Sustainable Design and Management of Buildings for Energy Efficiency and Healthy Environment

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Contents

Learning objectives

- Be familiar with the design criteria and process
- Understand the design strategies and impact on energy and indoor environmental quality;
- Grasp sustainable building design technologies;
- Understand the role of operation and management for healthy buildings.

1. Environmental Design Criteria

General of Design

— identifying user requirements

— designing to meet these requirements with minimal energy use

— establishing an integrated design team with a brief and contract that promotes energy efficiency

— setting energy targets at an early stage and designing within them

— designing for manageability, maintainability, operability and flexibility

— checking that the final design meets the targets.

Healthy Building and Environment

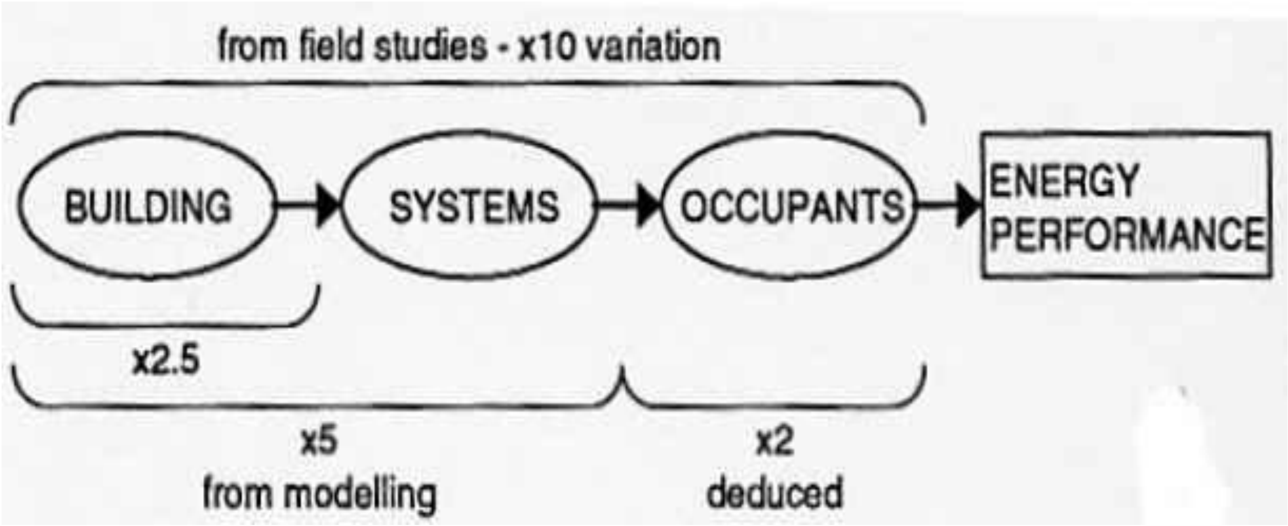
Start from Planning and Design

Design and construction stages (RIBA plan of work)		
Preparation	A	**Appraisal**
	B	**Design Brief**
Design	C	**Concept**
	D	**Design Development**
	E	**Technical Design**
Pre-Construction	F	**Product Information**
	G	**Tender Document**
	H	**Tender Action**
Construction	J	**Mobilisation**
	K	**Construction to Practical Completion**
Use	L	**Post Practical Completion**

RIBA Plan of work for building design and construction (Phillips, 2008).

2. Energy efficiency and passive design method

Building, system and occupant factors affecting energy consumption in non-domestic buildings
(Source: Nick Baker)



Strategic design process

Success depends on understanding the interactions between people, building fabric and services

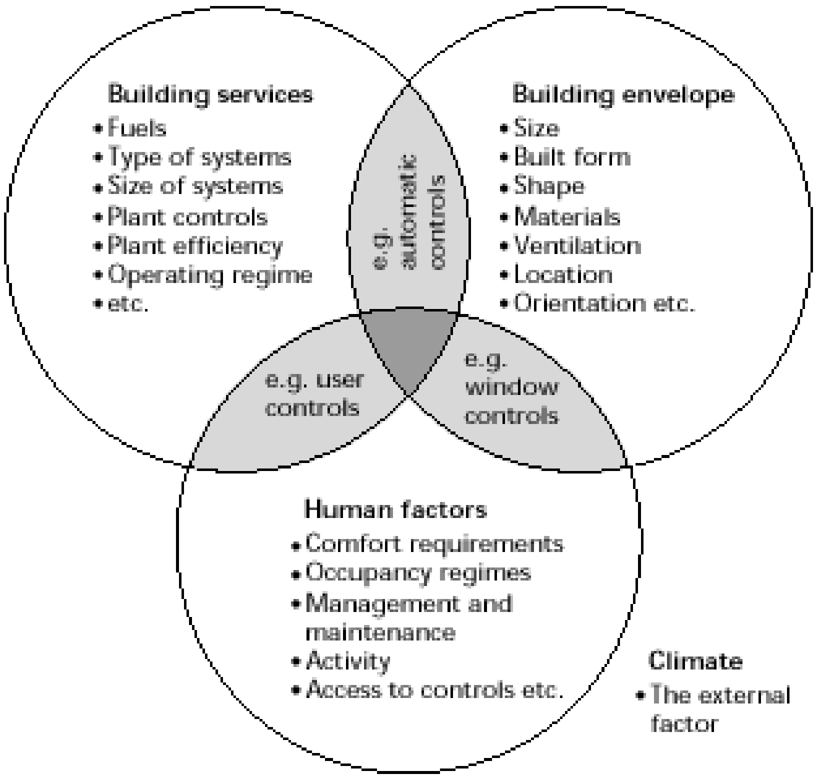
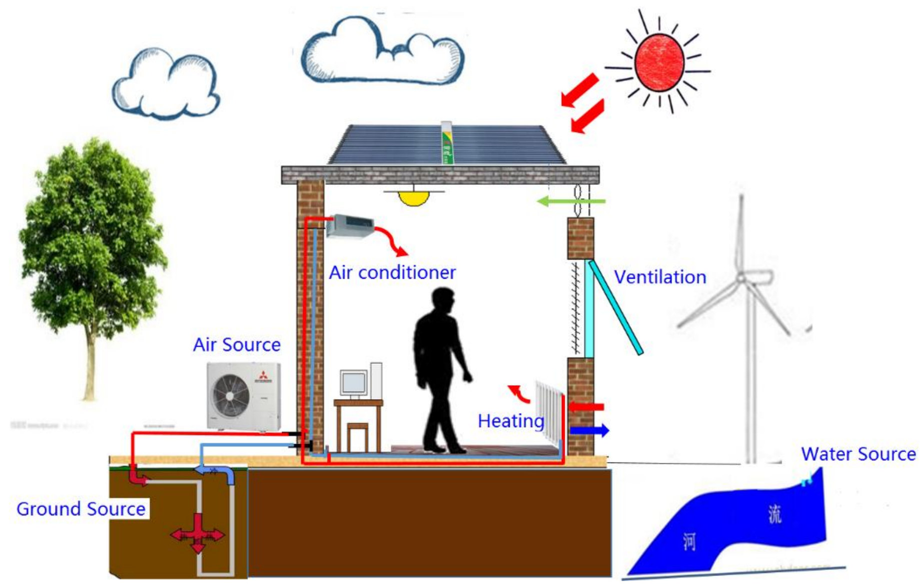
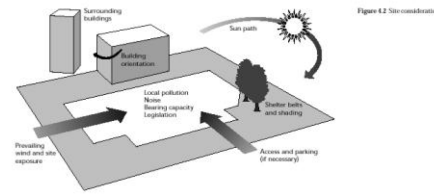


Figure 2.1 Key factors that influence energy consumption

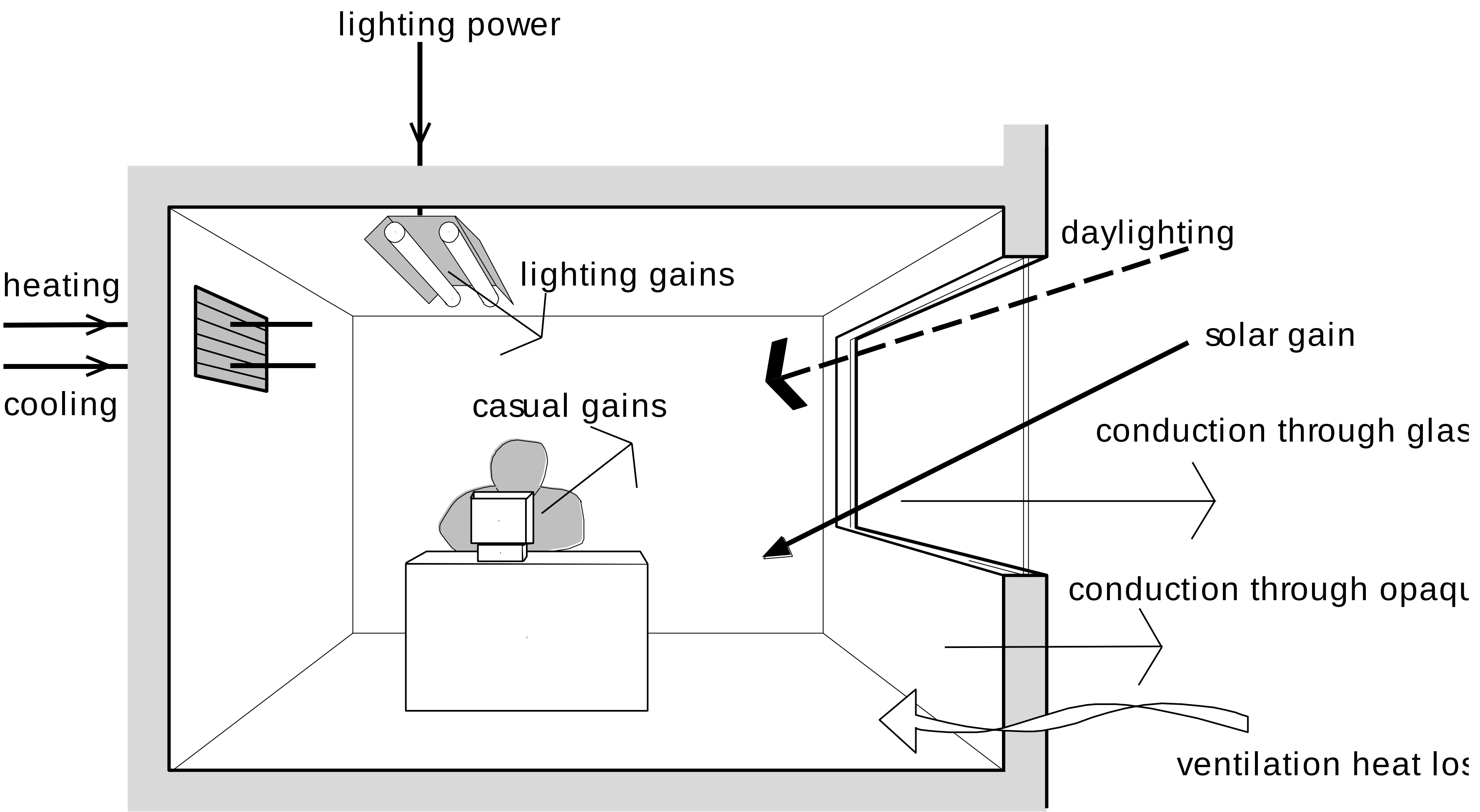


Strategic design process

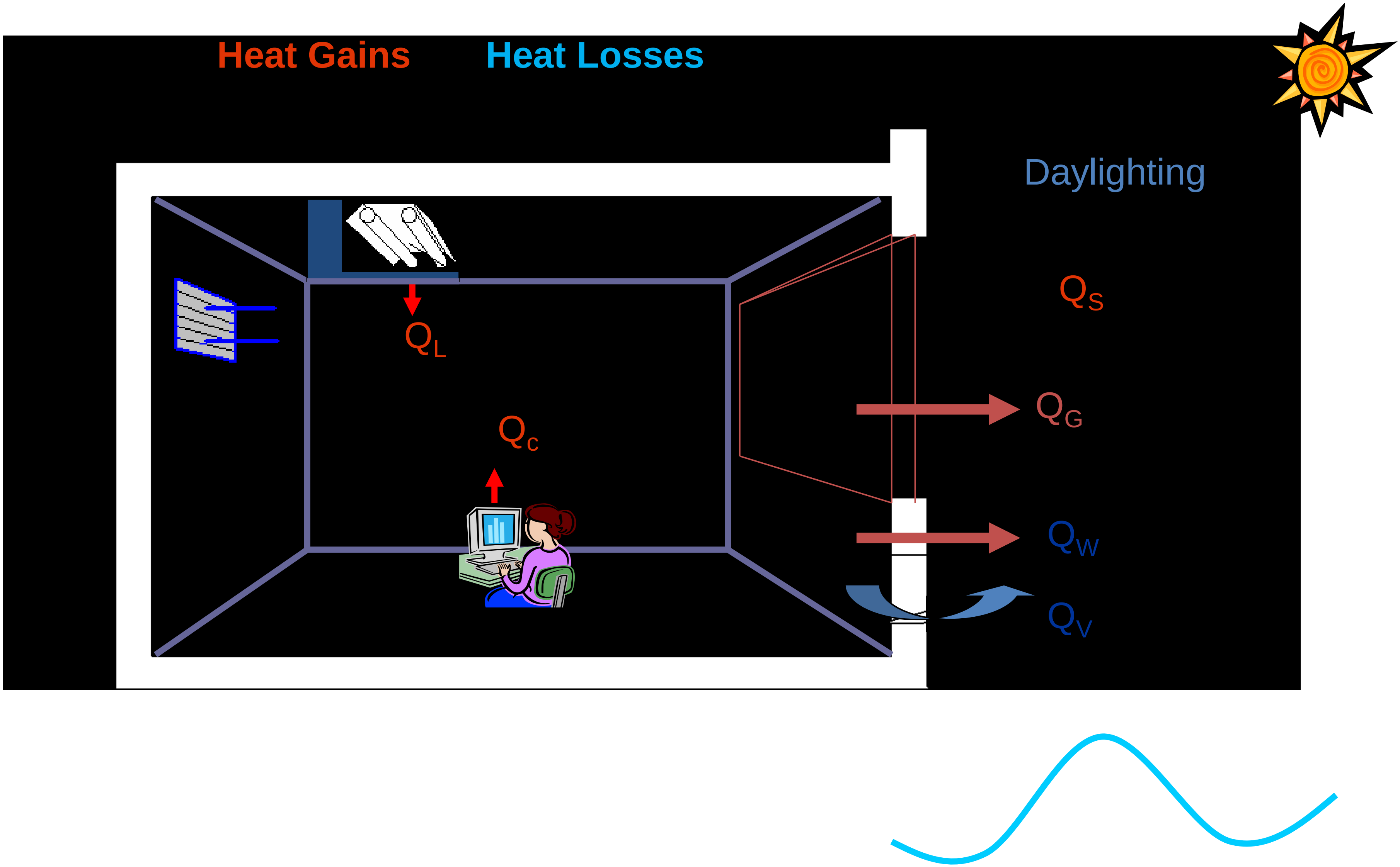


Indoor Air Quality

Site considerations
• Location and weather
• Microclimate
• Site layout
• Orientation
Built form
• Shape
• Thermal response
• Insulation
• Windows/glazing
Ventilation strategy
Daylighting strategy
Services strategy
• Plant and controls
• Fuels
• Metering


lighting power
heating
cooling
lighting gains
casual gains
daylighting
solar gain
conduction through glas
conduction through opaqu
ventilation heat los

Energy balance of the room



Heat Gain

Q_S: Solar Gain

Q_L: Lighting Gain

Q_C: Casual Gain - people, computer, etc

Q_H: Auxiliary Heating

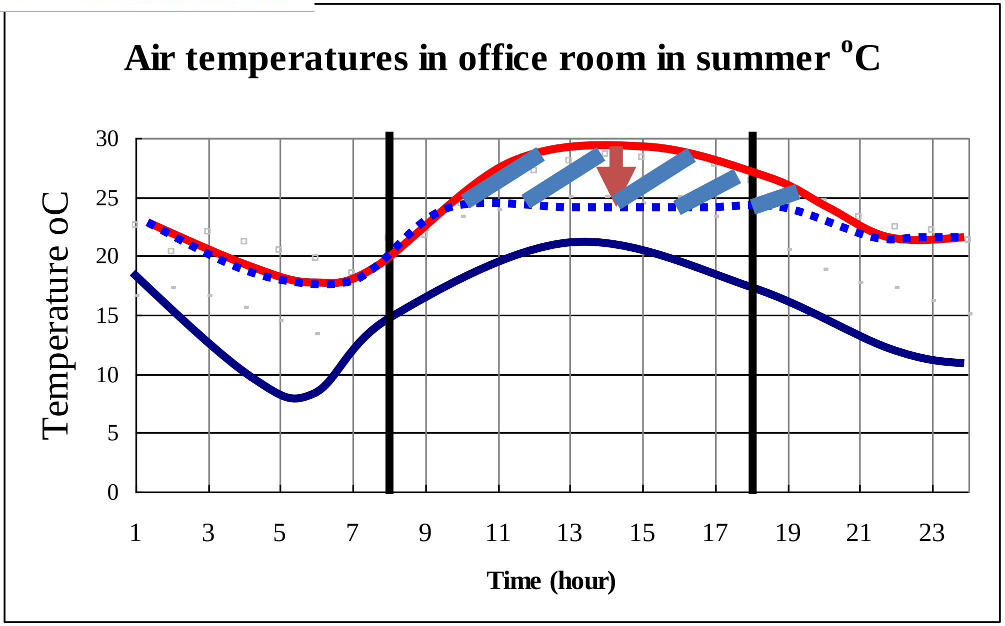
Heat Loss

Q_G: Conductive loss through window

Q_W: Conductive loss through wall

Q_V: Convective loss via ventilation

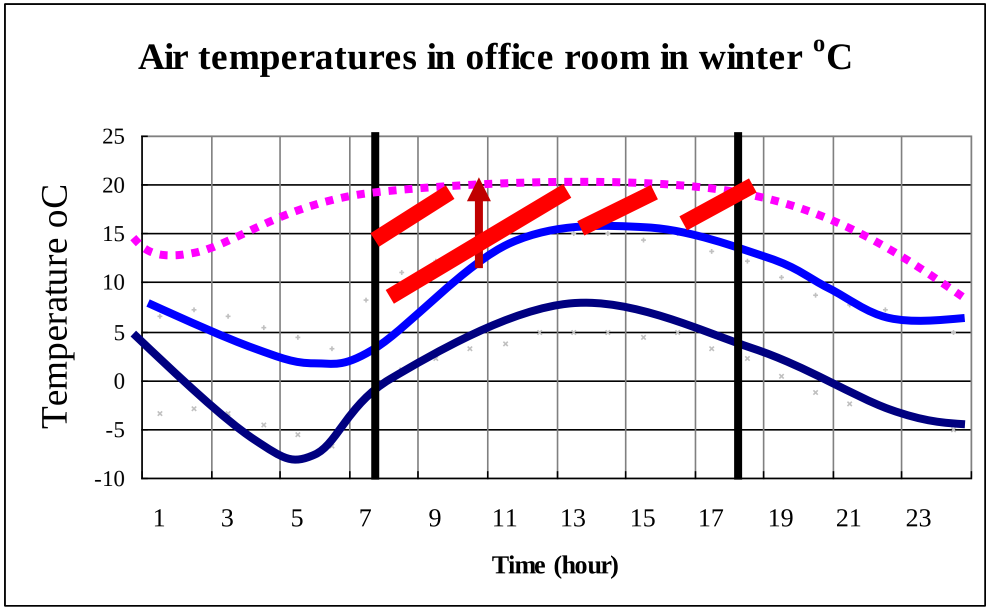
Q_C: Auxiliary cooling



Cooling energy

indoor

external



Heating energy

indoor

external

Passive building design

Definition

A building design that uses structural elements of a building to insulate, light, heat and cool a building, without the use of mechanical /electrical equipment.

Glass Building in London

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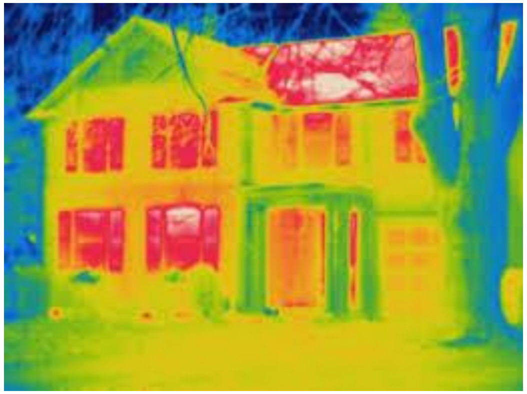
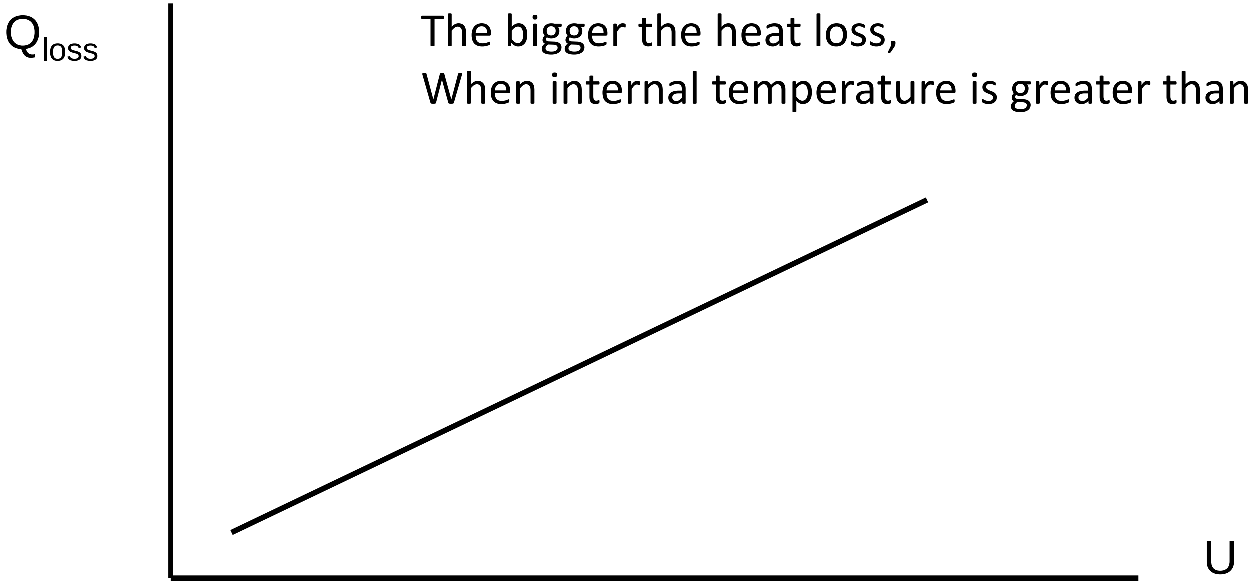
Envelope design

Heat loss through the envelope



$$Q_{loss}=U*A*(T_{in}-T_{out})$$

The bigger the U value,
The bigger the heat loss,
When internal temperature is greater than external

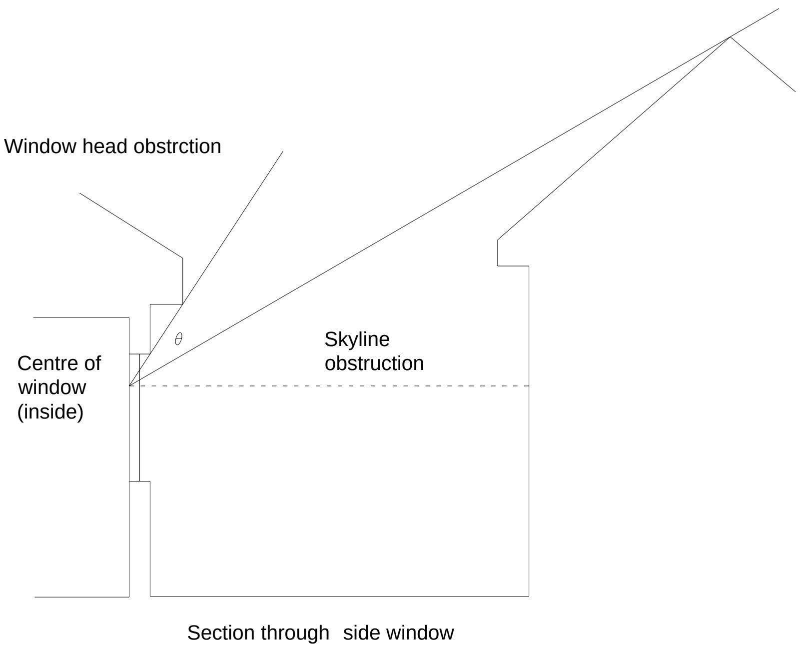


U-value improvement rates

Year	Walls	Floors	Window	Doors	roof lights	roof
1965	1.7					1.4
1976	1	1				0.6
1985	0.45	0.45				0.35
1991	0.45	0.35	3	3	3	0.35
1994	0.45	0.35	3	3	3	0.25
2000	0.35	0.25	2	2	2	0.2
2002	0.35	0.25	2	2	2	0.2
2006	0.3	0.22	1.8	2.2	1.8	0.2
2007-08	0.2	0.22	1.6	-	-	0.16
Code Level 6	0.11	0.11	-	-	-	0.11

Window and window systems design

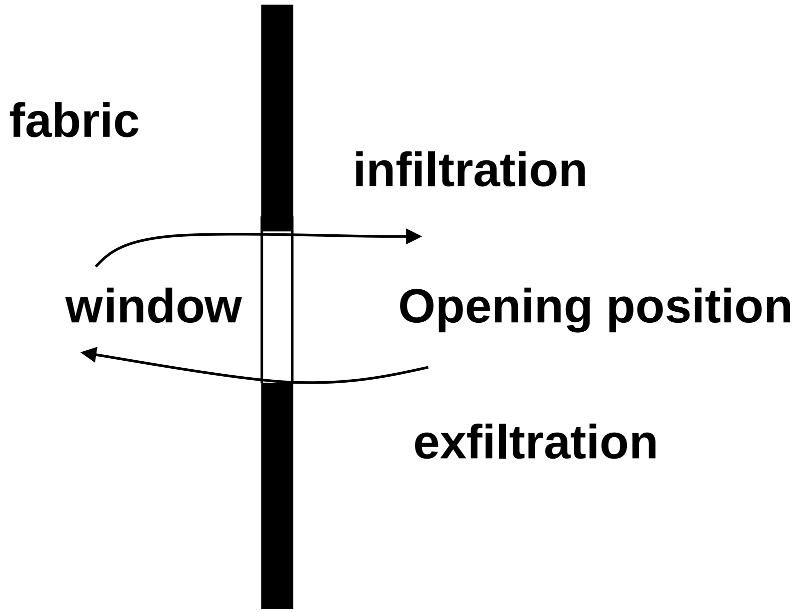


Important element in sustainable design

- Insulation
- Solar
- Lighting
- view
- ventilation

Associated with shading systems

Window Design



Microclimate around window

Windows influence natural Ventilation

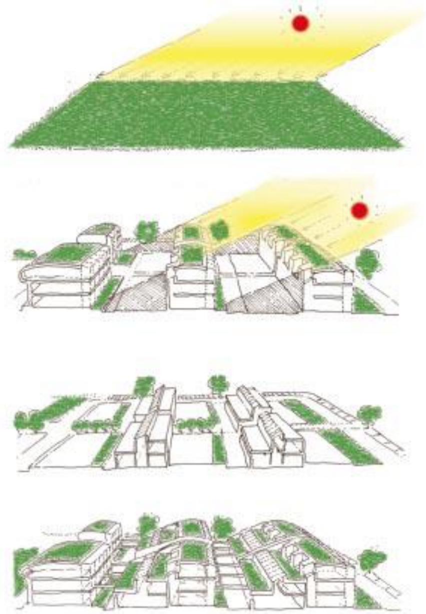
- Leakage between glass and frame
- Low surface temperature
- Admits solar radiation
- Opening styles create different micro climates

Glazing area

The amount of glazing obviously influences the amount of daylight available, but a larger window area is not always better as it may simply increase contrast. Large windows admit light but also lead to heat gains and heat losses, and thus potential thermal discomfort.

But, it could provider a better outdoor views and some psychological needs…

Case study -BedZed

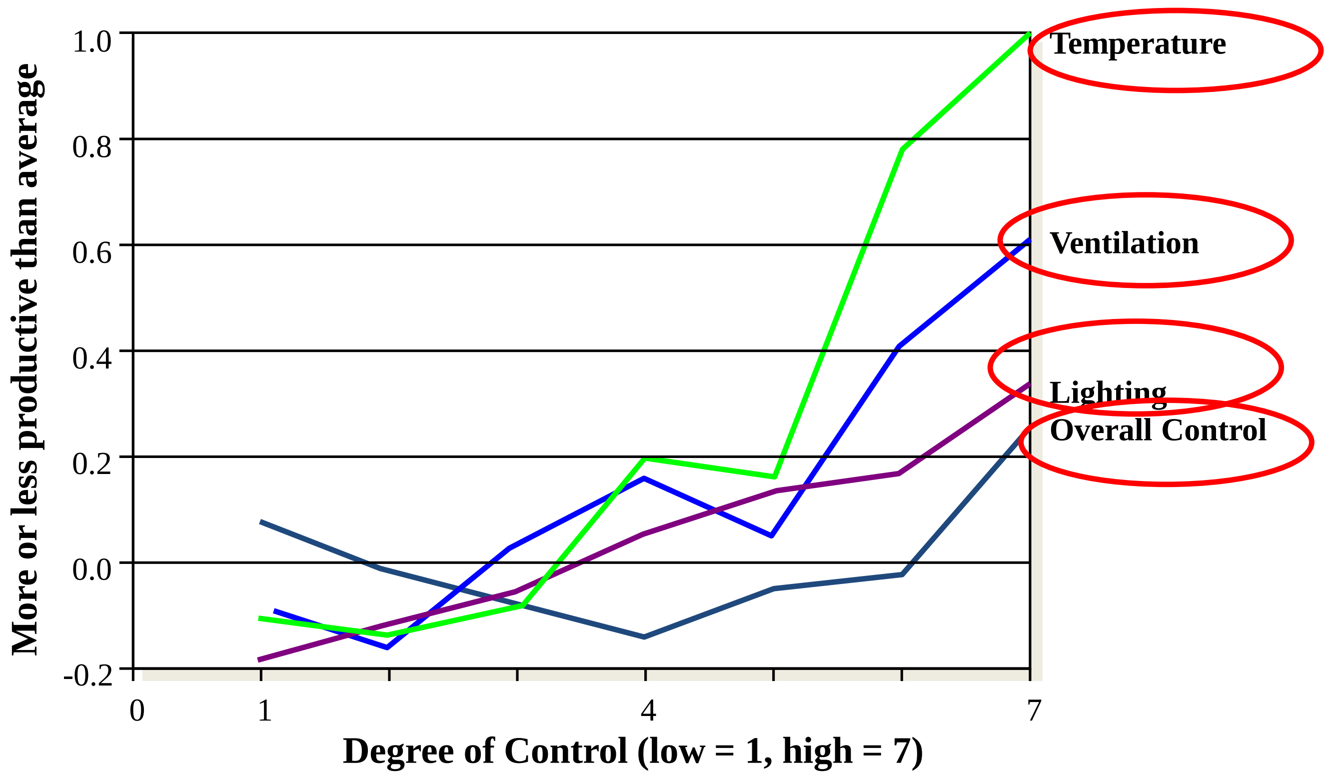


[Watch the BedZED video]

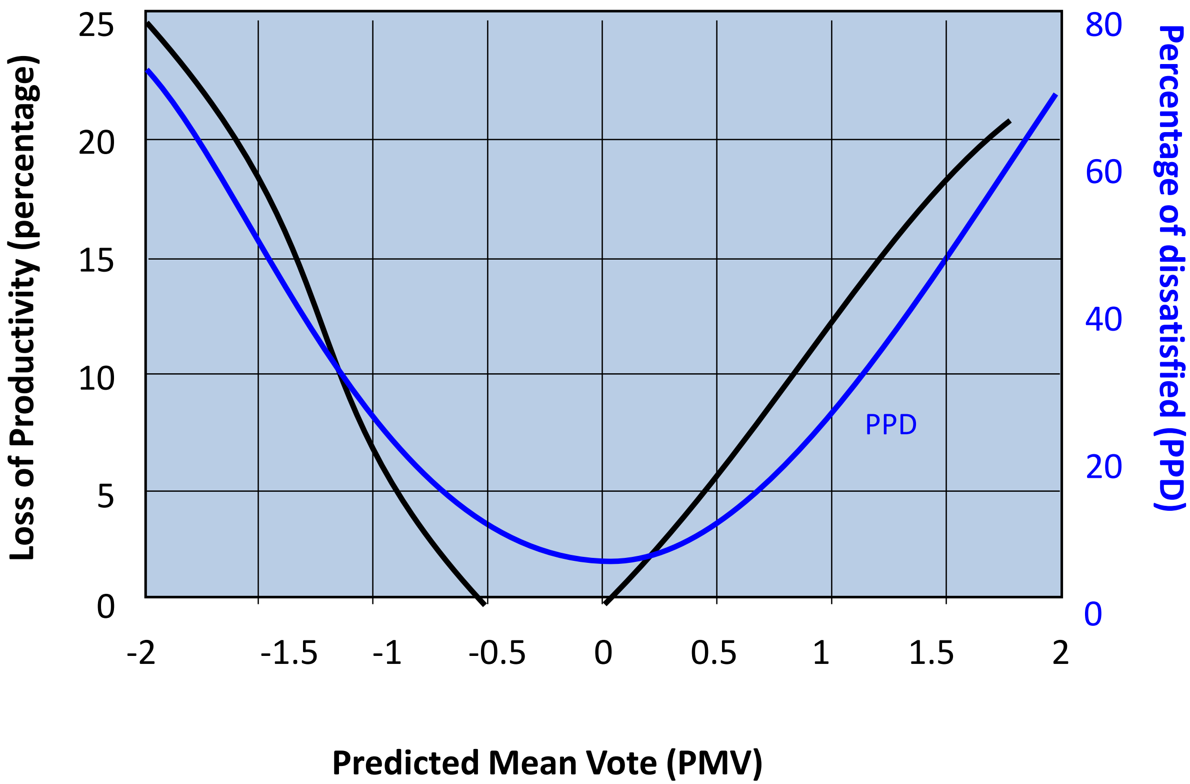
3. Indoor Environmental Quality and Impact

Workplace Productivity

Relationship between Self-reports of Productivity and Levels of Control Over Temperature, Ventilation, Lighting and Overall Control



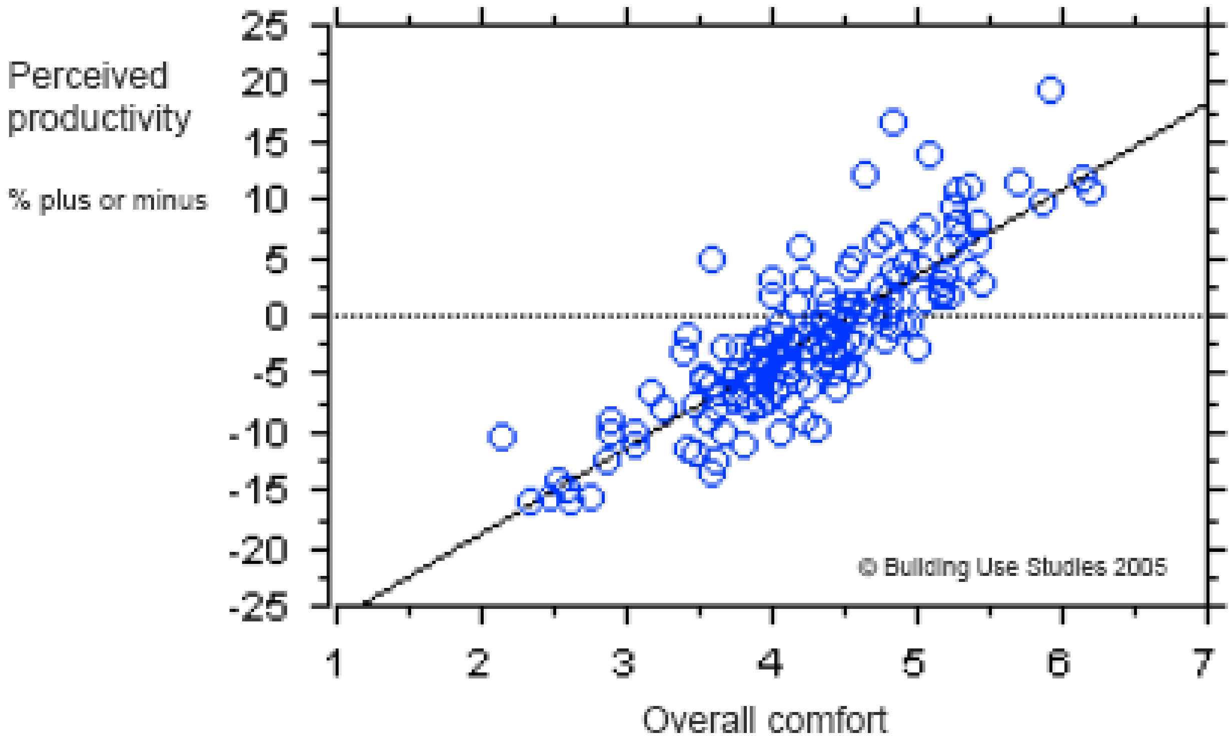
Relationship between the Loss of Productivity, PPD and the PMV



Source: Roelofsen, 2001

Loss of Productivity and PPD
as a function of the PMV

Perceived Comfort and Perceived Productivity

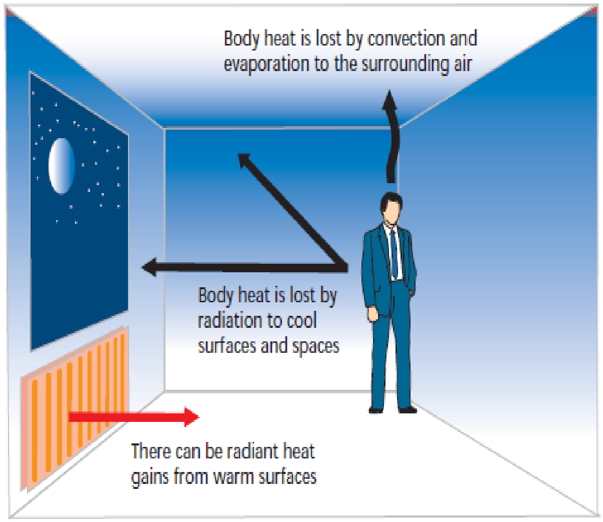


Interpretation:
This is based on n=151 buildings from Building Use Studies' international dataset for the variables overall comfort and perceived productivity. This is a strong and significant relationship.

$r=0.84$
$r^2=0.7$
$p=<0.0001$

Leaman and Bordass in Clements-Croome, 2005

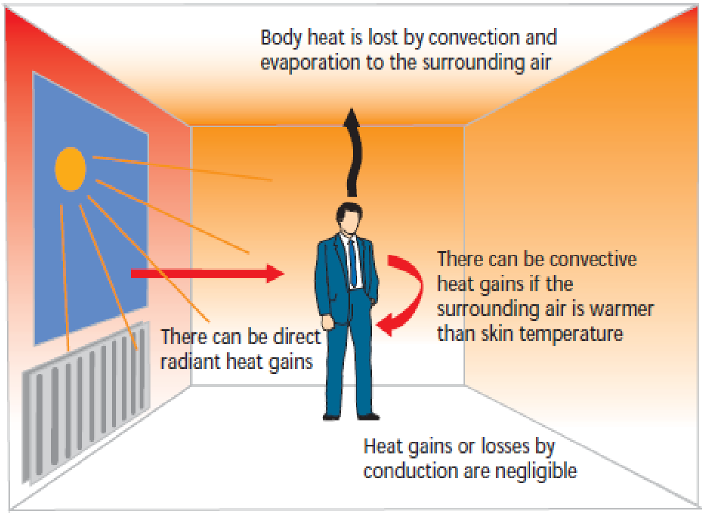
Thermal comfort



(a) Cool evening

Defined in the ISO 7730 standard as **that condition of mind which expresses satisfaction with the thermal environment**

Thermal comfort is where there is broad satisfaction with the thermal environment i.e. most people are neither too hot or too cold.



(b) Sunny day

What determines thermal comfort?

Environmental:

- Temperature
- Humidity
- Air movement
- Air quality

Individual:

- Metabolic rate
- Clothing insulation

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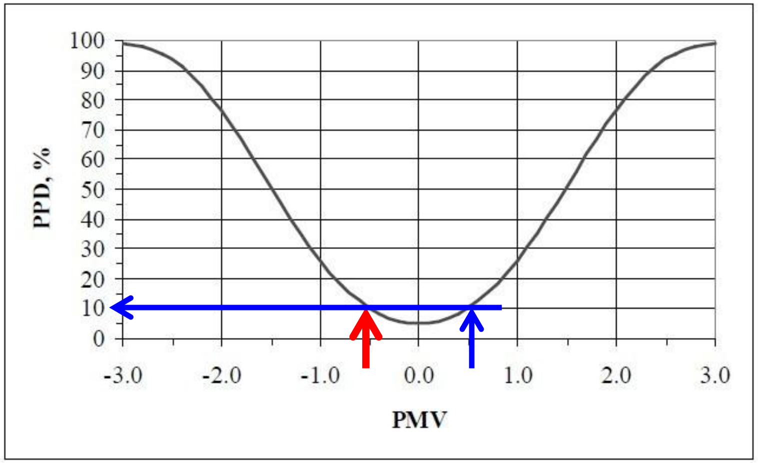
PMV/PPD

PMV: Predicted Mean Vote

The Index that predicts the value of the vote of a large group of people on the 7-point thermal sensation scale

-3	-2	-1	0	+1	+2	+3
cold	cool	slightly cool	Neutral	slight warm	warm	hot

PPD: Predicted Percentage Dissatisfied



International Standards

Current thermal comfort standards and guidelines

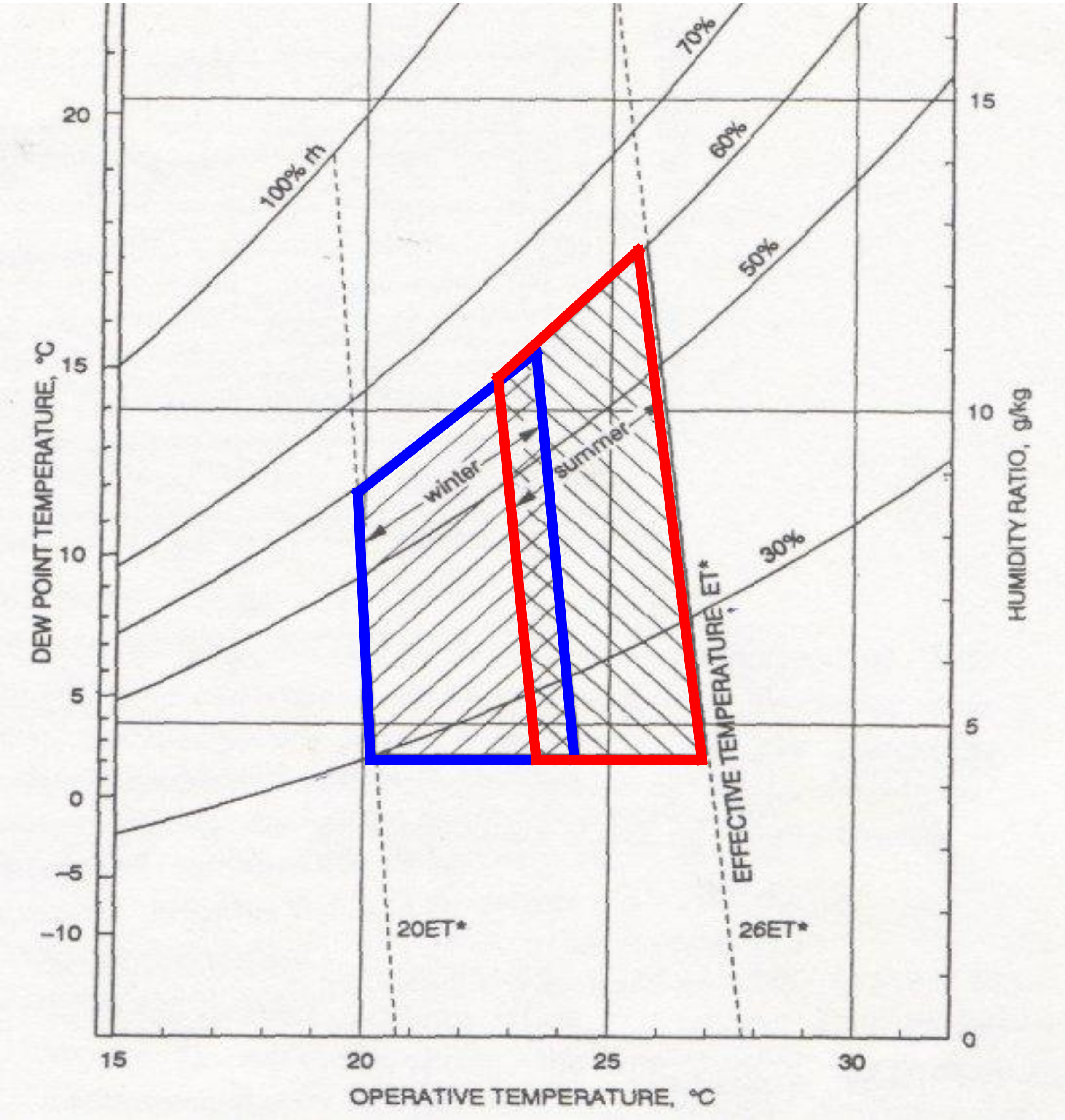
- ISO 7730,
- ASHRAE 55-1992, 95a
- EN 15251,
- CIBSE Guides A1 (thermal comfort)

They are based mainly on PMV

Operative temperature

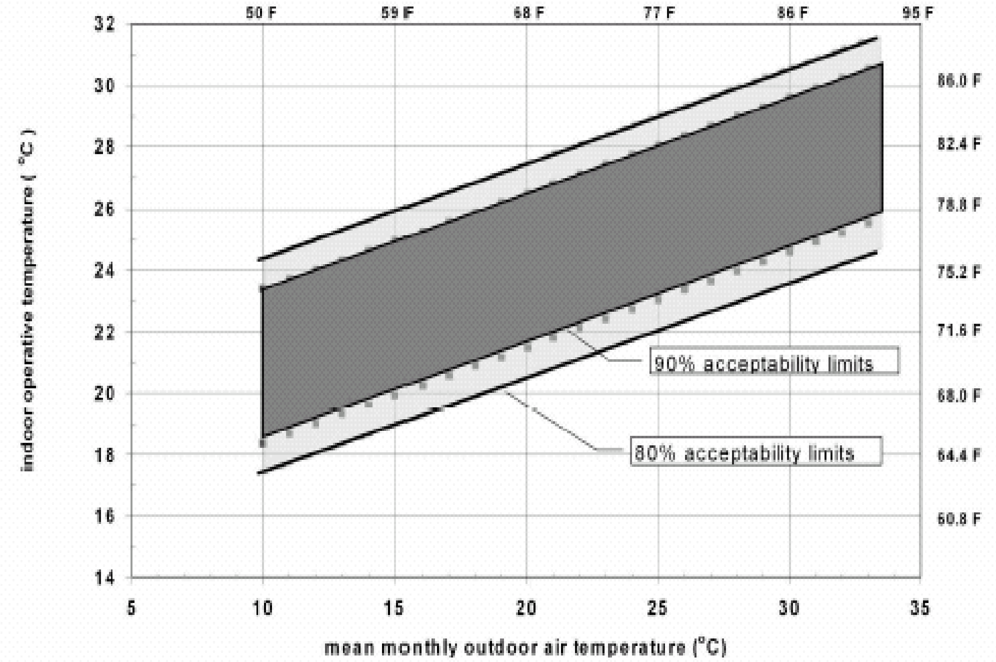
Acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing (< 1.2 met).

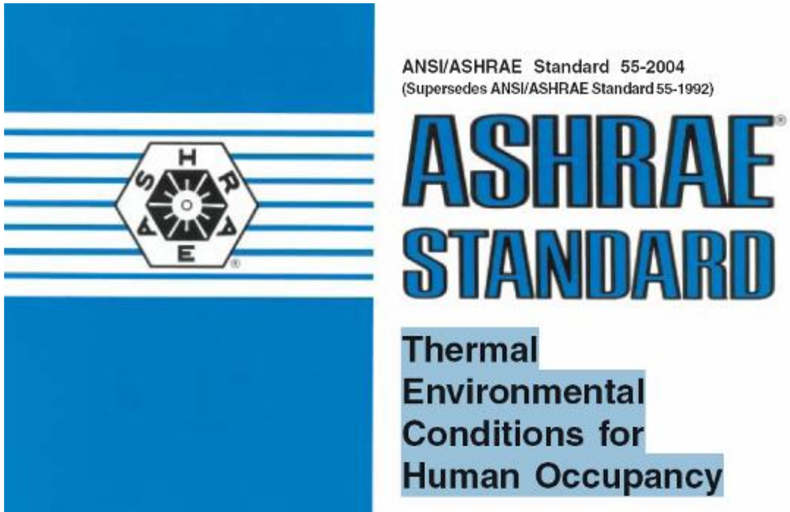
The ranges are based on a 10% dissatisfaction criterion.

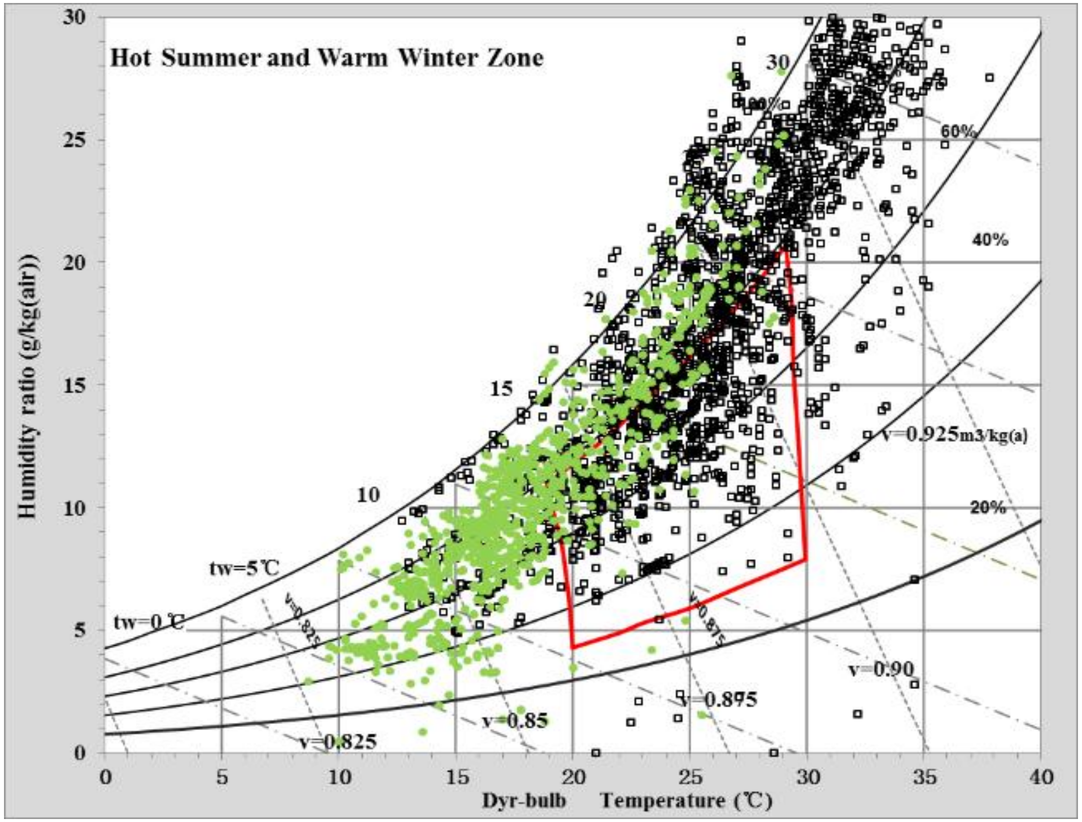


Adaptive thermal comfort

Acceptable ranges of air temperature for sedentary physical activities in naturally ventilated buildings.



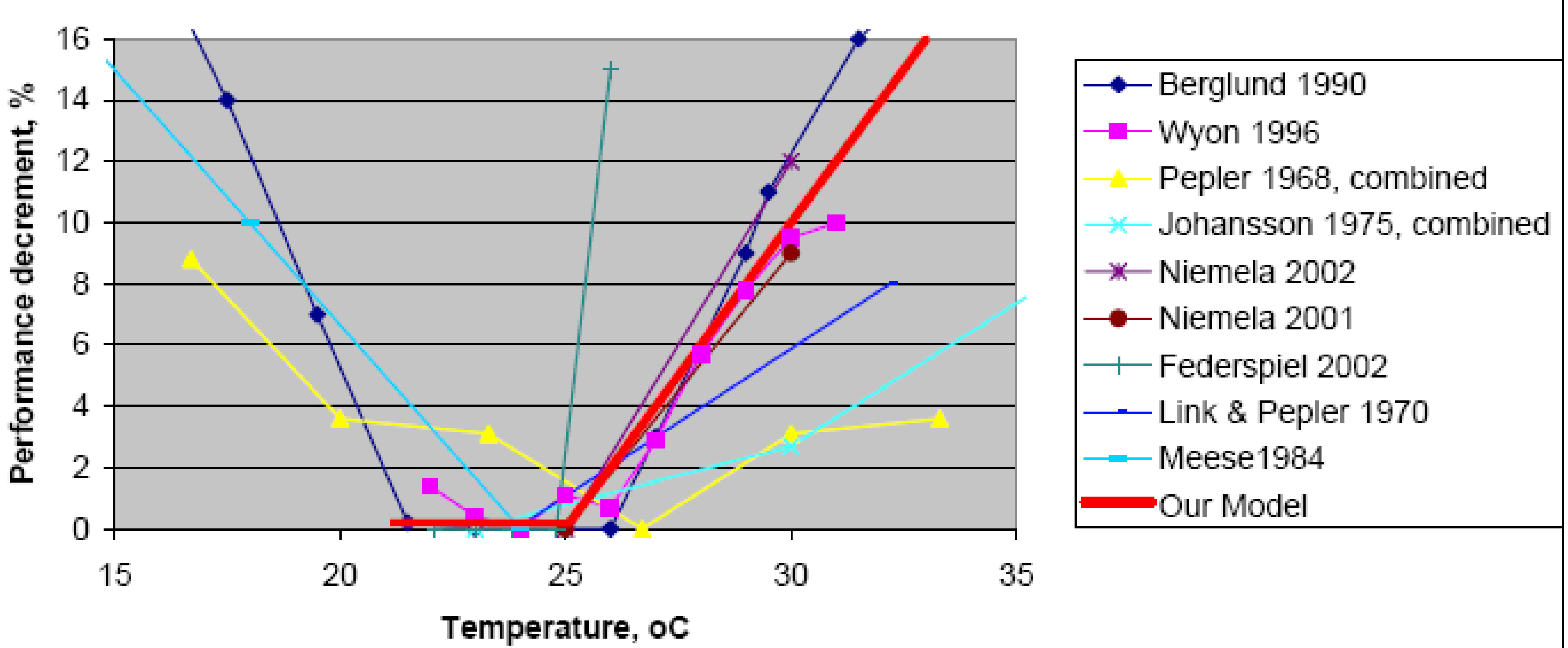




Hot Summer and Warm Winter Zone
Humidity ratio (g/kg(air))
Dyr-bulb Temperature (℃)
tw=5℃
tw=0℃
10
15
20
30
60%
40%
20%
v=0.925m3/kg(a)
v=0.90
v=0.875
v=0.85
v=0.825

Decrease of Performance with Temperature

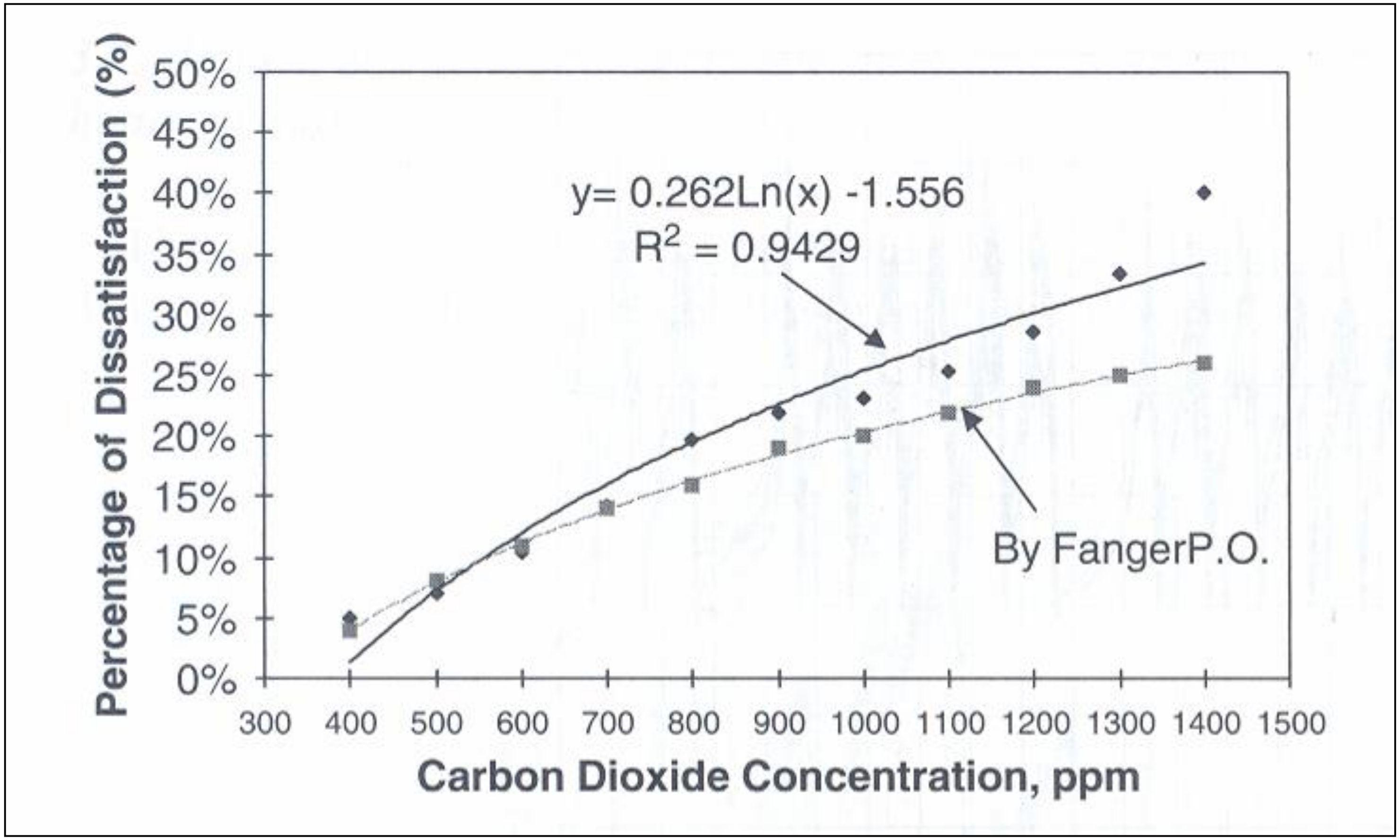
2% decrease per deg C above 25^{0}C and below 20^{0}C



(Seppanen et al, Proceedings of Healthy Buildings, Singapore, Volume 3

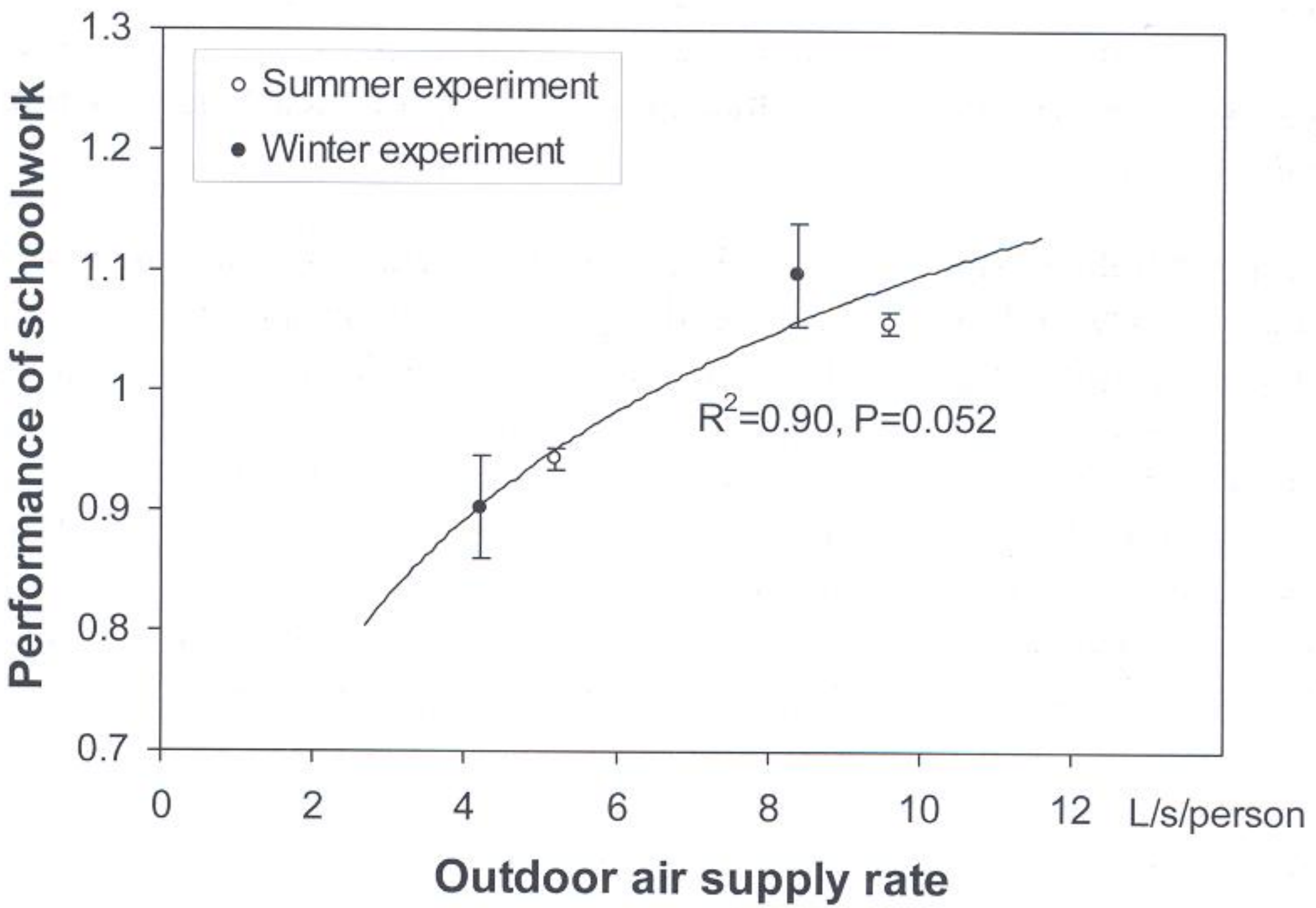
CO2 concentration and ventilation

Percentage of dissatisfaction again carbon dioxide concentration



Mu & Chan, (2005), Building calibration for IAQ Management in Building and Environment 41, 877-886

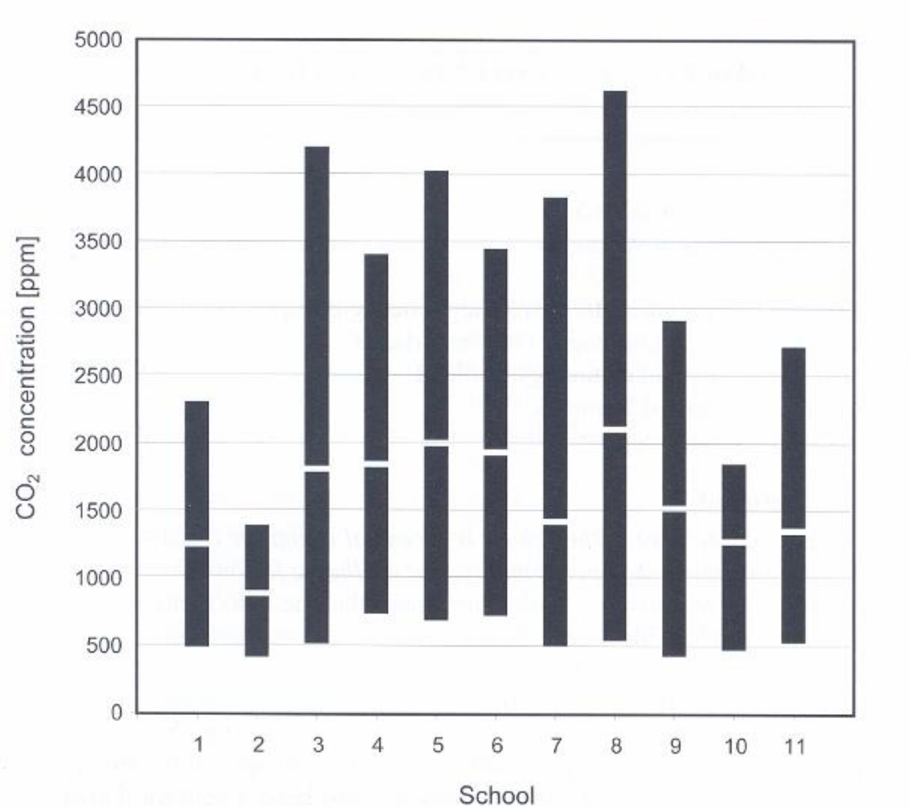
Performance of School Work as a Function of Outdoor Air Supply Rate4



Boerstra et al, Rehva Workshops Clima 2005

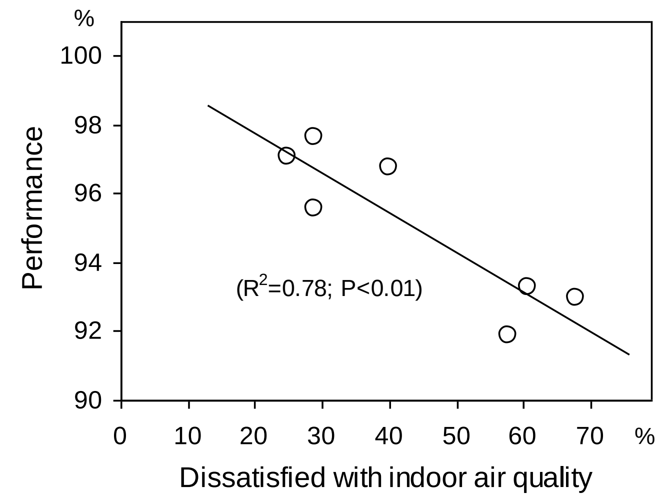
CO2 concentration and ventilation

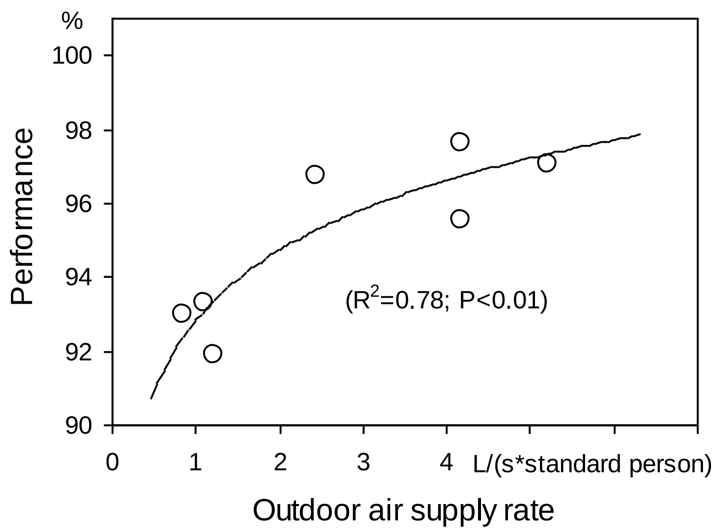
Average, Maximum and Minimum CO2 Concentrations in 11Dutch Primary Schools



(Source: Dijken et ai, 2005) in
Boerstra et al, Rehva Workshops Clima 2005

Performance of office work as a function of the outdoor air supply rate per standard person (olf)





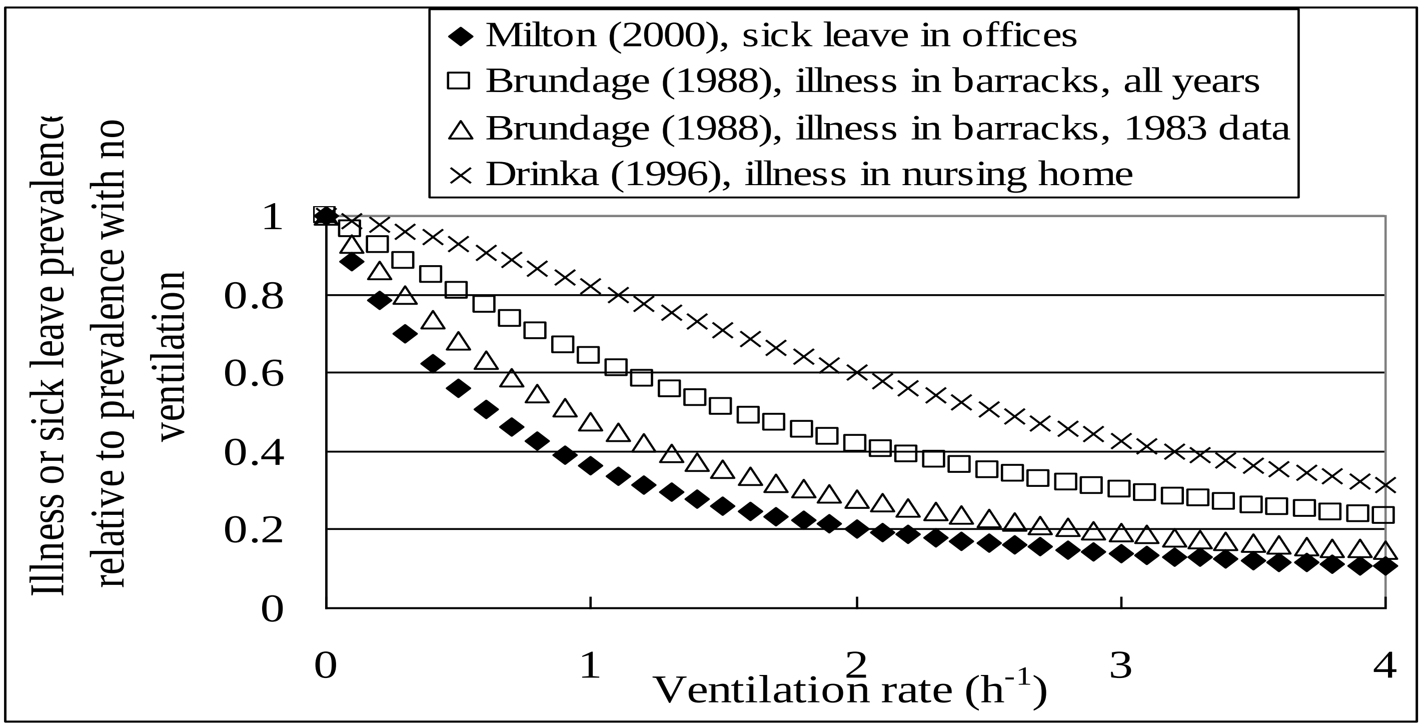
Performance of office work as a function of the indoor air quality

Wyon and Wargocki in Clements-Croome, 2005

Thermal comfort
Fresh air supply
Ventilation

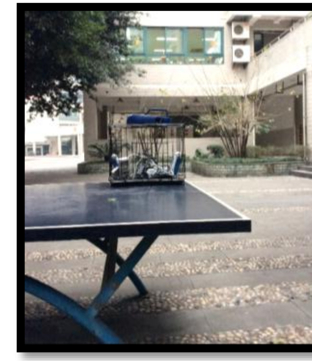
Productivity
Health

Predicted Trends in Illness or Sick Leave Versus Ventilation Rate



Seppanen and Fisk in Clements-Croome, 2005

Halton

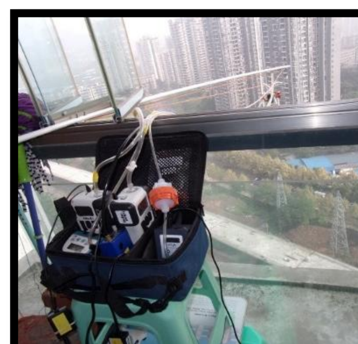


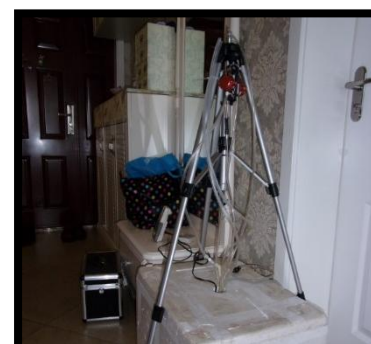
Typical Schedule

Transport | Transport | Outdoor activity

HOME | SCHOOL | HOME | HOME

Home: 55~65%; School: 30~35%





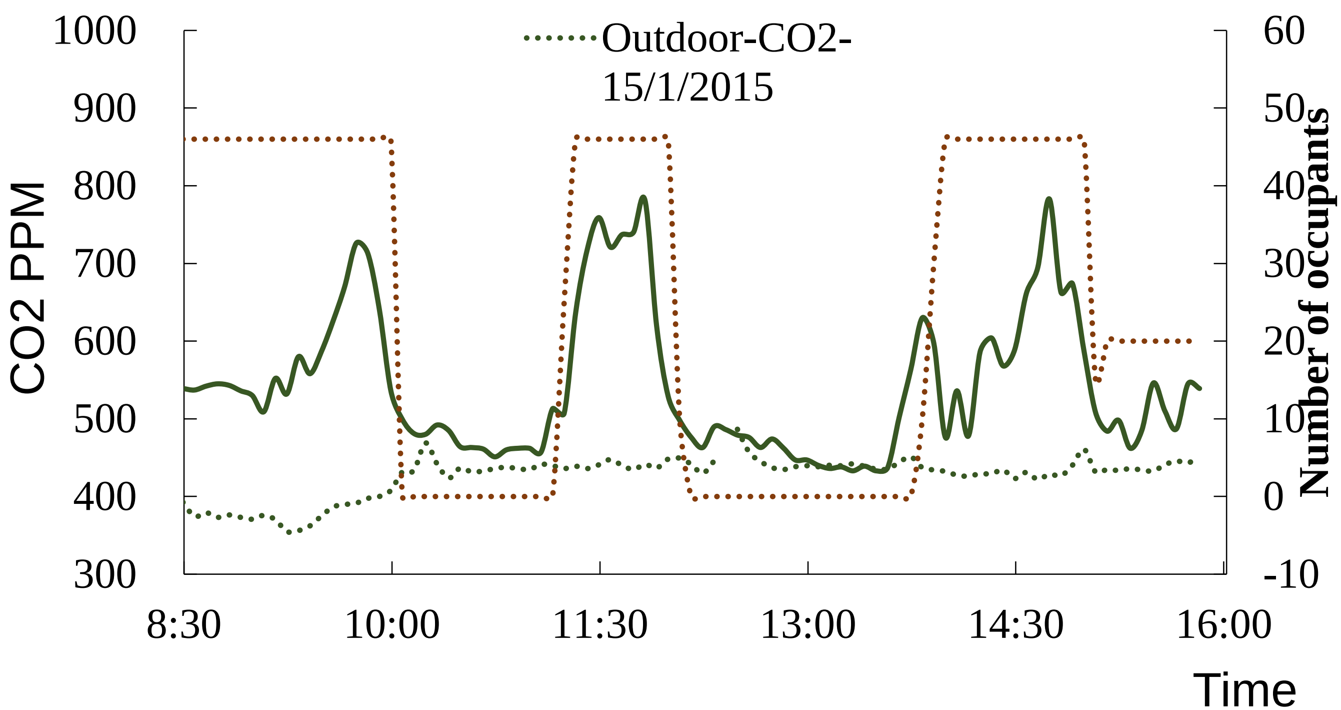
GII

CCH
H

Study in SCHOOL

Chongqing, China

CO_2 and Ventilation



Indoor CO_2

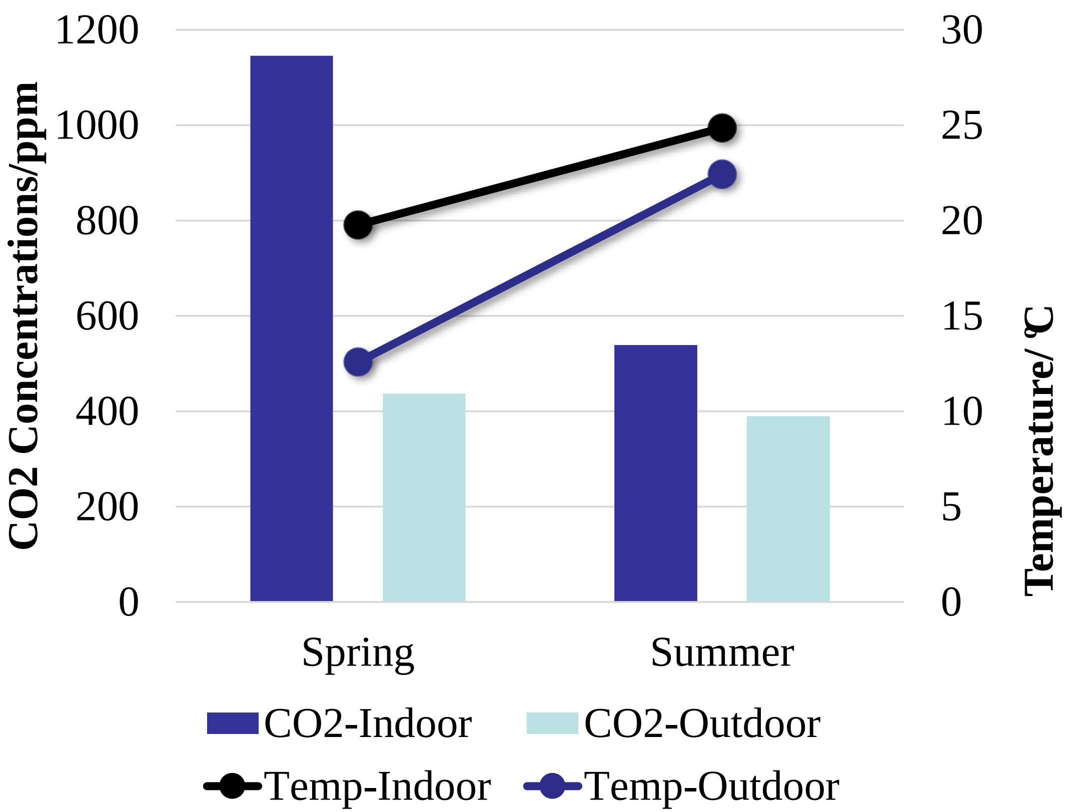
Efficiency of Ventilation

- Outdoor CO_2 concentration remains around 400ppm.
- Indoor CO_2 concentration varies mainly with the number of occupants under natural ventilation in this classroom.

Study in SCHOOL

Reading, UK

CO_2 and Ventilation



Outdoor temperature in spring is lower than summer, occupants tend to close the window to get warm

- Occupants are main heat source, the increased temperature difference of indoor and outdoor environment indicates enhanced airtightness in winter.
- With the increased airtightness, the indoor CO2 concentrations largely soars over 1100ppm.

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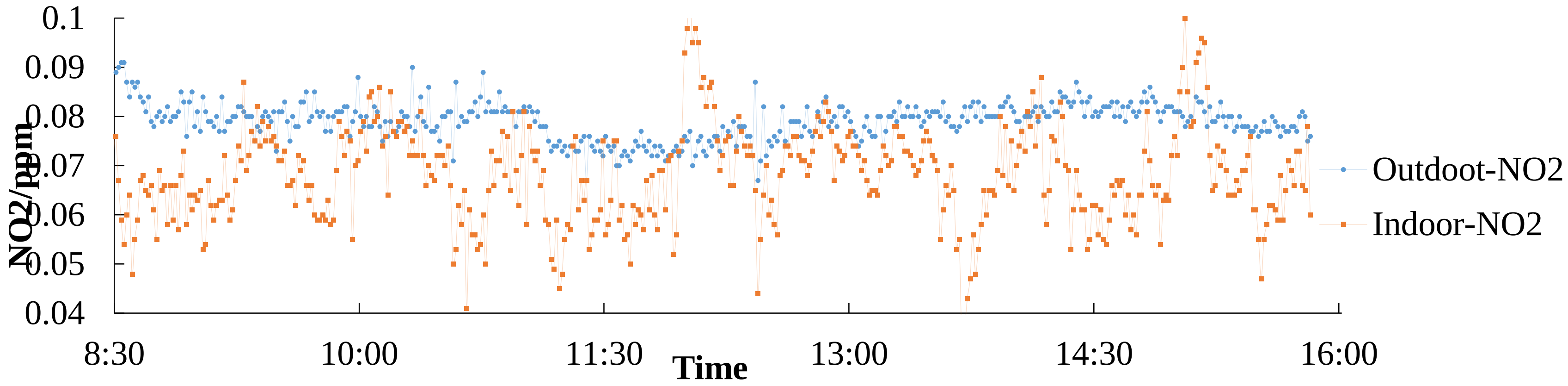
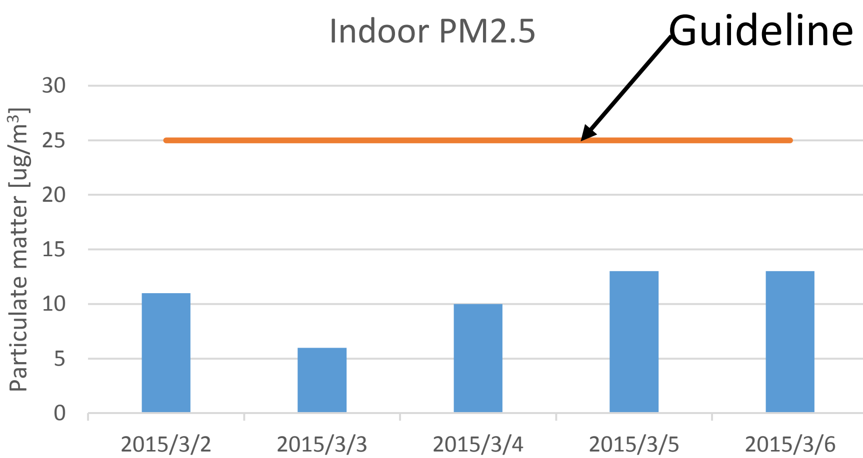
Study in SCHOOL Chongqing, China NO_2

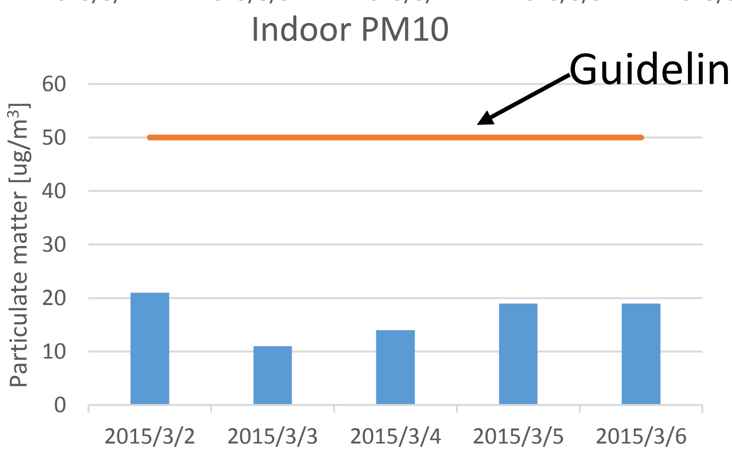


Selected school near main road with heavy traffic.

- Outdoor concentrations are steady with morning peak for rush-hour traffic.
- Indoor concentrations are varied under natural ventilation.
- Indoor average is a little lower than outdoor conditions, but both exceed Chinese standard (threshold for 20-h average is 80 $\mu g/m^3$, almost 0.042 ppm)

Chongqing, China





NO_2

The equipment we use

Dusttrak Drx
Aerosol Monitor 8534

Guideline Average value :
PM10: 50 ug/m^3
PM2.5: 25 ug/m^3

Microgram: equal to one billionth (1×10^{-9}) of a kilogram, one millionth (1×10^{-6}) of a gram, or one thousandth (1×10^{-3}) of a milligram.

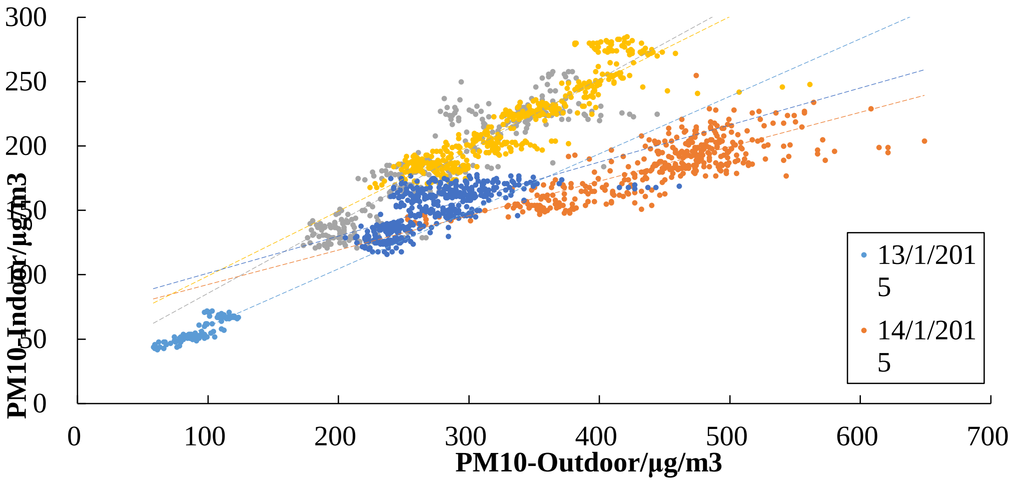
Reference: WHO. WHO air quality guidelines,2005. http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/

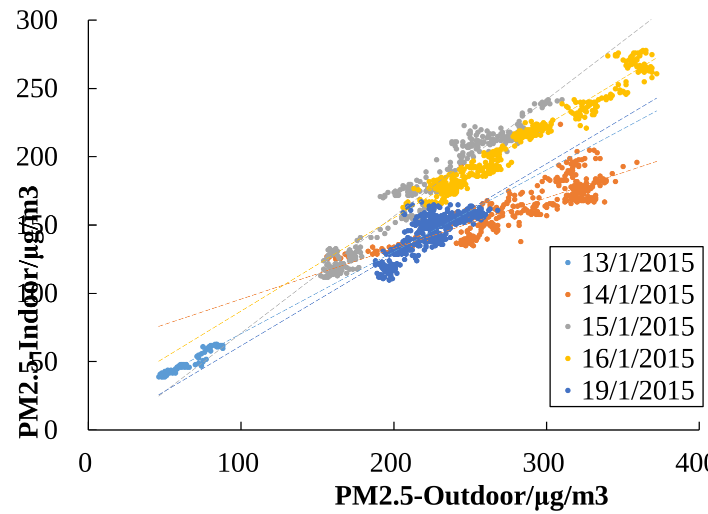
Study in SCHOOL

Chongqing, China

Particulate matter

Indoor/Outdoor relation





Winter

- The relationship between indoor and outdoor particulate matter shows liner relation in winter

  ——*the high level outside and the indoor environment can be easily affected by outdoor particles under natural ventilation.*

- $PM_{2.5}$ shows better regression effect than PM_{10}

  ——*the concentration of $PM_{2.5}$ subjects to the atmospheric environment much easier under server air pollution condition.*

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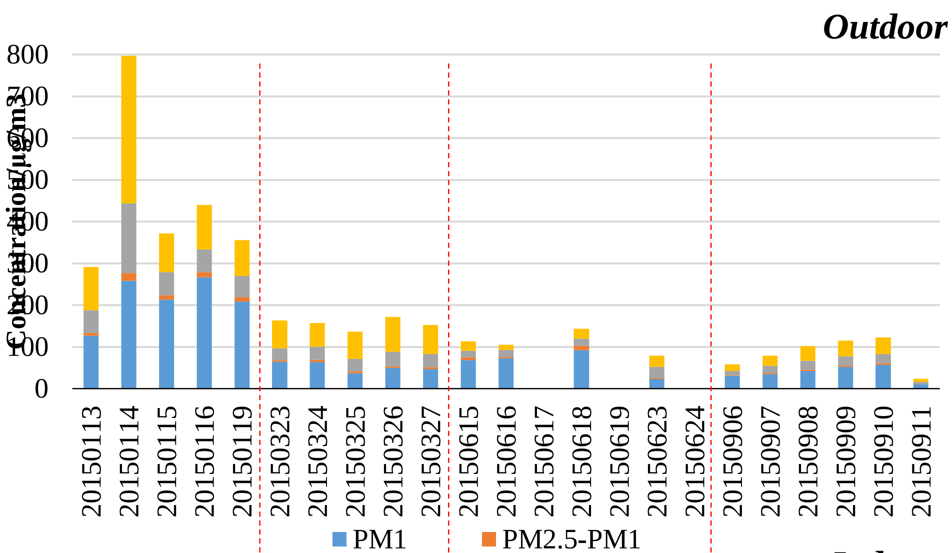
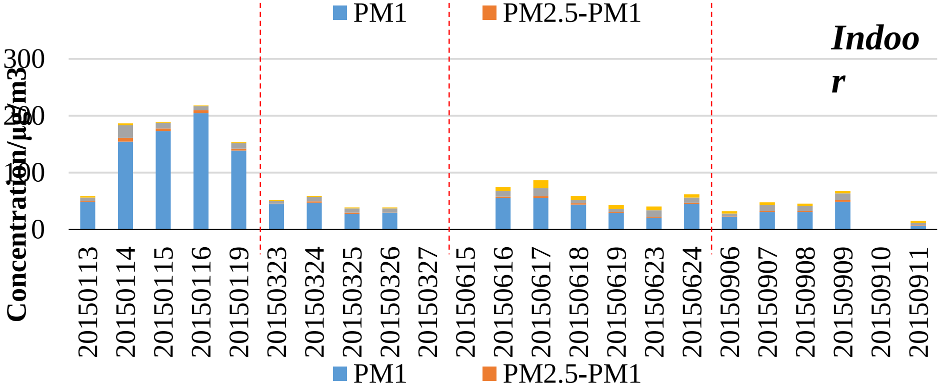
Study in SCHOOL

Chongqing, China

Particulate matter

Seasonal variation





- Concentrations of particulate matter are obviously higher in Winter.
- Fine particle is dominating at indoor environment.

✓ *Fine particle has higher infiltration rate;*

✓ *Fine particle is easily re-suspended with children's indoor activities.*

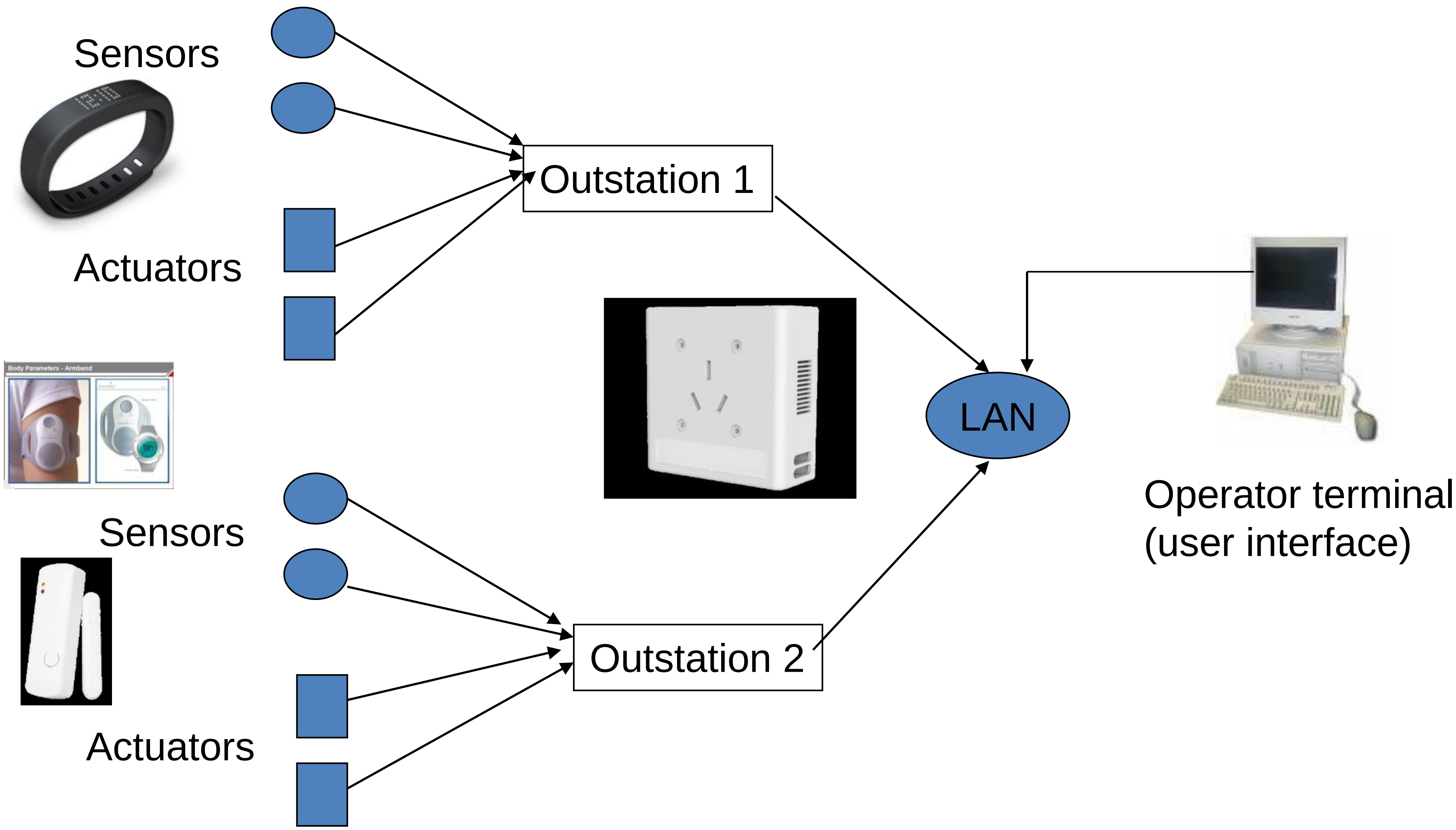
5. People-Centric Design and Management

Pentland Lakeside © www.nickwoodphoto.com

5. People-Centric Intelligent Operation and Management

- Use of space + settings
- Functionality + comfort
- Look, feel, brand, aesthetics
- Internal + external sense of place
- Environmental issues
- Space management
- Technology + cultural factors
- Urban realities: work + life

Building management systems, network and integration



LAN- local area network

5. People-Centric Design and Management

But not just ‘the building’: also inside, around + beyond

Summary:

- Importance of environmental architecture design;
- Balancing the energy and IEQ;
- Passive design technologies
- Design and operation buildings for People feeling good

  (Health, Productivity and Happy)

Reading lists:

- CIBSE Guide A Environmental design
- Yao R. ed, Design and management of sustainable built environments; Springer 2013ISBN 978-1-4471-4780-7

  Chapter 11- Energy efficient building design

  Chapter 20 –BRE Innovative Park- some lessons learnt from the demonstration buildings

Thank you for your listening!