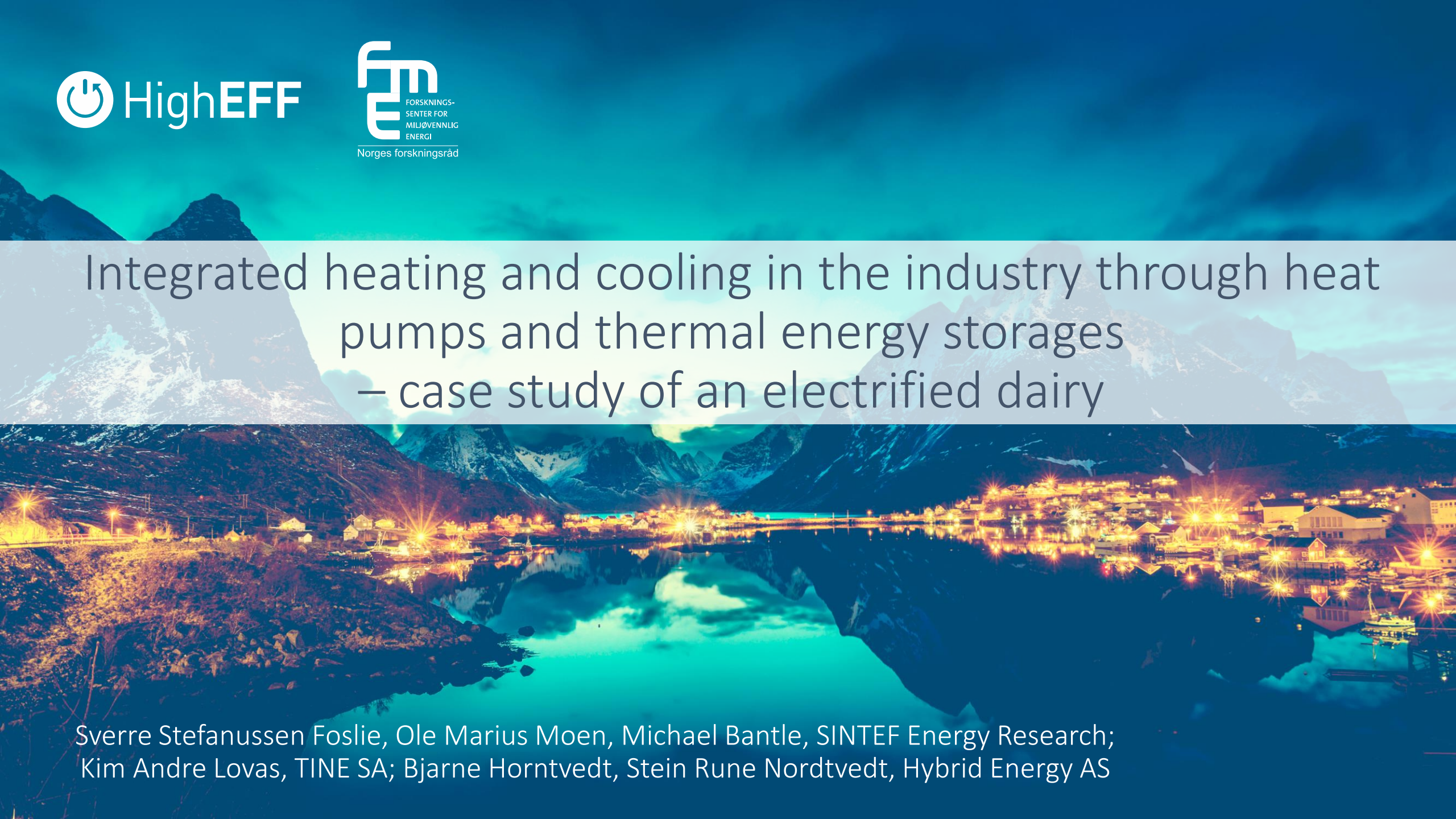
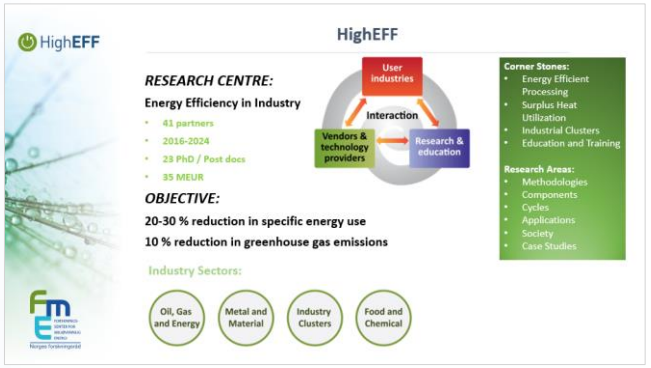


Integrated heating and cooling in the industry through heat pumps and thermal energy storages – case study of an electrified dairy

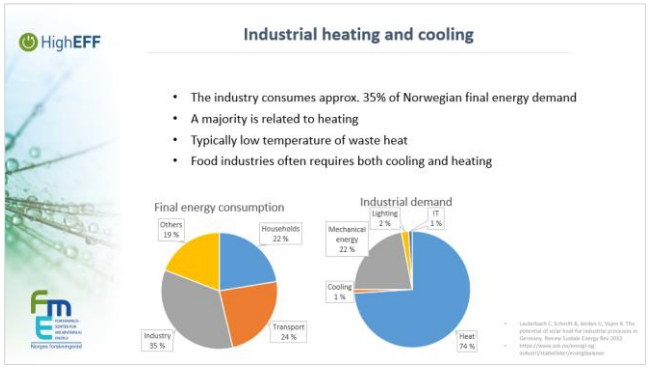
Sverre Stefanussen Foslie, Ole Marius Moen, Michael Bantle, SINTEF Energy Research;
Kim Andre Lovas, TINE SA; Bjarne Horntvedt, Stein Rune Nordtvedt, Hybrid Energy AS

Outline

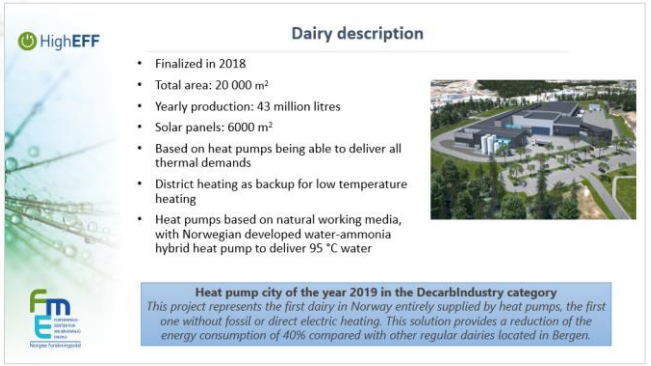
1. HighEFF project



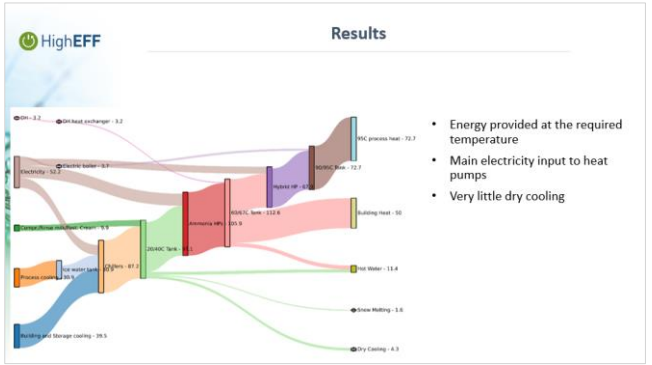
2. Industrial heating and cooling



3. Case study



4. Results



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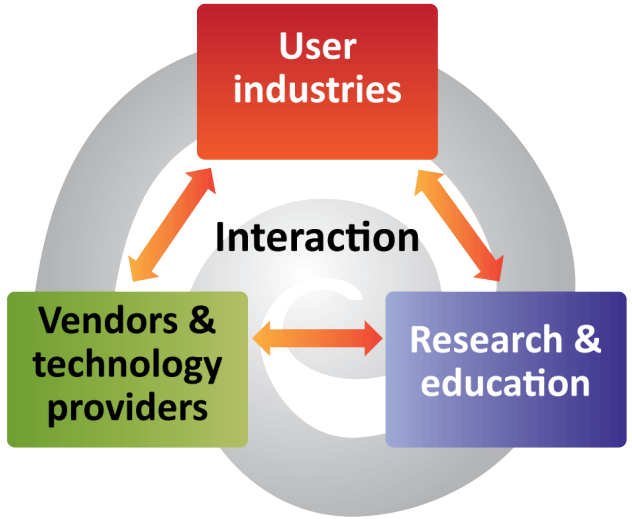
HighEFF

RESEARCH CENTRE:

Energy Efficiency in Industry

- 41 partners
- 2016-2024
- 23 PhD / Post docs
- 35 MEUR



OBJECTIVE:

20-30 % reduction in specific energy use

10 % reduction in greenhouse gas emissions

Corner Stones:

- Energy Efficient Processing
- Surplus Heat Utilization
- Industrial Clusters
- Education and Training

Research Areas:

- Methodologies
- Components
- Cycles
- Applications
- Society
- Case Studies

Industry Sectors:

- Oil, Gas and Energy
- Metal and Material
- Industry Clusters
- Food and Chemical

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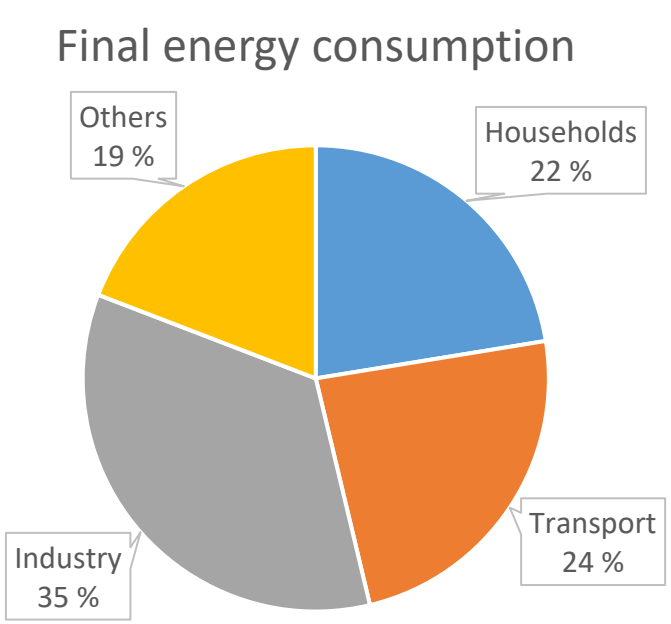
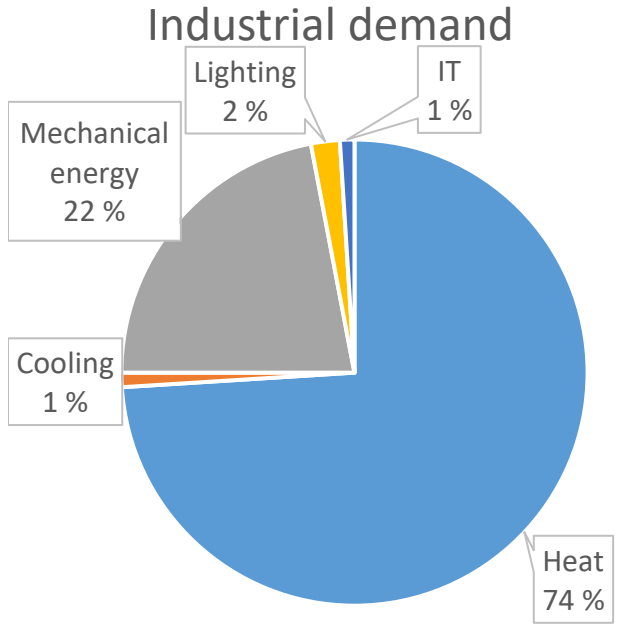
Industrial heating and cooling

Industrial heating and cooling

- The industry consumes approx. 35% of Norwegian final energy demand
- A majority is related to heating
- Typically low temperature of waste heat
- Food industries often requires both cooling and heating





- Lauterbach C, Schmitt B, Jordan U, Vajen K. The potential of solar heat for industrial processes in Germany. Renew Sustain Energy Rev 2012
- https://www.ssb.no/energi-og-industri/statistikker/energibalanse

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Case study

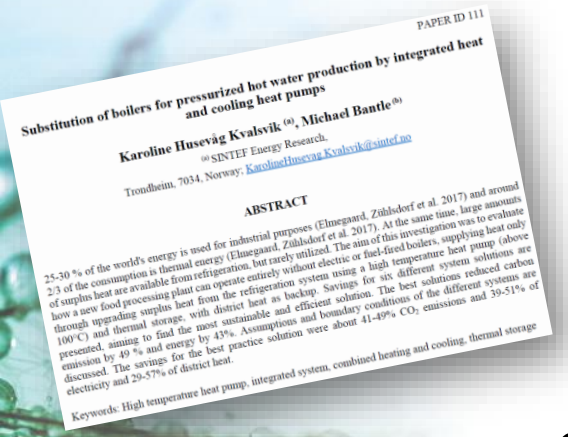
Dairy description

- Finalized in 2018
- Total area: 20 000 m^2
- Yearly production: 43 million litres
- Solar panels: 6000 m^2
- Based on heat pumps being able to deliver all thermal demands
- District heating as backup for low temperature heating
- Heat pumps based on natural working media, with Norwegian developed water-ammonia hybrid heat pump to deliver 95 °C water

Heat pump city of the year 2019 in the DecarbIndustry category

This project represents the first dairy in Norway entirely supplied by heat pumps, the first one without fossil or direct electric heating. This solution provides a reduction of the energy consumption of 40% compared with other regular dairies located in Bergen.

Heating system



PAPER ID 111

Substitution of boilers for pressurized hot water production by integrated heat and cooling heat pumps

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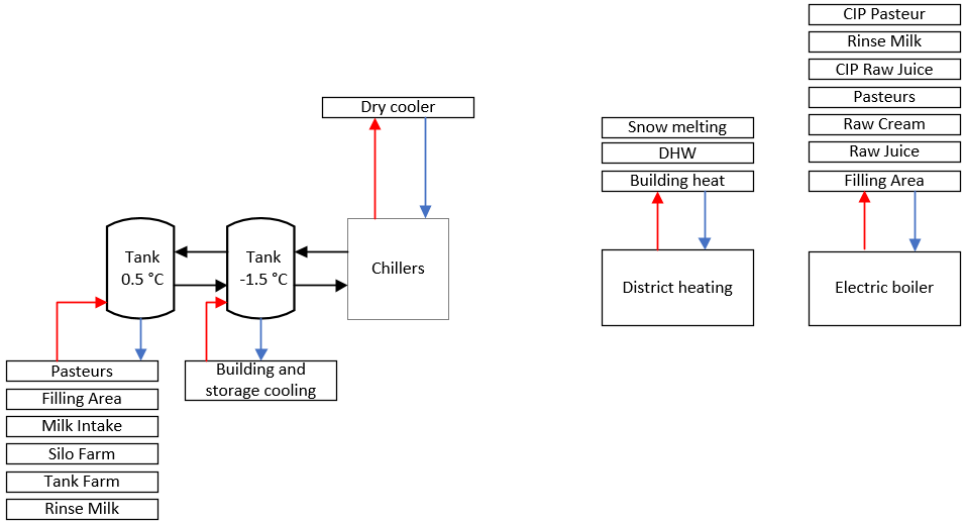
ABSTRACT

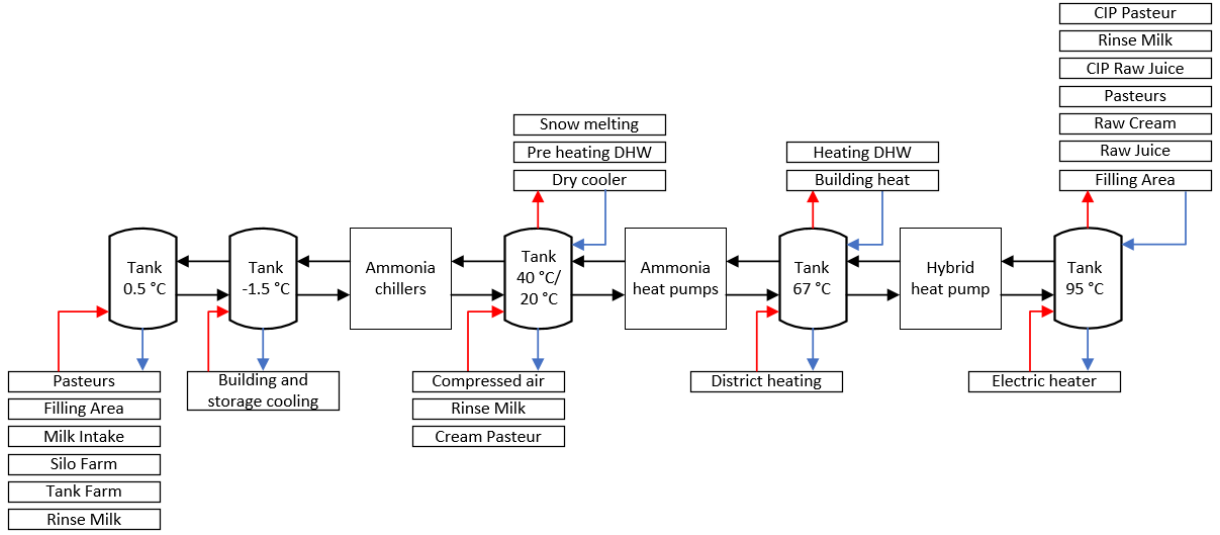
25-30 % of the world's energy is used for industrial purposes (Elmegaard, Zühlsdorf et al. 2017) and around 2/3 of the consumption is thermal energy (Elmegaard, Zühlsdorf et al. 2017). At the same time, large amounts of surplus heat are available from refrigeration, but rarely utilized. The aim of this investigation was to evaluate how a new food processing plant can operate entirely without electric or fuel-fired boilers, supplying heat only through upgrading surplus heat from the refrigeration system using a high temperature heat pump (above 100°C) and thermal storage, with district heat as backup. Savings for six different system solutions are presented, aiming to find the most sustainable and efficient solution. The best solutions reduced carbon emission by 49 % and energy by 43%. Assumptions and boundary conditions of the different systems are discussed. The savings for the best practice solution were about 41-49% CO_2 emissions and 39-51% of electricity and 29-57% of district heat.

Keywords: High temperature heat pump, integrated system, combined heating and cooling, thermal storage

- Traditional dairy
  - Separate heating and cooling systems
  - No thermal heat storage
  - Waste heat to dry cooling
  - Large temperature differences

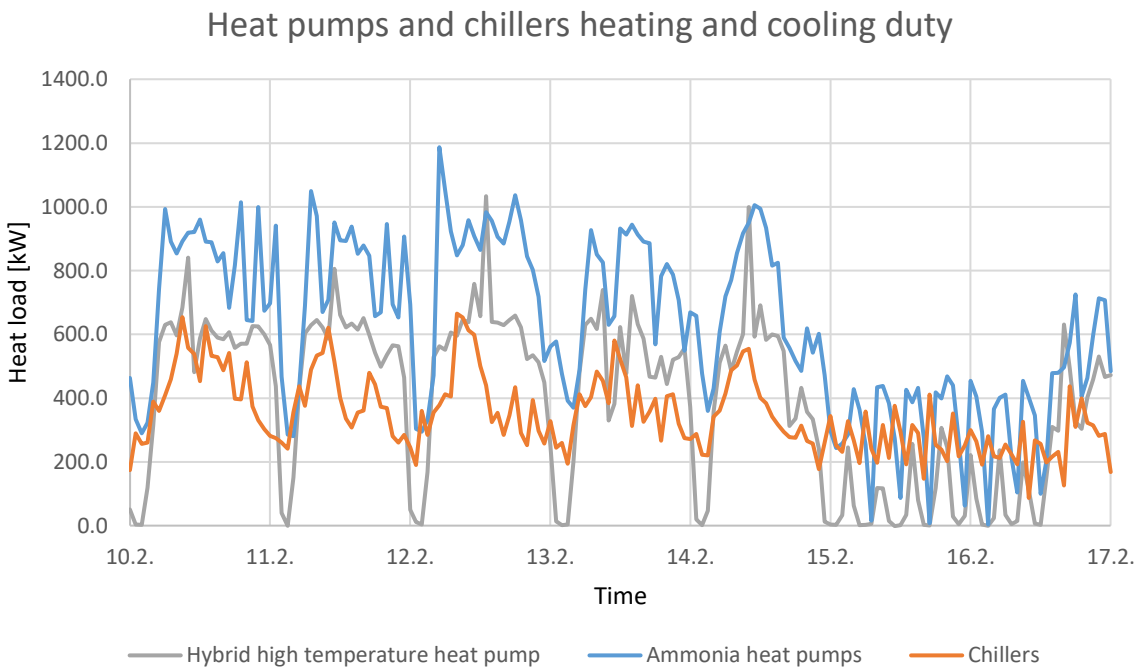


- Case dairy
  - Linked heating and cooling through heat pumps
  - Thermal storages
  - District heating and electricity for peaks
  - Dry cooling for excess waste heat



Measurements

- Monitored heat distribution system
  - Pressure transmitters, flow meters and temperature sensors on nearly all heating and cooling lines
  - Energy meters from electricity consumption and solar panels
  - Energy meter from district heating
- Evaluation of data quality
- Data analysis
  - Week 14, February 2020
- Investigation of parameters and performance
- Improvement suggestions



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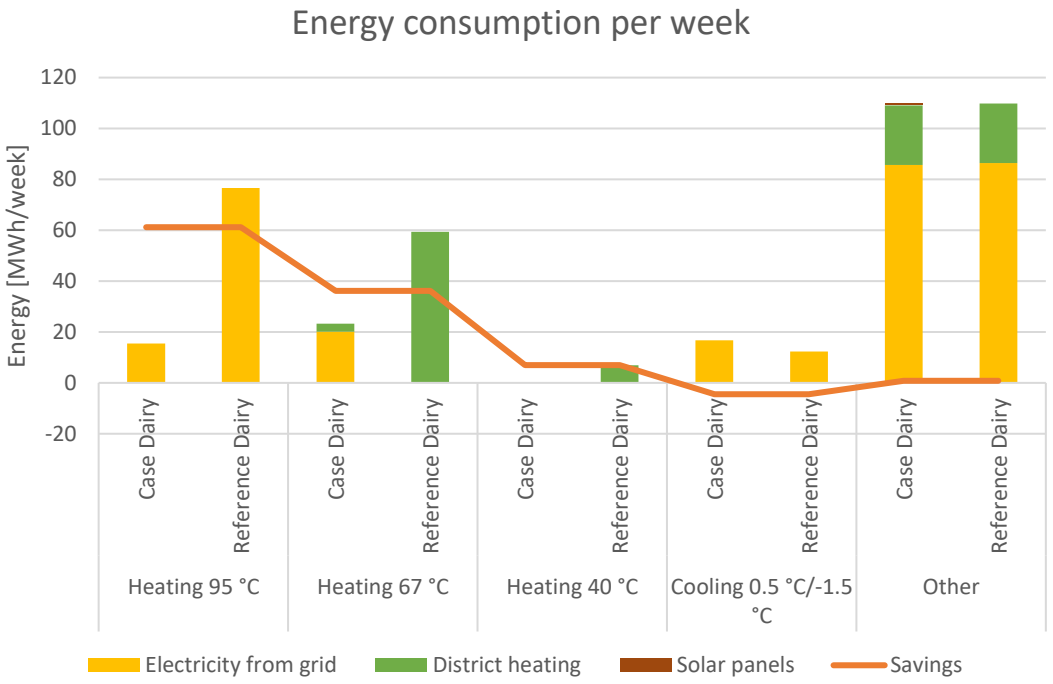
Results

Results

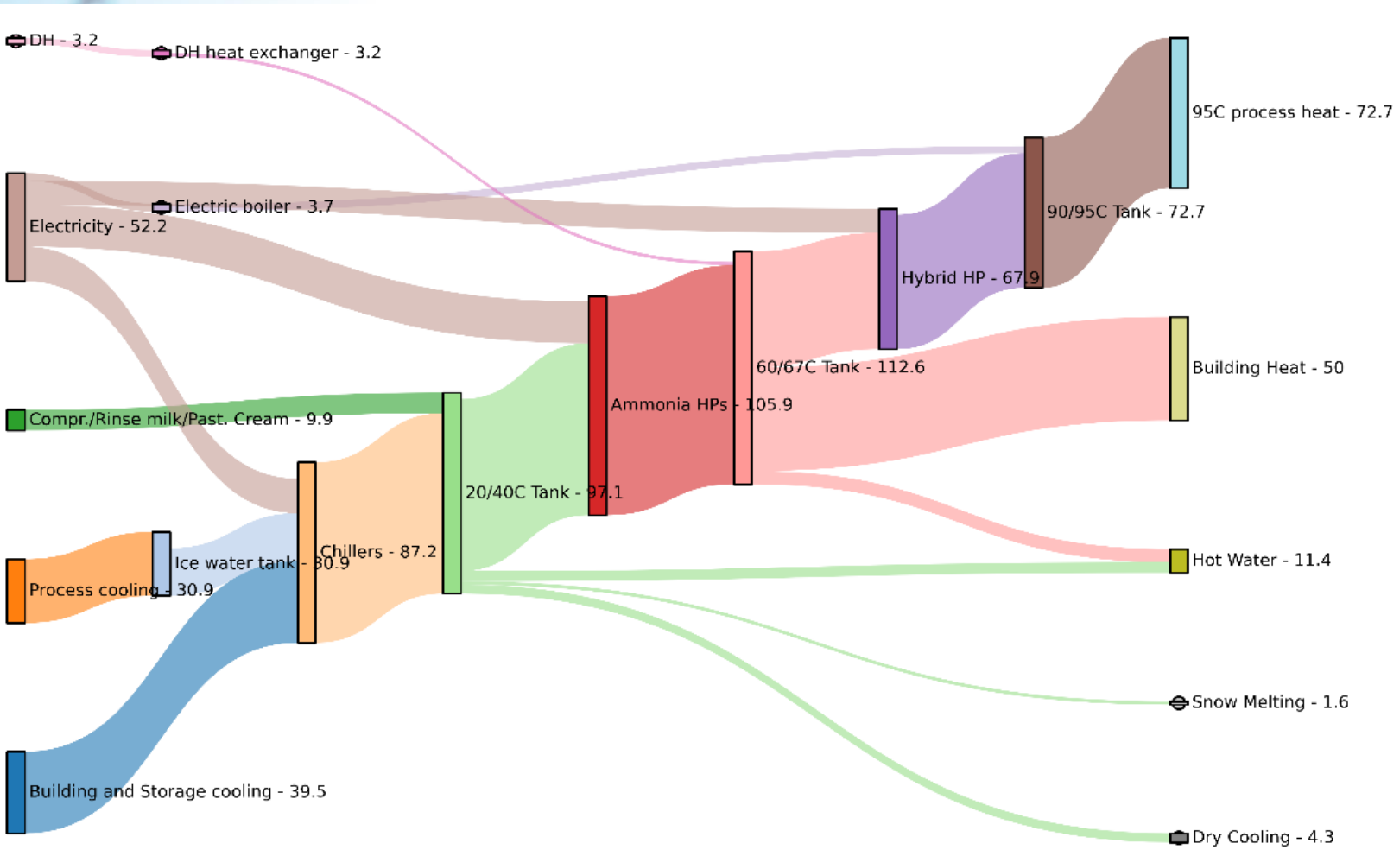
Significant energy savings in the heating processes

- Almost eliminated usage of boiler and district heating in the process
- High heat pump COP enables efficient utilization of surplus heat
- Heating and cooling demands well synchronized
- A small penalty in the chiller COP



	Case Dairy	Reference Dairy	Reduction
Energy consumption [kWh/ltr]	0.22	0.36	37.9 %
GWP [g CO_2 eq./ltr]	4.0	6.9	41.6 %

Results

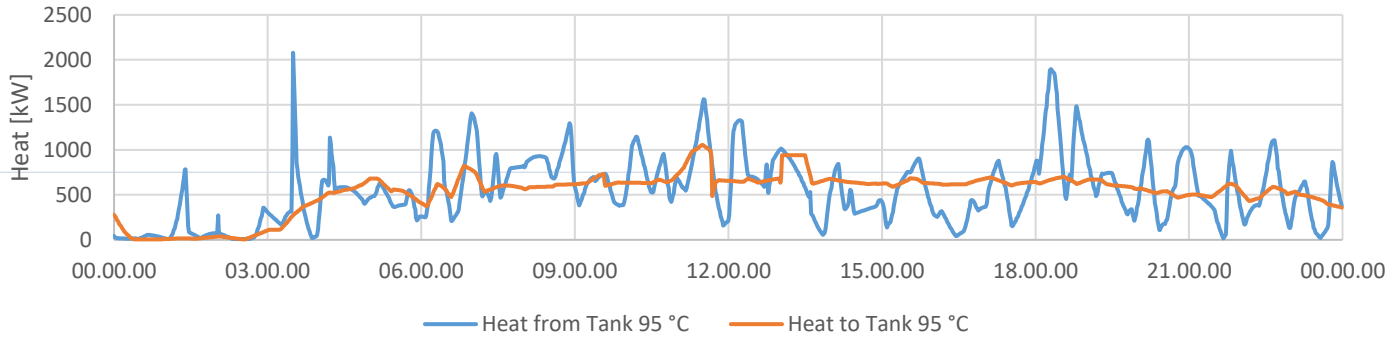


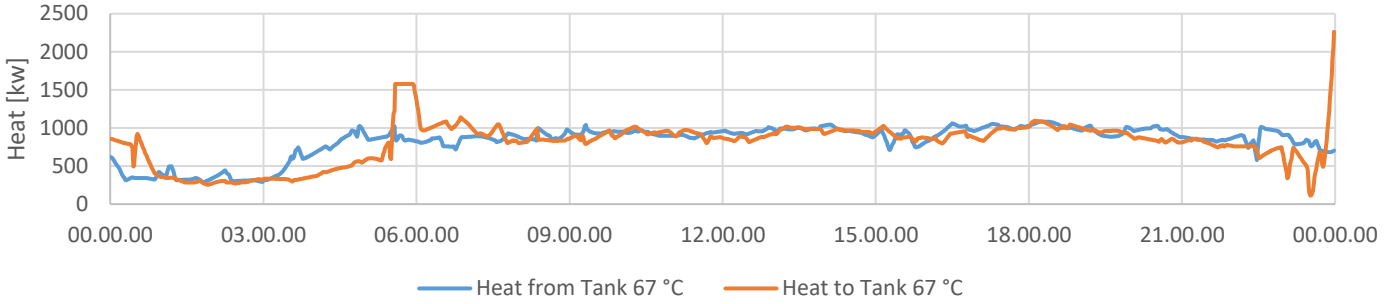
- Energy provided at the required temperature
- Main electricity input to heat pumps
- Very little dry cooling

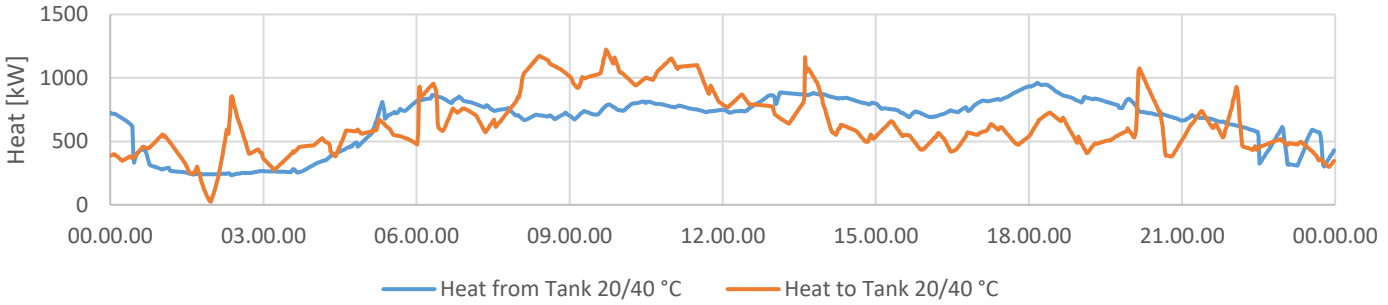
Results

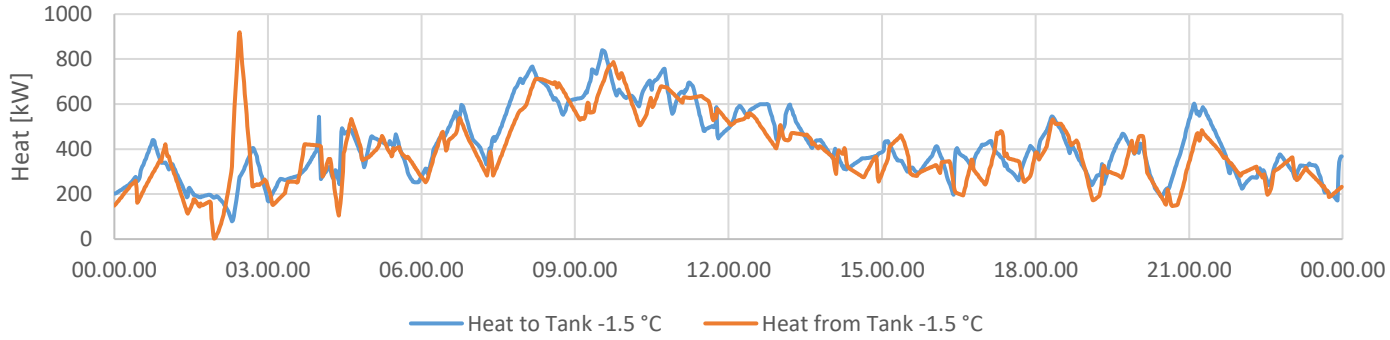
Thermal storage

- For high temperatures, peak power is reduced by 50%
- For low temperatures, the thermal storages have negligible effect
- Medium temperatures are important for heat pump operation









Summary

- By proper design, it is possible to design an industrial thermal process to be completely served by heat pumps
- Combining heating and cooling demands is energy efficient
- Stable system operation
- A break-in period is required to optimize operation
  - According to TINEs control systems, the specific energy consumption has reduced from 0.22 to 0.17 kWh/ltr from February to June
  - Continuous improvements through adjustments of set-point, on their way to the target of 0.15 kWh/ltr

- Special thanks to TINE and Hybrid Energy for delivering data and support

Thank you!

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