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

October 31, 2019

Prepared by
Cordin Arpagaus and Stefan Bertsch

NTB University of Applied Sciences of Technology Buchs
Institute for Energy Systems
Werdenbergstrasse 4
CH-9471 Buchs
Switzerland

Contact: cordin.arpagaus@ntb.ch
Tel. +41 81 755 34 94

Contents

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 NH_3), 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 CO_2 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 CO_2 reduction effect. Some examples show that CO_2 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.

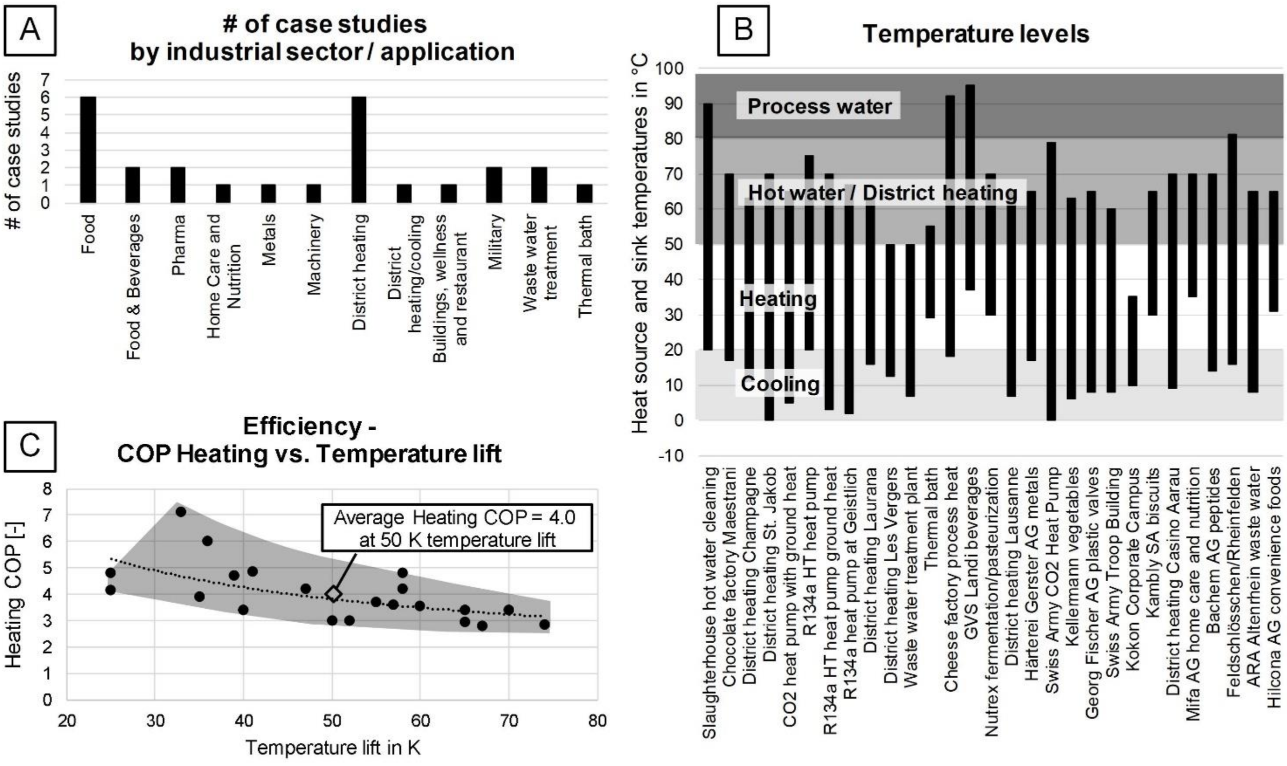
By intensifying public relations work, information and training of experts in this field of energy supply for industrial companies, efforts are being made to make heat pump technology more visible and to highlight its application potential.

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)



D

Savings	t CO_2/a	Energy savings
Slaughterhouse	510	2'590 MWh fossil fuels
Maestrani AG	179	n.a.
District Champagne	620	n.a.
District Laurana	1'746	1'435 MWh fossil fuels
Cheese factory Gais	n.a.	1.5 million kWh gas
GVS Landi	n.a.	26'000 L oil/a
Nutrex	310	up to 65'000 L oil/a
Härterei Gerster AG	160	800 MWh gas
Kellermann AG	960	n.a.
Kambly SA	100	25% energy
Casino Aarau	n.a.	40% energy by 2035
Mifa AG	960	20% energy
Bachem AG	300	n.a.
Feldschlösschen	n.a.	75% energy
ARA Altenrhein	3'000	n.a.

E

Refrigerants	
R134a	12
R717	7
R1234ze	5
R744	3
R245fa	1
R410A	1

F

Compressors	
Piston	19
Screw	7
Turbo	2
Scroll	1

G

Heat Pump manufacturers			
Carrier		Mayekawa	1
CTA	4	MTA	1
Enex	1	Ochsner	2
ENGIE	4	Scheco	2
Friotherm	2	SCM Frigo	
GEA	2	Sulzer	1
JohnsonControls	4	Thermea	1
Kibernetik	1	Viessmann	1

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 CO_2 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.

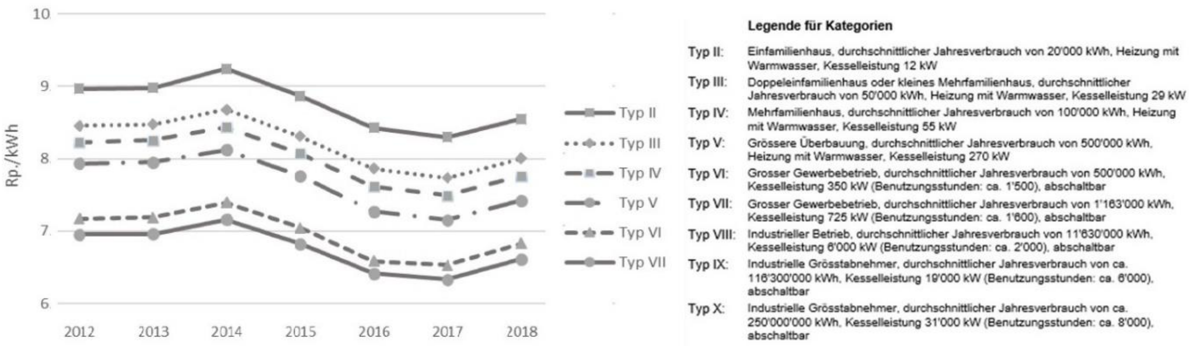


Figure 2-1: Average gas prices from 2012 to 2018 in Rp./kWh [1].

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

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

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).

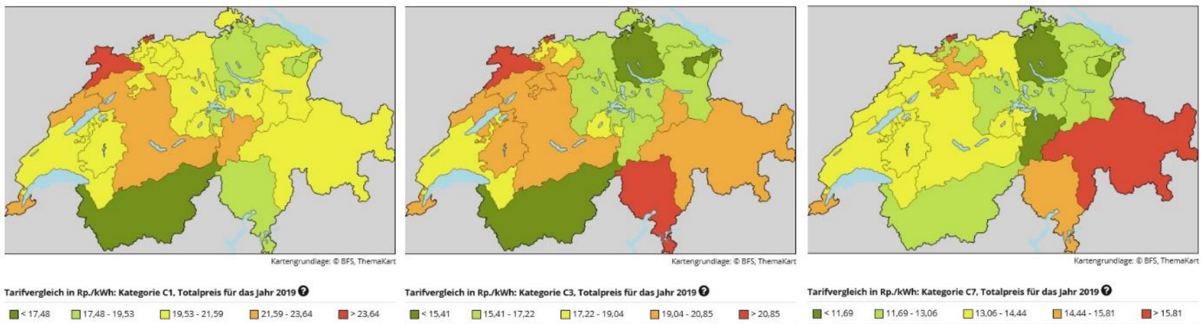


Figure 2-2: Average electricity prices from 2019 in Rp./kWh in different Swiss cantons for the industrial consumption profiles C1, C3, and C7 (https://www.strompreis.elcom.admin.ch/Map/ShowSwissMap.aspx).

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

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

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.

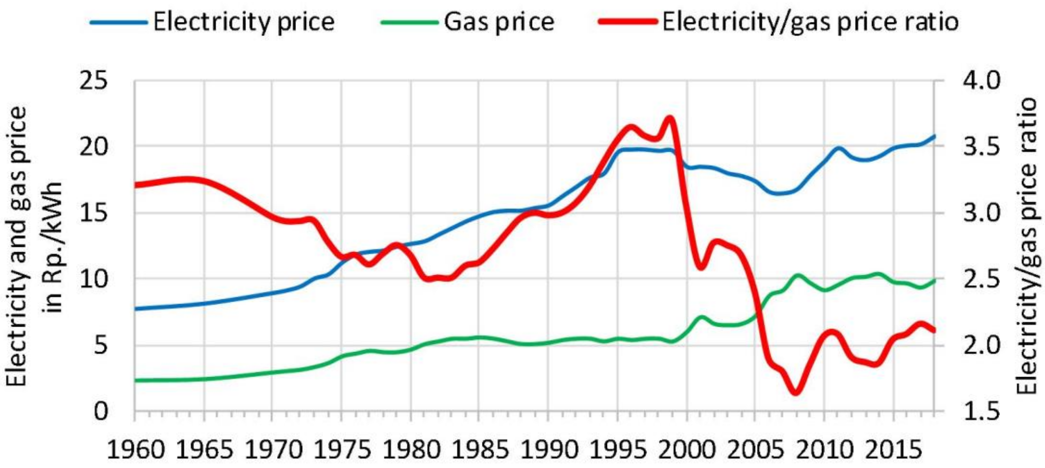


Figure 2-3: Development of electricity & gas prices and price ratio (secondary axis) in Switzerland from 1960 to 2018 (consumption profile: 20'000 kWh gas, 4'500 kWh electricity) [2].

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.

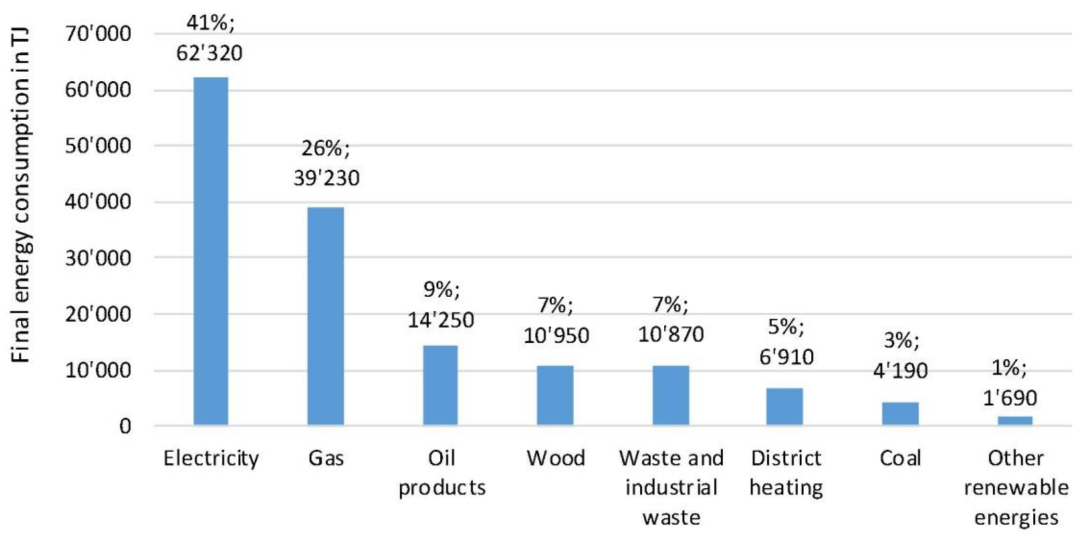


Figure 2-4: Industrial energy consumption in Switzerland by energy carriers according to the overall energy statistics (2018) [2].

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].

Market-oriented companies and employees by economic activity

according to NOGA 2008, in '000	2016 Companies	Employees
Total	**586.2**	**4 414.3**
Sector 1	**53.6**	**157.5**
Sector 2	**90.6**	**1 083.3**
of which:		
Manufacture of food, beverage and tobacco products	4.4	99.3
Manufacture of textiles, apparel and leather goods	2.9	14.9
Manufacture of wood and paper products, and printing	9.8	69.1
Manufacture of pharmaceutical products	0.2	45.4
Manufacture of metal products	7.4	83.5
Manufacture of computer, electronic and optical products; watches and clocks	2.0	108.2
Manufacture of electrical equipment	0.8	33.0
Electricity, gas and steam supply	0.8	30.3
Construction of buildings and Civil engineering	8.9	109.8
Sector 3	**442.0**	**3 173.5**

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.

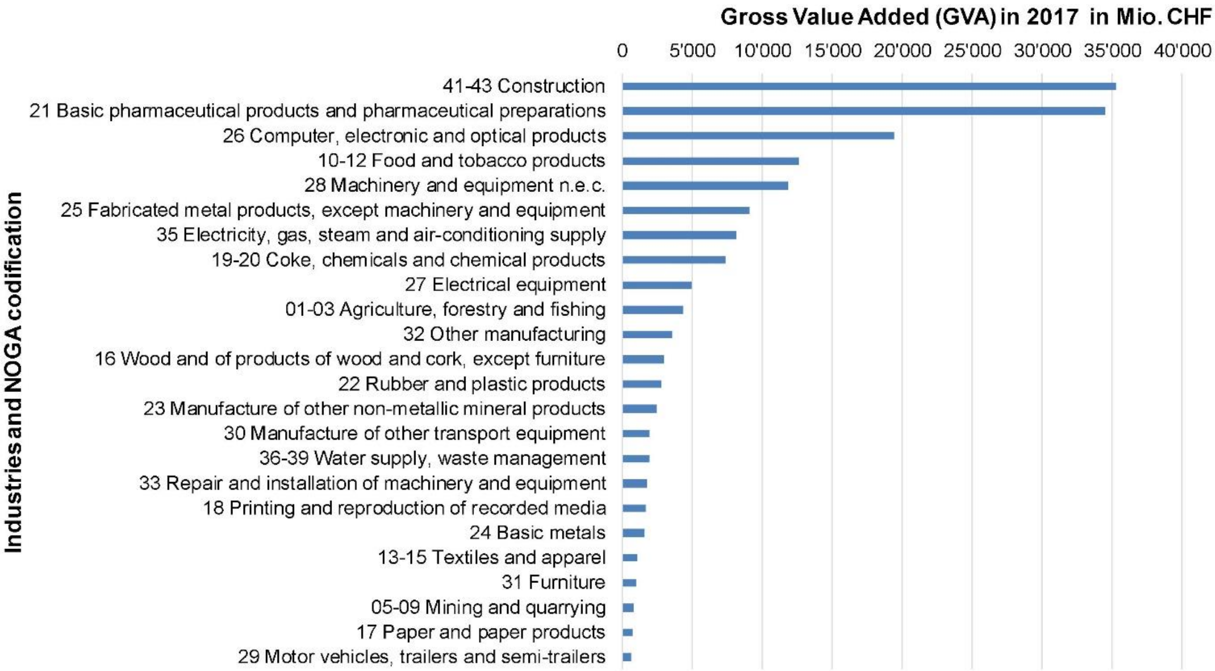


Figure 2-5: Industries Gross Value Added (GVA) in 2017 aggregated by sections [4].

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.

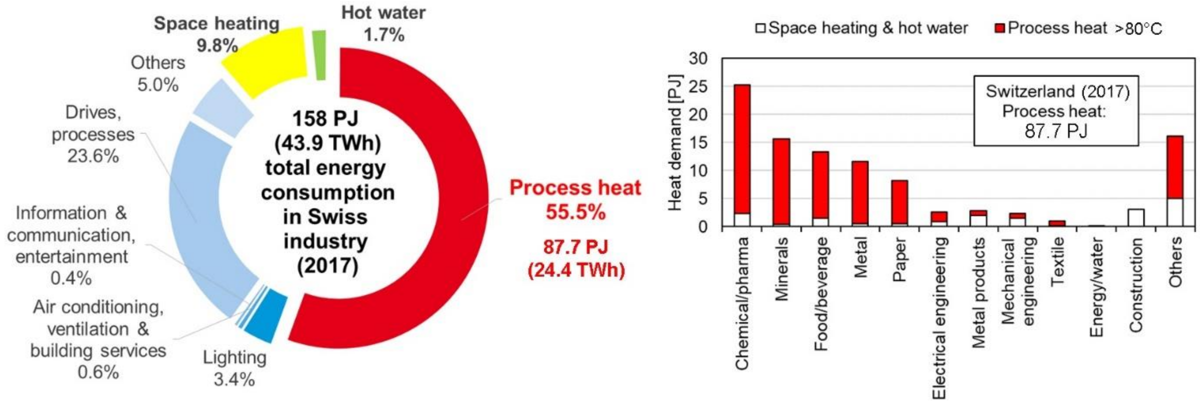


Figure 2-6: Industrial energy demand in Switzerland (2017) [5] by intended use and process heat demand divided by industrial sector and temperature range, showing the potential for industrial heat pumps.

According to the Swiss Federal Statistical Office [6], 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 [7] 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%).

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).

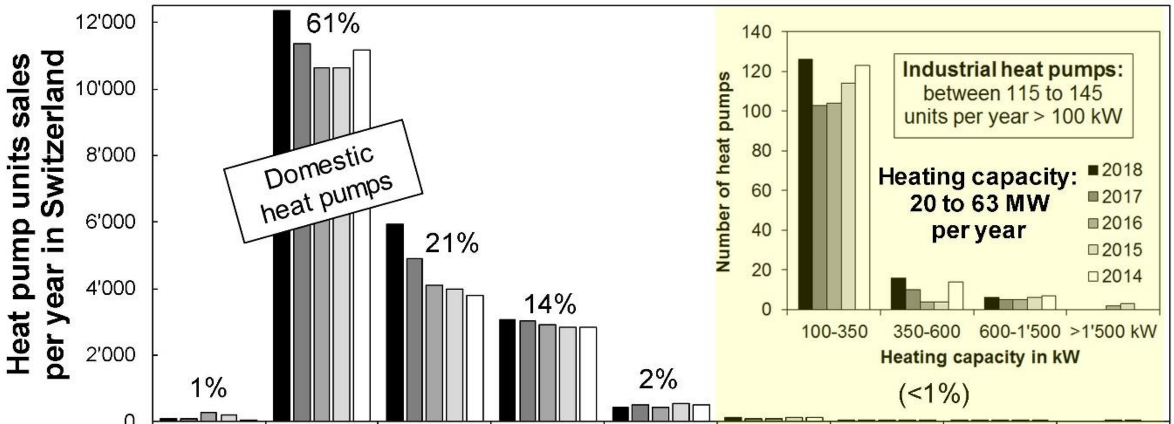
The Swiss heat pump market is dominated by domestic heat pumps with heating capacities of 5 to 13 kW. According to the SFOE, the market share of heat pumps in the residential market (e.g. new single-family houses) is about 80%.

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 (HTHPs) >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.



	<5 kW	5-13	13-20	20-50	50-100	100-350	350-600	600-1'500	>1'500 kW
■2018	84	12331	5920	3055	426	126	16	6	0
■2017	97	11354	4896	3024	506	103	10	5	0
■2016	268	10623	4116	2924	426	104	4	5	2
□2015	215	10626	3986	2822	542	114	4	6	3
□2014	47	11161	3779	2857	519	123	14	7	0

Heating capacity in kW and unit sales per year

Figure 2-7: Annual sales of heat pumps in Switzerland (2014 to 2018) in various heat capacity classes (www.fws.ch). Around 115 to 145 units are newly installed with a heating capacity of > 100 kW.

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 2-4: Characteristics of mechanically driven industrial heat pumps [7,8].

Nominal heating capacity	2 kW to 20 MW
Max. temperature	110 °C (160 °C)
COP at 40 K temperature lift	3.9 to 4.9
Max. temperature lift per stage	50 K
Average lifetime	20 years
Investment incl. installation (500 kW)	480 to 750 CHF/kW (450 to 700 EUR/kW)
Investment incl. installation (10 MW)	265 to 425 CHF/kW (250 to 400 EUR/kW)

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
- CO_2 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 producter (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 CO_2 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.

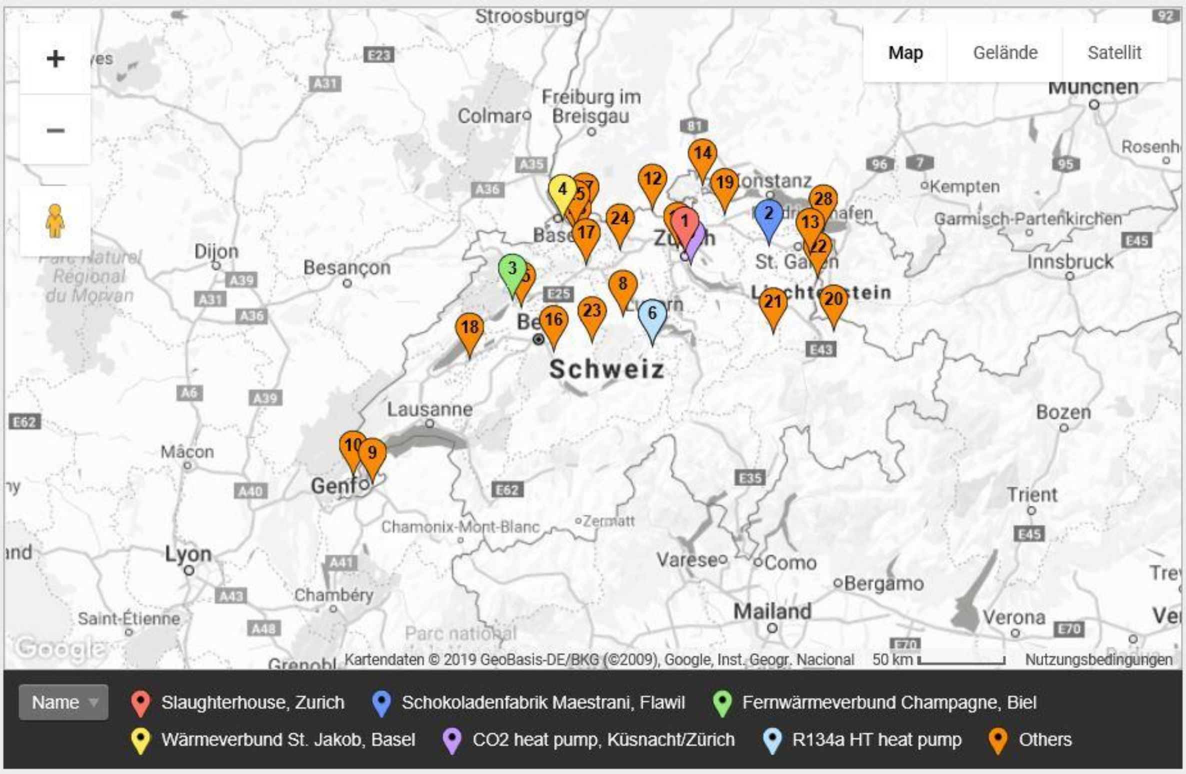


Figure 3-1: Swiss map with the locations of the described case studies of industrial heat pumps (https://de.batchgeo.com/map/Case-Studies-Switzerland).

Case Studies of Industrial Heat Pumps in Switzerland

No	Year	Project name	Location	Industry	Application	Heat source	Heat source in/out (°C)	Heat sink in/out (°C)	Heating/ cooling capacity (kW)	Heat pump manufacturer	Refrige-rant	Comp-ressor	Efficiency	Costs (HP: heat pump, O: Annual operation, M: Annual maintenance)	Savings (energy, CO2 emissions, energy cost)
CH01	2011	Slaughterhouse	Zurich	Food	Hot water, cleaning water	Waste heat (refrigeration, air)	W20/14	W30/90	800/564	Thermea	R744	Screw	COP 3.4	n.a.	2'590 MWh fossil fuels, 510 t CO2/a (30%)
CH02	2019	Chocolate factory Maestrani	Flawil	Food	Hot/cold water, heating	Water	W17/11	W60/70	276/184	CTA AG	R1234ze	Piston	n.a	HP: 140'000 CHF (excl. VAT)	179 t CO2 (2013 to 2020)
CH03	2017	Champagne	Biel	District heating	Hot water, heating	Water	W11/7	W48/63	650/474	CTA AG	R1234ze	Piston	n.a	HP: 280'000 CHF (excl. VAT)	620 t CO2/a
CH04	2018	St. Jakob	Basel	District heating	Hot water, heating	Air	Air -5	W55/65	181/ 111	CTA AG	R134a	Piston	n.a.	HP: 210'000 CHF (excl. VAT)	n.a.
CH05	2014	CO2 heat pump	Küsnacht ZH	n.a.	n.a.	Ground heat	B5/1	W22/65	101	ENGIE	R744	Piston	COP 3.57	n.a.	n.a.
CH06	2014	R134a HT heat pump	Kerns	n.a.	n.a.	Water	W20/15	W55/75	800	ENGIE	R134a	Piston	COP 3.68	n.a.	n.a.
CH07	2015	R134a HT heat pump	Kerns	n.a.	n.a.	Ground heat	B3/-1	W50/70	500	ENGIE	R134a	Piston	COP 2.82	n.a.	n.a.
CH08	2016	R134a heat pump at Geistlich	Wolhusen	Pharma	n.a.	Ground heat	B2/-1	W47/67	606	ENGIE	R134a	Piston	COP 2.94	n.a.	n.a.
CH09	2012	Laurana	Thônex	District heating	Hot water from waste heat recovery	Geothermal and waste heat recovery	W14-16/8	W58/63	338	Carrier	R134a	Screw	n.a.	M: 1'000 CHF/a (recommendation)	15% (input energy), 1'435 MWh fossil fuels, 1'746 t CO2/a (42%)
CH10	2018	Les Vergers	Meyrin	District heating	Heating of residential buildings	Ground water	W12.5/7.5	W35/50	5'000/3'910	Friotherm	R1234ze	Turbo	n.a.	n.a.	n.a.
CH11	2014	Waste water treatment plant	Zürich	Waste water	Hot water	Cleaned waste water	W7/2	W44/50	410	Scheco AG	R134a	Screw	n.a.	HP: 150'000 CHF, O: 4'500 h, M: 2'000 CHF without repair	n.a.
CH12	2008	Thermal bath	Bad Zurzach	Thermal bath	Hot water	Waste water from thermal bath	W29/5	W47/55	550	Scheco AG	R134a	Screw	n.a.	HP: 250'000 CHF, O: 5'000 h, M: 3'500 CHF without repair	n.a.
CH13	2018	Cheese factory	Gaiss	Food	Hot water, heating	Waste heat from data center	W18/14	W82/92	520	Ochsner	R1234ze	Screw	COP 2.85 (W18/W92) COP 4.2 (W18/W65)	n.a.	1.5 million kWh of gas
CH14	2017	GVS Landi	Schaffhausen	Food & Beverages	Process water for disinfection and cleaning	Waste heat from room cooling	W37	W80/95	63	Ochsner	R245fa	Screw	COP Heating 4.2 EER Cooling 3.2	n.a.	26'000 L oil/a, 40% CO2 emissions
CH15	2009	Nutrex	Busswil bei Büren	Food & Beverages	Vinegar fermentation and pasteurization	Heat from vinegar fermentation	W30	W70	194	Viessmann	R134a	Piston	COP 3.4	n.a.	up to 65'000 L oil/a, 310 t CO2/a, 50 kCHF/a (energy cost)
CH16	1985	City of Lausanne	Lausanne	District heating	hot water for residential buildings	Water of lake Leman	W6-7	W26-28/50-65	2 x 4'500	Sulzer	R717	Turbo	COP 4.8	n.a.	n.a.
CH17	2013	Härterei Gerster AG	Egerkingen	Metals	Process heat for hardening processes	Waste heat from cooling water	W17	W65	260	CTA AG	R134a	Piston	n.a.	n.a.	80% (energy), 160 to CO2/a, 800 MWh gas replaced by 190 MWh electricity
CH18	2016	Swiss Army CO_2 Heat Pump	Payerne	Military	tap water & facility heating	Outdoor air	A-9	W30/70	60	Enex	R744	Piston	n.a.	n.a.	n.a.
CH19	2012	Kellermann AG	Ellikon an der Thur	Food	Hot water for greenhouse heating	Groundwater and waste heat from cold rooms	W6/2	W53/63	1'000	Johnson Controls	R717	Piston	n.a.	n.a.	960 t CO2/a
CH20	2010	Georg Fischer AG	Grüsch	Technology	Heating for production of plastic valves	Water	W8/4	W65	382/252	SCM Frigo S.p.A	R134a	Piston	COP 4.8 (W10/W35) COP 3.0 (W10/W60)	HP: about 200'000 CHF	n.a
CH21	2015	Swiss Army Troop Building	Matt	Military	heating, hot water	Water	W8	W60	270/180	SK188W WPM	R134a	Piston	COP 3.0 (W8/W60)	HP: about 200'000 CHF	n.a
CH22	2013	Kokon Corporate Campus	Ruggell	Buildings, wellness and restaurant	heating, hot water	Water	W10/7	W27/35	341/275	MTA	R410A	Scroll	COP 4.16 (W10/W35)	HP: about 85'000 CHF	n.a
CH23	2017	Kambly SA	Trubschachen	Food	hot water for biscuit production	Waste heat recovery	W20-30/12-15	W40-55/65	471/350	Friotherm	R1234ze	Screw	COP 3.9 (471 kW:121 kW)	HP: 160'000 CHF, Installation: 350'000 CHF	25% (energy), 100 t CO2/a (90%), 15% (energy cost)
CH24	2014	Casino	Aarau	District heating/cooling	District heating and cooling network	Ground water	W9/5	W45/70	1'975 (cooling)	Johnson Controls	R717	Piston	COP Cooling 6.9 (W34.4/W69) COP Cooling 6.2 (W3.3/W34.4)	n.a.	40% (energy) by 2035
CH25	2017	Mifa AG Mibelle Group	Frenkendorf	Home Care and Nutrition	hot/cold water, waste heat recovery	Waste heat recovery	W35/n.a.	W49/70	885 (cooling)	Johnson Controls	R717	Piston	COP Cooling 6.6 (W32.5/W69)	n.a.	20% (energy), 960 t CO2/a (60%)
CH26	2016	Bachem AG	Bubendorf	Pharma	Peptides	Water	W14/8	W51/70	480/540	Johnson Controls	R717	Piston	COP 4.7 (W6/W45) COP 7.1 (W38/W71)	n.a.	300 t CO2/a
CH27	2013	Feldschlösschen, City of Rheinfelden	Rheinfelden	District heating	Brewery	Waste heat from cooling water	W16/10	W50/81	1'350	Mayekawa	R717	Piston	COP 3.41 (W16/W81) COP 4.88 (W30/W71)	n.a.	75% (energy cost), 93% from 12 GWh fossil energy, of which 18% electricity
CH28	2007	ARA Altenrhein	Altenrhein	Wastewater treatment	Sewage sludge drying	Waste heat from waste water	W8/2	W55/65	2 x 1'420	GEA	R134a	Piston	Annual COP 3.62 (B8/W65)	n.a.	3'000 t CO2/a
CH29	2012	Hilcona AG	Schaan	Food	Fresh convenience foods	Waste heat from chillers	W31	W65	507/437	GEA	R717	Piston	COP 6.0 (W31/W67)	n.a.	n.a.

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 CO_2 tax, the company had to reduce its CO_2 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).

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

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

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

The benefits of this installation are obvious:

- CO_2 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.

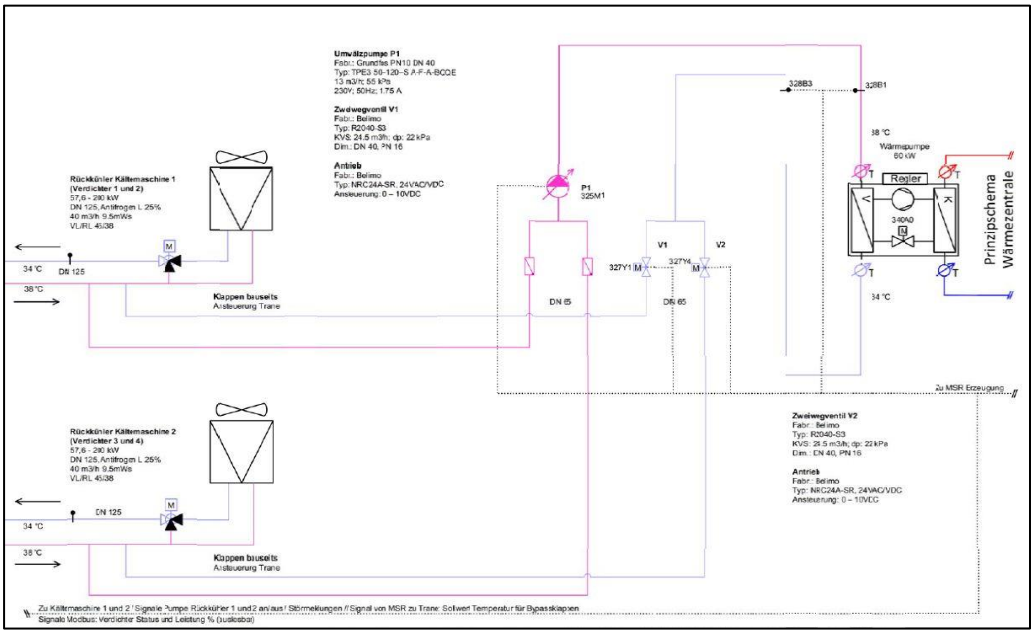


Figure 4-3: Principle drawing of the heat pump installation at the GVS Landi in Schaffhausen-Herblingen [15].

Contacts:

Landwirtschaftlicher Genossenschaftsverband Schaffhausen (GVS)
Gennersbrunnerstrasse 61
8207 Schaffhausen
Tel. +41 52 631 17 00
info@gvs.ch, www.gvs.ch

Daniel Christen
Projektleiter
ennovatis Schweiz AG
Bahnhofstrasse 7
CH-4600 Olten
Tel. +41 62 555 37 37
www.ennovatis.com
daniel.christen@ennovatis.ch

Andreas Vescoli
Ochsner Wärmepumpen GmbH
Uraniastraße 18
CH-8001 Zürich
Tel. +41 58 320 41 00
www.ochsner.com
andreas.vescoli@ochsner.com

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).

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.

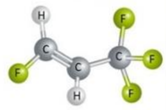
Heat pump type	IWWHS 570 ER6c2
HFO  R1234ze(E) (GWP of 6)	I: Industrial heat pump W: Water as heat source W: Water as heat sink H: High temperature heat pump S: Screw compressor 570: Heating capacity range in kW E: Economizer cycle R: Shell and tube heat exchanger 6: Refrigerant HFO R1234ze(E) c2: 2-stage compressor
Heating capacity	approx. 520 kW
Heat source	18/14 °C (in/out)
Heat sink	82/92 °C or 55/65 °C (in/out)
Heat source	Cooling water (waste heat) from the neighboring data center (16 to 20 °C)
Compressor type	2-stage screw with vapor injection
Refrigerant	R1234ze(E) (130 kg, safety group: A2L, mildly flammable)
First operation	2020/21 (using waste heat from the data center)

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

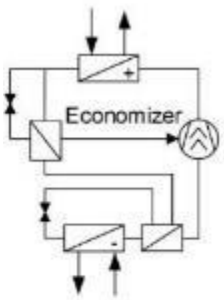
Table 4-1 shows the performance data of the heat pump at high and low temperature conditions in full and part load operation. Depending on the operating conditions, the COP of the heat pump is between 2.55 and 2.85 at 74 K temperature lift (W18-14/W82-92) and between 3.75 and 4.20 at 47 K lift (W18-14/W55-65). 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).

	High temperature (W18-14/W82-92)			**Low temperature (W18-14/W55-65)**		
Part load (%) (by slide valve control)	100*	75**	50**	100*	75**	50**
Effective part load (%)	100	81	62	97	75	54
Condenser capacity (kW)	520	419	321	505	390	279
Condenser water flow rate (m^3/h)	44.7	36.0	27.6	43.4	33.5	24.0
Temperature difference condenser (K)	10.0	10.0	10.0	10.0	10.0	10.0
Evaporator capacity (kW)	338	264	195	385	293	205
Evaporator water flow rate (m^3/h)	82.7	82.7	82.7	82.7	82.7	82.7
Temperature difference evaporator (K)	3.5	2.7	2.0	4.0	3.0	2.1
Compressor power (kW)	182	155	126	120	98	74

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.



Contacts:

Berg-Käserei Gais
Andreas Hinterberger
Forren 22
CH-9056 Gais
Tel. +41 71 793 37 33
gais@bergkaeserei.ch
www.bergkaeserei.ch

St.Gallisch-Appenzellische Kraftwerke AG
Peter Bischoff
Senior Projektleiter Wärme
Vadianstrasse 50
CH-9001 St.Gallen
Tel. +41 71 229 52 04
info@sak.ch, www.sak.ch

Amstein + Walthert St. Gallen AG
Raphael Schneider
Leiter Heizung / Kälte
Fürstenlandstrasse 41
CH-9000 St. Gallen
Tel. +41 71 221 15 48
raphael.schneider@amstein-walthert.ch
www.amstein-walthert.ch

OCHSNER Energie Technik GmbH
Thomas Ciepiela
Leiter Technik
Ochsner-Straße 1
A-3350 Haag
Tel. +43 676 70 35 840
thomas.ciepiela@ochsner-energietechnik.com
www.ochsner-energietechnik.com

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).

Figure 5-1: Company Maestrani in Flawil with chocolate product portfolio [18].

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 CO_2 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 CO_2 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.

Figure 5-2: The three tailor-made water/water CTA heat pumps (Type: PC-42.604-W.W-1234ze-HT-LN). The machine room offers space for up to 8 machines with a final cooling capacity of 2 MW.

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 m^3 and hot storage 30 m^3) 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°/70°C: decrystallisers from various production lines, heat kitchen, pelletizing lines, coating line, test line

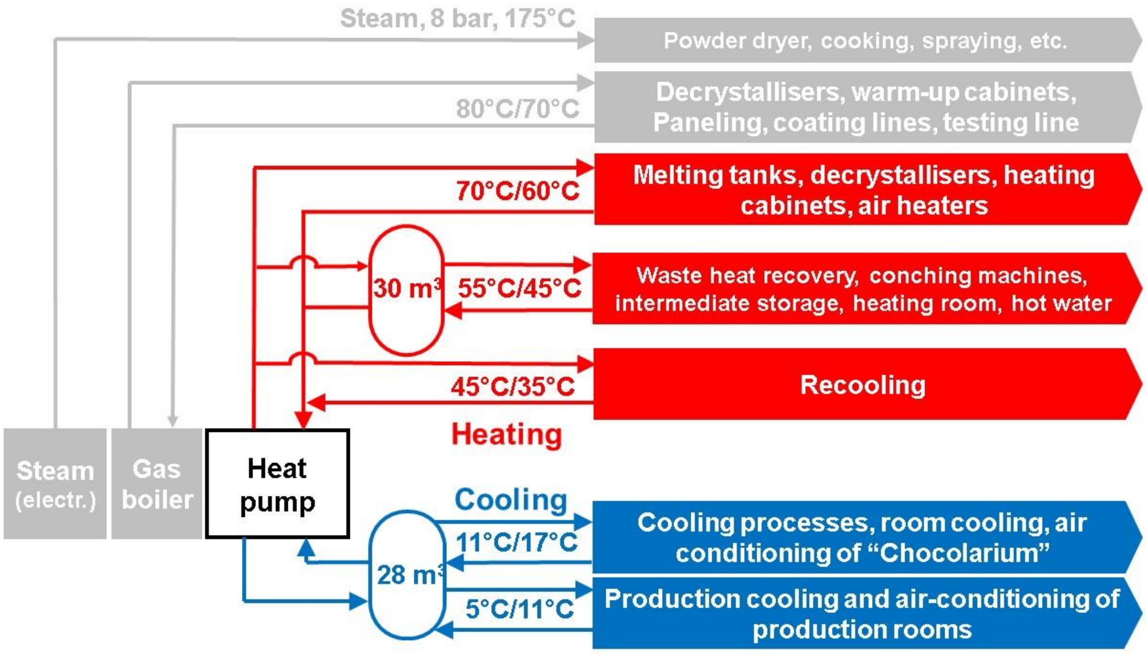


Figure 5-3: Simplified process diagram of the realized energy supply with cooling, heating and storage.

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].

	Cooling			Heating		
Hot water inlet / outlet [°C]	35 / 45	45 / 55	60 /70	35 / 45	45 / 55	60 / 70
Cold water inlet/outlet [°C]	11 / 5	11 / 5	11 / 5	17 / 11	17 / 11	17 / 11
Cooling capacity [kW]	222.6	192.9	141.8	217.7	246.3	183.7
Recooling or heating capacity [kW]	289.8	269.3	225.0	273.0	329.2	276.2
Power consumption [kW]	70.4	80.0	87.2	57.9	86.8	96.8
COP heating	**4.12**	**3.37**	**2.58**	**4.71**	**3.79**	**2.85**
COP cooling	**3.16**	**2.41**	**1.63**	**3.76**	**2.84**	**1.90**
COP total	**7.28**	**5.78**	**4.21**	**8.47**	**6.63**	**4.75**

Contacts:

CTA AG
Klima / Kälte / Wärme
Andrea Schmid
Marketing/Kommunikation
Hunzigenstrasse 2
CH-3110 Münsingen
Tel: + 41 31 720 10 00
andrea.schmid@cta.ch
www.cta.ch

CARNOTECH AG
Rolf Hofer
Ingenieurbüro für Haustechnik
Luzernerstrasse 2
CH-4800 Zofingen
Tel. +41 62 746 00 90
Rolf.Hofer@carnotech.ch

Maestrani Schweizer
Schokoladen AG
Toggenburgerstrasse 41
CH-9230 Flawil
Tel. +41 71 228 38 11
info@maestrani.ch
www.maestrani.ch

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 CTA*exklusiv* 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].

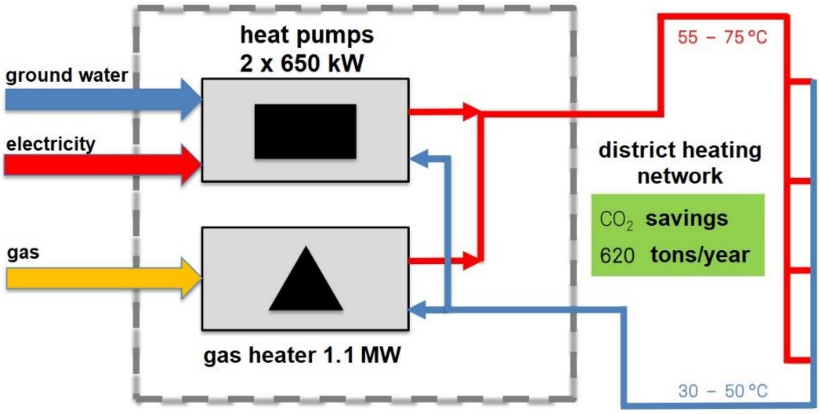


Figure 5-6: Heat supply system with two heat pumps (2 x 650 kW heating capacity) and a natural gas boiler (1'100 kW) saving 620 tons CO_2 per year [20].

Two tailor-made CTA*exklusiv* 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.

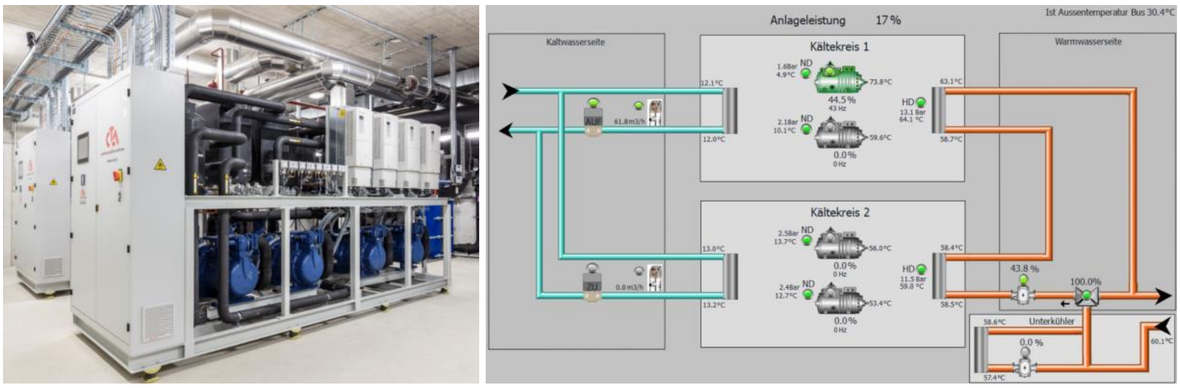


Figure 5-7: Two CTA*exklusiv* heat pumps with 4 speed-controlled reciprocating compressors (2 x 650 kW) [21].

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 leackage.

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 CO_2 can be saved per year compared to fossil heating [21].

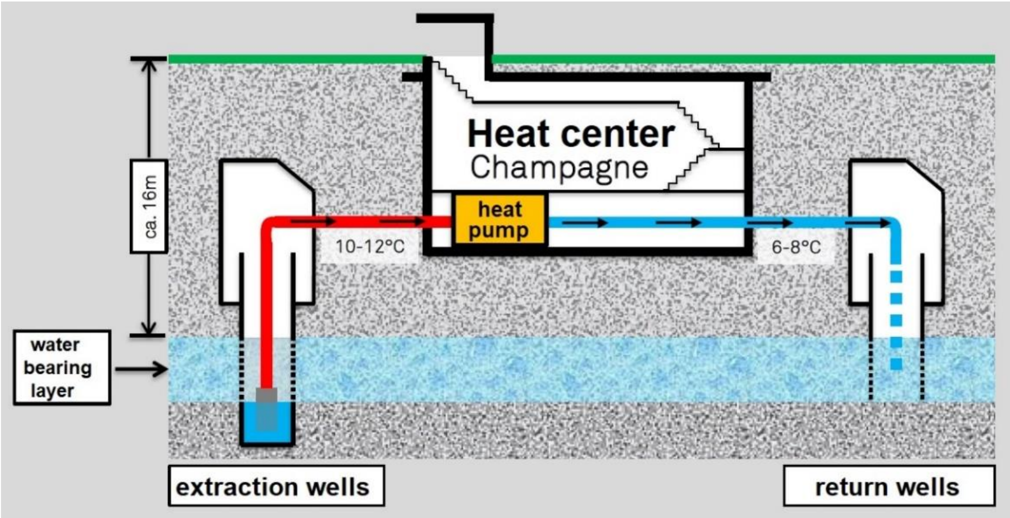


Figure 5-8: Scheme of groundwater extraction (around 6’000 L/min) in the heat center Champagne [20].

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

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

Contact:

CTA AG
Klima / Kälte / Wärme
Andrea Schmid
Marketing/Kommunikation
Hunzigenstrasse 2
CH-3110 Münsingen
Tel: + 41 31 720 10 00
andrea.schmid@cta.ch
www.cta.ch

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 CTA*exklusiv* 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 CO_2 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).

Figure 5-9: The St. Jakob football stadium in Basel, the St. Jakob garden swimming pool and the St. Jakobshalle are all connected to the St. Jakob heating network [22].

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 m^3 storage tank from where the various consumers draw their heat [23].

Figure 5-10: Two CTA*exklusiv* air/water heat pumps with up to 265 kW heating capacity each. The installation provides accessibility for maintenance and service [22,23].

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.

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

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].

Contacts:

CTA AG
Klima / Kälte / Wärme
Andrea Schmid
Marketing/Kommunikation
Hunzigenstrasse 2
CH-3110 Münsingen
Tel: + 41 31 720 10 00
andrea.schmid@cta.ch
www.cta.ch

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].

Figure 5-12: Heating oven at headquarters of Härterei Gerster AG in Egerkingen (SO) [24,25].

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 CO_2 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].

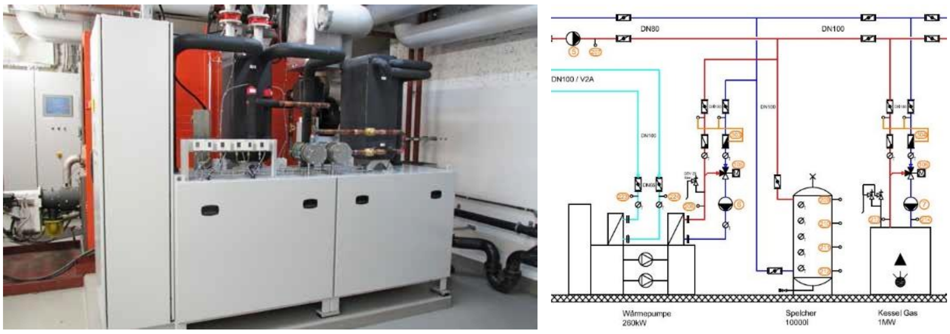


Figure 5-13: Heat pump (PHP-22.306-W.W-134-HT-LN) from CTA AG at Härterei Gerster AG [25]. Section of the schematic diagram with heat pump, 10 m^3 storage tank, and 1 MW gas boiler.

Contacts:

Terag Thermo-Energie AG
Roman Zietala
Projektleiter
Helblingstrasse 7
CH-4852 Rothrist
Tel. +41 62 748 10 53
roman.zietala@terag.ag
www.terag.ag

Härterei Gerster AG
Jürg Moser
Leiter Arbeitssicherheit, Umwelt- und Anlagenmanagement
Güterstrasse 3
CH-4622 Egerkingen
Tel. +41 62 388 70 51
Juerg.Moser@gerster.ch, www.gerster.ch

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 CO_2 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.

Name of project	**CO_2 heat pump**	**R134a HT heat pump**	**R134a HT heat pump with sound insulation housing**	**R134a heat pump**
Location	Küsnacht (Zurich)	Kerns	Kerns	Geistlich Wolhusen
Year of installation	2014	2014	2015	2016
Dimensions L x W x H in m	1.5 x 1.2 x 1.84	5.5 x 1.6 x 2.9	4.8 x 2.0 x 2.1	4.8 x 1.6 x 2.4
Heating/cooling capacity in kW	101	800	500	606
Heat source/sink	Brine/Water	Brine/Water	Brine/Water	Brine/Water
Heat source inlet/outlet in °C	5/1	20/15	3/-1	2/-1
Heat sink inlet/outlet in °C	22/65	55/75	50/70	47/67
COP	**3.57 (B5/W65)**	**3.68 (B20/W75)**	**2.82 (B3/W70)**	**2.94 (B2/W67)**

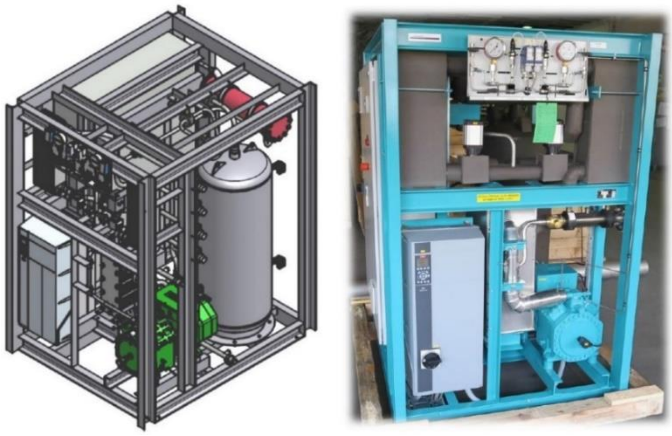


Figure 6-1: CO_2 heat pump in Küsnacht (Zurich) with one compressor.

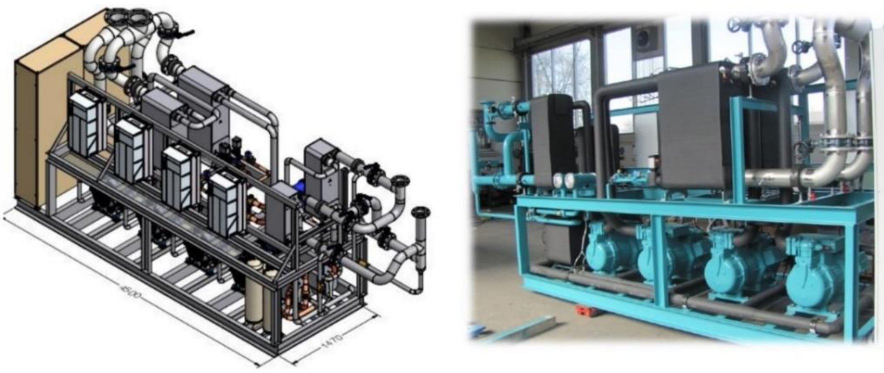


Figure 6-2: R134a HT heat pump in Kerns with four compressors.

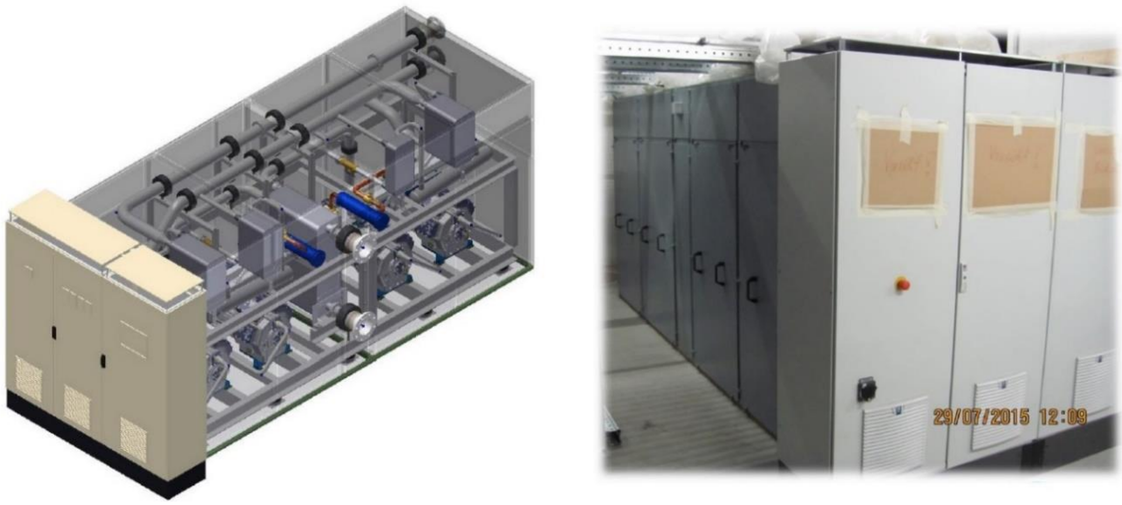


Figure 6-3: R134a HT heat pump in Kerns with sound insulation housing and four compressors.

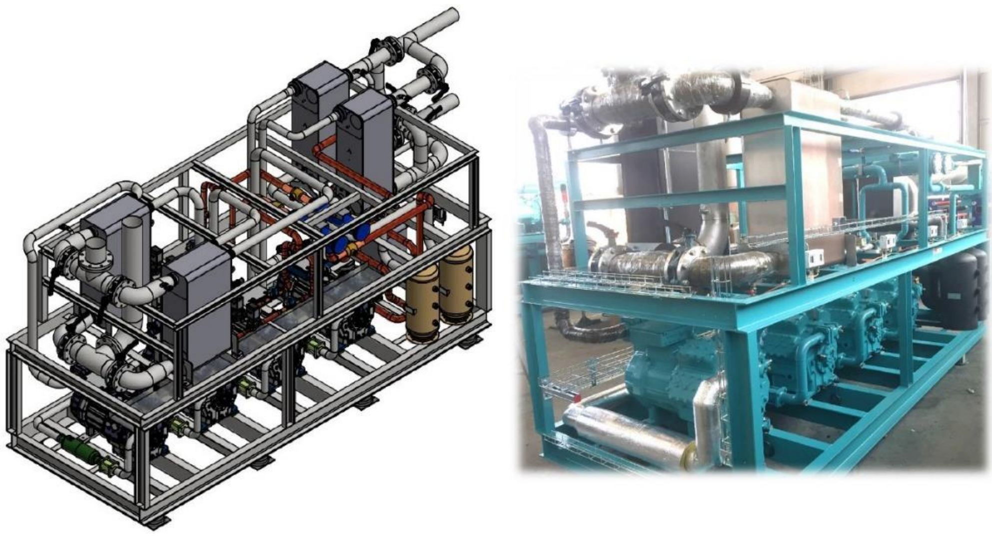


Figure 6-4: R134a heat pump at Geistlich in Wolhusen with four compressors.

Contacts:

ENGIE Kältetechnik GmbH
Mathias Blaser
Langegasse 19
A-6923 Lauterach
Tel. +43 55 74 67 05 46
Mathias.BLASER@engie.com
www.engie.at

7 Kibernetic AG

Kibernetik 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 Kibernetik AG (Buchs SG).

Projects (reference)	**Georg Fischer AG**	**Swiss Army military building**	**Wellness and restaurant Kokon Corporate Campus**
Location	Grüsch	Matt	Ruggell, Lichtenstein
Year of installation	2010	2015	2013
User (company)	Georg Fischer AG, Grüsch	Swiss Army	Kokon Immobilien AG
HP manufacturer	SCM Frigo (Italy)	SCM Frigo (Italy)	MTA (Germany)
HP model	SK 190S WPC (2 units)	SK 188W WPM (2 units)	Neptune NET 090
Contractor	Kibernetik AG	Bäbler Heizungen AG	Büchel Haustechnik Est.
Working fluid	R134a	R134a	R410A
Compressor	Reciprocating	Reciprocating	Scroll
Heating/cooling capacity in kW	382/252	270/180	341/275
Supply temperature (°C)	65	60	35
Heat source inlet/outlet in °C	8/4	8/n.a.	10/7
Heat sink inlet/outlet in °C	n.a/65	n.a/60	27/35
Thermal storage	heating/hot water	heating/hot water	Heating only
Heat pump costs in CHF	ca. 200'000	ca. 200'000	ca. 85'000
COP	**4.8 (W10/W35)** **3.0 (W10/W60)**	**3.0 (W8/W60)**	**4.16 (W10/W35)**

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 Grüsch, 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 Rohrleitugnssysteme AG in Grüsch producing plastic valves.

Figure 7-2 illustrates the hydraulic diagram of the heat pump installation at Georg Fischer AG in Grüsch. 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.

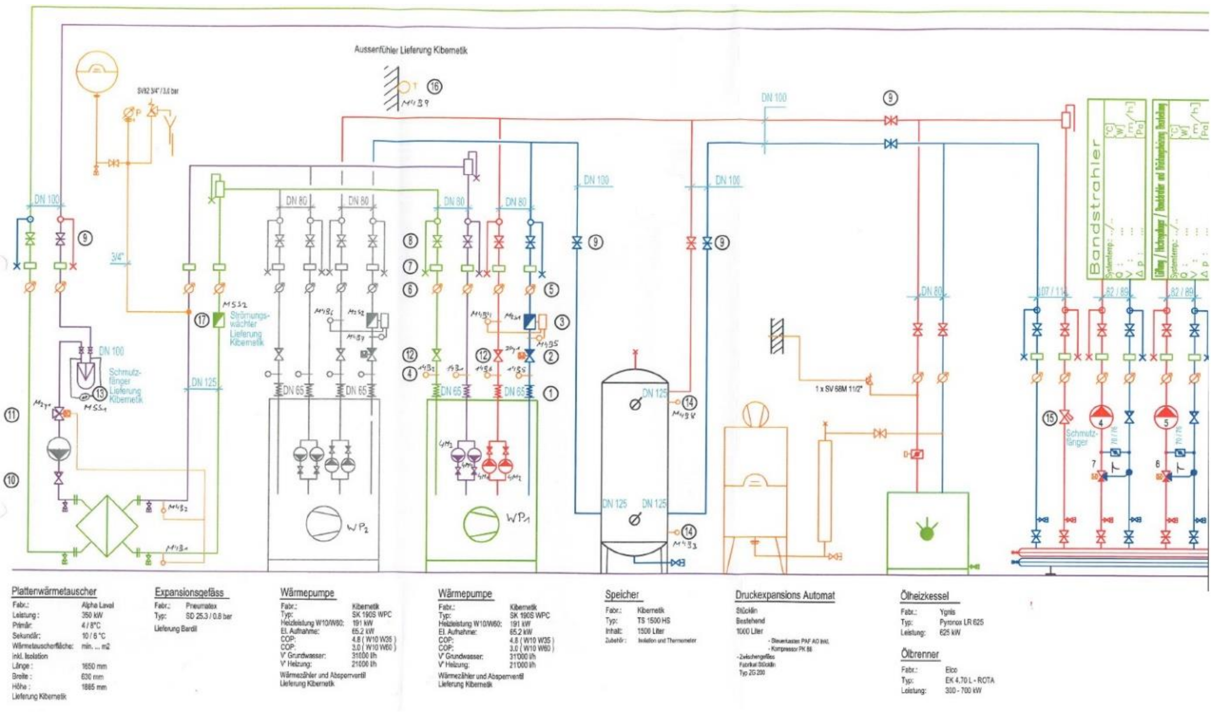


Figure 7-2: Hydraulic diagram of the heat pump installation at Georg Fischer AG in Grüsch (2 x SK 190S WPC from SCM Frigo with 191 kW heating capacity, COP 3.0, W10/W60).

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).

Figure 7-3: Troop accomodation building of the Swiss Army 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.

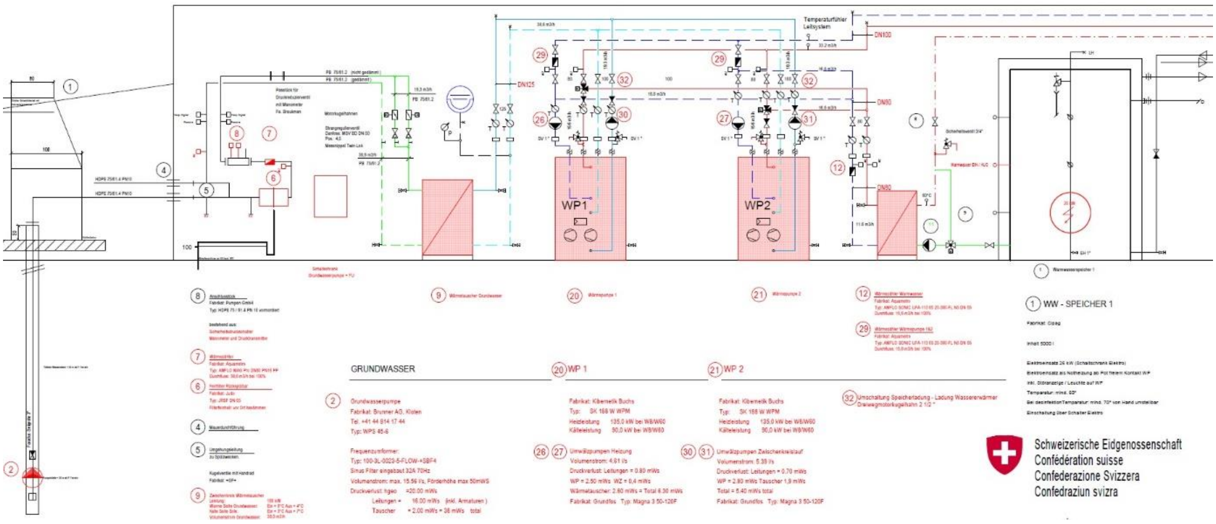


Figure 7-4: Hydraulic diagram of the heat supply at the troop accommodation building of the Swiss Army in Matt with two heat pumps from Kibernetik AG and a 5'000 L hot water storage tank.

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.

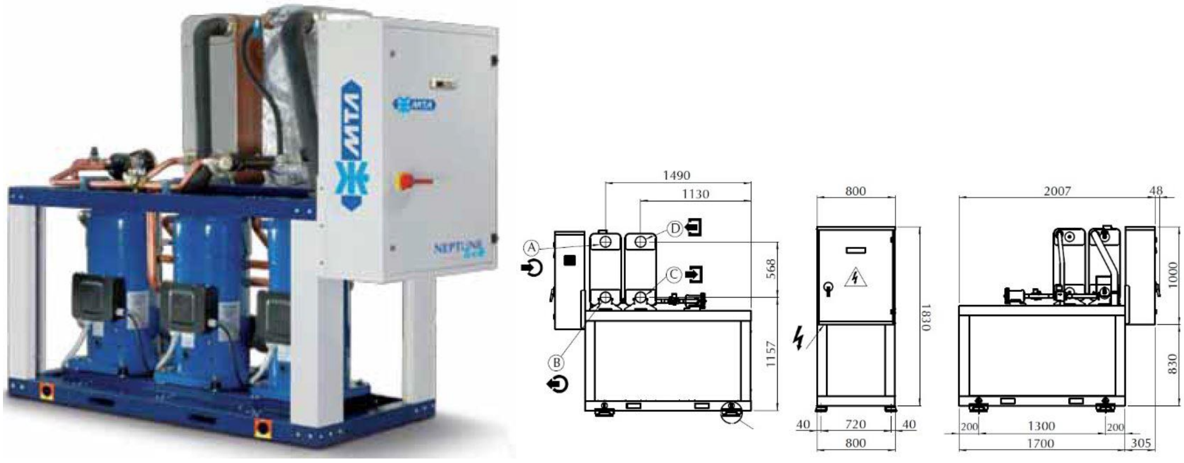


Figure 7-7: WTA Neptune Tech NET 090 heat pump with 3 hermetic scroll compressors positioned in parallel in one circuit (Dimensions L x W x H: 2.01 x 0.8 x 1.83 m) [26].

Contacts:

KIBERNETIK.

Kibernetik AG
Harry Fohmann
Teamleiter Wärmepumpen + Projektleiter
Langäulistrasse 62
CH-9470 Buchs SG
Tel. +41 81 750 52 00
harry.fohmann@kibernetik.com
www.kibernetik.ch

Georg Fischer Rohrleitungssysteme AG
Lösliweg 26
CH-7212 Seewis-Pardisla
Tel. +41 81 307 55 00
empfang.seewis@georgfischer.com
www.gfps.com/seewis

Truppenlager Matt
Dorfstrasse 75
CH-8766 Matt GL
Tel. +41 58 466 54 45
http://www.fnag.ch/referenzen5.html

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

KOKON Corporate Campus
Industriering 3
FL-9491 Ruggell
Tel. +423 262 27 04
info@kokon-cc.li
www.kokon.cc-li

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 [27]. More than 50 different vinegar varieties are sold for retail, caterers, restaurants and industry [28] (Figure 8-1).

Figure 8-1: Vinegar products of Nutrex made from wine, alcohol, apple juice and other fruit juices [27].

In 2008, COOP took the decision to achieve CO_2 neutrality within 15 years. Nutrex managed to achieve this goal already in 2009 by applying modern heat pump technology in its production site [29]. 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.

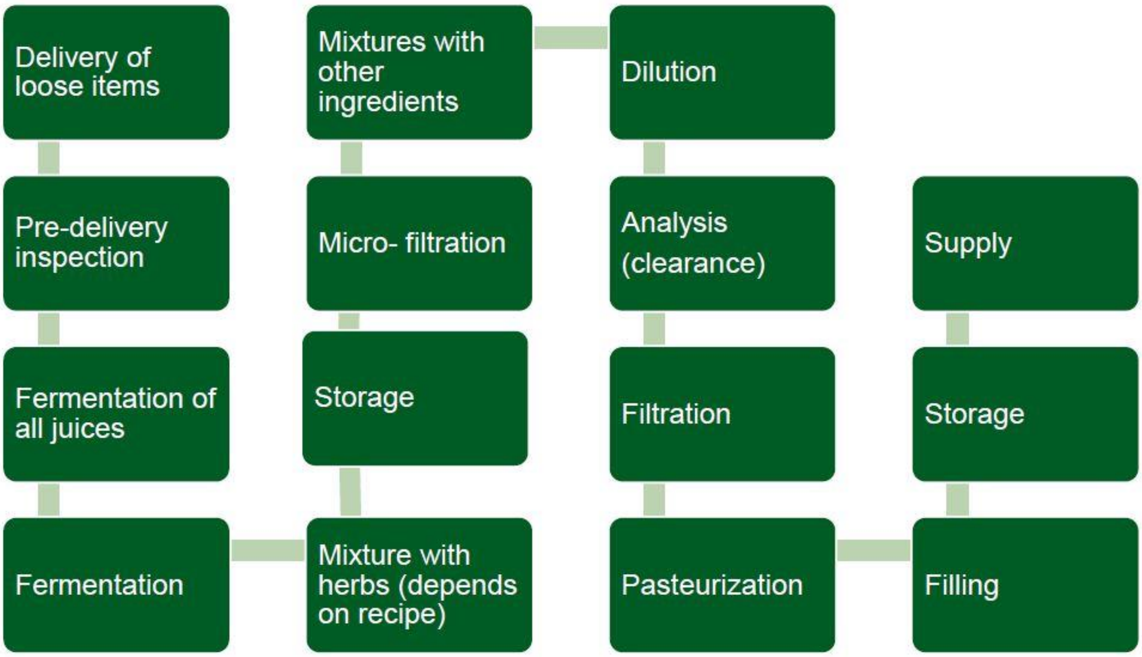


Figure 8-2: Production processes of vinegar with fermentation and pasteurization steps [28].

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].

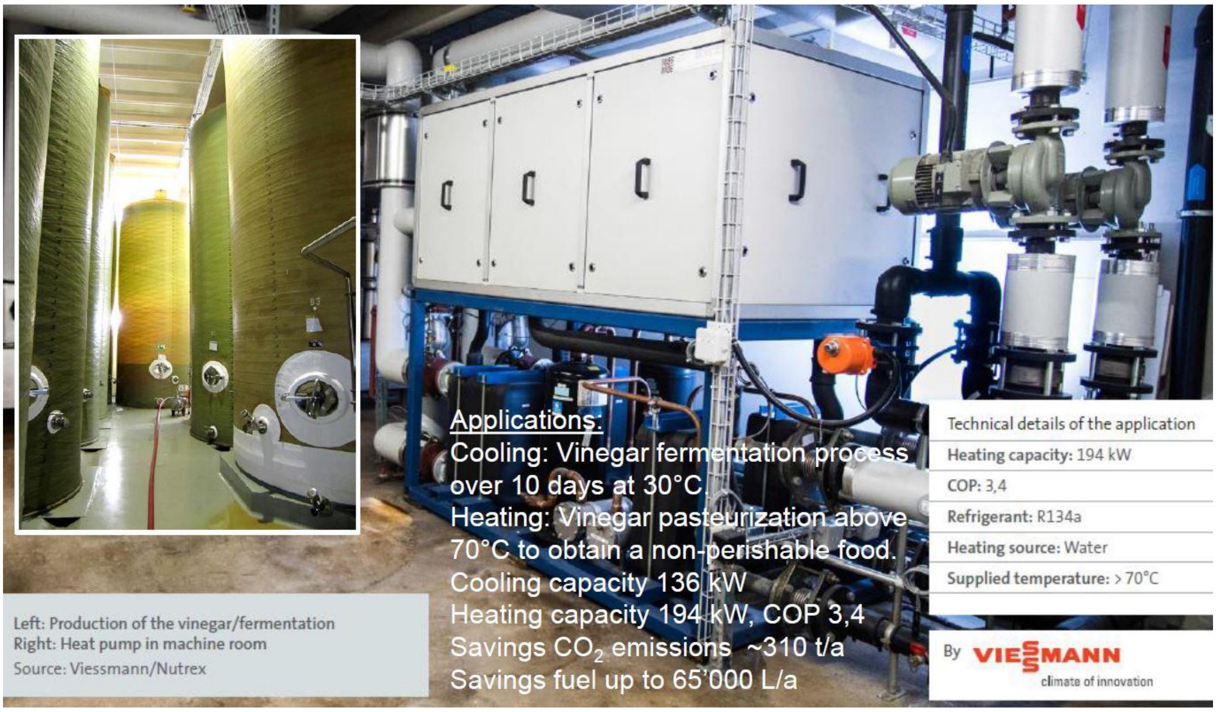


Figure 8-3: Vinegar fermentation and pasteurization using a heat pump from Viessmann [29].

Contacts:

Nutrex
Division der Coop
Genossenschaft
Juraweg 5
CH-3292 Busswil
Tel. +41 32 387 38 11
info@nutrex.ch
www.nutrex.ch

Viessmann (Schweiz) AG
Geschäftsbereich
Grosswärmepumpen
Dr. Stefan Irmisch
Rütimoosstrasse 5
CH-3076 Worb SBB
Tel. +41 31 818 16 16
info-gwp@viessmann.ch

9 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 NH_3 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.

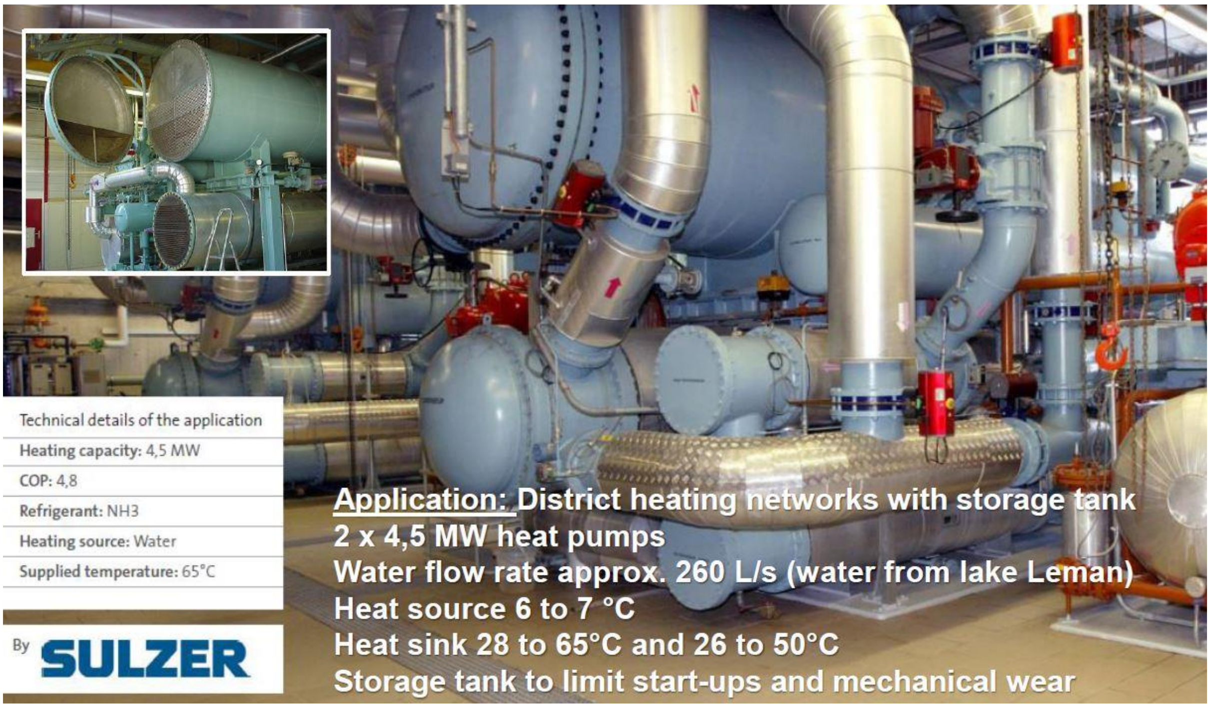


Figure 9-1: Two large NH_3 heat pumps in Lausanne (2x 4.5 MW) [29,31].

Contacts:

Friotherm AG
Langfeldstrasse 104
CH-8500 Frauenfeld
Tel. +41 52 724 77 00
info@friotherm.com, www.friotherm.com

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 planed, 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].

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

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.

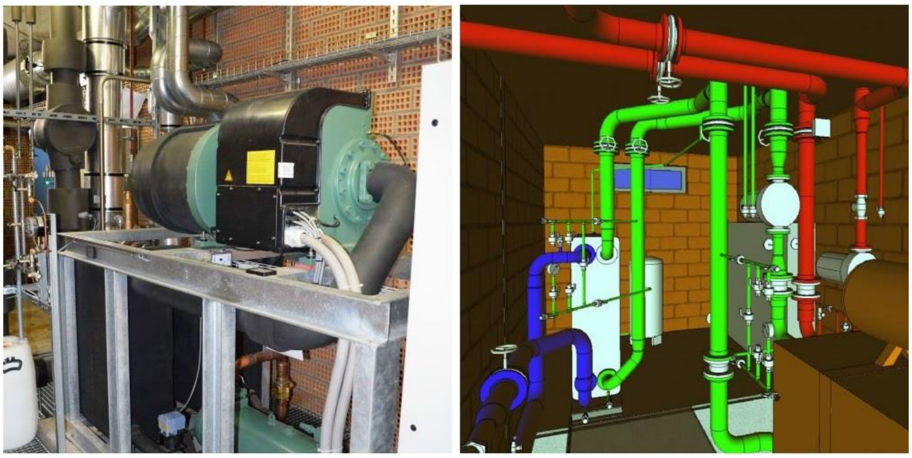


Figure 10-1: Screw compressor with integrated inverter and 3D layout of the energy center [32].

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].

Contact:

Scheco AG
Rolf Löhrer, Geschäftsleiter
In der Euelwies 17
CH-8408 Winterthur
Tel. +41 52 224 40 40
rolf.loehrer@scheco.ch, www.scheco.ch

scheco kühlt wärmt klimatisiert

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 thermeco$_2$ 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 CO_2 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 conneced 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 CO_2 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 CO_2 heat pumps of the type thermeco2 HHR 260 at the slaughterhouse in Zurich [35,37]

Table 11-1: Technical data of the heat pump system at the slaughterhouse in Zurich.

Machine type	**3 x thermeco$_2$ HHR 260**
Refrigerant	R744 (CO_2)
Compressors	12 x piston GEA CO_2 compressors (HGX34/150-4 SH CO2 T, transcritical)
Capacity control via master CPU	ajustable in 12 steps
Heating capacity	800 kW at 90 °C heat sink outlet / 30 °C heat sink inlet
Cooling capacity	564 kW at 20 °C heat source inlet / 14 °C heat source outlet
Energy savings	2‘590 MWh fossil fuels
CO_2 emissions reduction	30% (510 tons CO2/a)

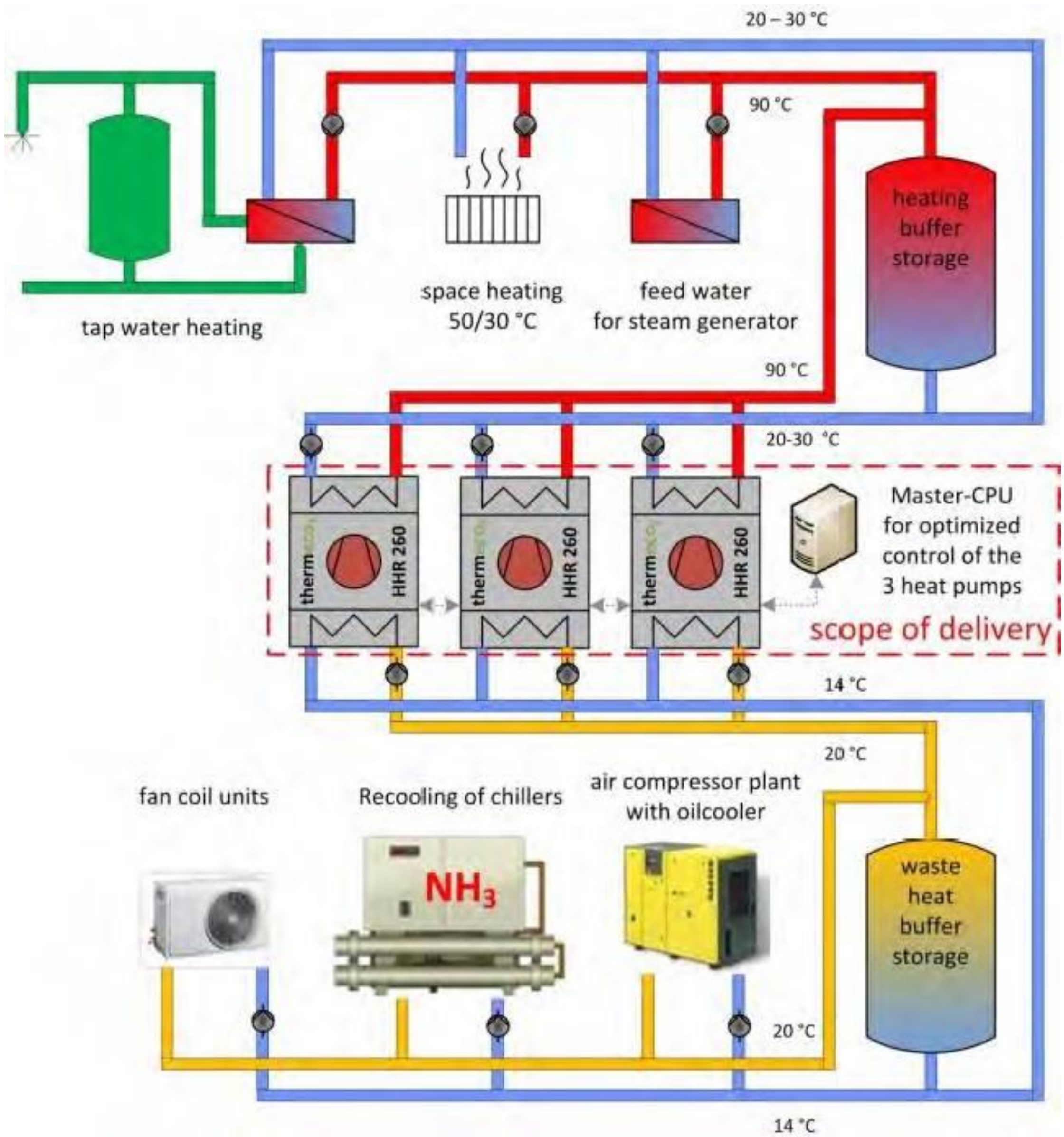


Figure 11-2: Function chart of the heat pump system at the Slaughterhouse in Zurich [36].

Contacts:

ewz Energielösungen
Daniela Schiesser-Küng
Leiterin Marktentwicklung
Business Development
Gämsenstrasse 2
CH-8006 Zürich
Tel. +41 58 319 44 17
daniela.schiesser@ewz.ch
www.ewz.ch/energielösungen

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 commisioned 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 m^3) 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 CO_2 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].

Total heating capacity (S8/W65)	2 x 1'420 kW
Heat sink (hot water) inlet/oulet	55/65 °C (45/55 °C)
Heat source (wastewater) inlet/oulet	8/2 °C
Hot water tank capacity	30 m^3
Waste water flow rate	344 m^3/h
Refrigerant	R134a
Annual COP	**3.62**
Reduction of CO_2 emissions	**approx. 3'000 t/a**

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

Contacts:

Durena AG
Othmar Arnold
Geschäftsleitung, Teilhaber
Murackerstrasse 6
CH-5600 Lenzburg
Tel. +41 62 886 93 79
info@durena.ch, www.durena.ch

Abwasserverband Altenrhein (AVA)
Wiesenstrasse 32
CH-9423 Altenrhein
Tel. +41 71 858 67 67
www.ava-altenrhein.ch

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.

Figure 13-1: The logistics building of the company kellermann.ch in Ellikon bei der Thur [40].

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 (NH_3, 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

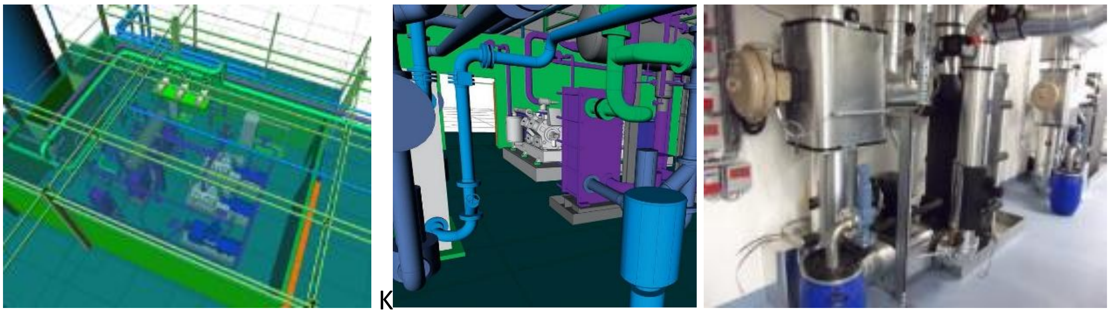


Figure 13-2: Cooling and heating with just one ammonia system (SSP KÄLTEPLANER.CH) [42].

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.

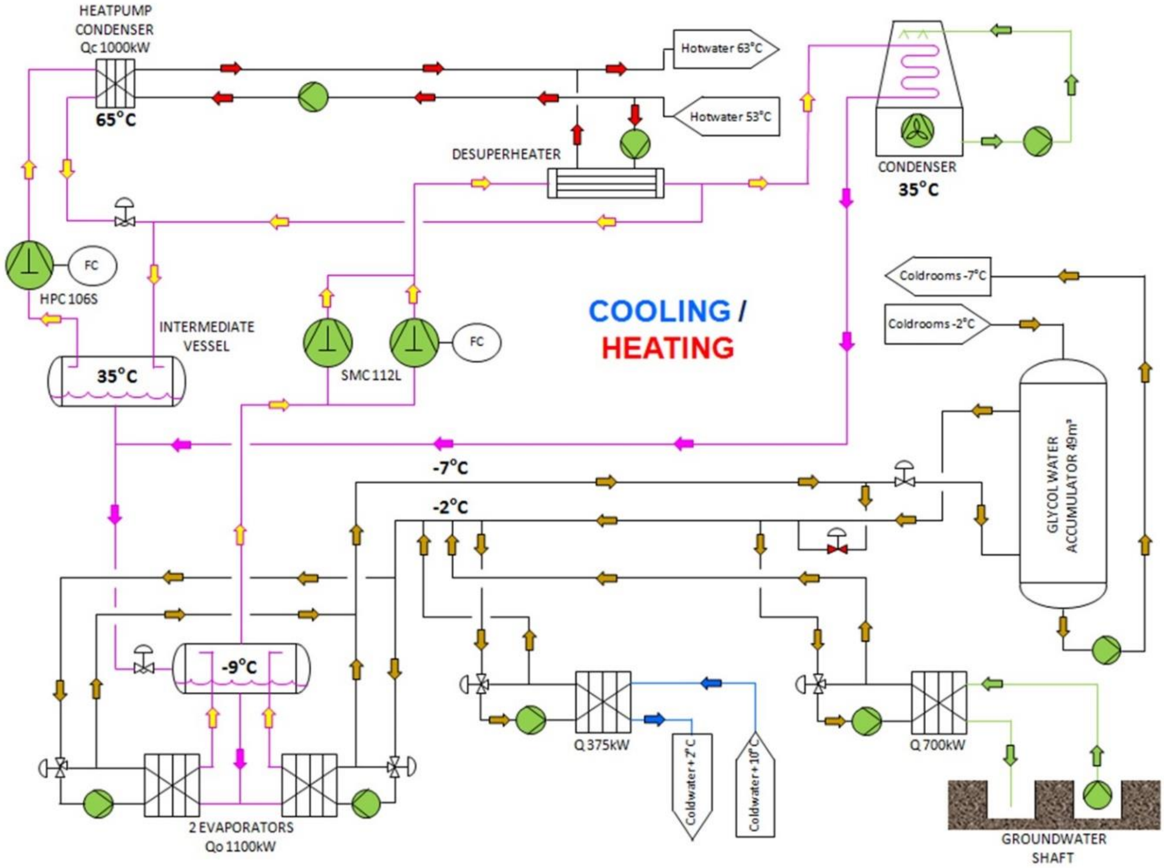


Figure 13-3: Principle drawing of the cooling and heating network [42].

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]. The greenhouses require an air temperature of approx. 60°C for heating.
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).

Contacts:

Kellermann.ch AG
Martin Kellermann
CEO - Vorsitz der Geschäftsleitung
Neue Horgenbachstrasse 2
CH-8548 Ellikon an der Thur
Tel: +41 (0) 52 725 00 00
martin@kellermann.ch
www.kellermann.ch

SSP KÄLTEPLANER AG
Beat Schmutz
Geschäftsleiter
Bittertenstrasse 15
CH-4702 Oensingen
Tel. +41 62 388 03 52
Beat.schmutz@kaelteplaner.ch
www.kaelteplaner.ch

Table 13-1 list some other projects using similar ammonia (NH_3) heat pump installations planed by SSP KÄLTEPLANER AG.

Table 13-1: Other projects from SSP KÄLTEPLANER AG with industrial ammonia (NH_3) heat pumps.

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

14 Frigo-Consulting AG

14.1 CO_2 heat pump for water heating

Frigo-Consulting is a leading engineering company for refrigeration technology in Switzerland and one of the worldwide leaders in CO_2 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 CO_2 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 CO_2 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 CO_2 in a transcritical cycle. The total heating capacity is 60 kW. The hot water is distributed via a two networks at different operating temperatures.

Figure 14-1: CO_2 heat pump from ENEX and heat distribution for the Swiss Army Training Hall in Payerne [43].

Contact:

Frigo-Consulting AG
Lerzenstrasse 8
CH-8953 Dietikon
Jonas Schönenberger
+41 (0)44 732 46 46
j.schoenenberger@frigoconsulting.ch
www.frigoconsulting.ch

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 CO_2 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 NH_3 heat pump (HPC108SV, SMC112LV, Sabroe) from Johnson Controls [45,46].

In the energy centre, around 80% of the required heat is generated practically CO_2-free with two NH_3 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.

Contacts:

Eniwa AG
Vertrieb Energie
Industriestrasse 25
CH-5033 Buchs AG
Tel. +41 62 835 00 10
info@eniwa.ch, www.eniwa.ch

eicher+pauli Liestal AG
Oliver Gässler
Eichenweg 6
4410 Liestal
Tel. +41 61 927 42 68, www.eicher-pauli.ch
Oliver.Gaessler@eicher-pauli.ch

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].

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 CO_2 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.

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 15-1: Ammonia (NH_3) heat pumps from Johnson Controls (Sabroe) at Mifa AG in Frenkendorf.

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

Figure 15-4: The installed NH_3 compressors (Sabroe, Johnson Controls) in the energy center of Mifa AG at Frenkendorf. Three compressors (JC/Sabroe SMC 116 LV) for the -29°C cold, two compressors (JC/Sabroe SMC 112 LV) for the ice water production with 2°C, and one heat pump (JC/Sabroe HPC 106 SV) for heat recovery providing 70 °C [47,48].

Contacts:

Mifa AG Frenkendorf
Rheinstrasse 99
CH-4402 Frenkendorf
Tel. +41 61 905 91 11

mibelle GROUP

eicher+pauli Zürich AG
Philippe Hennemann
Zweierstrasse 129
CH-8003 Zürich
Tel. +41 44 515 51 60
philippe.hennemann@eicher-pauli.ch
zuerich@eicher-pauli.ch
www.eicher-pauli.ch

eicher+pauli
Planer für Energie- und Gebäudetechnik

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 cyclinder 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 CO_2 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 (NH_3) heat pumps from Johnson Controls (Sabroe) at Bachem AG in Bubendorf.

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

Figure 15-5: Headquater of Bachem AG in Bubendorf with Sabroe HP 28 VSD NH_3 heat pumps [51].

As a guideline the service and maintenance costs of a large NH_3 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 NH_3 heat pump is about 30 to 35 years [52].

Contacts:

Bachem AG
Hauptstrasse 144
CH-4416 Bubendorf
Tel. +41 58 595 20 21
www.bachem.com

eicher+pauli Zürich AG
Zweierstrasse 129
CH-8003 Zürich
Tel. +41 44 515 51 60
philippe.hennemann@eicher-pauli.ch
zuerich@eicher-pauli.ch
www.eicher-pauli.ch

Walter Wettstein AG Kältetechnik
Mattenstrasse 11
CH-3073 Gümligen
Tel. +41 31 952 62 62
info@wwag.ch
www.wwag.ch

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.

Figure 16-1: Feldschlösschen Getränke AG in Rheinfelden with waste heat for the district heating network.

The annual energy consumption at Felschlösschen is a 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.

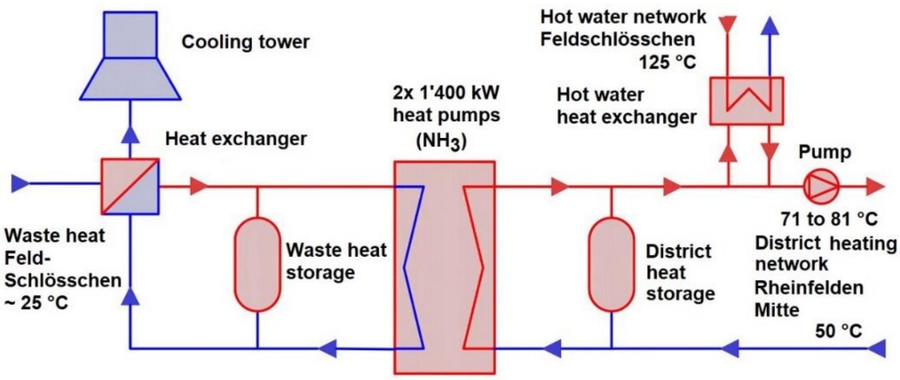


Figure 16-2: District heating network uses waste heat from beer production as heating energy. Overview of the waste heat utilization system with two NH_3 heat pumps and storage tanks (Gruner Gruneko AG [54]).

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

built. The total capacity of the new district heating system is around 6‘000 kW. Over 6‘000 tons of CO_2 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 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 NH_3 heat pumps (Mayekawa MYCOM, N6HK-DD, N6M-DD) before it is fed into the district heating network. Over 90% of the heat is generated CO_2-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 m^3) for the waste heat and Mayekawa MYCOM compressor [54].

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

Season	Waste heat (in/out)	District heating network (in/out)	Heating capacity district heating	COP (heating)
Winter	16/10 °C	50/81 °C	1’351 kW	3.41
Summer	30/24 °C	50/71 °C	1’296 kW	4.88

Contacts:

Feldschlösschen Getränke AG
Thomas Janssen
Leiter Technik & Umwelt
Theophil-Roningerstrasse
CH-4310 Rheinfelden
Tel. +41 58 123 46 41
thomas.janssen@fgg.ch
www.feldschloesschen.ch

Stadt Rheinfelden
Roger Erdin
Stadtschreiber
Marktgasse 16
CH-4310 Rheinfelden
Tel. +41 61 835 52 48
roger.erdin@rheinfelden.ch
www.rheinfelden.ch

Gruner Gruneko AG
Markus Butz
Abteilungsleiter
Energietechnik
Ivan Bagarić, Projektleiter
St. Jakobs-Strasse 199
CH-4020 Basel
Tel. +41 61 367 95 95
markus.butz@gruner.ch
ivan.bagaric@gruner.ch, www.gruner.ch

AEW Energie AG
Jürg Frutiger
Projektleiter
Obere Vorstadt 40
CH-5001 Aarau
Tel. +41 62 834 24 06
juerg.frutiger@aew.ch
www.aew.ch

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 CO_2 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.

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.

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 CO_2 emissions of around 100 tons per year.

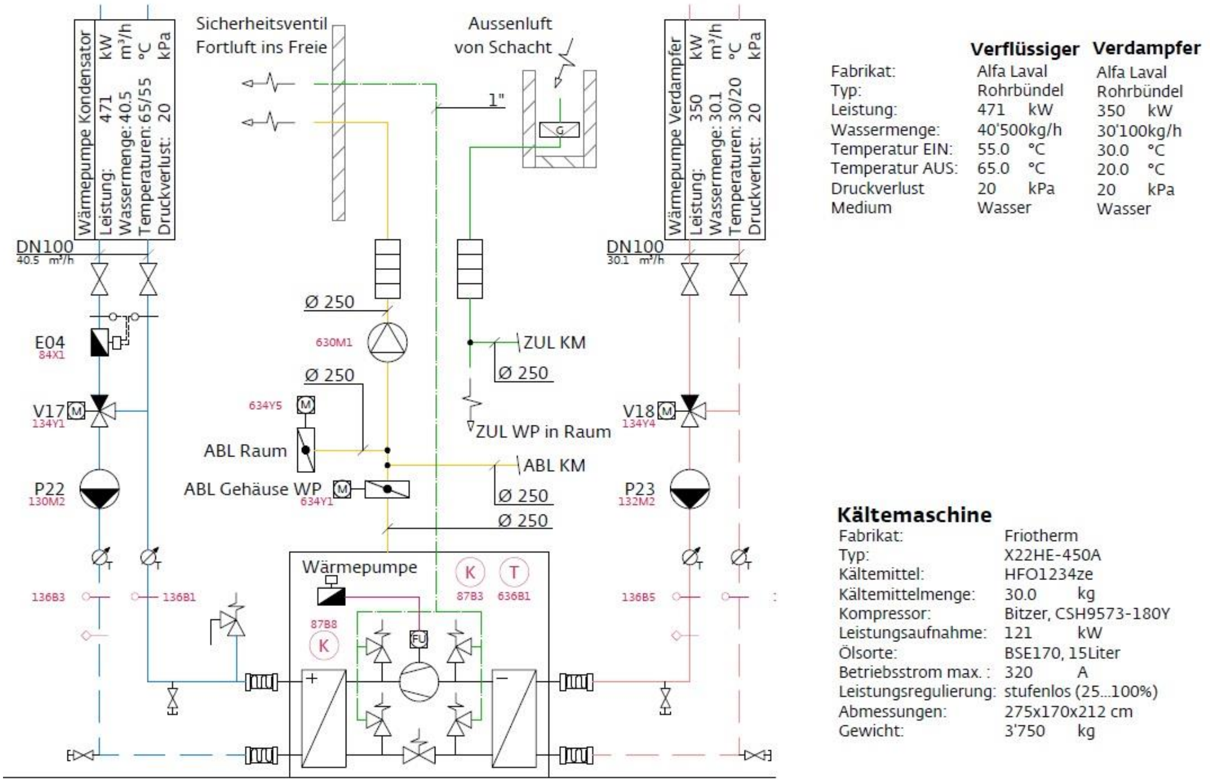


Figure 17-3: Principle drawing of the heat pump installation at Kambly SA.

Contacts:

Kambly SA
Stefan Suter
Leiter Technik
Mühlestrasse 4
CH-3555 Trubschachen
Tel. +41 34 495 01 11
stefan.suter@kambly.ch
www.kambly.ch

Lemon Consult AG
Marc Stöckli
Energy Efficiency Engineering
Sumatrastrasse 10
CH-8006 Zürich
Tel. +41 44 200 77 44
stoeckli@lemonconsult.ch
www.lemonconsult.ch

Friotherm AG
Langfeldstrasse 104
CH-8500 Frauenfeld
Tel. +41 52 724 77 00
info@friotherm.com
www.friotherm.com

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.

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 NH_3 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 m^3 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 wth 6 cylinders and oil separator for waste heat recovery. Right: GEA Grasso RB-5A chillers with screw compressor at Hilcona AG in Schaan (FL).

Conta cts:

Hilcona AG
Peter Ritzer, Leiter
Technischer Service
Bendererstrasse 21
LI-9494 Schaan
Tel. +41 58 895 97 20
peter.ritzer@hilcona.com, www.hilcona.com

LEMON • CONSULT • ENERGY • EFFICIENCY • ENGINEERING •

Lemon Consult AG
Marc Stöckli, Energy Efficiency Engineering
Sumatrastrasse 10
CH-8006 Zürich
Tel. +41 44 200 77 44
stoeckli@lemonconsult.ch
www.lemonconsult.ch

17.3 Toblerone chocolate production at Mondelēz Schweiz Production GmbH

The US-American manufacturer Mondelēz 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.

Contacts:

Mondelez Schweiz Production GmbH
Beat Geissbühler
Riedbachstr. 150
CH-3027 Bern
Tel. +41 58 440 52 62
Tel. +41 58 440 51 11 (Central)
bgeissbuehler@mdlz.com

Lemon Consult AG
Pascal Fotsch
Partner / Vorsitzender der Geschäftsleitung
Energy Efficiency Engineering
Sumatrastrasse 10
CH-8006 Zürich
Tel. +41 44 200 77 43
fotsch@lemonconsult.ch
www.lemonconsult.ch

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_{evap}/T_{cond}). Furthermore, in 2013, the district heating network was extend 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]).

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 m^2 area of residential buildings with 2'500 inhabitants. 69% of the heat demand is for space heating and 31% for hot water.

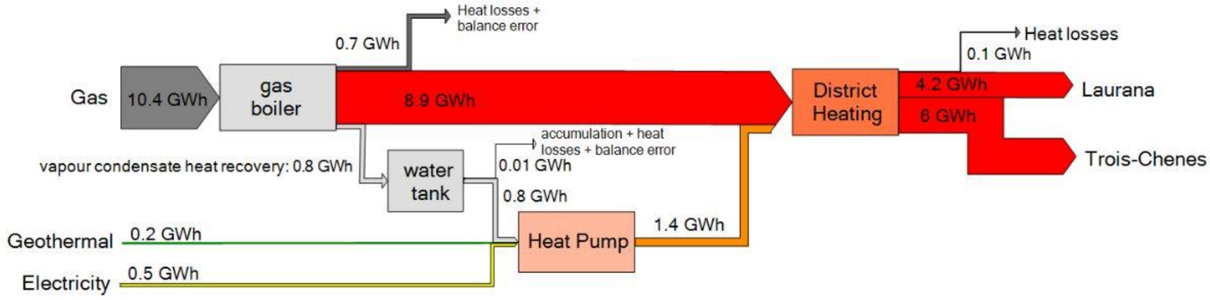


Figure 18-2: Sankey diagram of the heating system with annual flows measured from October 2014 to September 2015 [58,60].

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 occured in winter, when the heat pump operated at full load 90% of the time, 60% occured in summer at part load. The CO_2 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 18-1: Annual CO_2 emissions before and after the renovation of the district heating system (replacement of three oil boilers by three gas boilers and a dual-source heat pump [58].

CO_2 emissions before 2011	CO_2 emissions in 2014 to 2015 after the renovation	CO_2 savings by change from oil to gas boilers	CO_2 savings by change from gas boilers to heat pump	CO_2 savings total
4'114 t CO_2	2'368 t CO_2	1'229 t CO_2 (30%)	517 t CO_2 (12%)	1'746 t CO_2 (42%)

Contacts:

SIG Services Industriels de Genève
David Crochet
Gestionnaire d'actifs thermique
Ingénieur Thermique
CH-1211 Genève 2
Tel. +41 79 629 3971
david.crochet@sig-ge.ch
www.sig-ge.ch

CONTI & ASSOCIÉS Ingénieurs S.A.
INGÉNIEURS EN SYSTÈMES ÉNERGÉTIQUES

Conti & Associés Ingénieurs S.A.
Chemin de la Scie 4a
CH-1290 Versoix/Genève
Tel. +41 22 755 55 25
info@conti-ing.ch
www.conti-ingenergy.ch

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 1‘300 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 suppied 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.

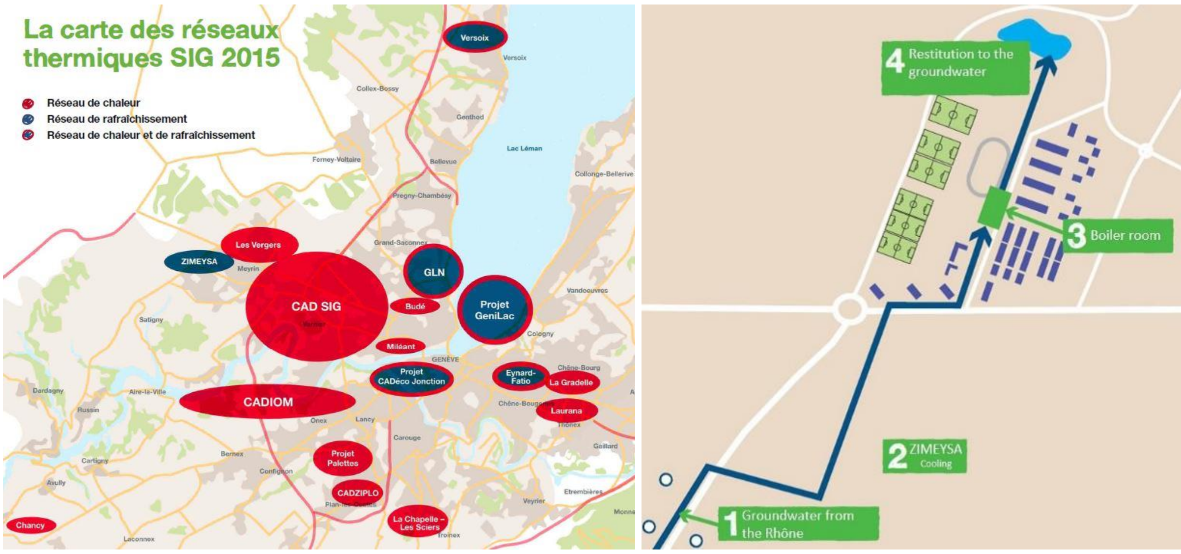


Figure 18-3: Thermal networks map suppied by SIG around Geneva with the heating network (red) in Les Vergers (Meyrin) and the cooling network (blue) in the industrial zone ZIMEYSA [61,62]

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.

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

Contacts:

SIG Services Industriels de Genève
David Crochet
Gestionnaire d'actifs thermique
Ingénieur Thermique
CH-1211 Genève 2
Tel. +41 79 629 3971
david.crochet@sig-ge.ch
www.sig-ge.ch

Friotherm AG
Langfeldstrasse 104
CH-8500 Frauenfeld
Tel. +41 52 724 77 00
info@friotherm.com
www.friotherm.com

Urbanisme, travaux
publics et énergie
Rue des Boudines 2
Case postale 367
CH-1217 Meyrin 1
Tel. +41 22 782 82 82
www.meyrin.ch

19 Literature

[1] Wettbewerbskommission, Jahresbericht des Preisüberwachers 2018, Preisentwicklung der Gaspreise, 2019. https://www.preisueberwacher.admin.ch/pue/de/home/themen/infrastruktur/gas.html.

[2] Bundesamt für Energie (BFE), Schweizerische Gesamtenergiestatistik 2018, (2019) 1–72. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/overall-energy-statistics.html.

[3] Statistical Federal Office (FSO), Statistical Data on Switzerland 2019, (2019) 1–52. https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen.assetdetail.7767426.html.

[4] Bundesamt für Statistik Schweiz (BfS), Industries production account (1995-2018), (2019). https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/wohlfahrtsmessung/alle-indikatoren/wirtschaft/branchenstruktur.assetdetail.9546430.html.

[5] C. Arpagaus, Hochtemperatur-Wärmepumpen: Marktübersicht, Stand der Technik und Anwendungspotenziale, 138 Seiten, ISBN 978-3-8007-4550-0 (Print), ISBN 978-3-8007-4551-7 (E-Book), VDE Verlag GmbH, Offenbach, Berlin, 2018.

[6] A. Kemmler, S. Kreidelmeyer, P. Wüthrich, M. Keller, M. Jakob, G. Catenazzi, Analyse des schweizerischen Energieverbrauchs 2000 - 2015 nach Verwendungszwecken. Im Auftrag des Bundesamtes für Energie, Bern, Oktober 2016., (2016) 1–96.

[7] S. Wolf, R. Flatau, P. Radgen, M. Blesl, Systematische Anwendung von Großwärmepumpen in der Schweizer Industrie, Endbericht, 10. Mai 2017, (2017) 1–47.

[8] S. Wolf, R. Flatau, P. Radgen, Rahmenbedingungen für die Anwendung von Grosswärmepumpen in der Schweizer Industrie, in: 23. Tagung Des BFE-Forschungsprogramms Wärmepumpen Und Kälte, 14. Juni 2017, HTI Burgd., 2017: pp. 1–10.

[9] C. Arpagaus, F. Bless, M. Uhlmann, J. Schiffmann, S.S. Bertsch, High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials, Energy. 152 (2018) 985–1010. doi:10.1016/j.energy.2018.03.166.

[10] R.M. Jakobs, Commercial and Industrial Heat Pump application, IEA HPT Annex 35/48, in: 22. Tagung Des BFE-Forschungsprogramms Wärmepumpen Und Kälte, 22. Juni 2016, HTI Burgd., 2016: pp. 69–77.

[11] N. Calame, F. Rognon, O. Sari, High Temperature Heat Pumps for Industrial Processes, in: 23. Tagung Des Forschungsprogramms Wärmepumpen Und Kälte Des Bundesamts Für Energ. BFE, 14. Juni 2017, Burgd., 2017: pp. 1–17.

[12] C. Arpagaus, Industrial heat pump references in Switzerland – Examples (Task 1, first draft), in: IEA TCP HPT Annex 48 Meet. May 13-14, 2019, Tokyo, Japan, 2019: pp. 1–26.

[13] C. Arpagaus, Industrial heat pump applications in Switzerland – Heat pump integration case studies, WS-4 Workshop: Successful Applications of Industrial Heat Pumps, in: ICR 2019, 25th IIR Int. Congr. Refrig. Montréal, Québec, Canada, August 28, 2019, 2019: pp. 1–21. https://cm.icr2019.org/webapp/timeslot/176.

[14] Ochsner Energie Technik, GVS Schaffhausen, 2017. http://ochsner-energietechnik.com/portfolio-item/1616/.

[15] H. Laister (Ochsner Energie Technik)r, Referenzanlagen in grossvolumigen Bauten, in: Symp. Energieeffizienz, Wind. 3.5.2018, 2018.

[16] C. Arpagaus, From Waste Heat to Cheese, HPT Mag. 37 (2019) 23–26. https://heatpumpingtechnologies.org/publications/from-waste-heat-to-cheese.

[17] C. Arpagaus, High Temperature Heat Pump in a Swiss Cheese Factory, in: 2nd Conf. High Temp. Heat Pumps, Sept. 9, 2019, Copenhagen, 2019. https://www.sintef.no/projectweb/hthp-conference/.

[18] C. Arpagaus, Maestrani setzt auf Energieeffizienz, Alimenta. (2019) Vol. 18 p. 24-26. https://www.foodaktuell.ch/maestrani-setzt-auf-energieeffizienz/.

[19] CTA, Maestrani in Flawil modernisiert seine Kältetechnik, 2017. https://www.cta.ch/de-ch/kaelte/1112/3063/?oid=2583&lang=de.

[20] ESB Energie Service Biel, AEK Energie AG, Spatenstich Wärmezentrale Champagne, Fernwärme aus Grundwasser, 2017. https://www.bielertagblatt.ch/sites/bielertagblatt.ch/files/58/29/5829effec9c8760d49eb4b148740c4b4.pdf.

[21] C. Brechbühler, Wärme aus dem Grundwasser heizt das Bieler Quartier Champagne, CTA Website. (2019). https://www.cta.ch/de-ch/kaelte/1112/3276/?oid=2695&lang=de.

[22] C. Brechbühler, 530 kW Wärmeleistung aus der Luft für Basel, CTA Website. (2019). https://www.cta.ch/de-ch/firma/825/3356/?oid=2755&lang=de.

[23] C. Brechbühler, Wärme aus der Luft fü r Base, Haustech 5/2019. (2019) 80–81. https://www.haustech-magazin.ch/stichwort/ht-52019/.

[24] NZZ, Geld für die Sparsamen Kostenfaktor Energie, Neue Zürcher Zeitung. (2014) 1–4. https://www.nzz.ch/wirtschaft/geld-fuer-die-sparsamen-1.18376660.

[25] EnAW, Härterei Gerster AG: Mit Wärmepumpe 80 Prozent Heizenergie eingespart, Konkret Klimaschutz & Energieeffizienz, 04/2014. (2014). https://enaw.ch/wp-content/uploads/2014/04/201404-haerterei_gerster_ag-d.pdf.

[26] MTA, Brochure NEPTUNE tech, Water-cooled water chillers, heat pumps and evaporation units, 2011. https://www.mta.de/fileadmin/user_upload/technisches_Handbuch_Neptune_tech_Englisch_5050ENEYY003D_F.pdf.

[27] Nutrex, Nutrex Factsheet, 2018. https://report.coop.ch/app/uploads/Factsheet_Nutrex_EN.pdf.

[28] Nutrex, Company presentation - Reismühle Brunnen/Nutrex, 2019. https://www.reismuehle-nutrex.ch/file/Präsentationen/Company profile 08_2019.pdf.

[29] EHPA, Large scale heat pumps in Europe: 16 examples of realized and successful projects, 2017. https://www.ehpa.org/fileadmin/documents/Large_heat_pumps_in_Europe_final.pdf.

[30] S. Irmisch, Viessmann (Schweiz) AG - Grosswärmepumpen: Die Energielösung für Kommunen, Gewerbe und Industrie, in: Wärmetagung 2017, 20./21.9.2017, Köln, 2017: pp. 1–38. https://www.waermepumpe.de/fileadmin/user_upload/bwp_service/Forum_Waermepumpe/Praesentationen/Vortrag_Irmisch_Waermetagung_klein.pdf.

[31] M. Zogg, History of Heat pumps: Swiss Contributions and International Milestones, 2008. https://www.zogg-engineering.ch/publi/HistoryHP.pdf.

[32] Scheco AG, Kläranlage - Sole/Wasser-Wärmepumpe für Wärmeverbund, 2014. http://www.scheco.ch/referenzen/klaeranlage/details/3366.

[33] Scheco AG, Thermalbad - Wasser/Wasser-Wärmepumpe für die Wärmerückgewinnung, 2009. http://www.scheco.ch/referenzen/thermalbad/details/2930.

[34] D. Von Känel, Grösste CO2-Wärmepumpe der Schweiz in Zürich - Neue Maschine für alte Fabrik, Baublatt, Nr. 15, 13. April 2012. (2012) 21–22. https://www.bauinnovationen.ch/fileadmin/ablage/Bauinnovationen/PDF_Artikel_Bauinnovationen/BB_1215_Schlachthof.pdf.

[35] GEA, Umweltfreundlich und effizient – dank Wärmepumpen mit GEA CO2-Verdichtern, Website. (2015). https://www.gea.com/de/stories/abattoir-zurich.jsp.

[36] H.-J. Laue, Application of Industrial Heat Pumps, Part 2, Final Report HPP-AN35-2, 2014. https://heatpumpingtechnologies.org/publications/application-of-industrial-heat-pumps-part-2/.

[37] EWZ, ewz: Grösste CO2- Wärmepumpenanlage der Schweiz, Ee-News.Ch. (2012). https://www.ee-news.ch/de/article/24010/ewz-groesste-co2-waermepumpenanlage-der-schweiz.

[38] Durena AG, Abwasserverband Altenrhein, ARA Altenrhein - Wärme aus dem gereinigten Abwasser zur Klärschlammtrocknung, 2007. https://www.durena.ch/images/durena/projektblaetter/alte_Projektbltter/Wrme_aus_gereinigtem_Abwasser_2007_ARA_Altenrhein.pdf.

[39] Abwasserverband Altenrhein (AVA), Kläranlage Altenrhein auf einen Blick, 2017. https://www.ava-altenrhein.ch/static/uploads/2019/05/2017Infotafeln.pdf.

[40] Johnson Controls, Fallstudie Energieeffizienter Gemüseanbau - Kellermann heitz mit Kälte, 2013. https://www.johnsoncontrols.com/de_de/-/media/jci/be/germany/solutions-by-industry/files/bts_case_study_kellermann_de.pdf.

[41] SSP Kälteplaner AG, Coole Heizung mit Kälte (Kellermann AG), 2013. http://kaelteplaner.ch/de/index.php?section=downloads&category=6&id=2.

[42] B. Schuppisser (Johnson Controls), Ecological Refrigeration and Heat Generation (Customer: Kellermann.ch), in: Eurammon Symp. June 28, 2013, Schaffhausen, Switz., 2013: pp. 1–16.

[43] Frigo-Consulting AG, Wärmeproduktion mittels CO2 Wärmepumpen, 2016. http://www.frigoconsulting.ch/de/Unternehmen/News/Newsmeldung?newsid=17.

[44] C. Hunziker (IBAarau), Fernwärme, Die Komfort-Energie, Umsetzungspraxis in Städten, Energiewende Aarau, in: Megatrends Und Effizienzfragen, 13. Forum Vom 29. Jan. 2014 Biel-Bienne, 2014: pp. 1–22.

[45] Eicher+Pauli AG, Fernwärme- und Fernkälteverbund Kasino Aarau, 2014. https://www.eicher-pauli.ch/media/archive1/referenzenneu/pdf/Ref-LI-090-Fernwaermeverbund-Kasino-Aarau.pdf.

[46] Eniwa AG, Factsheet Wärme-/ Kälteverbund Kasino, 2018. https://www.eniwa.ch/de/verbund-kasion.html.

[47] Eicher+Pauli AG, Neue Energiezentrale punktet mit Effizienz, Spektrum GebäudeTechnik – SGT 5/2018. (2018) 1–2. https://www.eicher-pauli.ch/images/content/publikationen_und_wettbebwerbe_ab_2015/publikationen/2018PublikationSGTNr5-2018MifaFrenkendorfPhilippeHennema.pdf.

[48] Eicher+Pauli AG, Neubau Energiezentrale Mifa AG, Frenkendorf, 2017. https://www.eicher-pauli.ch/media/archive1/referenzenneu/pdf/RefLI108MifaFrenkendorf.pdf.

[49] Mibelle Group, Mifa AG: Neue Energiezentrale, 2019. https://www.mibellegroup.com/index.php/de/nachhaltigkeit/nachhaltige-produktion/Mifa-AG-Neue-Energiezentrale.

[50] Johnson Controls, Brochure SABROE HPO/HPC/HPX high-pressure reciprocating compressor units, 2019. https://www.sabroe.com/fileadmin/user_upload/Marketing/Brochures/Compressors/HPO-HPS_HPX_SB-4106_GB120dpi.pdf.

[51] Eicher+Pauli AG, Ersatz Kälteversorgung Bachem AG, Bubendorf Pharmabetrieb erhält zuverlässige Kälteversorgung, 2016. https://www.eicher-pauli.ch/media/archive1/referenzenneu/pdf/RefLI099BachemAGKaelteversorgung.pdf.

[52] T. Sigrist, Walter Wettstein Kältetechnik AG, Grosswärmepumpen mit Kältemittel R717 (Ammoniak NH3), HK-Gebäudetechnik 10/05. (20015) 1–4. http://www.wwag.ch/files/download/dokumente/Technologien_Grosswaermepumpe.pdf.

[53] BFE, Wärmeverbund Wärme vom Schloss, Energeia Newsl. Des Bundesamtes Für Energ. BFE, 6/2015. (2015) 4–5. www.bfe.admin.ch/energeia.

[54] Gruner Gruneko AG, Abwärmenutzung bei Feldschlösschen für den Wärmeverbund Rheinfelden Mitte, 2015.

[55] Feldschlösschen, Medienmitteilung, 26. September 2014: Wärmeverbund Rheinfelden Mitte geht ans Netz - Die Zähringerstadt wird mit Bierwärme beheizt, 2014. https://feldschloesschen.swiss/media/23828/mm_waermeverbund.pdf.

[56] Lemon Consult, Sanierung Energieversorgung und Kälteverteilung bei Kambly SA, 2017. https://lemonconsult.ch/projekte/sanierung-energieversorgung-und-kaelteverteilung/.

[57] Ramseier AG, Kably Trubschachen: Ersatz Heizung, 2017. http://www.ramtech.ch/referenz/kambly-trubschachen-ersatz-heizung.

[58] J. Faessler, Services Industriels de Genève (SIG), Réseaux thermiques multi-ressources efficients et renouvelables: Retour d'expérience sur la rénovation de la chaufferie de quartier de Laurana-Parc à Thônex (GE), 2016. https://archive-ouverte.unige.ch/unige:93169.

[59] Conti & Associés Ingénieurs S.A., Laurana-parc Centrale de chauffe + Sondes géothermiques, 2016. http://www.conti-ingenergy.ch/references/centrales-de-quartier-avec-reseaux-de-chaleur-et-de-froid/laurana-parc.

[60] F. Jérôme, F. Carolina, H. Pierre, P. Daniel, Q. Loïc, Implementation challenges of geothermal Heat Pump with Gas boiler in existing District Heating, in: Eur. Geotherm. Congr. 2016 (EGC2016), Strasbourg, Fr. 19-24 Sept. 2016, 2016: pp. 19–24. https://archive-ouverte.unige.ch/unige:87897.

[61] SIG, L'énergie thermique - Chauffer et rafraîchir Genève grâce aux ressources renouvelables locales, 2015. https://ww2.sig-ge.ch/sites/default/files/inline-files/pdf_energie_thermique.pdf.

[62] SIG, L'écoquartier des Vergers: un concept thermique novateur utilisant les énergies renouvelables locales, 2016. https://www.lesvergers-meyrin.ch/ecoquartier/content/cad_plan_vergers_37x20_vf_11.03.2019.pdf.

20 Acknowledgements

This study was carried out within the framework of the IEA HPT Annex 48 project (Industrial Heat Pumps, Phase 2), which was funded by the Swiss Federal Office of Energy (SFOE) within the project "HTWP-Annex 48 – Beitrag über HTWP zum IEA TCP HPT Annex 48" (Vertragsnummer: SI/501782-01). This research project is also part of the Swiss Competence Center for Energy Research SCCER EIP (www.sccer-eip.ch) of the Swiss Innovation Agency Innosuisse. The authors acknowledge the listed companies and contacts for their support of providing information on the heat pump applications.