The importance of a "good" indoor environment now and in the future

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Requirements to the indoor environment

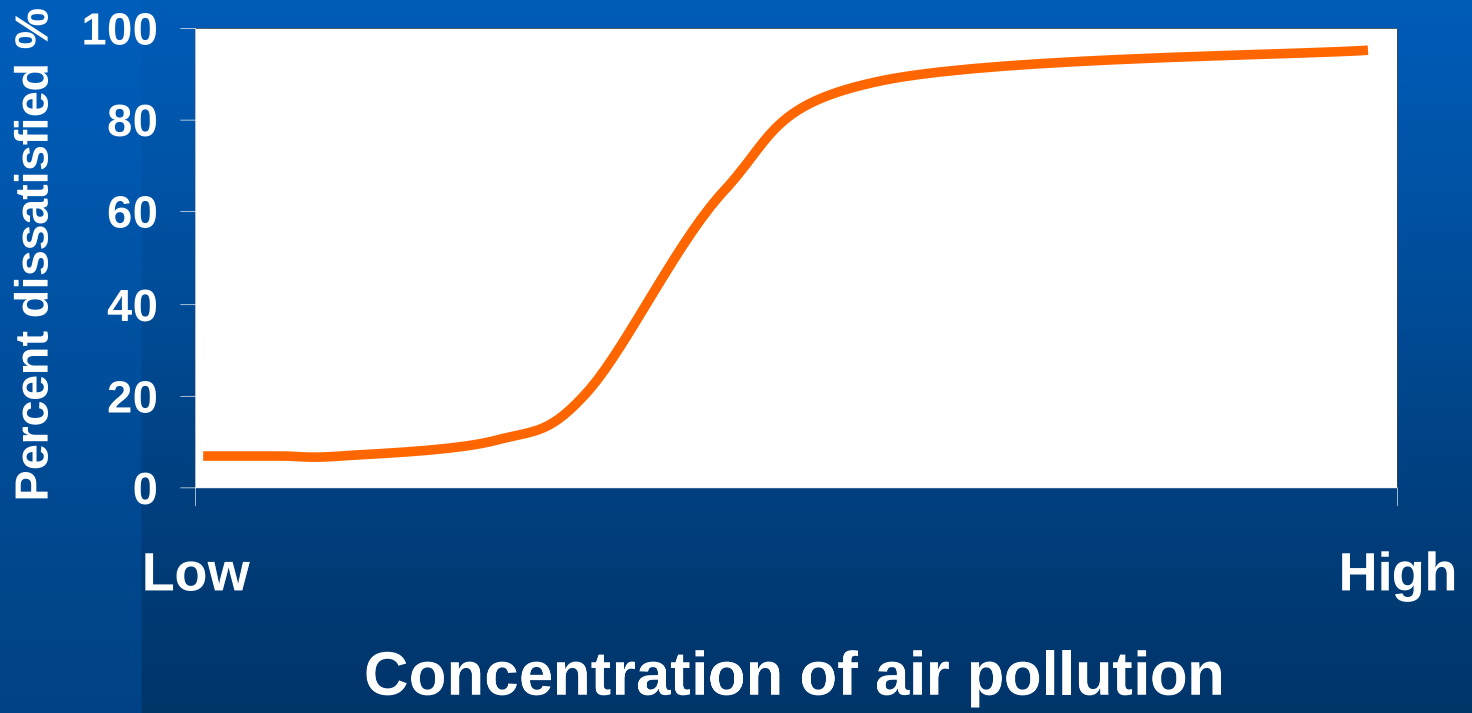
An indoor environment that is comfortable, healthy and inspiring

...at the lowest possible energy consumption

General solution

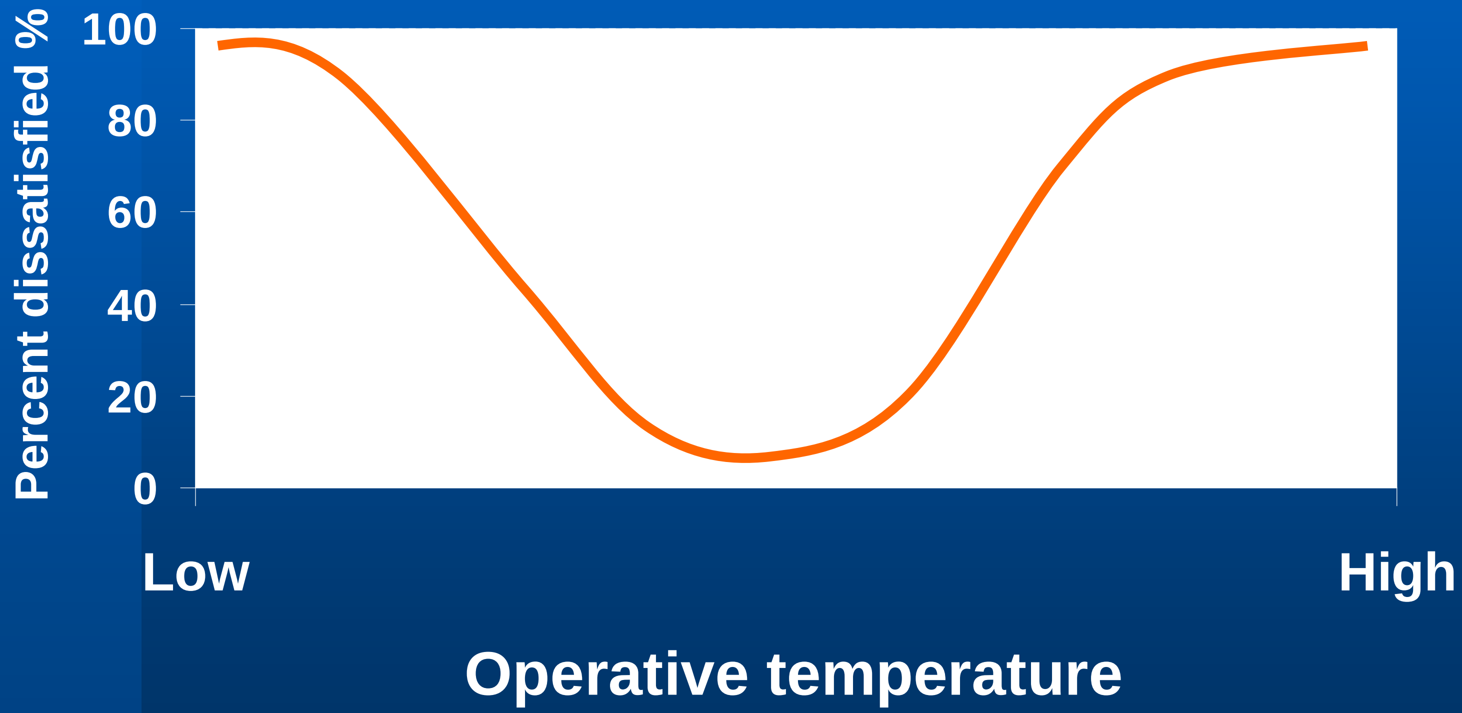
The not unhealthy, uniform indoor environment that results in fewest dissatisfied

Air quality



Percent dissatisfied %
100
80
60
40
20
0
Low
High
Concentration of air pollution

Thermal environment



Psychophysics

Psychophysics is dealing with the relationship between physical stimuli and their subjective correlates, or percepts.

Wikipedia.org

Physical

- Air temperature
- Radiant temperature
- Air velocity
- Air humidity

- Clothing insulation
- Activity level

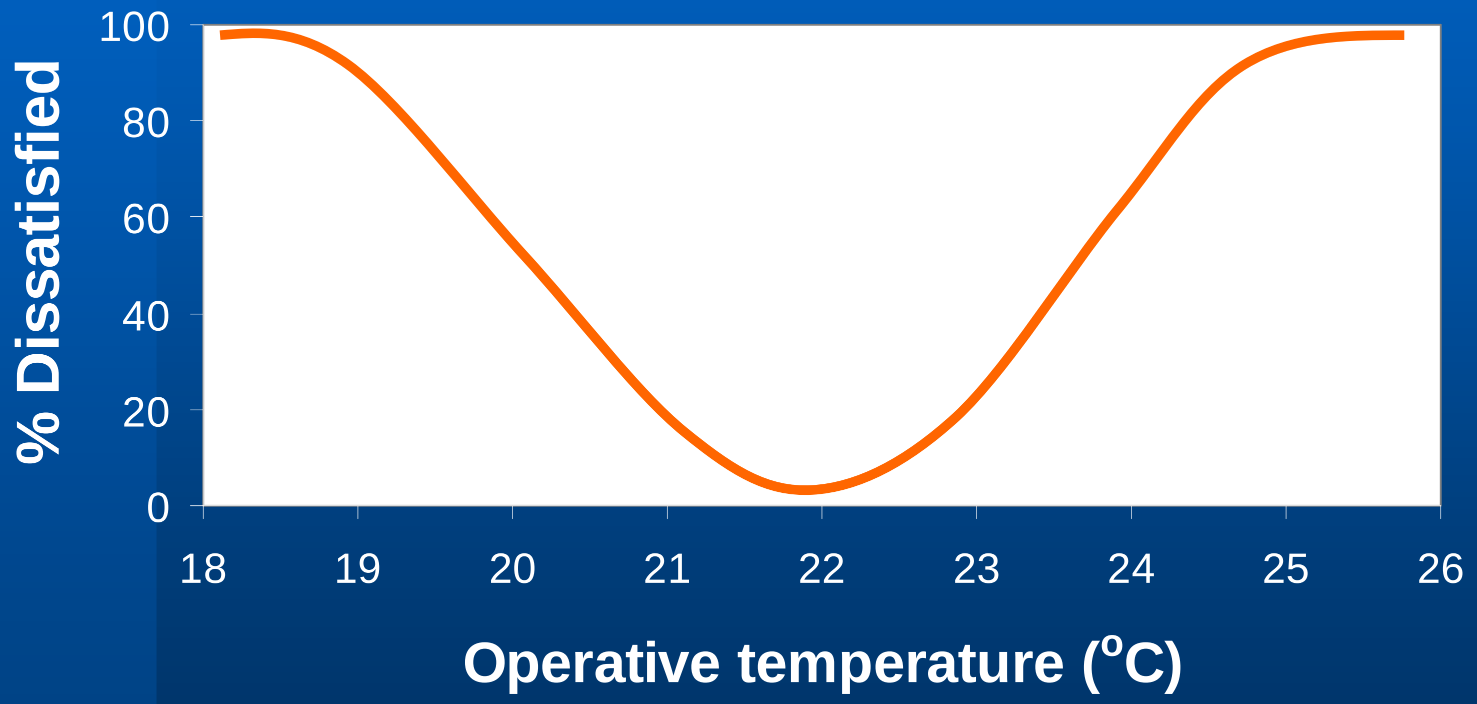
Physiological

- Skin temperature
- Sweating

Subjective

- Thermal sensation
- Dissatisfaction

Prediction of thermal sensation



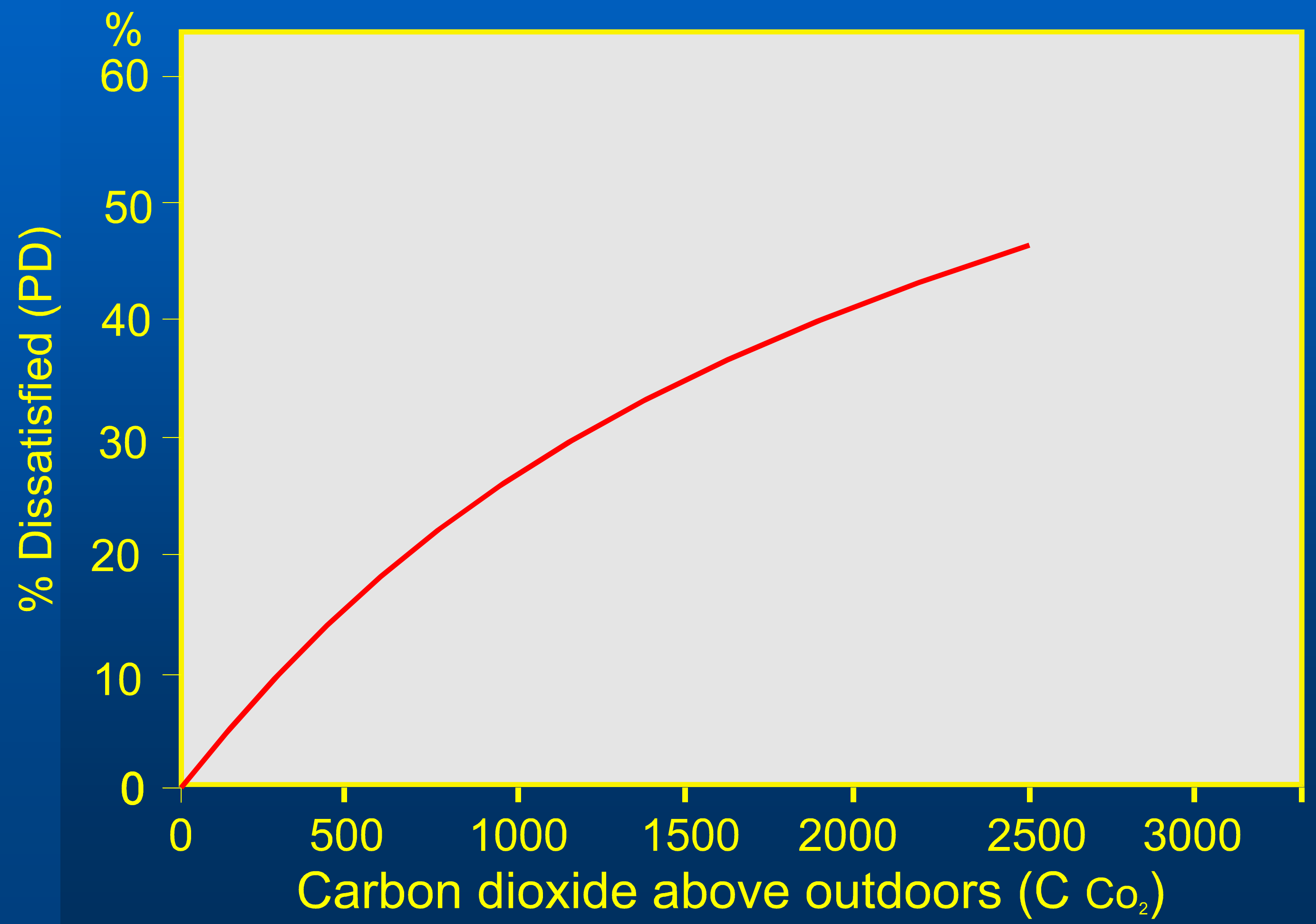
Prediction of:

Perceived thermal sensation = $f(t_a, t_{mrt}, rh, v, I_{cl}, M)$

Perception of draught = $f(t_a, v, Tu)$

Perceived air quality = $f(c, t_a, rh)$

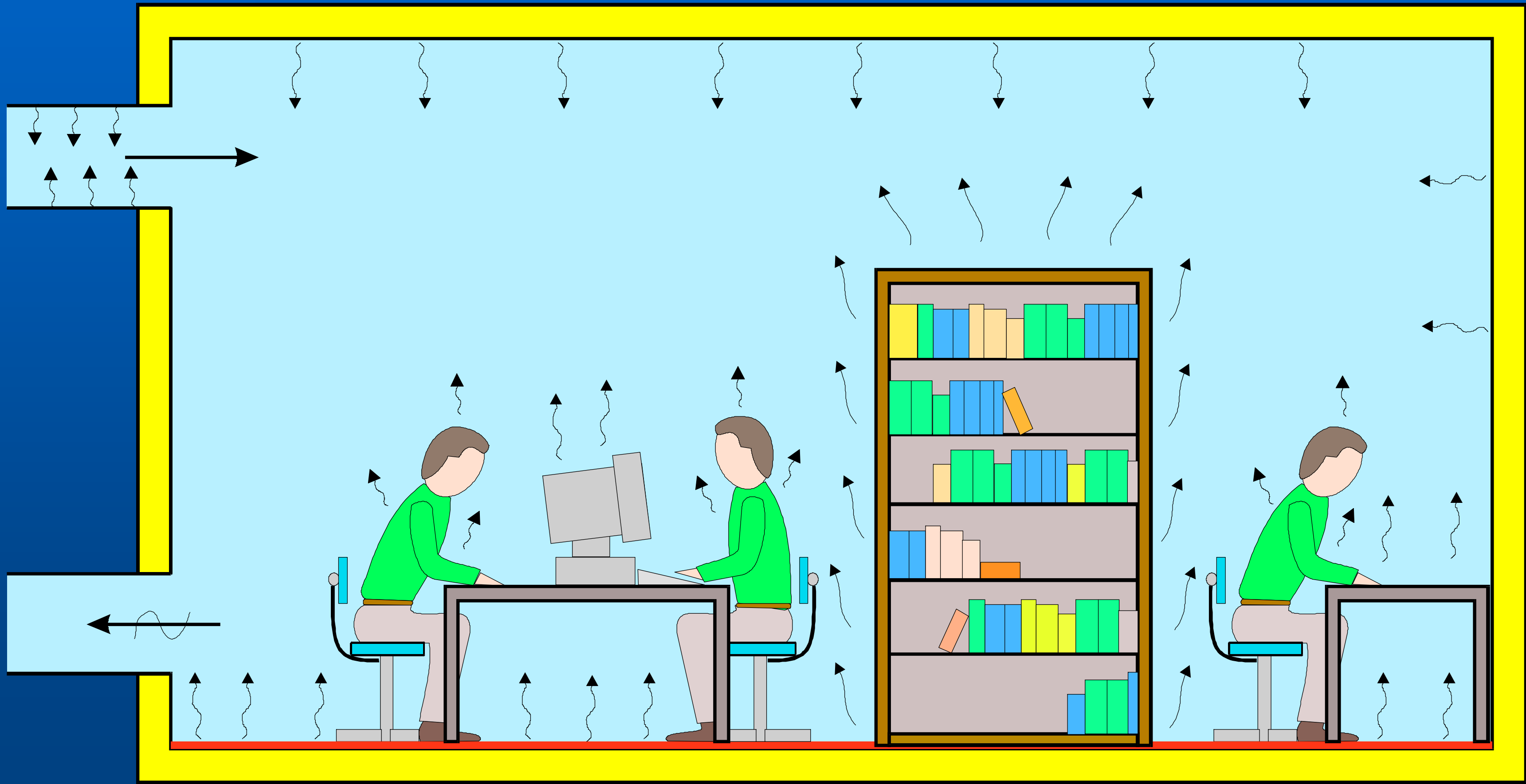
CO_2 as an indicator of bioeffluents



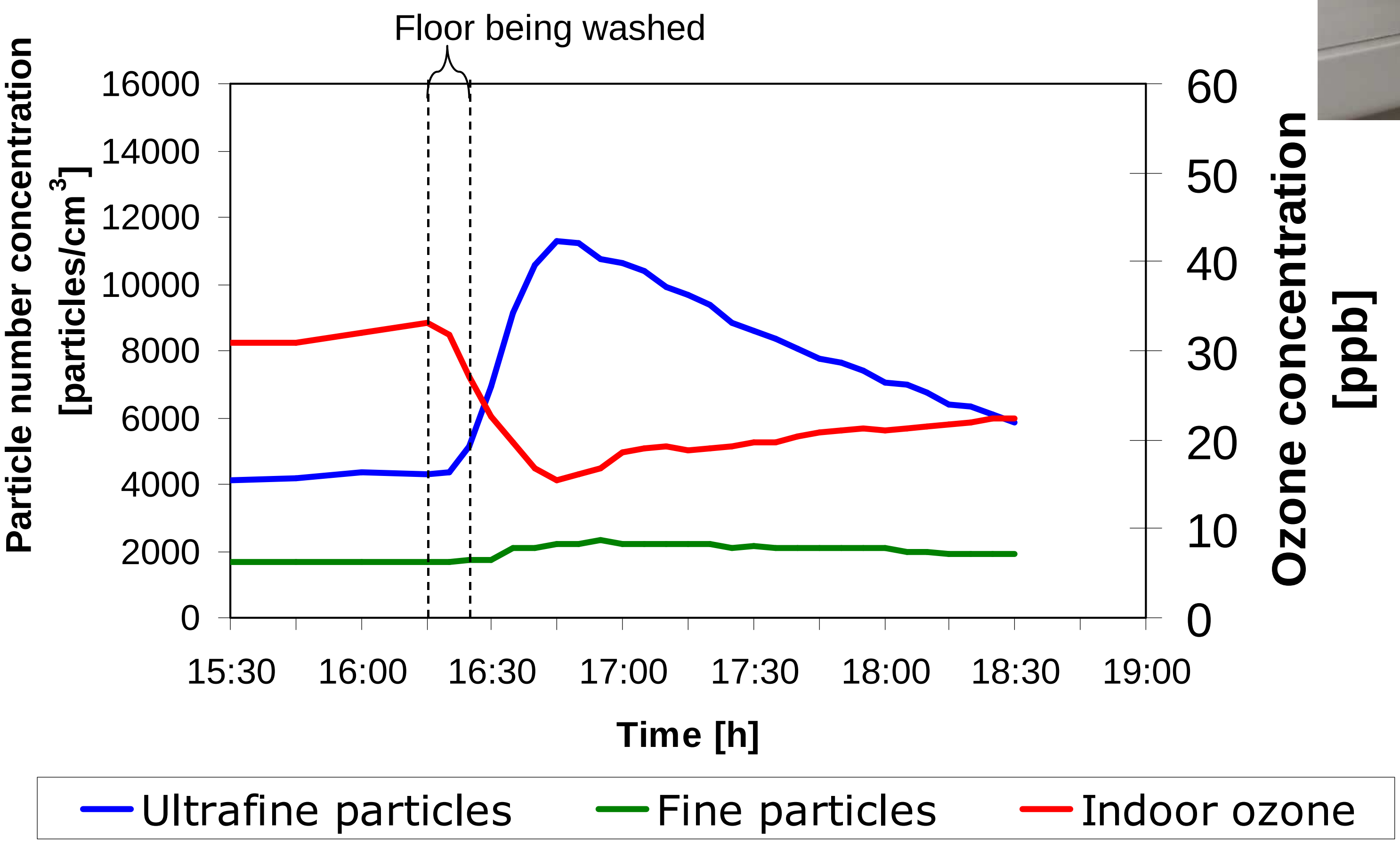
Ventilation Philosophies

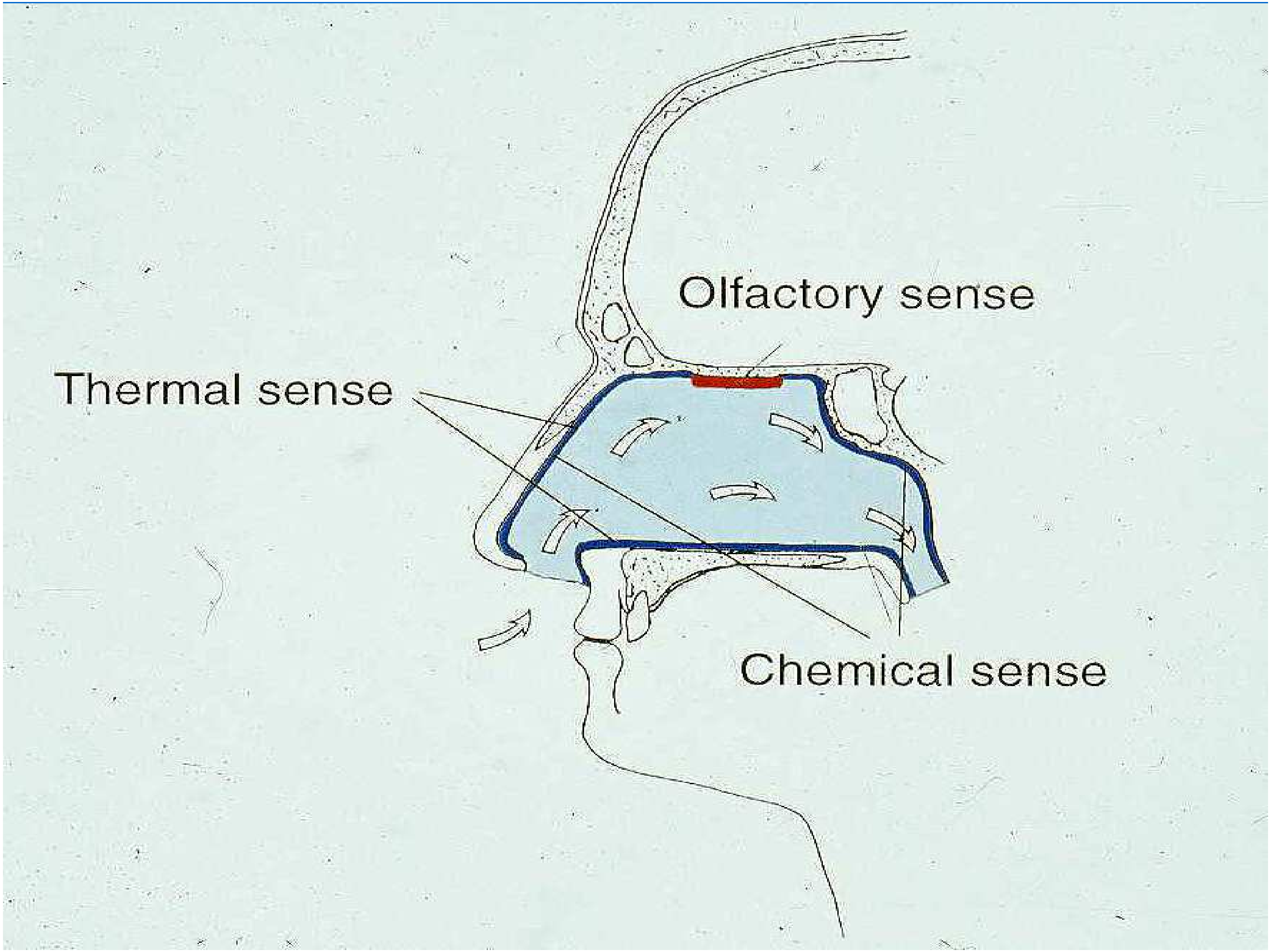
	Paradigm	Pollution source
2000	Comfort	People + building
1935	Contagion	People
1900	Poison	
1800		

Not only humans pollute!

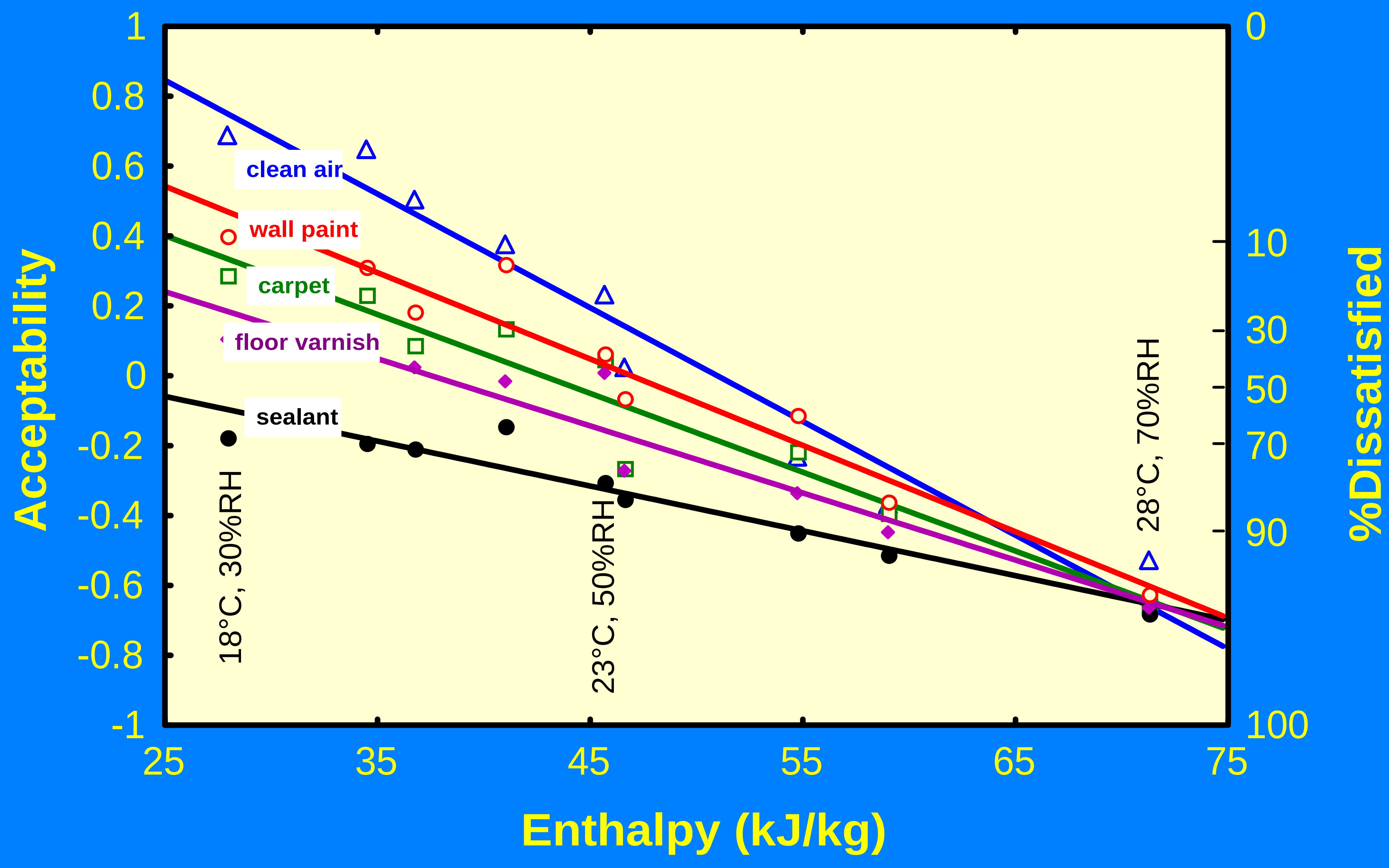


Chemical reactions in indoor air





Olfactory sense
Thermal sense
Chemical sense



Acceptability
%Dissatisfied
Enthalpy (kJ/kg)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
30
50
70
90
100
25
35
45
55
65
75
clean air
wall paint
carpet
floor varnish
sealant
18°C, 30%RH
23°C, 50%RH
28°C, 70%RH

Criteria for indoor air quality and ventilation

	Recommended ventilation rates		
	For occupants L/(s person)	For building emissions L/(s m^2)	
		Low polluting	Non low-polluting
Category A	10	1.0	2.0
Category B	7	0.7	1.4
Category C	4	0.4	0.8

(prEN 15251)

What's the energy penalty for selecting a higher category?

Required energy for ventilation and climatisation

Example conference room

Category	Low polluting	Non low-polluting
A	2.4	3.2
B	1.8	2.1
C	0.8	1.0

Annualized cost of a typical 45 m^2 office with 11 m^2 per occupant

Salaries	100
Rent	10
Capital equipment	14
O&M	4
Energy	1 (2-3)

(Woods 1989)

Estimated relations between perceived air quality and performance of office work

- 10% less dissatisfied with air quality $\Rightarrow$ 1.1% increase in performance
- Doubling ventilation rate $\Rightarrow$ 1.8% increase in performance
- Similar relations for temperature

Source of productivity gain	Potential annual health benefits	Potential US annual savings or productivity gain (1996 USD)
Reduced respiratory illness	16 – 37 mill avoided cases of common cold or influenza	6 – 14 billion USD
Reduced allergies and asthma	18% to 25% decrease in symptoms for 53 million allergy sufferers and 16 million asthmatics	1 – 4 billion USD
Reduced SBS symptoms	20% to 50% reduction in SBS symptoms experienced by 15 mill workers	10 – 30 billion USD
Improved worker performance from changes in thermal environment and lighting		20 – 160 billion USD
Total cost of energy in US commercial buildings		70 billion USD

(Fisk 2000)

Implications

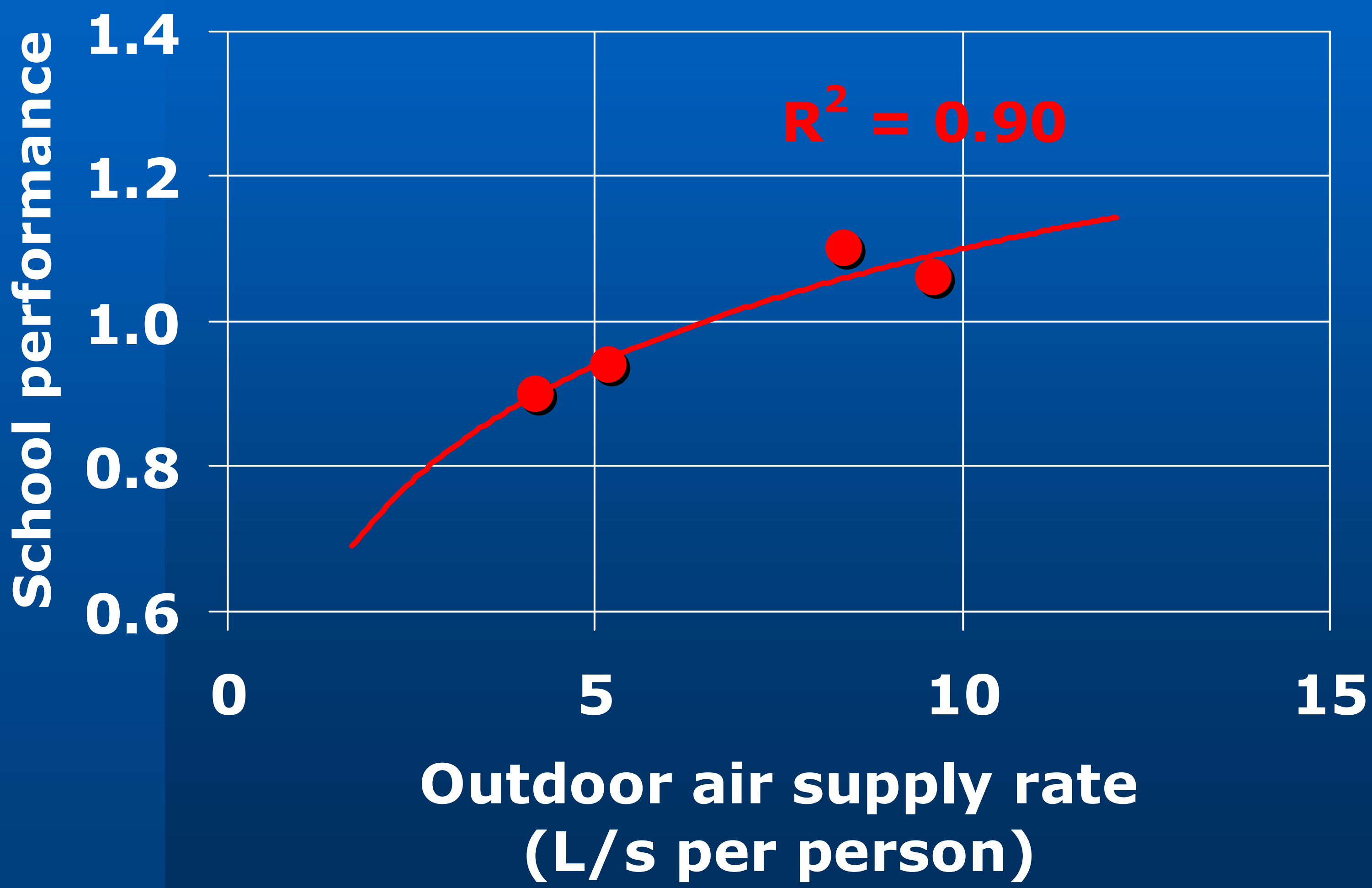
In the Nordic countries this will amount to approximately 3 – 20 billion USD from IEQ related improvements in worker performance

In a life cycle assessment of a building a lost annual productivity of 5% becomes completely dominating

Learning in schools

- Effect of reduced indoor temperature
- Effect of increased outdoor air supply rate

School performance & ventilation



What do we need in the future

- Multi-compound sensors?

- Artificial noses?

- Sensor networks?

- Delegate more control to the occupants?

- Sufficient air of good quality!