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

- Space heating: 9.8%
- Hot water: 1.7%
- Others: 5.0%
- Drives, processes: 23.6%
- Information & communication, entertainment: 0.4%
- Air conditioning, ventilation & building services: 0.6%
- Lighting: 3.4%

158 PJ (43.9 TWh) total energy consumption in Swiss industry (2017)

Process heat 55.5%

Data source: Bundesamt für Energie BFE (2018)
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 (2016)

Source: Wolf et al. (2017)
Heat pump sales in Switzerland – Total 2018: 21’964 units

Industrial heat pump sales between 115 and 145 units per year

Heating capacity in kW and unit sales per year

Data from 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 \( \leq 3 \) 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 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

<table>
<thead>
<tr>
<th>Max. heat supply temperature [°C]</th>
<th>Heating capacity [kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>165°C</td>
<td>10</td>
</tr>
<tr>
<td>160°C</td>
<td>100</td>
</tr>
<tr>
<td>130°C</td>
<td>1000</td>
</tr>
<tr>
<td>125°C</td>
<td>10000</td>
</tr>
<tr>
<td>120°C</td>
<td>100000</td>
</tr>
<tr>
<td>110°C</td>
<td>10</td>
</tr>
<tr>
<td>100°C</td>
<td>10</td>
</tr>
<tr>
<td>95°C</td>
<td>10</td>
</tr>
<tr>
<td>90°C</td>
<td>10</td>
</tr>
</tbody>
</table>

- Screw: Kobelco SGH 165, Viking Heat Booster R1336mzz(Z), Ochsner IWWDS RR3b, Viking Heat Booster R245fa, Ochsner IWWDS ER3c4, Kobelco SGH 120, Combitherm HWW R245fa, Mayekawa Eco Sirocco
- Piston: Oilin ChillHeat P, Engie thermeco2, Combitherm Unipod 22, Combitherm HWW R1234ze(E), Ochsner IWWHS ER3b

HeatBooster S4 (Viking Heating Engines AS)
Kobelco SGH 120/165 (Steam Grow HP)
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)
Application examples in Switzerland (food applications)
Principle of waste heat recovery by industrial heat pumps

Efficient transformation of useful 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
COP = \frac{\text{Useful heat}}{\text{Driving power}}

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
- ...

Process heat (high temperature)

Industrial heat pump

Process heat (high temperature)

Waste heat (low temperature)
Application examples in Switzerland

Cheese Factory in Gais Appenzell

From waste heat to cheese

Rechenzentrum Ost

Waste heat from server rooms 16 to 20 °C

~800 kW cooling capacity

Data centre

Cheese Factory

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: <42°C
  - Space heating/hot water: 65°C
  - Process Niveau 1: 92 °C
  - Process Niveau 2: 105°C

Source: Amstein + Walthert
Application examples in Switzerland

Cheese Factory in Gais Appenzell

Source: Amstein + Walthert
Application examples in Switzerland

Cheese Factory in Gais Appenzell

- **IWWHS 570 ER6c2**
- **~520kW**
- 2-stage screw compressor, economizer cycle
- **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 center)

Source: Amstein + Walthert

### 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><strong>COP</strong> (<em>H</em>)</td>
<td>2.85</td>
<td>2.70</td>
<td>2.55</td>
</tr>
</tbody>
</table>
Application examples in Switzerland

Chocolate Factory in Flawil

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

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

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
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

**Technical details of the application**

- Heating capacity: 194 kW
- COP: 3.4
- Refrigerant: R134a
- Heating source: Water
- Supplied temperature: >70°C

Source: EHPA (2017): Large scale heat pumps in Europe

Left: Production of the vinegar/fermentation
Right: Heat pump in machine room
Source: Viessmann/Nutrex
## Slaughterhouse Zurich – Meat Production

<table>
<thead>
<tr>
<th>Process applied</th>
<th>Hot water for cleaning processes up to 90°C and space heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Zurich (in the middle of the city, historical building)</td>
</tr>
<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>
<tr>
<td>Heat source</td>
<td>Waste heat from refrigeration processes (closed water loop with storage tank) and waste heat from compressed air generation</td>
</tr>
<tr>
<td>Heat source (°C) in/out</td>
<td>20/14</td>
</tr>
<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 utilization.

- **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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www.sccer-eip.ch
Thank you for your attention

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