



Indoor Environmental Quality: Comfort–Health–Productivity

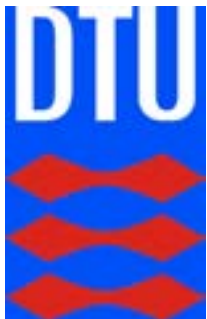
Professor Bjarne W. Olesen, Ph.D., FASHRAE

bwo@byg.dtu.dk

[*Society President*](#)

International Center for Indoor Environment and
Energy

Technical University of Denmark



COMFORT-PRODUCTIVITY

Building costs

People	100
Maintenance	10
Financing	10
Energy	1

**This clearly show that buildings are for
people
not for saving energy**

INTAKE FOR A PERSON PER DAY

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

Achieving Excellence in Indoor Environmental Quality

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

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



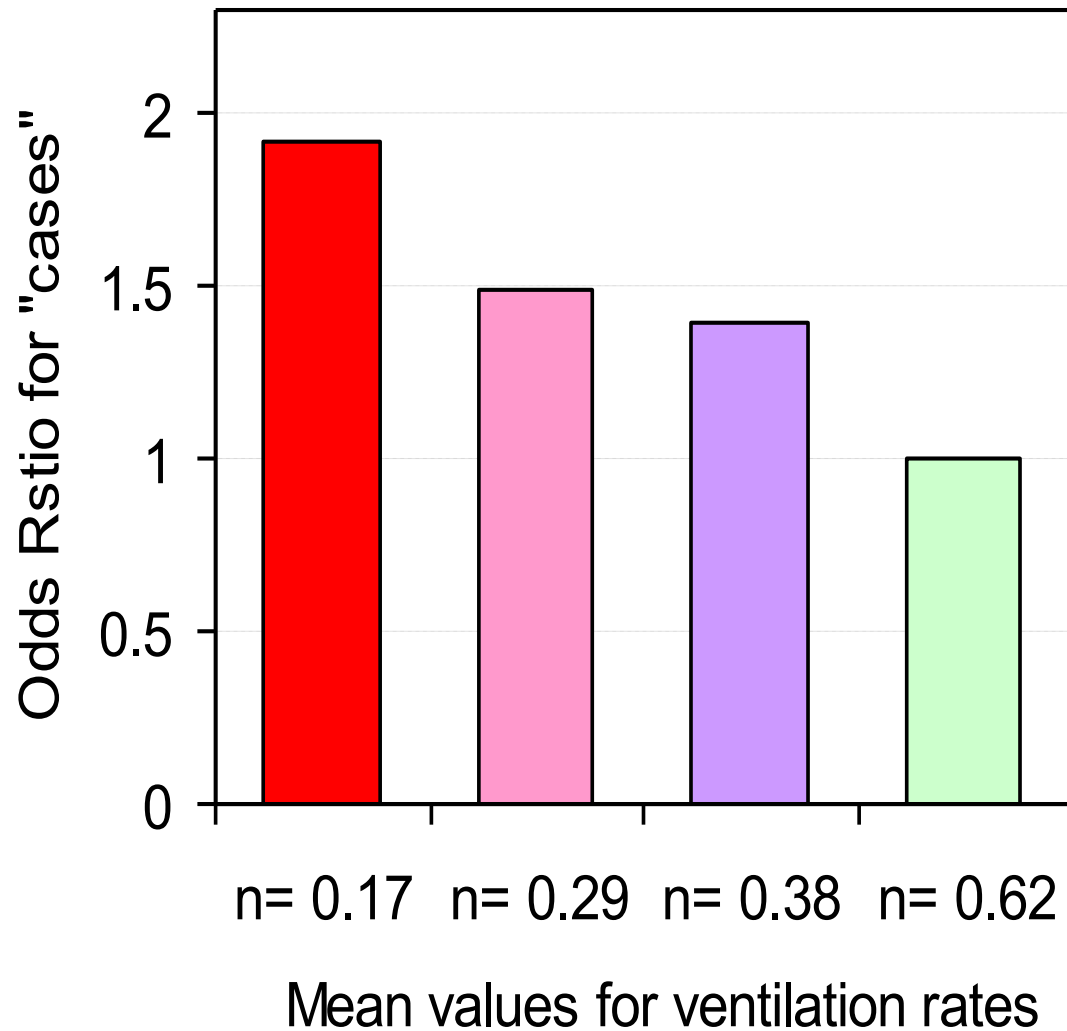
Hans Christian Andersen: The Princess on the Pea

Asthma and Allergy

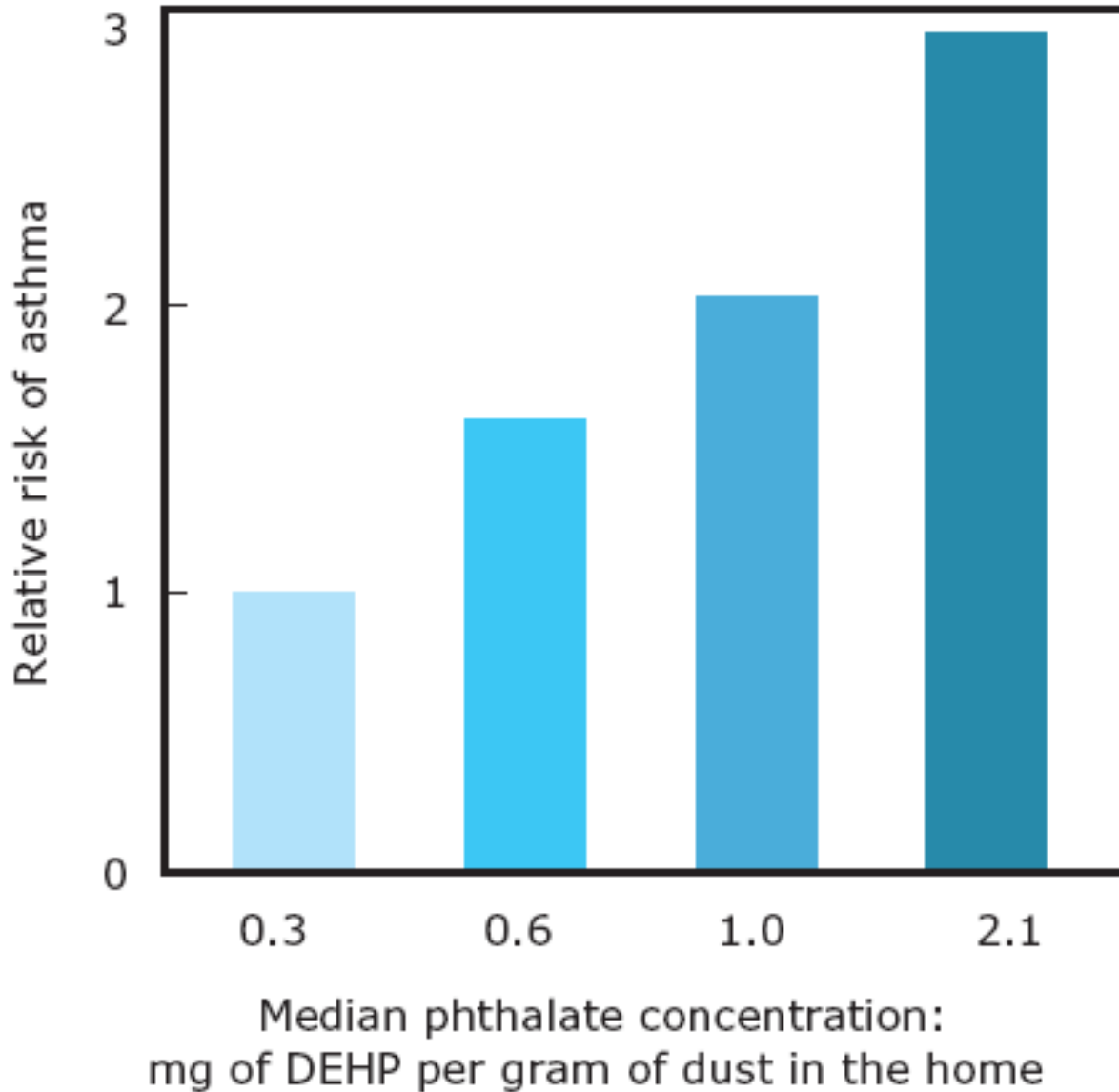
In several industrial countries 50% of school children is suffering from Asthma or Allergy. This number has doubled within the last 20 years

Importance of IEQ - asthma

- According to US CDC based on data collected in 2007, 2008, 2009
 - 8.2 % of population/26 million people affected
 - 10.5 million missed school days
 - 14.2 million missed work days
 - 475,000 hospital stays
 - 3,447 deaths
- Asthma triggers (CDC)
 - ETS
 - Dust mites
 - Outdoor air pollution
 - Cockroach allergens
 - Pets
 - Mold
 - Wood smoke
 - Respiratory infections



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).

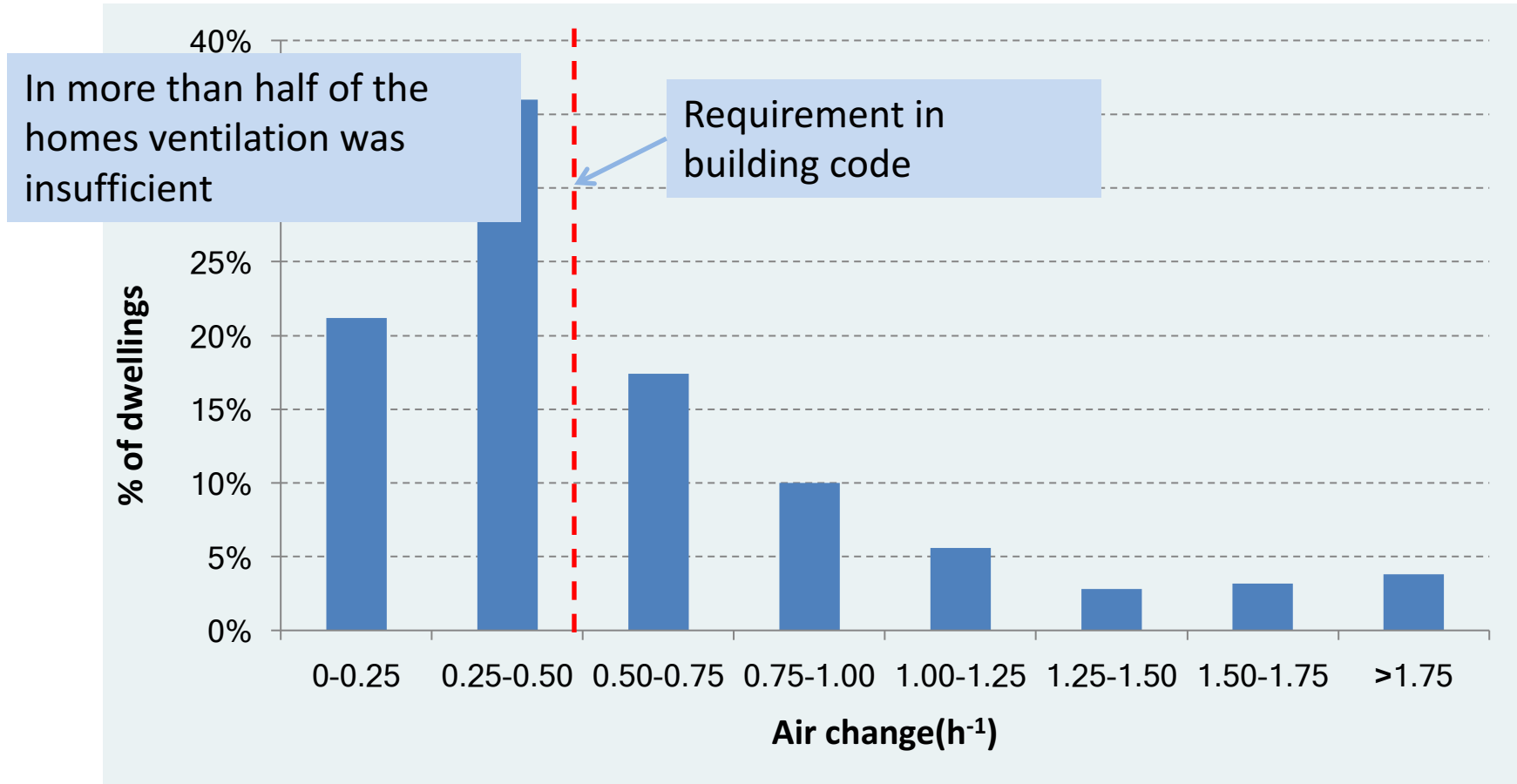


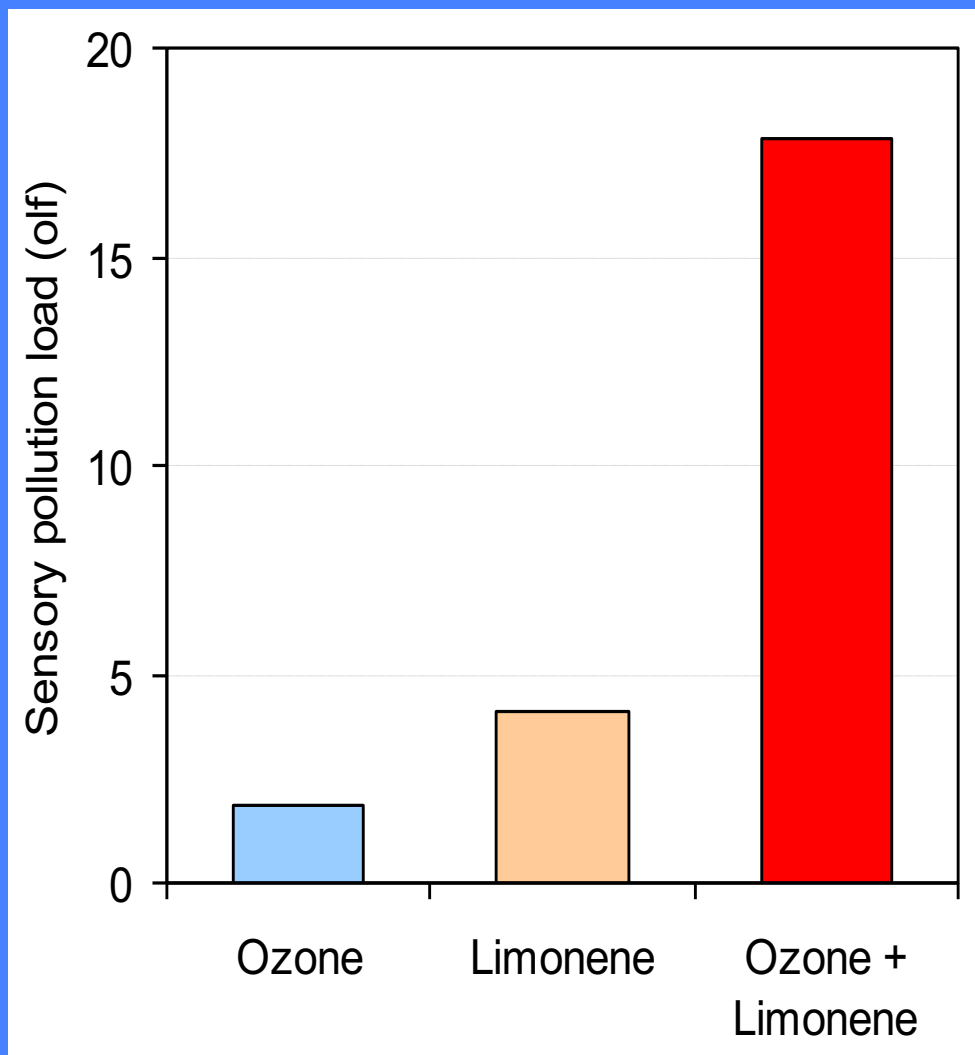
Plasticizers from polyvinyl chloride in dwellings increase the risk of asthma among children.

Each column represents about 90 dwellings.

DEHP: di(2-ethylhexyl) phthalate.

Air change in 500 Danish homes





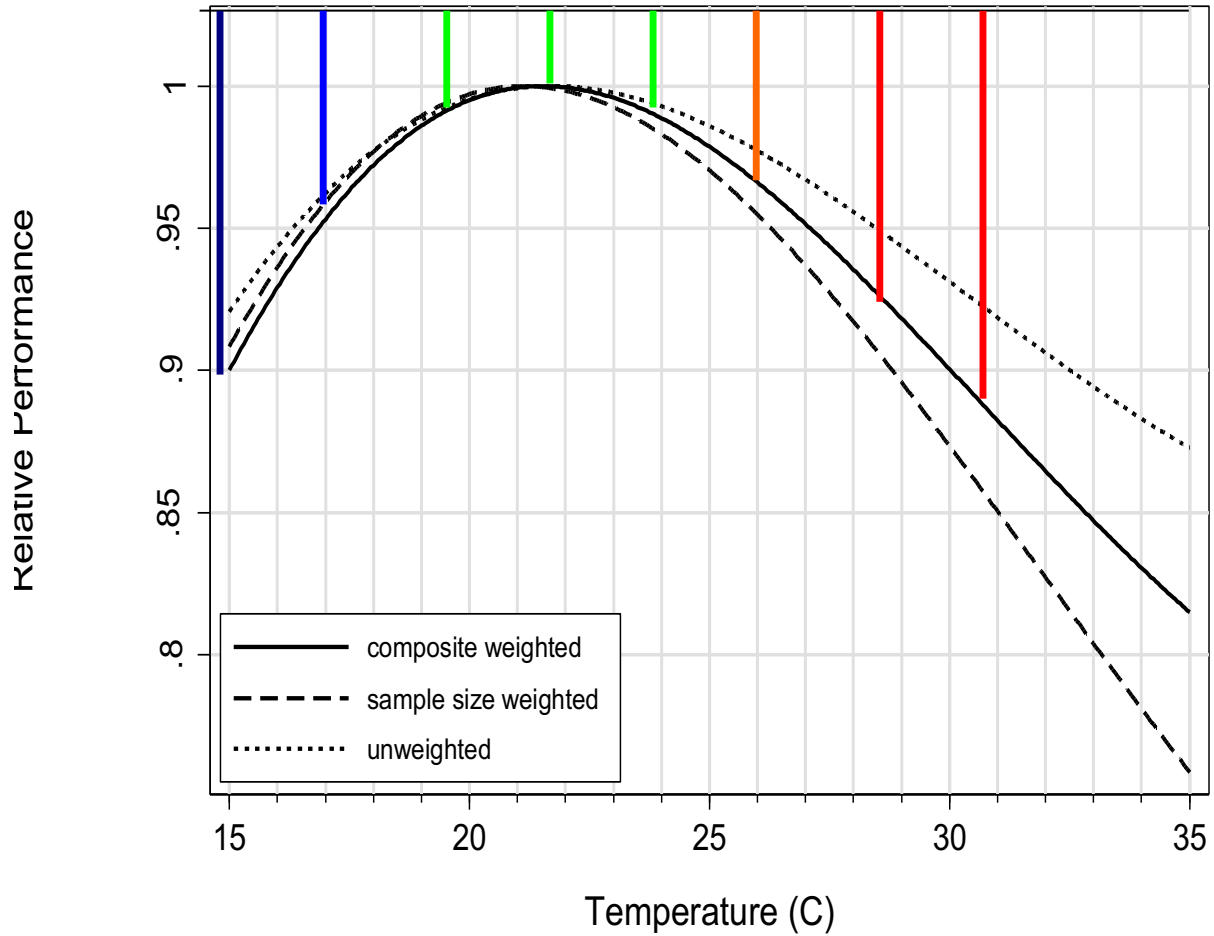
The sensory pollution load in an office where either ozone (15 ppb) or limonene (83 ppb) were present separately or both ozone and limonene (15 ppb+83 ppb respectively) were mixed in the office air (Tamás et al., 2005); the increased sensory pollution load is due to the presence of reaction products in the office air.

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 55-2013
 - Thermal environment conditions for human occupancy
- ASHRAE 62.1 and 62.2 -2013
 - Ventilation and indoor air quality
- EN15251
 - Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustic
- EN 13779
 - Ventilation for non-residential buildings - performance requirements for ventilation and room-conditioning systems

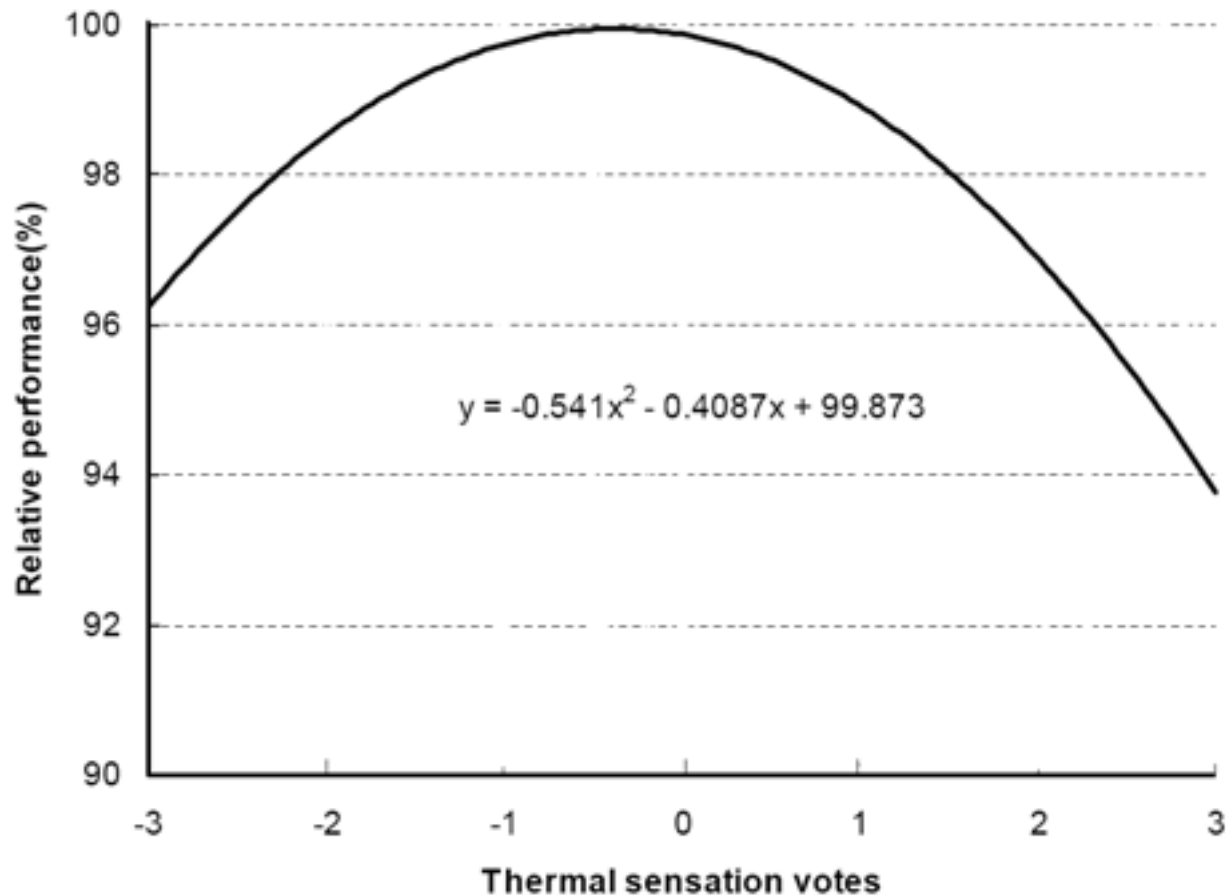
PMV-values

-1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0

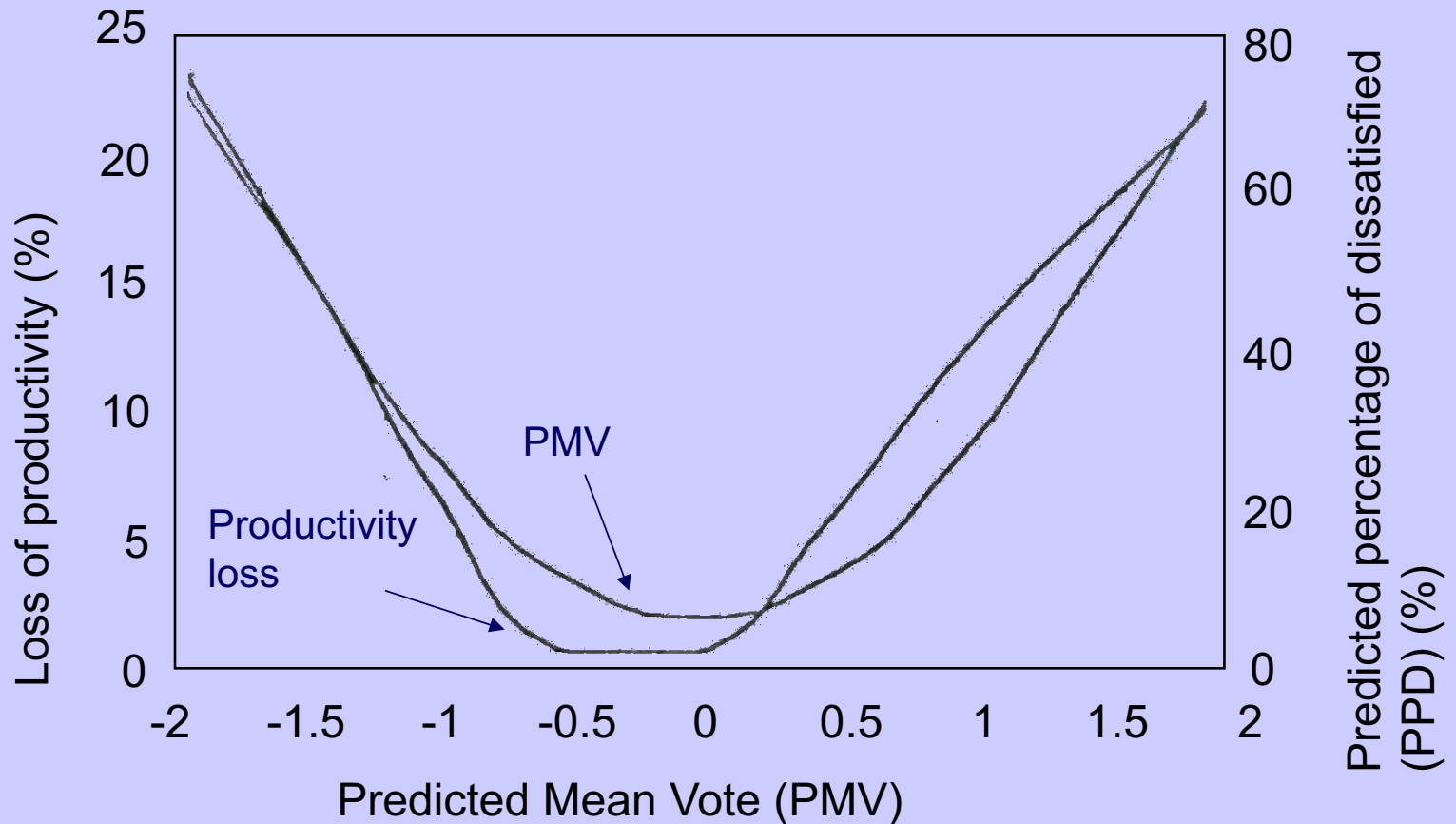


from Seppänen and Fisk 2005a

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



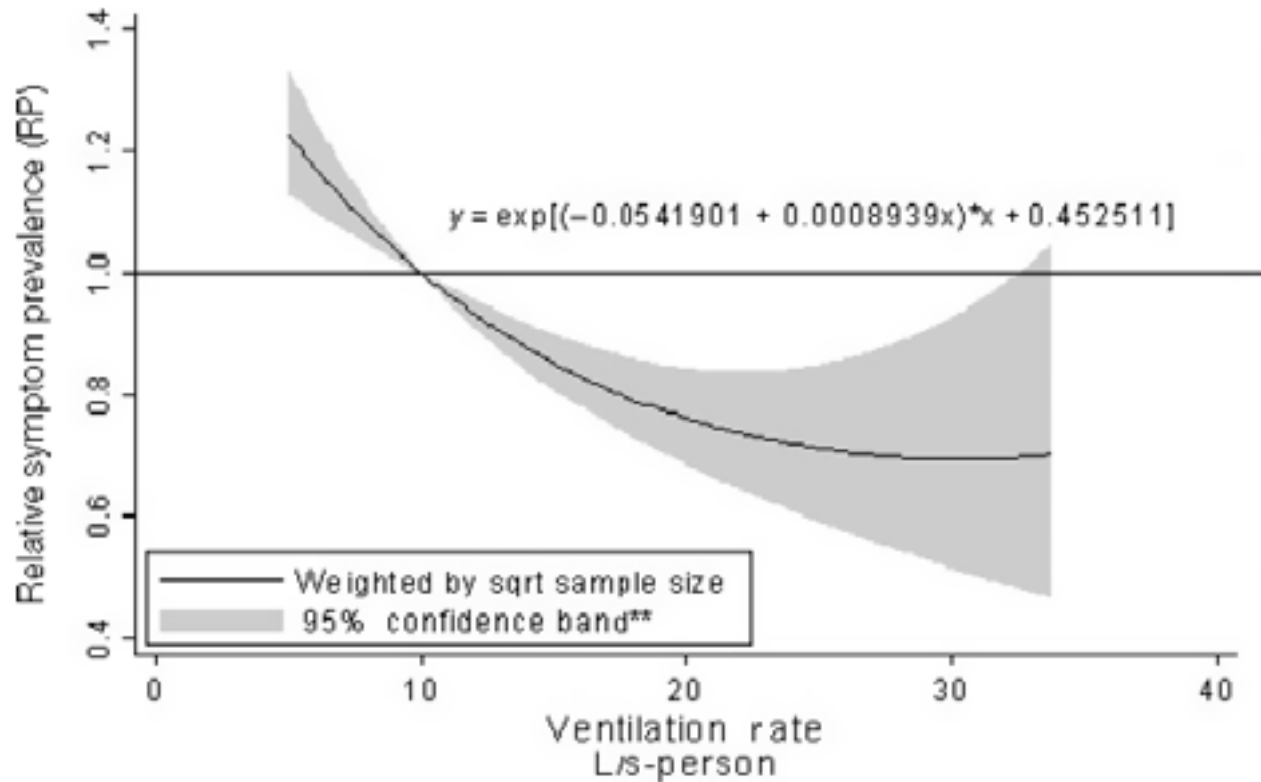
Thermal discomfort and estimated performance of office work, Roelofsen (2001)



CRITERIA FOR INDOOR AIR QUALITY ~VENTILATION RATES

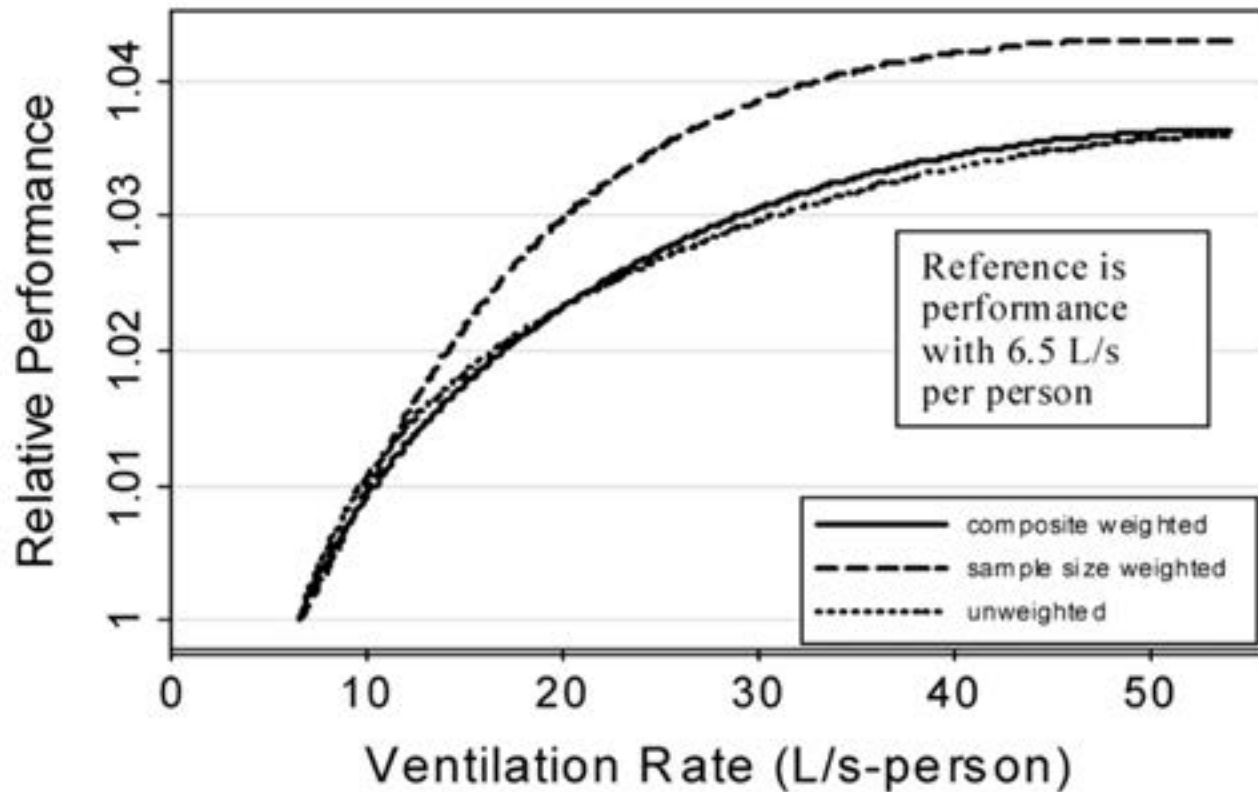
- COMFORT (Perceived Air Quality)
- HEALTH
 - PRODUCTIVITY
- ENERGY

Ventilation rates too low? SBS Symptoms



Source: W. Fisk, A Mirer, M. Mendell. 2009. Quantitative relationship of sick building syndrome symptoms with ventilation rates. Indoor Air

Ventilation rates too low? Productivity



Source: Seppänen, O. and W. Fisk. 2006. Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health. HVAC&R Research.

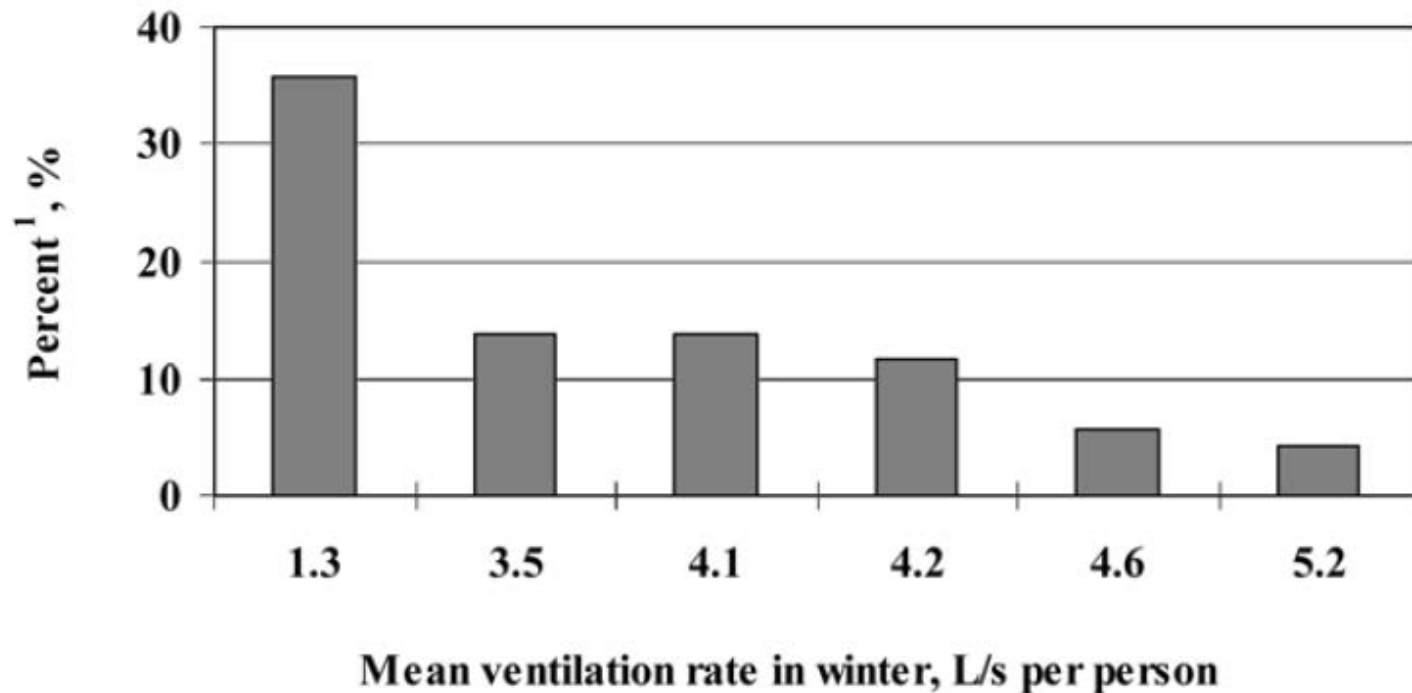


Figure 4. Associations between common cold infection rates and mean ventilation rate in winter in buildings constructed after year 1993. ¹ Proportion of occupants with ≥ 6 common colds in the previous 12 months.

Sun, et al. (2011)

Productivity

The results of these 3 studies were confirmed in actual workplace: a call-centre

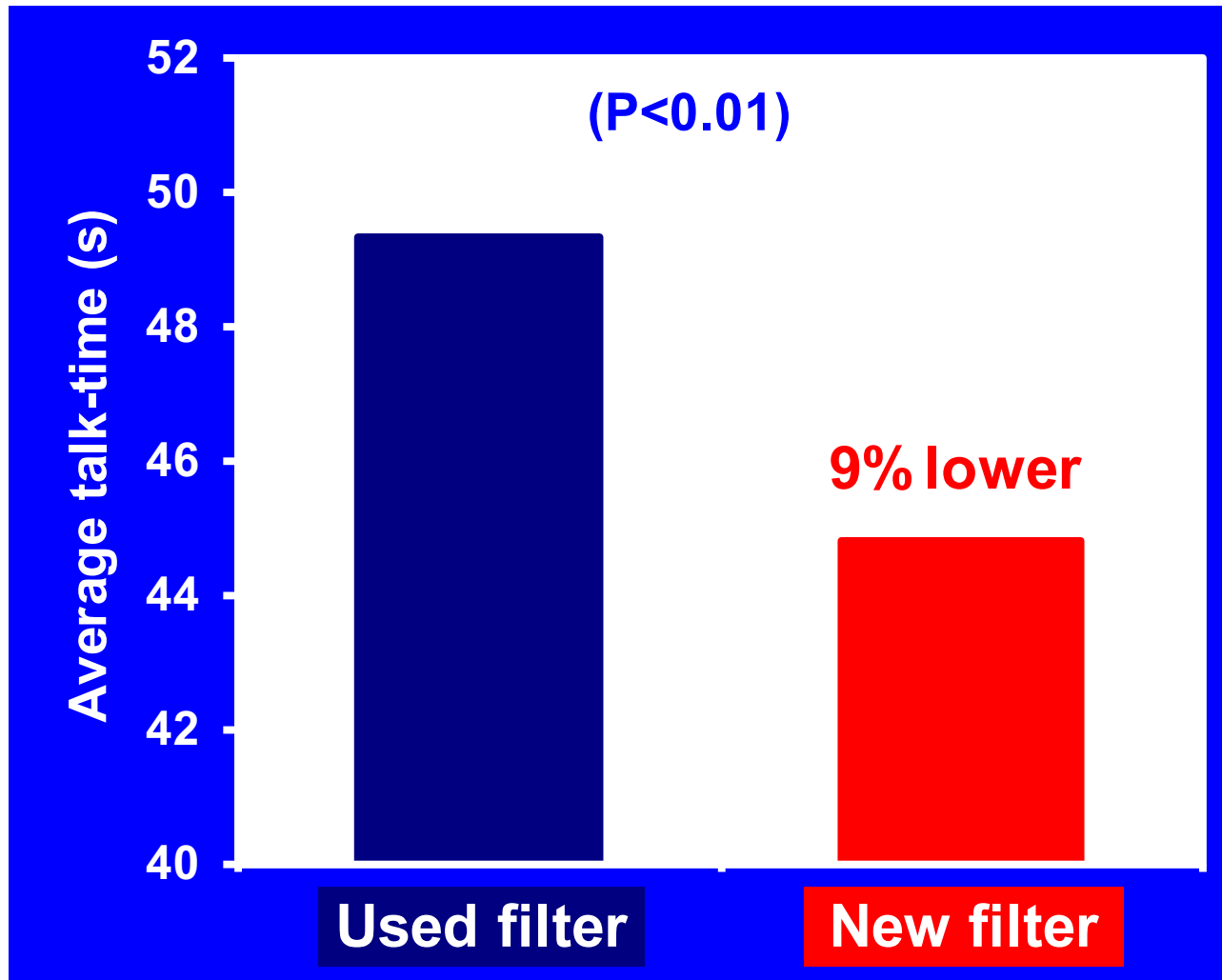


Performance measure

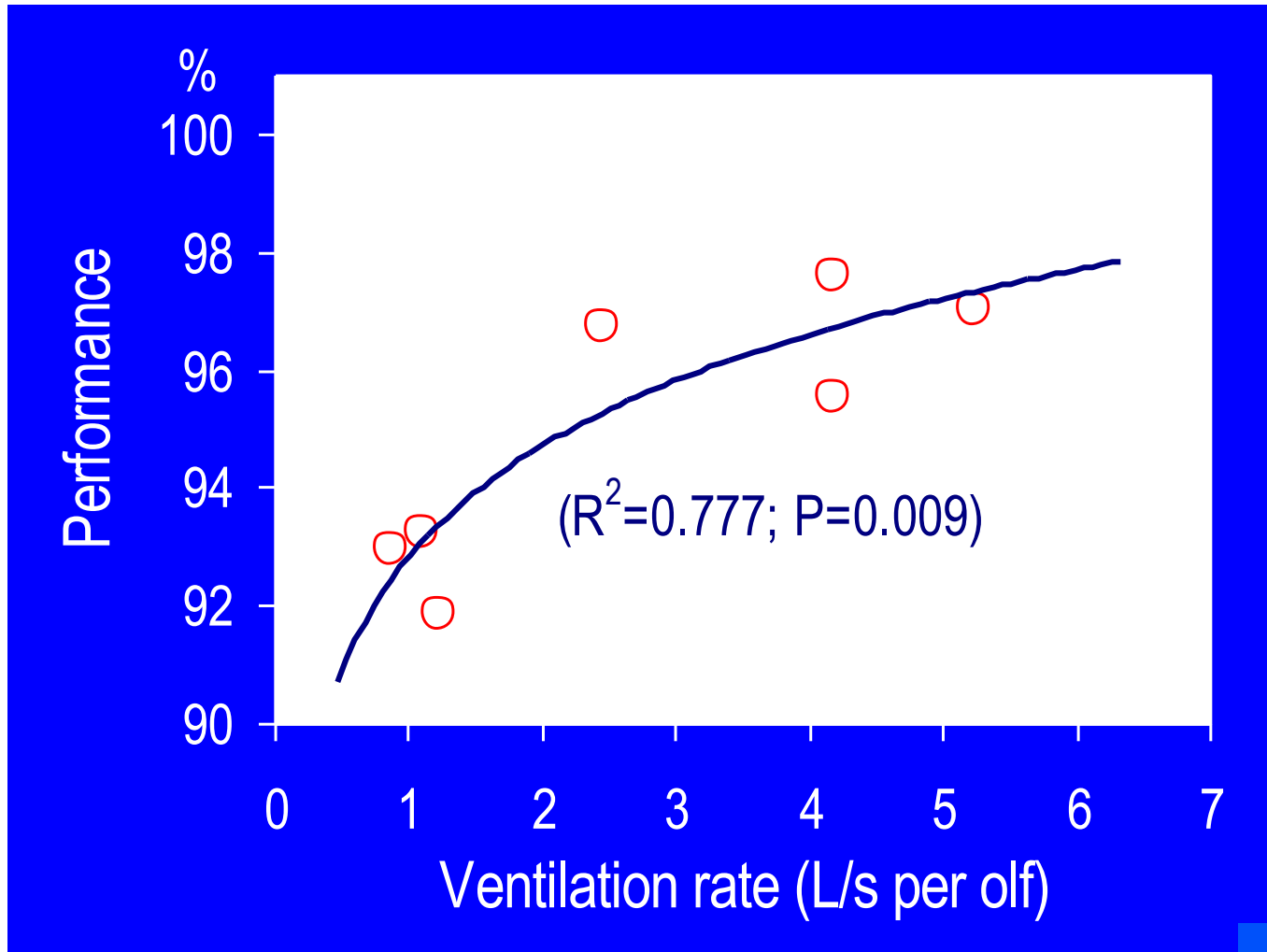
$$\text{Average talk time} = \frac{\text{Talk time}}{\text{Number of calls}}$$



Average talk-time with HIGH OUTDOOR AIR RATE



Ventilation vs performance





The effect of the indoor environment on student performance



ASHRAE Research Project- Learning efficiency. Intervention study

- 300 pupils, 10-12 years old
- Interventions: Temperature control and increased ventilation



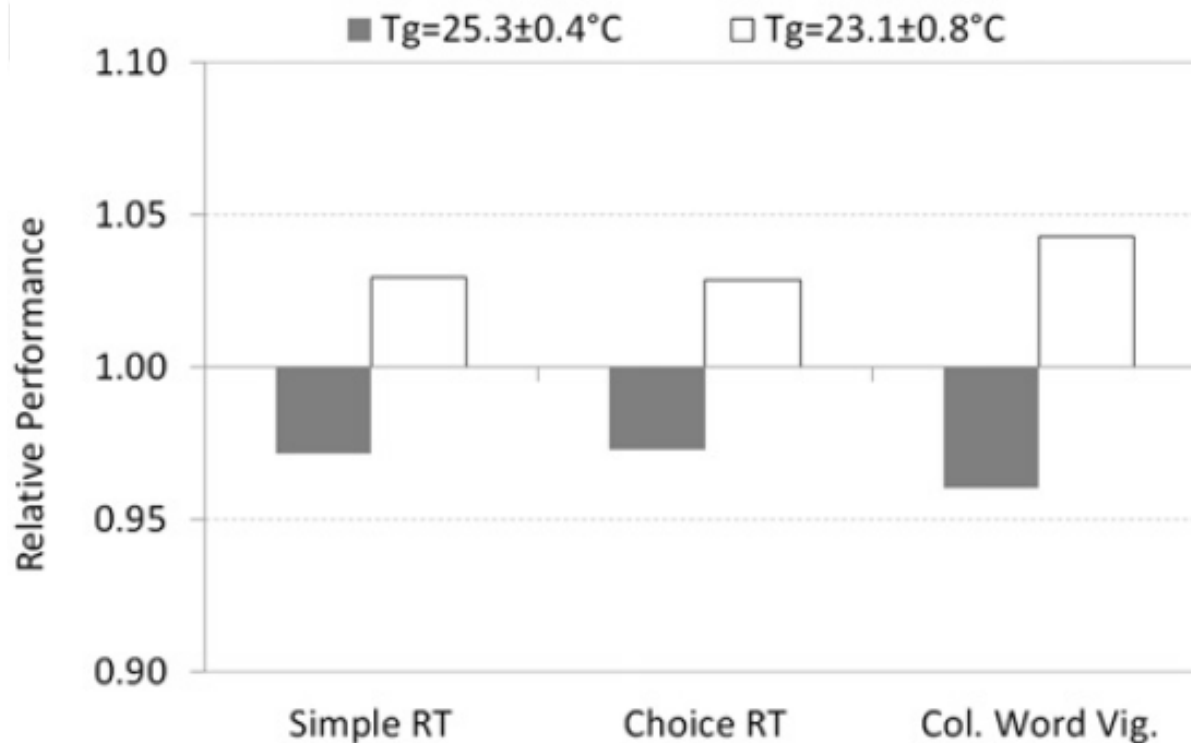
Installation of cooling



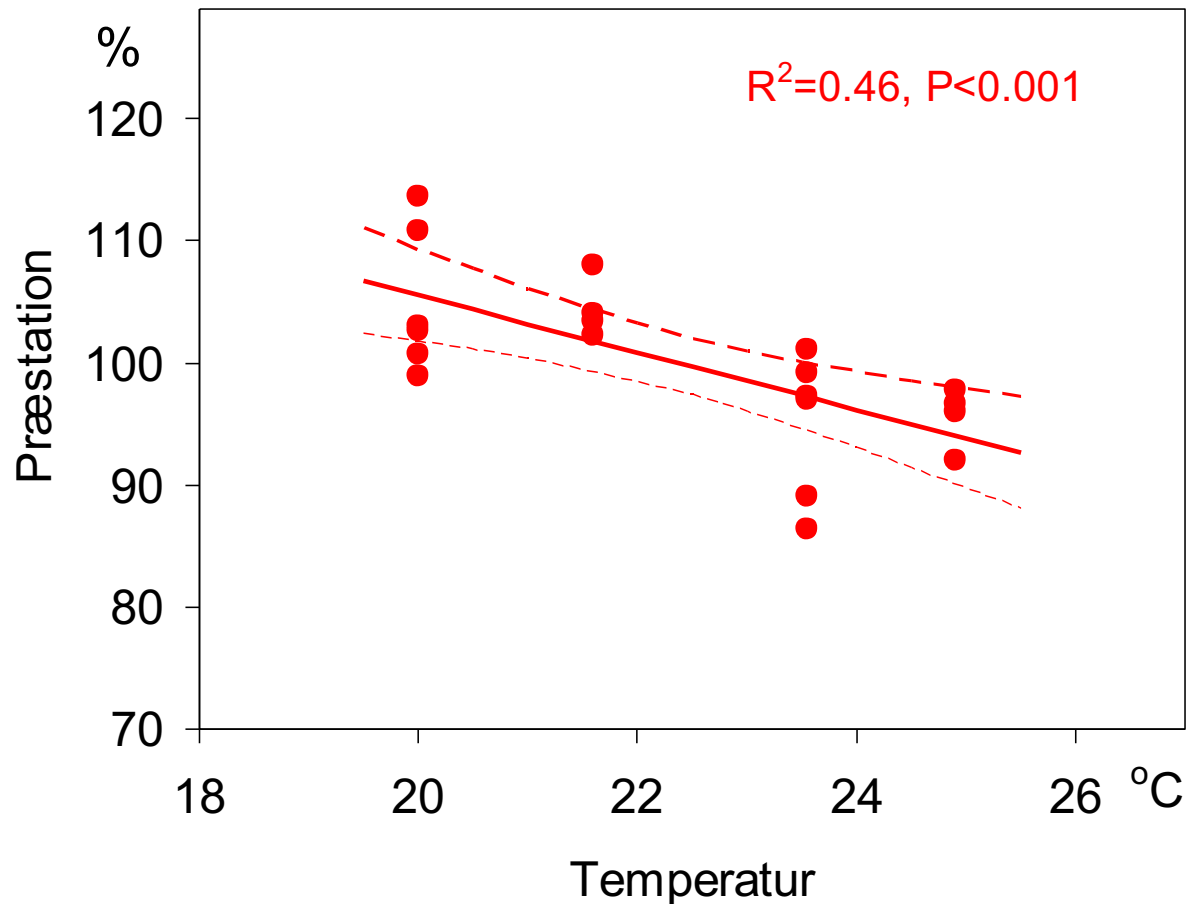
Increased ventilationen



Classroom Temperature

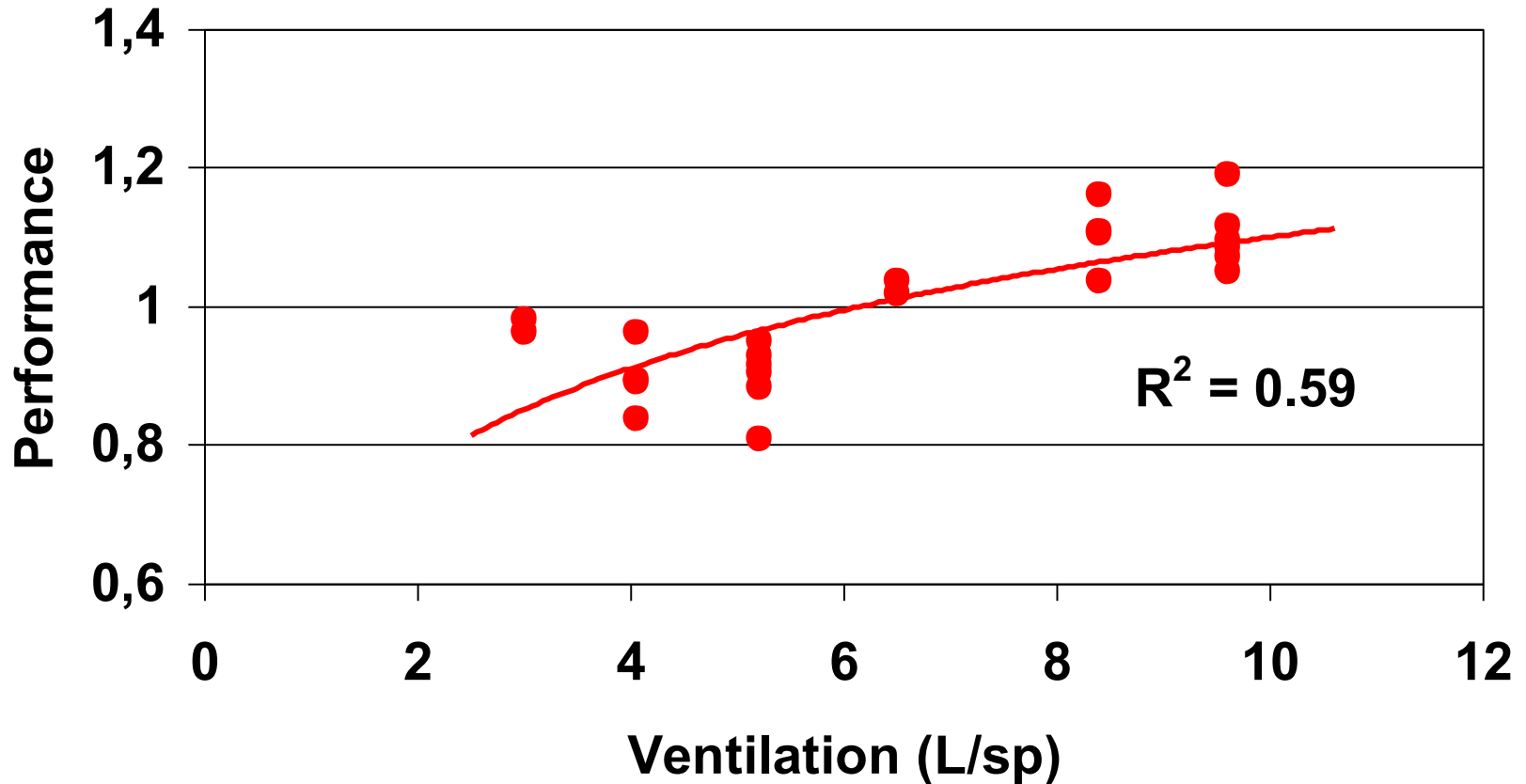


Effect of decreased room temperature



1°C lower mindre temperatur 2-4% higher performance

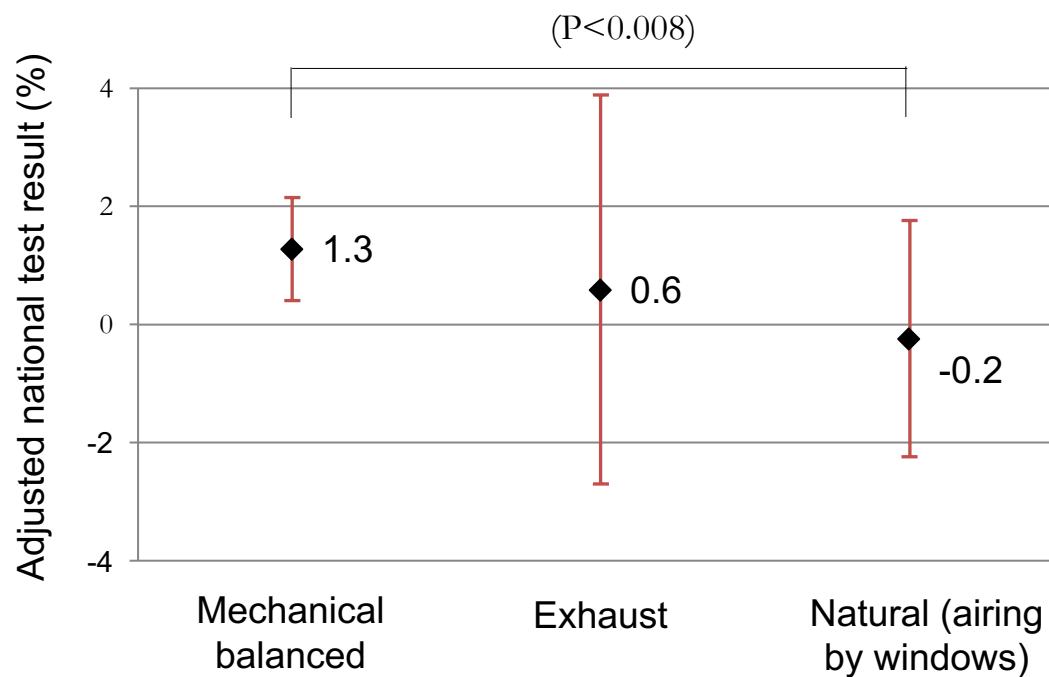
Performance of schoolwork as a function of classroom ventilation



Doubling ventilation rate ~14.5% higher performance

National standard educational tests

(math, language-based, science (chemistry/physics, geography, biology), foreign language)

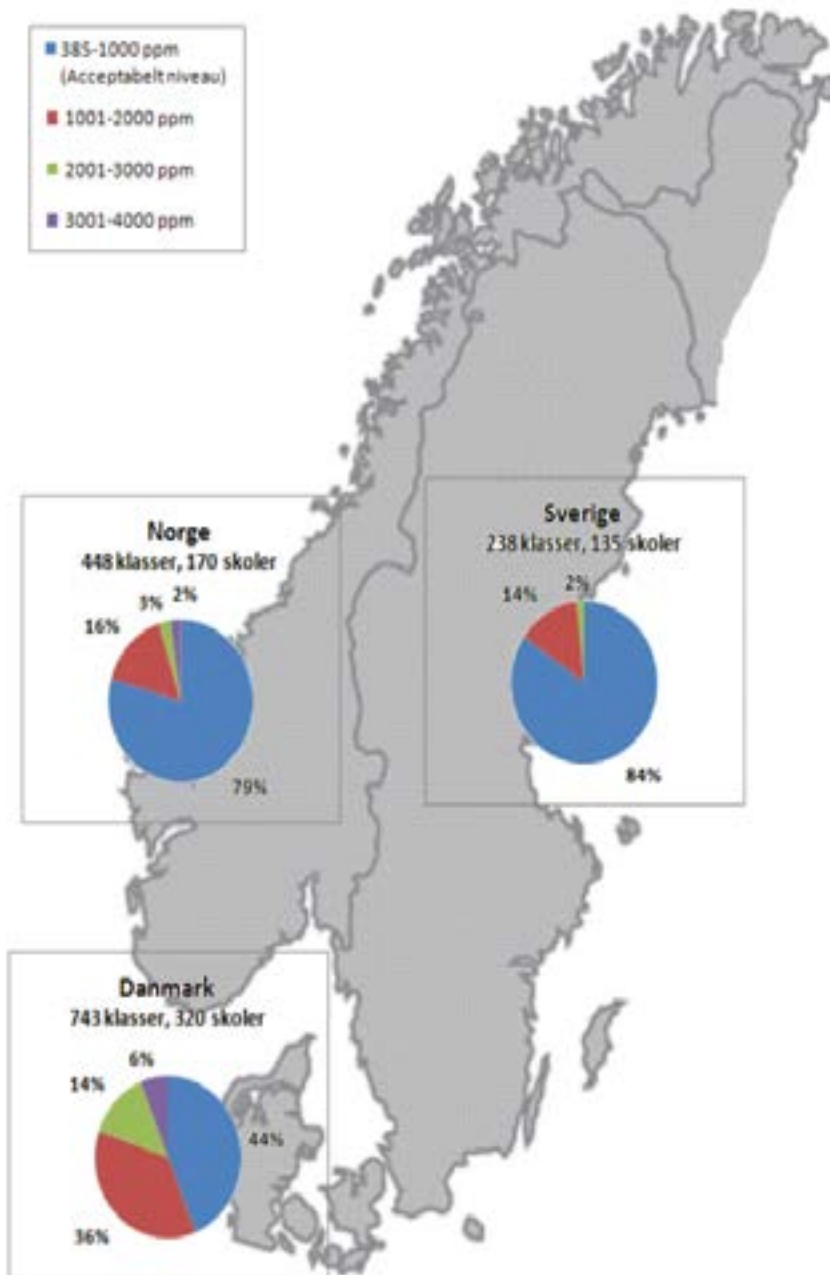


Two large studies performed to investigate IAQ in schools

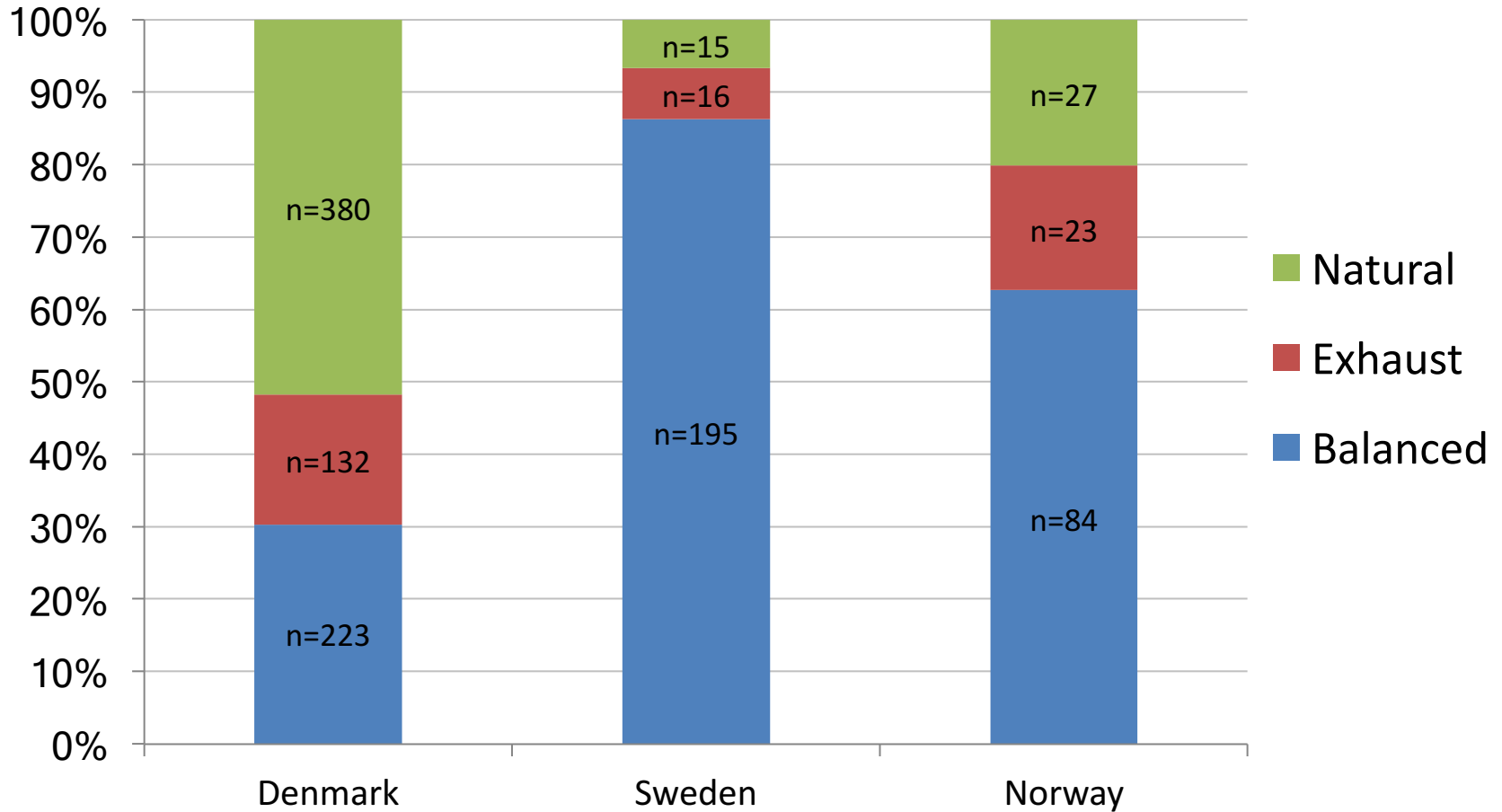
- Spot measurements in classrooms in Denmark, Sweden and Norway. (More than 1000 classrooms)
- Continuous measurements in 87 schools



Indoor Environment in Schools



Ventilation principles



Q&A

Bjarne W. Olesen

bwo@byg.dtu.dk