Secondary waste heat opportunities

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Heat Pump Fully Integrated with Thermochemical Store

Motivation

- Domestic heating occupies a significant share of heating demand.
- Waste heat recovery for district heating can help decarbonise heating in buildings.
- Thermal storage addresses the offset between the load demand and waste heat availability.
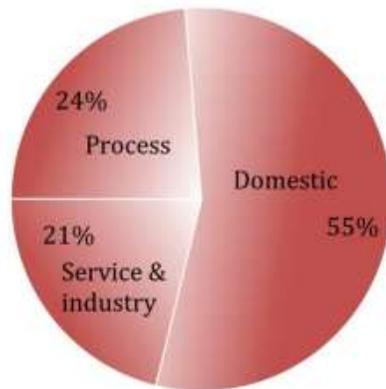

Sansom, 2014
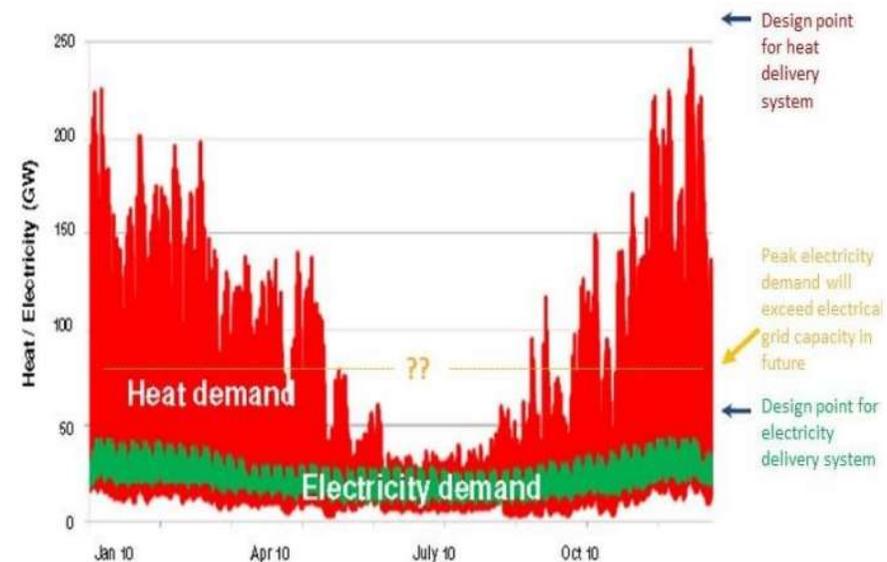
*Sansom, 2014*

Thermal storage classification

- Sensible storage: Cheapest form of storage. High losses to environment due to temperature differences.

- Latent storage (PCM): Better energy storage density (~100 kWh/m³). Thermal reliability and cost are the limiting factors.

- Thermochemical storage(TSM): Highest energy storage density. Lower heat losses and flexibility in storage temperature.


Lizana et al., 2017
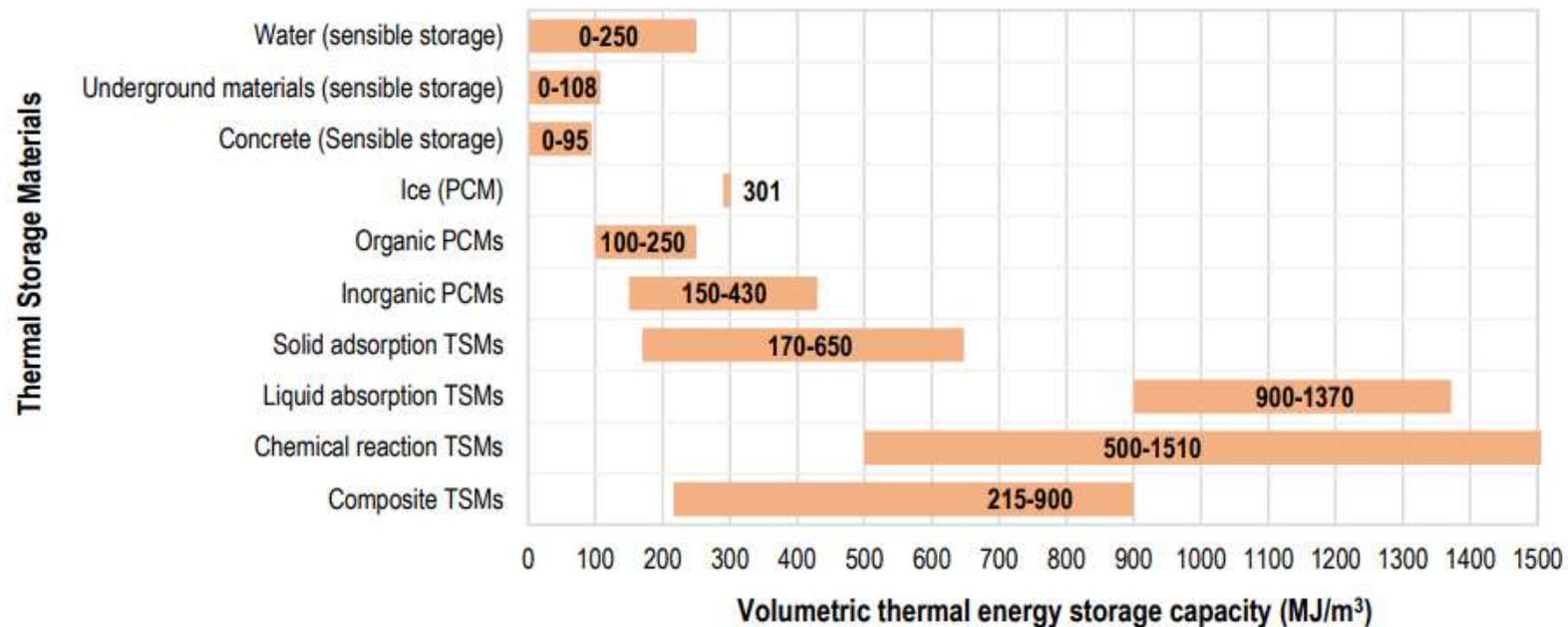
Absorption based storage materials

| Desiccant	Comments
Lithium bromide (LiBr)	Common in absorption plants (chillers), but not suitable in thermochemical network due to the high price.
Lithium chloride (LiCl)	Common in dehumidification systems, but not suitable in thermochemical network due to the high price.
Calcium chloride (CaCl$_2$)	High efficiency and low cost. Low temperature lift.
Sodium hydroxide (NaOH)	Very high efficiency. Not suitable in open processes.

System description
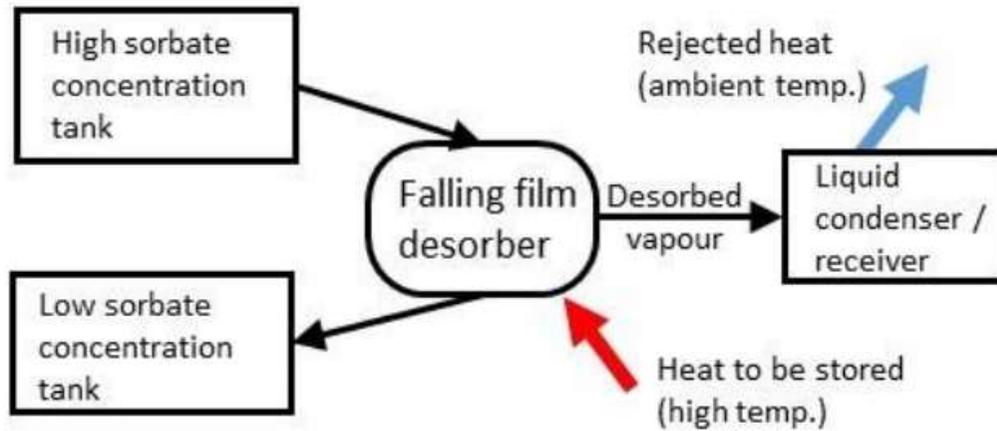
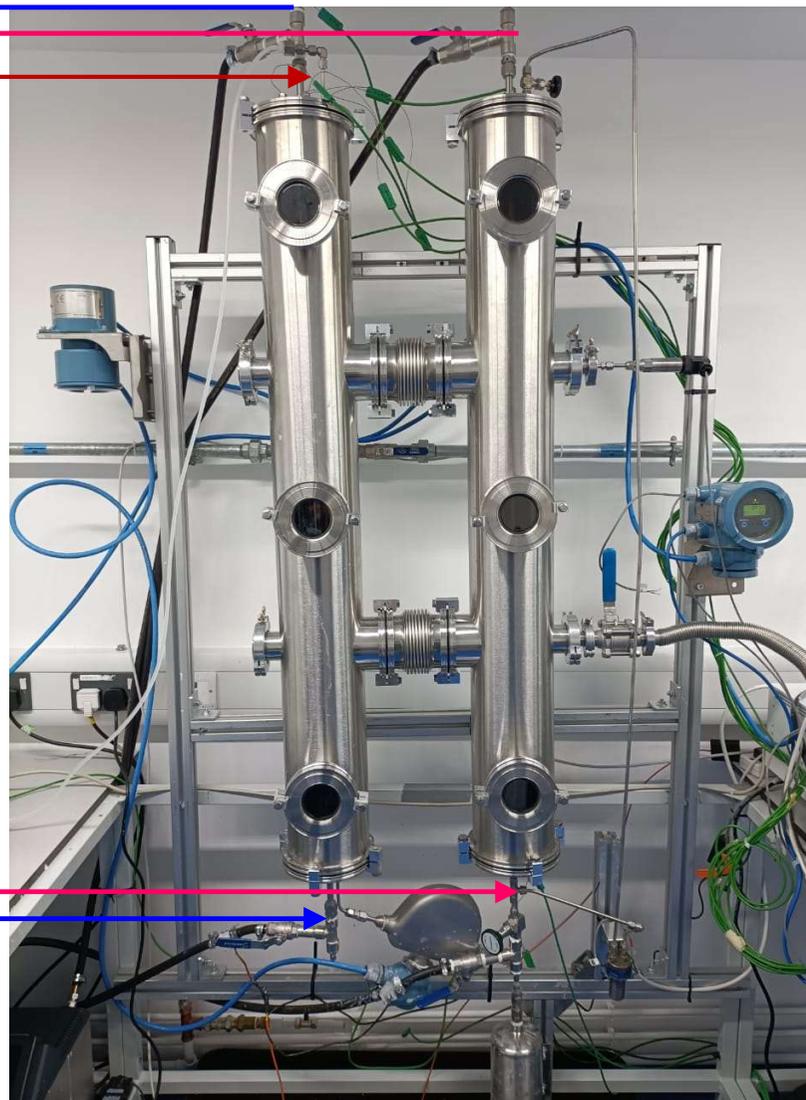Charging the simple absorption store, flow from high to low concentration tank
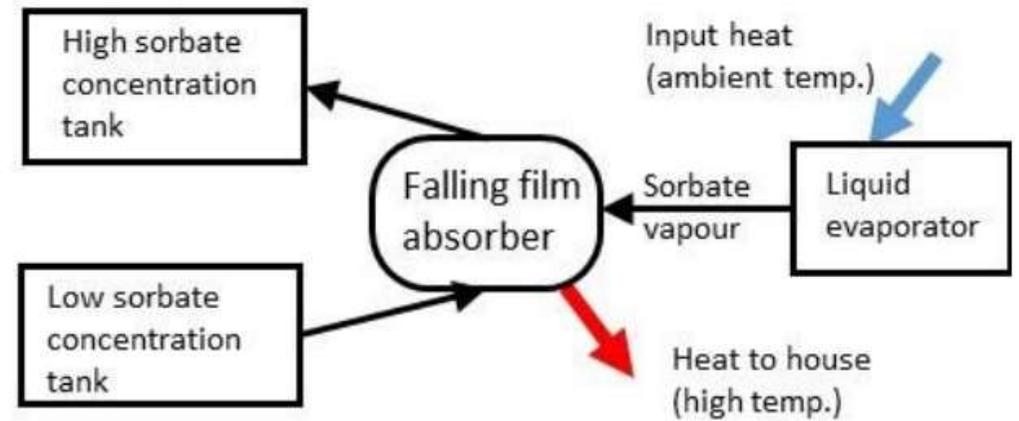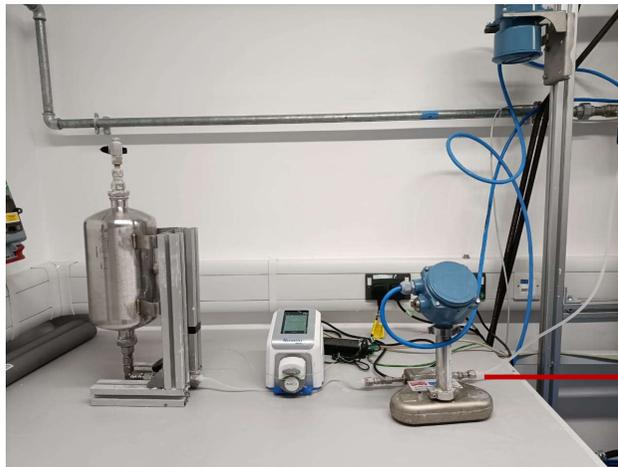
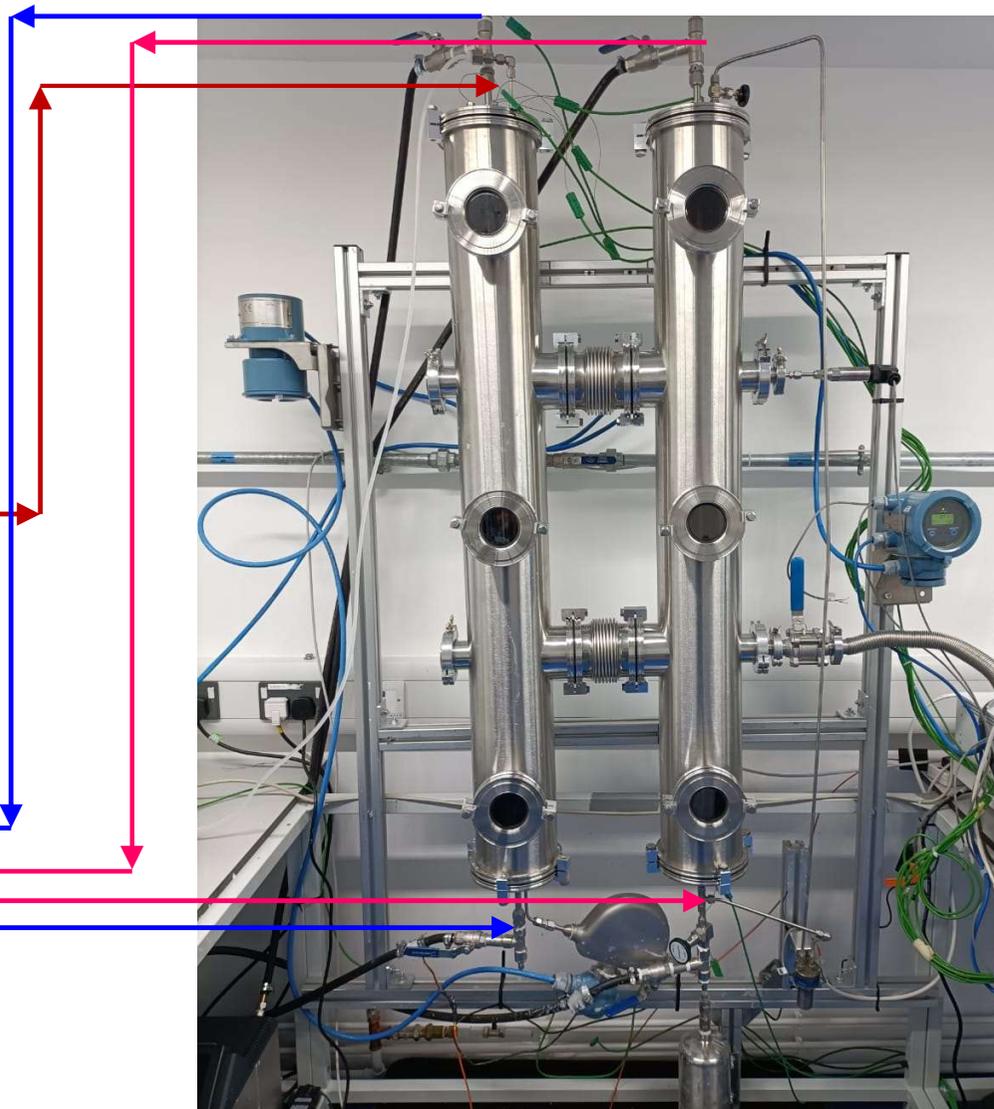Discharging the simple absorption store, flow from low to high concentration tank

Test rig facility

Absorption vessel

Evaporator vessel

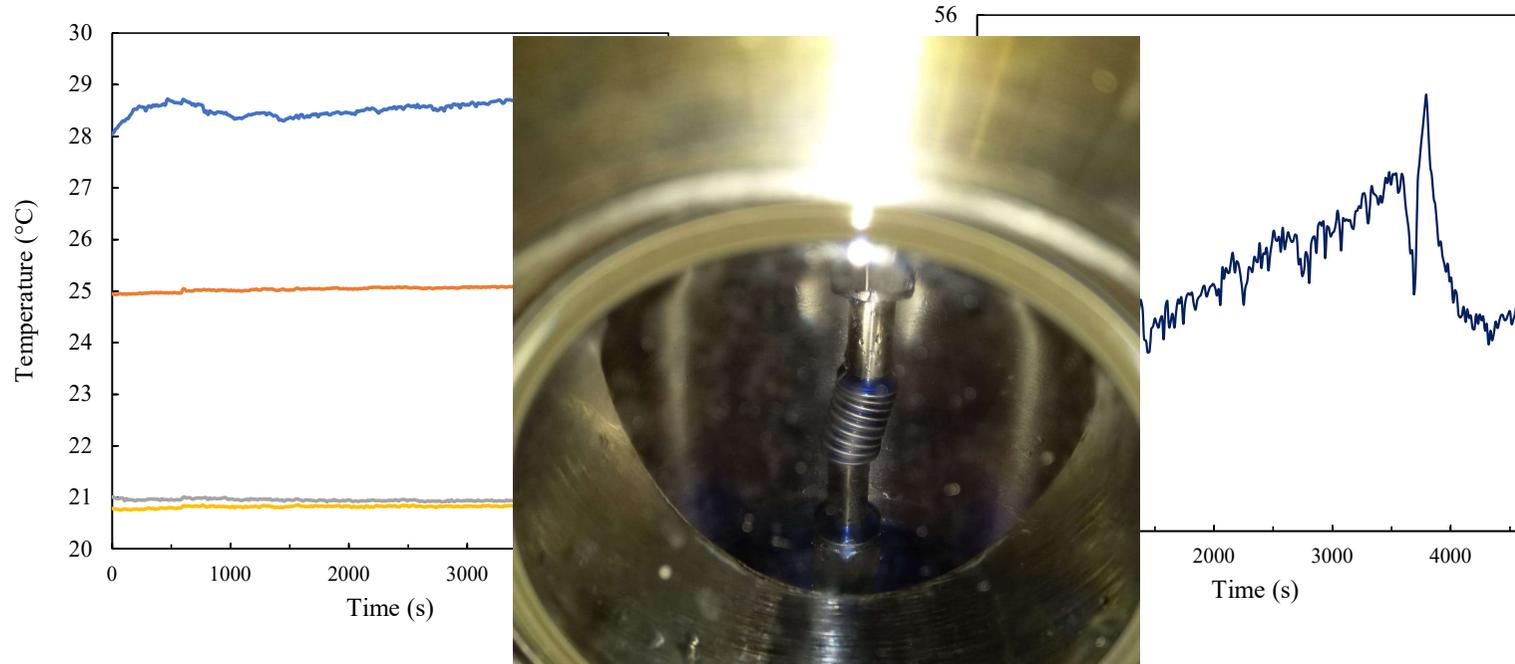0.6 mm fins
1.3 mm gap
5 mm deep

1.2 m

22 mm
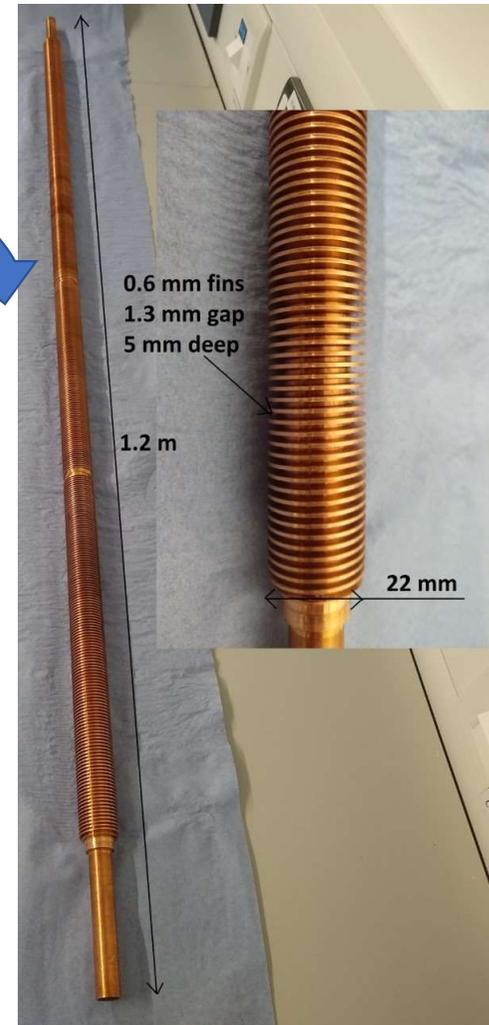
Test rig facility

Absorber HTF

Evaporator HTF

Preliminary test results

Test No.	Solution flow rate (g/min)		Water flow rate (g/min)		Soln. temp. (°C)		Abs. water. temp. (°C)		Heating power (W)
	inlet	outlet	absorber	evaporator	inlet	outlet	inlet	outlet	
1	7.54	8.41	206.32	675.12	27.19	25.94	25.04	28.51	48.37
2	3.43	3.56	203.86	694.60	25.25	25.69	25.08	26.12	12.17

Corrosion of copper tube lead to lower absorption and heating power.

Preliminary test results
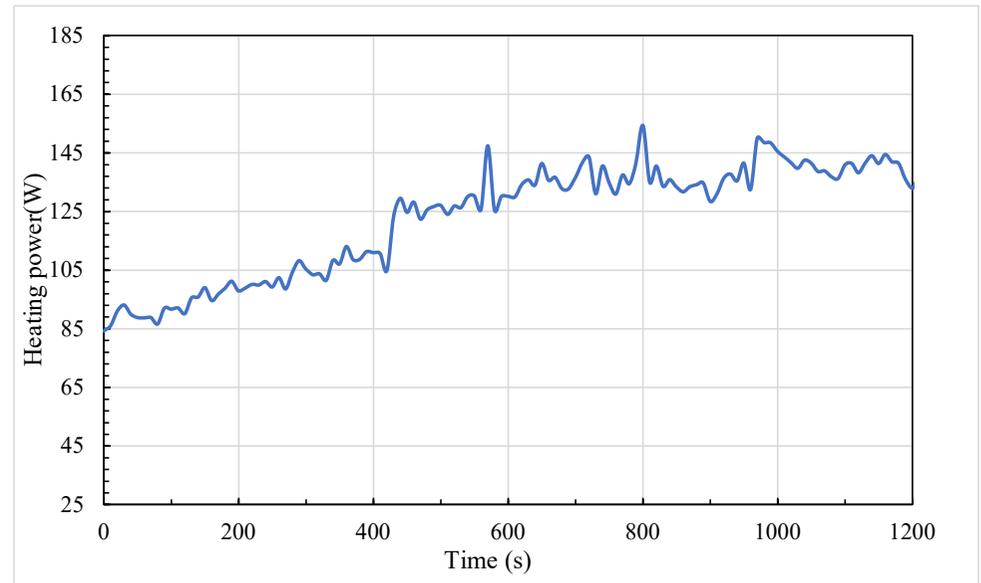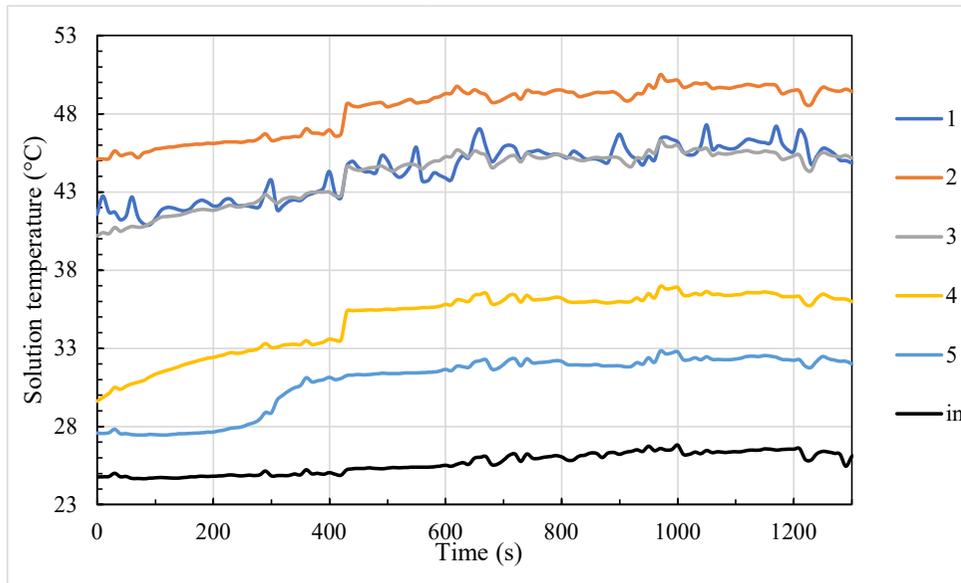
Test No.	Solution flow rate (g/min)		Water flow rate (g/min)		Soln. temp. (°C)		Abs. water. temp. (°C)		Heating power (W)
	inlet	outlet	absorber	evaporator	inlet	outlet	inlet	outlet	
1	6	11.1	208.08	694.60	25.25	32.28	28.08	37.6	145
2	8.7	11.7	200	700	25	30	28.1	34.2	88.0

- Performance greatly improved with nickel coating.
- Energy storage density of around 2070 MJ/ m^3 is observed. It is expected to go beyond 3000 MJ/ m^3 with insulation.

Analysis of limiting factors

Energy balance of the solution

$$m_{inlet}h_{inlet} + m_{vapor}h_{vapor} - m_{outlet}h_{outlet} = m_{HTF} * 4.18 * (T_{out} - T_{in}) + heat\ loss$$

Heat losses are estimated to be around 78 W

Heat transfer analysis

$$UA\left(\frac{(T_{sol,in} - T_{htf,out}) - (T_{sol,out} - T_{htf,in})}{\ln\left(\frac{(T_{sol,in} - T_{htf,out})}{(T_{sol,out} - T_{htf,in})}\right)}\right) = m_{htf} * 4.18 * (T_{htf,out} - T_{htf,in})$$

UA=23.8 W/K

Way forward

- Parametric study with varying flow rates and operating temperatures.

- Optimal operating point determination.

- Impact analysis of heat exchanger design parameters.

- Exploring alternative heat exchanger designs for performance enhancement.

References

- R. Sansom, Decarbonising Low Grade Heat for a Low Carbon Future (Ph.D. thesis), Imperial College London (2014), pp. 59-81.

- J. Lizana, R. Chacartegui, A. Barrios-Padura, J. Valverde, Advances in thermal energy storage materials and their applications towards zero energy buildings: A critical review, Applied Energy, Volume 203, 2017, Pages 219-239, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2017.06.008.

- B. Fumey, Heat and Mass Exchanger Design for Inter-seasonal Liquid Absorption Heat Storage (Ph.D. thesis), Ulster University (2020).