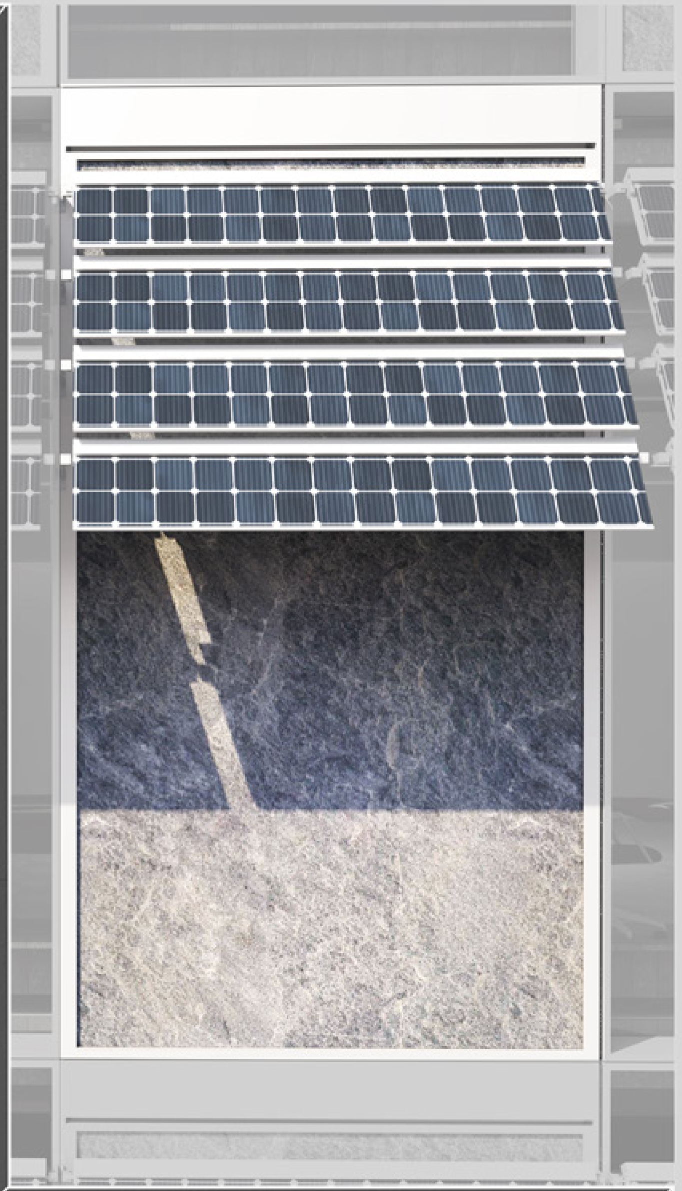
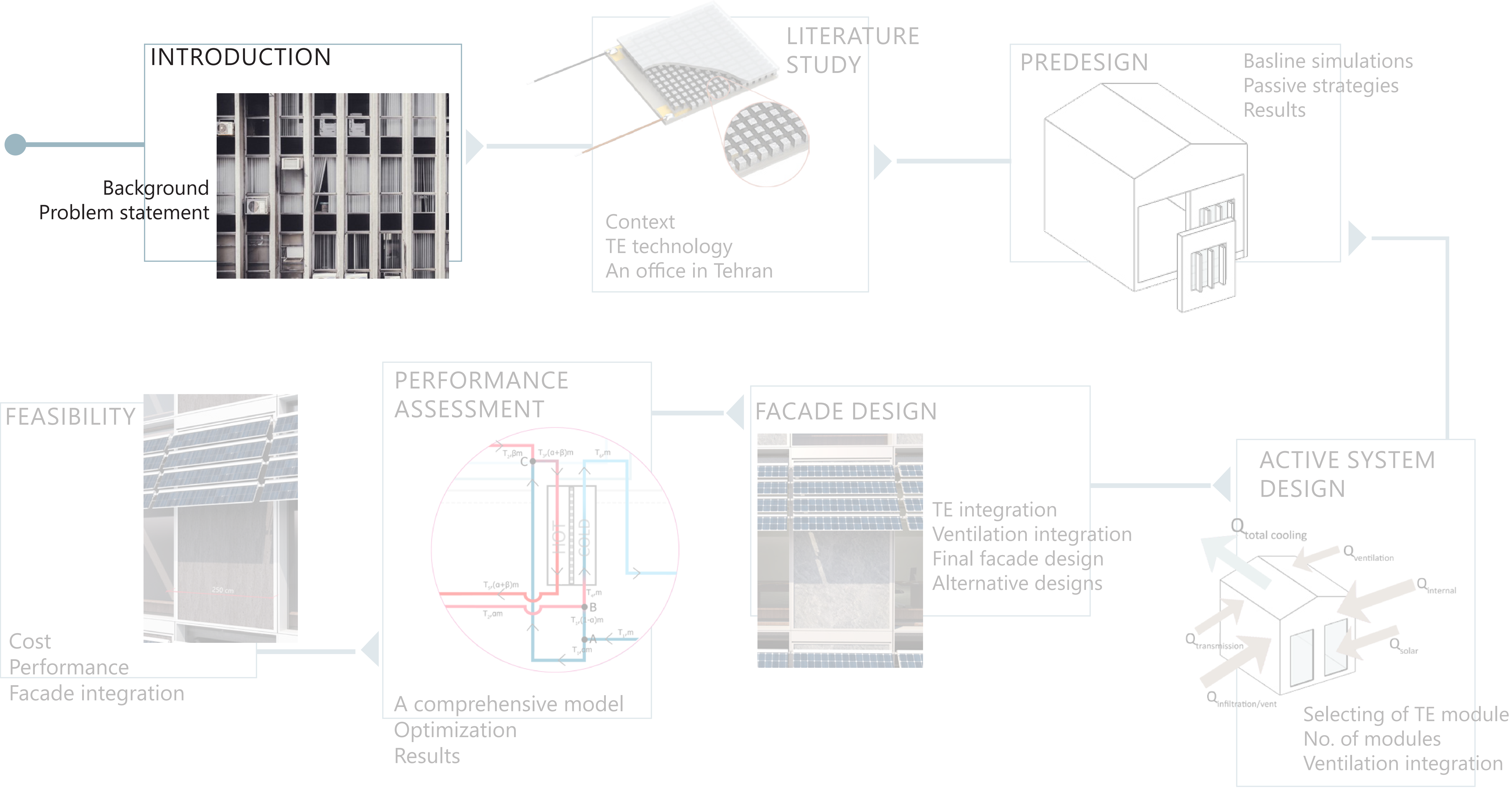
TE INTEGRATED FACADE



NARGES MIRYAZDI
JULY 2019

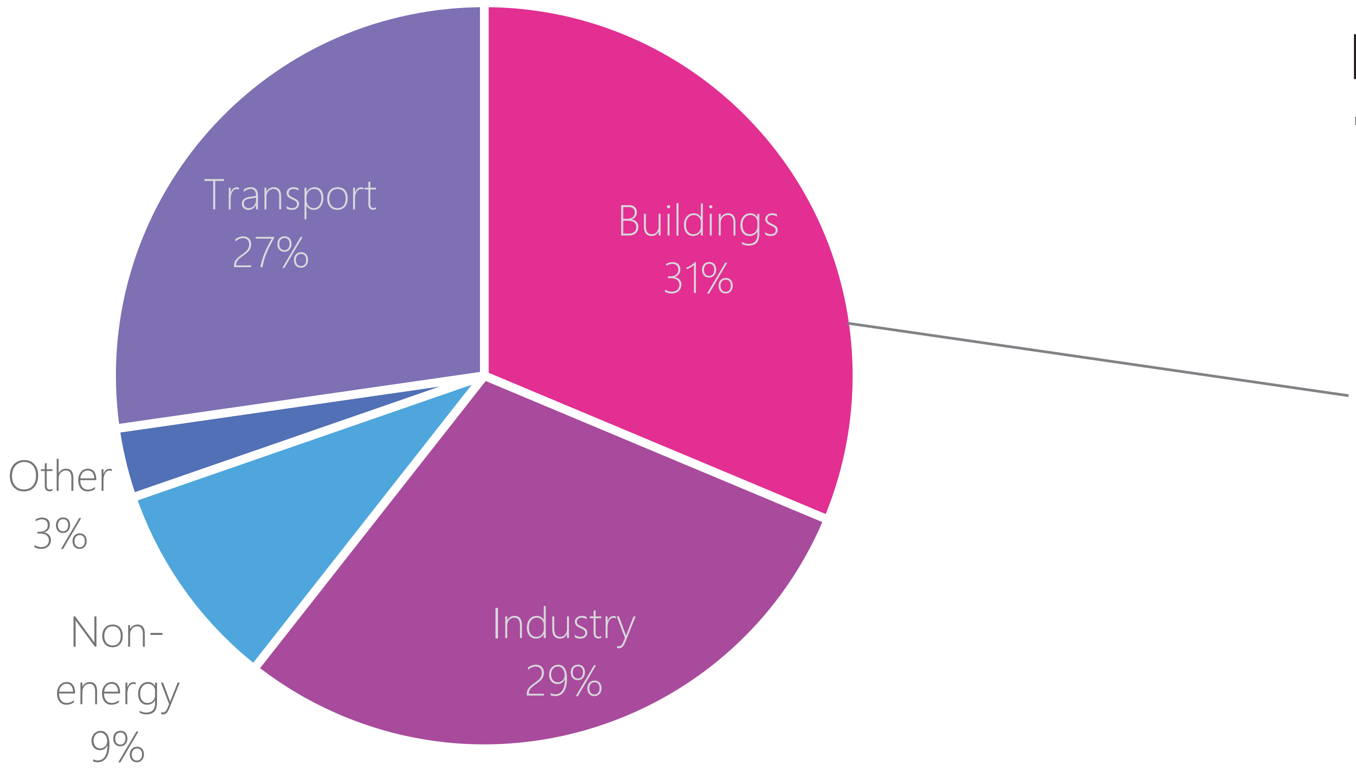
Supervisory team
Alejandro Prieto Hoces
Eric van den Ham


INTRODUCTION
Background
Problem statement
LITERATURE STUDY
Context
TE technology
An office in Tehran
PREDESIGN
Basline simulations
Passive strategies
Results
ACTIVE SYSTEM DESIGN
Q total cooling
Q ventilation
Q internal
Q transmission
Q solar
Q infiltration/vent
Selecting of TE module
No. of modules
Ventilation integration
FACADE DESIGN
TE integration
Ventilation integration
Final facade design
Alternative designs
PERFORMANCE ASSESSMENT
HOT
COLD
A
B
C
A comprehensive model
Optimization
Results
FEASIBILITY
Cost
Performance
Facade integration

BACKGROUND

Problems

1. Energy consumption



Sources: IEA, https://www.iea.org/topics/energyefficiency/buildings/

30% of the world delivered energy

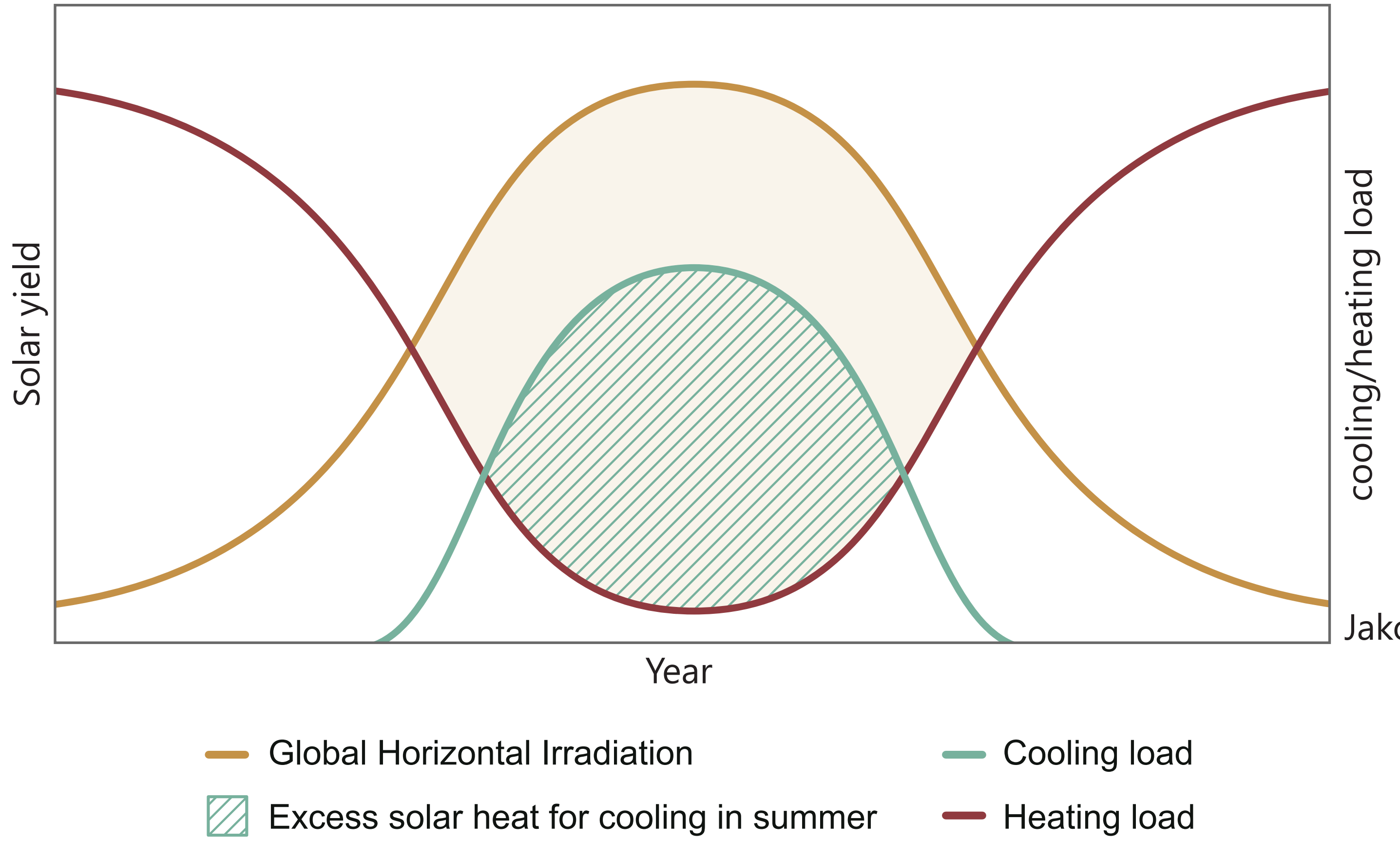
More than 50% of electricity consumption

Up to 70% is consumed by heating and cooling

BACKGROUND
Problems
2. Use of refrigrants

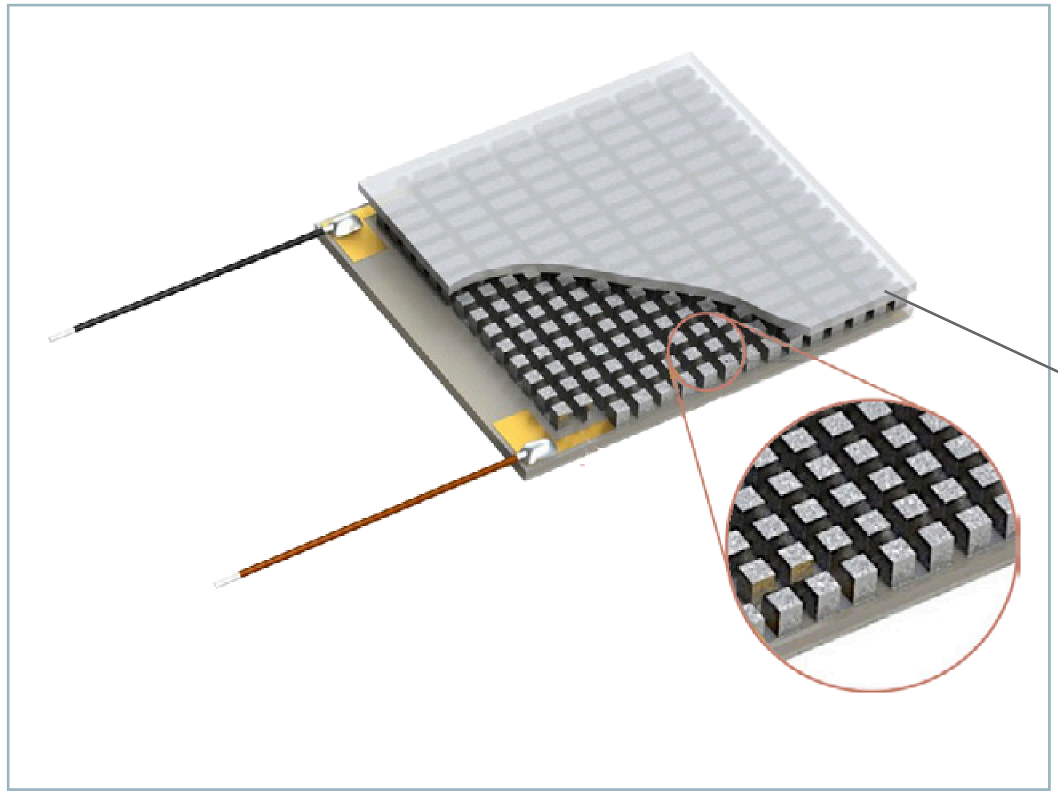
Global warming and
Ozone depletion potential

BACKGROUND
Alternative solution: Solar Energy



Jakob, U. (2016). Solar cooling technologies

BACKGROUND
Solar cooling technologies: Thermoelectric



Peltier element

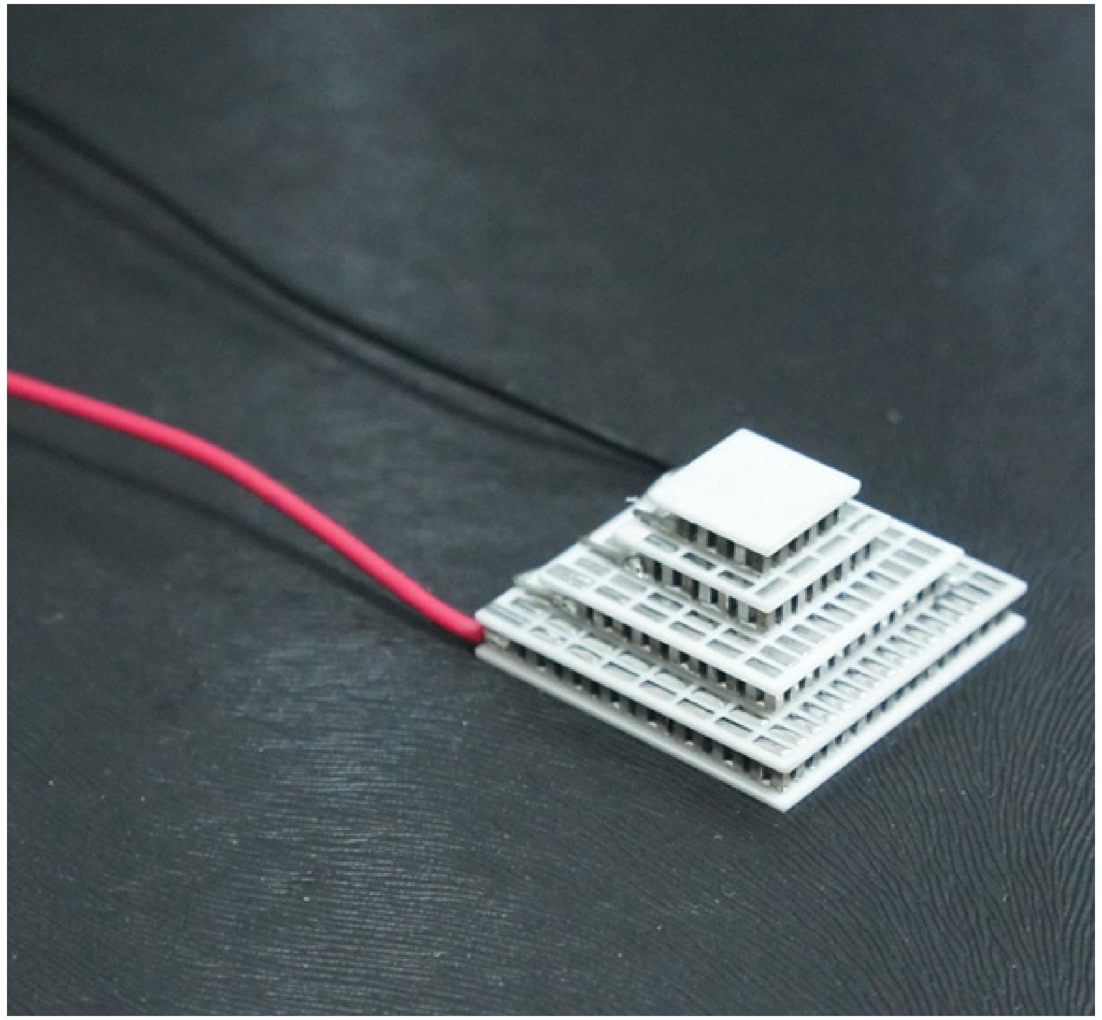
BACKGROUND

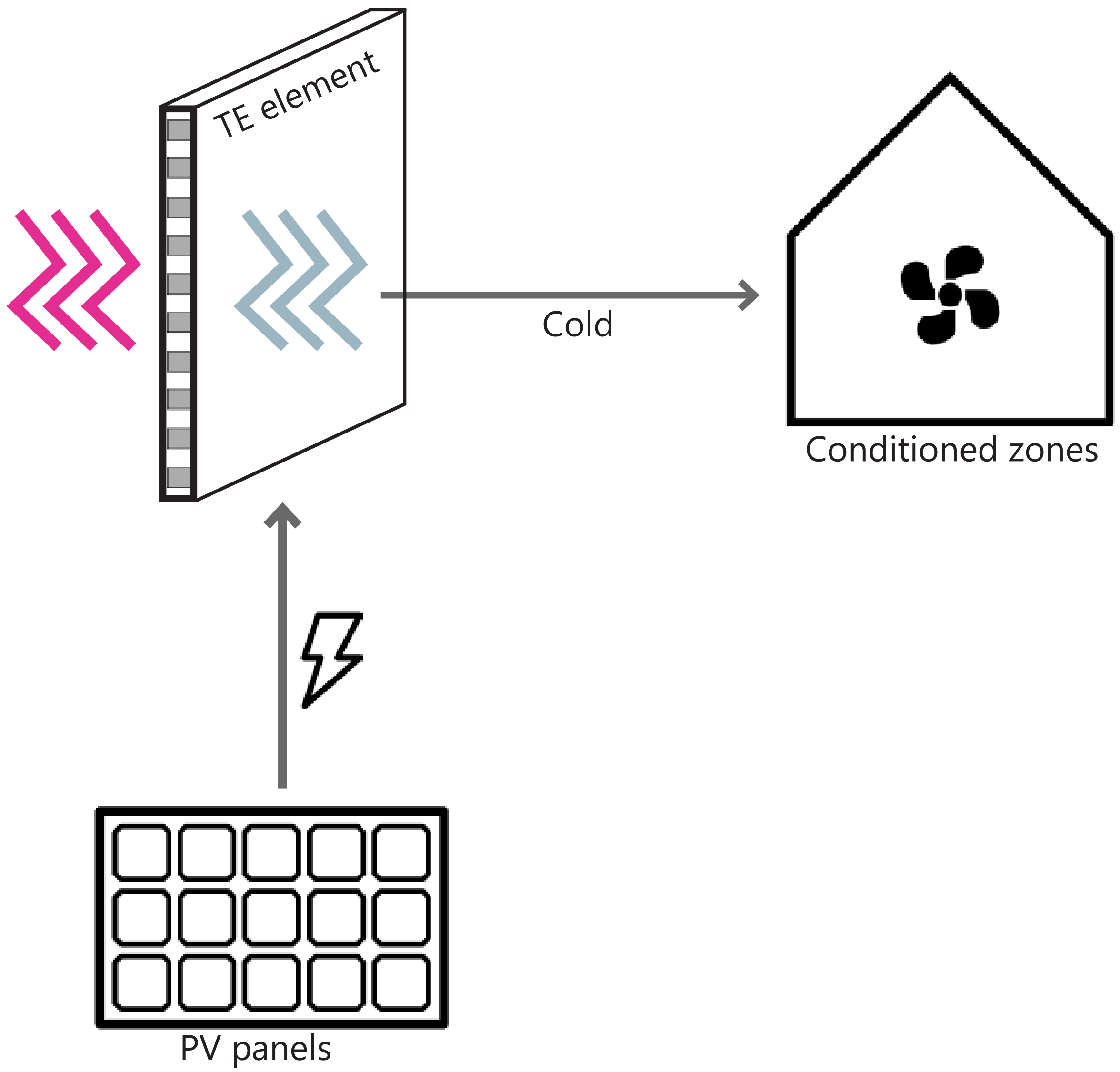
Why thermoelectric technology

1- Sustainable
Low GWP and ODP
Solar energy powered

2- Facade application
Silent, compact, simple to use
Low maintenance
Reliable
Heating and cooling

3- PV integration
DC current
No converter

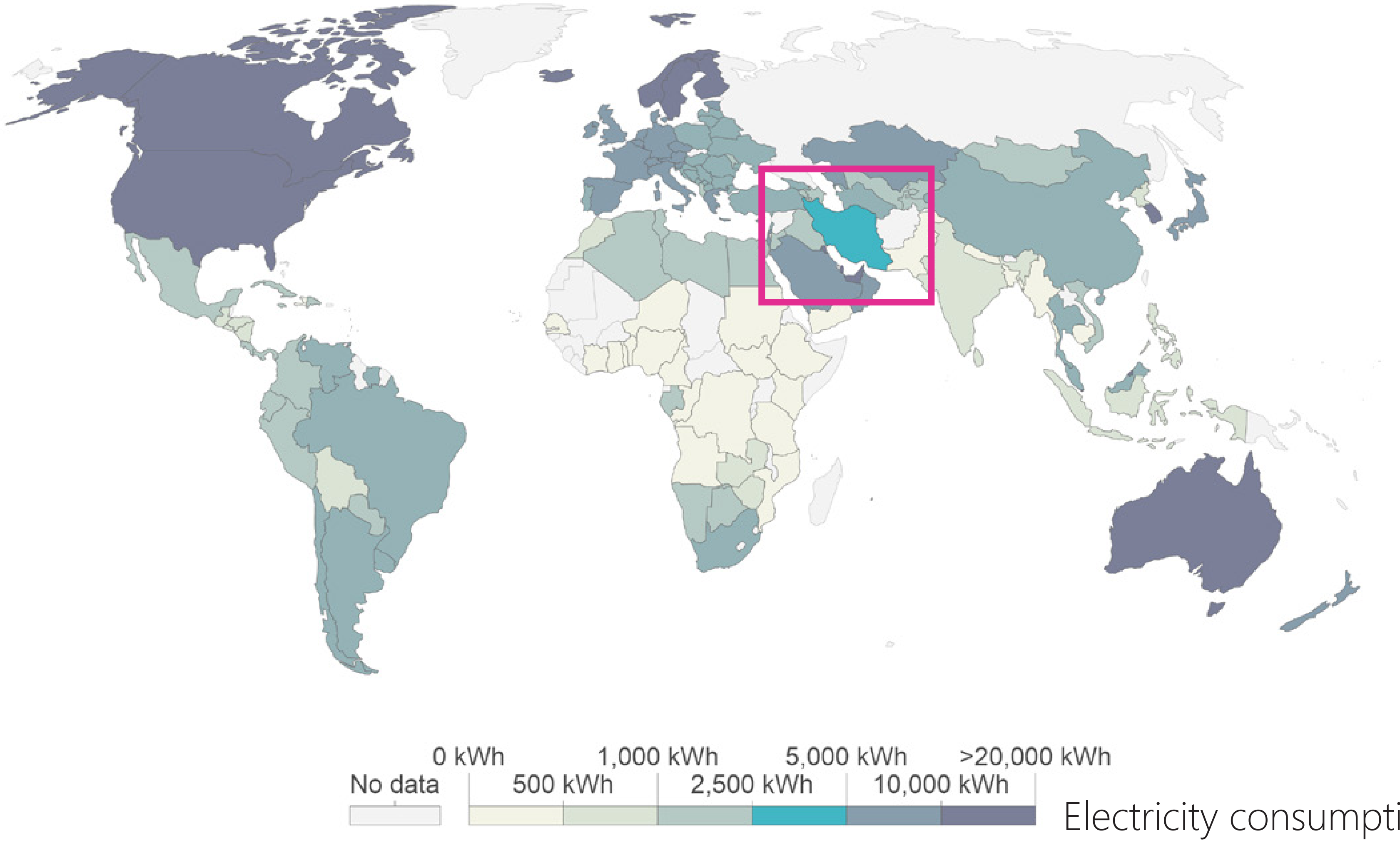




BACKGROUND
Thermoelectric technology

BACKGROUND
Iran-energy consumption

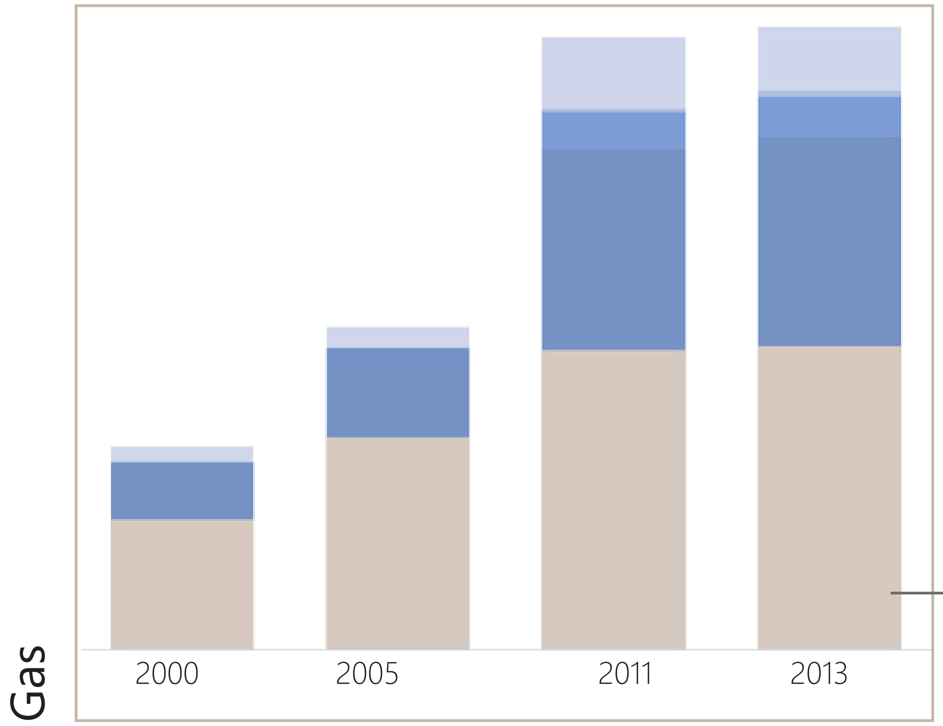
8^{th} producer of CO_2 in the world



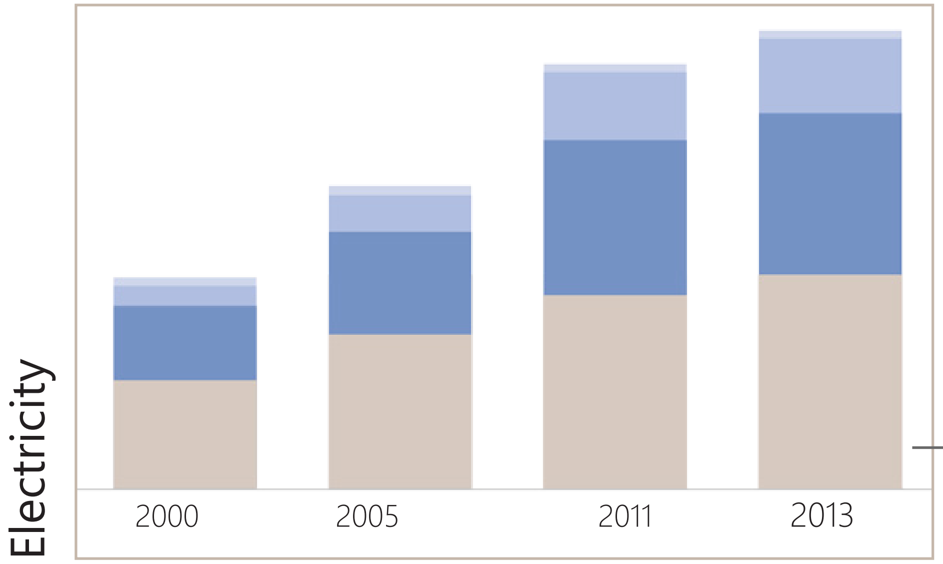
Electricity consumption kWh/capita in 2014

Source: International Energy Agency (IEA) via The World Bank

BACKGROUND
Iran-energy consumption



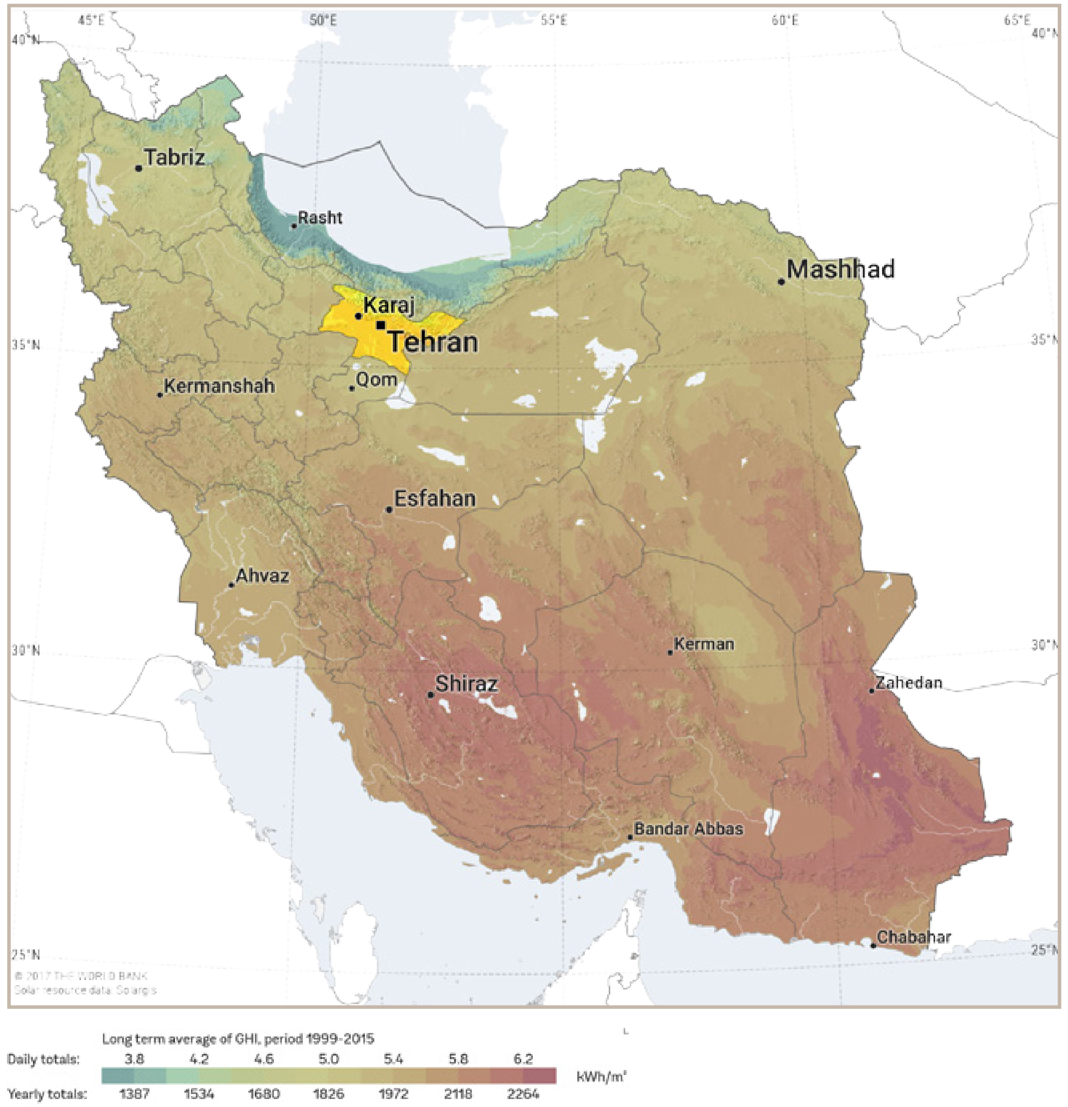
Building Industry
$46000*10^6 (m^3)$



Building Industry
95000 (GWh)

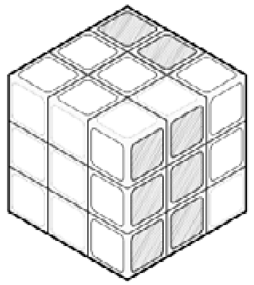
BACKGROUND
Tehran-Global Horizontal Irradiation

The annual solar radiation is 6350 MJ/m2 in Tehran

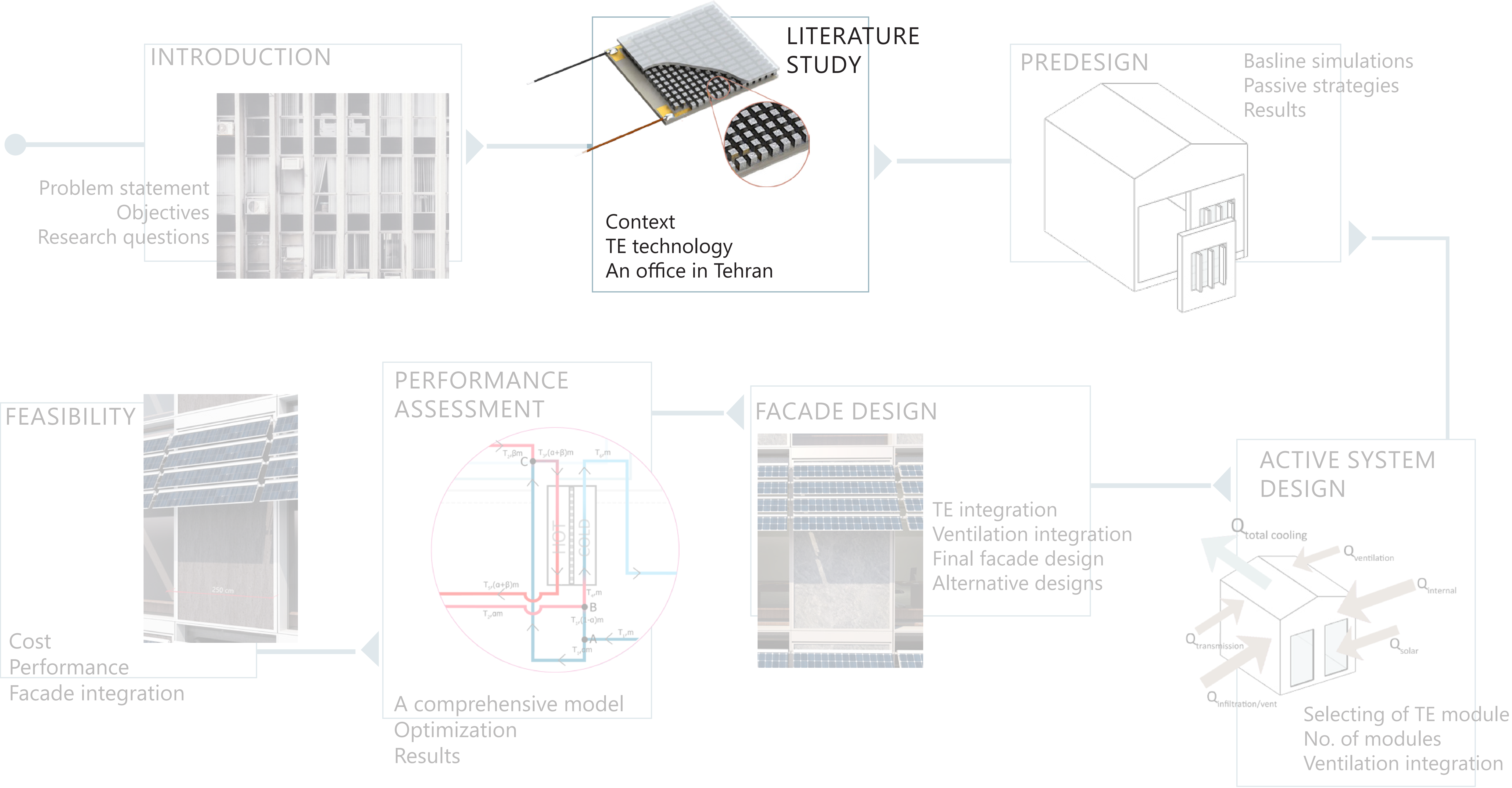


Source: World Bank Group, https://globalsolaratlas.info/
downloads/iran
Masoudi Nejad, 2015

PROBLEM STATEMENT

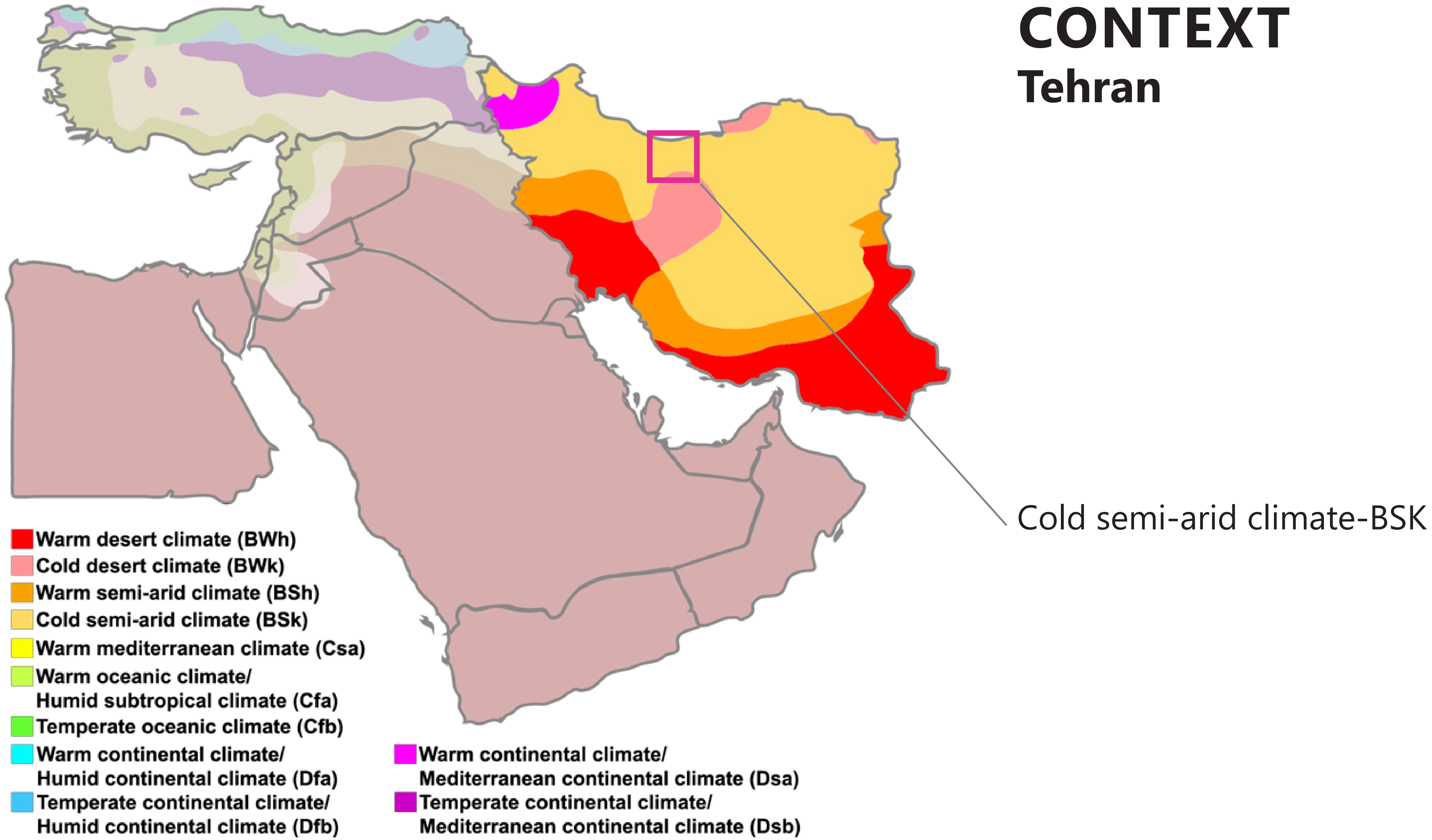


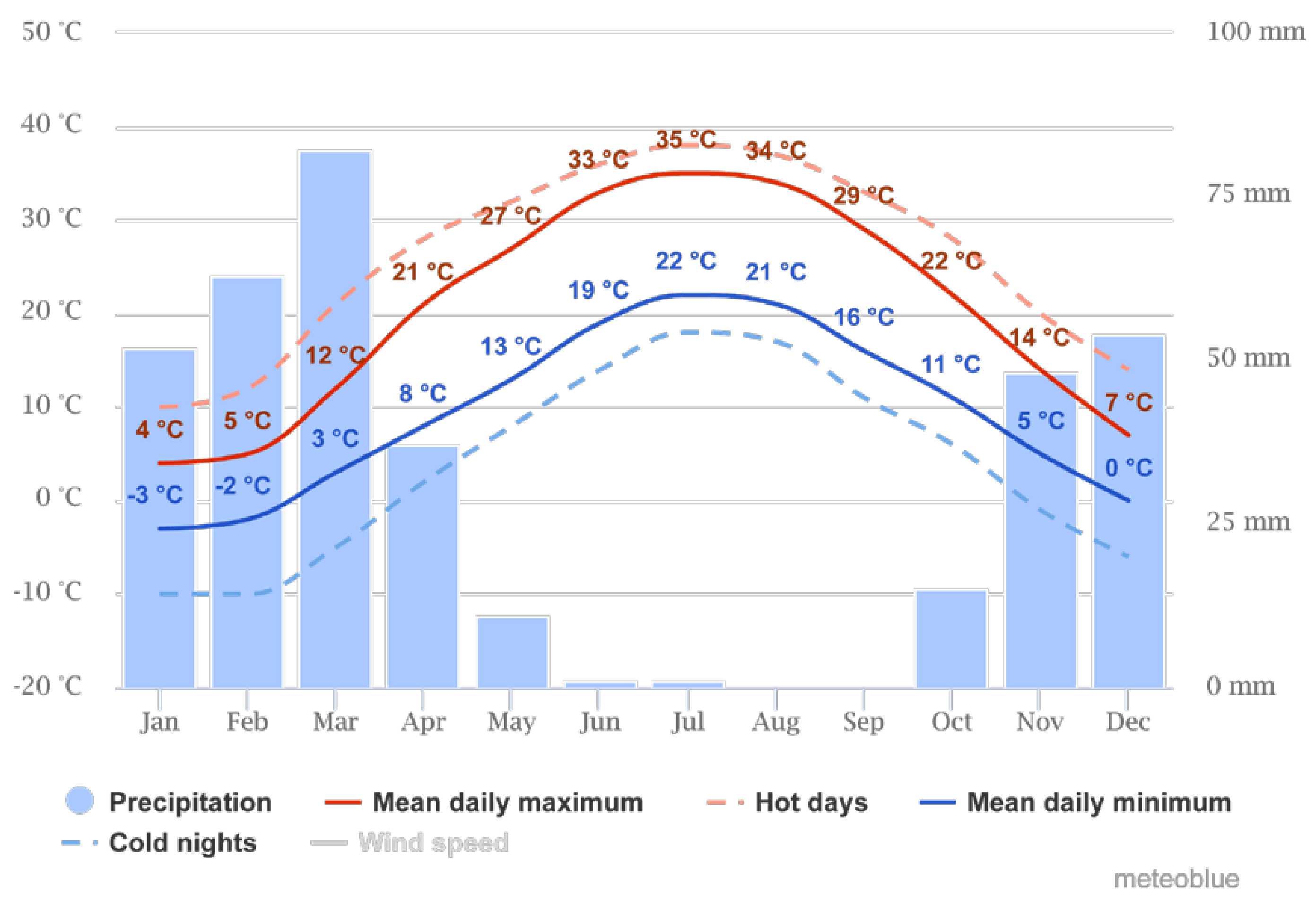
Is the designed facade capable of providing heating and cooling with electricity only from PV panels?


INTRODUCTION
Problem statement
Objectives
Research questions
LITERATURE STUDY
Context
TE technology
An office in Tehran
PREDESIGN
Basline simulations
Passive strategies
Results
ACTIVE SYSTEM DESIGN
Q total cooling
Q ventilation
Q internal
Q transmission
Q solar
Q infiltration/vent
Selecting of TE module
No. of modules
Ventilation integration
FACADE DESIGN
TE integration
Ventilation integration
Final facade design
Alternative designs
PERFORMANCE ASSESSMENT
HOT
COLD
A comprehensive model
Optimization
Results
FEASIBILITY
Cost
Performance
Facade integration

CONTEXT
Tehran

CONTEXT
Tehran

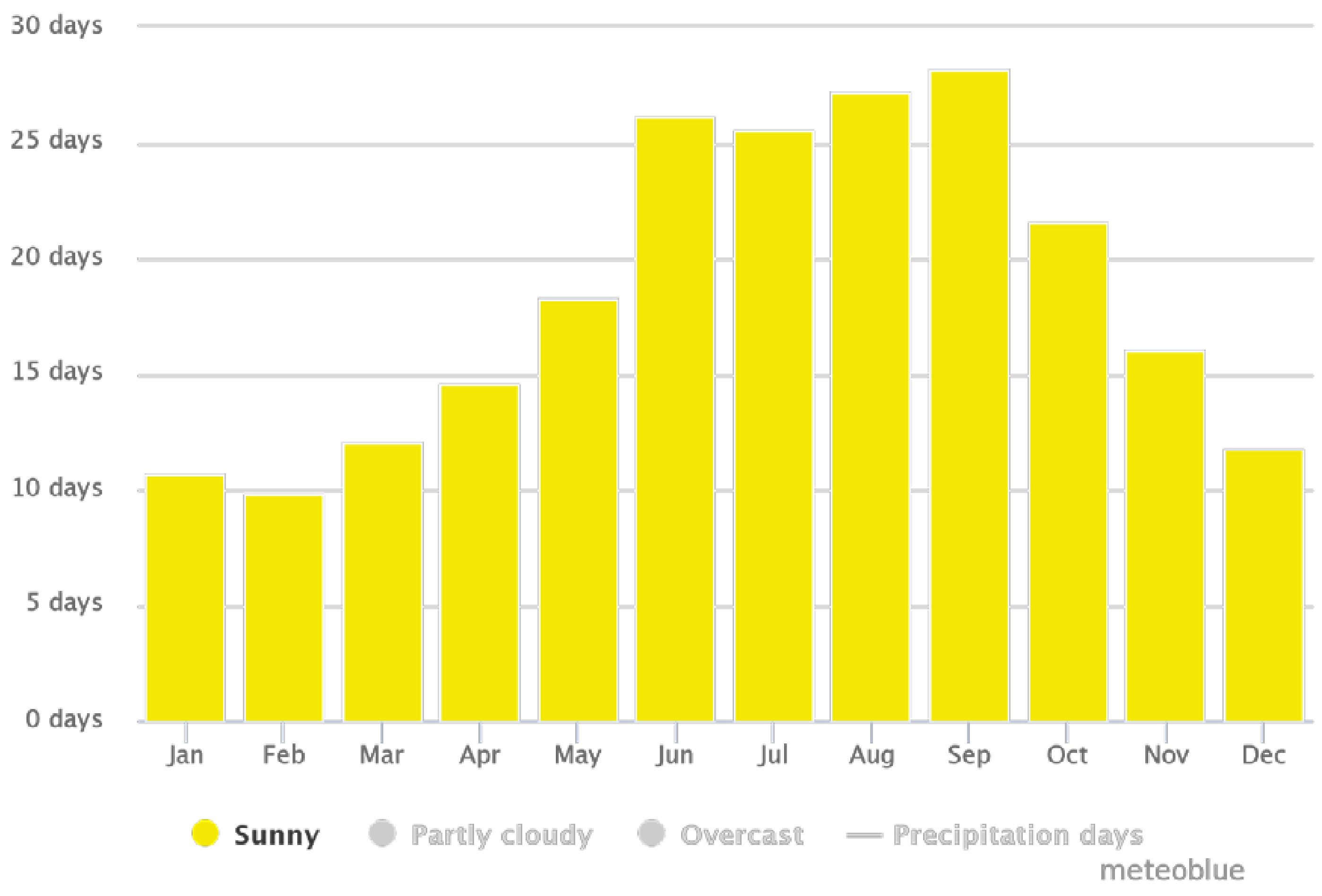




CONTEXT

Tehran

Large temperature swings between day and night
Four-seasons:
Mild springs and autumns
Long, hot and dry summers
Short but cold winters
Hottest month is July
Coldest Month is January



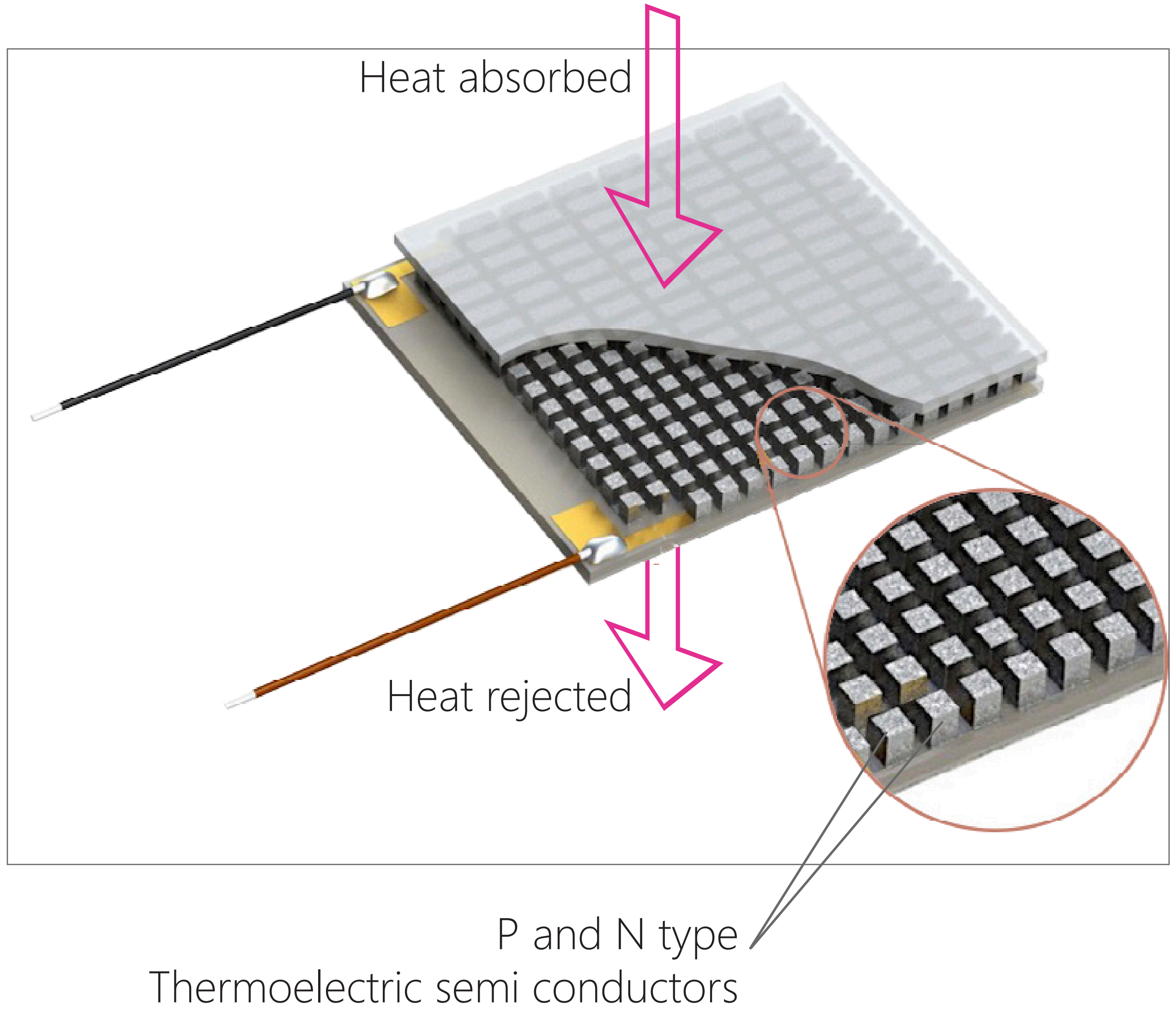
CONTEXT

Tehran

Availability of sun is relatively high

THERMOELECTRIC TECHNOLOGY
Mechanism

By applying electrical current difference in temperature will be created across the two junctions of TE module



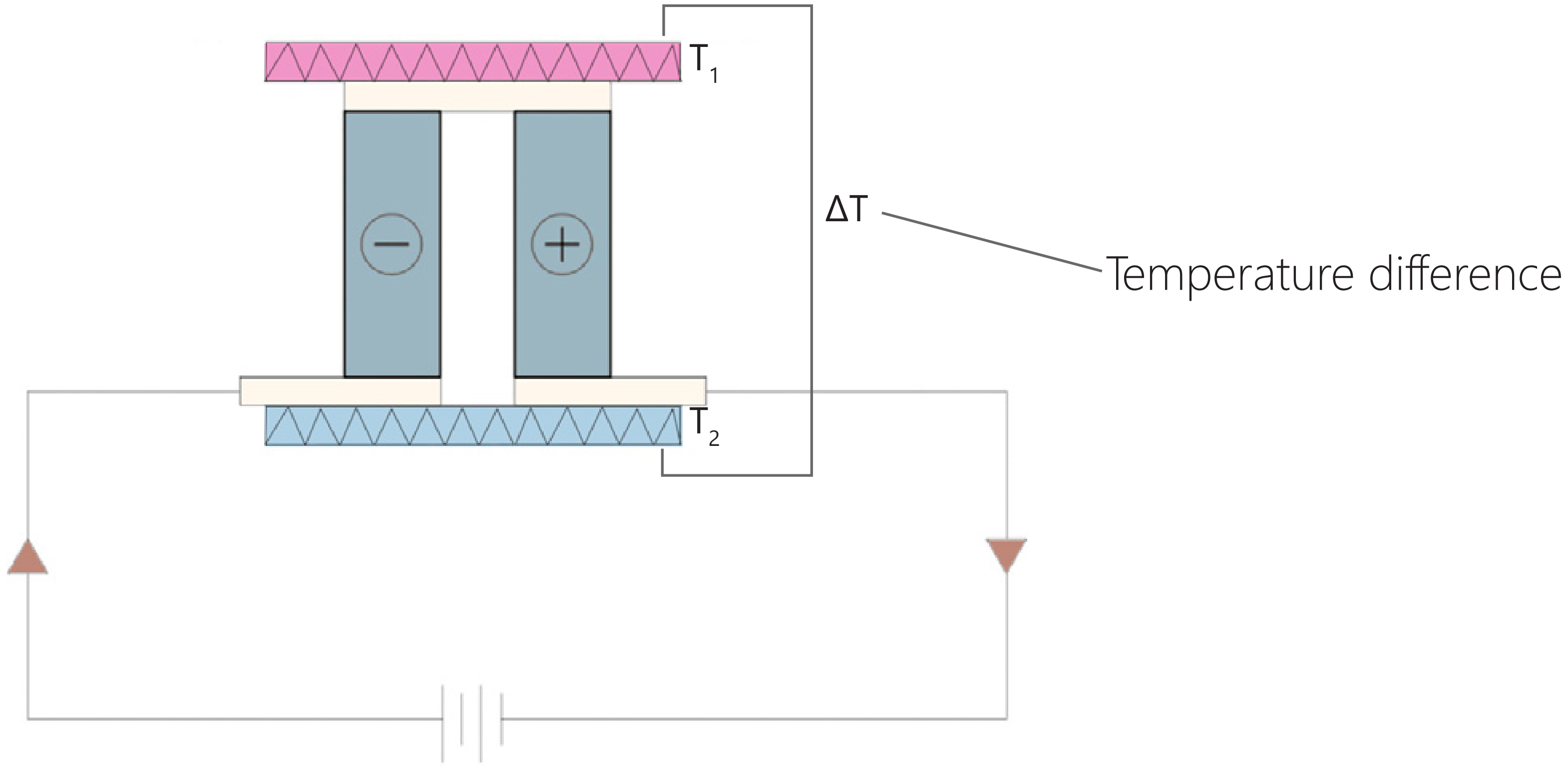
THERMOELECTRIC TECHNOLOGY
Facade integration

Prototypes
A Thermoelectric cooling heating unit

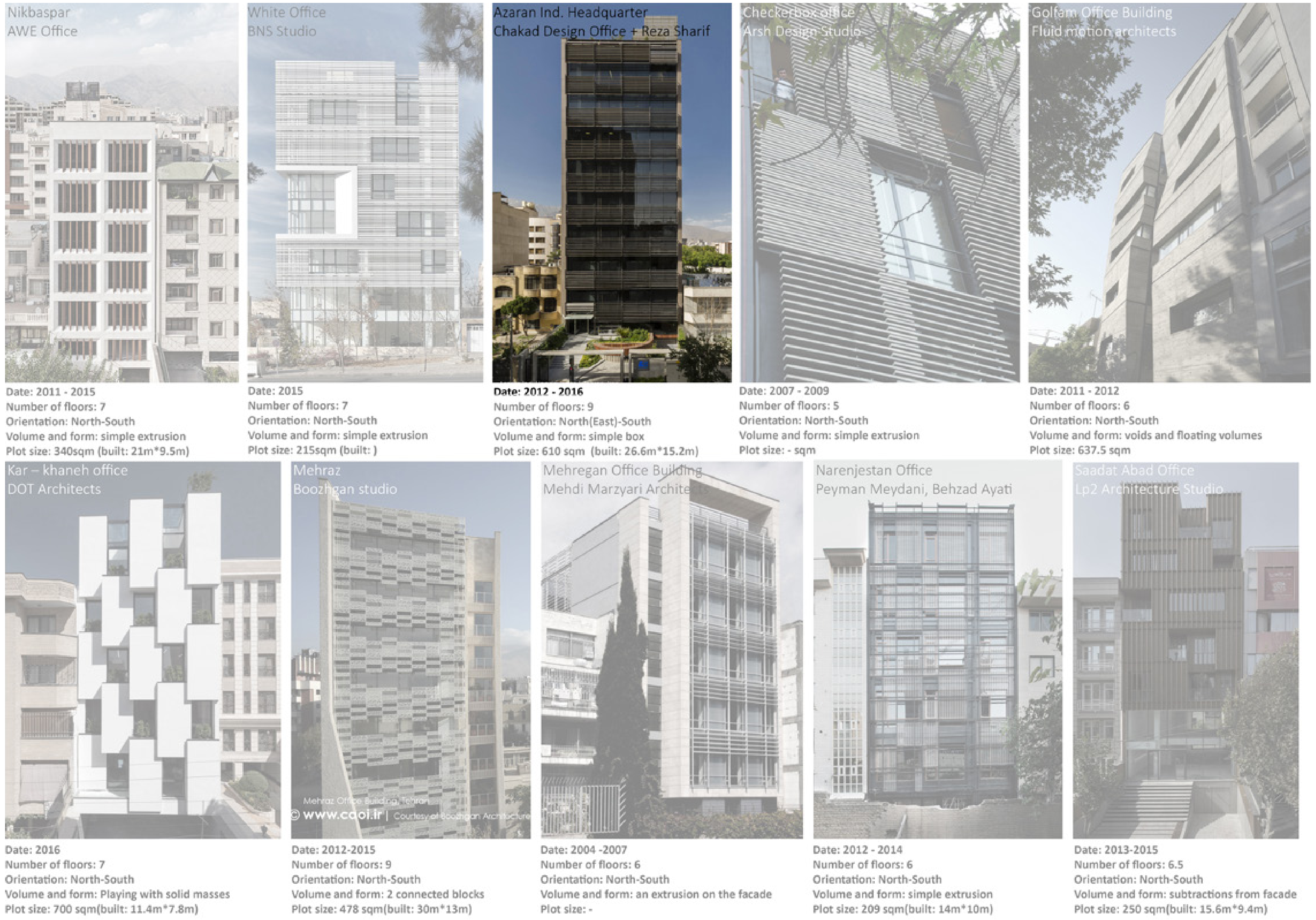
Low efficiency
High costs
Availability

By Ibañez-Puy, M., et al. 2017

THERMOELECTRIC TECHNOLOGY
Increasing the Performance



THERMOELECTRIC TECHNOLOGY
Increasing the Performance



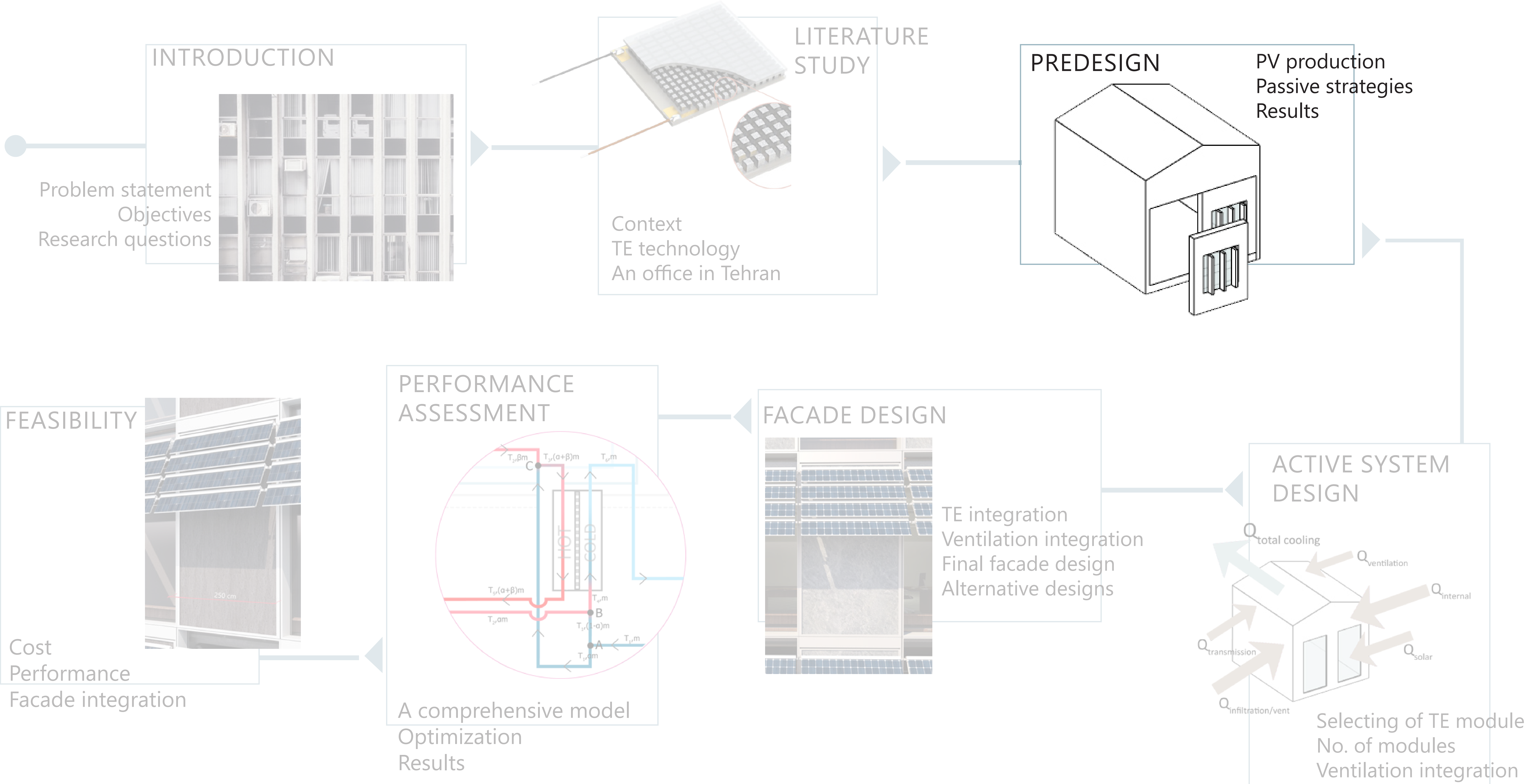
A CASE STUDY
A representative office

Built between 2004-2016
Number of floors: 5-9 average
90% are South-North oriented
Plot size: 430 sqm on average

A CASE STUDY
Azaran headquarters

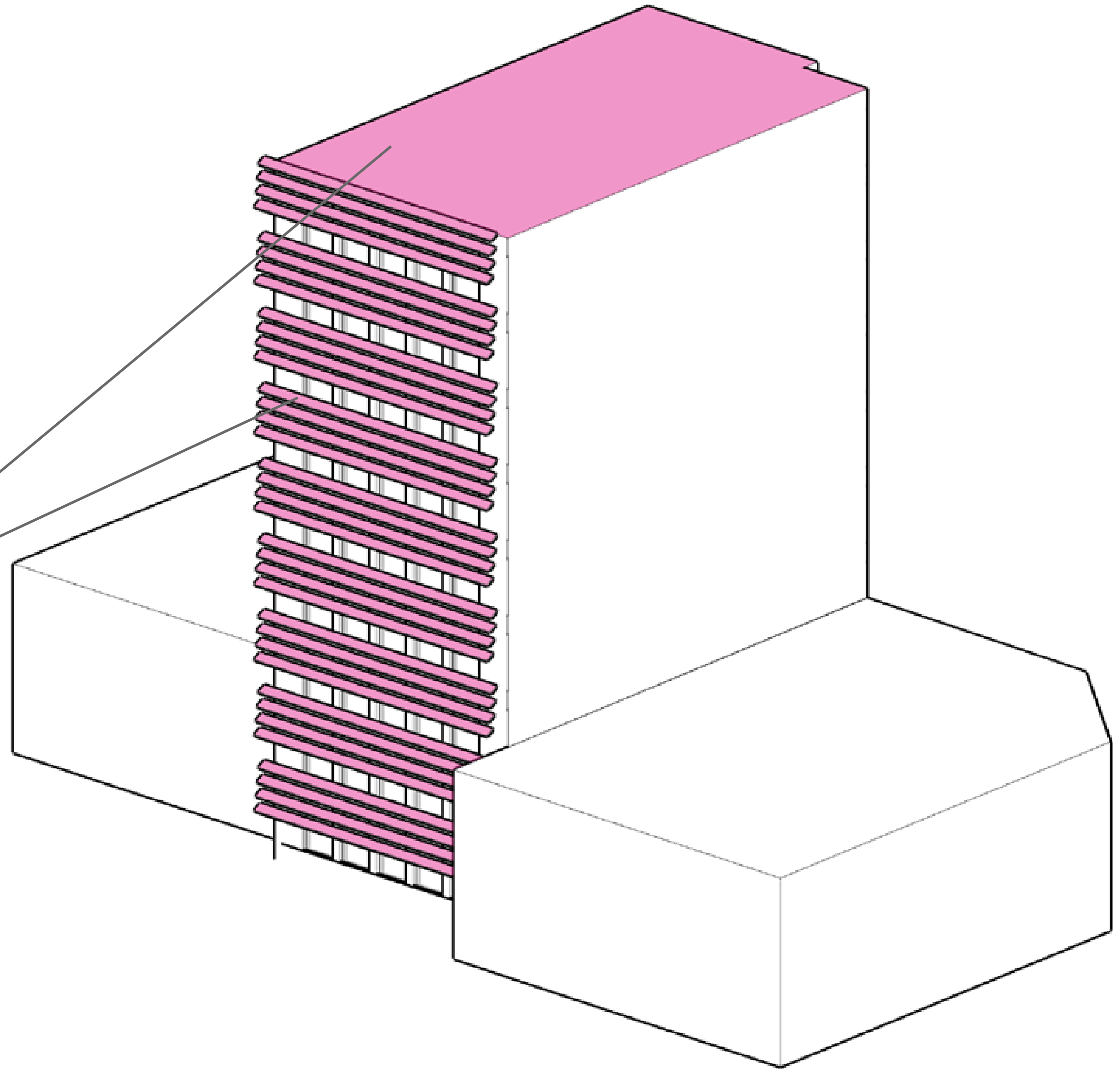
South facade

Azaran Ind. Headquarter
Architecture firm: Chakad Design Office + Reza Sharif Tehrani


INTRODUCTION
Problem statement
Objectives
Research questions
LITERATURE STUDY
Context
TE technology
An office in Tehran
PREDESIGN
PV production
Passive strategies
Results
ACTIVE SYSTEM DESIGN
Q total cooling
Q ventilation
Q internal
Q transmission
Q solar
Q infiltration/vent
Selecting of TE module
No. of modules
Ventilation integration
FACADE DESIGN
TE integration
Ventilation integration
Final facade design
Alternative designs
PERFORMANCE ASSESSMENT
HOT
COLD
A comprehensive model
Optimization
Results
FEASIBILITY
Cost
Performance
Facade integration

PREDESIGN
PV production

27.6 MWh per floor per year



PREDESIGN
Passive design

1. Reducing annual heating and cooling loads
2. Reducing peak loads and design capacity

↓ Peak loads → ↓ Design capacity → ↓

System sizing

Costs

COP required

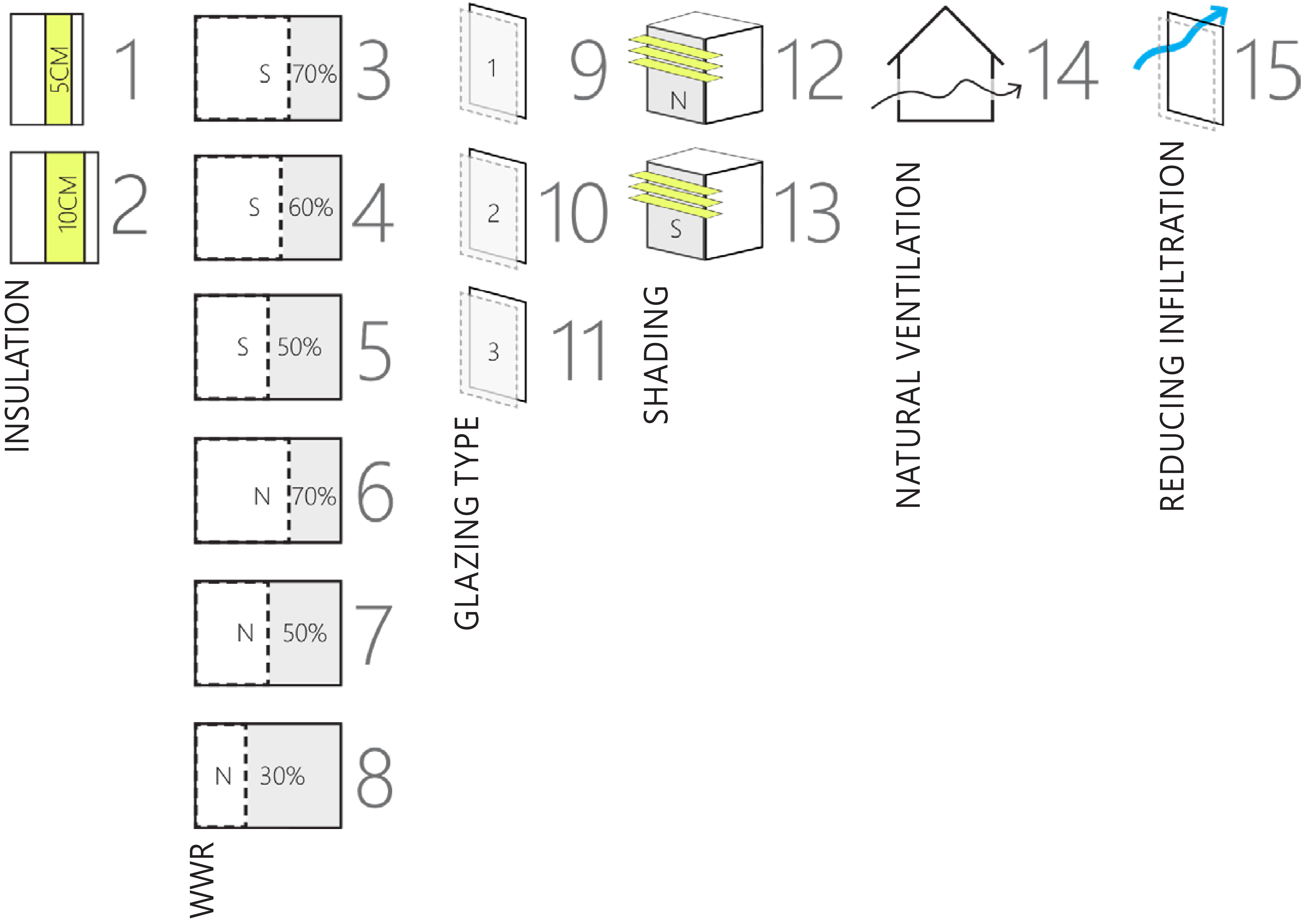
Waste of material

Weight

Space required

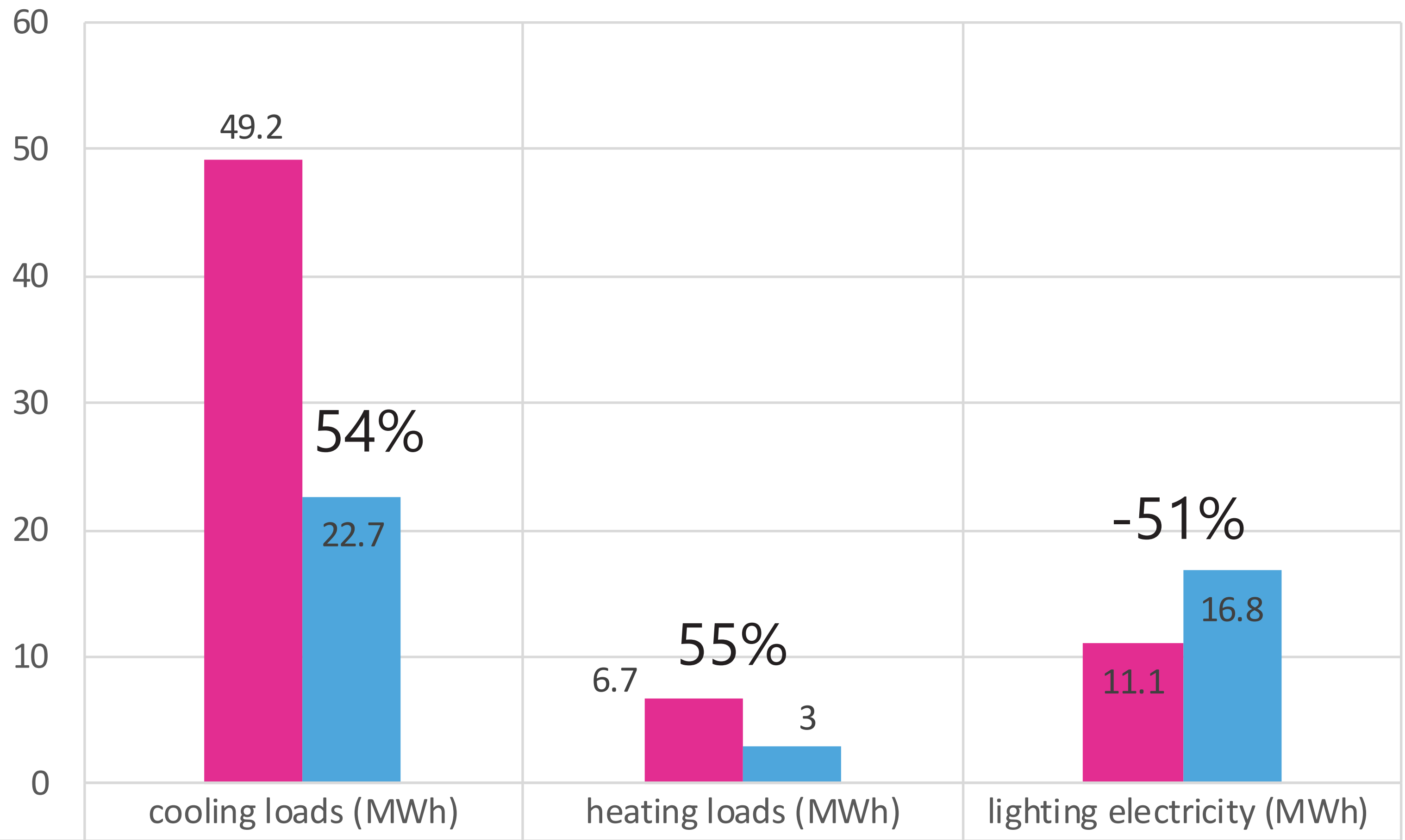
↓ Annual loads → Annual PV production

PASSIVE STRATEGIES
Iterations

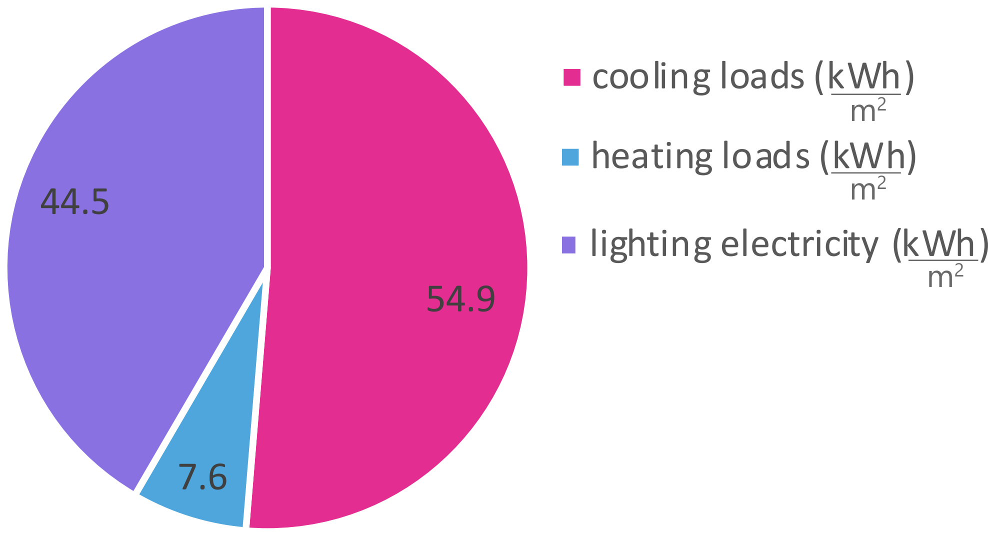


PASSIVE STRATEGIES

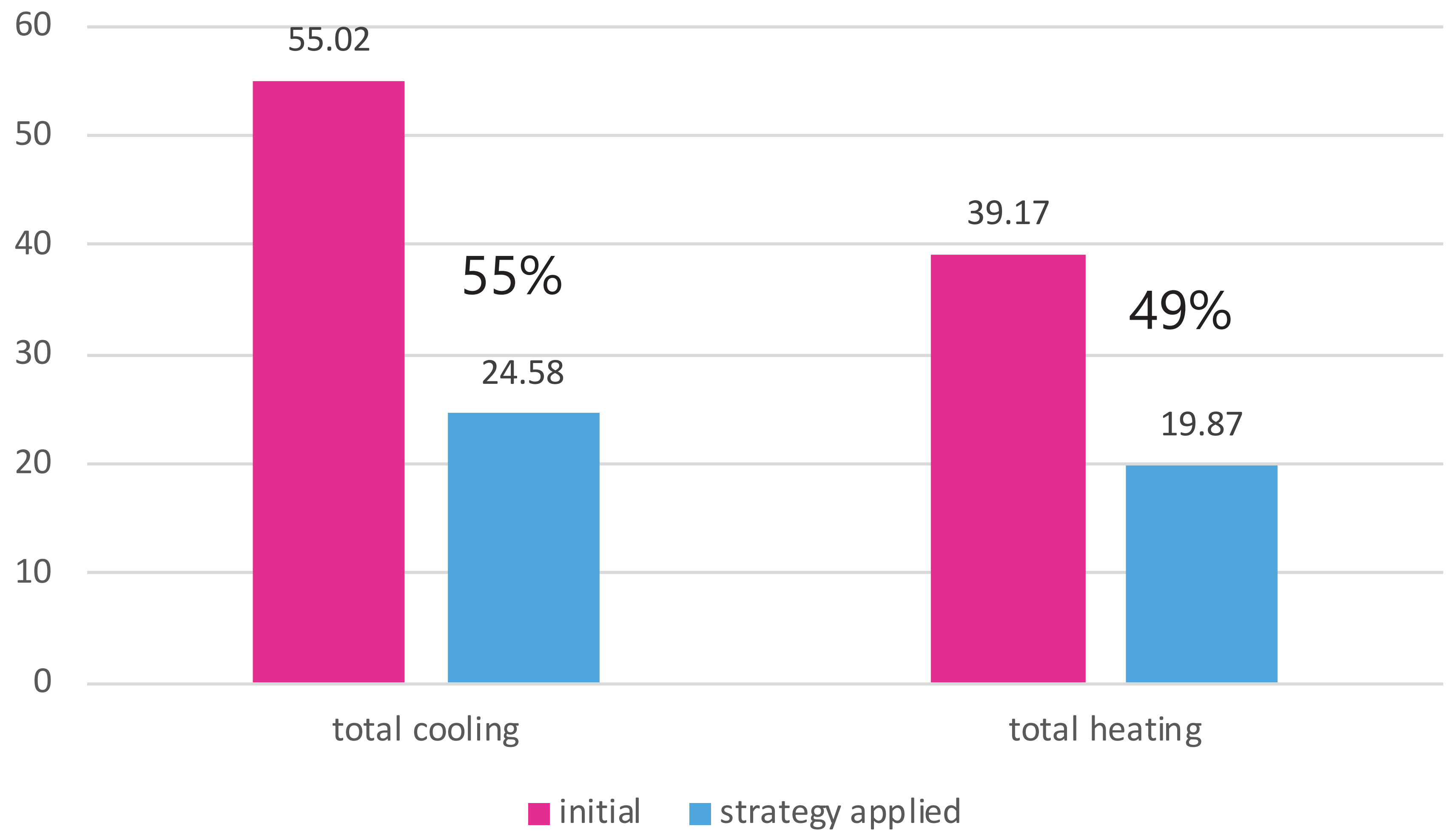
Results-annual demand

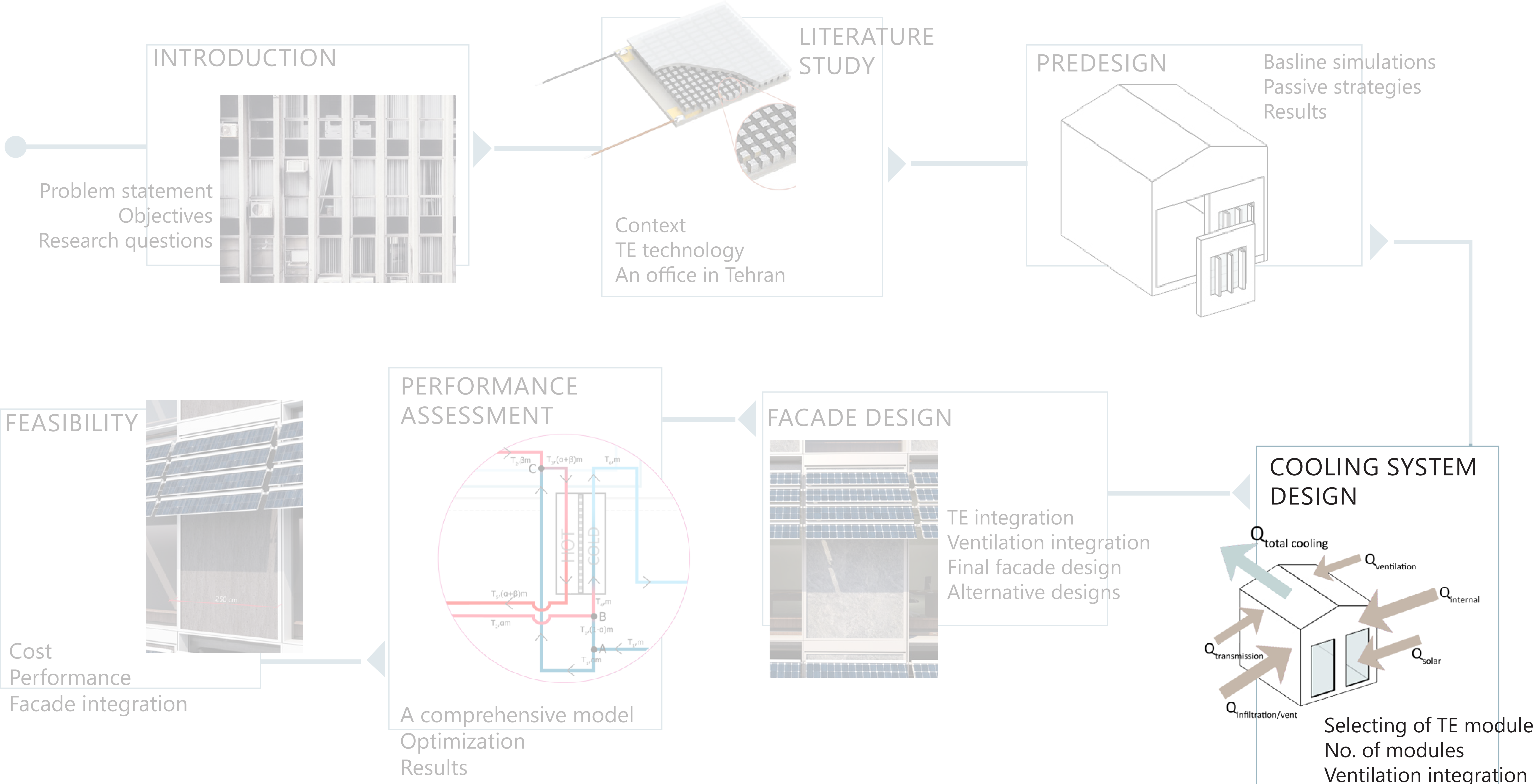


	cooling loads (MWh)	heating loads (MWh)	lighting electricity (MWh)
electricity consumption-baseline	49.2	6.7	11.1
electricity consumption-passive	22.7	3	16.8



PASSIVE STRATEGIES
Results-Design capacity

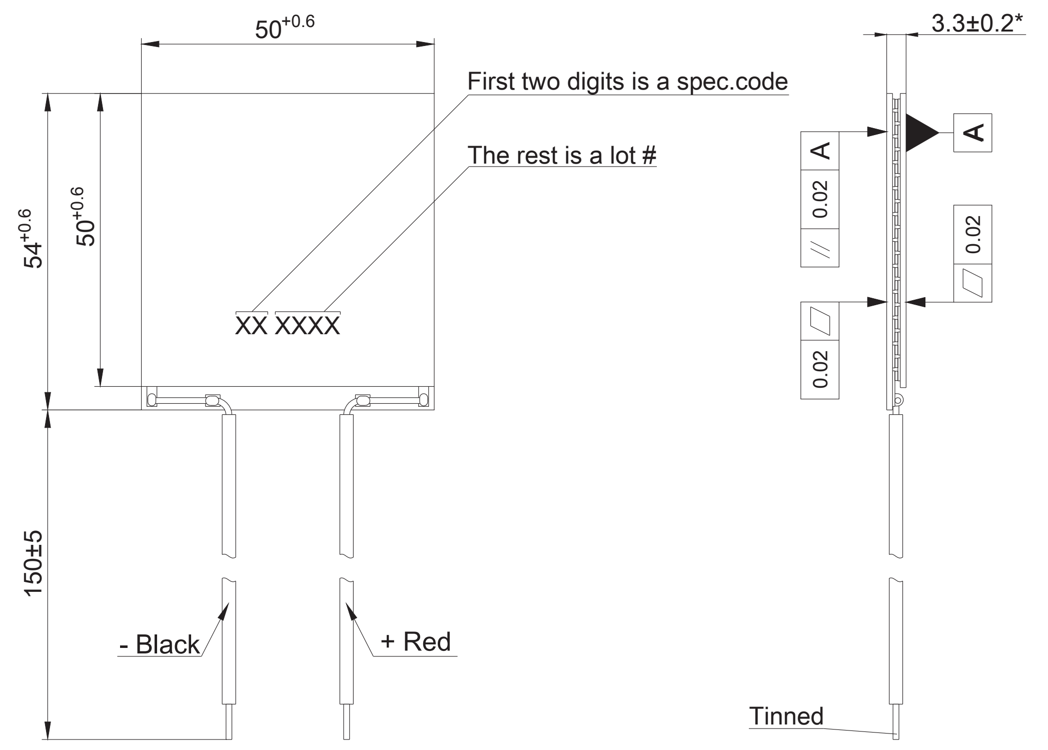



INTRODUCTION
Problem statement
Objectives
Research questions
LITERATURE STUDY
Context
TE technology
An office in Tehran
PREDESIGN
Basline simulations
Passive strategies
Results
COOLING SYSTEM DESIGN
Q total cooling
Q ventilation
Q internal
Q transmission
Q solar
Q infiltration/vent
Selecting of TE module
No. of modules
Ventilation integration
FACADE DESIGN
TE integration
Ventilation integration
Final facade design
Alternative designs
PERFORMANCE ASSESSMENT
HOT
COLD
C
B
A
A comprehensive model
Optimization
Results
FEASIBILITY
Cost
Performance
Facade integration

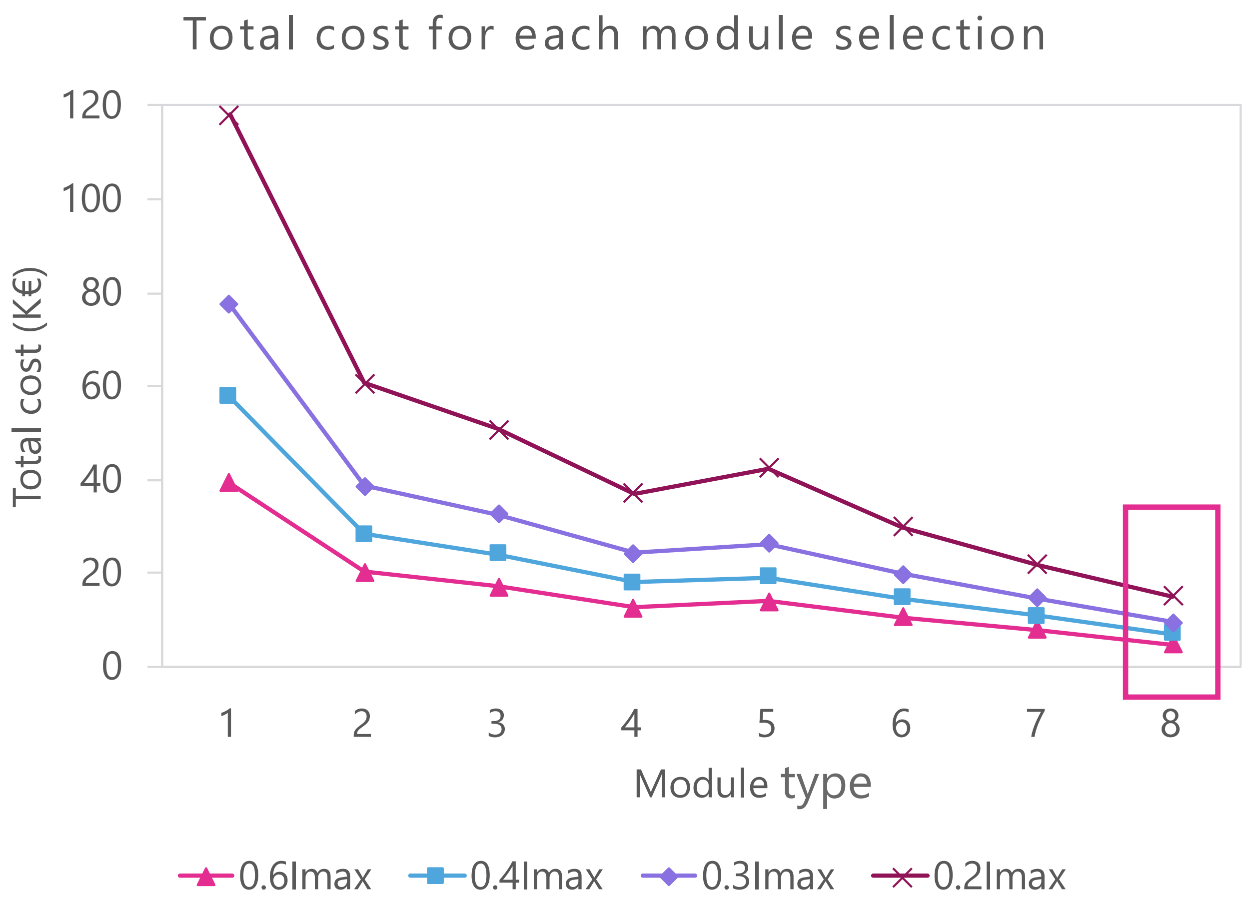
ACTIVE COOLING DESIGN
TE element selection

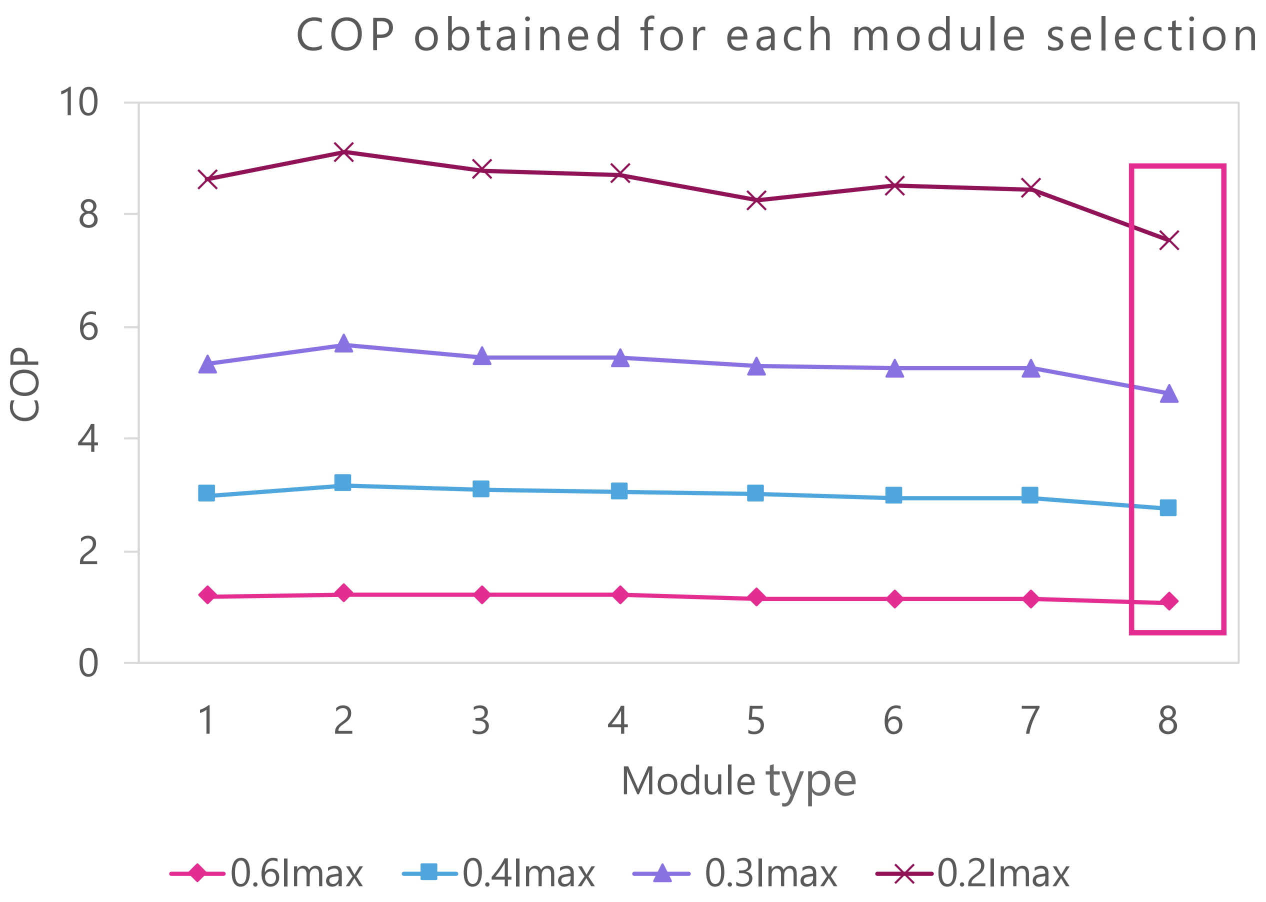
Comparison between 8 module types
Favorable properties:

Lower cost
Higher COP

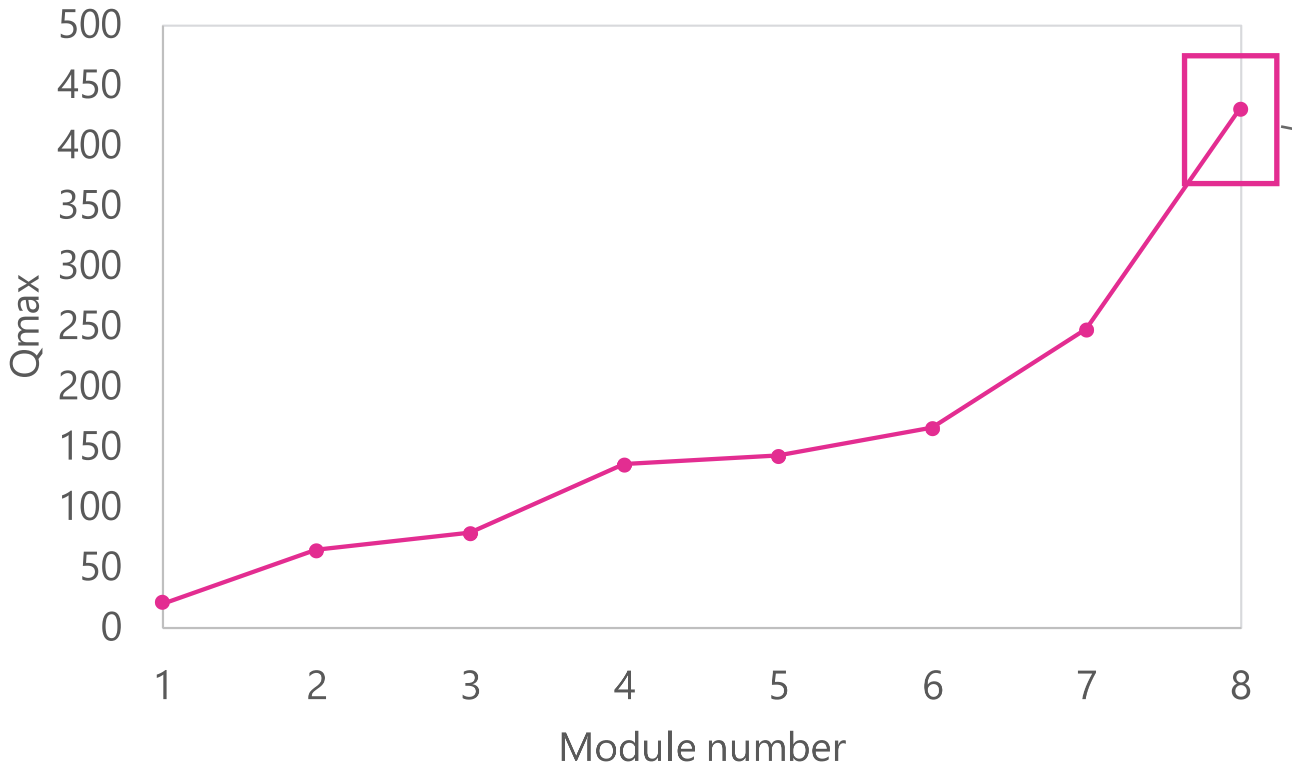


ACTIVE COOLING DESIGN
TE element selection





ACTIVE COOLING DESIGN
TE element selection

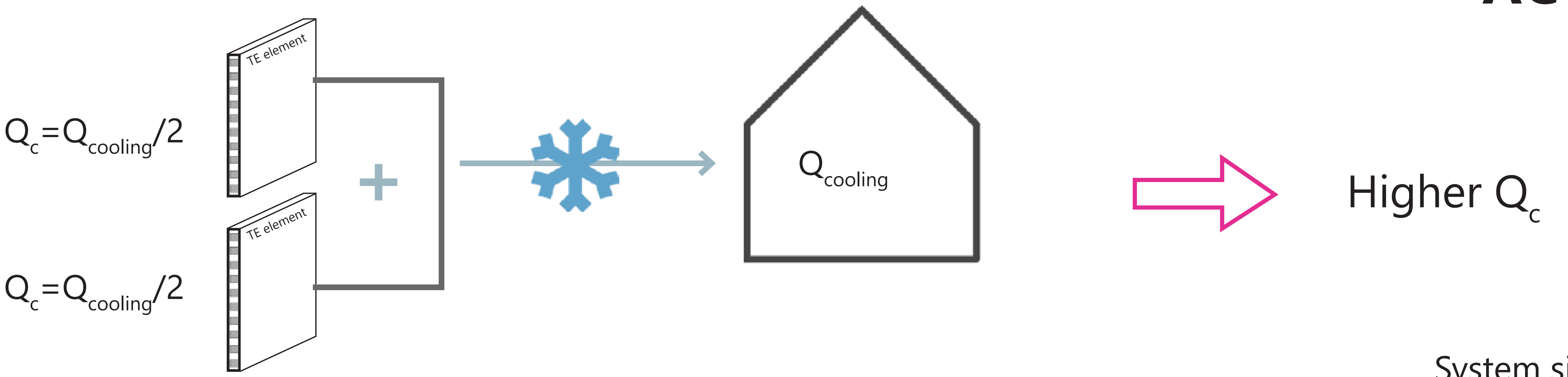


The module with highest cooling capacity

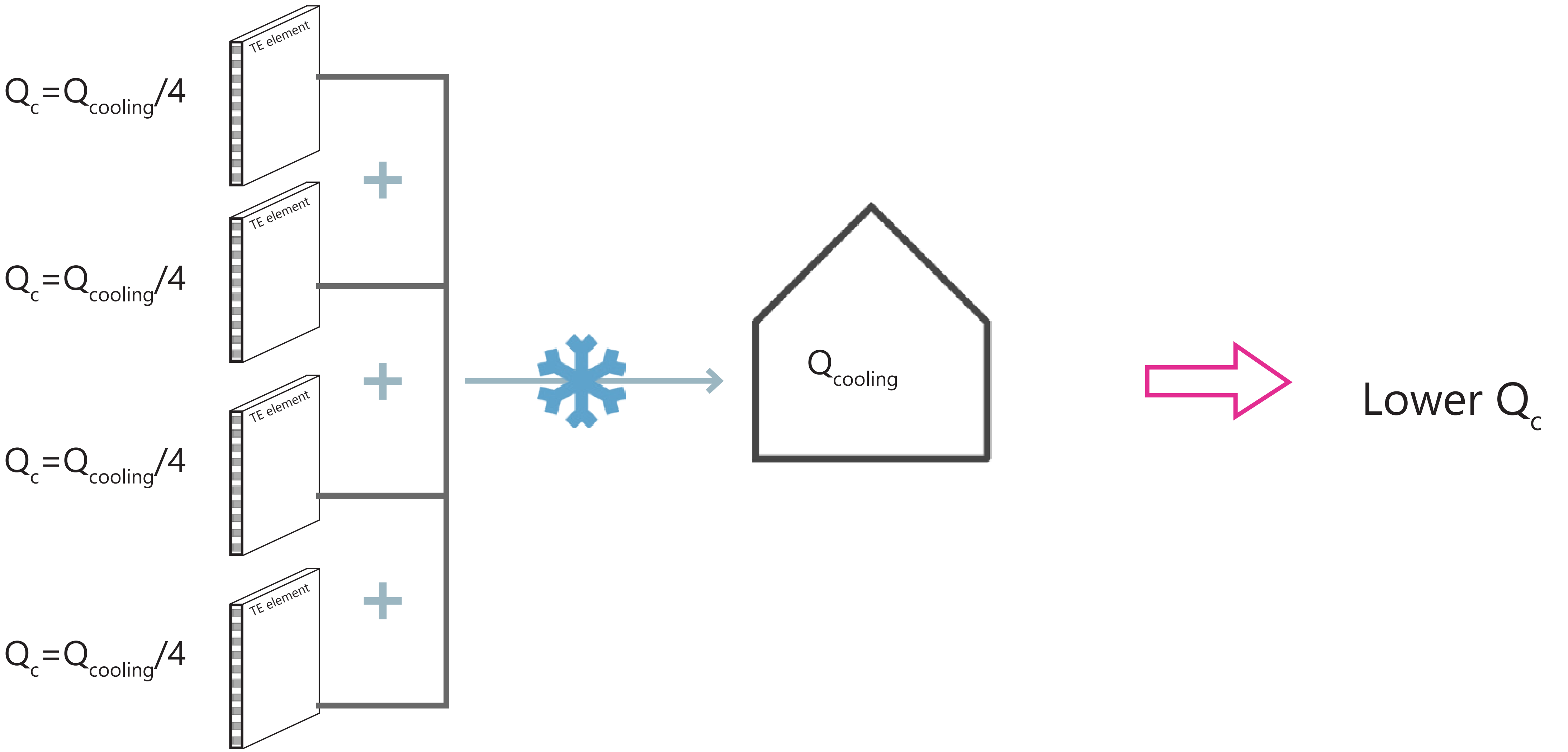
I_{max} (amps)	28
V_{max} (volts)	27.7
ΔT_{max} (°C)	66
Q_{max} (W)	430
AC resistance (ohms)	0.87
Number of couples	241
Dimensions (mm)	50*50*3.3

ACTIVE COOLING DESIGN

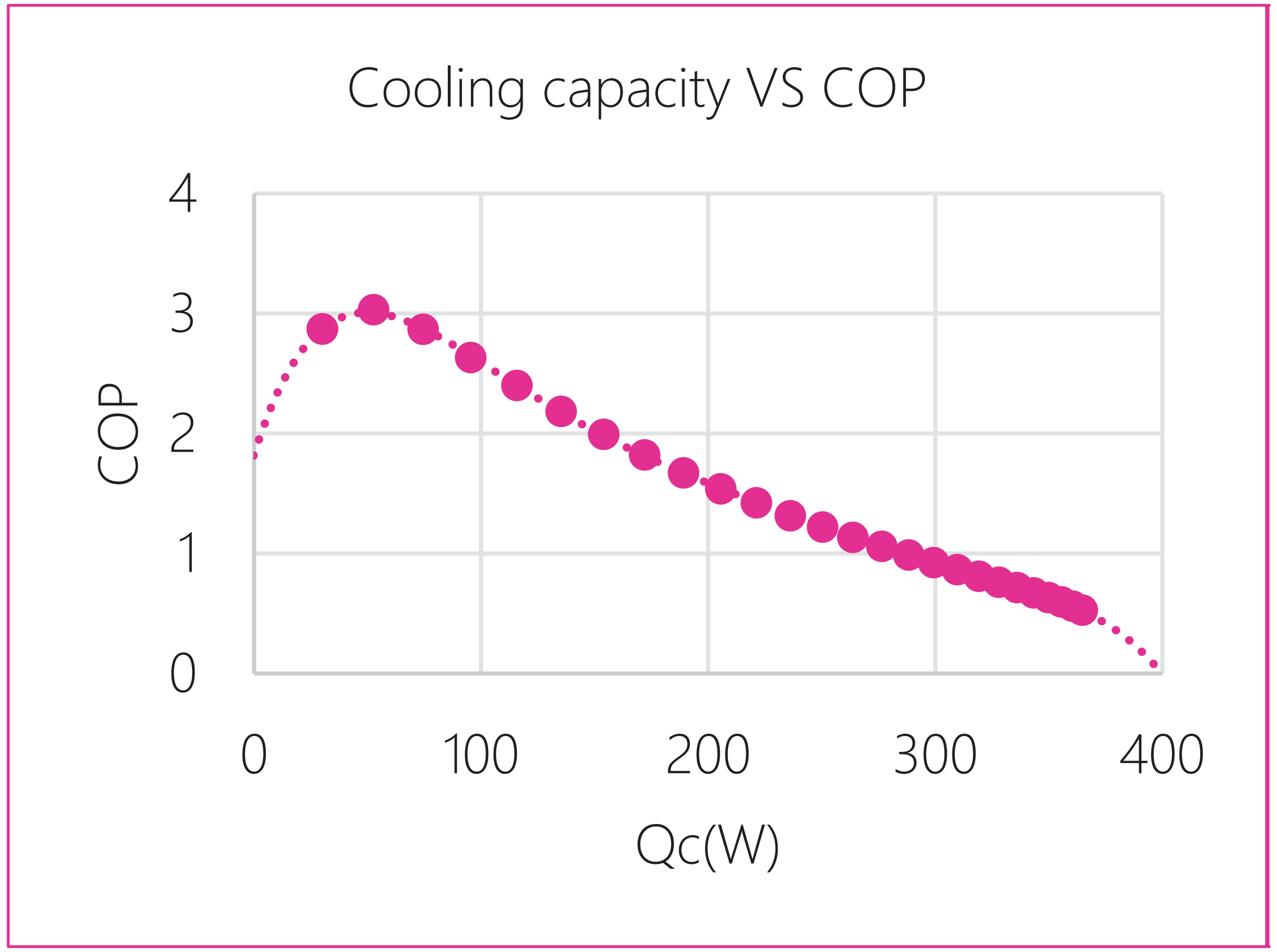
No. of TE modules



System sizing based on Peak of demand in summer



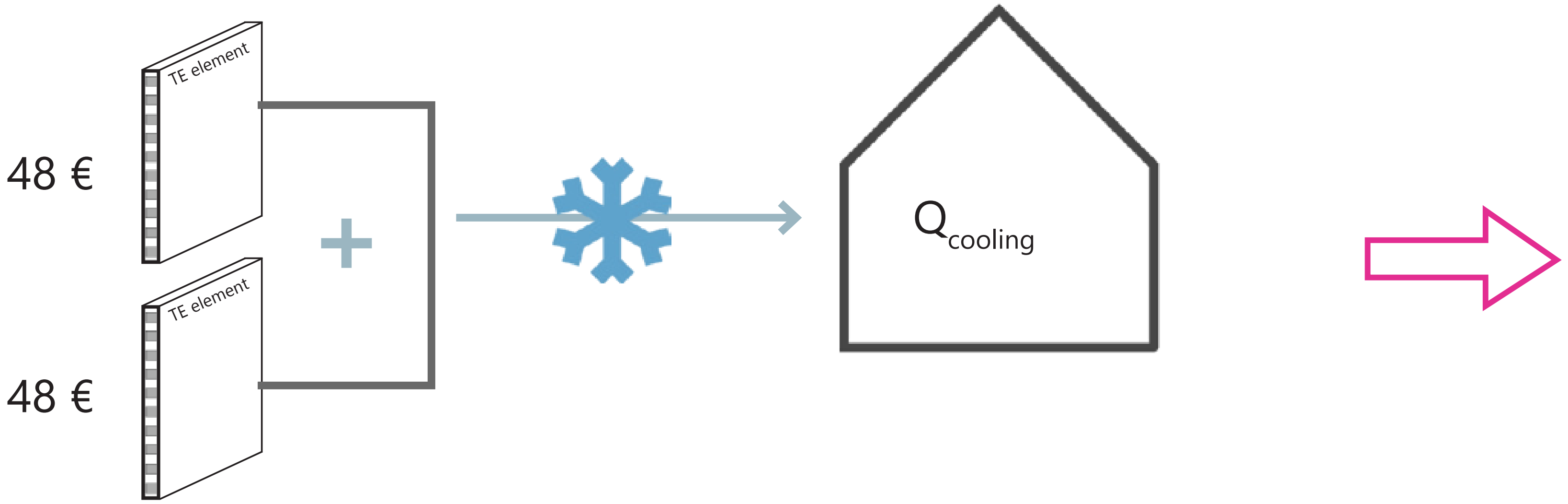
ACTIVE COOLING DESIGN
No. of TE modules



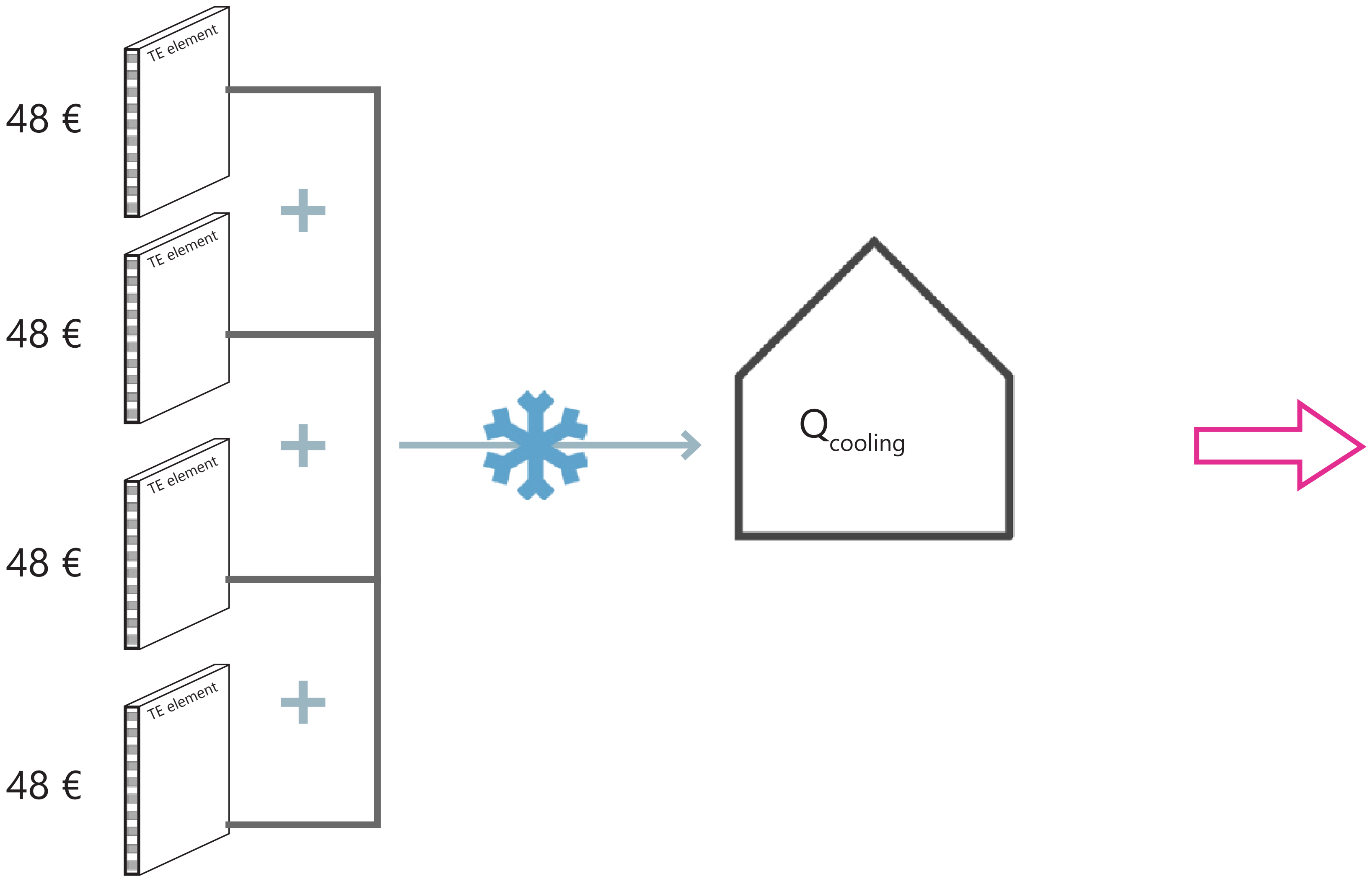
Why is it important?
Lower Q_c leads to higher COP

Higher COP → Less electricity is required for the same work

ACTIVE COOLING DESIGN
No. of TE modules



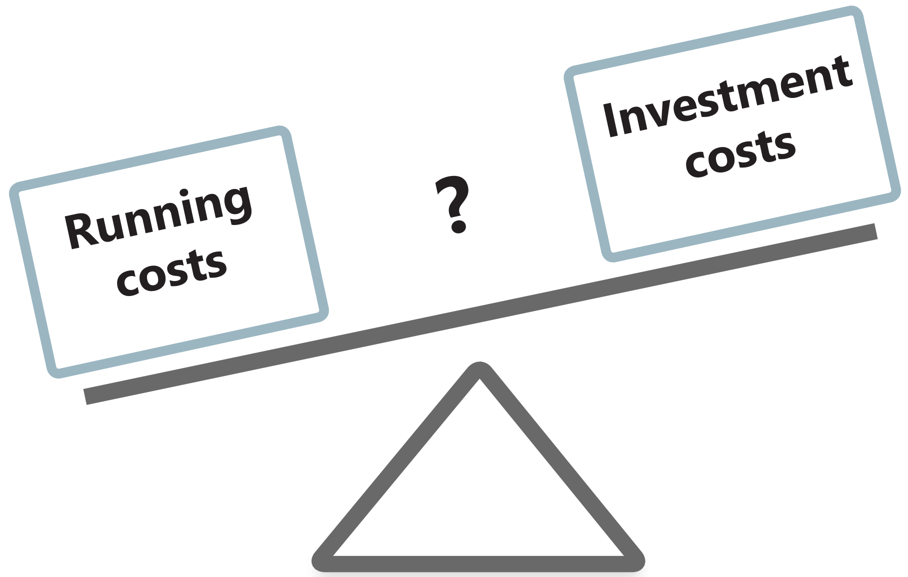
More electricity consumption BUT
less expensive



Less electricity consumption BUT
more expensive

ACTIVE COOLING DESIGN
No. of TE modules

More modules ⇒ Higher investment costs ⇒ Lower electricity costs

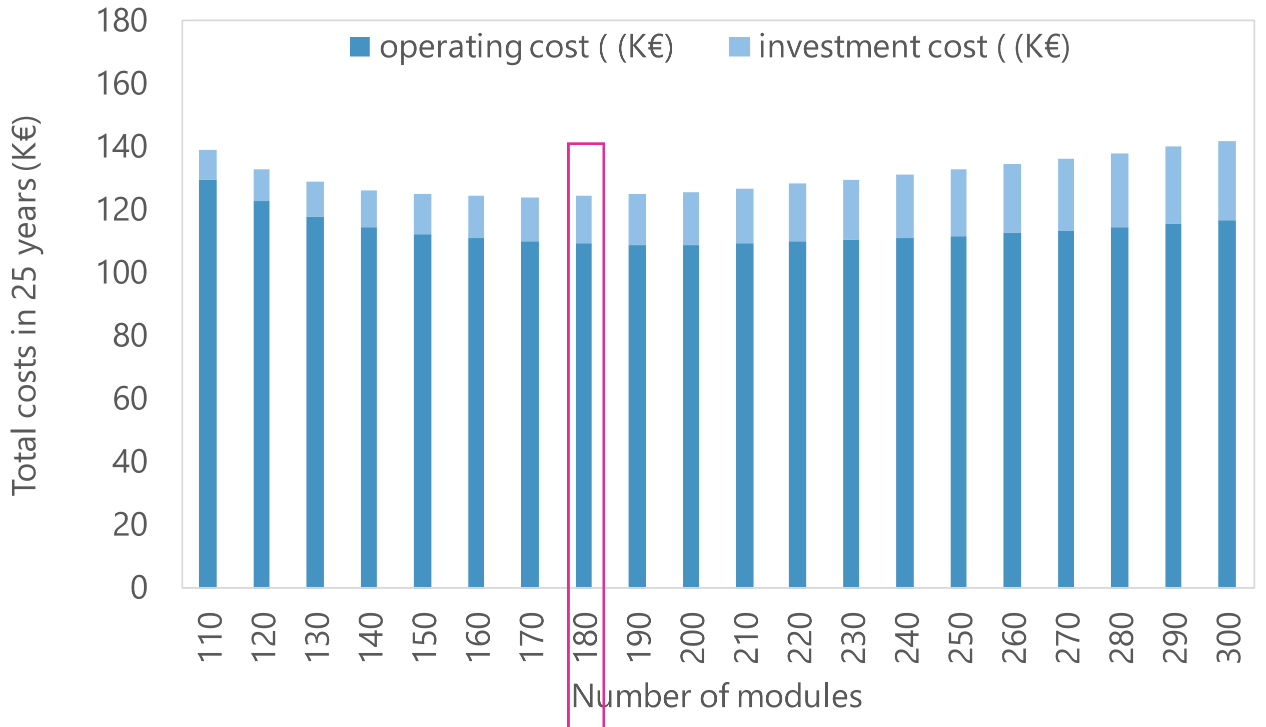


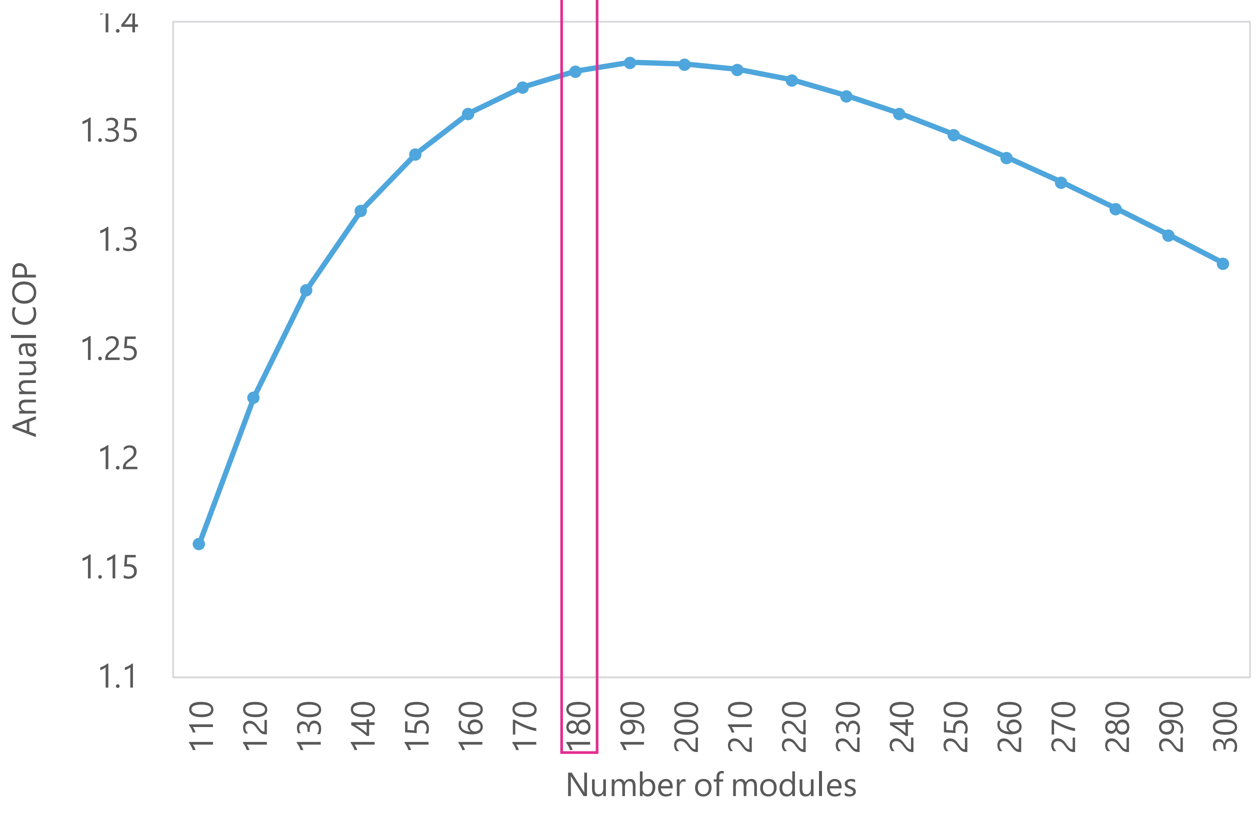
ACTIVE COOLING DESIGN
No. of TE modules

Investment costs	+	Operating costs	=	Total cost
Cost of modules Cost of heat sinks × 2 (1 on each side of the modules)		Cost of electricity in 25 years		Operating and investment costs in 25 years

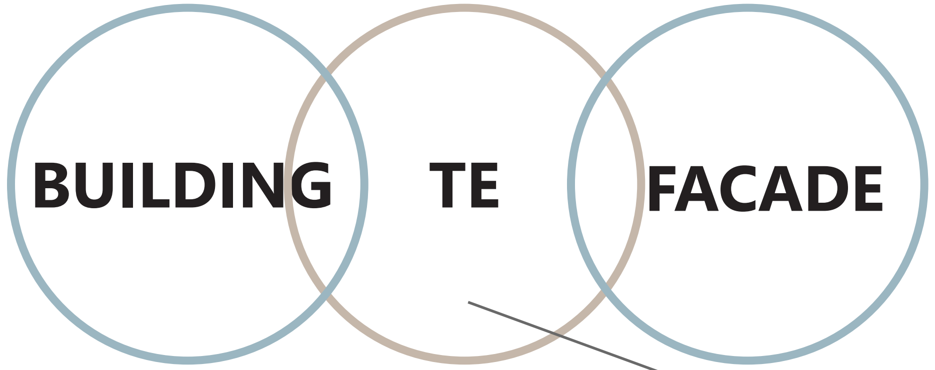
ACTIVE COOLING DESIGN
No. of TE modules

180 modules



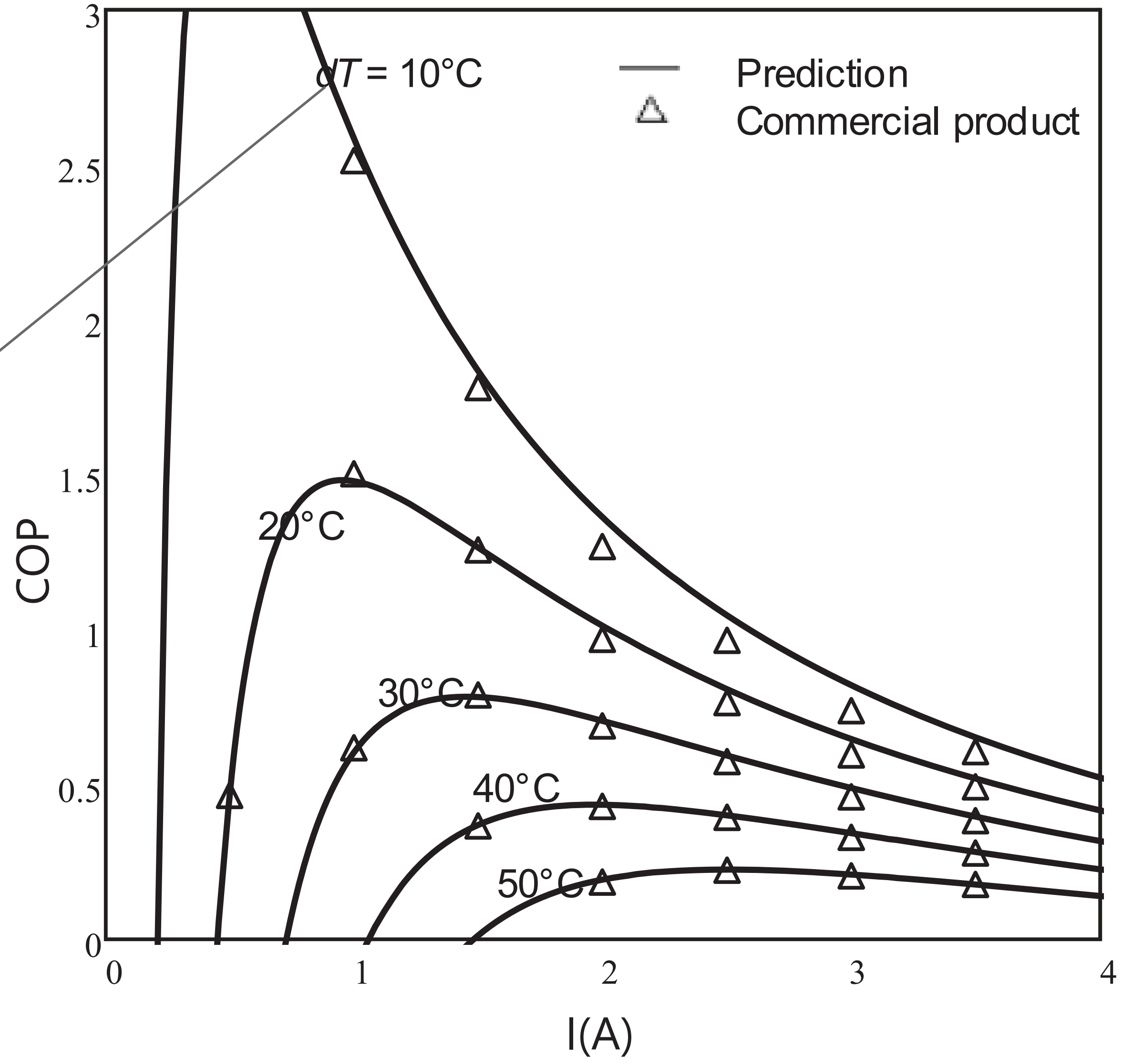


REDUCING ΔT
HOW?



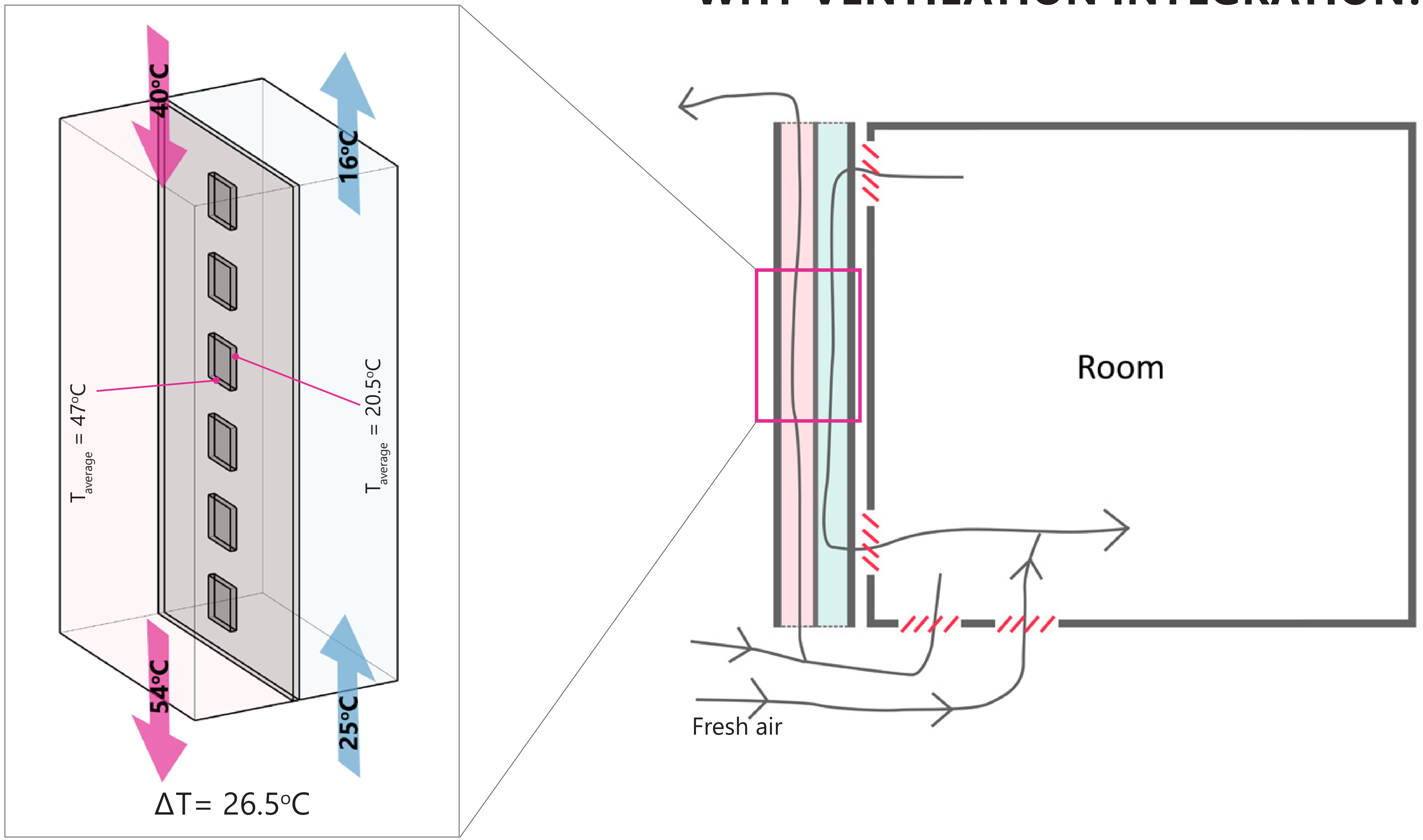
Reducing temperature difference is crucial to obtain higher COP

Integrating TE system in facade and ventilation of the building



REDUCING ΔT
WHY VENTILATION INTEGRATION?

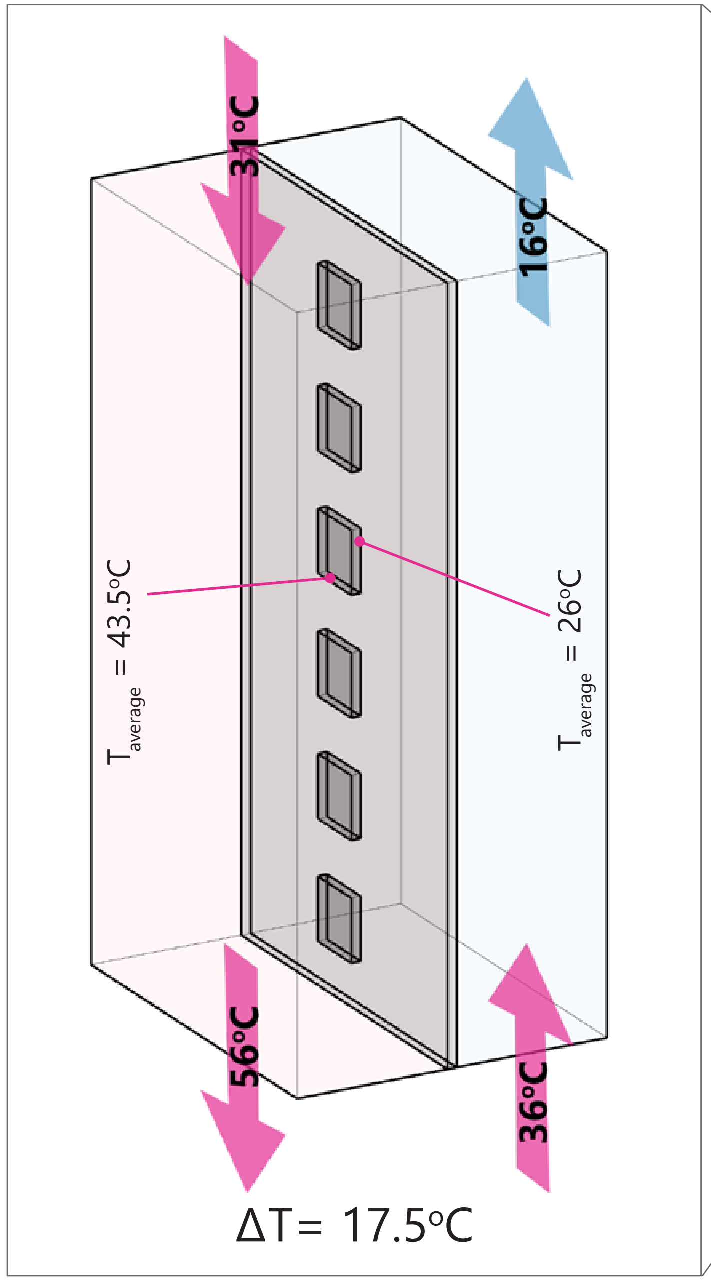
Not ventilation integrated

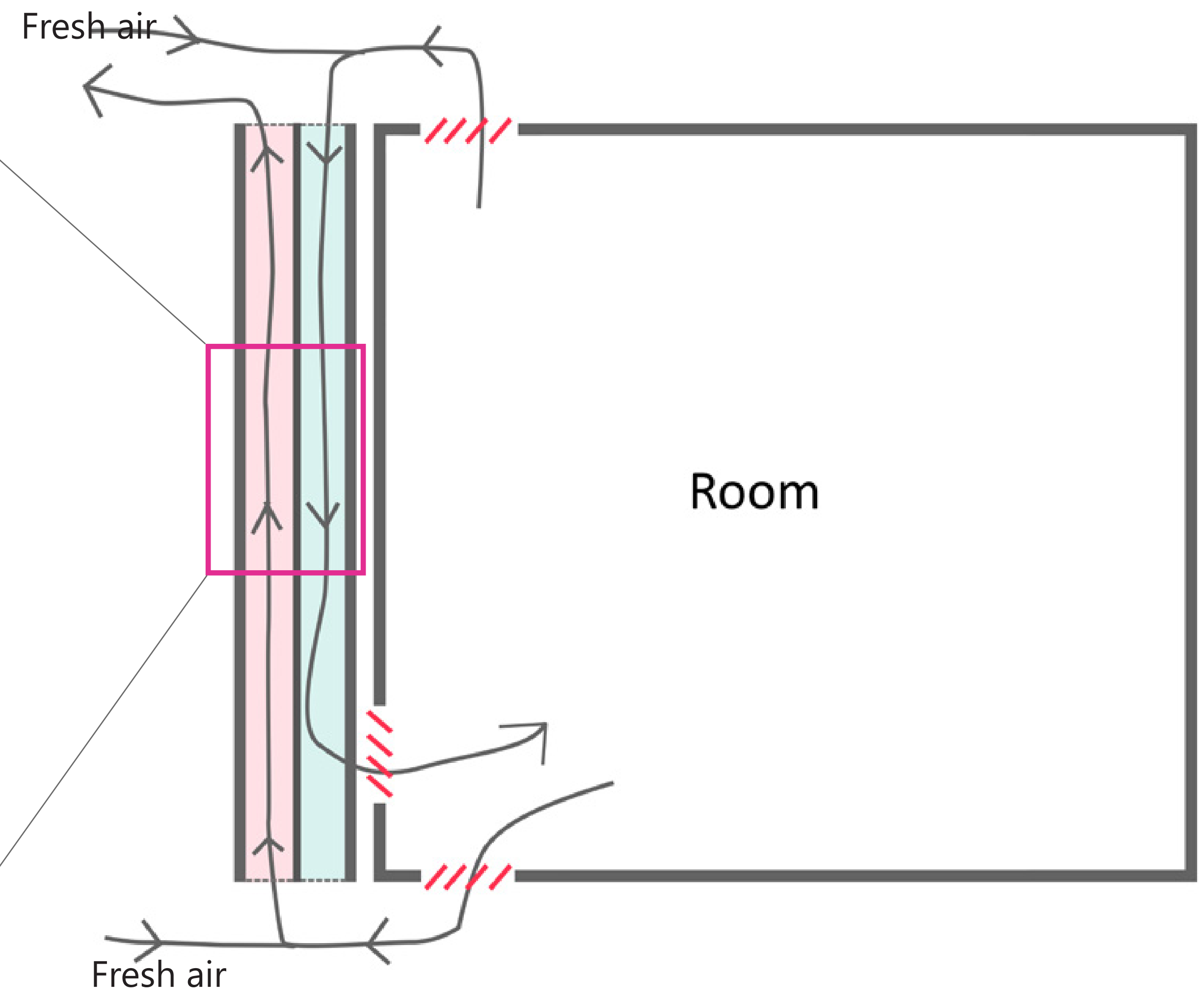


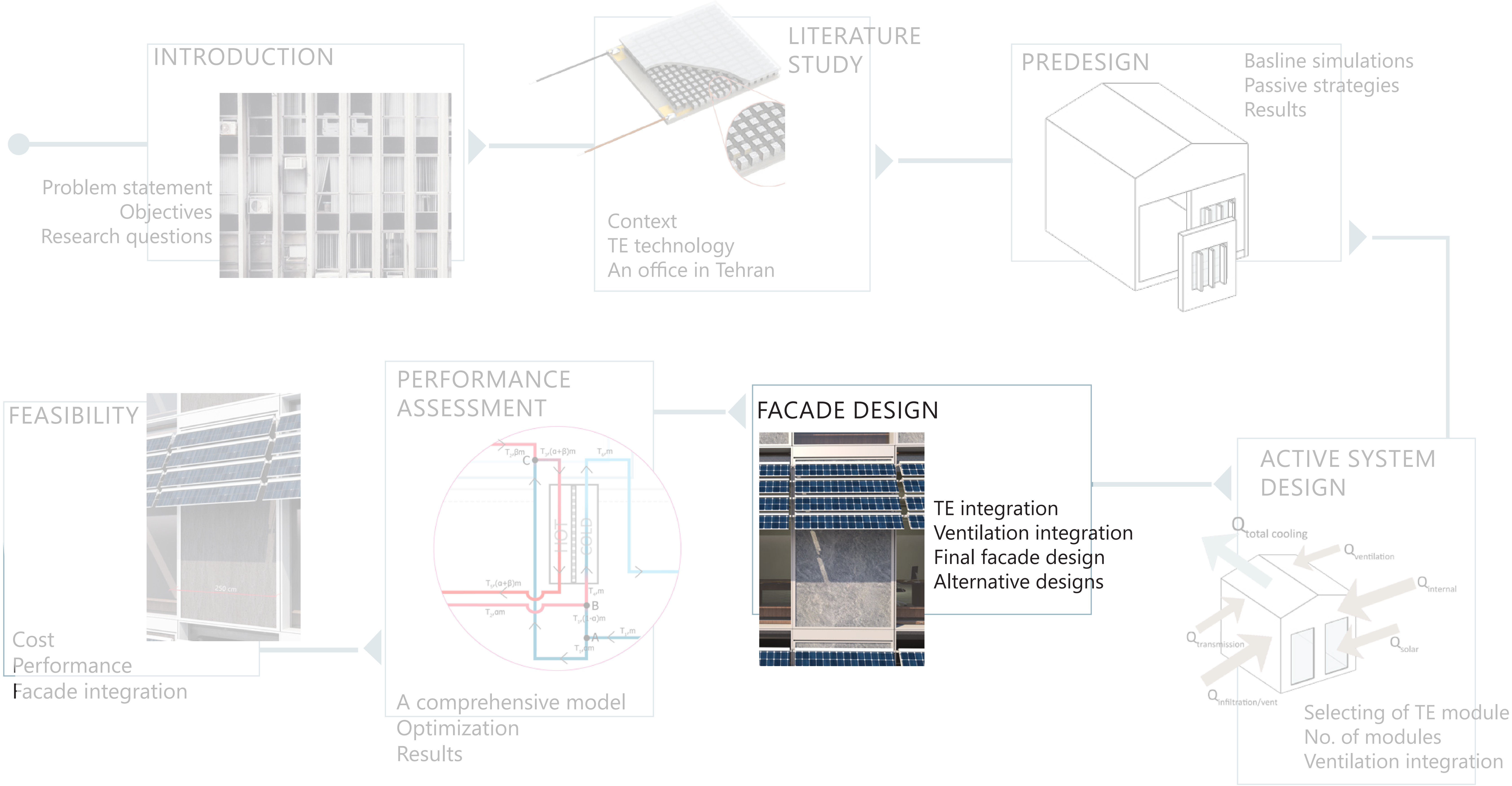
REDUCING ΔT

WHY VENTILATION INTEGRATION?

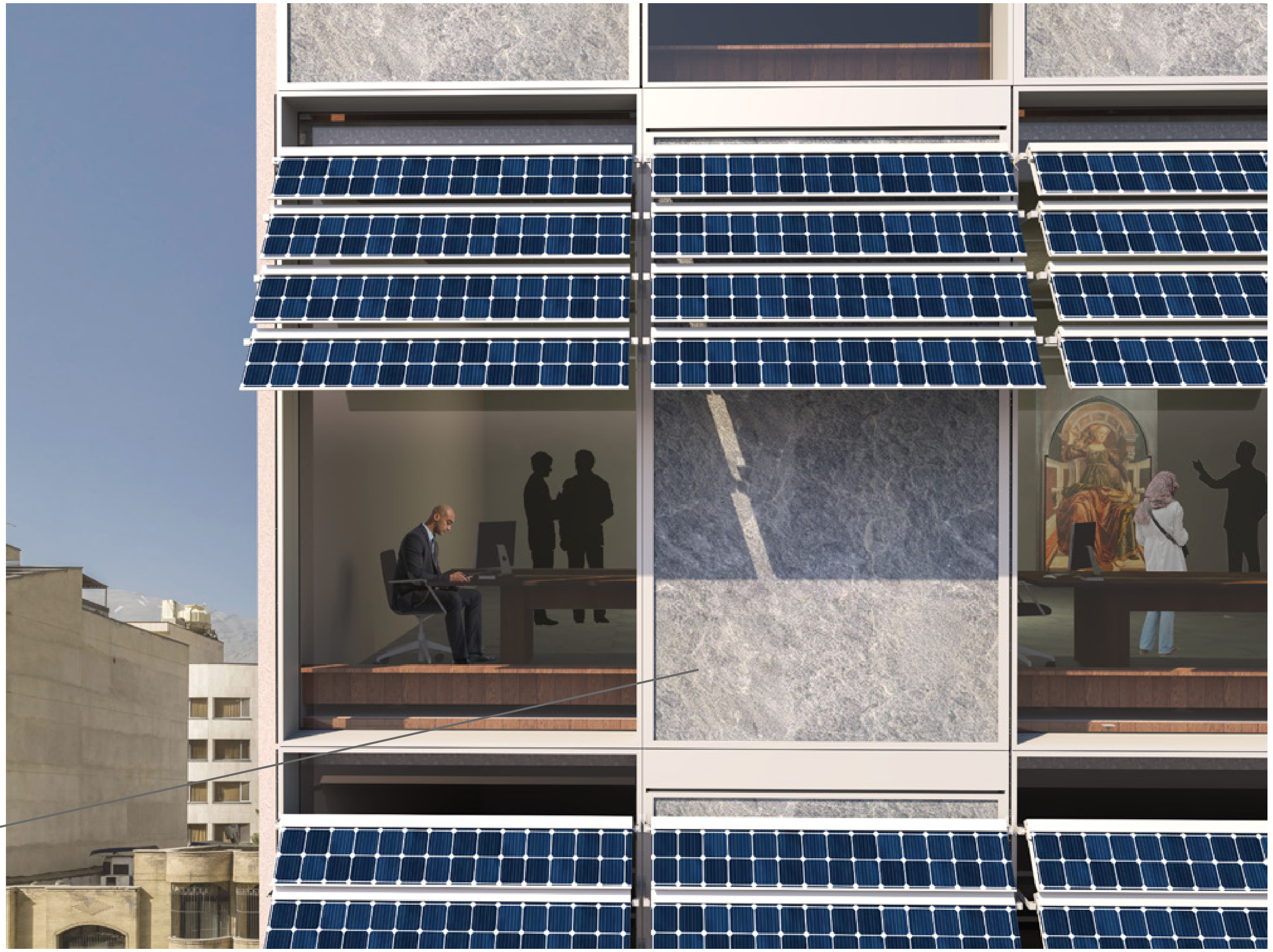
Ventilation integrated



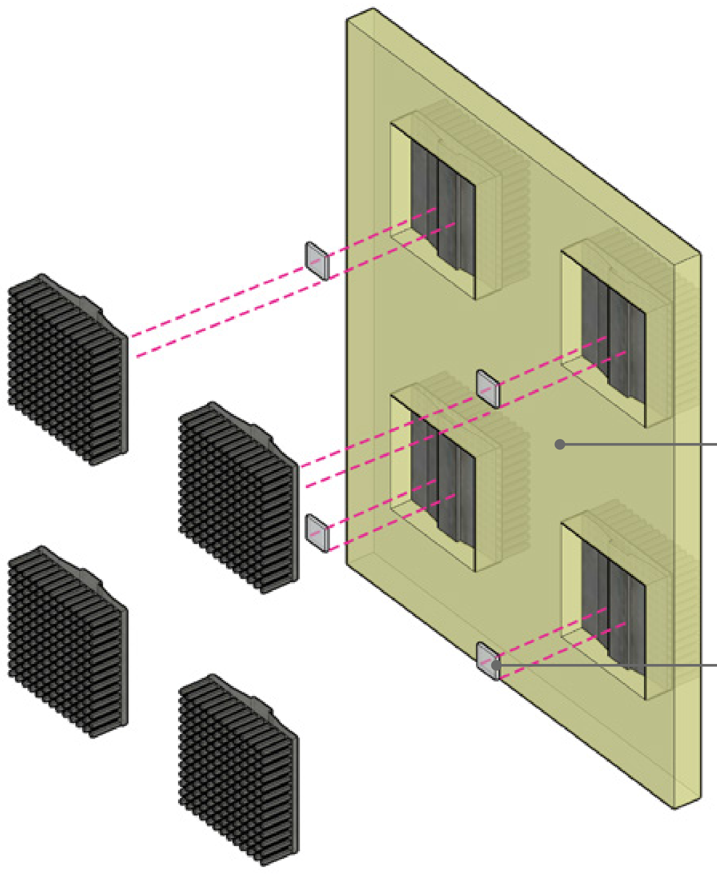



INTRODUCTION
Problem statement
Objectives
Research questions
LITERATURE STUDY
Context
TE technology
An office in Tehran
PREDESIGN
Basline simulations
Passive strategies
Results
ACTIVE SYSTEM DESIGN
Qtotal cooling
Qventilation
Qinternal
Qtransmission
Qsolar
Qinfiltration/vent
Selecting of TE module
No. of modules
Ventilation integration
FACADE DESIGN
TE integration
Ventilation integration
Final facade design
Alternative designs
PERFORMANCE ASSESSMENT
HOT
COLD
C
B
A
A comprehensive model
Optimization
Results
FEASIBILITY
250 cm
Cost
Performance
Facade integration

FACADE DESIGN



FACADE DESIGN
TE and heat sink integration



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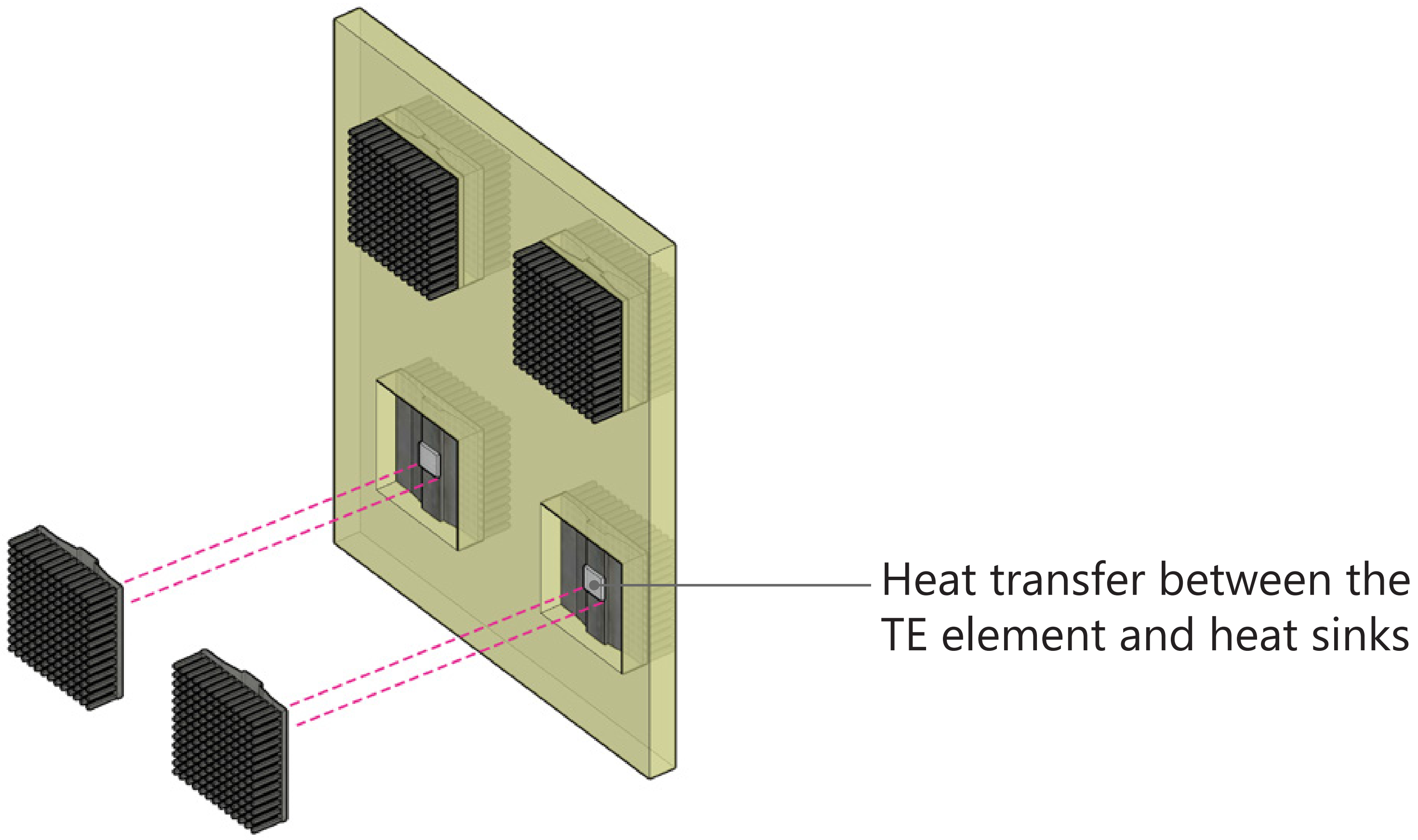

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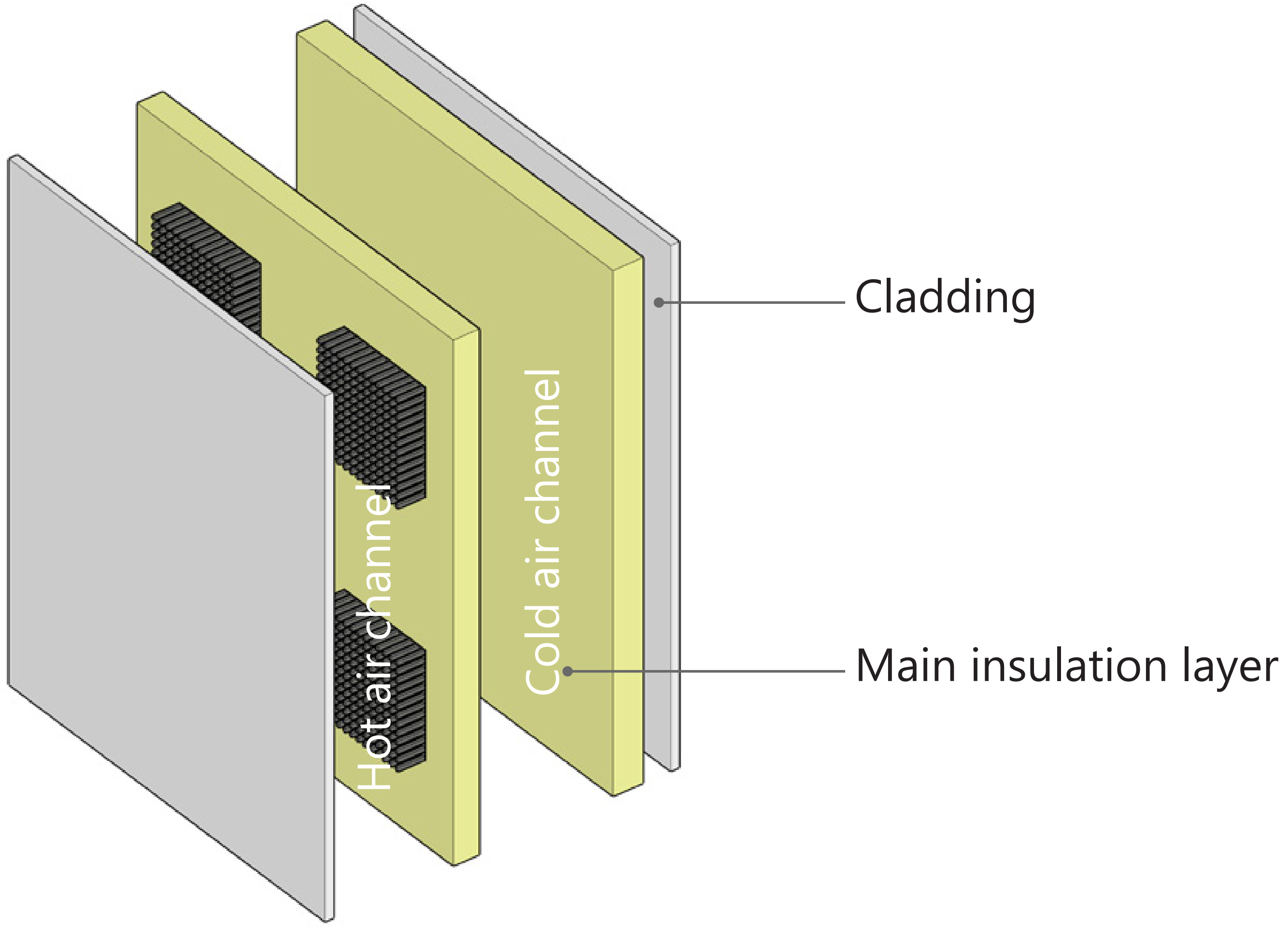
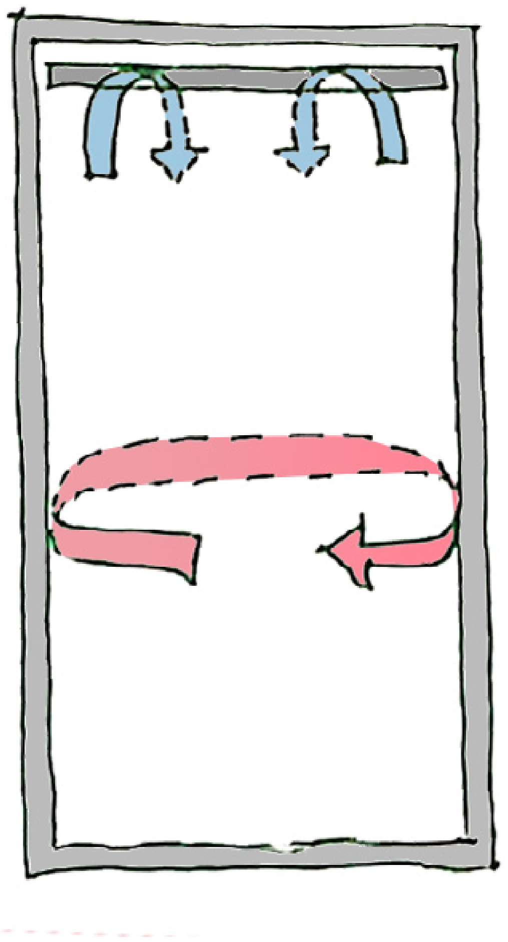
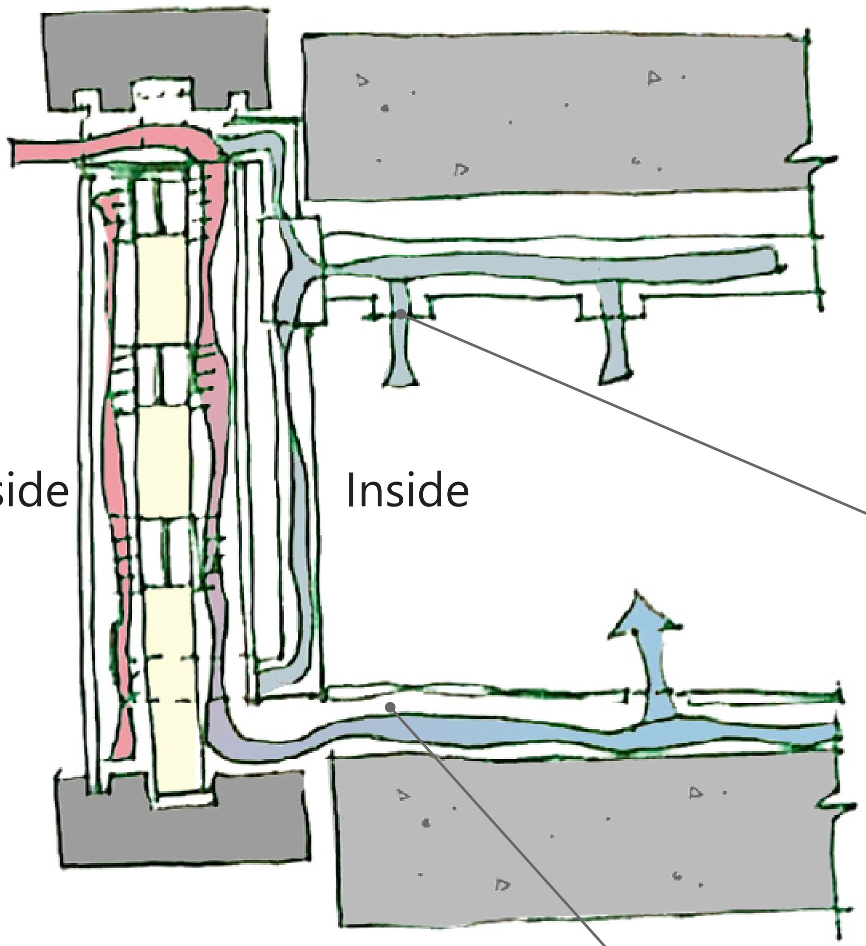


FACADE DESIGN
Ventilation integration

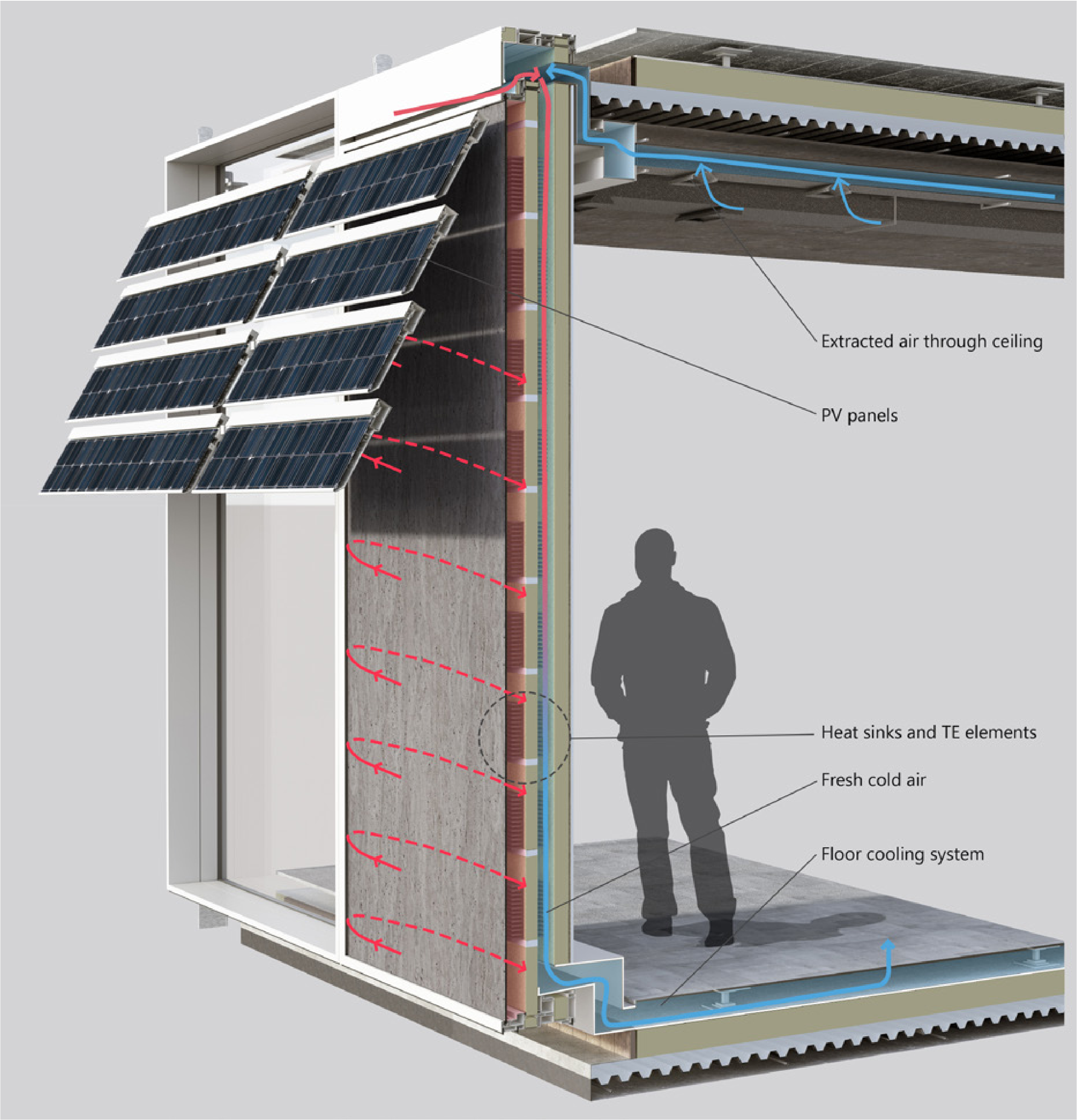
Air circulation in summer





FACADE DESIGN
Cooling operation

Realization in final facade design



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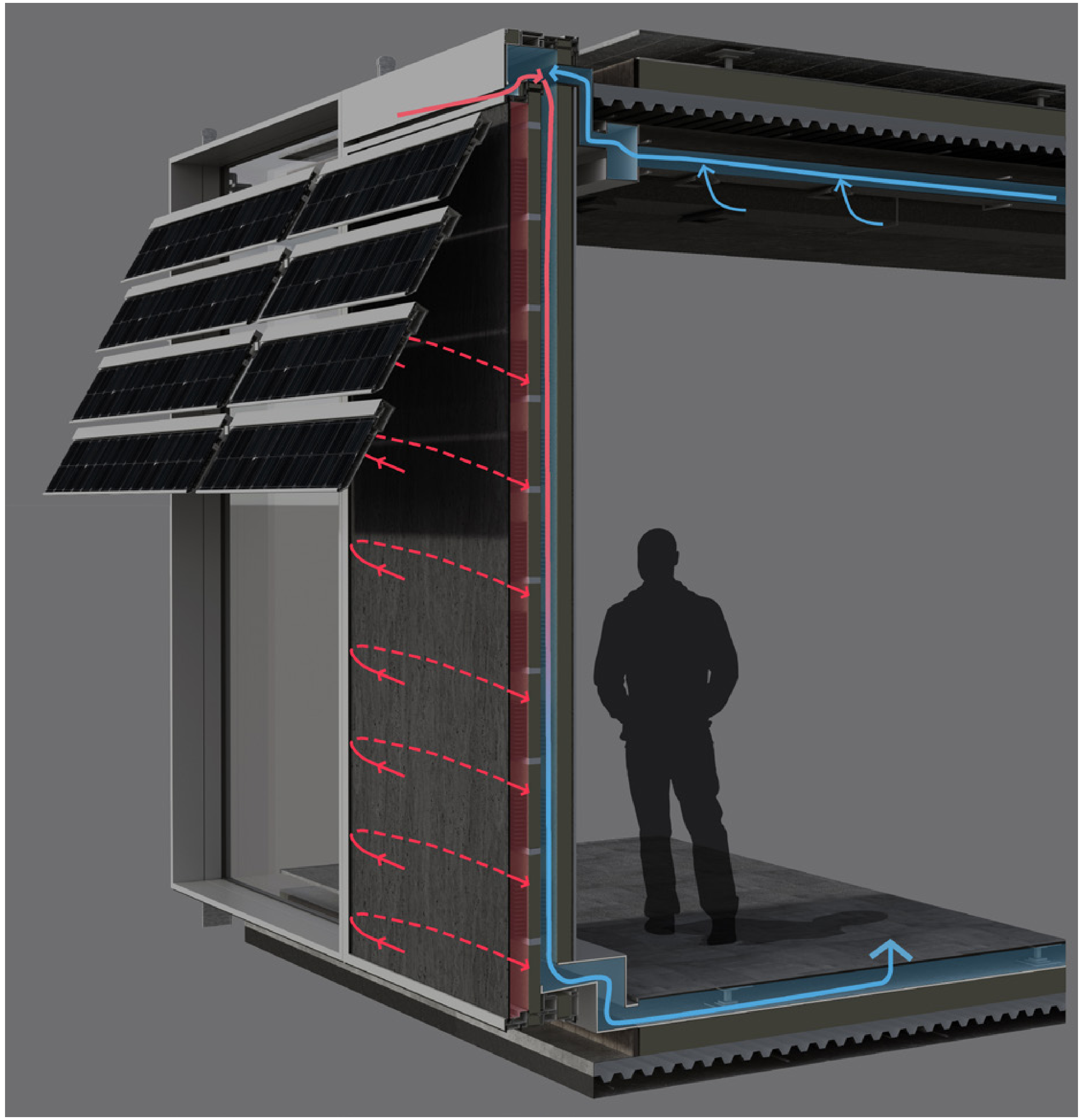
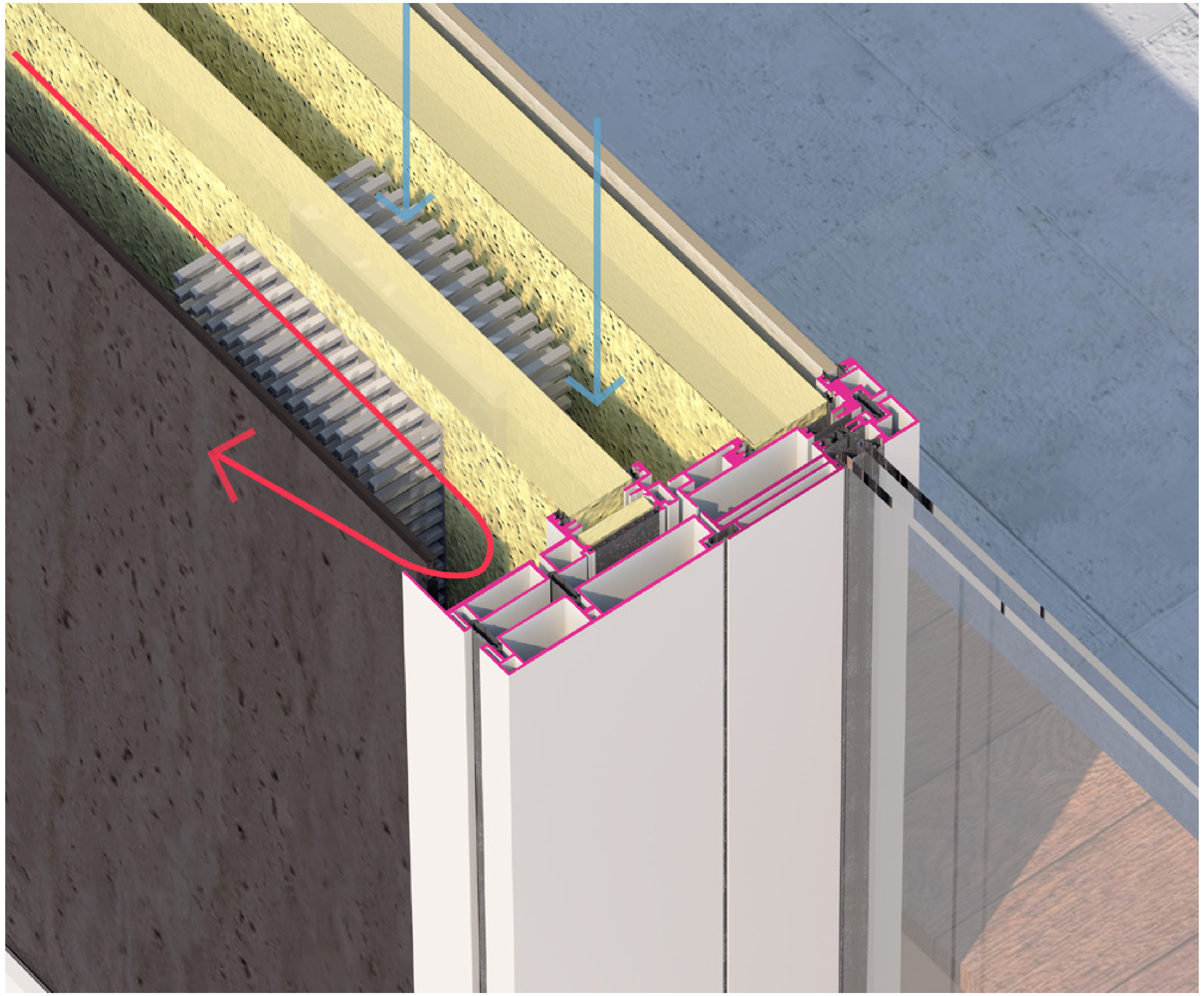
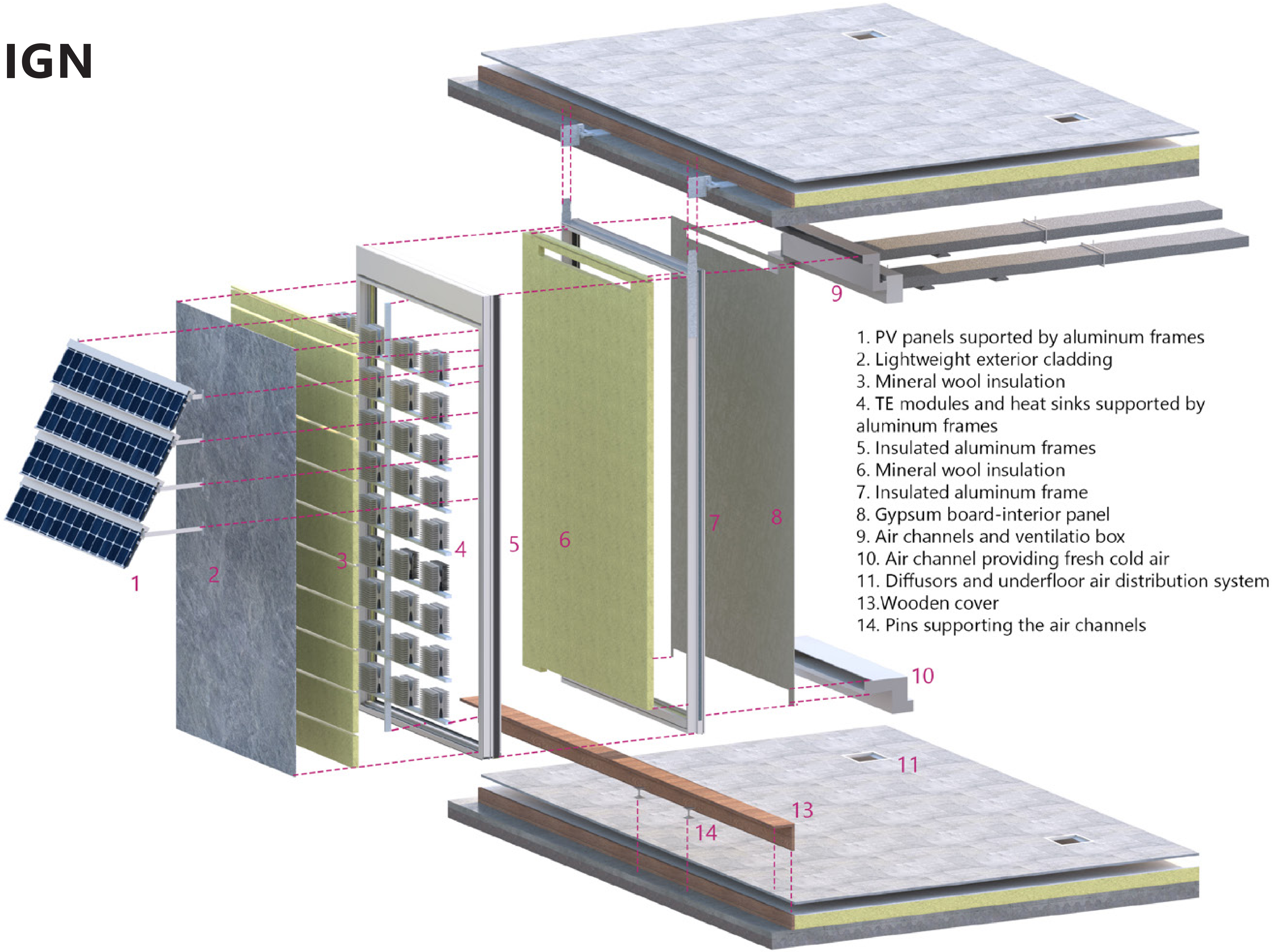


FACADE DESIGN
Detailing

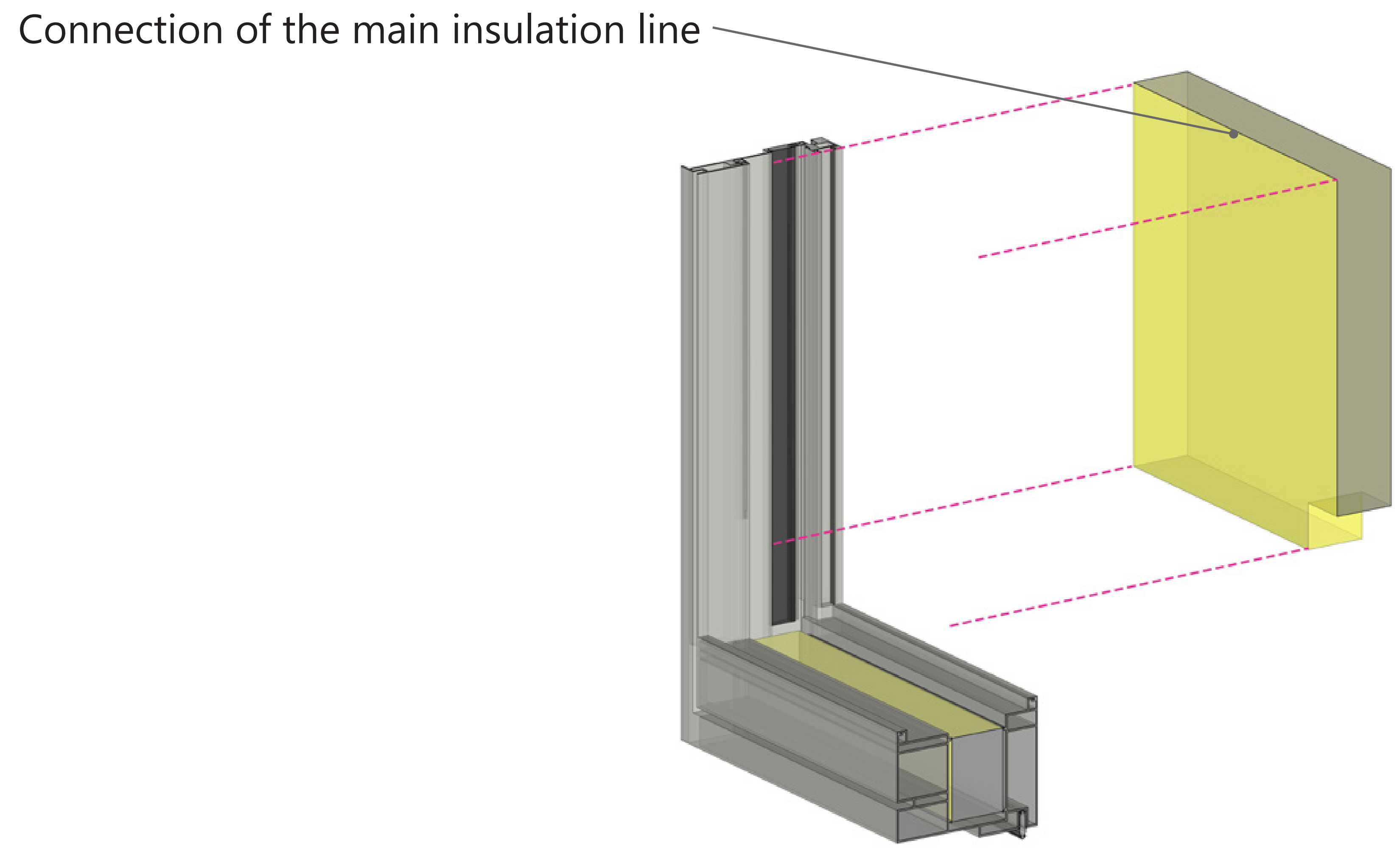
Section-Horizontal connection of a TE facade with a glazing unit



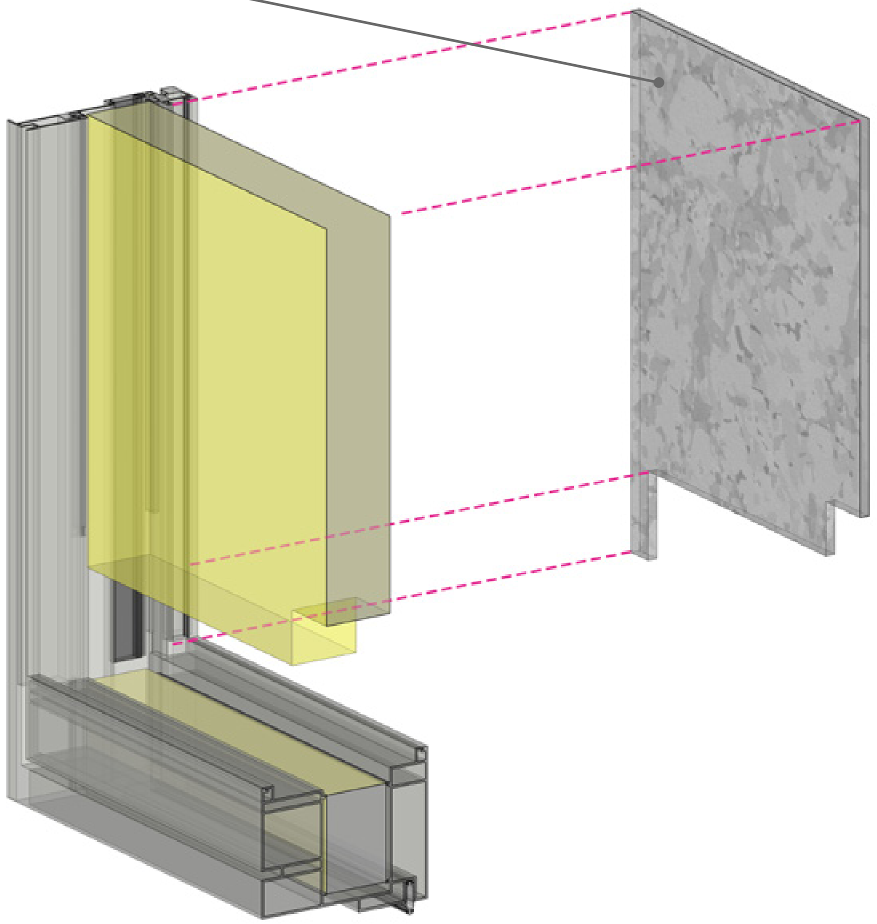
FACADE DESIGN
Materials



FACADE DESIGN
Factory assembly



FACADE DESIGN
Factory assembly



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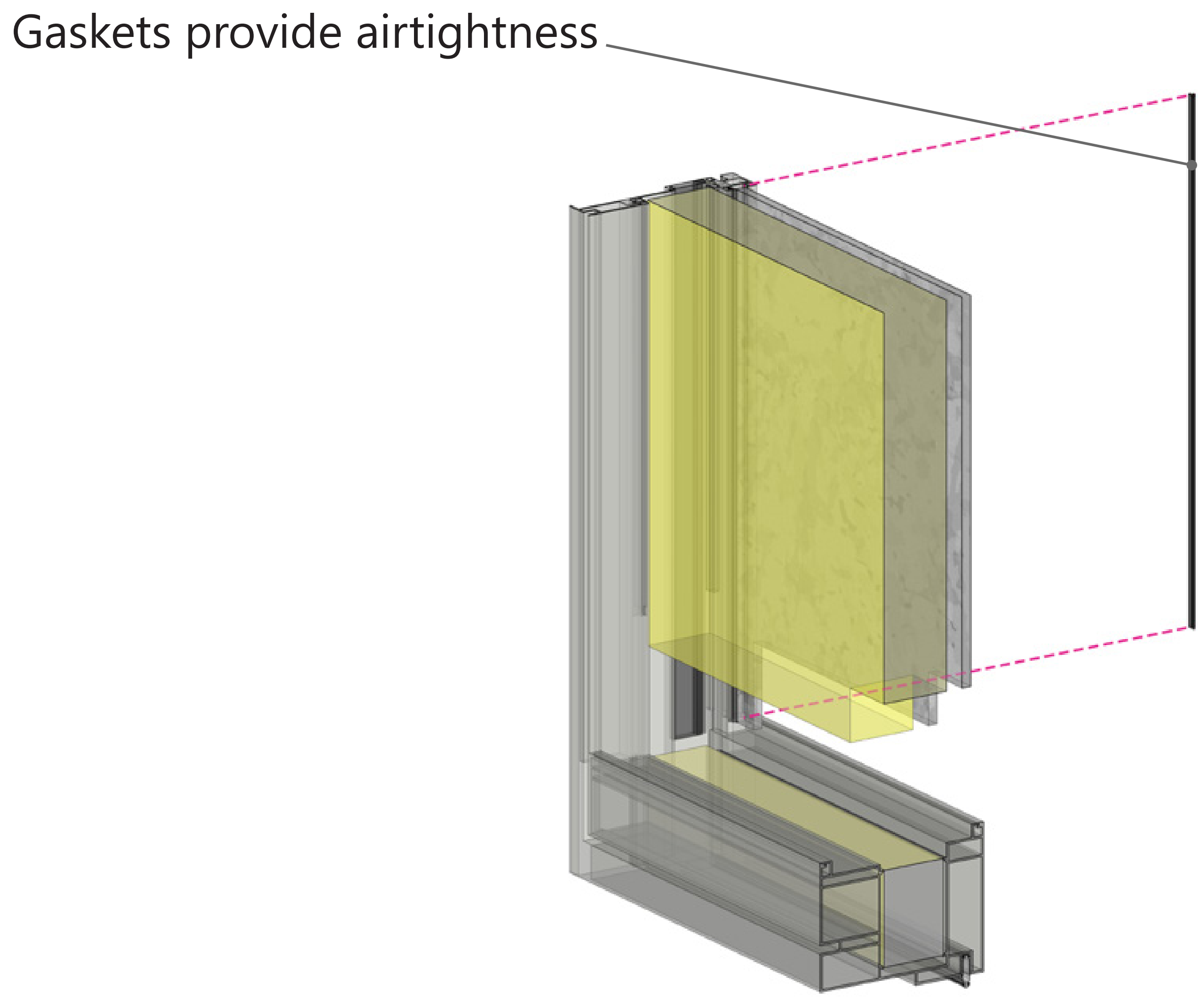

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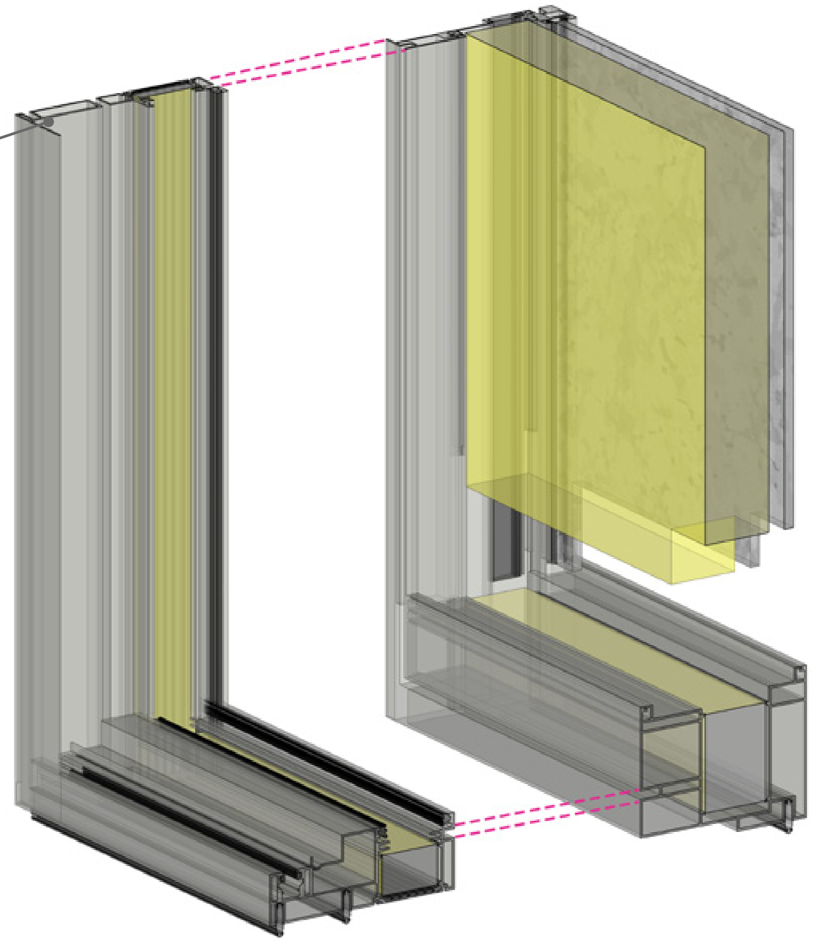

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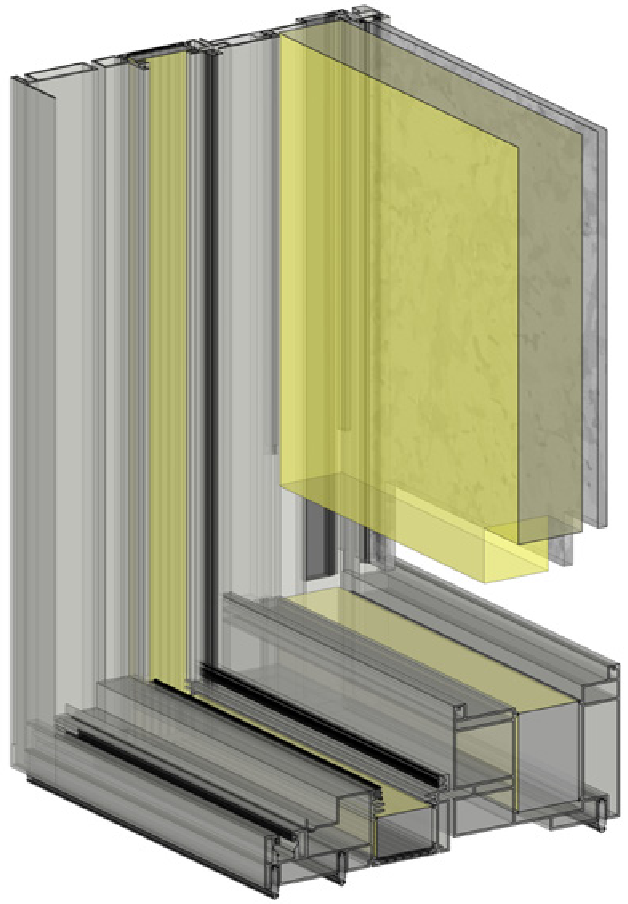
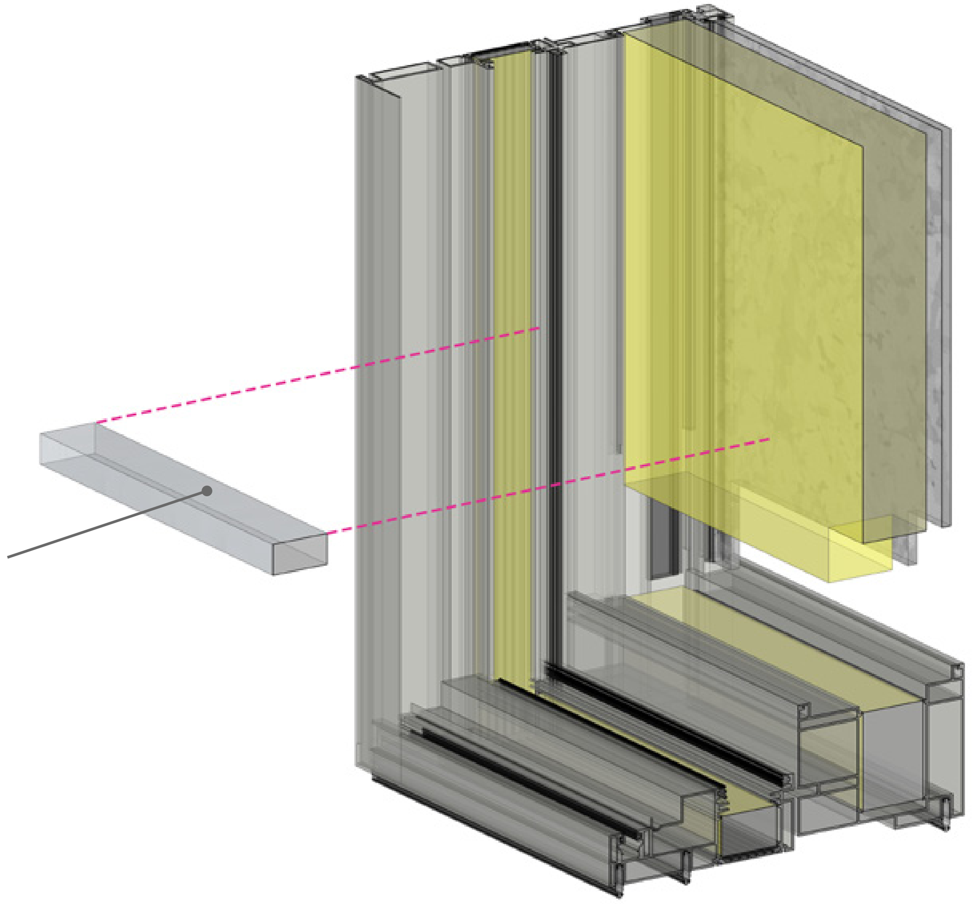
Factory assembly

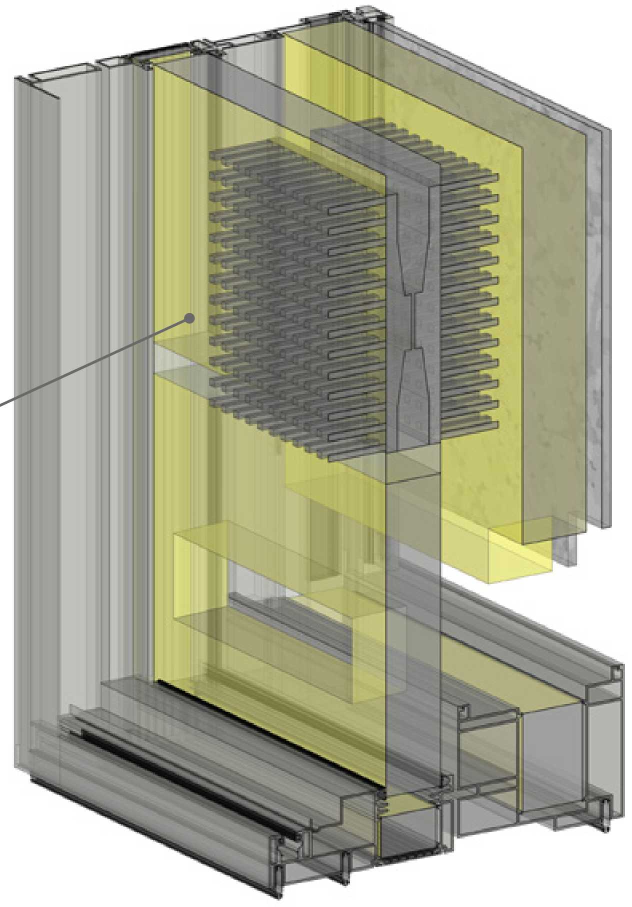


FACADE DESIGN
Factory assembly

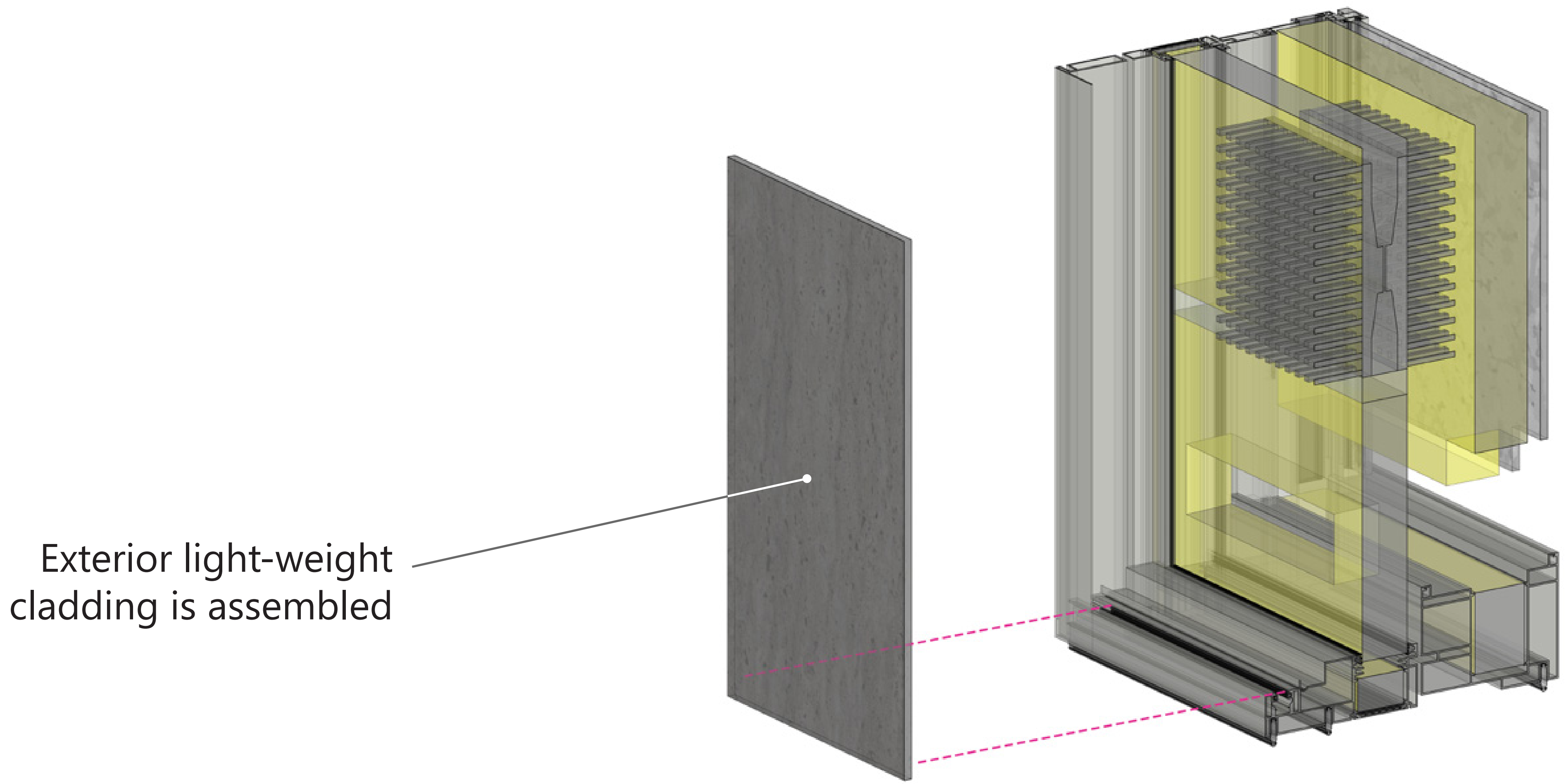


FACADE DESIGN
Factory assembly

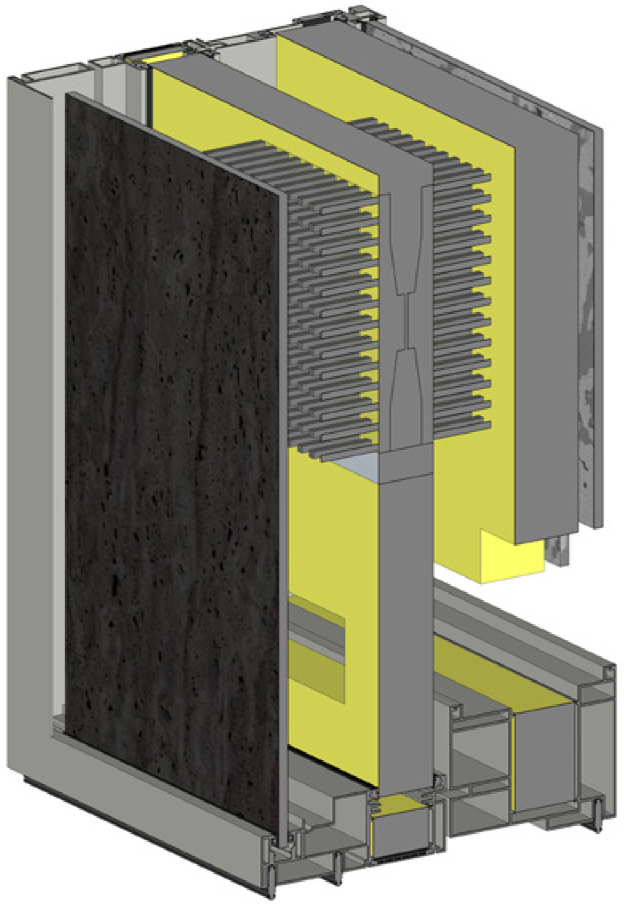
TE modules, heat sinks and their insulation layer is connected



FACADE DESIGN
Factory assembly

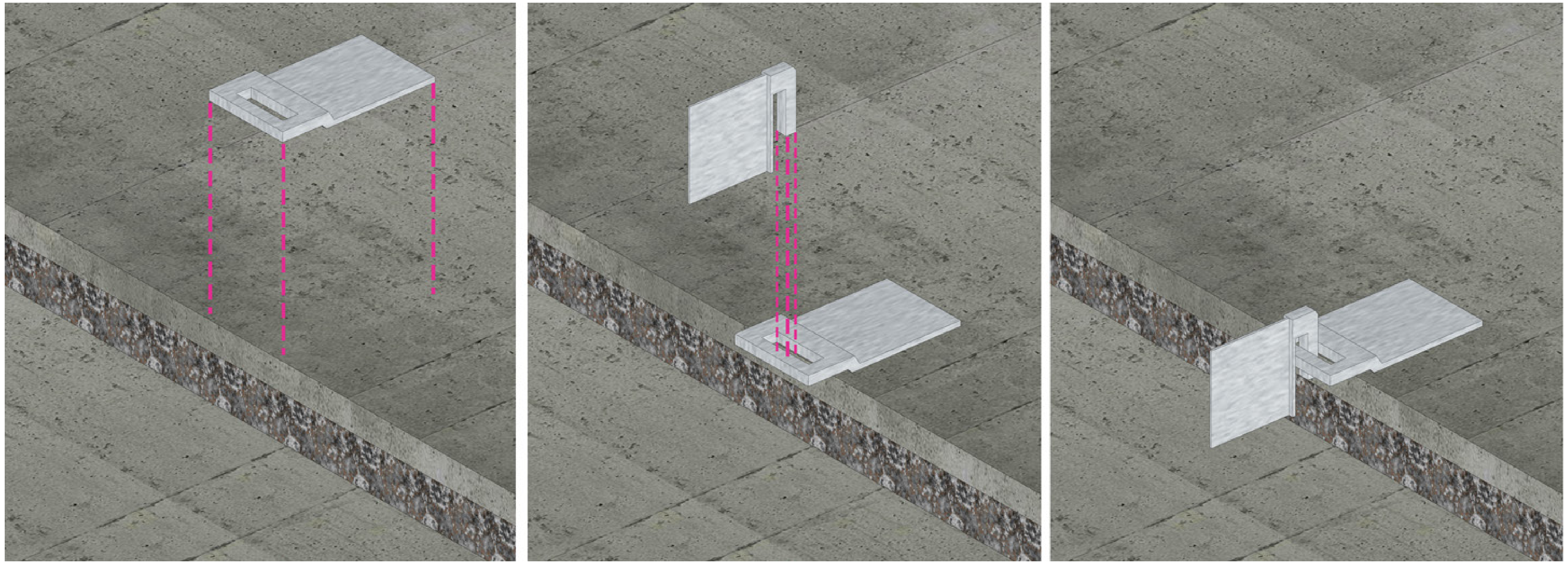


FACADE DESIGN
Factory assembly



FACADE DESIGN
On-site assembly

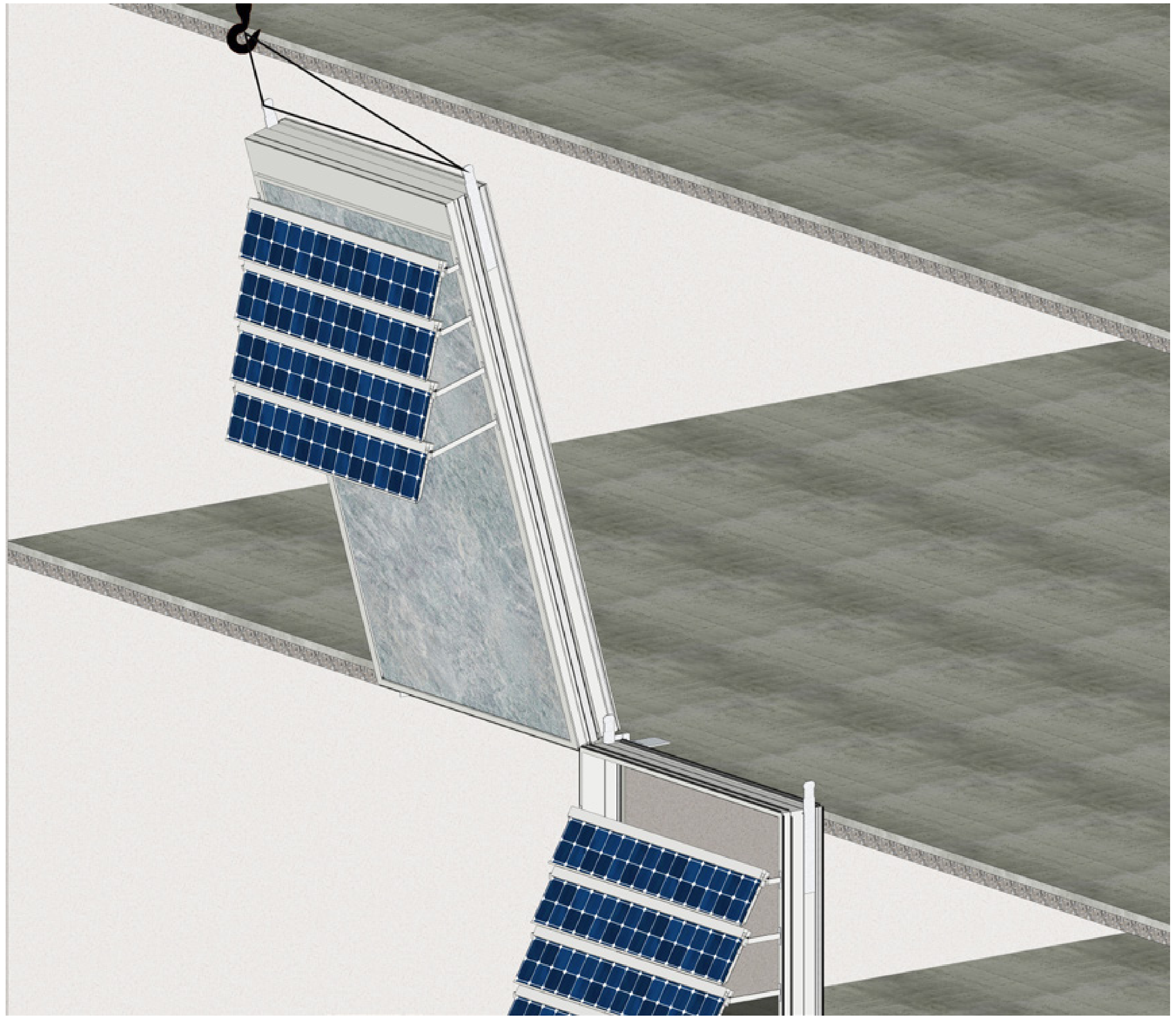
FACADE DESIGN
On-site assembly



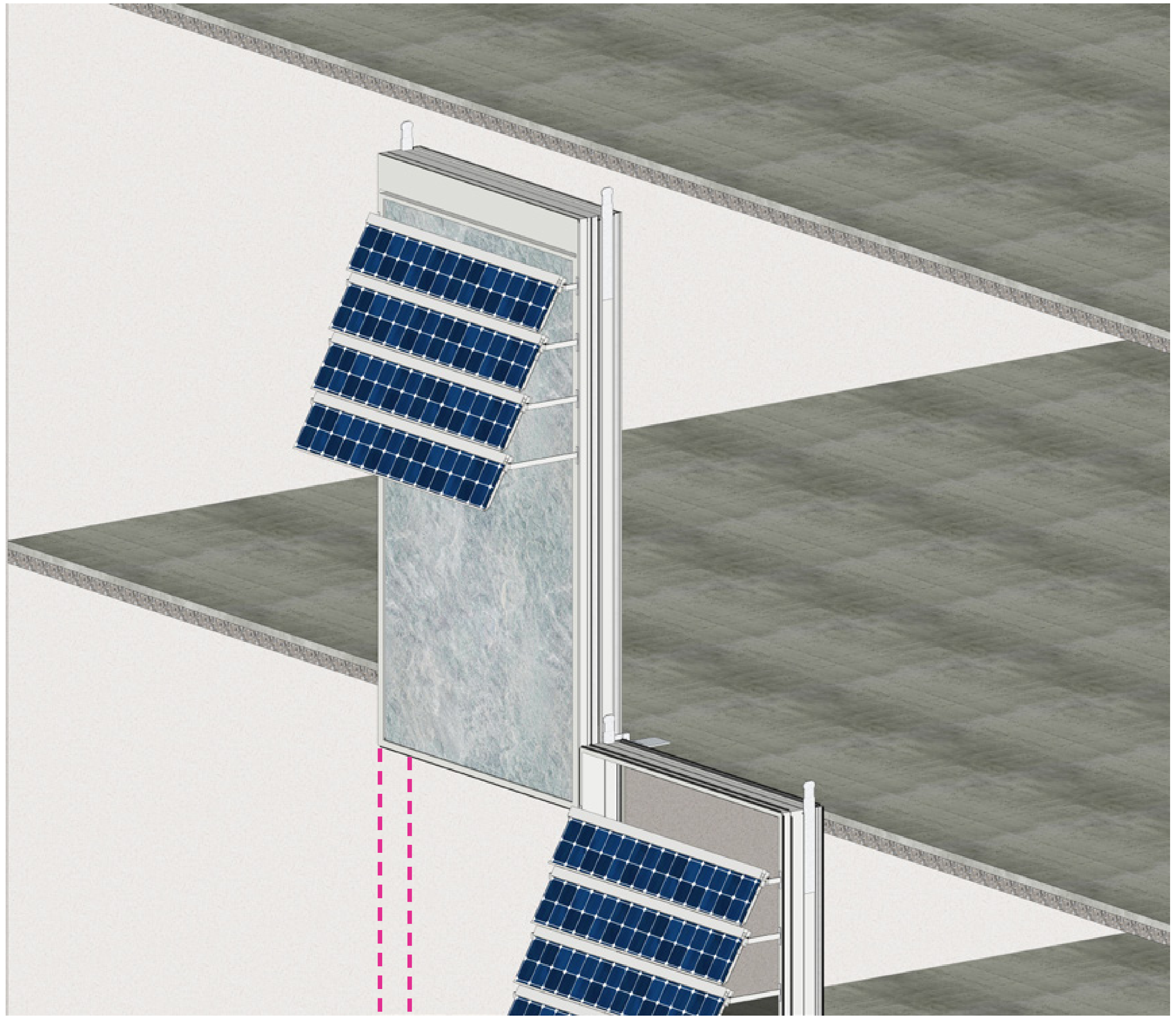
Structural brackets are connected to the floors

FACADE DESIGN
On-site assembly

Modules are assembled on site by crane

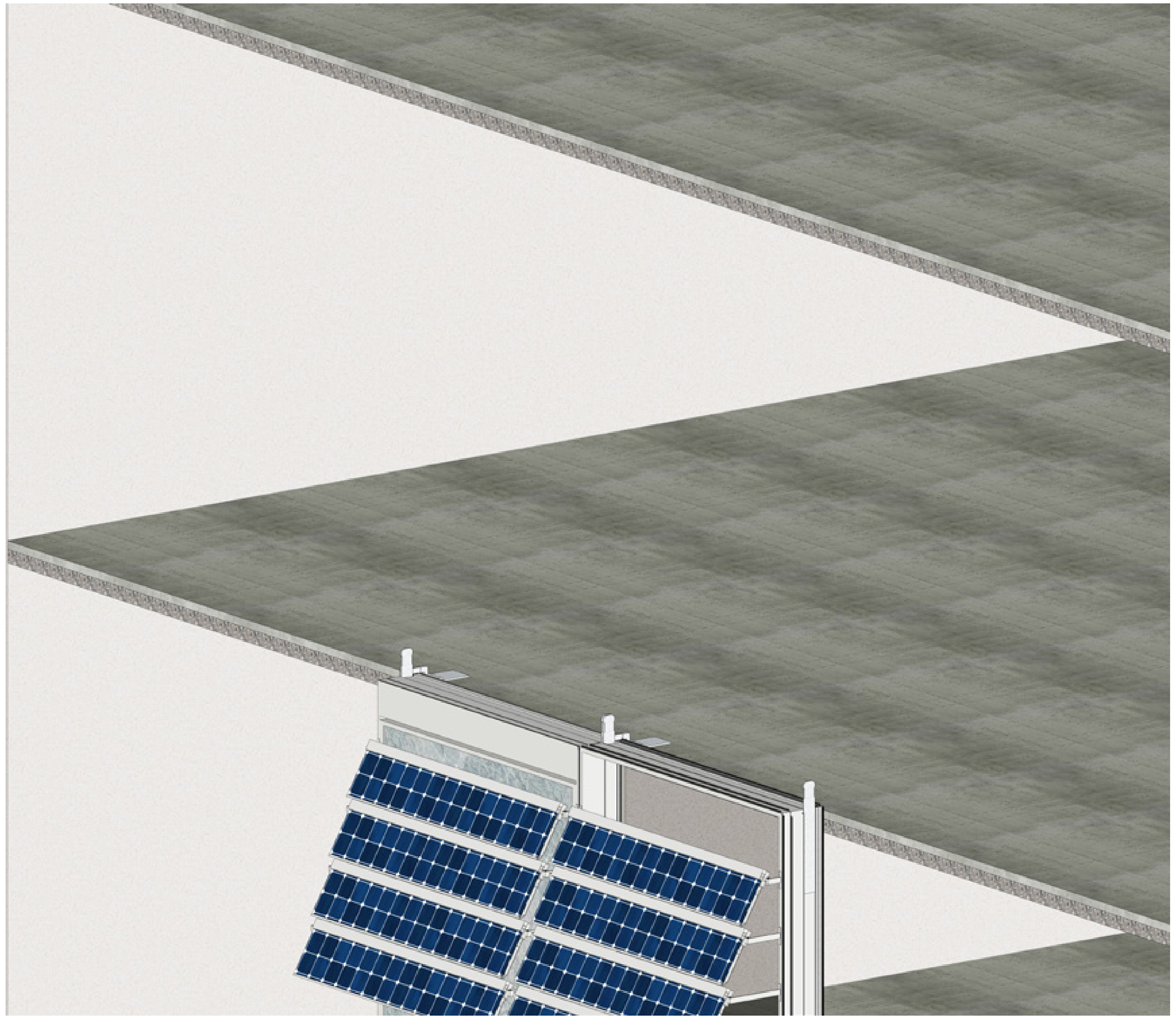


FACADE DESIGN
On-site assembly



FACADE DESIGN
On-site assembly

They slide into each other



FACADE DESIGN
On-site assembly

And are then fixed with screws
to the structural bracket

FACADE DESIGN
Alternatives

Original facade design

FACADE DESIGN
Alternatives

The designed TE facade

FACADE DESIGN
Alternatives

Heat sinks on as a cladding

FACADE DESIGN
Alternatives

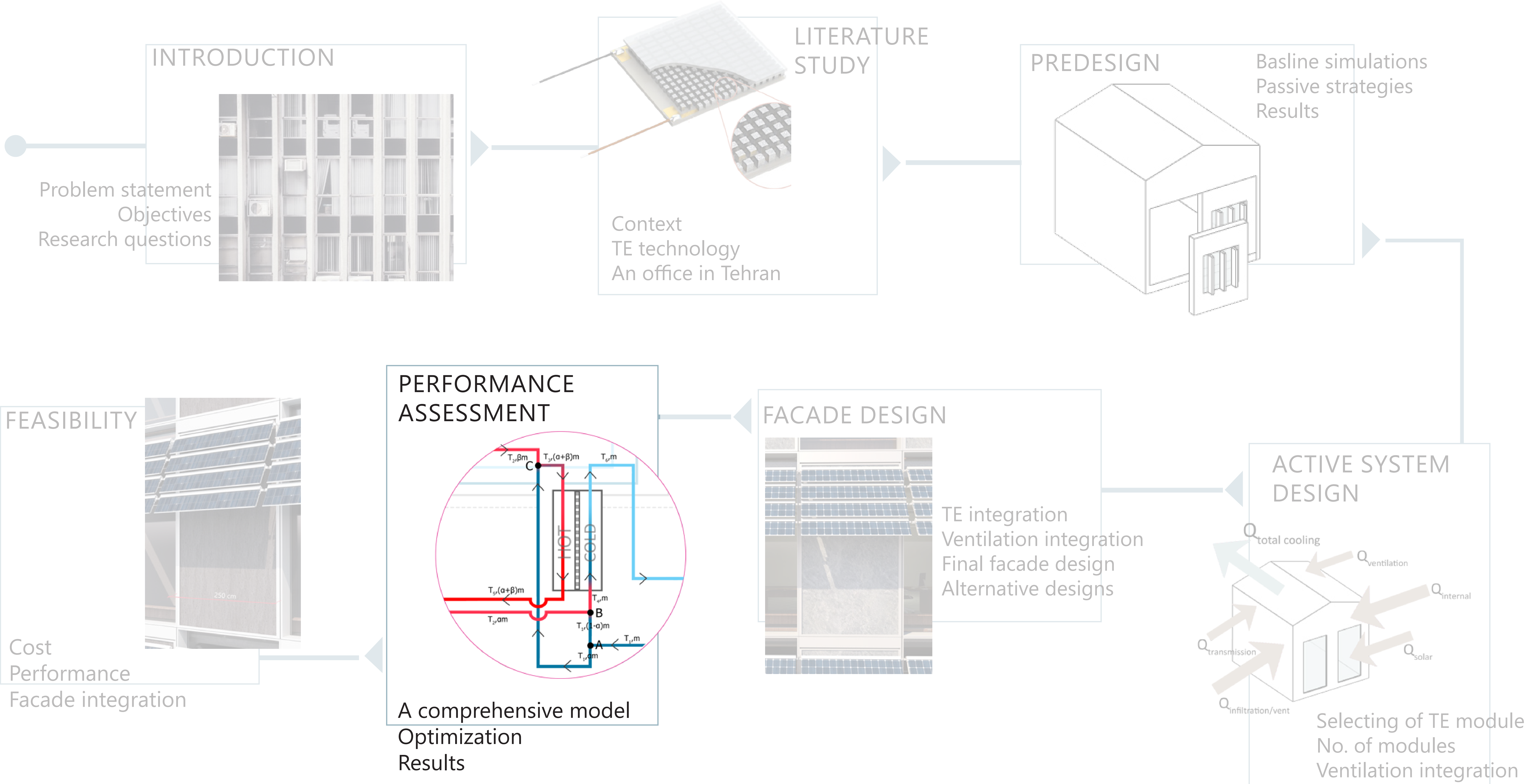
Different widths and colors

FACADE DESIGN
Alternatives

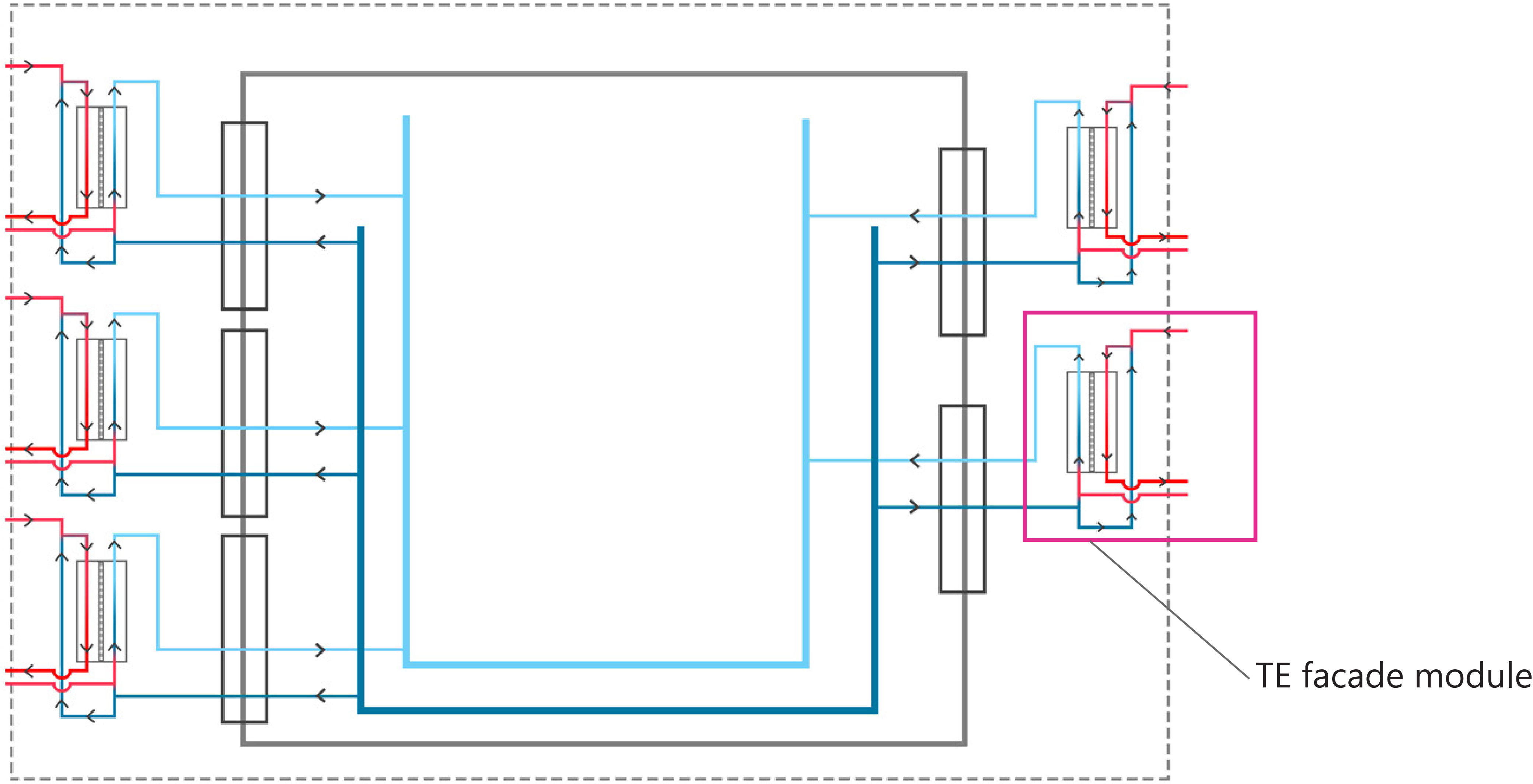
Glazed and TE units in one facade module

FACADE DESIGN
Interior

TE integrated facade

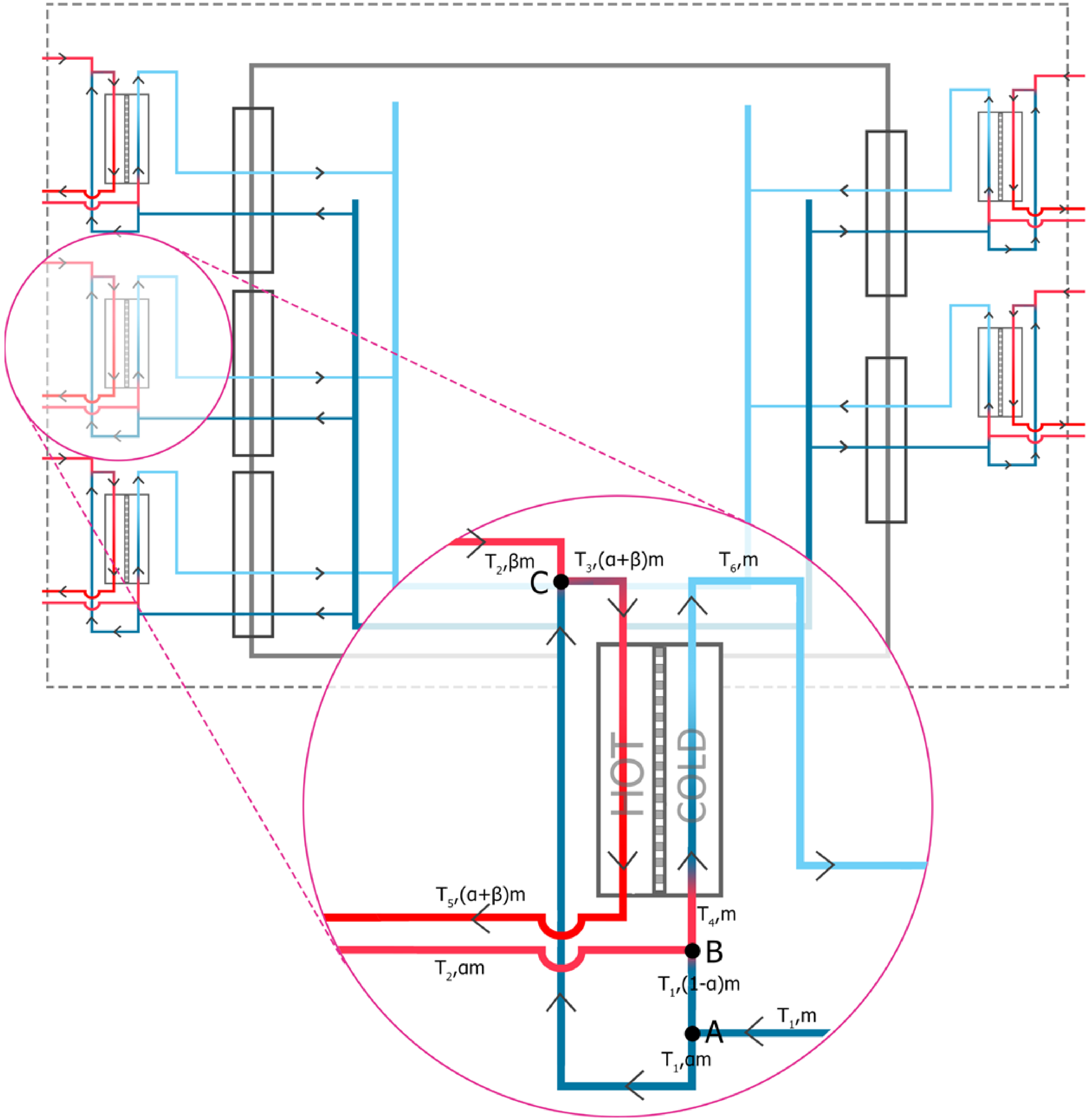

INTRODUCTION
Problem statement
Objectives
Research questions
LITERATURE STUDY
Context
TE technology
An office in Tehran
PREDESIGN
Basline simulations
Passive strategies
Results
ACTIVE SYSTEM DESIGN
Q total cooling
Q ventilation
Q internal
Q transmission
Q solar
Q infiltration/vent
Selecting of TE module
No. of modules
Ventilation integration
FACADE DESIGN
TE integration
Ventilation integration
Final facade design
Alternative designs
PERFORMANCE ASSESSMENT
HOT
COLD
C
B
A
A comprehensive model
Optimization
Results
FEASIBILITY
Cost
Performance
Facade integration

PERFORMANCE ASSESSMENT
Thermal model



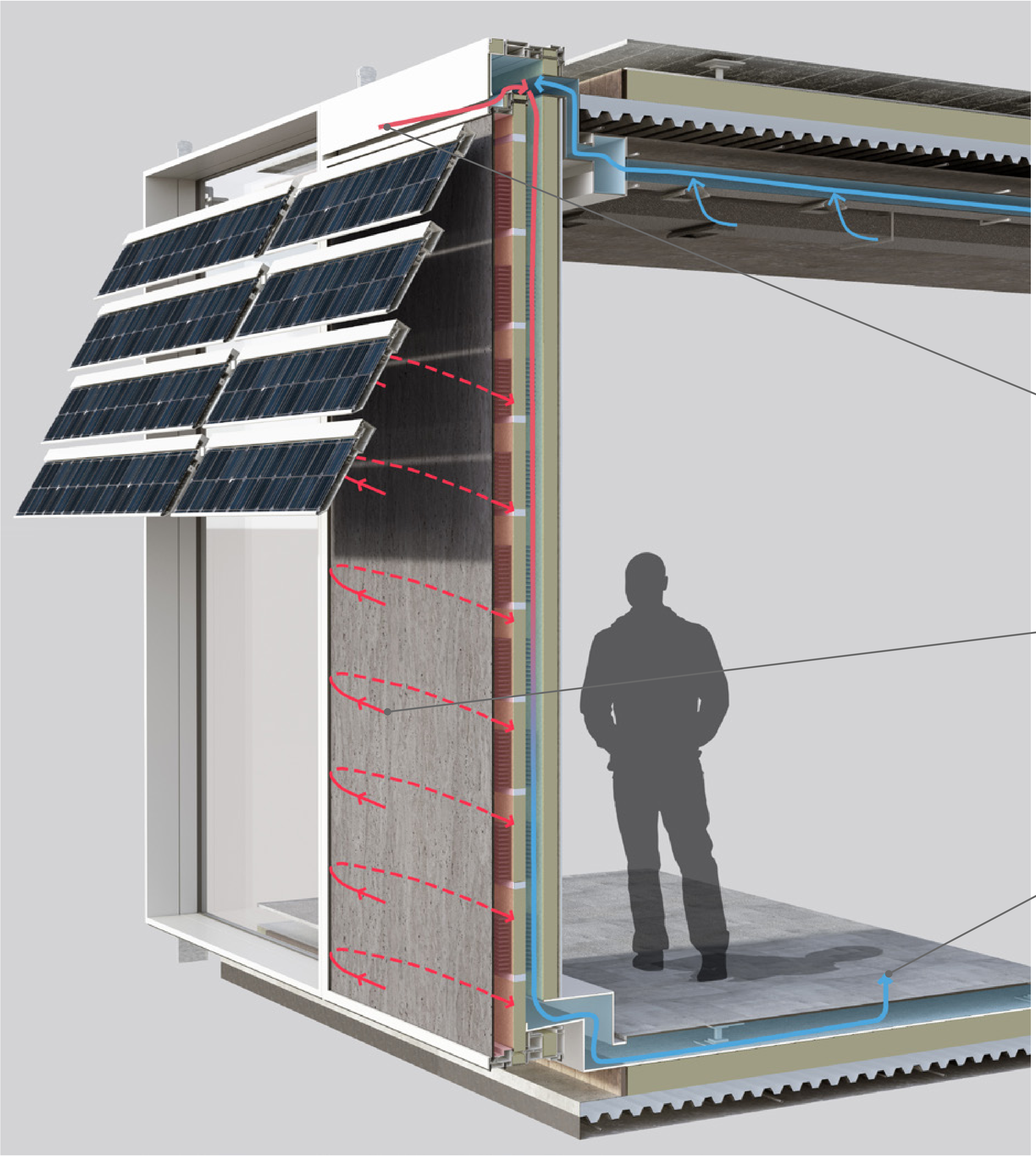
PERFORMANCE ASSESSMENT
Thermal model

Optimizing values of α, β and $\dot{V}$ which results in the best COP



PERFORMANCE ASSESSMENT
Thermal model

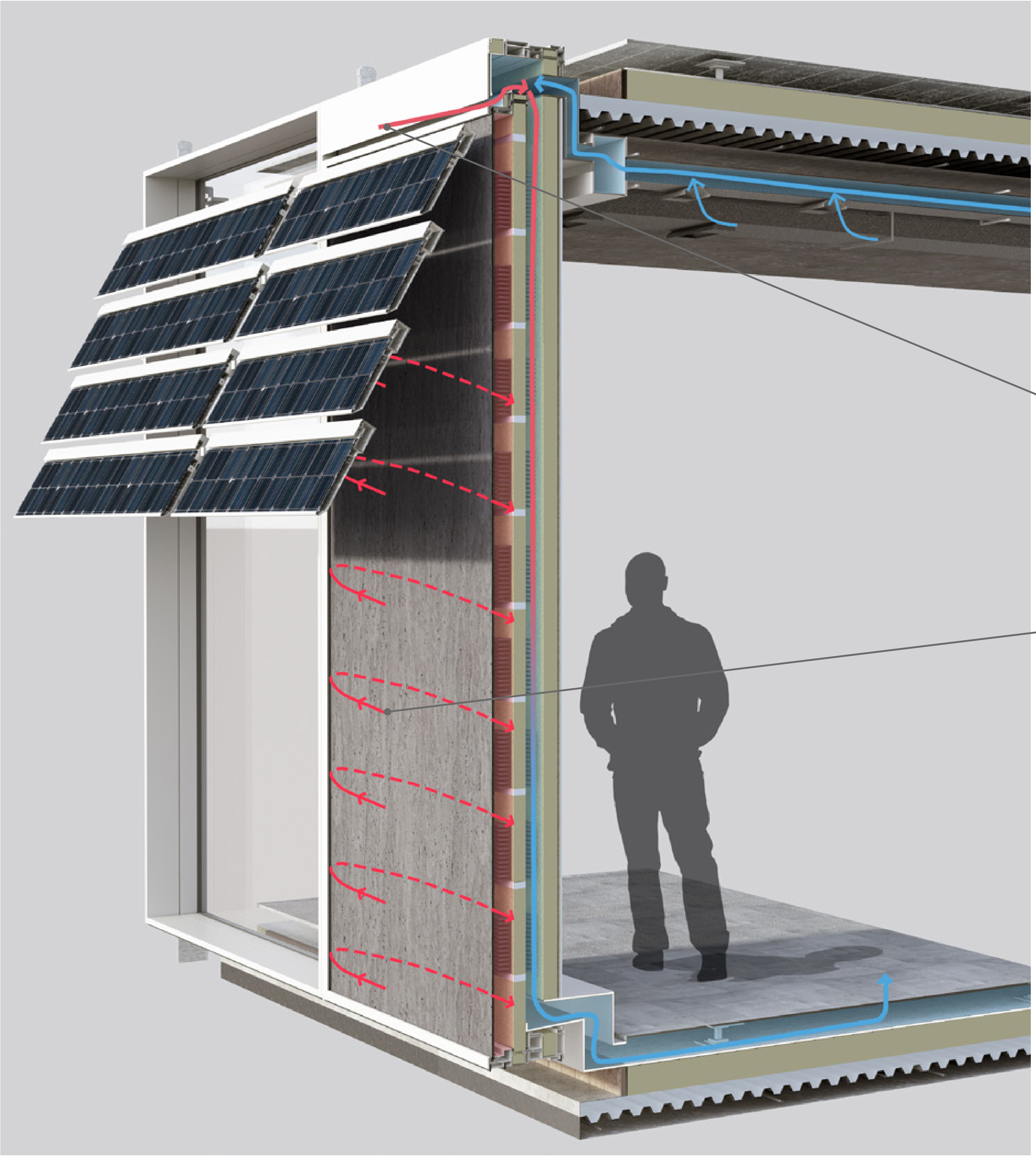
α, β and $\dot{V}$, determine the amount of air flow(m^3/s) that enters the cold side, hot side and the conditioned zones.



PERFORMANCE ASSESSMENT
Optimization-summer

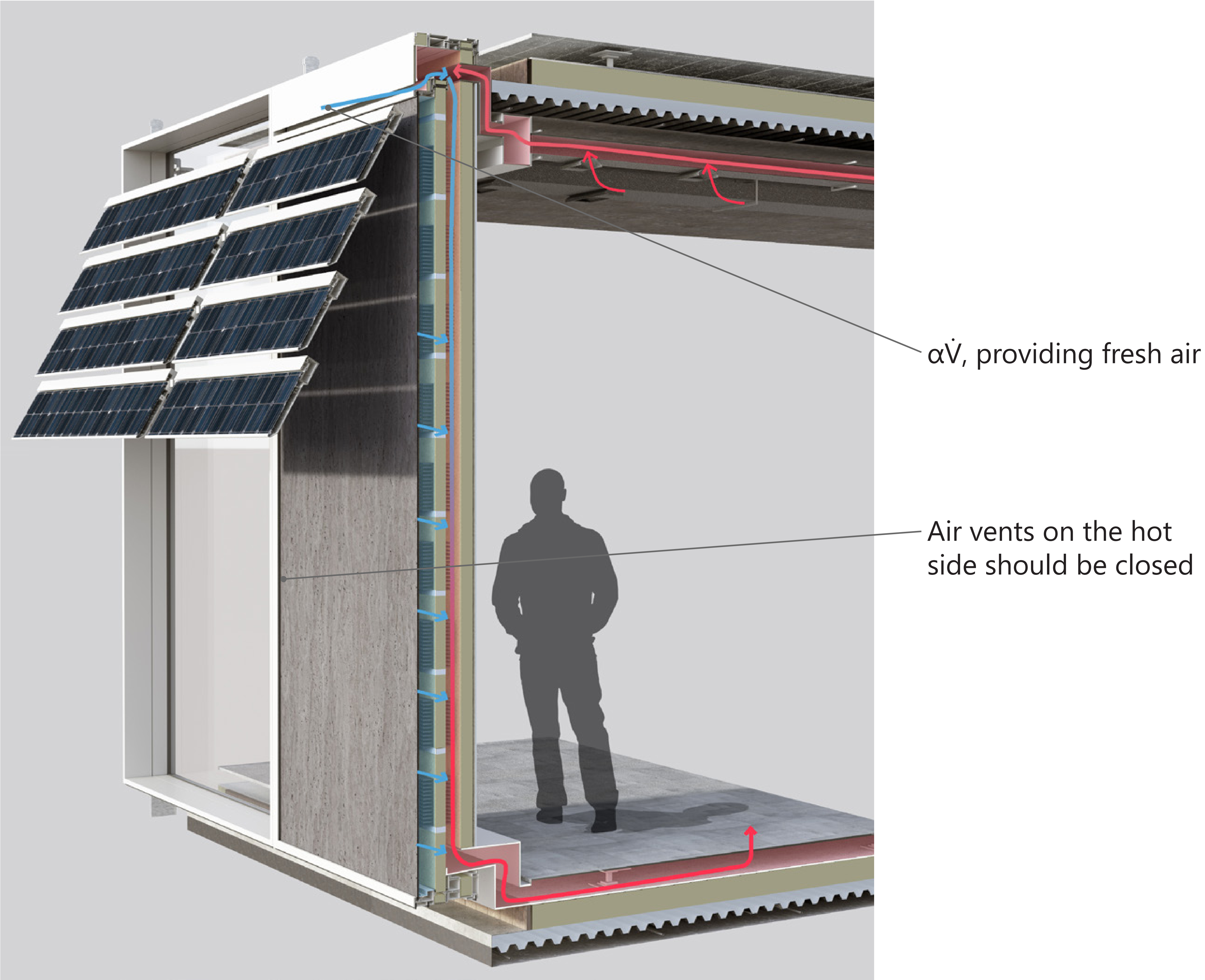
α should be minimum
β has an optimum value but increasing it helps with the efiiciency

COP of the system reaches **0.65 to 0.80** in summer peak conditions

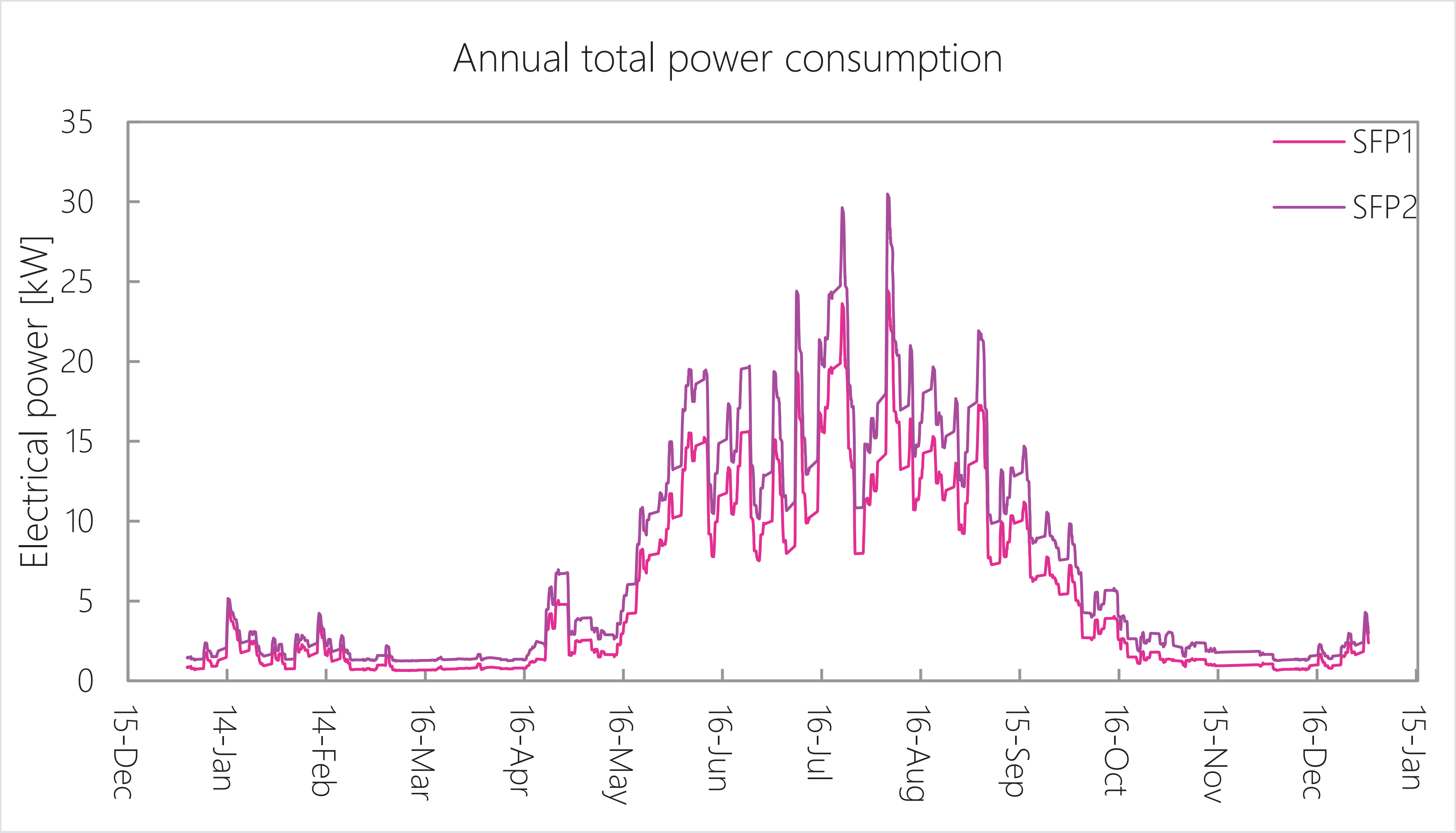


PERFORMANCE ASSESSMENT
Optimization-winter

α should be maximum = 1
β should be 0
COP of the system reaches **1.9 to 2.0** in winter peak conditions



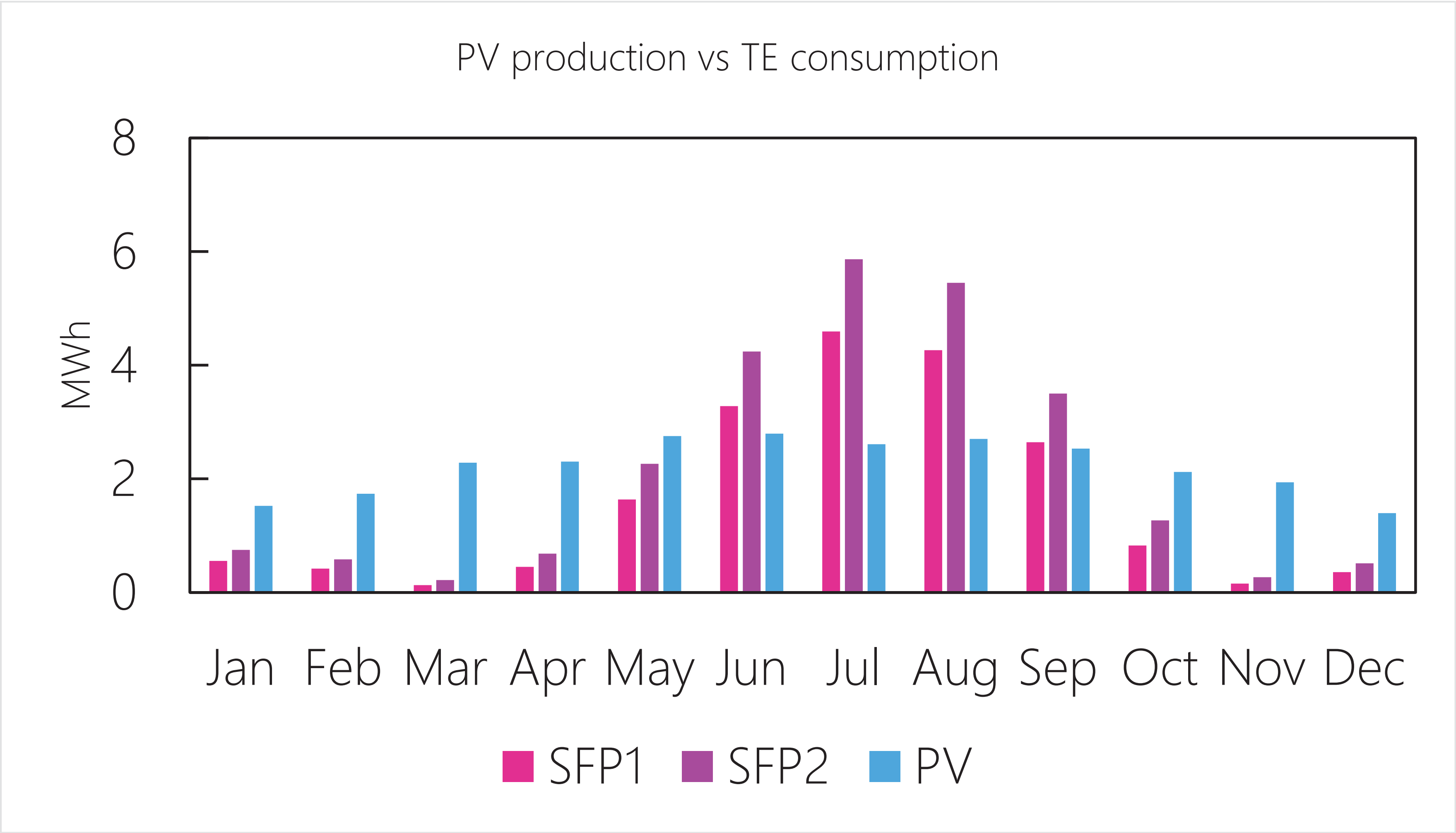
PERFORMANCE ASSESSMENT
Optimization-annual loads



Annual electricity consumption is covered by PV panels
Electricity consumotion in summer highest in June to September

Summer COP: 1 - 1.3
Winter COP: 2.1 - 3.0

PERFORMANCE ASSESSMENT
Optimization-annual loads

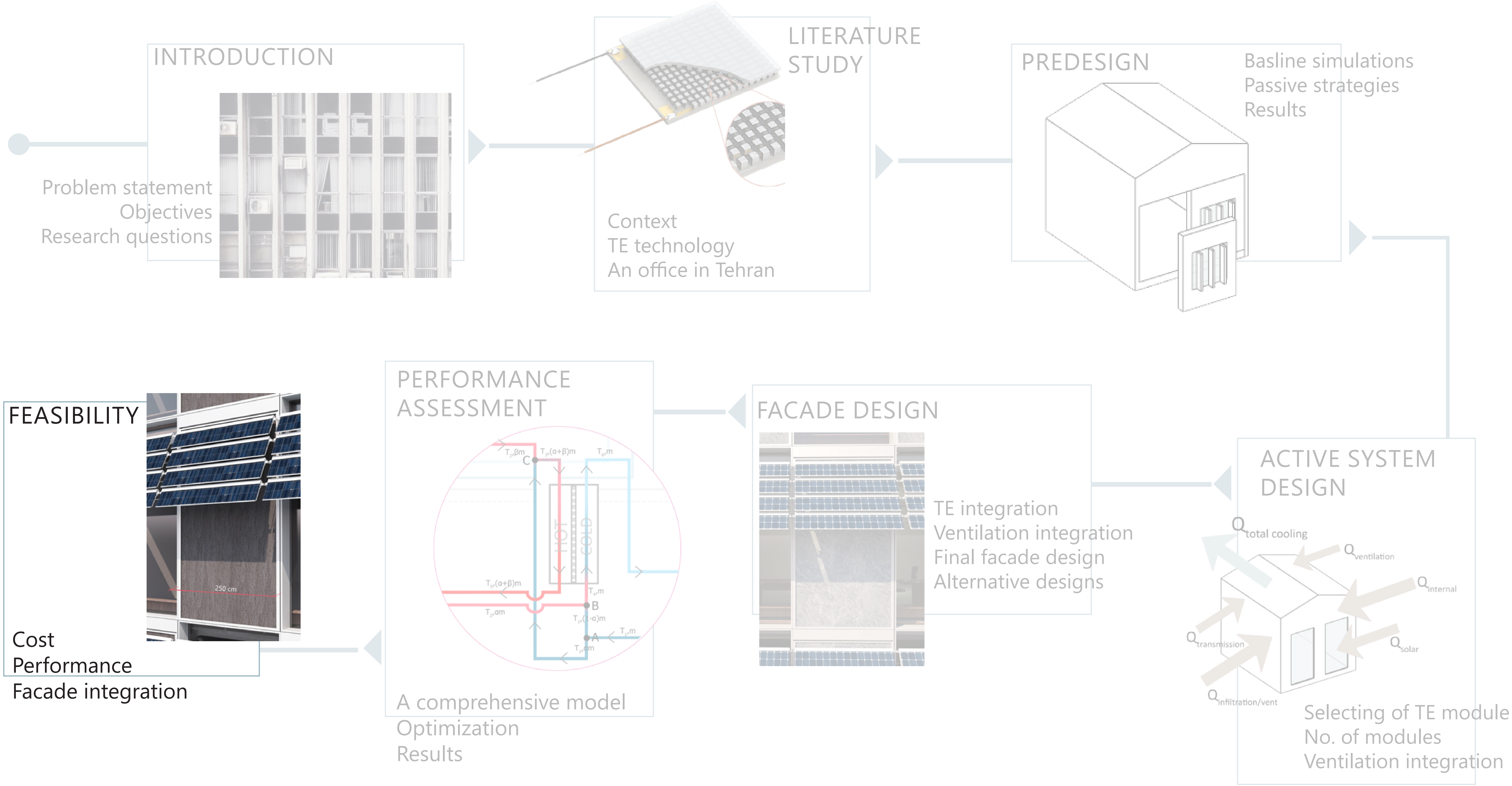


Reliance on grid electricity in June to September

Is the designed facade capable of providing heating and cooling with electricity only from PV panels?

Yes,
The electricity consumption can be annually covered by PV production

BUT;
No,
The system relies on Grid electricity in months of June to September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Problem statement
Objectives
Research questions
LITERATURE STUDY
Context
TE technology
An office in Tehran
PREDESIGN
Basline simulations
Passive strategies
Results
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TE integration
Ventilation integration
Final facade design
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COLD
A
B
C
A comprehensive model
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Results
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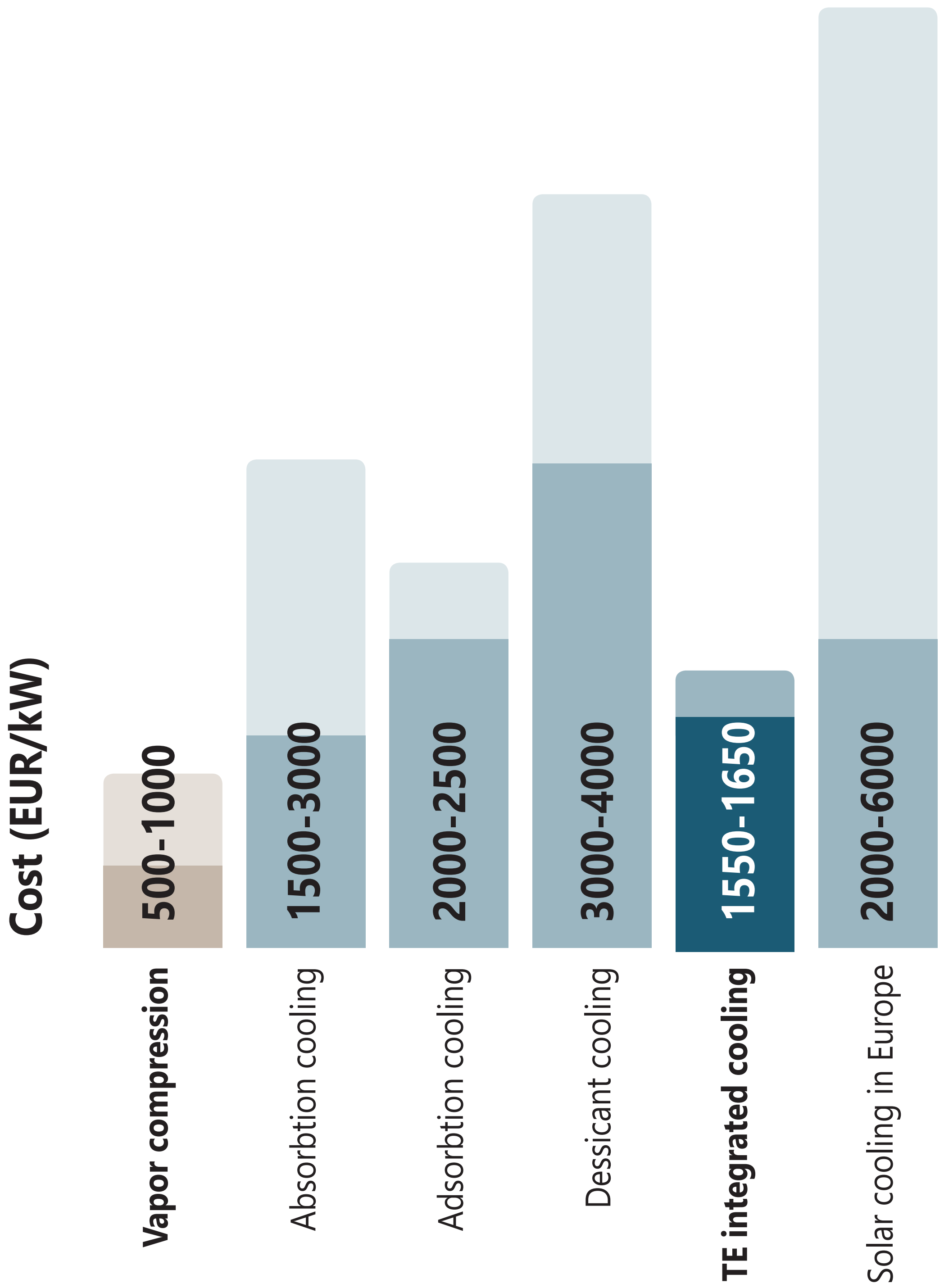
250 cm
Cost
Performance
Facade integration

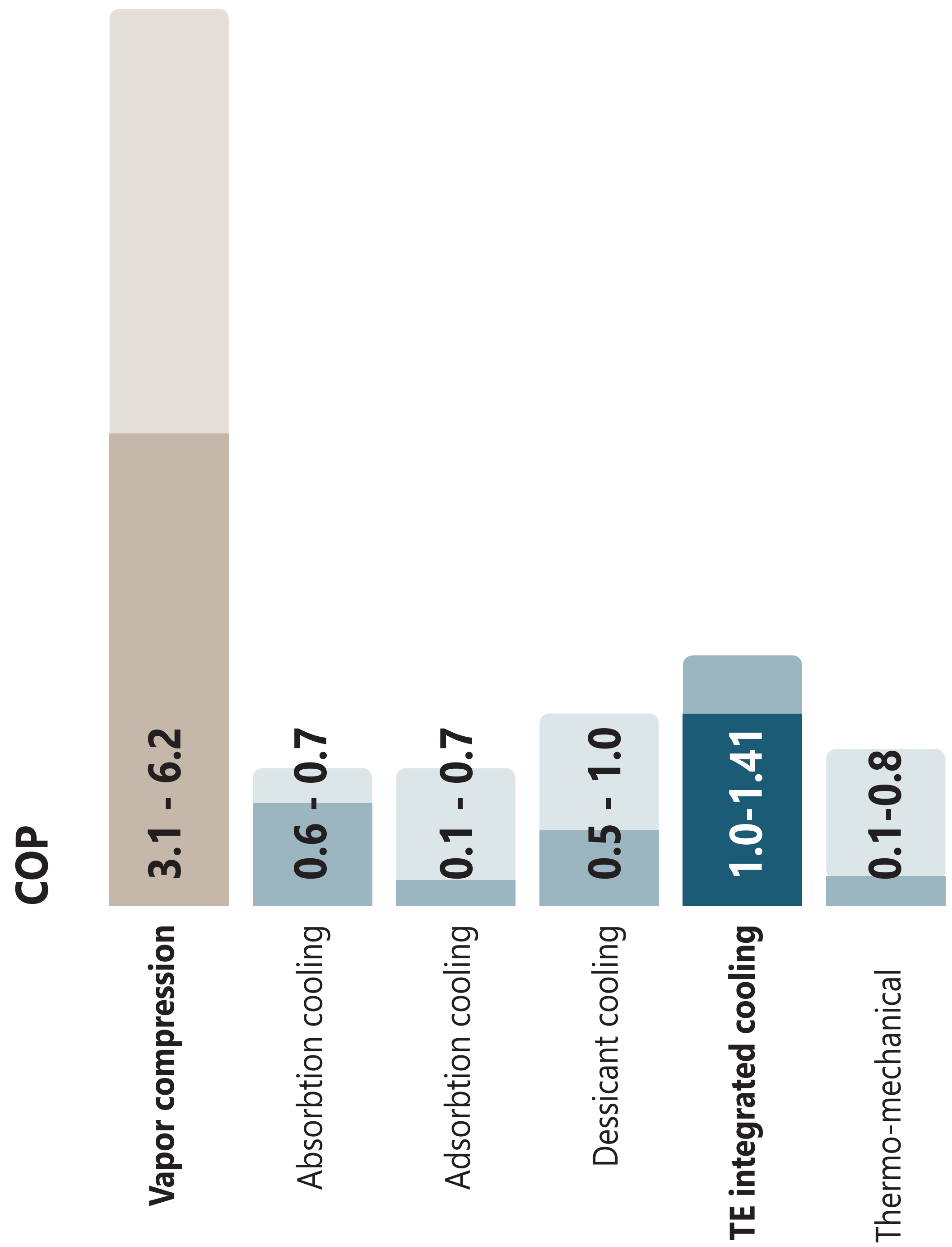
FEASIBILITY ANALYSIS
Cost

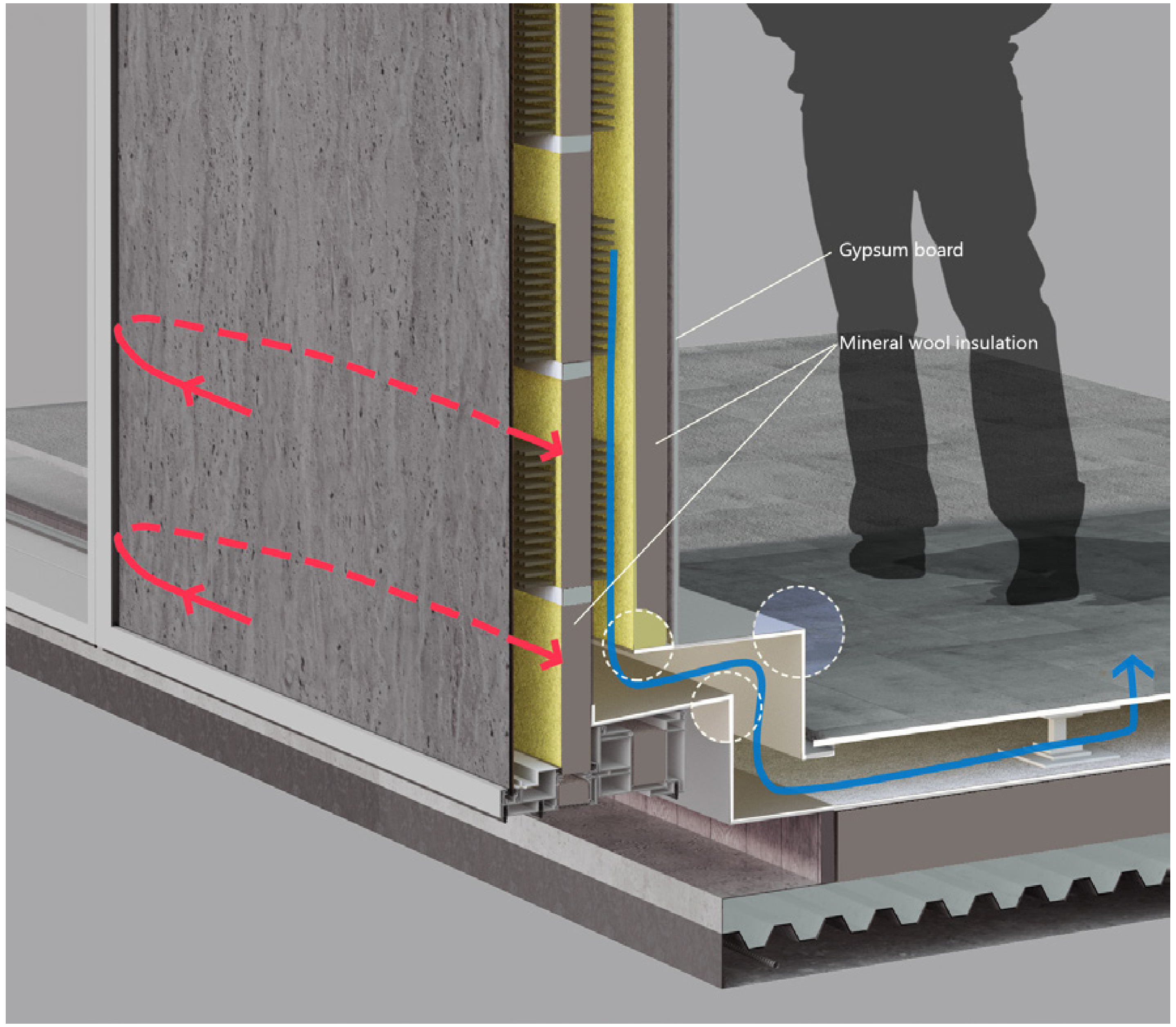
Cost-effective among other solar cooling technologies
More expensive than conventional vapor compression



FEASIBILITY ANALYSIS
Summer COP

Better performance than other solar cooling technologies
Much lower COP compared to vapor compression cooling

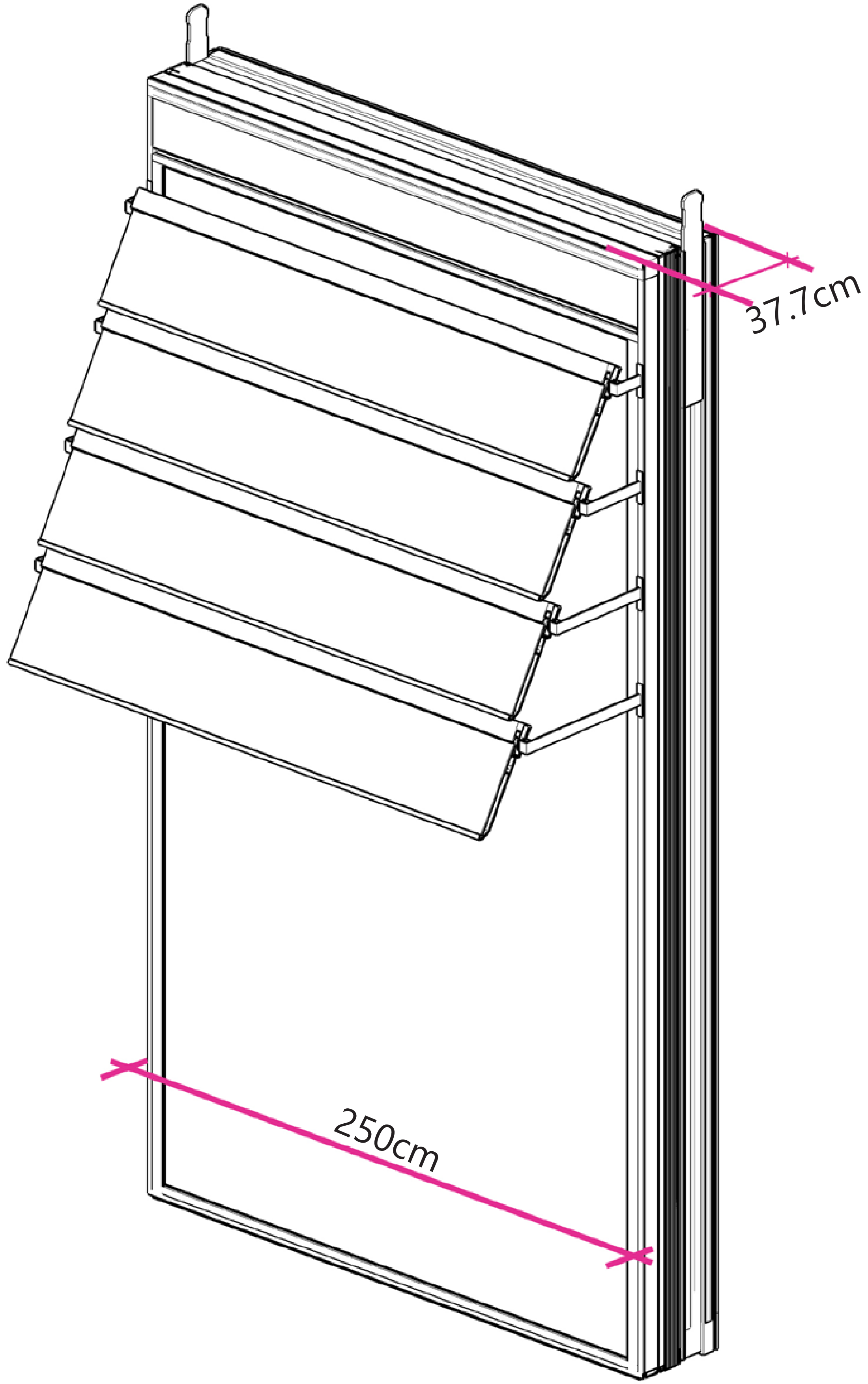




FEASIBILITY ANALYSIS

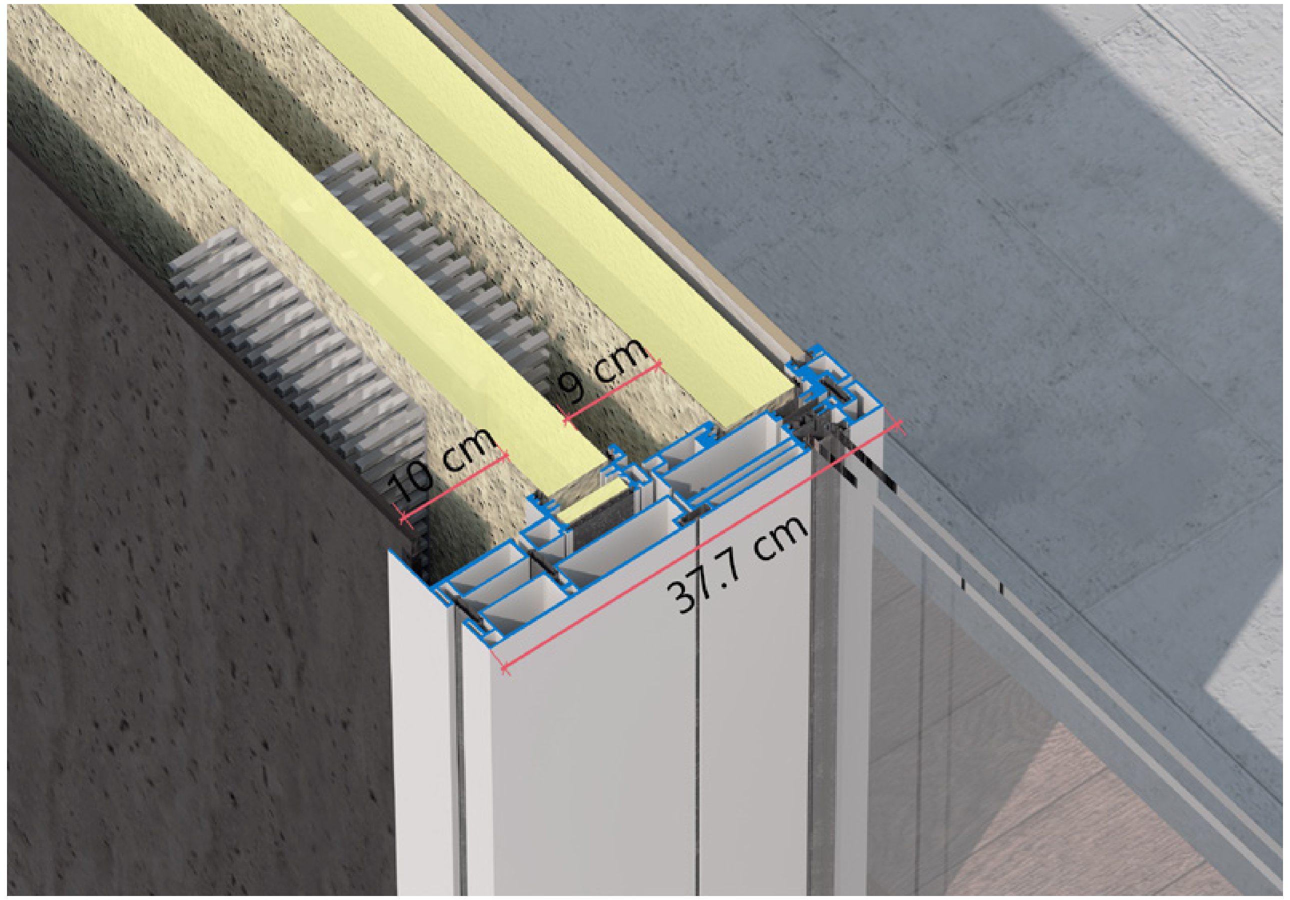
Facade integration

Hight noise levels
High air flow rates
Air movement and distribution
9 to 14 fans required per TE facade



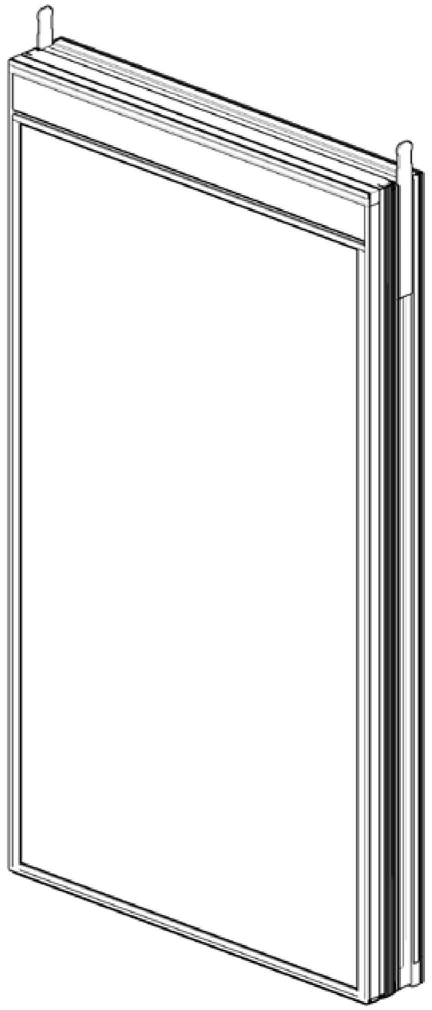
FEASIBILITY ANALYSIS
Facade integration

Limitations in terms of sizes
Width of the facade module



FEASIBILITY ANALYSIS
Weight

Heavier than normal non-functional facades
Not suitable for every facade application



1.6 to 3.3
A normal facade with light to heavy cladding

2.6
A normal glazed facade

CONCLUSION

Pros

1. A sustainable operation
2. A relatively good performance
3. Flexibility in design and suitable for facade integration
4. Summer and winter operation
5. Control over ventilation air

Cons

1. Difficulty in heat dissipation
2. Releasing hot air to the environment
3. Low COP at peak demand and reliance on grid electricity
4. High air flow rates
5. Weight

FUTURE WORK

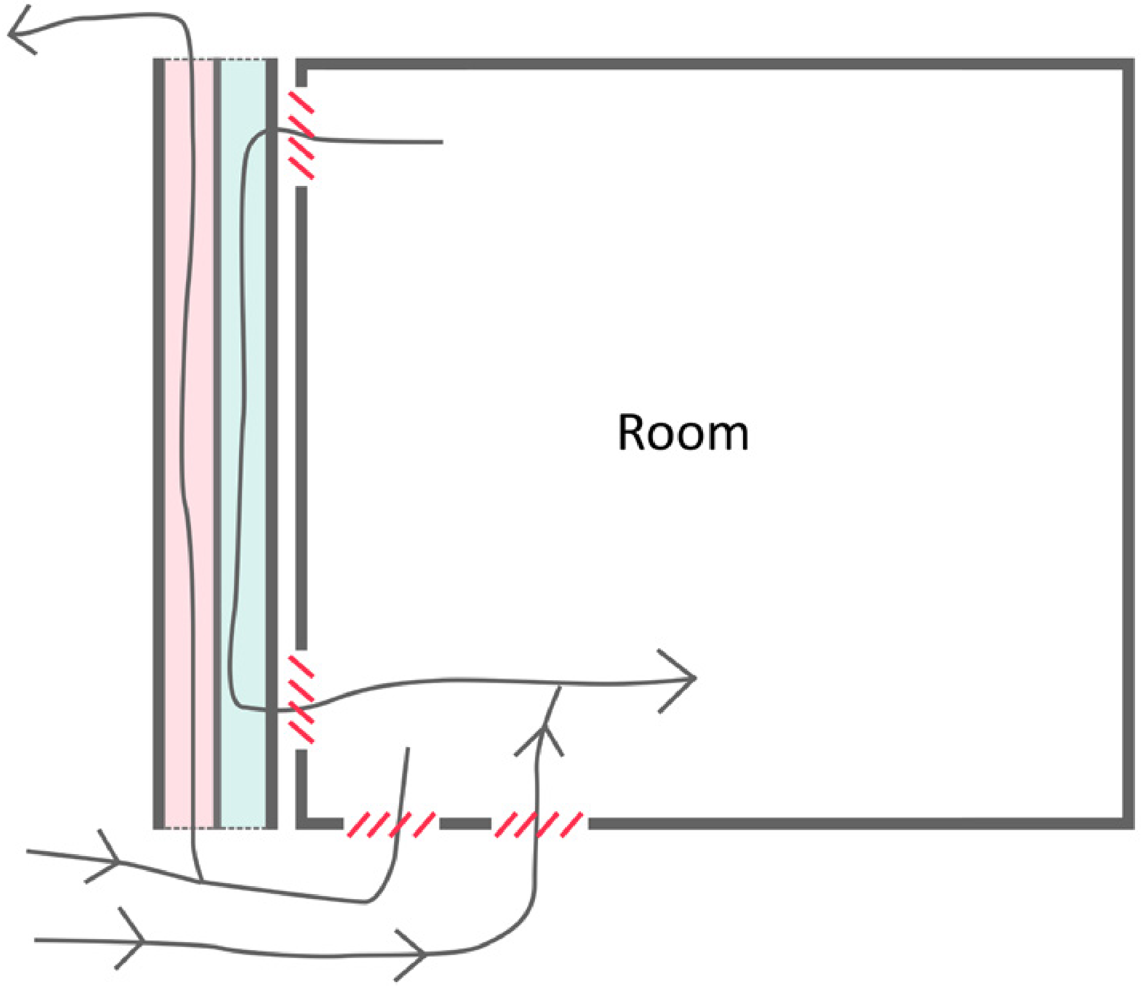
Better performance:
Designing special heat sinks
Other means of heat dissipation
CFD analysis of the air flow in the channels and over the heat sinks
Desining a controlling system
Integrating PCM to enhance the peak performance

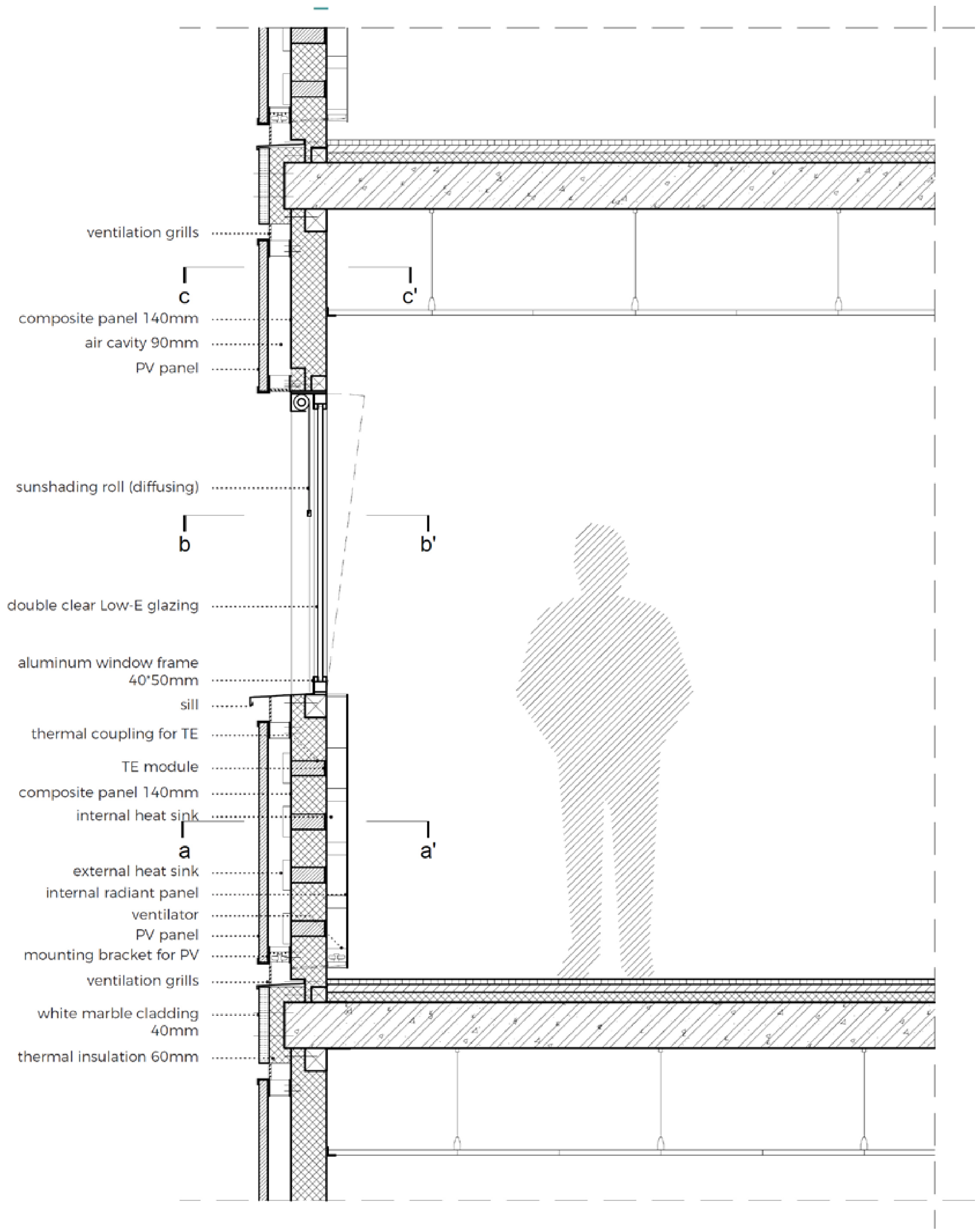
Facade integration:
Reducing noise problems
Reducing weight

Heat recovery:
Minimizing contribution to heat island effect

THANK YOU

NON-INTEGRATED TE SYSTEM

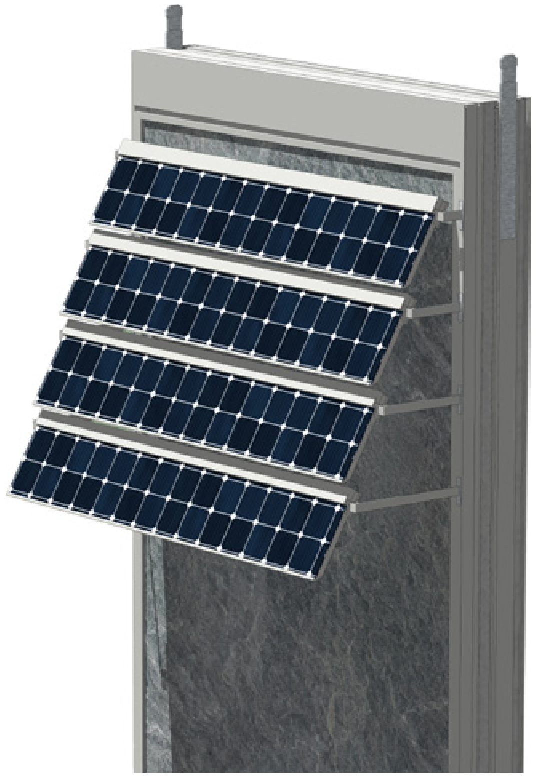




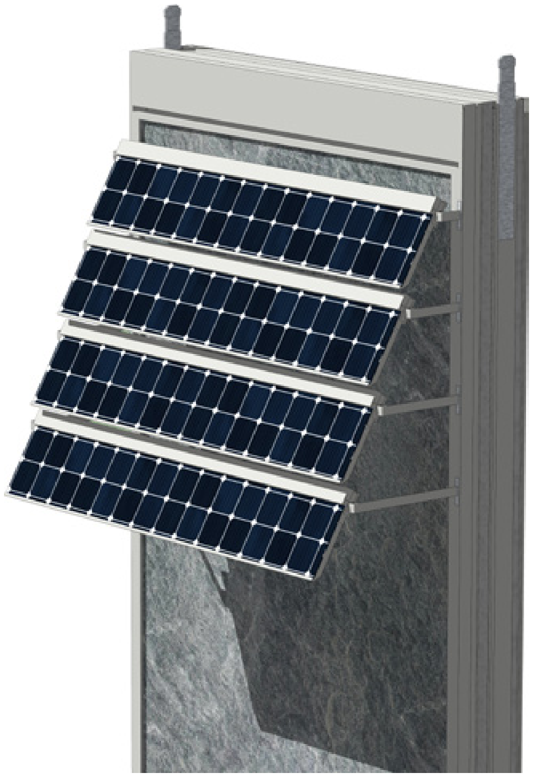
FACADE DESIGN
PV panels

Preventing overshading on each other

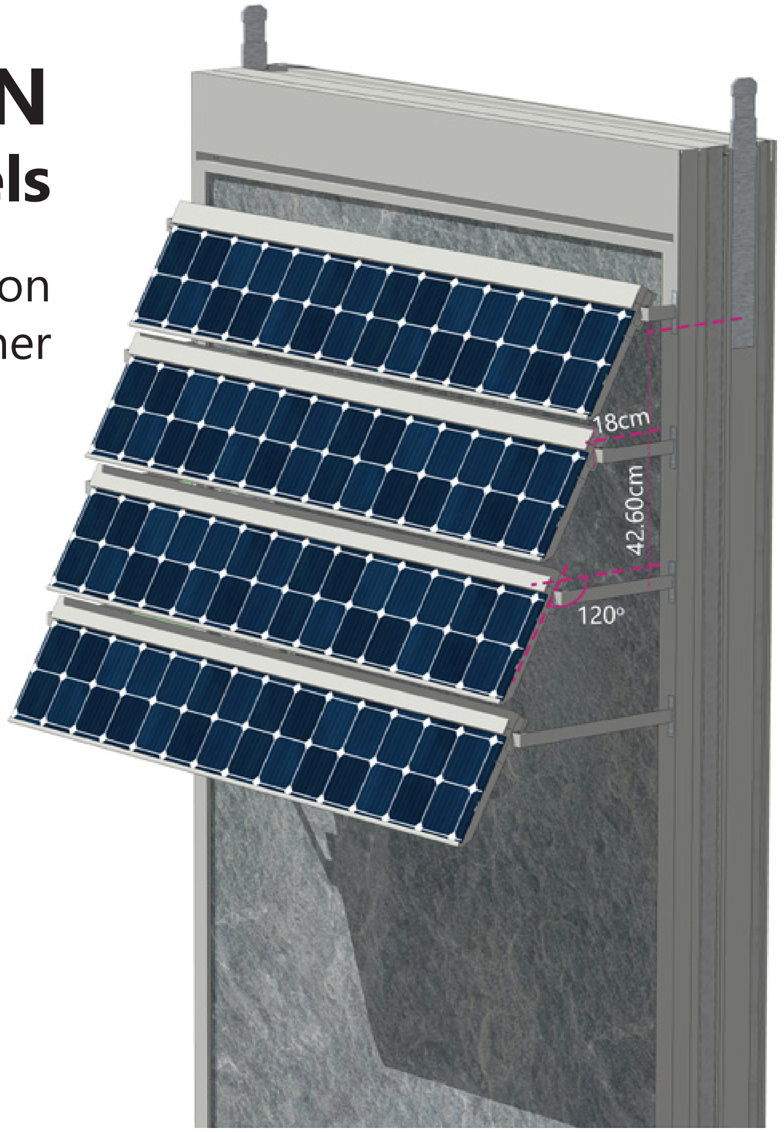
January-11:00 A.M



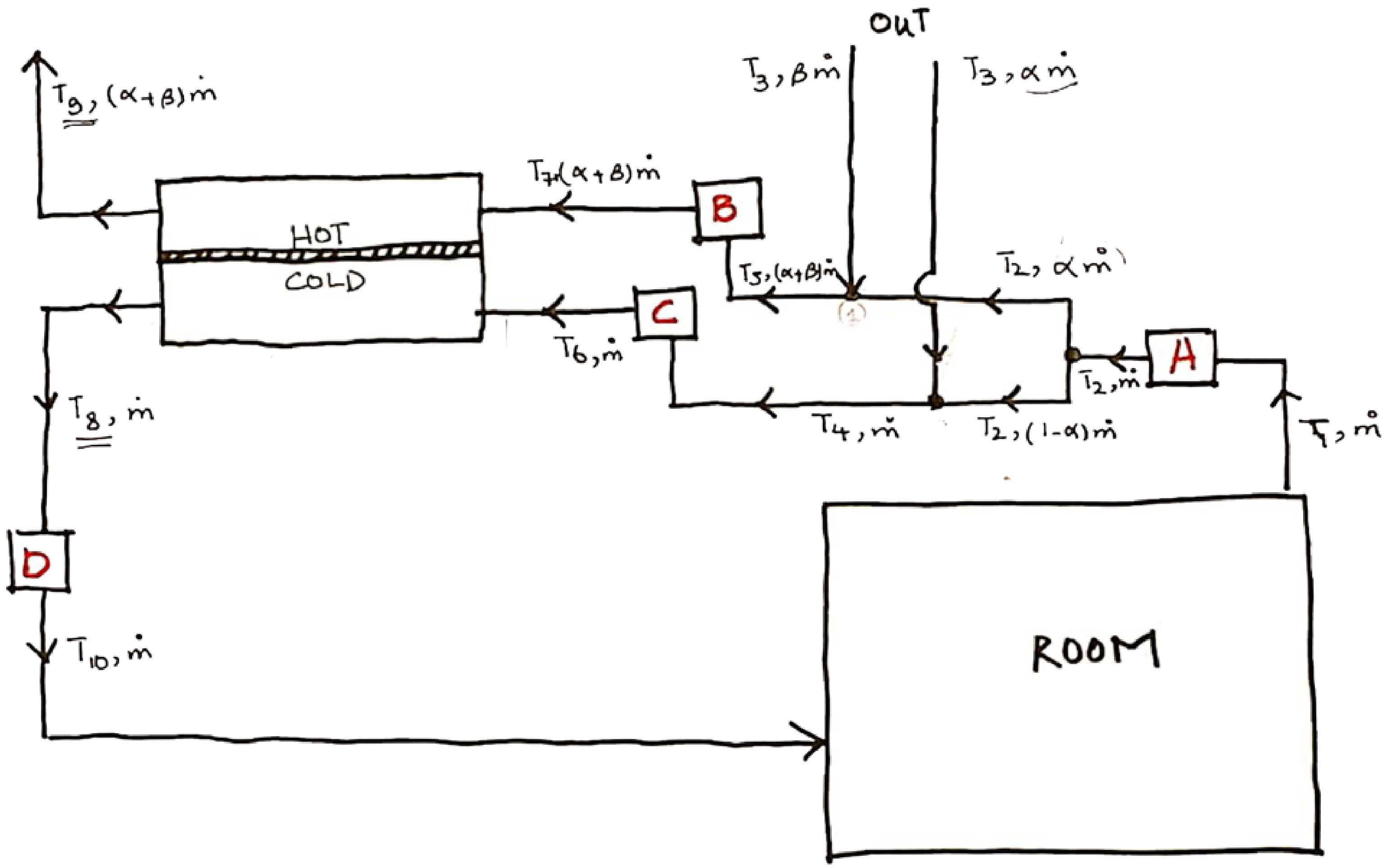
July-2:00 P.M

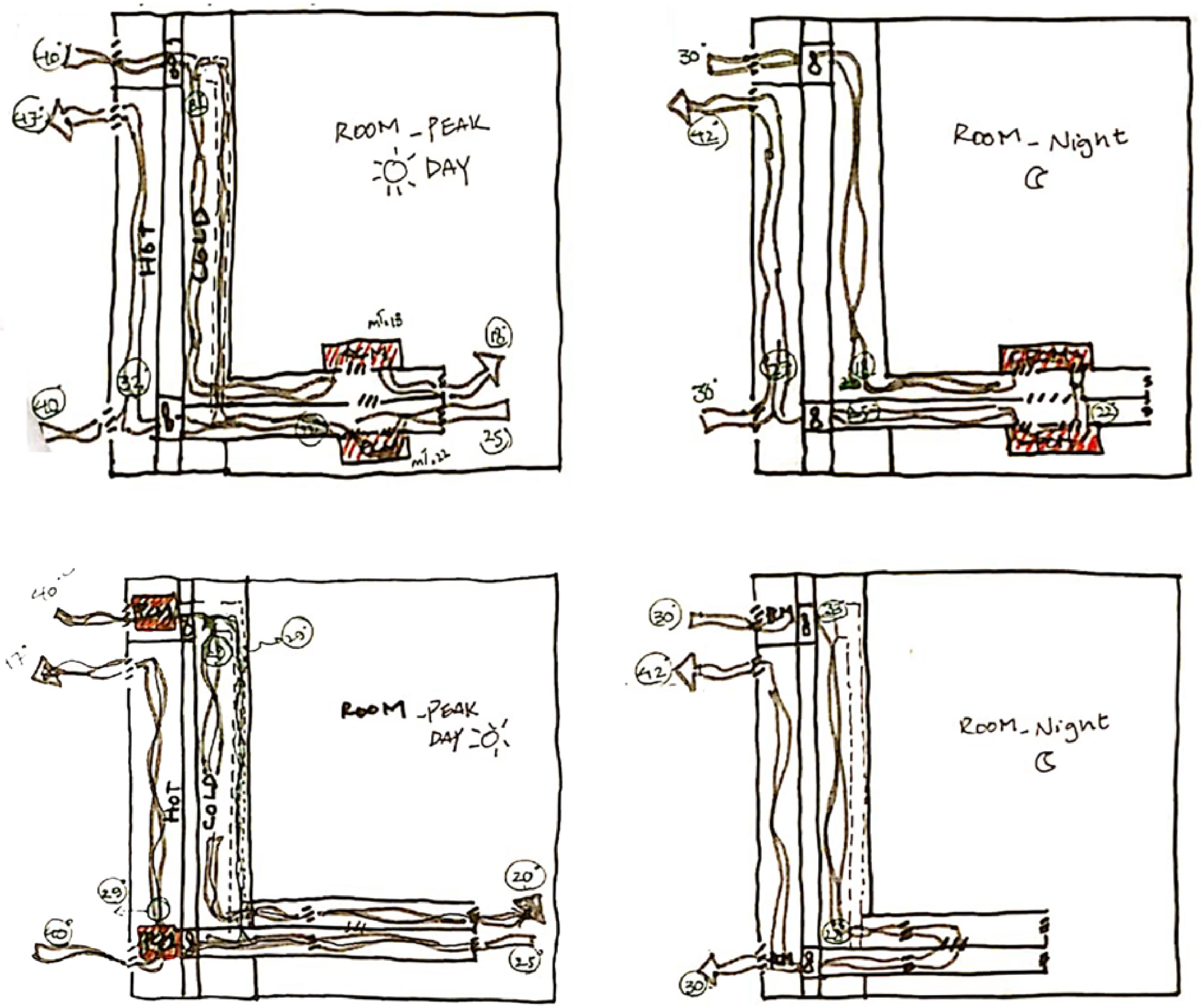


July-7:00 P.M



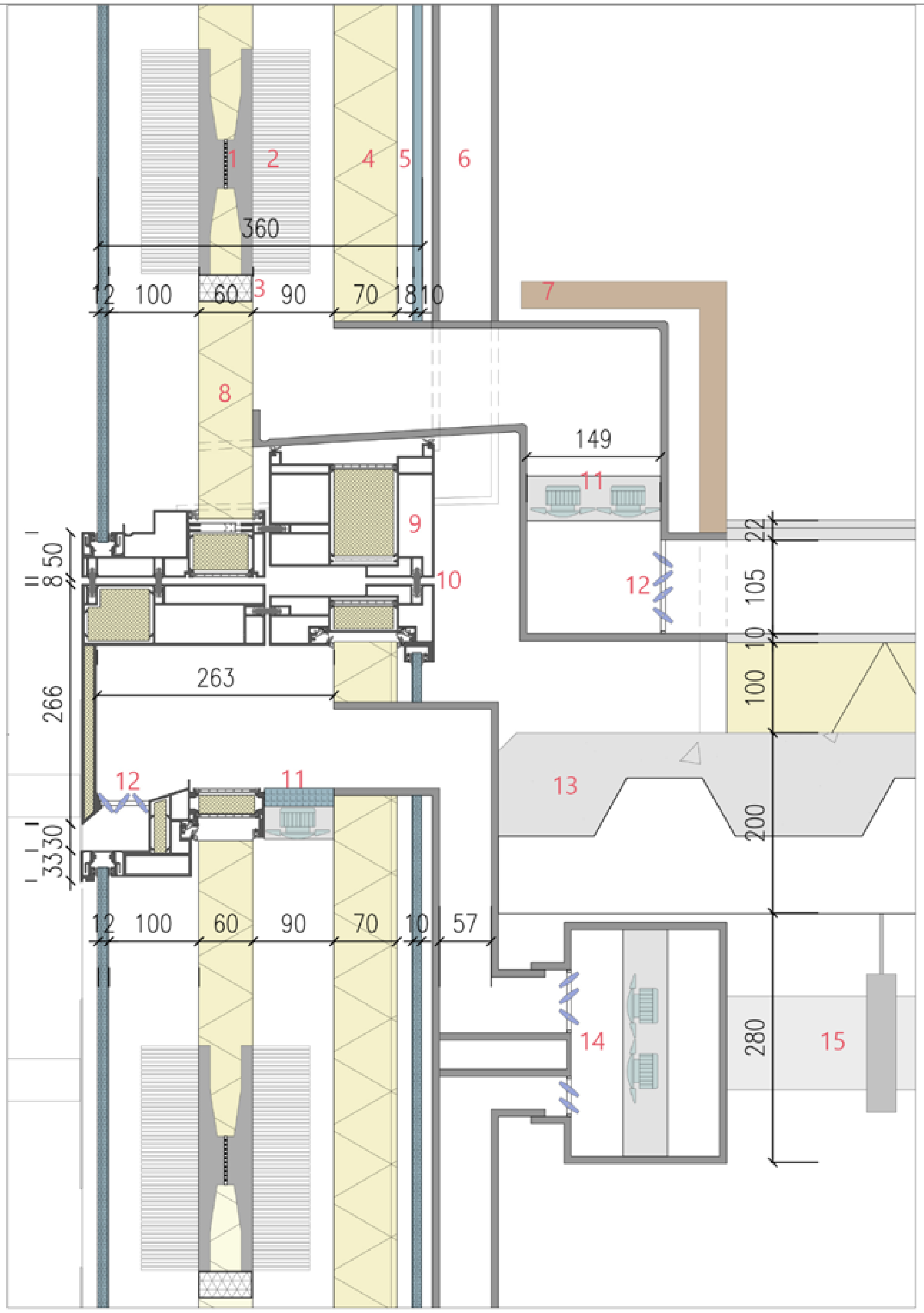
ENHANCING THE PERFROMANCE
PCM integration





FACADE DESIGN
Detailing

Section



1. TE element in contact with heat sink
2. Heat sinks
3. Aluminum frames supporting the heat sinks
4. Insulation-mineral wool
5. Gypsum board
6. Air channel
7. Wooden board
8. Insulation-mineral wool
9. Insulated aluminum frame
10. Gaskets
11. Fans and air filters
12. Dampers
13. Floor structure
14. Ventilation box
15. Extraction channels