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Centre for an Energy Efficient and Competitive Industry for the Future

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Experimental testing of novel cold TES for the food industry

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INT	Internal (restricted to consortium partners only)	

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Abstract
This deliverable is a presentation on the design of a cold thermal energy storage unit for industrial applications using CO_2 as refrigerant, with results from the first experiments. The presentation was held at the 25th IIR International Congress of Refrigeration in Montréal, Canada, in August 2019.

Design of a cold thermal energy storage unit for industrial applications using CO_2 as refrigerant

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25th IIR INTERNATIONAL CONGRESS OF REFRIGERATION
Montréal, Canada – 24th to 30th of August 2019

ICR 2019
THE 25th IIR INTERNATIONAL CONGRESS OF REFRIGERATION
August 24-30 | Montréal, Québec, Canada
Hosted by iif iir

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Norges forskningsråd

HighEFF

Outline of presentation

- Background and introduction
- Experimental test facility
- First experimental results
- Conclusions and summary
- Further work

Background

- Industrial refrigeration systems in food processing plants have high peak power demand
  - Standby during night

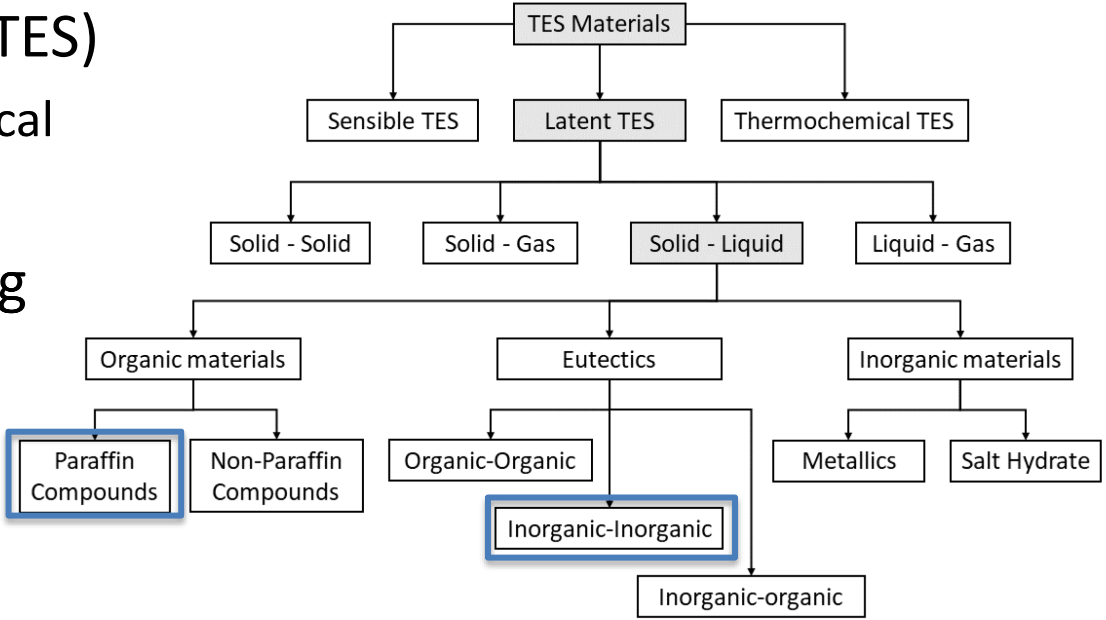
- New poultry processing plant in Trondheim, Norway

- **Target:** Peak shaving to avoid peak electricity tariff fees

Illustration: Norsk kylling A/S

Introduction

- Thermal energy storage (TES)
  - Sensible, latent and chemical
- Latent TES most promising
  - Phase change materials
  - Limit physical footprint
- TES for refrigeration
  - CTES with PCM



Sharma, A., Tyagi, V.V., Chen, C.R. and Buddhi, D., 2009. Review on thermal energy storage with phase change materials and applications. *Renewable and Sustainable energy reviews*, *13*(2), pp.318-345.

Introduction – What has been done in CTES?

Ice-on-coil

- Internal freeze/external melt
- Cold water for AC purposes

Active PCM systems

- Internal freeze/internal melt
- Using glycol as HTF

Way forward →

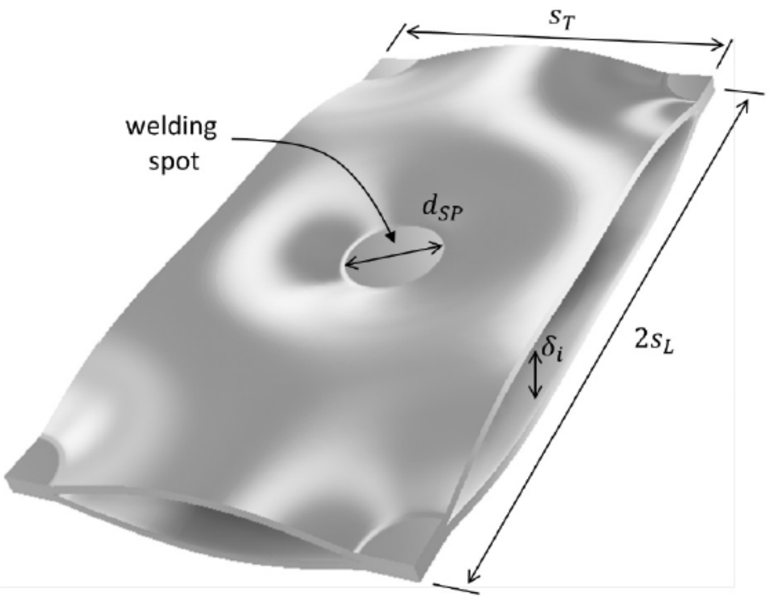
PCM system integrated in the refrigerant circuit

Passive PCM systems

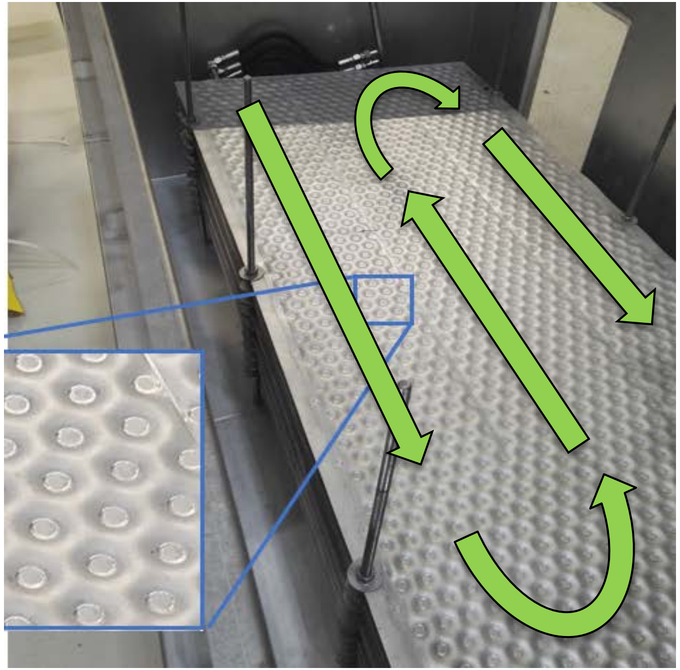
- Refrigerated storages, transport & domestic applications
- Insulation materials and slabs

Experimental test facility – Pilot CTES unit

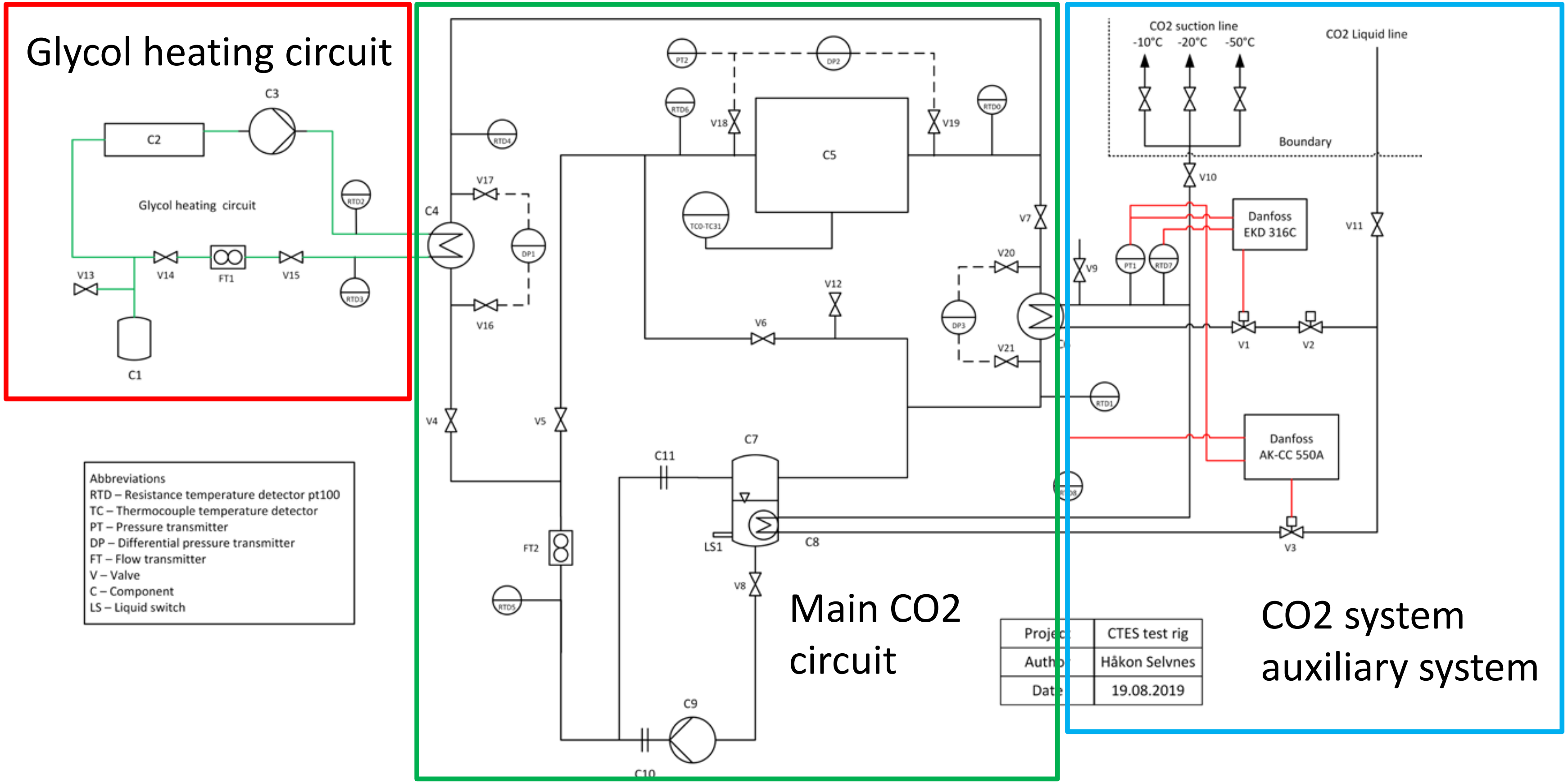
- Pillow plate design → vertically stacked plates



Piper, M. Zibart, A., Kenig, E., Y. 2017. New design equations for turbulent forced convection heat transfer and pressure loss in pillow-plate channels. *International Journal of Thermal Sciences*, *120*, pp.459-468.



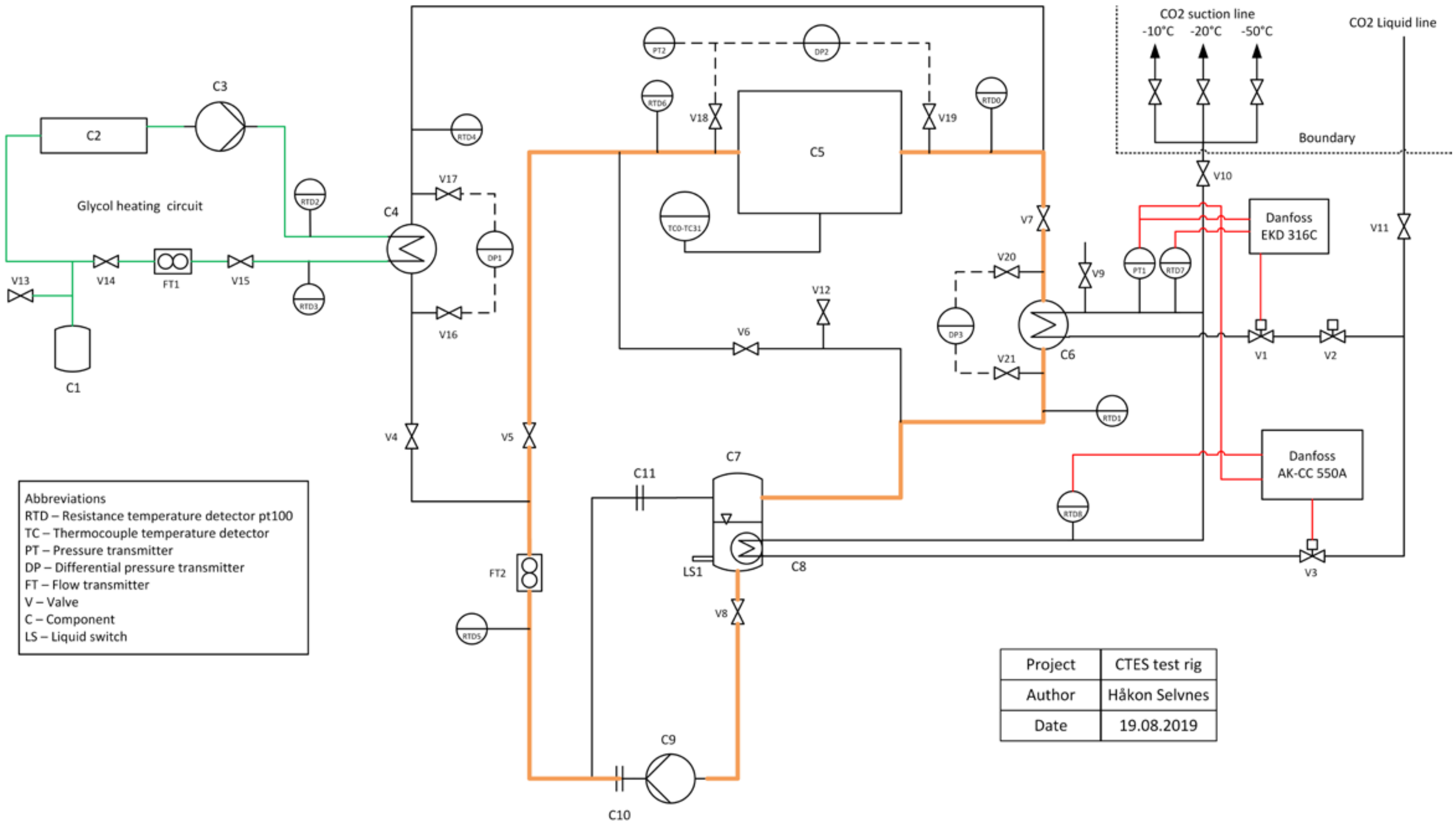
Experimental test facility – Overview



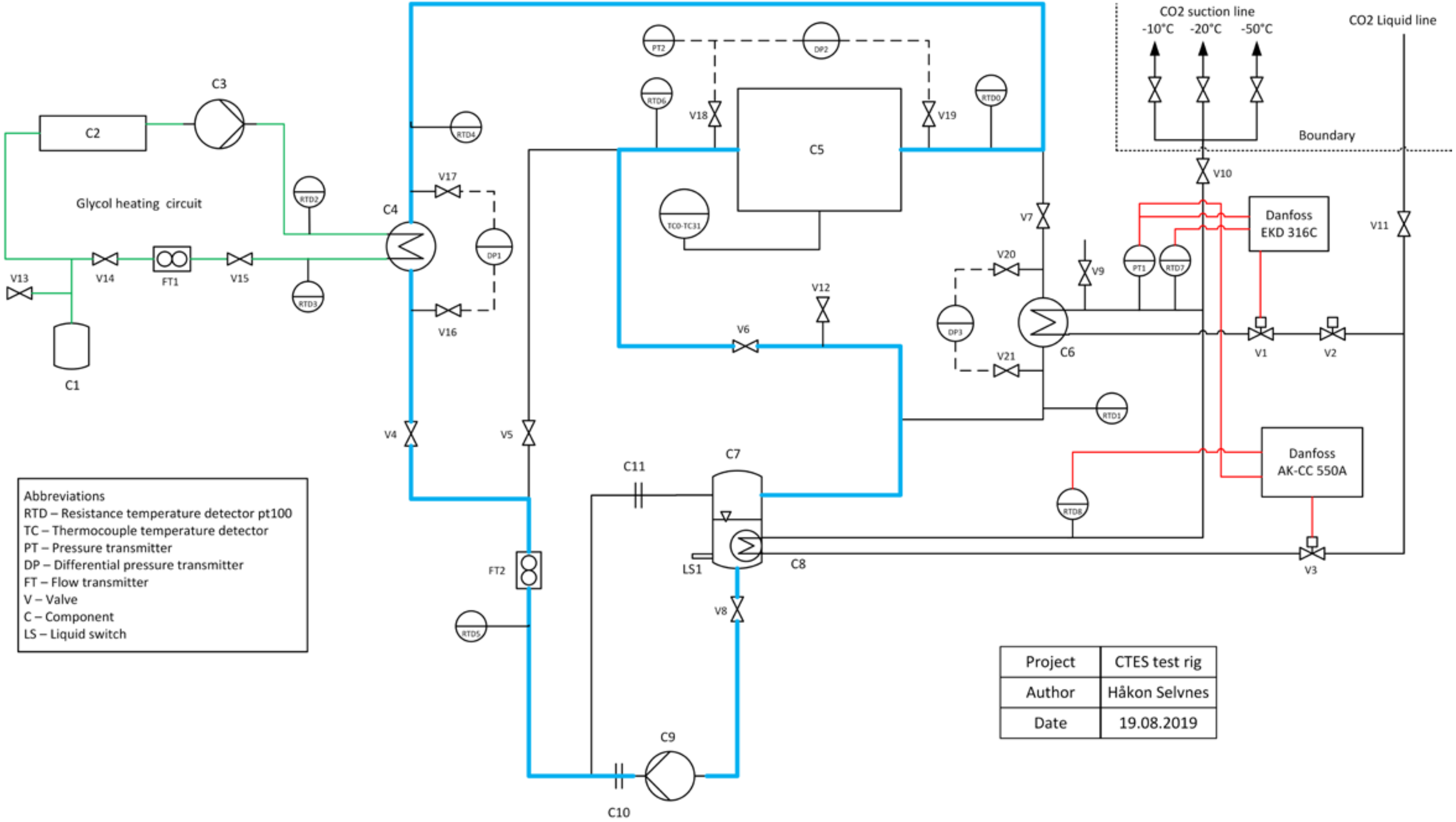
Project	CTES test rig
Author	Håkon Selvnes
Date	19.08.2019

Abbreviations
RTD – Resistance temperature detector pt100
TC – Thermocouple temperature detector
PT – Pressure transmitter
DP – Differential pressure transmitter
FT – Flow transmitter
V – Valve
C – Component
LS – Liquid switch

Experimental test facility – Charging mode



Experimental test facility – Discharging mode



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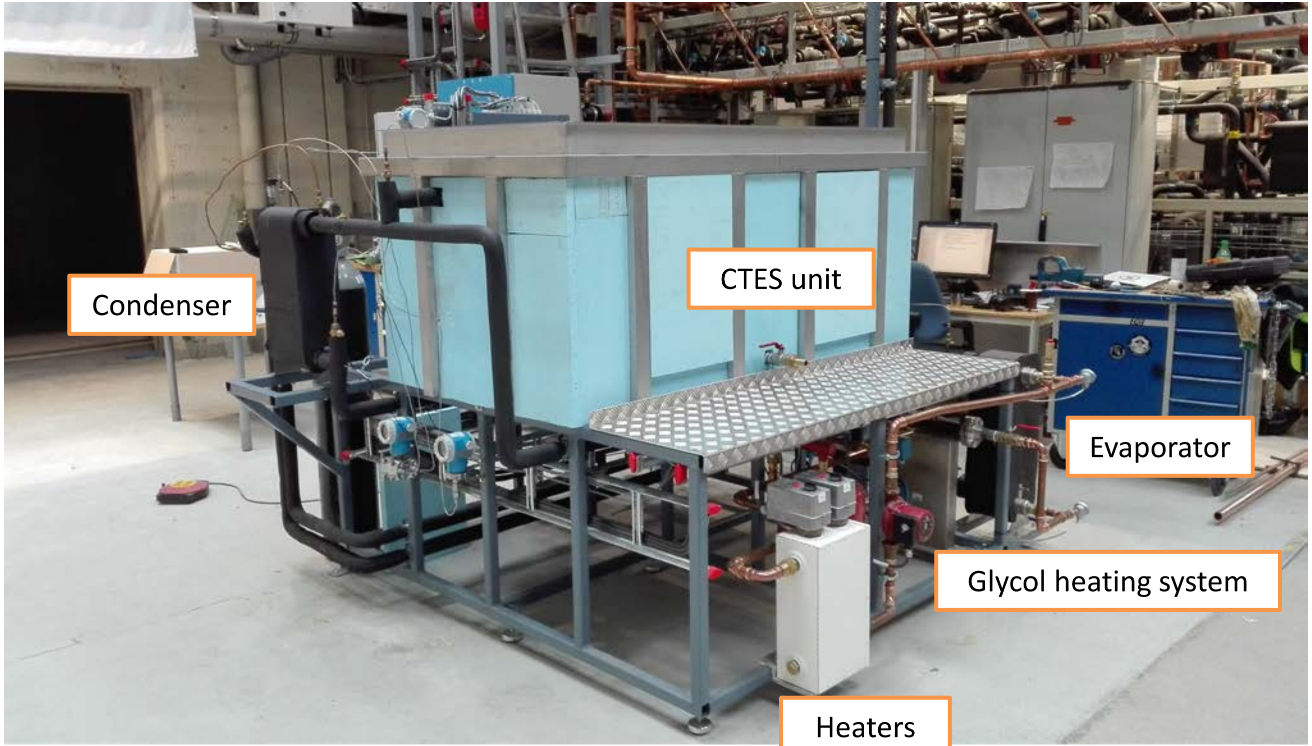
Experimental test facility – Parameter variation

Parameter	Range
Phase change material	+5°C to -45°C
Pillow plate distance	10 mm to 150 mm
Number of pillow plates	1 to 20 plates
CO_2 mass flow	4 to 12 kg/min
Glycol mass flow	20 to 50 kg/min
Glycol supply temperature	0°C to 50°C
Auxiliary CO_2 system evaporation temperature	-8°C to -52°C

Experimental test facility – Overview

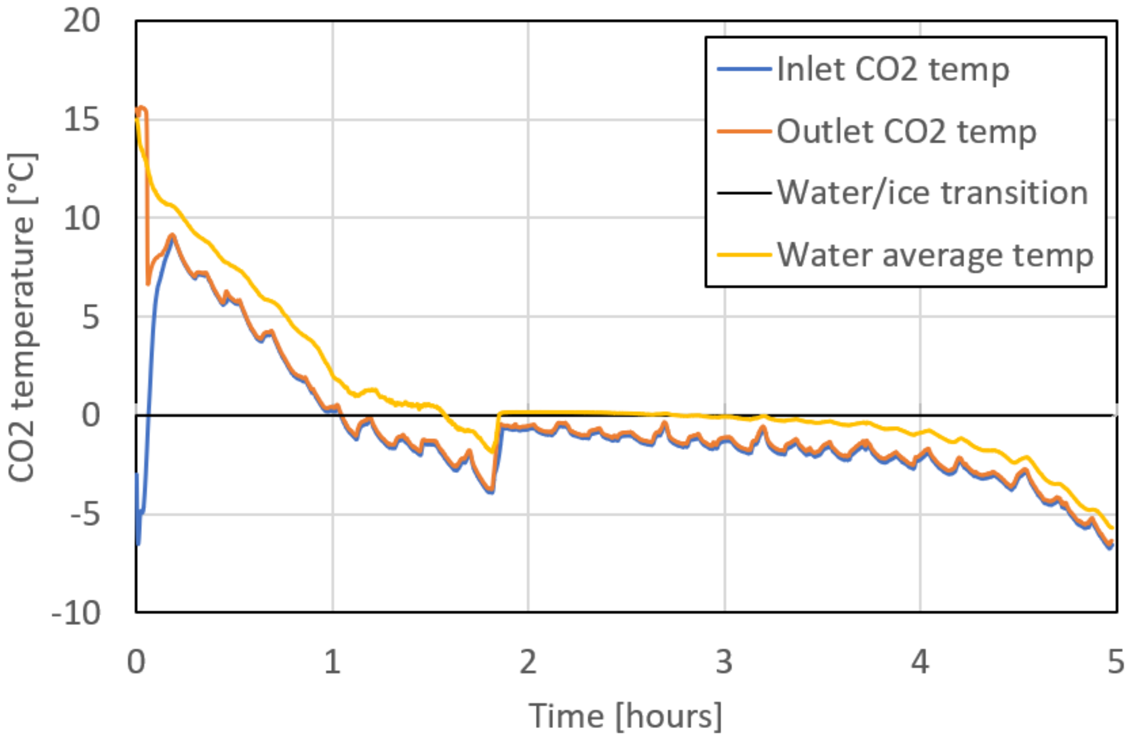


First results – Setup

Parameter	Value
Number of plates	9 plates (eq. to 19.70 m^2)
Distance between plates	50 mm
Phase change material	Water (0°C)
CO_2 mass flow rate	4 kg/min to 12 kg/min
Aux. CO_2 evaporation temperature	-25°C and -49°C

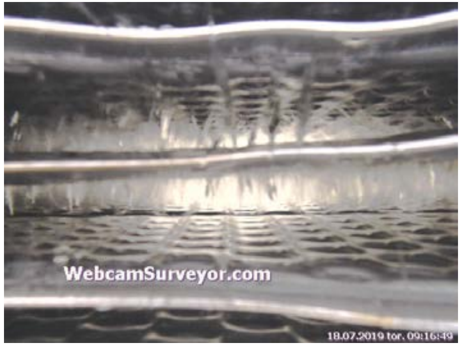
First results – Charging process

- Supercooling before freezing starts
- Pumped circulation
  - No CO_2 superheat

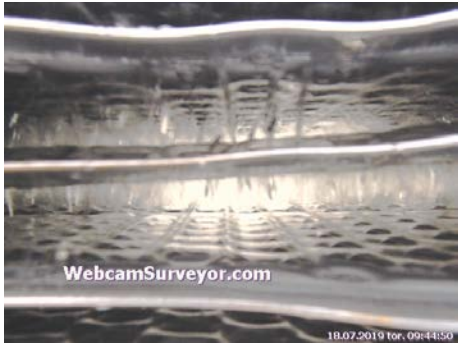


First results – Visual observation

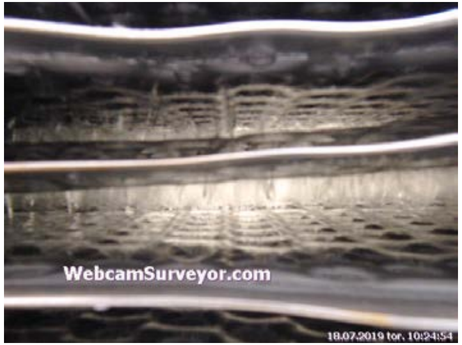
0 min



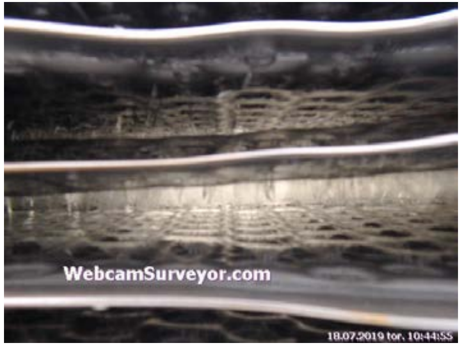
30 min



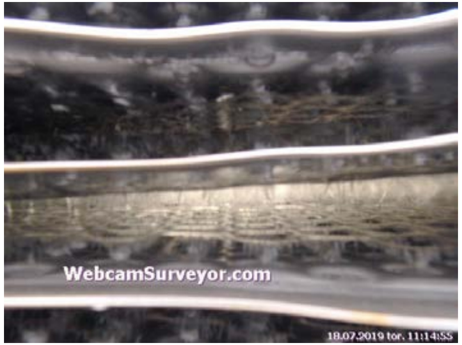
1 hour



1.5 hours

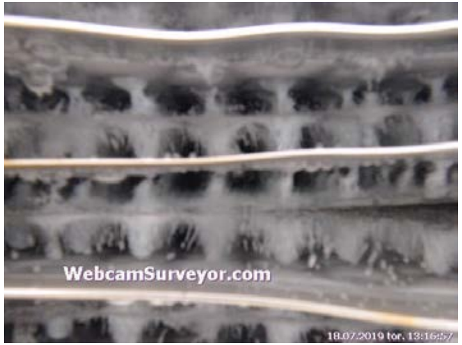


2 hours



2.5 hours

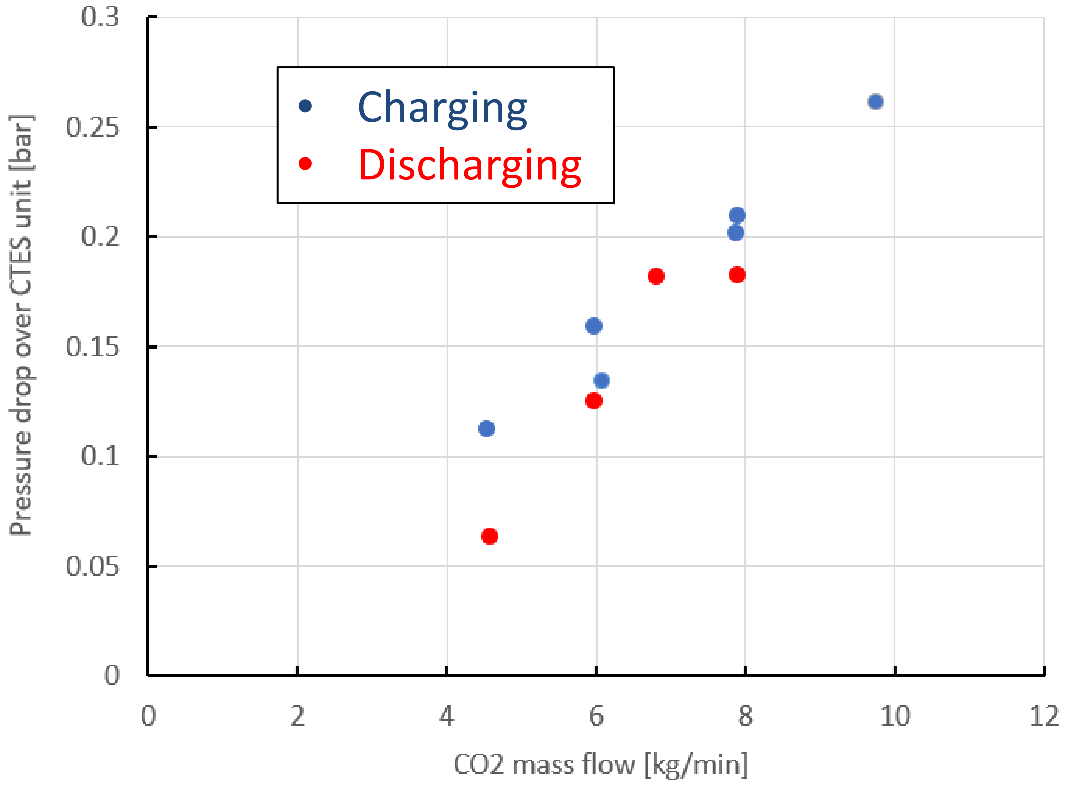
3.5 hours



4.5 hours

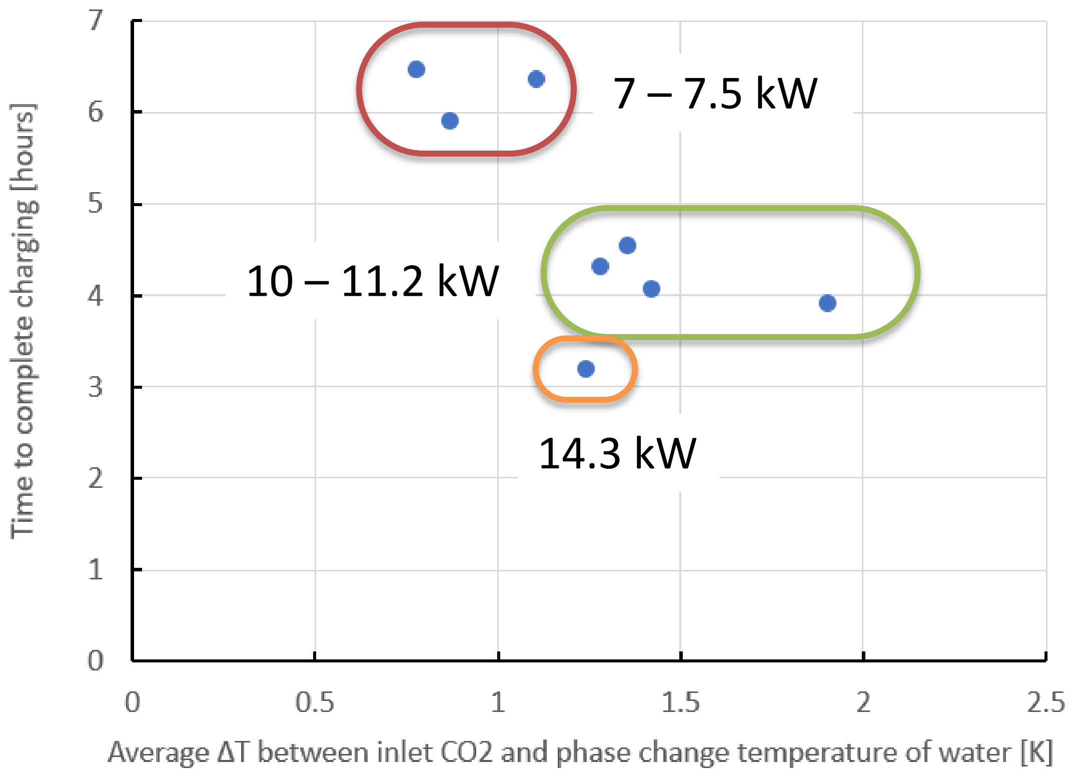
First results – Pressure drop

- Pressure drop increasing with higher mass flow
- Linear trend
- Similar for evaporation and condensation



First results – Charging time

- Total capacity 45.5 kWh
- Charging time decreasing with increasing ΔT
- Higher ΔT (5K to 10K) to investigate further



Conclusions and summary

- Design and construction of a pilot CTES unit and associated test facility successfully completed
- The facility can operate a CTES pilot unit integrated in a pump-circulated CO2 system simulating the bottom cycle of a cascade
- Some initial tests were conducted to study the charging and discharging processes.

Further work

- Pillow plates
  - Change distance between plates and number of plates
  - Plates with fins
- Phase change material
  - After a lab screening, select a PCM at -10°C for testing at full scale
- Lab facility
  - Include a gas quality sensor to the system
  - Include a height measurement of PCM

Acknowledgements

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THANK YOU FOR YOUR ATTENTION
Questions?

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