High Performance Buildings and Occupant Comfort

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EDUCATION PARTNER

High Performance Buildings and Occupant Comfort

By Peter Simmonds

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Learning Objectives for this Session

- **PPD/PMV analysis can be used for space comfort diagnostics.**
- **Using comfort analysis provides more information for the design team.**
- **Not all analysis tools are capable of simulating occupant comfort.**
- **Multiple use spaces still require to provide occupant comfort.**
- **To understand the limitations of maintaining comfort**
- **To understand the possible energy consumption.**

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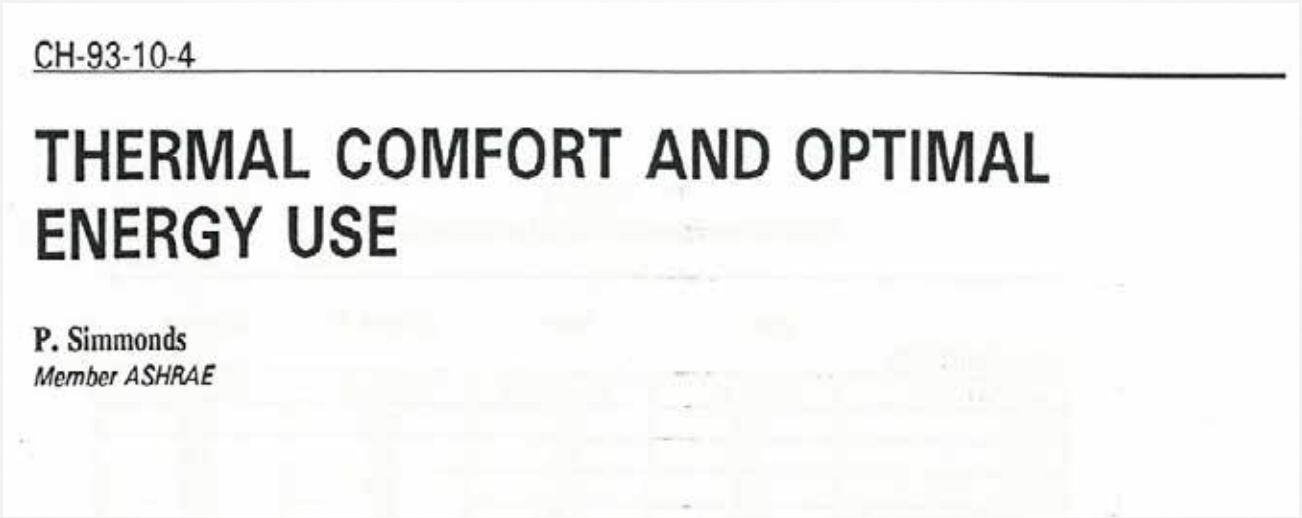
The Game

- How do we get to net zero?
- How do we provide occupant comfort?

25 years ago



CH-93-10-4

THERMAL COMFORT AND OPTIMAL ENERGY USE

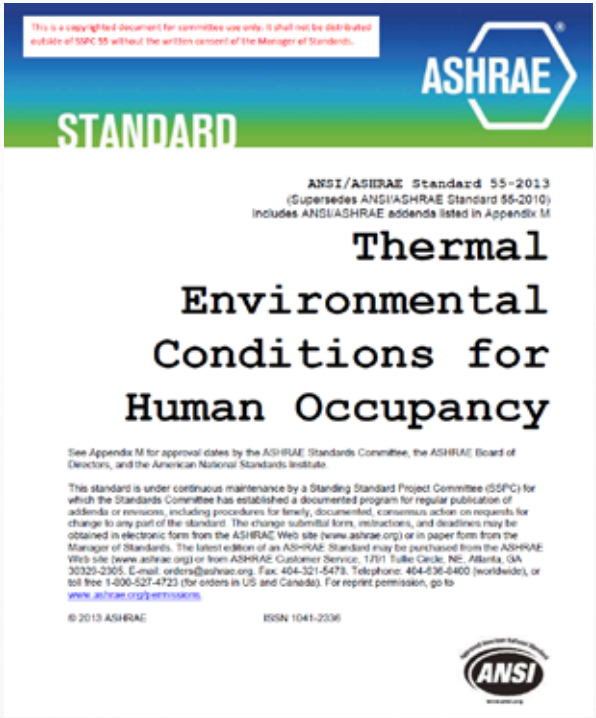
P. Simmonds
Member ASHRAE

25 years ago

ASHRAE 90.1, 2013 Appendix G, Exceptions:

- Setpoints and schedules for HVAC systems that automatically provide occupant thermal comfort via means other than directly controlling the air dry-bulb and wet-bulb temperature may be allowed to differ, provided that equivalent levels of occupant thermal comfort are demonstrated via the methodology in Section 5.2.3 of ASHRAE Standard 55, “Elevated Air Speed,” or Appendix D of Standard 55, “Computer Program for Calculation of PMV-PPD.”

Thermal Comfort Standard



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ASHRAE

STANDARD

ANSI/ASHRAE Standard 55-2013
(Supersedes ANSI/ASHRAE Standard 55-2010)
Includes ANSI/ASHRAE addenda listed in Appendix M

Thermal Environmental Conditions for Human Occupancy

See Appendix M for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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ANSI

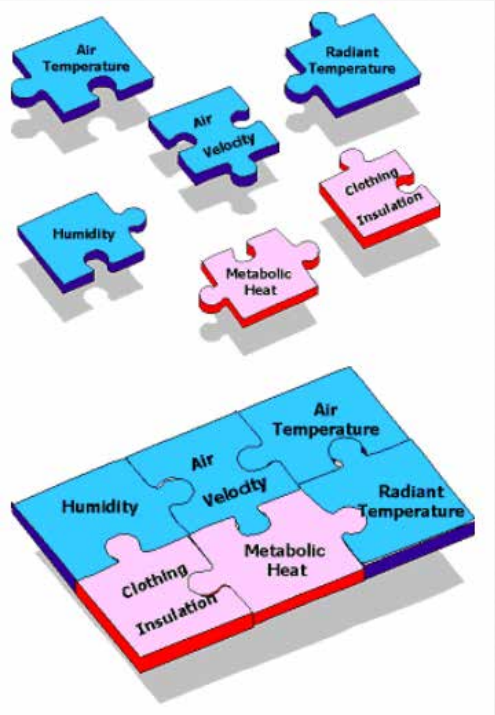
Thermal Comfort Definitions

Predicted Mean Vote (PMV):

an index that predicts the mean value of the votes of a large group of persons on the seven-point thermal sensation scale.

Predicted Percentage of Dissatisfied (PPD):

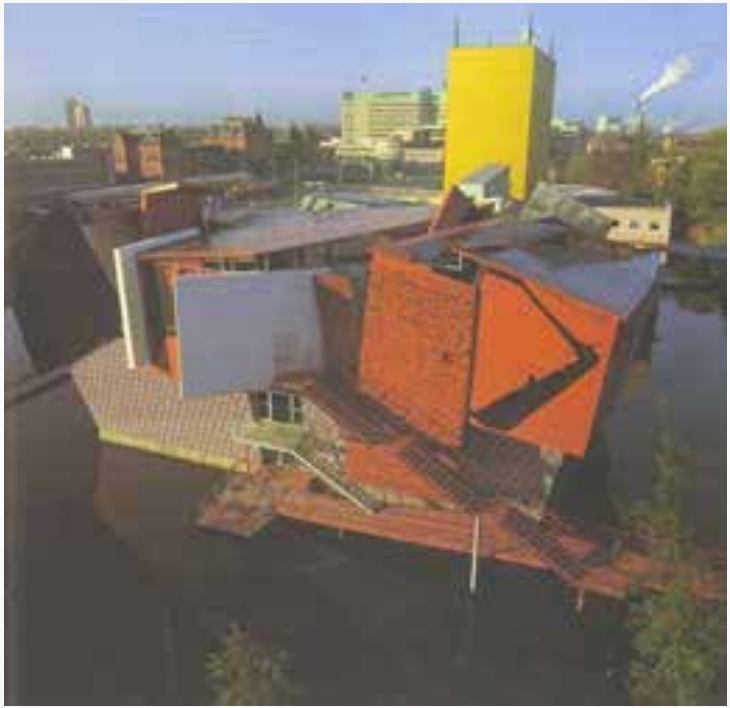
an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV.



THERMAL COMFORT

1) Metabolic rate.
2) Clothing insulation.
3) Air temperature.
4) Radiant temperature
5) Air speed.
6) Humidity

Early work



The Groninger Museum, Groningen, the Netherlands

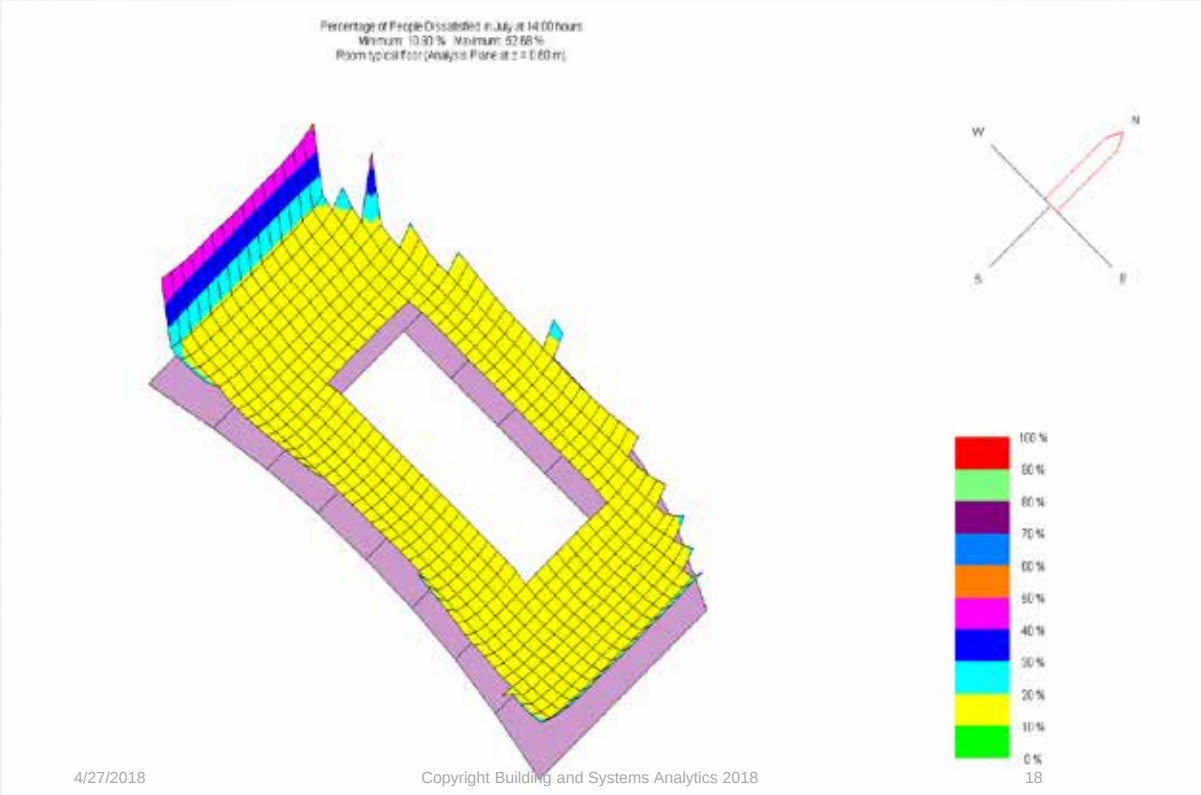
Akron Art Museum

Akron Art Museum

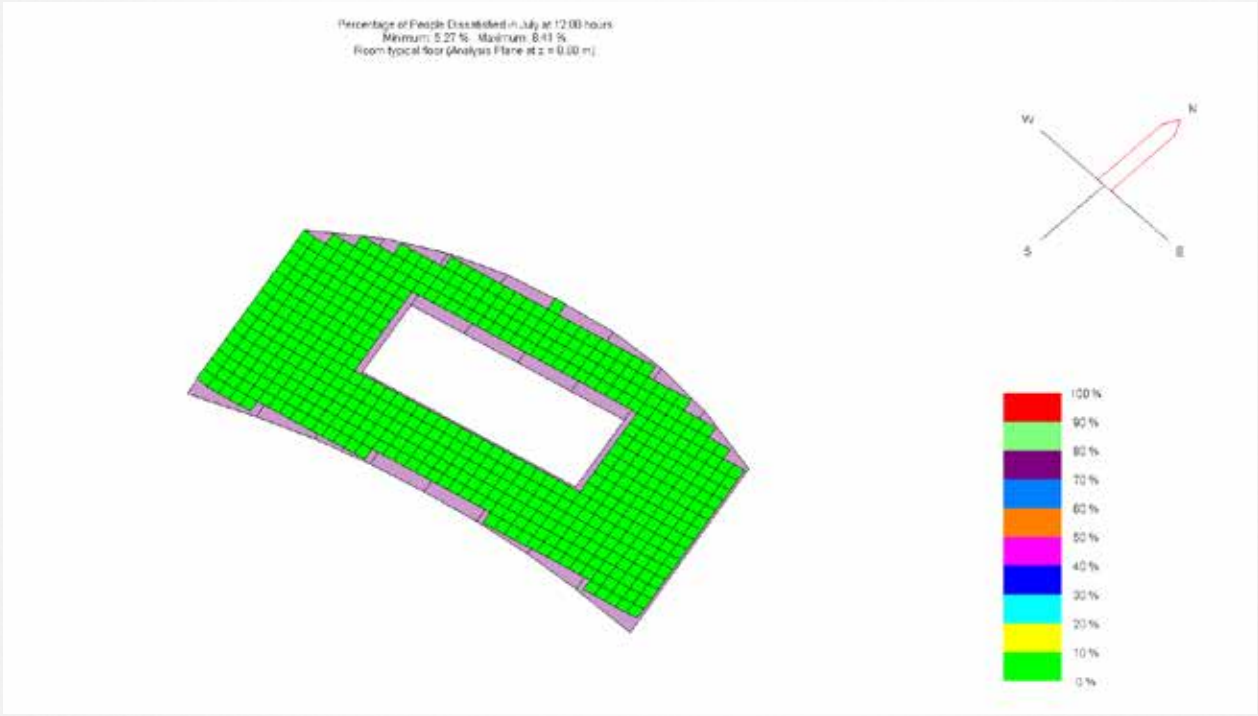
The original building

Pearl River, China

Thermal Comfort – GZDI Design



Thermal Comfort



Real Time Comfort Control

8 Canada Square, London

Typical Trading Floor

Past Experience

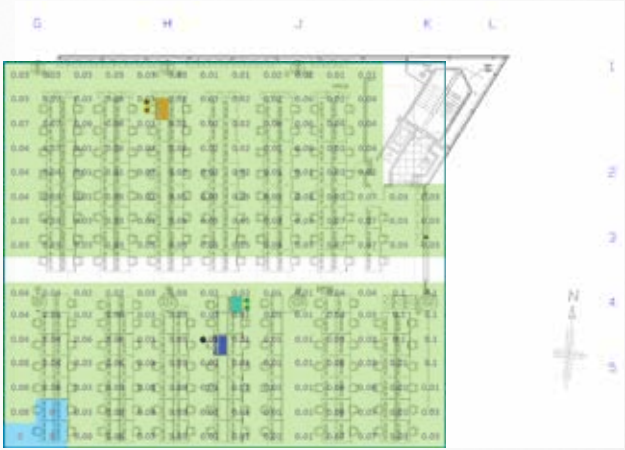
- No scientific approach to complaints
- Complaints received regarding draughts, ‘too hot’ , ‘too cold’
- Reactive activity based on individual experience / ‘knee jerk reaction’
- Average quantity of daily calls / emails received across all three floors were 3 per day
- Only factor that was measured that influenced thermal comfort was Air Temperature
- Controls / unit failures that were not identified

Recent Complaints

PPD = 5-7%

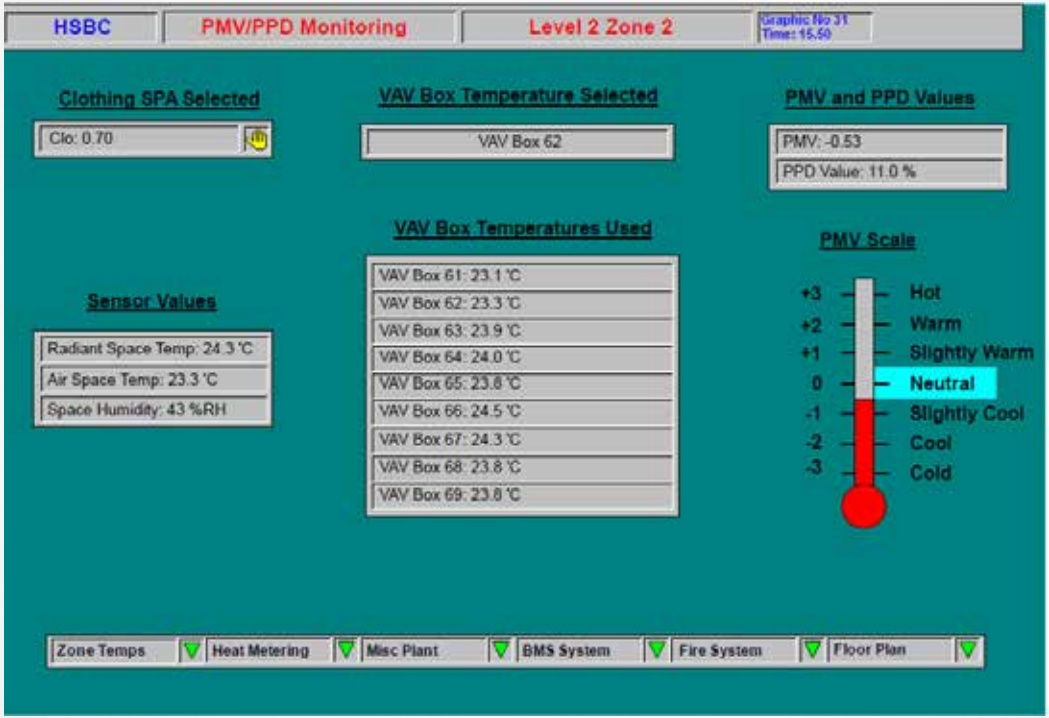
Complaints

Air Velocities

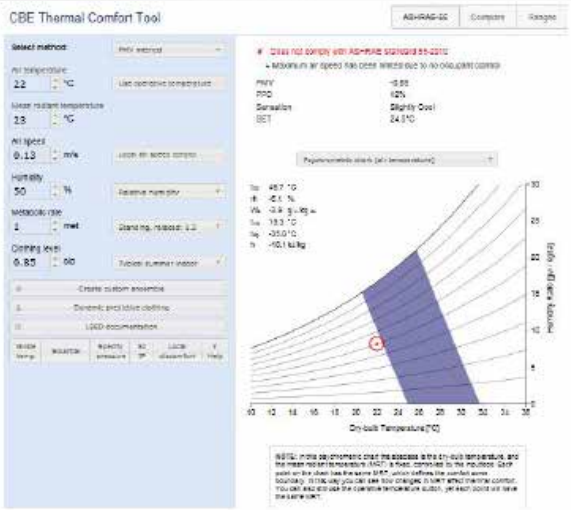


Profile shows complaints post Christmas Change activity

PPD/PMV Real Time Control



PPD Thermal Comfort Index



PPD at Room design of 22 °C

PPD at Room design of 24 °C

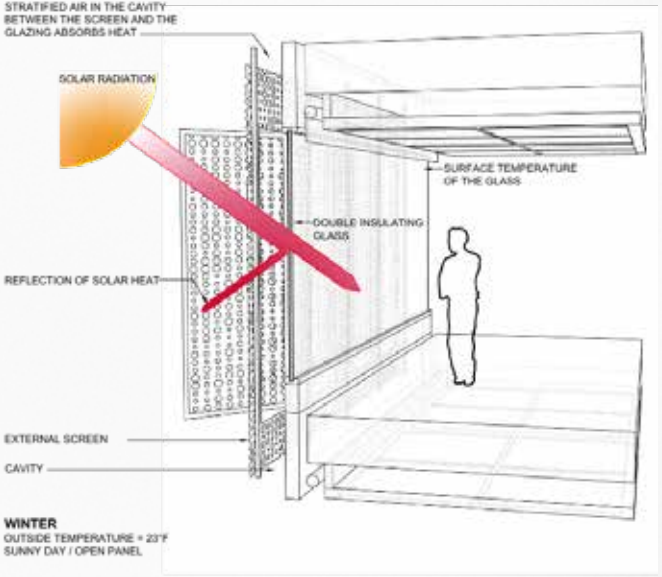
Reference: PPD Thermal Comfort Toolkit
http://smap.cbe.berkeley.edu/comforttool

Current Experience

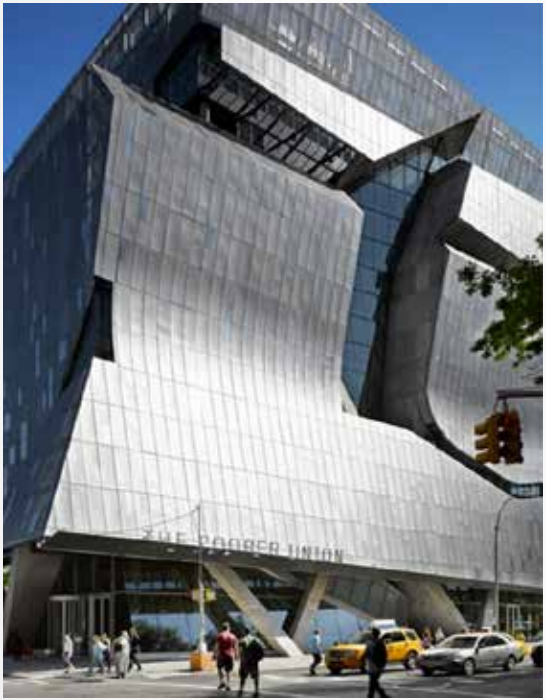
- Installed Predicted Percentage of Dissatisfied (PPD) system
- Now measure the 6 factors that influence thermal comfort – Air Temperature, Relative Humidity, Air Velocity, Radiant Temperature, Clothing, Metabolic Rate
- Average daily complaints now reduced to around 1 per day
- Smaller zones giving more accurate control
- Thermal comfort conditions are logged

Cooper Union

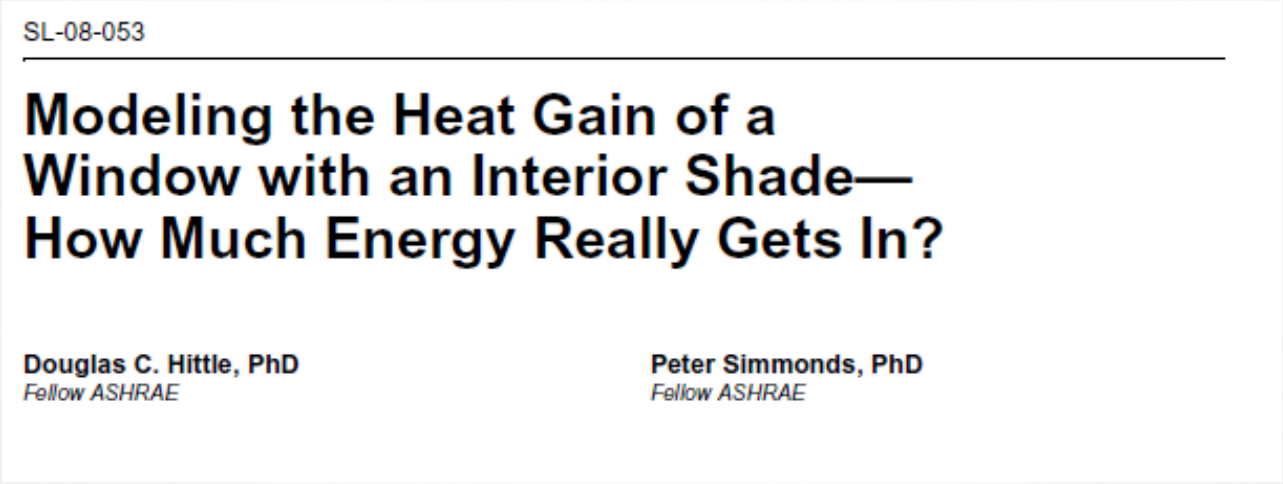
The efficiency of the façade-midseason



The Living Skin



Cooper Union



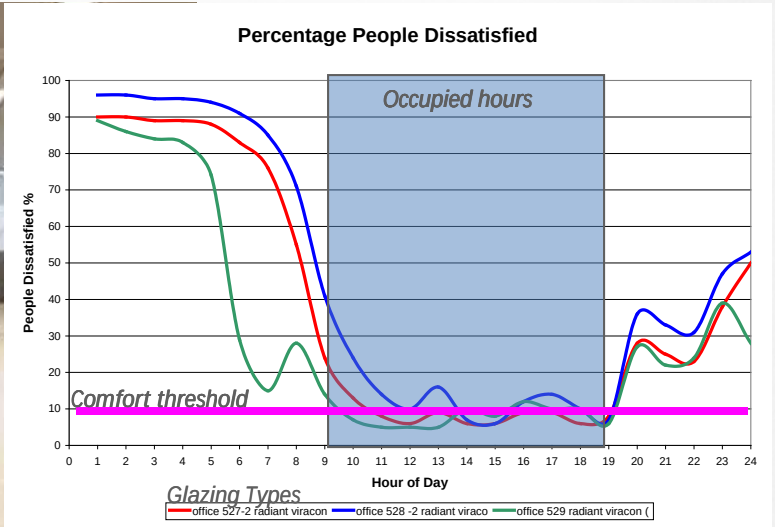
SL-08-053

Modeling the Heat Gain of a Window with an Interior Shade— How Much Energy Really Gets In?

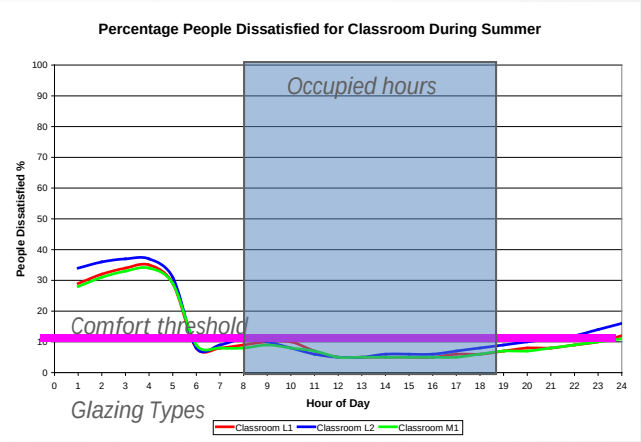
Douglas C. Hittle, PhD
Fellow ASHRAE

Peter Simmonds, PhD
Fellow ASHRAE

Cooper Union



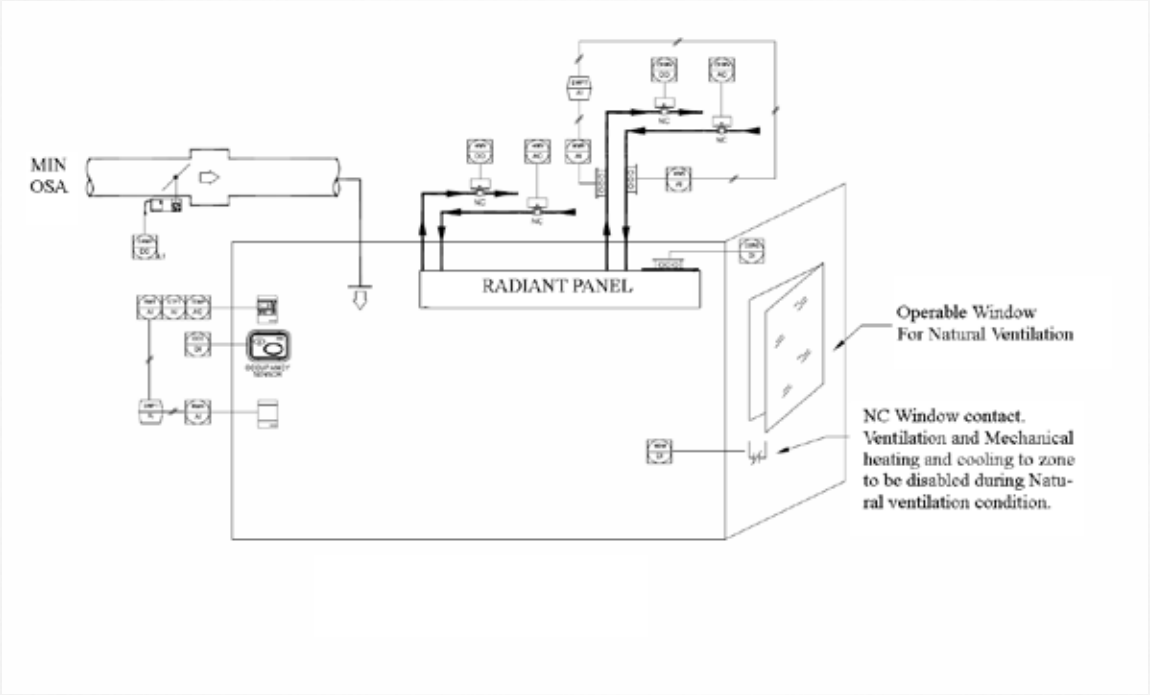
Cooper Union



Cooper Union- Results

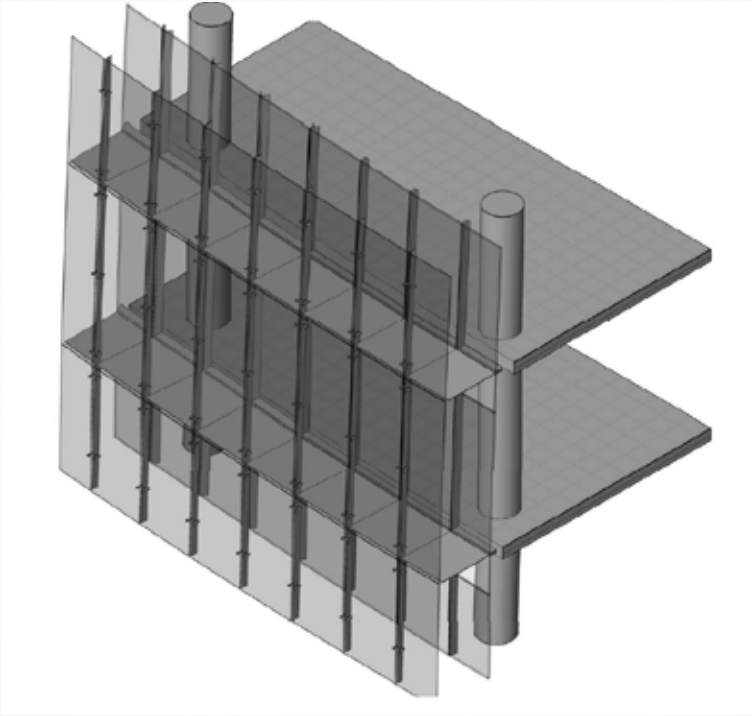
- The resulting utility costs are $400,770 compared to $602,672 for the budget case.
- The total energy cost savings is 34% and is therefore eligible for 7 LEED points.
- The proposed case is predicted at consuming 1,170,365 kWh of electricity per year and the budget case is predicted at consuming 2,184,932 kWh of electricity per year.
- This is a 46% reduction below the budget case.

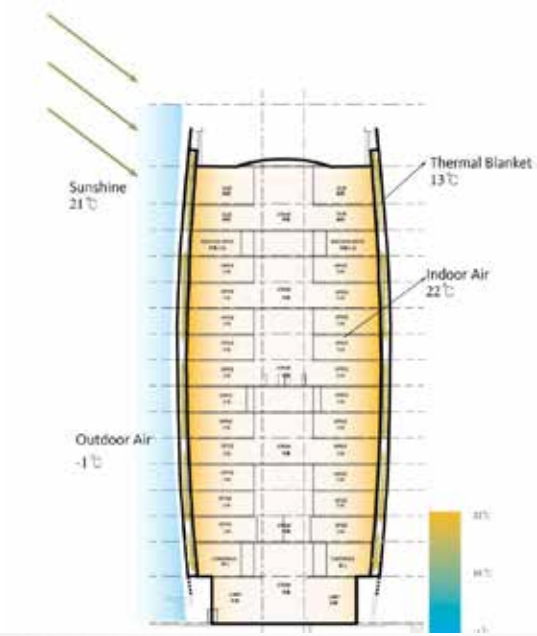
Space Control System

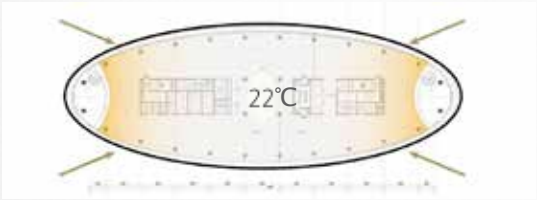


Harbin Bank, Beijing

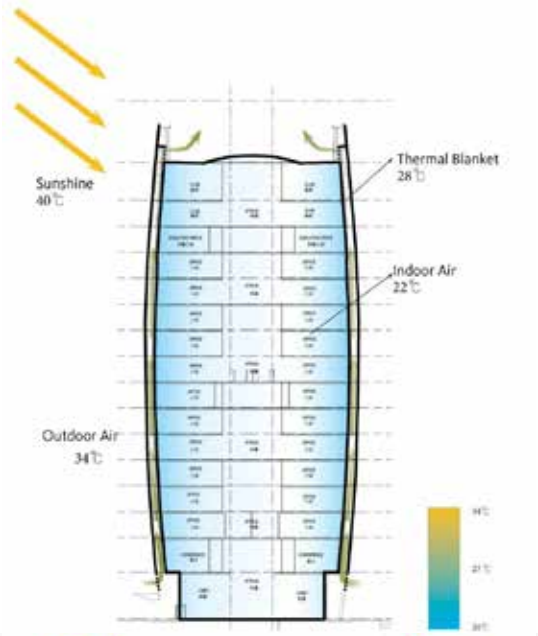
The Climate Facade

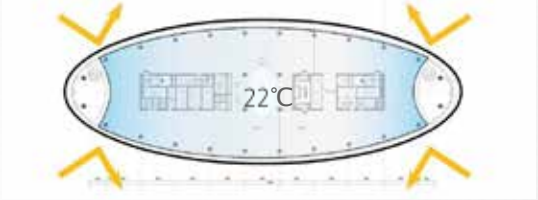






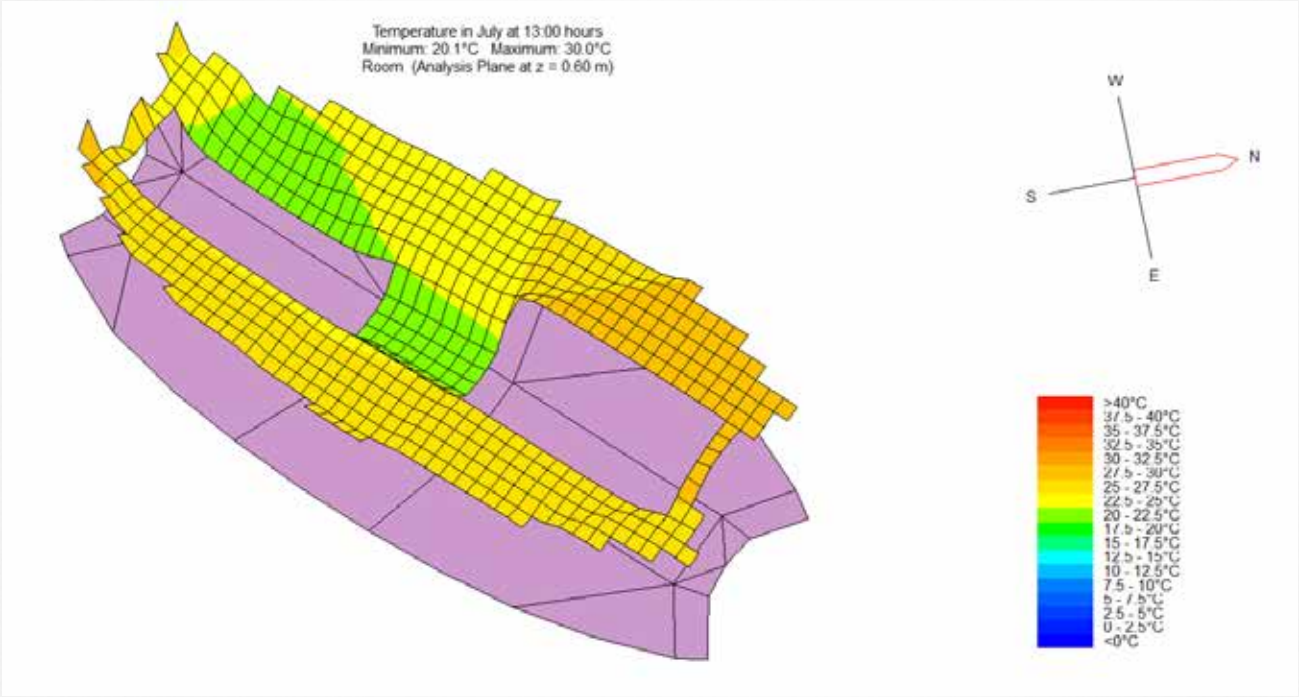
Winter



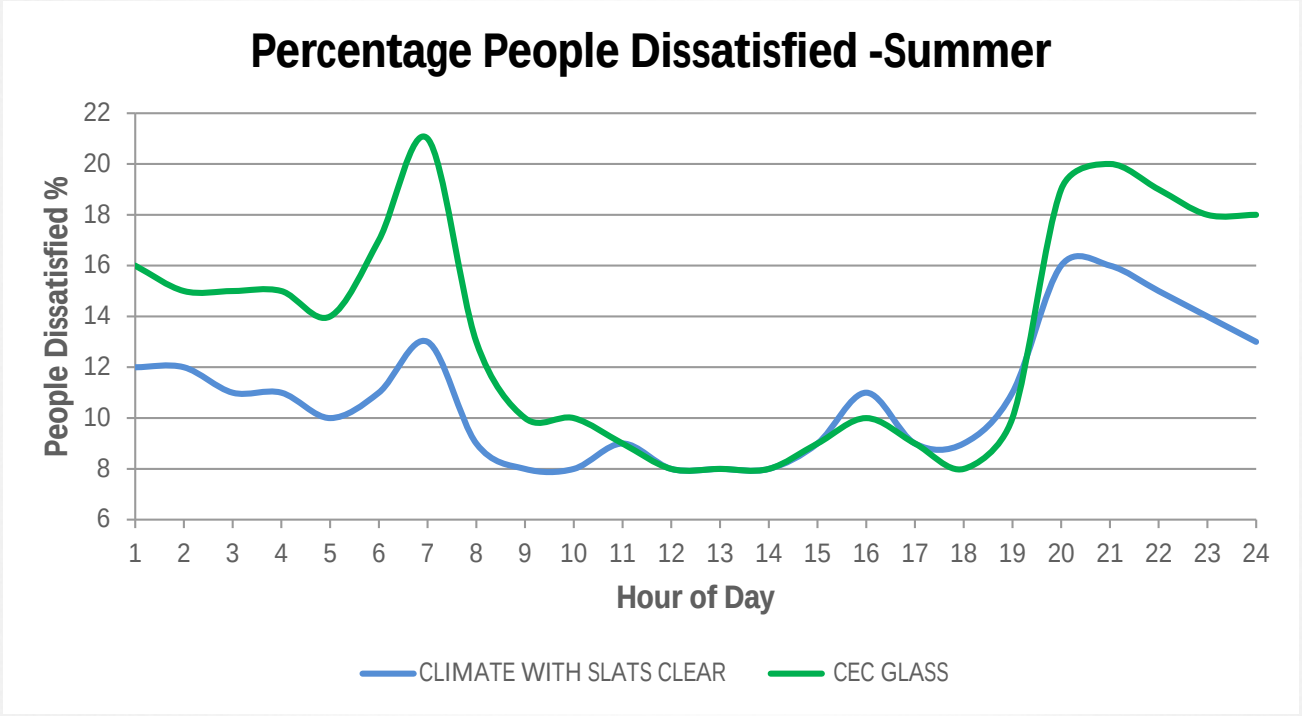


Summer

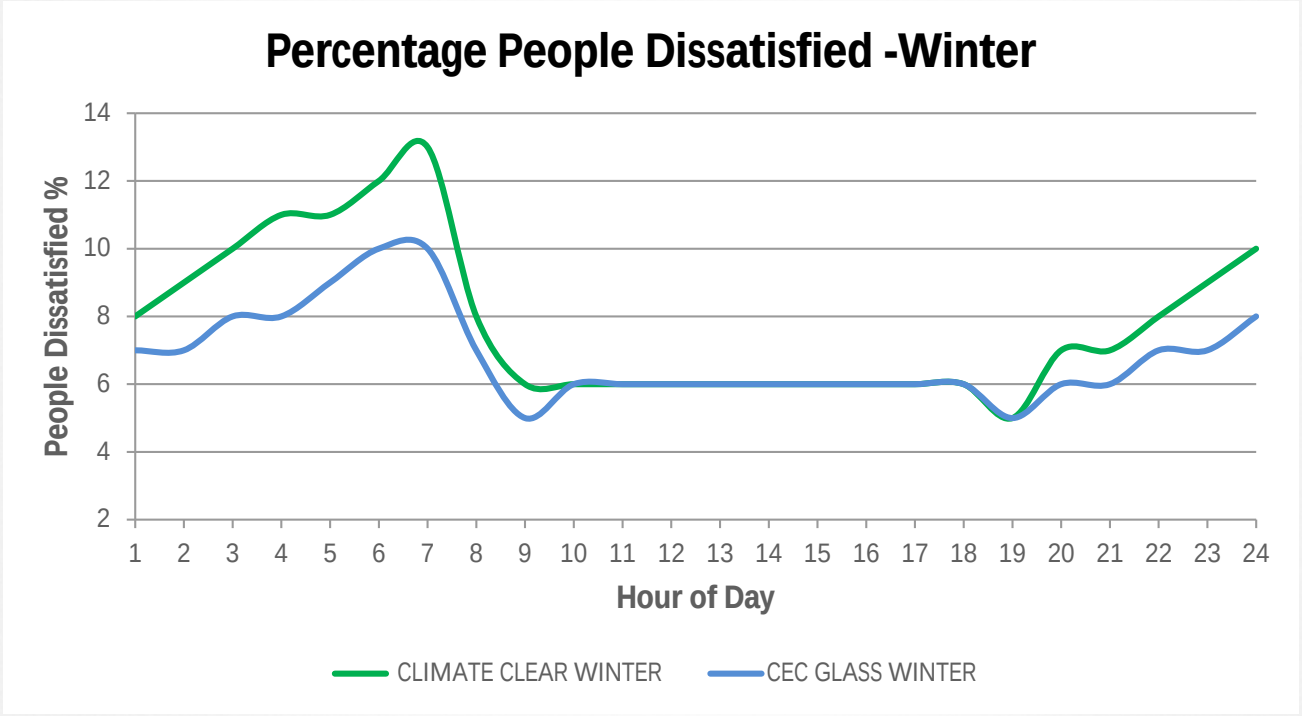
Analysis Plane



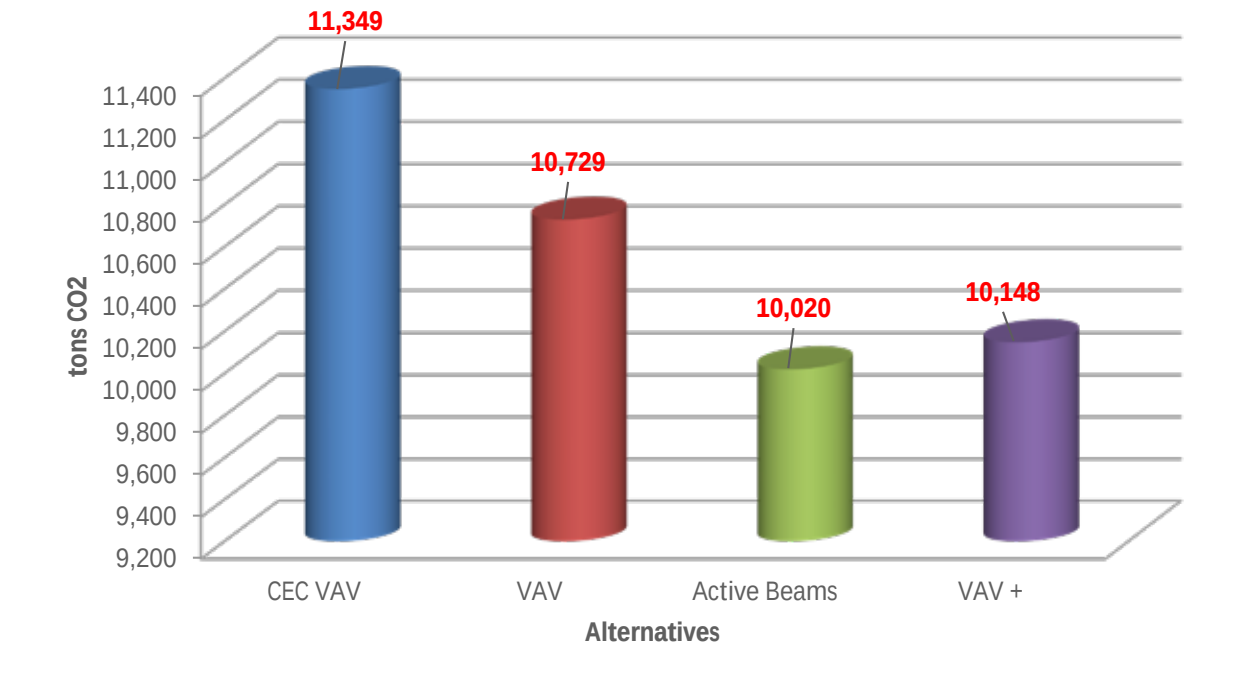
Summer Comparison



Winter Comparison



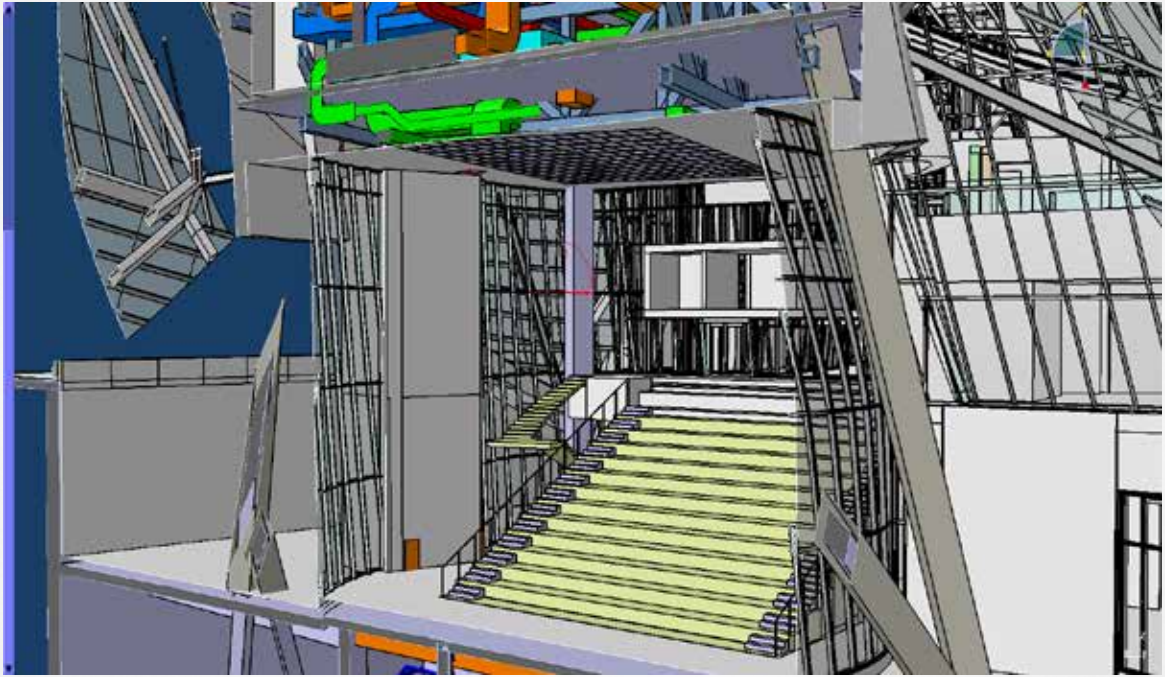
CO2 Emissions



Louis Vuitton Museum, Paris

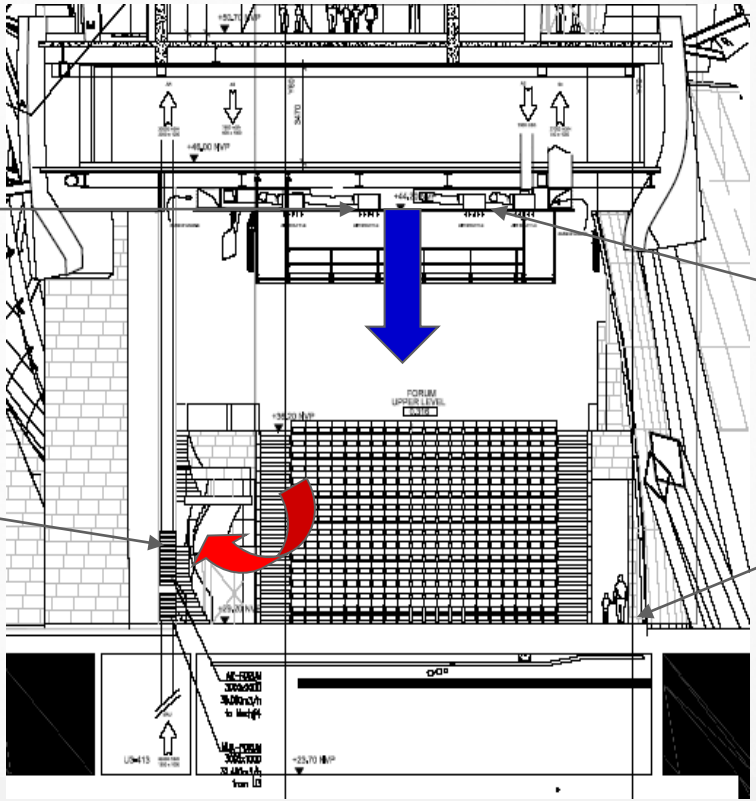
LVMH- Paris

The Forum



Forum Conditioning system

Variable volume displacement ventilation system

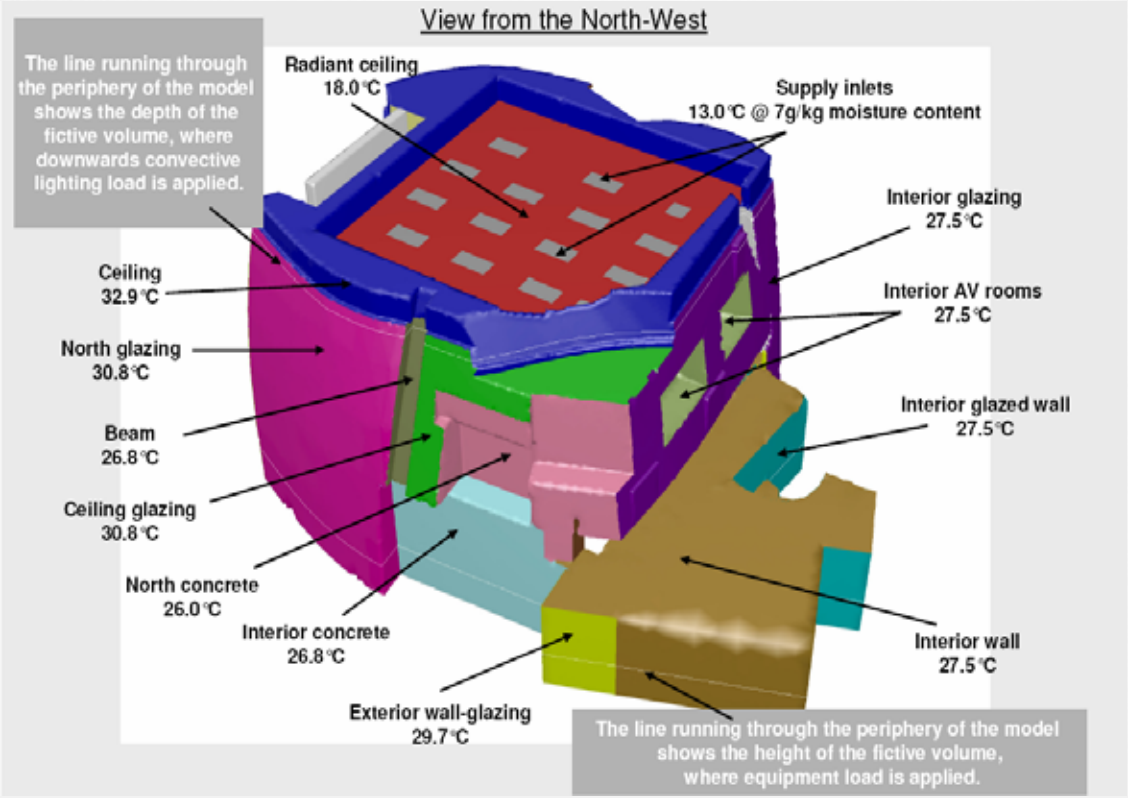


Radiant ceiling for heating and cooling

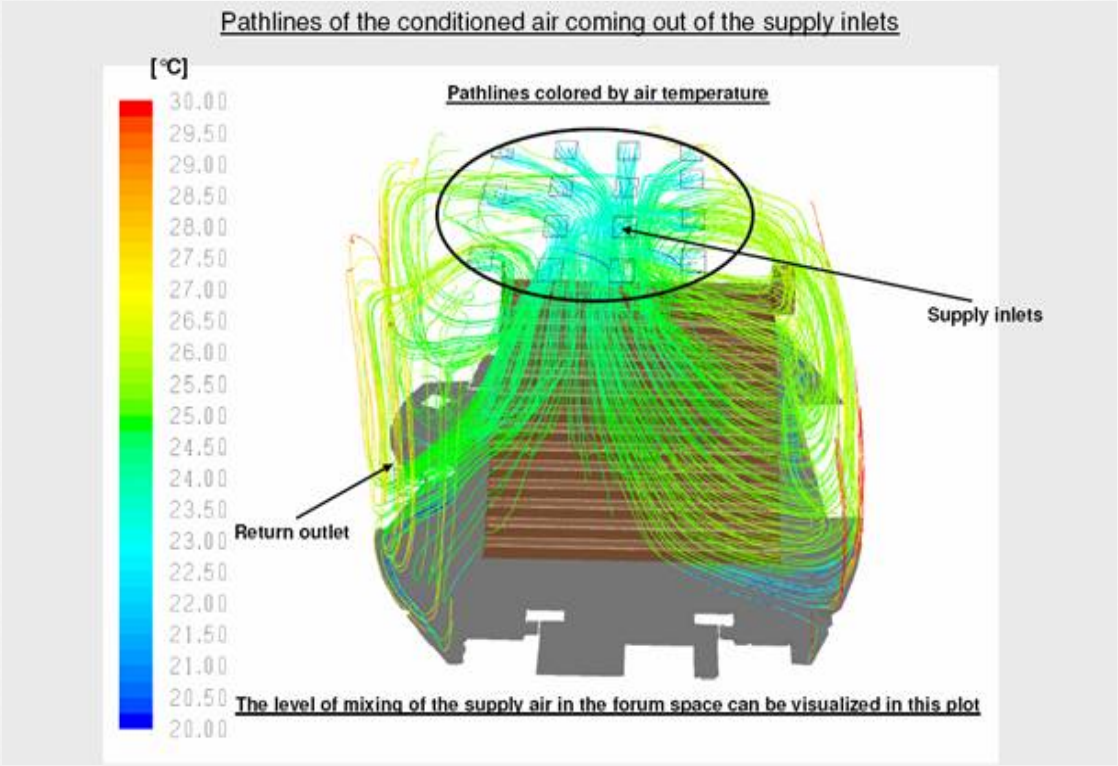
Exhaust air

Radiant floor for heating and cooling

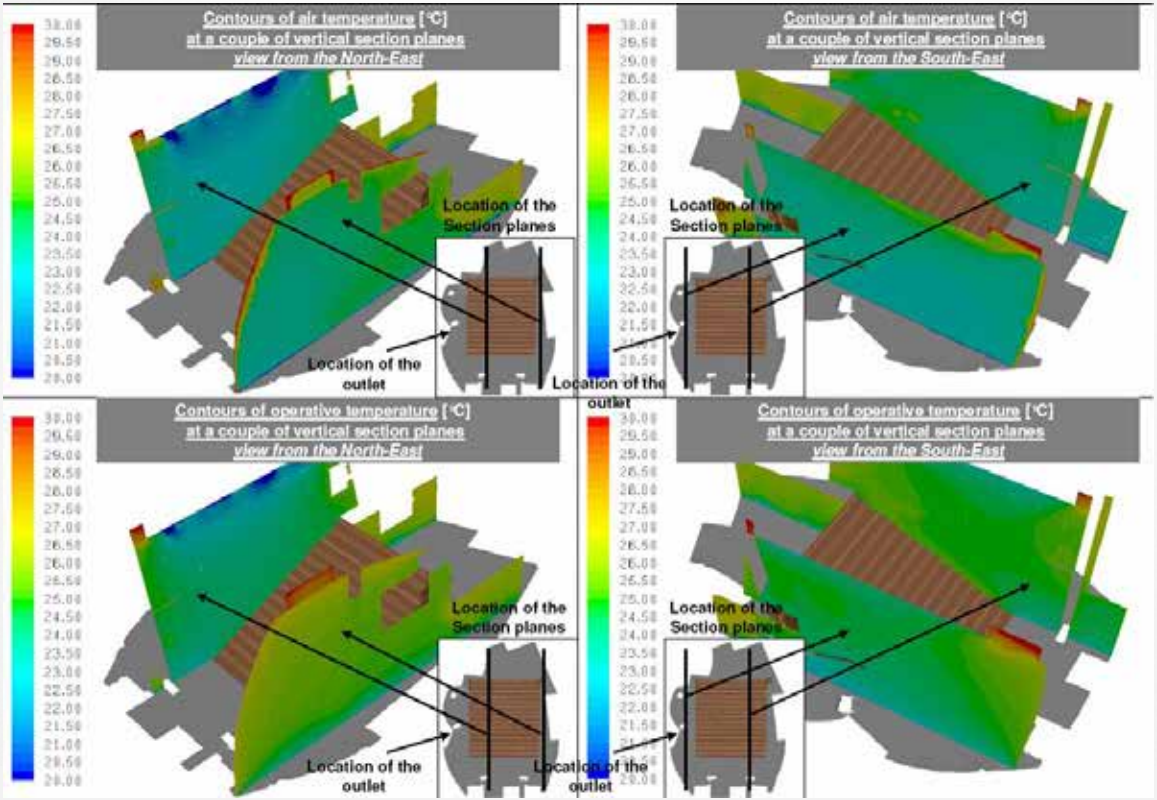
The Forum



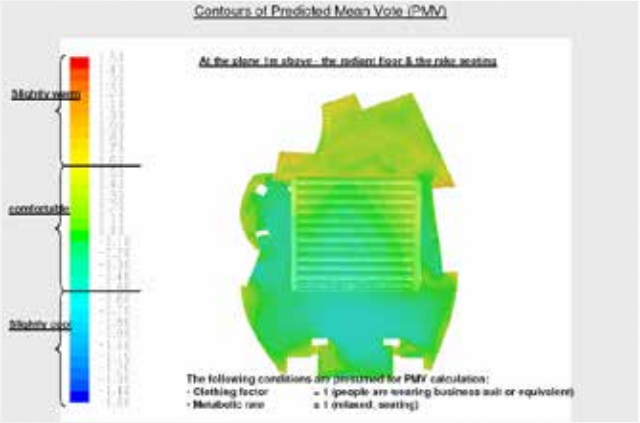
CFD for Comfort analysis

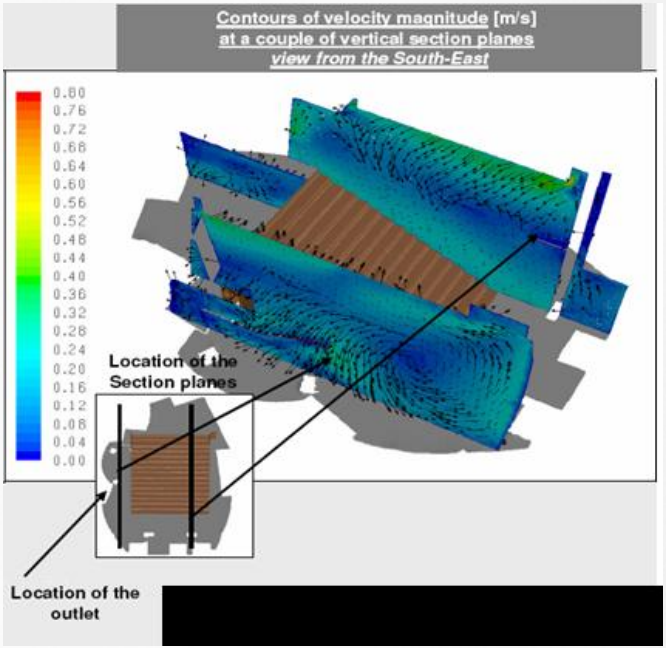


CFD for Comfort analysis



CFD for Comfort analysis





Claremont McKenna College

Typical Office

Meeting room

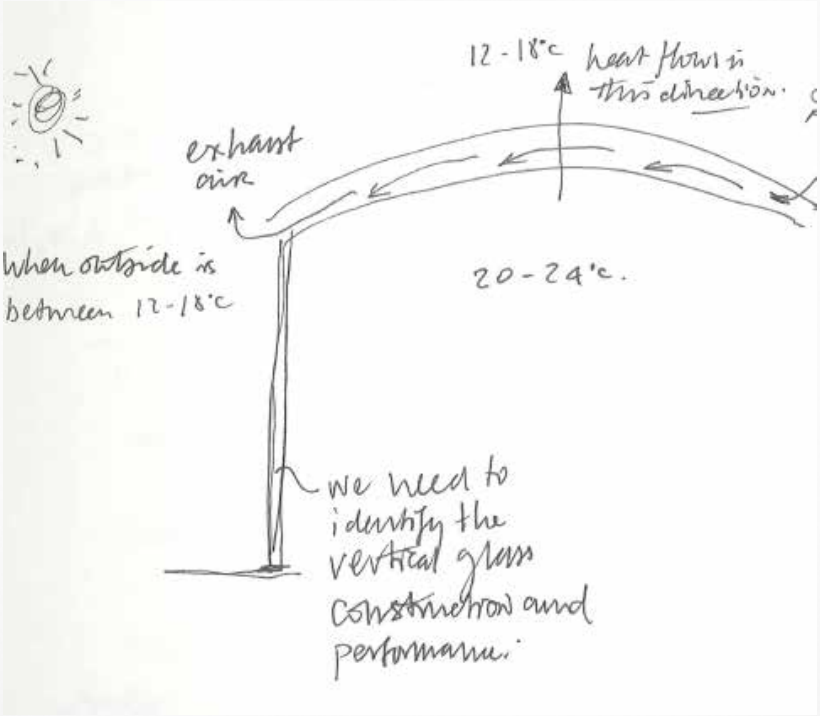
Claremont McKenna College

Energy consumption 48% lower than code required building.

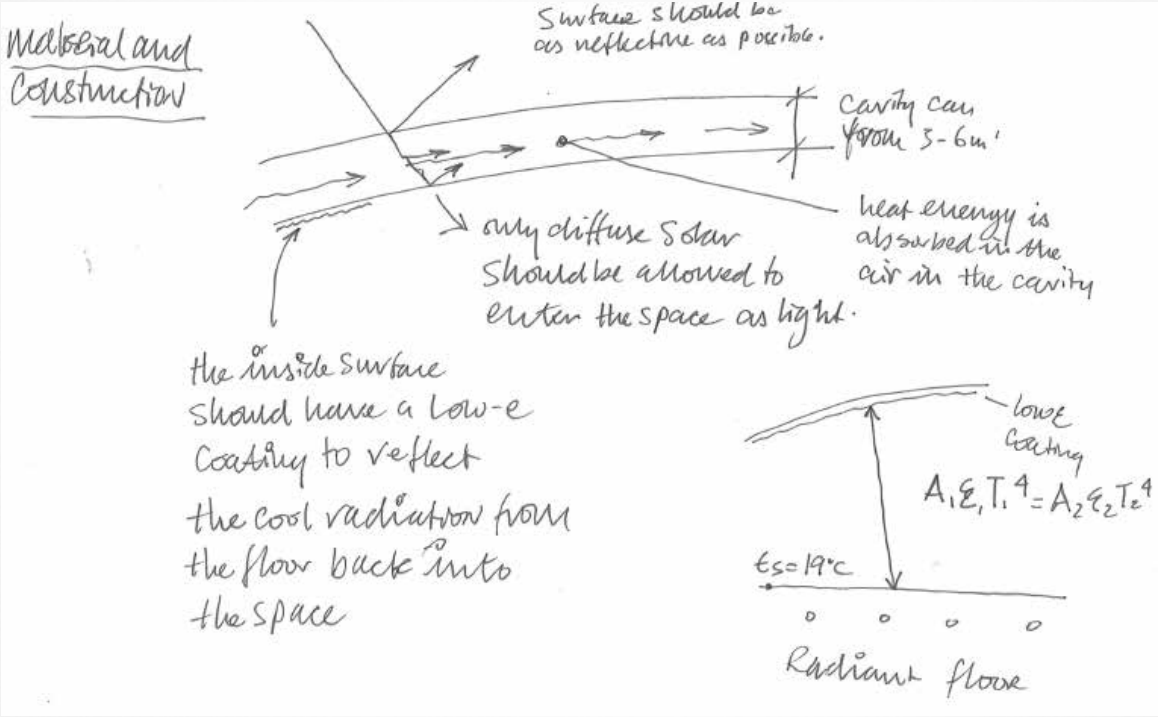
Terminal 2 – 680,000m2

Environmental Responsibility

Breathing Skin Concept



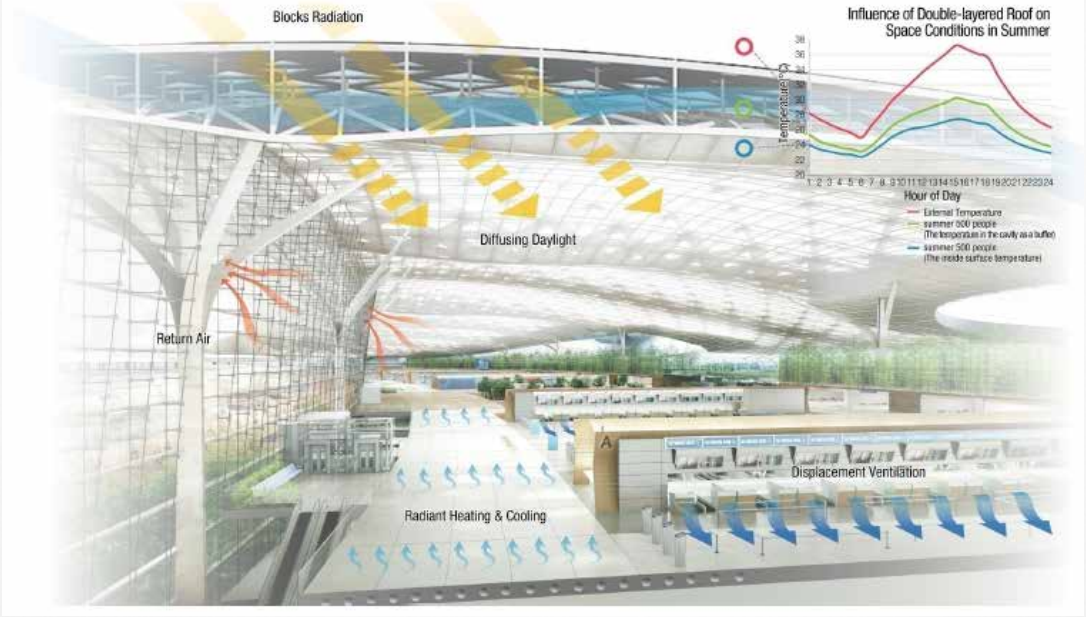
Radiation Exchange Concept



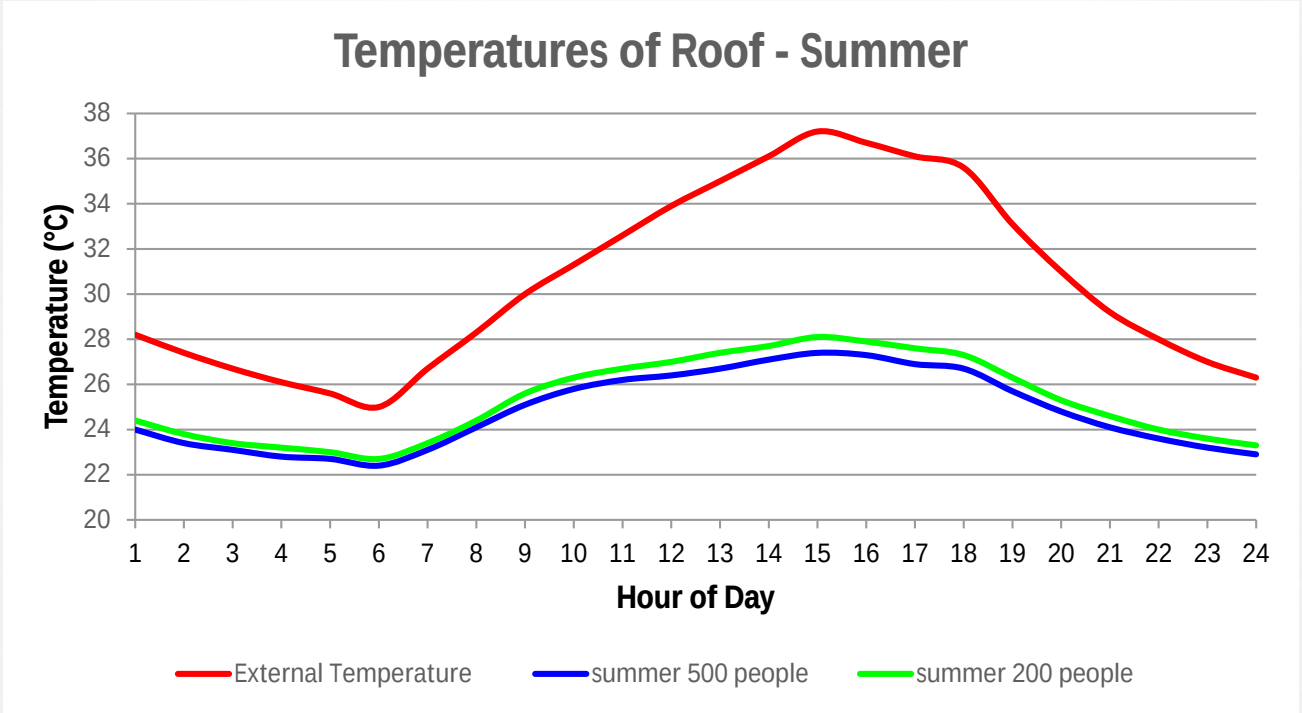
Radiant floor and displacement ventilation

Radiant Floor & Displacement Ventilation

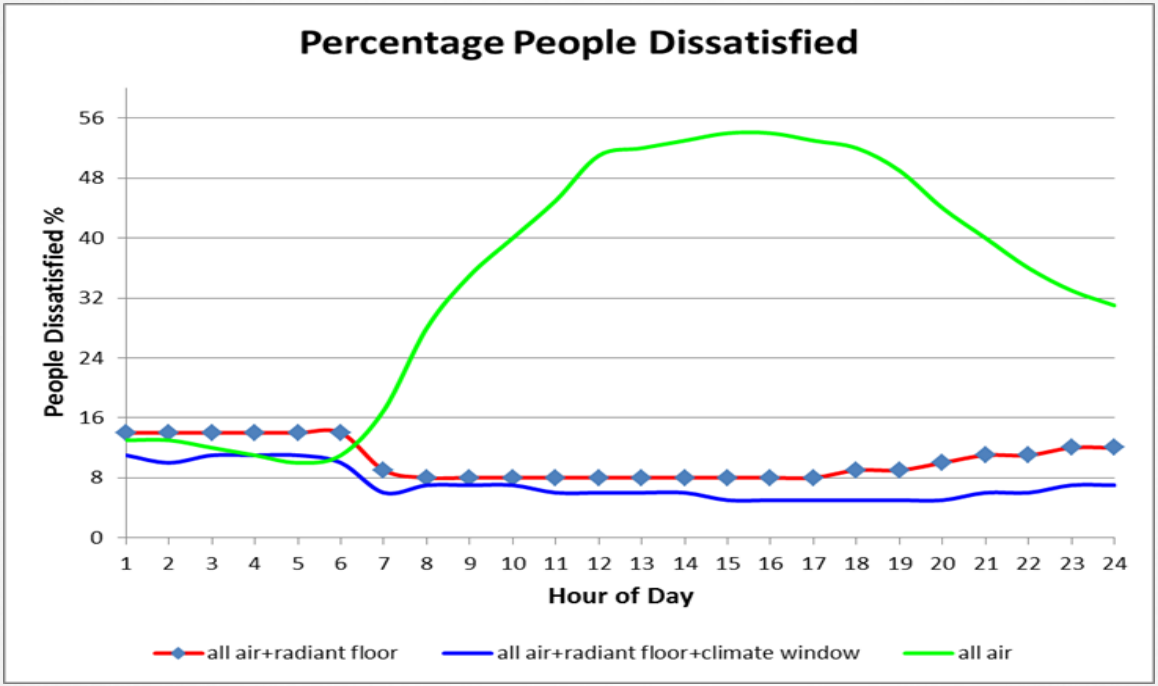
- A vertical closed-loop ground heat exchanger is used for radiant floor heating and cooling systems.
  A displacement ventilation system is connected to a cool tube system installed in a underground pathway.
  The radiant floor systems and the displacement ventilation system are designed to maintain a constant level of thermal comfort in the occupied zone.



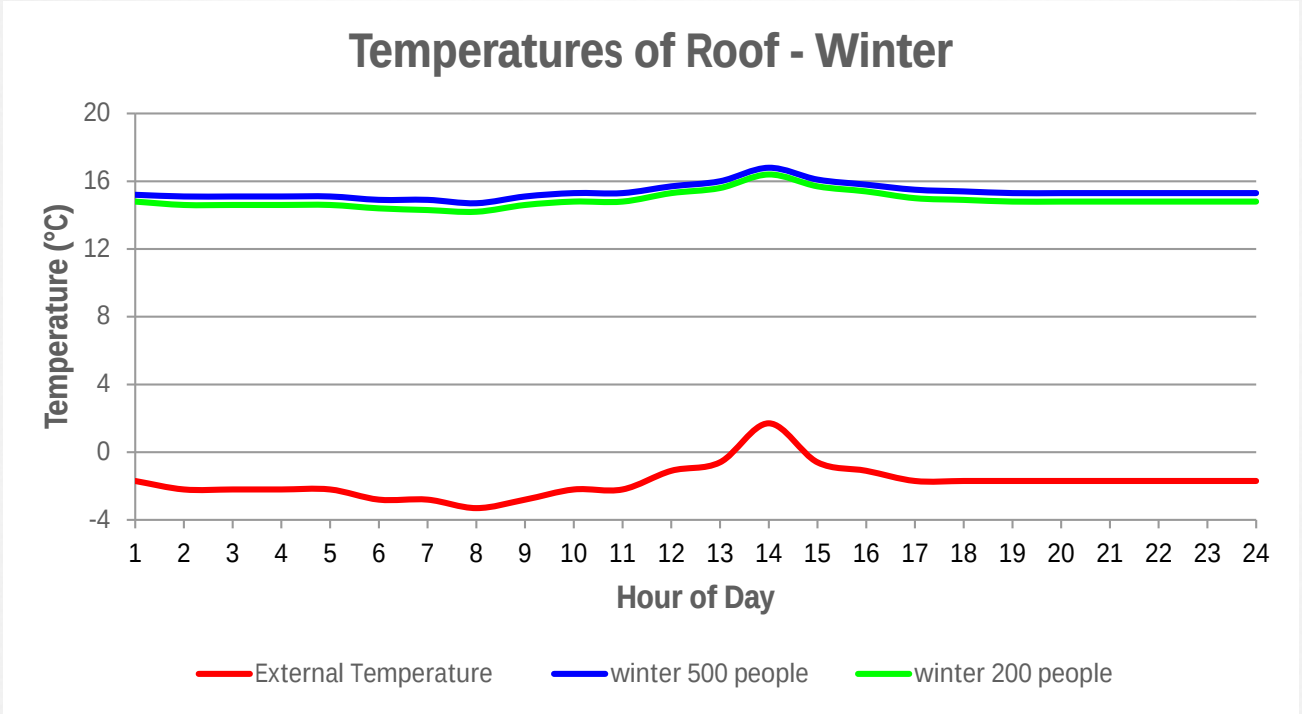
Roof Performance- Summer



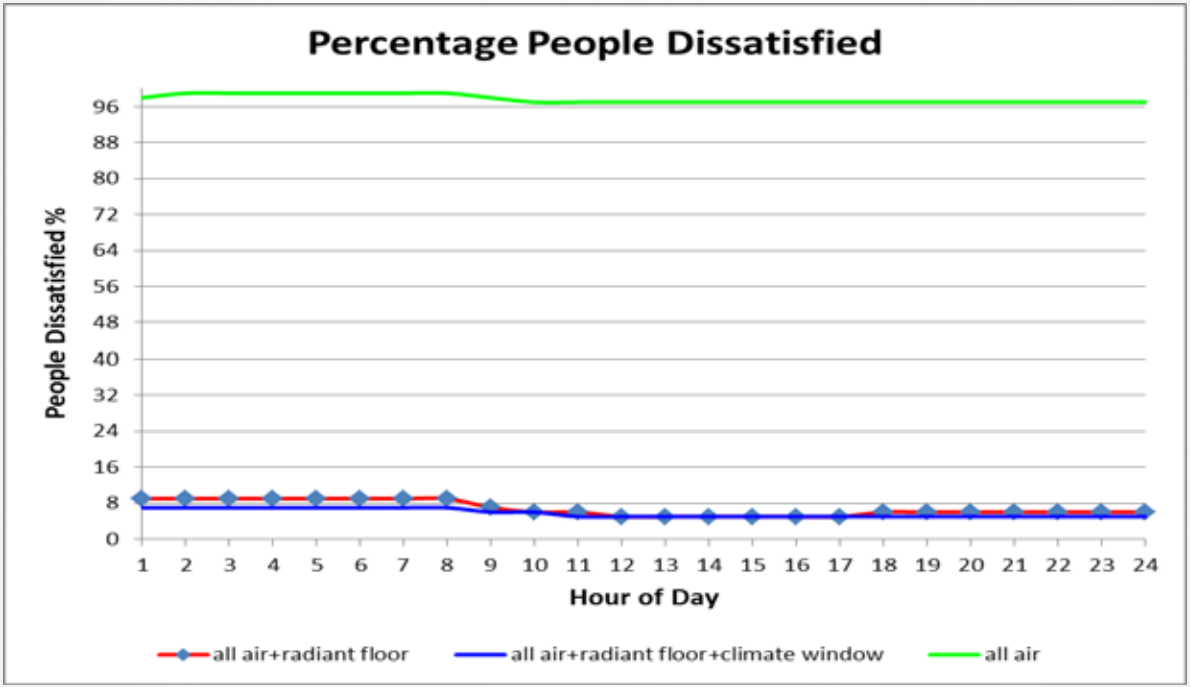
Occupant Comfort - Summer



Roof Performance- Winter



Occupant Comfort - Winter



Two Tabor Tower, Denver

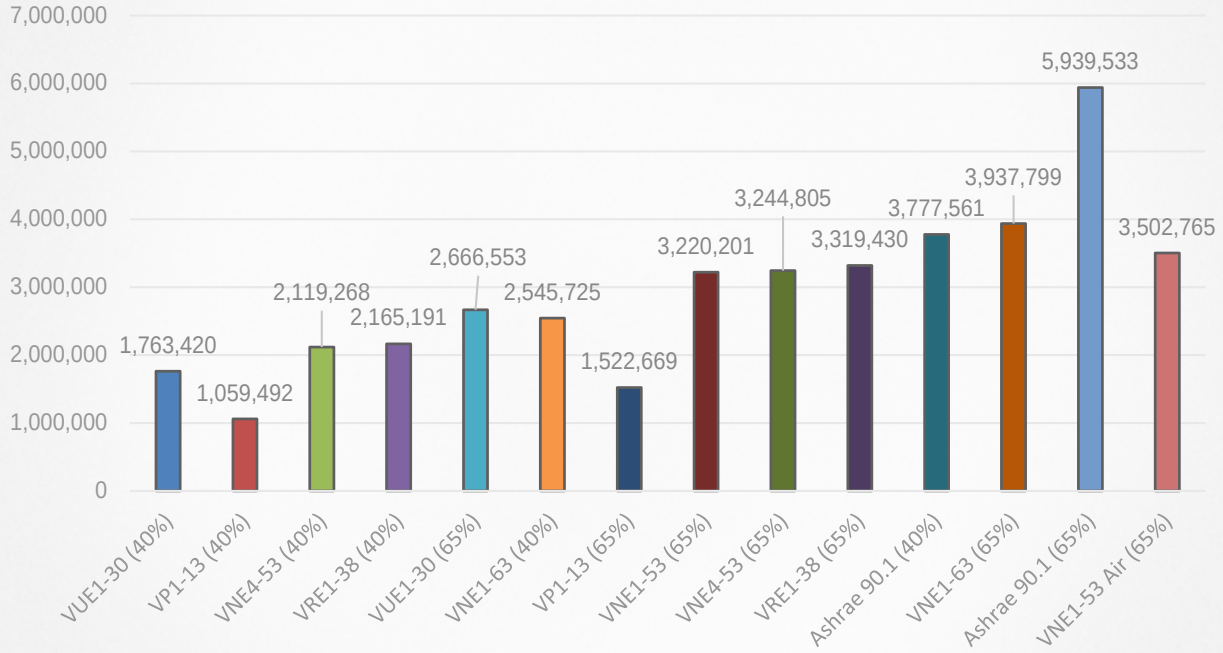
Two Tabor Tower, Denver

- The new 30 to 33-story Two Tabor Center has been designed with a focus on providing tenants a productive and healthy work environment that is employee-centric and provides easy access to the many amenities of Tabor Center and the 16th Street Mall.
- Two Tabor Center will add approximately 637,000 to 692,000 rentable square feet of class AA office space to Tabor Center, creating one of the largest office complexes in Denver with over 1,217,000 rentable square feet of office space. Retail space occupies the ground level of Two Tabor Center along 17 St. and Larimer Street. Entrances to a 1,700-space underground parking garage.

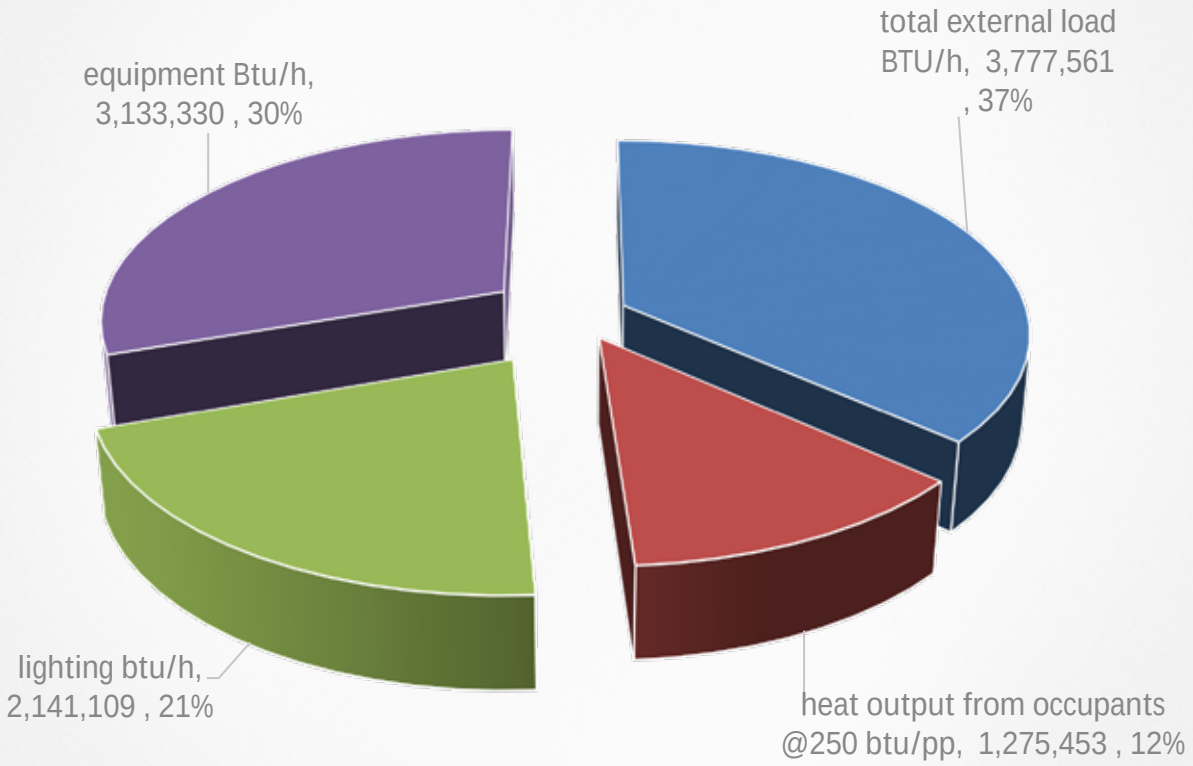
Comparison of glass types

	Cavity	floor area	Solar Radiation (btu/h)	Transmission (btu/h)	total	Envelope load per SF floor area (Btuh/sf)
VUE1-30 (40%)	Air(10%)/Argon (90%)	765,272	1,133,853	629,567	1,763,420	2.30
VNE4-53 (40%)	Air(10%)/Argon (90%)	765,272	1,496,149	623,118	2,119,268	2.77
VRE1-38 (40%)	Air(10%)/Argon (90%)	765,272	1,516,277	648,914	2,165,191	2.83
VP1-13 (40%)	Air(10%)/Argon (90%)	765,272	1,328,420	1,059,492	2,387,911	3.12
VNE1-63 (40%)	Air(10%)/Argon (90%)	765,272	1,905,410	640,315	2,545,725	3.33
VUE1-30 (65%)	Air(10%)/Argon (90%)	765,272	1,842,511	824,042	2,666,553	3.48
VNE1-53 (65%)	Air(10%)/Argon (90%)	765,272	2,431,243	788,959	3,220,201	4.21
VNE4-53 (65%)	Air(10%)/Argon (90%)	765,272	2,431,243	813,563	3,244,805	4.24
VRE1-38 (65%)	Air(10%)/Argon (90%)	765,272	2,463,950	855,480	3,319,430	4.34
VP1-13 (65%)	Air(10%)/Argon (90%)	765,272	2,158,682	1,522,669	3,681,351	4.81
ASHRAE 90.1 (40%)	Air(10%)/Argon (90%)	765,272	2,683,676	1,093,886	3,777,561	4.94
VNE1-63 (65%)	Air(10%)/Argon (90%)	765,272	3,096,291	841,508	3,937,799	5.15
ASHRAE 90.1 (65%)		765,272	4,360,973	1,578,560	5,939,533	7.76
VNE1-53 Air (65%)	Air (100%)	765,272	2,507,560	995,206	3,502,765	4.58

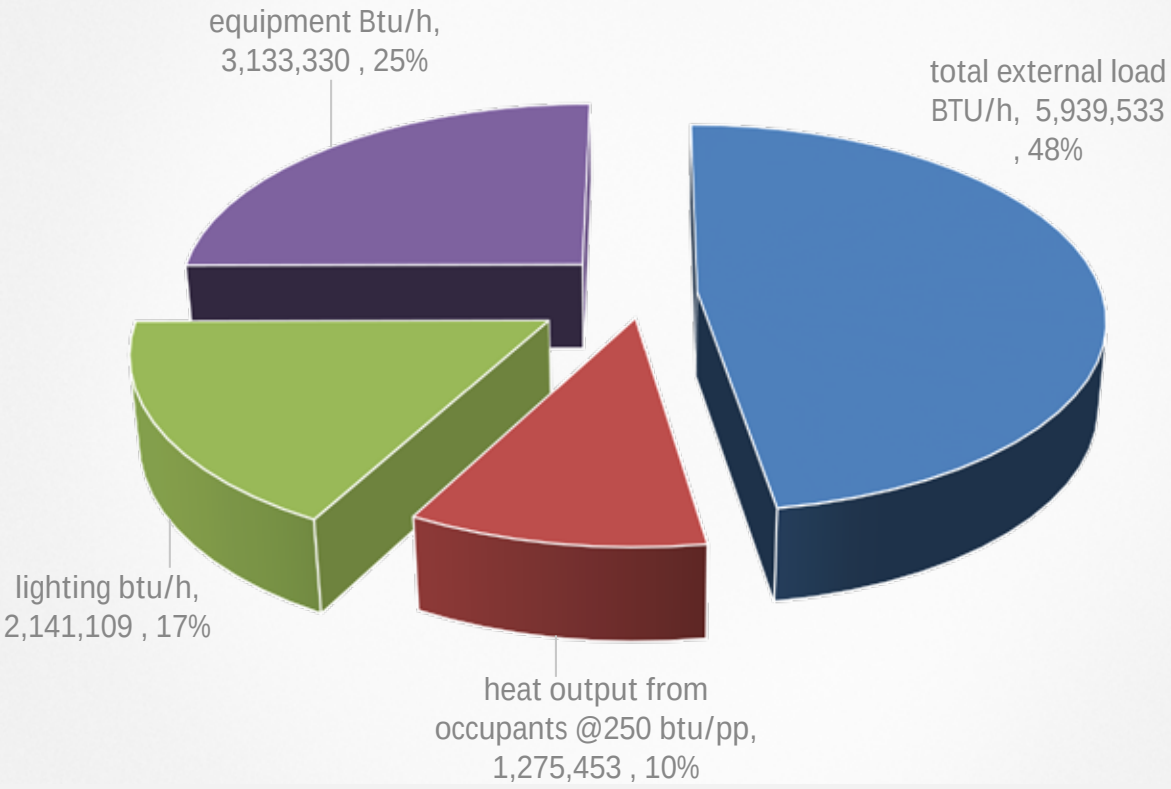
External Load (btu/h)



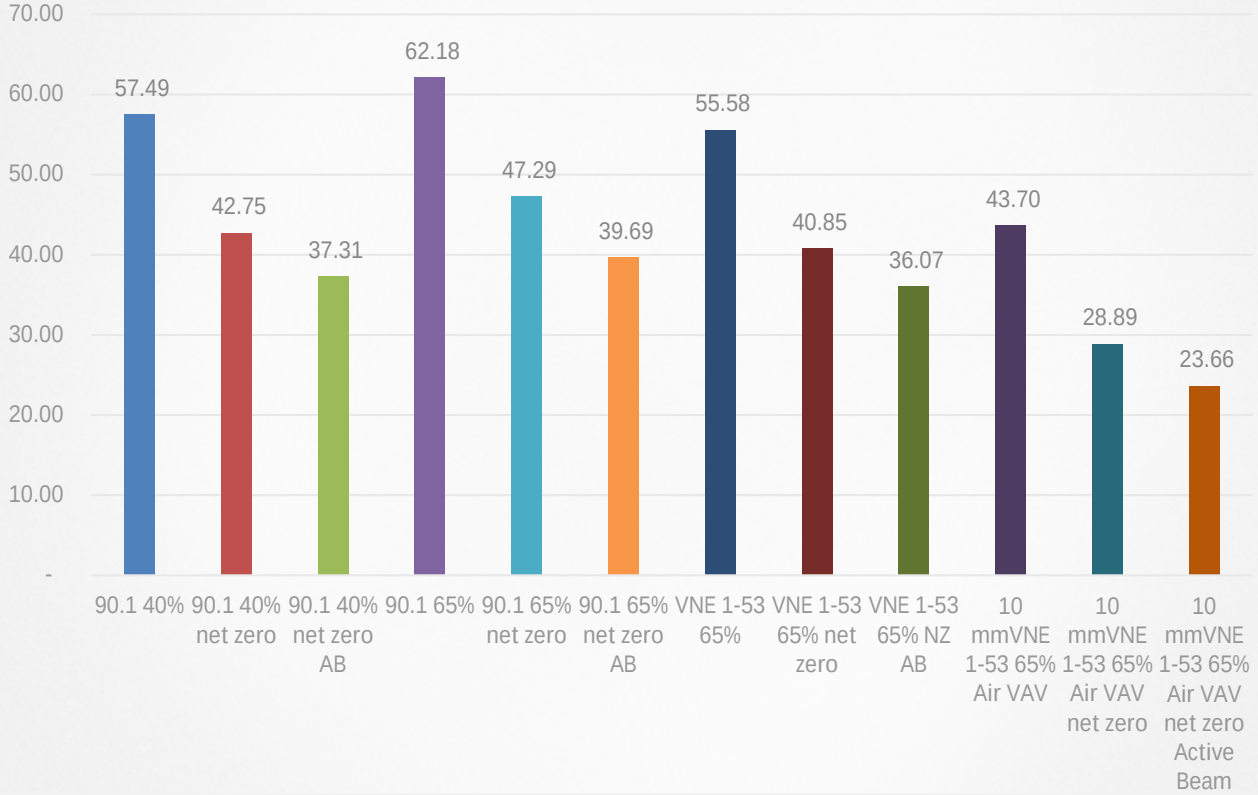
90.1 40% glass



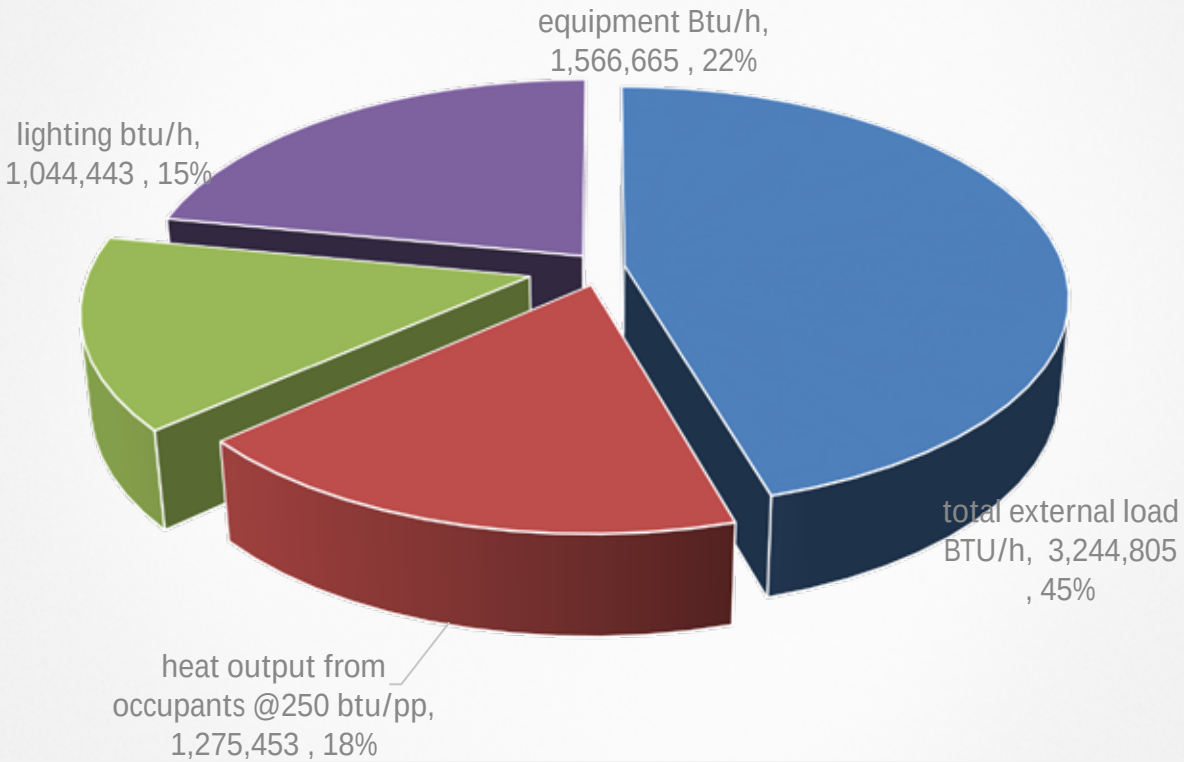
90.1 65% glass



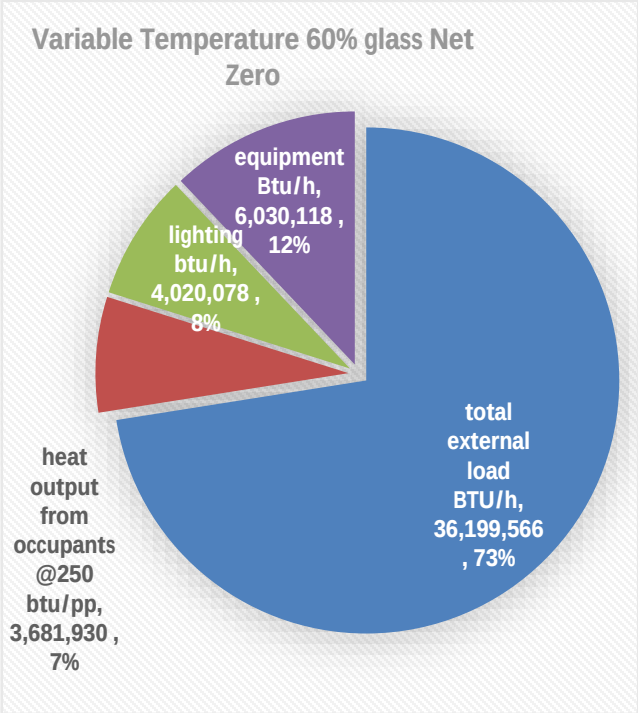
EUI (kBtu/ft2)

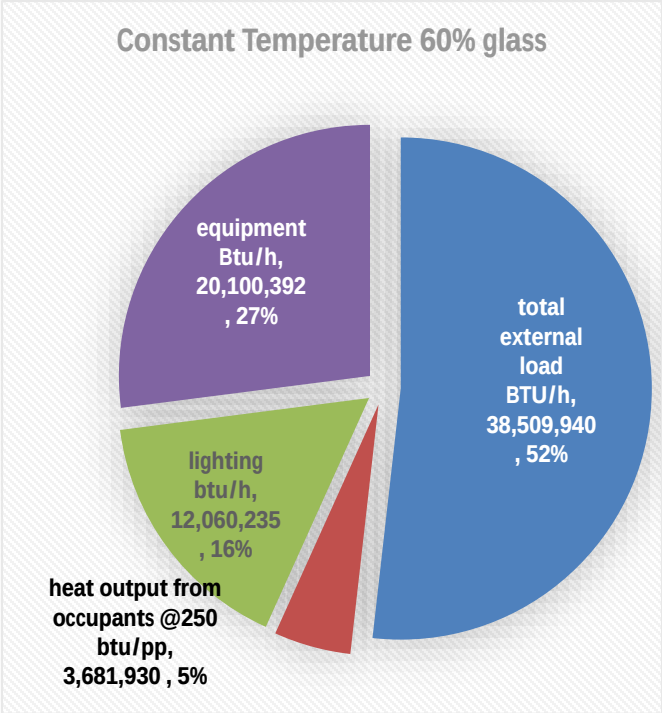


Summer 65% glazing Net Zero



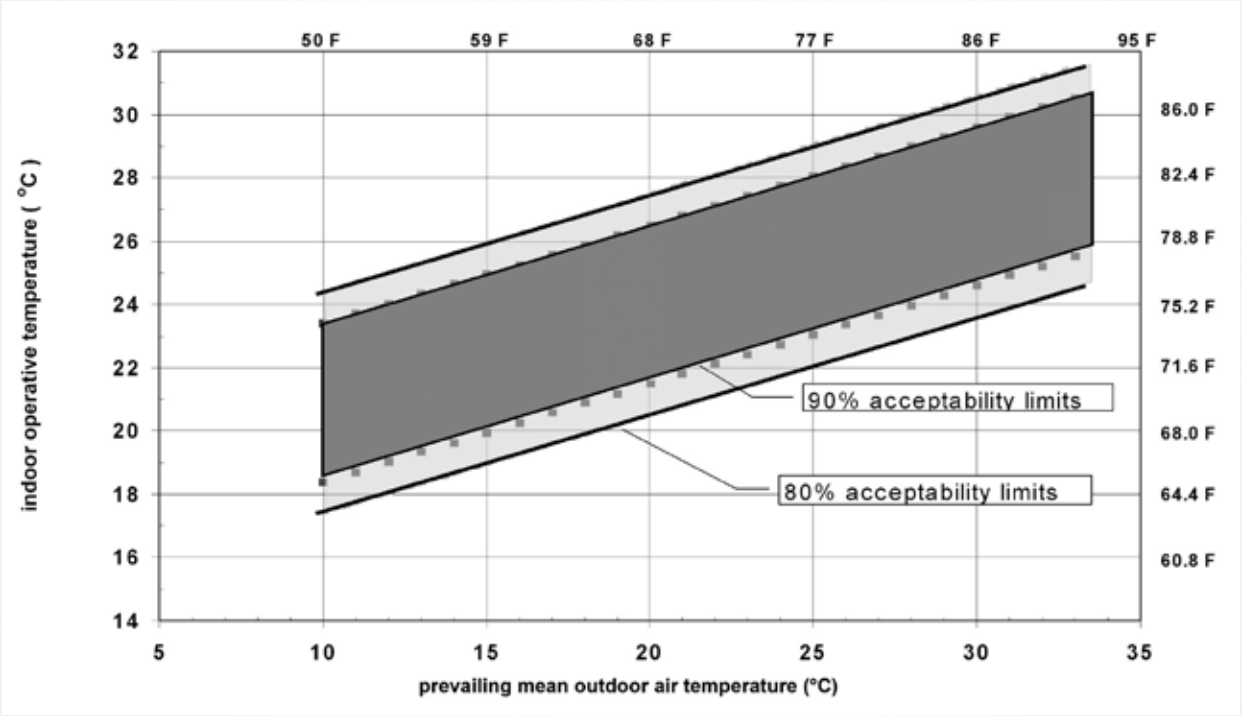
Comparison of Building Loads – Design Results





Wilshire/Gayley Residential

Acceptable Operative Temperature (to) Ranges for Naturally Conditioned Spaces



Exponentially weighted running mean temperature

$$T_{rm} = (1-a).\{T_{od-1} + a.T_{od-2} + a^2 T_{od-3} \ldots..\}$$

$$T_{rm}^{n} = (1-a).T_{od}^{n-1} + a.T_{rm}^{n-1}$$

a is a constant ($a < 1$),

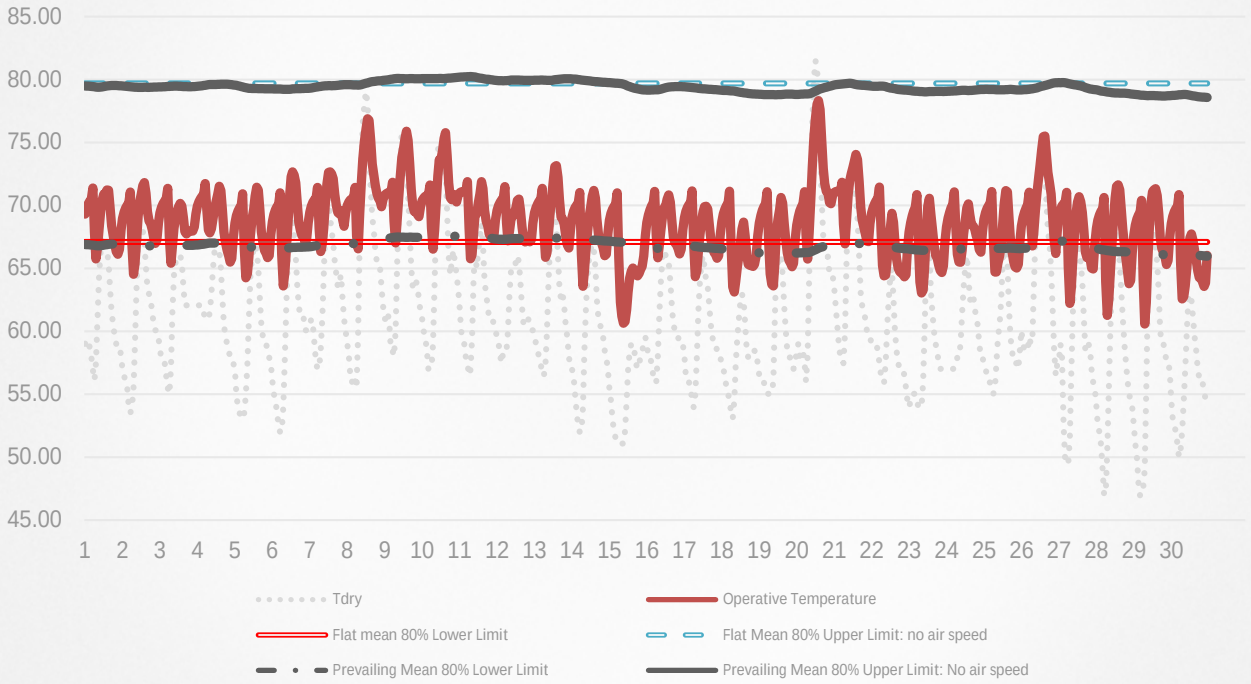
T_{rm} Running mean temperature

Trm^{n} is Trm on day n

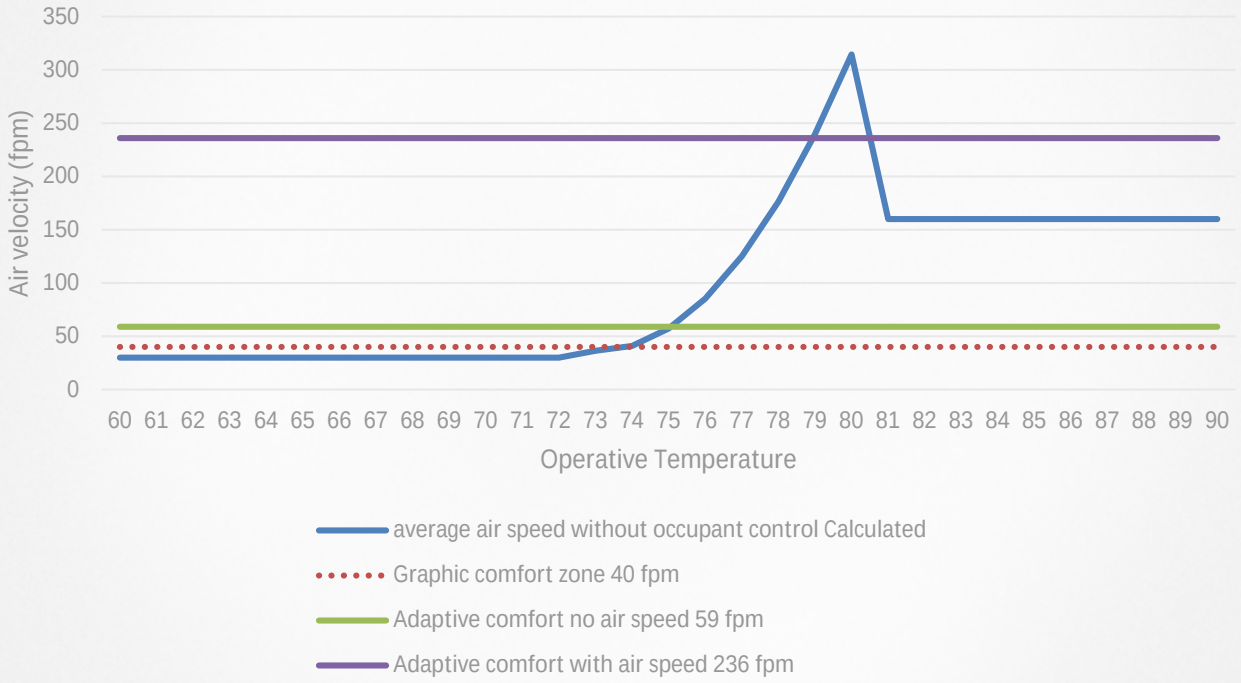
In this database TrmX = Trm for a = X/100

T_{od} Daily mean temperature

ASHRAE 55 Adaptive Comfort Comparison of Indoor Operative Temperature to Flat Mean and Prevailing Mean Criteria: Wilshire-Gayley, November, alpha = 0.7 for prevailing mean



comparison of maximum air velocities

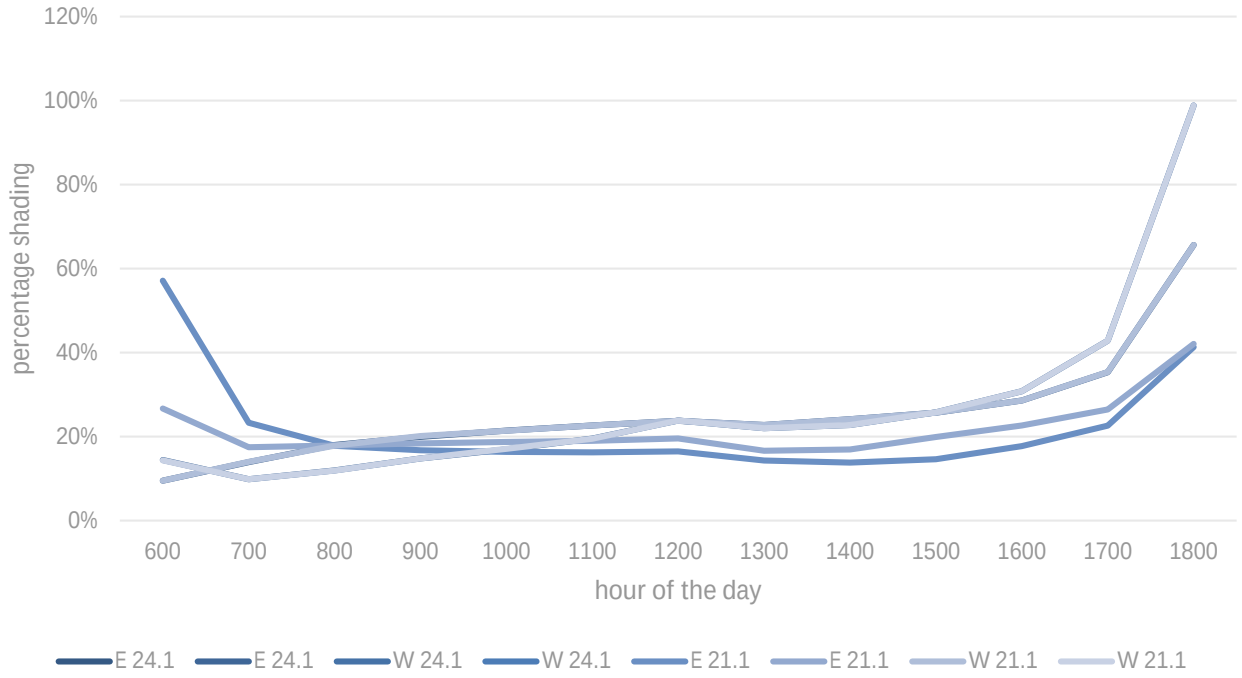


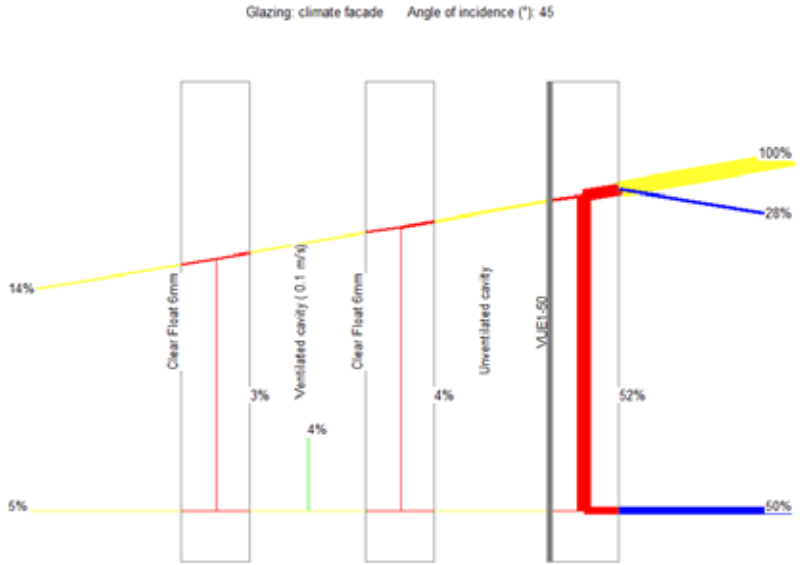
comparison of maximum air velocities

- For operative temperatures (t_o) above 25.5°C (77.9°F), the upper limit to average air speed (V_a) should be 0.8 m/s (160 fpm).
- For operative temperatures (t_o) below 22.5°C (72.5°F), the limit to average air speed (V_a) should be 0.15 m/s (30 fpm).
- For operative temperatures (t_o) between 22.5°C and 25.5°C (72.5°F and 77.9°F), the upper limit to average air speed (V_a) it is acceptable to approximate the curve in I-P and SI units by the following equation:
- $V_a = 50.49 – 4.4047\ t_o + 0.096425(t_o)^2$ (m/s, °C)
- $V_a = 31375.7 – 857.295\ t_o + 5.86288(t_o)^2$ (fpm, °F)

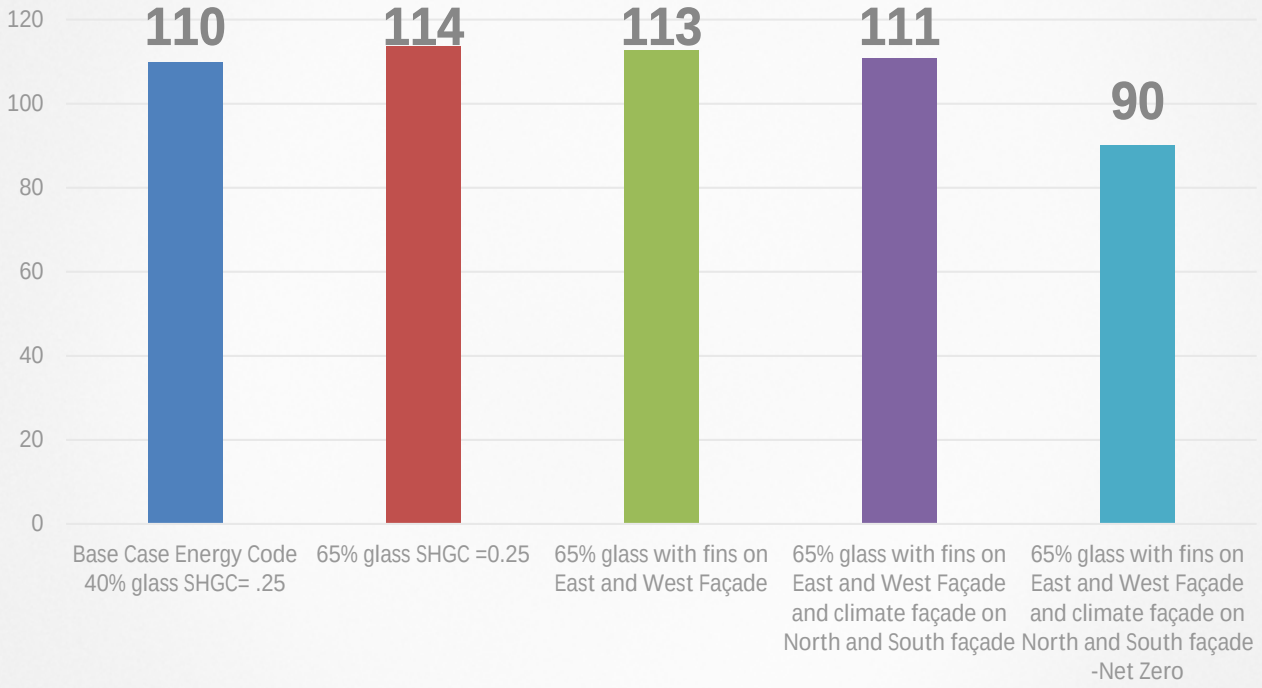
GuoXing Avenue Mixed Use
Haikou, Hainan, Chir

% shading through fins

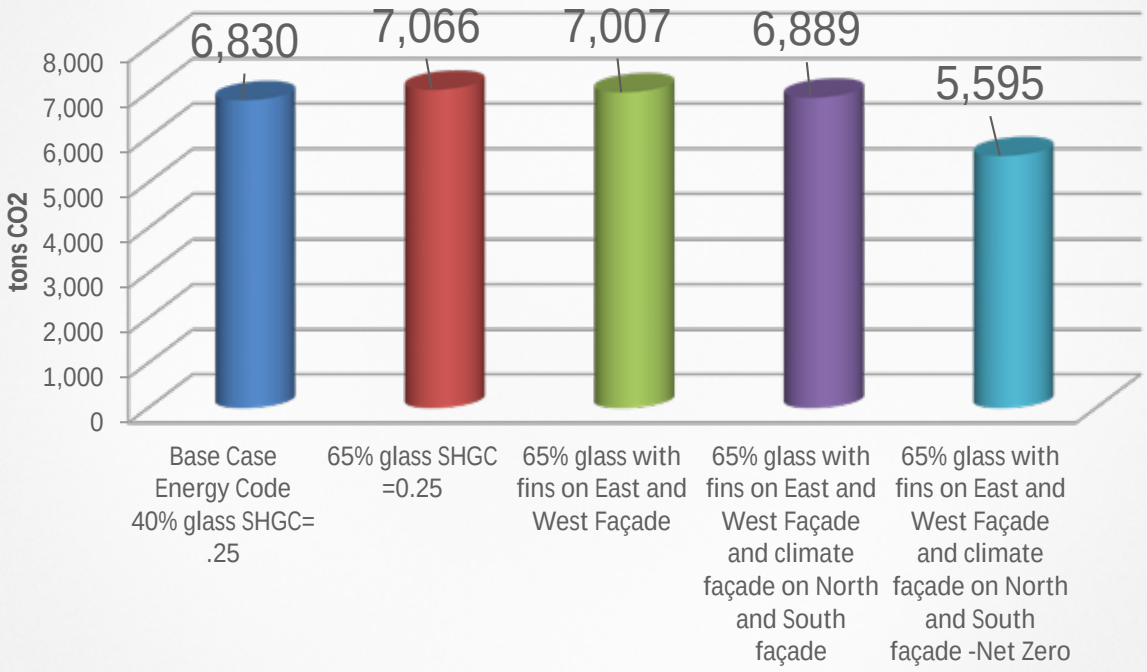



Glazing: climate facade
Angle of incidence (°): 45
14%
5%
Clear Float 6mm
3%
Ventilated cavity (0.1 m/s)
4%
Clear Float 6mm
4%
Unventilated cavity
VUEL50
52%
100%
28%
50%

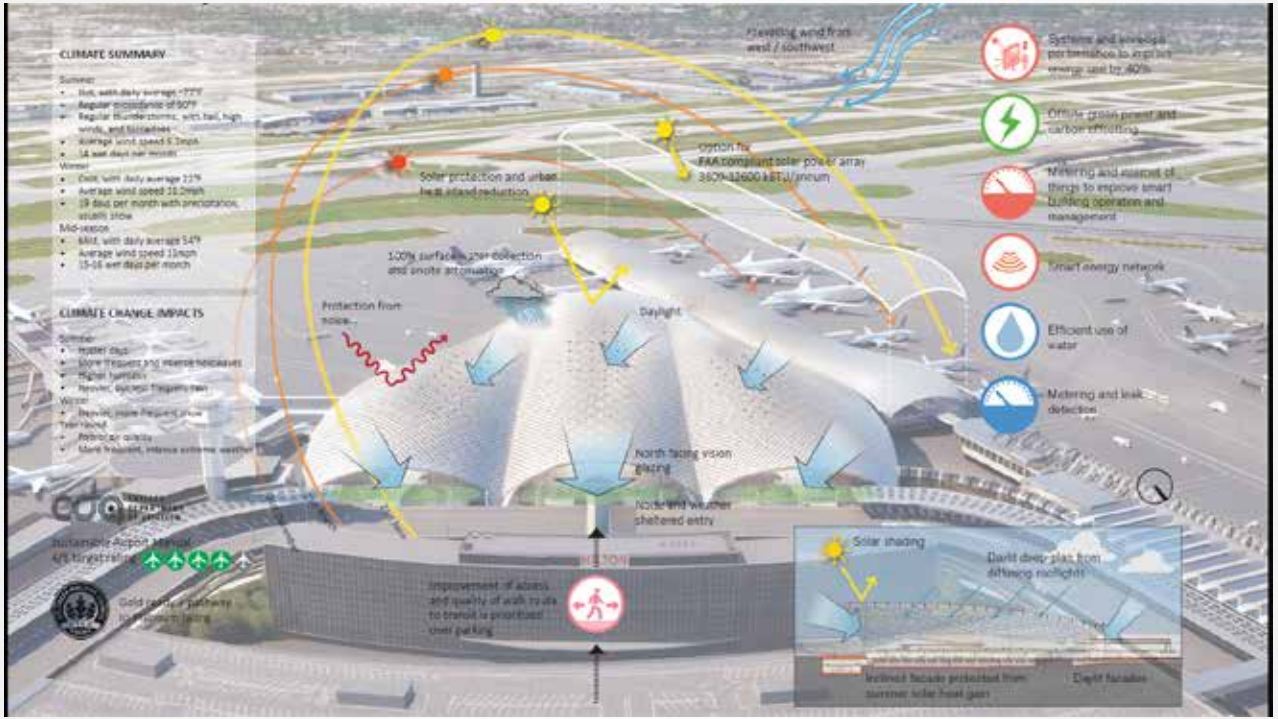
Comparison of EUI (kWh/m2)



CO2 Emissions

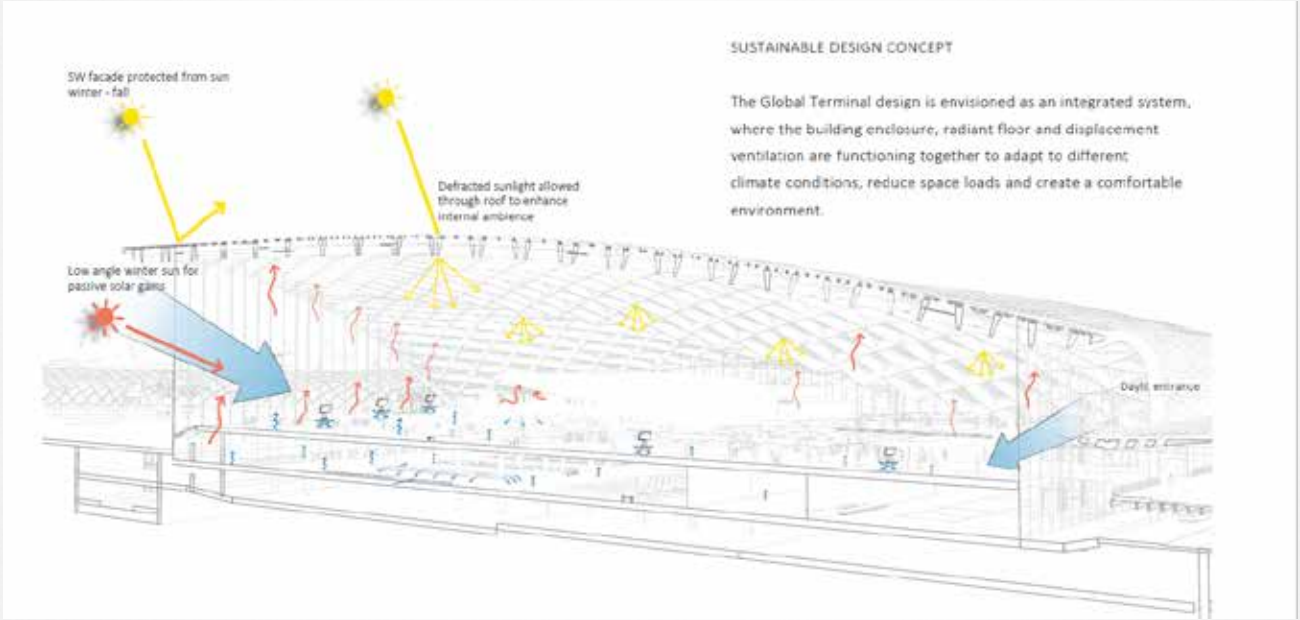


O’Hare Airport Expansion



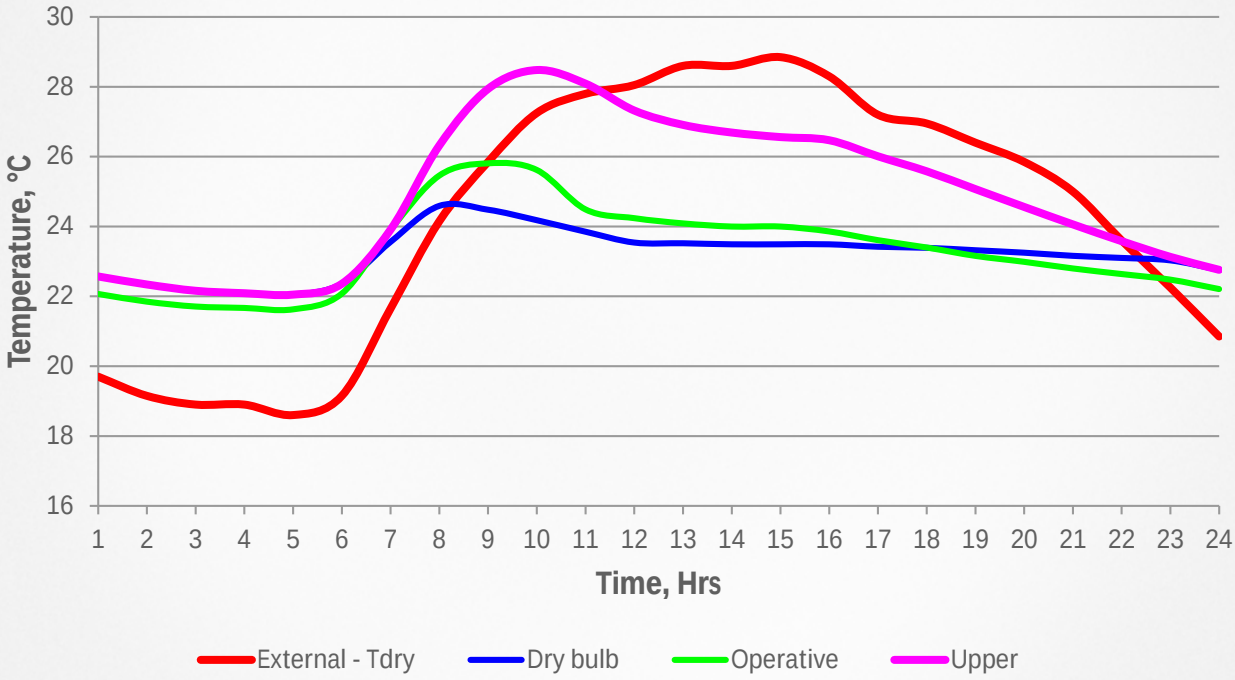
O’Hare Airport Expansion

O’Hare Airport Expansion

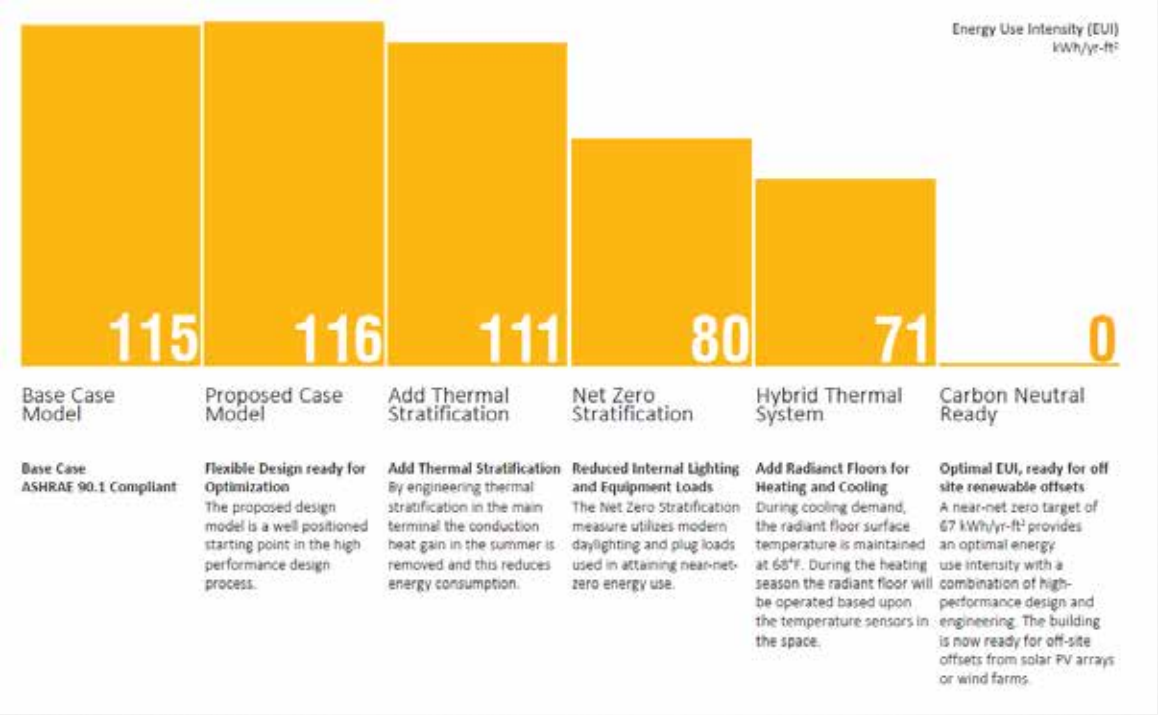


O’Hare Airport Expansion

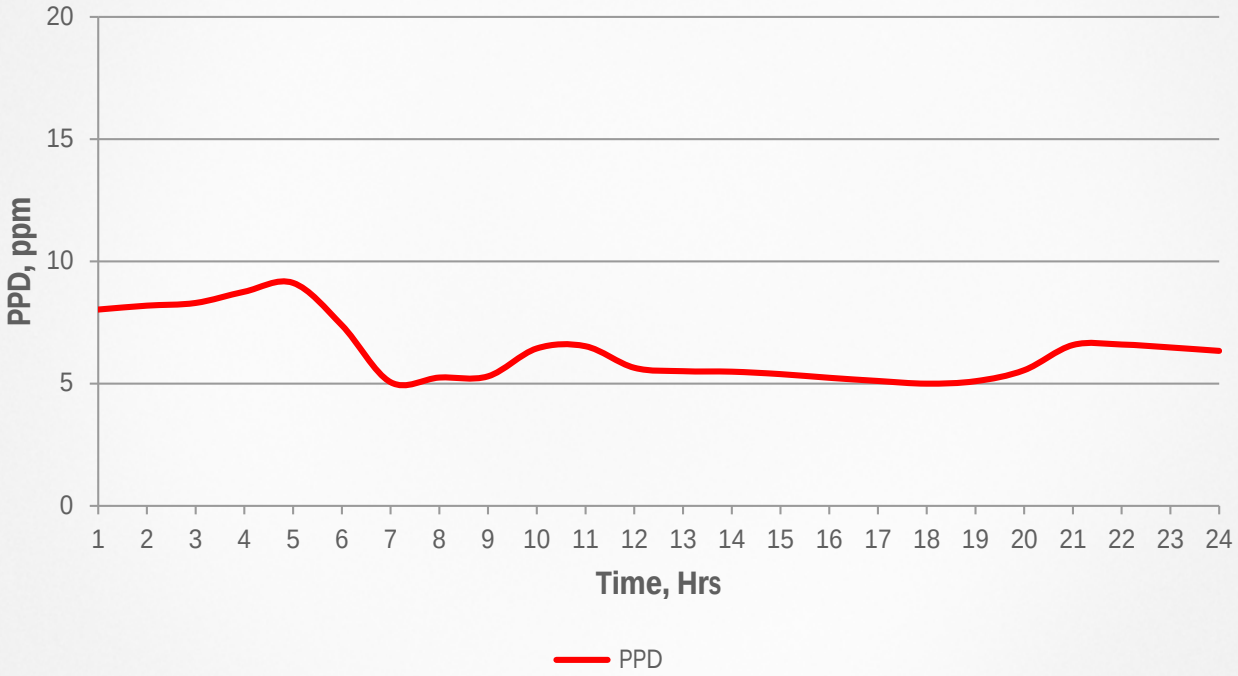
Stratified Conditions for 22nd JULY



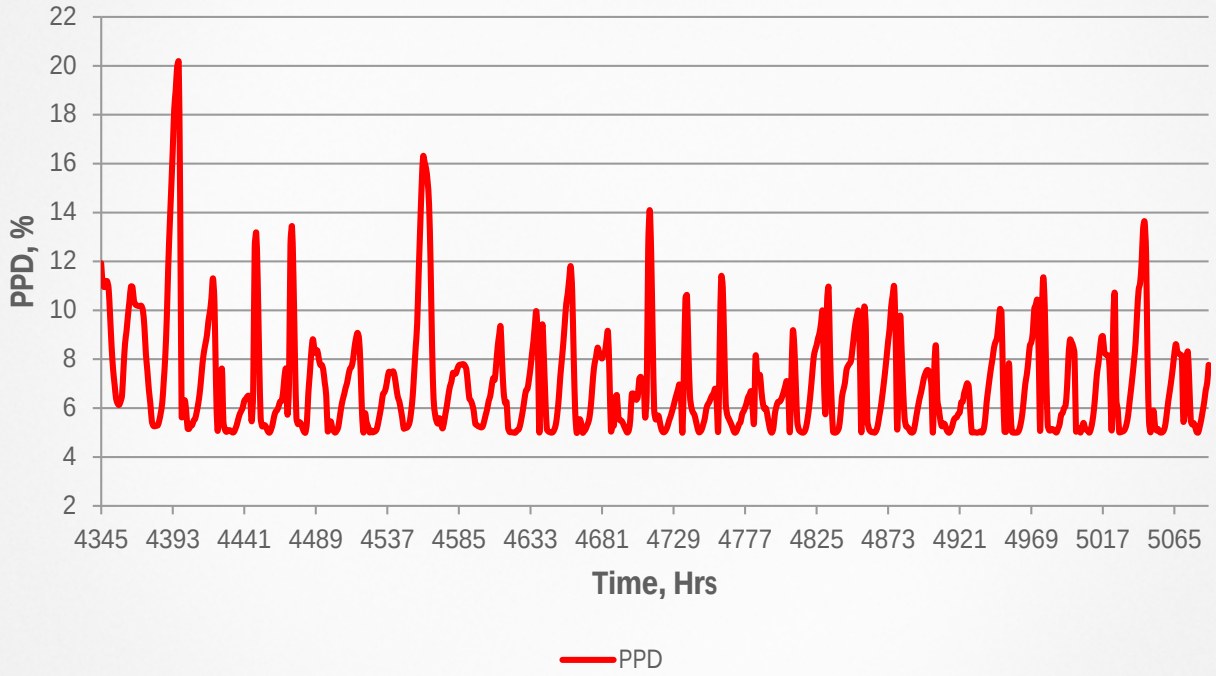
Energy Use Intensity (EUI) kBtu/h.ft2



PPD for a summers day in the Concourse



PPD for 1st to the 31st JULY - Concourse



1766-RP
Development of a Unified Tool for Analysis of Room Loads and Conditions

Principal Investigators:
Chip Barnaby
Peter Simmonds

January 27, 2017
Las Vegas

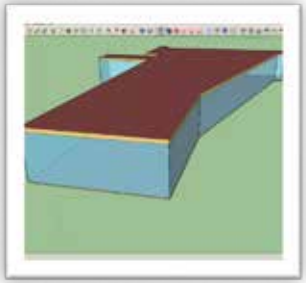
Goal

To integrate software previously developed by several ASHRAE research projects to create a single application that includes all of the necessary algorithms for calculating space heat balance and radiant energy exchange.

This application is provisionally named RPEHB and will be created by combining RPE (from 1383-RP) and the heat balance room model (originating in 987-RP and enhanced by 1199-RP and 1311-RP).

The Process in Practice

SketchUp

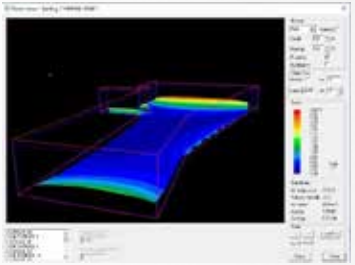


SketchUp takes the geometry and converts this into a building model that can be read by OpenStudio

OpenStudio

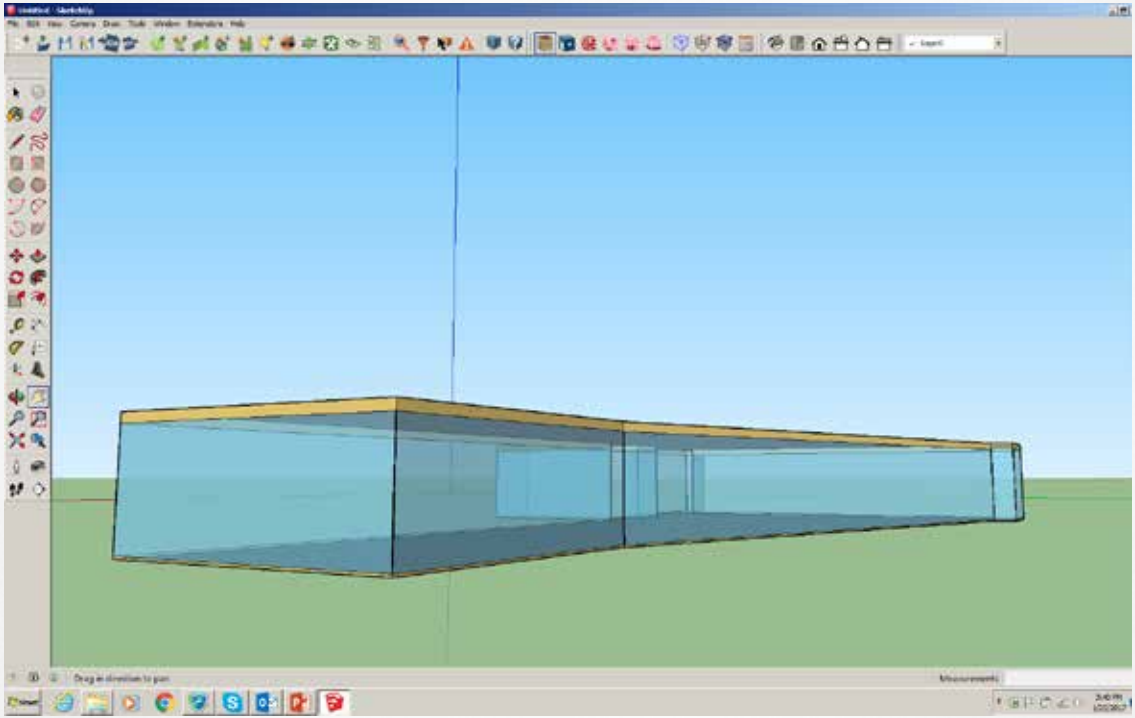
OpenStudio builds the simulation model with constructions, schedules, design weather, …

RPEHB

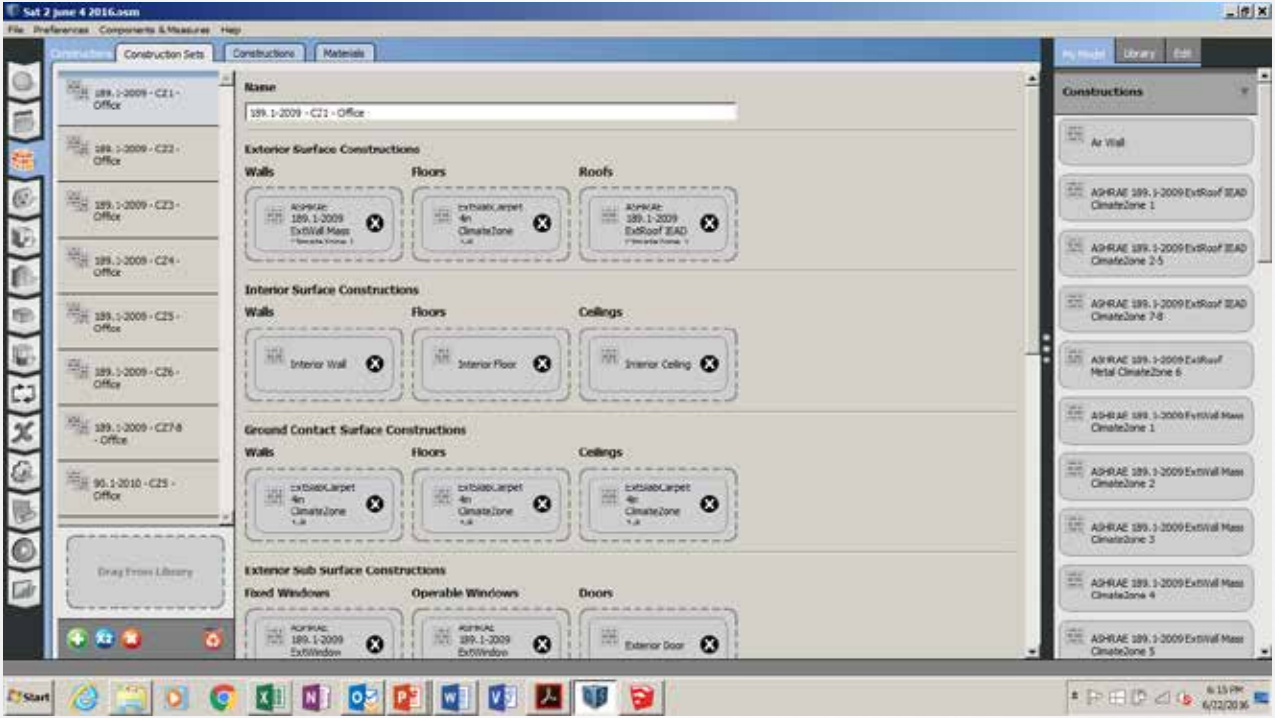


Visualization of simulation results that evaluate space conditions with and without radiant systems

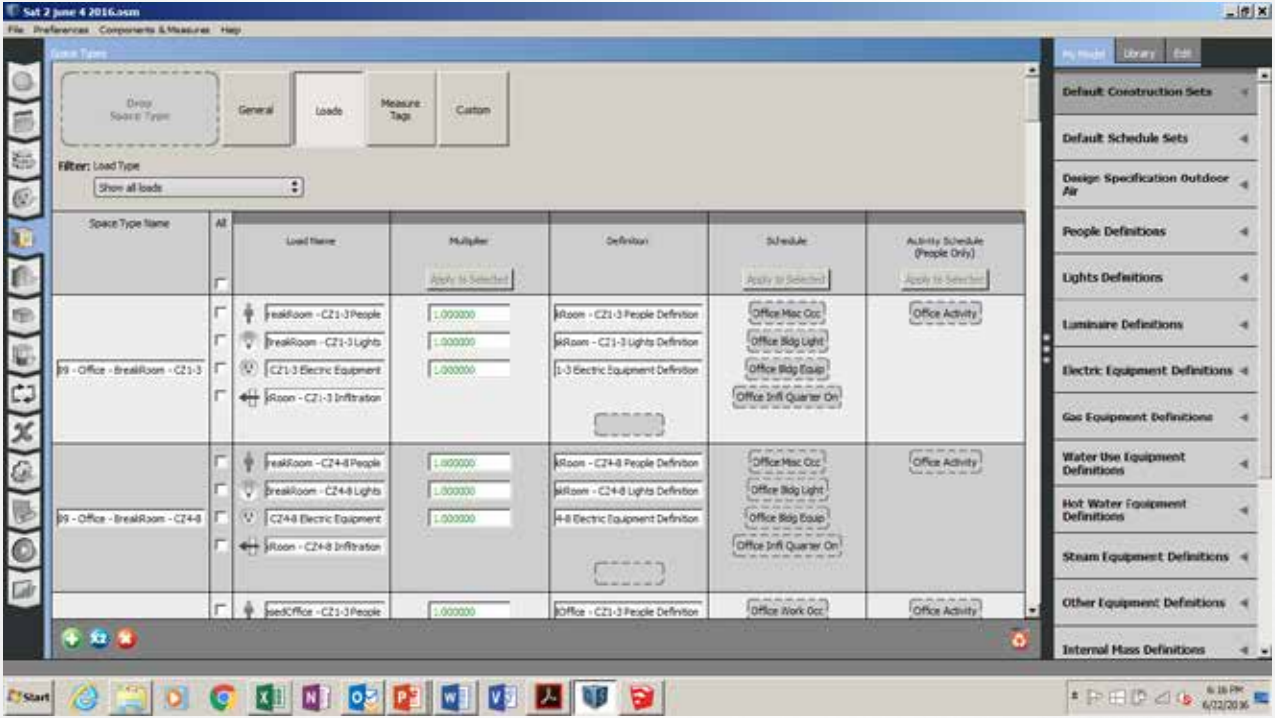
SketchUp



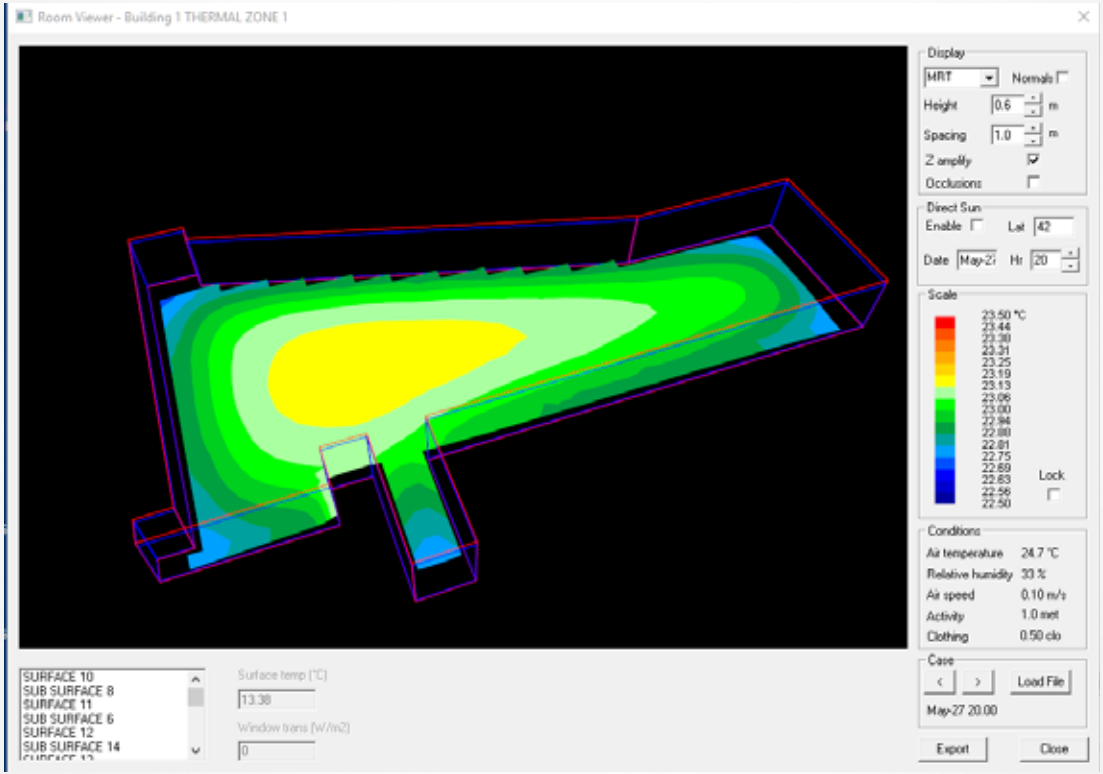
OpenStudio - constructions



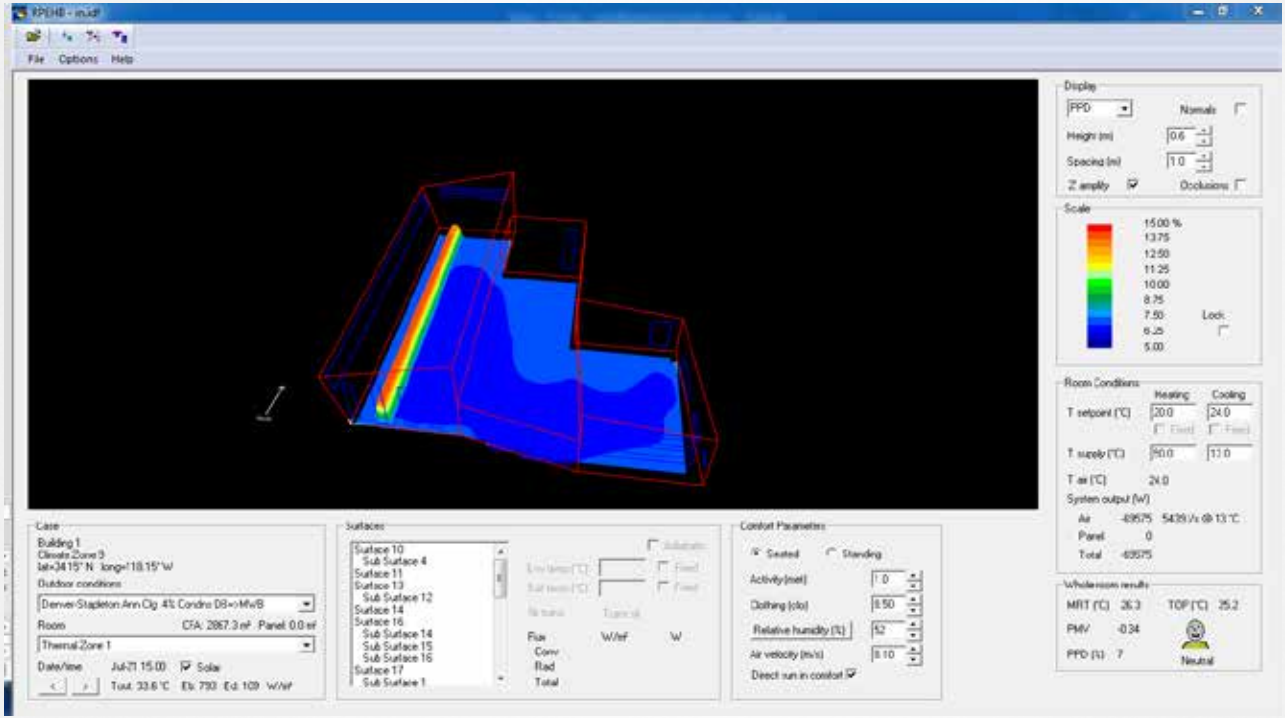
OpenStudio – room loads



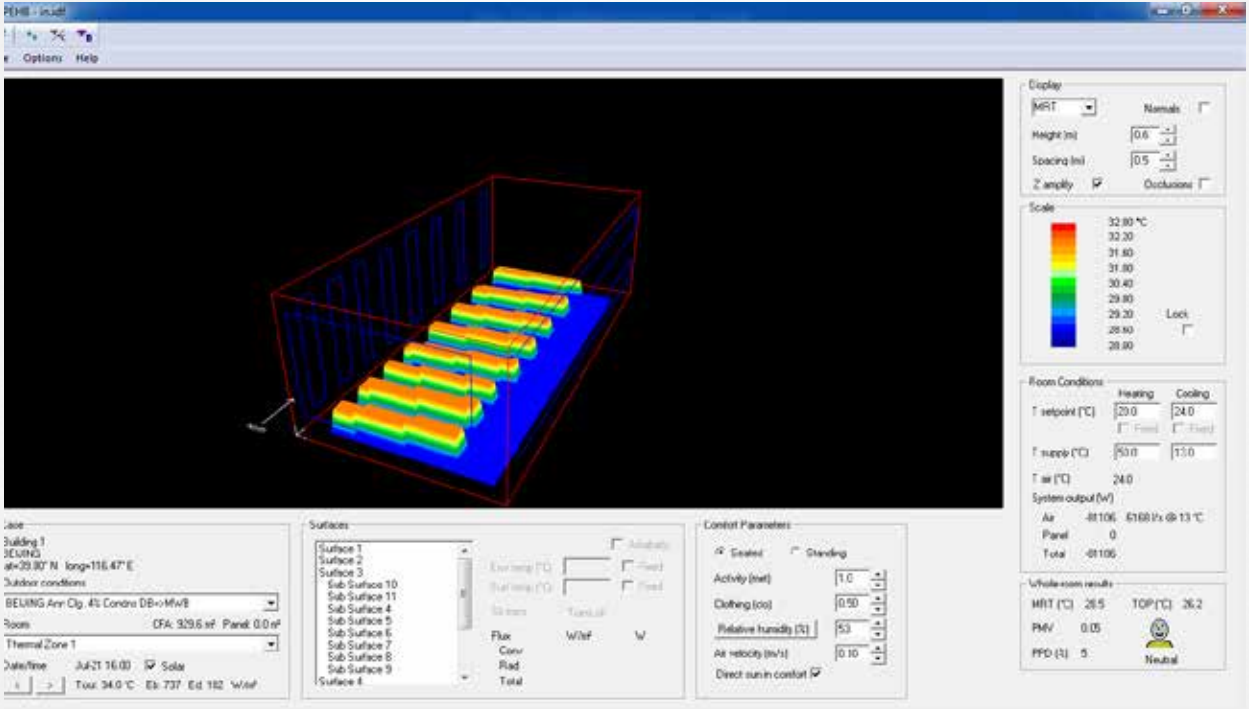
RPEHB – Import and Display



Explore Results ...



MRT



Can Current Zone Selections Provide Occupant Comfort?

BY PETER SIMMONDS, FELLOW ASHRAE; TOM HARTMAN, LIFE MEMBER ASHRAE

For HVAC system design, office buildings are typically divided into local thermal zones made up of multiple occupied spaces (*Figure 1*). Thermal zones are areas of the occupied building selected by the designer in which it is believed uniform thermal conditions can be maintained throughout with the means of local thermal distribution and control employed. The number and size of zones are based on several criteria, but designers typically employ rules of thumb in selecting and laying out thermal zones.

In an office building with similar internal loads throughout, such rules usually require a minimum of one zone for each of the perimeter exposures on each floor, a maximum number of separate spaces

ceiling or radiant floor that is individually controlled for that area."

Determining whether a zone configuration can achieve acceptable comfort for its occupants requires

Thank you

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