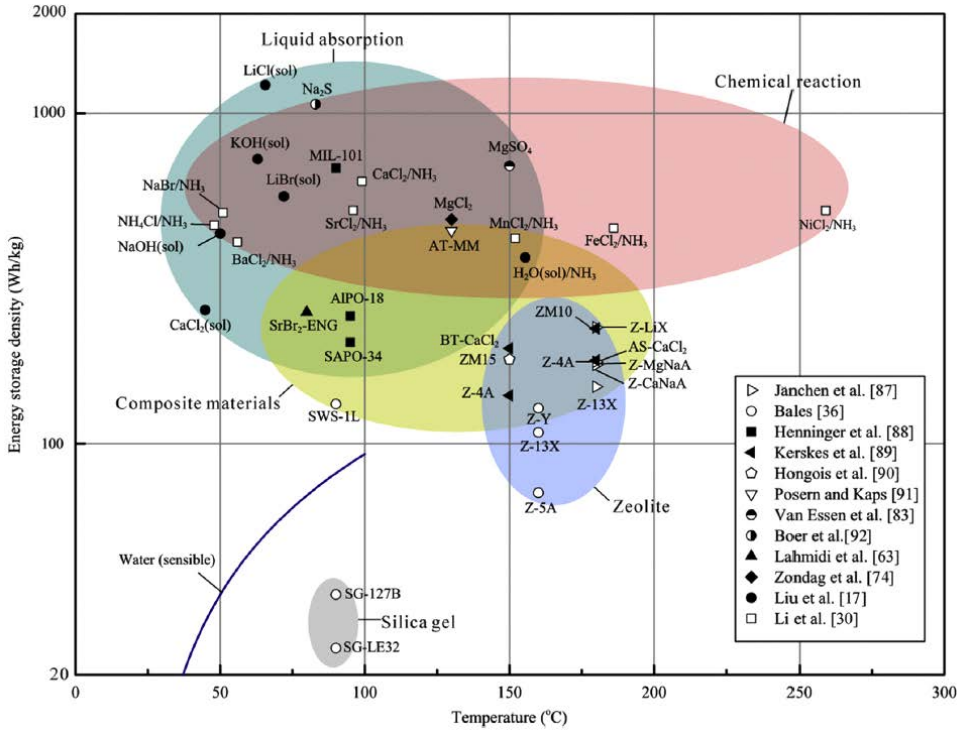
Developments in thermochemical heat storage

8th Swiss Symposium Thermal Energy Storage – January 22nd 2021, HSLU Lucerne / held online

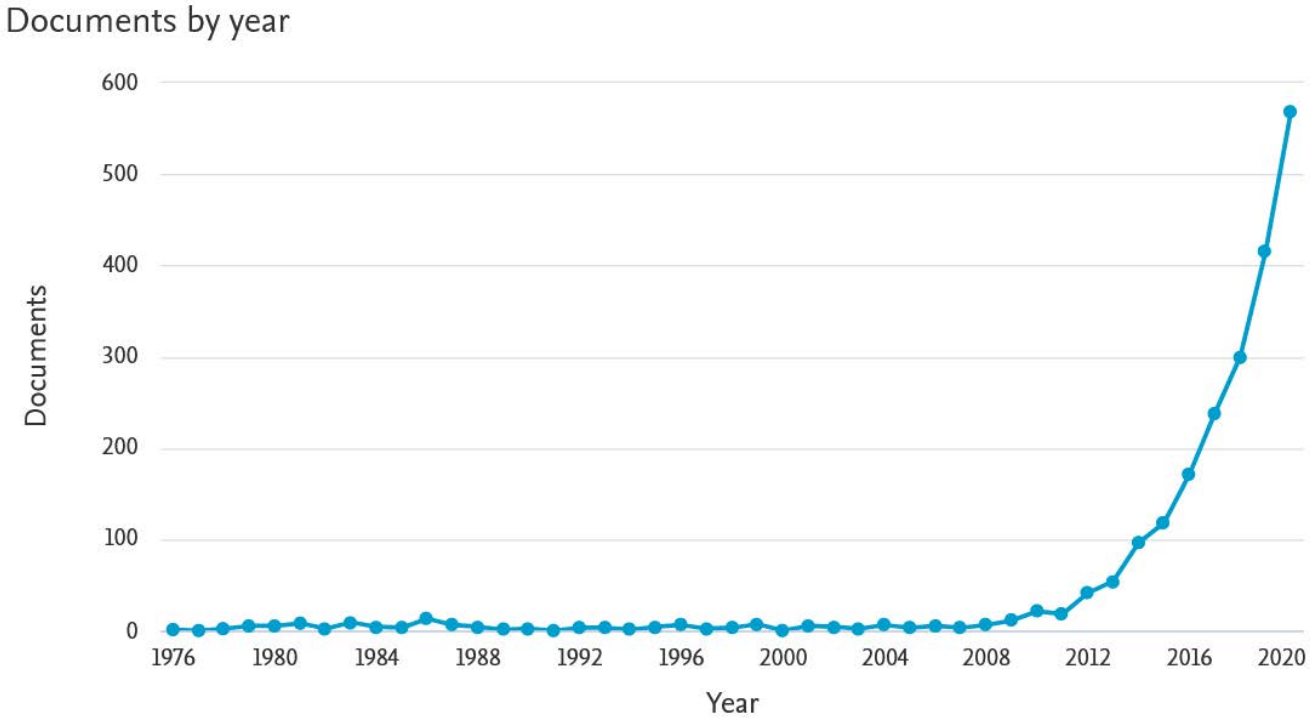
Dr. Luca Baldini – Empa, Building Energy Systems and Technologies Group BEST
Dr. Paul Gantenbein – OST, Institute for Solar Technology SPF

Overview thermochemical reactions/materials

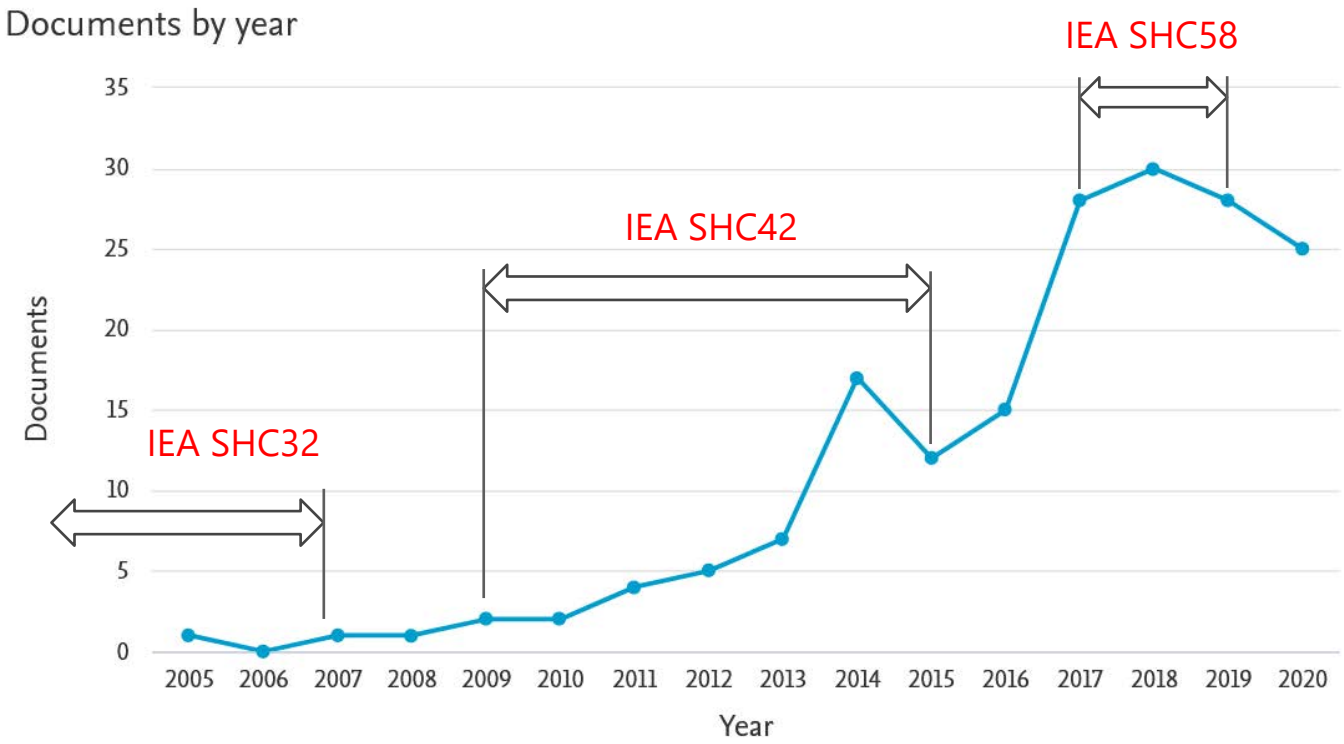


Yu, N., R. Wang, and L. Wang, *Sorption thermal storage for solar energy.* Progress in Energy and Combustion Science, 2013. **39**(5): p. 489-514.

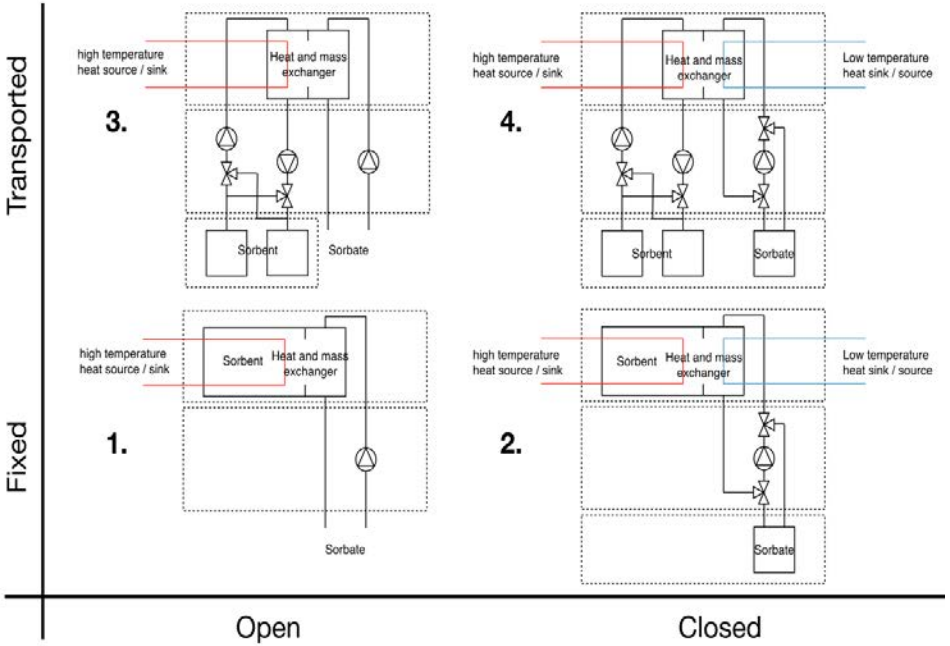
Thermochemical energy storage - publications



Sorption storage (TES) - publications



Sorption storage process types



System	Author	GTL_D [K]	GTL_S [K]	TE [K/K]
Open Fixed	Johannes et al. [58]	(165)	43	0.26
	Tatsidjodoung et al. [44]	(165)	44	0.27
	Michel et al. [61]	62	19	0.31
	Weber et al. [42]	172	42	0.24
	Zhang et al. [62]	(95)	27	0.28
	Aydin et al. [63]	120	21	0.18
	Gaeini et al. [60]	(175)	20	0.11
Open Transported	Nonnen et al. [64]	173	50	0.29
Closed Fixed	Finck et al. [69]	83	30	0.36
	Köll et al. [48]	163	25	0.15
	Palomba et al. [70]	60	25	0.42
	Zhao et al. [72]	67	22	0.33
	Jiang et al. [73]	136	47.4	0.35
	Brancato et al. [71]	60	24.5	0.41
	Yan et al. [77]	154	35	0.23
Closed Transported	Fumey et al. [45]	55	23	0.42
	Zhang et al. [78]	55	22	0.40
	Le Pierrès et al. [80]	43	12	0.28

Fumey, B., R. Weber, and L. Baldini, Sorption based long-term thermal energy storage – Process classification and analysis of performance limitations: A review. Renewable and Sustainable Energy Reviews, 2019. 111: p. 57-74.

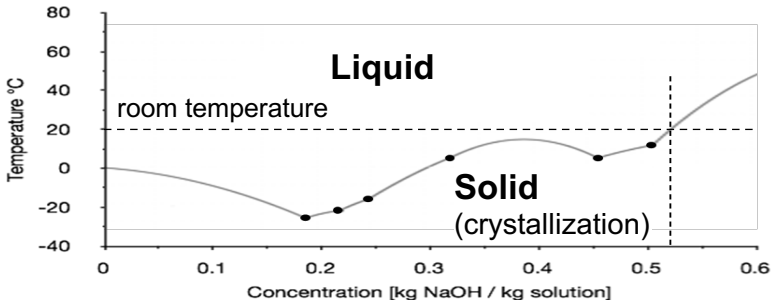
Liquid sorption – Sodium hydroxide (NaOH)

NaOH considered as sorbent

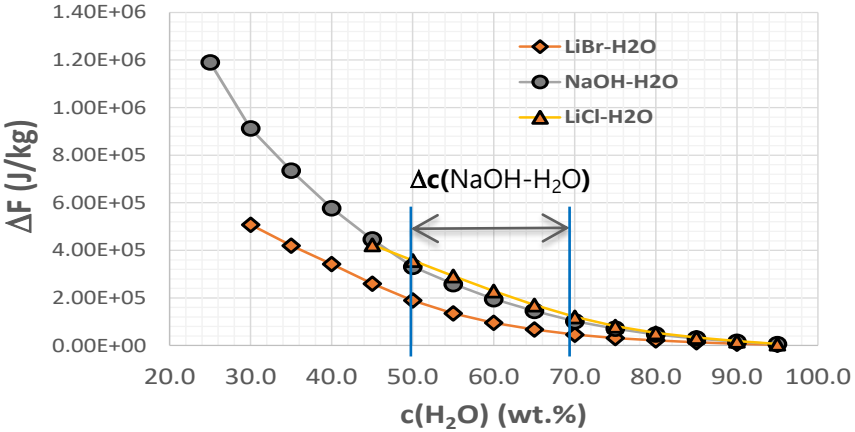
- Allowing for high volumetric energy storage
- Low cost / high availability storage material (50wt%: 180 $/m^3, i.e. ~ 0.5-0.8 $/kWh)

LiBr-H_2O and LiCl-H_2O are potential alternatives

- Higher costs
- Competing with Li batteries



Absorption potential ΔF in function of load c



Development roadmap

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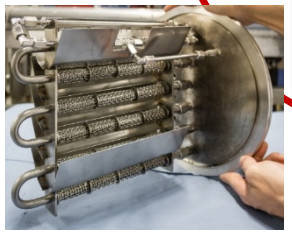
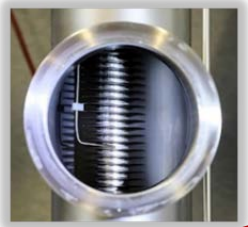
Physical scale

COMTES pilot plant



Rededesign of heat and mass exchanger



HE Storage
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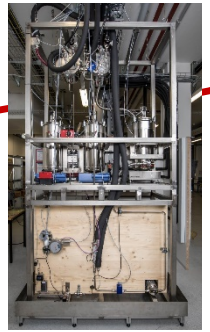
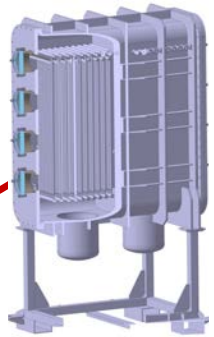
Confederaziun svizra

Bundesamt für Energie BFE
Swiss Federal Office of Energy SFOE

Lab-scale testing



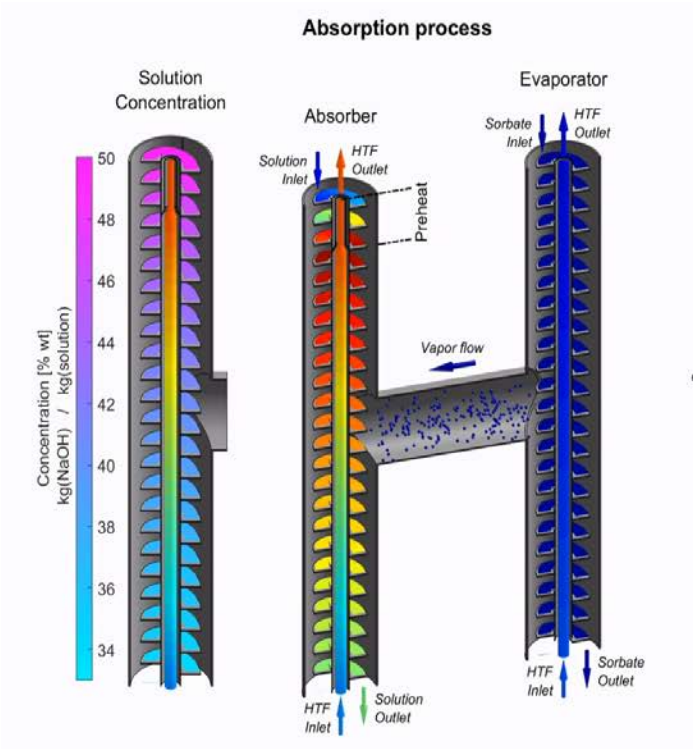


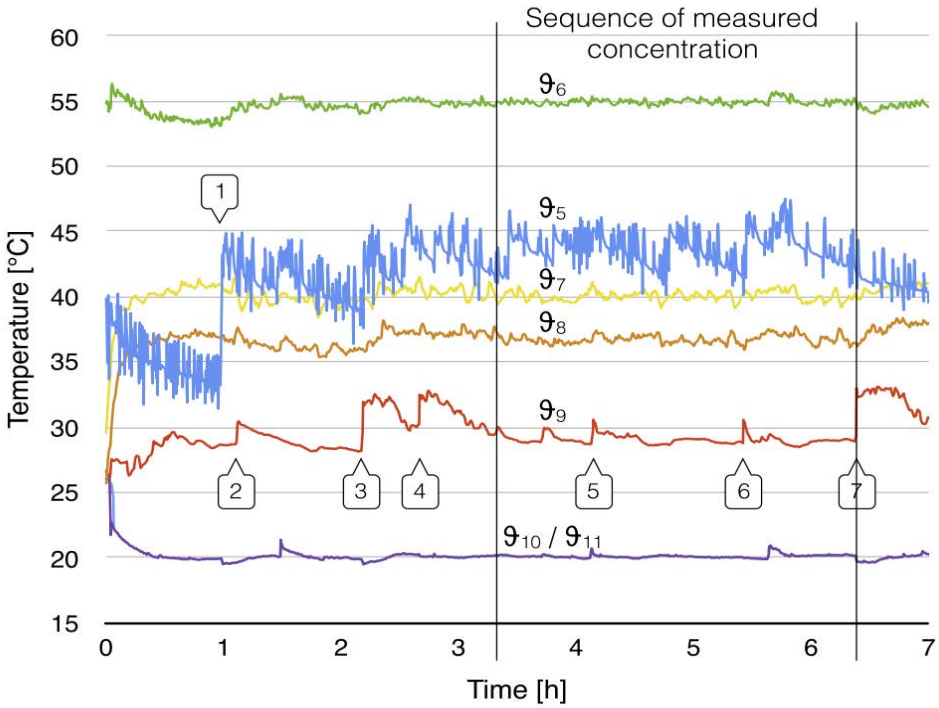
Heat and mass exchanger upscaling

ehub / NEST demonstrator plant

2014-2016 | 2017 | 2018 | 2019 | 2020 | Time

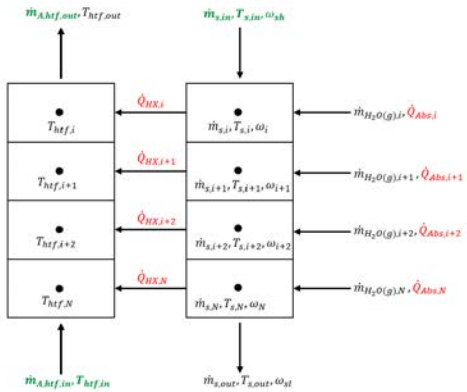
Spiral finned tube HMX - Lab-scale test rig

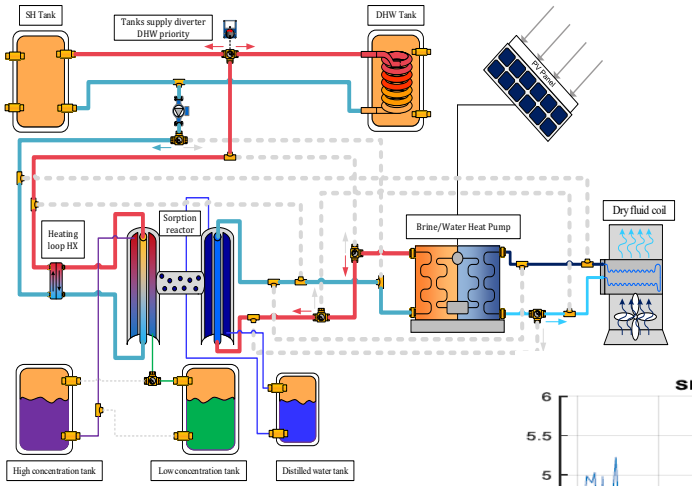


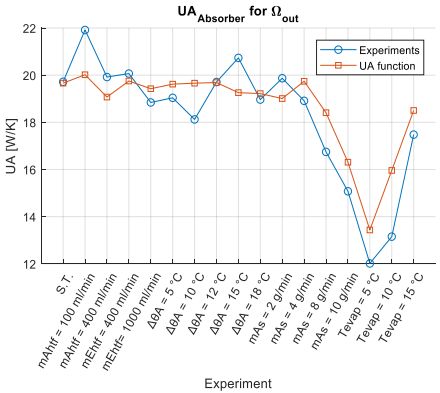


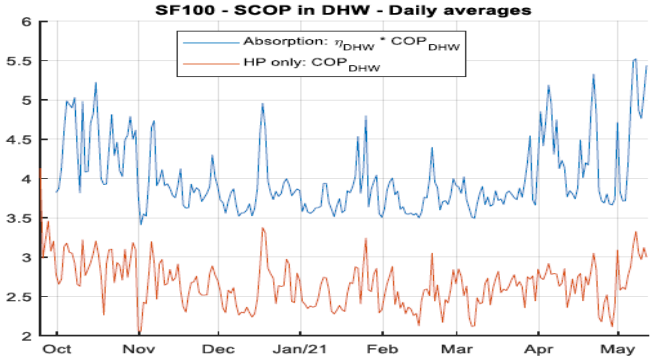
Fumey, B., R. Weber, and L. Baldini, Applied Energy, 2017. 200: p. 215-225. doi.org/10.1016/j.apenergy.2017.05.056.

Liquid sorption modelling / building integration



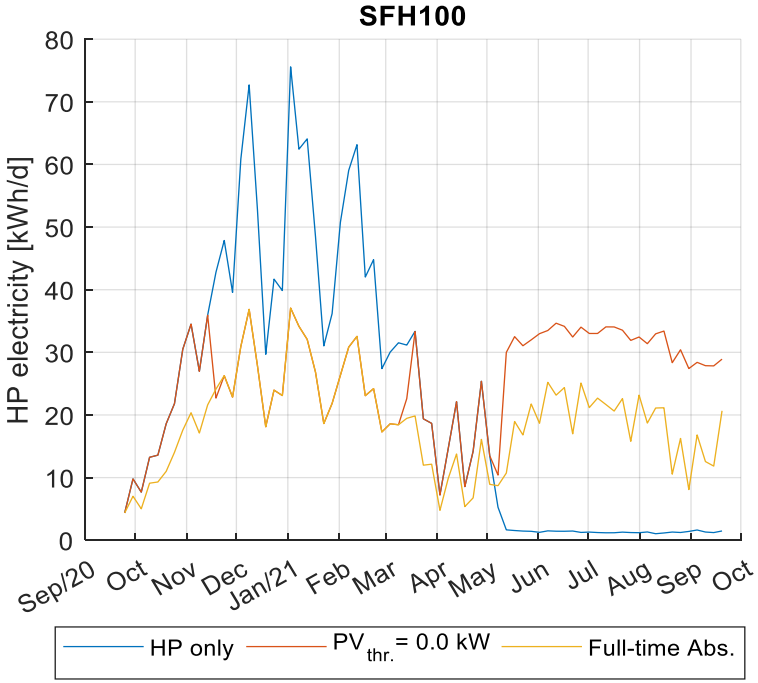


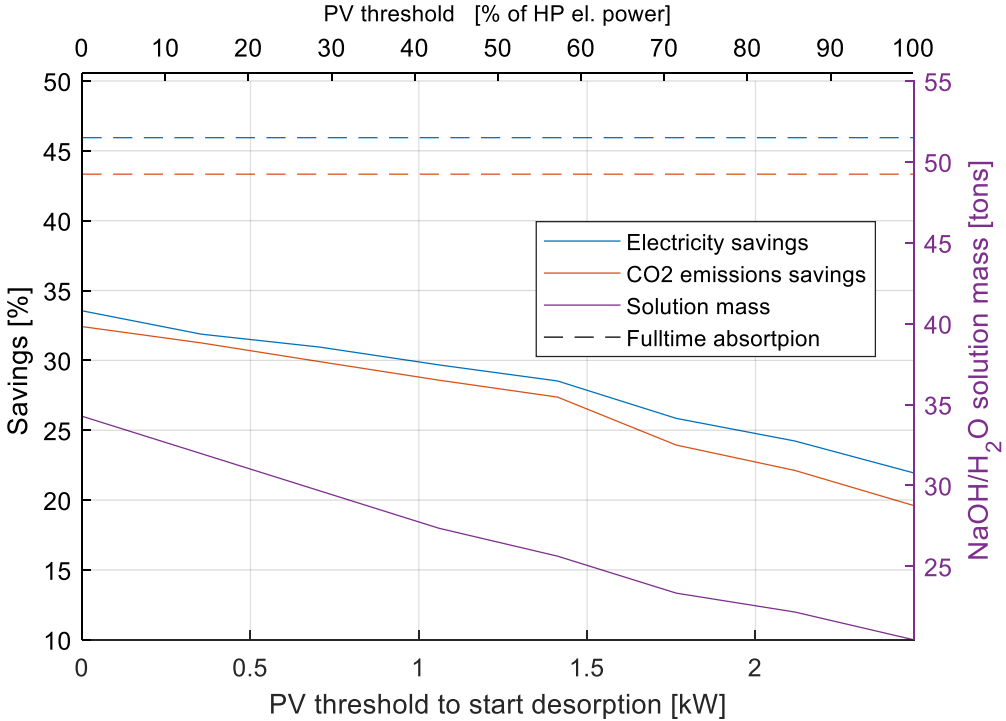




Stratos Tzinnis, Master thesis, ETH Zurich / Empa, 2020.

Seasonal load shifting / CO2 emission reduction

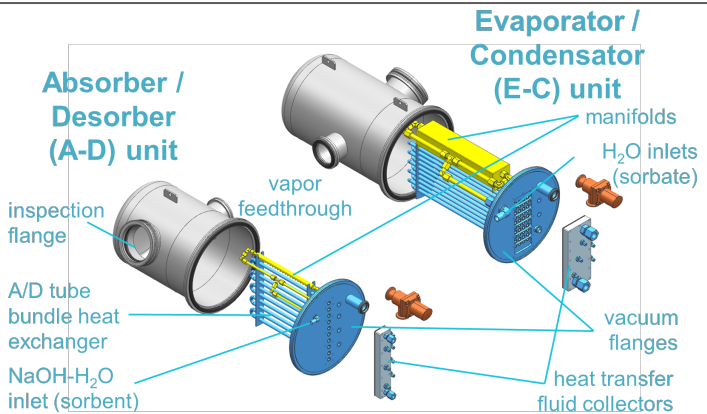


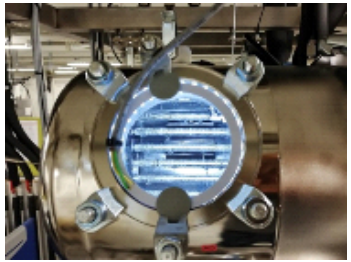


Baldini, L. and B. Fumey, Seasonal Energy Flexibility Through Integration of Liquid Sorption Storage in Buildings. Energies, 2020. 13(11): p. 2944.

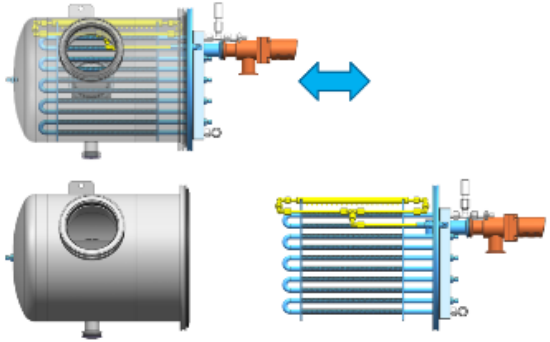
Technology Development

- Power Unit: Tube Bundle - Heat and Mass Transfer Unit
- Absorber - Desorber (A-D)

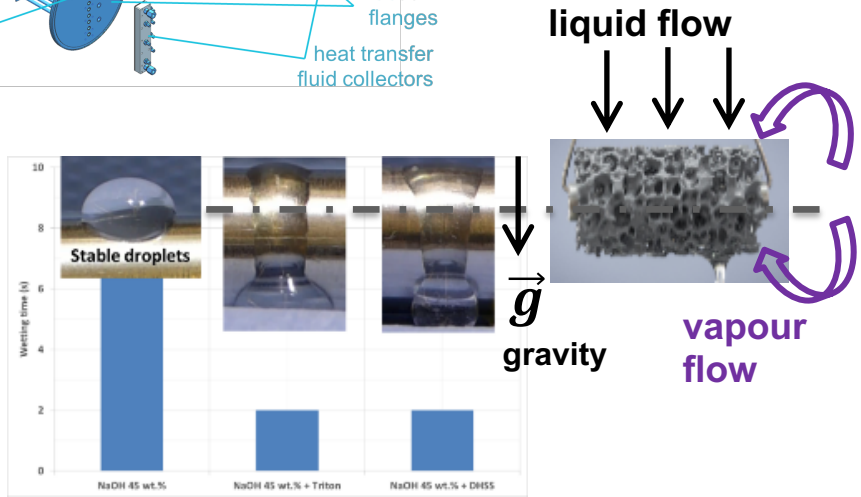




Heat & Mass Transfer Unit Containing Vacuum Envelope



Simple dismountable A-D (concept: gas / oil burner)



Liquid on Single Tube / Process Development

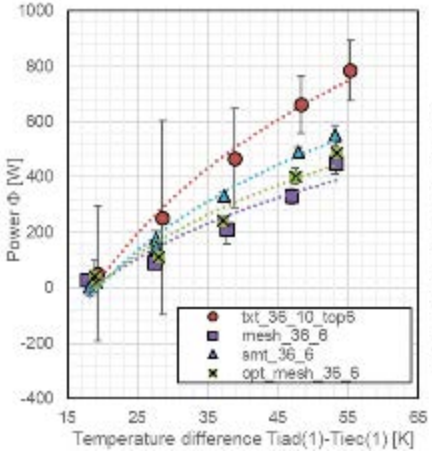
Power and Concentration Change

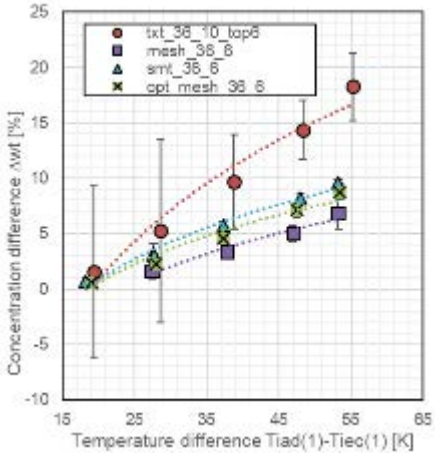
- **Characterisation of the 5 falling film A/D HMX** were carried out in both absorption and desorption modus

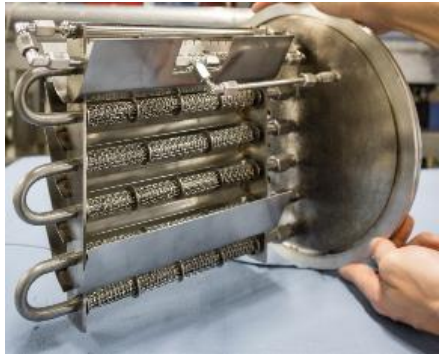
  => exchanged power, concentration difference as well as **heat and mass transfer coefficients and process efficiency** each HMX are the main output.

  => **Absorption Discharging: temperature lift ΔT (T_A -T_E) = 35 K (T_E 15 °C) & Δc = 10 wt.%**

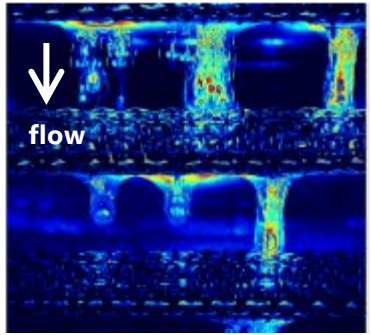
- **Optical characterisation** opened the view to some HMX weakness and initiated the start to develop versions with optimised geometries
- **Encouraging results** obtained with the optimised mesh wrapped tube geometry (up to 25 % more power compared to the reference smooth tube geometry in absorption - discharging - mode)







A-D: Optimized six-tube HMX

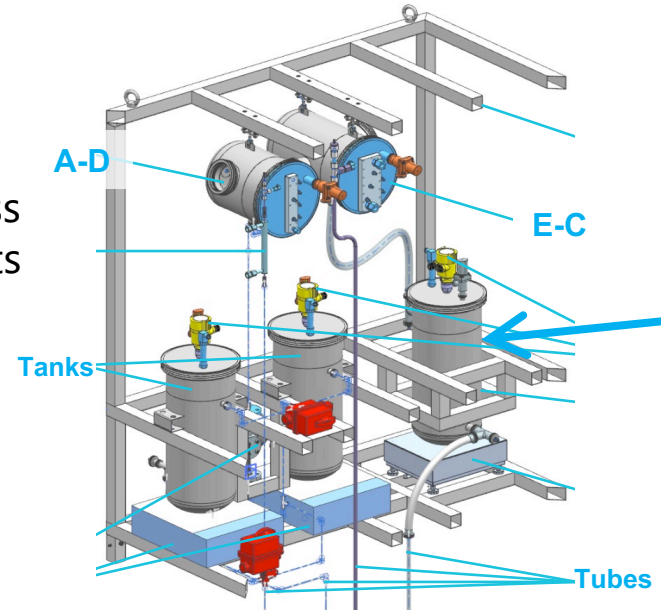


Optical visualisation of tube surface wetting - falling film formation

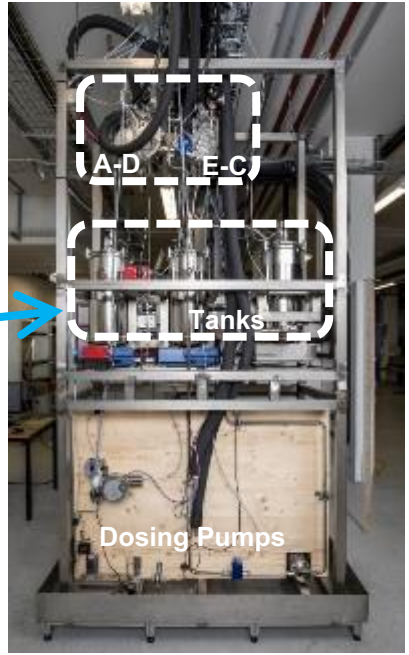
Liquid sorption storage – Falling film HMX

Design of a laboratory test rig

- Design and construction of a test rig dedicated to the investigation on heat and mass exchangers as key components of an storage system
- Accurate control and monitoring of the process parameters of the heat and mass exchanger units and the lye feed (subsystem)



CAD view of the top part of 1 kW absorption-desorption test rig



Experimental 1 kW absorption-desorption test rig

Liquid sorption storage

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Major learnings:

- Challenging to meet the goals of **high concentration difference while achieving sufficiently large power densities**
- There are still **mass transfer mechanisms/effects** taking place in the HMX which are **not fully understood/exploited** yet
- There is the **potential for low cost equipment** and further process optimisation will further improve this

Further research

- Further experimental assessment and **systematic performance improvement** of HMX design
- Building integration simulations, hardware-in-the-loop testing, r**eal-scale implementation and demonstration**

Thank you for your attention…

Contact:

luca.baldini@empa.ch
paul.gantenbein@ost.ch

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