Industrial Heat Pumps, Second Phase

IEA Heat Pump Programme Annex 48

Task 2: Structuring information on industrial heat pumps and preparation of guidelines
Austrian Report

August 2019

Prepared by
V. Wilk, J. Krämer
AIT – Austrian Institute of Technology GmbH
Center for Energy, Sustainable Thermal Energy Systems
Giefinggasse 2, 1210 Wien, Austria
Contact: veronika.wilk@ait.ac.at

A. Arnitz, R. Rieberer
Graz University of Technology
Institute of Thermal Engineering
Inffeldgasse 25/B, 8010 Graz, Austria
Contact: rene.rieberer@tugraz.at

Contents

1 Selection of best practice examples

A total of 68 Austrian case studies was collected in the framework of IEA HPT Annex 48 (2016-2019) and IEA HPT/IETS Annex 35/13 (2011-2014). To be considered as an example for an industrial heat pump, the heat pumps have to be integrated into an industrial or commercial process on the heat source and/or supply side. Only heat pumps in operation were considered. Projects that are still in the planning or commissioning phase are not included. The case studies cover various industries whose good suitability for heat pumps is already known, such as the food industry (17 examples), utility companies (11 examples) and the metalworking industry (11 examples).

The case studies that were selected for a more detailed description have proven to be beneficial in terms of environmental and economic benefits and their operators or installers agreed to their publication and were willing to provide detailed information. It is particularly important that image material is also available so that appealing dissemination documents can be produced. The examples also show a considerable multiplication potential as their integration solutions can be transferred to other processes and industries, such as recovery of waste heat.

Those are the Austrian case studies that are presented in detail in the following:

Food industry

- Brewery Puntigam: two heat pumps with a total heating capacity of 1200 kW, which use the fermentation heat of the brewing process to provide heat for heating and hot water preparation in a residential area in the "Brauquartier" in Graz
- Dairy Berglandmilch eGen/Tirol Milch Wörgl: three heat pumps with a total heating capacity of 4200 kW, which use the waste heat from the chillers as a heat source and provide district heating for the town of Wörgl
- Meat and sausage production F. Krainer: CO_2 heat pump with a heating capacity of 800 kW, which provides cold brine and hot water

Utilities

- Power plant Wien Energie Simmering: two heat pumps with 27-40 MW heating capacity that use cooling water from power plants and river water to feed district heating into the grid
- Biomass cogeneration plant Klagenfurt Ost: two absorption heat pumps with a total heating capacity of 20 MW, which are used for flue gas condensation in a biomass power plant and supply district heating

Metal industry

- Steel and rolling mill Marienhütte: two heat pumps with a total heating capacity of 11 MW, which use the waste heat from the cooling baths of the steel production and provide district heating
- Plansee SE Reutte: a high temperature heat pump with a total heating capacity of 380 kW is integrated into the cooling circuit of the sintering process and provides heat for the internal heating network

Plastic processing

- Injection moulding Bergs Kunststofftechnik: a 110 kW heat pump is used to recover process heat for heating purposes

Pharmaceutical industry

- EVER Neuro Pharma: a heat pump that recovers waste heat from production processes and provides heat and cold for air conditioning and heating purposes
- P&G Health Austria: a heat pump with about 500 kW heating capacity that recovers waste heat from refrigeration to provide heat for production halls

2 Description of best practice examples

2.1 Brewery Puntigam

„The use of fermentation heat as low temperature heat source for heat pumps leads to a win-win situation for all participants.“ (http://www.kelagwaerme.at/content/1372.htm 10.04.2018)

The C&P Immobilien AG builds about 800 apartments, offices and shops with an overall area of 65 000 m^2 in the city district Puntigam in Graz (see Figure 2-1). At the moment, two thirds of the construction work has been completed. In the final stage the “Brauquartier” offers living area for about 2 000 people with an annual heating demand for heating and hot water preparation of 3.8 GWh. The heat supply of the “Brauquartier” is based on a cooperation between the brewery Puntigam, which is a member of the Brau-Union Austria AG, the KELAG Energie & Wärme GmbH and the C&P Immobilien AG. Core of this cooperation is the use of fermentation heat (waste heat of NH_3 refrigeration system) which is released in the brewery Puntigam as heat source for two heat pumps and used for the heat supply of the “Brauquartier”.

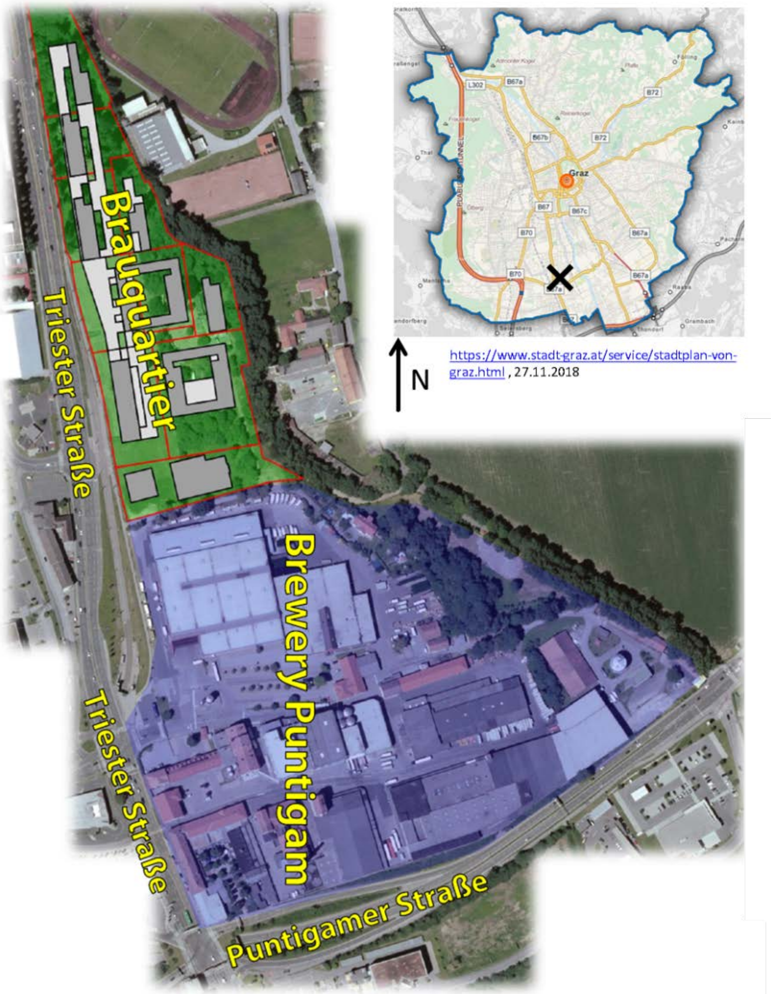


Figure 2-1: Location of the “Brauquartier” and the brewery Puntigam (similar to Koglbauer and Zanker, 2018a)

The heat pumps were commissioned at the company site of the brewery Puntigam in February 2018 and are property of the KELAG Energie & Wärme GmbH. One heat pump with a heating capacity of 420 kW can be used for hot water preparation with a temperature of up to 75 °C as well as for the building heating of the "Brauquartier" with a temperature of up to 46 °C. The other heat pump is used exclusively for the building heating of the "Brauquartier" with a temperature of up to 46 °C. The heat pumps are connected to the heating system of the "Brauquartier" via a district heating network with 3 pipes. The first pipe is used for the heat supply at a temperature of max. 75 °C, the second pipe is used for the heat supply at a temperature of max. 46 °C and the third pipe is used for the return flow. The separation of the heat supply for hot water preparation and building heating enables an efficient and stable operation of the heat pumps.
Figure 2-2 shows an energy flow diagram which considers the heat flow from the brewery Puntigam to the heat pumps (divided into sensible and latent heat which is released in the condenser of the NH_3-chillers), the electrical driving energy for the compressors of the heat pumps and to the heat supplied by the heat pumps to the "Brauquartier" (useable heat at 46 and 75°C). At peak load additional heating energy is required, which is provided by the existing steam generator at the brewery Puntigam. The steam generator is fired with natural gas and has a maximal heating capacity of 12 tons of steam per hour, this corresponds to a heating capacity of about 7 MW. From today's point of view about 10 % of the required annual heating demand has to be covered by the steam generator.

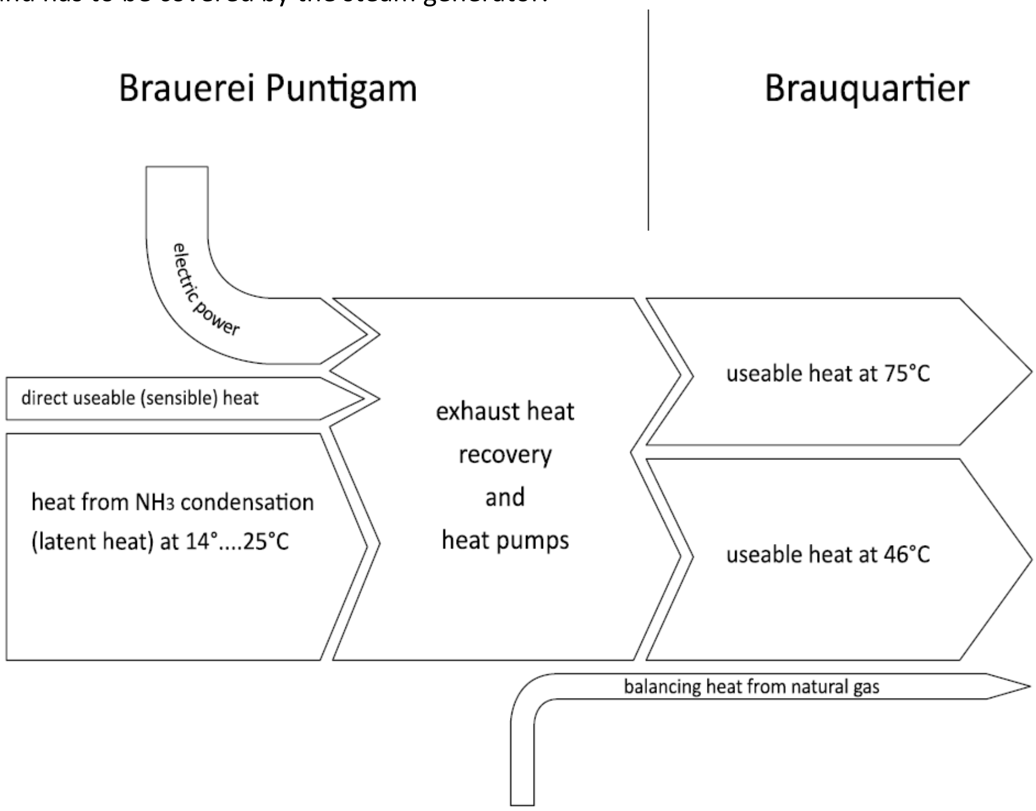


Figure 2-2: Energy flow diagram for the heat supply of the „Brauquartier" (Koglbauer und Zanker, 2018a)

The brewing process

The brewery Puntigam produces about 1. Mio. hectolitres beer per year. The applied brewery process is shown in Figure 2-3. The brewing barley is delivered to the brewery Puntigam and grinded in the malt mill. The grinded malt is heated in stages from 40 °C to 70 °C in the mash pan and then mixed with brewing water at a temperature of 85 °C. The brewing water is used as cooling water in the plate cooler where it is heated. Through the mixing with the brewing water the starch of the malt is converted into fermentable malt sugar (maltose, glucose). In the lauter tun the insoluble substances of the mash, the so called draff, is separated from the sugar-rich beer wort at a temperature of about 75 °C. In the next step the sugar-rich beer wort is heated in the wort pan to a temperature of about 100 °C and then the hop is added. In the wort pan water is evaporated until the desired concentration of the wort is reached. The remaining wort is the energy rich substrate for the cultivated yeast. The evaporated water is condensed in a heat exchanger and the heat which is released during the condensation is stored in a hot water storage at a temperature of 95 °C and used to cover the heat demand of the mash pan and the lauter tun. Due to this heat recovery, heat from the steam cycle is only required in the mash pan and lauter tun during start-up after the weekend.

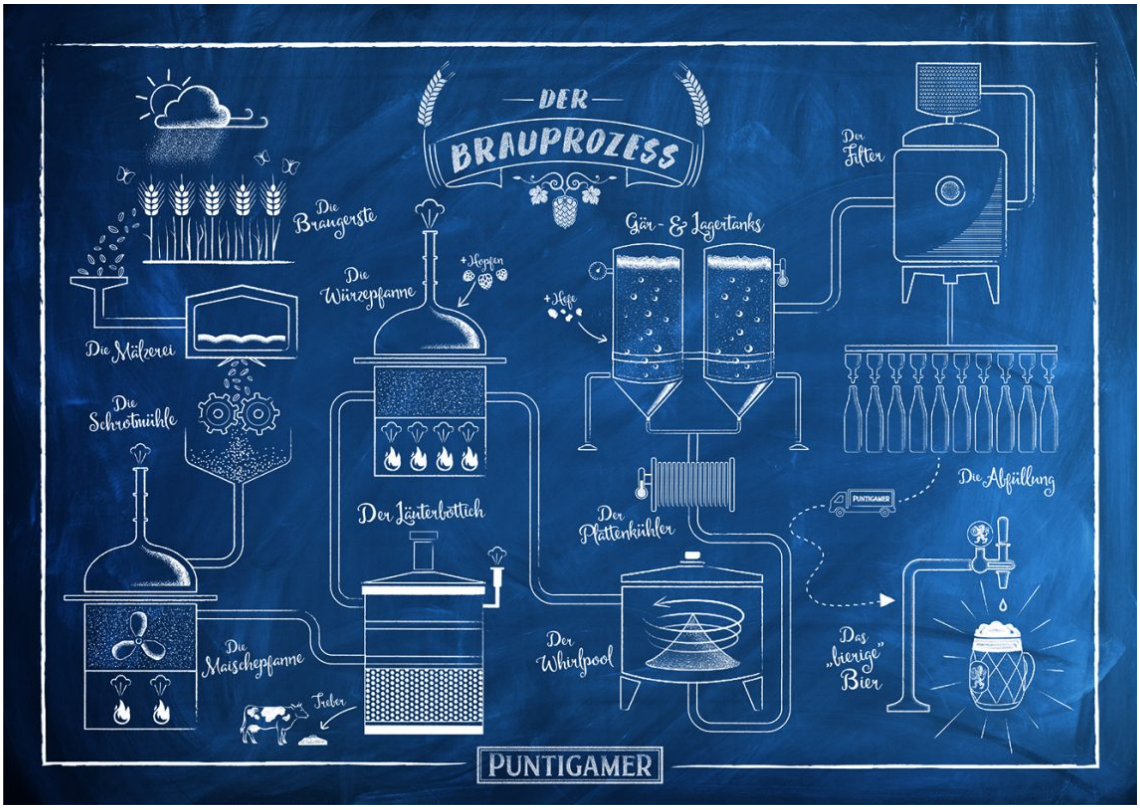


Figure 2-3: The brewing process of the brewery Puntigam (Puntigamer, 2018)

Solid substances in the boiling wort are separated in the “Whirlpool”. The solid substances consist mainly of proteins, tannins and hop components. After the whirlpool the remaining boiling wort is cooled in the plate cooler to a temperature of about 12 °C. The wort is cooled with the brewing water required in the mash pan. The brewing water is taken from a water well with a temperature of about 13-14 °C and is further cooled to a temperature of about 2 °C with the available NH_3-chillers. This ensures the cooling of the wort to a temperature of 12 °C in the plate cooler.

After the wort is cooled down, it flows into the fermentation and storage tanks, where air is blown in and cultivated yeast is added. According to Koglbauer and Zanker (2018b) the fermentation process in the fermentation tanks is initiated by the addition of cultivated yeast (Saccharomyces carlsbergensis, syn. S. pastorianus). During the fermentation process the glucose molecules are converted into ethanol and carbon dioxide by the cultivated yeast. The required converting steps are shown in Figure 2-4 (left), during the whole conversion 1.2 kJ heat per g glucose is released. The yeast requires about 20 % of this heat and the remaining 80 % are taken by the wort and have to be removed by the NH_3-chillers to hold the temperature of the wort within the fermentation tanks constant. The fermentation process can be divided into pre-, main- and post-fermentation. For the pre- and main-fermentation a temperature of 12 °C is hold for a duration of 2.5 - 3 weeks. Then the temperature is reduced during the post-fermentation to about 2 °C for another 1.5 - 2 weeks. The heat is removed from the 40 fermentation tanks (volume of one tank is about 400-500 m^3, see Figure 2-4- right) via heat exchangers, in which the NH_3 evaporates.

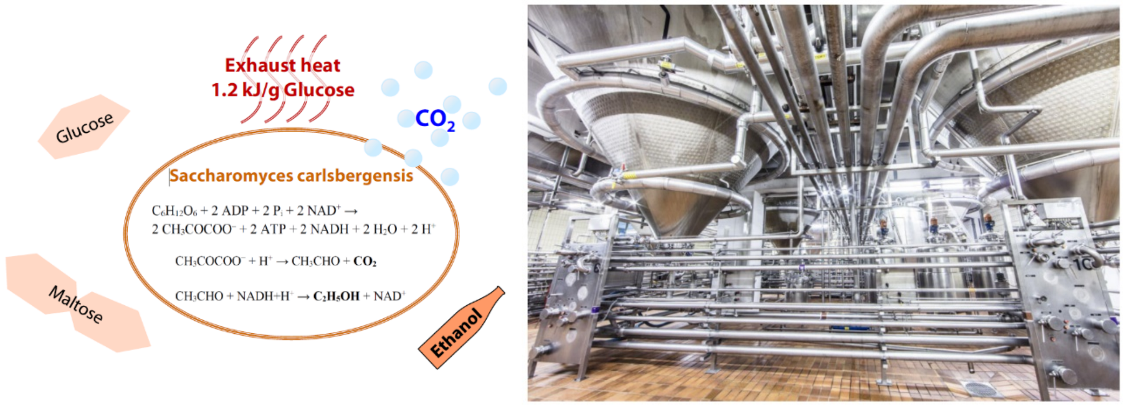


Figure 2-4: Chemical equation for the fermentation of glucose to ethanol and CO_2 (left) and the fermentation tanks at the brewery Puntigam (right) (Koglbauer and Zanker, 2018a)

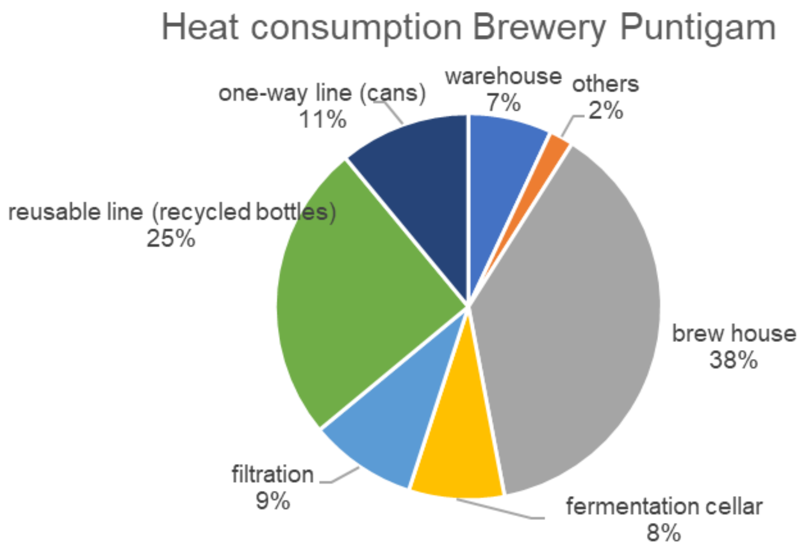


Figure 2-5: Division of the heat consumption of the brewery Puntigam (based on Brauerei Puntigam, 2019)

The young beer produced by the fermentation process is then stored in the storage tanks at a temperature of about 12 °C where a further post-fermentation occurs. In the winter months the storage tanks are cooled with ambient air, which reduces the electric energy consumption. The brewery process ends with the filtration of the beer and the filling for the transport.

Figure 2-5 shows a division of the heat consumption of the brewery Puntigam, which is distributed with 38 % to the brew house, with 25 % to the reusable line (recycled bottles), with 11 % to the one-way line (cans), with 9 % for filtration, with 8 % to the fermentation cellar and only

7 % for the heating of the warehouse. In the bottling (one-way line and reusable line), the filtration and the fermentation tanks heat is required for the automatic cleaning of the facilities (CIP-cleaning in place). CIP requires hot water at a temperature of 80 °C. Furthermore, these facilities are sterilized with hot water at a temperature of 85 °C. The reusable line requires more heat because the bottles have to be cleaned with lye at a temperature of 80 °C. Within the cleaning process of the bottles, a heat exchanger is used to preheat the lye with the sewage. The draining sewage has a temperature of 35 °C when it flows into the sewer system. The required heat input for the cleaning of the bottles is additionally influenced by the temperature of the delivered bottles (1 bottle has a mass of 380 g).

Hydraulic integration of the heat pumps into the cooling system of the brewery Puntigam and the district heating network of the "Brauquartier"

Figure 2-6 shows the hydraulic integration of the heat pumps into the cooling system of the brewery Puntigam and the connection to the district heating network of the "Brauquartier". Furthermore, the NH_3-refrigeration cycle and the cooling tower of the brewery Puntigam is shown.

The NH_3-refrigeration cycle uses 4 compressors, which reach a maximum cooling capacity of 1 460 kW (3 · 450 kW + 1 · 110 kW) at an evaporation temperature of about 0 °C. The maximum capacity which has to be removed from the condenser is about 1 800 kW and thus the efficiency (EER – energy efficiency ratio) is about 4.3.

A flooded evaporator is used with an NH_3-collector and a recirculation pump to circulate the liquid NH_3 between the collector and the consumers to take up heat. The evaporated NH_3 is sucked by the compressors at the head of the NH_3-collector and is compressed to high pressure.

At the high pressure side of the NH_3-refrigerant cycle the cooling tower is installed in parallel to the heat exchanger which is required to transfer the heat to the evaporators of the heat pumps via a brine cycle. The parallel arrangement ensures an operation of the NH_3-chillers independent of the heat pumps.

The cooling tower is an evaporative cooler and the NH_3 flows directly through the heat exchanger inside the cooling tower to minimize the condensation temperature of the NH_3-chillers. The evaporative cooler is designed to reach a cooling capacity of 2.2 MW and can be operated at three levels. At level one only the pump required for the water circulation is in operation, at level two an additional fan and at level three a second fan is activated. The levels are chosen in order to hold a certain condensation temperature of the NH_3-refrigeration cycle. The annual average of the condensation temperature is about 24.5 °C. The NH_3 is subcooled after the condenser by the use of well water and then collected in an NH_3-collector. Finally, it flows through the refrigerant throttle to the low pressure side and the refrigerant cycle is closed.

Figure 2-6 shows the connection of the heat pumps to the district heating network. The district heating water flows directly through the condensers of the heat pumps. Furthermore, there are two water storages each with a volume of 8 m^3 installed. An additional heat exchanger with a capacity of 2.5 MW is connected to the steam cycle of the brewery Puntigam which can be used to transfer heat to the supply pipes of the district heating network at peak load and as backup for the heat pumps.

The heating system of the "Brauquartier" is connected to the district heating network with a heat exchanger and 8 freshwater stations for hot water preparation are installed in different buildings. These components are not shown in Figure 2-6.

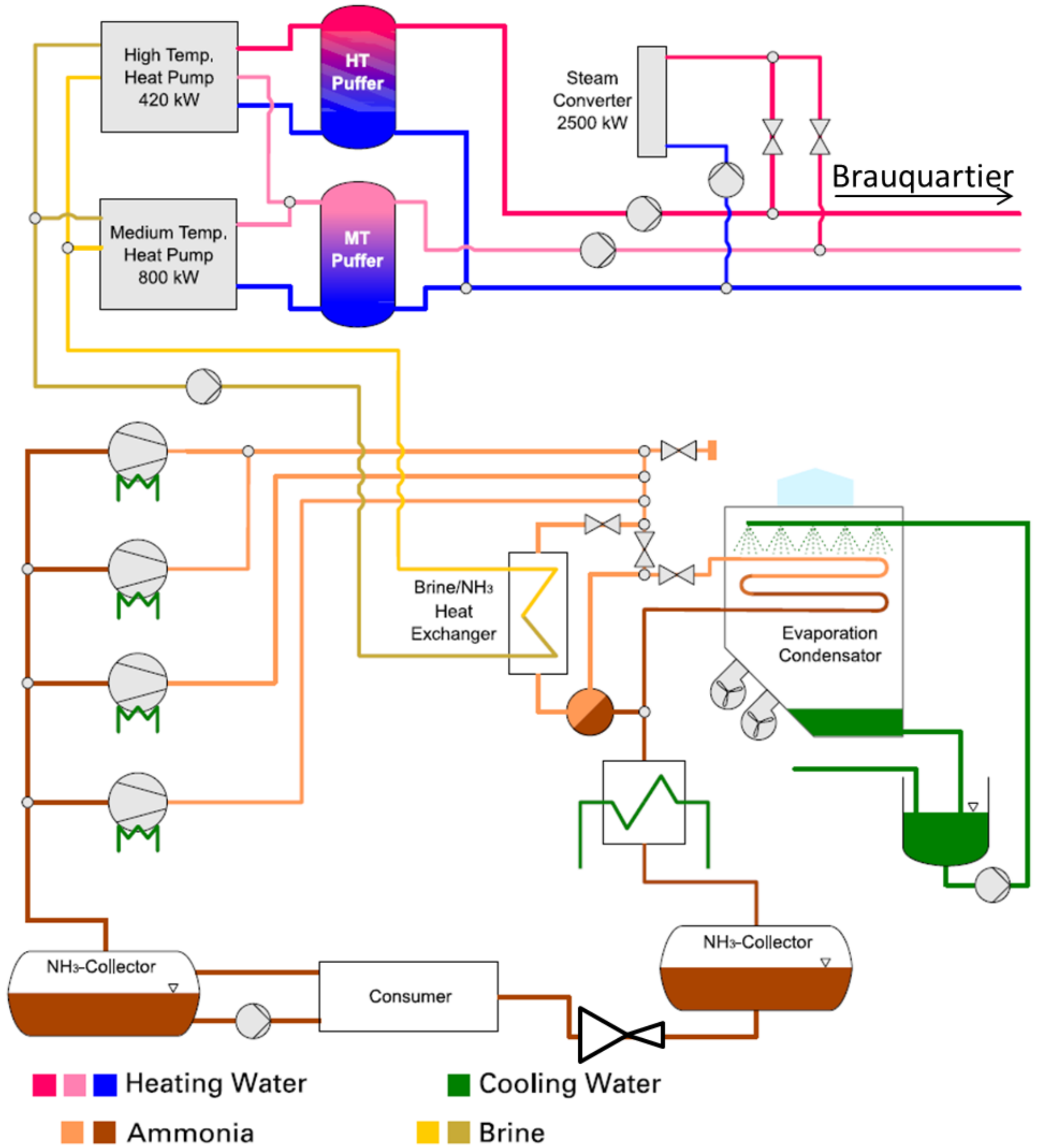


Figure 2-6: Hydraulic integration of the heat pumps to the cooling system of the brewery Puntigam and to the district heating network of the "Brauquartier" (Koglbauer and Zanker, 2018a)

Heat pumps

Both heat pumps were built by the company Frigopol Kälteanlagen GmbH and operate with the refrigerant R134a. Each heat pump consists of two parallel cycles with a compressor. The heat pump which is only used for the heating of the "Brauquartier" has a heating capacity of about 800 kW and reaches a COP of 4.7 at a district heating flow temperature of 46 °C and an inlet temperature of the brine in the range of 23 °C. The heat pump for hot water preparation has a heating capacity of 420 kW with a COP of 3.5 at a district heating flow temperature of 75 °C and an inlet temperature of the brine in the range of 23 °C. The hot water heat pump uses an additional heat exchanger for a sub cooling of the liquefied refrigerant which increases the efficiency. In the transition periods the hot water heat pump can be used for simultaneous

hot water preparation and building heating and thus the operating hours of this heat pump are increased.
The capacity control of the heat pumps is used to reach a desired flow temperature for the heating system of the “Brauquartier” in dependence of the ambient temperature. For hot water preparation the flow temperature is constant (75 °C) the whole year long. The heat pumps require one service a year, during this time the required heat is supplied via the heat exchanger which is connected to the steam cycle of the brewery Puntigam.

Challenges for heat pump applications

- The heat source has to be available the whole year long.
- There must be a central point for the extraction of the waste heat, which is used as heat source for the heat pumps.
- There must be a backup system, to ensure the heat supply even during a shutdown of the heat pumps or in the case of a failure of the heat source.
- A low temperature heating system and a separated supply of hot water and building heat are recommended.
- The utilization of synergies (simultaneous heating and cooling demand at the same location) enables the reduction of greenhouse gas emissions.

Heat pump facts

System

Sector:	Food industry
Process application:	Waste heat recovery
Location:	Graz (Austria)
Heat pump manufacturer:	Frigopol Kälteanlagen GmbH
Commissioning:	2018

Technology

Heat pump cycle:	compression, closed loop, each heat pump consists of two cycles	
Refrigerant:	R134a	
	Heat pump for hot water preparation	Heat pump for building heating
Compressor:	Piston compressor	Screw compressor
Condenser capacity kW:	420	800
Evaporator capacity kW:	300	670
Heat source inlet/outlet temperature in °C:	23/17	23/17
Heat sink inlet/outlet temperature in °C:	40/75	30/46
COP_H:	3.5	4.7
Operating hours:	In the final stage about 3200 annual operating hours	
Fossil backup system:	Steam generator	
Storage volume:	2 x 8 m^3	

Economic and ecologic effects

Investment costs:	1.5 Mio. € (total costs of the system)
Time for amortization:	10 years

Contact

Dipl.-Ing. Martin Unterfrauner
Kelag Energie & Wärme GmbH
+43 (50) 280 2989
martin.unterfrauner@kelagwaerme.at

Dr. Gerald Zanker
Brauerei Puntigam
+43 (316) 502 - 0
g.zanker@brauunion.com

Ao.Univ.-Prof. Dr. René Rieberer
TU Graz - Institut für Wärmetechnik
+43 (316) 873 7302
rene.rieberer@tugraz.at

Dipl.-Ing. Alexander Arnitz
TU Graz - Institut für Wärmetechnik
+43 (316) 873 7801
alexander.arnitz@tugraz.at

Literature

Koglbauer G., Zanker, G., 2018a, District Heating by Heat recovery from the Brewing Process of the Brewery Puntigam, Veröffentlichung, ISEC Sustainable Energy Conference 2018, Graz.

Koglbauer G., Zanker, G., 2018b, District Heating by Heat recovery from the Brewing Process of the Brewery Puntigam, Präsentation, ISEC Sustainable Energy Conference 2018, pp. 118-124, Graz.

Puntigamer, 2018, https://www.puntigamer.at/braukunst/, 07.11.2018

Compiled by A. Arnitz, R. Rieberer, Institute of Thermal Engineering, Graz University of Technology, 06.05.2019

2.2 Dairy Berglandmilch eGen/Tirol Milch Wörgl

Berglandmilch is the largest Austrian dairy with approx. 1500 employees at 10 locations. In 2017, around 1320 million kg of milk were processed, with a turnover of around € 910 million (Berglandmilch, 2018). Berglandmilch is owned by dairy farmers and markets milk and dairy products (brands such as Schärdinger, Tirol Milch, Stainzer and Lattella). At the Wörgl location, about 250 million liters of milk are processed annually, where all products of the Tirol Milch brand are produced. (Klimaaktiv, 2016)

Process heat and cooling are required in milk processing. Steam is used as a heating medium to reach the necessary temperatures and meet the hygienic requirements. A biomass boiler produces steam for the Wörgl site with a boiler output of 10 t/h. Refrigeration for raw material and product cooling is provided by ammonia compression chillers. In a joint project with Stadtwerke Wörgl, the waste heat with temperatures below 60-70 °C which can no longer be used economically in the dairy process, is fed into a newly constructed district heating grid. The district heating grid will be set up in several stages. Heat supply from Tirol Milch/Berglandmilch is the first stage, supplying around 25 % of the households in Wörgl. The heating grid has a capacity of approx. 13 MW and a pipe length of approx. 14 km.

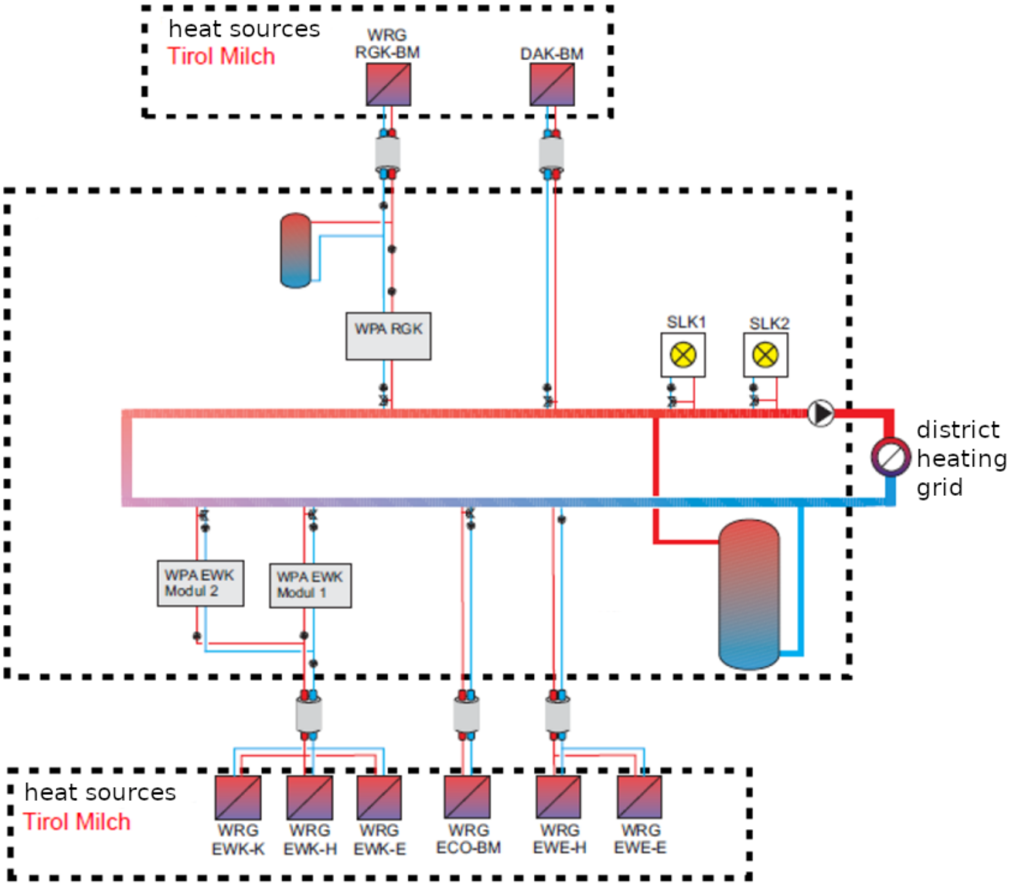


Figure 2-7: Hydraulic scheme of waste heat recovery and district heating grid (Klimaaktiv, 2016)

Direct heat utilization

A heat exchanger was installed in the biomass heating plant, which is used directly for district heating (WRG ECO-BM in Figure 2-7). Waste heat from the chillers is also directly integrated into the district heating supply, using the superheat from the refrigerant in the condenser (WRG EWE).

Heat pumps

Three Frigopol high temperature heat pumps were installed. The flue gas from the biomass heating plant is cooled and condensed in a heat exchanger. It is used as the heat source for the heat pump that provides the required temperature of 85 °C (WPA RGK). The other two heat pumps use the condensation heat of the refrigerant of the ice water chillers (WPA EWK). Each heat pump is equipped with two compressors arranged in two stages. They are compact screw compressors with speed control.

Heat pump for flue gas condensation (WPA RGK):

- Refrigerant R245fa, refrigerant charge 2 x 245 kg
- Two CSH screw compressors from Bitzer
- 1210 kW heating capacity, 930 kW cooling capacity
- Source inlet temperature 45 °C, outlet temperature 35 °C
- Sink inlet temperature 78 °C, outlet temperature 85°C
- COP: 3.9

The two compressors are arranged in two single-stage refrigeration cycles. The condenser and evaporator heat exchangers of the two stages are connected in series on the water side. The refrigeration cycle of the first stage has a higher evaporating temperature (37 °C) and a higher condensing temperature (88 °C). The evaporation temperature of the second stage is 32 °C, the condensation temperature is 84 °C. Both refrigeration cycles are equipped with a suction gas heat exchanger where the suction gas is superheated with the refrigerant coming from the condenser before compression.

Heat pumps for waste heat recovery of ice water chillers (data for one heat pump, WPA-EWK module 1 and 2):

- Refrigerant R134a, refrigerant charge 2 x 360 kg
- Two CSH screw compressors from Bitzer
- 1540 kW heating capacity, 1140 kW cooling capacity
- Source inlet temperature 27 °C, outlet temperature 22 °C
- Sink inlet temperature 58 °C, outlet temperature 78°C
- COP: 3.3

The two compressors are arranged in two refrigeration cycles. The two condenser heat exchangers are connected in series on the water side. The condensing temperature of the first stage is 71 °C, in the second stage it is 81 °C. The evaporators are arranged in parallel, the evaporation temperature of both stages amounts to 20 °C. There are also suction gas heat exchangers.

Figure 2-8: Frigopol high temperature heat pumps (Frigopol, 2018)

Why heat pumps?

For Berglandmilch/ Tirol Milch Wörgl, the resource efficient use of energy is an important concern. At the Wörgl site, intensive investments have already been made in increasing energy efficiency and in the use of renewable energies, e.g. through the construction of a biomass heating plant and a photovoltaic system. The waste heat, which cannot be used economically in the company's own operations due to the low temperature, can now be recovered due to district heating. Every year, 12800 MWh of waste heat are fed into the heating network, which makes an important contribution to the city of Wörgl's goal of reducing dependence on fossil fuels and being completely free of fossil energy by 2025.

Results and highlights

- Use of industrial waste heat in the heating network to supply 300 objects (25% of the households in Wörgl) with annual heating capacity of 25500 MWh/a
- Annual CO_2 savings of ca. 4530 t/a
- Annual cost savings of about 15000 €.
- Awarded with the klima:aktiv - environmental prize of the BMLFUW 2016 and the Energy Globe Tirol 2017

Heat pump facts

System

Sector:	Food industry
Process application:	Waste heat recovery
Location:	Wörgl (Austria)
Heat pump manufacturer:	Frigopol Kälteanlagen GmbH
Commissioning:	2015

Technology

Heat pump cycle:	compression, closed loop, each heat pump consists of two cycles	
	Heat pump for flue gas condensation	Heat pumps for waste heat recovery of ice water chillers
Refrigerant:	R245fa	R134a
Compressor:	Screw compressor	Screw compressor
Condenser capacity kW:	1210	1540
Evaporator capacity kW:	930	1140
Heat source inlet/outlet temperature in °C:	45/35	27/22
Heat sink inlet/outlet temperature in °C:	78/85	58/78
COP_H:	3.9	3.3

Economic and ecologic effects

Investment costs:	30000 € energy centre with heat pumps
Annual cost savings:	15000 €/a
CO_2 emission reduction:	4530 t/a

Contact

Frigopol Kälteanlagen GmbH, Johann Herunter, Alexander Baumhakel, Gamser Straße 21, 8523 Frauental

Stadtwerke Wörgl GmbH, Reinhard Jennewein, Othmar Frühauf, Zauberwinklweg 2a, 6300 Wörgl

Literature

Berglandmilch, 2018, www.berglandmilch.at 28.3.2018

Klimaktiv, 2016, Berglandmilch eGen / Standort Tirol Milch Wörgl, Best Practice Beispiel 2016 https://www.klimaaktiv.at/dam/jcr:337ea4ec-2f3f-47be-a606-06c547527ddd/Berglandmilch_Best%20practice_barrierefrei.pdf, 28.3.2018

Frigopol, 2018, Hochtemperatur-Wärmepumpen, http://www.frigopol.com/wp-content/uploads/54b8ce0cdfdd6.pdf, 28.3.2018

Compiled by V. Wilk, AIT Austrian Institute of Technology GmbH, status 22.07.2019

2.3 Meat and sausage production F. Krainer

Krainer is a renowned Styrian meat and sausage production company in Wagna. AMT Kältetechnik GmbH has installed a new CO_2 heat pump with a cooling capacity of approx. 600 kW and a heating capacity of 800 kW. It provides hot water at 60°C, which is used to clean the systems and for space heating. In addition, brine is produced at temperatures as low as -6°C to cool the raw materials and products, for the air conditioning and the maturing chambers.
It is a single-stage transcritical heat pump using CO_2 as refrigerant. The configuration is shown in Figure 2-9. The refrigerant is evaporated at low temperature and pressure in the evaporator and compressed to high pressure in the compressors. BOCK reciprocating compressors are used. The six compressors are connected in parallel; one of the compressors is controlled by a frequency converter in addition to the staged capacity control by switching on and off individual compressors. Supercritical refrigerant is present at the compressor outlet. In the two gas coolers, heat is transferred with gliding temperature, the pressure remains almost constant. The gas coolers are designed as plate heat exchangers. The first gas cooler supplies hot water at 60°C for heating purposes, the second is connected to a dry cooler. The refrigerant is expanded in the expansion valve and returns to the evaporator in liquid form. The evaporator is designed as a shell-and-tube heat exchanger.

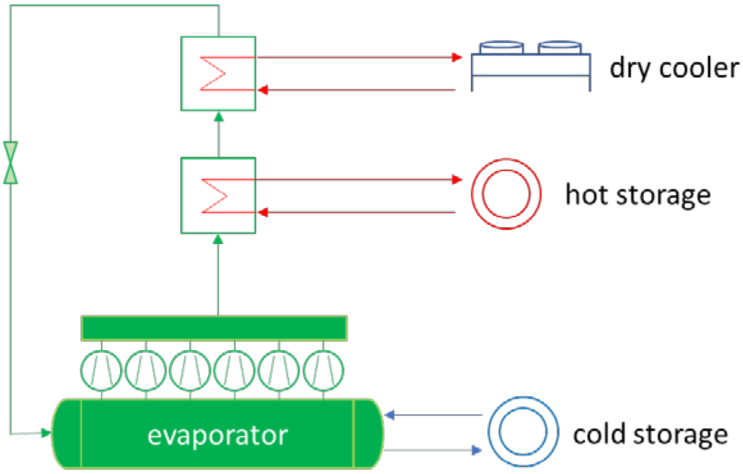


Figure 2-9: Schematic configuration of the CO_2 heat pump

Figure 2-10: CO_2 heat pump (Photo: AMT Kältetechnik GmbH)

Results

- Environmentally friendly refrigerant CO_2 (R744) with low global warming potential
- Annual CO_2 emissions savings of 467.13 t
- Commissioned in 2018
- Efficient operation due to the use of heat and cold

Heat pump facts

System

Sector:	Food industry
Process application:	Simultaneous heating and cooling
Location:	Wagna (Austria)
Heat pump manufacturer:	AMT Kältetechnik GmbH
Commissioning:	2018

Technology

Heat pump cycle:	compression, closed loop
Refrigerant:	R744 (CO_2)
Compressor:	Piston compressor
Heat source:	process cooling, air conditioning, maturing chambers
Heat sink:	hot water for cleaning purposes and space heating
Condenser capacity kW:	800
Evaporator capacity kW:	600

Economic and ecologic effects

CO_2 emission reduction:	467.13 t/a

Contact

David Kraxner, AMT Kältetechnik GmbH, Glatzau 58, 8082 Kirchbach, Austria

http://www.amt-kaelte.com/f-krainer-fleisch-und-wurstwaren-oktober-2017

compiled by V. Wilk, AIT Austrian Institute of Technology GmbH, status 16.07.2019

2.4 Power plant Wien Energie Simmering

Wien Energie GmbH is the largest energy supplier in Austria with over 2200 employees and an annual turnover of over 2 billion €. The annual investments amount to approx. 74 million €. Every year, around 2 million people, 230000 commercial and industrial customers and 4500 agricultural companies are supplied with electricity, natural gas, heating and cooling.

The Simmering power plant is located in the 11th district of Vienna. With around 1.2 GW_{el} and 1 GW_{th} of installed generation capacity, it provides electricity and heat to the City of Vienna. In addition to the gas and steam turbine plants, there is also a biomass power plant, a hydroelectric power plant and a photovoltaic plant operated there.

In 2018, a large heat pump was added, which uses the cooling circuit of the power plants as a source. The waste heat was previously transferred to the Danube Canal. When the power plants are shut down, operation with water from the Danube Canal as heat source for the heat pumps is also possible. Figure 2-11 shows a schematic representation of how the large heat pump is integrated into the power plant site.

The heat pump provides a thermal output of 27 - 40 MW_{th} with up to 95 °C outlet temperature. The temperature of the heat source is between 6 – 27 °C. The average COP is 3. The plant was commissioned at the end of 2018 and is expected to generate up to 150 GWh heat per year.

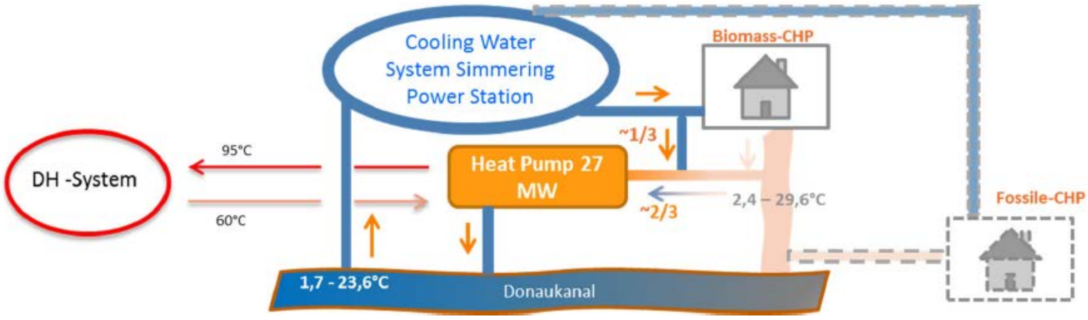


Figure 2-11: Integration of the large heat pump in Simmering (Segalla, 2018)

Figure 2-12 shows the functional diagram. The system consists of two identical compression heat pumps, which were installed by Friotherm. The refrigerant used is R1234ze.
The heat pumps are arranged in parallel on the source side. The evaporators are shell-and-tube heat exchangers with a total capacity of 18 - 27 MW. They are 12 m long, have a diameter of 1.8 m and each have approx. 2200 high-performance heat exchanger tubes made of CuNiFe alloy.

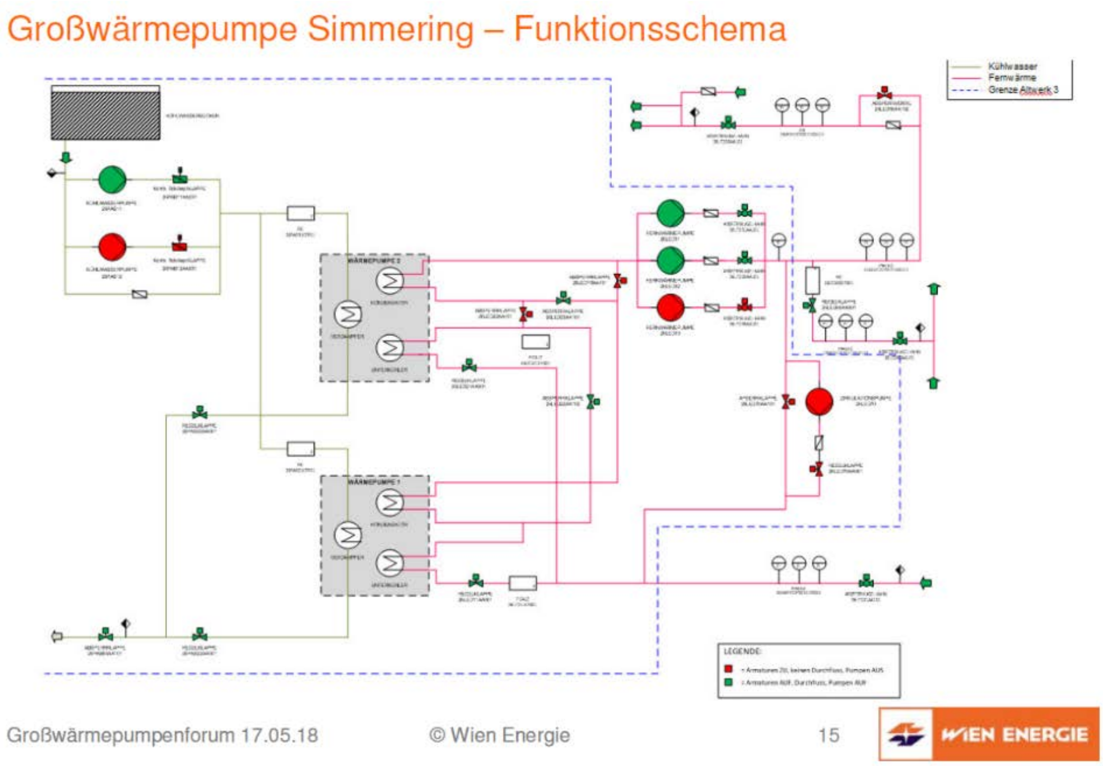


Figure 2-12: Functional diagram of the large heat pump (Segalla, 2018)

Each heat pump is equipped with a condenser and a subcooler. The district heating water first flows through both subcoolers in parallel, then through the condenser of the first stage, then through the condenser of the second stage. By changing the valve positions, the condensers can also be used in parallel. This allows the flow temperatures and output of the heat pump to be varied to make the best possible use of the heat pump.
Since the Vienna district heating network is operated with flow temperatures of up to 150 °C, the heat pump was integrated in a two-fold way: into a subnetwork with a lower operating

temperature and also into the high-temperature heating grid. The planning of the operation is carried out via the overall optimization of Wien Energie power plants. This heat pump is the largest in Central Europe and supplies the equivalent of 25000 households with district heating from waste heat and allows for 40000 tons of CO_2 savings per year. The investment for this plant amounts to € 15 million.

Figure 2-13: View of the large heat pump Wien Simmering (Segalla, 2018)

Figure 2-14: Evaporator (Club Wien, 2019)

Results and highlights

- Largest heat pump in Central Europe with up to 40 MW thermal output
- Supply of district heating equivalent to the heat supply for 25000 households
- Optimum integration into Wien Energie generation through flexible operation of the heat pump
- Use of waste heat from power plants and ambient heat from the Danube Canal

Heat pump facts

System

Sector:	Utility
Process application:	Waste heat recovery
Location:	Vienna (Austria)
Heat pump manufacturer:	Friotherm
Commissioning:	2018

Technology

Heat pump cycle:	compression, closed loop
Refrigerant:	R1234ze
Heat source outlet temperature °C:	95
Heat sink inlet temperature °C:	6-27
Condenser capacity MW:	27-40
COP_H	≈3

Economic and ecologic effects

CO_2 emission reduction:	40000 t/a
Investment costs:	15 000 000 €

Contact

Christoph Segalla, Projektleiter Großwärmepumpe Simmering, Wien Energie GmbH, christoph.segalla@wienenergie.at

Literature

Segalla, C., 2018, Power 2 Heat Anwendungen für das Fernwärmenetz, Großwärmepumpenforum Wien 2018.

Club Wien, 2019, https://club.wien.at/magazin/specials/stadtunbekannt-grosswaermepumpe-im-kraftwerk-simmering/, 16.6.2019

Compiled by V. Wilk, J. Krämer, AIT Austrian Institute of Technology GmbH, status 30.07.2019

2.5 Biomass cogeneration plant Klagenfurt-East

"The integration of an absorption heat pump in a biomass co-generation plant increases the efficiency and thus the amount of heat produced from biomass."

District heating network

The district heating network of Klagenfurt with a pipe length of about 165 km is operated by the Energie Klagenfurt GmbH and supplies about 27 000 connected customers. The flow temperature depends on the ambient temperature and varies between 85 °C and 120 °C. The volume flow rate of the district heating network is varied between 800 m^3/h and 1 600 m^3/h to hold the return temperature at about 60 °C. However, at low heating demand the return temperature may increase up to 80 °C.

A total of 90 % of the heating demand of the district heating network is supplied by three biomass cogeneration plants which are operated by the Bio-Energie Kärnten (Bioenergiezentrum GmbH). These are the biomass cogeneration plant Klagenfurt-East, Klagenfurt-South and Klagenfurt-North. The electrical and thermal capacities of these biomass cogeneration plants are summarized in Table 2-1. Since the biomass cogeneration plant Klagenfurt-East is in operation the existing natural gas cogeneration plant in the city center (34 MW_{el} and 120 MW_{th}) is only required to cover the peak load.

Table 2-1: Biomass cogeneration plants in Klagenfurt operated by the Bio-Energie Kärnten (Bioenergiezentrum GmbH) (Bioenergie Kärnten, 2018)

Location	Commissioning	Thermal capacity in MW_{th}	Electrical capacity in MW_{el}
Klagenfurt-South	2007	16	5
Klagenfurt-East	2017	50	10
Klagenfurt-North	2018 (expected)	20	5

Figure 2-15: New biomass cogeneration plant in Klagenfurt-East (Bioenergie Kärnten, 2018)

Steam cycle

Within the biomass cogeneration plant in Klagenfurt-East a biomass fired steam turbine cycle, a heat exchanger for direct flue gas condensation and an absorption heat pump for additional flue gas condensation are used to supply heat for the district heating network.

The steam turbine cycle uses a back-pressure turbine to produce electricity, it is arranged in parallel to a throttle for a variable power to heat ratio. At the inlet of the turbine, the steam has a pressure of about 65 bar (saturation temperature 280 °C) and a temperature of about 520 °C. A part of the steam mass flow is extracted from the turbine at medium pressure and condensed within the recuperator to preheat the boiler feed water. The low pressure level of the steam cycle is adjusted to reach the required temperature in the condenser of the steam cycle and to enable the required heat transfer to the supply water of the district heating network.

Absorption heat pump

The absorption heat pump was manufactured by the company EBARA (China) and was delivered in two parts with 70 tons each. The absorption heat pump uses H_2O/LiBr as working pair and reaches a heating capacity of about 20 MW and an efficiency of about COP_H=1.77 at heat source temperatures of about 45/35 °C (inlet/outlet of the evaporator), heat sink temperatures of about 60/70 °C (inlet of the absorber/outlet of the condenser) and driving temperatures of about 130/120 °C (inlet/outlet of the generator).
The evaporator of the absorption heat pump is connected to the heat exchanger for flue gas condensation with an additional hydraulic circuit. The volume flow rate within this hydraulic circuit is between 800 m^3/h and 1.000 m^3/h and the transferred heating capacity is about 7 – 8 MW.

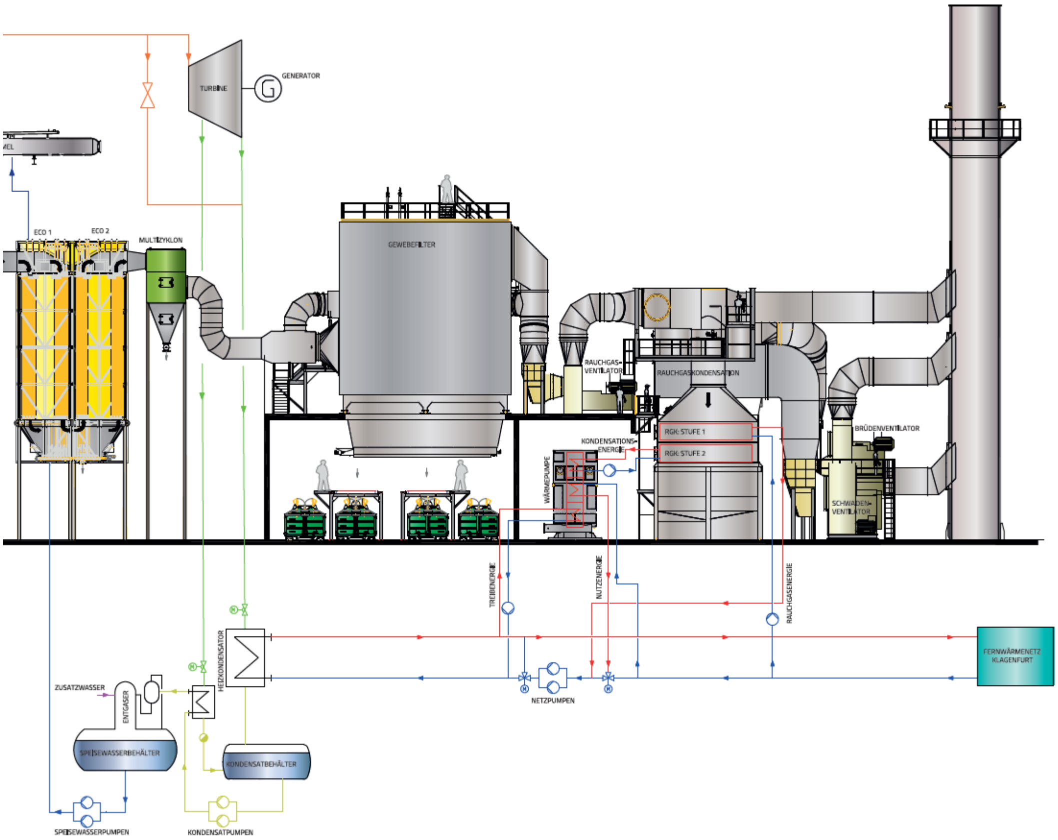


Figure 2-16: Hydraulic scheme of the biomass power plant including a part of the steam cycle and the connection to the district heating network (Bioenergie Kärnten, 2018)

The heat exchangers within the biomass cogeneration plant Klagenfurt-East are connected to the district heating network in the following order: From the return pipe of the district heating network a volume flow rate of about 60 - 100 m^3/h with a temperature of about 60 °C is pumped by an additional pump and heated (about 2.5 - 3 MW) by direct flue gas condensation to a temperature of about 65 °C. Furthermore, a variable volume flow rate, which can be adjusted by a three way valve (this volume flow rate is generally set as high as possible for best

efficiency of the absorption heat pump) is heated by the absorber and condenser of the absorption heat pump with a heating capacity up to 20 MW. The maximum possible temperature at the absorption heat pump condenser outlet is 77 °C.
After the parallel heating of the return flow by the heat exchanger for direct flue gas condensation and by the absorber and condenser of the heat pump the return flow is further heated by the condenser of the steam cycle to reach the desired flow temperature of the district heating network.
The optimum driving temperature for the absorption heat pump is about 130 °C at the inlet of the generator and the minimum possible driving temperature of the absorption heat pump is about 110 °C. The volume flow rate of the driving circuit is adjusted to reach a temperature difference at the generator of about 10 K. With the supply water of the district heating network as driving source and the minimum possible driving temperature an operation of the absorption heat pump is only possible if the flow temperature of the district heating network is higher or equal than 110 °C. This is in the winter months and in the transition periods.

Operating strategy

The overall operational goal of the system is to produce electricity at a constant power of 10 MW_{el} while the condensation temperature in the steam cycle is high enough to guarantee the required flow temperature of the district heating network. In order to achieve a constant electrical power output while the condensation temperature varies with the ambient temperature – to guarantee the required flow temperature – the steam mass flow through the turbine has to be adjusted. Keeping the overall operational goal in mind, the connection of an absorption heat pump to the condenser of a steam turbine cycle to produce heat within a district heating network leads to a beneficial operating characteristic. In times with high heating demand, especially in the winter months and in the transition period, the condensation temperature of the steam cycle is increased up to 133 °C. This leads to a lower pressure ratio within the steam cycle and thus a lower efficiency in electricity generation with the turbine. On the other hand, the higher condensation temperature increases the driving temperature of the absorption heat pump and thus increases the efficiency of the heat generation. In times with less heating demand, especially in the summer months, the condensation temperature of the steam cycle is reduced down to 85 °C which leads to a higher pressure ratio within the steam cycle and thus to a higher efficiency in electricity generation with the turbine, while the absorption heat pump is down because the driving temperature is too low.

Results and highlights

- Due to legal requirements related to the vapor clouds at the chimney of the biomass cogeneration plant an absorption heat pump was installed to increase the amount of flue gas condensation und thus to decrease the effort for devaporization.
- The integration of an absorption heat pump in a biomass cogeneration plant increases the efficiency and thus the utilization of biomass fuel.
- After the first two months the operation of the system is reliable and better than expected. Small changes as an adaption of the charge (H_2O/LiBr) and a thermal insulation of the absorption heat pump will improve the efficiency.
- A challenge is the fast capacity adjustment to cover the peak load in the morning and in the evening due to the systems inertia (biomass cogeneration plant and absorption heat pump). For example, the peak load in the morning increases the heating demand from 15 MW_{th} to 54 MW_{th} within 30 min.

Heat pump facts

System

Sector:	Utility
Process application:	Flue gas condensation
Location:	Klagenfurt (Austria)
Heat pump manufacturer:	Ebara
Commissioning:	2017

Technology

Heat pump cycle:	Absorption
Working pair	H_2O/LiBr
Heat source inlet/outlet temperatures in °C:	45/35
Driving temperatures in °C	130/120
Heat sink inlet/outlet temperatures in °C:	60/70
Condenser capacity MW:	20
COP_H	1.77

Economic and ecologic effects

Investment costs:	50 000 000 € (complete biomass cogeneration plant)

Project organisation

Energie Klagenfurt GmbH: operator of the district heating network
Bioenergie Kärnten (Bioenergiezentrum GmbH): operator of the biomass cogeneration plant Klagenfurt-East
Riegler & Zechmeister GmbH: engineering of the biomass cogeneration plant
S.O.L.I.D. Gesellschaft für Solarinstallation und Design mbH: supplier of the absorption heat pump

Contact

DI Markus Jeitler
Riegler & Zechmeister GmbH
jeitler@rz.co.at
+43 (0) 664 607 207 25

DI Moritz Schubert
S.O.L.I.D. Gesellschaft für Solarinstallation und Design mbH
+43 (0) 316 29 28 40-81
m.schubert@solid.at

Literature

Bioenergie Kärnten, 2018, https://www.bioenergie-kaernten.at/, 12.01.2018

Compiled by A. Arnitz, R. Rieberer, Institute of Thermal Engineering, Graz University of Technology, status 18.01.2018

2.6 Steel and rolling mill Marienhütte

„Due to the installation of two highly efficient large heat pumps, process waste heat from the steel and rolling mill Marienhüt-teGmbH can be used to deliver environmentally friendly heat to the existing district heating network in Graz as well as to the new low-temperature district heating network in the Reininghaus district of Graz. “

A long-standing cooperation between the two companies, the energy service provider and district heating network operator Energie Graz GmbH & Co KG and the steel and rolling mill Marienhütte GmbH, has resulted in a project that is economically viable for both partners and ecologically valuable for the Graz region. The core of this cooperation is the use of process waste heat from the steel and rolling mill “Marienhütte” for district heating purposes. This cooperation began in 1992 with the direct use of process waste heat at a temperature of up to 100 °C and was then continuously expanded. Due to the construction of a buffer storage facility the direct delivery of process waste heat to the district heating network was increased to about 60 GWh/year in the year 2011 (this is about 5 % of the heat supplied by the district heating network in 2017). A further expansion of this cooperation was inspired by the “Energie Graz” through the construction of a central energy station at the company site of the “Marienhütte” (see Figure 2-17) in 2015 and the commissioning of two heat pumps with a total heating capacity of up to 11.5 MW at this location in May 2016.

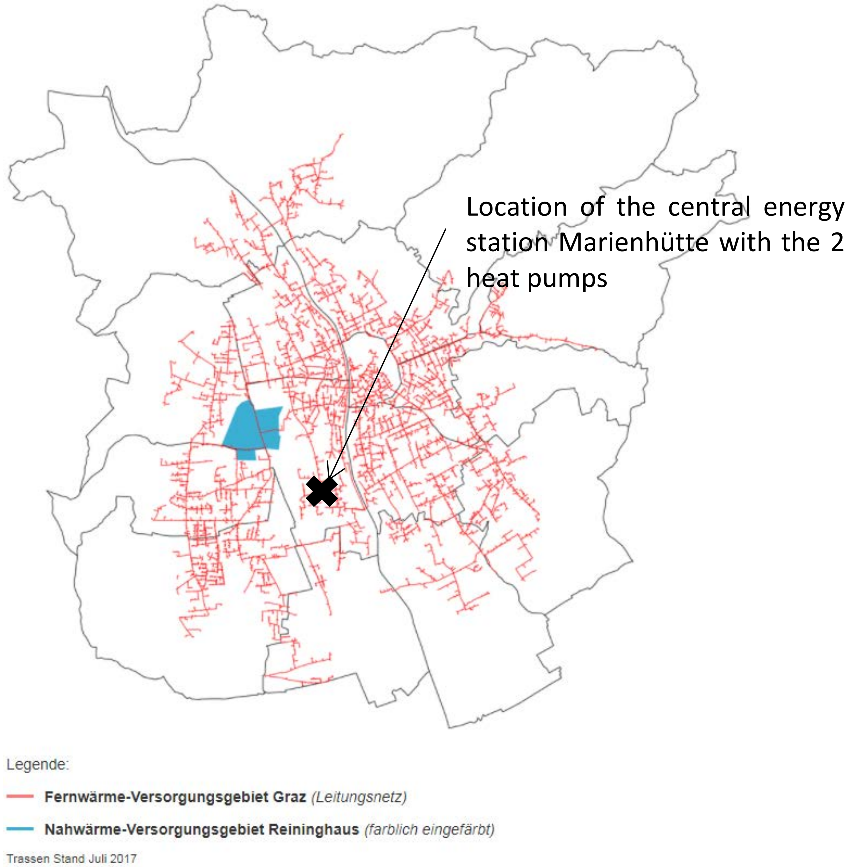


Figure 2-17: Existing district heating network in Graz with the location of the central energy station “Marienhütte” and the planned low-temperature district heating network Reininghaus (Energie Graz, 2017)

These heat pumps use process waste heat at a temperature of about 30 °C as heat source which otherwise cannot be used for district heating purposes. Since the commissioning of these heat pumps heat is delivered to the existing district heating network. In 2017, the construction of the new low-temperature district heating network in the Reininghaus district of Graz has started and the first part of a modular expandable thermal water storage tank was constructed including the hydraulic connection to the heat pumps. This storage tanks are integrated into an existing grain silo which was no longer in use ("Lechthaler Silo").
Energie Graz GmbH & Co KG ("Energie Graz") operates the district heating network in Graz (see Figure 2-17) and supplies around 65000 households with a heating demand of about 1200 GWh and a maximum heating capacity of 455 MW in the year 2017. The existing district heating network has a pipe length of about 790 km and is operated with a supply temperature in the range from 75 °C to 120 °C depending on the ambient temperature. The return temperature fluctuates between 55 °C in winter and 65 °C in summer, with an additional temperature fluctuation of up to 3 K during a day.
Furthermore, the apartments which will be built in the next years for about 12,000 inhabitants as part of the "Reininghaus" district development project will be supplied with heat from a new district heating network. This new district heating network will be operated with a supply temperature of about 70 °C and a return temperature of about 40 °C and will be "physically" decoupled from the existing district heating network. The required heat for this new district heating network will be provided mainly by the heat pumps commissioned at the central energy station in 2016. The modular, expandable thermal water storage tanks are used to bridge downtimes of the heat pumps. Furthermore, a heat exchanger is installed as a backup system to transfer heat from the existing district heating network to the new district heating network.
The **steel and rolling mill Marienhütte GmbH** ("Marienhütte") is the only manufacturer of ribbed structural steel in the form of bars or rings in Austria. Further products are plain bar steel and metallurgical ballast. In total about 400,000 tons of steel are produced per year. Electricity and natural gas are used as primary energy sources for the steel production. In the steel mill, only scrap is melted and casted into an intermediate product known as billets. In the next step these billets are rolled out in the rolling mill to various diameters. Figure 2-18 shows the available facilities attributed to the steel and rolling mill.

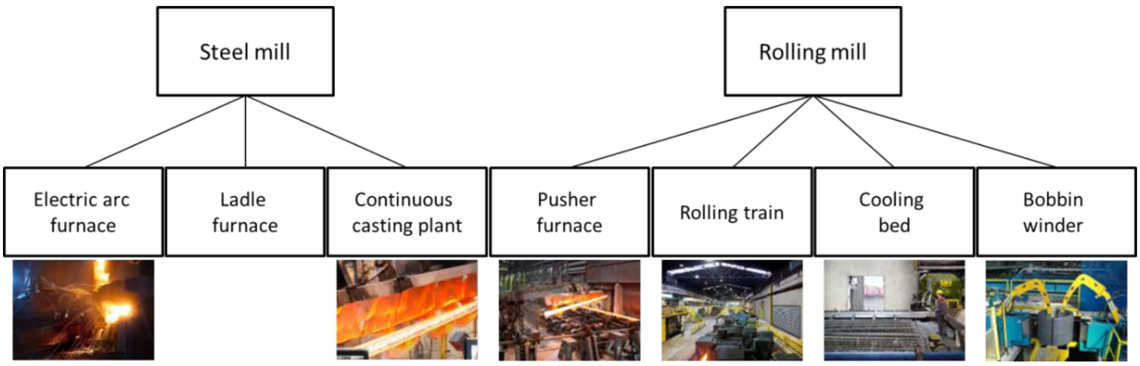


Figure 2-18: Production and manufacturing facilities in the "Marienhütte“ (Photo source: Marienhütte, 2018)

The "Marienhütte" uses only non-alloyed scrap as raw material for the steel production. The scrap is melted in the **electric arc furnace** (EAF) at a temperature of about 3500 °C, then the molten metal is metallurgically optimized in the **ladle furnace** and casted in the **continuous casting plant** at a temperature of about 1500 °C into the final product of the steelwork (billet 130 x 130 mm). The billets may be stored for the further use in the rolling mill or they may be

processed directly (without intermediate cooling) as a so-called "hot insert". This reduces the heat required for preheating and increases the energy efficiency in the production process significantly.
At the beginning of the production process in the rolling mill the cast billets are heated in the **pusher furnace** until the rolling temperature of about 1,150 °C is reached. The pusher furnace is fired with natural gas. The required combustion air is preheated with the heat of the exhaust gas in a recuperator to increase the efficiency of the furnace. The slide rails in the pusher furnace are cooled with cooling water to avoid thermal overloading of the material. The heat absorbed by the cooling water (temperature < 100 °C) is transferred to the district heating network. Then the billets are rolled in the **rolling train** into structural steel. In the next step the rolled bars are cooled in the **cooling bed** in the form of bars or in the **bobbin winder** in the form of coils. Finally, the material is packed and temporarily stored for transport.

The internal cooling circuits of the „Marienhütte“

The high temperature needed for steel production require active cooling to avoid overheating. For this purpose, three closed cooling circuits at high temperature (up to 100 °C) and two open cooling circuits at low temperature (about 30 °C) are used.
In two cooling circuits heat exchangers with a nominal capacity of about 30 MW are installed to deliver heat at a temperature of up to 100 °C directly into the existing district heating network. The first circuit (EAF 1) is used for the cooling of the electric arc furnace including the vessel and cover as well as the ladle furnace and in the second circuit (EAF 2) cools the hot gas pipe from the electric arc furnace (bend, post combustion chamber, pipe) and the slide rails of the pusher furnace. The individual devices are supplied in parallel with cooling water. These cooling circuits are required to avoid material overloading and to cool the exhaust gas pipes. The exhaust gas is filtered and cleaned in a dedusting system. The requirements for the control of the cooling system are rather low, the volume flow is controlled to a certain cooling water outlet temperature without a consideration of process variables (flue gas temperature, surface temperature, ...).
Another cooling circuit is used to cool the moulds in the continuous casting plant. The cooling of the moulds gives the steel strand a firm surface which is required to be taken up by the strand guiding system. In this closed cooling circuit, the temperature of the cooling water is about 90 °C. Cooling water flows through the moulds and the continuous casting plant in series. The cooling water volume flow is controlled to reach a certain surface temperature of the mould.
The rolling mill water management circuit (WaWi) is an open cooling circuit and is used for the open caliber cooling and the secondary cooling of the continuous casting. To remove the generated tinder from the cooling water, the cooling water is fed into a longitudinal clarifier in which the tinder can settle. Fine tinder is removed from the cooling water in a gravel filter before it enters the heat exchangers or cooling towers. The volume flow in this cooling circuit is controlled to reach a cooling water inlet temperature into the cooling bed below 29 °C.
Another open cooling circuit is used especially for the production of structural steel. In the "Marienhütte" structural steel is heat-treated with the so-called Tempcore® process (see Noville, 2015). After rolling, the rolling stock is quenched to a surface temperature of 200 °C and tempered again to a temperature of about 500 °C using the heat stored in the core of the rolling stock. The Tempcore® process requires additional cooling of the tempering section, which is supplied with cooling water parallel to the cooling bed. The cooling of the tempering section is decisive for the quality of the structural steel. The volume flow is controlled to reach a certain cooling rate of the rolling stock.

The hydraulic connection of the heat pumps

Figure 2-19 shows a simplified scheme of the hydraulic connection of the heat pumps to the heat source and sink. The heat pumps use process waste heat from the rolling mill water management (WaWi) circuit as a heat source. The connection to the evaporators of the heat pumps is realized using an additional circuit (MH-SK circuit) which is separated from the WaWi circuit with two heat exchangers (WT2). The water of the existing district heating network (FW circuit) or the water of the new low-temperature district heating network (NT-RH circuit) flows directly through the condensers of the heat pumps. In addition, the storage circuit and the heat exchanger (WT5) for the transfer of heat from the existing district heating network to the new low-temperature district heating network are shown.
The separation of the evaporator circuit from the WaWi circuit of the "Marienhütte" ensures an independent operation of the internal cooling circuits when the heat pumps are not in operation (e.g. in case of no heat demand, service of the heat pumps, etc.). In this case the heat transfer to the district heating network is interrupted and the process waste heat is dissipated to the environment using the existing cooling towers. With this integration concept the costs for the necessary heat removal from the "Marienhütte" are minimized while the heat pumps are in operation without any risk for the production process.

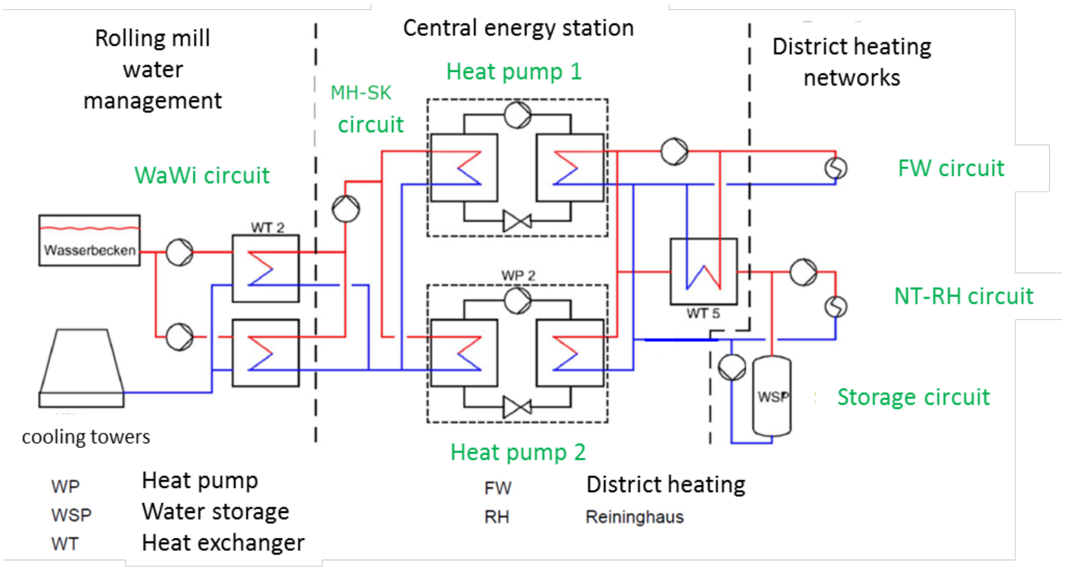


Figure 2-19: Hydraulic connection of the heat pumps to the WaWi cooling circuit of the steel and rolling mill and the connection to the existing and the new district heating network (simplified illustration) (Unger, 2018)

The evaporators of the two heat pumps are arranged in parallel and are supplied with heat via two heat exchangers (2 x 3.9 MW) which are also arranged in parallel. The evaporator inlet temperatures are between 32 - 35 °C and the evaporator outlet temperatures are between 25 – 29 °C. The circulating pumps and a mixing valve, which is not shown in Figure 2-19, can be used to control the temperature in the evaporator circuit (MH-SK circuit in Figure 2-19).
To deliver heat from the condensers to the existing district heating network, feed pumps are required which operate against the pressure difference between the supply and return pipe of the district heating network. In the existing district heating network, the pressure in the supply pipe is about 10.5 bar and the pressure in the return pipe is about 4 bar. When the heat pumps deliver heat to the new low-temperature district heating network, the flow through the condensers is provided directly by the pumps of the district heating network. Furthermore, a stor-

age charging pump is installed for the charging of the thermal water storage tanks (WSP in Figure 2-19).

The heat pumps

The installed heat pumps are two large heat pumps of the type Unitop produced by the company Friotherm. The dimensions of one heat pump are 8.2/3.7/3.3 m (L/W/H). One heat pump has a weight of about 30 tons and is filled with about 2 tons of the refrigerant R1234ze (GWP value lower than 1; see Bitzer, 2018). In each heat pump two turbo compressors are installed which can be operated in parallel or serial. A switching between parallel and serial operation is only possible during standstill. The maximum useful water temperature at the condenser outlet is 95 °C and can be reached in serial operation of the turbo compressors. In serial operation of the turbo compressors and temperatures at the condenser inlet/outlet of about 63/90 °C, a heating capacity of 3.3 MW per heat pump can be reached. In parallel operation of the turbo compressors and temperatures at the condenser inlet/outlet of about 43/69 °C, the maximum heating capacity increases to 5.75 MW per heat pump. The design temperatures at the evaporator inlet/outlet are about 33.8/29 °C in serial operation and about 33/25 °C in parallel operation. The heat pumps can also be used as cooling machines to deliver an optional cooling network (which is not realized yet).

Figure 2-20: Heat pump at the location of the „Marienhütte“ (Götzhaber et al., 2017)

The heating capacity of the heat pumps is controlled by the compressor speed, guide vane positions and the evaporation temperature. When the compressors are operated in parallel, the thermal output can be reduced to about 30 % and in serial operation the output can be reduced to 60 % of the design capacity.

Ideally the heat pumps are all year round in operation. When heat is delivered into the existing district heating network, it should be noted that the maximum useful temperature is 95 °C and at higher network supply temperatures the heat pumps have to be switched off to avoid a reduction of the supply temperature in the district heating network. In the new low-temperature district heating network Reininghaus the maximum supply temperature is 72 °C,

and in this case a year-round operation of the heat pumps will be possible with turbo compressors operating in parallel.
Every Sunday from 6 a.m. to 10 p.m., the "Marienhütte" shut down its production facilities for maintenance and cleaning work. To maintain the heat delivery to the low-temperature district heating network Reininghaus during this period, the thermal water storage tanks, the so-called "Lechthaler Silo", are used. If the storage capacity of these thermal water storage tanks would be insufficient, it is also possible to transfer heat from the existing district heating network to the low-temperature district heating network via a heat exchanger.

Advantages of the heat pump installation

- The start-up of the heat pumps takes about 20 minutes and a change of the heating capacity from 60 % to 100 % takes about 10 minutes.
- When switching from parallel to serial operation of the compressors, steady state conditions are reached again after 30 minutes.
- The installation of the heat pumps enables CO_2 savings of about 11389 tons of CO_2 per year compared to a heat generation with a natural gas heating plant assuming an idealized efficiency of 1 and annual full load hours of 5500 hours per year. The CO_2 emission factors used for this comparison were 0.248 kg/kWh_{el} for electricity and 0.24 kg/kWh_{Hi} for natural gas, according to data from the Umweltbundesamt (2018).
- The heat pump operation also has a positive effect on energy consumption in the "Marienhütte" by reducing the electrical consumption of the cooling towers.

Barriers for heat pump applications

Annual storage tanks are required for the realization of further heat pump projects in the district heating network of Graz. This is due to the low heat demand in summer which already can be covered completely by renewable energy and thus the consumption of the generated heat in summer has to be postponed until winter.

Experience, performance and operation

The efficiency of the heat pumps achieved during operation is above the contractually agreed value and the guaranteed heating capacity can be exceeded using the existing power reserves of the compressors.

Heat pump facts

System

Sector:	Metal processing
Process application:	Process waste heat
Location:	Graz (Austria)
Heat pump manufacturer:	Friotherm (Type Unitop 28CX-71210U)
Commissioning:	05/2016 (Heat delivery since 11/2016)

Technology

Heat pump cycle:	Compression, closed			
Refrigerant:	R1234ze			
Compressor:	Turbo-Compressor			
Condenser capacity in MW (4 guarantee points):	6,84	6,76	6,54	11,27
Evaporator capacity in MW (4 guarantee points):	4,83	4,7	4,78	8,79
Heat source in °C (4 guarantee points):	33,8/29	33,8/29	33,8/29	33/25
Heat sink in °C (4 guarantee points):	90/63	95/57	83,4/65	69/43
COP_H (4 guarantee points):	3,41	3,28	3,71	4,54
Operating hours:	8760-16*52=7.928 h (theoretical maximum)			
Backup system:	Cooling towers for the evaporator, existing district heating network for the condenser			
Storage volume:	source (no storage), sink (up to 1.840 m^3)			

Contact

Dipl.-WI (FH) Peter Schlemmer
Energie Graz GmbH & Co KG
+43 (316) 8057 1630
p.schlemmer@energie-graz.at

Dipl.-Ing. (FH) Helmut Unger
Energie Graz GmbH & Co KG
+43 (316) 8057 1632
h.unger@energie-graz.at

Dipl.-Ing. Herbert Fohringer
Stahl- und Walzwerk Marienhütte GmbH
+43 (316) 5975 201
gf@marienhuette.at

Ao.Univ.-Prof. Dr. René Rieberer
Institut für Wärmetechnik
TU Graz
+43 (316) 873 7302
rene.rieberer@tugraz.at

Dipl.-Ing. Alexander Arnitz
Institut für Wärmetechnik
TU Graz
+43 (316) 873 7801
alexander.arnitz@tugraz.at

ENERGIE GRAZ

TU Graz
Graz University of Technology
Institut für Wärmetechnik

Literature

Bitzer, 2018: Kältemittel-Report 20, https://www.bitzer.de/shared_media/ documentation/a-500-20.pdf, 15.11.2018

Energie Graz, 2017: https://www.energie-graz.at/egg/unternehmen/geschaftsbereiche/fernwarme/versorgungsgebiet, 10.01.2018

Götzhaber et al., 2017: Götzhaber, W., Meißner, E., Moravi, G., Prutsch, W., Schlemmer, P., Schmied, R., Slivniker, E., Zimmel, M., 2017, Wärmeversorgung Graz 2020/2030 – Wärmebereitstellung für die fernwärmeversorgten Objekte im Großraum Graz – Statusbericht 2017, Grazer Energieagentur Ges.m.b.H.

Marienhütte, 2018: https://www.marienhuette.at/technologie/herstellungsprozess/, 05.03.2018

Noville, 2015: Noville, J.F., TEMPCORE®, the most convienient process to produce low cost high strength rebars from 8 to 75 mm, Centre for Research in Metallurgy (CRM), Liège, Belgium

Schlemmer, 2017: Schlemmer, P., 2017, Energiemodell „Graz Reininghaus“, Präsentation, Fernwärmetage in Loipersdorf 09.03.2017.

Umweltbundesamt, 2018: http://www5.umweltbundesamt.at/emas/co2mon/co2mon.html, 16.10.2018

Unger, 2018: Unger, H., 2018, Energiemodell Reininghaus – Abwärmeauskopplung Marienhütte durch Energie Graz, Technischer Kurzbericht

Compiled by A. Arnitz, R. Rieberer Institute of Thermal Engineering, Graz University of Technology, status 15.11.2018

2.7 Sintering process at Plansee SE (Reutte)

The Tyrolean company Plansee is a leader in the field of high-performance materials and specialises in the manufacture of semi-finished products and products made of tungsten and molybdenum. Most production processes are heated with natural gas or are electrically driven, the waste heat generated is dissipated or recovered in cooling processes. A high temperature heat pump from Ochsner Energietechnik GmbH has been in operation for this purpose since 2013. It uses waste heat from the production plants and feeds it into the company's own district heating network, which is operated all year round. The heat pump contributes significantly to the company's target of consuming 20% less energy per kg of product. (Ochsner, 2016)

Figure 2-21: High temperature heat pump of Plansee AG (Fricke, 2016)

The waste heat from sintering furnaces for the production of sintered ceramics and sintered metal is used as heat source, these sintering processes run at 2000°C. Cooling water at 50°C is produced, which is fed to the heat pump. It is mixed with a partial flow of the return flow to achieve the required volume flow. The heat pump supplies water at 80-85°C for the district heating network. The integration of the heat pump into the sintering process is illustrated in Figure 2-22.

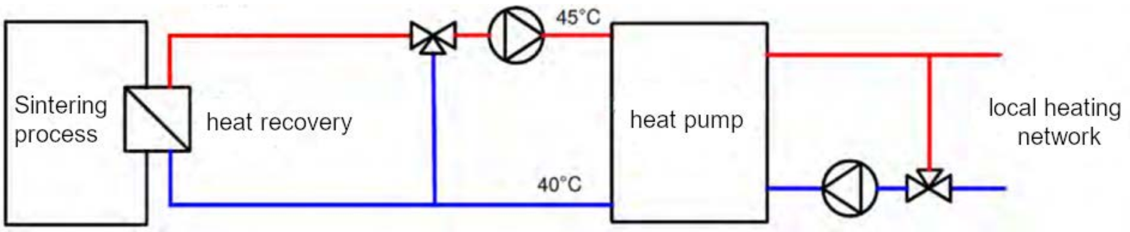


Figure 2-22: Integration of the high-temperature heat pump into the sintering process (based on Fricke, 2016)

The IWHS 400 ER3 heat pump is a single-stage machine shown schematically in Figure 2-23. The evaporator and condenser are designed as tube bundle heat exchangers, which are robust and insensitive to contamination. The compressor is a screw compressor, the refrigerant used is HFC ÖKO1 with low GWP. (Fricke, 2016)

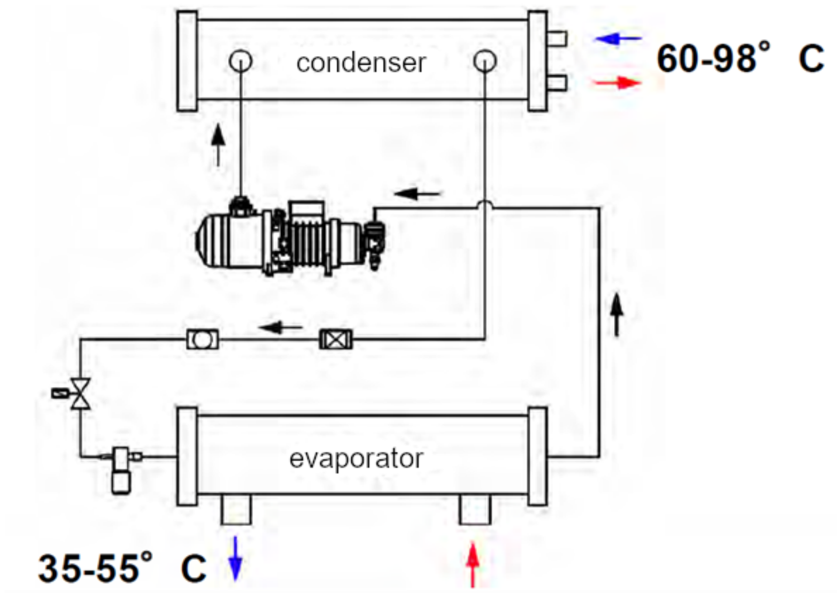


Figure 2-23: Schematic diagram of the single-stage high temperature heat pump (Fricke, 2016)

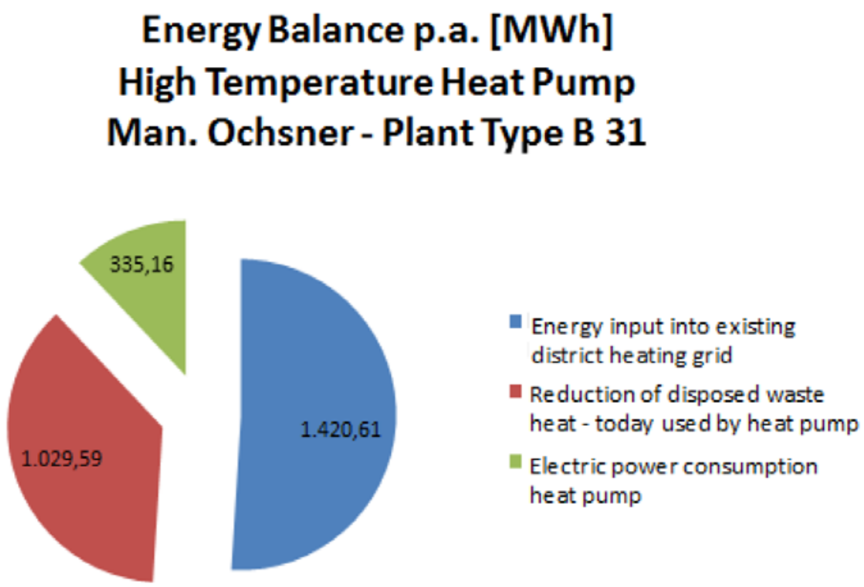


Figure 2-24: Annual energy balance of the high-temperature heat pump (Advantage Austria, 2014)

Figure 2-24 shows the annual energy balance of the heat pump. The electricity requirement is 335 MWh, therefore 1,421 MWh of process heat is supplied for the district heating network by using 1,029 MWh of waste hast. This corresponds to an average COP (coefficient of performance) of 4.24 in heating mode. Taking into account the savings in the cooling process, the heat pump achieves an even higher coefficient of performance.

The company expects to have fed a total of more than 7 GWh into the district heating network by the end of 2019. The investment costs are thus amortized, and the heat pump contributes to a favourable and sustainable energy supply.

Further heat recovery systems are planned in addition to the heat pump. The challenges will lie in designing the hydraulic coupling and control of the process systems. (Advantage Austria, 2014)

Results and highlights

- Commissioning in December 2013
- IWHS 400 ER3 with high temperature screw and ÖKO1 as refrigerant
- Feeding of 1 million kWh into the in-house district heating network and avoidance of 260 t CO_2 in the first 10 months (Plansee, 2014)
- Reduction of natural gas costs by 50 000€ in the first 10 months (Advantage Austria, 2014)

Heat pump facts

System

Sector:	Metal
Process application:	Process cooling
Location:	Reutte (Austria)
Heat pump manufacturer:	Ochsner Energietechnik GmbH
Commissioning:	2013

Technology

Heat pump cycle:	compression, closed loop, IWHS 400 ER3
Refrigerant:	ÖKO1
Compressor	Screw
Heat source inlet/outlet temperature in °C:	45/40
Heat sink inlet/outlet temperature in °C:	up to 85
Condenser capacity kW:	380
Evaporator capacity kW:	287
COP_H	4.24

Contact

Karl Ochsner, Ochsner Energietechnik GmbH, Ochsner-Straße 1, 3350 Haag, Germany
Wolfgang Schmidt, Plansee SE, Facility Management Supply

Link: http://ochsner-energietechnik.com/portfolio-item/plansee-reutte-a/

Literature

Fricke, 2016: M. Fricke, Großwärmepumpen: ein wichtiges Bauteil für Fernwärmenetze, Berliner Energietage 2016.

Ochsner, 2016: Ochsner Wärmepumpen, „Abwärme statt Abgas“, Machinery & Metalware, Herausgeber: Fachverband der Maschinen-,Metallwaren und Gießereiindustrie. 01/2016

Plansee, 2014: https://www.plansee.com/de/news-archiv/News/detail/neue-waermepumpe-spart-260-tonnen-kohlendioxid.html, 30.10.2014, access on 2.7.2018

Advantage Austria, 2014: http://www.advantageaustria.org/ro/oesterreich-in-romania/news/local/20141216_Plansee_Hochtemperaturwaermepumpe_eng.pdf, access on 2.7.2018

Compiled by V. Wilk, AIT Austrian Institute of Technology GmbH, status 18.08.2019

2.8 Injection moulding Bergs Kunststofftechnik

The injection moulding machines are cooled with cooling water that is supply via a heat exchanger using groundwater. The cooling water temperature amounts to 10 – 20 °C. The heat pump recovers the energy from the waste heat of the moulding machines and used the heated groundwater as the heat source. The heat pump provides hot water up to 60°C, which can be used to heat the office building, the production halls and a paint shop (Ochsner, 2018a). The heat pump integration is illustrated in Figure 2-21.
Heat pumps of this type achieve a COP_H of 4.3 at heat supply temperatures of 50 °C (Ochsner, 2018b). It is a single-stage heat pump using R134a as refrigerant. The compressor is a semi-hermetic compact screw compressor with variable control by a slider. Enhanced Vapor Injection (OVI) is used to increase the coefficient of performance, a schematic diagram shows Figure 2-22. A partial flow of the liquid refrigerant is expanded in an expansion valve after the condenser. It is evaporated in an economizer heat exchanger and fed back into the compressor at a medium pressure. The remaining refrigerant flow is thereby further subcooled in the economizer heat exchanger and expanded to evaporation pressure in another expansion valve. This refrigerant flow absorbs heat in the evaporator, evaporates and is compressed in the compressor. With Enhanced Vapor Injection, the compressor has a higher capacity at the same electricity consumption by compressing a larger mass flow.

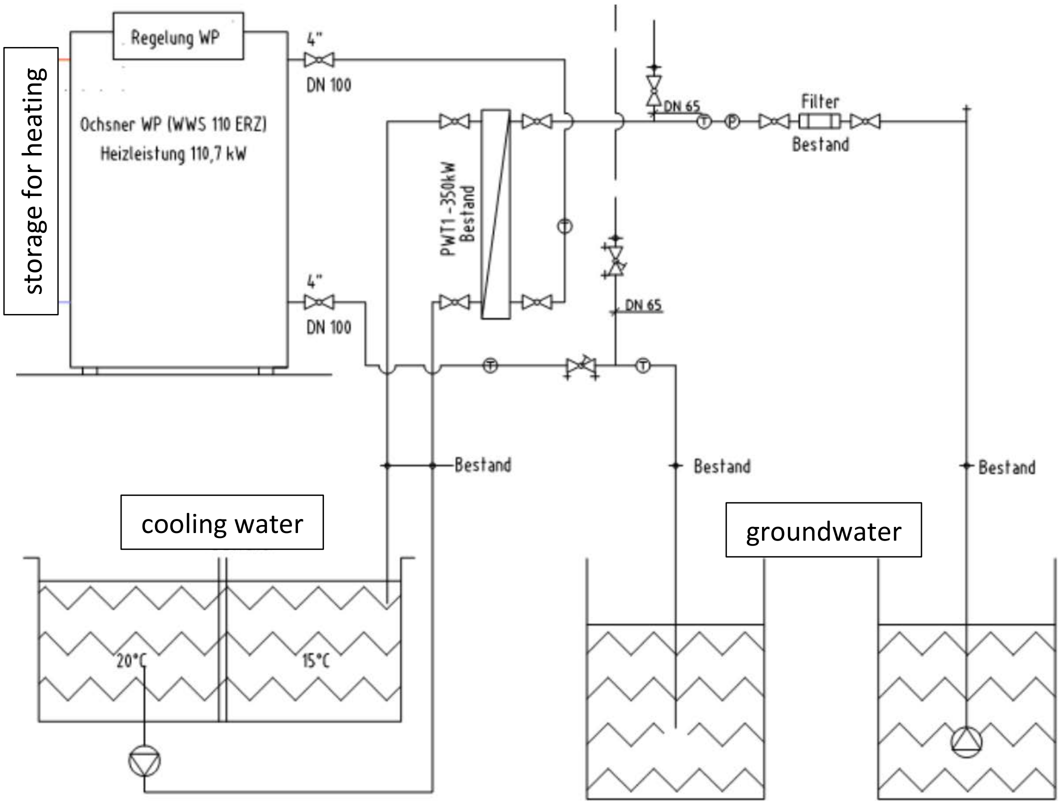


Figure 2-25: Heat pump integration for waste heat recovery for injection moulding (Ochsner, 2015).

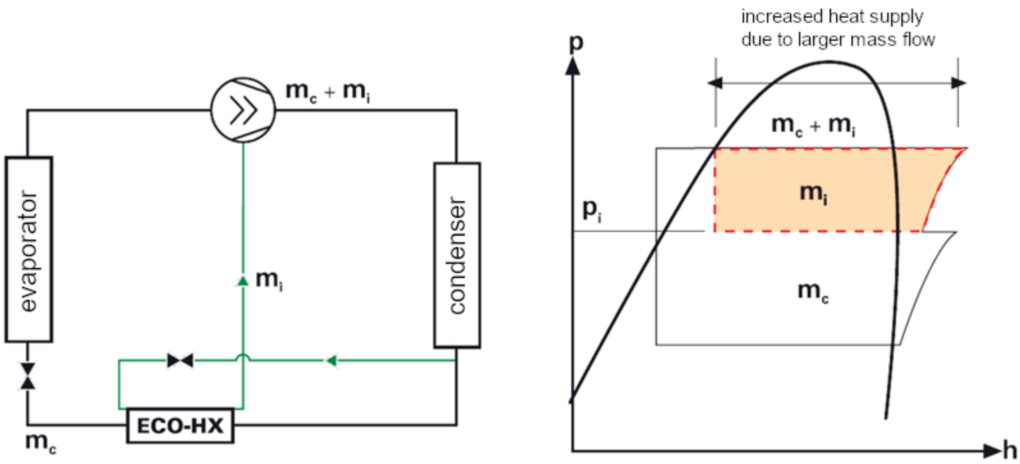


Figure 2-26: Enhanced Vapor Injection (OVI), (Ochsner, 2015)

Heat pump facts

System

Sector:	Plastic processing
Process application:	Waste heat recovery
Location:	Ennsdorf bei Enns (Austria)
Heat pump manufacturer:	Ochsner Energietechnik GmbH
Commissioning:	2010

Technology

Heat pump cycle:	compression, closed loop, IWWS110ER2
Refrigerant:	R134a
Heat source inlet/outlet temperature in °C:	20/10
Heat sink inlet/outlet temperature in °C:	up to 60
Condenser capacity kW:	110
COP_H	4.3

Contact

Karl Ochsner, Ochsner Energietechnik GmbH, Ochsner-Straße 1, 3350 Haag, Austria

Literature

Ochsner, 2018a, http://ochsner-energietechnik.com/portfolio-item/bergs-kunststofftechnik/, 02.07.2018

Ochsner, 2010, Application of large heat pumps for waste heat recovery and use of ambient heat, Presentation by Karl Ochsner sen. at EHPA 3rd European Heat Pump Forum, Brüssel, 2010

Ochsner, 2018b, http://ochsner-energietechnik.com/wp-content/uploads/2015/08/TI_MD_IWWS_R2_Industrie_W%C3%A4rmepumpen_DE_20160215_V04-Internet.pdf, 02.07.2018

Compiled by V. Wilk, AIT Austrian Institute of Technology GmbH, status 03.09.2018

2.9 EVER Neuro Pharma

EVER Pharma is a pharmaceutical company focused on the research, development, manufacture and marketing of special products in the fields of neurology, intensive care, anesthesia and oncology. The global headquarters are located in Unterach am Attersee in Salzburg, Austria. Complex injection preparations such as highly effective substances, crystal suspensions in vials, prefilled syringes, ampoules and implants are manufactured. The products are sold in more than 70 countries.

Heat pump

The machine is a flexible heat pump with three evaporators, two condensers and five piston compressors that can be operated independently of each other (Figure 2-27). The refrigerant used is R134a.

Key data

Manufacturer:	Viessmann/KWT
Type:	RV-WP-WW-6FE-50Y-5-1-S3-P-416
Heating capacity:	up to 502 kW
Cooling capacity:	up to 415 kW
COP:	up to 4
EER:	up to 5.06

The heat pump supplies heat and cold, which is used to condition the clean rooms. Figure 2-22 shows a simplified schematic representation of the integration of the heat pump.

Figure 2-27: Heat pump (Photo: Everpharma)

Cooling: For clean rooms, the outside air must be dehumidified in summer; for this purpose, the air is first cooled down and then heated; this cooling requirement is subsequently referred to as "cooling for air conditioning". Cooling for air conditioning has the highest priority to maintain clean room conditions. There are three different heat sources available for the heat pump evaporators:

- Well water (10/6 °C)
  Capacity: 229 kW, volume flow 54 m³/h
- Cooling for air conditioning (14/8 °C)
  Capacity: 431 kW, volume flow 61.64 m³/h
- Process cooling (30/12 °C)
  Capacity 311 kW, volume flow 14.89 m³/h

Heating: Heating is required for the ventilation systems with a flow temperature of 55°C. When the heating buffer tank is fully charged, the heat is released via the recooling unit. Therefore, there are two consumers on the heat sink side of the heat pump (condenser of the heat pump):

- Hot storage tank for space heating (40/55 °C)
  Capacity 502 kW, volume flow 29.14 m³/h
- Recooling unit (27/32 °C)
  Capacity 498 kW, volume flow 94.77 m³/h

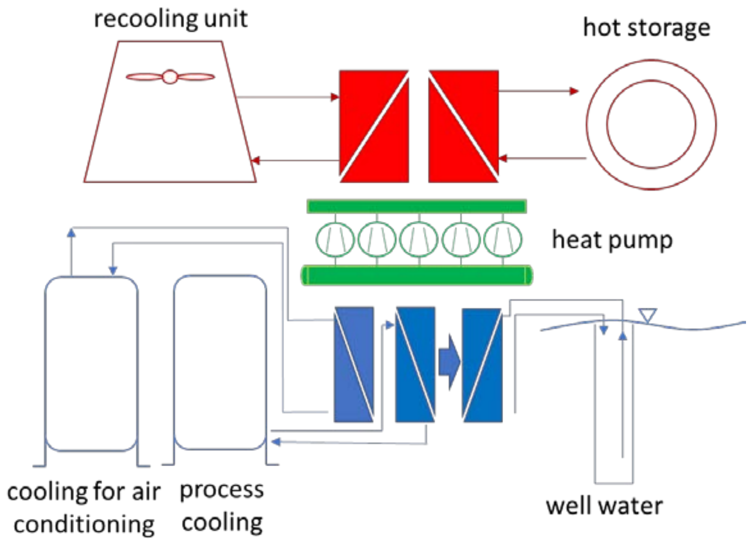


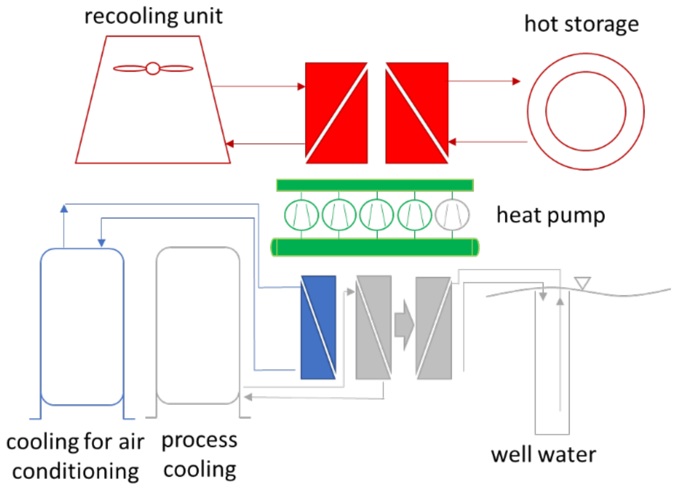
Figure 2-28: Simplified representation of the integration of the heat pump

Operation strategy

The heat pump can be operated flexibly in six different operating modes, which are described in the following.

Air conditioning / heating / residual heat (cooling operation):

The heat pump charges the hot storage and cold storage for air conditioning. Once the hot storage tank is charged, excess heat is released to the environment via the recooling unit. The focus is set on covering the cooling demand. In this operating mode, four compressors are used. An EER (energy efficiency ratio, ratio of cooling capacity to electrical capacity) of 4.6 is achieved.



Cooling capacity: 400 kW

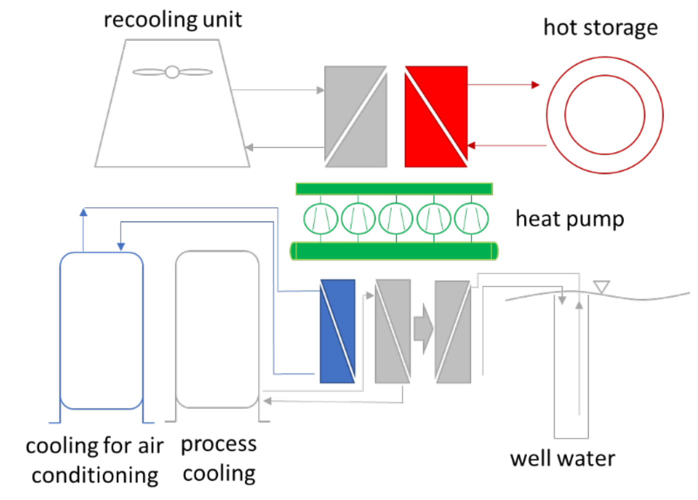
Heating capacity: 50 kW

Electricity consumption: 86.4 kW

EER: 4.62

Air conditioning / heating (heat pump operation):

The hot and cold storage tanks are charged (heating and air conditioning), the recooling unit is not active. In this operating mode, five compressors are in operation. A COP (coefficient of performance) of 3.68 is achieved.



Cooling capacity: 365.5 kW

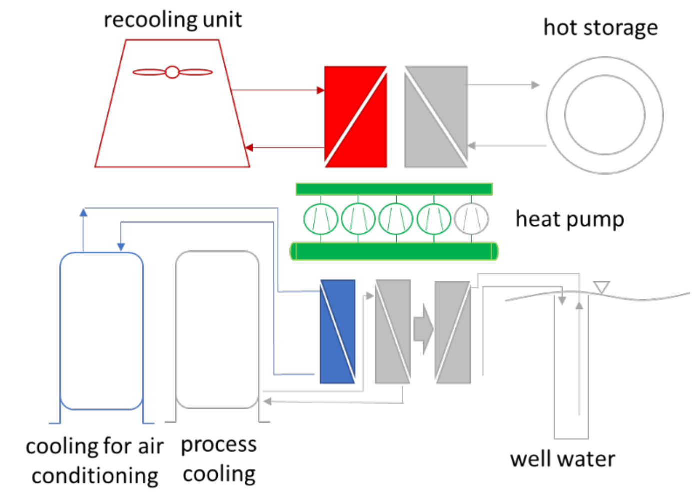
Heating capacity: 502 kW

Electricity consumption: 136.5 kW

COP: 3.68

Air conditioning / residual heat (cooling operation):

The heat pump charges the cold storage tank, the focus is set on providing cooling. No heat is used, the recooling unit is active. In this operating mode, four compressors are in operation.



Cooling capacity: 415.2 kW

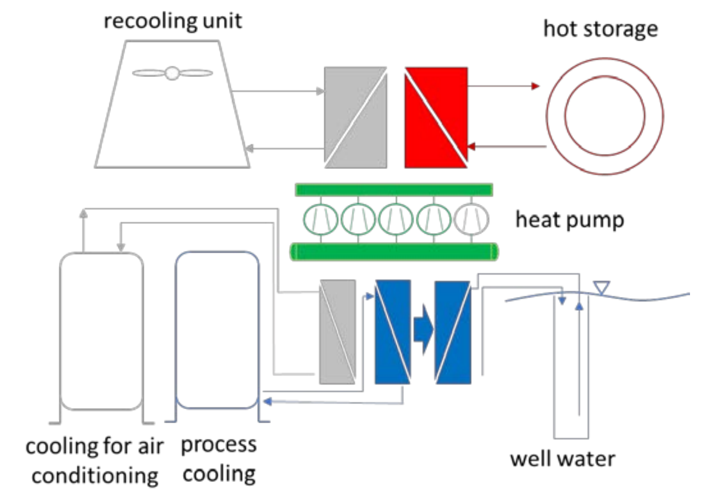
Heating capacity: -

Electricity consumption: 82.0 kW

EER: 5.06

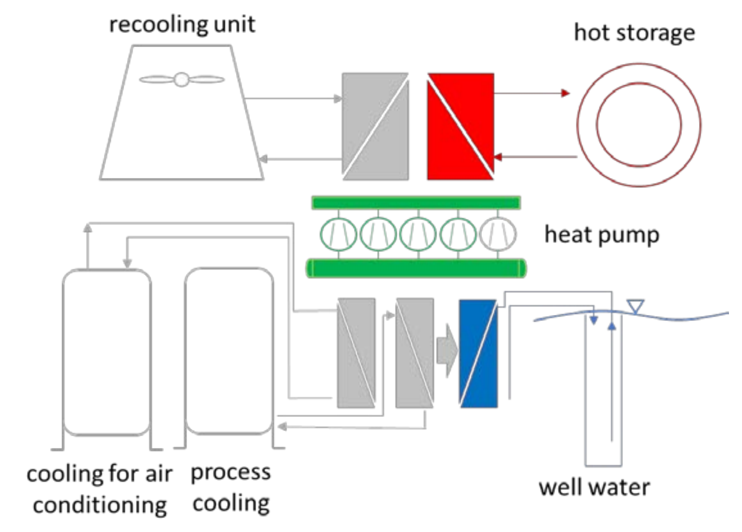
Heating / process cooling (heat pump operation):

The hot storage tank is being charged. The heat pump uses process cooling (machine cooling) as heat source. If the process waste heat is not fully used, well water is used for cooling. If not enough waste heat from machine cooling is available to cover the heating demand, one of the gas boilers is switched on.

	Cooling capacity: 317.5 kW Heating capacity: 423.7 kW Electricity consumption: 106.4 kW COP: 3.98

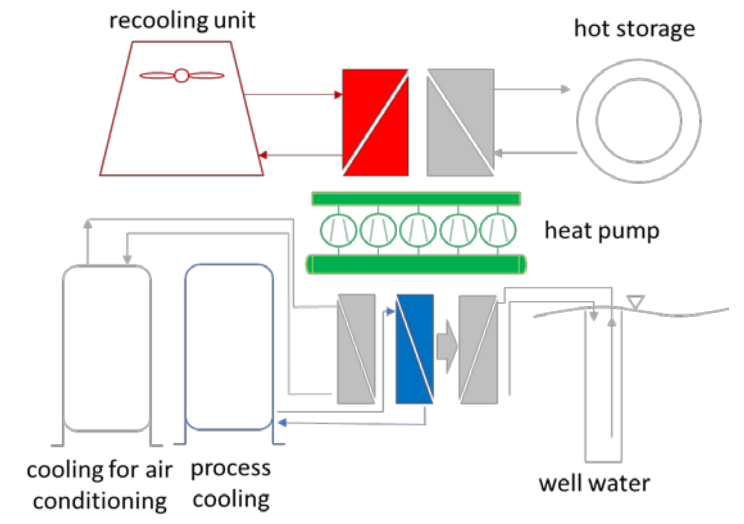
Heating / well water (heat pump operation):

The heat pump charges the hot storage tank, the recooling unit is not active. Well water is used as the heat source. If the heating capacity of the heat pump is not sufficient, one of the gas boilers is switched on.

	Cooling capacity: 234.2 kW Heating capacity: 329.3 kW Electricity consumption: 106.4 kW COP 3.46

Process cooling (cooling operation):

This operating mode is an emergency mode if no well water is available for process cooling. To prevent the closed cooling circuit from heating up further, the heat pump supplies the required process cooling. The provided heat is dissipated in the recooling unit.



Cooling capacity: 317.5 kW

Heating capacity: -

Electricity consumption: 82.0 kW

EER 5.06

Results and highlights

- Due to the large number of operating modes, the heat pump is fully utilised in summer and winter.
- Operation has been almost trouble-free and required low maintenance since 2015. The redundant compressors ensure a high level of operational reliability.
- The possibility of process cooling by the heat pump offers a further safety measure if the well cooling is not available for direct cooling.

Heat pump facts

System

Sector:	Pharmaceutical industry
Process application:	Waste heat recovery, air conditioning
Location:	Unterach (Austria)
Heat pump manufacturer:	Viessmann
Commissioning:	2015

Technology

Heat pump cycle:	compression, closed loop
Refrigerant:	R134a
Heat source inlet/outlet temperature in °C:	process cooling (30/12) cooling for air conditioning (14/8) well water (9/5)
Heat sink inlet/outlet temperature in °C:	40/55
Condenser capacity kW:	502
COP_H	up to 4

Contact

Gerhard Emhofer, Manfred Nussbaumer, EVER Neuro Pharma GmbH, Oberburgau 3, 4866 Unterach am Attersee

gerhard.emhofer@everpharma.com, manfred.nussbaumer@everpharma.com

www.everpharma.com

Compiled by J. Krämer, V. Wilk, AIT Austrian Institute of Technology GmbH, status 22.07.2019

2.10 P&G Health Austria

P&G Health Austria GmbH& Co. OG is a manufacturer of pharmaceuticals and nutritional supplements. At its production site in Spittal an der Drau, around two billion tablets are produced annually. This plant is P&G's global competence center for solid and semi-solid pharmaceuticals and food products with more than 400 employees. P&G Health Austria GmbH& Co. OG belongs to the US consumer goods company Procter & Gamble, which is represented in 70 countries and is headquartered in Cincinnati, Ohio. By 2030, P&G intends to generate a large part of the required energy from renewable sources.

Process description

Heating for pharmaceutical production at the Spittal/Drau plant is provided by heat exchangers in the ventilation system. These heat exchangers are supplied with hot water by two gas boilers and a heat pump. Cooling is also provided centrally, it is used for air conditioning in production, packaging and storage area. For this purpose, the ambient air is cooled and partly dehumidified. Production processes also require cooling. Process heat for production is provided by two steam boilers fueled with natural gas.

Cooling

Cold water for the cooling circuit is generated by several chillers: a Cofely chiller, type Quantum B 120P4C with a cooling capacity of 1 MW, a Daikin chiller, type EWLDC14I-SS with a cooling capacity of 1179 kW, and an air-cooled Climaveneta chiller with a cooling capacity of around 250 kW. The total available cooling capacity of the main systems is approx. 2.5 MW. The capacity of the chillers can be controlled in the range from 25% to 100%. During the summer months (May to September), the cooling circuit is operated with a flow temperature of 2°C and a return temperature of 7°C. In the winter months (September to May), the flow temperature is 6°C and the return temperature 11-12°C. The lower flow temperature in summer is required to dehumidify the air for the ventilation system. Before the integration of the heat pump, the condensation heat of the chillers was removed in a cooling tower.

Heating

Two gas boiler systems supply hot water with a flow temperature of more than 70°C.

Heat pump

A heat pump is integrated, which uses the waste heat generated by the chillers. The heat source is cooling water with a temperature of 20 to 30°C. The return water from the gas boiler system is used as the heat sink and is heated from around 40 to 60°C. Figure 2-23 shows a simplified scheme of integration.

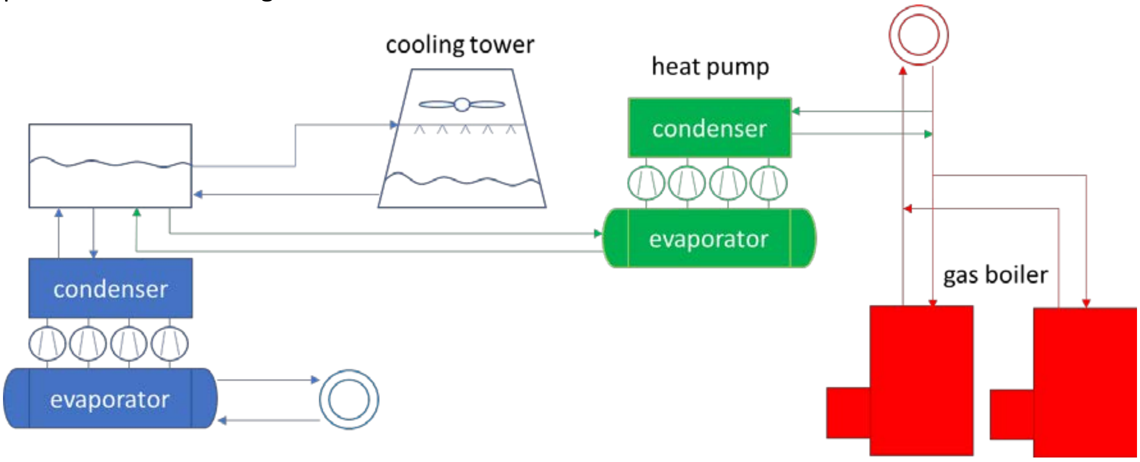


Figure 2-293: Simplified diagram of the integration of the heat pump into the heat and cold supply.

The heat pump was provided by Schiessl (type KEOS EV3BO-HGX6). In the design case, the heat pump recovers 375 kW of heat and delivers 506 kW to the heating system, the COP is 4.59.
R-134a is used as refrigerant, the system is equipped with three semi-hermetic reciprocating compressors (Figure 2-24).

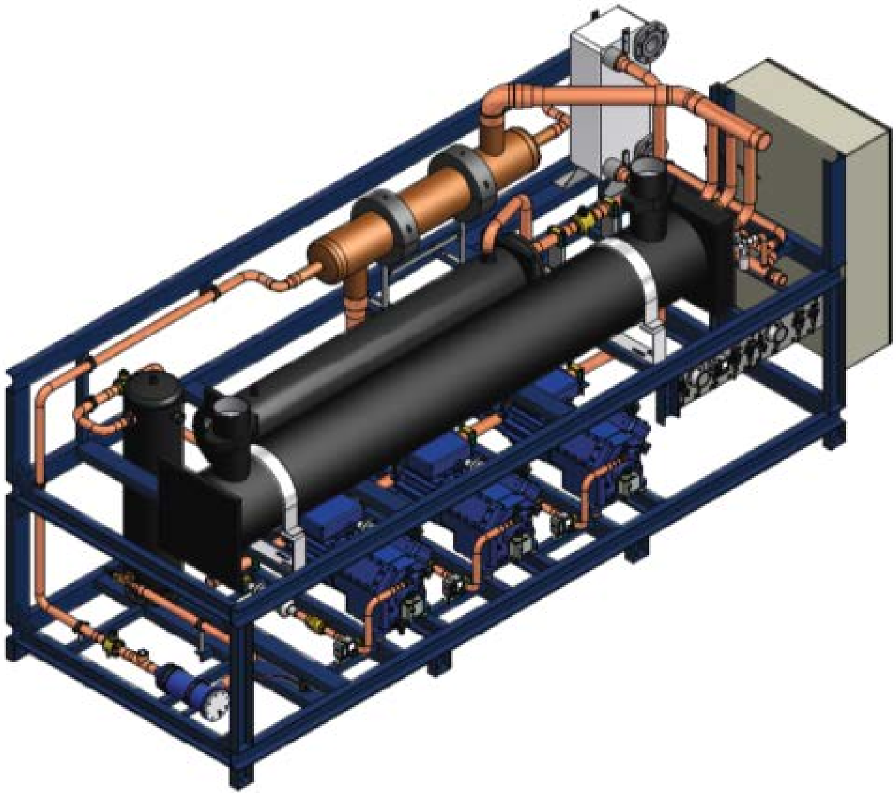


Figure 2-304: 3D layout of the heat pump

Experiences with the operation of the plant:

- Successful operation of the plant since 2016
- The heat pump reduces the operating costs of the cooling tower by 50% (electricity, chemicals, etc.). In addition to cost savings, water consumption has also been significantly reduced.
- The heat pump reduces the load of the gas boiler system, which leads to a saving in fuel consumption and thus to a reduction in greenhouse gas emissions.

Heat pump facts

System

Sector:	Pharmaceutical industry
Process application:	Waste heat recovery, air conditioning
Location:	Spittal an der Drau (Austria)
Heat pump manufacturer:	Schiessl
Commissioning:	2016

Technology

Heat pump cycle:	compression, closed loop
Refrigerant:	R134a
Compressor:	Piston compressors
Heat source inlet/outlet temperature in °C:	30/20
Heat sink inlet/outlet temperature in °C:	40/60
Condenser capacity kW:	506
COP_H	up to 4.6

Economic and ecologic effects

Payback time	5-6 years

Contact

Daniel Campanella, P&G Health Austria GmbH&Co. OG, Hösslgasse 20, 9800 Spittal an der Drau, campanella.d@pg.com

Compiled by J. Krämer, V. Wilk, AIT Austrian Institute of Technology GmbH, status 21.06.2019

3 Summary

A total of 68 applications of industrial heat pumps were collected in Austria. Among them, eight application examples are presented in detail in this report. They cover the industrial sectors that have shown the highest suitability for heat pumps so far, such as food industry, utilities, metal processing, plastics processing and pharmaceutical industry.

The majority of the examples are brown field installations, where the heat pumps have been integrated in an already existing process. In the food industry, heat recovery from refrigeration equipment is an important heat source and is described in two examples. Also, simultaneous heating and cooling occurs frequently in the food industry. One of the examples shows, how both sides of the heat pump are used in a beneficial way.

Another important heat source is flue gas condensation. There are two examples for flue gas condensation with heat pumps, one using an absorption heat pump and the other using a compression heat pump. The main aim is to further utilize the energy content of the fuel (biomass).

Reducing the amount of heat that has to be dissipated in recooling units, cooling towers or cooling baths is another motivation to integrate a heat pump. There are several examples provided that range from smaller scale with several 100 kW used for on-site heating to large capacities that are supplied to district heating grids.

All the selected heat pump application examples prove to have positive effects both in terms of energy cost reductions and environment impact. They also show high multiplication potential to other applications and sectors.