

LT-READY:

Affordable renovation concepts that provide thermal comfort with low-temperature heating

Saskia Rutten
4605586

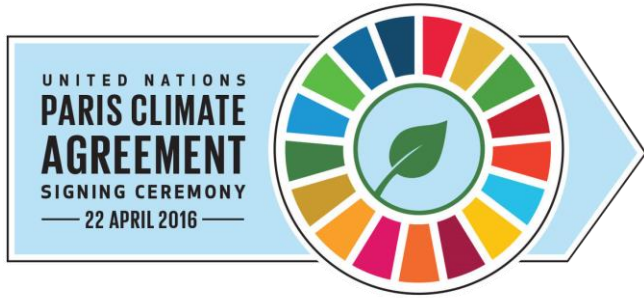
P5 presentation
30/6/2021

1st mentor
2nd mentor
Consultant

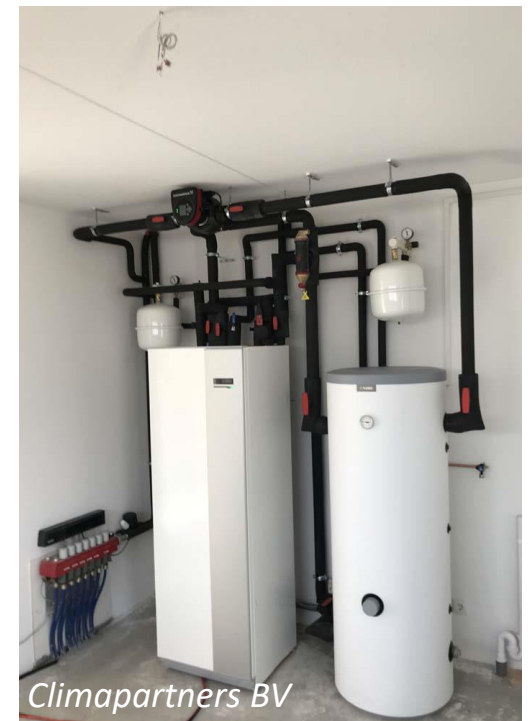
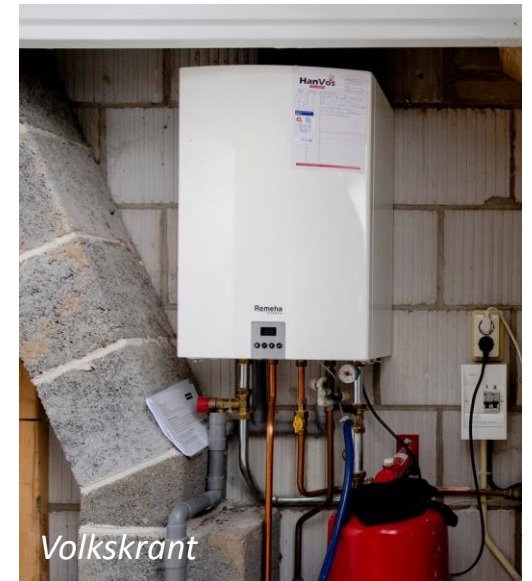
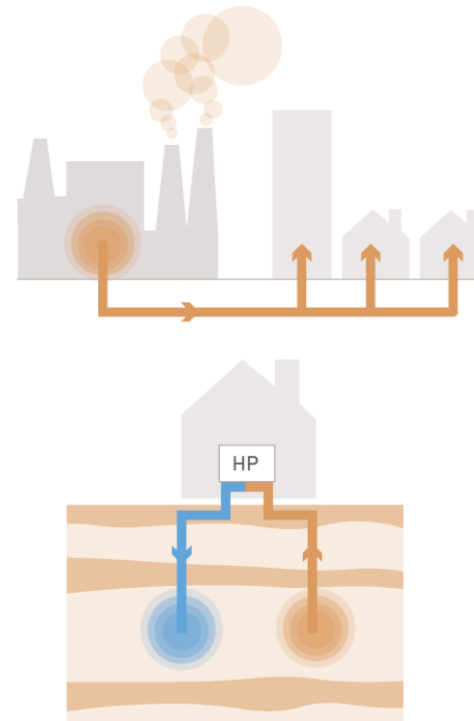
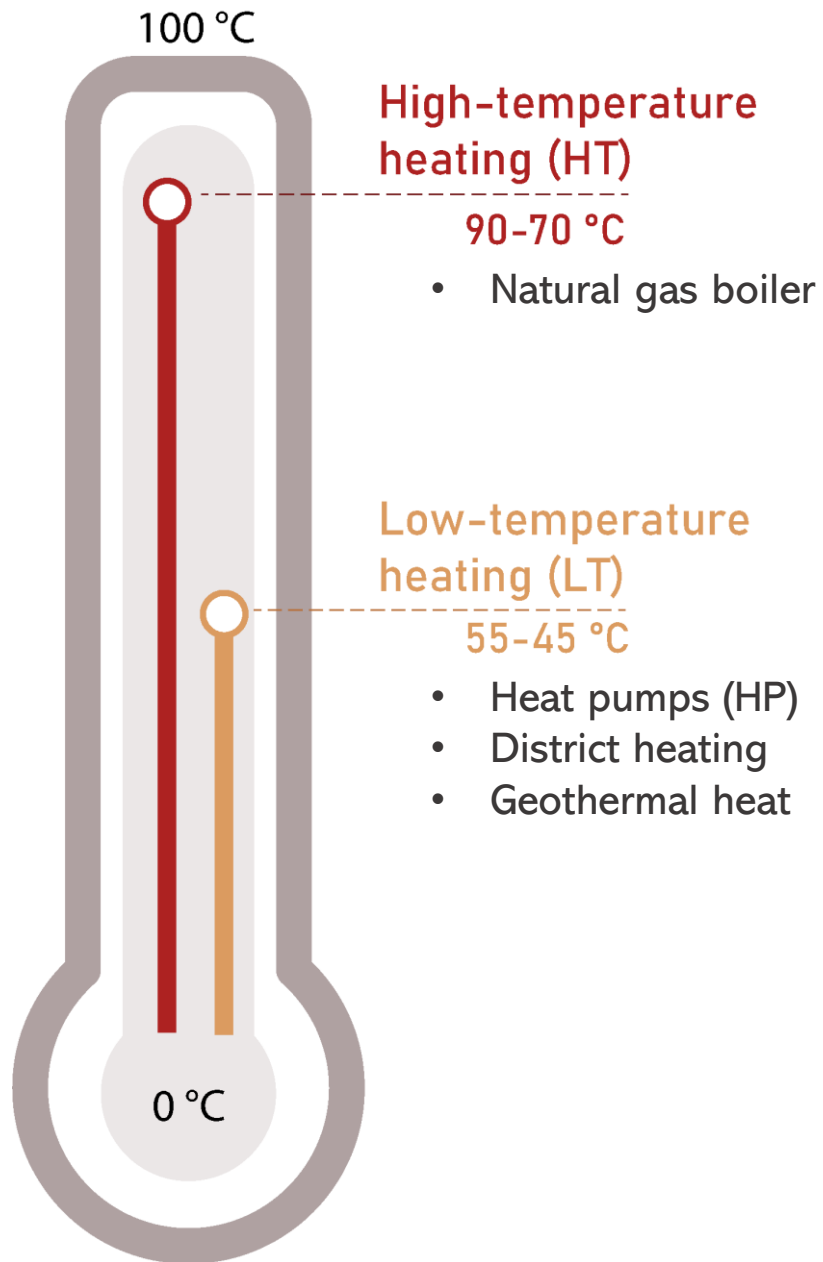
Dr. Ing. Thaleia Konstantinou
Ing. Eric van den Ham
Msc. Prateek Wahj

Board of examiners Dr. Ing. Eireen Schreurs

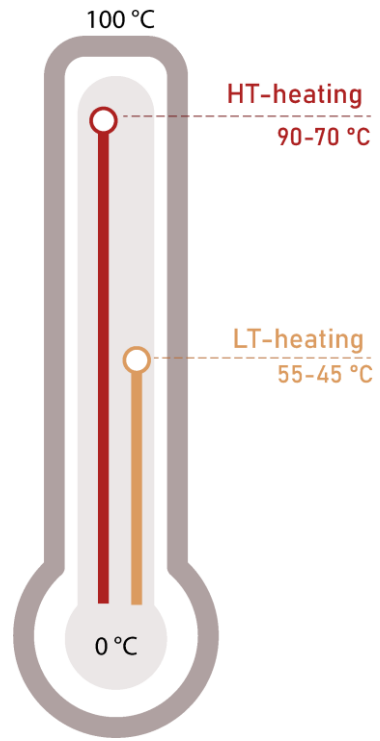




Heating sources



Heating capacity



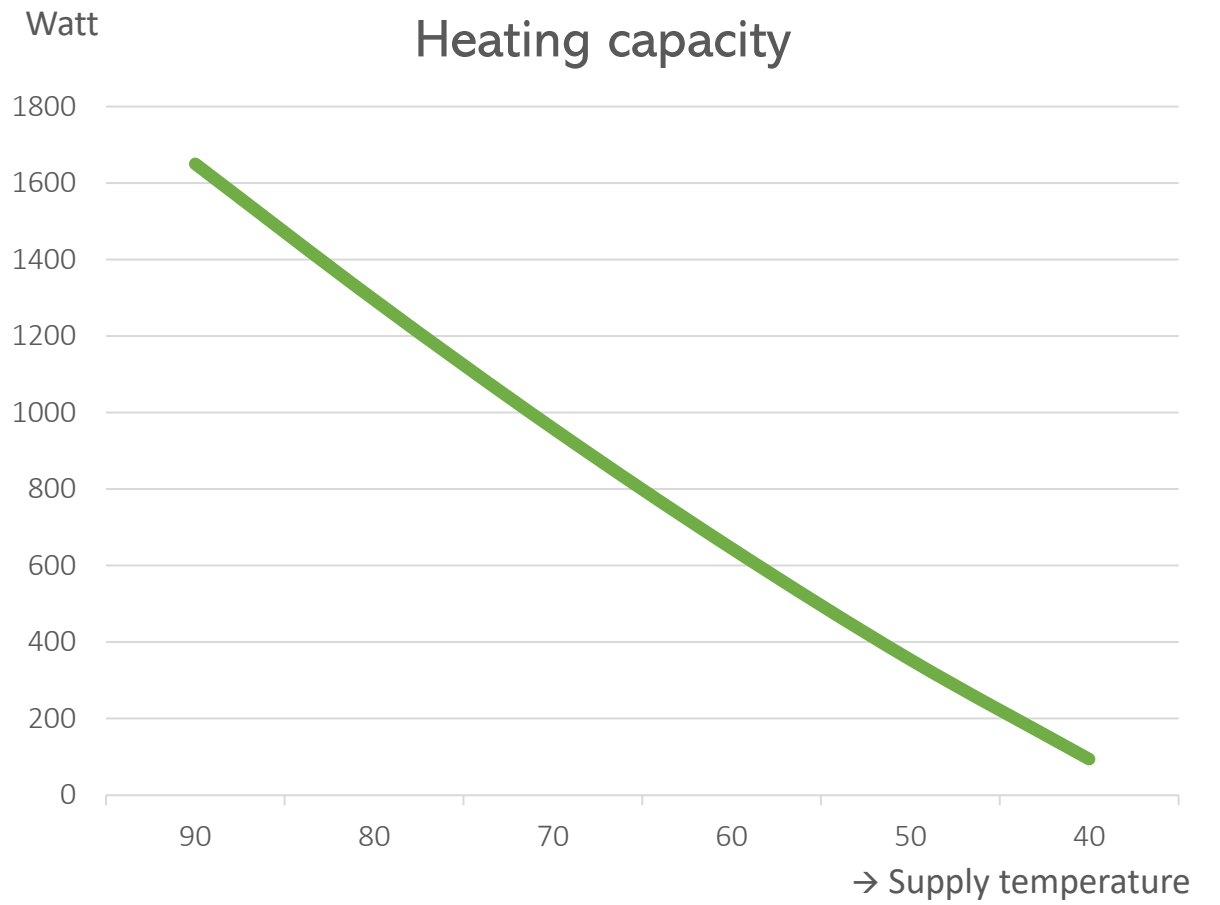
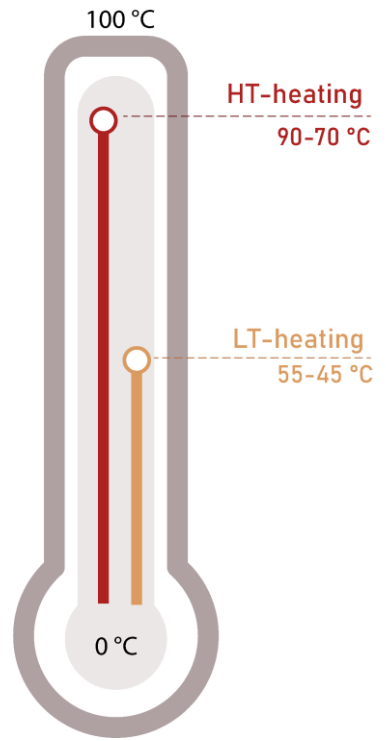
But why is a lower supply temperature important?

$$\text{Heating capacity} = k \cdot A \cdot \Delta\theta$$

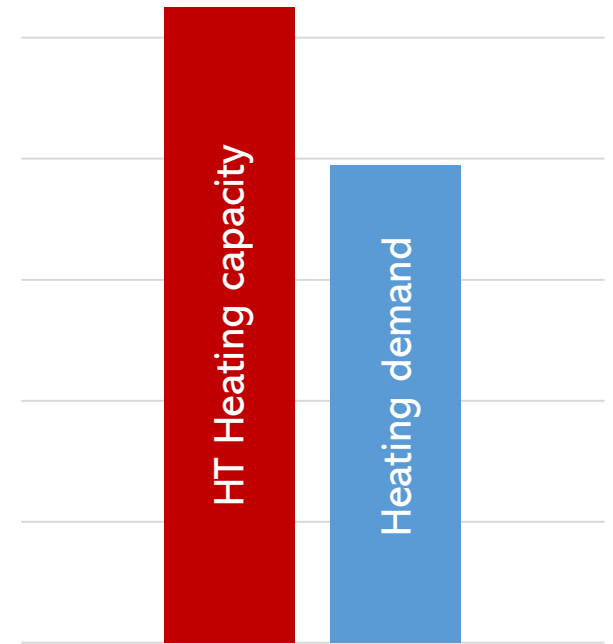
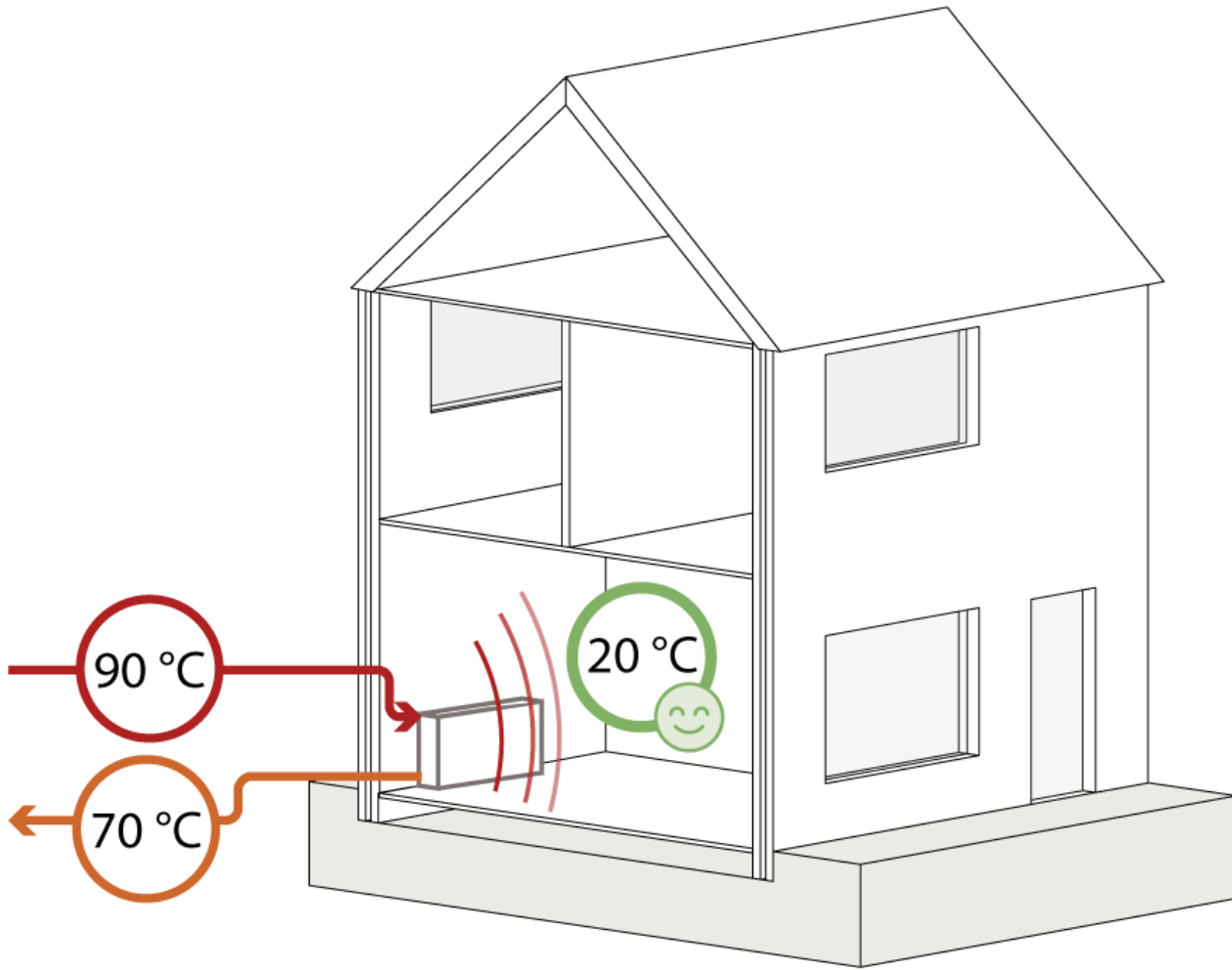
- k heating coefficient
- A area of radiator
- $\Delta\theta$ logarithmic mean difference

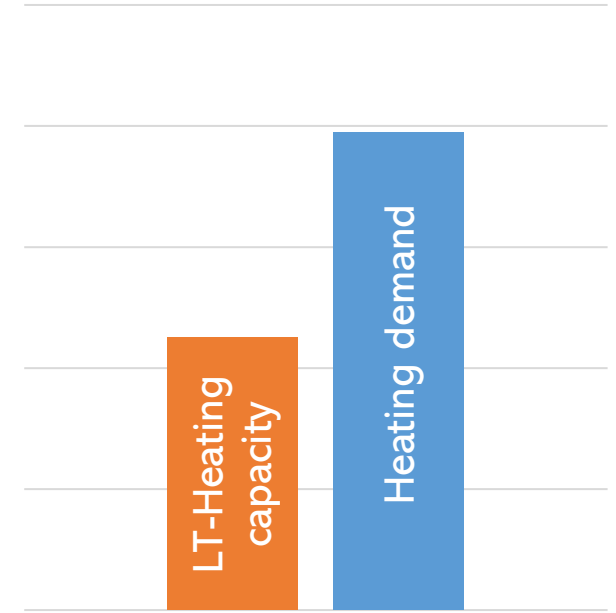
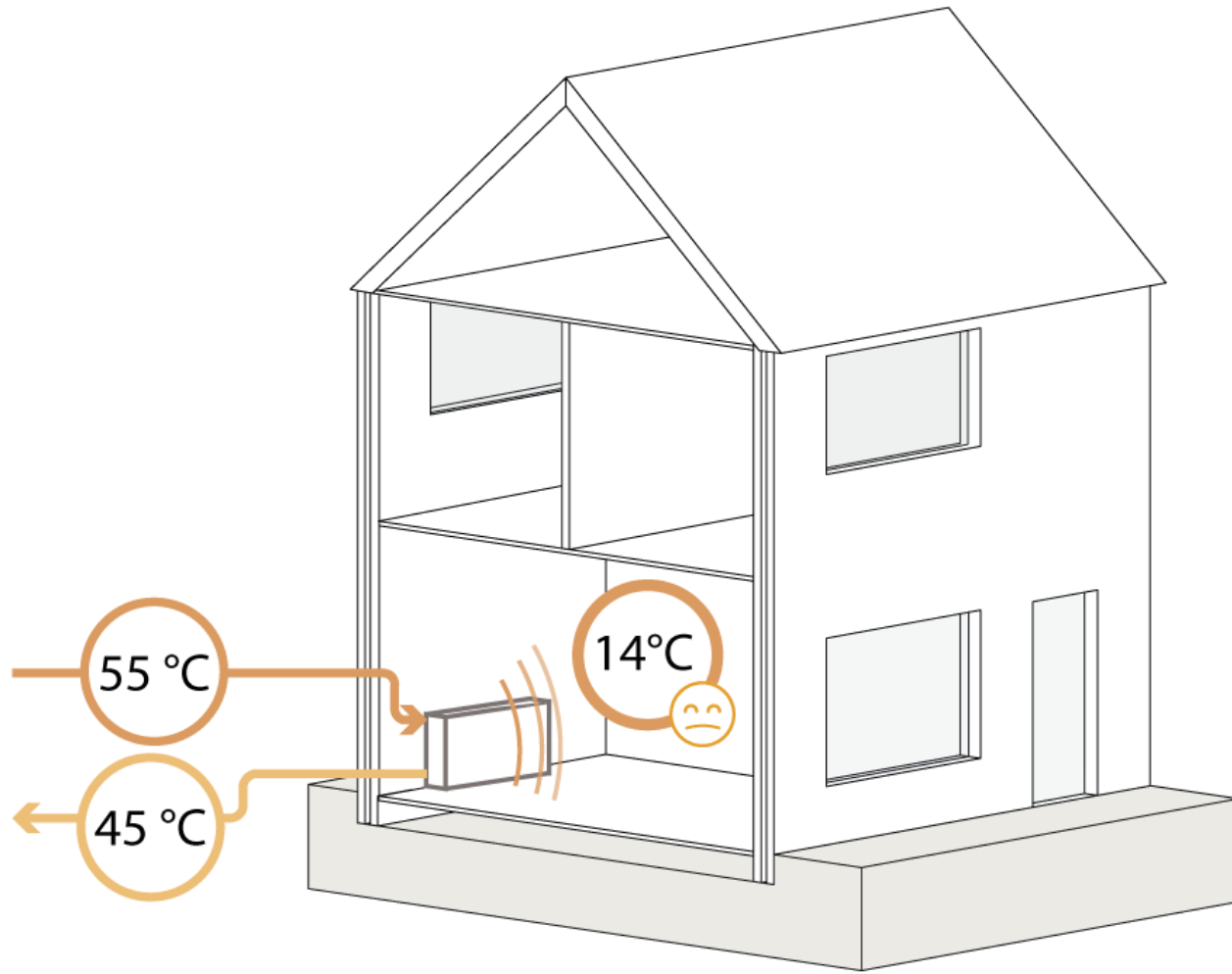
$$\frac{T_{\text{supply}} - T_{\text{return}}}{\ln \frac{T_{\text{supply}} - T_{\text{indoor}}}{T_{\text{return}} - T_{\text{indoor}}}}$$

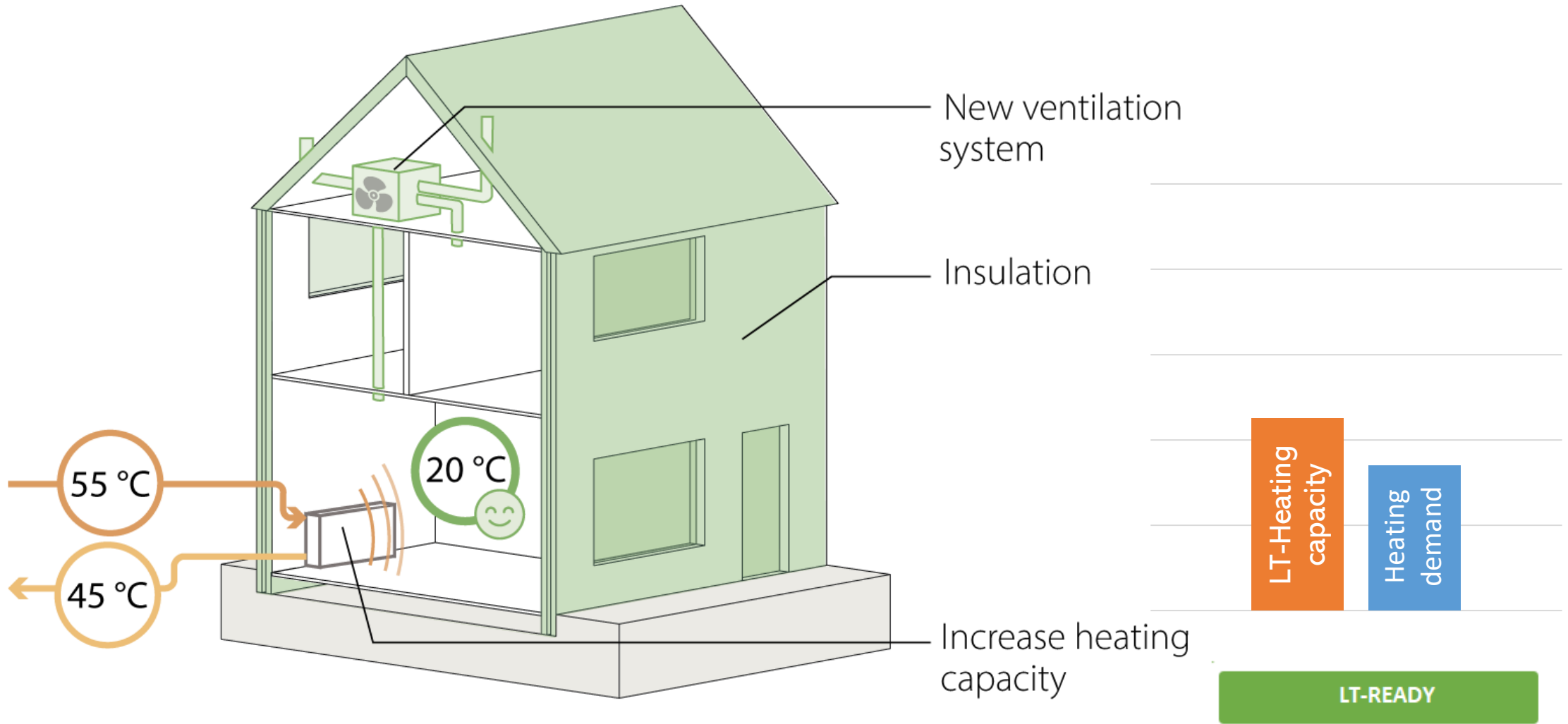
Heating capacity



Lower supply temperature leads to a less powerful radiator!









Tilburg wil 900 woningen in West verduurzamen, vraagt 12 miljoen euro subsidie

“Inwoners draaien op voor kosten om van het gas af te gaan”

di 1 jun 2021, 11:56 • 1043 keer gelezen Actueel



Rotterdam: 3 miljard euro nodig voor duurzame woningen

Corporatiemarkt.com



'Huizen aardgasvrij maken is complex en kost ook meer dan verwacht'



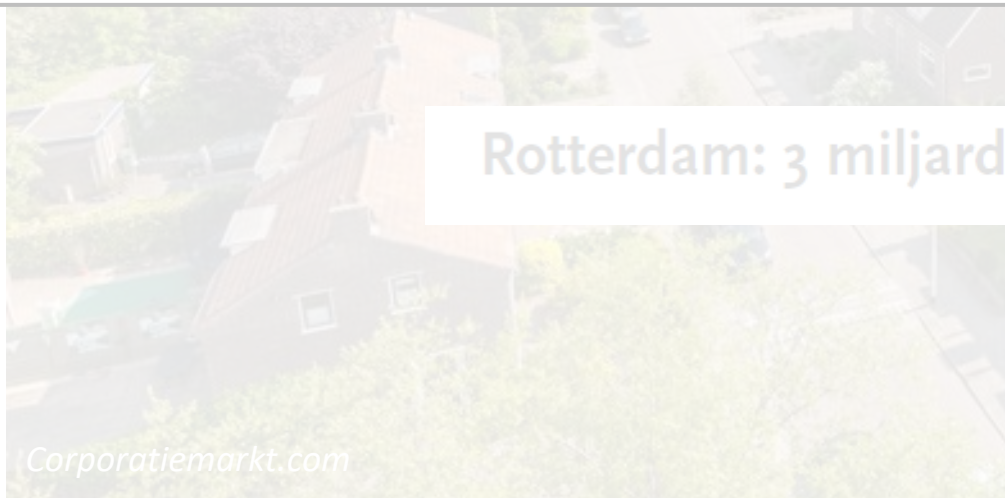
Tilburg wil 900 woningen in West verduurzamen, vraagt 12 miljoen euro subsidie

“Inwoners draaien op voor kosten om van het gas af te gaan”

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Rotterdam: 3 miljard euro nodig voor duurzame woningen



Corporatiemarkt.com

'Huizen aardgasvrij maken is complex en kost ook meer dan verwacht'

House owners:

- 52% available investment budget up to €10,000
- 72% willing to invest up to €5,000

Tilburg wil 900 woningen in West verduurzamen, vraagt 12 miljoen euro subsidie

“Inwoners draaien op voor kosten om van het gas af te gaan”

di 1 jun 2021, 11:56 • 1043 keer gelezen Actueel

Rotterdam: 3 miljard euro nodig voor duurzame woningen

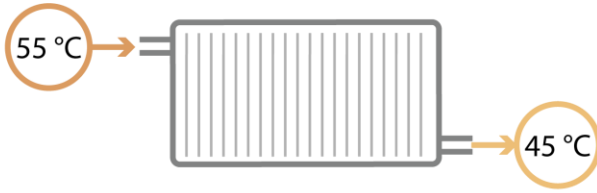
Corporatiemarkt.com

'Huizen aardgasvrij maken is complex en kost ook meer dan verwacht'

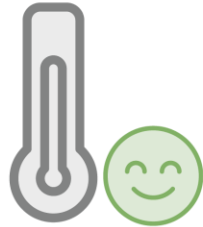
LT-Ready
concepts

Should:

Enable a lower supply
temperature



Maintain thermal comfort



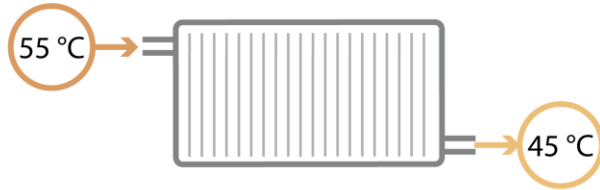
Be affordable (< € 10,000)



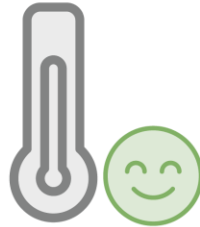
LT-Ready
concepts

Should:

Enable a lower supply
temperature



Maintain thermal comfort



Be affordable (< € 10,000)



Problem statement

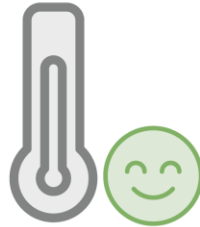
LT-Ready concepts

Should:

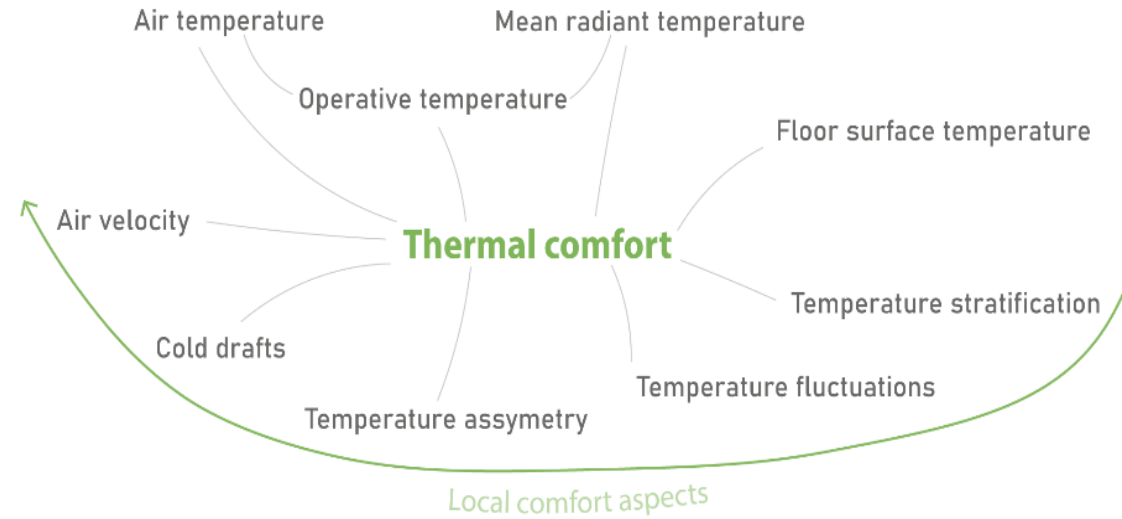
Enable a lower supply temperature



Maintain thermal comfort



Be affordable (< € 10,000)



“What **combination of renovation measures** for residential buildings is **affordable** and **provides thermal comfort**, when using **a lower supply temperature** for heating?”

Sub questions



Renovation measures



Thermal comfort criteria



Local comfort



Affordability

“What **combination of renovation measures** for residential buildings is **affordable** and **provides thermal comfort**, when using **a lower supply temperature** for heating?”

Research phases



Exploration

Phase 1

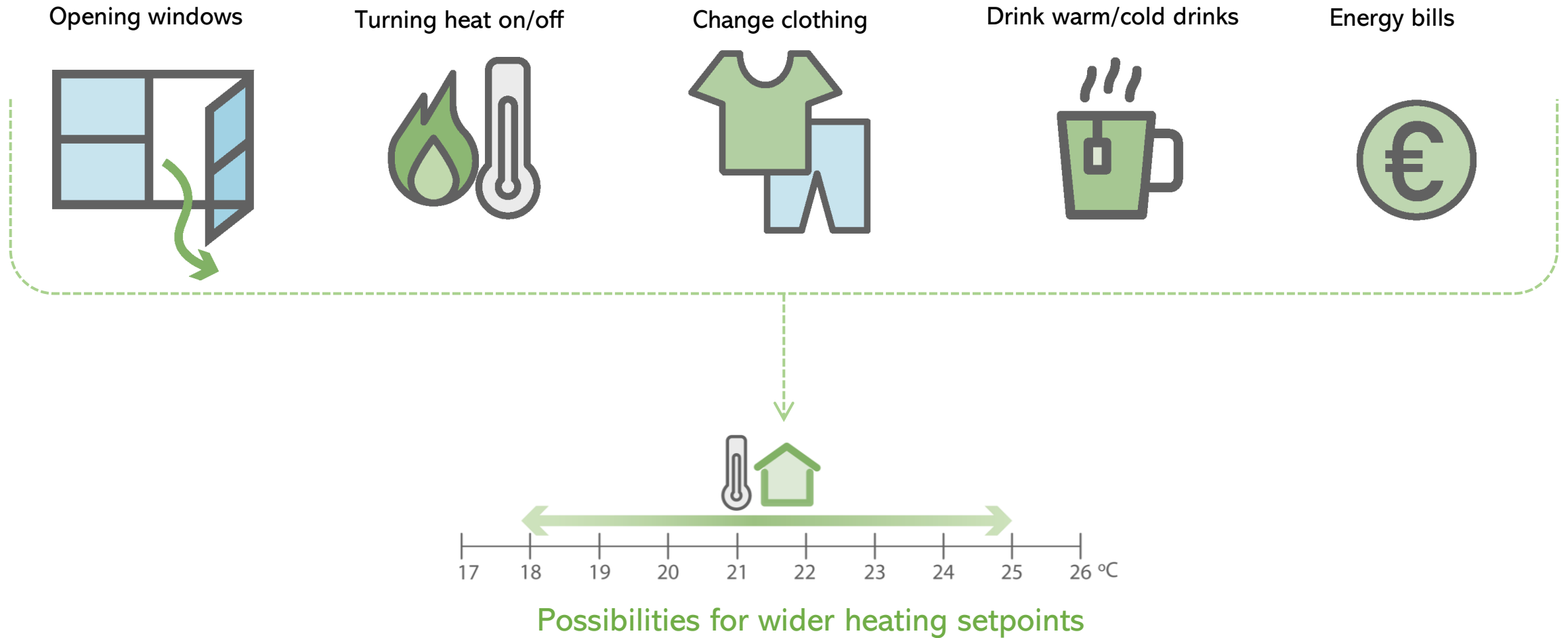


Thermal comfort



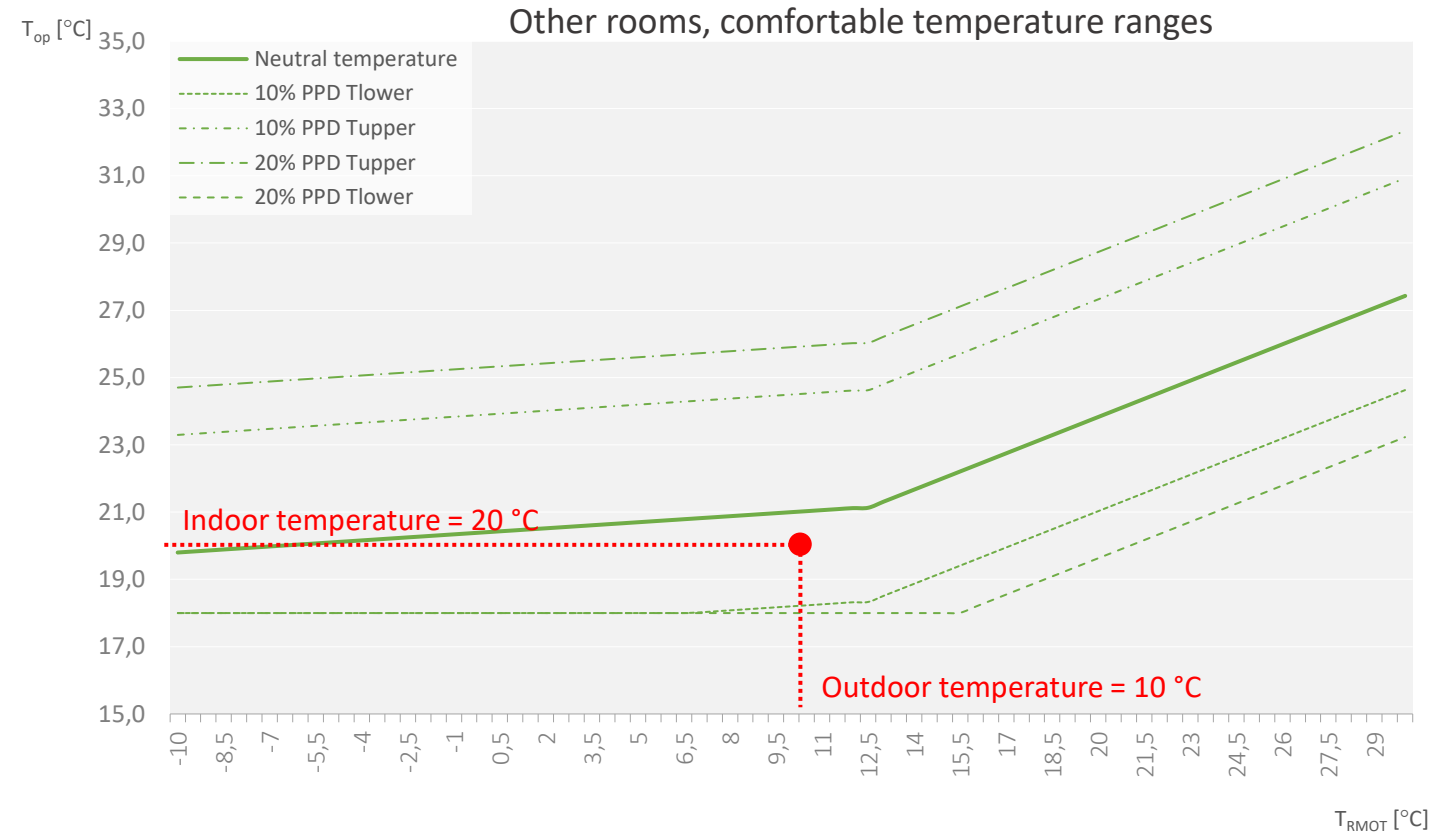
“That condition of mind which expresses satisfaction with the thermal environment” (ASHRAE 55)

Adaptive options in dwellings:



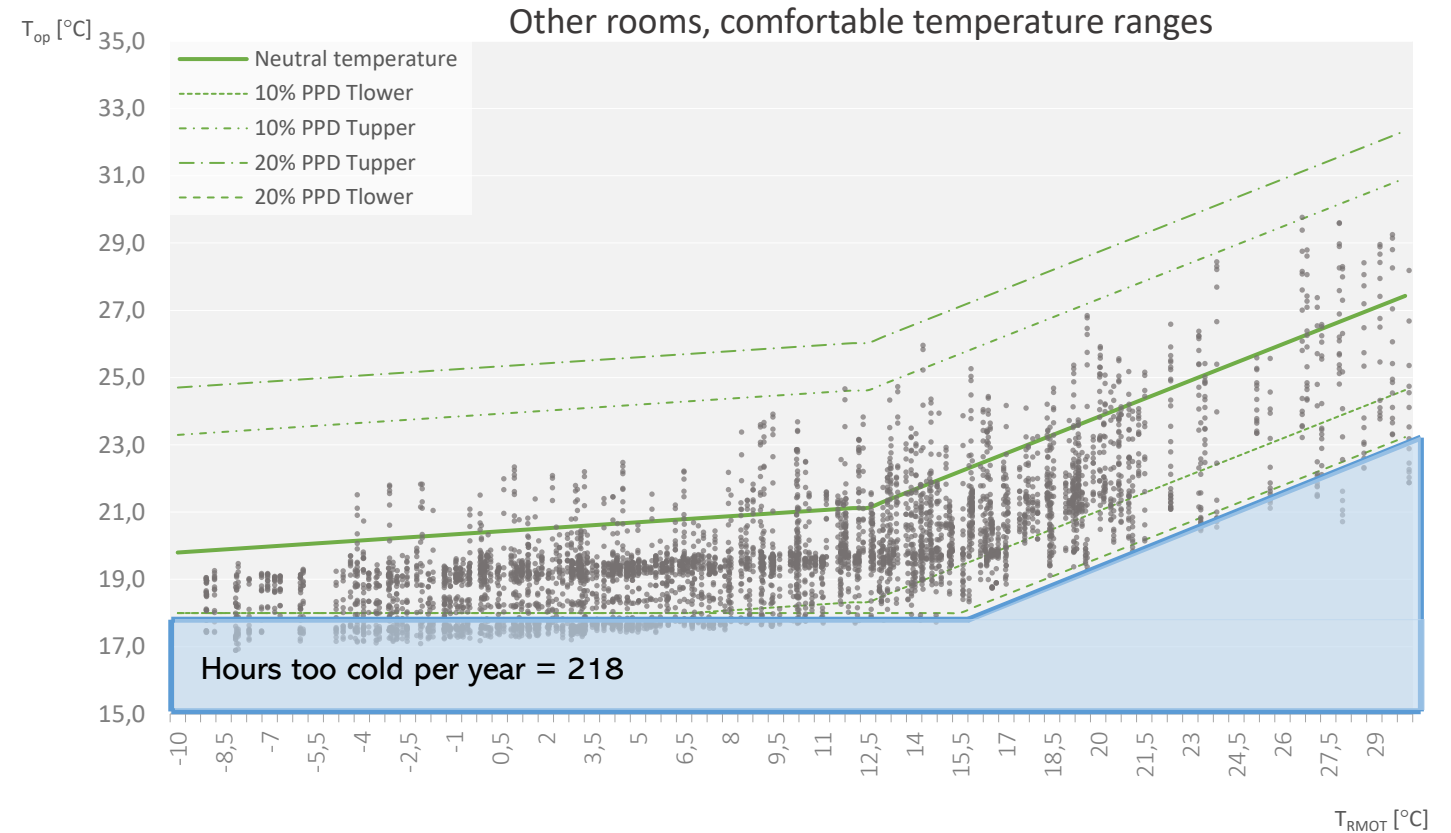
Thermal comfort

- Temperature range developed for dwellings
- Based on:
 - Running Mean outdoor temperature (T_{RMOT})
 - Operative temperature (T_{op})
 \approx comfort temperature
- For one hour



Thermal comfort

- Temperature range developed for dwellings
- Based on running:
 - Mean outdoor temperature (T_{RMOT})
 - Operative temperature (T_{op})
 \approx comfort temperature
- Used to determine the number of hours too cold per year



Renovation measures



Renovation measures

Measures on 3 different scales:



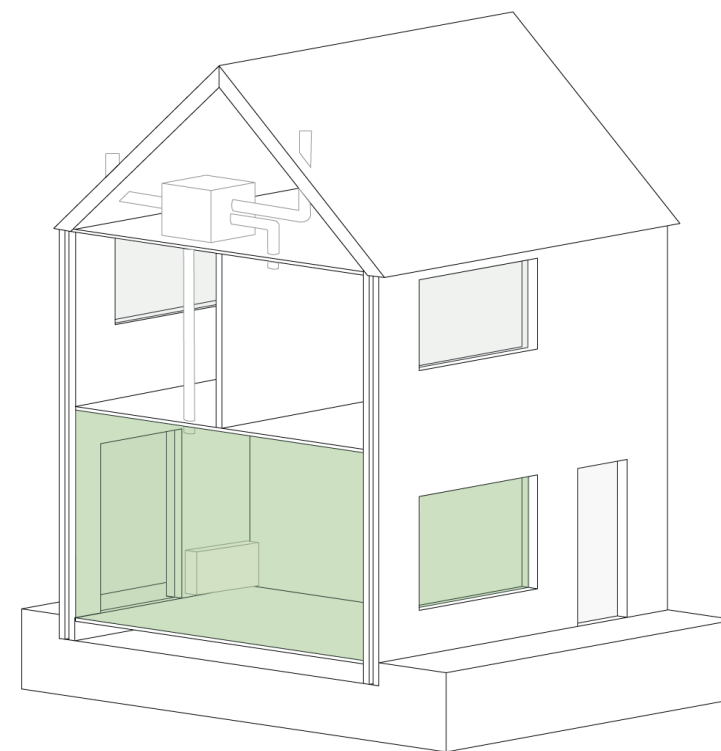
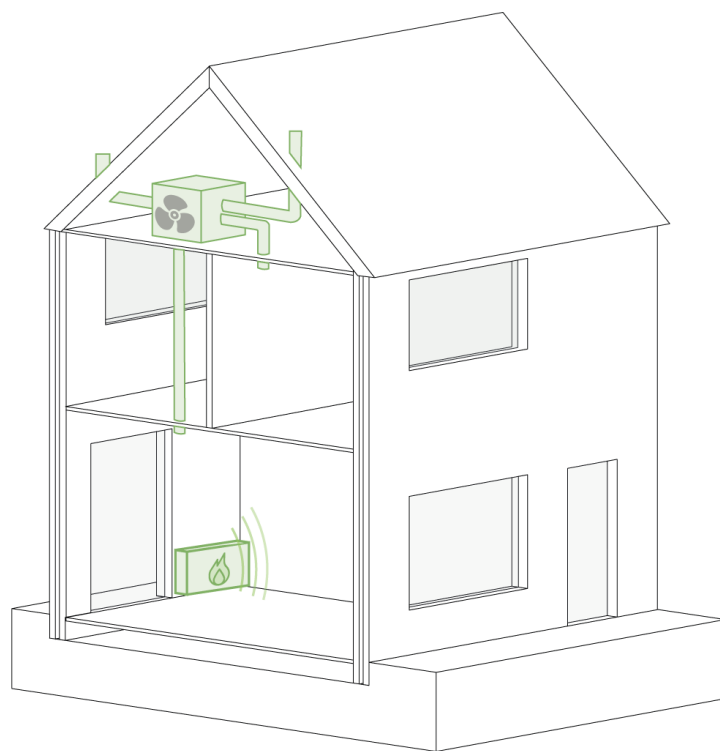
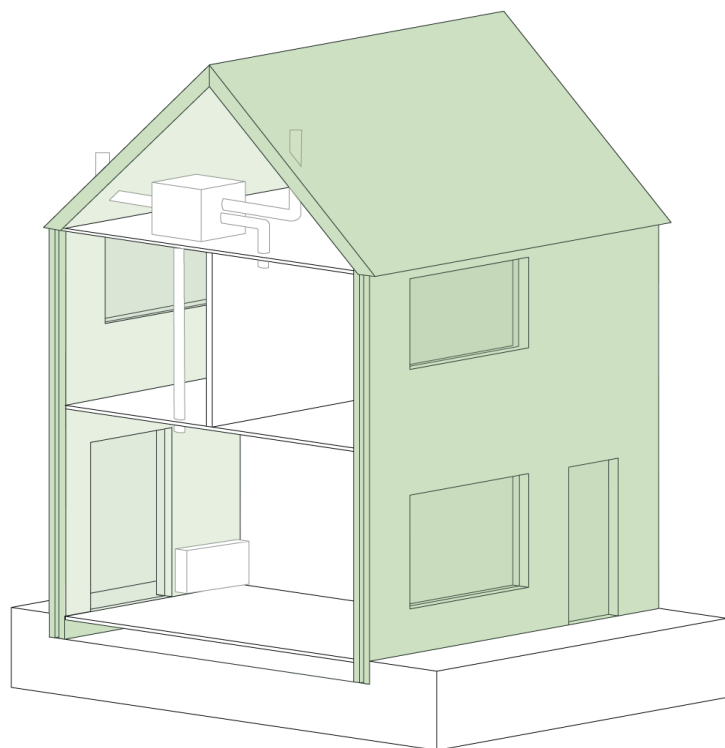
Envelope scale



Installation scale




Room-scale



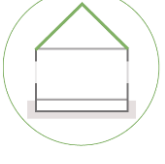




Renovation measures

Measures on 3 different scales:






Envelope scale

Wall	 <ul style="list-style-type: none">Cavity wall insulationInterior wall insulationExterior wall insulation
Windows	 <ul style="list-style-type: none">Secondary double glazingHR glazingHR+ glazingHR++ glazingTriple glazing
Roof	 <ul style="list-style-type: none">Attic floor insulationFlat roof insulation (outside)Pitched roof insulation (inside)Pitched roof insulation (outside)
Floor	 <ul style="list-style-type: none">Crawling space insulationBelow floor insulationAbove floor insulation
Air tightness	<ul style="list-style-type: none">Medium improvementHigh improvement



Installation scale

Ventilation	 <ul style="list-style-type: none">Exhaust ventilation (C1)Demand driven exhaust (C2)Balanced w. heat recovery (D1)Decentralized (D2)
Heating	 <ul style="list-style-type: none">Original radiatorsAdd-on fanLT-Radiator



Room-scale

- Heat reflective foil
- Heat reflective paint
- Radiant screen
- Infrared heating panel

- Location of furniture

- Ventilation grill designed for comfort

Determining renovation concepts

Phase 2



Cost analysis

Costs

Labour



Average

Insulation materials



+

Finish layer



BTW

Effect

Reduced heating demand / €

in [W(/m²)/ €]

Saved gas usage / €

in [m³/ €]

Payback period

in [years]

Cost analysis – selected measures



Envelope scale

		[€/m ²]
Wall	Cavity wall insulation	€26
	Interior wall insulation	€39-54
	Exterior wall insulation	€117
Windows	Secondary double glazing	€173
	HR glazing	€120
	HR+ glazing	€137
	HR++ glazing	€137
	Triple glazing	€181
Roof	Attic floor insulation	€22
	Flat roof insulation (outside)	€52-63
	Pitched roof insulation (inside)	€63-89
	Pitched roof insulation (outside)	€89-100
Floor	Crawling space insulation	€34
	Below floor insulation	€41
	Above floor insulation	€77
Air tightness		[€/dwelling]
	Medium improvement	€447
	High improvement	€1560



Installation scale

		[€/dwelling]
Ventilation	Exhaust ventilation (C1)	€2515
	Demand driven exhaust (C2)	€4304
	Balanced w. heat recovery (D1)	€6256
	Decentralized (D2)	€4835
Heating		[€/unit]
	Original radiators	-
	Add-on fan	€66
	LT-Radiator	€528-905



Room-scale

	[€/m ²]
Heat reflective foil	€6
Heat reflective paint	€13
Radiant screen	€62
Infrared heating panel	€158
Location of furniture	-
	[€/unit]
Ventilation grill designed for comfort	€58

Cost analysis – selected measures



Envelope scale

[€/m²]

Wall



Cavity wall insulation	€26
Interior wall insulation	€39-54
Exterior wall insulation	€117

Windows



Secondary double glazing	€173
HR glazing	€120
HR+ glazing	€137
HR++ glazing	€137
Triple glazing	€181

Roof



Attic floor insulation	€22
Flat roof insulation (outside)	€52-63
Pitched roof insulation (inside)	€63-89
Pitched roof insulation (outside)	€89-100

Floor



Crawling space insulation	€34
Below floor insulation	€41
Above floor insulation	€77

[€/dwelling]

Air
tightness

Medium improvement	€447
High improvement	€1560



Installation scale

[€/dwelling]

Ventilation



Exhaust ventilation (C1)	€2515
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Balanced w. heat recovery (D1)	€6256
Decentralized (D2)	€4835

Heating



Original radiators	-
Add-on fan	€66
LT-Radiator	€528-905



Room-scale

[€/m²]

Heat reflective foil	€6
Heat reflective paint	€13
Radiant screen	€62
Infrared heating panel	€158

Location of furniture	-
Ventilation grill designed for comfort	€58

Cost analysis – selected measures

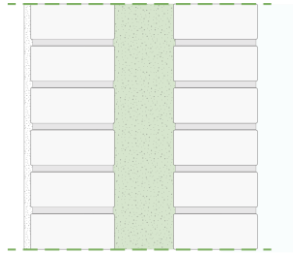


Envelope scale

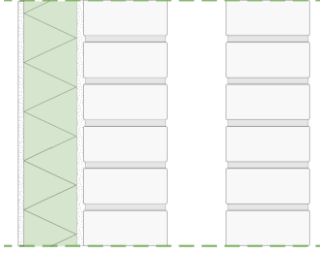
Wall



Cavity wall insulation
€26 / m²



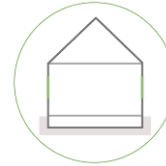
Interior wall insulation
€39-54 / m²



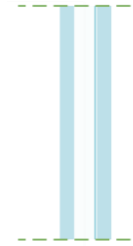
Exterior wall insulation
€117 / m²



Windows



HR++ glazing
€137 / m²



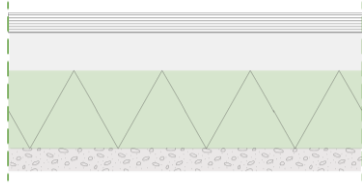
Triple glazing
€181 / m²



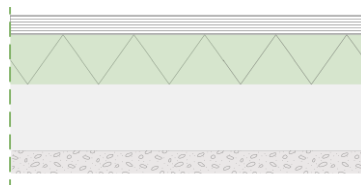
Floor



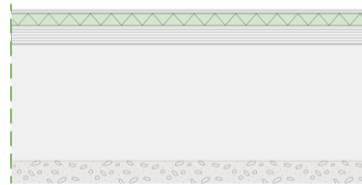
Insulation of crawling space floor
€34 / m²



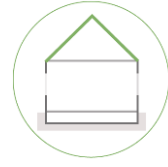
Insulation below floor
€41 / m²



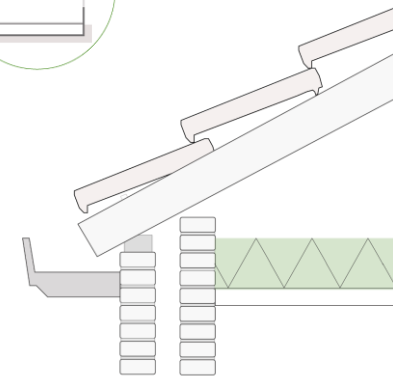
Insulation above floor
€77 / m²



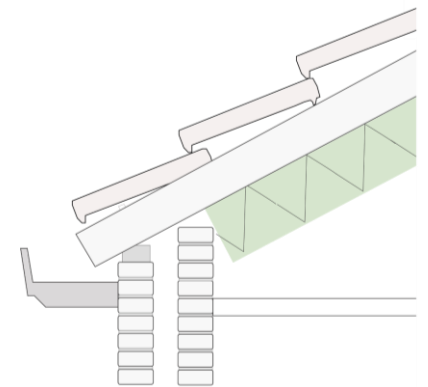
Roof



Attic floor
€22 / m²



Pitched roof insulation (inside)
€63-89 / m²



[€/dwelling]

Medium improvement
High improvement

€447
€1560

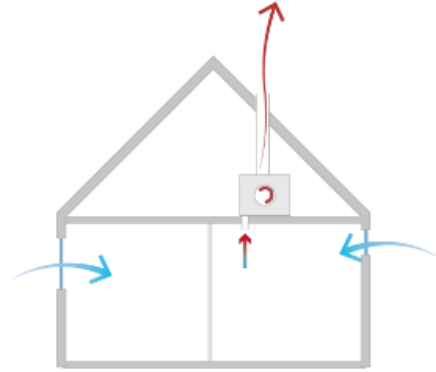
Air
tightness

Cost analysis – selected measures

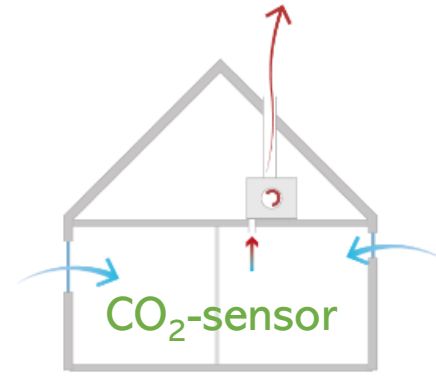


Installation scale

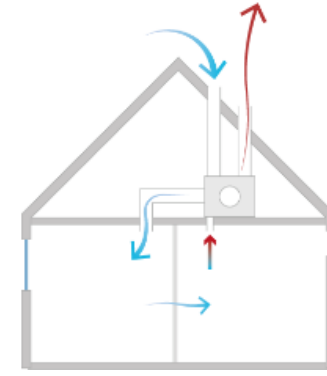
Ventilation



Exhaust ventilation (C1)
€2515



Demand-driven ventilation (C2)
€4304



Balanced ventilation with
heat recovery
€6256

Heating



Original radiators
€0



Add-on fans
€66 / unit



LT-radiator (higher heating
capacity
€528-905 / unit

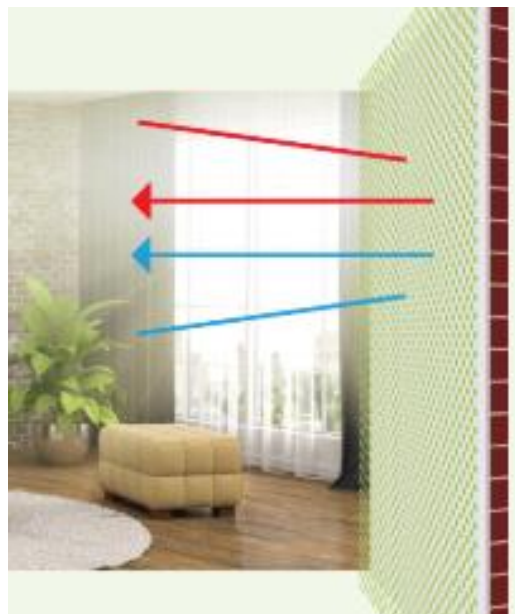


Room scale

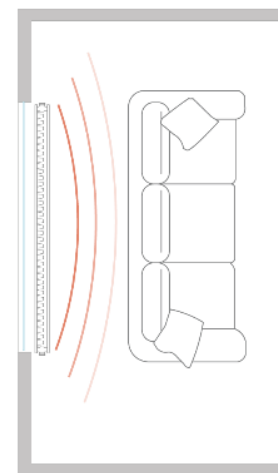
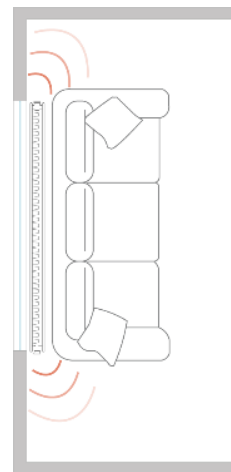
Radiant screen
€62 / m²



Heat reflective paint
€13 / m²



Location of furniture
€0



LT-Ready
concepts

1



(Re)place ventilation system

2



Additional measures to enable LT-heating

Requirements

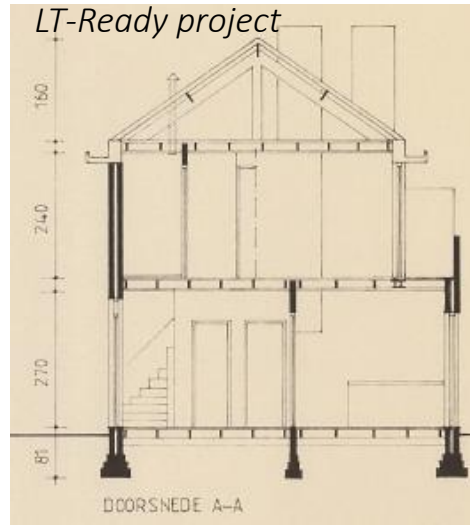
- Based on selected renovation measures
- Low budget < €10,000

Case study

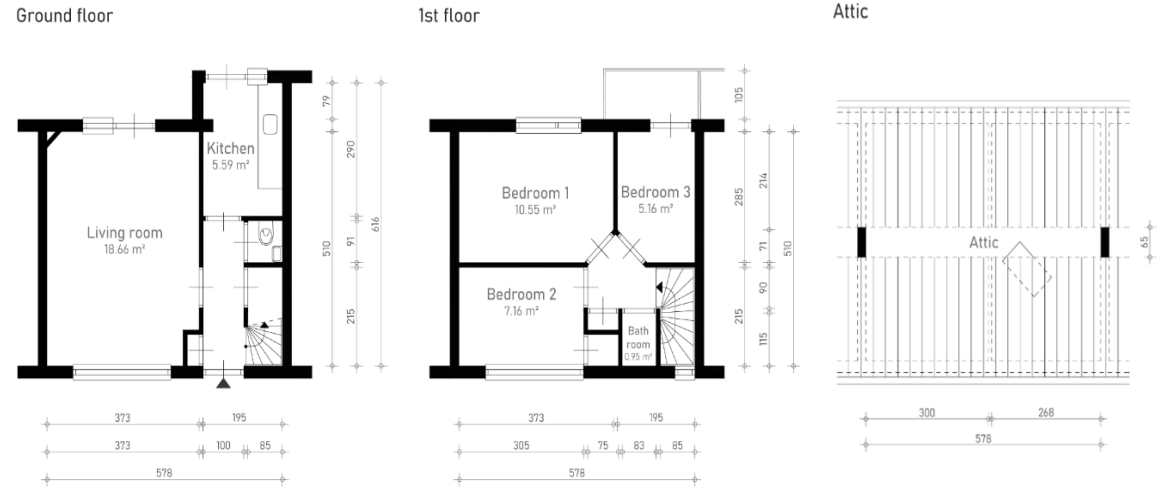
- Terraced housing
- Built in 1938
- Located in Amersfoort



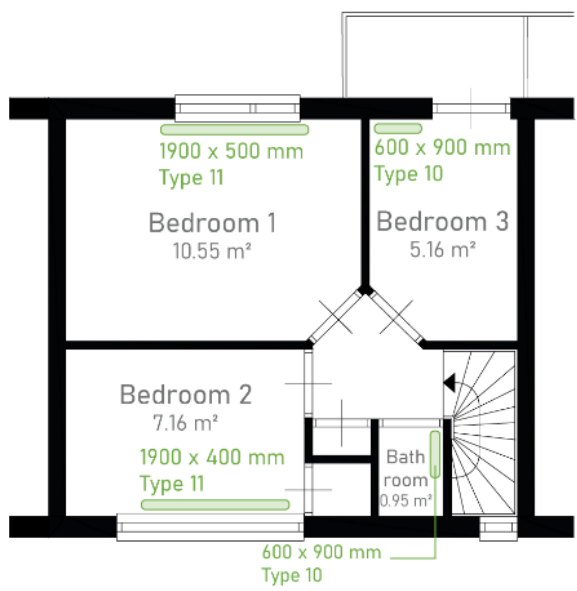
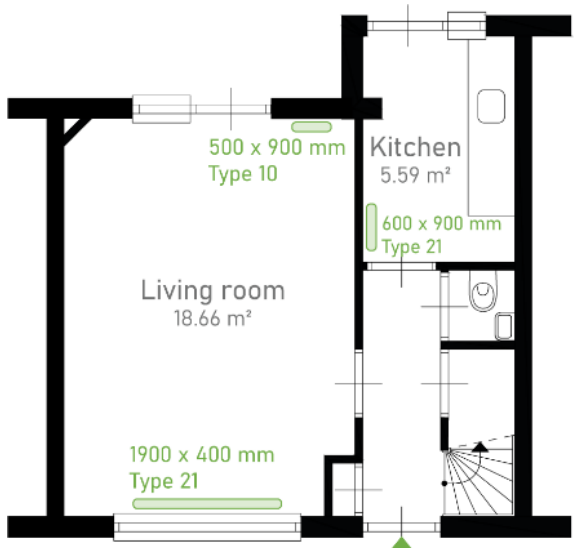
		R _c -value	U-value
Wall	Cavity wall (7 cm)	0.70	1.44
	Interior wall	0.42	2.36
	Separation wall	0.71	1.40
Floor	Ground floor without insulation	0.64	1.57
	Separation floor	0.64	1.57
Roof	Roof (outdated insulation)	1.74	0.58
Window	Double glazing		2.40



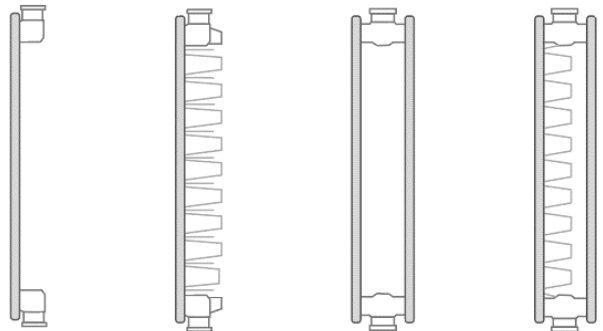
LT-Ready project



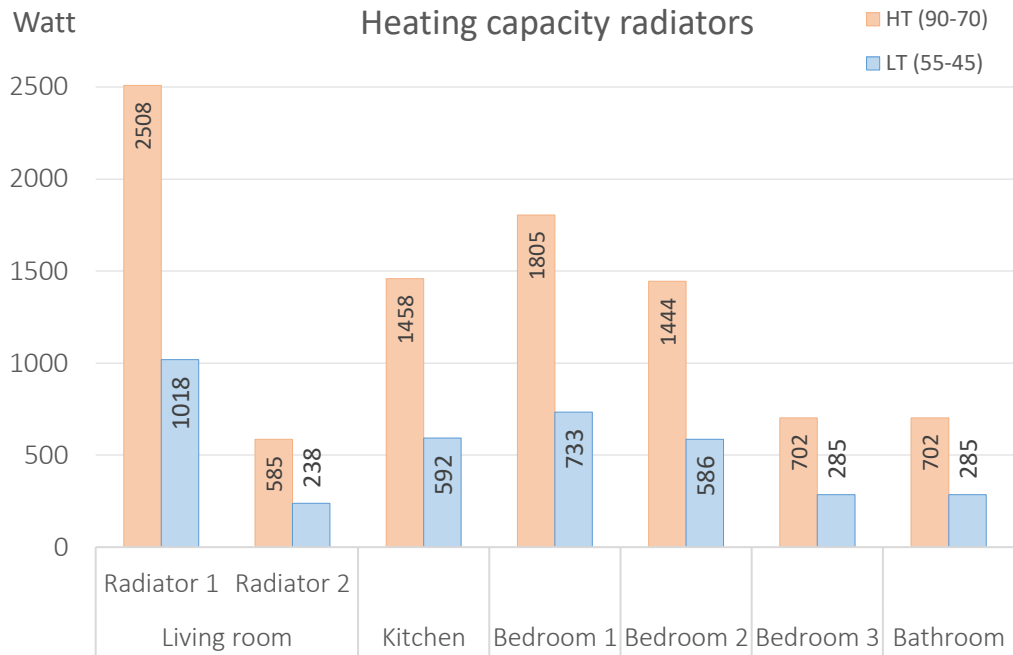
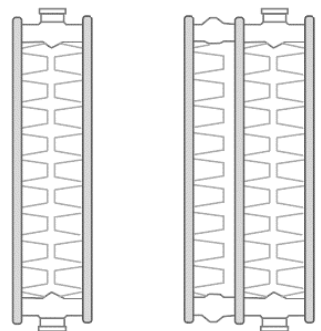
Case study – Heating system



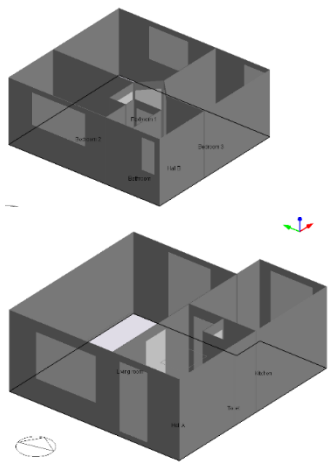
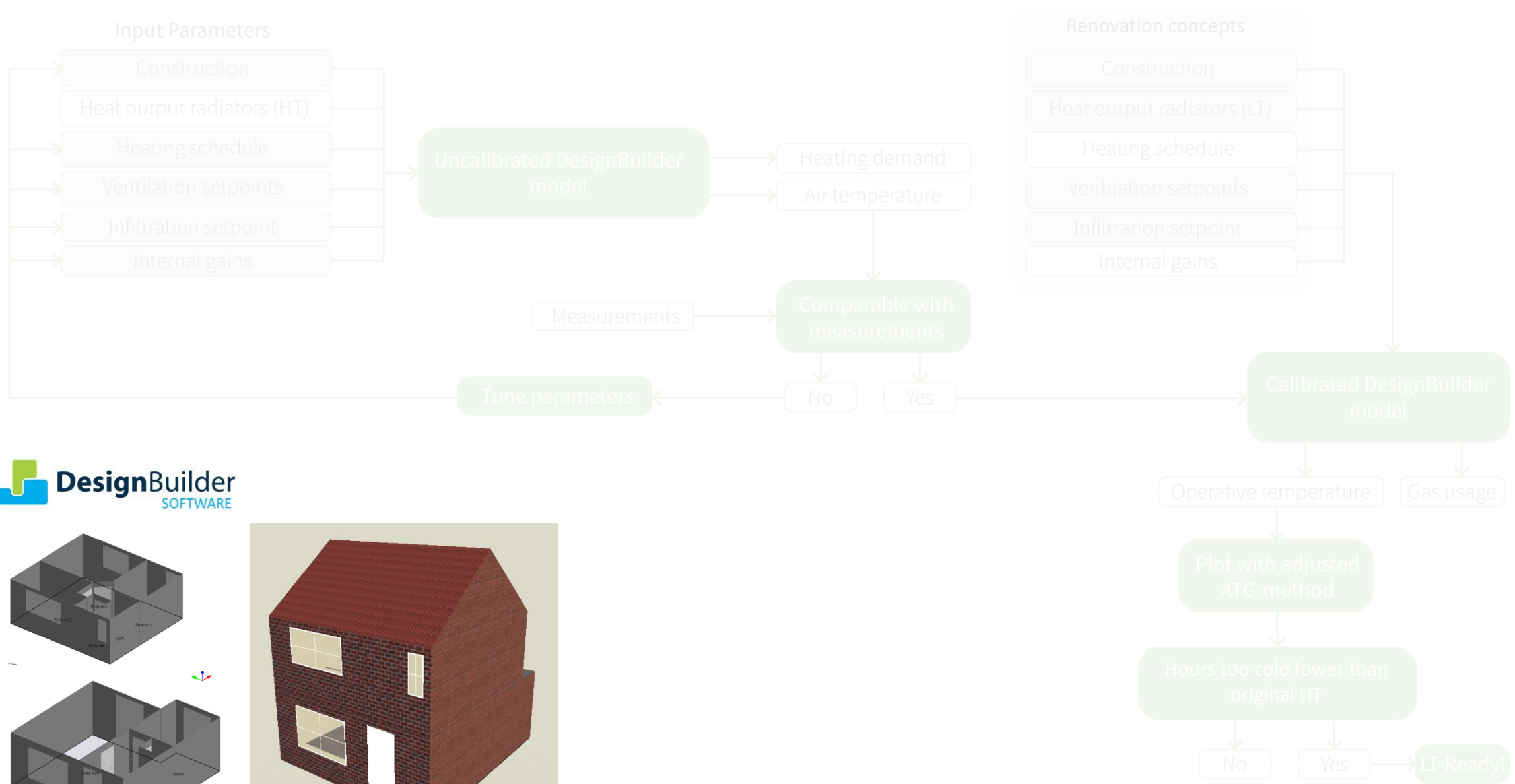
- Type 10**
1 plate
no convector
- Type 11**
1 plate
1 convector
- Type 20**
2 plates
no convector
- Type 21**
2 plates
1 convector



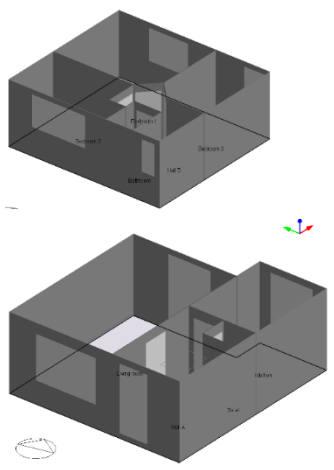
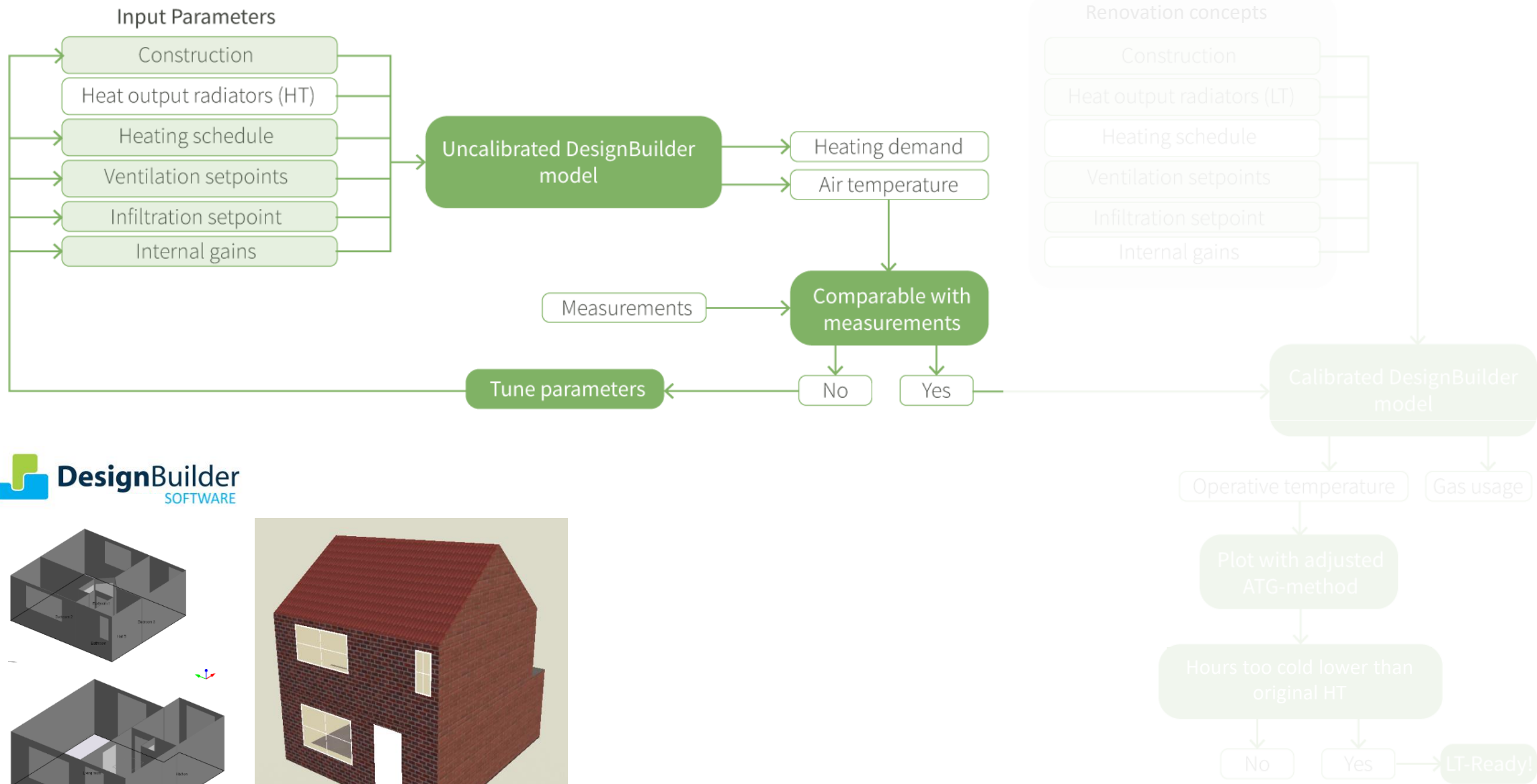
- Type 22**
2 plates
2 convectors
- Type 33**
3 plates
3 convectors



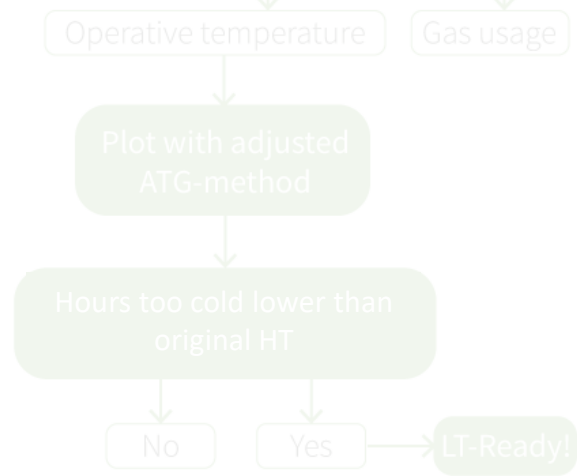
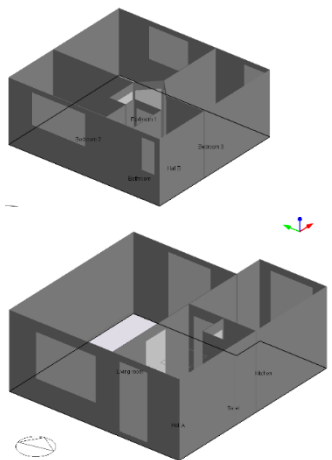
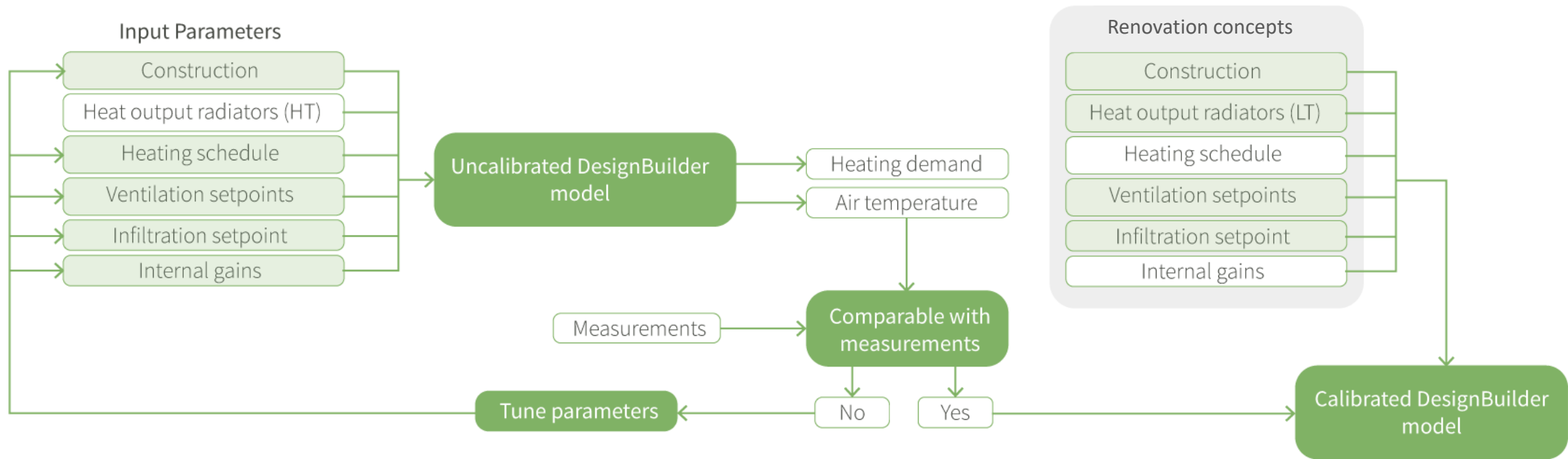
Dynamic simulations



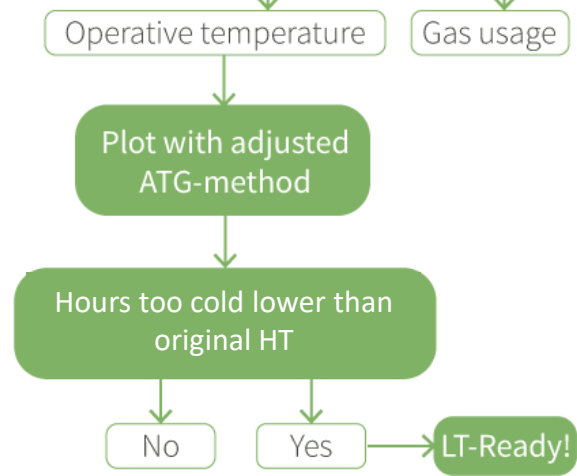
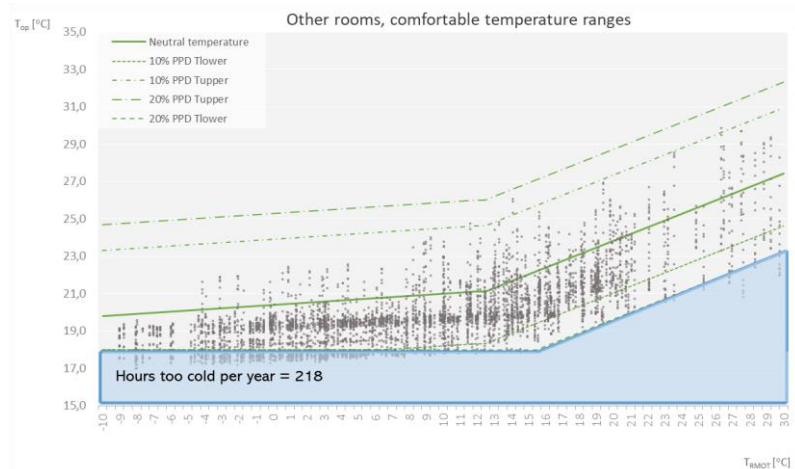
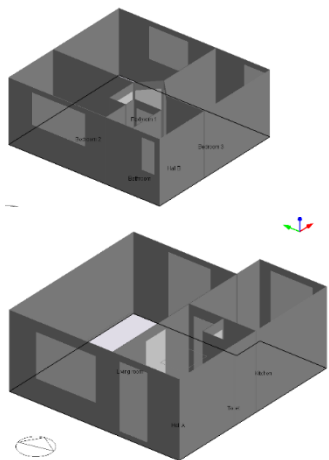
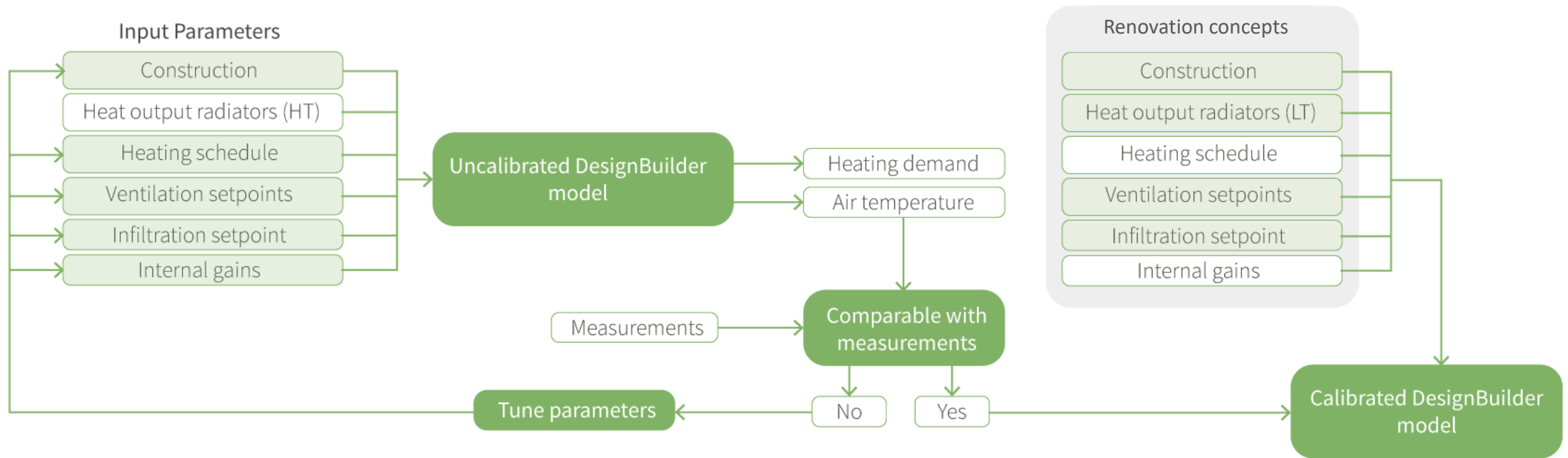
Dynamic simulations



Dynamic simulations



Dynamic simulations

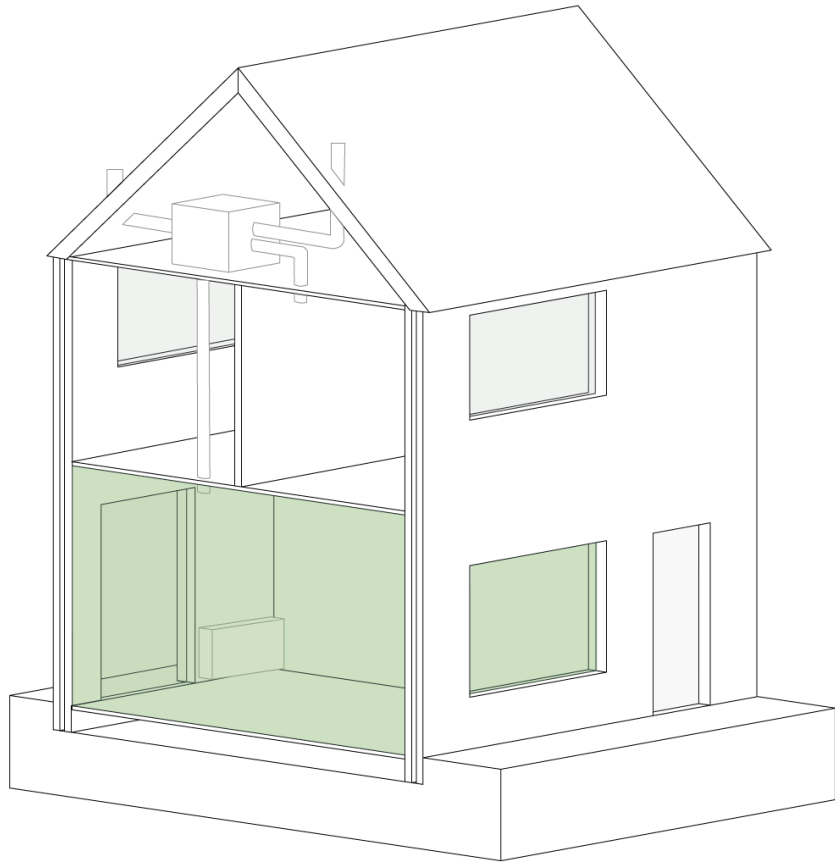


Original situation

HT (90-70) heating

144 hours too cold in living room

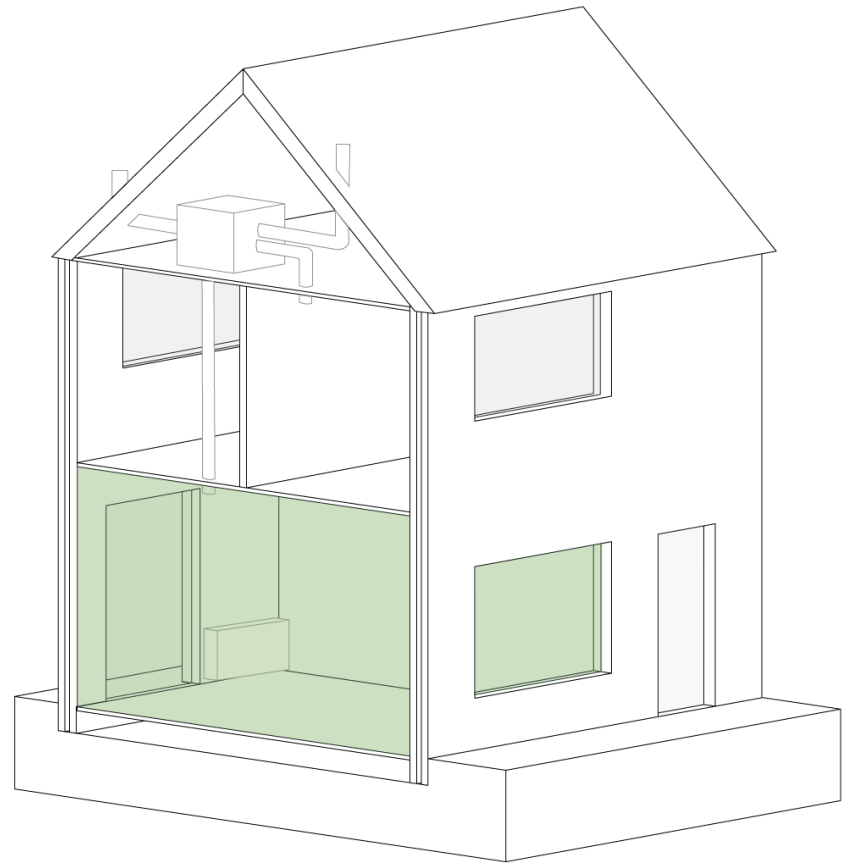
147.2 kWh/m²



LT (55-45) heating

554 hours too cold in living room

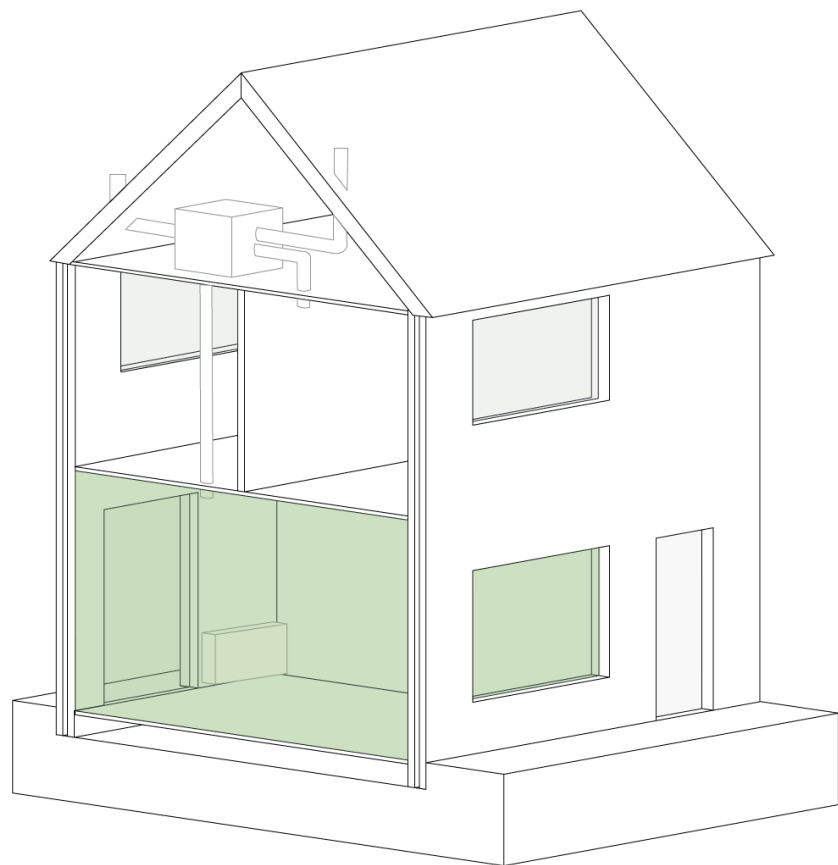
137.1 kWh/m²



Renovation scenarios

Original situation
HT (90-70) heating

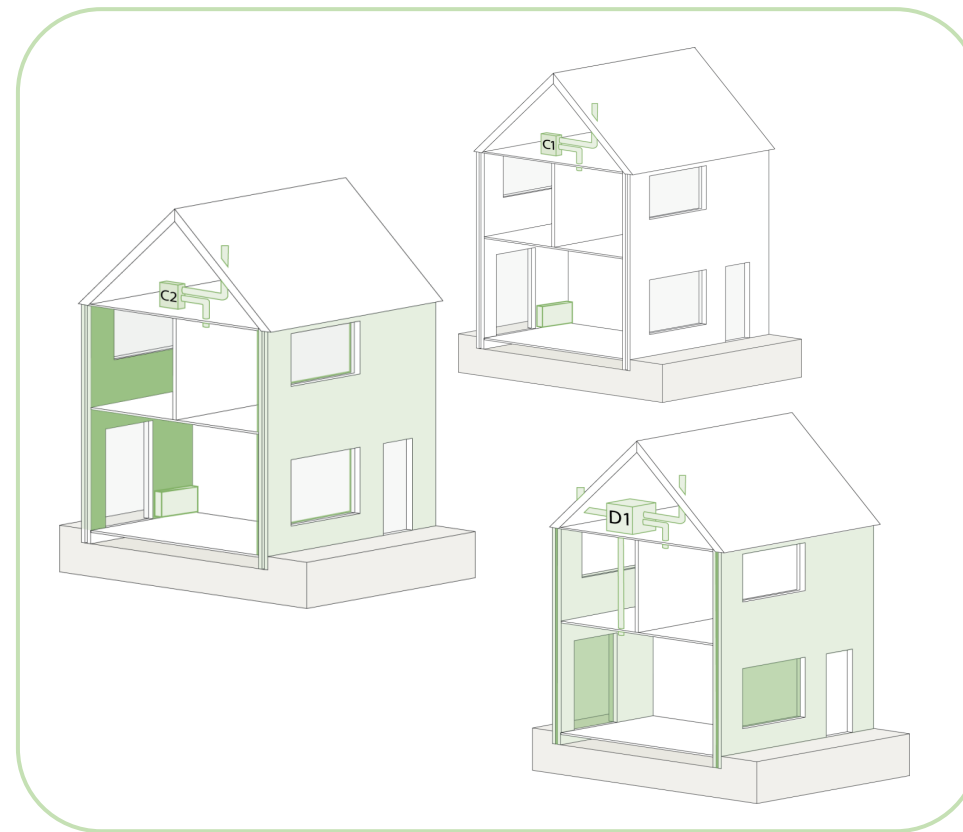
144 hours too cold **in living room**
147.2 kWh/m²



← Compared to →

Renovation concepts
LT (55-45) heating

LT-Ready < 144 hours too cold **in living room**

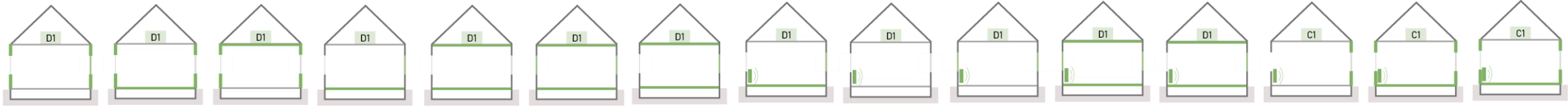
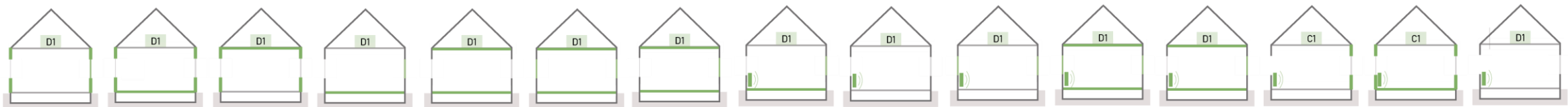


Renovation scenarios

Tested 100 concepts



LT-Ready: 40 concepts



Limitations

Context



Budget



Performance



Limitations

Context

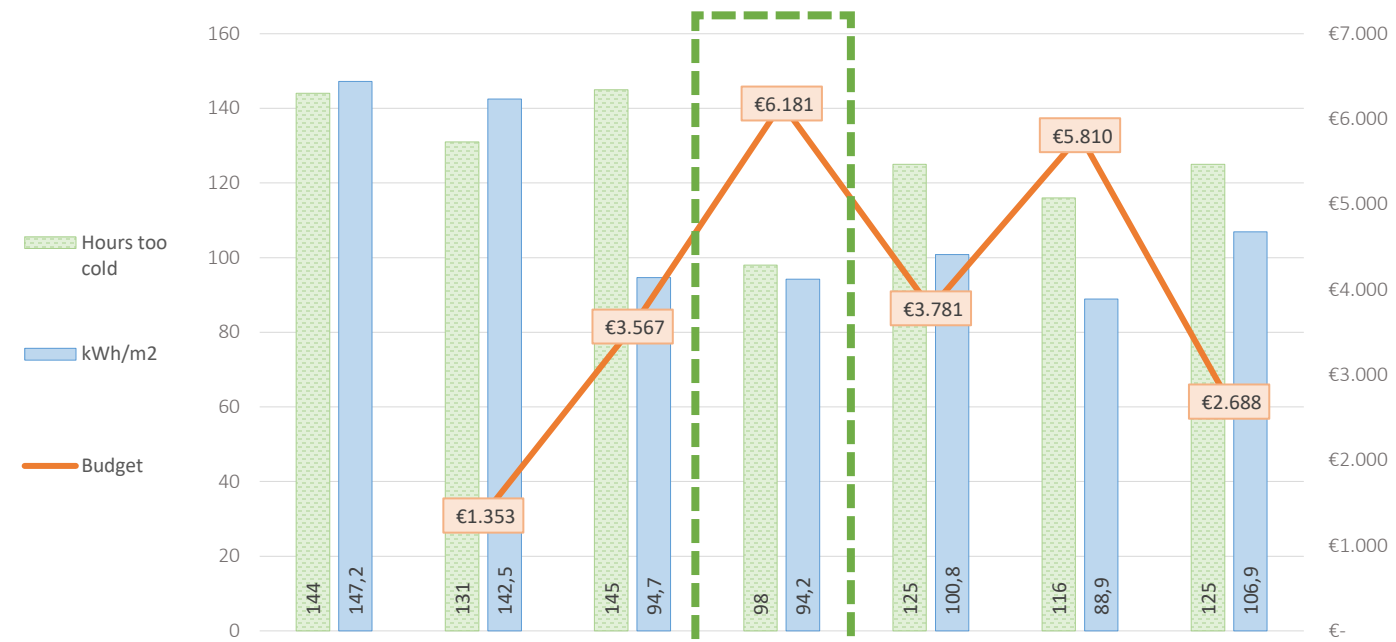


Renovation scenarios: Building limitations

1. Compare LT-Ready concepts within scenario
2. Select best option

→ However, other renovation concepts also possible!

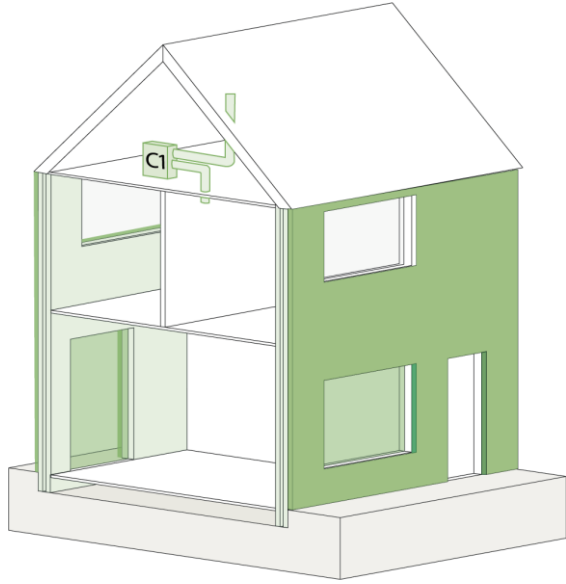
Already exhaust ventilation (C1) installed



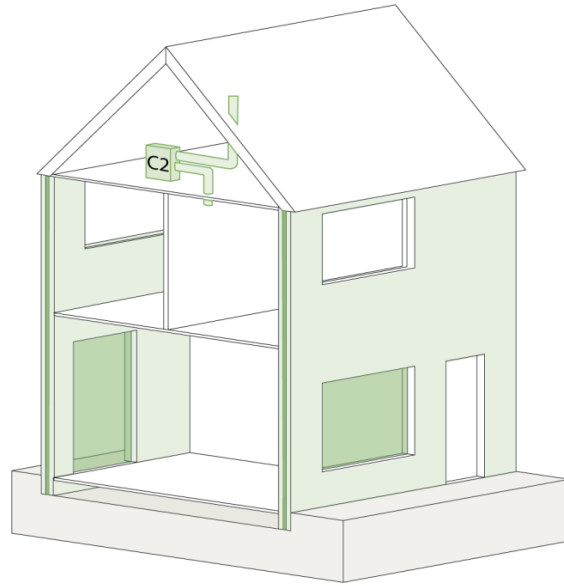
Option	Original	C1.5	C1.6a	C1.6b	C1.6c	C1.6d	C1.6e
Ventilation system	C1	C1	C1	C1	C1	C1	C1
Windows	Double gl.	Double gl.	HR++ (living)	HR++ (living)	HR++ (living)	HR++ (living)	HR++ (living)
Wall	Original	Original	Interior (R _c =2.8)	Exterior	Cavity	Cavity	Cavity
Roof	Original	Original	Original	Original	Original	Attic	Original
Floor	Original	Original	Original	Original	Below floor	Below floor	Original
Heating system	Original	LT-radiator	Original	Original	Original	Original	Add-on fan
Heating capacity	9204 W	6119 W	3737 W	3737 W	3737 W	3737 W	3988 W
Additional measures	-	-	-	-	-	-	-

Renovation scenarios: Building limitations

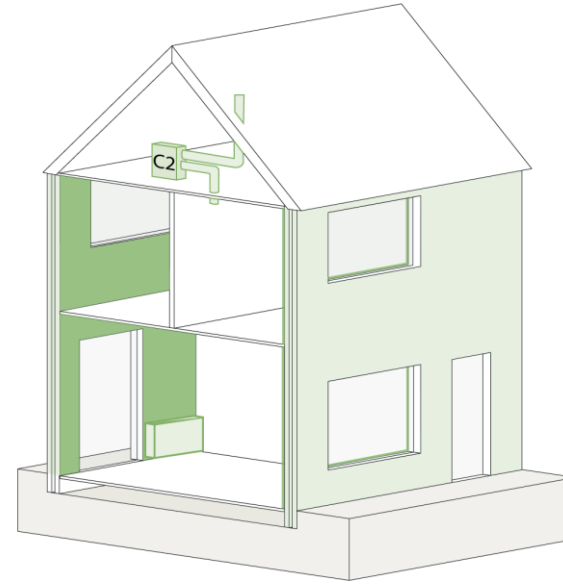
Already C1



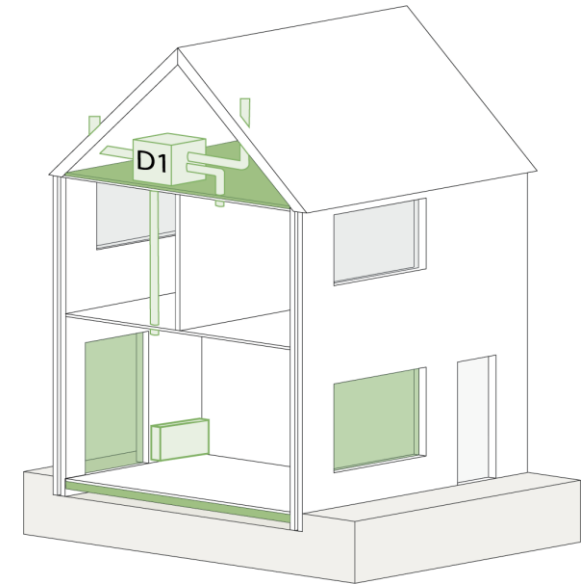
No space for D1



Cavity insulation not possible



Wall insulation not possible



Budget: €6,181

Exhaust ventilation (C1)
Exterior wall insulation
HR++ (living room)

98 hours too cold
94.2 kWh/m²

Budget: €6,795

Demand-driven ventilation (C2)
Cavity insulation
HR++ (living room)

69 hours too cold
85.3 kWh/m²

Budget: €7,160

Demand-driven ventilation (C2)
Interior insulation ($R_d=2.8$)

111 hours too cold
79.9 kWh/m²

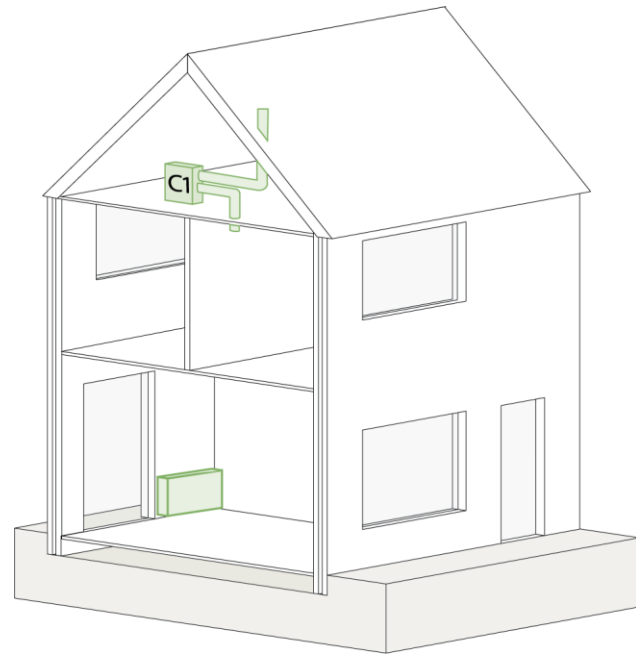
Budget: €9,603

Balanced ventilation (D1)
Attic insulation
Below floor insulation
HR++ (living room)
Add-on fans

111 hours too cold
79.9 kWh/m²

Renovation scenarios: Budget

< €5,000

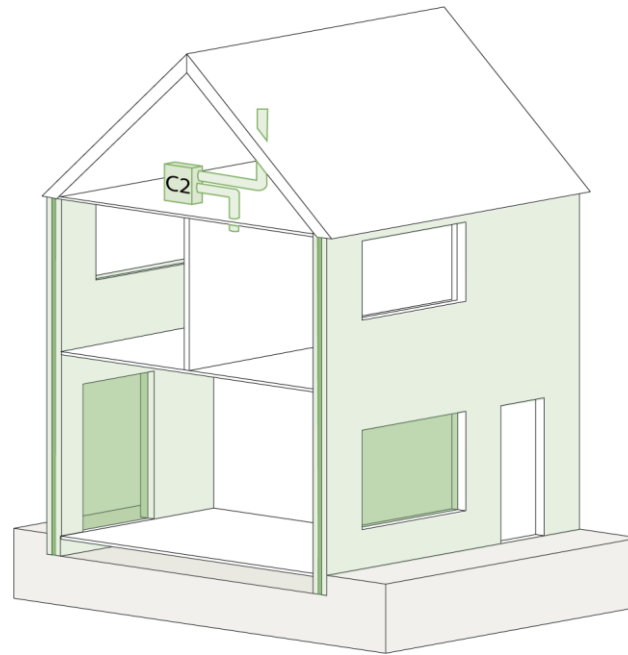


Budget: €3,638

Exhaust ventilation (C1)
LT-radiator

131 hours too cold
142.5 kWh/m²

€5,000 - €7,500

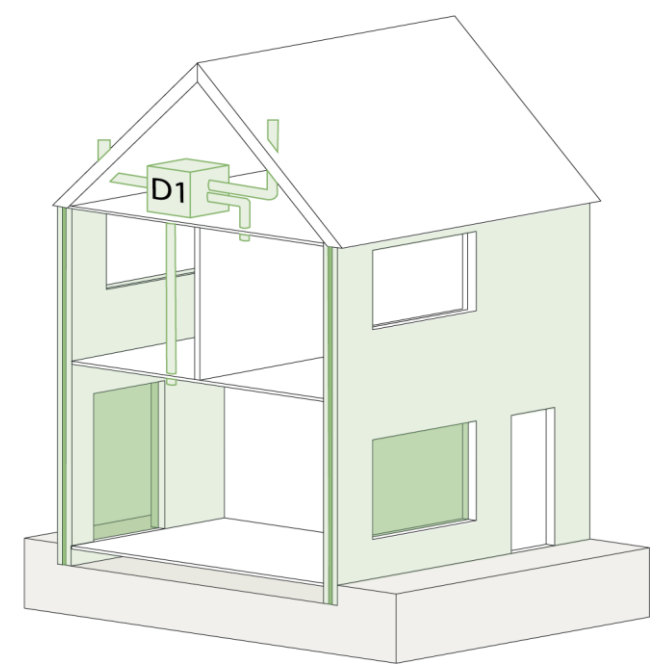


Budget: €6,795

Demand-driven ventilation (C2)
Cavity insulation
HR++ (living room)

69 hours too cold
85.3 kWh/m²

> €7,500



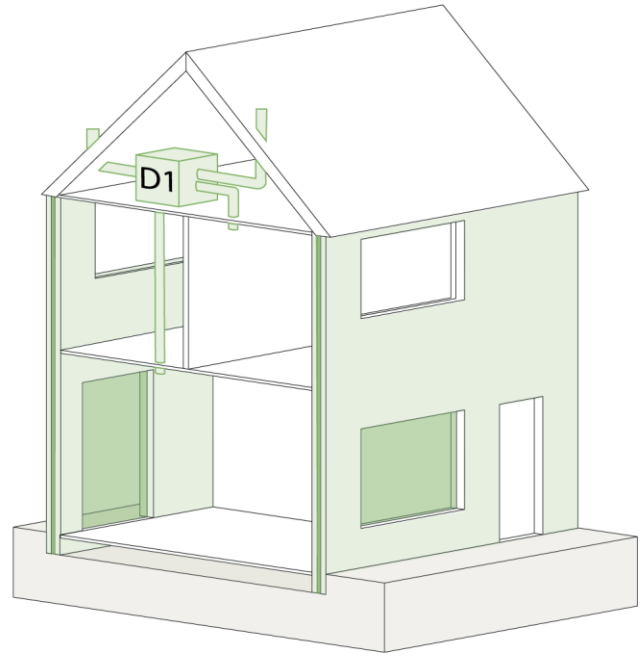
Budget: €8,641

Balanced ventilation (D1)
Cavity insulation
HR++ (living room)

41 hours too cold
76.8 kWh/m²

Renovation scenarios: Best performing on...

Thermal comfort & investment budget

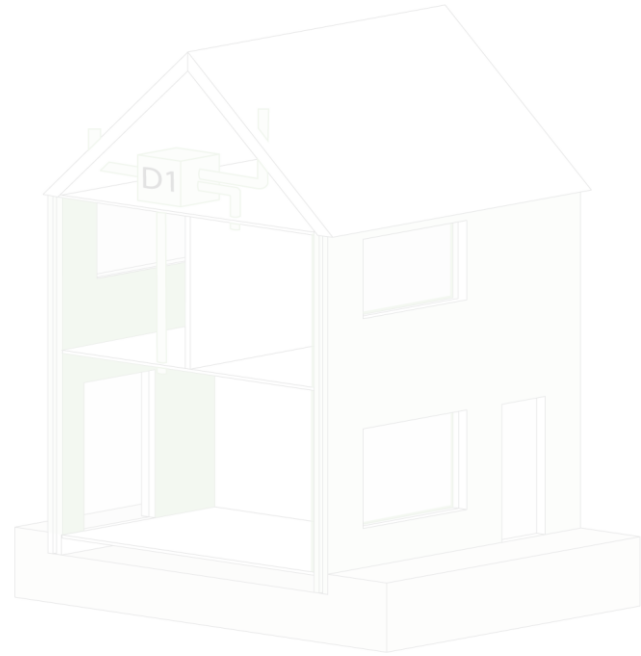


Budget: €8,641

- Balanced ventilation (D1)
- Cavity insulation
- HR++ (living room)

41 hours too cold
76.8 kWh/m²

Energy performance & investment budget



Budget: €8,782

- Balanced ventilation (D1)
- Interior insulation ($R_d=2.8$)

106 hours too cold
71.5 kWh/m²

Recommendations per ventilation type



Exhaust ventilation (C1) +

Variants

- 1 LT-Radiator
- 2 Wall insulation (extra $R_c=2.4$) **and** HR++ glazing
- 3 Cavity wall insulation **and** HR++ glazing **and** floor *or* roof insulation
- 4 Cavity wall insulation **and** HR++ glazing **and** add-on fan



Demand-driven exhaust ventilation (C2) +

Variants

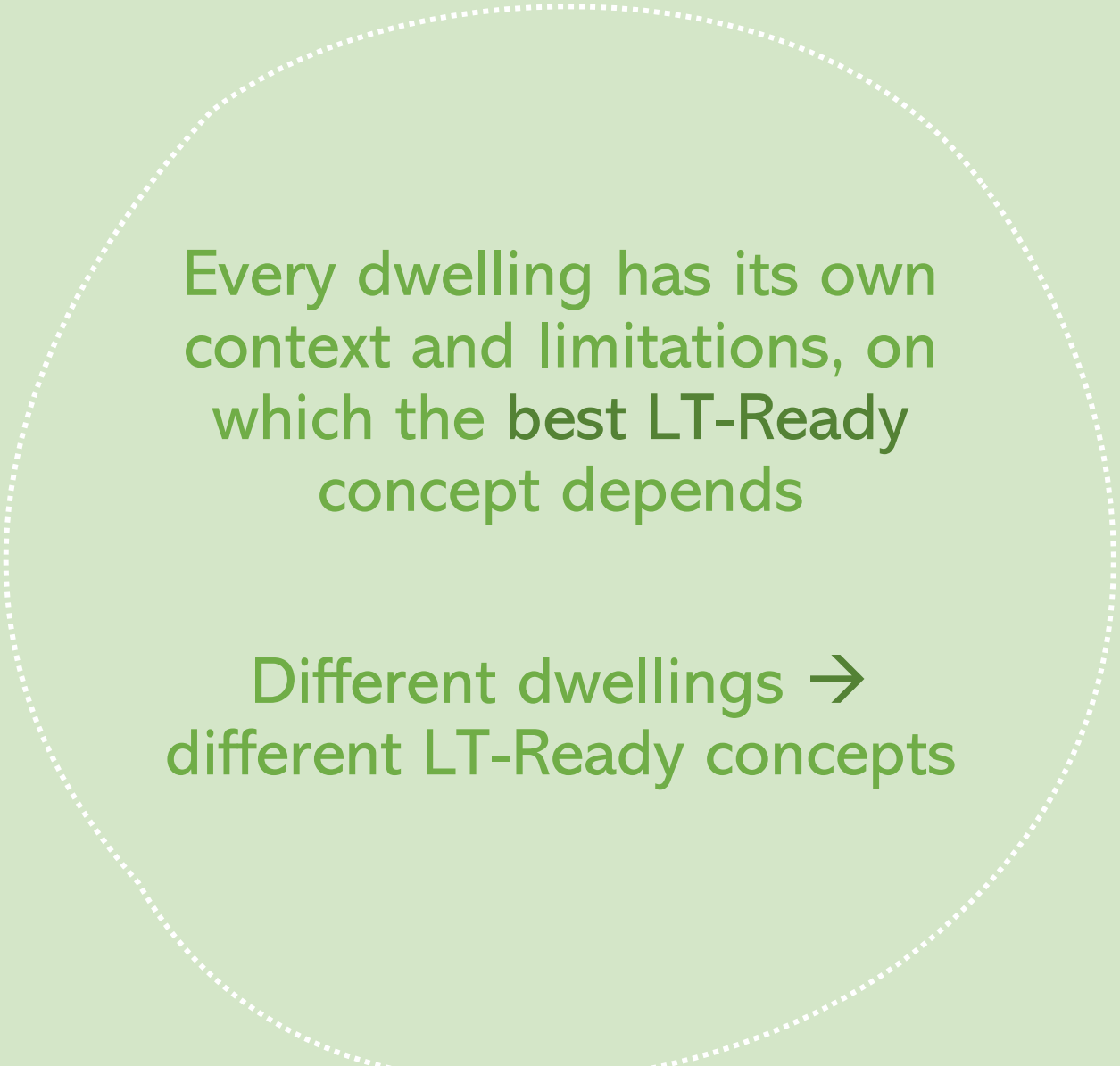
- 1 LT-Radiator
- 2 Exterior wall insulation
- 3 Wall insulation **and** HR++ glazing *or* radiant screen *or* add-on fans
- 4 HR++ glazing **and** floor insulation **and** attic insulation **and** add-on fans



Balanced ventilation with heat recovery (D1) +

Variants

- 1 LT-Radiator
- 2 Triple glazing
- 3 Wall insulation
- 4 HR++ glazing **and** floor insulation **and** roof insulation

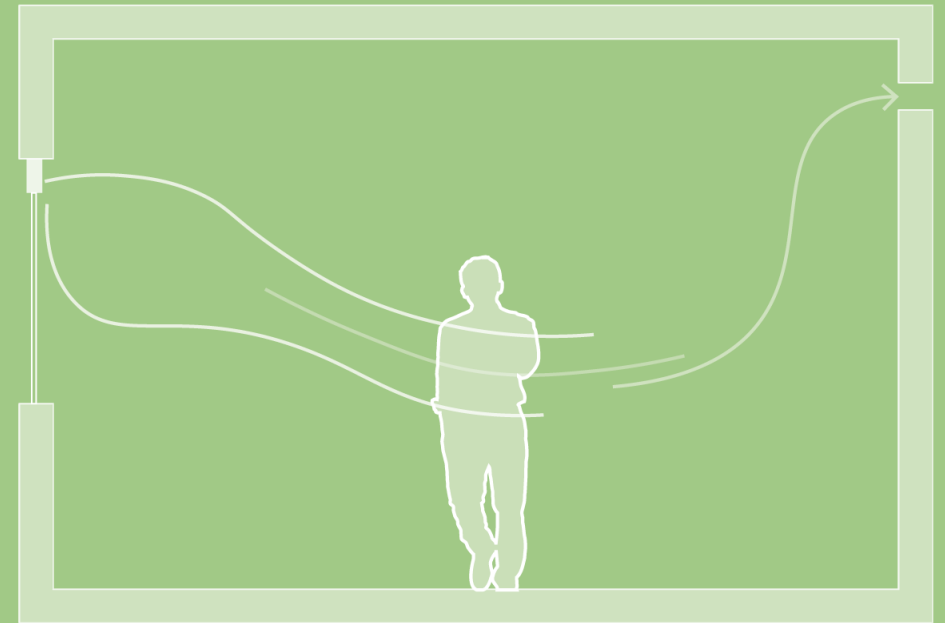


Every dwelling has its own
context and limitations, on
which the best LT-Ready
concept depends

Different dwellings →
different LT-Ready concepts

Additional local comfort analysis

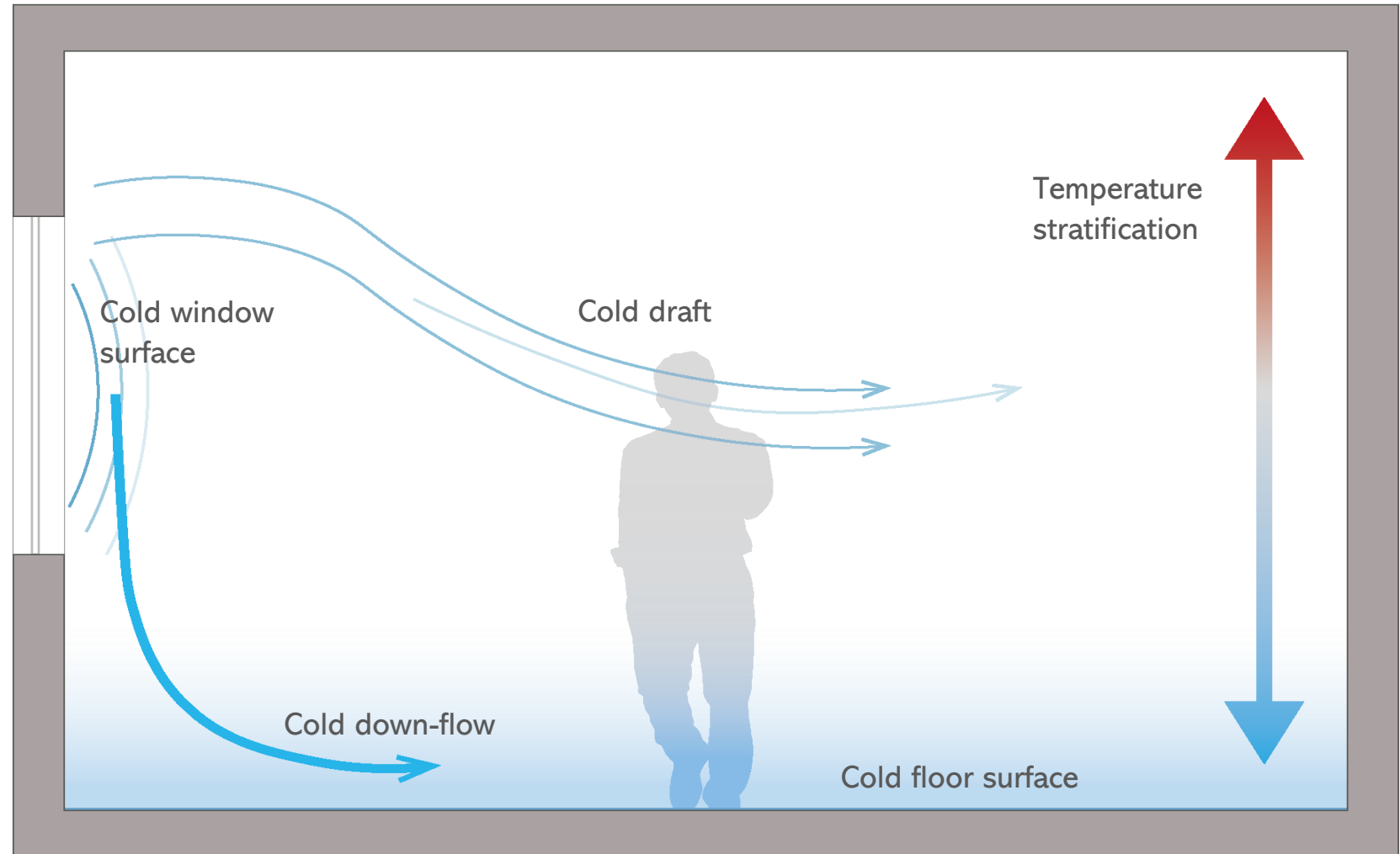
Phase 5



Local discomfort

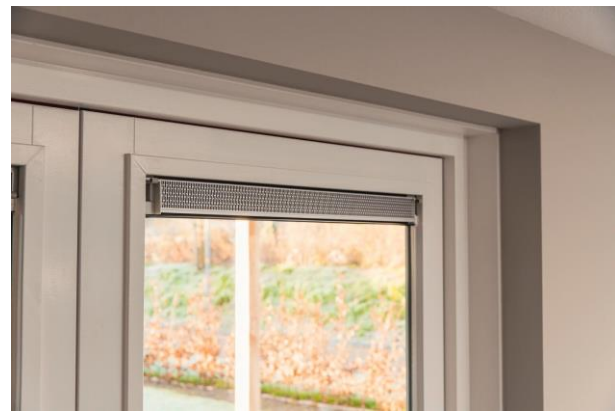
Local discomfort: comfortable temperature can still feel cold

Chance on local discomfort increases with LT-heating!



Local comfort analysis

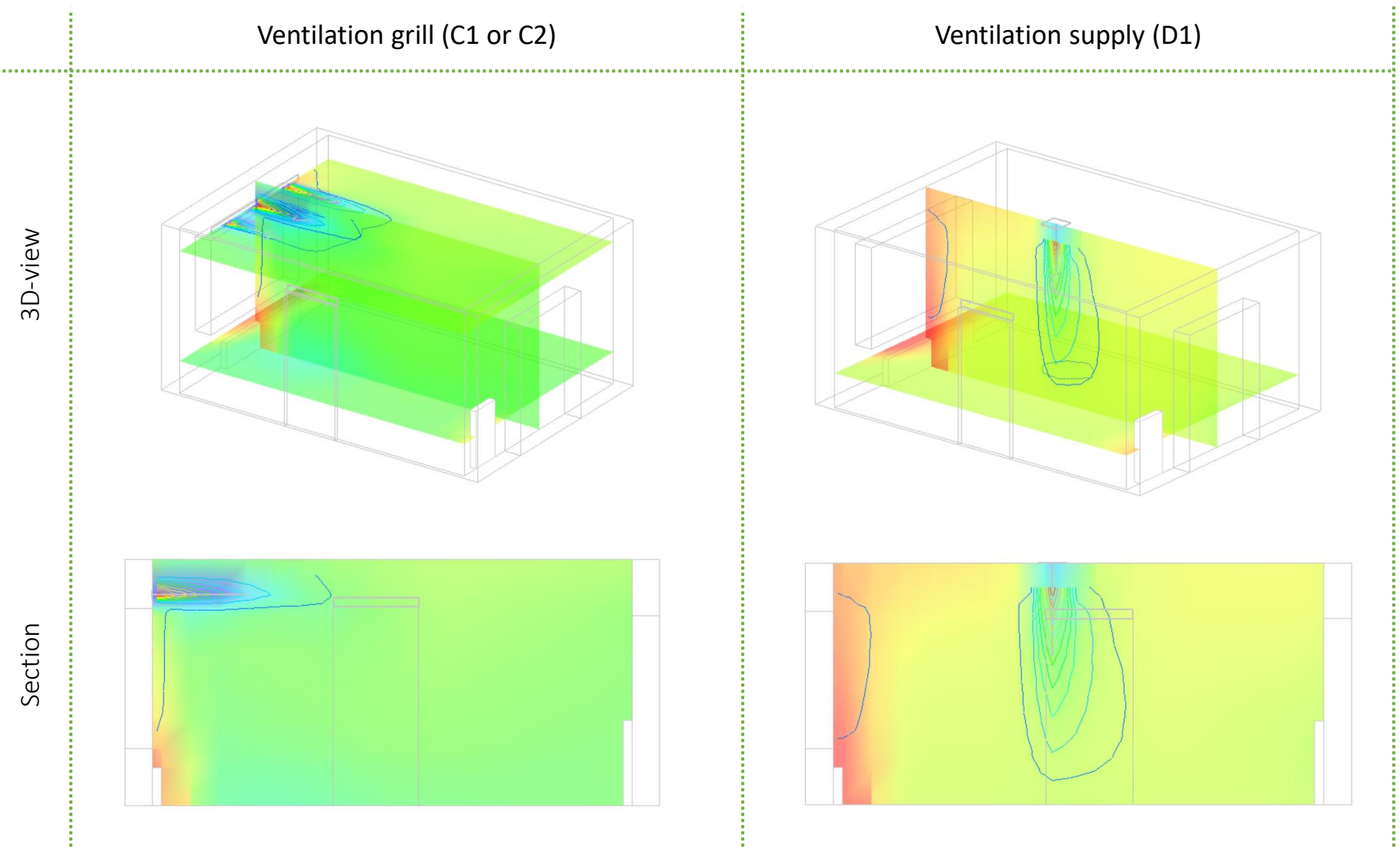
Ventilation grill



Ventilation supply



Ventilation system



3D-view

Section

Local comfort analysis

Add-on fan



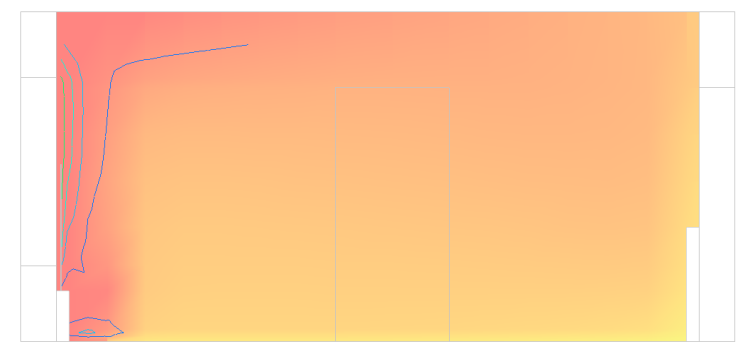
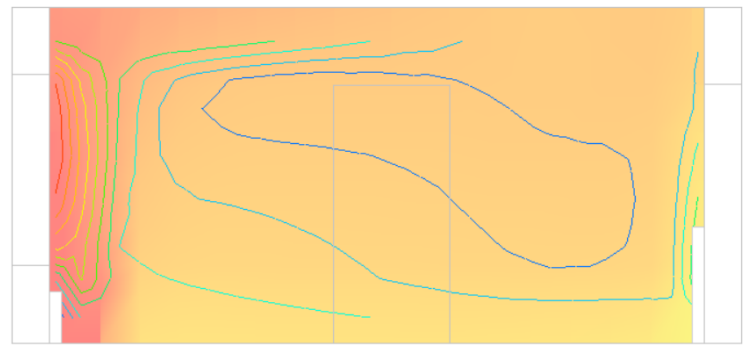
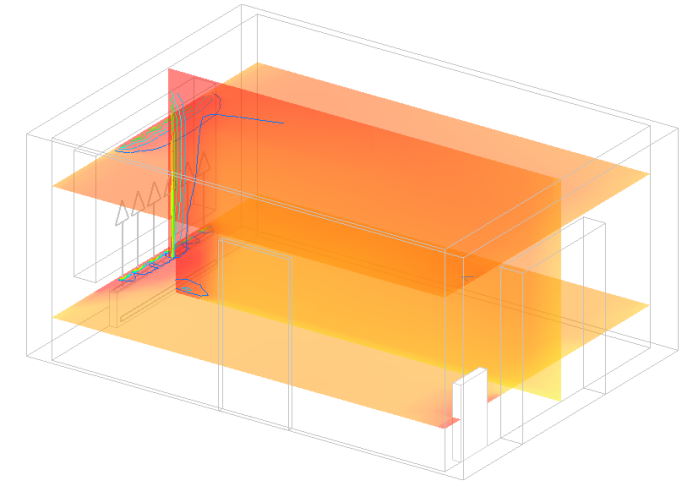
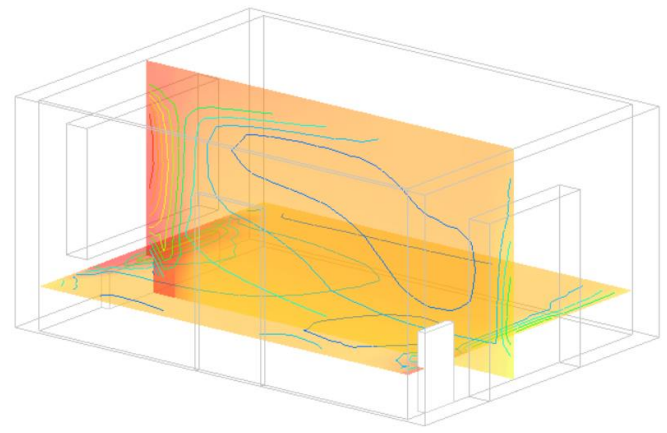
3D-view

Section

Add-on fans

Without add-on fan

With add-on fan



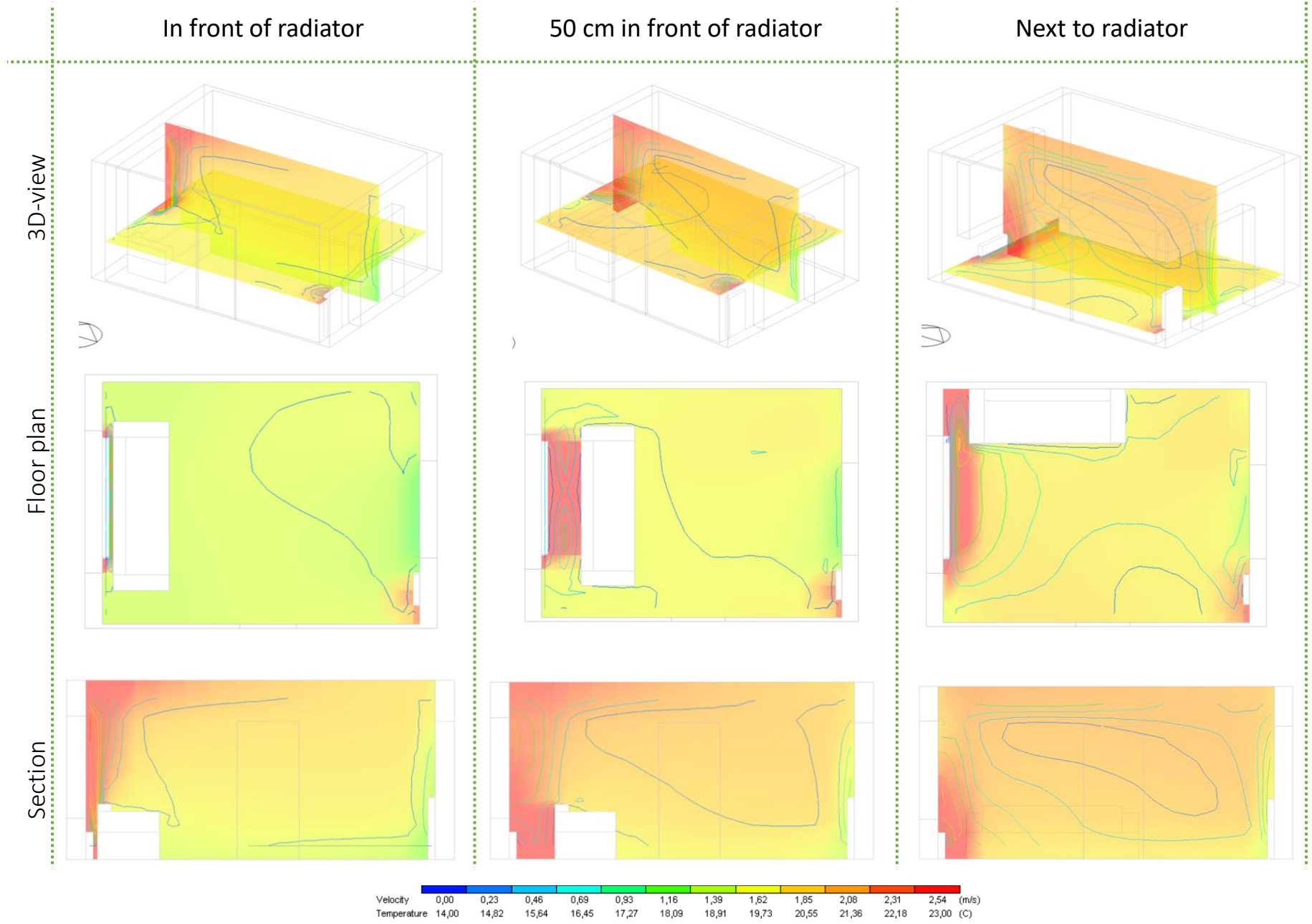
Velocity	0,00	0,23	0,46	0,69	0,93	1,16	1,39	1,62	1,85	2,08	2,31	2,54	(m/s)
Temperature	14,00	14,82	15,64	16,45	17,27	18,09	18,91	19,73	20,55	21,36	22,18	23,00	(C)

Local comfort analysis

Couch (Housebeautiful.com)



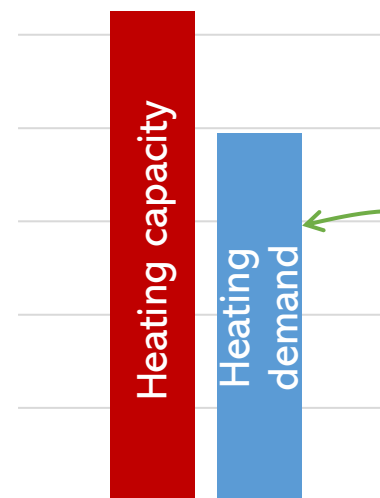
Location of couch



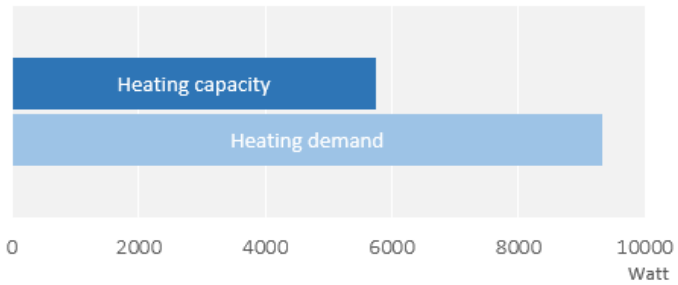
Case study dwelling → Dynamic simulations



Other dwellings → more general approach

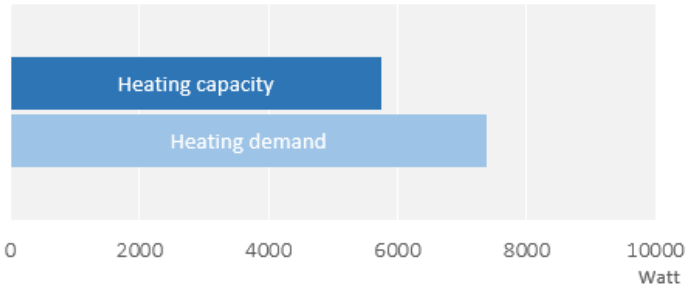


Not LT-READY



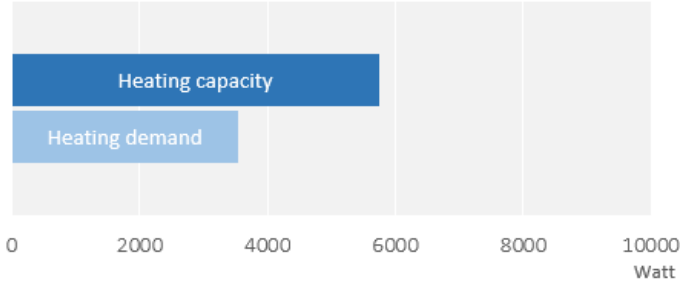
> 1.5 x heating capacity
Not LT-Ready for large part of the year

Almost LT-READY



< 1.5 x heating capacity
LT-Ready for large part of the year, but not on very cold days

LT-READY



LT-Ready for the entire year

Limited to terraced housing

The screenshot displays a software interface with a spreadsheet on the left and a results panel on the right. The spreadsheet is titled 'LT-READY Calculation sheet' and contains several sections: 'Radiators', 'Original', 'Concept 1, 2, 3', 'Comparison', 'Measures', and 'Cost analysis'. The results panel, titled 'Results', includes a bar chart comparing 'Heating capacity' and 'Heating demand', and three status indicators: 'LT-READY' (green), 'Almost LT-READY' (orange), and 'Not LT-READY' (red). The interface also shows a navigation bar at the bottom with tabs for 'Info', 'Radiators', 'Original', 'Concept1', 'Concept2', 'Concept3', 'Comparison', 'Measures', 'Cost analysis', and 'Blad2'. The status bar at the bottom indicates 'Gereed' and '100%' zoom.

Section	Description
Radiators	First, the current radiators placed in the dwelling must be filled in to determine the heating capacity of the radiators with lower supply temperatures.
Original	Second, the building envelope must be filled in to determine the required heating demand for the area and insulation values. This already gives an indication if the dwelling is LT-Ready.
Concept 1, 2, 3	After entering the original building in the calculation sheets, different renovation concepts can be applied. The expected heating demand and estimated costs are given, as well as an indication if the dwelling is LT-Ready.
Comparison	The different renovation concepts are compared with the original situation on their expected effect and budget. Nothing has to be filled in on this sheet.
Measures	An overview of all possible measures is provided in this sheet with expected U-values and cost indication. If wanted, the U-value and costs can be adjusted.
Cost analysis	The cost analysis can be consulted for the estimated effect of renovation measures and their costs.

Results

Estimated investment An indication of the estimated investment is given per renovation concept.

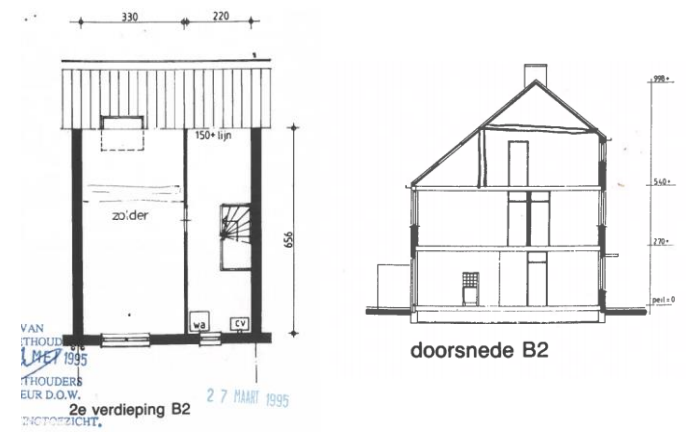
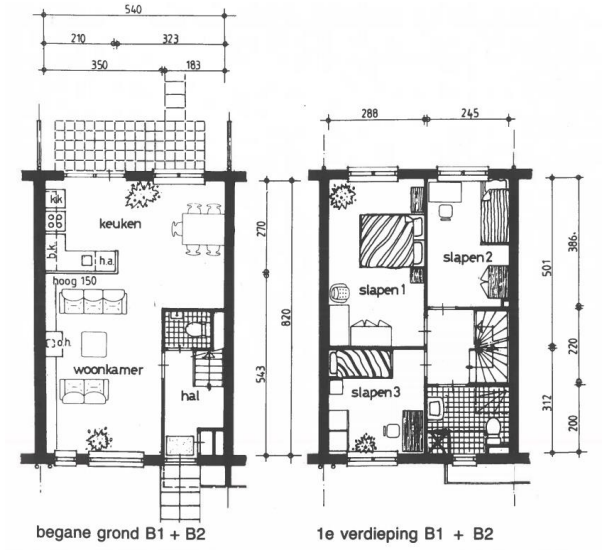
The **heating capacity** is the total heat provided by the radiators with a supply temperature of 55 °C.

The **heating demand** is the required heat to heat the room or dwelling to a comfortable indoor temperature (20 °C) and is calculated with ISSO 51.

LT-READY When the heating demand is lower than the heating capacity, the dwelling is LT-Ready and comfortable during the year when using a lower supply temperature.

Almost LT-READY The heating demand is slightly higher than the heating capacity. This means that on very cold days the dwelling is almost LT-Ready. However, during the largest part of the year the dwelling is probably LT-Ready.

Not LT-READY The heating demand is higher than the heating capacity. This means that on cold days the dwelling is not LT-Ready and will be too cold. Additional measures can be taken to improve thermal comfort.



VAN THOUDE
 1995
 THOUDE
 EUR D.O.W.
 27 MAART 1995
 ZACHTZICHT

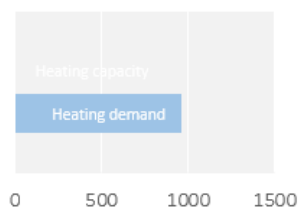
LT-READY Calculation sheet

This sheet can be used to determine if dwellings are ready to be heated with lower supply temperatures, or what is required to make them ready for low-temperature heating.

Radiators	First, the current radiators placed in the dwelling must be filled in to determine the heating capacity of the radiators with lower supply temperatures.
Original	Second, the building envelope must be filled in to determine the required heating demand for the area and insulation values. This already gives an indication if the dwelling is LT-Ready.
Concept 1, 2, 3	After entering the original building in the calculation sheets, different renovation concepts can be applied. The expected heating demand and estimated costs are given, as well as an indication if the dwelling is LT-Ready.
Comparison	The different renovation concepts are compared with the original situation on their expected effect and budget. Nothing has to be filled in on this sheet.
Measures	An overview of all possible measures is provided in this sheet with expected U-values and cost indication. If wanted, the U-value and costs can be adjusted.
Cost analysis	The cost analysis can be consulted for the estimated effect of renovation measures and their costs.

Results

Estimated investment



An indication of the estimated investment is given per renovation concept.

The **heating capacity** is the total heat provided by the radiators with a supply temperature of 55 °C.

The **heating demand** is the required heat to heat the room or dwelling to a comfortable indoor temperature (20 °C) and is calculated with ISSO 51.

LT-READY

When the heating demand is lower than the heating capacity, the dwelling is LT-Ready and comfortable during the year when using a lower supply temperature.

Almost LT-READY

The heating demand is slightly higher than the heating capacity. This means that on very cold days the dwelling is almost LT-Ready. However, during the largest part of the year the dwelling is probably LT-Ready.

Not LT-READY

The heating demand is higher than the heating capacity. This means that on cold days the dwelling is not LT-Ready and will be too cold. Additional measures can be taken to improve thermal comfort.

Tool - radiators

Info	Radiators	Original	Concept1	Concept2	Concept3	Comparison	Measures	Cost analysis
------	------------------	----------	----------	----------	----------	------------	----------	---------------

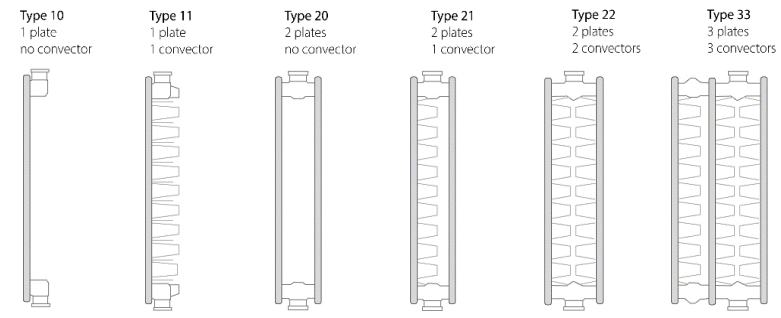


Measure height and width of radiators

Determine radiator types

Radiators

All radiators of the dwelling needs to be entered in this sheet to calculate the heating capacity. First, the heating setpoint temperature and temperatures of the lower supply temperatures has to be entered. Then, the radiator type must be entered which can be looked up in the image. Also the length and height of the radiators must be filled in. The heating capacity per radiator and the total heating capacities are shown in the graphs.

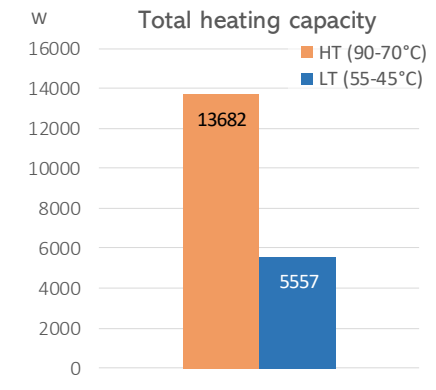
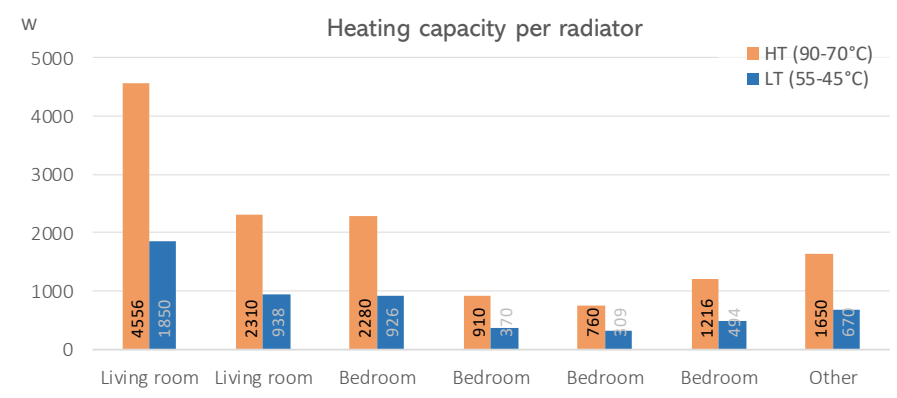


Setpoint temperature	20 °C
LT supply temperature	55 °C
LT return temperature	45 °C

Radiator	Living room	Living room	Bedroom	Bedroom	Bedroom	Bedroom	Other
Select type	33	22	11	10	11	11	22
Enter length	2250 mm	1400 mm	2400 mm	1400 mm	1000 mm	1600 mm	1000 mm
Enter height	450 mm	500 mm	500 mm	500 mm	400 mm	400 mm	500 mm

Heating capacity	HT (90-70°C)	LT (55-45°C)	Living room	Living room	Bedroom	Bedroom	Bedroom	Bedroom	Bedroom	Other
HT (90-70°C)	4556 W	2310 W	2280 W	910 W	760 W	1216 W	1650 W			
LT (55-45°C)	1850 W	938 W	926 W	370 W	309 W	494 W	670 W			

Total heating capacity	HT (90-70°C)	13682 W
	LT (55-45°C)	5557 W



Calculate heating capacity
(HT and LT)

Tool – original situation

Fill in:

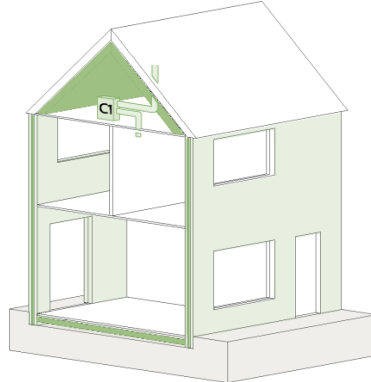
- Envelope areas and properties
- Air tightness

Original situation

The current building envelope must be entered (type and area) and the total floor area of the dwelling in the green boxes.

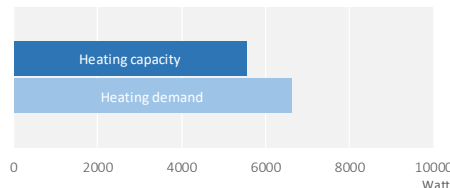
Total floor area	135 m ²
Floor area living room	51 m ²

Select	Area [m ²]
Windows	
Double glazing	22
Adjacent to living room	10
Wall	
Cavity wall insulation	50
Exterior wall	15
Adjacent to living room	120
Seperation wall with neighbours	38
Adjacent to living room	17
Interior walls adjacent to living room	
Roof	
Roof insulation	79
Roof	10
Adjacent to living room	0
Attic	
Floor	
Floor insulation below floor	58
Ventilation	Exhaust ventilation (C1)
Air tightness	Medium
Heating	Radiators

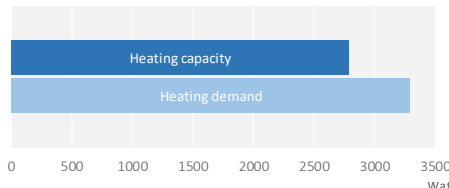


Dwelling	Living room
Heating capacity LT	2789 W
Heating demand	3297 W

Almost LT-READY



Almost LT-READY



U-values are different
 → Change in *Measures*-tab

Measures
 Overview of available renovation measures. The value of the green boxes can be changed to match the current situation.

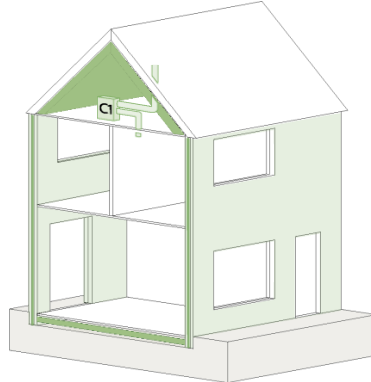
		U-value	Costs	
Windows	Double glazing	2,2	€ 0	per m ²
	HR++ glazing	1,1	€ 137	per m ²
	Triple glazing	0,8	€ 182	per m ²
Wall	Uninsulated wall	2,56	€ 0	per m ²
	Cavity wall insulation	0,33	€ 28	per m ²
	Interior wall insulation	0,65	€ 54	per m ²
	Exterior wall insulation	0,41	€ 117	per m ²
Roof	Uninsulated roof	2,05	€ 0	per m ²
	Insulated attic	0,42	€ 22	per m ²
	Roof insulation	0,40	€ 63	per m ²
Floor	Uninsulated floor	2,89	€ 0	per m ²
	Floor insulation below floor	0,45	€ 41	per m ²
	Floor insulation above floor	0,53	€ 74	per m ²
Ventilation	Natural ventilation (A)	0,75	€ 0	per dwelling
	Exhaust ventilation (C1)	1	€ 2.515	per dwelling
	Demand-driven exhaust ventilation (C2)	0,5	€ 4.304	per dwelling
	Balanced ventilation with heat recovery (D1)	0,2	€ 6.123	per dwelling
Heating	Radiators	'Radiator'-sheet	€ 0	per unit
	Add-on fans (per room)	extra 20%	€ 197	per unit
	LT-radiators (per room)	2500	€ 528	per unit
Airtightness	Not improved	0,00019	€ 0	per dwelling
	Medium	0,00010	€ 447	per dwelling
	High	0,00005	€ 1.560	per dwelling

Tool – original situation

Original situation

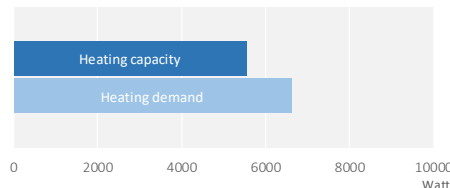
The current building envelope must be entered (type and area) and the total floor area of the dwelling in the green boxes.

Select	Area [m ²]
Windows	
Double glazing	22
Adjacent to living room	10
Wall	
Cavity wall insulation	50
Exterior wall	15
Adjacent to living room	120
Seperation wall with neighbours	38
Adjacent to living room	17
Interior walls adjacent to living room	79
Roof	
Roof insulation	10
Roof	0
Adjacent to living room	58
Floor	
Floor insulation below floor	
Ventilation	
Exhaust ventilation (C1)	
Air tightness	
Medium	
Heating	
Radiators	

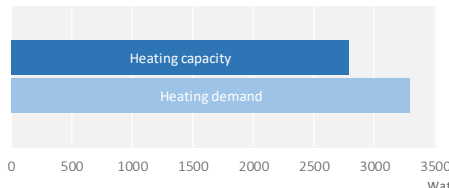


Category	Heating capacity LT	Heating demand
Dwelling	5557 W	6608 W
Living room	2789 W	3297 W

Almost LT-READY



Almost LT-READY



Calculates heating demand
Compared with LT heating capacity

Try different renovation concepts

Calculates estimated investment

Concept 1

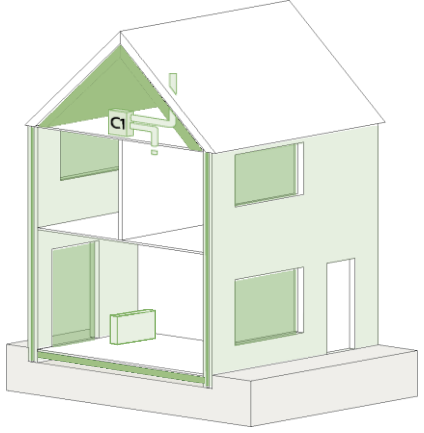
Renovation concepts can be tested to by changing the green boxes. The grey boxes cannot be changed. This results in the estimated costs for a renovation and the estimation if the dwelling is LT-Ready or not.

Total area 135 m²

Select	Area [m ²]
Windows: HR++ glazing	22
Wall: Cavity wall insulation	50
Roof: Roof insulation	Roof: 40 Attic: 0
Floor: Floor insulation below floor	58
Ventilation: Exhaust ventilation (C1)	
Air tightness: Medium	
Heating: Add-on fans (per room)	

Estimated costs

- € 3.014
- € 0
- € 0
- € 0
- € 0
- € 0
- € 197



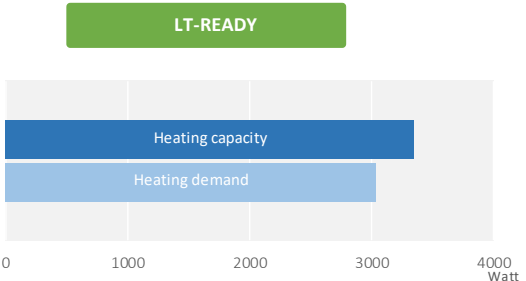
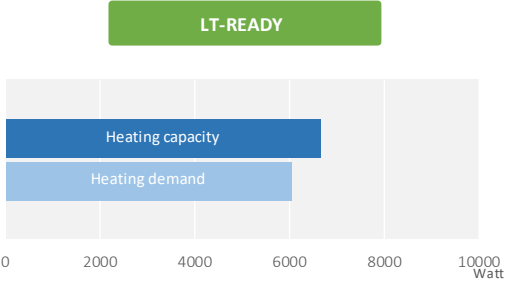
Estimated investment € 3.211



Dwelling
 Heating capacity LT: 6668 W
 Heating demand: 6033 W



Living room
 Heating capacity LT: 3346 W
 Heating demand: 3035 W



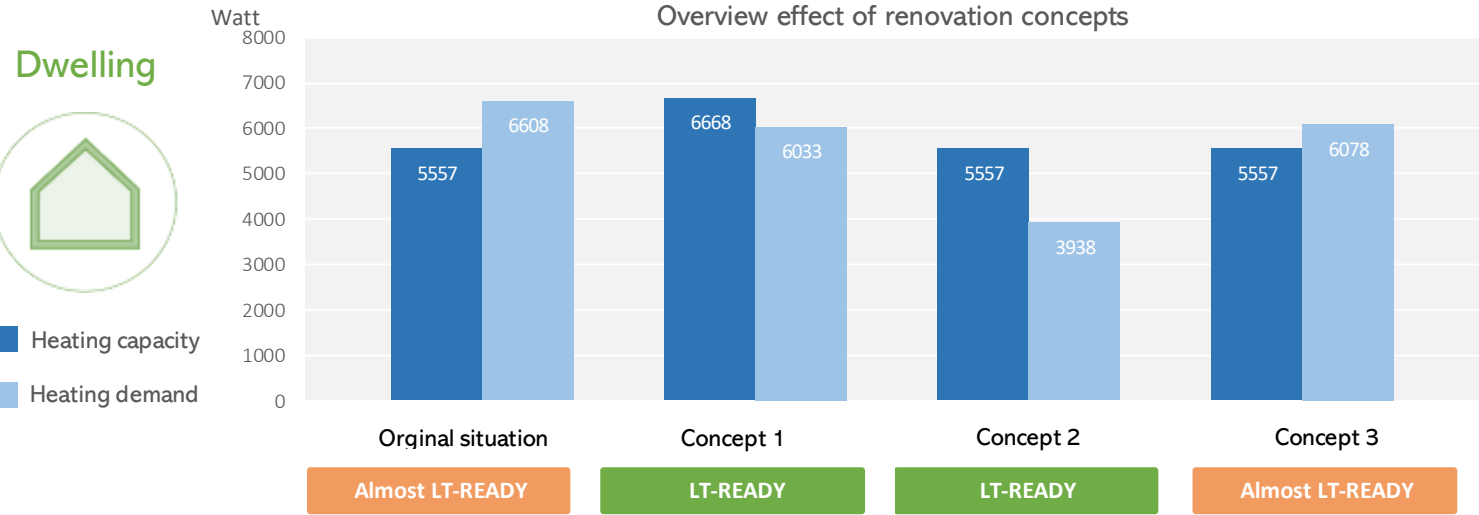
Compare renovation concepts

Comparison

The different renovation concepts are compared with the original situation, in order to select the best performing renovation concept per situation.

Available heating capacity 5557 W

	<u>Original</u>	<u>Concept 1</u>	<u>Concept 2</u>	<u>Concept 3</u>
Windows	Double glazing	HR++ glazing	Double glazing	Triple glazing
Wall	Cavity wall insulation	Cavity wall insulation	Cavity wall insulation	Cavity wall insulation
Roof	Roof insulation	Roof insulation	Roof insulation	Roof insulation
Floor	Floor insulation below floor	Floor insulation below floor	Floor insulation below floor	Floor insulation below floor
Ventilation	Exhaust ventilation (C1)	Exhaust ventilation (C1)	Balanced ventilation with heat recovery (D1)	Exhaust ventilation (C1)
Air tightness	Medium	Medium	High	Medium
Heating system	Radiators	Add-on fans (per room)	Radiators	Radiators
Estimated investment		€ 3.211	€ 7.683	€ 4.010



LT-READY:

Affordable renovation measures that provide thermal comfort with low-temperature heating

What is low-temperature heating?

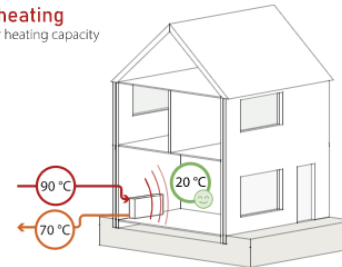
With low-temperature heating, the supply temperature of the central heating system lies is 55 °C or lower, instead of using a supply temperature of 90 to 70 °C as with traditional heating.

The total heating capacity of the radiators will be reduced, which means the dwelling needs to have some insulation to be thermally comfortable. In this case, the current radiators can still provide most of the time enough heat.

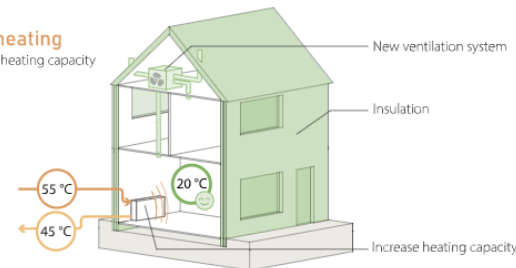
Why low-temperature heating?

Sustainable heating sources, like geothermal heat or solar heat, mostly supply heat at lower temperatures. Also a lower supply temperature is required for heat pumps.

HT-heating Higher heating capacity



LT-heating Lower heating capacity



Provides information on:

- **What** is low-temperature heating?
- **Why** low-temperature heating?
- Available **renovation measures**
- **Examples** of LT-Ready renovations

Download tool!



Link: www.ltreadytool.nl

LT-READY:

Affordable renovation measures that provide thermal comfort with low-temperature heating

What is low-temperature heating?

With low-temperature heating, the supply temperature of the central heating system lies is 55 °C or lower, instead of using a supply temperature of 90 to 70 °C as with traditional heating.

The total heating capacity of the radiators will be reduced, which means the dwelling needs to have some insulation to be thermally comfortable. In this case, the current radiators can still provide most of the time enough heat.

Why low-temperature heating?

Sustainable heating sources, like geothermal heat or solar heat, mostly supply heat at lower temperatures. Also a lower supply temperature is required for heat pumps.

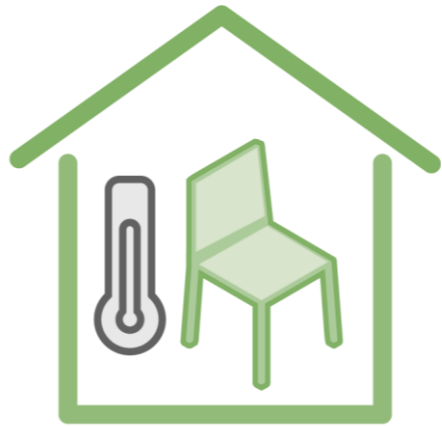
The diagram illustrates two scenarios for a house. The top scenario, labeled 'HT-heating Higher heating capacity', shows a house with a radiator emitting heat waves. The supply temperature is 90 °C and the return temperature is 70 °C. The indoor temperature is 20 °C. The bottom scenario, labeled 'LT-heating Lower heating capacity', shows a house with a radiator emitting fewer heat waves. The supply temperature is 55 °C and the return temperature is 45 °C. The indoor temperature is 20 °C. This scenario includes 'New ventilation system' and 'Insulation' on the walls, and notes an 'Increase heating capacity' for the radiator.

Conclusion

“What combination of renovation measures for residential buildings is affordable and provides thermal comfort, when using a lower supply temperature for heating?”

- Different combinations possible within a budget of €10,000
- Overall best performing LT-Ready concept for case study:
 - *Balanced ventilation with heat recovery (D1)*
 - *Cavity wall insulation*
 - *HR++ glazing*
- However, “best” combination depends on *context*:
 - *Building limitations*
 - *Available investment budget*
- Within every context, still different LT-Ready renovation concepts possible
- Decision for renovation measures influence on local comfort
- LT-Ready tool can be used to determine renovation concepts for other terraced housing





Thermal comfort only in living room

- Other rooms can still be uncomfortable



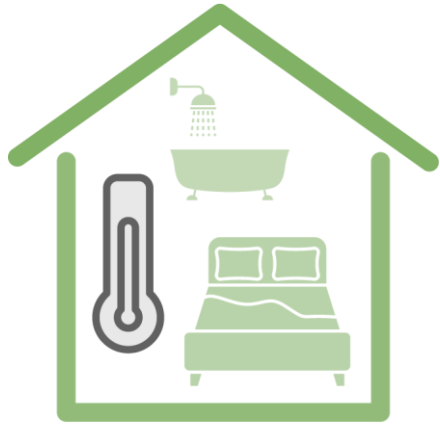
Dynamic simulations

- Many required input values
- Should be interpreted carefully



Focus on affordable renovations

- More expensive, but also more effective renovation option disregarded



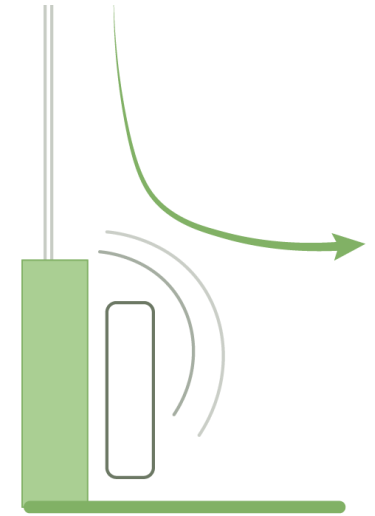
Thermal comfort other rooms

- Determine LT-Readiness of entire dwelling



Different building types

- (Semi-)detached, apartments and corner housing
- Expect different results



Local comfort and LTH

- Experimental research to effect
- Cold draft & down-flow when using current radiators



Learned a lot this year and proud of results

About LT-heating, thermal comfort and dynamic simulations

How to transfer the gained knowledge to others



Learned to motivate myself during difficult times

Try to stay positive when things get difficult!



Realized there is a lot of work to do for an LT-Ready future

But it is definitely possible!



Thank you!



Appendix

References: Literature

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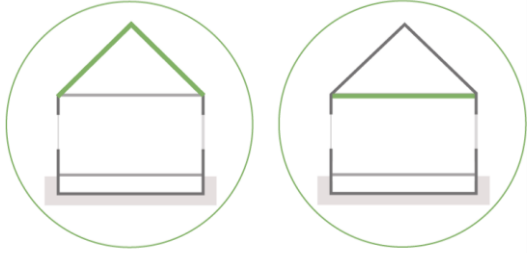





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Recommendations – envelope scale

		Thermal comfort in living room	Energy performance
Wall			
Windows			
Roof			
Floor			

Recommendations - installation scale

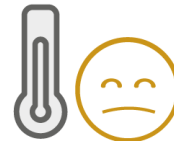
		Thermal comfort in living room	Energy performance
Ventilation		Exhaust ventilation (C1)  	 
		Demand driven exhaust ventilation (C2)  	 
		Balanced ventilation with heat recovery (D1)  	 
LT-radiators		 	 
Add-on fan		 	 

Recommendations – room scale

Thermal comfort in living room

Energy performance

Heat reflective paint



Radiant screen

