

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

Saskia Rutten

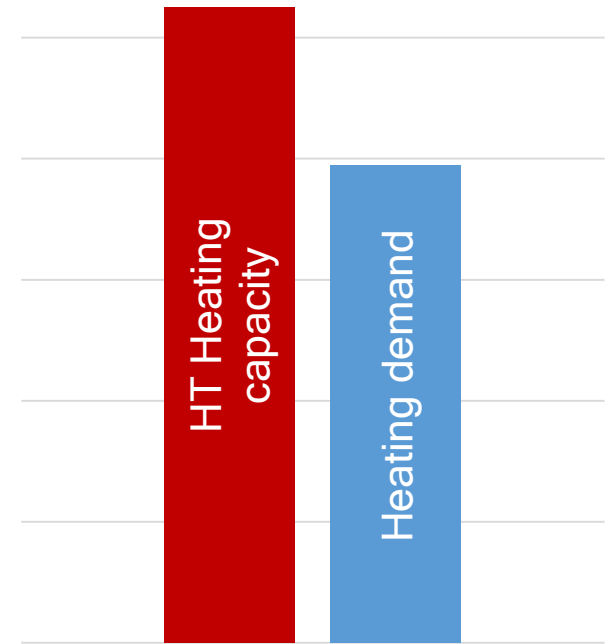
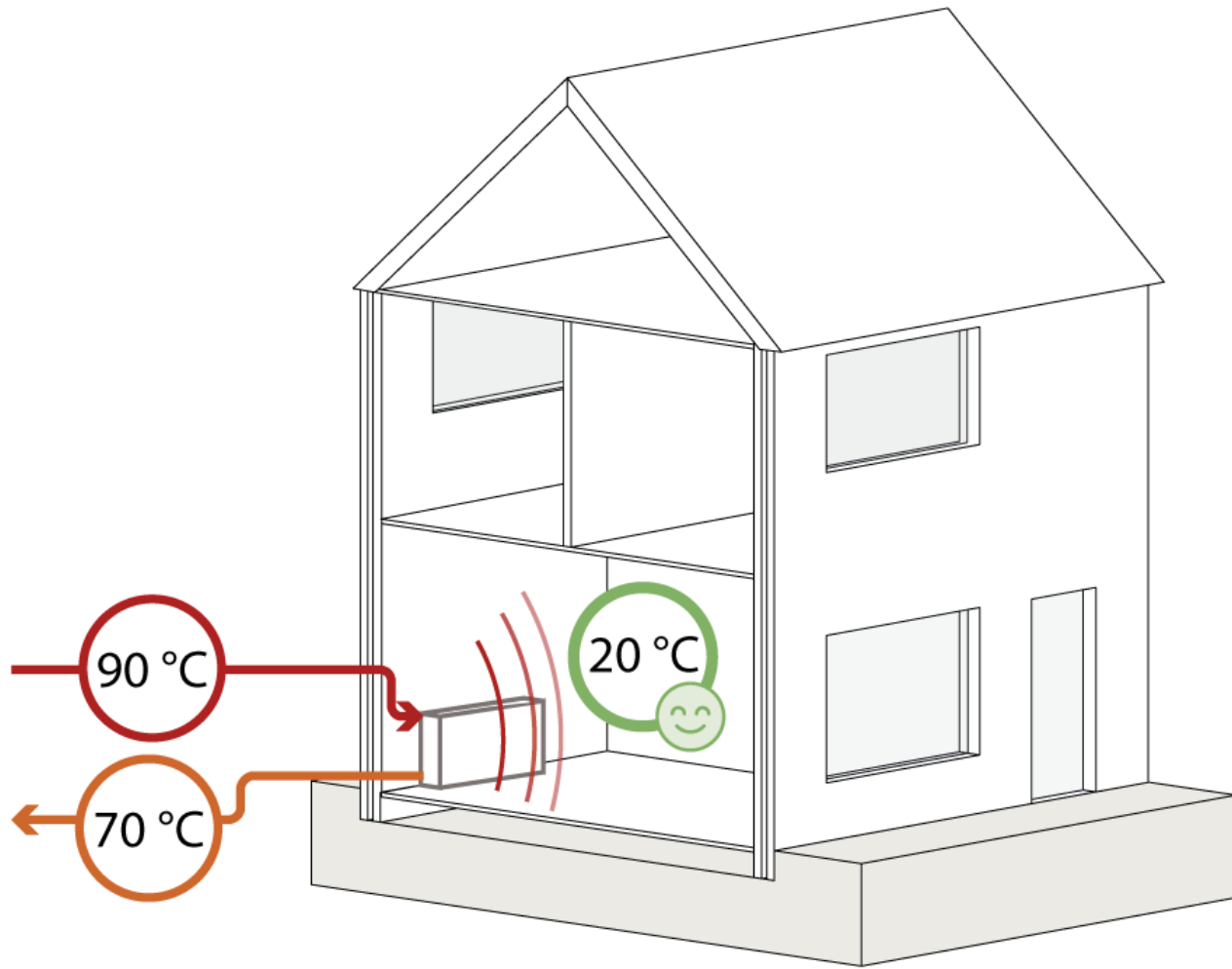
14/10/2021

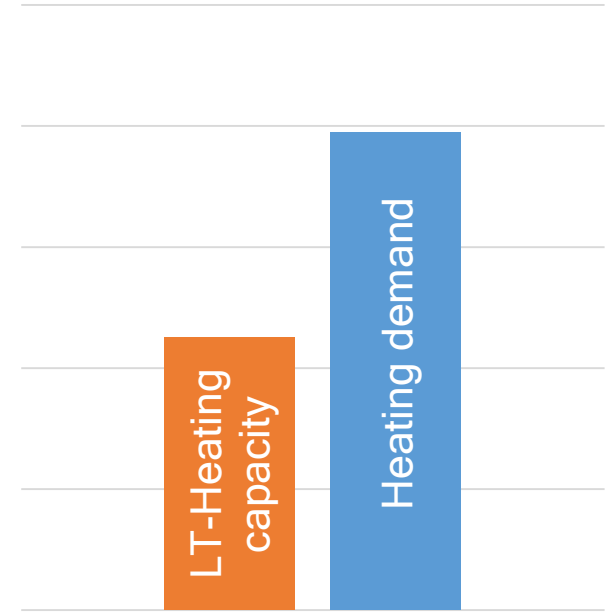
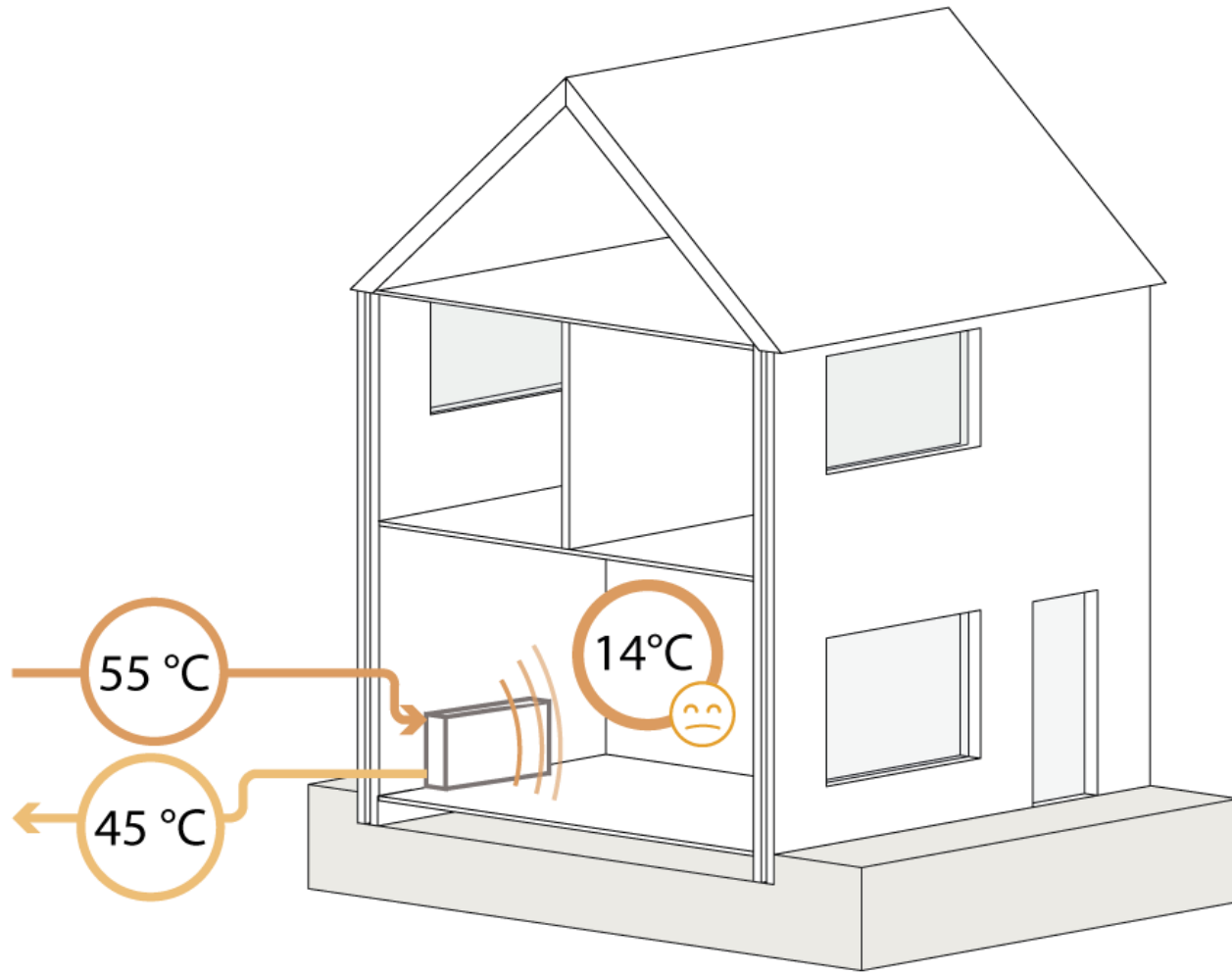


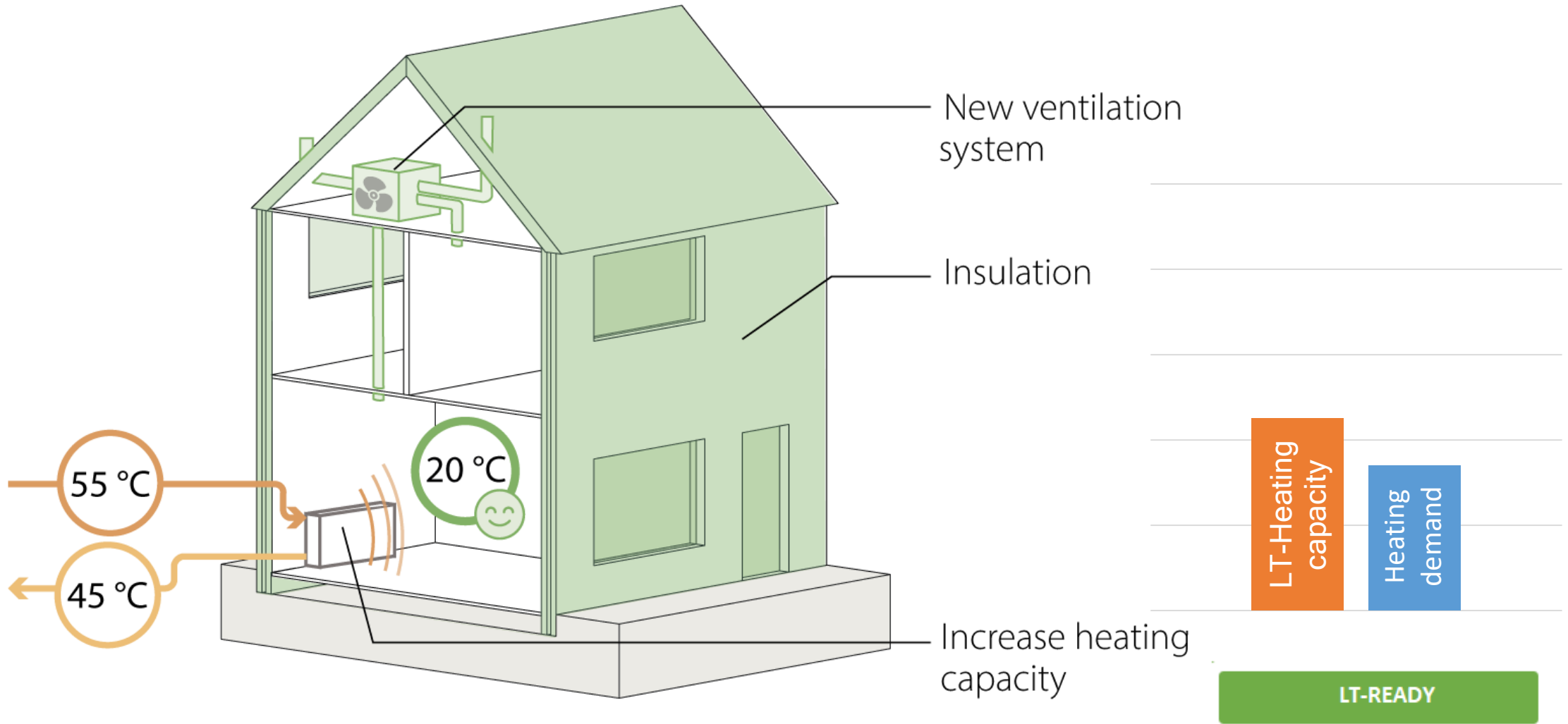
- Saskia Rutten
- Graduated in July 2021, Msc Building Technology (TU Delft)
- Research assistant LT-Ready with Paula van den Brom & Eric van der Ham
- 1 September, started working at DGMR
- Consultant on building physics and installations
- Contact sru@dgmr.nl



dGm^R



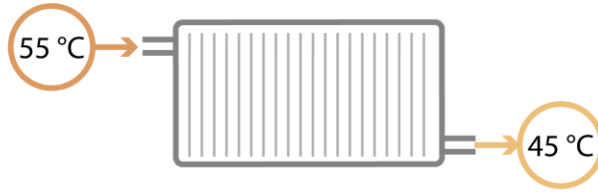




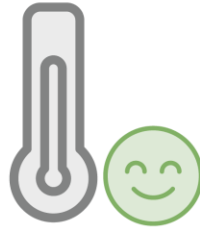
LT-Ready
concepts

Should
:

Enable a lower supply
temperature



Maintain thermal comfort



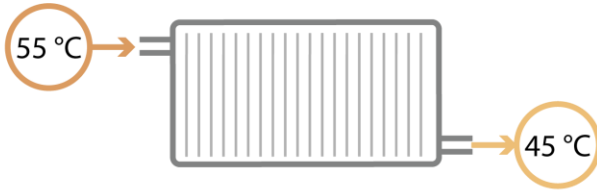
Be affordable (< € 10,000)



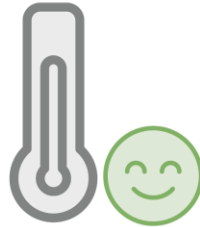
LT-Ready concepts

Should
:

Enable a lower supply temperature



Maintain thermal comfort



Be affordable (< € 10,000)



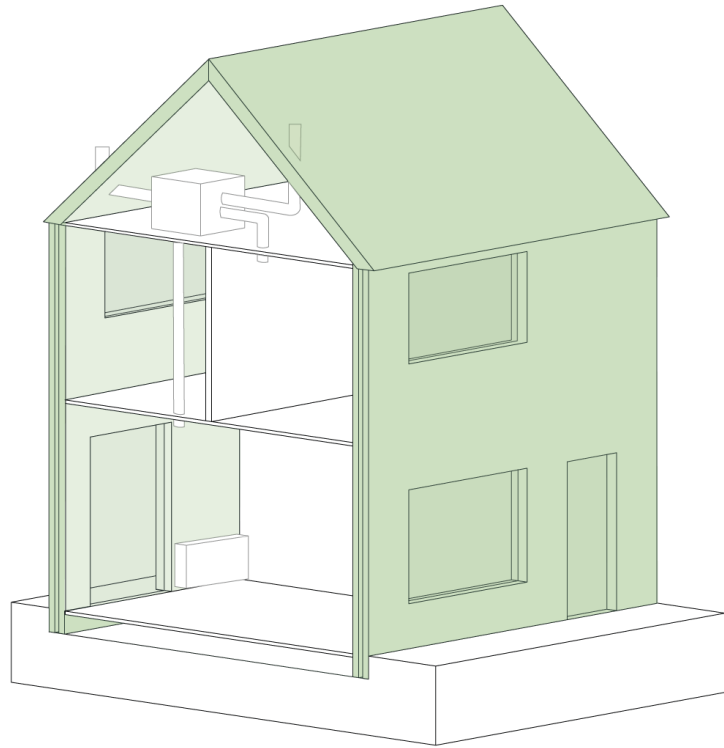
Determining renovation concepts



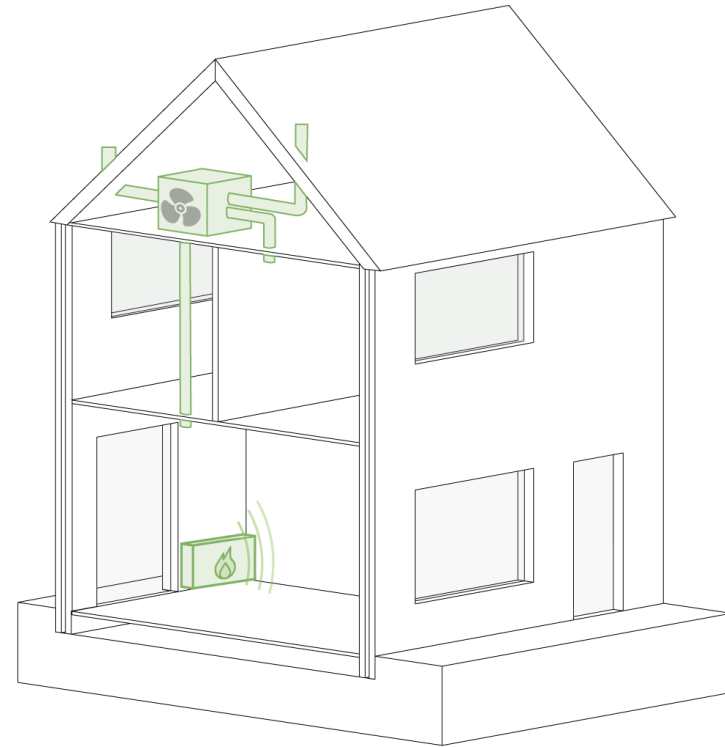
Renovation measures



Envelope scale



Installation scale



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]

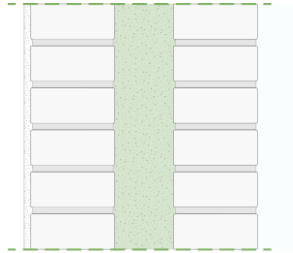


Envelope scale

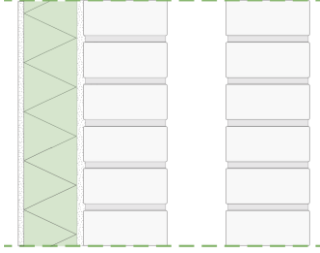
Wall



Cavity wall insulation
€26 / m²



Interior wall insulation
€39-54 / m²



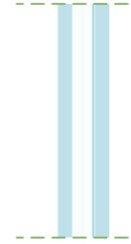
Exterior wall insulation
€117 / m²



Windows



HR++ glazing
€137 / m²



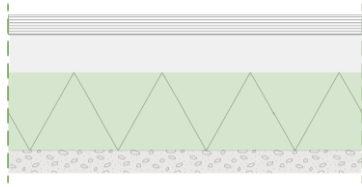
Triple glazing
€181 / m²



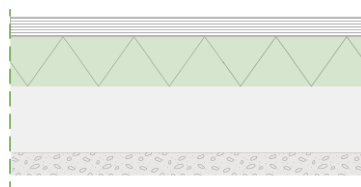
Floor



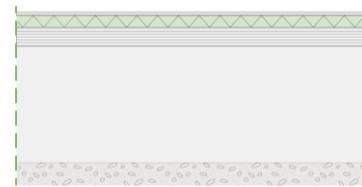
Insulation of crawling space floor
€34 / m²



Insulation below floor
€41 / m²



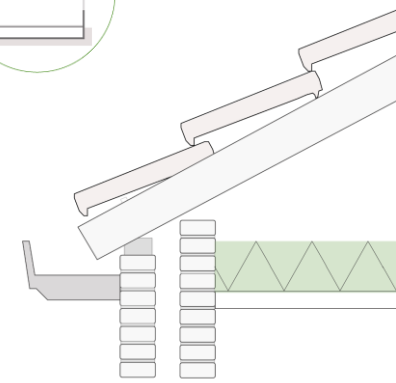
Insulation above floor
€77 / m²



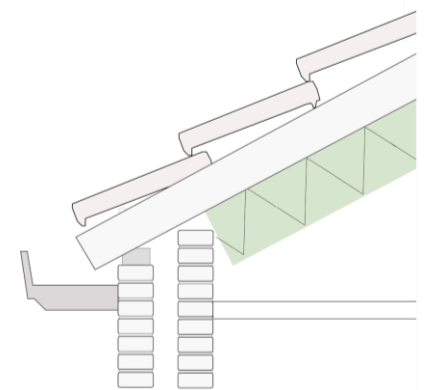
Roof



Attic floor
€22 / m²



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



[€/dwelling]

Medium improvement
High improvement

€447
€1560

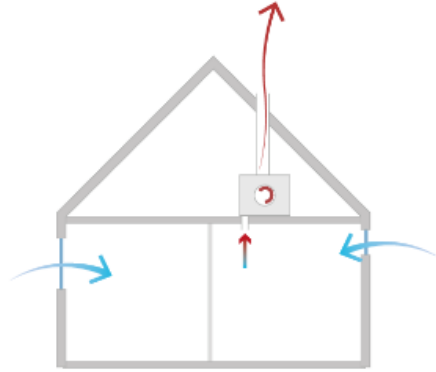
Air
tightness

Cost analysis – selected measures

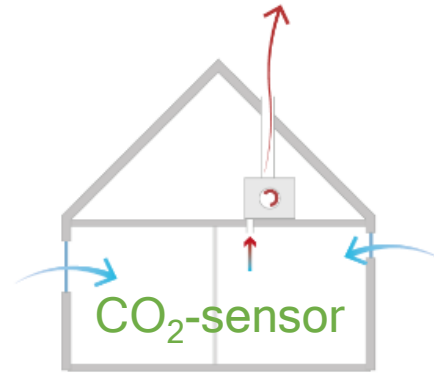


Installation scale

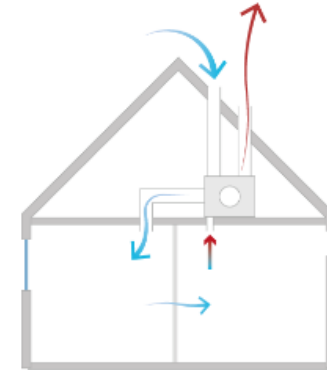
Ventilation



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

LT-Ready
concepts

1



(Re)place ventilation system

2

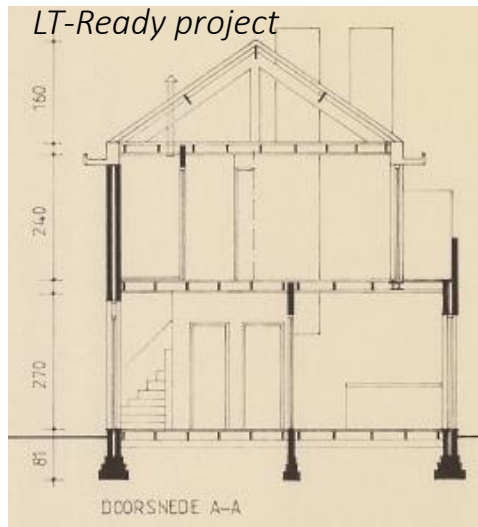


Additional measures to enable LT-heating

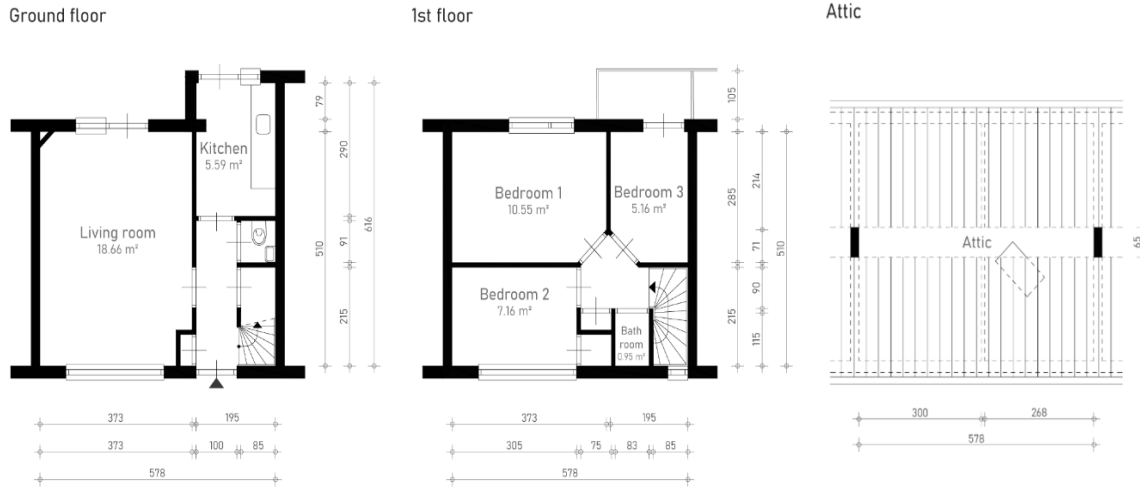
Within a budget of €10,000

Case study

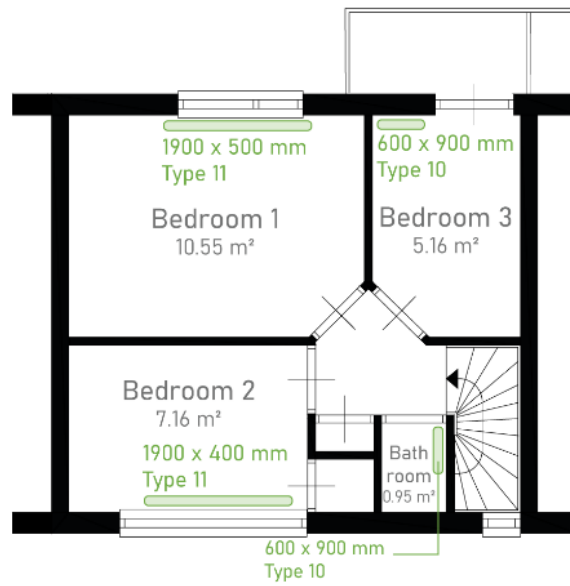
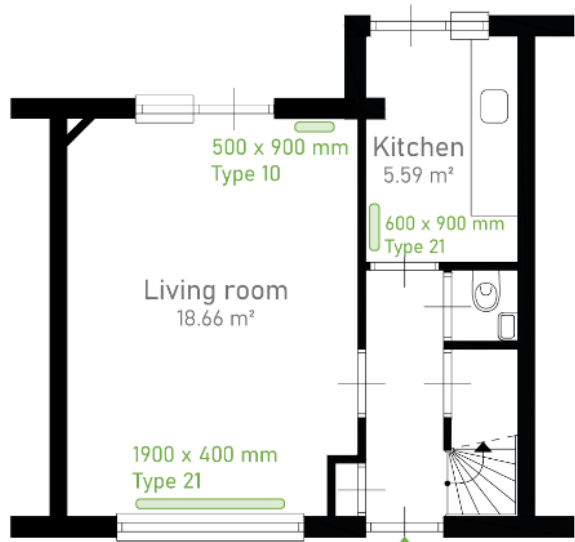
	R_c -value	U-value
Wall (cavity 7 cm)	0.70	1.44
Ground floor	0.64	1.57
Roof (outdated insulation)	1.74	0.58
Windows		2.40



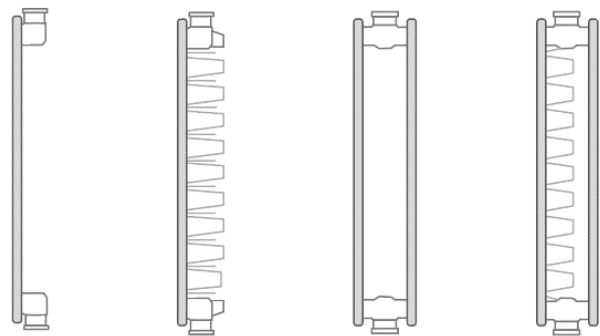
LT-Ready project



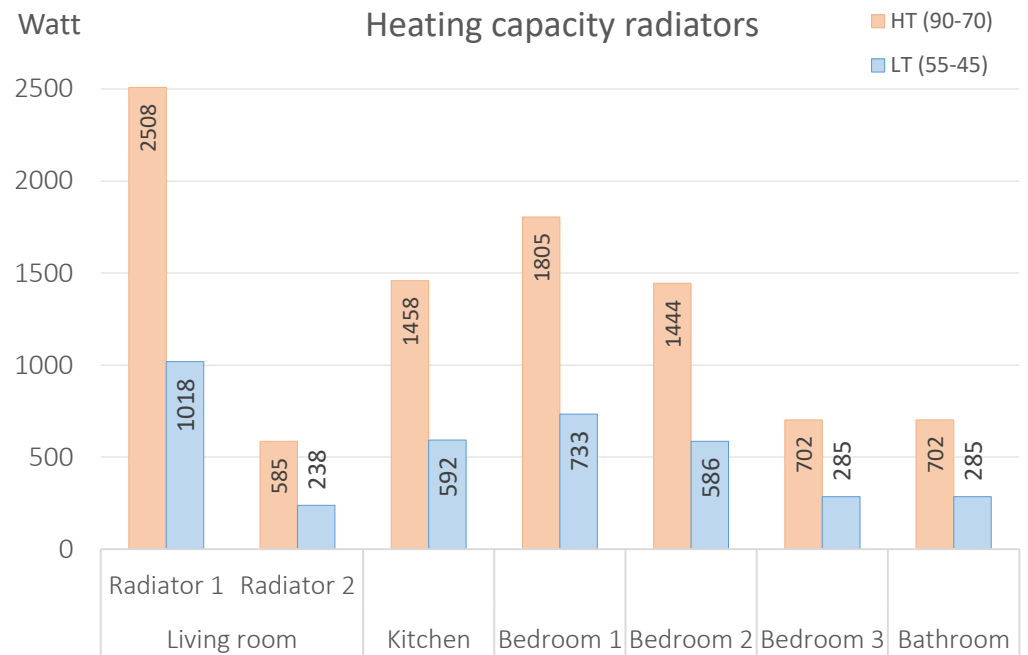
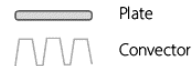
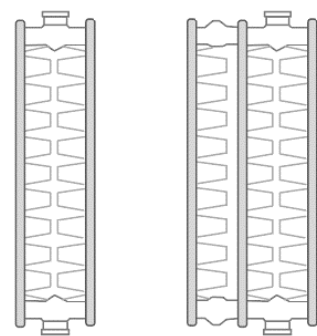
Case study – Heating system



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

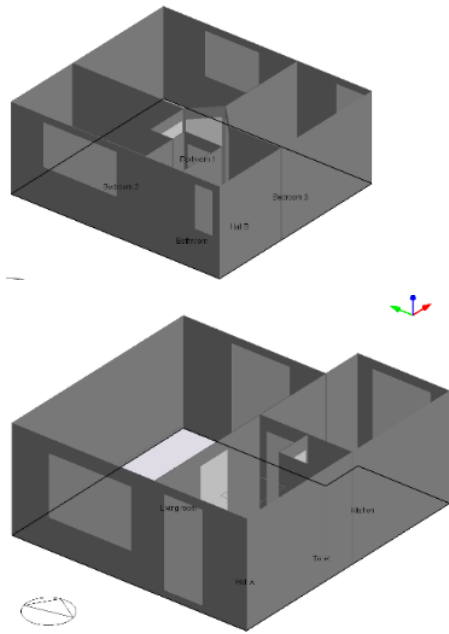


- Type 22**
2 plates
2 convectors
- Type 33**
3 plates
3 convectors

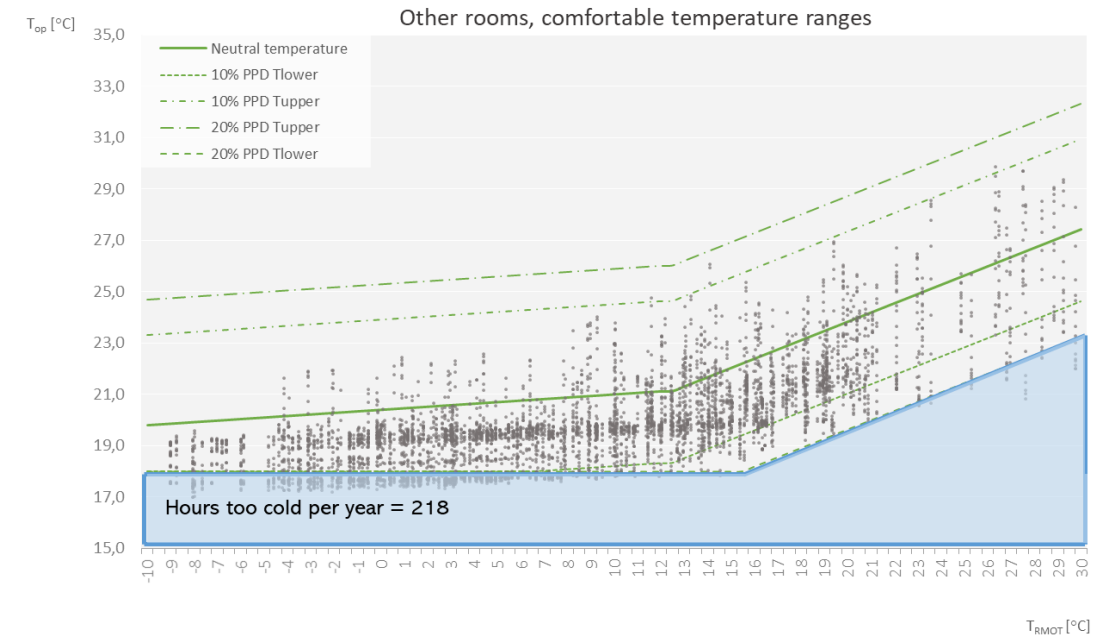


Thermal comfort evaluation

Dynamic simulations



- Determine hours **too cold** per year
- Adaption of ATG-method for dwellings



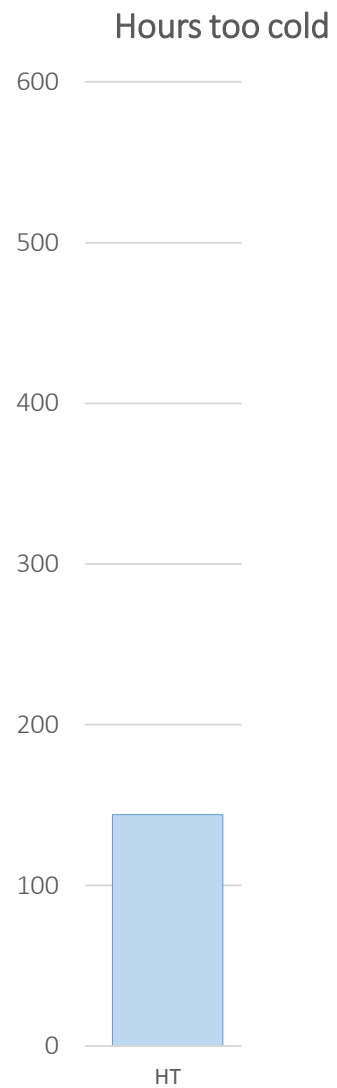
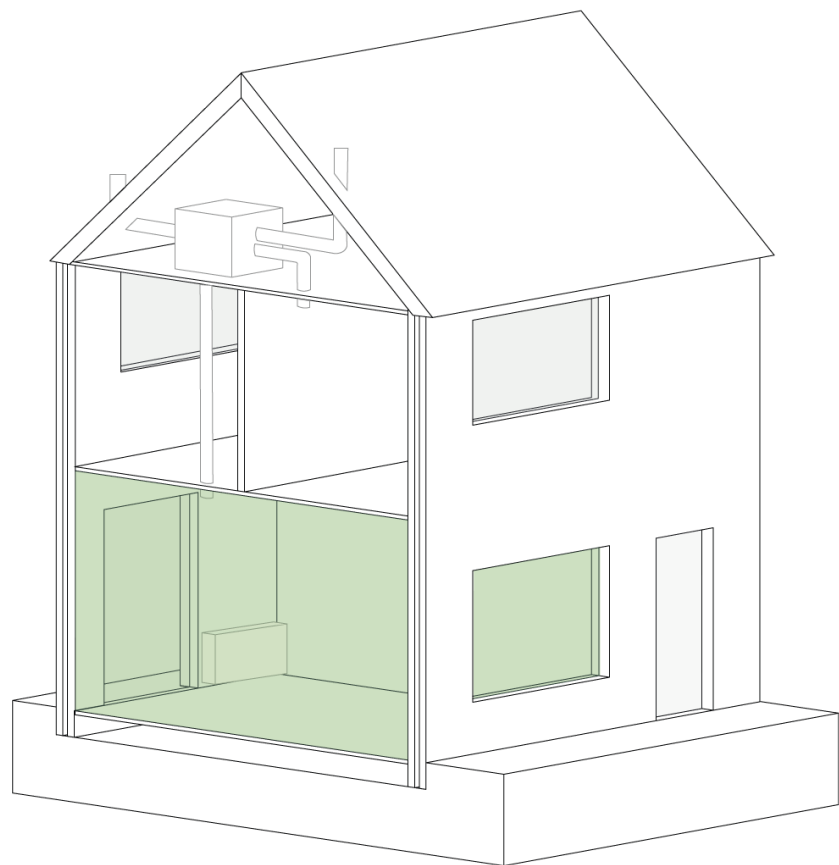
Thermal comfort evaluation

Original situation

HT (90-70) heating

144 hours too cold in living room

147.2 kWh/m²



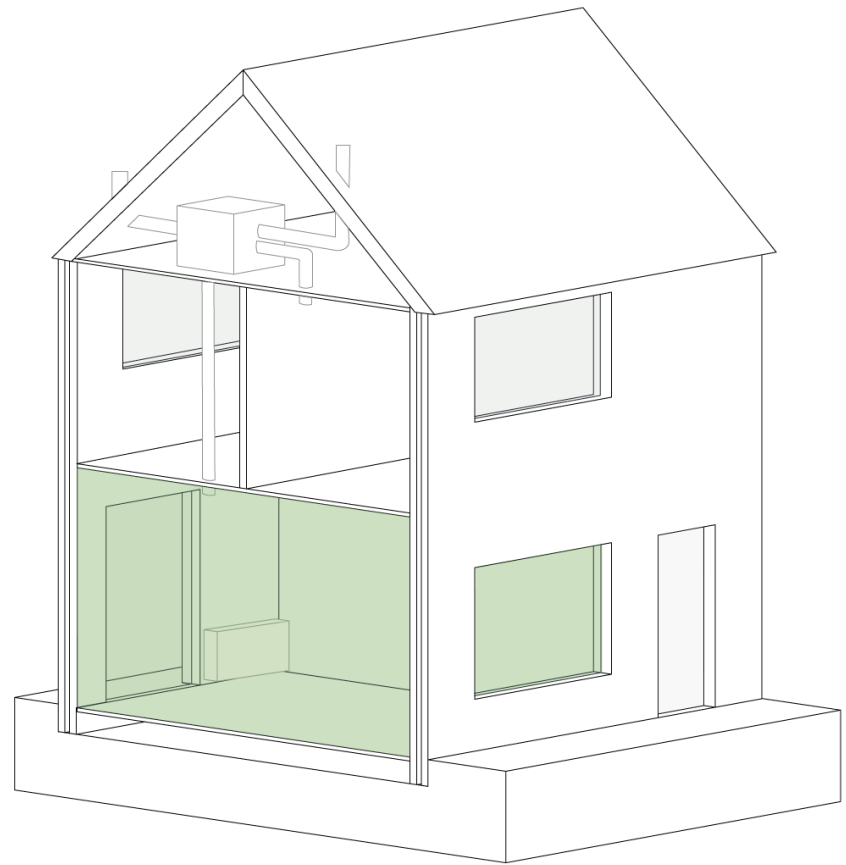
Thermal comfort evaluation

Original situation

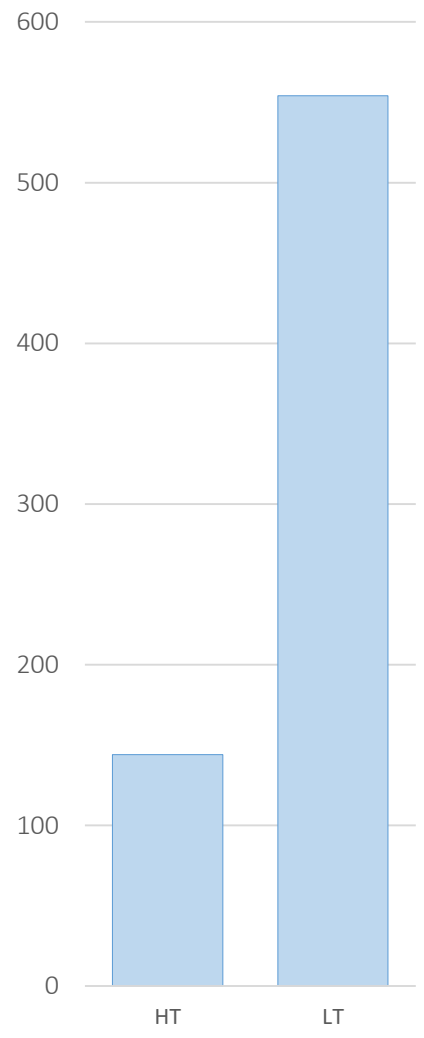
HT (90-70) heating

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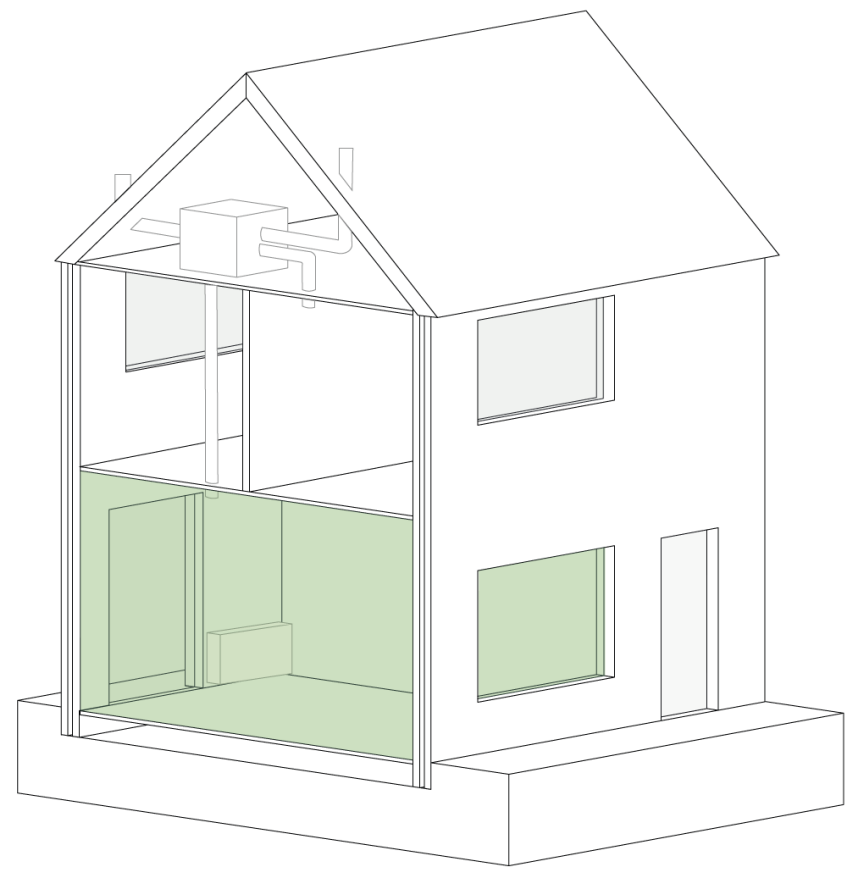
Hours too cold



LT (55-45) heating

554 hours too cold in living room

137.1 kWh/m²



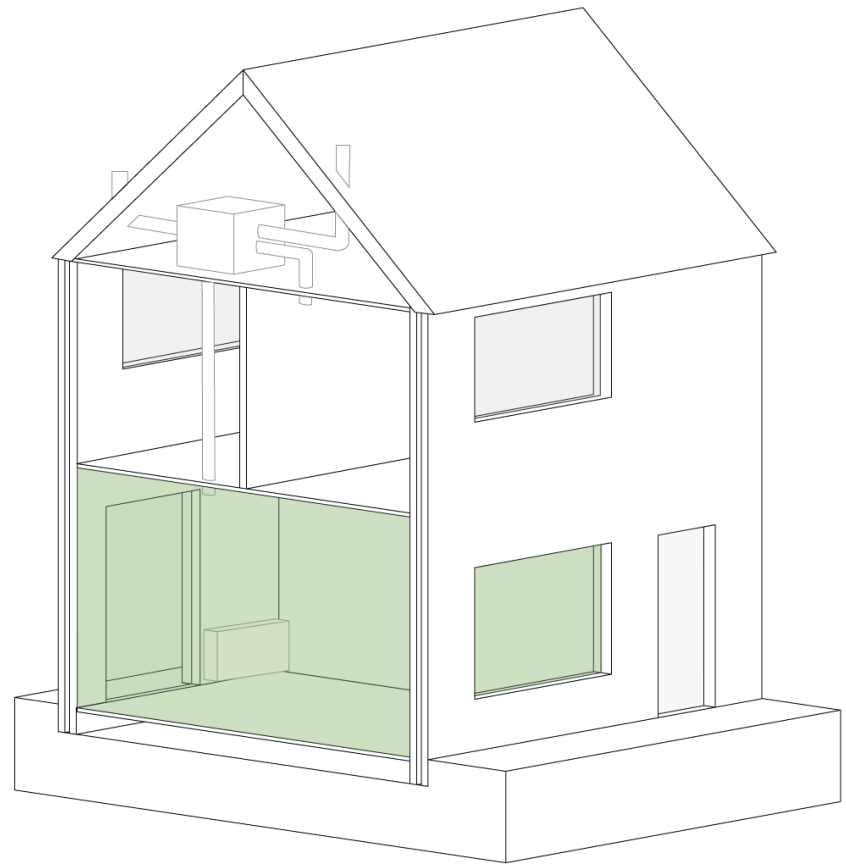
Thermal comfort evaluation

Original situation

HT (90-70) heating

144 hours too cold in living room

147.2 kWh/m²



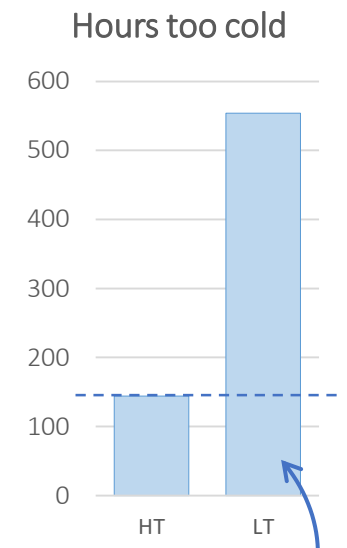
Compared to



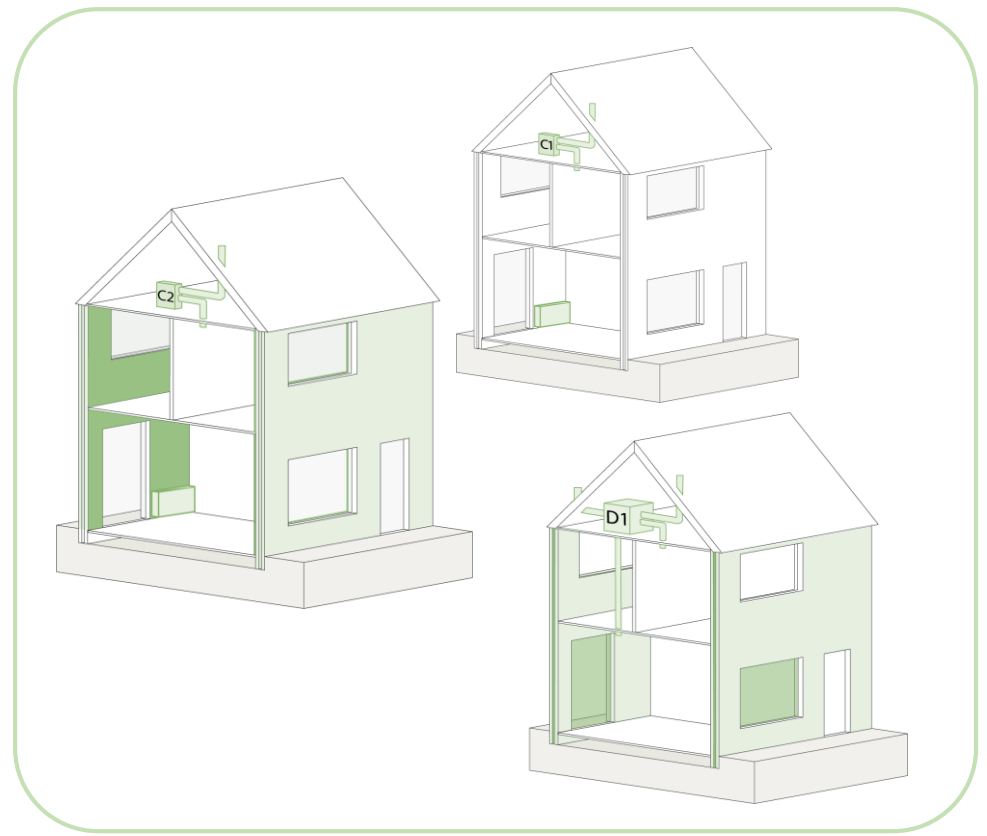
Renovation concepts

LT (55-45) heating

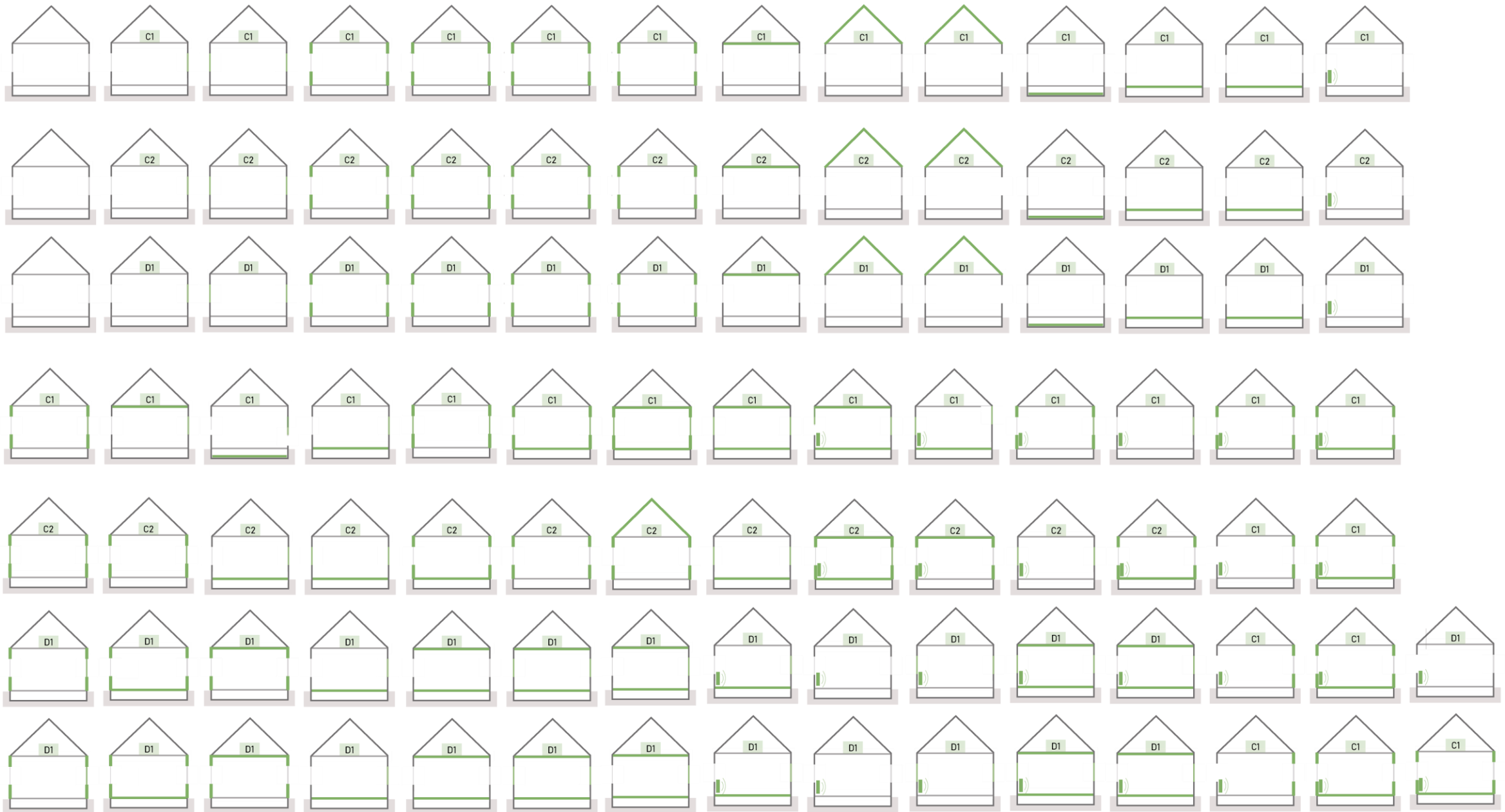
LT-Ready < 144 hours too cold in living room



LT-Ready!



Renovation scenarios Tested 100 concepts

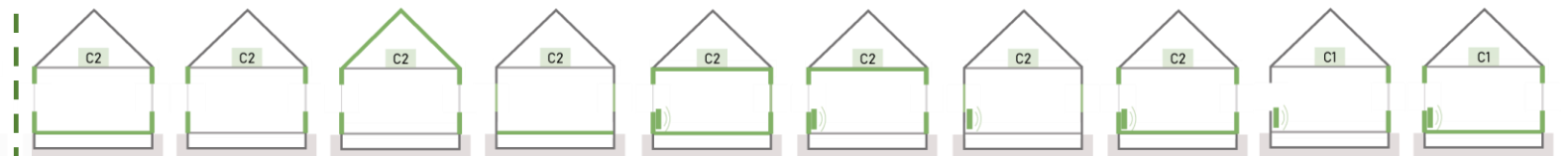


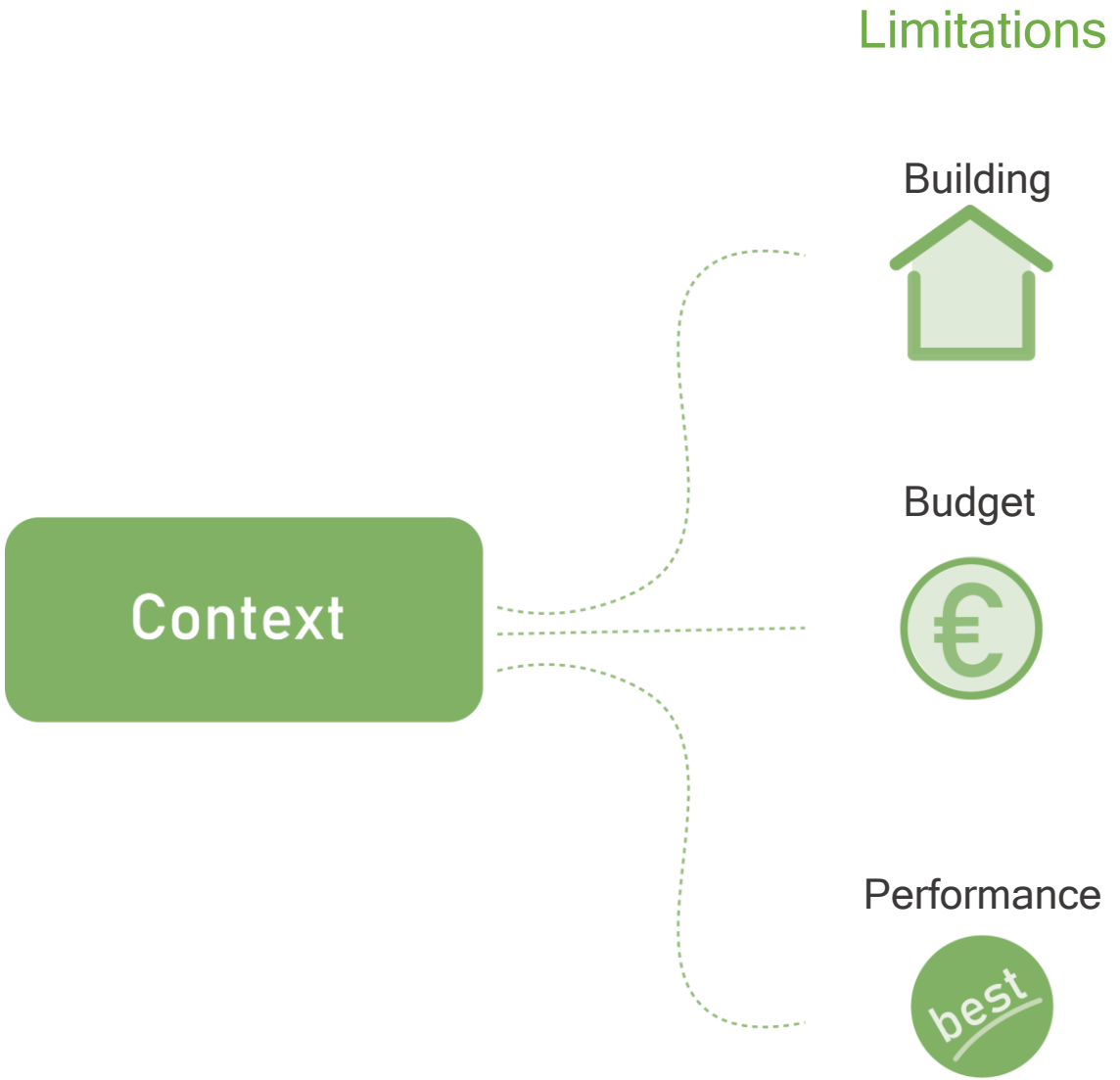
Renovation scenarios

Tested 100 concepts



LT-Ready: 40 concepts





Limitations

Building



Budget



Performance

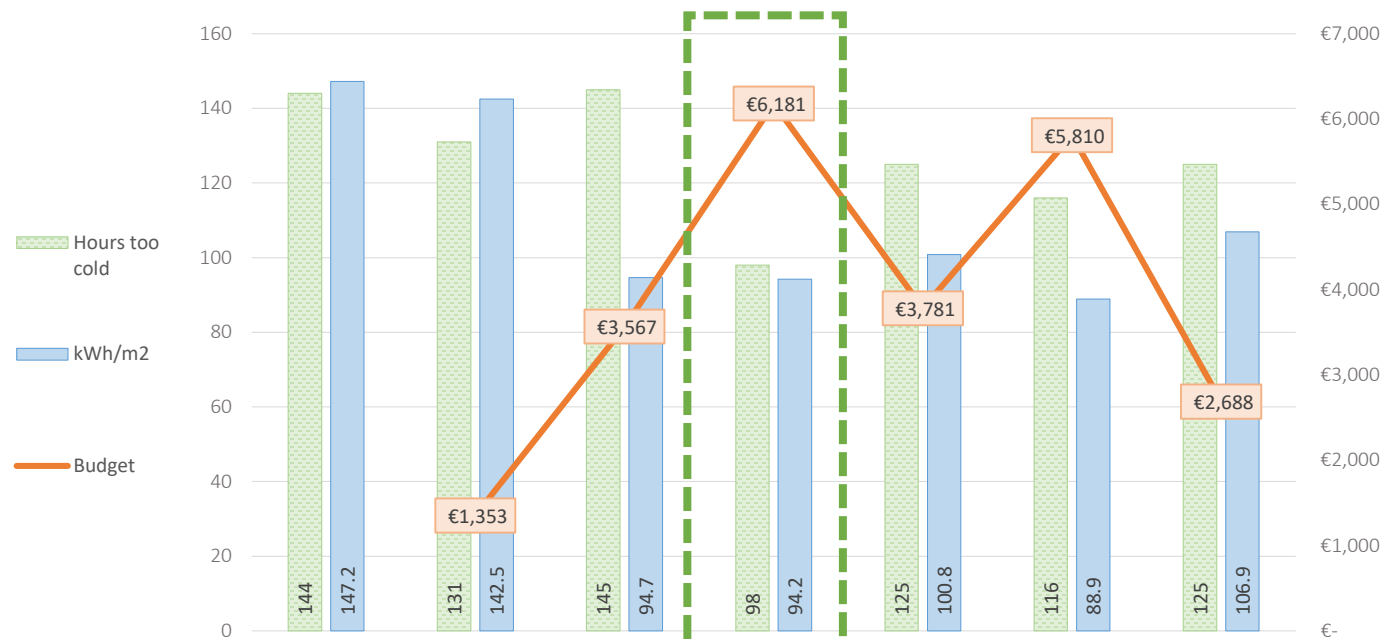


Renovation scenarios: Building limitations

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

→ However, other renovation concepts also possible!

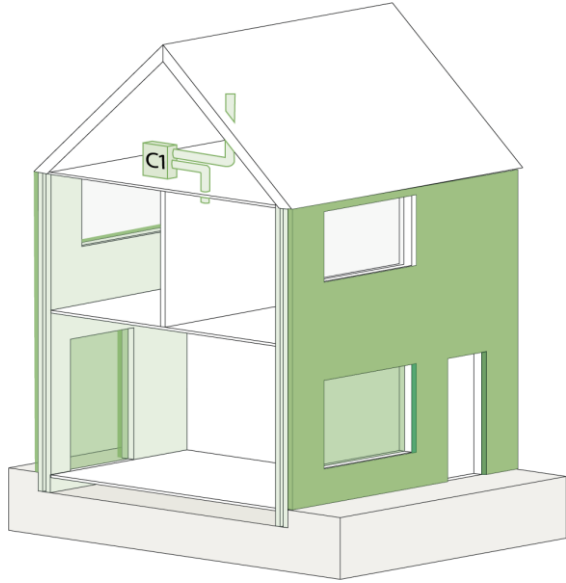
Already exhaust ventilation (C1) installed



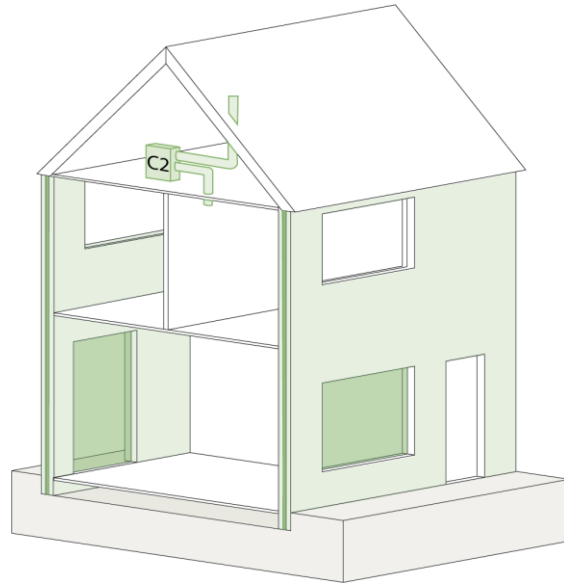
Option	Original	C1.5	C1.6a	C1.6b	C1.6c	C1.6d	C1.6e
Ventilation system	C1	C1	C1	C1	C1	C1	C1
Windows	Double gl.	Double gl.	HR++ (living)	HR++ (living)	HR++ (living)	HR++ (living)	HR++ (living)
Wall	Original	Original	Interior (R _c =2.8)	Exterior	Cavity	Cavity	Cavity
Roof	Original	Original	Original	Original	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

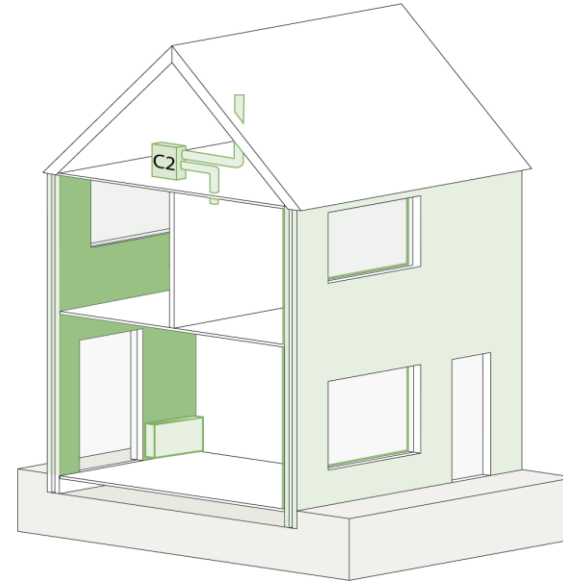
Already C1



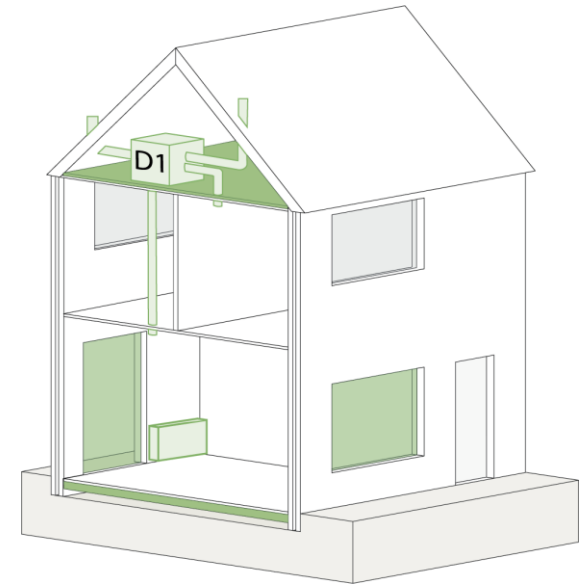
No space for D1



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

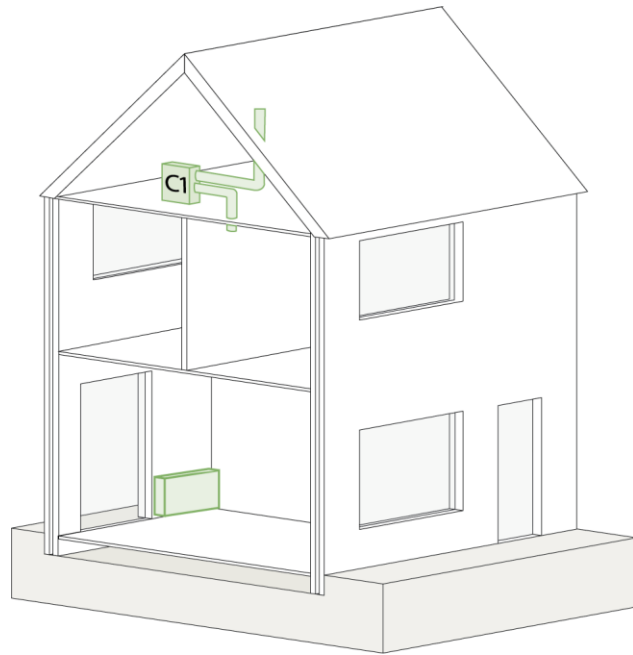
Budget: €9,603

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

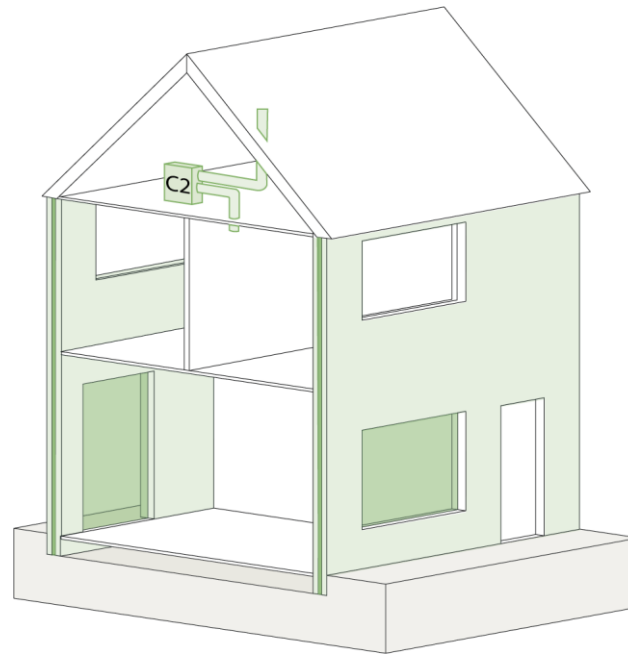


Budget: €3,638

Exhaust ventilation (C1)
LT-radiator

131 hours too cold
142.5 kWh/m²

€5,000 - €7,500

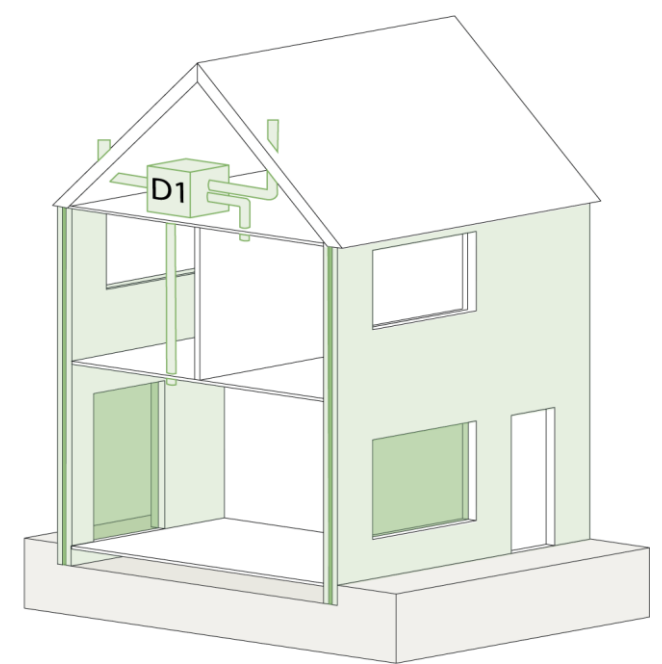


Budget: €6,795

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

69 hours too cold
85.3 kWh/m²

> €7,500



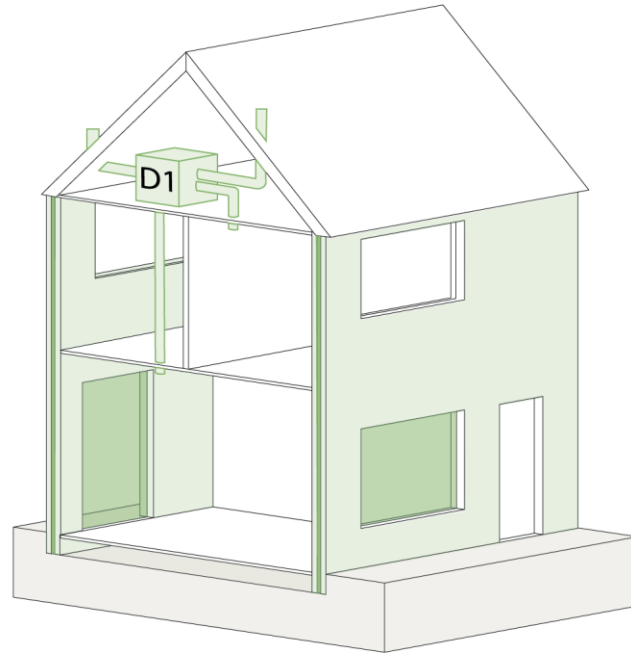
Budget: €8,641

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

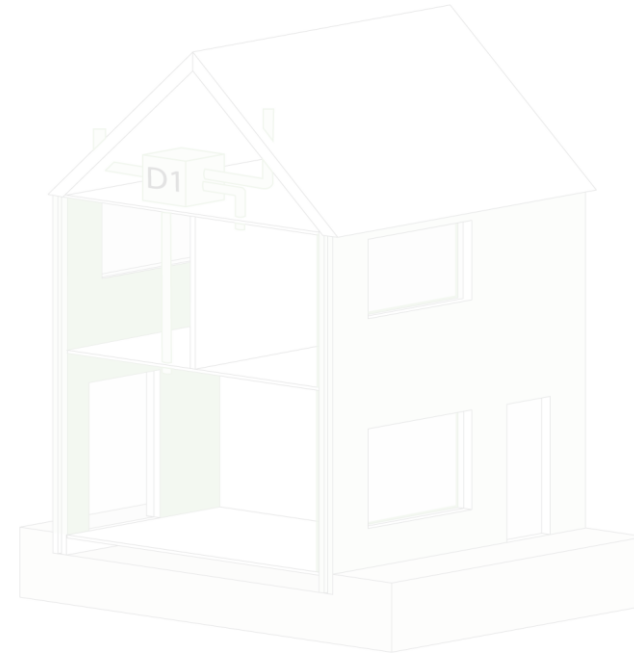


Budget: €8,641

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) +

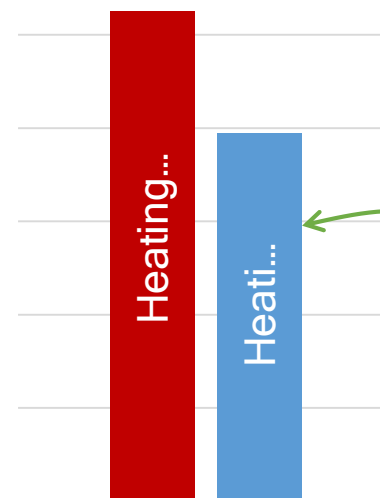
Variants

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

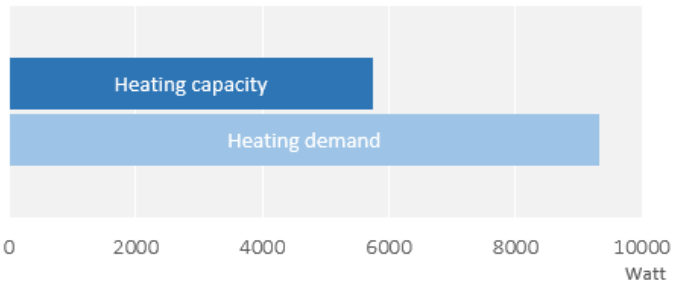
Case study dwelling → Dynamic simulations



Other dwellings → more general approach

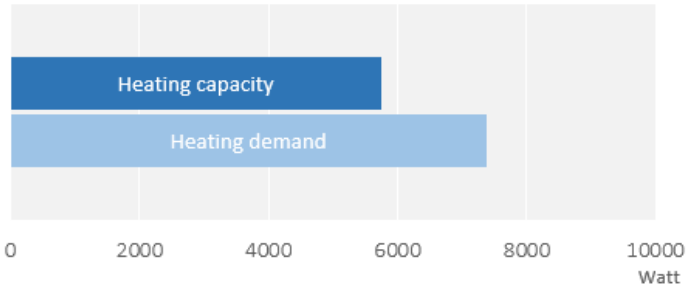


Not LT-READY



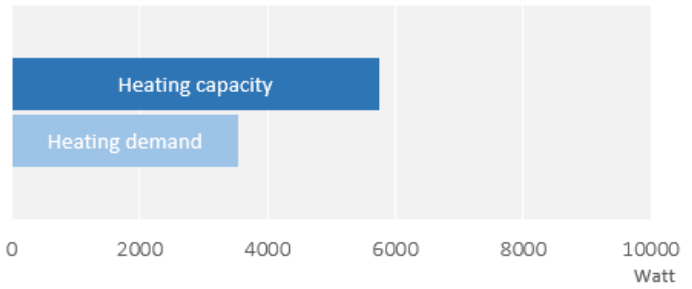
> 1.5 x heating capacity
Not LT-Ready for large part of the year

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

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.

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.

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.

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.

Heating capacity: ~3000
Heating demand: ~2500

Buttons: LT-READY, Almost LT-READY, Not LT-READY

Bottom tabs: Info, Radiators, Original, Concept1, Concept2, Concept3, Comparison, Measures, Cost analysis, Blad2

Bottom left: Gereed

Bottom right: 100%

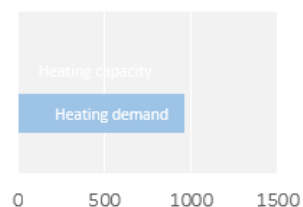
LT-READY Calculation sheet

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.
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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
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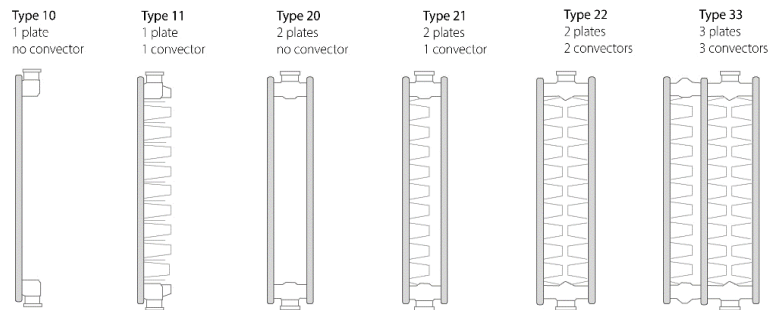


Measure height and width of radiators

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.

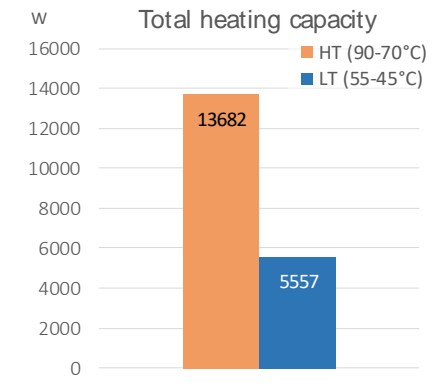
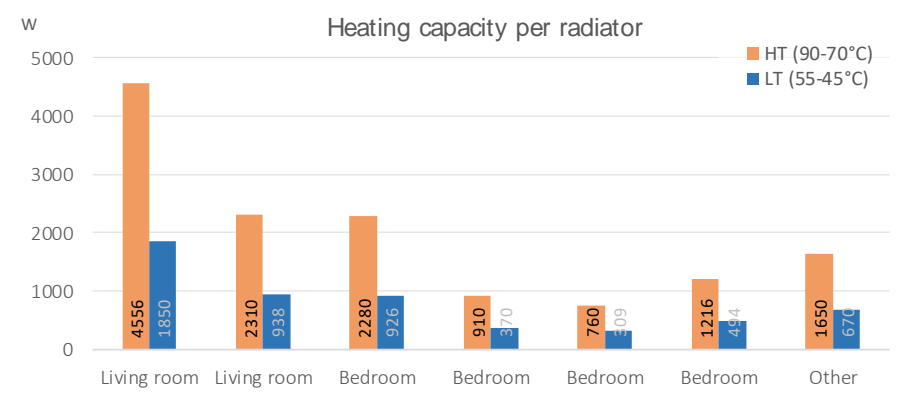


Setpoint temperature	20	°C
LT supply temperature	55	°C
LT return temperature	45	°C

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
	4556 W	1850 W	2310 W	938 W	2280 W	926 W	910 W	370 W	760 W	309 W
	1216 W	494 W	1650 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:

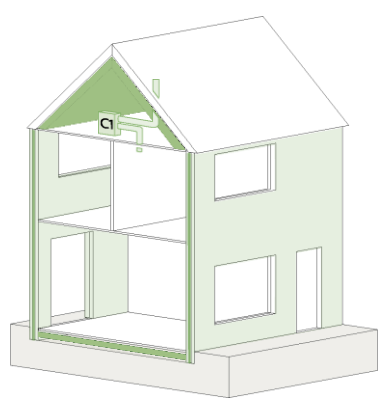
- Envelope areas and properties
- Air tightness

Original situation

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

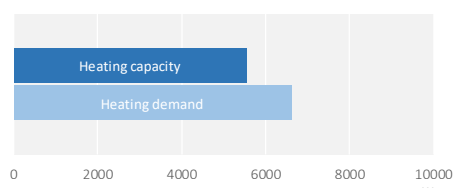
Total floor area	135 m ²
Floor area living room	51 m ²

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

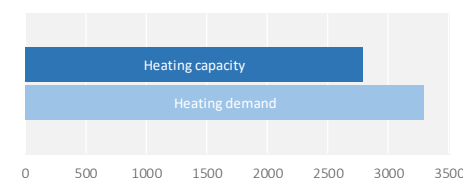


Dwelling	Living room
Heating capacity LT	2789 W
Heating demand	3297 W

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

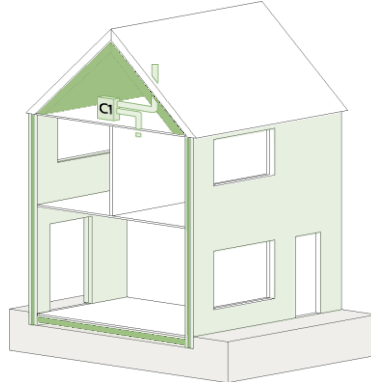
Tool – original situation

Original situation

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

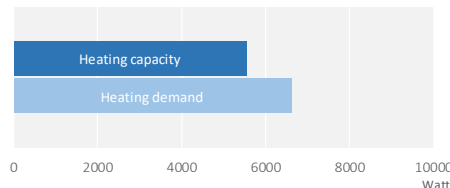
Total floor area		135 m ²
Floor area living room		51 m ²

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: 15
	Separation wall with neighbours: 120
	Adjacent to living room: 38
	Interior walls adjacent to living room: 17
Roof	
Roof insulation	79
	Roof: 79
	Adjacent to living room: 10
	Attic: 0
Floor	
Floor insulation below floor	58
Ventilation	Exhaust ventilation (C1)
Air tightness	Medium
Heating	Radiators

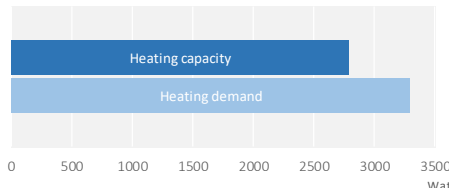


Category	Heating capacity LT	Heating demand
Dwelling	5557 W	6608 W
Living room	2789 W	3297 W

Almost LT-READY



Almost LT-READY



Calculates heating demand
Compared with LT heating capacity

Try different renovation concepts

Calculates estimated investment

Concept 1

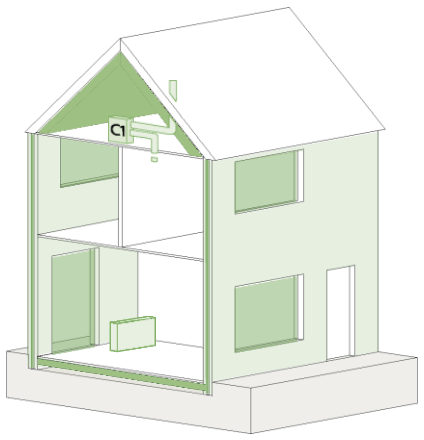
Renovation concepts can be tested to by changing the green boxes. The grey boxes cannot be changed. This results in the estimated costs for a renovation and the estimation if the dwelling is LT-Ready or not.

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



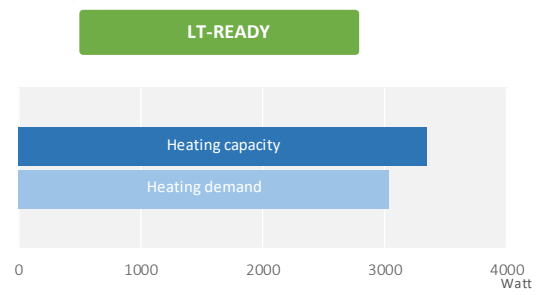
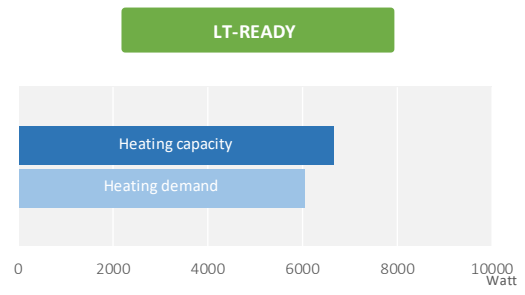
Estimated investment € 3.211



Dwelling
 Heating capacity LT 6668 W
 Heating demand 6033 W



Living room
 Heating capacity LT 3346 W
 Heating demand 3035 W



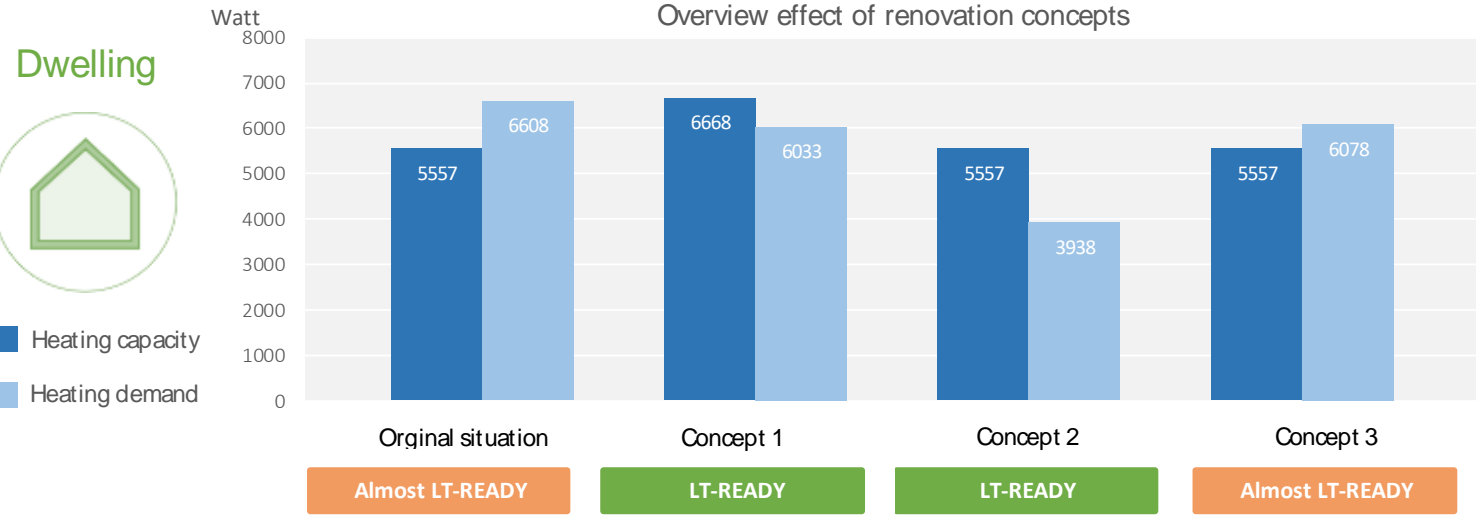
Compare renovation concepts

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?

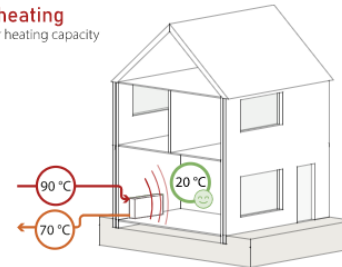
With low-temperature heating, the supply temperature of the central heating system lies is 55 °C or lower, instead of using a supply temperature of 90 to 70 °C as with traditional heating.

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.

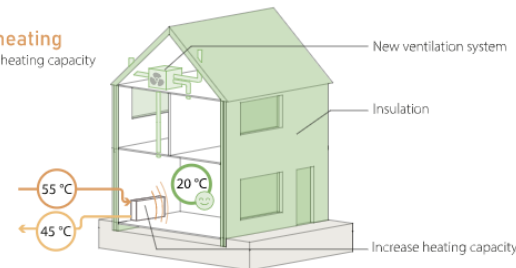
Why low-temperature heating?

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



Download tool!



Link: www.ltreadytool.nl

LT-READY:

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

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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 the transition from High-Temperature (HT) heating to Low-Temperature (LT) heating. The top part shows a house with HT-heating, where the supply temperature is 90°C and the return is 70°C, resulting in a higher heating capacity. The bottom part shows a house with LT-heating, where the supply temperature is 55°C and the return is 45°C, resulting in a lower heating capacity. To compensate for this, the house is shown with a new ventilation system, insulation, and an increase in heating capacity.



Thank you!

Contact:
sru@dgmr.nl