs Mixed Mode

Complementary Design		Zoned Design
Concurrent	**Change-over**	
Mechanical cooling and Natural ventilation occur in Same space Same time	Mechanical cooling and Natural ventilation occur in Same space Different times	Mechanical cooling and Natural ventilation occur in Different spaces Same time
		

ASHRAE 55 Adaptive Comfort standard not applicable

ASHRAE 55 Adaptive Comfort standard not applicable

ASHRAE 55 Adaptive Comfort standard applicable to permanent NV space

Images courtesy of Dr. Gail Brager of UC Berkeley

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NV Top 10 Feasibility Questions

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
1. Building Envelope	Is the building envelope performance optimized to minimize solar gain into the building? Target a maximum total solar load of 4 W/ft2 of sun patch floor area in a cooling condition.
2. Internal Heat Loads	Is the total internal heat load minimized to less than 2 W/ft2 for naturally conditioned space or, within the cooling capacity of auxiliary systems?
3. Weather Normals: Mean Maximum/ Mean Minimum	In looking at the climate data's monthly mean minimum and mean maximum, are there at least six months where the monthly maximum is less than 80°F but mean minimum is higher than 32°F?
4. Frequency of Occurrence Psychrometric Chart	In further looking at climate data, does the frequency of occurrence psychrometric chart for occupied hours have more than 30% of the time between 60°F to 80°F and less than 70% relative humidity?
5. Ambient Environment, Possible Locations of Openings	Is the surrounding environment suitable for direct intake of air from outside? (i.e., there are no security concerns, the ambient environment is sufficiently quiet, air quality meets Standard 62.1 standards, openings are not near street level, near highways or industrial plants, or at elevation of a neighbor's discharge).

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NV Top 10 Feasibility Questions

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
6. Window Locations and Sizes, Accessibility	Can the equivalent of 4% to 5% of the floor area as window opening area be found with direct access to the window by everyone within 20 ft?
7. Wind Rose, Feasible Flow Paths: Inlet to Outlet Under All Wind Conditions	Can one rely on wind-driven effects for cooling? Is there a direct low-pressure airflow path from a low-level opening to a high-level opening within the space, and will it be preserved once furniture/TI work is complete?
8. High Afternoon Temperatures	Does the climate have regular outside air temperatures over 80°F? If yes, review whether exposed thermal mass is possible.
9. Diurnal Range on Hot Days	Does the climate have a diurnal range that has nighttime temperatures below 65°F for at least 8 hours a night on the worst-case days? If yes, move to multizone modeling of thermal mass and consider night purge.
10. Dew-Point Temperatures Throughout Year	Throughout the year, do you have consistent outside air dew points throughout the year of less than 64°F? If yes, move to multizone modeling and consider a radiant cooling system.

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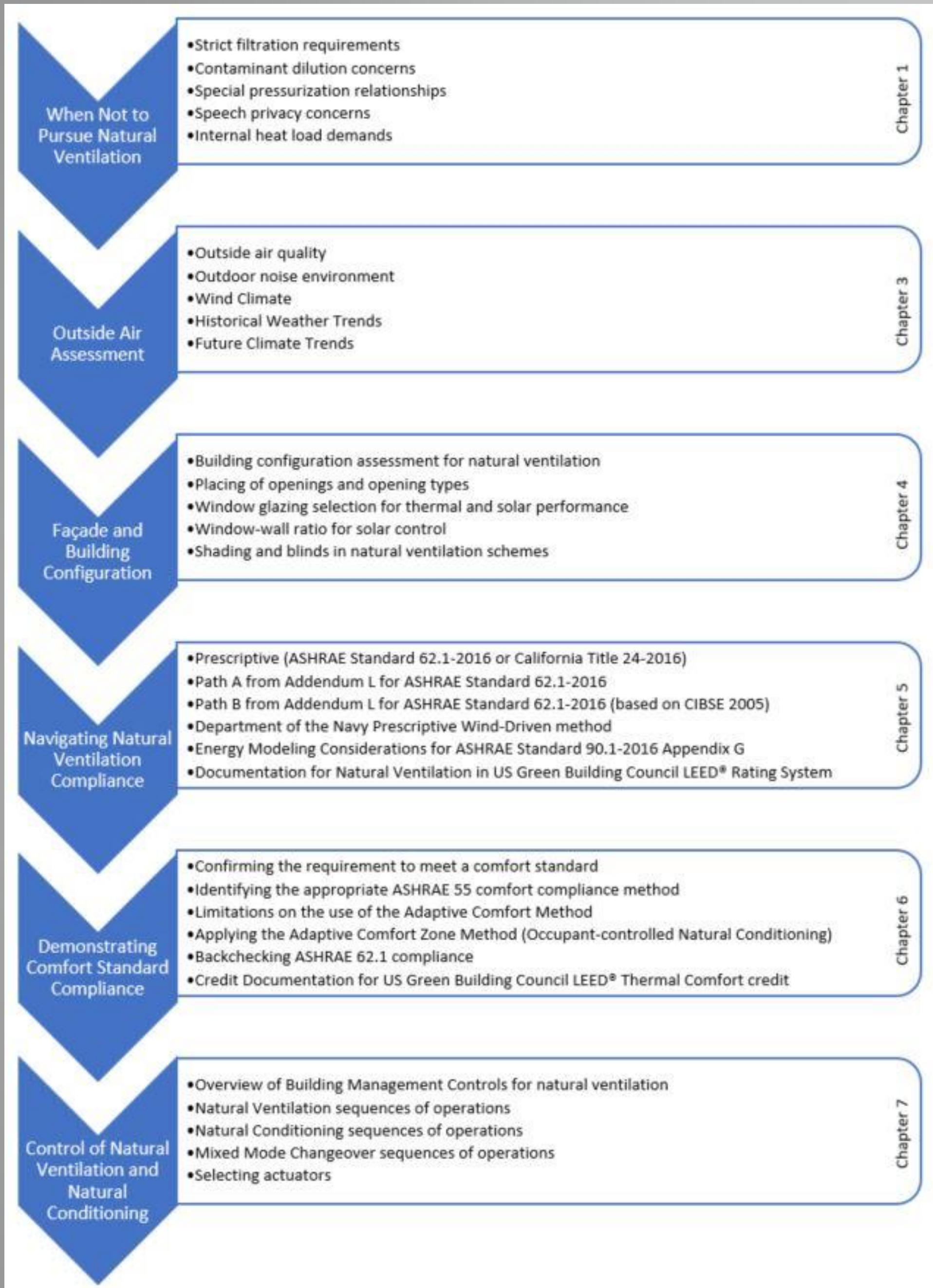

- Some content shared is from an upcoming Design Guide for Natural Ventilation (coauthored with Peter Simmonds, FASHRAE)

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Upcoming Design Guide Steps

- When Not to Pursue Natural Ventilation
- Outside Air Assessment
- Façade and Building Configuration
- Navigating Natural Ventilation Compliance
- Demonstrating Comfort Standard Compliance
- Control of Natural Ventilation and Natural Conditioning

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When Not to Pursue Natural Ventilation

- Strict Filtration Requirements
- Contaminant Dilution Concerns
- Special Pressurization Relationships
- Speech Privacy Concerns
- Internal Heat Load Demands

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Internal (and Solar) Loads

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
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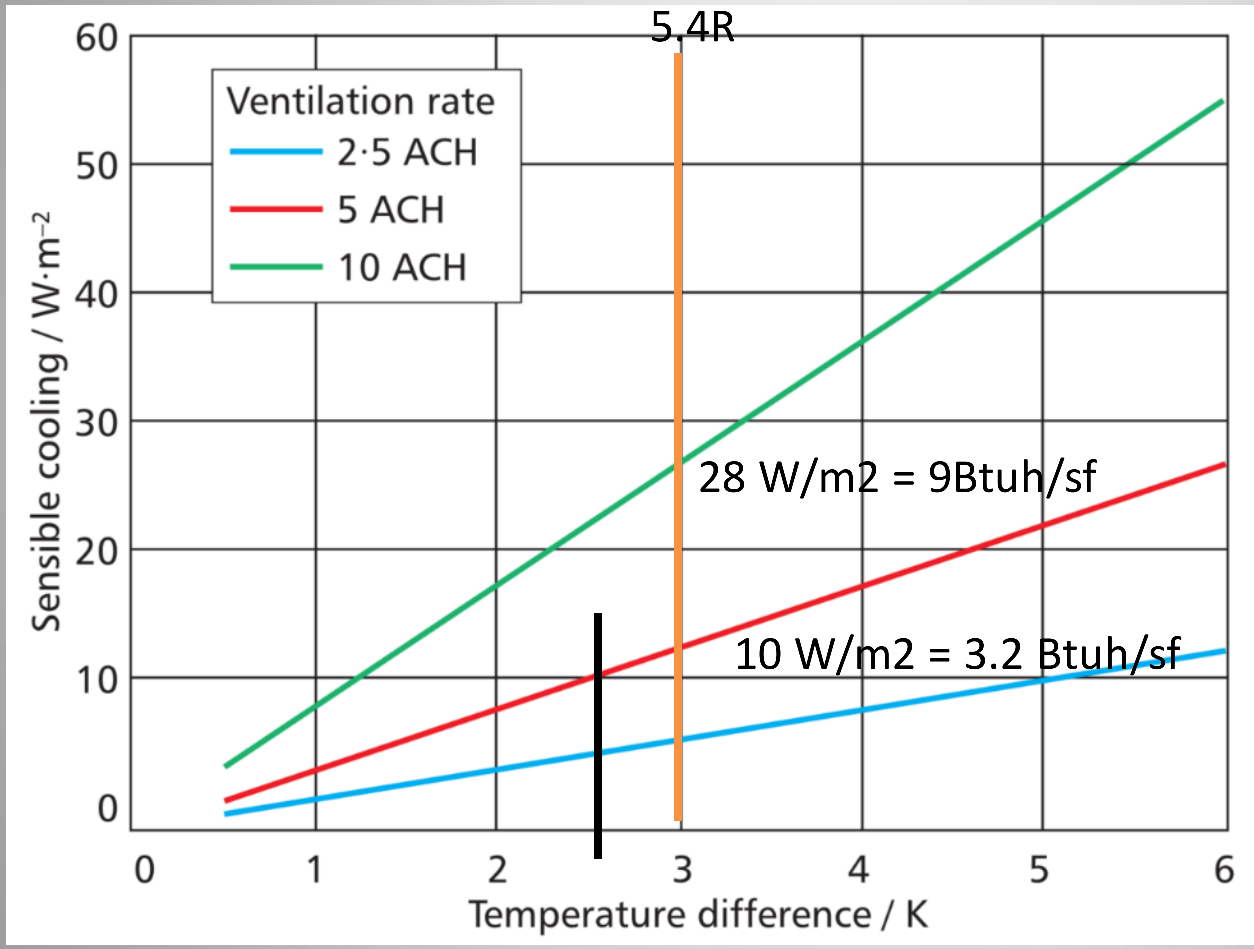
2. Internal Heat Loads	Is the total internal heat load minimized to less than 2 W/ft2 for naturally conditioned space or, within the cooling capacity of auxiliary systems?

- Take a 100 sf office
- 1 person, one PC
- Targeting 5 ac/hr with a 4.5°F (2.5° C) differential to outdoors

CIBSE NV capacity chart

- Size no higher than 3K difference



Images courtesy of CIBSE

Description	Reference	Heat Load in SI (1W/sf)
Total Available	--	10 W/m^2
One person: Seated Very Light Work, High velocity air movement	2017 ASHRAE Handbook Fundamentals (ASHRAE 2017b), page 18.4, Table 1	70 W x (1-0.27)/9.29 m^2 = 5.5 W/m^2
One tablet PC, average 15 min peak power consumption	2017 ASHRAE Handbook Fundamentals (ASHRAE 2017b), page 18.12, Table 8A	36 W/9.29 m^2 = 3.9 W/m^2
Differential available for lighting and solar loads	--	0.6 W/m^2

- According to CIBSE, you have a maximum of 28W/m2 (2.8W/sf) available at 3K differential (indoor-outdoor Temp)

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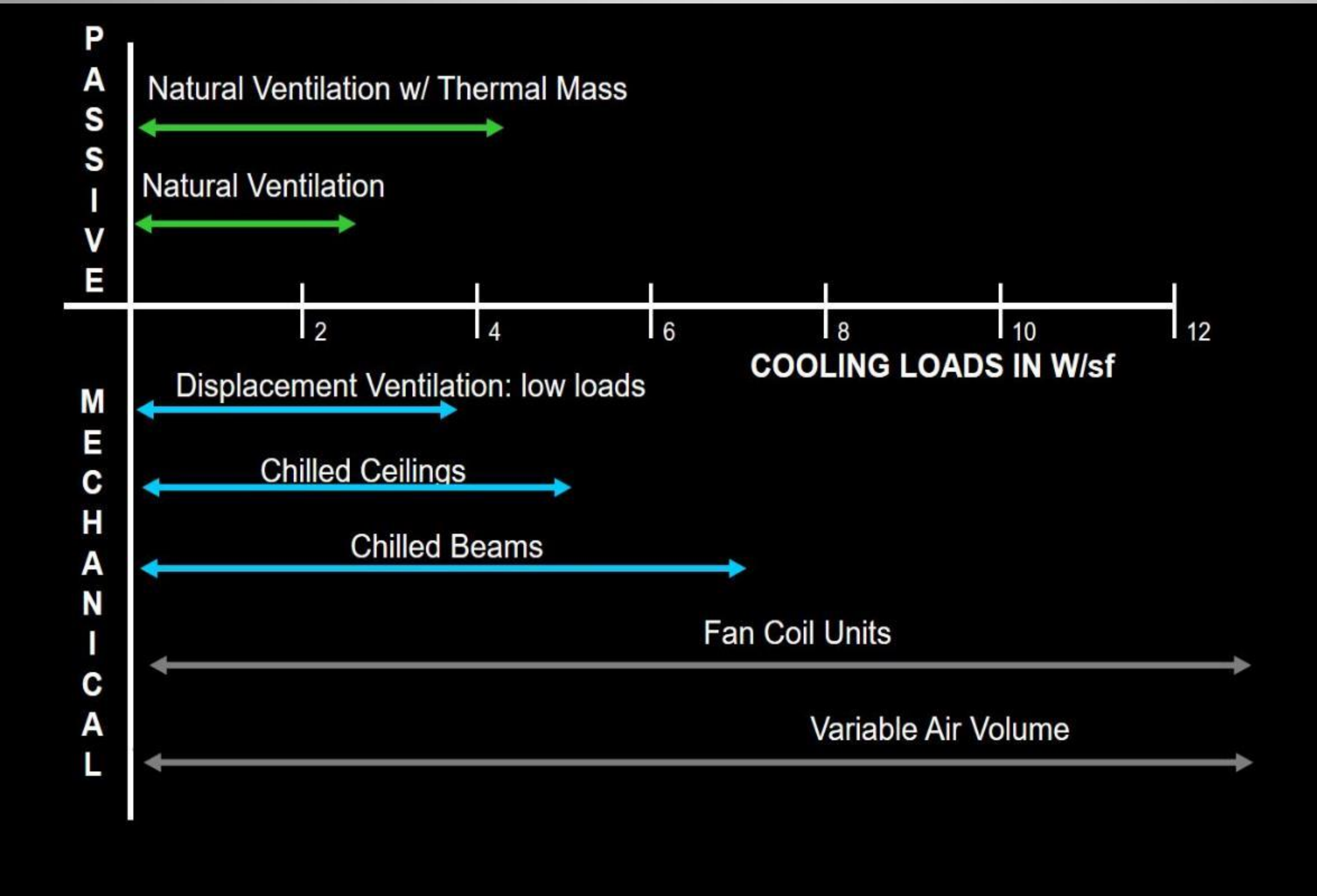
Will natural ventilation work?



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Outdoor Air Assessment

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
3. Weather Normals: Mean Maximum/ Mean Minimum	In looking at the climate data's monthly mean minimum and mean maximum, are there at least six months where the monthly maximum is less than 80°F but mean minimum is higher than 32°F?
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EnergyPlus Weather Data

- https://energyplus.net/weather

Search Results for: Fresno

Your search matched 3 results.

- Fresno 723890 (TMY2)
- Fresno Air Terminal 723890 (TMY)
- Fresno Air Terminal 723890 (TMY3)

USA_CA_Fresno.Air.Terminal.723890_TMY3.zip

USA_CA_Fresno.Air.Terminal.723890_TMY3.ddy
USA_CA_Fresno.Air.Terminal.723890_TMY3.epw
USA_CA_Fresno.Air.Terminal.723890_TMY3.stat

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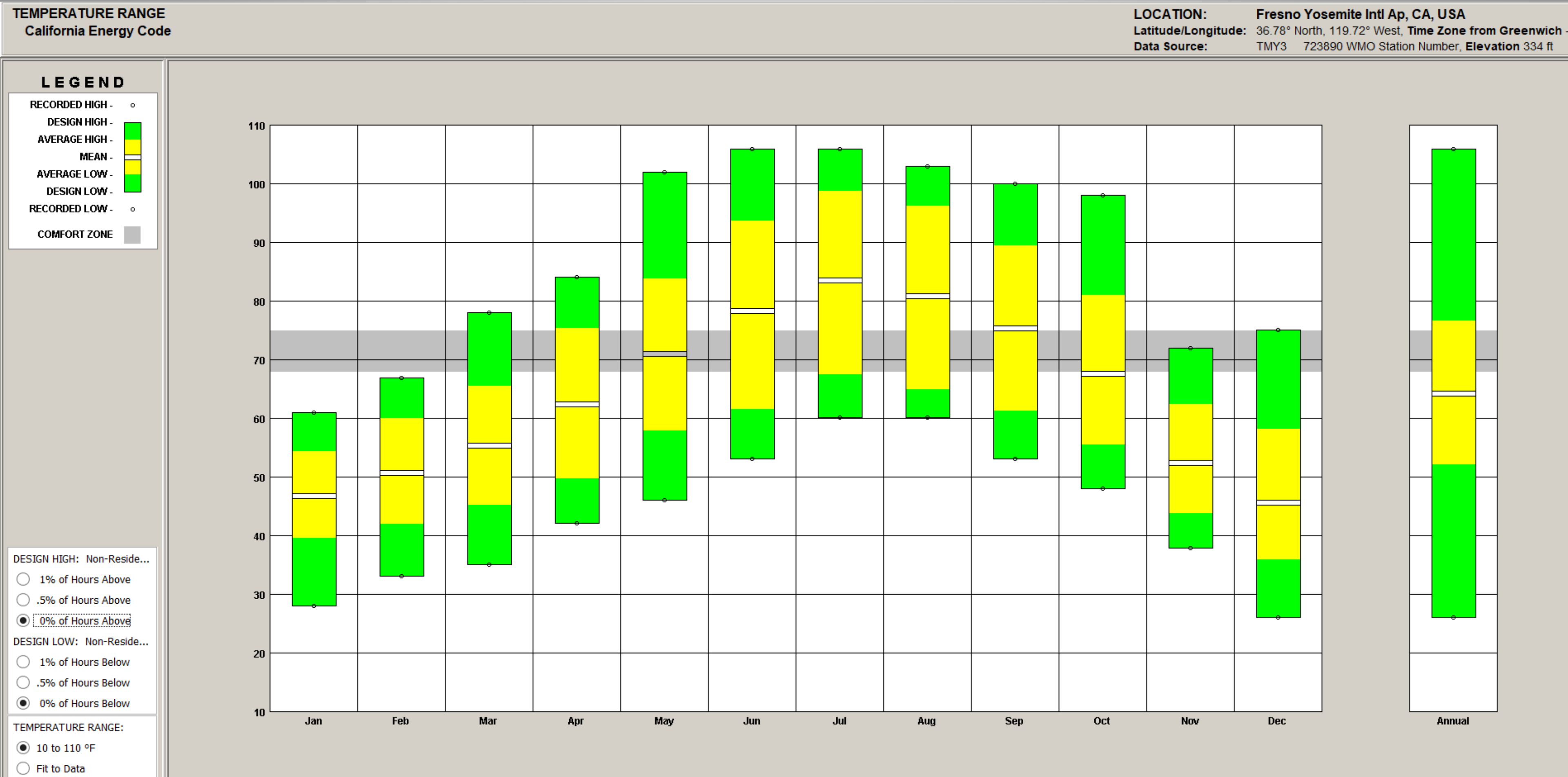
Average Hourly Statistics for Dry Bulb temperatures °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0:01- 1:00	6.0	7.7	10.0	12.6	17.3	20.1	23.1	21.8	19.7	15.9	8.7	4.6
1:01- 2:00	5.7	7.4	9.4	11.8	16.4	18.9	22.1	20.7	18.6	15.2	8.4	4.3
2:01- 3:00	5.7	7.1	8.9	11.3	15.7	17.9	21.3	19.9	18.0	14.8	8.2	3.7
3:01- 4:00	5.8	6.7	8.5	10.8	15.0	17.0	20.5	19.1	17.3	14.3	7.9	3.6
4:01- 5:00	5.5	6.4	8.1	10.3	14.6	16.5	19.7	18.5	16.8	13.8	7.6	3.5
5:01- 6:00	5.2	6.1	8.0	10.1	15.3	17.7	20.7	18.6	16.6	13.3	7.6	3.3
6:01- 7:00	5.2	6.0	8.4	11.9	17.2	20.0	22.8	20.4	18.1	14.0	7.6	3.2
7:01- 8:00	5.6	7.1	10.2	14.4	19.4	22.7	25.3	23.0	20.4	16.3	8.6	3.7
8:01- 9:00	7.0	9.2	12.3	16.6	21.2	25.1	27.4	25.6	23.2	18.7	10.3	5.7
9:01-10:00	8.5	10.9	14.0	18.5	22.8	27.0	29.6	27.8	25.5	21.1	11.9	8.3
10:01-11:00	9.8	12.4	15.4	20.1	24.3	29.1	31.8	29.9	27.4	23.1	13.5	10.2
11:01-12:00	11.0	13.7	16.3	21.6	25.8	31.0	33.6	32.2	28.9	24.5	14.6	11.8
12:01-13:00	11.7	14.5	17.3	22.5	27.0	32.3	35.0	33.7	30.3	25.8	15.7	13.0
13:01-14:00	12.0	15.0	18.1	23.2	28.0	33.3	35.9	34.7	31.0	26.7	16.4	13.8
14:01-15:00	12.1	15.2	18.3	23.4	28.5	33.9	36.6	35.4	31.3	27.1	16.6	13.9
15:01-16:00	11.9	15.2	18.4	23.3	28.5	34.1	37.0	35.6	31.4	26.9	16.2	13.6
16:01-17:00	11.1	14.7	17.6	22.9	27.9	33.4	36.7	35.3	31.0	25.8	14.9	11.7
17:01-18:00	9.9	13.4	16.2	21.7	26.8	32.8	35.7	34.4	29.5	23.8	13.4	9.8
18:01-19:00	9.3	12.4	14.8	19.7	25.1	30.8	33.8	32.0	27.0	22.0	12.4	8.8
19:01-20:00	8.5	11.3	13.8	18.2	23.4	28.2	31.2	29.8	25.6	20.6	11.5	7.5
20:01-21:00	8.0	10.2	12.7	16.7	22.0	26.4	29.3	28.3	24.3	19.4	10.7	6.7
21:01-22:00	7.5	9.5	11.8	15.5	20.5	24.5	27.5	26.4	22.9	18.2	10.0	6.0
22:01-23:00	7.2	8.7	11.2	14.5	19.3	23.0	25.9	24.9	22.0	17.1	9.6	5.6
23:01-24:00	6.8	8.1	10.9	13.7	18.3	21.7	24.4	23.2	20.6	16.3	9.1	5.1
Max Hour	15	16	16	15	16	16	16	16	16	15	15	15
Min Hour	7	7	6	6	5	5	5	5	6	6	7	7

Max C	12.1	15.2	18.4	23.4	28.5	34.1	37	35.6	31.4	27.1	16.6	13.9
Min C	5.2	6	8	10.1	14.6	16.5	19.7	18.5	16.6	13.3	7.6	3.2
Max F	53.8	59.4	65.1	74.1	83.3	93.4	98.6	96.1	88.5	80.8	61.9	57.0
Min F	41.4	42.8	46.4	50.2	58.3	61.7	67.5	65.3	61.9	55.9	45.7	37.8

Do Postprocessing yourself: Fresno passes Question 1



Can also drop the *.epw file into Climate Consultant (free software from UCLA) and visually observe Average High and Average Low per month http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php

Image courtesy of UCLA by virtue of software usage

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Outdoor Air Assessment

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
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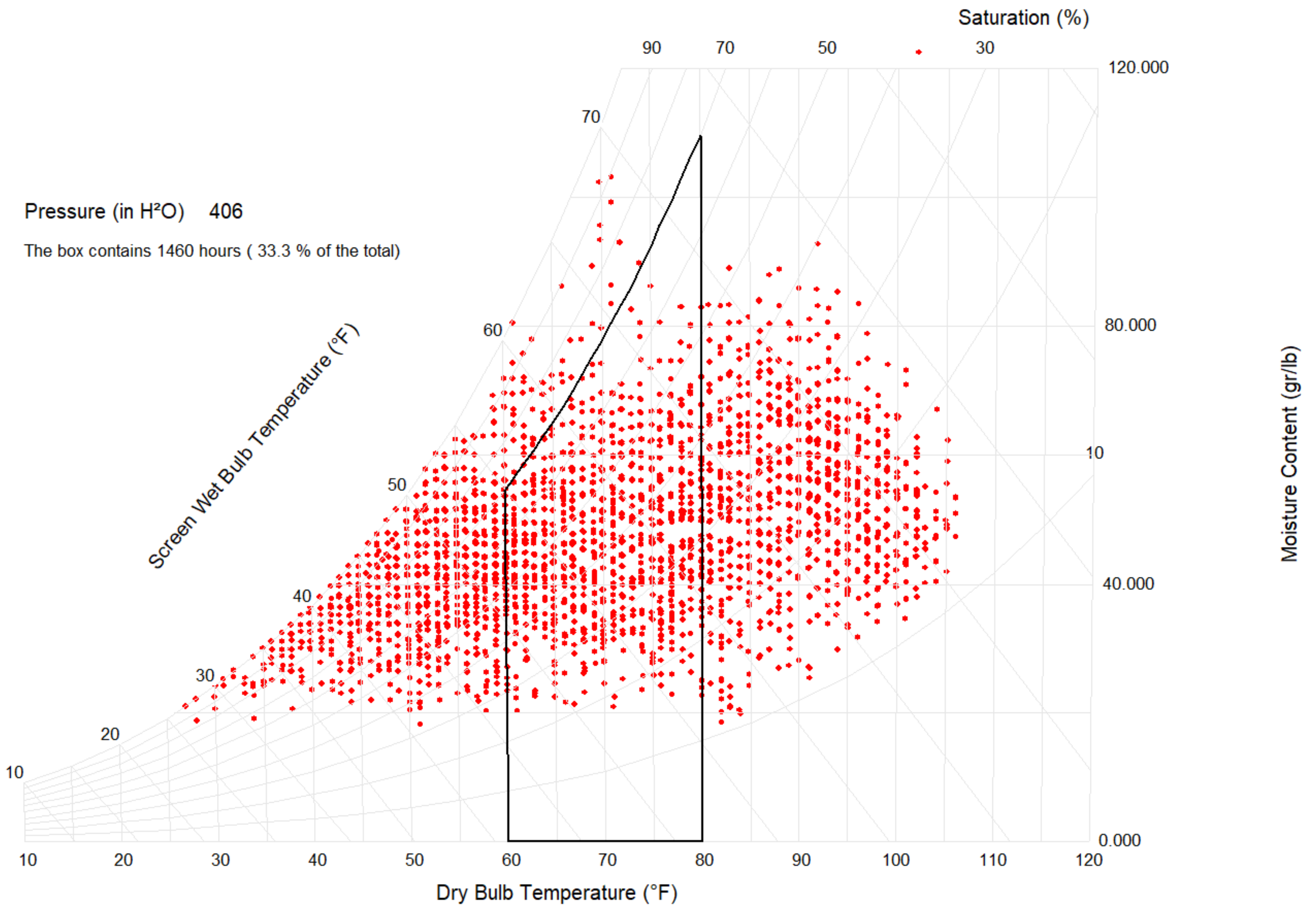

Do Postprocessing yourself on a spreadsheet with the *.epw 8760 hour file
Fresno passes Question 2

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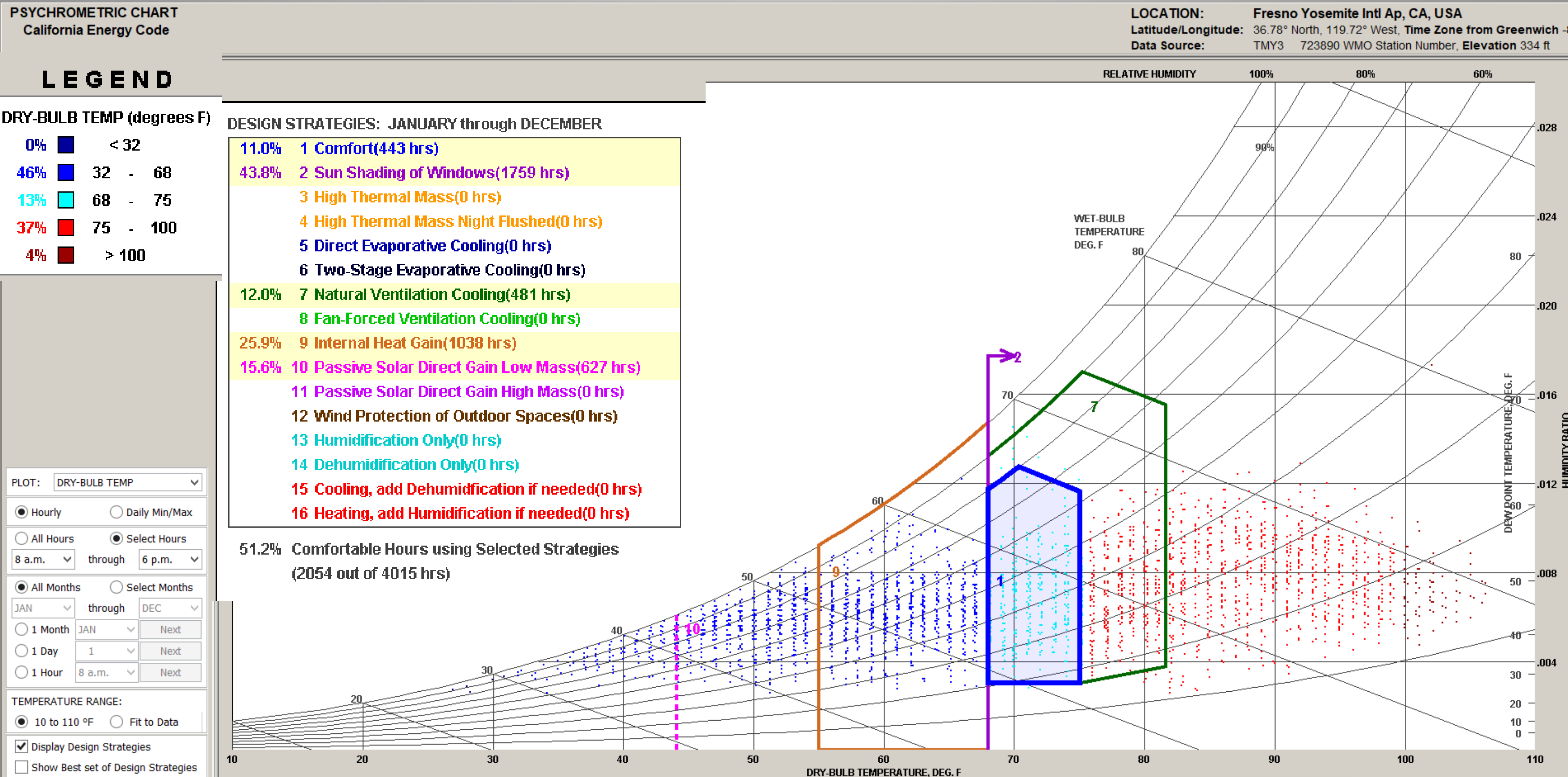

Can also shortcut with the Climate Consultant (free software from UCLA) Psychrometric chart, pick the design strategies that apply only to the natural ventilation state and check for comfortable hours instead of the fixed 60-80°F temperature range

Image courtesy of UCLA by virtue of software usage

A note on rising OSA temperatures

- Professional integrity would require us to review what the likely 20-50 year potential increases in local air temperature might be if an engineered natural conditioning system is being proposed.
- Can purchase climate-shifted *.epw files for purchase from one of the predominant energy analysis software vendors

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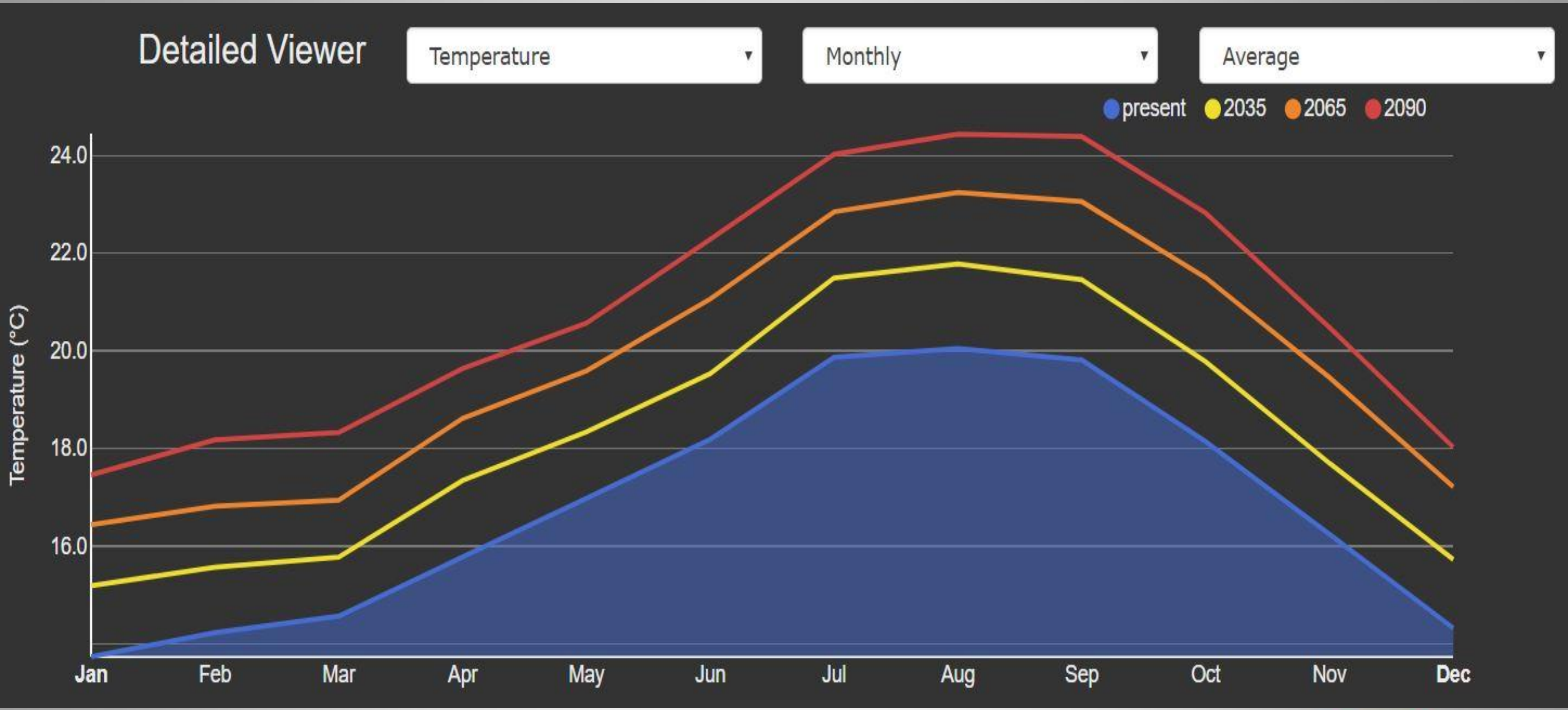
Sample from Los Angeles



Anticipates a mean monthly temperature rise of 3 C (5.4F) by 2050 using the RCP 8.5 emission scenarios and 50% warming percentile

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ASHRAE does not endorse any specific manufacturers, companies, or services in this presentation

Check Air Quality and Access

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7. Wind Rose, Feasible Flow Paths: Inlet to Outlet Under All Wind Conditions	Can one rely on wind-driven effects for cooling? Is there a direct low-pressure airflow path from a low-level opening to a high-level opening within the space, and will it be preserved once furniture/TI work is complete?

Based on general air quality data analysis, must get Client permission to proceed given non-attainment status of Fresno County/ San Joaquin Valley to proceed past Question 5 generically (see below).

Then do a Local site check: Check for effluents and emissions from roofs nearby, typically check the outside air quality results

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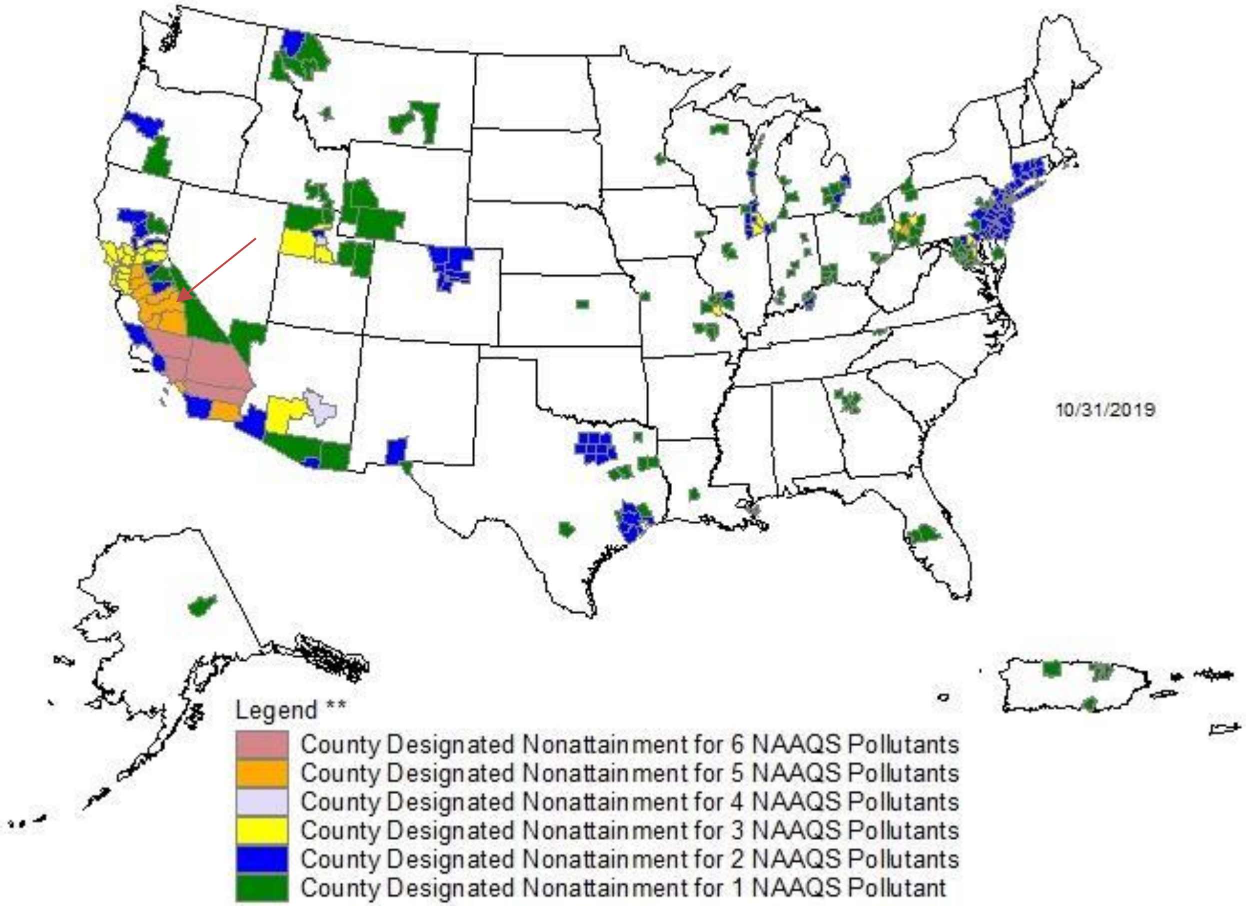
Counties Designated "Nonattainment"

for Clean Air Act's National Ambient Air Quality Standards (NAAQS) *



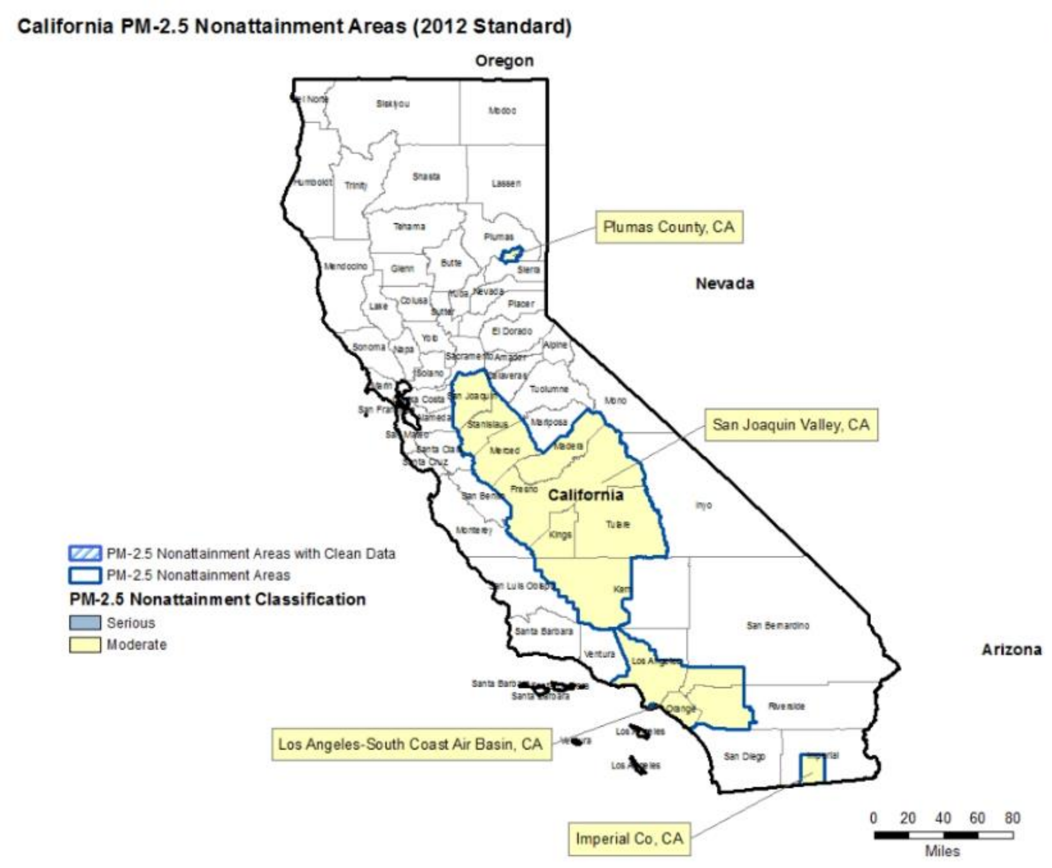
Guam - Piti and Tanguisson power stations are designated nonattainment for the SO2 (1971) NAAQS
Piti and Cabras power stations are designated nonattainment for the SO2 (2010) NAAQS

* The National Ambient Air Quality Standards (NAAQS) are health standards for Carbon Monoxide, Lead (1978 and 2008), Nitrogen Dioxide, 8-hour Ozone (2008), Particulate Matter (PM-10 and PM-2.5 (1997, 2006 and 2012), and Sulfur Dioxide.(1971 and 2010)

** Included in the counts are counties designated for NAAQS and revised NAAQS pollutants. Revoked 1-hour (1979) and 8-hour Ozone (1997) are excluded. Partial counties, those with part of the county designated nonattainment and part attainment, are shown as full counties on the map.

Check whether the county is in a Nonattainment status for the NAAQS standards

Fresno is non-compliant for 5 pollutants per EPA Greenbook online https://www3.epa.gov/airquality/greenbook/mapnpoll.html



Drilling into a deeper level for the nonattainment details, it appears that it is PM-2.5 and 8 hour Ozone that are actually in non-compliance as part of the San Joaquin Valley area.

https://www3.epa.gov/airquality/greenbook/ancl2.html

Per ASHRAE 62.1, must inform client with local air quality results

CA	**San Joaquin Valley**				
	PM-10 (1987)	East Kern Co, CA	126	1	Serious
	PM-2.5 (1997)	San Joaquin Valley, CA	3,842	8	Serious
	PM-2.5 (2006)	San Joaquin Valley, CA	3,842	8	Serious
	PM-2.5 (2012)	San Joaquin Valley, CA	3,842	8	Moderate
	8-Hour Ozone (2008)	Kern Co (Eastern Kern), CA	95	1	Serious
	8-Hour Ozone (2008)	San Joaquin Valley, CA	3,842	8	Extreme
	8-Hour Ozone (2015)	Kern County (Eastern Kern), CA	95	1	Moderate
	8-Hour Ozone (2015)	San Joaquin Valley, CA	3,842	8	Extreme

Wind Rose: prevailing winds?

Local wind regime check: are there any prevailing winds to accommodate?
Can again use Climate Consultant (free software from UCLA) to generate wind rose or use other tools

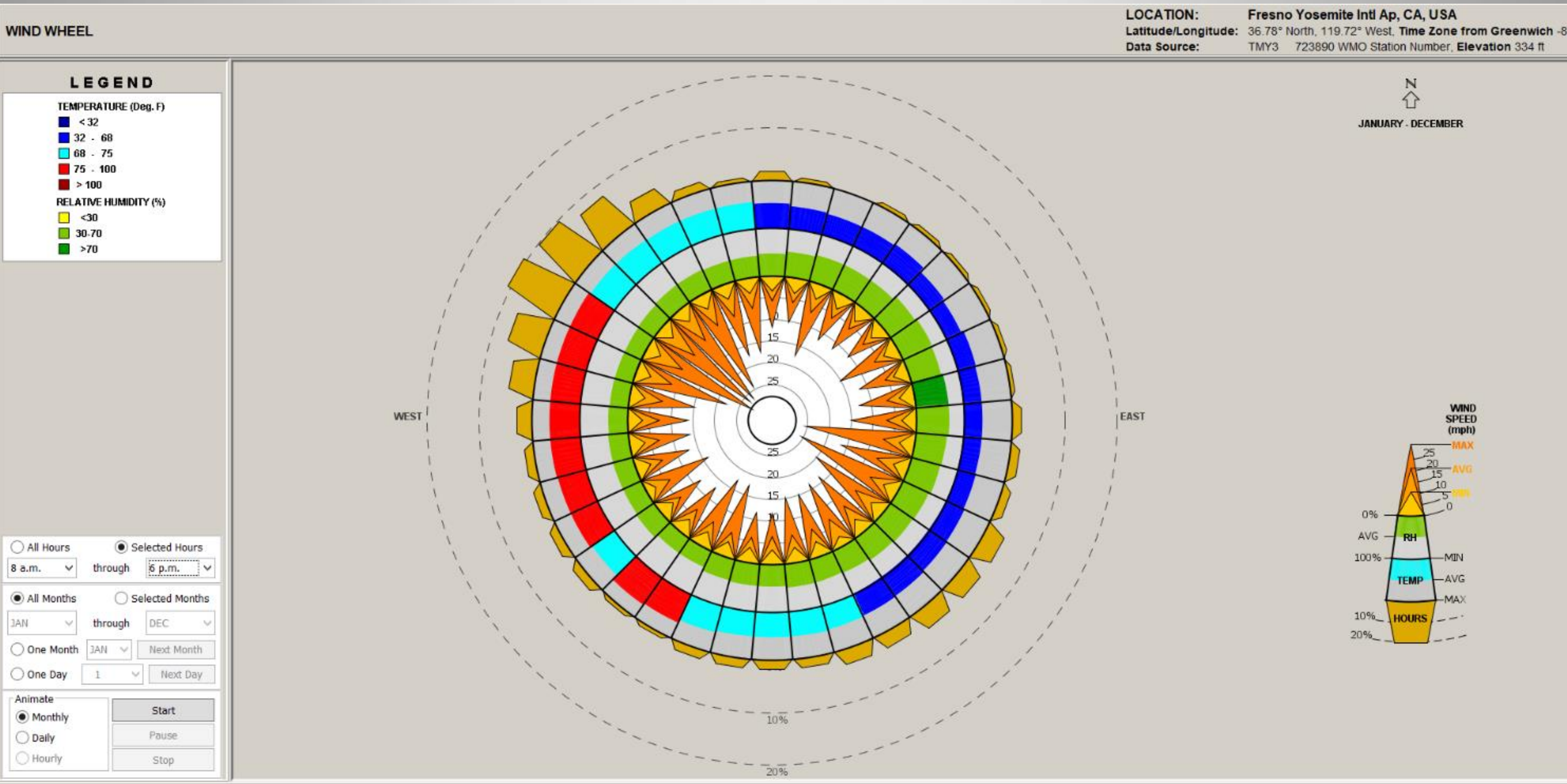


Image courtesy of UCLA by virtue of software usage

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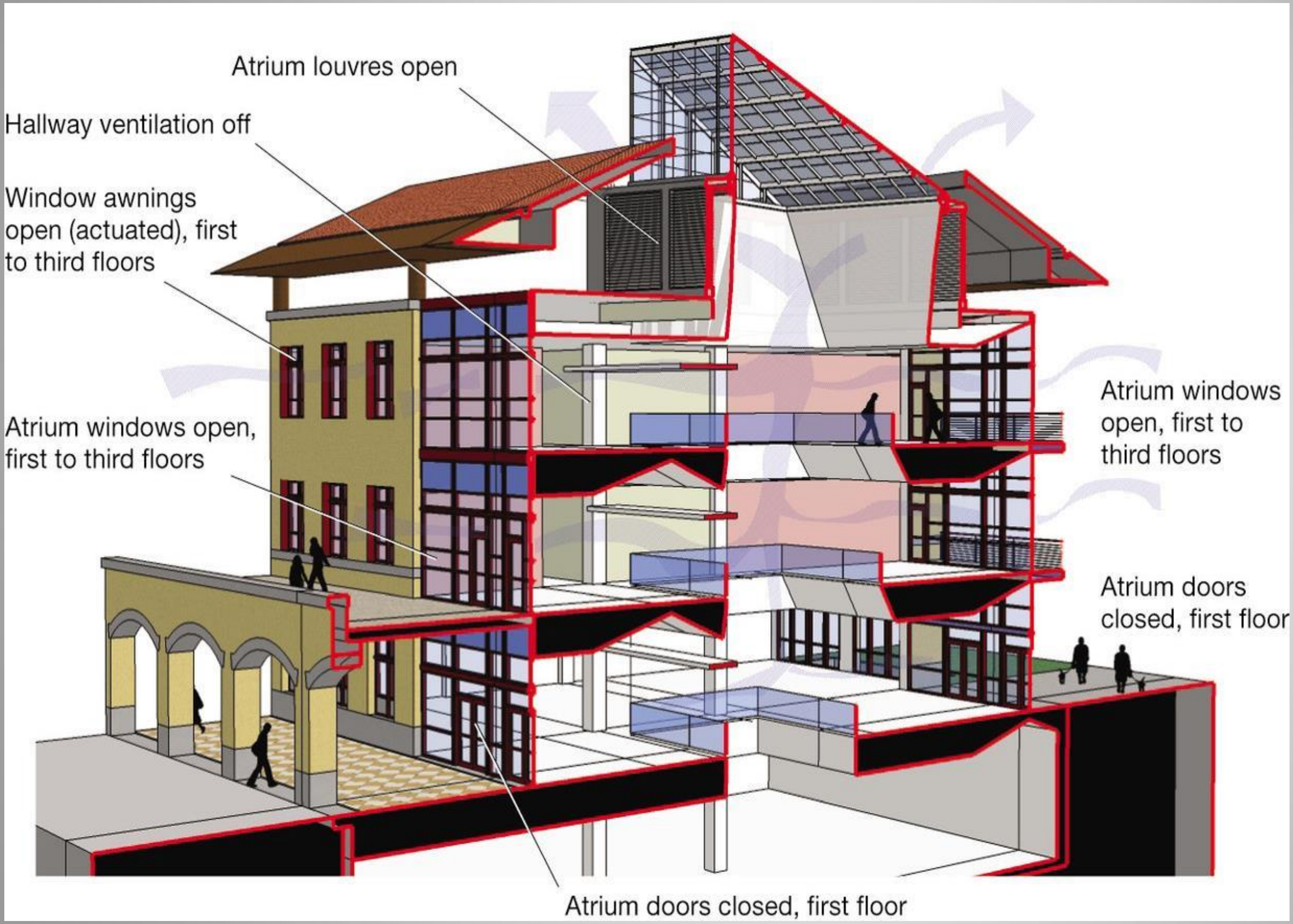
Façade and Building Configuration

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
6. Window Locations and Sizes, Accessibility	Can the equivalent of 4% to 5% of the floor area as window opening area be found with direct access to the window by everyone within 20 ft?
7. Wind Rose, Feasible Flow Paths: Inlet to Outlet Under All Wind Conditions	Can one rely on wind-driven effects for cooling? Is there a direct low-pressure airflow path from a low-level opening to a high-level opening within the space, and will it be preserved once furniture/TI work is complete?

Question 6 is related to the code/standard that is being applied
For prescriptive compliance:

Standard	Maximum distance to operable element	Minimum size of openings
ASHRAE Standard 62.1-2016	25ft (7.6m)	4% of served area
California Title 24-2016 California Energy Commission	20ft (6.1m)	5% of served area

Airflow Paths Observational Analysis



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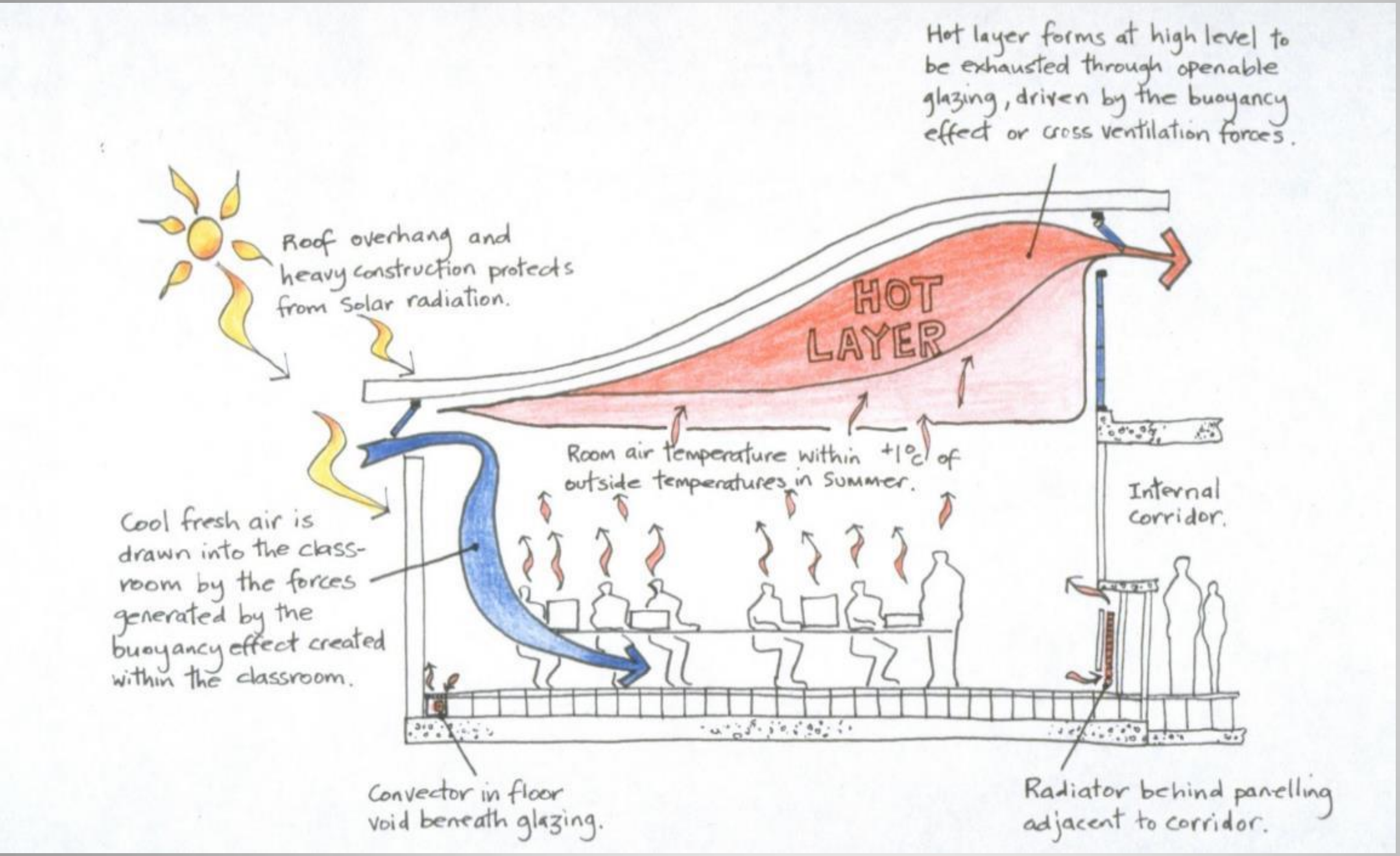
Airflow Paths Observational Analysis



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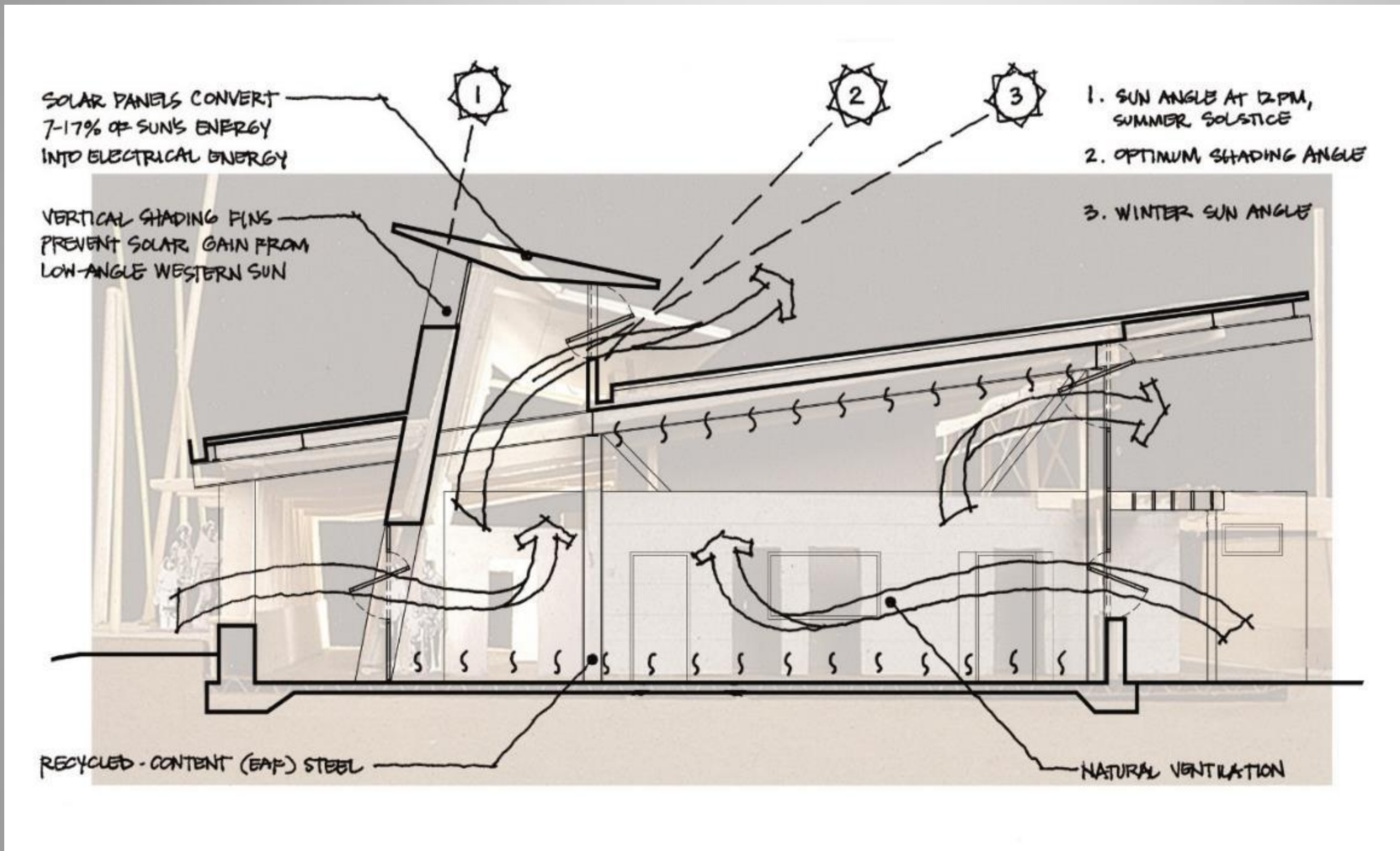
Airflow Paths Observational Analysis



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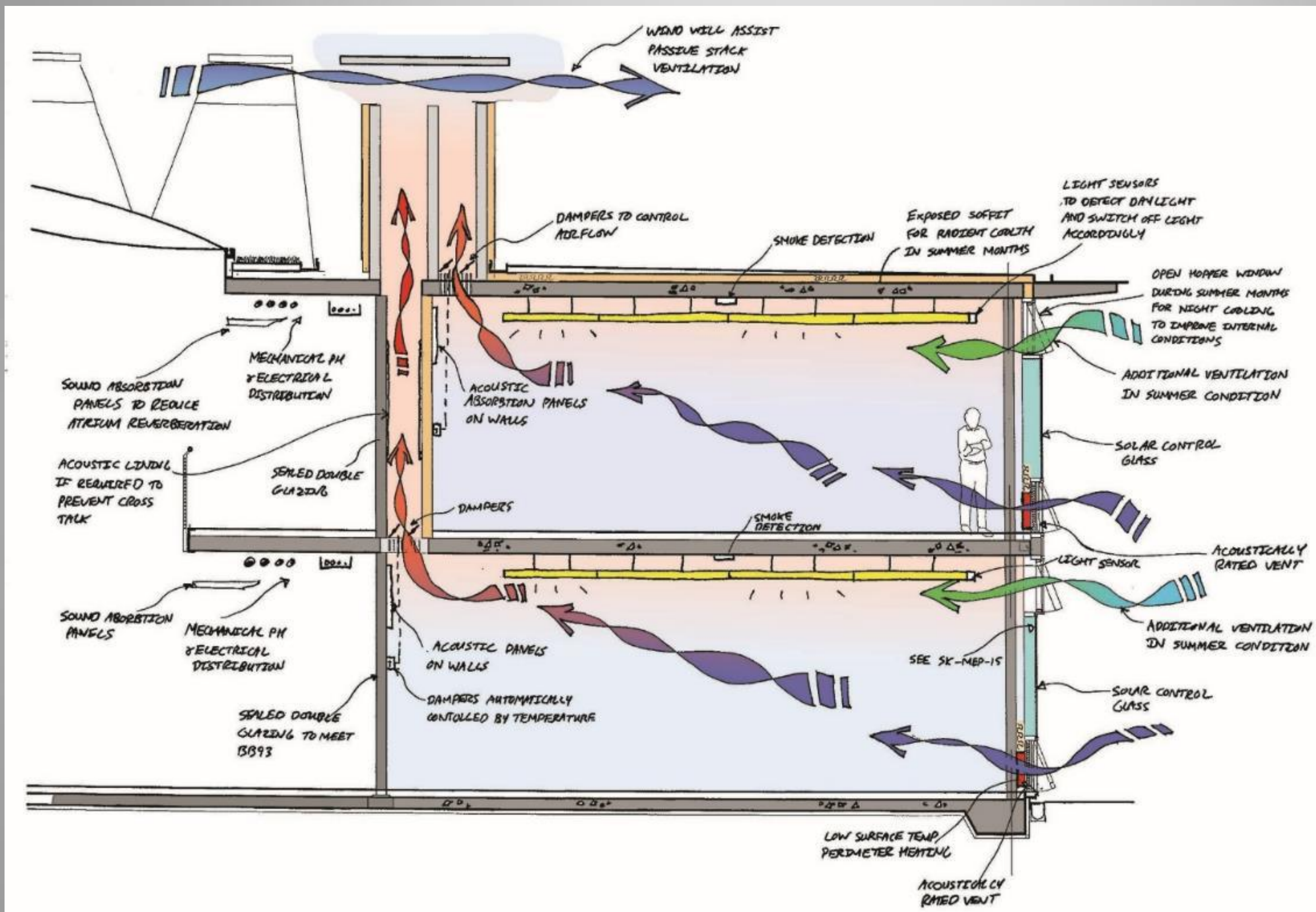
Airflow Paths Observational Analysis



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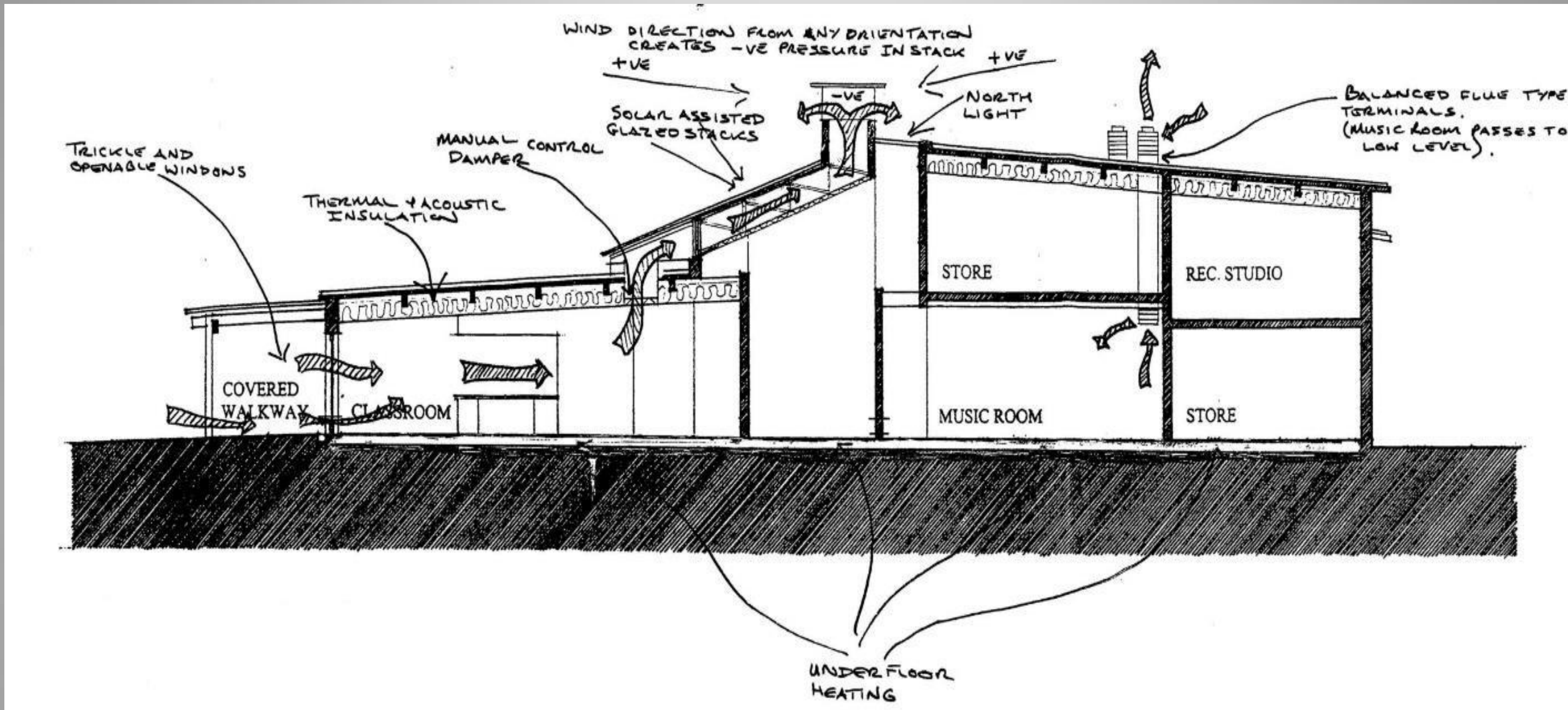
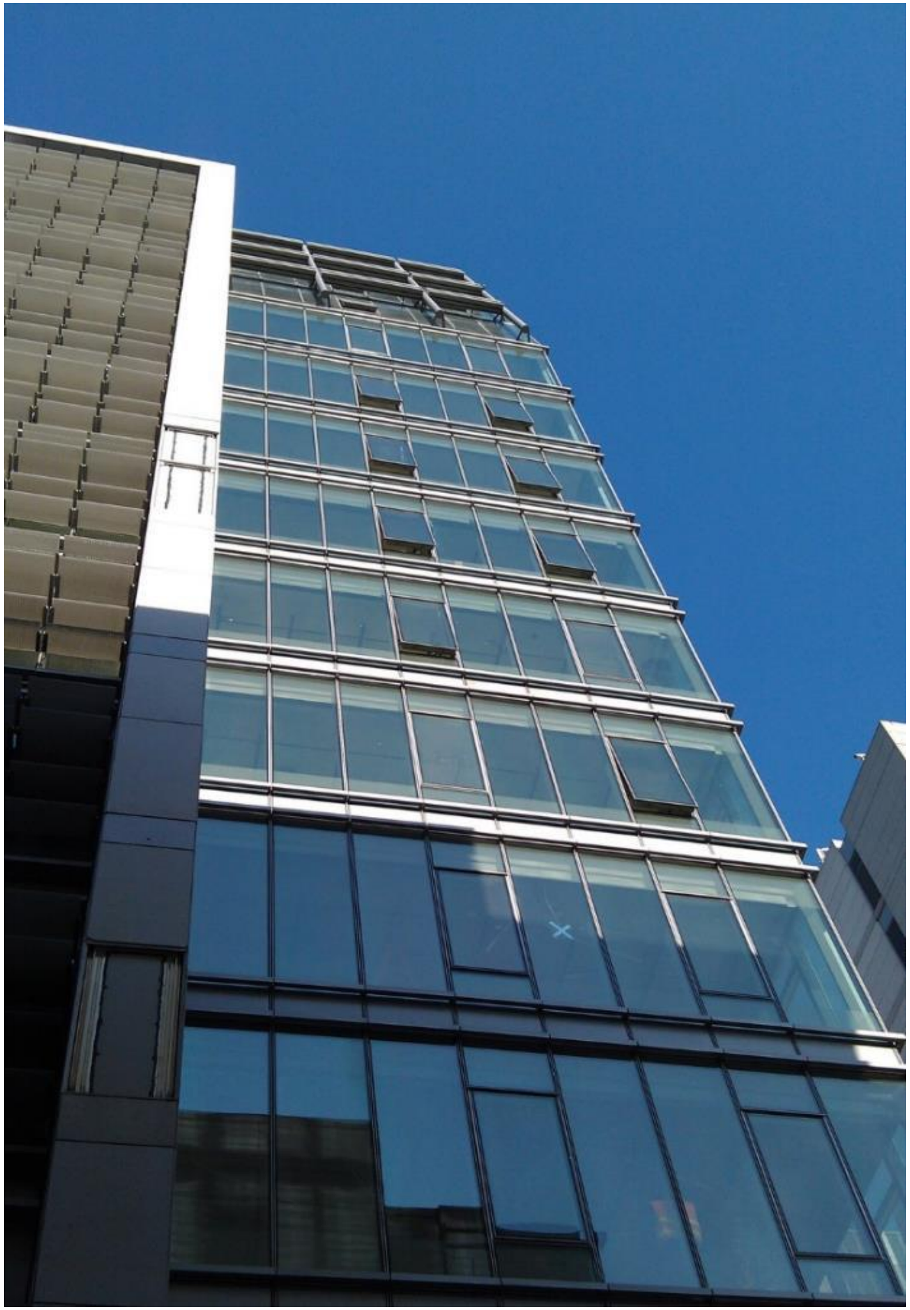
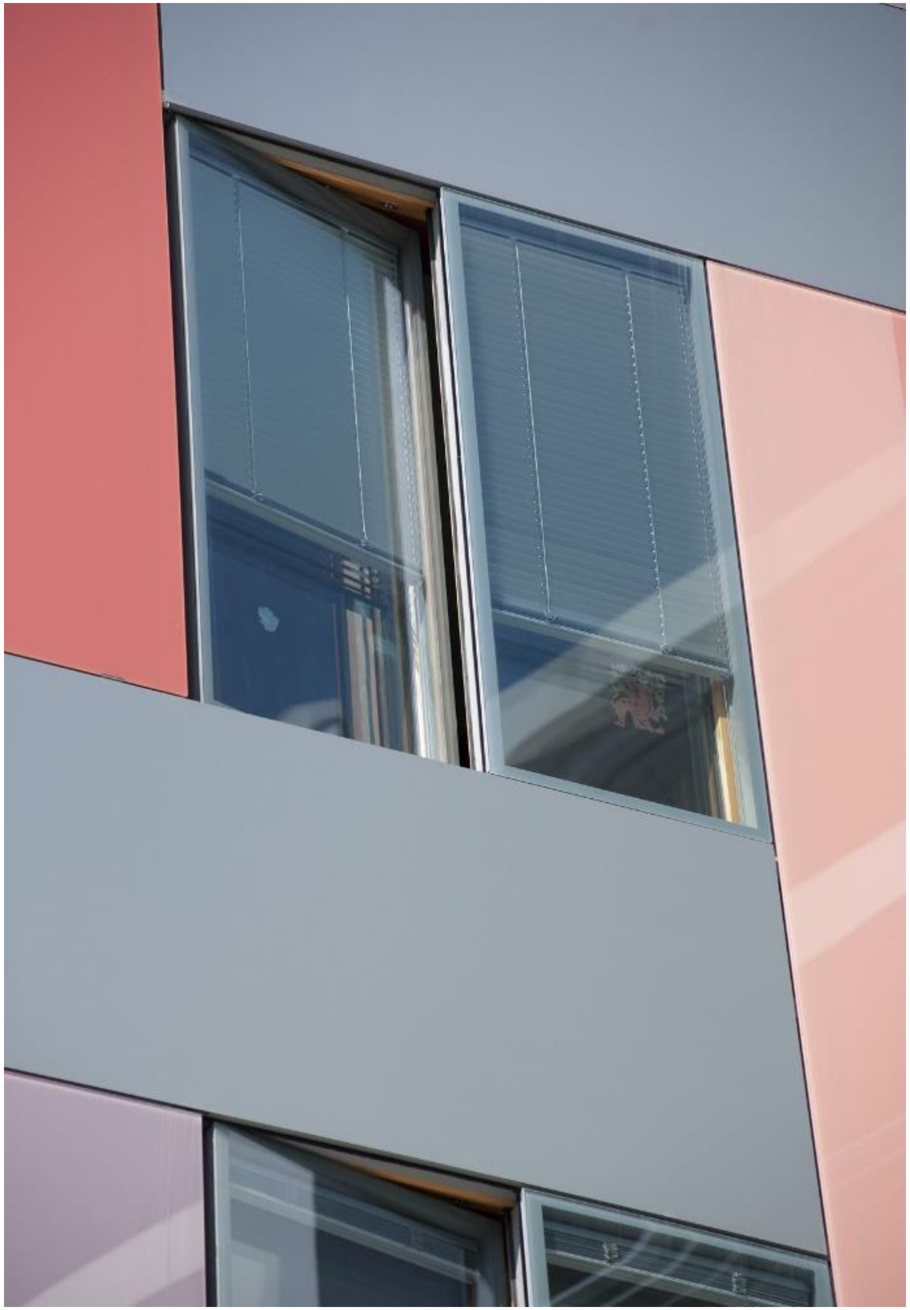
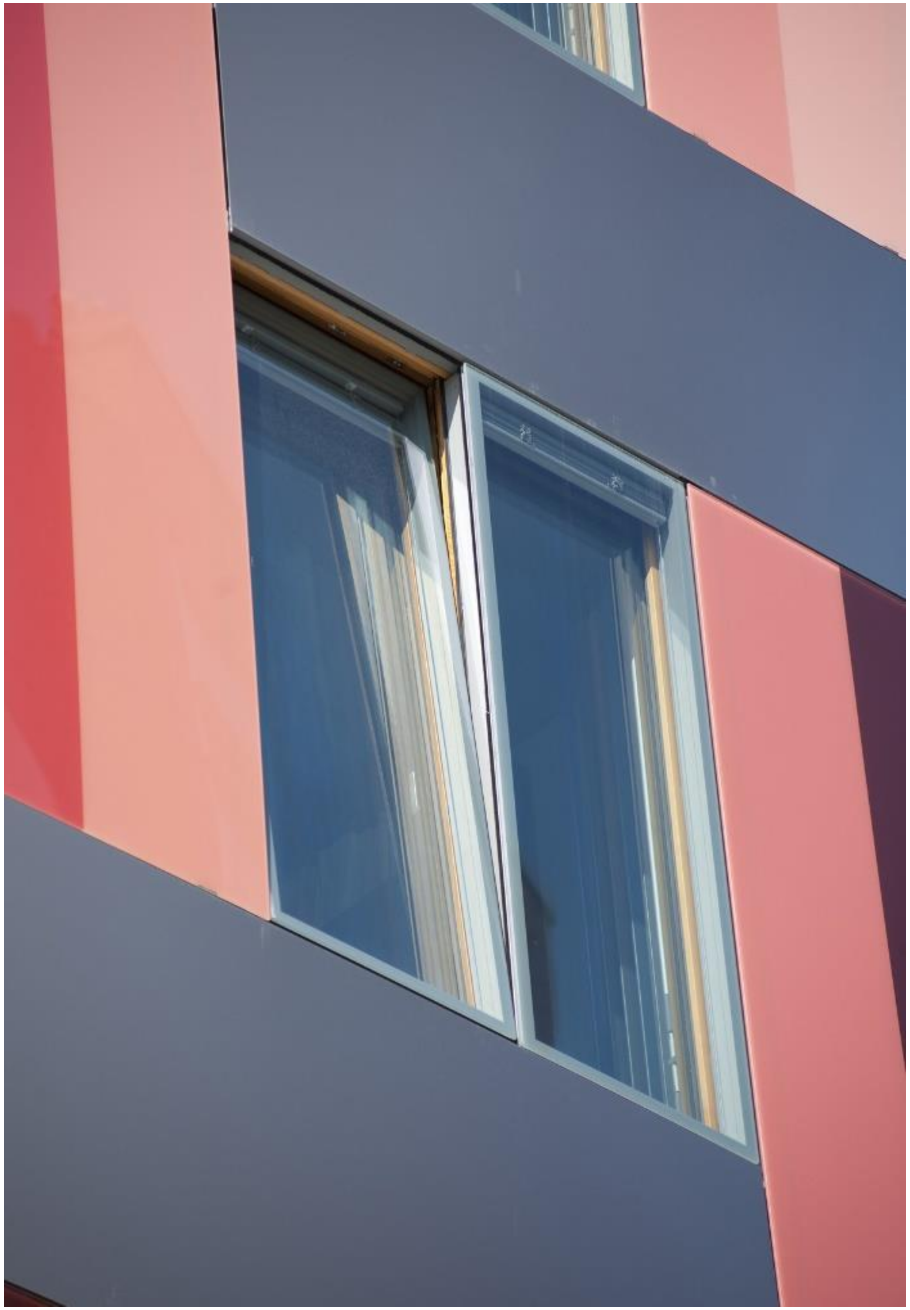
Airflow Paths Observational Analysis






expo 1

Navigating Natural Ventilation Compliance

Paths of Compliance

Method Type	Path	Summary Description	Basis of Path
Prescriptive Single zone	ASHRAE Standard 62.1-2016 (ASHRAE 2016b)	4% Total Opening Method	Historical Rule of Thumb
Prescriptive Single Zone	Proposed Addendum (DA-71) to ASHRAE Standard 62.1: Path A	Two opening, Flow Adjusted Percentage Method	Lookup table for 2 vertically spaced openings for buoyancy driven ventilation. Compliance based on pre-analysis of generic spaces.
Prescriptive Multi-zone single cell buildings	Proposed Addendum (DA-71) to ASHRAE Standard 62.1: Path B	Iterative Calculation Method based on CIBSE (2005) Section 4.3	Buoyancy, Wind, Buoyancy+ Wind Ventilation subpaths available
Engineered System Performance Multi-zone	ASHRAE Standard 62.1 2016 (ASHRAE 2016b) An engineered natural ventilation is allowed by exception in Section 6.4, Exception 1 is allowed by the authority having jurisdiction.	Performance-based Calculation to show equivalency to Prescriptive Minimum Ventilation Rate requirements in Table 6.2.2.1	Computer-based dynamic heat transfer and bulk airflow modeling tools for simulation of building physics related to natural ventilation airflow
Prescriptive Single zone	2016 California Title 24-Part 6 (Energy Code), which conflicts with 2016 California Title 24 Part 4 (Mechanical Code)	5% Total Opening Method 4% Total Opening Method	Historical Rules of Thumb

Multi-cell and Engineered Paths

- Engineering analysis carries burden of proof that the normal prescriptive ventilation flow requirements are met
- Typically an 8760 operation under natural ventilation conditions and window-opening sequences of operation (or assumed manual opening patterns)

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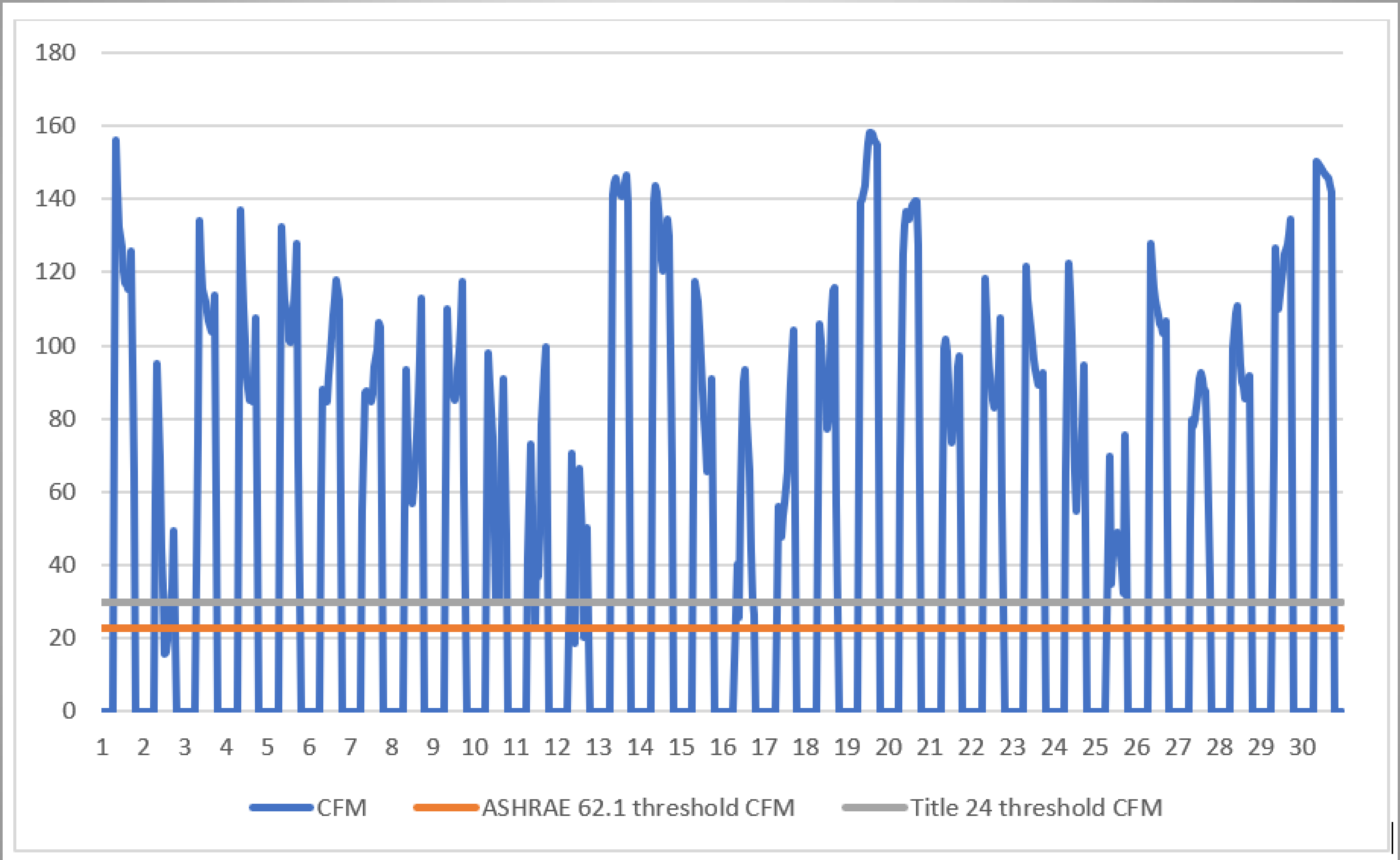
When dynamic modelling is used



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Interaction with ASHRAE 90.1

- Natural conditioning may be modeled for a thermal zone in the proposed design when the following conditions are met:
  - a. Outside air intake from natural ventilation systems shall not be less than the minimum required outdoor air ventilation rates during occupied times in the proposed building model.
  - b. Controls for cooling system operation and availability of natural ventilation are automatic.
  - c. Rating authority approves of the proposed procedure.
- Per the ASHRAE Standard 90.1 User's Manual (ASHRAE 2017d), a hybrid system must be modelled for the proposed scheme regardless of whether cooling equipment is provided or not. The natural ventilation/conditioning system is designated as the primary cooling system, and the backup secondary system shall equal the default as represented in the baseline.

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Energy Modeling within Title 24

- Title 24 (California Energy Commission 2015a) energy model documentation does require specific items to be modelled for natural ventilation and mixed mode ventilation use in alternate compliance method calculations for energy calculations
  - Per Section 2.5.3, Handling Proposed Design with No HVAC Equipment, HVAC systems must be provided if the natural ventilation cannot hold unmet load hours of 150 in any zone.
  - Per Section 3.2.2.3, software shall report out an exceptional condition when natural ventilation is used so that opening areas and access distances can be checked.
  - Outdoor air Ventilation is allowed to arise from Natural ventilation or Mixed mode ventilation as per Section 5.6.5.4. Documentation for natural ventilation system airflow rates entered into the energy model shall be provided.
  - Mixed mode systems require mechanical ventilation as supplemented by natural ventilation. Naturally ventilated spaces may be modelled as a thermal zone (Section 5.3) if there are automatic controls to hold the windows open when the space is occupied. If zone setpoint are fulfilled using natural ventilation, then the secondary mechanical systems (ventilation, cooling, and heating) may be shut off within the model.

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Special controls for mixed mode Title 24

- (n) **Mechanical System Shut-off.** Any directly conditioned space with operable wall or roof openings to the outdoors shall be provided with interlock controls that disable or reset the temperature setpoint to 55°F for mechanical heating and disable or reset the temperature setpoint to 90°F for mechanical cooling to that space when any such opening is open for more than 5 minutes. The "open" signal shall shut off the space cooling but still provide the required mechanical ventilation unless it can be proven that the natural ventilation meets the prescriptive code requirements. Window switches are required even if natural ventilation does provide the ventilation. Motorized windows are still considered manual if occupants have override capabilities (as essentially required under the base definition of occupant access in clause 120.1(b)1 as noted above.
- **EXCEPTION 1 to Section 140.4(n):** Interlocks are not required on doors with automatic closing devices.
- **EXCEPTION 2 to Section 140.4(n):** Any space without a thermostatic control (thermostat or a space temperature sensor used to control heating or cooling to the space).

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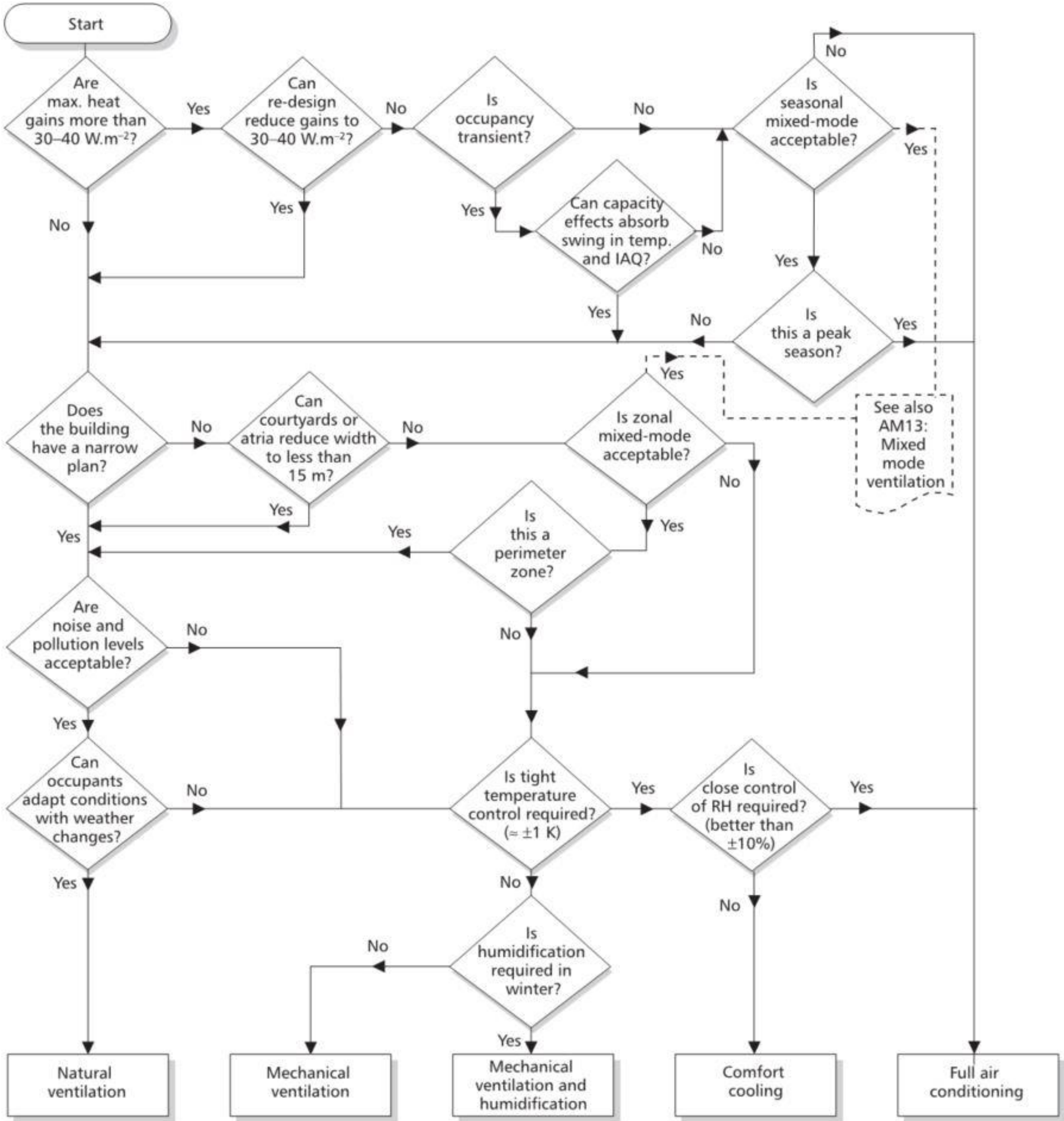
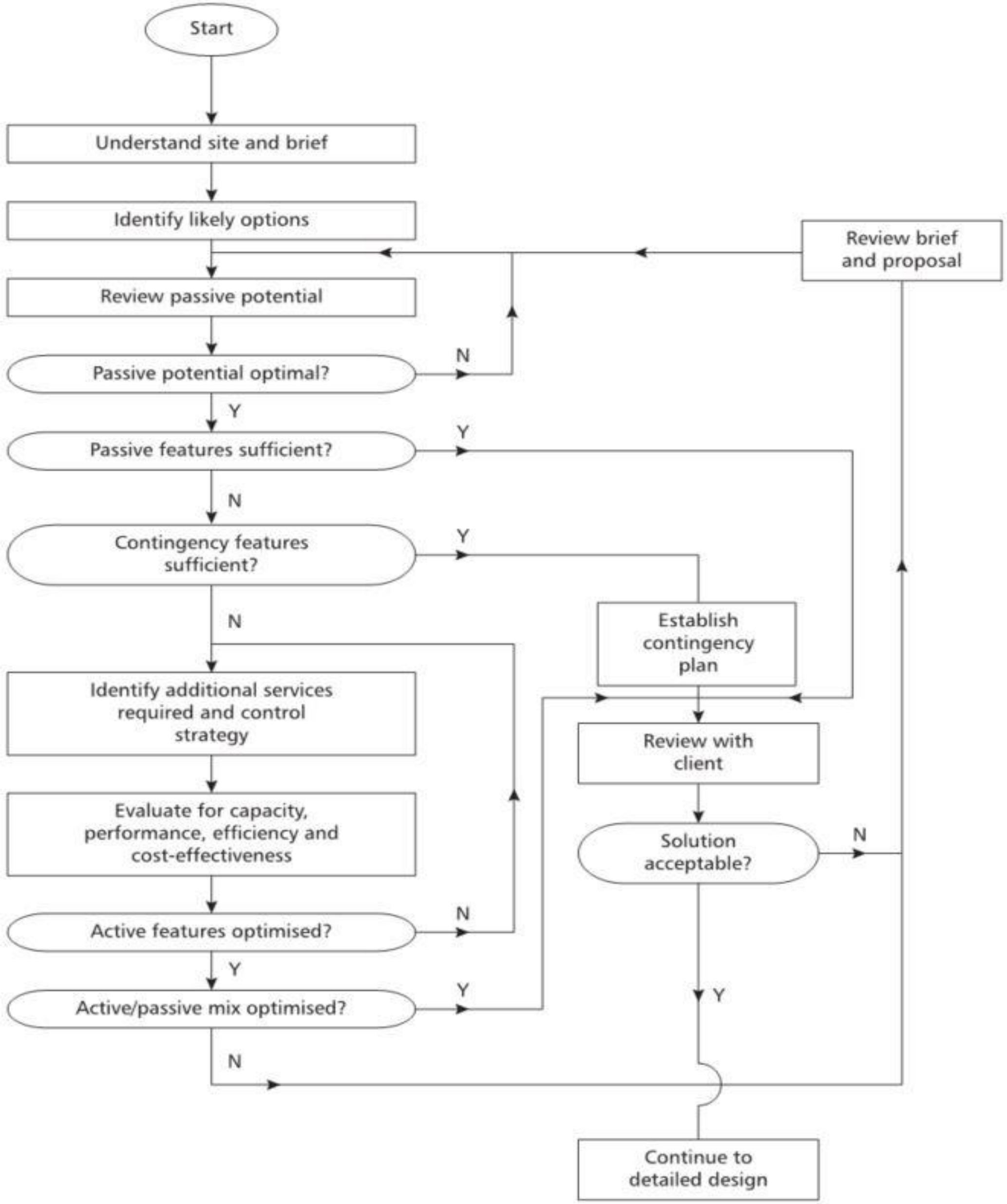


LEED minimum ventilation compliance



LEED mixed mode ventilation compliance path

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Demonstrating Comfort Standard Compliance

- Compliance with ASHRAE 55 is rarely explicitly adopted within codes, but it is a reasonable expectation.
- It is important to differentiate which comfort criteria one is trying to comply with at the beginning of the project

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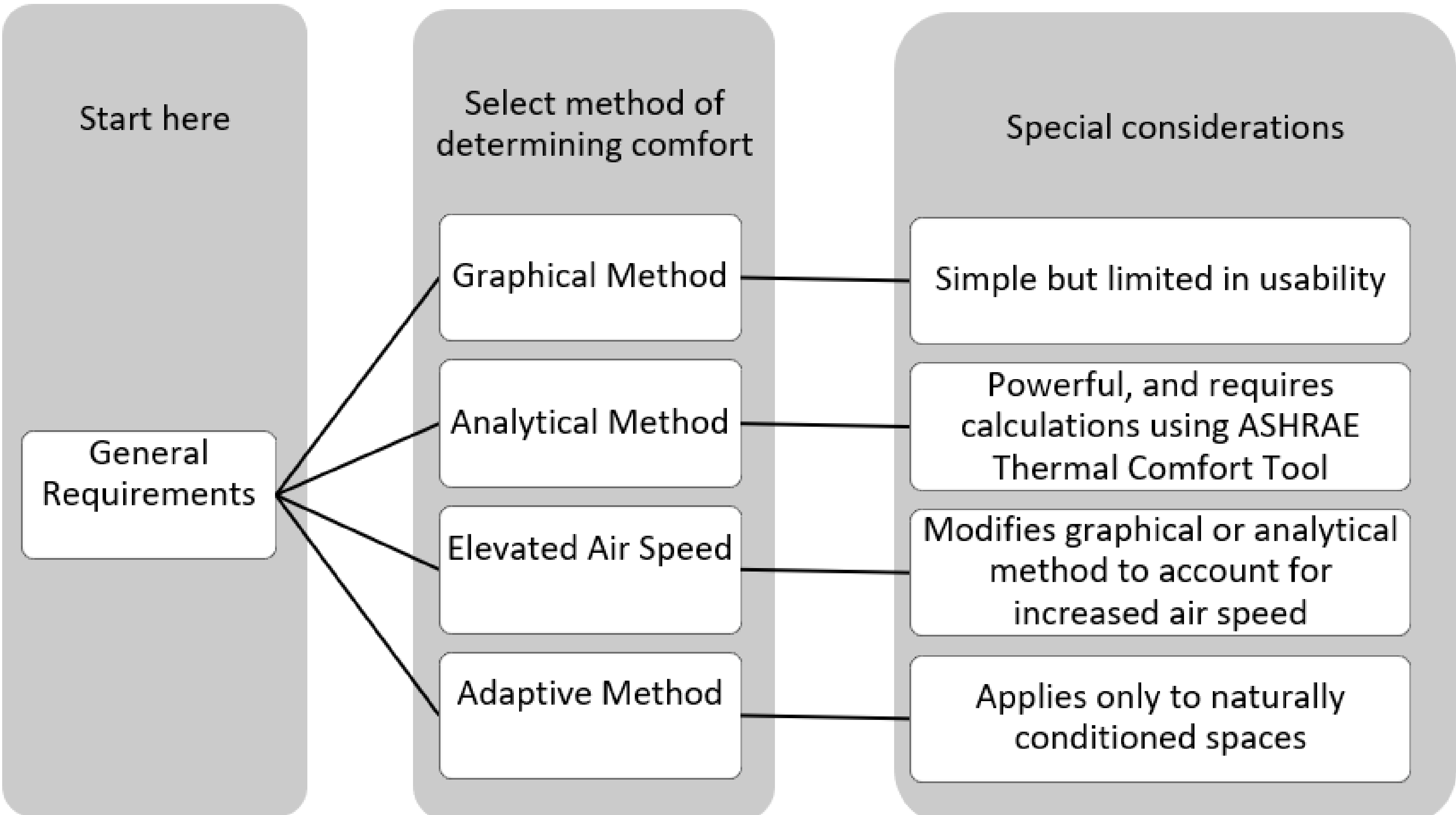
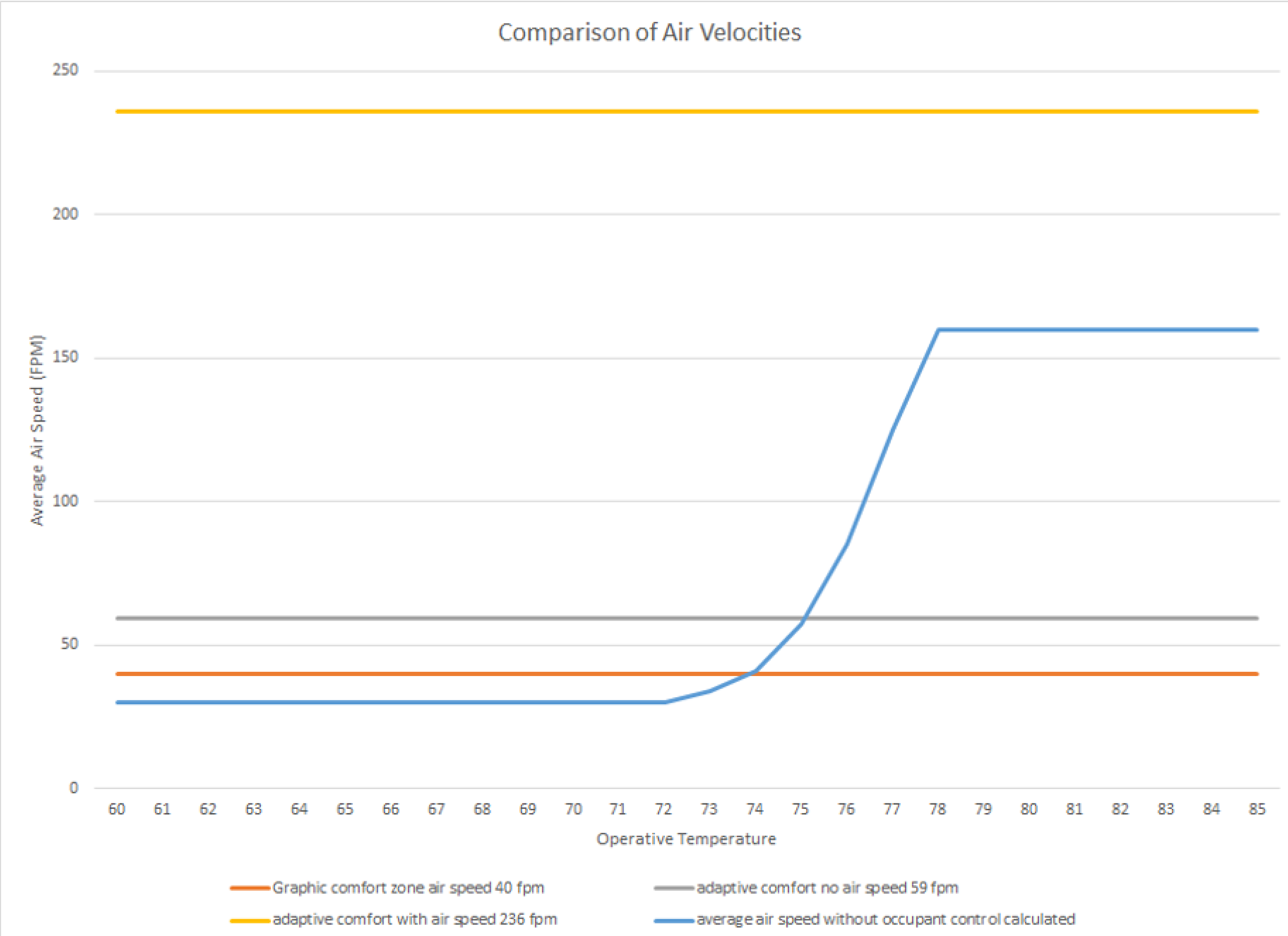
Per ASHRAE 55 User's Manual





Comparison of Air Velocities
Average Air Speed (FPM)
250
200
150
100
50
0
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
Operative Temperature
Graphic comfort zone air speed 40 fpm
adaptive comfort no air speed 59 fpm
adaptive comfort with air speed 236 fpm
average air speed without occupant control calculated

Limitations on Use of Adaptive Comfort Model

- **No Mechanical Cooling System Installed**
- **Limits on metabolic rates:** 1.0 to 1.3 met
- **Adaptability of Clothing:** 0.5 to 1.0 clo
- **Constraints on Outdoor Air Temperatures:** The prevailing mean outdoor temperature is greater than 10°C (50°F) and less than 33.5°C (92.3°F)

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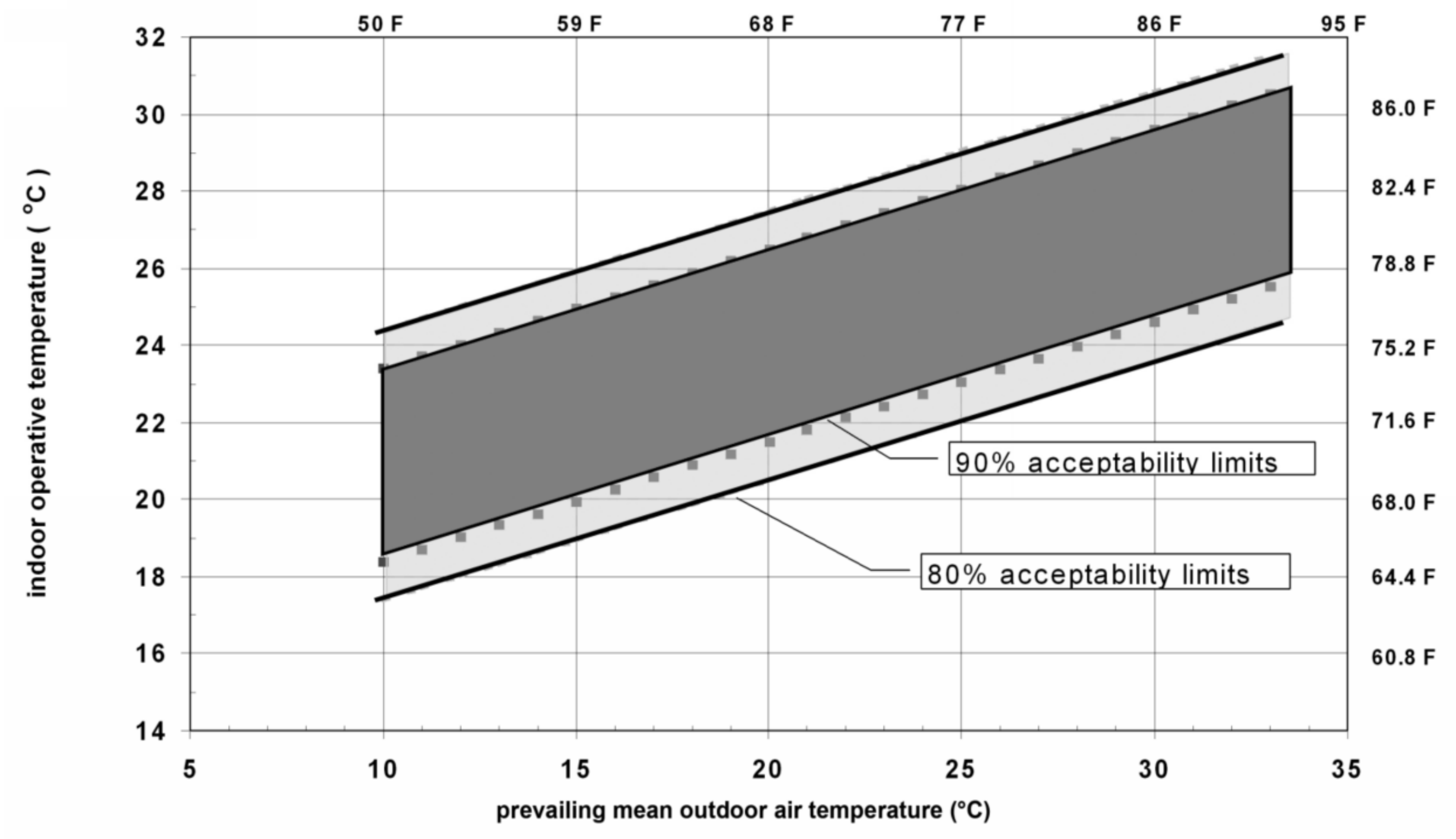
The Adaptive comfort criteria



Per ASHRAE 55 User Manual - It is important to note that only the 80% acceptability limit is used when a user is to show compliance with the Adaptive Method.

The equations

- Upper 80% acceptability limit (°C) = 0.31 $t_{pma(out)}$ + 21.3
- Upper 80% acceptability limit (°F) = 0.31 $t_{pma(out)}$ + 60.5
- Lower 80% acceptability limit (°C) = 0.31 $t_{pma(out)}$ + 14.3
- Lower 80% acceptability limit (°F) = 0.31 $t_{pma(out)}$ + 47.9
- where $t_{pma(out)}$ is the simple arithmetic mean of all of the mean daily outdoor air temperatures of no fewer than the last 7 days and no greater than the last 30 days, and the mean daily outdoor air temperature of each day is the simple arithmetic mean of all the outdoor dry bulb temperature observations for a 24 hours period.

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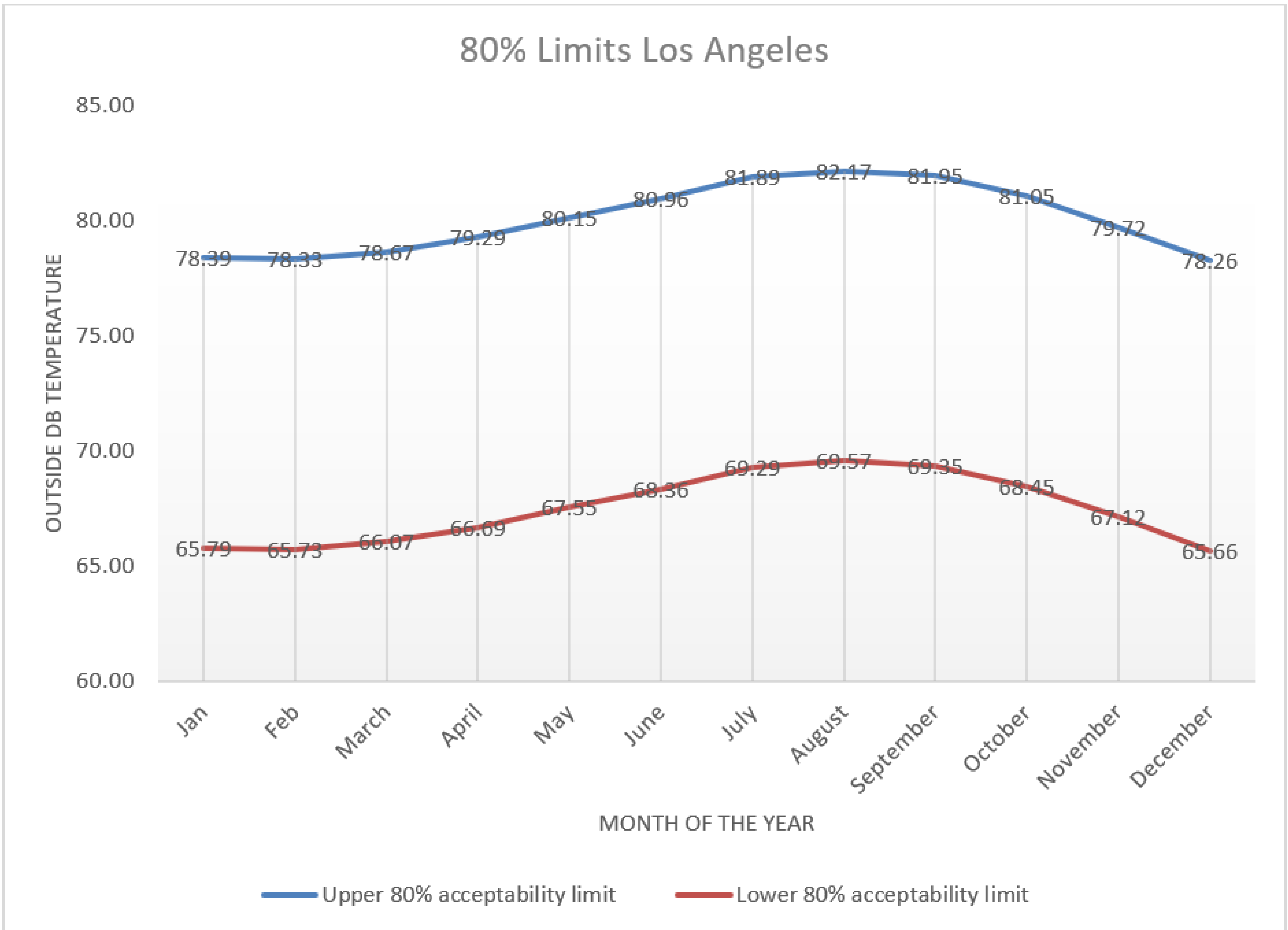
80% Limits Los Angeles
85.00
80.00
75.00
70.00
65.00
60.00
OUTSIDE DB TEMPERATURE
78.39
78.33
78.67
79.29
80.15
80.96
81.89
82.17
81.95
81.05
79.72
78.26
65.79
65.73
66.07
66.69
67.55
68.36
69.29
69.57
69.35
68.45
67.12
65.66
Jan
Feb
March
April
May
June
July
August
September
October
November
December
MONTH OF THE YEAR
Upper 80% acceptability limit
Lower 80% acceptability limit

Steps to the Analysis

- Evaluate the applicability of the design against the requirement for operable elements and the four constraints noted above.
- Calculate the Comfort Zone Thresholds for Compliance
- Determine Comfort using a dynamic thermal simulation
- Resolve Comfort Conditions if space is found to be non-compliant.

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Other considerations

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
8. High Afternoon Temperatures	Does the climate have regular outside air temperatures over 80°F? If yes, review whether exposed thermal mass is possible.
9. Diurnal Range on Hot Days	Does the climate have a diurnal range that has nighttime temperatures below 65°F for at least 8 hours a night on the worst-case days? If yes, move to multizone modeling of thermal mass and consider night purge.
10. Dew-Point Temperatures Throughout Year	Throughout the year, do you have consistent outside air dew points throughout the year of less than 64°F? If yes, move to multizone modeling and consider a radiant cooling system.

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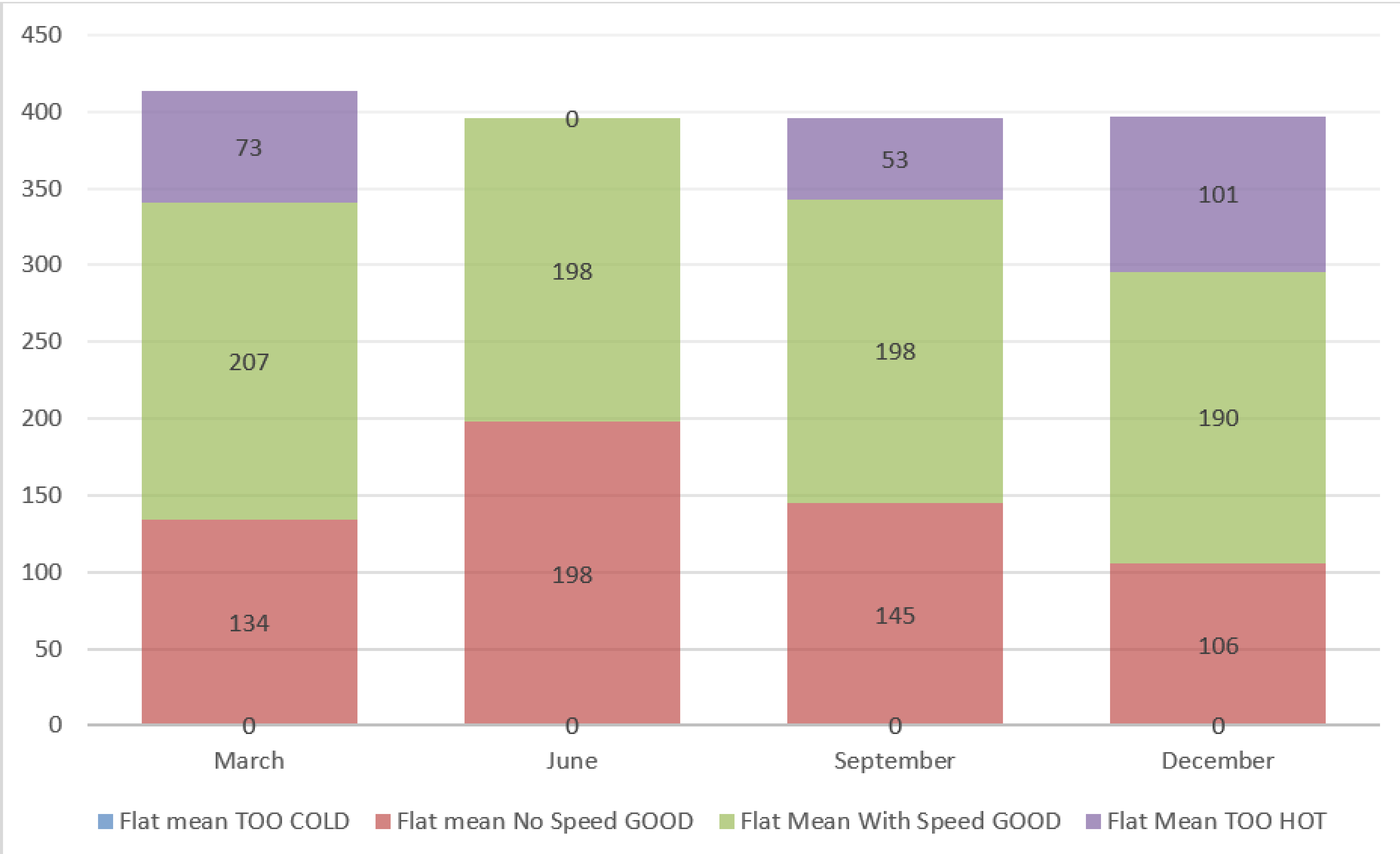
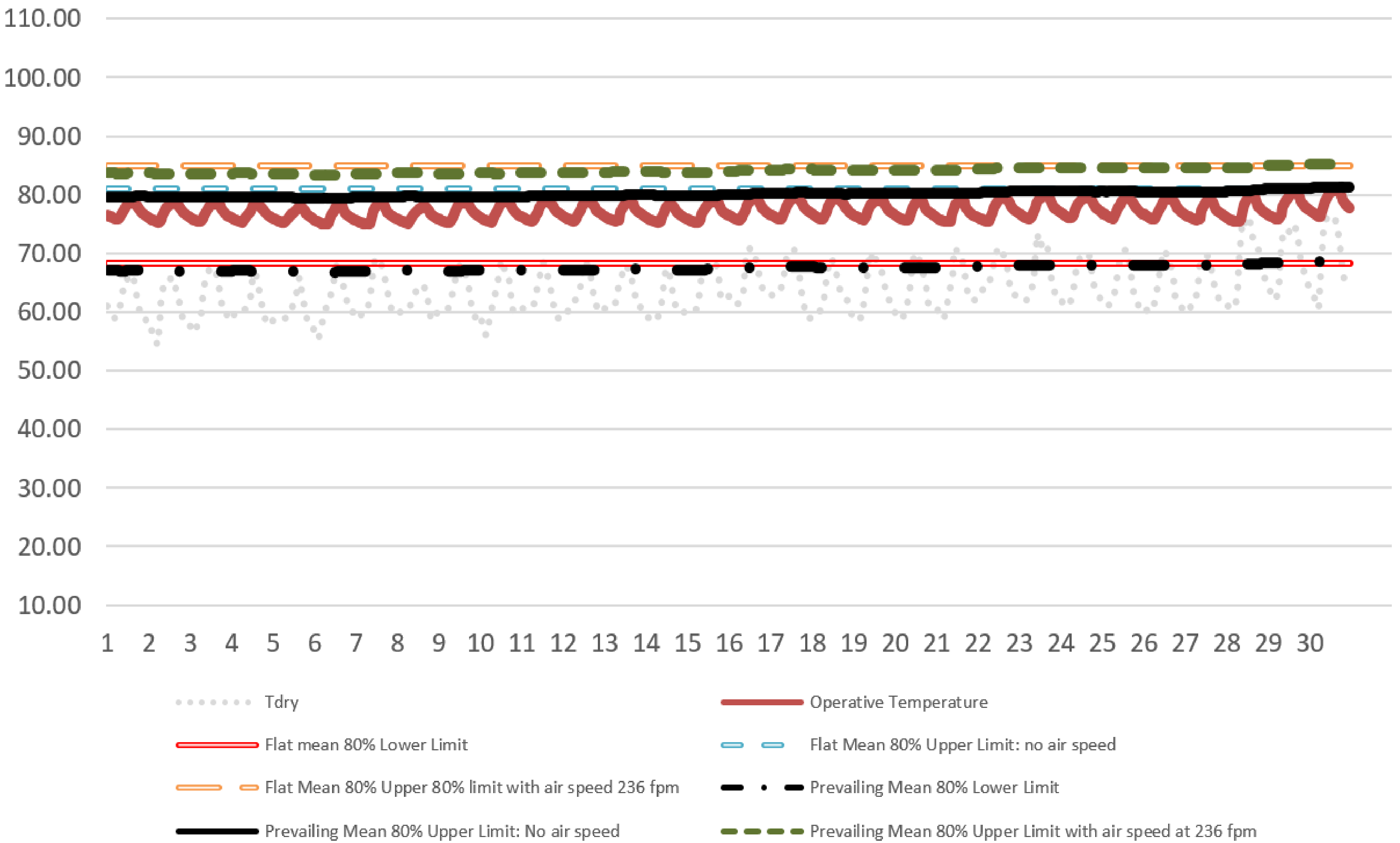
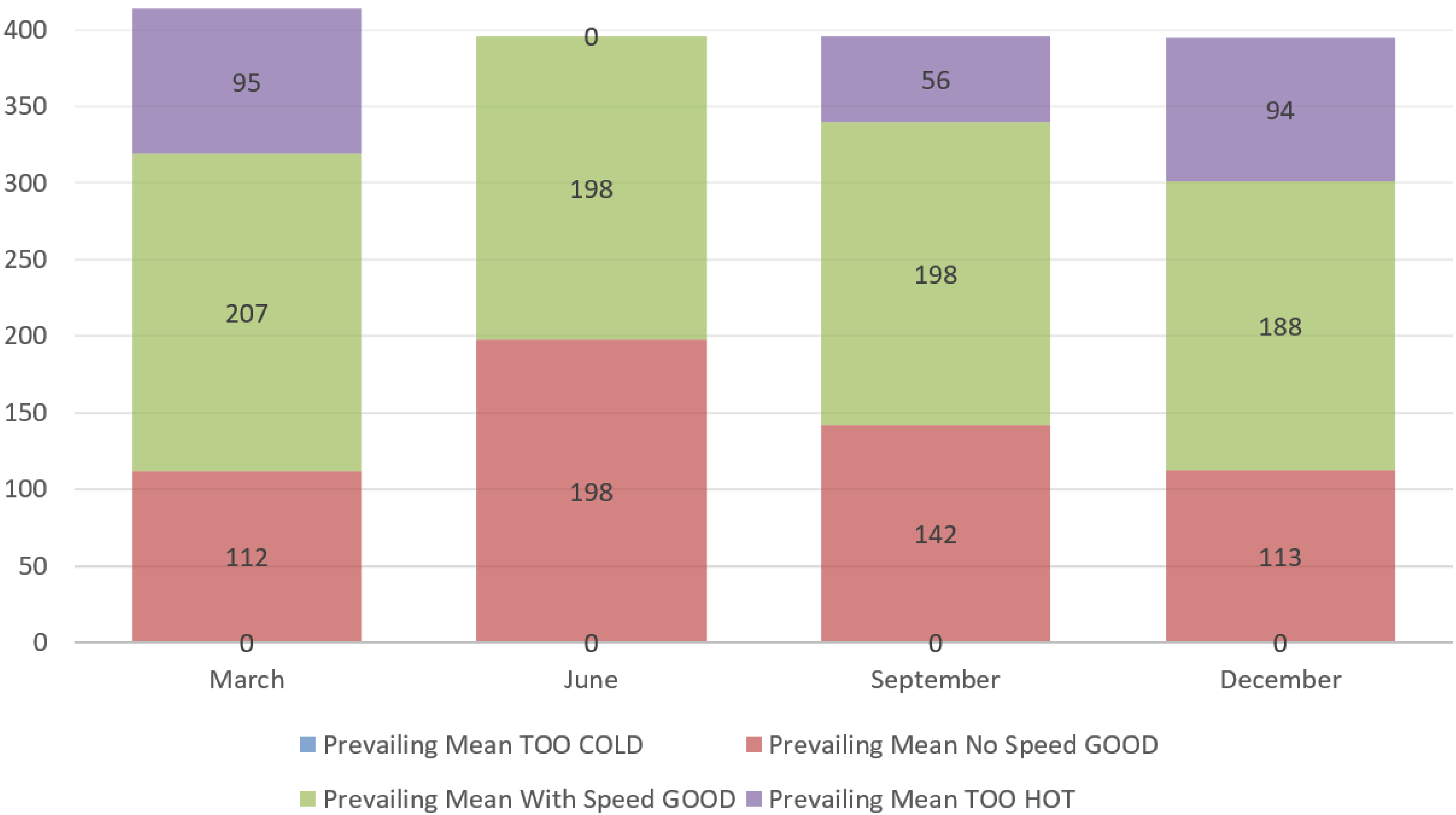
Flat mean approach (by month) for an office occupancy example (LA)



Prevailing (rolling) mean for same office



Prevailing mean Compliance Summary



Flat mean Compliance Summary

Other considerations

Data to Review	Question to be Asked (If Answer is Yes, Move to Next Question)
8. High Afternoon Temperatures	Does the climate have regular outside air temperatures over 80°F? If yes, review whether exposed thermal mass is possible.
9. Diurnal Range on Hot Days	Does the climate have a diurnal range that has nighttime temperatures below 65°F for at least 8 hours a night on the worst-case days? If yes, move to multizone modeling of thermal mass and consider night purge.
10. Dew-Point Temperatures Throughout Year	Throughout the year, do you have consistent outside air dew points throughout the year of less than 64°F? If yes, move to multizone modeling and consider a radiant cooling system.

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Control of Natural Ventilation and Natural Conditioning

- Both require that the occupant have control over the opening used to bring air into the building.
- The simplest level of control therefore is merely manual control of the window.
- ASHRAE Standard 62.1 (ASHRAE 2016b) section 6.4.3 states that openings must be "readily accessible" and that controls should "be designed to coordinate operation of the natural and mechanical ventilation systems."
- ASHRAE Standard 55 (ASHRAE 2017a) Section 6.4 requires the elements be "occupant controlled" with the definition including "manually controlled or controlled through the use of electrical or mechanical actuators under direct occupant control."

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Control Sequence of Operations Type (see subsequent sections and Appendices for more details)		Outdoor Sensors Active in SOO							Indoor Sensors Active in SOO						Device Active in SOO				
		Outdoor Air Bulb Temperature	Outdoor Relative Humidity	Wind Speed	Wind Direction	Rain/Precipitation Presence	Outdoor Air Pollutants	Static Outside Air Pressure	Indoor Air Temperature	Indoor Relative Humidity	Indoor CO_2 Level	Thermal Mass Surface Temperature	Window/Louver Closed Position Status	Favorable Condition Indicator	Manual Action	Motorized Opening Actuator & Position Status	Zonal Heating Device	Zonal Cooling Device	Zonal Ventilation Supply
Natural Ventilation	Manual										1		2		X				B
	Manual button/switch for motorized window										1		2		X	X			B
	Automatic window			E	H	E	e	H			1		2			X H			B
Heating	Cold Hours Heating Concurrent	X							X		1				T	T	X		T
	Cold Hours Heating Changeover	X							X		1						X		B
Natural Conditioning	Manual								X		1		2		X				B
	Manual button/switch for motorized window								X		1		2		X	X			B
	Manual with favorable condition indicator	X							X		1		2	3	X				B
	Automatic window with temperature control	X		E	H	E	e	H	X		1		2			X H			B
Cooling	Natural Conditioning with Hot Hours Cooling Changeover	X	4						X	4	1		2	3				X	B
Night Purge	Automatic window for night time purge of heat from thermal mass	X	X	E	H	E	e	H	X			X	5			X H 5			

LEED NV monitoring SOO

- For the two LEED® Minimum Air Quality Performance Prerequisite options that do not require an exhaust fan, either of the following can be used:
- Window position status shall be monitored continuously during occupied hours. When a window is “closed”, the zone shall go into alarm for ventilation and the backup ventilation system shall be started.
- Indoor CO_2 shall be monitored continuously during occupied hours. When the CO_2 level rises higher than ambient outdoor CO_2 plus [pick one of: 700ppm (ASHRAE Standard 62.1 – ASHRAE 2016b) or 600 ppm (California Title 24 – California Energy Commission 2015a)], the zone shall go into alarm for ventilation and the backup ventilation system shall be started.

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Typical automatic window ventilation compliance SOO

- At the start of occupancy hours, the Automatic Window shall be opened.
- If a window should be open and it is not, then an alarm shall be raised and the backup ventilation system shall be started.
- At [30 minutes] past the end of occupancy hours, the Automatic Window shall be closed.
- If a window should be closed and it is not, then an alarm shall be raised.
- In the event of wind speeds exceeding {To Be Determined through trial and error or design team wind modeling}, close the windows.
- In the event of wind speeds exceeding {To Be Determined through trial and error or design team wind modeling} and rain is sensed, close the windows.
- (Optional) if outdoor PM2.5 pollutants rise above {To Be Set by Owner based on sensor quality}, close the windows.

- It should be noted that the full automation of windows to the exclusion of manually-controlled windows would make a space ineligible to apply the Natural Conditioning Comfort Range in ASHRAE Standard 55 (ASHRAE 2017a).

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Automatic window in high rise building SOO options

- When roof wind speeds rise above {To Be Determined through trial and error or design team wind modeling} and from directions {To Be Determined through trial and error or design team wind modeling}, close the windows.
- When roof wind speeds rise above {To Be Determined through trial and error or design team wind modeling} and from directions {To Be Determined through trial and error or design team wind modeling}, reduce range of opening to a high limit of {50%} of full stroke.
- When differential static pressure at a given elevation between opposing faces of a building exceeds {To Be Determined through trial and error or design team wind modeling}, reduce range of opening to a high limit of {50%} of full stroke.

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Basic concurrent to change over heating sequence

- When indoor temperature falls below {68°F (20°C)} activate the heating element.
- If automatic windows are present, close the windows to the minimum "trickle" mode.
- If dedicated trickle vents in the zone are available, close all automatic windows and open the Trickle vents.
- If neither trickle vents nor trickle mode of automatic windows are available, start the backup mechanical ventilation system.
- (Typical) Modulate zone heating to hold a setpoint of {70.5°F (21°C)} with a {5°F (2.5°C)} deadband.
- *(Special for California) Within the California Energy Code Title 24, item #5 must be overridden and the zonal control is required to be placed in a setback of {55°F (13°C)} with a {5°F (2.5°C)} deadband instead whenever a window switch is "not closed."*

- Heating mode shall remain operational until outdoor air temperature exceeds {68°F (20°C)}.
- When the heating mode is terminated, revert systems back to normal natural ventilation operation.

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Basic temperature monitoring sequence for ASHRAE 55 adaptive comfort compliance

- When indoor temperature falls below {68°F (20°C)} activate the zonal heating mode.
- When the heating mode is terminated, revert systems back to normal natural ventilation mode.
- Indoor temperature shall be monitored and an alarm raised when the indoor temperature rises above { Upper 80% acceptability limit (°F) = 0.31 $t_{pma(out)}$ + 60.5 (Upper 80% acceptability limit (°C) = 0.31 $t_{pma(out)}$ + 21.3) per ASHRAE Standard 55},
  where $t_{pma(out)}$ is the simple arithmetic mean of all of the mean daily outdoor air temperatures of no fewer than the last 7 days and no greater than the last 30 days, and the mean daily outdoor air temperature of each day is the simple arithmetic mean of all the outdoor dry bulb temperature observations for a 24 hours period.
- Indoor air temperature shall be monitored. Number of hours of exceedance of the Upper 80% acceptability limit shall be logged and stored per zone for at least 365 days.

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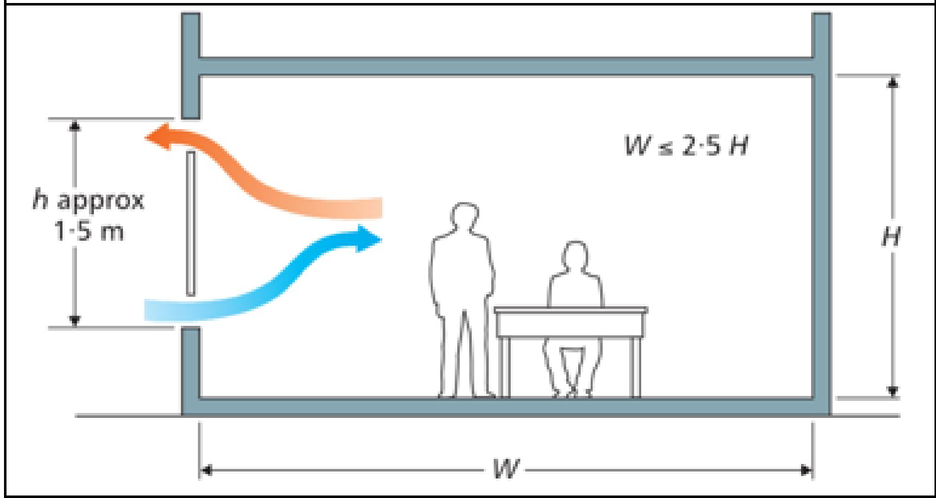
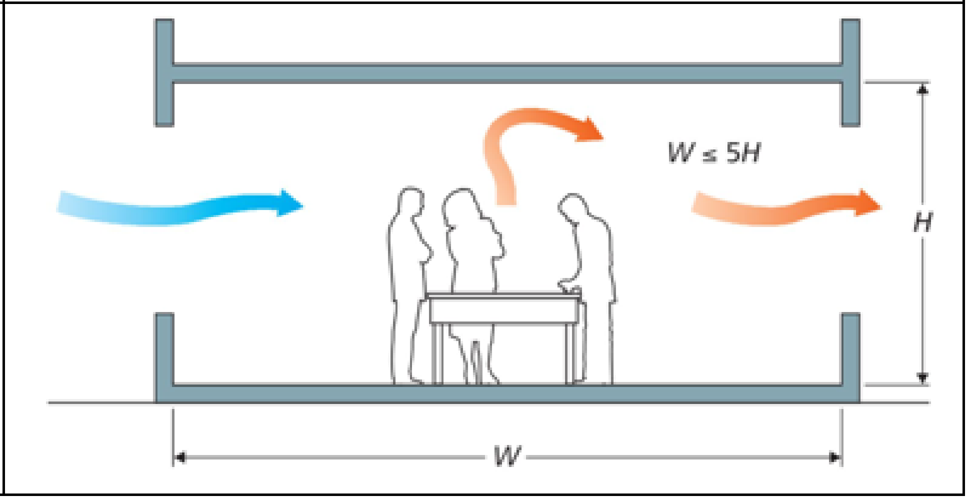
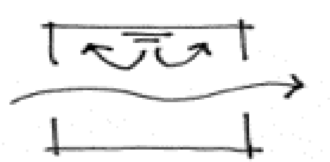
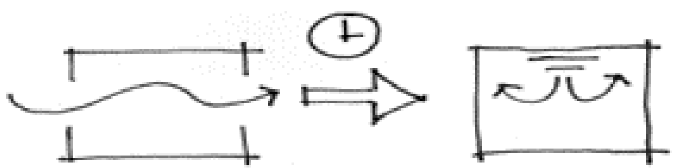
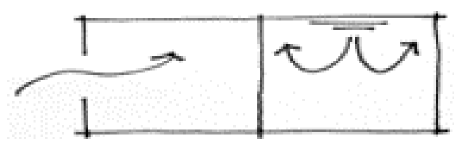
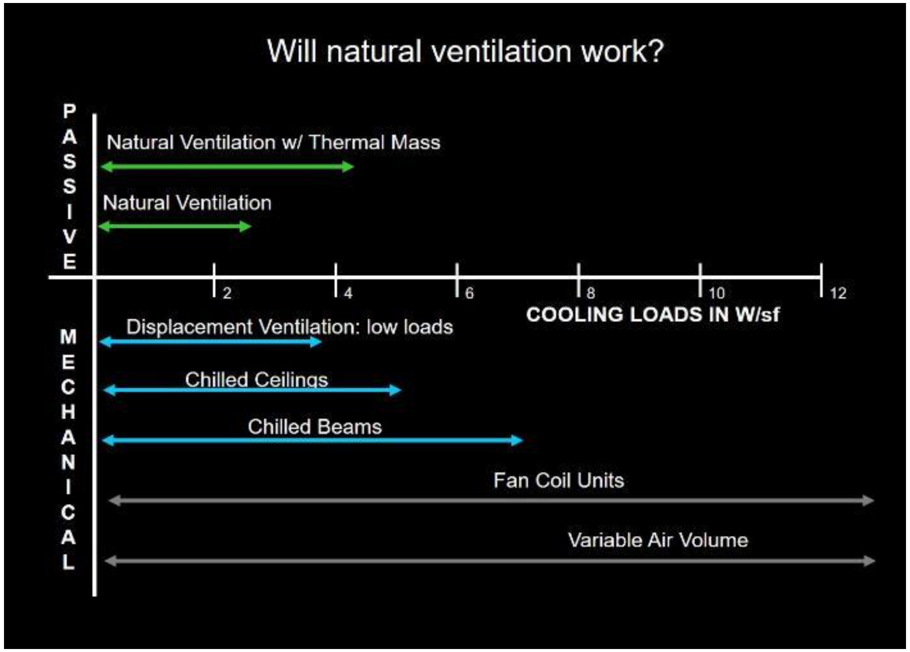
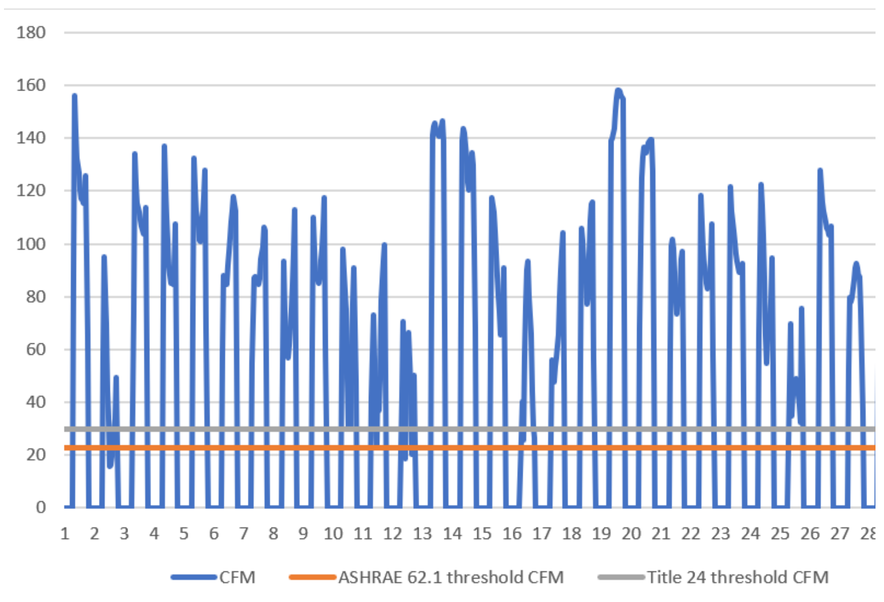
Buoyancy-Driven Natural Ventilation, also known as “Stack Effect”	Wind-Driven Natural Ventilation

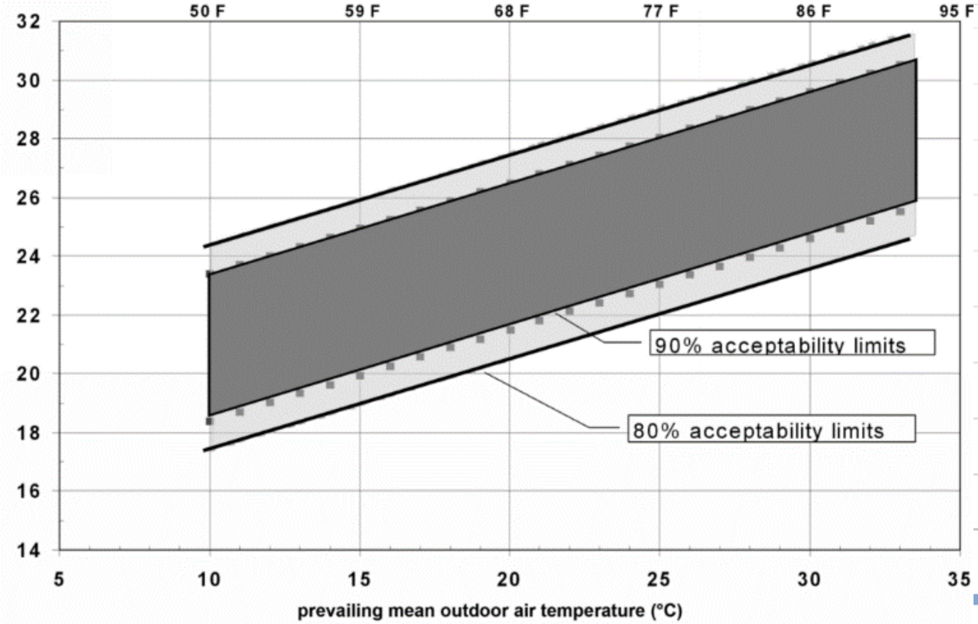




Complementary Design		**Zoned Design**
Concurrent	**Change-over**	
Mechanical cooling and Natural ventilation occur in Same space Same time	Mechanical cooling and Natural ventilation occur in Same space Different times	Mechanical cooling and Natural ventilation occur in Different spaces Same time
		


Will natural ventilation work?
PASSIVE
Natural Ventilation w/ Thermal Mass
Natural Ventilation
2
4
6
8
10
12
COOLING LOADS IN W/sf
MECHANICAL
Displacement Ventilation: low loads
Chilled Ceilings
Chilled Beams
Fan Coil Units
Variable Air Volume


180
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
CFM
ASHRAE 62.1 threshold CFM
Title 24 threshold CFM


50 F
59 F
68 F
77 F
86 F
95 F
32
30
28
26
24
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16
14
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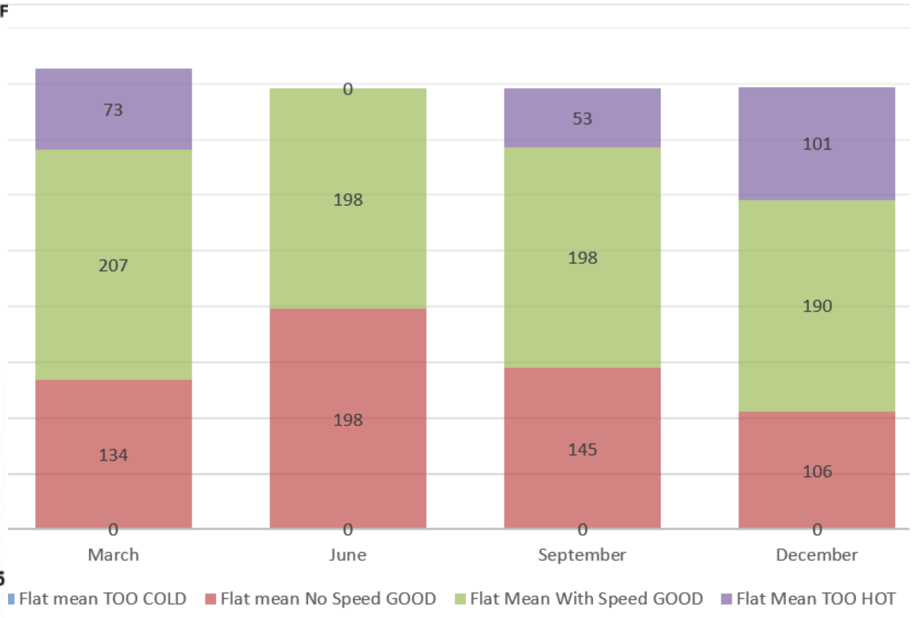
25
30
35
90% acceptability limits
80% acceptability limits
prevailing mean outdoor air temperature (°C)


73
207
134
0
198
198
0
53
198
145
0
101
190
106
0
March
June
September
December
Flat mean TOO COLD
Flat mean No Speed GOOD
Flat Mean With Speed GOOD
Flat Mean TOO HOT

Questions?

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November 7, 2019
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