MINIMAL RENOVATION STRATEGIES FOR LOW-TEMPERATURE HEATING

with optimal comfort

presentation **P5**

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Master thesis **Building Technology**
Delft University of Technology

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TU Delft
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Content

Research Framework

research framework

methodology

research

conclusions

Research Framework

background

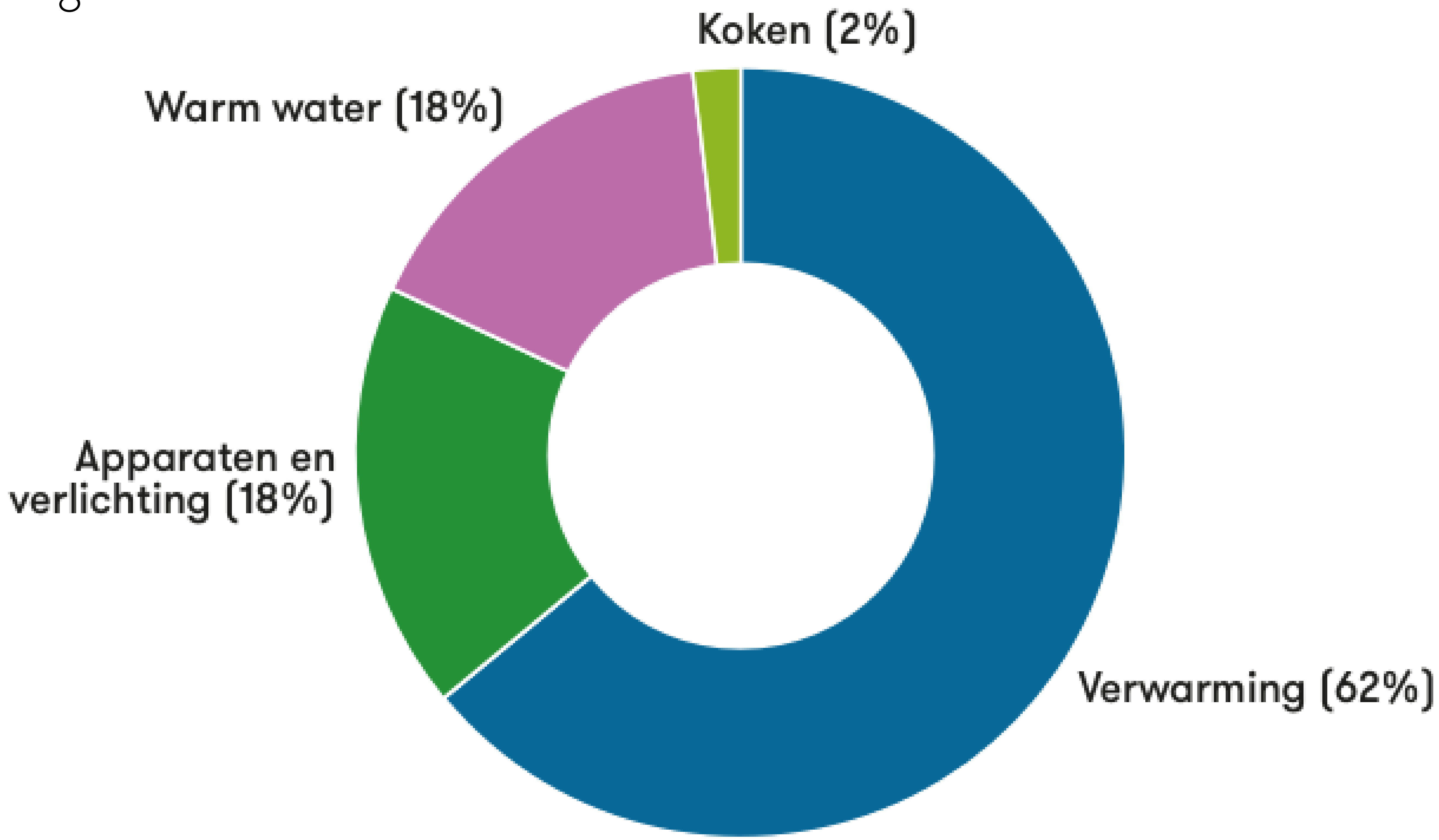
1. Climate Agreement (Rijksoverheid, 2019):

Goal for the built environment is to be (almost) CO_2 neutral by 2050

Research Framework

background

the average household in the Netherlands spends 62% of the total energy usage on space heating (Milieu Centraal, 2020)



Share of applications in the energy consumption of an average household in the Netherlands in 2019
Milieu Centraal, 2020

Research Framework

background

1. Climate Agreement (Rijksoverheid, 2019):

Goal for the built environment is to be (almost) CO_2 neutral by 2050

2. Phased out gas extraction in Groningen (Wiebes, 2019):

The natural gas extraction in Groningen will be phased out, as it has led to earthquakes in the region

78% of the total heating requirement is covered by natural gas (CBS & ECN, 2017)

Research Framework

background

1. Climate Agreement (Rijksoverheid, 2019)

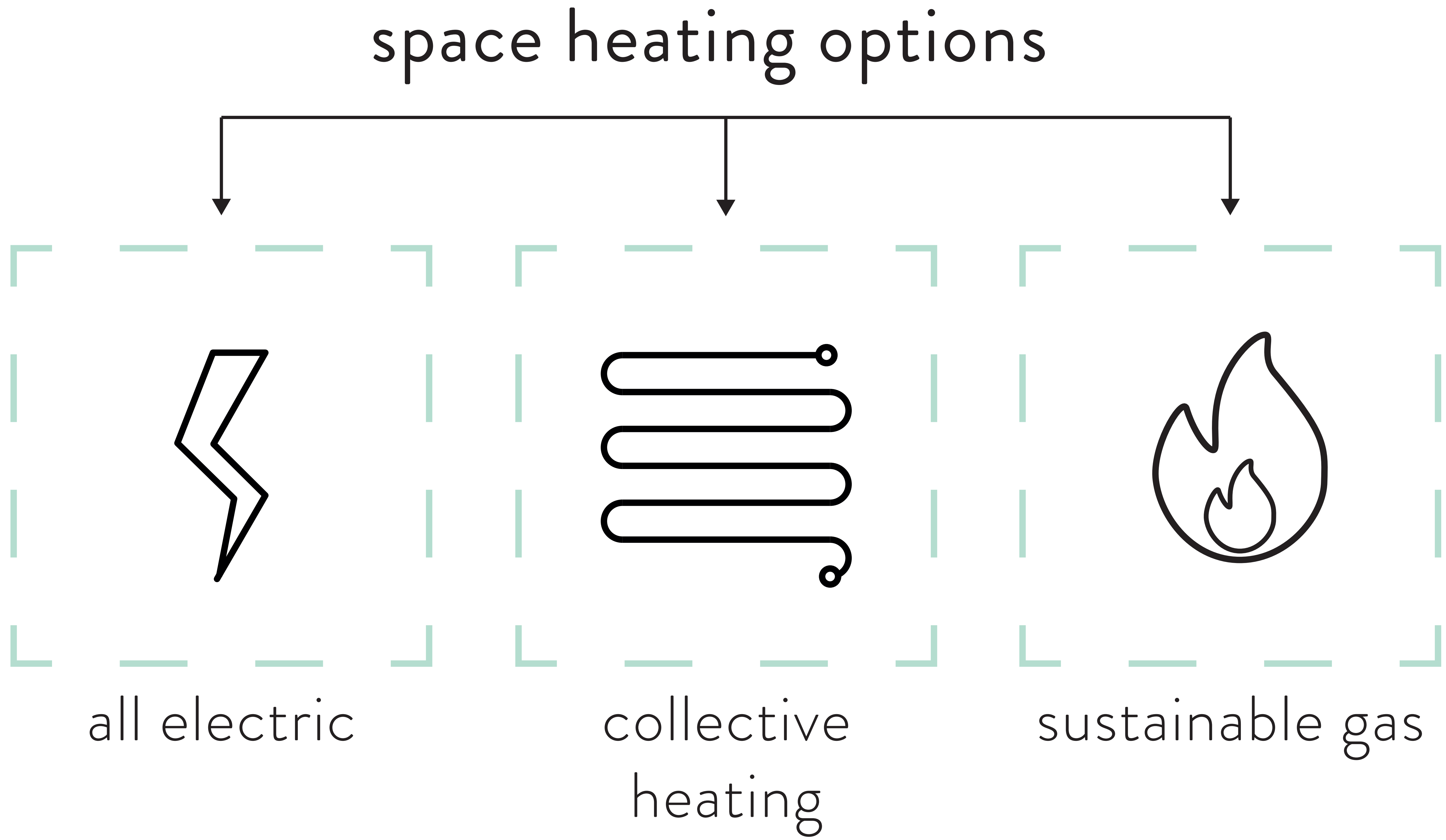
2. Phased out gas extraction in Groningen (Wiebes, 2019)

↓

Other sustainable solutions for space heating needed

Research Framework

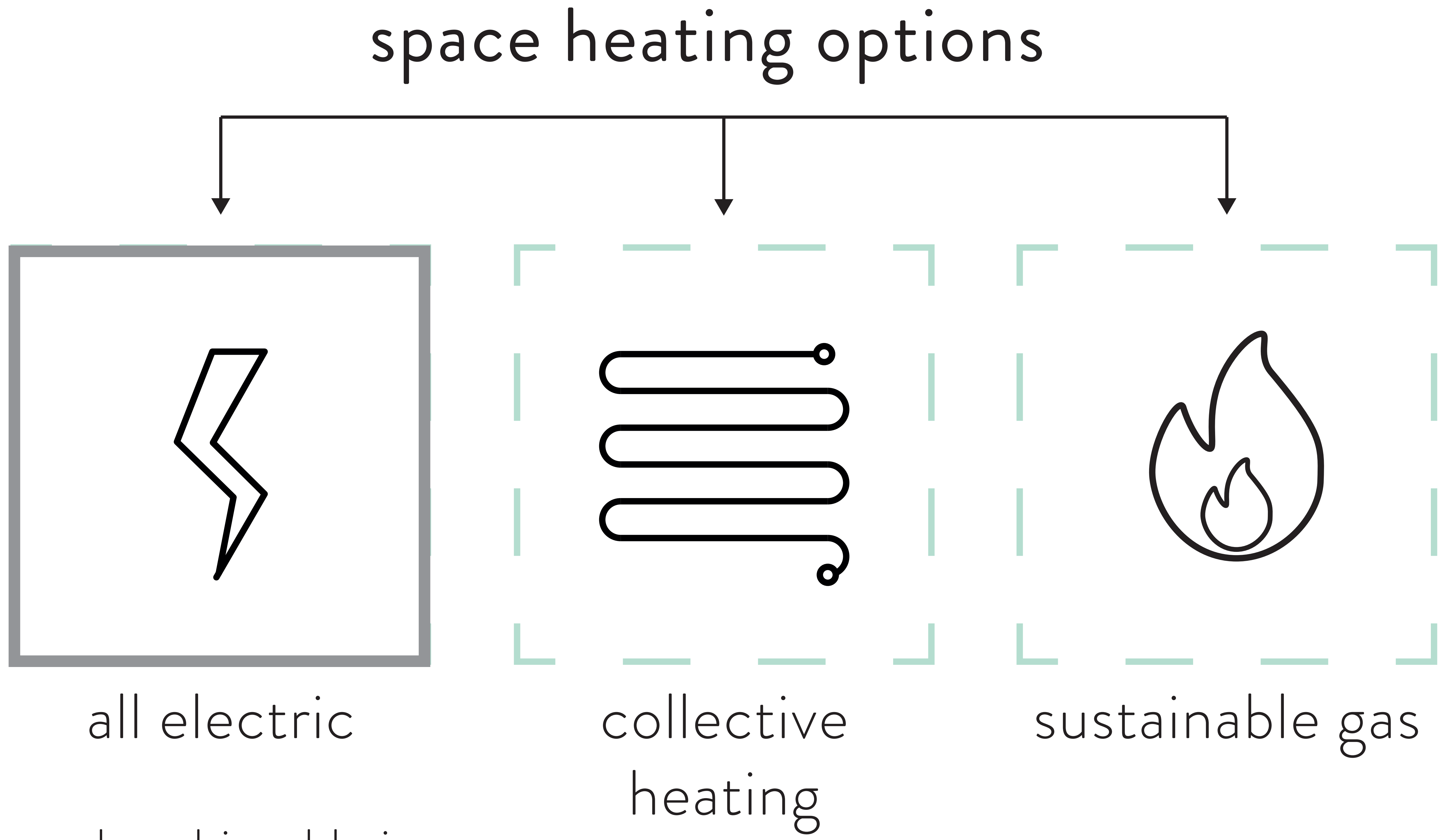
background



(Based on Ecofys and Greenvis, 2016)

Research Framework

background



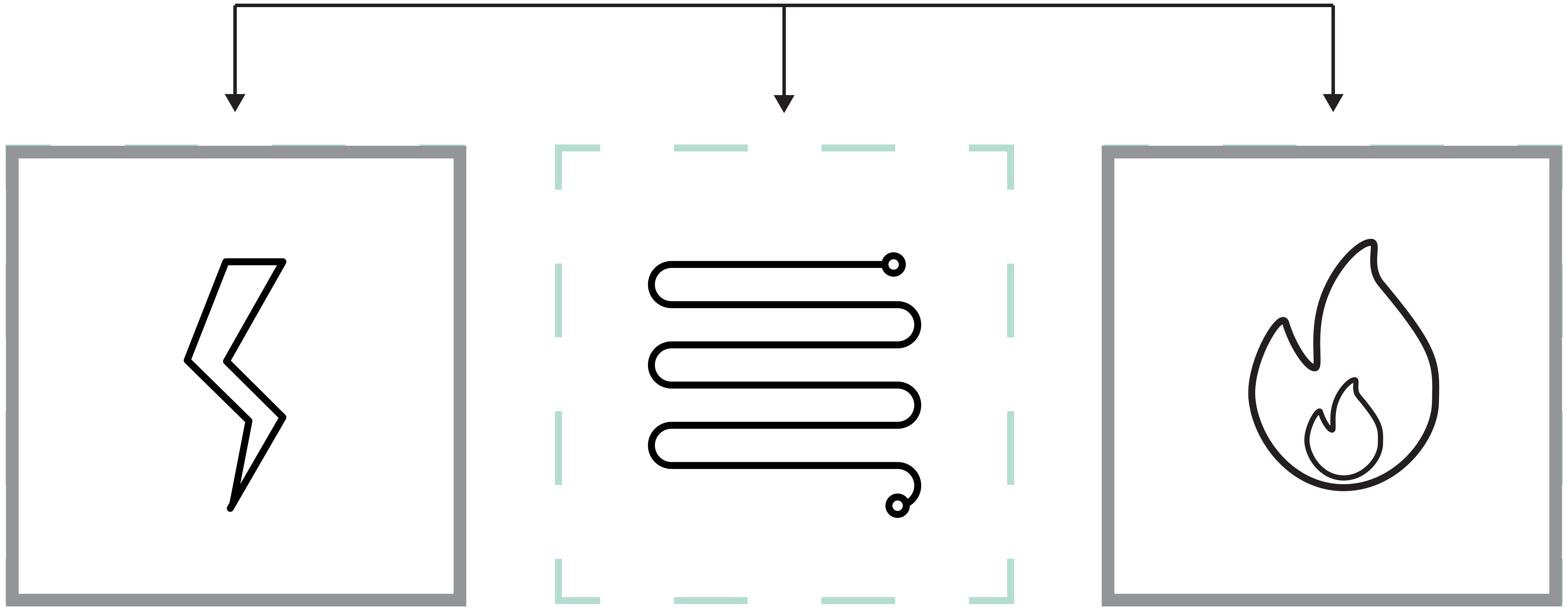
- only achievable in very well insulated houses

(Based on Ecofys and Greenvis, 2016)

Research Framework

background

space heating options



all electric

collective heating

sustainable gas

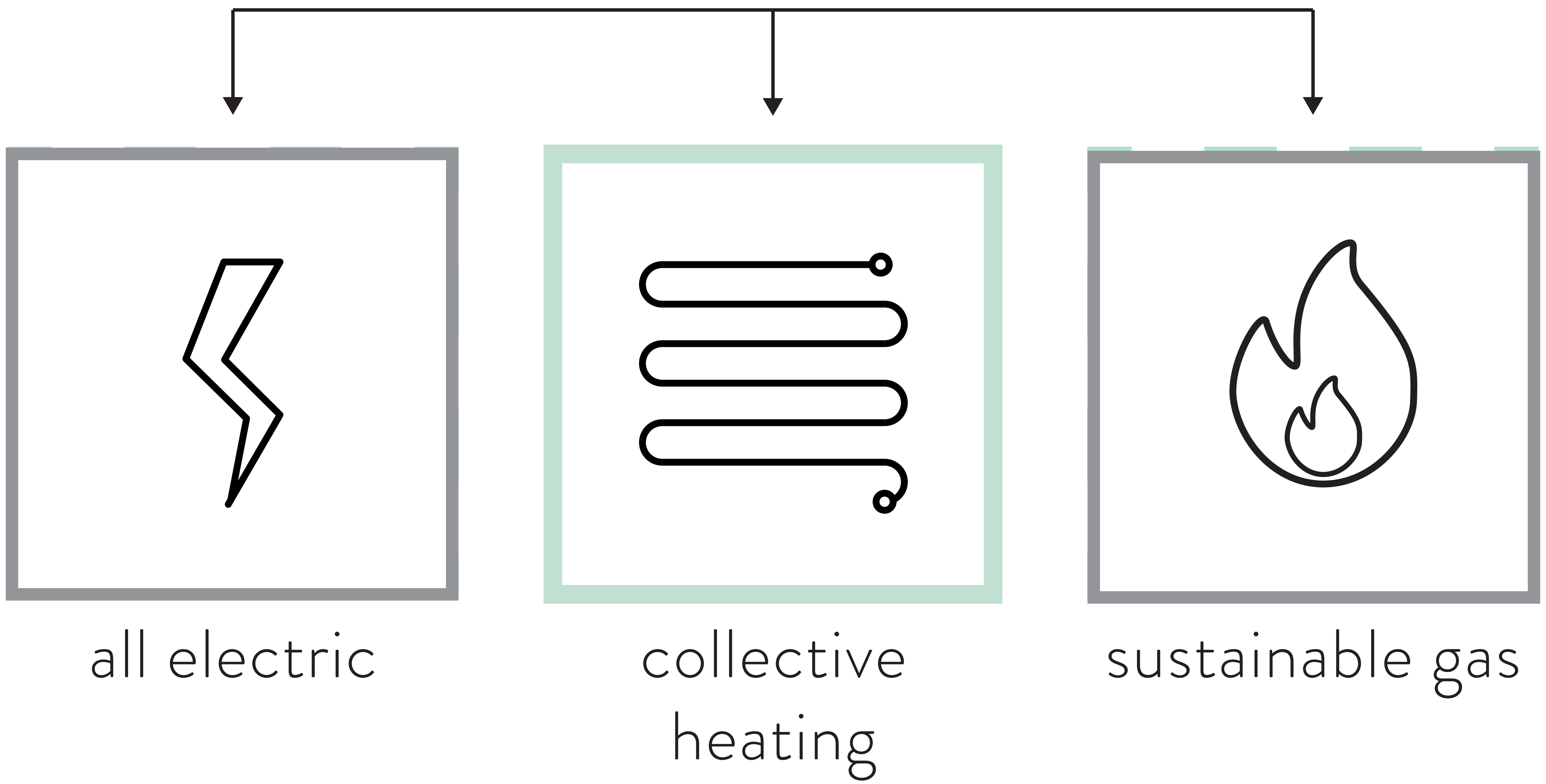
- availability in the future still unsure

(Based on Ecofys and Greenvis, 2016)

Research Framework

background

space heating options



(Based on Ecofys and Greenvis, 2016)

Research Framework

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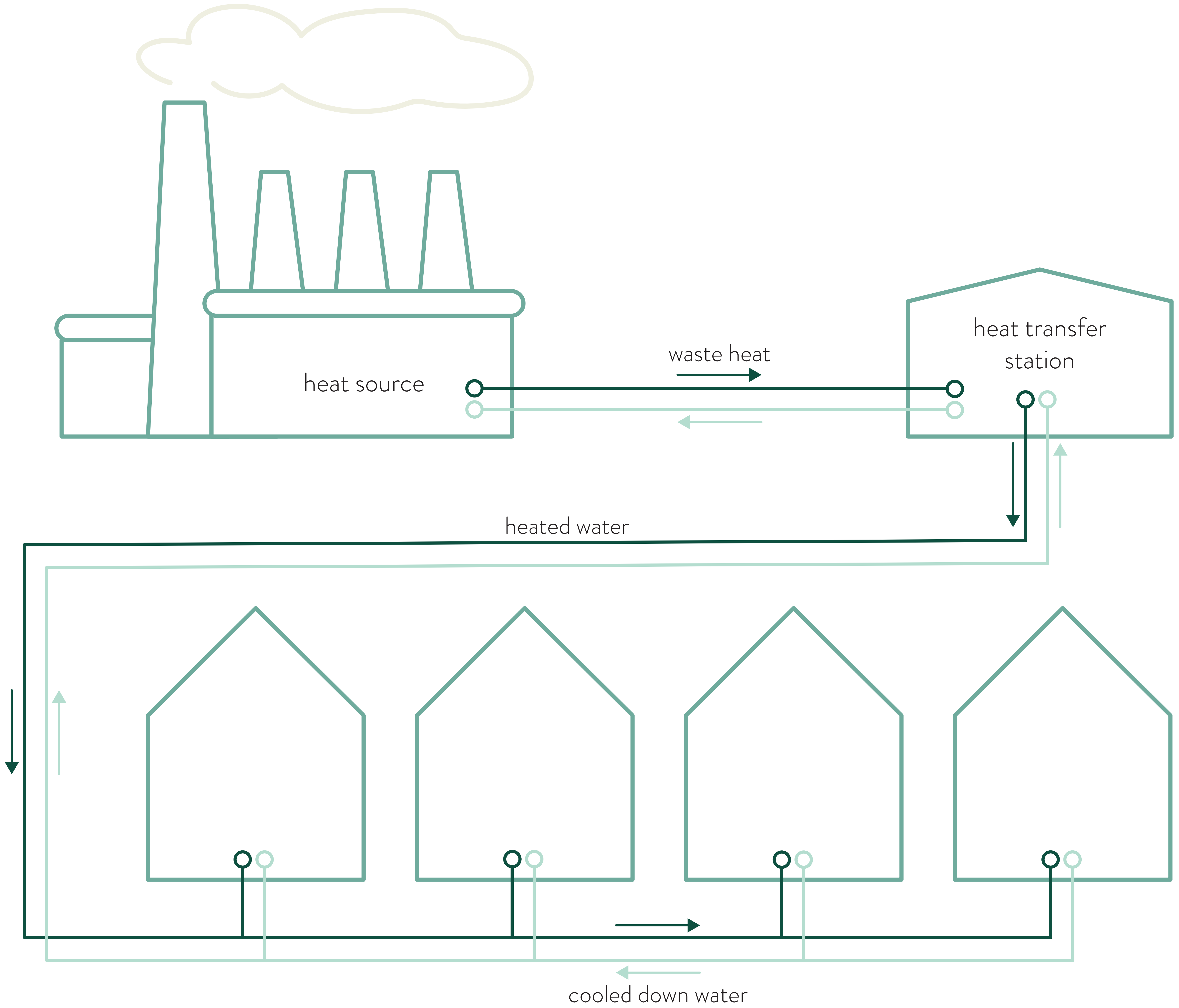
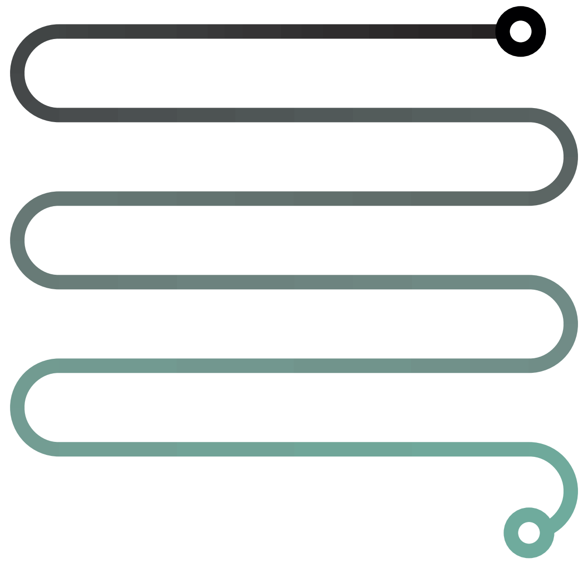
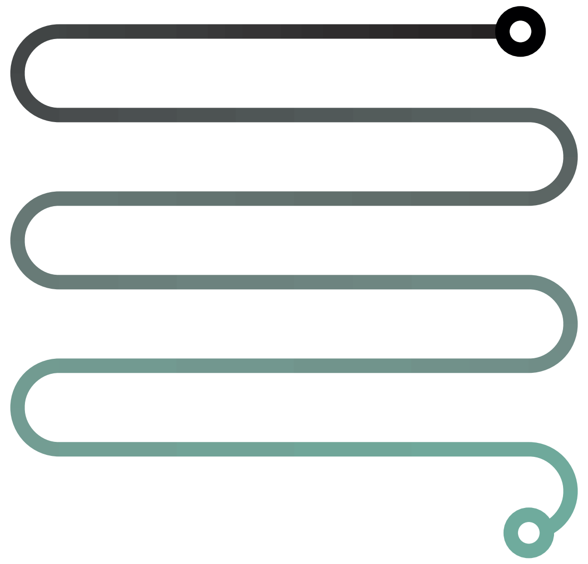


Research Framework

background



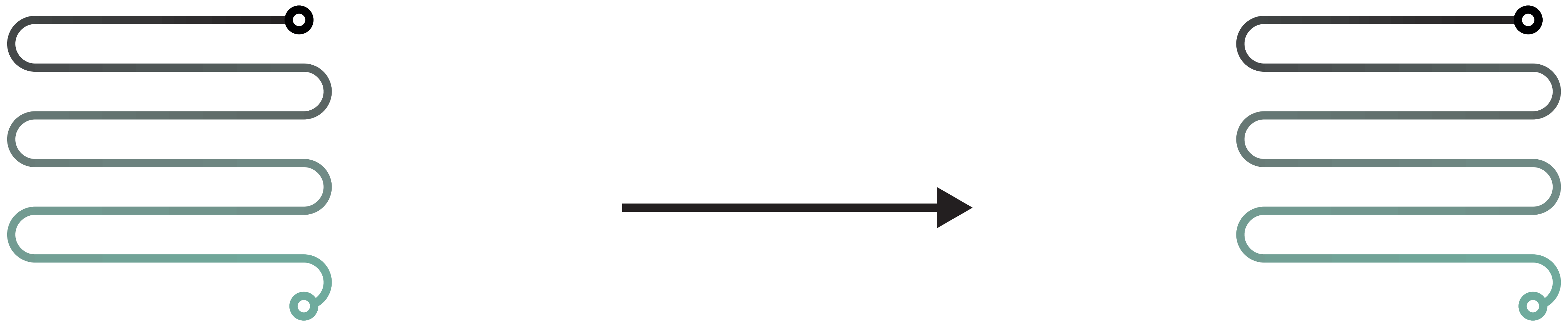
90 degrees Celsius



55 degrees Celsius

Research Framework

background



90 degrees Celsius

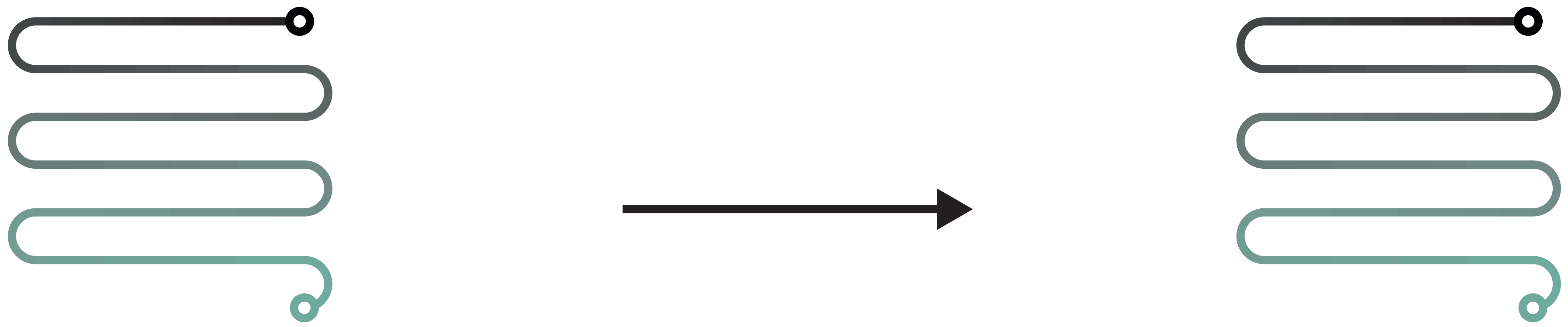
55 degrees Celsius

1. Conventional heat sources that supply high-temperature heat will be phased out in the future

(CE Delft, 2019,Ecofys and Greenvis, 2016, Interreg North-West Europe, 2018)

Research Framework

background



90 degrees Celsius

55 degrees Celsius

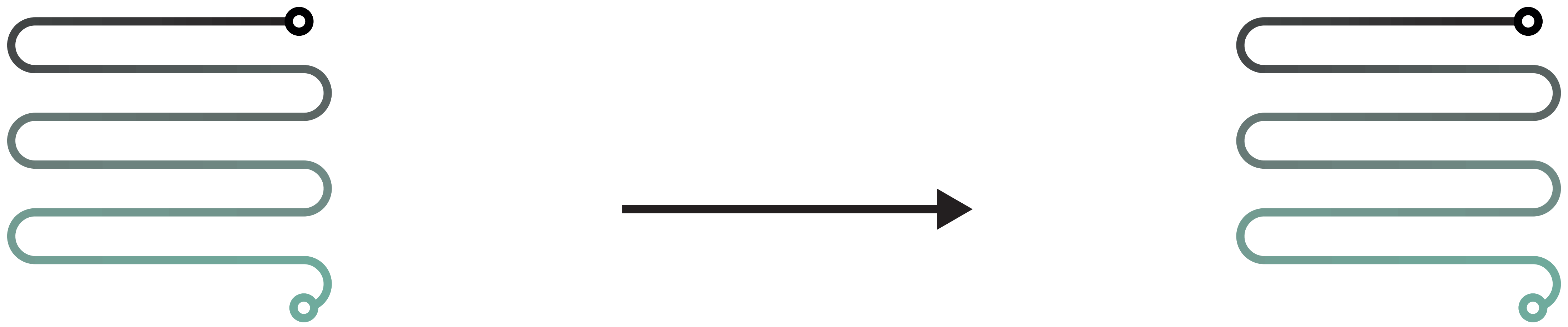
1. Conventional heat sources that supply high-temperature heat will be phased out in the future

2. Increasing efficiency of industrial processes

(CE Delft, 2019,Ecofys and Greenvis, 2016, Interreg North-West Europe, 2018)

Research Framework

background



90 degrees Celsius

55 degrees Celsius

1. Conventional heat sources that supply high-temperature heat will be phased out in the future

2. Increasing efficiency of industrial processes

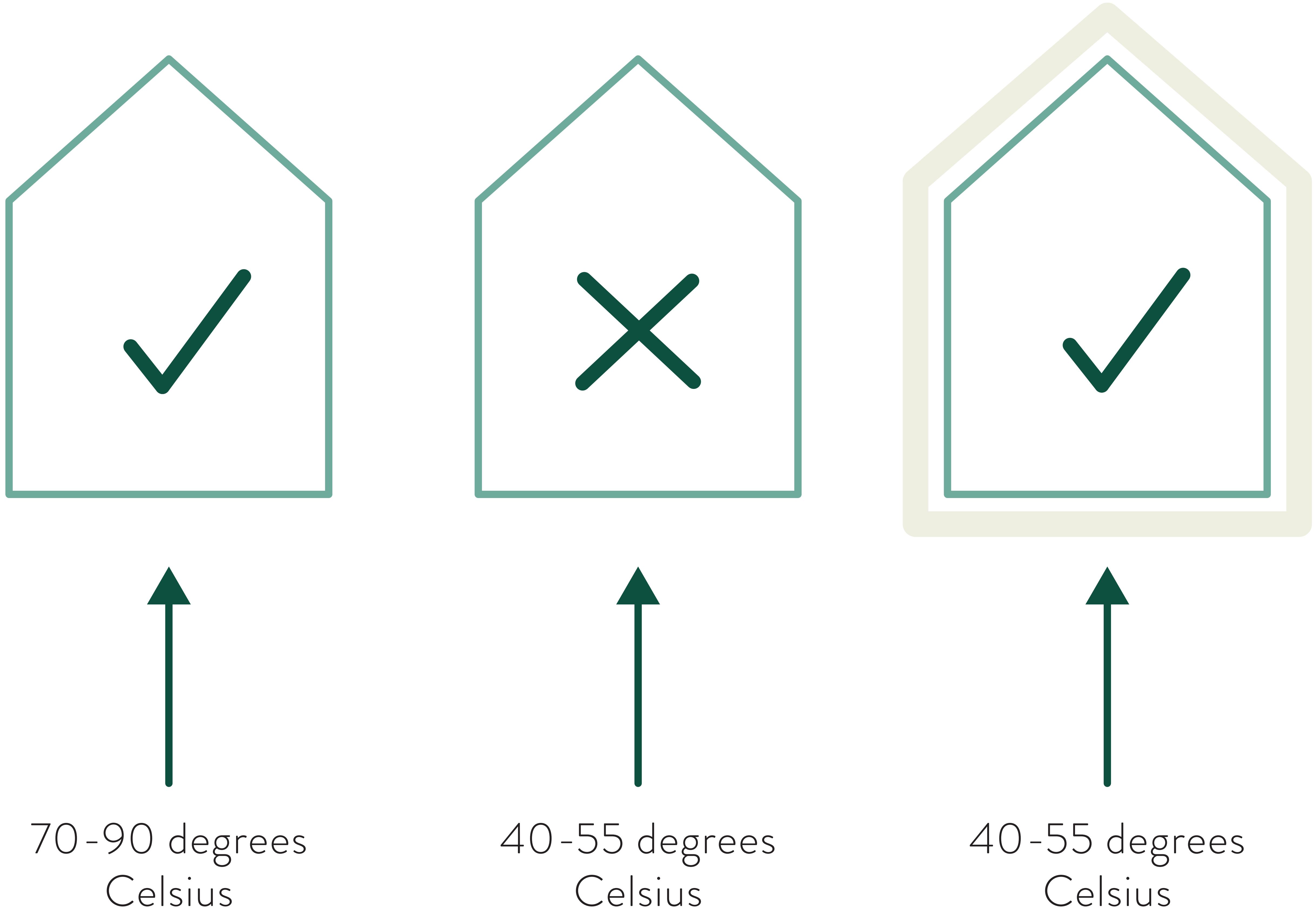
3. A reduction in waste streams available from waste incineration plants

(CE Delft, 2019,Ecofys and Greenvis, 2016, Interreg North-West Europe, 2018)

Research Framework

background

...A large part of the existing Dutch housing stock is not ready for the transition to low-temperature heating.



Research Framework

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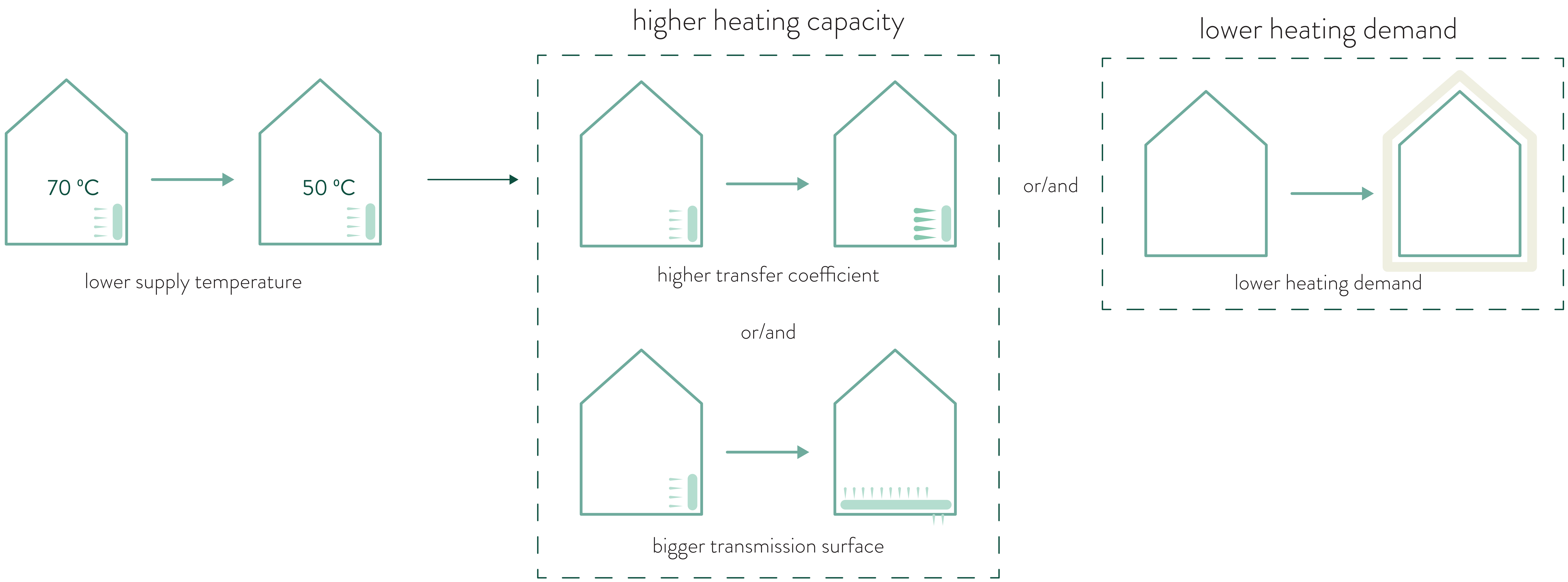

Research Framework

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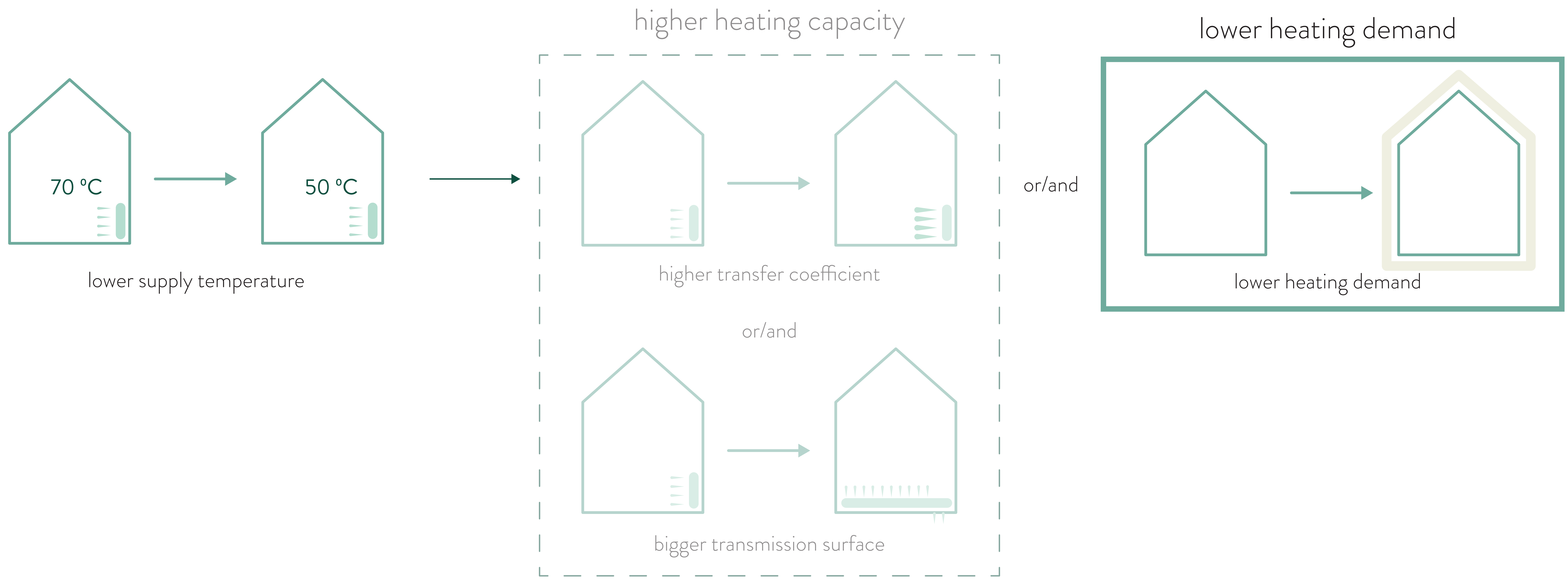
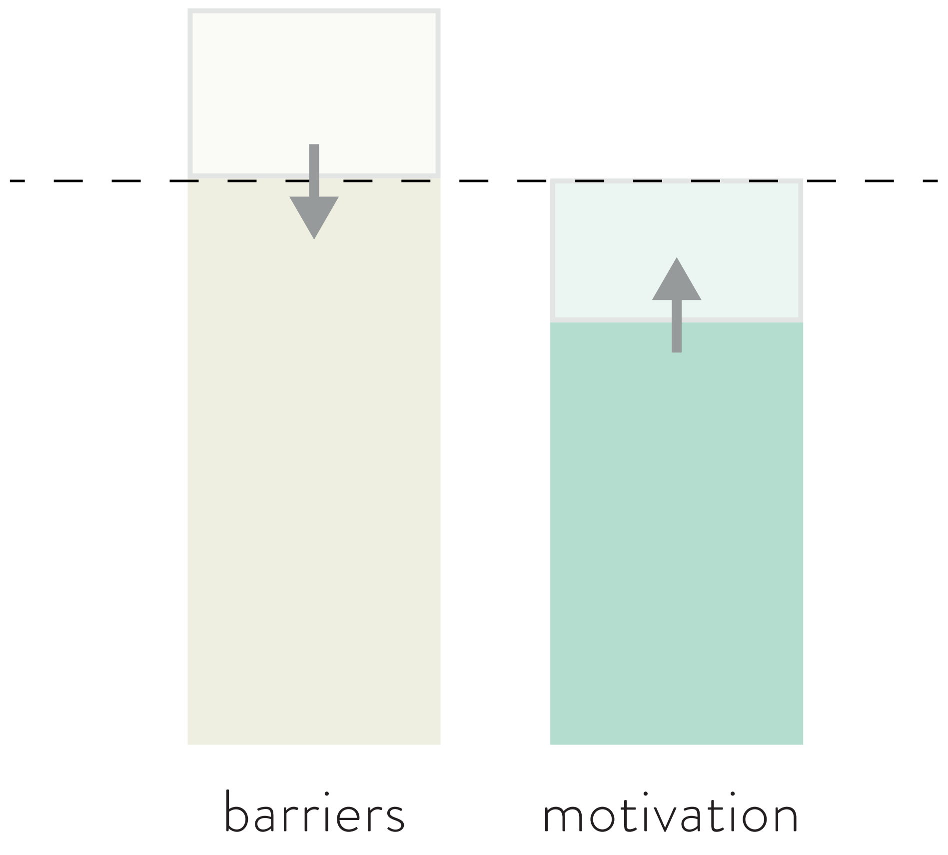


… The renovation rates of preparing housing for the integration of low-temperature heating are too low, which restricts the progress of the energy transition.

Research Framework

problem statement



... An improvement of the thermal comfort and indoor climate is one of the top motivators of homeowners to perform renovation measures (Bjørneboe et al., 2018).

... However, research is lacking on the use of energy renovation to optimise thermal comfort.

Research Framework

specific problem statement

… Switching the selling point of energy renovation to the improvement of thermal comfort could potentially increase renovation rates, but research on optimising thermal comfort in this field is lacking.

Research Framework

research question

... Which minimal renovation strategies are needed to prepare different single-family housing typologies for the integration of low-temperature heating and optimize the thermal comfort of the residence?

Research Framework

sub-questions

... Which sensitive parameters for renovation can be recognized in the single-family housing stock?

... Which renovation measures can be applied to prepare a building for low-temperature heating?

... How can the thermal comfort of a house be optimized through the implementation of renovation measures?

Methodology

research framework

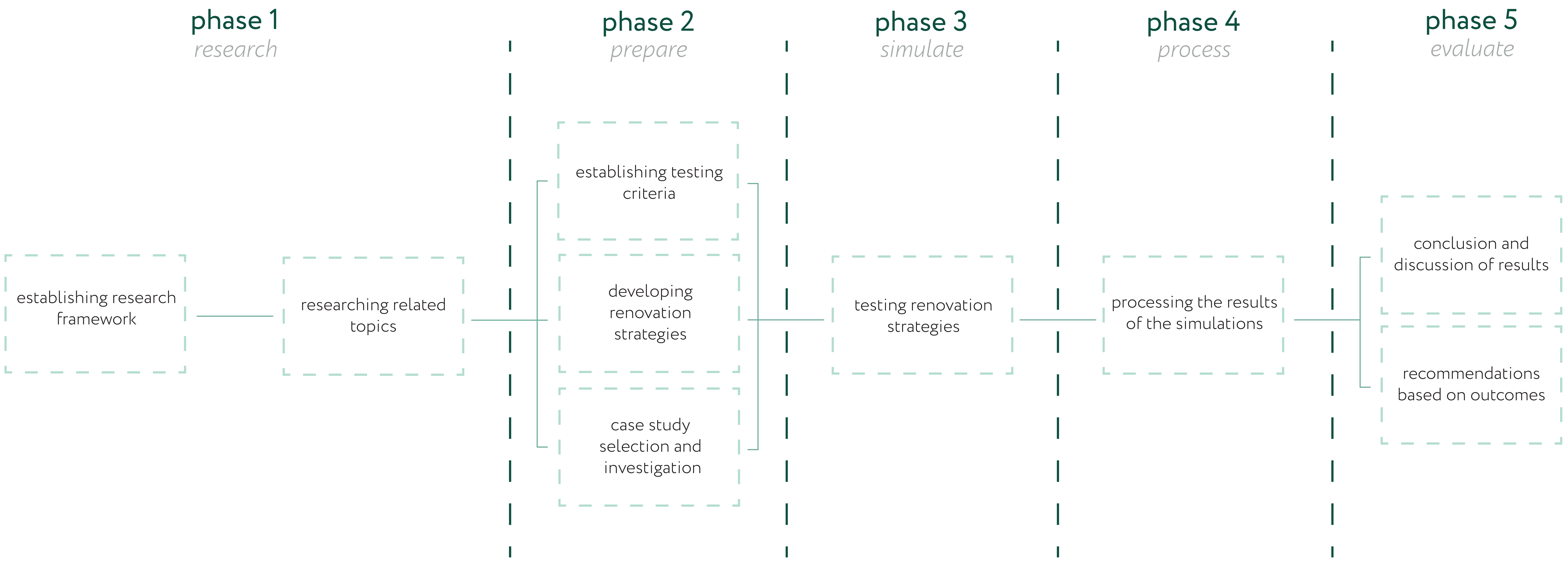
methodology

research

conclusions

Methodology

flowchart



Research

research framework

methodology

research

conclusions

Research

boundary conditions: housing typologies

single-family housing types*

terraced housing

semi-detached housing

freestanding housing

construction periods*

till 1964

1965 - 1974

1975 - 1991

1992 - 2006

*based on Agentschap NL, 2011

all images are derived from Funda, 2022

Research

boundary conditions: housing typologies

single-family housing types*

terraced housing

semi-detached housing

freestanding housing

construction periods*

till 1964

1965 - 1974

1975 - 1991

1992 - 2006

*based on Agentschap NL, 2011

all images are derived from Funda, 2022

Research

boundary conditions: housing typologies

single-family housing types*

terraced housing

semi-detached housing

freestanding housing

construction periods*

till 1964

1965 - 1974

1975 - 1991

split in two sections
1975 - 1987
1988 - 1991

1992 - 2006

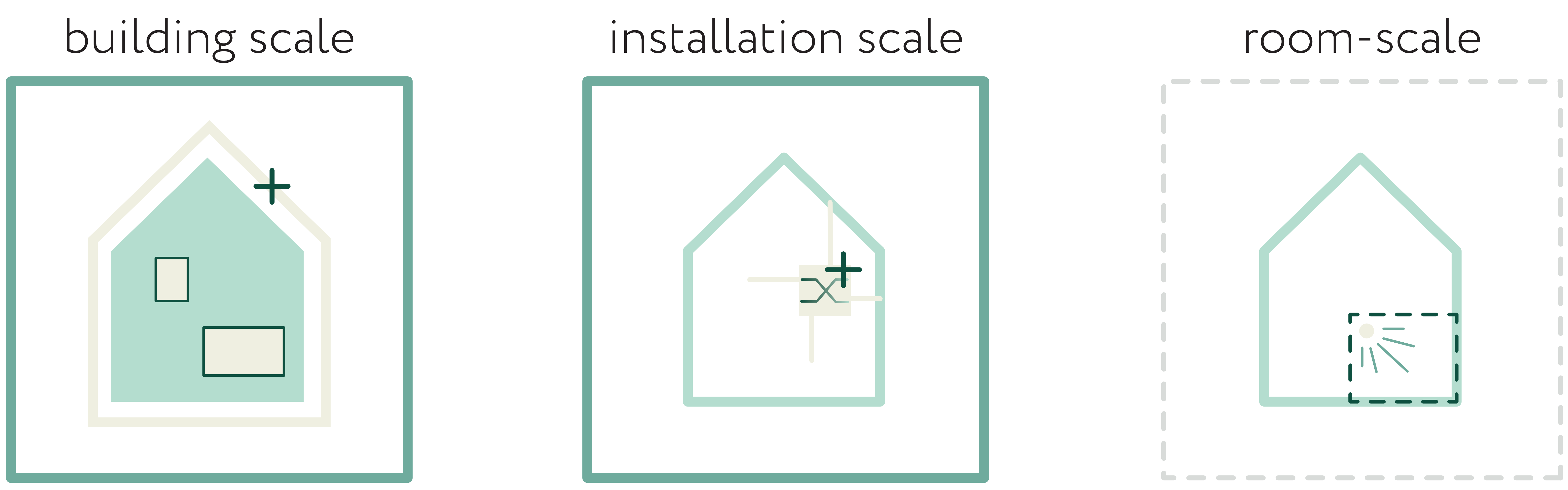
not considered within research

*based on Agentschap NL, 2011

all images are derived from Funda, 2022

Research

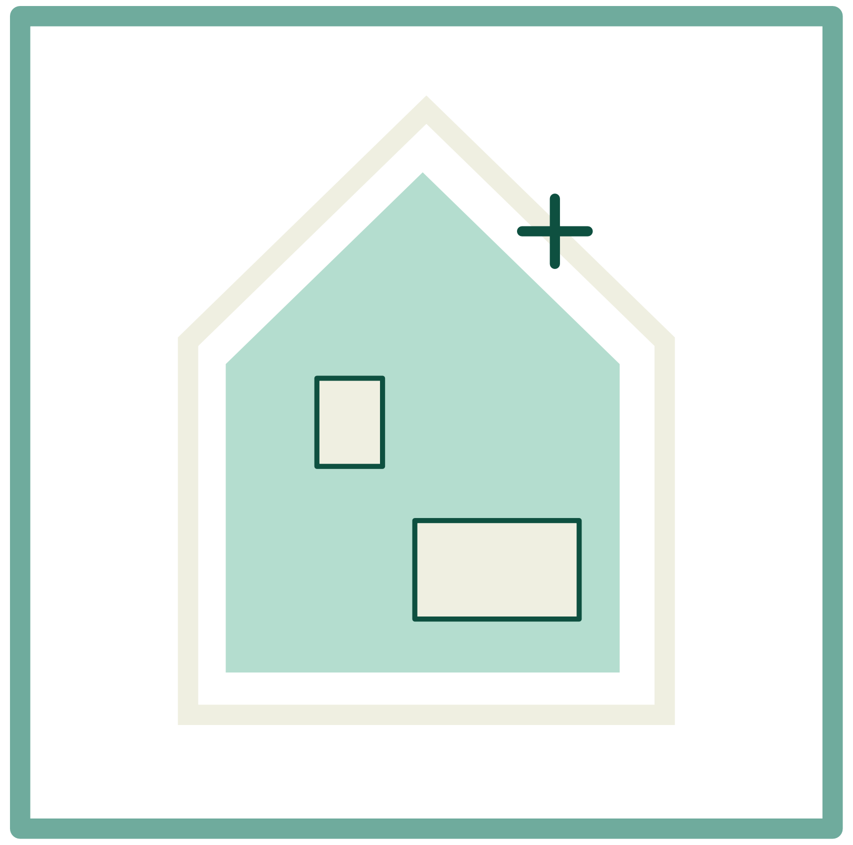
boundary conditions: renovation measures



Research

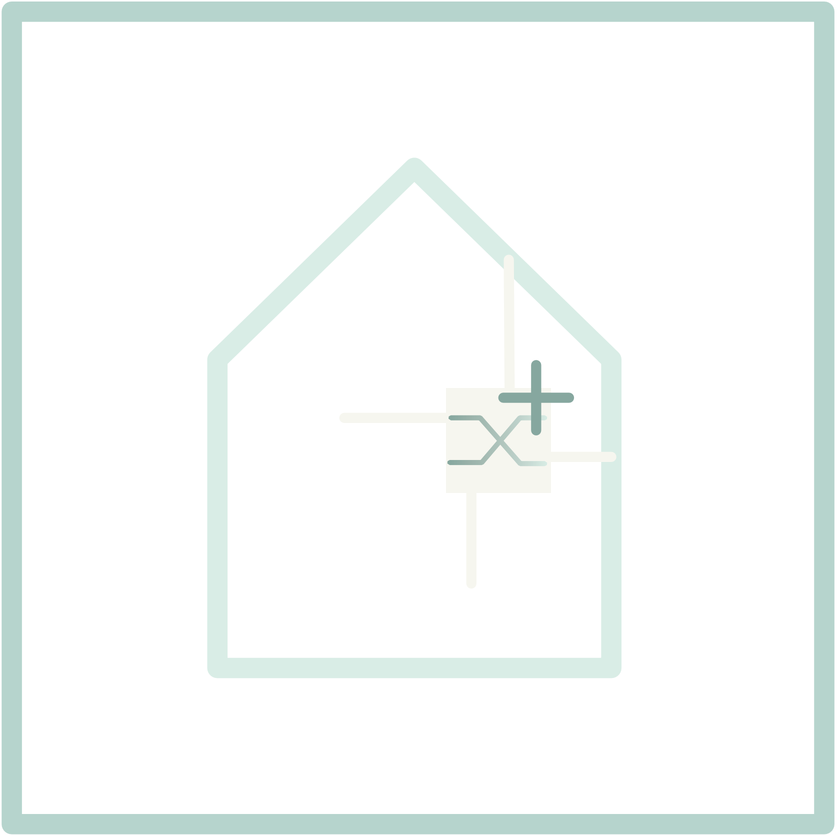
boundary conditions: renovation measures

building scale

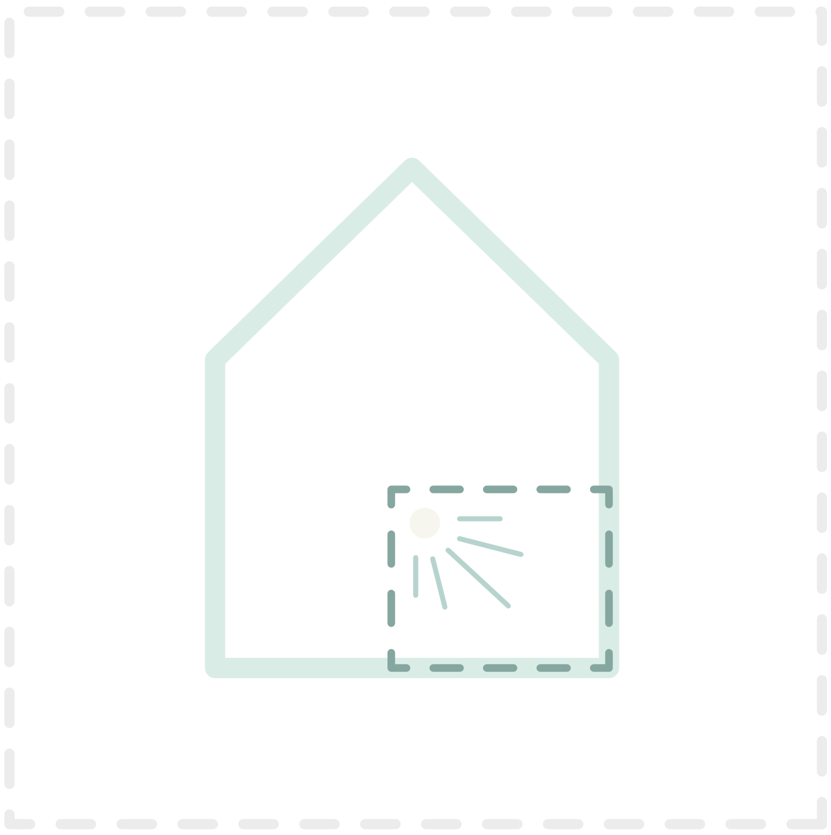


- wall insulation
- floor insulation
- roof insulation
- glazing type

installation scale



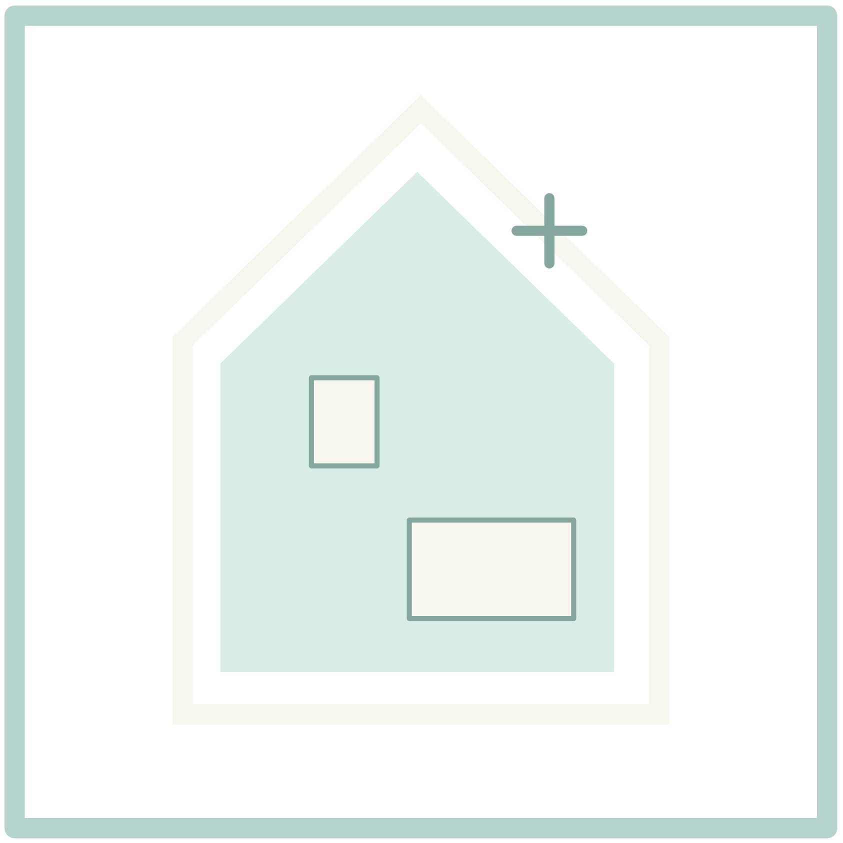
room-scale



Research

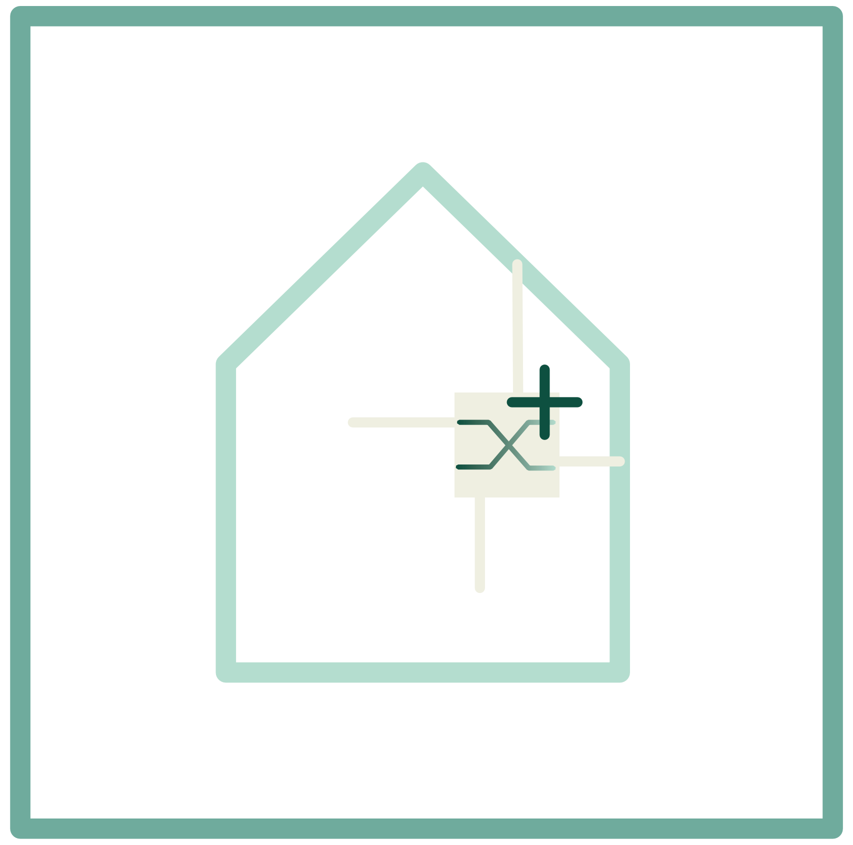
boundary conditions: renovation measures

building scale



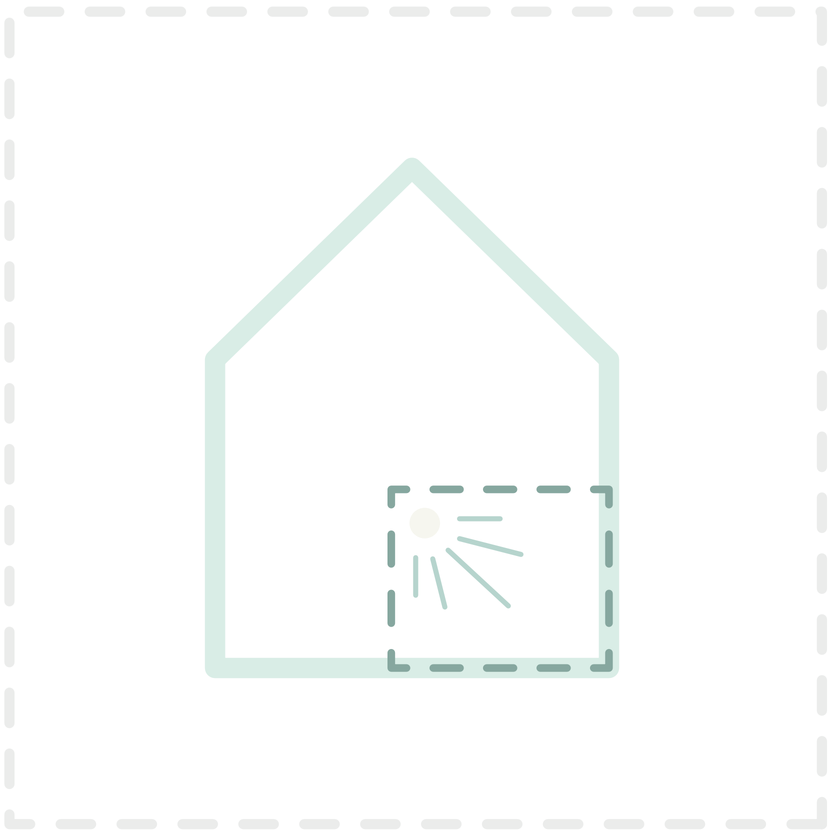
- wall insulation
- floor insulation
- roof insulation
- glazing type

installation scale



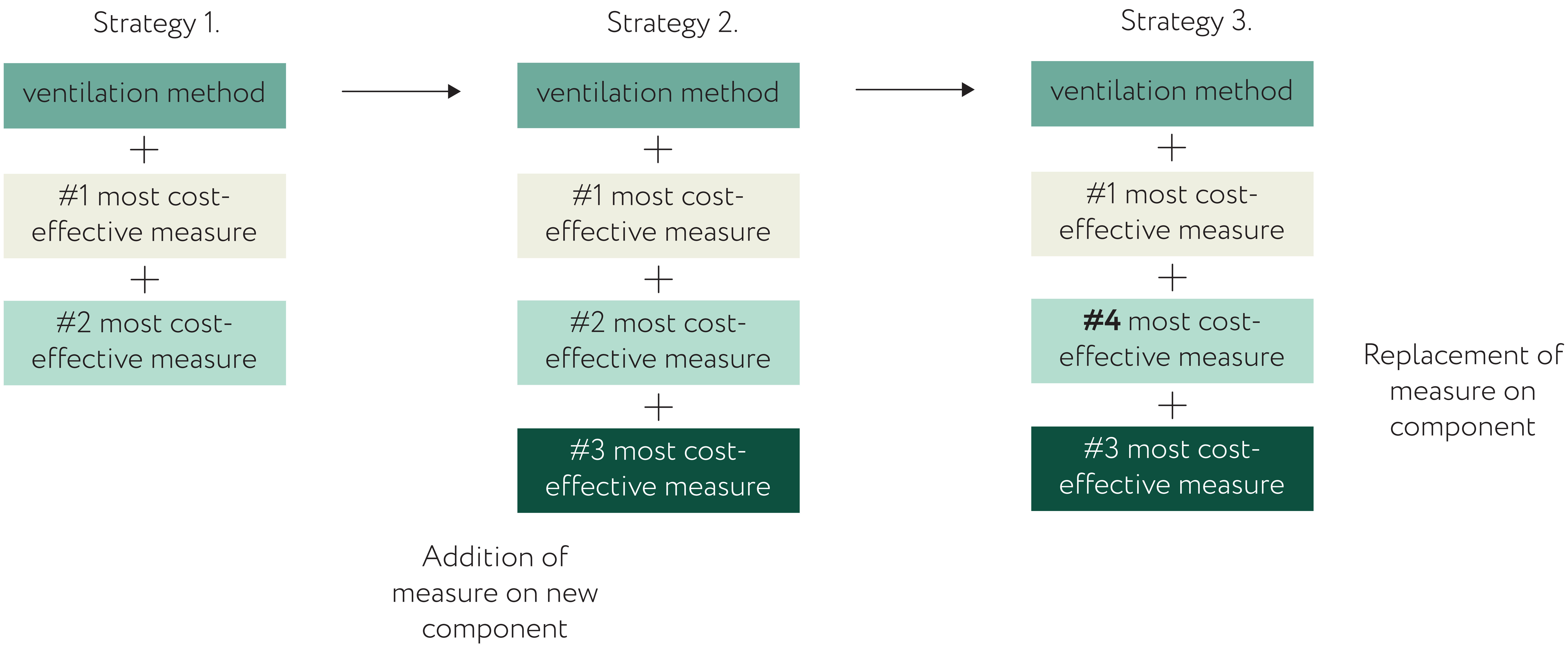
- ventilation system

room-scale



Research

boundary conditions: renovation strategies



Research

case study

facade of the case study
LTReady project

building type: terraced dwelling

constructed year: 1979

location: Utrecht, the Netherlands

Research

testing criteria

1. low-temperature ready

- heating demand
- air temperature

2. optimize thermal comfort

- MRT
- draught rate
- radiant asymmetry

Research

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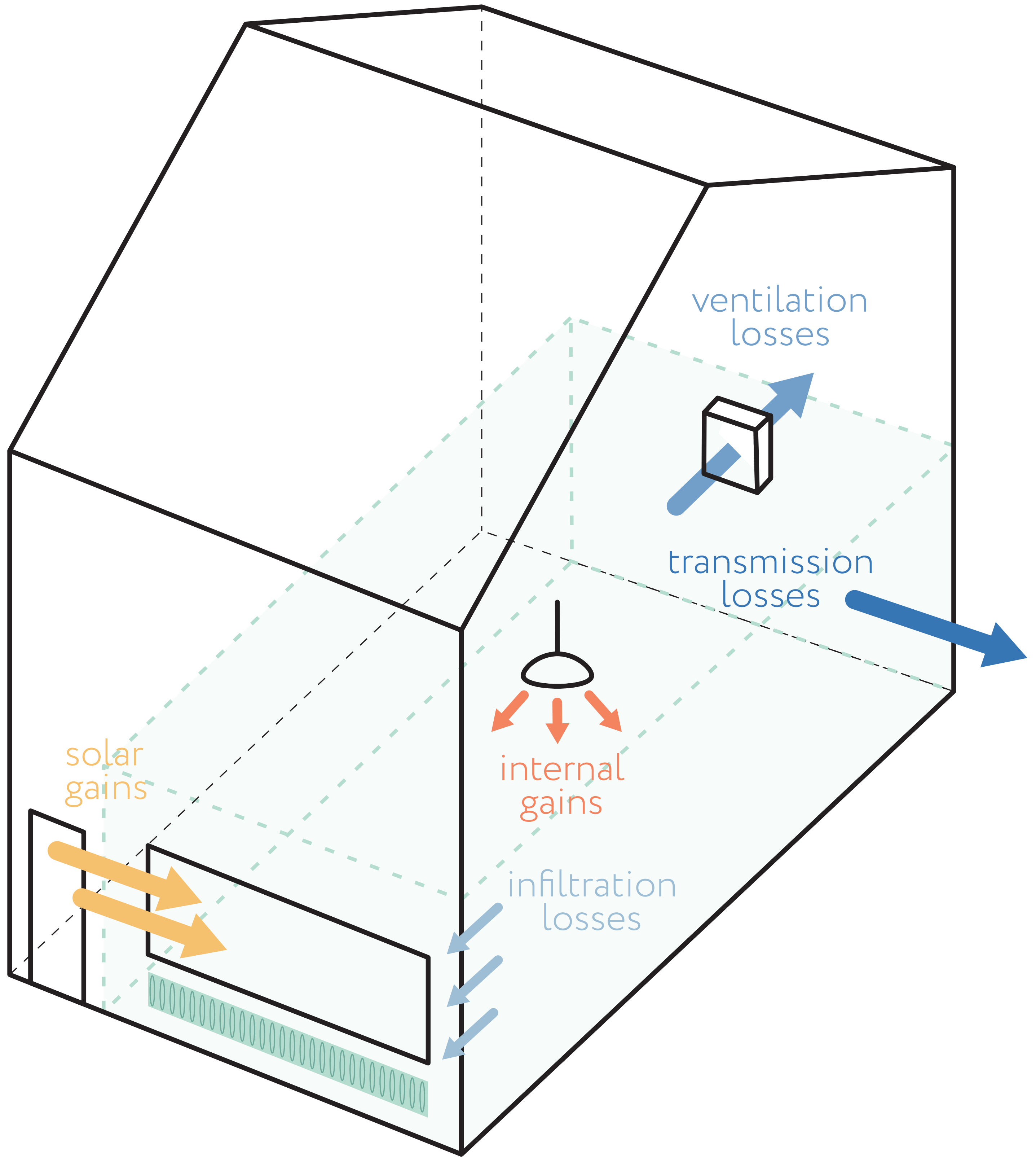
Research

testing criteria

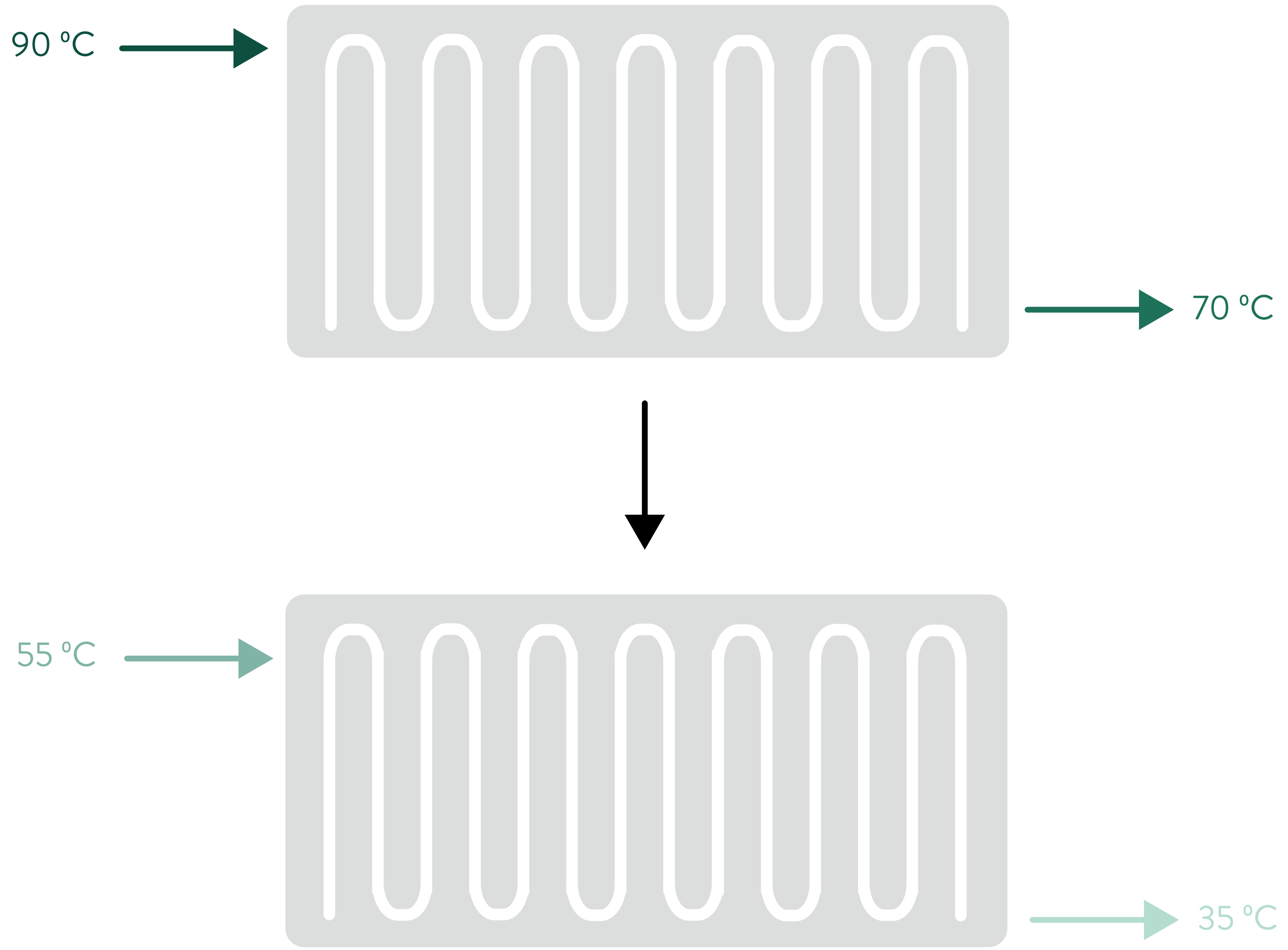


$$\dot{Q}_{demand} = \dot{Q}_{trans} + \dot{Q}_{vent} + \dot{Q}_{inf} + \dot{Q}_{int} + \dot{Q}_{sun}$$

$$\dot{Q}_{demand} \leq \dot{Q}_{output}$$

Research

testing criteria



± 70% lower capacity with low-temperature heating

$$\dot{Q}_{demand} \leq \dot{Q}_{output}$$

Research

testing criteria

low-temperature ready, when:

heating demand

- capacity of the heating system is able to cover 125% of the heating demand during the winter design week

AND

air temperature

- during the winter design week, the underreporting cannot be bigger than 1 °C for more than 10% of the time

Research

outcomes

	Pre 1964		1965 - 1974		1975 - 1987		reference: case study, 1979	
	Strategy	Low Temperature Ready	Strategy	Low Temperature Ready	Strategy	Low Temperature Ready	Strategy	Low Temperature Ready
	basis	N.A.	basis	N.A.	basis	N.A.	basis	N.A.
	basis low-temp		basis low-temp		basis low-temp		basis low-temp	
no change in ventilation system	1		1		1		1	
	2		2		2		2	
	3		3		3		3	
	4		4		4		4	
	5		5		5		5	
	6		6		6		6	
HR++ glazing →	7		7		7		7	
	8		8		8		8	
	9		9		9		9	
triple glazing →	10		10		10		10	
ventilation system C3	11		11		11		11	
	12		12		12		12	
	13		13		13		13	
roof insulation +10 cm →	14		14		14		14	
	15		15		15		15	
	16		16		16		16	
HR++ glazing →	17		17		17		17	
	18		18		18		18	
	19		19		19		19	
	20		20		20		20	
ventilation system D2	21		21		21		21	
	22		22		22		22	
	23		23		23		23	
	24		24		24		24	
	25		25		25		25	
	26		26		26		26	
HR++ glazing →	27		27		27		27	
	28		28		28		28	
	29		29		29		29	
	30		30		30		30	

not low-temperature ready
according to heating demand calculation low-temperature ready
according to heating demand calculation AND air temperature measurements low-temperature ready

Research

outcomes

reference: case study, terraced

	Strategy	Low Temperature Ready
	basis	N.A.
	basis low-temp	
no change in ventilation system	1	
	2	
	3	
	4	
	5	
	6	
HR++ glazing →	7	
	8	
	9	
triple glazing →	10	
ventilation system C3	11	
	12	
	13	
roof insulation +10 cm →	14	
	15	
	16	
	17	
	18	
	19	
	20	
ventilation system D2	21	
	22	
	23	
roof insulation +10 cm →	24	
	25	
	26	
HR++ glazing →	27	
	28	
	29	
	30	

semi-detached housing

Strategy	Low Temperature Ready
basis	N.A.
basis low-temp	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
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17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	

freestanding housing

Strategy	Low Temperature Ready
basis	N.A.
basis low-temp	
1	
2	
3	
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9	
10	
11	
12	
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not low-temperature ready
according to heating demand calculation low-temperature ready
according to heating demand calculation AND air temperature measurements low-temperature ready

Research

outcomes

... Only case study dwelling can be made low-temperature ready, due to relative oversizing of the heating capacity

Typology	pre 1964	1965 - 1974	1975 - 1987	reference: case study	semi-detached	freestanding
Relative oversizing of the heating system*	108%	125%	179%	255%	225%	194%

*the ratio between the heating capacity and the heating demand of a winter design week

Research

outcomes

... Only case study dwelling can be made low-temperature ready, due to relative oversizing of the heating capacity

.... High effectiveness* of insulation measures for early construction periods

Typology	pre 1964	1965 - 1974	1975 - 1987	reference: case study	semi-detached	freestanding
Effectiveness wall insulation (cavity)	-58%	-59%	-42%	-25%	-31%	-31%
Effectiveness roof insulation (10 cm)	-84%	-67%	-63%	-39%	-38%	-37%
Effectiveness floor insulation (10 cm below)	-82%	-82%	-69%	-33%	-35%	-32%

*Effectiveness of measure indicated by the reduction of heat loss through the specific component in %

Research

outcomes

... Only case study dwelling can be made low-temperature ready, due to relative oversizing of the heating capacity

.... High effectiveness of insulation measures for early construction periods

.... Differences in contribution of heat losses of components per typology

Typology	pre 1964	1965 - 1974	1975 - 1987	reference: case study	semi-detached	freestanding
Heat loss glazing	9%	10%	14%	11%	9%	8%
Heat loss wall	16%	17%	12%	15%	26%	38%
Heat loss ground floor	9%	10%	7%	3%	3%	3%
Heat loss roof	28%	17%	18%	10%	9%	8%
Heat loss infiltration	28%	39%	39%	38%	33%	28%
Heat loss ventilation	9%	12%	16%	22%	19%	16%

Research

testing criteria

1. low-temperature ready

- heating demand
- air temperature

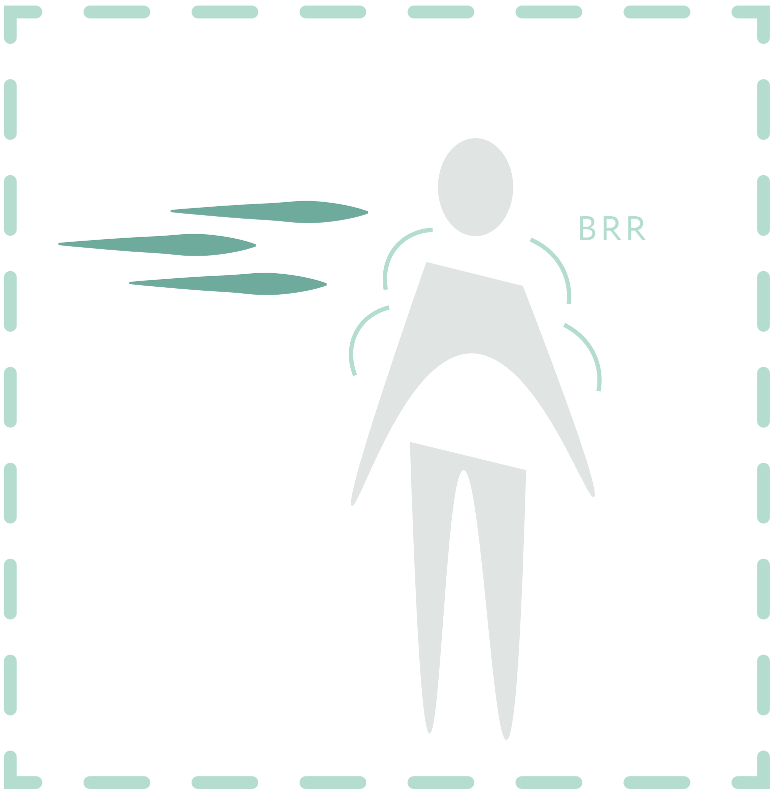
2. optimize thermal comfort

- MRT
- draught rate
- radiant asymmetry

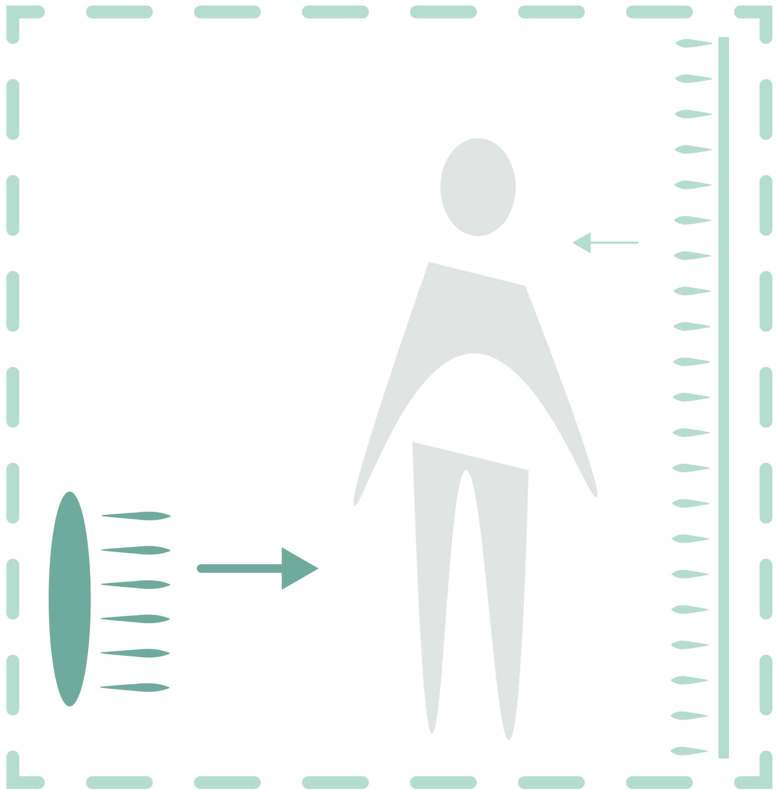
local thermal discomfort

vertical temperature gradient

floor surface temperature



draught



radiant asymmetry

Research

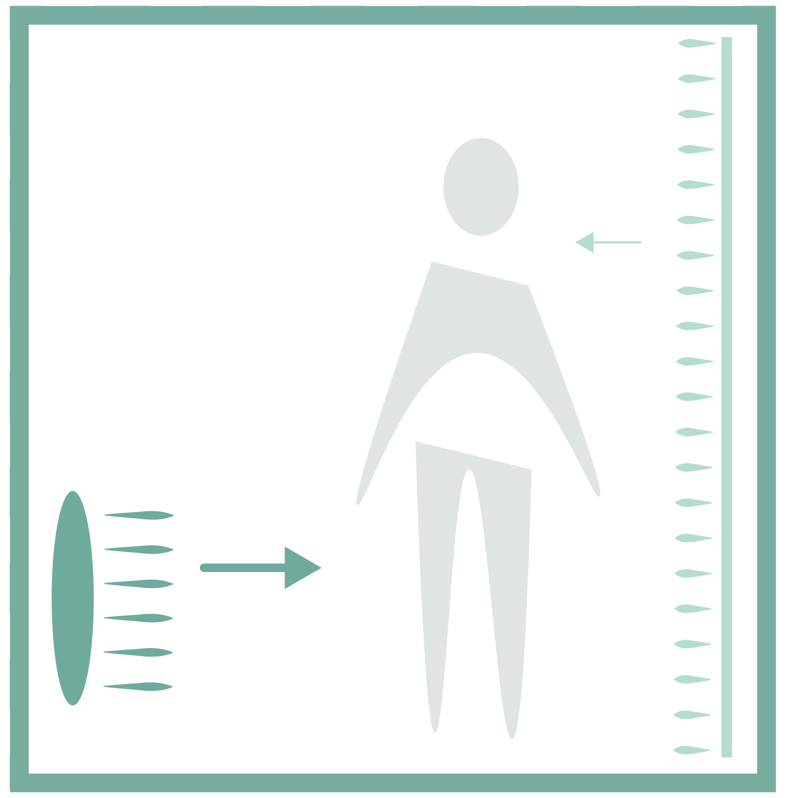
testing criteria

local thermal discomfort

vertical temperature gradient

floor surface temperature

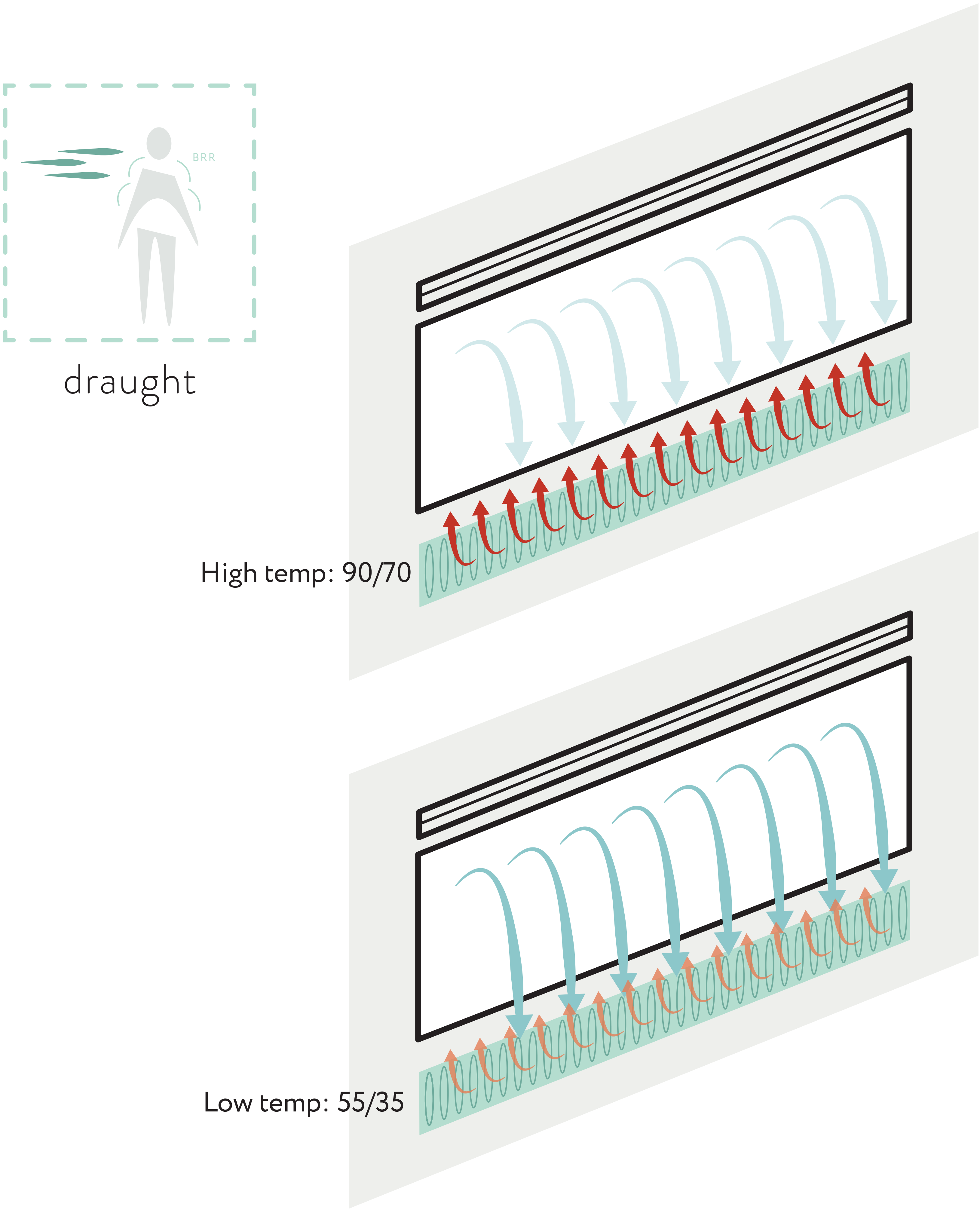
draught

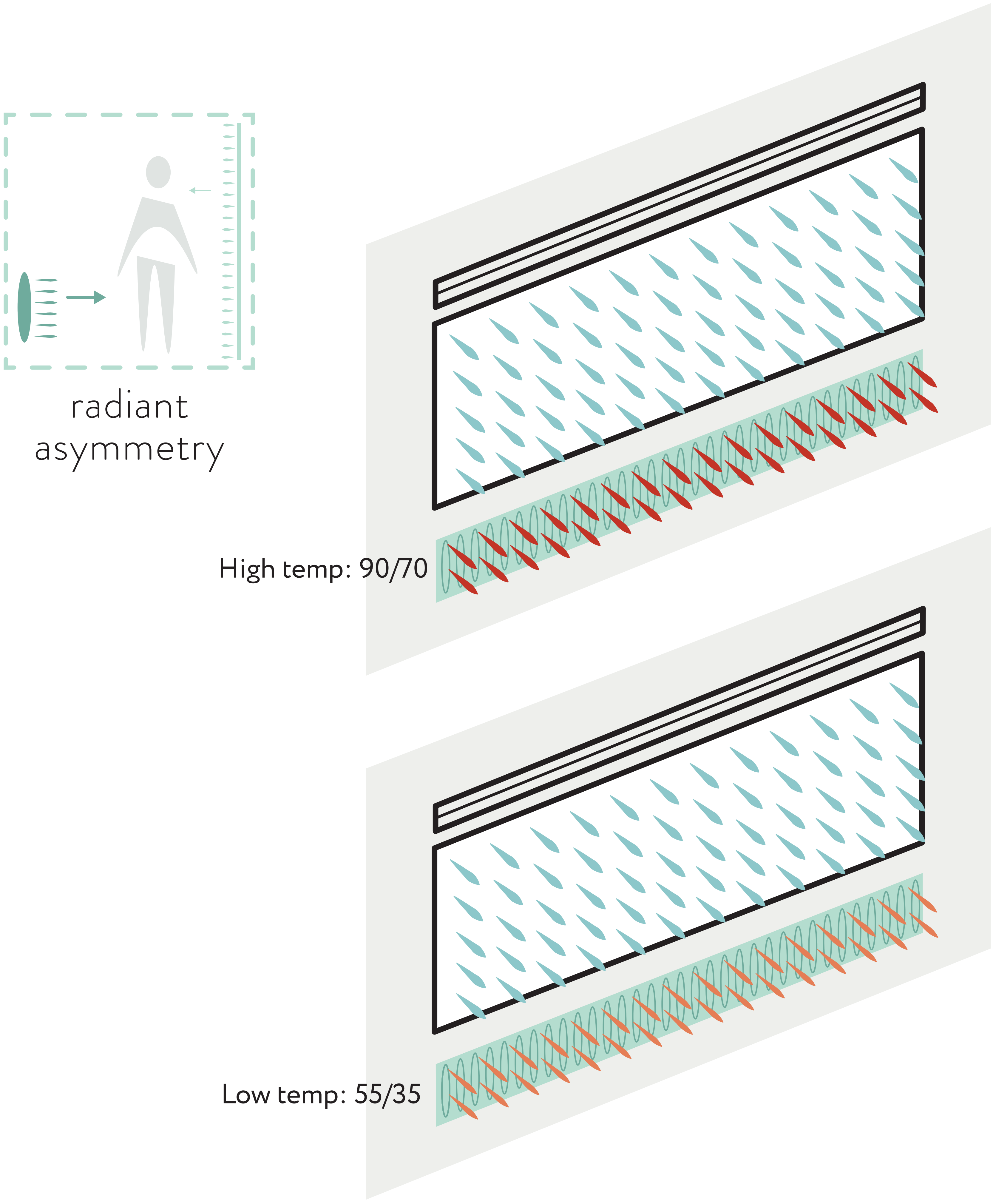


radiant asymmetry

Research

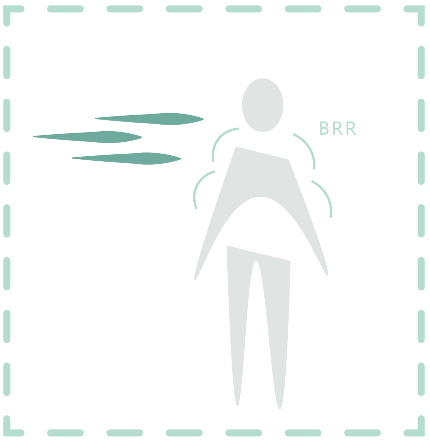
testing criteria





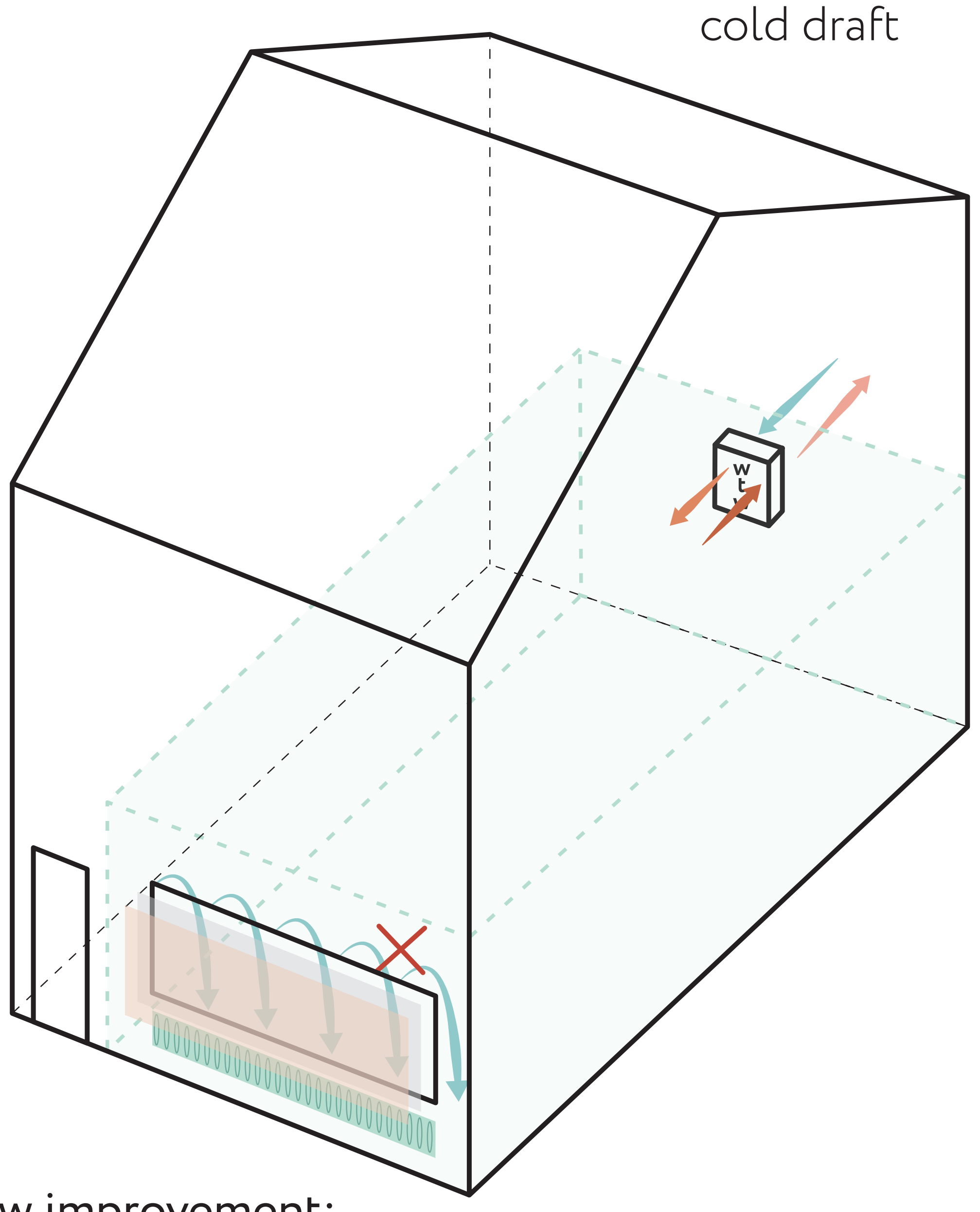
Research

testing criteria

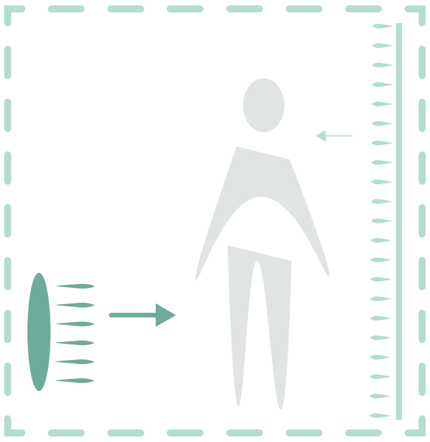


draught

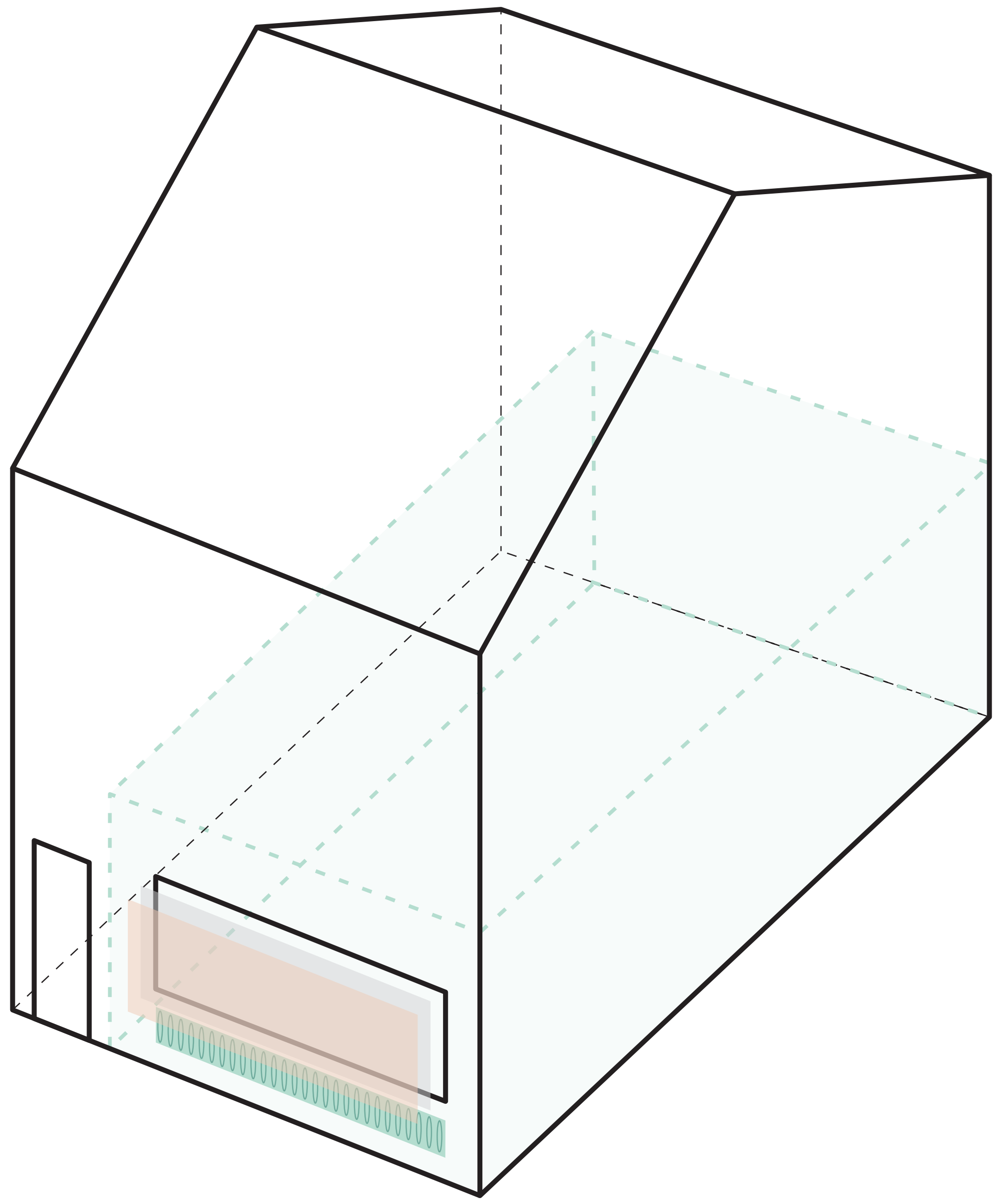
Ventilation type D.2:
positive effect
air entering is pre-heated, leading to less cold draft



Window improvement:
positive effect
improved U-value leads to less downdraught



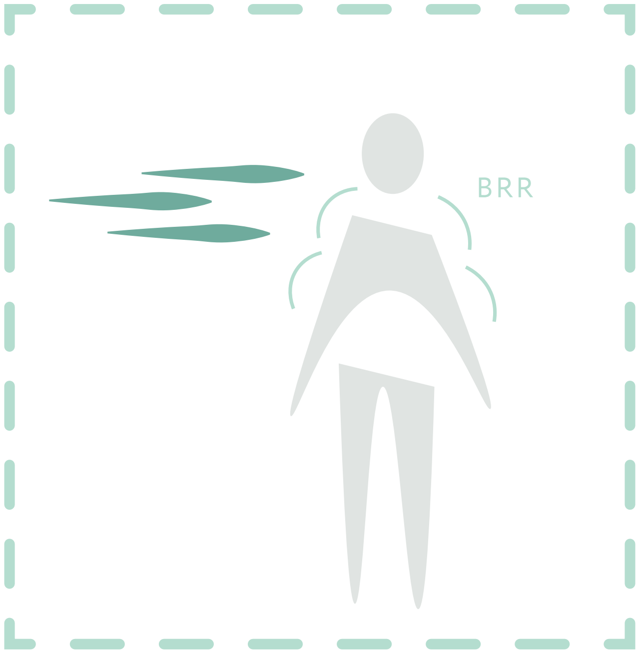
radiant asymmetry



Window improvement:
positive effect
improved U-value leads to less 'cold' radiation from the window

Research

testing criteria



draught

radiant asymmetry

$$DR = ([34 - t_a] \times [v - 0{,}05]^{0{,}62}) \times (0{,}37 \times v \times t_u + 3{,}14)$$

DR = predicted percentage of people dissatisfied due to draught in %

t_a = local air temperature in °C - DesignBuilder CFD

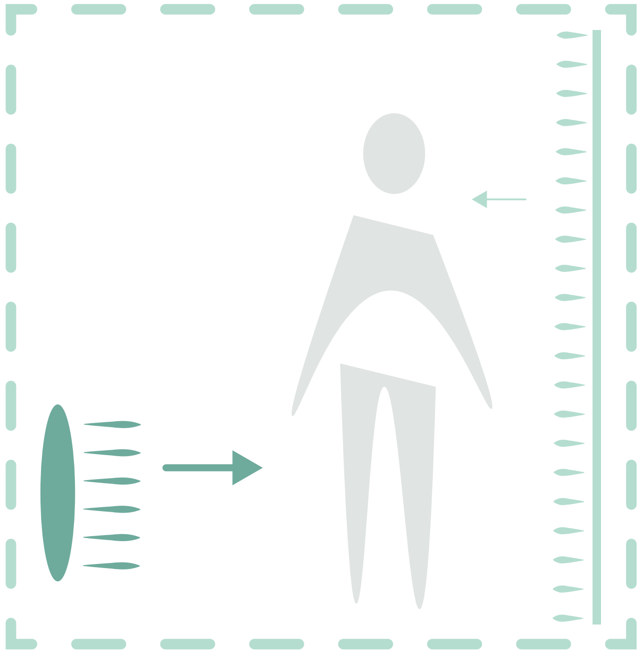
v = local average airspeed in m/s - DesignBuilder CFD

T_u = local turbulence intensity in % - estimation

Research

testing criteria

draught



radiant asymmetry

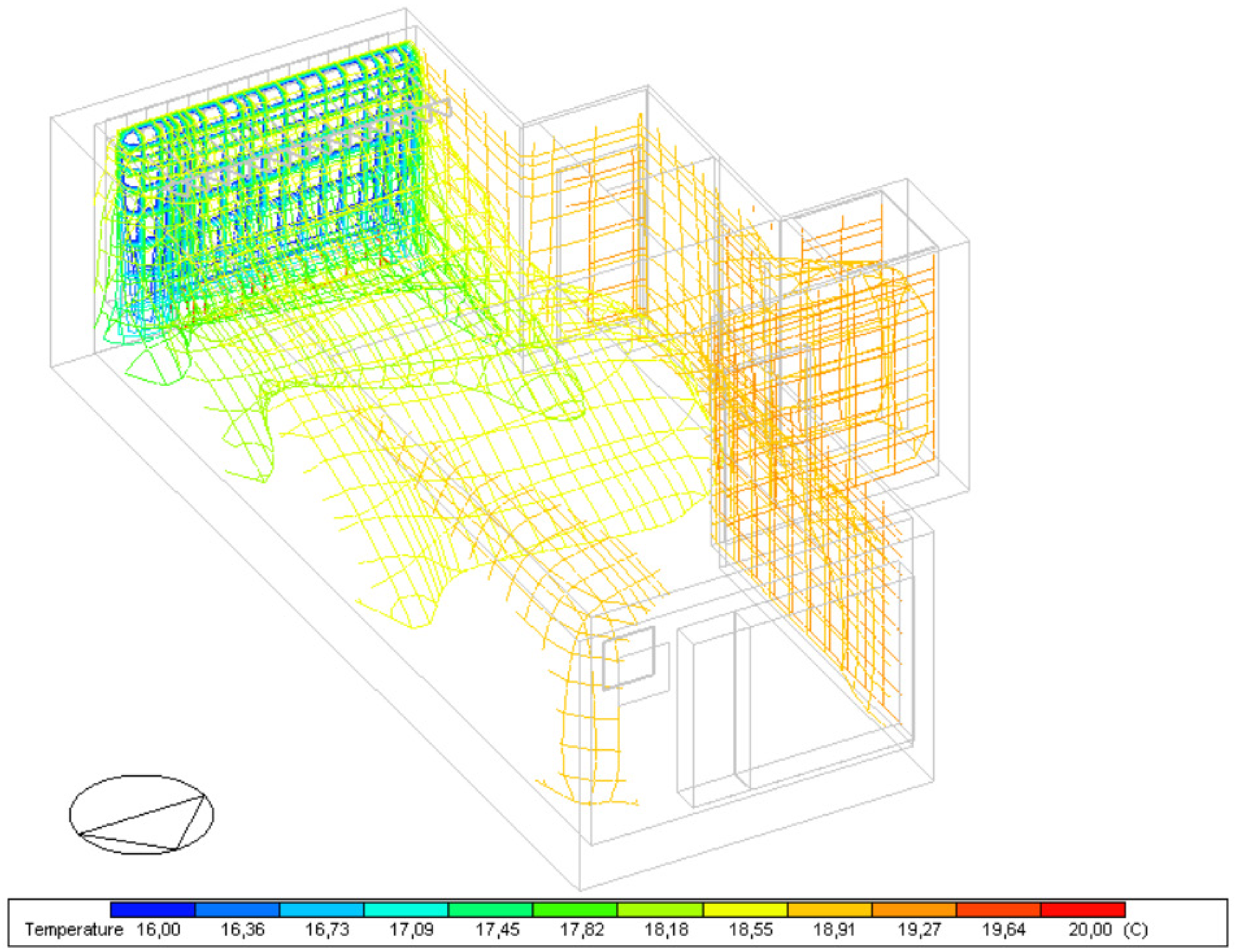
MRT = mean radiant temperature in °C – DesignBuilder CFD, Stralingsverloop

VF = viewfactor – Stralingsverloop

Research

testing criteria

sensitive parameter	type of boundary condition	options
glazing type	window surface temperature	- double glazing - HR glazing - HR++ glazing - triple glazing
insulation level	wall surface temperature air temperature	- existing level - medium level (strategy 2) - high level (strategy 6)
ventilation type	air temperature supply air	- ventilation type C1 and C3 - ventilation type D2
radiator supply temperature	radiator surface temperature	- 90 °C - 55 °C - 35 °C - 20 °C

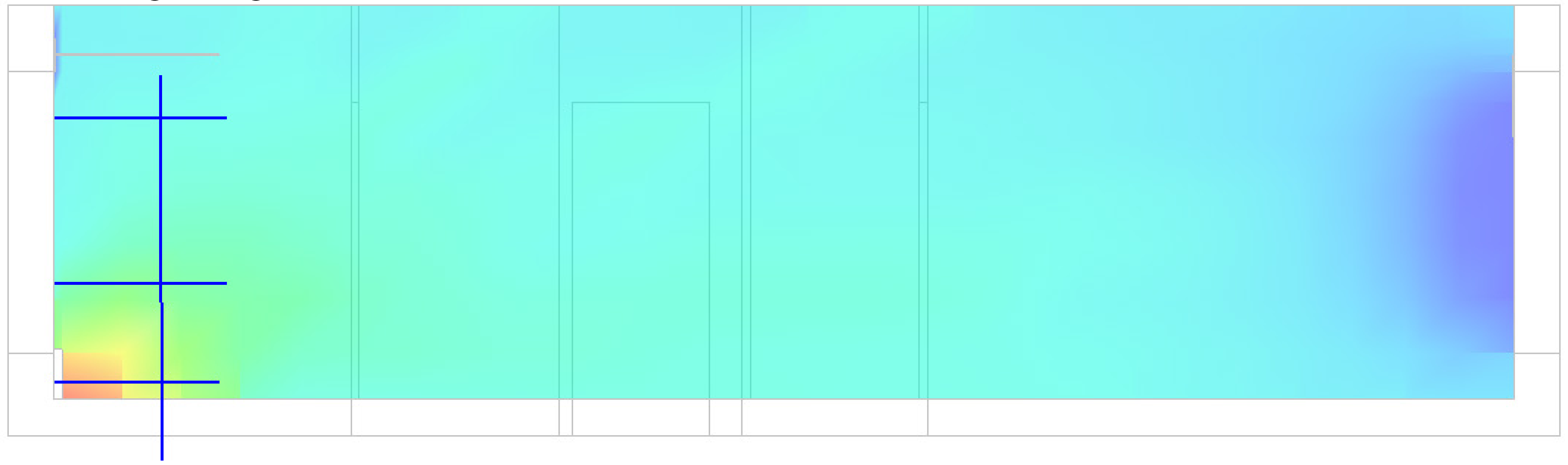


Research

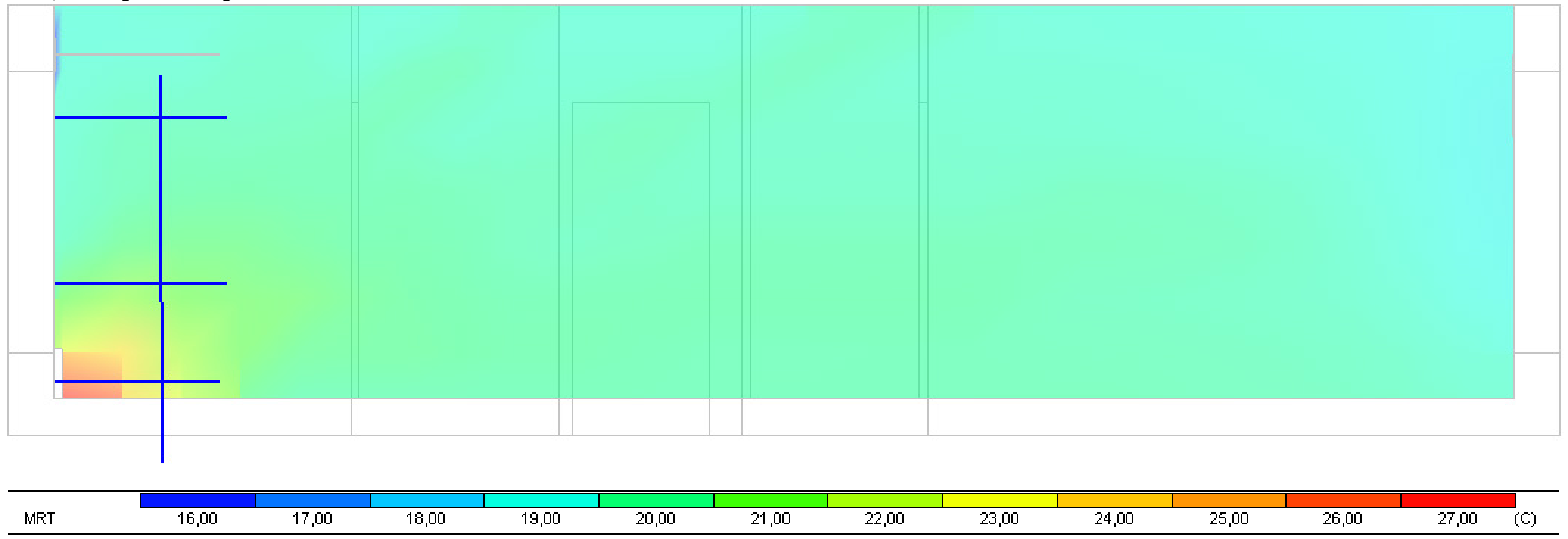
outcomes

sensitive parameter	type of boundary condition	options
glazing type	window surface temperature	- double glazing - HR glazing - HR++ glazing - triple glazing

double glazing



triple glazing



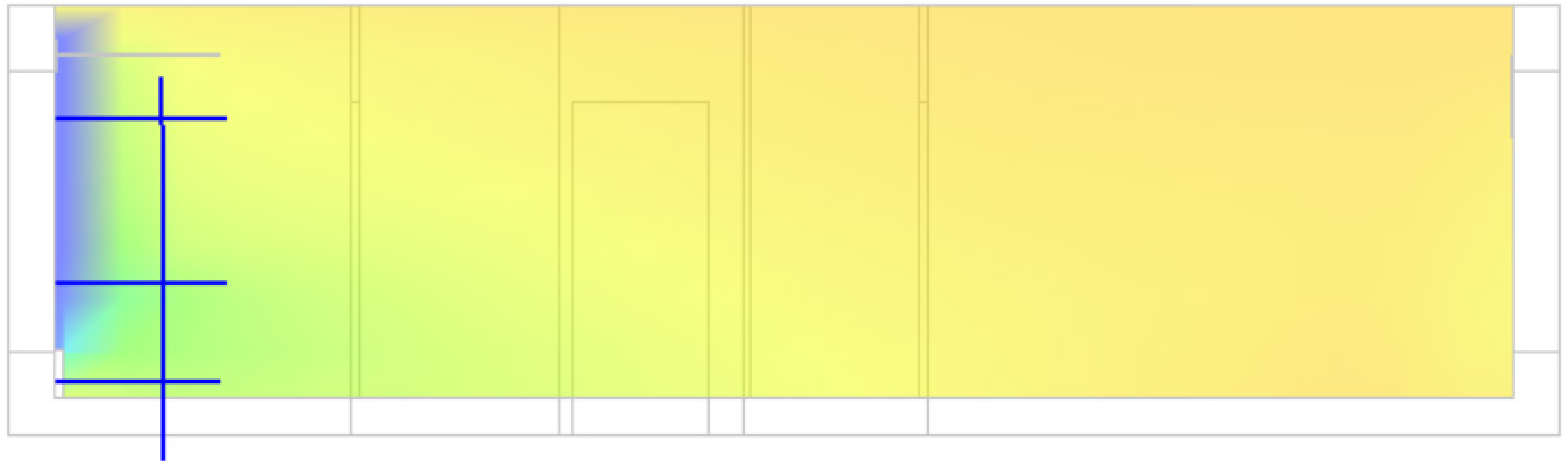
CFD analysis of different glazing types, extracted from DesignBuilder (other parameters are constant)

Research

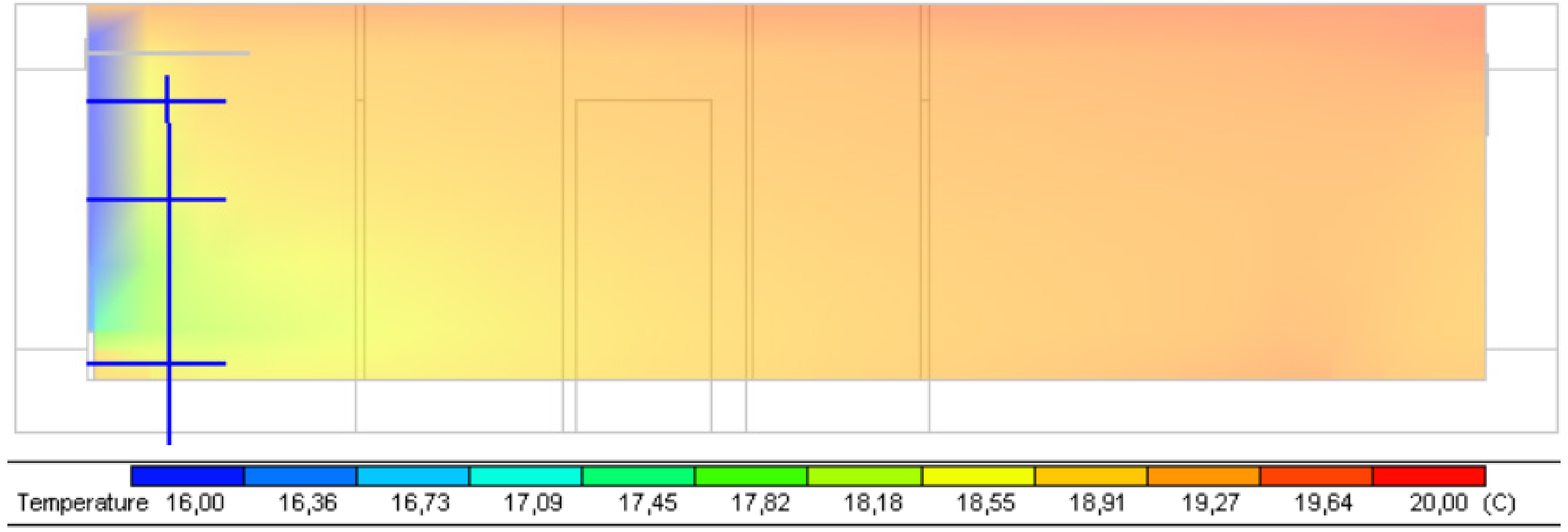
outcomes

sensitive parameter	type of boundary condition	options
insulation level	wall surface temperature air temperature	- existing level - medium level (strategy 2) - high level (strategy 6)

existing level



high level (strategy 6)



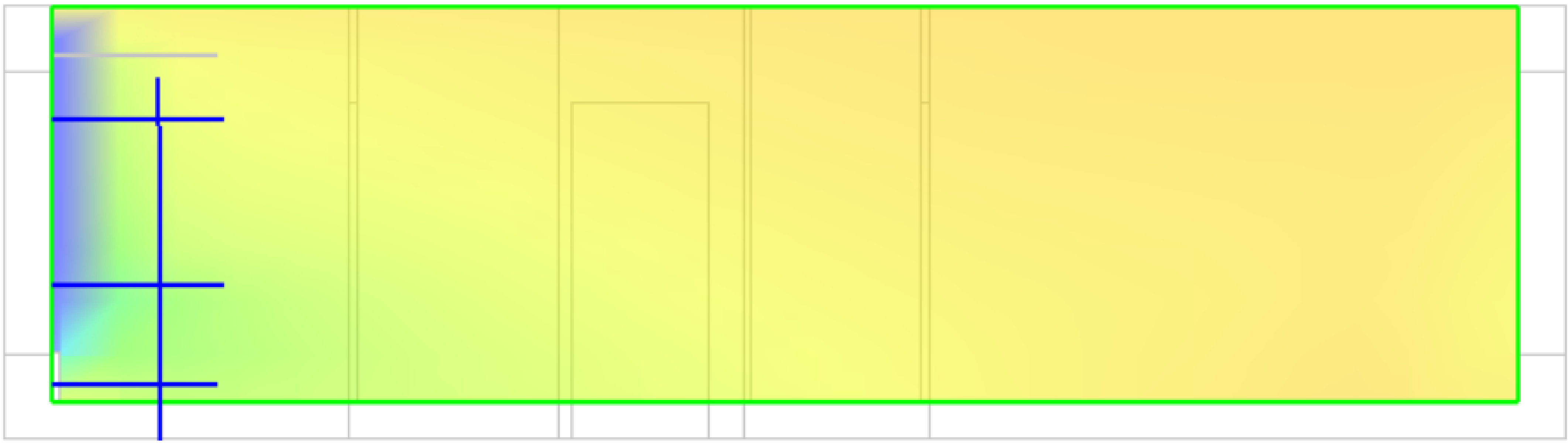
CFD analysis of different insulation values, extracted from DesignBuilder (other parameters are constant)

Research

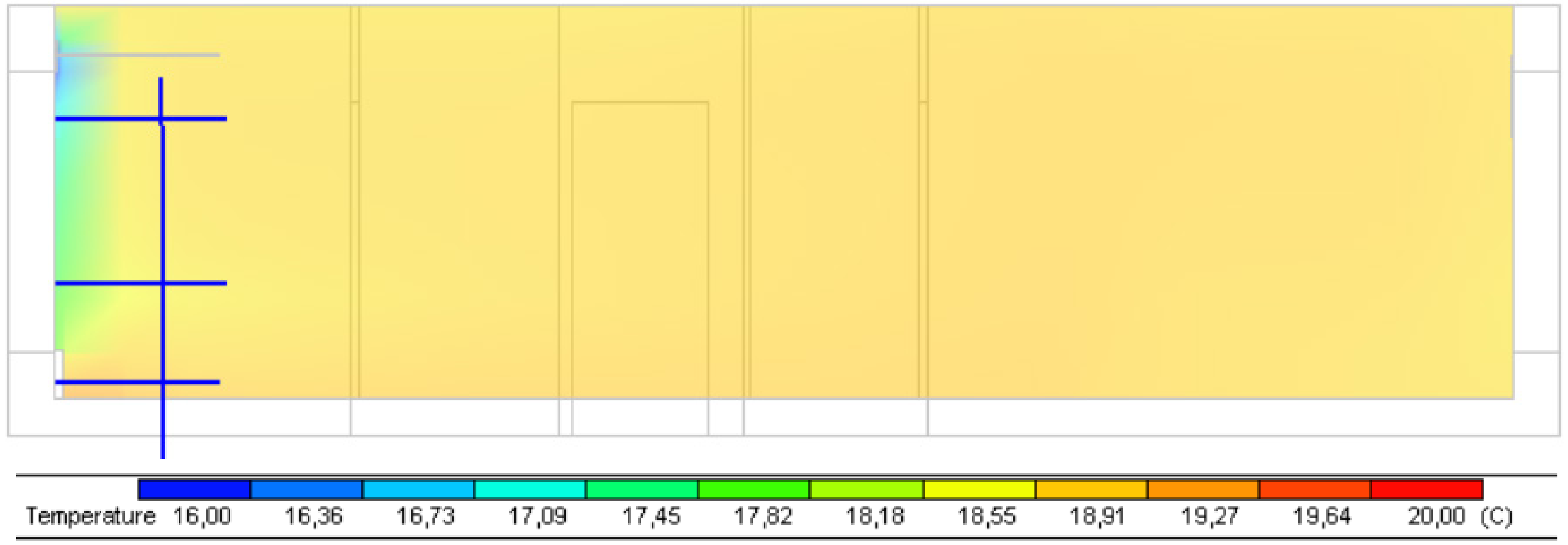
outcomes

sensitive parameter	type of boundary condition	options
ventilation type	air temperature supply air	- ventilation type C1 and C3 - ventilation type D2

ventilation type C1 and C3



ventilation type D2



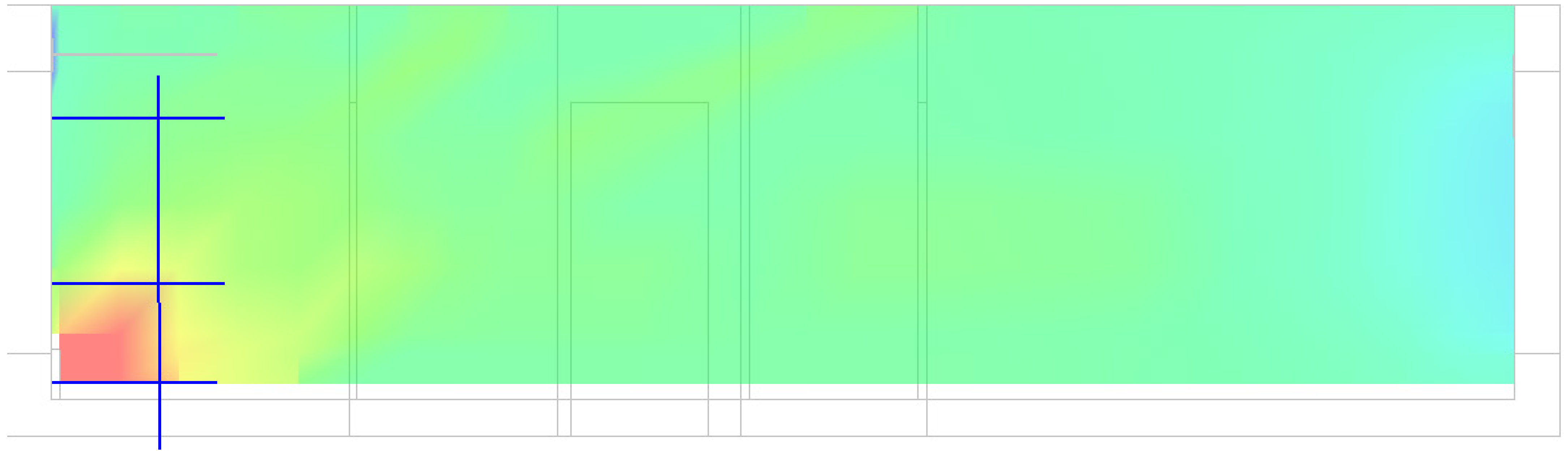
CFD analysis of different ventilation types, extracted from DesignBuilder (other parameters are constant)

Research

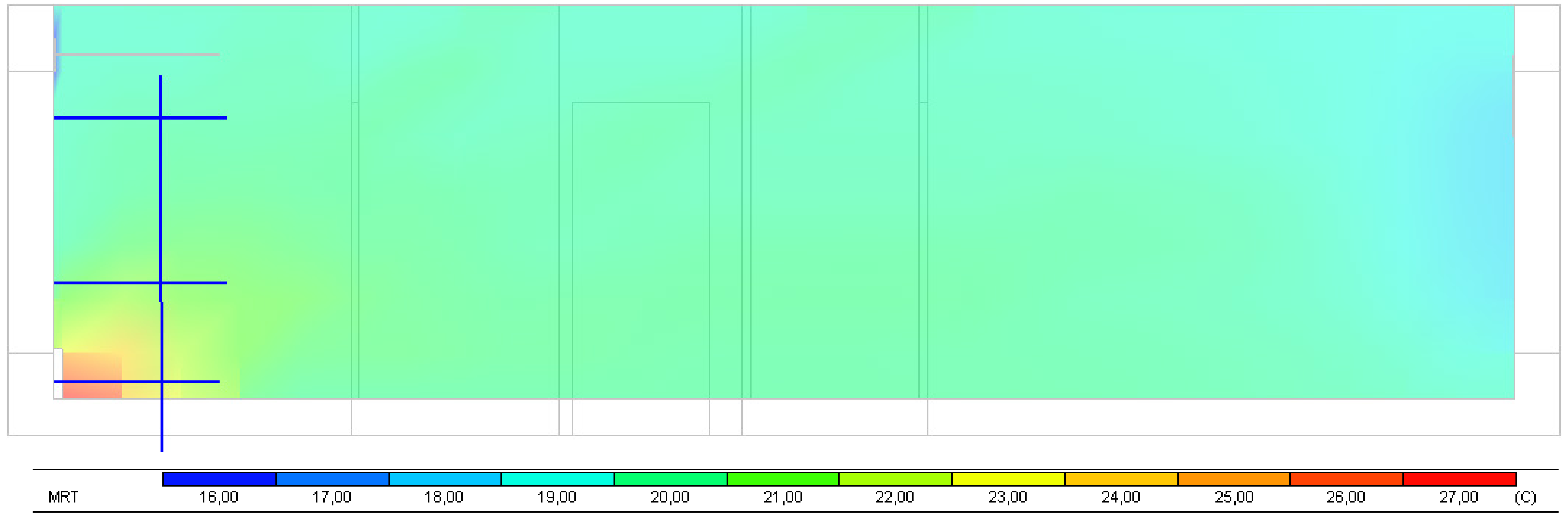
outcomes

sensitive parameter	type of boundary condition	options
radiator supply temperature	radiator surface temperature	- 90 °C - 55 °C - 35 °C - 20 °C

radiator temperature at 90 °C



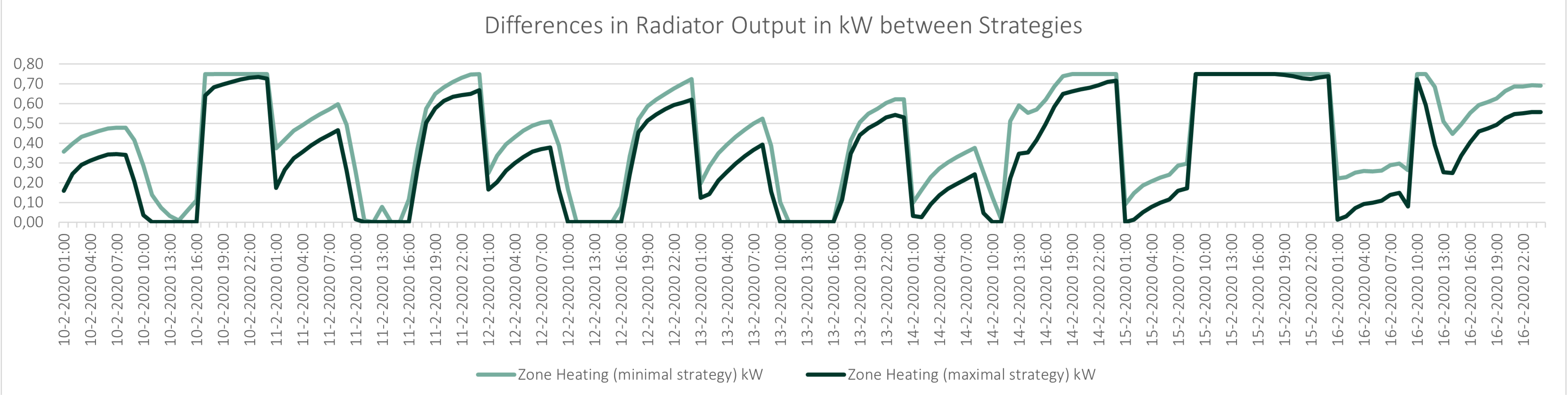
radiator temperature at 55 °C



CFD analysis of different radiator temperatures extracted from DesignBuilder (other parameters are constant)

Research

outcomes



graph outlining the measured radiator outputs in the living room of different strategies

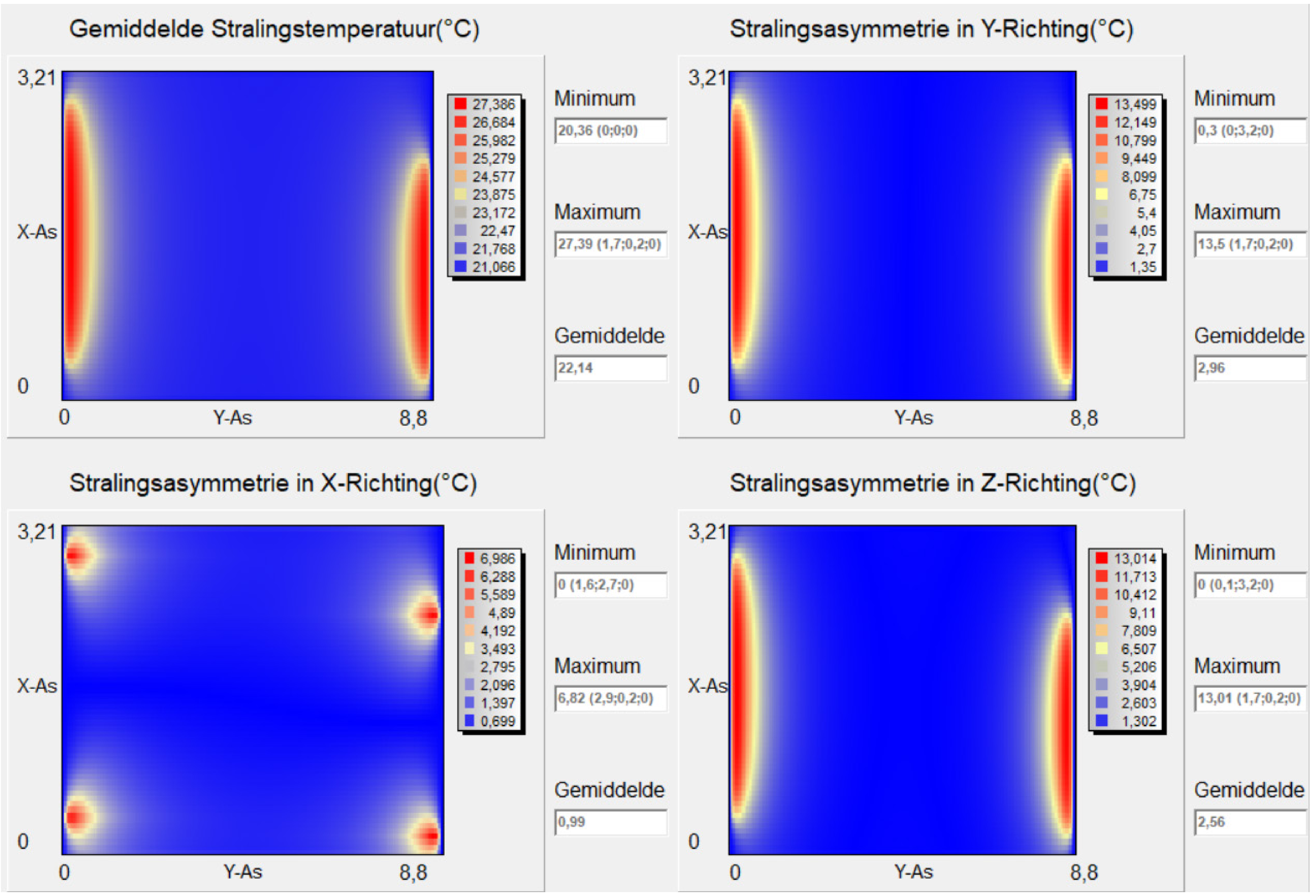
minimal strategy: balance ventilation and cavity wall insulation

maximal strategy: balance ventilation, 10 cm of exterior wall insulation, 15 cm of interior roof insulation and HR++ glazing

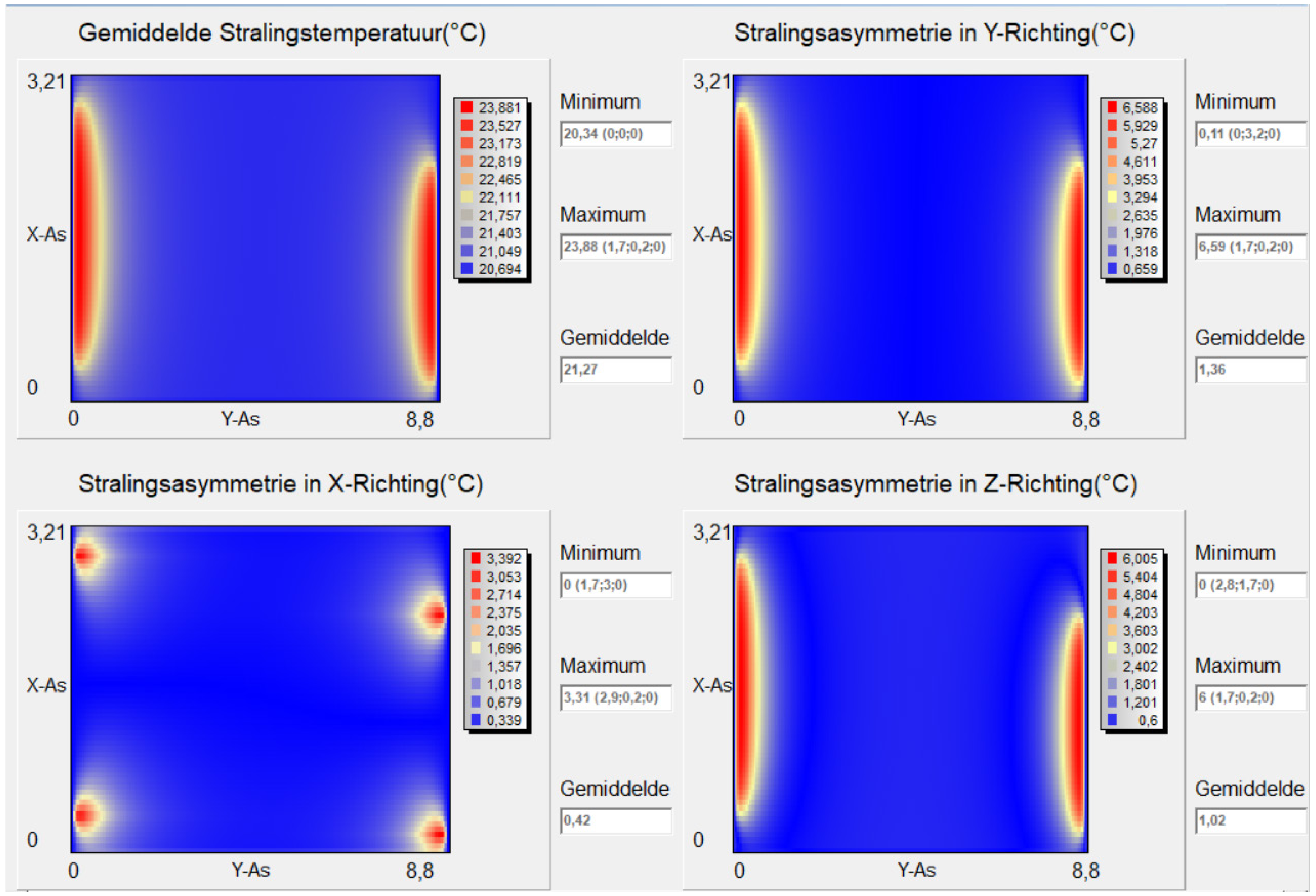
Research

outcomes

high temperature (90/70) radiator



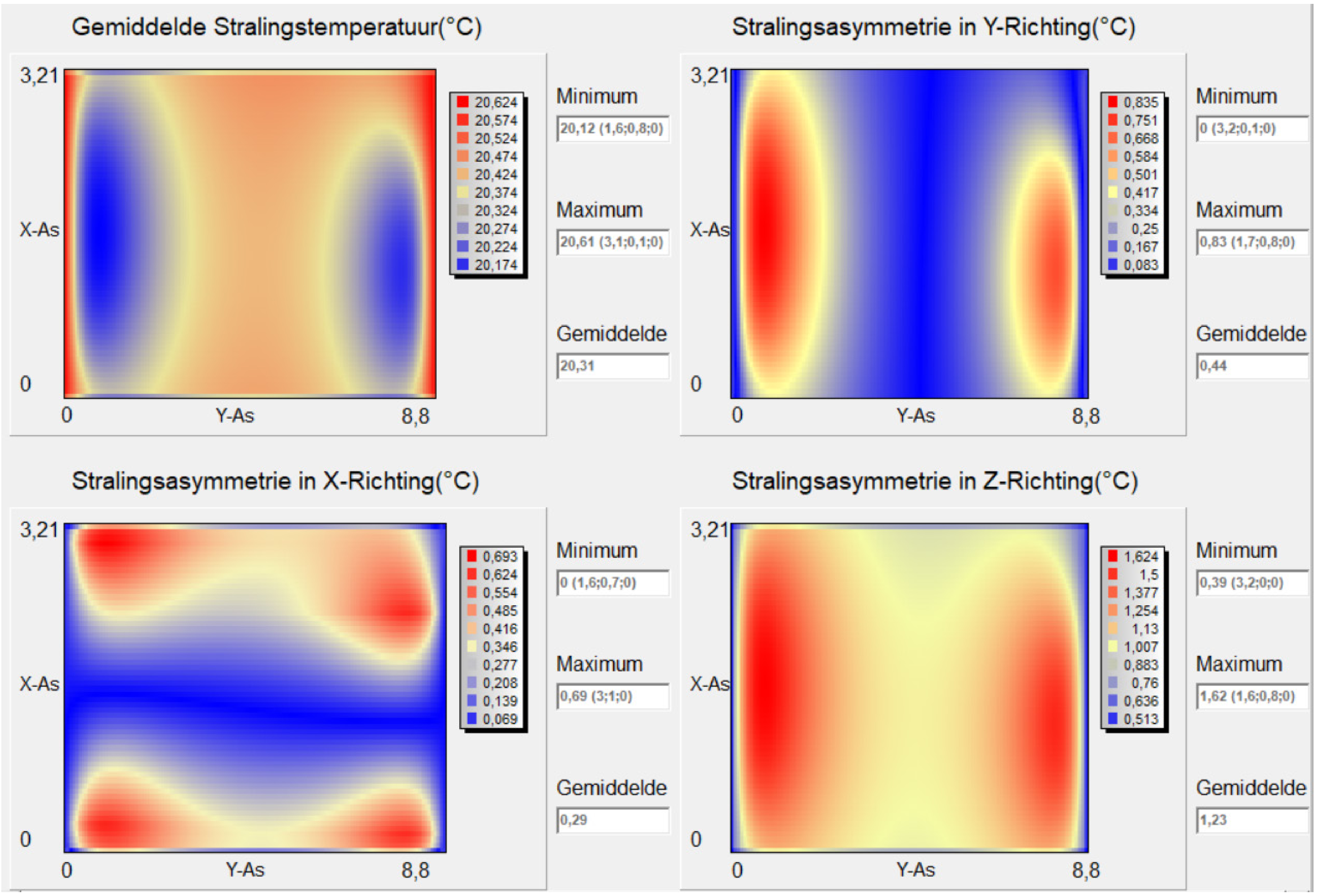
low temperature (55/35) radiator



Research

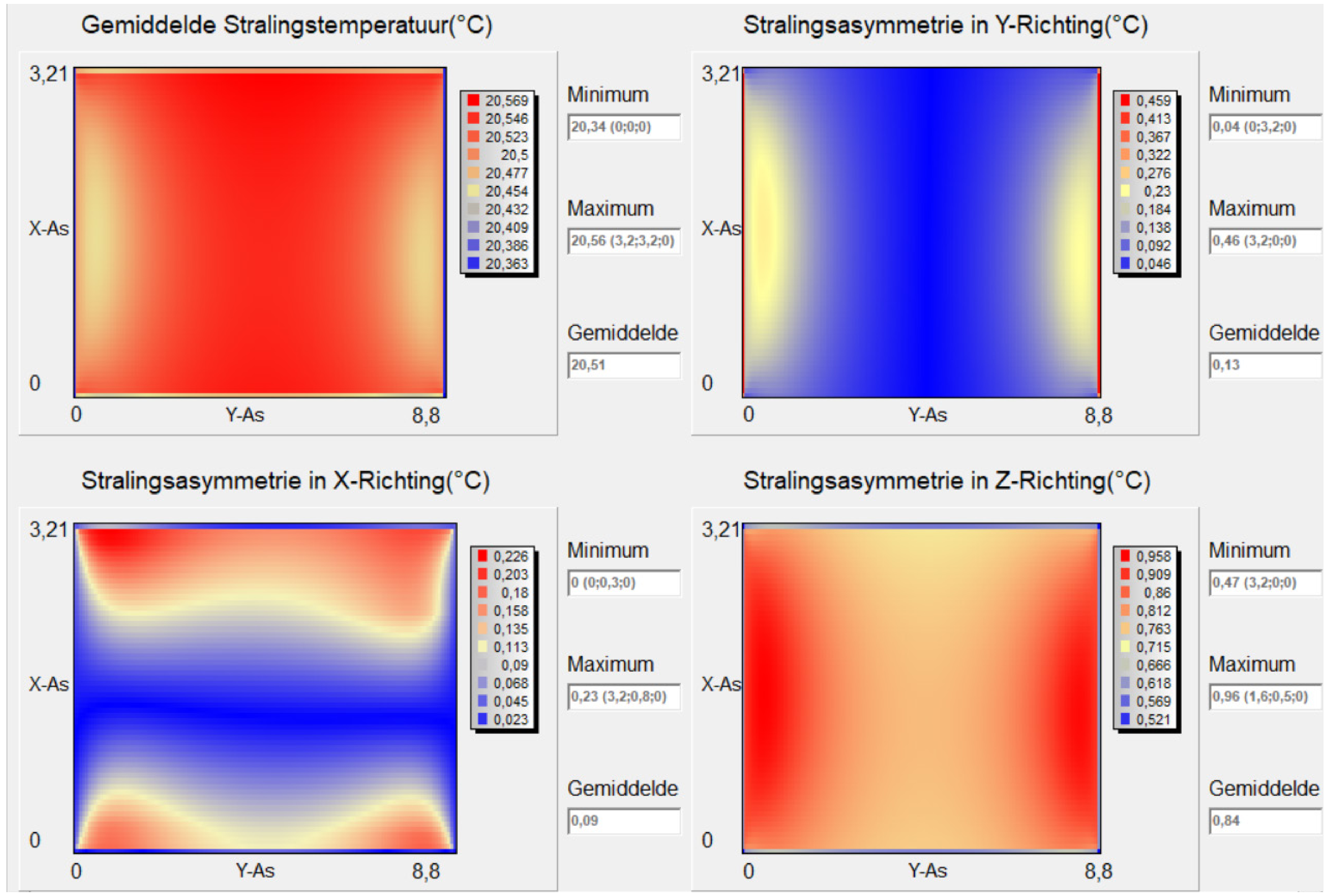
outcomes

regular double glazing



in both situations no radiator is assumed

triple glazing



Conclusion

research framework

methodology

research

conclusions

Conclusion

recap research question

... Which minimal renovation strategies are needed to prepare different single-family housing typologies for the integration of low-temperature heating and optimize the thermal comfort of the residence?

Conclusion

recap low-temperature ready

... Only case study dwelling can be made low-temperature ready, due to relative oversizing of the heating capacity

.... Differences in effectiveness of insulation measures per typology

.... Differences in contribution of heat losses of components per typology

Conclusion

recap optimal thermal comfort

... Draught can be compensated best by installing balance ventilation with heat recovery

... When this is not possible, improved glazing can also have a positive effect

.... Glazing with a lower U-value can help oppose thermal discomfort experienced as a result of radiant asymmetry

... Insulation has no significant effect

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MINIMAL RENOVATION STRATEGIES FOR LOW-TEMPERATURE HEATING

with optimal comfort

presentation **P5**

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