An analysis of heat pumps for industrial applications

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Case study:

Heating capacity = 200 kW
Temperature heat sink = 60 °C
Temperature heat source = 35 °C
Annual operating hours = 7 860 h/a

Compression heat pump (chp)
\[ \text{COP}_{h,chp} = 5 \]

- 40 kW electrical driving power
- Electrical energy price \( c_{el} = 5.4 \text{ to } 9.8 \text{ ct/kWh} \)
- 160 kW industrial waste heat at low temperature
- 200 kW useful heat at medium temperature

Absorption heat pump (ahp)
\[ \text{COP}_{h,ahp} = 1.8 \]

- 111 kW driving heat at high temperature
- Thermal energy price \( c_{th} = 3.3 \text{ ct/kWh} \)
- 89 kW industrial waste heat at low temperature
- 111 kW driving heat at high temperature
Estimation of the operating costs

Operating cost ratio

$$\frac{r_{op}}{c_{op, chp}} = r_{ec} \cdot r_{COP_h}$$

Ratio of COP

$$r_{COP_h} = \frac{COP_{h, ahp}}{COP_{h, chp}} = \frac{1.8}{5} = 0.36$$

Ratio of energy prices

$$r_{ec, large} = \frac{c_{el}}{c_{th}} = \frac{5.4}{3.33} = 1.62$$

$$r_{ec, small} = \frac{c_{el}}{c_{th}} = \frac{9.8}{3.33} = 2.94$$
Acknowledgment

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Payback period for a replacement of a natural gas boiler

\[
\tau_{pb} = \frac{C_{ic}}{\Delta C_{op}}
\]
\[c_{gas} = 5.1 \text{ ct/kWh}\]

<table>
<thead>
<tr>
<th></th>
<th>ahp</th>
<th>chp</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of driving energy</td>
<td>3.3</td>
<td>7.6</td>
<td>ct/kWh</td>
</tr>
<tr>
<td>Investment costs</td>
<td>72 593</td>
<td>44 451</td>
<td>EUR</td>
</tr>
<tr>
<td>Payback period</td>
<td>1.2</td>
<td>0.68</td>
<td>a</td>
</tr>
</tbody>
</table>

Equal payback periods at
\[c_{el} = 16.6 \text{ ct/kW h}_{el}\]
Industrial heat pumps

Utilization of 100 % waste heat at low temperature

Compression heat pump (chp)
\[ \text{COP}_{h,\text{chp}} = 5 \]

- 25 % electrical driving power
- 125 % useful heat at medium temperature
- 100 % industrial waste heat at low temperature

Absorption heat pump (ahp)
\[ \text{COP}_{h,\text{ahp}} = 1.8 \]

- 125 % driving heat at high temperature
- 225 % useful heat at medium temperature

\[ \tau_{bp,\text{ahp}} = 1.09 \alpha \]