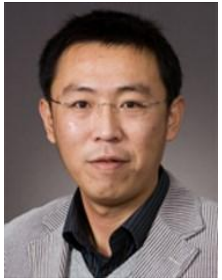
INTELLIGENT HUMAN-BUILDING INTERACTION LAB
FOR INVESTIGATIONS OF ENERGY EFFICIENCY MEASURES

Thomas Olofsson

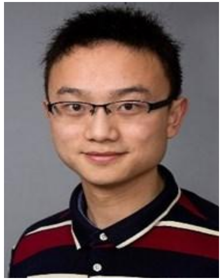
Professor, Energy Efficiency

UMEÅ UNIVERSITY

TEAM MEMBERS



- Weizhuo Lu, Prof.
- Head of IHBI lab
- Expert of building energy renovation and ICT technologies



- Kailun Feng, Assistant Prof.
- Expert of building’s climate resilience, energy-efficient renovation, and big data analysis

- Chanachok Chokwitthaya, Staff scientist.
- Expert of immersive virtual environment and demand response

- Thomas Olofsson, Prof.
- Expert of indoor built environment, HAVC system and energy efficiency

“SCANVAC WEBINAR - Overheating control needed in Nordic dwellings"

TREND

- Climate change and increasing temperatures
- Transition from fossil fuels to renewable energy
- Influences the production, distribution and use of energy
- Transformation of the industry sector
- Transformation of the transportation sector
- Transformation of the building and service sector

General background to our research profile

The building sector has a major impact on, and is impacted by, the transformation, distribution and use of the planet resources

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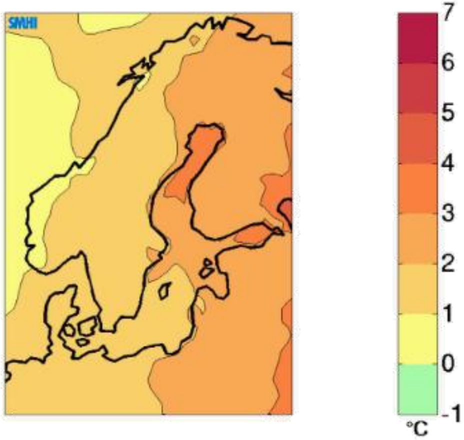
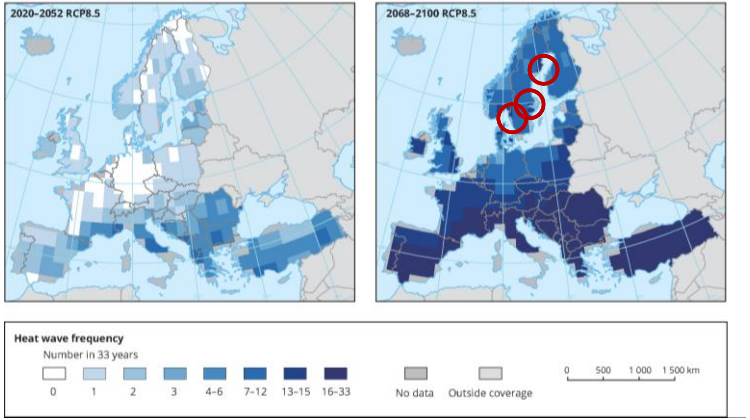
LAB: CLIMATE CHANGE



Umeå 2030 +2.1 degrees
(SMHI 2014)

A building in northern Sweden



Umeå heat waves
(European Environment Agency, 2022)

How will the built environments in Sweden become in future climate?
How will people adapt to future built environments?

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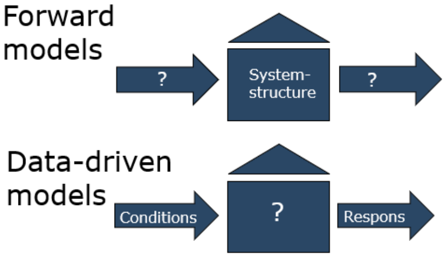
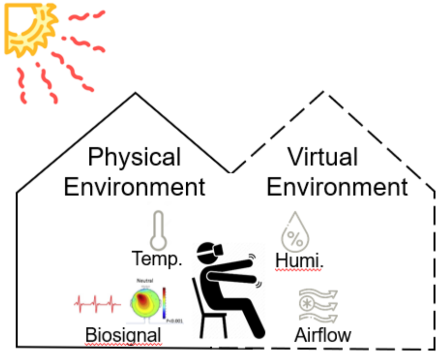
APPROACHES TO INVESTIGATE THE SYNTHESIS OF ENERGY SUPPLY AND ENERGY USE IN BUILDINGS

Simulations



IHBI LAB



IHBI lab:

Live-in Lab

Surveys/Interviews

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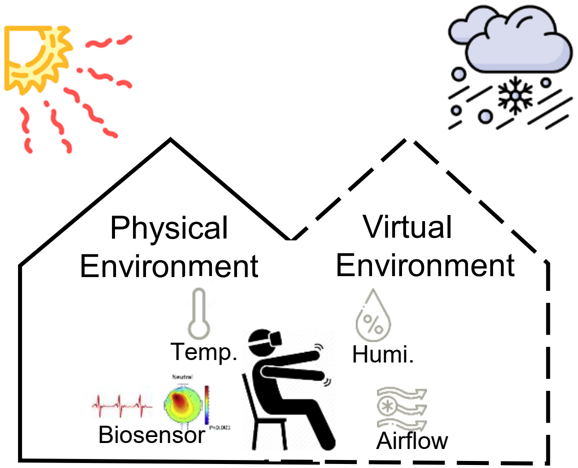
LAB: CLIMATE CHANGE

Climate change



Adaptation behahvior

Psychological and physiological effects

Built environment resilient upgrading

IHBI Lab:
Future climate simulator

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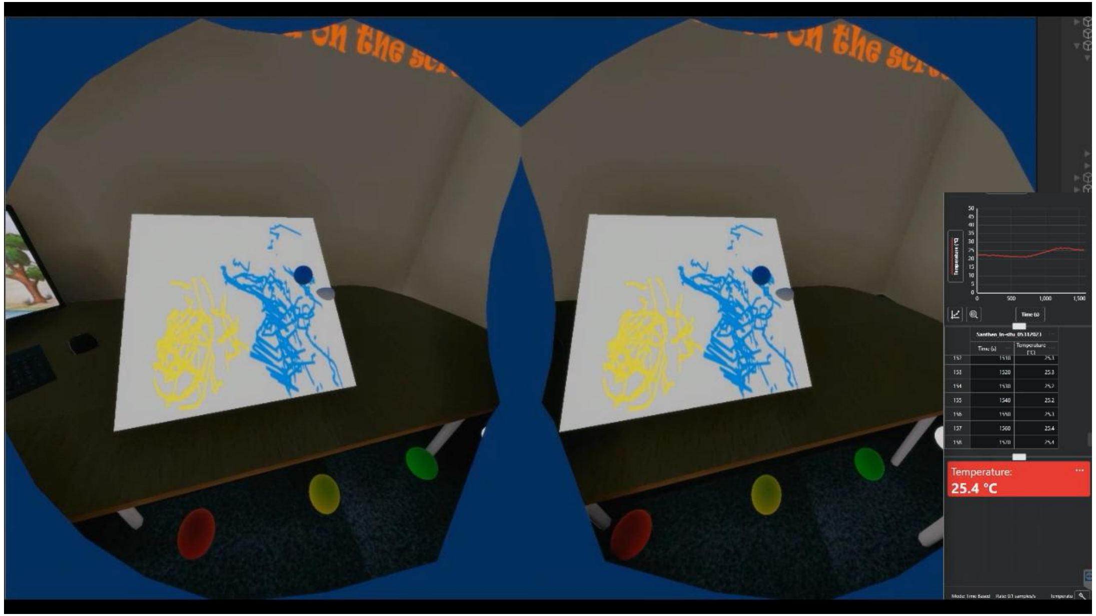
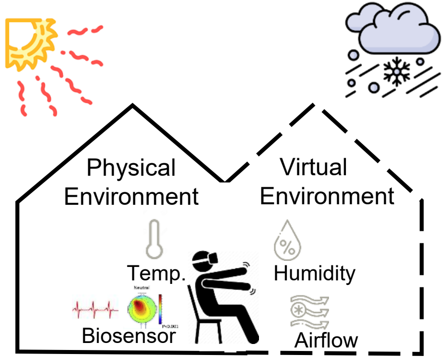
LAB: WORKING ENVIRONMENT



The relations between

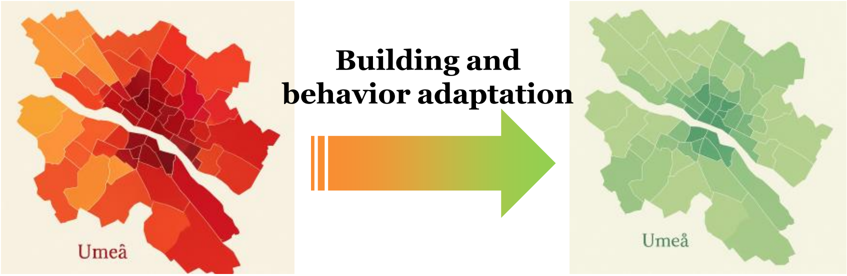
- Various working activities;
- Working environments (thermal, lighting, and others);
- Thermal perception.

LAB: CLIMATE CHANGE



IHBI Lab:
Future climate simulator

Building stock
climate simulation



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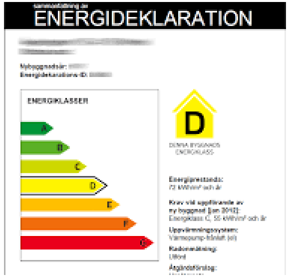
STUDY 1: CLIMATE RESILIENCE COMPARISON

A (*Disadvantage Community*):
- Income property rate: 41% (SCB 2023);
- Apartment buildings (1965-1974) with energy-inefficient devices and poor insulation, most buildings' windows cannot be open fully.

B (*Other Community*):
- Income property rate: 10%;
- Most are single-family houses

Method: Buildings’ big data

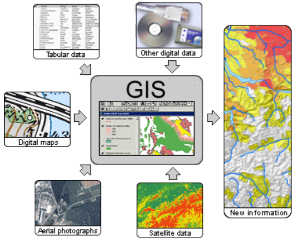


Swedish Energy Performance Certificate (EPC dataset)

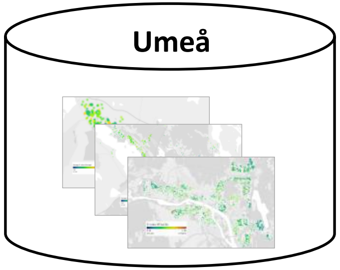
Boverket

Buildings Energy, Technical Status and Indoor Environment certificate (BETSI dataset)

Buildings’ Big Database



Geographical information system (GIS)



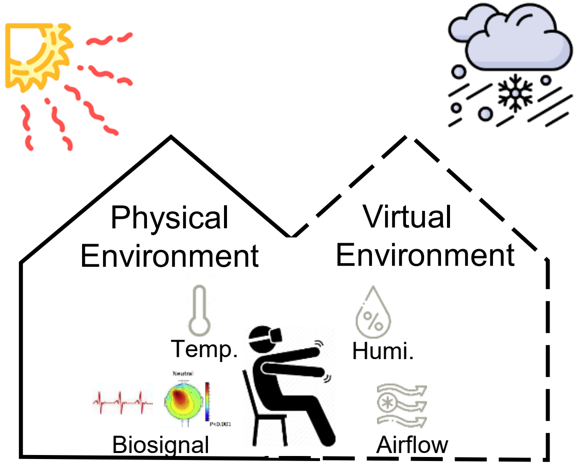
City level building property datasets

Study 1: Climate resilience comparison

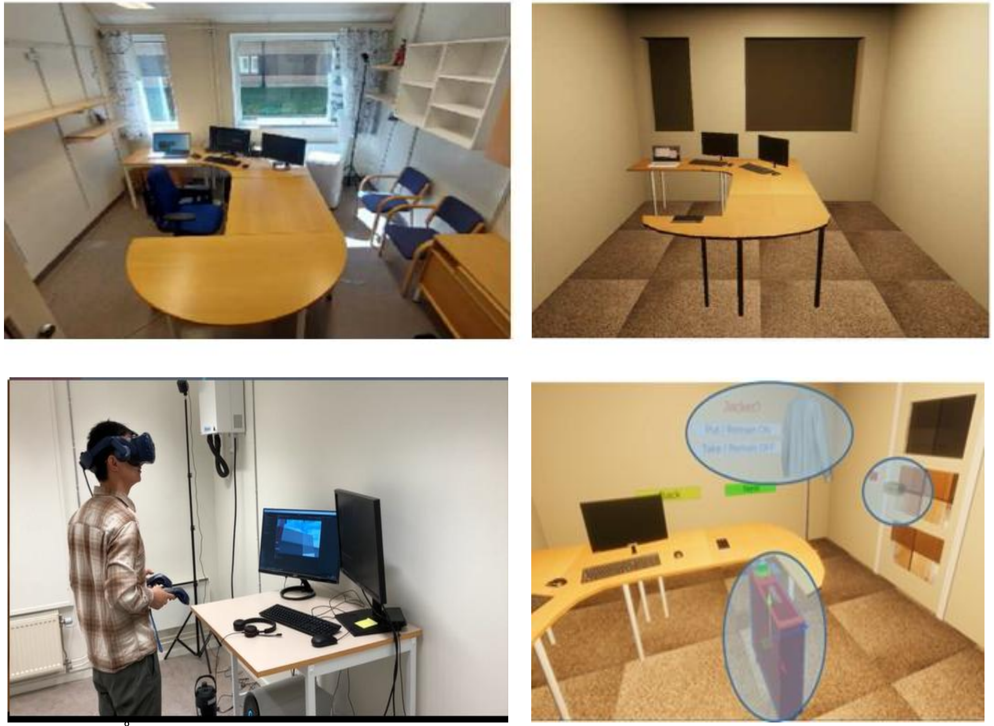
The collected building attributes for comparison

ID	Attribute Name	Unit	Ranges	Data Resource
1	Building type*		Single-family houses (SFH), multi-family houses (MFH)	EPC dataset
2	Housing area*	m^2	125 and 160 for SFH, 88 for MFH	EPC and BETSI datasets
3	Orientation to north*	degree	0-180	GIS calculation
4	Ventilation system*		SFH: natural air ventilation, MFH: mechanical ventilation	BETSI dataset
5	U-values of components*	W/m^2K		(Penaka et al. 2024)
6	Building geometry			BETSI dataset
7	Construction year		SFH: before 1960, MFH: 1961~1975	EPC dataset
8	Window-wall rate	%	SFH: 30%, MFH: 25%	Estimation based on construction year
9	Heating system		SFH: electric heater, MFH: oil boiler	BETSI dataset
10	Occupancy in area	Person/m^2	SFH: 0.03, MFH: 0.04	Estimation
11	Lighting, occupancy, and other equipment schedule	%	0~100	Estimation based on the residential purpose

Method: Adaptation behavior collection

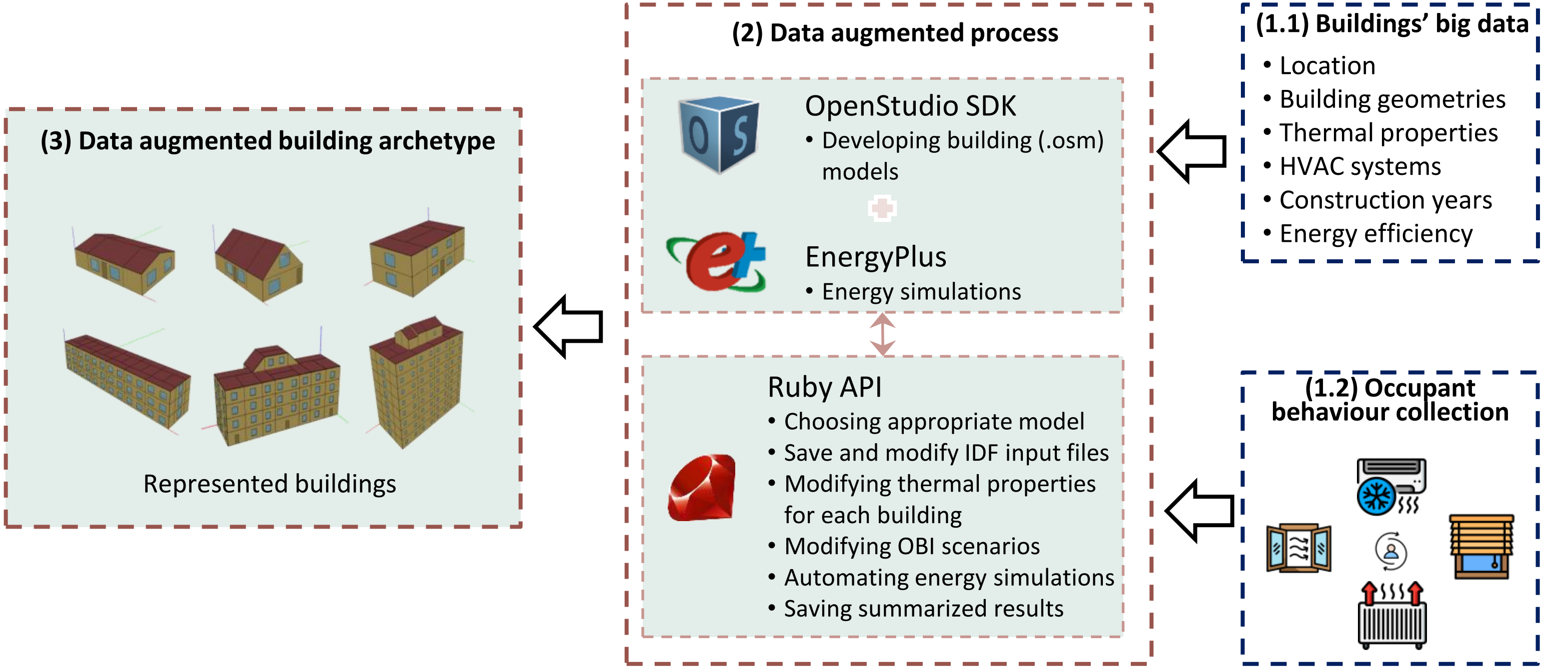


The hybrid virtual-physical experiment

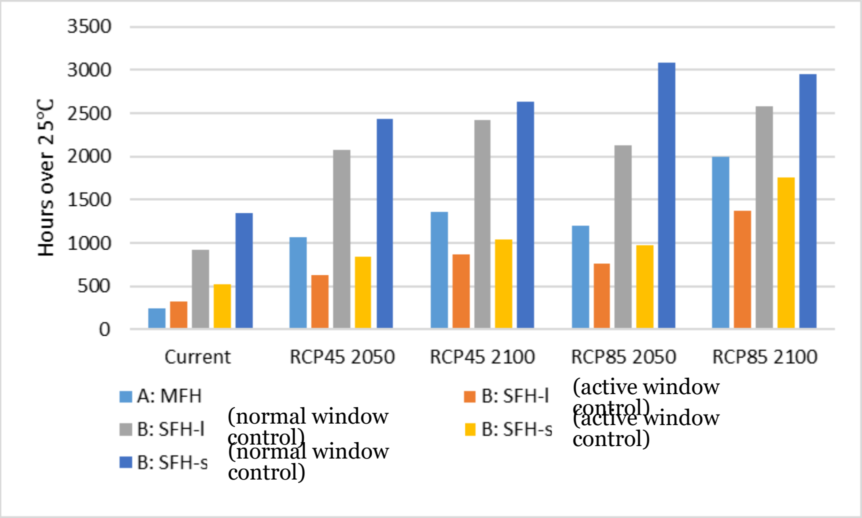


Method: Buildings’ big data

Data augmented building archetype approach.



RESULTS



Total hours in one year over 25°C for buildings in (A) disadvantage community and (B) another general community.

**Active window control: people will use window more often to maintain good indoor temperature, considering indoor and outdoor temperatures.*

Insights:

1) <u>If residents do not have adaptive behave</u> (e.g., active window control), the buildings in general community even will be more influenced by heatwaves in future**.**
2) <u>If residents all have adaptive behave,</u> the buildings in disadvantaged community will be more influenced by heatwaves compared to other community.

STUDY 2: CLIMATE RESILIENCE OF CITY BUILDINGS

- It is inevitable that **cities will be affected by global warming** in the future. It is important to conduct **climate change assessments and adaptive preparations.**
- An effective method is to **cluster buildings and analyze effective measures for each building group**.

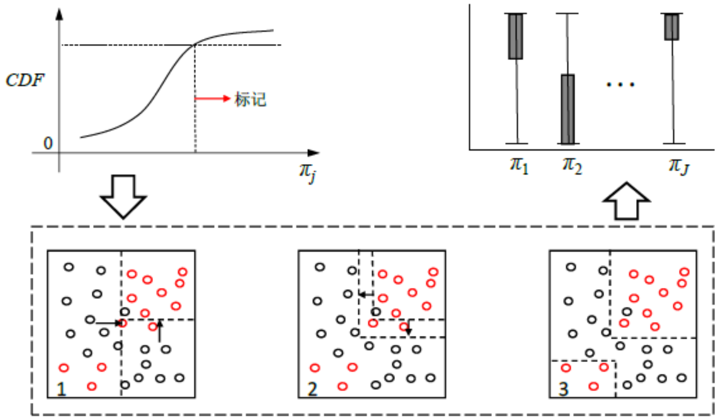
Expected results:

- 1. Which groups of buildings have **poor** and **good** heat resilience?
- 2. The **properties make building less resilient** to climate change (building physics, inner devices, occupant behaviors, others)?
- 3. **Building and behavior adaptations**, and their performances?

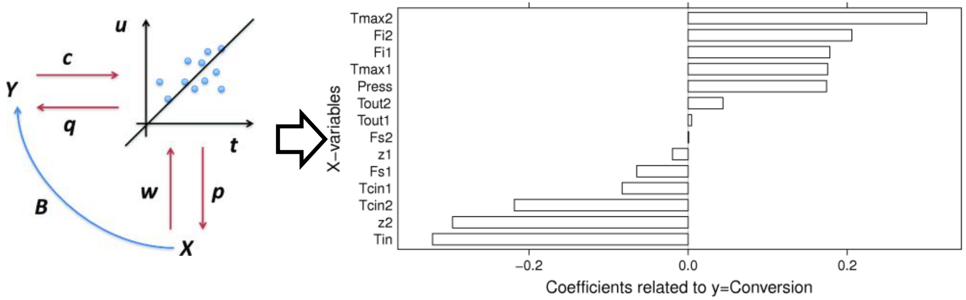
METHODS

Operative Temperature: A single temperature that combines the effects of air temperature and mean radiant temperature;

PPD (Predicted Percentage of Dissatisfied) is a thermal comfort index that estimates the percentage of people in a room who would feel dissatisfied with the thermal conditions. It's calculated based on the Predicted Mean Vote (PMV), by uses factors like air temperature, humidity, air movement, radiant temperature, clothing insulation, and metabolic rate



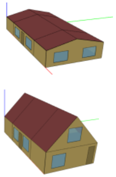
PRIM algorithm to identify vulnerable buildings



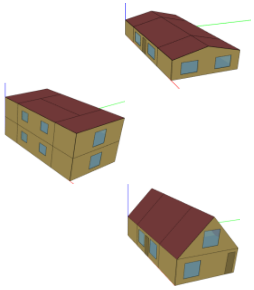
PLS regression to identify important variables

Results

Cluster A-D: vulnerable building groups

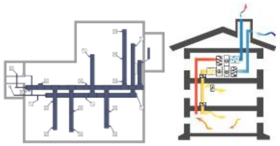


Cluster A - vulnerable	428 SFH in Umea
Building Size is small around 125m²	
Construction year before 1995	
EPC class is within A to E	
0.09241 <= U value of roof <= 0.2665	



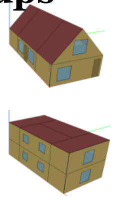
Cluster B	1177 SFH in Umea
HVAC system: Natural	
Window Size (one side) >= 4.328	
Main building orientation is South	

Cluster C	962 SFH in Umea
HVAC system: Natural	
Window Size (one side) >= 4.328	
U value of roof <= 0.3023	
Main building orientation is West	

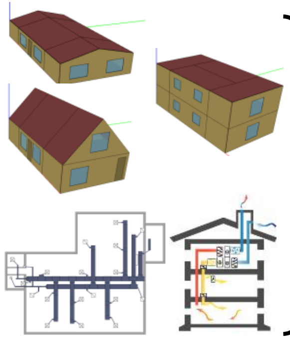


Cluster D	222 SFH in Umea
Building Size is large around 160 m²	
HVAC system: mechanical or mechanical with heatrecovery	
0.2063 <= U value of floor <= 0.3461	
Main building orientation is West/South/East	

Cluster I-II: robust building groups

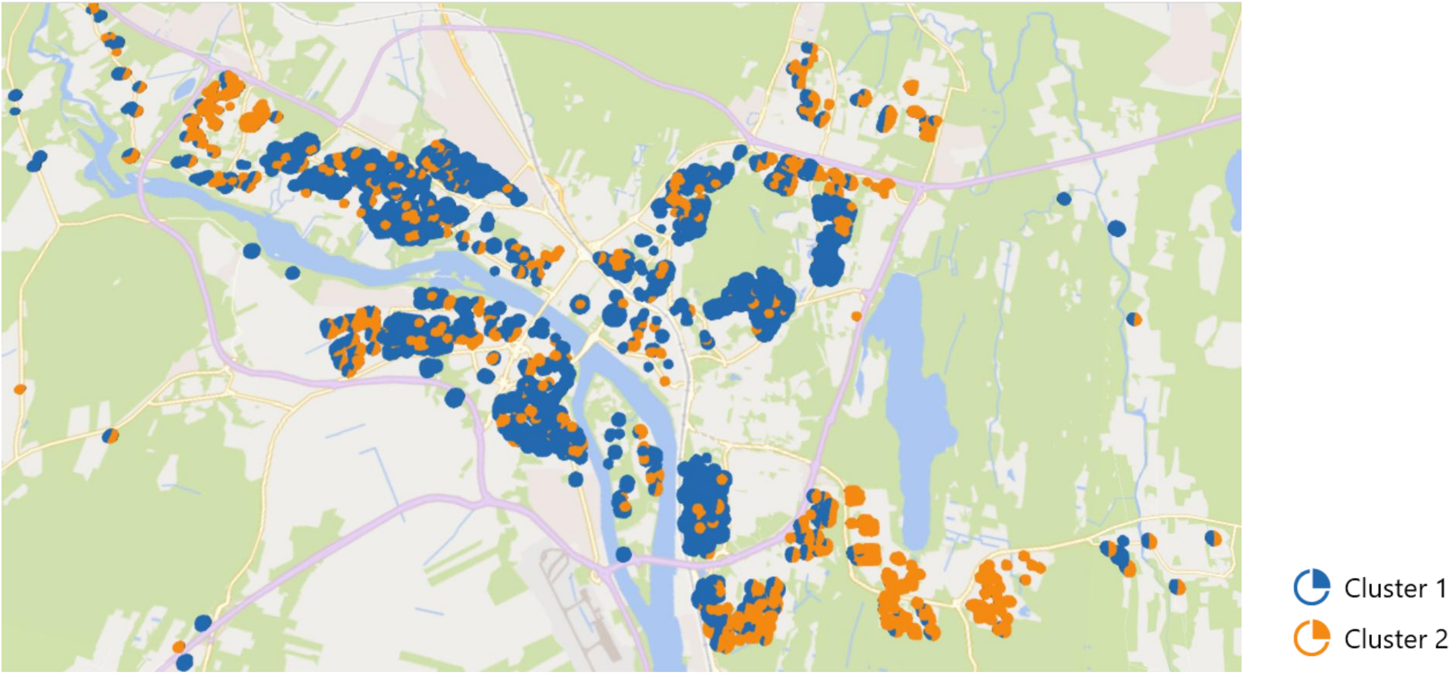


Cluster I - robust	587 SFH in Umea
Construction year after 1976	
}Building Size is small around 125m²	
U value of floor <= 0.2903	



Cluster II	570 SFH in Umea
HVAC system: mechanical or mechanical with heatrecovery	
Building Size is large around 160 m²	
EPC class is within A to E	

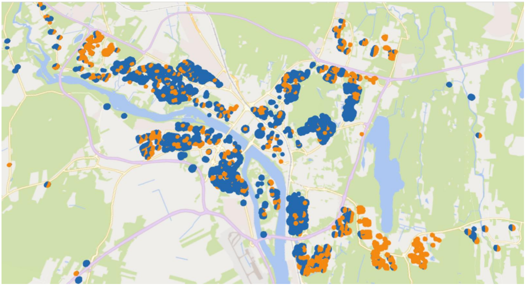
Results



Proportion and location of vulnerable and robust buildings in Umeå (SFH)

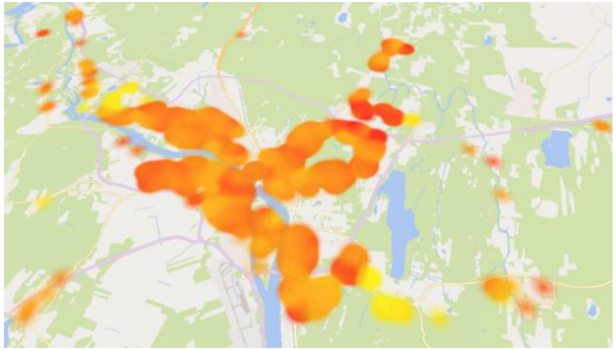
Cluster A-D: vulnerable building groups
Cluster I-II: robust building groups

Results

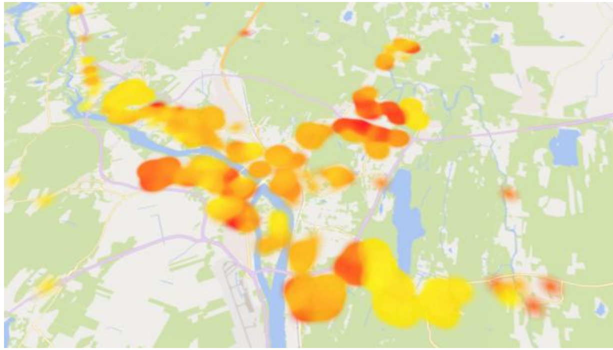


Cluster

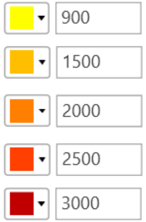
Cluster robust



Performance of vulnerable buildings under future climate (indoor overheat hours > 25 °C)



Performance of robust buildings under future climate (indoor overheat hours > 25 °C)

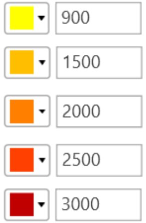


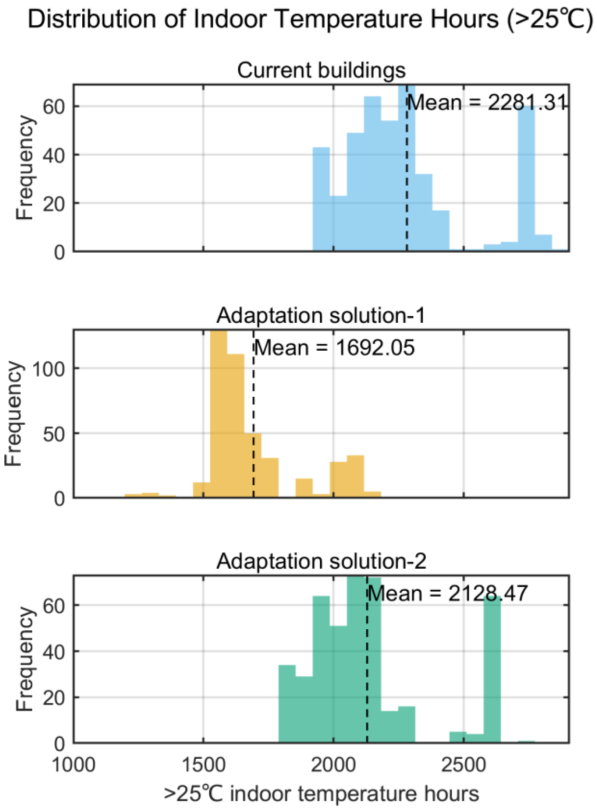
Building adaptation and behavior adaptation
(RCP-8.5, 2030 extreme heat)

a. Grp. A buildings without adaptation

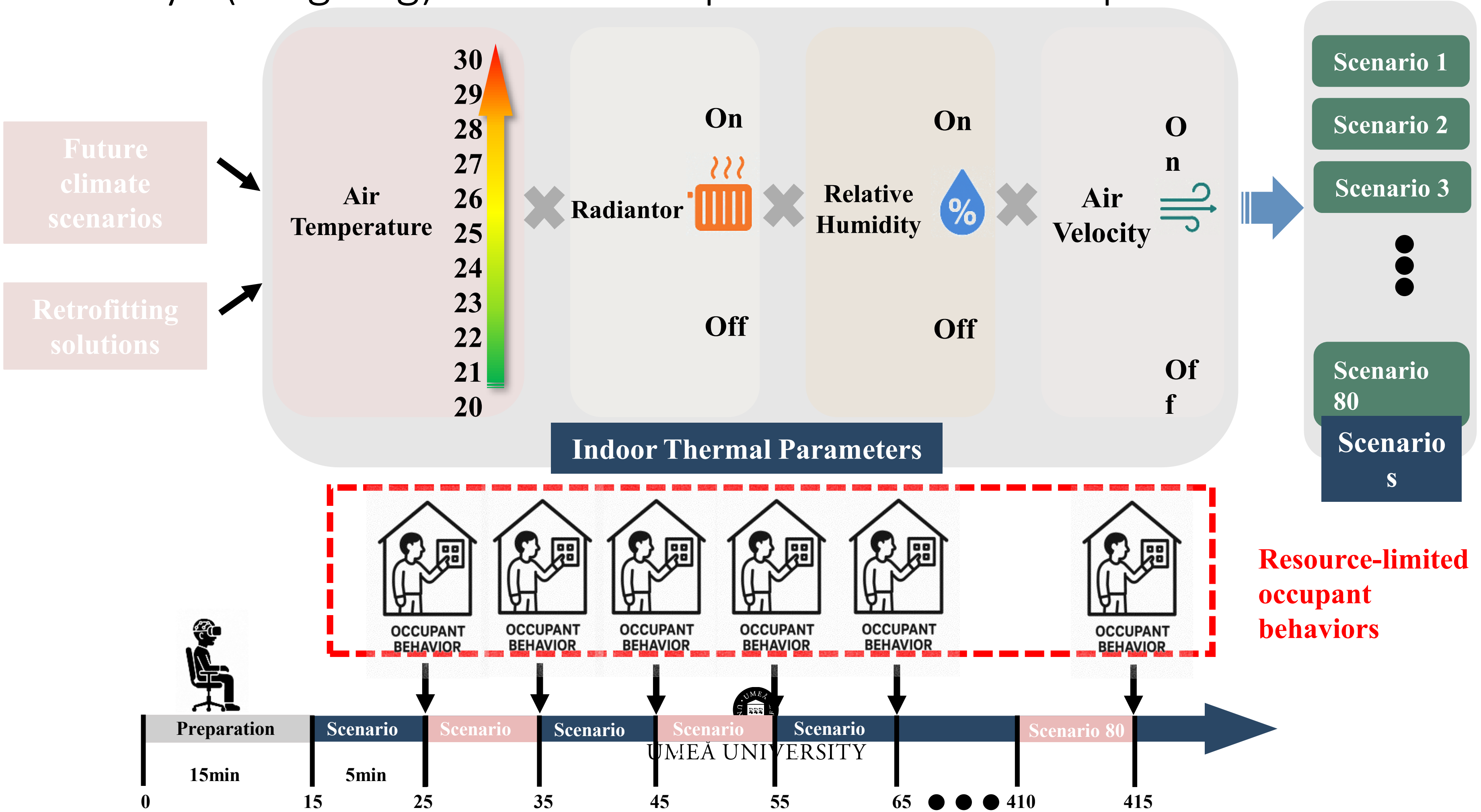
b. Grp. A buildings with adaptation-1

c. Grp. A buildings with adaptation-2





Study 3(on-going): Climate adaptation behavior experiment



THANK YOU!

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