Cost-effective passive house renovations of Swedish single-family houses

- A methodology discussion

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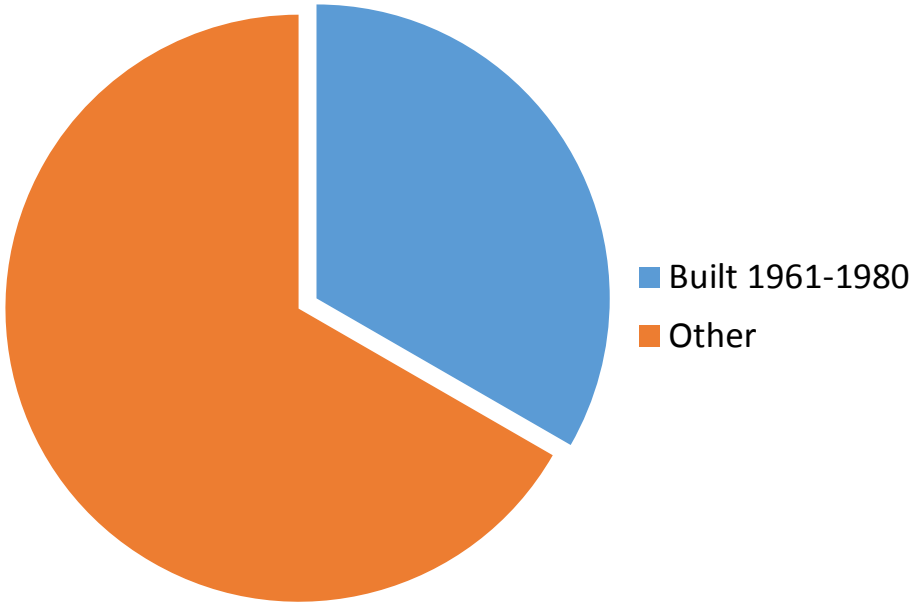
Background

Single-family houses

- Built 1961-1980
- High energy use
- Need of renovation
- Built standardized

Share of total two million single-family houses (2012)



Building energy simulations

IDA ICE

Energy demand/Energy use

Energy prices

Operational cost

Cost-effective	**Passive house renovation**	**of**	**Single-family houses**
Life-cycle costs	Requirements		Case study
Investment cost	Renovation measures		Typology
Operational cost	Material cost		Structures
Maintenance cost	Labour cost		HVAC
Net-present value	Investment cost		Reference houses
Internal rate of return			Renovation need

Method - Overview

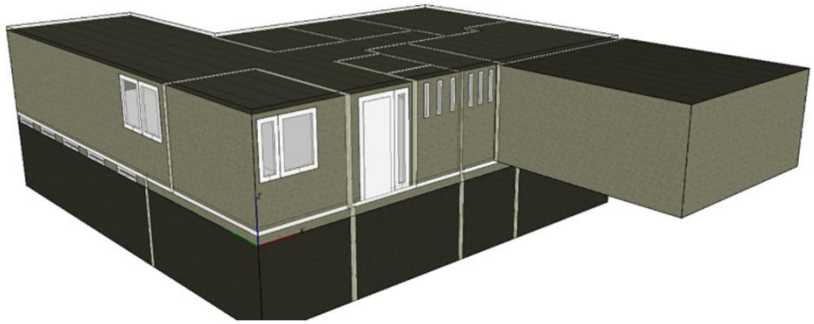
Cost-effective passive house renovation of Swedish single-family houses

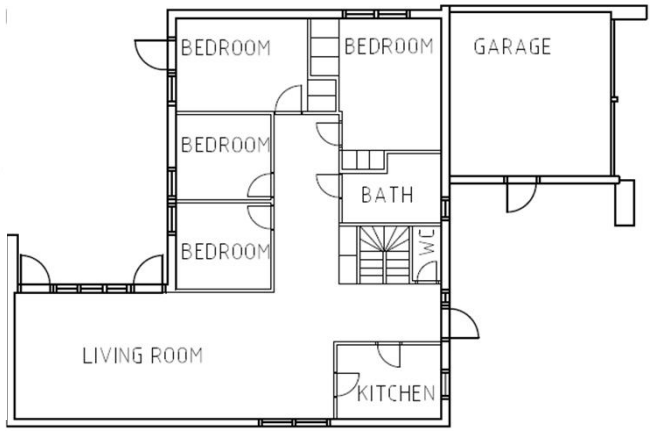
Software

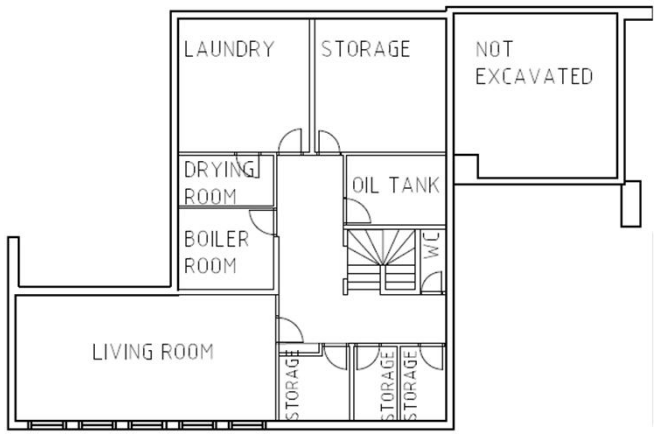
Software

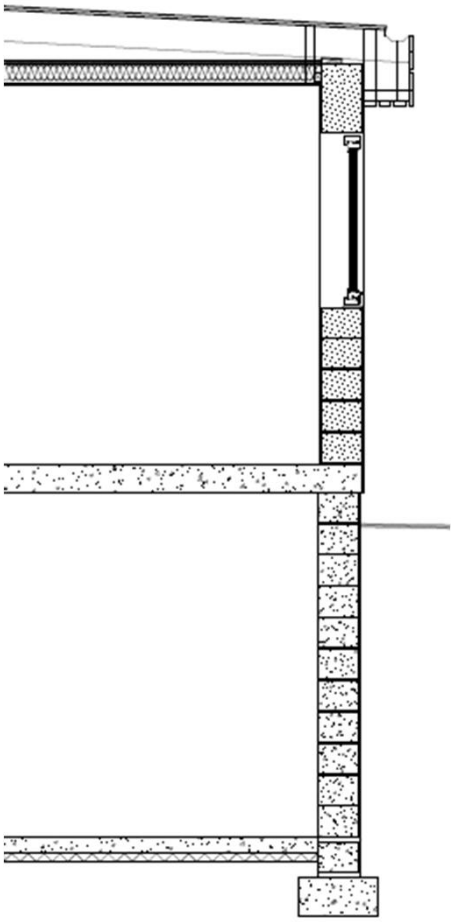
Case study

Reference house 1









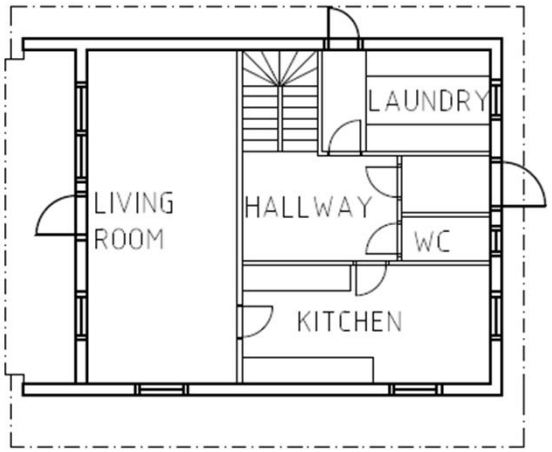
Year built:	1965
Heated floor area:	230 m^2
Ventilation:	Passive stack

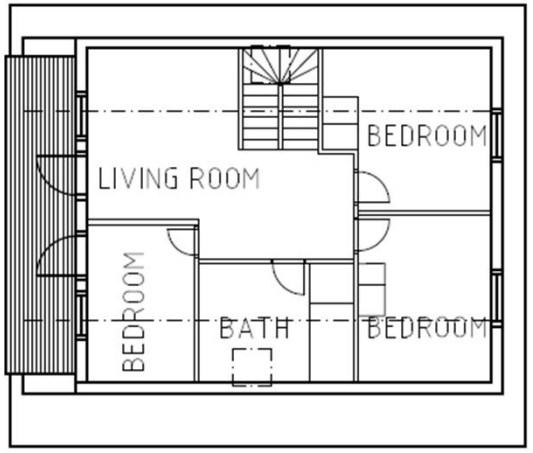
Lightweight concrete walls,
concrete slab foundation

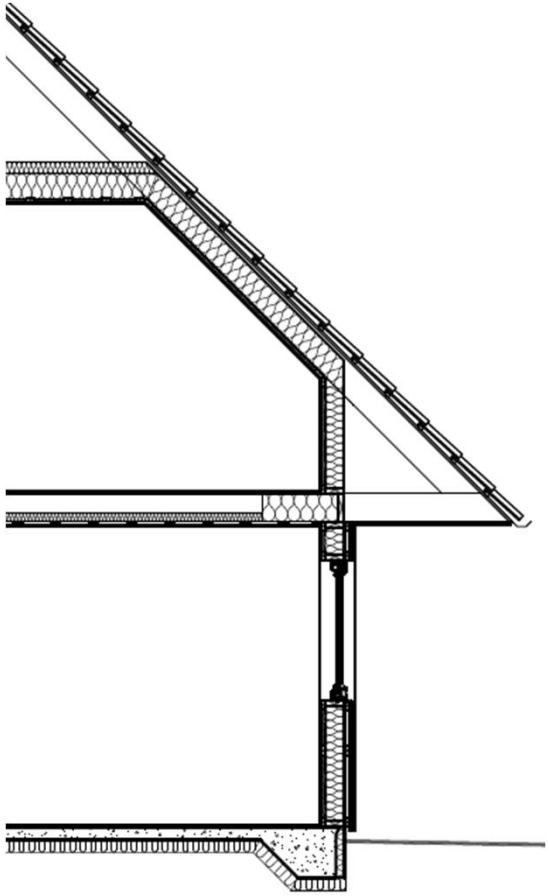
Reference house 2

Year built: 1977
Heated floor area: 142 m^2
Ventilation: Balanced, heat recovery

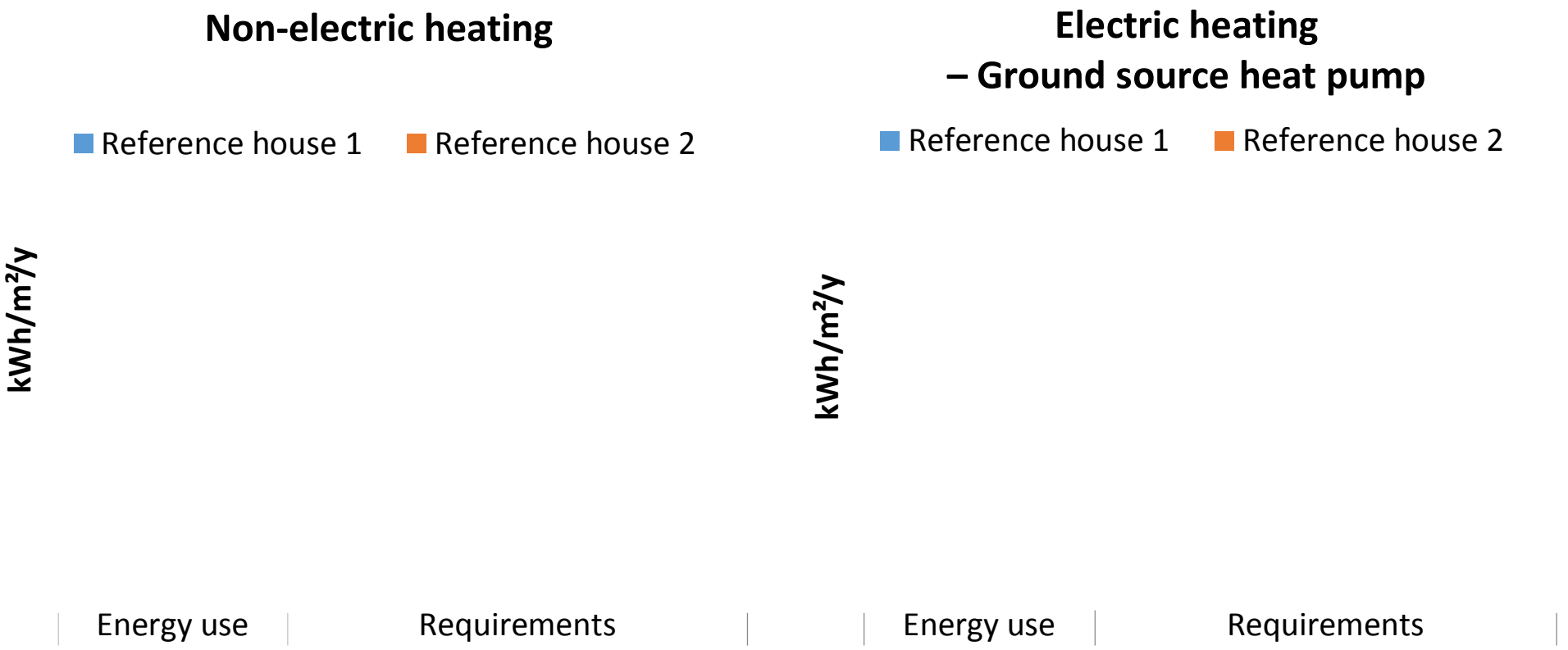
Stud framework walls - intermediate mineral wool, concrete slab foundation







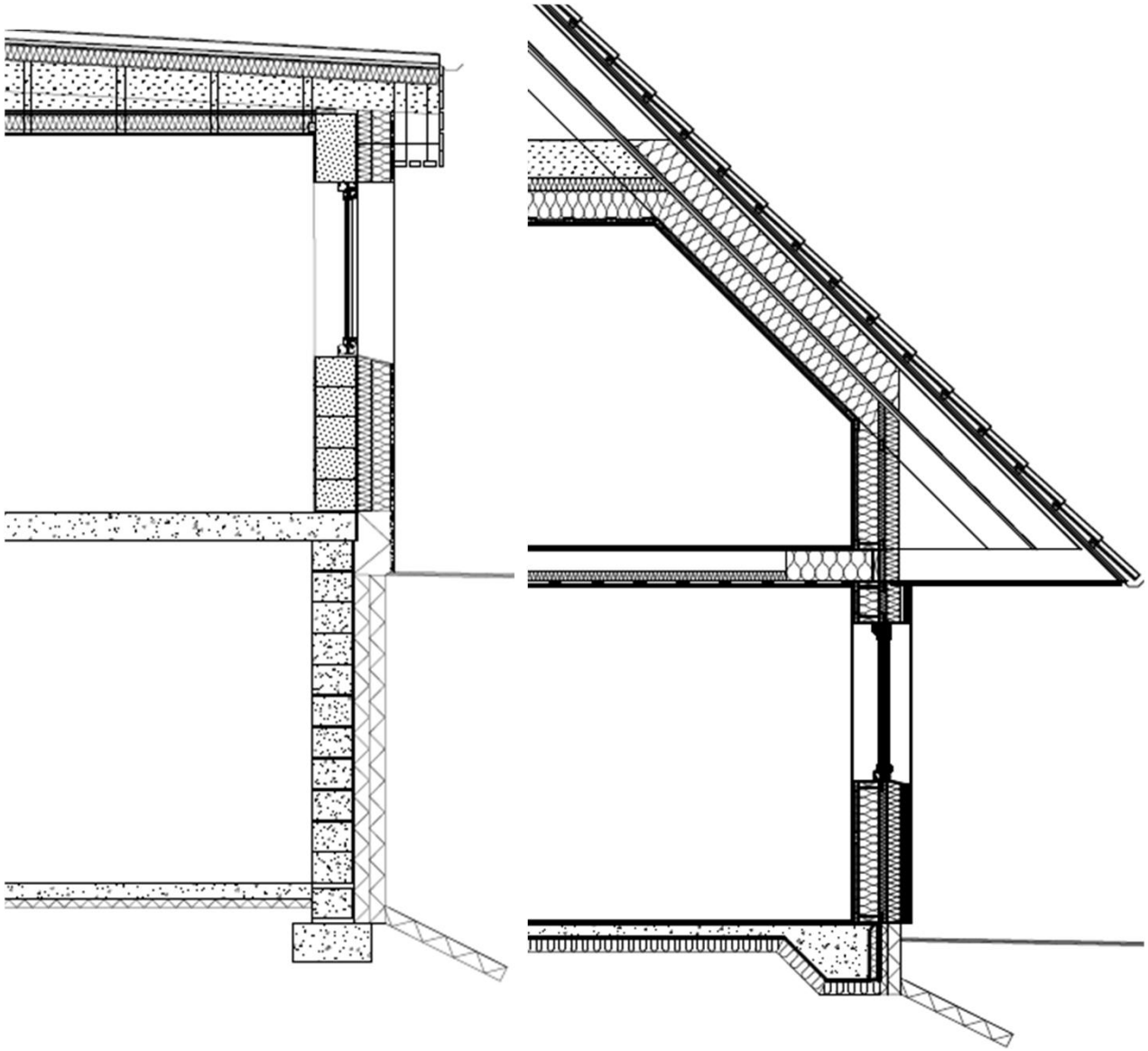
Energy use & requirements



Passive house renovation

Renovation measures

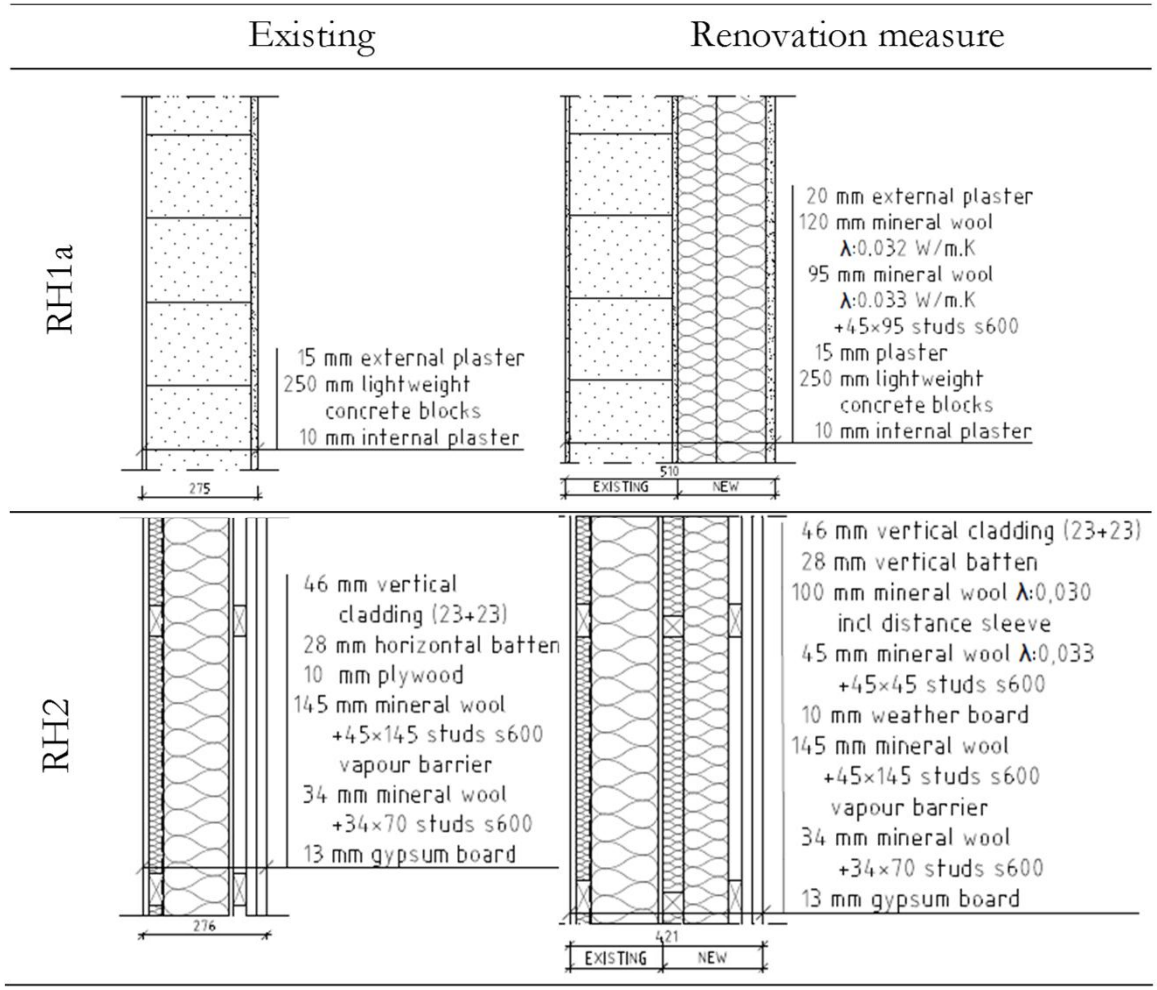
- Foundation
- External walls
- Windows & doors
- Roof



Passive house renovation

Renovation measures

- External walls



Renovation measure - Installations

Ventilation systems

- Balanced, with heat recovery
- Exhaust air heat pump

Heat generation and distribution

- Direct electric heating
- Electric heating
- Heat pumps
  - Ground source
  - Exhaust air
- Pellet
- District heating

Local renewable energy production systems

Solar domestic hot water (SDHW)

- 50 % of annual DHW

Photovoltaic (PV)

- **P3.** Cost-effective installations
  - Optimize tilt & orientation
- **P4.** Total annual demand
  - NZEB
- **P3.** Energy storage
  - Batteries

Cost-effective evaluation

$$LCC_{total} = C_{investment} + C_{operation} + C_{maintenance}$$

Software: BELOK Totaltool 2

Input data

Marginal costs	
Real interest rate	2%
Service life	
• Installations	20 years
• Building envelope	40 years
Energy prices	
• Annual average price	
• Price increase over inflation	0%

Renovation packages

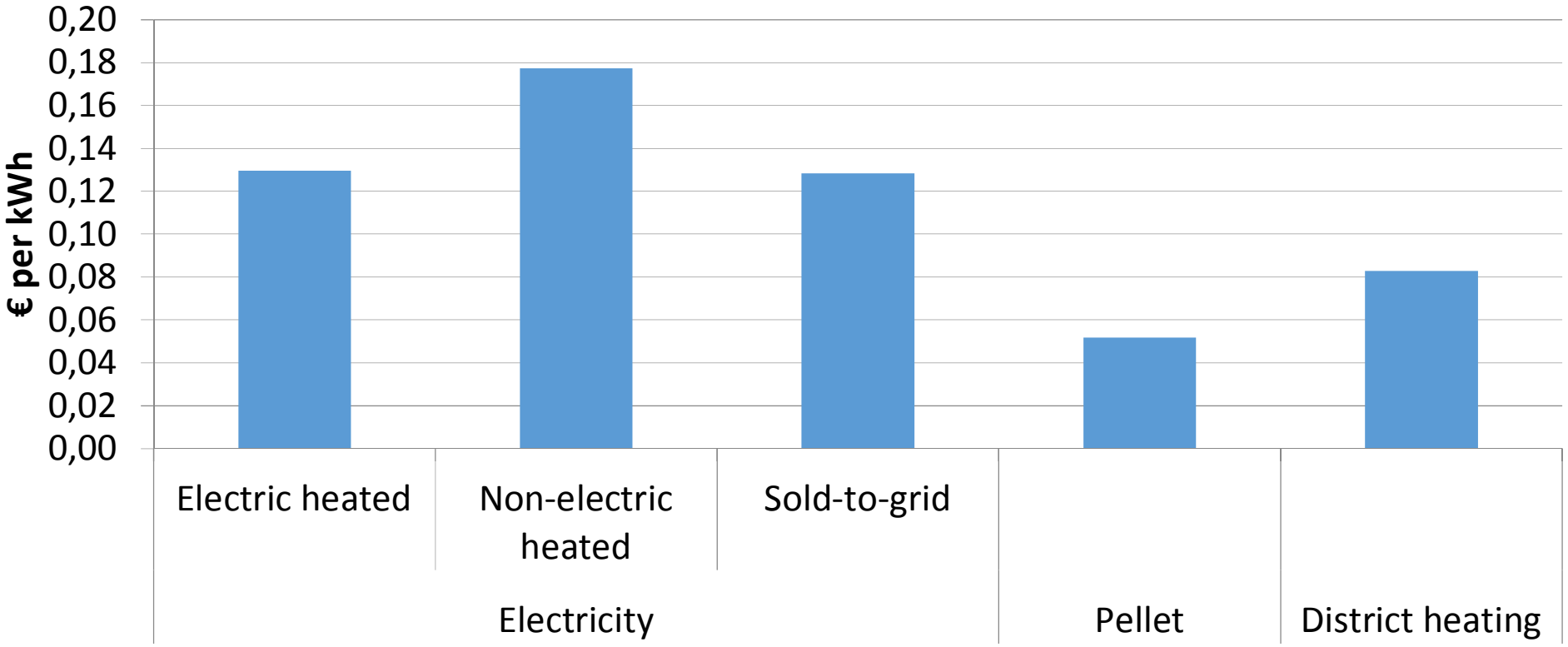
Renovation levels

1. Minimum level (Min.)
2. Building regulation level (BR)
3. Passive House level (PH)

Results

- Annual energy cost
- Investment cost
- Life-cycle cost
  - Net-present value
  - Internal rate of return

Energy prices – Annual average



Annual energy cost

		Reference house 1 (€ per year)			Reference house 2 (€ per year)		
Renovation level		1. Min.	2. BR	3. PH	1. Min.	2. BR	3. PH
Heat generation systems	Direct electric heating	5 580	3 030	1 630	3 800	2 500	1 310
	GSHP	1 510	880	**570**	1 200	750	**480**
	ASHP	2 690	1 050	**700**	2 210	1 240	730
	Pellet-fired boiler	2 740	1 460	**830**	1 920	1 310	670
	District heating	3 650	1 960	**1 080**	2 520	1 690	880

Results – Net present value & annual operational costs

Heat generation systems	Renovation level		Reference house 1-230 m²			Reference house 2-142 m²			Units
			Minimum	BR	PH	Minimum	BR	PH	
	Direct electric heating	Investment cost	-	31 300	48 300	-	24 000	39 700	€
		Net Present Value	-	- 44 100	- 61 300	-	- 11 600	- 27 500	€
		Internal rate of return	-	8.5	7.6	-	4.5	5.0	%
	GSHP	Investment cost	15 800	44 800	59 800	15 400	37 500	51 300	€
		Net Present Value	- 87 300	- 85 800	- 74 000	- 47 000	- 37 300	- 31 100	€
		Internal rate of return	24.0	10.0	7.3	14.2	5.8	4.3	%
	EAHP	Investment cost	9 900	41 200	53 100	9 900	33 900	43 800	€
		Net Present Value	- 65 300	- 88 100	- 82 900	- 46 500	- 48 500	- 45 000	€
		Internal rate of return	28.0	10.9	8.6	20.8	7.6	6.1	%
	Pellet-fired boiler	Investment cost	-	31 300	48 300	-	34 300	39 700	€
		Net Present Value	-	- 4 100	- 2 800	-	18 900	6 100	€
		Internal rate of return	-	2.7	2.0	-	- 1.6	0.3	%
	District heating	Investment cost	-	31 300	48 300	-	24 000	39 700	€
		Net Present Value	-	- 16 800	- 21 400	-	1 300	- 4 600	€
		Internal rate of return	-	4.7	4.0	-	1.7	2.0	%

Renewable energy - Results

	Heat generation		Reference house 1 Investment cost (€)	Reference house 1 NPV (€)	Reference house 1 IRR (%)	Reference house 2 Investment cost (€)	Reference house 2 NPV (€)	Reference house 2 IRR (%)
SDHW	Direct electric heating		5 500	1 670	3.3	5 500	- 820	0.5
	Pellet-fired boiler		5 500	- 3 050	- 2.6	5 500	- 4 200	- 4.8
	District heating		5 500	- 1 540	- 0.4	5 500	- 3 130	- 2.8
PV	Non-electric	Without batteries	11 400	3 390	5.2	11 900	4 000	5.6
		14 kWh battery	14 500	1 810	3.2	15 000	2 570	3.7
	GSHP	Without batteries	19 900	3 230	3.8	17 000	3 350	4.2
		14 kWh battery	23 000	110	2.0	20 100	270	2.1
	Electric heating	Without batteries	19 900	3 710	4.0	27 400	5 930	4.4
		14 kWh battery	23 000	700	2.3	30 400	2 910	3.0

Conclusions

- Energy use reduced cost-effective
  - Energy demand by 65%
  - Bought energy by up to 90%

- Depend on type of heat generation

- Investment cost increased by 100 000 to 150 000 SEK
  (PH to BR renovation)

Thank you!

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