District Heating Substation with Electrical Booster Supplied by 40°C Warm District Heating Water

EUDP project - District Heating unit with Electrical Booster for Ultra-Low-Temperature District Heating

Msc. Marek Brand, Ph.D.
marek.brand@danfoss.com
Application Specialist
Danfoss District Energy Application Center
Why reducing the DH supply temperature?

- Improve energy efficiency and better use of renewables
  - Big scale heat pumps -> increase of COP
  - Solar-thermal plants

- Enable use of low-grade waste heat

- Reduce heat loss from DH network
  - Importance increased with reduced demand of buildings

- Temperature levels:

<table>
<thead>
<tr>
<th>DH supply temperatures</th>
<th>DH network heat loss [%]</th>
<th>Need of on-site heat source</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;60°C</td>
<td>Traditional DH</td>
<td>100%</td>
</tr>
<tr>
<td>50°C</td>
<td>Low-temperature DH</td>
<td>81%</td>
</tr>
<tr>
<td>40°C</td>
<td>Ultra-low-temperature DH</td>
<td>56%</td>
</tr>
</tbody>
</table>

Development ⇒ of new unit
Substation with electrical booster

- DH substation + instantaneous electrical heater (on DHW side)
  - DH designed inlet temperature: 40°C
  - DHW temperature: (37°C) -> 45- 60°C
  - Substation bypass: 40°C
  - DHW output: 24 kW
  - Max. el. power: 11 kW -> 35 A main fuse
- Theoretical share of electricity on
  - DHW : \((10^\circ) \Rightarrow 37°C \Rightarrow 45°C = 23%\)
  - \((10^\circ) \Rightarrow 37°C \Rightarrow 55°C = 40%\)
- Total heat demand:

<table>
<thead>
<tr>
<th>Building area: 120 m²</th>
<th>Construction year</th>
<th>Space heating demand [MWh/y]</th>
<th>DHW demand* [MWh/y]</th>
<th>Theoretical share of el. on total heating energy [%] DHW 45°C</th>
<th>Theoretical share of el. on total heating energy [%] DHW 55°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-energy house</td>
<td>2010</td>
<td>6,3</td>
<td>1,8</td>
<td>5,1</td>
<td>8,9</td>
</tr>
<tr>
<td>Existing building - newer</td>
<td>1997</td>
<td>16,4</td>
<td>1,8</td>
<td>2,3</td>
<td>4</td>
</tr>
<tr>
<td>Existing building - old</td>
<td>1970</td>
<td>20</td>
<td>1,8</td>
<td>1,9</td>
<td>3,3</td>
</tr>
</tbody>
</table>

* Measured in the project

Scheme of electrical booster
Demonstration area and conditions

- City of Odder
- Five buildings from 1997
- Mainly floor heating + few radiators

- DH network and testing conditions

![](image)

One of the buildings

Supply temperature

62°C El. heater OFF + street bypass 60°C

41°C El. heater ON + house bypass 40°C
Performance – user perspective

**Measuring setup**

**Performance of electric booster**

<table>
<thead>
<tr>
<th>Building area: 120 m²</th>
<th>Construc tion year</th>
<th>SH demand [MWh/y]</th>
<th>DHW demand [MWh/y]</th>
<th>Share of el. on total heating energy [%] DHW 45°C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-energy house</strong></td>
<td>2010</td>
<td>6,3</td>
<td>1,8</td>
<td>5,1%</td>
</tr>
<tr>
<td><strong>Existing building</strong></td>
<td>1997</td>
<td>16,4</td>
<td>1,8</td>
<td>2,3%</td>
</tr>
<tr>
<td><strong>Existing building</strong></td>
<td>1970</td>
<td>20</td>
<td>1,8</td>
<td>1,9%</td>
</tr>
</tbody>
</table>
Economy

Reduced heat price can come from:

- **Low-grade heat (40°C):**
  - Sea water heat pump (sea water cooled from 4°C - 2°C):
    - COP ≈ 2.9 for 80/40°C
    - COP ≈ 4.2 for 50/30°C => reducing the el input 31 %
    - COP ≈ 5.2 for 40/25°C => reducing the el input 43 %
  - Use of low-grade waste heat in price level 100 - 332 DKK/MWh
  - Return temperature reduction: Biomass CHP reduction 40 → 25°C brings 6% lower heat production price
  - DH network heat loss reduction

<table>
<thead>
<tr>
<th>DH network supply temperature [°C]</th>
<th>heat loss [MWh/d]</th>
<th>Average supply</th>
<th>Average return</th>
<th>Return temp during idling [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>62°C</td>
<td>0,056</td>
<td>61,1</td>
<td>57,5</td>
<td>58</td>
</tr>
<tr>
<td>41°C</td>
<td>0,033</td>
<td>42,0</td>
<td>35,5</td>
<td>37</td>
</tr>
<tr>
<td>Heat loss reduction [%]</td>
<td>41%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Example – existing building (1997)

**Annual cost [DKK/house/y]**

<table>
<thead>
<tr>
<th></th>
<th>benchmark 100% DH</th>
<th>variant A (DH price 70%)</th>
<th>variant B (DH price 70% &amp; 50% fuses)</th>
<th>variant C (DH price 70% &amp; el. price 70% &amp; 50% fuses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced heat loss from DH network</td>
<td>0</td>
<td>-452</td>
<td>-452</td>
<td>-452</td>
</tr>
<tr>
<td>Energy bill for DH part</td>
<td>9328</td>
<td>6336</td>
<td>6336</td>
<td>6336</td>
</tr>
<tr>
<td>Energy bill for electricity part</td>
<td>0</td>
<td>1156</td>
<td>1156</td>
<td>809</td>
</tr>
<tr>
<td>Electric booster unit</td>
<td>0</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Installation</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Fuses - improvement</td>
<td>0</td>
<td>500</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Total</td>
<td>9328</td>
<td>7889</td>
<td>7639</td>
<td>7293</td>
</tr>
<tr>
<td>Simple payback time [y]</td>
<td>0,0</td>
<td>11,8</td>
<td>7,1</td>
<td>5,9</td>
</tr>
</tbody>
</table>

**Expected lifetime [y]**

- Electrical booster unit [DKK] 5000
- Installation [DKK] 2000

**DH original price [DKK/MWh]**

- 512,5

**El. original price [DKK/kWh]**

- 2,14

- Add 10 A to fuses [DKK] 10000

- Electrical booster enables lower price for district heating through higher heat source efficiencies and reduced heat loss from DH network
Next steps

- Continue with testing and improvements
  - Better el. heater
- More economical analyzes
- Make it as a product
- Find out how long we can run with 40°C supply temperature

Fig. 3. Supply temperature curves for all the investigated cases.
Conclusions

- It works, keep high DHW comfort
- Electricity share 2-7% from annual heating energy
- Reasonable payback time also in not “optimal case”
- DHW not as “the requirement” for minimal DH supply temperature
- 40°C supply temperature:
  - Reduced DH heat loss by 50% compared to 80/40/8°C
  - Improves energy efficiency of heat sources
  - Enables low-grade heat sources
- It might be “NEED” for the future DH systems
- Possible to use in both, low-energy but also existing buildings
Thank you

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