



Maastricht University

# THE ECONOMICS OF HEALTH IN BUILDINGS

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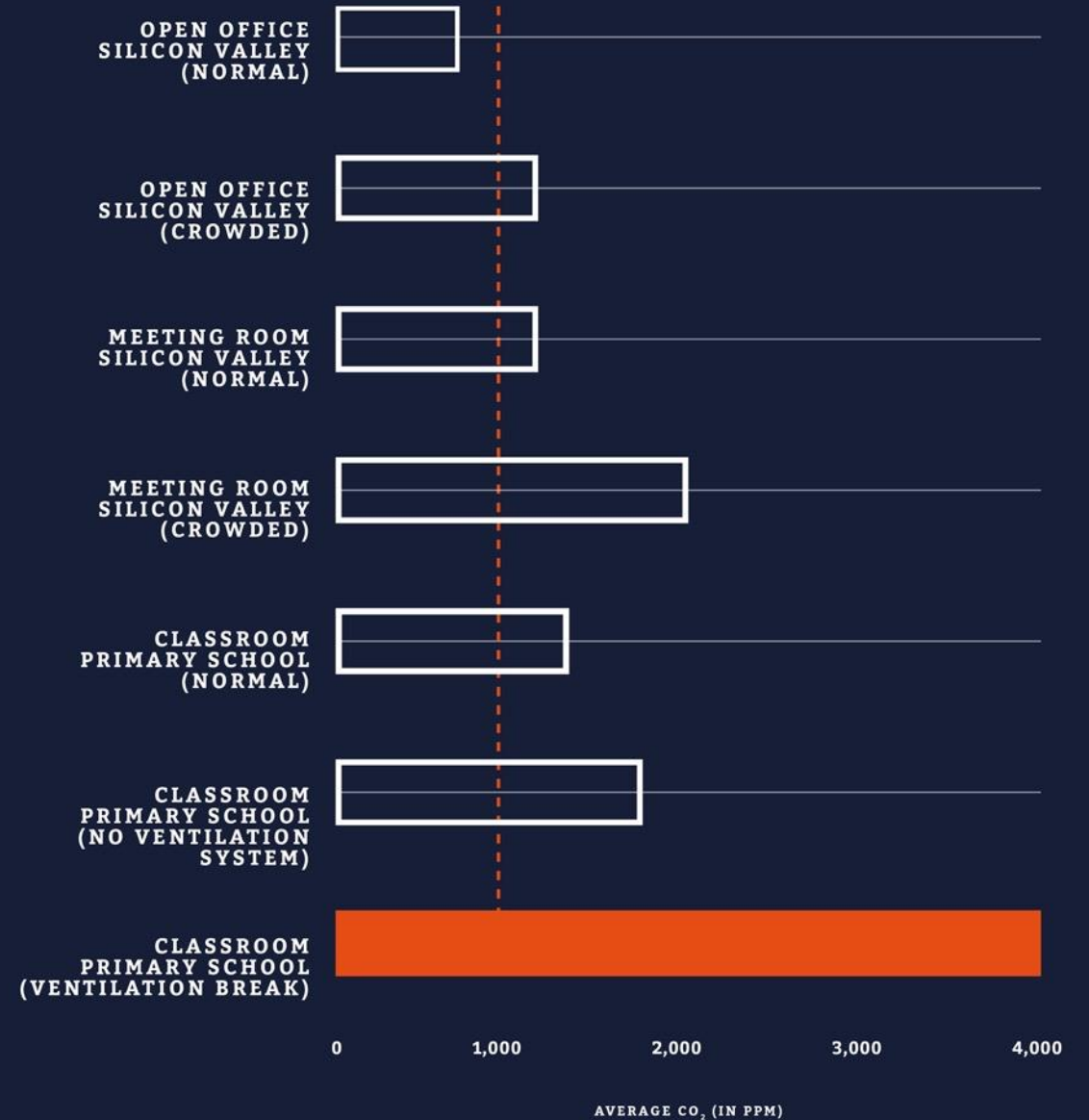
**[maastrichtrealestate.com](http://maastrichtrealestate.com)**

**90%  
OF TIME  
INDOORS**

**(98% for elderly)**



**BUT INDOOR  
CO<sub>2</sub> LEVELS  
ARE TYPICALLY  
(MUCH)  
TOO HIGH**



**WHAT IS THE IMPACT OF INDOOR ENVIRONMENTAL QUALITY ON**

**HUMAN HEALTH  
&  
COGNITIVE PERFORMANCE?**



**Homes**



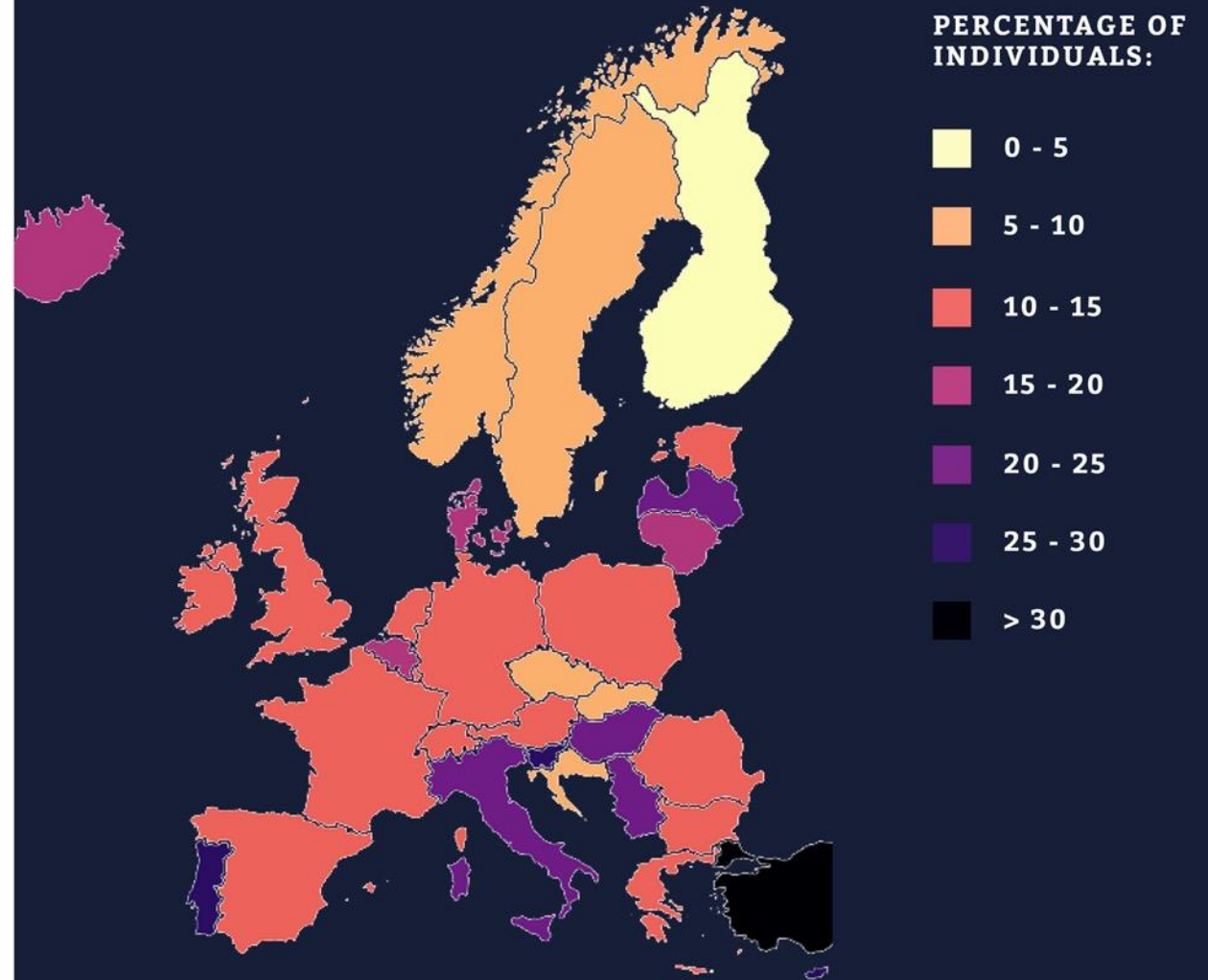
**Offices**



**Schools**

# DWELLING PROBLEMS ARE NOT OVER IN EUROPE

Percentage individuals living in a deficient dwelling (leaking roof, damp walls, or rot in windows/doors)



# OUR (GERMAN) APPROACH

**Health-housing estimates  
based on long-term  
household panel**

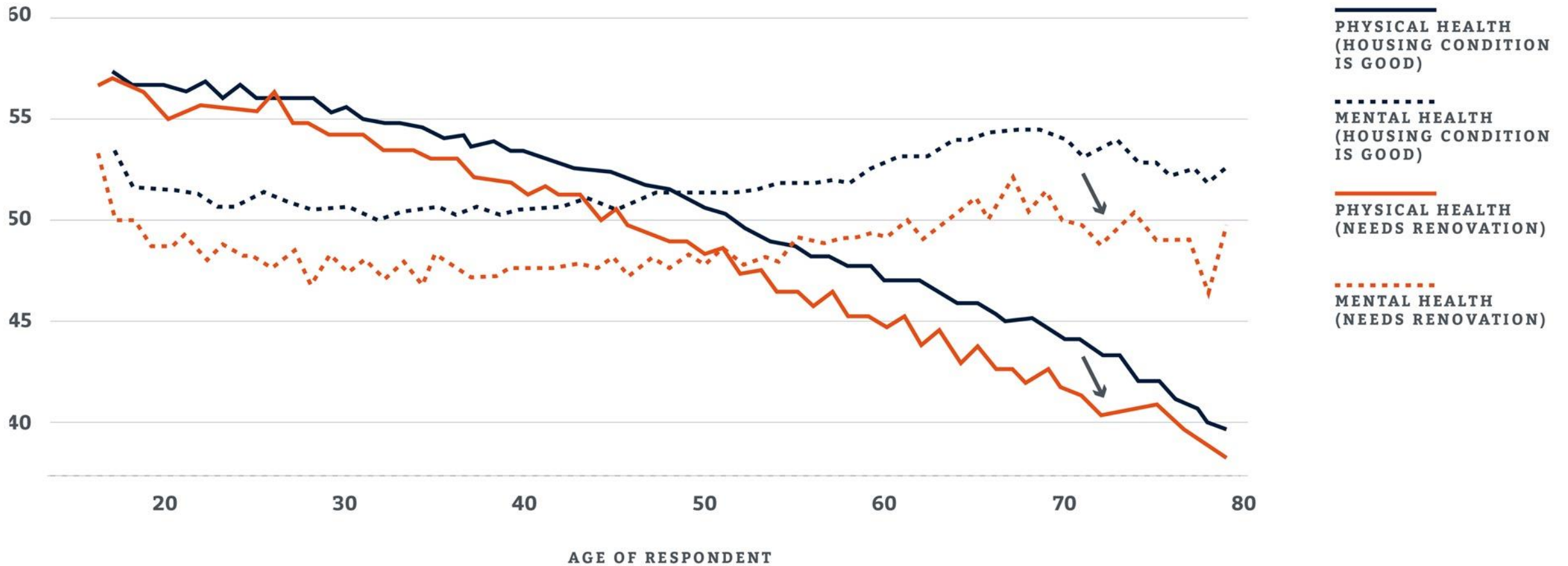


**What is the impact of housing conditions on occupants' health?**

- German household survey, representative of population
- Survey waves 1992-2014 in (West) Germany
  - 360,912 observations
  - 57,581 individuals followed up to 20 years
- Every year, individuals are asked to evaluate:
  - Health (mental and physical)
  - Demand for health care (general practitioner and hospital)
  - Conditions of their home

# THE HEALTH BURDEN OF HOUSING

ADJUSTED SELF-REPORTED HEALTH MEASURES AFFECTED BY HOUSING QUALITY



# MOVING TO PRODUCTIVITY

What is the impact  
of moving to a new  
“healthy” office building?



- CONSTRUCTED  
IN THE 1980S
- NO VENTILATION  
SYSTEM



- VENTILATION  
BASED ON THE  
PRINCIPLES  
OF NATURAL  
CIRCULATION
- GREEN WALL



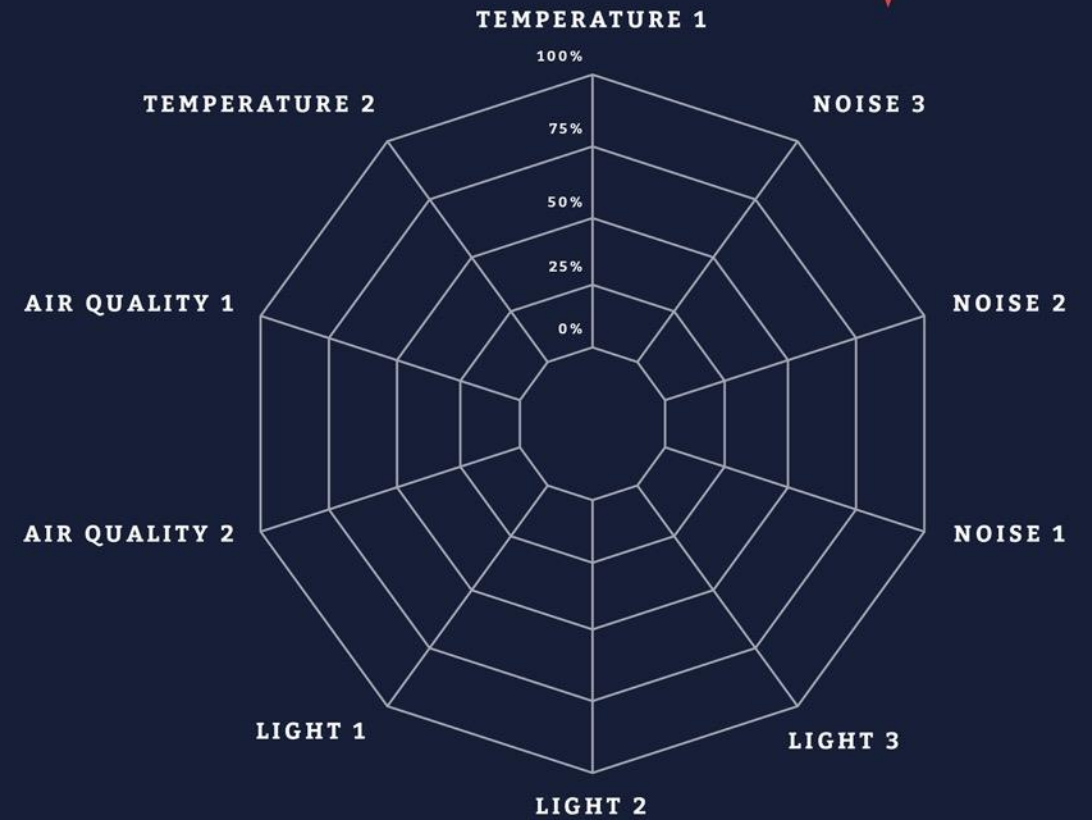
# THE MOVING EXPERIMENT

## MEASUREMENT DESIGN



# IMPACT ON PERCEIVED WORKING CONDITIONS

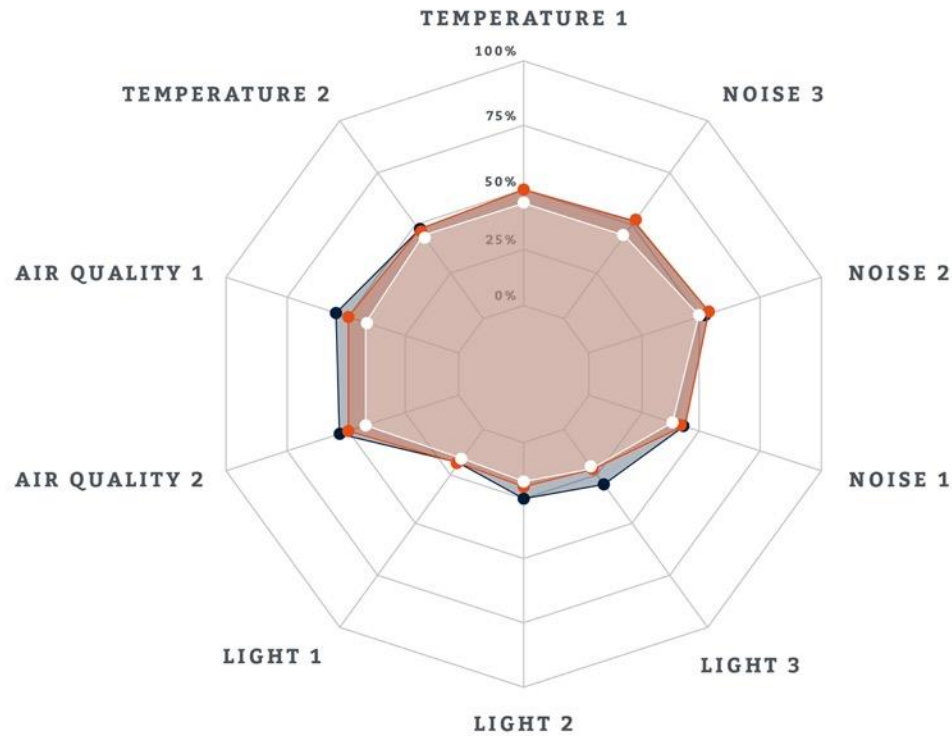
Percentage of employees  
reporting problems on IEQ  
dimension



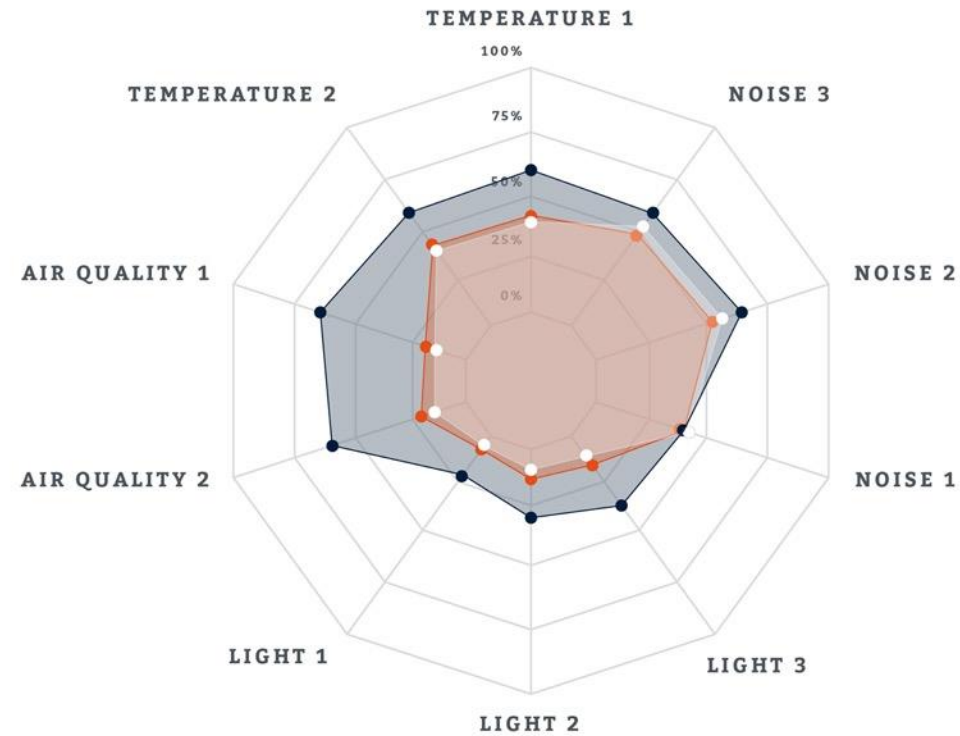
# IMPACT ON PERCEIVED WORKING CONDITIONS

PERCENTAGE OF EMPLOYEES  
REPORTING PROBLEMS  
WITH IEQ DIMENSIONS

STAYED IN OLD BUILDING

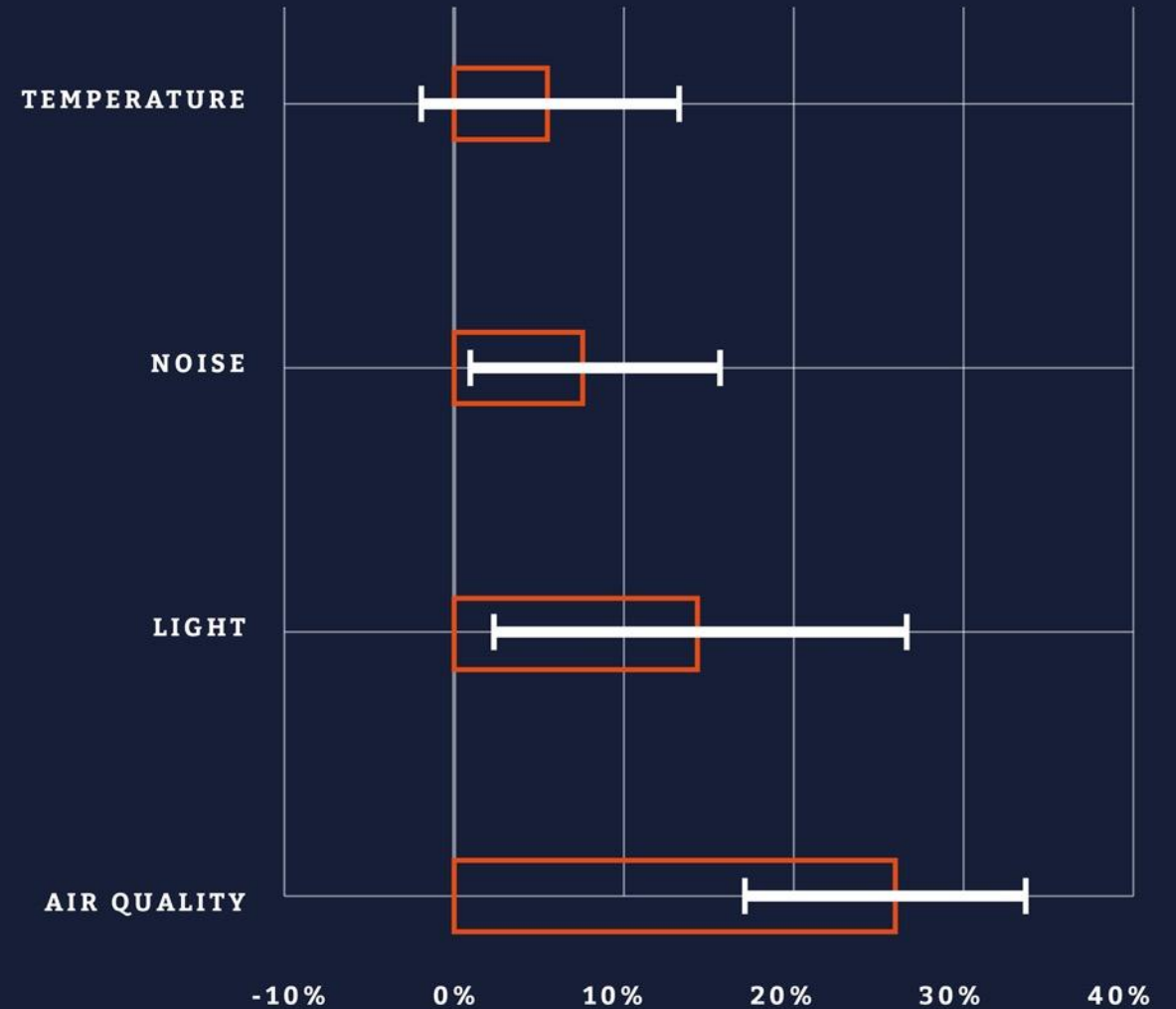


MOVED TO NEW BUILDING



# IMPACT ON WORKER HEALTH

Decrease in sick building symptoms mostly due to air quality improvement



DROP IN PROPORTION REPORTING SICK BUILDING SYNDROME ASSOCIATED WITH IEQ CATEGORY. ESTIMATES BASED ON FIXED EFFECTS REGRESSION

# HEALTHY CLASSROOMS AND PUPIL PERFORMANCE



# WHERE IEQ MATTERS MOST

Primary school years  
are critical for  
cognitive development

1.9BN

children (0-14)  
globally

8H/DAY

average time  
spent at school

72.2  
MILLION

pupils and students  
enrolled in the EU

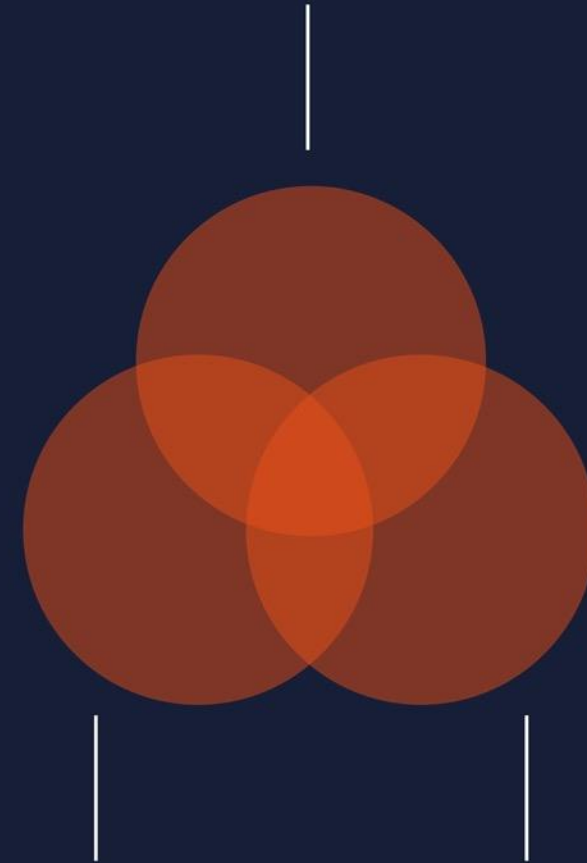
D+

24% of US public  
school buildings  
are rated as being in  
poor condition

# PRIMARY SCHOOLS OFFER AN IDEAL SETUP FOR ACADEMIC RESEARCH

From lab setting  
to field study

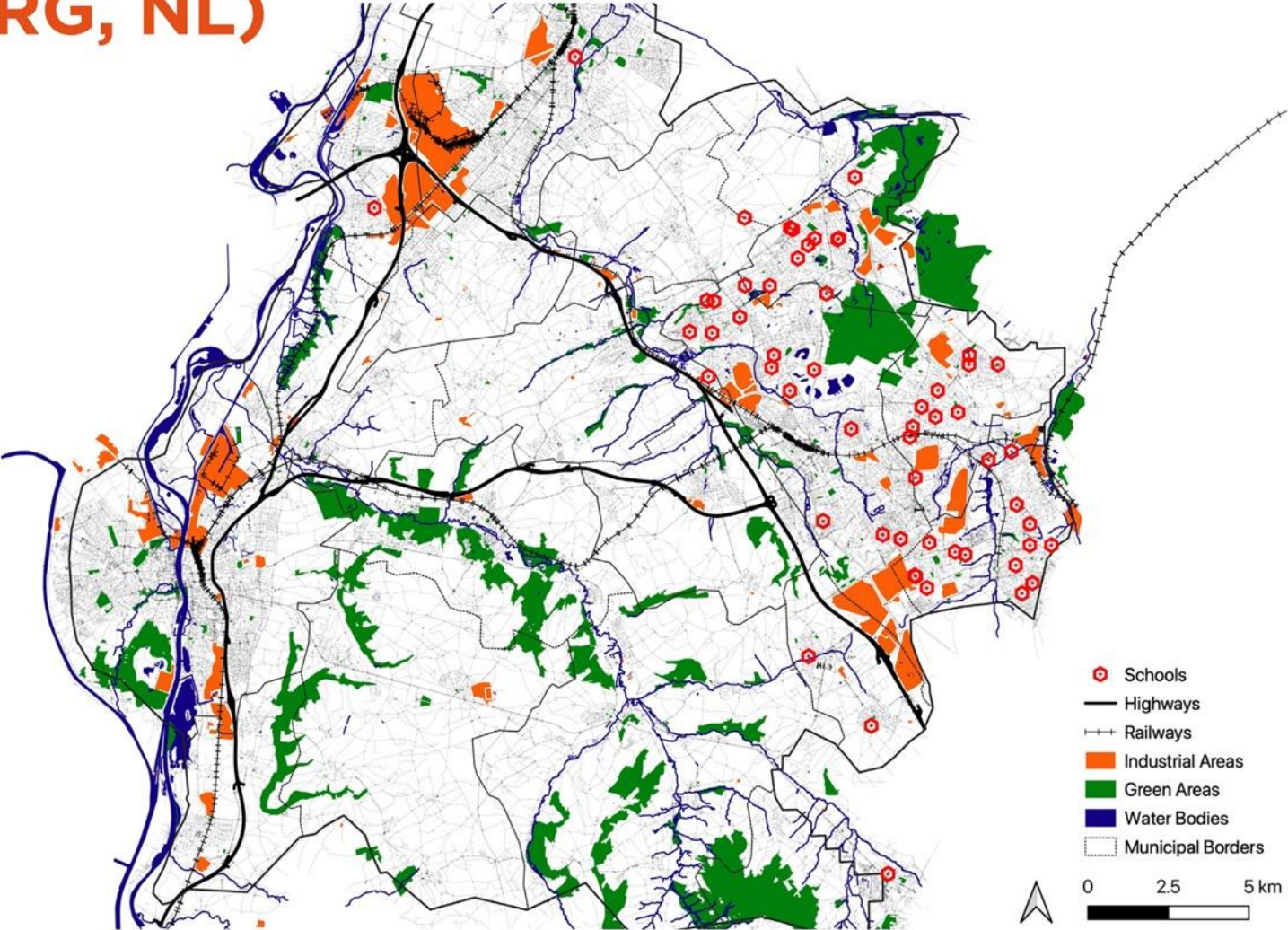
Measurable and standardized outcomes



Individuals randomly  
assigned to rooms

High exposure to  
traceable environ-  
ments (8 h/day)

# OOSTELIJKE MIJNSTREEK (LIMBURG, NL)





# SENSOR NETWORKS

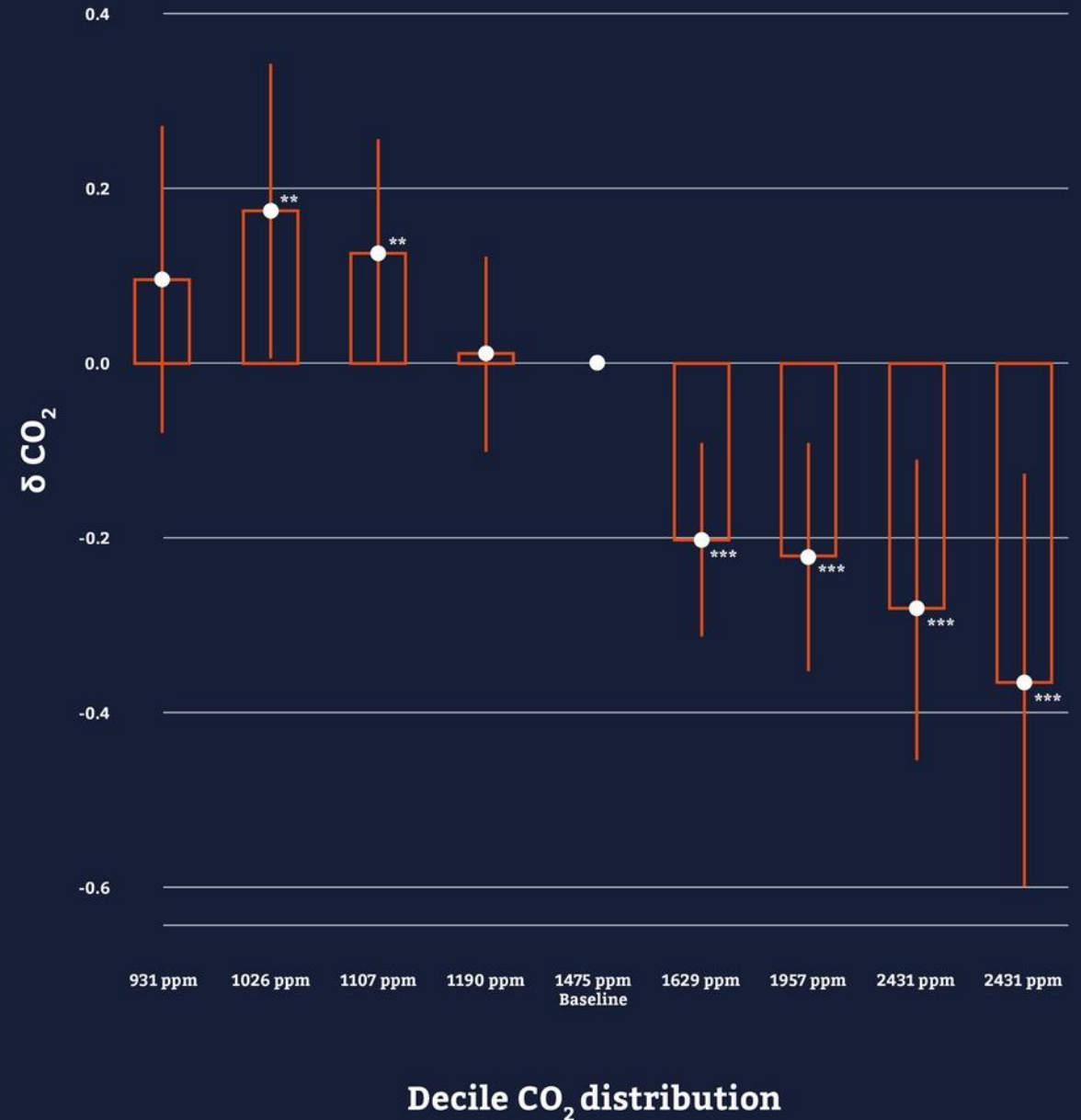
High frequency monitoring system in 280 classrooms for 5 years

Temperature  
Humidity (rH)  
Carbon dioxide (CO<sub>2</sub>)  
Fine particles (PM1+)  
Sound (dBA)  
Light (lux)

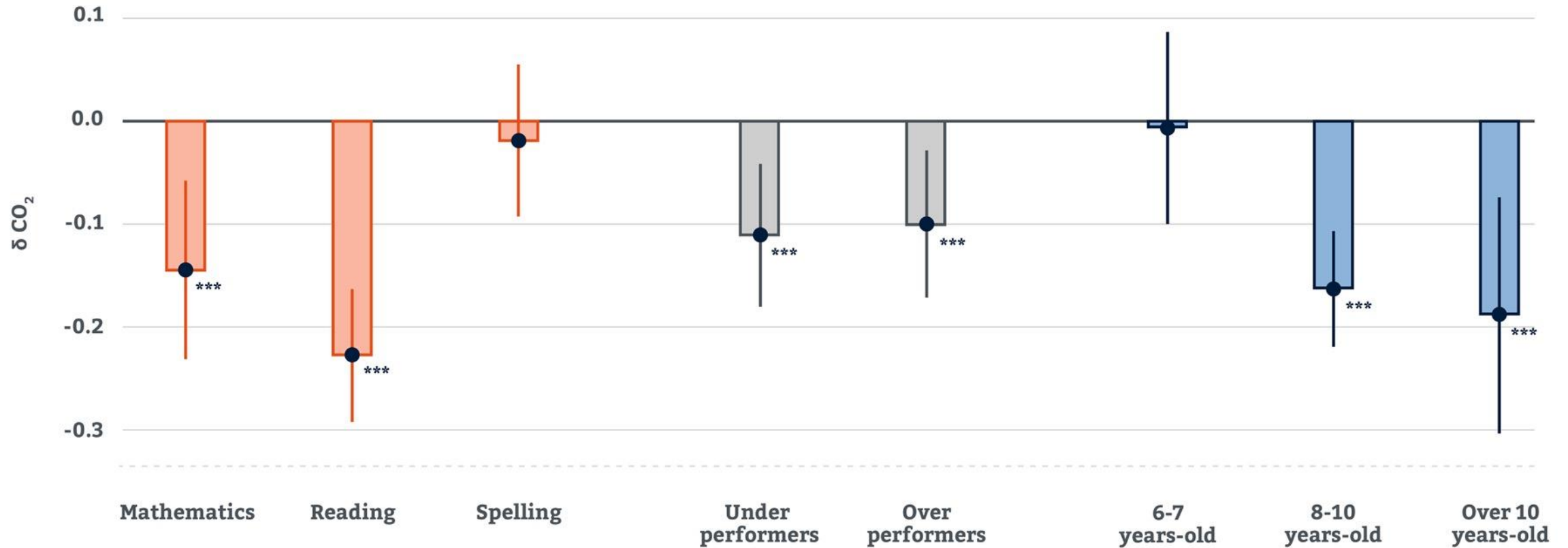


# SIGNIFICANT IMPACT OF AIR QUALITY ON PERFORMANCE

Higher CO<sub>2</sub> concentrations  
associated with lower  
learning outcomes -  
600ppm increase in CO<sub>2</sub>  
leads to 15% lower  
test scores.



# ...ESPECIALLY FOR MATH AND READING



## CONCLUSION:

# BUILDINGS AFFECT HUMAN HEALTH AND PERFORMANCE

**Lessons from research**

### What we know

Buildings and health are related:

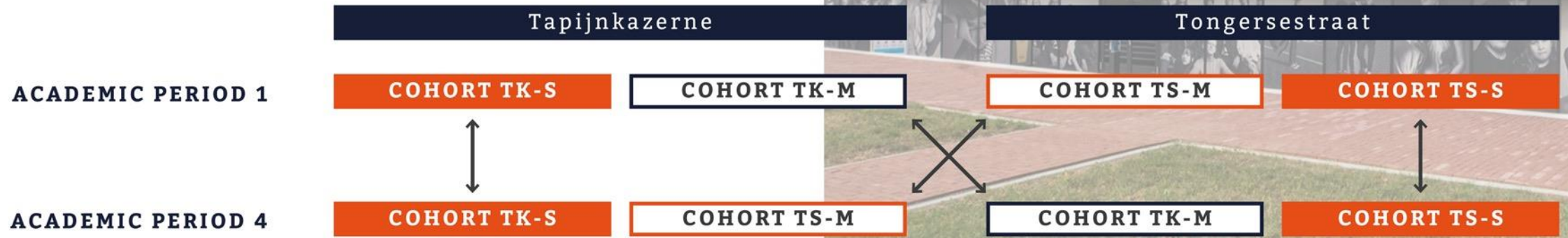
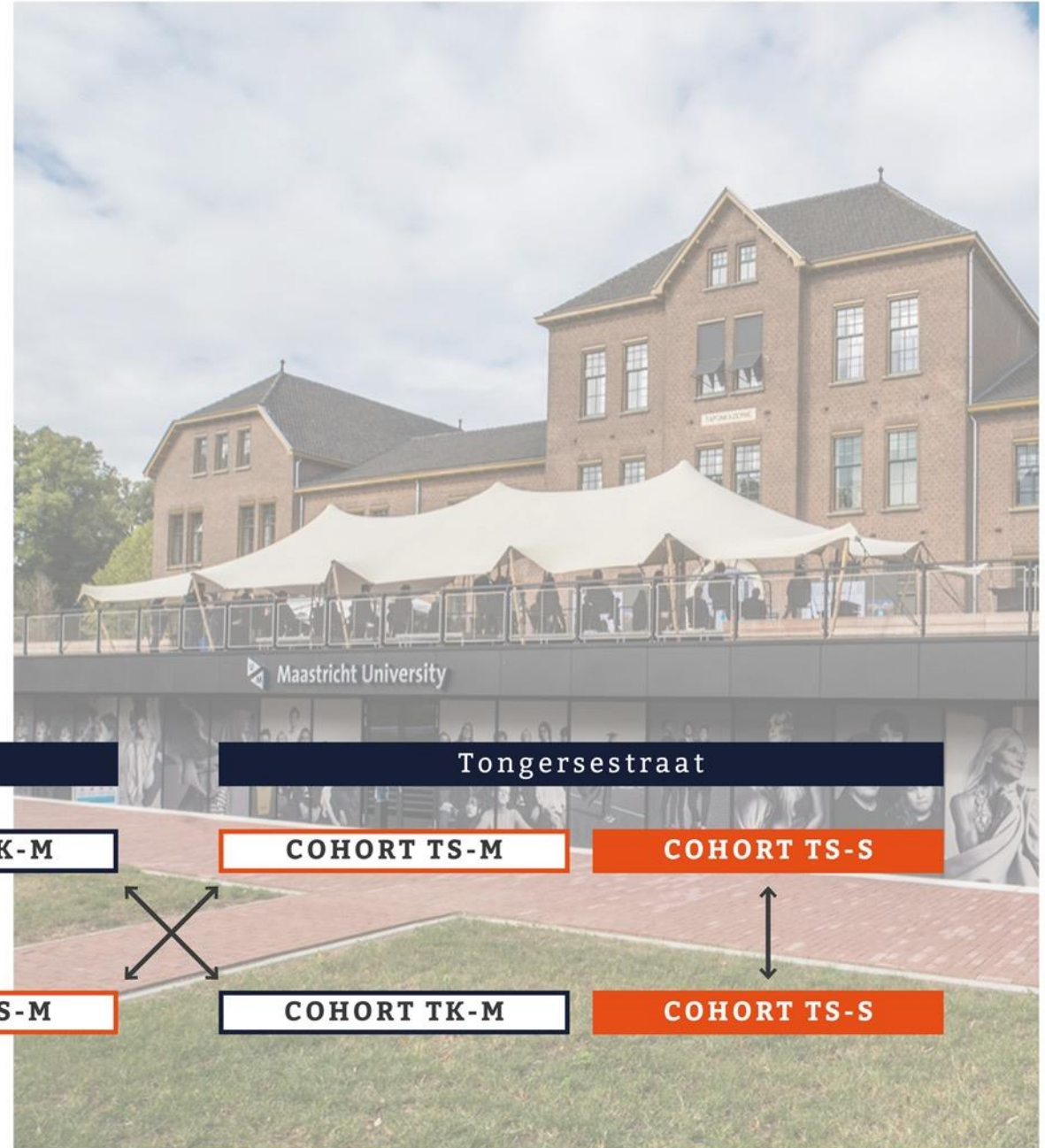
- Schools
- Homes
- Offices

### What we don't know

Effects on:

- University students
- Specific health KPIs
- Financial performance of healthy buildings

# THE IMPACT OF HEALTHY BUILDING ON COURSE GRADES AND WELL-BEING OF UNIVERSITY STUDENTS



# THE IMPACT OF CO<sub>2</sub> ON HEALTH AND COGNITION IN A CONTROLLED SETTING





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