Industrial heat pump applications in Switzerland – Heat pump integration case studies

WS-4 – Workshop: Successful Applications of Industrial Heat Pumps

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NTB Buchs

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Content

- Introduction to Industrial Heat Pumps in Switzerland
- Application examples in the food industry
- Conclusions
Process heat demand in Switzerland

Data source: Bundesamt für Energie BFE (2018)

This corresponds to:

$= 6.6 \times \text{the total heat production of all 30 waste incineration plants in Switzerland (3.7 TWh in 2018)}$

(www.vbsa.ch)
Potential for industrial heat pumps in Switzerland

Growing importance of heat pumps in Swiss industry (expert survey)

- **Priority 1**: Food
- **Priority 2**: Chemistry, Pharmaceuticals, Paper, Mechanical Engineering & Textiles
- **Priority 3**: Metal products, metals, minerals

Source: BFE (2018)
Source: Wolf et al. (2017)
Industrial heat pump sales between 115 and 145 units per year

Heat pump sales in Switzerland – Total 2018: 21’964 units

Heat pumps units sales per year in Switzerland

Domestic heat pumps

Heating capacity in kW and unit sales per year

Data source: www.fws.ch
Market view

Challenges to further spread industrial heat pumps into the market

- Low level of awareness of the technical possibilities and economically feasible application potential of industrial heat pumps among users, consultants, investors, system planners, manufacturers and installers

- Lack of knowledge about the integration of heat pumps into existing industrial processes

- Tailor-made designs, i.e. small batch sizes (low economies of scale)

- Longer amortization periods than for gas or oil-fired boilers (required are ≤ 3 years). With lower electrical current and higher gas prices smaller amortization periods are reached.

- Competing heating technologies (with fossil fuels at low energy prices)

- Requirements of heat storage to compensate for the time lag between demand and supply (e.g. heat pump for band load, gas boiler for heating peaks)

- Lack of available compressors for high temperatures and refrigerants with low global warming potential (GWP) and zero ozone depletion potential (ODP)
R245fa is predominantly used in industrial HTHP … but has a high GWP of 804

> 26 industrial HTHP products with heat supply temperature ≥ 90 °C available

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Kobelco SGH 120/165
(Steam Grow HP)

Refrigerants
- R134a/R245fa
- R1336mzz(Z)
- R245fa
- R245fa
- R245fa
- R245fa
- R717 (NH₃)
- R245fa
- R245fa
- R744 (CO₂)
- R744 (CO₂)
- R134a/R1234ze(E)
- R1234ze(E)
- R1234ze(E)
- R1233zd(E)
- R134a
- R717 (NH₃)
- R717 (NH₃)
- R717 (NH₃)
- R717 (NH₃)
- R134a
- R717 (NH₃)
- R1234ze(E)
- R134a/R245fa
- R744 (CO₂)
The next step … testing new HFO & HCFO refrigerants

Laboratory scale HTHP at NTB Buchs to research new low GWP HFO and HCFO refrigerants R1224yd(Z), R1233zd(E), and R1366mzz(Z)

Paper in TS-413.2 – Technical Session Industrial Heat Pumps (3), August 29, 2019 10:40 to 12:00, Room 524b

Reference:
- $T_{\text{Sink, out}} = 110 \, ^\circ\text{C}$
- $T_{\text{Source, in}} = 60 \, ^\circ\text{C}$
- $\Delta T_{\text{Lift}} = 50 \, \text{K}$
- $\Delta T_{\text{Source}} = 3 \, \text{K}$
- $\Delta T_{\text{Sink}} = 5 \, \text{K}$

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Paper will be presented at 2nd Conference on HTHP in Copenhagen, Sept. 9, 2019
Application examples in Switzerland
(food applications)
Efficient transformation of useful (waste) heat to higher temperatures

- Distillation: 100 - 300°C
- Drying processes: 40 - 250°C
- Evaporation: 40 - 170°C
- Pasteurisation / Sterilisation: 70 - 120°C
- ...

Heat pump efficiency

\[
\text{COP} = \frac{\text{Useful heat}}{\text{Driving power}}
\]

Process heat (high temperature)

Primary energy
(Gas, oil, coal, biomass)

Exhaust air from ovens: 20 – 100°C
Waste compressed air: 30 – 70°C
Waste water: 20 – 60°C
Cooling water: 20 – 50°C
...

Industrial heat pump

Primary energy

Waste heat (low temperature)
Application examples in Switzerland

Cheese Factory in Gais Appenzell

From waste heat to cheese

Data Centre

~ 800 kW cooling capacity

Waste heat from server rooms 16 to 20 °C

Cheese Factory

District heating network

Cheese Factory

- Energy demand ~1’800 MWh/a
- ~10 Mio. liters of milk per year
- ~300 tons of cheese per year
- Temperature levels:
  - Heat recovery (washing water, ventilation heating): <42 °C
  - Space heating/hot water (storage): 65 °C
  - Process heat 1 (cheese vats, cleaning water): 92 °C
  - Process heat 2 (multi-purpose heater, pasteurisation): 105 °C
Application examples in Switzerland

Cheese Factory in Gais Appenzell

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Application examples in Switzerland

Cheese Factory in Gais Appenzell

- IWWHS 570 ER6c2
- ~520 kW
- 2-stage screw compressor
- **Economizer cycle**
  - Refrigerant mass flow $\uparrow$
  - Discharge temp. $\downarrow$
  - Subcooling $\uparrow$ (COP $\uparrow$)
- **R1234ze(E)**
  (130 kg, safety group: A2L, mildly flammable, special measures for fire protection and escape routes)
- **2020/21 first operation**
  (using waste heat from data centre)

### Performance data (W18-14/W82-92)

<table>
<thead>
<tr>
<th>Part load (%)</th>
<th>100</th>
<th>75</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective part load (%)</td>
<td>100</td>
<td>81</td>
<td>62</td>
</tr>
<tr>
<td><strong>Condenser heating capacity (kW)</strong></td>
<td>520</td>
<td>419</td>
<td>321</td>
</tr>
<tr>
<td>Condenser water flow rate (m³/h)</td>
<td>44.7</td>
<td>36.0</td>
<td>27.6</td>
</tr>
<tr>
<td>Temperature difference condenser (K)</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Evaporator capacity (kW)</td>
<td>338</td>
<td>264</td>
<td>195</td>
</tr>
<tr>
<td>Evaporator water flow rate (m³/h)</td>
<td>82.7</td>
<td>82.7</td>
<td>82.7</td>
</tr>
<tr>
<td>Temperature difference evaporator (K)</td>
<td>3.5</td>
<td>2.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Compressor power (kW)</td>
<td>182</td>
<td>155</td>
<td>126</td>
</tr>
<tr>
<td>$\text{COP}_{\text{H}} (-)$</td>
<td>2.85</td>
<td>2.70</td>
<td>2.55</td>
</tr>
</tbody>
</table>
Temperature range from 5 to 70 °C
Space for 8 heat pumps à 220 kW
Application: Cooling and heating of chocolate conching machines
Savings fossil fuels = 2'590 MWh
Savings CO₂ emissions = 30% (510 t/a)

<table>
<thead>
<tr>
<th></th>
<th>Cooling</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling capacity</td>
<td>222.6 kW</td>
<td>183.7 kW</td>
</tr>
<tr>
<td>Electrical power</td>
<td>70.4 kW</td>
<td>96.8 kW</td>
</tr>
<tr>
<td>Heat source in/out</td>
<td>5/11°C</td>
<td>11/17°C</td>
</tr>
<tr>
<td>Heating capacity</td>
<td>289.8 kW</td>
<td>276.2 kW</td>
</tr>
<tr>
<td>COP</td>
<td>4.12</td>
<td>2.85</td>
</tr>
<tr>
<td>Hot water in/out</td>
<td>35/45°C</td>
<td>60/70°C</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R-1234ze</td>
<td>R-1234ze</td>
</tr>
<tr>
<td>Piston compressors</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>No. of cooling cycles</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Application examples in Switzerland

GVS Schaffhausen, Landi – Beverages

Heat sink: 80 to 95 °C
- process water for disinfection of beverage filling plants and wine tanks
- space heating of storage rooms
- district heating of production site

Heat source: 37 °C
- waste heat from refrigeration (cooling of storage rooms)

Savings:
- CO₂-emissions (~40%)
- ~26,000 Liter oil/year (~1 barrel/day)

Heat pump type: ISWHS 60 ER3
Heating capacity: 63 kW
Cooling capacity: 48 kW
Compressor: Screw, ÖKO 1 (R245fa)
COP Heating: 4,2
EER Cooling: 3,2
Year of installation: 2017

Source: Ochsner, Ennovatis Schweiz AG
Nutrex – Vinegar fermentation and pasteurization

Applications:
- **Cooling:** Vinegar fermentation process over 10 days at 30°C
- **Heating:** Vinegar pasteurization >70°C to obtain a non-perishable food
- Cooling capacity: 136 kW
- Heating capacity: 194 kW, COP 3.4
- Savings CO₂ emissions: ~310 t/a
- Savings fuel: up to 65’000 L/a

Source: EHPA (2017): Large scale heat pumps in Europe
### Slaughterhouse Zurich – Meat Production

**Process applied**
- **Hot water for cleaning processes up to 90°C and space heating**

<table>
<thead>
<tr>
<th>Location</th>
<th>Zurich (in the middle of the city, historical building)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of installation</td>
<td>2011</td>
</tr>
<tr>
<td>HP manufacturer</td>
<td>Thermea, Germany</td>
</tr>
<tr>
<td>Contractor</td>
<td>ewz Energiedienstleistungen</td>
</tr>
<tr>
<td>Consultant</td>
<td>City of Zurich</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>CO₂ (R744)</td>
</tr>
<tr>
<td>Compressor</td>
<td>Screw</td>
</tr>
<tr>
<td>Heating/cooling capacity (kW)</td>
<td>800/564</td>
</tr>
</tbody>
</table>

**Heat source**
- Waste heat from refrigeration processes (closed water loop with storage tank) and waste heat from compressed air generation

<table>
<thead>
<tr>
<th>Heat source (°C) in/out</th>
<th>20/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat sink (°C) in/out</td>
<td>Water, 30/90</td>
</tr>
<tr>
<td>Efficiency (COP)</td>
<td>3.4</td>
</tr>
<tr>
<td>Savings CO₂ emissions</td>
<td>30% (510 t/a), saving of 2'590 MWh fossil fuels</td>
</tr>
</tbody>
</table>
Potential applications

- Hot water generation for washing and cleaning processes (food, meat, product washing) in combination with cooling generation
- Hot air generation and air preheating for drying processes (wood, paper, sewage sludge, starch, bricks, pet food) by waste heat recovery
- Process steam generation (low pressure steam) for the sterilization and pasteurization of food (e.g. milk) using cooling water or humid exhaust air
- Heat recovery by flue gas condensation in biomass incinerators
- Local and district heating networks (e.g. of municipal utilities and municipalities)
Conclusions

- 115 to 145 units of industrial heat pumps (>100 kW) sold per year
- Refrigerants used: R245fa, R134a, R1234ze, R744 (CO₂)
- The next generation of refrigerants with very low GWP needs to be introduced
- Laboratory HTHP at NTB allows testing new HFO & HCFO refrigerants
- Application examples in the Swiss food industry:
  - chocolate (hot water, space heating, cooling)
  - cheese (process heat)
  - vinegar (fermentation, pasteurization)
  - meat (cleaning processes)
- Max. identified heat sink temperature: 92 °C (cheese factory)
- Potential applications: hot water, hot air, steam
- Savings: 30 to 40% reduction of CO₂ emissions & large amounts of fossil fuels
Acknowledgements

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Thank you for your attention

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