

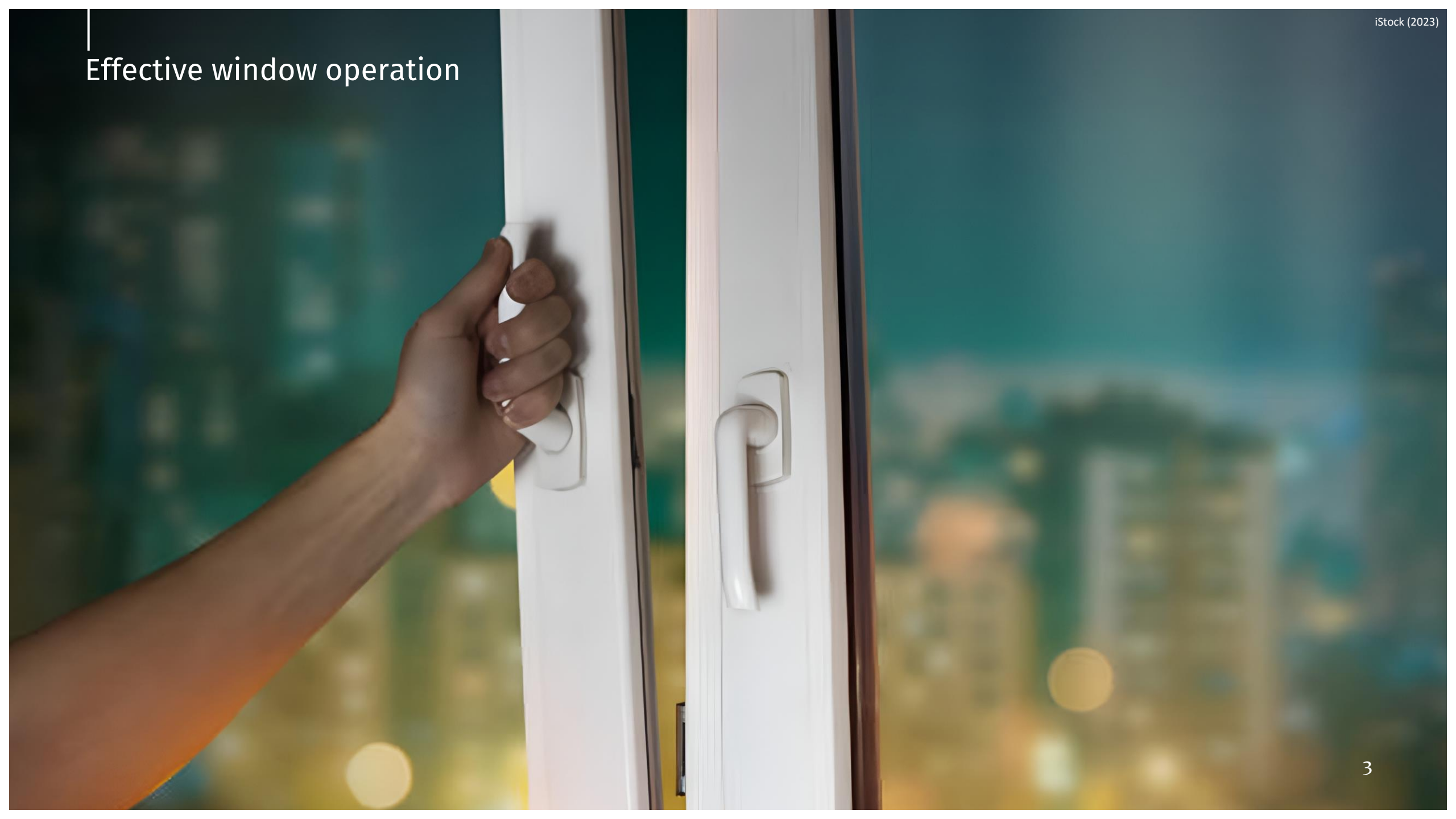
**Kennisdag 'De bouwsector in transitie: digitale  
revolutie of terug naar de natuur?'**



# EFFECTIVITEIT VAN RAAMFEEDBACKSYSTEMEN IN KANTOORTUINEN

**DOOR SPREKER: SERHAN YUKSEL**  
**ADVISEUR BRANDVEILIGHEID, BOUWFYSICA EN DUURZAAMHEID BIJ ARUP**

# Effective window operation



Indoor air quality



# Indoor air quality



# Outdoor air quality

New York, USA



# Outdoor air quality



# Outdoor air quality





Thermal comfort



# Energy efficiency



# HVAC Installations



Window feedback



## Introduction

### Problem Statement



#### Manual window control

- **Risk of inefficient energy use**
- **Occupants can satisfy their comfort**



#### Automated window control

- **Energy efficient window operation**
- **At the expense of occupants' comfort, satisfaction and productivity**

## Introduction

### Problem Statement

#### Window Feedback System



- Occupants can satisfy their comfort



- Occupants are informed about window operation impact

To what extent can **window feedback systems** improve the **indoor environment** and **occupant satisfaction** in open-plan workplaces?

# Literature Research

## Window opening behaviour

Drivers of human window opening behaviour:

External		Internal		
Physical	Contextual	Psychological	Physiological	Social
Outdoor temperature Indoor temperature Air velocity Relative humidity Solar radiation CO2 concentration PM2.5 concentration Noise	Occupancy Window Design Distance to façade Façade orientation Thermal mass Installations (HVAC) Interior doors Rainfall	Expectations Concerns Habits Lifestyle/schedule Knowledge/education Stress level	Age Gender Health Clothing Activity level Food and beverages	Social norms Interrelationships

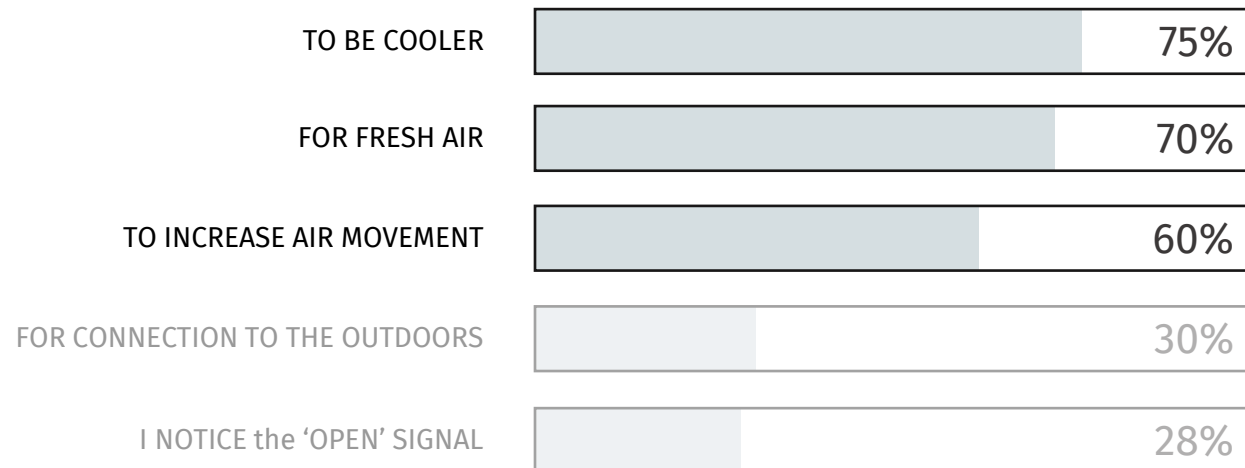
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Reasons for window opening (Ackerly & Brager, 2013):



Reasons for window closing:

- HEAT LOSS
- RAIN
- WIND



# Literature Research

## Parameters for measurements and evaluation

### Thermal comfort

#### Heat balance approach

- Indoor air temperature
- Indoor mean radiant temperature
- Indoor air velocity
- Air humidity
- Metabolism
- Clothing

#### Adaptive approach

- Monthly mean outdoor air temperature
- Operative temperature

### Indoor Air Quality

- Carbon dioxide (CO<sub>2</sub>)
- Particulate matter (PM<sub>10</sub> & PM<sub>2.5</sub>)
- Volatile Organic Compounds (VOC)
- Formaldehyde (HCHO)
- Radon (Rn)
- Ozone (O<sub>3</sub>)
- Carbon monoxide (CO)

### Energy efficiency

- Indoor temperature
  - Outdoor temperature
  - Window opening time
  - Air flow rate
    - Air velocity
    - Openable window area
- OR
- CO<sub>2</sub> concentration
  - Number of occupants

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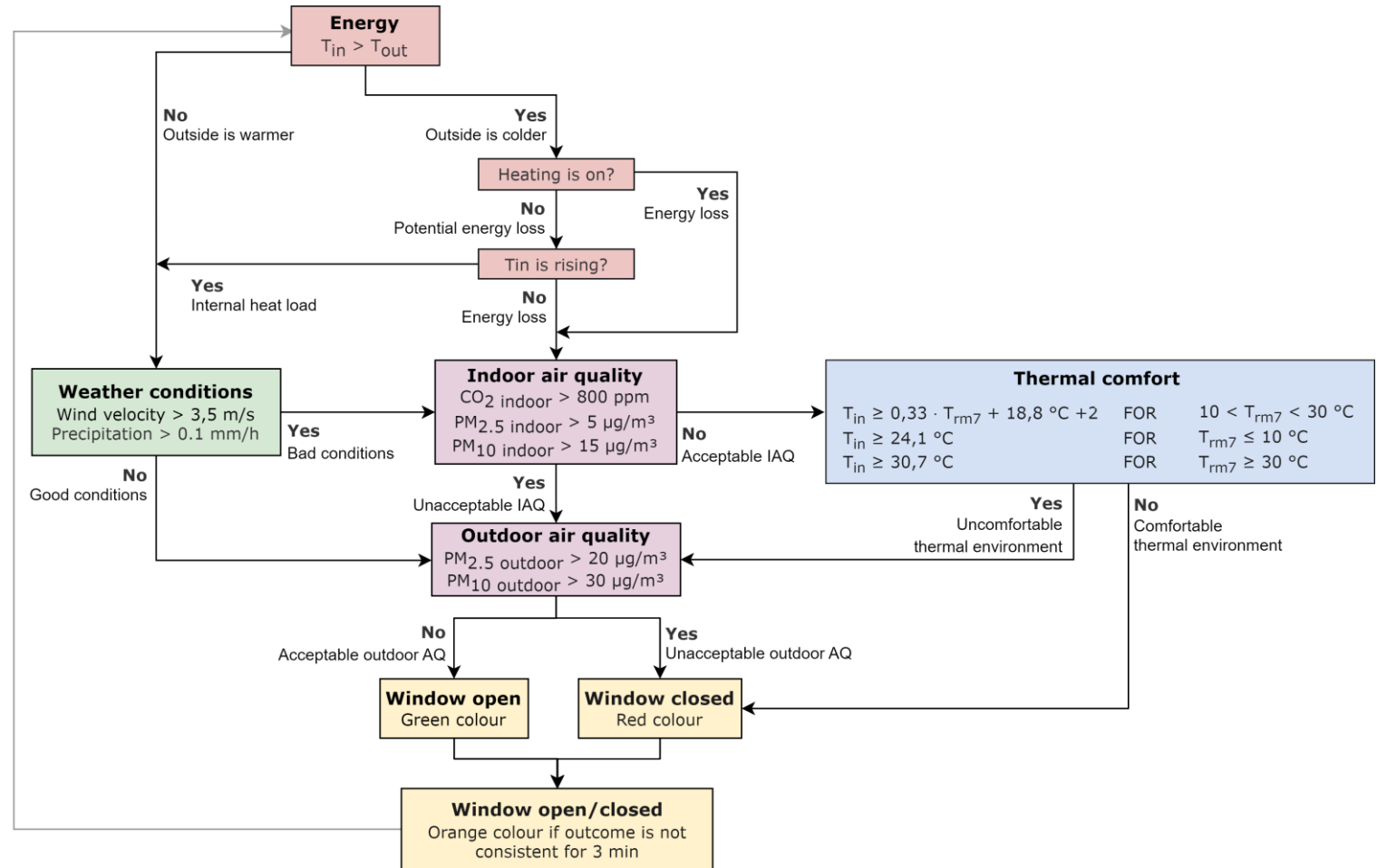
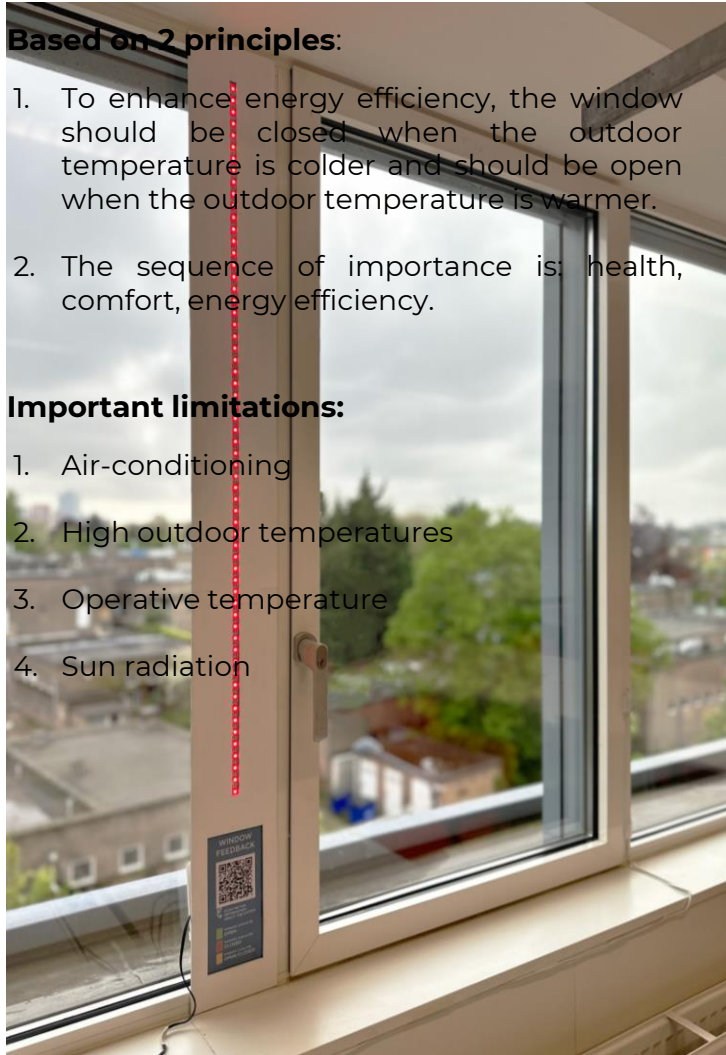
# Design Algorithm

## Based on 2 principles:

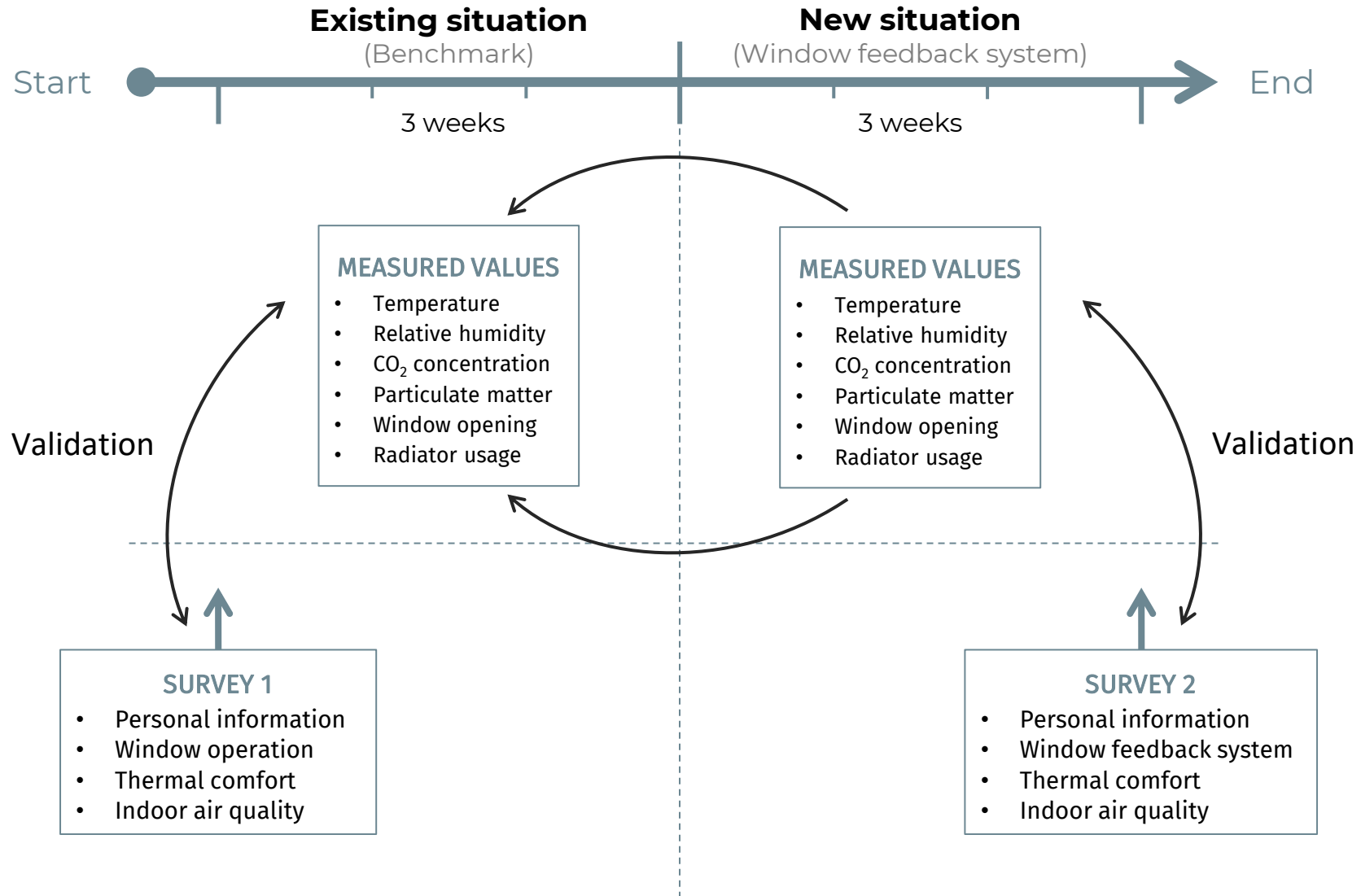
- To enhance energy efficiency, the window should be closed when the outdoor temperature is colder and should be open when the outdoor temperature is warmer.
- The sequence of importance is: health, comfort, energy efficiency.

## Important limitations:

- Air-conditioning
- High outdoor temperatures
- Operative temperature
- Sun radiation

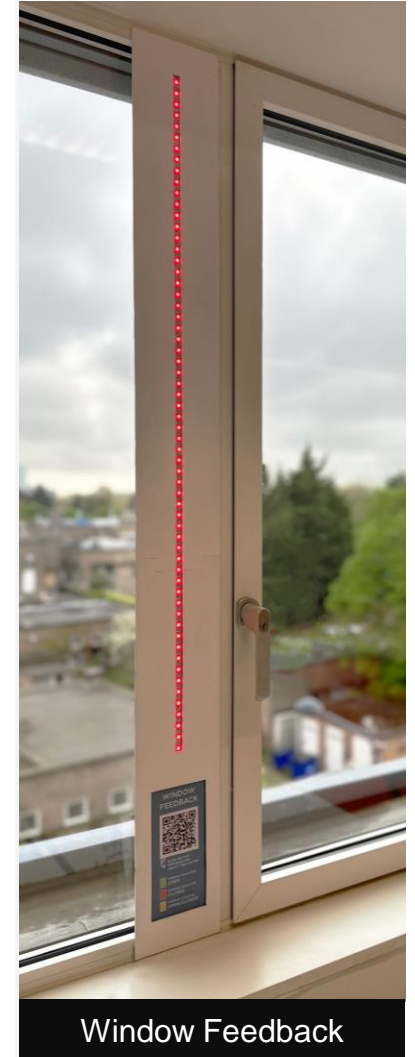
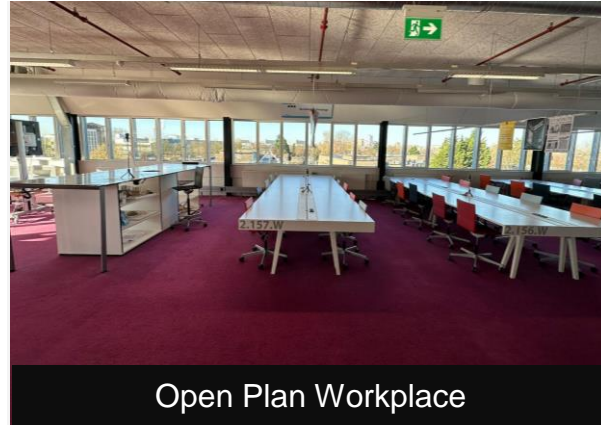
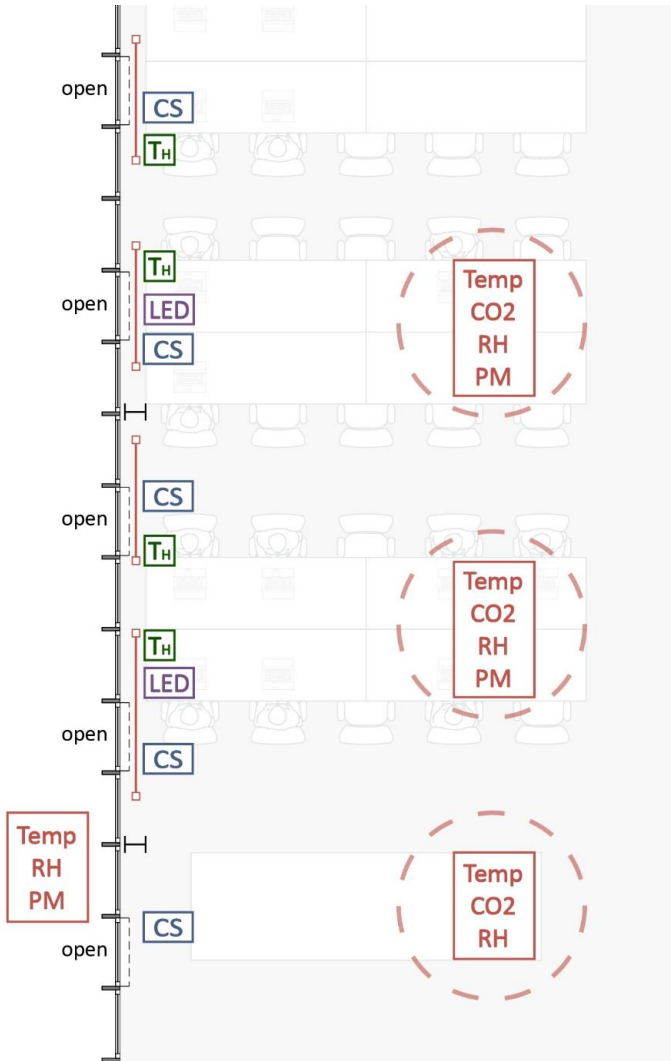


Experiment  
 Methodology

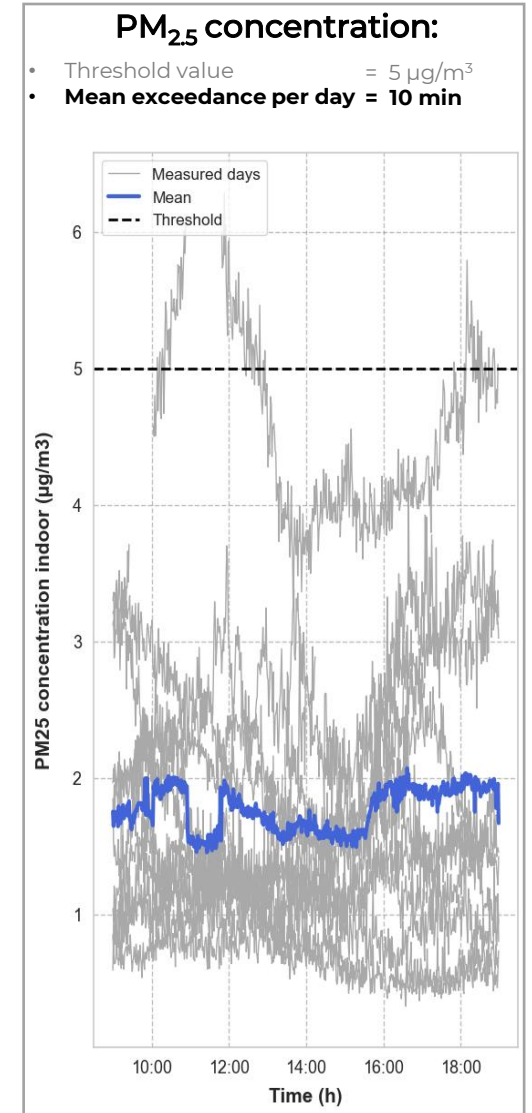
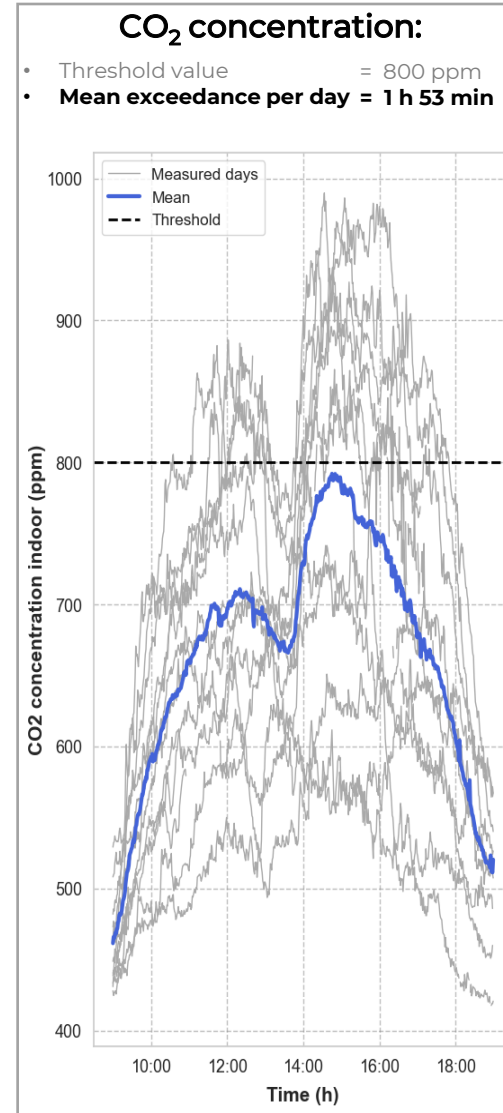
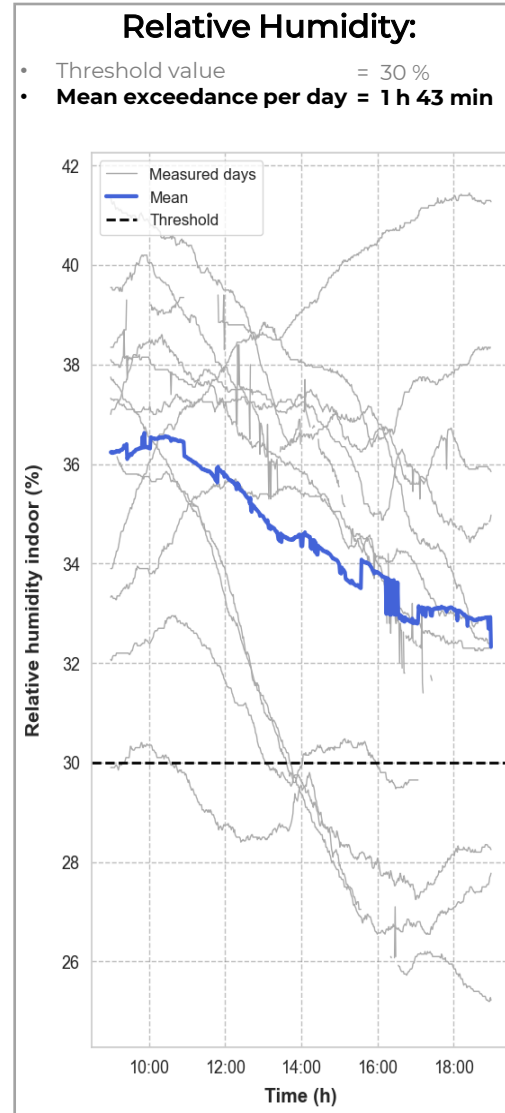
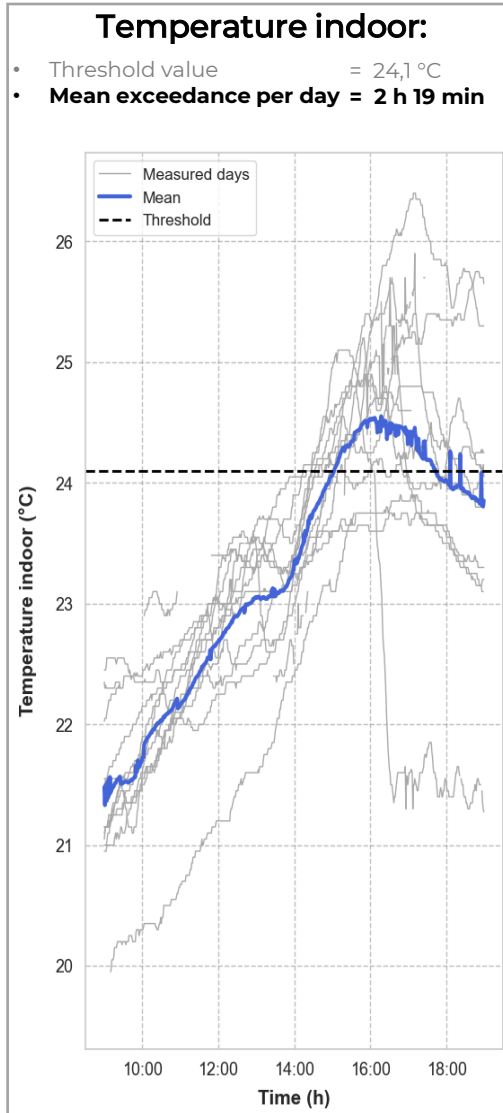


# Experiment

## Measurement set-up



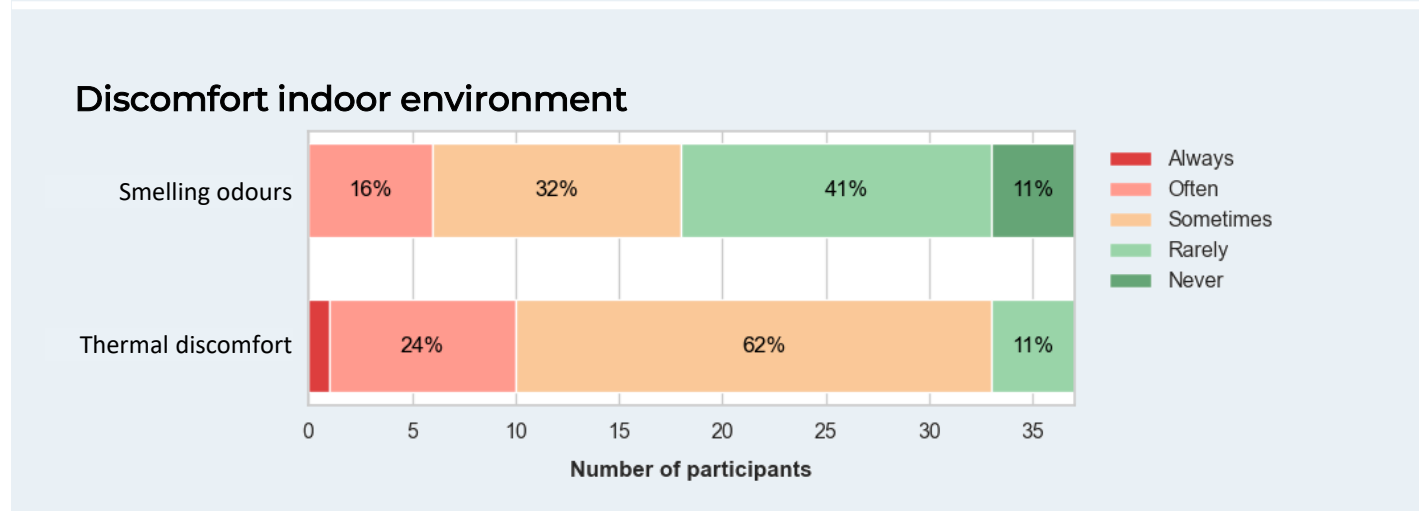
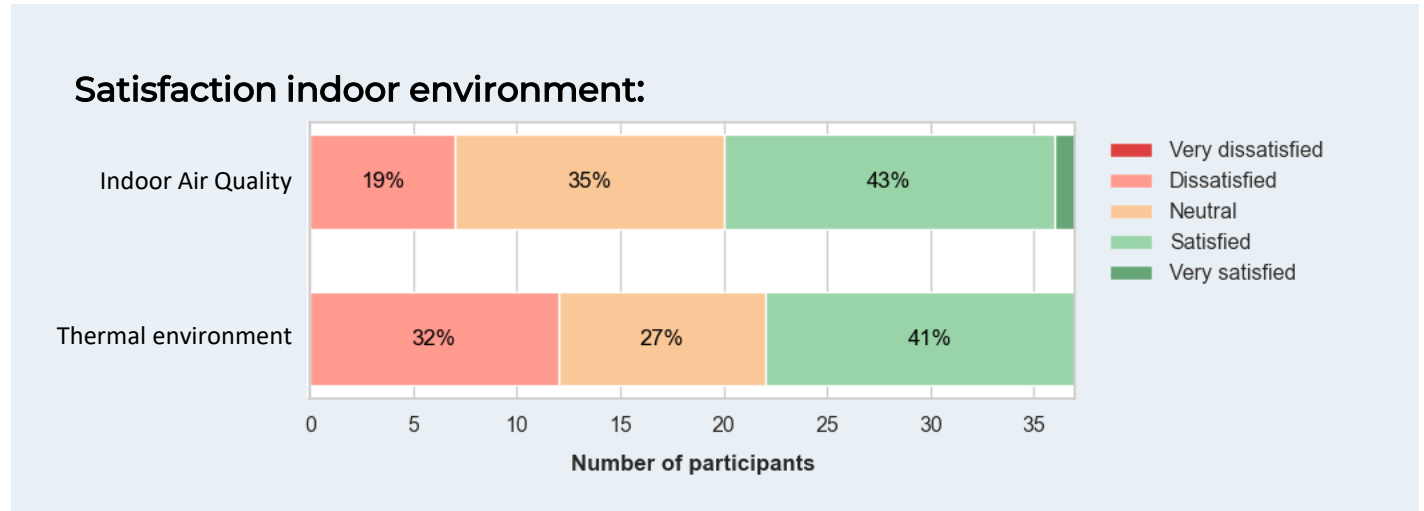
## Results & Discussion: Existing situation





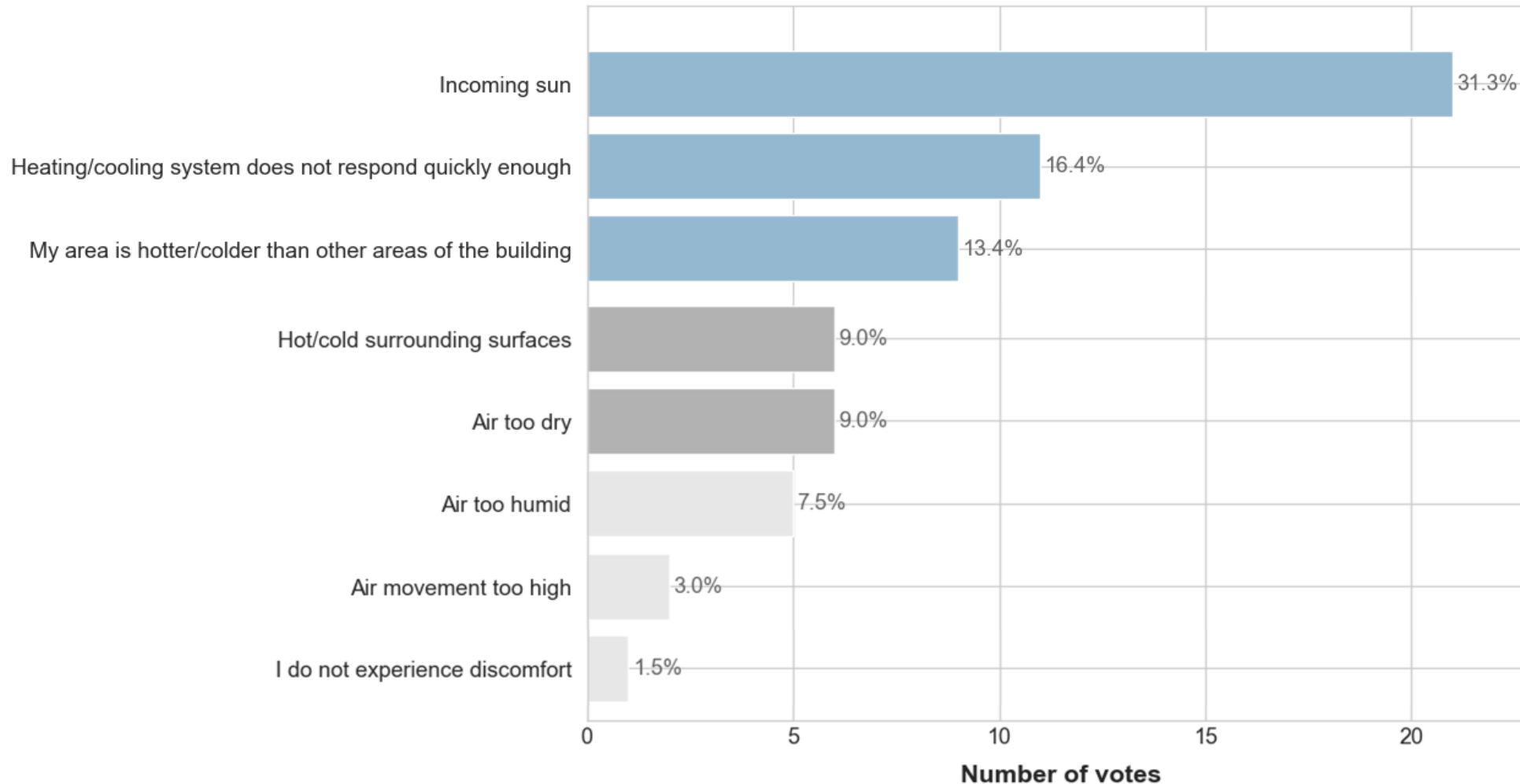
## Results & Discussion: Existing situation

1. **40%** of the respondents is **satisfied** with the **indoor air quality** and **thermal environment**
2. **48%** of the respondents is **smelling odours** sometimes or more often
3. **89%** of the respondents is experiencing **thermal discomfort** sometimes or more often



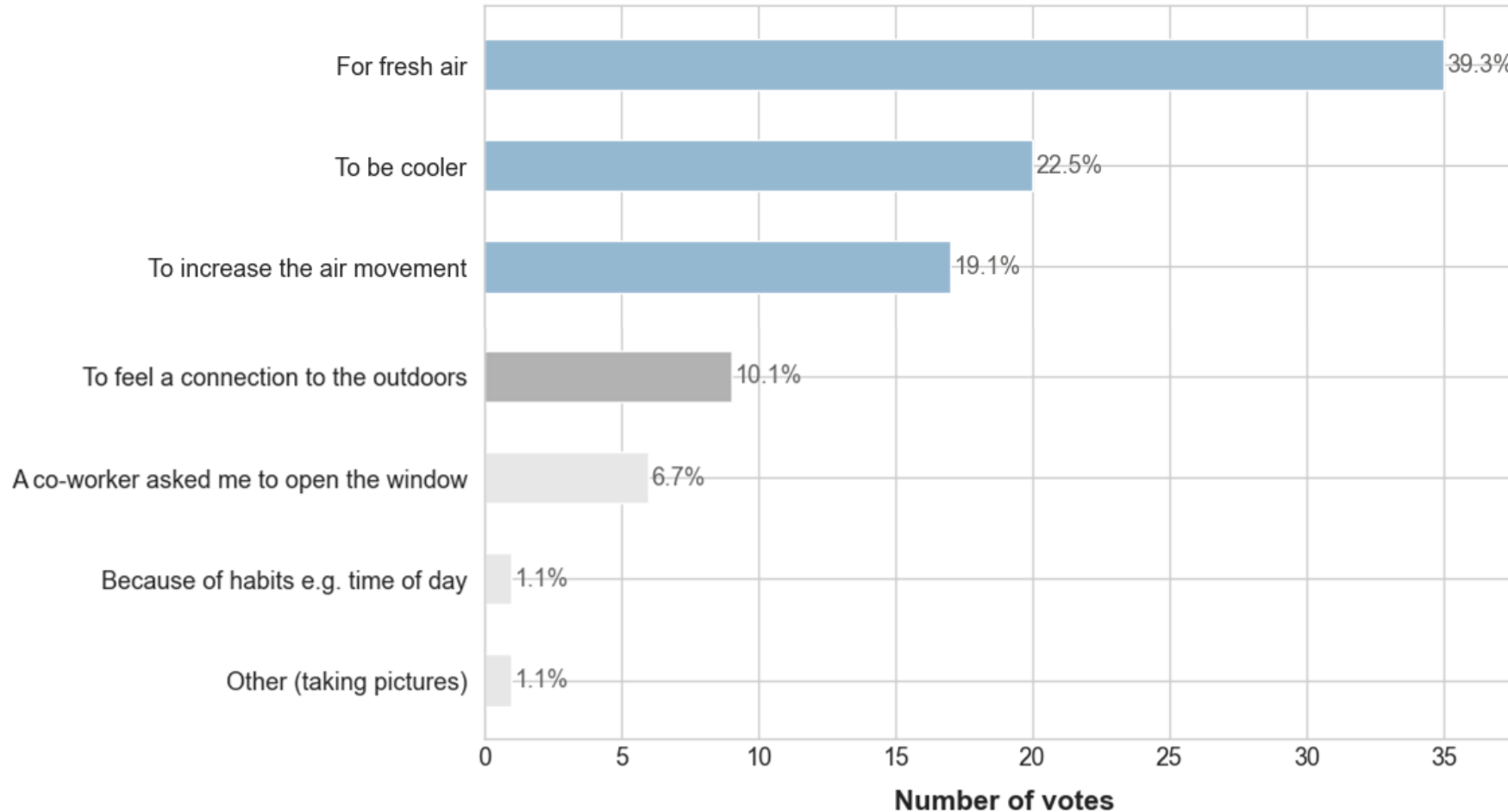
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### Sources of thermal discomfort



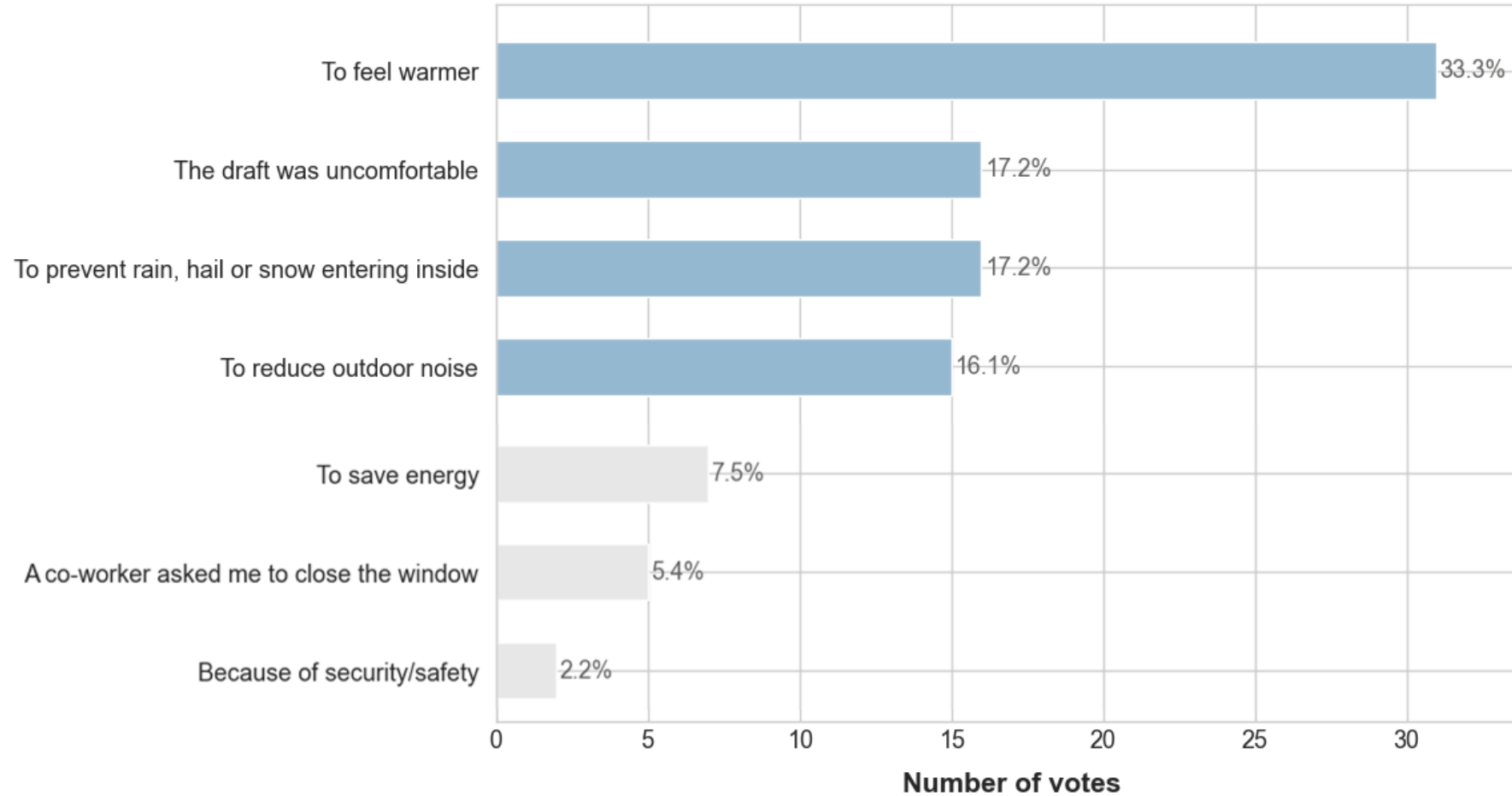
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### Reasons for window opening

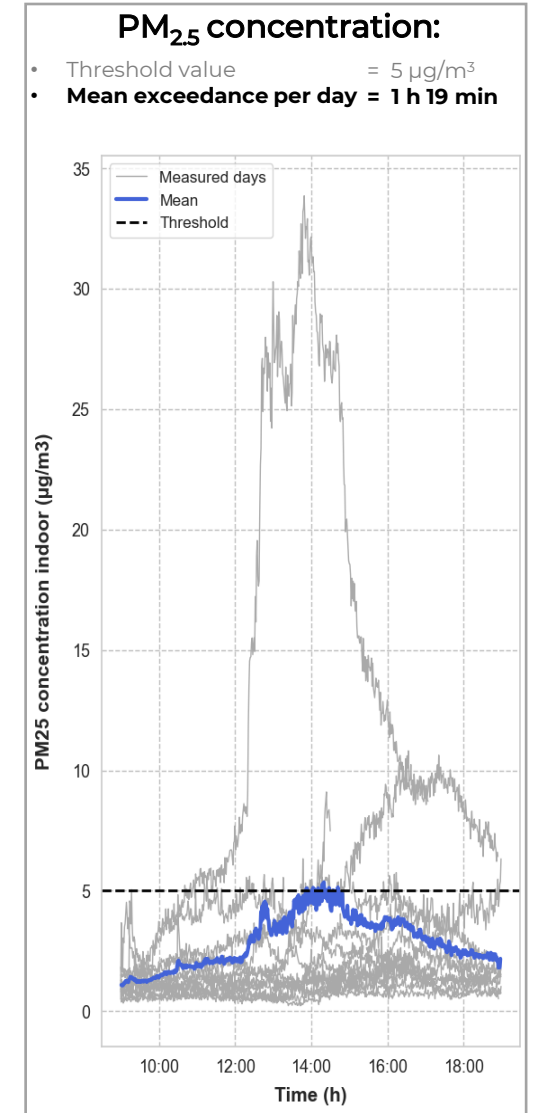
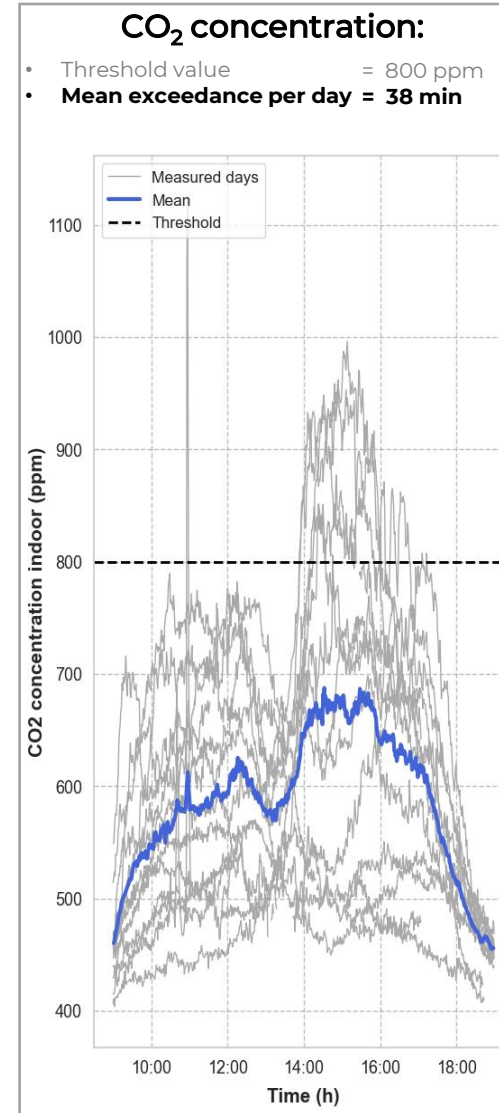
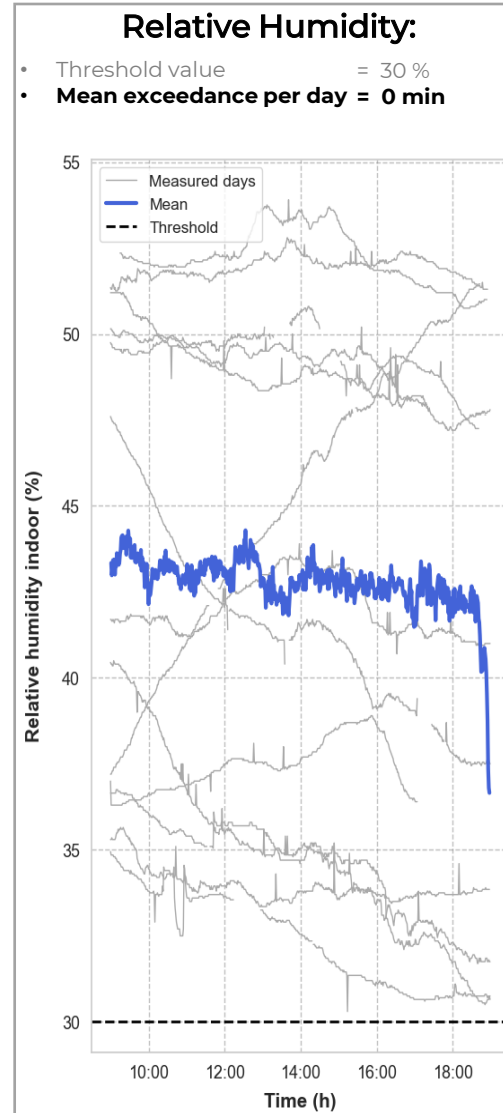
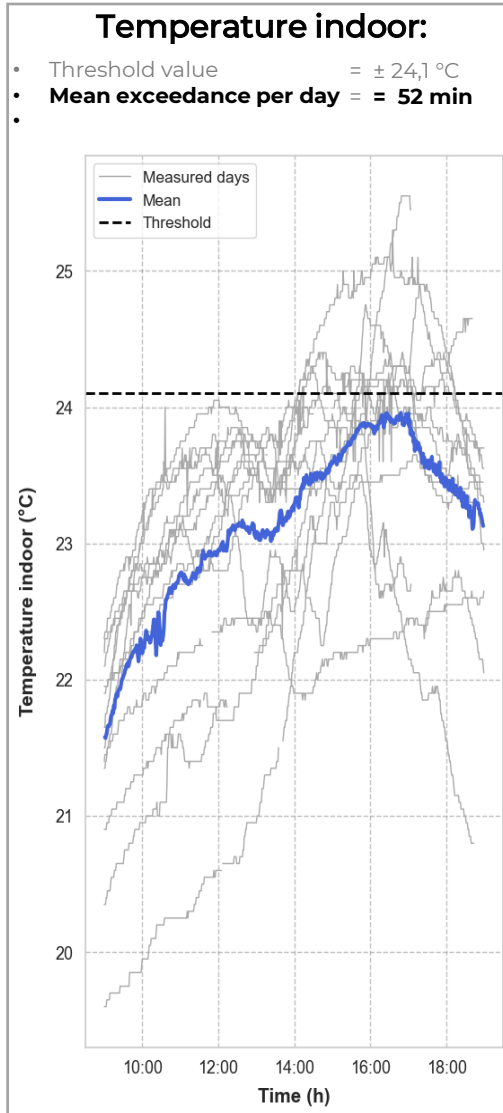


## Results & Discussion: Existing situation

### Reasons for window closing

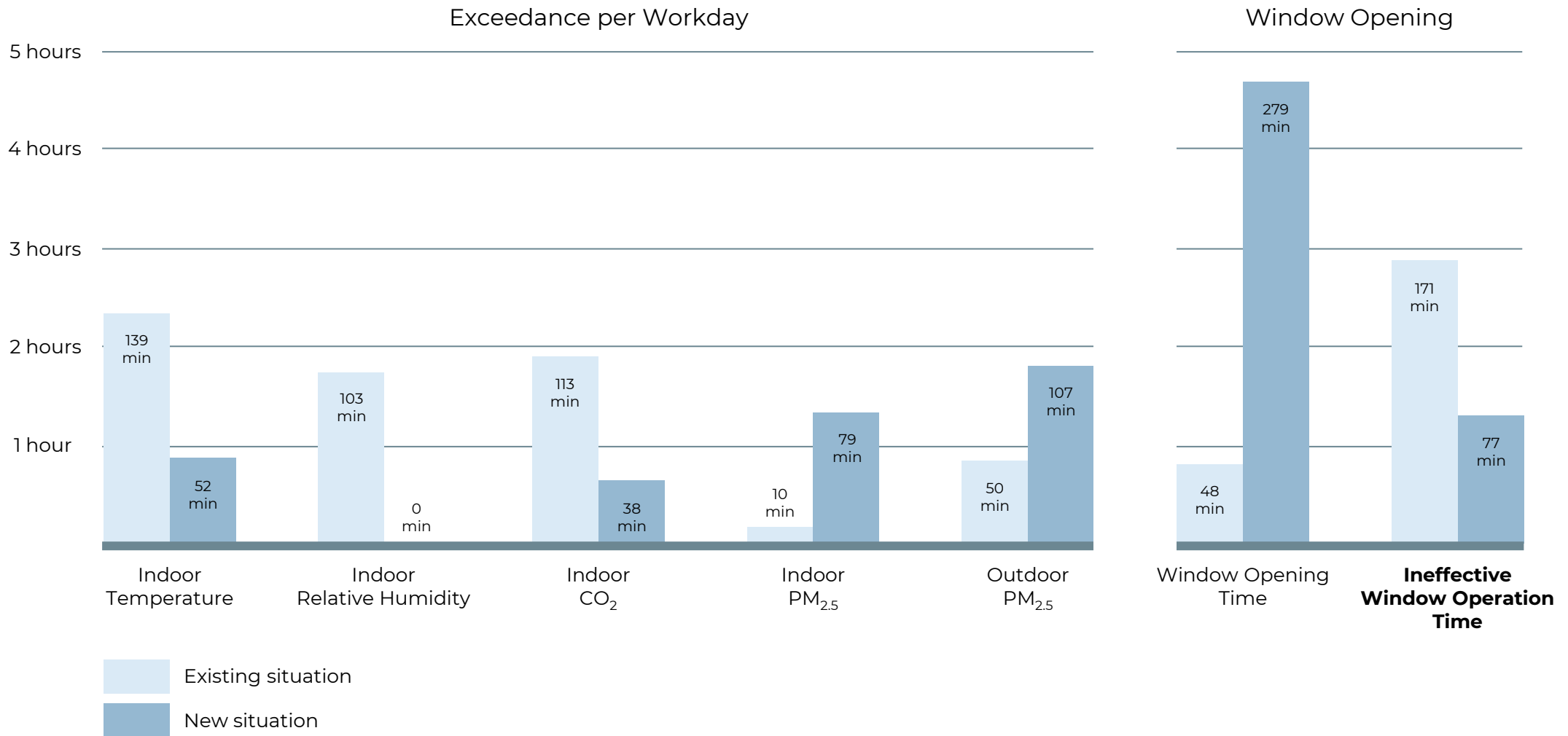


## Results & Discussion: **New situation**



## Results & Discussion: Objective measurements

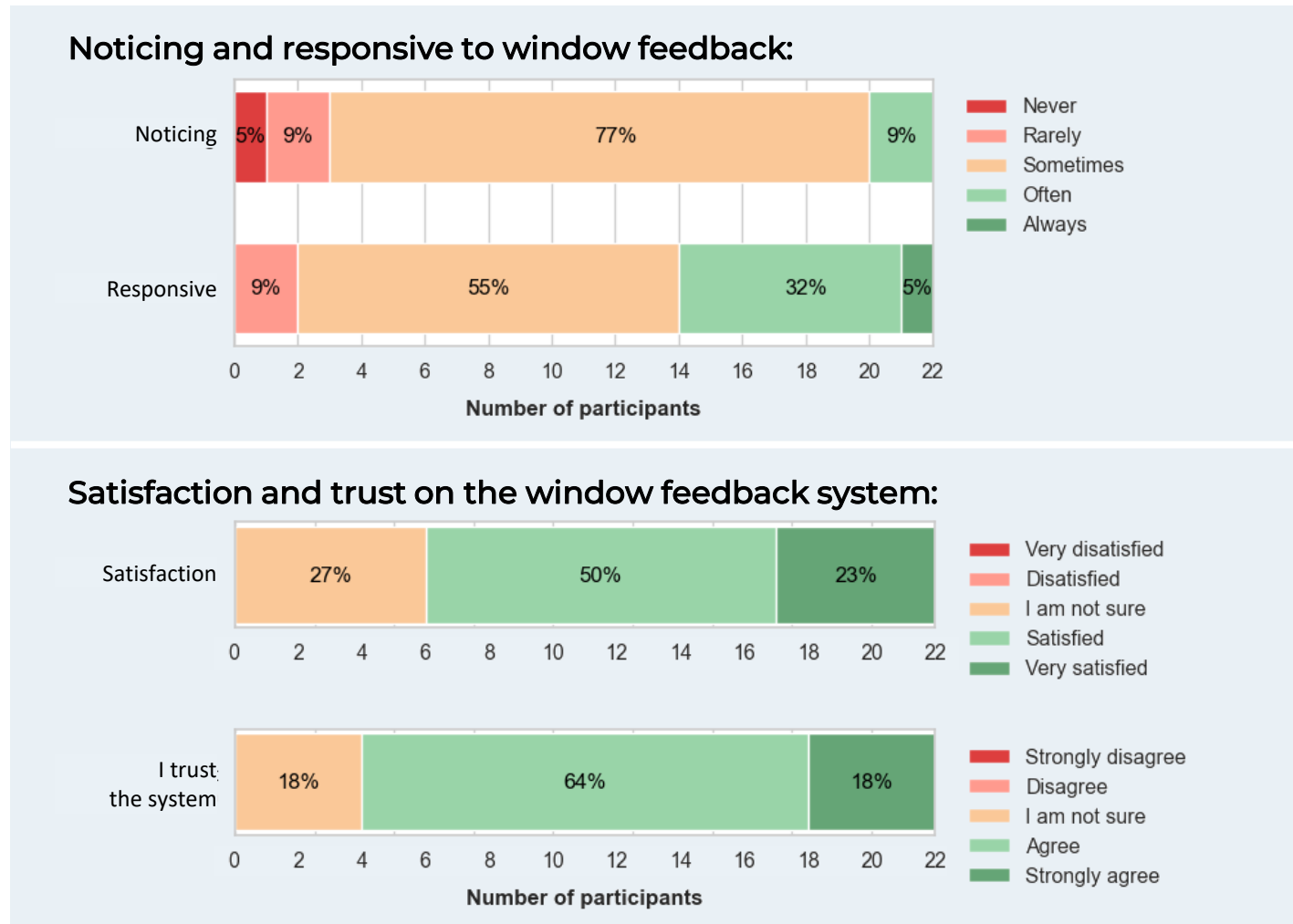
### Comparison



## Results & Discussion: Subjective measurements

### Comparison

1. **82%** of the respondents **understood** the meaning of the **window feedback colours**
2. Occupants did **understand** the **purpose** of the system
3. Occupants **did notice and respond** to the system
4. Occupants were **satisfied** with the implementation and **did trust** the system



## Conclusion

### The window feedback system does contribute to a better environment

1. Window Opening time increased with **481%**
2. Ineffective window operation reduced with **55%**
  - Temperature improved with **63%**
  - Relative humidity improved with **100%**
  - CO<sub>2</sub>-concentration improved with **66%**
3. Occupants do **understand and trust** the window feedback system
4. About **90% of the 22 respondents** do notice and respond to the provided feedback

### Design guidelines

1. Include an additional **parameter display**
2. Do **not** include **blinking lights** or **feedback messages** to phone/computers
3. ...

