UNIVERSITÀ DI PADOVA

National Workshop on Heat Pumping Technologies

November, 17th 2026 – Area della Ricerca CNR, Pisa

Heat pumps, heat transfer and heat storage: the research activity at University of Padova

THERMAL ENERGY INNOVATION
Research group

teiresearch.com

Stefano Bortolin

OUTLINE

- Introduction
- Heat pumps
- Thermal energy storage with PCMs
- Two-phase heat transfer
- Frost formation
- Solar energy conversion
- Conclusions

Thermal Energy Innovation - TEI Research group

https://www.teiresearch.com/

Research activities are conducted in laboratories located in Padova (Dip. di Ingegneria Industriale - DII, Dip. di Ingegneria Civile, Edile e Ambientale - ICEA)
and in Vicenza (Dip. di Tecnica e Gestione dei Sistemi Industriali - DTG)

- **Heat transfer in micro-geometries (Padova)**
- **Industrial and building heat transfer (Padova)**
- **Refrigeration and heat pump technology (Padova)**
- **Solar energy conversion (Padova)**
- **Two-phase heat transfer (Padova)**
- **Refrigeration and air-conditioning (Vicenza)**
- **Nano heat transfer (Vicenza)**







Coordinator: prof. Simone Mancin

People: 15 academics, 4 post-docs, 13 Phd students

UNIVERSITÀ DI PADOVA
Dipartimento
di Ingegneria Industriale - DII

UNIVERSITÀ DI PADOVA
Dipartimento
di Tecnica e Gestione
dei Sistemi Industriali - DTG

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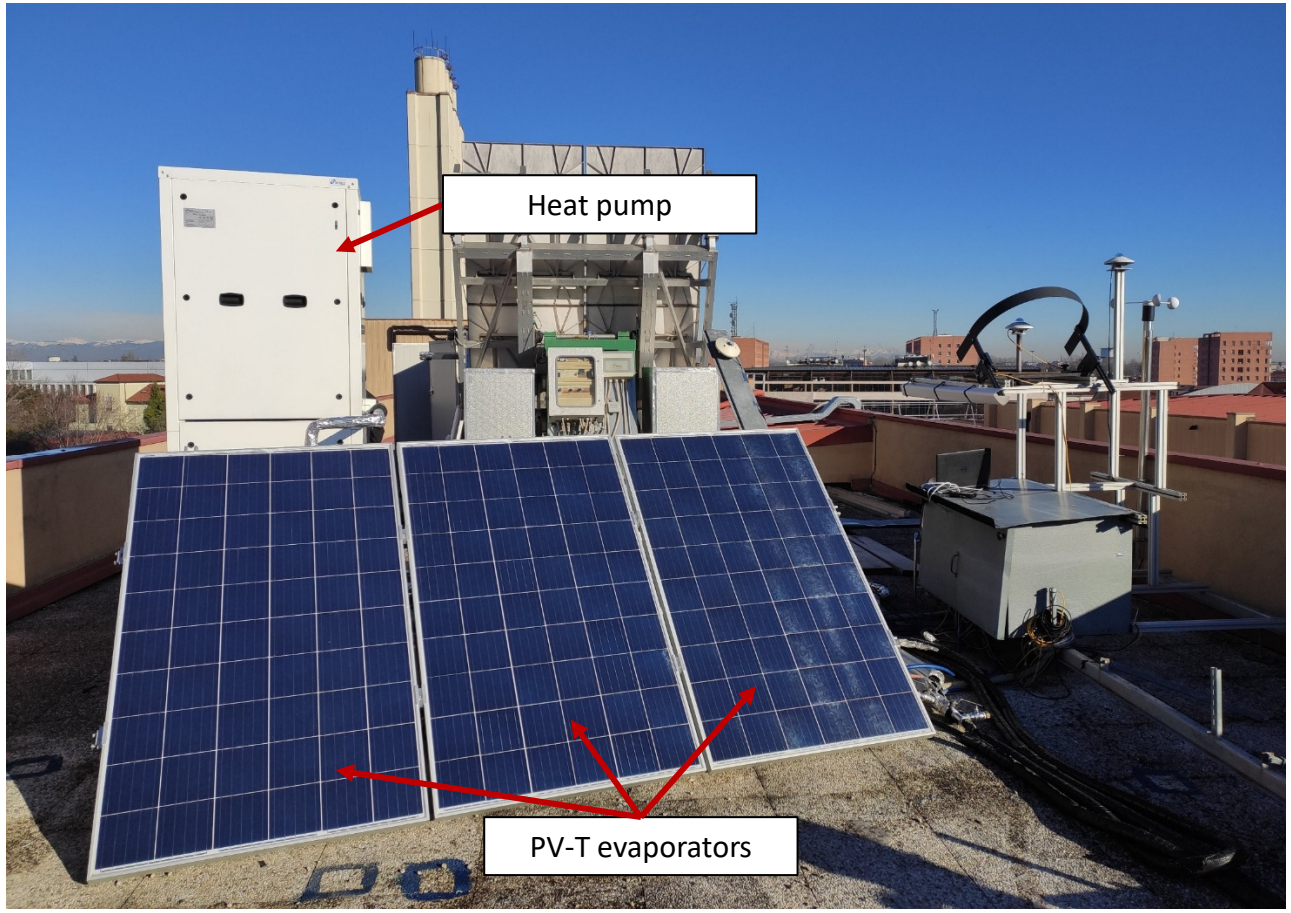
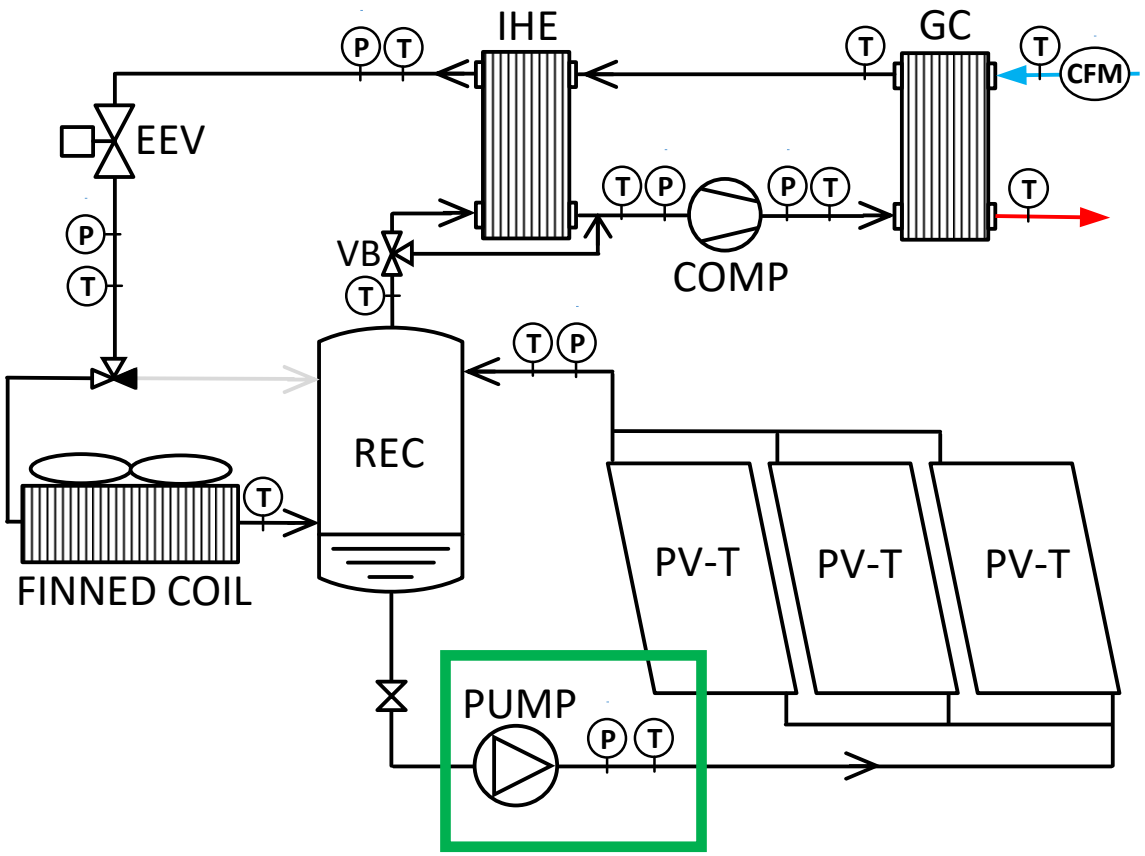
di Ingegneria Civile,
Edile e Ambientale - ICEA

DUAL SOURCE HEAT PUMP



- Dual-source solar-air heat pump for **water heating** (5 kW maximum heating capacity)
- **CO_2** as refrigerant
- **Transcritical** cycle
- **Two evaporators**:
  - Solar-source, Photovoltaic and Thermal (PV-T) collectors
  - Air-source, finned coil heat exchanger

DUAL SOURCE HEAT PUMP



Finned coil as evaporator

Direct expansion evaporator

+

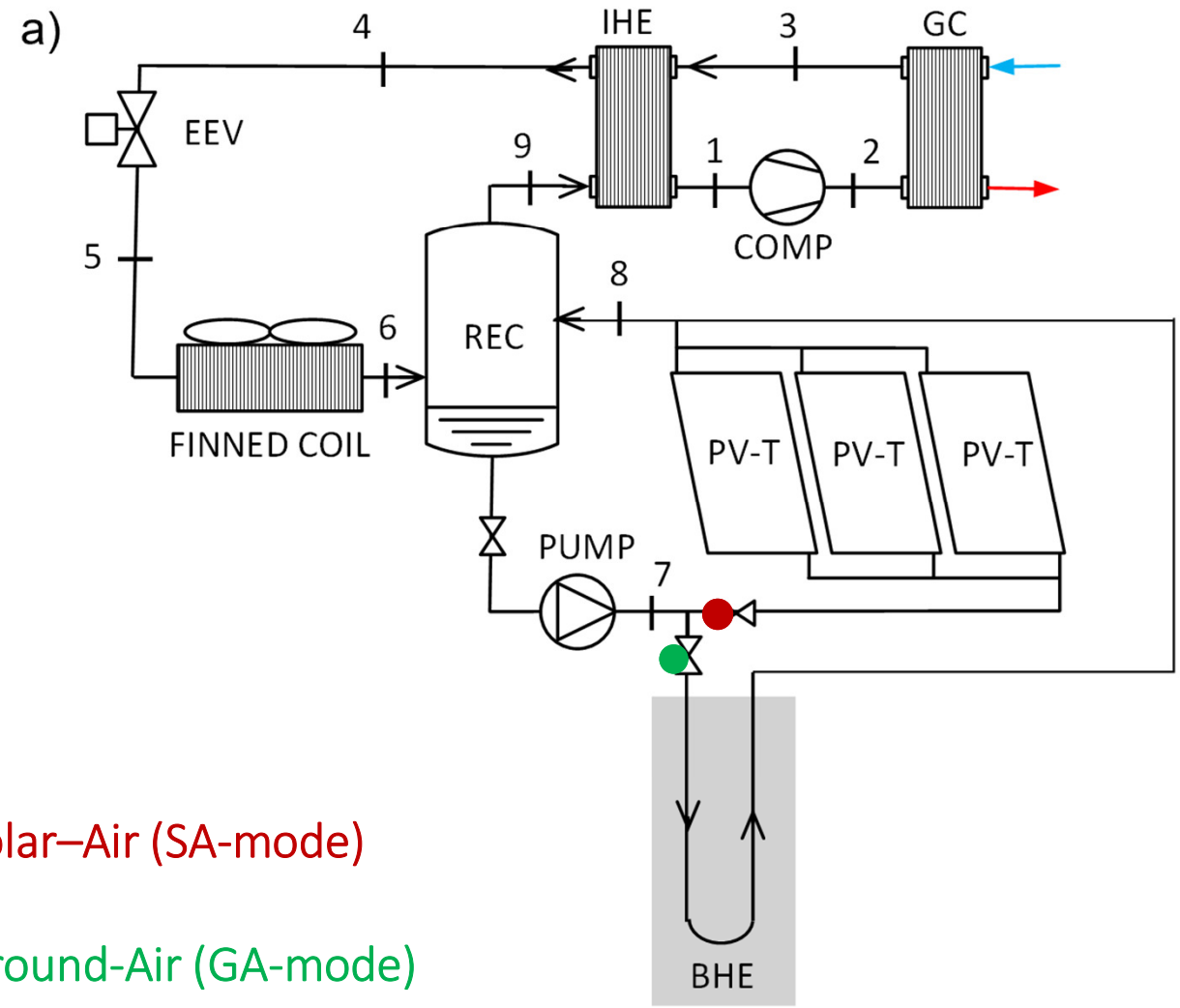
PV-T collectors as evaporator

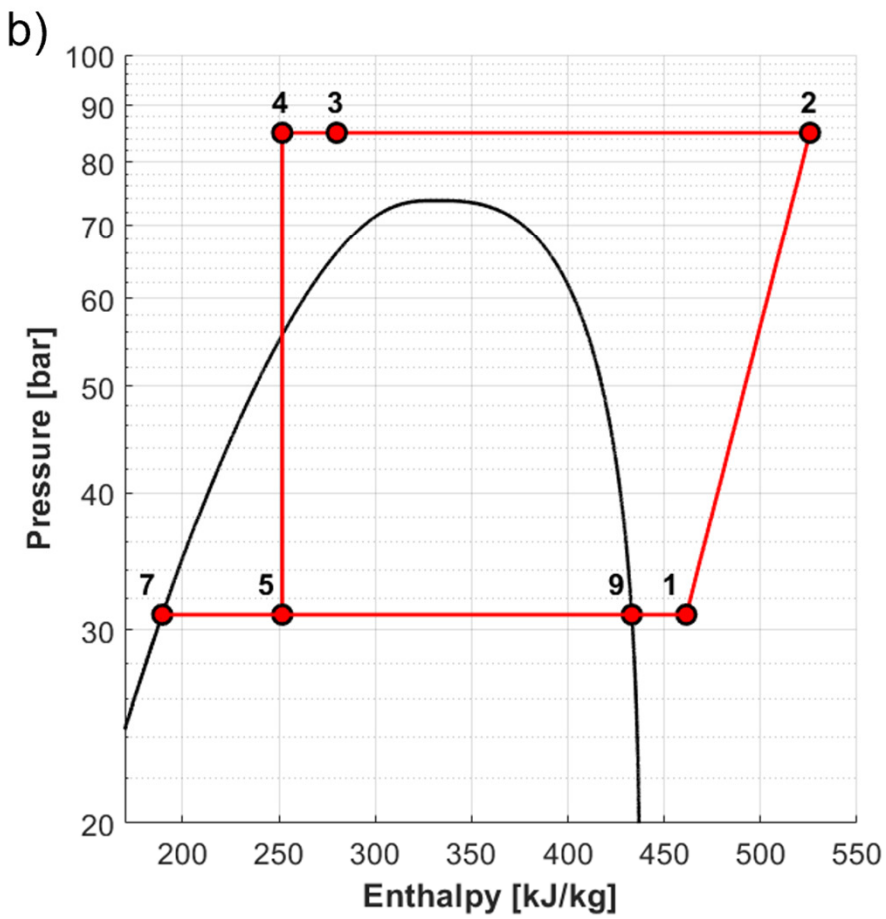
Flooded evaporator loop in forced circulation





MODELING OF MULTISOURCE HEAT PUMPS

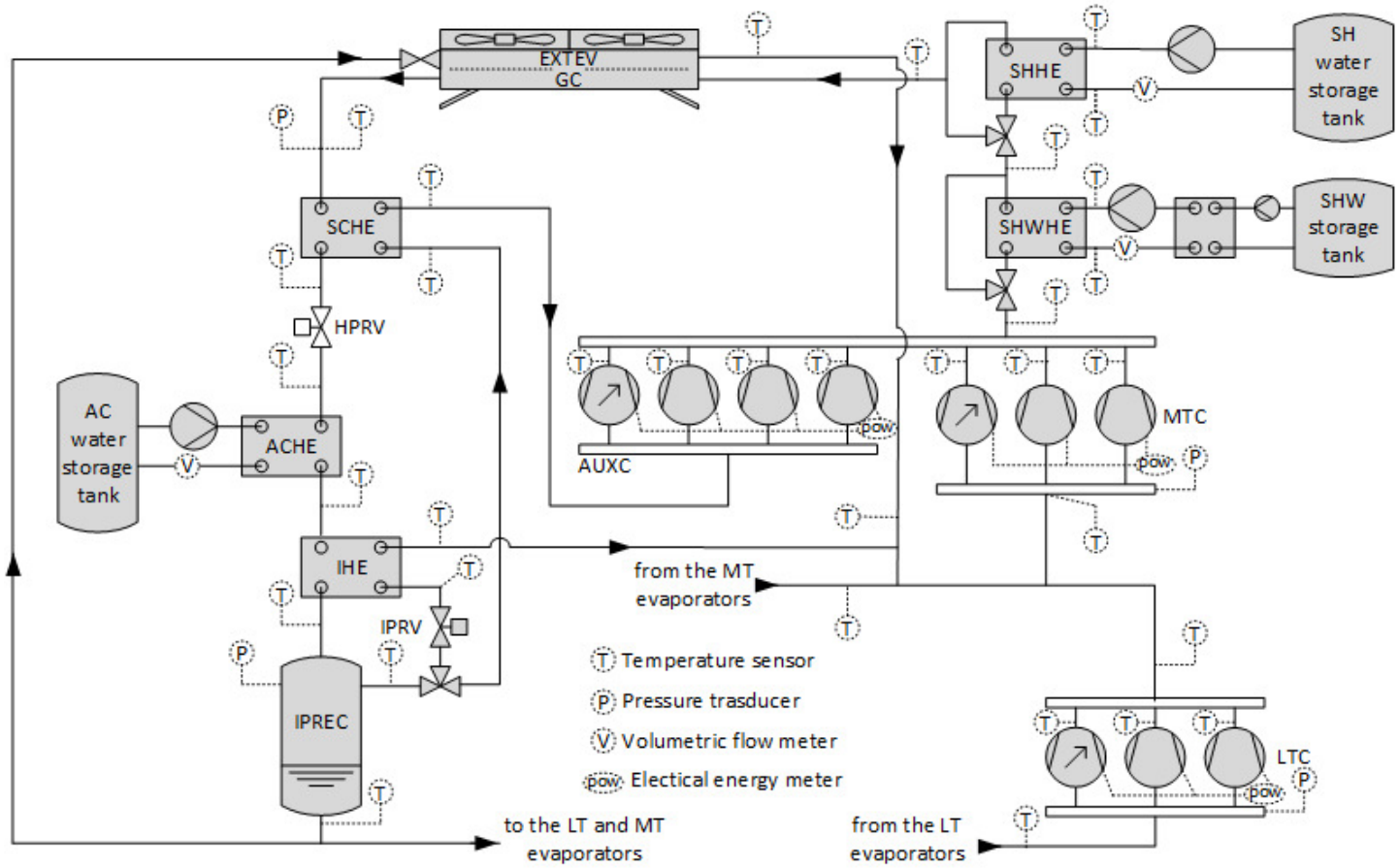




Solar–Air (SA-mode)

Ground-Air (GA-mode)

MODELLING OF COMPLEX SYSTEMS FOR HEATING AND COOLING



Booster system with parallel compression (B-PC)

+ sanitary hot water production
+ space heating
+ air-conditioning

NOMINAL COOLING CAPACITIES

15 kW at low temperature (LT)

65 kW at medium temperature (MT)

Transient models in Matlab-Simulink to predict real operating conditions **with rapid variations** of boundary conditions (valve regulation, compressor start/stop,…)

ZENITH – ZERO EMISSION INDUSTRIAL TECHNOLOGIES

HORIZON EUROPE PROJECT

Decarbonising industrial energy

ZEnITh develops an integrated, plug-and-play solution combining high-temperature heat pumps, latent thermal energy storage (LTES) and AI-based energy management.

HORIZON-CL4-INDUSTRY-2025-01-TWIN-TRANSITION-34

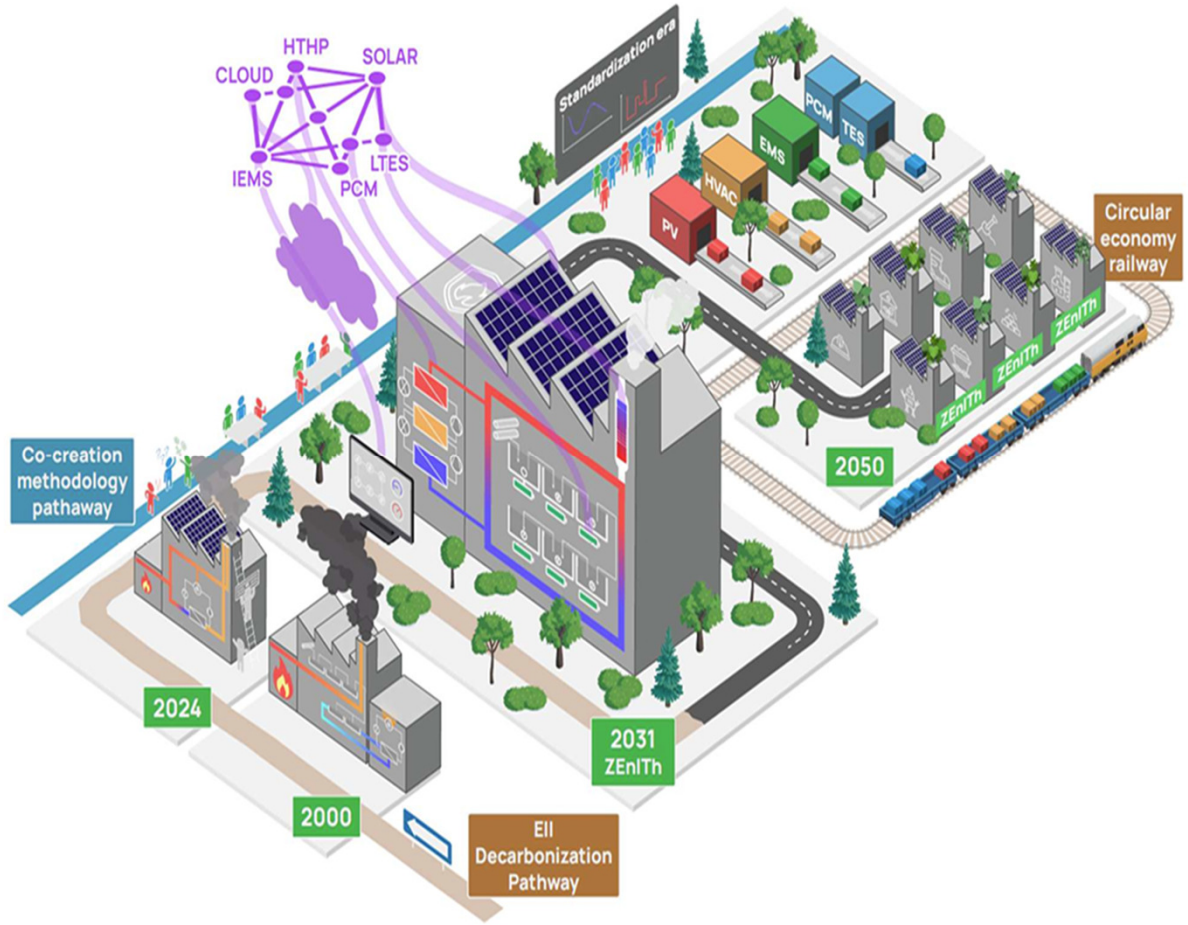
INDUSTRIAL DEMONSTRATION

Aluminium anodisation industry

The project will demonstrate the technology in an electrochemical aluminium surface-treatment process.

INTEGRATED HEAT SOLUTION

≈650 kWth high-temperature heat pump + >300 kWh LTES, charged using recovered waste heat.



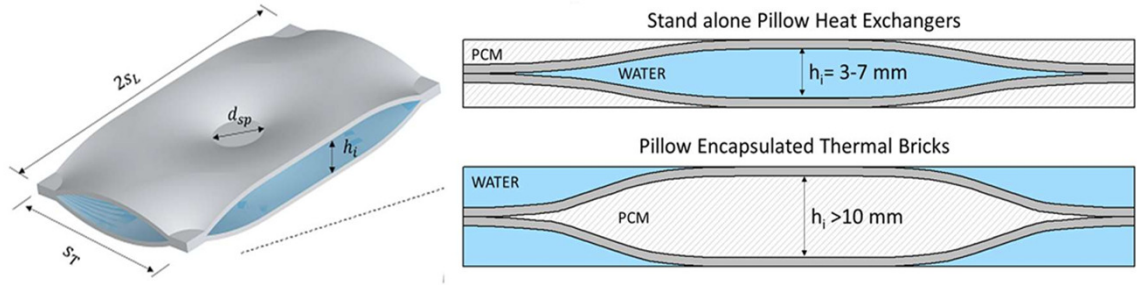
PLANNED ACTIVITIES AT UNIPD

Thermal energy storage

Developing latent heat storage solutions based on phase-change materials (PCMs).

01 Flexible PPHX concept

The pillow-plate heat exchanger (PPHX) can operate with PCM inside or outside.

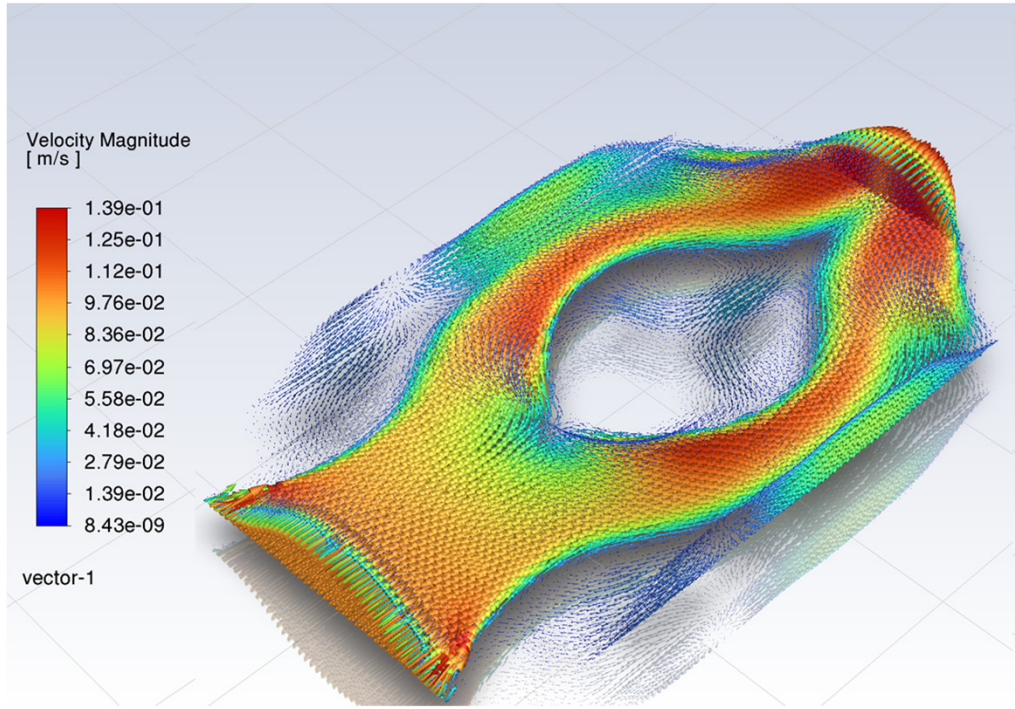


02 Experimental characterisation

Test PPHX prototypes and 20 kWh demonstrators, investigating the effects of fluid flow rate, inlet temperature, PCM and tank temperature.

03 PCM properties and modelling

Characterize selected organic and eutectic PCMs from 20 °C to 130 °C, and develop validated numerical models to support PPHX design and demo-case selection.



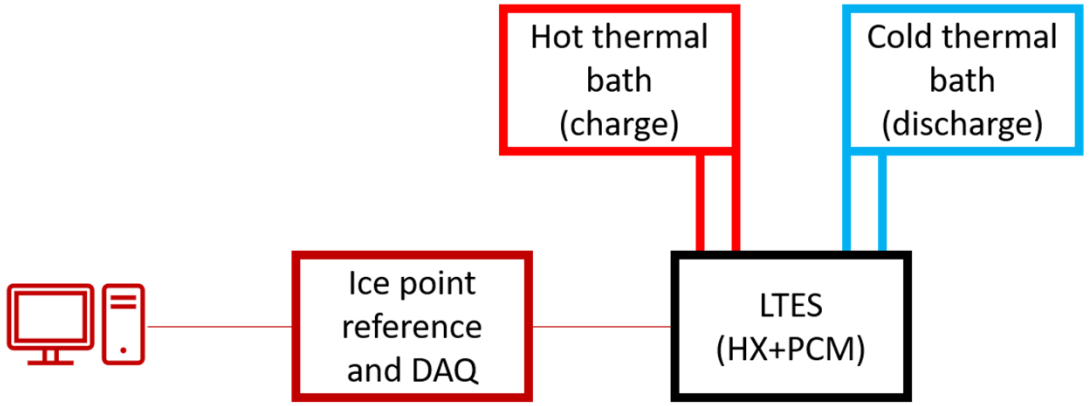
LATENT THERMAL ENERGY STORAGE: DOMESTIC HOT WATER



Boiler water tank → LTES

LTES to be charged by an air-to-water or water-to-water HP

LTES to provide water at >40°C



2 thermal baths to “simulate” the heat pump for charging and the domestic water users

Melting point ~ 62°C
Latent enthalpy > 200 kJ kg^{-1}

RT62HC



A new generation of ecological heat storage materials utilising the processes of phase change between solid and liquid (melting and congealing) to store and release large quantities of thermal energy at nearly constant temperature. The RUBITHERM® phase change materials (PCM's) provide a very effective means for storing heat and cold, even when limited volumes and low operating temperature differences are applicable.

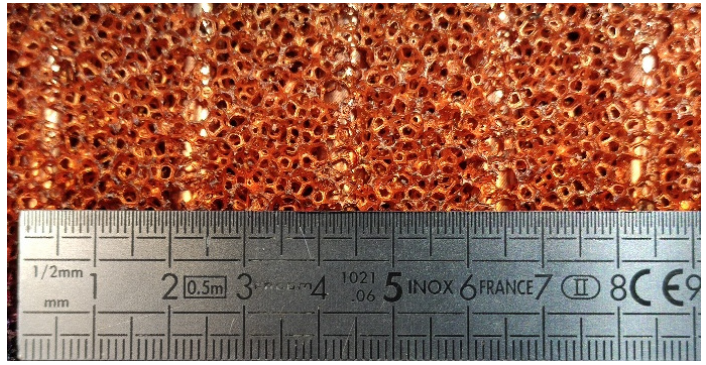
We look forward to discussing your particular questions, needs and interests with you.

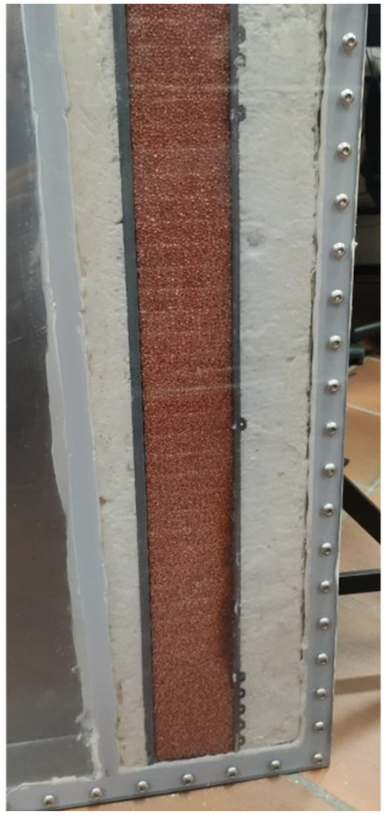
Properties RT-line:
- stable performance throughout the phase change cycles
- high thermal storage capacity
- limited supercooling
- non toxic
- melting temperature range between -9 °C and 100 °C available

The most important data:

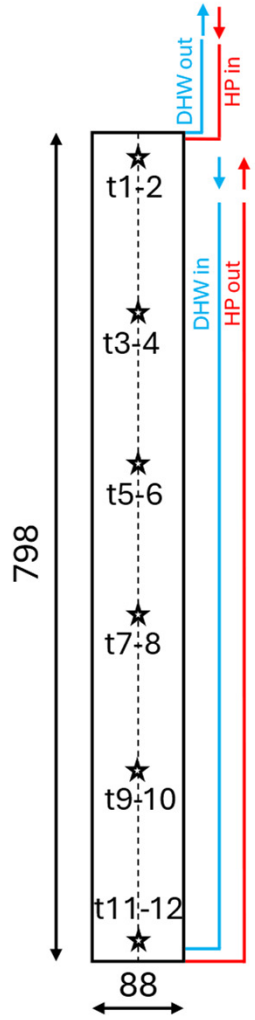
	Typical Values	
Melting area	62-63 (main peak: 63)	[°C]
Congealing area	62 (main peak: 62)	[°C]
Heat storage capacity ± 7,5% (Combination of latent and sensible heat in a temperatur range of 55°C to 70°C.)	230	[kJ/kg]*
	64	[Wh/kg]*
Specific heat capacity	2	[kJ/kg·K]
Density solid (at 25°C)	0,99	[kg/l]
Density liquid (at 80°C)	0,85	[kg/l]
Heat conductivity	0,2	[W/(m·K)]
max. operation temperatur	90	[°C]
Corrosion	slight corrosive effect on metals	

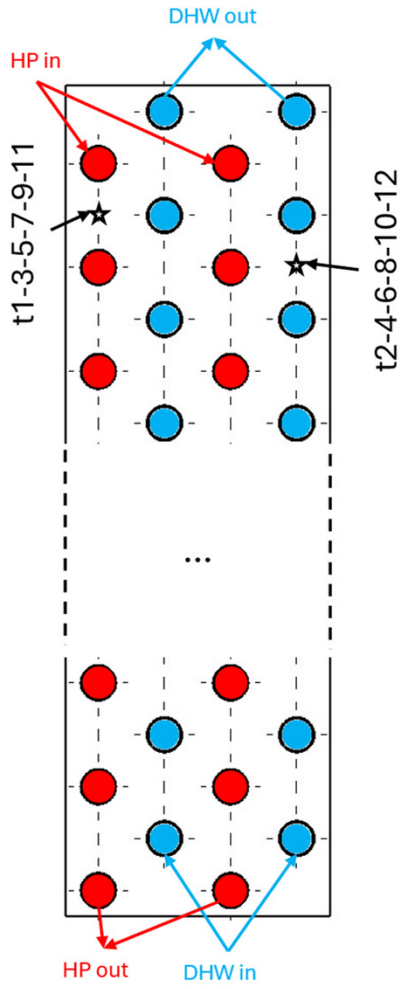
LATENT THERMAL ENERGY STORAGE: DOMESTIC HOT WATER

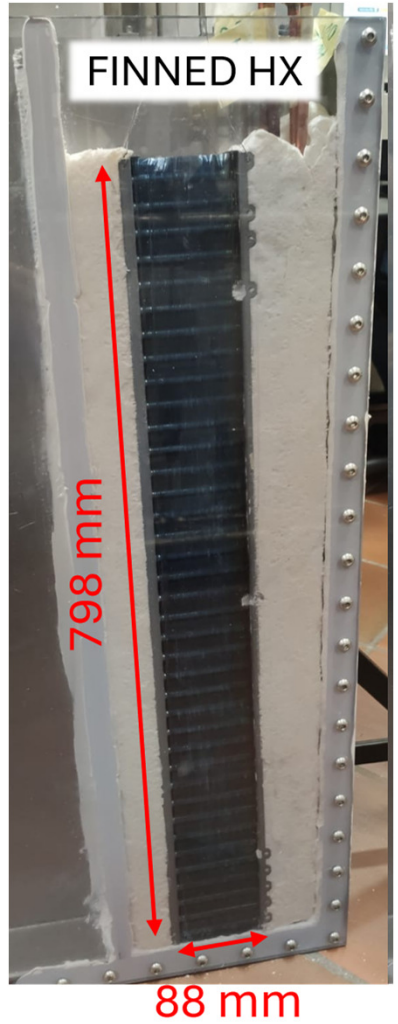




Foam HX



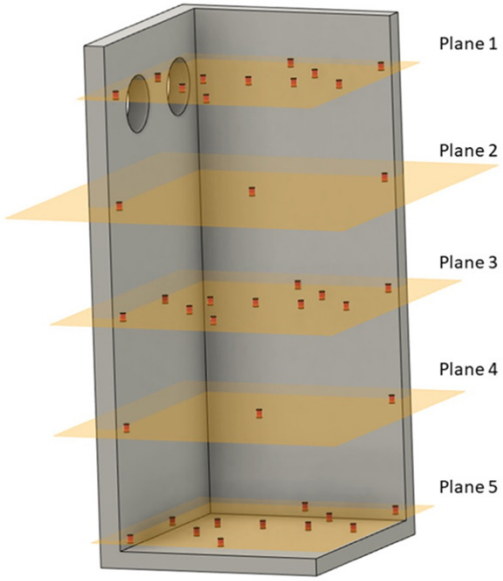




LATENT THERMAL ENERGY STORAGE



(a)



(b)

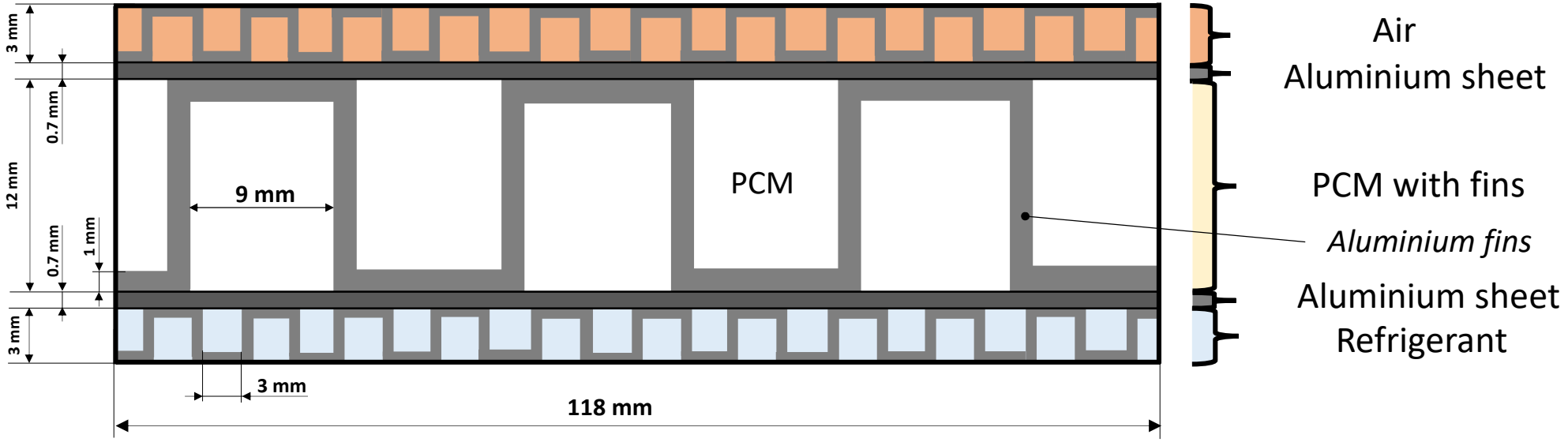


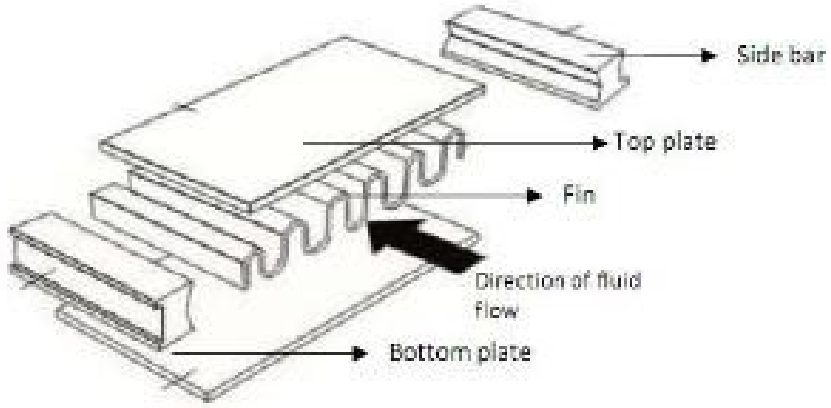


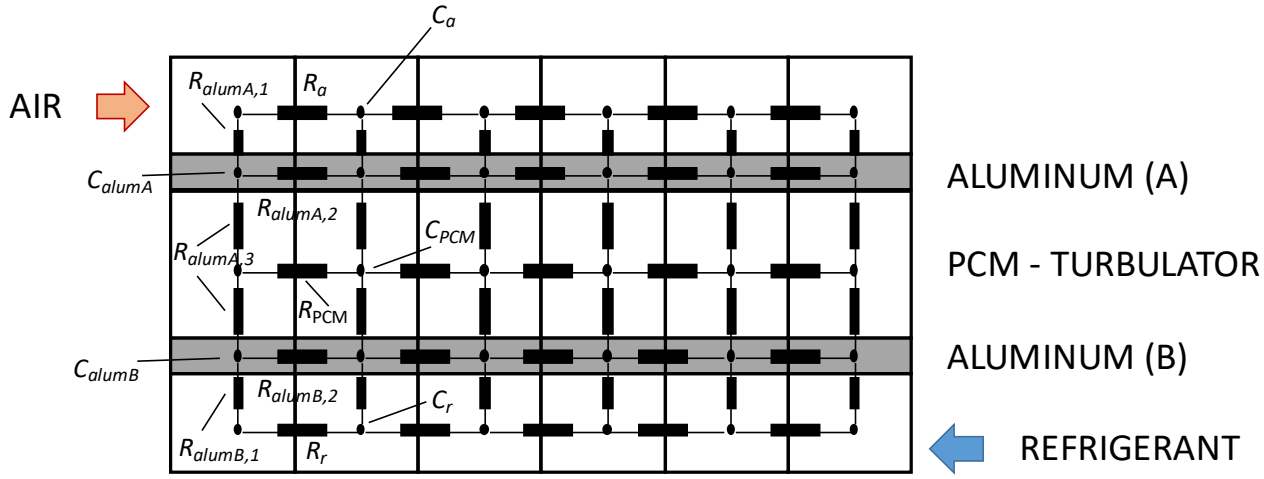


A 18 kWh latent thermal energy storage that uses the roll-bond technology to store and release thermal energy by exploiting the solid/liquid phase change process of 300 kg of a biobased phase change material.

LATENT THERMAL ENERGY STORAGE

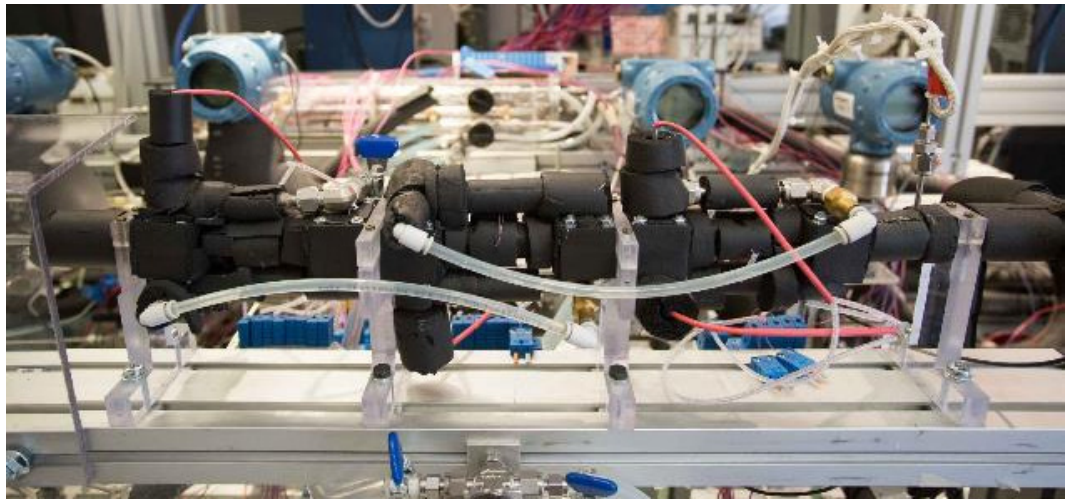


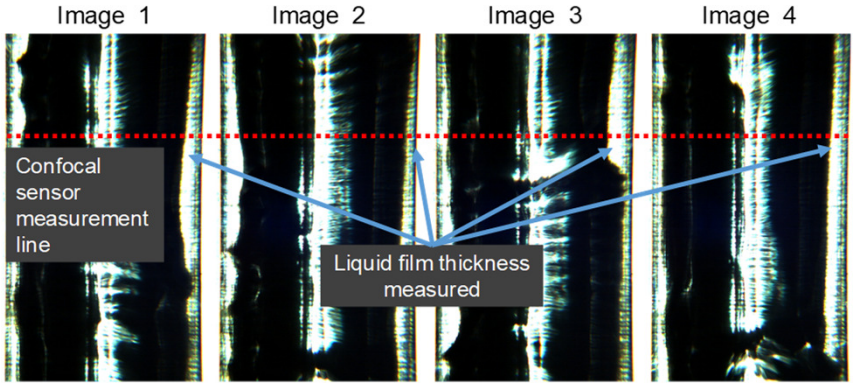




CONDENSATION AND FLOW BOILING HEAT TRANSFER

-brazed plate heat exchangers
-smooth tubes (1 mm – 8 mm)
-microfin tubes



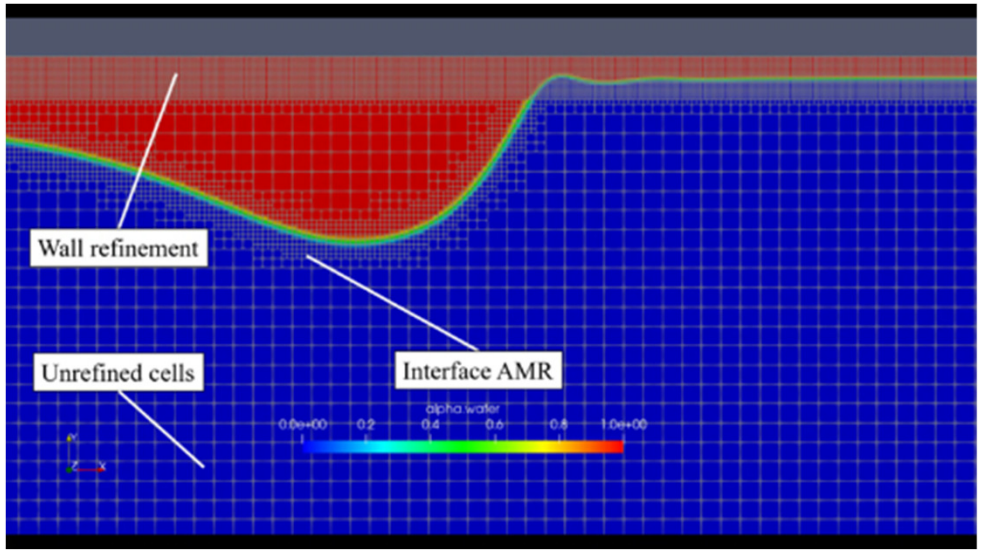




Some refrigerants tested:

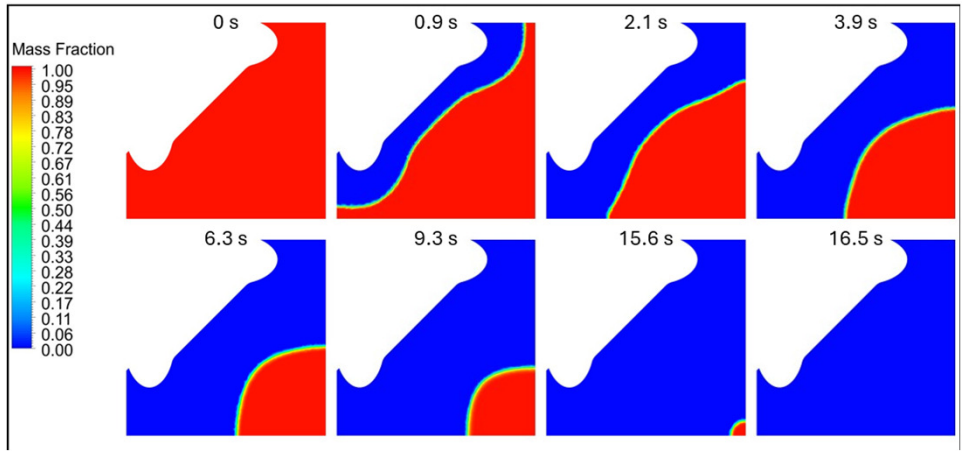
R290
R600a
R1270
R32
R1234yf
R1234ze(E)
R1234ze(Z)
R1233zd(E)
R152a
HFO-HFC mixtures
CO2-Propane mixtures

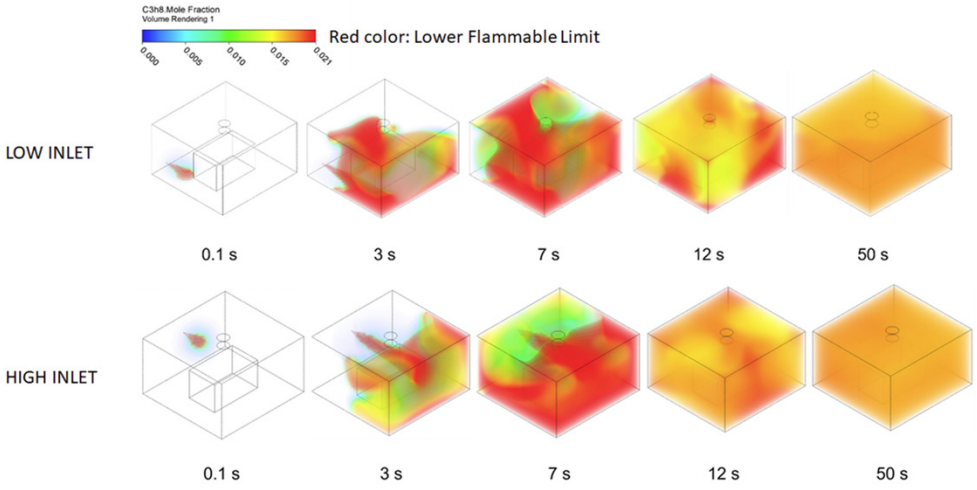
CFD NUMERICAL SIMULATIONS

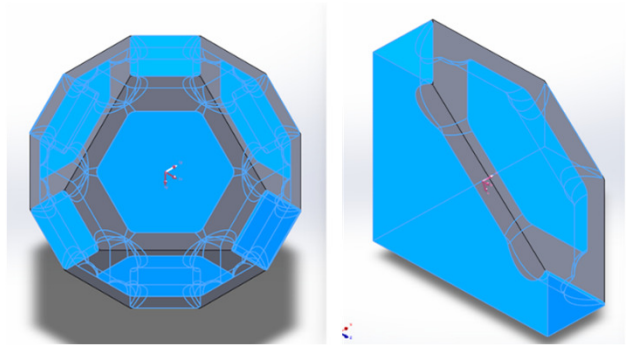


In-tube condensation

PCM

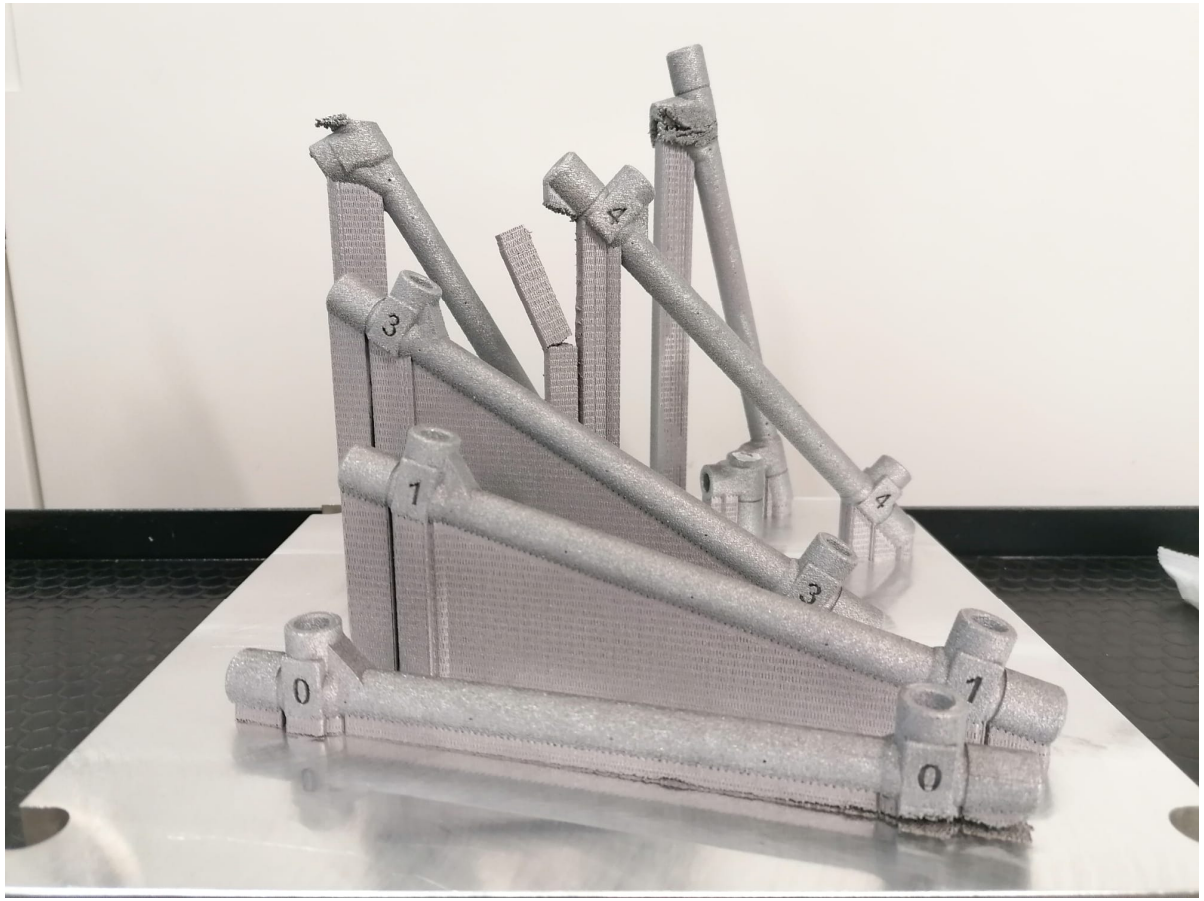


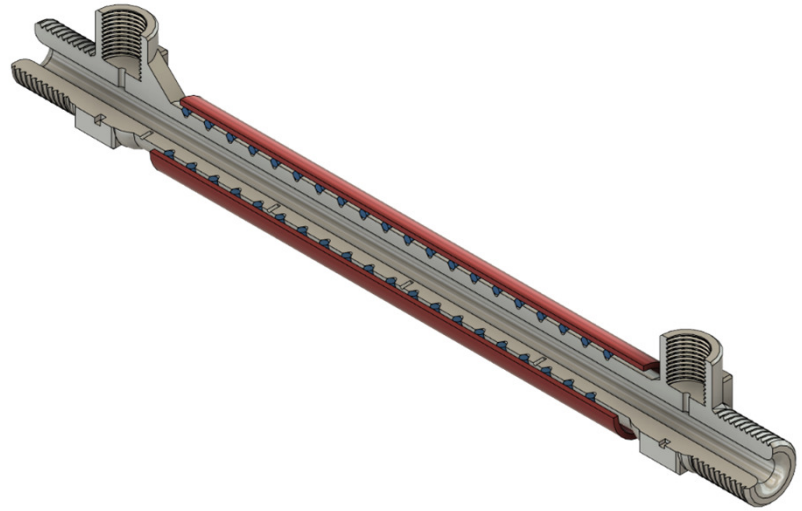


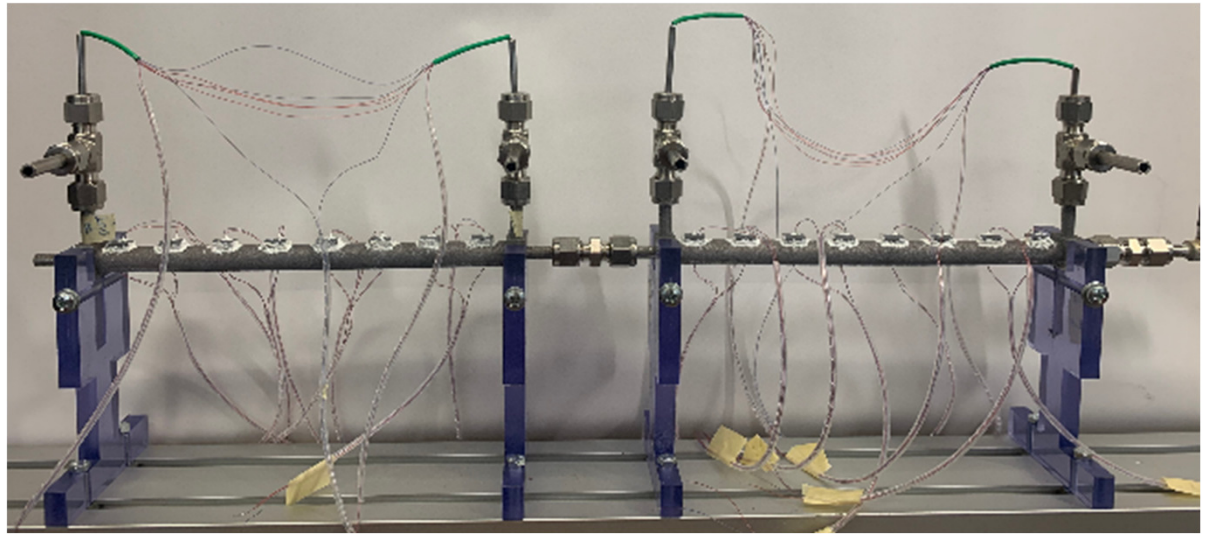


Propane leakage

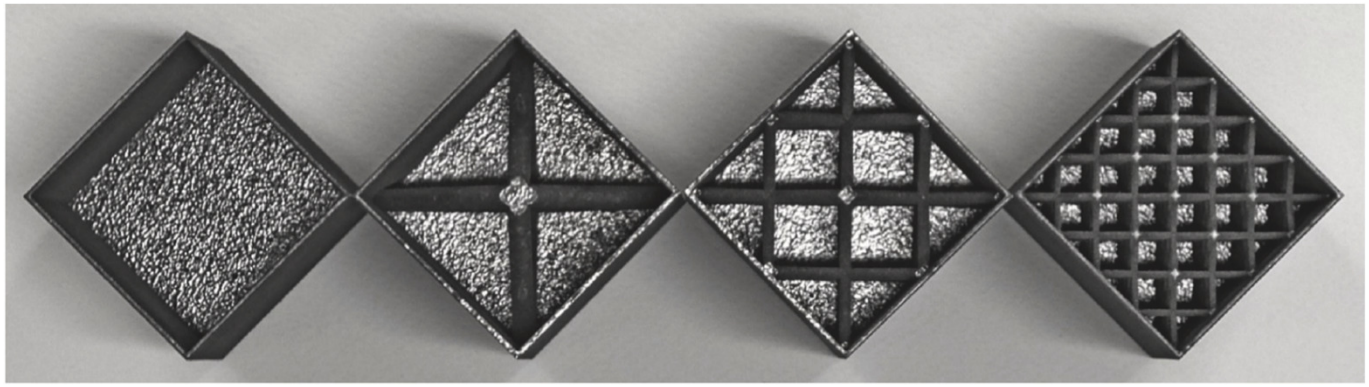
ADDITIVE MANUFACTURING OF HEAT EXCHANGERS

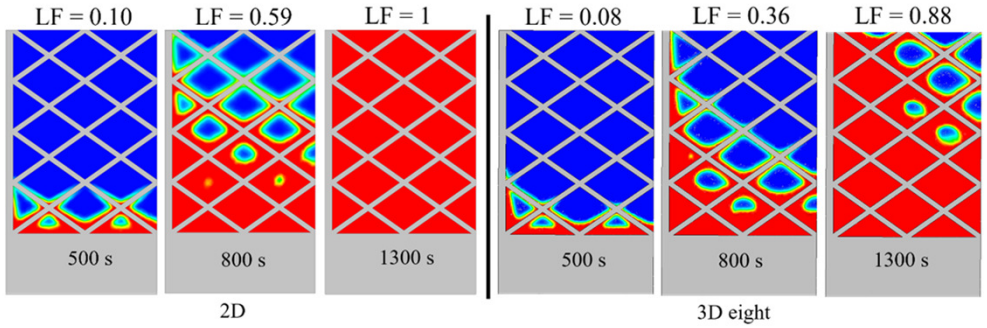


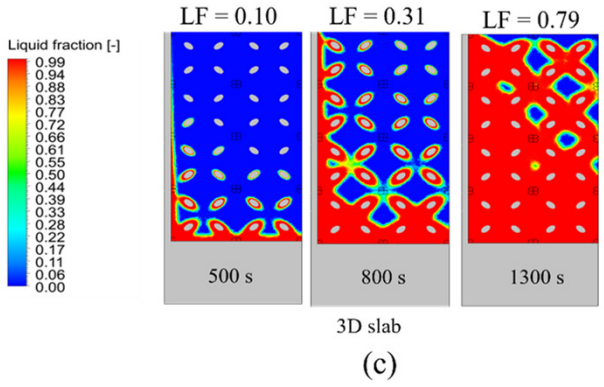


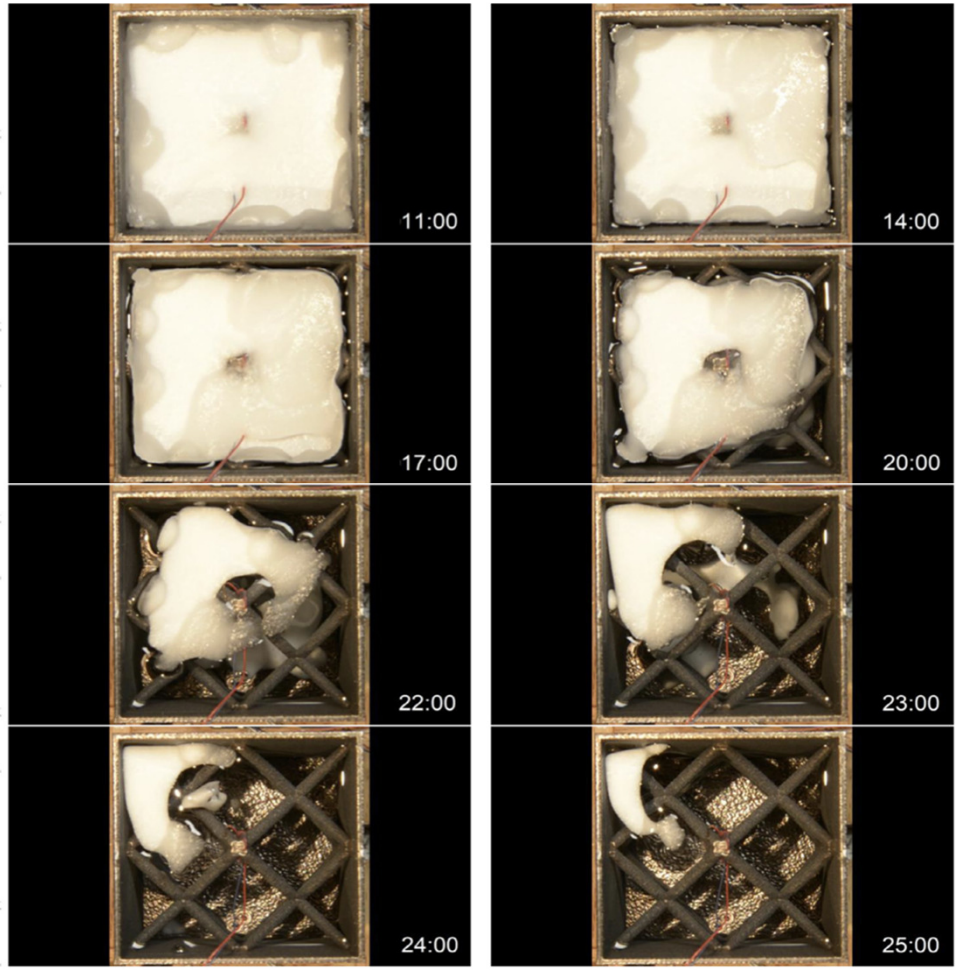


ADDITIVE MANUFACTURING FOR LTES

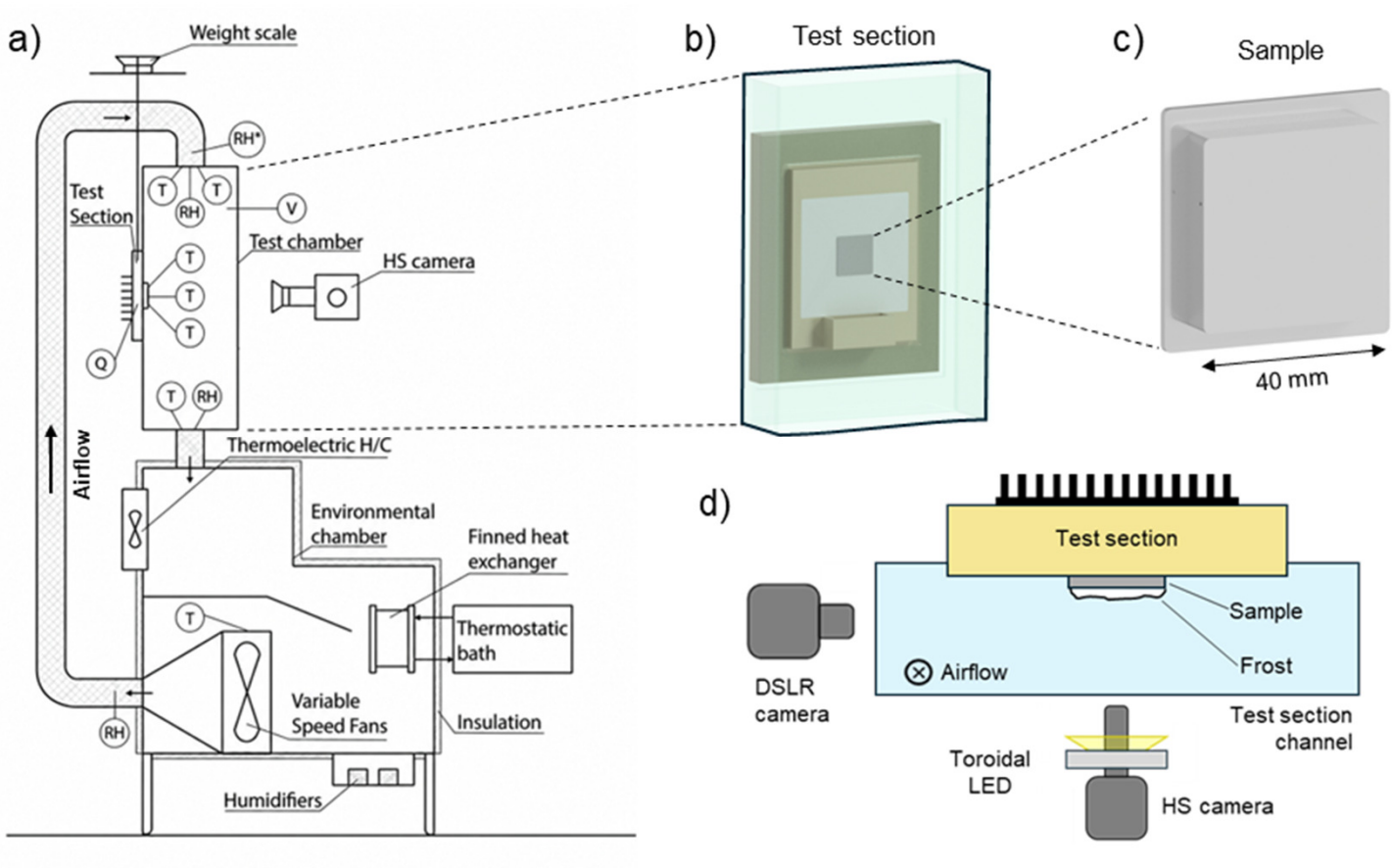


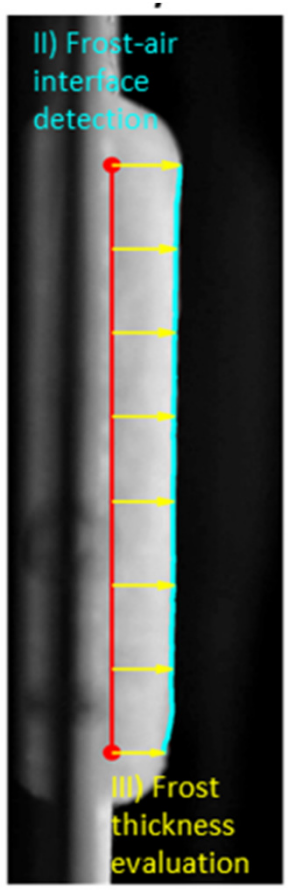


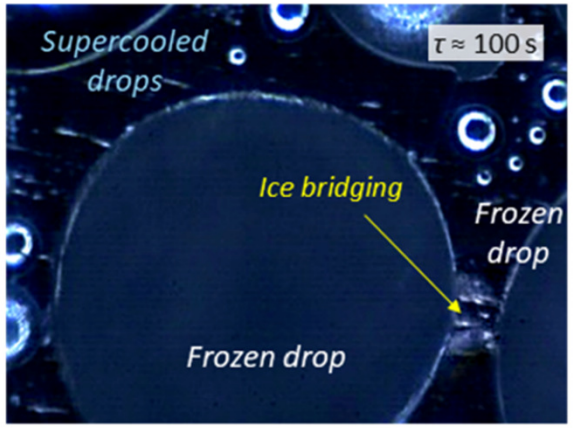


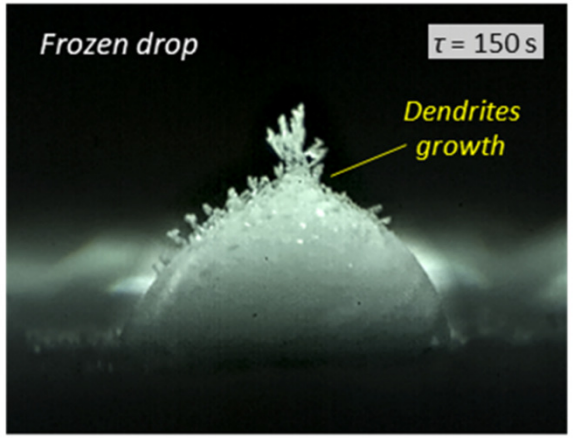


FROST FORMATION ON ENGINEERED SURFACES









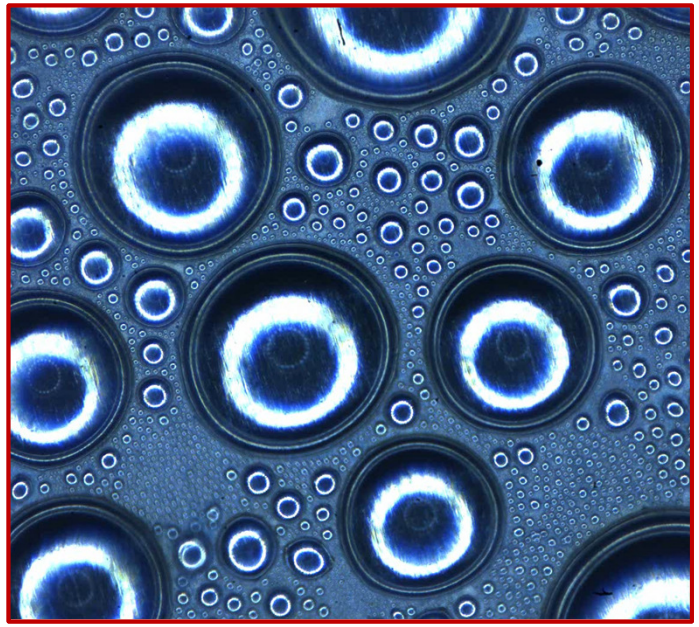
SURFACE ENGINEERING FOR ENHANCED CONDENSATION

Developing advanced surface coatings to enhance phase-change heat transfer in heat pumps and thermal systems

SURFACE DESIGN

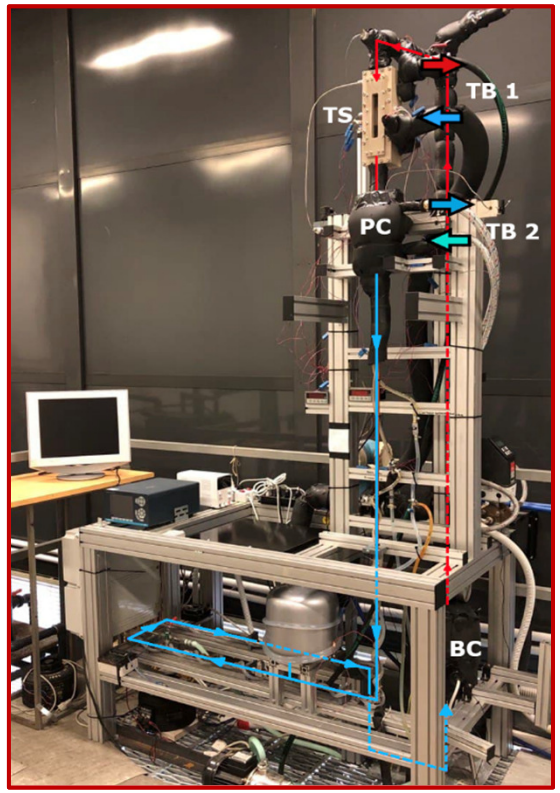
Develop low surface energy coating (PFAS-free) to **promote and sustain dropwise condensation** (DWC) instead of filmwise condensation.

Up to **10× higher heat transfer coefficients** (HTC) compared to filmwise condensation.

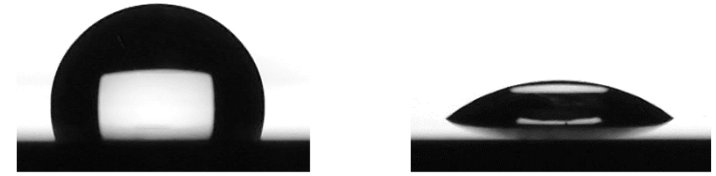


EXPERIMENTAL VALIDATION

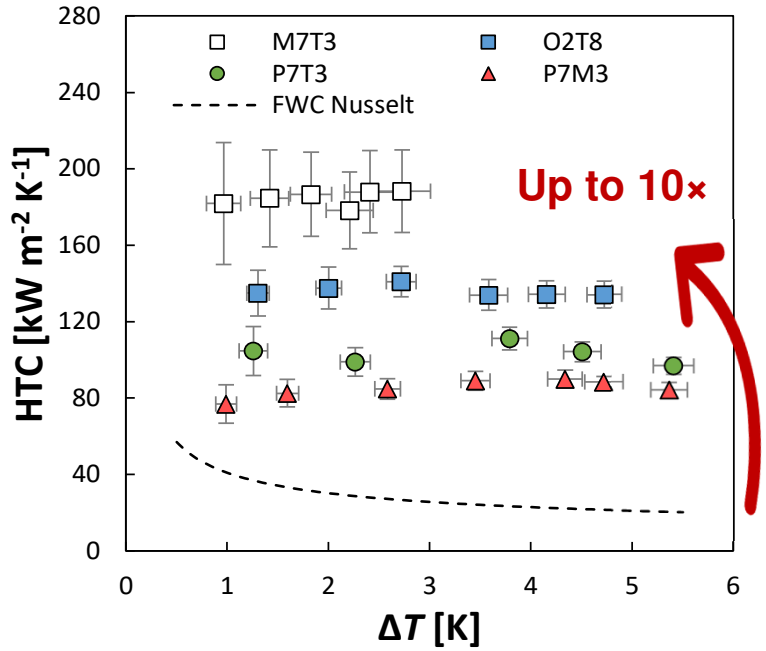
Measure heat transfer performance and visualise droplet dynamics during steam condensation.



WETTABILITY & PERFORMANCE



HYDROPHOBIC HYDROPHILIC

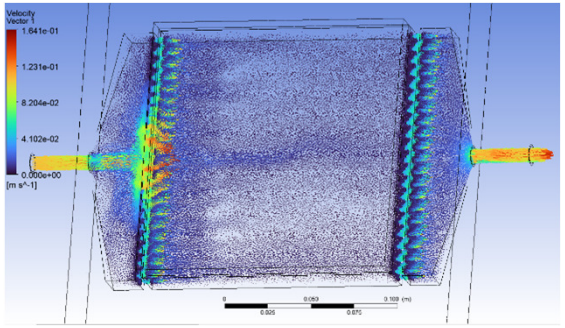


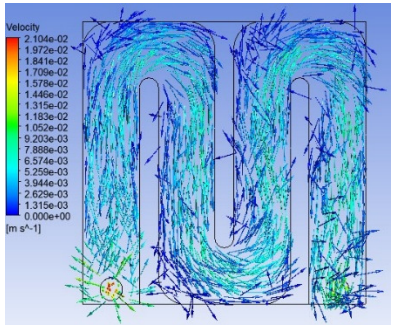
DIRECT ABSORPTION SOLAR COLLECTORS (DASCS) WITH CARBON NANOFLUIDS

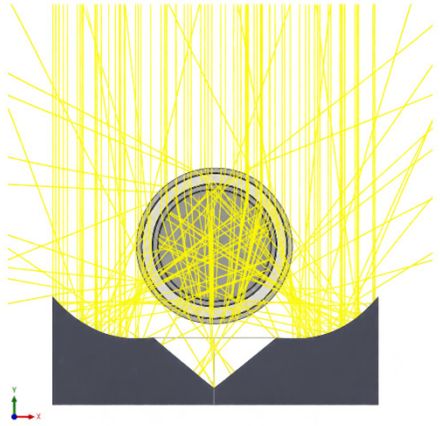
Development and characterization of volumetric solar thermal collectors using carbon-based nanofluids for solar radiation absorption.

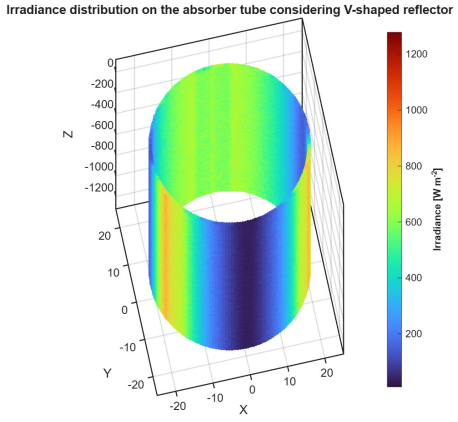
NETWORK FOR ENERGY SUSTAINABLE TRANSITION

Design of volumetric solar receivers and reflectors

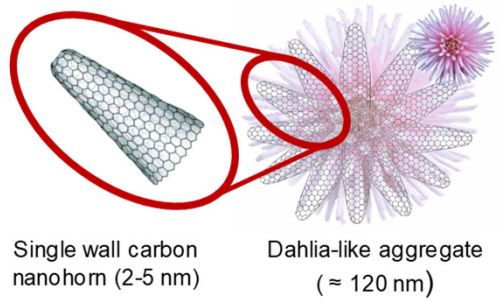


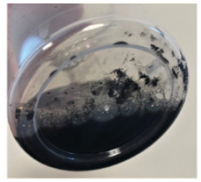




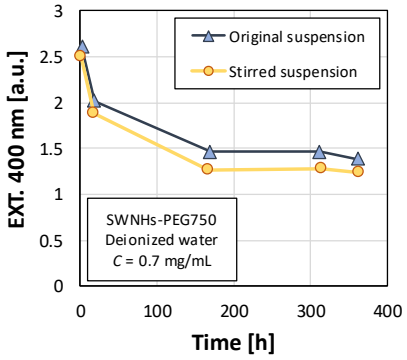


Nanofluid development and characterization





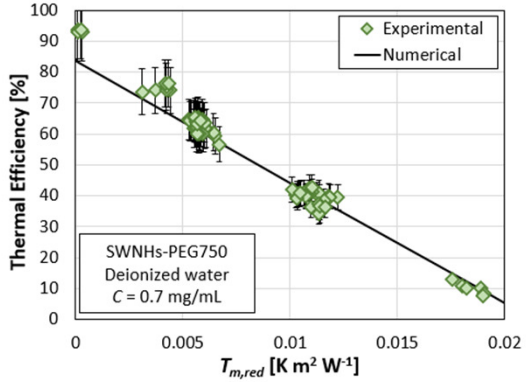




Indoor and outdoor testing







CONCENTRATING SOLAR THERMAL TECHNOLOGIES



SOLAR THERMAL ENERGY STORAGE

Objective: Development of medium-temperature latent thermal energy storage (LTES) using phase change materials (PCMs), such as erythritol (115–125 °C phase change range), for integration with a linear parabolic solar concentrator.

CONCLUSIONS

- Simultaneous multisource operation is a promising strategy to increase the performance and flexibility of heat pumps for building heating applications.
- PCMs allows to store thermal energy and then release it when needed: in this way it is possible to efficiently decouple the availability of renewable energy sources from the heating demand and contribute to decarbonization of the HVAC sector.
- There is need for precise system sizing, optimization of the packaging structure, and advanced control strategies to improve the performance of integrated heat pump and LTES systems.
- Engineered surfaces can be used to increase the two-phase heat transfer coefficient and delay frost formation.
- High temperature heat pumps, condensation/boiling data at high saturation temperatures must be investigated.
- CFD numerical simulations during phase change processes are emerging as engineering tools but they still requires experimental validation.

Thanks for your attention!

Stefano Bortolin
Department of Industrial Engineering
University of Padova
stefano.bortolin@unipd.it
https://www.teiresearch.com/