

Renewable-based heat supply to a conventional and an energy-efficient multi-apartment building

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Aim

- Cost and primary energy analyses of renewable heating for
 - A conventional multi-apartment building
 - An energy efficient multi-apartment building

Heating options

- Electric heating with and without solar water heating (SWH)
 - Ground-source heat pump (EHP)
 - Resistance heater (ERH)
- Wood pellet boiler (WPB) with and without SWH
- District heating (DH)
 - Helsingborg (1100 GWh/yr)
 - Växjö (630 GWh/yr)
 - Ronneby (110 GWh/yr)



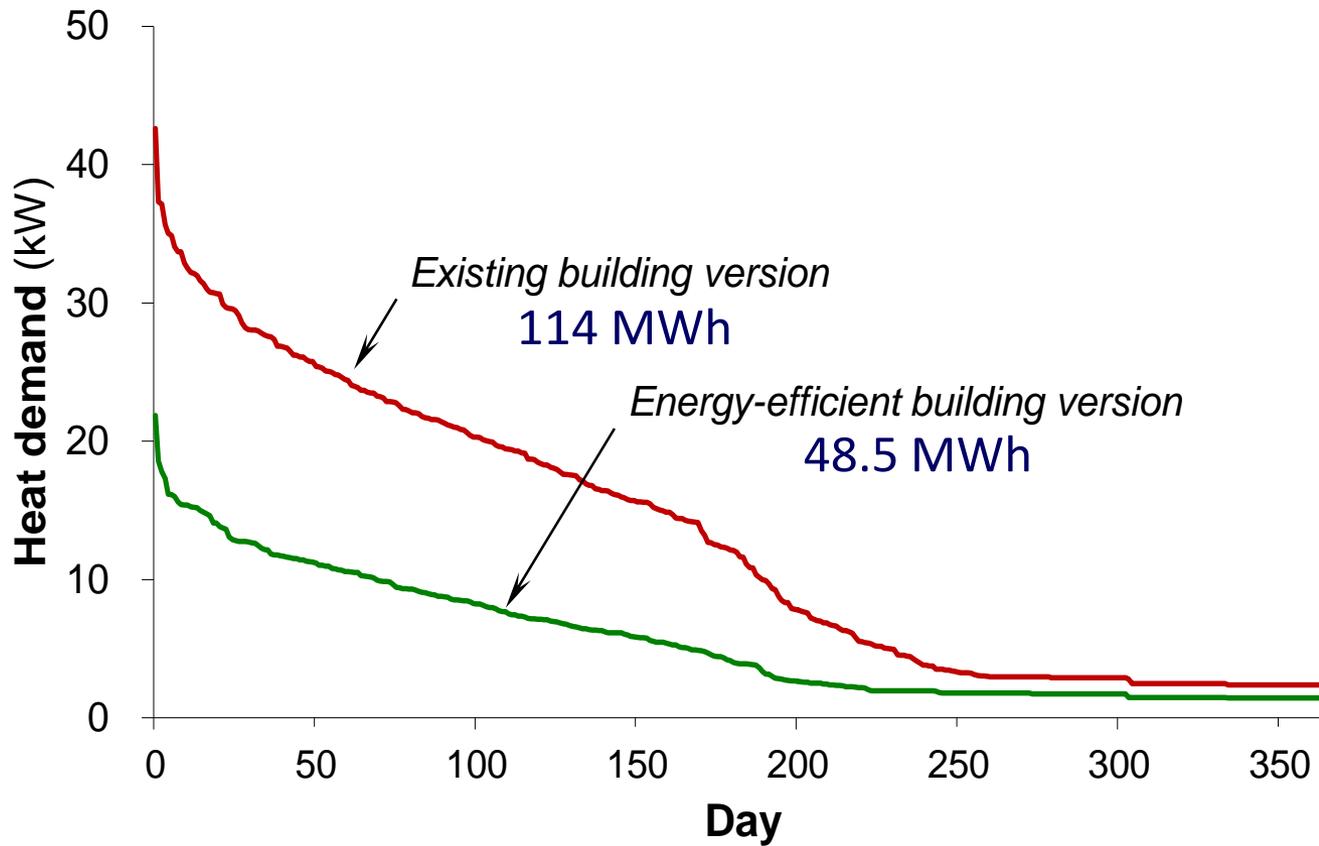
Case study building

- A building in Växjö is used as a reference:
 - ❑ wood-framed
 - ❑ 4 stories
 - ❑ 16 apartments
 - ❑ 1190 m² area

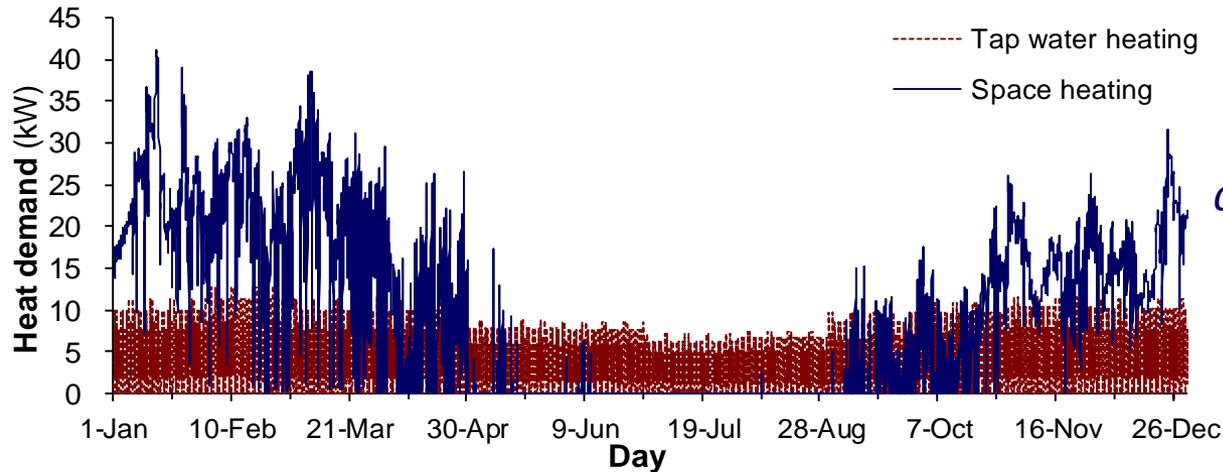


- Building use water-based heat delivery network within the apartments

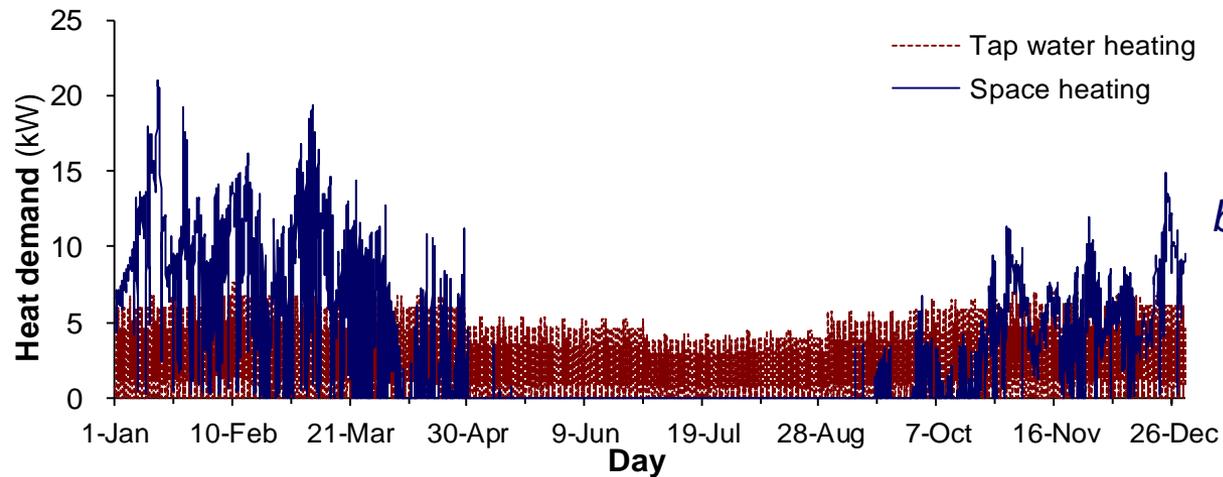
Final heat use of the case study building



Final heat use of the case study building



*a) Existing version:
114 MWh*



*b) Energy-efficient
version: 48.5 MWh*



Energy efficiency measures

<i>Description</i>	<i>Effect of improvement</i>
Improved water taps	Reduced hot water used by 40%
10 cm additional mineral wool insulation added to the roof	U-value from 0.13 to 0.09 W/m ² K
Windows replaced by triple-glazed units (low e-coating and krypton filled)	U-value from 1.9 to 0.90 W/m ² K
Doors replaced by triple-glazed units (low e-coating and krypton filled)	U-value from 1.19 to 0.90 W/m ² K
25 cm additional mineral wool insulation added to external walls	U-value from 0.20 to 0.10 W/m ² K
Incorporation of ventilation heat recovery unit with 80% efficiency	Reduced ventilation heat loss by 57%
Electric efficient household appliances	Reduced household electricity by 44%

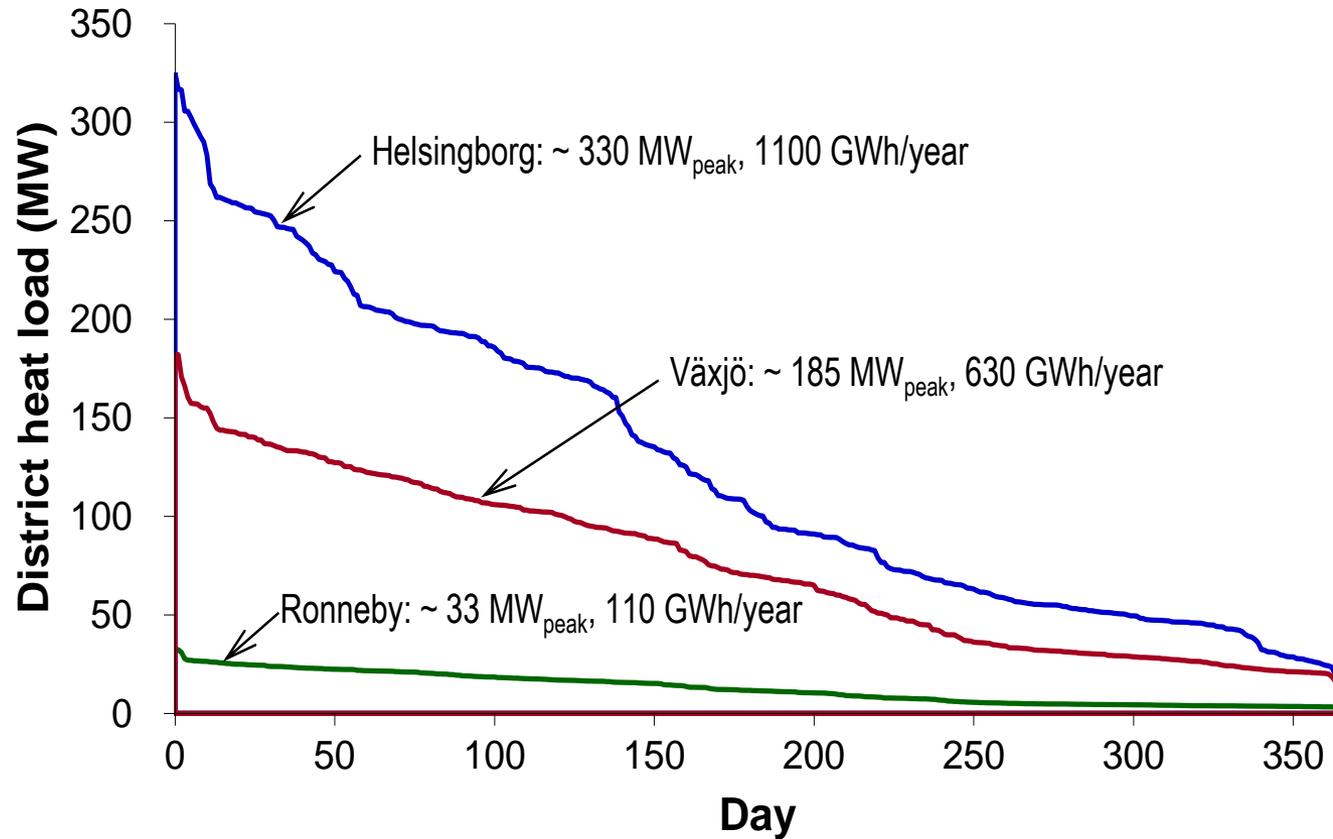


Some assumptions

- Cost level of 2013
- A real discount rate of 6%
- Life time of investments
 - District heat and electricity production units 25 year
 - Other installations 20years
- Lower heating value (LHV) of fuels
- Wood fuel cost of €23/MWh



District heating

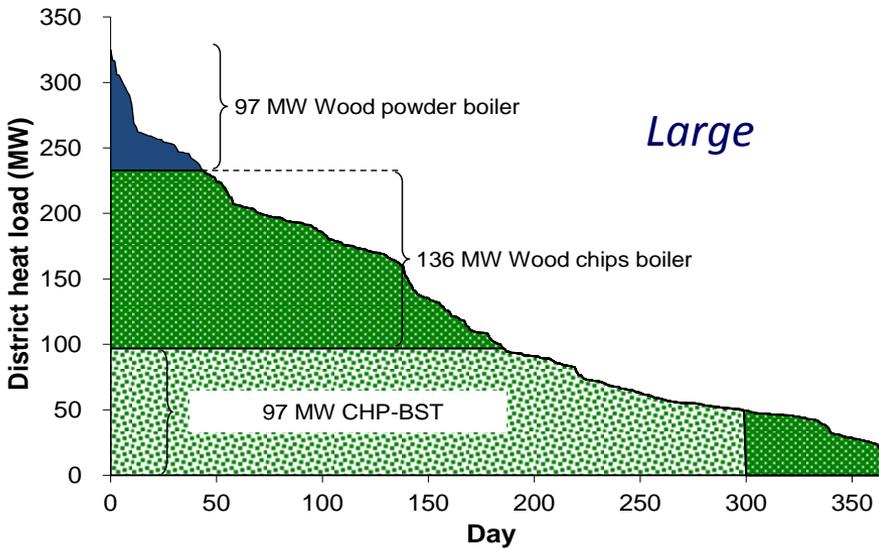
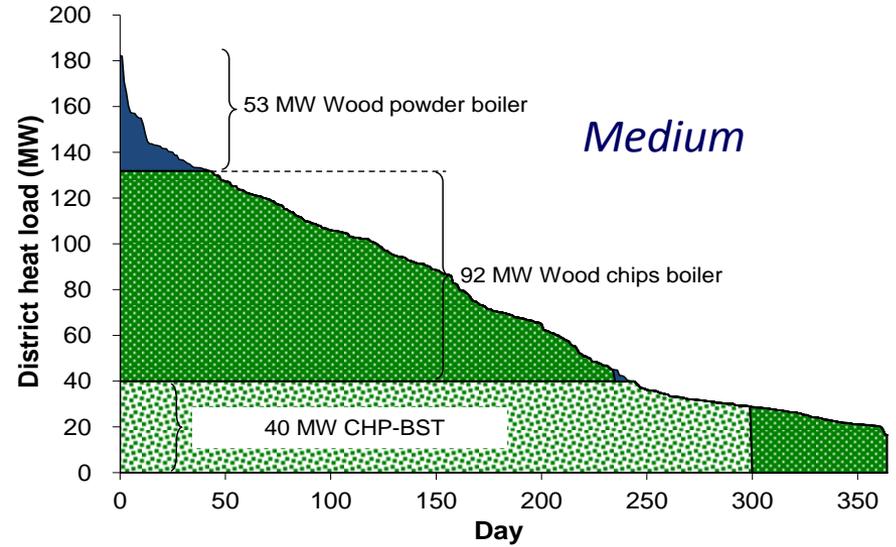
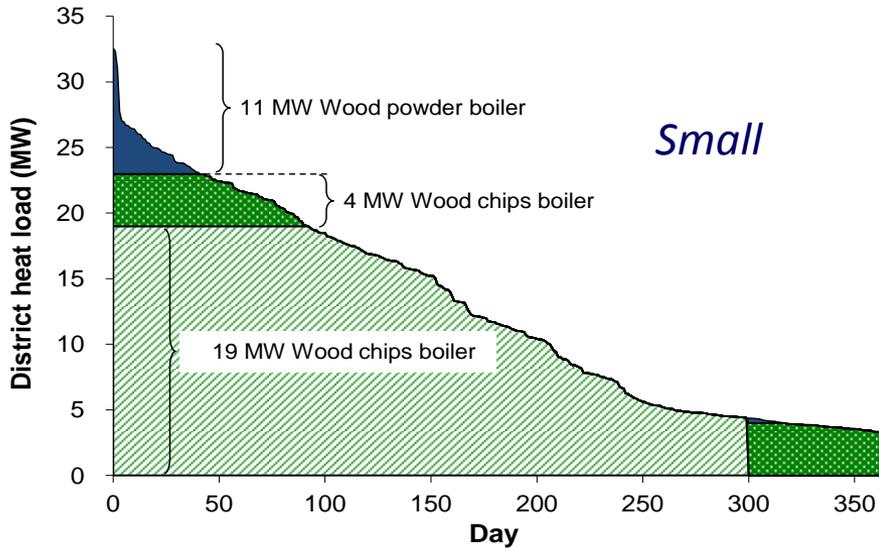


Technologies for district heat production

- ***Heat-only production***
 - Heat pump
 - Wood chip boiler
 - Wood powder boiler
- ***CHP plant***
 - Biomass integrated gasification with gas engine
 - Biomass-based organic Rankine cycle
 - Biomass steam turbine



District heat production



<i>DH production scale</i>	<i>DH production cost (€/MWh)</i>	<i>Primary energy use (MWh/MWh_{heat})</i>
- Small	40.0	0.93
- Medium	34.2	0.75
- Large	31.8	0.65



Standalone plants - production cost and fuel use

<i>Technology</i>	<i>Production cost €/MWh</i>	<i>Fuel use MWh_{fuel}/MWh</i>
- Biomass	81.7	2.17
- Wind power - offshore	84.3-88.9	-
- Wood pellets	34.7	1.22
- Wood powder	33.6	1.18

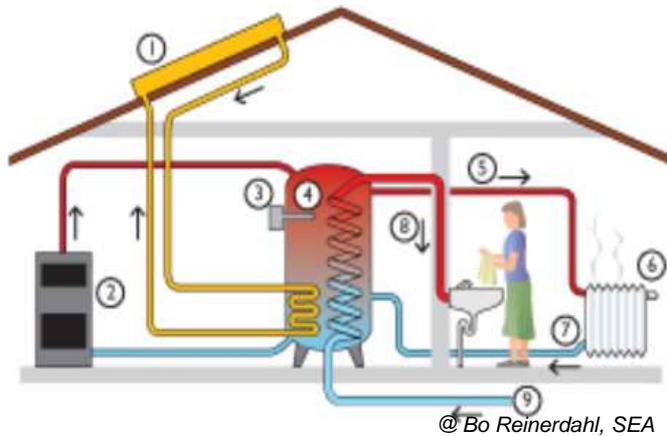


Distribution losses and costs

- DH distribution losses of 13.2% (for costs see DH connection)
- Electricity transmission and distribution
 - Losses of 7.4%
 - Costs: a yearly fixed charge of €24.2/kW + €18.4/MWh
- Wood pellets distribution costs of €6.0/MWh (local user)



Heat supply with SWH



- A buffer water storage tank of at least 10 lit/kW of peak heat demand is being used
- Installed capacity of each production unit based on the minimum-cost heat production of the combined system

Technical specification of heating options

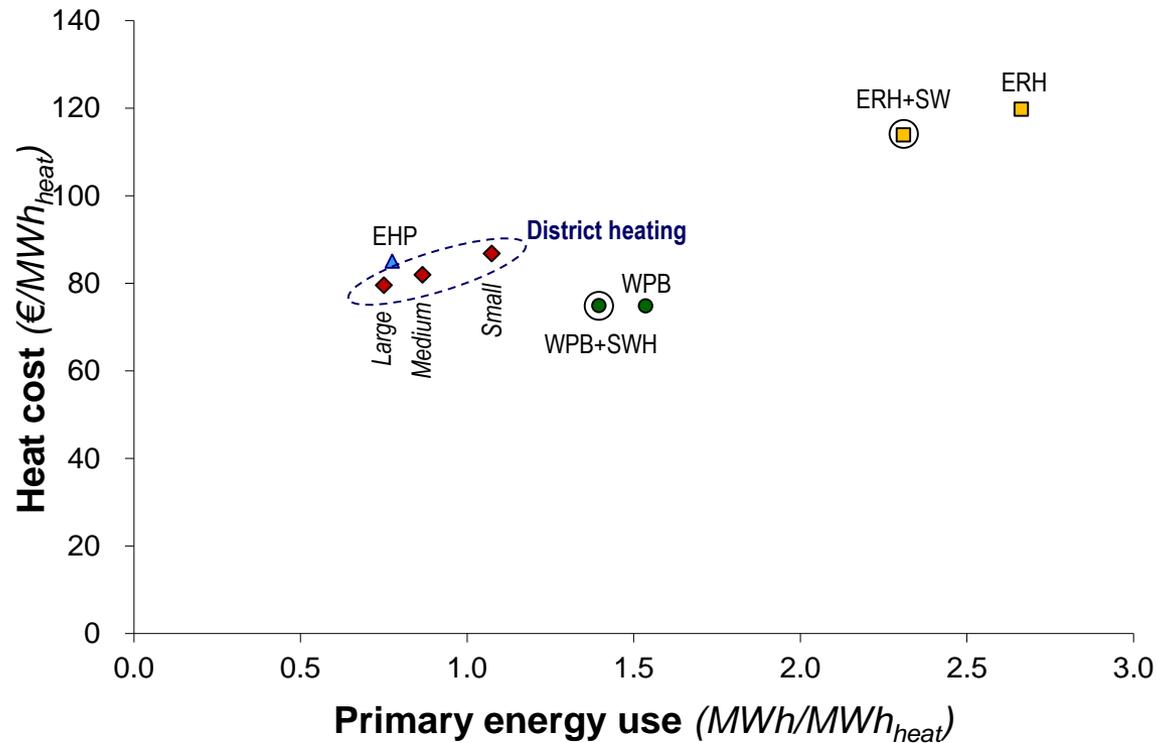
Technology	Reference size (kW_{heat})	Investment cost (kW_{heat})	Additional initial cost (€)	O&M costs (€/yr)
- DH connection*	250	70	4000	1250 /unit
- EHP	20-300	1100	-	400 /unit
- ERH	13	146	-	10/kW/unit
- SWH	140	380d	-	100 /unit
- WPB	100-1000	170	15000	6.3 /kW
Heat storage	<i>(lit)</i>	<i>(€/lit)</i>		
- Tank for options without SWH	500-1000	4.4	-	-
- Tank for options with SWH	500-1000	6.0	-	-

* Including all costs for distribution of DH as heat pipes and substation



Heat costs and primary energy use

Existing building version

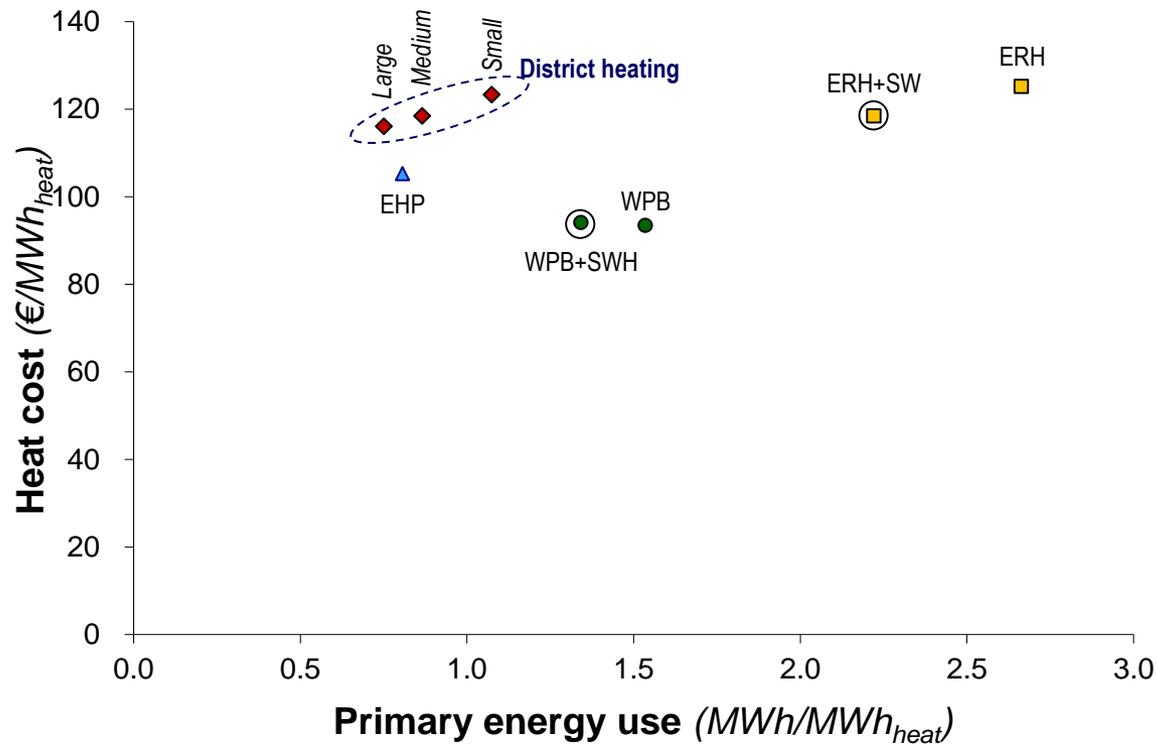


Data in circles are for systems combined with SWH.



Heat costs and primary energy use

Energy-efficient building version

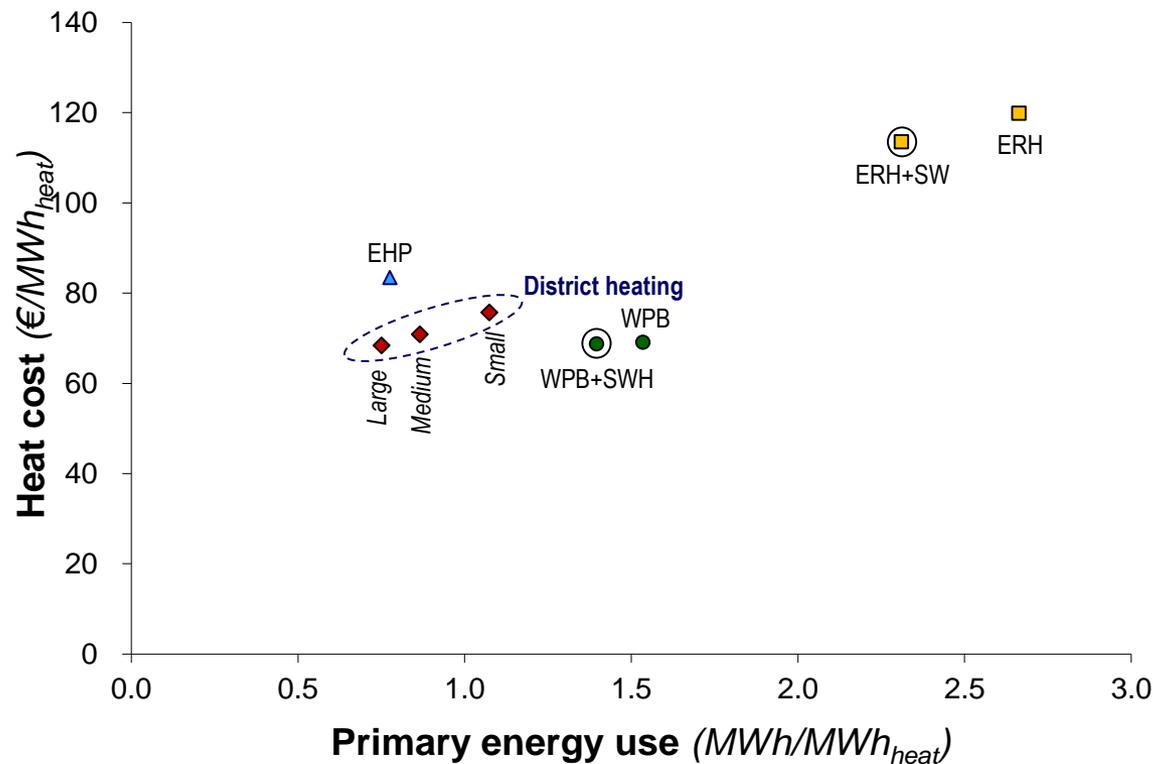


Data in circles are for systems combined with SWH.



Heat costs and primary energy use: Double size of the reference building

Existing building version

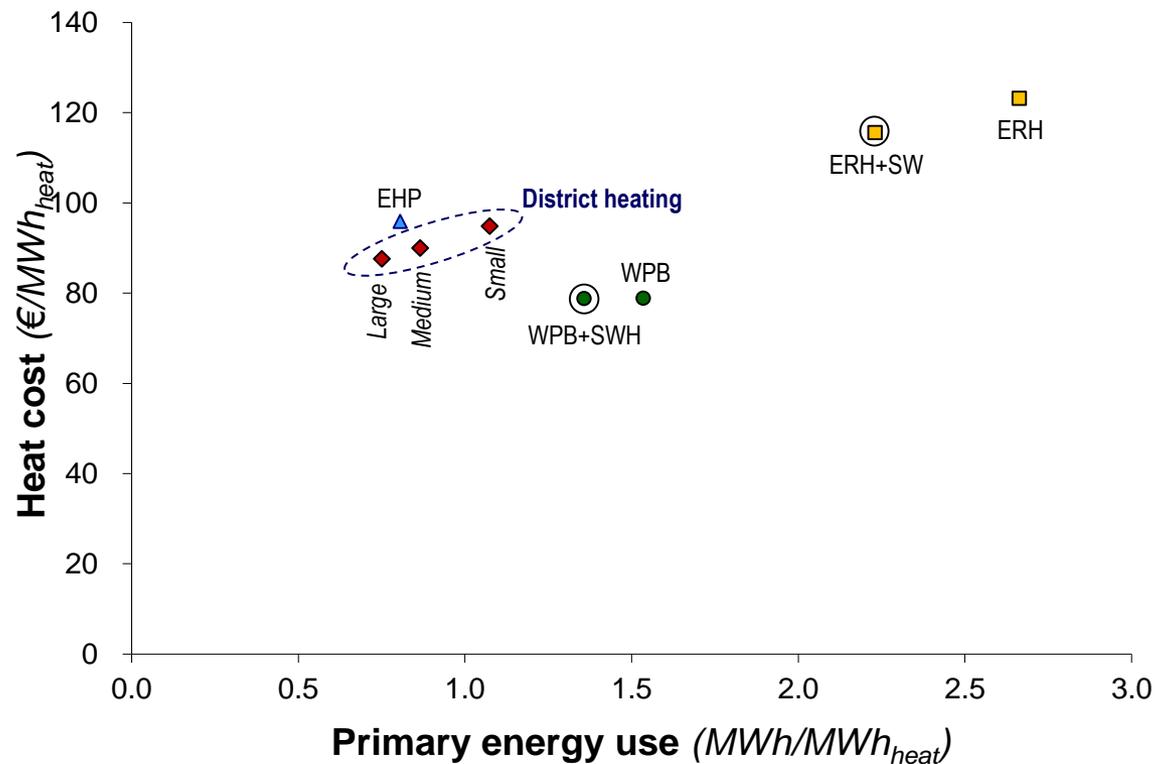


Data in circles are for systems combined with SWH.



Heat costs and primary energy use: Double size of the reference building

Energy-efficient building version

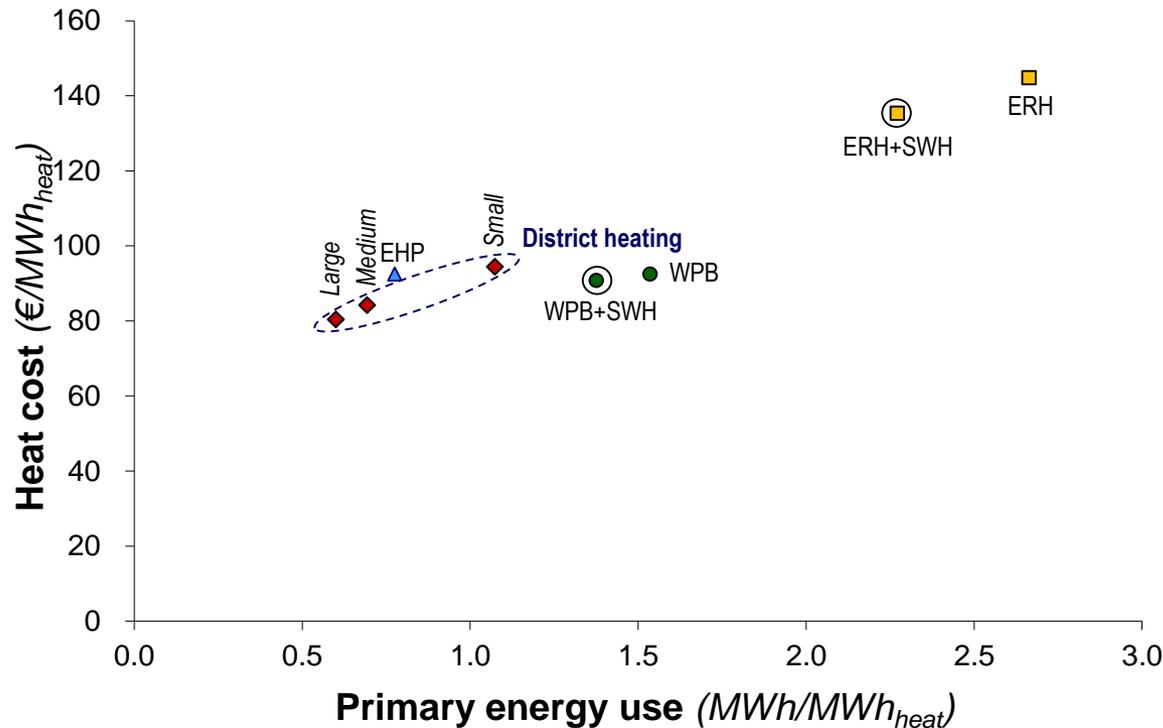


Data in circles are for systems combined with SWH.



Heat costs and primary energy use: If wood fuel price increase 50%

Existing building version

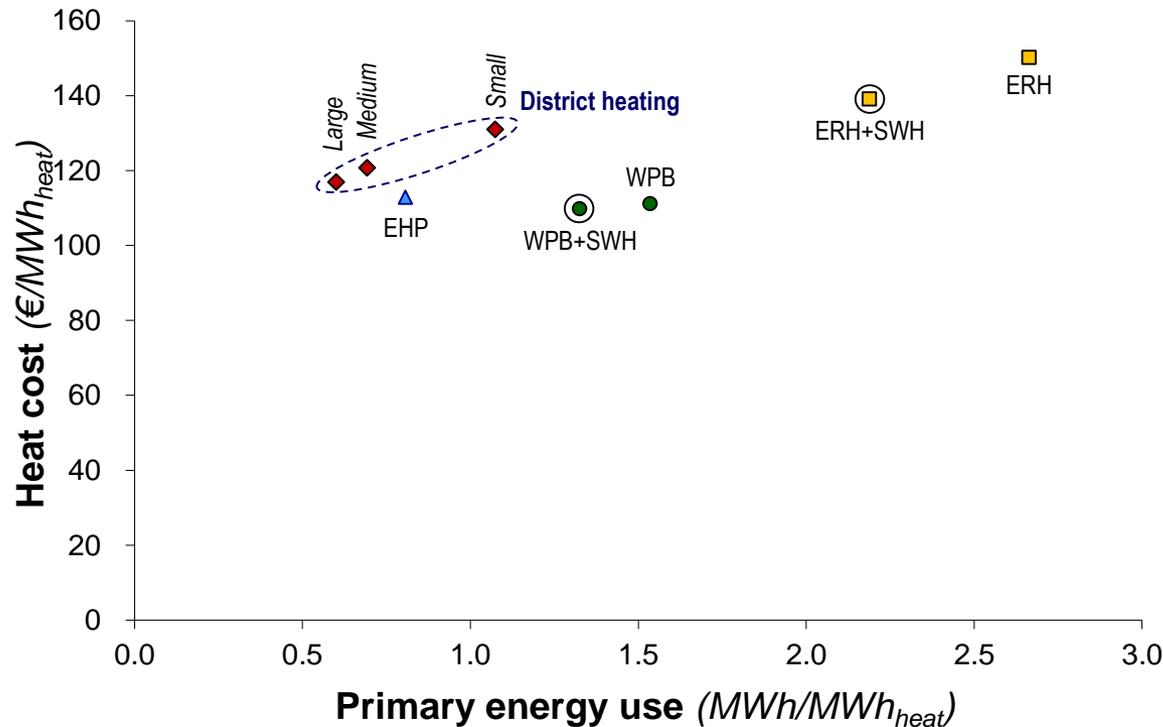


Data in circles are for systems combined with SWH.



Heat costs and primary energy use: If wood fuel price increase 50%

Energy-efficient building version



Data in circles are for systems combined with SWH.



Next step

- Competitiveness of low temperature district heating
- Integrated heat supply system, combination of district heating and local heat supply options



Heat production excluding DH

<i>Parameter</i>	EHP	ERH	WPB	EHP+SWH	ERH+SWH	WPB+SWH
Existing building version						
Area of SWH (m^2)	█	█	█	9,4	28,3	15,3
Local fuel use (GWh/yr)	█	█	142,4	█	█	129,2
Electricity (GWh/yr)	33,2	113,9	0,5	30,7	98,8	0,5
Primary energy use (MWh/MWh_{heat})	0,78	2,66	1,54	0,72	2,31	1,40
Heat cost (€/MWh)	85,2	119,8	74,8	93,7	113,9	74,9
Energy-efficient building version						
Area of SWH (m^2)	█	█	█	5,6	14,6	8,8
Local fuel use (GWh/yr)	█	█	61,0	█	█	53,1
Electricity (GWh/yr)	14,8	48,8	0,2	13,2	40,7	0,2
Primary energy use ^a (MWh/MWh_{heat})	0,81	2,66	1,54	0,72	2,22	1,34
Heat cost (€/MWh)	105,4	125,2	93,5	117,1	118,5	94,1