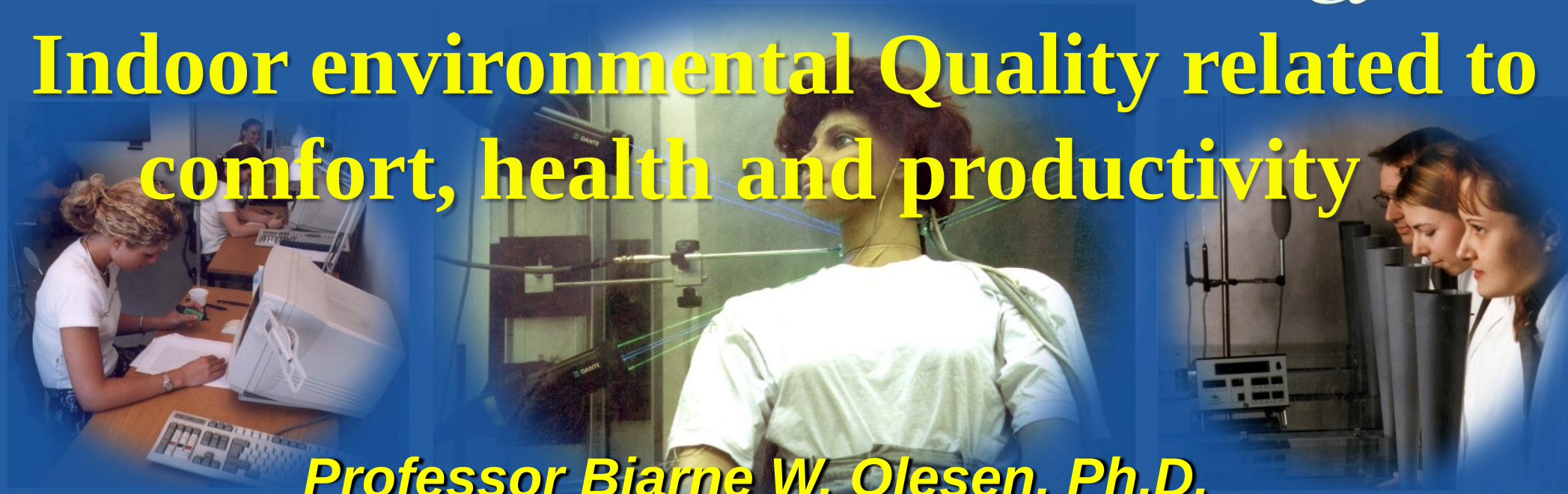
International Centre for Indoor Environment and Energy

Indoor environmental Quality related to comfort, health and productivity



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COMFORT-PRODUCTIVITY
Building costs

People	100
Maintenance	10
Financing	10
Energy	1

Achieving Excellence in Indoor Environmental Quality

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

INTAKE FOR A PERSON PER DAY

- **1 kg FOOD**
- **2 kg LIQUID**
- **15 kg AIR**

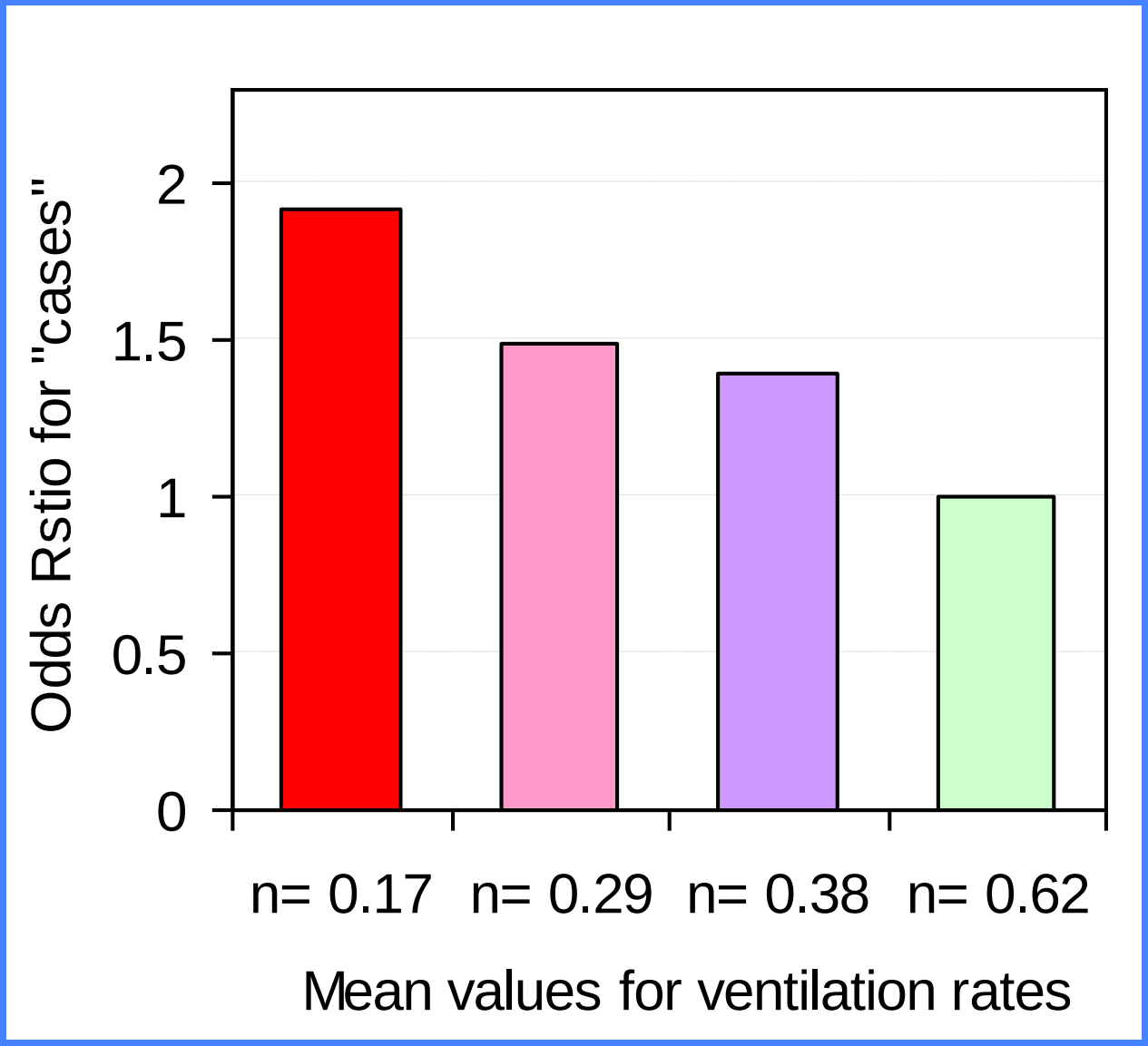
Global impact on people

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

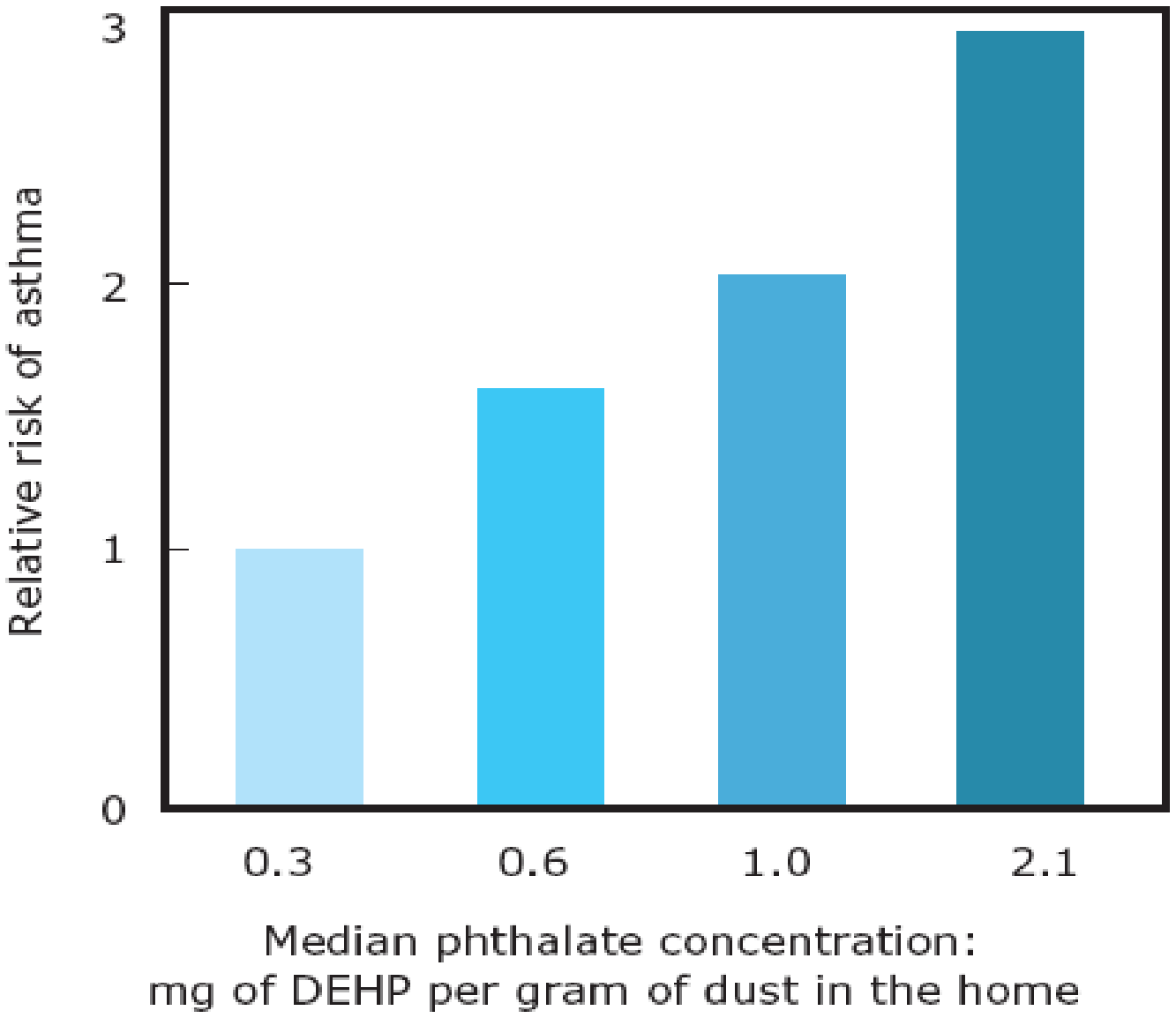
Hans Christian Andersen: The Princess on the Pea

Asthma and Allergy

In several industrial countries 50% of school children is suffering from Asthma or Allergy. This number has doubled within the last 20 years



Odds ratio for being a "case", i.e. children with at least two symptoms of possible three (wheezing, rhinitis, eczema) as a function of ventilation rates, in single family houses. (Bornehag et al., 2003).

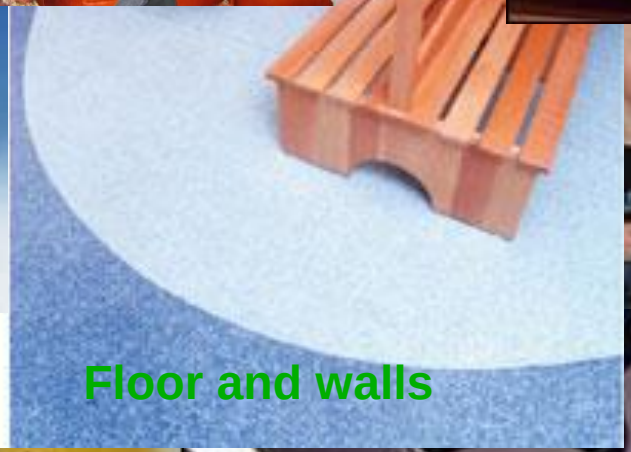


Plasticizers from polyvinyl chloride in dwellings increase the risk of asthma among children.

Each column represents about 90 dwellings.

DEHP: di(2-ethylhexyl) phthalate.

PVC=Modern ”Western” Lifestyle



STANDARDS

- **ISO EN 7730-2005**
  - Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort effects.
- **ASHRAE 55-2004**
  - Thermal environment conditions for human occupancy
- **ASHRAE 62.1 and 62.2 -2004**
  - Ventilation and indoor air quality
- **CR 1752**
  - Ventilation of buildings-Design criteria for the indoor environment
- **EN 13779**
  - Ventilation for non-residential buildings - performance requirements for ventilation and room-conditioning systems

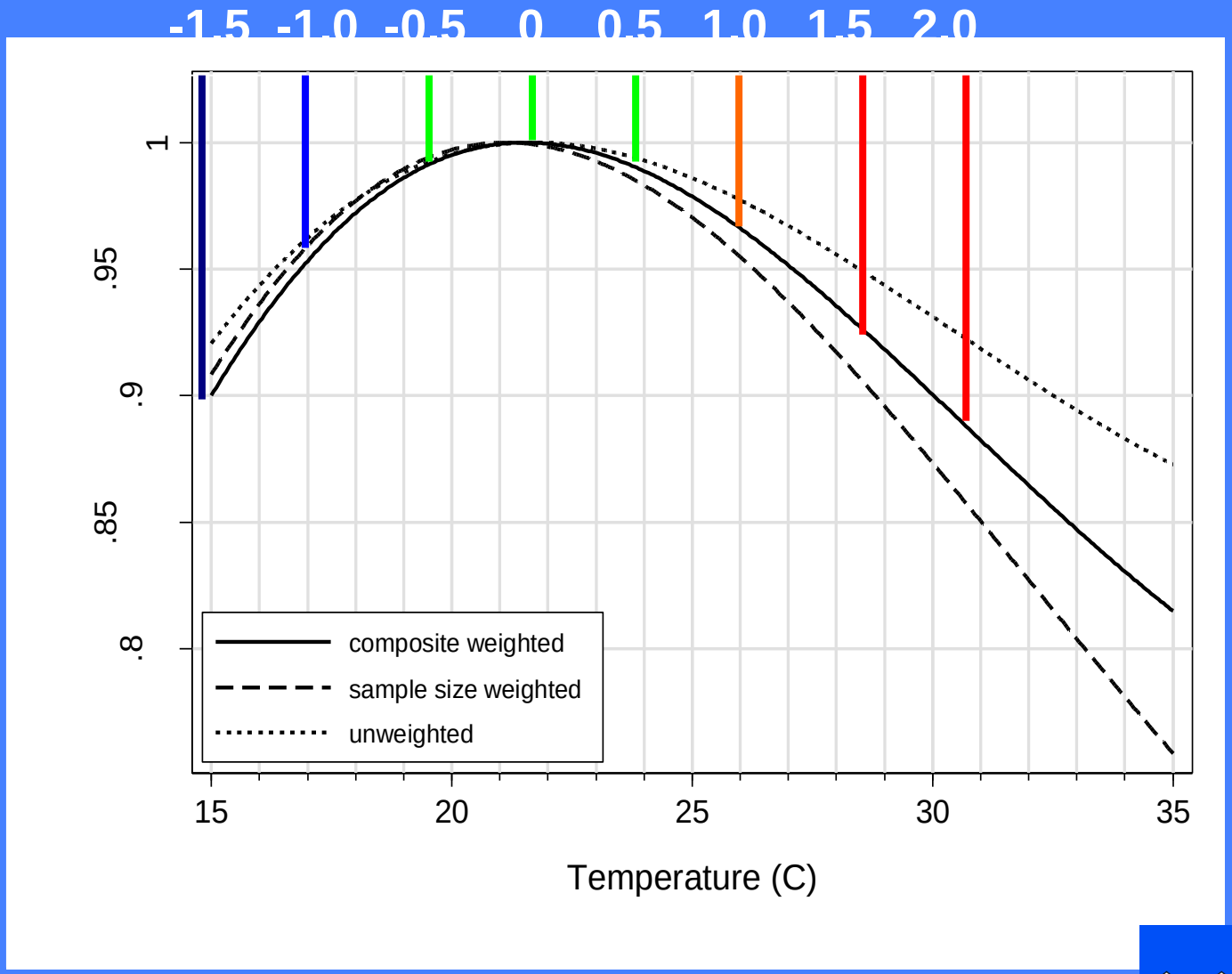
EN15251

Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics

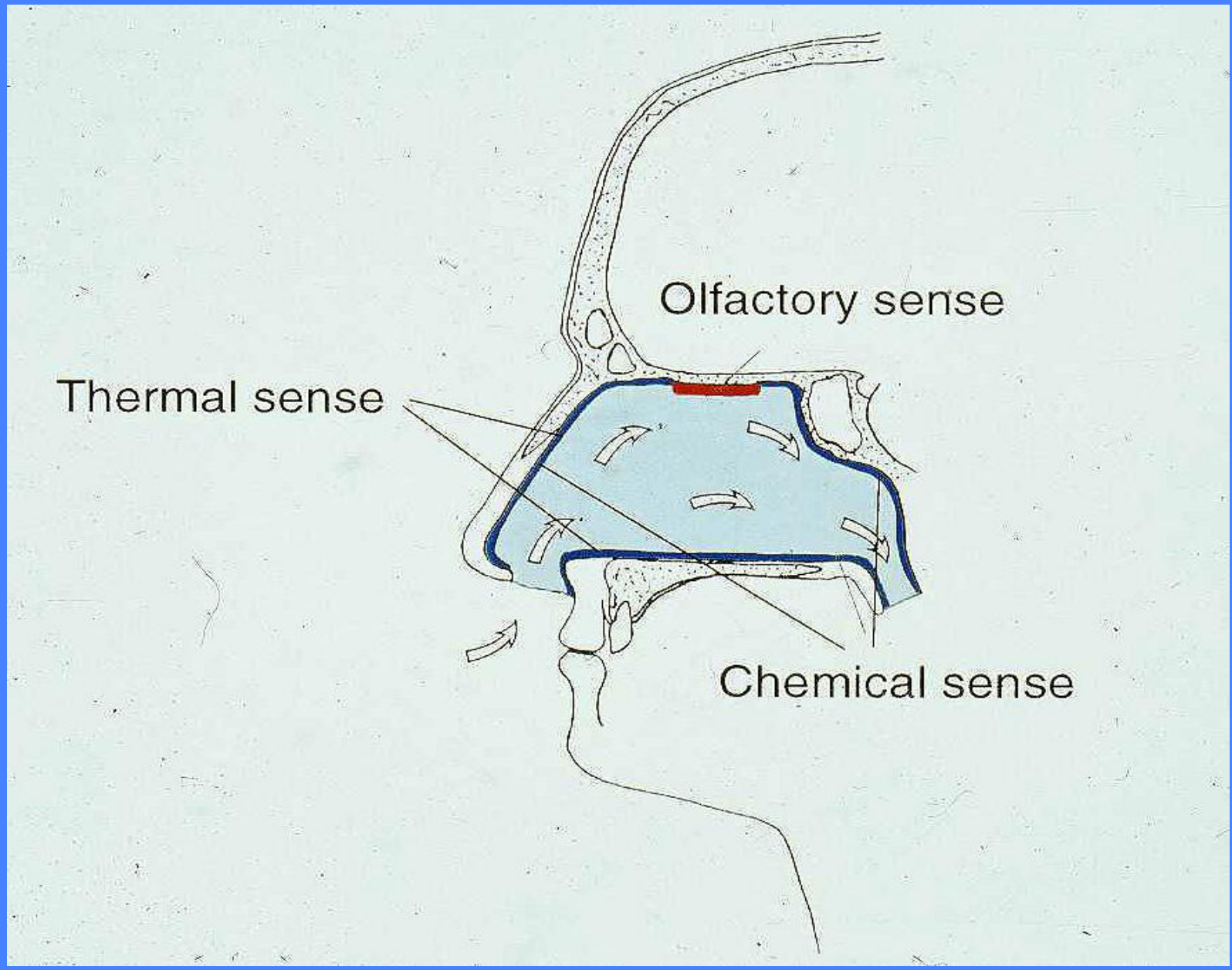
Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment

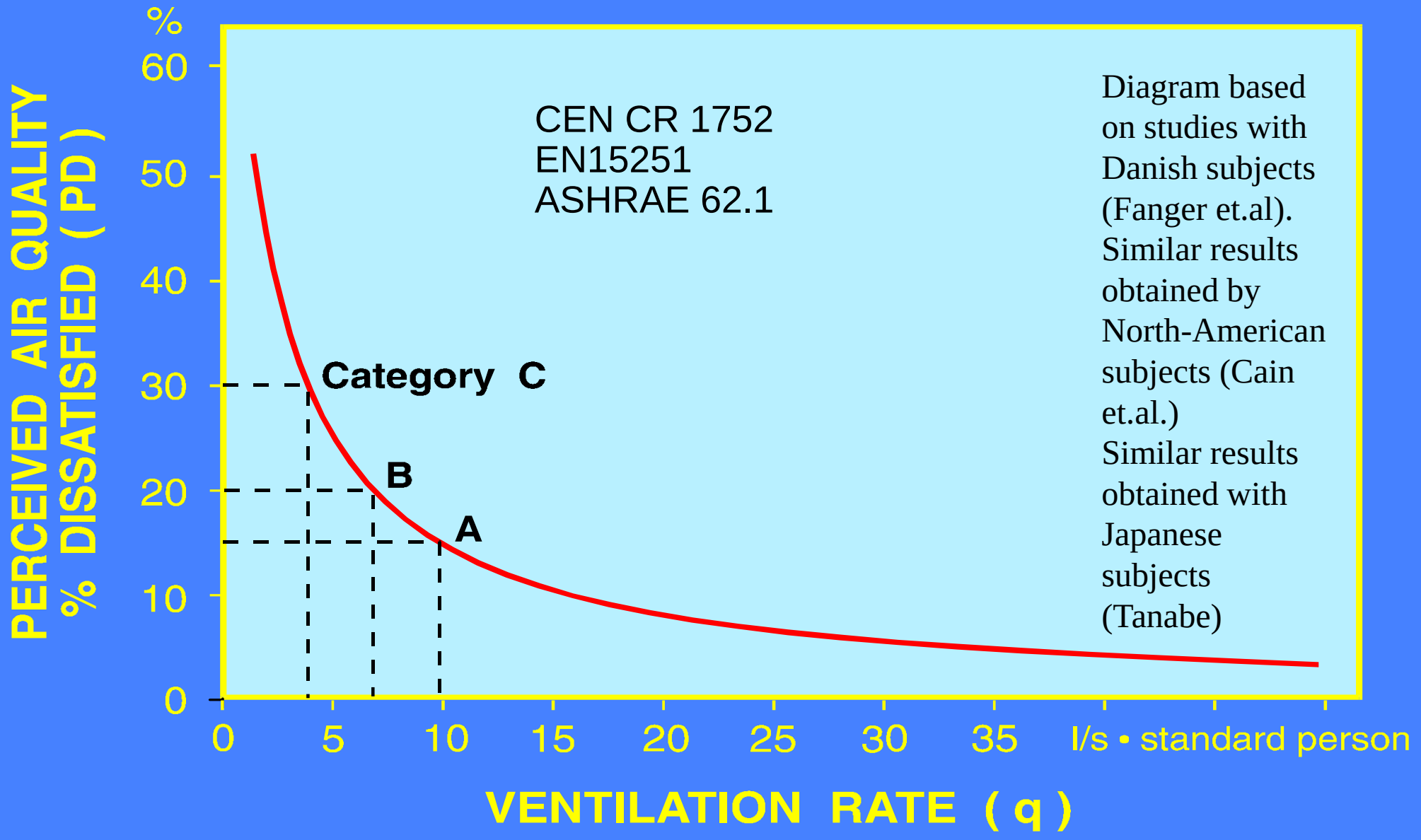
Type of building/ space	**Category**	**Operative Temperature for Energy Calculations** °C	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met		**Heating (winter season), ~ 1,0 clo**	**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**

PMV-values



from Seppänen and Fisk 2005a

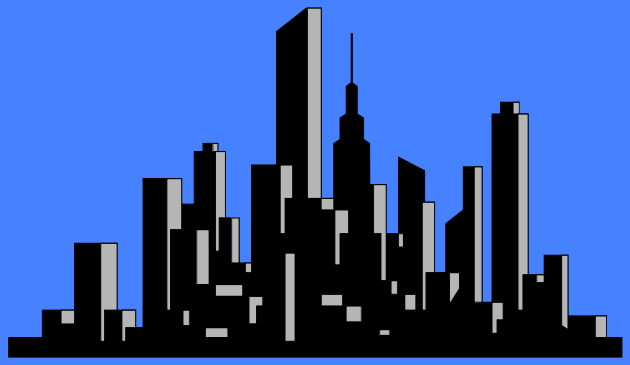

Olfactory sense
Thermal sense
Chemical sense


%
60
50
40
30
20
10
0
PERCEIVED AIR QUALITY
% DISSATISFIED (PD)
CEN CR 1752
EN15251
ASHRAE 62.1
Diagram based on studies with Danish subjects (Fanger et.al). Similar results obtained by North-American subjects (Cain et.al.) Similar results obtained with Japanese subjects (Tanabe)
Category C
B
A
0
5
10
15
20
25
30
35
l/s • standard person
VENTILATION RATE (q)

Concept for calculation of design ventilation rate

People Component

Building Component



Breathing Zone Outdoor Airflow

$$V_{bz} = R_p P_z + R_s S_d + R_a A_z$$

- V_{bz}: Breathing Zone Outdoor Airflow
- $R_p P_z$: People Component
  - R_p: Minimum l/s/Person
  - P_z: Number of People
- $R_s S_d$: ~~Ventilation per Smoker~~ × ~~Number of Smokers~~
- $R_a A_z$: Building Component
  - A_z: Building Area
  - R_a: Minimum l/s/m²

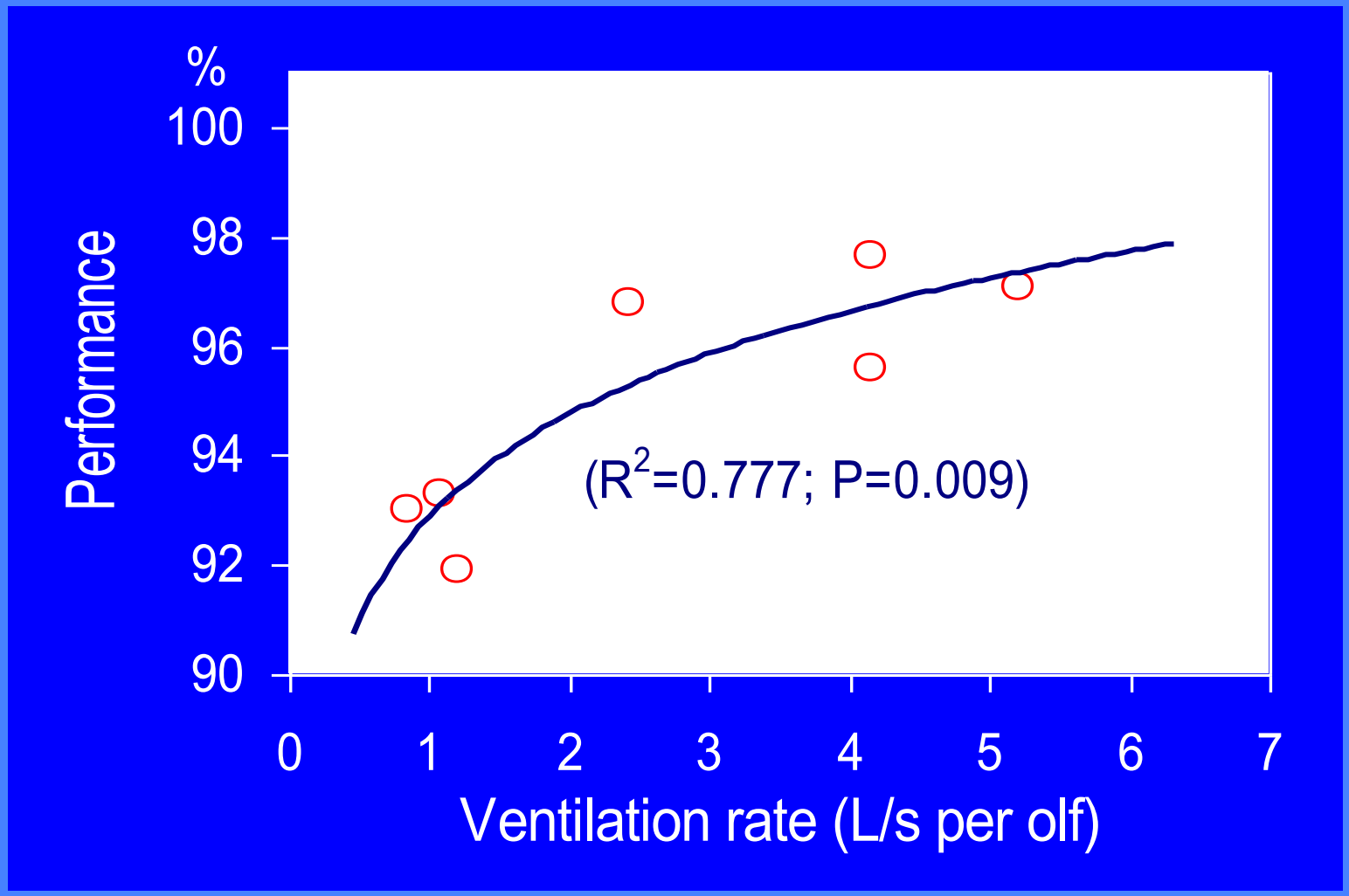
Recommended ventilation rates for non-residential buildings for three categories (EN15251)

Type of building or space	Cate-gory	*Per person* l/s,person	*Per floor area* l/s,m²	*Per person* l/s,person	*Per floor area* l/s,m²	*Per person* l/s,person	*Per floor area* l/s,m²
		Very low polluted building, revision		Low polluted building, revision		Non-low polluted building, revision	
Single office	I	5,0	1,5	10,0	2,0	20,0	3,0
	II	**3,0**	**1,0**	**7,0**	**1,4**	**14,0**	**2,1**
	III	2,0	0,6	4,0	0,8	8,0	1,2
Landscaped office	I	7,5	1,5	15,0	1,7	30,0	2,7
	II	**4,5**	**1,0**	**10,5**	**1,2**	**21,0**	**1,9**
	III	3,0	0,6	6,0	0,7	12,0	1,1
Conference room	I	1,0	1,5	2,0	6,0	4,0	7,0
	II	**0,6**	**1,0**	**1,4**	**4,2**	**2,8**	**4,9**
	III	0,4	0,6	0,8	2,4	1,6	2,8

Residential buildings

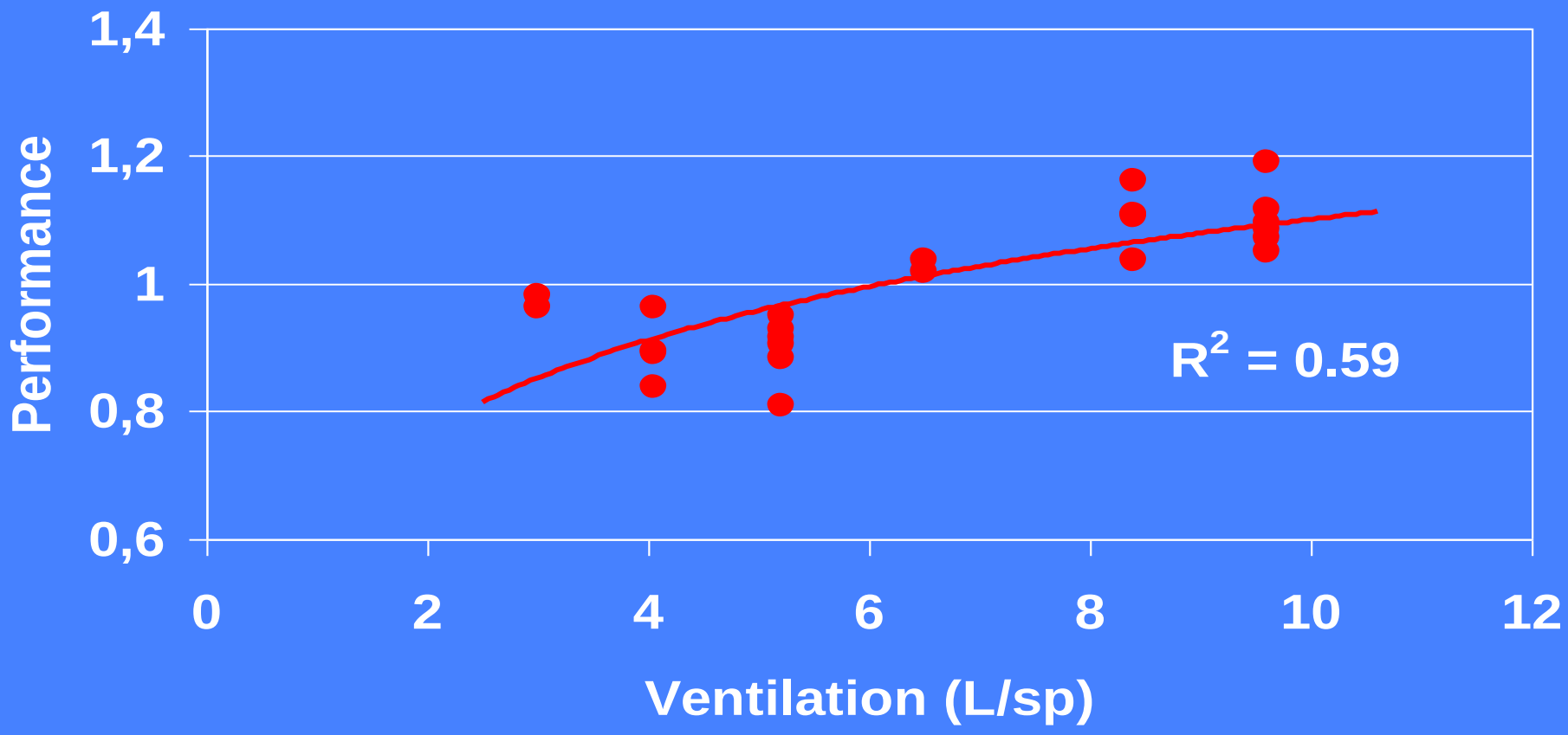
Category	Air change rate [1]		Living room and bedrooms, mainly outdoor air flow		Exhaust air flow, l/s		
	l/s,m² (1)	ach	l/s, pers [2] (2)	l/s/m² (3)	Kitchen (4a)	Bathrooms (4b)	Toilets (4)
I	0,49	0,7	10	1,4	28	20	14
II	0,42	0,6	7	1,0	20	15	10
III	0,35	0,5	4	0,6	14	10	7

Ventilation vs performance



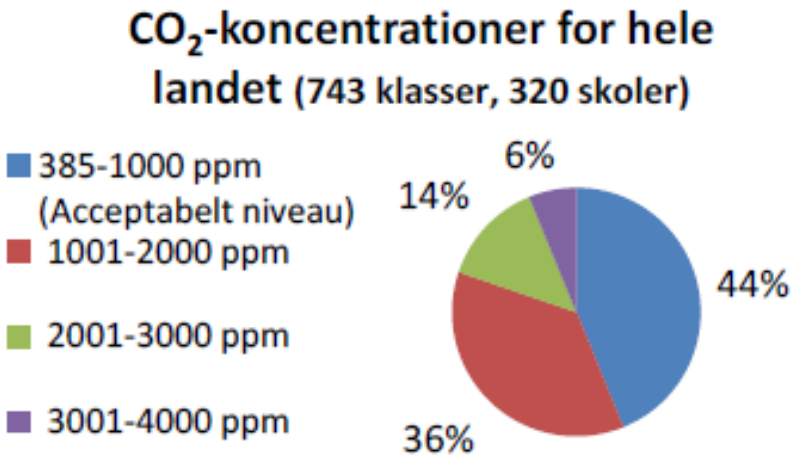
The effect of the indoor environment on student performance

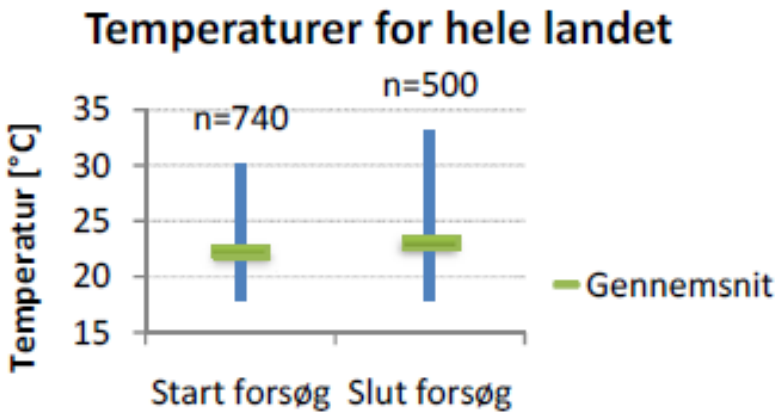
Performance of schoolwork as a function of classroom ventilation



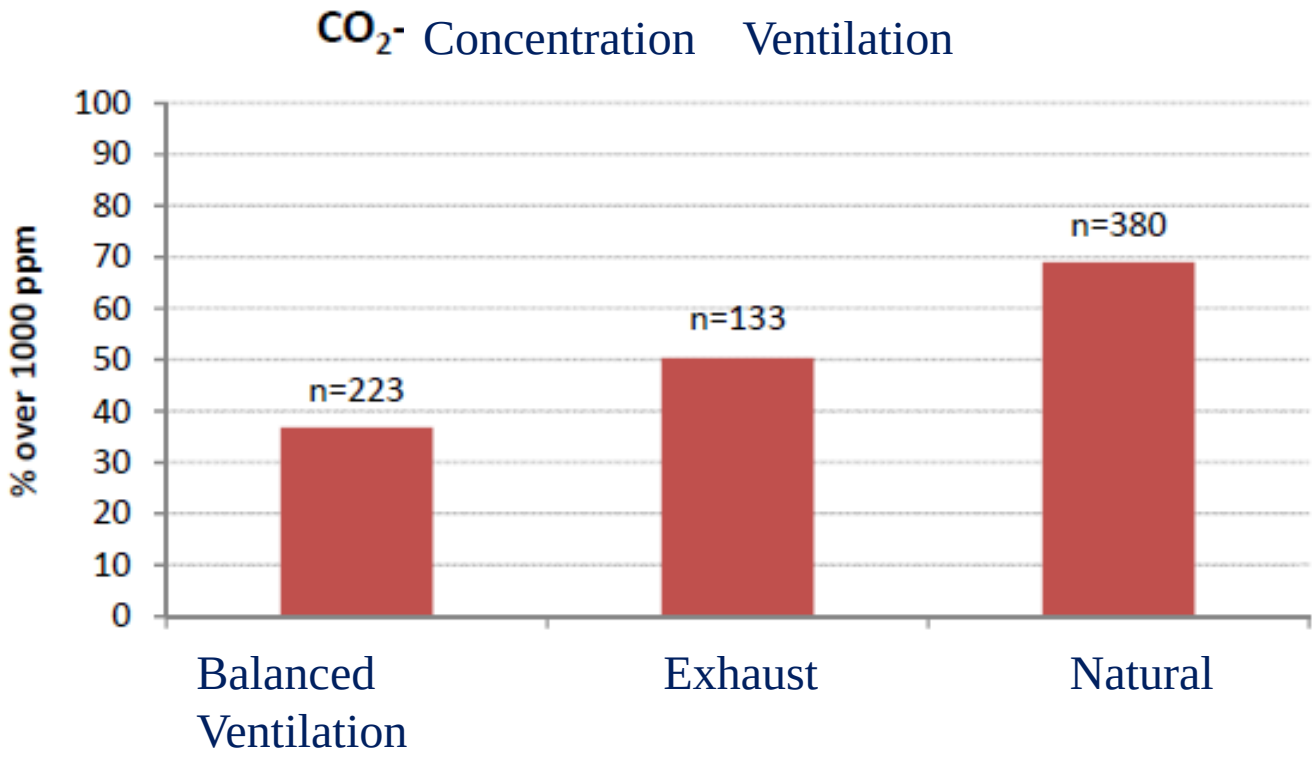
Doubling ventilation rate ~14.5% higher performance

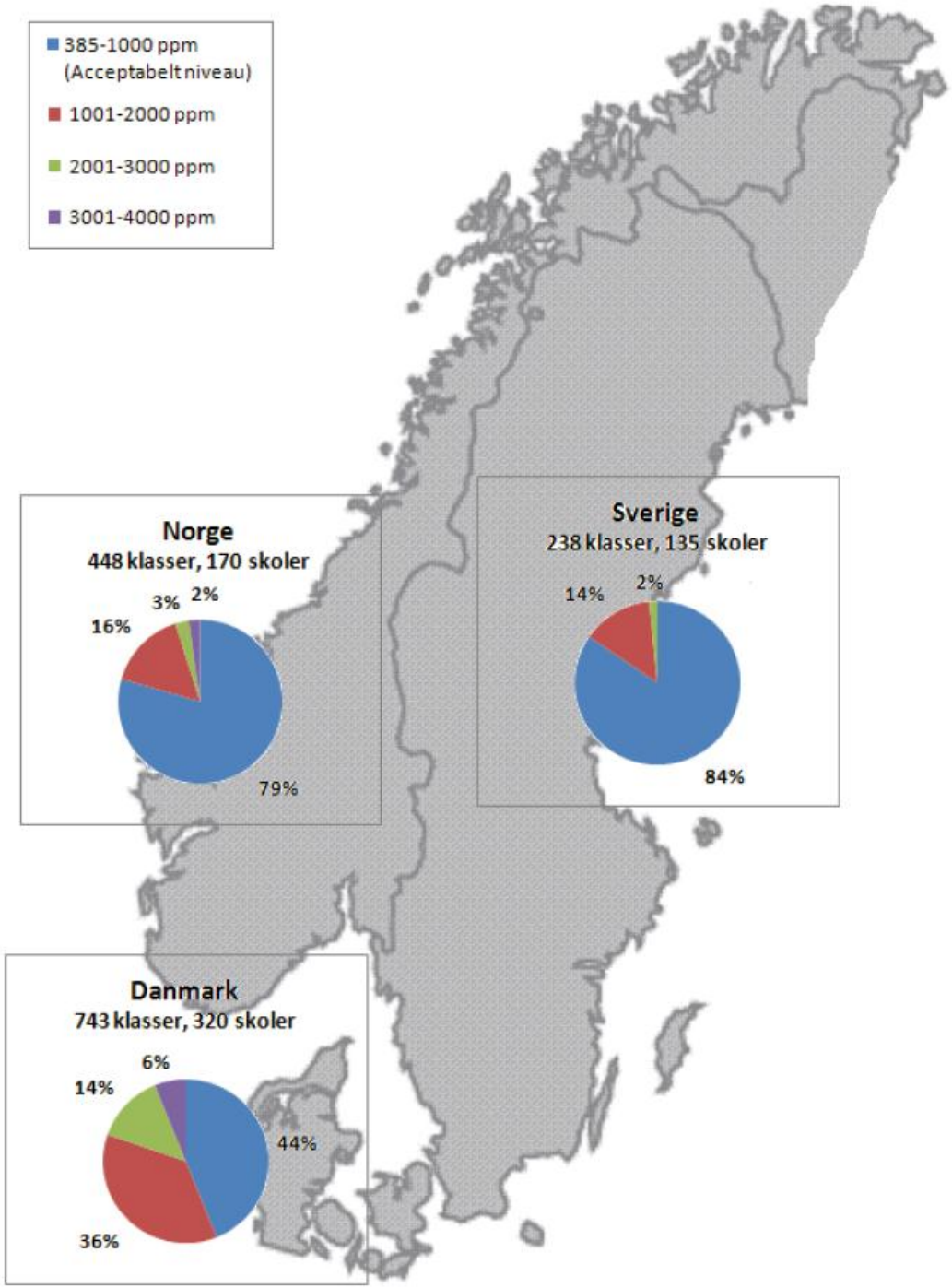
Indoor Environment in Schools





Indoor Environment in Schools





Indoor Environment in Schools

Indoor Air Quality and Thermal Comfort in near 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
  - Is individual room control important?
    - » Comfort
    - » Energy
- **Indoor Air Quality**
  - Tighter buildings
  - Cannot rely on infiltration
  - Can you heat with the ventilation system?
    - » Air distribution
    - » Ventilation effectiveness
    - » Individual room control

ICIEE

DTU

Indoor Air Quality and Thermal Comfort in near 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.