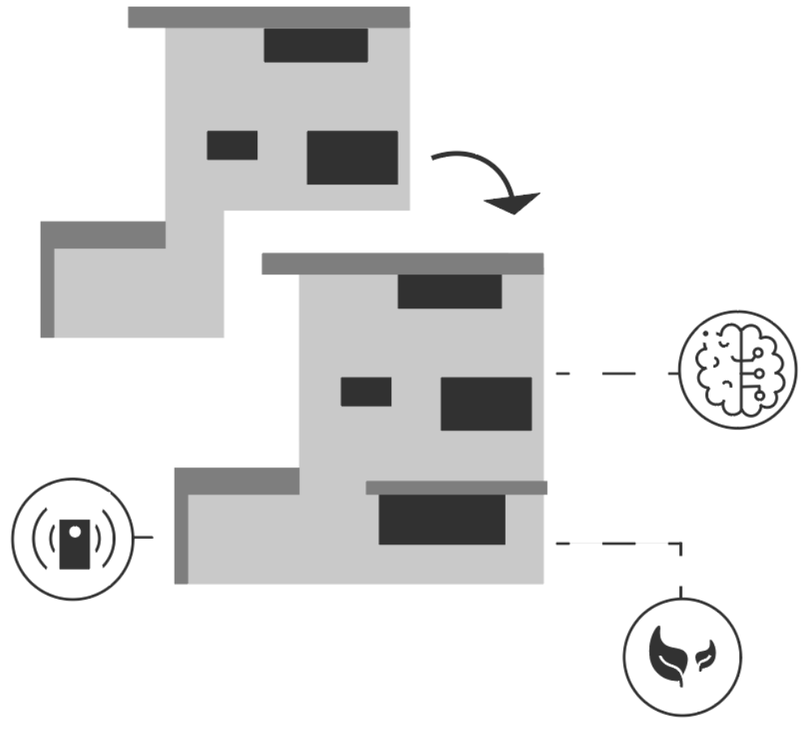
I Am HOME

Transforming an existing house into a smart house to provide for the well-being of its residents.



First Mentor:
Serdar Asut

Second Mentor:
Seyran Khademi

External Examiner
Dennis Pohl

P5 Presentation

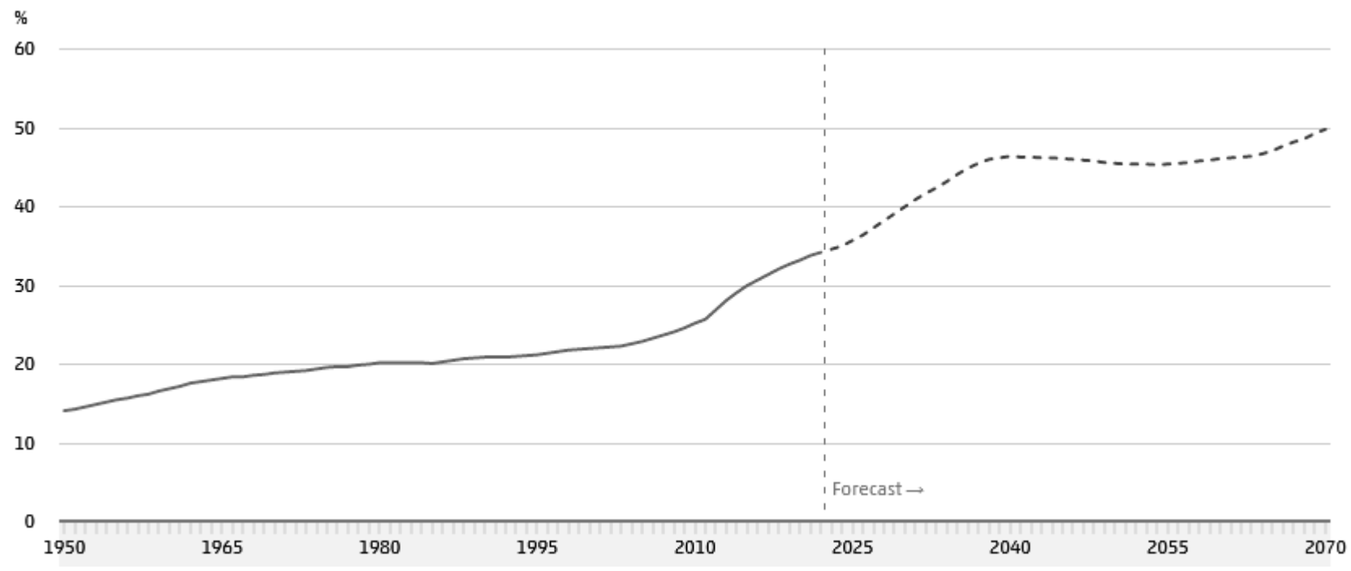
Lena Balakina
4592980

Introduction

Problem statement

Grey pressure

Numbers of over-65s relative to number of 20 to 64-year-olds



(CBS, n.d.)

Research Question

Main question: “How can a house be transformed into a smart house to improve the well-being of its residents using smart devices and the help of artificial intelligence?"

Research Question

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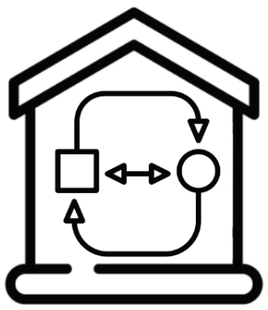
Sub Question 1: What is the state of the art regarding smart house devices and artificial intelligence used in the Built Environment?

Research Question

Main question: “How can a house be transformed into a smart house to improve the well-being of its residents using smart devices and the help of artificial intelligence?"



Sub Question 2: How can a smart house change the spatial relationship and function in a house?

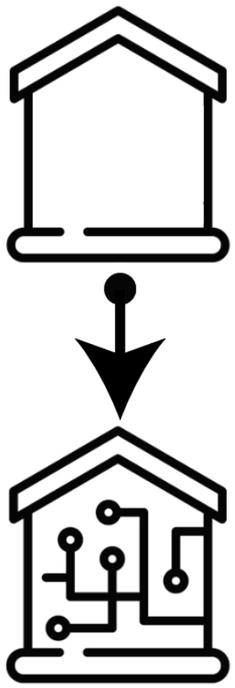
Research Question

Main question: “How can a house be transformed into a smart house to improve the well-being of its residents using smart devices and the help of artificial intelligence?"

Sub Question 3: How can these smart and intelligent devices be implemented in the transformation of a smart house, and how will the architectural qualities of the house change?

Research Question

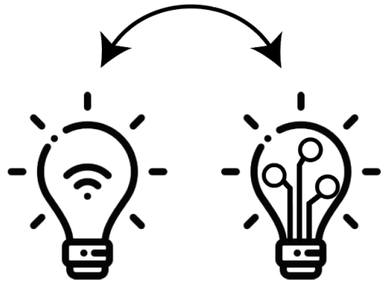
Main question: “How can a house be transformed into a smart house to improve the well-being of its residents using smart devices and the help of artificial intelligence?"

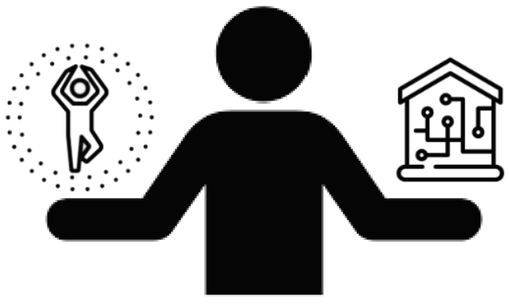


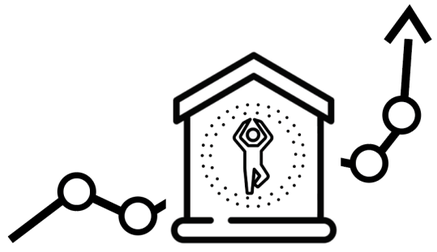
Sub Question 4: What are the steps to transform our current houses into smart houses?

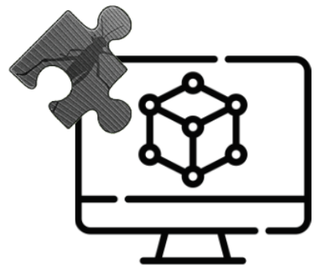
Introduction

Background Question









Background

Rushed modern life

Internet of Things

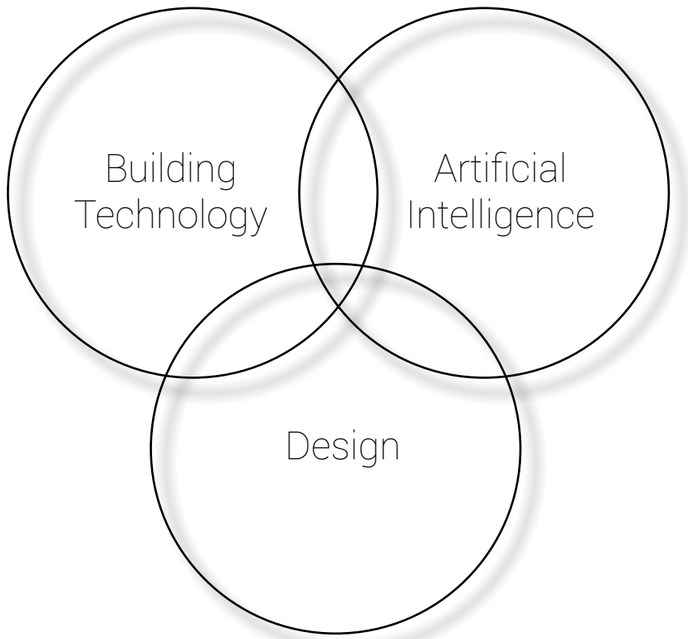
Expected annual growth +11.43%

(Statistica, n.d.)

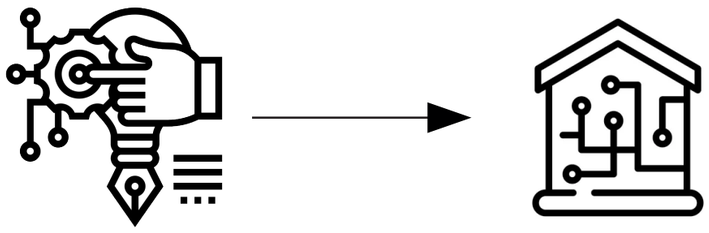
Artificial Intelligence

Introduction

Multidisciplinary



Smart home



Objectives

Main Objective: Transform an existing house into a smart house to provide for the well-being of its resident.

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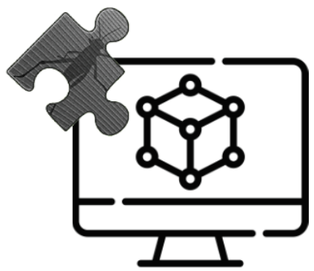
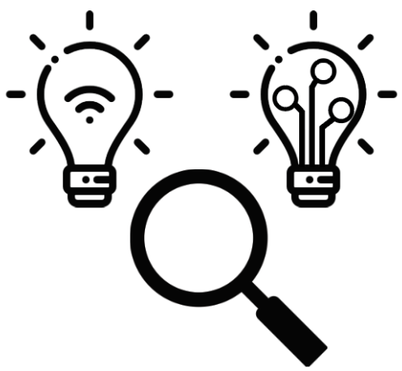


Sub Objective 1: Doing a simulation for this case study to measure the outcomes of the hypothetical transformation.

Objectives

Main Objective: Transform an existing house into a smart house to provide for the well-being of its resident.

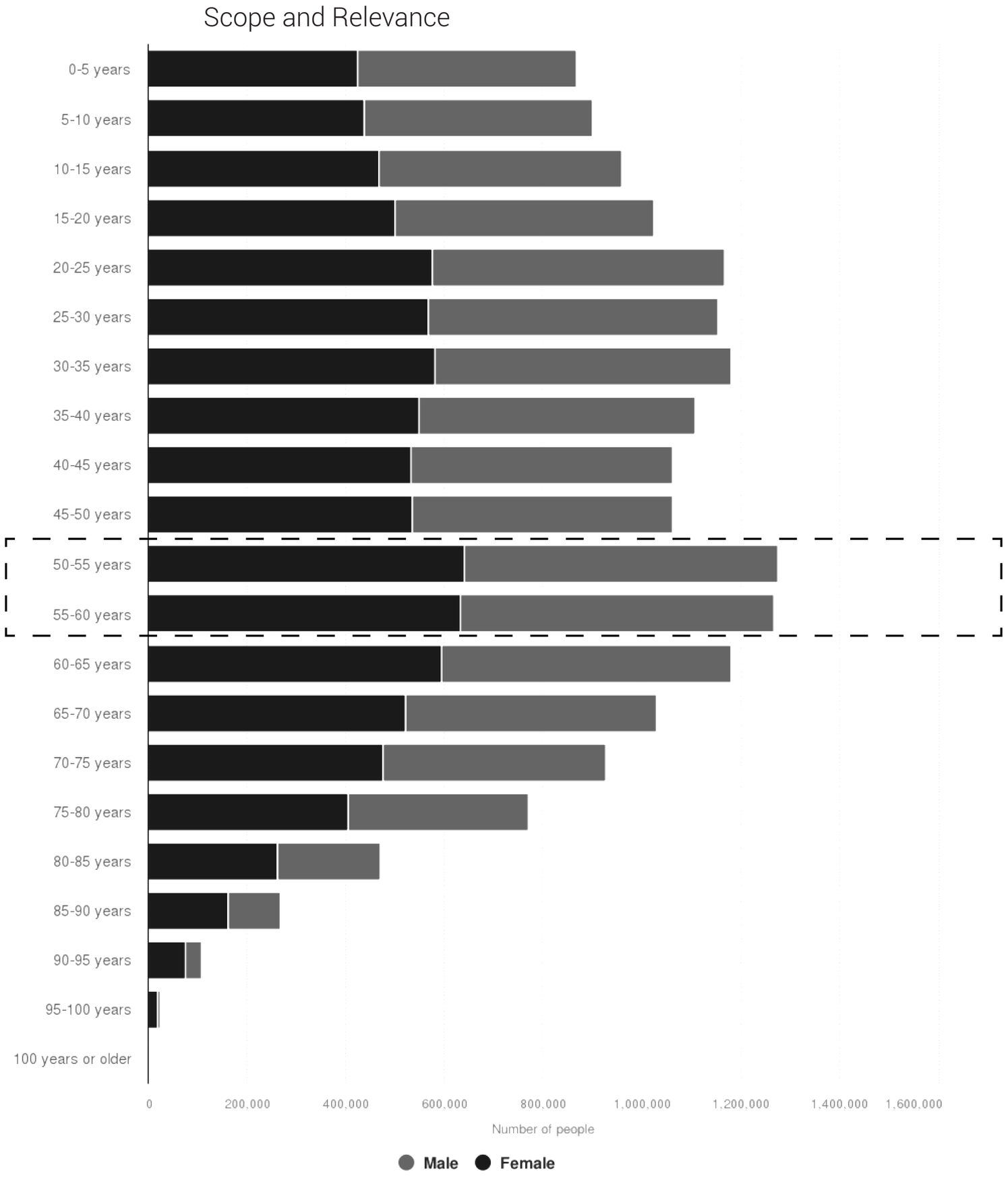


Sub Objective 2: Investigate the market and the state of the art of smart house devices, creating a list of the smart devices on the market and identifying the scale of how smart the devices are.

Objectives

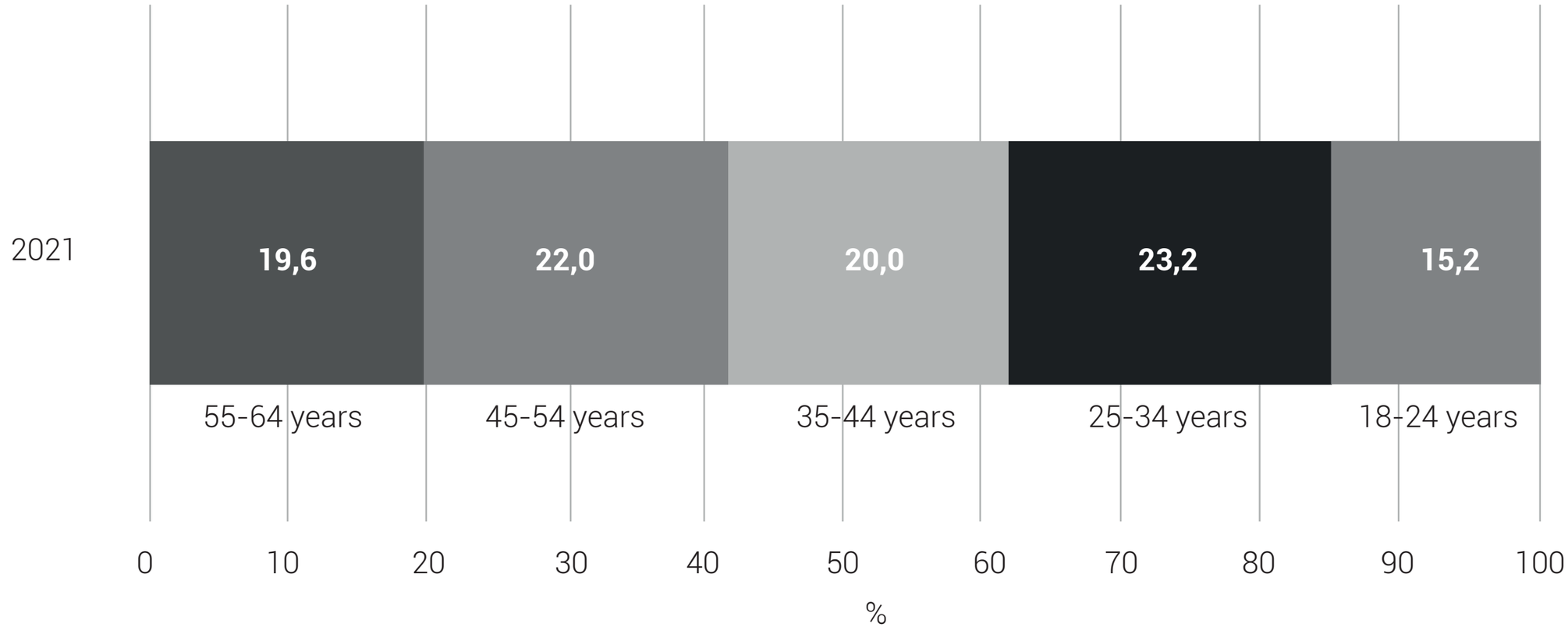
Main Objective: Transform an existing house into a smart house to provide for the well-being of its resident.

Sub Objective 3: Proposing a guideline to transform an existing house into a smart house.



Population of te Netherlands in 2023, by age and gender

Smart Home Users By Age - The Netherlands



(Statistica, n.d.)

Methodology

Literature Review including Market Analysis:
Exploration of current state of smart home devices and artificial intelligence in the Built Environment.

Case study:
House Analysis, Climate analysis, Design steps and Prototype
Façade drawings, floor planning, 3D modeling, and computational design.

Data Collection and Tools

Mixed-Method Approach

Qualitative data: Interview Smart Home Device company
Quantitative data: Simulations

Limitations

Generalization of the multidisciplinary

Health is a broad term and can be interpreted differently

Dependence on simulations carried out using Ladybug Tools, however real life outcomes may be more nuaced.

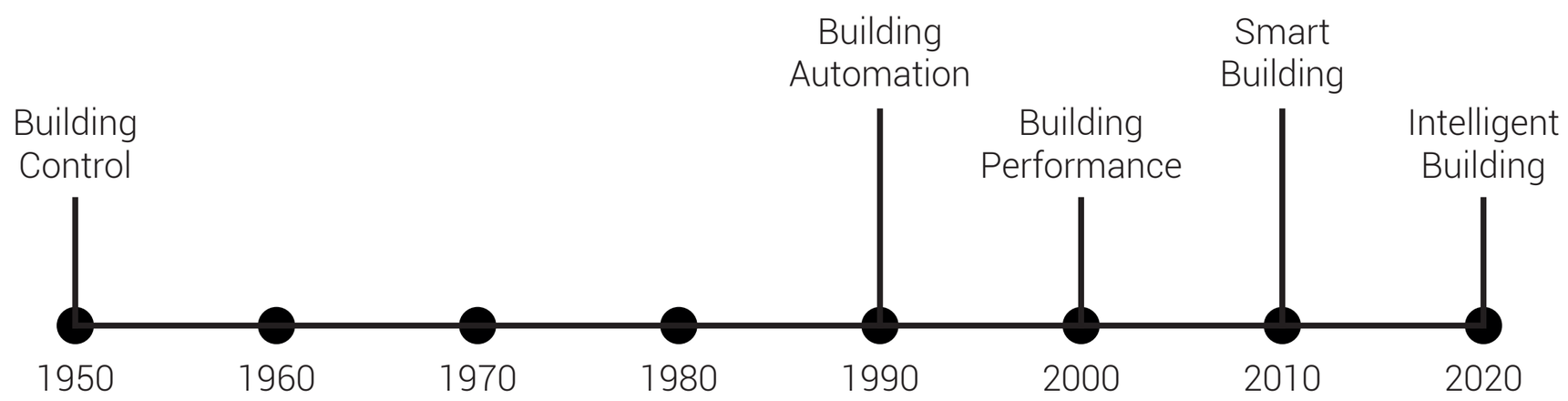
Rapid technical changes

Literature Review

State of the Art

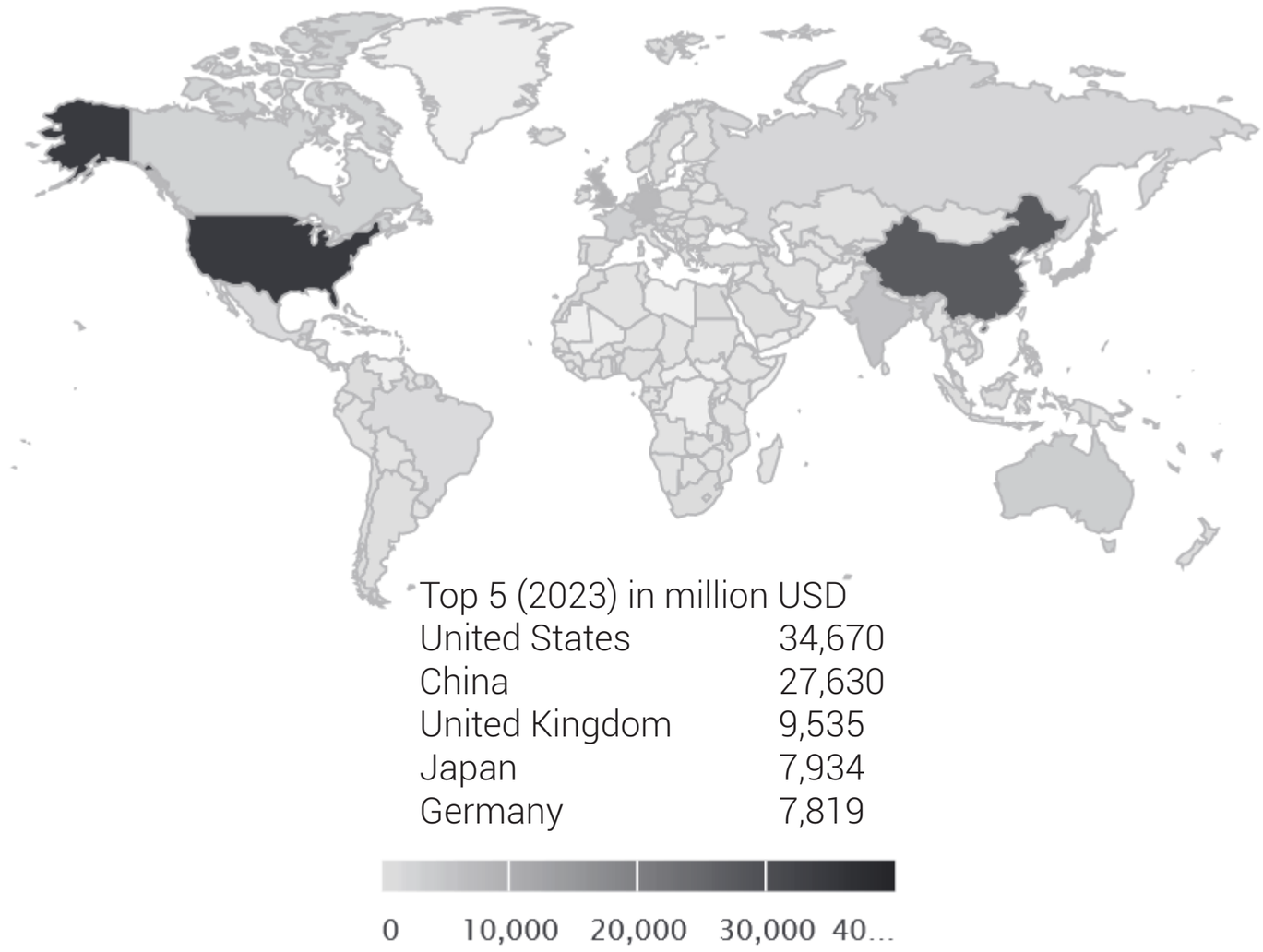
This evolution started with the rise of broadband internet, expanded with the widespread use of smartphones and apps, and has currently advanced to incorporate IoT and AI technologies. (H. Yang et al., 2018)

Intelligent buildings primarily consisted of automation systems rather than being truly intelligent systems. (Kaboli & Shirowzhan, 2021)

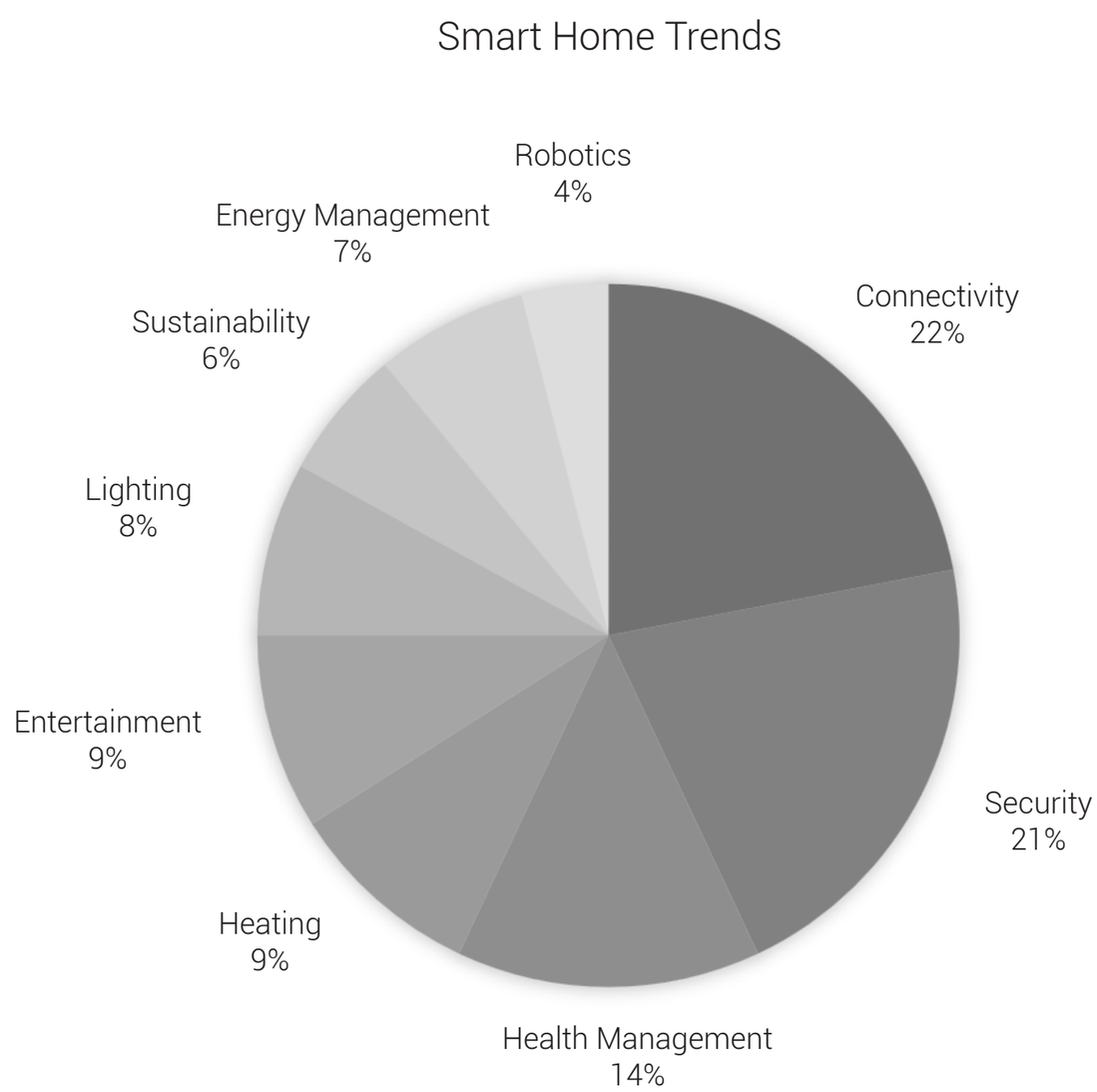


adapted from Kaboli & Shirowzhan (2021)

Smart Home Revenue Global Comparison



(StartUs Insights, n.d.)



(StartUs Insights, n.d.)

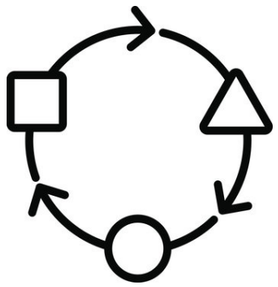
Difference between Smart and Intelligent

Smart buildings combine building elements with a focus on adaptability,
while intelligent buildings focus on reactive intelligence that utilizes information data.
(Buckman et al., 2014)

Smart = adaptable

Defined rules

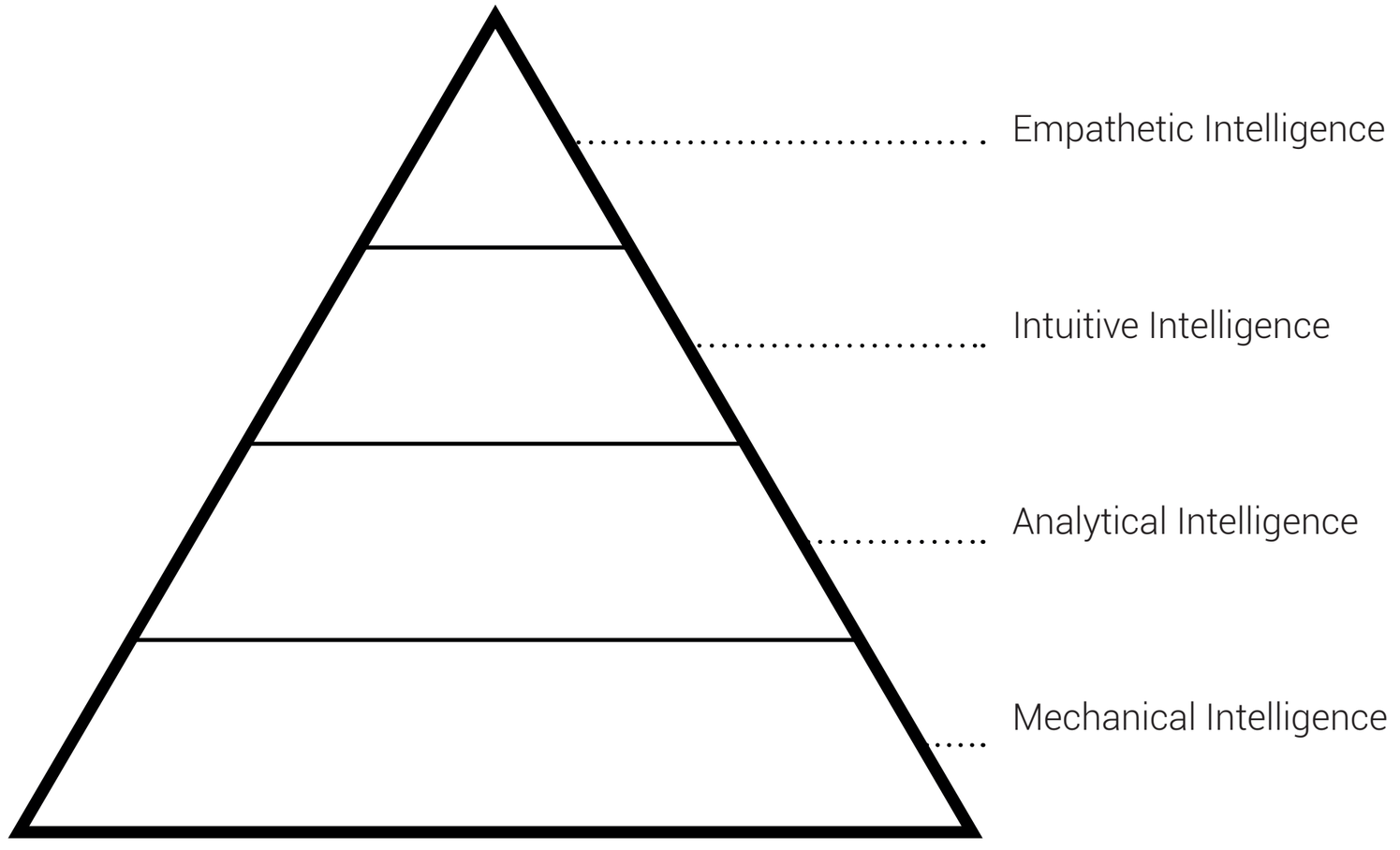
Intelligent = reactive



Understanding and
interpretation of data

(Kaboli & Shirowzhan, 2021)

Different levels of intelligence



Four categories according to Chi et al. (2020)

Well-being, Health and Indoor Comfort

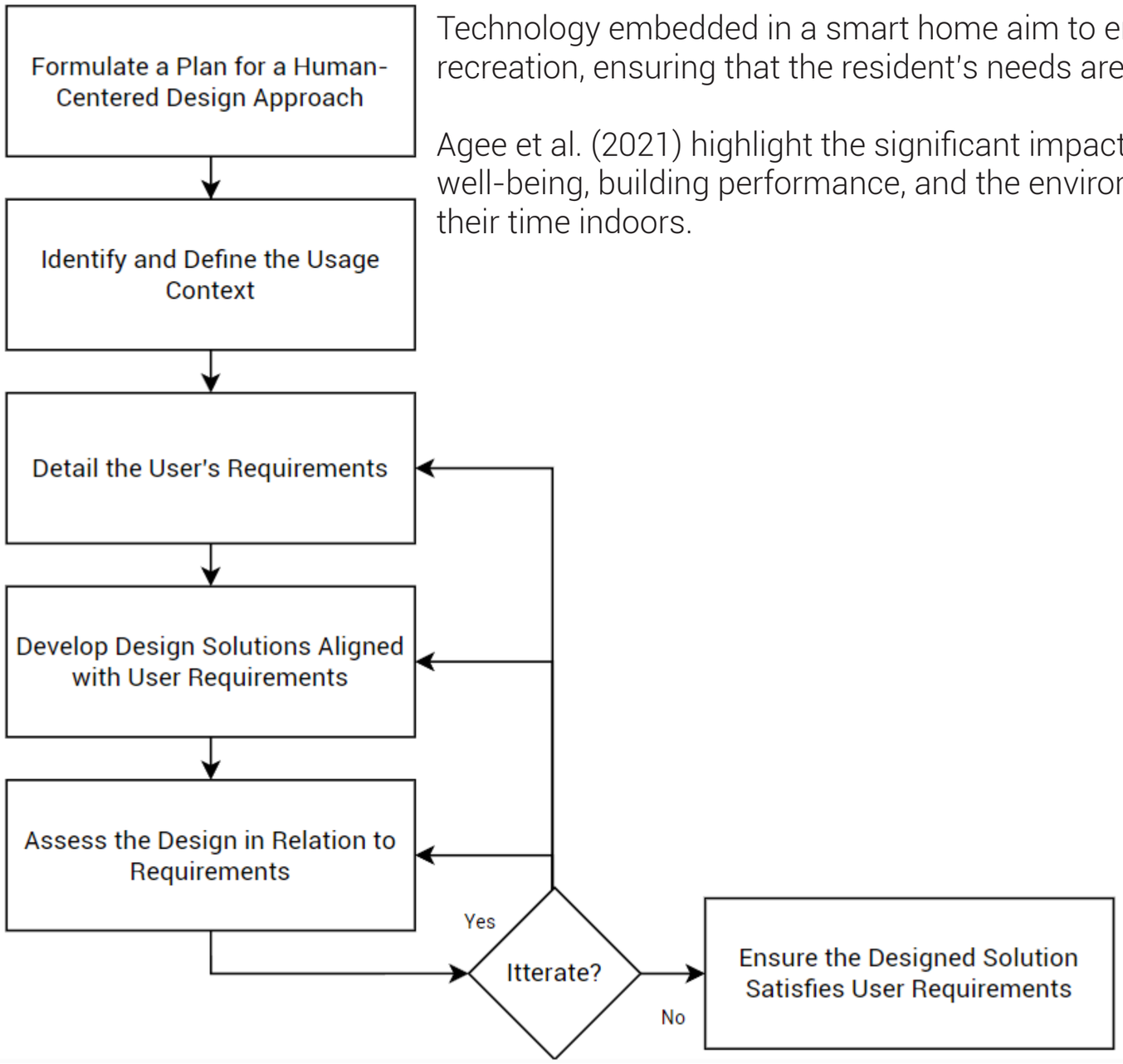
Five different domains of well-being (Ross et al., 2020)

1. Good ***health*** and optimum nutrition
2. Connectedness, positive values, and contribution to society
3. Safety and supportive environment
4. Learning, competence, education skills, and employability
5. Agency and resilience

Assessment class	Indoor Air Quality	Lighting	Thermal Comfort
Healthy	CO < 8 ppm CO2 < 550 ppm	lx > 110	118.5≤ Air Temp. ≤ 24.5 °C 43 ≤ Relative Humidity ≤ 47% Airspeed < 0.45 m/s
Uncertain	CO < 10 ppm 550 ≤ CO2≤ 650 ppm	90 ≤ lx ≤ 110	17.5≤ Air Temp. ≤ 18.5 °C 37 ≤ Relative Humidity ≤ 43% 67 ≤ Relative Humidity ≤ 73% 0.45 ≤ Airspeed ≤ 0.55 m/s
Non-Healthy	CO > 10 ppm CO2 > 650 ppm	lx < 90	Air Temp. < 17.5 °C Air Temp. > 25.5 °C Relative Humidity < 37% Relative Humidity > 73%

(Heinzerling et al., 2013)

Smart Home Transformations



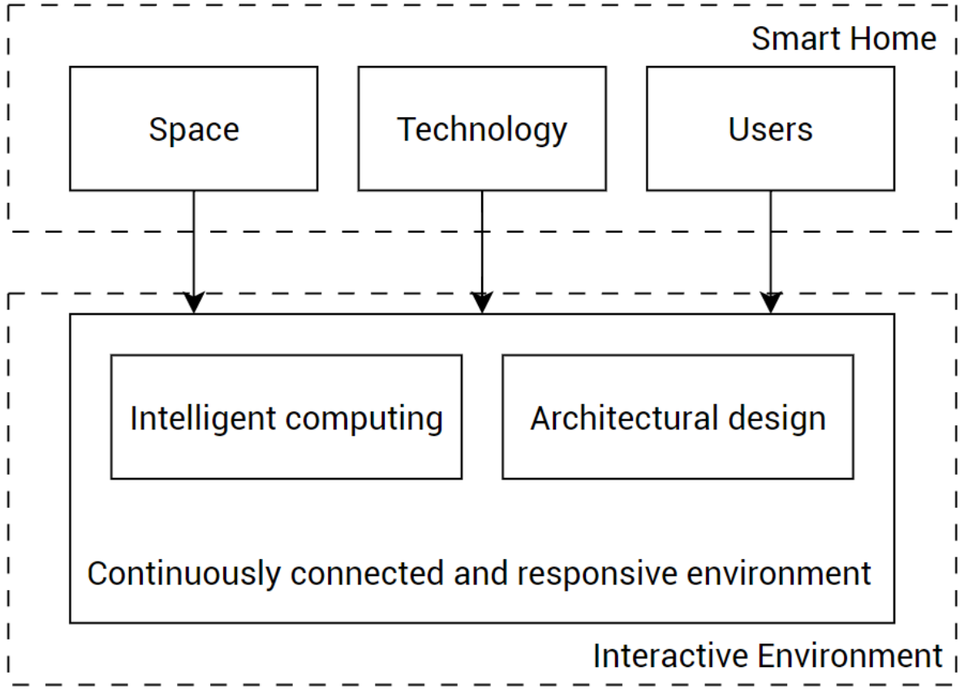
Technology embedded in a smart home aim to enhance human use, comfort, and recreation, ensuring that the resident's needs are at the forefront of the design process.

Agee et al. (2021) highlight the significant impact of human-building interactions on well-being, building performance, and the environment, noting that people spend most of their time indoors.

Smart Home Domain

Kim et al. (2020) created a framework addressing three critical aspects of smart homes: space, technology, and users.

The goal is to merge intelligent computing and architectural design, resulting in continuously connected, responsive environments that offer essential residential services tailored to inhabitants.



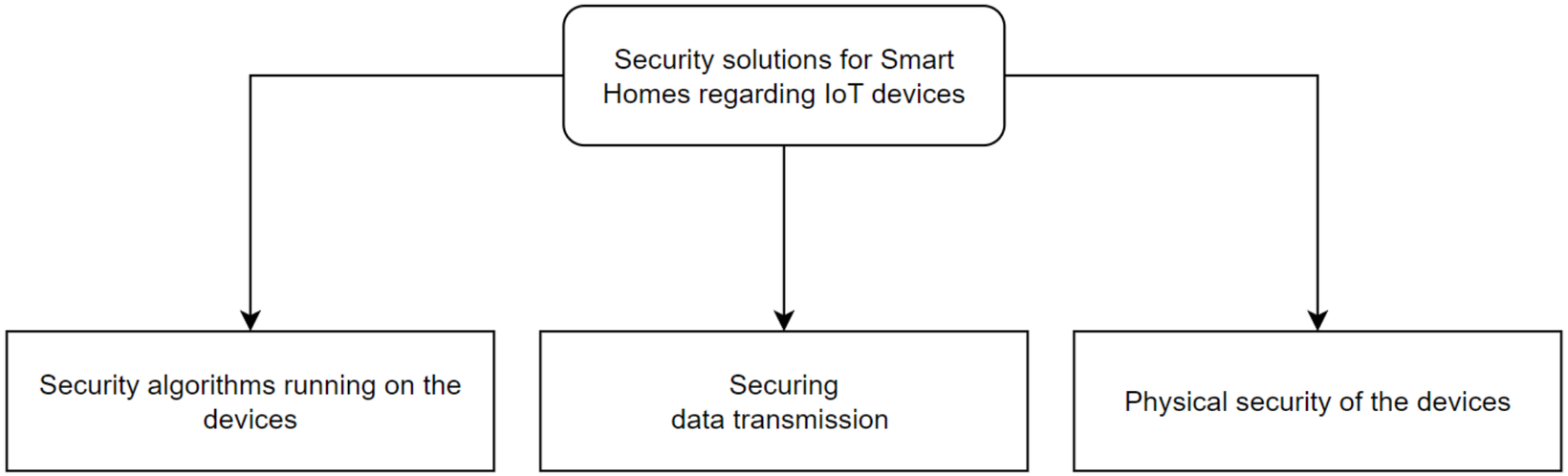
Privacy and Security Concerns

Challenges and issues associated with implementing smart home safety and security systems are, according to Sarhan (2020):

- Physical attacks
- Device failure
- Power outage
- Internet outage
- Software compatibility
- Security threads

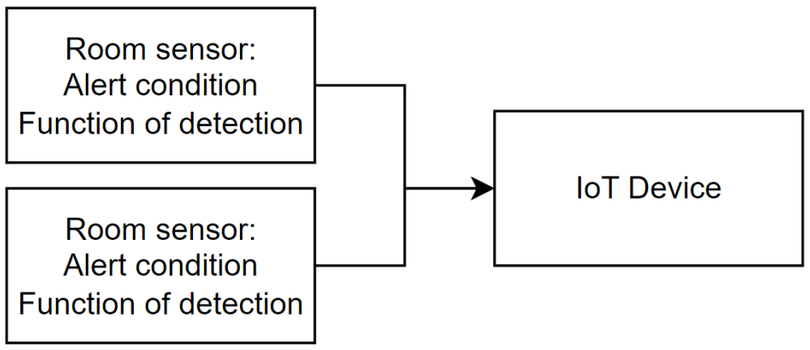
Security Solutions

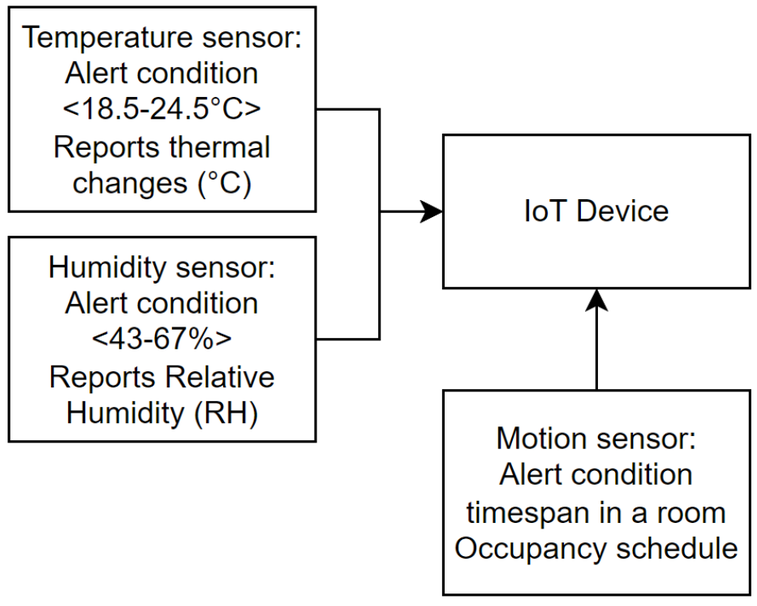
Three security solutions smart homes for IoT devices according to (Lin & Bergmann, 2016)



Security Solutions for the resident in a Smart Home

Sensor devices communication with IoT devices
(Suzuki et al., 2018)





Market Analysis

Smart Home Devices and categorization

Smart Home Technology Classification			
Daily Living Environment and Quality of Life	Residential Security	Activity Monitoring (CCTV)	
		Threat and Intrusion Monitoring	Door
			Window
		Carbon Monoxide Alarm (co)	
		Water Flooding Alarms	
		Intelligent Electronic Door Lock	
		GPS	
	Environmental Renovation	Smart Workspace Renovation	
		Smart Bedroom	
		Kitchen	
		Restroom	
Energy Management, Sustainability and Indoor Comfort	Environment Detection (automation)	Indoor Air Quality	
		Light Control	
		Temperature Control	
		Humidity Control	
		Ventilation Control	
	Energy-saving control system	Electrical Control -on/off	
	Energy Monitoring	Visualization	
Healthcare and Life Security	Wearable Devices	Fall Detection	
		Abnormal Behavior Detection	
		Gait Analysis	
		Emotion Recognition	
		Behavior Change Detection	Sleep
			Eating
			Medicine
			Blood Sugar
			Heart Rate
			Temperature
	Non-wearable Devices	Fall Detection	
		Telemedicine	
Social Contact and Entertainment	Integrating Face Recognition		
	Speech Control System		
	Gesture Control System		
	Socially Assistive Robot		
	Virtual Reality (VR) and Augmented Reality (AR) Device		

(Liao et al., 2023)

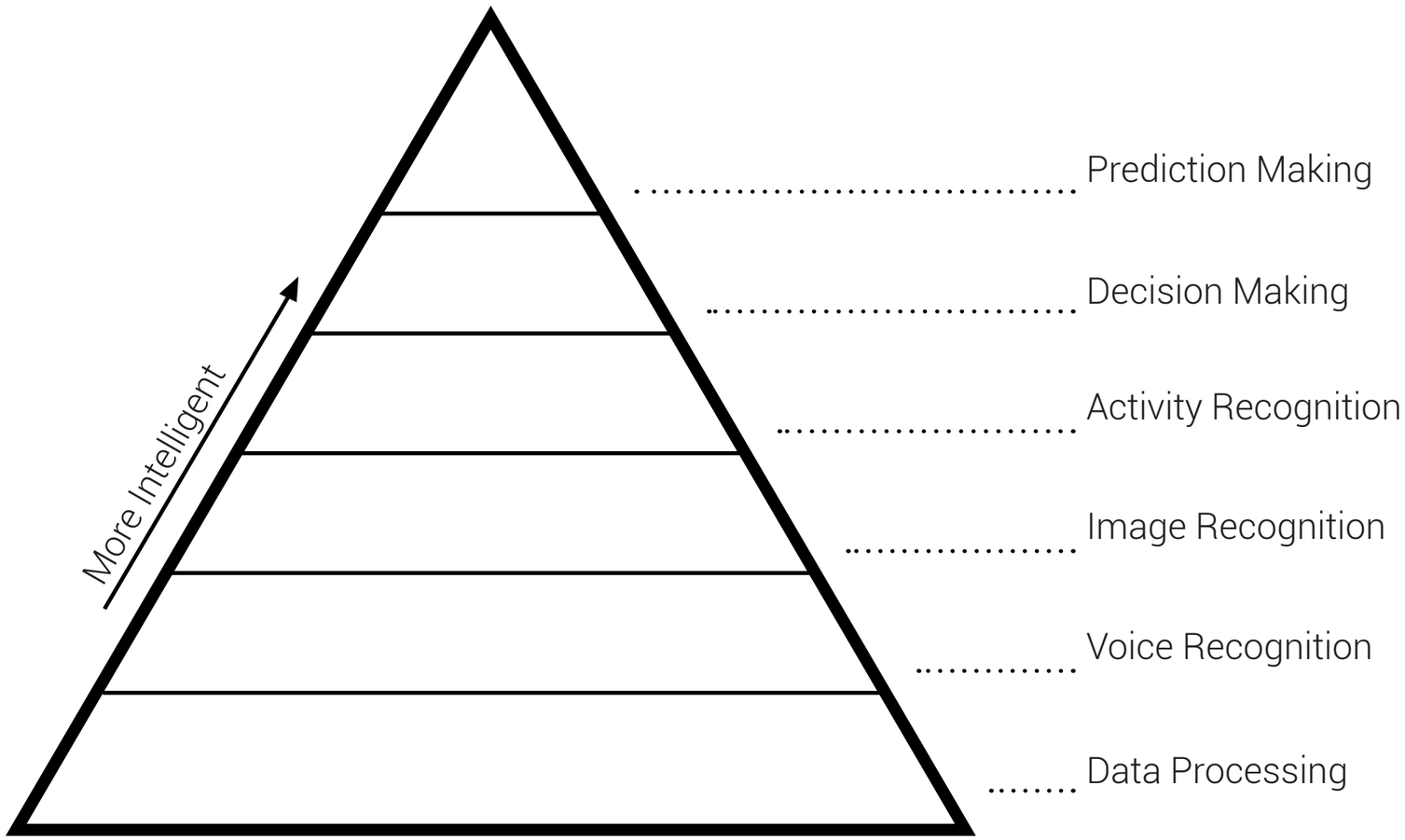
Intelligent Devices

Core clusters according to Guo et al. (2019):

1. Device management
2. Energy management
3. Healthcare
4. Intelligent interaction
5. Security

Automation (mechanical intelligence)	Weak AI (analytical intelligence)	Strong AI (intuitve intelligence)	Affective AI (empathetic intelligence)
Rulebase Performing routine Performing a speciic task	Solving problems Answering questions Using algorithms	Thinking creatively Able to adjust Learn from mistakes	Able to recognize, under-stand and influence Experiences things Emotional intelligence

Artificial Intelligence within Smart Devices

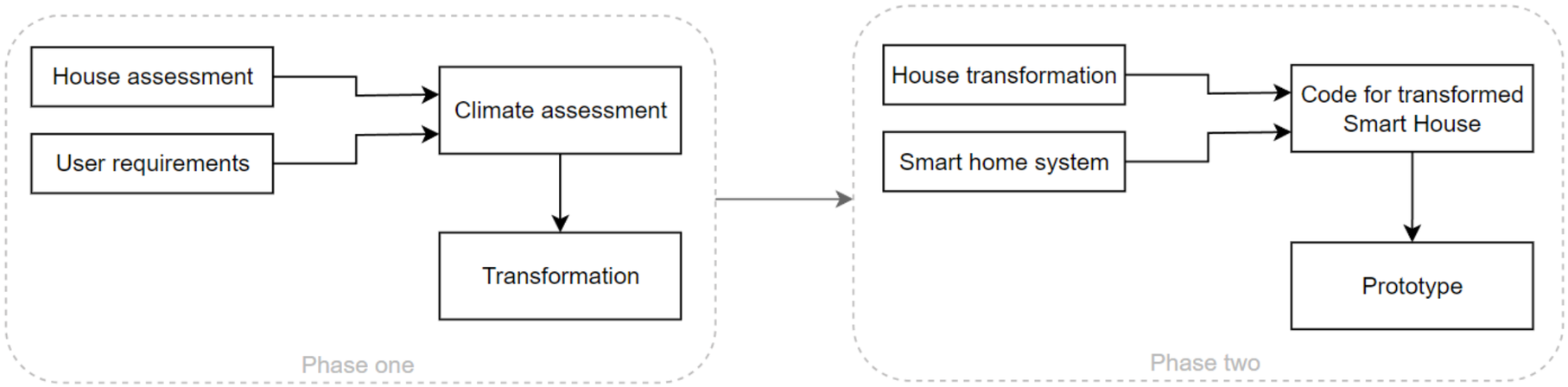


According to Chi et al. (2020)

Case Study

Case study

Design approach



Case study


Fluitenberg
A28
Vliegveld Hoogeveen
Oude Diep
Ziekenhuislocatie
Bethesda (Treant)
Hoogeveen
Industriehaven
1.
2.
3.
4.
5.
6.
11.
12.
13.
14.
15.
16.
Bentinckspark
Schutlanden
Scholenpark
19.
7.
8.
9.
17.
18.
Hoogeveensche
Vaart
10.
ERFLANDEN
E233
A37
N48
N


Case study location
Speeltuin
Hoogeveensche
Vaart
Speeltuin
Speeltuin Edelhert
Speelveld Damhert
Mondzorg Hoogeveen
Het Vlinderplateau
Speeltuin
Speeltuin Eekhoorn
Speeltuin Sleedoornpage
Waterpartij
Erflanden
E233
A37
A28
N40
N

Case study

House

(GoogleMaps, n.d.)

Ground Floor

First Floor

Second Floor

Adapted from Funda (n.d.)

List of requirements based on ***hypothetical*** resident

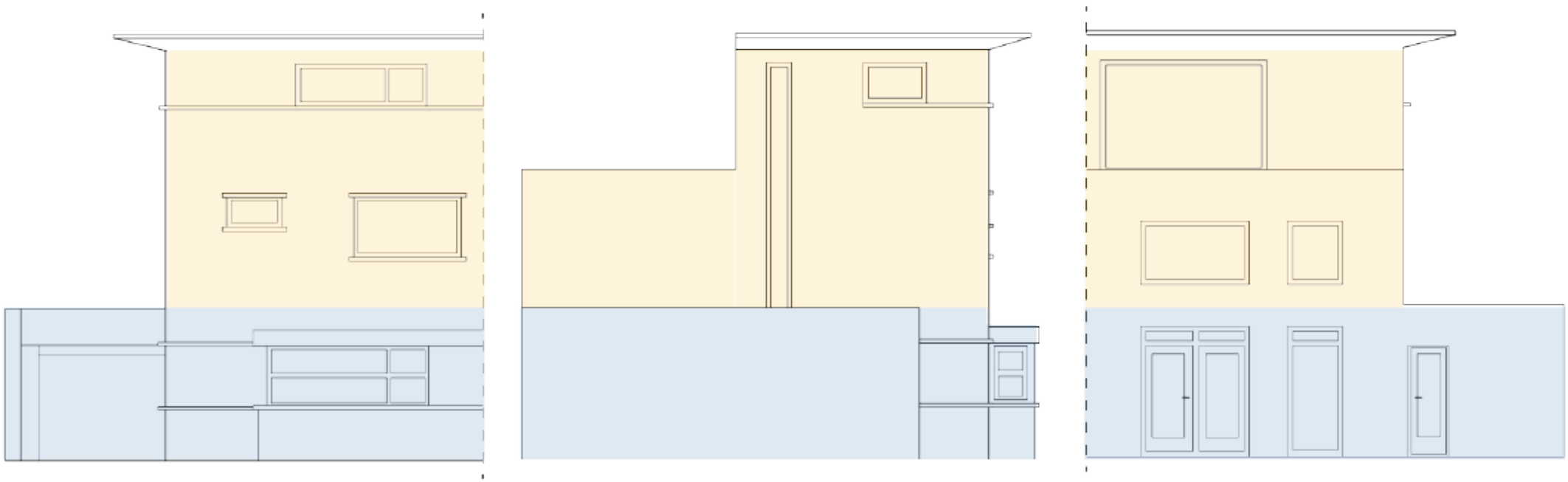
Case study

Resident type	Character	Physical ability and health condition	Living and activities
Middle-aged resident	60 year-old resident, working, living alone.	Has a history of illness, has been concerned about his health, and feels lonely.	Not used smart devices but is open to learning it. Works fulltime

Issues	Low physical activity Social isolation Low strength and tires easily
Need	Family interaction Social implication Health care and consultancy Automation of daily routines
Technical Solution Function	Health care and management Recognizing crisis Assistance Activity tracking and alarm Health check and care smart device Indoor comfort
Devices	Voice talker/secretary Virtual trainer Smart home devices for tracking the indoor enviornment
Spatial solution Unit and design	Personal exercise space Remote workspace Meeting space
Common space	Exercise space Rest area Health measurement space

House analysis

Social - private analysis



North facade

East facade

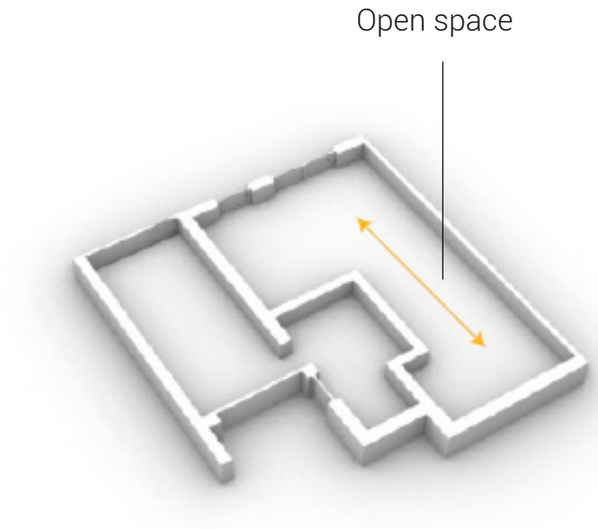
South facade

Private areas

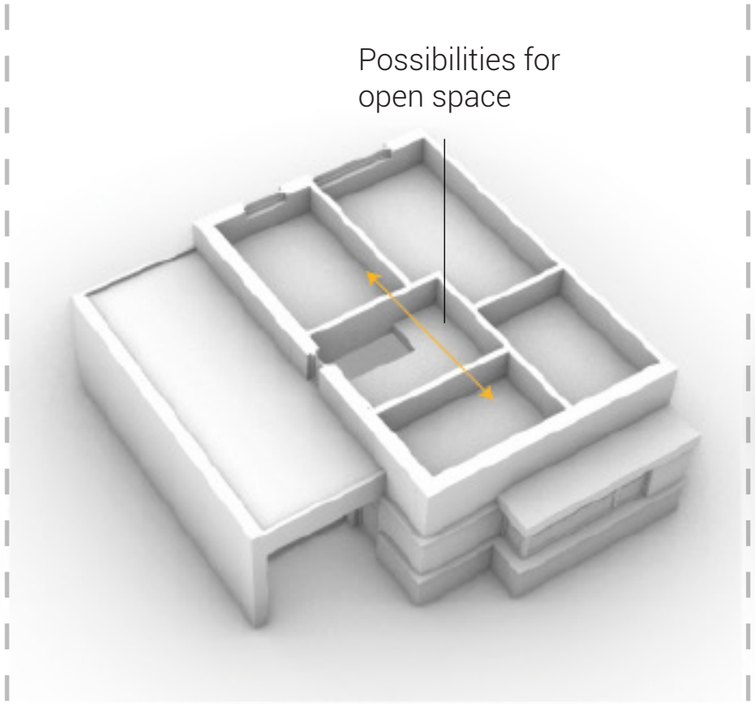
Social areas

Case study

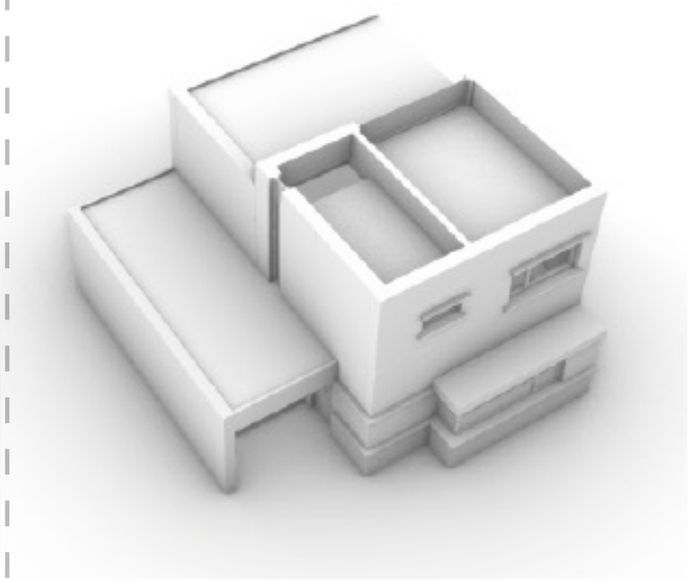
House analysis



Ground floor



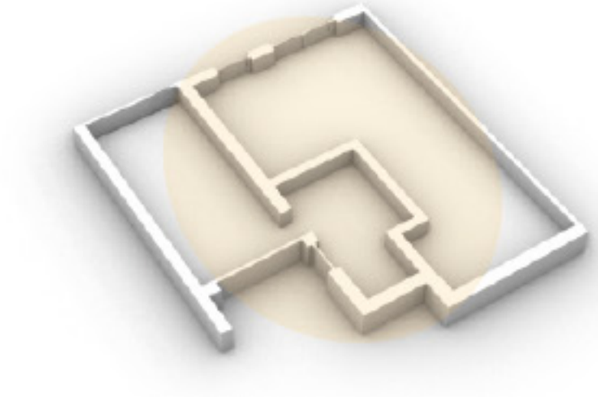
First floor



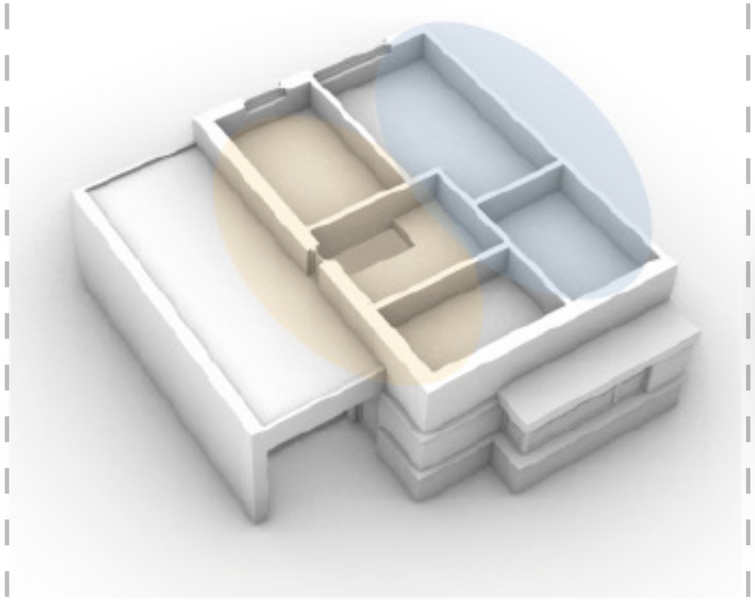
Second floor

Case study

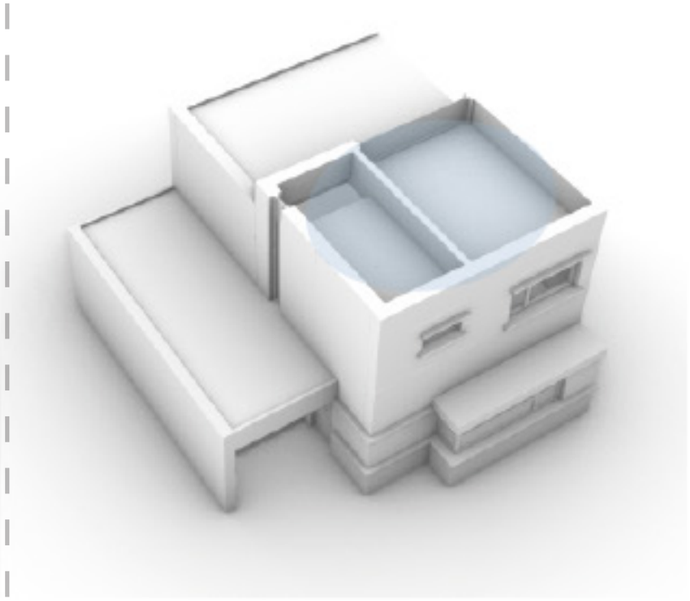
House analysis



Ground floor



First floor



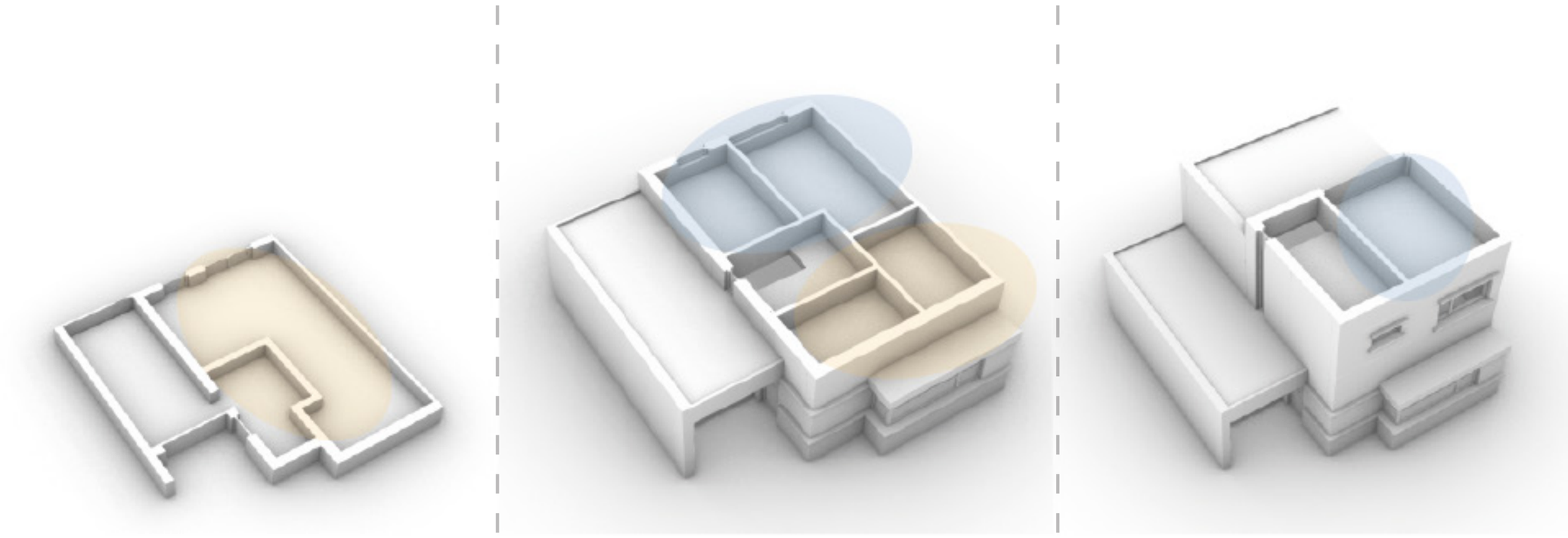
Second floor

High-traffic areas

Low-traffic areas

Case study

House analysis



Ground floor

First floor

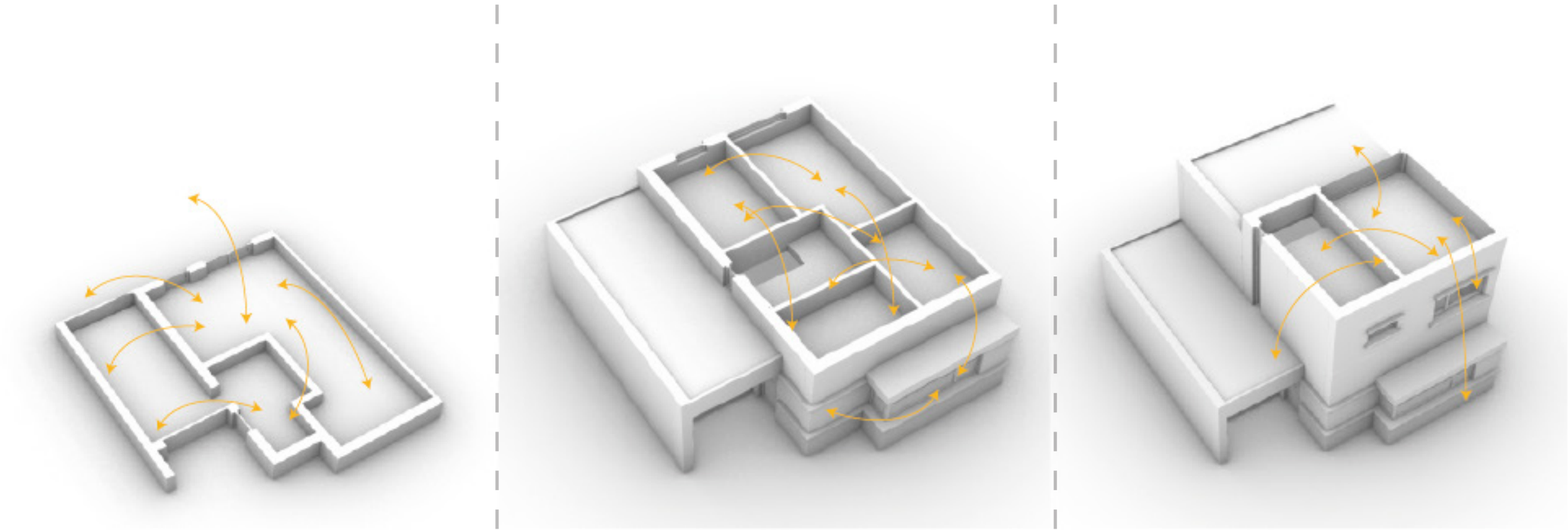
Second floor

Daytime areas

Nighttime areas

Case study

House analysis potential



Ground floor

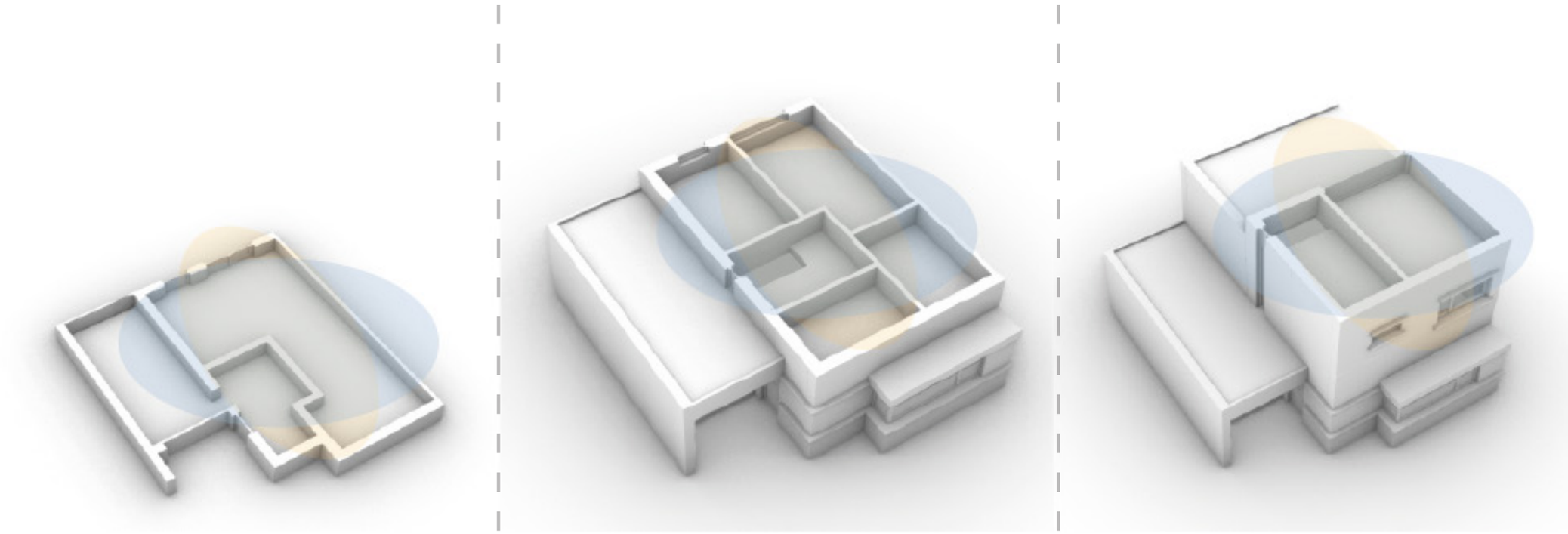
First floor

Second floor

Spatial dyamics smart home

Case study

House analysis potential



Ground floor

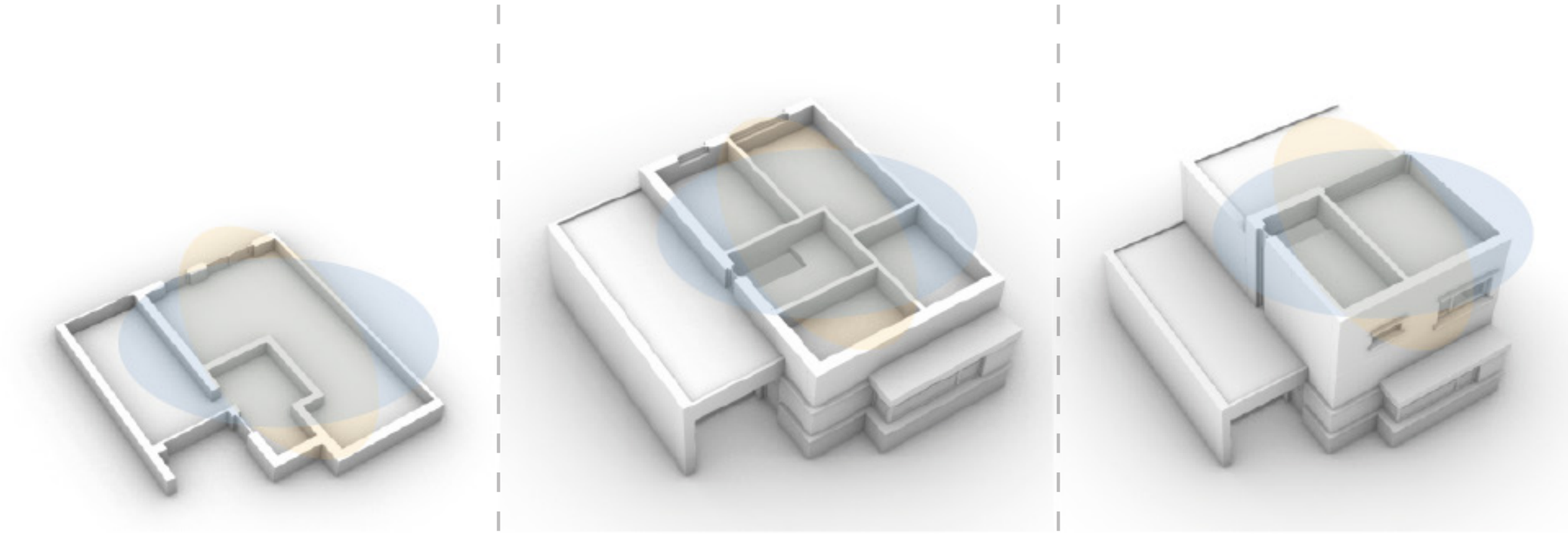
First floor

Second floor

Day- and nighttime areas smart home

Case study

House analysis potential



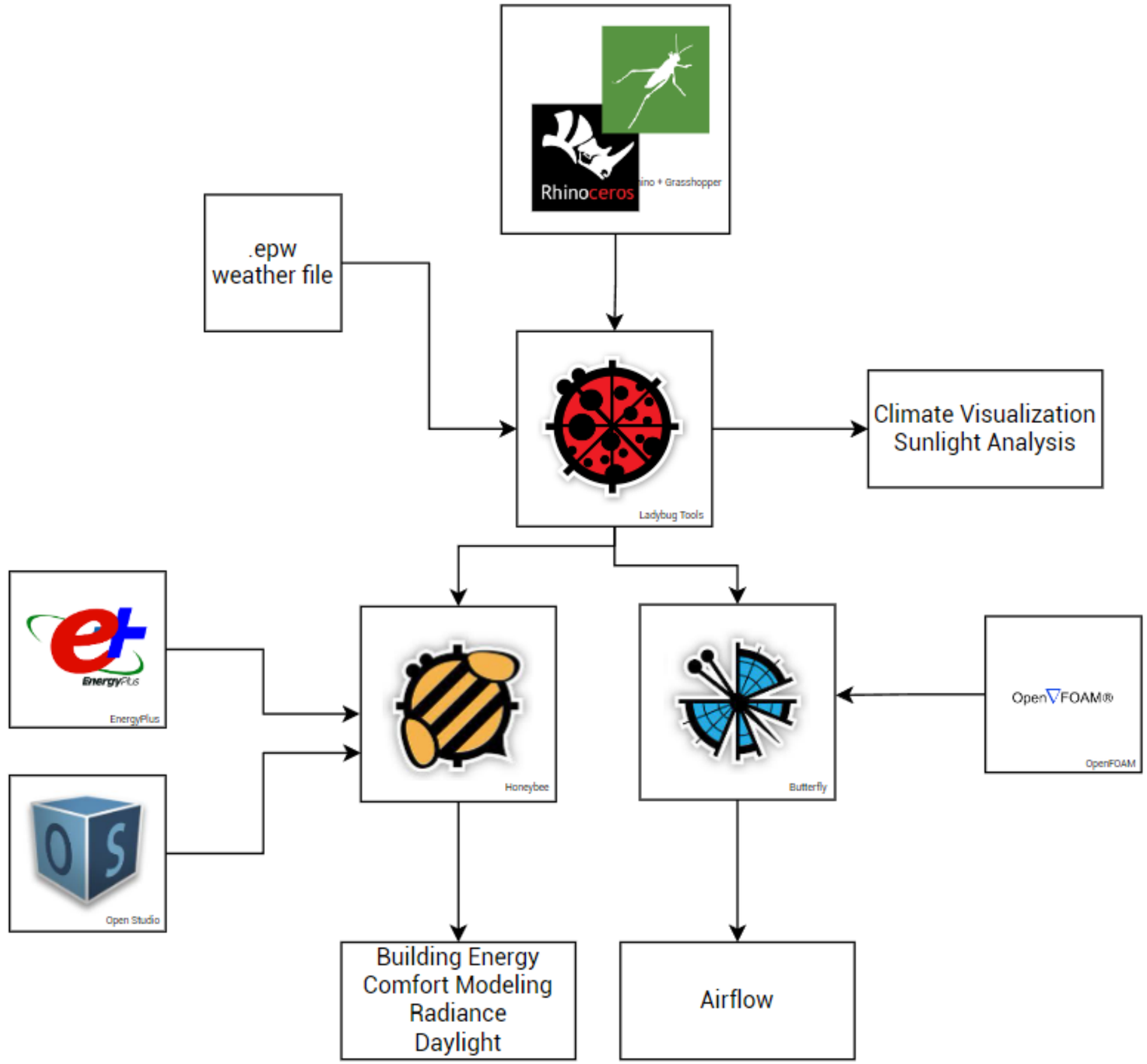
Ground floor

First floor

Second floor

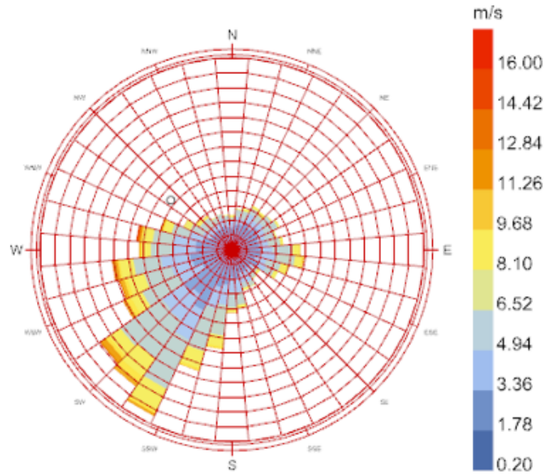
Optimal use of the smart home

Case study



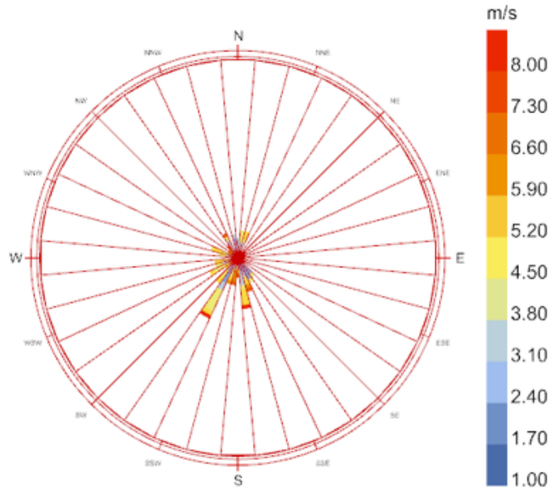
Workflow Climate Analyses

Case study



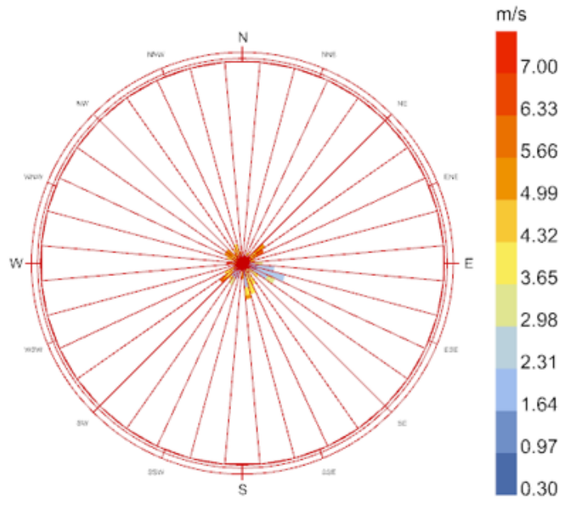
Wind Speed (m/s)
city: Hoogeveen
country: NLD
time-zone: 1.0
source: SRC-TMYx
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 1.13% of the time = 99 hours.
Each closed polyline shows frequency of 0.6% = 50 hours.

Average yearly windspeed



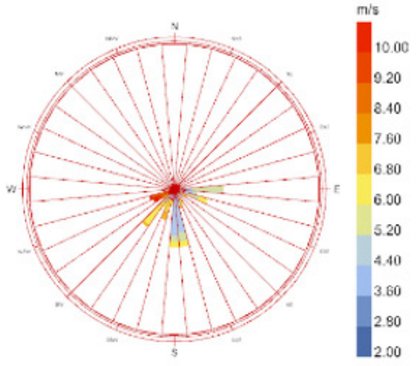
Wind Speed (m/s)
city: Hoogeveen
country: NLD
time-zone: 1.0
source: SRC-TMYx
period: 1/13 to 1/19 between 0 and 23 @1
Calm for 0.0% of the time = 0 hours.
Each closed polyline shows frequency of 29.8% = 50 hours.

Coldest week



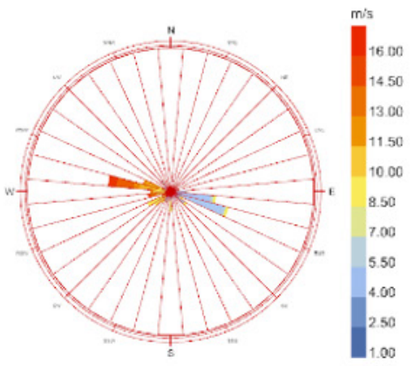
Wind Speed (m/s)
city: Hoogeveen
country: NLD
time-zone: 1.0
source: SRC-TMYx
period: 8/24 to 8/30 between 0 and 23 @1
Calm for 2.38% of the time = 4 hours.
Each closed polyline shows frequency of 30.5% = 50 hours.

Hottest week



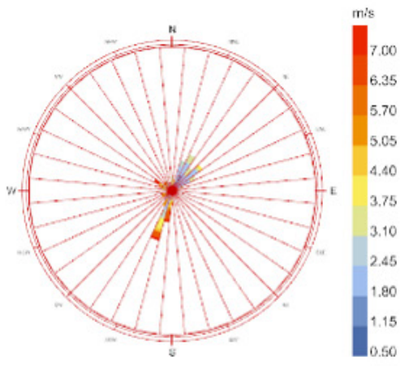
Wind Speed (m/s)
city: Hoogeveen
country: NLD
time-zone: 1.0
source: SRC-TMYx
period: 1/6 to 1/12 between 0 and 23 @1
Calm for 0.0% of the time = 0 hours.
Each closed polyline shows frequency of 29.6% = 50 hours.

Winter



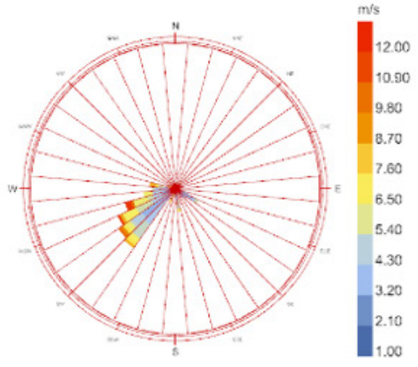
Wind Speed (m/s)
city: Hoogeveen
country: NLD
time-zone: 1.0
source: SRC-TMYx
period: 3/29 to 4/4 between 0 and 23 @1
Calm for 1.19% of the time = 2 hours.
Each closed polyline shows frequency of 30.1% = 50 hours.

Spring



Wind Speed (m/s)
city: Hoogeveen
country: NLD
time-zone: 1.0
source: SRC-TMYx
period: 7/20 to 7/26 between 0 and 23 @1
Calm for 0.6% of the time = 1 hours.
Each closed polyline shows frequency of 29.9% = 50 hours.

Summer

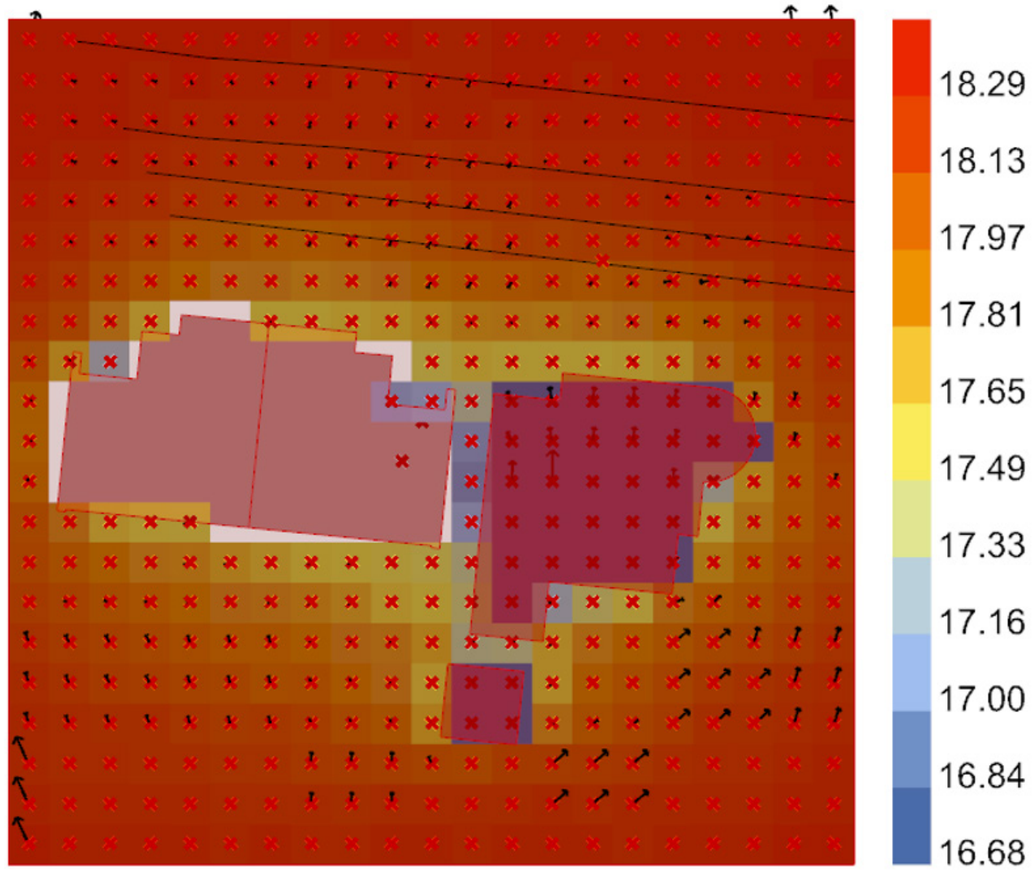


Wind Speed (m/s)
city: Hoogeveen
country: NLD
time-zone: 1.0
source: SRC-TMYx
period: 10/27 to 11/2 between 0 and 23 @1
Calm for 0.6% of the time = 1 hours.
Each closed polyline shows frequency of 29.9% = 50 hours.

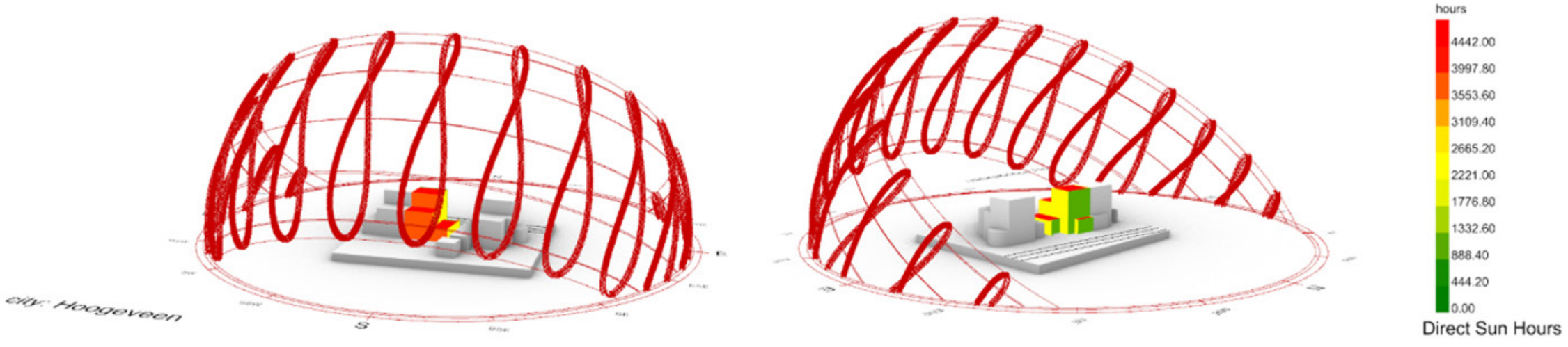
Autumn

Windrose location

Case study



Outdoor wind analysis

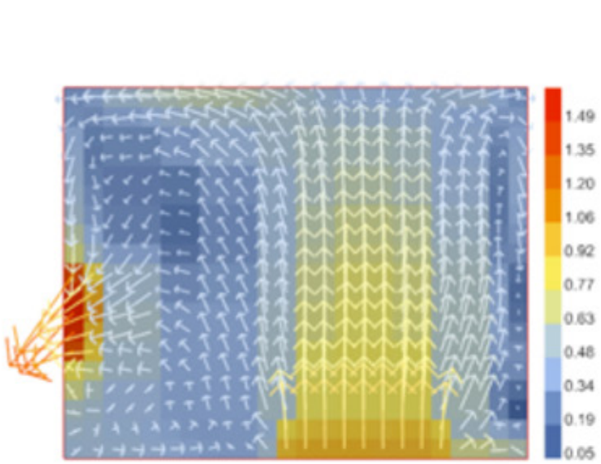


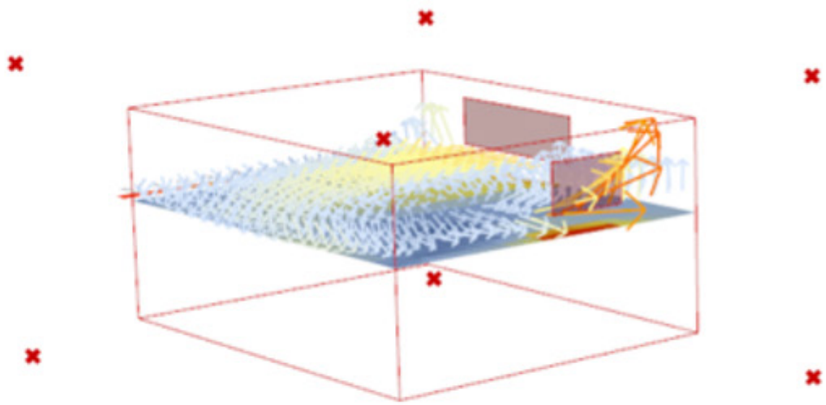
Outdoor sun hour analysis

Case study

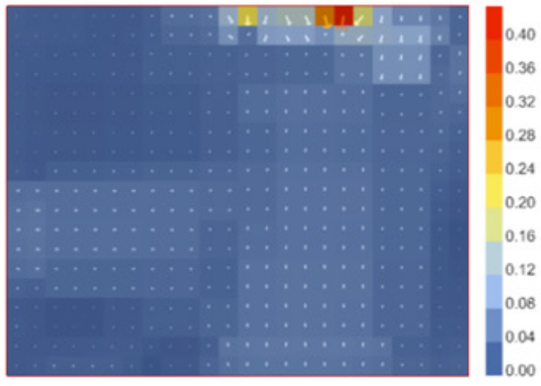
Climate analysis

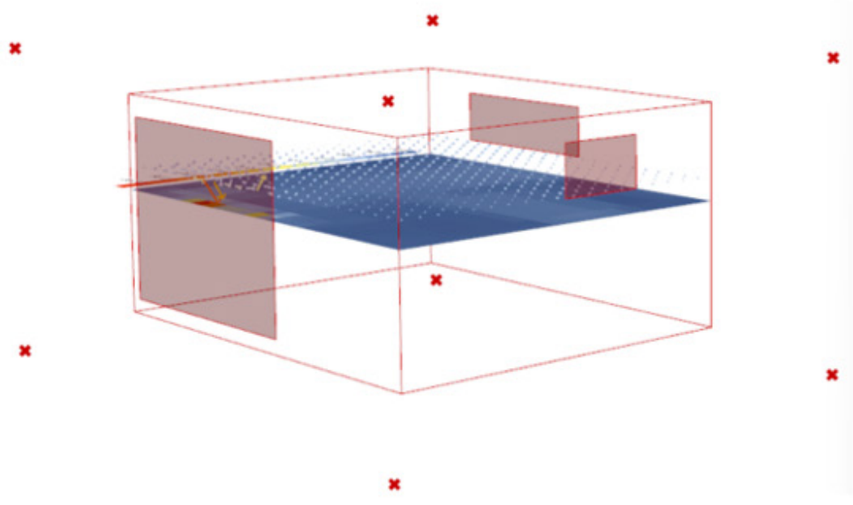
Wind analysis and heatmap closed south side window



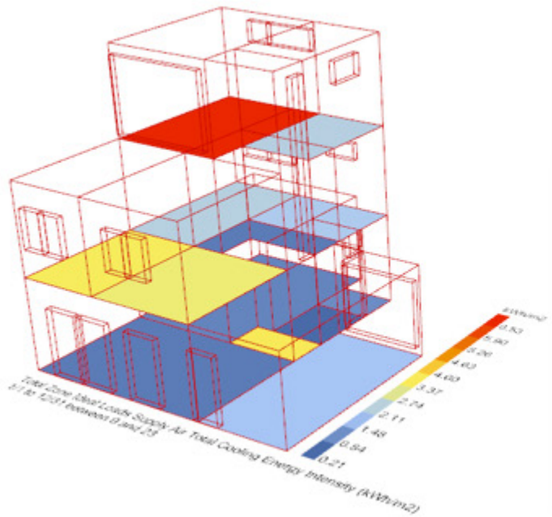


Wind analysis and heatmap open south side window

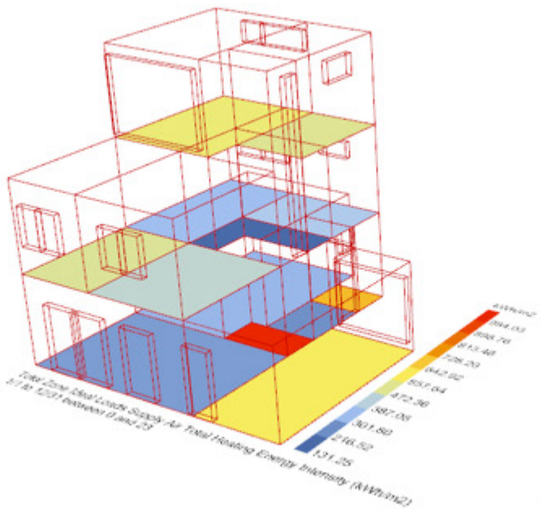




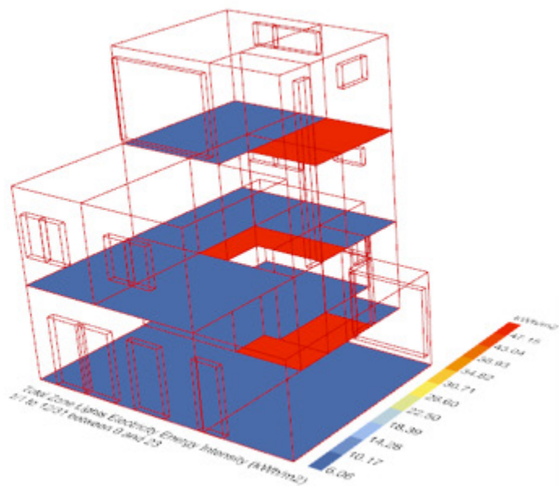
Energy analysis



Cooling Energy Intensity



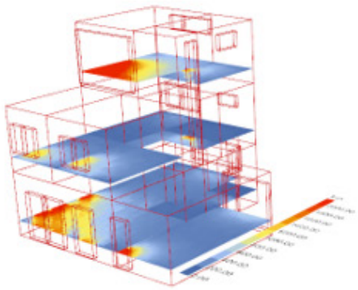
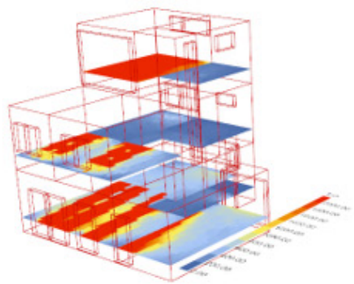
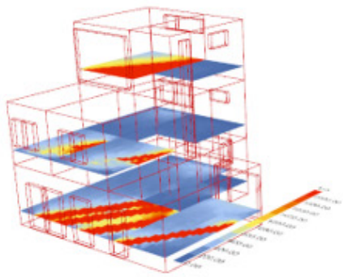
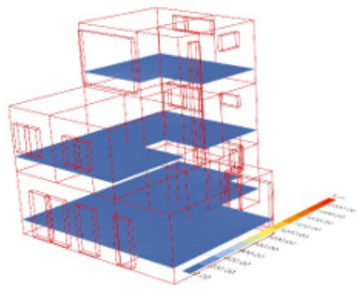
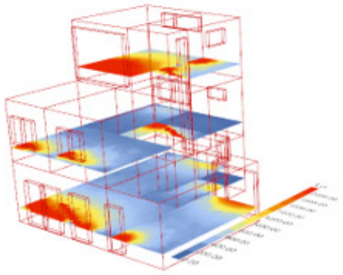
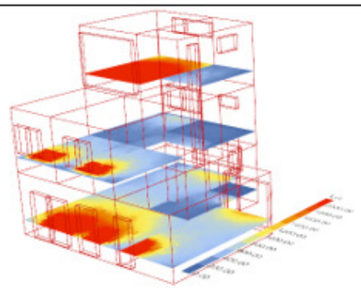
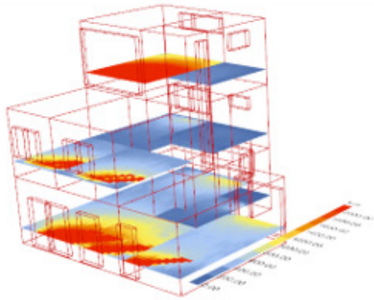
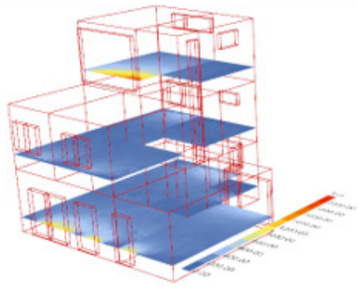
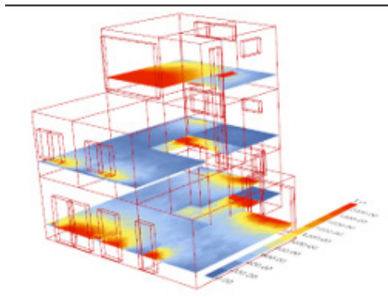
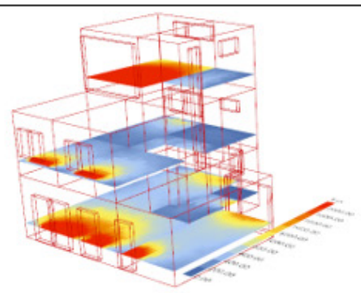
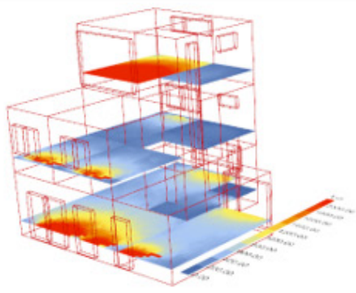
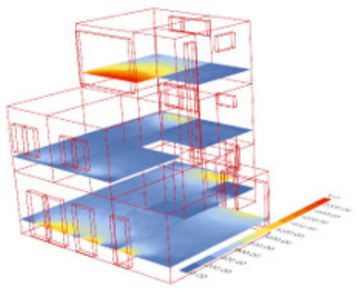
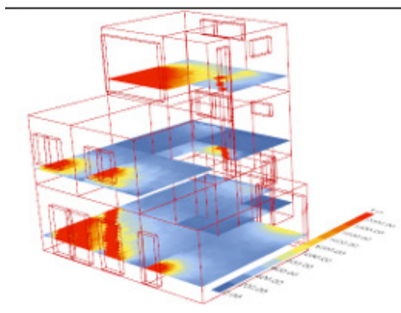
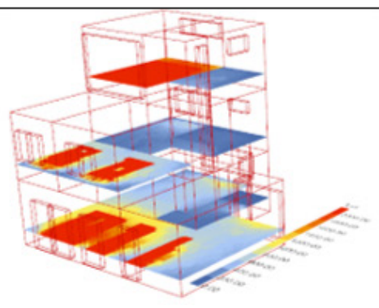
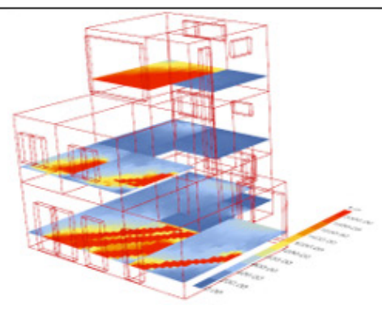
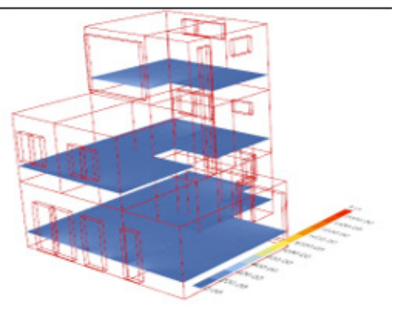
Heating Energy Intensity



Lighting Energy Intensity

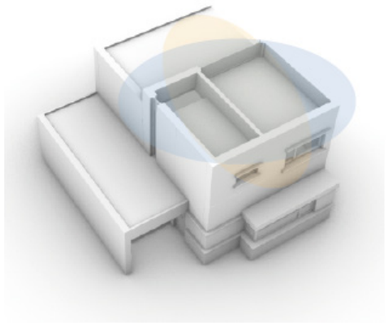
Case study

Radiance analysis

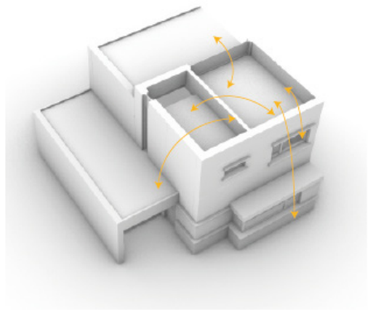
	9.00	12.00	15.00	18.00
January 6th				
March 29th				
Juy 20th				
October 27th				

Case study

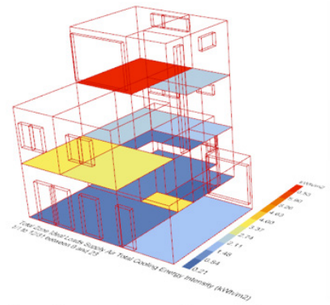
Findings of the analysis



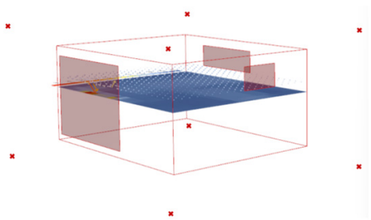
Redesign underused spaces



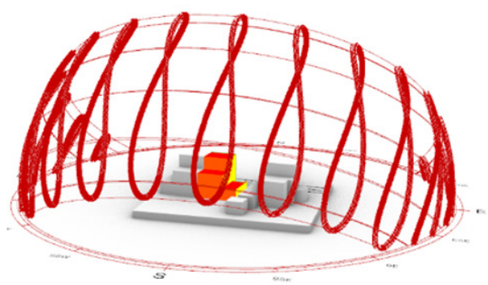
Smart home technology



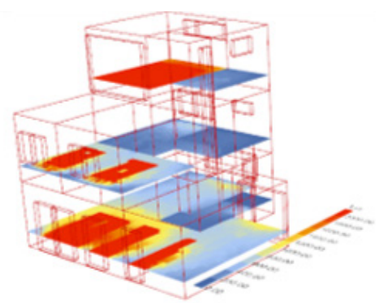
Tackle indoor heat



Enhance natural ventilation



Sunlight management

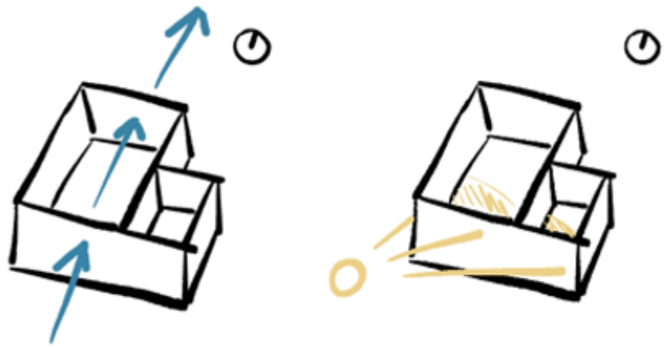


Energy efficiency emphasis

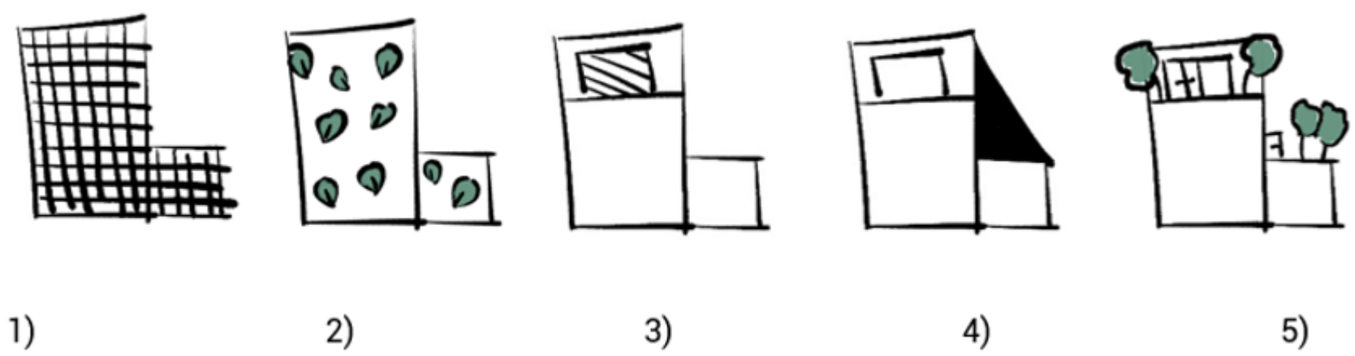
Case study

Focus on the
South façade

Tranformation integrations

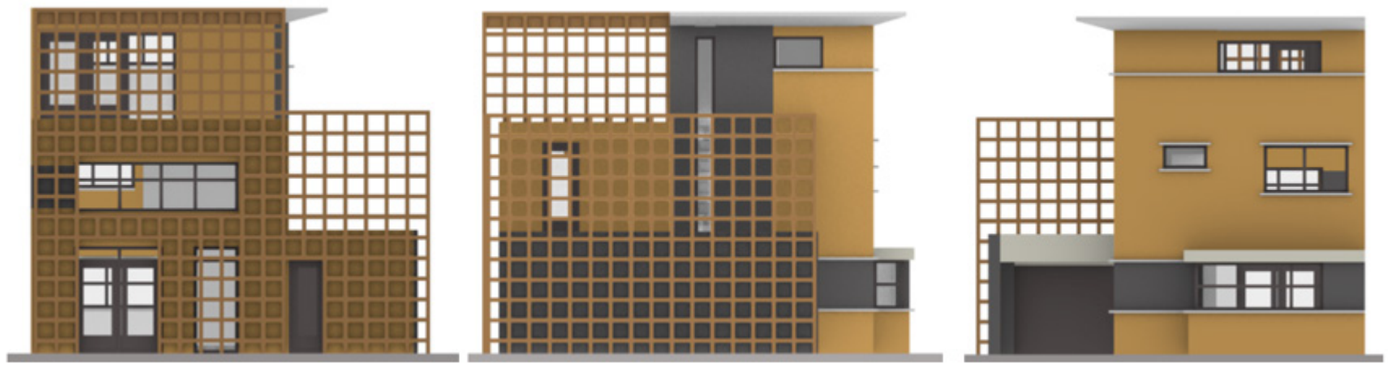


1) Second façade for more shading and protection from the sun
2) Adding green to the façade
3) More shading possibilities for big windows
4) More outside spaces
5) Adaptation of green for the outside spaces



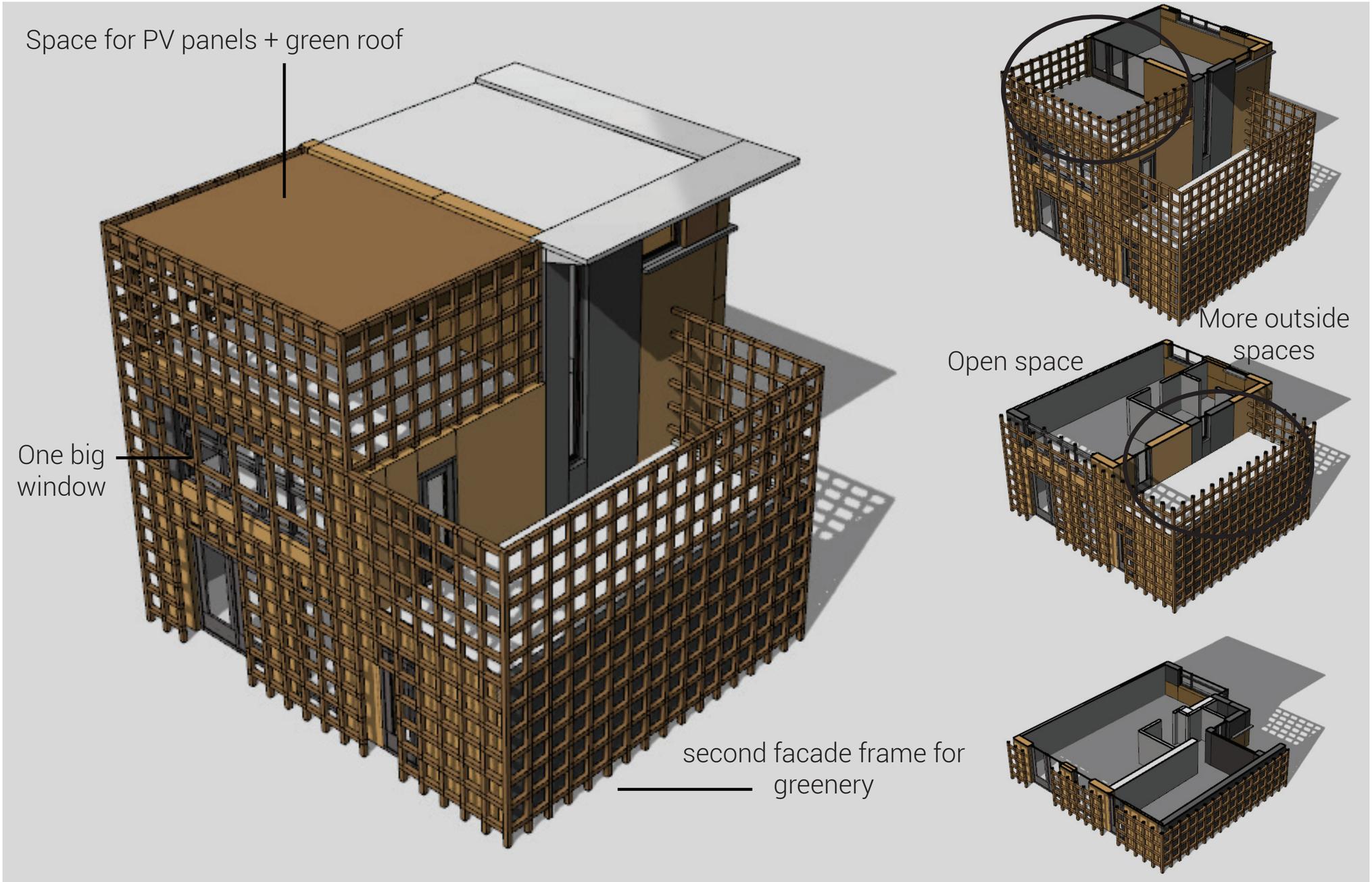
Tranformation integrations

A secondary façade will be installed 30 cm apart from the existing southern facade, functioning as a potential green facade to prevent overheating.



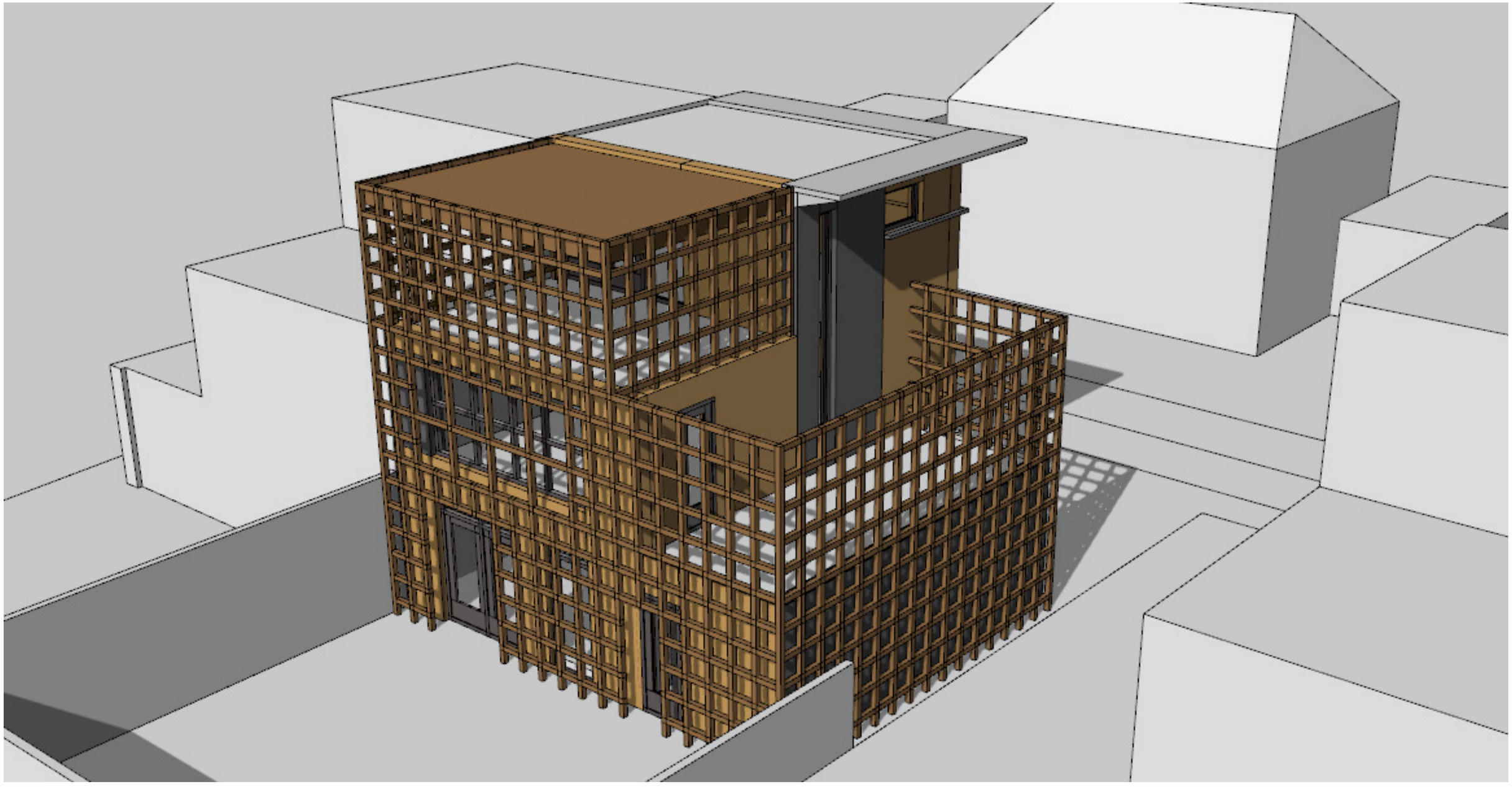
Case study

Tranformation integrations



Case study

Building in context

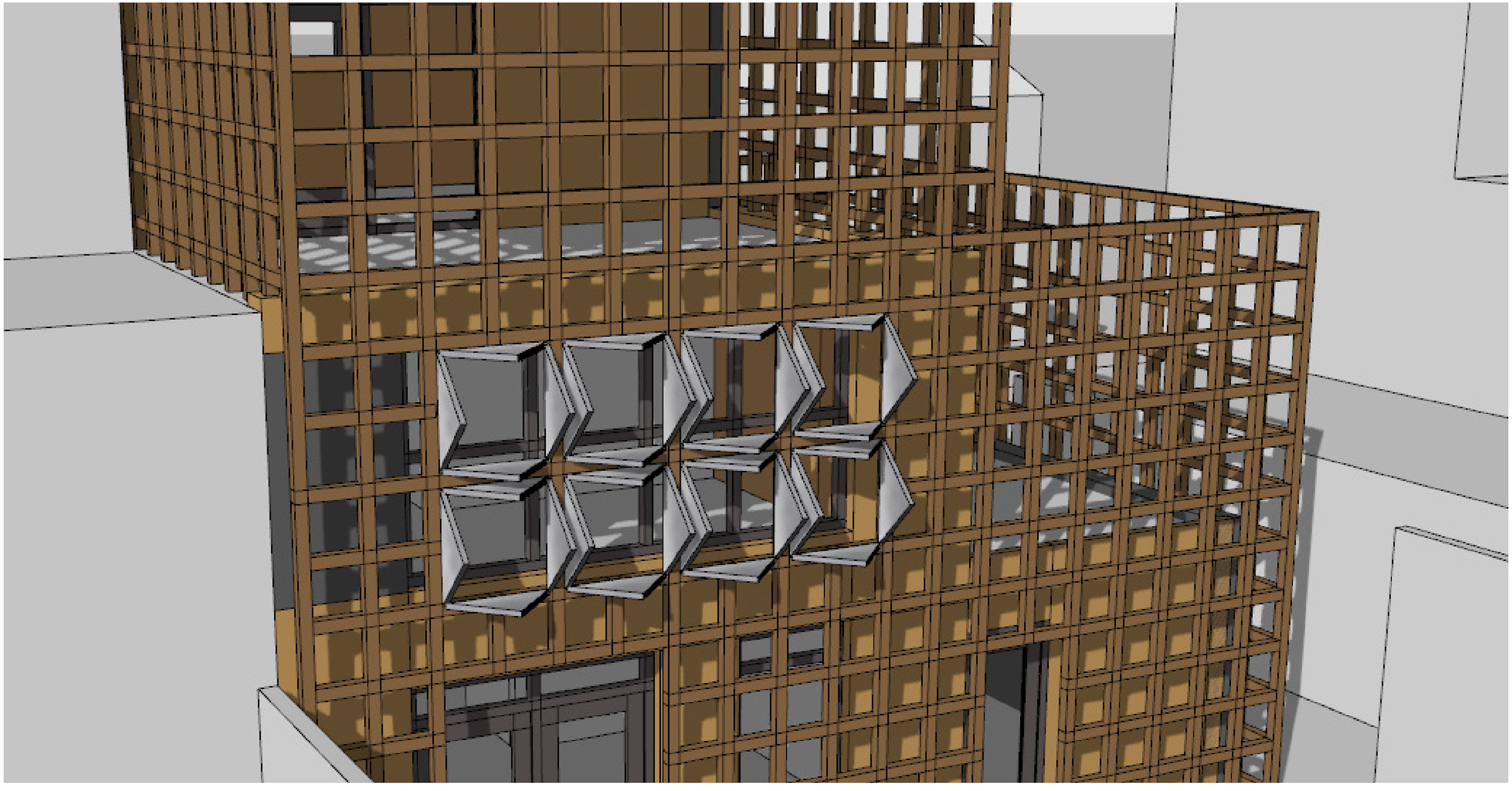


Case study

Building in context

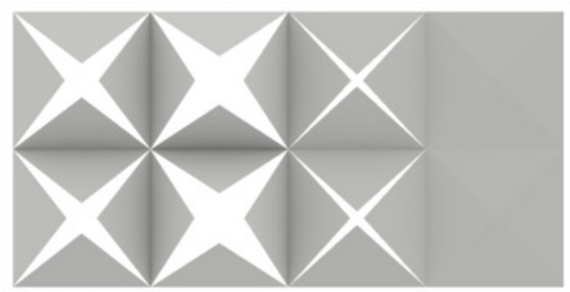
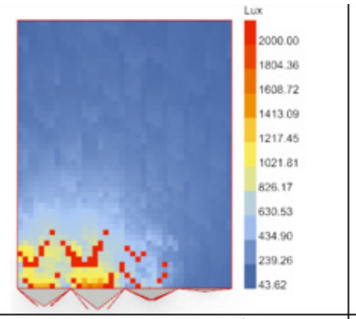
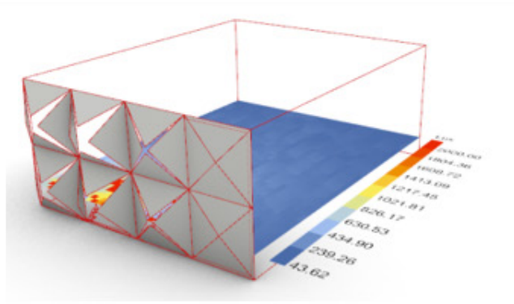
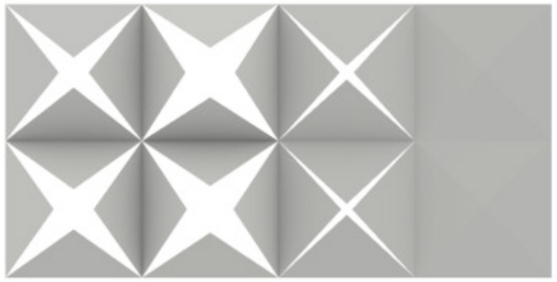
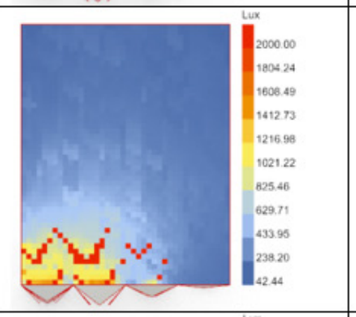
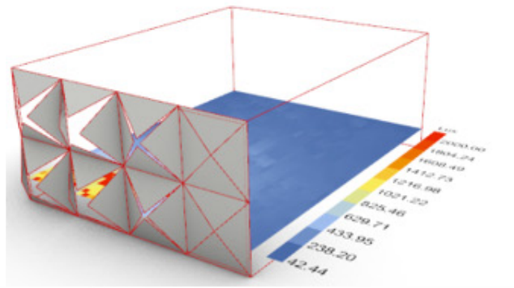
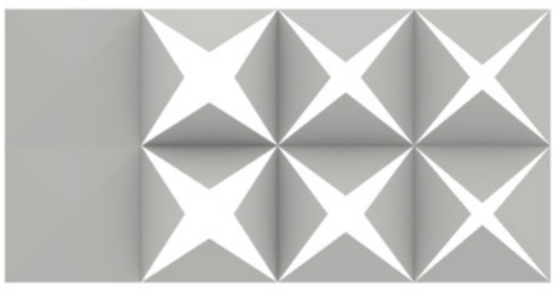
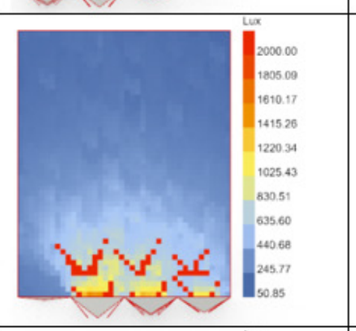
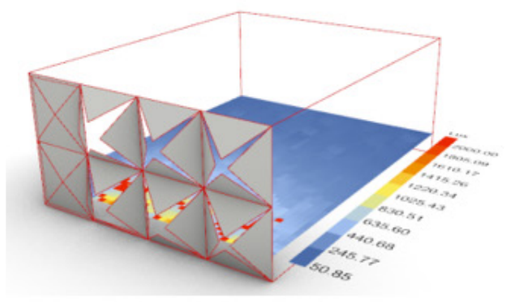
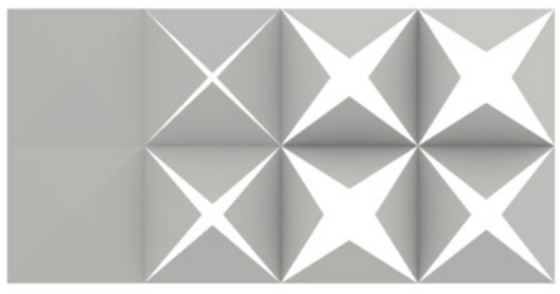
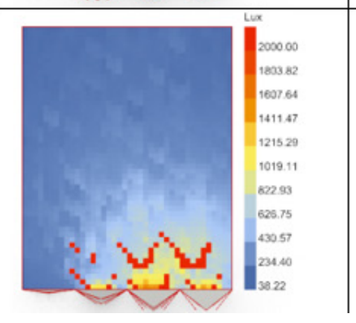
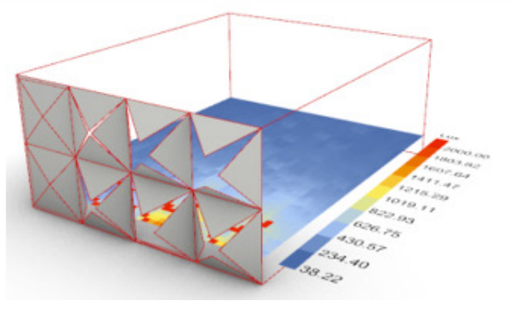
Case study

Integration kinetic shading system

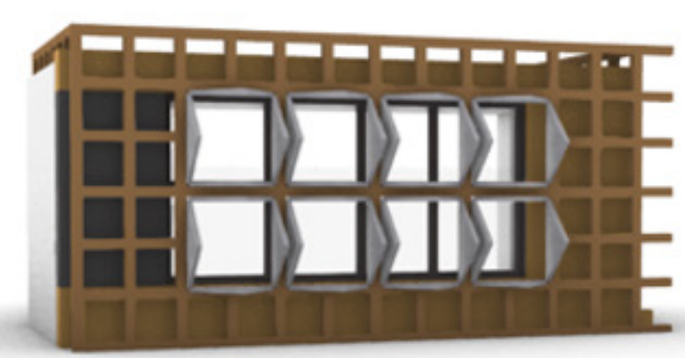


Case study

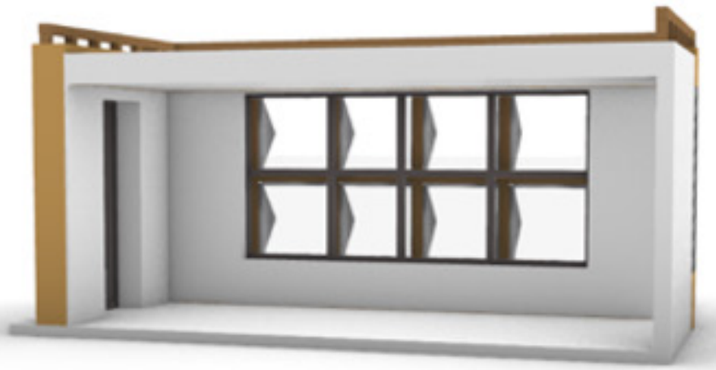
Testing kinetic shading system and heatmaps

	Front view	Top view	Perspective
9.00			
12.00			
15.00			
18.00			

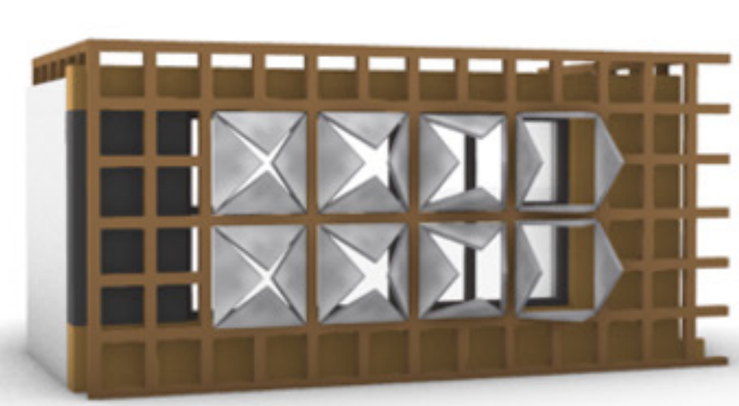
Integration kinetic shading system



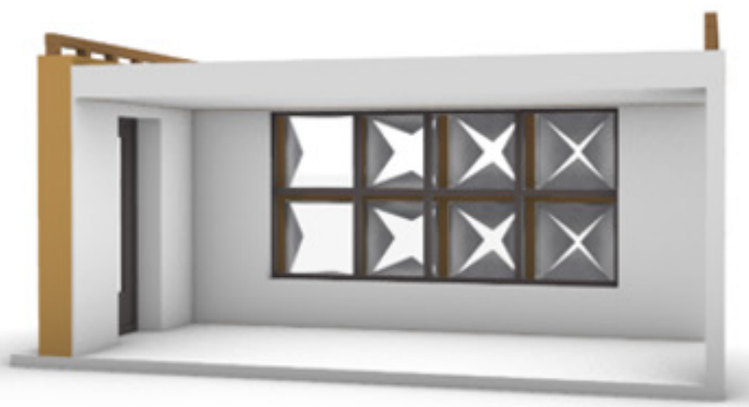
South façade opened



View from inside

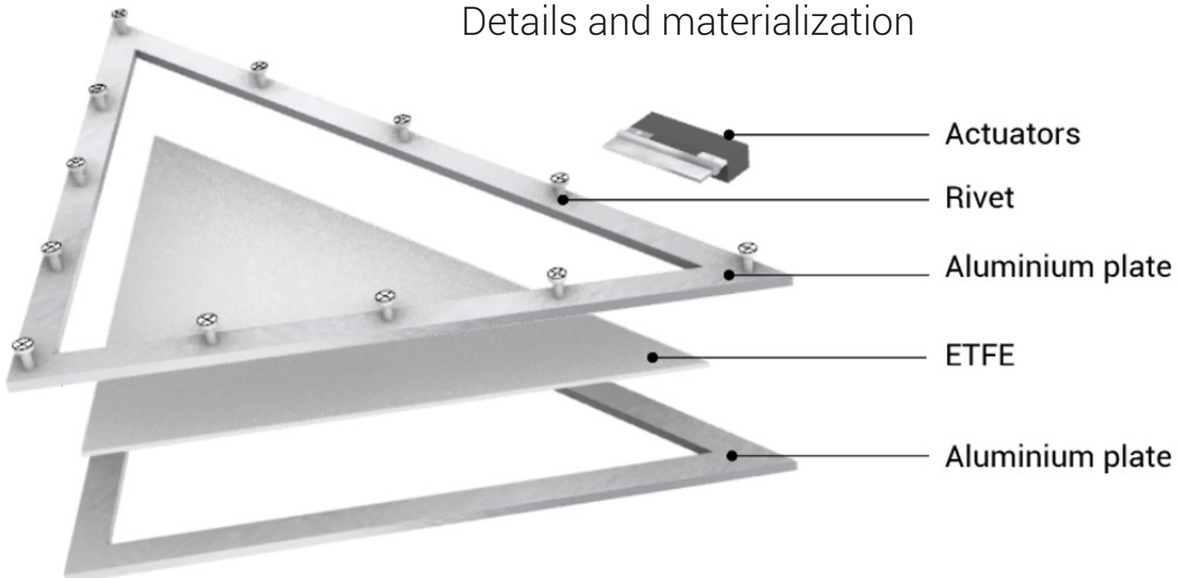


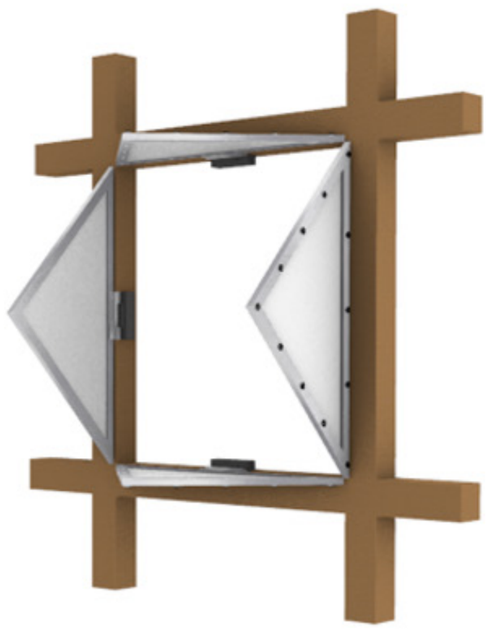
South façade end of a sunny day

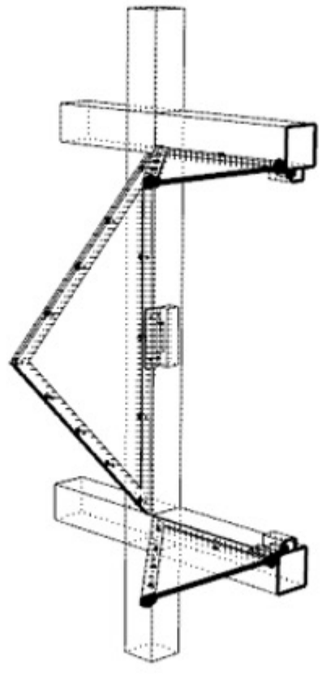


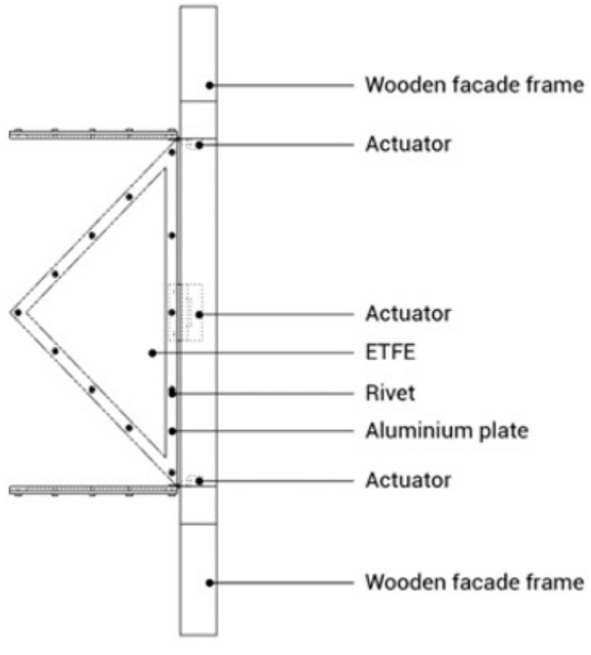
View from inside

Details and materialization





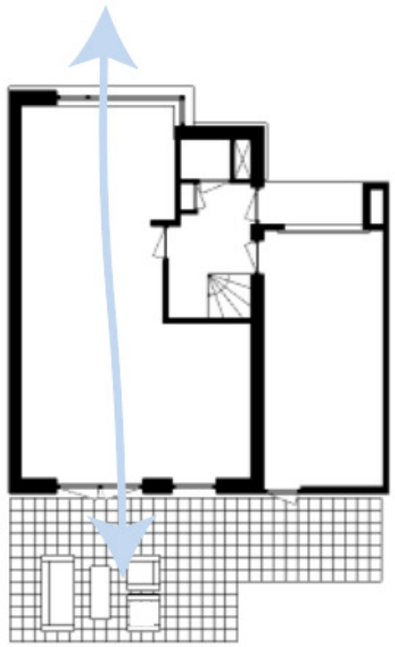




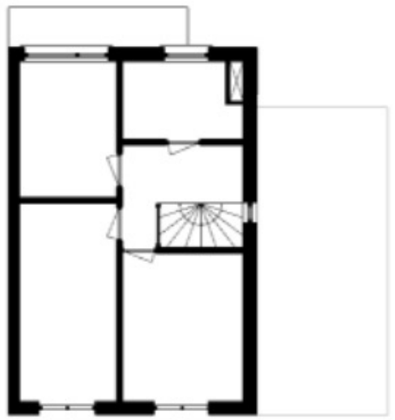
Case study

Cross ventiation

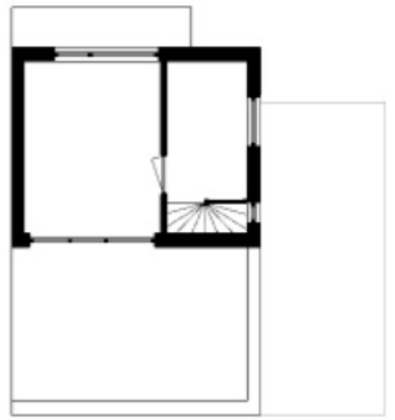
Before



Groundfloor

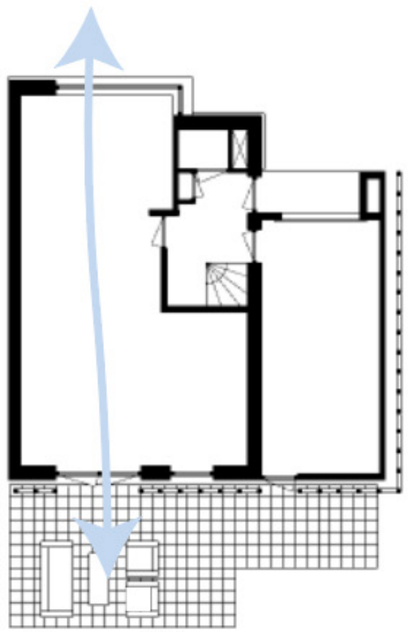


Floor 1

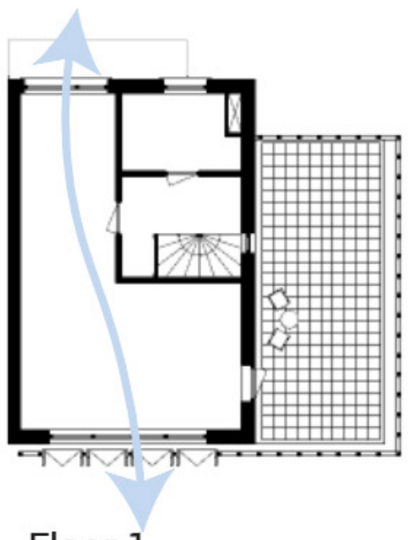


Floor 2

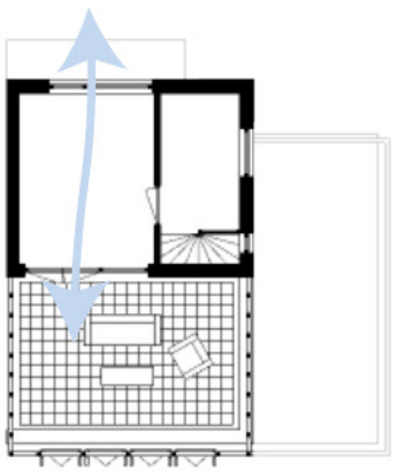
After



Groundfloor



Floor 1

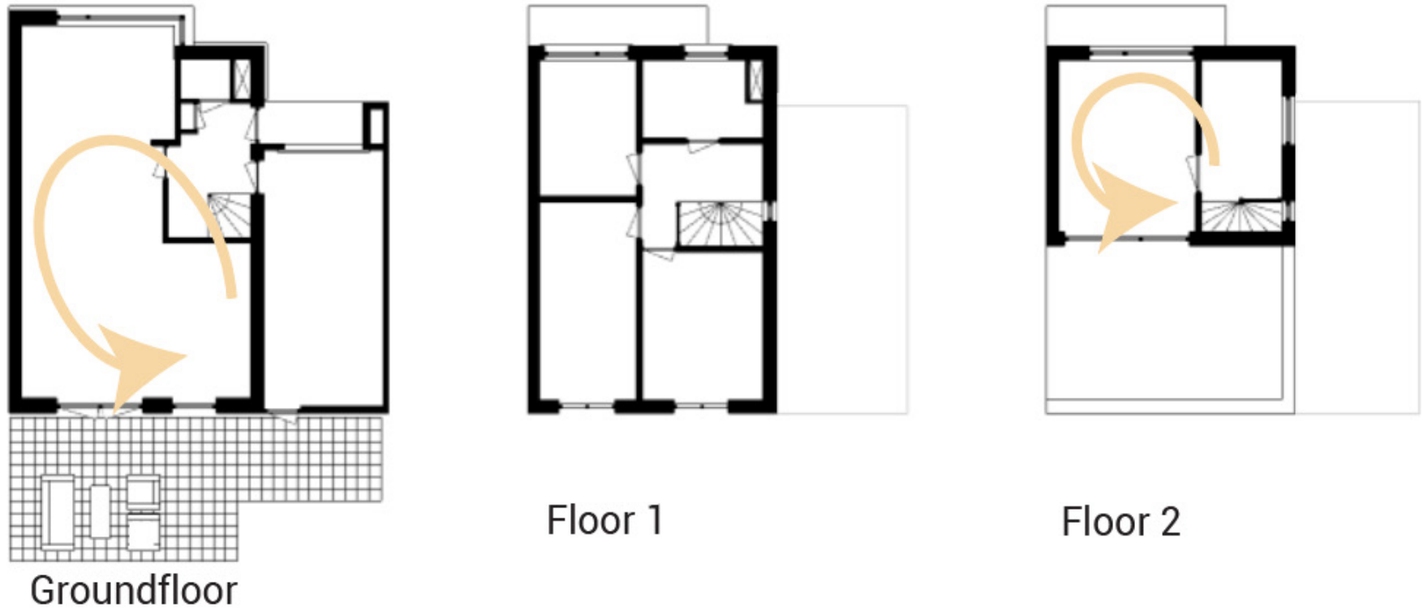


Floor 2

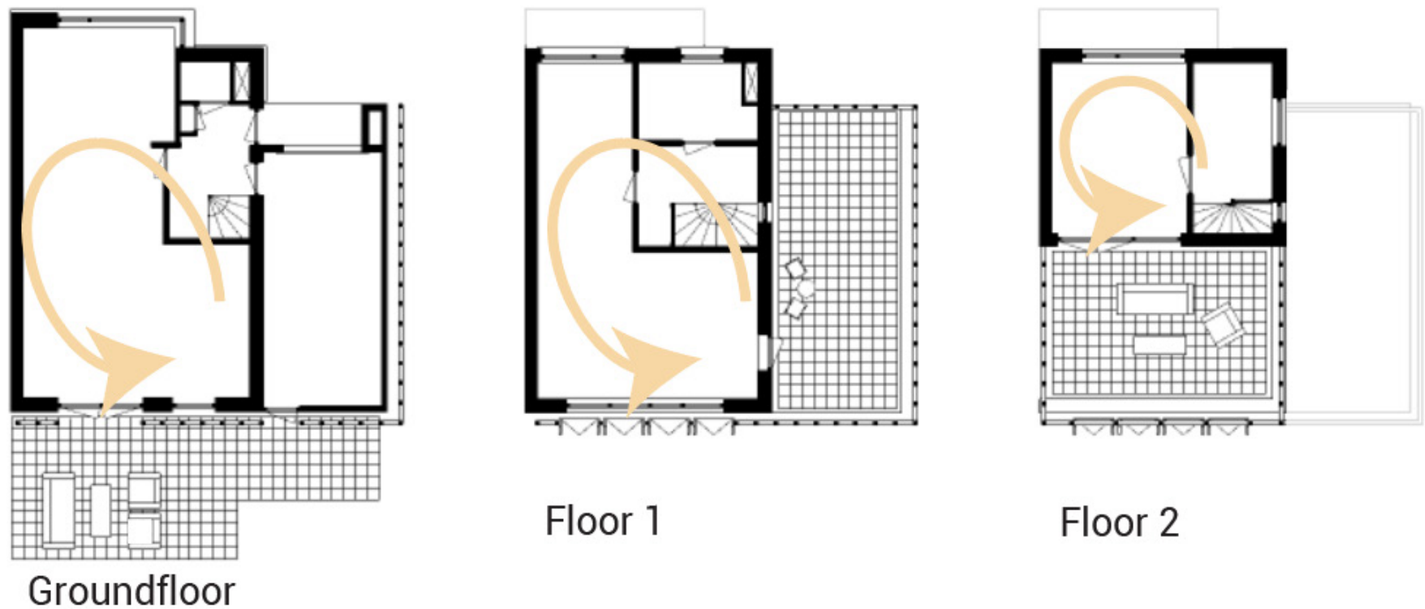
Case study

Open spaces

Before



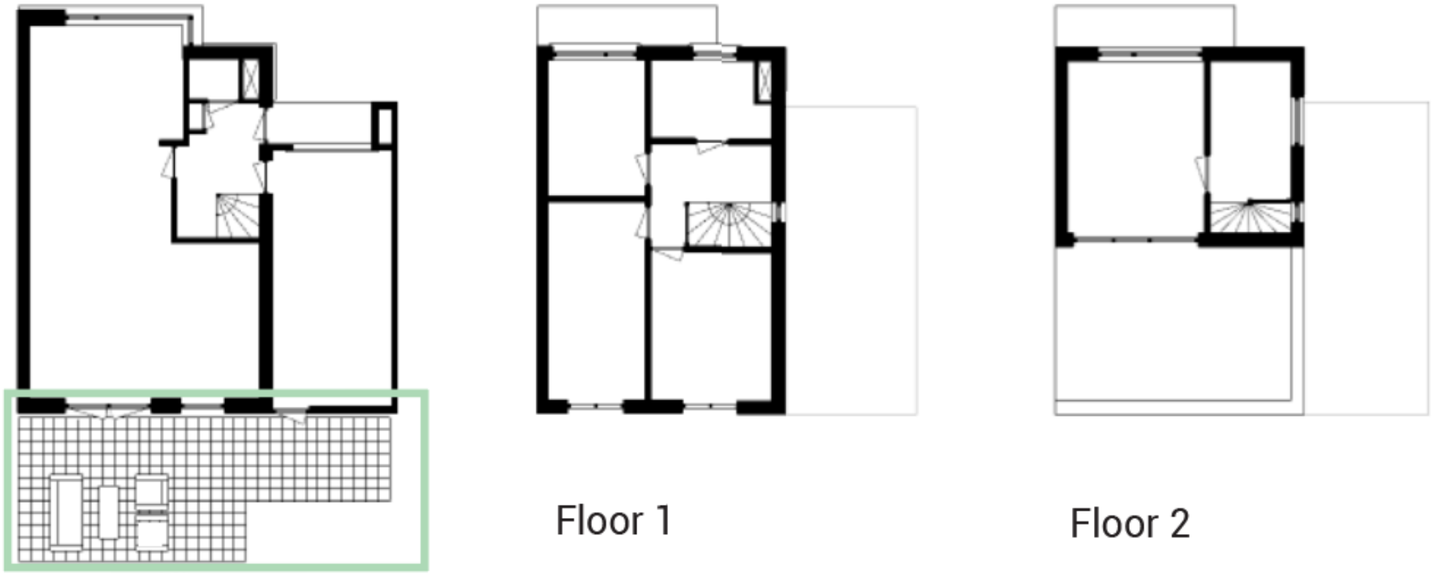
After



Case study

Outdoor spaces

Before

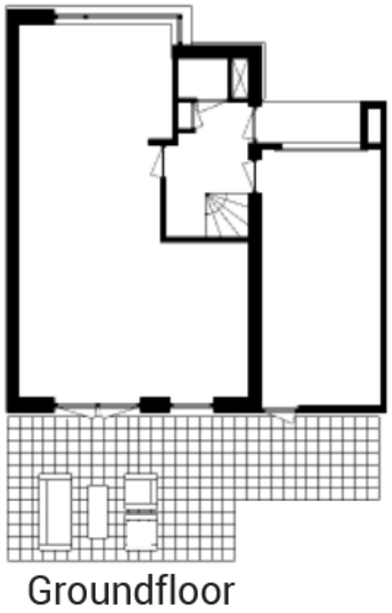


After

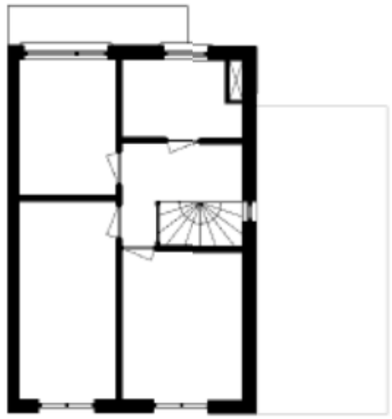
Case study

Second facade

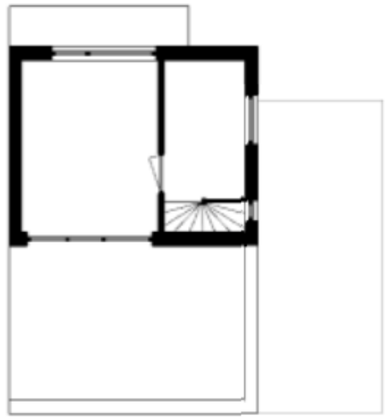
Before



Groundfloor

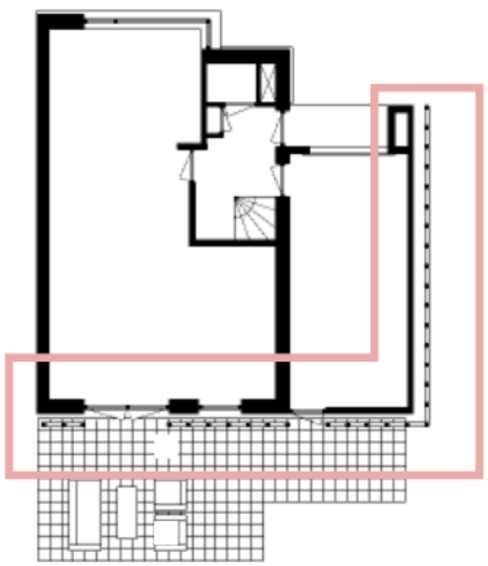


Floor 1

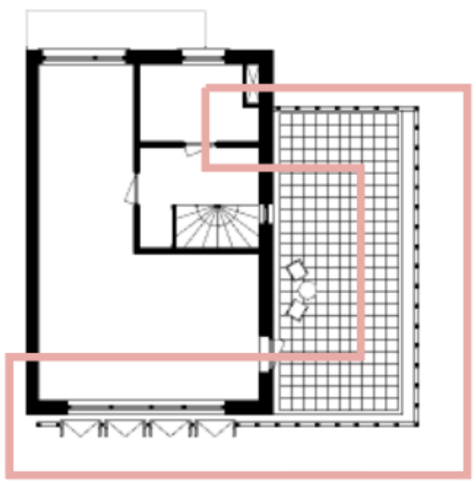


Floor 2

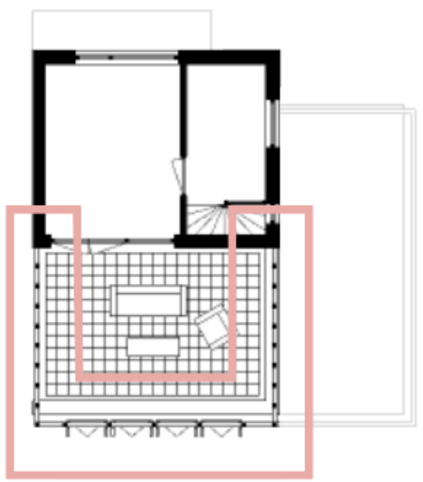
After



Groundfloor



Floor 1



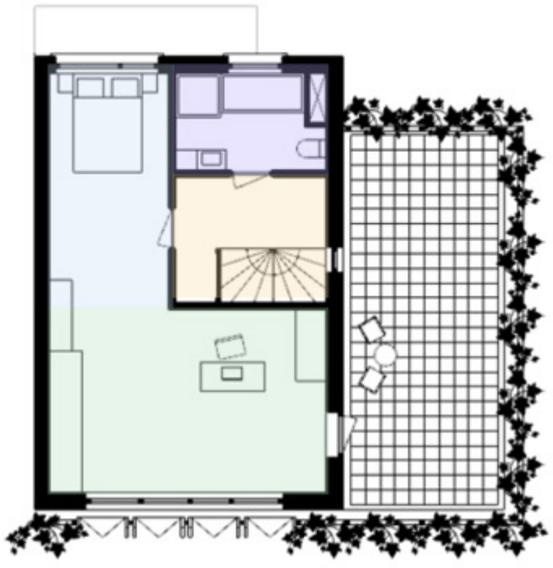
Floor 2

Case study

Redesign of the functionalities

Groundfloor

- Toilet
- Livingroom
- Corridor
- Kitchen + dining area
- Garage



Floor 1

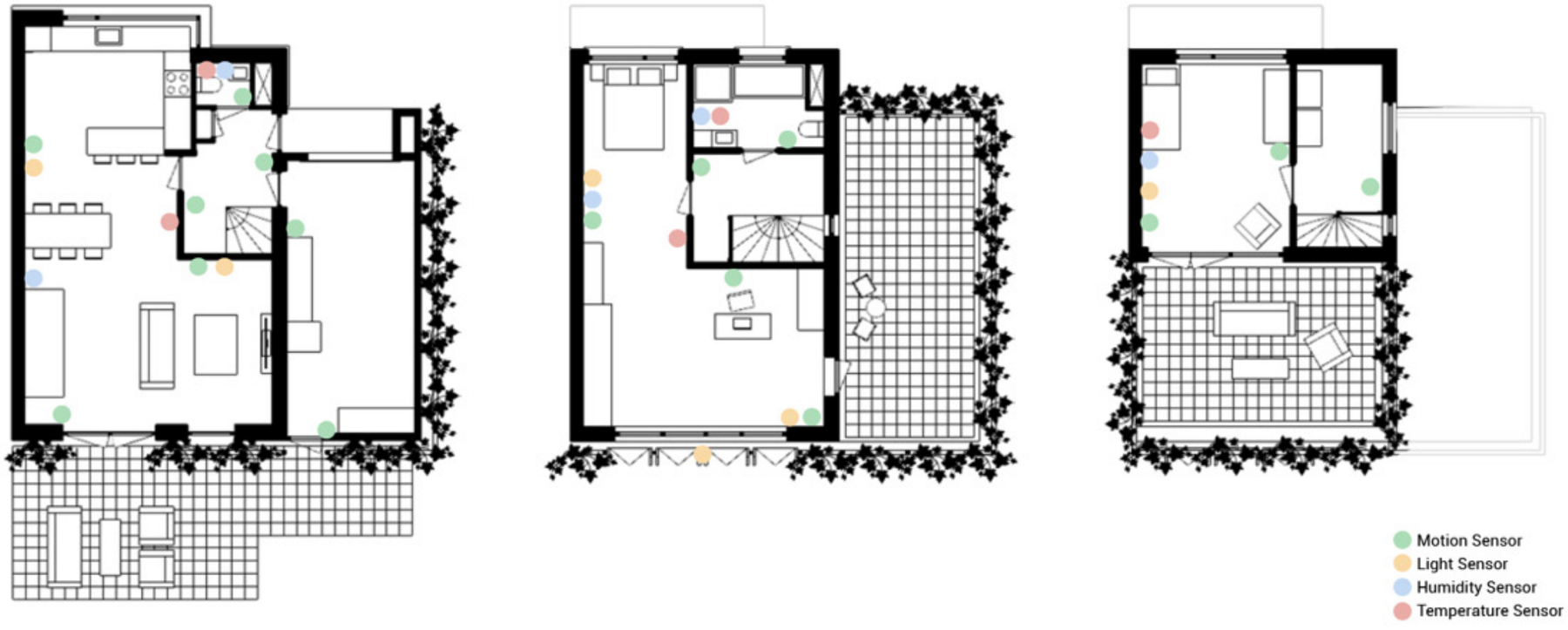
- Bathroom
- Working space
- Corridor
- Bedroom

Floor 2

- Guestroom + exercize room
- Corridor

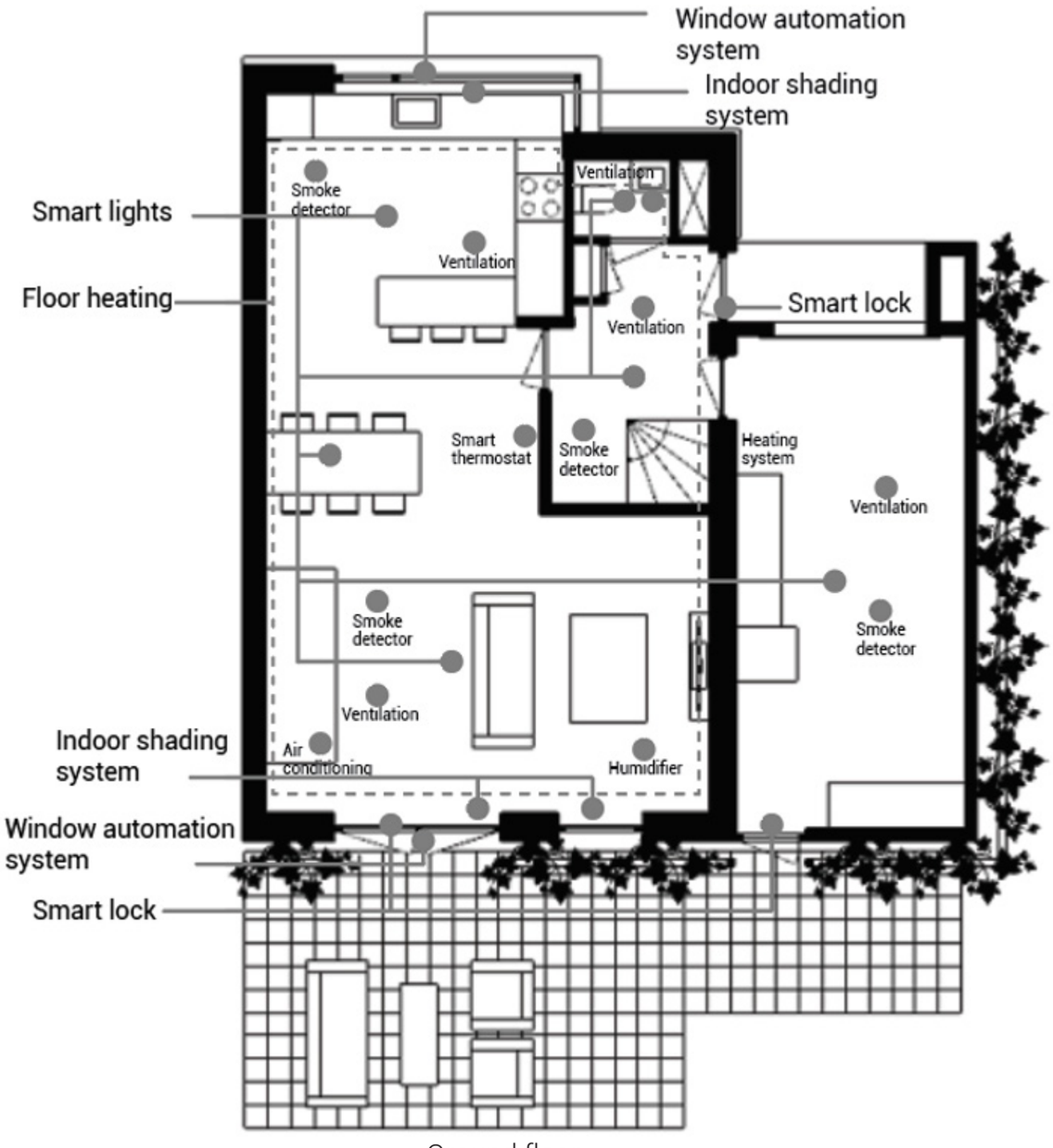
Case study

Sensor integration



Case study

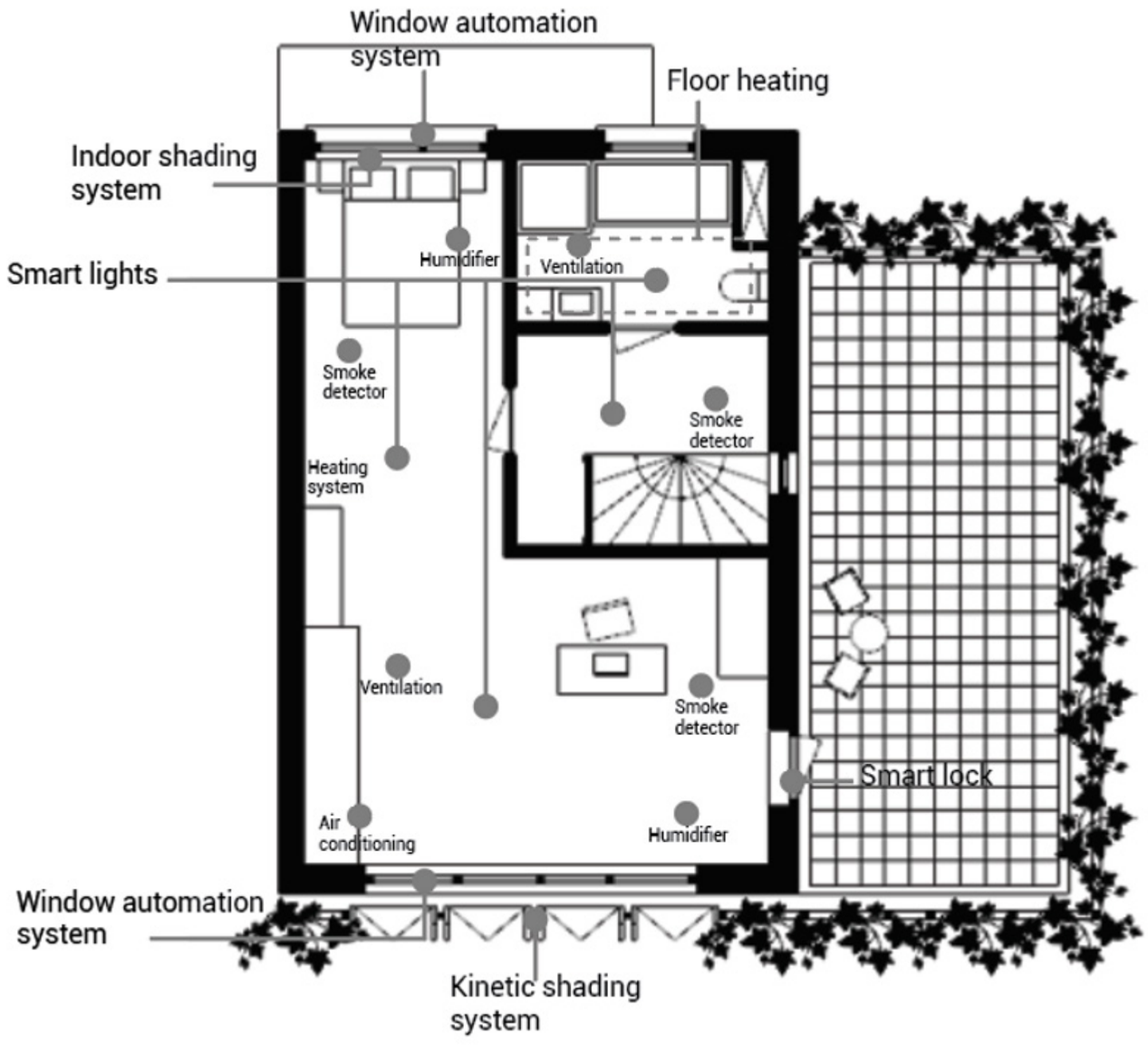
Smart devices integration



Ground floor

Case study

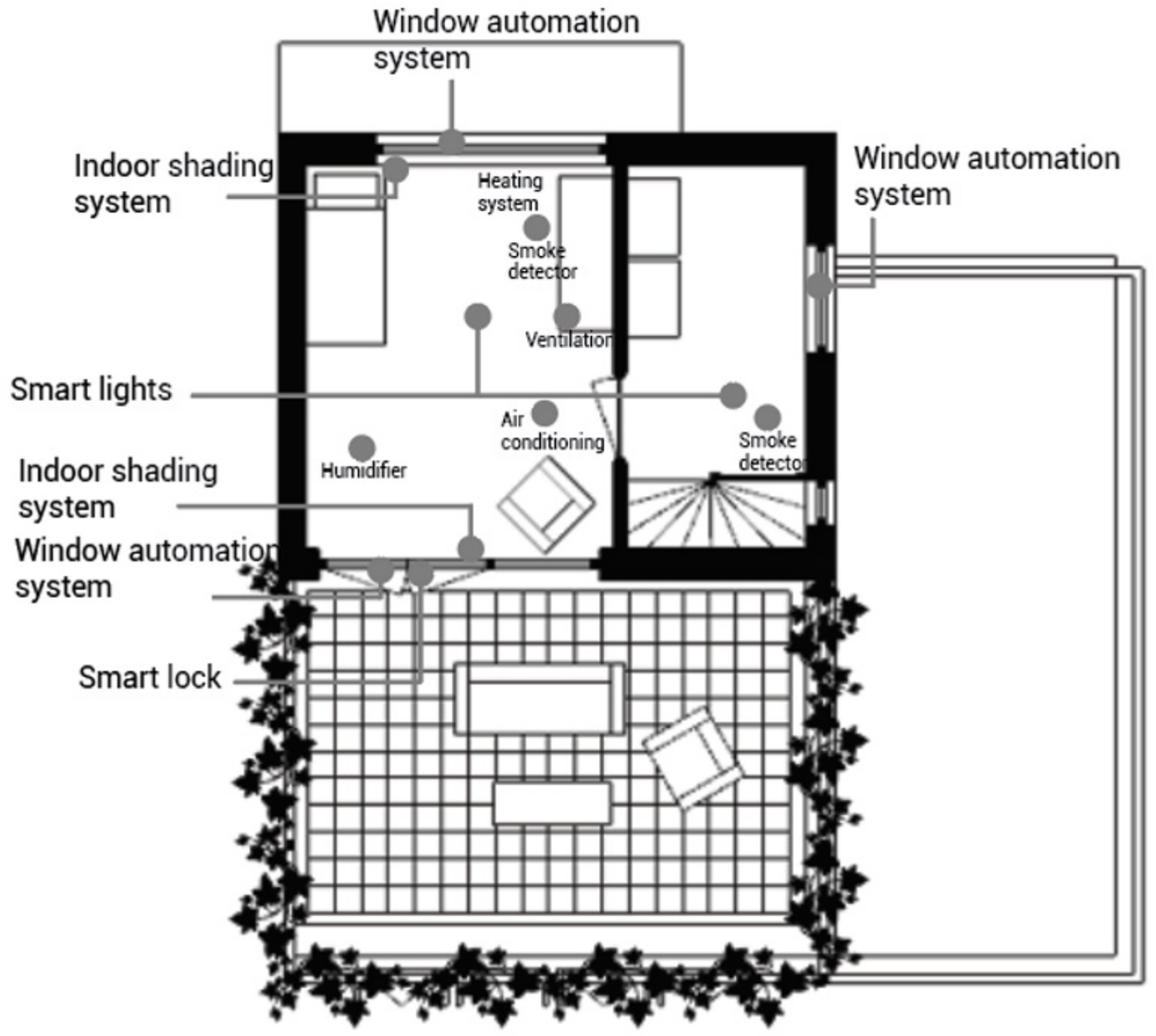
Smart devices integration



First floor

Case study

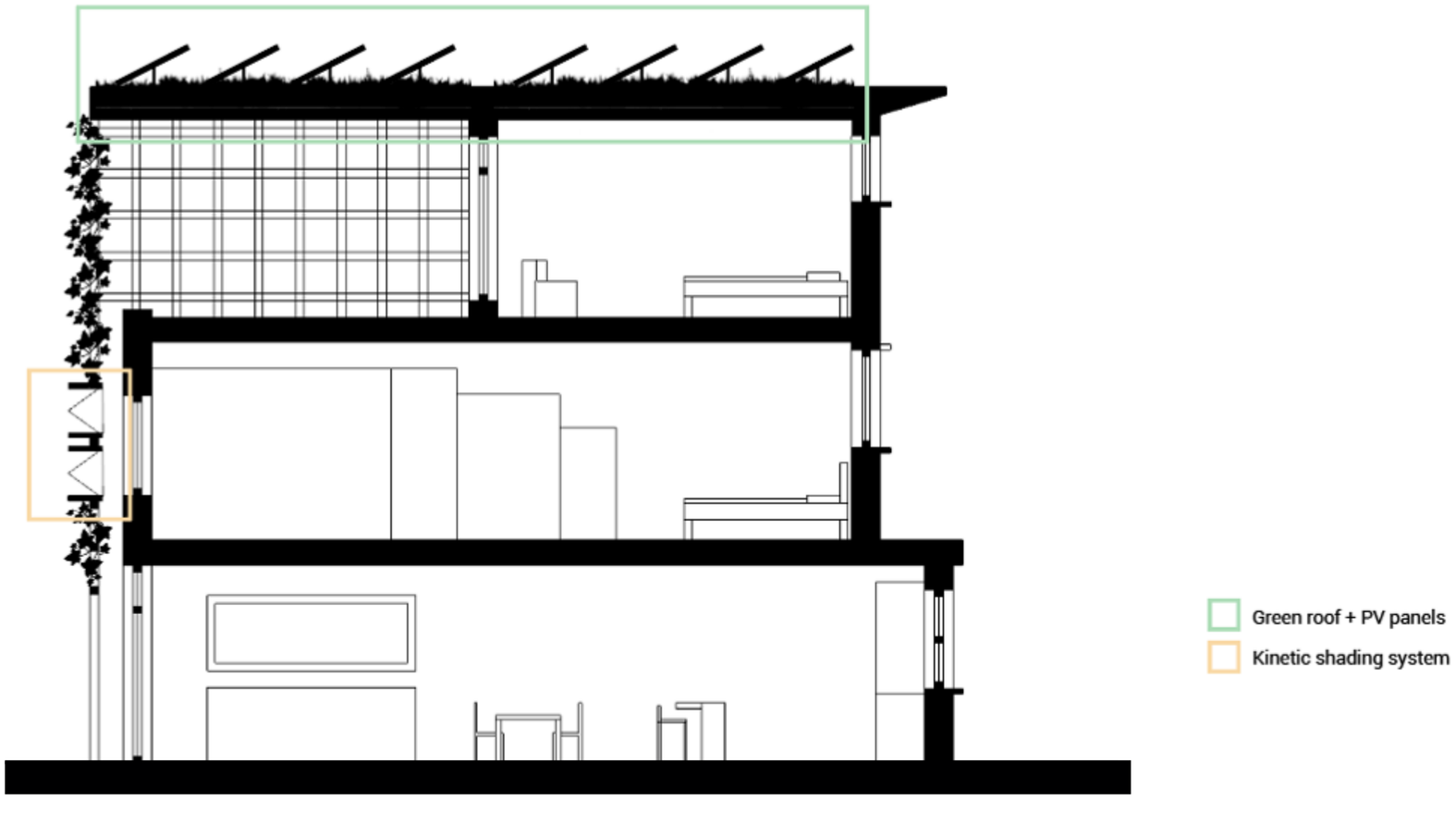
Smart devices integration



Second floor

Case study

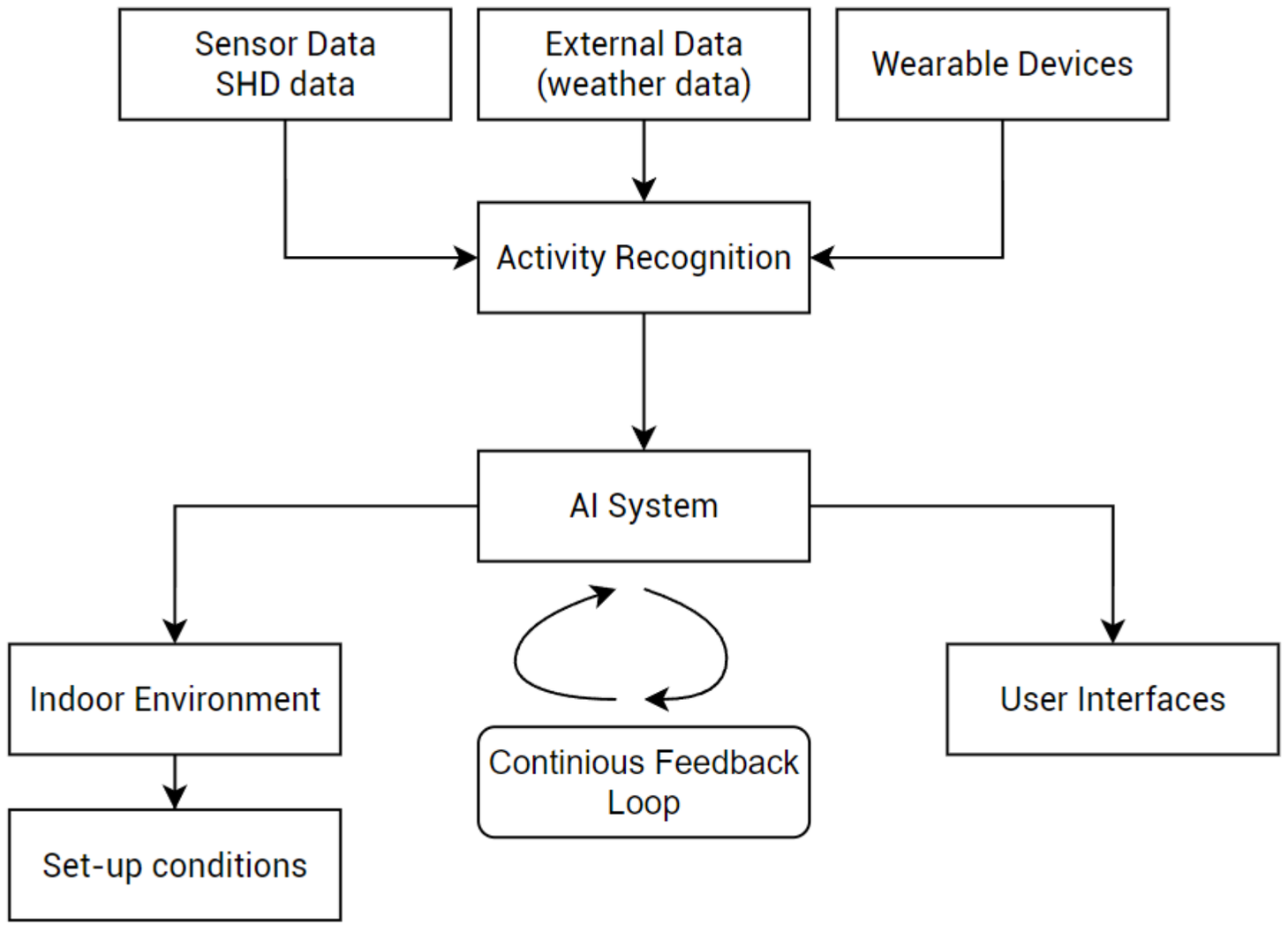
Green roof, PV panels and kinetic shading system



Section A

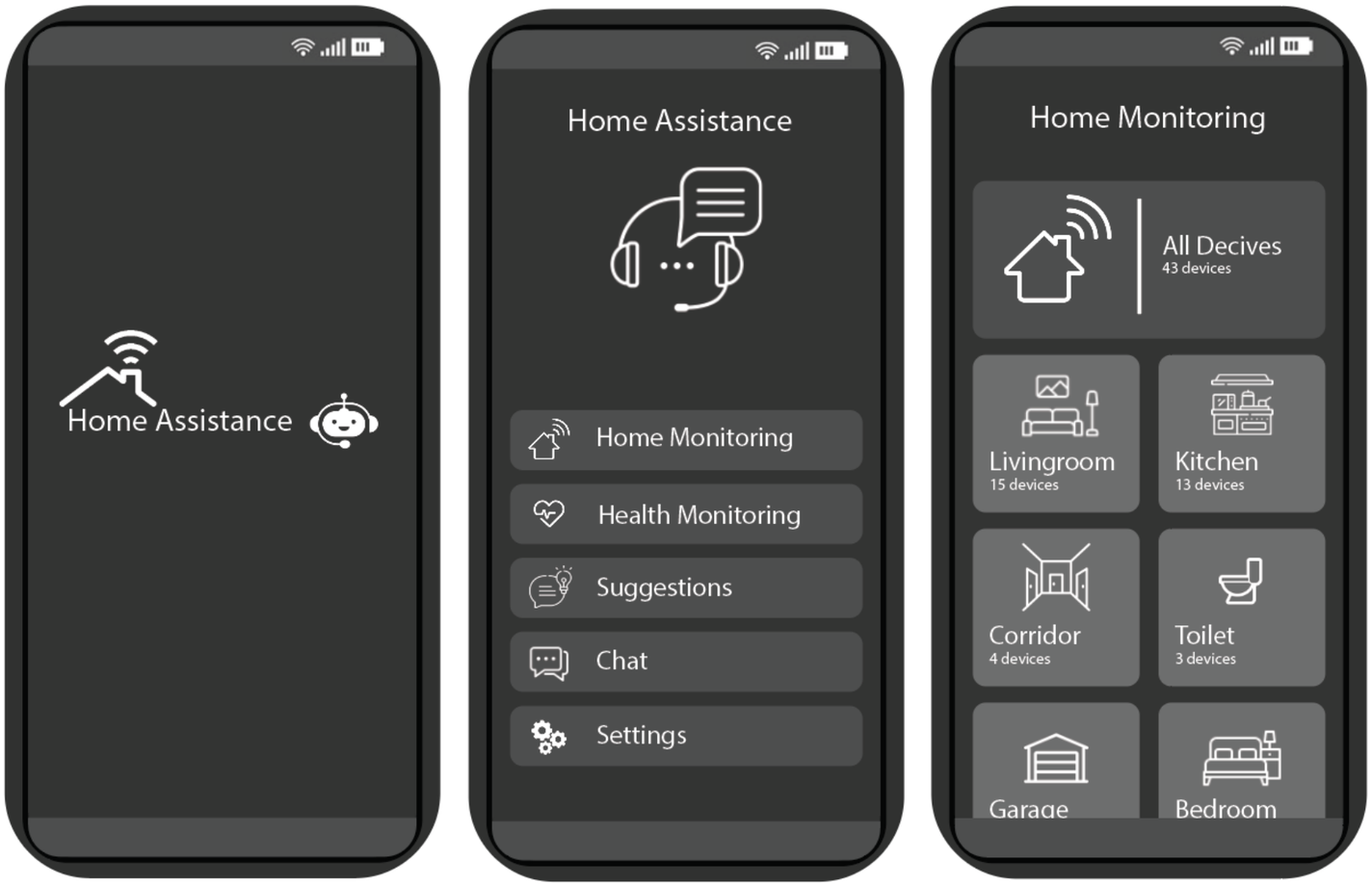
Case study

Proposed AI system of the smart home



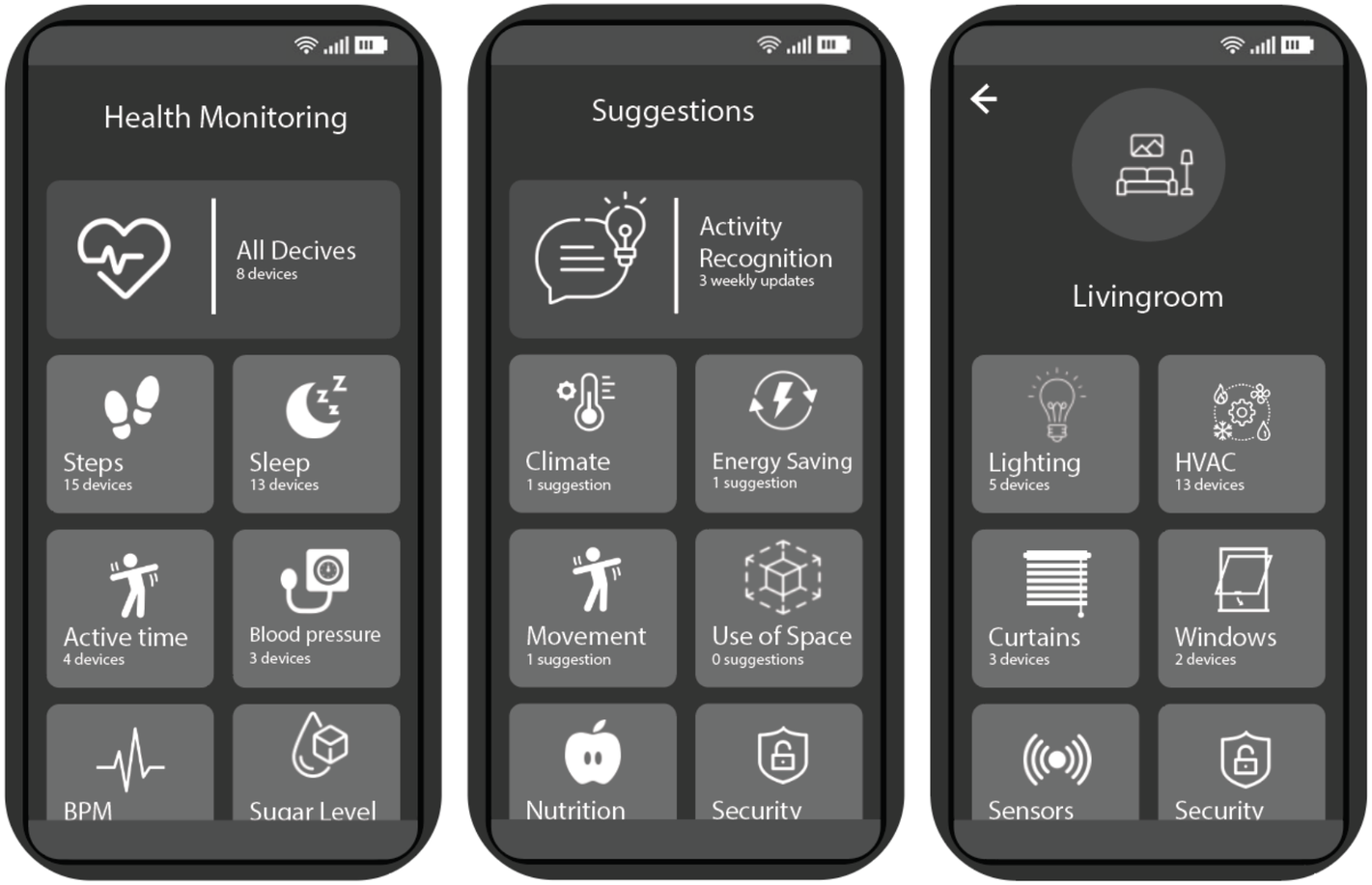
Case study

AI system and user interface suggestion



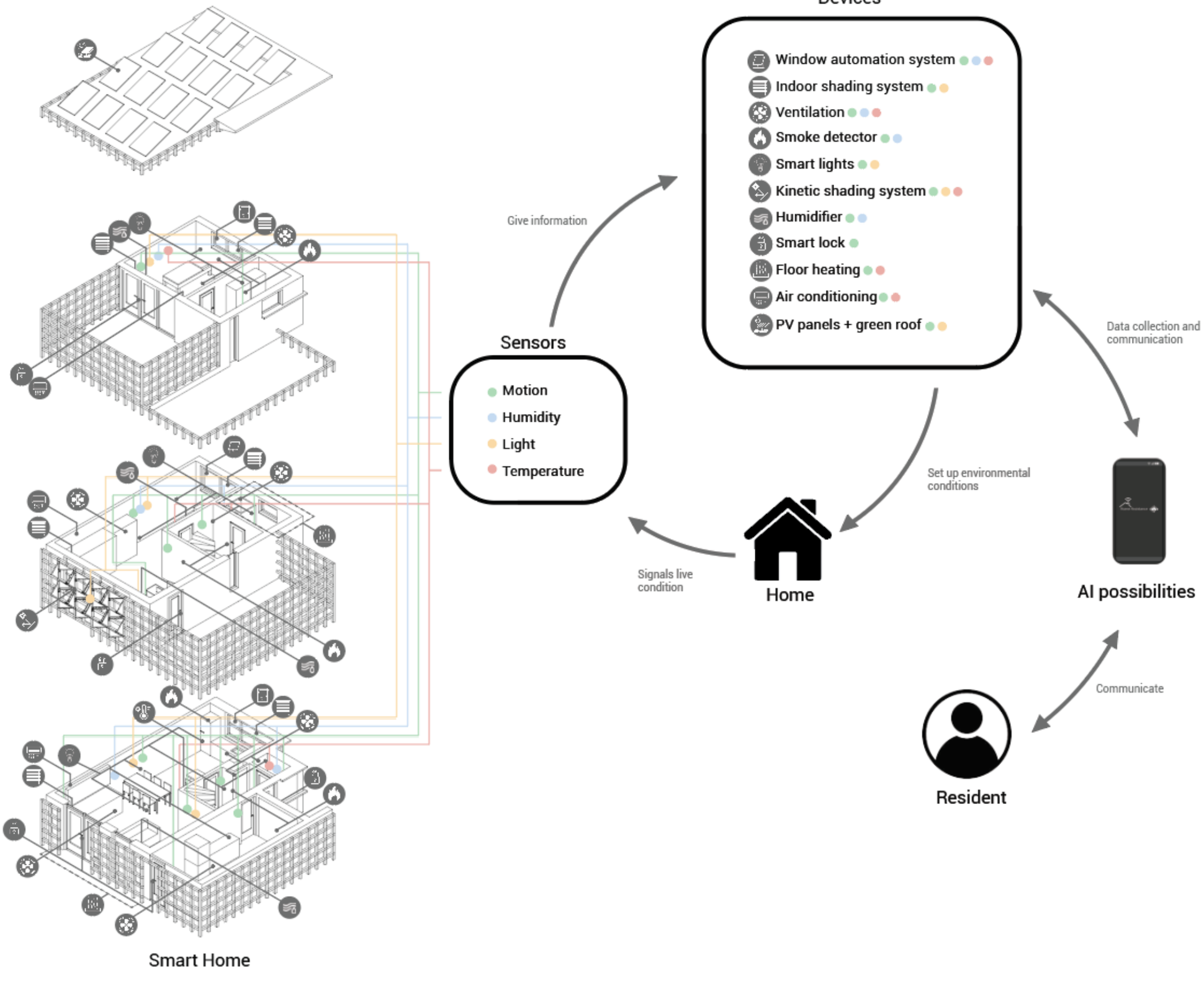
Case study

AI system and user interface suggestion



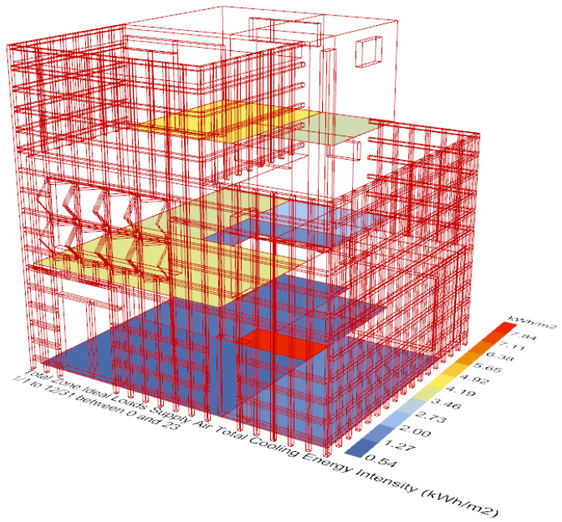
Case study

Smart Home System

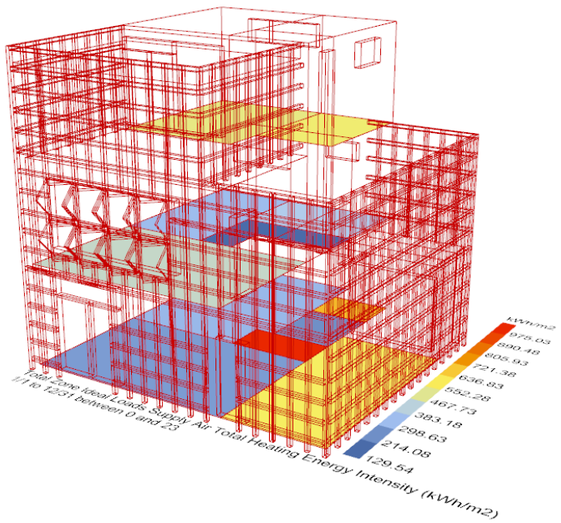


Case study

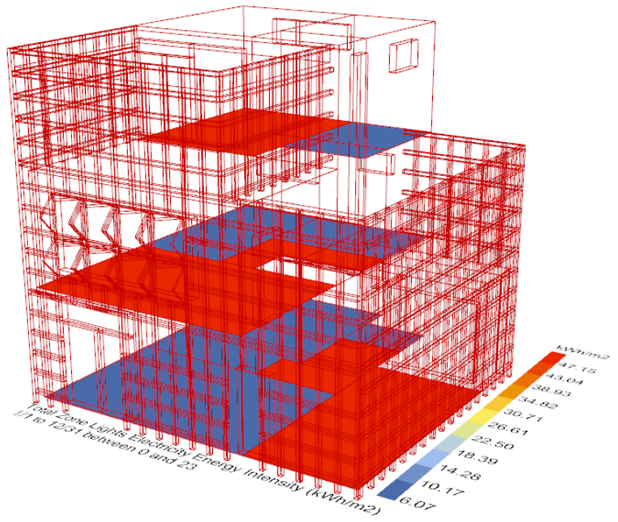
Energy analysis after tranformation



Cooling Energy Intensity

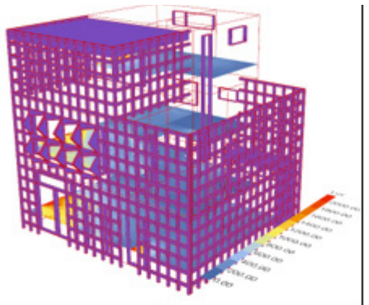
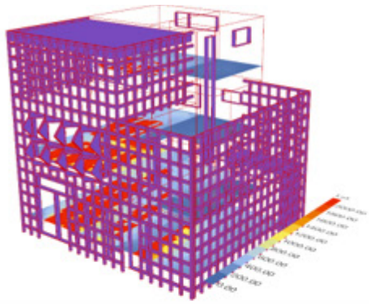
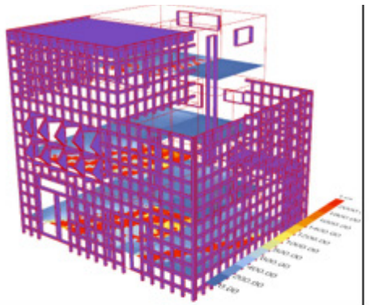
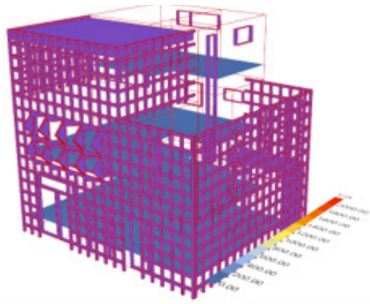
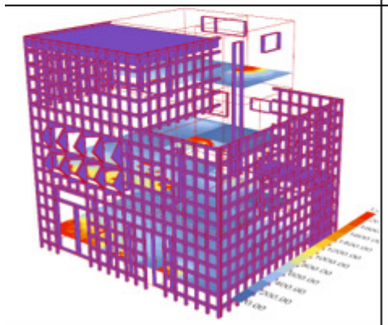
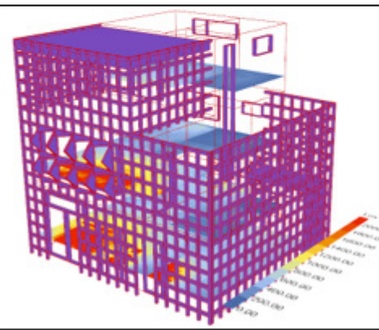
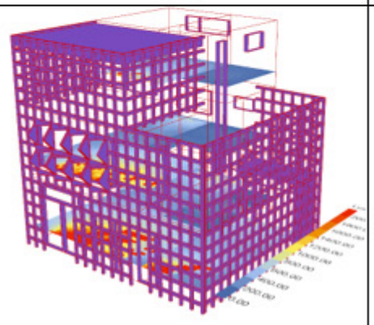
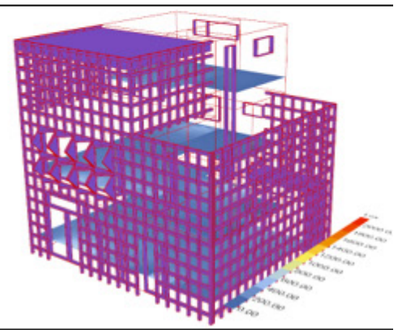
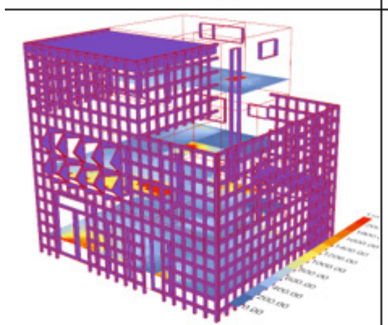
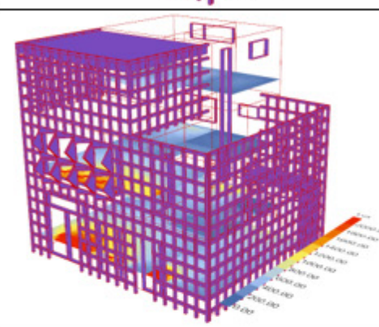
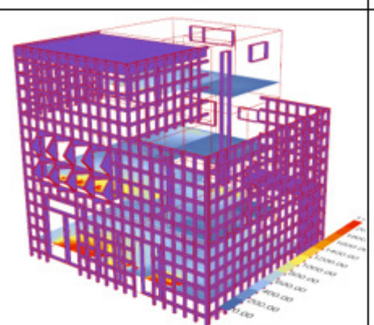
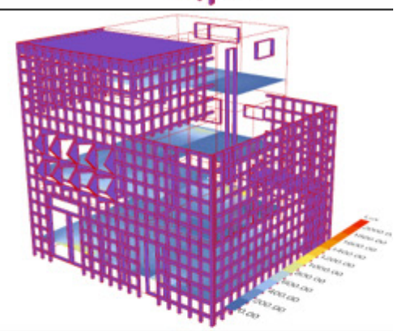
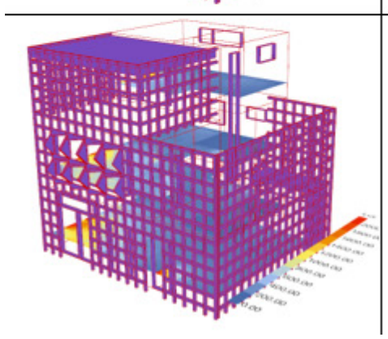
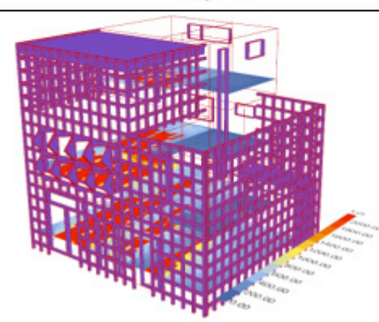
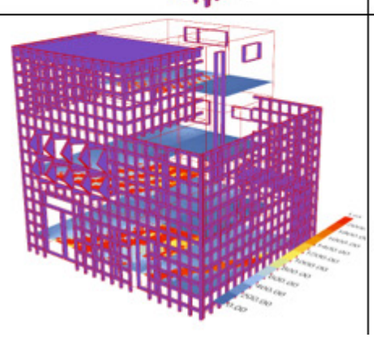
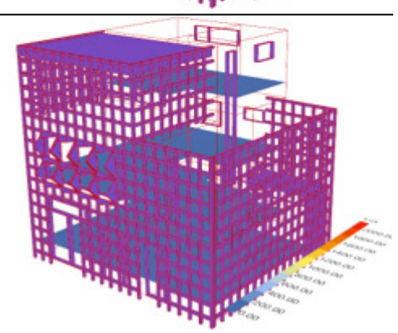


Heating Energy Intensity



Lighting Energy Intensity

Radiance analysis after tranformation

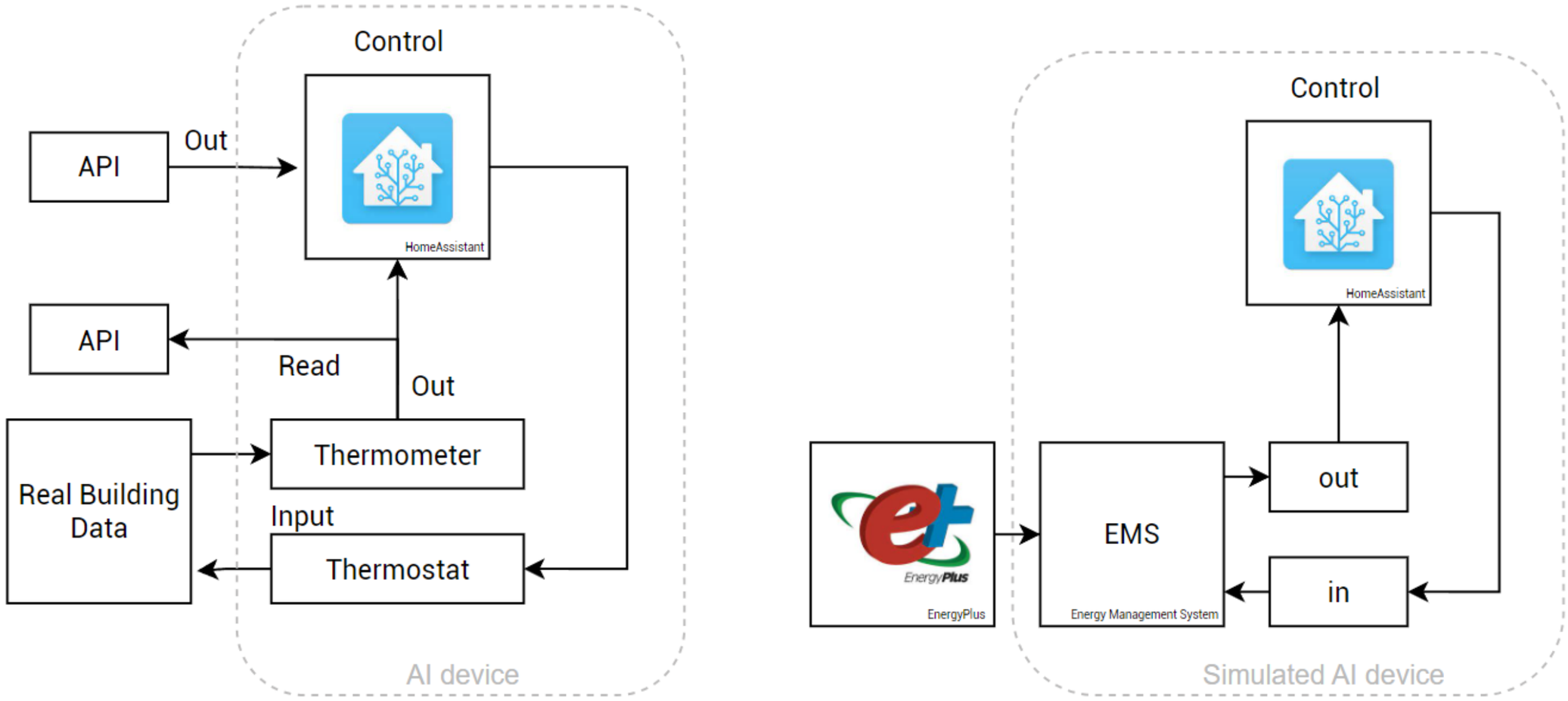
	9.00	12.00	15.00	18.00
January 6th				
March 29th				
Juy 20th				
October 27th				

Case study

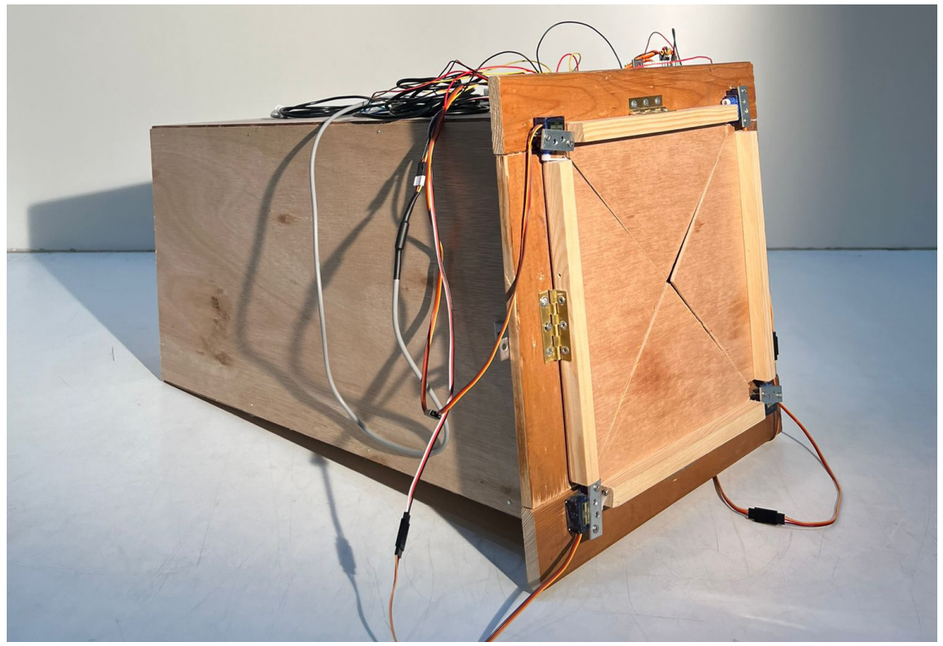
Integration of the AI-driven control system in real-life and simulated environment

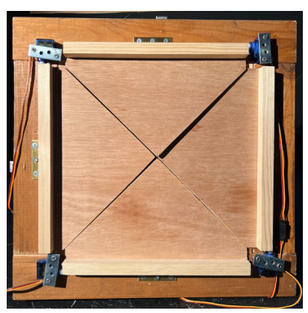
Real Building

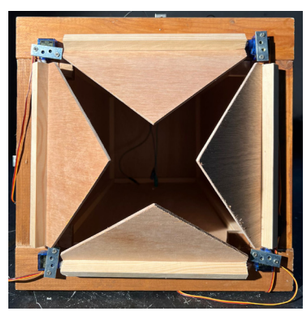
Simulation

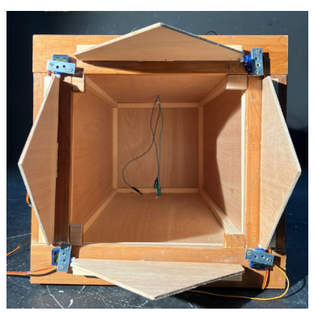


Prototype



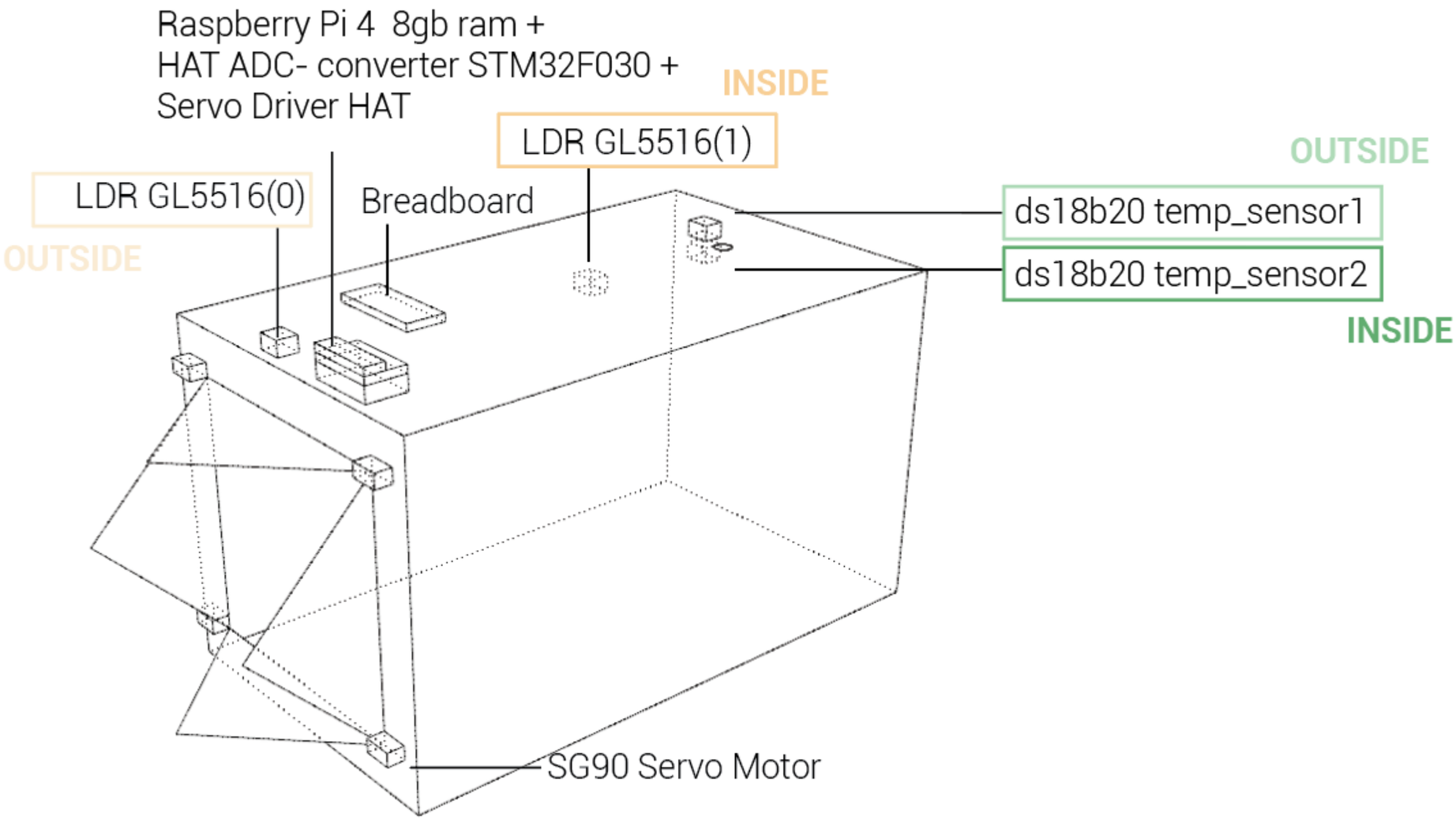






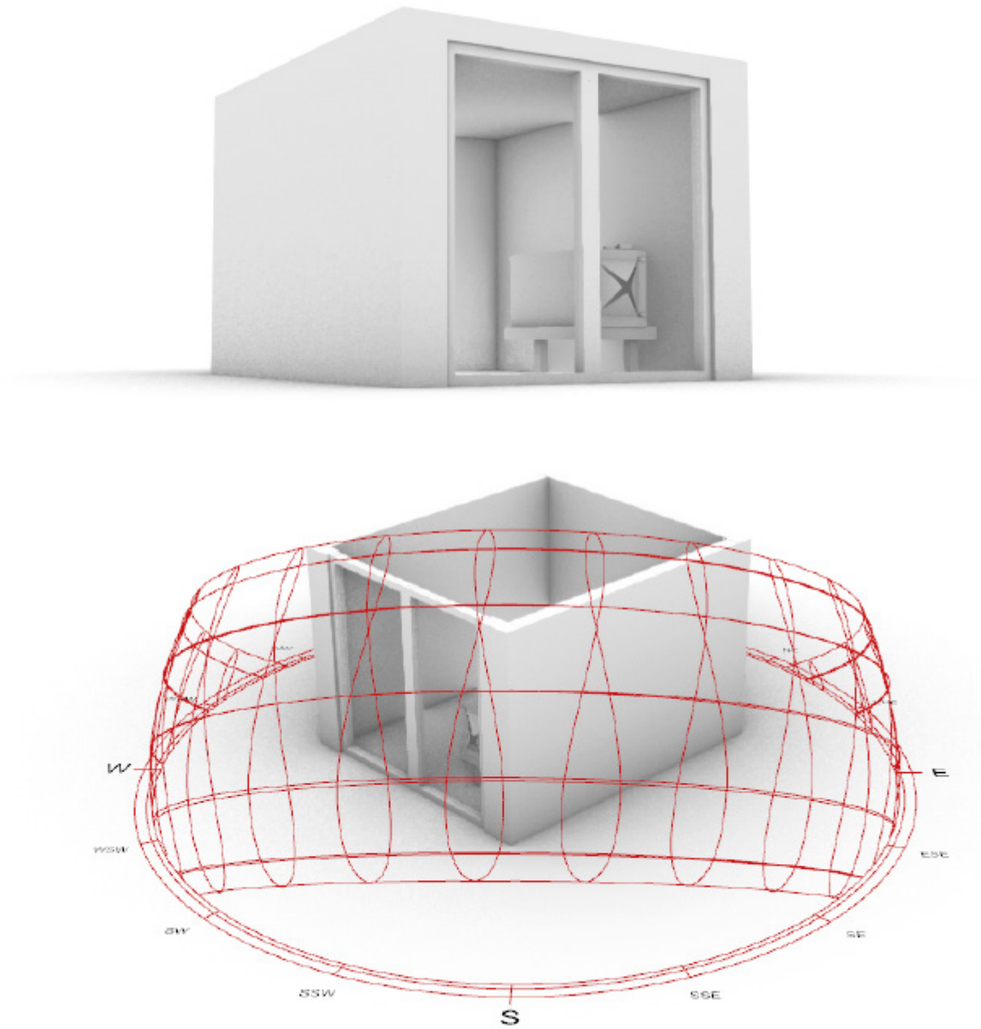
Case study

Prototype setup



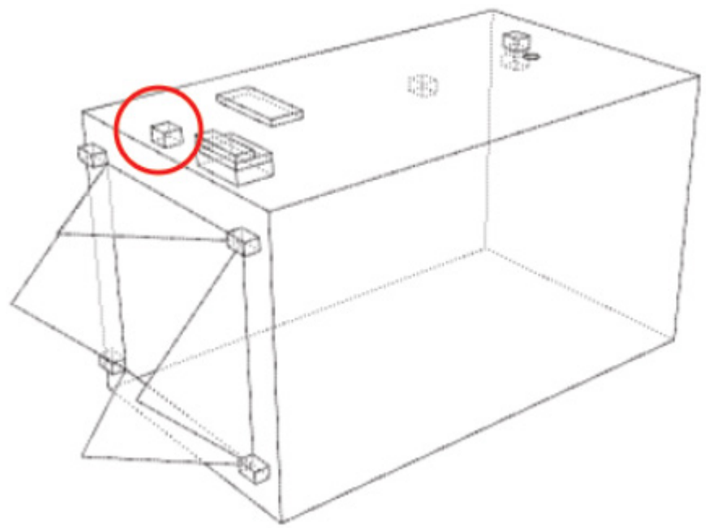
Case study

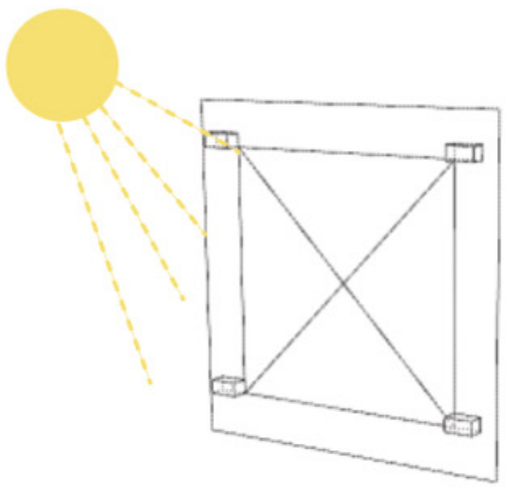
Prototype in context



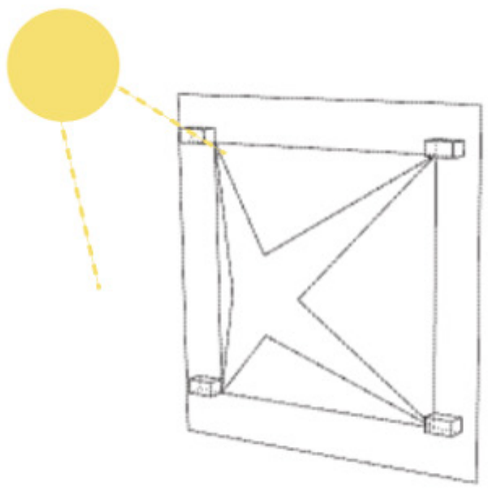
Case study

Experiment 1

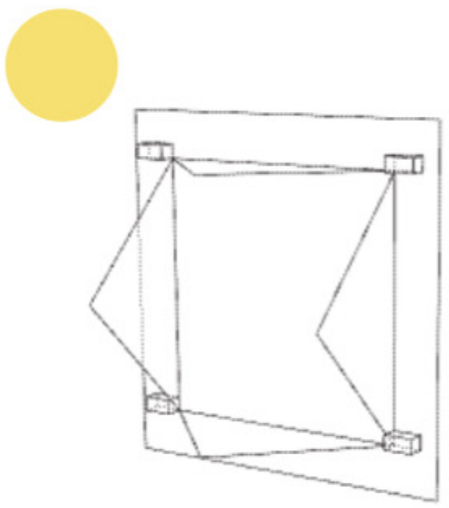




outside 4095 lux

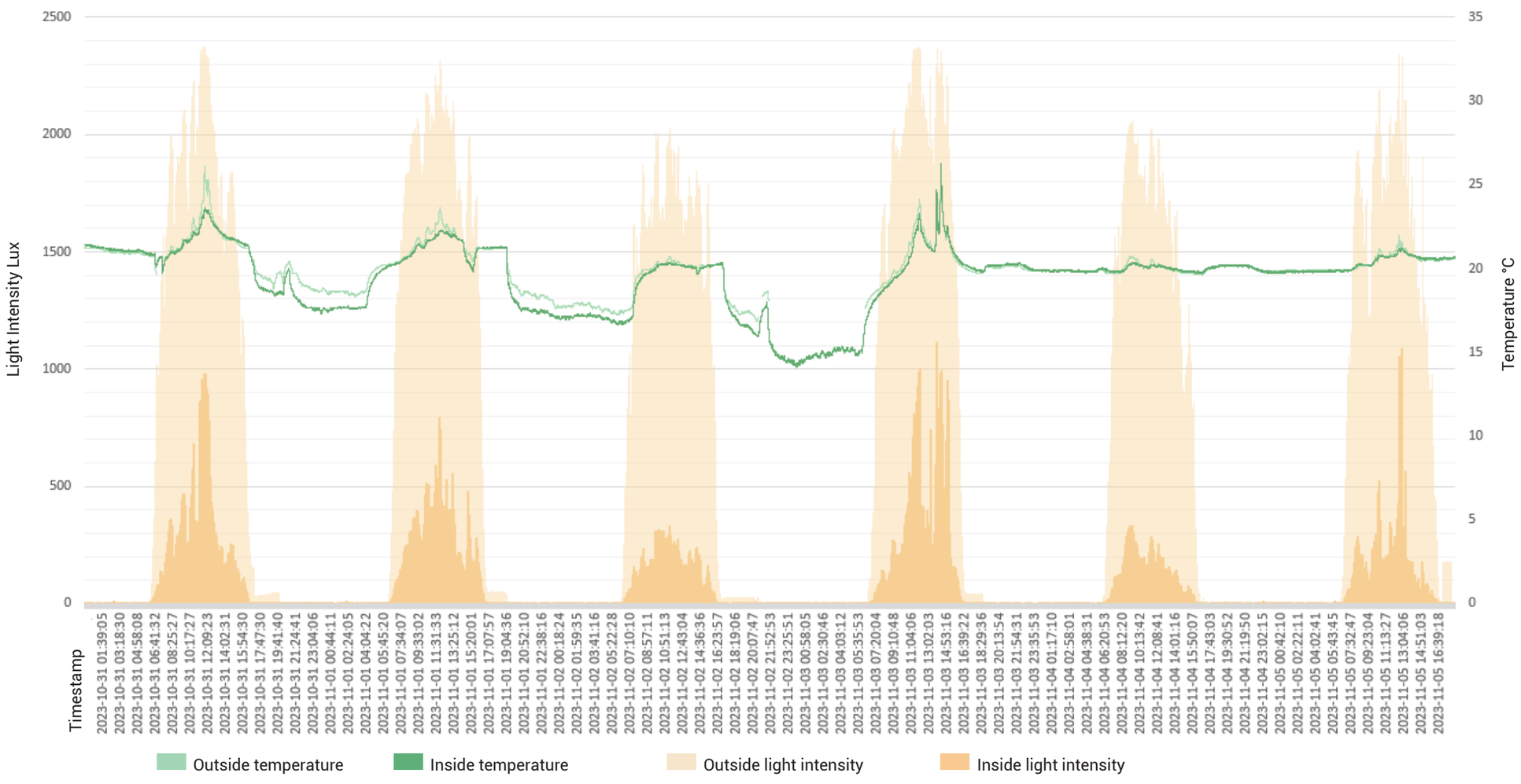


outside 2048 lux

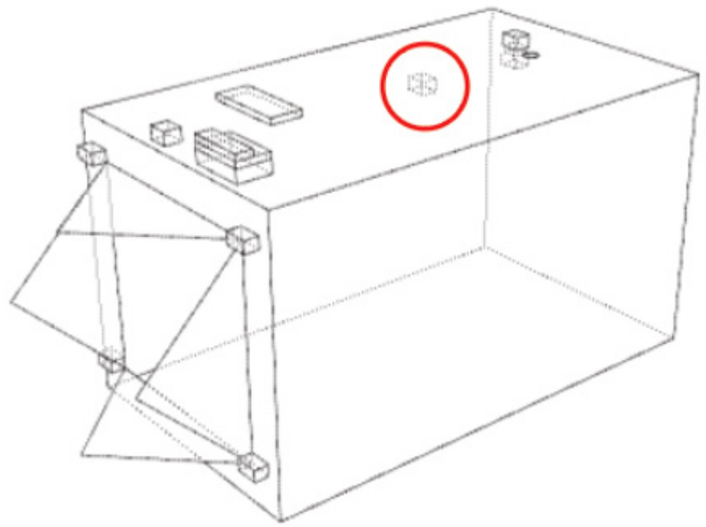


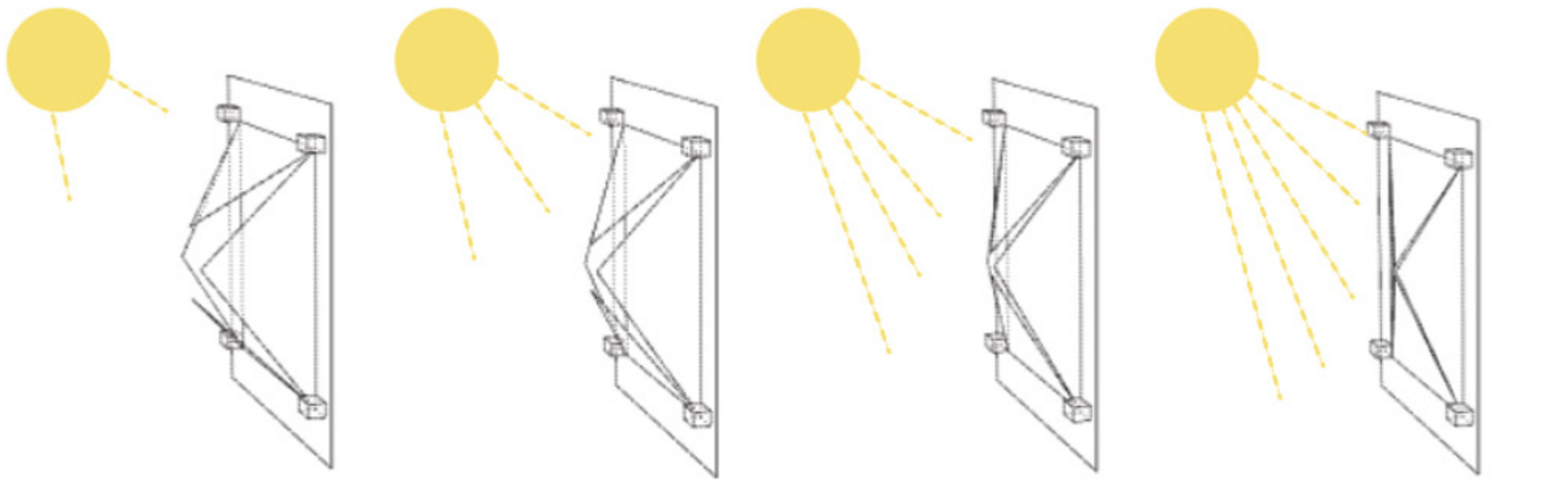
outside 0 lux

Simulations of the prototype - Experiment 1



Experiment 2





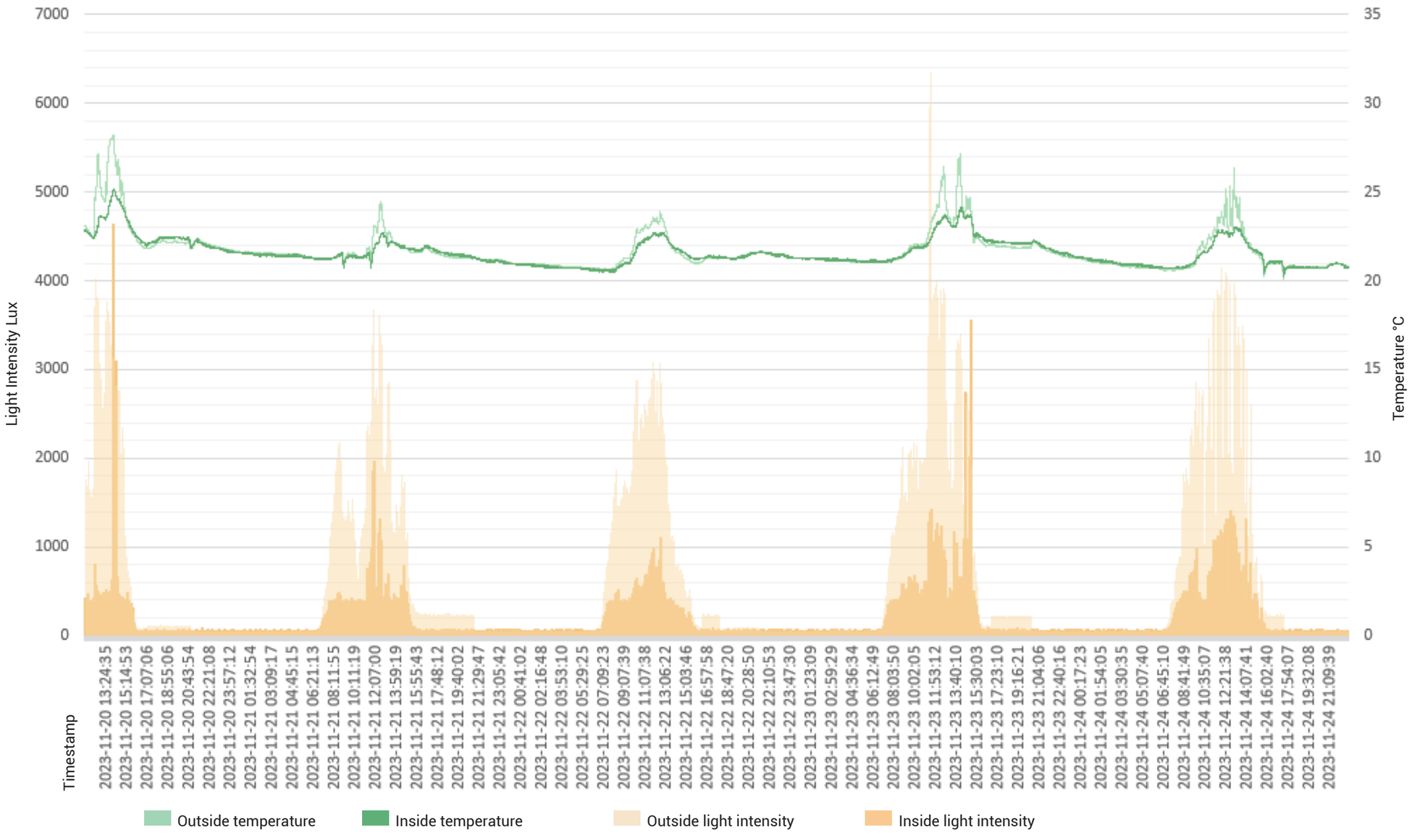
Inside +/-300 lux

Inside +/-300 lux

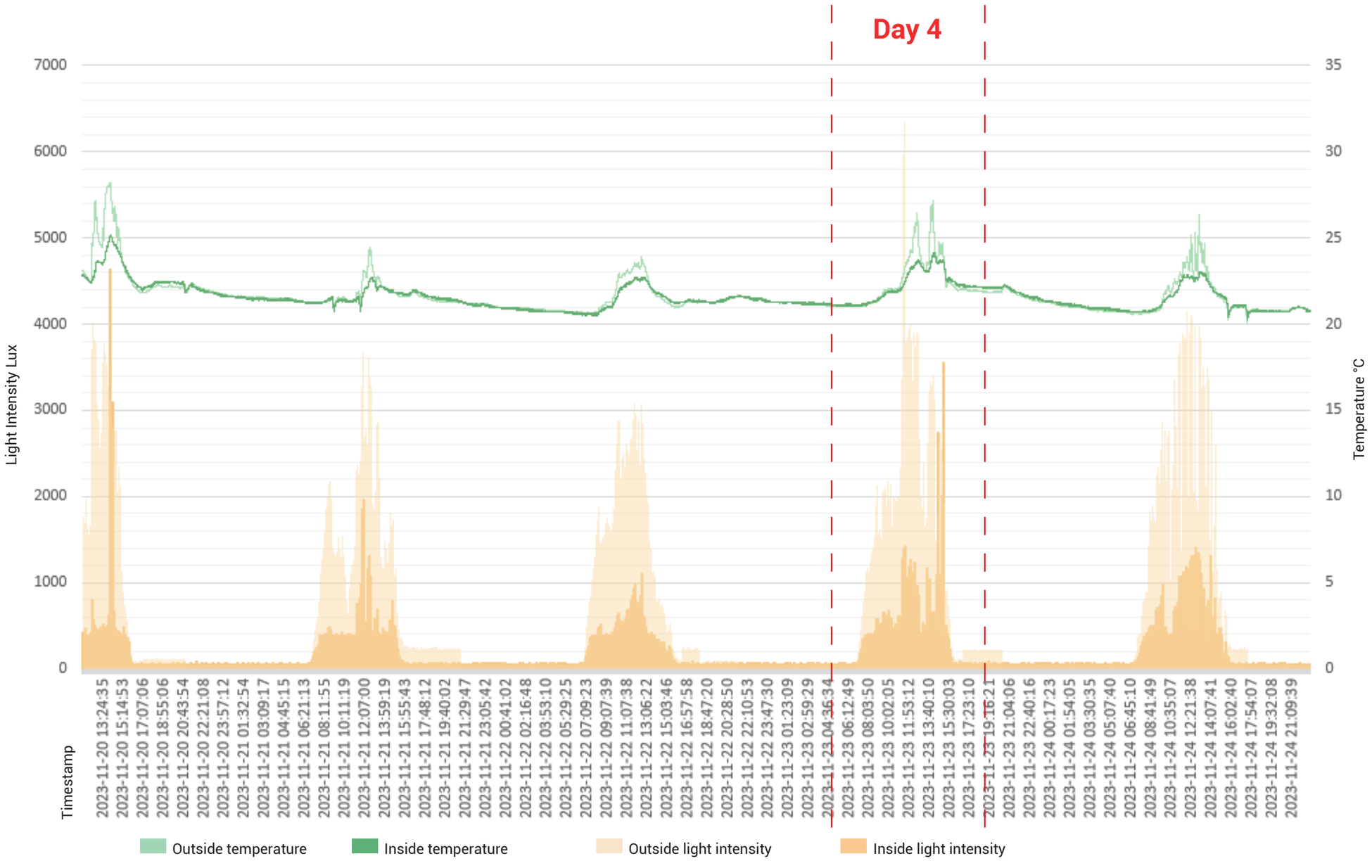
Inside +/-300 lux

Inside +/-300 lux

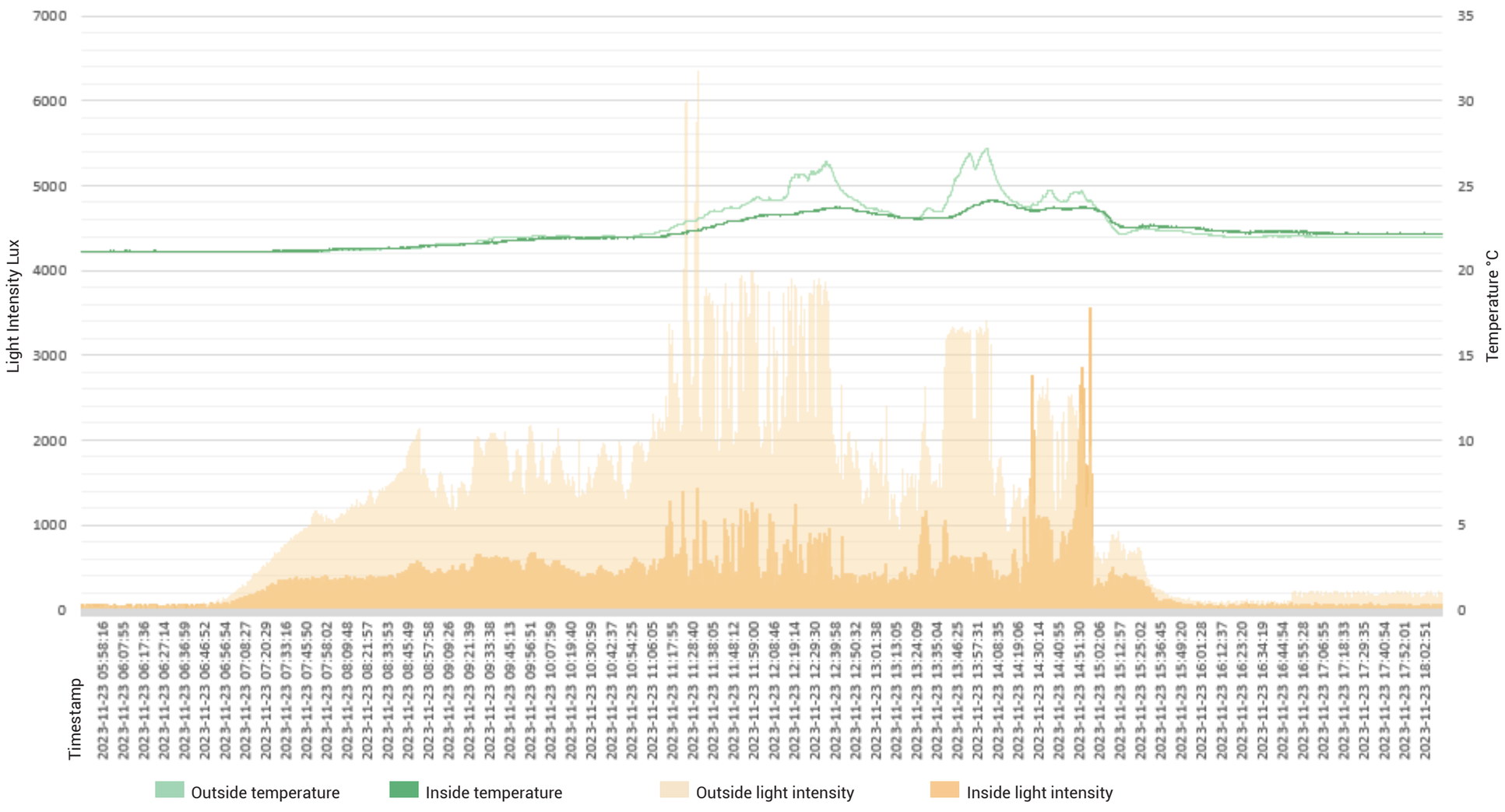
Simulations of the prototype - Experiment 2



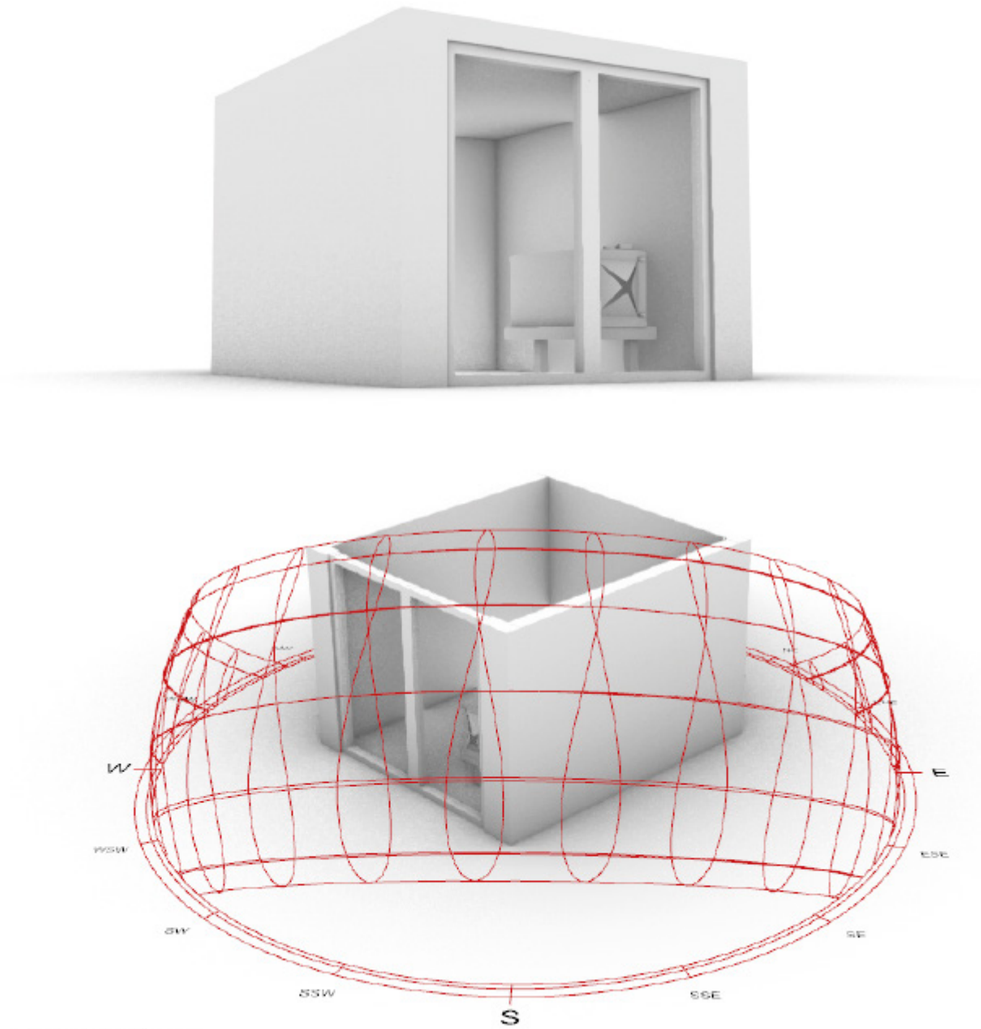
Simulations of the prototype - Experiment 2



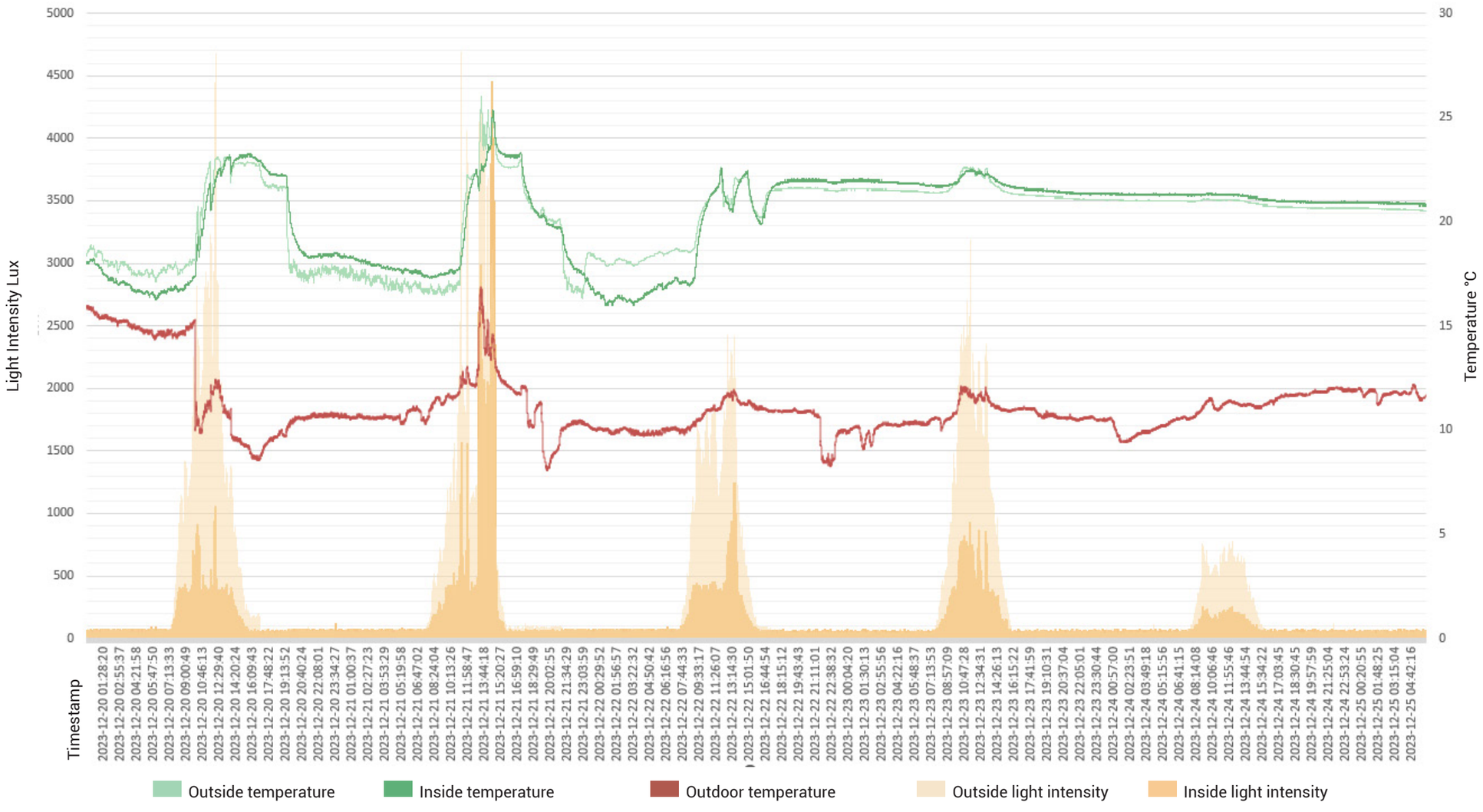
Simulations of the prototype - Experiment 2 Day 4



Prototype in context



Simulations of the prototype - Experiment 2 with added outdoor sensor



Key Findings of the Experiments

Experiment 1:
Temperature differences increase when the outside light intensity is above 2300 lux.

Experiment 2:
Controlling the shading system based on inside light intensity is much more effective for tackling the heating than setting up the system based on the outside light intensity.

Implementing a shading system is a practical solution for preventing overheating, affecting indoor comfort, and promoting the resident's well-being.

Setting one specific light intensity setting for the indoor lighting is a challenge, future research can look into this to make it possible by using AI.

Discussion and Conclusion

Discussion

Discussion points

Exploring the Limits of Understanding

The extent to which these devices truly understand and cater to the nuanced needs of residents remains a subject of ongoing research.

Data Privacy Concers

Collection of vast amounts of personal data, raising serious privacy and security concern.

AI Decision-Making and Transparency

How AI systems make decisions can be unclear, resulting in a potential deficit in transparency and accountability.

Indoor Climate Change

Transforming a house into a smart home involves more than just adding devices; it also involves redefining indoor climate control, affecting the living environment.

Conclusion

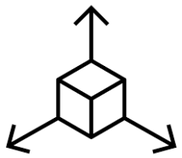
Main conclusion points

Embracing Innovation in Home Design

Transformation of existing house into a smart house challenges designers to think beyond traditional construction and consider how integrated technology can enhance living spaces.

Anticipating Future Needs

The transformation process begins with understanding the residents' future needs, guiding the selection of tailored smart technologies.



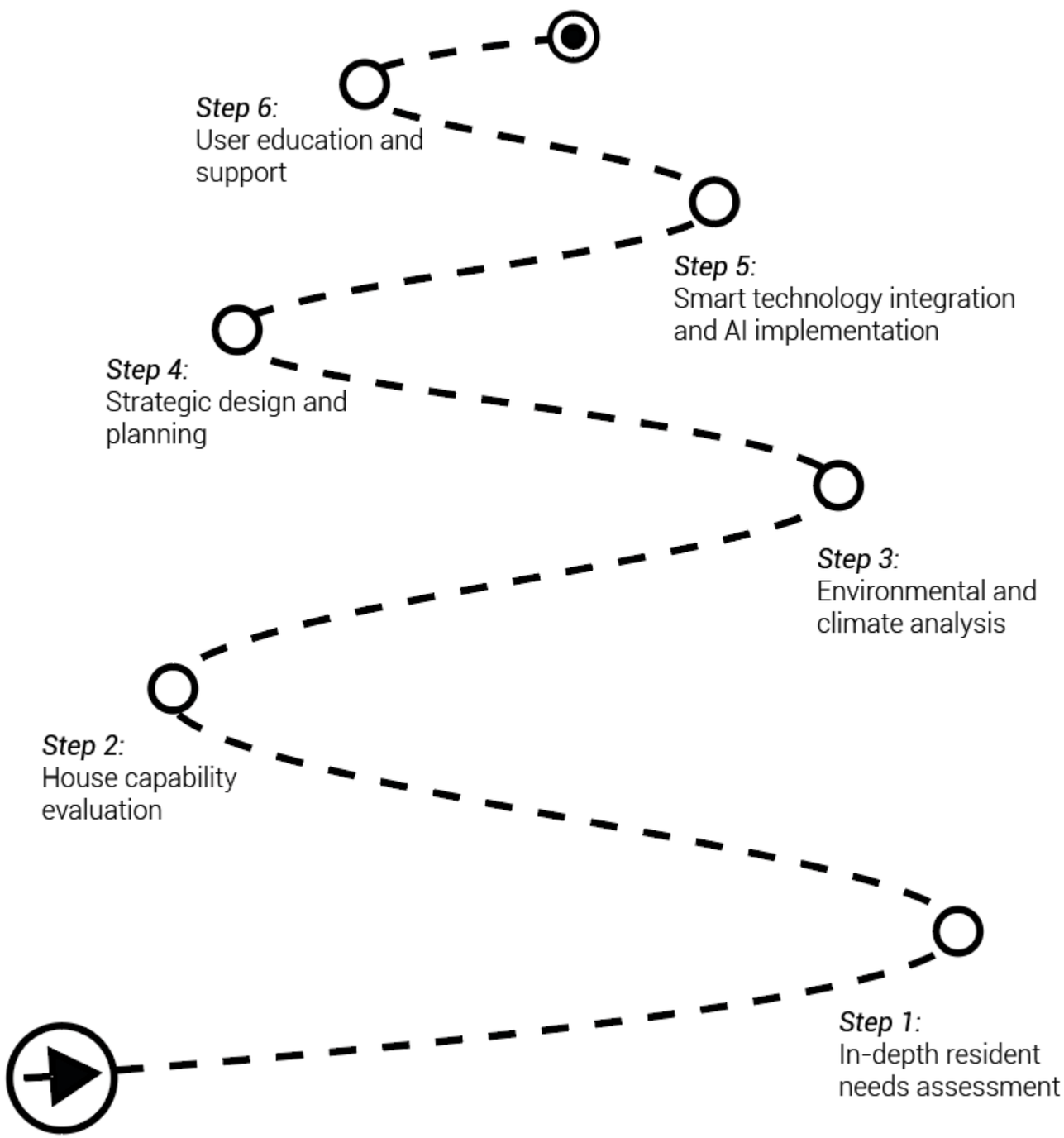
Redefining Spatial Dynamics

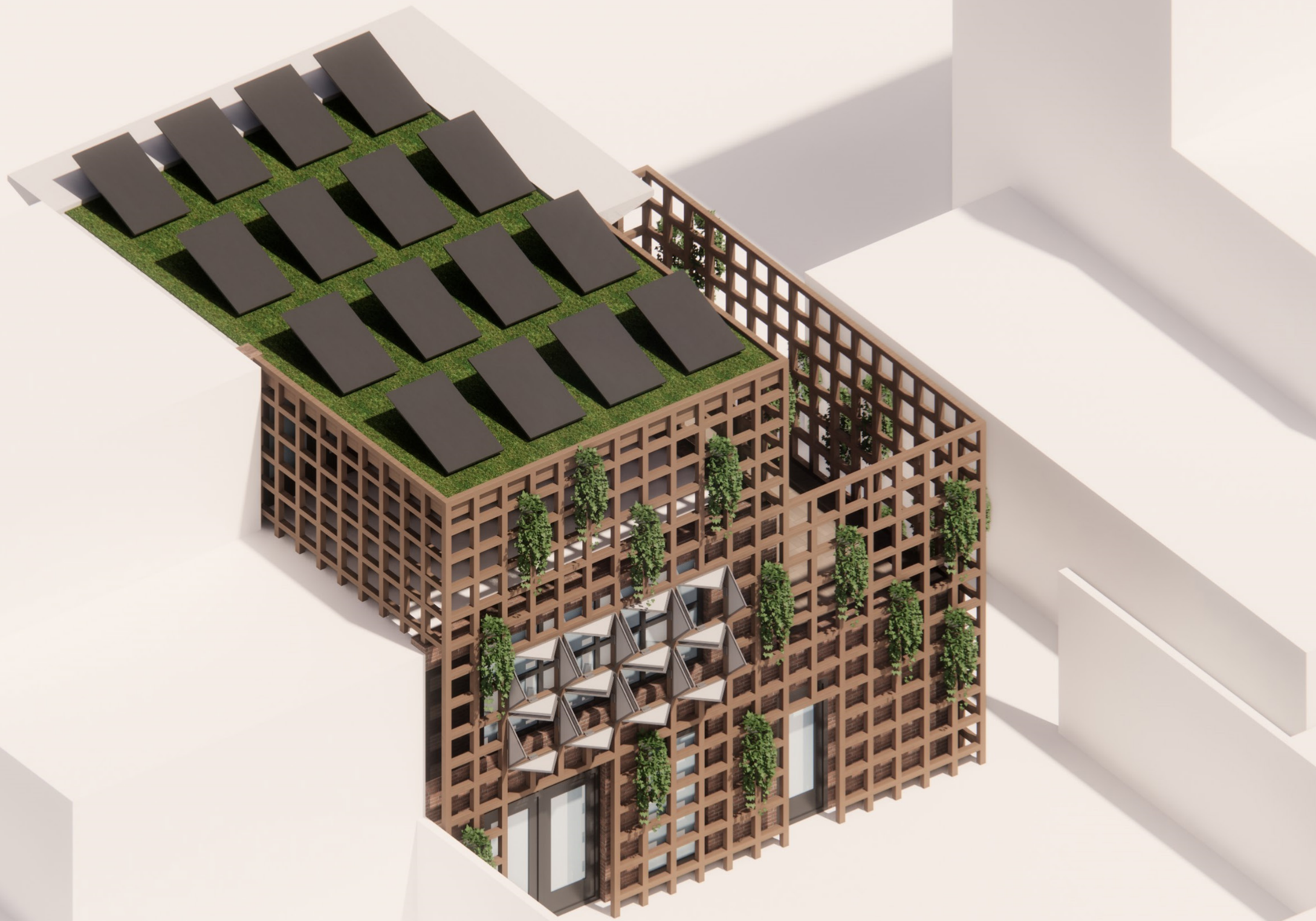
Smart homes change spatial relationships by automating and adapting spaces according to resident behaviors, emphasizing comfort, safety, and health monitoring.

The Role of Artificial Intelligence

AI is able to play a key role in learning residents' habits, automating tasks, and providing a more responsive living environment.

Conclusion


Step 6:
User education and support
Step 5:
Smart technology integration and AI implementation
Step 4:
Strategic design and planning
Step 3:
Environmental and climate analysis
Step 2:
House capability evaluation
Step 1:
In-depth resident needs assessment



Thank you.