Assessment of the economic viability of the integration of industrial waste heat into existing district heating grids

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Motivation

- Remarkable amount of industrial waste heat currently unused
- Low-temperature heat demand in district heating grids
- Increase efficiency of the overall energy system by using this excess heat in district heating grids

→ Need for an understanding of the economic performance of industrial waste-heat-to-grid systems
Research question

“What is the economic feasibility of the integration of industrial waste heat into existing district heating grids under different conditions?”

→ identify the parameters that have the highest influence on the economic efficiency of industrial waste-heat-to-grid systems

→ estimate expectable supply costs for industrial waste-heat-to-grid systems
METHODOLOGY
Methodology overview

(1) A **techno-economic modeling tool** is developed that simulates industrial waste-heat-to-grid systems on an hourly basis.

(2) **Data research** is conducted on costs of industrial waste heat recovery and feed in district heating grid systems.

(3) A **reference scenario** is defined and a **sensitivity analysis** is carried out in order to identify the parameters with the highest influence on the economic feasibility.
System concept used for the analysis

Source 1: process water
Source 2: compressor
Source 3: flue gas

Losses in the pipes - internally
Losses in the pipes - externally
District heating grid

Industrial site
External area

Absorption Circuit
Distribution Circuit
Transfer Station
Pump
Economic representation

- Calculated on the basis of one representative year
- Dynamic economic assessment: discounted cash flow calculation
- Chosen assessment value: Levelized Costs of Heat (LCOH)

\[
LCOH = \frac{\sum_{t=0}^{\tau} C_t (1 + r)^{-t}}{\sum_{t=0}^{\tau} E_t (1 + r)^{-t}}
\]
DATA & DEFINITION OF REFERENCE CASE
Costs for the waste-heat-to-grid system

➢ **Heat Exchangers, transfer station**: investment, O&M

\[ c_{\text{invest}} = a \cdot Base^b + c \]

<table>
<thead>
<tr>
<th>heat exchanger</th>
<th>base value in the cost curve</th>
<th>parameters of the cost curve</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>plate heat exchanger</td>
<td>heat transfer surface [m²]</td>
<td>410</td>
<td>-0.30</td>
</tr>
<tr>
<td>compressor heat exchanger</td>
<td>rated motor power [kW]</td>
<td>199</td>
<td>-0.32</td>
</tr>
<tr>
<td>tube bundle heat exchanger</td>
<td>heat transfer surface [m²]</td>
<td>363</td>
<td>-0.10</td>
</tr>
<tr>
<td>transfer station</td>
<td>transfer power [kW]</td>
<td>1,048</td>
<td>-0.63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>plate heat exchanger</td>
<td>300 - 400</td>
<td>€/m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>compressor heat exchanger</td>
<td>50 - 80</td>
<td>€/kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tube bundle heat exchanger</td>
<td>500 - 550</td>
<td>€/m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transfer station</td>
<td>10 - 15</td>
<td>€/kW</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

➢ **Pipes**: investment for pipes and insulation
  • 27 – 213 €/m inside plant area (above ground, 25 – 150 mm)
  • 300 – 500 €/m outside plant area (underground, 25 – 150 mm)

➢ **Pumps**: Investment, O&M, electricity
  • 1500 – 6900 € (32 – 150 mm)
  • 11 ct.EUR/kWh electricity
Definition of the reference case

<table>
<thead>
<tr>
<th>parameter</th>
<th>unit</th>
<th>reference case</th>
<th>range of sensitivity analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>available waste heat power</td>
<td>MW</td>
<td>1</td>
<td>0,5 - 3</td>
</tr>
<tr>
<td>$T_{\text{return, district heating grid}}$</td>
<td>°C</td>
<td>50</td>
<td>40, 50, 60</td>
</tr>
<tr>
<td>$T_{\text{flow, district heating grid}}$</td>
<td>°C</td>
<td>70 - 90</td>
<td>no variation</td>
</tr>
<tr>
<td>economic assessment period</td>
<td>a</td>
<td>10</td>
<td>1 - 20</td>
</tr>
<tr>
<td>interest rate</td>
<td>%</td>
<td>7</td>
<td>no variation</td>
</tr>
<tr>
<td>distance between the transfer station and the grid</td>
<td>m</td>
<td>250</td>
<td>100 - 1000</td>
</tr>
<tr>
<td>load profile</td>
<td>-</td>
<td>2 shifts, no weekends, no holidays</td>
<td>2 / 3 shifts, weekends yes/no, holidays yes/no</td>
</tr>
</tbody>
</table>
RESULTS
return temperatures of the district heating grid, economic assessment periods, cost components

<table>
<thead>
<tr>
<th>Temperature [°C]</th>
<th>40°C</th>
<th>50°C</th>
<th>60°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Period</td>
<td>5 a</td>
<td>10 a</td>
<td>15 a</td>
</tr>
</tbody>
</table>

- **Levelized Costs of Heat (LCOH)** [ct. EUR/kWh]
- **Economic Assessment Period [a]**
- **Return Flow Temperature [°C]**

- **Pump**
- **Pipes external**
- **Pipes internal**
- **Transfer Station**
- **HEx 3 - Flue gas**
- **HEx 2 - Compressor**
- **HEx 1 - Process Water**
Sensitivity comparison

LCOH for T_{return,flow, X}/LCOH for T_{return,flow} = 40°C

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>economic assessment period</td>
<td>1 a</td>
<td>20 a</td>
</tr>
<tr>
<td>distance between the transfer station and the grid</td>
<td>100 m</td>
<td>1000 m</td>
</tr>
<tr>
<td>available waste heat power</td>
<td>0.5 MW</td>
<td>3 MW</td>
</tr>
</tbody>
</table>

Temperature of the return flow (T_{return,flow, X})/sensitivity parameter

50°C

60°C
return flow temperature, distance to grid
available waste heat power, full load hours

![Graph showing the relationship between Levelized Costs of Heat (LCOH) and Available Waste Heat Power, Full Load Hours.]

Levels of operation:
- 3-shift, no weekend, no holiday
- 2-shift, no weekend, no holiday
- 2-shift, no weekend, holiday
- 2-shift, weekend, holiday

Available Waste Heat Power [MW]
- 0.50
- 0.75
- 1.00
- 1.25
- 1.50
- 1.75
- 2.00
- 2.25
- 2.50
- 2.75
- 3.00

Levelized Costs of Heat (LCOH) [ct. EUR/kWh]
- 0.2
- 0.4
- 0.6
- 0.8
- 1.0
- 1.2
- 1.4
- 1.6
- 1.8

Full Load Hours [h/a]
- 1,000
- 2,000
- 3,000
- 4,000
- 5,000
- 6,000
- 7,000
- 8,000
- 9,000
CONCLUSIONS & DISCUSSION
Conclusions & discussion

Highly influencing factors on the economic efficiency of industrial waste-heat-to-grid systems:

- return temperature of the district heating grid
- distance between transfer station and the district heating grid
- economic assessment period
- available waste heat power
- full load hours of the system

For many combinations of these parameters → costs below 1 ct.EUR/kWh (purchase prices in Europe 4 – 5 ct.EUR/kWh)

However, this is a first and theoretical estimation!
Further important aspects – at the plant side

- **Variation of load and temperature profiles for waste heat from various processes:** strong assumption that all processes have the same load profiles for this study
  - Storage tank needed, increase of costs especially for short economic assessment periods

- **Differences in materials treated within the processes:** sometimes need for special materials of the heat exchangers to avoid erosion
  - Remarkable increase in the investment costs possible
Further important aspects – at the grid side

- **High flow temperatures in some existing district heating grids:** In primary parts of large district heating grids also temperatures up to 110°C and above occur (vs. 70 – 90°C in this study)

  → reachable with waste heat or heat pump needed?

- **Limitations regarding the amount of waste heat to be integrated:** depends on the existing supply structure in the grid (base load in summer approx. 10% of peak load in winter)

  → could be a barrier for implementation if base load is filled with waste incineration (often occurring in large cities)
Questions for the discussion

- What is your experience regarding costs for HEx and piping?

- Do you know data sources for further research: costs for components / transaction / permission?

- Do you have (heard of / seen) calculations for industrial waste-heat-to-grid systems? What were the results there?

→ Thank you!