Application examples of industrial and high temperature heat pumps

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Dr. Cordin Arpagaus, OST
Content

- Introduction
  - Definitions of industrial HP and HTHP
  - Market situation
  - Market challenges
  - Commercially available HTHPs
- Application examples
  - 25 case studies
  - Temperature levels
  - Efficiency
  - Integration level
  - Energy and CO₂ emissions savings
  - Potential applications and processes for HTHPs
- Summary
Definitions

- **Industrial heat pump**

  “Heat pump with >100 kW heating capacity applied for industrial processes but also for district heating and large residential buildings.”

Definition of IEA HPT Annex 48 project

- **High temperature heat pump**

Market situation

- Annual sales of heat pumps in Switzerland for various heating capacities

![Heat Pump Sales Chart and Table](Data source: www.fws.ch)
Market challenges

- Electricity to gas price ratio

For small scale industrial end-users with
2 GWh/a to 20 GWh/a electricity
3 GWh/a to 28 GWh/a gas
Market challenges

- Specific investment costs (incl. installation) per kW of heating

Data based on price information from European heat pump suppliers
>26 industrial HPs with heat supply ≥ 90 °C are commercially available

**Refrigerants**
- R134a/R245fa
- R1336mzz(Z)
- R245fa
- R245fa
- R245fa
- R245fa
- R717 (NH₃)
- R245fa
- R245fa

**HeatBooster S4**
(Viking Heat Engines AS)

**Kobelco SGH 120/165**
(Steam Grow Heat Pump)
Application examples

- Presents case studies of successful applications of industrial heat pumps in Switzerland
- Promotes further market penetration of industrial heat pumps
- Highlights typical applications in large-scale
- Establishes a framework for comparison

Locations of the investigated heat pumps in the Swiss map

Note: The graph does not represent the actual range of heat pump installations in Switzerland, but refers to the contact network.

Link: https://de.batchgeo.com/map/Case-Studies-Switzerland
## Overview of 25 case studies

<table>
<thead>
<tr>
<th>Company, Location</th>
<th>Industry / Sector</th>
<th>Application</th>
<th>Integration level</th>
<th>Capacity (kW)</th>
<th>Temperature range (°C)</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughterhouse, Zurich</td>
<td>Food</td>
<td>Hot water, cleaning water</td>
<td>Process</td>
<td>800</td>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>Chocolate factory Maesrani, Flawil</td>
<td>Food</td>
<td>Hot water, heating, cooling</td>
<td>Process</td>
<td>276</td>
<td>17</td>
<td>70</td>
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<tr>
<td>Cheese factory, Gais Appenzell</td>
<td>Food</td>
<td>Hot water, heating</td>
<td>Process</td>
<td>520</td>
<td>18</td>
<td>92</td>
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<tr>
<td>Kambly SA, Trubschachen</td>
<td>Food</td>
<td>Hot water for biscuit production</td>
<td>Process</td>
<td>471</td>
<td>20</td>
<td>65</td>
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<tr>
<td>Kellermann AG, Ellikon an der Thur</td>
<td>Food</td>
<td>Hot water for greenhouse heating</td>
<td>Plant</td>
<td>1'000</td>
<td>6</td>
<td>65</td>
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<tr>
<td>Hicona AG, Schaan</td>
<td>Food</td>
<td>Hot water for fresh convenience foods</td>
<td>Plant</td>
<td>507</td>
<td>31</td>
<td>67</td>
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<tr>
<td>Nutrex, Busswil bei Büren</td>
<td>Food &amp; Beverages</td>
<td>Vinegar fermentation and pasteurization</td>
<td>Process</td>
<td>194</td>
<td>30</td>
<td>70</td>
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<tr>
<td>GVS Schaffhausen Landi</td>
<td>Food &amp; Beverages</td>
<td>Process/hot water, heating, cooling</td>
<td>Plant</td>
<td>63</td>
<td>37</td>
<td>95</td>
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<tr>
<td>Bachem AG, Bubendorf</td>
<td>Pharma</td>
<td>Heating and cooling of peptides</td>
<td>Process</td>
<td>480</td>
<td>14</td>
<td>70</td>
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<tr>
<td>R134a heat pump, Geistlich Wolhusen</td>
<td>Pharma</td>
<td>Hot water, heating</td>
<td>Plant</td>
<td>606</td>
<td>2</td>
<td>67</td>
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<tr>
<td>Mifa AG Mibelle Group, Frenkendorf</td>
<td>Home Care and Nutrition</td>
<td>Hot/cold water, heating, cooling</td>
<td>Plant</td>
<td>885</td>
<td>35</td>
<td>70</td>
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<tr>
<td>Härterei Gerster AG, Egerkingen</td>
<td>Metals</td>
<td>Process heat for hardening process</td>
<td>Plant</td>
<td>260</td>
<td>17</td>
<td>65</td>
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<tr>
<td>Georg Fischer AG, Grisch</td>
<td>Machinery</td>
<td>Heating for production of plastic valves</td>
<td>Plant</td>
<td>382</td>
<td>8</td>
<td>65</td>
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<tr>
<td>Feldschlösschen, City of Rheinfelden District heating, brewery</td>
<td>District heating</td>
<td>Hot water, district heating</td>
<td>Plant</td>
<td>1'350</td>
<td>16</td>
<td>81</td>
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<tr>
<td>Champagne, Biel District heating</td>
<td>District heating</td>
<td>Hot water, heating</td>
<td>Network</td>
<td>650</td>
<td>11</td>
<td>63</td>
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<tr>
<td>St. Jakob, Basel District heating</td>
<td>District heating</td>
<td>Hot water, heating</td>
<td>Network</td>
<td>181</td>
<td>0</td>
<td>65</td>
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<tr>
<td>Laurana, Thônex District heating</td>
<td>District heating</td>
<td>Hot water, heating</td>
<td>Network</td>
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<td>14</td>
<td>63</td>
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<tr>
<td>Les Vergers, Meyrin</td>
<td>District heating</td>
<td>Heating of residential buildings</td>
<td>Network</td>
<td>5'000</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>City of Lausanne</td>
<td>District heating</td>
<td>Hot water for residential buildings</td>
<td>Network</td>
<td>4'500</td>
<td>6</td>
<td>68</td>
</tr>
<tr>
<td>Casino Aarau</td>
<td>District heating/cooling</td>
<td>District heating and cooling network</td>
<td>Network</td>
<td>1'750</td>
<td>9</td>
<td>70</td>
</tr>
<tr>
<td>Kokon Corporate Campus, Ruggell</td>
<td>Wellness and restaurant</td>
<td>Hot water, heating</td>
<td>Building</td>
<td>341</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>Swiss Army, CO2 HP Payerne</td>
<td>Military</td>
<td>Tap water and facility heating</td>
<td>Building</td>
<td>60</td>
<td>9</td>
<td>45</td>
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<tr>
<td>Swiss Army Troop building, Matt Military</td>
<td>Hot water, heating</td>
<td>Building</td>
<td>270</td>
<td>8</td>
<td>60</td>
<td>CH21</td>
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<tr>
<td>ARA Altenrhein</td>
<td>Waste water treatment</td>
<td>Hot water for sewage sludge drying</td>
<td>Plant</td>
<td>2'846</td>
<td>8</td>
<td>65</td>
</tr>
<tr>
<td>Waste water treatment plant, Zürich</td>
<td>Waste water treatment</td>
<td>Hot water</td>
<td>Plant</td>
<td>410</td>
<td>7</td>
<td>50</td>
</tr>
<tr>
<td>Bad Zurzach</td>
<td>Thermal bath</td>
<td>Hot water</td>
<td>Plant</td>
<td>550</td>
<td>29</td>
<td>55</td>
</tr>
</tbody>
</table>
Temperature levels of heat source and sink

- **Highest supply temperatures** slightly above 90 °C (e.g. cheese factory, slaughterhouse, beverages)
- **Average temperature glides on the heat source and sink** about 6 ± 5 K and 20 ± 14 K
- An increased **integration of HTHP is necessary** to exploit the process heat potential of the industry (see review paper Arpagaus et al., 2018).
Efficiency: Heating COP vs. temperature lift

Average Heating COP = 4.0 at 50 K temperature lift
# Energy savings and CO₂ emissions reduction

<table>
<thead>
<tr>
<th>Case study</th>
<th>Energy savings</th>
<th>CO₂ emission savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughterhouse ZH hot water</td>
<td>2'560 MWh fossil fuels</td>
<td><strong>30%</strong> (510 t CO₂/a) (520 t CO₂/a*)</td>
</tr>
<tr>
<td>Chocolate factory Maestrani</td>
<td>882 MWh gas*</td>
<td>179 t CO₂/a (2013 to 2020)</td>
</tr>
<tr>
<td>District heating Champagne</td>
<td>3'054 MWh gas*</td>
<td>620 t CO₂/a</td>
</tr>
<tr>
<td>District heating Laurana</td>
<td>1'435 MWh fossil fuels</td>
<td><strong>42%</strong> (1'746 t CO₂/a)</td>
</tr>
<tr>
<td>Cheese factory Gais Appenzell</td>
<td>1'500 MWh gas</td>
<td>305 t CO₂/a*</td>
</tr>
<tr>
<td>GVS Landi beverages</td>
<td>26'000 L oil/a</td>
<td><strong>40%</strong> (69 t CO₂/a*)</td>
</tr>
<tr>
<td>Nutrex AG fermentation</td>
<td>up to 65'000 L oil/a</td>
<td>310 t CO₂/a (up to 172 t CO₂/a*)</td>
</tr>
<tr>
<td>Härterei Gerster AG metals</td>
<td><strong>80%</strong> (800 MWh gas)</td>
<td>160 t CO₂/a (162 t CO₂/a*)</td>
</tr>
<tr>
<td>Kellermann vegetables</td>
<td>4'729 MWh gas*</td>
<td>960 t CO₂/a</td>
</tr>
<tr>
<td>Kambly SA biscuits</td>
<td><strong>25%</strong> (493 MWh gas*)</td>
<td><strong>90%</strong> (100 t CO₂/a)</td>
</tr>
<tr>
<td>District heating casino Aarau</td>
<td>40% by 2035</td>
<td>n.a.</td>
</tr>
<tr>
<td>Mifa AG home care and nutrition</td>
<td><strong>20%</strong> (4'729 MWh gas*)</td>
<td><strong>60%</strong> (960 t CO₂/a)</td>
</tr>
<tr>
<td>Bachem AG peptides</td>
<td>1'478 MWh gas*</td>
<td>300 t CO₂/a</td>
</tr>
<tr>
<td>Feldschlösschen/Rheinfelden</td>
<td><strong>75%</strong> (11'160 MWh fossil)</td>
<td>2'265 t CO₂/a*</td>
</tr>
<tr>
<td>ARA Altenrhein waste water</td>
<td>14'778 MWh gas*</td>
<td>3'000 t CO₂/a</td>
</tr>
</tbody>
</table>

*values calculated assuming CO₂ emission factors of 0.203 t CO₂/MWh gas and 0.00265 t CO₂/L oil (BAFU, 2019)

- **Significant CO₂ reduction** effects by replacing gas and oil boilers by heat pumps and savings of large amounts of fossil fuels.
- In some cases, CO₂ emissions reduced by **30%** to **90%**.
- Range of energy savings between **20%** and **80%**.
Application example at a cheese factory

From waste heat to cheese

Data Centre
- Waste heat from server rooms 16 to 20 °C
- ~ 800 kW cooling capacity

Cheese Factory
- Energy demand ~1’800 MWh/a
- ~10 Mio. liters of milk per year
- ~300 tons of cheese per year
Waste heat from server cooling of the data center is fed into a district heating network at approx. 20 °C. The cheese factory uses this waste heat as heat source in a HTHP to generate process heat for the cheese production.

Around 1.5 million kWh of natural gas is saved per year!
Application example at a cheese factory

- Type: IWWHS 570 ER6c2
- Cycle: Economizer
- Heating capacity: ~ 520kW
- Compressor: 2-stage screw
- Refrigerant: HFO R1234ze(E) (130 kg, safety group: A2L)
- 2020/21 first operation

COP vs. temperature lift

- W18/W92: 74 K lift → 2.55 to 2.85
- W18/W65: 47 K lift → 3.75 to 4.20
Application example at GVS Schaffhausen, Landi – Beverages

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

- 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)

Source: Ochsner, Ennovatis Schweiz AG
### Application example at 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>

Source: [ewz](https://www.ewz.ch)
Application example at chocolate factory

**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)

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**Sources:** www.maestrani-schokolade.ch, www.cta.ch

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<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>

HP manufacturer: CTA AG
Contractor: Seiz AG
Consultant: Carnotech AG
Summary

- 25 application examples of industrial heat pumps shown from various Swiss companies
- Mostly from the food sector (hot water, process heating and cooling)
- Average COP about 4.0 at 50 K temperature lift
- Highest supply temperature slightly over 90 °C
- Significant energy savings (20% to 80%) and CO₂ reduction effects (30% to 90%) achieved by replacing gas and oil boilers by electrically driven heat pumps
- Possible multiplication effects of similar heat pump systems
- Framework of evaluation criteria established
- Potential applications for industrial HTHPs identified (hot water, hot air, steam)
Thank you for your attention!

Dr. Cordin Arpagaus

OST
Eastern Switzerland University of Applied Sciences
Institute for Energy Systems IES

cordin.arpagaus@ost.ch
Tel. +41 58 257 34 94
www.ost.ch/ies


Potential applications for industrial HTHPs

- **Hot water and steam for sterilization of food and beverages**
- **Process heat for concentration and pasteurization of milk and juices**
- **Hot water and steam for washing and sterilizing bottles and wine tanks during bottling processes**
- **Steam and hot water for slaughterhouse cleaning**
- **Process heat for pasteurization and hot water in cheese factories**

- **Brick drying**: Air preheating to 120 °C by means of moist exhaust air (70 °C, 50% r.h.)
- **Wood drying**: Air heating to 120 to 150 °C with moist exhaust air
- **Starch drying**: Air preheating for steam generation 160 °C
- **Drying of animal fodder**: Low pressure steam for chamber dryer
- **Spray drying**: Air preheating for milk powder production
- **Paper drying**: Low-pressure steam 130 °C using cooling water (60°C) or humid exhaust air (76 °C, 56 % r.h.) as heat source
Potential applications for industrial HTHPs

- **District heating** networks: Hot water production up to 120 °C
- **Hospitals**: Steam 125 °C for autoclaves, sterilization and laundry drying
- **PET bottle industry**: Process heat between 100 and 150 °C for injection molding of plastic preforms
- **Sugar industry**: Process heat between 80 and 150 °C for the processing of sugar beets, steam generation at 138 °C for the production of 90 °C feed water
- **Breweries**: Process heat of around 100 °C for the brewing process (e.g. mashing, lautering, wort boiling)
- **Milk processing**: Milk pasteurization (HT 100 to 120 °C), sterilization (115 to 135 °C) and UHT (135 to 150 °C), spray drying of milk powder (preheating the drying air to 120 to 150 °C)
- **Chemical industry**: Steam 120°C for alcohol distillation using the waste heat of the cooling tower or the condensation heat of the distillation column (65 °C)
- **Wellness sauna**: CO₂ heat pumps for different temperature levels up to 120 °C