ASHRAE Distinguished Lecturer Talk

ASHRAE India Chapter
New Delhi
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Ventilation, IAQ and Energy Issues in hot humid climates – Past, Present and Future

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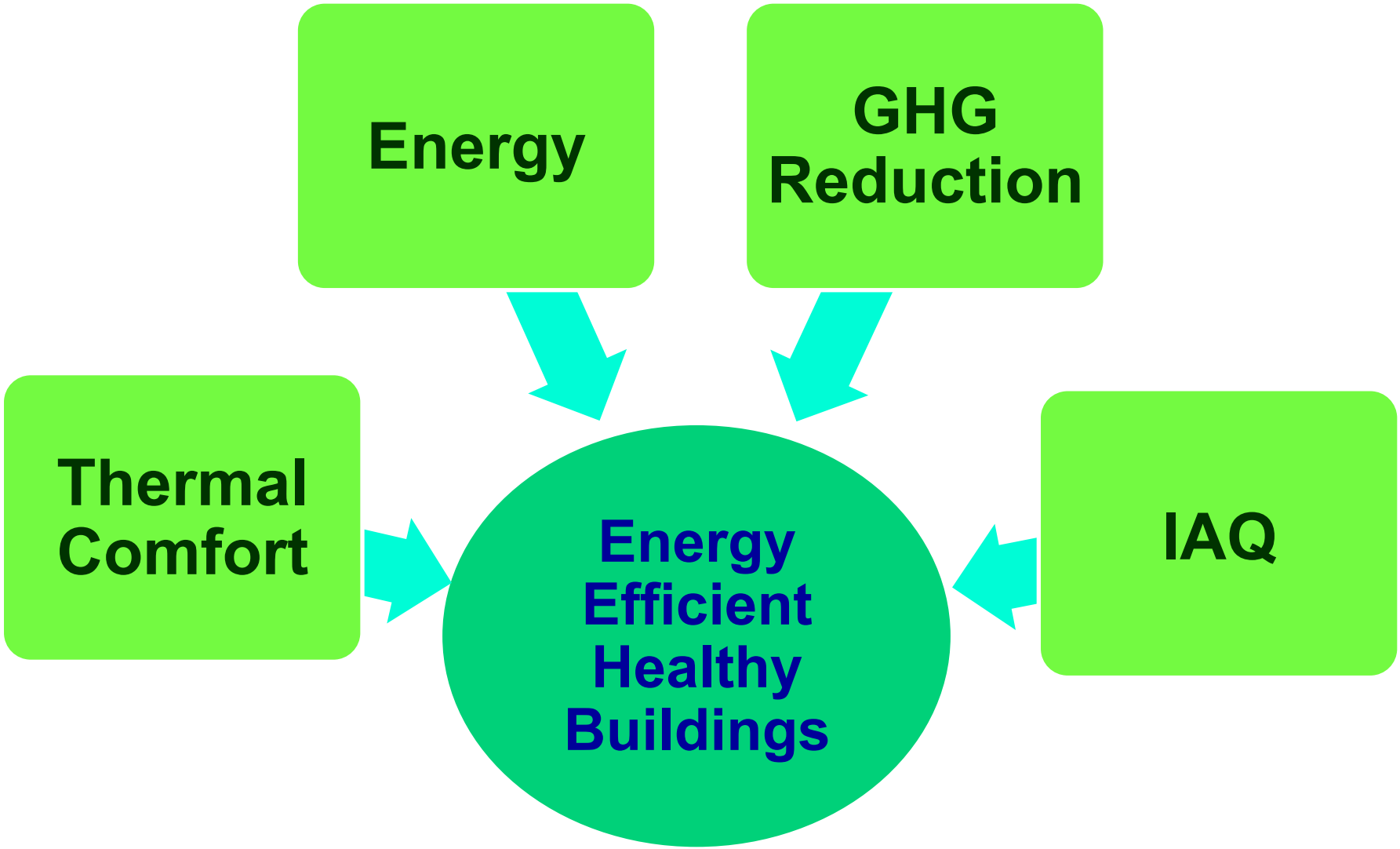
Learning Objectives

1. Describe an integrated IAQ-Energy audit methodology
2. Interpret the IAQ and Energy audit data from case studies in a hot and humid climate
3. Describe the key features of Thermal Comfort and Ventilation Standards (a) ASHRAE Standards 55 & 62.1 and (b) Singapore Standards
4. Describe the Singapore Green Mark Scheme for rating buildings for environmental sustainability


Energy
GHG Reduction
Thermal Comfort
Energy Efficient Healthy Buildings
IAQ

IAQ Scenario

Mendell, M.J., W.J. Fisk, K. Kreiss, H. Levin, D. Alexander, W.S. Cain, J.R. Girman, C.J. Hines, P.A. Jensen, D.K. Milton, L.P. Rexroat and K.M. Wallingford, 2002. Improving the health of workers in indoor environments: Priority research needs for a national occupational research agenda. American Journal of Public Health, Vol 92, No.9, 1430 -1440.

…… improving building environments may result in health benefits for more than 15 million of the 89 million US indoor workers, with estimated economic benefits of $5 to $75 billion annually.

Why IAQ

Fisk, W. J., Black, D. and Brunner, G. (2011), Benefits and costs of improved IEQ in U.S. offices. Indoor Air, 21, Issue 5 : 357–367

Benefits and costs of improved IEQ in U.S. offices

Scenarios

- Increasing vent rates when below 10 or 15 l/s per person
- Adding O/A economisers and controls when absent
- Eliminating winter indoor temps >23°C
- Reducing dampness and mold problems

Estimated Benefits

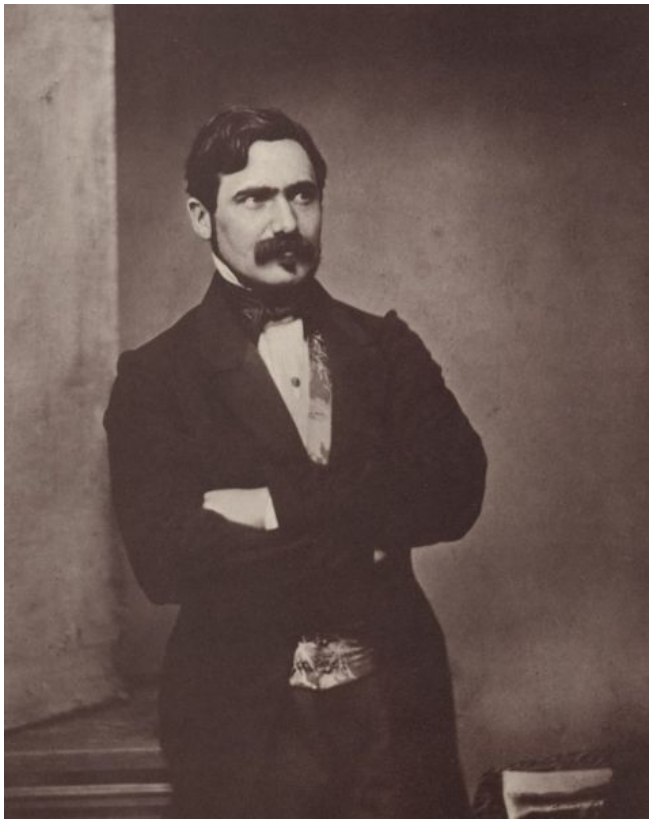
- Increased work performance
- Reduced SBS symptoms
- Reduced absenteeism
- Improved thermal comfort for millions of office workers

Combined potential annual economic benefit of a set of nonoverlapping scenarios ≈$20 billion

Quantitative estimates have a high uncertainty – BUT opportunity for substantial benefits is clear

IAQ - Source Control

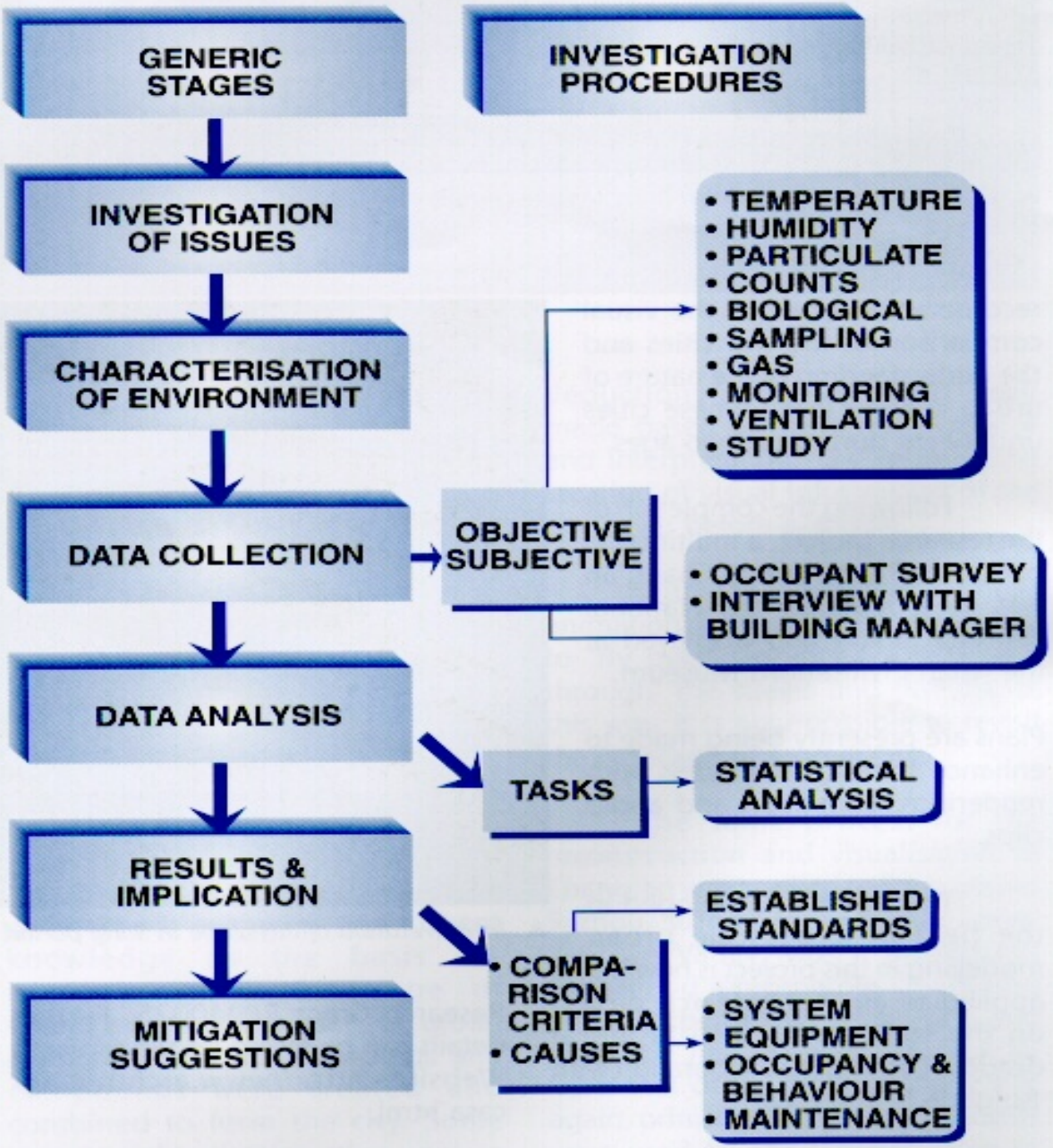
“If there is a pile of manure in a space, do not try to remove the odor by ventilation. Remove the pile of manure.”



Max Joseph von Pettenkofer (1818-1901), german chemist

IAQ Audit -
CASE STUDIES

IAQ Audit



▲ *Indoor Air Quality Audit Methodology developed through the Research Projects*

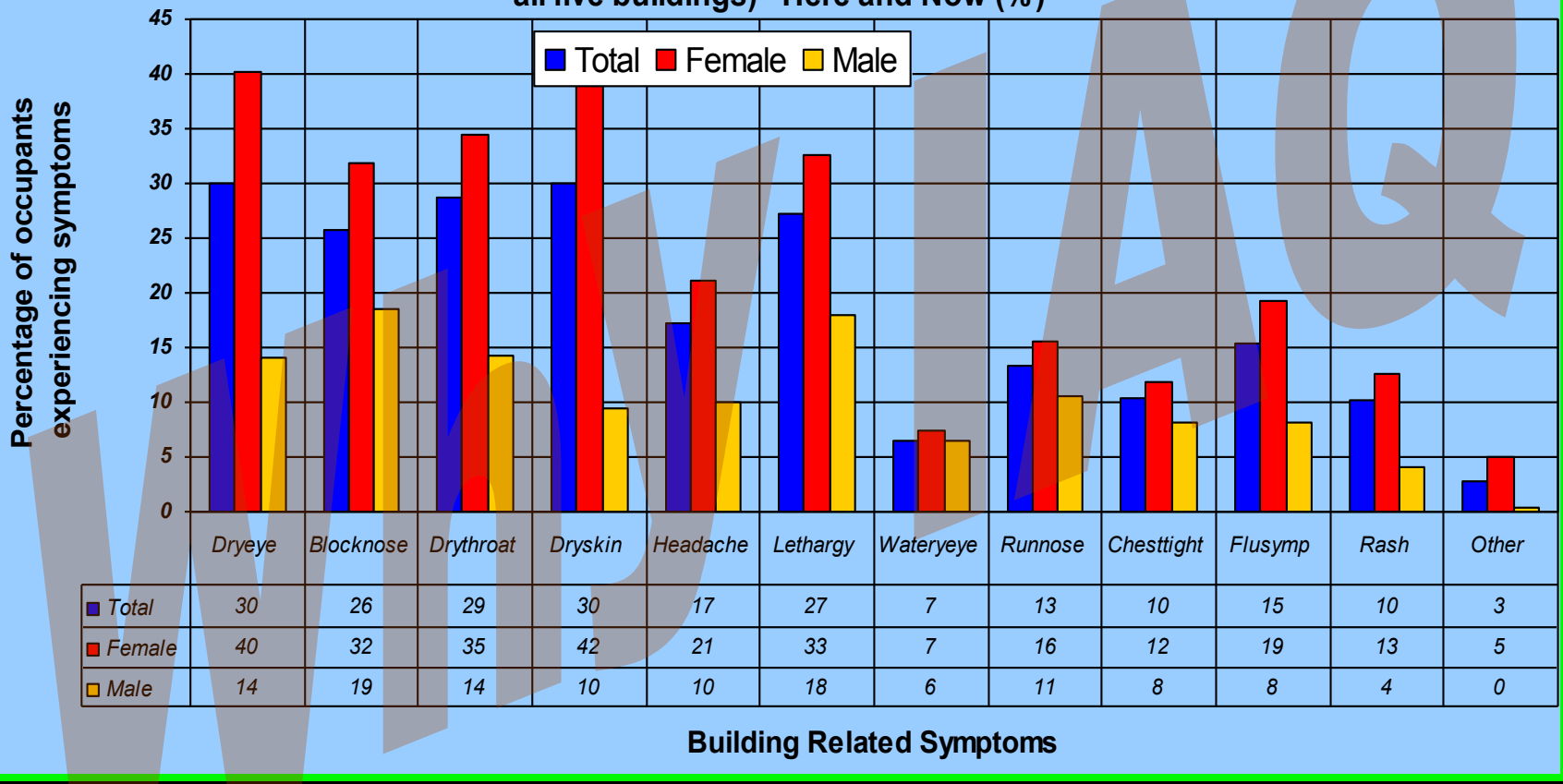
OBJECTIVES OF AUDIT

- Establish status of Indoor Air Quality (IAQ)
- Identify strategies for improving IAQ
- Basis for developing an IAQ audit and management program

Questionnaire Study

Sick Building Syndrome

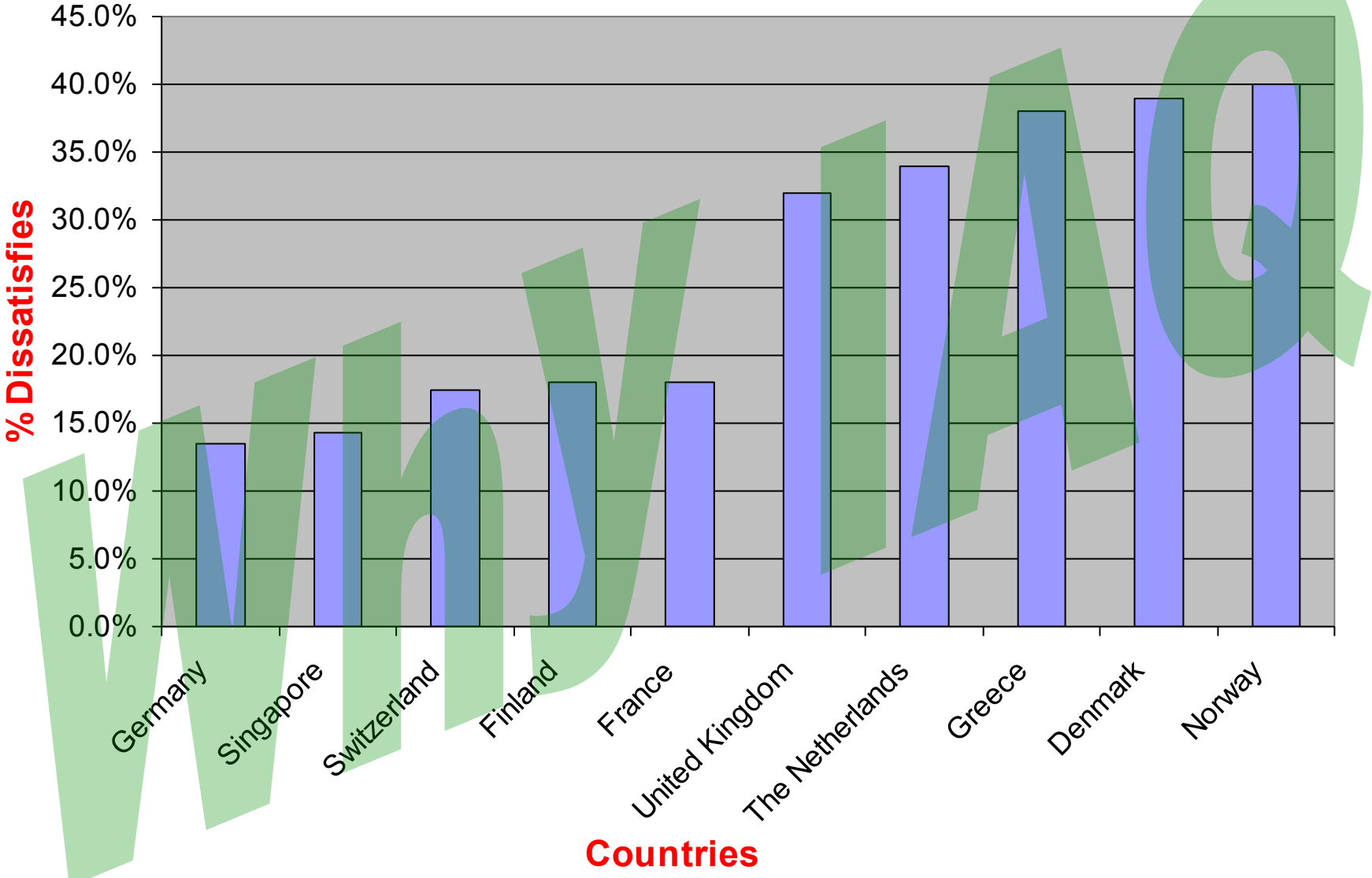
Figure 11 : A comparison of MALE and FEMALE Building Related Symptoms (Mean of all five buildings) - Here and Now (%)



	Dryeye	Blocknose	Drythroat	Dryskin	Headache	Lethargy	Wateryeye	Runnose	Chesttight	Flusymp	Rash	Other
Total	30	26	29	30	17	27	7	13	10	15	10	3
Female	40	32	35	42	21	33	7	16	12	19	13	5
Male	14	19	14	10	10	18	6	11	8	8	4	0

Sekhar SC, KW Tham and KWD Cheong, Indoor Air Quality And Energy Performance of Air-conditioned Office Buildings In Singapore, Indoor Air – International Journal of Indoor Air Quality and Climate, 2003, Volume 13, Issue 4, pp. 315-331.

Acceptability of Indoor Air Quality (% Dissatisfied) - A Comparison of Singapore and EU studies



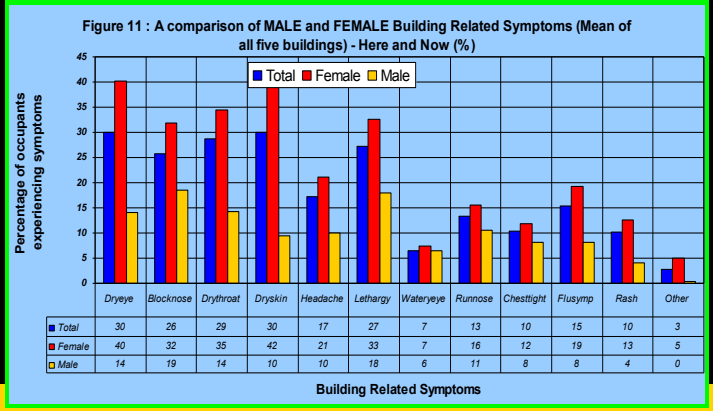


Figure7 : Indoor air acceptability versus thermal comfort

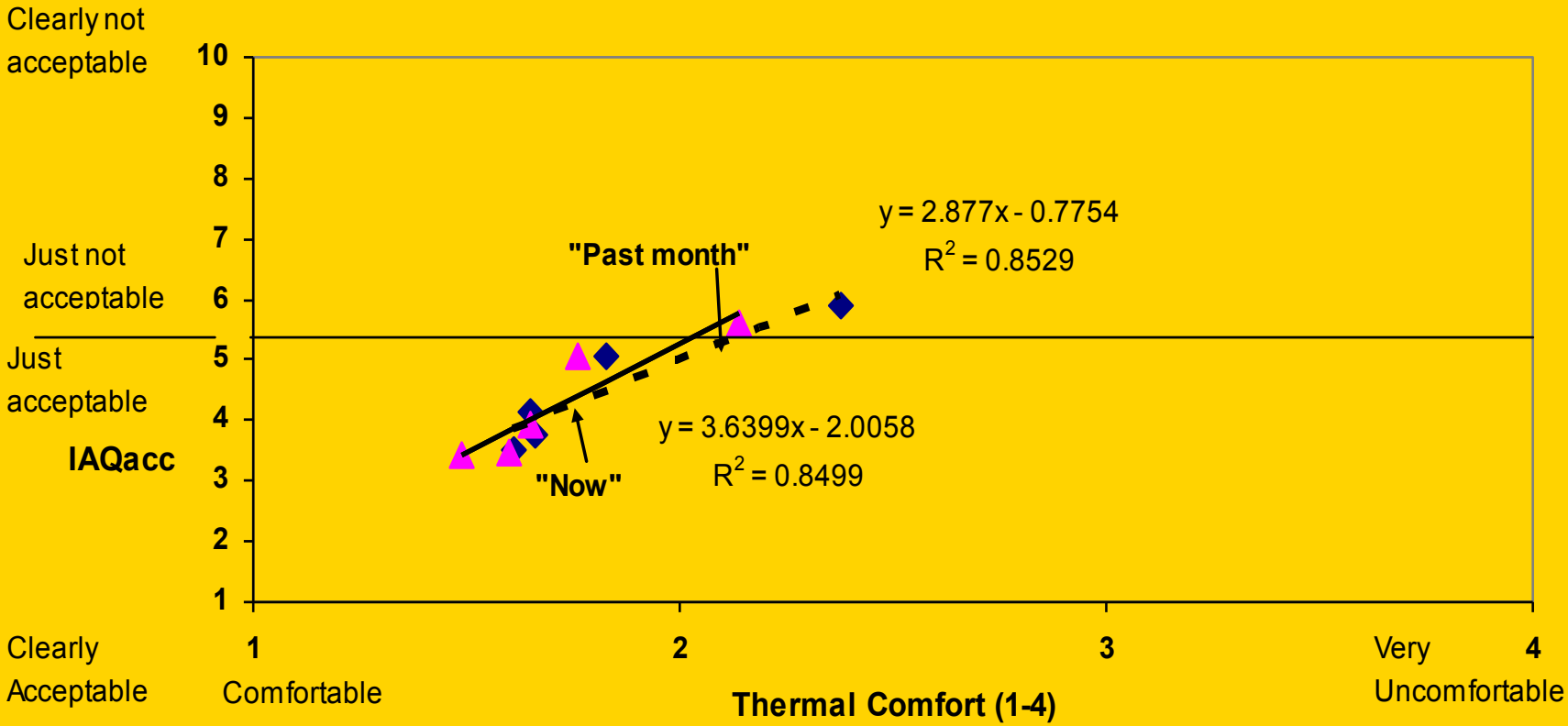
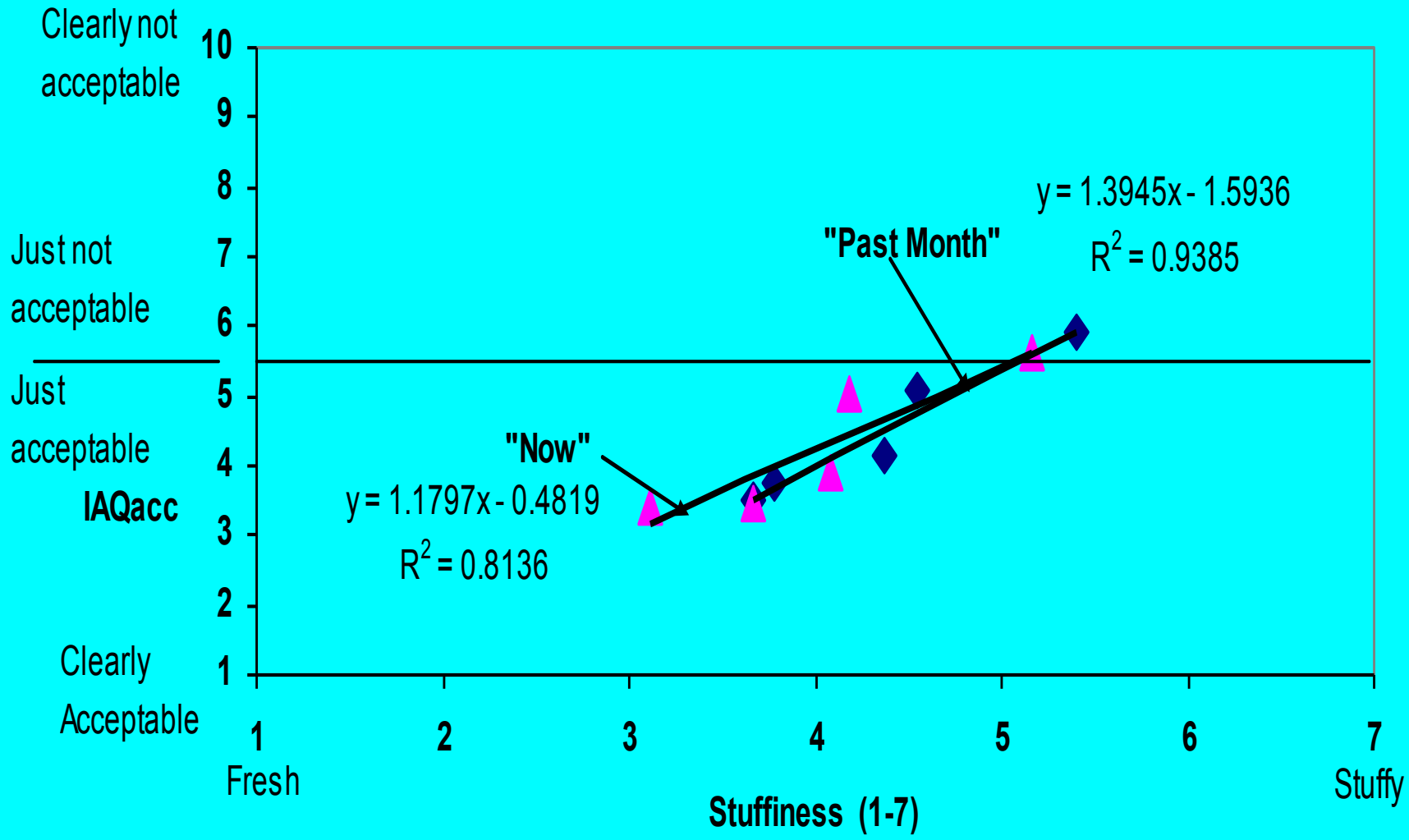


Figure 9 : Indoor air acceptability versus stuffiness



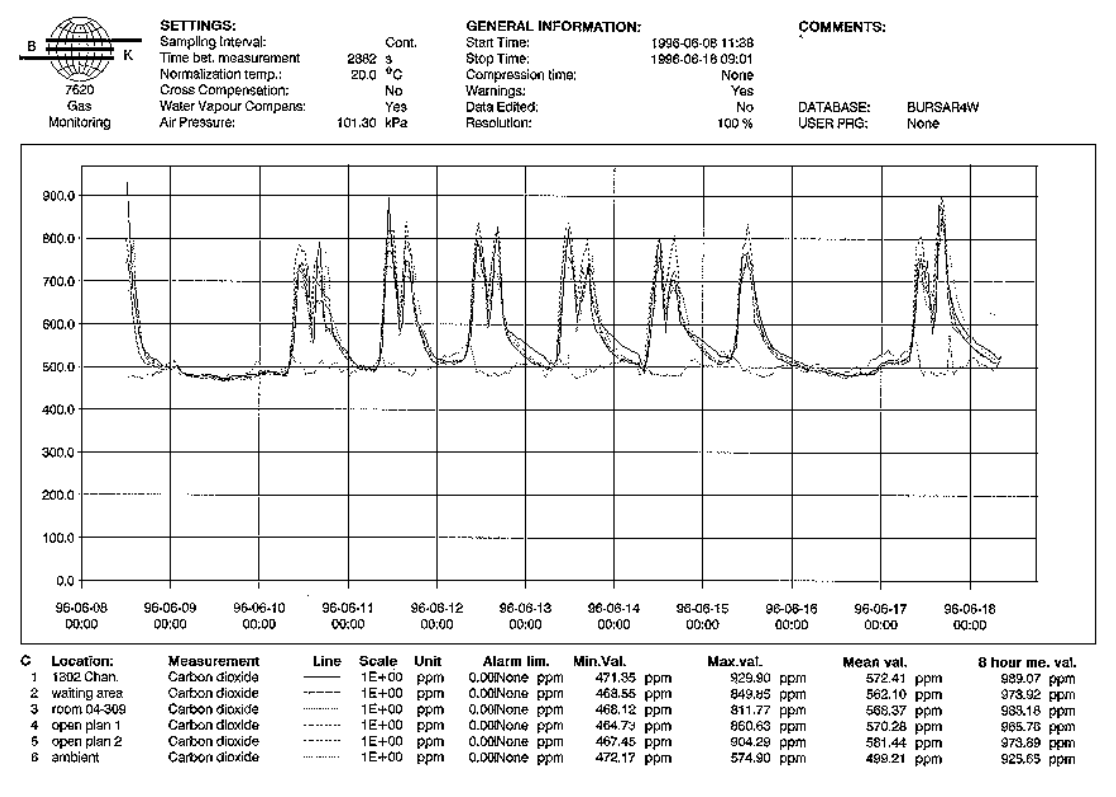
Objective Measurements – IAQ parameters

DIMENSIONS OF INDOOR AIR QUALITY

- Chemical
- Biological
- Physical

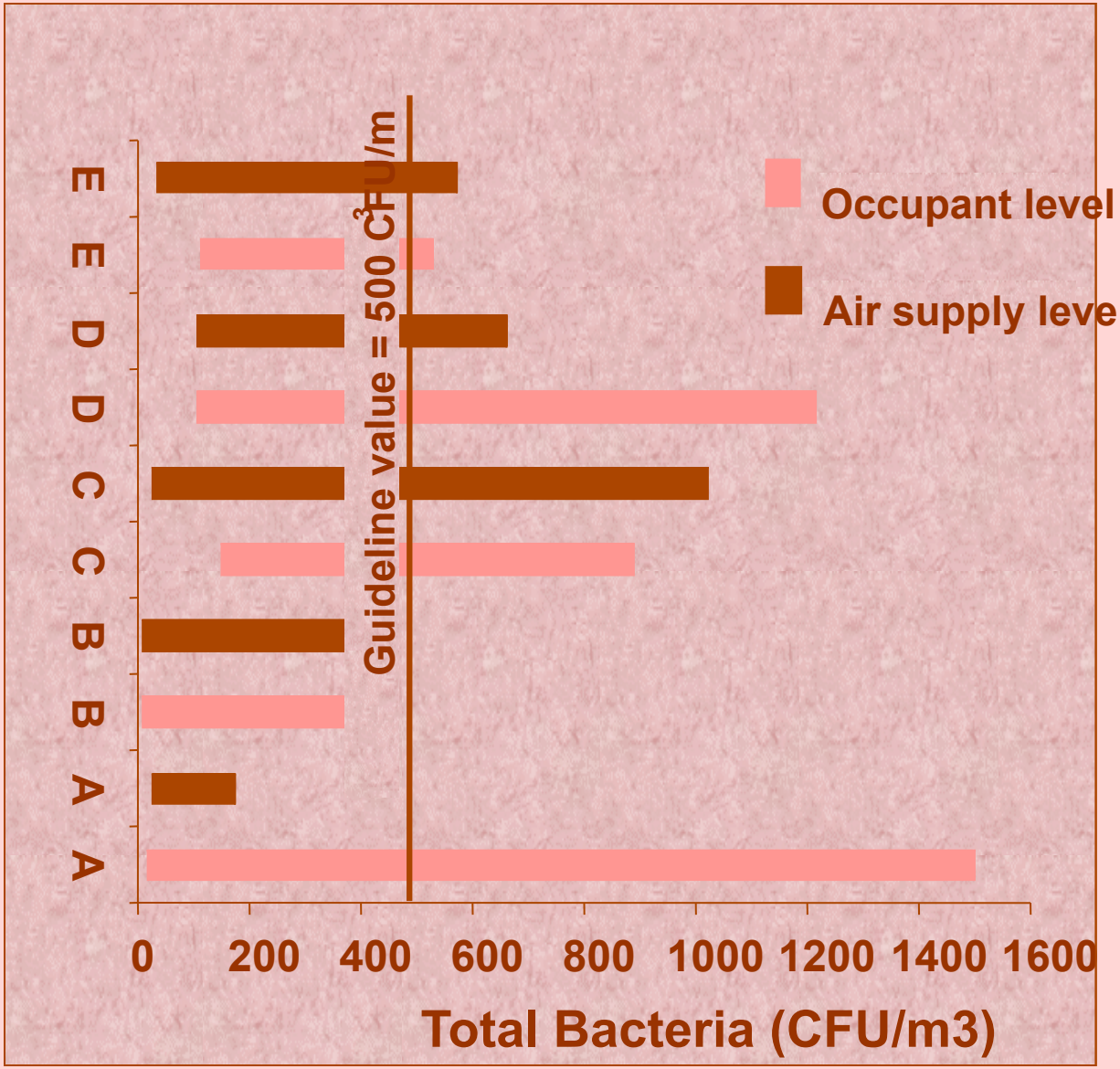
CHEMICAL

- Sources
  - Interior furnishings
  - Equipment
  - Stationery
  - Outside sources
- Particular chemicals
  - TVOCs
  - Formaldehyde
  - Carbon Monoxide
  - Carbon Dioxide



BIOLOGICAL

- Sources
  - Occupants
  - Visitors
  - Food
  - Outside sources
- Particular contaminants
  - Total Bacteria
  - Yeasts & Molds



Objective Measurements – Ventilation parameters

VENTILATION STUDIES IN NINE AIR-CONDITIONED OFFICE BUILDINGS IN SINGAPORE

Period of Study : 1993 - 1997

Factors affecting ventilation performance

- space layout
- fresh air quantity
- supply diffusers and return grilles

Indoor air flow pattern

- Short circuiting
- Piston flow
- Perfect mixing

Flow pattern affects

- Indoor Air Quality (IAQ)
- Building energy consumption

VENTILATION CHARACTERISTICS

THE VENTILATION MODEL

Age-of-air

Laverage amount of time elapsed since molecules in a sample entered the building

- measured by tracer gas techniques

"youngest" air found where the outdoor air comes into the room –

"oldest" air found at any other point in the room

Tracer Gas Monitoring

- TRACER GAS MEASUREMENTS
- AGE OF AIR VALUES
  - LOCAL MEAN AGE OF AIR
  - ROOM AVERAGE AGE OF AIR
- AIR CHANGE RATE
- Air Exchange Effectiveness (also known as Ventilation Effectiveness)

type of tracers used usually colourless, odourless, inert gases (e.g. SF6)

Important aspect of TG measurements can be made in occupied buildings

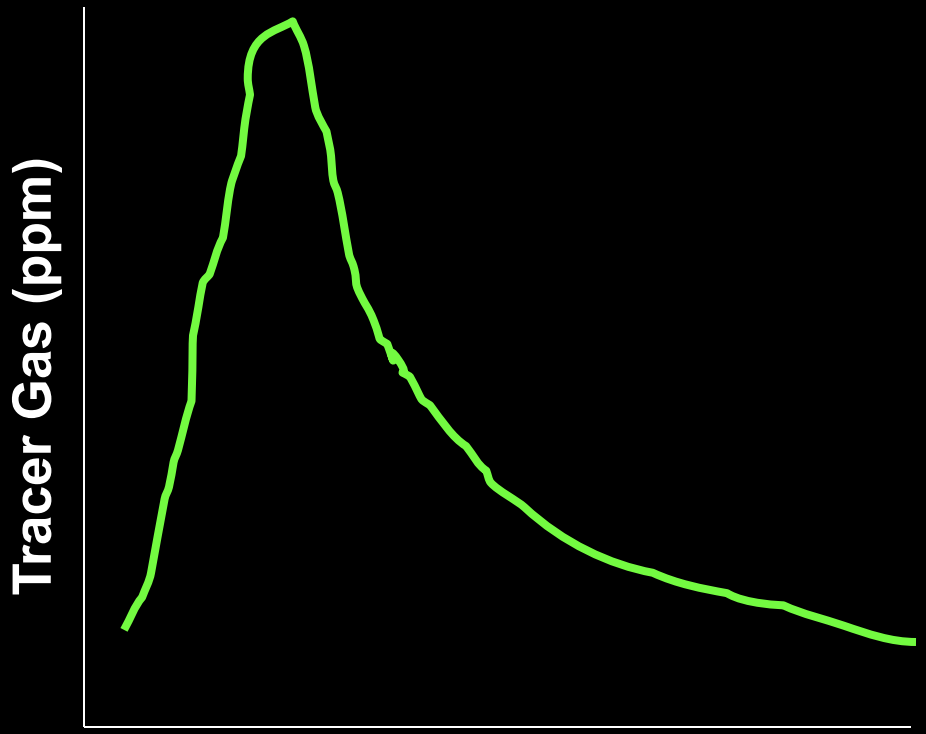

MULTI - GAS
MONITOR
AND

Concentration-decay method

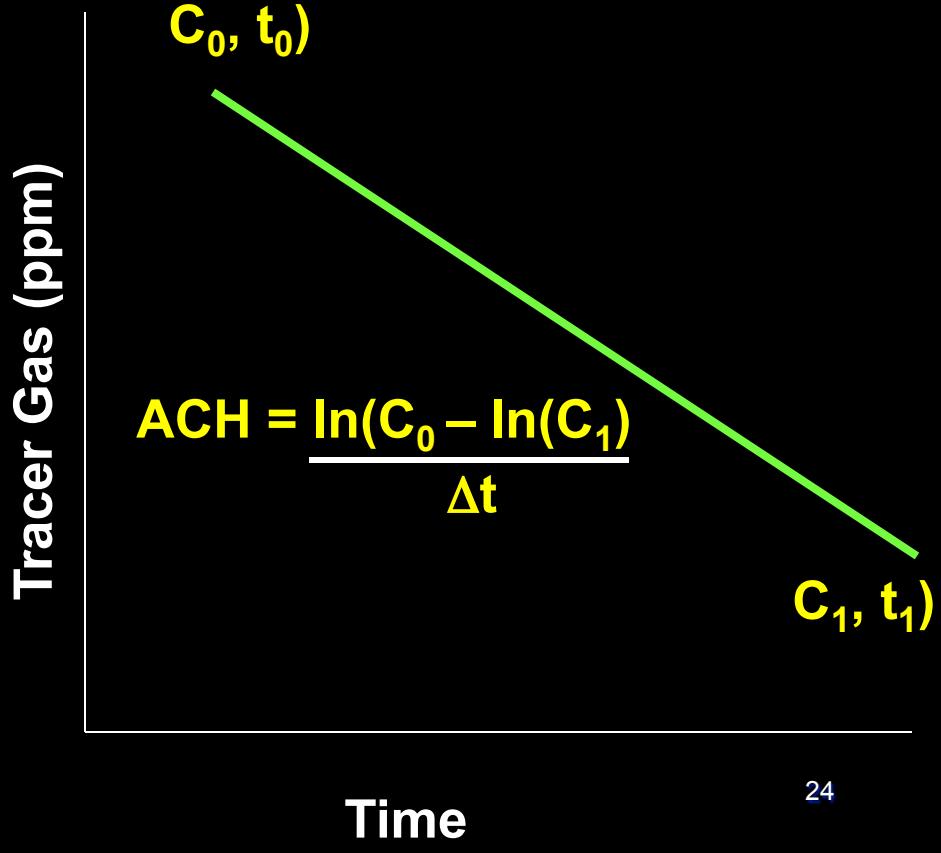
Air Change per Hour (ACH)

- slope of the tracer gas concentration decay curve

Linear Plot



Semi Log Plot



Air Exchange Effectiveness

Perfectly mixed air - datum for all three AEE parameters
AEE = 1

AEE_G = 2.0 "perfect" displacement flow

AEE_G < 1.0 shortcircuiting
AEE_G > 1.0 displacement flow

the greater the deviations from unity,
more pronounced are the two flow patterns

Key building characteristics

Floor by Floor AHUs
CAV system

A, C

Floor by Floor AHUs
VAV system

B, D, E,
BB, DD, EE

3 CentralAHUs
VAV system

CC

Figure 1 : Summary of Air Change per Hour (ACH) values

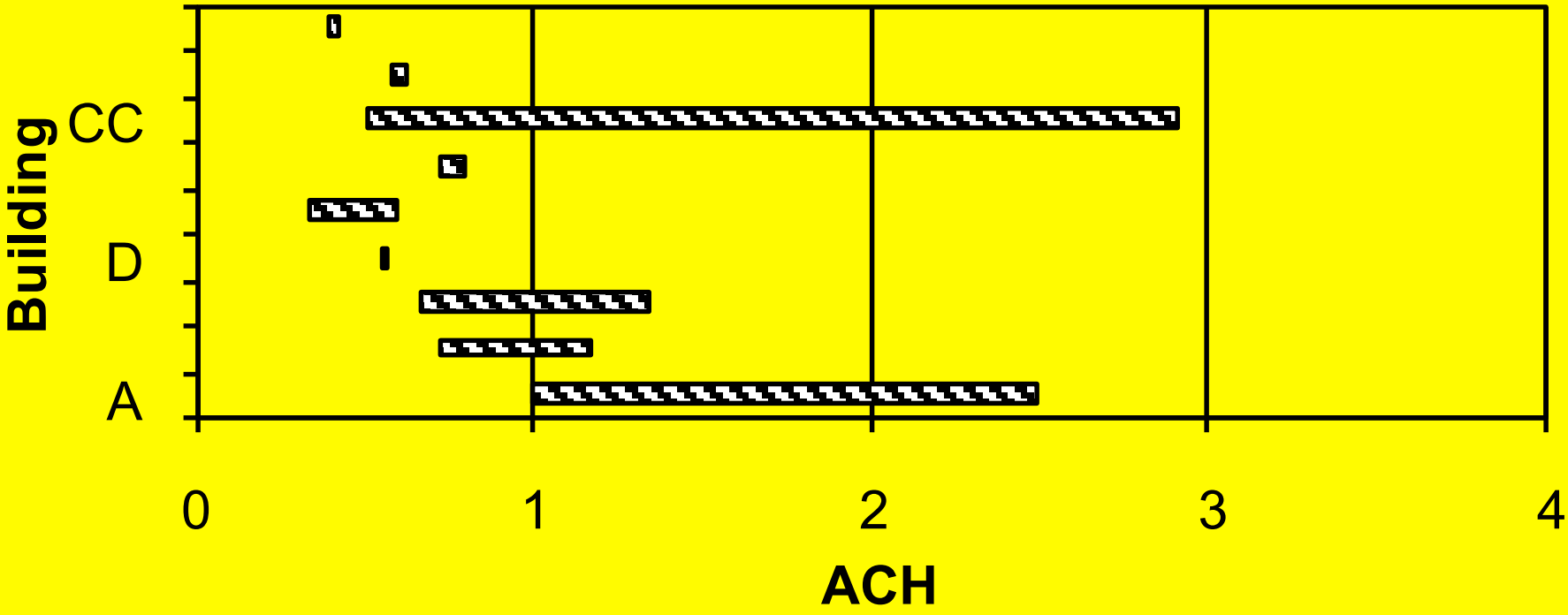


Figure 2 : Comparison of fresh air provision based on design occupancy

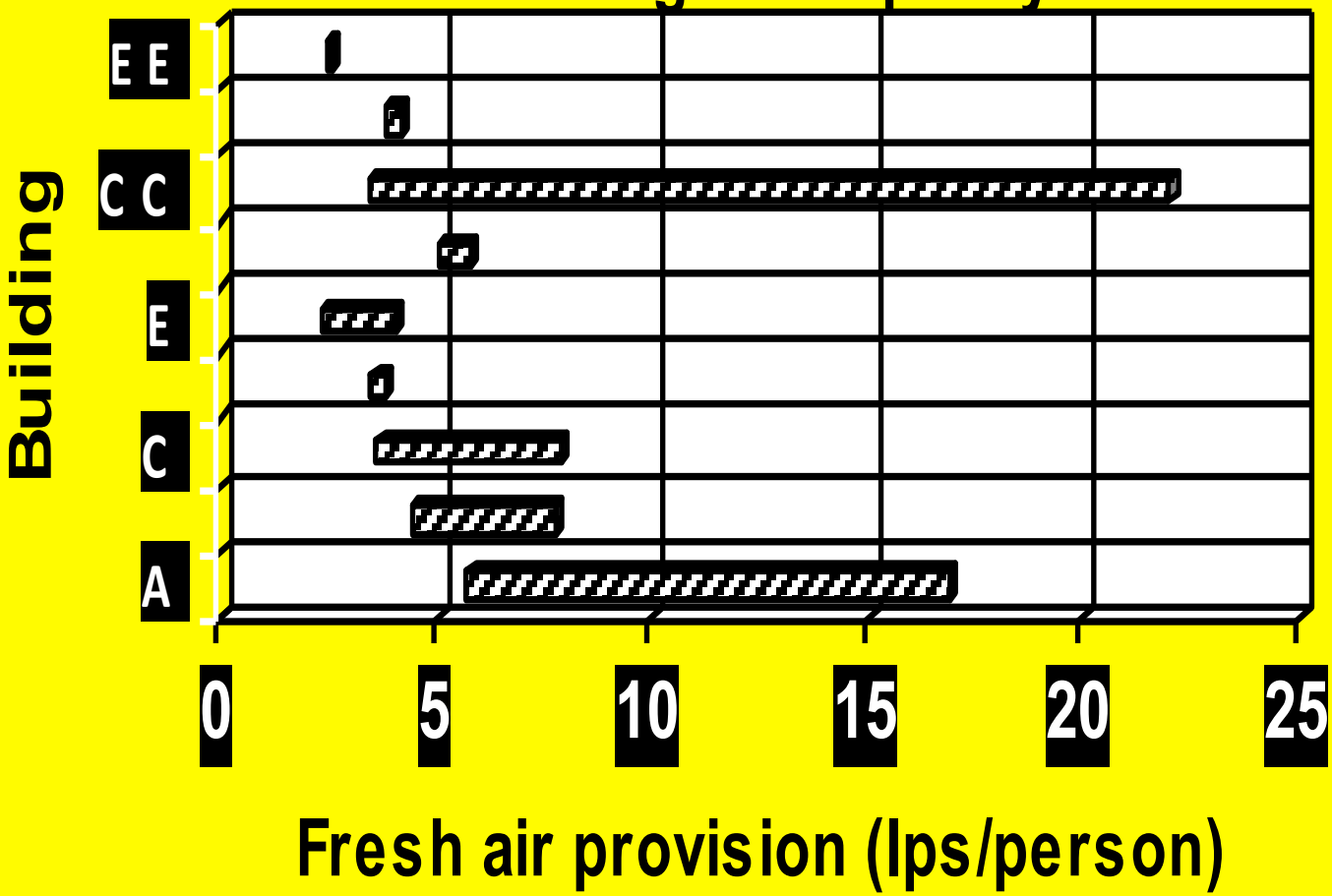
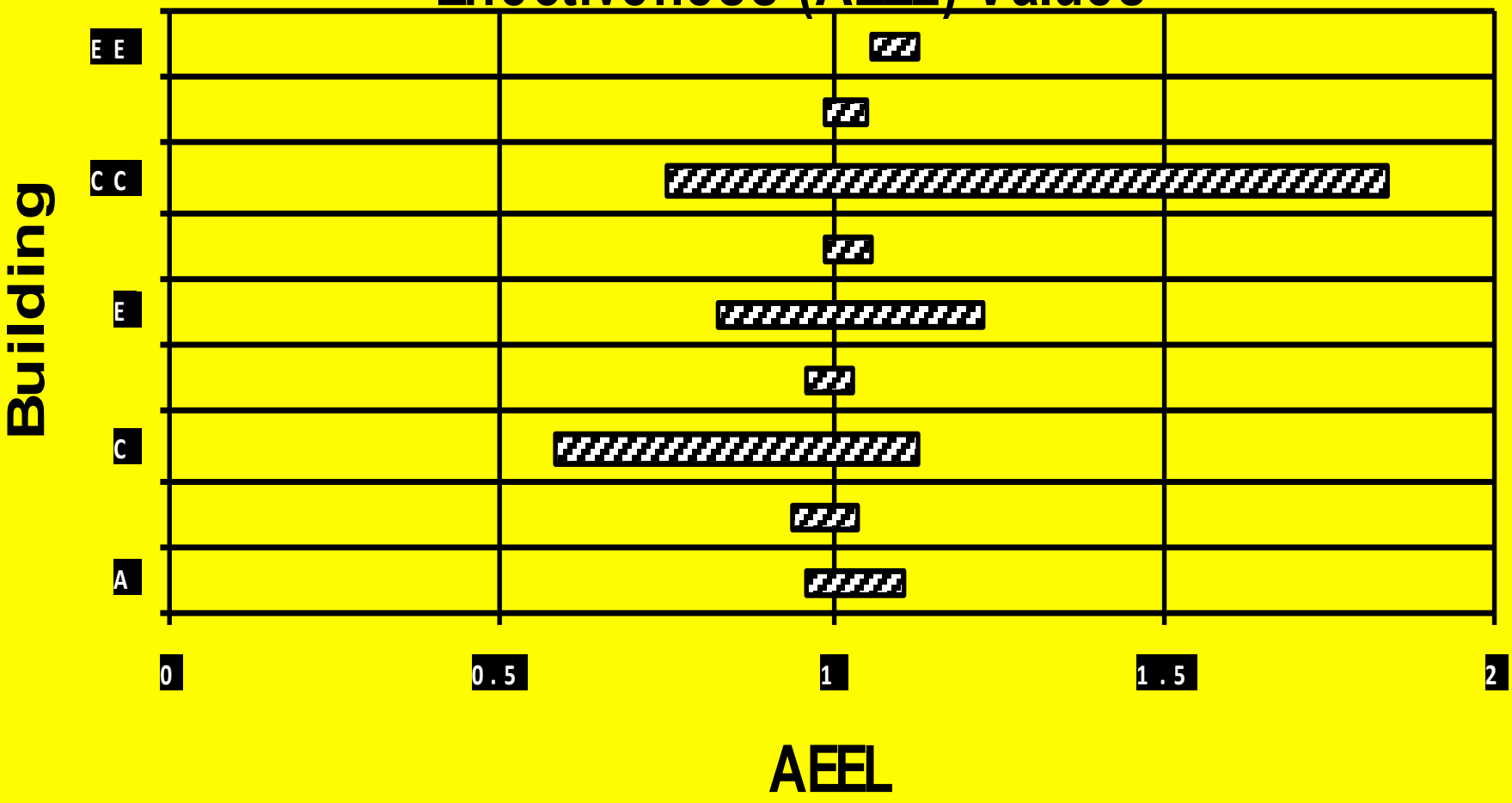
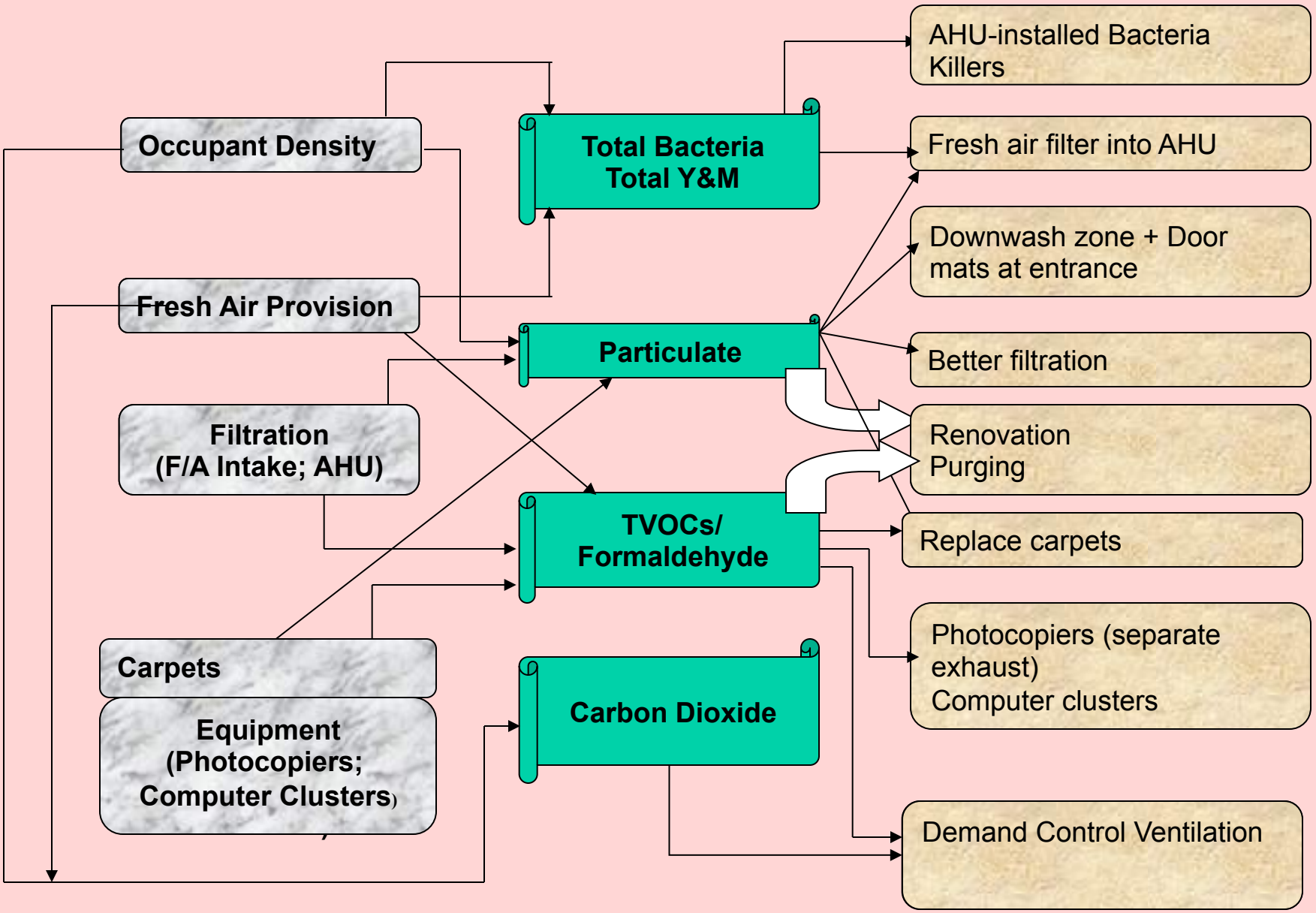


Figure 5 : Comparison of Localised Air Exchange Effectiveness (AEEL) Values



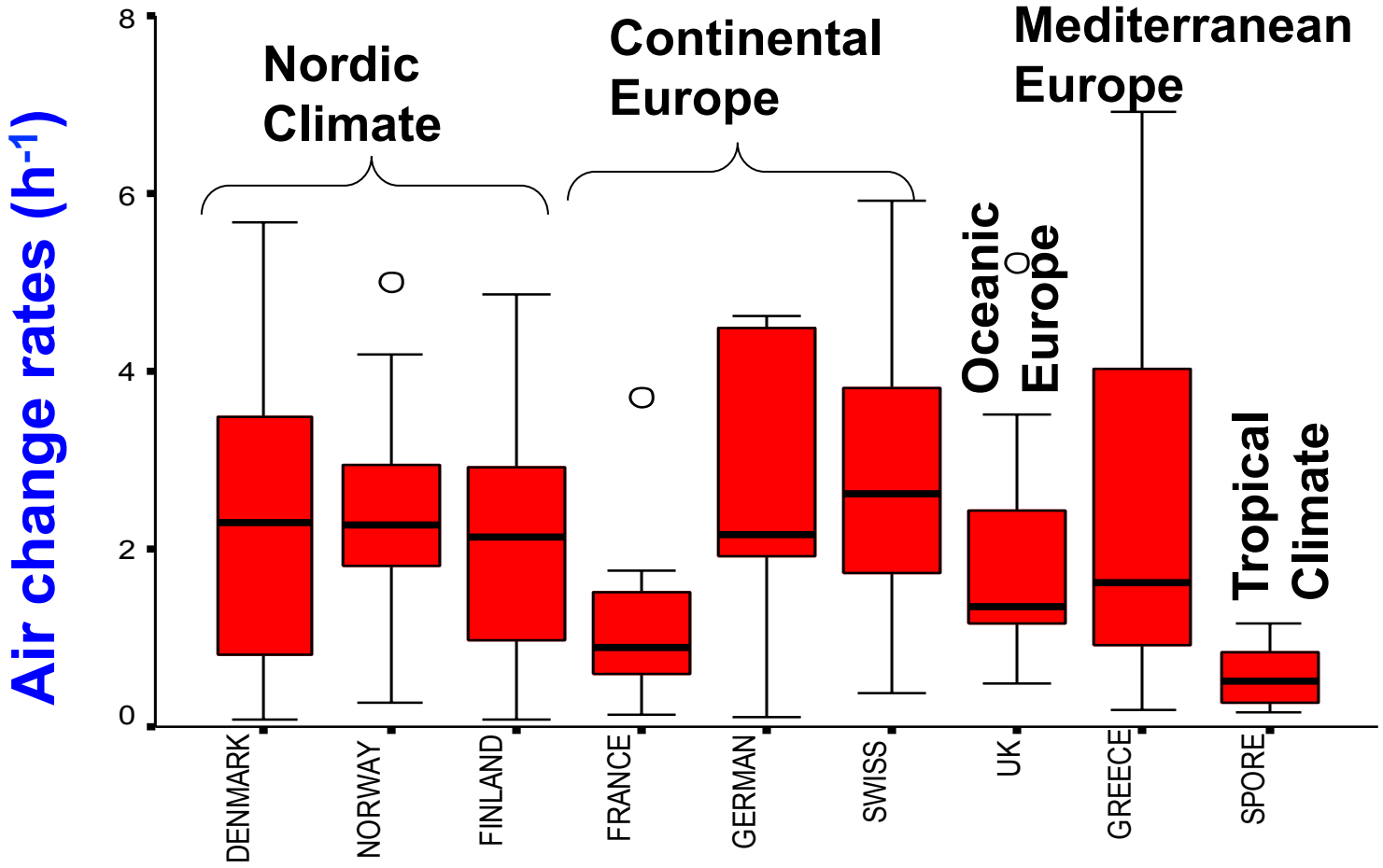
Conclusions – 9 Buildings Study

- Tracer gas analysis : In-situ ventilation measurements
- Significant variations in ACH values
- Minor short-circuiting profiles in some zones
- AEE values generally indicative of well-mixed flow patterns


Causes
Pollutants
Recommendations
Occupant Density
Fresh Air Provision
Filtration
(F/A Intake; AHU)
Carpets
Equipment
(Photocopiers;
Computer Clusters)
Total Bacteria
Total Y&M
Particulate
TVOCs/
Formaldehyde
Carbon Dioxide
AHU-installed Bacteria Killers
Fresh air filter into AHU
Downwash zone + Door mats at entrance
Better filtration
Renovation
Purging
Replace carpets
Photocopiers (separate exhaust)
Computer clusters
Demand Control Ventilation

Some other Observations

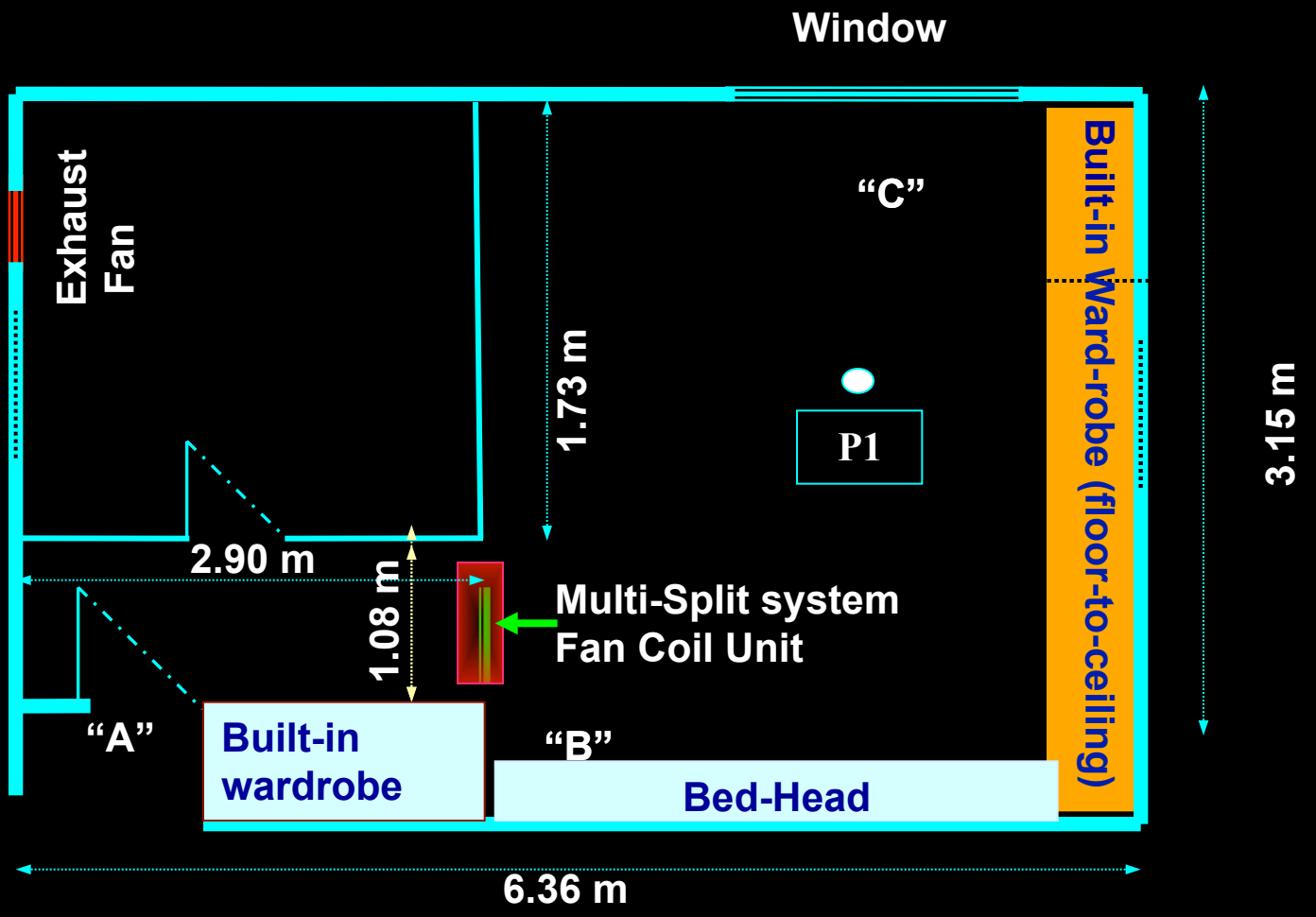
Zuraimi MS, Roulet C-A, Tham KW, Sekhar SC, David Cheong KW, Wong NH & Lee HK, 2004. "A comparative study of VOCs in Singapore and European Office Buildings", Building and Environment, *Volume 41, Issue 3, March 2006, Pages 316-329*



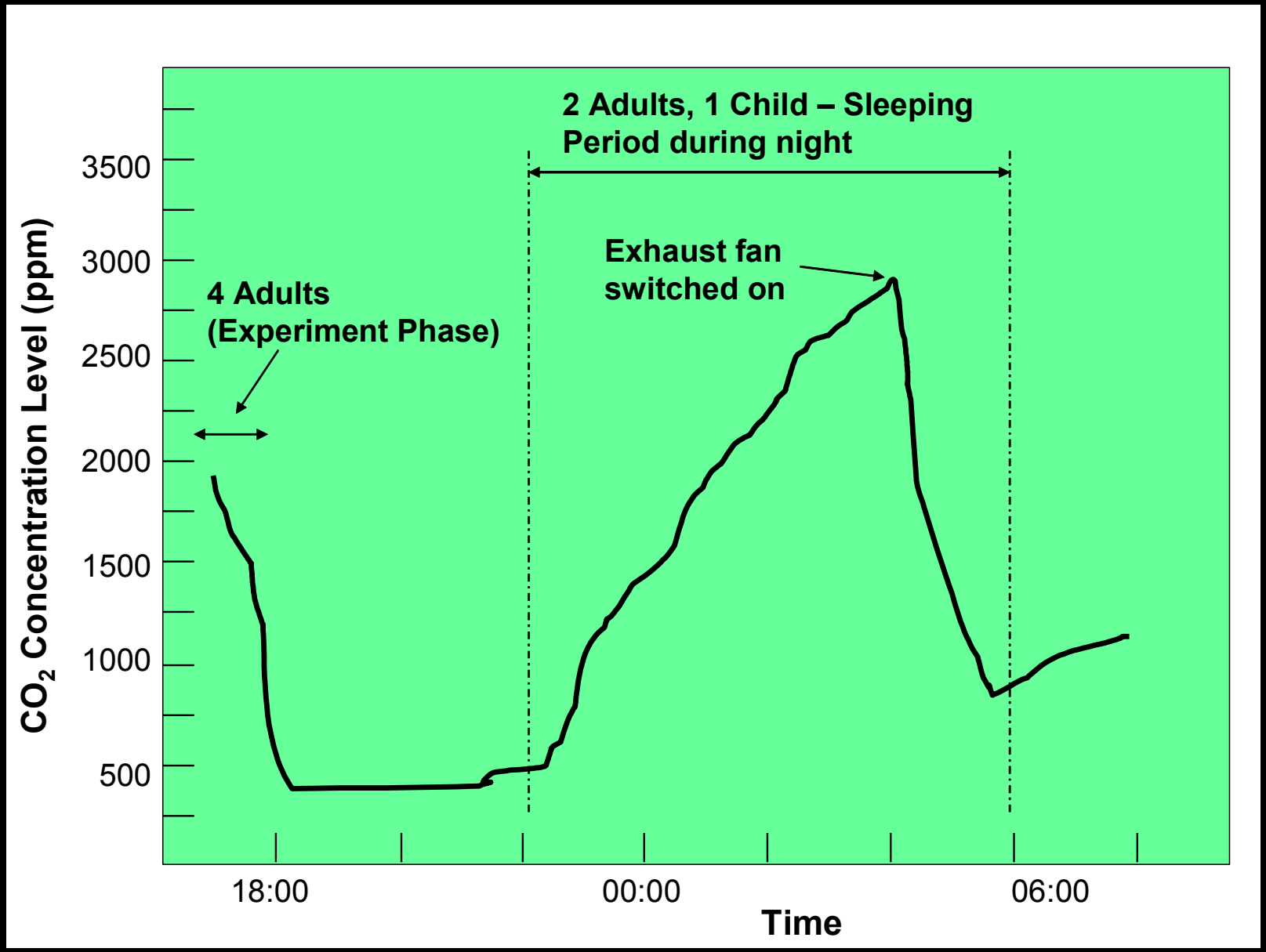
Air change rates (ACH) measured in the European and Singapore buildings studied

VENTILATION & IAQ ISSUES IN SPLIT SYSTEM AIR-CONDITIONING UNIT IN A RESIDENTIAL BUIDLING IN SINGAPORE

Year of study : 2002/2003



Master Bed-room in a condominium apartment (8th Storey)



CO2 concentration during measurement and night-time sleeping periods

Thermal Comfort

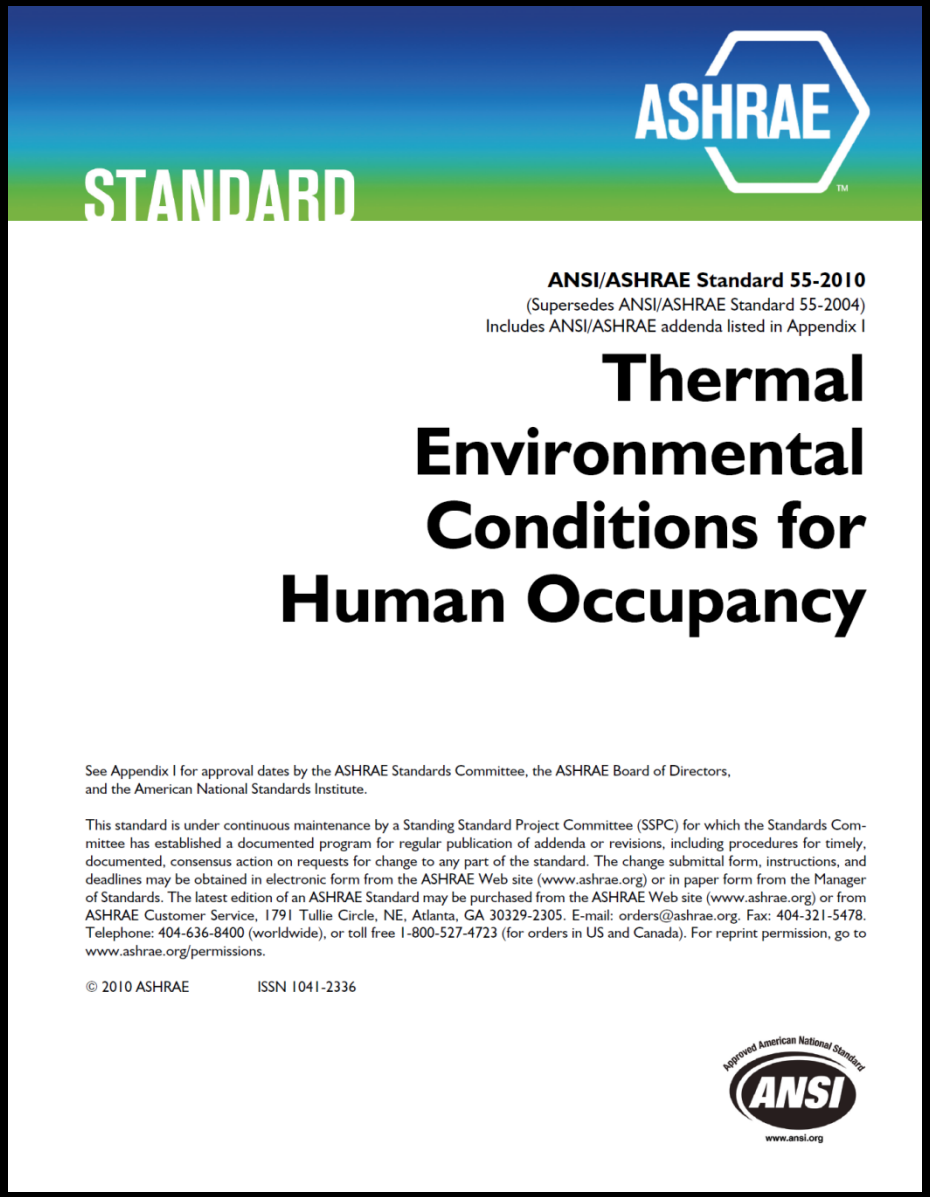
Ventilation

and

IAQ

Standards

Current version – ASHRAE Standard 55-2013



STANDARD

ASHRAE

ANSI/ASHRAE Standard 55-2010
(Supersedes ANSI/ASHRAE Standard 55-2004)
Includes ANSI/ASHRAE addenda listed in Appendix I

Thermal Environmental Conditions for Human Occupancy

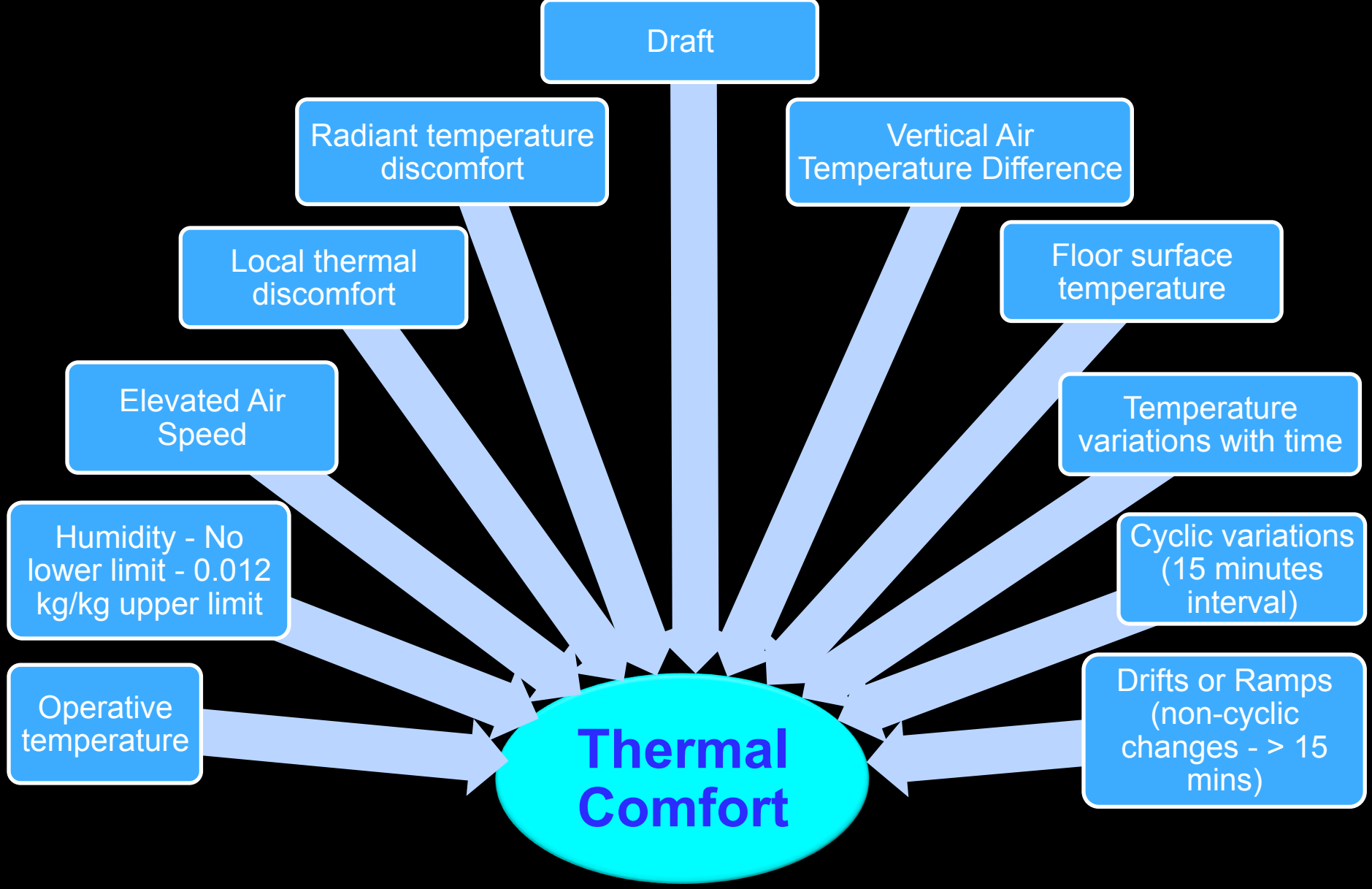
See Appendix I for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

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.

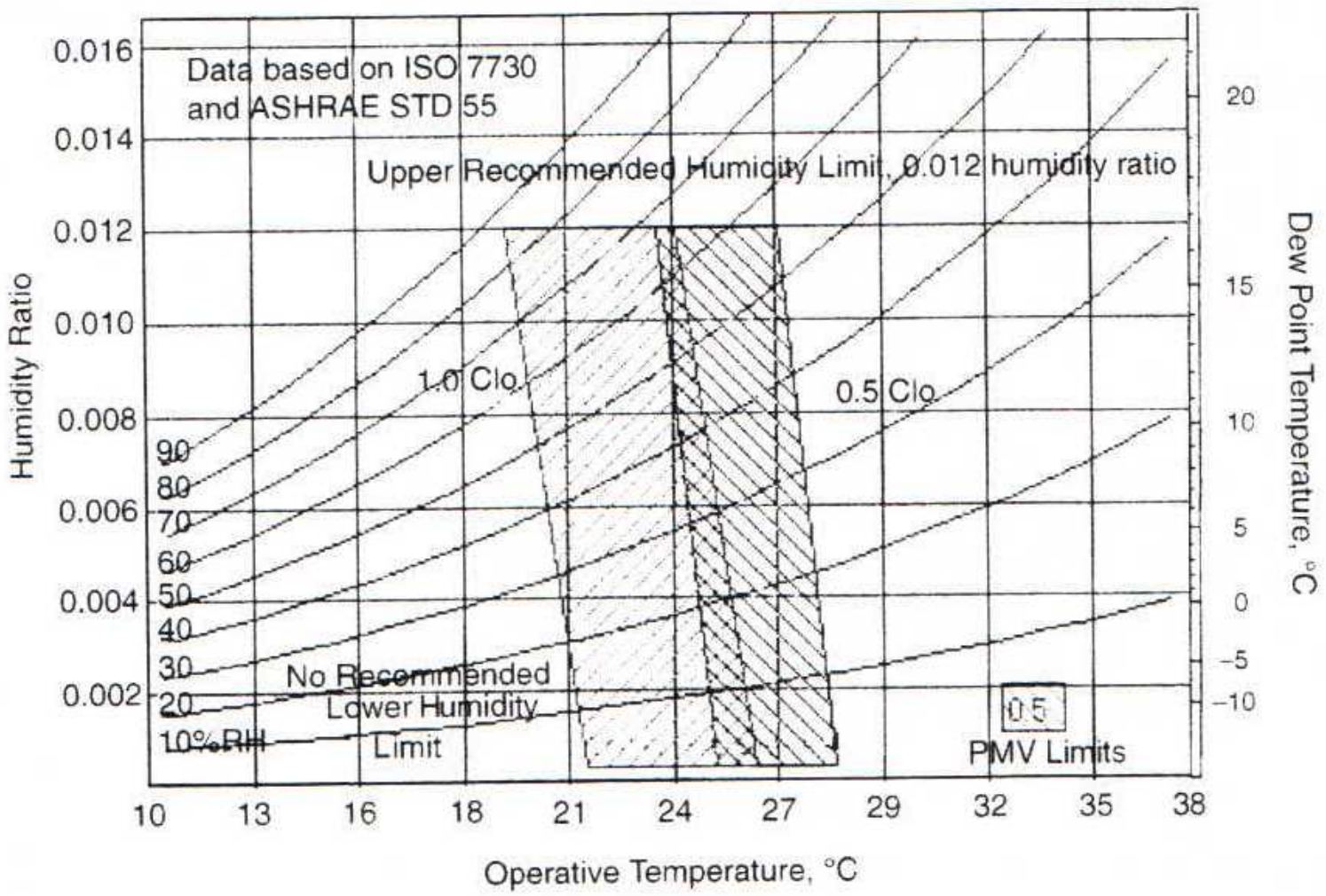
 ISSN 1041-2336

Approved American National Standard
ANSI
www.ansi.org

SSPC 55 to maintain and revise Standard 55. Standard on continuous maintenance. Standard 55 placed on continuous maintenance January 24, 2004 (Anaheim). SSPC 55 authorized 1/26/1994.



ASHRAE Standard 55-2010


Data based on ISO 7730
and ASHRAE STD 55
Upper Recommended Humidity Limit, 0.012 humidity ratio
1.0 Clo
0.5 Clo
No Recommended
Lower Humidity
Limit
PMV Limits
0.5
Humidity Ratio
Dew Point Temperature, °C
Operative Temperature, °C
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
90
80
70
60
50
40
30
20
10%RH
20
15
10
5
0
−5
−10
10
13
16
18
21
24
27
29
32
35
38

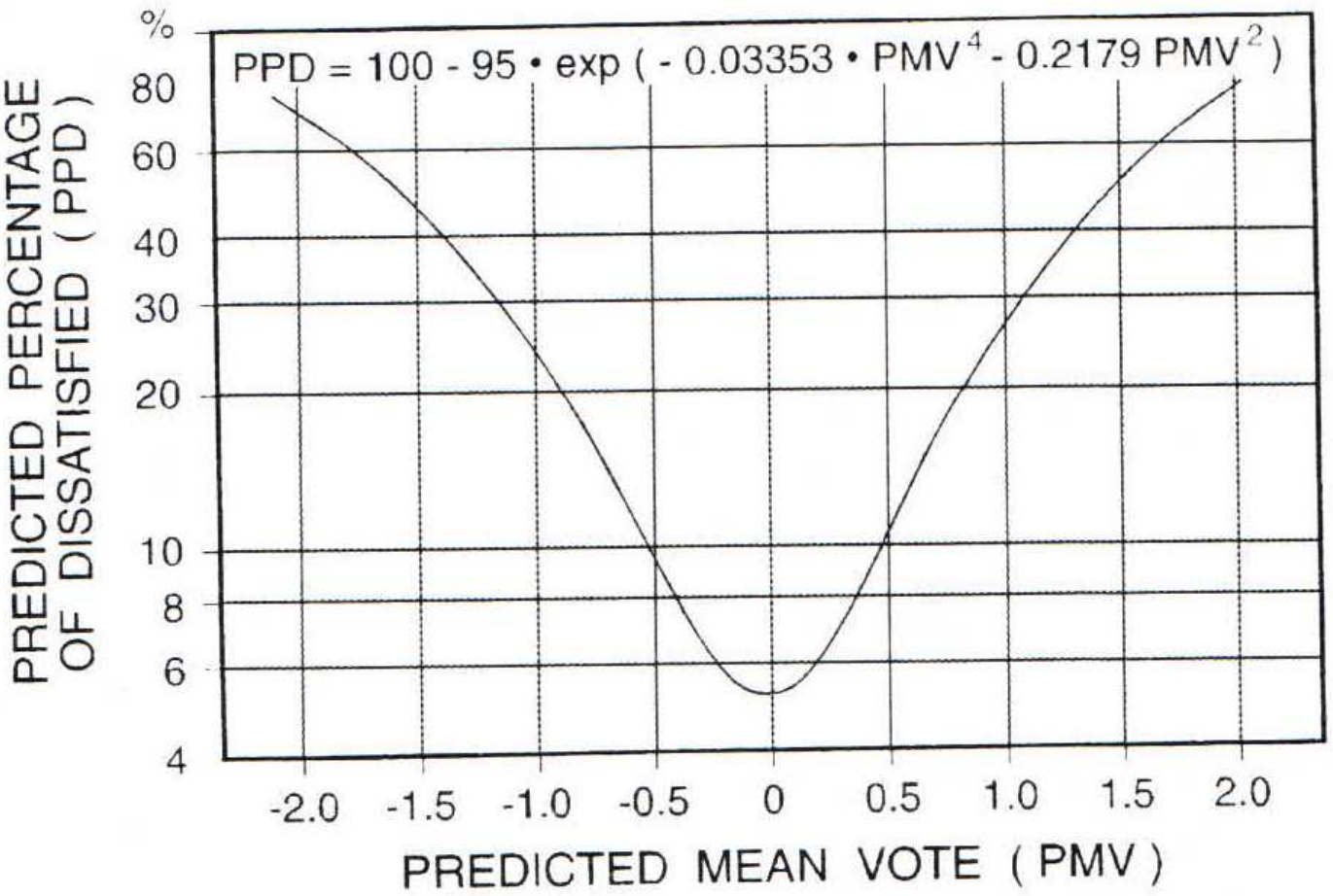


Figure 5.2.1.2 Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV).

Occupant controlled NV spaces

Adaptive model – global database of 21,000 meas – primarily in office buildings

No mechanical cooling system

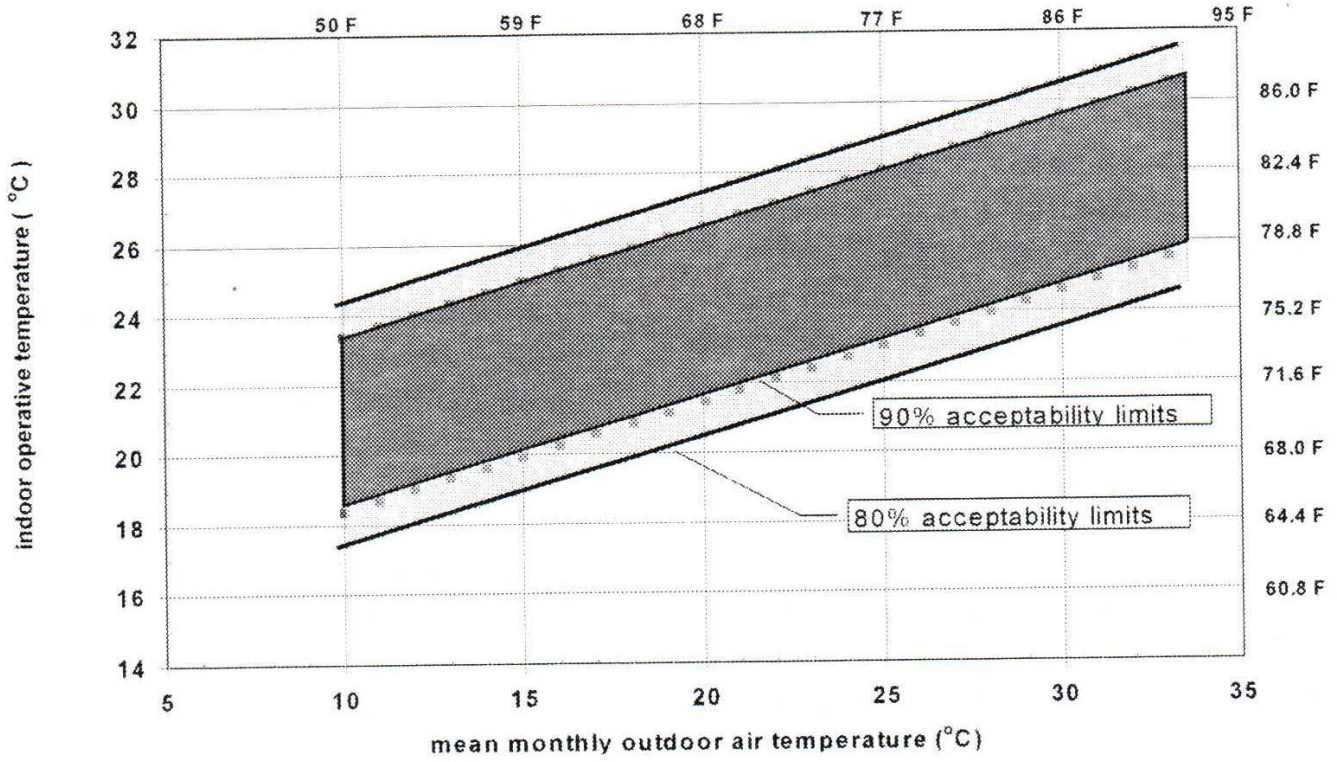


Figure 5.3 Acceptable operative temperature ranges for naturally conditioned spaces.

No humidity or air speed limits required

Allows for local thermal discomfort in typical buildings

Operable windows – open to outdoors

Accounts for people's clothing adaptation in NV spaces

Mech Vent with unconditioned air possible

ASHRAE®

ANSI/ASHRAE Standard 62.1-2013
(Supersedes ANSI/ASHRAE Standard 62.1-2010)
Includes ANSI/ASHRAE addenda listed in Appendix J

Ventilation for Acceptable Indoor Air Quality

See Appendix J 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 website (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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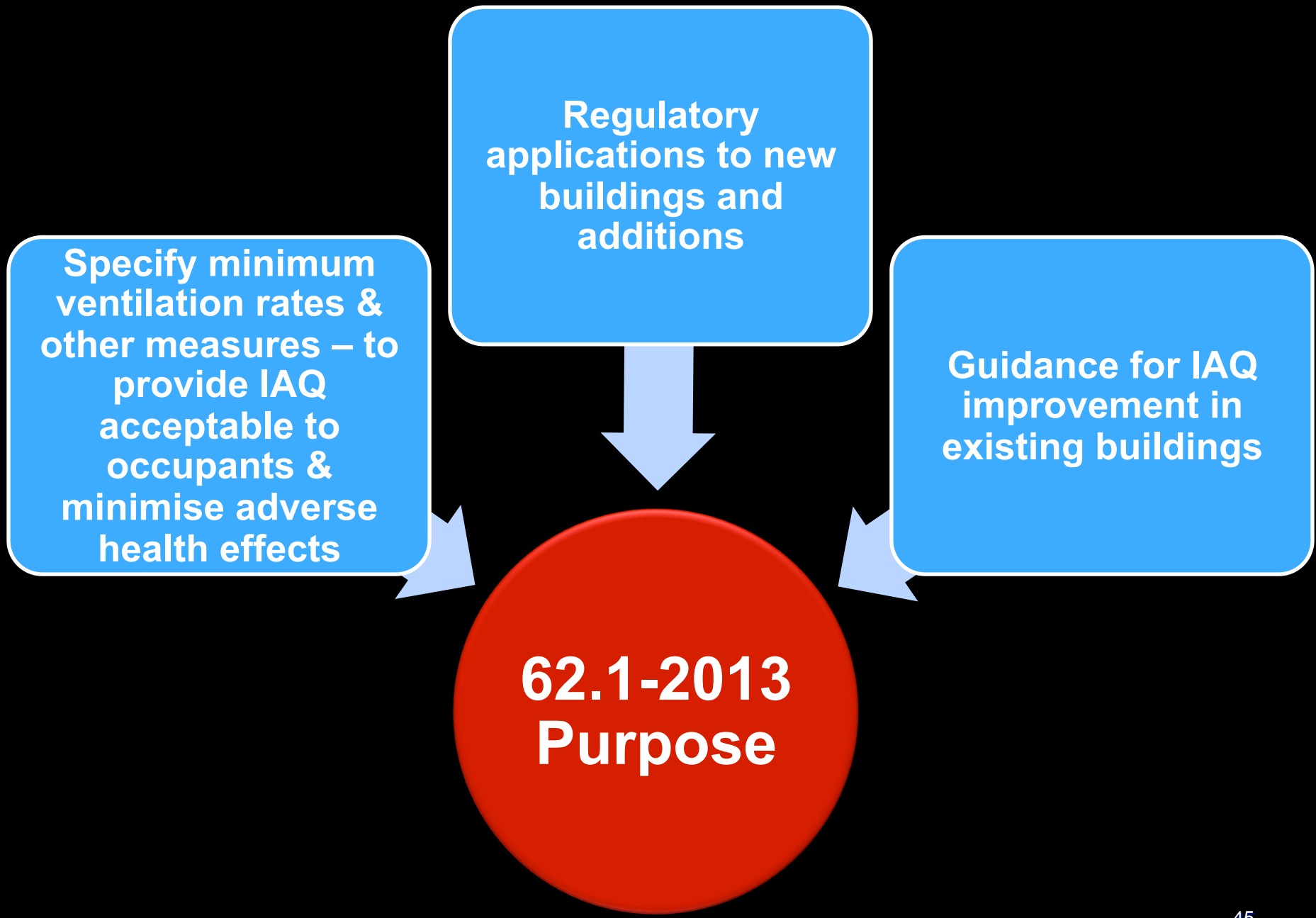
ASHRAE Standard 62.1

VRP

- Prescribes rates & procedures based on typical space contaminant sources & source strengths

IAQP

- Requires calculation of rates based on analysis of contaminant sources, concentration targets and perceived air quality targets.

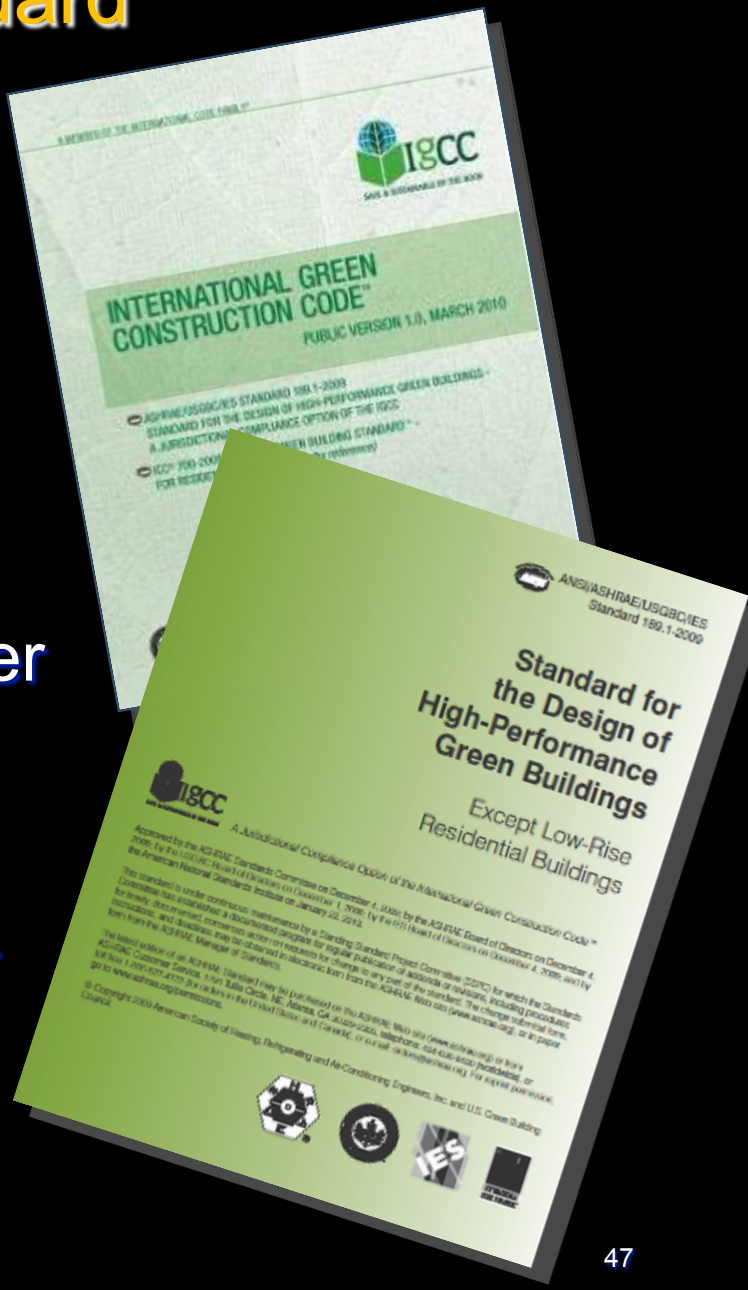

Regulatory applications to new buildings and additions
Specify minimum ventilation rates & other measures – to provide IAQ acceptable to occupants & minimise adverse health effects
Guidance for IAQ improvement in existing buildings
62.1-2013 Purpose

air in which there are no known contaminants at harmful concentrations as determined by *cognizant authorities* and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction

Acceptable Indoor Air Quality

Green Building Standard

- Published in January 2010
- Serves as benchmark for sustainable green buildings – does not apply to all buildings
- Addresses energy, impact on the atmosphere, sustainable sites, water use, materials and resources and IEQ
- Jurisdictional compliance option for International Green Construction Code



www.ashrae.org/greenstandard

Standard 189.1

- Standard for Design of High-Performance Green Buildings
- An ANSI standard developed in model code language
- Provides minimum requirements for high-performance, green building

Standard 189.1 Topic Areas

- SS — Sustainable Sites
- WE — Water Use Efficiency
- EE — Energy Efficiency
- IEQ — Indoor Environmental Quality
- MR — Building's Impact on the Atmosphere, Materials & Resources
- CO — Construction and Operations Plans

SINGAPORE

SS 553 : 2009 Code of Practice for Air-conditioning and Mechanical Ventilation in Buildings (formerly CP 13)

SS 554 : 2009 Code of Practice for Indoor Air Quality for Air-Conditioned Buildings

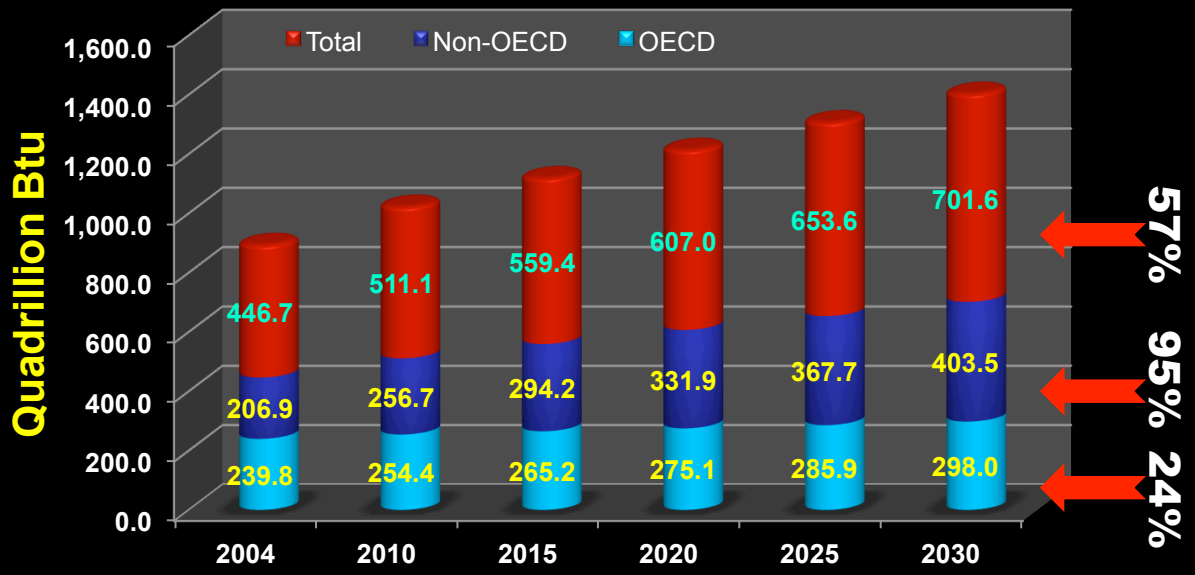
Published November 2009

Table 1 – Outdoor air supply requirement for comfort air-conditioning

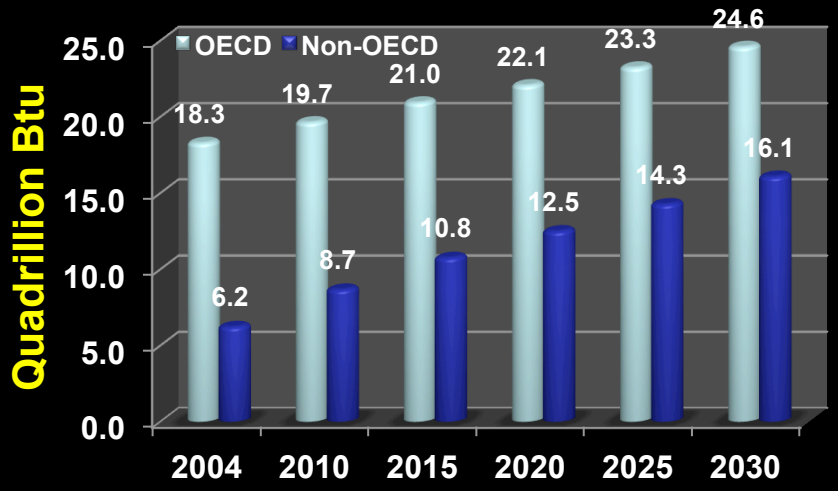
Type of building/ Occupancy	Minimum outdoor air supply			Air Class [1]	ASHRAE Std 62.1-2010 (l/s/person)
	L/s per m^2 floor area	m^3 /h per m^2 floor area	l/s per person		
Restaurants	3.4	12.2	5.1	2	5.1
(i) Dance halls	7.0	25.0	10.5	1	10.3
Offices	0.6	2.0	5.5	1	8.5
(ii) Shops, supermarkets and department stores	1.1	3.8	5.5	1 or 2	7.8/7.6/7.8
Theatres and cinemas seating area	2.0	7.3	3.0	1	2.7
Lobbies and corridors	0.3	1.1	3.3	1	2.7
Concourses	1.1	4.0	3.3	1	3.5
(iii) Hotel guest rooms	15.0L/s per room	54.0 m^3 /h per room	5.5	1	5.5
(iv) Classrooms					
Primary school children and above	2.8	10.0	4.2	1	4 – 7.4
Childcare Centres	2.8	10.0	8.4	1	8.6

Energy Scenario

World Marketed Energy Consumption by Region, 2004-2030



OECD and Non-OECD Commercial Sector Delivered Energy Consumption, 2004-2030



Commercial and Services sectors – includes different building types

- **Office buildings, schools, stores, correctional institutions, restaurants, hotels, hospitals, museums, banks, stadium**

Sources : 2004 – EIA, International Energy Annual 2004 (May-July 2006), Projections – EIA, System for the Analysis of Global Energy Markets (2007)

BCA Green Mark Scheme Singapore

BCA GREEN MARK

New Buildings

- New Dev
- Redevelopment
- A&A to existing buildings
- Major retrofitting

Existing Buildings

- Under operation with no significant retrofitting works

Green Mark Assessment Criteria

Points for Green Mark Criteria

BCA Green Mark for Non-Residential Building Version 4.1

15 January 2013

BCA GREEN MARK

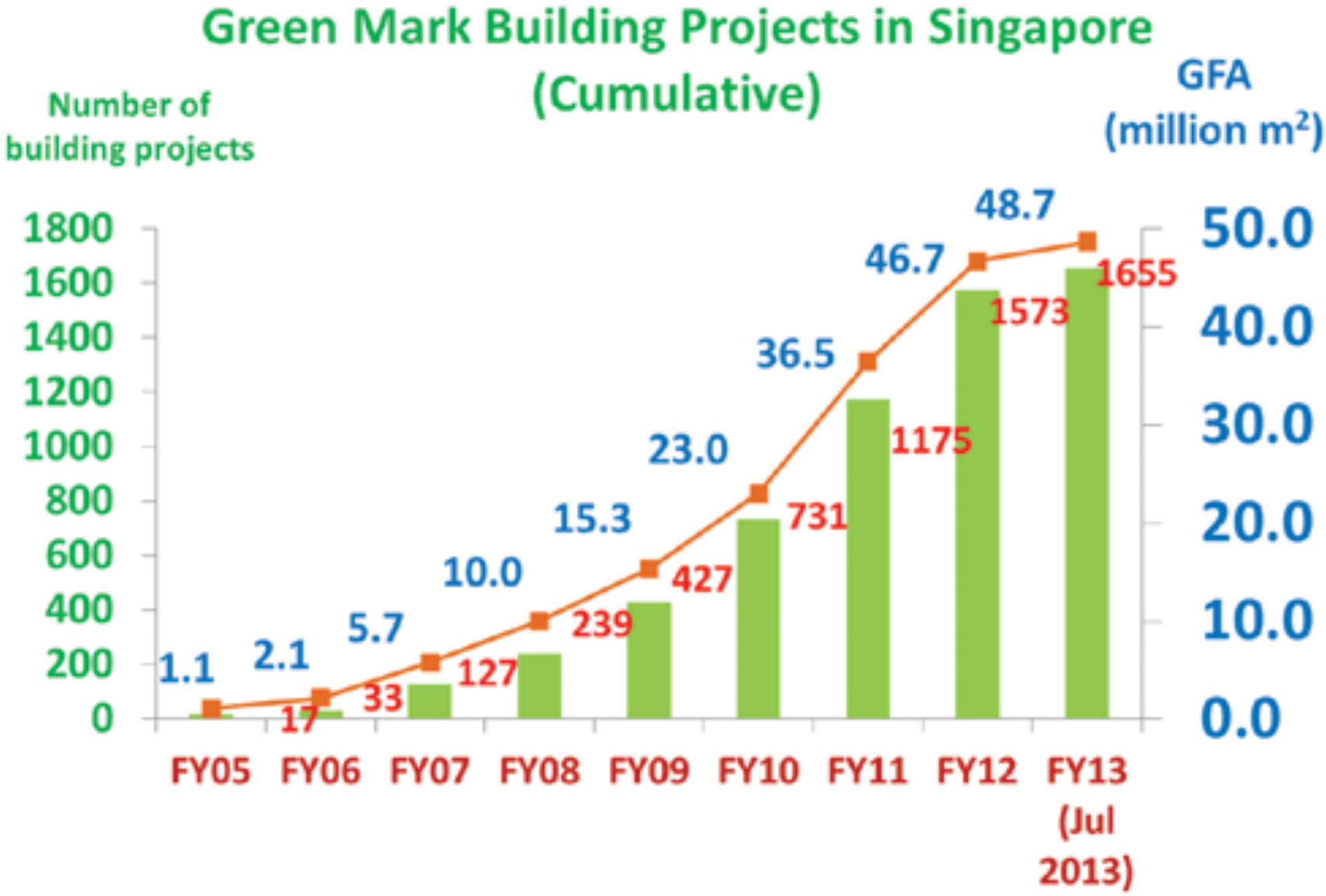
http://www.bca.gov.sg/GreenMark/green_mark_criteria.html

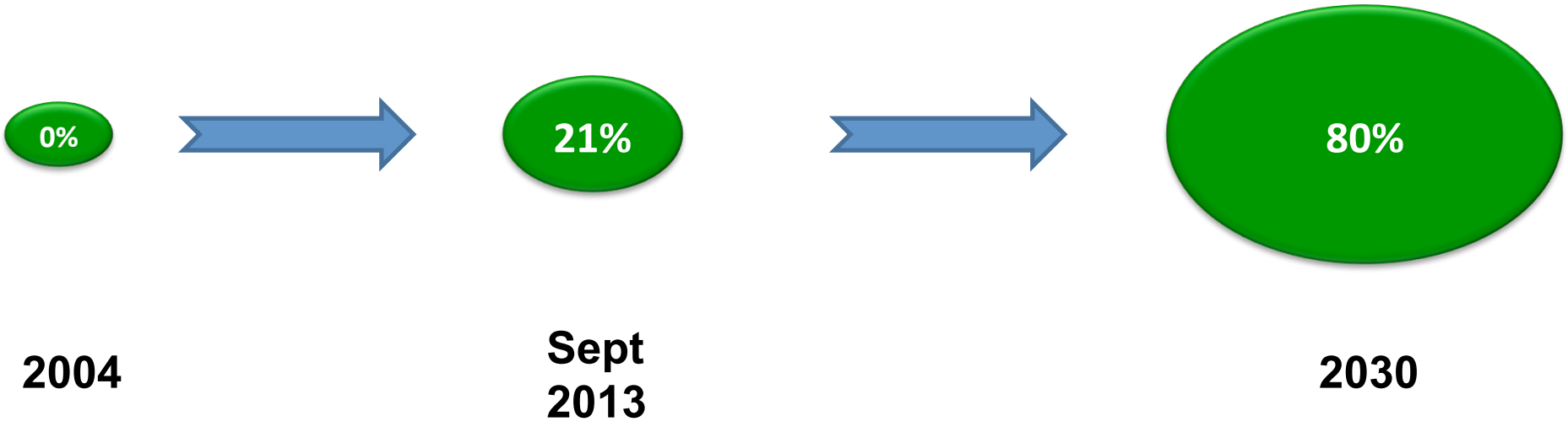
BCA Green Mark Schemes	Description	Effective Date
Non-Residential New Buildings (Version 4.1)	Applicable for new buildings such as offices, commercial, industrial and institutional buildings with or without air-conditioning systems.	15 Jan 2013 onwards
Residential New buildings (Version 4.1)	For new private and public residential developments.	15 Jan 2013 onwards
Existing Buildings (Version 3)	Applicable to existing commercial, industrial and institutional buildings under operation.	26 Jul 2012 onwards
Existing Buildings (Version 2.1)	Applicable to existing commercial, industrial and institutional buildings under operation. Assessment by this criteria is necessary for application of GMIS (Existing Building).	1 Dec 2009 onwards
Existing Residential Buildings (Version 1)	For existing private and public residential developments.	19 May 2011 onwards
Existing Schools (Version 1)	Applicable to MOE main stream schools (excluding International schools, Universities and Institute of Higher Learning: Polytechnics and ITE).	4 Aug 2011 onwards
Office Interior (Version 1.1)	Applicable for tenant renovation and maintenance practices.	01 Nov 2012 onwards
Landed Houses (Version 1)	For landed housing projects.	27 May 2009 onwards
Infrastructure (Version 1)	For infrastructure projects e.g. as barrages, roads, bridges.	27 May 2009 onwards
District (Version 2)	For district projects.	01 Jan 2013 onwards
Restaurants (Version 1)	For Restaurants.	12 Sep 2011 onwards
Supermarket (Version 1)	For Supermarket.	11 Oct 2012 onwards
Existing Data Cetres (Version 1	For Existing Data Cetres.	11 Oct 2012 onwards
Retail (Version 1	For Retail Tenants.	11 Oct 2012 onwards
New Parks (Version 1)	For New Parks	26 May 2010 onwards
Existing Parks (Version 1)	For Existing Parks	22 may 2008 onwards

Green Mark Award Rating

Version NRB 4.1, 15 Jan 2013

Green Mark Points	Green Mark Rating
90 and above	**Green Mark Platinum** GMIS Req → Energy Modeling → At least 30% Energy Savings
85 to < 90	**Green Mark Gold^{PLUS}** GMIS Req → Energy Modeling → At least 25% Energy Savings
75 to < 85	**Green Mark Gold**
50 to < 75	**Green Mark Certified**


Green Mark Building Projects in Singapore
(Cumulative)
Number of building projects
GFA (million m²)
1800
1600
1400
1200
1000
800
600
400
200
0
50.0
40.0
30.0
20.0
10.0
0.0
1.1
2.1
5.7
10.0
15.3
23.0
36.5
46.7
48.7
17
33
127
239
427
731
1175
1573
1655
FY05
FY06
FY07
FY08
FY09
FY10
FY11
FY12
FY13 (Jul 2013)



PERCENTAGE OF GREEN BUILDINGS IN SINGAPORE

NATIONAL LIBRARY BUILDING

2005
Green Mark Platinum

- 16-storey state-of-the-art library with a 3-level basement
- two blocks - library collections - space for other public activities
- a 618-seat theatre
- owner's commitment at conceptualisation stage - design considerations : impact on environment, energy and water efficiency.
- Computer simulation & modeling - to find the best bldg orientation & confign - buffer from direct solar heat & optimising natural vent & daylighting.
- passive design solutions with env-friendly technologies

KEY GREEN FEATURES

- Building orientated away from the E-W sun - sun shading features west face of building
- Energy efficient features - daylight sensors with automatic blinds at the building facades, motion sensors & energy efficient lightings
- An open plaza area between the two blocks - allows natural ventilation and daylighting
- Extensive landscaping, sky terraces and roof gardens - to lower local ambient temp
- Rain sensor - part of the automatic irrigation system for rooftop gardens. Water efficient taps & cisterns used to conserve water

Zero Energy Building @ BCA Academy

(Special Buildings)

2010
Green Mark Platinum

Key Features:

- Estimated energy savings: 388,720 kWh/yr
- Estimated water savings: 3,620 m^3/yr
- ETTV: 43.79 W/m^2

Key Features:

- Sunshading devices and efficient glazing.
- ACMV System (high performance chillers, displacement ventilation, personalised ventilation, under-floor air distribution system).
- Photovoltaic Technology of 190kWp capacity.
- Solar assisted stack ventilation.
- Mirror ducts, light pipes and light shelves.
- Sensors and monitoring system for all rooms.

2012
Green Mark Platinum

PLATINUM

BCA
GREEN MARK FOR BUILDINGS AWARD

Carlton City Hotel Singapore
New Non-Residential Buildings

Client / Developer
Carlton Properties (Singapore) Pte. Ltd.

Project Manager
KPK Quantity Surveyors (Singapore) Pte Ltd

Architect
DP Architects Pte Ltd

M&E Engineer
Beca Carter Hollings & Ferner (S.E.Asia) Pte Ltd

Structural Engineer
T.Y.Lin International Pte Ltd

Quantity Surveyor
KPK Quantity Surveyors (Singapore) Pte Ltd

Main Contractor
Kajima Overseas Asia Pte Ltd

Landscape Consultant
Site Concepts International Pte Ltd

Lighting Consultant
The Lightbox Pte Ltd

Interior Designer
Hirsch / Bedner Associates Pte Ltd

Façade Consultant
Aurecon Singapore (Pte.) Ltd.

ACMV Contractor
Shinryo Corporation (Singapore Branch)

A/V Consultant
Acviron Acoustics Consultants Pte Ltd

Sign & Way Finding Strategy Consultant
Design Datum Pte Ltd

ESD Consultant
Kaer Pte Ltd

Key Features

- Estimated energy savings: 3,653,132 kWh/yr; estimated water savings: 12,800 m^3/yr; ETTV: 31.41 W/m^2.
- Chiller plant system efficiency of ≤ 0.65kW/ton.
- Extensive use of LED lighting.
- Regenerative Drive Lift.
- Electric vehicle charging station.
- Air Handling Units (AHUs) and Fan Coil Units (FCUs) condensate water recycling system.
- Non-chemical anti-termite system.
- Air purification system to improve indoor air quality.

2013

PLATINUM

BCA
GREEN MARK FOR BUILDINGS AWARD

EduSports Building
New Non-Residential Buildings

Client / Developer
National University of Singapore

Architect
DP Architects Pte Ltd

M&E Engineer
Beca Carter Hollings & Ferner (S.E.Asia) Pte Ltd

Structural Engineer
Beca Carter Hollings & Ferner (S.E.Asia) Pte Ltd

Quantity Surveyor
Rider Levett Bucknall Pte Ltd

Main Contractor
Ando Singapore Pte Ltd

Landscape Consultant
Sitetectonix Pte Ltd

ESD Consultant
Arup Singapore Pte Ltd

Key Features

- Estimated energy savings: 1,859,308 kWh/yr; estimated water savings: 789 m^3/yr; ETTV: 31.5 W/m^2.
- Naturally ventilated semi-outdoor atrium.
- Extensive green roof.
- Waste management including provision of recycling facilities, recycling of e-waste and organic waste and implementation of biodegradable food packaging.
- High performance, self-cleaning façade with cool paint coating.
- UV emitters in AHUs to improve indoor air quality.
- Drought tolerant plants to reduce water consumption.
- Educational features including LCD display of energy/water consumption

GOLD^PLUS

BCA
GREEN MARK FOR BUILDINGS AWARD

Changi City
New Non-Residential Buildings

Client / Developer
Ascendas Frasers Pte. Ltd.

Project Manager
Ascendas Frasers Pte. Ltd.

Architect
Aedas Pte. Ltd.

M&E Engineer
Beca Carter Hollings & Ferner (S.E.Asia) Pte Ltd.

Structural Engineers
Retail and Hotel:
DE Consultants (S) Pte. Ltd.
Business Park:
AECOM Singapore Pte Ltd

Quantity Surveyor
KPK Quantity Surveyors (Singapore) Pte Ltd

Main Contractor
Nakano Singapore Pte. Ltd.

Landscape Consultant
Belt Collins International (Singapore) Pte. Ltd.

ESD Consultant
Arup Singapore Pte Ltd

Key Features

- Estimated energy savings: 15,050,221 kWh/yr; estimated water savings: 299,582 m^3/yr; ETTV: 40.77 W/m^2.
- Designation control system for lifts in office building.
- AHU installed with UVC emitter to improve indoor air quality.
- Skylight at retail atrium to provide natural daylight.
- Recycling of AHU condensate in office building and hotel.

2013

PLATINUM

BCA
GREEN MARK FOR BUILDINGS AWARD

Fusionopolis Phase 2A @ one-north
New Non-Residential Buildings

Clients / Developers
JTC Corporation
A*STAR

Project Manager
PM Link Pte Ltd

Architect
P&T Consultants Pte Ltd

M&E Engineer
Parsons Brinckerhoff Pte Ltd

Structural Engineer
Arup Singapore Pte Ltd

Quantity Surveyor
KPK Quantity Surveyors (Singapore) Pte Ltd

Main Contractor
GS Engineering & Construction Corp

Landscape Consultant
Martin Lee Designs

ESD Consultant
Parsons Brinckerhoff Pte Ltd

Key Features

- Estimated energy savings: 14,839,226 kWh/yr; estimated water savings: 156,890 m^3/yr; ETTV: 34.75 W/m^2.
- Chiller plant system efficiency of 0.63kW/ton.
- Permanent measurement and verification instrumentation for the monitoring of chilled-water plant efficiency and heat balance.
- Low-e double glazing of vision panels.
- Integrated design of heat pipes for cooling coil at Modular Air Handling Units (MAHU) for efficient dehumidification and temperature control.
- Use of high performance fan filter units with low power consumption DC motors.
- Use of SGLS certified carpets, laminates, waterproofing system, external paint and dry-wall partitions. Timber decking, raised floor, ceiling panel made up of more than 30% of recycled content.

2013

PLATINUM

BCA
GREEN MARK FOR BUILDINGS AWARD

Mount Elizabeth Novena Hospital
New Non-Residential Buildings

Clients / Developers
Parkway Novena Pte Ltd
Parkway Irrawaddy Pte Ltd

Architect
Consultants Incorporated
Architects + Planners

Interior Design
HOK International
(Singapore) Pte Ltd

M&E Engineer
Parsons Brinckerhoff Pte Ltd

Lighting Consultant
The Lightbox Pte Ltd

Structural Engineer
T.Y.Lin International Pte Ltd

Quantity Surveyor
Langdon & Seah
Singapore Pte Ltd

Main Contractor
Penta Ocean Construction Co., Ltd

Landscape Consultant
Mace Studio Pte Ltd

TBP & ESD Consultant
ZEB-Technology Pte Ltd

Key Features

- Estimated energy savings: 13,176,532.28 kWh/yr; estimated water savings: 4,574.42 m^3/yr; ETTV: 31.76 W/m^2.
- Efficient chiller plant room design with an efficiency of 0.625 kW/ ton.
- Pre-cool AHU to improve indoor air quality, energy efficiency and Relative Humidity (RH) control.
- Demand control ventilation with carbon monoxide (CO) sensors for car park and carbon dioxide (CO2) sensors.
- Permanent instrumentation for measurement and verification of chiller plant.
- 10kWp onsite energy generation through photovoltaic panels.
- Energy efficient lighting design with LED and other efficient lighting systems.
- Lifts and escalators installed with Variable Voltage Variable Frequency (VVVF) motor and sensors.
- Extensive greenery at various levels.

2013

PLATINUM

BCA
GREEN MARK FOR BUILDINGS AWARD

National Heart Centre Singapore
New Non-Residential Buildings

Client / Developer
Ministry of Health

Project Manager
PM Link Pte Ltd

Architect
ONG&ONG Pte Ltd

M&E Engineer
Squire Mech Pte Ltd

Structural Engineer
Beca Carter Hollings
& Ferner (S.E.Asia) Pte Ltd

Quantity Surveyor
Langdon & Seah
Singapore Pte Ltd

Main Contractor
Shimizu Corporation

Landscape Consultant
ONG&ONG Pte Ltd

Medical Planner
Broadway Malyan Asia Pte. Ltd.

Façade Consultant
Arup Façade Engineering

ESD Consultants
Lincolne Scott Ng Pte Ltd
WSP Ng Pte Ltd

Key Features

- Estimated energy savings: 6,197,418 kWh/yr; estimated water savings: 12,534 m^3/yr; ETTV: 36.4 W/m^2.
- High performance building fabric.
- Chiller plant system efficiency of 0.607kW/ton with accurate permanent monitoring measurement and verification tools.
- Heat recovery.
- Rainwater harvesting.
- Recycling of AHUs Condensate.
- UVC emitters in all AHUs.
- Provision of charging stations for electric vehicles.

Final Words

- IAQ & Energy Issues
- Impact of ventilation and IAQ on occupant productivity and health
- IAQ Audit – IAQ parameters, Ventilation parameters, Human Response
- Relevant Standards
- Energy Scenario
- Integrated IAQ Energy Assessment

Thank You for your Attention