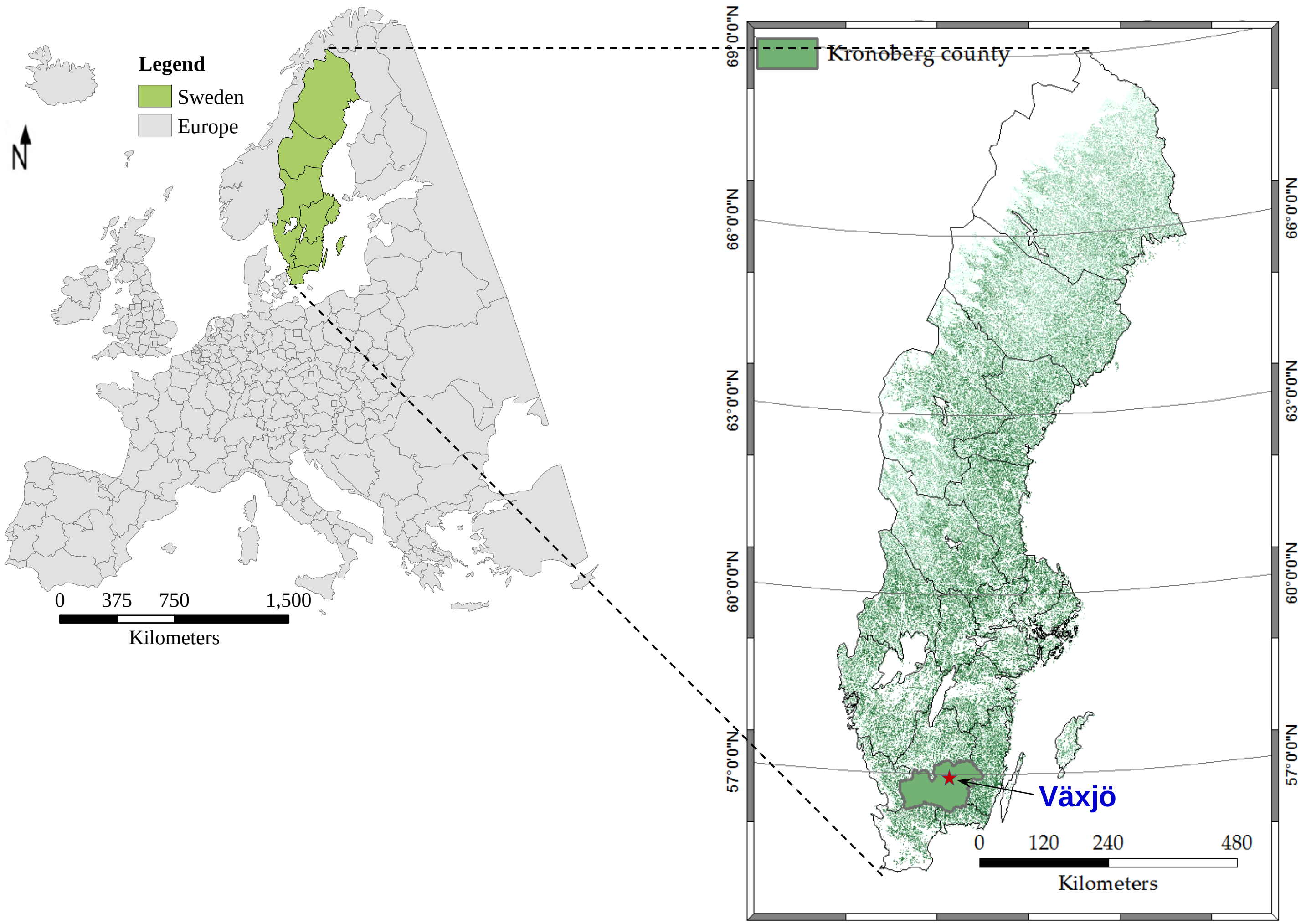
Primary energy and cost implications of low temperature district heat to new residential areas

Leif Gustavsson and Nguyen Le Truong
Linnaeus University, 351-95 Växjö, Sweden

Objectives

We analyze cost and energy efficiency of different district heat distribution alternatives to a newly planned residential area in Växjö, Sweden

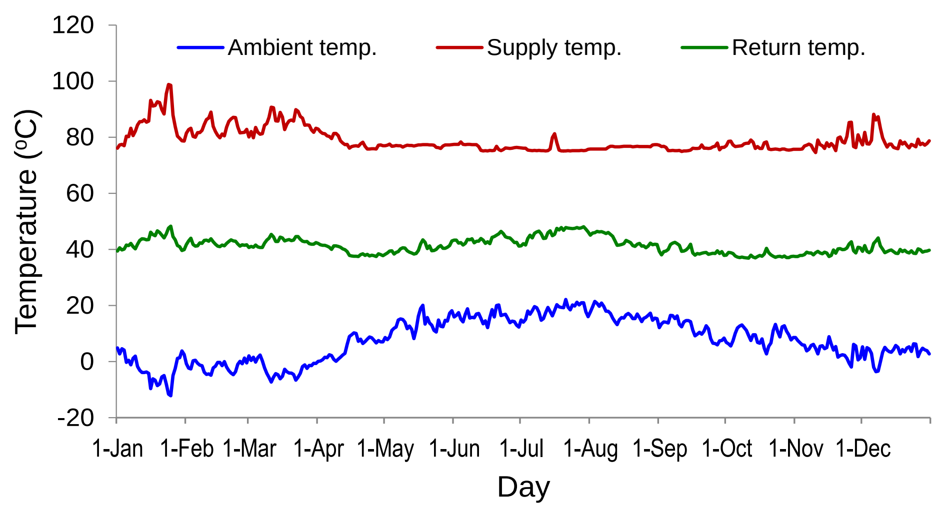
Location of Växjö, Sweden in Europe



Project site and situations in Växjö

- Växjö is a city of about 65 000 inhabitants
- With a district heating system (DHS)
  - ~ 185 MW_{peak} and ~ 630 GWh_{heat}/year
  - ~ 98% of production is based on biomass
  - Two CHP plants and several boilers

Measured temperatures in 2013



Four land exploitation alternatives

Low exploitation of row houses and villas, 9010 m^2 heated floor area

Medium-exploitation of apartment buildings and row houses, 23 540 m^2 heated floor area

High-exploitation of apartment buildings, 29 350 m^2 heated floor area

Dense-exploitation of apartment buildings, 41 727 m^2 heated floor area

Number of buildings

Land exploitation	Villas	Row houses	6-storey buildings	8-storey buildings	10-storey buildings
Low	39	29	-	-	-
Medium	21	29	8	-	-
High	-	29	15	-	-
Dense	-	29	-	13	3

We consider for each land exploitation alternative

- Two building energy efficiency levels
  - Swedish building code (BBR 2015)
  - Swedish passive house criteria (Passive 2012)

- Three different district heat supply/ return temperatures
  - 80/40^{o}C (conventional system)
  - 65/30^{o}C
  - 50/20^{o}C

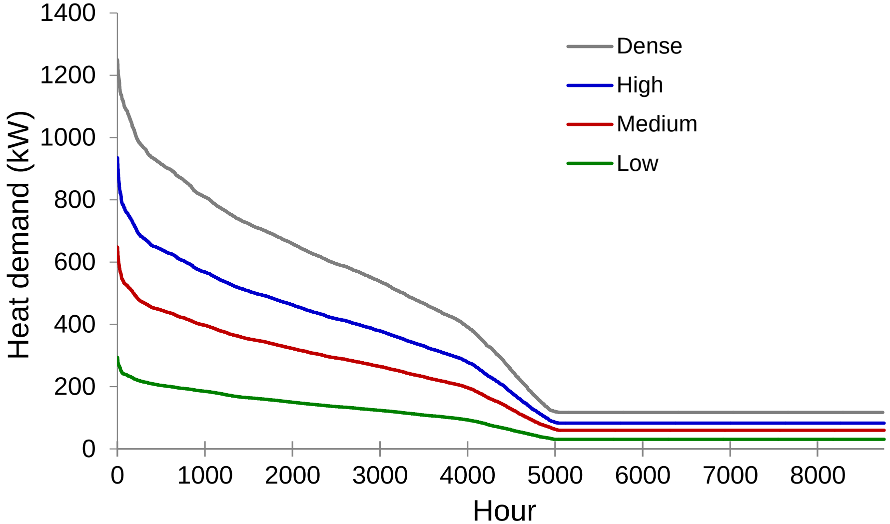
Key energy properties of building code and passive house buildings

Description	U-values	
	Building code	Passive house
Ground floor	0.11	0.11
Exterior walls	0.33	0.10
Windows	1.2	0.8
Doors	1.2	0.8
Roof	0.13	0.05
Infiltration (l/s m^2 @50 Pa)	0.8	0.3
Mechanical ventilation	80% heat recovery	80% heat recovery

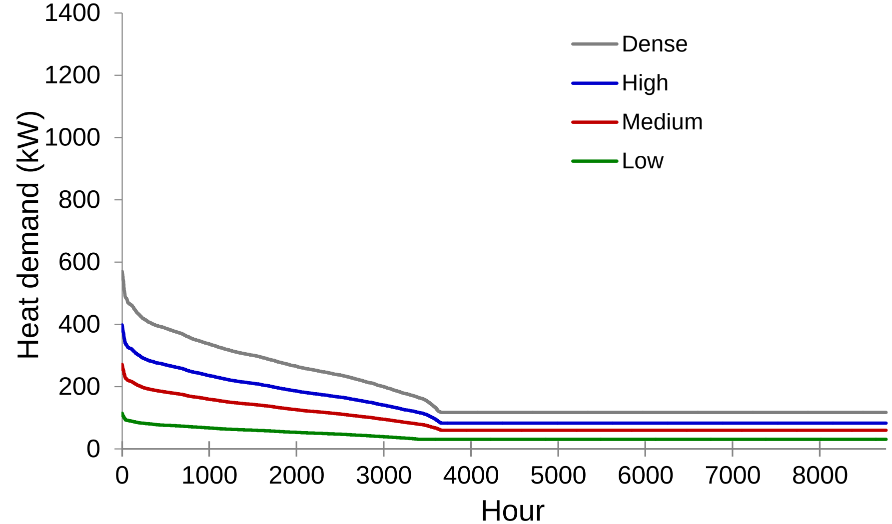
Space heating capacity (kW)

House/building type	Building standard	
	Building code	Passive house
Villas		
o 100 m^2	5.68	2.06
o 110 m^2	5.81	2.16
o 120 m^2	5.94	2.26
o 150 m^2	6.32	2.55
Row houses		
o Type 1 (Regular)		
Beginning	5.78	2.14
Middle row	3.99	1.80
End	5.87	2.29
o Type 2 (Offset of walls)		
Beginning	5.78	2.14
Middle row	4.34	1.93
End	6.20	2.42
Multi-apartment buildings		
o 6-storey, 24 apartments	54.47	27.82
o 8-storey, 32 apartments	70.96	36.28
o 10-storey, 40 apartments	87.46	44.80

Space- and hot water heating



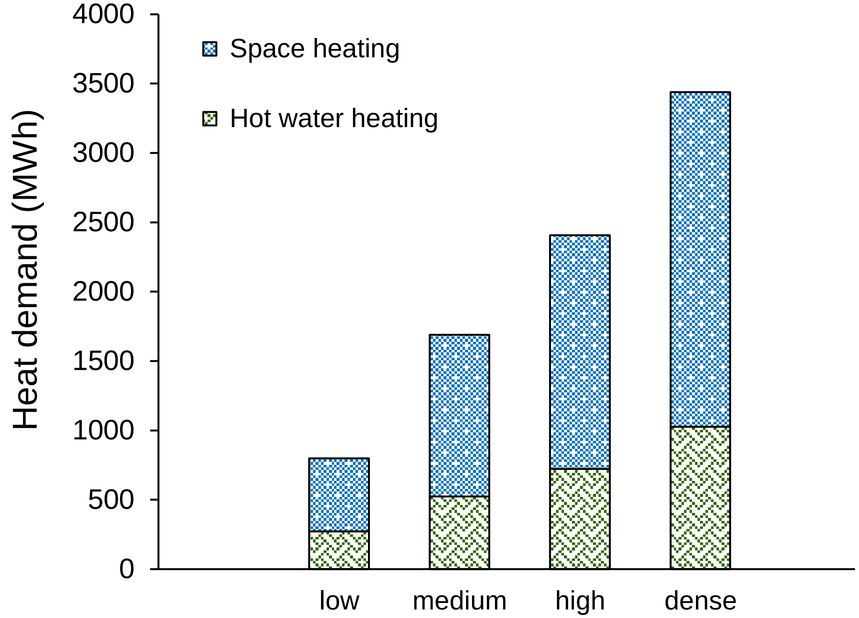
Building code



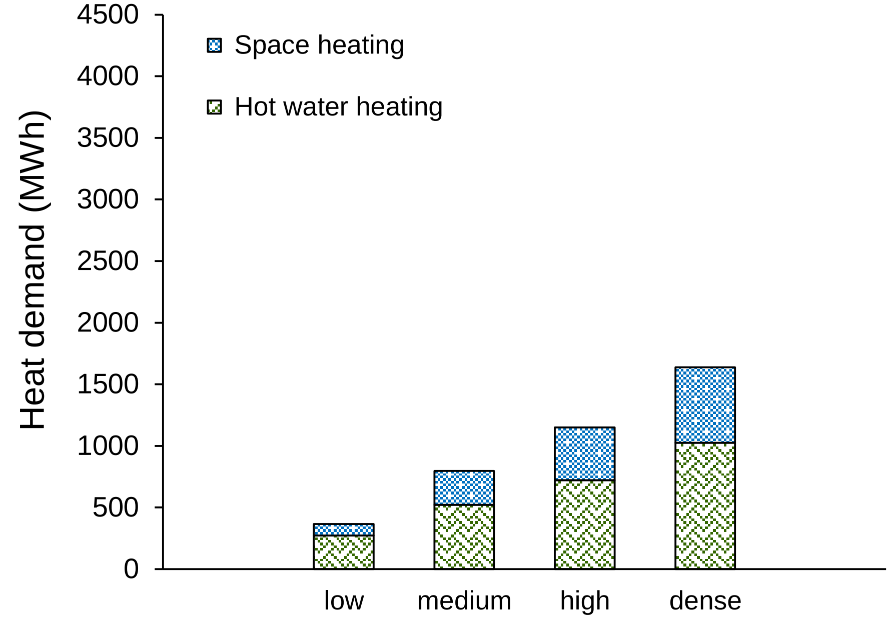
Passive house

Based on hour by hour energy balance calculations

Annual heat demand for space and hot water heating

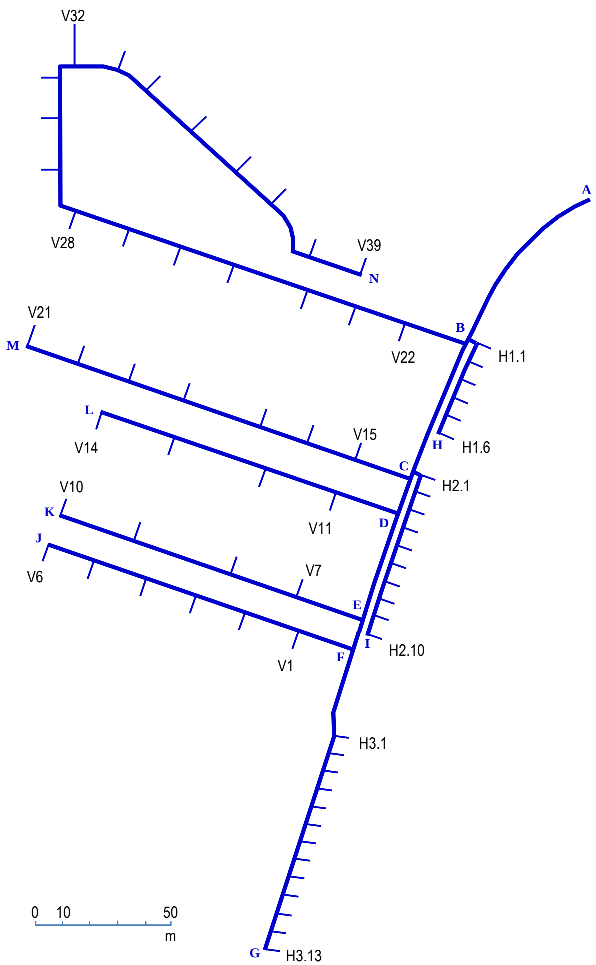


Building code

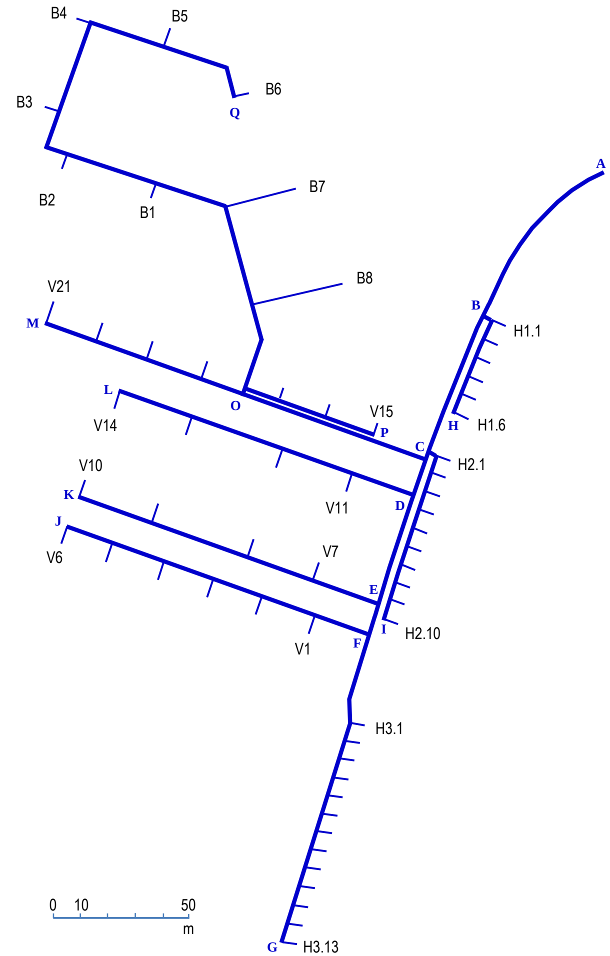


Passive house

Heat supply network

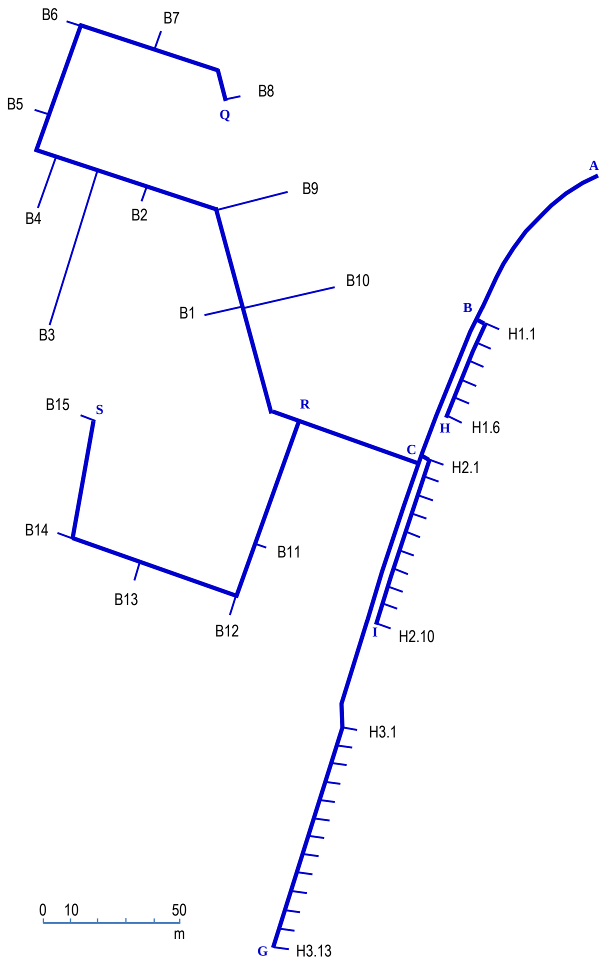


Low exploitation, 1718m

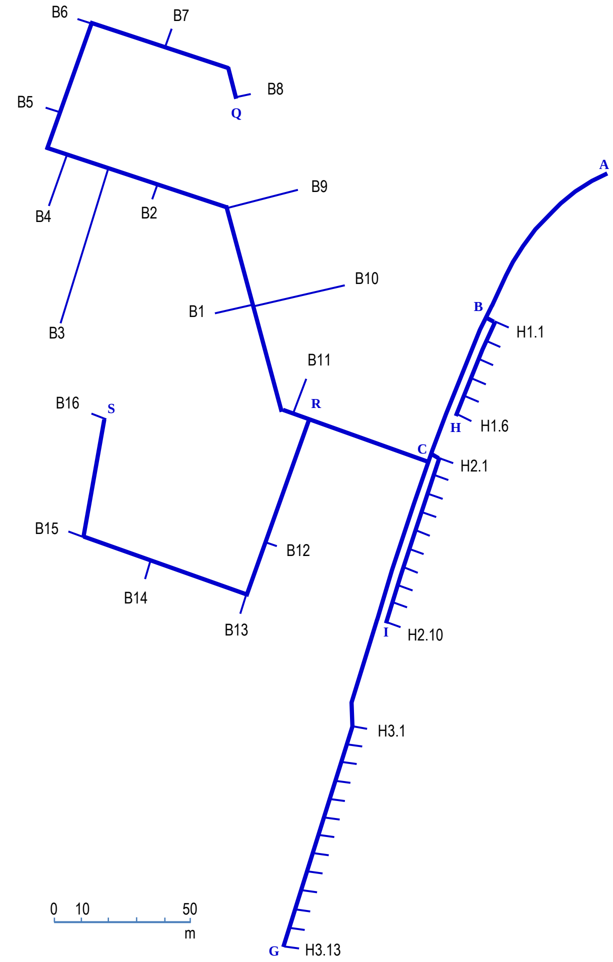


Medium exploitation, 1686m

Heat supply network

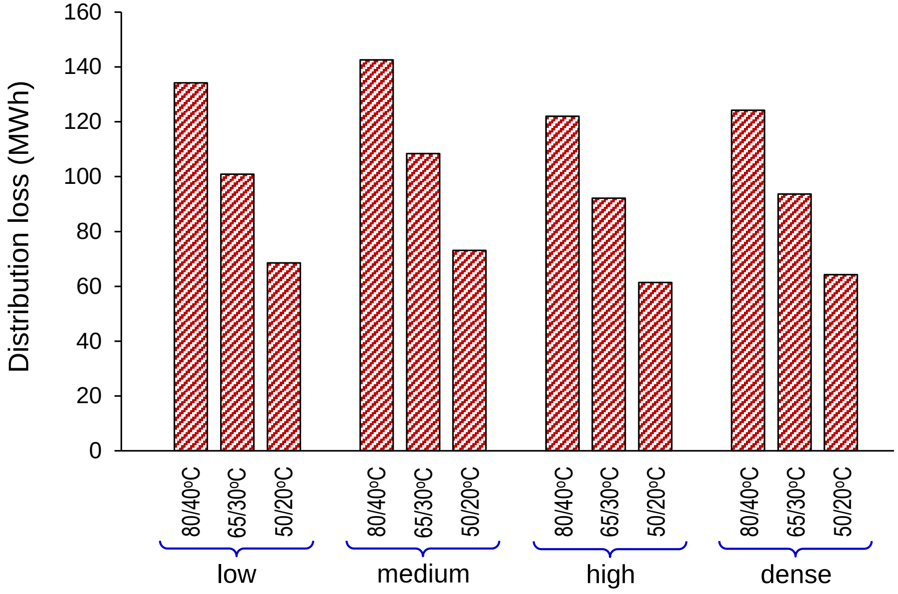


High exploitation, 1341m



Dense exploitation, 1351m

District heat distribution losses



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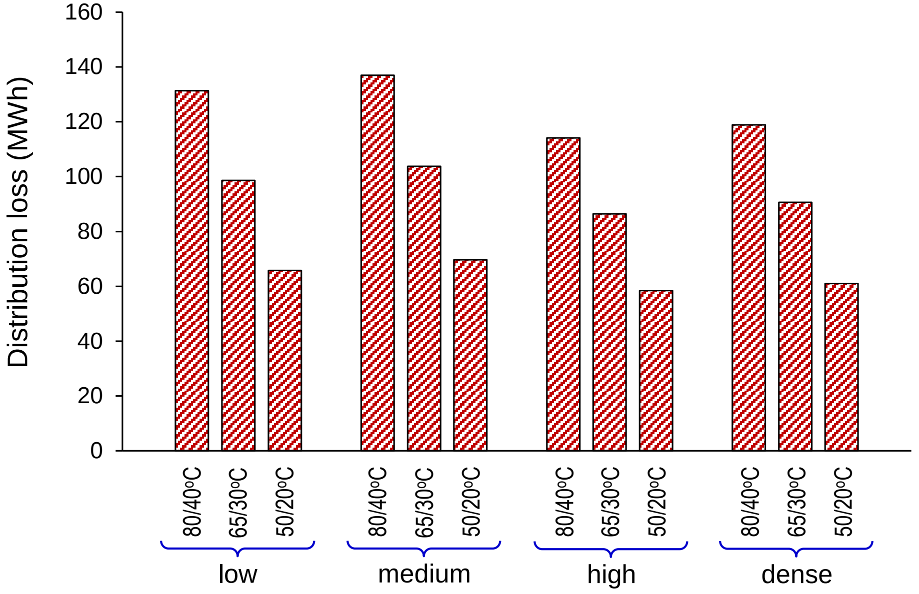
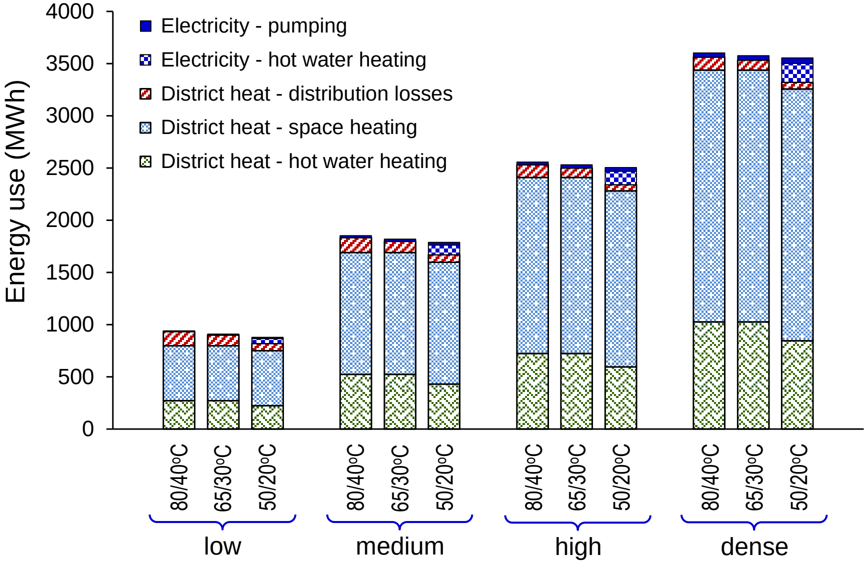
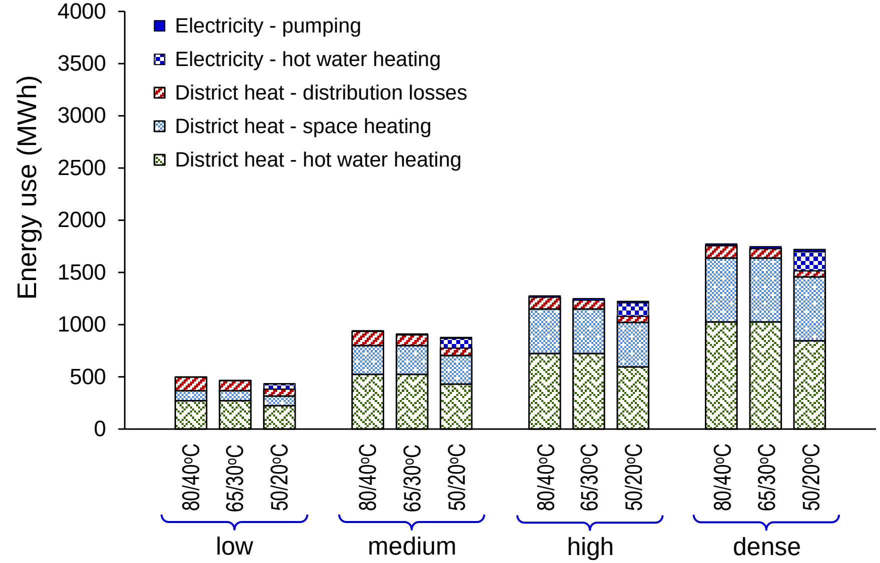


Passive house

District heat use, electricity use and distribution losses



Building code



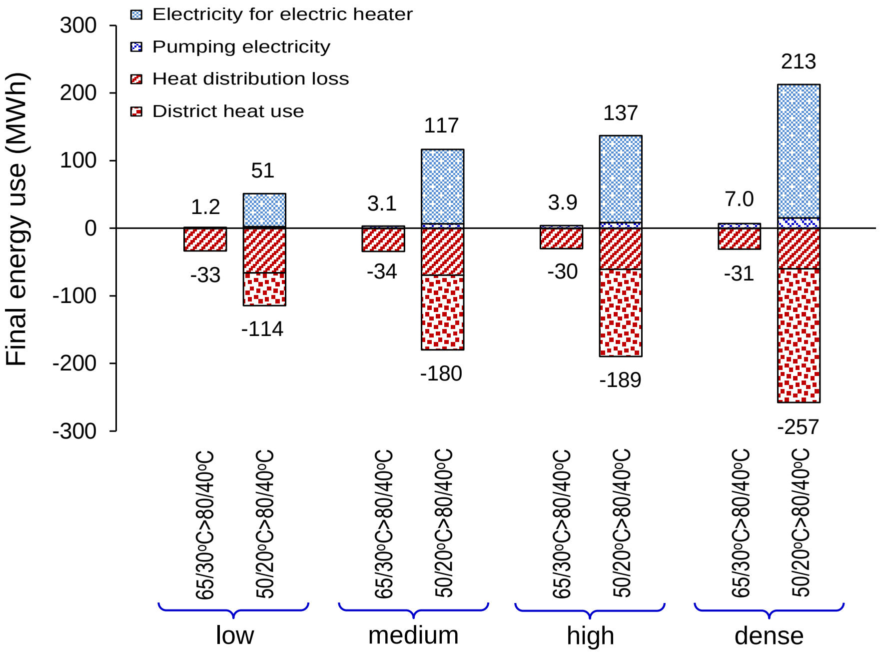
Passive house

Reduced district heat distribution losses compared to the 80/40ºC system

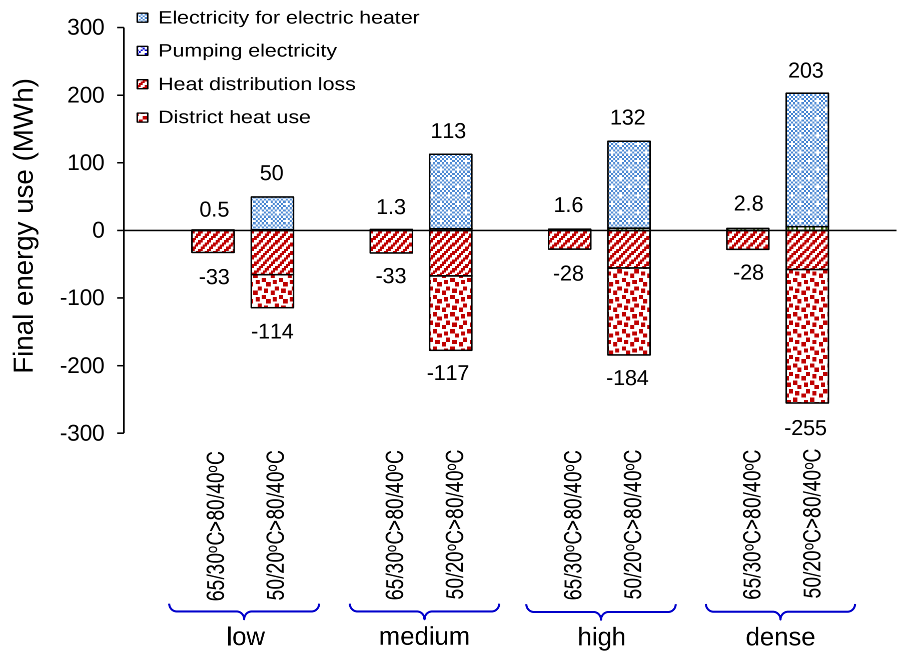
65/30ºC system 24-25%

50/20ºC system 48-50%

Annual changed final energy use when lower supply/return temperatures are used instead of a 80/40ºC system

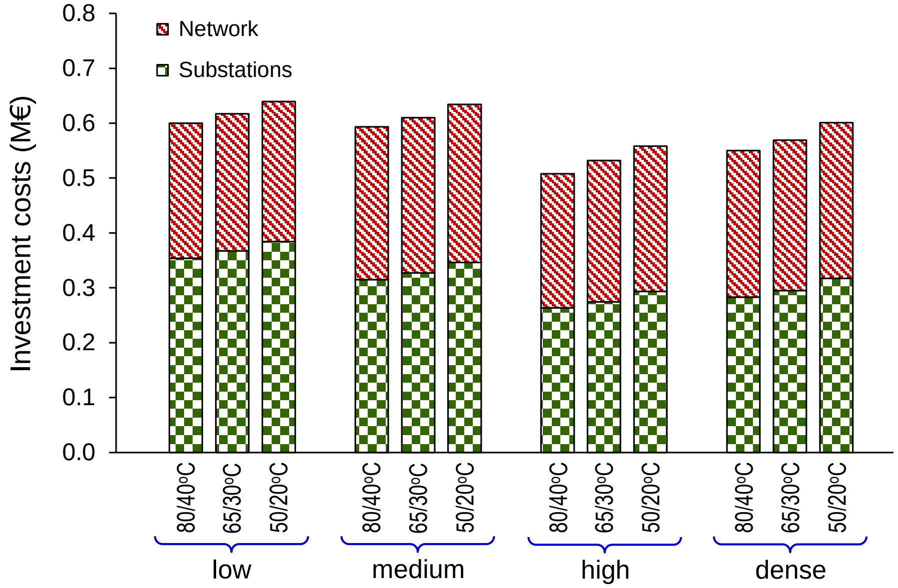


Building code



Passive house

Investment costs for networks and substations



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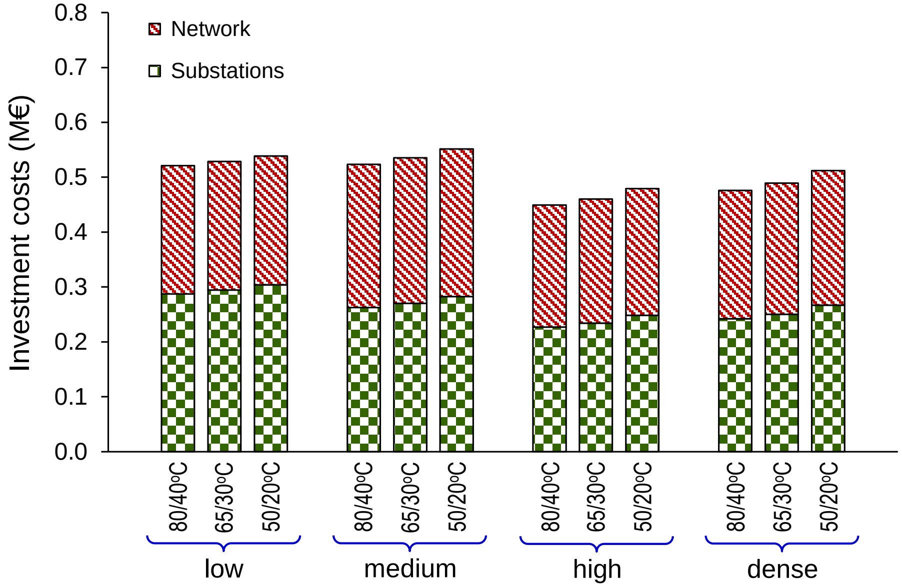


Passive house

Cost implication of reduced supply/return temperatures in local network with 80/40^{o}C as baseline

The net present value of

- reduced distribution network heat losses and reduced use of district heat

minus

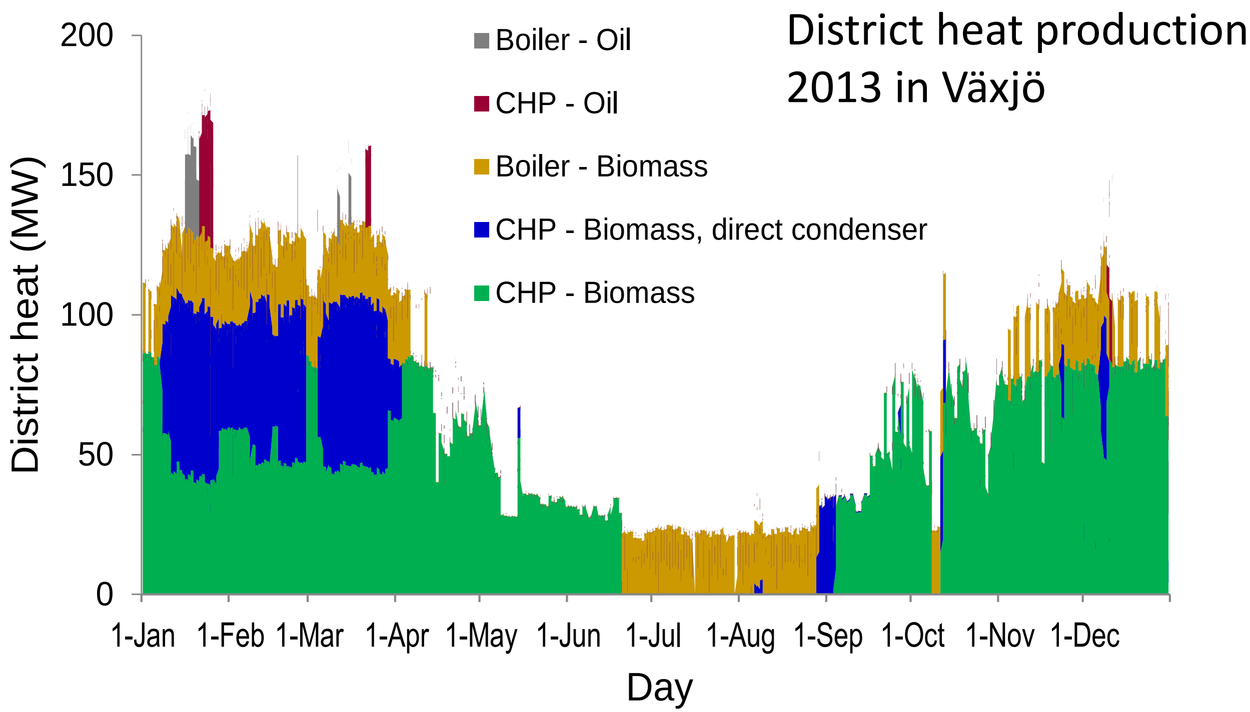
- increased use of electricity for pumping and boosting hot water temperature

and minus

- the increased investment cost for the low district heat temperature alternatives

is calculated assuming different real discount rates and lifetimes

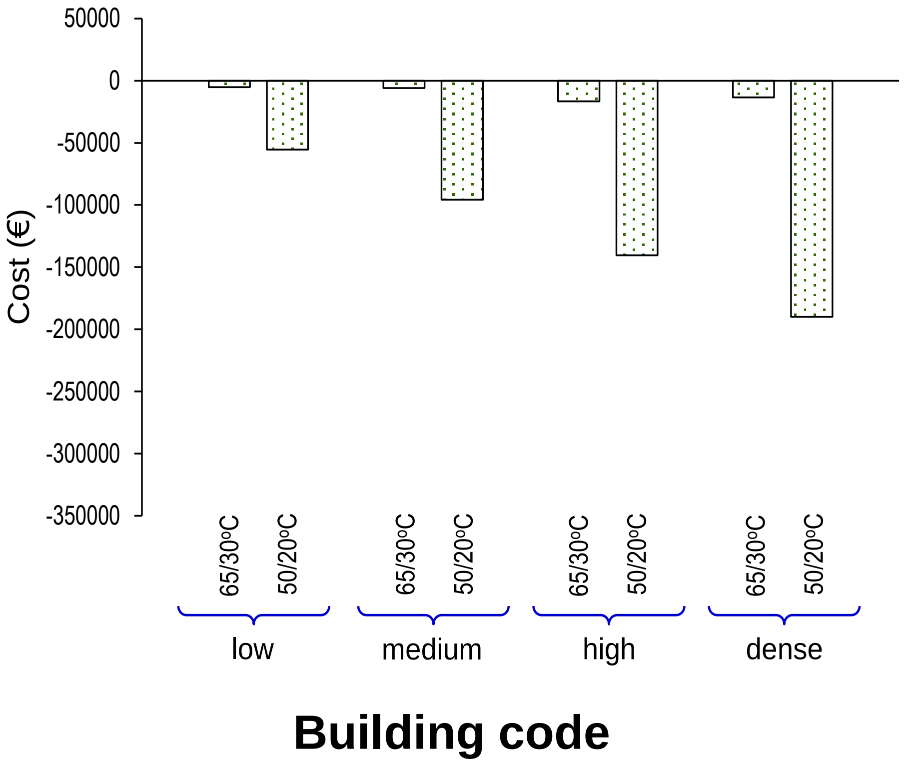
District heat and electricity cost

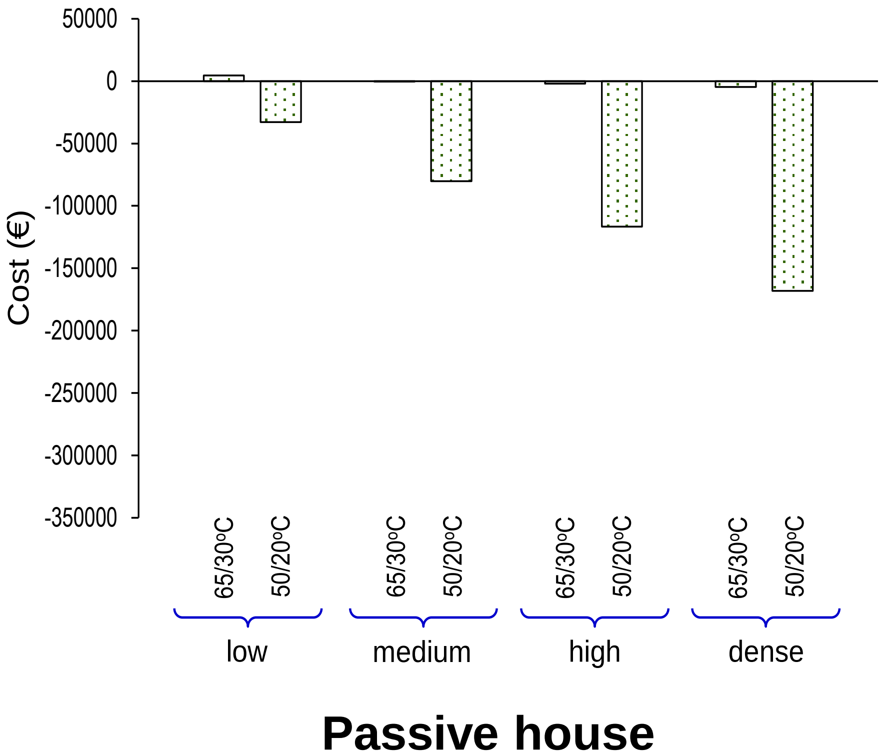


- ❑ Marginal costs of district heat production: 29.1 €/MWh
- ❑ Costs of electricity use: 92.6 €/MWh

Changed cost of lower district heat temperatures – discount rate 6%, lifetime 30 years

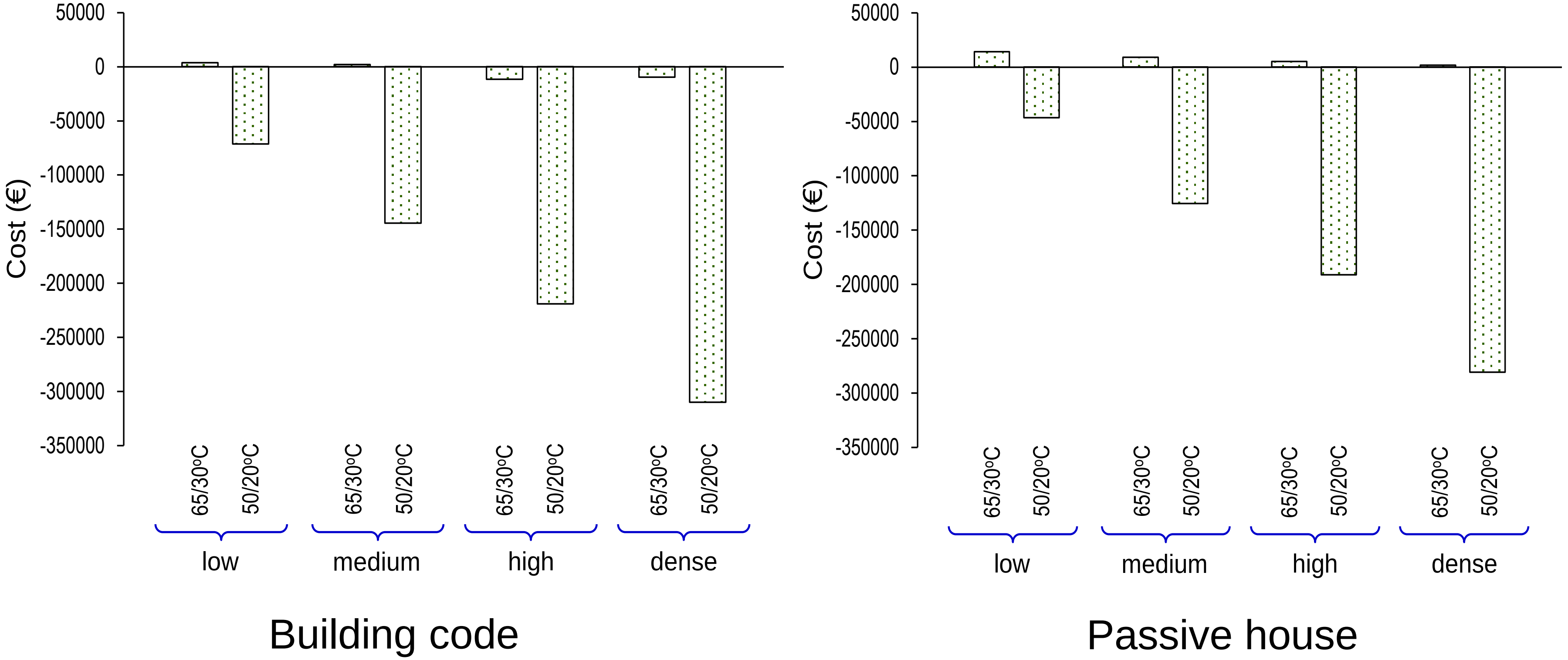
Negative values are cost increase



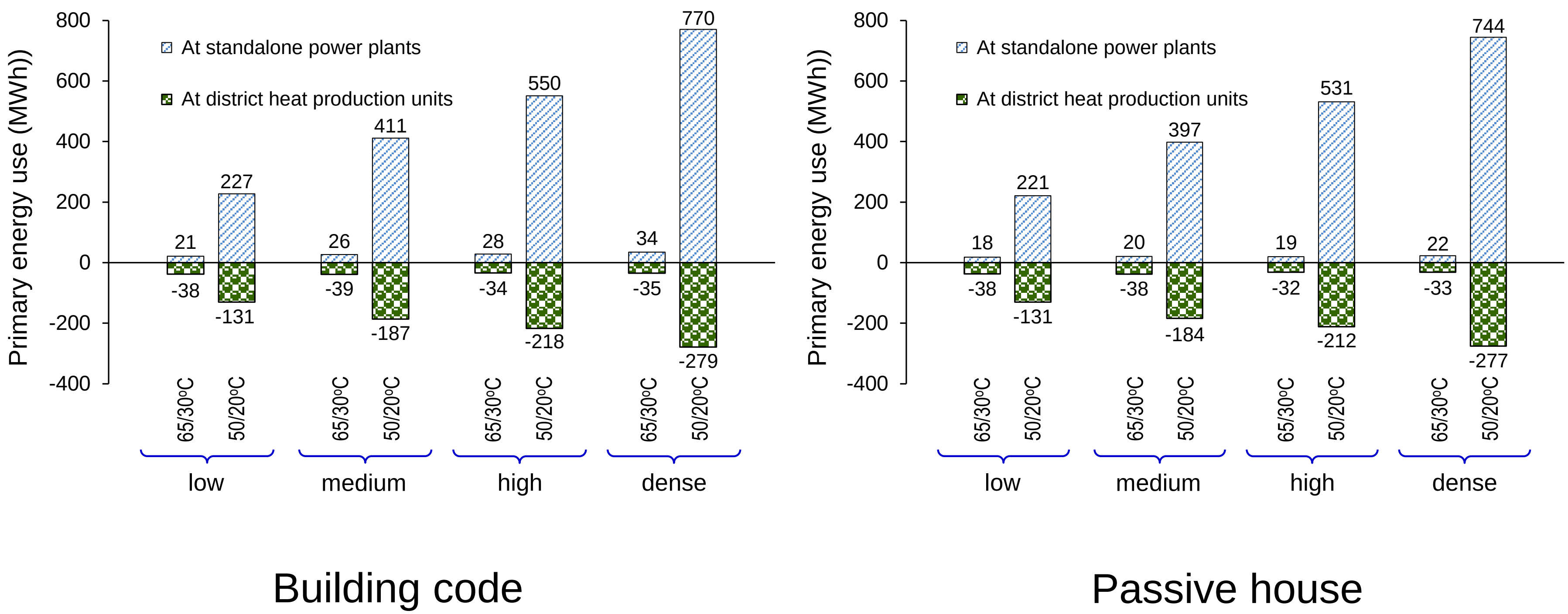


Changed cost of lower district heat temperatures – discount rate 3%, lifetime 45 years

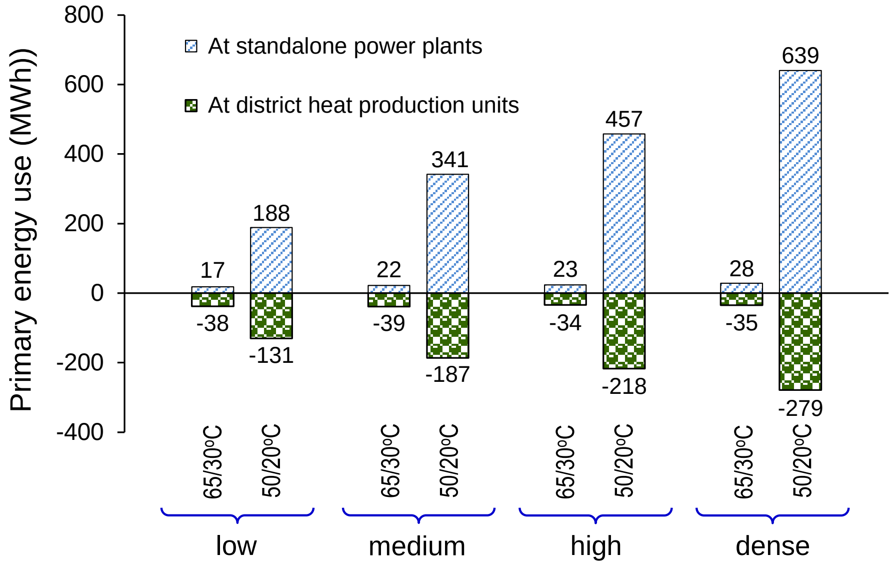
Negative values are cost increase



Changed primary energy use for lower district heat temperatures - coal-based power plants



Changed primary energy use for lower district heat temperatures - fossil gas-based power plants



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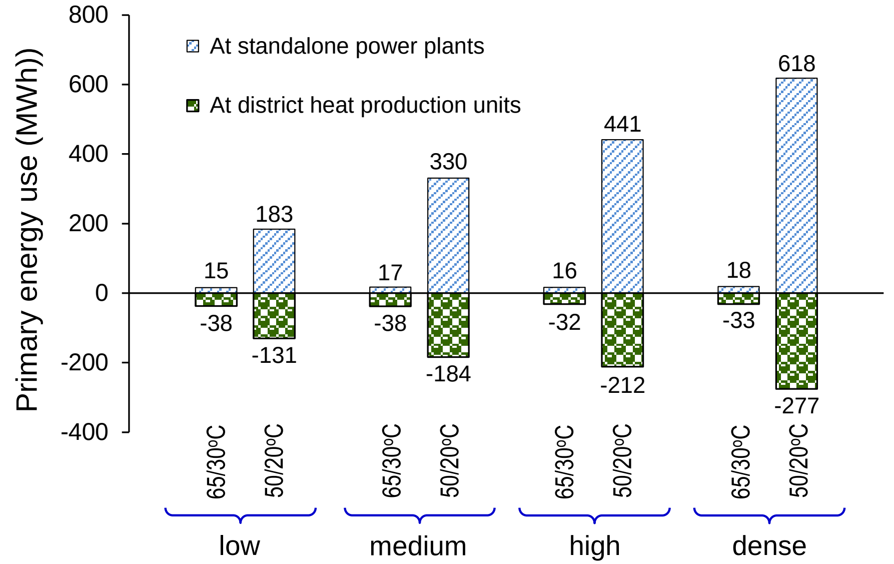
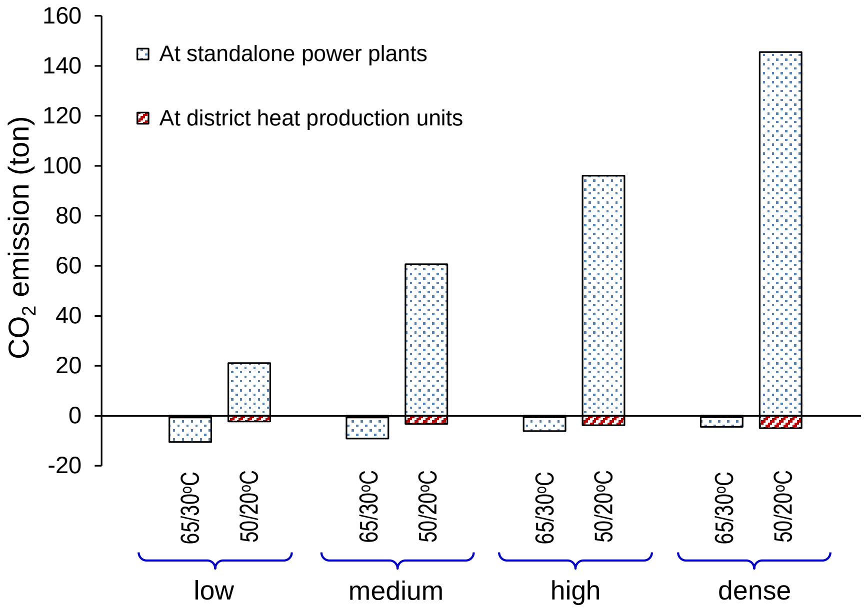


Passive house

Changed CO_2 emission for lower district heat temperatures - coal-based power plants



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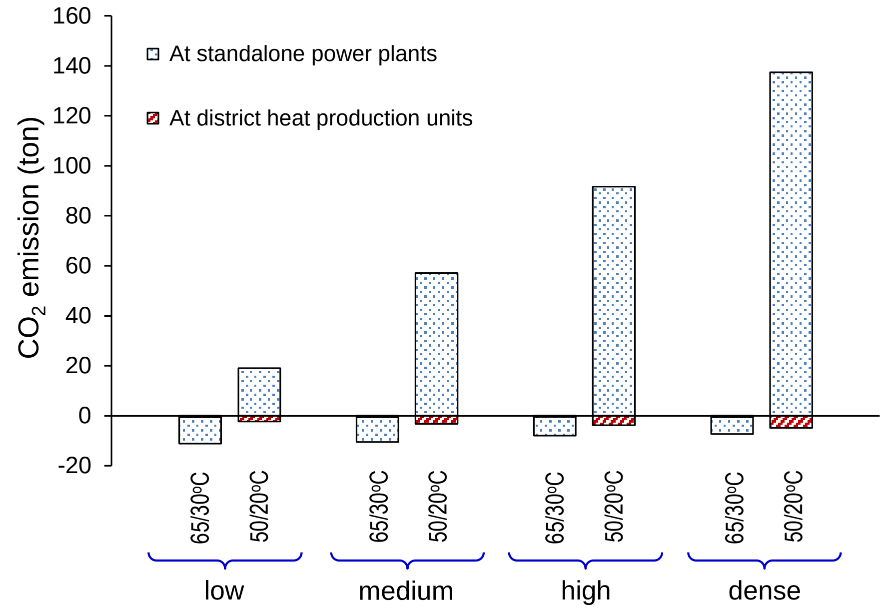
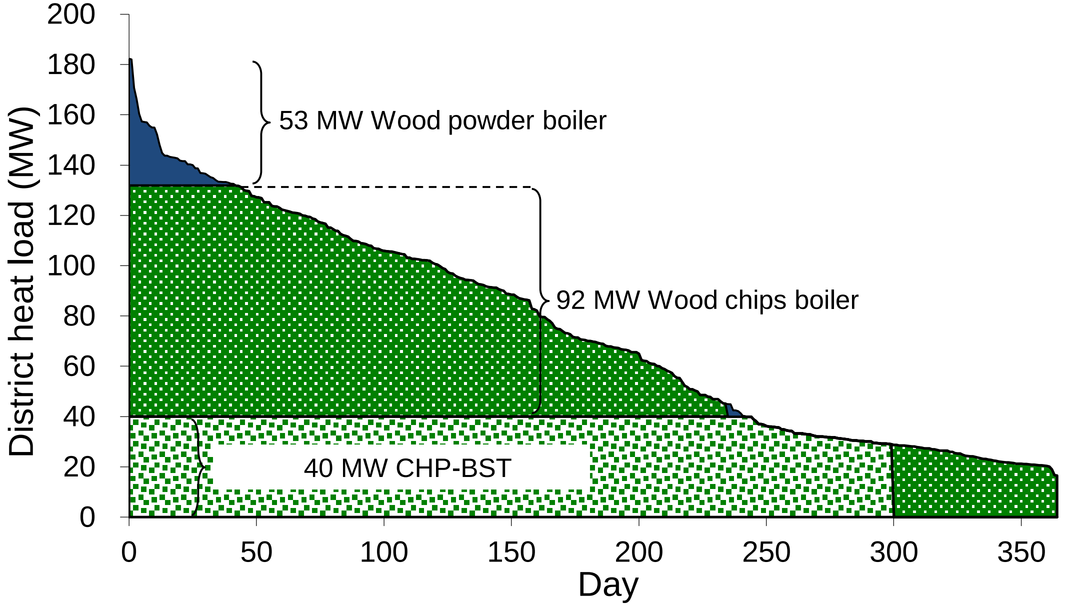


Passive house

Bioenergy based production

Costs are based on cost-optimal bio-based district heat production using 2013 heat load curve in Växjö and biopower production including capital costs

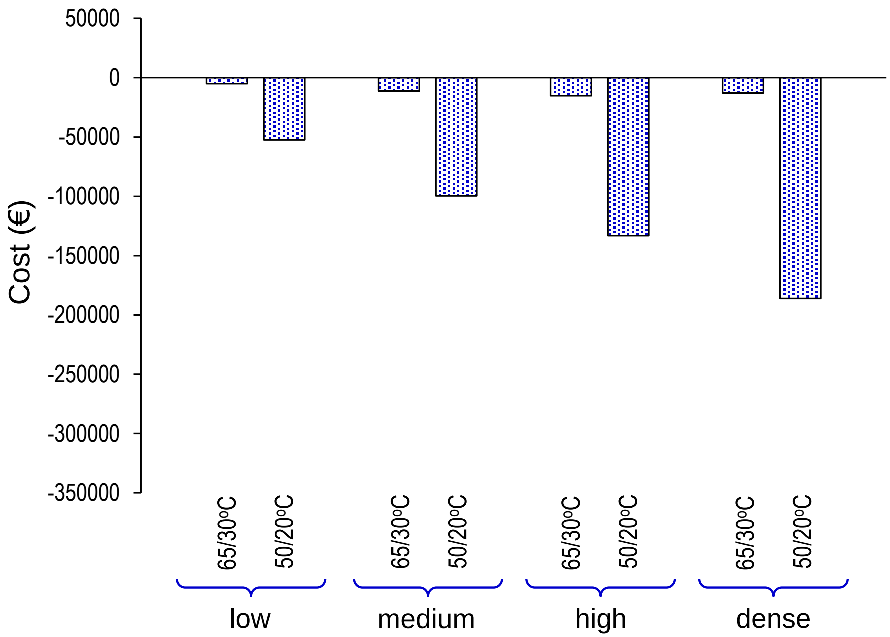


Costs of district heat production: 34.8 €/MWh

Costs of biomass-based electricity: 95.2 €/MWh

Changed cost of lower district heat temperatures – discount rate 6%, lifetime 30 years, bio-based production

Negative values are cost increase



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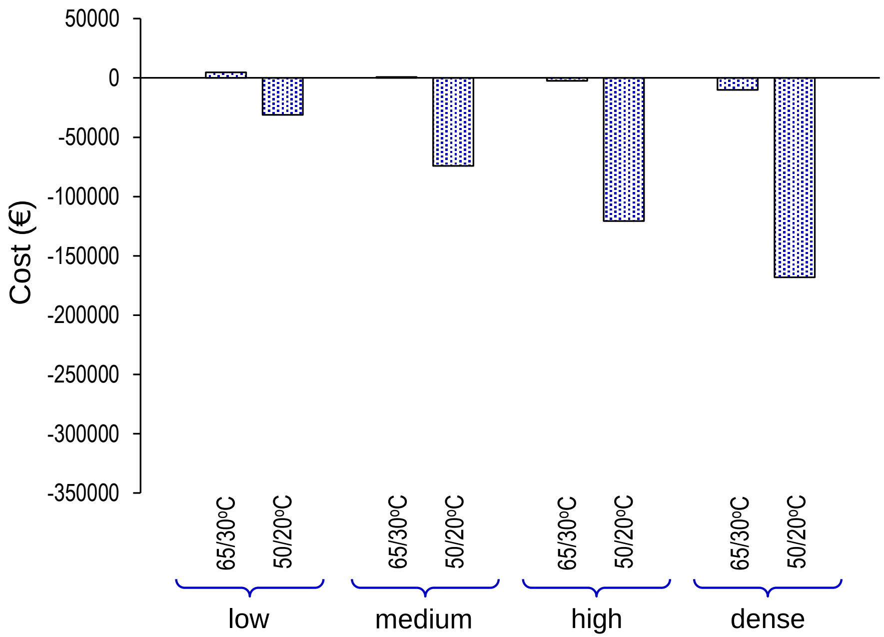
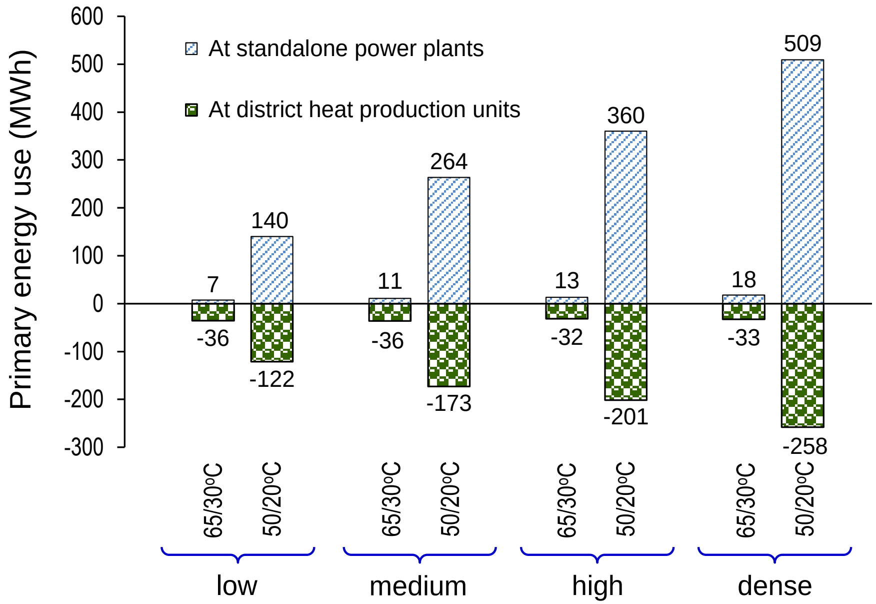
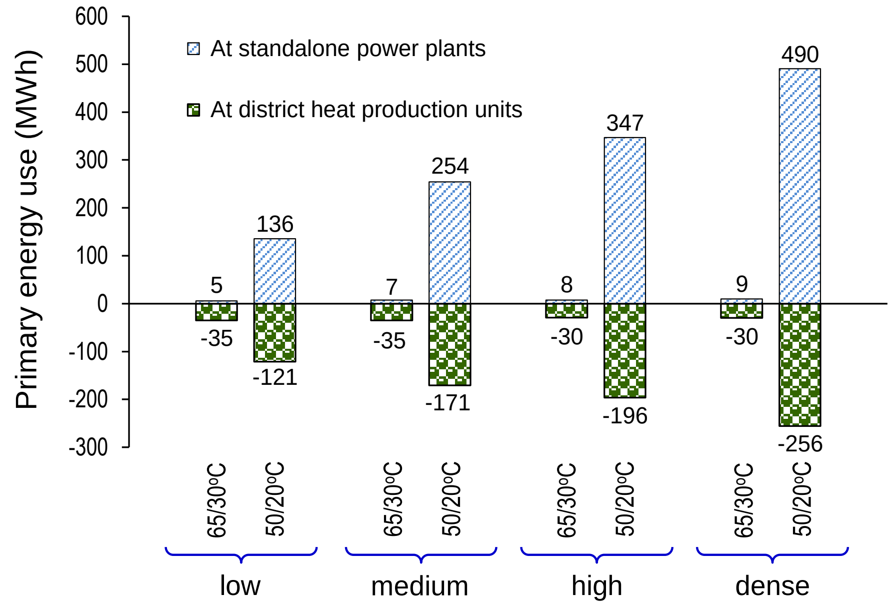


Passive house

Changed primary energy use for lower district heat temperatures – bio-based production



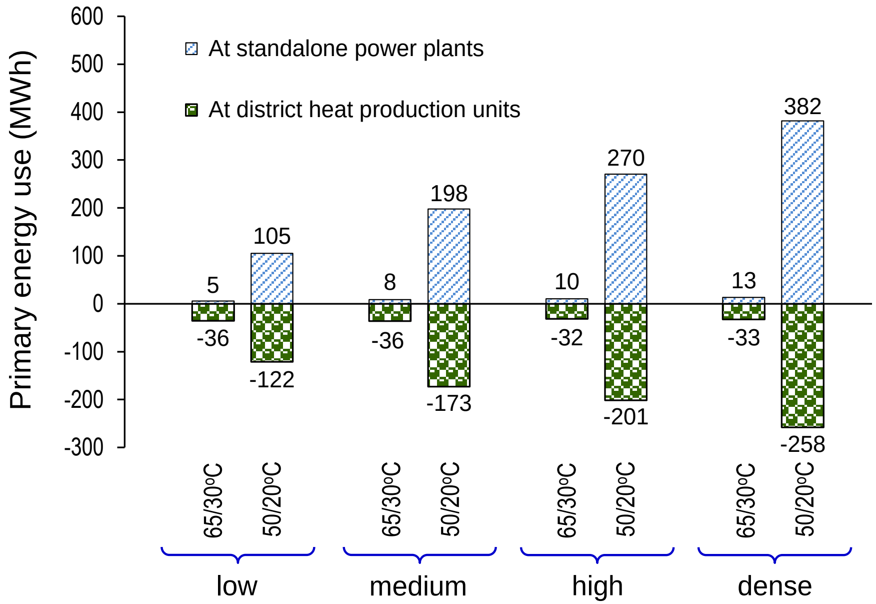
Building code



Passive house

Changed primary energy use for lower district heat temperatures – bio-based production + 25% wind power

(no primary energy use for wind power)



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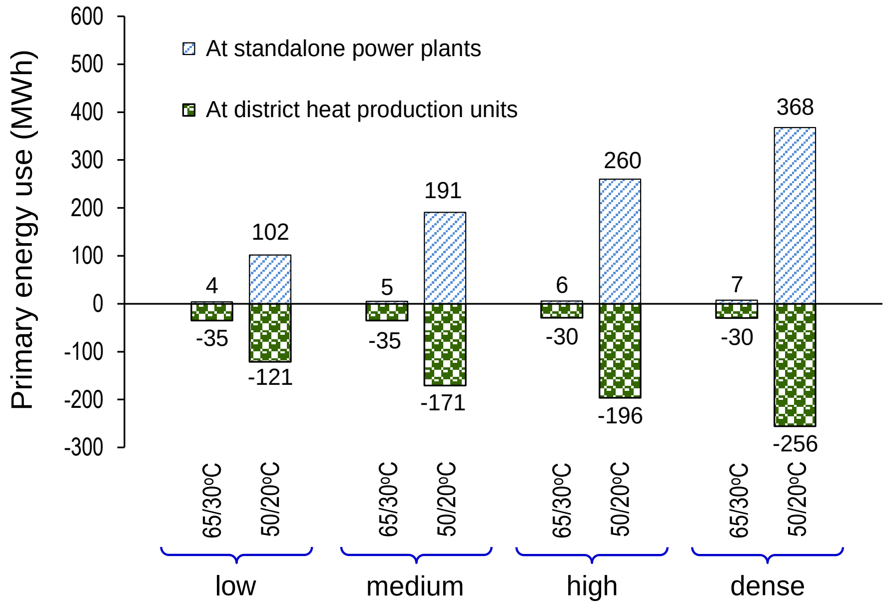

Passive house

Not considered

1. District heat production benefits of operating CHP-plants (heat pumps, waste heat, etc) at lower district heating temperatures
2. Reduced distribution heat losses in the overall distribution system due to lower supply/return temperatures
3. Implications on internal space heat distribution in buildings due to lower supply/return temperatures
4. Plastic pipes for district heat distribution

Discussion and Conclusions

1. Heat demand of a residential area depends strongly on building energy performance and land exploitation level
2. The heat density of the residential areas has a minor impact on the local district heat distribution losses
3. Reduced district heat supply/return temperatures strongly reduce the local district heat distribution losses
4. A 50/20^{o}C system increases electricity use, to boost hot water temperature to avoid the risk of legionella bacteria
5. A 65/30^{o}C system may be more cost and primary energy efficient when a 50/20^{o}C

Thank you!