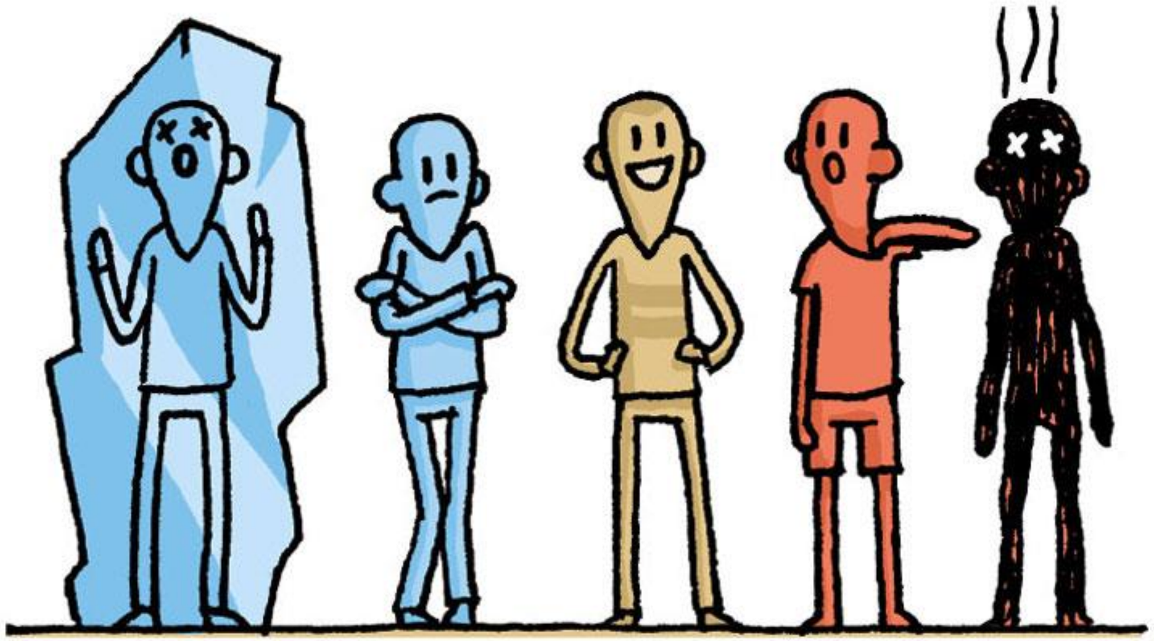

A hybrid simulation and optimization based approach to optimize window opening considering thermal comforts in buildings

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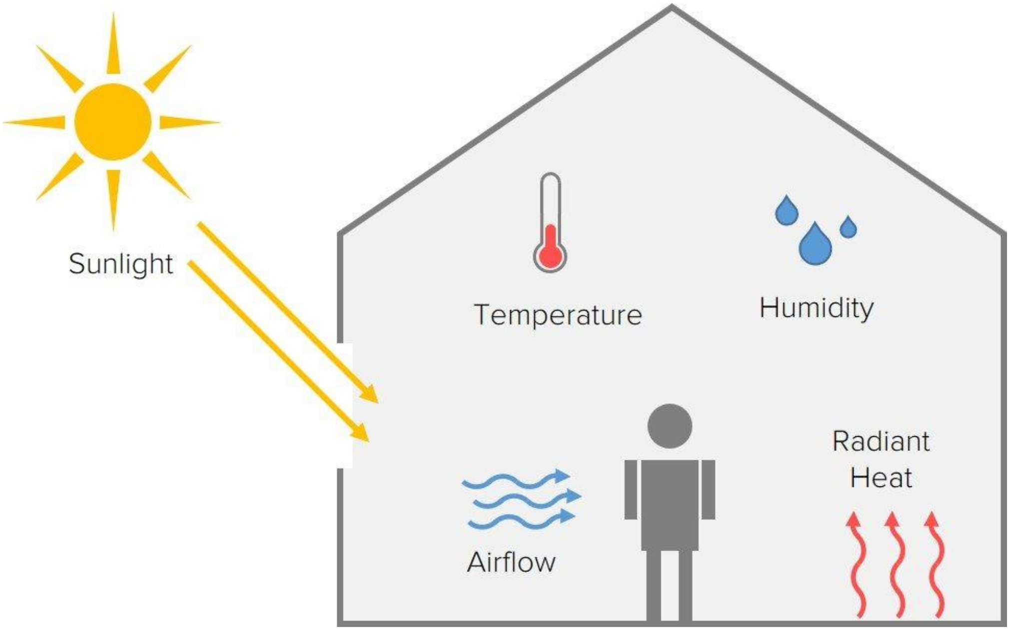
Outlines

- Introduction
- Research questions
- Aim and objectives
- Methodology
- Results and discussions
- Conclusions

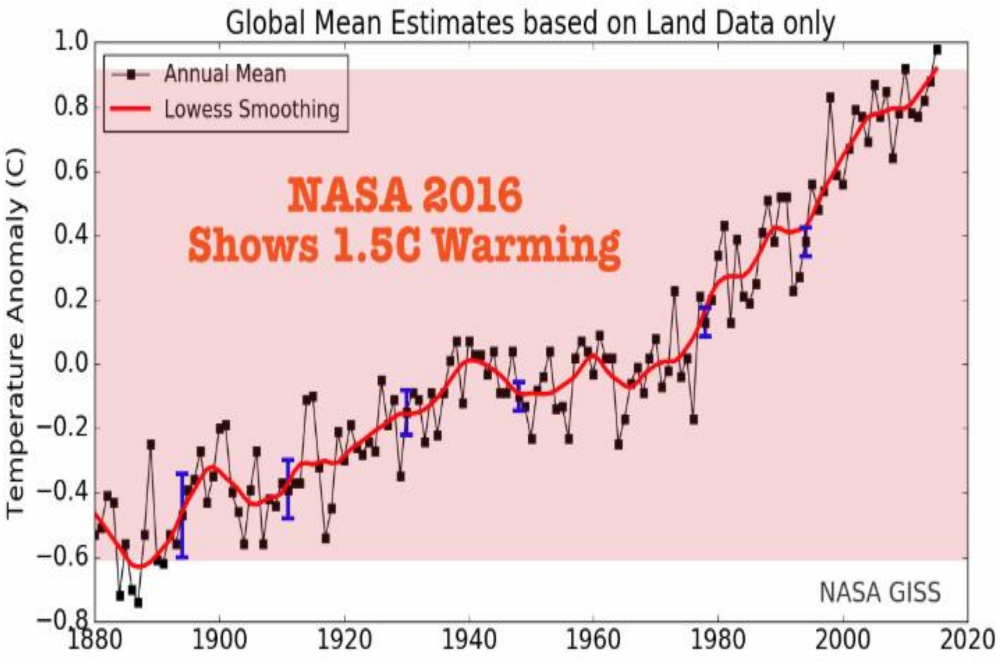


Introduction

Problems

- Highest risk for heat-related death for bedroom located on the second floor without air conditioning (Naughton et al., 2002).
- Over 2000 additional deaths were recorded during the 2003 heat wave in the UK (Wright et al. (2005))
- NASA currently shows a total of 1.5C warming in their land only temperature record (NASA GISS)

Global warming NASA 2016 data



Measured mean bedroom temperature during 2003 heat wave

London	24.0-27.6
Birmingham	27.2-28.4

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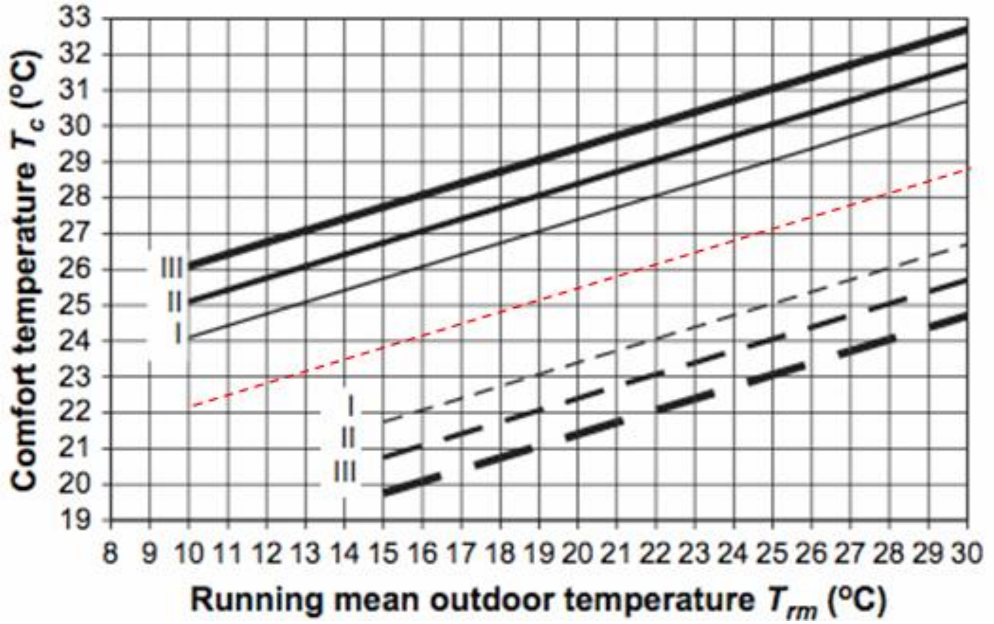
Natural ventilation and thermal comfort

- Natural ventilation can reach much higher ventilation rates than mechanical ventilation systems, which are especially designed for fresh air supply.
- The summer cooling potential and thermal comfort strongly depends on the natural ventilation strategy.
- Adaptive thermal comfort accounts for people's clothing adaptation in naturally ventilated buildings.

Adaptive thermal comfort criteria: EN15251



Research questions

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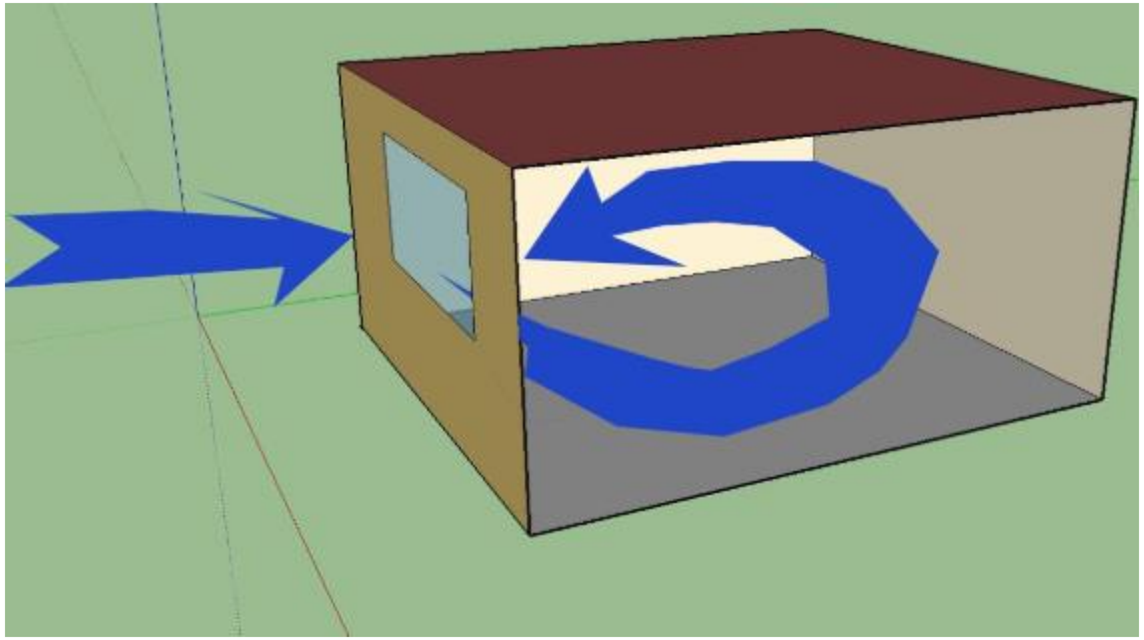
1. What is the influence of outdoor temperature on indoor temperature?

2. What is the influence of window opening area on indoor temperature?

3. What is the influence of opening schedules on indoor temperature?



Aims and objectives

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This research is aimed at optimizing window opening for natural ventilation to meet thermal comfort of occupants in the buildings.

The objectives of this research are to:

1. conduct the state-of-the-art review in thermal comfort, building indoor temperature forecasting and window opening optimization.
2. investigate the impact of outdoor weather on building performance.
3. develop simulation of window opening for predicting environmental parameters and cooling demand.
4. and develop optimization model for optimally controlling window opening.

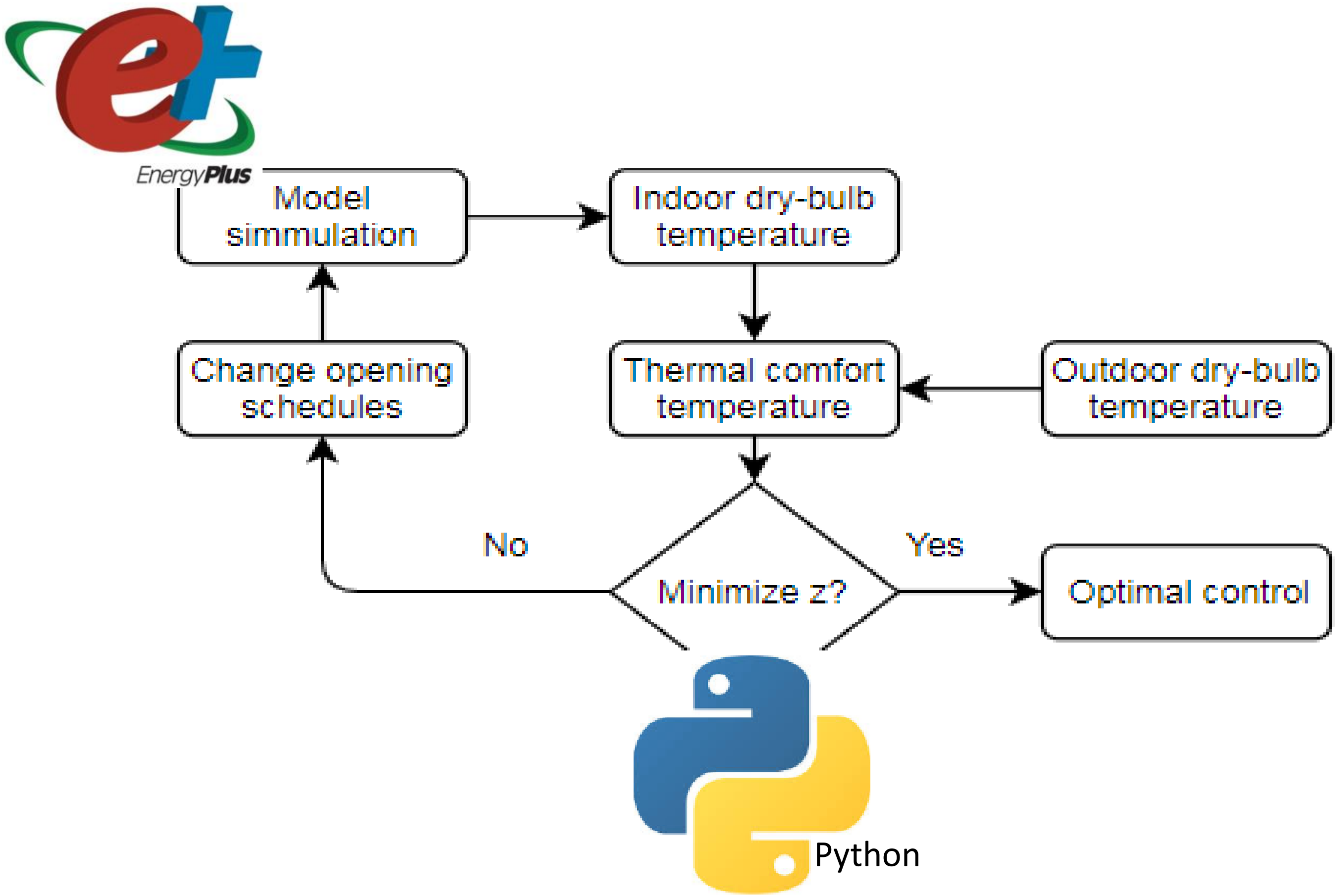
Methodology

Building thermal and energy simulation model

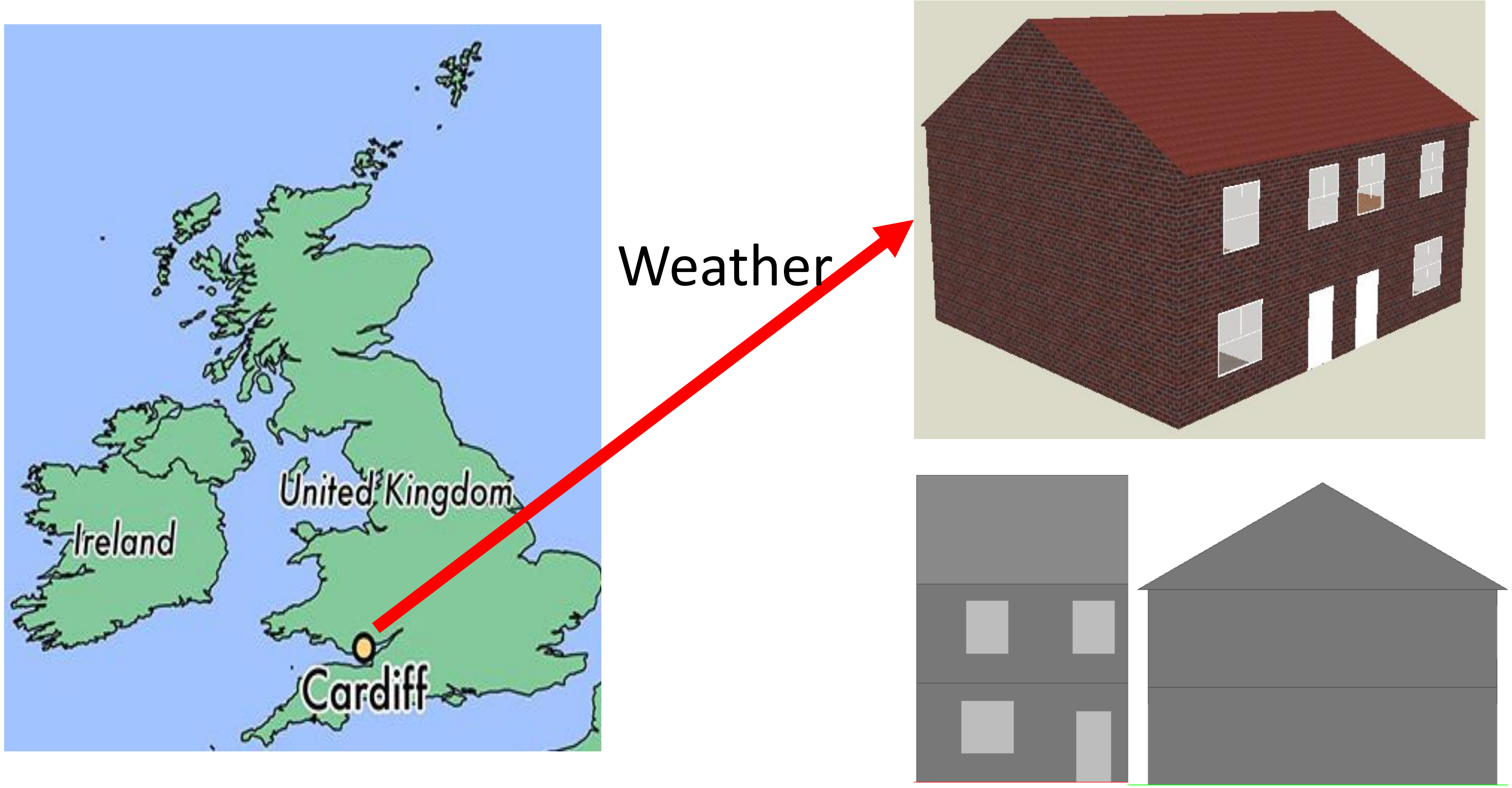
- Window schedule
- Window opening area
- Energy demand
- Indoor temperature variation

Optimization method

- Problem formulation
- Optimal solution

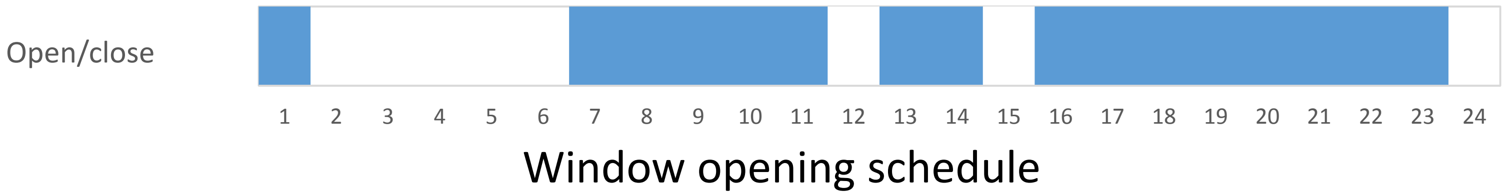


Methodology – Building model



EnergyPlus
3D model

Methodology – Opening area and schedules

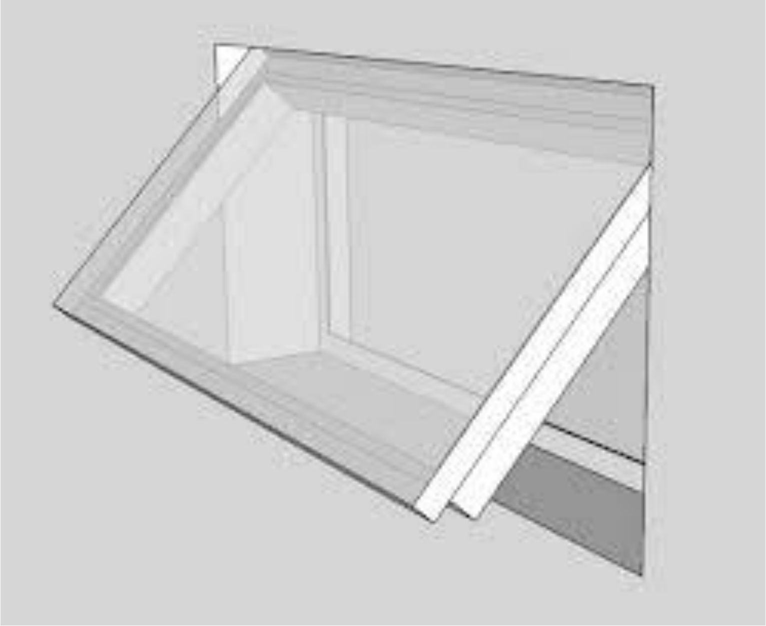


Window opening area

- Open – 50% of window area was assumed to be opened
- Close – 0% of window area was opened

Window opening hourly schedules setting

- Shading - Open
- Blank - Close



Methodology – Optimization

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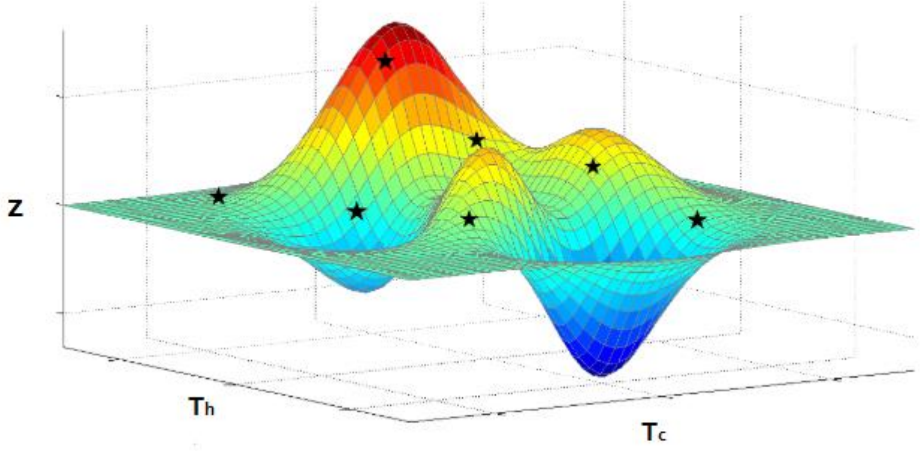
Problem formulation

Cost function z can be formulated as:

$$\min z = \sum_{h=1}^{H} (T_h - T_c)^2$$

Where z is the gap between the indoor dry-bulb (T_c) and thermal comfort temperature at each hour $h \in \{1, 2, \dots H\}$ (T_h).

When A_h represents the window opening area in percentage ($0\%\ or\ 50\%$), $H = 24$ represents the optimization horizon is a day and T_c should be in the category II adaptive comfort zone.



Results and discussions

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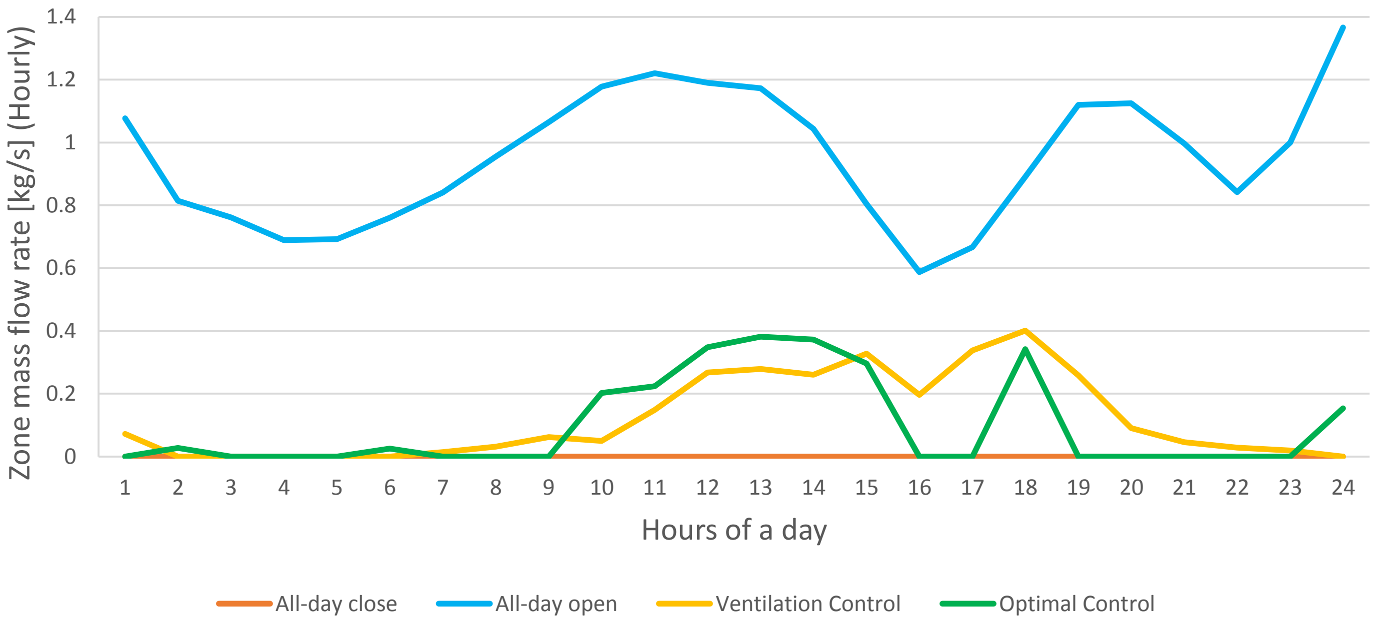
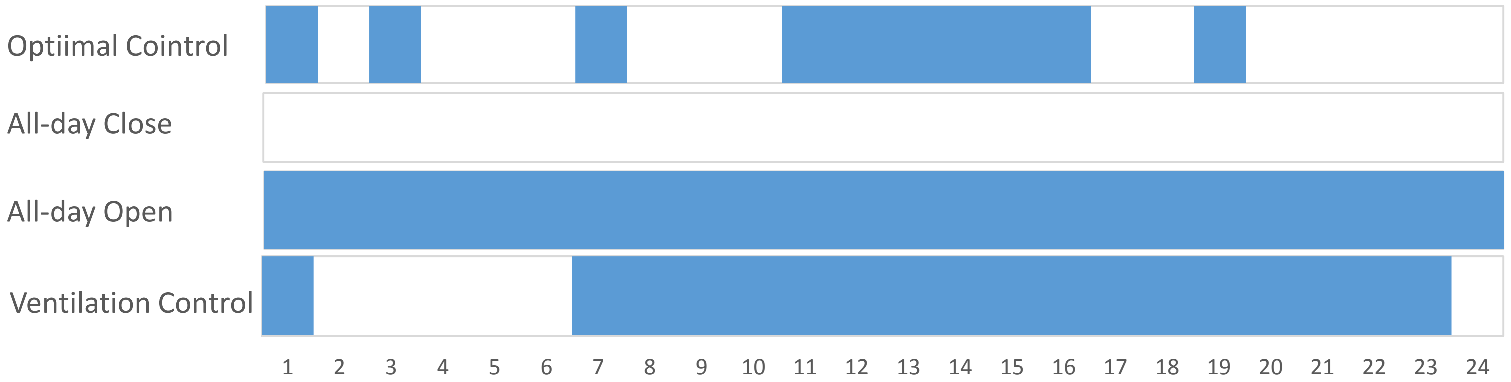
Mass Flow Rate through the window





Opening Schedules

Results and discussions

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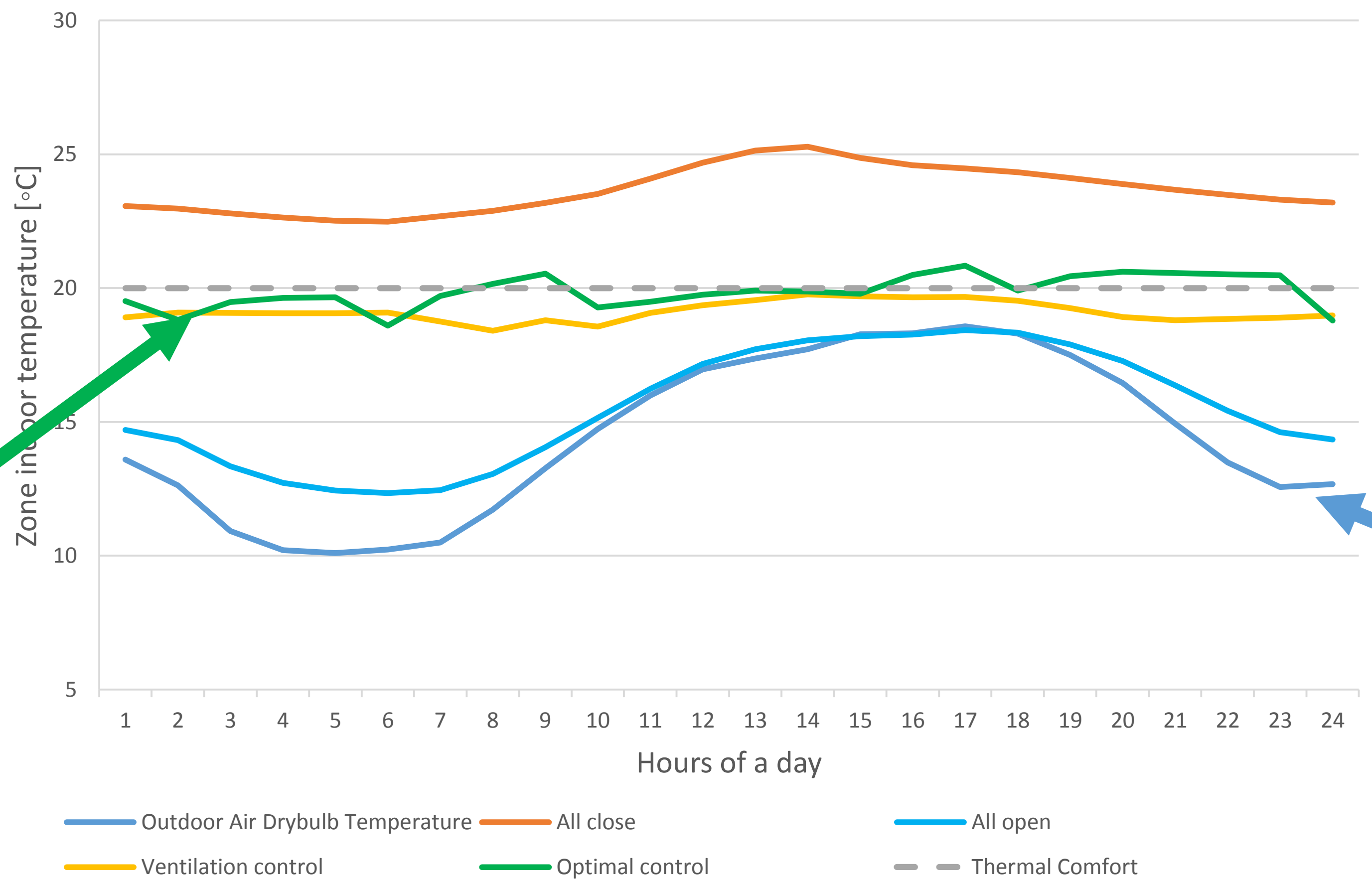
Indoor Temperature with different opening schedules



Indoor Operative Temperature with Optimal Control

Outdoor Dry-bulb Temperature

Results and discussions

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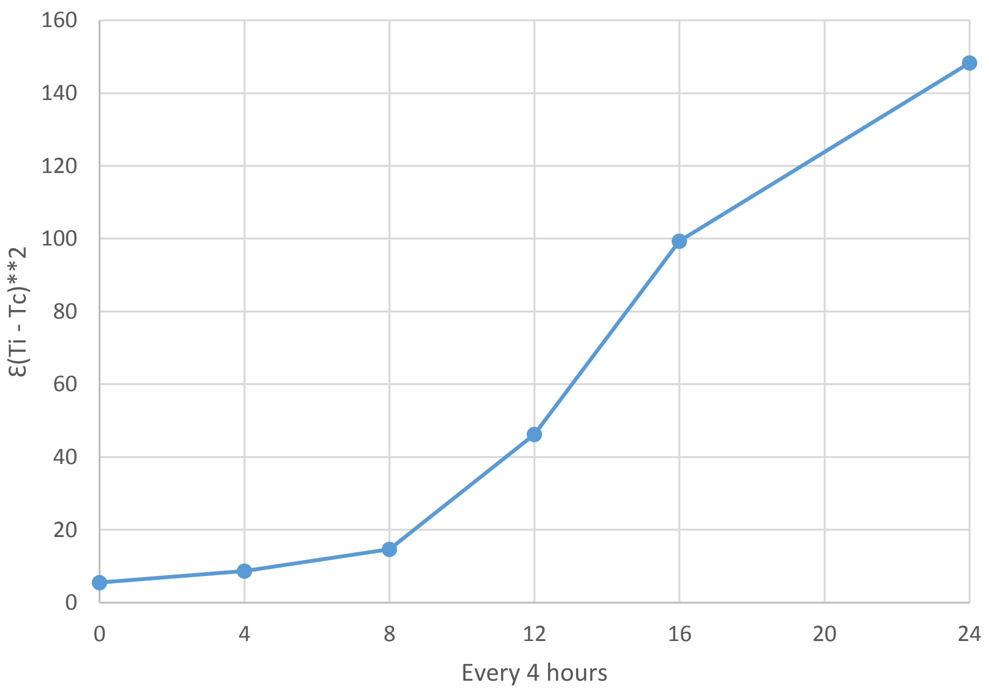
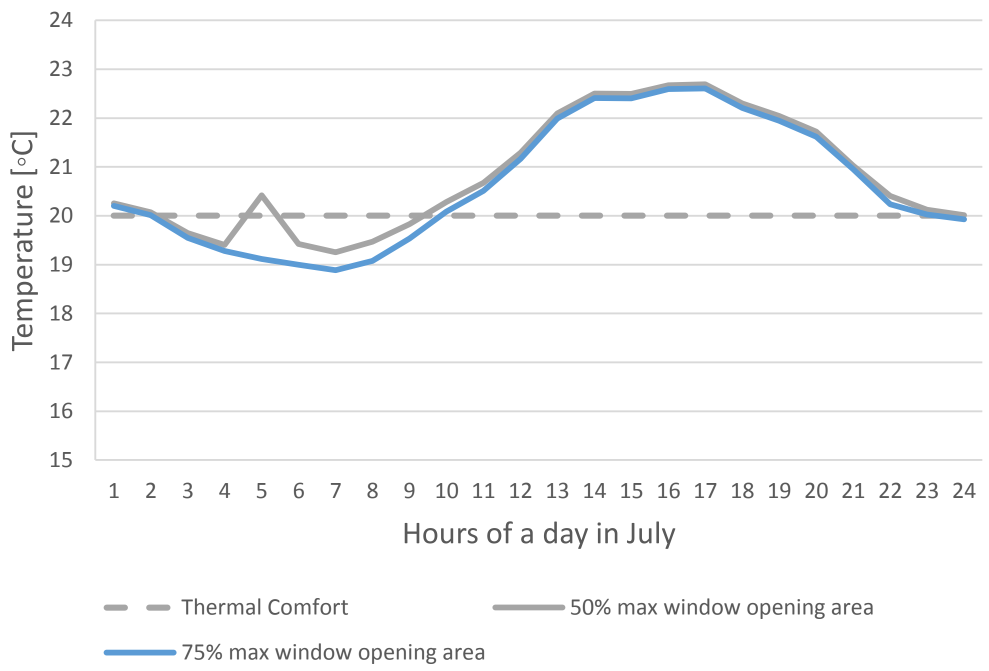
During the 2030s Cardiff Weather



Cumulative gaps from thermal comfort (20◦C) with optimal control



Increasing window opening area would not reduce temperature too much

Conclusions

- Optimal control of window opening using hybrid simulation and optimization can effectively increase thermal comfort comparing with fixed opening schedules such as all-day open and all-day close, and simple control methods such as ventilation control

- Larger window opening area is required to increase ventilation in future climate.

- In the 2030s, optimal control of night ventilation can still effectively improve thermal comfort during the night. However, increasing window area for better day-time ventilation is not very effective due to high temperature and solar gain during the day.

Thank you!