International Centre for Indoor Environment and Energy

Background and use of new standardization on indoor environment EN15251/ISO NWI 17772

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COMFORT-PRODUCTIVITY
Building costs

People	100
Maintenance	10
Financing	10
Energy	**1**

We build buildings for people, not for saving energy

Health

Global impact on people

- In developing regions 5000 persons die per day due to poor IAQ

- In developed countries increase in asthma and allergy

COMFORT

Large individual differences between people

Hans Christian Andersen: The Princess on the Pea

Achieving Excellence in Indoor Environmental Quality

- Physical factors
  - Thermal Comfort
  - Air quality (ventilation)
  - Noise-Acoustic
  - Illumination
- Personal factors
  - Activity
  - Clothing
  - Adaptation
  - Expectation
  - Exposure time

EXPERTS

- *EN15251revision*
  - *Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics*
- Members of TC156-WG19 (JWG156/371) are experts and responsible for the work
- Must be nominated by national standardisation institute
- ISO WI 17222 under JWG ISO TC163/205

GENERAL

- Main concept and structure will be maintained
- A standard in mandatory language and a guideline will be developped.
- The standard will include an Annex B with tables including default values and Annex A with empty tables.
- Both prEN15251rev and ISO-DIS 17772 will be ready for public comments in October 2014

Cooperation with ISO JWGTC163/205 on NWI-17772

- CEN revision of EN15251 JWGTC156/371
  - TC371 EPBD
  - TC89 Buildings
  - TC169 Lighting
  - TC228 Heating and Cooling systems
  - TC247 Control
- ISO WI 17222 under JWG ISO TC163/205

Categories

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like some disabilities, sick, very young children and elderly persons, to increase accessibility.
II	. Normal level of expectation
III	An acceptable, moderate level of expectation
IV	This category should only be accepted for a limited part of the year

Thermal Environment

- **Buildings without mechanical cooling**
  - Buildings that do not have any mechanical cooling and rely on other techniques to reduce high indoor temperature during the warm season like moderately-sized windows, adequate sun shielding, use of building mass, natural ventilation, night time ventilation etc. for preventing overheating.
    - Note: The definition is related to people's expectation regarding the internal temperature in warm seasons. Opening of windows during day and night time is not regarded as mechanical cooling. Any mechanical assisted ventilation (fans) is regarded as mechanical cooling

- **Mechanical cooling**
  - Cooling of the indoor environment by mechanical means used to provide cooling of supply air, fan coil units, cooled surfaces, etc.

Recommended categories for design of mechanical heated and cooled buildings

Category	Thermal state of the body as a whole		*Local thermal discomfort*			
	PPD %	Predicted Mean Vote	*Draught Rate, DR %*	*Vertical air tempe-rature difference %*	*Warm or cool floor %*	*Radiant Tempe-rature Asym-metry %*
I	< 6	-0.2 < PMV < + 0.2	*<10*	*< 3*	*< 10*	*< 5*
II	< 10	-0.5 < PMV < + 0.5	*<20*	*< 5*	*< 10*	*< 5*
III	< 15	-0.7 < PMV < + 0.7	*<30*	*< 10*	*< 15*	*< 10*
IV	< 25	-1.0 < PMV < + 1.0				

Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment

Type of building/ space	Category	Operative Temperature for Energy Calculations °C	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met		**Heating (winter season), ~ 1,0 clo**	**Cooling (summer season), ~ 0,5 clo**
	I	**21,0 – 23,0**	**23,5 - 25,5**
	II	**20,0 – 24,0**	**23,0 - 26,0**
	III	**19,0 – 25,0**	**22,0 - 27,0**

LOCAL THERMAL DISCOMFORT influence design and dimensioning

- FLOOR SURFACE TEMPERATURE
- VERTICAL AIR TEMPERATURE DIFFERENCE
- DRAUGHT
- RADIANT TEMPERATUR ASYMMETRI

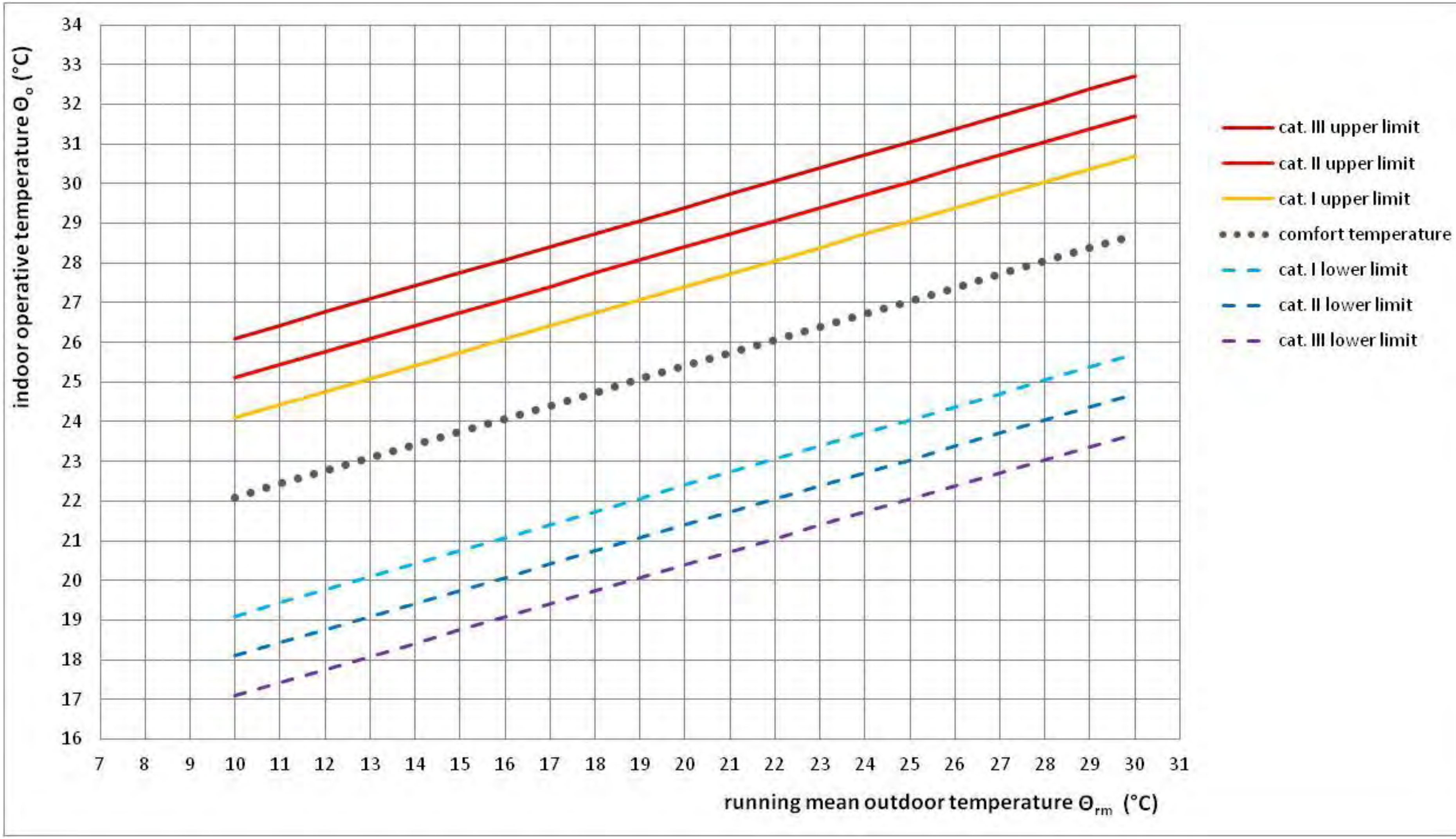
Included in ISO EN 7730 and ASHRAE 55

ADAPTATION IN NATURAL VENTILATED BUILDINGS ?

- Behavioural
  - Clothing, activity, posture
- Psychological
  - Expectations

Thermal Environment

- **The adapted method**
  - Only applies for occupants with sedentary activities without strict clothing policies where thermal conditions are regulated primarily by the occupants through opening and closing of openings in the building envelope (windows).
  - For buildings and spaces were the building design and the natural ventilation system is not adequate to meet the required temperature categories the design documents must state, using one of the methods described in TR15251, how often the conditions are outside the required range


indoor operative temperature Θo (°C)
running mean outdoor temperature Θrm (°C)
cat. III upper limit
cat. II upper limit
cat. I upper limit
comfort temperature
cat. I lower limit
cat. II lower limit
cat. III lower limit
34
33
32
31
30
29
28
27
26
25
24
23
22
21
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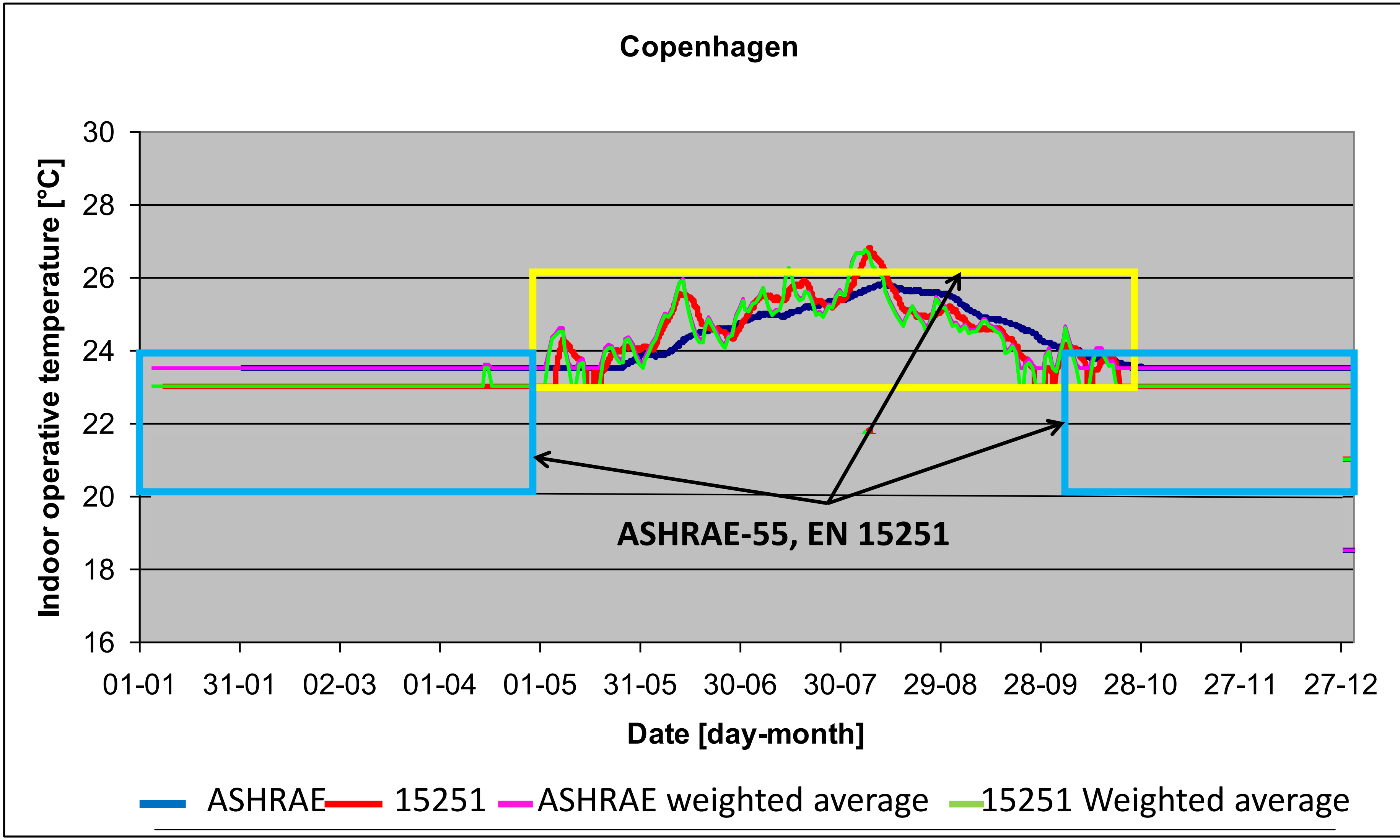
19
18
17
16
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31



Copenhagen
Indoor operative temperature [°C]
30
28
26
24
22
20
18
16
01-01
31-01
02-03
01-04
01-05
31-05
30-06
30-07
29-08
28-09
28-10
27-11
27-12
Date [day-month]
ASHRAE-55, EN 15251
ASHRAE
15251
ASHRAE weighted average
15251 Weighted average

EXPECTATIONS

- If you buy a FIAT-500 you do not expect the performanec of a PORSCHE
- If you buy a PORSCHE you do not expect the performanec of a FIAT-500
- But which one would you like to drive??????

Increased Air speed

– Indoor operative temperature correction (ΔΘ_o) that can be applied when buildings are equipped with fans, personal ventilation systems etc that provide building occupants with precise, stepless control over air speed at workstation level. The correction value depends on the air speed range of the appliance.

Average Air Speed (V_a) 0.6 m/s	**Average Air Speed (V_a) 0.9 m/s**	**Average Air Speed (V_a) 1.2 m/s**
1.2°C	1.8°C	2.2°C

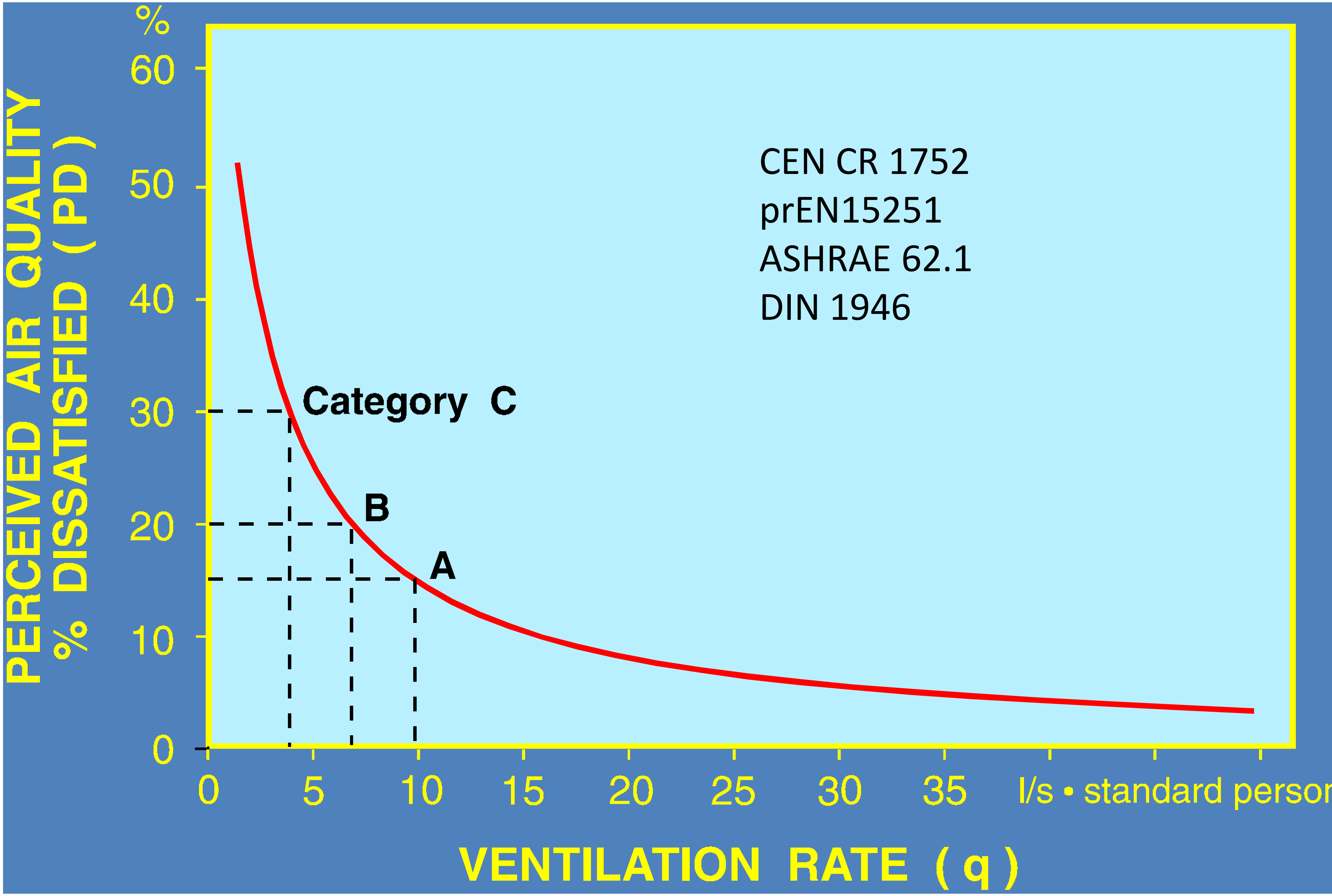
Indoor Air Quality-Ventilation

The ventilation rate required from a health point of view is calculated by this equation:

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v} \qquad \text{Eq (1)}$$

where:

- Q_h is the ventilation rate required for dilution, in litre per second;
- G_h is the pollution load of a pollutants, in micrograms per second;
- $C_{h,i}$ is the guideline value of a pollutants, see Annex L, in micrograms per litre;
- $C_{h,o}$ is the supply concentration of a pollutants at air intake, in micrograms per litre;
- ε_v is the ventilation effectiveness.

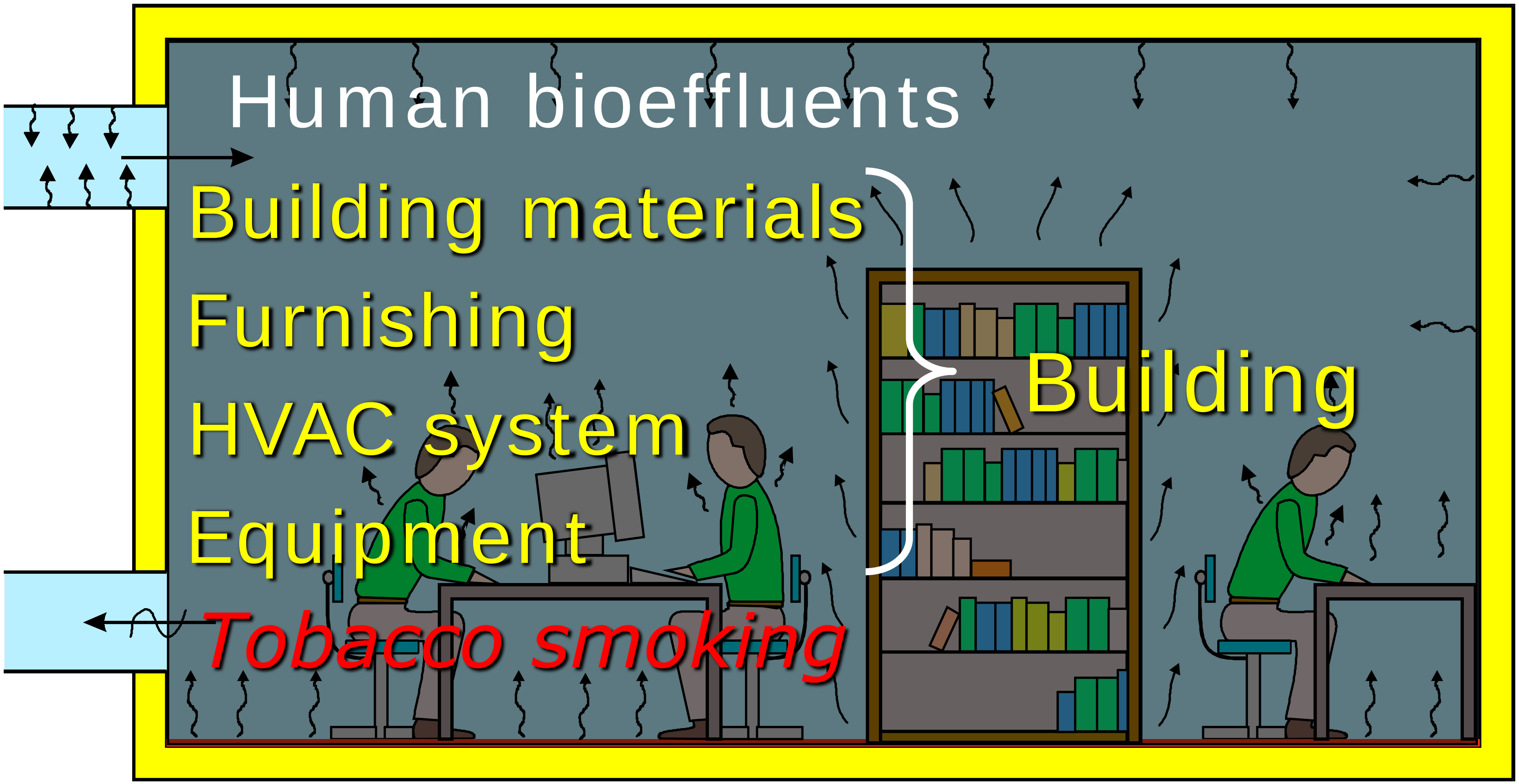


%
60
50
40
30
20
10
0
PERCEIVED AIR QUALITY
% DISSATISFIED (PD)
CEN CR 1752
prEN15251
ASHRAE 62.1
DIN 1946
Category C
B
A
0
5
10
15
20
25
30
35
l/s • standard person
VENTILATION RATE (q)

People

Category	Expected Dissatisfied Percentage	Airflow per non-adapted person l/s/pers
I	15	10
II	20	7
III	**30**	**4**
IV	**?**	**?**

Indoor pollution sources



Building

Category	Very low polluting building l/(s m²)	Low polluting building l/(s m²)	Non low-polluting building l/(s m²)
I	0,5	1,0	2,0
II	0,35	0,7	1,4
III	**0,3**	**0,4**	**0,8**
IV			
Minimum total ventilation rate for health	4 l/s person	6 l/s person	8 l/s person

Building Type

SOURCE	Low emitting products for low polluted buildings	Very low emitting products for very low polluted buildings
Total VOCs TVOC (as in CEN/TS 16516)	< 1.000 µg/m³	< 300 µg/m³
Formaldehyde	< 100 µg/m³	< 30 µg/m³
Any C1A or C1B classified carcinogenic VOC	< 5 µg/m³	< 5 µg/m³
R value (as in CEN/TS 16516)	< 1.0	< 1.0

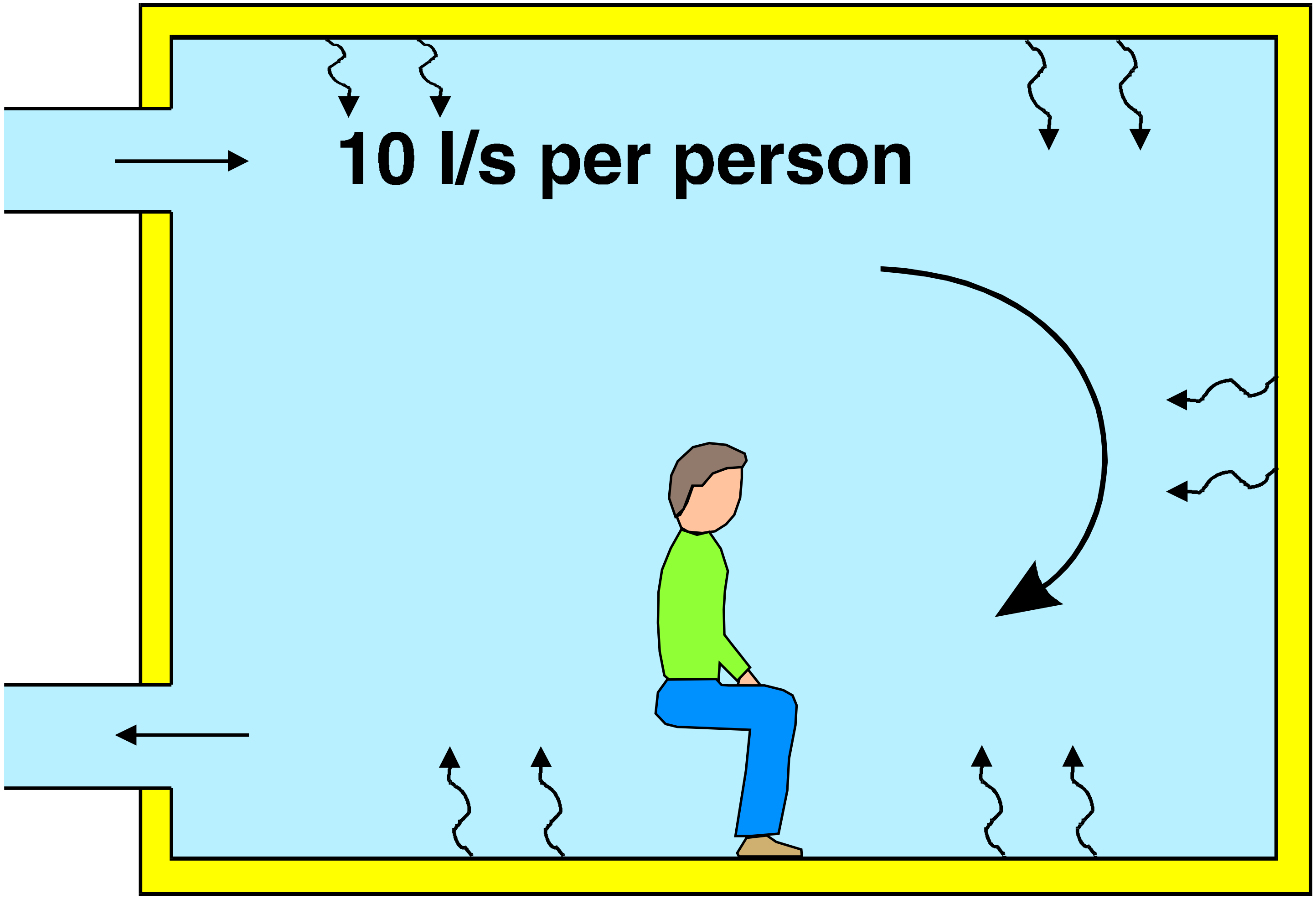
Breathing zone outdoor airflow (V_{bz}),

- $V_{bz} = R_{pP}P_z + R_{aA}A_z$
-

- where:
  - A_z = Zone floor area: the net occupiable floor area of the zone m^2
  - P_z = Zone population: the largest number of people expected to occupy the zone during typical usage.
  - R_{Pp} = Outdoor airflow rate required per person: these values are based on non-adapted (adapted) occupants.
  - R_{Aa} = Outdoor airflow rate required per unit area.

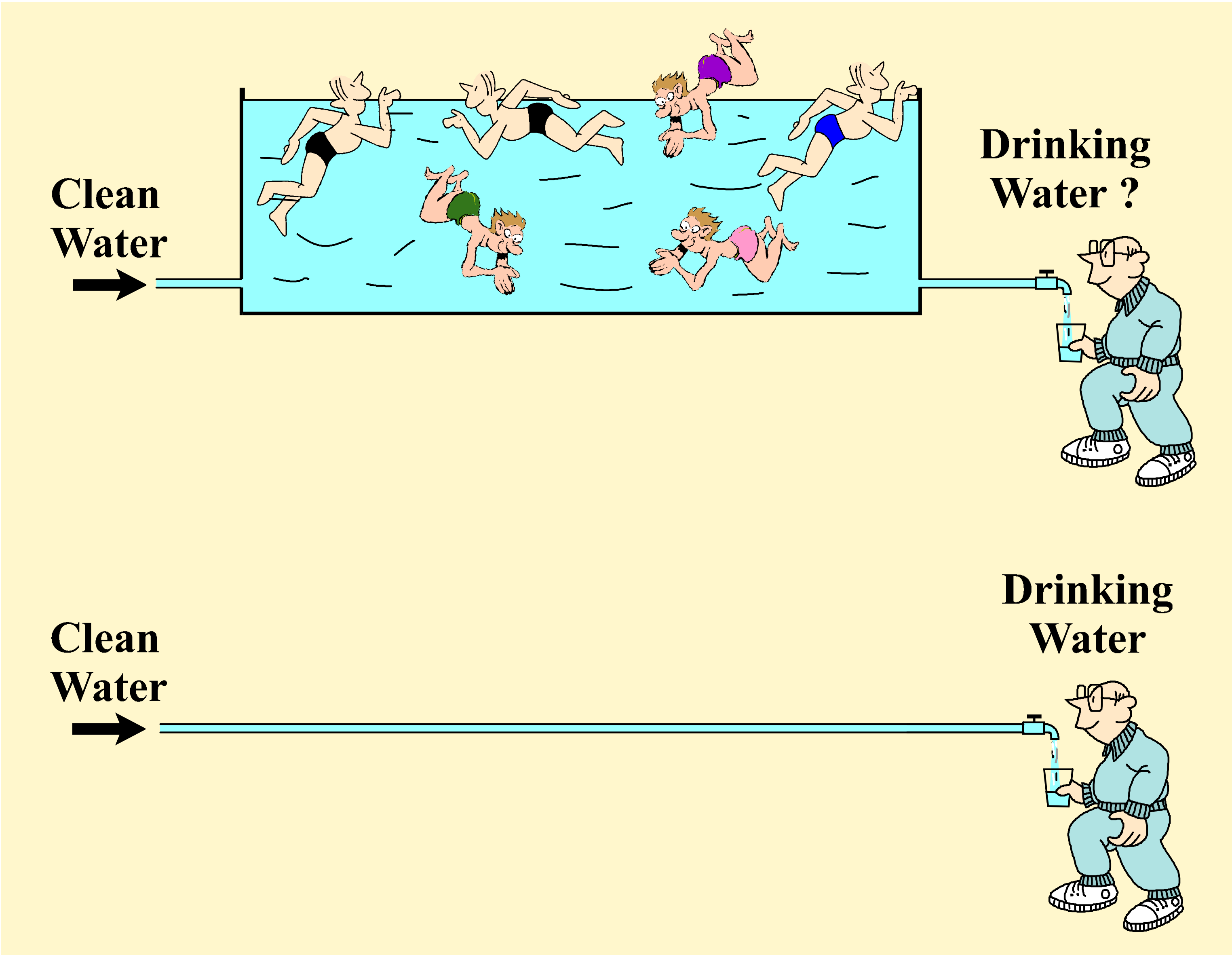
Example of design ventilation air flow rates for a single-person office of 10 m^2 in a low polluting building (un-adapted person)

Category	Low-polluting building l/s/m^2	Airflow per non-adapted person l/s/person	Total design ventilation air flow rate for the room l/s	l/s person	l/s m^2
I	1,0	10	20	20	2
II	0,7	7	14	14	1,4
III	**0,4**	**4**	**8**	**8**	**0,8**



Less than 1 % is used

Ventilation today ...


Clean Water
Drinking Water ?
Clean Water
Drinking Water

Total outdoor airflow

$$V_{tot} = V_{bz} / \varepsilon$$

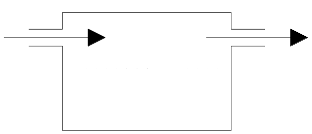
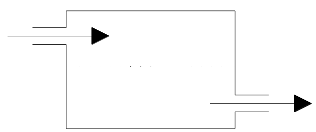
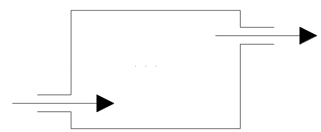
Air Distribution Effectiveness

$$\varepsilon_V = \frac{C_E - C_S}{C_I - C_S}$$

CEN Report CR 1752 (1998)

Concentrations:

- **C_E exhaust air**
- **C_S supply air**
- **C_I breathing zone**

Mixing ventilation		Mixing ventilation		Displacement ventilation		Personalized ventilation	
							
T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T room °C	Vent. effect. -
< 0	0,9 - 1,0	< -5	0,9	<0	1,2 - 1,4	-6	1,2 - 2,2
0 - 2	0,9	-5 - 0	0,9 - 1,0	0-2	0,7 - 0,9	-3	1,3 - 2,3
2 - 5	0,8	> 0	1	>2	0,2 - 0,7	0	1,6 - 3,5
> 5	0,4 - 0,7						

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Demand Controlled Ventilation

- Commercial buildings
  - Level of occupancy
  - CO_2 concentration (1000 ppm)
- Residential buildings
  - Time of day (at home, outside)
  - Occupied room (living room, bedroom)

Table B4. Examples of recommended CO_2 concentrations above outdoor concentration for energy calculations and demand control.

Category	Corresponding CO2 above outdoors in PPM for energy calculations
I	350
II	500
III	800
IV	< 800

CRITERIA FOR LIGHTING

EN 12464-1 2011	Type of area, task or activity	$\bar{E}_m$ lx	UGR_L –	U_o –	R_a –	Specific requirements
5.26.2 5.26.5	Offices - Writing, typing, reading, data processing, - Conference and meeting rooms	**500**	**19**	**0,60**	**80**	DSE-work, see 4.9 Lighting should be controllable.
5.36.1-5.36.3	Educational buildings - Classrooms, tutorial rooms, Classroom for evening classes and adults education, Auditorium, lecture halls	**500**	**19**	**0,60**	**80**	Lighting should be controllable.
5.36.24	Educational premises – Educational buildings - Sports halls, gymnasiums, swimming pools	**300**	**22**	**0,60**	**80**	See EN 12193 for training conditions.

Daylight factor, 2-5%, Ra colour rendering index

CRITERIA FOR LIGHTING

For rooms that are used during the day (work places, living rooms, dining rooms, kitchens, or child's play rooms) the minimum daylight factor is:

	I	II	III
Daylight factor	> 5% on average	> 3% on average	> 2% on average

CRITERIA FOR LIGHTING

To reduce the prevalence of SAD (seasonal Affective Disorder; “winter depression”), high light levels are particularly important during winter.

In residential buildings as a minimum one of the main habitable rooms in residential buildings direct sunlight should be available between fall and spring equinox:

	I	II	III
Direct sunlight availability, percentage of probable sunlight hours	> 10%	> 7,5%	> 5%

Indoor System Noise Criteria

Noise from **outside** by natural ventilation?

Building	Type of space	Equivalent Continuous Sound Level, Leq, nT,A [dB(A)]		
		I	II	III
Residential	Living room	≤30	≤34	≤38
	Bed room	≤26	≤30	≤34
Places of assembly	Auditoriums	≤20	≤24	≤28
	Libraries	≤24	≤28	≤32
	Cinemas	≤20	≤24	≤28
Hospitals	Bedrooms night-time	≤22	≤26	≤30
	Bedrooms daytime	≤24	≤28	≤32
Hotels	Hotel rooms (during night-time)	≤24	≤28	≤32
	Hotel rooms (during daytime)	≤26	≤30	≤34
Offices	Small offices	≤24	≤28	≤32
	Landscaped offices	≤26	≤30	≤34
Restaurants	Restaurants	≤28	≤32	≤36
Schools	Classrooms	≤24	≤28	≤32
	Teacher rooms	≤28	≤32	≤36

Table G.12 — Example of conventional input data related to occupancy

Building type	a	b	c	d	e	f	g	h	i) Other types				Unit
Building category Input data	Single-family houses	Apartment blocks	Offices	Education buildings	Hospitals	Restaurants	Trade services	Sports facilities	Meeting halls	Industrial buildings	Warehouses	Indoor swimming pools	
Internal set-point temperature in winter	20	20	20	20	22	20	20	18	20	18	18	28	°C
Internal set-point temperature in summer	26	26	26	26	26	26	26	26	26	26	26	28	°C
Area per person (occupancy)	60	40	20	10	30	5	10	20	5	20	100	20	m^2/person
Average heat flow per person	70	70	80	70	80	100	90	100	80	100	100	60	W/person
Metabolic gain per conditioned floor area	1,2	1,8	4,0	7,0	2,7	20,0	9,0	5,0	16,0	5,0	1,0	3,0	W/m^2
Presence time per day (monthly average)	12	12	6	4	16	3	4	6	3	6	6	4	h
Annual electricity use per conditioned floor area [a]	20	30	20	10	30	30	30	10	20	20	6	60	kWh/m^2
Part of electricity use within conditioned part of building	0,7	0,7	0,9	0,9	0,7	0,7	0,8	0,9	0,8	0,9	0,9	0,7	—
Airflow rate with external air per conditioned floor area [a]	0,7	0,7	0,7	0,7	1,0	1,2	0,7	0,7	1,0	0,7	0,3	0,7	$m^3/(h \cdot m^2)$
Airflow rate with external air per person	42	28	14	7	30	6	7	14	5	14	30	14	$m^3/(h \cdot person)$
Heating need for hot water per conditioned floor area [a]	10	20	10	10	30	60	10	80	10	10	1,4	80	kWh/m^2

[a] These figures refer to the gross conditioned area, calculated with external building dimensions. This area includes all conditioned space contained within the thermal insulation layer. For example, an internal unheated (but indirectly heated) staircase is included, but a cellar is not.

TR15251

- **6 Design input criteria for dimensioning of buildings, heating, cooling, ventilation and lighting systems**
  - **6.1 Thermal environment**
  - **6.1.1 Mechanically heated and/or cooled buildings**
  - **6.1.2 Buildings without mechanical cooling**
  - **6.1.3 Local thermal discomfort**
  - **6.1.4 Recommended criteria for personalized systems**
- **6.2 Design for Indoor air quality (ventilation rates)**
  - **6.2.1 General**
  - **6.2.2 Health criteria**
  - **6.2.3 Perceived air quality**
  - **6.2.6 Filtration and air cleaning**
  - **6.2.7 Recommended methods for substitute ventilation air by air cleaning**
- **6.3 Humidity**
- **6.4 Lighting**
- **6.5 Noise**
- **7 Indoor environment parameters for energy calculation**

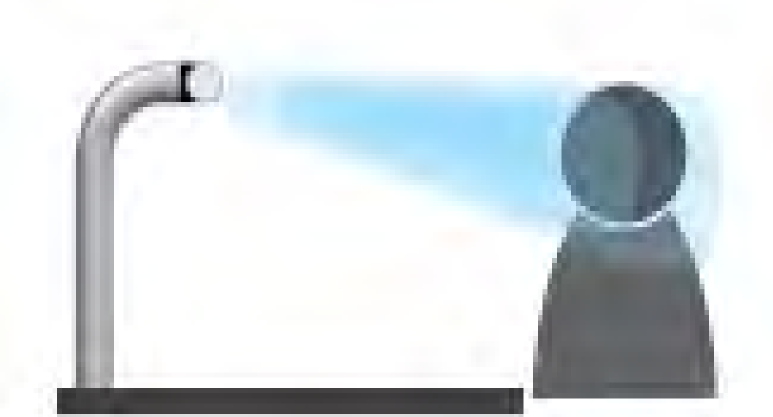
Adapted or Un-adapted ?

- Bioeffluents (body odour)
  - Adapted need only one third of outside air (~7 l/s to 2.5 L/s)
- Tobacco smoke (ETS)
  - Only limited adaptation (odour, irritation)
- Building materials and HVAC systems
  - No adaptation

Adapted or Un-adapted ?

- Conference rooms. Adapted?
- Classrooms. Adapted?
- Restaurants. Un-adapted?
- Department stores. Un-adapted

Personalized systems



- Can "standard" criteria be directly applied also to a personal system, where the occupants try to meet their own preferences?
- If the occupants have a personalized system is it then possible to relax on the requirements to the general environment?
- These are some of the issues that will be discussed in the revision of the standard

AIR CLEANING

- Filters
- Photo catalytic Oxidation (PCO)
- Electrostatic
- Desiccant air cleaners
- Others

AIR CLEANING

- The criteria for the ventilation rates are mainly based on perceived air quality PAQ, which is measured by a human test panel.
- It is therefore also important to be able to test the air cleaning efficiency in relation to the perceived air quality.
- The air cleaning efficiency can be expressed as:
-
- $\varepsilon_{PAQ} = Q_o / Q_{AP} \cdot (PAQ/PAQ_{AP} - 1) \cdot 100$ %
- where
- ε_{PAQ} air cleaning efficiency for perceived air quality
- Q_o ventilations rate in l/s
- Q_{AP}
- PAQ perceived air quality without the air cleaner, decipol
- PAQ_{AP} perceived air quality without the air cleaner, decipol
-
- The Clean Air Delivery Rate is calculated as:
- $CADR = \varepsilon_{PAQ} \cdot Q_{AP} \cdot (3{,}6/V)$ h^{-1}
- where
- $Q_{AP}\cdot$ air flow through the air cleaner l/s
- V volume of the room m^3.

TR15251

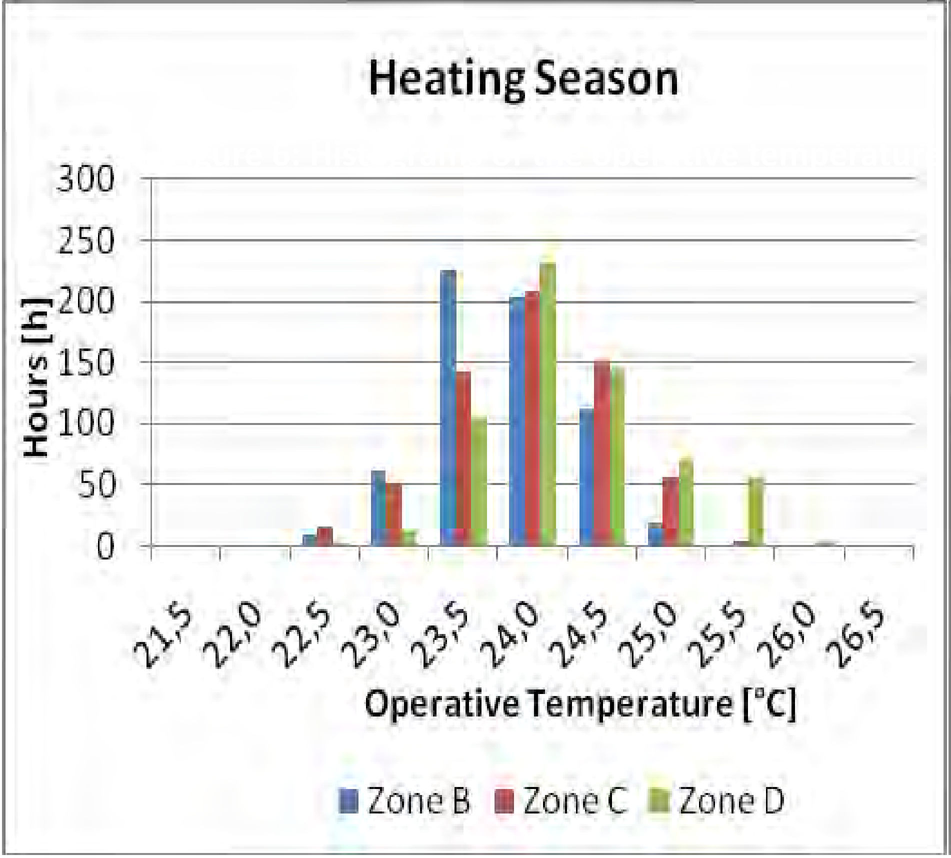
- **8 Evaluation of the indoor environment and long term indicators**
  - **8.1 Design indicators**
  - **8.2 Calculated indicators of indoor environment**
  - **8.3 Measured indicators**
  - **8.4 Subjective evaluations**
- **9 Inspections and measurement of the indoor environment in existing buildings**
- **10 Classification and certification of the indoor environment.**

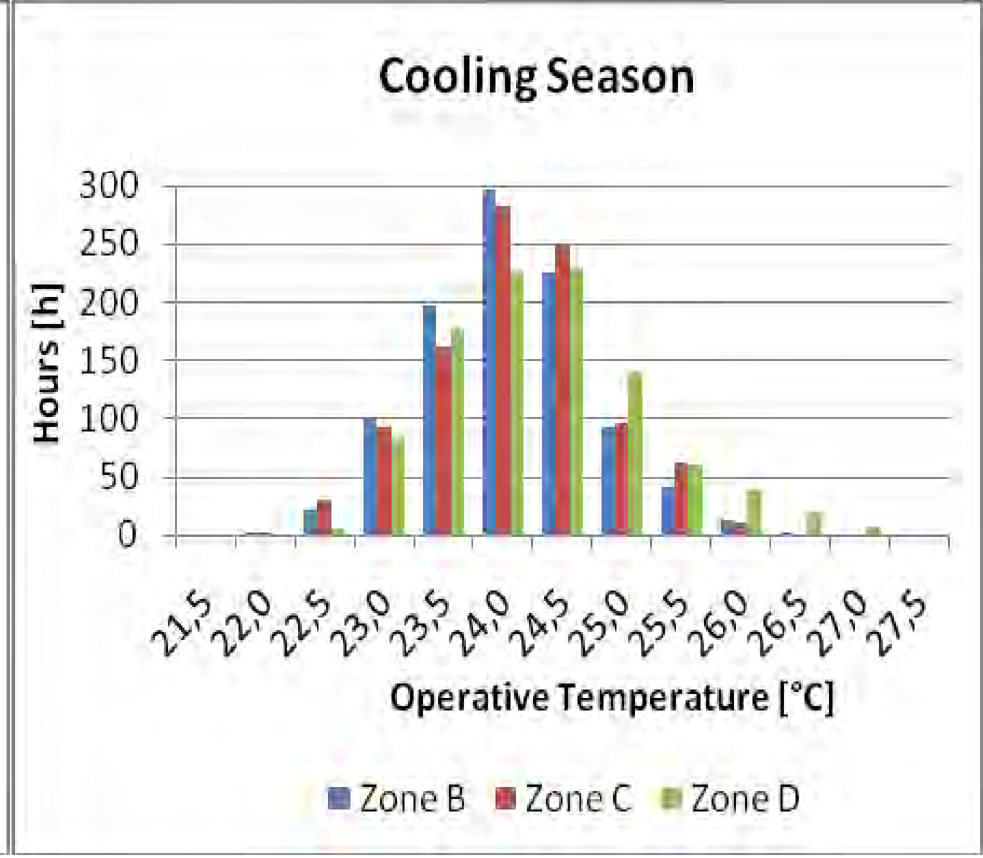
EN 15251rev DEVIATIONS

x% / y% of period	Daily Hours 25% 50%	Weekly Hours 20% 35%	Monthly Hours 12% 25%	Yearly Hours 3% 6%
Working time Total hours	**2 4** 8	**8 15** 40	**21 44** 175	**63 126** 2100
Total time **Total hours**	**6 12** 24	**33 58** 166	**86 180** 720	**259 518** 8640

Yearly performance
Indoor Environment

- How to present data
  - Thermal Comfort
  - Indoor Air quality



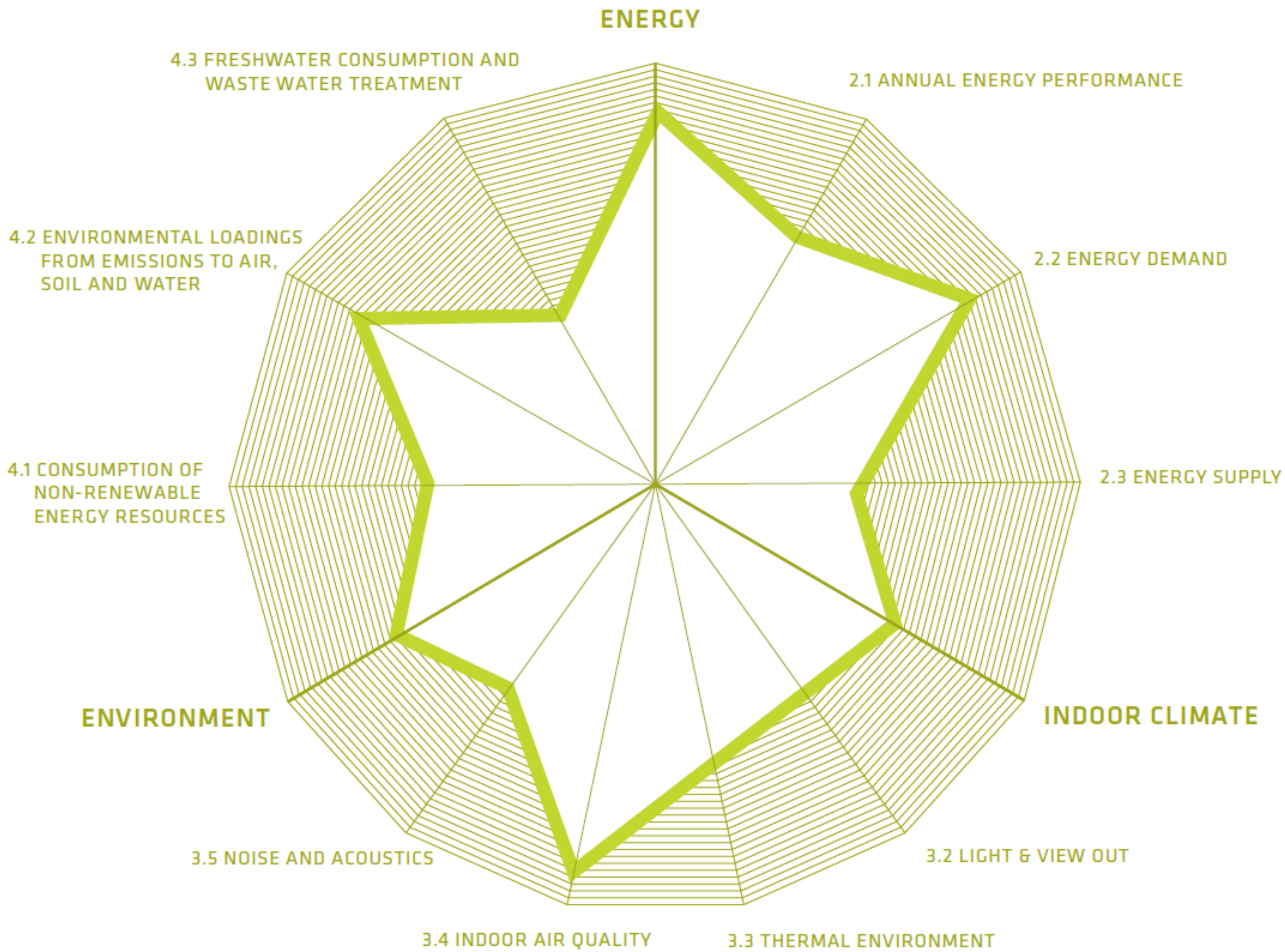


	Percentage [-] in Winter period			
	I (21.0 - 23.0 ° C)	**II (20.0 - 24.0 ° C)**	**III (19.0 - 25.0 ° C)**	**IV (Other)**
1st Floor	**8,3**	**67,4**	**96,6**	**3,4**

	Percentage [-] in Summer period			
	I (23.5 - 25.5 °C)	**II** (23.0 - 26.0 °C)	**III** (22.0 - 27.0 °C)	**IV** (Other)
1st Floor	**85,5**	**97,0**	**100,0**	**-**

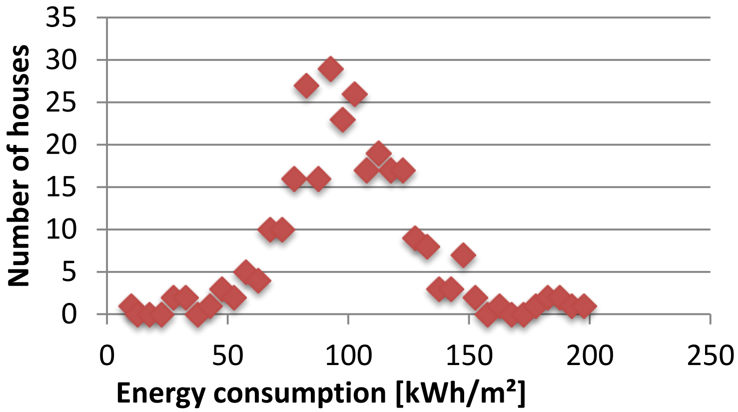
Quality of indoor environment in % of time in four categories				
Percentage	**5**	**7**	**68**	**20**
Thermal Environment	**IV**	**III**	**II**	**I**
Percentage	**7**	**7**	**76**	**10**
Indoor Air Quality	**IV**	**III**	**II**	**I**

Combined evaluation



Investigation of heat consumption in 290 identical houses

- Highest consumption up to 20 times higher than lowest
- Savings
  - 90 % if all use same as lowest consumer
  - 45 % if all use same as the 10 % lowest
  - 30 % if all use same as the 25 % lowest



Occupant Behaviour

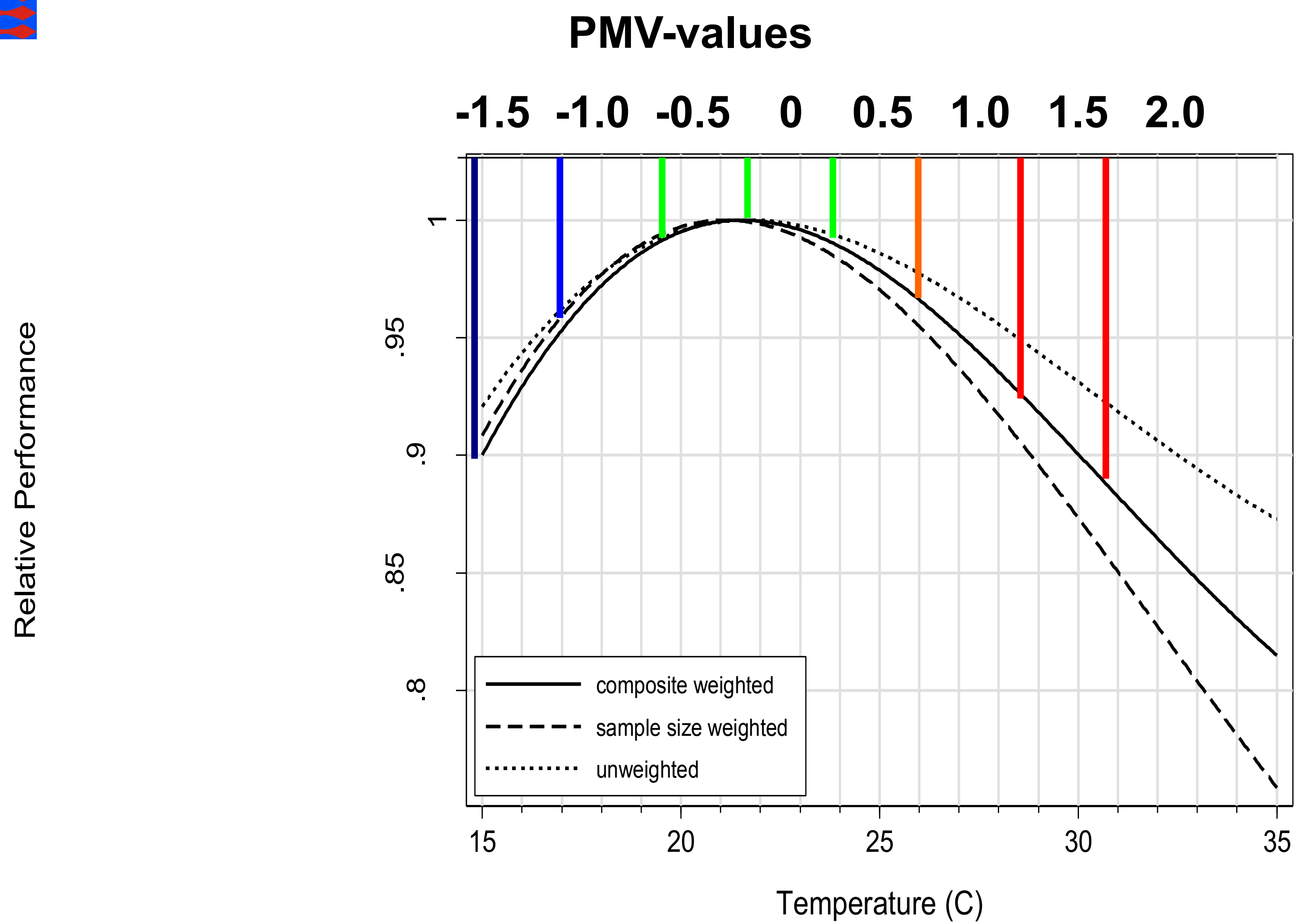
- Can impact the energy consumption with a factor 3-6
- Often main reason why predicted energy use do not match measured energy use
- Assumptions regarding occupant behaviour are used as input parameters to energy calculation
  - Set point
  - Window opening
  - Solar shading
  - Time of occupancy
  - Etc.
- A topic dealt with by IEA ECBCS Annex 53 and new Annex 63

Behaviour changes as a tool of energy conservation?

- Is it possible to achieve energy savings by facilitation of behaviour changes?
- Can direct and current information about consequences of actions facilitate behaviour changes?
- Will information about actual price of heating and advice about behaviour facilitate changes in habits?

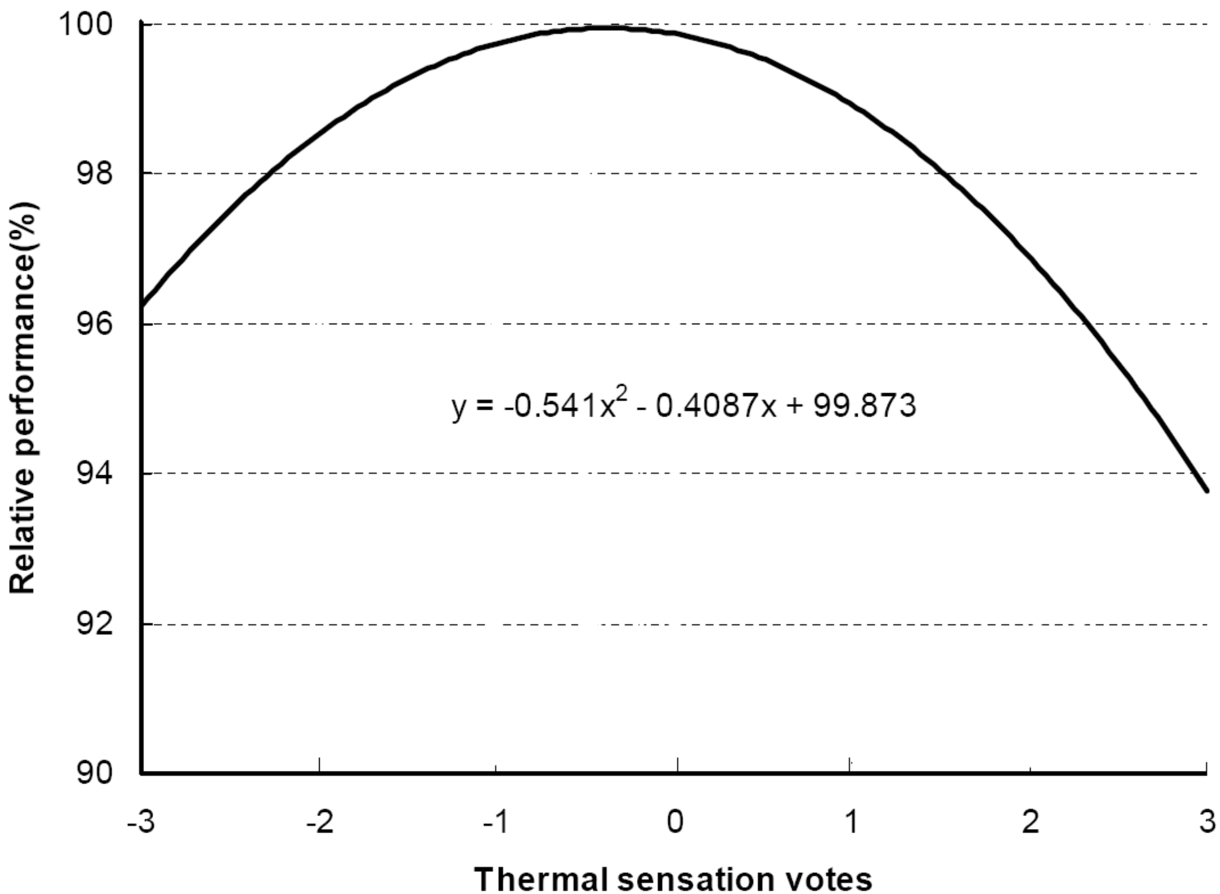
Indoor Air Quality and Thermal Comfort in Zero Energy Buildings

- Thermal Comfort
  - More uniform conditions (radiant asymmetry, vertical air temperature differences)
  - Less draught risk (reduced heat supply, no cold surfaces)
  - Less difference between air and operative temperature
  - Over heating
- Indoor Air Quality
  - Tighter buildings
  - Can not rely on infiltration
  - New materials and chemicals
  - Can you heat with the ventilation system?
    - Air distribution
    - Ventilation effectiveness
    - Individual room control

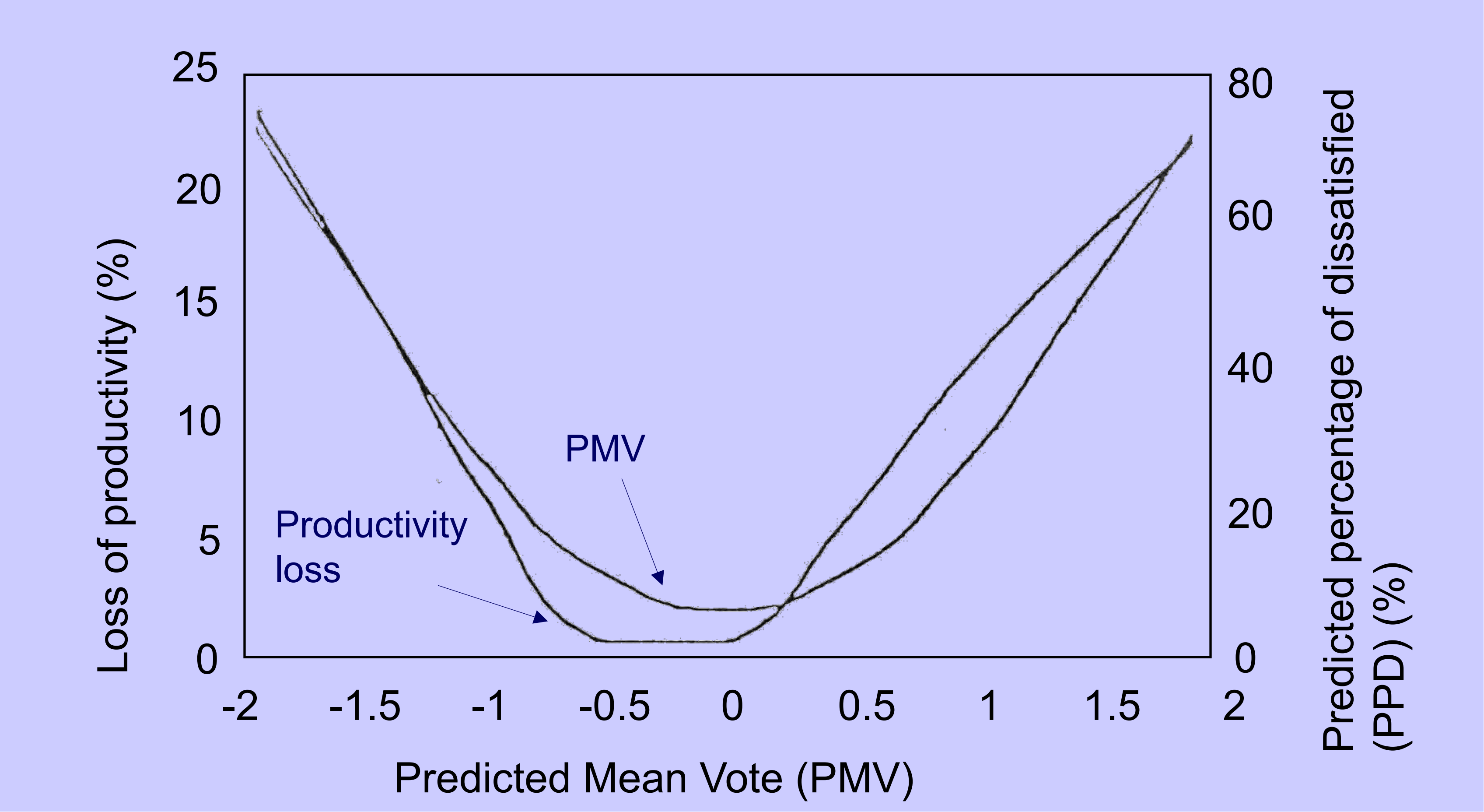


from Seppänen and Fisk 2005a

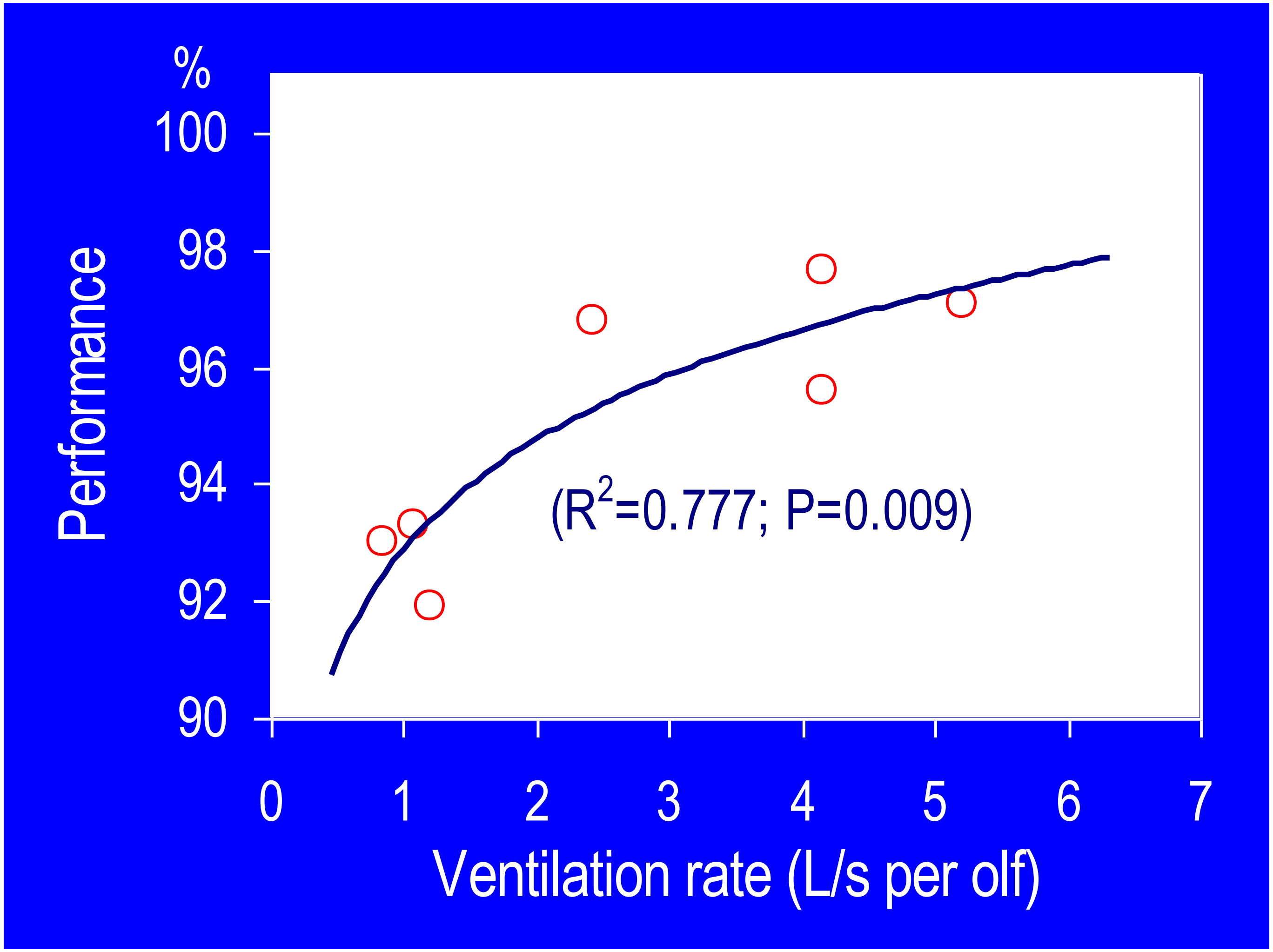
Thermal discomfort and estimated performance of office work Lan, Wargocki & Lian, 2010



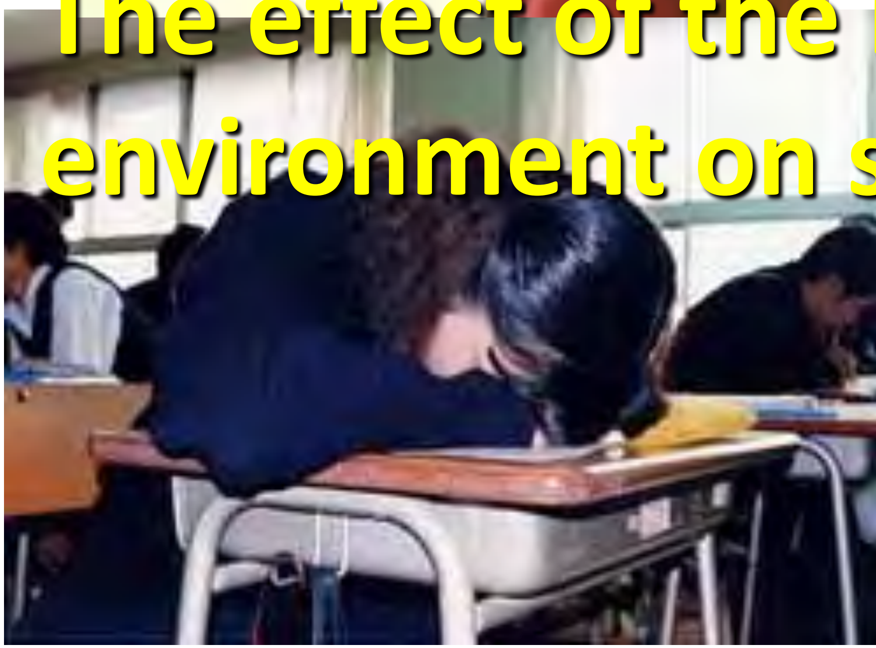
Thermal discomfort and estimated performance of office work, Roelofsen (2001)

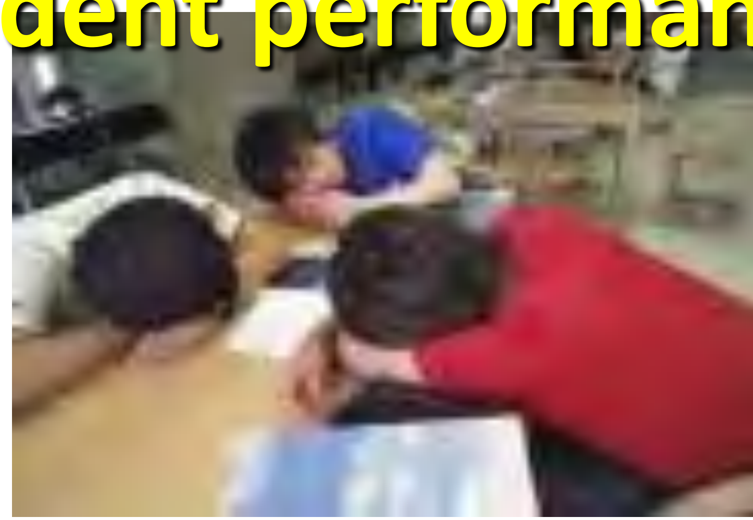


Ventilation vs performance

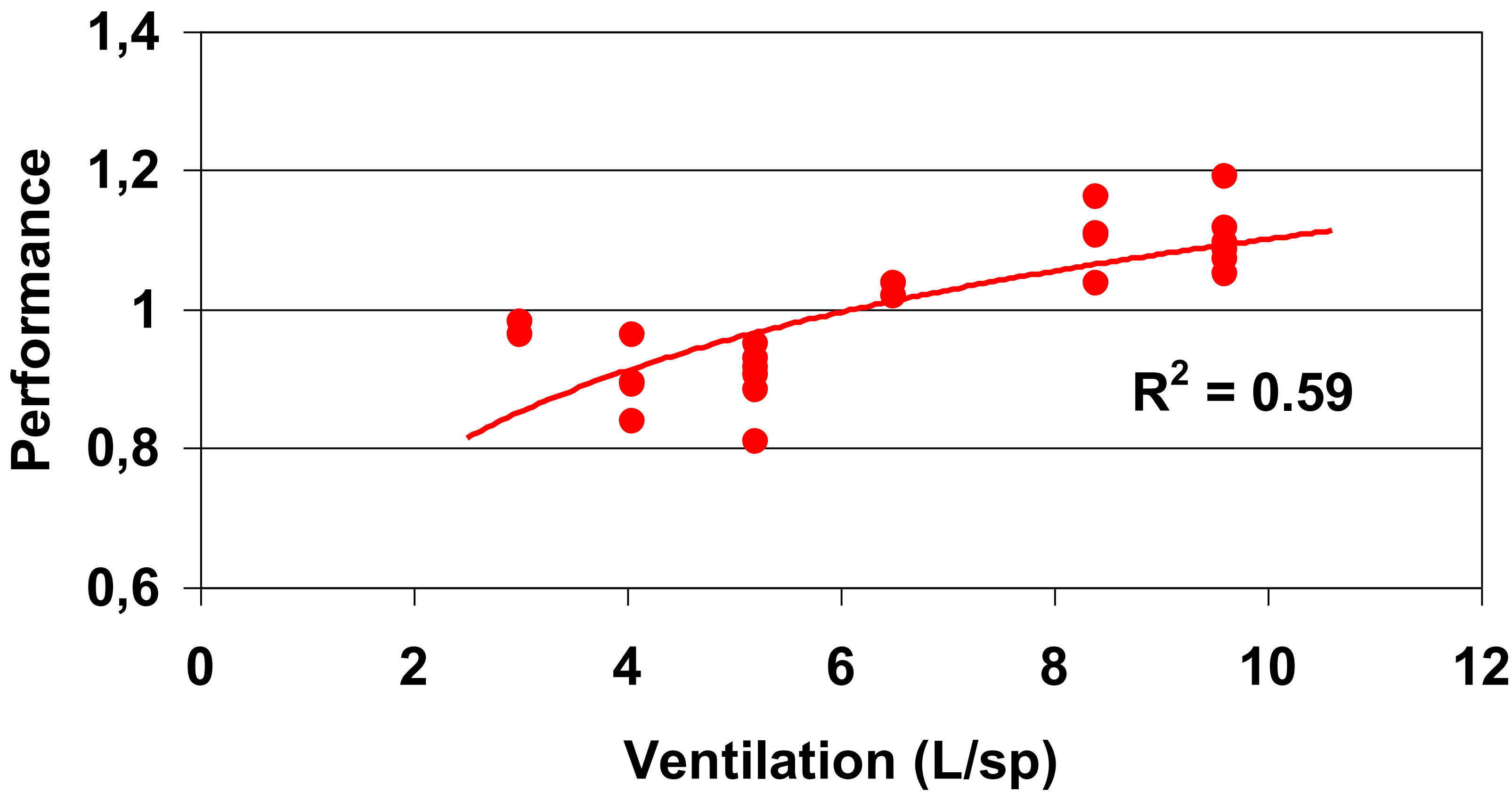


The effect of the indoor environment on student performance





Performance of schoolwork as a function of classroom ventilation



Doubling ventilation rate ~14.5% higher performance

Indoor Air Quality and Thermal Comfort in Zero Energy Buildings

If an energy efficient measure also improve the indoor environment it will

- Lower Health Risk
- Increase Comfort
- Increase Productivity
- Always be cost efficient.