Cost analysis for Cold District Heating versus Low Temperature District Heating

Oddgeir Gudmundsson
Jan Eric Thorsen, Marek Brand
Danfoss - Heating Segment - Application Centre
Danfoss A/S, DK-Nordborg
The knowledge doubling curve
- The American futurist Richard Buckminster Fuller

- In 1982 the American futurist Richard Buckminster Fuller estimated the time it has taken to double the human knowledge in the past
  - Fuller estimated that it took 1500 years to double the human knowledge of the base year zero!
  - From year 0 to year 1988 it is estimated the knowledge has 128 folded!
  - IBM estimates that today the human knowledge doubles every 13 months!
  - In the near future it could be every 12 hours…

![Knowledge doubling curve graph]
Waves of innovation

- When looking back in time it seems that innovations come in waves with increasing frequency
- The world is speeding forward and we in the DH industry should work hard to develop and position our technologies in respect to future innovations
The age of data has arrived.

Global Information Storage Capacity in optimally compressed bytes

- Paper, film, audiotape and vinyl: 66%
- Analog videotapes (VHS, etc): 94%
- Portable media, flash drives: 2%
- Portable hard disks: 2.4%
- CDs and minidisks: 6.8%
- Computer servers and mainframes: 8.9%
- Digital tape: 11.8%
- DVD/Blu-ray: 22.8%
- PC hard disks: 44.5%
- Others: < 1% (hard, chip cards, memory cards, floppy disks, mobile phones, PDAs, cameras, camcorders, video games)

% digital:
1%  3%  25%  94%

2002: "beginning of the digital age"
50%

District heating generations
- Mega trends

Temperature level
- 1G: >200°C
- 2G: >100°C
- 3G: <100°C
- 5G: 50-60°C (70°C)

Energy efficiency
- 1G: Steam system, steam pipes in concrete ducts
- 2G: Presurised hot-water system, heavy equipment, large boiler stations
- 3G: Prefabricated, pre-insulated pipes, industrialised, compact substations (also with insulation), metering and monitoring
- 4G: 4th Generation, low energy demands, smart energy (optimum interaction of energy sources, distribution, and consumption), 2-way CH

Future energy source
- Biomass conversion
- District heating
What could be next steps with reducing the temperature levels?

- **Basic requirement:**
  - The systems are supplying heat for both space heating and DHW purposes
Cold District Heating

- Individual ground source heat pump with borehole heat exchangers
- Centralized borehole heat exchanger field supplying multiple houses
What are the main differences going from LTDH to CDH?

- Limited cooling of the supply
- Results in large pipes and large flow rate

- No need for insulation on the pipes
- Cheaper pipes

Cost of pipes to deliver 100 kW
LTDH → DN25 → 770 DKK
CDH → DN50 → 500 DKK → CDH ~35% cheaper

Capacity difference is by factor 5!
What are the main differences going from LTDH to CDH?

- Limited cooling of the supply
  - Results in large pipes and large flow rate
- No need for insulation on the pipes
  - Cheaper pipes

Capacity difference is by factor 5!

Cost of pipes to deliver 100 kW
LTDH ➔ DN65 ➔ 1.650 DKK
CDH ➔ DN150 ➔ 1.200 DKK  CDH ~27% cheaper

Pipe size to deliver 750 kW
LTDH ➔ DN65
CDH ➔ DN150
Pipe network design

- The design of the distribution network is dependent on the operating cost and the operating limits of the equipment.

- The main operating costs are:
  - Distribution heat loss
  - Pumping cost

<table>
<thead>
<tr>
<th>Importance?</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTDH</td>
</tr>
<tr>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
</tr>
</tbody>
</table>
Heat demand of buildings in the study

- Low energy buildings are the future. But perhaps not low heating demand..

- The idea was to go with the current DK building standard but take into account people behavior

<table>
<thead>
<tr>
<th>Buildings fulfilling: Building Class 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single family house: 6,25 MWh/year (159 m²)</td>
</tr>
<tr>
<td>Row house apartment: 4,3 MWh/year (110 m²)</td>
</tr>
<tr>
<td>Apartment building: 3,85 MWh/year (95 m²)</td>
</tr>
</tbody>
</table>

- Likely this is too low estimation of heat demand..

- According to studies performed at DTU a more realistic demand could be:
  - Single family house: 10 MWh/year (159 m²)
  - Row house apartment: 7,5 MWh/year (110 m²)
  - Apartment building: 6,9 MWh/year (95 m²)
Case 1
– Small network with 15 consumers

• **Basic idea:** Avoid individual boreholes and do a collective borehole field to supply decentralized heat pumps

• **Reasoning:** Fewer boreholes = less cost

• **Economic comparison:** Centralized heat pump vs. decentralized heat pumps
Case 1
– Small network with 15 end consumers

- Basic results are following:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CDH</td>
<td>427.000</td>
<td>1.035.000</td>
<td>0</td>
<td>108.000</td>
<td>25.000</td>
<td>48.700</td>
<td>0</td>
<td>181.700</td>
</tr>
<tr>
<td>LTDH</td>
<td>498.000</td>
<td>300.000</td>
<td>223.500</td>
<td>71.000</td>
<td>19.000</td>
<td>46.300</td>
<td>10.000</td>
<td>146.300</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDH-LTDH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35.400</td>
</tr>
</tbody>
</table>

Could LTDH be justified in this case?
- Not necessarily..
- Because:
  - Cost of the central HP does not include the housing cost

Average TCO/year/house
- CDH ~12.100 DKK
- LTDH ~9.800 DKK

Assumptions:
Pipe network:
- Experience from Sweden
- CDH assuming prices from cold water distribution
House units:
- Decentralized heat pump: 69.000 DKK ➔ COP of 4.0
- Multi-apartment heat pump: 223.500 DKK ➔ COP of 4.2
- DH substation: 20.000 DKK
- Multi-apartment substation: 94.000 DKK
Central unit:
- Heat pump ➔ COP of 4.2
Other:
- Electricity cost is the same for both cases
- Applied interest rate is 5%
Case 2
- Medium sized distribution network with 383 end consumers

- Are the results from case 1 scalable?
- **Benefits towards CDH:** Larger the system the more heat loss, could that work in favor of DH?
- **Benefits towards LTDH:** The larger the system becomes the more money is available to invest in the centralized solution

- **System simplification:**
  To avoid multiple borehole fields it is assumed that there is a nearby lake that can be used as a heat source
## Case 2
- Medium sized distribution network with 383 end consumers

- Basic results are following:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CDH</td>
<td>5.728.000</td>
<td>20.419.000</td>
<td>0</td>
<td>1.956.000</td>
<td>508.000</td>
<td>988.000</td>
<td>0</td>
<td>3.452.000</td>
</tr>
<tr>
<td>LTDH</td>
<td>8.095.000</td>
<td>6.036.000</td>
<td>6.258.000</td>
<td>1.419.000</td>
<td>451.000</td>
<td>940.000</td>
<td>213.000</td>
<td>3.023.000</td>
</tr>
<tr>
<td>Difference CDH-LTDH</td>
<td>537.000</td>
<td>57.000</td>
<td>48.000</td>
<td>-213.000</td>
<td>429.000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- LTDH is favorable!

Average TCO/year/house:
- CDH ~9,000 DKK
- LTDH ~7,900 DKK

Assumptions:
- Pipe network:
  - Experience from Sweden
  - CDH assuming prices from cold water distribution
- House units:
  - Decentralized heat pump: 69.000 DKK ➔ COP of 4.0
  - Multi-apartment heat pump: 223.500 DKK ➔ COP of 4.2
  - DH substation: 20,000 DKK
  - Multi-apartment substation: 94,000 DKK
- Central unit:
  - Heat pump ➔ COP of 3.5
- Other:
  - Electricity cost is the same for both cases
  - Applied interest rate is 5%
Case 3
- What if there is no lake?

• Now we would compare multiple small CDH systems with one large LTDH

• In this case the comparison will be between case 1 and case 2 supplied with air source heat pump
Comparison of TCO between CDH and LTDH with A2W heat pump

- Basic results are following:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LTDH</td>
<td>8.095.000</td>
<td>6.036.000</td>
<td>6.258.000</td>
<td>1.419.000</td>
<td>451.000</td>
<td>1.129.000</td>
<td>256.000</td>
<td>3.255.000</td>
</tr>
<tr>
<td>Case 3 – A2W LTDH</td>
<td>TCO/house</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.500</td>
</tr>
<tr>
<td>Case 1 – CDH</td>
<td>TCO/house</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.000</td>
</tr>
</tbody>
</table>

- LTDH is still favorable!
- Note: The cost of drilling the geothermal wells for CDH are excluded!

Average TCO/year/house:
- CDH ~12.000 DKK
- LTDH ~8.500 DKK

Assumptions:
Pipe network:
- Experience from Sweden
- CDH assuming prices from cold water distribution
House units:
- Decentralized heat pump: 69.000 DKK ➔ COP of 4.0
- Multi-apartment heat pump: 223.500 DKK ➔ COP of 4.2
- DH substation: 20.000 DKK
- Multi-apartment substation: 94.000 DKK
Central unit
- Heat pump ➔ COP of 4.2
Other:
- Electricity cost is the same for both cases
- Applied interest rate is 5%
What could influence the results?

- **Heat sources**
  1. Currently there is a wide price range for both small and large heat pumps
  2. A major benefit of district heating is the option to use the cheapest available heat

- **COP of the heat pumps**
  - For single family heat pumps a COP of 4.0 was used
  - For the larger W2W heat pumps COP of 4.2 was used
  - For the larger A2W heat pumps COP of 3.5 was used

- **Source of the electricity**
  - Being a large consumer gives some possibilities to receive cheaper electricity

Annual average:
- 3.3 for FH, 3 for radiators
- 4.3
- 3.7
Cost of electricity for industry
- Info from the “Drejebog til store varmepumpeprojekter i fjernvarmesystemet”

- The cost of electricity to an industry identity, such as DH utility, varies:
  - How the consumer is connected to the grid
  - Location (which electricity company is the supplier)

- Bottom line is that it matters whom is buying the electricity!
  - In this analysis it was although considered that the same electricity price would be used in both individual heat pumps and centralized heat pumps
Conclusions

• The main obstacle for CDH is the high cost of decentralized heat pumps

• Given the assumptions, the benefits of CDH over LTDH are not obvious.
  • Even in case of air source heat pumps the CDH is not an economically feasible solution

• **Advantages of LTDH over CDH**
  • If alternative heat sources become available it would be simpler and more cost efficient to add them to the LTDH than the CDH system
  • LTDH will be simpler to operate due to more centralized location of equipment
  • If the DHU can get cheaper electricity prices it will significantly favor the LTDH
  • In a large system a centralized thermal storage would allow to optimize the operation in case of:
    • Fluctuating electricity prices from renewables
    • Peak load smoothing

• **Advantages of CDH over LTDH**
  • With the low supply temperatures it would be possible to provide cooling during the summer period
Thank you for your attention

Contact information:
Dr. Oddgeir Gudmundsson
Director, Projects
og@danfoss.com
www.linkedin.com/in/oddgeirgudmundsson
Data sources

- Main data sources are coming from:

  - **Estimation of cost of laying down the distribution network:**
    - The costs were adapted to inflation between 2007 and 2016 (12%)
    - Cost of uninsulated PE/PEX pipes and installation in case of CDH is coming from the Vandprishåndbogen

  - **Centralized heat pump data**
    - Cost of heat pumps with various capacities

  - **Decentralized equipment**
    - DH substation:
      - Danfoss A/S
    - Heat pump cost and efficiency data
      - Cost of decentral heat pump is acquired from Søren Andersen from Skjold-Andersen.
Electricity prices

- Residential electricity price in DK is: 1.79 DKK/kWh (excluding VAT)
  - Electricity for space heating with a heat pump is subsidized: 1.15 DKK/kWh (ex. VAT)

- Depending on at what stage in the power distribution system the electricity is taken the industry can avoid certain taxes and transportation fees.
- In case the DH company can access the power grid at high voltages it will make a significant benefit towards the centralized solution
- See next slide on possible variations of electricity price for large consumers and DHU

- Data from the European commission on electricity prices by countries shows that the electricity prices vary between household and industry
  - This needs to be considered when comparing the systems outside DK