Residential buildings with low heat demand.

The impact of design variables on the heat demand of residential buildings in the Netherlands.

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P5 presentation 22-05-2017

Sustainable Design Graduation Studio

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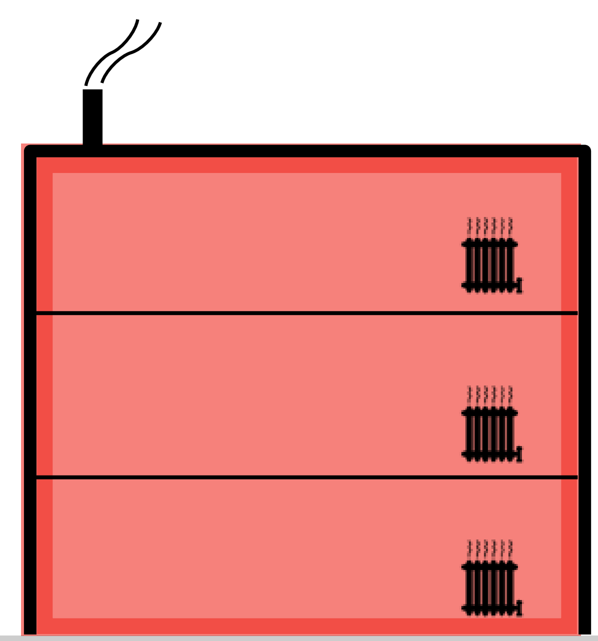


TU Delft

OVERVIEW

1. INTRODUCTION

1.1 Problem statement

1.2 Research questions

1.3 Methodology

1.1 Problem statement

- End of the fossil fuel age

- Societal demands on energy use

- Designers need to make the right decisions

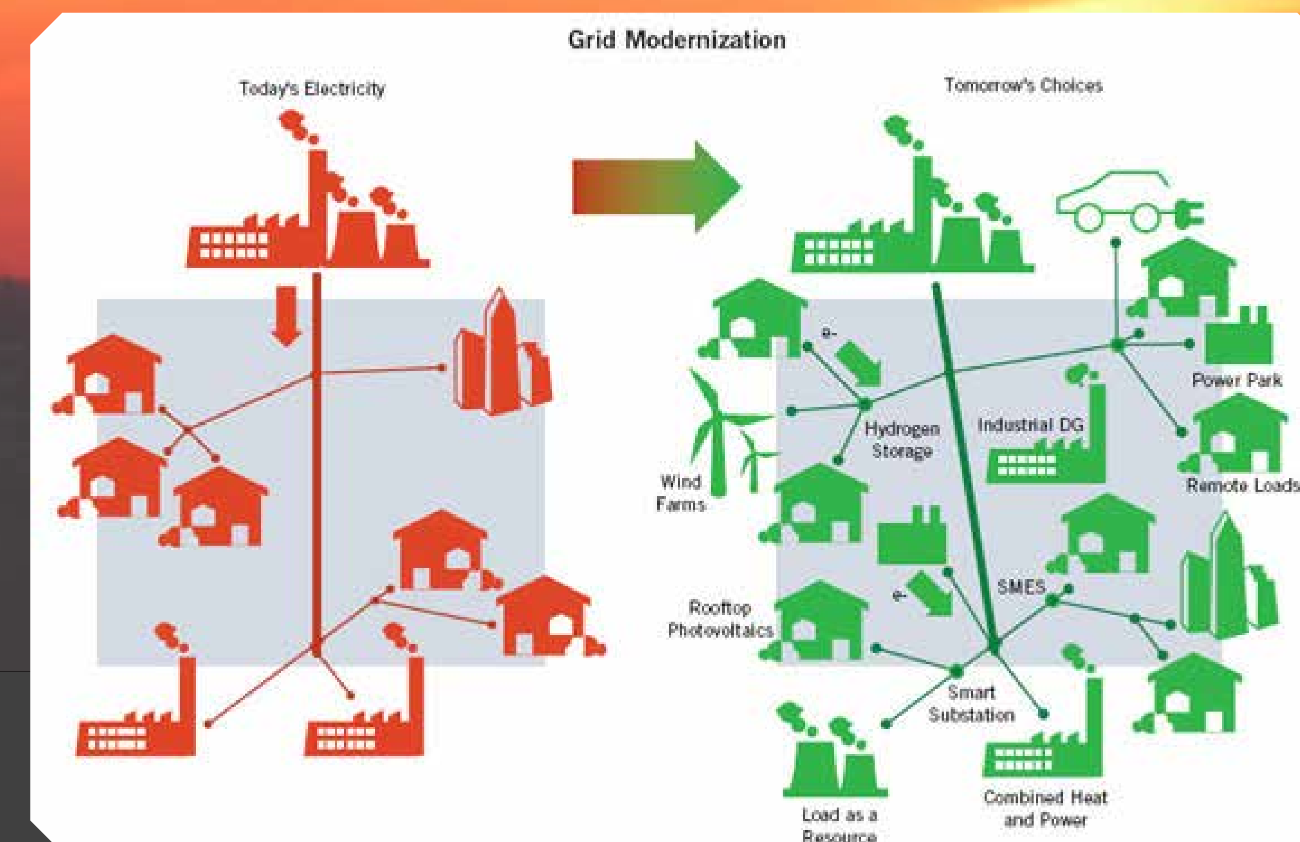
End of the fossil fuel age

Climate change spurs reduction of greenhouse emissions.

Geopolitical situation favors a move away from fossil fuel dependency.

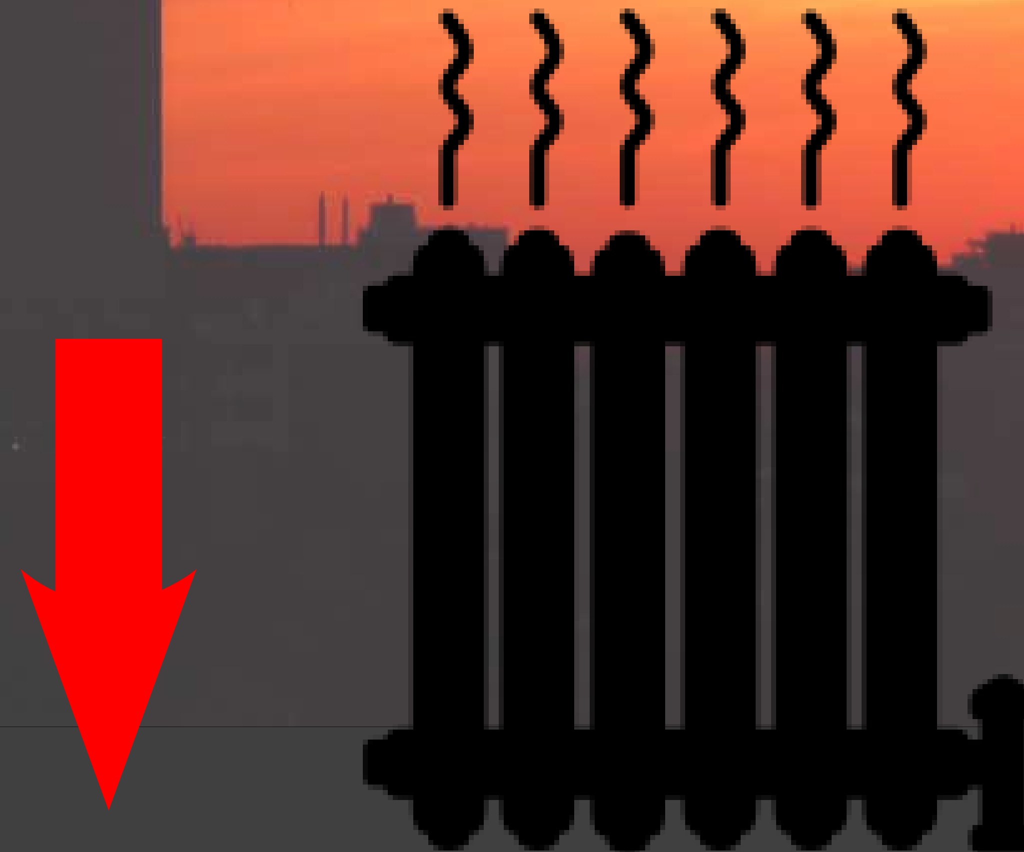
Societal demands on energy use

Dutch regulations: all new buildings (nearly) energy neutral starting 2021.



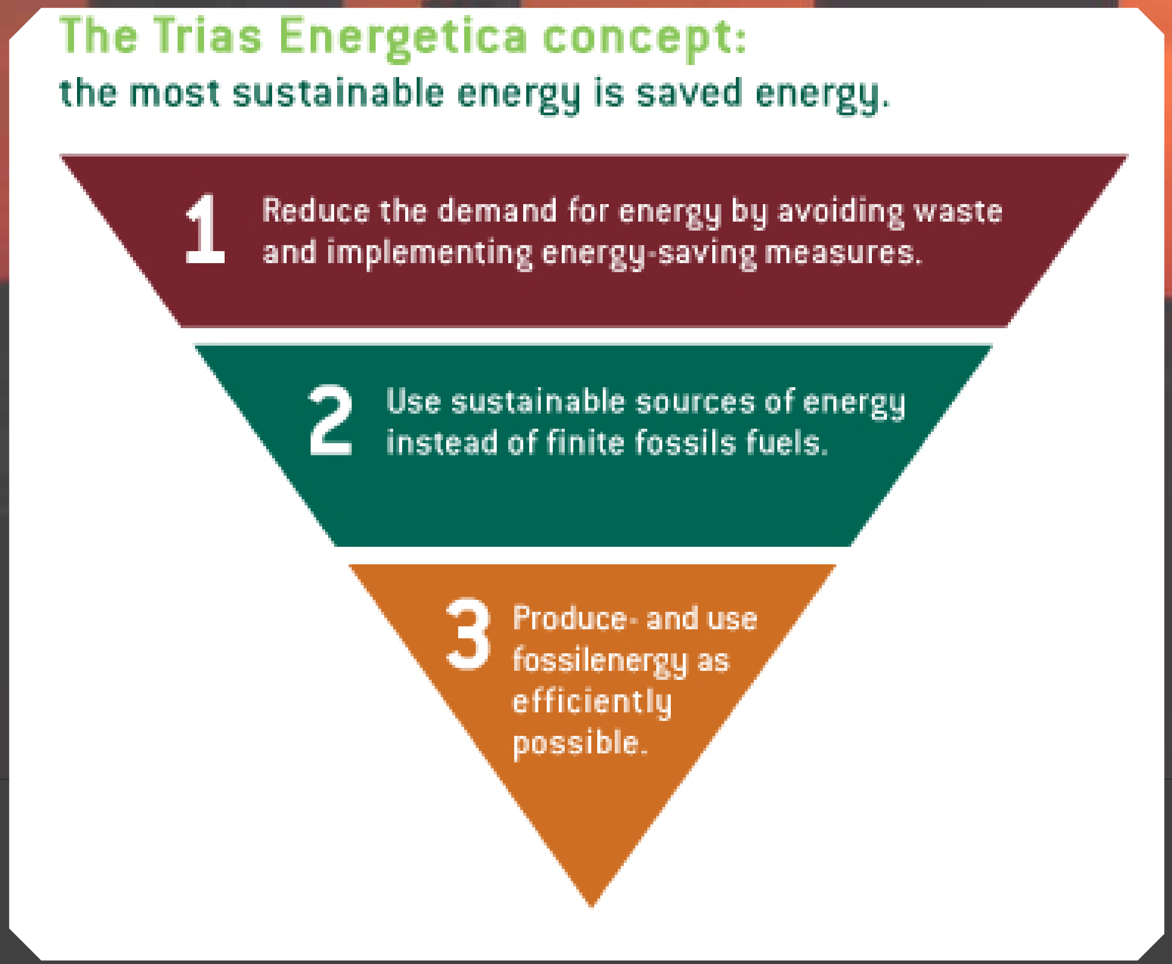
Rise of decentralized residential energy supply and storage.

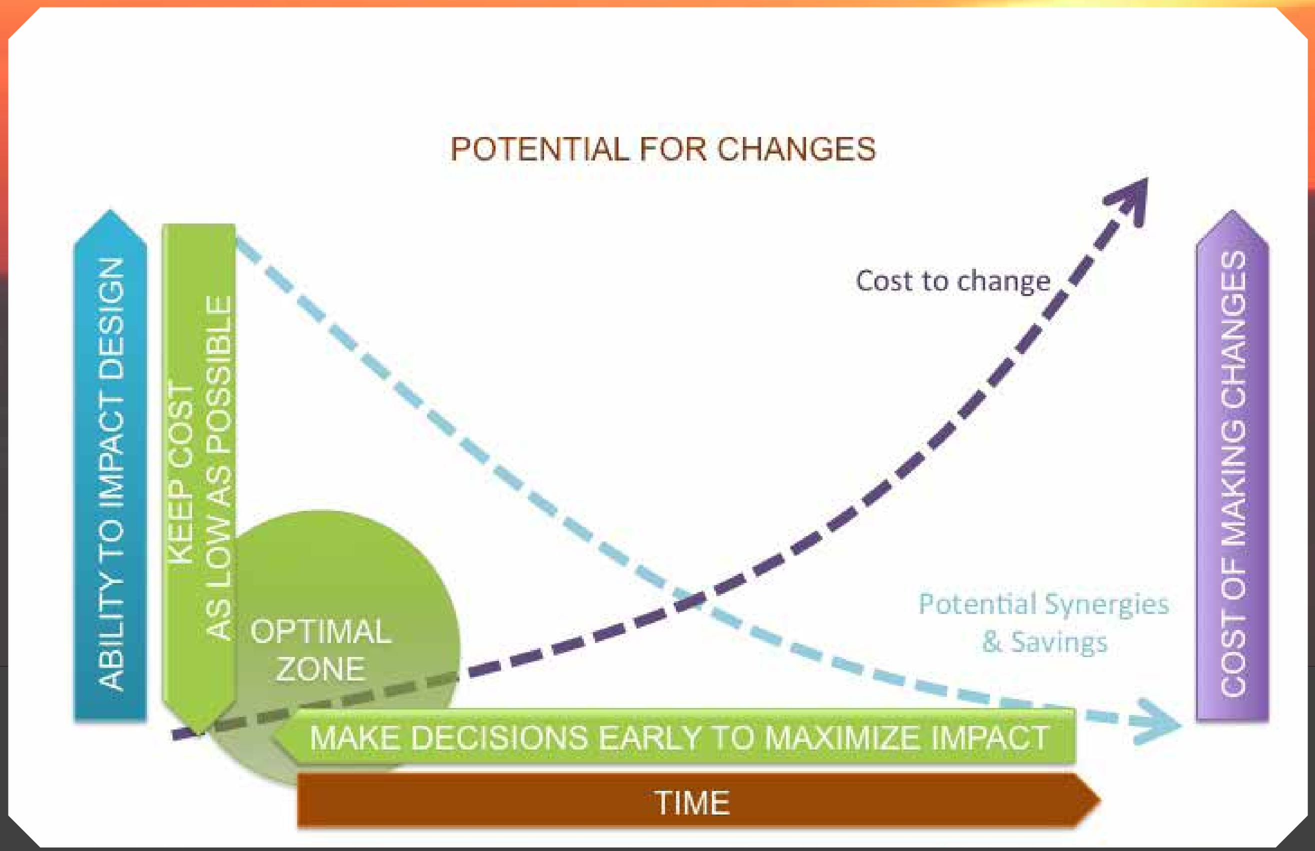
Societal demands on energy use



Reduction of heat demand

Designers need to make the right decisions





The first step is always heat demand reduction (Trias energetic etc.).

Early decisions have large impact for low cost.

1.2 Research questions

- Main question

- Sub questions

Main question:

What is the impact of design variables
on the heat demand of a residential building in the Netherlands
and what guidelines can be established for designers?

Sub-questions:

- *What design variables are relevant to the heat demand of a building?*
- *How can the impact of design variables on the heat demand of a building be calculated?*
- *How can the knowledge of this impact best be applied to an actual building?*
- *How can guidelines for designers best be formulated?*

Categorize - Quantify - Qualify

1.	1. = 100	2. 60
2.	2. = 60	3. 80
3.	3. = 80	1. 100

1.3 Methodology

- Goals

- Process

Goals:

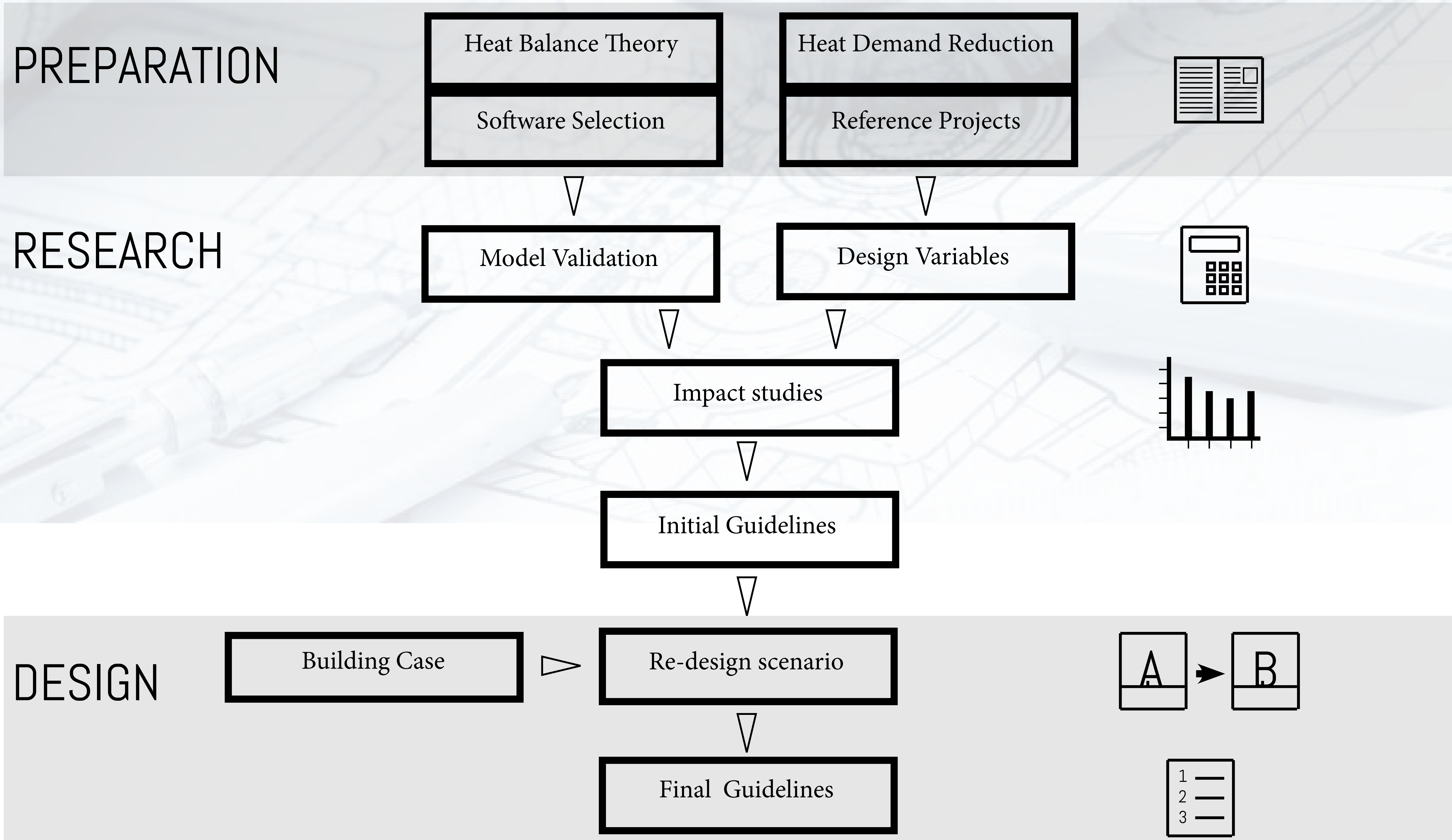
1. Make inventory of relevant design variables through literature review and reference study.

2. Establish and validate a method to calculate the impact of design variables on heat demand.

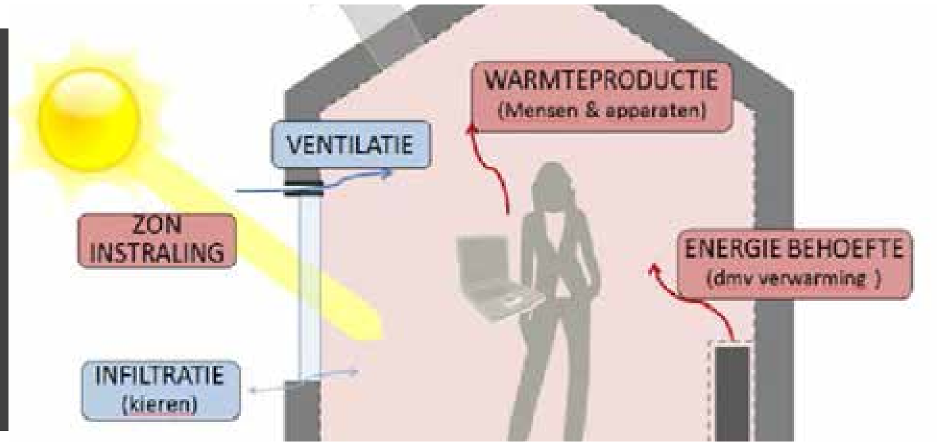
3. Study the impact of the design variables and apply the conclusions to a case study building.

4. Establish clear guidelines for designers.

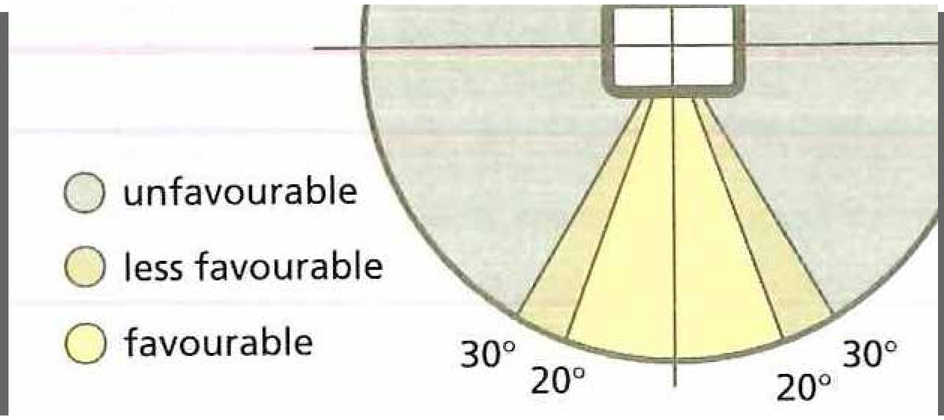
Process:


PREPARATION
Heat Balance Theory
Software Selection
Heat Demand Reduction
Reference Projects
RESEARCH
Model Validation
Design Variables
Impact studies
Initial Guidelines
DESIGN
Building Case
Re-design scenario
Final Guidelines
A
B
1
2
3

2. LITERATURE REVIEW

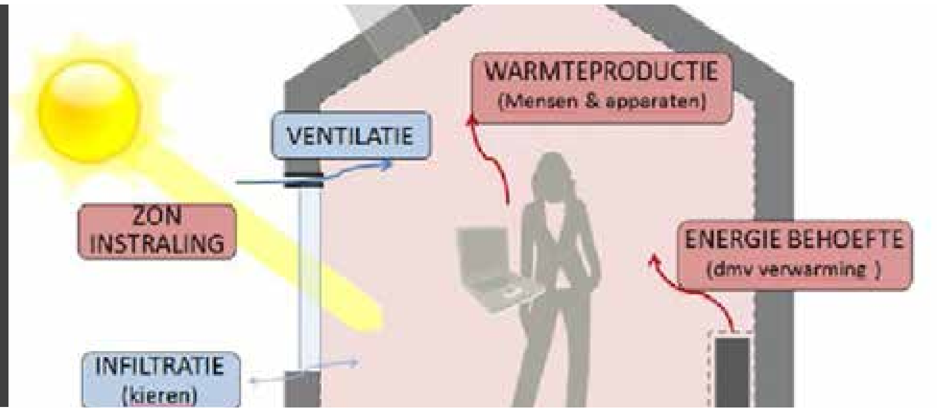


2.1 Heat balance theory



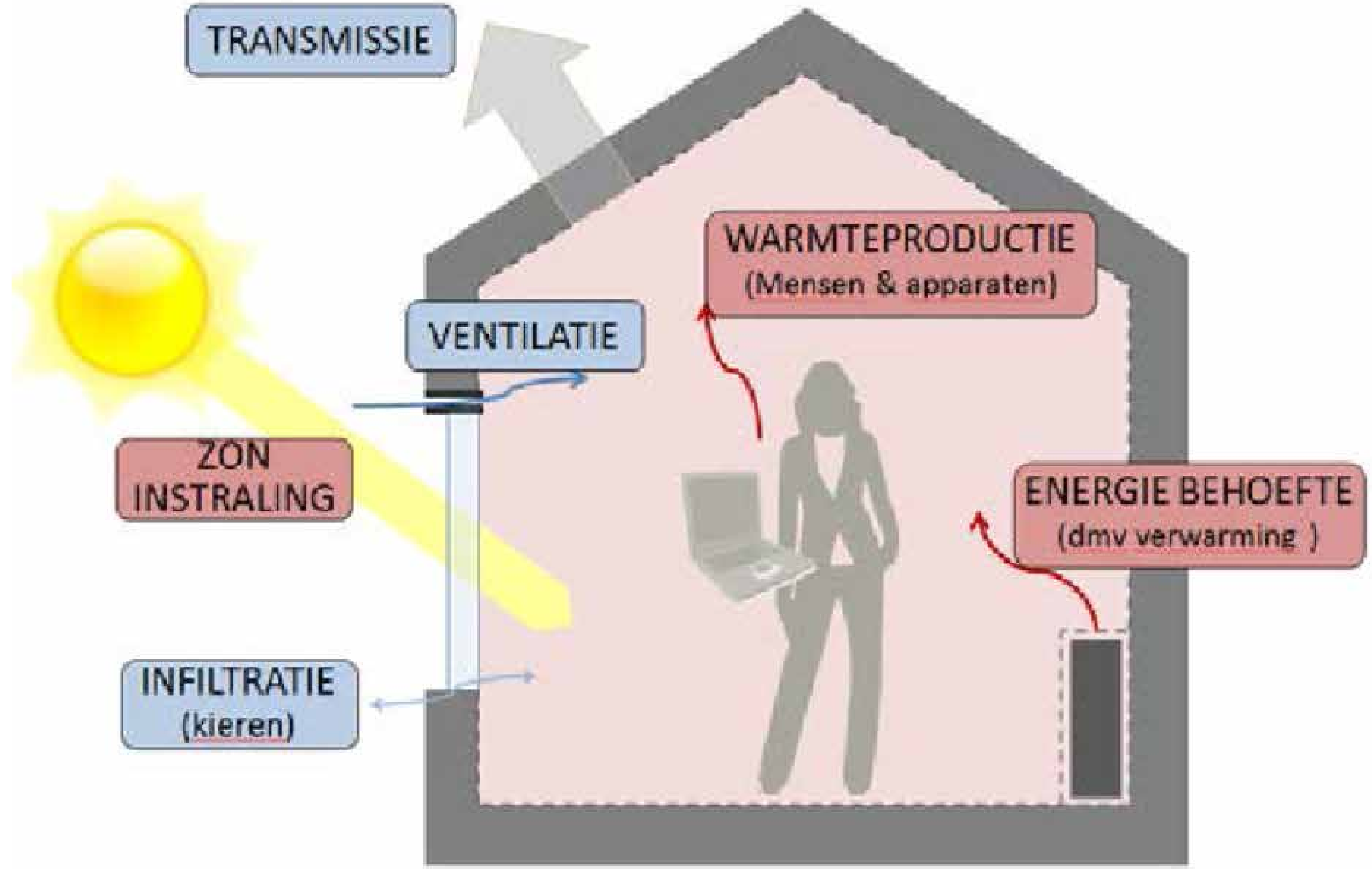
2.2 Design variables

2.3 Reference projects



2.1 Heat Balance theory

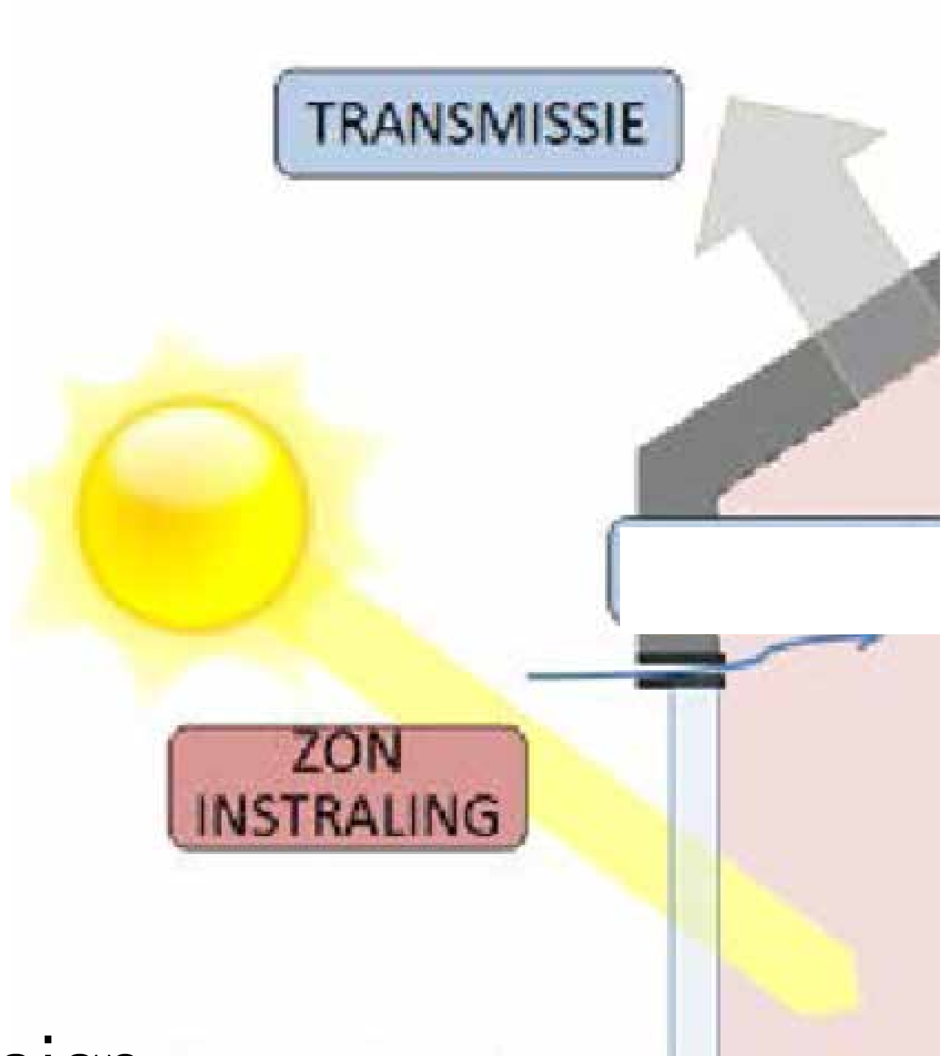
- General Theory
- Transmission Heat Loss
- Solar Heat Gain



General Theory

-Ventilation heat loss
- Infiltration heat loss
- Transmission heat loss

+ Internal heat gain
+ Solar heat gain



Most influenced by building design

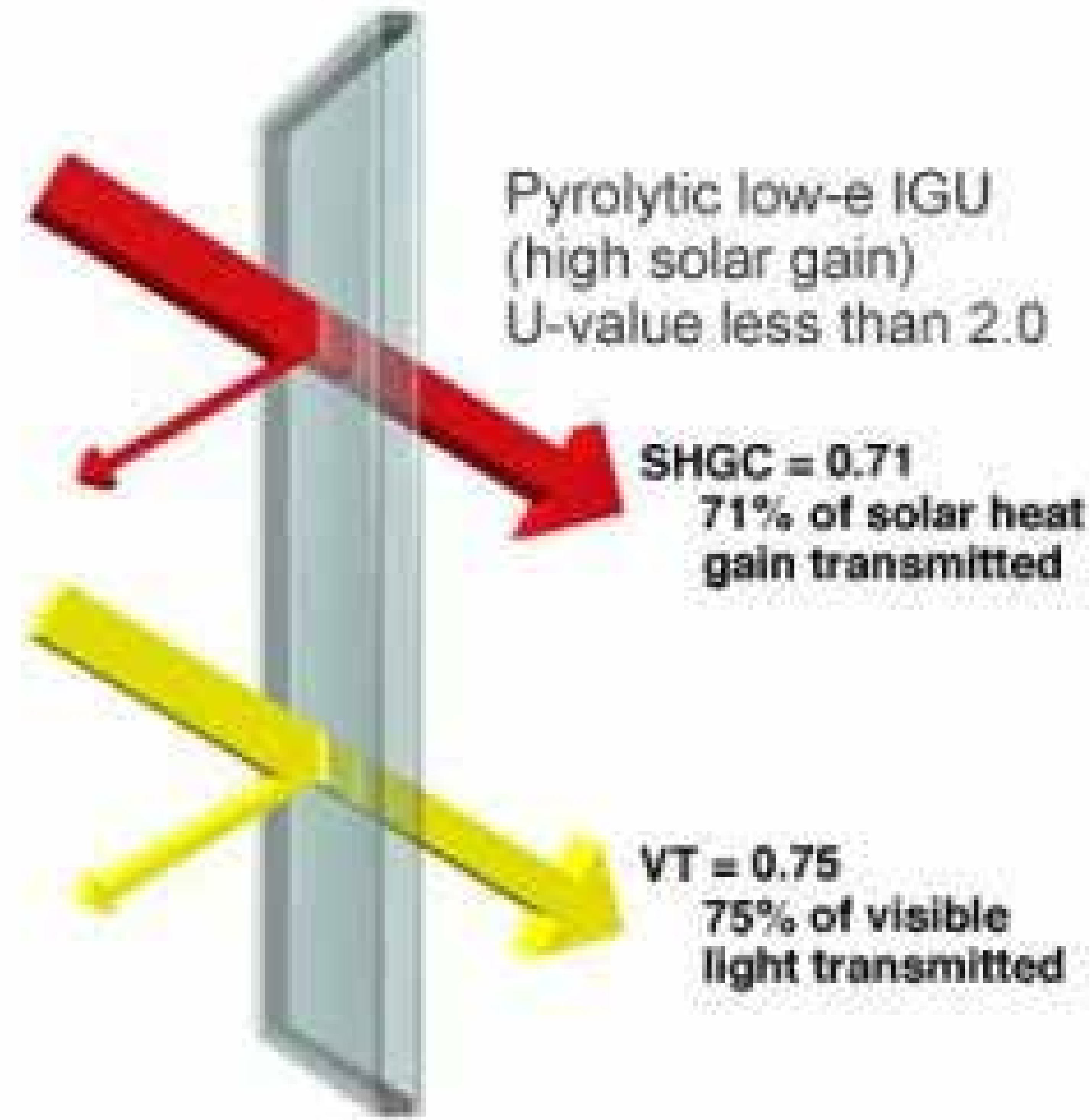
-Ventilation heat loss
- Infiltration heat loss
- Transmission heat loss

+ Internal heat gain
+ Solar heat gain

Transmission heat loss

- temperature difference interior-exterior causes heat flow.

- material in between determines rate of flow.

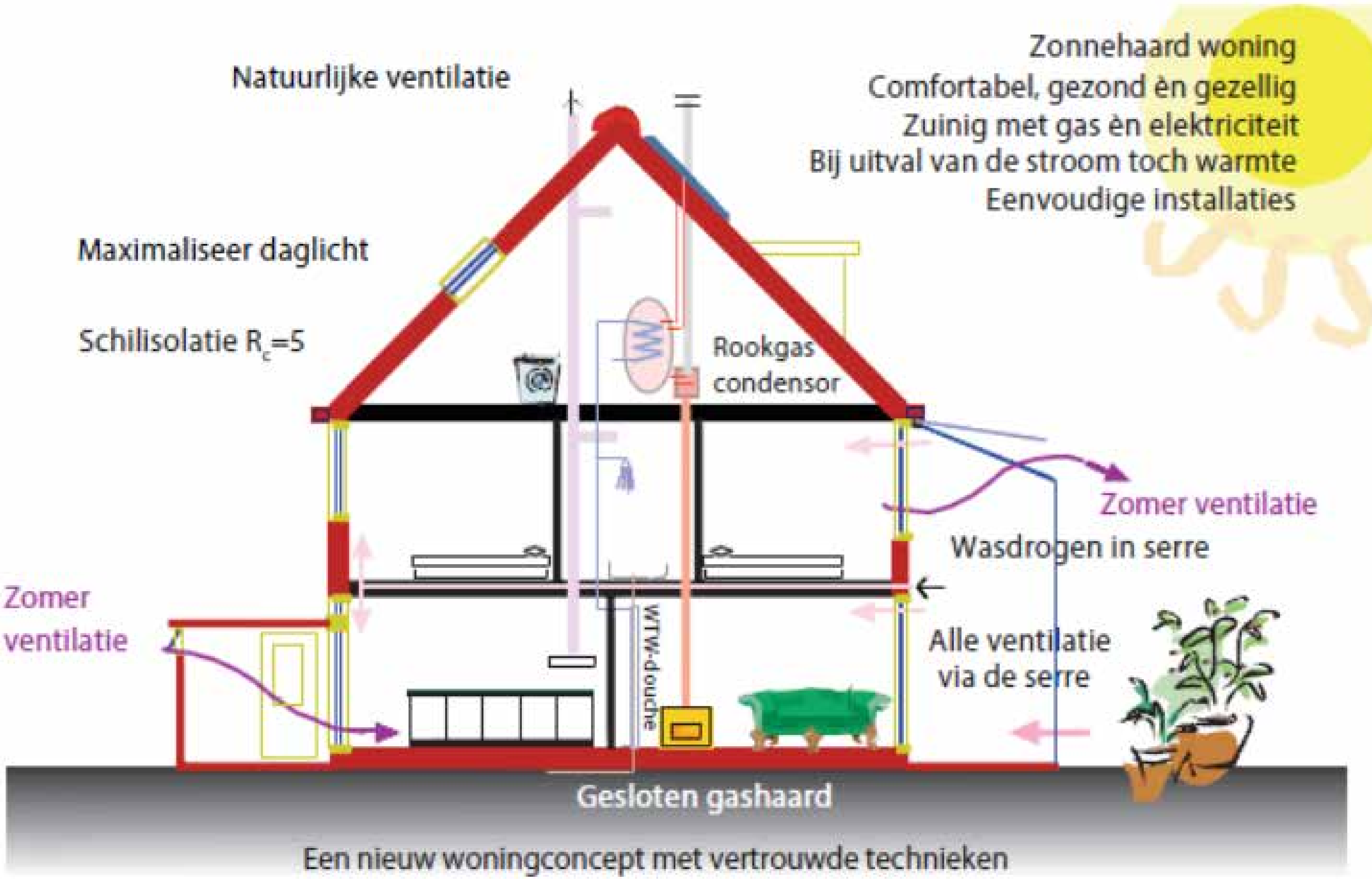


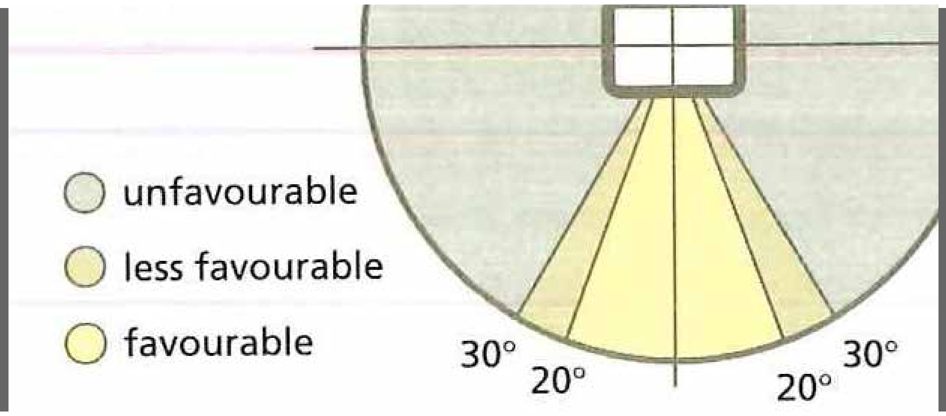
Solar heat gain

+ window surface area

+ solar tranmittance of the window

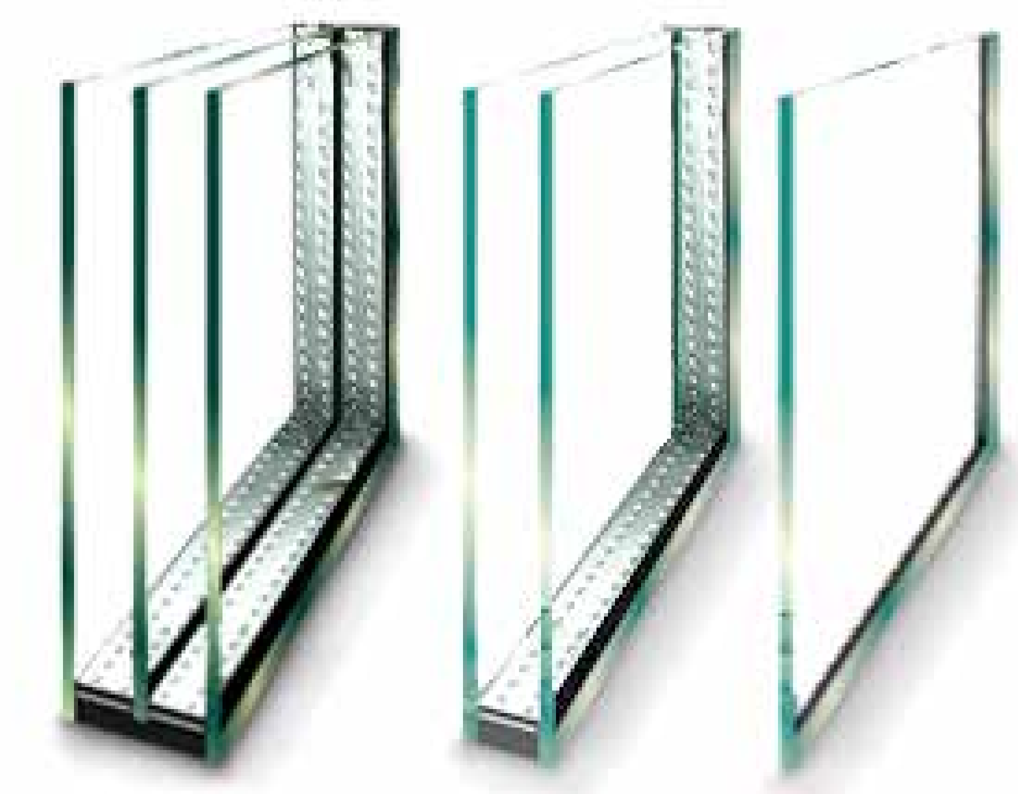
+ angle of sunlight and obstructions


Zonnehaard woning
Comfortabel, gezond èn gezellig
Zuinig met gas èn elektriciteit
Bij uitval van de stroom toch warmte
Eenvoudige installaties
Natuurlijke ventilatie
Maximaliseer daglicht
Schilisolatie R_c=5
Rookgas condensor
Zomer ventilatie
Wasdrogen in serre
Zomer ventilatie
Alle ventilatie via de serre
WTW-douche
Gesloten gashaard
Een nieuw woningconcept met vertrouwde technieken



2.2 Design Variables

- Insulation
- Orientation
- Building Shape
- Sunspaces

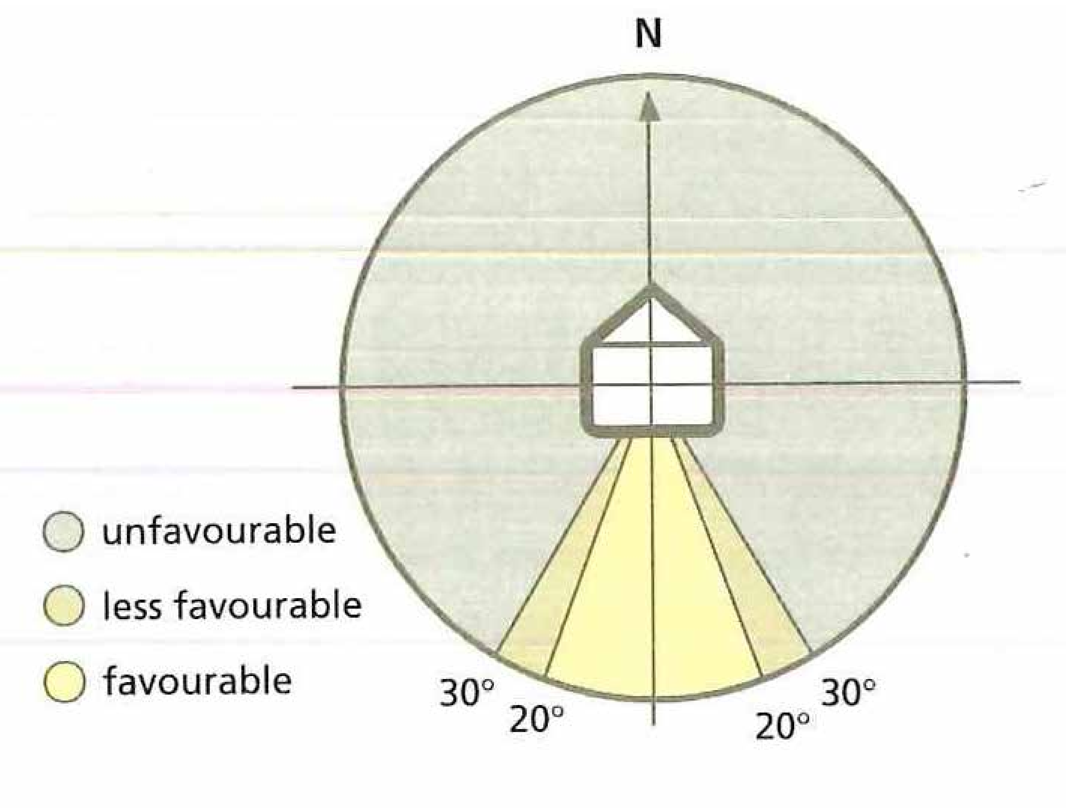


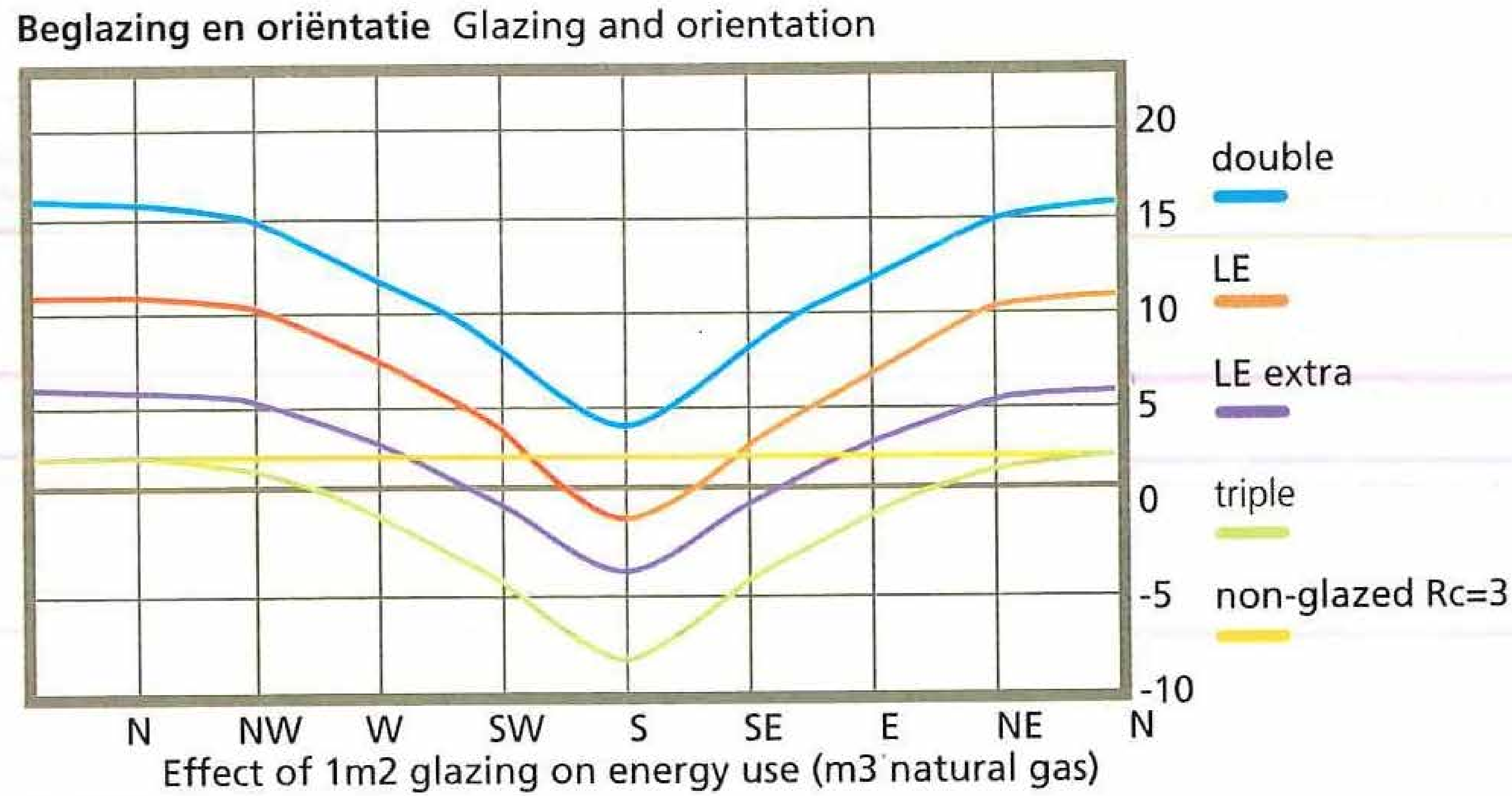
Insulation

- Reduces transmission heat loss.

- Walls (Building code: Rc >= 4.5)

- Windows (Building code: U =< 1.6)

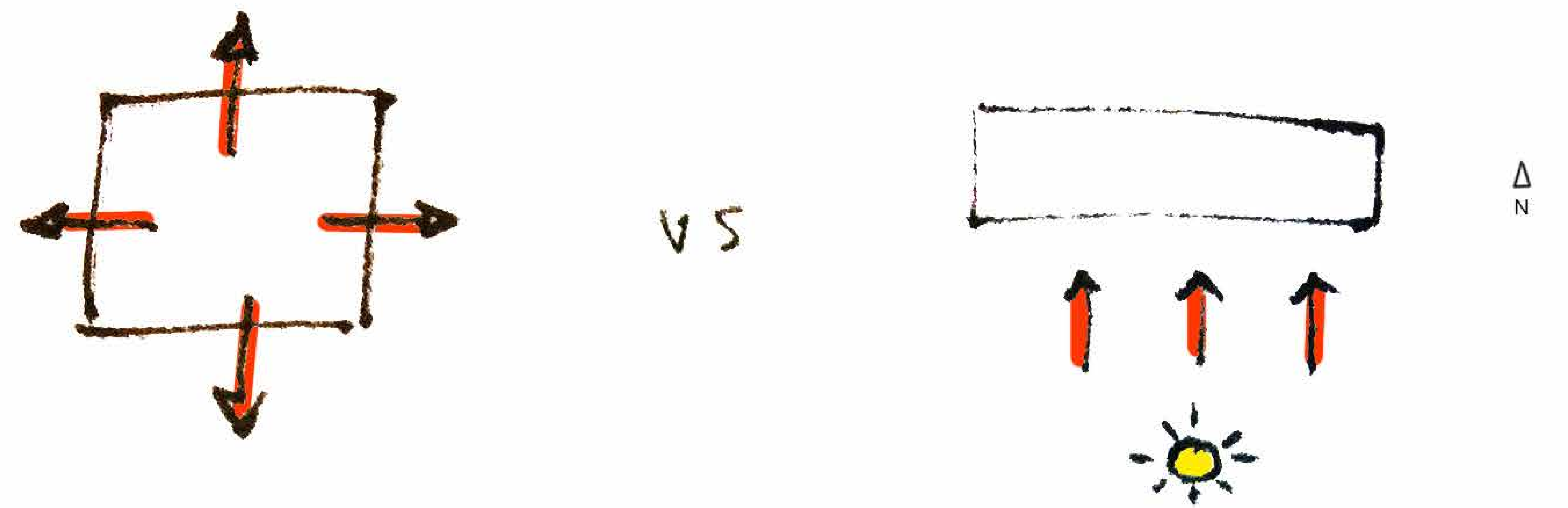




Orientation

+ Increases solar heat gain.

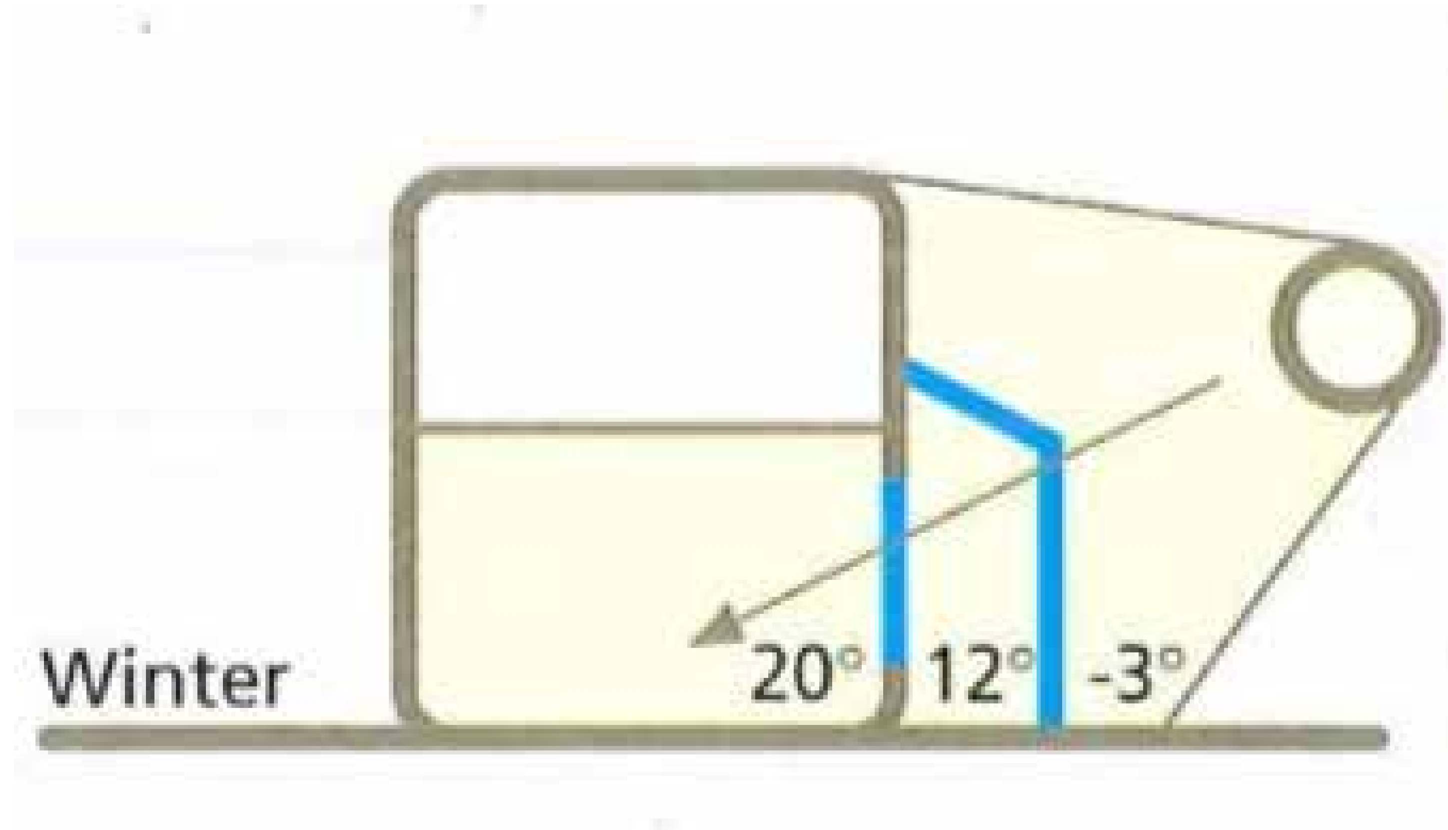
+ Benefits from window insulation.



Building shape

- Compactness: less facade surface area per interior volume means less transmission heat loss.

+ Shape factor: more surface facing the sun (south) means more solar heat gain.

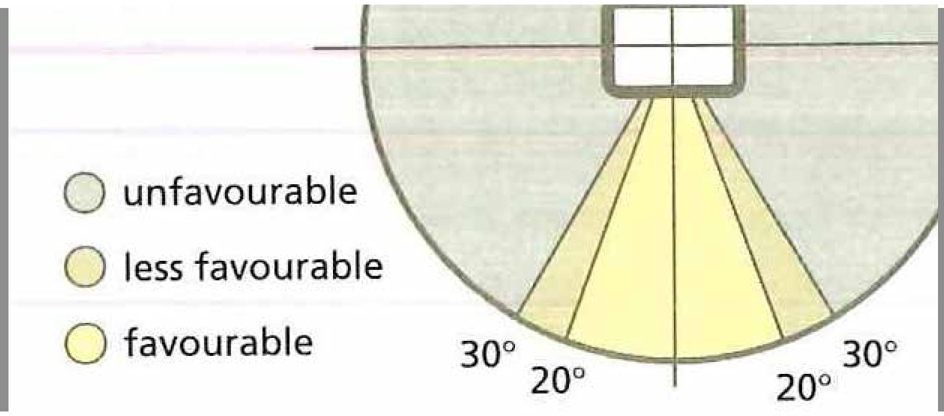


Sunspaces

+ Increased solar heat gain potential.

- Acts as buffer zone that decreases transmission heat loss.

+ Can provide comfortable use during cold season.



2.3 Reference projects

- Freiburg SSSH
- BedZED

Freiburg SSSH

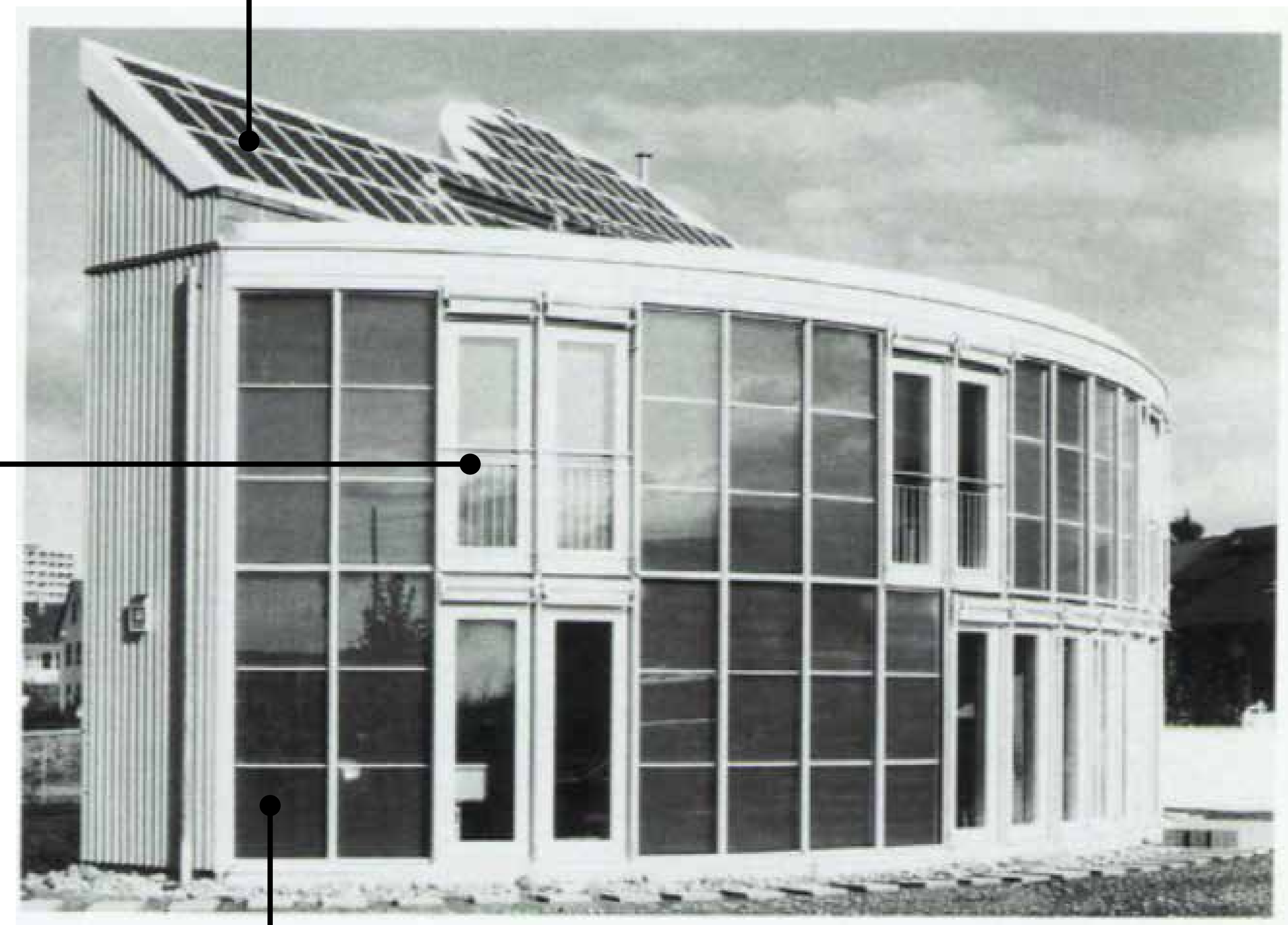
Self-Sustaining Solar House

- *Expected heat demand: 2 kWh/m²*
- *high-tech*

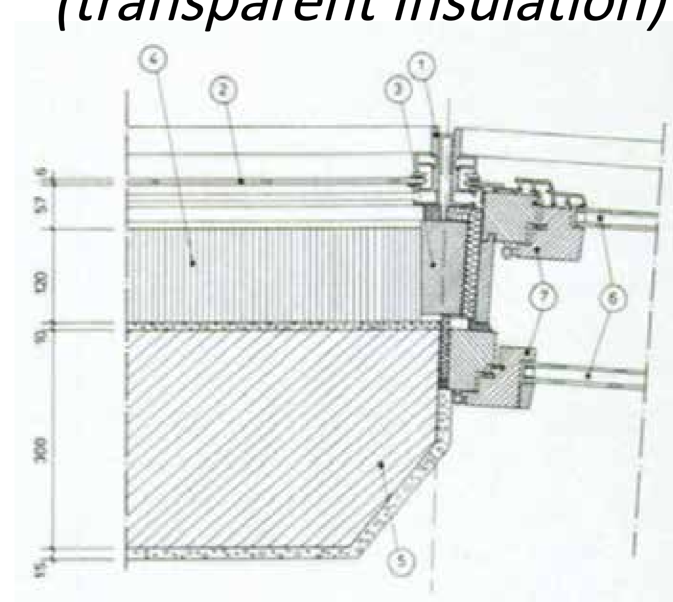
Freiburg SSSH

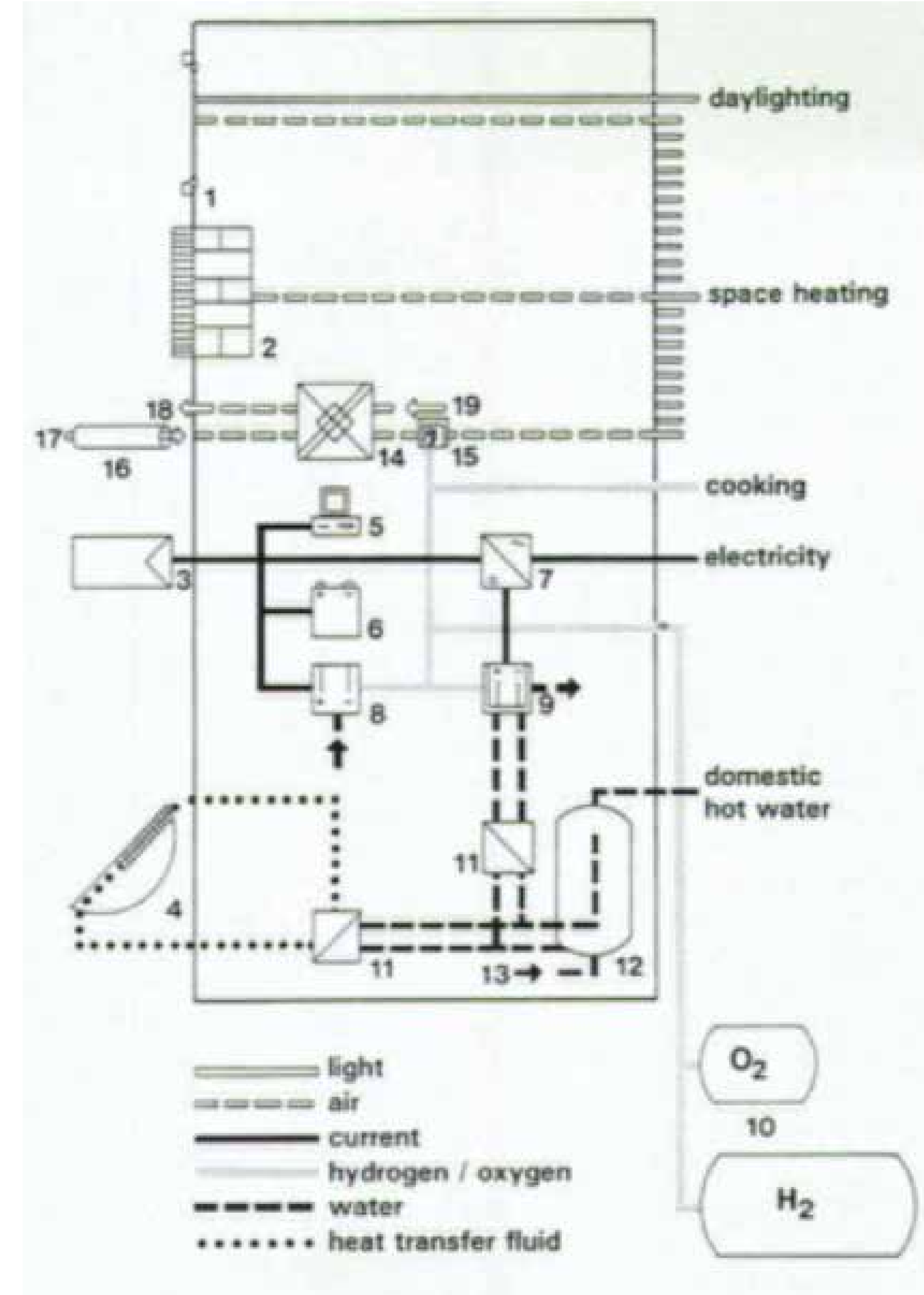
PV panels and Solar collectors

All rooms have windows oriented towards sun.



Heat storage in walls with TI (transparent Insulation)



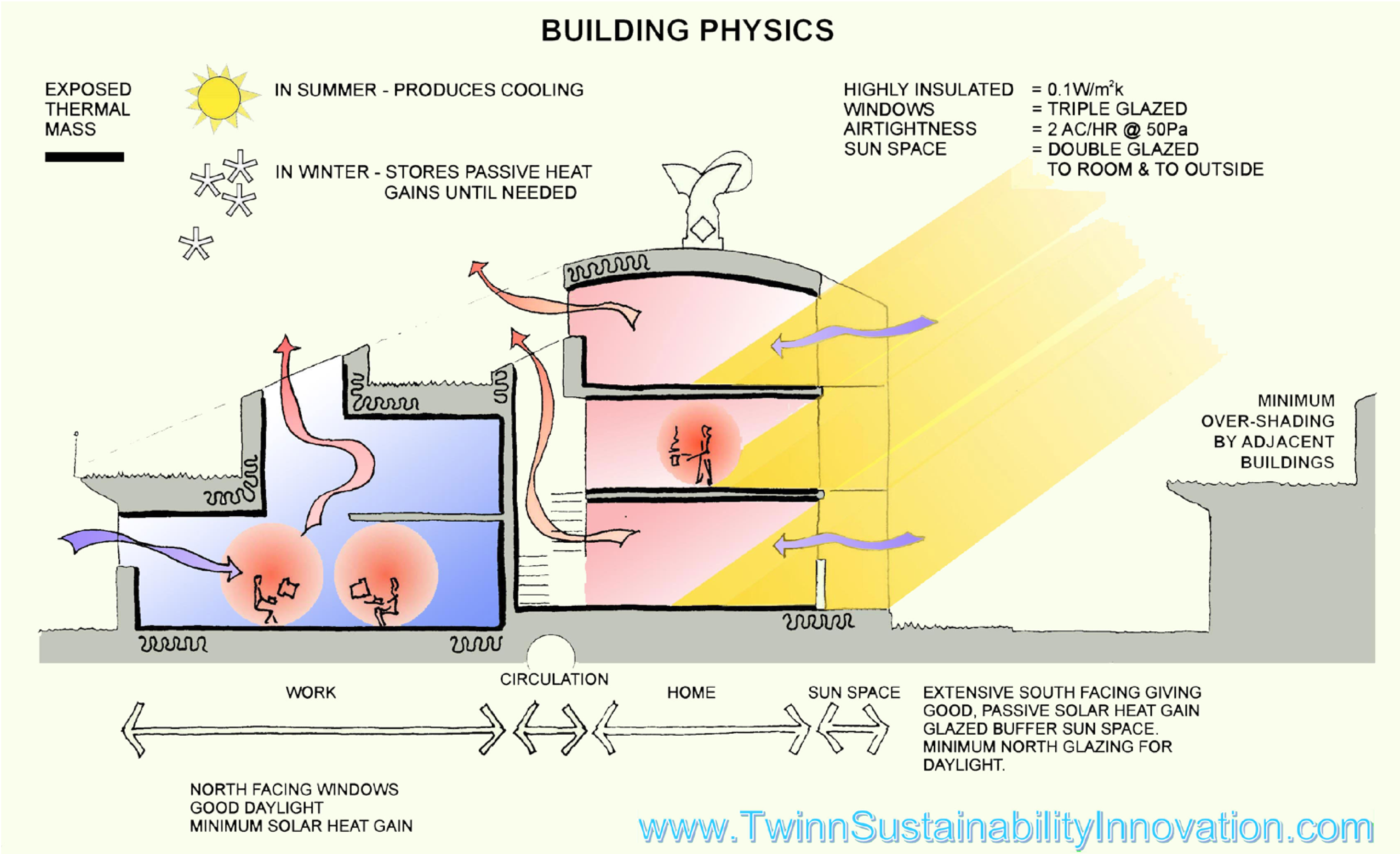


Hydrogen power storage

BedZED
Beddington Zero Energy Development

- *Passive house principle*
- *Combined use: house and office*
- *No primary heating system*
- *Centralized backup heating system*
- *Sunspace*

BedZED


BUILDING PHYSICS
EXPOSED THERMAL MASS
IN SUMMER - PRODUCES COOLING
IN WINTER - STORES PASSIVE HEAT GAINS UNTIL NEEDED
HIGHLY INSULATED = 0.1W/m²k
WINDOWS = TRIPLE GLAZED
AIRTIGHTNESS = 2 AC/HR @ 50Pa
SUN SPACE = DOUBLE GLAZED TO ROOM & TO OUTSIDE
MINIMUM OVER-SHADING BY ADJACENT BUILDINGS
WORK
CIRCULATION
HOME
SUN SPACE
EXTENSIVE SOUTH FACING GIVING GOOD, PASSIVE SOLAR HEAT GAIN
GLAZED BUFFER SUN SPACE.
MINIMUM NORTH GLAZING FOR DAYLIGHT.
NORTH FACING WINDOWS
GOOD DAYLIGHT
MINIMUM SOLAR HEAT GAIN
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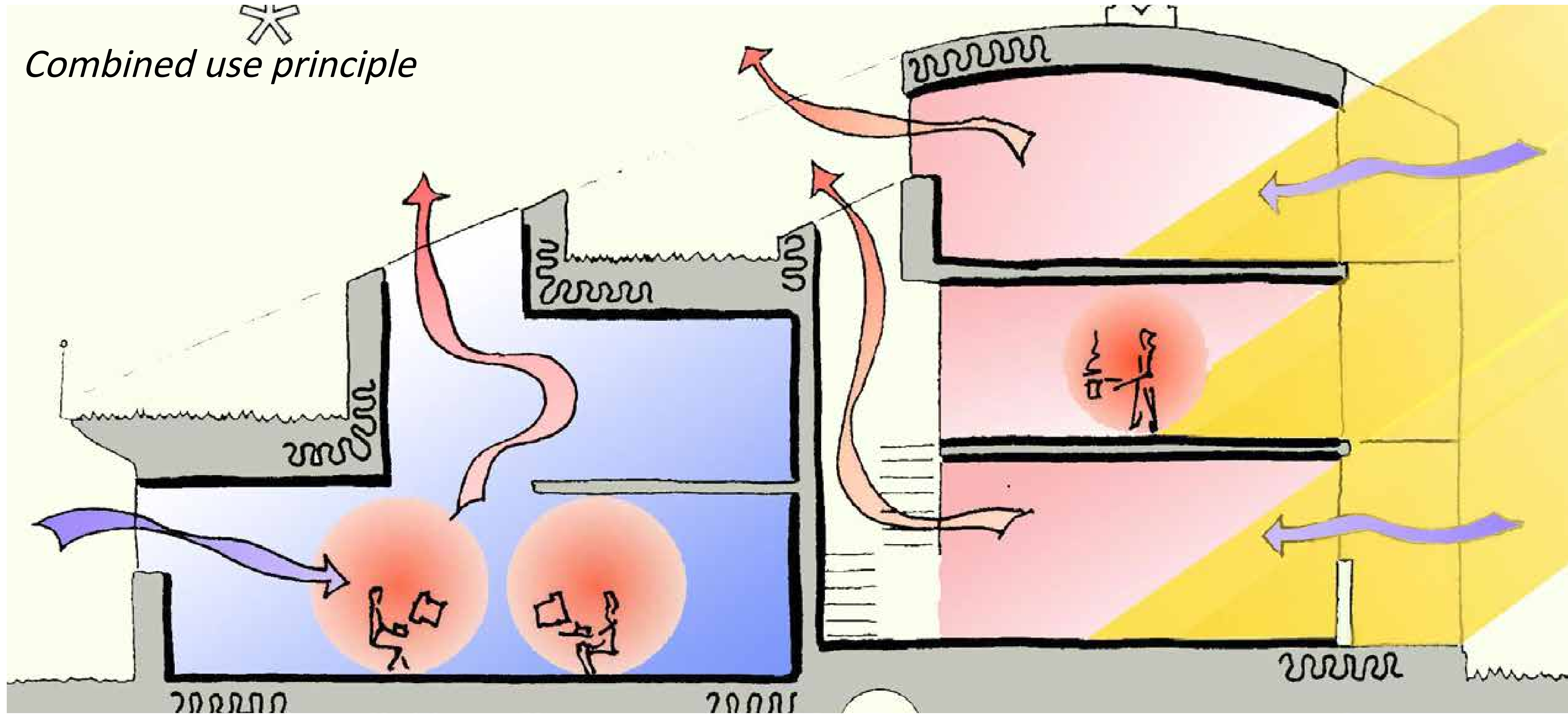
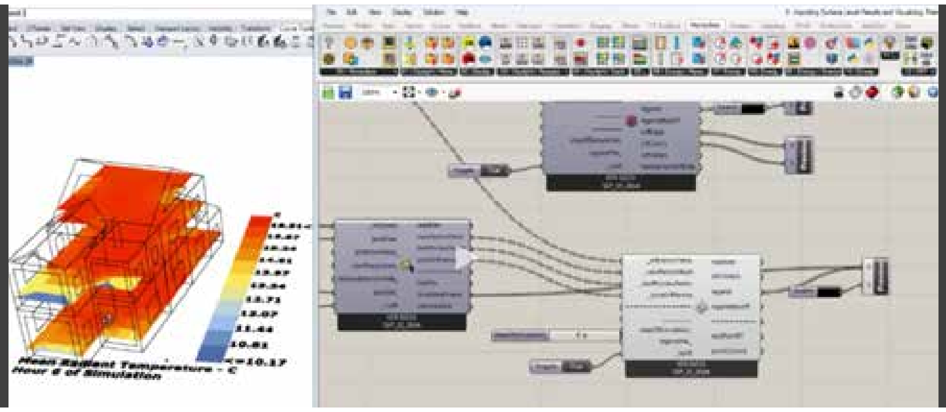
BedZED



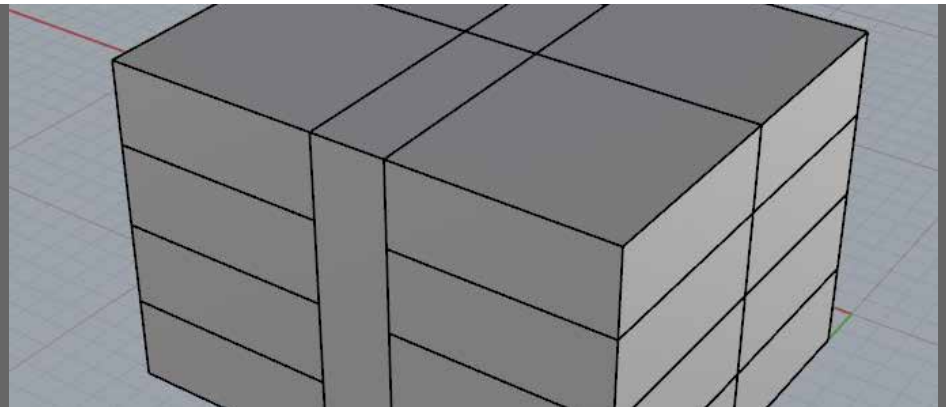
Internal heat gain *Solar heat gain*

HIGHLY INSULATED	= 0.1W/m^{2}k
WINDOWS	= TRIPLE GLAZED
AIRTIGHTNESS	= 2 AC/HR @ 50Pa
SUN SPACE	= DOUBLE GLAZED TO ROOM & TO OUTSIDE

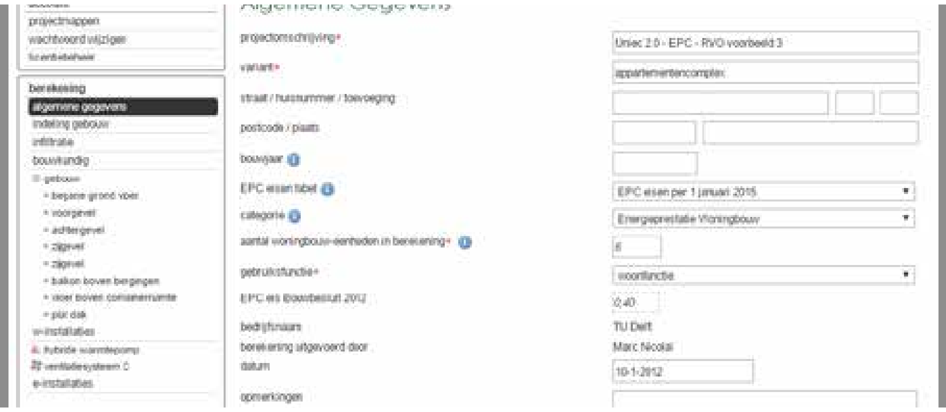
3. HEAT DEMAND CALCULATION



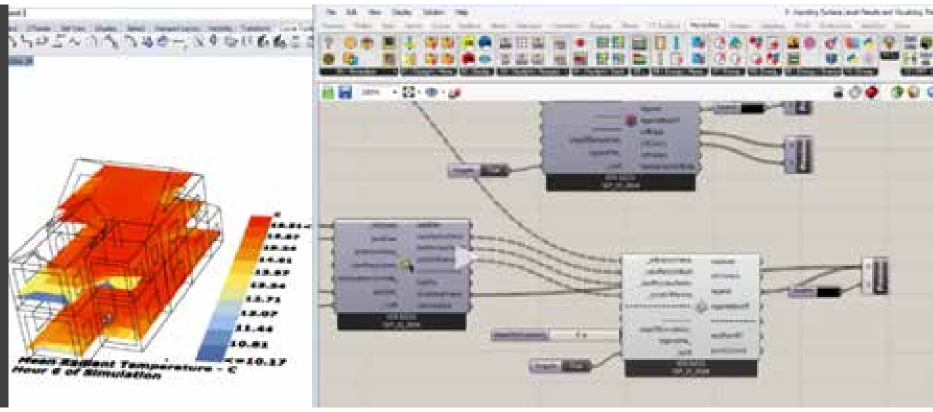
3.1 Software selection



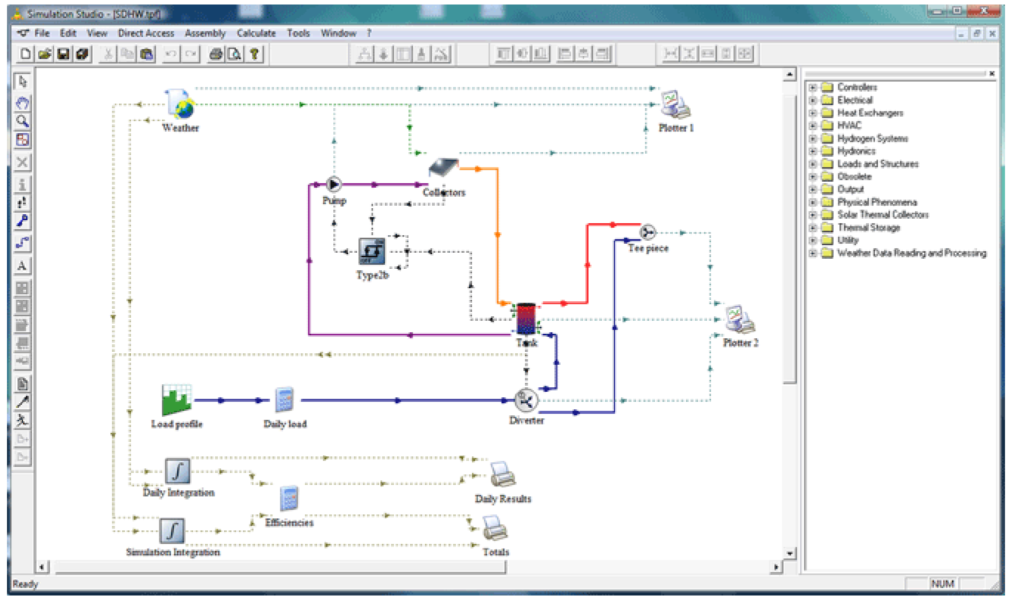
3.2 Case building modelling



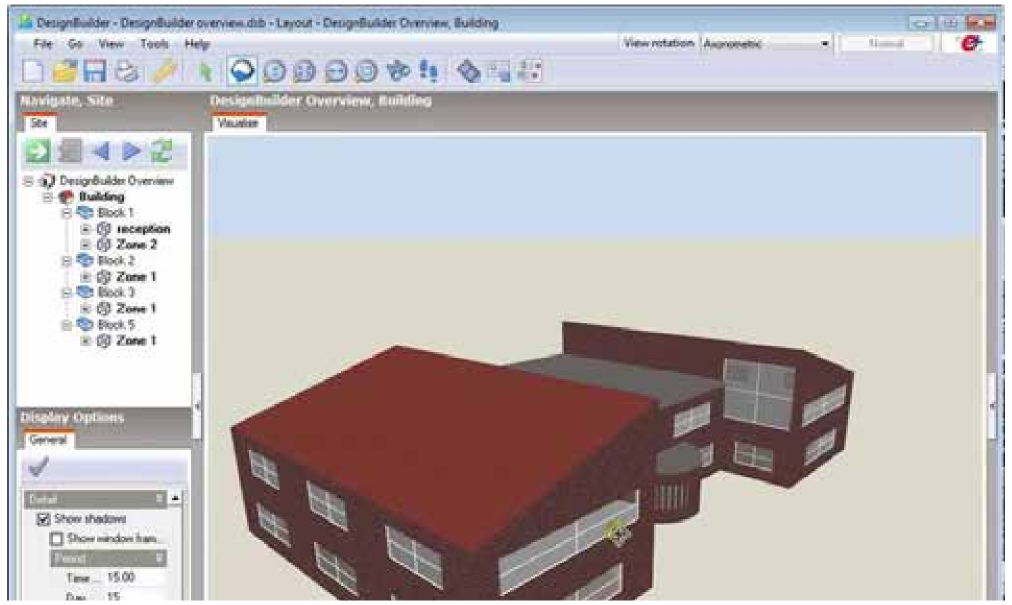
3.3 Validation calculations



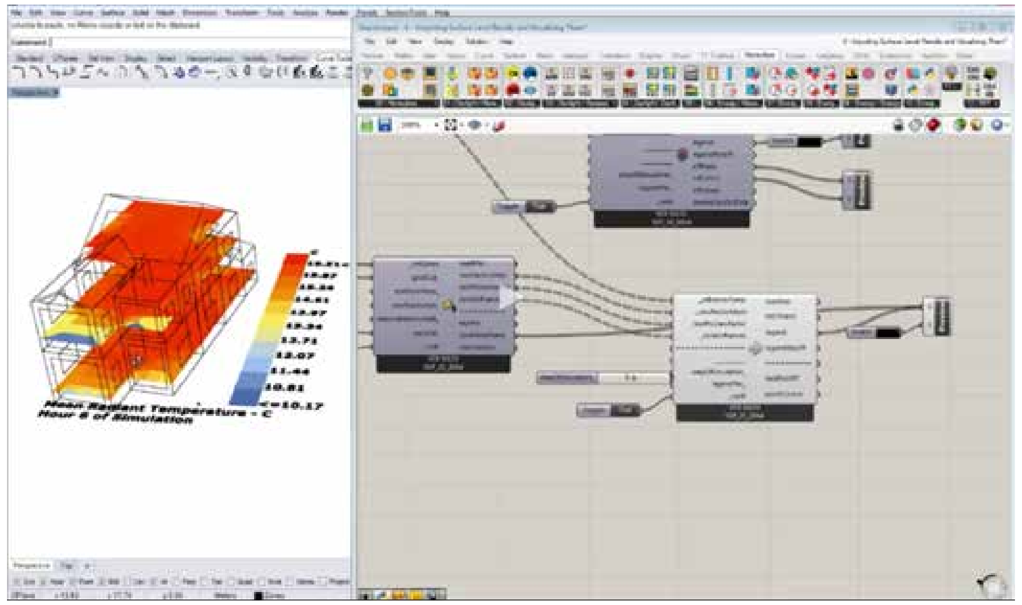
3.1 Software selection



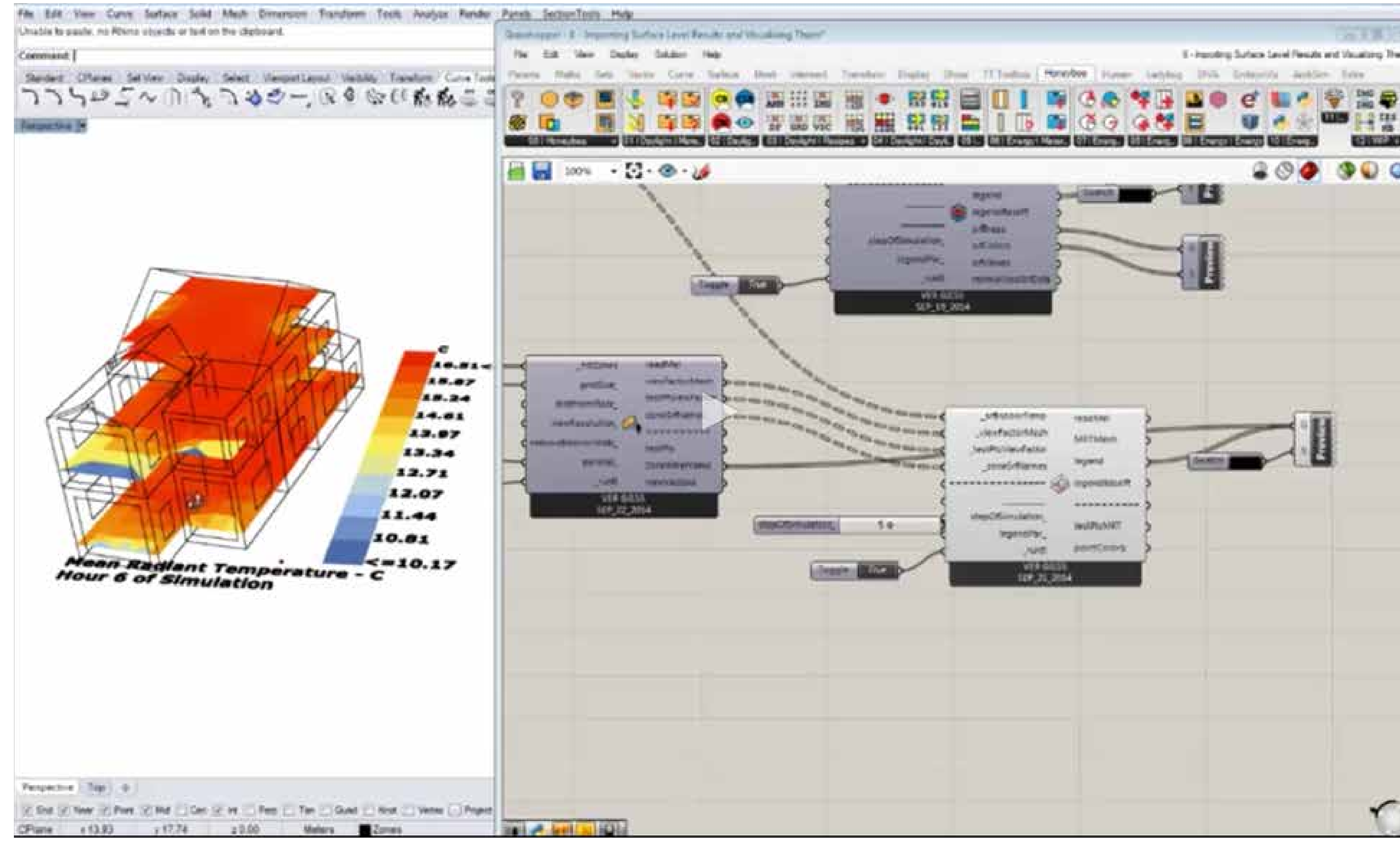
TRANSYS



DesignBuilder

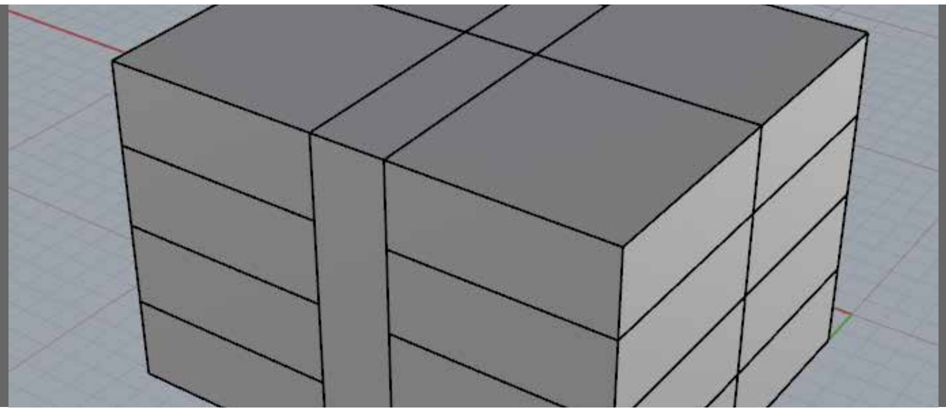


Honeybee



Honeybee

+ Flexible, transparent calculation modules
+ Easy to learn
+ Wide range of relevant input and output
+ Used by other student last year



3.2 Case building modelling

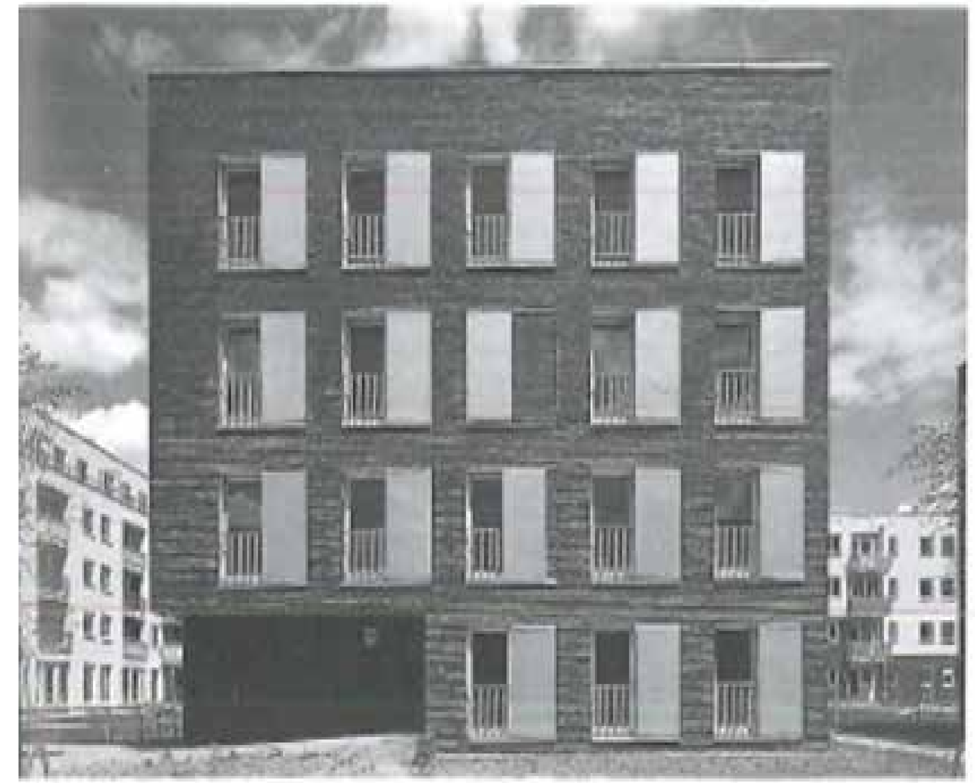
- Zones
- Rhino model
- Honeybee model

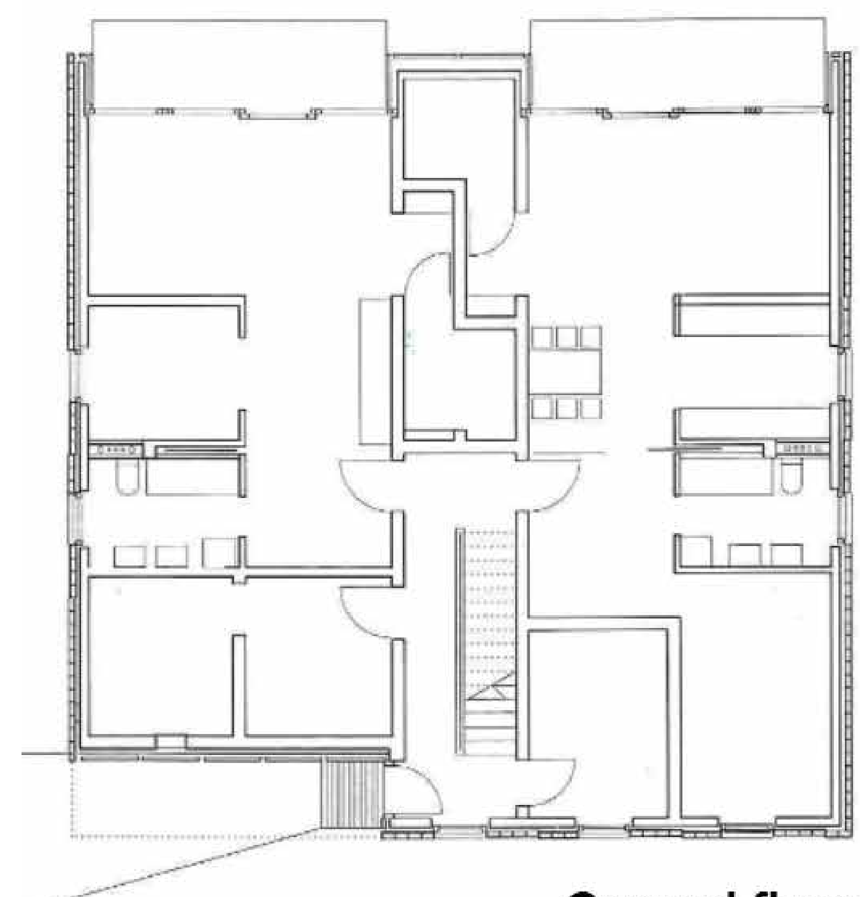
3.2 Case building modelling

Zones

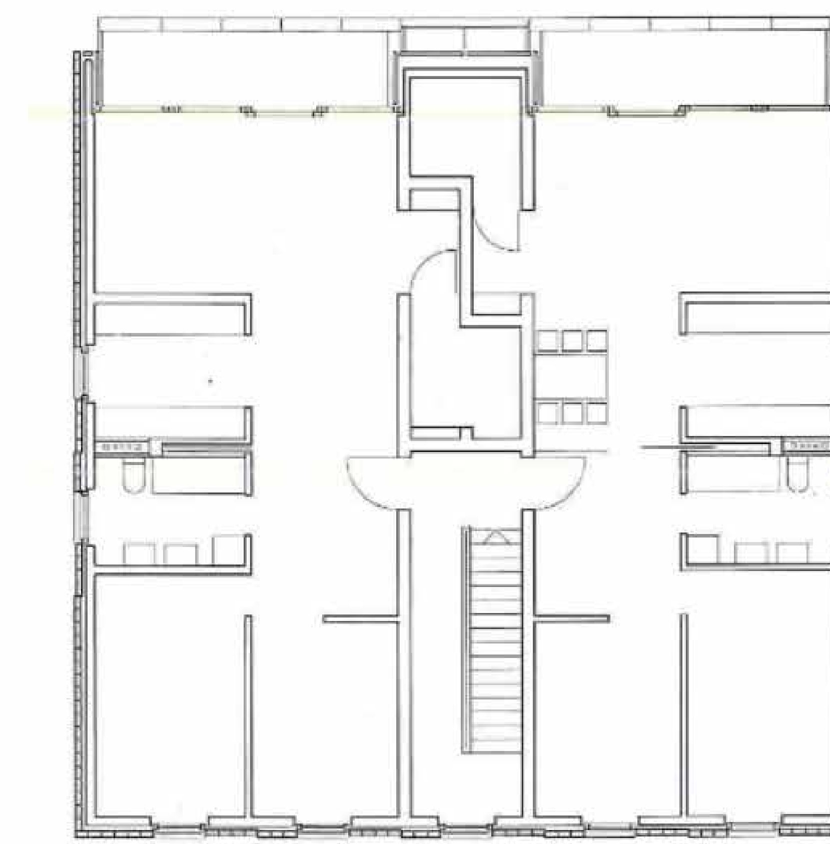
Rhino model

Honeybee



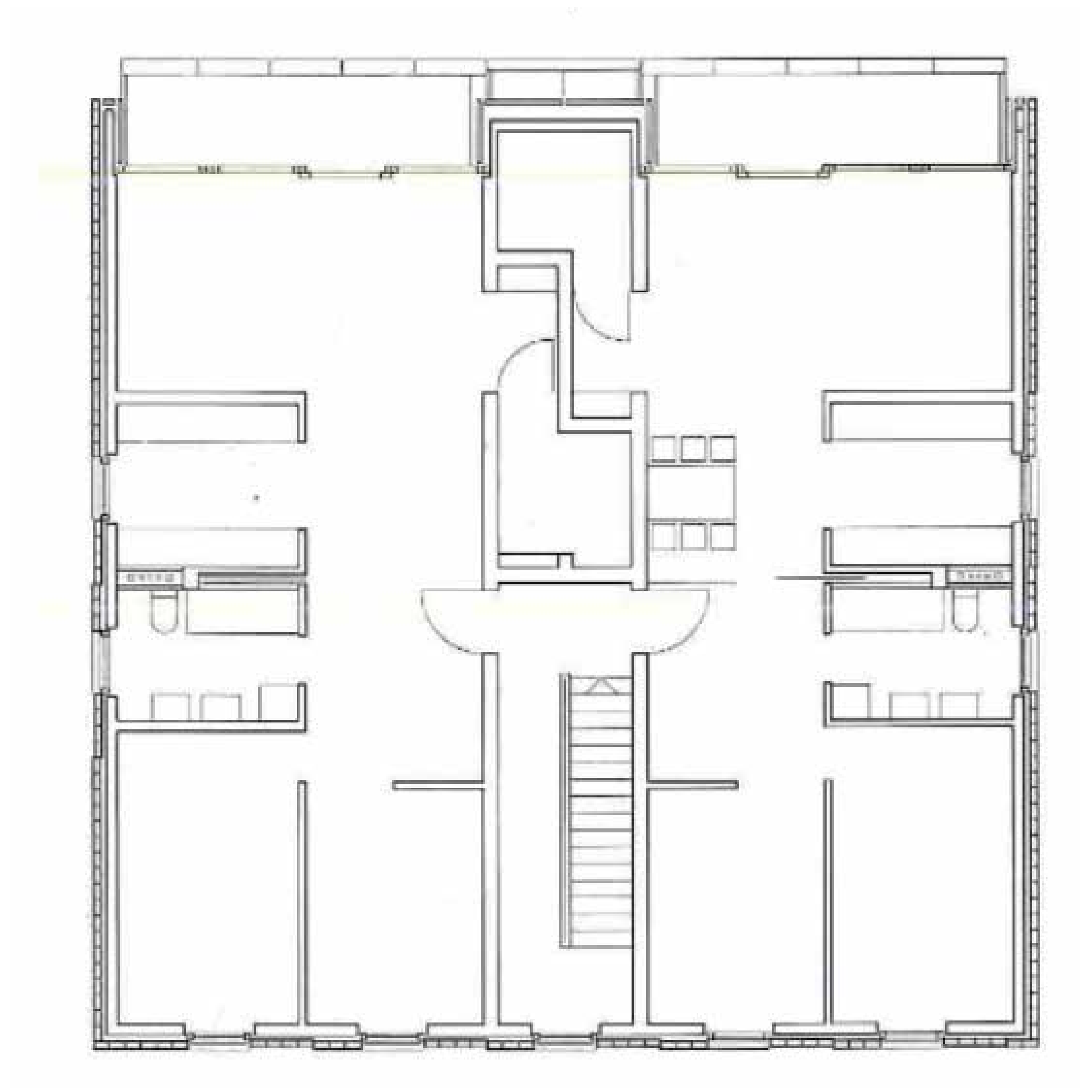


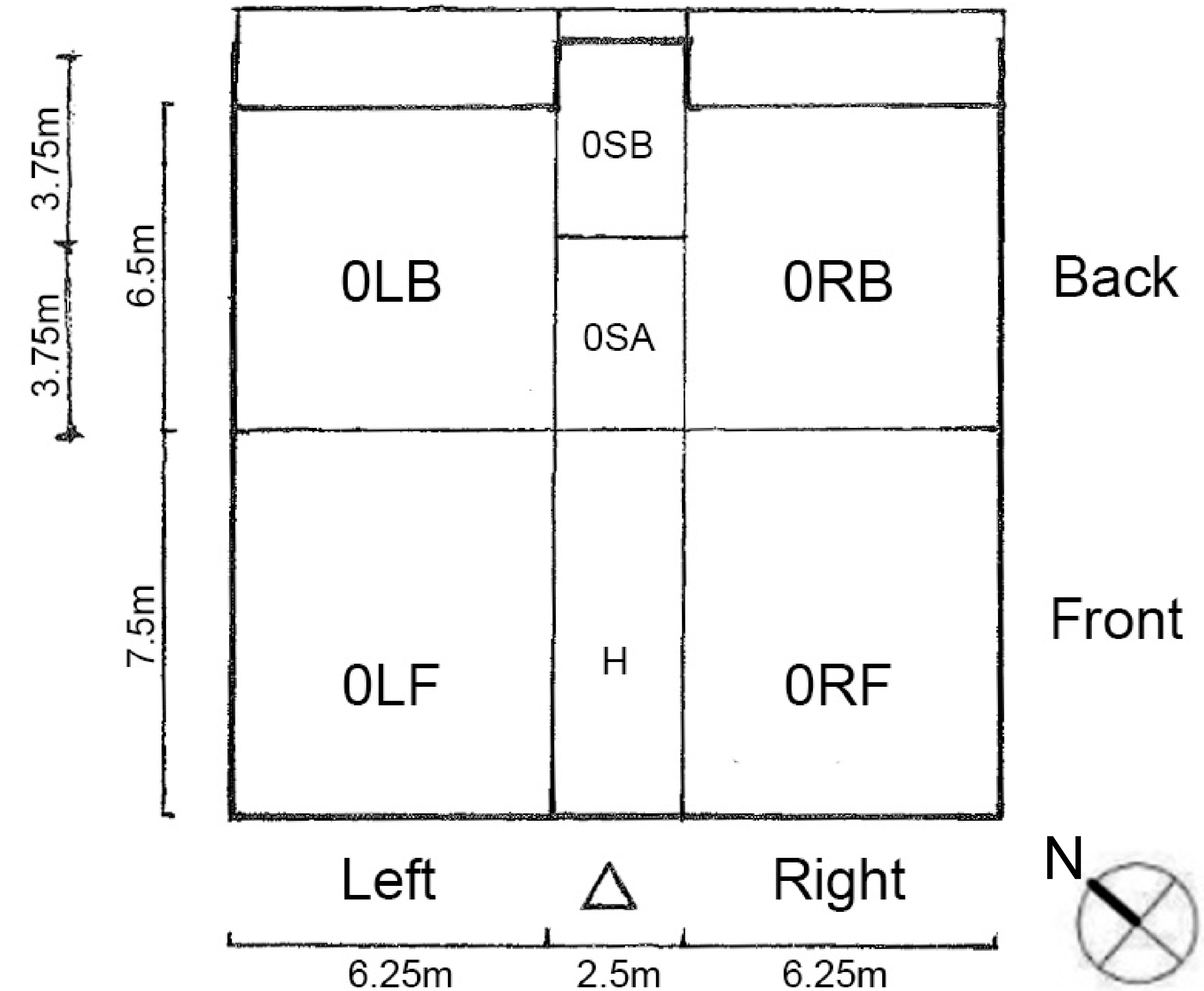
Ground floor



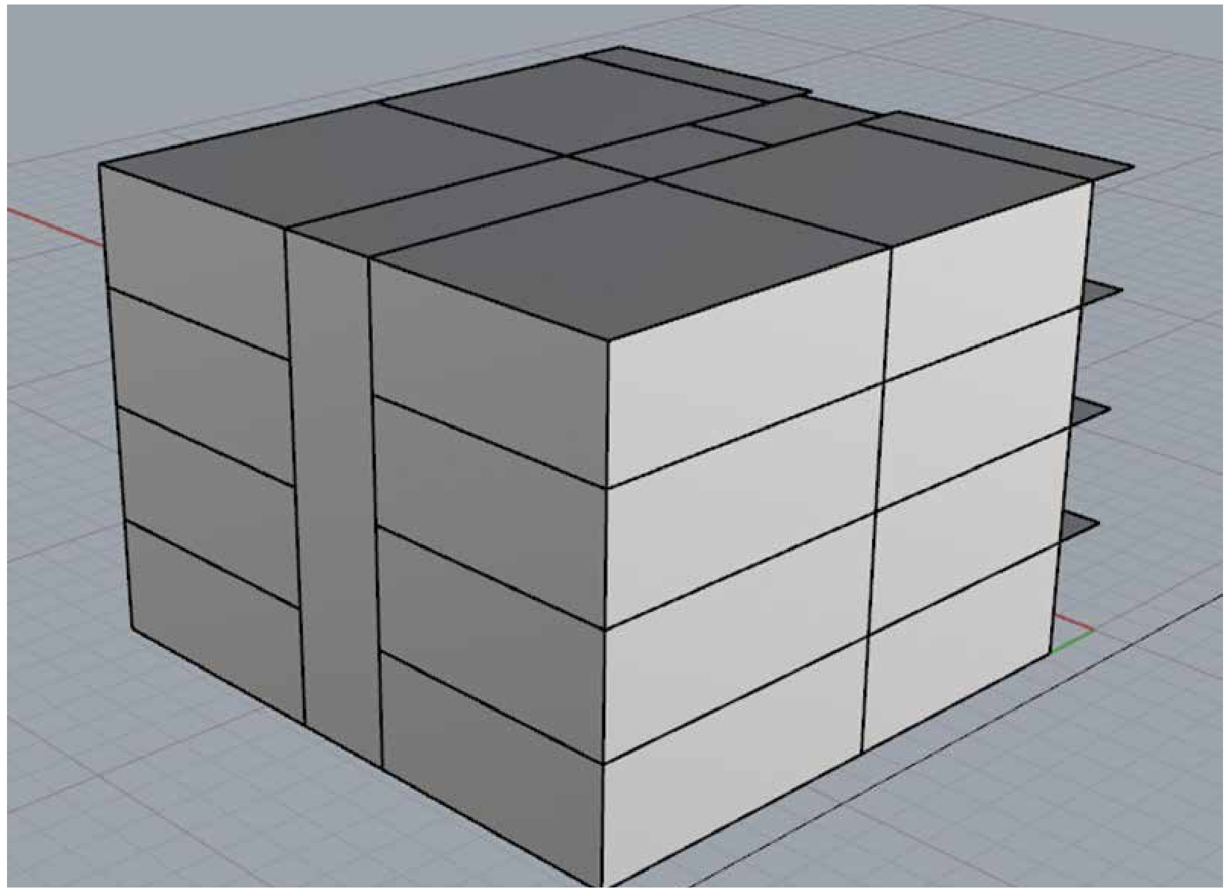
Upper floors

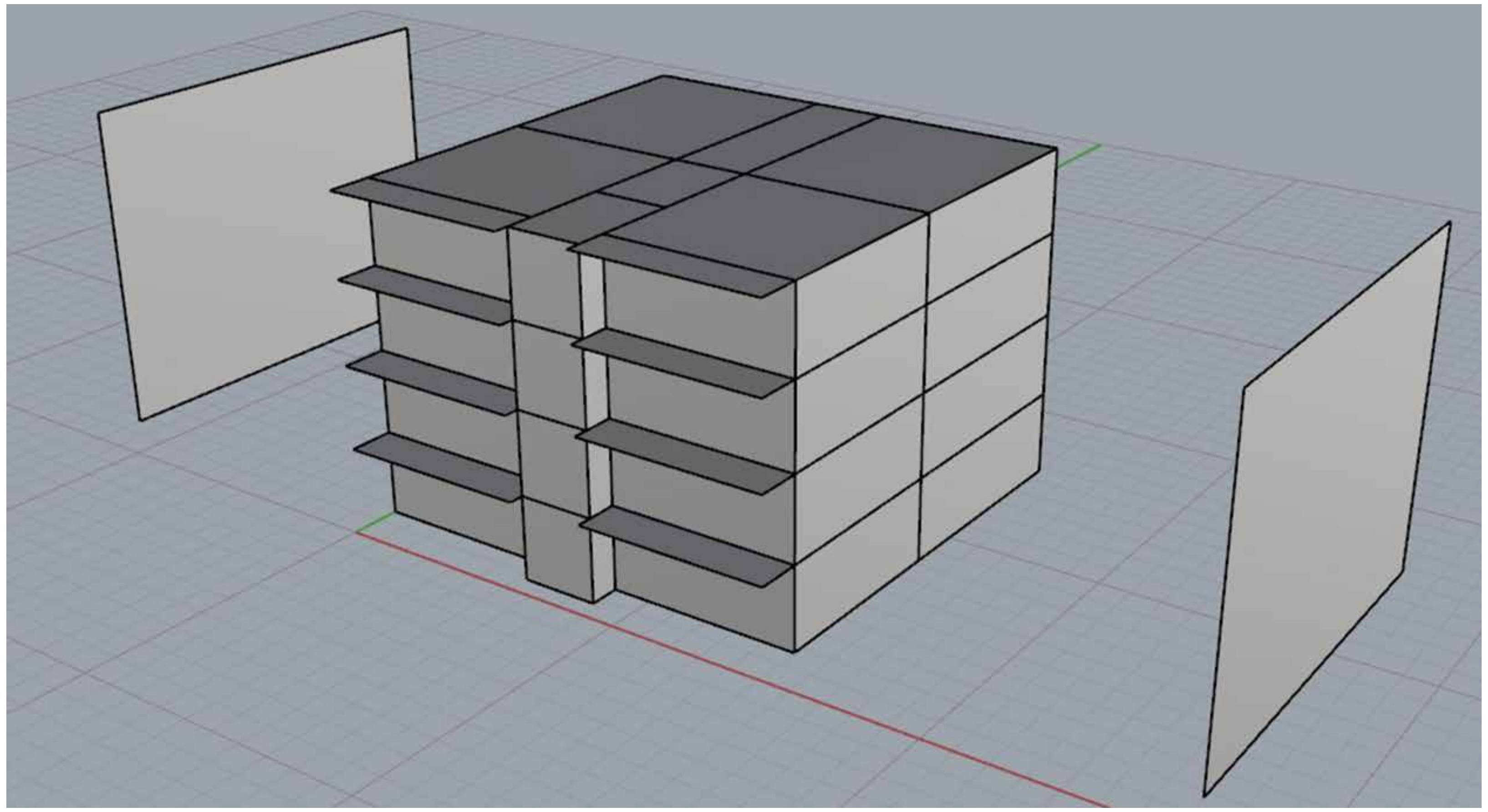
Zones





3.75m
3.75m
6.5m
7.5m
0SB
0SA
0LB
0RB
Back
0LF
H
0RF
Front
Left
Right
6.25m
2.5m
6.25m
N

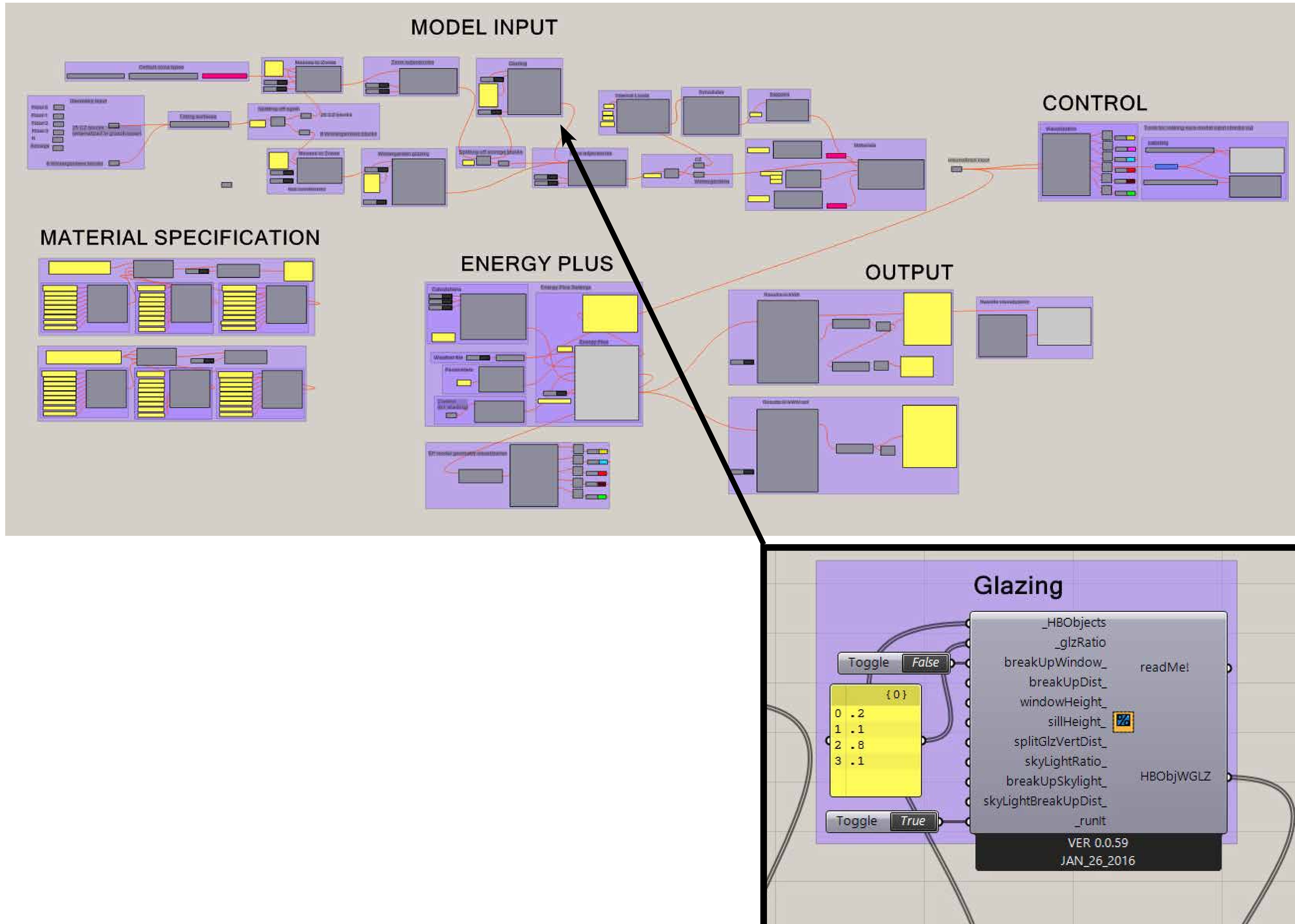




shading elements

Rhino model

Honeybee


MODEL INPUT
CONTROL
MATERIAL SPECIFICATION
ENERGY PLUS
OUTPUT
Glazing
_HBObjects
_glzRatio
breakUpWindow_
breakUpDist_
windowHeight_
sillHeight_
splitGlzVertDist_
skyLightRatio_
breakUpSkylight_
skyLightBreakUpDist_
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HBObjWGLZ
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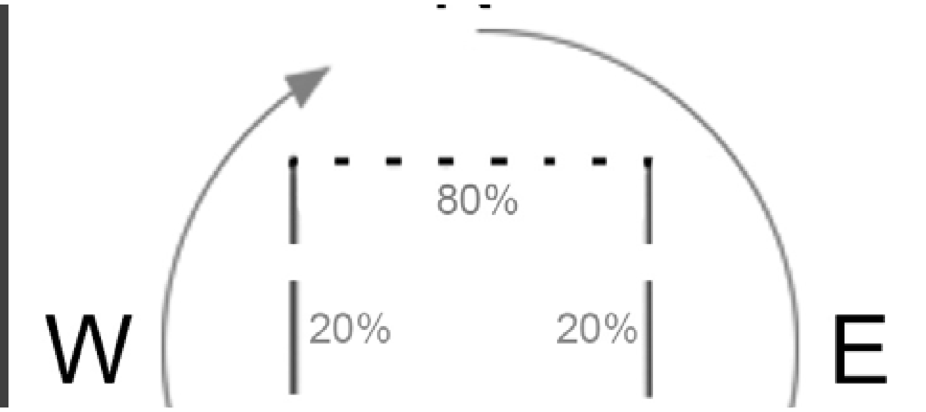
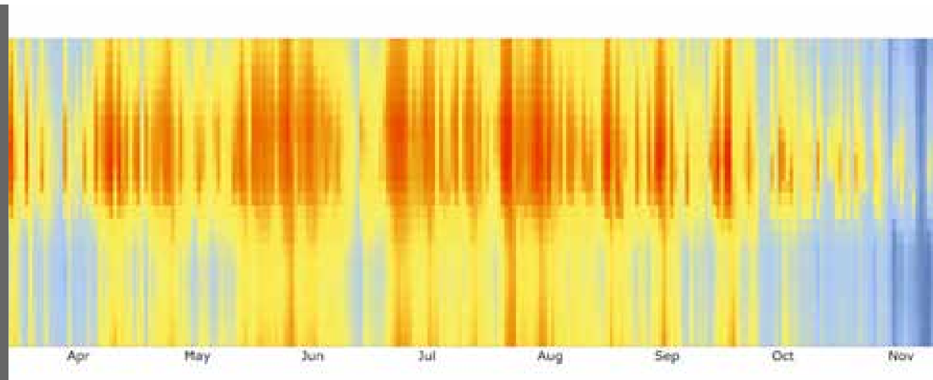
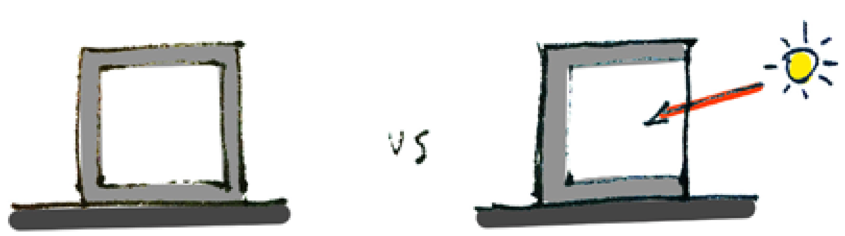
4. IMPACT STUDIES



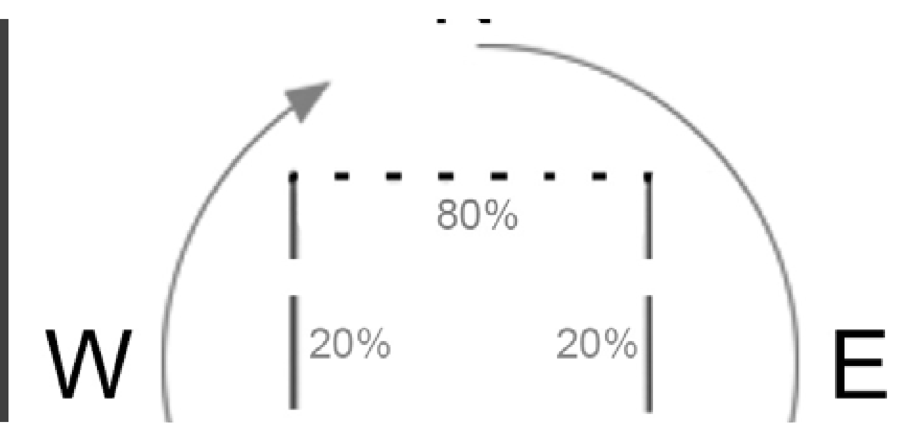
4.1 Study description



4.2 Study results



4.3 Study conclusions



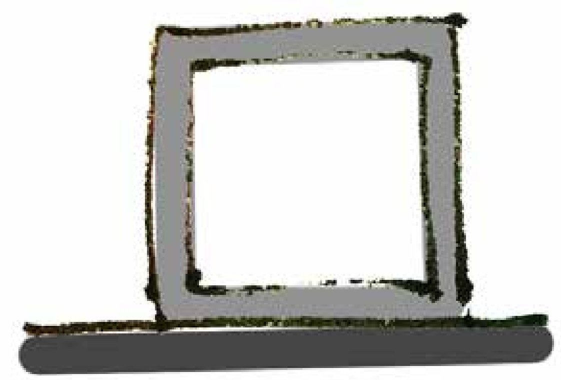
4.1 Study description

- Context
- Variables
- Study Goals

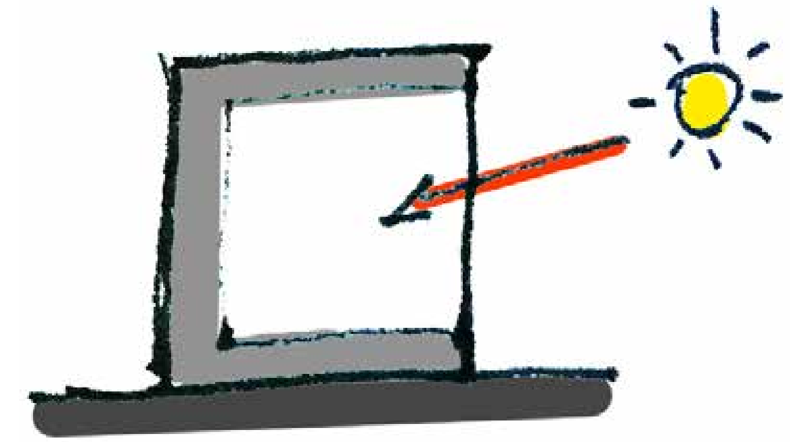
Context

annual kWh/m² heating demand	
BENG max.:	25
Passive House max.:	15
Freiburg SSSH:	2

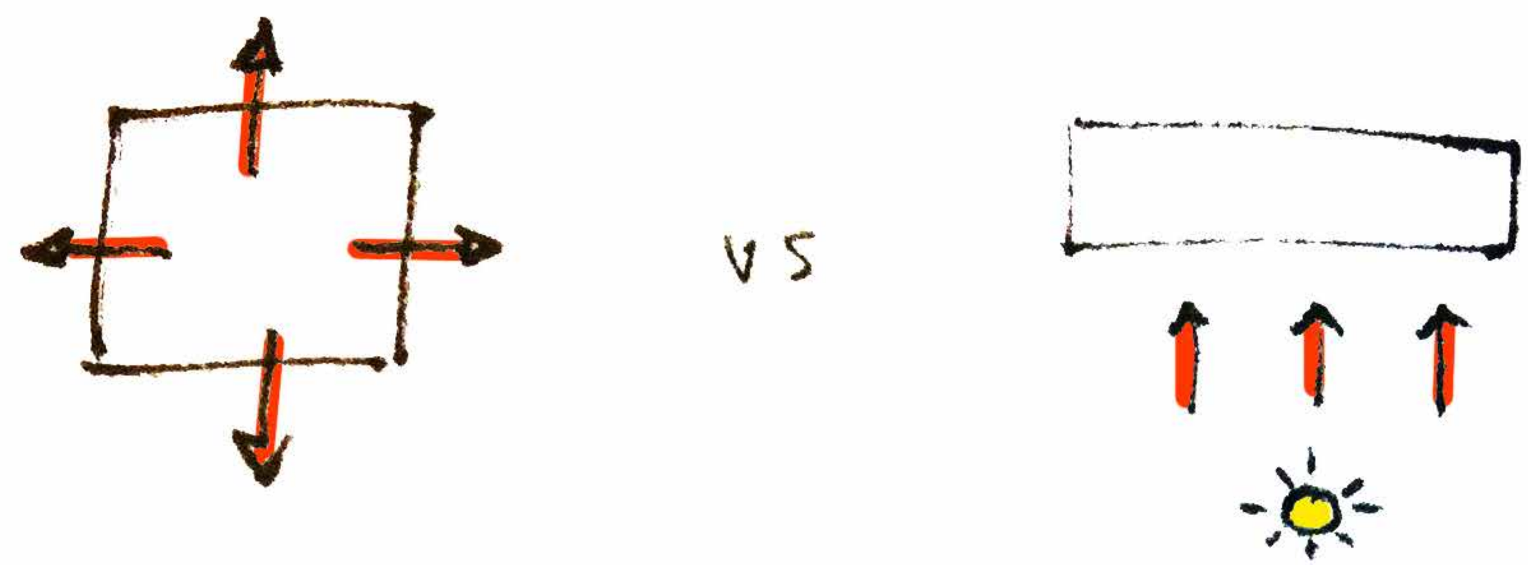
Variables



Insulation



Orientation



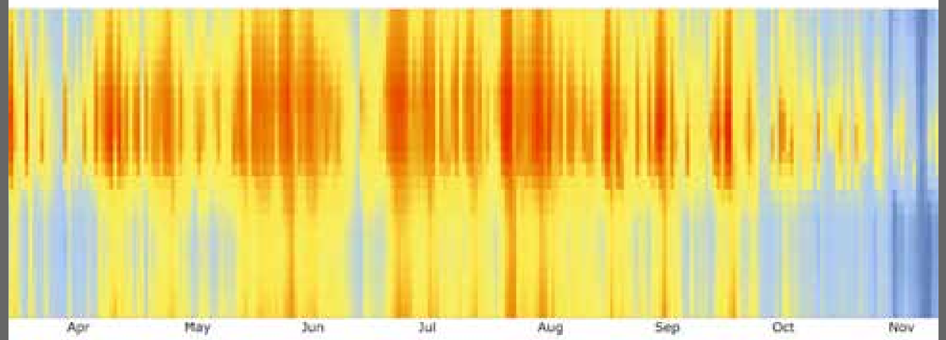
Compactness (Shape A)

Increased sun surface (Shape B)

Goals

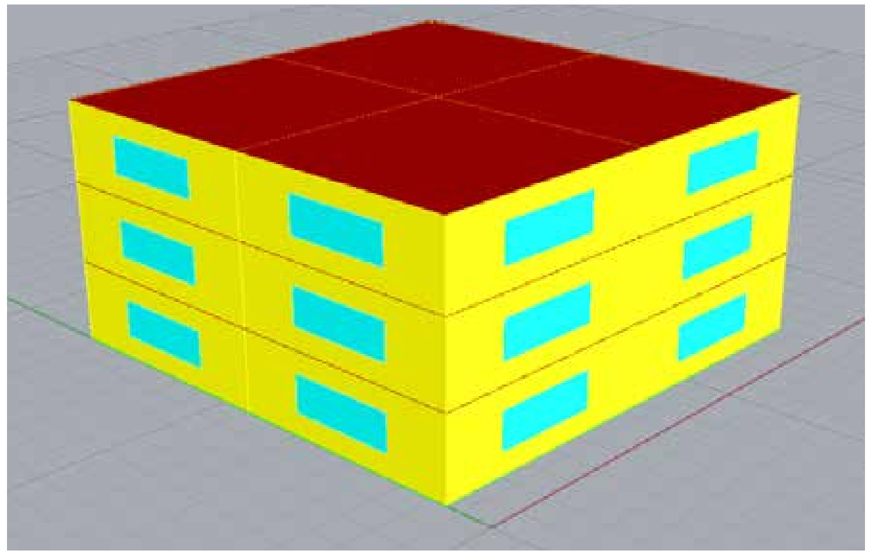
1. Quantify impact of variables in terms of kWh/m^2 heating demand

2. Explore positive effects of sunspaces

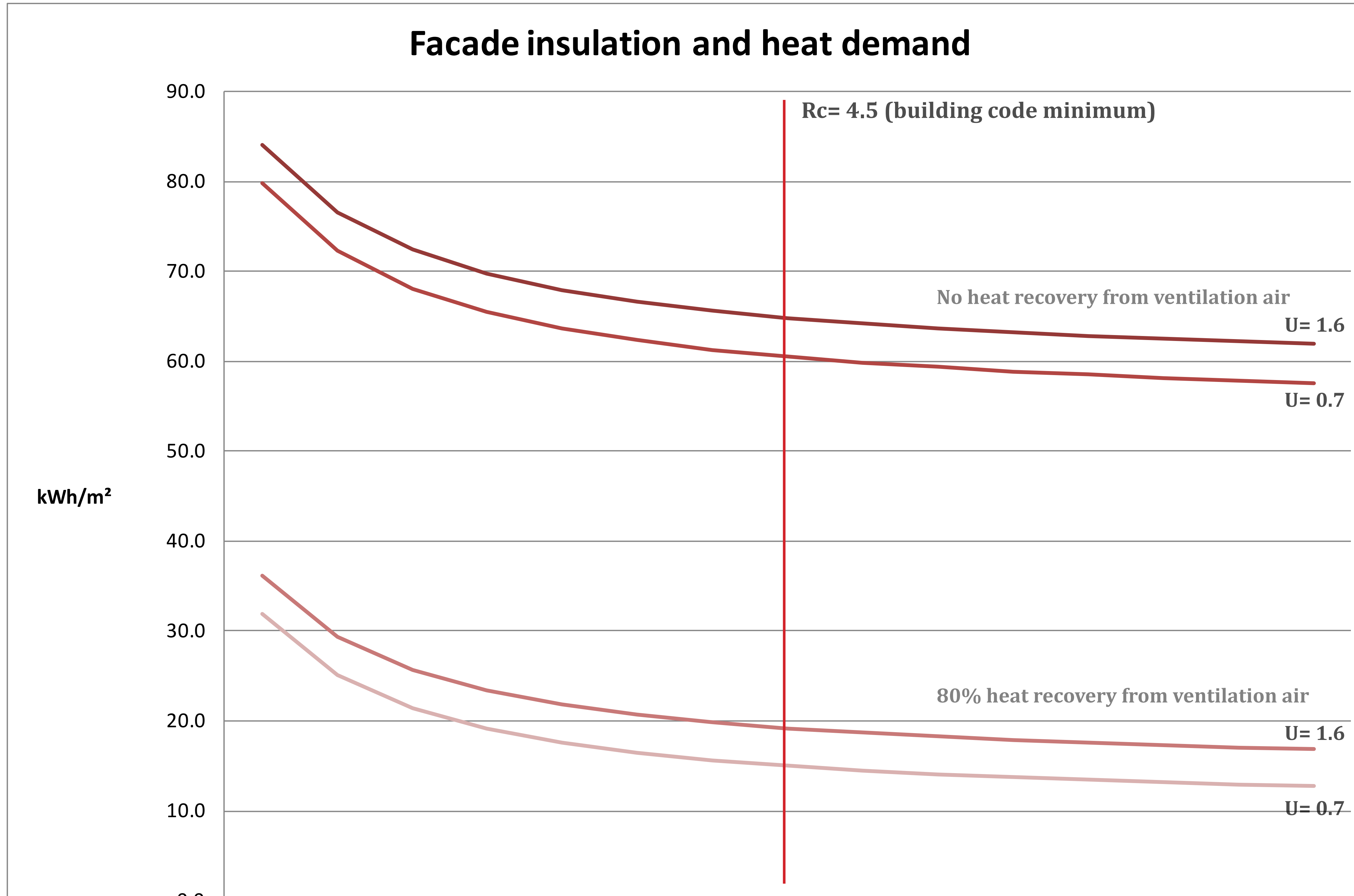


4.2 Study results

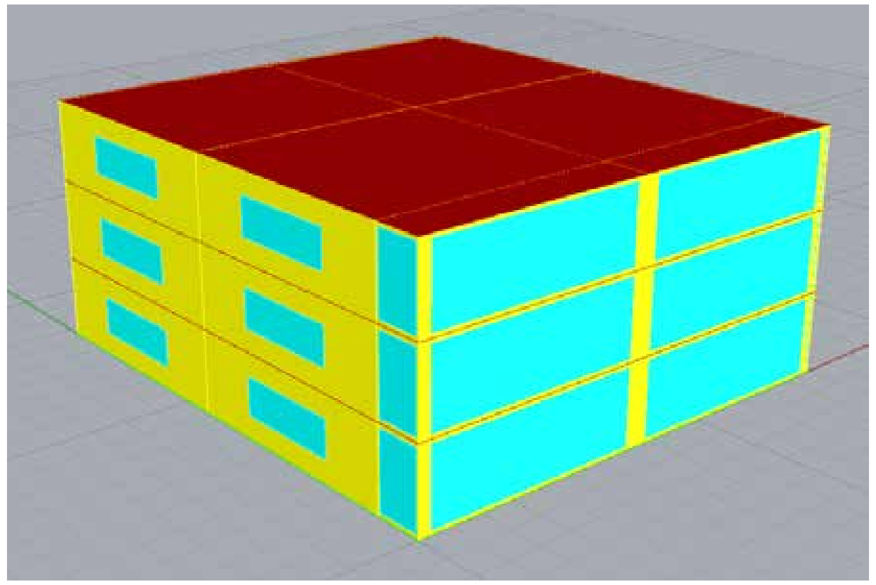
- Insulation
- Orientation
- Building shape
- Sunspace comparison

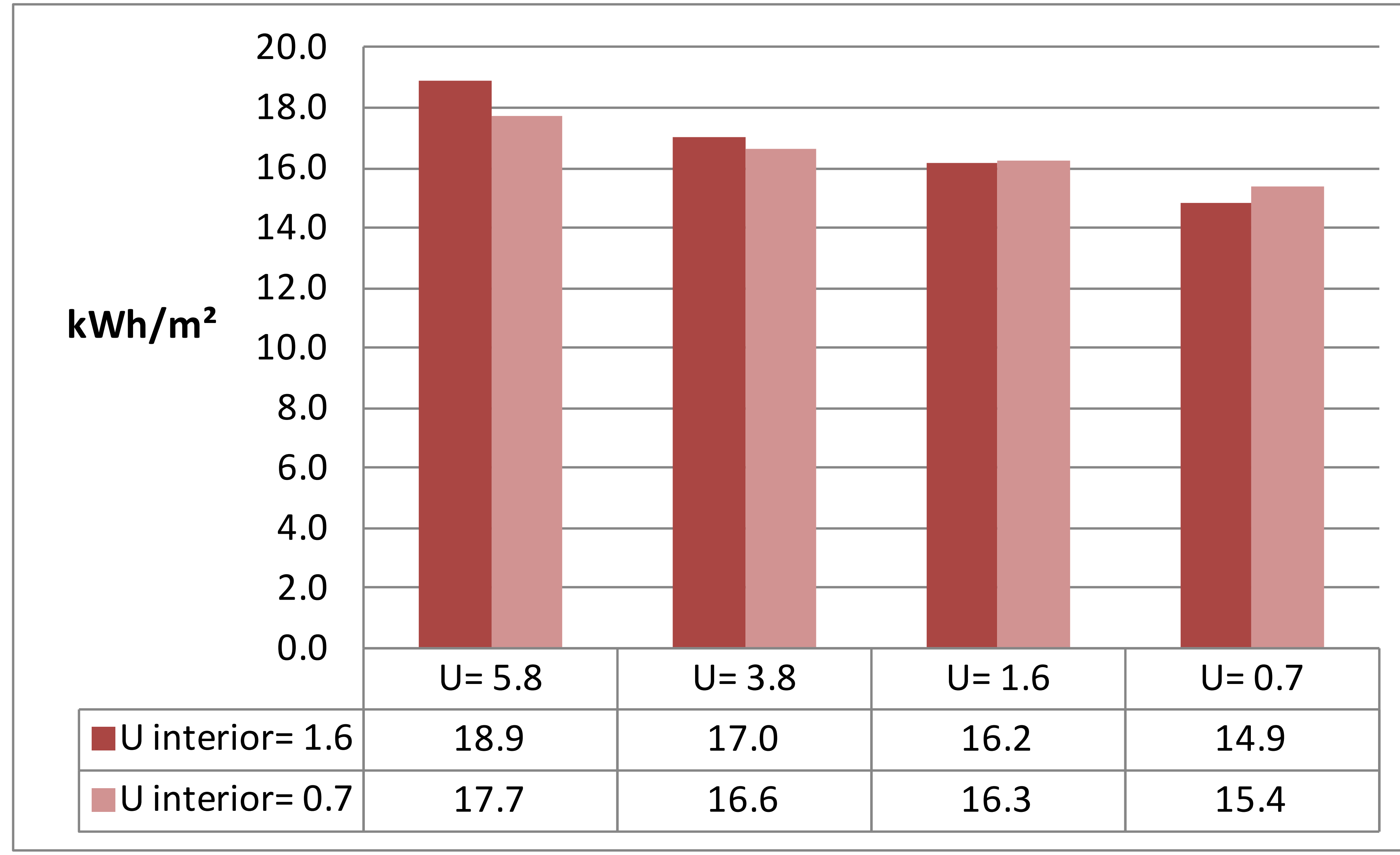


Insulation: plain facade



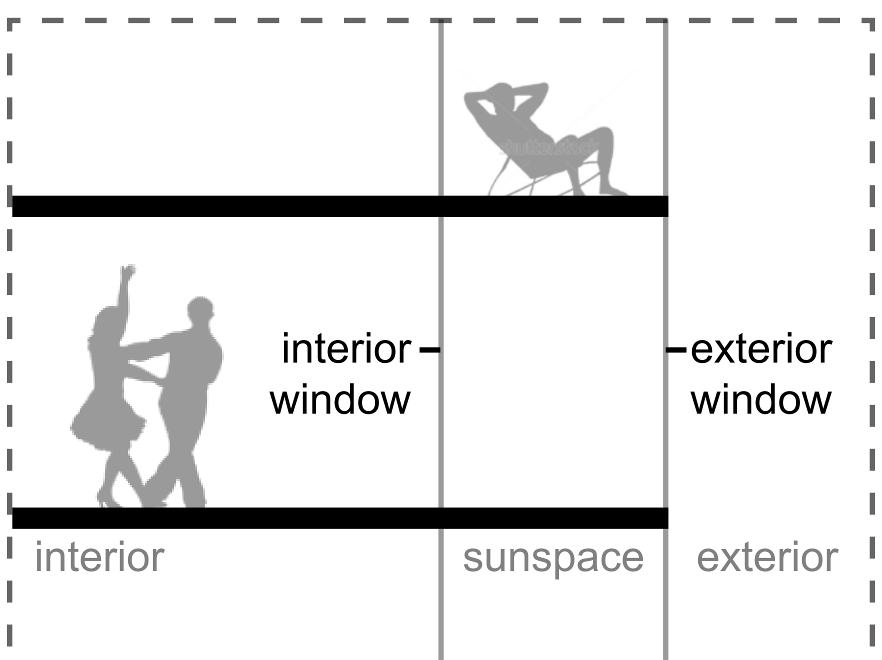
	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
U=1.6, no HR	84.0	76.5	72.4	69.8	68.0	66.7	65.6	64.9	64.2	63.7	63.3	62.9	62.5	62.3	62.0
U=0.7 no HR	79.9	72.3	68.1	65.5	63.7	62.3	61.3	60.5	59.9	59.3	58.9	58.5	58.2	57.9	57.6
U=1.6 with HR	36.1	29.3	25.6	23.4	21.8	20.7	19.9	19.2	18.7	18.2	17.9	17.6	17.3	17.1	16.9
U=0.7 with HR	31.9	25.0	21.4	19.1	17.6	16.5	15.7	15.0	14.5	14.1	13.7	13.4	13.2	12.9	12.7

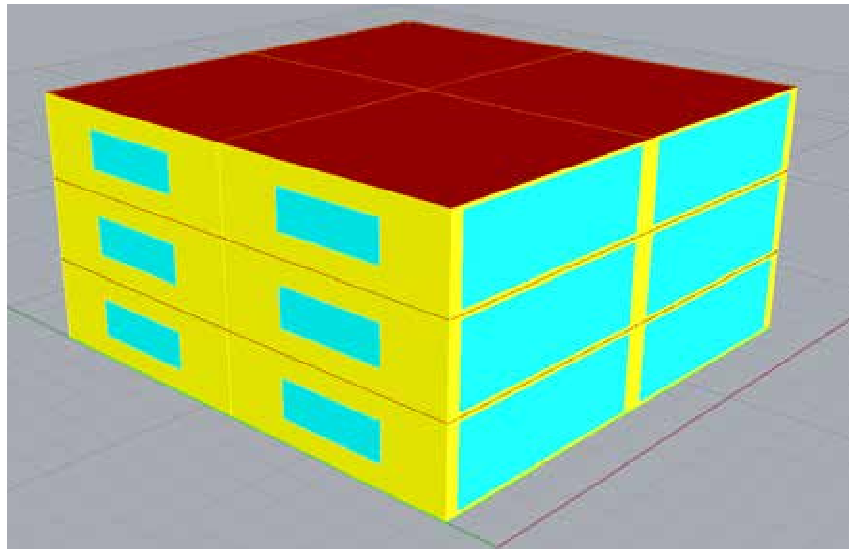




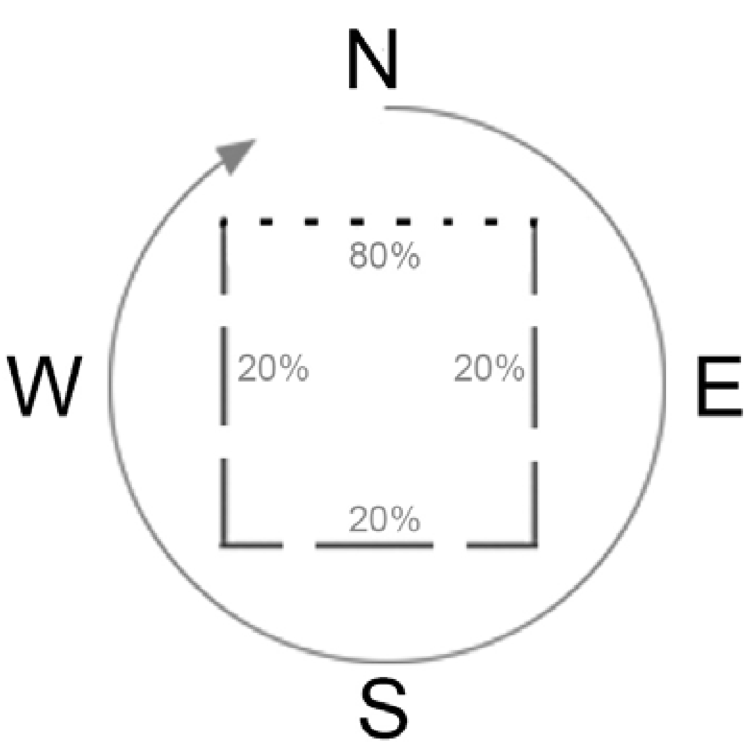
	U= 5.8	U= 3.8	U= 1.6	U= 0.7
U interior= 1.6	18.9	17.0	16.2	14.9
U interior= 0.7	17.7	16.6	16.3	15.4

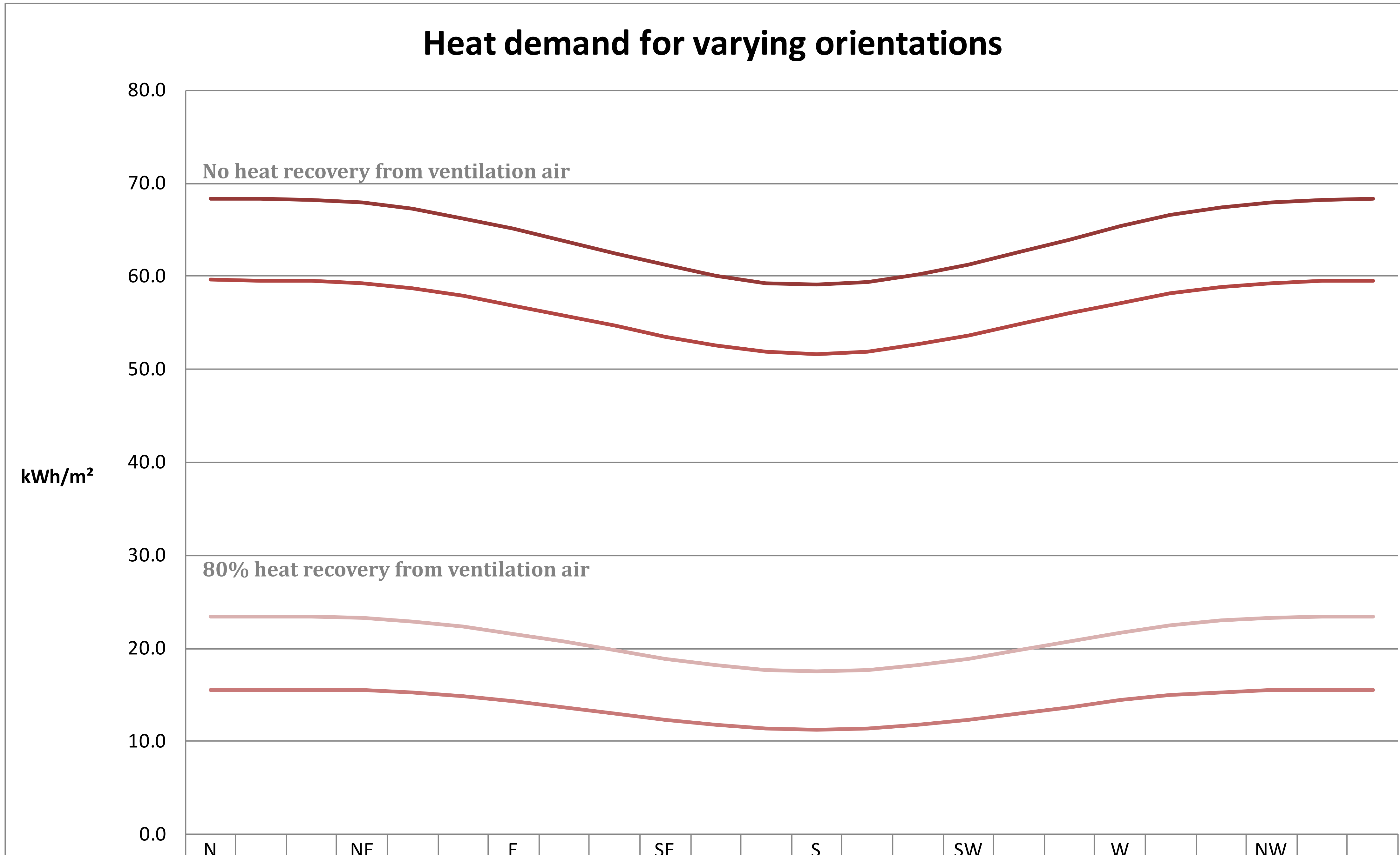
Insulation: sunspaces



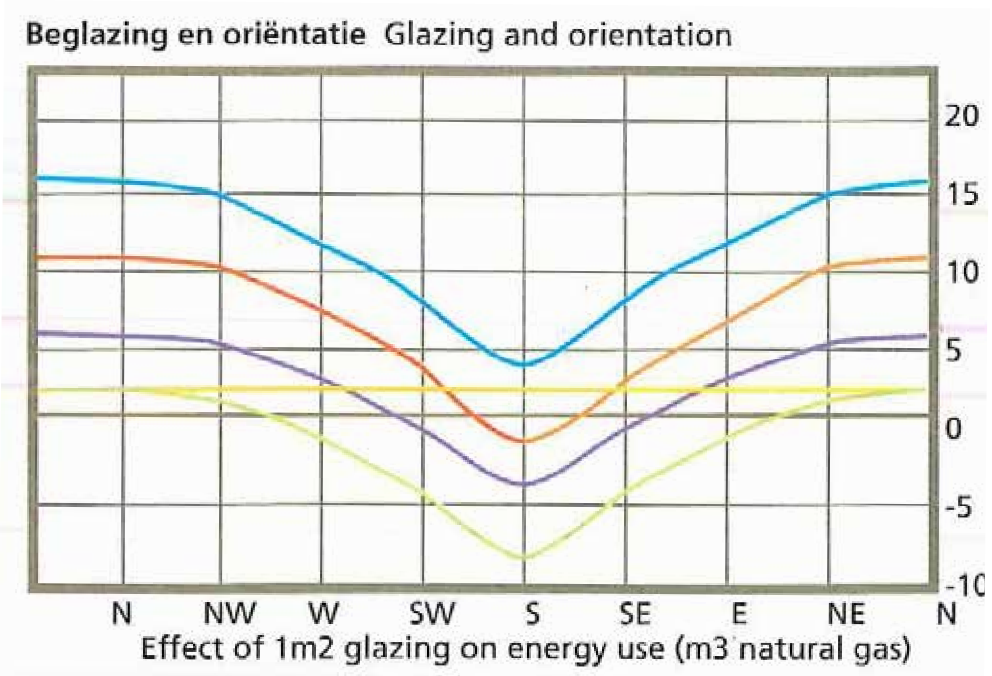


Orientation: plain facade

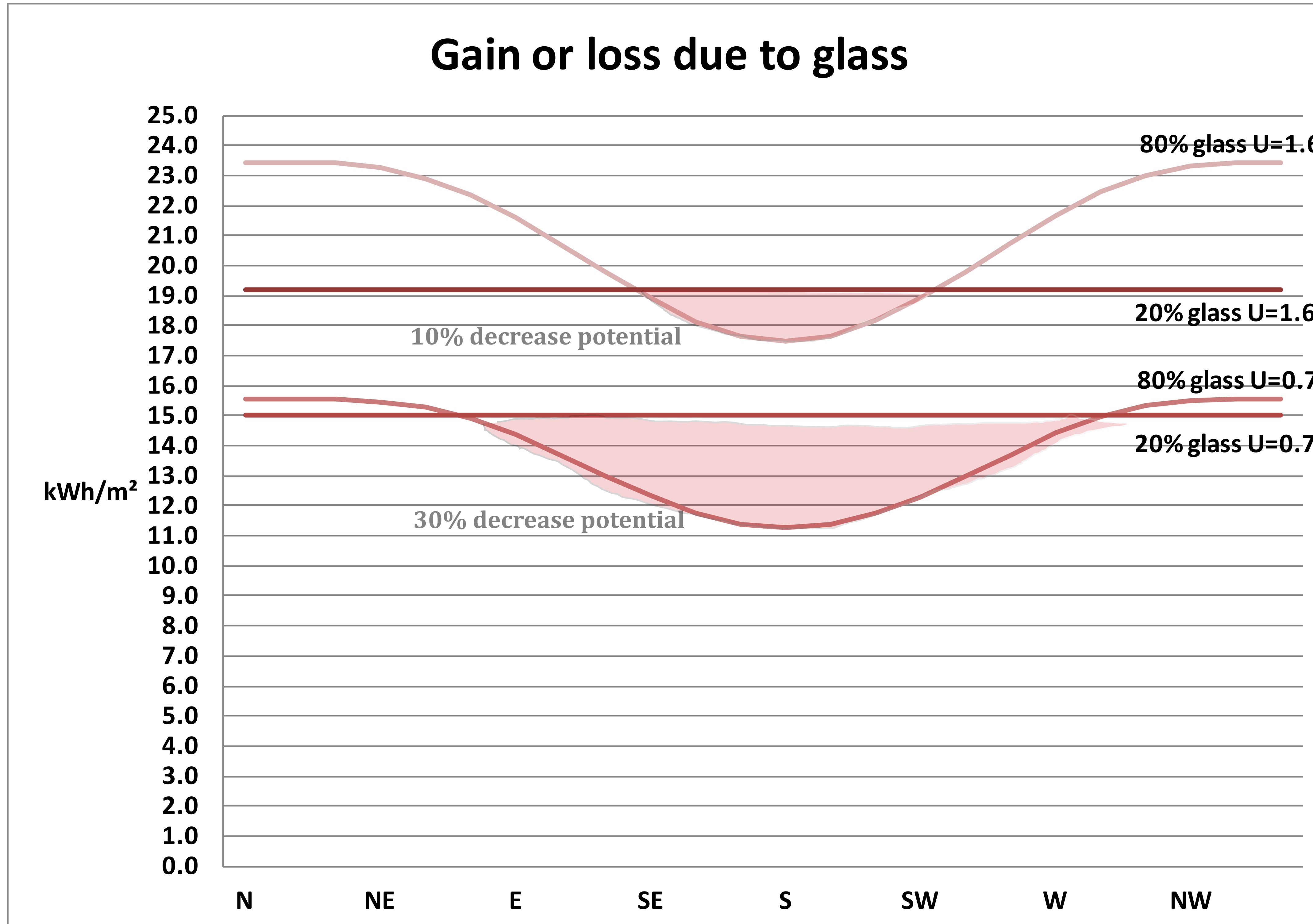


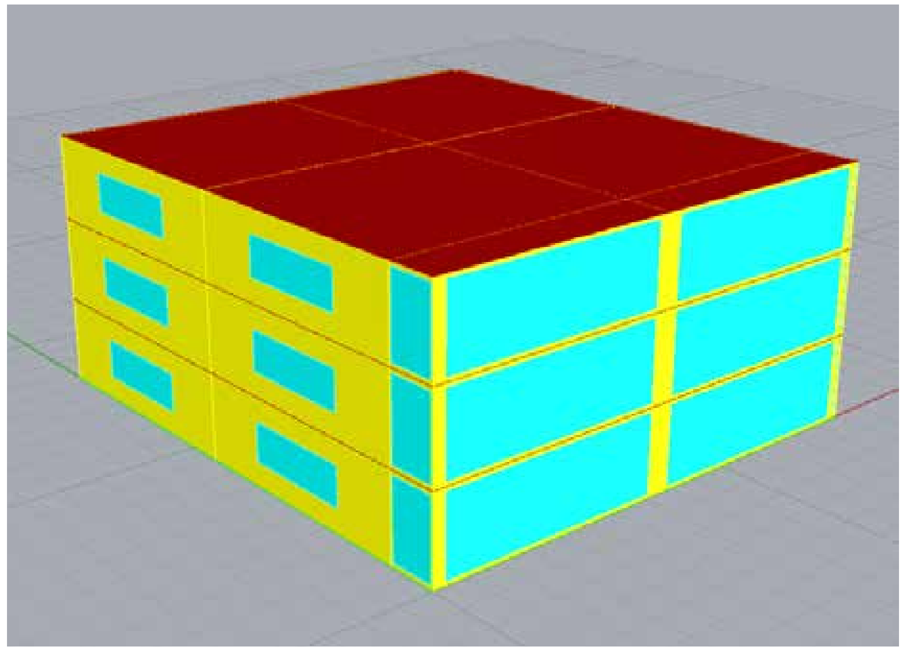


	N			NE			E			SE			S			SW			W			NW		
U=1.6	68.4	68.4	68.3	67.9	67.2	66.3	65.1	63.8	62.5	61.2	60.0	59.3	59.1	59.4	60.2	61.3	62.6	64.0	65.4	66.6	67.5	68.0	68.2	68.4
U=0.7	59.6	59.6	59.5	59.2	58.7	57.9	56.9	55.8	54.7	53.5	52.5	51.8	51.6	51.9	52.6	53.6	54.8	56.0	57.2	58.1	58.8	59.3	59.5	59.6
U=1.6 +HR	23.4	23.4	23.4	23.3	22.9	22.3	21.6	20.7	19.8	18.9	18.1	17.6	17.5	17.7	18.2	18.9	19.8	20.7	21.7	22.4	23.0	23.3	23.4	23.4
U=0.7 +HR	15.5	15.5	15.5	15.5	15.3	14.9	14.4	13.7	13.0	12.3	11.8	11.4	11.3	11.4	11.7	12.3	13.0	13.7	14.4	15.0	15.3	15.5	15.5	15.5

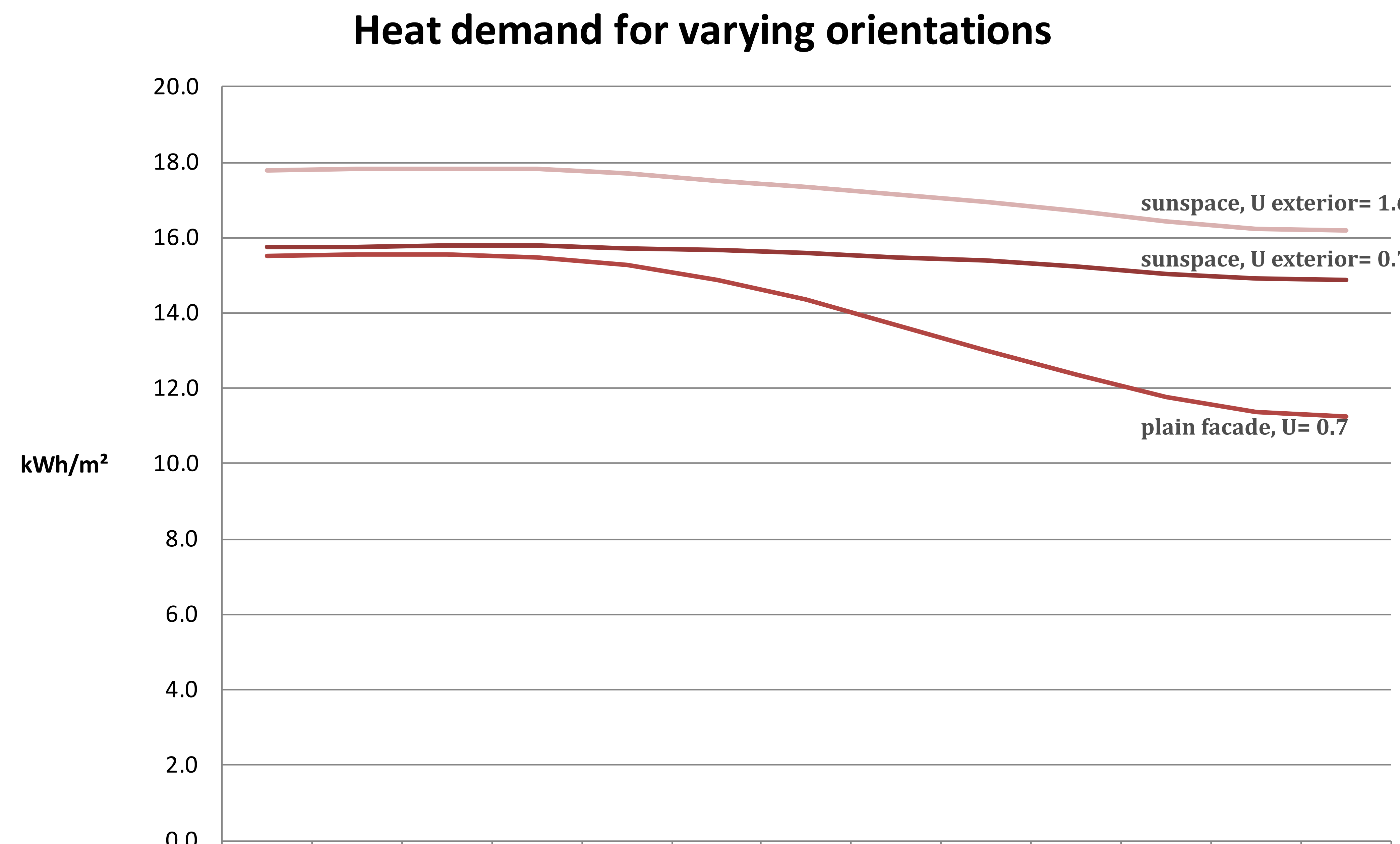


Orientation: plain facade

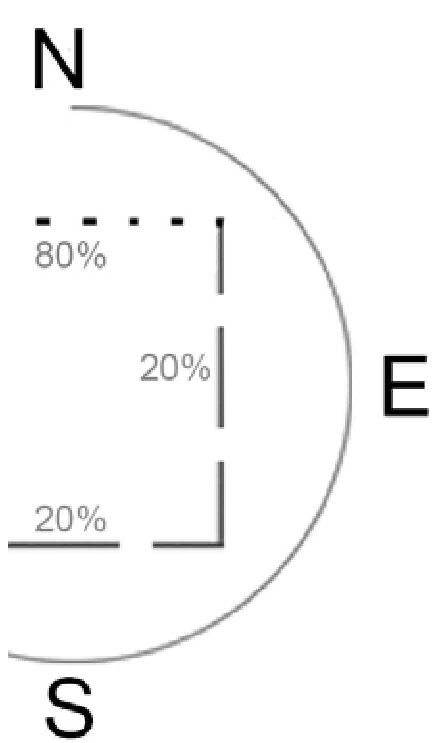


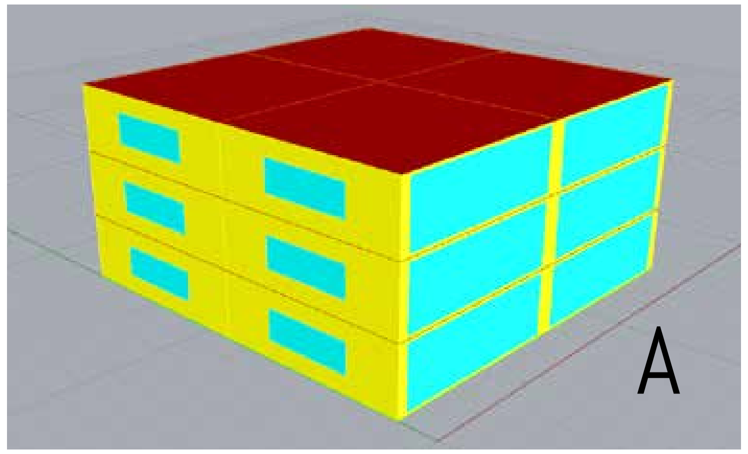


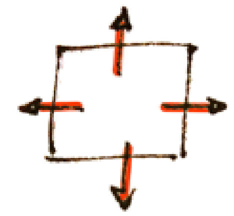
Orientation: sunspaces

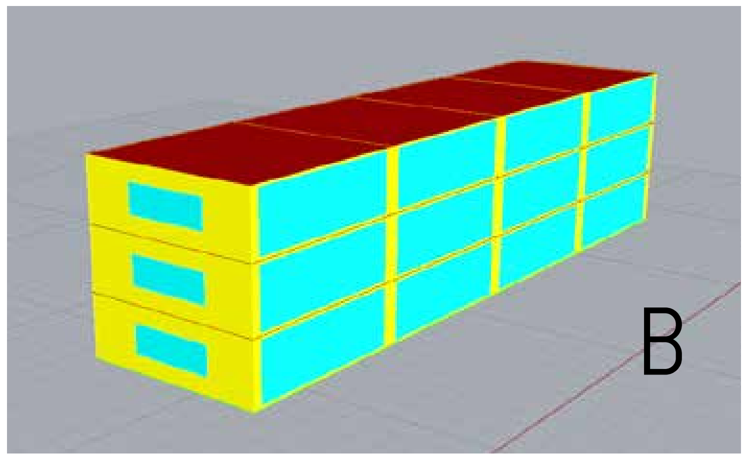


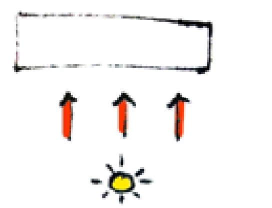
	N			NE			E			SE			S
U ext=1.6	17.8	17.8	17.8	17.8	17.7	17.5	17.3	17.1	16.9	16.7	16.4	16.2	16.2
U ext=0.7	15.7	15.8	15.8	15.8	15.7	15.7	15.6	15.5	15.4	15.2	15.1	14.9	14.9
no sunspace	15.5	15.5	15.5	15.5	15.3	14.9	14.4	13.7	13.0	12.3	11.8	11.4	11.3





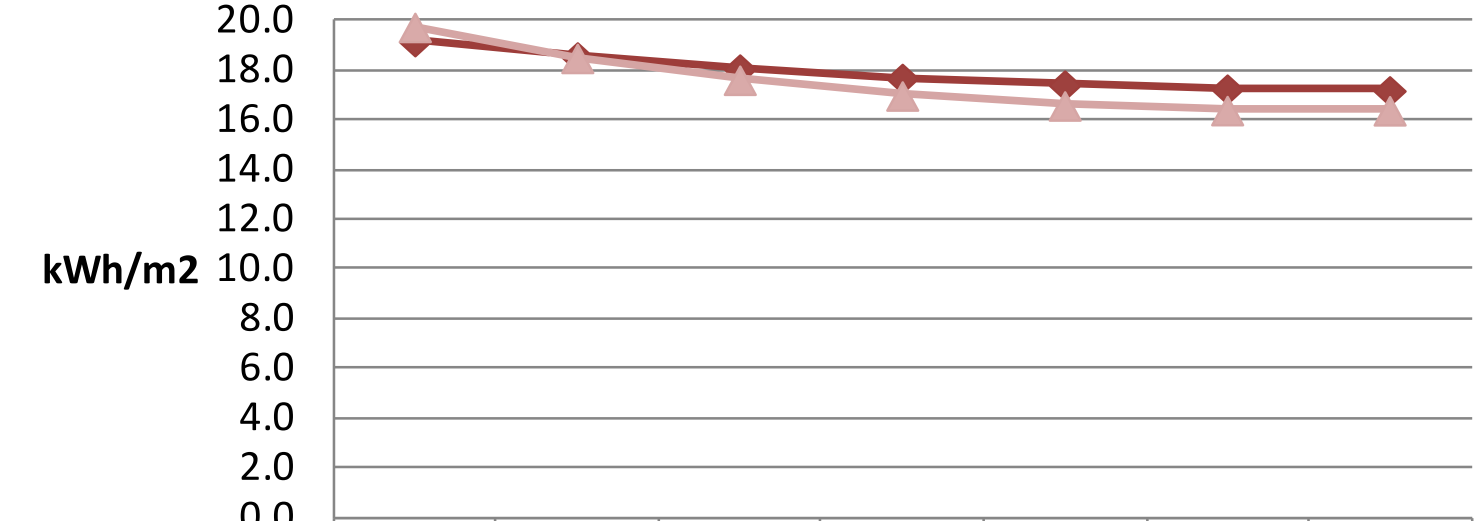




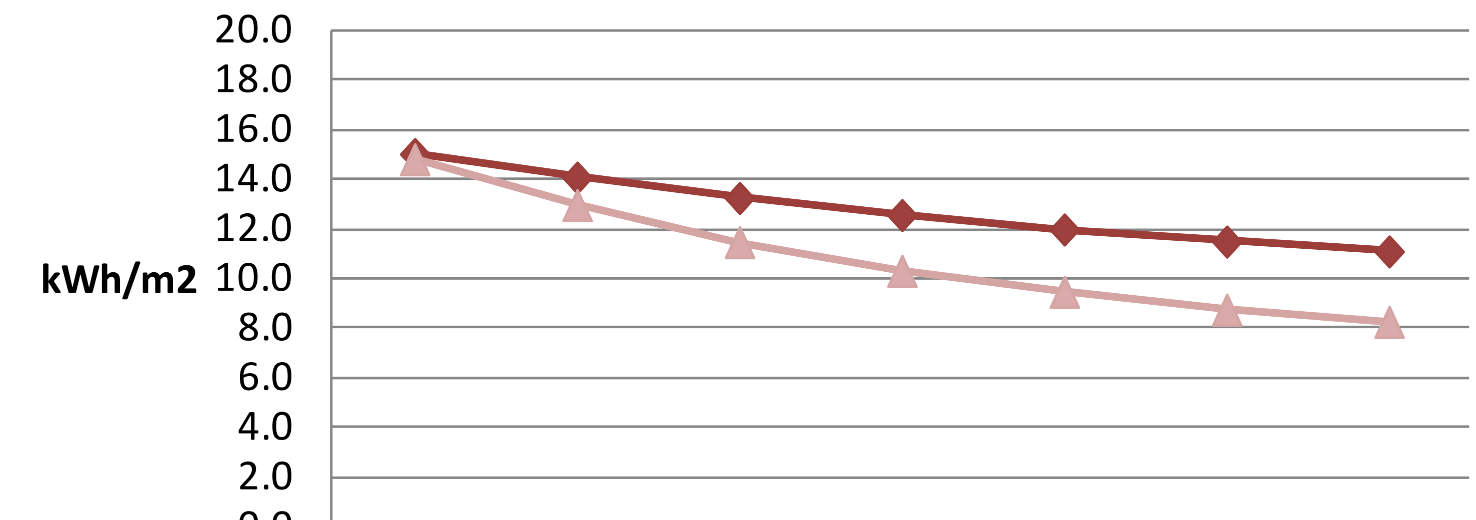


Building Shape: plain facade

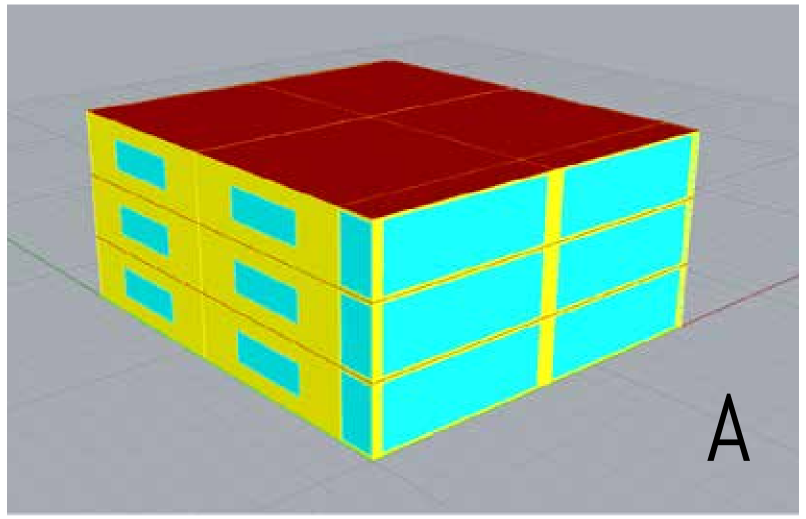
extra variable: % glass in facade

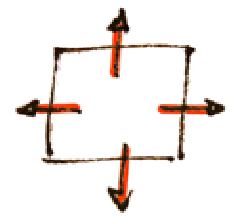


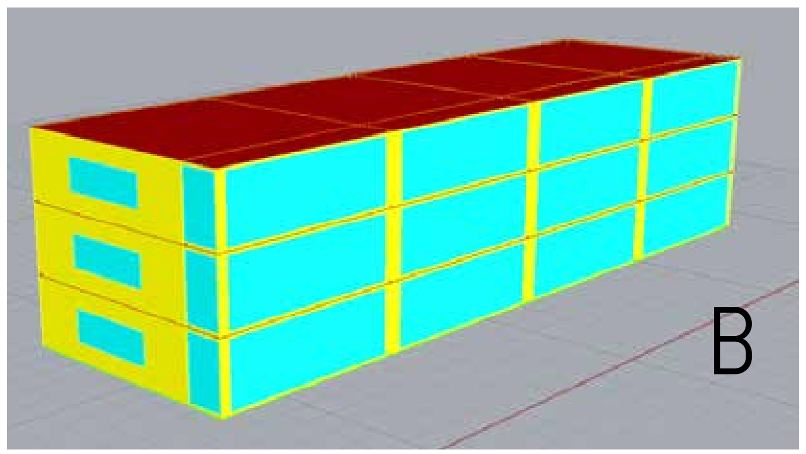
	20%	30%	40%	50%	60%	70%	80%
Shape A	19.2	18.6	18.1	17.7	17.4	17.3	17.2
Shape B	19.8	18.5	17.6	17.0	16.6	16.4	16.4

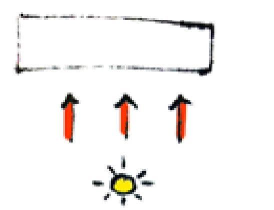


	20%	30%	40%	50%	60%	70%	80%
Shape A	15.0	14.1	13.2	12.6	12.0	11.5	11.1
Shape B	14.8	13.0	11.5	10.3	9.5	8.7	8.3

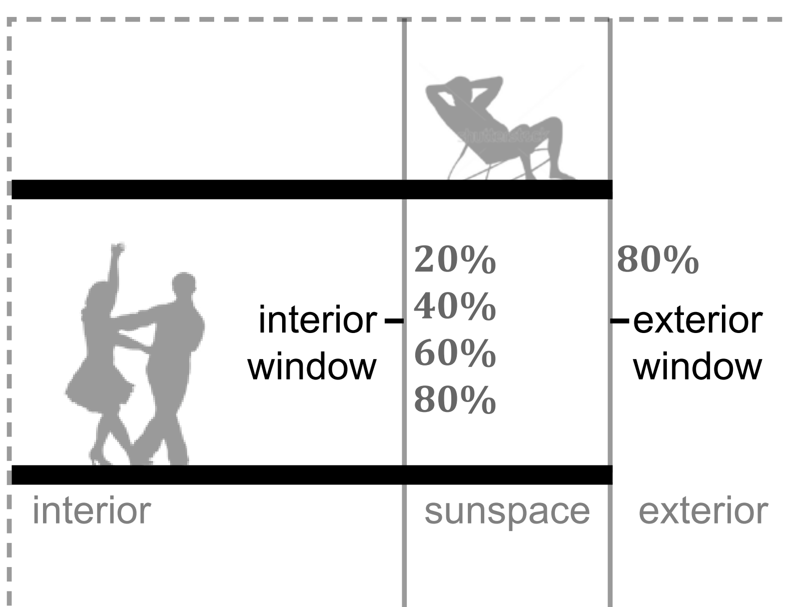


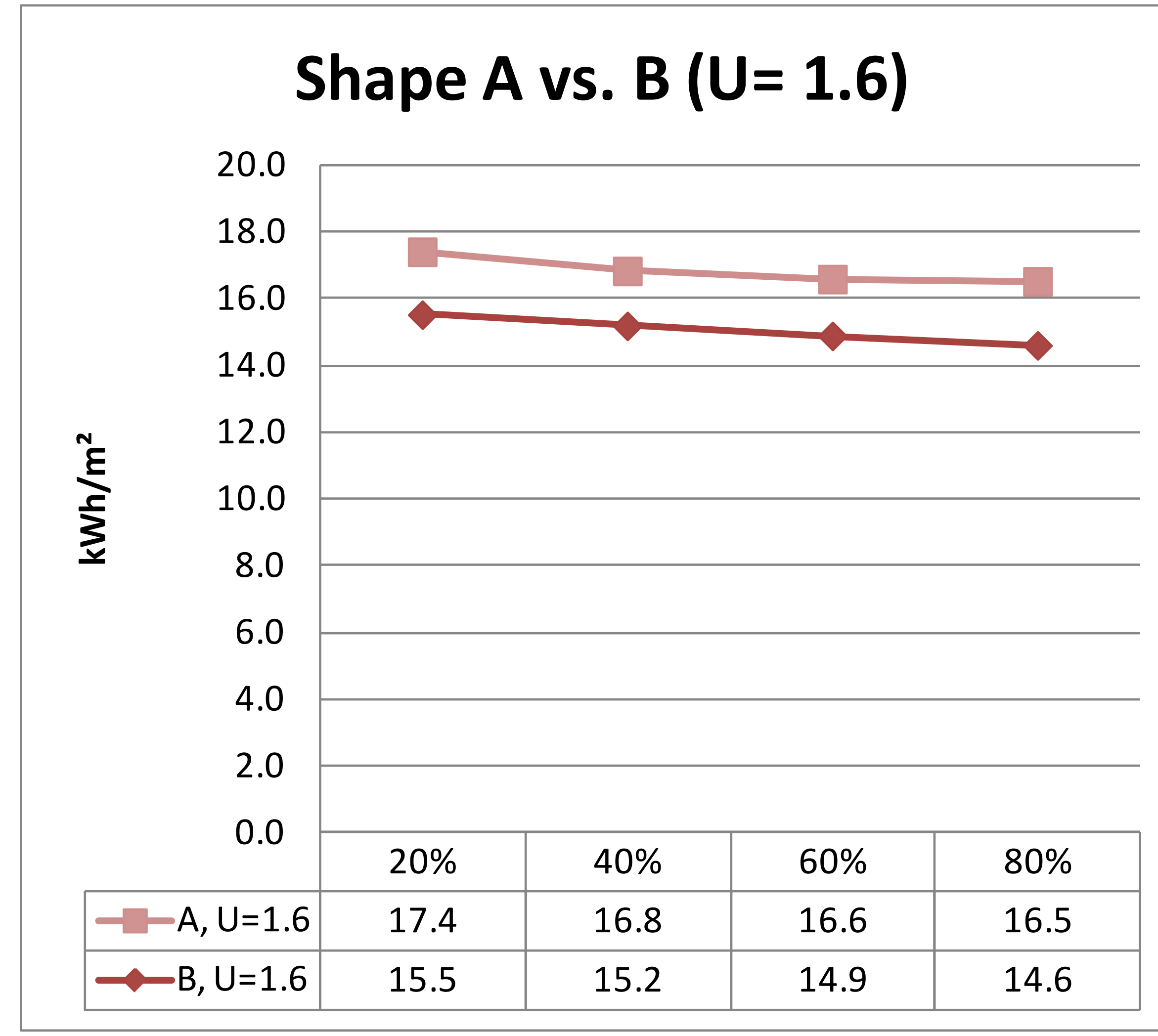




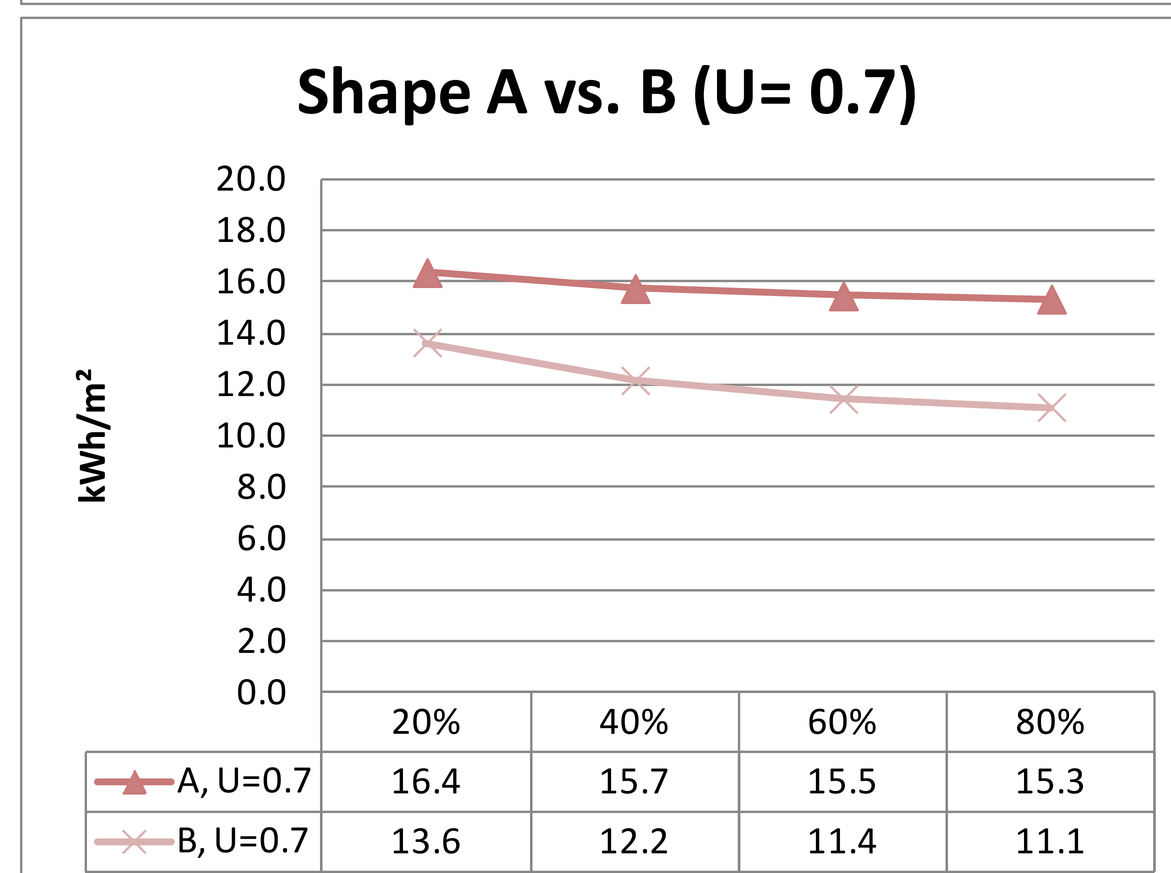


Building Shape: sunspaces



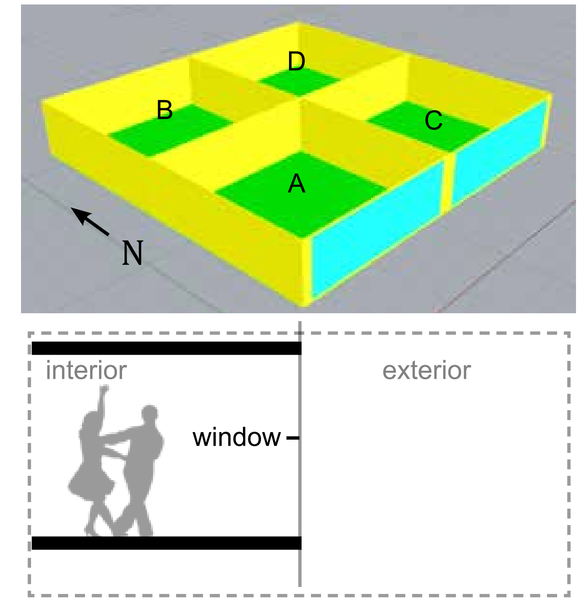


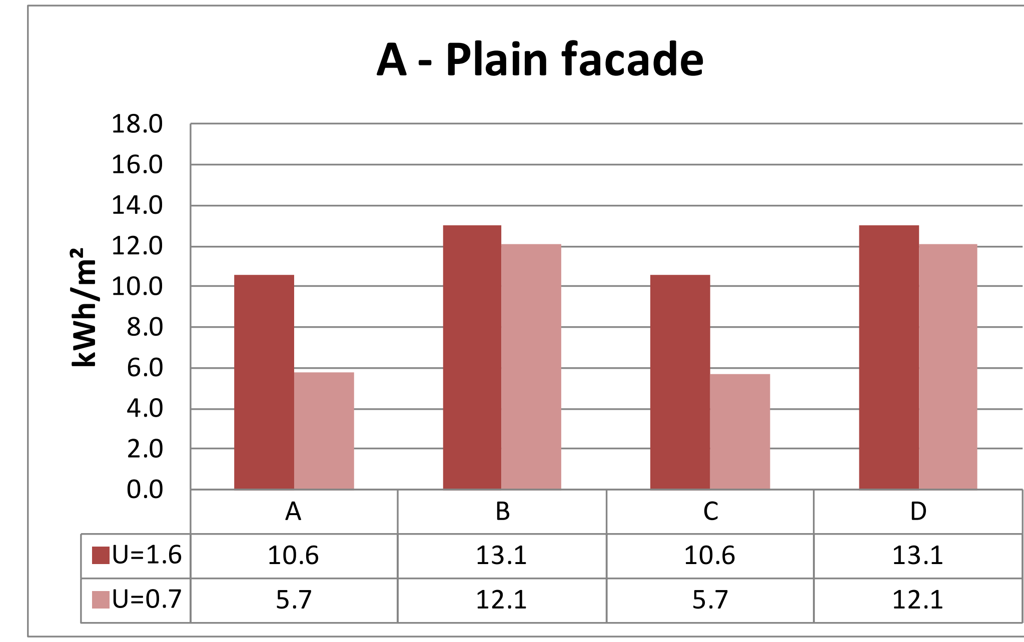
	20%	40%	60%	80%
A, U=1.6	17.4	16.8	16.6	16.5
B, U=1.6	15.5	15.2	14.9	14.6



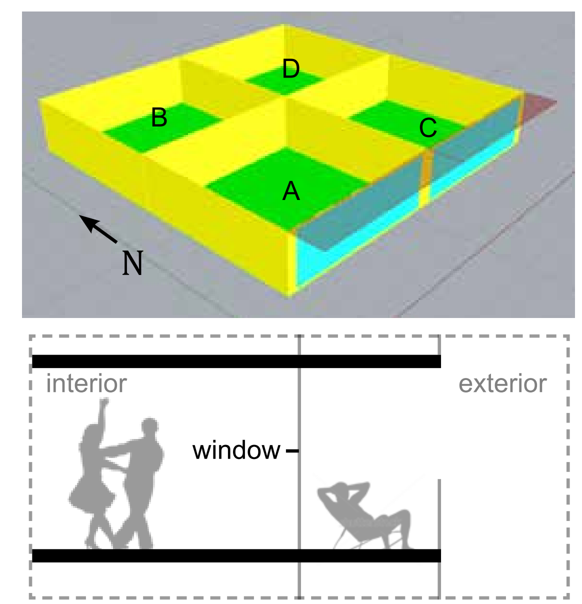
	20%	40%	60%	80%
A, U=0.7	16.4	15.7	15.5	15.3
B, U=0.7	13.6	12.2	11.4	11.1

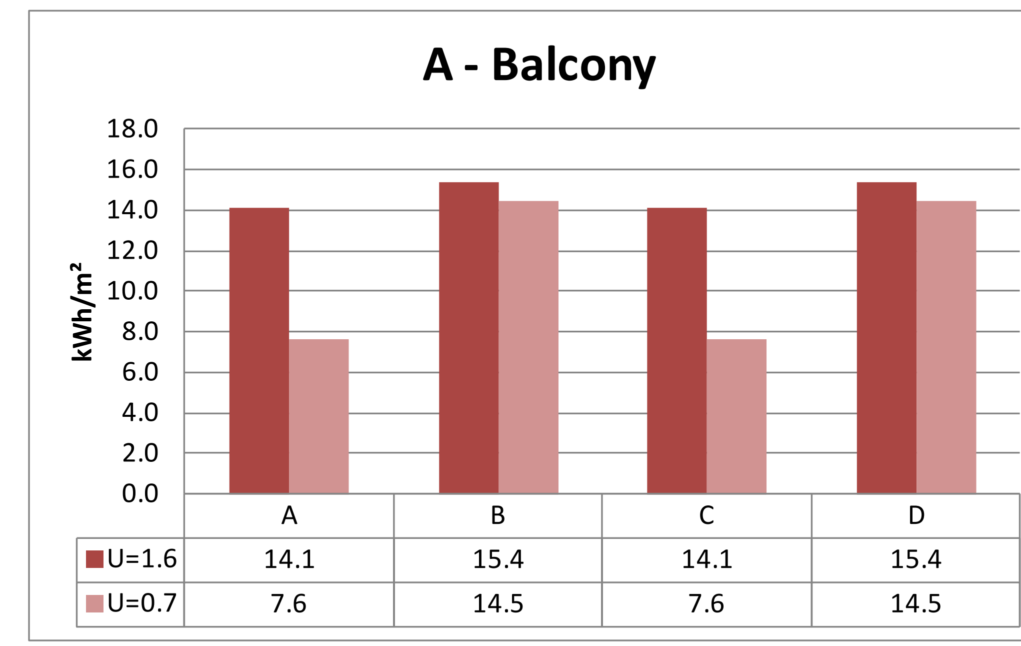
Comparison studies: Shape A



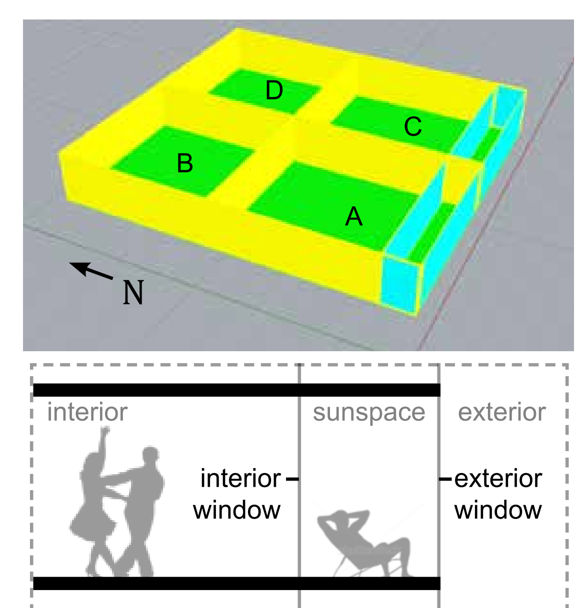


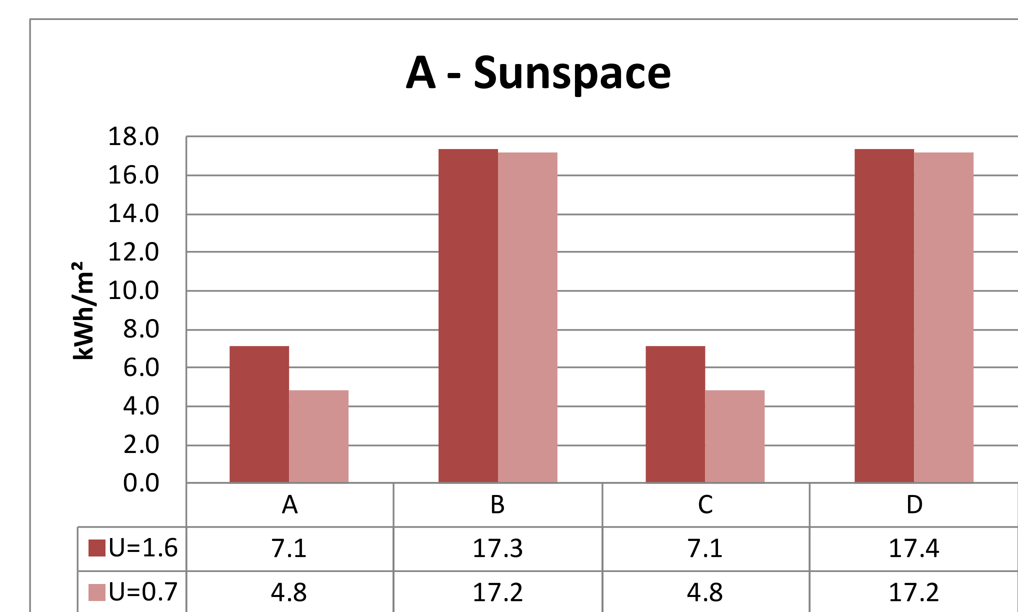
	A	B	C	D
U=1.6	10.6	13.1	10.6	13.1
U=0.7	5.7	12.1	5.7	12.1



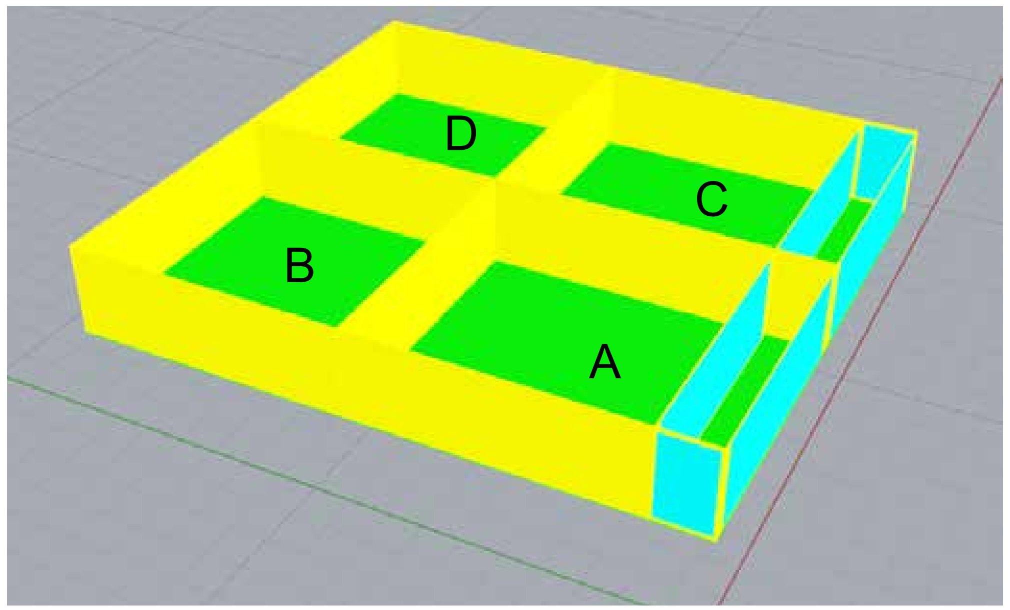


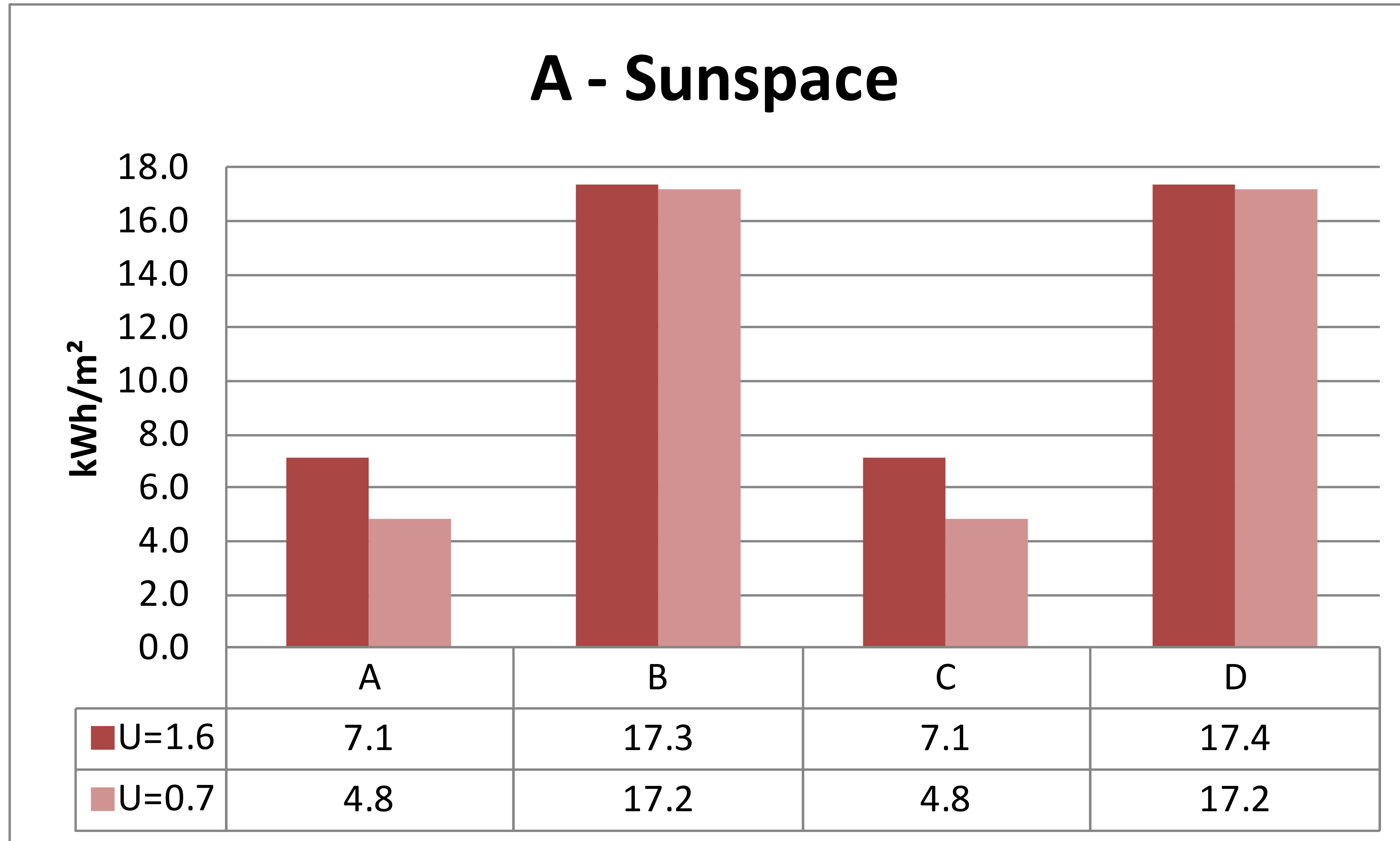
	A	B	C	D
U=1.6	14.1	15.4	14.1	15.4
U=0.7	7.6	14.5	7.6	14.5





	A	B	C	D
U=1.6	7.1	17.3	7.1	17.4
U=0.7	4.8	17.2	4.8	17.2

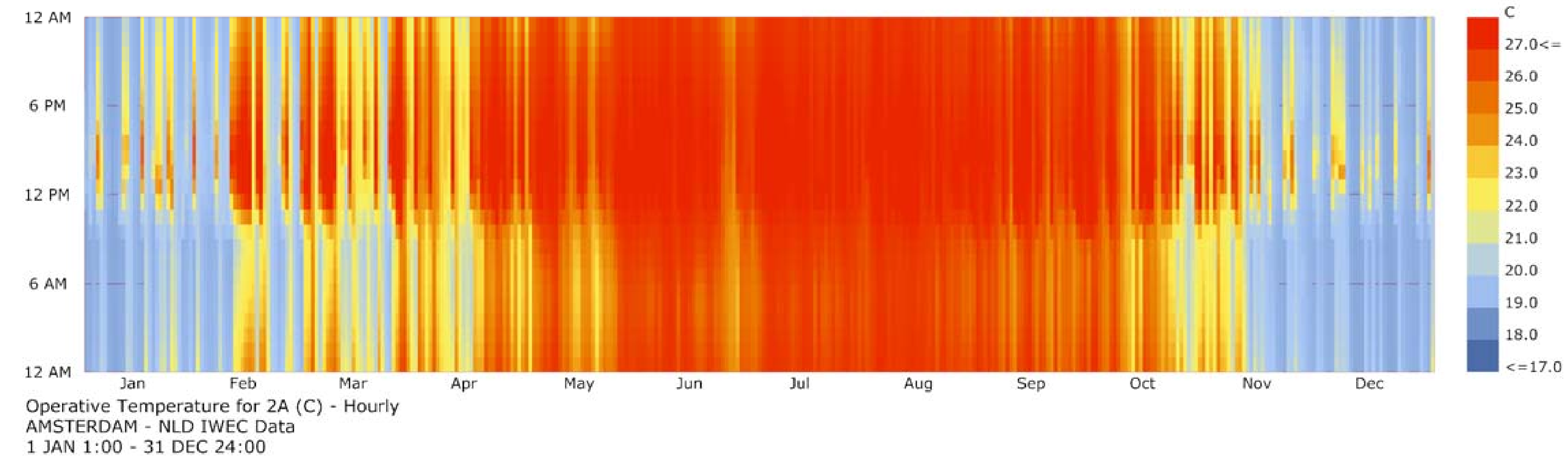




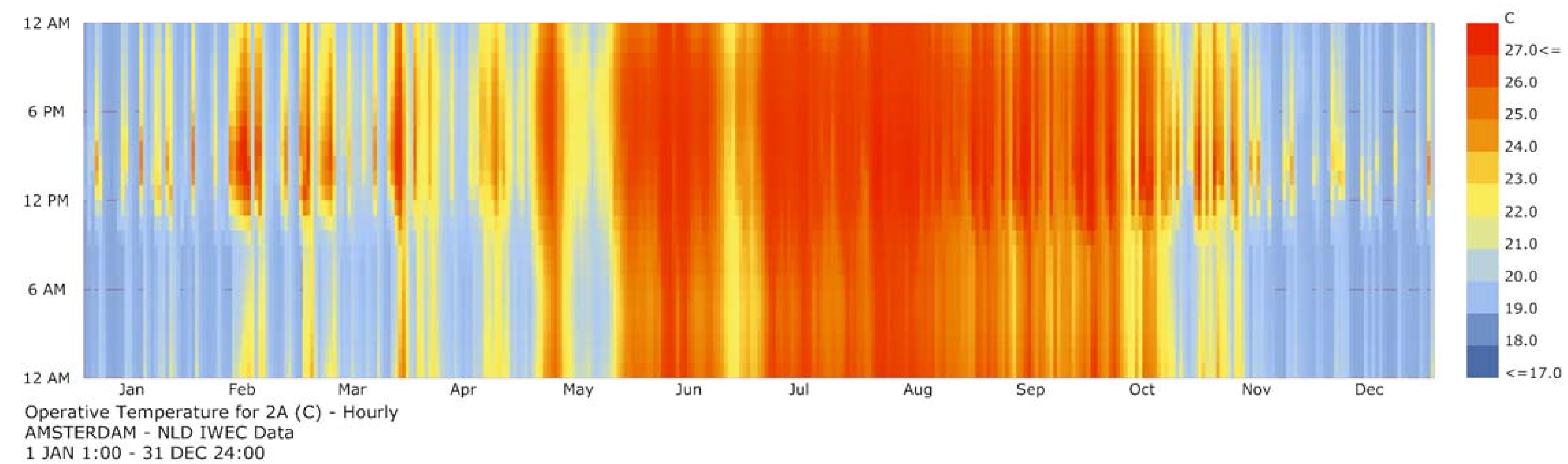
	A	B	C	D
U=1.6	7.1	17.3	7.1	17.4
U=0.7	4.8	17.2	4.8	17.2

why?

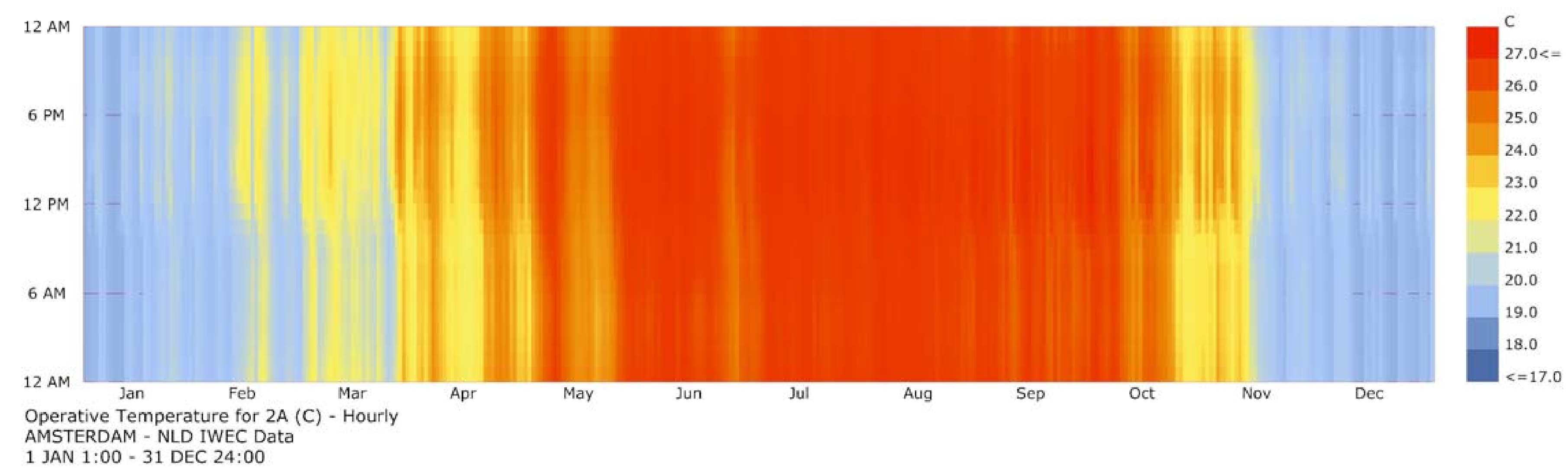
Operative temperature



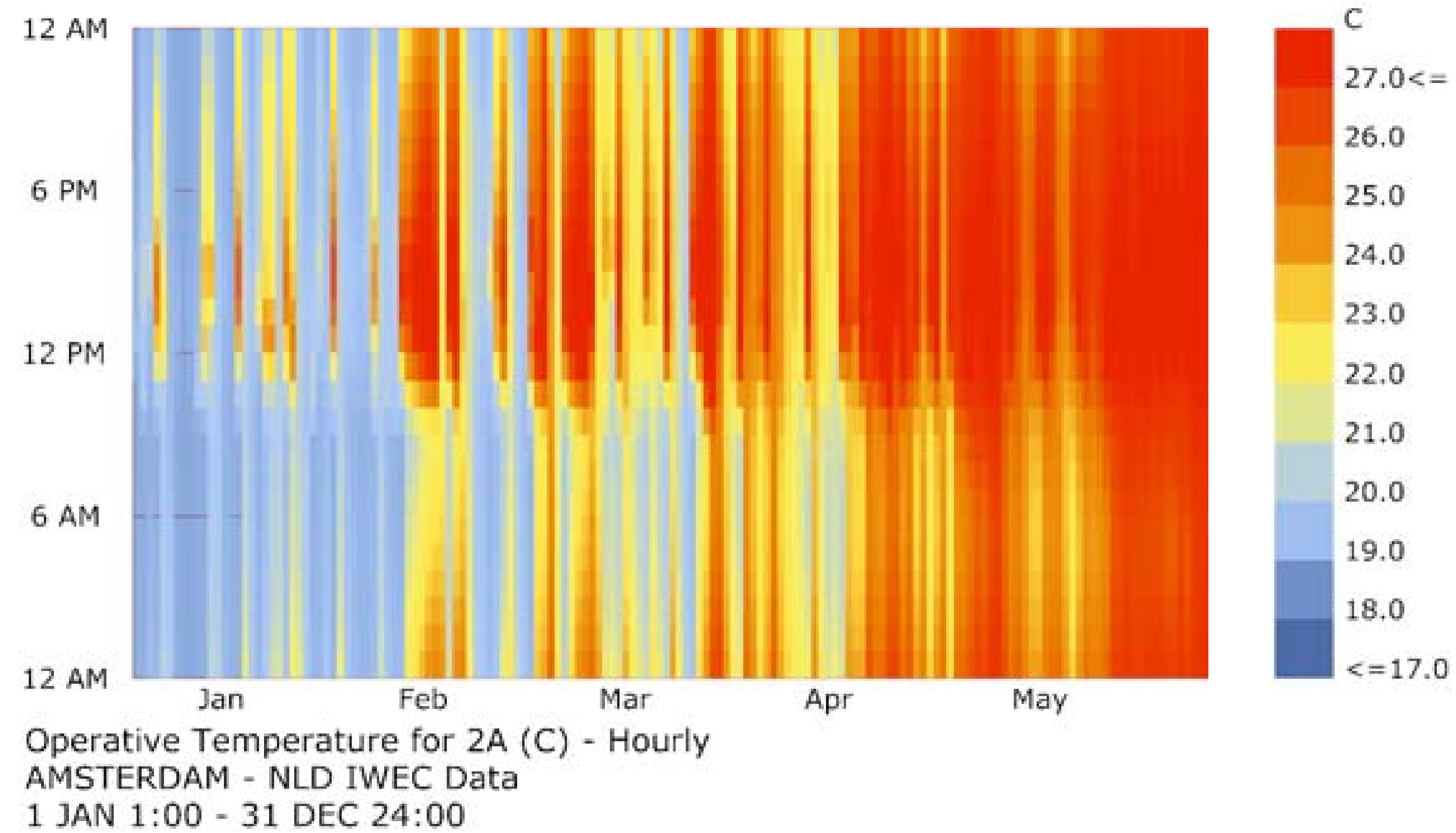
Balconies



Sunspaces

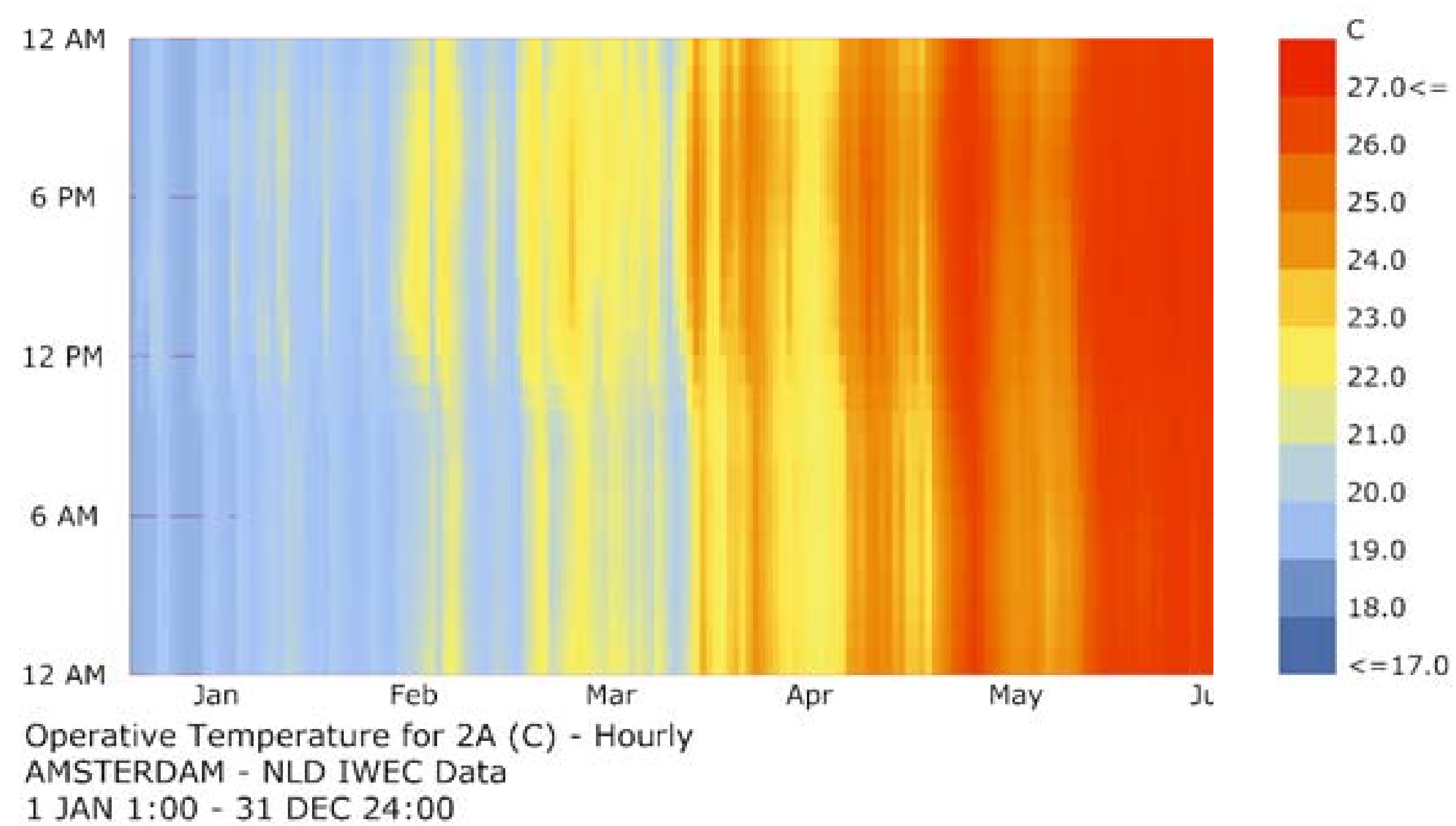


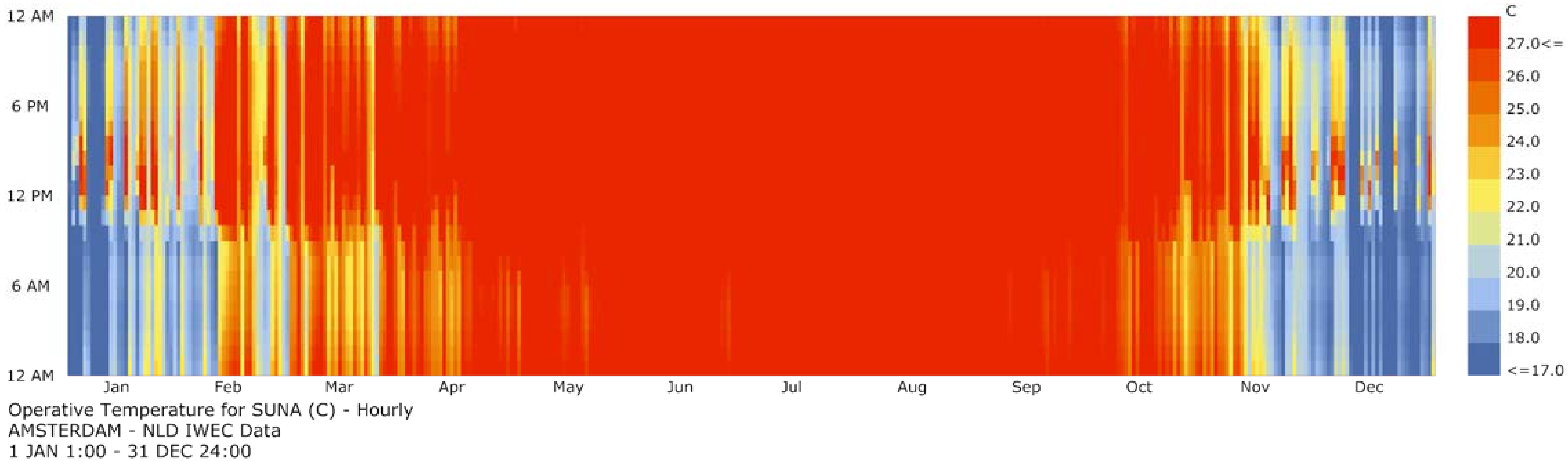
Plain facade



Shape A temperatures

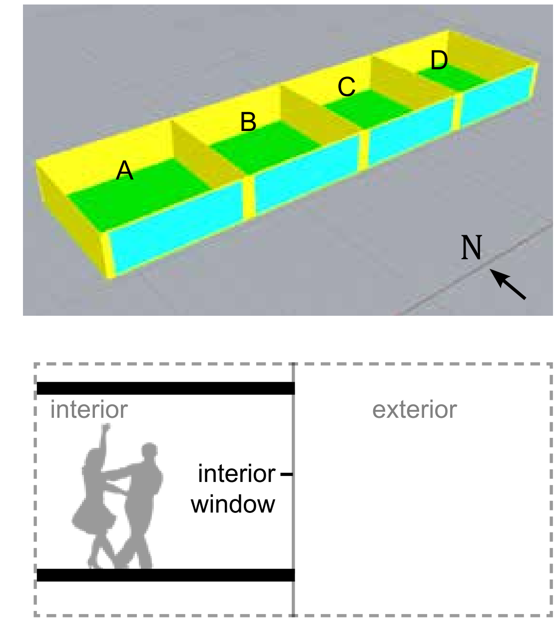
Sunspaces

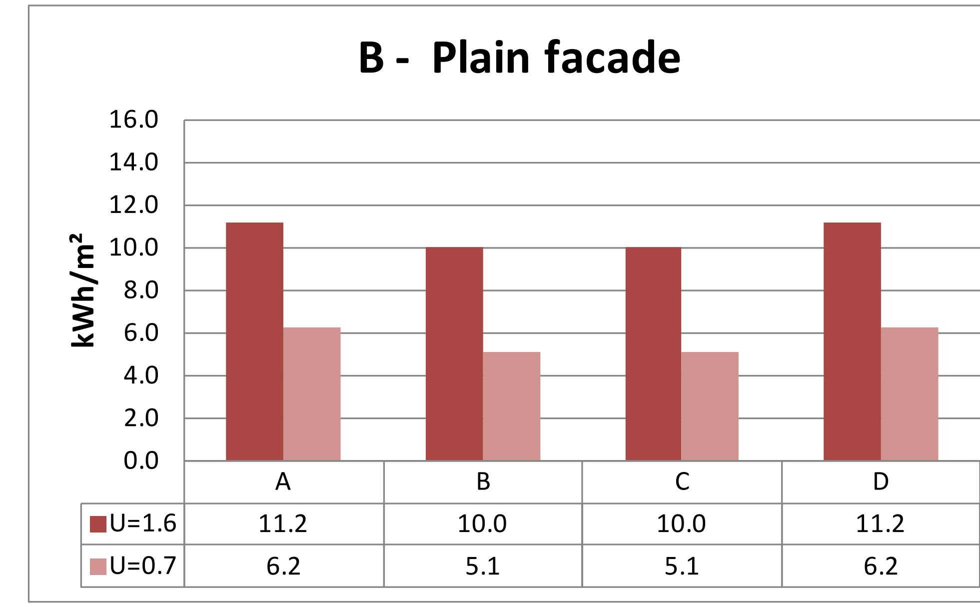




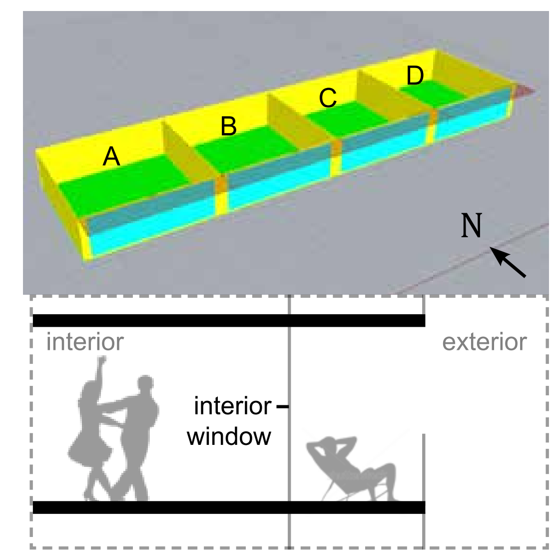
Shape A temperatures: sunspace

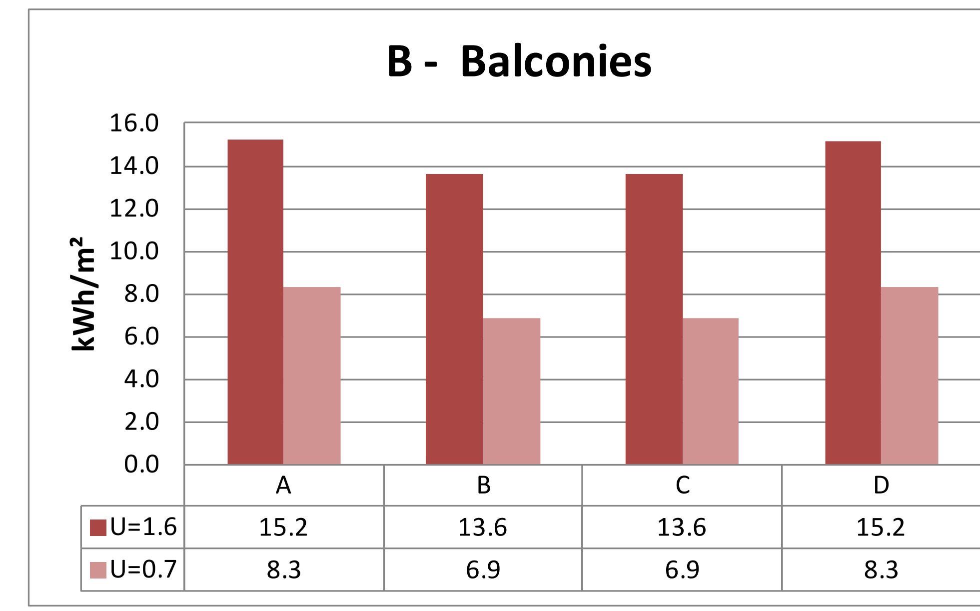
Comparison studies: Shape B



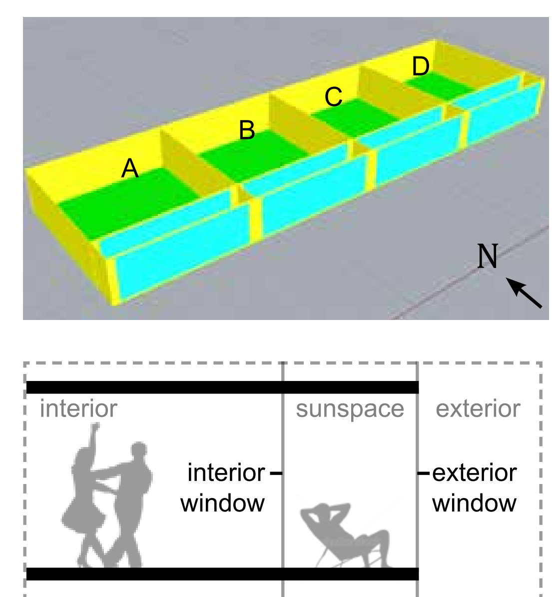


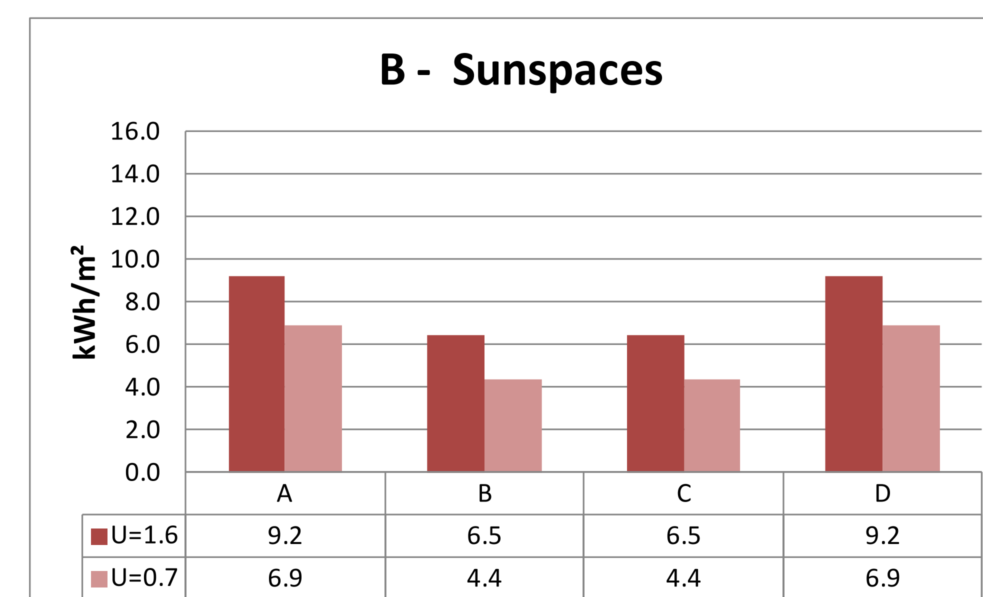
	A	B	C	D
U=1.6	11.2	10.0	10.0	11.2
U=0.7	6.2	5.1	5.1	6.2



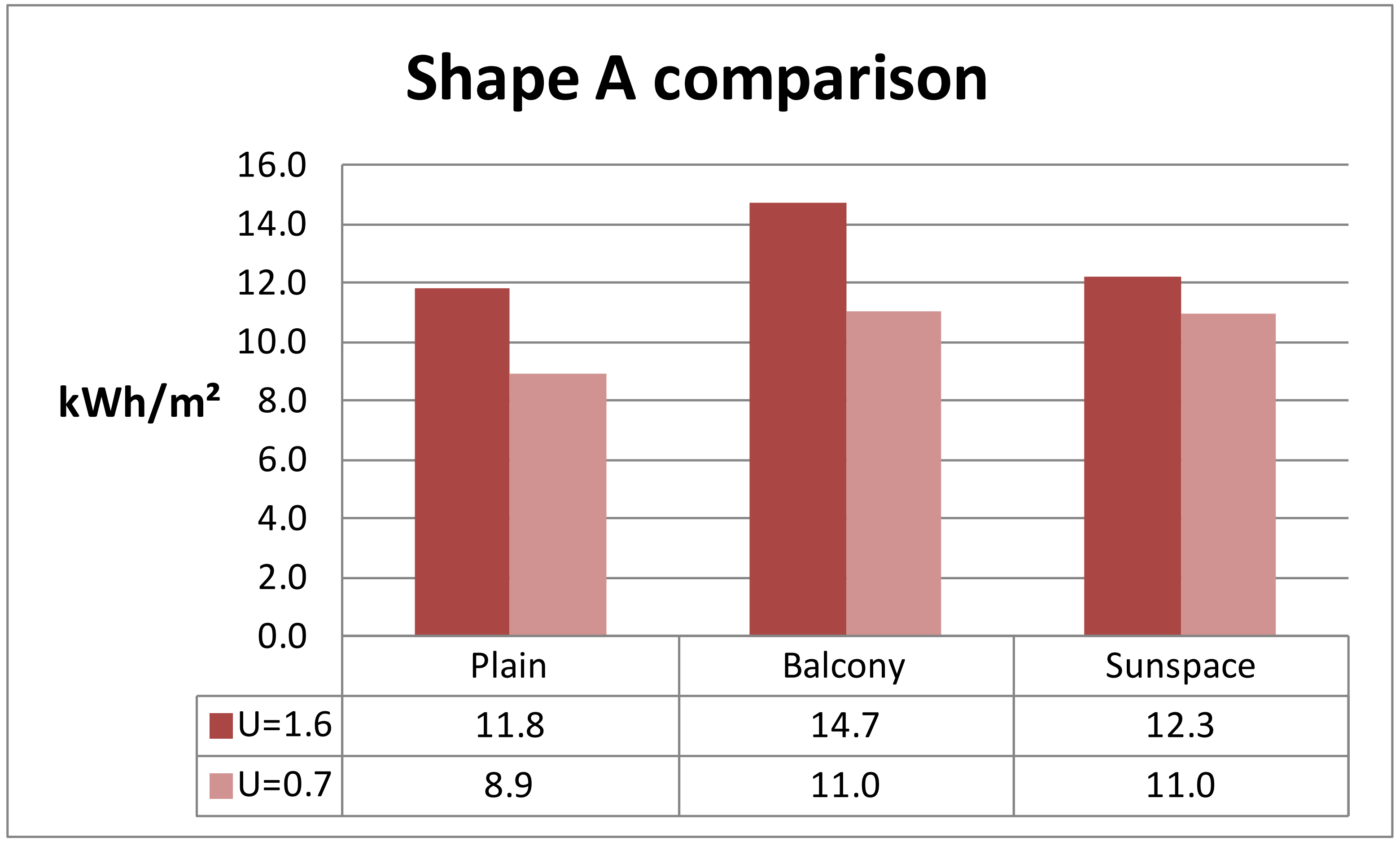


	A	B	C	D
U=1.6	15.2	13.6	13.6	15.2
U=0.7	8.3	6.9	6.9	8.3

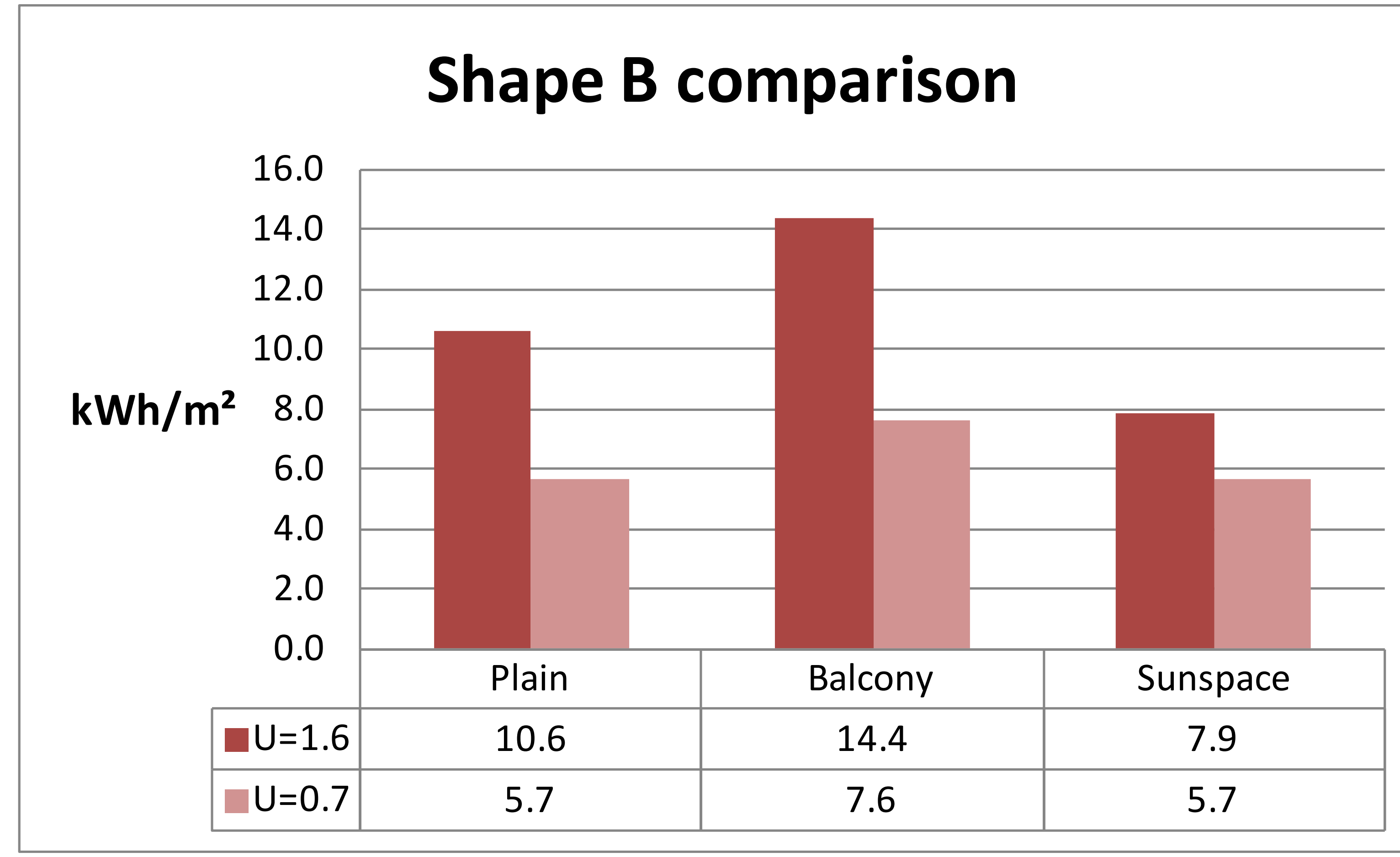




	A	B	C	D
U=1.6	9.2	6.5	6.5	9.2
U=0.7	6.9	4.4	4.4	6.9

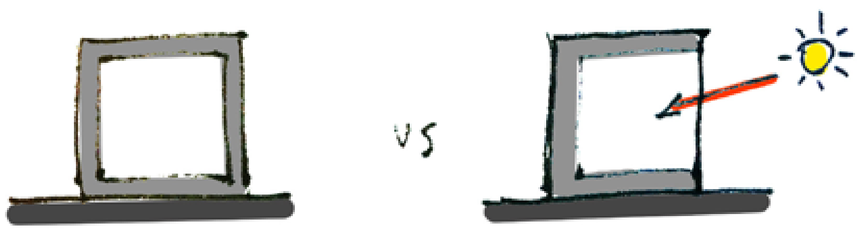


	Plain	Balcony	Sunspace
U=1.6	11.8	14.7	12.3
U=0.7	8.9	11.0	11.0



	Plain	Balcony	Sunspace
U=1.6	10.6	14.4	7.9
U=0.7	5.7	7.6	5.7

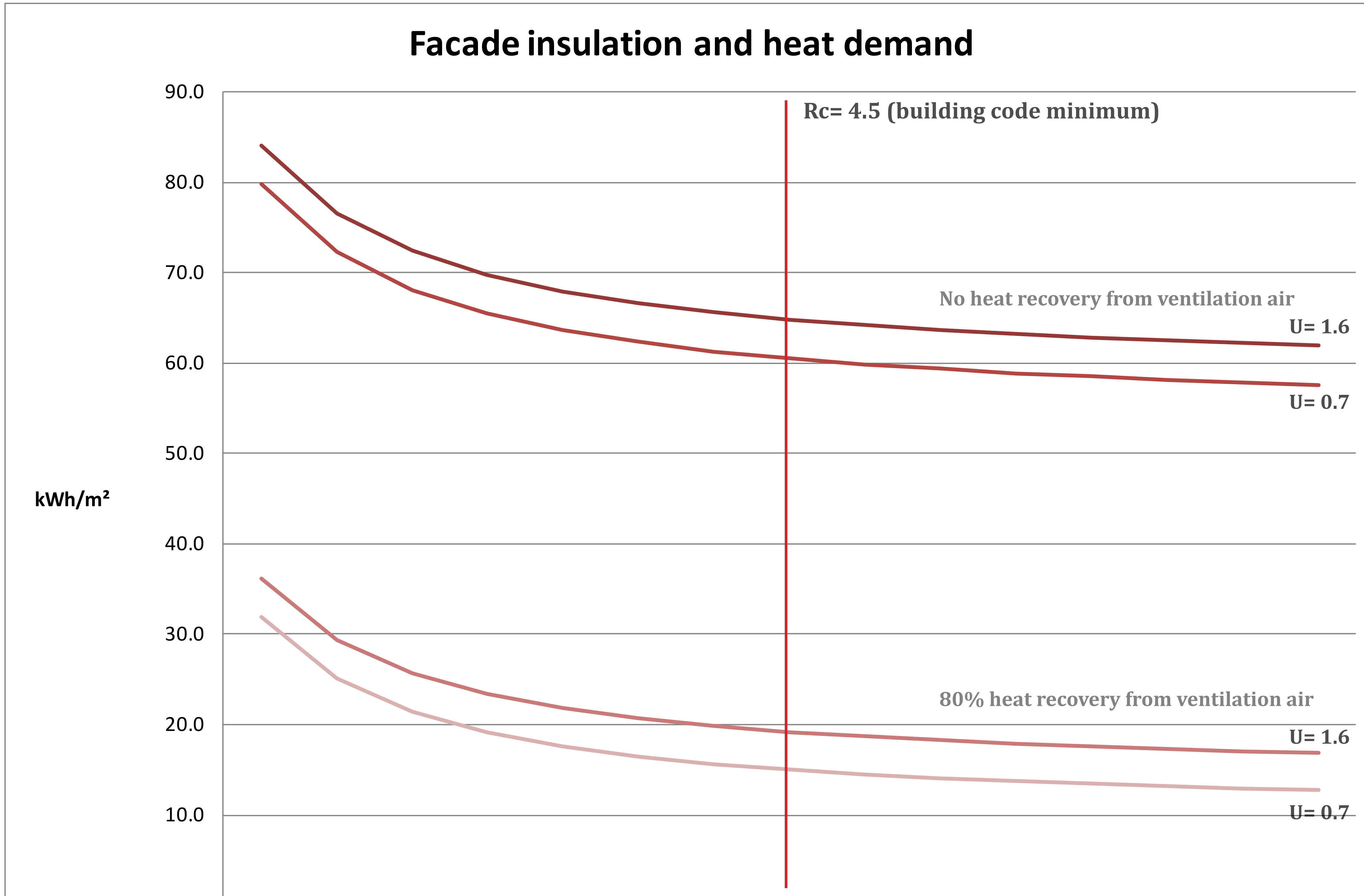
Comparison studies: overview



4.3 Study conclusions

. Insulation
. Orientation
. Building Shape
. Sunspaces

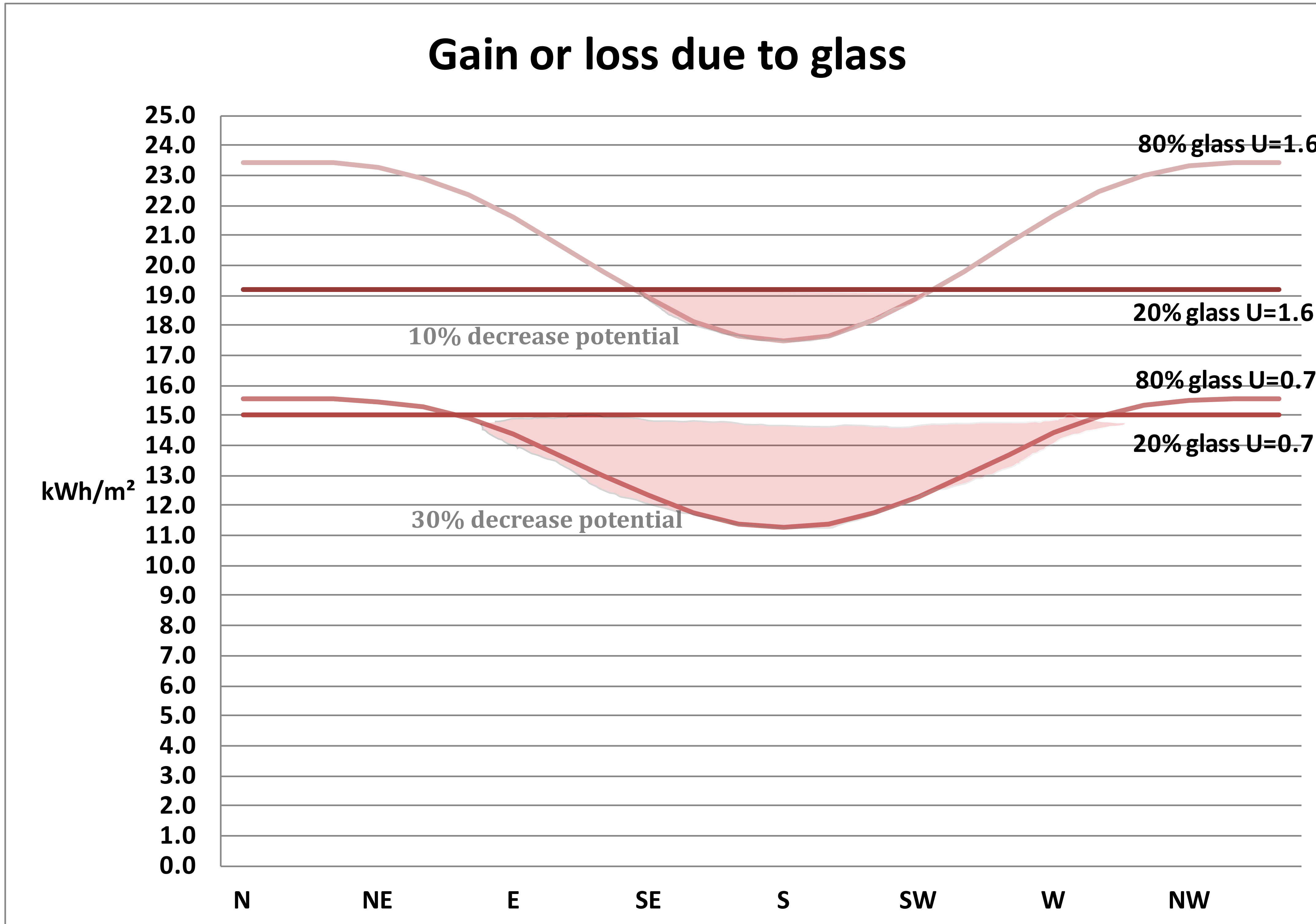
Insulation



	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
U=1.6, no HR	84.0	76.5	72.4	69.8	68.0	66.7	65.6	64.9	64.2	63.7	63.3	62.9	62.5	62.3	62.0
U=0.7 no HR	79.9	72.3	68.1	65.5	63.7	62.3	61.3	60.5	59.9	59.3	58.9	58.5	58.2	57.9	57.6
U=1.6 with HR	36.1	29.3	25.6	23.4	21.8	20.7	19.9	19.2	18.7	18.2	17.9	17.6	17.3	17.1	16.9
U=0.7 with HR	31.9	25.0	21.4	19.1	17.6	16.5	15.7	15.0	14.5	14.1	13.7	13.4	13.2	12.9	12.7

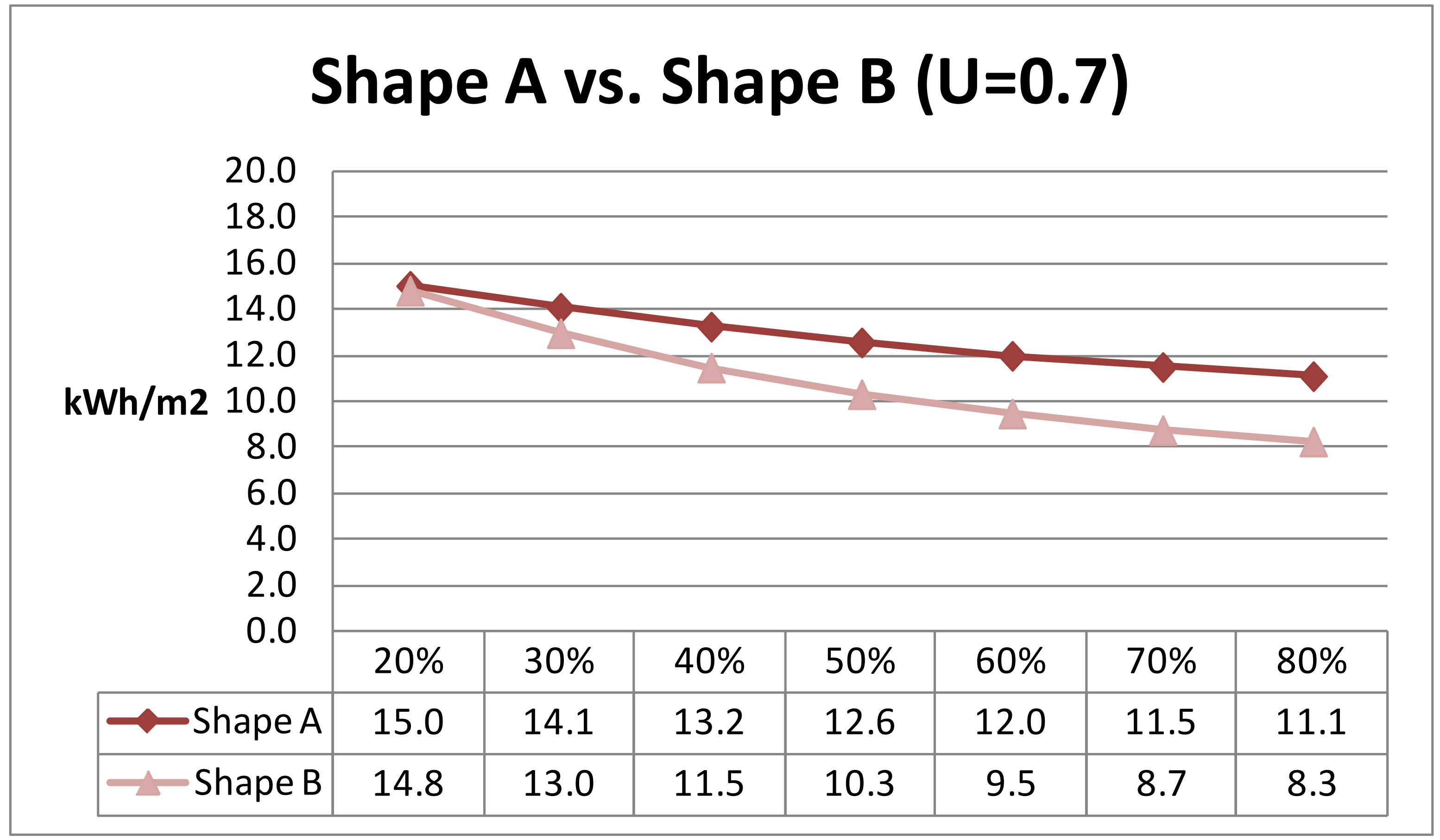
Heat recovery has huge impact,
insulation over Rc= 4.5 has very limited impact.

Orientation



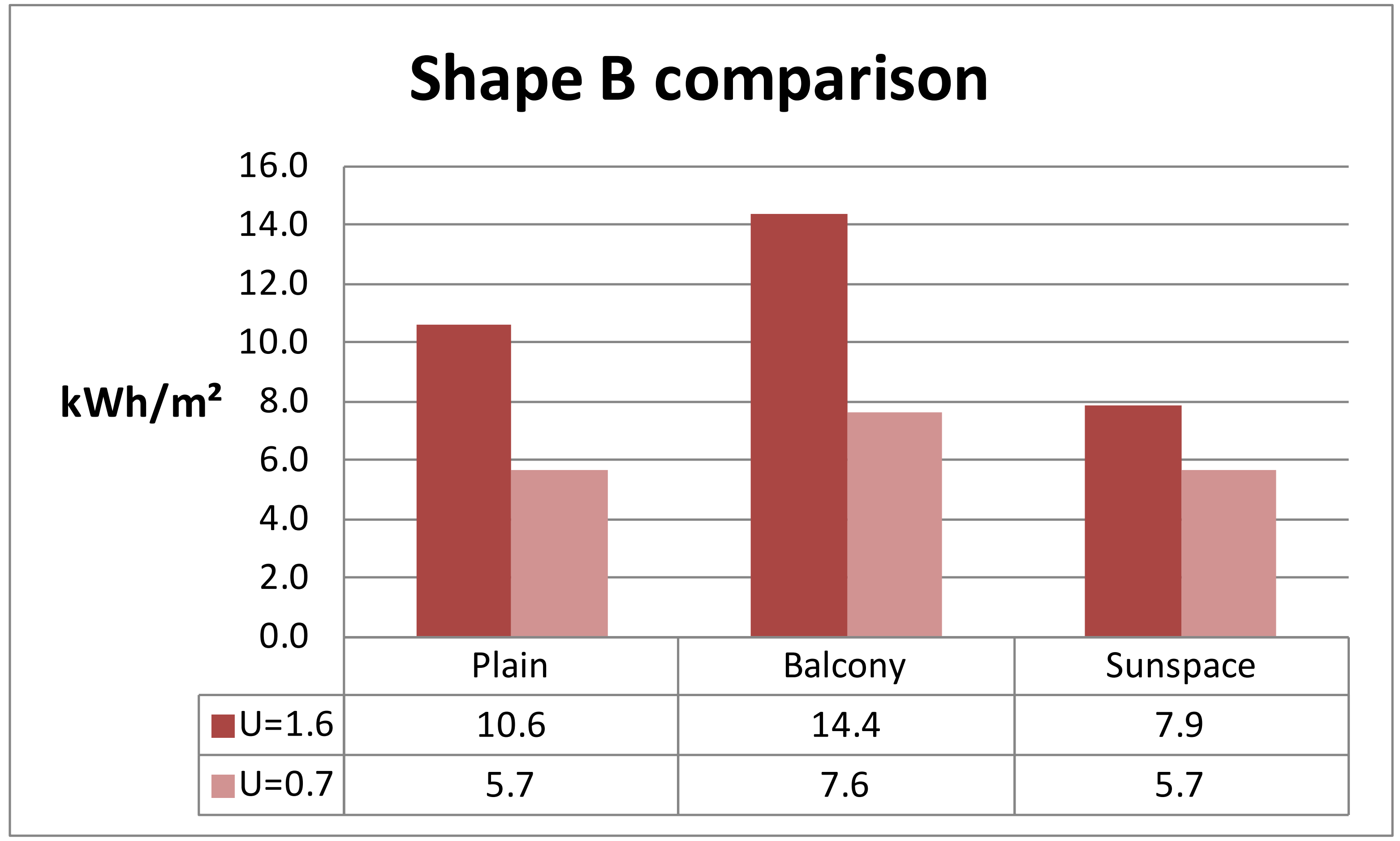
Orientation has extreme impact.

Building shape



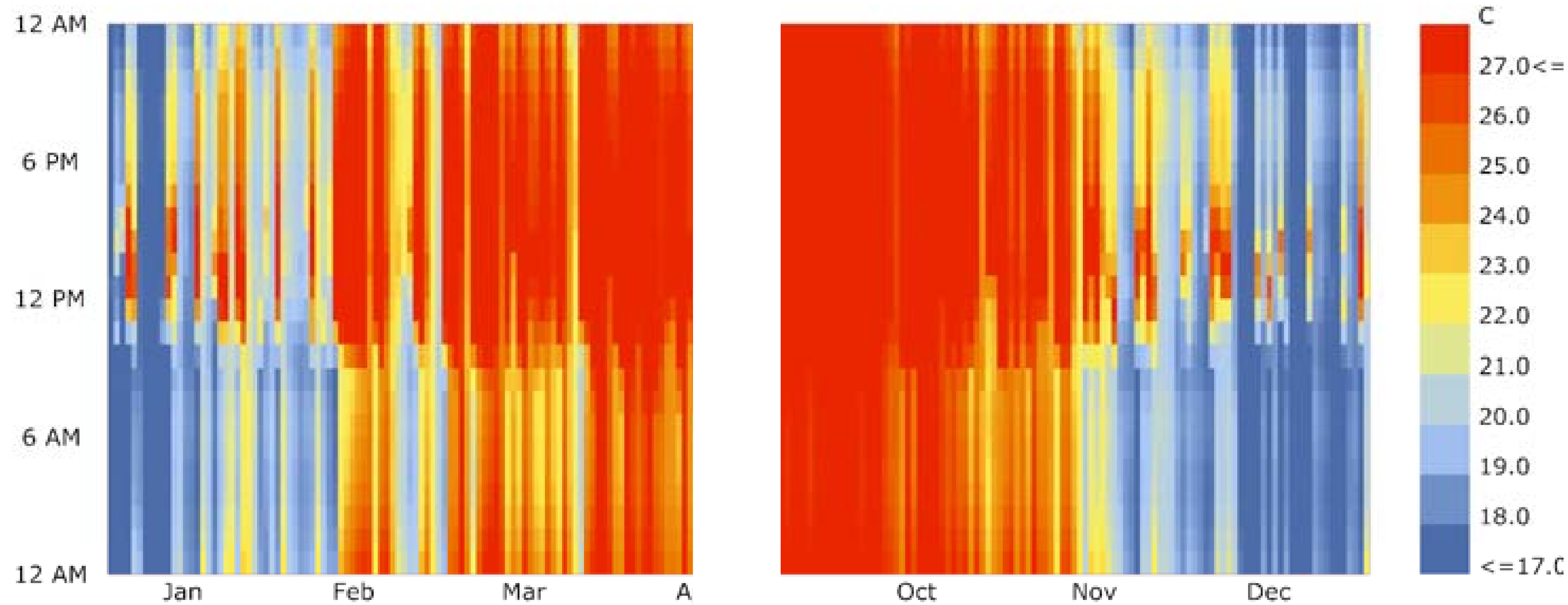
Shape B, sun surface far outweighs compactness when well insulated.

Sunspaces



	Plain	Balcony	Sunspace
U=1.6	10.6	14.4	7.9
U=0.7	5.7	7.6	5.7

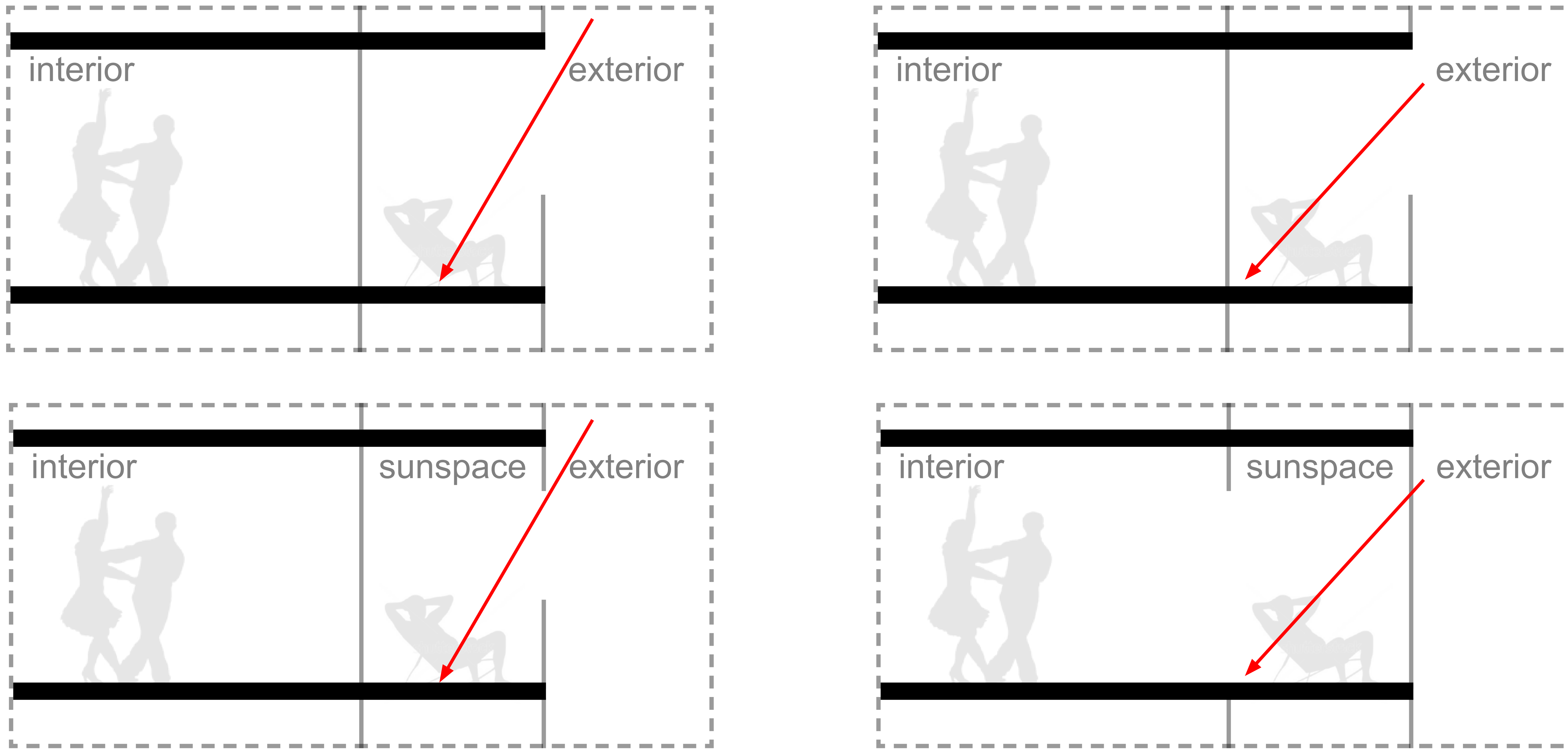
Sunspaces



Operative Temperature for SUNA (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

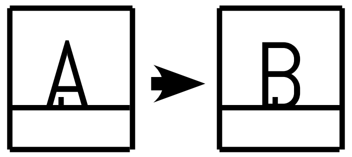
Flexible use

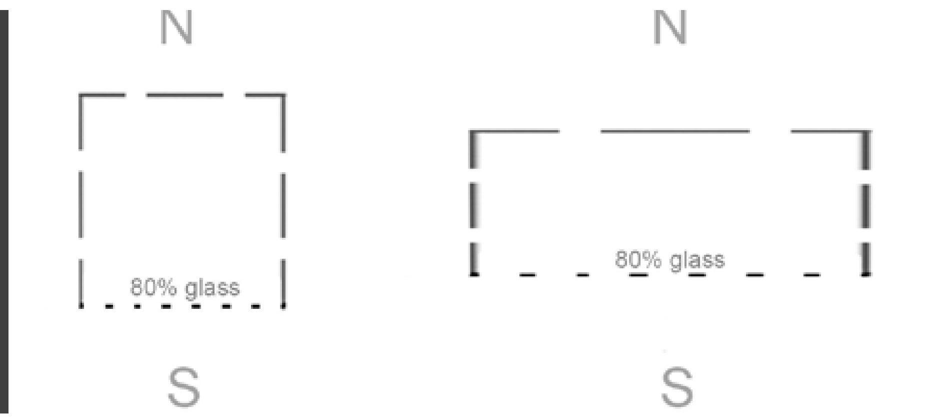
Sunspaces



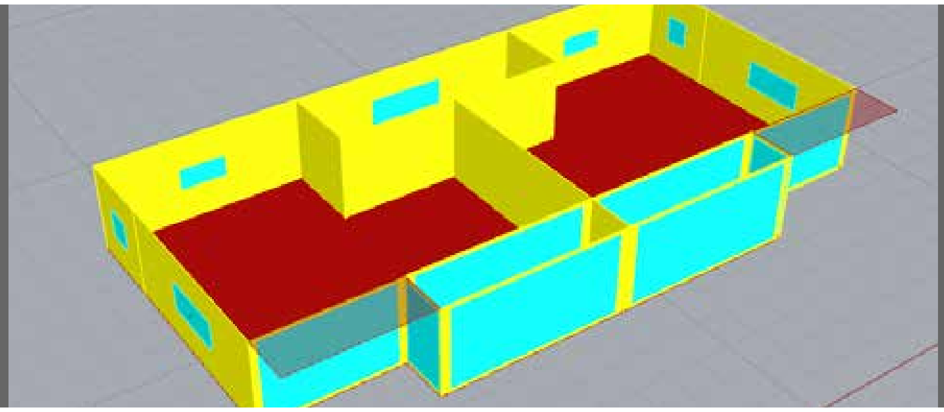
Summer   *Winter*

5. RE-DESIGN CASE

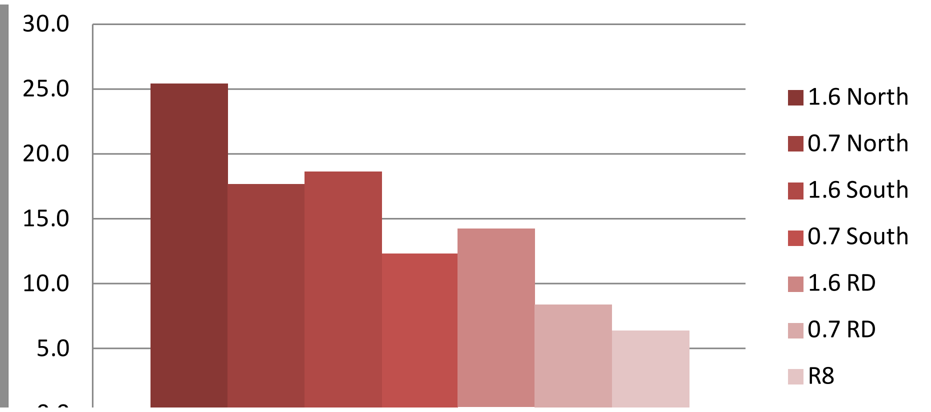




5.1 Re-Design Process



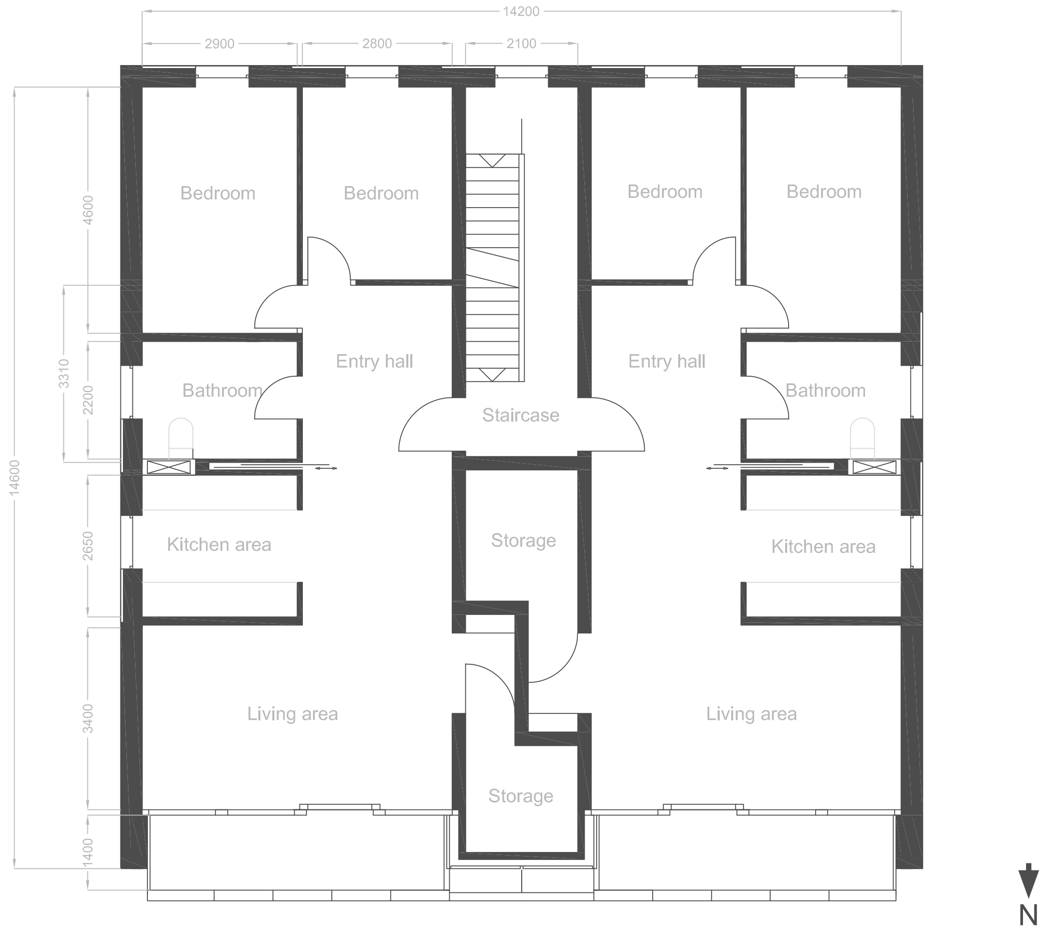
5.2 Re-design Modelling

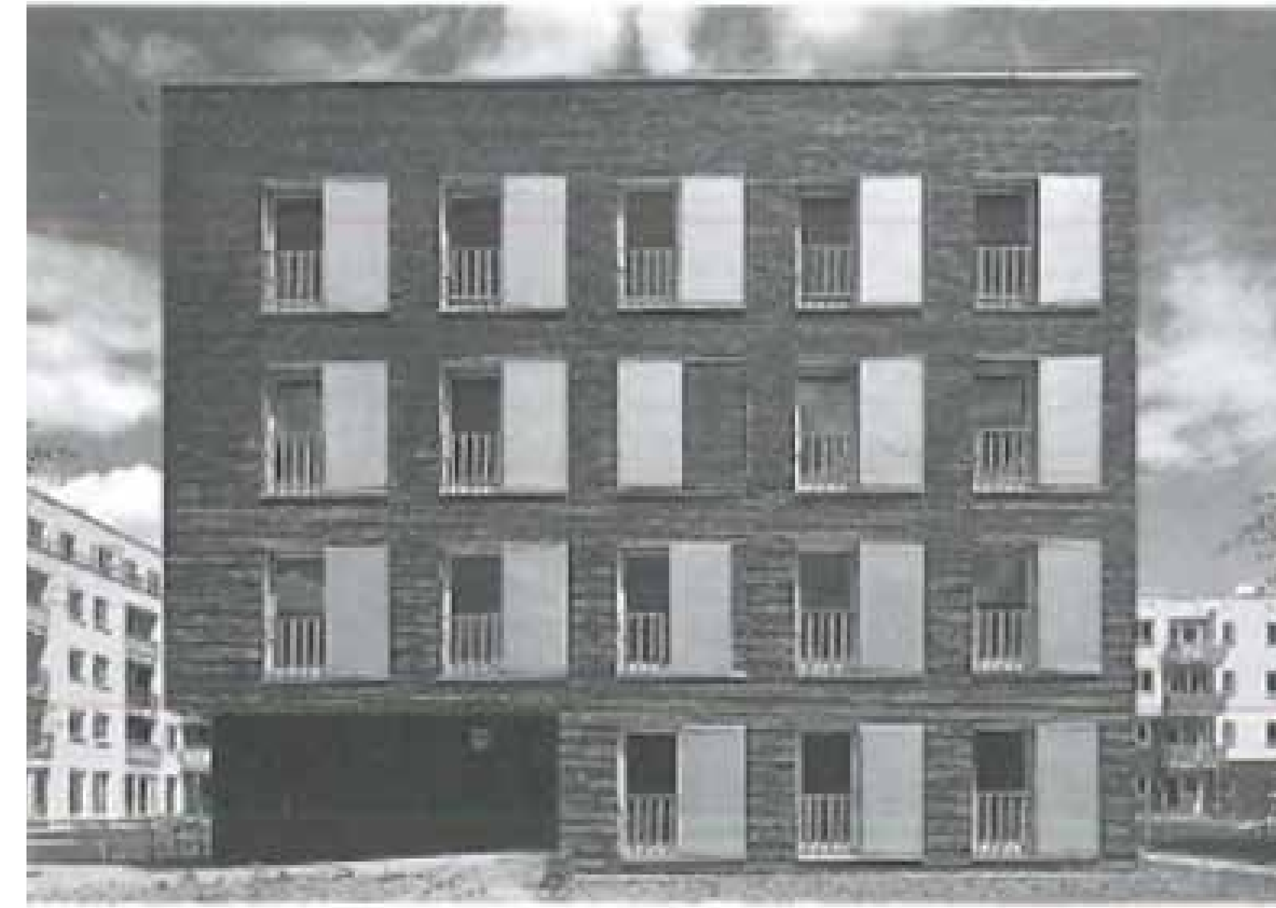


5.3 Analysis

5.1 Re-design process

. Case building
. Design steps
. Final re-design

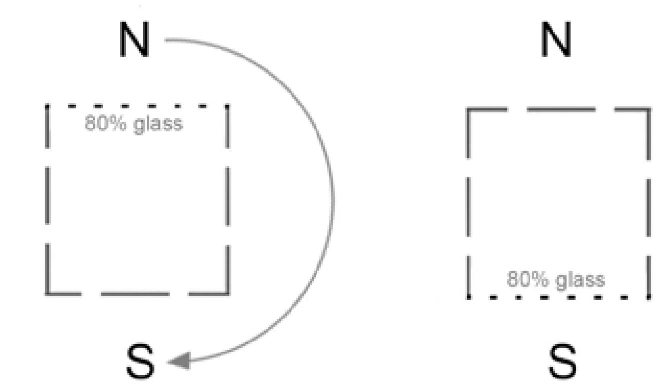




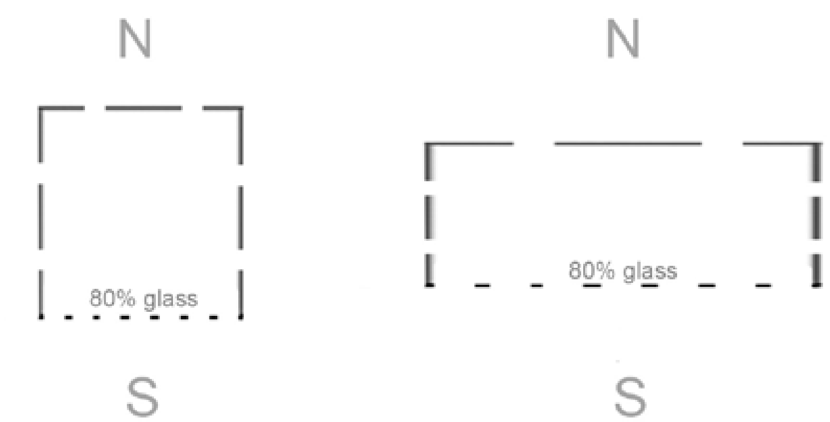
Case building

Design steps

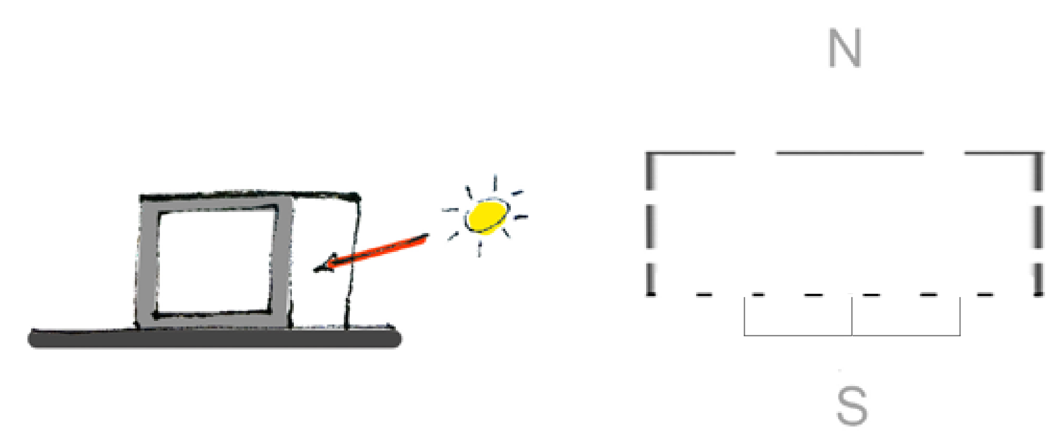
Step 1: Orientation change



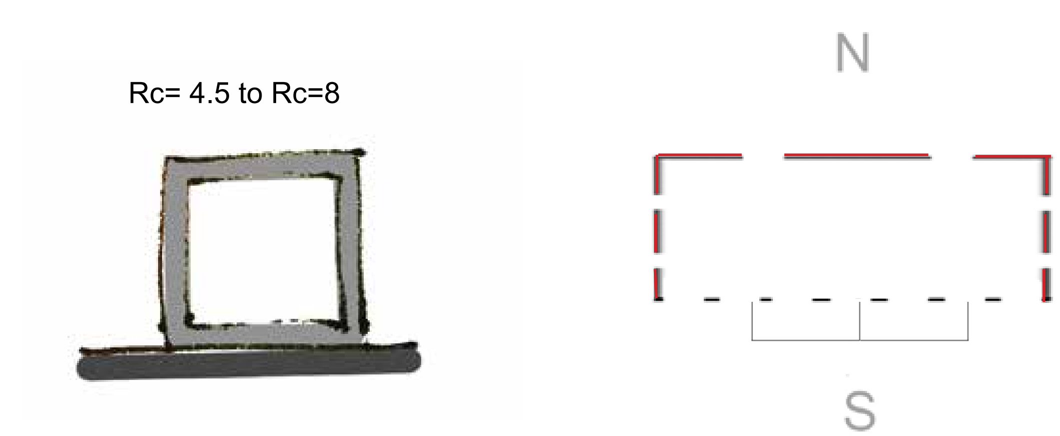
Step 2: Shape change (A to B)

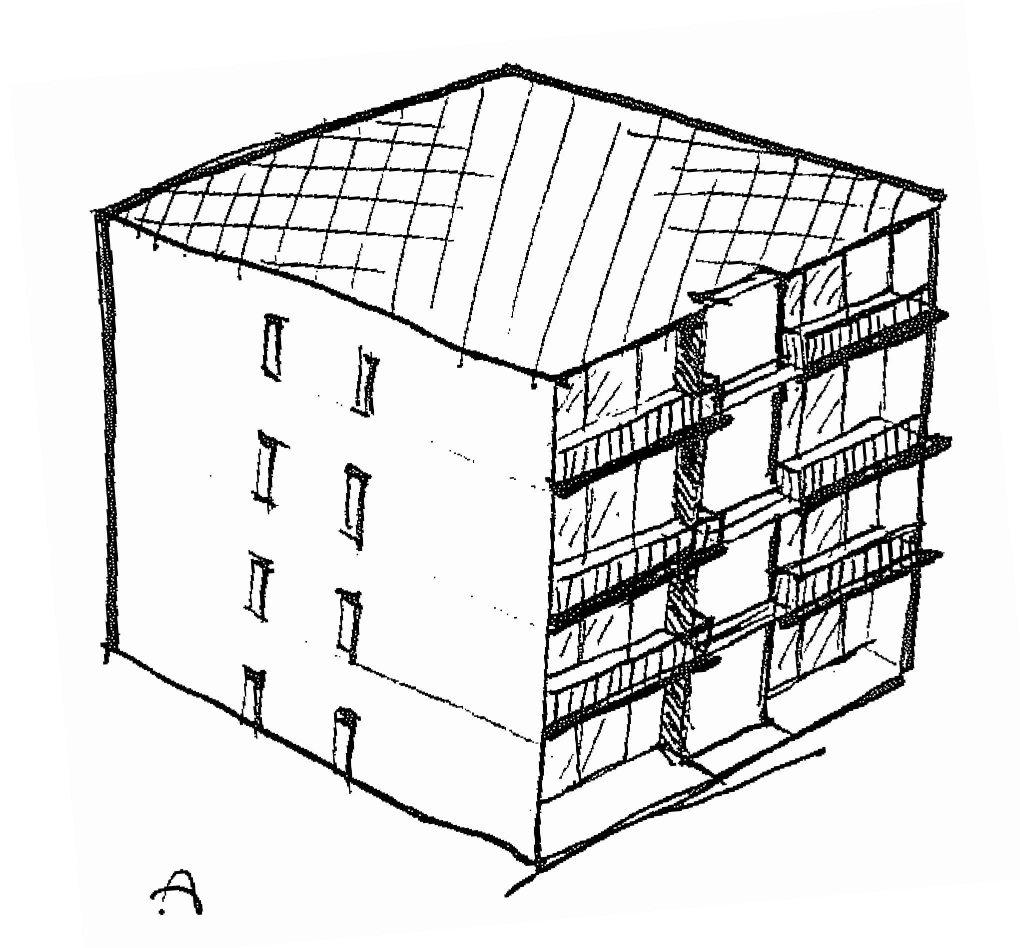


Step 3: Sunspace and sunshade

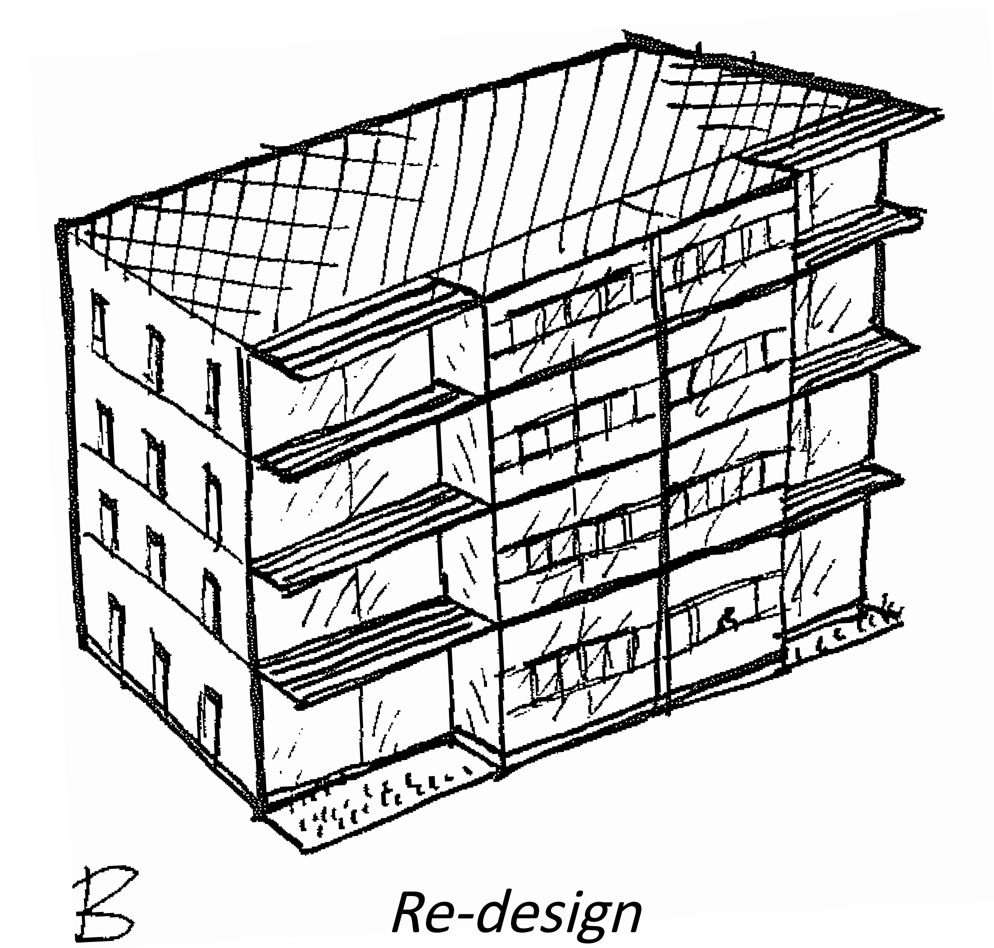


Step 4: Improve Insulation



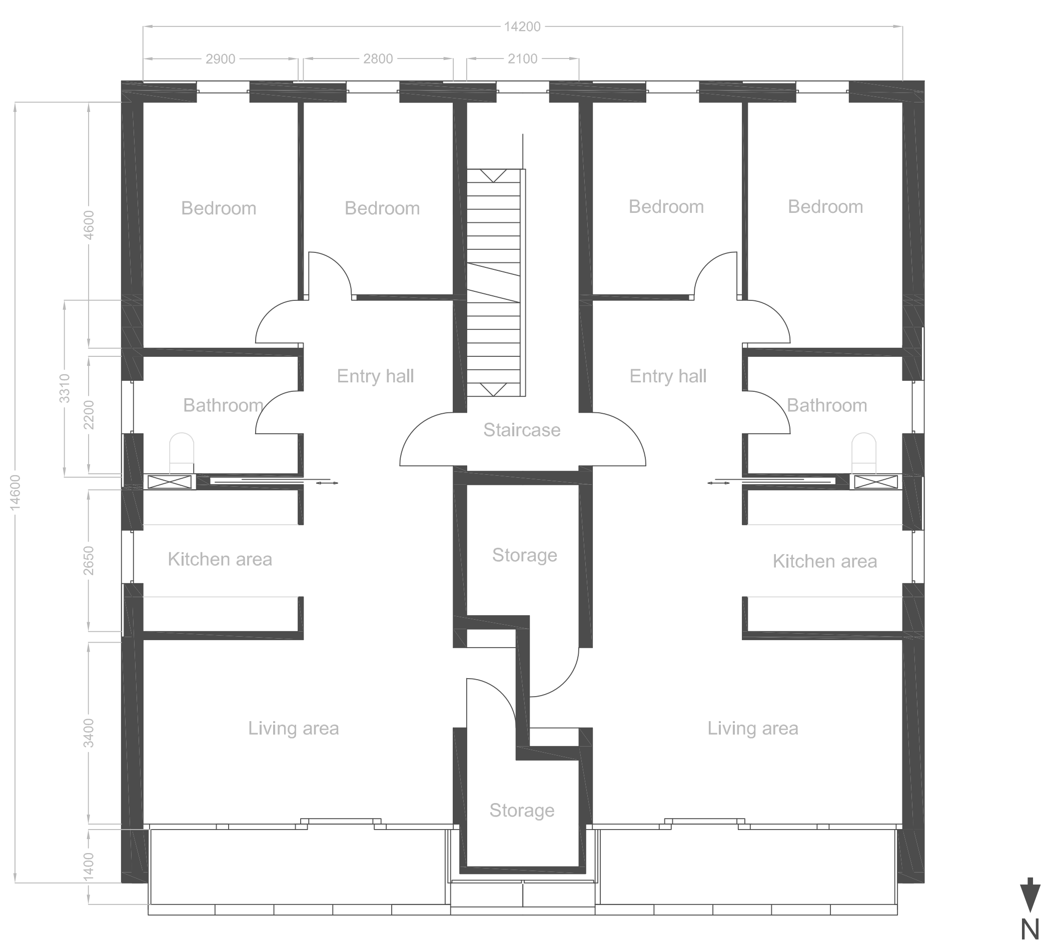


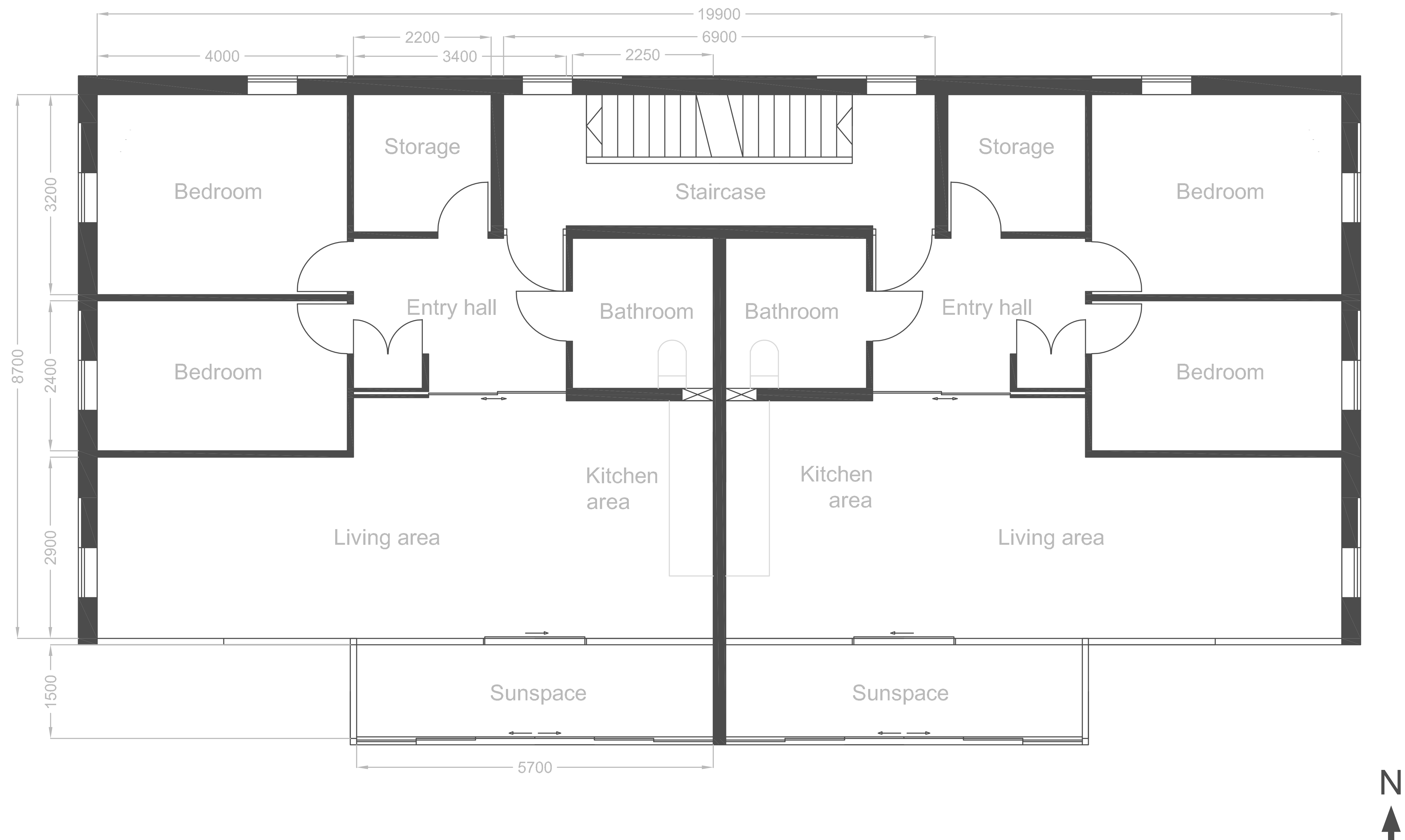
Original design



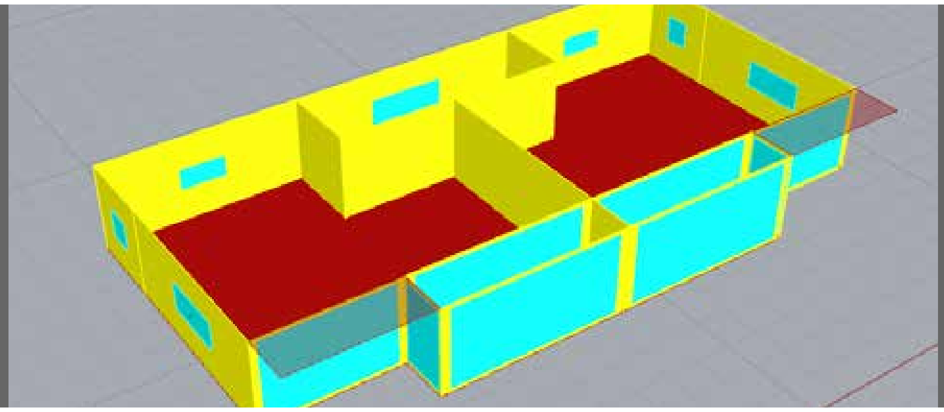
Re-design

Final re-design





Re-design floorplan



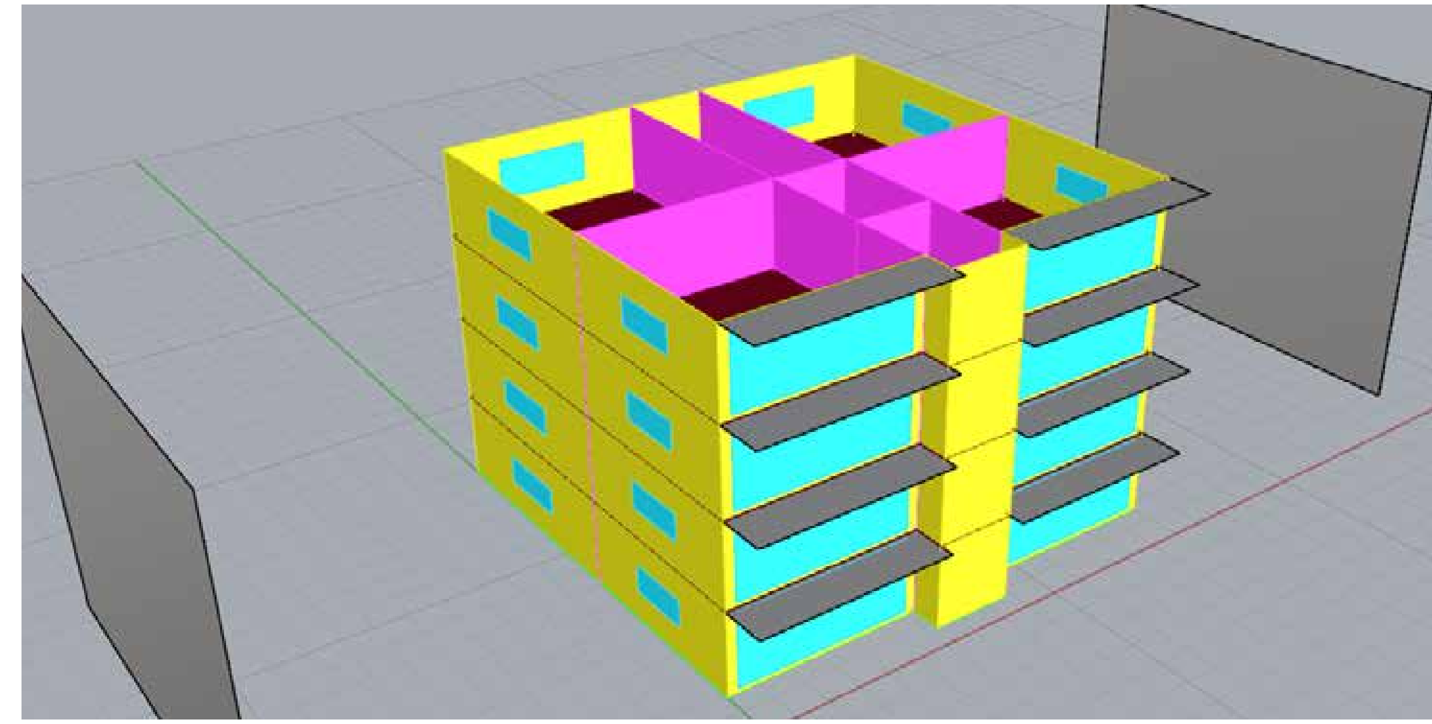
5.2 Re-design modelling

. Zones
. Models

Zones

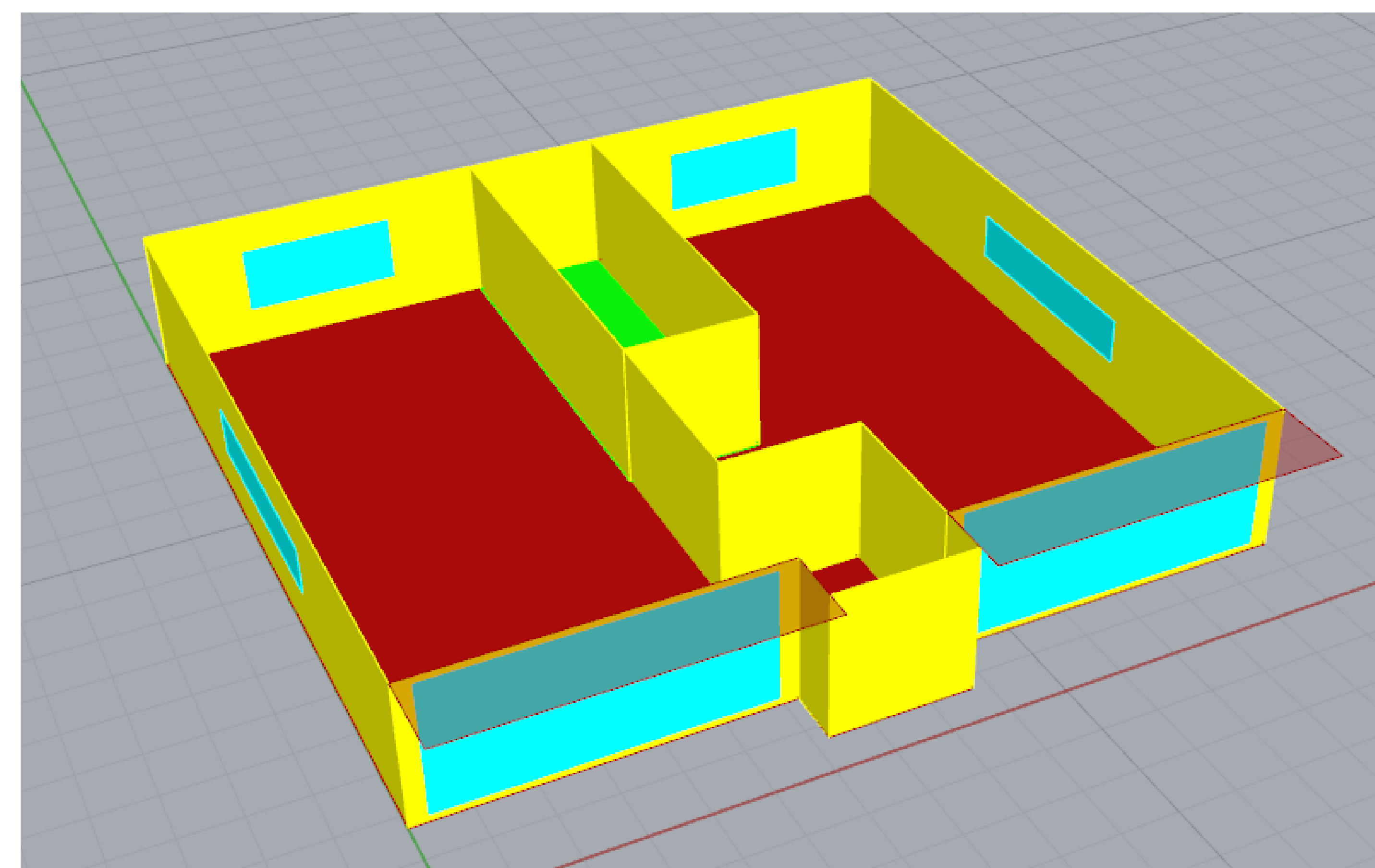
Validation model

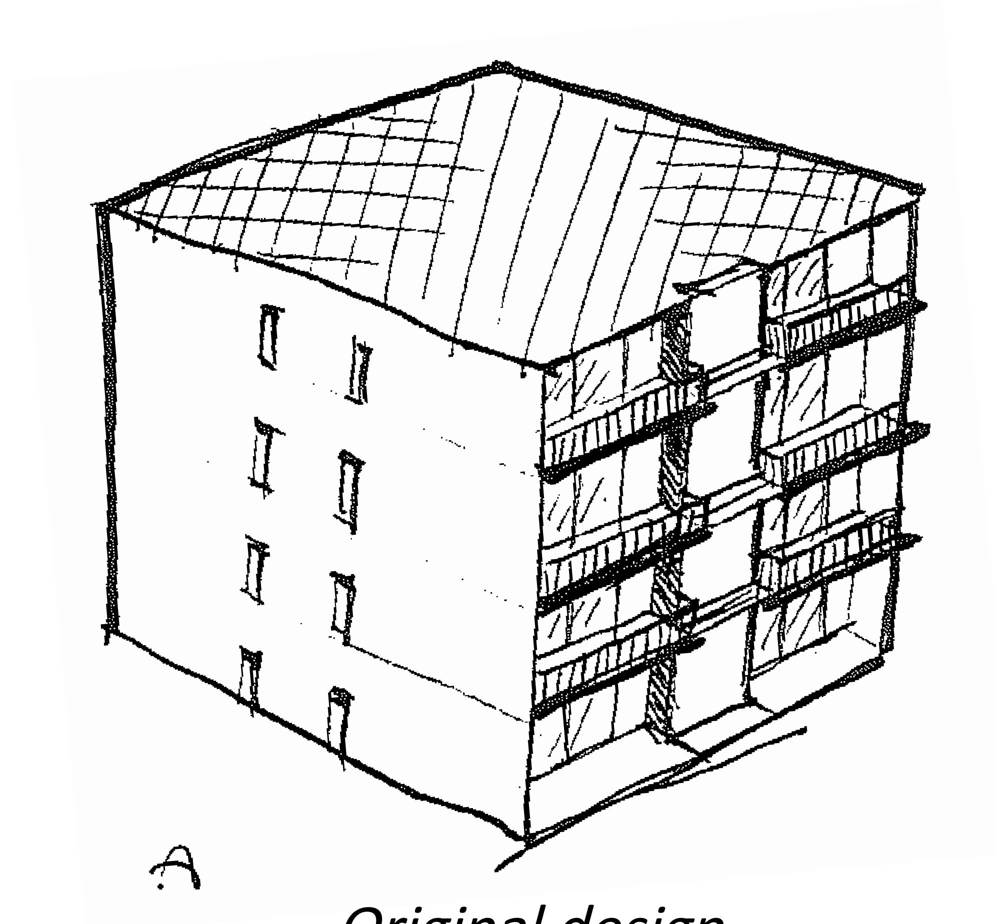
- *many zones*
- *all floors*



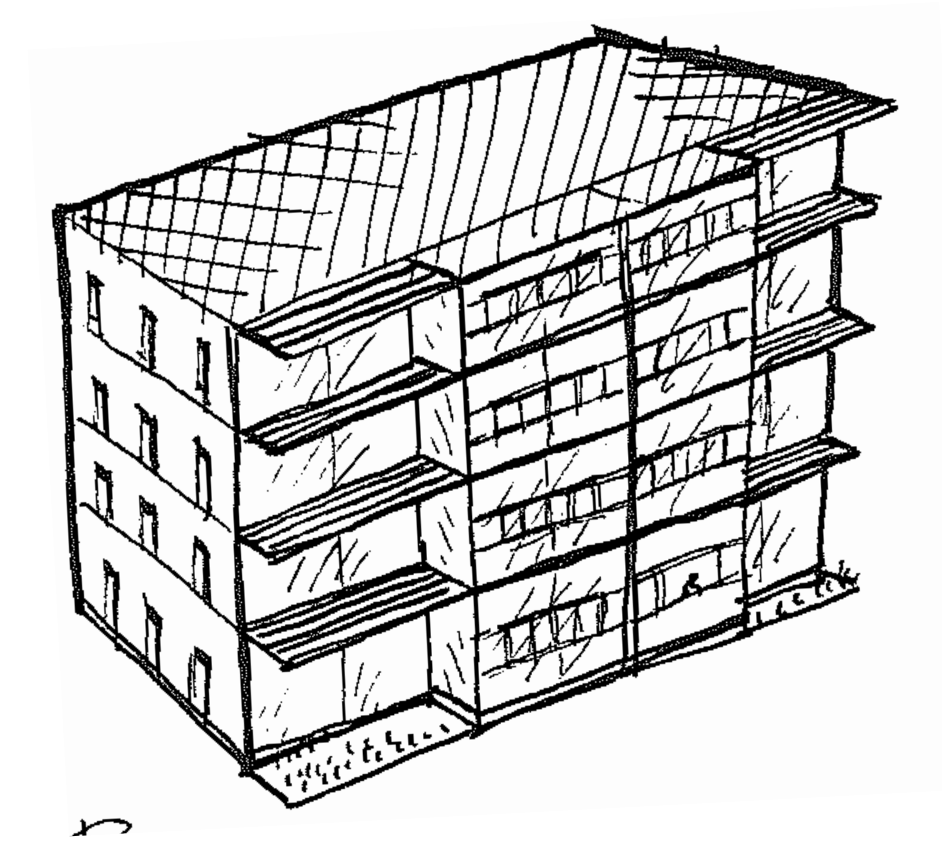
Final model

- *one zone per appartment*
- *one floor*



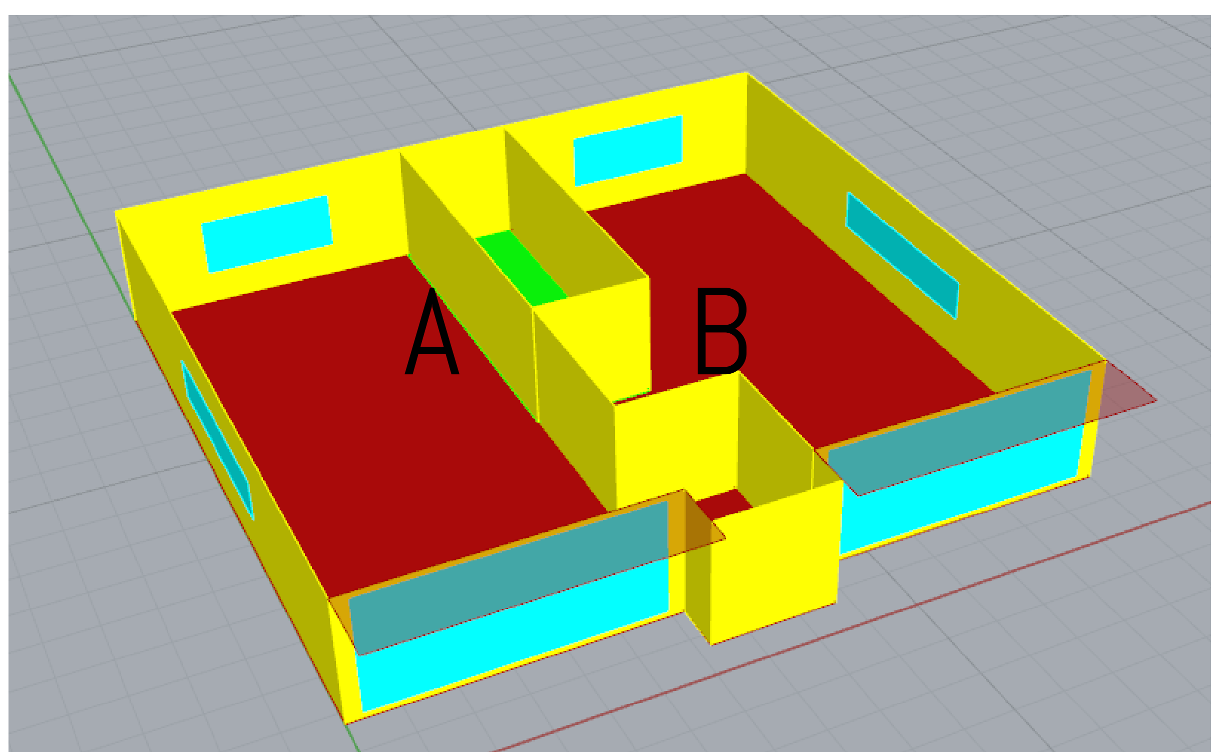


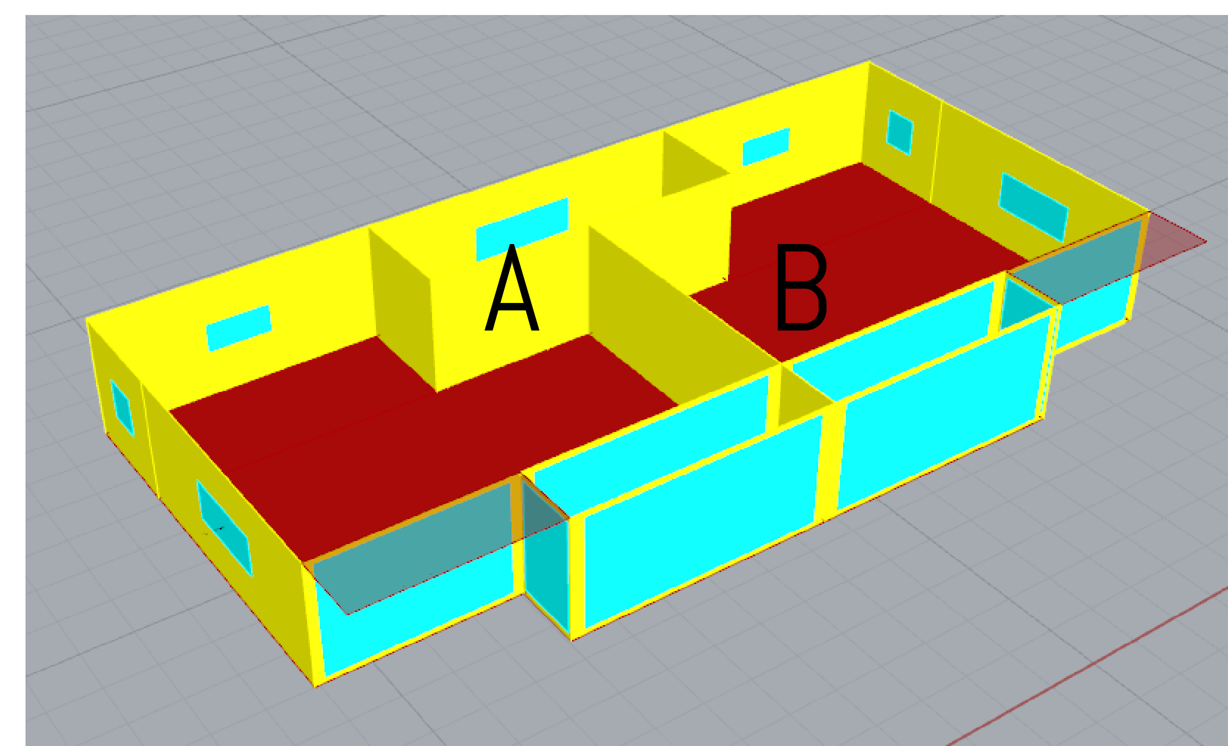
Original design

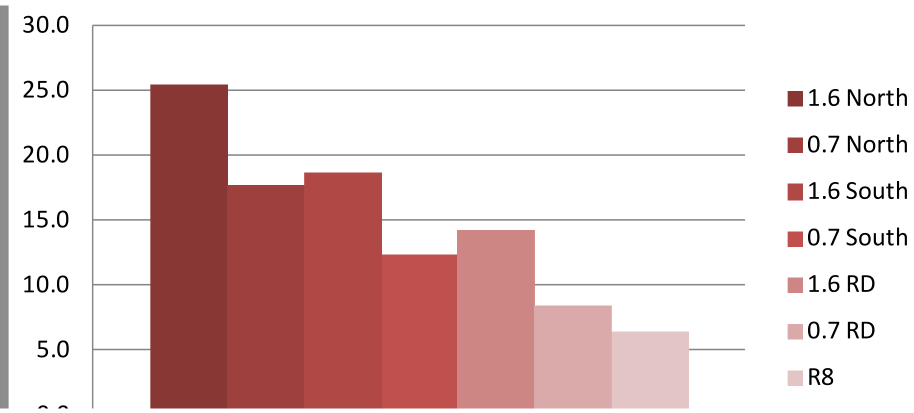


Re-design

Models



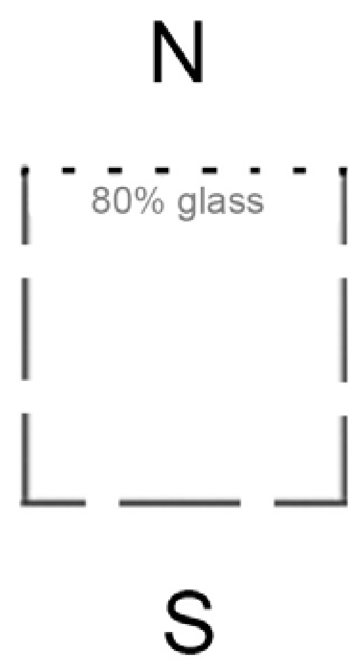




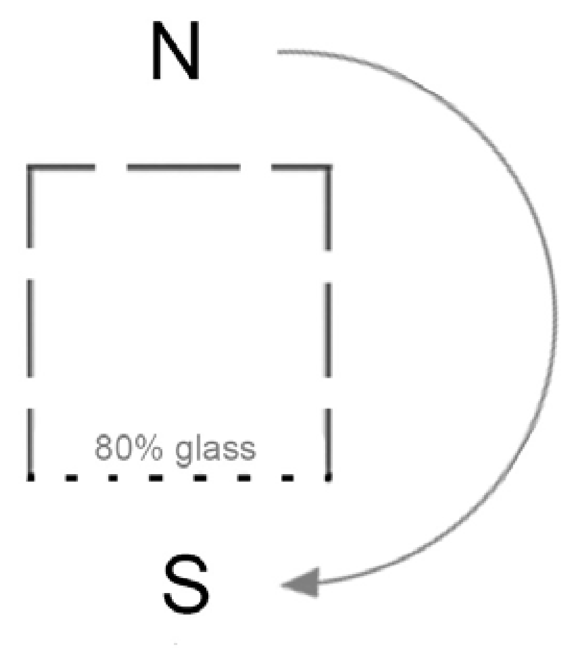
5.3 Analysis

. Results
. Conclusions

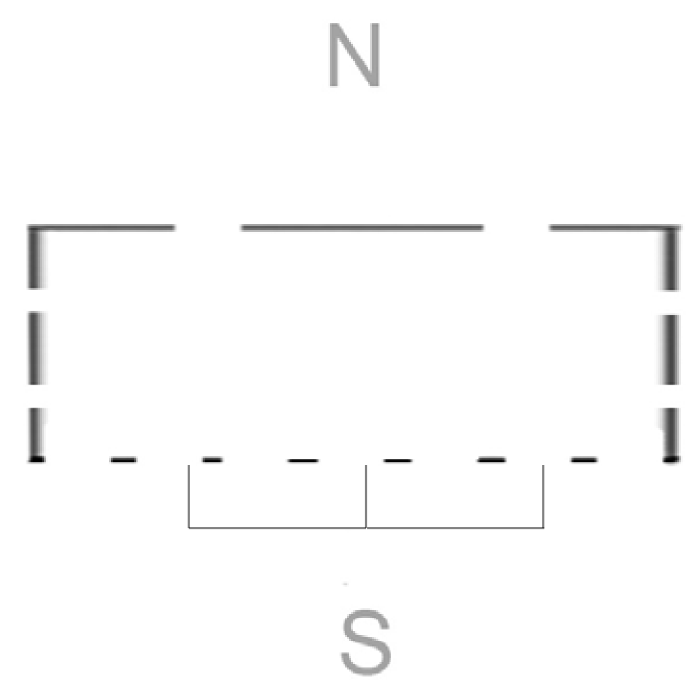
1. U glass
25.4 kWh/m² (U=1.6)
17.7 kWh/m² (U=0.7)



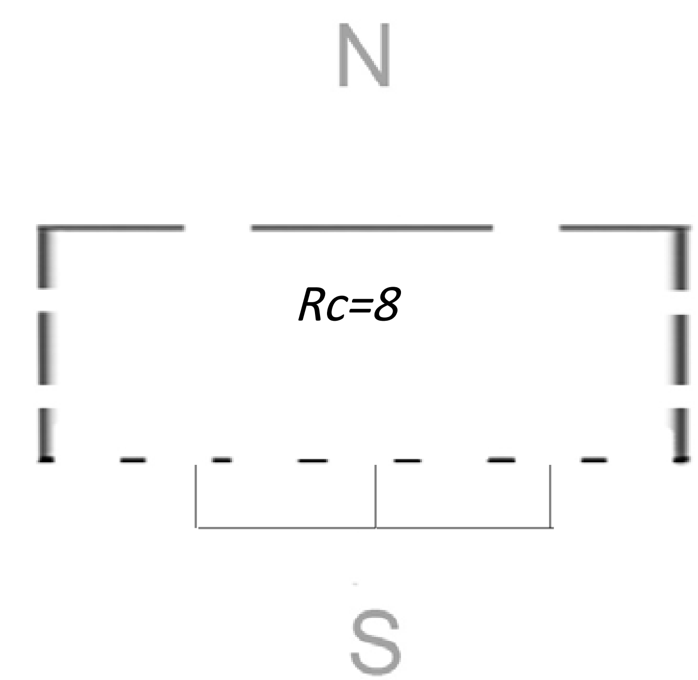
2. S glass
18.6 kWh/m² (U=1.6)
12.3 kWh/m² (U=0.7)



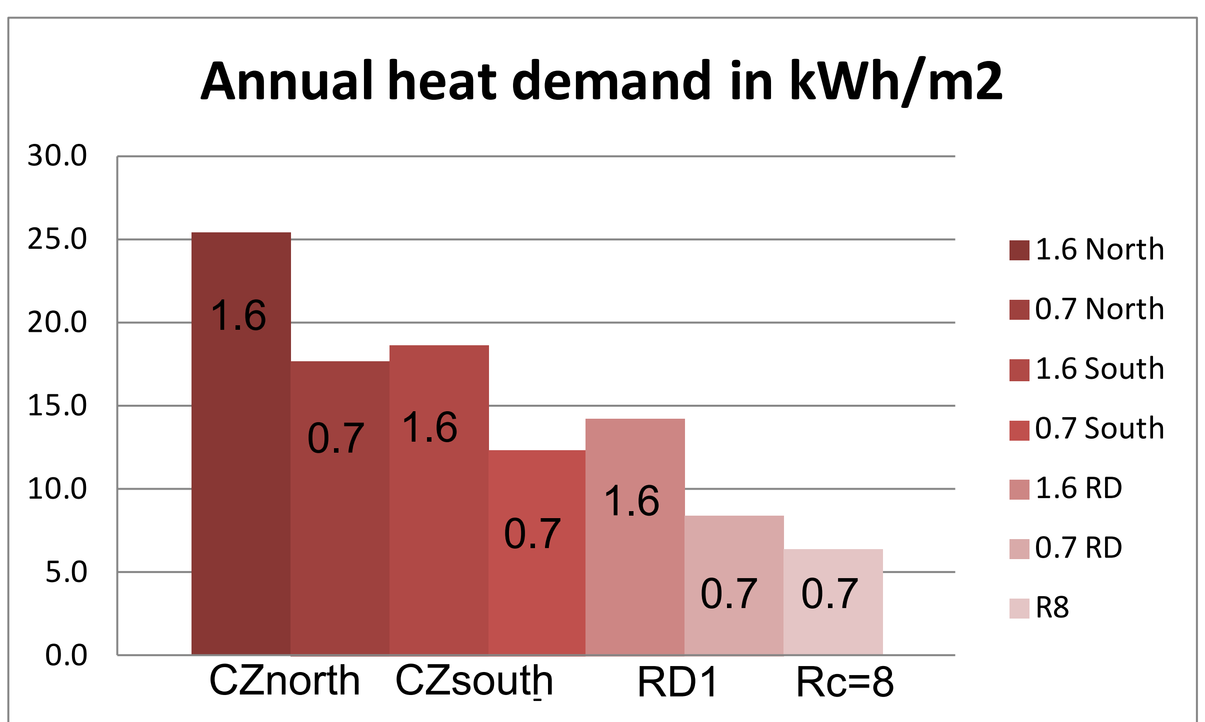
3. Shape B + sunspace
14.2 kWh/m² (U=1.6)
8.4 kWh/m² (U=0.7)



4. Facade insulation
6.4 kWh/m² (U=0.7)



Results



Absolute reduction [kWh/m²]
1. -U glass = 7.7
2. S glass = 5.4
3. Shape B = 3.9
4. Rc = 2

Relative reduction
1. -U glass = 30%
2. S glass = 31%
3. Shape B = 31%
4. Rc = 24%

Conclusion

Ranked by highest (absolute) impact on heat demand:

1. change of U value glass from 1.6 to 0.7
2. South facing glass
3. Shape change A to B
4. Facade insulation

6. DESIGN GUIDELINES

6.1 Guideline development

- Criteria
- Approach
- Guidelines application

Criteria

- *Easily readable*
- *Translate technical story into design story*
- *Short but precise*
- *Link to reasearch*
- *Explain why*

Approach

1. Priority List as overview

- *readable*
- *short*
- *design story*

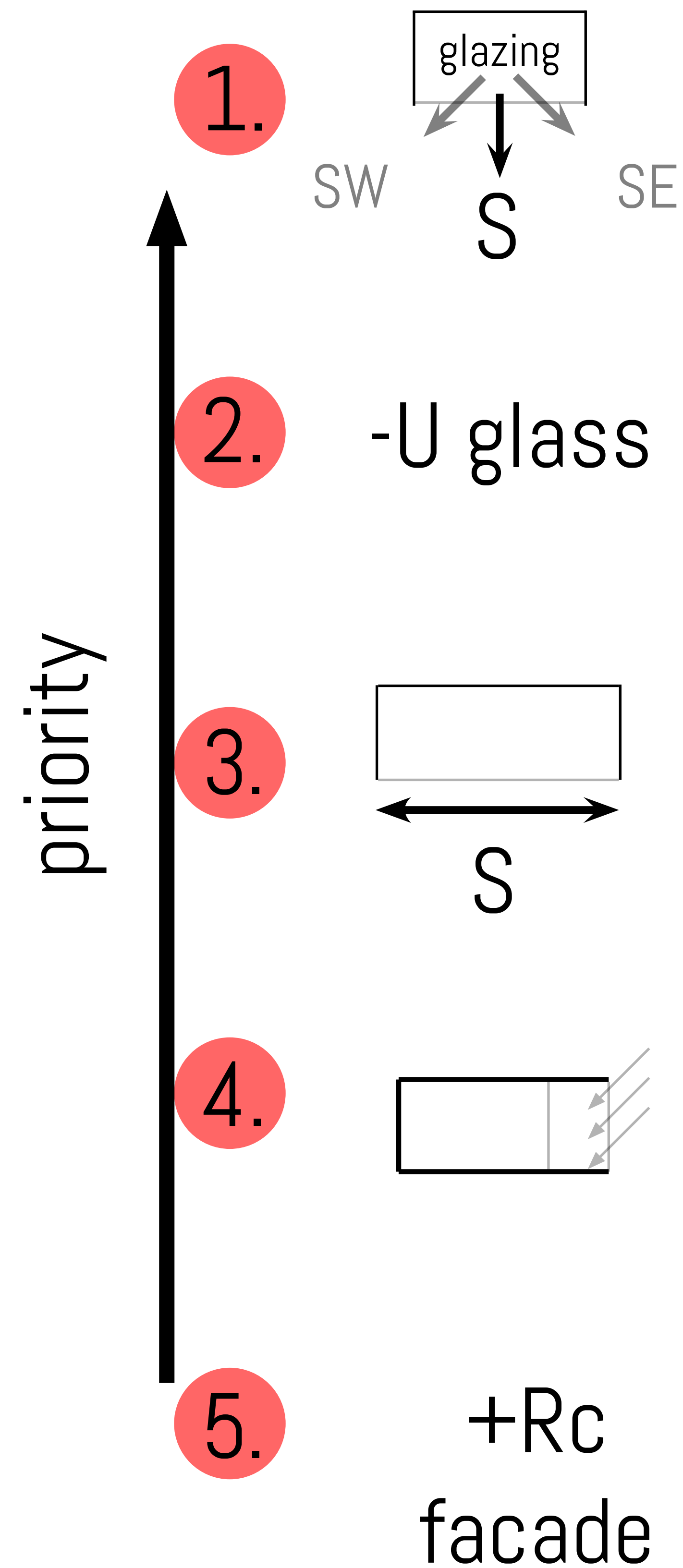
2. Explanation per priority point

- *link to research*
- *explain why*

6.2 Design Guidelines

- Priority points
- Explanation per point

Priority points



1. Have as much glazing face (roughly) South.

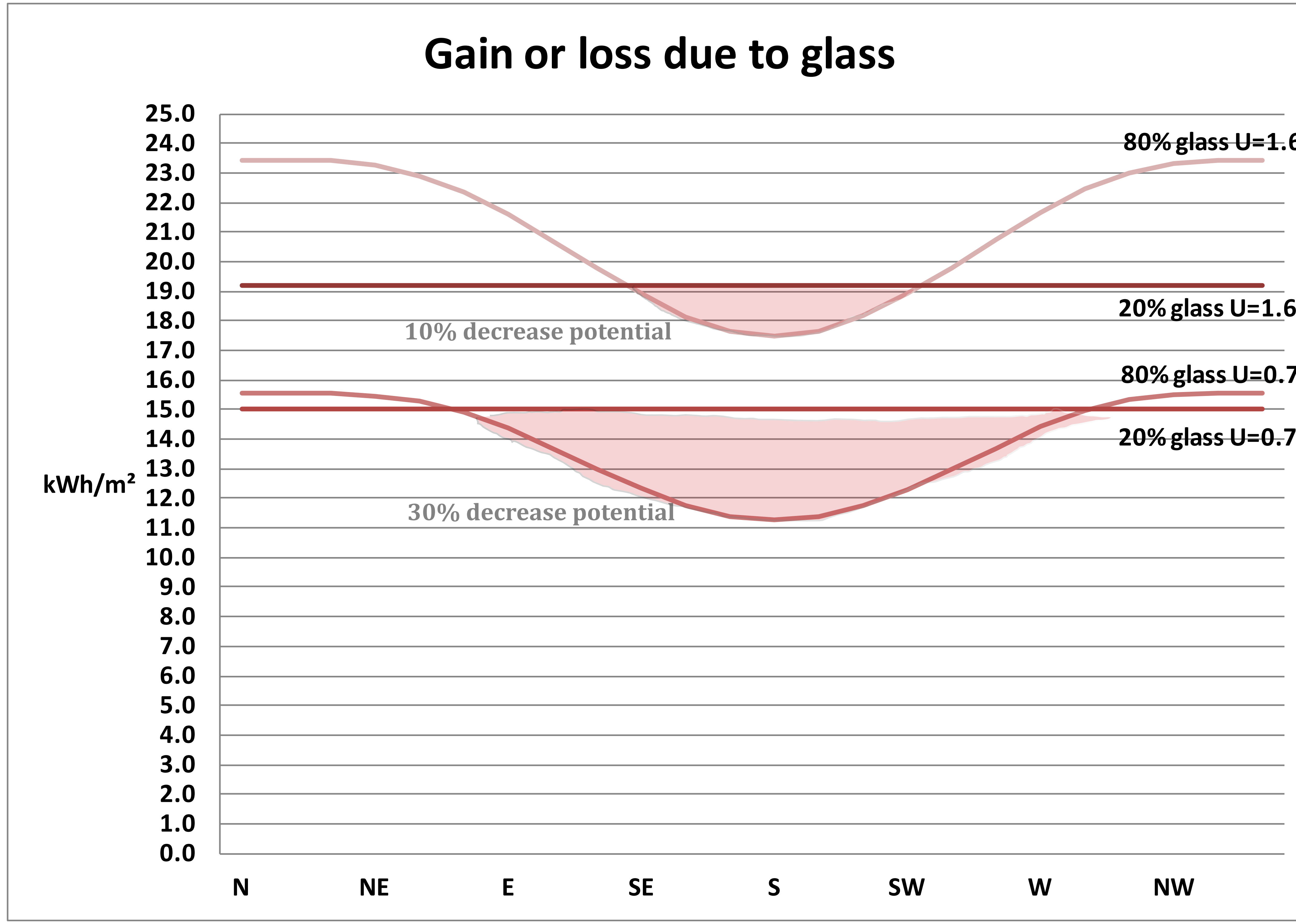
2. Increase insulation of glazing.

3. Maximize sun surface.

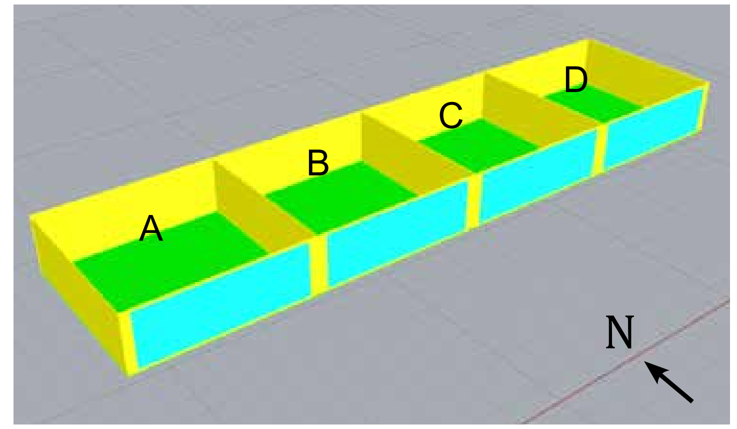
4. Sunspaces if applicable.

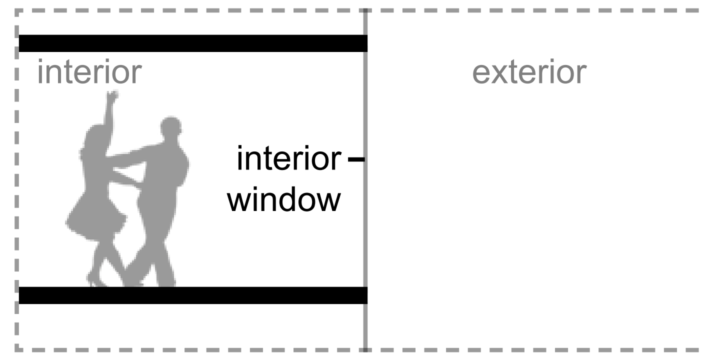
5. Increase insulation value of facade.

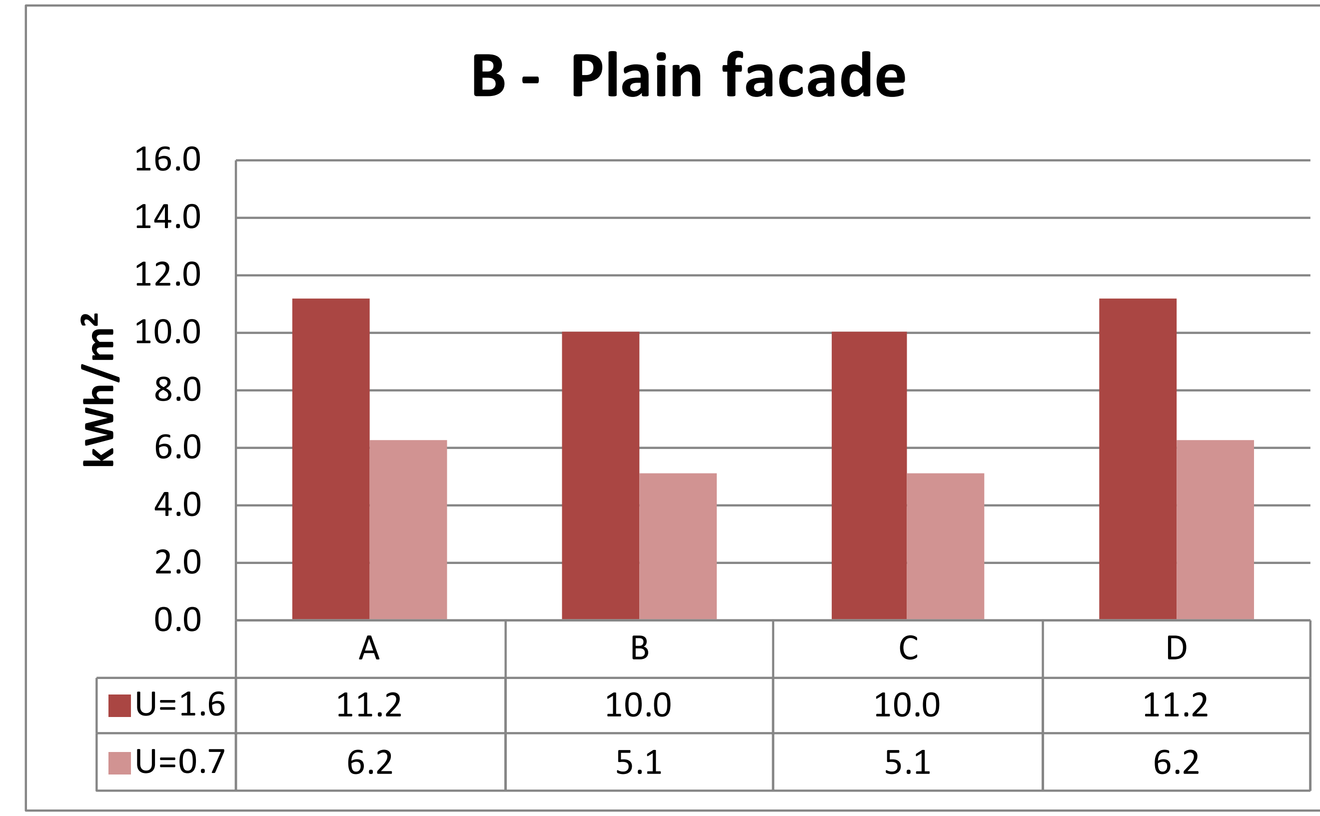
Point 1. Glass facing south



Glass facing south has massive heat demand reduction potential.



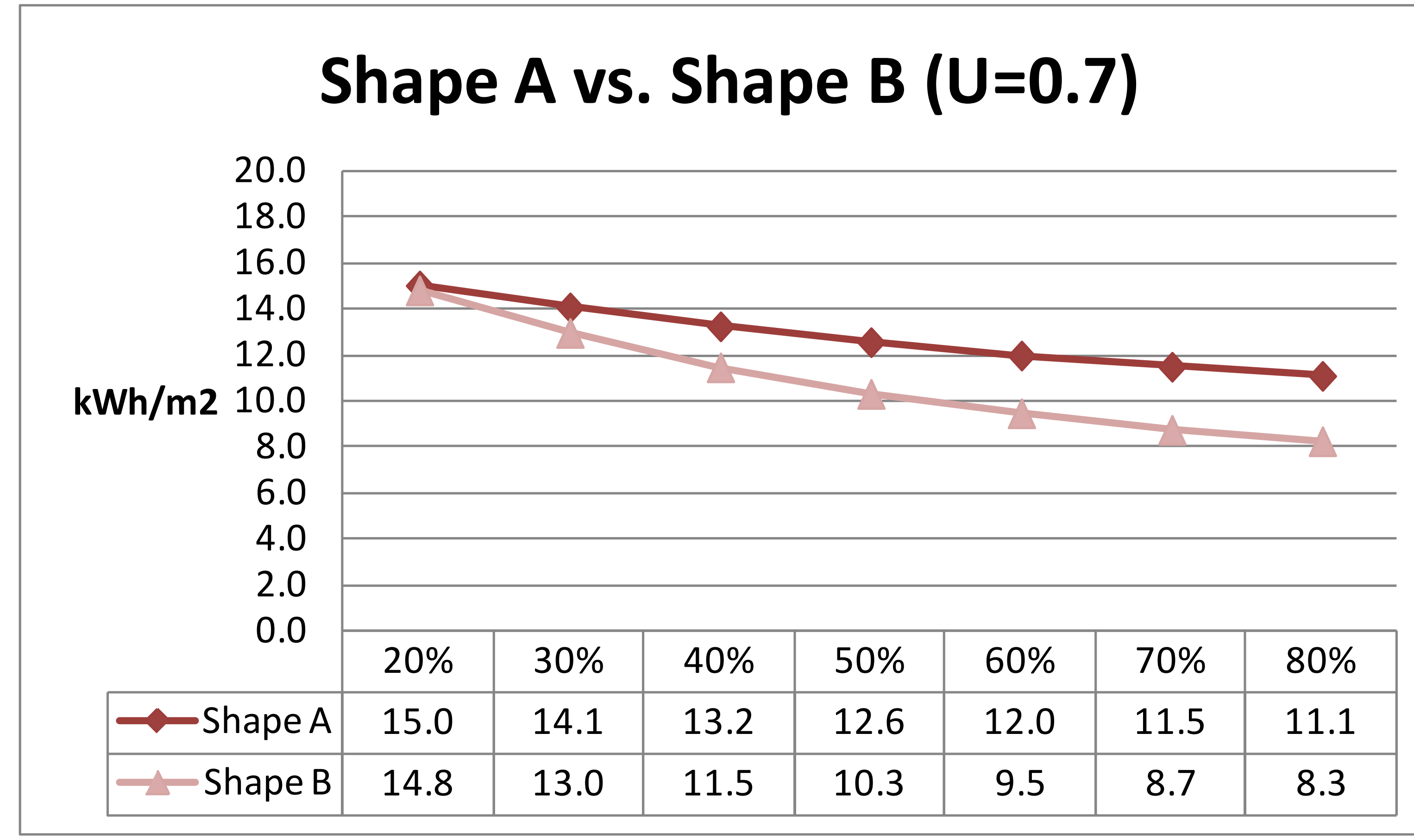




	A	B	C	D
U=1.6	11.2	10.0	10.0	11.2
U=0.7	6.2	5.1	5.1	6.2

Point 2. Insulation of glazing

50% savings:
When maximizing solar gain, a U value decrease from 1.6 to 0.7 can cut heat demand in half.



Point 3. Sun surface

Sun surface greatly outweighs compactness when window insulation value is high.

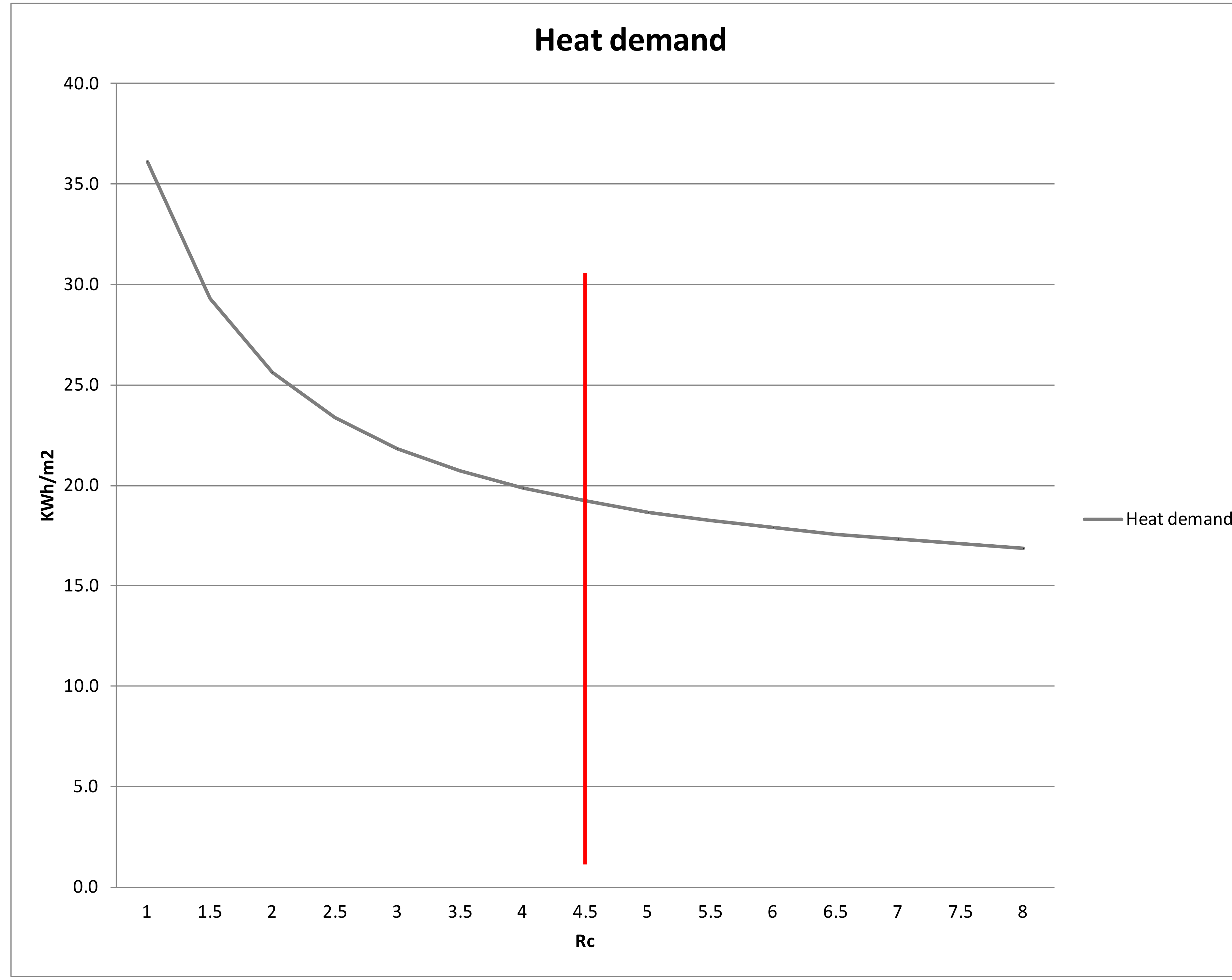
Point 4. Sunspaces

Heat buffer, reduces heat loss

Flexible use

Advantages of keeping heat out in summer and drawing it in in winter.

Point 5. Insulation of facade



Building code minimum Rc value is 4.5.
Impact of increase beyond 4.5 is minimal.

6.3 Final Words

- Reflection
- Future study recommendations

Reflection

. better research structure
. more illustrations!

Future study recommendations

Fin