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Experimental evaluation of a heat pump-latent storage system for increasing renewable share of the residential stock

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HYBUILD
Hybrid Energy Storage for Buildings

Summary

- System description
- Experimental facilities
- Experimental methods
- Results
- Conclusions

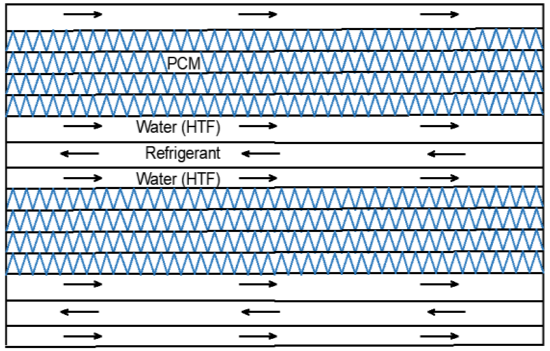
SYSTEM DESCRIPTION/1

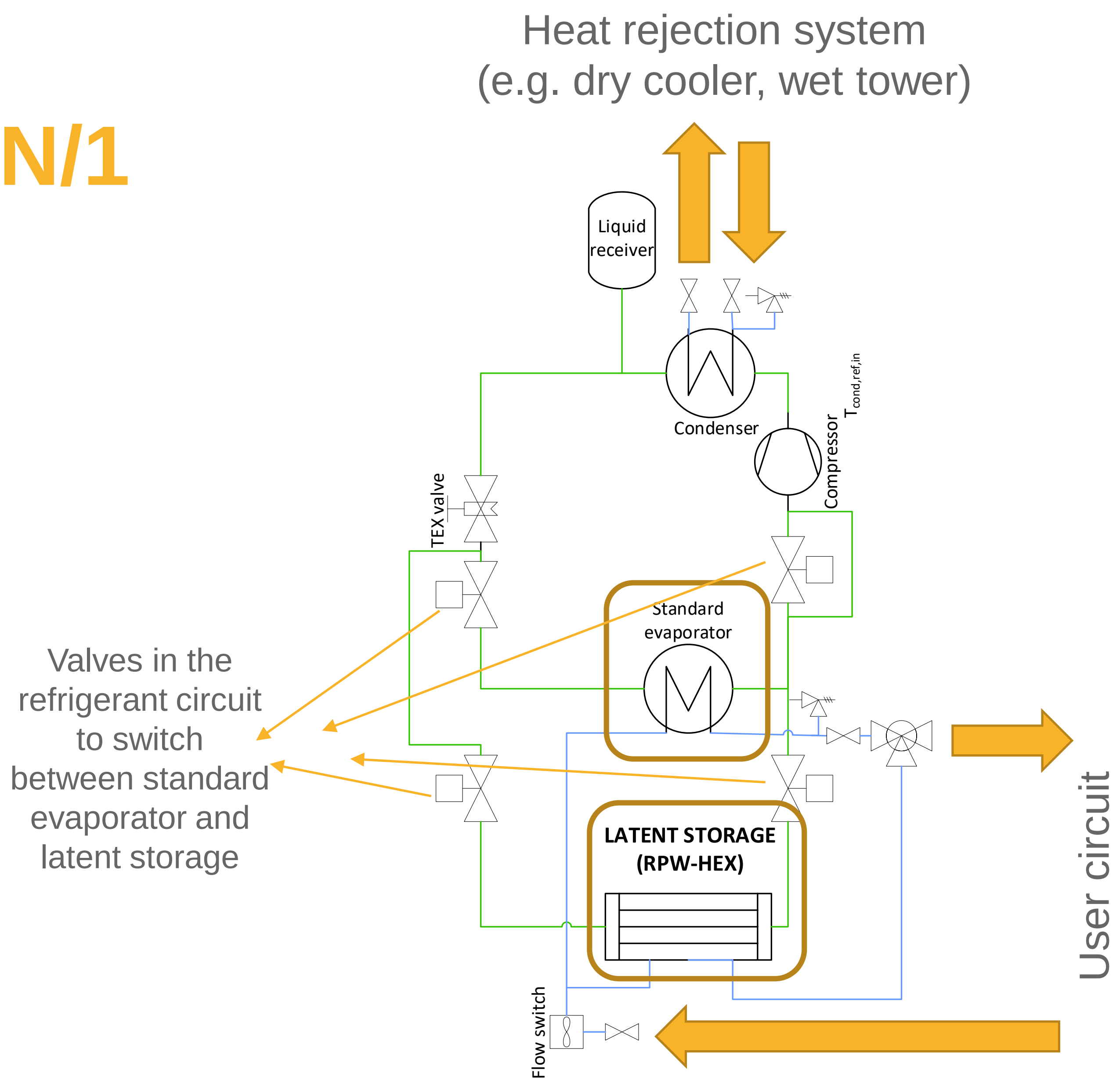
MAIN CONCEPT:

Integrated chiller - latent heat storage directly embedded in the compression cycle. The Phase Change Material (PCM) has a melting temperature of 4°C, suitable to store the cooling energy from the chiller.

MAIN NOVELTY:

The latent storage is a three-fluid heat exchanger with channels for the heat transfer fluid (HTF), the PCM and the refrigerant.





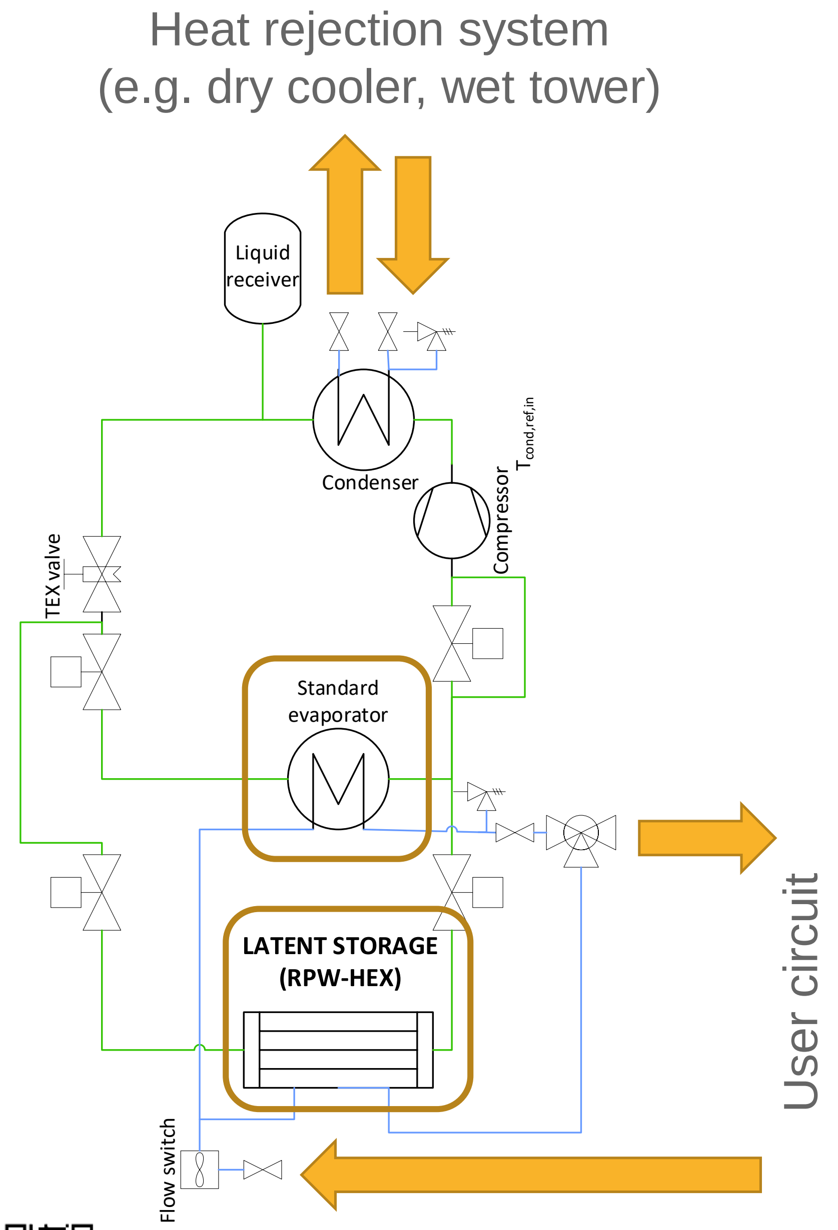
SYSTEM DESCRIPTION/2

MAIN CONCEPT:

Integrated chiller - latent heat storage directly embedded in the compression cycle. The Phase Change Material (PCM) has a melting temperature of 4°C, suitable to store the cooling energy from the chiller.

Refrigerant	R410a
Compressor rotation range in %	30-100%
Nominal cooling power in kW	13

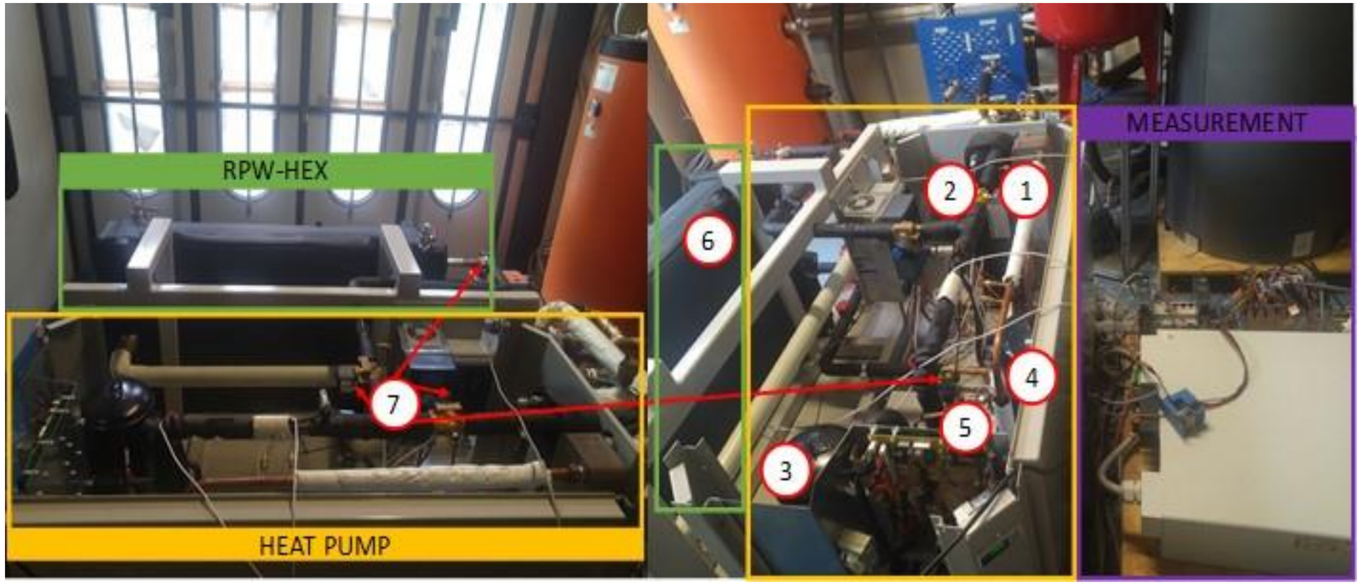
	R410a	HTF	PCM (RT4)
Number of passages	20	20	42
Fin #	73	18	33
Fluid volume in l	5.34	4.6	46
core length x width x depth in mm	1000 x 585 x 160		
empty weight in kg (Al)	190		

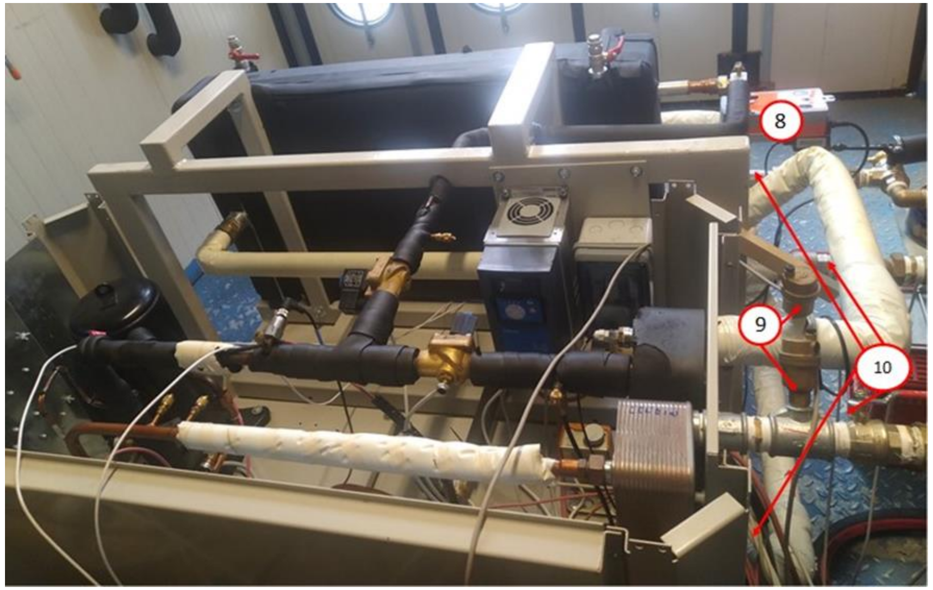


A complete system description and experimental activity overview are given in Palomba et al., Energies 2021, 14(9), 2580; https://doi.org/10.3390/en14092580

[1] https://www.rubitherm.eu/en/index.php/productcategory/organische-pcm-rt

EXPERIMENTAL FACILITIES /1





1: condenser, 2: standard evaporator, 3: compressor, 4: liquid receiver, 5: expansion valve, 6: latent storage, 7: solenoid valves in the refrigerant circuit, 8: 3-way valve in the hydraulic circuit, 9: air traps, 10: manual ball valves.

EXPERIMENTAL FACILITIES /2

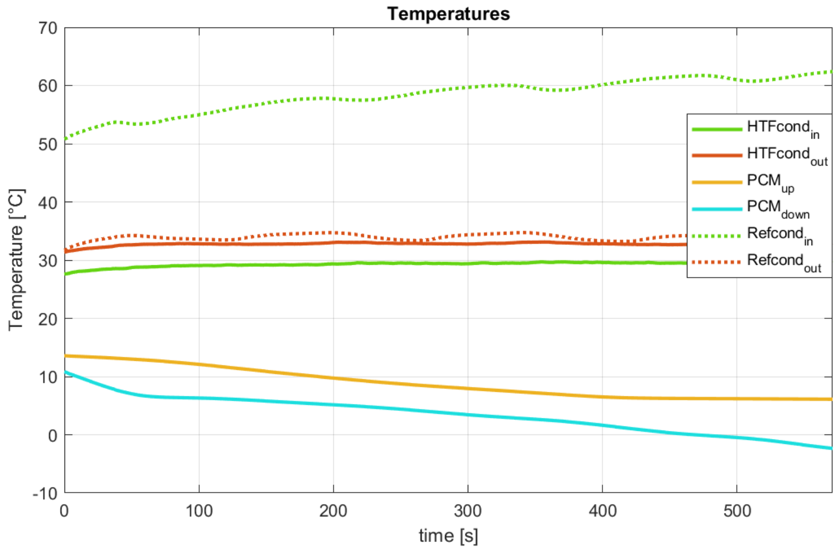
Testing rig with three different heat sources (electric heater and two R410a compression chillers) connected to sensible heat storages to supply the desired temperature levels to different thermal systems. Temperature regulation thanks to high-speed (< 2 s) mixing valves.

EXPERIMENTAL TESTS

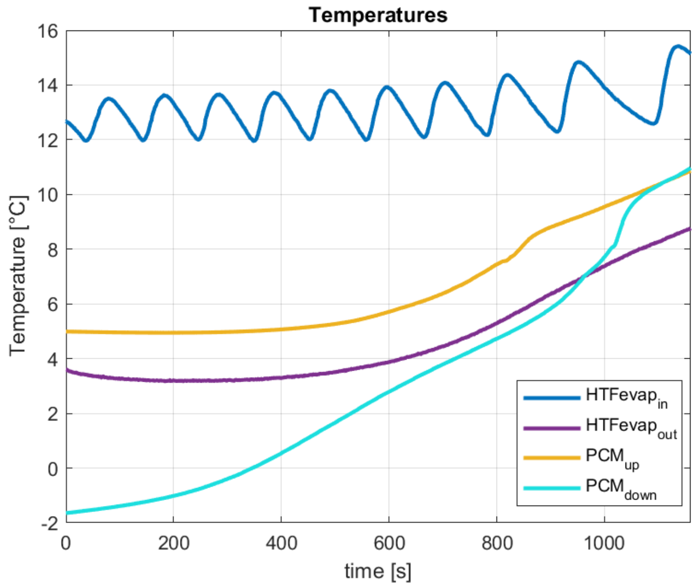
OPERATING MODES

- Operation with standard evaporator
- Charge of the latent storage: HTF is not circulating, the compression cycle is used to supply melting heat to PCM.
- Discharge of the latent storage: the chiller is not operated, heat is extracted from the PCM by the HTF.
- Parallel mode, i.e. contemporary charge and discharge of the latent storage.

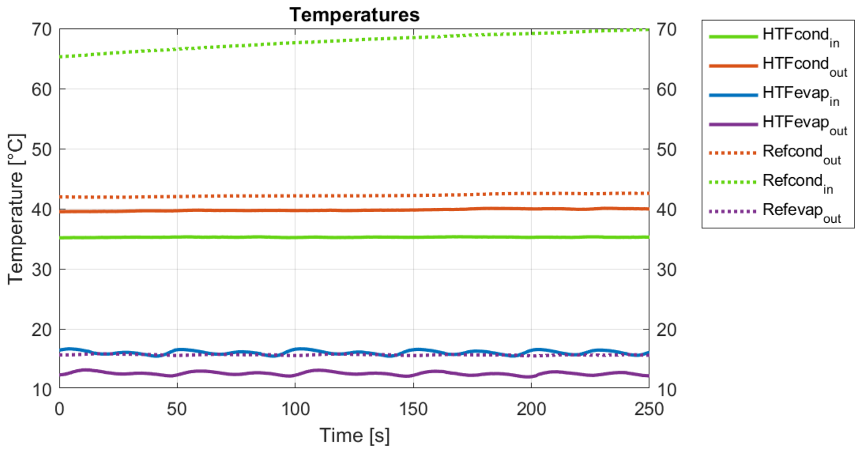
CHARGE



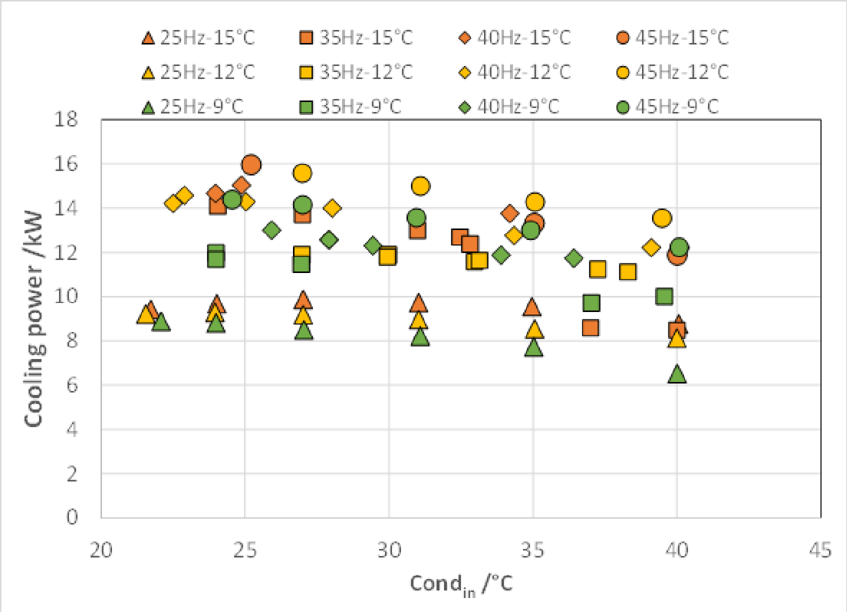
DISCHARGE



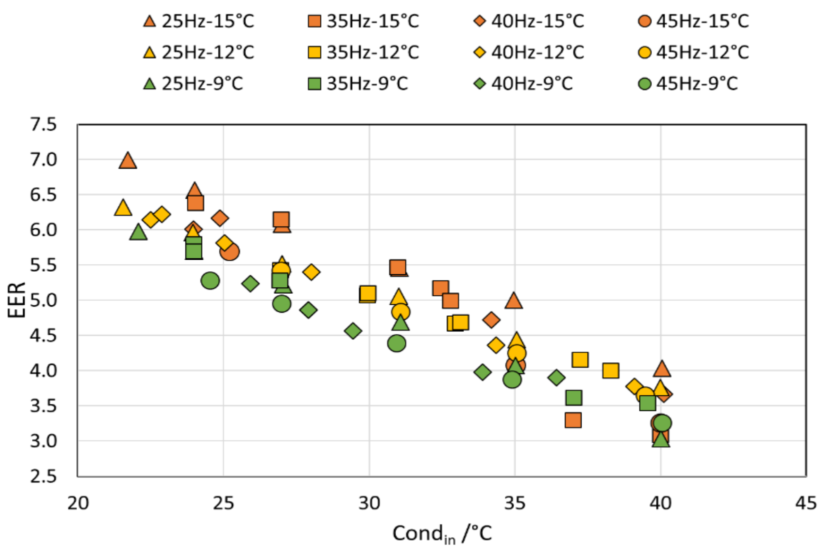
PARALLEL OPERATION



RESULTS – STANDARD EVAPORATOR



Cooling power for different operating temperatures and part load of the compressor

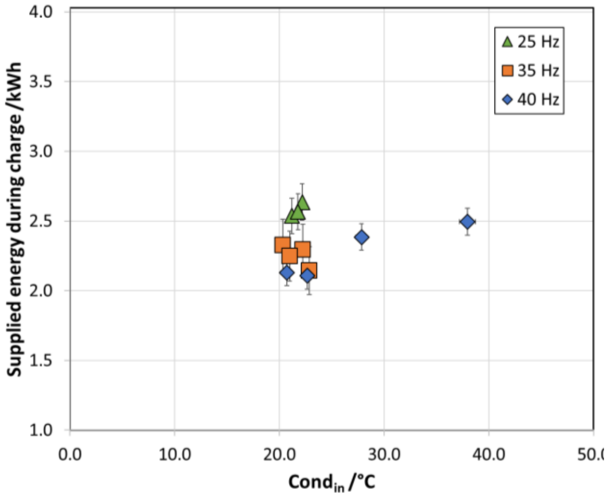


EER for different operating temperatures and part load of the compressor

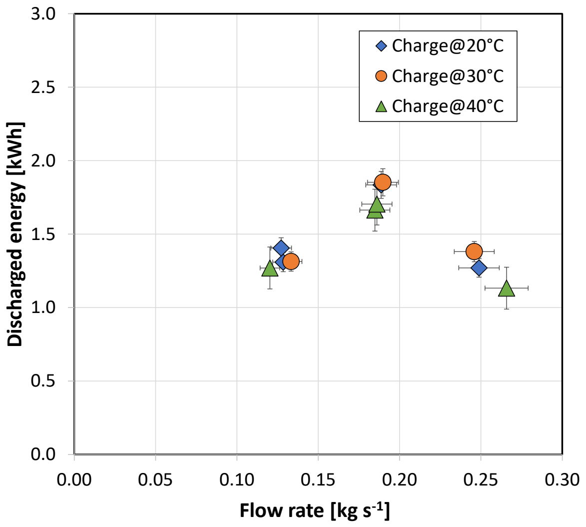
*EER=cooling power/electricity consumption

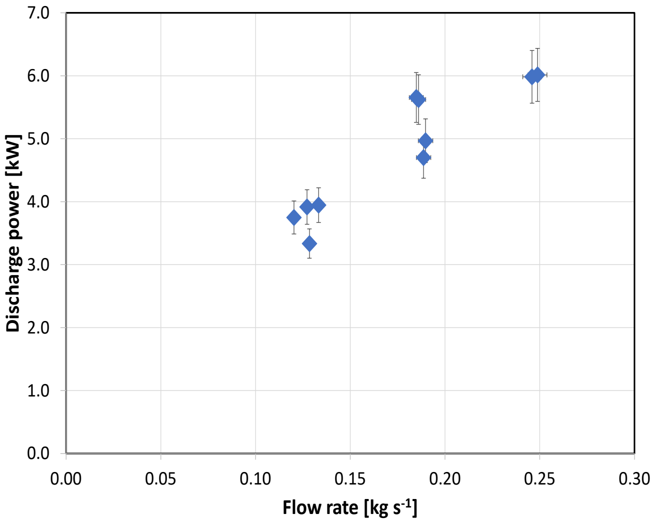
- The cooling power is higher for higher part load
- For each part load, cooling power and EER decrease with increasing condenser inlet and with decreasing evaporator inlet.
- At lower condensing temperature, i.e. below 32°C, reducing the compressor speed makes the heat pump work more efficiently: the EER for operation at 25 Hz is higher than for the operation at higher compressor speed.

RESULTS –CHARGE AND DISCHARGE OF LATENT STORAGE



Energy supplied during charge of the RPW-HEX as a function of condensation temperature and compressor driving frequency.

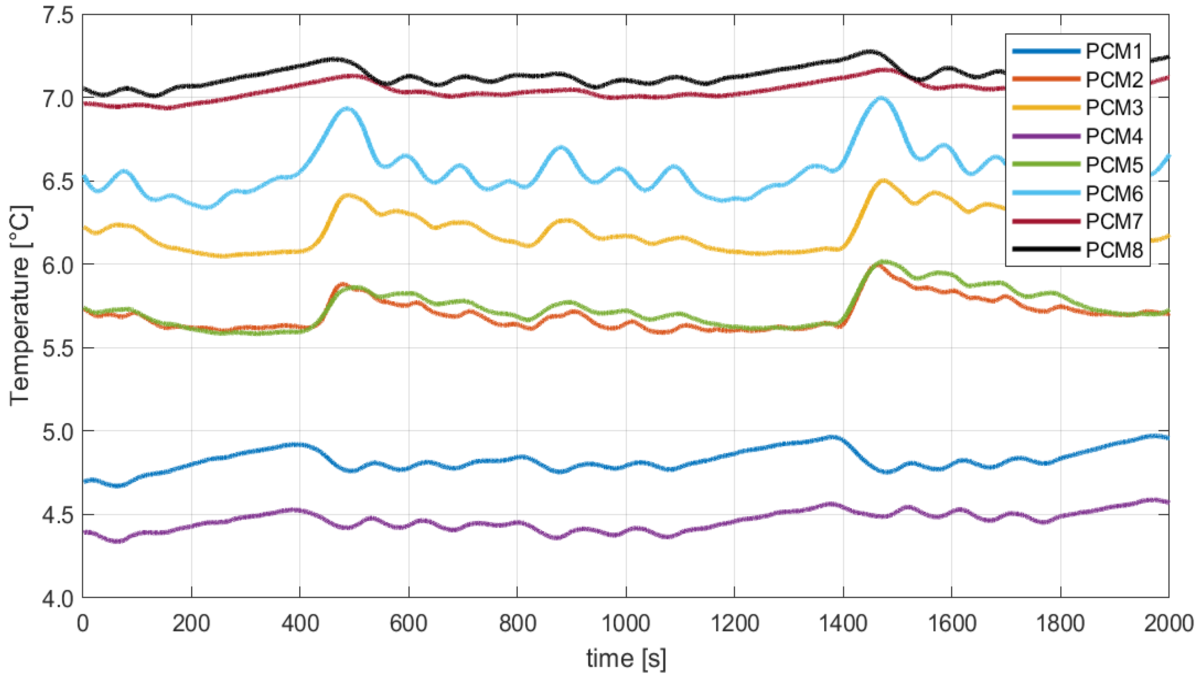




Discharged energy and discharge power as a function of flow rate for evaporator HTF inlet=12°C.

- The amount of energy that the PCM can store is 2.0-2.3 kWh.
- Increasing the flow rate increases the discharge power, passing from about 3-4 kW at 0.12 kg/s to 5-6 kW at 0.18-0.25 kg/s. However, increasing the flow rate reduces the energy recoverable.
- The optimal flow rate for the operation of the storage in discharge mode is 10-12 kg/min, corresponding to 6.0-7.2 m^3/h

RESULTS –PARALLEL CHARGE/DISCHARGE OF LATENT STORAGE



- PCM is in the order of 3 K, with the lower values for the PCM4 temperatures, i.e. the closest point to refrigerant inlet.
- constant cooling supply to the user is guaranteed, which is in the order of 2/3 of the cooling energy delivered under the same operating conditions during the operation with the standard evaporator.

CONCLUSIONS

In the present work, the results of the experimental testing of an integrated latent storage with heat pump system are reported.

- The latent storage is realised through a three-fluids heat exchanger, to maximise the compactness and the heat transfer efficiency.
- 2-3 kWh can be stored in the latent storage. The optimal flow rate for discharge is 10-12 kg/min.
- Under operation with the standard heat evaporator, EER ranged between 3.0 and 7.5. For low condenser inlet, part load operation is more efficient than full load.
- The extensive testing campaign under different operating modes highlighted the possibility, with the investigated layout, to deliver cooling energy to an end-user improving the overall efficiency and flexibility in operation.

ACKNOWLEDGEMENTS

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In memory of Dr. Andreas Strehlow.

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Thank you

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