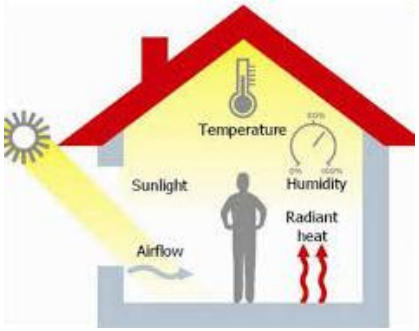
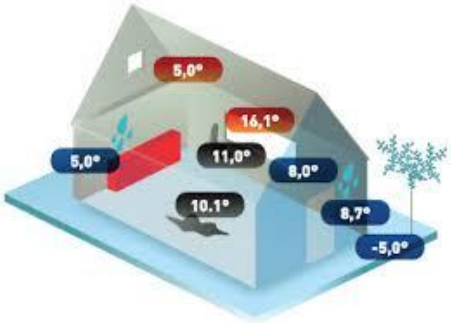
# CIVIL 212
# Indoor Climate
Fall 2025




# Introduction to the topic/field

11 September, 2025

Human-Oriented Built Environment Lab
Website: hobel.epfl.ch
Twitter: @licinadusan

**Assoc. Prof. Dusan Licina, Ph.D.**
School of Architecture, Civil and Environmental Engineering
École polytechnique fédérale de Lausanne
dusan.licina@epfl.ch

# Today's objectives…

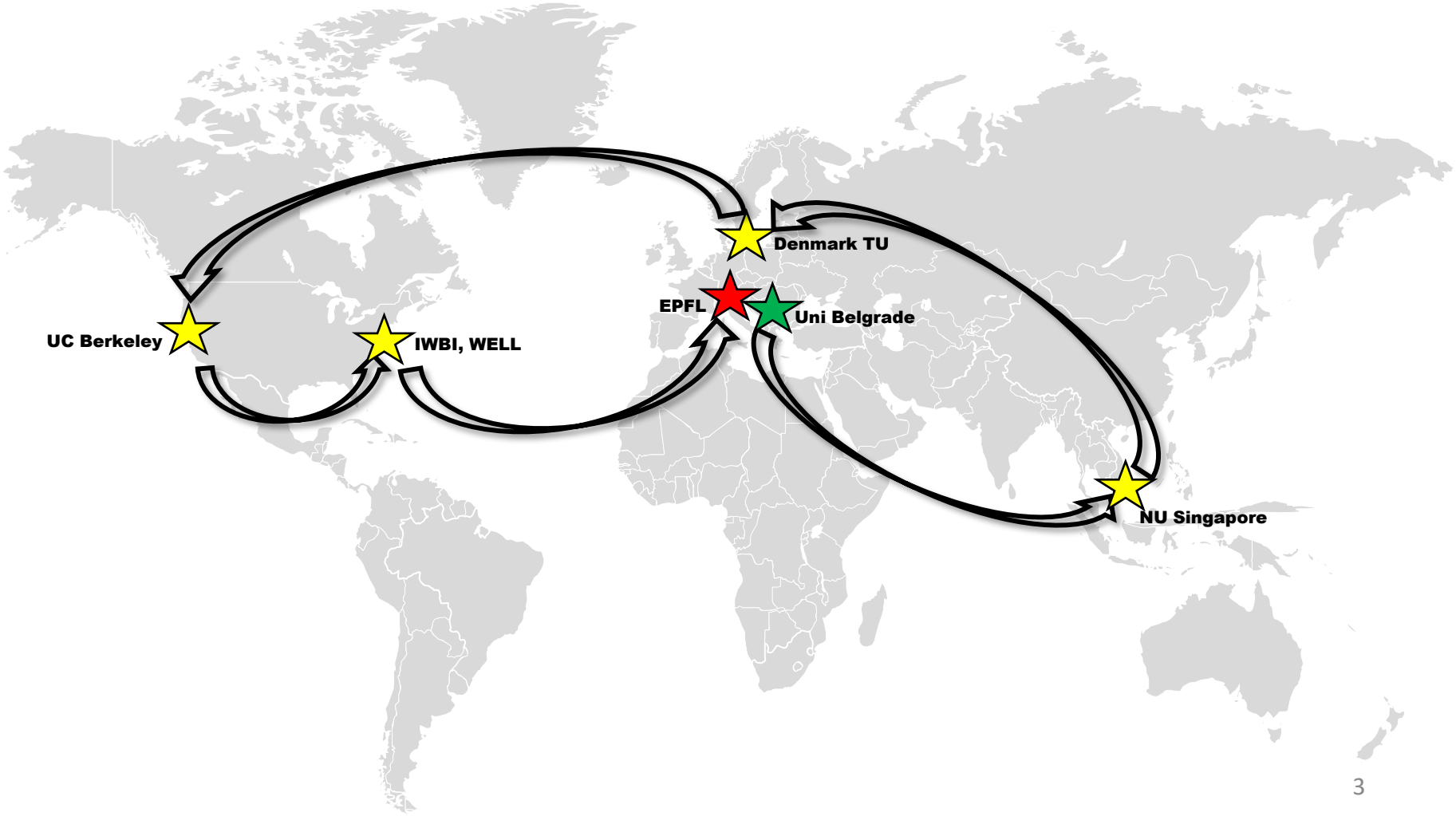
- Introduce myself & the lab
- Introduce the course
- Introduce yourselves
- Discuss the course syllabus
  - Course information, outline, schedule, ground rules
  - Why are we all here?

35 minutes

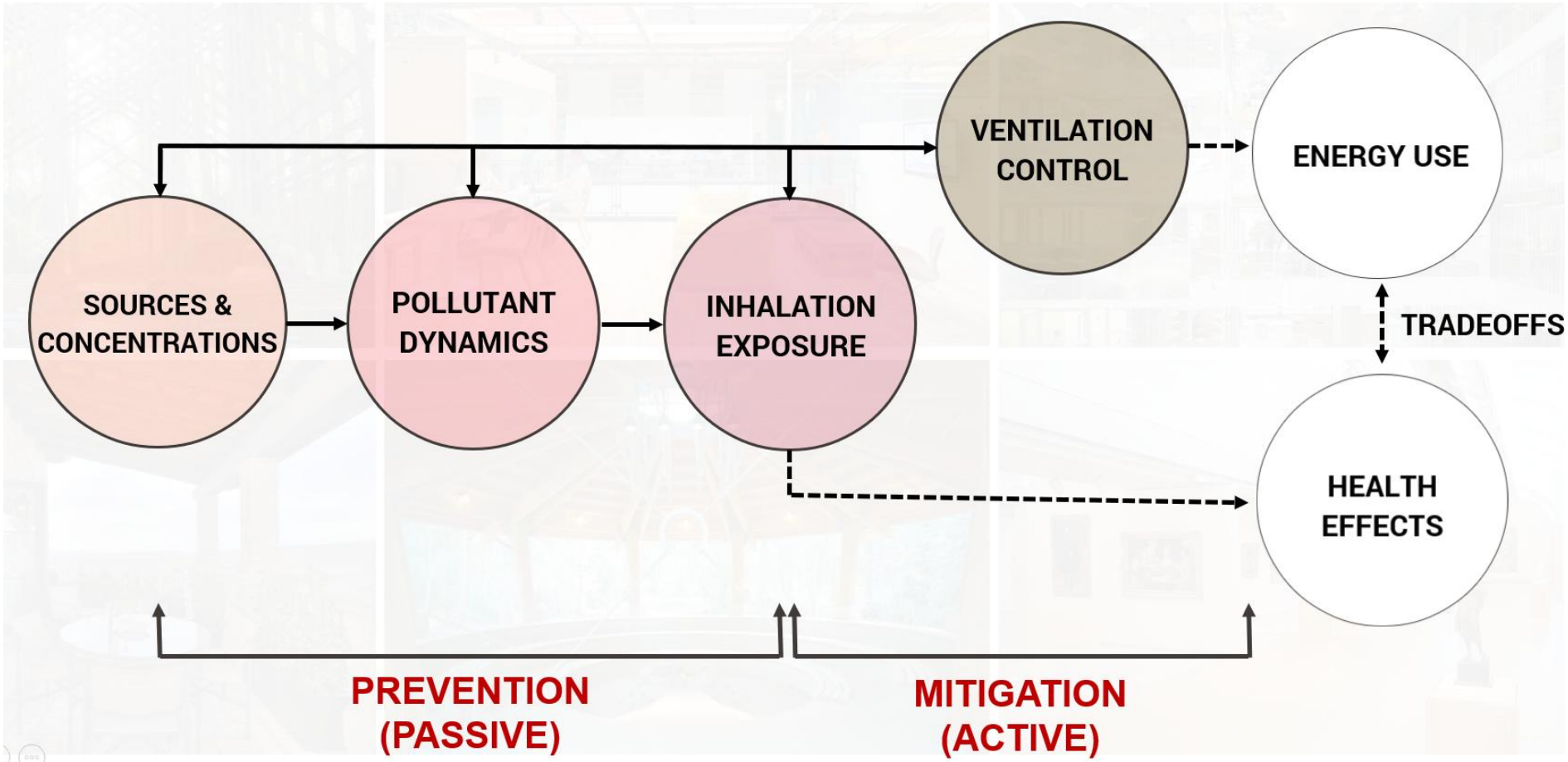
- Introduce the topic & indoor climate field
  - Why do we study indoor climate?

55 minutes

# My indoor climate trajectory…



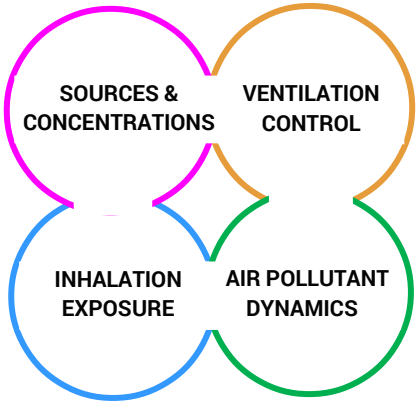
# HOBEL – Research domains



# HOBEL – Team

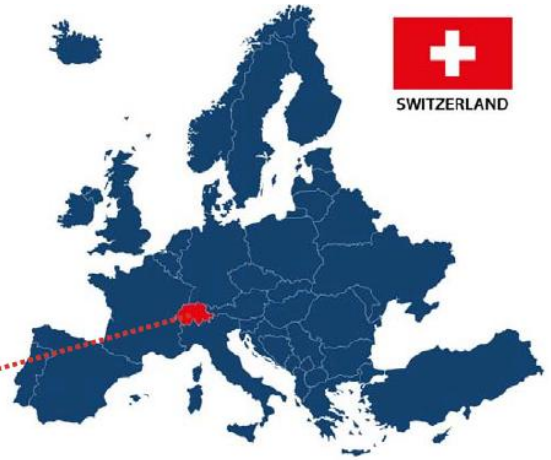
**Prof. Dusan Licina**
Head of HOBEL

**Claudia Gil**
Admin of HOBEL




# HOBEL – Where are we?

Capital of the State of Fribourg




# Unique laboratory facilities…

**FULL-SCALE CHAMBER**

**SMALL-SCALE CHAMBERS**

**BREATHING & COUGHING THERMAL MANIKINS**


**HIGH-END INSTRUMENTS**


# Course information

**Civil 212: Fundamentals of Indoor Climate**

## Classroom and Meeting Time

- Thursdays, 17h15 – 19h00 (sorry about it but the section had no other available time slots)
- Room: INJ218

## Office hours for consultations

- Thursdays, 16h00 to 17h00 (before the class)
- Office GC A1 354 or online (by appointment only - please email me to schedule an appointment)

## Prerequisites

- None, but good familiarity with building physics courses is beneficial.

# What you'll take away from this course?

**Goal**: To understand the key concepts of indoor climate: thermal comfort and indoor air quality. By the end of this course, you will be able to…

- 🧠 **Understand**
  - The fundamentals of indoor climate (thermal comfort & IAQ).
  - Why they matter for building design, operation, and health.
- ⚙️ **Apply**
  - Methods to assess thermal comfort and air quality.
  - Evaluate effectiveness of control mechanisms.
- 💬 **Communicate**
  - Read and discuss scientific articles.
  - Present your findings to the class.

# Course resources

Purchasing textbook(s) is **not compulsory** for this course

- I will rely on a mixture of notes from various textbooks, technical papers and publications

The reference textbooks from which I will draw information, for your consideration:

- C-A Roulet. Santé et qualité de l'environnement intérieur dans les bâtiments
- Allen, J., Macomber, J. (2020). Healthy Buildings: How Indoor Spaces Drive Performance and Productivity. Harvard University Press
- Parsons K. Human Thermal Comfort. CRC Press (2019)
- Spengler, J., McCarthy, J., and Samet, J. Indoor air quality handbook, McGraw-Hill Professional (2001).
- Awbi, H. B, Ventilation of buildings, E&FN SPON, (2003).
- Peer-reviewed papers and websites

Understanding the presentation slides uploaded to Moodle will be sufficient for achieving the learning outcomes and passing the exam

# About you…

**Background**

- Have you heard about indoor climate before?
- Any experience from work or studies in related fields?

**Just for fun**

- 🌍 Who has lived outside Switzerland?
- 🌍 Who has lived in more than 3 different countries?
- 🧀 Who has tried fondue?
- 😴 Who has ever fallen asleep in a stuffy classroom?
- 🏀 Who will be EuroBasket champion?

# Course deliverables

**Grading:**

- Exam(s)
  - One midterm exam (1st half of the course)
  - Second exam (2nd half of the course)

- Course Project
  - Oral presentation on a selected topic
  - Details summarized in the course syllabus (Moodle)

# Course grading

| | |
|---|---|
| Exam 1 | 35 pts |
| Exam 2 | 30 pts |
| Course project | 35 pts |
| Total | 100 pts |

**Grading scale:**

| | |
|---|---|
| 5.50 - 6.00 | ≥ 90% |
| 5.00 - 5.49 | 80-89.9% |
| 4.50 - 4.99 | 70-79.9% |
| 4.00 - 4.49 | 60-69.9% |
| 0.00 - 3.99 | < 59.9% |

# A note on course project

Your project = explore one topic from the course in more depth

- 🎯 **Purpose**: Dive deeper into one indoor climate topic & share it with peers.
- 👥 **Process**: Work in small groups.
- 💻 **Deliverable**: Oral presentation (PPT slides).
- 💬 **Feedback**: Discussion with classmates + teacher.
- 📖 **Support**: More details in the syllabus & during the semester.

# Other relevant details…

**Materials (Moodle)**

- Lecture notes & updated syllabus posted **1–3 days before class**.
- **Pre-lecture notes ≠ Post-lecture notes**: I hide a few slides to spark discussion; full set comes after class.

**Communication**

- Class announcements via **email** (EPFL address).
- Please **whitelist** my address so I don't end up in spam.
- Prefer a different address? **Email me once** to let me know: *dusan.licina@epfl.ch*

**Your part (how to succeed)**

- **Ask questions** and share experiences during class.
- **Join discussions** when prompted (short prompts, think-pair-share).
- **Participate** in all quick polls & quizzes (in-class, low-stakes).

# Any questions so far?

# What do you think when you hear “climate”?

# What do I think when I hear “climate”

# What are differences among these climates?


*Adapted from Pantelic et al. 2022 Front. Built Environ.*

# In-class exercise

Try to make a rough diary about the time that you spend in different indoor and outdoor environments during the last 7 days. Then, share your findings within a class…

*Follow this guide:*

- *Separate % of time between indoor and outdoor*
- *Separate % of time spent indoors: between residential, transport, and work environments (campus buildings in your case)*

# The climate we're exposed to: It's indoors!


**The Corsi code:**

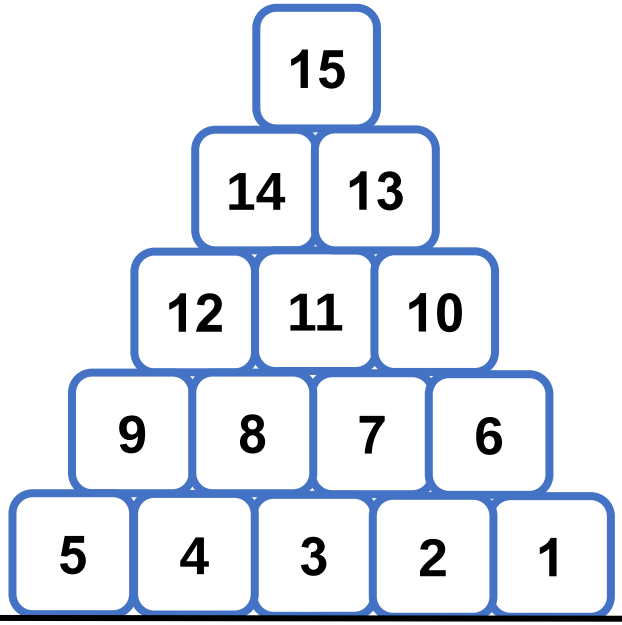
| | |
|---|---|
| **79** | **Average life expectancy** |
| **70** | **Indoors** |
| **50** | **At home** |
| **26** | **In bed** |
| **5** | **In transit** |
| **4** | **Outside** |

*Prof. Richard Corsi, UT Austin, USA*

- We spend most of our time **indoors.**
  - -Around 90% of the time, on average

*(Source: Klepeis et al., 2001 J Exp Anal Environ Epidem)*

# Any questions so far?


See you in 15 mins…

# Indoor environmental quality (IEQ)

- IEQ includes:
  - Indoor air quality
  - Thermal comfort
  - Acoustical quality
  - Lighting quality


# IEQ, Stress mechanisms, and Human Health

**ACOUSTIC QUALITY**

**AIR QUALITY**

**LIGHTING QUALITY**

**THERMAL QUALITY**

**STRESS MECHANISMS**

- Anti-stress
- Circadian rhythm
- Endocrine disruption
- Oxidative stress
- Inflammation, irritation
- Ceil changes/death

**DISEASE / DISORDER**

- Depression
- Obesity
- Diabetes
- Chronic resp. diseases
- Cardiovascular diseases
- Cancers

# Indoor climate and the role of buildings

- Any building has primarily a protective role to occupants
- Occupied buildings should meet indoor climate requirements
- Indoor climate depends on various aspects which should be considered as a whole
- What happens if we don’t know building physics and indoor climate?

# What happens when you don’t understand indoor climate?

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# What happens when you don’t understand indoor climate?

*(Source: https://wet2drysolution.com/)*

# What happens when you don’t understand indoor climate?

ESPN NFL NBA MLB Soccer MMA NCAAF •••

NBA Home Scores Schedule Standings Stats Teams Draft Playoff Basketball Battle

## Warm weather causes water on floor

Chris Forsberg
ESPN Staff Writer

Jan 26, 2010

BOSTON -- Monday's game took Boston Celtics coach Doc Rivers back to his playing days for all the wrong reasons.

Unseasonably warm temperatures caused condensation to form on the floor of the TD Garden during Boston's 95-89 win over the Los Angeles Clippers Monday, leading to a brief delay as workers mopped the court to keep it dry late in the first quarter.

Source: (https://www.espn.com/nba/news/story?id=4858097)

# What happens when you don't understand indoor climate?

When you don't understand indoor climate (or more broadly building science), and you are in charge of engineering, design, construction, or maintenance of a building...

… the result is:

Higher **energy use** & **costs**

Increased **GHG & pollutant emissions**

Poor **thermal comfort**

Poor **indoor air quality**

Reduced **productivity & learning**

Impacts on **health & well-being**

# Indoor climate implications

- Health and well-being
- Cognitive performance
- Energy and ecological impacts
- Cost

IBN: Institute for Forestry in the Netherlands. *behnisch architekten* .

# Influence of indoor climate: Health and well-being

## Comfort and health

- Headaches
- Eye strain/damage
- Dry throat and runny nose
- Skin irritation
- Infections
- Fatigue
- Seasonal Affective Disorder
- Asthma & breathing disorders
- Stress & depression
- Other serious disorders, including cardio-vascular, etc.

## Organizational outcomes

- Productivity loss
- Absenteeism
- Presenteeism (working while sick)
- Staff turnover/retention
- Revenue
- Medical costs
- Medical complaints
- Physical complaints
- Task efficiency & deadlines met, etc.

# Air quality and health: Global Burden of Disease

## Leading global health risk factors (2016)

*(Source: GBD 2016 Risk Factors Collaborators, Lancet 390: 1345-1422, 2017)*

| Males | Females |
|---|---|
| 1. Smoking | 1. High blood pressure |
| 2. High blood pressure | 2. High body-mass index |
| 3. Low birthweight & short gestation | 3. High fasting plasma glucose |
| 7. Ambient particulate matter | 6. Ambient particulate matter |
| 10. Household air pollution | 8. Household air pollution |
| 16. Unsafe water | 13. Unsafe water |
| 21. Unsafe sanitation | 16. Unsafe sanitation |
| 23. No access to handwashing | 20. No access to handwashing |
| 30. Second-hand smoke | 21. Second-hand smoke |

# Residential air quality and health

- Residential indoor air pollution is estimated to result in **5-14%** of the annual non-communicable, non-psychiatric **disease burden** in the U.S.
  - Excludes SHS and radon *(Source: Logue et al., Environ. Health Perspect. 2012, 120, 216-222)*

- Cumulative lifetime **cancer risks** of **1-10** excess cases **per 10'000** people
  *(Sources: Wallace et al., Environ. Health Perspect. 1991, 95, 7-13; Sax et al., Environ. Health Perspect. 2006, 114, 1558-1566; Hun et al., Environ. Health Perspect. 2009, 117, 1925-1931)*

Household air pollution – 3rd most important cause of ill health for the world's population

*(Source: Lim et al. 2012, Lancet)*

Biomass fuels in households are responsible annually for ~0.7 to 2.1 million premature deaths in low-income countries, from a mix of lower-respiratory infections, chronic obstructive pulmonary disease, and lung cancer.

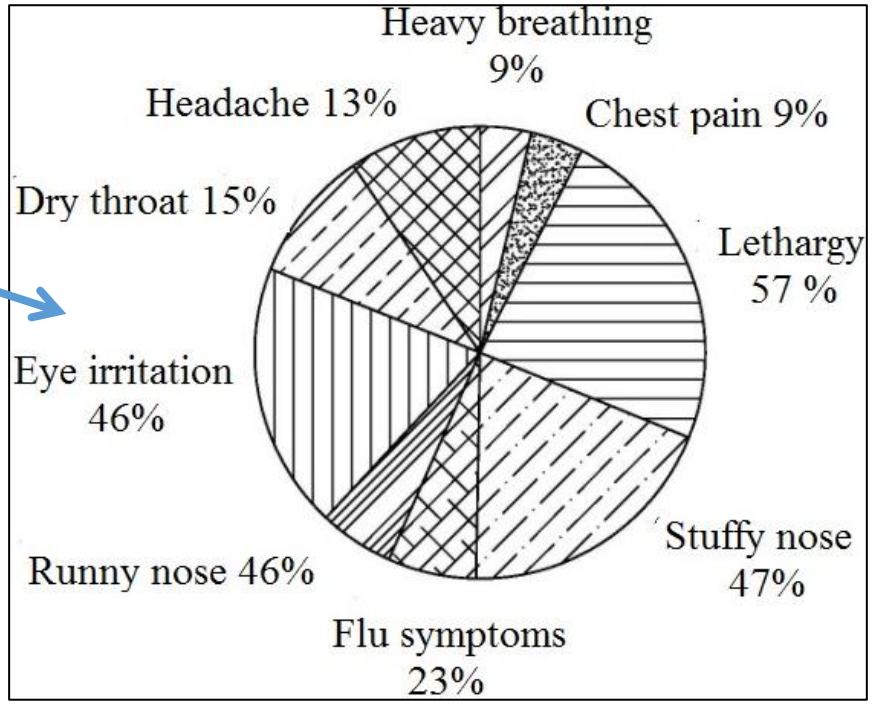
# Sick building Symptoms and Building-Related Illnesses

Sick Building Syndrome (SBS) symptoms

Building-Related Illnesses

Exposure to indoor air climate

- SBS symptoms - Building occupants experience acute health and comfort effects that are linked to the time spent indoors
- BRI - Health problems accompanied by physical signs that persist




*(Source: US EPA, 1991)*

# Influence of indoor climate: Performance

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv


10 Questions

## Ten questions concerning thermal and indoor air quality effects on the performance of office work and schoolwork

Pawel Wargocki*, David P. Wyon

*DTU-ICIEE, Technical University of Denmark, Denmark*

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*Keywords:*
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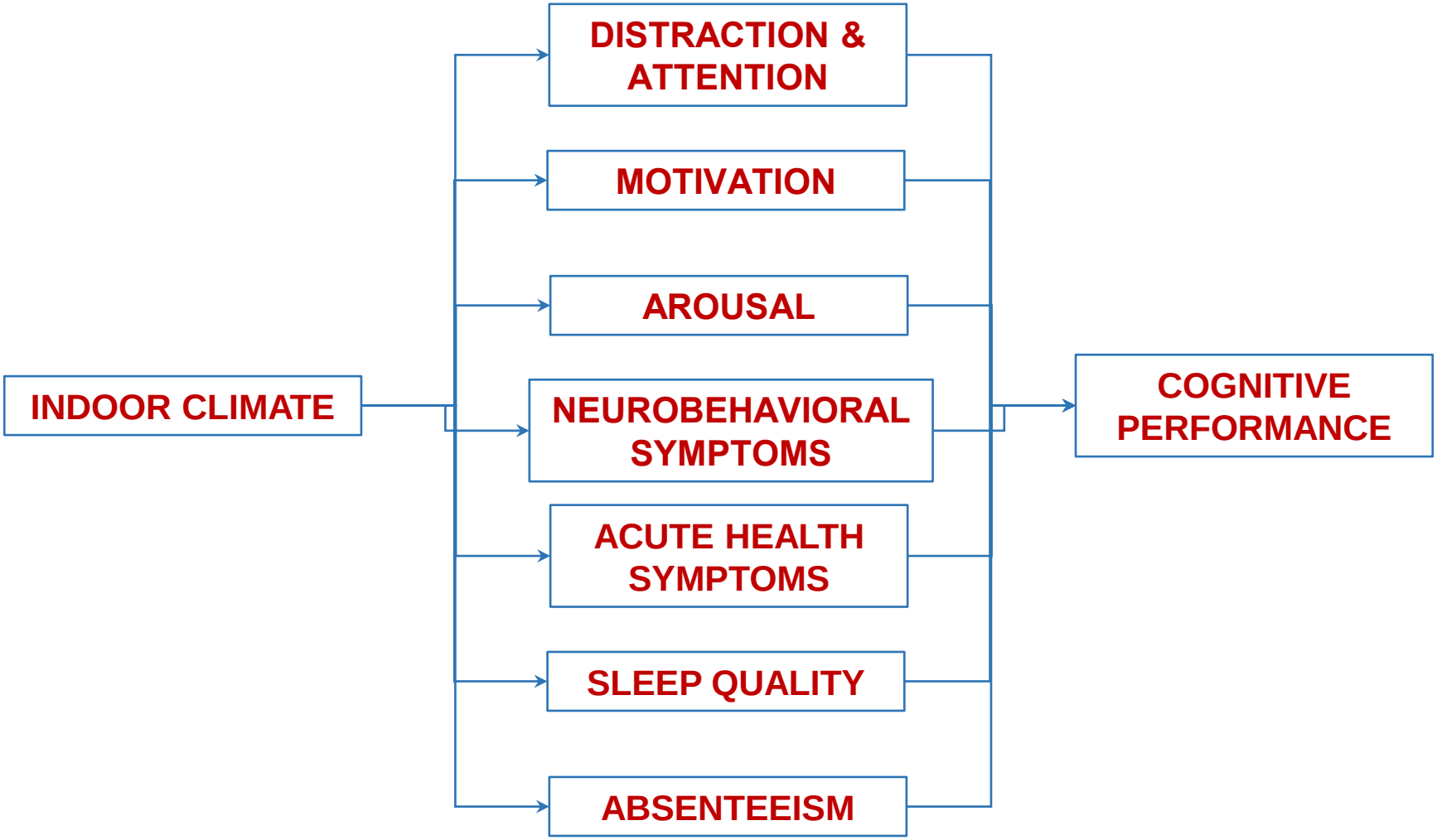
Schoolwork
Learning
Cognitive performance
Thermal environment
Indoor air quality

ABSTRACT

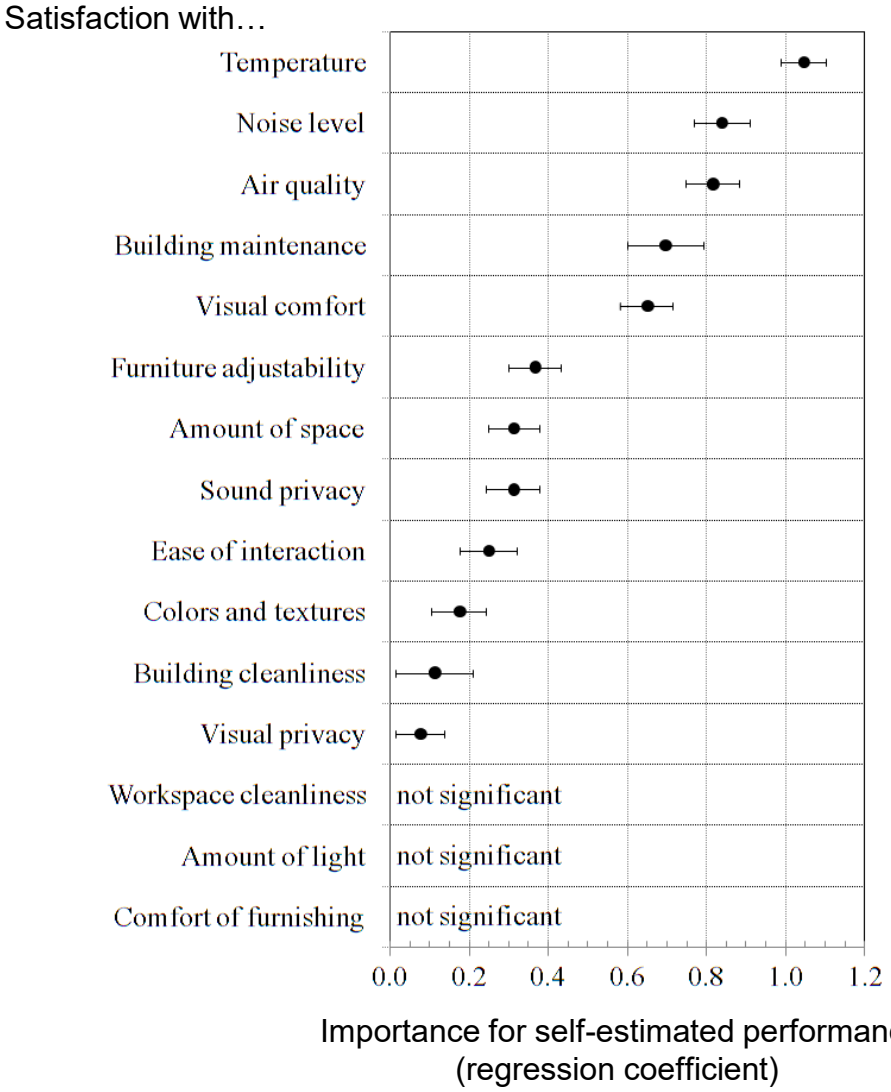
Energy conservation in buildings as a way to reduce the emission of greenhouse gases is forcing an urgent re-examination of how closely thermal and air quality conditions should be controlled in buildings. Allowing conditions to drift outside the optimum range would conserve very large amounts of energy and would in most cases have only marginal effects on health or subjective comfort. The question that then arises is whether occupant performance would be negatively affected and if so, by how much. This information is required for cost-benefit analyses. The answers in this paper are based on laboratory and field experiments that have been carried out since the massive increase in energy costs that took place in the 1970s. Although only a few of the mechanisms by which indoor environmental effects occur have been identified, it is already clear that any economies achieved by energy conservation will be greatly exceeded by the costs incurred due to decreased performance. Reducing emissions by allowing indoor environmental conditions to deteriorate would thus be so expensive that it would justify greatly increased investment in more efficient use of energy in buildings in which conditions are not allowed to deteriorate. Labour costs in buildings exceed energy costs by two orders of magnitude, and as even the thermal and air quality conditions that the majority of building occupants currently accept can be shown to reduce performance by 5–10% for adults and by 15–30% for children, we cannot afford to allow them to deteriorate still further.

# Influence of indoor climate: Performance




*(Source: Wargocki and Wyon (2017))*

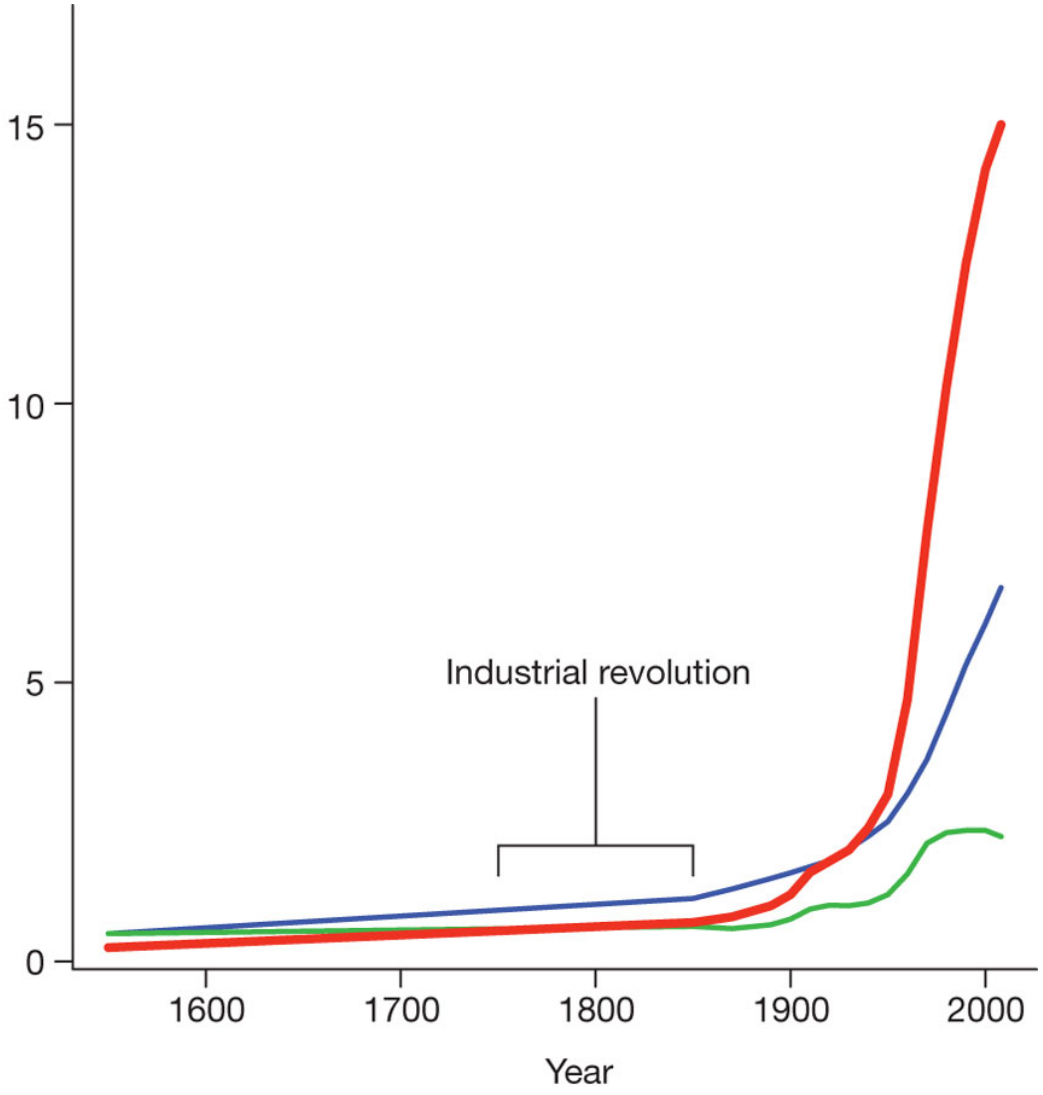
# Influence of indoor climate: Performance




- Satisfaction with temperature, noise level and air quality = satisfaction with IEQ
- For example, ~15% increase in satisfaction with temperature would increase self-estimated job performance by ~1%
- Question to think about – how important is 1%?

*(Source: Wargocki et al. 2012)*

# Energy use – how much indoor climate matters?



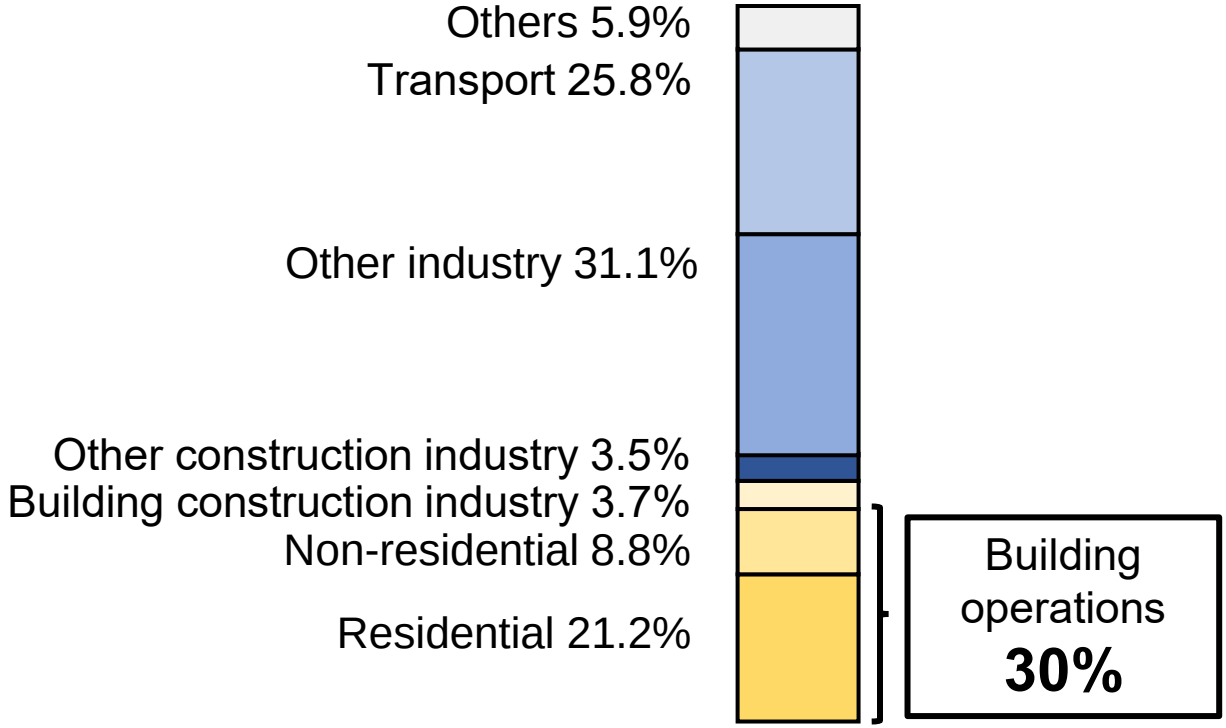

Total energy consumption (TW)

Population (billions)

Energy per capita (kW)

*(Source: Ehrlich et al. 2012, Nature)*

# Where should we focus our efforts?

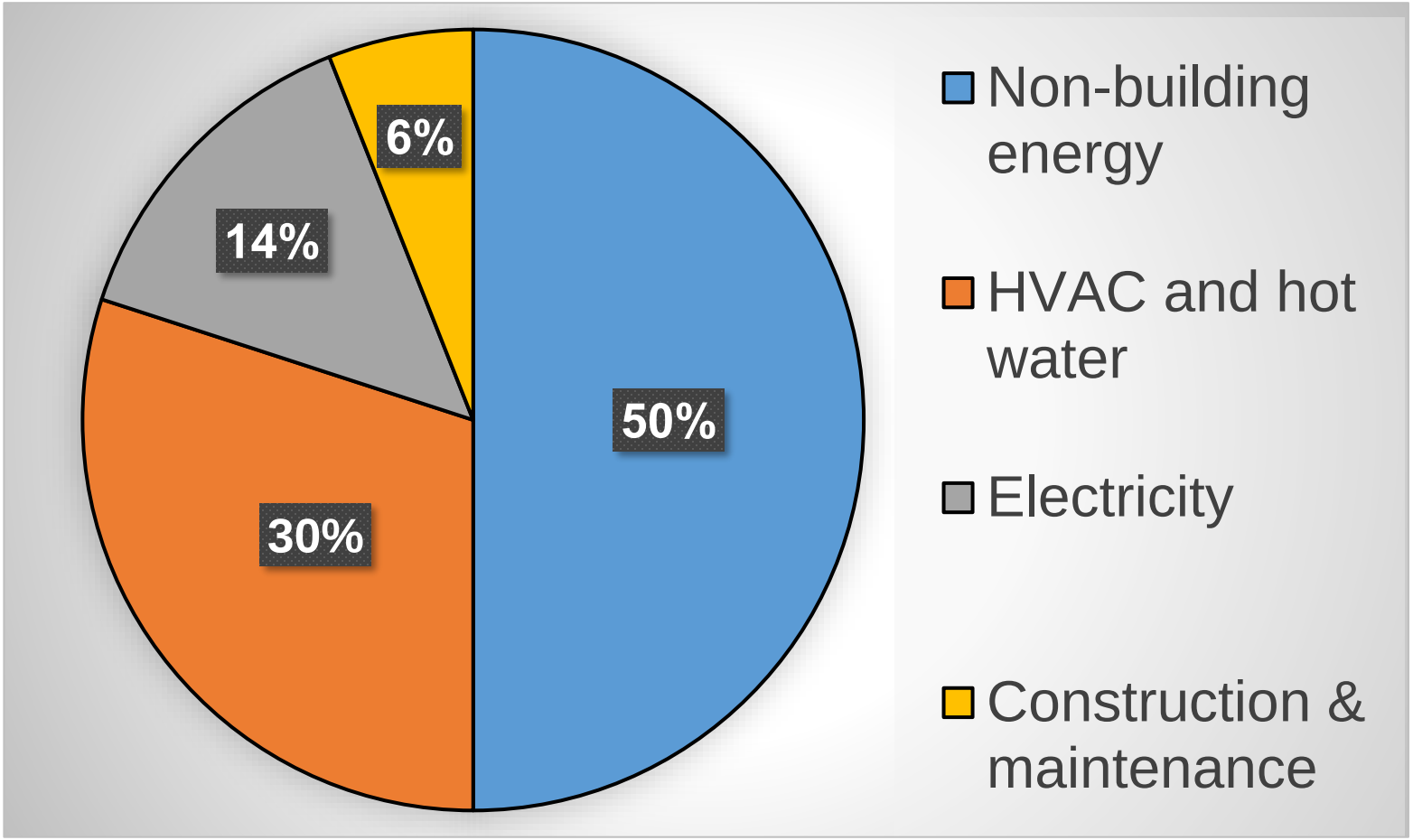




*Adapted from IEA 2021: Buildings, Sectorial Overview*

# Influence of indoor climate: Energy

Energy consumption in Switzerland




*(Source: Swiss Federal Office of Energy)*

# Where do we stand with energy in Switzerland?



- The energy policy of Switzerland aims at reducing the emissions of $CO_2$ by 20% by 2020 and by 70-85% on the horizon 2050 compared to emissions in 1990
  - Read about Energy Strategy 2050 here:

    https://www.bfe.admin.ch/bfe/en/home/policy/energy-strategy-2050.html#tab__content_bfe_en_home_politik_energiestrategie-2050_jcr_content_par_tabs
- The energy efficiency and the use of renewable energies are both strategic options that are being implemented in general especially for the housing stock

# How to save energy?

(Image source: Pyongyang at night: AP Photo/Damir Sagolj, Reuters)

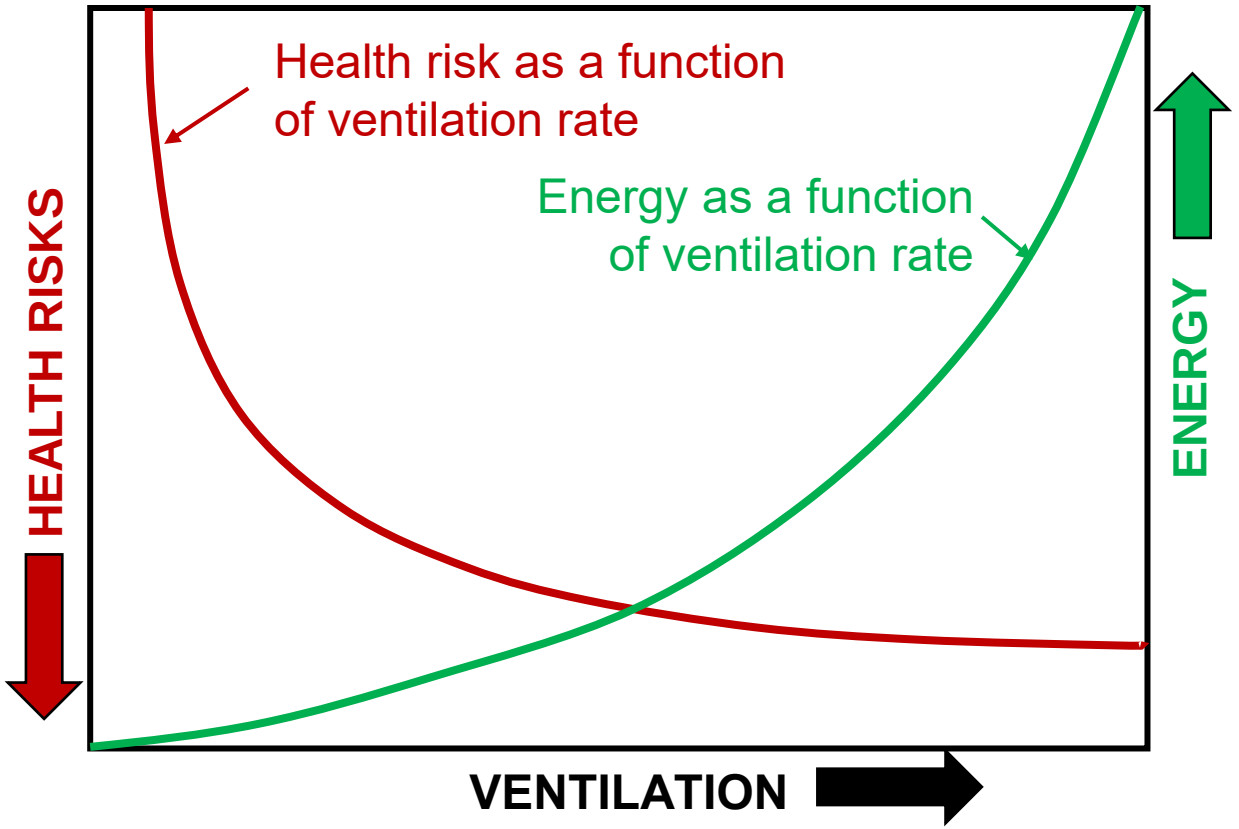
# Are indoor climate and energy in conflict?

**DECARBONIZATION**
**WITHOUT INDOOR CLIMATE**


**=**

**SICK BUILDINGS**

# Are indoor climate and energy in conflict?

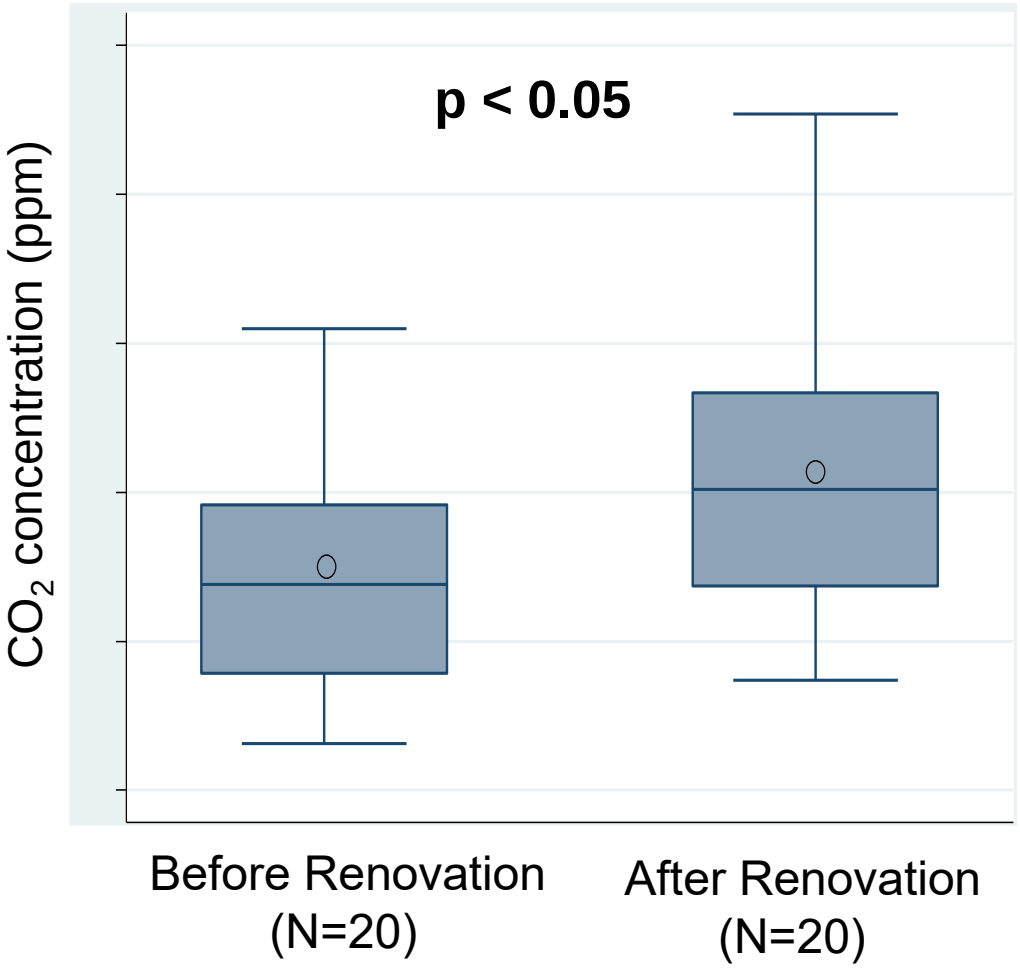



If you had to choose: is indoor climate more about Health or Energy ?

# Case Study – Energy renovation and IAQ

- Comparison of air quality before and after renovation
  - Residential buildings
  - 20 apartments
  - Natural ventilation
  - Winter season

Building envelope tightening reduces ventilation which, if not properly compensated by intentional ventilation can lead to deteriorated indoor air quality.




*(Source: Foldvary et al, Building and Environment 2017)*

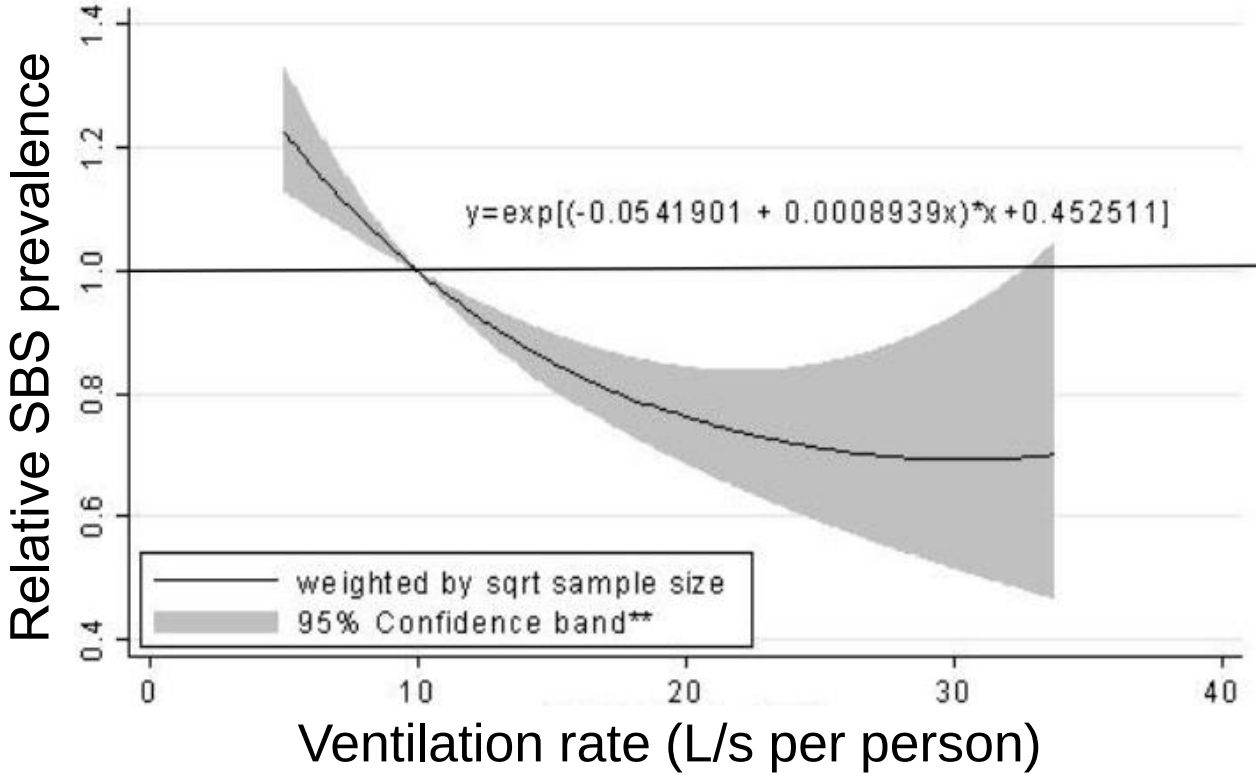
# Energy conservation could decrease IAQ

- Low ventilation rates cause an increased risk of allergies, SBS symptoms, and respiratory infections

*(Source: Sundell at al. 2011)*

- Low ventilation rates in dwellings increased the risk of allergic symptoms among children *(Source: Bornehag et al. 2005)*

*(Source: Fisk et al 2009 Indoor Air)*



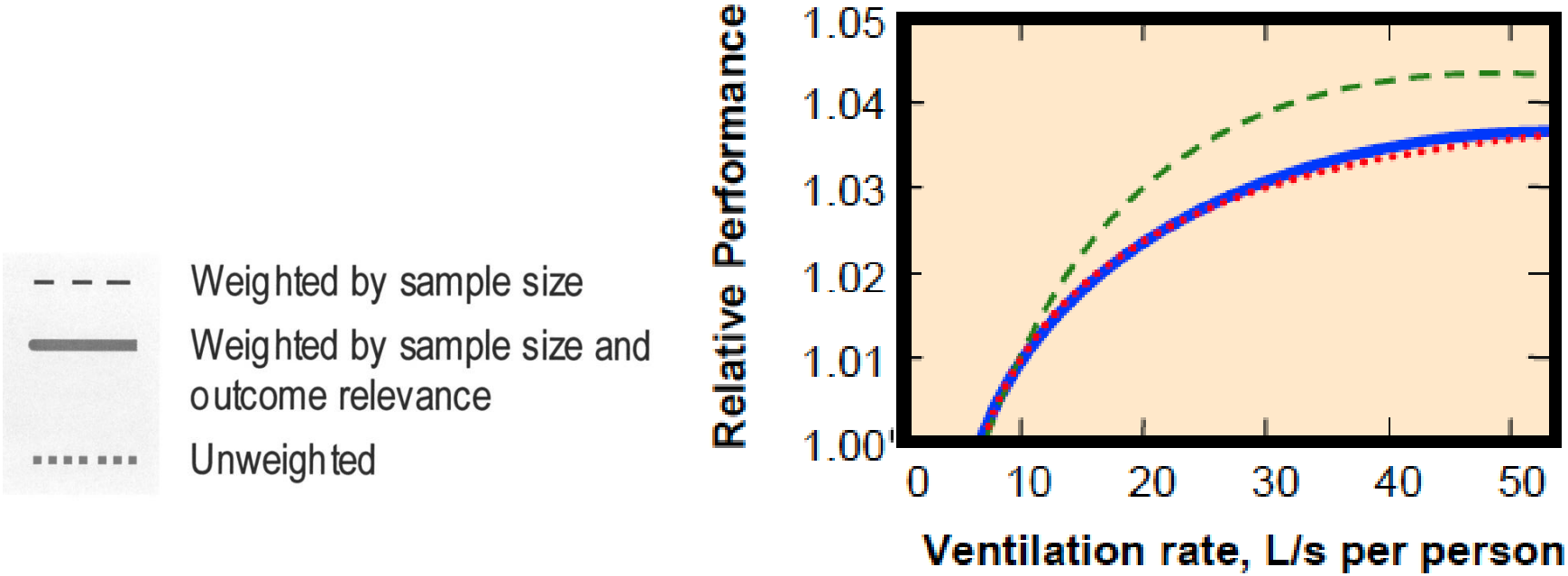
# Energy, IAQ and health

- Improved ventilation in a manufacturing facility led to reduced sick days

*(Source: Milton et al. (2000) Indoor Air)*

- Increased ventilation leads to slight increase (5%) in productivity

*(Source: Wargocki et al. (2000) Indoor Air)*



# How much $ we could save?

- Health and productivity gains from better indoor environments in the U.S.
  - $6-14 billion from reduced respiratory disease
  - $1-4 billion from reduced allergies and asthma
  - $10-30 billion from reduced sick building syndrome
  - $20-160 billion from direct improvements in worker performance

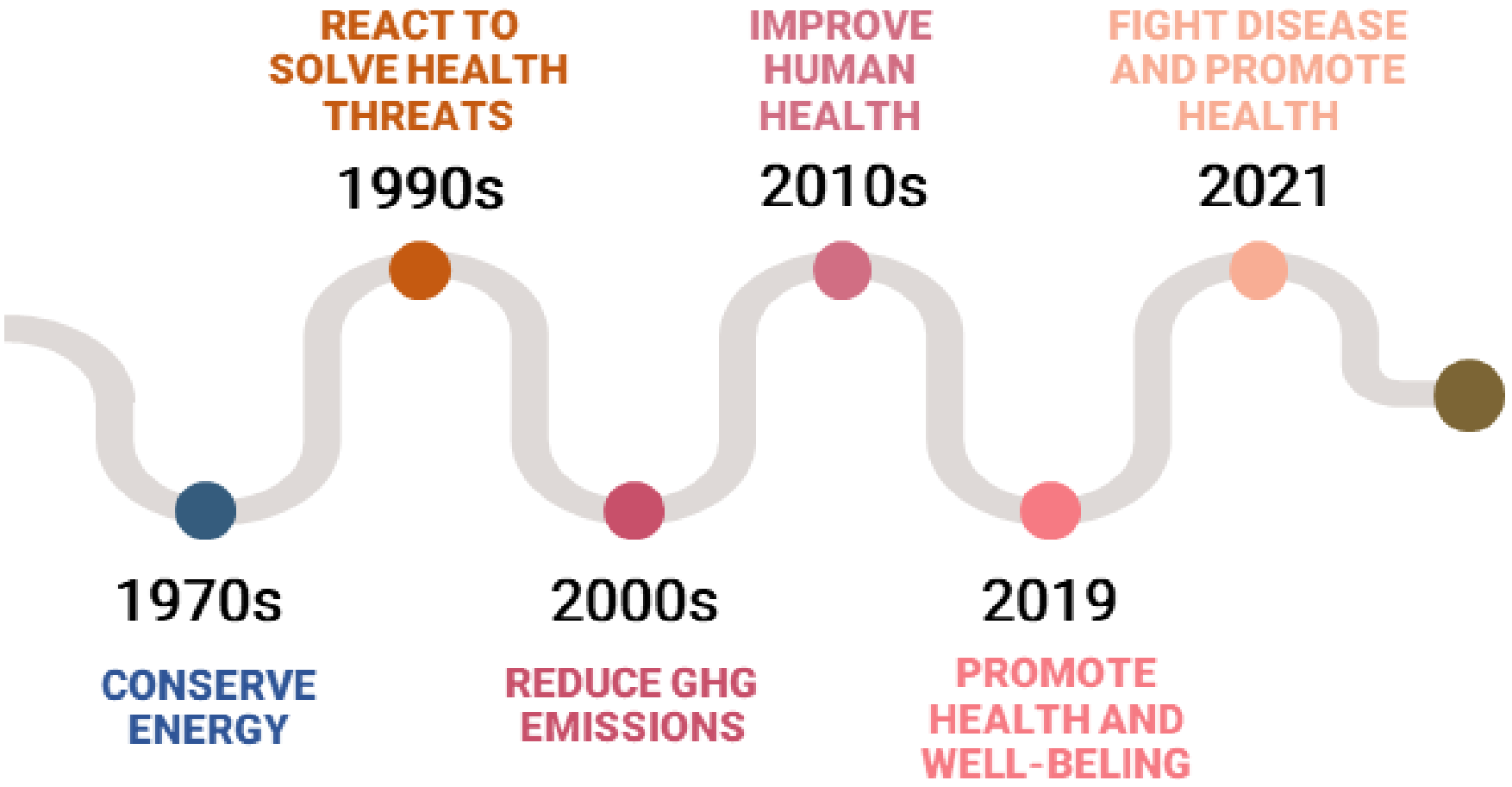
*(Source: Fisk, 2000'; Annual Reviews of Energy and Environment)*

- $37-208 billion annual savings possible

*(Source: Fisk, 2000; ASHRAE Journal)*

- Are building practitioner aware of this?
  - There is an increased awareness, but….
  - Recent COVID-19 pandemic is contributing to this paradigm shift

# Priorities in buildings have been changing…




*(Source: Licina et al 2021, Submitted)*

# Any questions?

# Additional thoughts and the big picture

- Indoor climate isn't really a standalone discipline
  - Involves engineers, architects, public health professionals, analytical chemists, building scientists, architects, contractors, medical professionals, epidemiologists, academics, biologists, psychologists, economists, etc.
  - Many different approaches

- The big picture is that:
  - We are interested in indoor climate because of its impact on:
    - Worker productivity/safety
    - Human comfort
    - Health effects
    - Material degradation
    - Biological growth/disinfection
    - Energy use

# In summary

Buildings are complex systems and are trending toward greater complexity. This is not necessarily a good thing.

Buildings (indoor climate) exert profound influence on their occupants, and vice versa

We have an ample opportunity to reduce energy use and its associated external costs. The challenge is to improve the quality of the indoor climate at the same time.

General notion is that building energy use and good indoor climate are always in conflict. However, if a building is well designed and operation, this will not be the case.

# Bravo for surviving the first class!

Next time:

- Brush up of:
  - Heat, Air, Moisture
  - Psychometrics: Definitions and charts (+exercise)
  - Heat transfer in buildings

*"We should design indoor environments that are better than the best environment found in nature"* — *Ole Fanger*