HEAT TO POWER

– techno-economic assessment of heat-to-power use in district heating networks

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Built Environment
Energy and circular economy
30% 
2014 – 2020

(IEA, 2016)

Electricity price volatility [EUR/MWh]

<table>
<thead>
<tr>
<th>Country</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>2015: 0</td>
</tr>
<tr>
<td></td>
<td>2020: 203</td>
</tr>
<tr>
<td>Germany</td>
<td>2015: 0</td>
</tr>
<tr>
<td>Poland</td>
<td>2015: 0</td>
</tr>
<tr>
<td>France</td>
<td>2015: 0</td>
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</tbody>
</table>
Coming up…

§ Thermal grids vision
§ Heat to power
§ Levelised cost of electricity (LCOE) from thermal grid heat
Thermal grids future

Residential buildings

Renewable sources

Industrial waste heat

Prosumers

Commercial buildings

New demand

Heating or CHP plant

Future interactions

Gas grid

Thermal grid

Electricity grid
Temperatures

2\textsuperscript{nd} gen: High temp.

3\textsuperscript{rd} gen: Medium temp.

4\textsuperscript{th} (next)gen: Low temp.

Max. peak Europe: \textbf{120 °C}

Annual average...

Sweden 86 °C

Denmark 74 °C...

80 °C

(Lund et al., 2014; Østergaard and Svendsen, 2017)

(Dansk Fjernvarme, 2016; Frederiksen and Werner, 2013)
Technology selection

- Thermodynamic power cycles
  - Organic Rankine cycle (ORC)
  - Kalina cycle
  - Goswami cycle
  - Commercial ORC-like cycles
- Direct processes
  - Thermoelectric
  - Piezoelectric
  - Thermionic
  - Thermo-photovoltaic
- Appropriate operating temperature and power demand
- Competitive cost
- Efficiency
- Commercially available
- Selected: ORC and commercial cycles
Organic Rankine cycle

Heat source

Hot circuit

Cold circuit

Heat sink

$T_{H1}$

$T_{H2}$

$T_{C1}$

$T_{C2}$

$E_{OUT}$
Levelised Cost of Electricity (LCOE)

the net present value of the unit-cost of electricity over the lifetime of a generating asset

\[
LCOE = LFC + LVC = \frac{TIC \times r}{Q} + M \left( \frac{1}{1 - (1 + r)^{-T}} \right) Q
\]

(Blumsack, 2014)

- Heat source temperatures: 80 °C and 120 °C
- Heat sink temperature 20 °C
- Shutdown time: 48 hours, 1 month, 3 months
- Heat has zero cost
- Pump electricity not included
- Data from 3 heat to power vendors

LFC = Levelised Fixed Cost
LVC = Levelised Variable Cost
TIC = Total Installed Cost
r = discount rate (6 %)
T = technology lifetime (years)
Q = annual energy output
M = operational costs
Calculated LCOE

<table>
<thead>
<tr>
<th>Annual shutdown time</th>
<th>Vendor 3</th>
<th>Vendor 2</th>
<th>Vendor 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td></td>
<td></td>
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<tr>
<td>48 Hours</td>
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Levelized cost of electricity, LCOE (€/MWh)

- 80 °C
- 120 °C
69 € /MWh in context…

54 € /MWh UK annual average (peak 75 €)

121 € /MWh New York annual average

63 € /MWh UK offshore wind
Conclusions

Levelized cost of electricity

- Most sensitive to:
  - Installation cost
  - Heat availability / annual operation time
- Cold sink source important

Upcoming analysis

- LCOE sensitivity to hot / cold temperature
- Test case with district heating network data
- Include levelized cost of heat
- Scenarios economically & technically feasible
THANKS!

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References


