BIG ASS SOLUTIONS

Air Movement for Energy-Efficient Comfort in Conditioned Spaces

BIG ASS FANS

必愛風有限公司

Andy Chou

Managing Director – East Asia

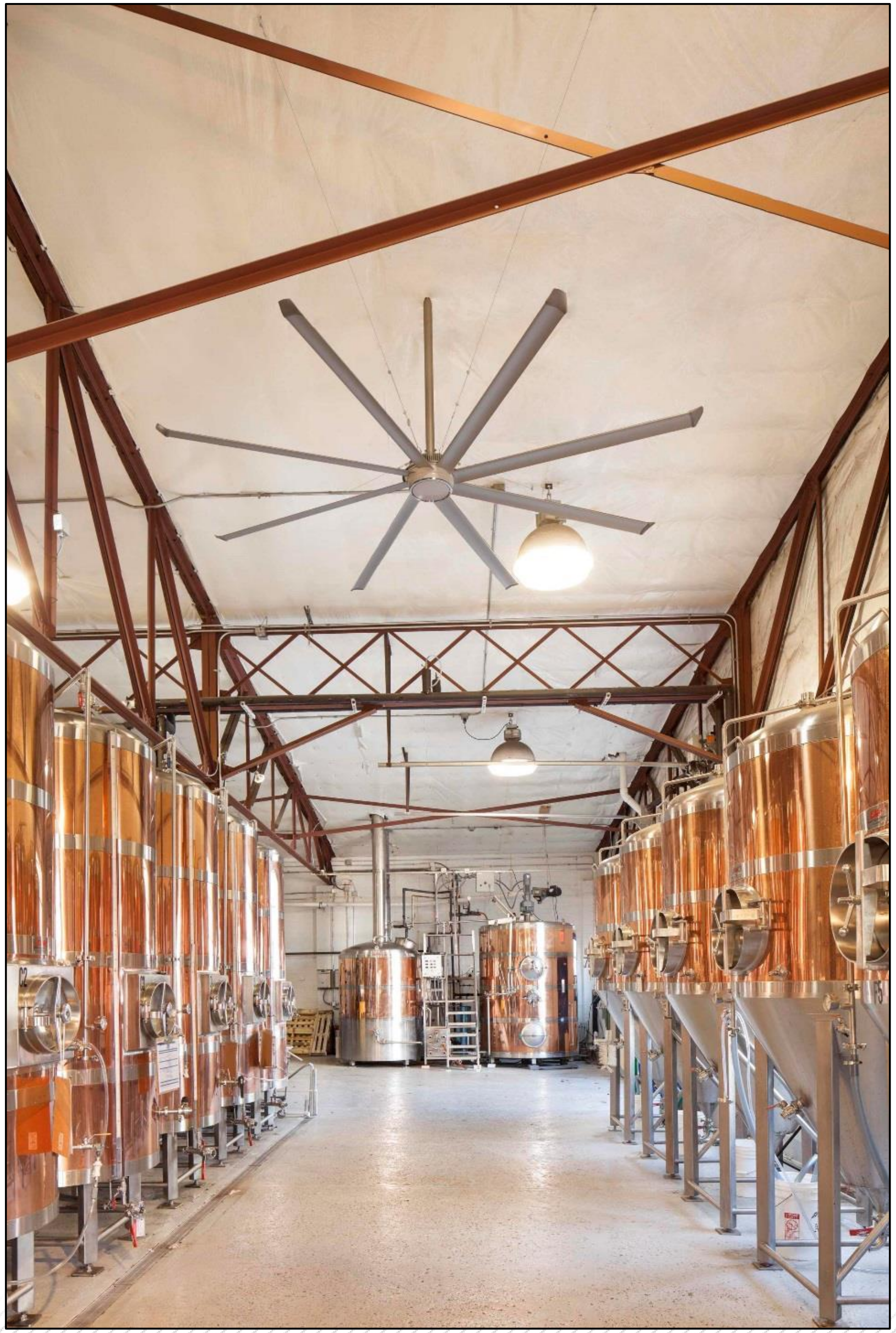
必愛風有限公司

Matt Chan

AE specialist – East Asia
matt.chan@bigassfans.hk
+852 2710 5324

Big Ass Fans provides Continuing Professional Development in collaboration with the agencies listed.

Course Credit: **1 CPD hour**



Blue Stallion Brewing

Course Description

As we move increasingly towards market viable net-zero buildings with initiatives like the Hong Kong Environmental Bureau’s *Energy Saving Plan for Hong Kong's Built Environment*, we must reevaluate the role that typical building components play in a facility’s energy efficiency.

ASHRAE 55 has highlighted the impact of elevated air speed on thermal comfort, and in recent years innovative designs have reestablished air movement as an integral part of occupant comfort and energy conservation. Furthermore, recent changes to Appendix G of ASHRAE 90.1 allow the inclusion of energy savings from using elevated air speed in energy simulations.

When integrated into new building designs, air movement allows a reduction of air conditioning capacity and ductwork. In the winter, low speed air circulation redirects heated air trapped at the ceiling, resulting in significant energy savings. Project teams working on net-zero buildings have proven the effectiveness of incorporating air movement in building plans as part of an integrated design strategy.

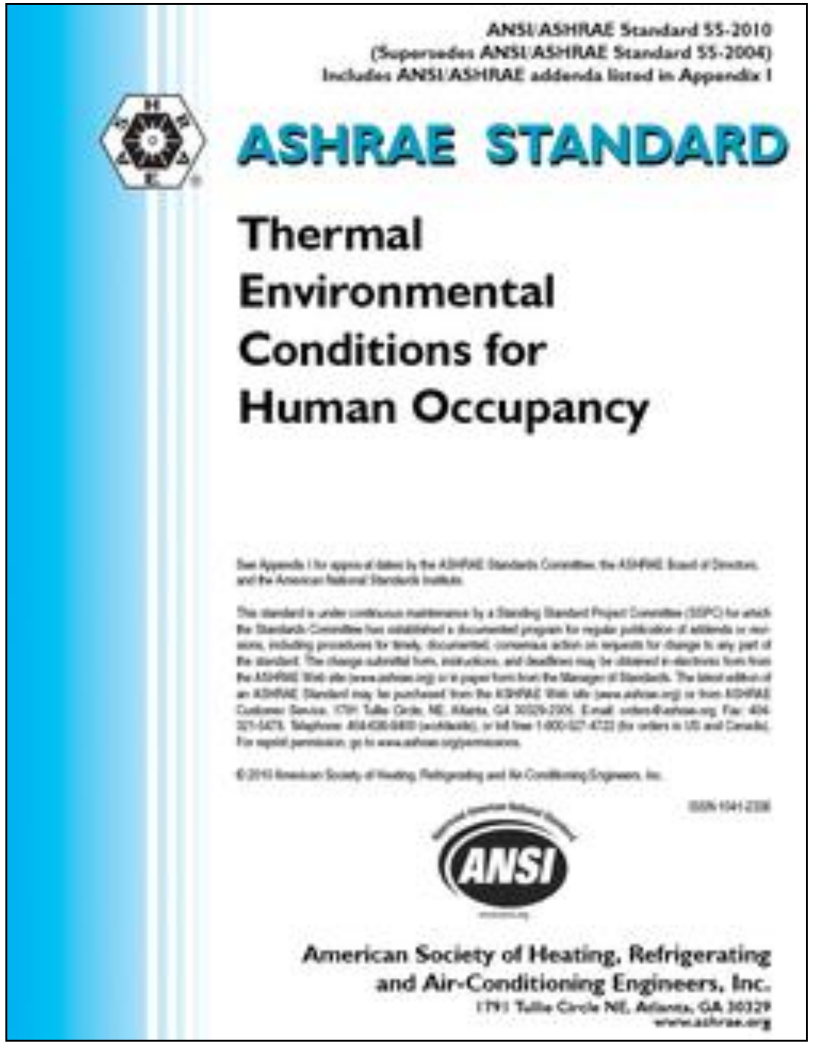
Bullitt Center Office

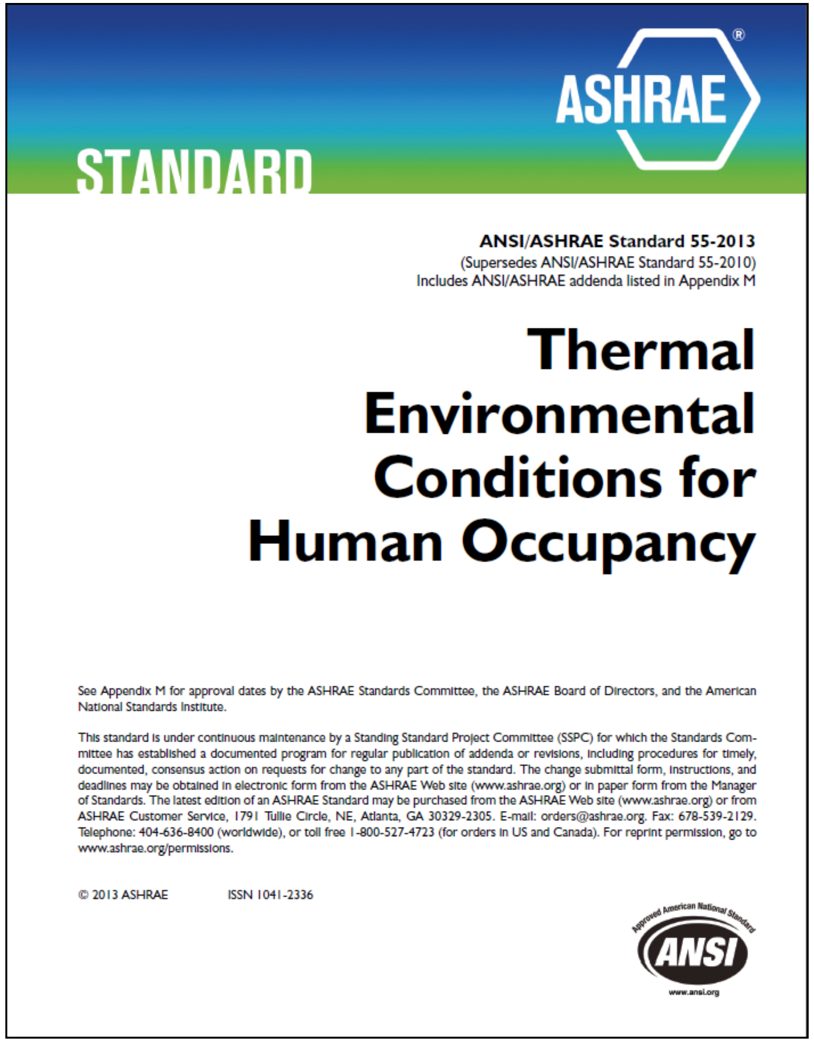
Learning Objectives

1. Identify the factors that affect thermal comfort.
2. Explain the use of elevated air speed for efficient air distribution and energy savings within air conditioned spaces.
3. Describe the additional design benefits of minimizing ductwork, lowering HVAC costs, improving ventilation rates and reducing condensation.
4. Understand stratification and the significant energy saving potential from destratification

ASHRAE 55

ASHRAE Standard 55: Thermal Comfort





Purpose of Standard 55

"Specify the combination of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants…"

Said another way:
Comfort for most

ASHRAE Standard 55-2013

Residence

What is Thermal Comfort?

Definition:
“That condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.”

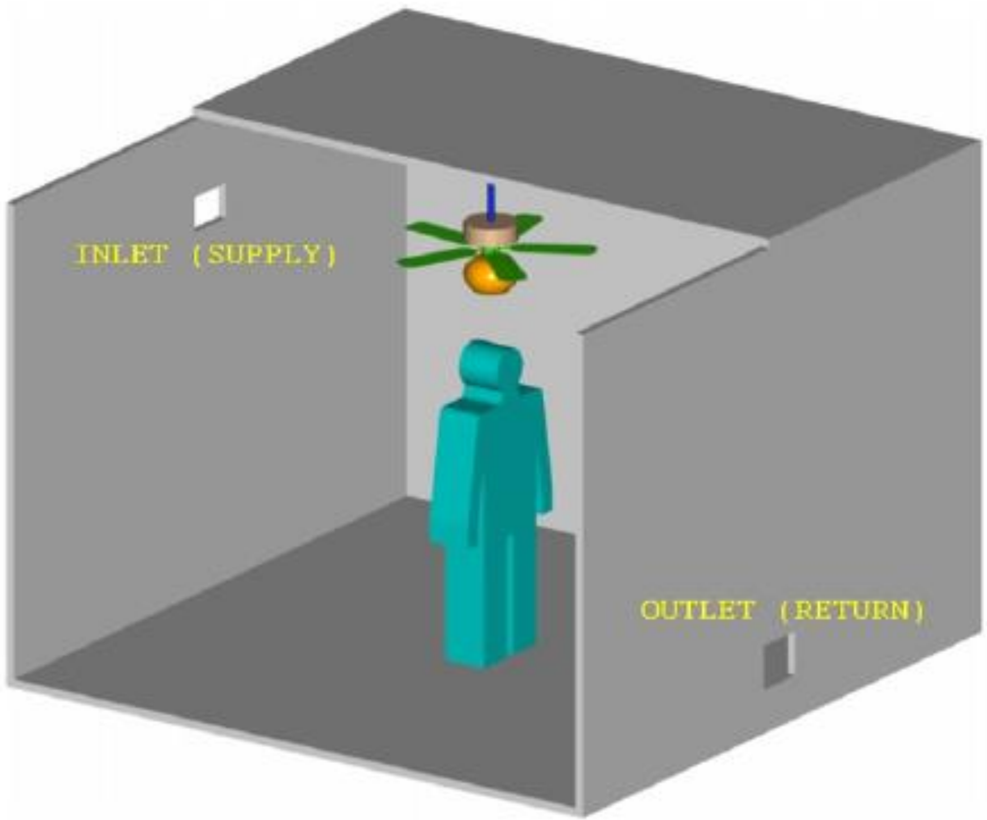
ANSI/ASHRAE Standard 55-2010, Section 3

It Is All A Matter Of Perspective

ASHRAE 55 and Elevated Air Speed

ASHRAE Journal, 2012*:

"Standard 55-2010 has been updated from the 2004 standard with provisions that allow elevated air speed to broadly offset the need to cool the air in warm conditions. The can be applied to natural ventilation applications, and to conventional overhead (and other) air-distribution systems up to an air speed of 150fpm (0.8 m/s) with no local control, and up to 240 fpm (1.2 m/s) with local control."



(a) Typical arrangement (not to scale)

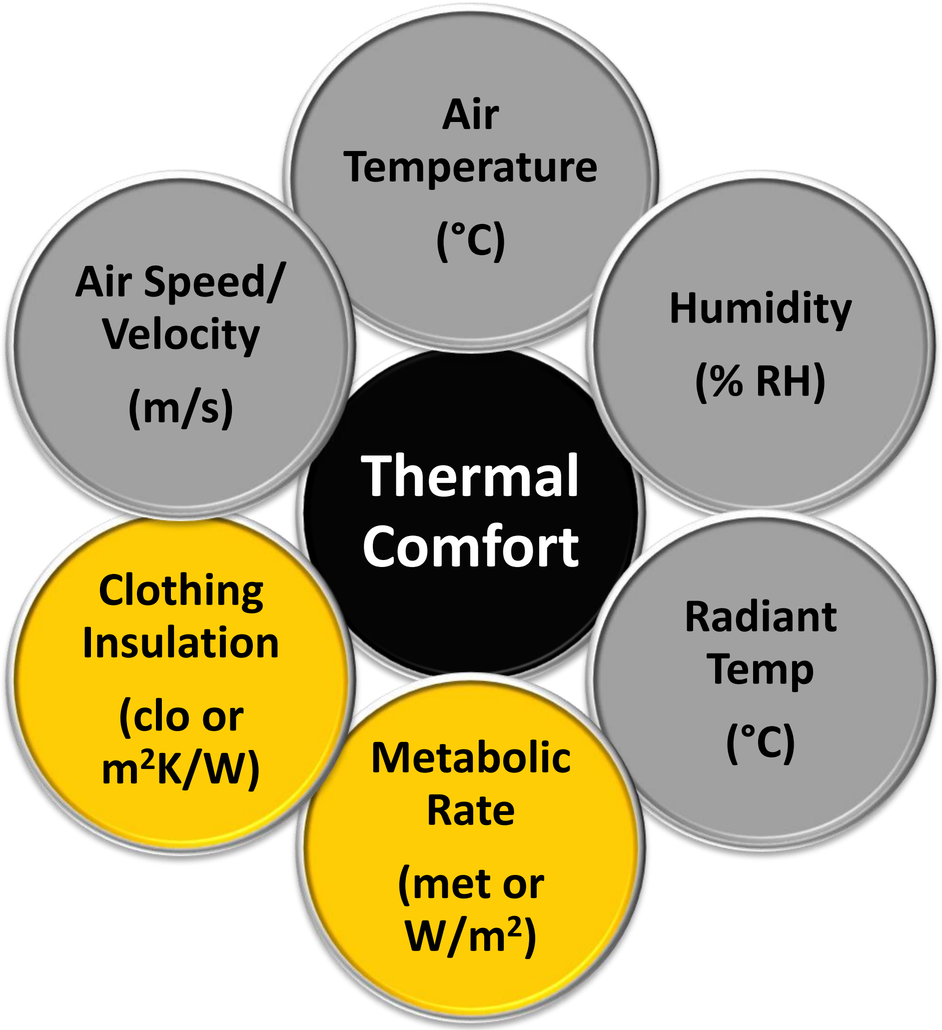
*John, David A., P.E., 2012 *Designing Air-Distribution Systems To Maximize Comfort*
Picture Credit: Ho, Son H.; Rosario, Luis; Rahman, Muhammad M. 2008 Applied Thermal Engineering *Thermal comfort enhanced by using a ceiling fan*

Thermal Comfort

Thermal Comfort: What Affects It?

Transylvania University Arena

Thermal Comfort: What Affects It?



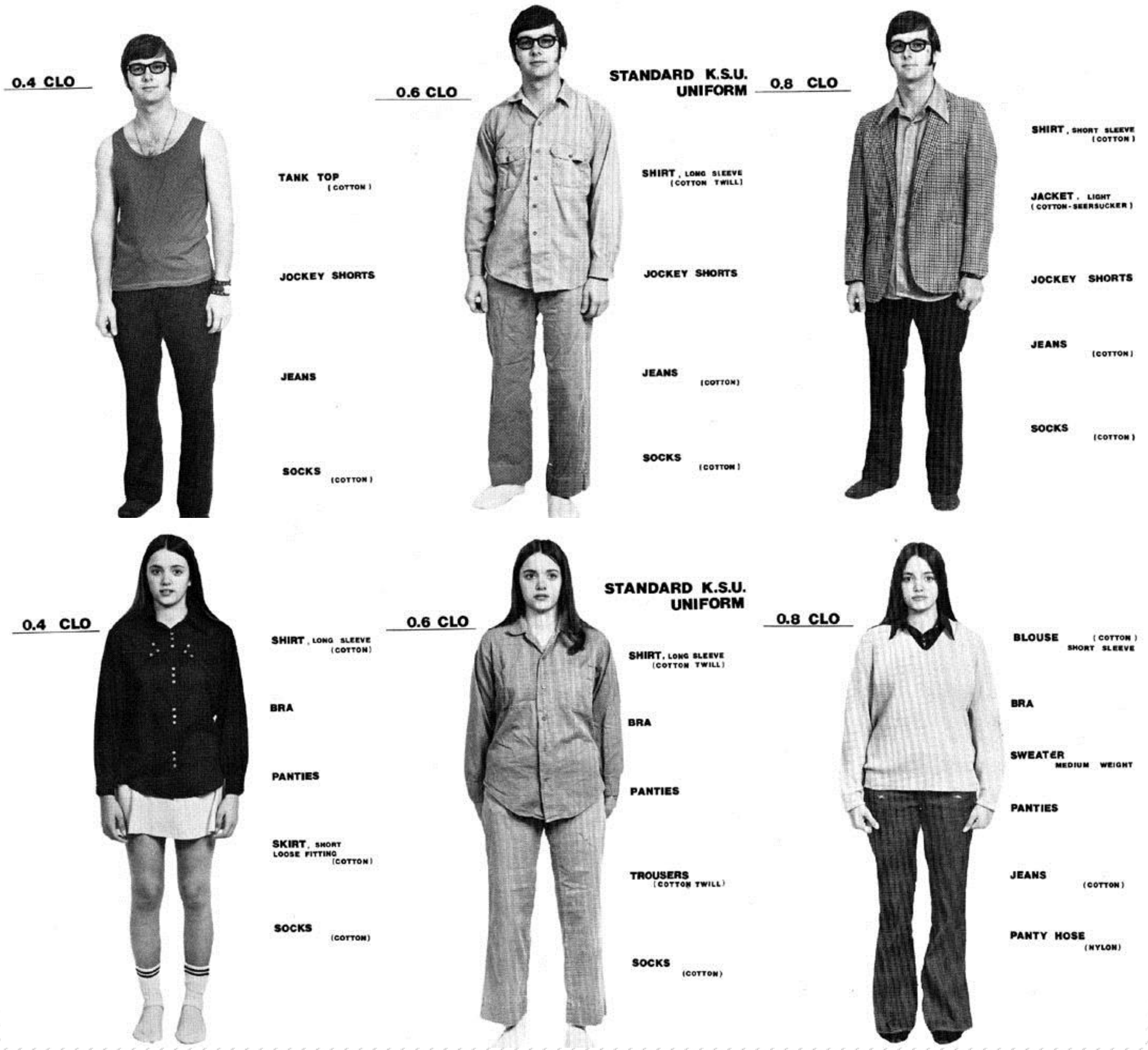
Environmental Factors

Personal Factors

Clothing Insulation

- Clothing = thermal insulation
- Increased insulation = reduced heat loss

Clothing	Clo*
Shoes	0.02
Socks	0.03
Underwear	0.04
Trousers	0.15
Polo	0.17
Total	**0.41**



Metabolic Rate

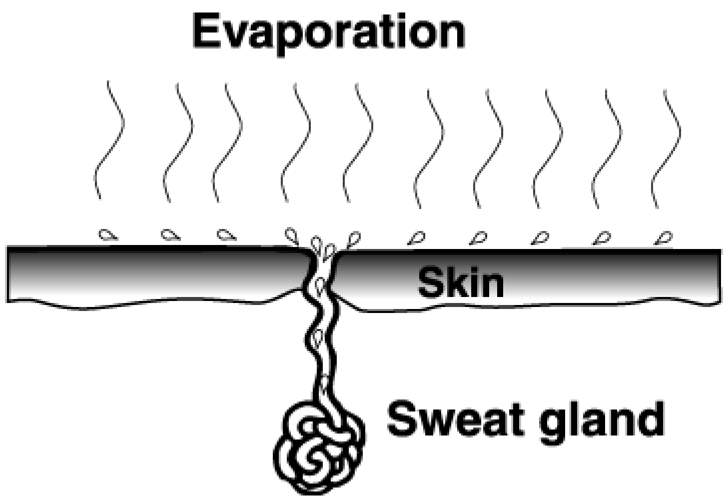
- The amount of energy expended in a given period by a person
- 1 met = energy produced for an average person seated at rest
- Increased met rate = increased heat generation

Air Temperature

Average temperature of the air surrounding the occupant

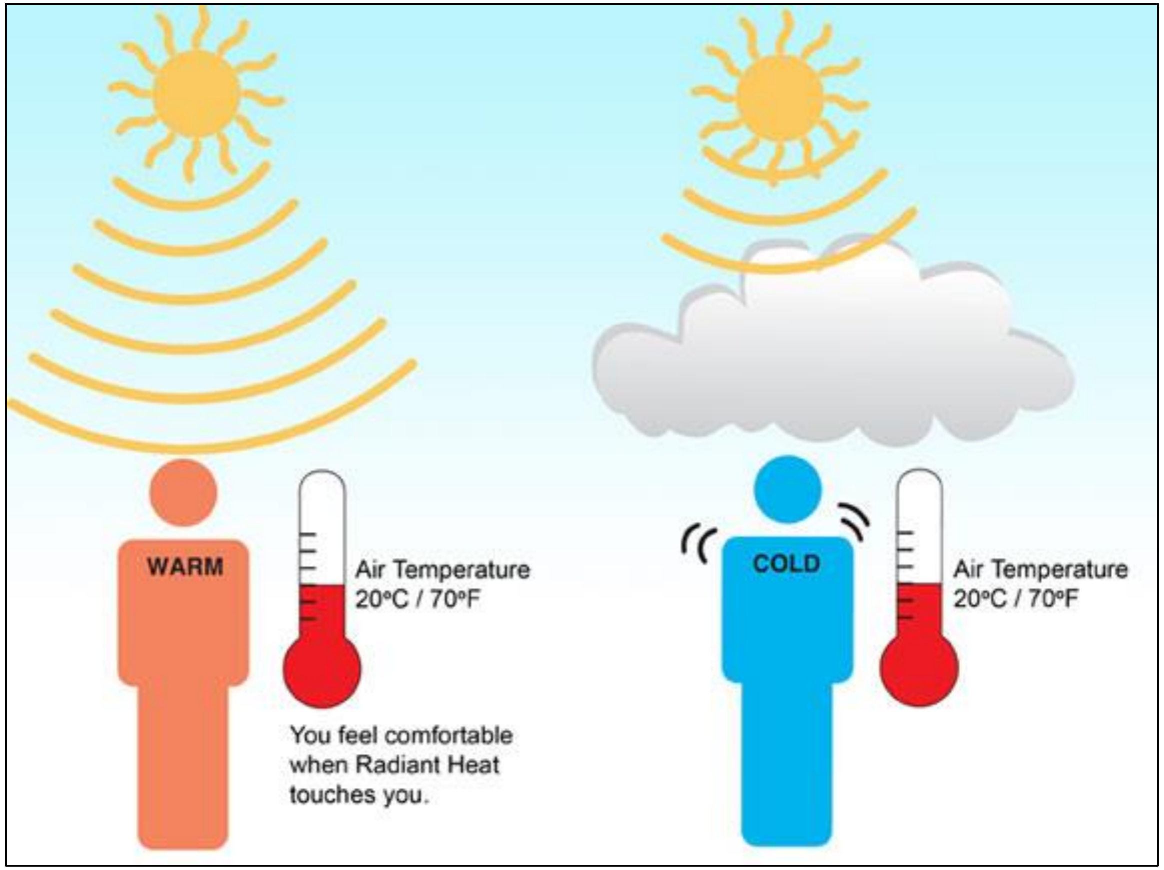
Humidity

- Amount of moisture in the air
- Relative humidity or humidity ratio
- Sweat evaporates off skin more easily at lower humidity



Radiant Temperature

Heat is exchanged between objects at different temperatures via radiation



The Masonry Heaters Association of North America

Air Velocity

- Influences flow of heat to and from the body
- Impacts rate of moisture evaporation from the skin

All six factors work together and can be equally important

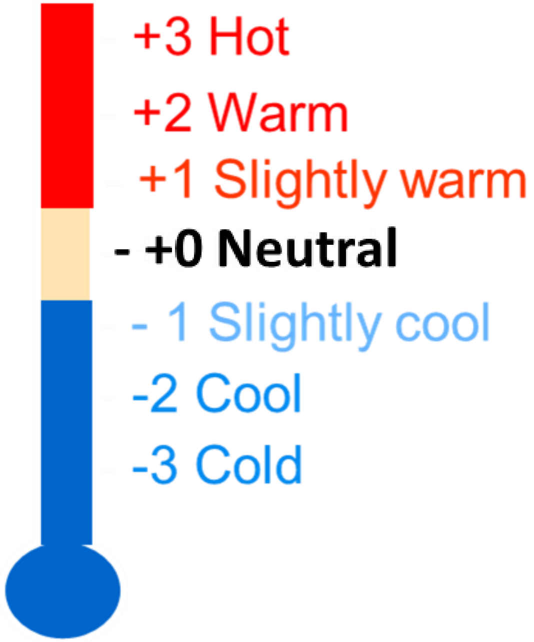
Predicting Comfort

How to Calculate Thermal Comfort

Predicted **P**ercentage of **D**issatisfied (PPD)

Predicted **M**ean **V**ote (PMV)

Operative Temperature



Comfort Zone

PPD < 10%

PMV: -0.5 to +0.5

Graphic Comfort Zone Method

Requirements for use:

- Mechanically conditioned space
- Occupant activity level = 1.0 – 1.3 met
- Clothing worn = 0.5 to 1.0 clo
- 0.012 humidity ratio
- Air Speed < 40 fpm

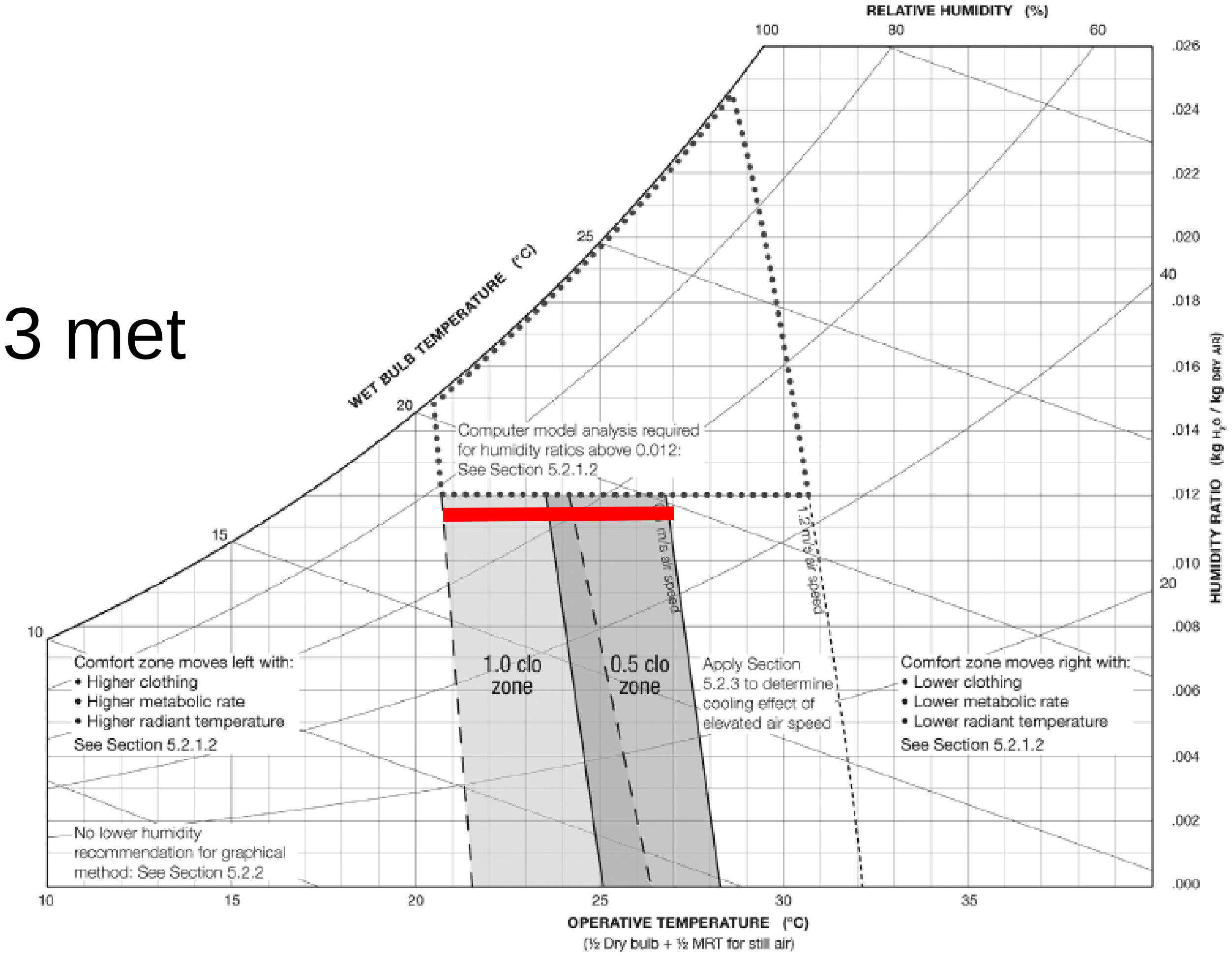
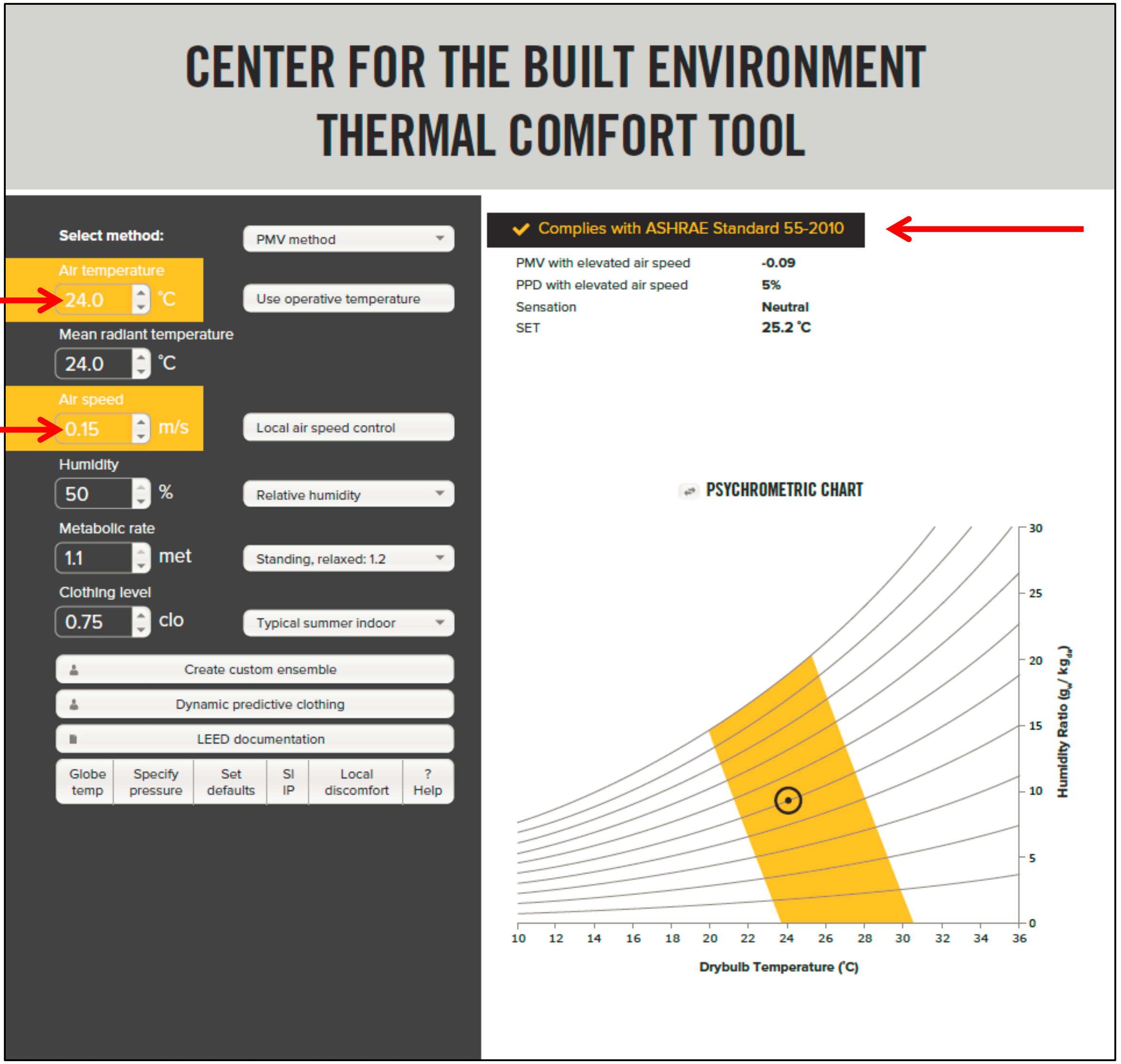


Figure 5.2.1.1 Graphical Comfort Zone Method – ASHRAE Standard 55 -2010

Computer Model Method

Requirements for use:

- Occupant activity level = 1.0 – 2.0 met
- Clothing worn ≤ 1.5 clo



http://smap.cbe.berkeley.edu/comforttool

https://www.ashrae.org/resources--publications/bookstore/thermal-comfort-tool

Thermal Comfort Survey

E1. THERMAL ENVIRONMENT POINT-IN-TIME SURVEY

1. Record the approximate outside air temperature _____ and seasonal conditions:

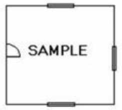
☐ Winter ☐ Spring ☐ Summer ☐ Fall

2. What is your general thermal sensation? (Check the one that is most appropriate)

*(**Note to survey designer:** This scale must be used as-is to keep the survey consistent with ASHRAE Standard 55.)*

☐ Hot
☐ Warm
☐ Slightly Warm
☐ Neutral
☐ Slightly Cool
☐ Cool
☐ Cold

3. Either (a) place an "X" in the appropriate place where you are located now:



*(**Note to survey designer:** Provide appropriate sketch for your space or building.)*

or (b) place an "X" in the check box that best describes the area of the building where you are located now.

☐ North
☐ East
☐ South
☐ West
☐ Core
☐ Don't know

4. On which floor of the building are you located now?

☐ 1st
☐ 2nd
☐ 3rd
☐ Other (provide the floor number):________________

5. Are you near an exterior wall (within 15 ft)?

☐ Yes
☐ No

6. Are you near a window (within 15 ft)?

☐ Yes
☐ No

7. Using the list below, please check each item of clothing that you are wearing right now. (Check all that apply):

*(**Note to survey designer:** This list can be modified at your discretion.)*

☐ Short-Sleeve Shirt	☐ Dress	☐ Nylons
☐ Long-Sleeve Shirt	☐ Shorts	☐ Socks
☐ T-shirt	☐ Athletic Sweatpants	☐ Boots
☐ Long-Sleeve Sweatshirt	☐ Trousers	☐ Shoes
☐ Sweater	☐ Undershirt	☐ Sandals
☐ Vest	☐ Long Underwear Bottoms	
☐ Jacket	☐ Long Sleeve Coveralls	
☐ Knee-Length Skirt	☐ Overalls	
☐ Ankle-Length Skirt	☐ Slip	

☐ Other: (Please note if you are wearing something not described above, or if you think something you are wearing is especially heavy.) ________________

8. What is your activity level right now? (Check the one that is most appropriate)

☐ Reclining
☐ Seated
☐ Standing relaxed
☐ Light activity standing
☐ Medium activity standing
☐ High activity

© 2009, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (www.ashrae.org). For personal use only. Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

E2. THERMAL ENVIRONMENT SATISFACTION SURVEY[1]

1. Either (a) place an "X" in the appropriate place where you spend most of your time:

*(**Note to survey designer:** Provide appropriate sketch for your space or building.)*

or (b) place an "X" in the check box that best describes the area of the building where your space is located.

☐ North
☐ East
☐ South
☐ West
☐ Core
☐ Don't know

2. On which floor of the building is your space located?

☐ 1st
☐ 2nd
☐ 3rd
☐ Other (provide the floor number)________________

3. Are you near an exterior wall (within 15 ft)?

☐ Yes
☐ No

4. Are you near a window (within 15 ft)?

☐ Yes
☐ No

5. Which of the following do you personally adjust or control in your space? (Check all that apply.)

*(**Note to survey designer:** This list can be modified at your discretion.)*

☐ Window blinds or shades
☐ Room air-conditioning unit
☐ Portable heater
☐ Permanent heater
☐ Door to interior space
☐ Door to exterior space
☐ Adjustable air vent in wall or ceiling
☐ Ceiling fan
☐ Adjustable floor air vent (diffuser)
☐ Portable fan
☐ Thermostat
☐ Operable window
☐ None of these
☐ Other: ________________

[1] This survey has been adapted from the CBE occupant IEQ survey developed by the Center for the Built Environment at the University of California at Berkeley.

Please respond to the following questions based on your overall or average experience in the past [six] months.

(***Note to survey designer:*** The above statement can be modified for a different span of time.)

6. How satisfied are you with the temperature in your space? (Check the one that is most appropriate)

Very Satisfied ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Dissatisfied

7. If you are dissatisfied with the temperature in your space, which of the following contribute to your dissatisfaction:

a. In warm/hot weather, the temperature in my space is (check the most appropriate box):

*(**Note to survey designer:** Include a scale or, as shown below, check boxes.)*

☐ Always too hot
☐ Often too hot
☐ Occasionally too hot
☐ Occasionally too cold
☐ Often too cold
☐ Always too cold

b. In cool/cold weather, the temperature in my space is (check the most appropriate box):

*(**Note to survey designer:** Include a scale or, as shown below, check boxes.)*

☐ Always too hot
☐ Often too hot
☐ Occasionally too hot
☐ Occasionally too cold
☐ Often too cold
☐ Always too cold

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

☐ Morning (before 11am)
☐ Mid-day (11am–2pm)
☐ Afternoon (2pm–5pm)
☐ Evening (after 5pm)
☐ Weekends/holidays

Elevated Air Speed and Perceived Cooling

Designing for Thermal Comfort: Cooling

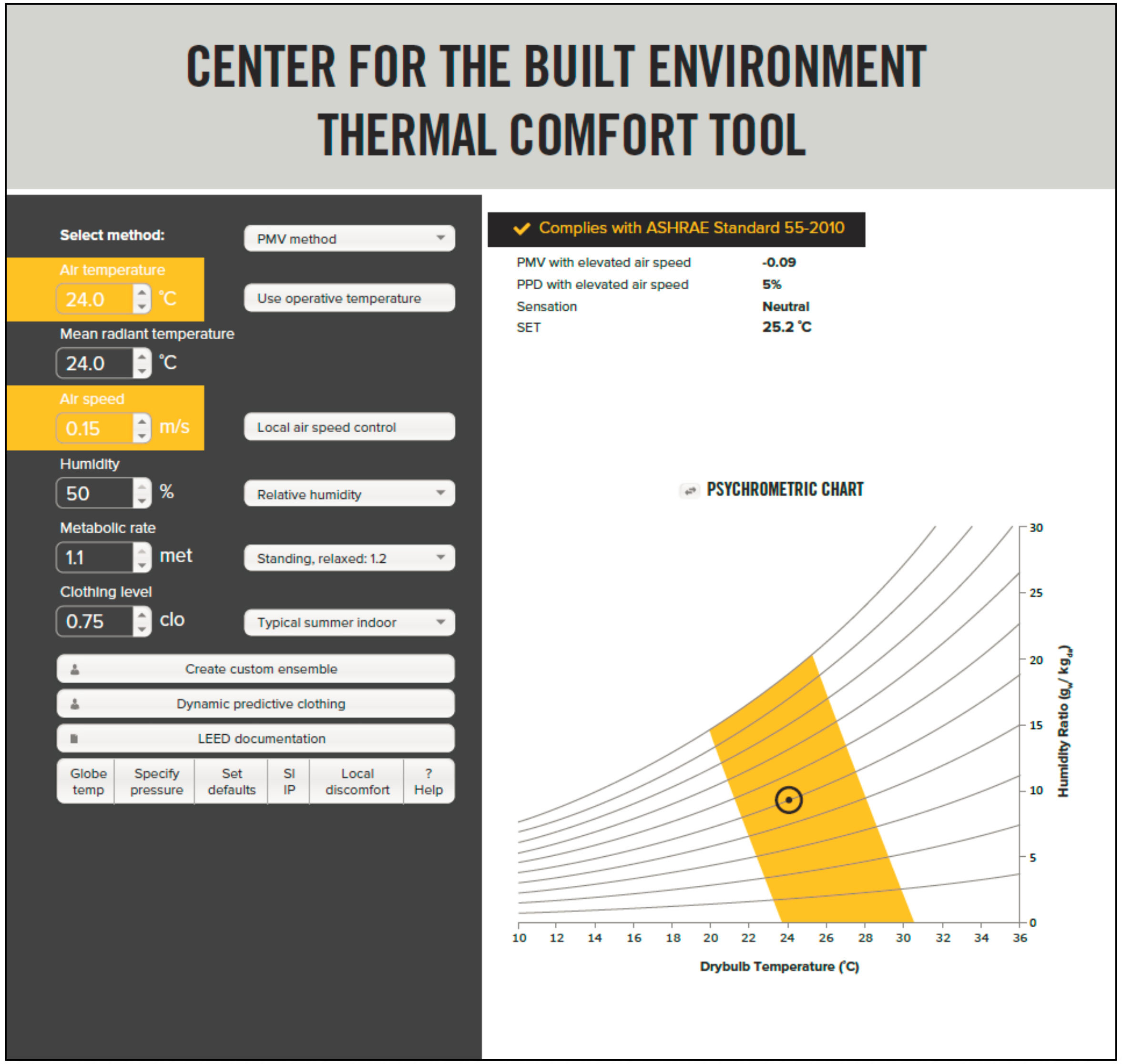
<u>Typical Cooling Values</u>

- Air temperature (24°C)
- Humidity (50% RH)
- Metabolic rate (1.1 met)
- Radiant temperature (24°C)
- Clothing insulation (0.75 clo)
- Air speed (0.15 m/s)

	Typical
PPD	5%
PMV	-0.01

Berea College Residence Hall

Baseline Model

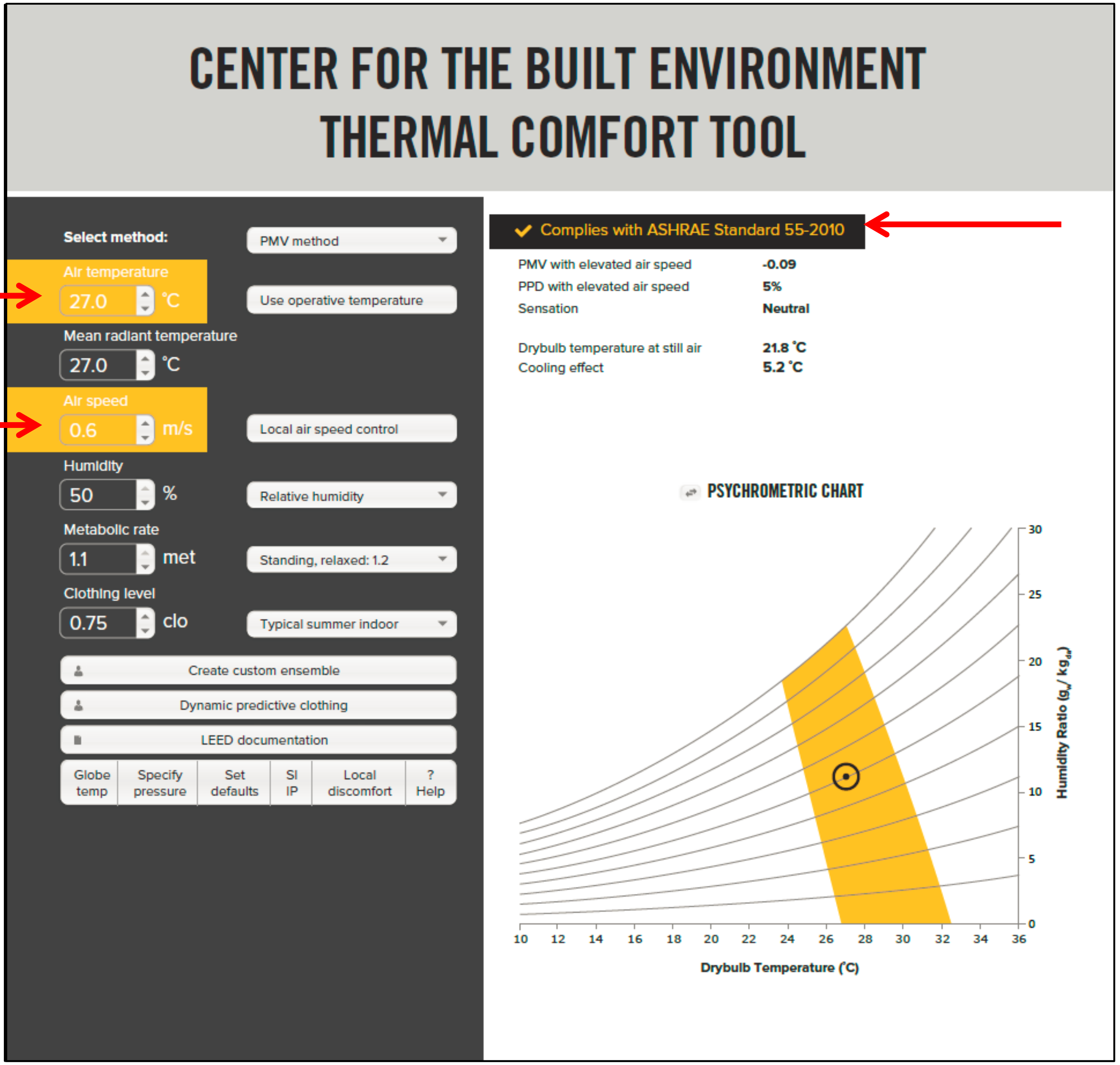


Designing for Thermal Comfort: Cooling

Typical Cooling Values / Alternate Cooling Values

- Air temperature (24°C) [Air temperature (27°C)]
- Humidity (50% RH)
- Metabolic rate (1.1 met)
- Radiant temperature (24°C / 27°C)
- Clothing insulation (0.75 clo)
- Air speed (0.15 m/s) [Air speed (0.6 m/s)]

	Alternate
PPD	5%
PMV	-0.09



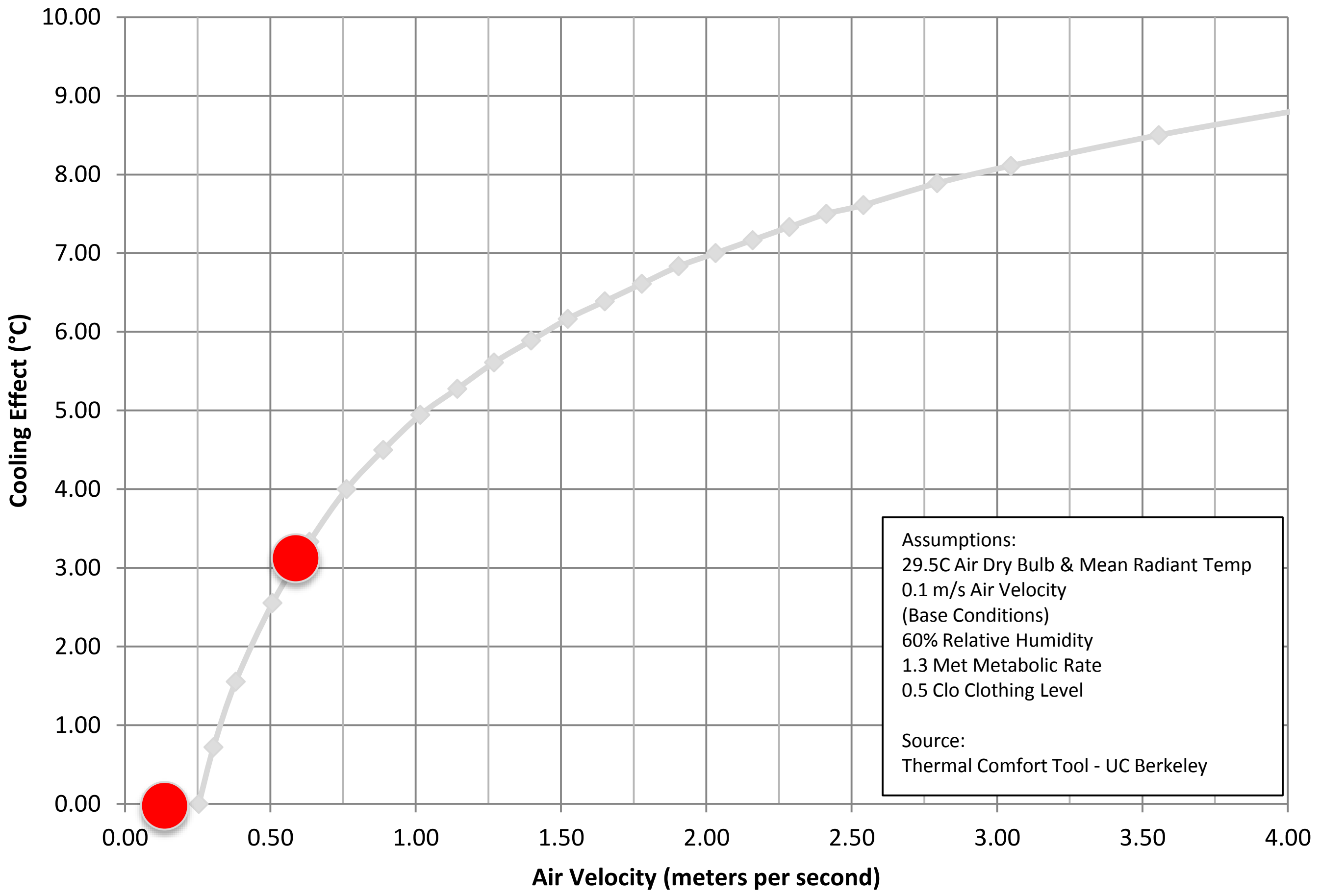
Cooling Effect from Elevated Air Speed

Designed at 0.15 m/s

Raised to 0.6 m/s

3°C effect

Up to 18% saved energy



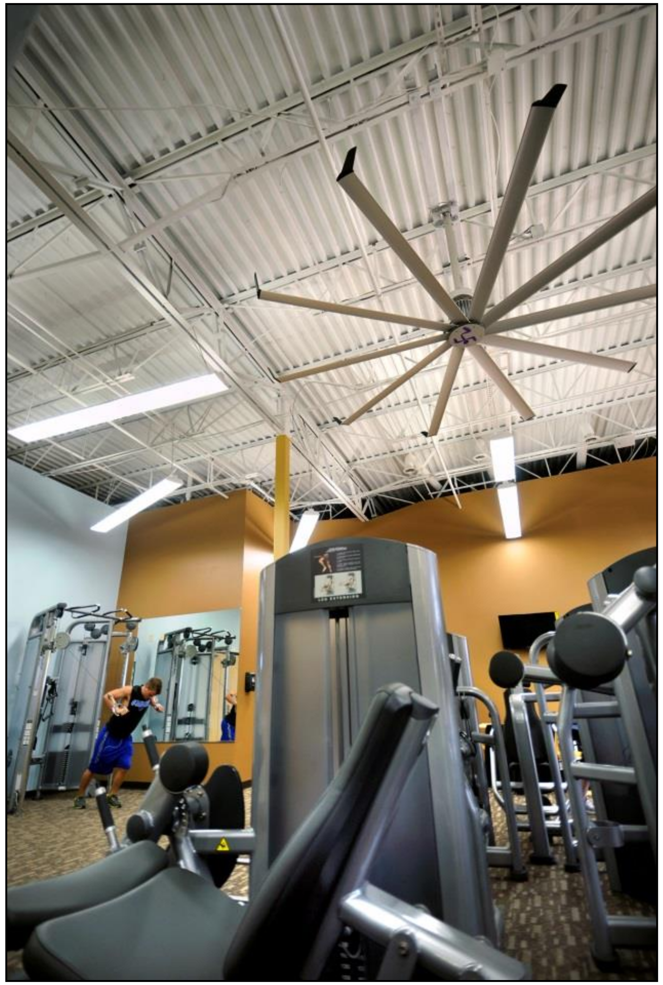
Air Movement Offset Temperature Increase

According to the CNIS,WWF and EPD one degree Celsius higher set on the air conditioner, equals a 6-7% saving of power consumption.

*Energy Institute of National Development and Reform Commission, China National Institute of Standardization (CNIS)
“20 to 20 Energy Savings Manual (2012)
http://www.epd.gov.hk/epd/english/how_help/tips_savearth/green_tips_1.html
https://apps.wwf.org.hk/eng/consumerguide/pdf/LowCarbon_web.pdf

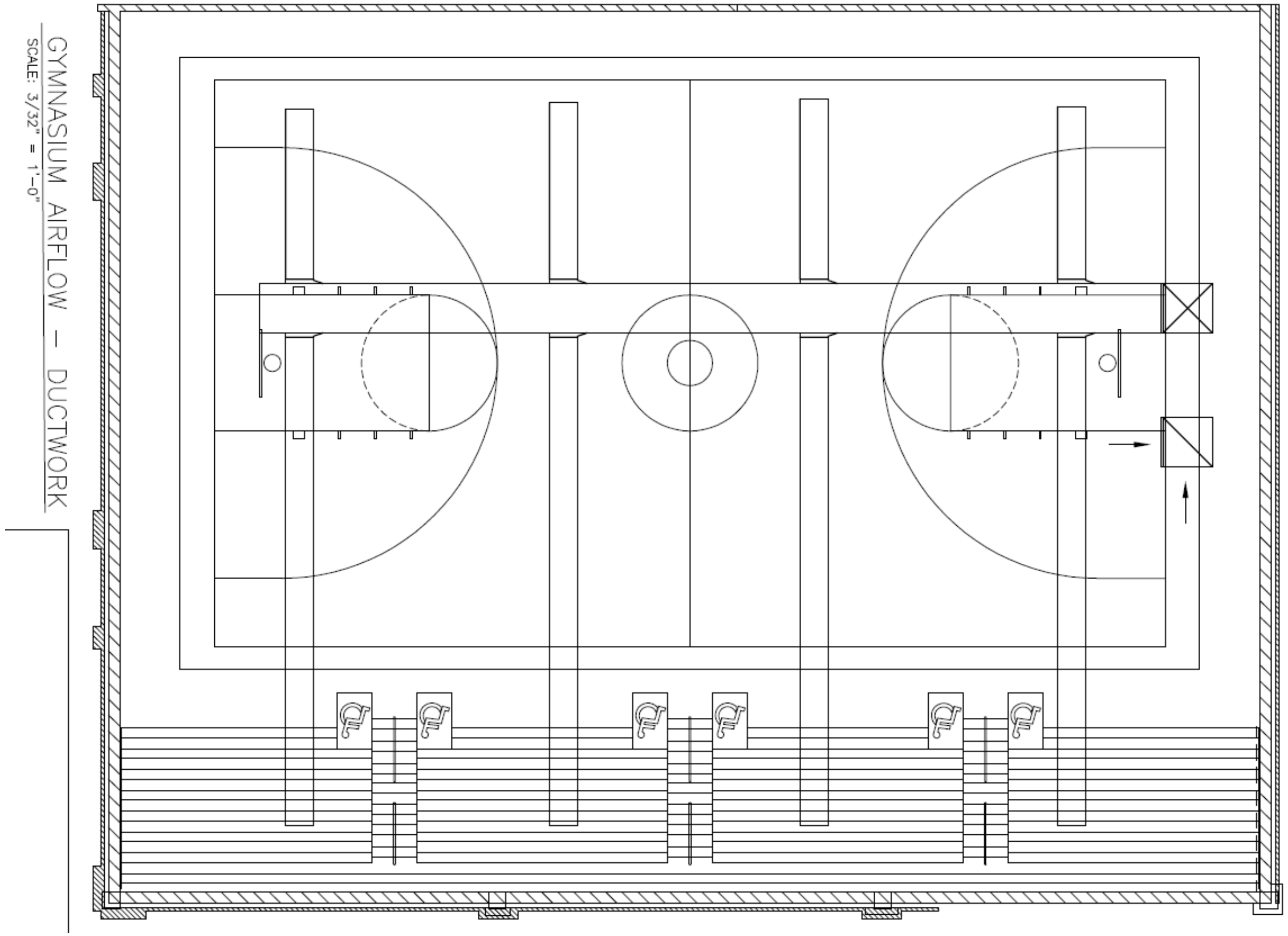
Ancillary Benefits of Elevated Air Speed – Material Cost Reduction

Elevated Air Speed in Non-Sensitive Spaces



Higher air speeds = greater potential savings

Example 1: School Gym, A/C Only



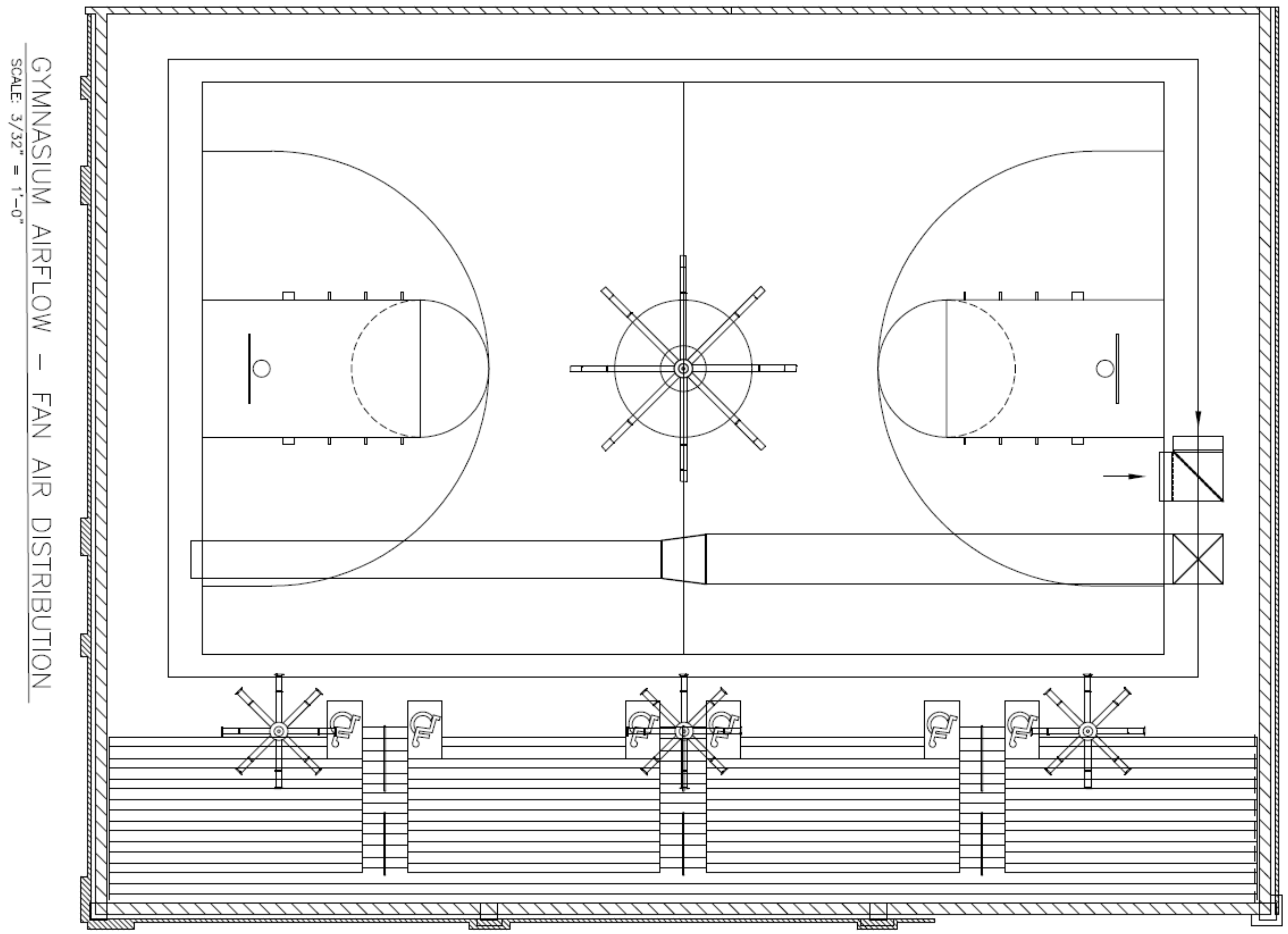
728 sq m

Setpoint: 23 C
Feels Like: 23 C

Materials + Installation: $620/sq m (HKD)

RS Means 2013 Mechanical Cost data

Example 1: School Gym, A/C + Fans



728 sq m

Setpoint: 27 C
Feels Like: 23 C

Materials + Installation: $570/sq m (HKD)

RS Means 2013 Mechanical Cost data

Example: School Gym, New Construction

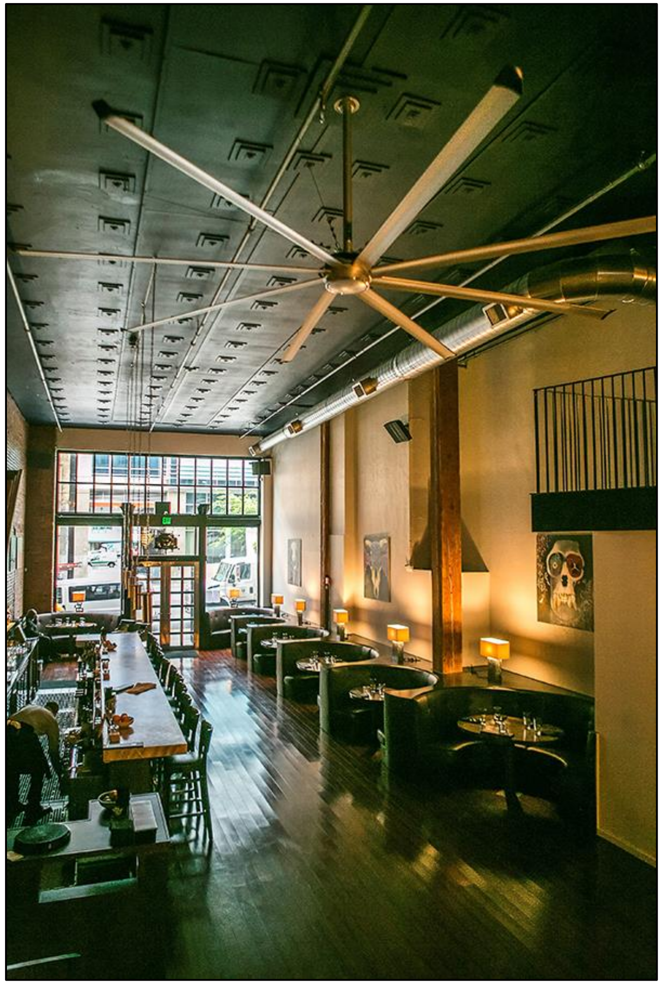
	Difference
Materials + Install Cost (HKD)	$50/sq m
A/C Electricity Consumption	38%
Annual Utilities Cost	17%

FIGURES:	Material and Install Cost (HKD)	Annual Utility Cost	AC Electricity Consumption	Gymnasium Energy Consumption
AC Only	$448,335	$30,737	21,498 kWh	38,841 kWh
Fans + AC	$412,168	$25,653	13,382 kWh	30,725 kWh

Example 1: School Gym, A/C Only

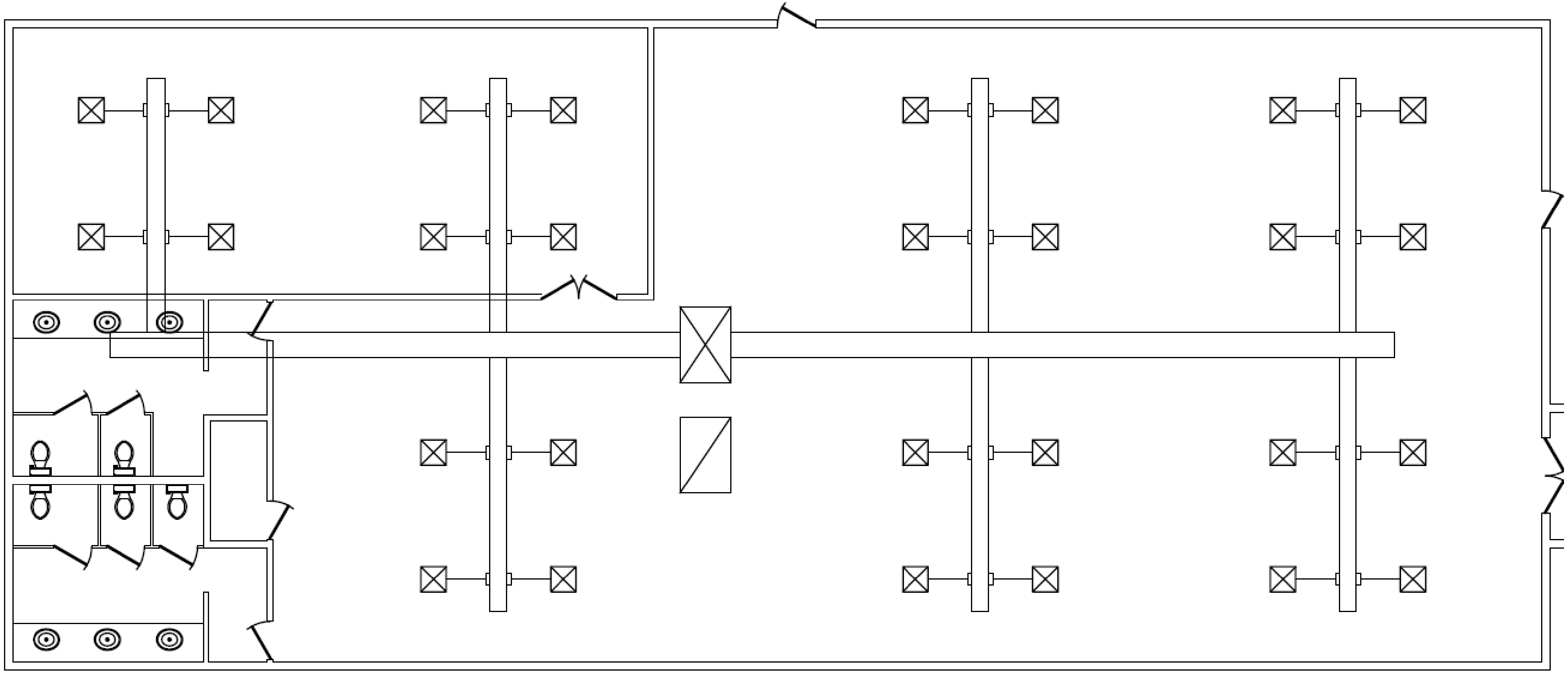
Example 1: School Gym, Fans + A/C

Elevated Air Speed in Sensitive Spaces



Low air speeds = No disturbance in the space

Example 2: Office Space, A/C Only



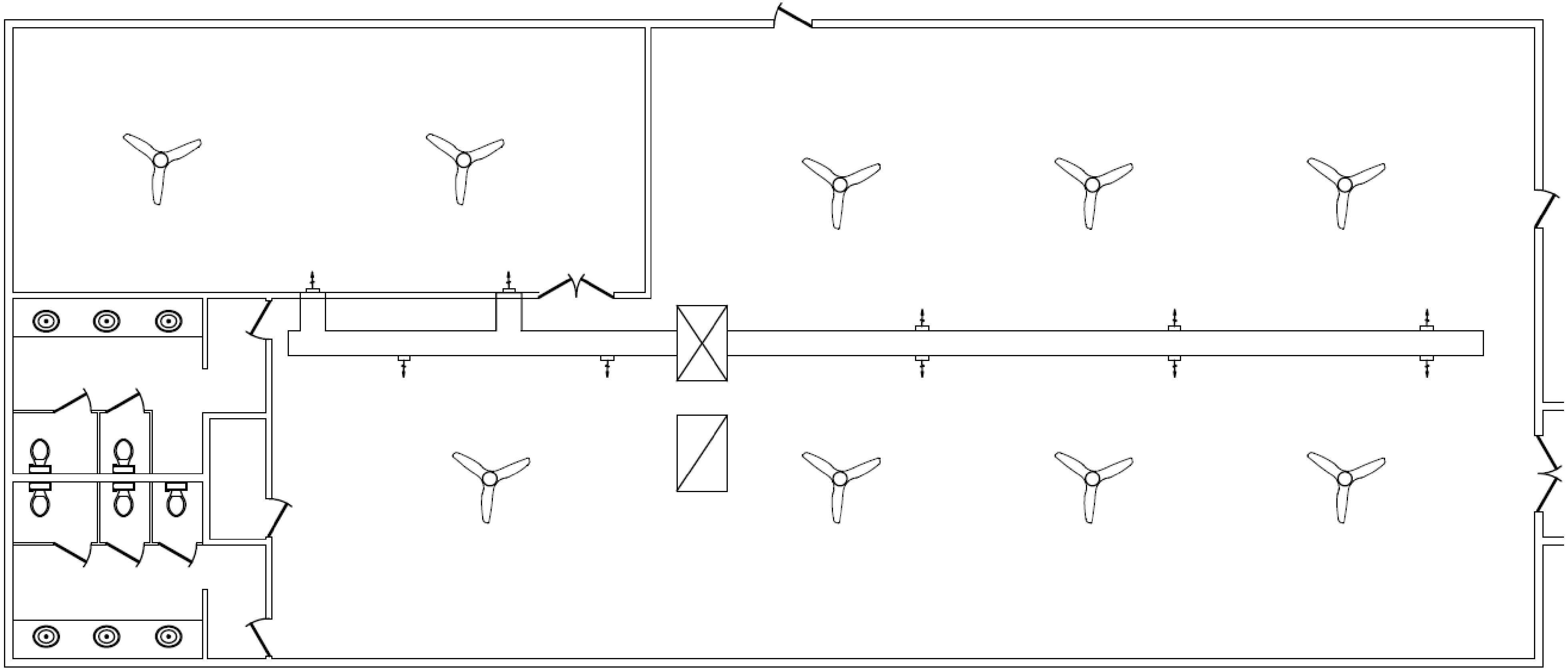
558 sq m

Setpoint: 23 C
Feels Like: 23 C

Material + Installation: $470/sq m (HKD)

RS Means 2013 Mechanical Cost data

Example 2: Office Space, Fans + A/C



558 sq m

Setpoint: 25.5 C

Feels Like: 23 C

Material + Installation: $207/sq m (HKD)

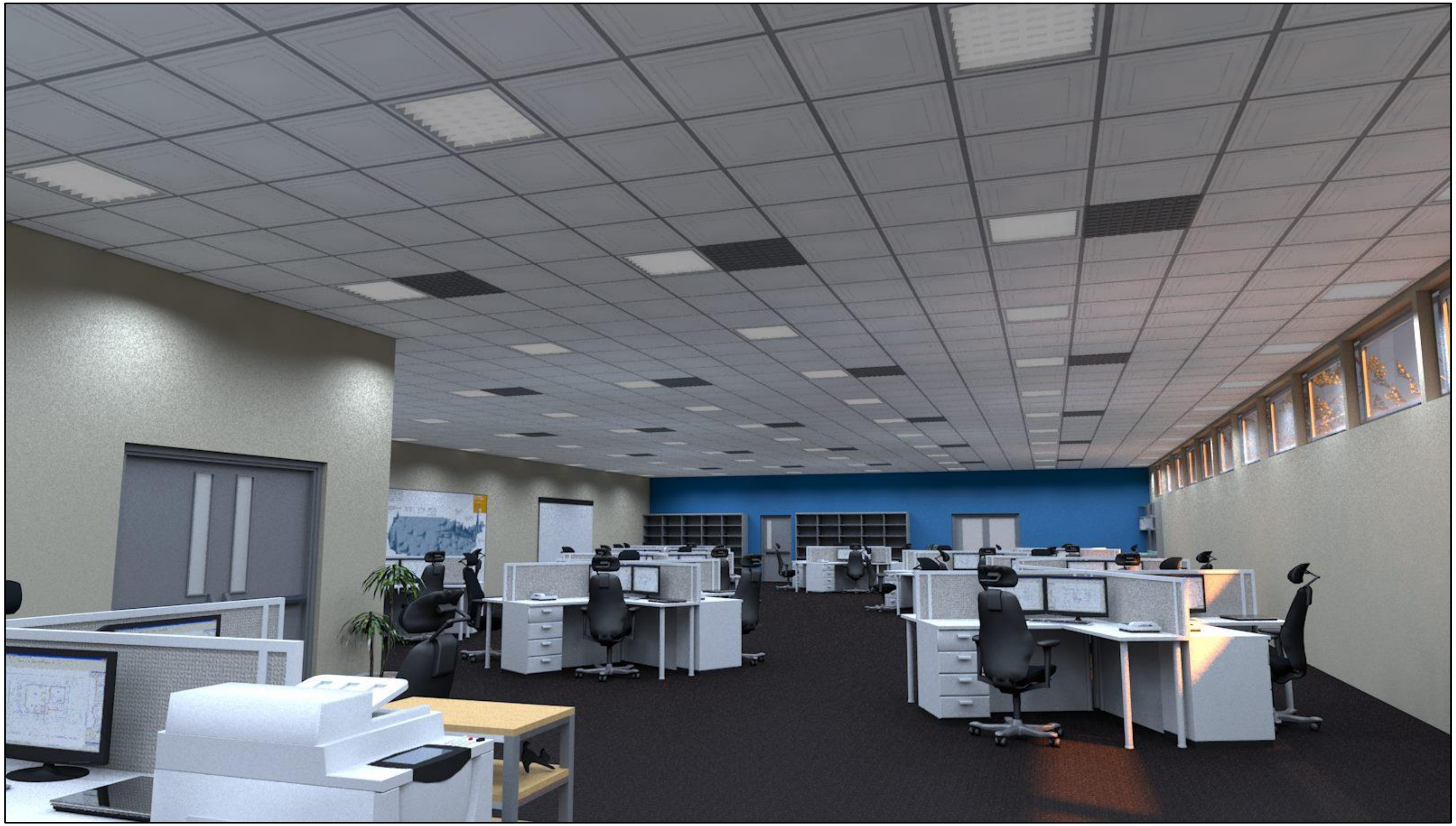
RS Means 2013 Mechanical Cost data

Example 2: Office Space

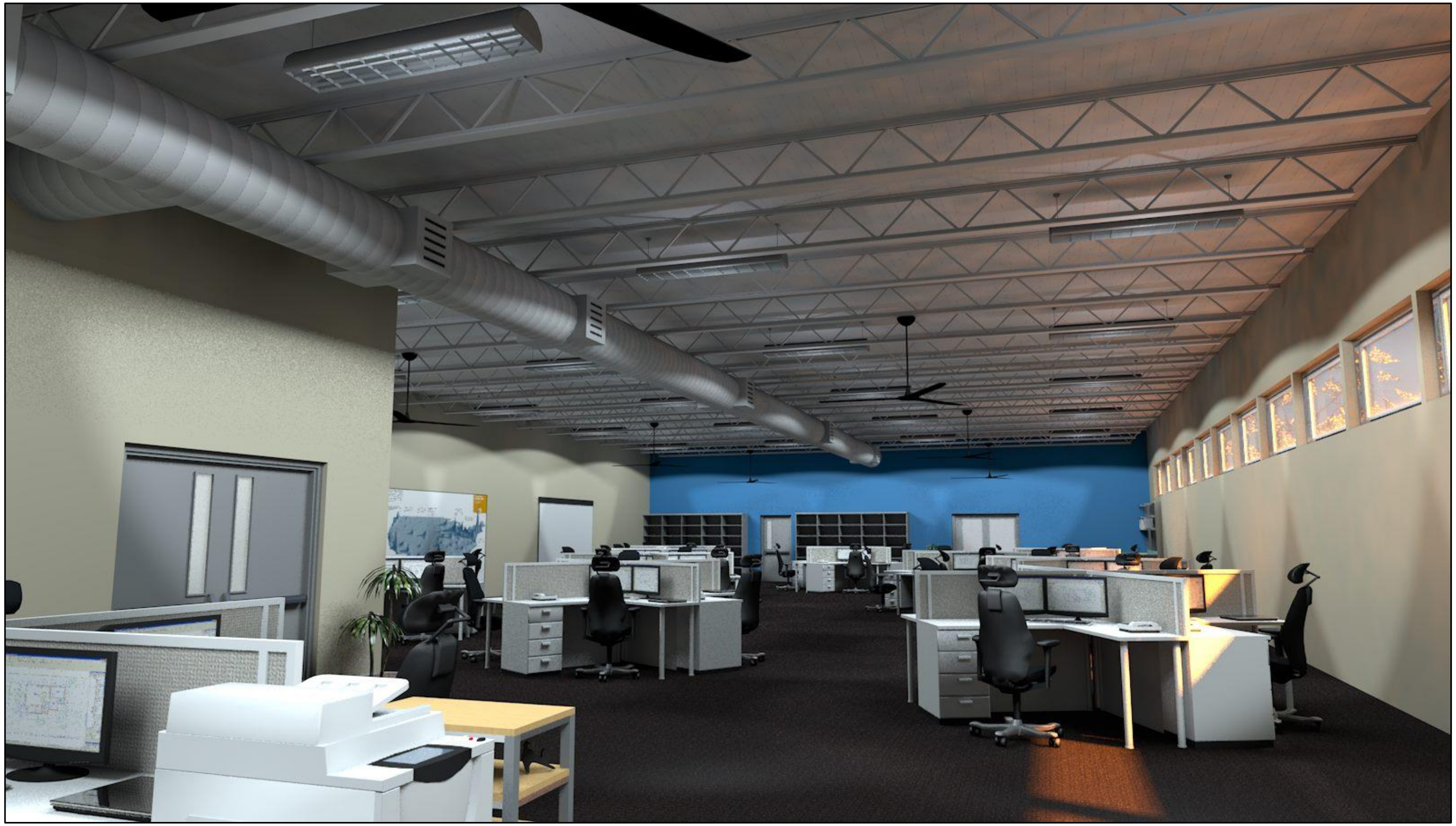
	Difference
Materials + Install Cost (HKD)	$263/sq m
A/C Electricity Consumption	24%
Annual Utilities Cost	10%

FIGURES:	Material and Install Cost (HKD)	Annual Utility Cost	AC Electricity Consumption	Office Energy Consumption
AC Only	$261,051	$40,905	27,972 kWh	57,416 kWh
Fans + AC	$114,576	$36,743	21,319 kWh	50,763 kWh

Example 2: Office Space, A/C Only



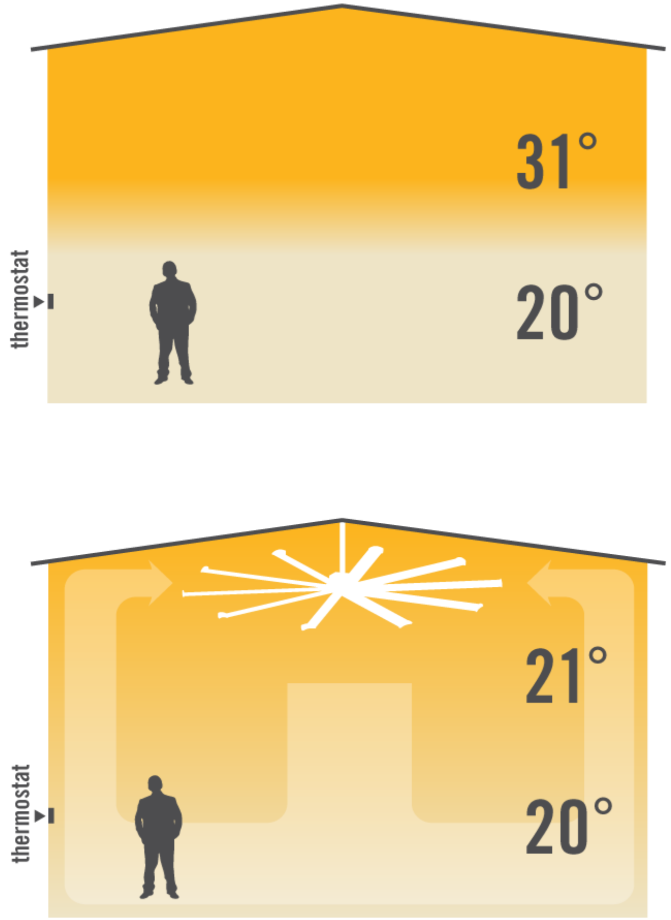
Example 2: Office Space, Fans + A/C



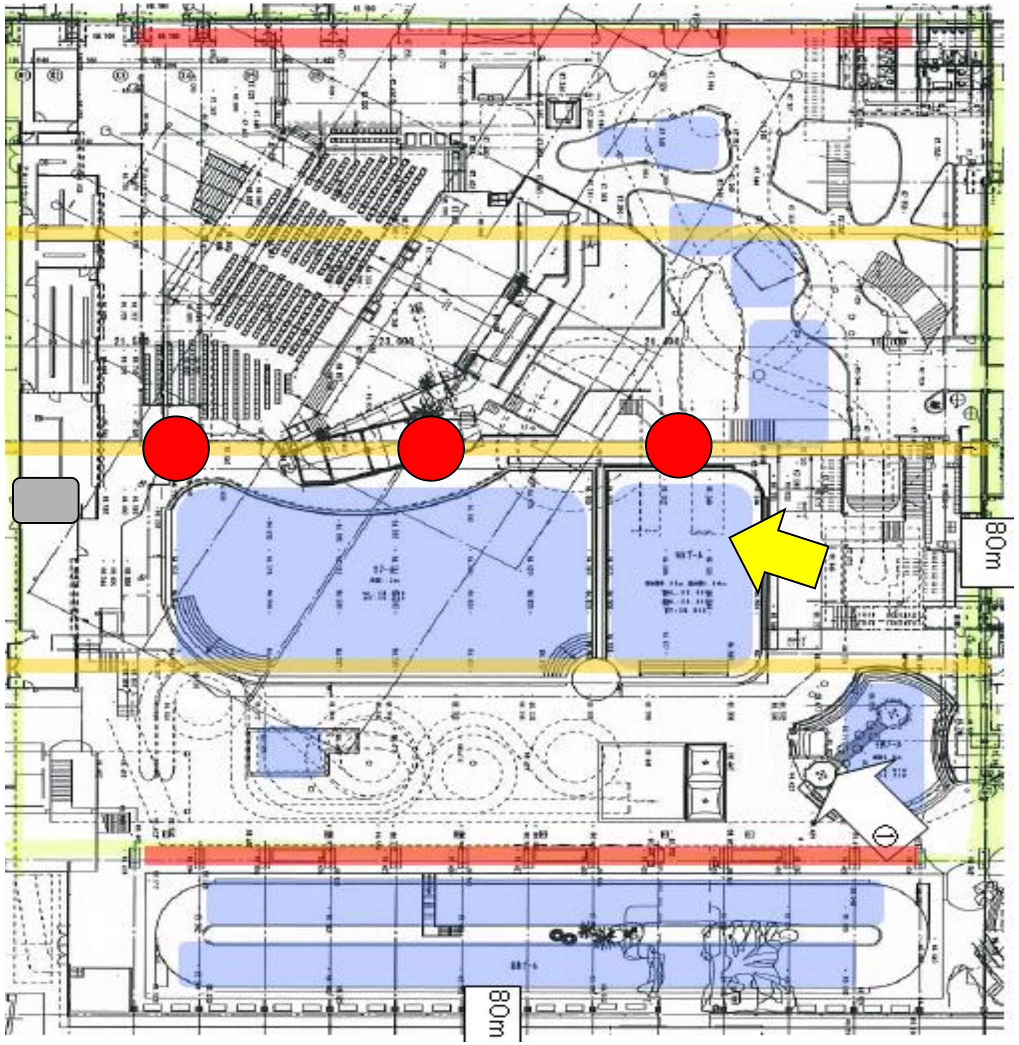
Ancillary Benefits of Elevated Air Speed – Destratification

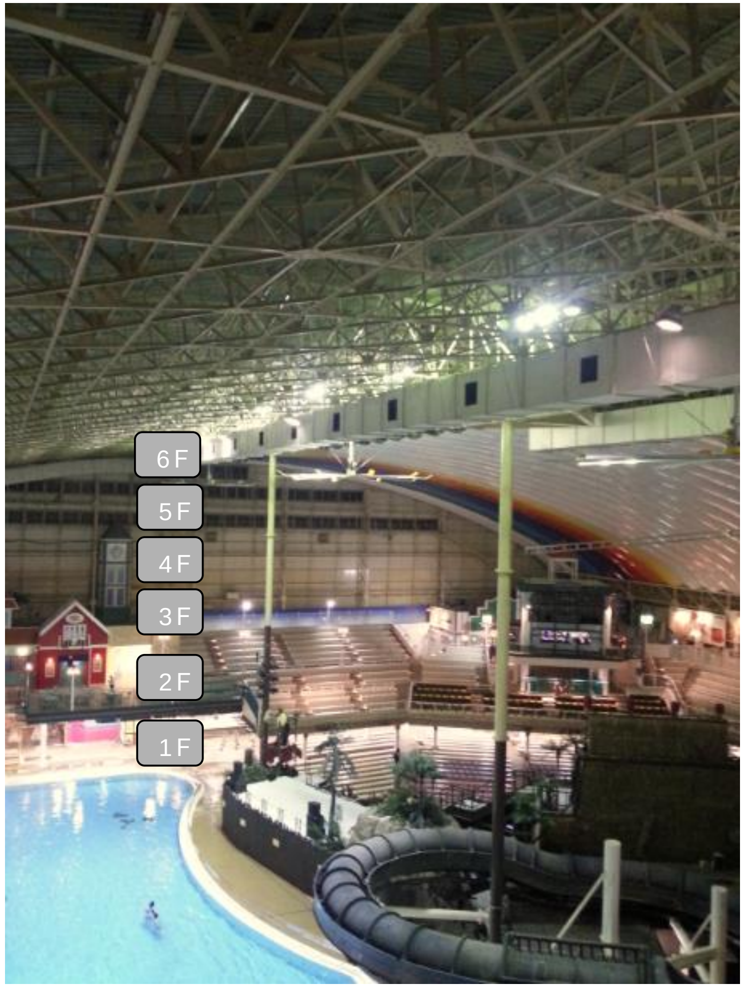
Heating and Stratification

- Hot air rises
- Difficult to get uniformity
- Stratification of 1 – 1.5°C/m
- Higher average space temperature, heat loss, equipment runtime



DESTRATIFICATION – CASE STUDY

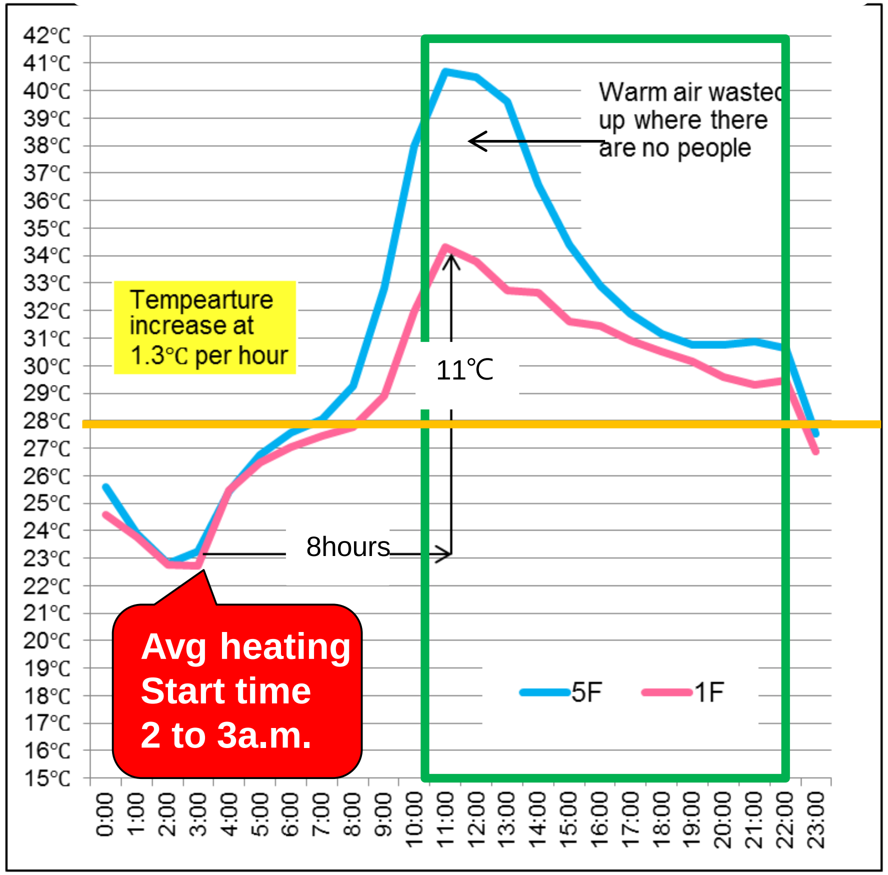




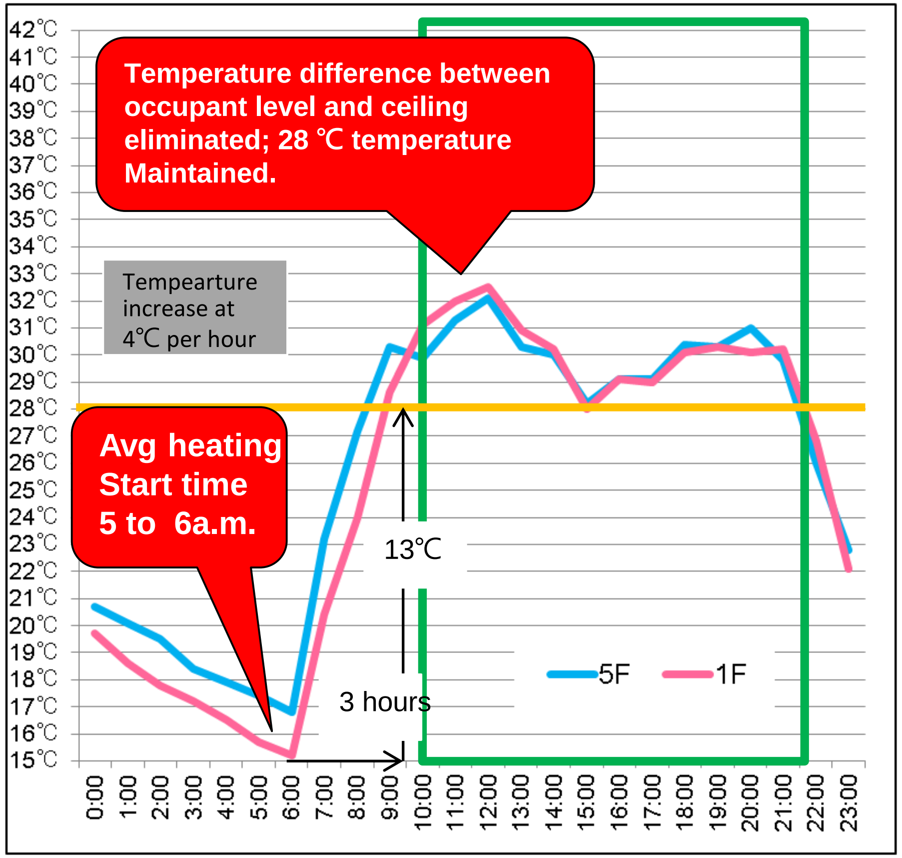
Destratification – Case Study

BENEFITS① DESTRATIFICATION

Before Fan Installation



After Fan Installation



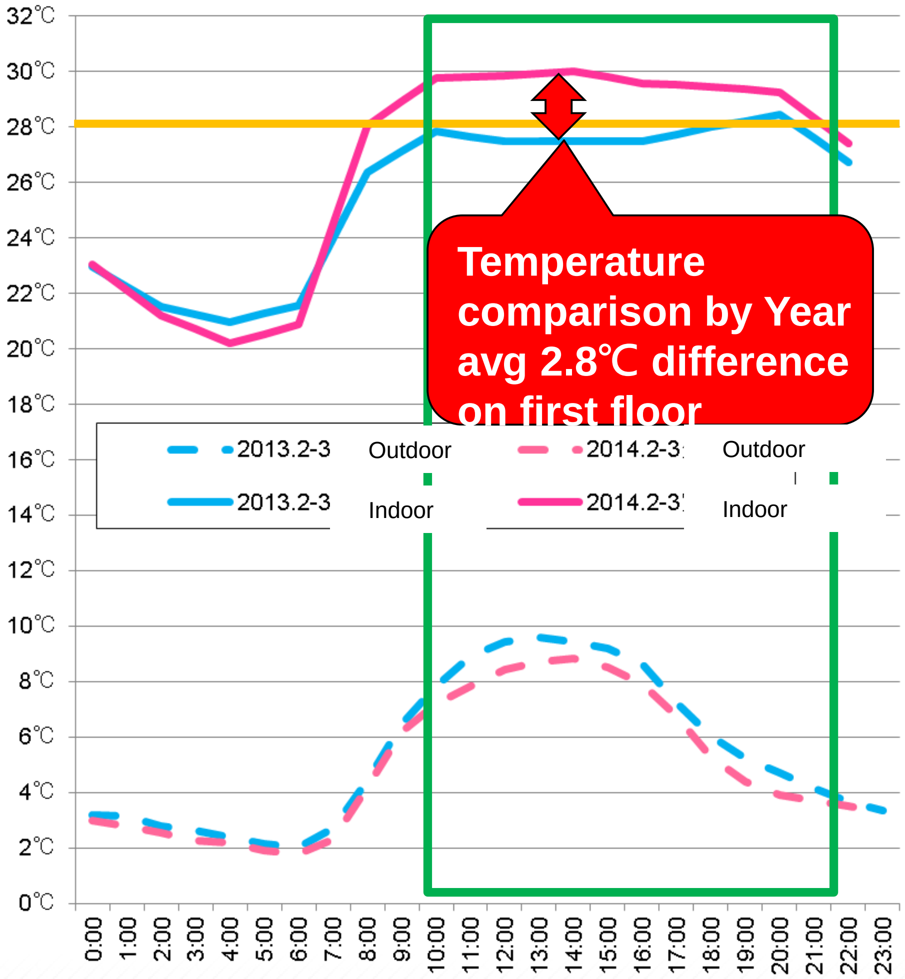
BENEFIT ② FEB TO MARCH PERFORMANCE

BASIC DATA

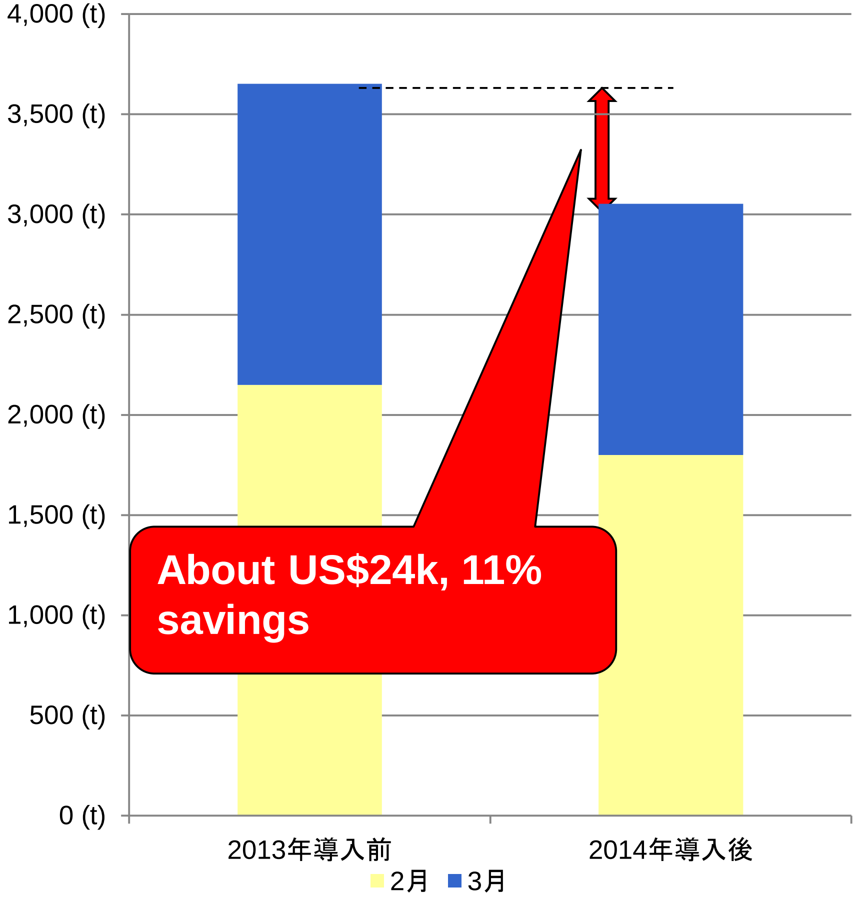
		Feb/Mar 2013	Feb/Mar 2014	Difference	備考
	Snow	16	97	81	There were 56 fewer good weather hours than The previous year
	Rain	94	103	9	
	Cloudy	442	486	44	
	Total Bad weather hours	552	686	134	
Good Weather Hours	Clear	1164	1,030	−134	
	Sunshine	341	338	−4	
Avg Outdoor Temp (℃)		5.39	4.86	−0.5	14 year record cold
Indoor Pool Side Temperature (℃) /10)		26.57	29.35	**2.8**	Indoor temperature raised
Boiler Steam output (t) (heating oil)		3,663	3,256	−406	11% reduction from previous year
Total Heating Hours		3,429	2,756	−673	20% reduction from previous year
Energy Costs 1000yen/2 months		¥21,975	¥19,539	**¥−2,437**	1kg steam = 6 yen
CO2発生量(t)		730	649	−81	燃料使用料KL(蒸気量(t)÷13.6)x39.1(発熱量)GJ/klx0.0189xtC/GJx44/12

FEBRUARY-MARCH TOTAL PERFORMANCE BENEFITS

Year Comparison Feb＆Mar Avg Indoor and Outdoor Temperature

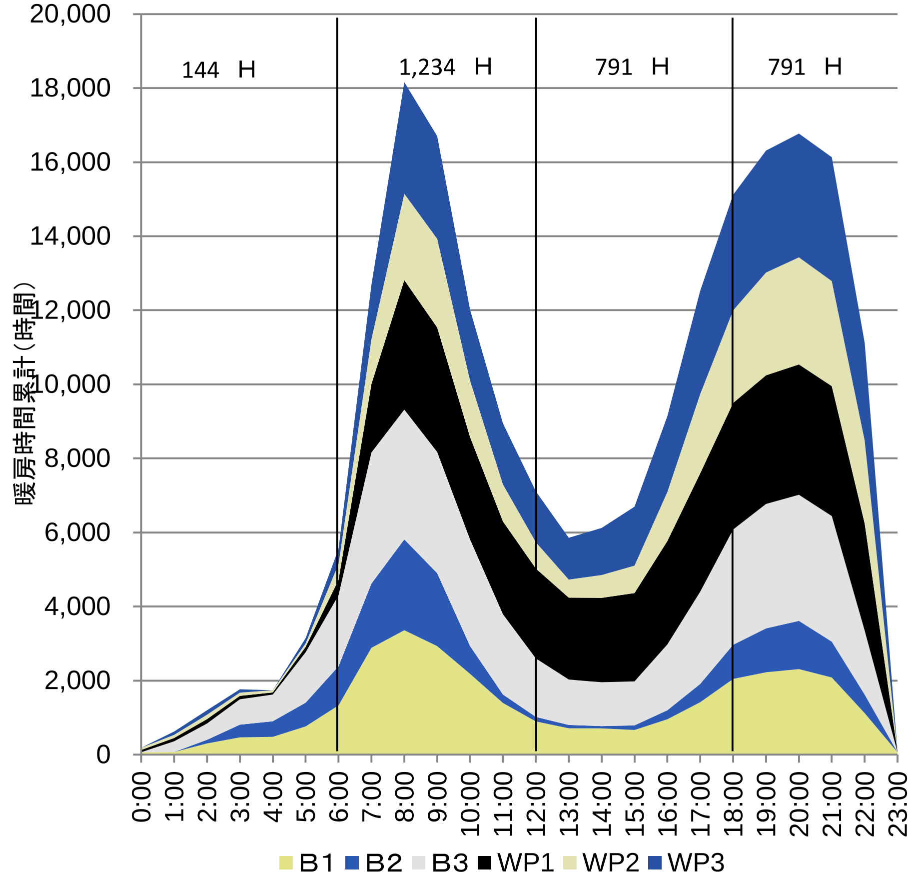


Year Comparison Feb & Mar Boiler Steam Flow

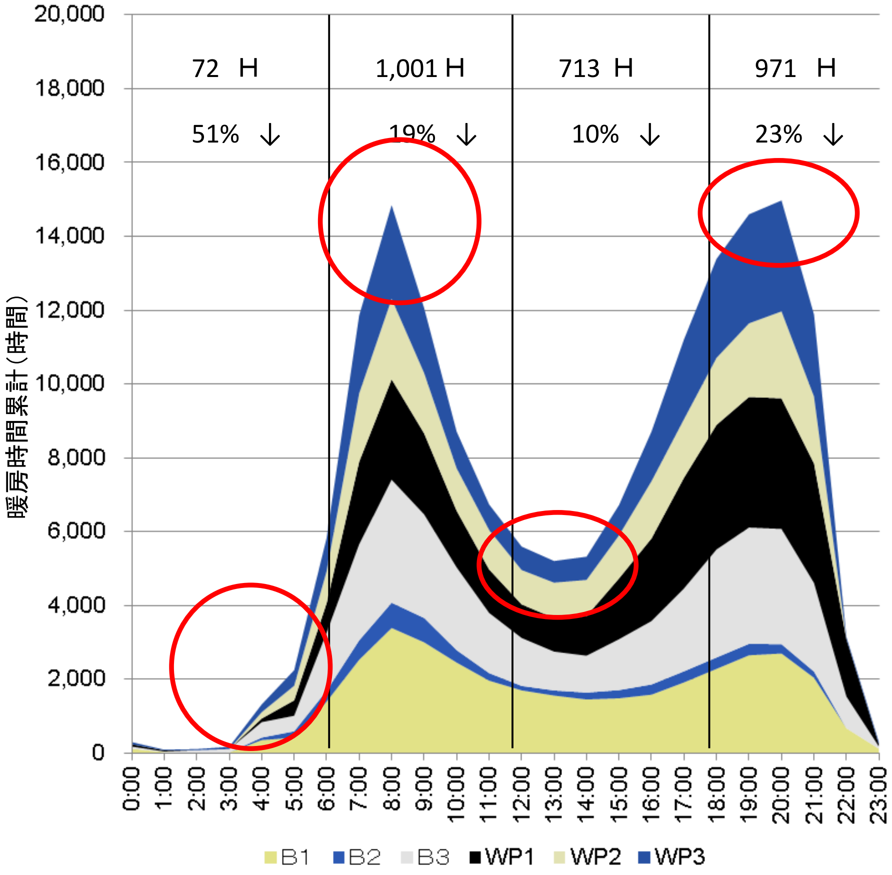


HEATING TIME COMPARISON

3,429 Total Heating Hours (2013)



2,755 Total Heating Hours (2014)



Feb· Mar Two month reduction of 673 heating hours (20% reduction)

SUMMARY

[Challenge before the introduction]

① Heating cost of about US$1million per year

Costs continued to increase due to Yen depreciation and rising energy prices

② Dilemma of saving energy versus customer satisfaction

③ Need 24 hour monitoring of air conditioning system

※Could only raise the temperature 1~1.5℃ per hour, requiring a heating start time of 2-3a.m. in winter

④ Wasted energy from stratification

[Effect after the introduction]

① **Cost savings of about US$100k** per year

With equivalent weather conditions, test data indicates the possible savings of US$15k per month

② Energy savings, **without compromising the comfort of customers**

③ Night management hours decreased, and heating start time delayed

※

Heating time doubled to 3~4℃ per hour

Heating start time can start at 6-7a.m.

④ Realization of energy efficiency

SUPPLEMENTAL BENEFITS

[Cost reduction, even in winter, in addition to improving comfort]

① During the summer vent out warm air

In the summer the dome would fill with heat

The fans will allow for the warm air to vent through ceiling window and improve comfort

② Production equipment

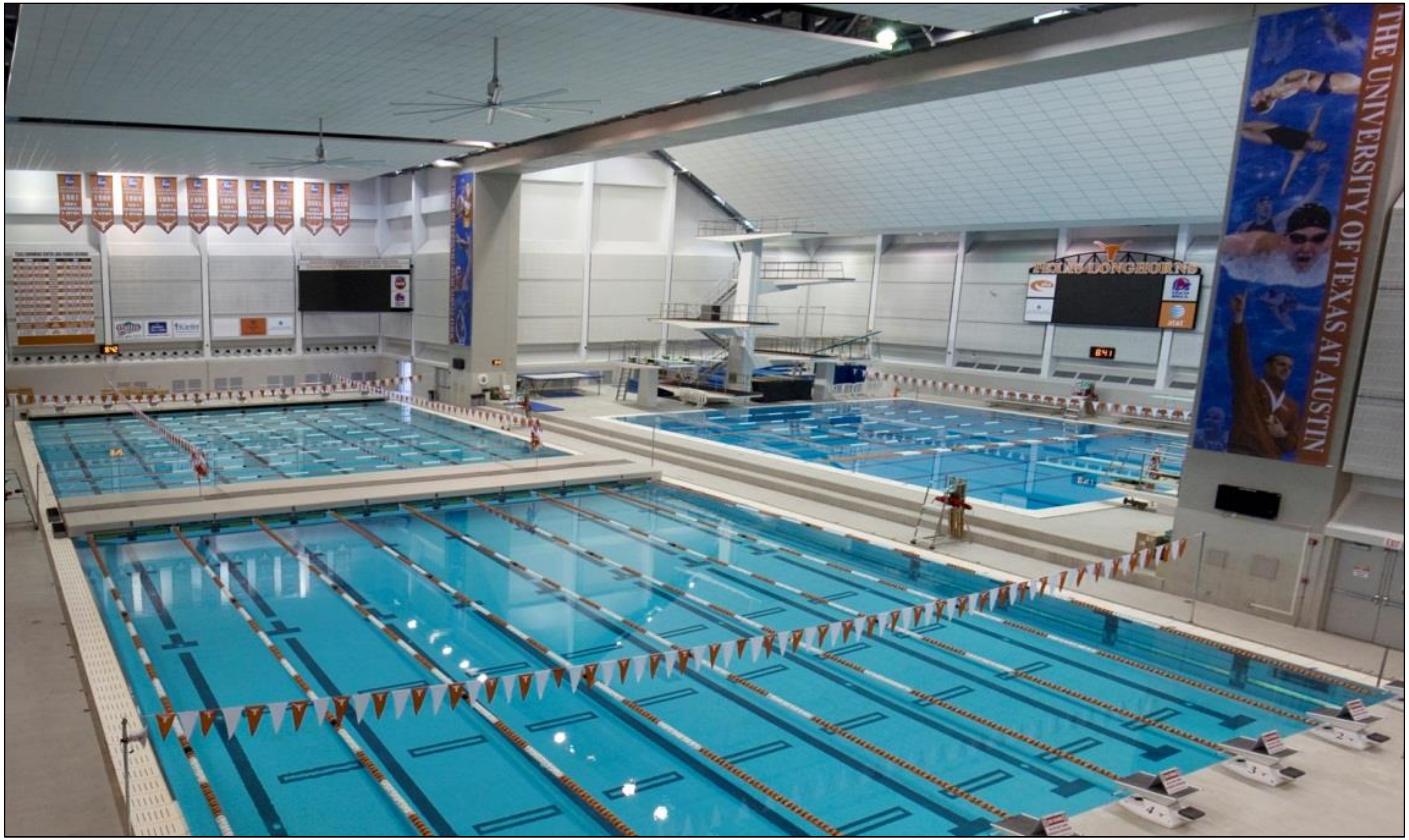
It is like having a Hawaiian ocean breeze in the building

③ Improved environment for plants

Ancillary Benefits of Elevated Air Speed – Others

Air Movement and Ductwork Minimization

Air Movement and Indoor Air Quality



Texas Swim Center at University of Texas, Austin

Air Movement and Condensation Mitigation

Problem:

- Moist air + cold surface = condensation

Leads to:

- Mold Growth
- Corrosion of metal
- Safety

Solution:

- Disturbing stagnant air film
- Increasing surface temperature

O'Neill Flat Rolled Metals

O’Neal Flat Rolled Metals

- Spring & Fall temperature swings

  + high thermal mass product

  + moist air

  = condensation!!
- $250,000 USD annual product loss reduction
- Increased worker safety

O’Neill Flat Rolled Metals

Elevated Air Speed contributes to Green Building Standards

Elevated Air Speed and Green Building Standards

LEED BD+C

- EA Prereq 2 Minimum Energy Performance
- EA Credit 2 Optimize Energy Performance
- EA Credit 4 Demand Response
- EA Credit 6 Enhanced Refrigerant Management

BEAM Plus

- EU P1 – Minimum Energy Performance
- EU 1 – Reduction of CO_2 Emissions
- EU 1 – Option 2 – Passive Design
- EU 2 – Peak electricity reduction
- EU 9 – Energy Efficient appliances

Elevated Air Speed and Green Building Standards

LEED BD+C

- EQ Prerequisite 1: Minimum Indoor Air Quality Performance
- EQ Credit 1: Enhanced Indoor Air Quality Strategies
- EQ Credit 5 Thermal Comfort
- IN Credit 1: Innovation

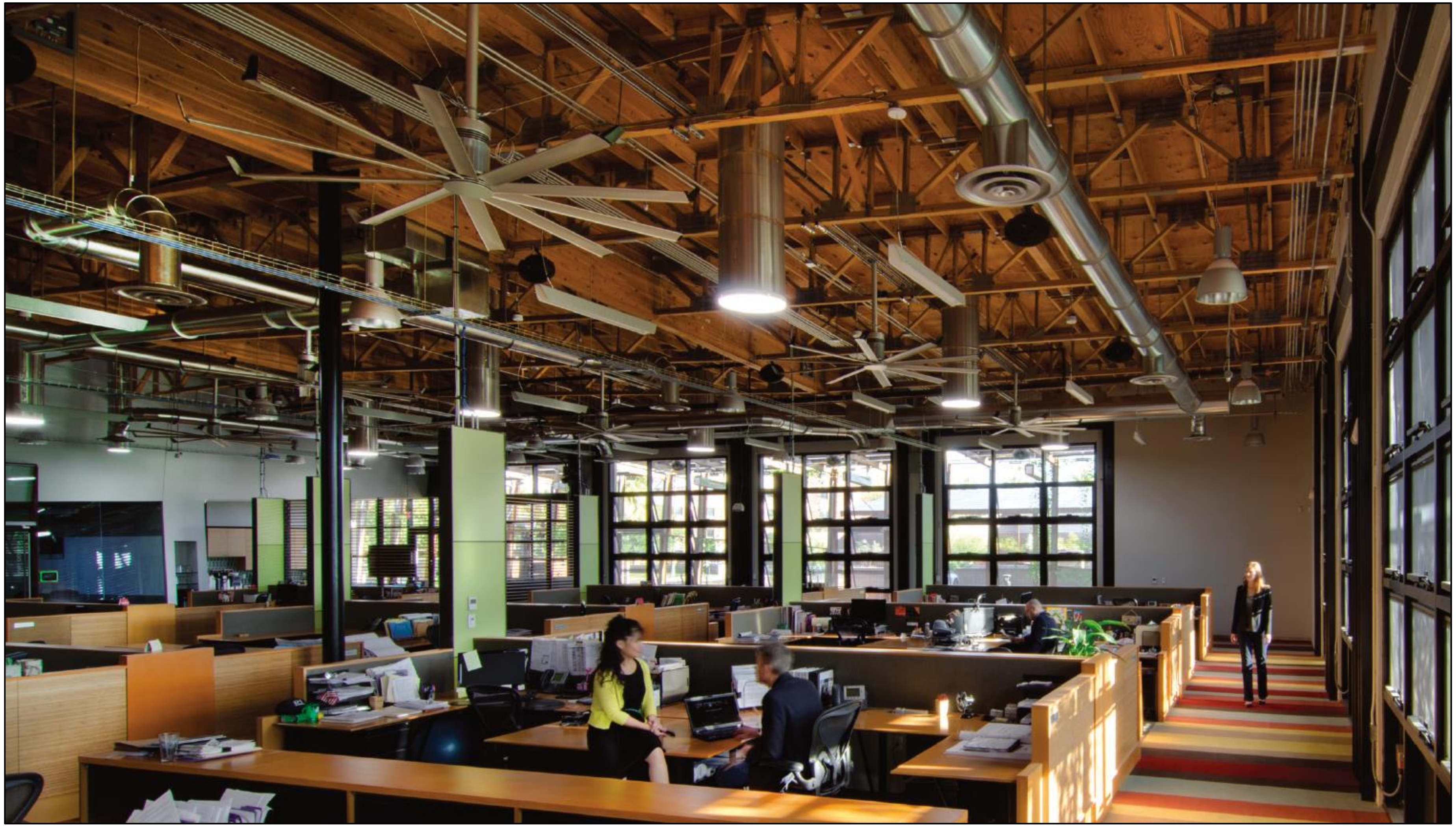
BEAM Plus

- IEQ P1 – Minimum ventilation performance
- IEQ 9 – Increased ventilation
- IEQ 14 – Thermal comfort in naturally ventilated premises

DPR Construction

Fans are a huge component to our passive cooling comfort system. Our net-zero design would not work without them. The fans also add to our look; we've received a lot of compliments on them.

U.S. GREEN BUILDING COUNCIL
LEED PLATINUM
USGBC ™



Zero Carbon Building

We highly recommend the use of fans for ventilation wherever possible and for supplementing the air-conditioning system to save energy.

HK-BEAM ECO BUILDING
環保建築
PLATINUM

- Green building is continuing to grow internationally
- Several green rating systems
- Incorporating elevated air speed in a project can contribute to earning credits

Portland Community College, Newberg, OR Net-Zero Energy

Case Studies

Case Study: Berea College Deep Green Residence Hall

Challenge: **Enhanced HVAC Efficiency**

- Berea College, a pioneer in sustainable living
- The project required innovative HVAC design
- including sustainable components and beautiful design.

Case Study: Berea College Deep Green Residence Hall

- Use of ceiling fans made from sustainable Moso

- 58% energy savings when compared to standard dorms.

Together, these innovations allow for:

- higher set points
- contribute to a healthy environment
- LEED Platinum certification

Case Study: Bullitt Center

Challenge: **Increased Energy Savings**

- Target Living Building certification
- Requires both water and energy self-sufficiency

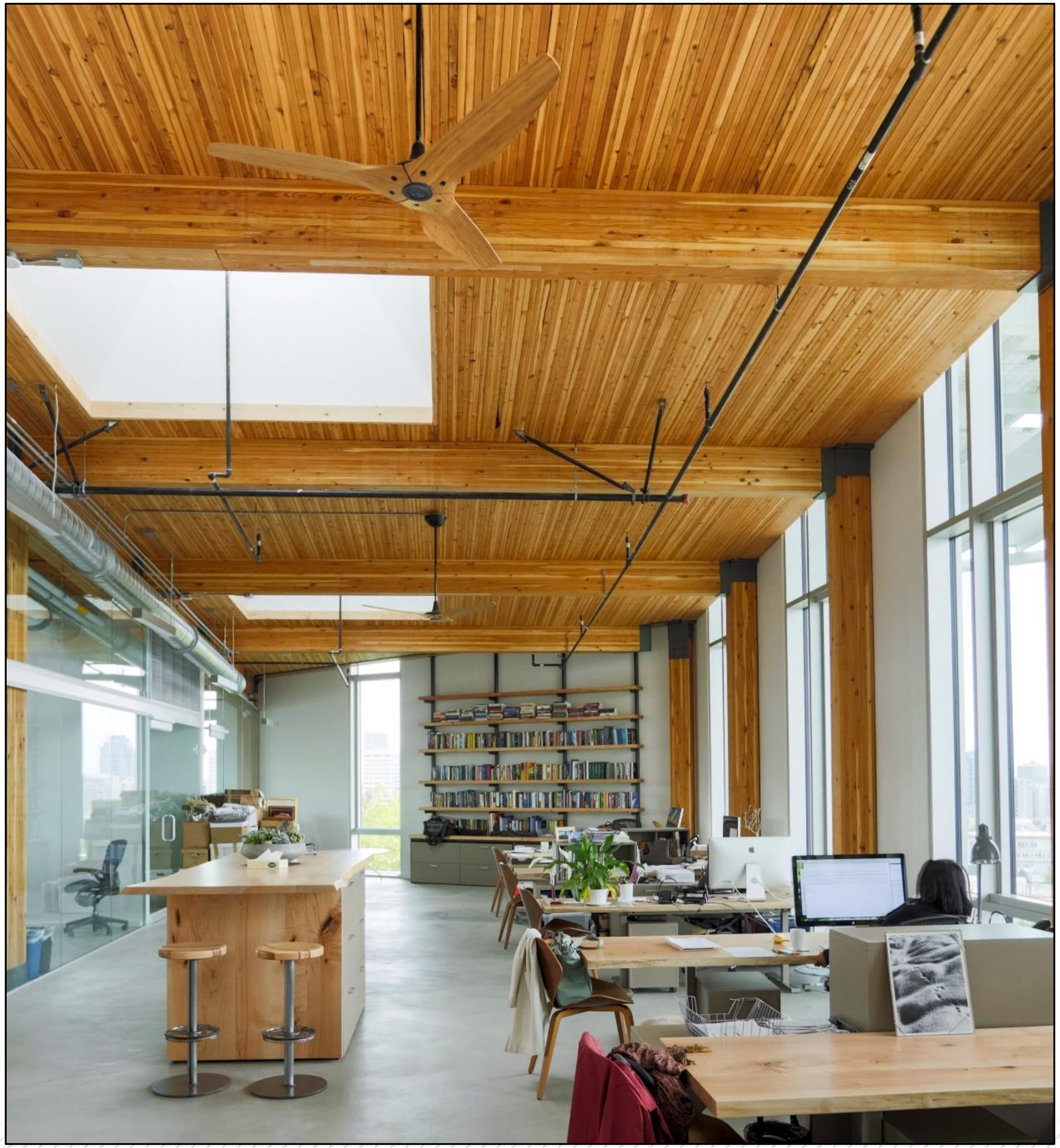
Credit: BullittCenter.org

Case Study: Bullitt Center

Tenants have turned to energy efficient products such as ceiling fans that deliver an 80% improvement in energy efficiency over conventional ceiling fans.

The solutions with ceiling fans contributed to a building that:

- Energy savings and higher IAQ
- Energy efficiency is 83% greater than a typical Seattle office building
- Target the Living Building certification



Zero Carbon Building

Challenge: **Natural Ventilation and Thermal Comfort**

- Hong Kong’s first zero-emission building
- Ingenious ventilation and cooling solution
- Typical air conditioner unable to meet the designers’ goal

Zero Carbon Building

Pairing HVLS fans with other innovative solutions to the ZCB's energy use goals, accomplished:

- an increased in air distribution
- complement the operation of the chilled beam and underfloor displacement

W Bali – Seminyak Retreat & Spa

Challenge: **Improve Guest Comfort**

- Attempts to mechanically regulate temperature
- Costly and inefficient
- Unwilling to sacrifice the comfort of their guests

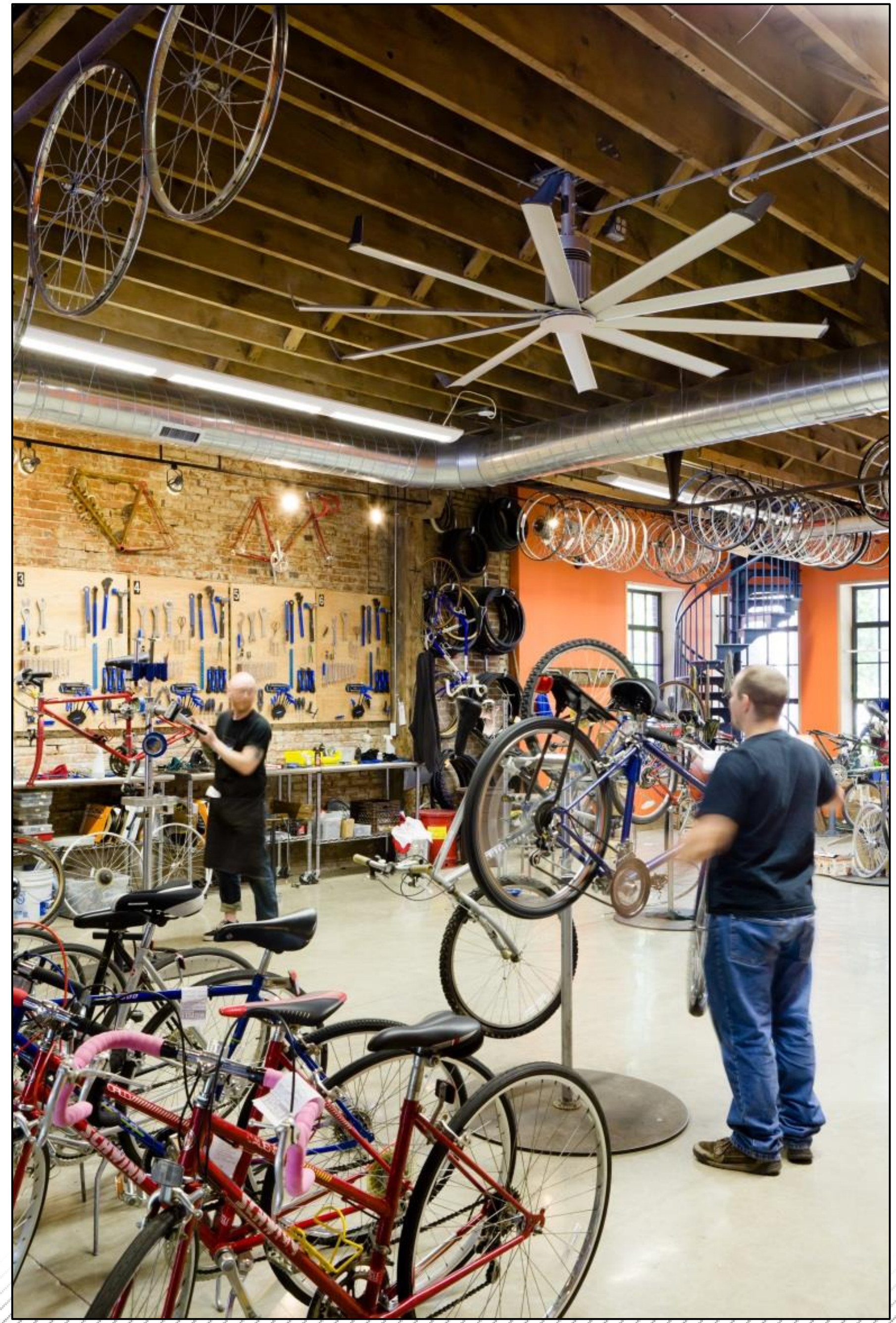
W Bali – Seminyak Retreat & Spa

- Increase the thermal comfort of patrons and employees
- Striking design feature
- Not disrupting the guests’ activities

Summary

Air Movement =

- Improve thermal comfort
- Summer and Winter energy savings
- Sustainable design
- Improve air distribution
- Reduce condensation



Questions?