Industrial Heat Pumps, Second Phase

IEA Heat Pump Programme Annex 48

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

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Contents

1 Selection of 7 best practice examples

A total of 31 cases from Germany were considered in the framework of IEA HPT Annex 48. The decision which of these a “best practice” one was taken according by the following criteria:

- A good example for the application
- High efficiency
- High energy saving
- High reduce of CO_2-emissions
- A “lighthouse-project”.

The chosen projects are:

- Cafeteria in Soest (Commercial)
- Emil Frei in Bräunlingen (Chemical)
- Ludwig Michl in Waakirchen (Machinery)
- Purkart Systemkomponenten in Großrückerswalde (Machinery)
- Tivoli Malz in Hamburg (Food)
- District Heating Bergheim I (District Heating)
- Swiss Krono in Heiligengrabe (Machinery).

2 Description of best practice examples

2.1 Cafeteria in Soest

Using the example of the cafeteria at the University of Applied Sciences Soest with year-round warm water and occasionally heat supply by heat pump, 25 % of heat costs are saved to the utmost satisfaction of the customer. Furthermore, the environmental impact was reduced to approximately 50 %.

Cafeteria Soest	
Industry	Commercial
Application	Cafeteria
Process applied	heating/hot water supply
Location	Soest, Germany
Year of installation	2011
User (company)	University of Applied Sciences
HP manufacturer	Thermea, D
Contractor	n. a.
Consultant	n. a.
HP technology	MHP
HP system	water cooled chiller
Working fluid	R.744
Compressor	Screw
Heating/Cooling capacity (kW)	52.7/39.1
Supply temperature (°C)	80
Heat source	water
Heat source temperature (°C) IN	12
Heat source temperature (°C) OUT	6
Evap. temperature (°C)	n. a.
Heat sink	water
Heat sink temperature (°C) IN	20
Heat sink temperature (°C) OUT	80
Cond. temperature (°C)	n. a.
Heat source/ heat sink	heating only
Thermal storage	hot water
Savings energy (%)	n. a.
Savings CO_2 emissions (%)	50 (26 t/a)
Savings energy cost (%)	n. a.
Others: additional effects	full cost advantage for 15 years: 4,100 €/a; COP = 3.7
Source	IEA HPT ANNEX 35 Task 4

2.2 Emil Frei Bräunlingen

In 2009 Emil Frei was looking for a heating concept for their newly built logistics center in Bräunlingen. At the same location the company also produces powder coatings, what offered the chance to use a process cooling network as a heat source. In 2010 an integrated heating and cooling concept using a heat pump was implemented. The heat pump covers most of the heating demand of the production hall and the storage and shipping warehouse. The heating network runs at a temperature of 45 °C. At outside air temperatures below 0 °C an auxiliary oil heater is used to cover the rest of the heating load. As heat source for the heat pump a cooling water network is used. Through different production steps cooling water is heated up to 18 °C. The low temperature difference between hot and cold side of the heat pump ensures a heating COP of 5. In summer the heat pump is also used for cooling the production halls. Excess heat is then rejected to the environment.

Emil Frei in Bräunlingen	
Industry	Chemical
Application	Coating
Process applied	space heating and cooling
Location	Bräunlingen, Germany
Year of installation	2010
User (company)	Emil Frei GmbH
HP manufacturer	Glen Dimplex GmbH, D
Contractor	n. a.
HP technology	MHP
HP system	water cooled chiller
Working fluid	R404A
Compressor	n. a.
Heating/Cooling capacity (kW)	240
Supply temperature (°C)	45
Heat source	water
Heat source temperature (°C) IN	18
Heat source temperature (°C) OUT	n. a.
Heat sink	water
Heat sink temperature (°C) IN	n. a
Heat sink temperature (°C) OUT	45
Heat source/ heat sink	heating and cooling
Thermal storage	n. a.
Costs Heat Pump	210,000 € (total)
Savings energy (%)	n. a.
Savings CO_2 emissions (%)	n. a.
Savings energy cost (%)	23,000 €/a
Others: additional effects	COP = 5 ROI = 5
Source	IEA HPT ANNEX 35 Report Task 4

2.3 Ludwig Michl in Waakirchen

Ludwig Michl GmbH designs and manufactures metal products. With 80 employees the company processes 1,000 t of sheet metal per year and achieves an annual turnover of 9 to 10 million euro /Ludwig Michl GmbH 2013/. Motivation for a complete restructuring of the heating and cooling system was the acquisition of two new machines that needed to be cooled. Before the company installed a centralized cooling system each machine emitted its waste heat into the production hall. Especially in summers this lead to unpleasantly high air temperatures. The additional heat emitted by the new machines even lead to malfunctions in machine control units due to overheating.
When new machinery was procured in 2007 also a new centralized heating and cooling system was installed. The central unit of the system shown in Figure 1 are five absorption heat pumps, operated in parallel. Each of them has a heating capacity of 34 kW and a cooling capacity 16 kW and is equipped with a pump on both sides. These pumps for hot and cold water are controlled by the heat pump control system, which is connected to a higher-level control system via mod bus. The higher level system controls the distribution of heating and cooling. Cooling is supplied to two laser cutting and welding machines, to an edging machine, to a server room and the production hall. The heat sources are connected in parallel to ensure a supply temperature of 20 °C. A 3 m³ stratified cold water storage allows a decoupling of volume flows of the heat pump and the cooling circuit.

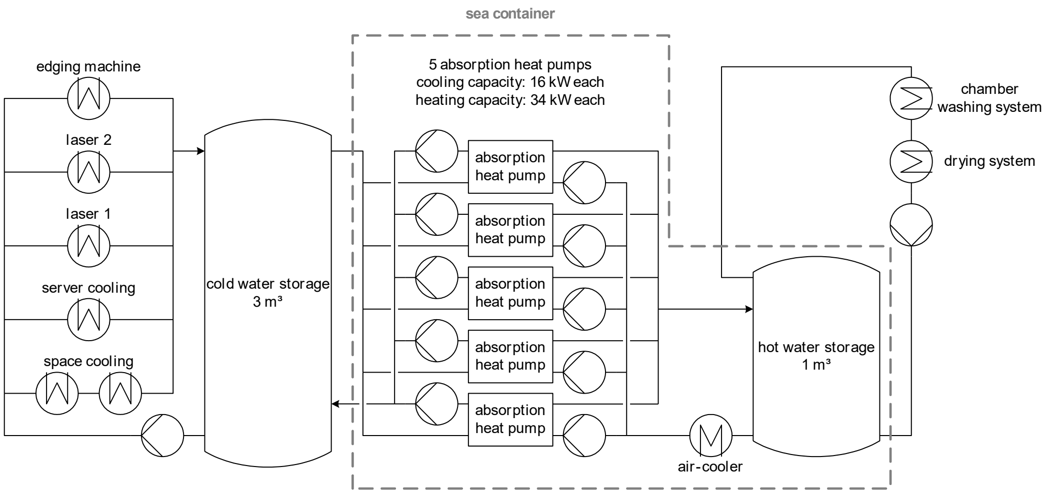

Figure 1: Heating and cooling system at Ludwig Michl GmbH

The heat pumps can be switched on/off individually to adjust the cooling capacity. Hot water is produced at 60 °C to cover the heat demand of a chamber washing system and a hot air dryer. Both machines are connected in series as the dryer can also operate with lower temperatures. The chamber washing system, however, is very temperature dependent. If the temperature of the washing solution falls below a critical value, the solution starts to foam up. Like on the cold side volume flows of the heat pump and the heating circuits are decoupled by a 1 m³ storage. In case of a heat surplus, the heat can be emitted to the environment via an air cooler. To save space in the production hall, heat pumps, hot water storage and air cooler are housed in a sea container next to the building. As this container is neither heated in winter nor insulated sufficiently to inherently prevent freezing of the water circuits, the heat pumps are operated in an active anti-freeze mode in winter. The heating and cooling system is operated monovalent. Therefore system failures have to be patched immediately to prevent a production break down.

By connecting the control system to an e-mail notification system staff is enabled to react quickly.
In the first months LPG was used to power the heat pumps. After the local gas supplier had connected the company to the gas network, the energy supply was switched to natural gas. The costs of 50,000 € for the extension of the gas network were covered by the local gas supplier. The investment costs for the integrated heating and cooling system amounted to 125,000 €. The Project was funded by Deutsche Bundesstiftung Umwelt (DBU) with 30,000 €. The payback period for the investment was 4 years. Compared to the old system up to 40 % of the CO_2-Emissions could be saved /Ludwig Michl 2007, Robur 2008; Lehnhardt 2008/.

Ludwig Michl in Waakirchen	
Industry	Machinery
Application	Metall processing
Process applied	heating and cooling
Location	Waakirchen, Germany
Year of installation	2007
User (company)	Ludwig Michl GmbH, Waakirchen
HP manufacturer	Robur GmbH, D and I
Contractor	n. a.
Consultant	n. a.
HP technology	THP
HP system	water cooled chiller
Working fluid	R-717
Compressor	gas driven
Heating/Cooling capacity (kW)	194
Supply temperature (°C)	60
Heat source	water
Heat source temperature (°C) IN	20
Heat source temperature (°C) OUT	n. a.
Heat sink	water
Heat sink temperature (°C) IN	n. a.
Heat sink temperature (°C) OUT	60
Heat source/ heat sink	heating, washing process, drying process
Thermal storage	cold and hot water
CostHeat Pump	125,000 € (total)
Savings energy (%)	n. a.
Savings CO_2 emissions (%)	40
Savings energy cost (%)	n. a.
Others: additonal effects	COP = 2.3 integrated ROI = 4 a
Source	IEA HPT ANNEX 35 Report Task 4

2.4 Purkart Systemkomponenten in Großrückerswalde

Purkart Systemkomponenten designs and manufactures metal products. In 2011 the company implemented a new integrated heat recovery system to reduce energy costs. Figure 2 shows a scheme of the new integrated heating and cooling network. Waste heat generated in production process is now used to cover the space heating and process heat demand. While waste heat from compressed air generation could directly be integrated into the heating network the temperatures of other heat sources are too low. Here a heat pump is used to upgrade the temperature to 60 °C to provide heat for space heating and industrial processes (e.g. phosphating and degreasing of metal parts). The heat pump extracts about 190 kW from a cooling network and cools down cooling water from 30 to 25 °C. Cooling is needed for a laser welding machine. To guarantee the cooling the old free cooling plant is kept as a backup system. In addition to the welding machine the exhaust gas from a curting oven is used as a heat source. The exhaust gas leaves the oven at temperatures of 200 to 300 °C. Formerly unused is it now condensed which raises the thermal efficiency of the oven to 99% based on the lower caloric value. In case there is no use for this heat can still be released by the old exhaust stacks. To buffer peak loads, a 16 m³ stratified storage is installed on both hot and cold side of the heat pump. Hereby heating and cooling demands are decoupled. The large volume of the tanks enables the system to run for 30 to 60 minutes without heat demand or supply. Monitoring and optimization of the plant performance could increase the operating time of the heat pump from 5 to 8 hours per day. Due to the high sensivity of the cooling of the laser welding machine hydraulic balancing had to be performed several times. The implementation of the heat recovery system now saves 33% of the total natural gas demand. Payback time for this system is expected to be 6 years assuming a return of 18% and an increase of energy prices of 3% per year /Preuß 2011; SAENA 2012; Brandenburg 2011/.

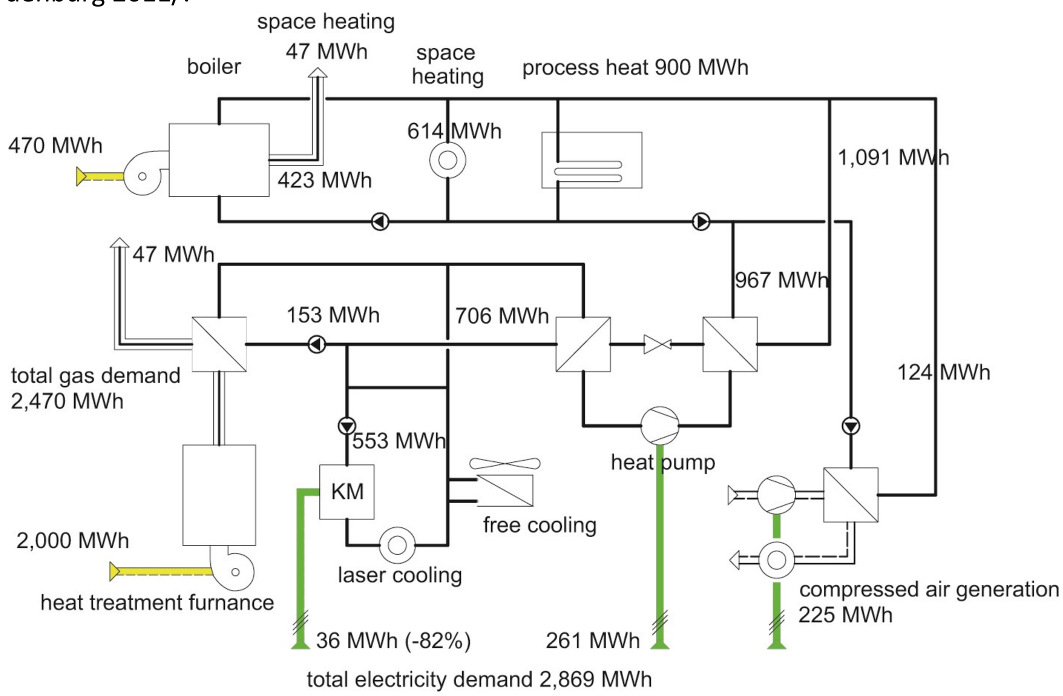

Figure 2: New heat recovery system with an integrated heat pump /Preuß 2011/

Purkart Systemkomponenten in Großrückerswalde	
Industry	Machinery
Application	Metall processing
Process applied	heating and cooling
Location	Großrückerswalde, Germany
Year of installation	2011
User (company)	Purkart Systemkomponenten GmbH & Co.KG, Großrückers-walde
HP manufacturer	Combitherm GmbH, D
Contractor	n. a.
Consultant	FWU Ingenieurbüro GmbH
HP technology	MHP
HP system	Air-source HP chiller
Working fluid	R134a
Compressor	n. a.
Heating/Cooling capacity (kW)	274
Supply temperature (°C)	65
Heat source	Laser cooling and exhaust air pro-duction
Heat source temperature (°C) IN	35
Heat source temperature (°C) OUT	25
Heat sink	water
Heat sink temperature (°C) IN	n.a
Heat sink temperature (°C) OUT	60
Heat source/ heat sink	space heating and process heat
Thermal storage	cold and hot water
Cost Heat Pump	570,000 € (total, whole system)
Savings energy (%)	33
Savings CO_2 emissions (%)	n. a.
Savings energy cost (%)	n. a.
Others: additional effects	COP = 3.8 ROI = 6 a
Source	IEA HPT ANNEX 35 Report Task 4

2.5 Tivoli Malz in Hamburg

Tivoli Malz GmbH is holder of Global Malt GmbH & Co. KG and a mayor malt producer in Germany and Poland with an annual production of 400,000 t. At its production site in Hamburg the company installed a CHP plant in combination with a heat pump to lower energy costs. With an annual production of 105,000 t of malt the site accounts for more than one fourth of the company's production capacity. (Information from 2013)

Malt is a major ingredient for beer brewing. It is produced from cereal, which is left to germinate under humid conditions. The germination process is stopped by drying the germs in a kiln. This process typically needs a large amount of hot and dry air at 65 °C or above. Humid exhaust air is released at 28 °C. This waste heat stream can be used to preheat inlet air. This is usually carried out by means of recuperative glass tube heat exchangers. In addition to this branch technology standard Tivoli Malz GmbH integrated a heat pump to recover an additional amount of 2.7 MW waste heat. A very low temperature difference between heat source and heat sink leads to a high COP of 6. With Ammonia a natural refrigerant was chosen, because of its high volumetric capacity which results in a relatively little filling quantity and compact dimensions of the heat pump. The heat pump provides a heating capacity of 3.3 MW with about 6,000 operating hours at full load per year. Up to 3,000 l of water are condensed per hour. The inlet air is then further heated by a CHP plant that covers the total electricity demand of the production site. A gas powered auxiliary heater lifts the inlet air temperature up to 65 °C, before it enters the kiln /Mönch 2011; Tivoli Malz 2012; Brauwelt 2010/.

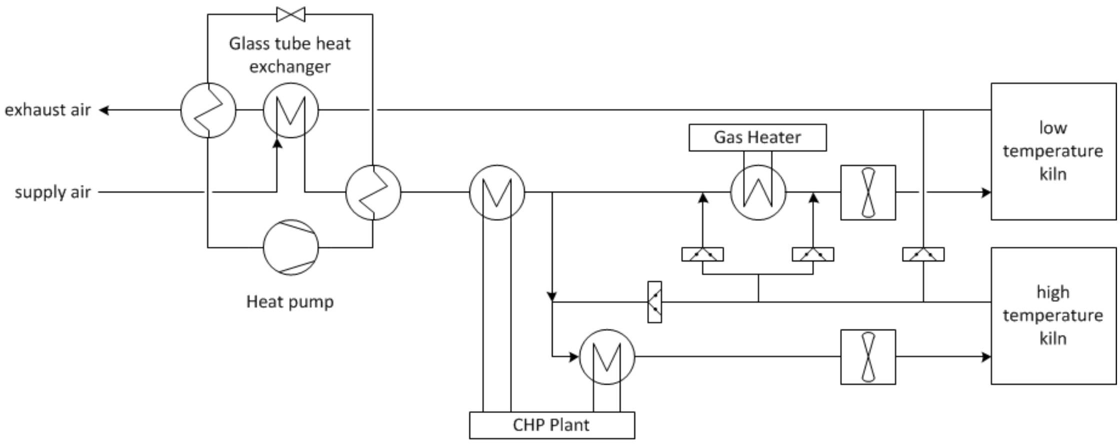

Figure 3: Process scheme of the energy supply for the kiln

Tivoli Malz in Hamburg	
Industry	Food
Application	Malt production
Process applied	process heat
Location	Hamburg, Germany
Year of installation	2010
User (company)	Tivoli Malz GmbH, Hamburg
HP manufacturer	GEA Refrigeration GmbH, Berlin
Contractor	n. a.
Consultant	Zimmermann GmbH, Seevetal
HP technology	MHP
HP system	Air-source HP chiller
Working fluid	R717
Compressor	Screw
Heating/Cooling capacity (kW)	3,250
Supply temperature (°C)	35
Heat source	process exhaust air
Heat source temperature (°C) IN	23
Heat source temperature (°C) OUT	n. a.
Heat sink	Air
Heat sink temperature (°C) IN	22
Heat sink temperature (°C) OUT	35
Heat source/ heat sink	process heat
Thermal storage	n. a.
Cost Heat Pump	1,684,250 € (total)
Savings energy (%)	n. a.
Savings CO_2 emissions (%)	6,300 t/a
Savings energy cost (%)	n. a.
Others: additional effects	COP = 6.3
Source	IEA HPT ANNEX 35 Report Task 4

2.6 District Heating Bergheim I

A lignite mine is located in the proximity of the town, where the sump water is extracted from the mine to prevent the ground water to seep into the pit.

This water was used by the cooling towers of a nearby power plant, and the rest was dumped into a nearby river. As this water has a temperature of 26°C, it is now collected by two heat pumps to cool it down to 10°C, and the heat is used to supply a local district heating system. The first unit was commissioned in March 2014, and given it is success, the second unit was installed at the beginning of 2015. Now, the system is providing heat to the offices of Erftverband, which house approximately 500 employees. Based on an energy demand of 1,200 MWh, the local non-profit water supply and distribution association saves 58,000 Euro/year.

Source: /EHPA 2017/

District Heating Bergheim I	
Industry	District Heating
Application	District Heating
Process applied	space heating and hot water
Location	Bergheim, Germany
Year of installation	2014
User (company)	Erftverband
HP manufacturer	Viessmann
Contractor	n. a.
Consultant	n. a.
HP technology	MHP
HP system	water cooled chiller
Working fluid	R134a
Compressor	n. a.
Heating/Cooling capacity (kW)	2x293
Supply temperature (°C)	max. 73
Heat source	sump water
Heat source temperature (°C) IN	10
Heat source temperature (°C) OUT	n. a.
Heat sink	water
Heat sink temperature (°C) IN	n. a.
Heat sink temperature (°C) OUT	55 to 60
Heat source/ heat sink	space heating and hot water
Thermal storage	n. a.
Savings energy (%)	n. a.
Savings CO_2 emissions (%)	n. a.
Savings energy cost	58,000 €/a
Others: additional effects	COP = 4.4
Source	EHPA Brochure 2017

2.7 Swiss Krono in Heiligengrabe

This production process heavily consumes electrical and thermal power sources owing to several energy-intensive manufacturing steps. (> 200 GWh electrical and > 1300 GWh thermal). These processes especially include slicing of tree trunks, drying of woodchips, and compacting them to form chipboard. To minimize energy consumption for the chipboard products, Swiss Krono has implemented a large number of energy-reducing measures. One of the primary measures is two GEA heat pumps to provide hot water with an energy equivalent of 10 MW and at a hot water temperature of 80 °C. Mixed with the 2 MW waste heat from a cogeneration unit, the total of 12 MW for hot water is used to pre-dry the entire amount of wood chips.

The energy efficiency of the heat pump solution here becomes more apparent if we consider the energy source for the heat pumps. A company-owned biomass-power plant provides electrical power of 20 MW. The exhaust vapors of the power plant are condensed by two air-cooled condensers. This energy source was previously ignored. Now, however, the condensate (at 39°C) is used as the energy source for the two heat pumps. As part of a closed water loop within the biomass-power plant, Swiss Krono installed two heat exchangers to separate the water circuit of the power plant from the water circuit of the heat pump, and to transfer the heat to the source side of the heat pump. Under current conditions, the COP (Coefficient of Performance) of the heat pumps is 4.5. Pre-drying reduces the moisture content of the wooden chips and saves energy used for the final drying in two rotary dryers.

Based on 6,500 operating hours of each of the two heat pumps in 2016, an energy equivalent reduction of approximately 32 GWh and a CO_2 equivalent reduction of 6,700 tons have been achieved.

Source /EHPA 2017/

Swiss Krono in Heiligengrabe	
Industry	Machinery
Application	Chipboards manufacturing
Process applied	hot water
Location	Heiligengrabe, Germany
Year of installation	ca. 2016
User (company)	Swiss Krono Tex GmbH & Co.KG
HP manufacturer	GEA Refrigeration GmbH, Berlin
Contractor	n. a.
Consultant	n. a.
HP technology	MHP
HP system	water cooled chiller
Working fluid	R717
Compressor	Screw
Heating/Cooling capacity (kW)	2x5,000
Supply temperature (°C)	78
Heat source	water/ethylene glycol 34%
Heat source temperature (°C) IN	n. a.
Heat source temperature (°C) OUT	n. a.
Heat sink	water
Heat sink temperature (°C) IN	n. a.
Heat sink temperature (°C) OUT	78
Heat source/ heat sink	process heat
Thermal storage	n. a.
Savings energy (%)	n. a.
Savings CO_2 emissions	6.7 t/a
Savings energy cost (%)	n. a.
Others: additional effects	COP = 4.5
Source	EHPA Brochure: 2017

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