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

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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

<table>
<thead>
<tr>
<th>Day</th>
<th>Ambient temp.</th>
<th>Supply temp.</th>
<th>Return temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Jan</td>
<td></td>
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</tr>
<tr>
<td>1-Feb</td>
<td></td>
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<tr>
<td>1-Mar</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1-Apr</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1-May</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Jun</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Jul</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Aug</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Sep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Oct</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1-Nov</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Dec</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Low exploitation of row houses and villas, 9010 m² heated floor area

Medium-exploitation of apartment buildings and row houses, 23 540 m² heated floor area

High-exploitation of apartment buildings, 29 350 m² heated floor area

Dense-exploitation of apartment buildings, 41 727 m² heated floor area
### Number of buildings

<table>
<thead>
<tr>
<th>Land exploitation</th>
<th>Villas</th>
<th>Row houses</th>
<th>6-storey buildings</th>
<th>8-storey buildings</th>
<th>10-storey buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>39</td>
<td>29</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Medium</td>
<td>21</td>
<td>29</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High</td>
<td>-</td>
<td>29</td>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dense</td>
<td>-</td>
<td>29</td>
<td>-</td>
<td>13</td>
<td>3</td>
</tr>
</tbody>
</table>
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°C (conventional system)
  - 65/30°C
  - 50/20°C
# Key energy properties of building code and passive house buildings

<table>
<thead>
<tr>
<th>Description</th>
<th>Building code</th>
<th>Passive house</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Exterior walls</td>
<td>0.33</td>
<td>0.10</td>
</tr>
<tr>
<td>Windows</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Doors</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Roof</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>Infiltration (l/s m² @50 Pa)</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td>80% heat recovery</td>
<td>80% heat recovery</td>
</tr>
</tbody>
</table>
## Space heating capacity (kW)

<table>
<thead>
<tr>
<th>House/building type</th>
<th>Building standard</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Building code</td>
<td>Passive house</td>
</tr>
<tr>
<td>Villas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o 100 m²</td>
<td>5.68</td>
<td>2.06</td>
</tr>
<tr>
<td>o 110 m²</td>
<td>5.81</td>
<td>2.16</td>
</tr>
<tr>
<td>o 120 m²</td>
<td>5.94</td>
<td>2.26</td>
</tr>
<tr>
<td>o 150 m²</td>
<td>6.32</td>
<td>2.55</td>
</tr>
<tr>
<td>Row houses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Type 1 (Regular)</td>
<td>Beginning</td>
<td>5.78</td>
</tr>
<tr>
<td></td>
<td>Middle row</td>
<td>3.99</td>
</tr>
<tr>
<td></td>
<td>End</td>
<td>5.87</td>
</tr>
<tr>
<td>o Type 2 (Offset of walls)</td>
<td>Beginning</td>
<td>5.78</td>
</tr>
<tr>
<td></td>
<td>Middle row</td>
<td>4.34</td>
</tr>
<tr>
<td></td>
<td>End</td>
<td>6.20</td>
</tr>
<tr>
<td>Multi-apartment buildings</td>
<td>6-storey, 24 apartments</td>
<td>54.47</td>
</tr>
<tr>
<td></td>
<td>8-storey, 32 apartments</td>
<td>70.96</td>
</tr>
<tr>
<td></td>
<td>10-storey, 40 apartments</td>
<td>87.46</td>
</tr>
</tbody>
</table>
Space- and hot water heating

Based on hour by hour energy balance calculations
Annual heat demand for space and hot water heating

Building code

Passive house

Heat demand (MWh)

Space heating

Hot water heating

Heat demand (MWh)

Space heating

Hot water heating

Annual heat demand for space and hot water heating
Heat supply network

Low exploitation, 1718m

Medium exploitation, 1686m
Heat supply network

High exploitation, 1341m

Dense exploitation, 1351m
District heat distribution losses

Building code

Passive house
District heat use, electricity use and distribution losses

Building code

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

65/30°C system 24-25%

50/20°C system 48-50%

Passive house
Annual changed final energy use when lower supply/return temperatures are used instead of a 80/40°C system

<table>
<thead>
<tr>
<th>Building code</th>
<th>Final energy use (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Electricity for electric heater</td>
</tr>
<tr>
<td>Medium</td>
<td>Heat distribution loss</td>
</tr>
<tr>
<td>High</td>
<td>Pumping electricity</td>
</tr>
<tr>
<td>Dense</td>
<td>District heat use</td>
</tr>
</tbody>
</table>

### Low
- 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)
  - 50°C-80°C/80°C: Energy use (MWh) 50°C-80°C/80°C: Energy use (MWh)
  - 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)

### Medium
- 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)
  - 50°C-80°C/80°C: Energy use (MWh) 50°C-80°C/80°C: Energy use (MWh)
  - 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)

### High
- 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)
  - 50°C-80°C/80°C: Energy use (MWh) 50°C-80°C/80°C: Energy use (MWh)
  - 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)

### Dense
- 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)
  - 50°C-80°C/80°C: Energy use (MWh) 50°C-80°C/80°C: Energy use (MWh)
  - 65°C-80°C/80°C: Energy use (MWh) 65°C-80°C/80°C: Energy use (MWh)
Investment costs for networks and substations

![Diagram showing investment costs for networks and substations in different building codes and Passive house types.](image-url)
Cost implication of reduced supply/return temperatures in local network with 80/40°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.
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

Building code

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

Negative values are cost increase

Building code

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

Building code

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

- At standalone power plants
- At district heat production units

Primary energy use (MWh)

Primary energy use (MWh)

Building code

Passive house

Linneuniversitetet Kalmar Växjö
Changed CO$_2$ emission for lower district heat temperatures - coal-based power plants

**Building code**

- 65/30°C
- 50/20°C

- medium
- high
- dense

**Passive house**

- 65/30°C
- 50/20°C

- medium
- high
- dense
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

Cost (€)

Building code

Passive house

Linneuniversitetet
Kalmar Växjö
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)

Building code

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°C system increases electricity use, to boost hot water temperature to avoid the risk of legionella bacteria.

5. A 65/30°C system may be more cost and primary energy efficient when a 50/20°C
Thank you!