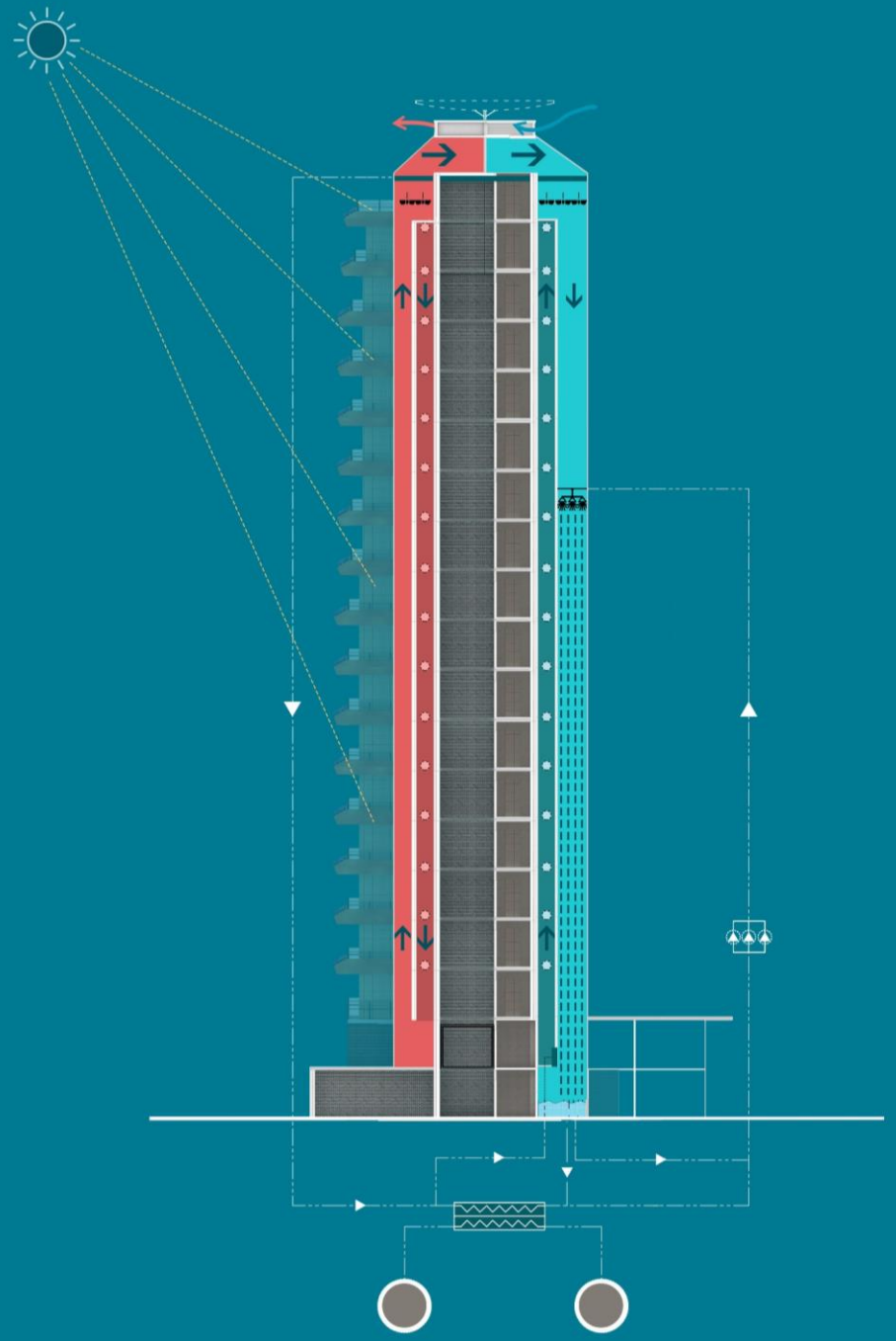


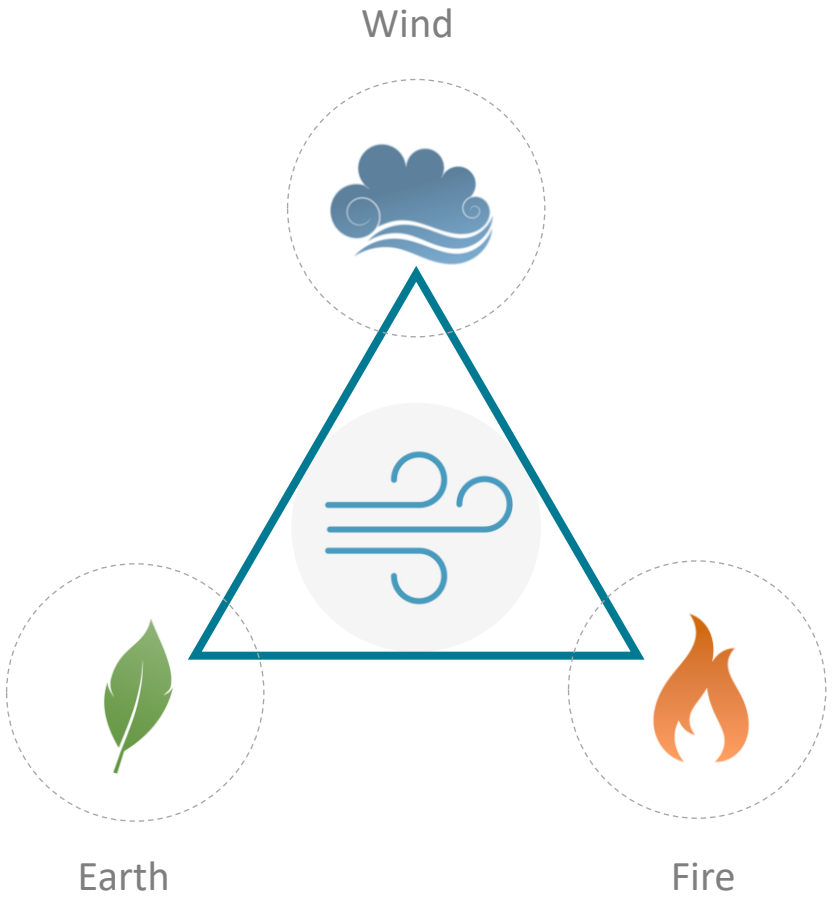
Housing Refurbishment using the Earth, Wind & Fire system

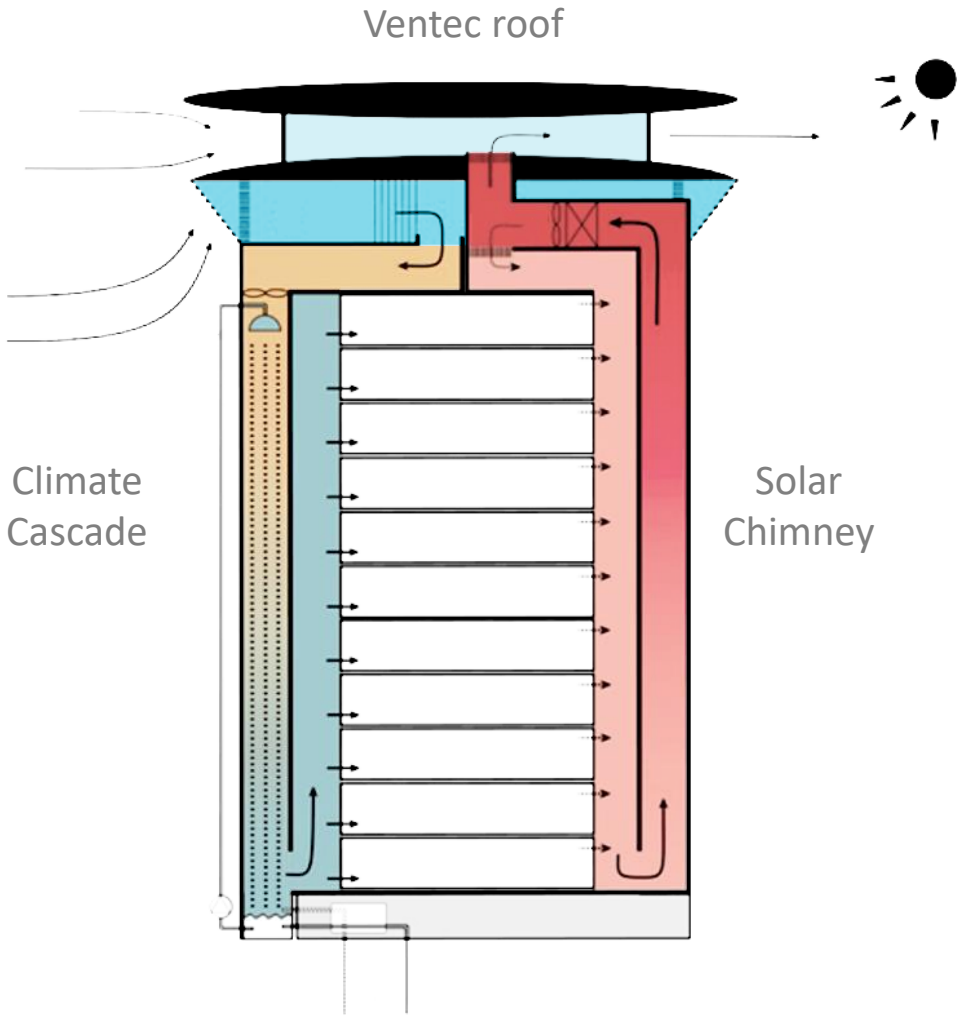
Towards a nearly energy-neutral housing in the Netherlands

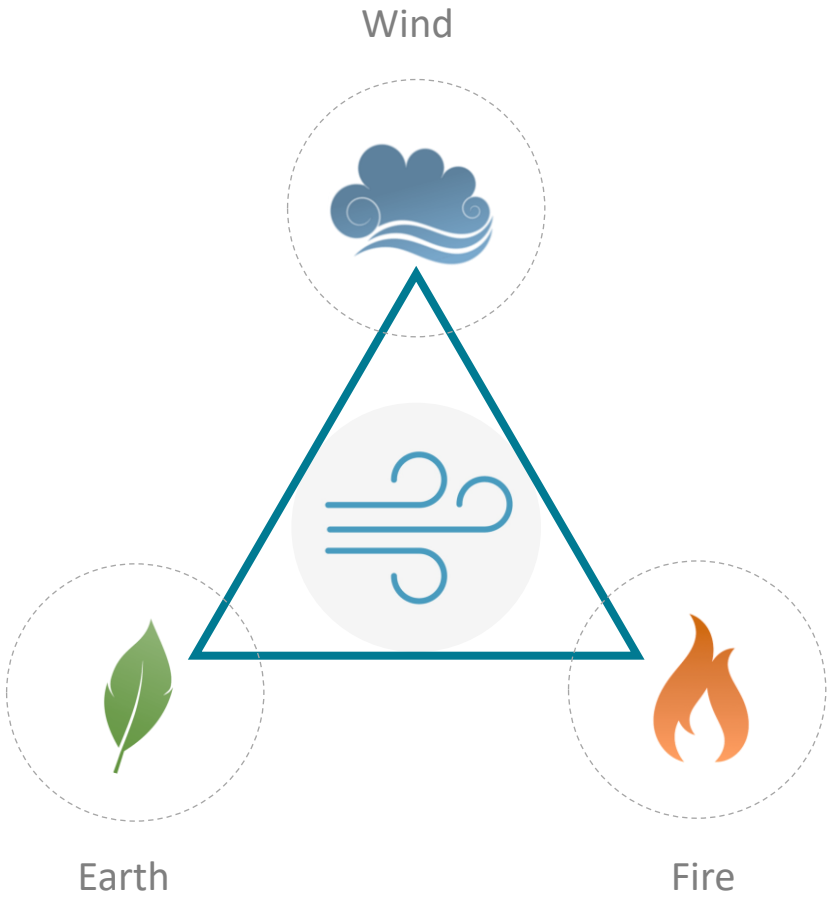
Graduation Presentation I Yamini Patidar I 5055288

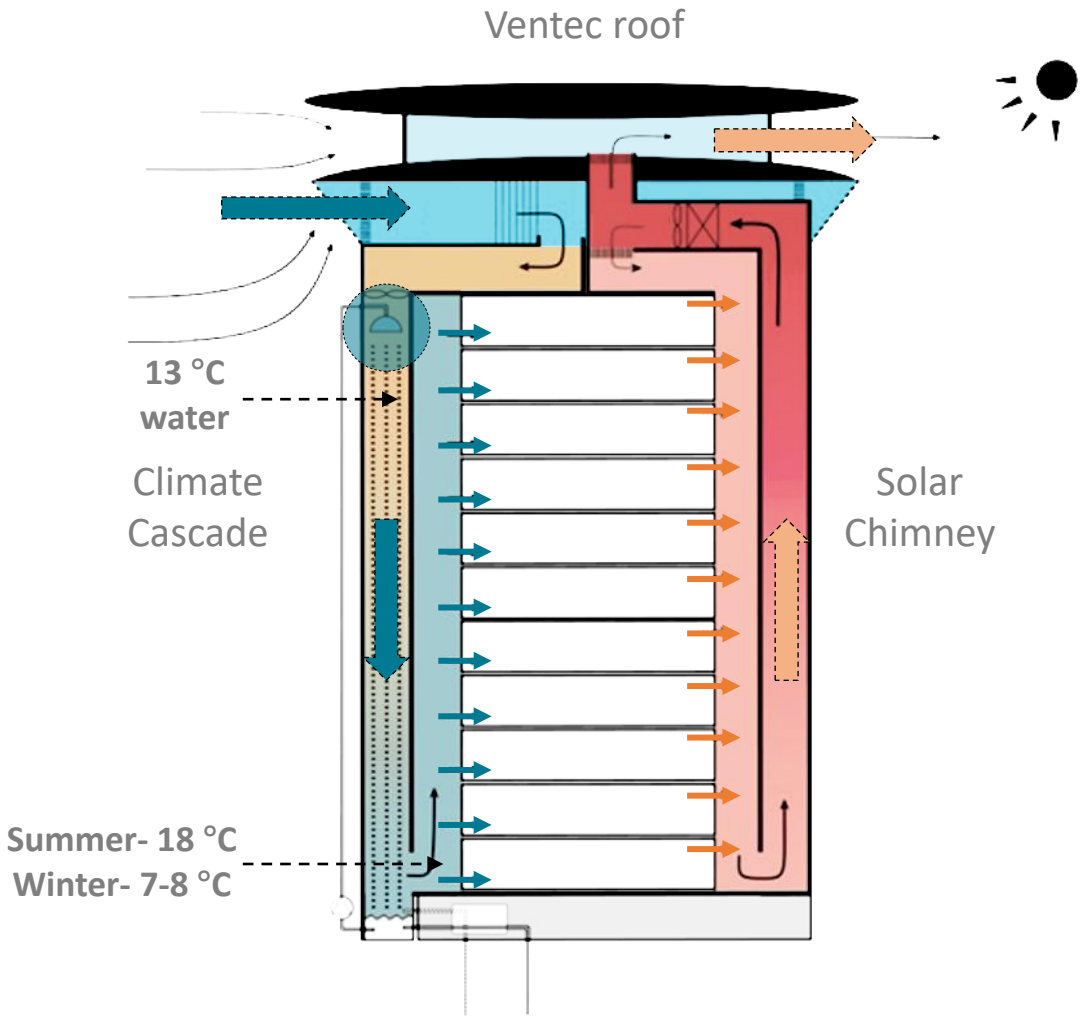
Mentors:
Dr. Regina Bokel, Dr. Ing. Marcel Bilow

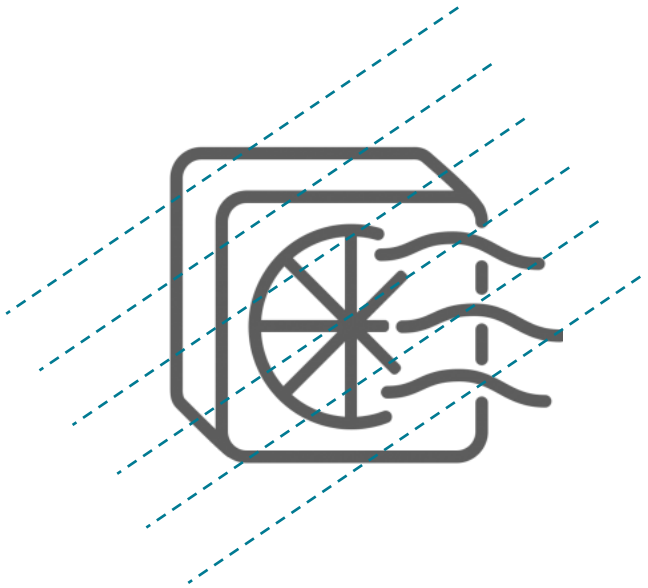
Guest mentor:
Dr. Ben Bronsema


Wind
Earth
Fire

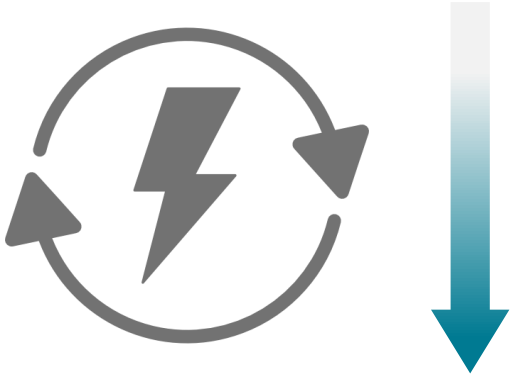

Ventec roof
Climate
Cascade
Solar
Chimney


Wind
Earth
Fire


Ventec roof
13 °C
water
Climate
Cascade
Solar
Chimney
Summer- 18 °C
Winter- 7-8 °C



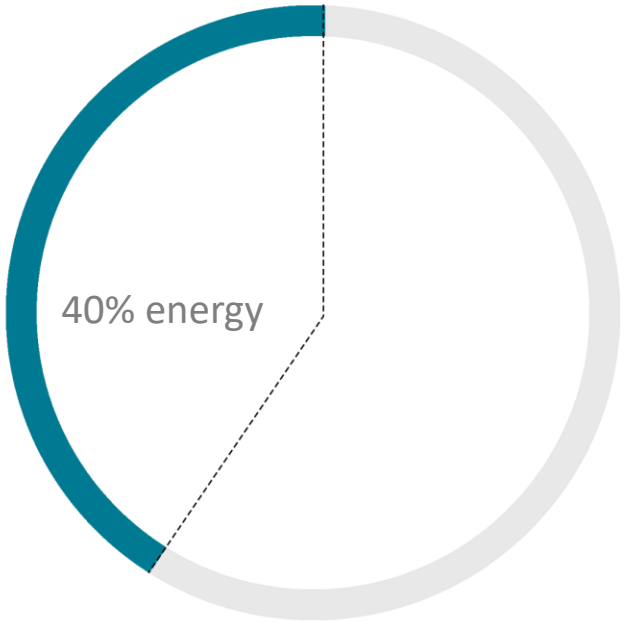
Elimination of HVAC

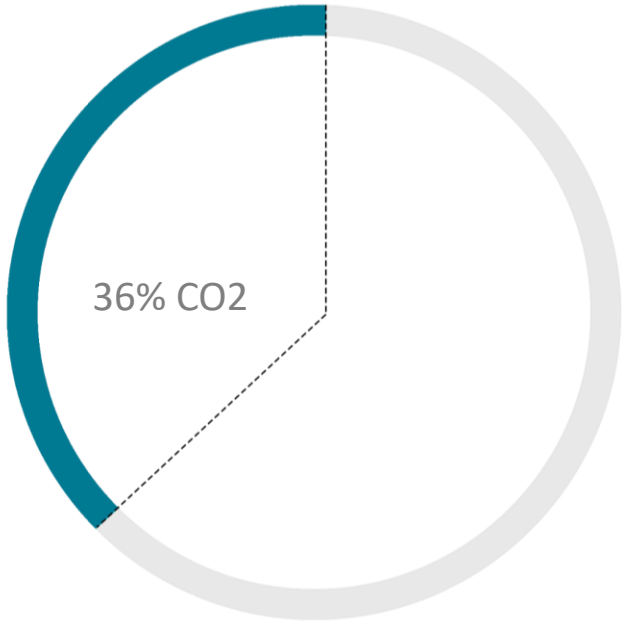


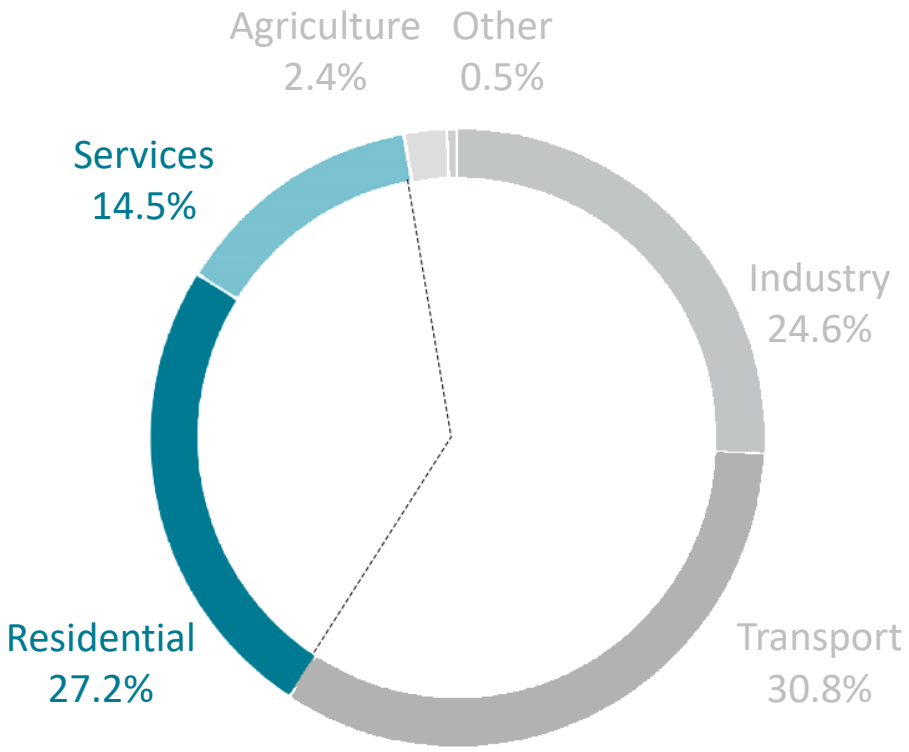
Minimized energy consumption

Healthy indoor environment

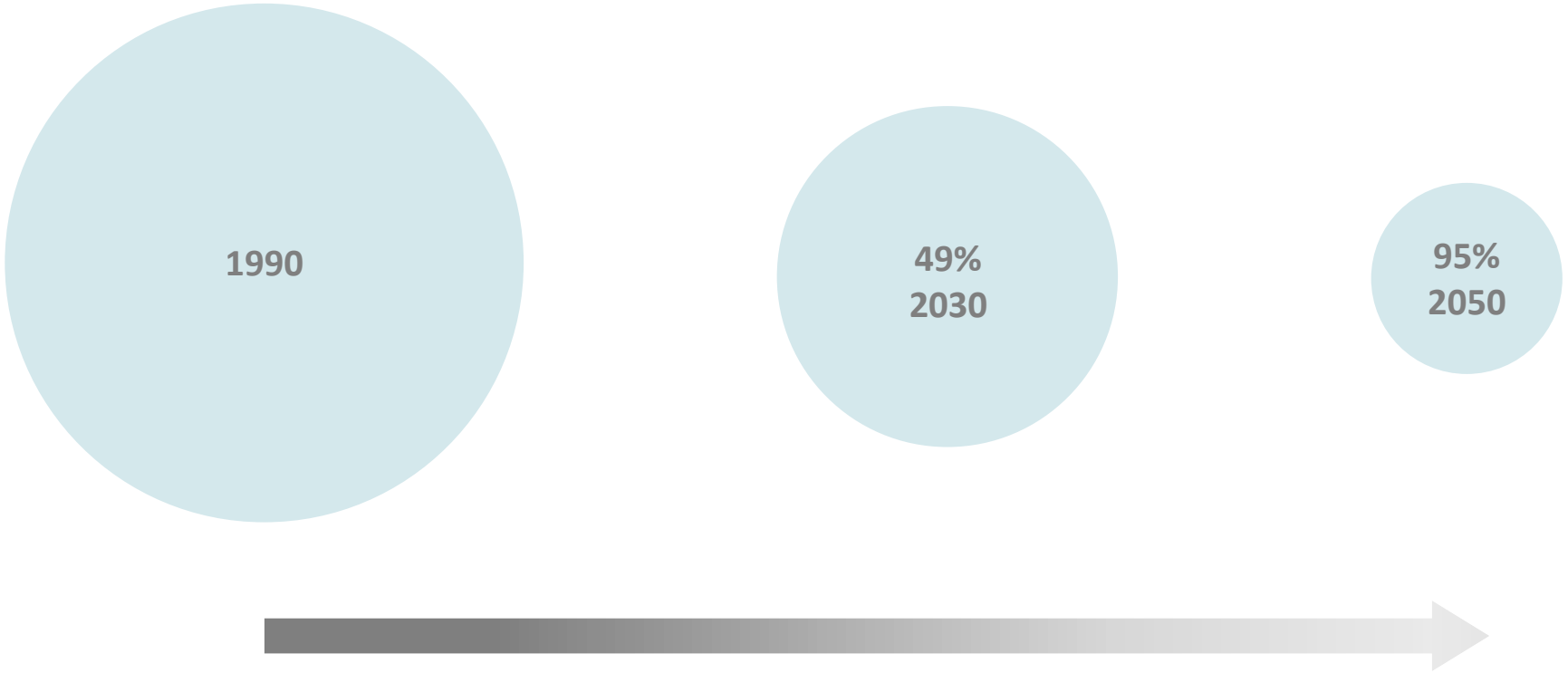
What is the relevance of the **EWF system**
in the larger societal context?

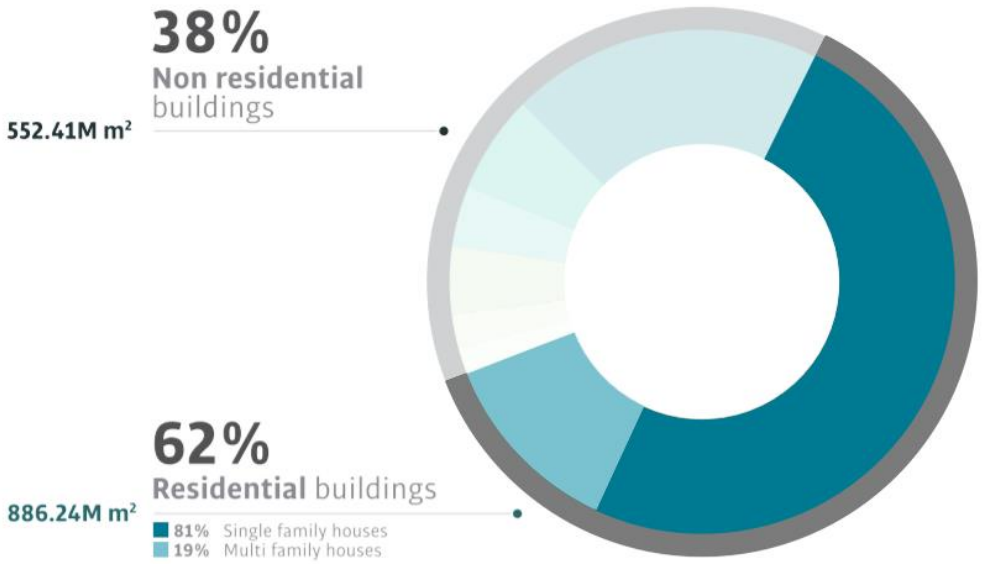






Source: Eurostat (2014)


1990
49%
2030
95%
2050



80%
Before 1995

Source: CBS, EU Building Observatory

2020

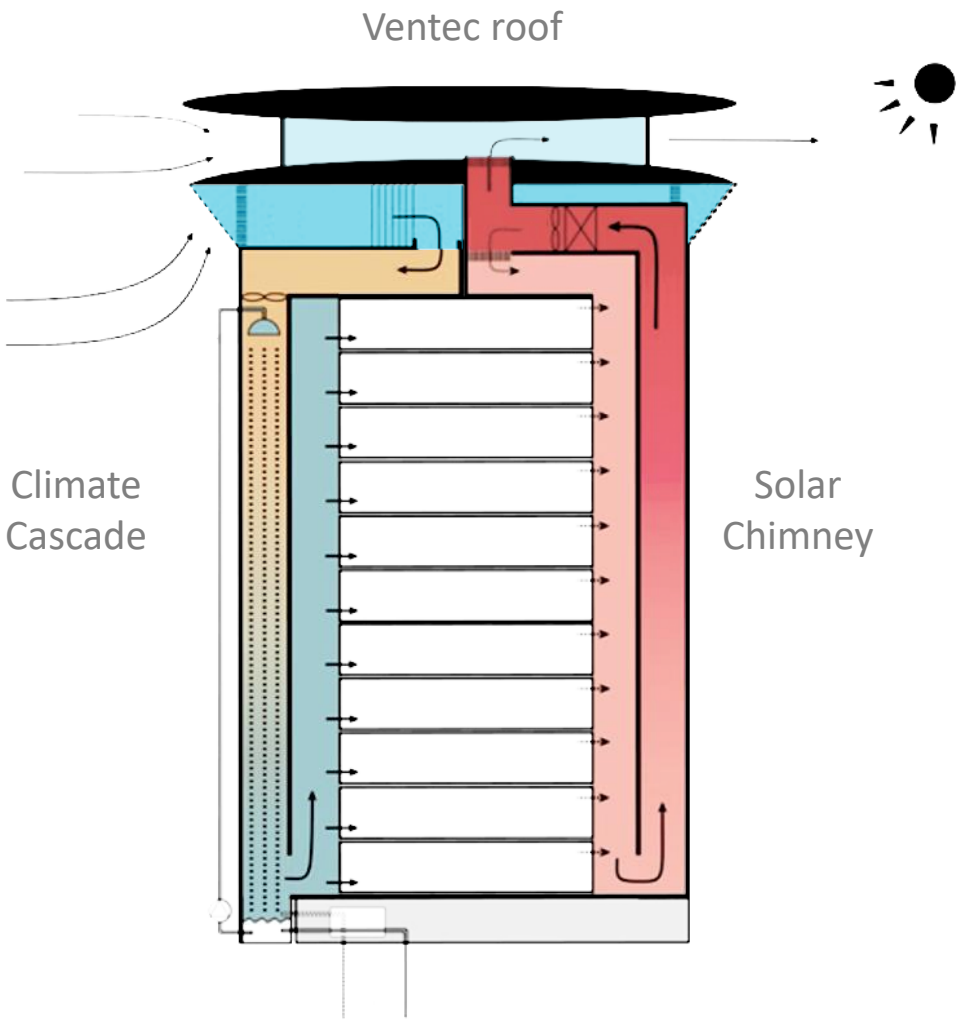
New construction

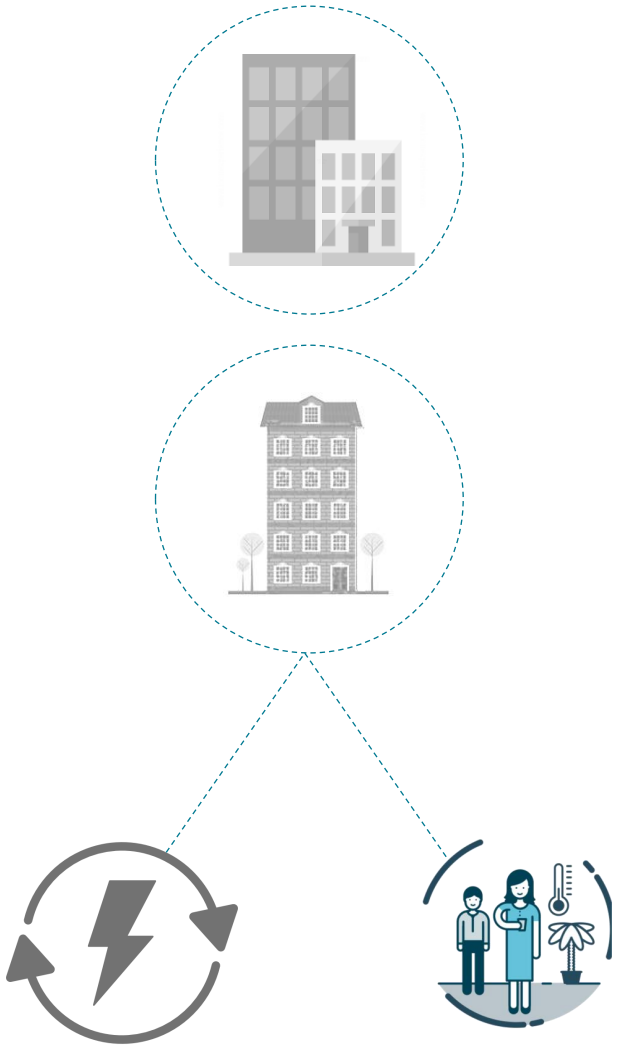
Before 1995

Old housing stock

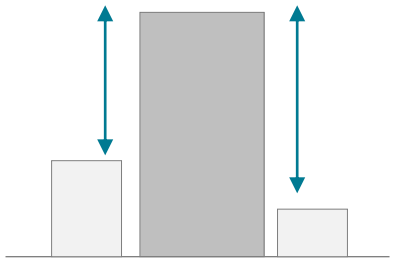
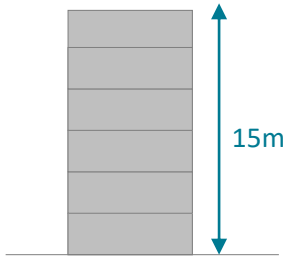
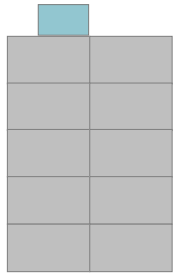
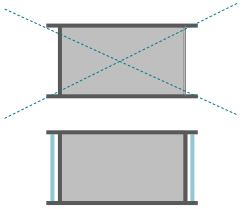
2050

Refurbishment


Ventec roof
Climate
Cascade
Solar
Chimney



“How can the **Earth, Wind & Fire** system be integrated in the **Housing refurbishment** in the Netherlands to achieve a **nearly energy neutral design** and improve the **indoor comfort** of the building?”

Context	Building height	Structure	Facade	Building typology
Height difference	**Minimum 15m building height**	**Load-bearing capacity**	**Façade type**	**Multi-family**
			Load-bearing façade not feasible 	**With/without gallery** **Built before 1995**

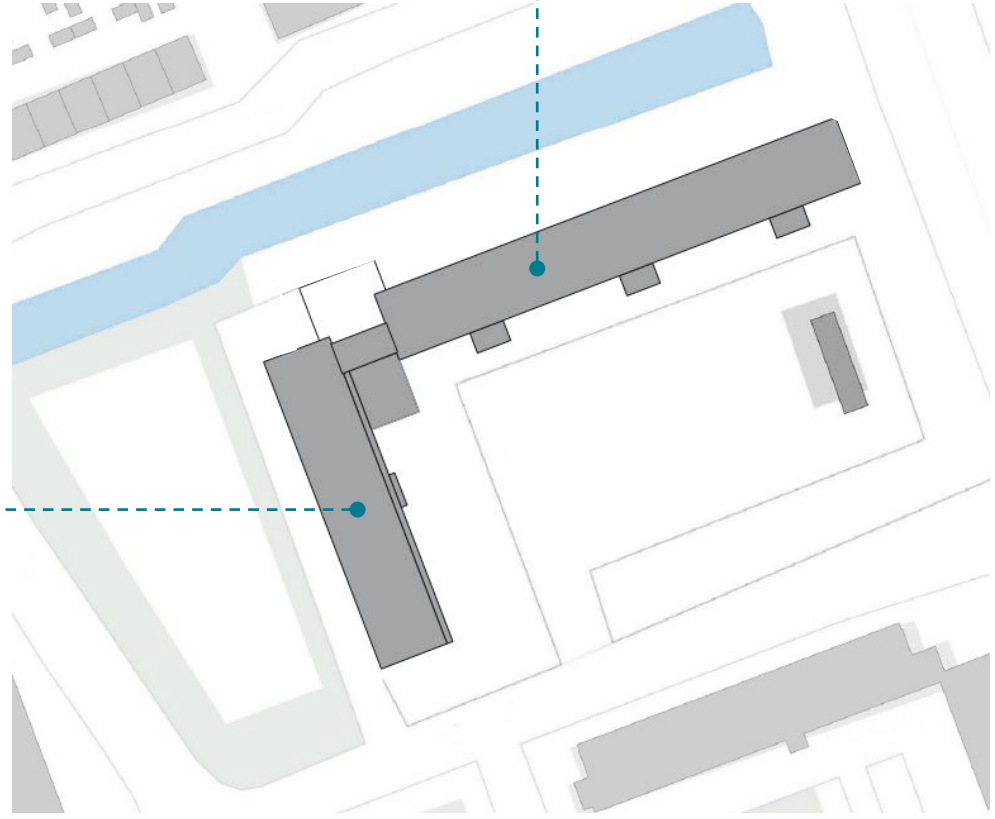
Arthur Van Schendelplein, Delft

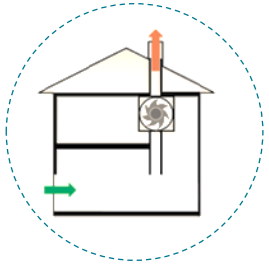
Apartment type : gallery apartment
Construction period : 1969
Building area : 19800 m2
Parking area : lower two floors
Floor height : 2.8 m
No. of Occupants : 644

Source: Heeswijk architecten

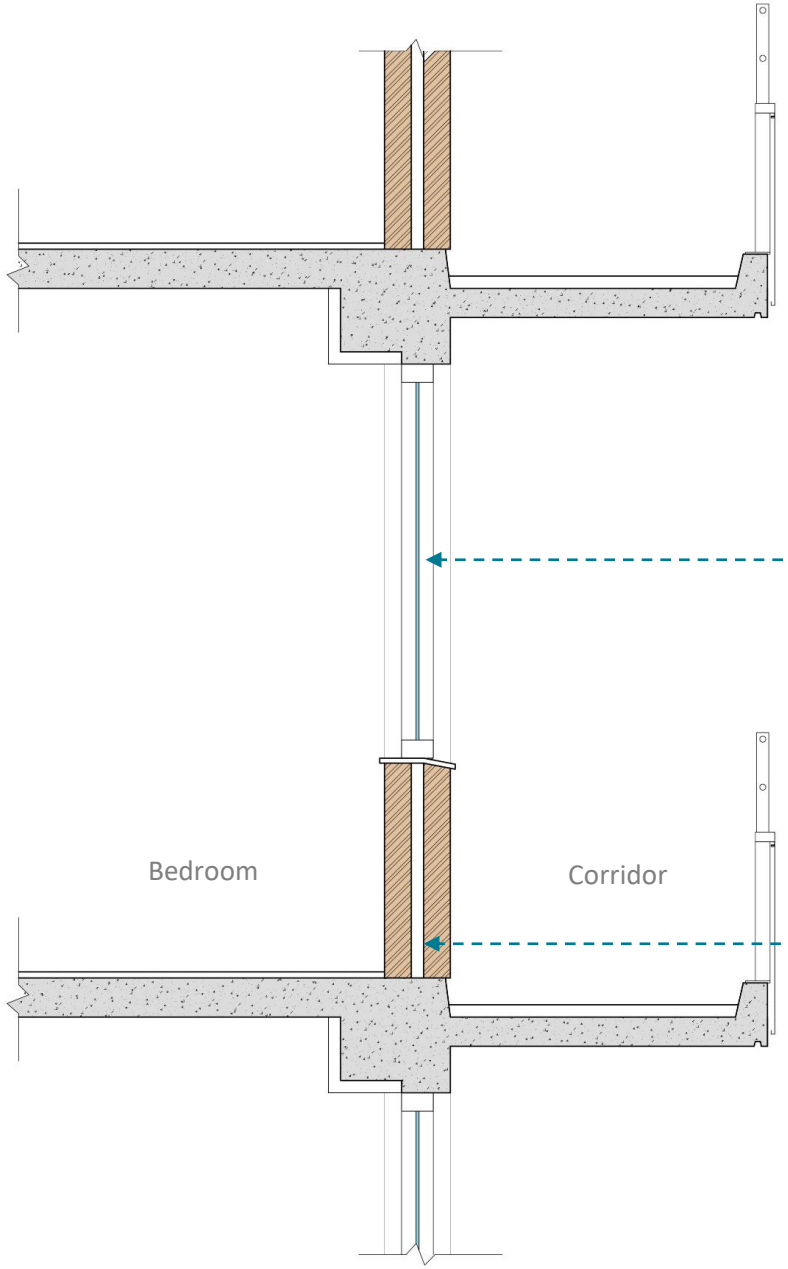
Taller block- 18 floors

Shorter block- 10 floors





Source: Heeswijk architecten



Single Glazing

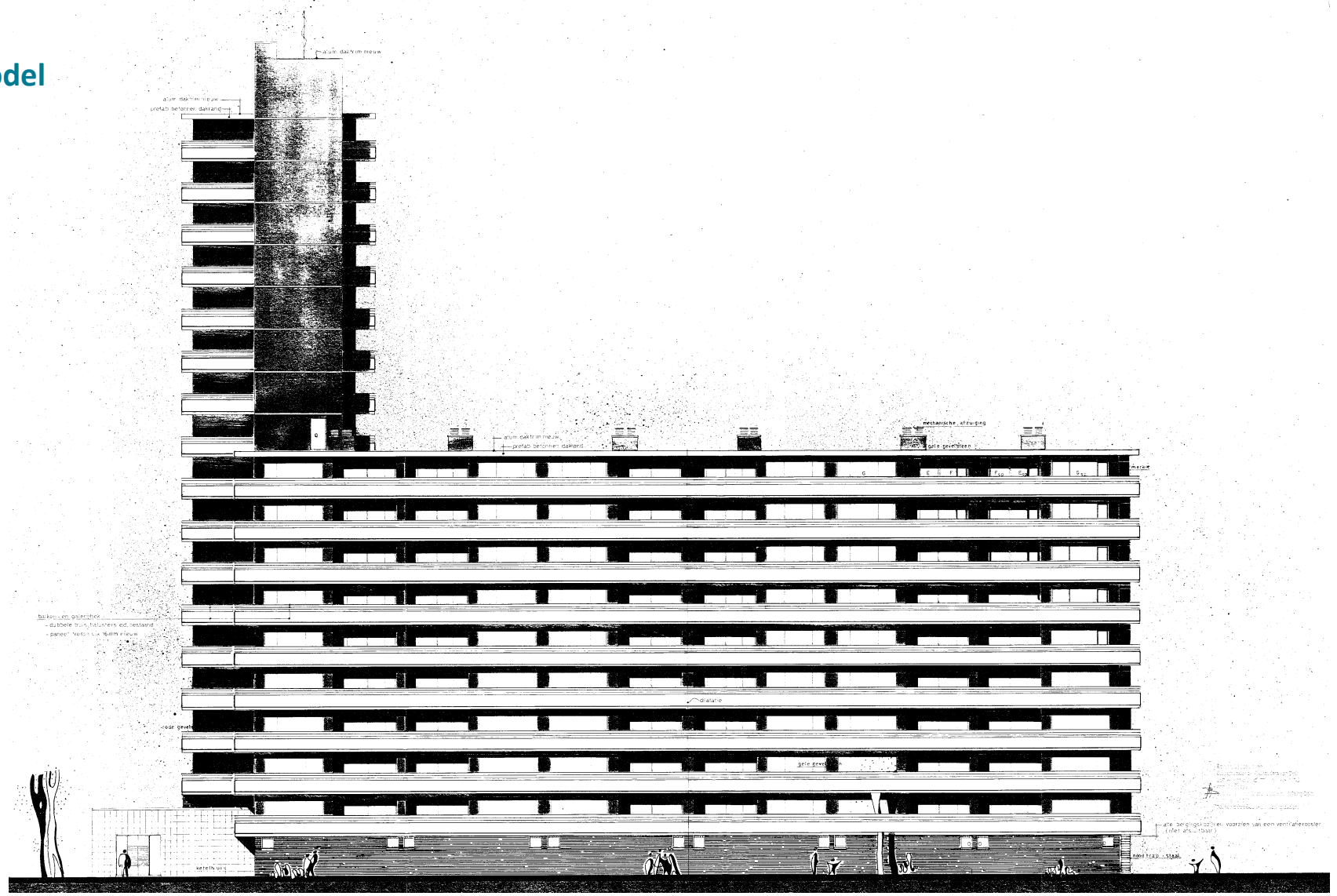
U-value:
Existing: 6 W/m2K
Required: 1.65 W/m2K

Cavity brick wall

R-value:
Existing: 0.7 m2K/W
Required: 4.7 m2K/W

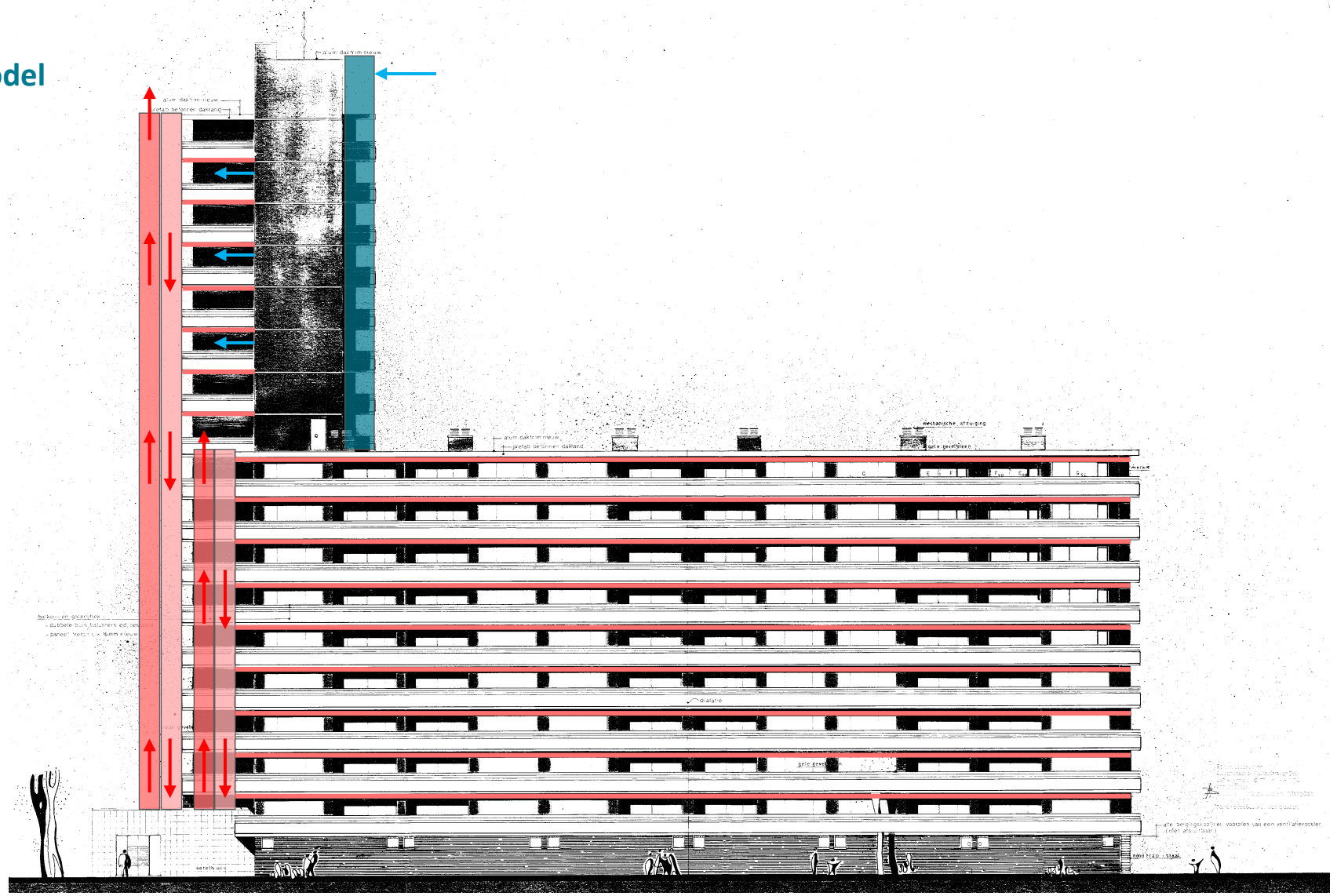
Source: ikwilhuren.nl

Total Refurbishment model



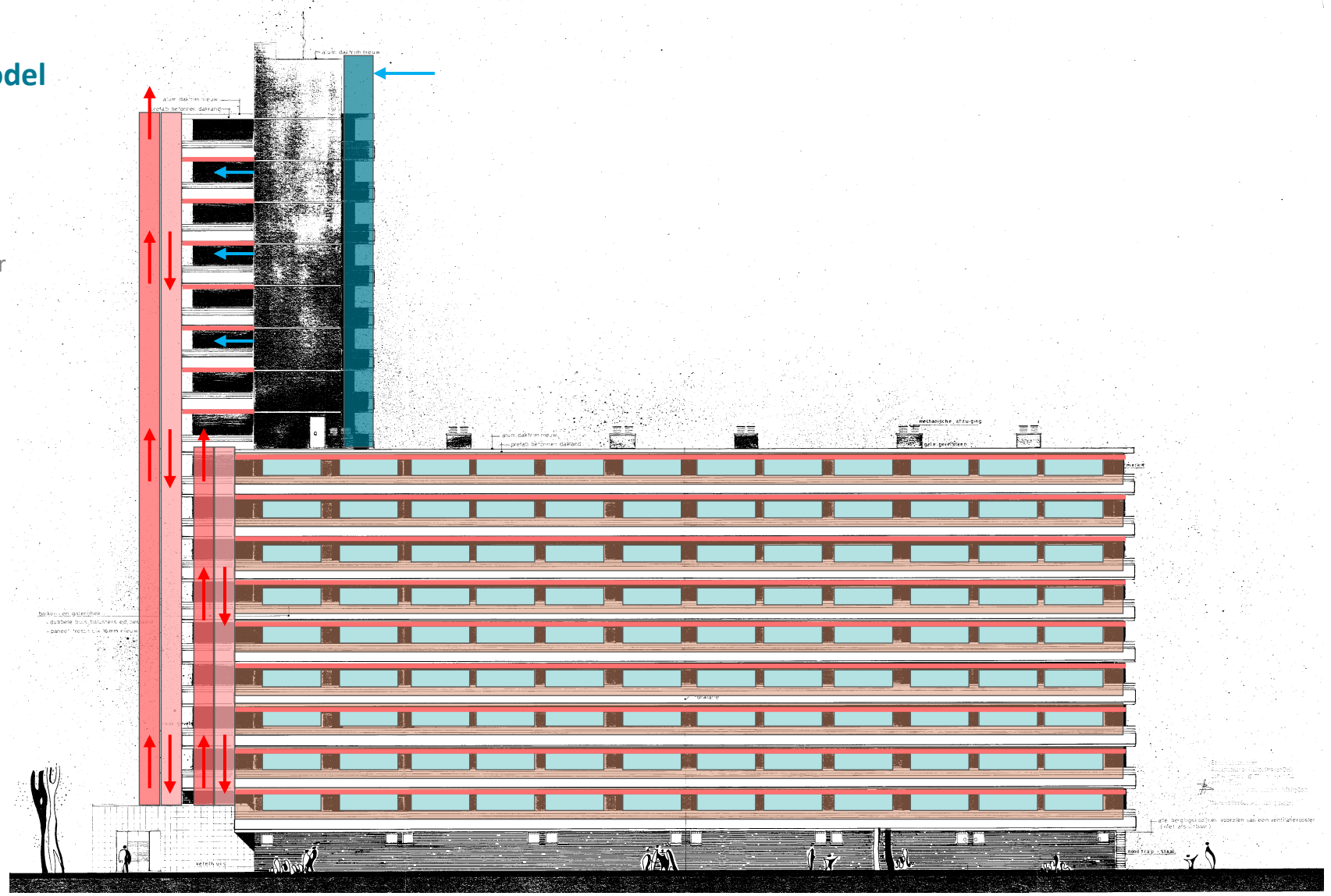
Total Refurbishment model

- Ventilation system- Climate cascade and Solar Chimney



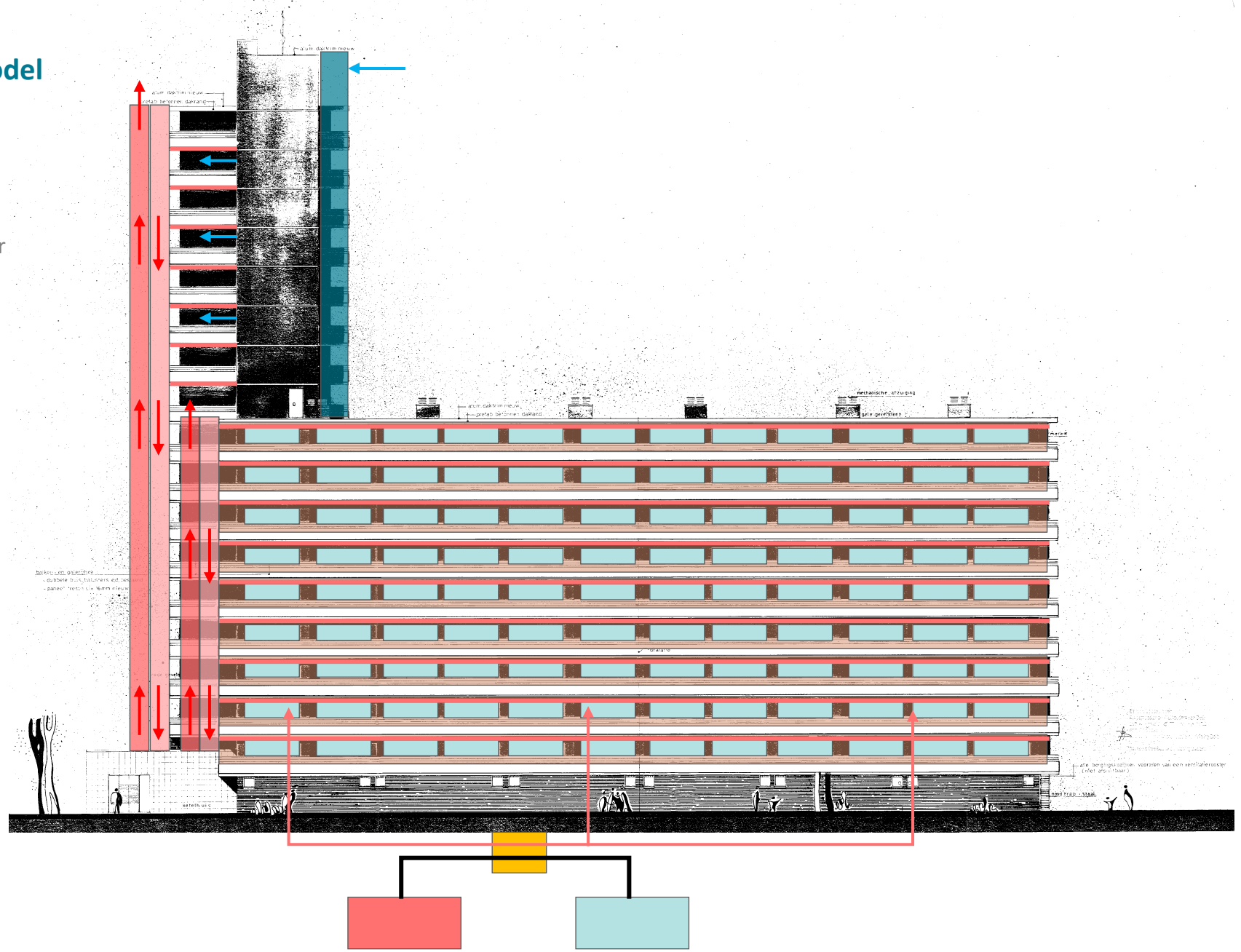
Total Refurbishment model

- Ventilation system- Climate cascade and Solar Chimney
- Envelope insulation (partial or total)
- Window replacement (for air tightness and U-value)



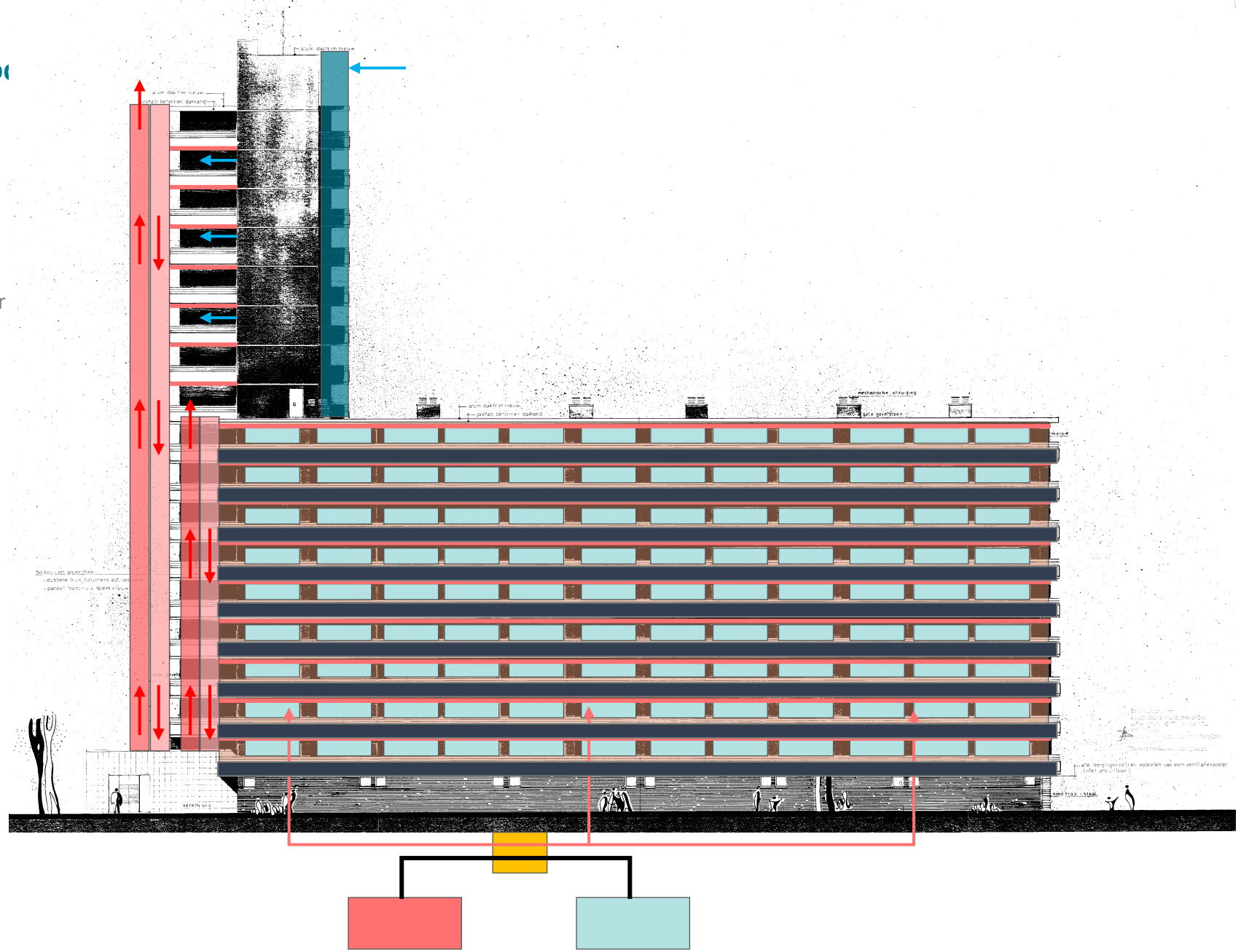
Total Refurbishment model

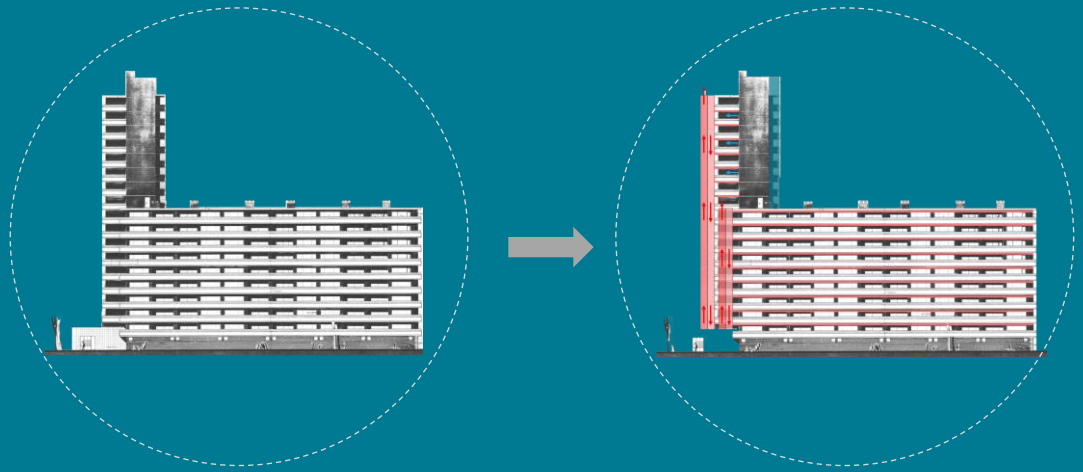
- Ventilation system- Climate cascade and Solar Chimney
- Envelope insulation (partial or total)
- Window replacement (for air tightness and U-value)
- Heat pump and ATES



Total Refurbishment mo

- Ventilation system- Climate cascade and Solar Chimney
- Heat pump and ATES
- Envelope insulation (partial or total)
- Window replacement (for air tightness and U-value)
- Solar panels on façade.

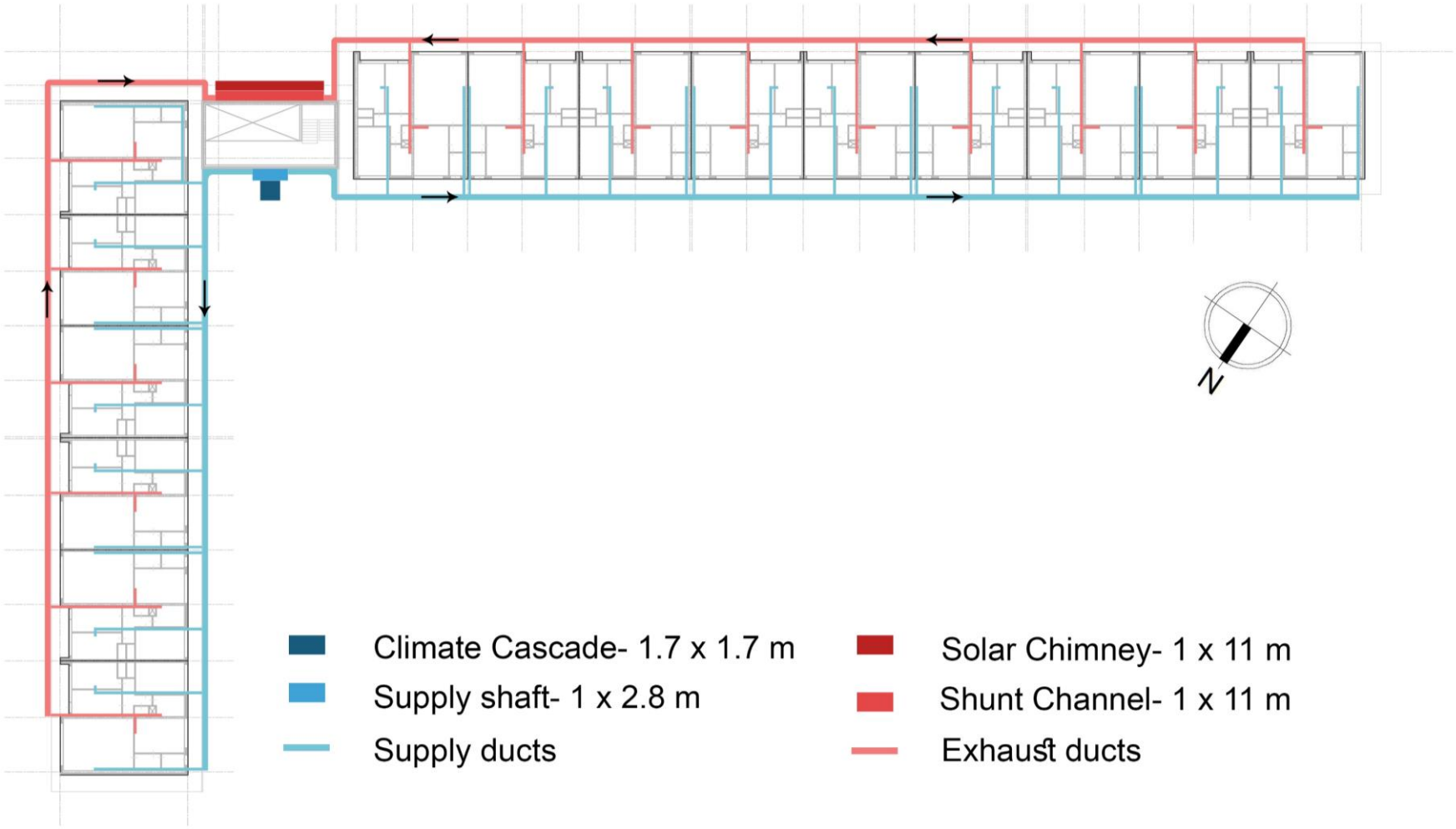




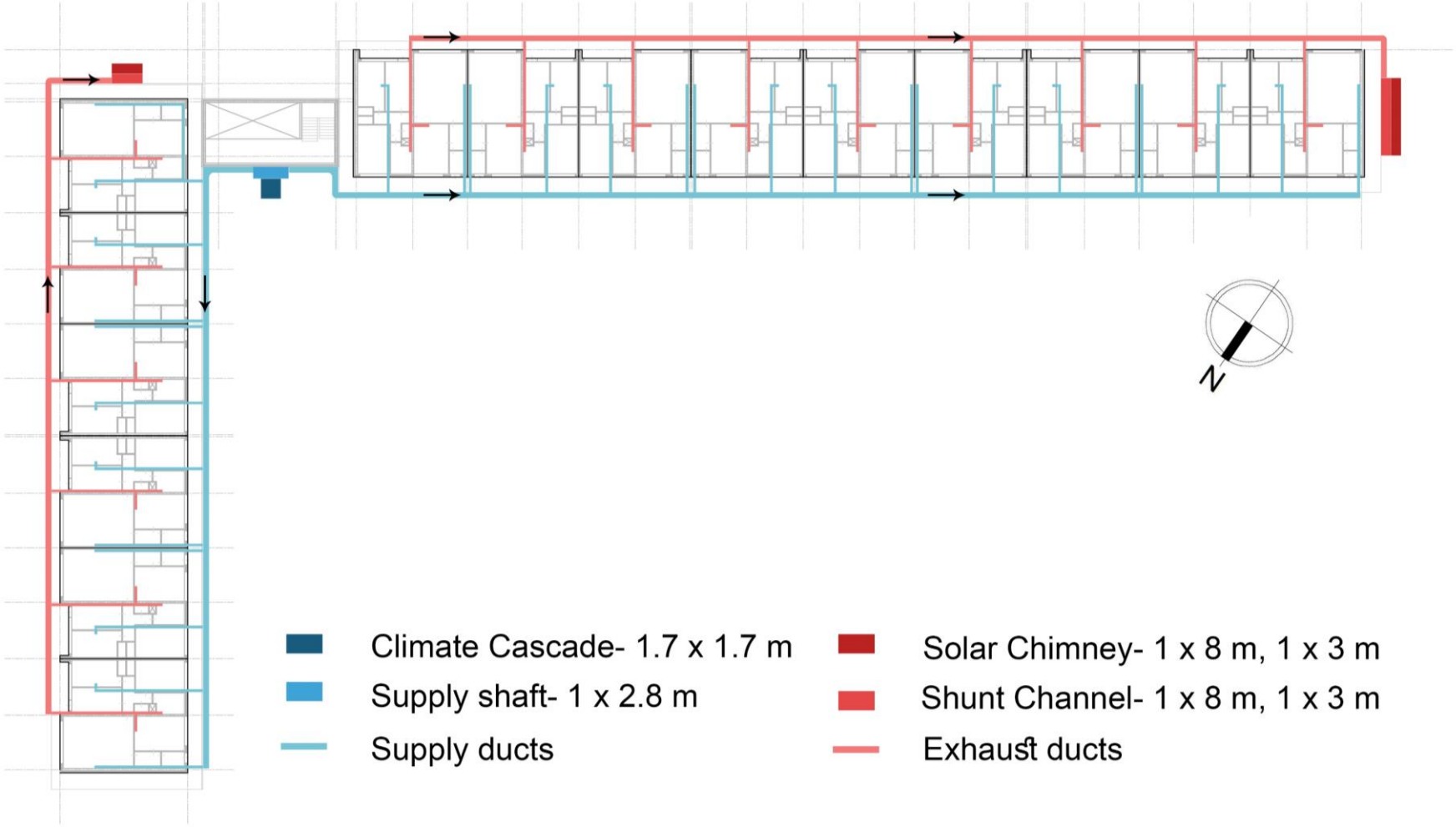
Step 01- EWF integration

Does the variation in **placement, number, size** and **technical parameters** for the Climate Cascade and Solar Chimney elements affect the **energy performance**?

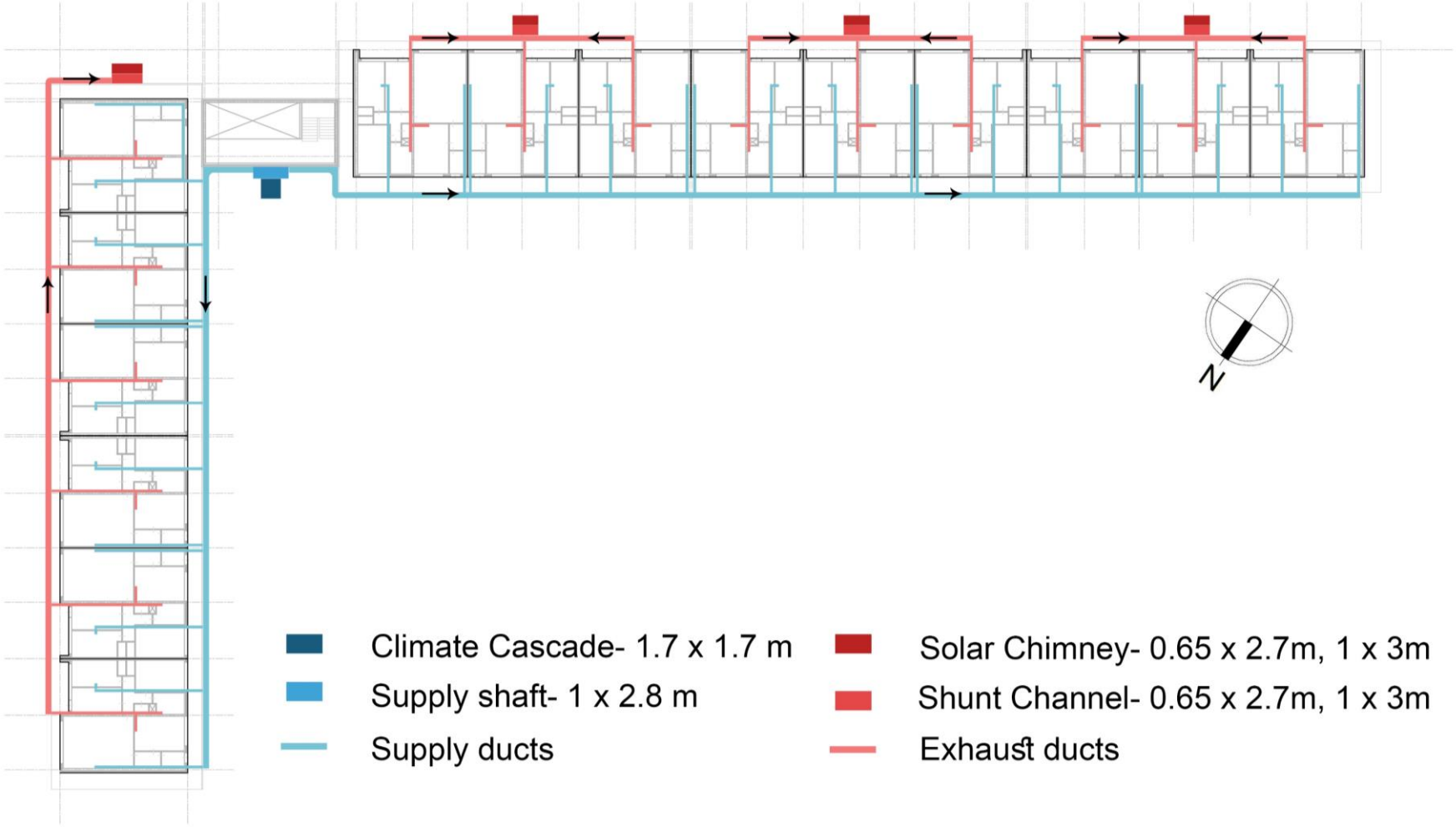
1 Climate Cascade, 1 Solar Chimney



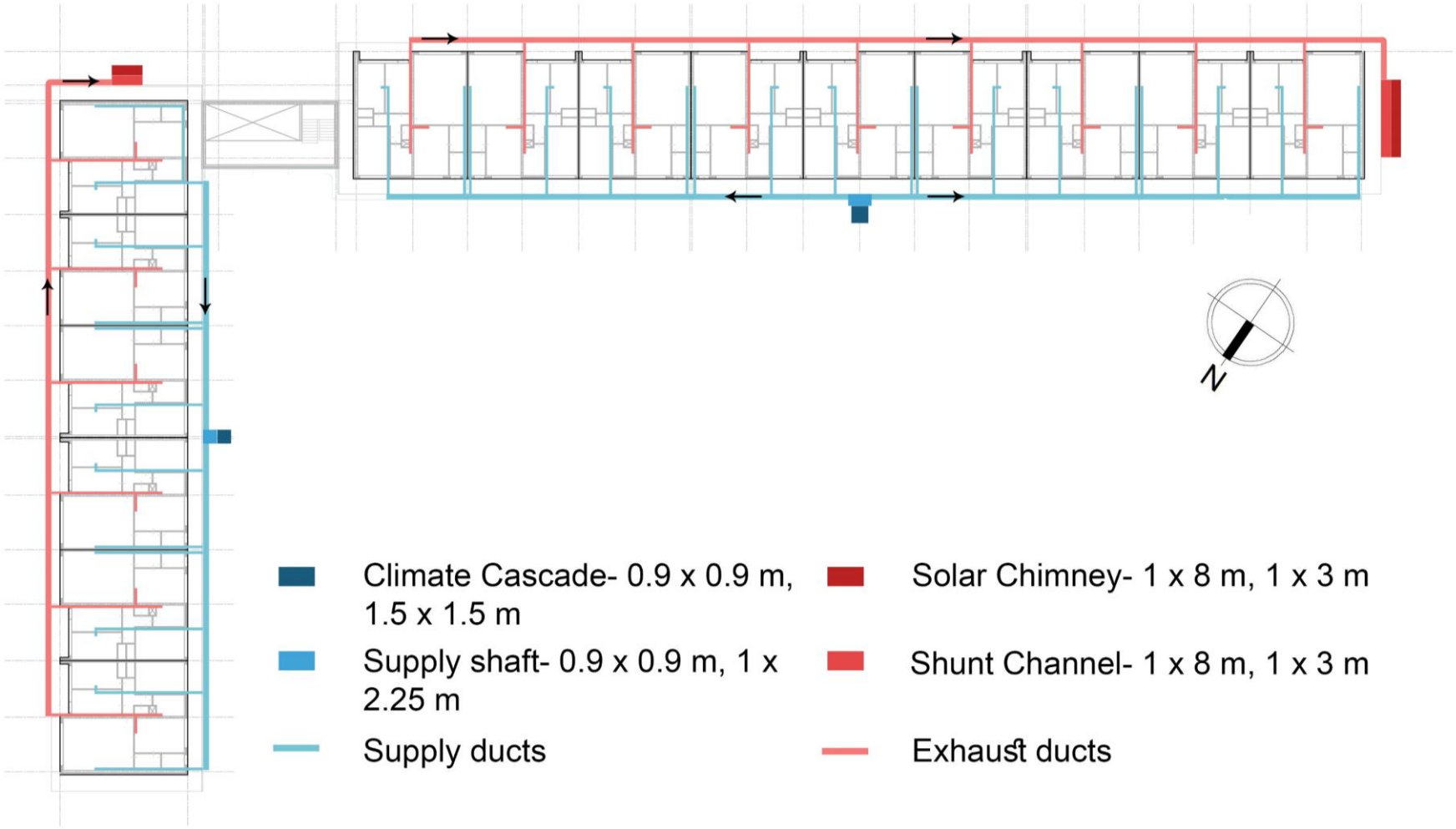
1 Climate Cascade, 2 Solar Chimneys



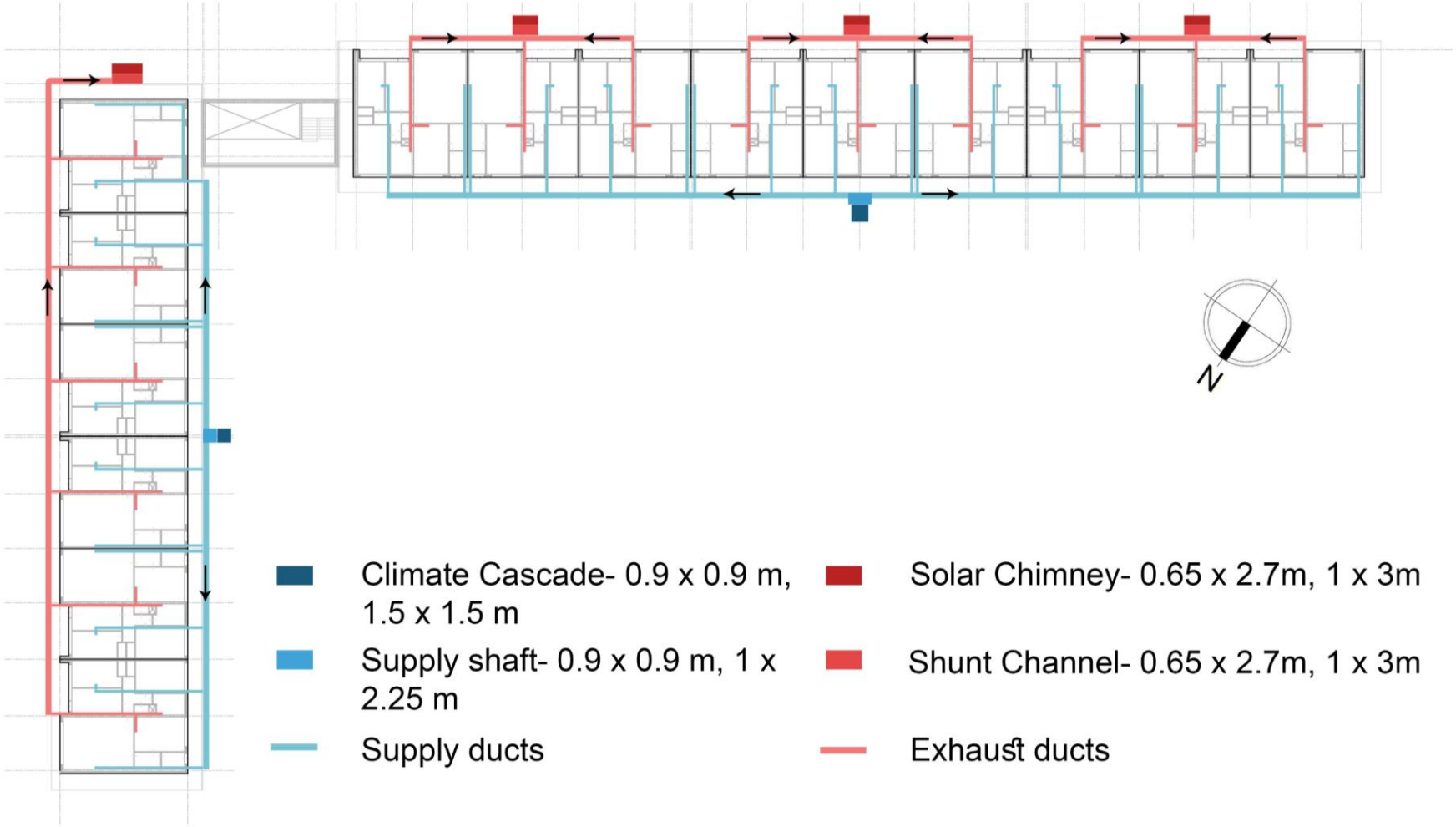
1 Climate Cascade, 4 Solar Chimneys

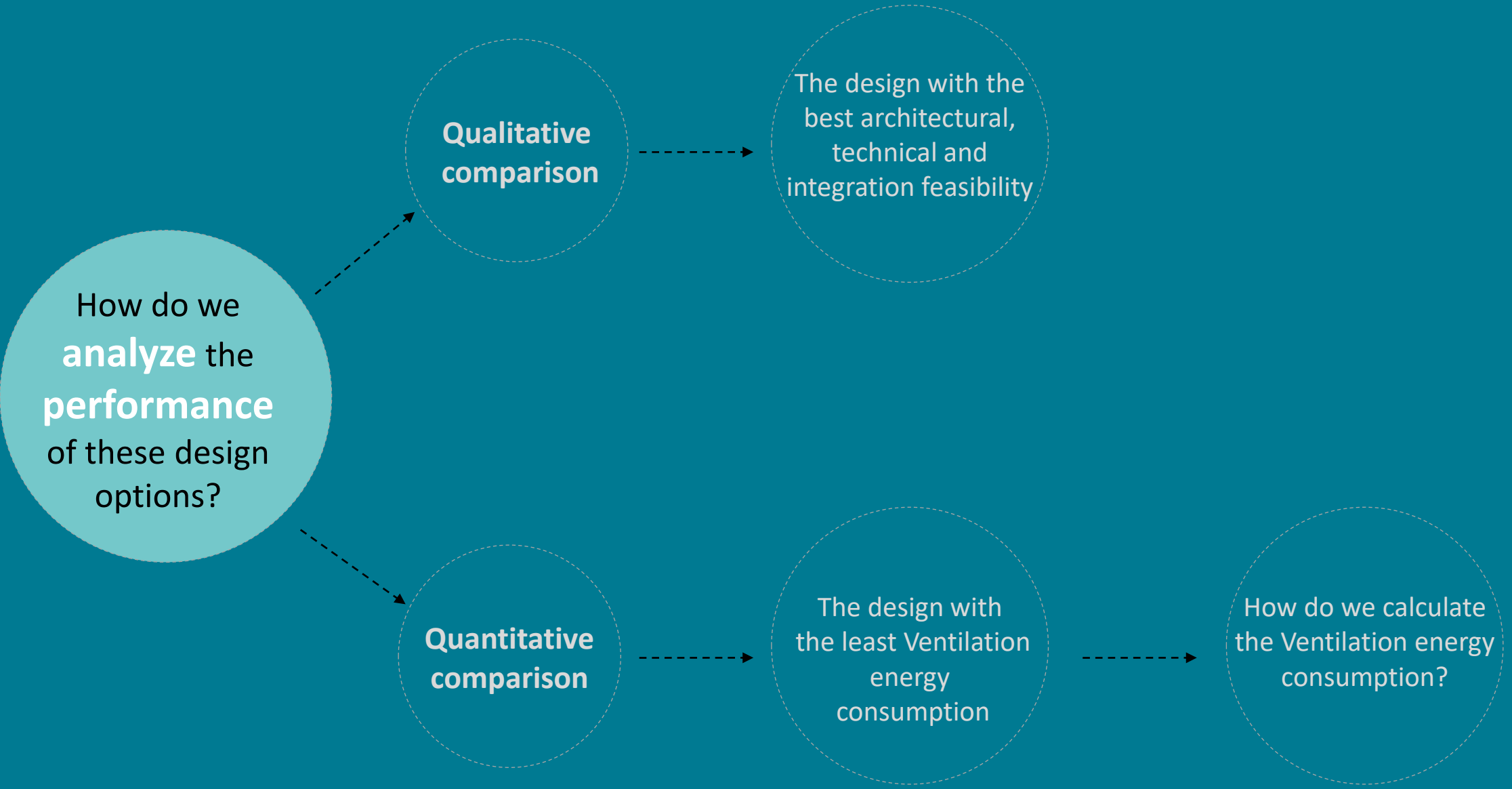


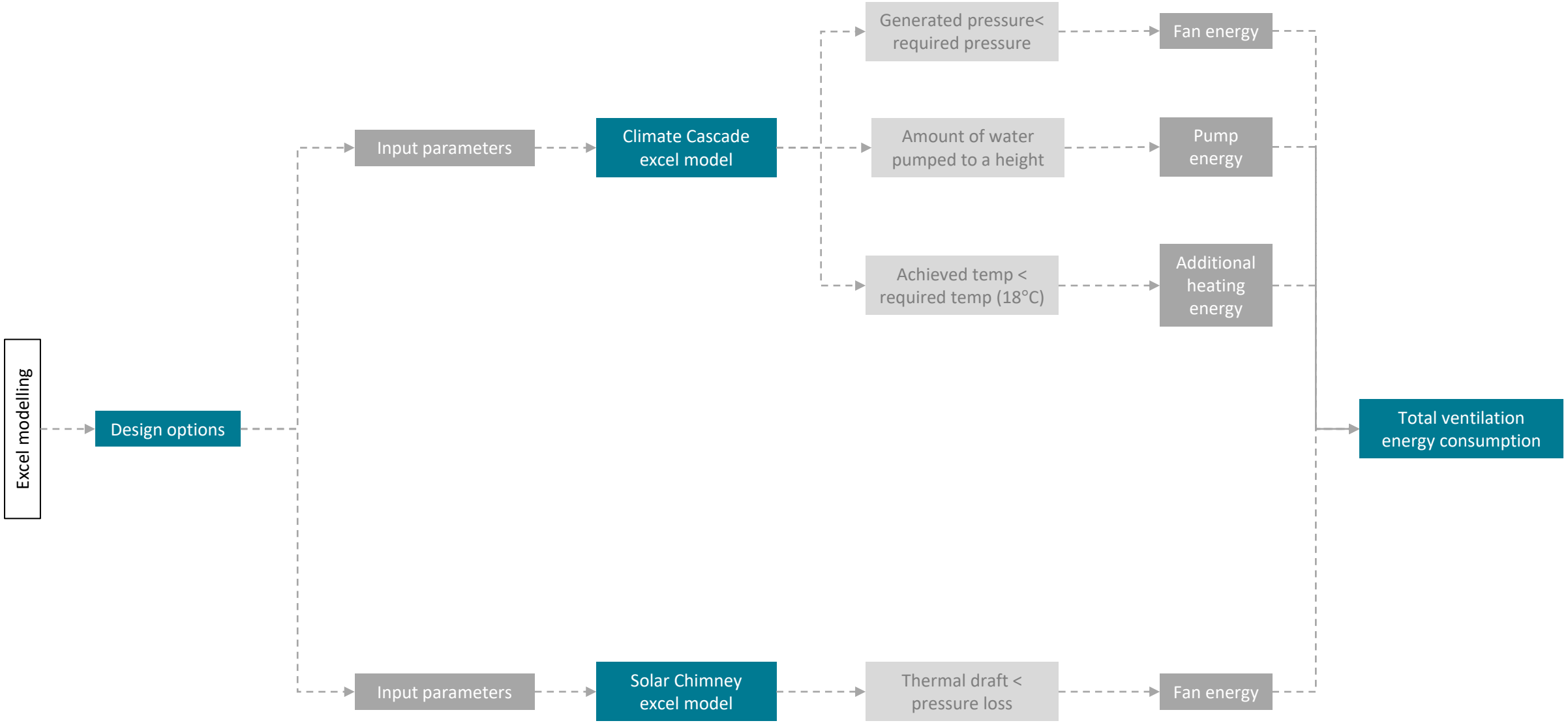
2 Climate Cascade, 2 Solar Chimneys



2 Climate Cascade, 4 Solar Chimneys



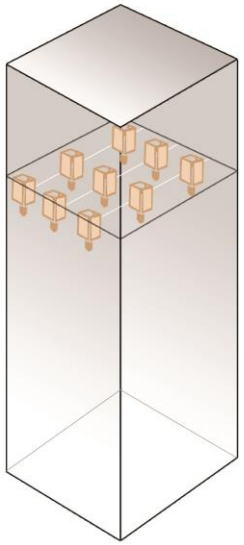

How do we **analyze** the **performance** of these design options?
Qualitative comparison
The design with the best architectural, technical and integration feasibility
Quantitative comparison
The design with the least Ventilation energy consumption
How do we calculate the Ventilation energy consumption?


Excel modelling
Design options
Input parameters
Climate Cascade excel model
Generated pressure< required pressure
Fan energy
Amount of water pumped to a height
Pump energy
Achieved temp < required temp (18°C)
Additional heating energy
Input parameters
Solar Chimney excel model
Thermal draft < pressure loss
Fan energy
Total ventilation energy consumption

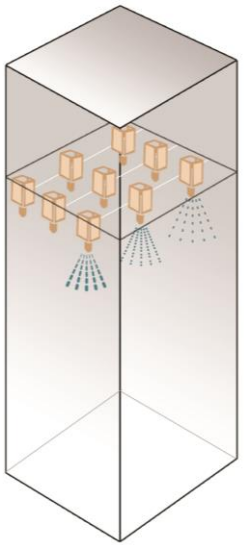
CLIMATE CASCADE

Design Conditions

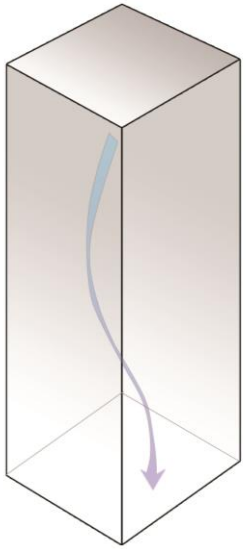
Variables



Nozzles



Spray spectrum

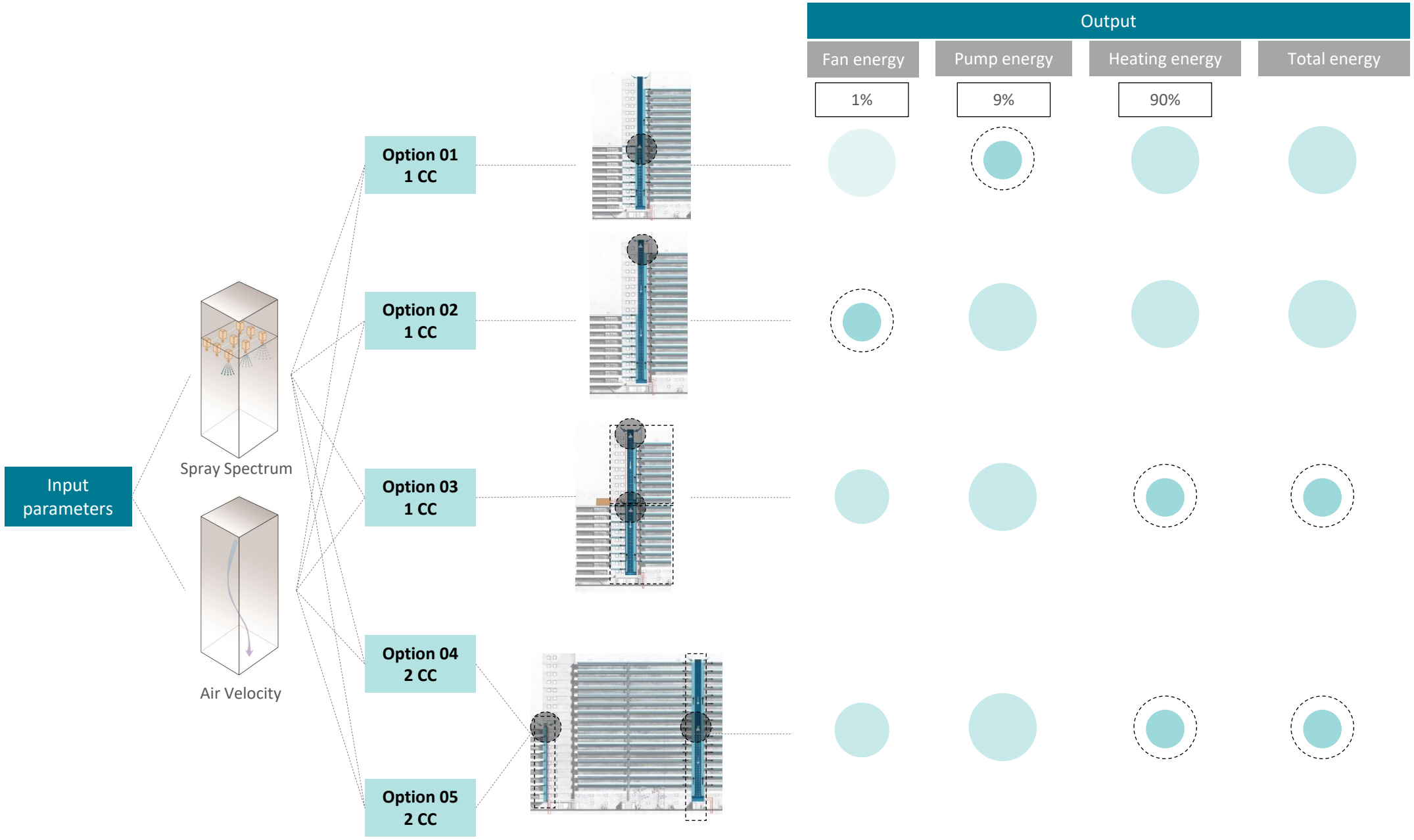


Air Velocity

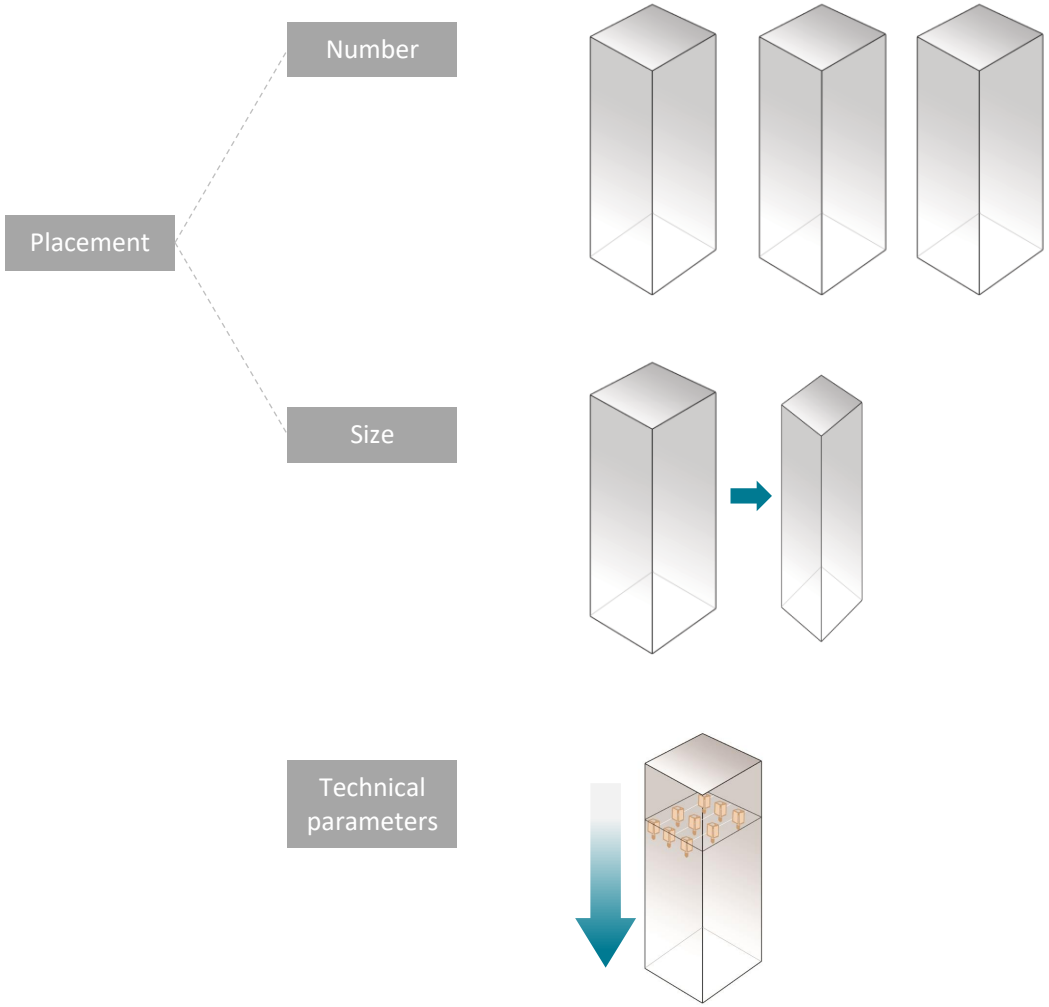
Evaluation Parameters

Total energy consumption-

fan+ pump+ additional heating


Output
Fan energy
Pump energy
Heating energy
Total energy
1%
9%
90%
Input parameters
Spray Spectrum
Air Velocity
Option 01
1 CC
Option 02
1 CC
Option 03
1 CC
Option 04
2 CC
Option 05
2 CC

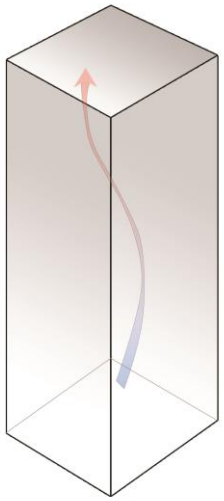
Does the variation in **placement, number, size** and **technical parameters** affect the **energy performance**?



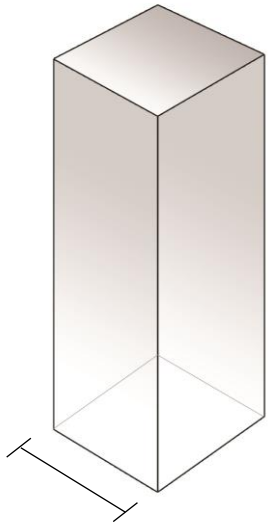
SOLAR CHIMNEY

Design Conditions

Variables



Air Velocity



Chimney Depth

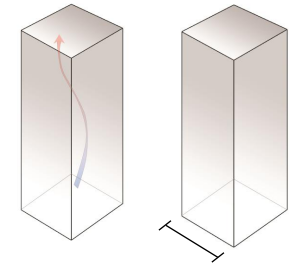
Evaluation Parameters

High thermal draft

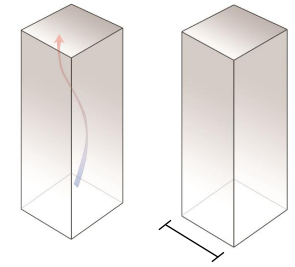
High T_out

Low fan energy

Input parameters



1 m/s velocity, 1m depth



1.5 m/s velocity, 0.65m depth

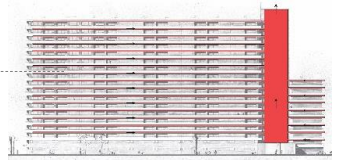
Option 01
1 SC

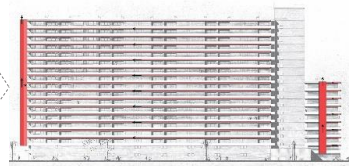
Option 02
2 SC

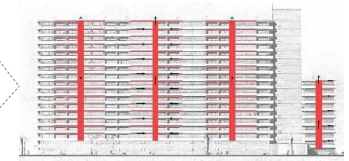
Option 04
2 SC

Option 03
4 SC

Option 05
4 SC

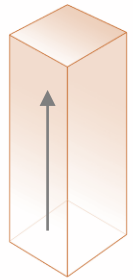






Output

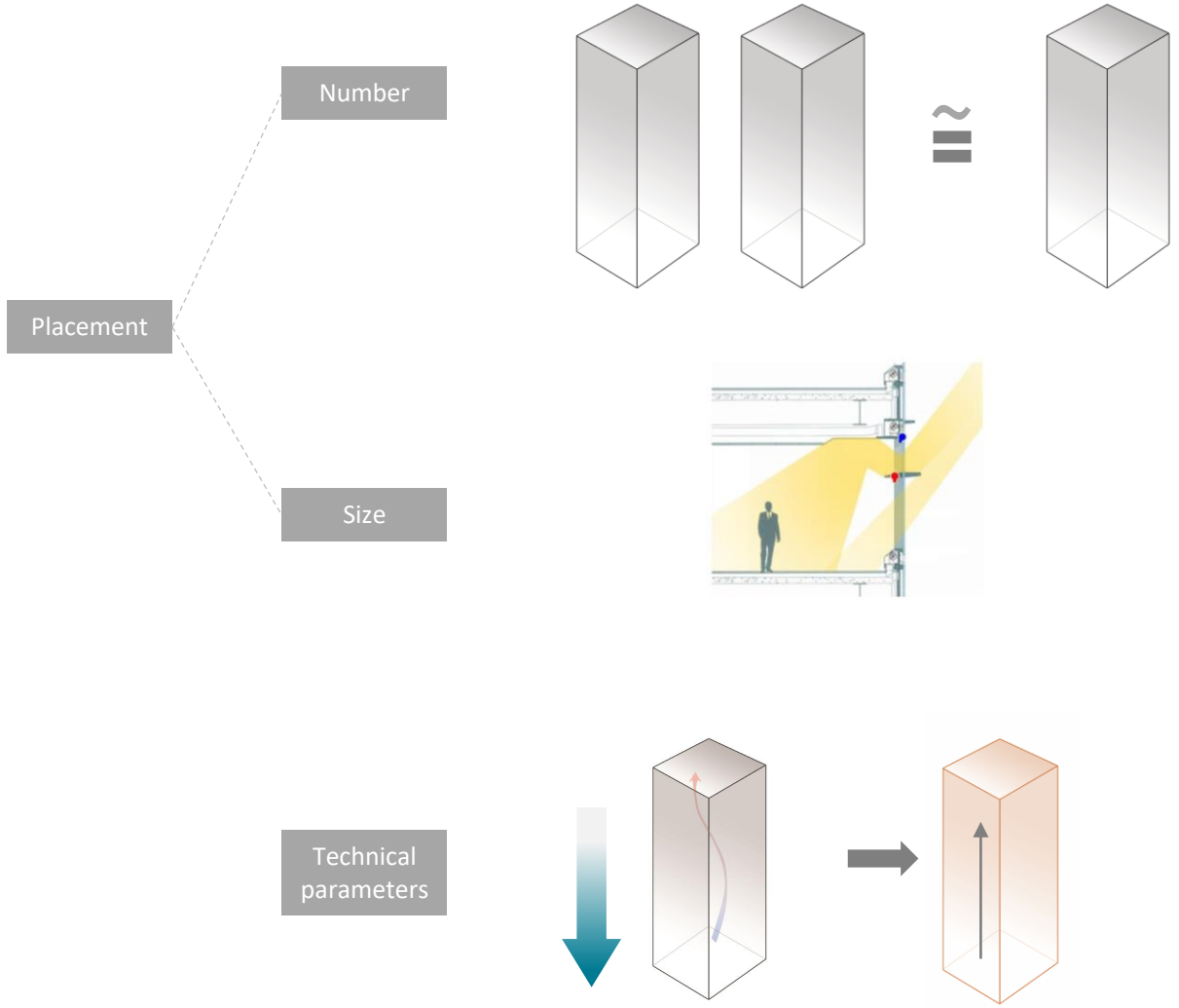
Fan energy

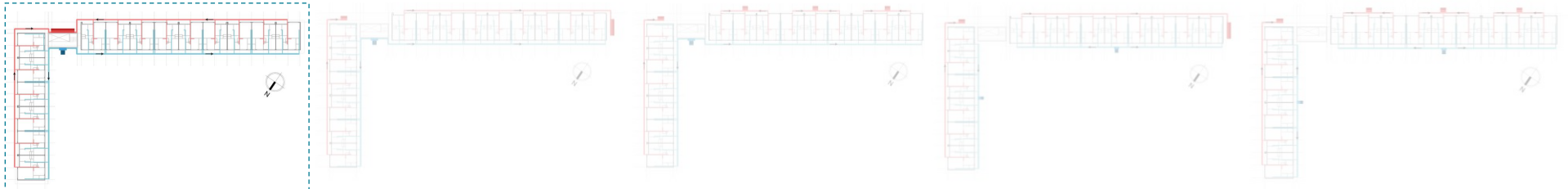


High thermal draft

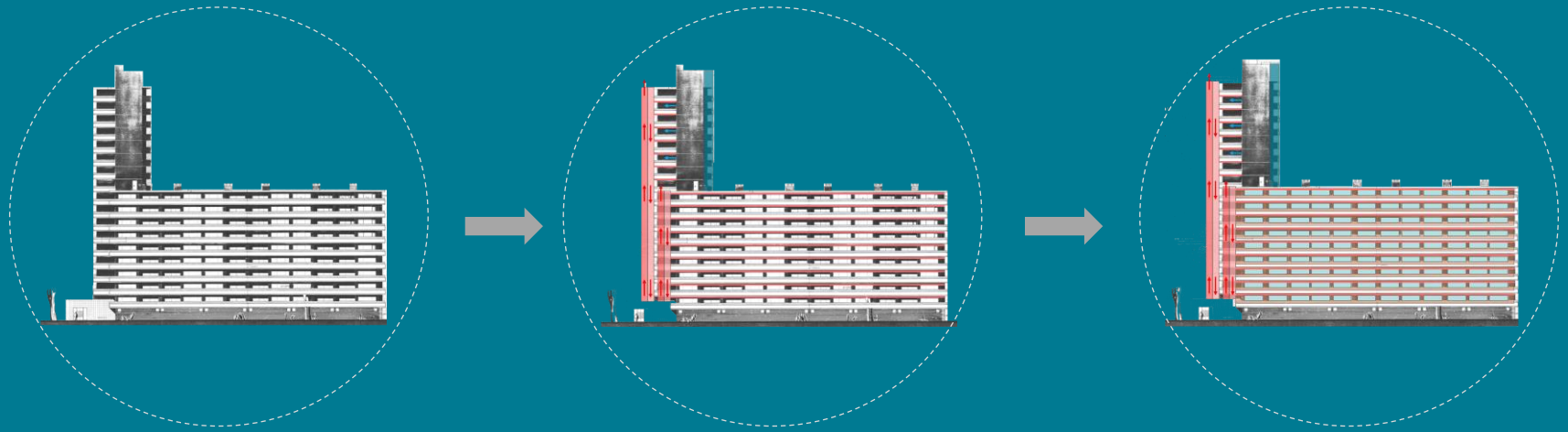
Less fan energy

Does the variation in **placement, number, size** and **technical parameters** affect the **energy performance**?



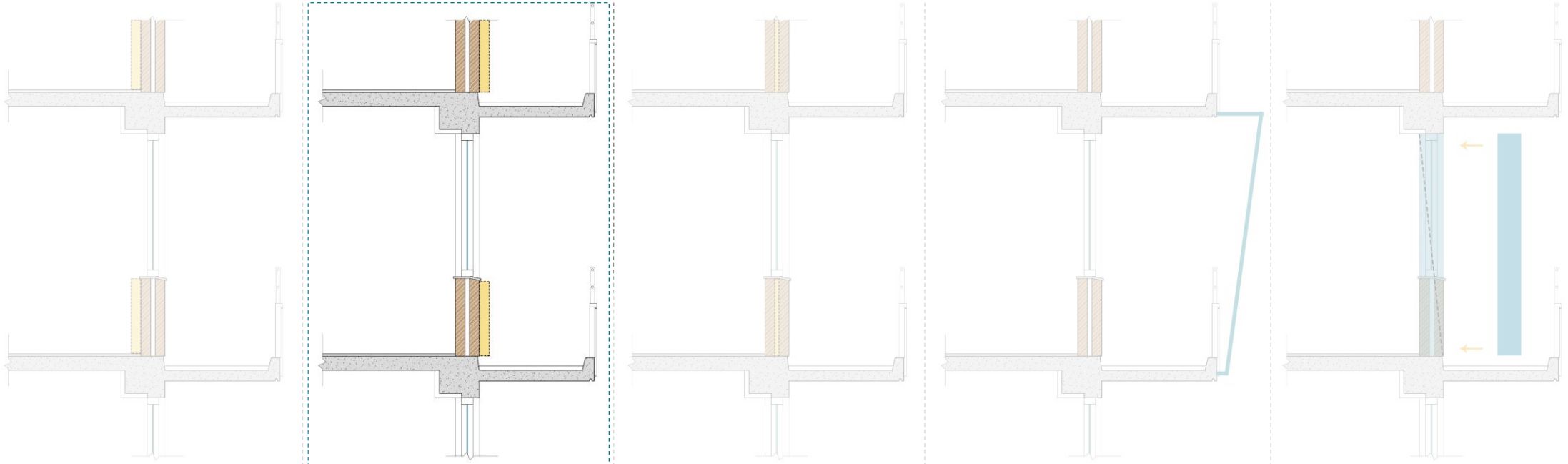


	1 CC, 1 SC	1 CC, 2 SC	1 CC, 4 SC	2 CC, 2 SC	2 CC, 4 SC
Daylight & clear view to outside	★★★★★	★★★★★	★★★	★★★★	★★★
Effect of duct length	★★	★★	★★★★	★★★★	★★★★★
Feasibility of Ventec roof	★★★★★	★★★	★★	★★★	★★
Sending recovered heat to CC	★★★★★	★★★	★★	★★★	★★
Installation/ equipment	★★★★★	★★★	★★	★★★	★★
Maintenance	★★★★★	★★★	★★	★★★	★★
Architectural aesthetics	★★★★★	★★	★★★★	★★	★★★★



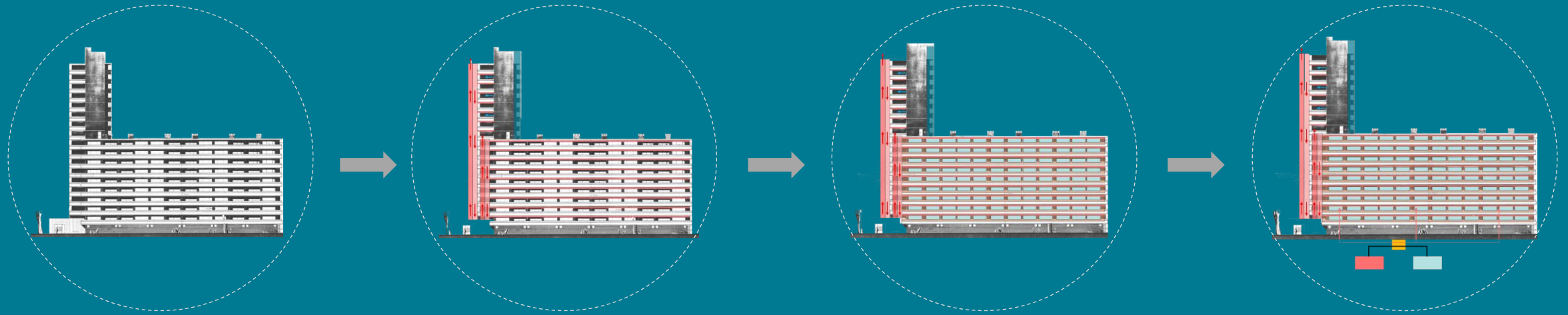
Step 02- Façade renovation

What façade renovation strategies can be incorporated in the building to improve its energy performance?



	Internal insulation	External insulation	Cavity insulation	Second skin	Replacing the facade
R-value m^2 K/W	3.0 - 4.2	3.0 - 4.2	1- 1.6	0.5- 1	as per design

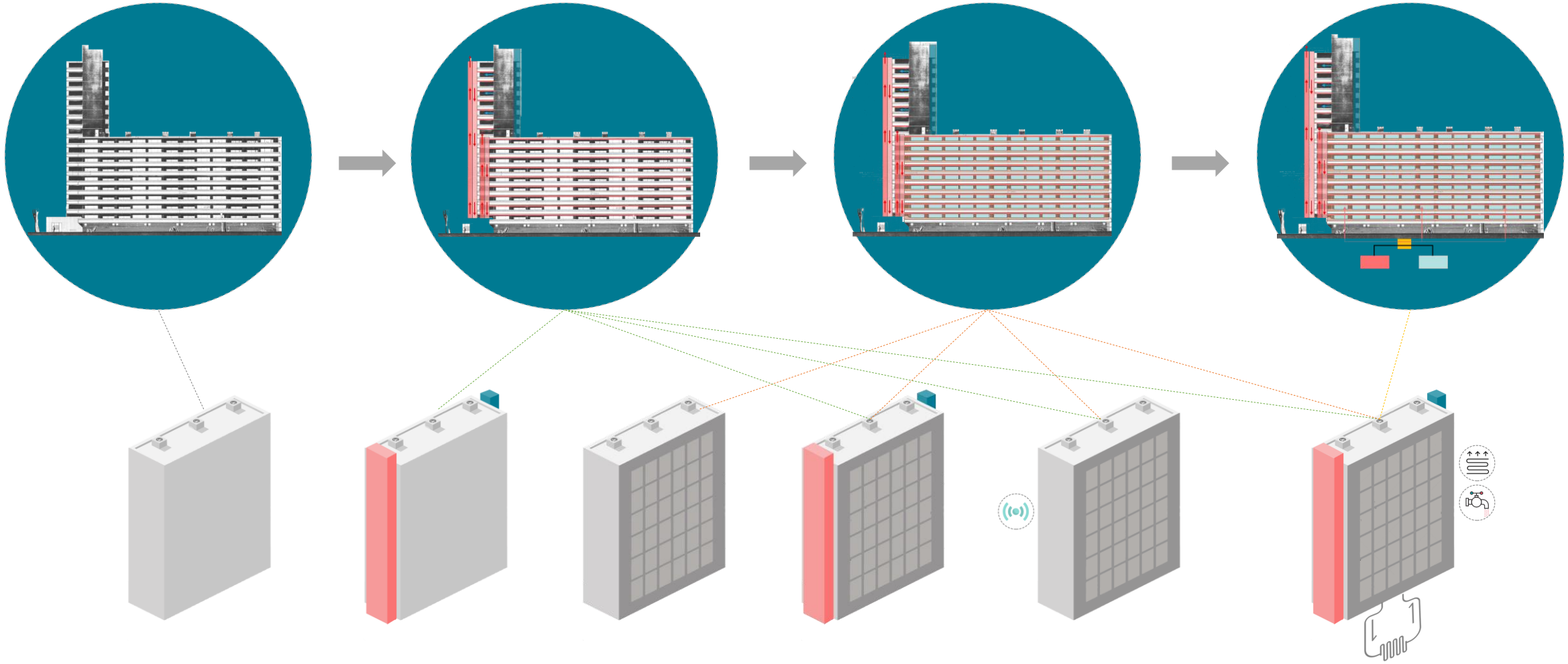
Level of intervention



ASSESSMENT

How does the refurbishment strategy impact the overall energy performance of the building?

To what extent does the EWF system help in reducing the energy consumption and improving the thermal comfort of the building?



Case 1: Existing

Radiator heating and natural ventilation

Case 2: EWF

Radiator heating and EWF ventilation

Case 3: Façade renovation

Radiator heating and natural ventilation with renovated facade

Case 4: EWF & façade renovation

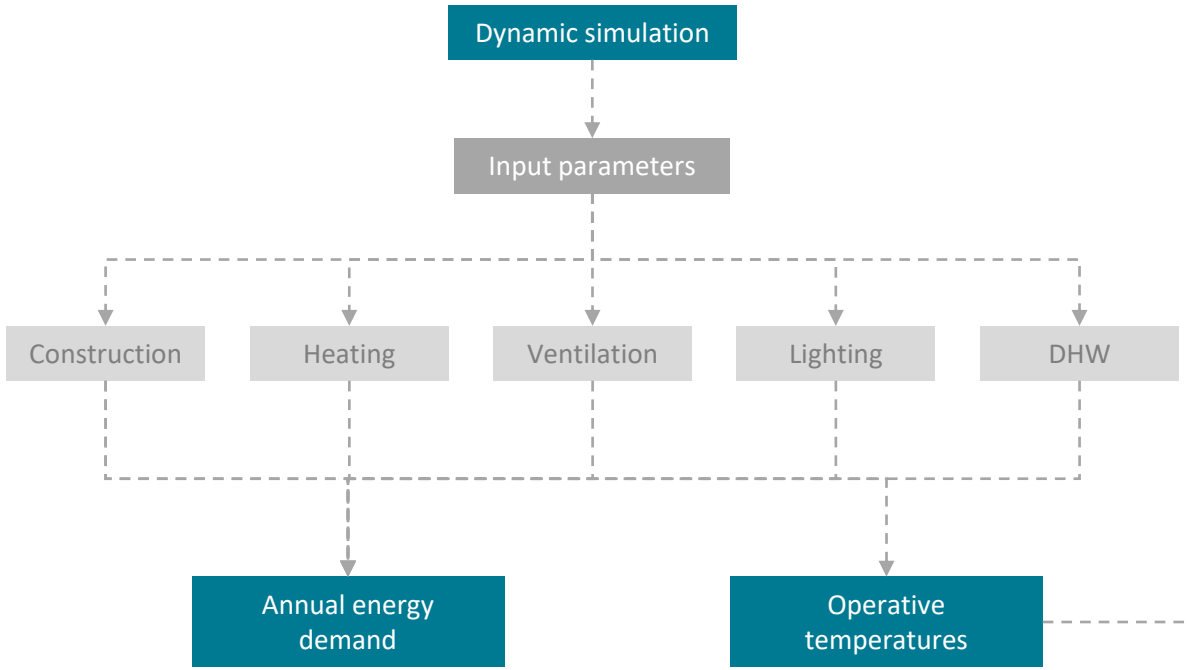
Radiator heating and EWF ventilation with renovated facade

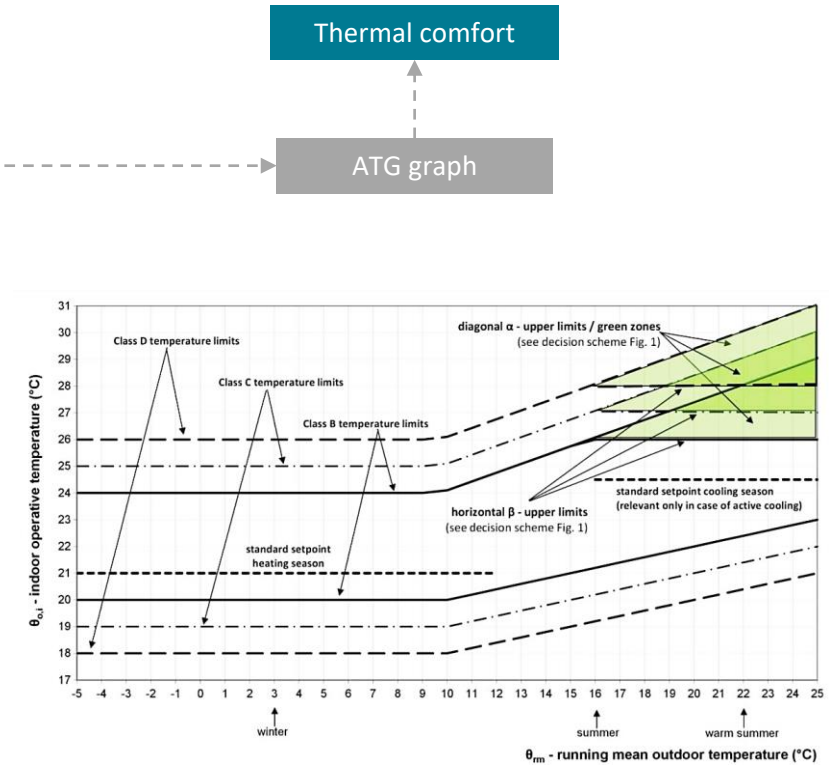
Case 5: Façade renovation variation 2

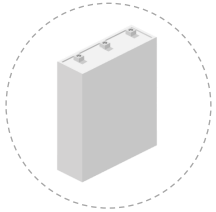
Radiator heating and controlled ventilation with renovated facade

Case 6: EWF & Façade renovation variation 2

ATES for heating & DHW, EWF ventilation with renovated facade


Dynamic simulation
Input parameters
Construction
Heating
Ventilation
Lighting
DHW
Annual energy demand
Operative temperatures


Thermal comfort
ATG graph
Class D temperature limits
Class C temperature limits
Class B temperature limits
diagonal α - upper limits / green zones
(see decision scheme Fig. 1)
standard setpoint cooling season
(relevant only in case of active cooling)
horizontal β - upper limits
(see decision scheme Fig. 1)
standard setpoint
heating season
θo,i - indoor operative temperature (°C)
winter
summer
warm summer
θrm - running mean outdoor temperature (°C)



Case 1- Existing

Energy consumption

Space Heating

161.5 kWh/m2

Ventilation

1.5 kWh/m2

Total

231 kWh/m2

Thermal comfort

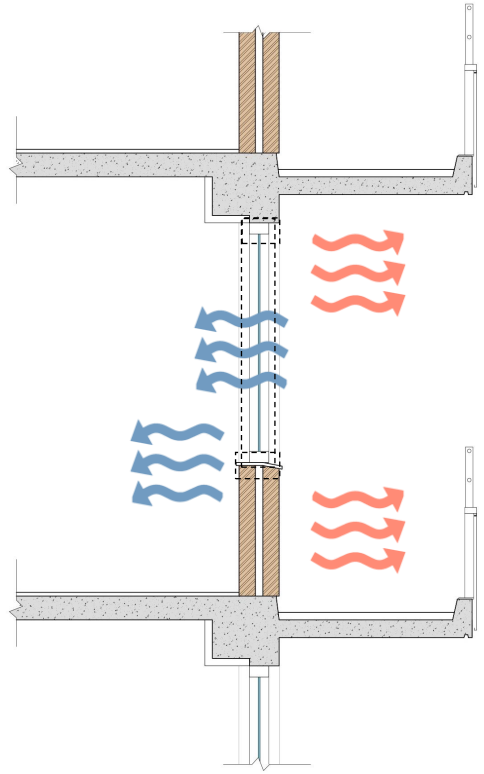
Discomfort %

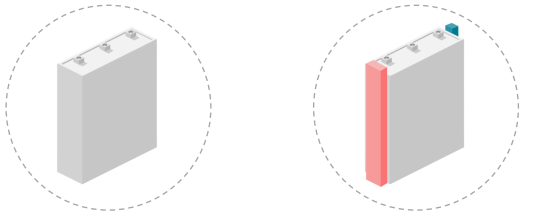
33%

Summer discomfort hours

95

Class C





Case 1- Existing

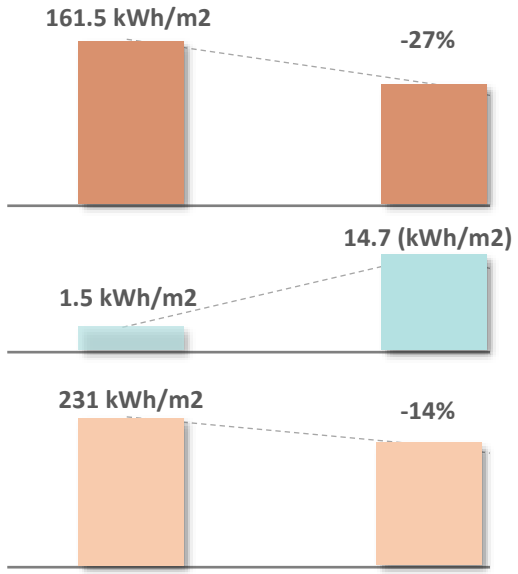
Case 2- EWF

Energy consumption

Space Heating

Ventilation

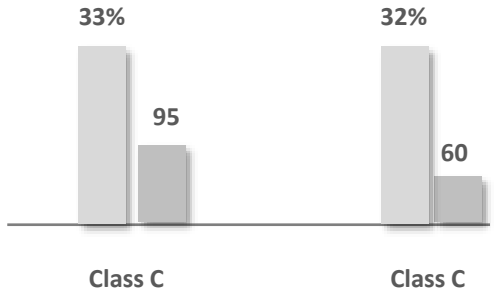
Total

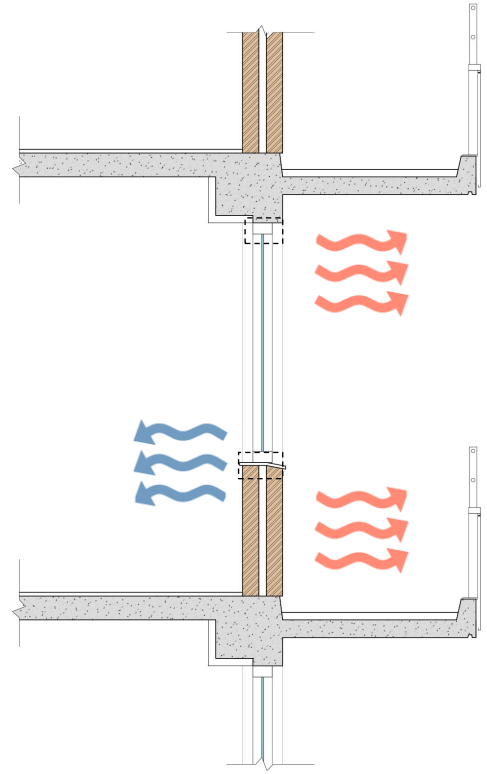


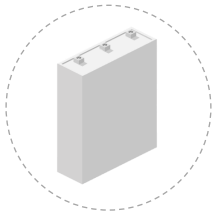
Thermal comfort

Discomfort %

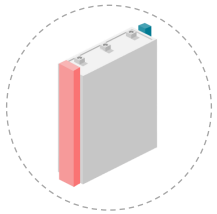
Summer discomfort hours



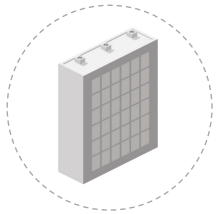




Case 1- Existing



Case 2- EWF



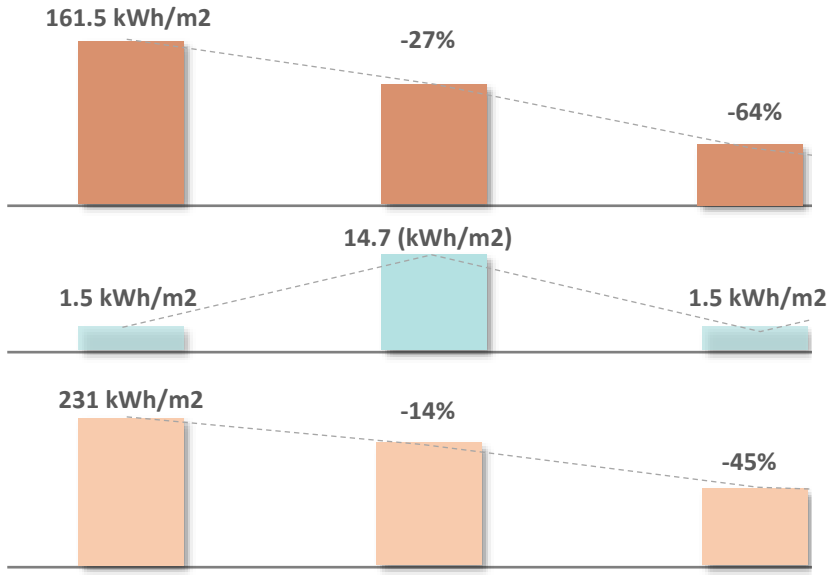
Case 3- Façade renovation

Energy consumption

Space Heating

Ventilation

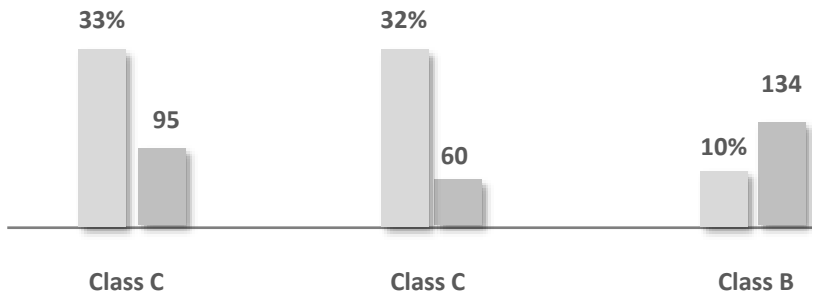
Total

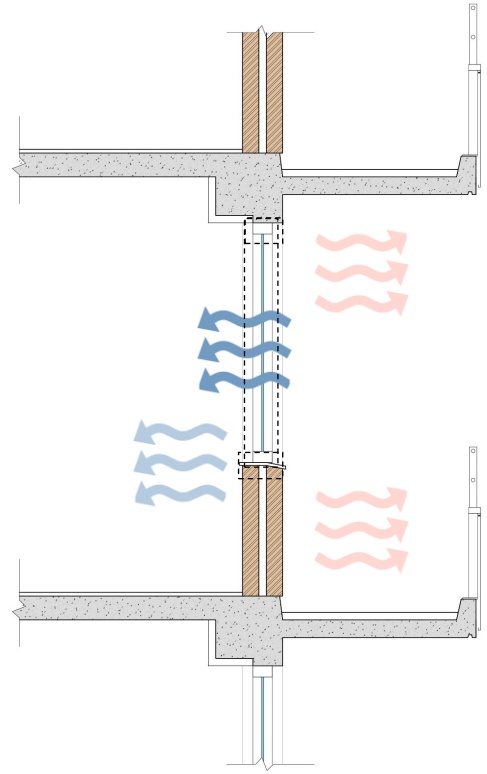


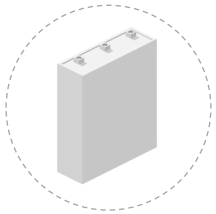
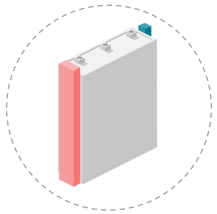
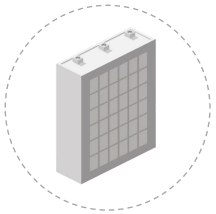
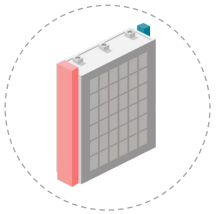
Thermal comfort

Discomfort %

Summer discomfort hours





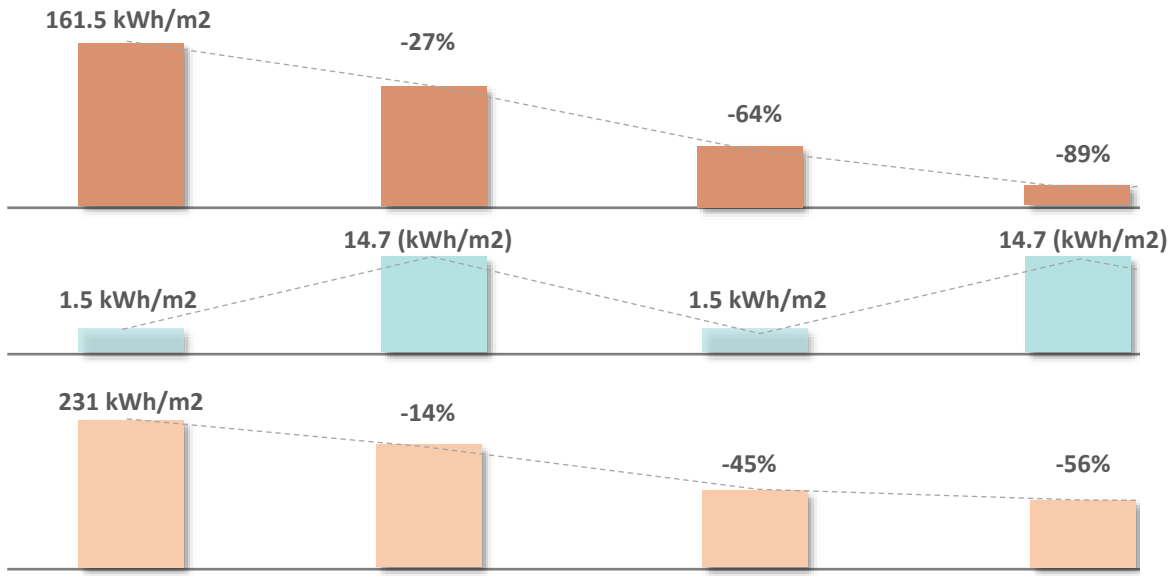
Case 1- Existing | Case 2- EWF | Case 3- Façade renovation | Case 4- EWF & Façade renovation

Energy consumption

Space Heating

Ventilation

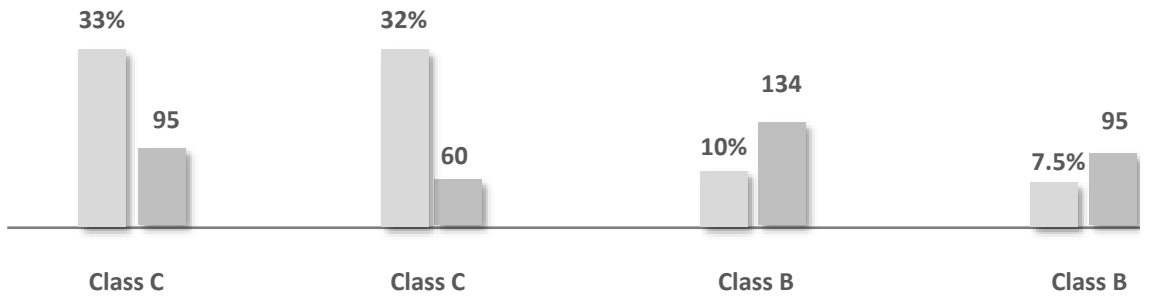
Total

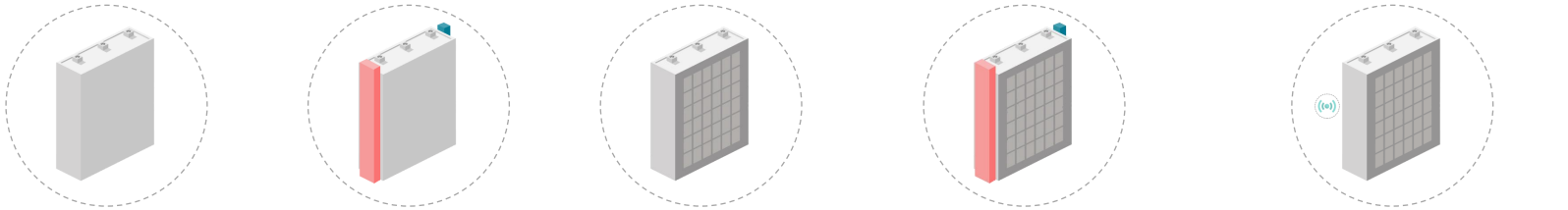


Thermal comfort

Discomfort %

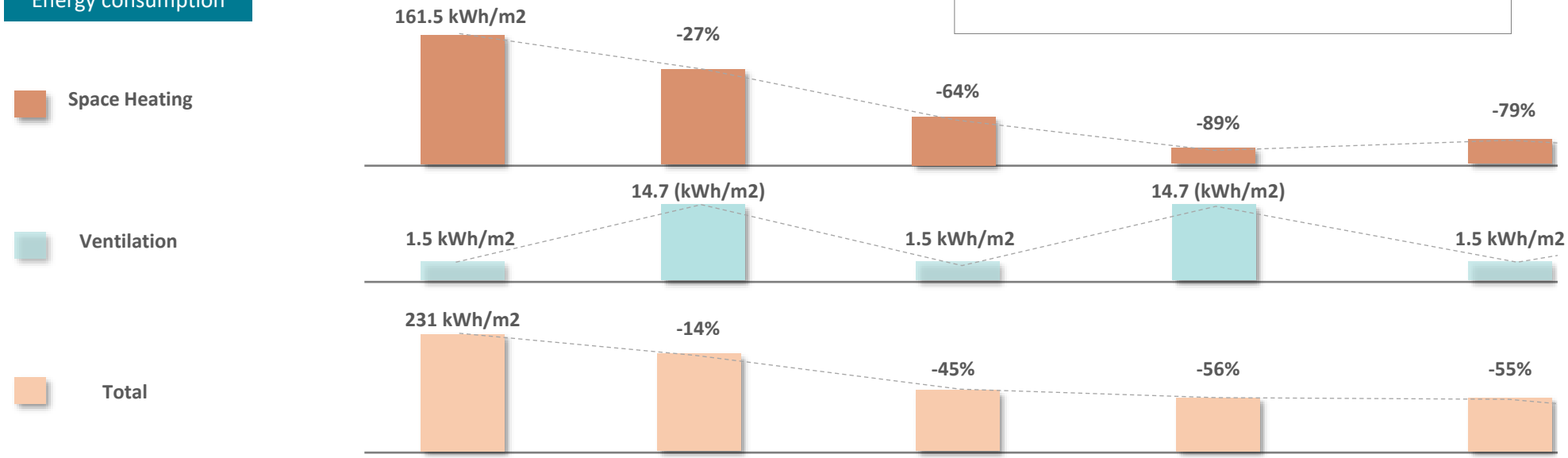
Summer discomfort hours



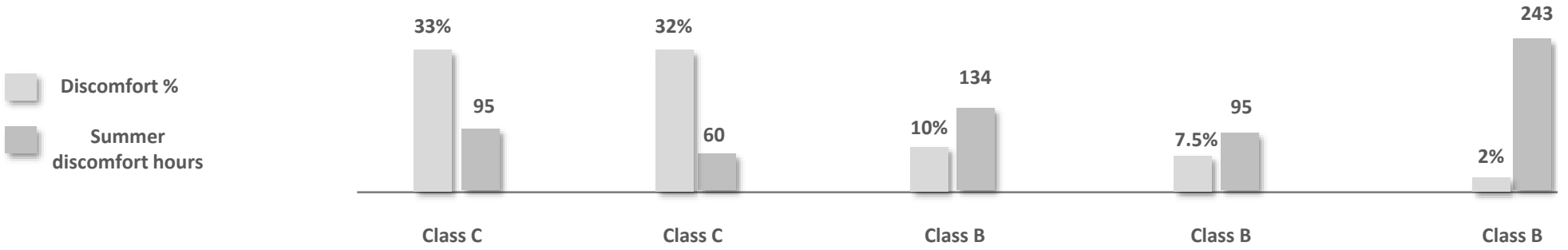


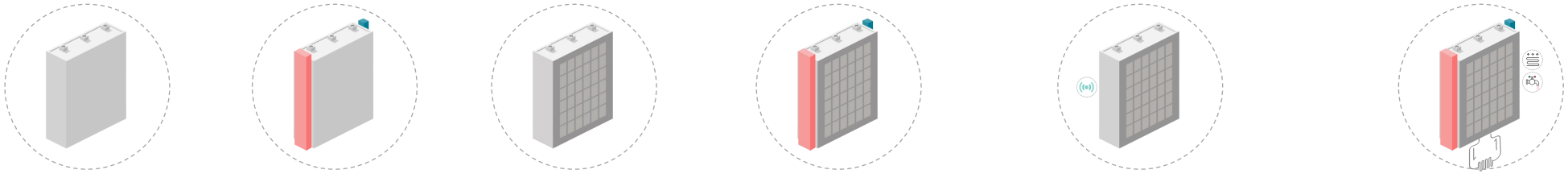
Case 1- Existing | Case 2- EWF | Case 3- Façade renovation | Case 4- EWF & Façade renovation | Case 5- Façade renovation variation 02

Energy consumption



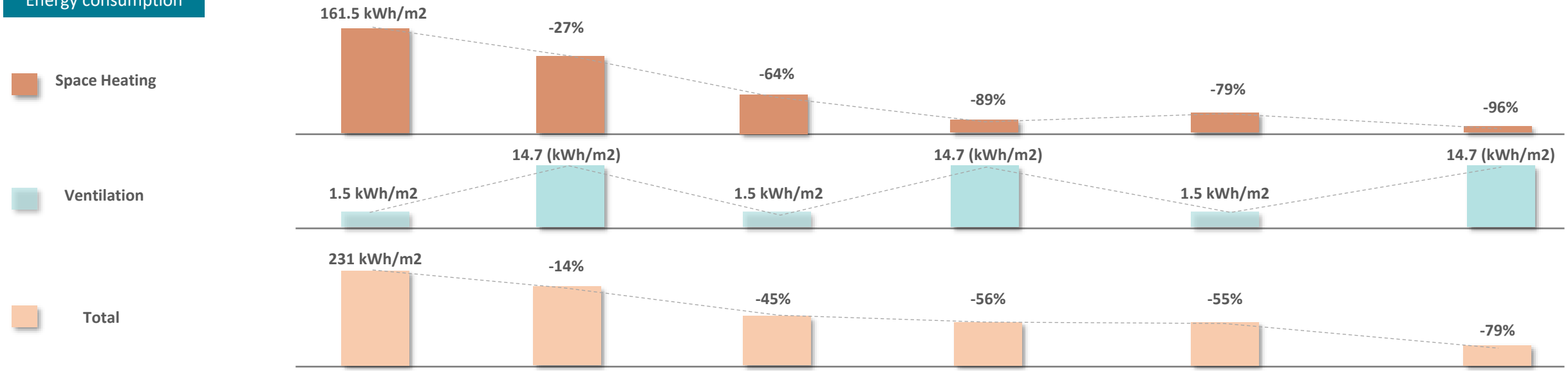
Thermal comfort



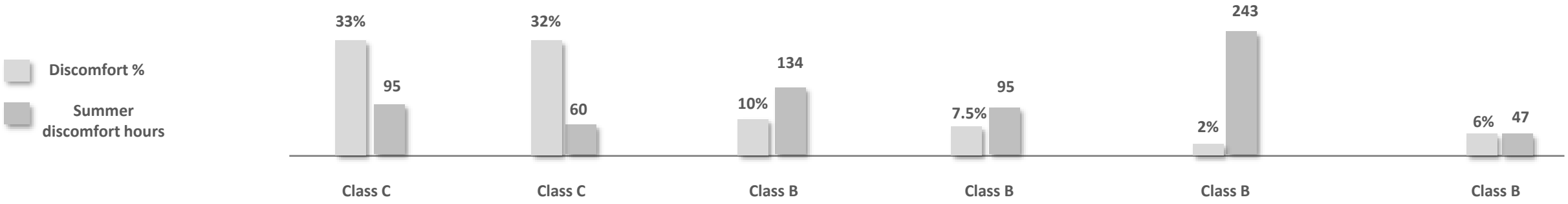


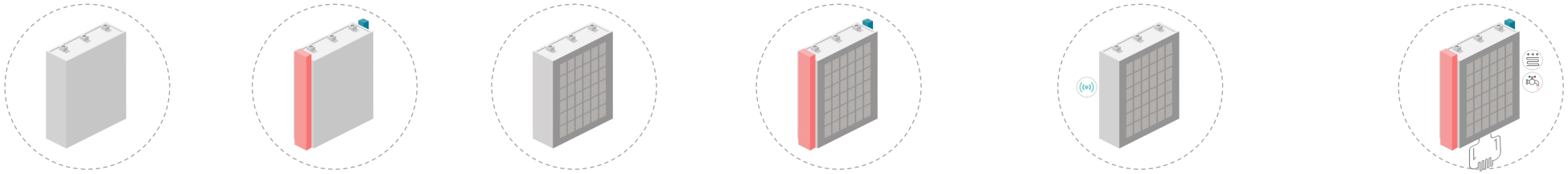
Case 1- Existing	Case 2- EWF	Case 3- Façade renovation	Case 4- EWF & Façade renovation	Case 5- Façade renovation variation 02	Case 6- EWF & Façade renovation variation 02

Energy consumption



Thermal comfort





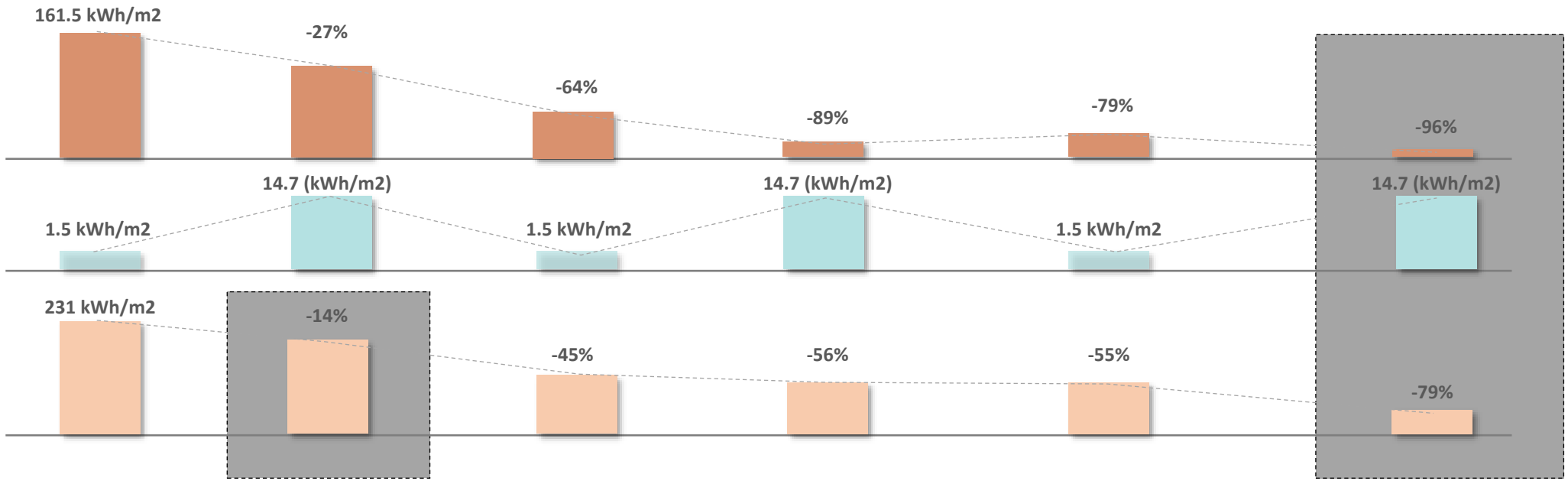
Case 1- Existing	Case 2- EWF	Case 3- Façade renovation	Case 4- EWF & Façade renovation	Case 5- Façade renovation variation 02	Case 6- EWF & Façade renovation variation 02

Energy consumption

Space Heating

Ventilation

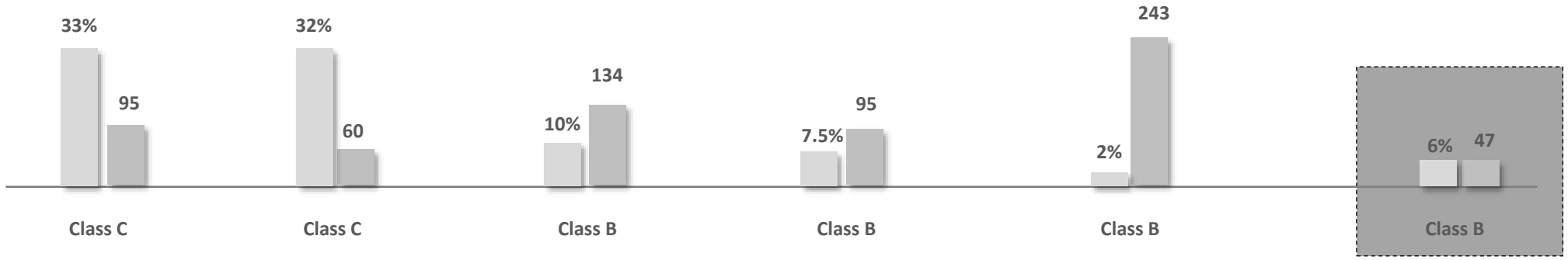
Total

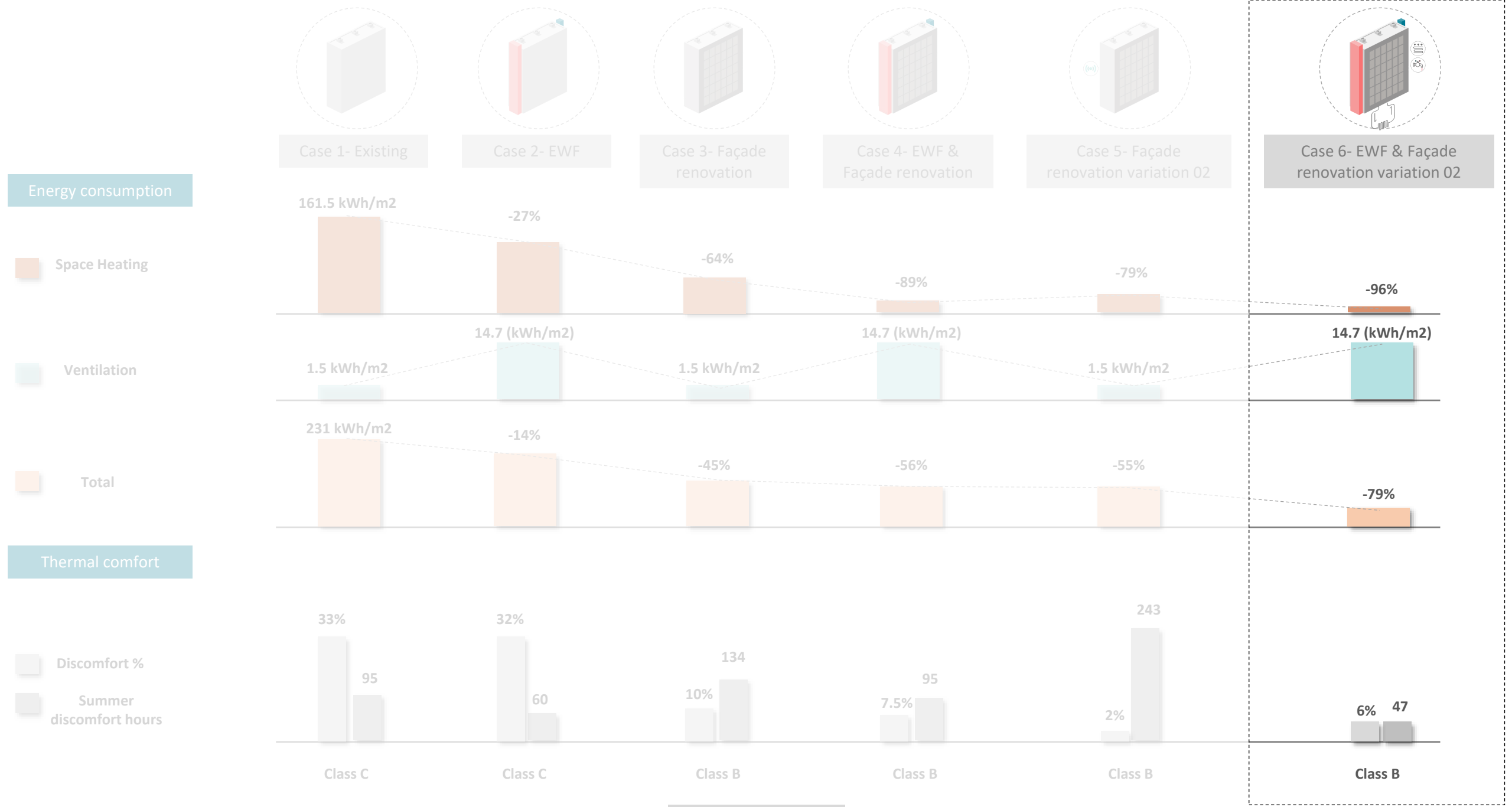


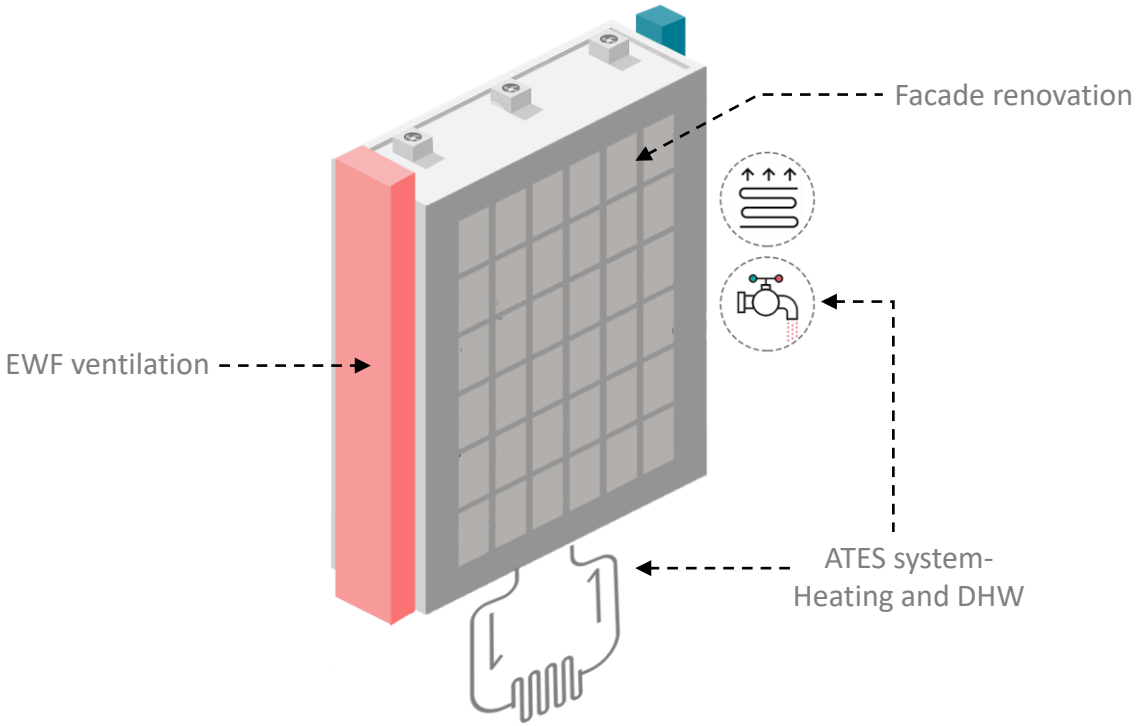
Thermal comfort

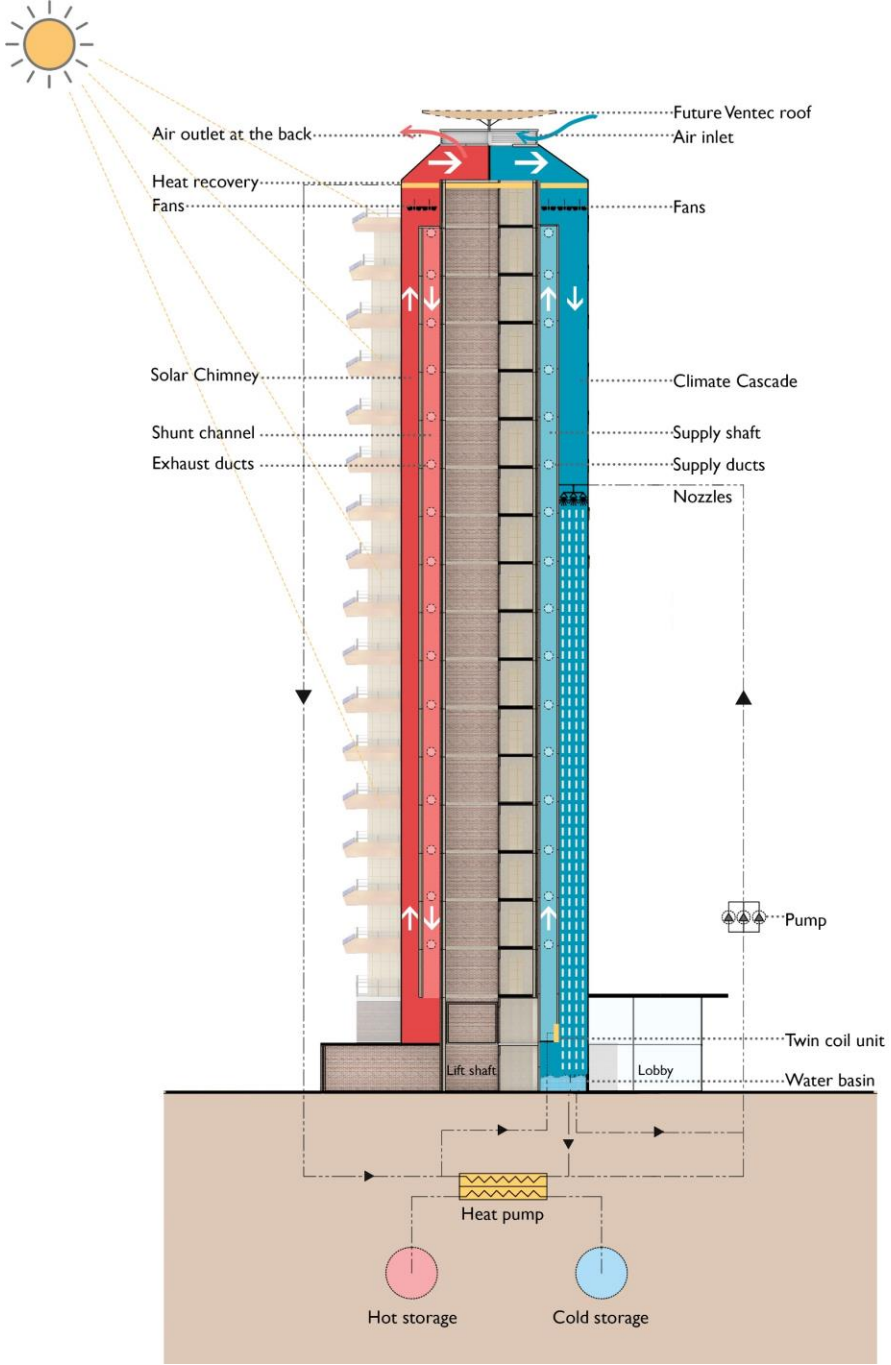
Discomfort %

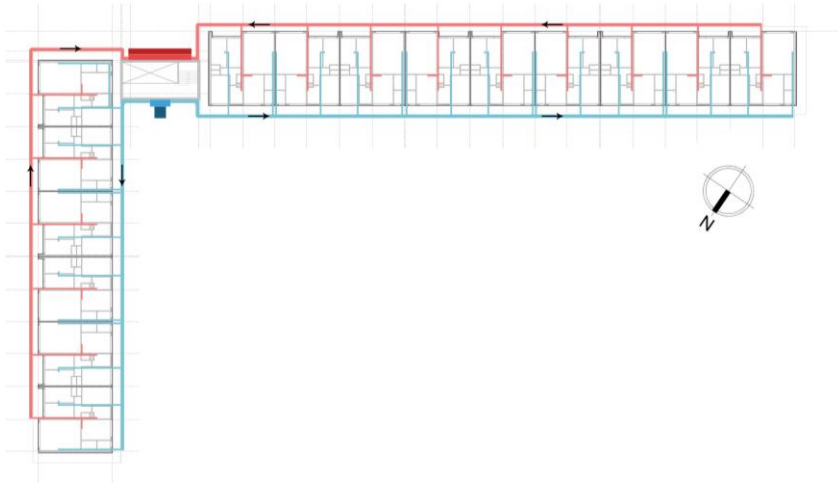
Summer discomfort hours

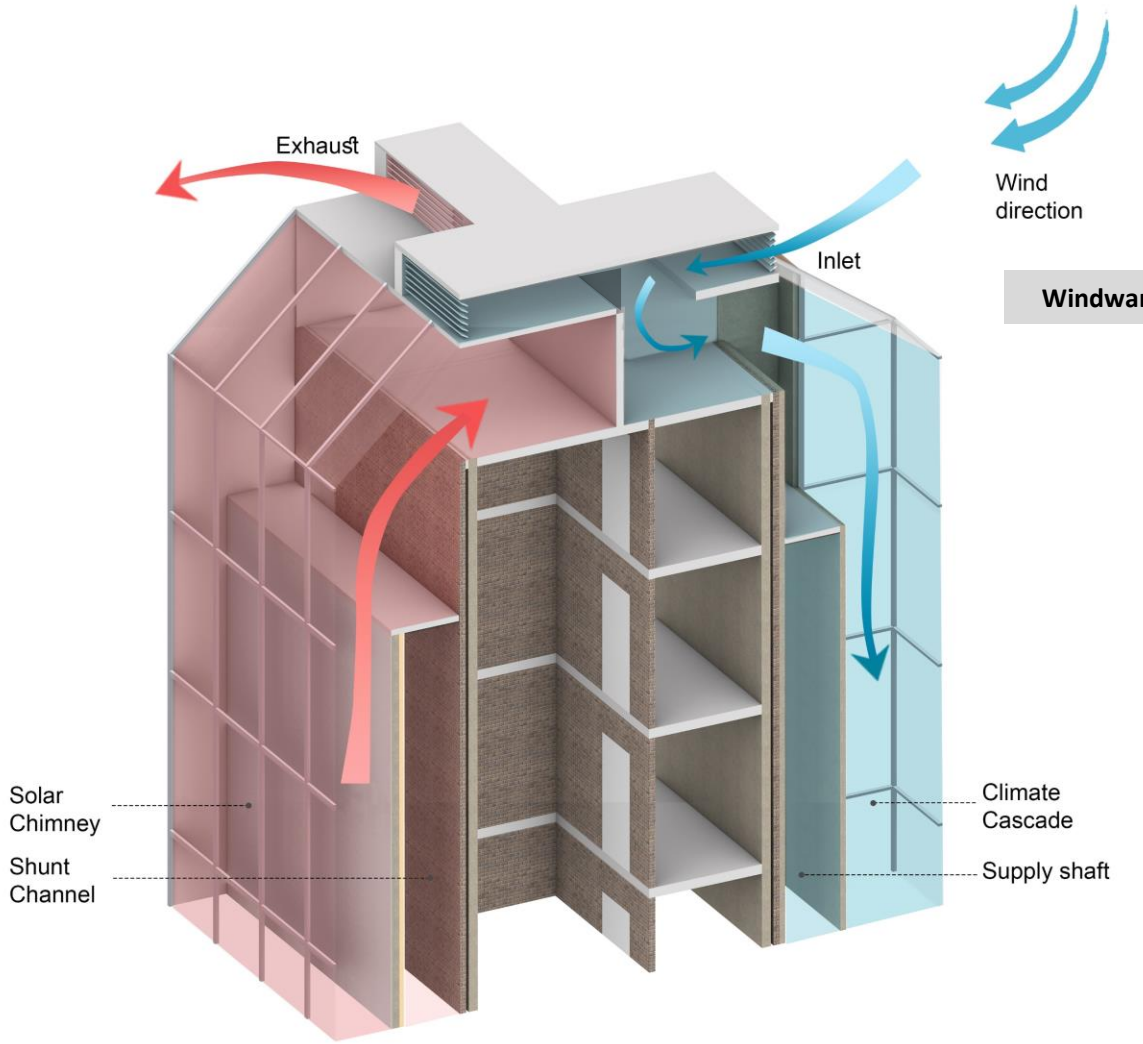


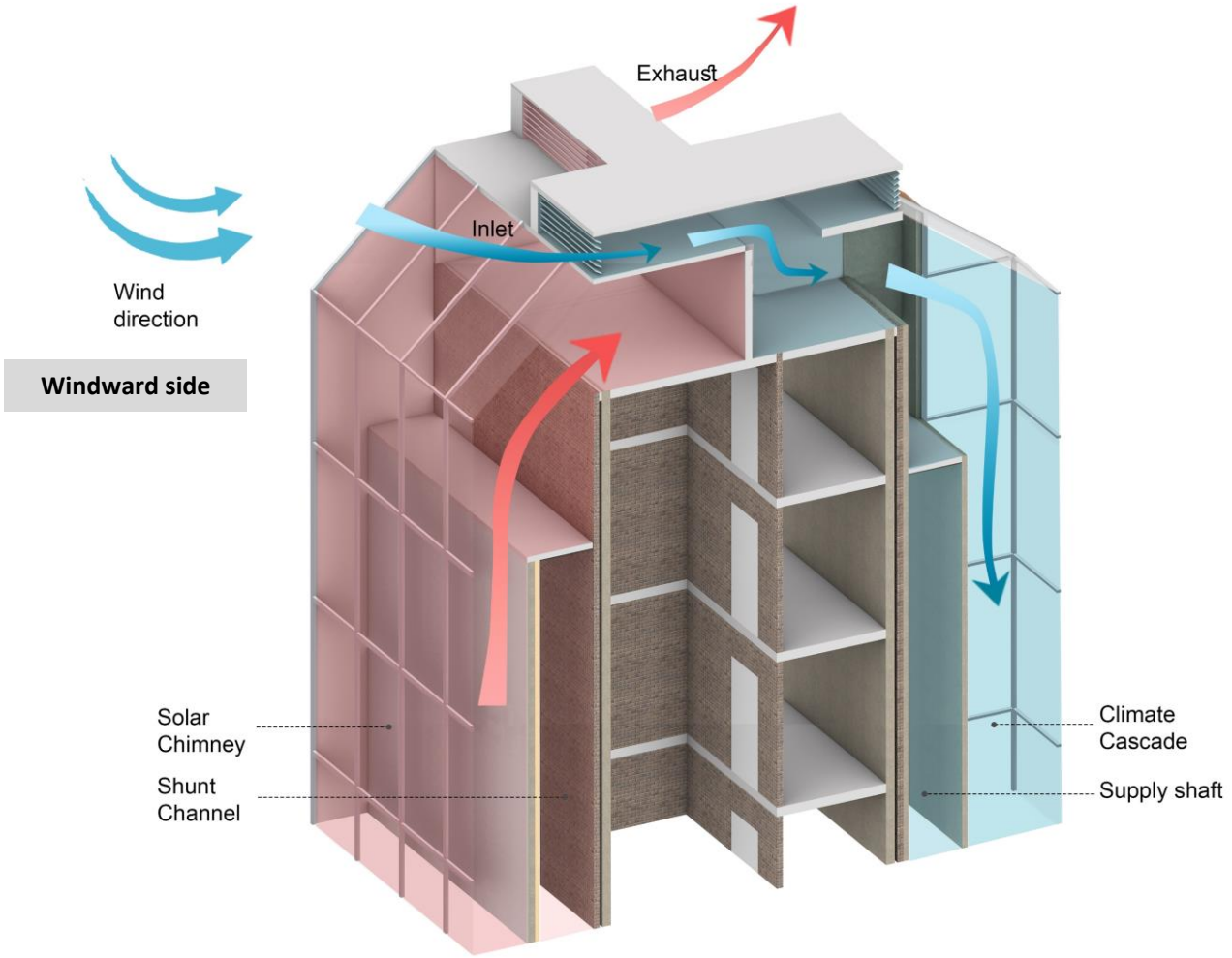

Case 1- Existing
Case 2- EWF
Case 3- Façade renovation
Case 4- EWF & Façade renovation
Case 5- Façade renovation variation 02
Case 6- EWF & Façade renovation variation 02
Energy consumption
Space Heating
Ventilation
Total
161.5 kWh/m2
-27%
-64%
-89%
-79%
-96%
1.5 kWh/m2
14.7 (kWh/m2)
1.5 kWh/m2
14.7 (kWh/m2)
1.5 kWh/m2
14.7 (kWh/m2)
231 kWh/m2
-14%
-45%
-56%
-55%
-79%
Thermal comfort
Discomfort %
Summer discomfort hours
33%
95
32%
60
10%
134
7.5%
95
2%
243
6%
47
Class C
Class C
Class B
Class B
Class B
Class B

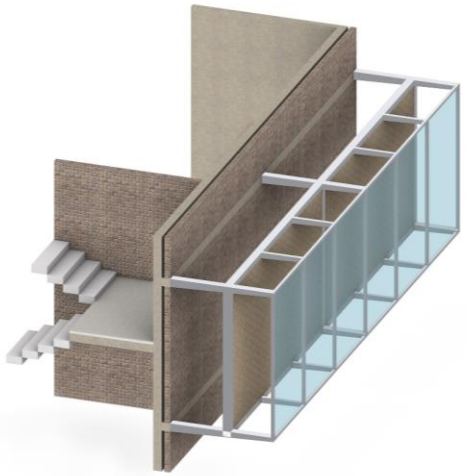

Facade renovation
EWF ventilation
ATES system-
Heating and DHW


Future Ventec roof
Air outlet at the back
Air inlet
Heat recovery
Fans
Fans
Solar Chimney
Climate Cascade
Shunt channel
Supply shaft
Exhaust ducts
Supply ducts
Nozzles
Pump
Twin coil unit
Lift shaft
Lobby
Water basin
Heat pump
Hot storage
Cold storage

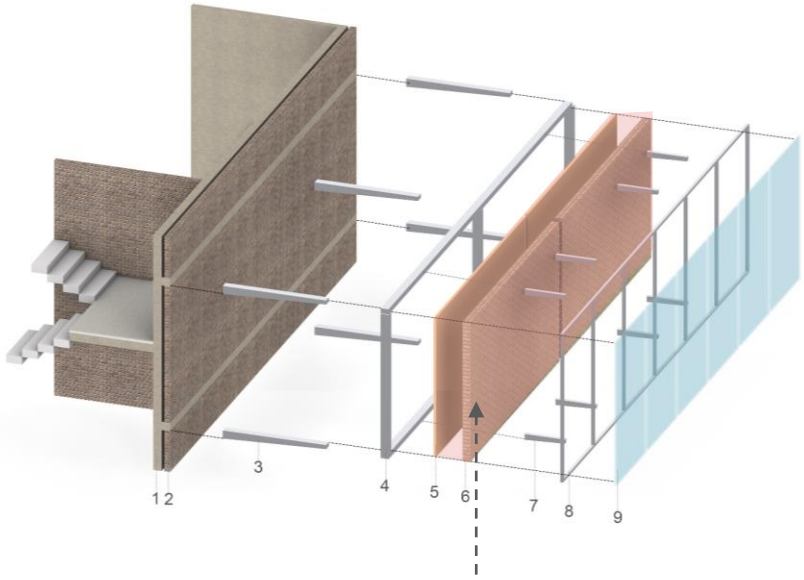

N


Exhaust
Wind direction
Inlet
Windward side
Solar Chimney
Shunt Channel
Climate Cascade
Supply shaft


Exhaust
Inlet
Wind
direction
Windward side
Solar
Chimney
Shunt
Channel
Climate
Cascade
Supply shaft

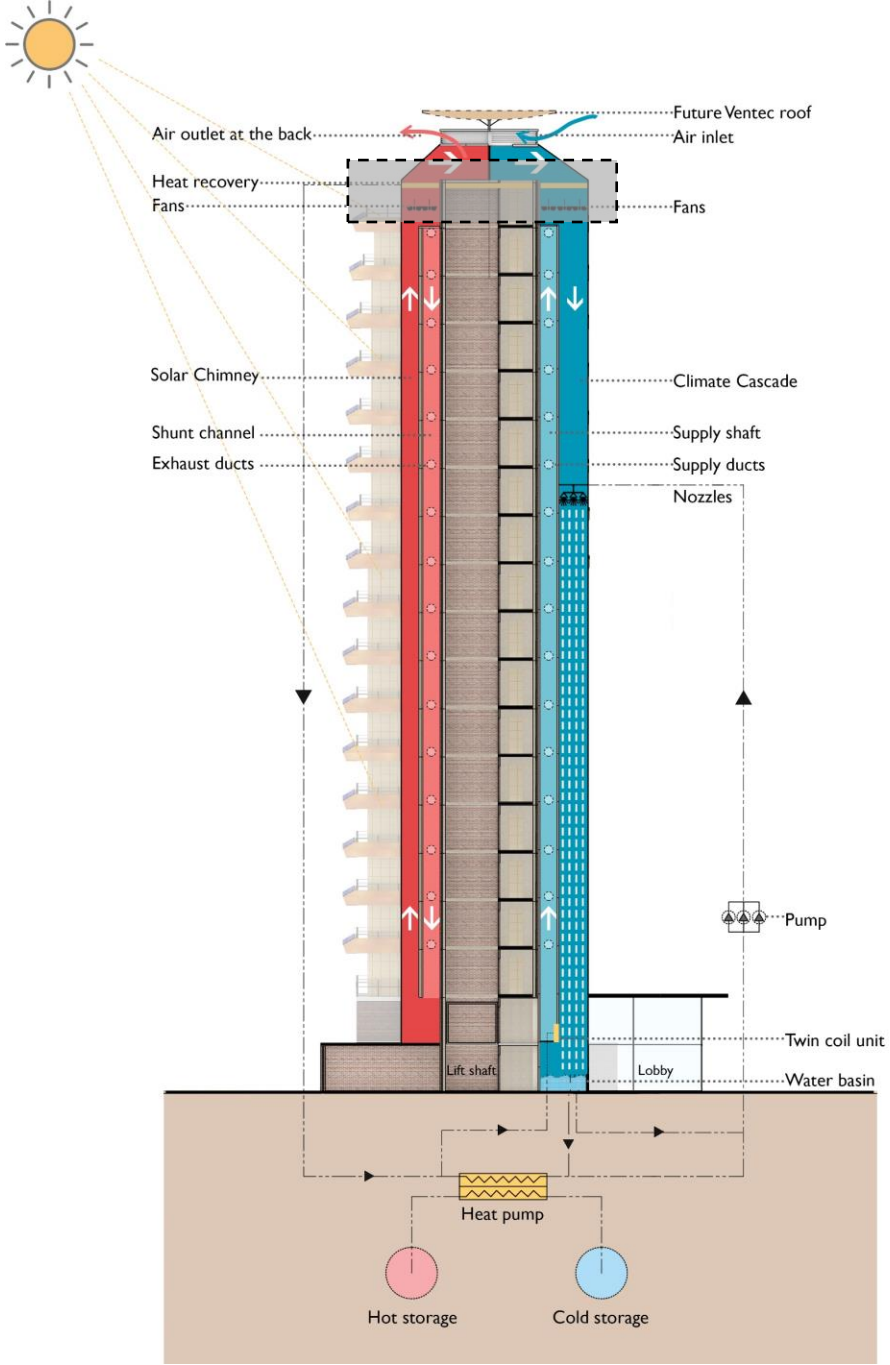


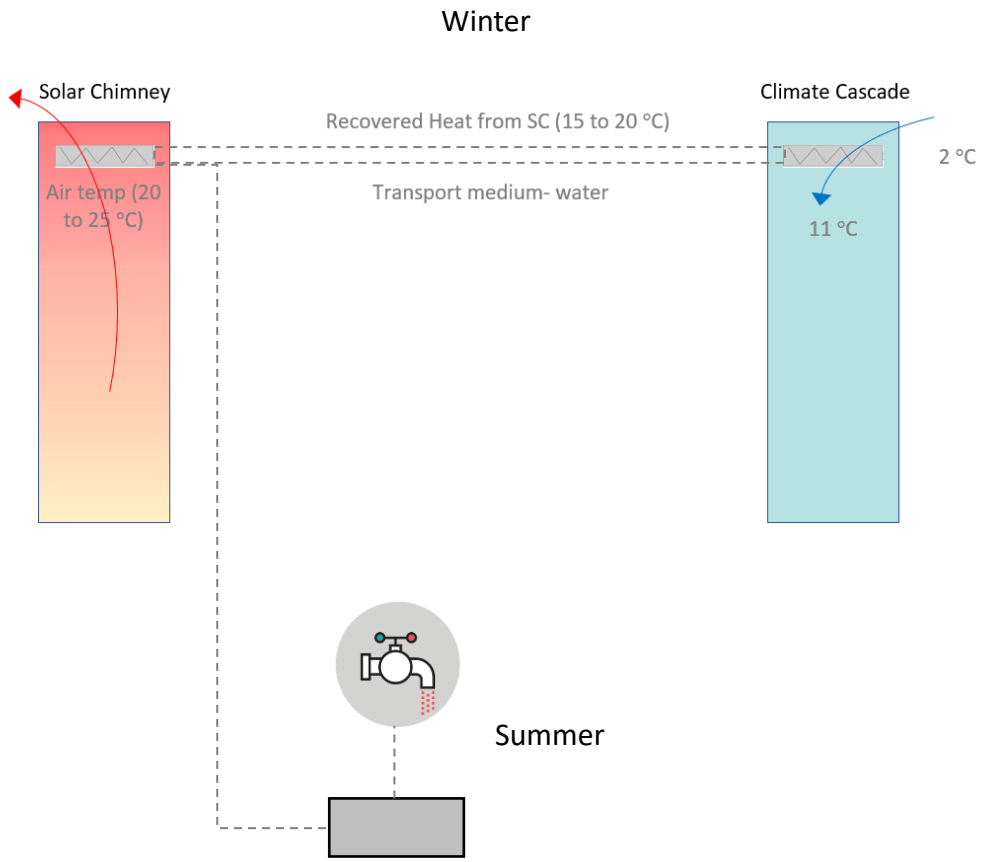
1. Existing concrete wall
2. Existing brick wall
3. Horizontal steel section
4. Steel frame to support shunt wall
5. Insulation 70mm
6. Brick wall 110mm
7. Horizontal steel section to support chimney glazing
8. Transrom and mullion
9. Glazing

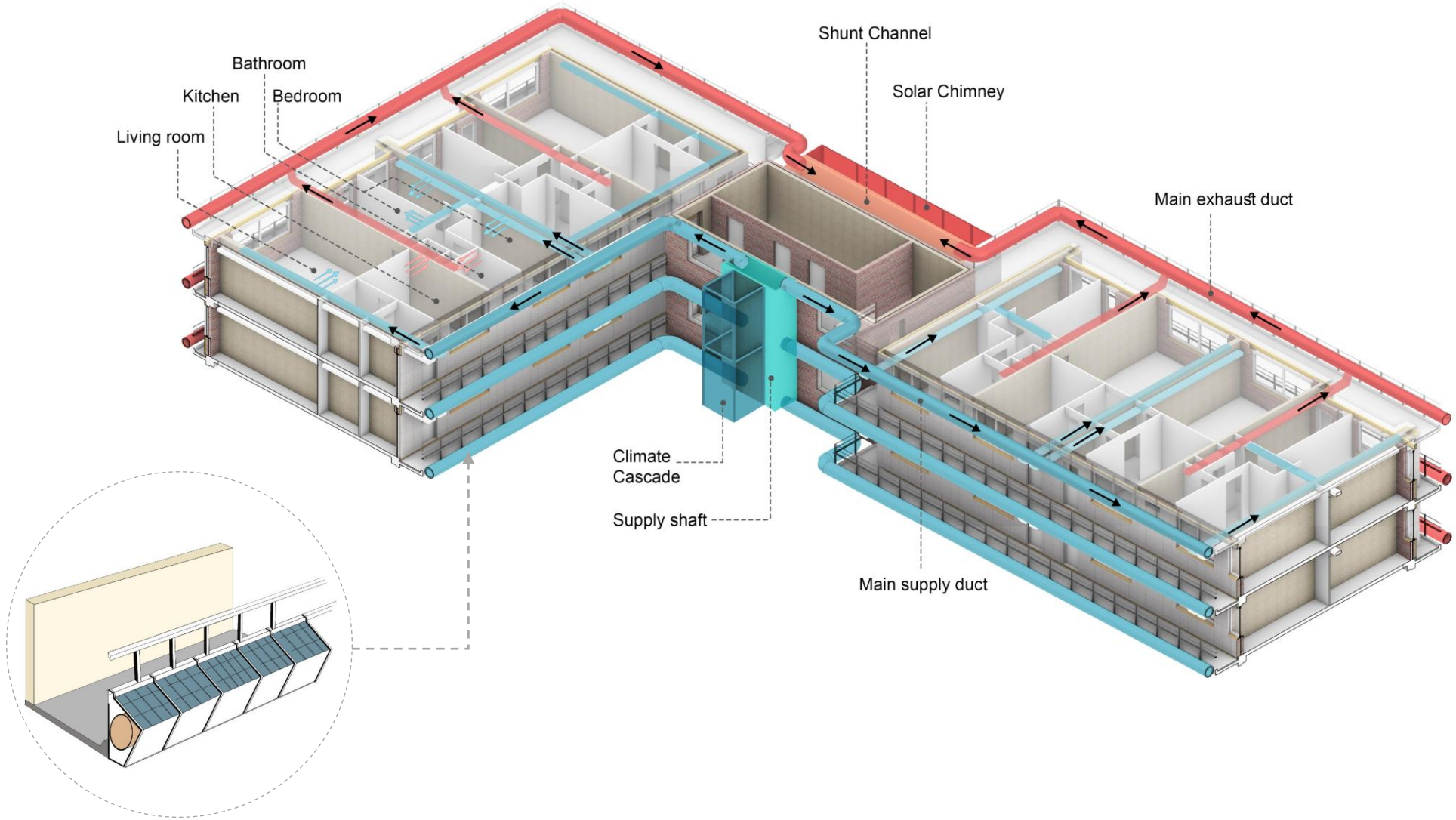


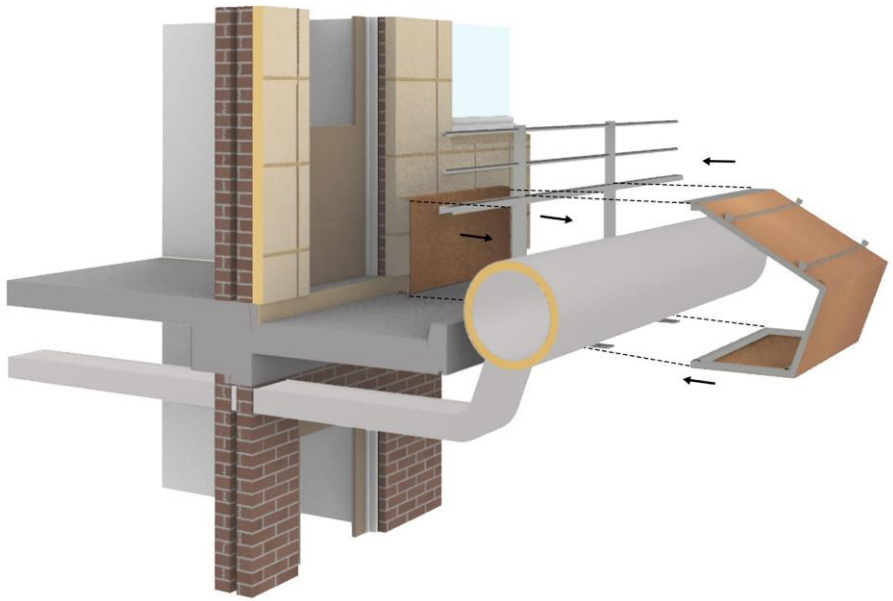
High thermal wall

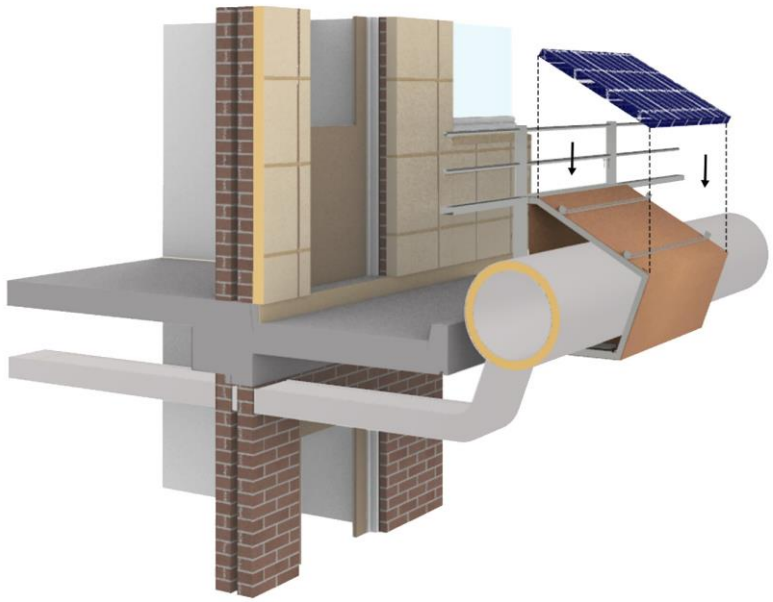
Solar Chimney

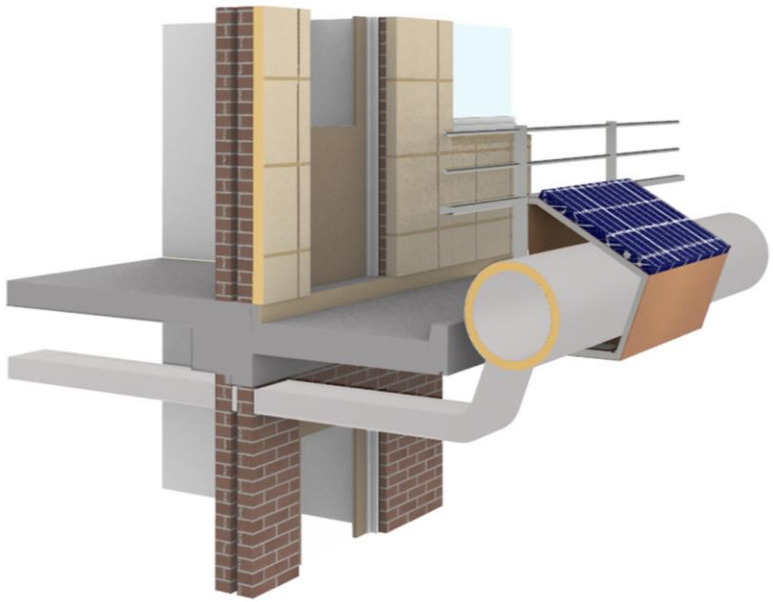

Future Ventec roof
Air outlet at the back
Air inlet
Heat recovery
Fans
Fans
Solar Chimney
Climate Cascade
Shunt channel
Supply shaft
Exhaust ducts
Supply ducts
Nozzles
Pump
Twin coil unit
Lift shaft
Lobby
Water basin
Heat pump
Hot storage
Cold storage

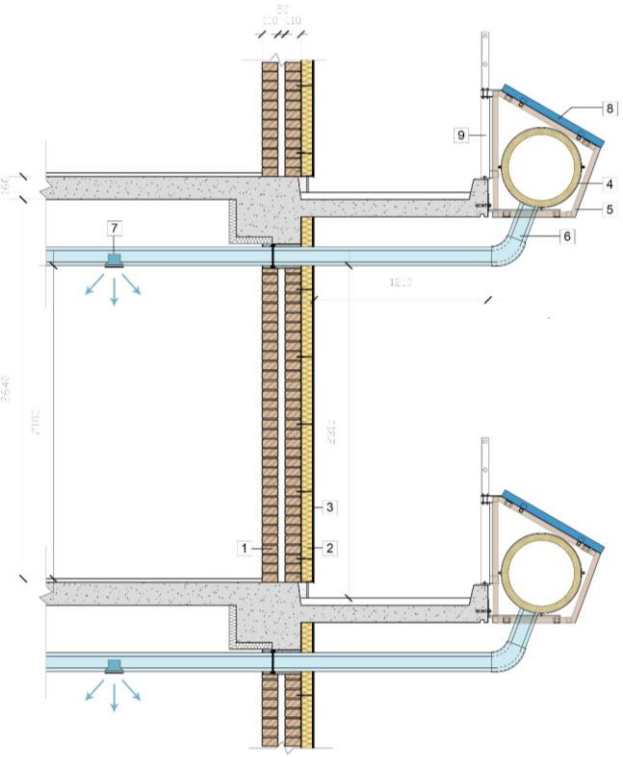

Winter
Solar Chimney
Climate Cascade
Recovered Heat from SC (15 to 20 °C)
2 °C
Air temp (20 to 25 °C)
Transport medium- water
11 °C
Summer

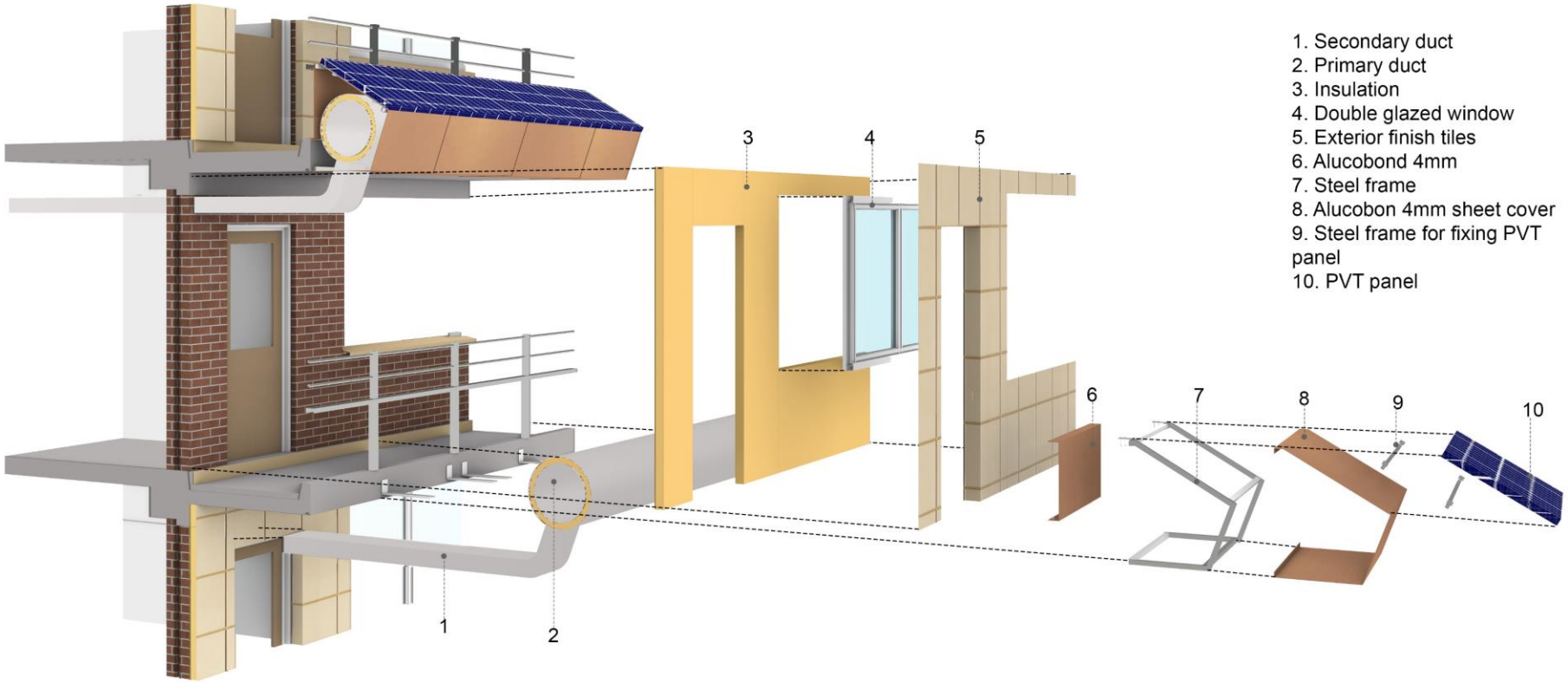

Shunt Channel
Bathroom
Kitchen
Bedroom
Living room
Solar Chimney
Main exhaust duct
Climate
Cascade
Supply shaft
Main supply duct



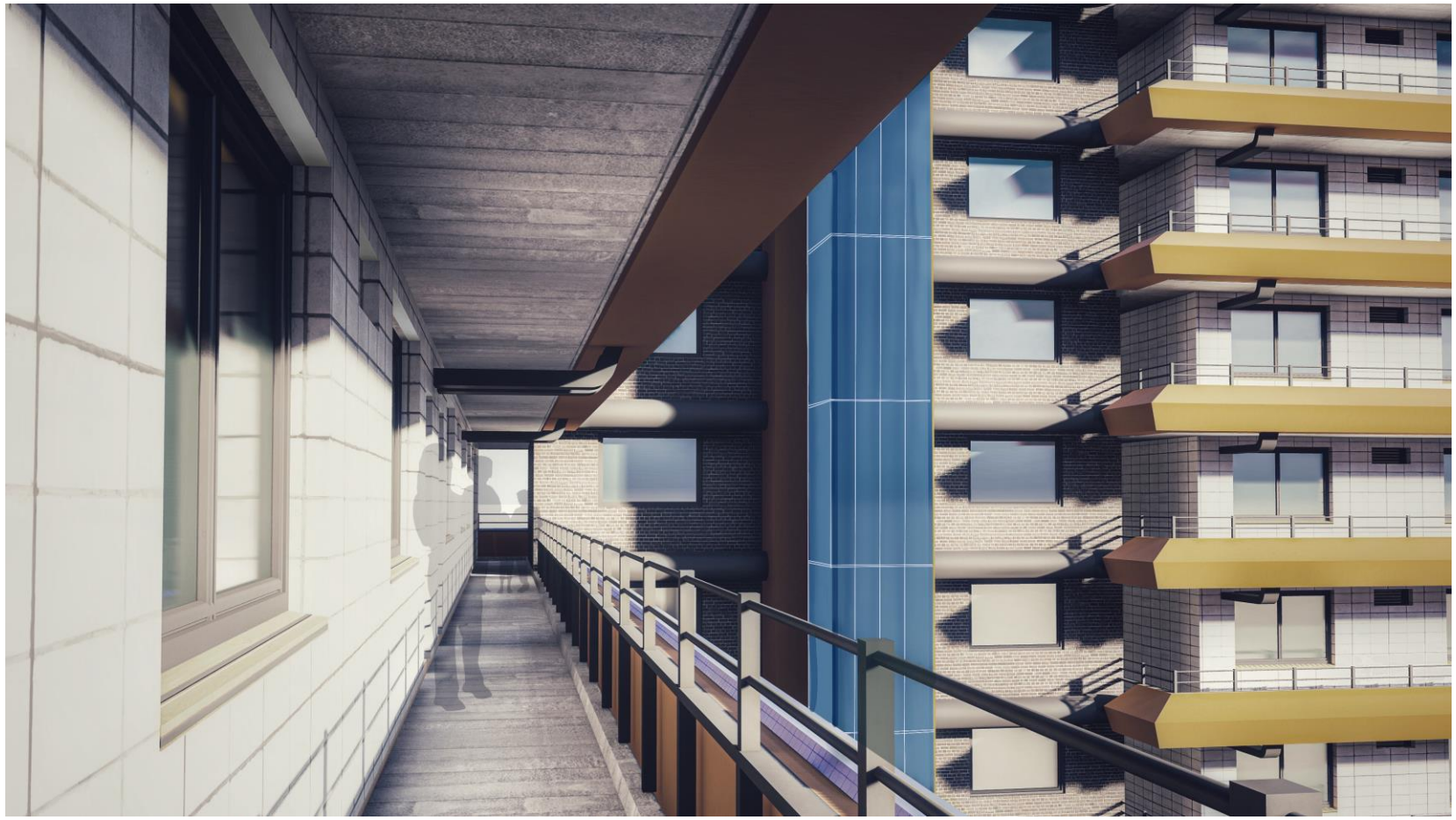


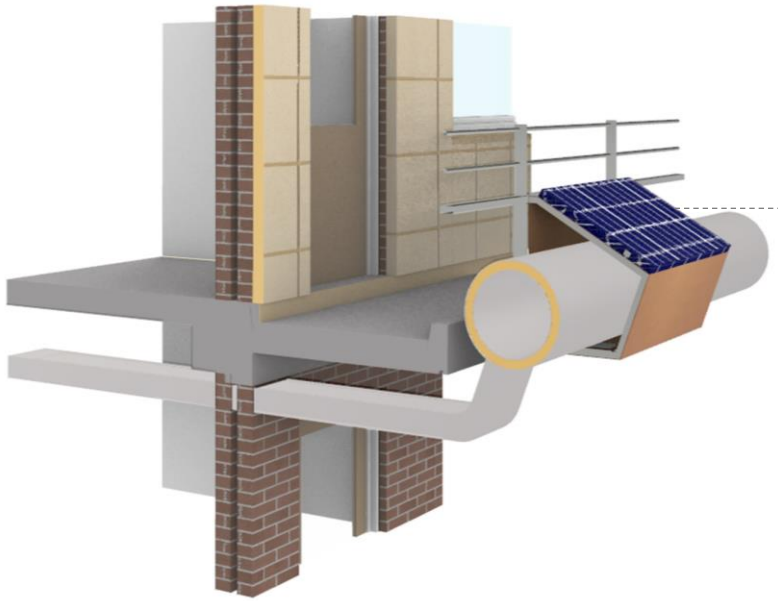






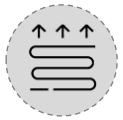
1. Secondary duct
2. Primary duct
3. Insulation
4. Double glazed window
5. Exterior finish tiles
6. Alucobond 4mm
7. Steel frame
8. Alucobon 4mm sheet cover
9. Steel frame for fixing PVT panel
10. PVT panel





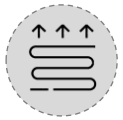
19%

BENG evaluation



BENG Assessment			
Usable Floor area (UFA)(m2)	17820		
BENG category	Criteria	Formula	Results
BENG 1	<65	Heating	
BENG 2	<50	(E_total-Lighting)/UFA	
BENG 3	>40	E_ren/ (E_total + E_ren)	

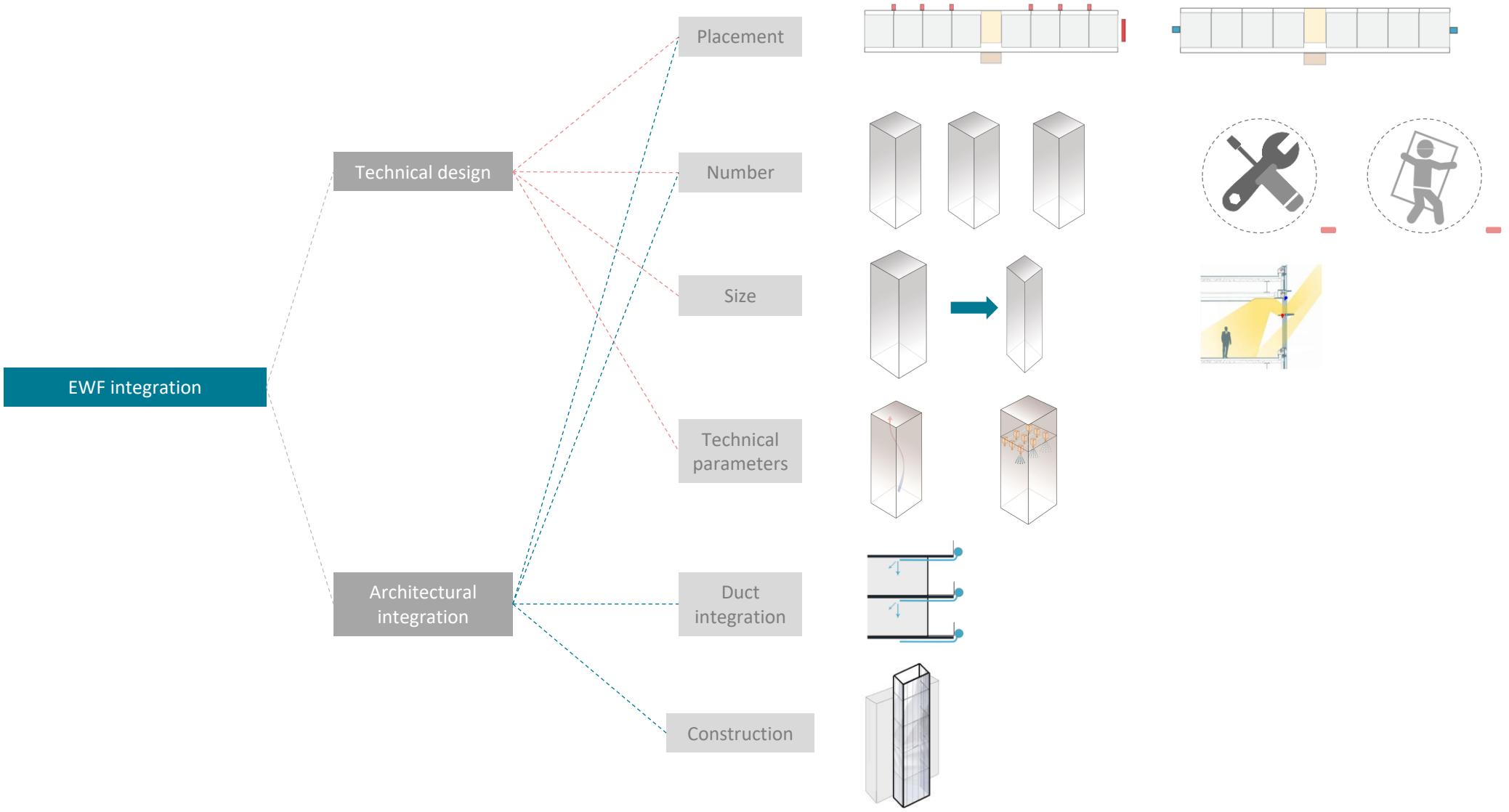
BENG evaluation



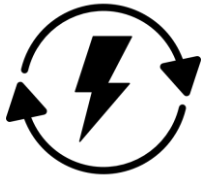
BENG Assessment				
Usable Floor area (UFA)(m2)	17820			
BENG category	Criteria	Formula	Results	
BENG 1	<65	Heating	57.9	Satisfied
BENG 2	<50	(E_total-Lighting)/UFA	40.14	Satisfied
BENG 3	>40	E_ren/ (E_total + E_ren)	51.28%	Satisfied

Applicability of **EWF in Housing** in terms of its **energy-efficiency** and **thermal comfort** potential.

Factors affecting the **integration** and the performance of the EWF system in itself.


EWF integration
Technical design
Architectural integration
Placement
Number
Size
Technical parameters
Duct integration
Construction

Energy efficiency and thermal comfort potential



Energy efficiency-EWF

14%

Energy efficiency-EWF & façade renovation

57%

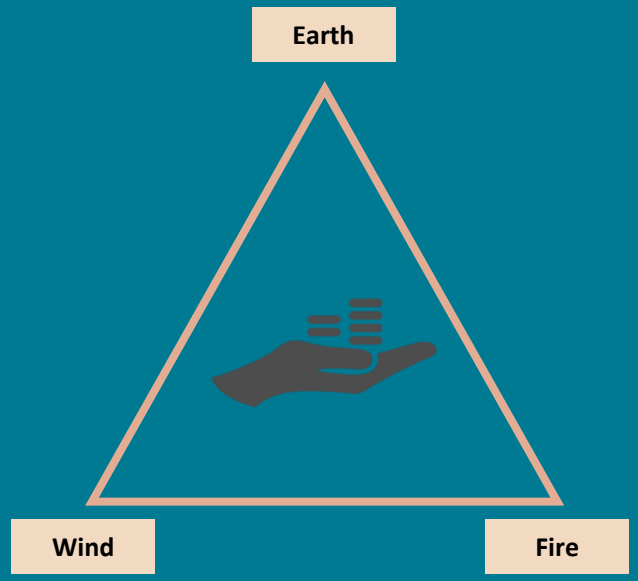
Energy neutrality

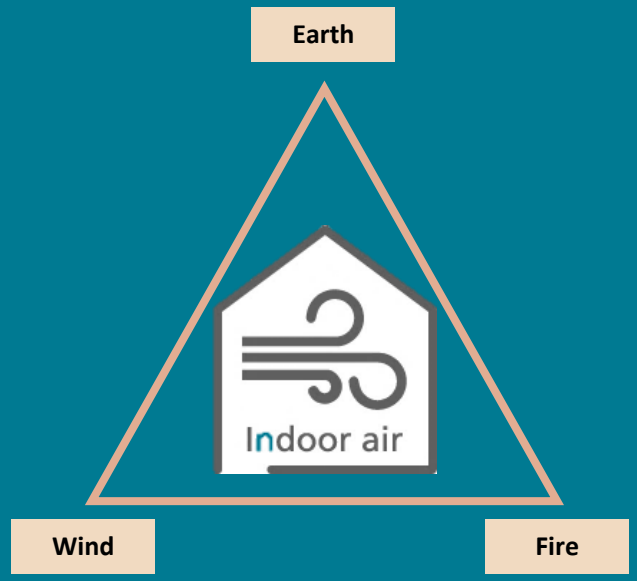
79%

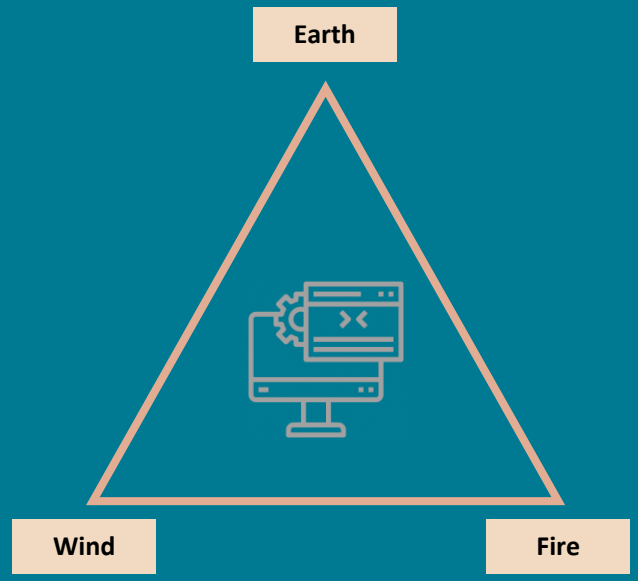
Thermal comfort

EWF system is a viable solution for achieving **energy-efficiency** for the housing refurbishment in the Netherlands.

Recommendations







“Architecture will therefore become more informed by the wind, by the sun, by the earth, by the water and so on.”

- Richard Rogers

Thank You!