Industrial Heat Pumps, Second Phase

IEA Heat Pump Technology (HPT) Programme Annex 48

Task 1 Report: Case Studies of Industrial Heat Pumps in Switzerland

Final Report

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Contents

1 Summary .......................................................................................................................... 1-3
2 Introduction ....................................................................................................................... 2-6
   2.1 Gas price in Switzerland ......................................................................................... 2-6
   2.2 Electricity price in Switzerland ............................................................................. 2-7
   2.3 Electricity to gas price ratio ................................................................................ 2-8
   2.4 Importance of industry sectors in Switzerland .................................................... 2-9
   2.5 Industrial process heat demand in Switzerland .................................................... 2-10
   2.6 Annual sales of heat pumps in Switzerland ......................................................... 2-11
   2.7 Barriers to the wider spread of industrial heat pumps ......................................... 2-12
   2.8 Investment costs .................................................................................................... 2-12
3 Case Studies Framework ................................................................................................. 3-13
   3.1 Definition and framework .................................................................................... 3-13
   3.2 Selection of best practice examples .................................................................... 3-14
   3.3 Case studies located in the Swiss map ............................................................... 3-15
4 Ochsner Energie Technik GmbH .................................................................................. 4-17
   4.1 GVS Schaffhausen – disinfection of bottling plant and wine tanks ..................... 4-17
   4.2 Cheese factory in Gais Appenzell ................................................................. 4-19
5 CTA AG ............................................................................................................................ 5-21
   5.1 Heating and cooling for chocolate production at Maestrani ..................... 5-21
   5.2 District heating network Champagne in Biel .................................................. 5-24
   5.3 District heating network St. Jakob in Basel ..................................................... 5-26
   5.4 Heat treatment of metal parts at Härterei Gerster AG ..................................... 5-28
6 ENGIE Kältetechnik GmbH ......................................................................................... 6-29
   6.1 Reference examples of heat pumps for hot water ........................................... 6-29
7 Kibernetic AG .................................................................................................................. 7-31
   7.1 Hot water for plastic valves manufacturing at Georg Fischer AG ................ 7-31
   7.2 Heating and hot water for the Swiss Army troop building in Matt (GL) ........ 7-32
   7.3 Heating of the KOKON Corporate Campus buildings .................................. 7-33
8 Viessmann (Schweiz) AG ............................................................................................. 8-35
   8.1 Vinegar fermentation and pasteurization at Nutrex ................................... 8-35
9 Friootherm AG ................................................................................................................ 9-37
   9.1 District heating in Lausanne with large heat pumps ........................................ 9-37
10 Scheco AG ....................................................................................................................... 10-38
   10.1 Heat recovery of the cleaned wastewater from a sewage treatment plant .... 10-38
   10.2 Thermal bath with heat pump for heat recovery ............................................. 10-39
11 EWZ Energielösungen ..................................................................................................... 11-40
   11.1 Heat pump system at the Slaughterhouse in Zurich ....................................... 11-40
Contents

12 Durena AG.........................................................................................................................12-42
  12.1 Heat from purified waste water for sewage sludge drying ..................................12-42
13 SSP KÄLTEPLANER.CH ..................................................................................................13-43
  13.1 Heating and cooling at the vegetable producer Kellermann AG ......................13-43
14 Frigo-Consulting AG........................................................................................................14-46
  14.1 CO₂ heat pump for water heating..............................................................14-46
15 eicher+pauli AG..............................................................................................................15-47
  15.1 District heating and cooling network Casino Aarau....................................15-47
  15.2 Heating and cooling supply at Mifa AG in Frenkendorf (BL).......................15-48
  15.3 Heat recovery at Bachem AG in Bubendorf (BL).........................................15-49
16 Gruner Gruneko AG ....................................................................................................16-51
  16.1 Waste heat recovery at Feldschlösschen Getränke AG in Rheinfelden...........16-51
17 Lemon Consult AG .........................................................................................................17-53
  17.1 Kambly SA, Trubschachen – biscuit producer...........................................17-53
  17.2 Waste heat recovery from the refrigeration plant at Hilcona AG (Schaan) ........17-55
  17.3 Toblerone chocolate production at Mondelez Schweiz Production GmbH ....17-56
18 SIG (Services Industriels de Genève).............................................................................18-57
  18.1 District heating network Laurana-Parc in Geneva ...................................18-57
  18.2 District heating network Les Vergers in Meyrin ........................................18-59
19 Literature .......................................................................................................................19-61
20 Acknowledgements .......................................................................................................20-65
1 Summary

IEA HPT Annex 48: The project IEA HPT Annex 48 (Industrial Heat Pumps, Phase 2) initiated by the IEA HPT TCP (Technology Collaboration Programme on Heat Pumping Technologies of the International Energy Agency) attempts to overcome existing market barriers for industrial heat pumps. The University of Applied Sciences of Technology Buchs (NTB) participates in the project and informs the Swiss industry about the latest results, on behalf of the Swiss Federal Office of Energy (SFOE).

Goal of the study: The aim of this report is to present case studies of successful applications of industrial heat pumps in Switzerland.

Evaluation method: Various heat pump manufacturers, planners, consultants, and installers have been contacted to collect best practice case studies on heat pump technology and application. The industrial companies referred to in this report were open to disclose information about their heat pump application and provided technical data and informational material to illustrate and describe the case studies. The contact details of the respective contact persons are listed. In addition, other published information from the internet was also used as data source.

Market situation: In Switzerland, the number of industrial heat pumps is gaining in importance, as the sales statistics of the Swiss Heat Pump Association show. In 2018, around 145 heat pumps with a heating capacity of higher than 100 kW were sold in Switzerland. In Swiss industry, fossil-fuelled heat generation systems for heating and hot water production are still favoured, mainly due to relatively low gas prices and available gas boiler systems. A lower electricity to gas price ratio would encourage the further market penetration of industrial heat pumps. Major application potentials are in the food, paper, metal and chemical industries as well as in local and district heating networks.

29 case studies: In total, 29 case studies are presented in this report covering different industries.

Food industry: Most case studies are from the food industry, where heat pumps are used to produce hot water, hot air or process heat. Examples are described for the production of chocolate (heating and cooling processes), cheese (process heat), vinegar (fermentation, pasteurisation), vegetables (greenhouse heating, cooling of storehouses), fresh convenience foods (hot water from waste heat of the chillers), or meat (hot water for cleaning processes) (Figure 1-1, A).

In the food industry, heat recovery from refrigeration systems (i.e. condensers of refrigeration chillers) is an important heat source and is applied in several examples. In addition, heating and cooling are often carried out simultaneously, so that both sides of the heat pump are used advantageously and the overall COP increases. The operating temperatures are relatively low, so that heat pumps can be used in many manufacturing processes.

District heating: Large heat pumps play an important role in district heating networks in providing hot water (60 to 70 °C) and space heating (35 to 45 °C) for entire districts and neighbourhoods. Examples from various energy suppliers, municipalities and municipal utilities are described. In general, the heat sources used are natural resources such as groundwater (see e.g. Champagne in Biel or the city of Aarau), lake water (e.g. Lausanne) or river water (e.g. Les Vergers, Laurana), air (e.g. St. Jabkob district in Basel), geothermal energy, but also waste heat from nearby industrial plants (e.g. Feldschlösschen in Rheinfelden).

Other applications: Other case studies on industrial heat pumps are from the metalworking industry (heat treatment of metal parts, production of hot water and process heat from waste heat of cooling processes), as well as from sewage treatment plants (hot water from waste water) and thermal baths (hot water from thermal waste water).

Temperature levels: The highest supply temperatures of over 90 °C were observed in the case studies of the Gais cheese dairy in Appenzell and the slaughterhouse in Zurich (Figure 1-1, B). Heat pumps that supply heat of around 80 °C have been on the market for many years. However, in order to exploit the
process heat potential of the industry, high temperature heat pumps (HTHP) need to be used. More than 26 electrically driven HTHPs from 15 manufacturers have been identified on the global market with supply temperatures above 90 °C, in some cases even above 120 °C and a maximum of 165 °C.

**Heat pump producers:** The heat pump manufacturers of the described case studies are Carrier, CTA, Enex, ENGIE, Friotherm, GEA, Johnson Controls, Kibernetik, Ochsner, Mayekawa, MTA, Scheco, SCM Frigo, Sulzer, Thermea, and Viessmann (in alphabetic order) (Figure 1-1, G).

**Heating capacity and compressor types:** The typical heating capacities of the examples range from several 100 kW to large capacities in the MW range, which are fed into district heating networks. Mainly piston, screw and turbo compressors are used (Figure 1-1, F).

**Refrigerants:** The main refrigerants used are R134a, R717 (ammonia NH₃), R1234ze(E) (hydrofluoroolefin HFO), R744 (CO₂), R245fa, and R410A (Figure 1-1, E). Classic cooling applications typically use NH3 chillers, often with Sabroe compressors from Johnson Controls. With the stricter F-gas regulation, refrigerant selection will focus more on the use of low GWP refrigerants.

**Efficiencies:** The published heating COPs of the compression heat pumps range from about 2.8 to 7.1 (average: 4.0 at 50 K temperature lift). Figure 1-1 (C) shows (for 21 data points) a slight decrease between COP and temperature lift.

**Energy savings and reduction of CO₂ emissions:** The case studies show that successful heat pump integration has a positive impact on both energy costs and environmental impact (Figure 1-1, D). Replacing gas and oil boilers with heat pumps leads to a significant CO₂ reduction effect. Some examples show that CO₂ emissions are reduced by 30 to 40% and large amounts of fossil fuels are saved.

**Outlook:** In the future, even more case studies have to be collected to demonstrate the application potential of heat pumps in industry, especially at higher temperatures, where the application potential is large. The aim is to further overcome existing market barriers. The energy transition and the climate debate have a significant impact on industry and increased the use of renewable energies to further reduce CO2 emissions. This is where industrial heat pumps have a market opportunity.

By intensifying public relations work, information and training of experts in this field of energy supply for industrial companies, efforts are being made to make heat pump technology more visible and to highlight its application potential.

The case studies in Switzerland are useful in order to identify possible multiplication effects of similar heat pump systems in other companies with similar heating and cooling situations.

A learning effect for the Swiss industry is also expected from more than 350 case studies of the other participating IEA HPT Annex 48 countries (Austria, France, Germany, Denmark, Japan, and USA). The case studies are in practice and have a high multiplication potential, as their integration solutions can be transferred to other processes and industries.

**Promising industrial applications of heat pumps are:**

- Hot air generation and air preheating for drying processes (i.e. wood, paper, sewage sludge, starch, bricks, and pet food) through waste heat recovery.
- Process steam generation (low pressure steam) for the sterilisation and pasteurisation of food (e.g. milk) using cooling water or humid exhaust air
- Hot water generation for washing and cleaning processes (i.e. food, meat, product washing) in combination with cooling generation
- Heat recovery by flue gas condensation in biomass incinerators
- Production of injection moulded components from plastics (heating in the extruder and cooling in the injection mould)
- Local and district heating networks (e.g. of municipal utilities and municipalities)
Figure 1-1: Summarizing results. (A) Number of presented case studies by industry/application. 
(B) Heat source and heat sink temperatures of the heat pumps per case study. 
(C) Heating COP of the heat pumps as a function of the temperature lift (21 data points). 
(D) Savings in CO₂ emissions and energy thanks to heat pump integration. 
(E) Type and frequency of refrigerants used in the heat pumps. 
(F) Heat pump manufacturers and number of heat pumps applied in the case studies.
2 Introduction

2.1 Gas price in Switzerland

The average gas prices of all Swiss gas network operators are monitored for nine standardised customer categories (Type II to X) on the website http://gaspreise.preisueberwacher.ch, which creates transparency on the Swiss gas market and makes it possible to compare prices between the various Swiss gas supply companies. The surveys can also be used to monitor price trends over several years. Figure 2-1 shows that the gas price increased between 2012 and 2014 and declined from 2014 to 2017. The trend reversed at the beginning of 2018 [1]. Table 2-1 shows the gas prices for all customer categories on October 12, 2019. For a large industrial company (Typ X) the gas price is 6.37 Rp./kWh.

![Figure 2-1: Average gas prices from 2012 to 2018 in Rp./kWh [1].](image)

Table 2-1: Gas prices in Switzerland reported on October 12, 2019 (http://gaspreise.preisueberwacher.ch).

<table>
<thead>
<tr>
<th>Customer categories</th>
<th>Average gas price in Rp./kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type II Single family house, 20’000 kWh</td>
<td>9.03</td>
</tr>
<tr>
<td>Type III Small multi-family house, 50’000 kWh</td>
<td>8.49</td>
</tr>
<tr>
<td>Type IV Multi-family house, 100’000 kWh</td>
<td>8.25</td>
</tr>
<tr>
<td>Type V Larger building block, 500’000 kWh</td>
<td>7.92</td>
</tr>
<tr>
<td>Type VI Large commercial enterprise, 500’000 kWh</td>
<td>7.38</td>
</tr>
<tr>
<td>Type VII Large commercial enterprise, 1’163’000 kWh</td>
<td>7.10</td>
</tr>
<tr>
<td>Type VIII Industrial company, 11’630’000 kWh</td>
<td>6.56</td>
</tr>
<tr>
<td>Type IX Large industrial company, 116’300’000 kWh</td>
<td>6.35</td>
</tr>
<tr>
<td>Type X Large industrial company, 250’000’000 kWh</td>
<td>6.37</td>
</tr>
</tbody>
</table>
2.2 Electricity price in Switzerland

The new Electricity Supply Act (StromVG) has been in force since 2008. The law led to a partial liberalisation of the electricity market. End consumers with an annual consumption of more than 100 MWh are free to choose their supplier. The networks remain the monopoly of the electricity supply companies.

Many electricity suppliers do not have a unit price for all customers, but make their tariffs dependent on the quantity and timing of electricity consumption. Tariff structures can be complex and vary from supplier to supplier. To enable a price comparison, 15 predefined consumption categories are used (see Table 2-2). The average electricity price in 2019 in Rp./kWh for an average commercial enterprise (C3 with max. power consumption of 50 kW) is between 17.22 to 19.04 Rp./kWh.

![Figure 2-2: Average electricity prices from 2019 in Rp./kWh in different Swiss cantons for the industrial consumption profiles C1, C3, and C7](https://www.strompreis.elcom.admin.ch/Map/ShowSwissMap.aspx).

Table 2-2: Consumption profiles of electricity in Switzerland and average electricity price in 2019 [www.strompreis.elcom.admin.ch](http://www.strompreis.elcom.admin.ch).

<table>
<thead>
<tr>
<th>Consumption profiles of typical households, commercial and industrial enterprises</th>
<th>Average electricity price in 2019 in Rp./kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1 2-room apartment with electric cooker</td>
<td>1,600 kWh/a 22,38 - 24,74</td>
</tr>
<tr>
<td>H2 4-room apartment with electric cooker</td>
<td>2'500 kWh/a 20,32 - 22,46</td>
</tr>
<tr>
<td>H3 4-room apartment with electric stove and electric boiler</td>
<td>4'500 kWh/a 17,48 - 19,32</td>
</tr>
<tr>
<td>H4 5-room apartment with electric stove and tumbler (without electric boiler)</td>
<td>4'500 kWh/a 19,25 - 21,27</td>
</tr>
<tr>
<td>H5 5-room single-family house with electric stove, electric boiler and tumbler</td>
<td>7'500 kWh/a 17,01 - 18,80</td>
</tr>
<tr>
<td>H6 5-room single-family house with electric stove, electric boiler, tumbler and electric resistance heater</td>
<td>25'000 kWh/a 14,78 - 16,34</td>
</tr>
<tr>
<td>H7 5-room single-family house with electric stove, electric boiler, tumbler, heat pump 5 kW for heating</td>
<td>13'000 kWh/a 16,63 - 18,38</td>
</tr>
<tr>
<td>H8 Large, highly electrified freehold flat</td>
<td>7'500 kWh/a 18,56 - 20,52</td>
</tr>
<tr>
<td>C1 Very small commercial enterprise, max. power consumption: 8 kW</td>
<td>8'000 kWh/a 19,53 - 21,59</td>
</tr>
<tr>
<td>C2 Small commercial enterprise, max. 15 kW</td>
<td>30'000 kWh/a 18,81 - 20,79</td>
</tr>
<tr>
<td>C3 Average commercial enterprise, max. 50 kW</td>
<td>150'000 kWh/a 17,22 - 19,04</td>
</tr>
<tr>
<td>C4 Large commercial enterprise, max. 150 kW, low voltage</td>
<td>500'000 kWh/a 16,21 - 17,91</td>
</tr>
<tr>
<td>C5 Large industrial company, max. 150 kW, medium voltage, own transformer station</td>
<td>500'000 kWh/a 13,66 - 15,10</td>
</tr>
<tr>
<td>C6 Large industrial company, max. 400 kW, medium voltage, own transformer station</td>
<td>1'500'000 kWh/a 13,88 - 15,34</td>
</tr>
<tr>
<td>C7 Large industrial company, max. 1,630 kW, medium voltage, own transformer station</td>
<td>7'500'000 kWh/a 13,06 - 14,44</td>
</tr>
</tbody>
</table>
2.3 Electricity to gas price ratio

In 2018, the electricity to gas price ratio for a single-family house with heat pump (H7 = 17.51 Rp./kWh, II = 9.03 Rp./kWh), a large commercial enterprise (C4 = 17.06 Rp./kWh, VI = 7.38 Rp./kWh), and a large industrial company (C7 = 13.75 Rp./kWh, X = 6.37 Rp./kWh) are around 1.94, 2.31, and 2.16, respectively. Overall, the price ratio in Switzerland is lower than the average for the EU-28 countries of around 2.4, 3.3 and 3.0, which favours investment in electric heat pump systems.

Figure 2-3 shows the historical development of the relative cost of electricity to gas in Switzerland from 1960 to 2018. The lower the ratio, the better the competitive position for using heat pumps. As can be seen the ratio is lower than it has been in the past.

Figure 2-3: Development of electricity & gas prices and price ratio (secondary axis) in Switzerland from 1960 to 2018 (consumption profile: 20'000 kWh gas, 4'500 kWh electricity) [2].

Figure 2-4 gives an overview on the energy carriers used to supply the final energy demand in industry [2]. Electricity and gas are dominant, with 41% and 26% respectively.

Figure 2-4: Industrial energy consumption in Switzerland by energy carriers according to the overall energy statistics (2018) [2].
2.4 Importance of industry sectors in Switzerland

To estimate the importance of the industrial sectors statistical data on Switzerland can be analysed [3,4]. Table 2-3 shows the number of Swiss market-oriented companies and the number of employees by industrial sector in 2016. For example, there are 4’400 companies manufacturing food, beverage and tobacco products with 99’300 employees. About 200 companies produce pharmaceutical products with 45’400 employees.

Table 2-3: Statistical data on the number of Swiss market-oriented companies and employees by economic activity in 2016 [3].

<table>
<thead>
<tr>
<th>Market-oriented companies and employees by economic activity</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>according to NOGA 2008, in '000</td>
<td>Companies</td>
</tr>
<tr>
<td>Total</td>
<td>586.2</td>
</tr>
<tr>
<td>Sector 1</td>
<td>53.6</td>
</tr>
<tr>
<td>Sector 2</td>
<td>90.6</td>
</tr>
<tr>
<td>of which:</td>
<td></td>
</tr>
<tr>
<td>Manufacture of food, beverage and tobacco products</td>
<td>4.4</td>
</tr>
<tr>
<td>Manufacture of textiles, apparel and leather goods</td>
<td>2.9</td>
</tr>
<tr>
<td>Manufacture of wood and paper products, and printing</td>
<td>9.8</td>
</tr>
<tr>
<td>Manufacture of pharmaceutical products</td>
<td>0.2</td>
</tr>
<tr>
<td>Manufacture of metal products</td>
<td>7.4</td>
</tr>
<tr>
<td>Manufacture of computer, electronic and optical products; watches and clocks</td>
<td>2.0</td>
</tr>
<tr>
<td>Manufacture of electrical equipment</td>
<td>0.8</td>
</tr>
<tr>
<td>Electricity, gas and steam supply</td>
<td>0.8</td>
</tr>
<tr>
<td>Construction of buildings and Civil engineering</td>
<td>8.9</td>
</tr>
<tr>
<td>Sector 3</td>
<td>442.0</td>
</tr>
</tbody>
</table>

FSO, Statistical Data on Switzerland 2019

Figure 2-5 gives an overview of the industries production account aggregated by sections. Construction provides the highest Gross Value Added (GVA), followed by the pharmaceutical industry, computer, electronic and optical products (incl. watches), and food and tobacco industry.

Figure 2-5: Industries Gross Value Added (GVA) in 2017 aggregated by sections [4].
2.5 Industrial process heat demand in Switzerland

The theoretical application potential for the use of heat pumps in industrial processes can be estimated from the heat demand of the individual industrial sectors and the temperature levels of the applied industrial processes. The graphs in Figure 2-6 show the distribution of the industrial heat demand in Switzerland by sector and temperature level. In addition to space heating and hot water, industry has a great need for process heat for manufacturing, processing and refining products. In general, process heat is supplied above about 80 °C.

According to the Swiss Federal Statistical Office, around 19% of total final energy consumption in Switzerland goes to the industrial sector (as of 2017). This corresponds to a total energy consumption of about 158 PJ, which is the largest energy consumer (Figure 2-6, left). The energy consumption of the industry can again be differentiated according to its intended use, with process heat (>80 °C) accounting for around 55.5% or 87.7 PJ (24.4 TWh) of the total heat demand. The most important potentials for process heat lie in the chemicals/pharmaceuticals, minerals, food/beverages, metal and paper sectors (Figure 2-6, right).

A market study in 2017 on the use of large heat pumps in Swiss industry showed that the importance of industrial heat pumps will increase significantly over the next five years, particularly in the food, chemical, pharmaceutical and paper industries.

The largest research gap was identified in the areas of refrigerants (with low GWP) (46%), achievable temperature range (19%), component optimisation (e.g. temperature-resistant compressors) (15%), cycle optimization (12%), and demonstration projects (12%), while the greatest development needs were found in the limited temperature range (58%), cost reduction (investment, maintenance, and operation) (42%), efficiency improvement (27%), and the provision of more (modular) standardized products (15%).
Introduction

2.6 Annual sales of heat pumps in Switzerland

Figure 2-7 shows the number of installed heat pumps in the Swiss market for the last five years with the distribution of the heating capacity ranges. In 2018, a total of 21'964 new heat pump units were installed (www.fws.ch).

The Swiss heat pump market is dominated by domestic heat pumps with heating capacities of 5 to 13 kW. According to the SFOE, the market share of heat pumps in the residential market (e.g. new single-family houses) is about 80%.

These figures show that heat pumps are well established on a small scale in Switzerland. However, on a larger scale, i.e. industrial heat pumps, other heat generating systems are preferred using fossil fuels. Only around 115 to 145 heat pump units with a heating capacity of more than 100 kW are newly installed annually. Despite the rather small numbers of units, large heat pumps represent an important energy potential and numbers are rising.

Overall, the installed heating capacity of industrial heat pumps (>100 kW) corresponded to an average of about 38 MW per year in the last three years. Assuming an investment costs factor (incl. installation) of about 480 to 750 CHF/kW [7,8], a potential investment volume of 18 to 28 Mio. CHF can be estimated for industrial heat pumps (>100 kW) in Switzerland.

Unfortunately, there is no market data available with information on the temperature level of the heat pumps. Therefore, the number of heat pumps with high supply temperature (HHTPs) >100 °C is unknown, but assumed to be small due to the lack of products.

All over Europe, the number of industrial heat pumps installed is also largely unknown, as no sales figures are published by the EHPA (European Heat Pump Association) and there is no clear distinction made by the manufacturers between refrigeration systems and heat pumps.
2.7 Barriers to the wider spread of industrial heat pumps

Despite the great ecological potential and the already commercially available heat pump products on the market, there are still some market barriers to the wider spread of industrial heat pumps. These include in particular [5,8–11]:

- 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)

A major hurdle for the accelerated market diffusion of heat pump technology in the industrial sector lies in its cost-effectiveness. On the one hand, large heat pumps are individually and specially developed or products manufactured in small batch sizes. Larger lot sizes would increase productivity due to the economy of scale. A possible way would be a greater modularization of the heat pumps, so that some parts of the heat pump circuit or the hydraulic integration could be produced in larger quantities. If sufficient installation space is available at the customer site, several standard heat pumps could be connected to a large heat pump system.

Another hurdle lies in the lack of available compressors and refrigerants, which again increases prices. On this topic increased research effort has started worldwide over the last few years.

Finally, it is not always easy to implement a heat pump into an existing plant, since it needs well thought out integration on the heat sink and heat source side. In order to overcome this hurdle, successful integrations need to be demonstrated and published. The time lag between heat supply and availability of the heat sink in industrial processes is of crucial importance. The storage of the heat produced can help to optimise the non-simultaneous demand and waste heat utilization.

2.8 Investment costs

Wolf et al. [7,8] described the specific investment costs (incl. installation) of industrial heat pumps in Switzerland (> 500 kW thermal) as a function of the heating capacity in kW (see Table 2-4). The factor for mechanical compression heat pumps is around 480 to 750 CHF per kW of heating capacity. For larger plants (10 MW thermal), the investment costs including installation are around 265 to 425 CHF per kW. The achievable COPs for compression heat pumps depends on the temperature lift.

<table>
<thead>
<tr>
<th>Table 2-4: Characteristics of mechanically driven industrial heat pumps [7,8].</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal heating capacity</td>
</tr>
<tr>
<td>Max. temperature</td>
</tr>
<tr>
<td>COP at 40 K temperature lift</td>
</tr>
<tr>
<td>Max. temperature lift per stage</td>
</tr>
<tr>
<td>Average lifetime</td>
</tr>
<tr>
<td>Investment incl. installation (500 kW)</td>
</tr>
<tr>
<td>Investment incl. installation (10 MW)</td>
</tr>
</tbody>
</table>
3 Case Studies Framework

3.1 Definition and framework

Within the IEA HPT Annex 48 project Industrial Heat Pumps are defined as follows:

*Heat pumps in the medium and high power range and temperatures up to 200 °C, which can be used for heat recovery and heat upgrading in industrial processes, but also for heating, cooling and air-conditioning in commercial and industrial buildings.*

In order to improve the comparability of the different case studies, a framework was developed which describes the case studies in detail. Data on installation, heat pump, costs, effect, satisfaction and experience are collected. The framework contains the following information:

**Identification**
- Number #
- HPT Annex-#
- Name of the project
- Reference (URL/source of literature)
- Member country

**Setup**
- Industry, application
- Process applied
- Location, year of installation
- End user
- Heat pump manufacturer
- Contractor, consultant

**Heat pump technology**
- HP-technology, HP-system
- Working fluid
- Compressor type
- Number of units
- Heating capacity, cooling capacity
- Supply temperature
- Heat source and heat sink (inlet and outlet temperatures)
- Evaporation and condensation temperatures
- Thermal storage (if available)

**Cost**
- Heat pump
- Installation
- Annual operation in hours
- Annual maintenance

**Effects**
- Energy savings
- CO₂ emission reduction
- Energy cost savings
- Additional effects
- Remarks
3.2 Selection of best practice examples

A total of 29 Swiss case studies were collected in the framework this project (see summarizing table in the next section). The case studies were evaluated by desk research and expert discussions with manufacturers and industrial companies, which are described in more detail in the following sections. Only heat pumps in operation were considered. The heat pumps are integrated into an industrial or commercial process. The individual companies have agreed to provide detailed information (e.g. pictures) in order to create appealing distribution documents. Some case studies of industrial heat pumps in Switzerland have already been presented at the IEA HPT Workshop in Tokyo [12] and at the ICR 2019 conference [13].

The majority of the 29 examples come from the food industry (9 examples, 31%) followed by utilities that operate district heating networks (7 examples, 24%). The rest covers various industries such as pharmaceuticals (2), home care and nutrition (1), metals (1), machinery (1), buildings/wellness/restaurants (1), military (2), waste water treatment (2) and thermal baths (1).

The case studies from the food industry are:

- Cheese factory (process heat)
- Chocolate factory (heating and cooling processes)
- Vegetable producer (greenhouse heating, cooling of storehouses)
- Fresh convenience products (hot water from waste heat of the chillers)
- Vinegar (fermentation, pasteurisation)
- Meat producer (hot water for cleaning processes)
- Beverage producer (cleaning of bottles and wine tanks)
- Biscuits producer (hot water from waste heat recovery)

The heat sinks of the application examples include room heating, hot water, district heating and process heat. As heat sources waste heat from cooling processes (heat recovery), groundwater, lake water, river water, waste water, geothermal energy and ambient air are used.

According to the Japanese colleagues in the IEA HPT Annex 48 project, possible decision criteria for best practice examples are as follows:

- High temperature application (> 100 °C)
- High heat capacity of heating and cooling (> 5'000 kW)
- Low GWP refrigerant
- Simultaneous heating and cooling or skilful use of waste heat (Yes)
- High energy savings (> 50%)
- High reduction of CO₂ emissions (> 50%)
- High energy cost savings (> 50%)
3.3 Case studies located in the Swiss map

Figure 3-1 shows the locations of the 29 case studies on the Swiss map (Online link: https://de.batchgeo.com/map/Case-Studies-Switzerland). The locations are numbered according to the following summarizing table.

![Swiss map with the locations of the described case studies of industrial heat pumps](https://de.batchgeo.com/map/Case-Studies-Switzerland).
<table>
<thead>
<tr>
<th>No</th>
<th>Year</th>
<th>Project name</th>
<th>Location</th>
<th>Industry</th>
<th>Application</th>
<th>Heat source</th>
<th>Heat source in/out (°C)</th>
<th>Heat sink in/out (°C)</th>
<th>Heating/cooling capacity (kW)</th>
<th>Heat pump manufacturer</th>
<th>Refrigerant</th>
<th>Compressor</th>
<th>Efficiency</th>
<th>Costs (HP: heat pump, O: Annual operation, M: Annual maintenance)</th>
<th>Savings (energy, CO2 emissions, energy cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH01</td>
<td>2011</td>
<td>Slaughterhouse</td>
<td>Zurich</td>
<td>Food</td>
<td>Hot water, cleaning water</td>
<td>Waste heat (refrigeration, air)</td>
<td>W20/14</td>
<td>W30/90</td>
<td>800/364</td>
<td>Thermea</td>
<td>R744</td>
<td>Screw</td>
<td>COP 3.4</td>
<td>2'950 MWh fossil fuel, 510 t CO2/a (30%)</td>
<td></td>
</tr>
<tr>
<td>CH02</td>
<td>2019</td>
<td>Chocolate Factory Maestricht</td>
<td>Flawil</td>
<td>Food</td>
<td>Hot/cold water, heating</td>
<td>Water</td>
<td>W17/13</td>
<td>W60/70</td>
<td>276/184</td>
<td>CTA AG</td>
<td>R1234ze</td>
<td>Piston</td>
<td>n.a.</td>
<td>HP: 140'000 CHF (excl. VAT) 1791 CO2 (2013 to 2020)</td>
<td></td>
</tr>
<tr>
<td>CH03</td>
<td>2017</td>
<td>Champagne</td>
<td>Biel</td>
<td>District heating</td>
<td>Water</td>
<td>W12/7</td>
<td>W48/63</td>
<td>650/474</td>
<td>CTA AG</td>
<td>R1234ze</td>
<td>Piston</td>
<td>n.a.</td>
<td>HP: 280'000 CHF (excl. VAT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH04</td>
<td>2018</td>
<td>St. Jakob</td>
<td>Basel</td>
<td>District heating</td>
<td>Water</td>
<td>W14/10</td>
<td>W55/65</td>
<td>181/111</td>
<td>CTA AG</td>
<td>R1234ze</td>
<td>Piston</td>
<td>n.a.</td>
<td>HP: 210'000 CHF (excl. VAT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH05</td>
<td>2014</td>
<td>CO2 heat pump</td>
<td>Kisnaschitz ZH</td>
<td>n.a.</td>
<td>Ground heat</td>
<td>Water</td>
<td>W10 / 1</td>
<td>W22/65</td>
<td>101</td>
<td>ENGIE</td>
<td>R744</td>
<td>Piston</td>
<td>COP 3.57</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>CH07</td>
<td>2015</td>
<td>R134a heat pump</td>
<td>Kerns</td>
<td>n.a.</td>
<td>Ground heat</td>
<td>W32/1</td>
<td>W50/70</td>
<td>500</td>
<td>ENGIE</td>
<td>R1234ze</td>
<td>Piston</td>
<td>COP 2.82</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH08</td>
<td>2016</td>
<td>R134a heat pump at Geissrich</td>
<td>Wollhusen</td>
<td>Pharma</td>
<td>n.a.</td>
<td>Ground heat</td>
<td>W32/1</td>
<td>W47/67</td>
<td>606</td>
<td>ENGIE</td>
<td>R1234ze</td>
<td>Piston</td>
<td>COP 2.94</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>CH09</td>
<td>2012</td>
<td>Laurana</td>
<td>Thônex</td>
<td>District heating</td>
<td>Hot water from waste heat recovery</td>
<td>Geothermal and waste heat recovery</td>
<td>W14-16/8</td>
<td>W58/63</td>
<td>338</td>
<td>Carrier</td>
<td>R1234ze</td>
<td>Screw</td>
<td>n.a.</td>
<td>M: 1'000 CHF/a (recommendation) 15% (input energy), 1'493 MWh fossil fuel, 1'746 t CO2 (42%)</td>
<td></td>
</tr>
<tr>
<td>CH10</td>
<td>2018</td>
<td>Les Vergers</td>
<td>Meyrin</td>
<td>District heating</td>
<td>Heating of residential buildings</td>
<td>Ground water</td>
<td>W13/5-7,5</td>
<td>W35/50</td>
<td>5'000/1910</td>
<td>Fristrom</td>
<td>R1234ze</td>
<td>Turbo</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH11</td>
<td>2014</td>
<td>Waste water treatment plant</td>
<td>Zürich</td>
<td>Waste water</td>
<td>Hot water</td>
<td>Cleaned waste water</td>
<td>W7/2</td>
<td>W44/50</td>
<td>410</td>
<td>Schuco AG</td>
<td>R1234ze</td>
<td>Screw</td>
<td>n.a.</td>
<td>HP: 150'000 CHF, O: 4'500 t, M: 2'000 CHF without repair</td>
<td></td>
</tr>
<tr>
<td>CH12</td>
<td>2008</td>
<td>Thermal bath</td>
<td>Bad Zursach</td>
<td>Thermal bath</td>
<td>Hot water</td>
<td>Water from thermal bath</td>
<td>W29/5</td>
<td>W47/55</td>
<td>550</td>
<td>Schuco AG</td>
<td>R1234ze</td>
<td>Screw</td>
<td>n.a.</td>
<td>HP: 250'000 CHF, O: 5'000 t, M: 5'500 CHF without repair</td>
<td></td>
</tr>
<tr>
<td>CH13</td>
<td>2018</td>
<td>Cheese factory</td>
<td>Gaiss</td>
<td>Food, Hot water, heating</td>
<td>Waste heat from data center</td>
<td>W18/14</td>
<td>W82/92</td>
<td>520</td>
<td>Ochsen</td>
<td>R1234ze</td>
<td>Screw</td>
<td>COP 2.85 (W18/W28) COP 4.2 (W18/W65)</td>
<td>1.5 million kWh of gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH14</td>
<td>2017</td>
<td>GVS Landi</td>
<td>Schaffhausen</td>
<td>Food &amp; Beverages</td>
<td>Process water for disinfection and cleaning</td>
<td>Waste heat from room heating</td>
<td>W37</td>
<td>W80/95</td>
<td>63</td>
<td>Ochsen</td>
<td>R2455s</td>
<td>Screw</td>
<td>COP Heating 4.2 EIR Cooling 3.2</td>
<td>26'000 t oil/a, 40% CO2 emissions</td>
<td></td>
</tr>
<tr>
<td>CH15</td>
<td>2009</td>
<td>Nutrix</td>
<td>Russwil bei Büren</td>
<td>Food &amp; Beverages</td>
<td>Vinegar fermentation and pasteurization</td>
<td>Heat from vinegar fermentation</td>
<td>W30</td>
<td>W70</td>
<td>194</td>
<td>Viscouman</td>
<td>R1234ze</td>
<td>Piston</td>
<td>COP 3.4</td>
<td>up to 65'000 t oil/a, 310 t CO2/a, 50 kWh/a (energy cost)</td>
<td></td>
</tr>
<tr>
<td>CH16</td>
<td>1985</td>
<td>City of Lausanne</td>
<td>Lausanne</td>
<td>District heating</td>
<td>Hot water for residential buildings</td>
<td>Water of lake Leman</td>
<td>W6-7</td>
<td>W26-38/50-65</td>
<td>2 x 4'500</td>
<td>Sulzer</td>
<td>R717</td>
<td>Turbo</td>
<td>COP 4.8</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>CH17</td>
<td>2013</td>
<td>Härterei Gernzer AG</td>
<td>Egerkingen</td>
<td>Metals</td>
<td>Process heat for hardening processes</td>
<td>Waste heat from cooling water</td>
<td>W17</td>
<td>W65</td>
<td>260</td>
<td>CTA AG</td>
<td>R1234ze</td>
<td>Piston</td>
<td>n.a.</td>
<td>80% (energy), 160 to CO2/a, 800 MWh gas replaced by 190 MW/h electricity</td>
<td></td>
</tr>
<tr>
<td>CH18</td>
<td>2016</td>
<td>Swiss Army CCH Heat Pump</td>
<td>Payerne</td>
<td>Military</td>
<td>Tap water &amp; facility heating</td>
<td>Outdoor air</td>
<td>A-9</td>
<td>W30/70</td>
<td>60</td>
<td>Enex</td>
<td>R744</td>
<td>Piston</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH19</td>
<td>2012</td>
<td>Kellermann AG</td>
<td>Eikon an der Thur</td>
<td>Food</td>
<td>Hot water for greenhouse heating</td>
<td>Groundwater and waste heat from cold rooms</td>
<td>W6/2</td>
<td>W53/63</td>
<td>1'000</td>
<td>Johnson Controls</td>
<td>R717</td>
<td>Piston</td>
<td>n.a.</td>
<td>960 t CO2/a</td>
<td></td>
</tr>
<tr>
<td>CH20</td>
<td>2010</td>
<td>Georg Fischer AG</td>
<td>Grösch</td>
<td>Technology</td>
<td>Heating for production of plastic valves</td>
<td>Water</td>
<td>W8/4</td>
<td>W55</td>
<td>382/252</td>
<td>SCM Frigo s.p.A</td>
<td>R1234ze</td>
<td>Piston</td>
<td>COP 4.8 (W10/W35) COP 3.0 (W10/W40)</td>
<td>HP: about 200'000 CHF</td>
<td></td>
</tr>
<tr>
<td>CH21</td>
<td>2015</td>
<td>Swiss Army Troop Building</td>
<td>Matt</td>
<td>Military</td>
<td>Heating, hot water</td>
<td>Water</td>
<td>WB</td>
<td>W60</td>
<td>270/180</td>
<td>5115 kW</td>
<td>R1234ze</td>
<td>Piston</td>
<td>COP 3.0 (W6/W60)</td>
<td>HP: about 200'000 CHF</td>
<td></td>
</tr>
<tr>
<td>CH22</td>
<td>2013</td>
<td>Koken Corporate Campus</td>
<td>Ruggell</td>
<td>Buildings &amp; restaurant</td>
<td>Heating, hot water</td>
<td>Water</td>
<td>W10/7</td>
<td>W27/35</td>
<td>341/275</td>
<td>MTA</td>
<td>R410a</td>
<td>Scroll</td>
<td>COP 4.16 (W10/W35)</td>
<td>HP: about 85'000 CHF</td>
<td></td>
</tr>
<tr>
<td>CH23</td>
<td>2017</td>
<td>Kambly SA</td>
<td>Trubschachen</td>
<td>Food</td>
<td>Hot water for biscuit production</td>
<td>Waste heat recovery</td>
<td>W20-30/12-14</td>
<td>W40-55/65</td>
<td>471/350</td>
<td>Fritherm</td>
<td>R1234ze</td>
<td>Screw</td>
<td>COP 3.9 (471 kW 121 kW)</td>
<td>HP: 167'000 CHF, Installation: 35/000 CHF 25% (energy), 100 t CO2/a (90%), 15% (energy cost)</td>
<td></td>
</tr>
<tr>
<td>CH24</td>
<td>2014</td>
<td>Casino</td>
<td>Aarau</td>
<td>District heating/cooling</td>
<td>District heating and cooling network</td>
<td>Ground water</td>
<td>W9/5</td>
<td>W45/70</td>
<td>375/7 (cooling)</td>
<td>Johnson Controls</td>
<td>R717</td>
<td>Piston</td>
<td>COP Cooling 6.3 (W4/W69) COP Cooling 6.2 (W3/W34)</td>
<td>n.a.</td>
<td>40% (energy) by 2035</td>
</tr>
<tr>
<td>CH25</td>
<td>2017</td>
<td>Mifs AG Mibelle Group</td>
<td>Frankendorf</td>
<td>Home Care and Nutrition</td>
<td>Hot/cold water, waste heat recovery</td>
<td>Waste heat recovery</td>
<td>W35/4</td>
<td>W49/70</td>
<td>885 (cooling)</td>
<td>Johnson Controls</td>
<td>R717</td>
<td>Piston</td>
<td>COP Cooling 6.2 (W3/W34)</td>
<td>20% (energy), 960 t CO2/a (80%)</td>
<td></td>
</tr>
<tr>
<td>CH26</td>
<td>2016</td>
<td>Bachem AG</td>
<td>Bubendorf</td>
<td>Pharma</td>
<td>Peptides</td>
<td>Water</td>
<td>W13/8</td>
<td>W51/70</td>
<td>480/540</td>
<td>Johnson Controls</td>
<td>R717</td>
<td>Piston</td>
<td>COP 4.7 (W6/W45) COP 7.1 (W3/W71)</td>
<td>500 t CO2/a</td>
<td></td>
</tr>
<tr>
<td>CH27</td>
<td>2013</td>
<td>Feldschlösschen, City of Rheinfelden</td>
<td>Rheinfelden</td>
<td>District heating</td>
<td>Brewery</td>
<td>Waste heat from cooling water</td>
<td>W16/10</td>
<td>W50/81</td>
<td>1'350</td>
<td>Mayekawa</td>
<td>R717</td>
<td>Piston</td>
<td>COP 3.41 (W16/W81) COP 4.8B (W3/W71)</td>
<td>75% (energy cost), 93% from 12 GWh fossil energy, of which 18% electricity</td>
<td></td>
</tr>
<tr>
<td>CH28</td>
<td>2007</td>
<td>ARA Altenhein</td>
<td>Altenhein</td>
<td>Wastewater treatment</td>
<td>Sewage sludge drying</td>
<td>Waste heat from wastewater</td>
<td>W8/2</td>
<td>W55/65</td>
<td>2 x 1'420</td>
<td>GEA</td>
<td>R1234ze</td>
<td>Piston</td>
<td>Annual COP 3.62 (BB/W65)</td>
<td>3'000 t CO2/a</td>
<td></td>
</tr>
<tr>
<td>CH29</td>
<td>2012</td>
<td>Hincona AG</td>
<td>Schaan</td>
<td>Food</td>
<td>Fresh convenience foods</td>
<td>Waste heat from chillers</td>
<td>W31</td>
<td>W65</td>
<td>507/437</td>
<td>GEA</td>
<td>R1234ze</td>
<td>Piston</td>
<td>COP 6.0 (W31/W67)</td>
<td>n.a.</td>
<td></td>
</tr>
</tbody>
</table>

IEA HPT Annex 48, Task 1 Report: Case Studies of Industrial Heat Pumps in Switzerland, October 2019
4 Ochsner Energie Technik GmbH

4.1 GVS Schaffhausen – disinfection of bottling plant and wine tanks

Over the past two years, the agricultural cooperative association Schaffhausen (GVS) and its energy service provider Ennovatis Schweiz AG have implemented a number of projects to significantly reduce energy consumption [14]. In order to be exempted from the CO₂ tax, the company had to reduce its CO₂ emissions by 40% on the basis of different measures.

Figure 4-1 shows the GVS LANDI AG in Schaffhausen-Herblingen [15]. As the company has an active cooling demand throughout the year, a lot of waste heat is also generated in winter by the existing chillers, which are exhausted using air-coolers. The waste heat from these air-coolers is used as a heat source for a new high temperature heat pump from Ochsner (Type: ISWHS 60 ER 3, economizer cycle) (Figure 4-2).

On the heating side of the HTHP, the heat can be fed directly into a local heating network (80 to 85 °C) or it is needed for the production of process hot water for the disinfection of the bottling plant and the wine tanks (80 to 95 °C). The local heating network serves the entire production area of the company with several properties. The technical data of the heat pump are:

- Model type: ISWHS 60 ER3 with screw compressor and refrigerant ÖKO 1 (R245fa)
- Heating / cooling capacity: 63 kW / 48 kW
- Heat source: Waste heat from chiller (cooling of storage rooms) (37 °C)
  - Heat sinks: Process water for disinfection of beverage filling plants and wine tanks (80 to 95 °C), district heating of production site (80 to 85°C), heating and cooling of warehouses
- COP heating: 4.2
- EER cooling: 3.2

Figure 4-1: GVS LANDI AG in Schaffhausen-Herblingen [15].

Figure 4-2: Ochsner heat pump (Type: ISWHS 60 ER 3, economizer cycle) in the heat center of the agricultural cooperative association Schaffhausen (GVS) (Photos from ennovatis Schweiz AG).
The benefits of this installation are obvious:

- CO₂ emissions significantly reduced and target achieved
- Approximately 26,000 litres of oil saved annually
- High performance figures are achieved

First operation was in 2017. The system is currently monitored by ennovatis energy management software. This means that additional optimisation potential can be implemented based on the recordings.

![Principle drawing of the heat pump installation at the GVS Landi in Schaffhausen-Herblingen][15].

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4.2 Cheese factory in Gais Appenzell

The mountain cheese factory in Gais Appenzell produces various semi-hard and mountain cheese specialties, as well as raclette cheese. The milk is supplied by approximately 60 milk suppliers from the Appenzellerland region. Approximately 10 million litres of milk are processed per year. The factory is connected to a district heating network, which is fed by waste heat from the neighbouring data center (see Figure 4-4).

![Image of cheese factory and data center]

Figure 4-4: Waste heat from the server cooling of the data center is fed into a district heating network at around 20 °C. The mountain cheese factory utilizes this waste heat as heat source in a HTHP to generate process heat for the cheese production [16].

A high temperature heat pump from Ochsner (Figure 4-5) converts waste heat (excess heat) at 20 °C as a heat source into process heat of up to 100 °C to process the milk for cheese production [16,17]. The water exits the heat pump at 14 °C before it flows back into the district heating network. This way, the cheese factory replaces the energy of around 1.5 million kWh of natural gas per year.

![Image of high temperature heat pump]

Figure 4-5: Ochsner high temperature heat pump (Type: IWWHS 570 ER6c2) with technical data [17].
The temperature levels of the process heat at the cheese factory are as follows:

- Waste heat recovery (washing, ventilation heating): <42 °C
- Space heating and hot water (i.e. for cheese storage house): 65 °C
- Process heat 1 (i.e. for cheese vats, cleaning water): 92 °C
- Process heat 2 (i.e. for multi-purpose heater, pasteurisation): 105 °C

Table 4-1 shows the performance data of the heat pump at high and low temperature conditions in full and part load operation. Depending on the operating conditions, the COP of the heat pump is between 2.55 and 2.85 at 74 K temperature lift (W18-14/W82-92) and between 3.75 and 4.20 at 47 K lift (W18-14/W55-65). The economizer cycle of the heat pump with vapour injection into the two-stage screw compressor enables an efficient solution for high temperature lifts.

Table 4-1: Performance data of the high temperature heat pump at high and low temperature conditions [16,17] (* experimentally tested data, ** extrapolated).

<table>
<thead>
<tr>
<th>Part load (%) (by slide valve control)</th>
<th>High temperature (W18-14/W82-92)</th>
<th>Low temperature (W18-14/W55-65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective part load (%)</td>
<td>100* 75** 50**</td>
<td>100* 75** 50**</td>
</tr>
<tr>
<td>Condenser capacity (kW)</td>
<td>520 419 321</td>
<td>505 390 279</td>
</tr>
<tr>
<td>Condenser water flow rate (m³/h)</td>
<td>44.7 36.0 27.6</td>
<td>43.4 33.5 24.0</td>
</tr>
<tr>
<td>Temperature difference condenser (K)</td>
<td>10.0 10.0 10.0</td>
<td>10.0 10.0 10.0</td>
</tr>
<tr>
<td>Evaporator capacity (kW)</td>
<td>338 264 195</td>
<td>385 293 205</td>
</tr>
<tr>
<td>Evaporator water flow rate (m³/h)</td>
<td>82.7 82.7 82.7</td>
<td>82.7 82.7 82.7</td>
</tr>
<tr>
<td>Temperature difference evaporator (K)</td>
<td>3.5 2.7 2.0</td>
<td>4.0 3.0 2.1</td>
</tr>
<tr>
<td>Compressor power (kW)</td>
<td>182 155 126</td>
<td>120 98 74</td>
</tr>
</tbody>
</table>

The economizer cycle provides the following main advantages:

1. High refrigerant mass flow at compressor outlet, resulting in high heating capacity (i.e., even at high temperature lifts and low evaporation temperatures).
2. Reduced compressor outlet temperature, which is positive with regard to the temperature limits.
3. Strong subcooling of the condensate to increase the COP.

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5 CTA AG

5.1 Heating and cooling for chocolate production at Maestrani

Maestrani Schweizer Schokoladen AG is a family owned private company with about 150 employees. Every year, the company produces around 3’500 tons of chocolate. The product portfolio comprises around 300 different products, distributed among the three brands Minor, Munz and Maestrani (Figure 5-1).

The production of chocolate and the requirements for air conditioning and temperature control during production are energy intensive. To reduce energy consumption from around 7’200 MWh in 2016 to 5’300 MWh in 2019, Maestrani has invested in a new, modern energy center [18,19]. Together with the Energy Agency for Economic Affairs (EnAW), a comprehensive package of measures was agreed, which commits Maestrani to reduce CO₂ emissions at its production site in Flawil by at least 179 tons between 2013 and 2020, in particular by reducing electricity and gas consumption for heating and process gas. The primary goal is to produce CO₂ neutral chocolate in the coming years. Carnotech AG from Zofingen has planned the new energy supply with a modular "cold-guided" concept. The main challenges were to cover a wide temperature range from 5 to 70 °C, to combine cooling and heat generation efficiently, and to control the temperature precisely.

Since 2016, tailor-made water-water heat pumps from the Swiss company CTA AG in Münsingen have been implemented (Figure 5-2). Seiz Haus- und Industrietechnik AG from Flawil has professionally installed the systems. Part of the factory is supplied with energy, as well as the visitor centre "Maestrani’s Chocolarium" with integrated shop, which has been opened in April 2017.
Today, three identical CTA heat pumps are in operation, generating cold (around 222 kW per machine) or heat (around 276 kW per machine) as required. Each heat pump is equipped with 4 reciprocating compressors and 2 refrigerant circuits. In its final configuration, the energy center can be extended to up to 8 machines thanks to its modular design, which corresponds to a cooling capacity of around 2 MW.

The environmental friendly refrigerant HFO R1234ze(E) with a very low global warming potential (GWP) was chosen. Since R1234ze(E) is slightly flammable (safety class A2L), the system is monitored and safely operated thanks to gas sensors, ventilation and alarming.

Figure 5-3 shows a simplified process diagram of the realized energy supply. The two storage tanks (cold storage 28 m³ and hot storage 30 m³) enable the compensation of temporal fluctuations depending on energy demand and demand.

The temperature levels of the individual production processes are:

- 5°C/11°C: production cooling and air conditioning of the production rooms
- 11°C/17°C: cooling processes, room cooling, air-conditioning of "Chocolarium" visitor centre
- 45°C/35°C: recooling
- 55°C/45°C: heat recovery (WRG), conching machines (Figure 5-4), intermediate storage of products, space heating, hot water preparation, heating "Chocolarium"
- 70°C/60°C: fat and cocoa melting tanks, various decrystallisers, heating cabinets, air heater
- 80°C/70°C: decrystallisers from various production lines, heat kitchen, pelleting lines, coating line, test line

![Figure 5-3: Simplified process diagram of the realized energy supply with cooling, heating and storage.](image)

The chocolate production runs in 2-shift operation. Refrigeration is required continuously. The processes above 70 °C are covered by a gas boiler with a heating capacity of around 640 kW. When the chocolate production comes to a standstill during the Christmas holidays, the gas boiler is put into operation. It is also used for redundancy reasons and as an emergency heating system to bridge the gap between keeping the chocolate warm and the production process.

Finally, an electric steam generator with a heating output of around 400 kW and a compressed air system for pneumatic control of the production systems are in operation. Although there is no basic steam load, steam can be made available at short notice as required, especially for the sugar dryers.
(8 bar, 175 °C), mould washing plant (5 bar, 159 °C), cooking plant (1.5 bar, 127 °C), chocolate banana production (1.35 bar, 126 °C) or spraying (1.05 bar, 120 °C).

Figure 5-4: Large conching machine in production. Agitator to keep the chocolate mass warm at 45 °C.

Table 4-1 shows six operating points for cooling and heating, which show the application limits of the heat pumps [19]. Heating COPs range between 2.85 and 4.12 for a temperature lift of W17/W70 and W11/W45 respectively.

Table 5-1: Six operating points for cooling and heating [19].

<table>
<thead>
<tr>
<th></th>
<th>Cooling</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot water inlet / outlet [°C]</td>
<td>35 / 45 45 / 55</td>
<td>60 / 70 35 / 45 45 / 55</td>
</tr>
<tr>
<td>Cold water inlet/outlet [°C]</td>
<td>11 / 5 11 / 5</td>
<td>11 / 5 17 / 11</td>
</tr>
<tr>
<td>Cooling capacity [kW]</td>
<td>222.6 192.9</td>
<td>141.8 217.7</td>
</tr>
<tr>
<td>Recooling or heating capacity [kW]</td>
<td>289.8 269.3</td>
<td>225.0 273.0</td>
</tr>
<tr>
<td>Power consumption [kW]</td>
<td>70.4 80.0</td>
<td>87.2 57.9</td>
</tr>
<tr>
<td>COP heating</td>
<td>4.12 3.37</td>
<td>2.58 4.71</td>
</tr>
<tr>
<td>COP cooling</td>
<td>3.16 2.41</td>
<td>1.63 3.76</td>
</tr>
<tr>
<td>COP total</td>
<td>7.28 5.78</td>
<td>4.21 8.47</td>
</tr>
</tbody>
</table>

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5.2 District heating network Champagne in Biel

Since May 2018, the district heating network in Biel's Champagne district supplies heat for heating and hot water (50/63°C, max. hot water 75°C) (Figure 5-5). The construction, financing and operation of the district heating network (1.6 km pipeline) is carried out by Energie Service Biel (ESB) in cooperation with AEK Energie AG [20]. The heat supply system consists of two tailor-made CTAexklusiv heat pumps (2 x 650 kW heating capacity) and a natural gas boiler (1’100 kW).

Figure 5-5: District heating network in Champagne [20].

Figure 5-6: Heat supply system with two heat pumps (2 x 650 kW heating capacity) and a natural gas boiler (1’100 kW) saving 620 tons CO₂ per year [20].

Two tailor-made CTAexklusiv heat pumps are applied in the heat center of Champagne using groundwater (11/7°C) (Figure 5-7). The two machines have a weight of around five tons each and deliver 650 kW of heating power per machine with their four speed-controlled reciprocating compressors. The climate-friendly refrigerant HFO R1234ze is used.

Figure 5-7: Two CTAexklusiv heat pumps with 4 speed-controlled reciprocating compressors (2 x 650 kW) [21].
The heat comes from the groundwater, which is extracted at a temperature of 10 to 12 °C and cooled by the heat pumps by 4 °C (Figure 5-8). The groundwater is transferred to the heat pumps via an intermediate circuit. This ensures that the sensitive groundwater has no direct contact with the refrigerant even in the case of leakage.

The Champagne heating network is a lighthouse project in many respects. First, the heat pumps are highly efficient. The heating COP is around 3.45 at W11/W63 (Table 5-2). In addition, thanks to the natural heat source, up to 620 tons of CO₂ can be saved per year compared to fossil heating [21].

![Figure 5-8: Scheme of groundwater extraction (around 6'000 L/min) in the heat center Champagne [20].](image)

**Table 5-2: Technical data of the heat pump (CTA-PHP-42.1124-2W.2WS-1234ze-HT) from CTA AG.**

<table>
<thead>
<tr>
<th>Operating point</th>
<th>100%</th>
<th>75%</th>
<th>50%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor frequency in Hz</td>
<td>60</td>
<td>45</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Condenser inlet/outlet in °C</td>
<td>49.3/63.0</td>
<td>49.3/63.0</td>
<td>49.3/63.0</td>
<td>56.2/63.0</td>
</tr>
<tr>
<td>Evaporator inlet/outlet in °C</td>
<td>11.0/7.0</td>
<td>11.0/7.0</td>
<td>11.0/8.2</td>
<td>11.0/9.6</td>
</tr>
<tr>
<td>Heating capacity in kW</td>
<td>650.0</td>
<td>488.0</td>
<td>325.0</td>
<td>163.0</td>
</tr>
<tr>
<td>Cooling capacity in kW</td>
<td>474.0</td>
<td>360.8</td>
<td>237.9</td>
<td>118.6</td>
</tr>
<tr>
<td>Power consumption incl. frequency converter loss in kW</td>
<td>189.3</td>
<td>137.3</td>
<td>94.0</td>
<td>47.9</td>
</tr>
<tr>
<td><strong>COP heating</strong></td>
<td>3.43</td>
<td>3.55</td>
<td>3.46</td>
<td>3.40</td>
</tr>
</tbody>
</table>

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5.3 District heating network St. Jakob in Basel

In 2018, IWB (Industrielle Werke Basel), the energy supplier of the city of Basel, installed two identical CTAexklusiv air-water heat pumps with 265 kW heating capacity each (total 530 kW) in the St. Jakob district heating network [22]. These replace a block heat and power plant powered by natural gas and thus contribute to a further reduction in CO₂ emissions from the heat supply in Basel. The district heating network supplies the St. Jakob football stadium, the St. Jakob garden swimming pool and the St. Jakobshalle (Figure 5-9).

Each heat pump is equipped with four compressors, which enables operation on demand (Figure 5-10). There are two 11 m long air coolers on the roof of the building (Figure 5-11). These extract heat from the air and the heat pumps produce up to 70 °C of hot water, depending on the operating point (Table 5-3). This energy is transferred to a 42 m³ storage tank from where the various consumers draw their heat [23].
Figure 5-11: One of the two 11 m long air coolers, which extract the source energy from the air [22].

Table 5-3: Technical data of the air-water heat pump (CTA-PHP-42.612-B.WS-134-HT-LN) from CTA AG.

<table>
<thead>
<tr>
<th>Operating point</th>
<th>A-5/W55</th>
<th>A5/W55</th>
<th>A5/W70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor source temperature in °C</td>
<td>-5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Condenser inlet/outlet in °C</td>
<td>47.8/55.0</td>
<td>55.0/65.0</td>
<td>60.5/70.0</td>
</tr>
<tr>
<td>Heating capacity in kW</td>
<td>180.5</td>
<td>265.0</td>
<td>251.9</td>
</tr>
<tr>
<td>Cooling capacity in kW</td>
<td>110.4</td>
<td>171.2</td>
<td>155.6</td>
</tr>
<tr>
<td>Power consumption in kW</td>
<td>73.4</td>
<td>98.0</td>
<td>100.8</td>
</tr>
<tr>
<td><strong>COP heating</strong></td>
<td><strong>2.46</strong></td>
<td><strong>2.70</strong></td>
<td><strong>2.50</strong></td>
</tr>
</tbody>
</table>

In summer, the heat pumps cover the complete hot water consumption of the connected consumers. For temperatures higher than 5 °C (the average temperature in Basel is 10 °C) the machines produce hot water at 70 °C [23]. When the outside temperature is less than 5 °C (and down to -5 °C), the heat pumps still produce usable heat at 55 °C, which is used for hot water return heating. The remaining heating up to 80 °C is carried out in winter by two gas boilers, which are used to cover peak loads (bivalent heat generation) in the central heating system [22].

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5.4 Heat treatment of metal parts at Härterei Gerster AG

The family owned company Härterei Gerster AG with around 100 employees, founded in 1950, is a contract hardening company for customers in the mechanical engineering and automotive industries that thermally hardens metal parts (Figure 5-12). The metal parts are heated up to 1'000 °C and cooled quickly to improve the material properties like wear and corrosion resistance. 50 oven systems and 50 inductive hardening systems are in place. The company spends an extraordinary amount of money on energy [24]. Together with the Energy Agency EnAW, Härterei Gerster AG has formulated and implemented various successful energy-saving measures [25].

The two natural gas-fired boilers were replaced by a heat pump (PHP-22.306-W.W-134-HT-LN, R134a, 260 kW) from CTA AG for almost half a million Swiss francs (Figure 5-13). The heat pump uses the waste heat from the industrial water network, which is used for cooling of all production plants, e.g. for the quenching process in vacuum furnaces, to supply process heat (65 °C) to all rooms. Thanks to the heat pump, 800 MWh of natural gas can be saved (= 80% savings of gas consumption or 160 tons of CO₂ emissions). The waste heat is sufficient to supply the complete operation in summer by recovering the process heat. The payback time is almost ten years. Therefore, the canton Solothurn contributed 30'000 CHF to the project and the Swiss Climate Foundation 48'000 CHF [24].

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6 ENGIE Kältetechnik GmbH

6.1 Reference examples of heat pumps for hot water

ENGIE offers innovative solutions for the entire life cycle of heating, air-conditioning and ventilation systems as well as for process technology. Individually planned solutions aim to achieve the best energy values and the greatest possible CO₂ savings. Since 2017, the refrigeration division is an independent subsidiary of the ENGIE Group and based in Oensingen. The company is specialized in the construction and servicing of compression chillers and heat pumps.

Table 6-1 shows four reference heat pumps in Switzerland from ENGIE Kältetechnik GmbH installed in 2014 to 2016 producing hot water. Figure 6-1 to Figure 6-4 illustrate the heat pumps.

Table 6-1: Four reference examples of heat pumps for hot water from manufacturer ENGIE Kältetechnik GmbH.

<table>
<thead>
<tr>
<th>Name of project</th>
<th>CO₂ heat pump</th>
<th>R134a HT heat pump</th>
<th>R134a HT heat pump with sound insulation housing</th>
<th>R134a heat pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Küsnacht (Zurich)</td>
<td>Kerns</td>
<td>Kerns</td>
<td>Geistlich Wolhusen</td>
</tr>
<tr>
<td>Year of installation</td>
<td>2014</td>
<td>2014</td>
<td>2015</td>
<td>2016</td>
</tr>
<tr>
<td>Dimensions L x W x H in m</td>
<td>1.5 x 1.2 x 1.84</td>
<td>5.5 x 1.6 x 2.9</td>
<td>4.8 x 2.0 x 2.1</td>
<td>4.8 x 1.6 x 2.4</td>
</tr>
<tr>
<td>Heating/cooling capacity in kW</td>
<td>101</td>
<td>800</td>
<td>500</td>
<td>606</td>
</tr>
<tr>
<td>Heat source/sink</td>
<td>Brine/Water</td>
<td>Brine/Water</td>
<td>Brine/Water</td>
<td>Brine/Water</td>
</tr>
<tr>
<td>Heat source inlet/outlet in °C</td>
<td>5/1</td>
<td>20/15</td>
<td>3/-1</td>
<td>2/-1</td>
</tr>
<tr>
<td>Heat sink inlet/outlet in °C</td>
<td>22/65</td>
<td>55/75</td>
<td>50/70</td>
<td>47/67</td>
</tr>
<tr>
<td>COP</td>
<td>3.57 (B5/W65)</td>
<td>3.68 (B20/W75)</td>
<td>2.82 (B3/W70)</td>
<td>2.94 (B2/W67)</td>
</tr>
</tbody>
</table>

Figure 6-1: CO₂ heat pump in Küsnacht (Zurich) with one compressor.

Figure 6-2: R134a HT heat pump in Kerns with four compressors.
Figure 6-3: R134a HT heat pump in Kerns with sound insulation housing and four compressors.

Figure 6-4: R134a heat pump at Geistlich in Wolhusen with four compressors.

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7 Kibernetic AG

Kibernetic AG in Buchs offers ideal solutions for heating, cooling and energy saving. The history of the company began in 1965 with an innovation in ice cream production. Now, the product range includes ice machines, heat pumps, air conditioning systems, swimming pool heat pumps and photovoltaics. Table 7-1 shows three reference water-water heat pumps in Switzerland from Kibernetic AG for heating (35 °C) and hot water supply (60 to 65 °C).

Table 7-1: Reference examples of water-water heat pumps from Kibernetic AG (Buchs SG).

<table>
<thead>
<tr>
<th>Projects (reference)</th>
<th>Geor Fischer AG</th>
<th>Swiss Army military building</th>
<th>Wellness and restaurant Kokon Corporate Campus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Grüsche</td>
<td>Matt</td>
<td>Ruggell, Lichtenstein</td>
</tr>
<tr>
<td>Year of installation</td>
<td>2010</td>
<td>2015</td>
<td>2013</td>
</tr>
<tr>
<td>User (company)</td>
<td>Georg Fischer AG, Grüsche</td>
<td>Swiss Army (Italy)</td>
<td>Swiss Army (Italy)</td>
</tr>
<tr>
<td>HP manufacturer</td>
<td>SCM Frigo (Italy)</td>
<td>SCM Frigo (Italy)</td>
<td>MTA (Germany)</td>
</tr>
<tr>
<td>HP model</td>
<td>SK 190S WPC (2 units)</td>
<td>SK 188W WPM (2 units)</td>
<td>Büchel Haustechnik Est.</td>
</tr>
<tr>
<td>Contractor</td>
<td>Kibernetic AG</td>
<td>Bäbler Heizungen AG</td>
<td>Bäbler Heizungen AG</td>
</tr>
<tr>
<td>Working fluid</td>
<td>R134a</td>
<td>R134a</td>
<td>R134a</td>
</tr>
<tr>
<td>Compressor</td>
<td>Reciprocating</td>
<td>Reciprocating</td>
<td>Scroll</td>
</tr>
<tr>
<td>Heating/cooling capacity in kW</td>
<td>382/252</td>
<td>270/180</td>
<td>341/275</td>
</tr>
<tr>
<td>Supply temperature (°C)</td>
<td>65</td>
<td>60</td>
<td>35</td>
</tr>
<tr>
<td>Heat source inlet/outlet in °C</td>
<td>8/4</td>
<td>8/n.a.</td>
<td>10/7</td>
</tr>
<tr>
<td>Heat sink inlet/outlet in °C</td>
<td>n.a/65</td>
<td>n.a/60</td>
<td>27/35</td>
</tr>
<tr>
<td>Thermal storage</td>
<td>heating/hot water</td>
<td>heating/hot water</td>
<td>Heating only</td>
</tr>
<tr>
<td>Heat pump costs in CHF</td>
<td>ca. 200'000</td>
<td>ca. 200'000</td>
<td>ca. 85'000</td>
</tr>
<tr>
<td>COP</td>
<td>4.8 (W10/W35)</td>
<td>3.0 (W8/W60)</td>
<td>4.16 (W10/W35)</td>
</tr>
</tbody>
</table>

7.1 Hot water for plastic valves manufacturing at Georg Fischer AG

Georg Fischer AG is a leading global manufacturer of plastic valves for industry and drinking water distribution. In Grüsche, around 180 employees produce millions of valves per year. These are used to control, regulate and measure the flow of liquids in piping systems (Figure 7-1).

Figure 7-1: Georg Fischer Rohrleitungsseitigsysteme AG in Grüsche producing plastic valves.

Figure 7-2 illustrates the hydraulic diagram of the heat pump installation at Georg Fischer AG in Grüsche. Two R134a heat pump units (Type SK 190S WPC from SCM Frigo) are installed in parallel together with a 1'500 L storage tank and an oil-fired boiler for redundancy.
7.2 Heating and hot water for the Swiss Army troop building in Matt (GL)

The military shooting range and training site at Wichlen (Glarus) and the neighboring communities have training and accommodation facilities for 3 military companies of the Swiss Army. In Matt, the troop accommodation building has 326 beds (Figure 7-3).

![Troop accommodation building in Matt with 326 beds](http://www.fnag.ch/referenzen5.html)

Hot water and heating is supplied with two groundwater heat pumps (SK 188 W WPM) from Kibernetik AG (135 kW heating capacity and 90 kW cooling capacity at W8/W60, COP of 3.0) and a 5'000 L hot water storage tank (Figure 7-5). Figure 7-4 illustrates the hydraulic diagram of the heat supply center. The groundwater is fed to the heat pumps via a plate heat exchanger and a water/glycol intermediate circuit.
Figure 7-4: Hydraulic diagram of the heat supply at the troop accommodation building of the Swiss Army in Matt with two heat pumps from Kibernetik AG and a 5'000 L hot water storage tank.

Figure 7-5: The two groundwater heat pumps from Kibernetik AG and the hot water storage tank installed at the Swiss army troop accommodation building in Matt.

7.3 Heating of the KOKON Corporate Campus buildings

The KOKON Corporate Campus in Ruggell (Liechtenstein) is a future-oriented workspace combining all amenities for employees (Figure 7-6). There are fully equipped offices of every size, 700 parking spaces, restaurants with a stylish ambience and sunny outdoor terraces, Kids Care, Fitness & Spa (Wellness) as well as an Event & Congress Center as an ideal location for events.

Figure 7-6: KOKON Corporate Campus in Ruggell (Liechtenstein) with workspace, restaurants and wellness.
For heating the buildings a water-water heat pump (Type: Neptune Tech NET 090 from MTA, Figure 7-7) with a heating/cooling capacity of 341/275 kW is installed [26]. The heat pump provides heat from 27 to 35 °C using 3 hermetic scroll compressors in parallel position and refrigerant R410A. With a heat source of 10/7 °C a heating COP of 5.17 is achieved.

Figure 7-7: WTA Neptune Tech NET 090 heat pump with 3 hermetic scroll compressors positioned in parallel in one circuit (Dimensions L x W x H: 2.01 x 0.8 x 1.83 m) [26].

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8 Viessmann (Schweiz) AG

8.1 Vinegar fermentation and pasteurization at Nutrex

Nutrex (meaning: NUT = Nutritio, REX = King) was founded in 1942 and is the leading supplier for vinegar in Switzerland. Since 1971 it is a division of the COOP Genossenschaft. With 15 employees, Nutrex produces approx. 8.9 million litres of vinegar per year in Busswil (Bern) of which 0.5 million liters are in organic (bio) quality. More than 50 different vinegar varieties are sold for retail, caterers, restaurants and industry (Figure 8-1).

In 2008, COOP took the decision to achieve CO₂ neutrality within 15 years. Nutrex managed to achieve this goal already in 2009 by applying modern heat pump technology in its production site. For the production of vinegar two specific processes are used: fermentation and pasteurization (Figure 8-2). These two processes fit perfectly for the application of a heat pump and serve as its heat source and sink. Vinegar fermentation occurs as the alcohol is converted into acid by bacteria. It is an exothermic reaction and stops when the mixture is getting too warm. To stabilize the process the large tanks need to be cooled at 30 °C over 10 days (Figure 8-3). On the other side, vinegar pasteurization takes place above 70 °C to obtain a non-perishable food.
At Nutrex a heat pump (Viessmann, R134a, piston compressor) was installed with a cooling capacity of 136 kW and a heating capacity of 194 kW (Figure 8-3). The heat pump runs with a COP of around 3.4. Beside of the pasteurization, the produced heat is used for heating of the laboratory and of the building. Since the replacement of conventional oil heating in 2009, Nutrex has achieved a CO$_2$-free production. The use of the heat pumps has reduced the CO$_2$ emissions by approximately 310 tons/year and saves up to 65'000 liters of fuel/year [29]. The energy savings are about 50'000 CHF/year [30].

Figure 8-3: Vinegar fermentation and pasteurization using a heat pump from Viessmann [29].

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Friotherm AG

9.1 District heating in Lausanne with large heat pumps

Friotherm originates from the Sulzer Group and offers heat pumps, refrigeration systems and services of high quality and reliability. Following a management buyout in 2005, Friotherm AG is an independent company located in Frauenfeld.

The Lausanne heat pump plant built in 1985 by Sulzer is one of the largest heat pumps in Europe [29,31]. Two 4.5 MW NH₃ heat pumps use the water of lake Leman (approx. 260 L/s at 6 to 7 °C) as heat source to supply heat in two district heating networks (e.g. the school and university in Lausanne) (Figure 9-1). The lake water is extracted from 65 m depth at 700 m from the beach. The water is cooled down by about 3 K in the evaporator and is released into a nearby river.

The two identical heat pumps have an economizer port for the oil-injected screw compressors. The two heat pumps can either be operated in series (two-stage heat pump) or in parallel (then one heat pump is on stand-by mostly) depending on the heating conditions. Ammonia was chosen mainly with regard to its excellent thermodynamic properties. A storage tank limits the start-ups of the heat pumps and thus mechanical wear.

The heat pumps supply 28 to 65 °C in a high temperature network and 26 to 50 °C in a low temperature network. For the peak loads, when the outside temperature is very low, the heat pumps are supported by two gas boilers. Measurements gave the following average Lorenz efficiencies of the heat pumps: 58.1% at 5/50°C, 59.7% at 6/45°C and 45.4% at 7/30°C [31], corresponding to heating COPs of about 4.2, 4.9, and 6.0 respectively.

Figure 9-1: Two large NH₃ heat pumps in Lausanne (2x 4.5 MW) [29,31].

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10 Scheco AG

Scheco AG in Winterthur with 55 employees is a leading company in the refrigeration, air conditioning and heat pump industry in Switzerland. The company is a pioneer in refrigeration technology. The company has a long history dating back to 1865. In 1932 the first fully automatic refrigeration plants were built in Winterthur.

Today, Scheco AG serves a wide range of customers in the commercial, industrial and building technology sectors. Sustainable and reliable systems and equipment are planned, manufactured and documented in accordance with the applicable laws, guidelines and local regulations, in particular:

- ISO 9001
- Pressure Equipment Ordinance (2014/68/EU)
- Chemicals Risk Reduction Ordinance ChemRRV
- SN EN 378/1-4 Refrigerating systems and heat pumps
- Machinery Directive 2006/42/EC

For industrial customers various products and solutions are offered. Table 10-1 shows technical data of two case studies of industrial heat pumps for waste water treatment in a sewage treatment plant and waste heat recovery in a thermal bath.

Table 10-1: Technical data of two industrial heat pumps from Scheco AG for waste water treatment and waste heat recovery in a thermal bath [32,33].

<table>
<thead>
<tr>
<th>Name of the project</th>
<th>Sewage treatment plant</th>
<th>Thermal bath</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of installation</td>
<td>2014</td>
<td>2008</td>
</tr>
<tr>
<td>Application</td>
<td>hot water for district heating</td>
<td>hot water for thermal water</td>
</tr>
<tr>
<td>Process applied</td>
<td>heat recovery</td>
<td>heat recovery</td>
</tr>
<tr>
<td>Heat source</td>
<td>(cleaned) waste water</td>
<td>waste water</td>
</tr>
<tr>
<td>Heating capacity</td>
<td>410 kW</td>
<td>550 kW</td>
</tr>
<tr>
<td>Heat sink inlet/outlet</td>
<td>44/50 °C</td>
<td>47/55 °C</td>
</tr>
<tr>
<td>Heat source inlet/outlet</td>
<td>7/2 °C</td>
<td>29/55 °C</td>
</tr>
<tr>
<td>Compressor</td>
<td>Screw with integrated inverter for part-load control</td>
<td>Triple screw</td>
</tr>
<tr>
<td>Working fluid</td>
<td>R134a</td>
<td>R134a</td>
</tr>
<tr>
<td>Heat pump costs</td>
<td>150’000 CHF</td>
<td>250’000 CHF</td>
</tr>
<tr>
<td>Annual operation</td>
<td>4’500 h/a</td>
<td>5’000 h/a</td>
</tr>
<tr>
<td>Annual maintenance costs</td>
<td>2’000 CHF without repair</td>
<td>3’500 CHF without repair</td>
</tr>
<tr>
<td>Reference</td>
<td>[32]</td>
<td>[33]</td>
</tr>
</tbody>
</table>

10.1 Heat recovery of the cleaned wastewater from a sewage treatment plant

Heat recovery from cleaned waste water of a sewage treatment plant in Zurich supplies hot water for a local heating network. A heat pump from Scheco AG with a heating capacity of 410 kW that runs with R134a generates heating water of 50 °C from waste water (heat source) with a temperature of 7 °C. The heat pump works with a compact inverter-controlled screw compressor, which enables a large control range with very good part load performance [32]. Figure 10-1 shows the screw compressor with the integrated inverter for part-load control and a 3D layout of the energy center. The heat pump costs amounted to around 150 kCHF. The annual maintenance costs are around 2 kCHF without repairs.
10.2 Thermal bath with heat pump for heat recovery

There are around 30 thermal baths in Switzerland. Most thermal baths are committed to the sustainable use of resources in the fields of energy and climate protection. The aim is to further reduce energy consumption significantly over the next few years. Popular measures are:

- pool covering to reduce heat radiation over night,
- power saving with energy-saving lamps and LED lighting,
- shower heads, which reduce water consumption,
- sauna systems with special energy management, and
- the installation of heat pumps, which extracts energy from the used thermal water.

Figure 10-2 shows the installation of a water/water heat pump in a thermal bath in Northwestern Switzerland, which extracts the energy from the 29 °C used water of the thermal pools and raises it to a higher usable temperature level of 55 °C [33]. The heat is used to heat the pools and to prepare hot thermal water. The heat pump has three screw compressors and a heating capacity of 550 kW.

Figure 10-2: Installation of the new water/water heat pump for heat recovery of waste thermal water with two special cranes in the area of the thermal bath [33].

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11 EWZ Energielösungen

11.1 Heat pump system at the Slaughterhouse in Zurich

The slaughterhouse in Zurich, opened as a municipal facility in 1909, has been operated by the Schlachtbetriebe Zürich AG since 1995. The City of Zurich, represented by Umwelt- und Gesundheitsschutz Zürich (UGZ), is the owner of the site and the buildings. The slaughterhouse is located in a historic building in the middle of the city. 500 employees process more than 24’000 tons of meat annually [34]. Heat is mainly used for the production of hot water for cleaning processes (hygiene), domestic hot water, and space heating (50/30°C).

Since 2011, a heat pump system is in operation with 3 heat pumps thermeco₂ HHR 260 (Thermea, Germany, today ENGIE) that delivers 800 kW heating capacity and water up to 90 °C (Figure 11-2). The heat pumps are driven by twelve transcritical GEA CO₂ compressors (HGX34/150-4 SH CO2 T) [35] (Table 11-1). ewz planned, financed, built and operates the heat pump system.

The heat pump system uses the waste heat from an existing ammonia refrigeration machine, an oil-cooled air compressor plant and fan-coil units. For this reason, the heat is collected in a waste heat buffer storage tank connected with the heat pump evaporators. Apparently, the plant is the largest built in Switzerland [34]. The heated water is used for slaughtering and cleaning purposes and for feed water for a steam generator and the heating system. The COP of the heat pump is 3.4 at 90°C/30°C [36]. The heating system is additionally supported by a gas boiler as back-up heater.

The warm side of the heat pumps is connected with a hot water buffer storage. The processes are provided from this buffer storage.

With the heat pump, 2’590 MWh of fossil fuels can be saved per year. The annual reduction in CO₂ emissions is 510 tons, which is around 30 % lower than before using steam boilers. The environmentally friendly energy supply in the slaughterhouse makes an important contribution on the way to becoming the 2000-watt society of the city of Zurich. The case study serves as a model for numerous slaughterhouses in Switzerland and other countries.

![Figure 11-1: Three CO₂ heat pumps of the type thermeco2 HHR 260 at the slaughterhouse in Zurich](image)

![Table 11-1: Technical data of the heat pump system at the slaughterhouse in Zurich](table)

<table>
<thead>
<tr>
<th>Machine type</th>
<th>3 x thermeco₂ HHR 260</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant</td>
<td>R744 (CO₂)</td>
</tr>
<tr>
<td>Compressors</td>
<td>12 x piston GEA CO₂ compressors (HGX34/150-4 SH CO2 T, transcritical)</td>
</tr>
<tr>
<td>Capacity control via master CPU</td>
<td>adjustable in 12 steps</td>
</tr>
<tr>
<td>Heating capacity</td>
<td>800 kW at 90 °C heat sink outlet / 30 °C heat sink inlet</td>
</tr>
<tr>
<td>Cooling capacity</td>
<td>564 kW at 20 °C heat source inlet / 14 °C heat source outlet</td>
</tr>
<tr>
<td>Energy savings</td>
<td>2’590 MWh fossil fuels</td>
</tr>
<tr>
<td>CO₂ emissions reduction</td>
<td>30% (510 tons CO2/a)</td>
</tr>
</tbody>
</table>
Figure 11-2: Function chart of the heat pump system at the Slaughterhouse in Zurich [36].

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12 Durena AG

12.1 Heat from purified waste water for sewage sludge drying

Durena AG, founded in 1990, employs around 20 people in Lenzburg, Zurich and Altdorf and provides complete and high-quality energy engineering services. A selected reference in the field of heat pumps is the waste heat recovery from waste water for sewage sludge drying. Durena AG does planning and site management of such projects (from concept to construction and execution) [38].

In 2005, it was decided to replace the existing sewage sludge drum drying plant at the waste water treatment plant ARA Altenrhein with a low-temperature belt drying plant. Durena AG was commissioned to implement a new plant concept. The cleaned waste water is fed into a water basin. Automatic basket filters filter the water and two heat exchangers serve as hydraulic network separators (Figure 12-1). The liquid sludge is dewatered and then dried in low-temperature sewage sludge dryers [39]. Two identical heat pumps from GEA with 2x 1’420 kW heating capacity extract the heat from the waste water and generate the heat for the two belt dryers (Table 12-1). A hot water storage tank (30 m³) absorbs short-term load fluctuations and extends the running time of the heat pumps. In addition, heat recovery from the nearby combined heat and power plants is integrated into the heat generation process. The two belt dryers are supplied with the necessary heat energy via 24 air heater groups. Due to the low drying temperatures of less than 60 °C, low-temperature sewage sludge dryers have various advantages:

- waste heat from waste water to be used for dryer heating
- fossil heat generation can be omitted
- large quantities of CO₂ emissions are avoided

The generation of thermal energy for sewage sludge drying from waste water is an economically and ecologically useful way. Operating experience confirms the high efficiency and availability of this proven technology.

Table 12-1: Technical data of the two GEA heat pumps [38].

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total heating capacity (S8/W65)</td>
<td>2 x 1’420 kW</td>
</tr>
<tr>
<td>Heat sink (hot water) inlet/outlet</td>
<td>55/65 °C (45/55 °C)</td>
</tr>
<tr>
<td>Heat source (wastewater) inlet/outlet</td>
<td>8/2 °C</td>
</tr>
<tr>
<td>Hot water tank capacity</td>
<td>30 m³</td>
</tr>
<tr>
<td>Waste water flow rate</td>
<td>344 m³/h</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R134a</td>
</tr>
<tr>
<td>Annual COP</td>
<td>3.62</td>
</tr>
<tr>
<td>Reduction of CO₂ emissions</td>
<td>approx. 3'000 t/a</td>
</tr>
</tbody>
</table>

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Figure 12-1: Front view of the two heat pumps and plate heat exchangers for waste water with filter systems [38], [39].
13 SSP KÄLTEPLANER.CH

13.1 Heating and cooling at the vegetable producer Kellermann AG

Kellermann in Ellikon an der Thur is one of the largest vegetable producers in Switzerland. The company produces lettuce and salad vegetables outdoors and tomatoes in glasshouses [40–42]. To support growth of tomatoes it is necessary to heat the air during a longer yearly period. Salad and vegetables need cooling for rapid cooling and storage. Convenience products require cooling for cold water (washing) and storage.

An extension of the logistics building resulted in a large additional cooling requirement. At the same time, the greenhouses are heated throughout the year. An integral concept was developed by the company SSP KÄLTEPLANER.CH for a large, central cooling system with a heat pump to heat the greenhouses. The concept design included cooling and heating with just one ammonia (NH₃, R717) system using groundwater as heating source. The goals of the basic concept and design were [42]:

- Central refrigeration plant for about 1’000 kW refrigeration capacity, optimal for heat recovery and easy to maintain
- Highly ecological and effective technology with an environmental friendly refrigerant
- Cold distribution with glycol water
- Heat recovery 1’000 kW (ground water available)
- High quality standard for operation and plant safety

The cooling and heating demand varies depending on the season and vegetable harvest quantity. In winter, for example, the cooling capacity demand decreases due to lower outside temperatures, while the heat requirement in the greenhouses increases accordingly. The system can respond to these changes with three different operating modes - either cooling or heating mode or combined cooling and heating mode. Figure 13-3 shows the principle drawing of the cooling and heating network [42].
The installed refrigeration system consists of two Sabroe low-pressure piston compressors (SMC 112L, permanent magnet motors with electronic variable speed inverters), one evaporative condenser and two plate evaporators. The system is filled with ammonia as refrigerant.

Figure 13-3: Principle drawing of the cooling and heating network [42].

Figure 13-4: Ammonia compressors from Johnson Controls with brand Sabroe (HPC version 106S, 40 bar) with permanent magnet motors with electronic variable speed inverters [40,42].
In pure cooling mode, the heat is absorbed via the two evaporators and dissipated via the condenser. The cooling COP\(_{C}\) is then 3.61 (-9°/+35°C) [40]. The cold produced is distributed via a glycol-water network at -7 °C for rapid cooling and coldrooms (with accumulator tank of 49 m\(^3\)). The cold water is cooled from 10 °C to 2 °C (at 40 m\(^3\)/h).

The coupling to the heating system is carried out via a desuperheater (max. 130 kW, 53 to 63 °C) or via an additional heat pump (1’000 kW), which consists of a Sabroe high-pressure piston compressor (HPC 106S, 40 bar), a condenser (65 °C) and an intermediate pressure tank (35 °C). The desuperheater is used to supply heat to the heating system continuously. The heat pump switches on if there is additional heat demand. The heating COP\(_{H}\) of the compressor is 7.57 (35°C/65°C) [40].

If there is no cooling demand, like in winter, groundwater is used as the additional heat source (max. 700 kW). In pure heating mode, the COP\(_{H}\) of the heat pump process is 3.6. The total capacity of the refrigeration system is 1’100 kW and the total capacity of the heat pump 1’000 kW. To control the system a Siemens S7 controller is applied.

The coupling of the refrigeration with a heat pump system enables Kellermann to significantly reduce the costs of refrigeration and heat generation. The heat pump generates 4 to 5 GWh of heating energy per year. This saves the company about 500’000 m\(^3\) natural gas for heating the greenhouses. The environment benefits are a reduction of CO\(_2\) emissions by 790 tons per year. If the heat pump is operated with "green electricity", the system even saves the environment 960 tons of CO\(_2\) per year.

The project has been supported by the private organisation Klimastiftung Schweiz and ProKilowatt, which is supported by the Swiss Federal Office for Energy (BFE).

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Table 13-1 list some other projects using similar ammonia (NH\(_3\)) heat pump installations planed by SSP KÄLTEPLANER AG.

<table>
<thead>
<tr>
<th>Company</th>
<th>Industry</th>
<th>Application</th>
<th>Contact, Tel.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell Oensingen</td>
<td>Meat production</td>
<td>Domestic hot water</td>
<td>Stefan Zimmerli, +41 58 326 31 24</td>
</tr>
<tr>
<td>Bigler Büren</td>
<td>Meat production</td>
<td>Domestic hot water</td>
<td>Pascal Nagel +41 32 352 09 22</td>
</tr>
<tr>
<td>Grischuna Landquart</td>
<td>Meat production</td>
<td>Hot water/process</td>
<td>Daniel Brunold, +41 79 449 86 14</td>
</tr>
<tr>
<td>Galliker Transport AG</td>
<td>Logistics center</td>
<td>Heating</td>
<td>Alexander Herde, +41 62 748 82 95</td>
</tr>
<tr>
<td>Migros</td>
<td>Food distribution Neuendorf</td>
<td>Heating</td>
<td>Martin Stöckli +41 62 388 72 25</td>
</tr>
<tr>
<td>EWZ Zurich</td>
<td>Heating network Riedbach</td>
<td>District heating</td>
<td>Thomas Crivelli, +41 58 319 49 86</td>
</tr>
<tr>
<td>EWZ Zurich</td>
<td>Heating network Bullingerstrasse</td>
<td>District heating</td>
<td>Thomas Crivelli, +41 58 319 49 86</td>
</tr>
</tbody>
</table>
14 Frigo-Consulting AG

14.1 CO₂ heat pump for water heating

Frigo-Consulting is a leading engineering company for refrigeration technology in Switzerland and one of the worldwide leaders in CO₂ refrigeration planning. The company is headquartered in Berne and has two branches in Switzerland (Lausanne, Zurich) and four branches in Europe (Italy, Poland, Romania and Spain).

By order of the Swiss Federal Department of Defence, Civil Protection and Sport (DDPS) Frigo-Consulting implemented two CO₂ heat pump in the Swiss Army Training Hall of Payerne [43]. To meet the requirements of the Swiss army, the following technical criteria were of major importance for this project:

- energy efficiency,
- ecological aspects,
- high temperature levels, and
- adaptation of the performance levels on demand.

Figure 14-1 illustrates the two CO₂ heat pumps manufactured by the Italian company ENEX Srl. (www.enex.it). The Airheat heat pumps are designed to work at outdoor air conditions down to -9 °C. The application is facility heating and the production of hot tap water from 30 to 70°C. The air-water heat pumps run with piston compressors using CO₂ in a transcritical cycle. The total heating capacity is 60 kW. The hot water is distributed via a two networks at different operating temperatures.

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15 eicher+pauli AG

15.1 District heating and cooling network Casino Aarau

The city of Aarau with about 20,200 inhabitants has set the goal of complying with the criteria of the 2000-Watt-Society by significantly reducing CO₂ emissions and the share of fossil fuels of the final energy demand for heat < 40% by 2035 [44]. On behalf of IB Aarau (Eniwa AG, Buchs AG), eicher+pauli designed an innovative cooling and heating system for the district heating and cooling (10 °C) network [45]. The owner and operator IB Aarau invested around 18 million CHF into the project [44]. eicher+pauli planned and implemented the energy centre for the district heating (70 °C) and cooling network in an old civil defence facility under the casino parking lot in the middle of the city of Aarau (Figure 15-1). A chimney concept was implemented to ventilate the shelter, which leads about 100 m through the ground and finally along the facade of a cinema complex over the roofs.

![Figure 15-1: City of Aarau with the district heating (1.2 km) and cooling (1.1 km) network. Tunnel for the heat network and two NH₃ heat pump (HPC108SV, SMC112LV, Sabroe) from Johnson Controls [45,46].](image)

In the energy centre, around 80% of the required heat is generated practically CO₂-free with two NH₃ heat pumps (Sabroe) from Johnson Controls (cooling capacities/power consumption: HPC 108 SV, 1060/153 kW, COP 6.9 at 34.4/69°C, SMC 112 LV, 915/147 kW, COP 6.2 at 3.3/34.4 °C). The main heat source is groundwater (9/5°C), which is available in large quantities. A gas boiler heating system (2 x 1.7 MW capacity) serves as redundancy and is switched on to cover peak loads of the heat demand. Free-cooling extracted from the groundwater supplies the cold to the consumers. If free-cooling is not sufficient enough, the heat pump chillers are switched on. The combined heat pump/cooling system achieves a heating energy of 10’400 MWh and a cooling energy of 3’200 MWh.

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15.2 Heating and cooling supply at Mifa AG in Frenkendorf (BL)

As part of the Mibelle Group, Mifa AG in Frenkendorf (BL) is a company of the Migros M-industry. Here, detergents and cleaning agents as well as margarines and edible fats are produced (Figure 15-2). In the Home Care and Nutrition segments, the company is number three on the European private label market [47].

![Mifa AG in Frenkendorf](image1)

Figure 15-2: Mifa AG in Frenkendorf producing detergents, cleaning agents as well as margarines and edible fats (Mibelle Group / Mifa AG).

eicher+pauli was commissioned with the renewal of the heating and cooling supply of Mifa AG in Frenkendorf (BL). For Mifa AG/Mibelle-Group and the Migros industry this means an important step into a sustainable future. A new energy center was built for around CHF 11 million with the following highlights [47–49] (Figure 15-3):

- Heat and cooling generation by means of combined heat pump / chiller with heat recovery
- Use of waste heat from compressed air production
- Reduction of gas consumption and CO₂ emissions by around 60% (960 tons per year)
- Reduction of electricity consumption by around 20%
- Reduction of water consumption by around 70%

The new energy center supplies two separate heating networks with temperatures of 110 °C (high temperature) and 70 °C (medium temperature for hot water and heating). In the high-temperature network, the fossil steam boilers have been replaced by efficient hot-water boilers, which also ensure peak coverage of the low-temperature network [47]. Waste heat from the compressed air system and the exhaust gas condensation is used for operation of the medium-temperature network.

![Energy Center](image2)

Figure 15-3: New energy center of Mifa AG in Frenkendorf [47,48].
In total, the new energy centre contains 6 heat pumps and refrigeration units (Figure 15-4). The heating capacity of the heat pump is about 885 kW, the total cooling capacity of the minus and plus cooling 804 kW and 1'814 kW respectively (Table 15-1).

<table>
<thead>
<tr>
<th>Units</th>
<th>Compressor Sabroe</th>
<th>Temperature</th>
<th>Application</th>
<th>Capacity</th>
<th>Power</th>
<th>COP (cooling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x heat pump</td>
<td>HPC 106 SV (piston)</td>
<td>38/57°C, 49/70°C</td>
<td>Hot water, heating</td>
<td>885 kW</td>
<td>134 kW</td>
<td>6.6 (32.5/69°C)</td>
</tr>
<tr>
<td>3x refrigeration</td>
<td>SMC 116 LV</td>
<td>-29 °C</td>
<td>Process cooling</td>
<td>402 kW</td>
<td>79 kW</td>
<td>5.1 (-29/1 °C)</td>
</tr>
<tr>
<td>2x refrigeration</td>
<td>SMC 112 LV</td>
<td>4/2 °C</td>
<td>Ice water</td>
<td>907 kW</td>
<td>161 kW</td>
<td>5.6 (-1/32.5 °C)</td>
</tr>
</tbody>
</table>

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15.3 Heat recovery at Bachem AG in Bubendorf (BL)

Bachem AG, headquartered in Bubendorf (BL), is a global Pharmaceutical and Biotechnology Company specialized in the production of peptide-derived active pharmaceutical ingredients. The production plants require process cooling with high availability and operational reliability. As the demand for refrigeration has increased in recent years and the old plants were no longer able to meet this demand alone, eicher+Pauli was commissioned to plan a new refrigeration supply system.

Two existing chillers (2x Sabroe HPO 28 VSD, 237/284 kW heating/cooling capacity) were refurbished and are used to cover the peak load and redundancy. A new combined ammonia-powered chiller/heat pump was installed (8 cylinder Sabroe HPO 28 VSD type [50]) to cover the increased demand and at the same time enable heat recovery [51]. The resulting regenerative heat energy is used for heating and domestic hot water. This saves around 300 tons of CO₂ annually.
This concept ensures a reliable and safe cooling supply for production. An intelligent building automation system regulates the optimal interaction of the three heat pumps. The cold water (8°C flow, 14°C return) is fed into the cooling network via a pipeline from the new technical center.

Table 15-2: Ammonia (NH₃) heat pumps from Johnson Controls (Sabroe) at Bachem AG in Bubendorf.

<table>
<thead>
<tr>
<th>Units</th>
<th>Compressor</th>
<th>Temperatures (refrigerant)</th>
<th>Application</th>
<th>Heating/cooling capacity</th>
<th>Power (cooling)</th>
<th>COP (cooling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x (existing)</td>
<td>Sabroe HPO 28 VSD</td>
<td>6/45 °C</td>
<td>Process cooling</td>
<td>237/284 kW</td>
<td>50.4 kW</td>
<td>4.7</td>
</tr>
<tr>
<td>1x (new)</td>
<td>Sabroe HPO 28 VSD</td>
<td>38/71 °C</td>
<td>Heating/hot water</td>
<td>513/585 kW</td>
<td>72.6 kW</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Figure 15-5: Headquater of Bachem AG in Bubendorf with Sabroe HP 28 VSD NH₃ heat pumps [51].

As a guideline the service and maintenance costs of a large NH₃ heat pump are approx. 2.5 to 3% of the system costs [52]. This means that sufficient money needs to be budgeted for compressor maintenance, which is carried out after 4 to 6 years, depending on the annual operating hours of the plant like 20'000 h, 30’000 h or 40’000 h depending on compressor type. The life expectancy of a large NH₃ heat pump is about 30 to 35 years [52].

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16 Gruner Gruneko AG

16.1 Waste heat recovery at Feldschlösschen Getränke AG in Rheinfelden

Feldschlösschen Getränke AG is the leading brewery and the largest beverage retailer in Switzerland with its headquarters in Rheinfelden (AG). Beer has been brewed on the hill above Rheinfelden since 1876 (Figure 16-1). Today the Feldschlösschen brewery produces around one million litres of beer per week [53]. Since 2000, Feldschlösschen is a subsidiary of the Danish Carlsberg Brewery Group.

The annual energy consumption at Feldschlösschen is about 45 GWh, of which two thirds are heat and one third electricity [53]. The used fuels are natural gas, biogas from the in-house pre-treatment plant, alcohol from the dealcoholisation plant, and heating oil. The heat is required in various process steps during beer production. Around 40% is used in the brewhouse, where the wort is boiled and then cooled again. The two other major thermal energy consumers are the dealcoholisation plant (for the production of alcohol-free beer) and the tunnel pasteuriser (for pasteurising a large part of the production).

In cooperation with AEW Energie AG, the city of Rheinfelden and the Feldschlösschen brewery, a district heating network for Rheinfelden Mitte was built. Gruner Gruneko AG was commissioned by AEW Energie AG with the technical planning, execution and commissioning of the energy system [54]. In September 2014, the district heating network was put into operation. Figure 16-2 shows the principle diagram of waste heat recovery from the beer production for the district heating network.

The new heating network Rheinfelden Mitte supplies more than 600 households all year with heating water for room heating and domestic hot water (Salmenpark complex, Schifflände area, and parts of the old town of Rheinfelden) [55]. In the buildings of the Feldschlösschen castle a heating center was
The total capacity of the new district heating system is around 6'000 kW. Over 6'000 tons of CO₂ emissions can be saved annually.

Feldschlösschen has four cooling systems distributed over the entire brewery area. The waste heat from the brewery's cooling systems (refrigeration plants) and the brewery's own waste water is collected in a waste heat ring (Figure 16-2). The waste heat has a temperature of about 12 to 30 °C, depending on the beer production volume and season [55]. This waste heat is stored in low-temperature storage tanks in the cellar of the brewery house (Figure 16-3). The waste heat of around 25 °C is lifted up to 81 °C in winter and 71 °C in summer by two 1'400 kW NH₃ heat pumps (Mayekawa MYCOM, N6HK-DD, N6M-DD) before it is fed into the district heating network. Over 90% of the heat is generated CO₂-free. The remaining heat (at peak load, emergency supply) is supplied by a gas-fired heat generation plant into the heat network. The heating COP of the heat pumps is about 3.41 in winter (W16/W81) and 4.88 in summer (W30/W71) (Table 16-1).

Figure 16-3: Storage tanks (3 x 58 m³) for the waste heat and Mayekawa MYCOM compressor [54].

Table 16-1: Summer and winter conditions of the waste heat and district heating network.

<table>
<thead>
<tr>
<th>Season</th>
<th>Waste heat (in/out)</th>
<th>District heating network (in/out)</th>
<th>Heating capacity district heating</th>
<th>COP (heating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>16/10 °C</td>
<td>50/81 °C</td>
<td>1'351 kW</td>
<td>3.41</td>
</tr>
<tr>
<td>Summer</td>
<td>30/24 °C</td>
<td>50/71 °C</td>
<td>1'296 kW</td>
<td>4.88</td>
</tr>
</tbody>
</table>

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17 Lemon Consult AG

17.1 Kambly SA, Trubschachen – biscuit producer

The Swiss biscuit producer Kambly SA based in Trubschachen (Figure 17-1), renewed its energy supply system to eliminate oil for heating, reduce CO₂ emissions, and increase energy efficiency. The company Lemon Consult was commissioned to optimize the energy supply for heating/cooling and cold distribution [56].

![Figure 17-1: Kambly SA in Trubschachen [56] producing biscuits.](image)

In a first stage, the existing two oil boilers for process and building heat were dismantled and the old heat pump from 2002 was replaced by a new, more efficient, and larger heat pump with 471 kW heating capacity (Figure 17-2 and Figure 17-3).

![Figure 17-2: Heat pump from Friotherm AG (Type X22HE-450A) running with screw compressor from Bitzer (CSH9573-180Y) and HFO refrigerant R1234ze.](image)

The heat pump is from Friotherm (Type: X22HE-450A), which runs with a screw compressor from Bitzer (Type: CSH9573-180Y) and low GWP HFO refrigerant R1234ze. The waste heat from the air conditioning units and biscuit baking ovens is recovered at 20 to 30 °C and transformed to 65 °C by the
heat pump for hot water generation for all buildings. To cover production-free times two condensing gas boilers with 450 kW heating capacity each are installed, additionally. The heat pump and a 6’000 litres stainless steel water storage tank have been installed in the old oil tank rooms [57]. With a power consumption of 121 kW a nominal heating COP of 3.9 is achieved (30W/65W).

Overall, the new energy supply system with the heat pump saves 25% energy and led to a reduction in CO2 emissions of around 100 tons per year.

Figure 17-3: Principle drawing of the heat pump installation at Kambly SA.

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17.2 Waste heat recovery from the refrigeration plant at Hilcona AG (Schaan)

Hilcona AG is the market leader for fresh convenience foods in Germany, Austria and Switzerland with more than 2’000 employees. Founded in 1935 as a tinned food factory in Liechtenstein, the Hilcona Group today comprises a number of factories and several distribution sites. In Europe, the product range focuses on fresh pasta, muesli and menu components. The main export markets are Germany, France, Austria and the Benelux countries as well as Poland.

![Figure 17-4: Hilcona AG in Schaan producing fresh convenience foods.](image)

The installed refrigeration system for the production of the convenience foods in Schaan (LI), consists of a two-stage ammonia plant with two cooling networks at -8 °C (75/25 water/glycol mixture) and +8 °C (water). Three chillers are in place with a total cooling capacity of around 3’000 kW. Each chiller is specified with a cooling capacity of 980 kW driven by a Grasso RB-5A screw compressor. From the oil coolers, heat is extracted for heating and hot water (in: 45/50 °C, out: 65/70 °C).

A NH₃ heat pump type GEA Grasso 65HP with 6 piston cylinders is used for waste heat recovery of the refrigeration plant. The heat pump has a heating/cooling capacity of 507/437 kW at 31/65 °C and feeds a 60 m³ storage tank for space heating and hot water. The evaluation of the energy costs and energy consumption in 2016 resulted in 5’805 operating hours with a heat production of 2.25 GWh and an electricity consumption of 0.37 GWh, resulting an annual average COP of 6.04.

![Figure 17-5: Left: GEA Grasso 65HP with 6 cylinders and oil separator for waste heat recovery. Right: GEA Grasso RB-5A chillers with screw compressor at Hilcona AG in Schaan (FL).](image)

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17.3 Toblerone chocolate production at Mondelez Schweiz Production GmbH

The US-American manufacturer Mondelez International (formerly Kraft Foods) is one of the world’s largest snacking companies and its portfolio includes chocolate, biscuits, gum and candy. In Switzerland, the legendary Swiss chocolate Toblerone with honey and almond nougat are produced, as well as Stimerol and V6 brands. Toblerone is recognized by its triangular shape invented in 1908 by Theodor Tobler and Emil Baumann. Since 1985, all Toblerone products have been manufactured exclusively in Brünnen near Bern with around 220 employees around the clock. The factory produces around 35’000 tons of chocolate per year. Toblerone is available around the world, 97 % of the production is exported. In the production, a heat pump is used with a heating capacity of 450 kW (COP 5.5, ~ 0.5 GWh/a).

Figure 17-6: Toblerone chocolate is manufactured exclusively in Brünnen near Bern.

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18 SIG (Services Industriels de Genève)

18.1 District heating network Laurana-Parc in Geneva

Laurana-Parc is a 12 multifamily building complex from the 1960s located in Geneva. Due to conformity to local legislation, the district heat production system needed a renovation in 2011, which implied the replacement of three oil boilers (cumulated thermal power of 3.3 MW) by three new gas boilers (cumulated thermal power of 9.8 MW, equipped with a two-stage heat recovery system) and a dual-source heat pump with a thermal power of 0.34 MW (14/60 °C, $T_{\text{evap}}/T_{\text{cond}}$). Furthermore, in 2013, the district heating network was extended to connect approximately 20 other multifamily buildings of the city sector called Trois-Chênes. This 12 million CHF project was financed and executed by the local energy utilities “Services Industriels de Genève” (SIG) [58]. SIG provides local services in the fields of energy and telecommunications. It supplies 225’000 customers throughout the canton of Geneva with water, gas, electricity and thermal energy.

Figure 18-1 shows the renovated central heating center of Laurana-Parc with the installed heat pump from Carrier (30HXC 080, option 150 high temperature version) [58,59]. The heat pump works with refrigerant R134a is driven by a screw compressor that offers 6 part load stages (minimum power of 19%), a nominal heat output of 327 kW and a nominal COP of 4.3 (at 10/45°C, evap/cond) [58].

The heat sources for the heat pump are geothermal (borehole field of 44 heat exchangers of 300 m, total 13’200 m linear meters) and waste heat from the steam condensate of the gas boilers (1’800 m$^3$ waste heat water tank). In real operating conditions the average heat source temperatures are in the range of 14-16/8 °C (in/out) and sink temperatures about 58/63 °C (in/out), which result in a nominal heating capacity of 338 kW and COP of 3.45.

![Figure 18-1: Central heating center at Laurana-Parc with the installed heat pump from Carrier (30HXC 080 - option 150 high temperature version). The heat pump uses R134a and runs with a screw compressor. The nominal heating capacity is 338 kW at 14-16/8 °C heat source and 58/63 °C sink temperature with a COP of 3.45 [58] (Photos from Conti & Associés Ingénieurs S.A. [59]).](image-url)
The Energy Systems Group of the University of Geneva monitored the heating system for two years [58,60]. Figure 18-2 presents the energy balance from 1 October 2014 until 30 September 2015 and shows that 94% of the energy to the district heating is supplied by gas, 1.5% by geothermal energy and the remaining 4.5% by electricity. In total, the extended district heating network (with the sectors Laurana and Trois-Chênes combined) has a high linear density (7.3 MWh/m/year) and delivers heat for about 100’000 m² area of residential buildings with 2’500 inhabitants. 69% of the heat demand is for space heating and 31% for hot water.

![Sankey diagram of the heating system with annual flows measured from October 2014 to September 2015](image)

For the monitored year, the measured seasonal performance factor of the heat pump was 3.0, which is explained by the high temperature heat production (average temperature lift ΔT of 45 K). The heat pump covered 30 to 60 % of the district heat demand (Laurana sector only). 30% coverage occurred in winter, when the heat pump operated at full load 90% of the time, 60% occurred in summer at part load. The CO₂ emissions associated with the boiler substitutions resulted in a reduction by about 42%. The heat pump saves 1’435 MWh fossil fuels per year (Table 18-1).

<table>
<thead>
<tr>
<th>CO₂ emissions before 2011</th>
<th>CO₂ emissions in 2014 to 2015 after the renovation</th>
<th>CO₂ savings by change from oil to gas boilers</th>
<th>CO₂ savings by change from gas boilers to heat pump</th>
<th>CO₂ savings total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4’114 t CO₂</td>
<td>2’368 t CO₂</td>
<td>1’229 t CO₂ (30%)</td>
<td>517 t CO₂ (12%)</td>
<td>1’746 t CO₂ (42%)</td>
</tr>
</tbody>
</table>

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18.2 District heating network Les Vergers in Meyrin

In 2011, the municipality of Meyrin voted to build the „Les Vergers“ eco-neighbourhood with more than 30 residential buildings containing 1300 housing units, which is one of the largest eco-neighbourhoods in Switzerland [61,62]. For the heating of the buildings and domestic hot water supply the technical solution realized is based on a centralized heating center with a heat pump drawing its energy from the groundwater of the accompanying Rhône river (at a depth of 25 metres at 12 °C) and distributing the heat at around 50 °C to the buildings. Figure 18-3 shows the location of the district heating network in the thermal networks map supplied by SIG (Services Industriels de Genève).

In order to meet the Minergie A label applied to each building, photovoltaic solar collectors are installed on the roofs. This solution enables local renewable electrical energy generation to be partially supplied to the heat pump heating, auxiliaries and building ventilation. Overall, the district heating energy concept of Les Vergers reaches a rate of 80% renewable energy. In addition, the cold groundwater crosses the ZIMEYSA industrial zone and delivers cold energy, which allows consumers with cooling demand to significantly reduce their electricity consumption.

Figure 18-3: Thermal networks map supplied by SIG around Geneva with the heating network (red) in Les Vergers (Meyrin) and the cooling network (blue) in the industrial zone ZIMEYSA [61,62]

The installed heat pump is a Unitop® from Friotherm AG with 5 MW heating capacity and turbo compressor (Figure 18-4). Table 18-2 show the technical data. The used refrigerant is HFO R1234ze.

Figure 18-4: Typical Unitop® heat pump from Friotherm AG used for district heating networks.
Table 18-2: Technical data of the Unitop® heat pump from Friotherm AG at Les Vergers in Meyrin for the district heating network with 30 residential buildings containing 1’300 apartments.

<table>
<thead>
<tr>
<th>Application</th>
<th>District heating of residential buildings heating and hot water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of installation</td>
<td>2018</td>
</tr>
<tr>
<td>Heat pump model</td>
<td>Friotherm Unitop</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R1234ze</td>
</tr>
<tr>
<td>Compressor</td>
<td>Turbo</td>
</tr>
<tr>
<td>Heating/cooling capacity</td>
<td>5'000/3'910 kW</td>
</tr>
<tr>
<td>Heat sink / source</td>
<td>Water / groundwater from Rhône river</td>
</tr>
<tr>
<td>Heat sink temperature (in/out)</td>
<td>35/50 °C</td>
</tr>
<tr>
<td>Heat source temperature (in/out)</td>
<td>12.5/7.5 °C</td>
</tr>
</tbody>
</table>

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19 Literature


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