From Waste Heat to Cheese

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In the idyllic Appenzell village of Gais, Switzerland, the mountain cheese factory processes almost 10 million litres of milk annually. A high temperature heat pump converts waste heat from the neighboring data centre into process heat to heat and process the milk. This saves the mountain cheese factory around 1.5 million kWh of natural gas per year.

Introduction

Mountain cheese factory Gais

The cheese factory Gais is located at 919 m above sea level in the hilly Appenzellerland between Lake Constance and Säntis mountain in Switzerland [1]. The factory produces various semi-hard and mountain cheese specialities, as well as raclette cheese [2]. The milk is supplied by approximately 60 milk suppliers from the Appenzellerland region.

The key energy data of the cheese factory with the temperature levels of the process heat are as follows:

- Energy demand: approximately 1,800 MWh per year
- Milk processing: approximately 10 million litres of milk per year
- Temperature levels:
  - Waste heat recovery (i.e. from ice water production and refrigeration, for preheating washing water, ventilation heating,): < 42 °C
  - Space heating and hot water (i.e. for cheese storage house): 65 °C
  - Process heat 1 (i.e. for cheese vats, cleaning water): 92 °C
  - Process heat 2 (i.e. for multi-purpose heater, pasteurisation): 105 °C

Fig. 1: From Waste Heat to Cheese [3]. Data centre (Rechenzentrum Ostschweiz) built by the St. Gallisch-Appenzellische Kraftwerke AG in Gais Appenzell [1] feeds the waste heat into a district heating network. The mountain cheese factory uses this waste heat as a heat source in a high temperature heat pump to generate process heat for cheese production.

Waste heat from the neighboring data centre as heat source

Next to the mountain cheese factory is the new data centre of Eastern Switzerland, which offers the highest levels of energy efficiency and security. It belongs to the St. Gallisch-Appenzellische Kraftwerke AG and the St. Galler Stadtwerke. The building is completely redundantly connected up to every single server rack. The availability standard of 99.998% is at bank level (Tier IV). With an area of 2 x 450 m^2 it offers space for 2 x 150 racks.

Thanks to photovoltaics and a sophisticated adiabatic cooling system, the data centre is the most energy efficient data centre in Switzerland. The Power Usage Effectiveness (PUE) value, which is the ratio of the total energy consumption of the data centre to the energy consumption of the server racks installed, is 1.15. Thus, only 15% additional energy is needed for cooling and heat exchange. The server racks set up in the data centre are cooled with fresh outside air thanks to its location at high altitude in Gais. On hot days, the heat exchangers are additionally sprayed with water from a rainwater and groundwater system [1]. Facade and roof surfaces cover a photovoltaic system, which generates 230,000 kWh of electricity annually. This corresponds to the energy requirements of about 50 single-family houses [1].

At 100% capacity utilisation of the data centre, the adiabatic cooling system generates approximately 1.5 MW of waste heat, which feeds it into a district heating network (water circuit). The temperature level of the waste heat is approximately 20 °C [1].

The neighbouring mountain cheese factory is connected to the district heating network and uses part of the waste heat as a heat source for a high-temperature heat pump (figure 2) to heat and process the milk. The water exits the heat pump at 14 °C before it flows back into the heating network. This way, the cheese factory replaces the energy of around 1.5 million kWh of natural gas per year.

The heat produced by the heat pump is temporarily stored in a stratified storage tank [3]. The capacity of the heat pump is regulated by the storage tank charge state. The management of the water stratification within the storage tank is accomplished by controlling the loading and unloading profiles. The individual processes in the cheese production are supplied with heat from this storage tank. The lower heat levels of the storage tank are used for hot water heating and space heating.

Amstein+Walthert St. Gallen AG was responsible for the overall planning of the building services engineering [3]. In order to achieve high operational reliability for 100% redundant processes, two gas boilers with 620 kW and 220 kW heating capacity were installed, in addition to the heat pump. These gas boilers can be turned on if required. Nevertheless, the general operational goal is a long running time of the heat pump with few switching on and off cycles, as well as a minimum gas consumption for the boilers [3].

In addition to the cheese factory, the waste heat from the data centre is used for heating and hot water production of another 150 households in the neighbourhood or, if

Fig. 2: High temperature heat pump installed at the technical room of the mountain cheese factory [4].
The mildly flammable refrigerant R1234ze(E) demands special measures for fire protection and escape routes.

Table 1: Technical data of the high temperature heat pump installed at the mountain cheese factory.

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

required, used by other companies. This makes the data centre a major thermal power plant for the Gais region. This sector coupling creates a synergy between the companies.

At the moment, the new building of the cheese factory is still under construction and the data centre is underutilised to supply enough waste heat to its new neighbours. For the waste heat application of the data centre, St. Gallisch-Appenzellische Kraftwerke AG implements an energy-contracting model with the users. The official start-up of the new cheese factory with the high temperature heat pump and waste heat integration from the data centre will take place at the end of 2020 and beginning of 2021.

Results

High temperature heat pump in the mountain cheese factory

Table 1 lists some technical data of the high temperature heat pump and Table 2 shows performance data of the heat pump at high (W18-14/W92) and low (W18-14/W65) temperature conditions in partial load operation. The dimensions of the high temperature heat pump are 4.1 x 1.4 x 2.4 m (L x W x H) with a weight of about 4 000 kg.

The heat pump incorporates a highly efficient and compact semi-hermetic two-stage screw compressor, which has no oscillating components, offers low vibration levels and is wear-free. The effective performance level of 50%, 75%, and 100% is controlled via a slide valve. Efficient forced lubrication guarantees continuous and maintenance-free operation. When the compressor is switched on, a mechanical start-up relief is provided by pressure equalisation. The use of solid shell-and-tube heat exchangers

Table 2: Performance data of the heat pump at high (W18-14/W82-92) and low (W18-14/W55-65) temperature conditions [3] (experimentally tested data, ** extrapolated).*

Operating point: High temperature (W18-14/W82-92)			
Part load (%)	100*	75**	50**
Effective part load (%)	100	81	62
Condenser capacity (kW)	520	419	321
Condenser water flow rate (m³/h)	44.7	36.0	27.6
Temperature difference condenser (K)	10.0	10.0	10.0
Evaporator capacity (kW)	338	264	195
Evaporator water flow rate (m³/h)	82.7	82.7	82.7
Temperature difference evaporator (K)	3.5	2.7	2.0
Compressor power (kW)	182	155	126
COP_H (-)	2.85	2.70	2.55

Operating point: Low temperature (W18-14/W55-65)			
Part load (%)	100*	75**	50**
Effective part load (%)	97	75	54
Condenser capacity (kW)	505	390	279
Condenser water flow rate (m³/h)	43.4	33.5	24.0
Temperature difference condenser (K)	10.0	10.0	10.0
Evaporator capacity (kW)	385	293	205
Evaporator water flow rate (m³/h)	82.7	82.7	82.7
Temperature difference evaporator (K)	4.0	3.0	2.1
Compressor power (kW)	120	98	74
COP_H (-)	4.20	4.00	3.75

as evaporator and condenser enable maximizing service life and operational safety.

Low global warming potential HFO (hydrofluoroolefin) refrigerant R1234ze(E) (GWP100 of 6) is applied, as an alternative to R134a (GWP100 of 1,430). The refrigerant charge is about 130 kg. The slight flammability of the refrigerant (safety class A2L) influenced the positioning of the technical room for the heat pump in the building. In order to comply with the standards for heat pumps from 400 kW or 600 kW capacity, various measures were implemented for fire protection and escape routes.

The heat pump has an economizer cycle with vapour injection into the two-stage screw compressor, which is an efficient solution for high temperature lifts as part of the condensate flow is expanded to a medium pressure level. The resulting liquid-vapor mixture is then evaporated to saturation by subcooling the remaining condensate and injected into the screw compressor. The economizer cycle provides the following main advantages:

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

The heat pump provides approximately 520 kW heating capacity at 100% part load and temperatures of up to 100 °C on the heating side. The heating capacity is slightly higher with a higher temperature lift, as an effect of the economizer cycle with a two-stage screw compressor. The COP is between 2.55 and 2.85 at 74 K temperature lift and between 3.75 and 4.20 at 47 K lift [3]. In part load operation, the COP reduces slightly due to the lower decrease of the compressor power relative to the heating capacity. This is a well-known effect of slide valve control.

Conclusions

The mountain cheese factory Gais transforms waste heat from the neighbouring data centre with a high temperature heat pump to process heat levels of up to 100 °C in order to process the milk. Waste heat of around 1.5 MW at 20 °C is fed from the data centre into a local district heating network. This way, the cheese factory saves the energy of around 1.5 million kWh of natural gas per year. Depending on the operating conditions, the COP of the heat pump is between 2.55 and 2.85 at 74 K temperature lift (W18-14/W82-92) and between 3.75 and 4.20 at 47 K lift (W18-14/W55-65). The economizer cycle of the heat pump with vapour injection into the two-stage screw compressor enables an efficient solution for high temperature lifts.

This case study shows how large amounts of heat can be exchanged across industries in the small Swiss village of Gais. It is hoped that such synergies for heating and cooling will also be recognised at other locations in order to further decarbonise the Swiss industry.

References

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https://doi.org/10.23697/10.23697/f615-5t27