



Heat pumps for simultaneous heating and cooling in the dairy sector

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Agenda

- Dairy sector and energy consumption
- Current solutions for heating and cooling in dairy sector
- Heat pumps recent development
- Alternative for zero carbon heating and cooling in dairy sector

Dairy sector

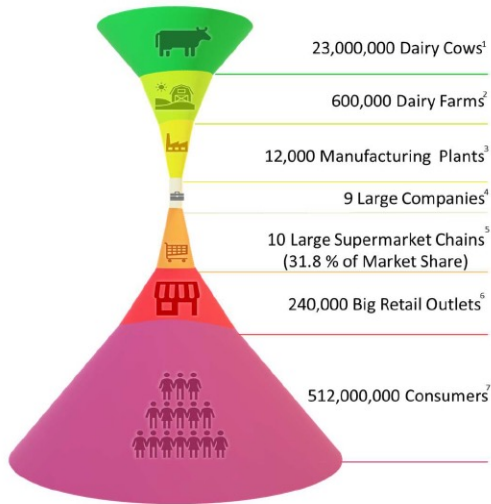


Figure 1.13: Hierarchy of the Dairy Supply Chain depicting by an hourglass shape, showing the concentrated power of the largest manufacturing companies and Supermarket chains in EU.

¹ (Eurostat, 2019)

² (Publications Office of the European Union 2014)

³ (Laiti and Fran 2016)

⁴ (Battum and Ledman 2019)

^{5,6} (Publications Office of the European Union 2014)

⁷ (Europa, n.d.)

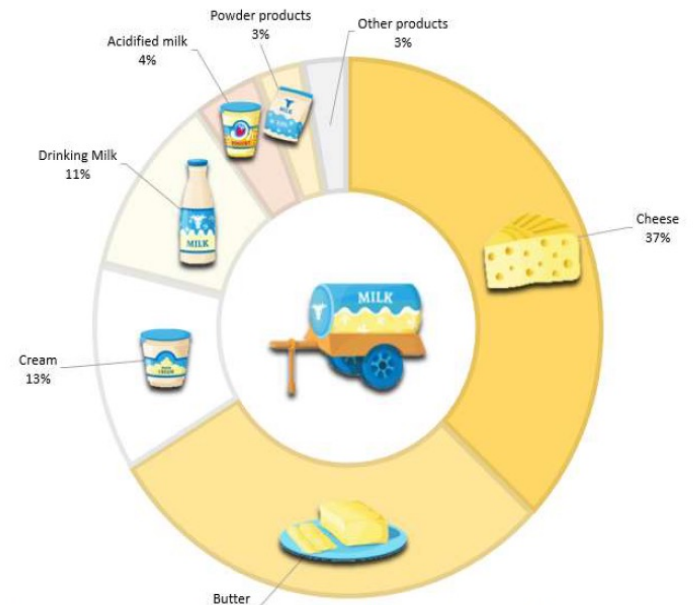
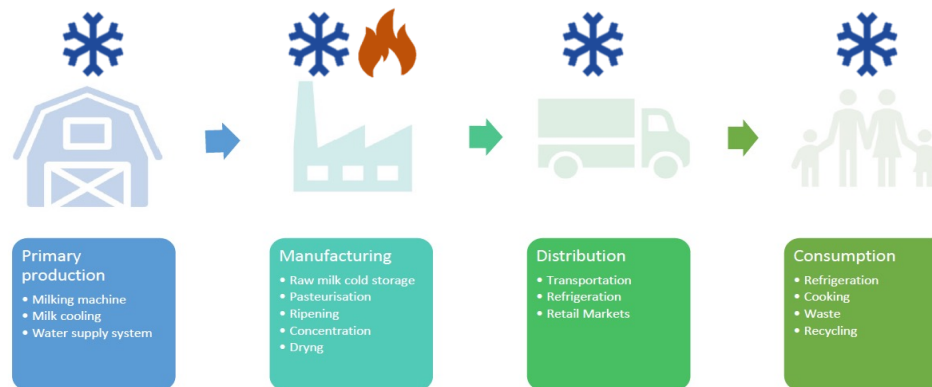


Figure 1.5. Percentage of raw milk processed for different dairy product. (Eurostat, 2018)



Main points of energy consumption during each step in the dairy supply chain.

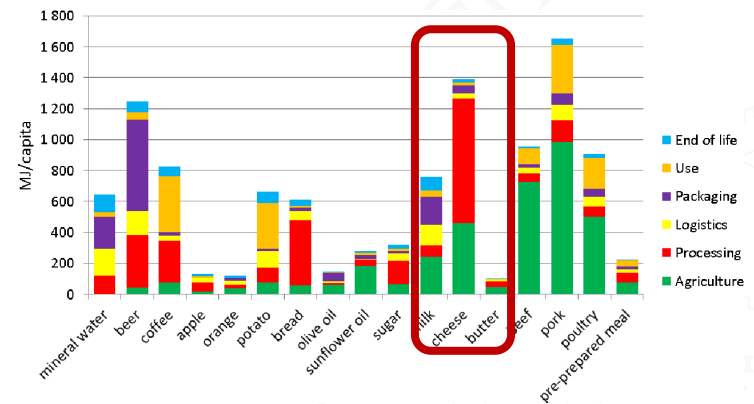
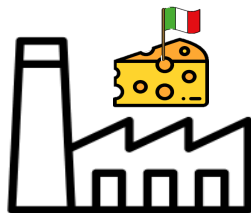
Dairy sector

- The EU dairy sector is both a victim of and contributes to climate change.
 - Farming in the EU is responsible for just over 10% of economy-wide GHG emissions.
 - Changing weather and climate patterns lead to disease outbreaks, animal heat stress, worsened reproductive performance, decline in water resource availability, and reduction of soil fertility.
- Addressing the mitigation challenge correctly should enable
 - greater resilience in the sector and across the supply chain
 - providing longer-term sustainability
 - improved efficiency and cost-saving on farms and in the production process.



Environmental impact of dairy processing

- Dairy processing plants
 - very energy-intensive
 - responsible for an annual emissions of CO₂ between 50 and 100 g CO₂ per kg milk*
- Case study:
 - AS-IS scenario 43 g of CO₂ per kg of milk of which about 59% is due to burned natural gas for thermal energy
 - TO-BE scenario, assuming the use of a heat pump with COP=6 and 80% heat recovery, 45 g of CO₂ per kg of milk



*Source: M. Sevenster, F. De Jong A sustainable dairy sector – global, regional and life cycle facts and figures on greenhouse-gas emissions CE, Delft (2008)

Drawbacks in current dairy processing

- Highest heat demands for processes
 - boilers to pasteurize products
 - and then cooled back down again by a refrigeration plant.
- massive waste of energy.

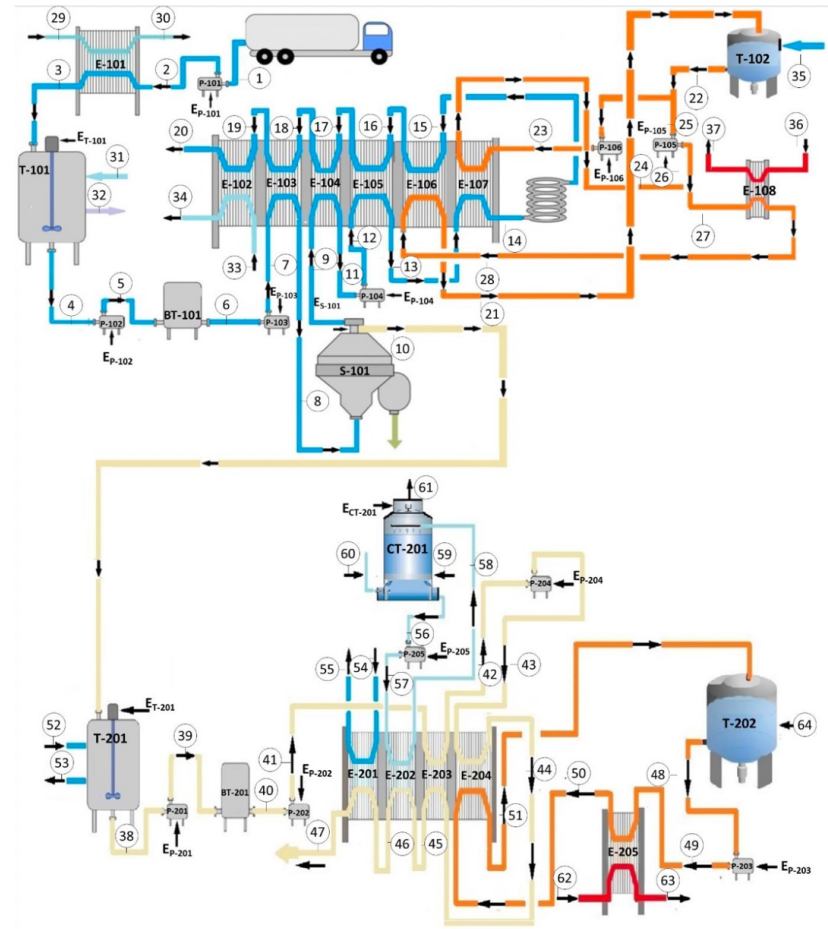
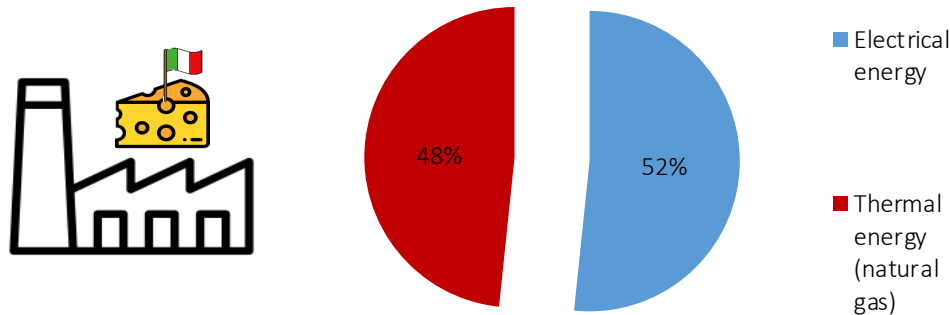


Figure 3 Flow chart illustration of the connected milk and cream pasteurisation process lines using pasteurisation units flowcharts from the study of (van den Bos Verma et al., 2020).

Energy consumption in the dairy sector

- Dairy processes require simultaneous heating for milk processing and refrigeration for storage → challenges in optimizing energy usage.
- Heat pumps can recover waste heat from refrigeration systems to supplement heating needs → synergistic relationship between the two processes
- Case study:
 - 48% thermal energy for heating purposes,
 - 52% electrical energy of which about 80% for cooling requirements



Commercial Heat pumps for combined production



GEA BLU-RED FUSION

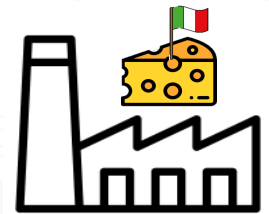


Combined cooling and heating operation

Type ¹⁾	Heat carrier (°C)	Heating capacity (kW)	Cooling capacity (kW)	COP combined ²⁾
	inlet/outlet	R717	R717, +12/+6 °C	line
BG300-RG500	+40/+70	425	325	6.70
BG450-RG500	+40/+70	625	480	6.82
BG600-RG800	+40/+70	875	675	6.84
BG900-RG800	+40/+70	1100	840	6.78
BG1200-RG1100	+40/+70	1670	1275	6.80
BA1500-RAMH	+40/+70	1950	1400	5.55
BA1800-RAML	+40/+70	2250	1610	5.52
BA1800-RARM	+40/+70	2350	1680	5.50
BA1800-RARN	+40/+70	2425	1730	5.47
BG450-RAEC	+70/+80	625	410	4.40
BG600-RAED	+70/+80	840	560	4.55
BG900-RAHE	+70/+80	1150	770	4.59
BG1200-RAHG	+70/+80	1500	1015	4.74
BG1200-RAMH	+70/+80	1755	1185	4.72
BA1500-RAML	+70/+80	2050	1365	4.57
BA1800-RARM	+70/+80	2360	1570	4.56
BA1800-RARN	+70/+80	2425	1605	4.53

Integration of RES

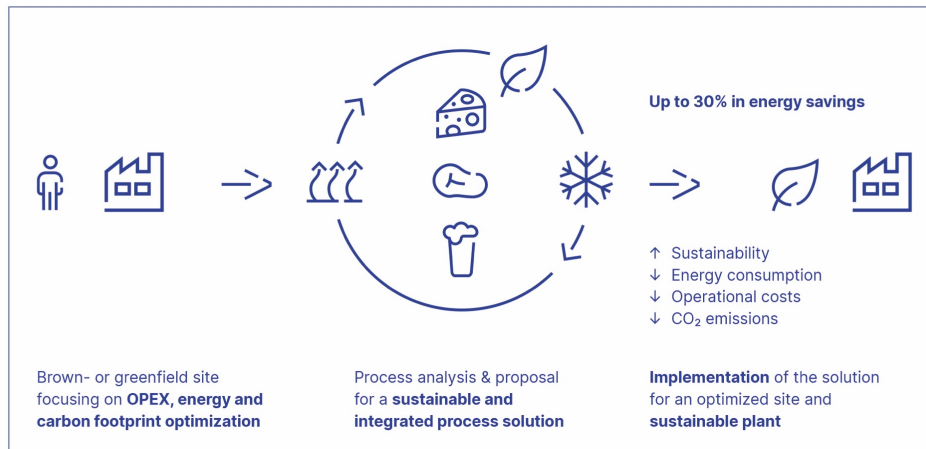
- The main benefit of a heat pump can be obtained with the integration of renewable energy sources and waste heat recovery
- It is possible to reach zero carbon emission
- Case study:
 - AS-IS scenario - 25 g of CO₂ per kg of milk represents the lower bound that can be reached if all the electricity consumption of covered through RES
 - TO-BE scenario – all the energy consumption is electricity, and the lower bound is zero carbon emission → GREEN ENERGY (RES + Waste heat recovery)



Holistic view



- Smart integration between the process demands and cooling and heating requirements
- A holistic view led to the decision to include a heat pump in a cheese manufacturer
- The heat released from the cooling process can be transformed into hot water at 90 °C. More than enough for pasteurization.

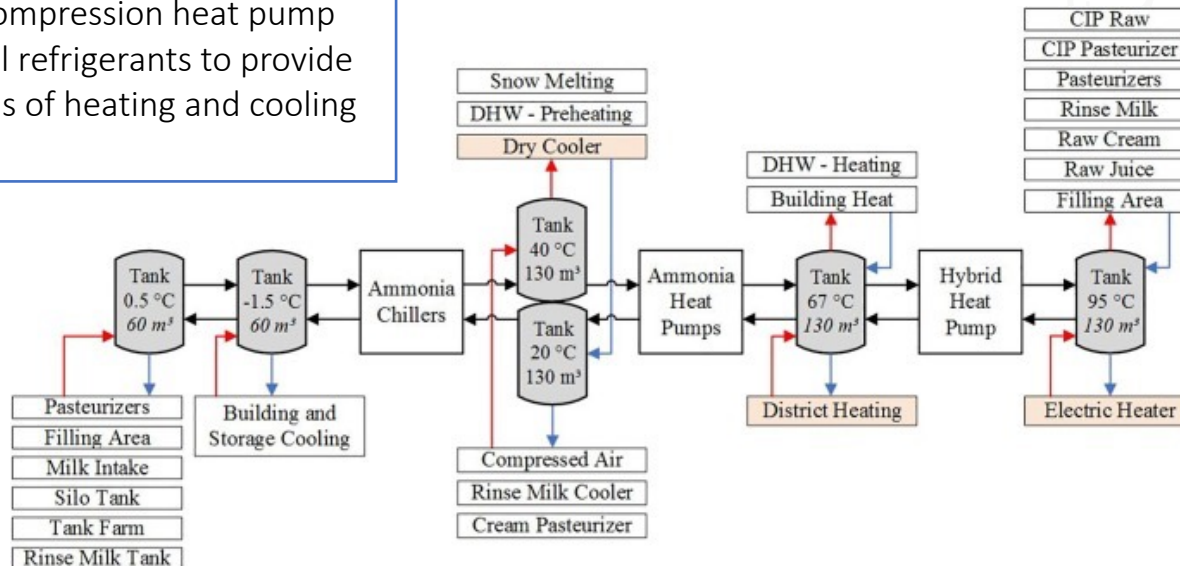


Case study 1: dairy in Bergen, Norway

- Commissioned in 2018,
- the new dairy replaces a former facility in Minde, Norway

System	Refrigerant	Units	Source	Sink	Total capacity
Chillers	NH ₃	3	4 °C/-1.5 °C	20 °C/40 °C	2400 kW (cooling)
NH ₃ HPs	NH ₃	2	40 °C/20 °C	60 °C/67 °C	1577 kW (heating)
HACHP	NH ₃ -H ₂ O	1	67 °C/60 °C	73 °C/95 °C	940 kW (heating)

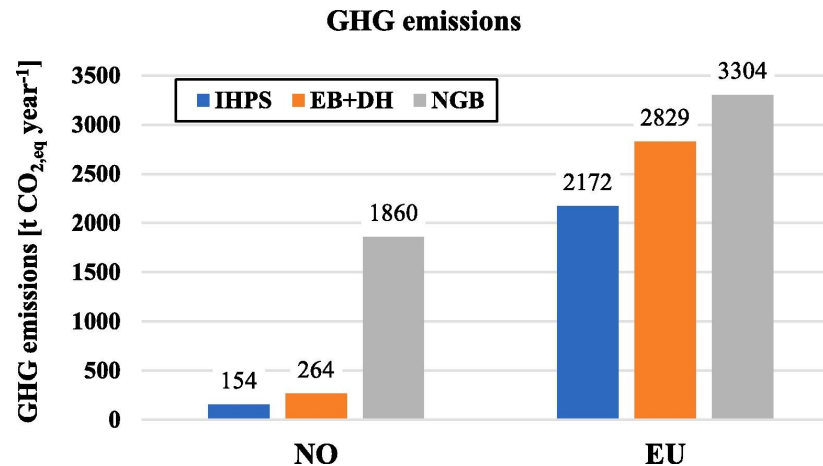
Hybrid absorption-compression heat pump (HACHP) with natural refrigerants to provide all temperature levels of heating and cooling demands



Source: Ahrens, M. U., Foslie, S. S., Moen, O. M., Bantle, M., & Eikevik, T. M. (2021). Integrated high temperature heat pumps and thermal storage tanks for combined heating and cooling in the industry. Applied Thermal Engineering, 116731. <https://doi.org/10.1016/j.applthermaleng.2021.116731>

Case study 1: dairy in Bergen, Norway

- 33.0% of all energy came from waste heat recovery or solar energy
- waste heat recovery rate of over 95%
- Comparison with conventional systems
 - external energy savings of up to 38%
 - GHG reduction of up to 92%



Case study 2: innocent

Location: Rotterdam, The Netherlands



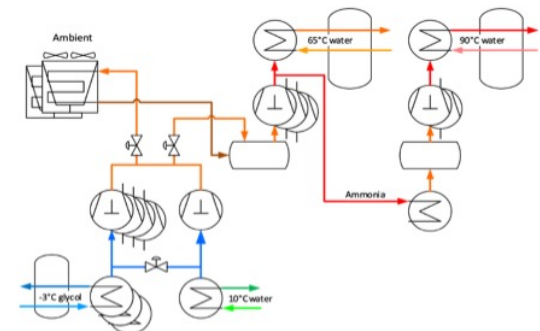
Technical Details

After the design team had reduced the energy demand and applied the use of efficient heat exchangers to re-use as much energy as possible it was important to find an effective way to take excess low-grade heat and to upcycle it using heat pumps into two tiers of temperature (65 °C and 90 °C). These are the energy reservoir temperatures for the main process applications: pasteurization and CIP systems using 90 °C heat and general cleaning and heating systems fed from 65 °C heat.

The blender will be self-sufficient: innocent generates its own energy using solar panels and large wind turbines.

Combined heating and cooling plant

Refrigerant	NH ₃
Compressor types	All are piston compressors
Glycol Cooling	-3°C; 5000 kW process users (pasteurizers, heat exchangers, tanks), cold stores
Cold Water	10°C; 2500 kW conditioning filling & packing hall, other HVAC
Warm Water	65°C; 2300+2200 kW process users (juice melters), HVAC + feed for 90°C heat pump
Hot Water	90°C; 2500 kW process users (pasteurizers), CIP



Graphical representation of combined heating and cooling plant

LIFE-CET BETTED Project

- Starting in 02/2024
- Duration 36 months
- Aim: to facilitate companies in the dairy supply chains to foster the market **uptake** of **energy efficiency measures** including the use of **renewables** and the deployment of **heat pumps** at the **value chain** level.

10 Partners
8 countries



Conclusions

- The integration of heat pump technology for joint heat and refrigeration systems in the dairy sector presents a promising avenue for sustainable dairy processing.
- Integration with renewable energy sources and waste heat recovery can lead to zero carbon emission
- Heat pumps for combined production are in commerce
- Only a few pilot case studies
- Further research:
 - Detailed analysis of the case study



Thank you!



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