Improving the performance of District Heating Systems in Central and Eastern Europe

Goran Krajačić

5th International Conference on Smart Energy Systems

Copenhagen, 10th of September 2019
KeepWarm - 11 partners from 8 countries
What can we do for them?

To overcome barriers to district heating deployment in CEE, KeepWarm works in a multi-stage approach to conduct the following activities:

- Increase the capacity of specialists working in DHS companies by offering **training** workshops
- Support them with the development of viable **business plans**
- Advise them on how to **mobilise funding** for bankable pilot projects
- Exhibit replicable DHS **demo cases**
- Facilitate the multi-level integration of DHS retrofits into key **strategies and plans**
RES in DH in Croatia

- Biomass cogeneration
  - 3 MWe, 10 MW\(_{th}\) (Osijek, Sisak)
  - 1 MWe, 4,5 MW\(_{th}\) (Glina)
  - ...

- Biomass boiler
  - 1 MW\(_{th}\) (Pokupsko)

- Solar thermal
  - 400 m\(^2\); 260,8 kW\(_{th}\) (Vukovar)

- Geothermal?
  - Krapinske toplice, Topusko, Varaždinske toplice

- Heat pumps?
District heating system in Velika Gorica

<table>
<thead>
<tr>
<th>SYSTEM PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTRACTED POWER</td>
<td>46,56 MW (installed 59 MW)</td>
</tr>
<tr>
<td>HEATED AREA</td>
<td>338,379.91 m²</td>
</tr>
<tr>
<td>NUMBER OF HEATING SUBSTATIONS</td>
<td>120</td>
</tr>
<tr>
<td>PIPELINE LENGHT</td>
<td>10.671m</td>
</tr>
<tr>
<td>PERCENTAGE OF PREINSULATED PIPES</td>
<td>70%</td>
</tr>
</tbody>
</table>
Inputs

Energy flows in DHS Velika Gorica

MWh

Energy conversion and distribution

53.431
71%

15.650
21%

6.184
8%

Heat production and consumption - Vidričeva

Heat [MWh]

Delivered heat

Heat losses

Month

[12]

Delivered heat

[12]

Heat losses

[12]
Gas consumption

Hourly gas consumption - typical week [MWh]

Hourly gas consumption [MWh]
Seasonal storage - Velika Gorica

Critical volume criteria

- do not reject any heat produced
- reach the maximum usage of the accumulation

https://doi.org/10.2298/TSCI151106106A
DHC – integration V. Gorica
DH expansion?

<table>
<thead>
<tr>
<th>District</th>
<th>Heat Demand [MWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buzin</td>
<td>22 500</td>
</tr>
<tr>
<td>Veliko Polje – Velika Mlaka</td>
<td>32 900</td>
</tr>
<tr>
<td>Velika Gorica</td>
<td>158 350</td>
</tr>
<tr>
<td>International airport Zagreb</td>
<td>47 900</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project</th>
<th>Scenarij 1</th>
<th>Scenarij 2 - vrelovod</th>
<th>Scenarij 2 - OEI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment $I_0$</td>
<td>11,685,090,00 €</td>
<td>18,539,400,00 €</td>
<td>75,700,000,00 €</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>1,168,509,00 €</td>
<td>1,853,940,00 €</td>
<td>2,385,000,00 €</td>
</tr>
<tr>
<td>Fuel cost</td>
<td>-</td>
<td>-</td>
<td>825,000,00 €</td>
</tr>
<tr>
<td>Production</td>
<td>158,350 MWh</td>
<td>171,650 MWh</td>
<td>90,000 MWh</td>
</tr>
<tr>
<td>LCOE</td>
<td>13,30 €/MWh</td>
<td>19,47 €/MWh</td>
<td>103,5 €/MWh</td>
</tr>
<tr>
<td>LCOE total</td>
<td>48,37 €/MWh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Interconnecting DH grids of Zagreb and Velika Gorica

Final energy demand: 652,6 GWh
Generation demand: 774,0 GWh

Final energy demand: 859,8 GWh
Generation demand: 1019,7 GWh

Final energy demand: 54,9 GWh
Generation demand: 61,0 GWh

In Cooperation with CITIES project and DTU Compute
Case study assumptions

• Connection piping price assumptions from: *Frederiksen, Werner: District Heating and Cooling* – adjusted for inflation and currency exchange

  • Piping cost:

<table>
<thead>
<tr>
<th></th>
<th>Start – up cost (M€)</th>
<th>Additional cost per capacity (M€/MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velika Gorica</td>
<td>3,87</td>
<td>0,35</td>
</tr>
</tbody>
</table>

• Perfect foresight
• DH distribution losses modelled exogenously
• Transmission pipe loss: 5%
• Technology costs from: *Technology datasheet for energy plants* by Energinet and DEA
• CO2 price: 22€ / ton
• Electricity distribution and transmission fees: 40 €/MWh_{ele} (in total)
Case study – investment options

- 1) Thermal energy storage
- 2) Electric boiler and/or heat pump
- 3) Connection pipe:
  – Zagreb south to Velika Gorica

<table>
<thead>
<tr>
<th></th>
<th>Investment cost (EUR/MW_{\text{heat}})</th>
<th>Annualized investment cost (EUR/(MW year))</th>
<th>Fixed cost (EUR/(MW year))</th>
<th>Variable cost (EUR/MWh)</th>
<th>Total efficiency</th>
<th>Lifetime (years)</th>
<th>Discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric boiler</td>
<td>75,000</td>
<td>7,079</td>
<td>1,100</td>
<td>0.8</td>
<td>98%</td>
<td>20</td>
<td>7%</td>
</tr>
<tr>
<td>Heat pump</td>
<td>700,000</td>
<td>60,067</td>
<td>2,000</td>
<td>2</td>
<td>400% (COP)*</td>
<td>25</td>
<td>7%</td>
</tr>
<tr>
<td>Thermal storage</td>
<td>3,000</td>
<td>225</td>
<td>8.6</td>
<td>0.1</td>
<td>98%</td>
<td>40</td>
<td>7%</td>
</tr>
</tbody>
</table>

*COP: Coefficient of Performance
Results techno-economic assessment

- Optimal investment portfolio: 972 MWh thermal storage and 20.75 MW pipe capacity (peak final energy demand: 23.48 MW)

<table>
<thead>
<tr>
<th></th>
<th>Storage</th>
<th>Connection pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost (€)</td>
<td>2,916,000</td>
<td>11,127,275</td>
</tr>
<tr>
<td>Annuity (€ / year)</td>
<td>218,727</td>
<td>834,647</td>
</tr>
<tr>
<td>Total O&amp;M (€ / year)</td>
<td>8,359</td>
<td>66,017</td>
</tr>
<tr>
<td>Total yearly costs (€/year)</td>
<td>8,359</td>
<td>1,127,750</td>
</tr>
</tbody>
</table>

- *compared to the best available alternative (gas and individual heat pump)*

- **€/MWh of heat sold**
  - Capital price to recover investment: 20.5
  - Calculated ‘room’ for DH heat price*: 18.7

In Cooperation with CITIES project and DTU Compute
Results

In Cooperation with CITIES project and DTU Compute

Cropex day ahead weighted average price for 2017: 53.81 €/MWh (source: Cropex)
DK1 and DK2 on Nordpool day ahead: 30.08 and 31.97 €/MWh (source: Nordpool)
Gas price in 2017: 26 €/MWh for non-household consumers in Croatia (source: Eurostat)

<table>
<thead>
<tr>
<th>Connected DH systems:</th>
<th>All heat supplied via interconnection</th>
<th>Optimal portfolio (M€/year)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velika Gorica and Zagreb</td>
<td>3,93</td>
<td>3,29</td>
<td>-16.3 %</td>
</tr>
</tbody>
</table>

Overall savings after the interconnection!
But highly sensitive to electricity and gas prices

!! Socio-economic costs sensitive to electricity prices > income from electricity sales – around 117 M€
Solar DH in V. Gorica assumptions

- Storage loss: 10%
- Equipment costs (pipelines, pumps, valves, etc.) = 10% of the investment cost
- Other costs (design, regulation system, etc.) = 12% of the investment costs
- Discount rate: 5%
- Lifetime: collector field – 25 years, storage – 50 years
Method

• Isentropic model for the calculation of collector output
• EnergyPLAN model
• Storage capacity – based on 100% solar heat utilization
• Heat price – modified calculation based on Guadalfajara et all:A simple method to calculate Central Solar Heating Plants with Seasonal Storage, 2013
Conclusions for Solar DH – work in progress

- around 15% of heat demand can be covered via solar collectors using only small buffer storage (SF 15% = 190 MWh storage)
- heat prices range between 53€ and 69€ per MWh
Compete with n. gas heating

Gas prices (including taxes) for household consumers, second half 2018

Source: Eurostat (online data codes: nrg_pc_202)
Support DH through policy?

N. Gas price composition

Wholesale day-ahead gas prices on gas hubs in the EU
This project is funded by the EU’s Horizon 2020 research and innovation programme under grant agreement No 784966, and lasts from April 2018 – September 2020. This project receives co-funding from the German Federal Ministry of Economic Cooperation and Development.