SEASONAL THERMOCHEMICAL HEAT STORAGE FOR DOMESTIC HEATING SYSTEMS

Patrucco Enrico, Castellazzi Paola, Rossetti Andrea

RSE S.p.A. – Ricerca Sistema Energetico

Generation Technologies and Materials

+39 3203713289

enrico.patrucco@rse-web.it

CONTENT

- Introduction to heat storage technologies for seasonal applications
- Basics of thermochemical heat storage
- RSE experimental facility for thermochemical heat storage
- Experimental results

INTRODUCTION TO HEAT STORAGE

INTRODUCTION TO HEAT STORAGE

Goals and solutions

330 TWh/year in Italy

Use of renewable energy for space heating

How to maximize the use of **non-programmable** renewable energy sources, especially **solar**, for space heating during winter (and phase out fossil fuels)? We need alternative energy carriers and storage technologies.

Why long-term thermal energy storage?

Some **candidates**: PV + Power2Gas + Gas storage, PV + electrochemical storage. Problems related to low round-trip efficiency and costs. **Thermal energy storage** can be a promising alternative.

INTRODUCTION TO HEAT STORAGE

Heat storage technologies

Sensible (SHS)

$$Q_{STOR} = m\, c_p\, \Delta T$$

Latent (PCM)

$$Q_{STOR} = m\, [c_{p,s}(T_{FUS} - T_i) + X_{FUS}\, \Delta H_{FUS} + c_{p,l}(T_f - T_{FUS})$$

Thermochemical (TCM)

$$Q_{STOR} = m\, X_R\, \Delta H_R$$

INTRODUCTION TO HEAT STORAGE

Heat storage technologies compared

TES technology	Energy density [kWh/m³]	Duration	Efficiency [%]	TRL
Sensible (SHS) - water	10 - 50	hours - seasonal	25 - 90	7 - 9
Latent (PCM)	50 - 150	hours - weeks	50 - 90	4 - 7
Thermochemical (TCM)	120 - 600	hours - seasonal	75 - 100	3 - 4

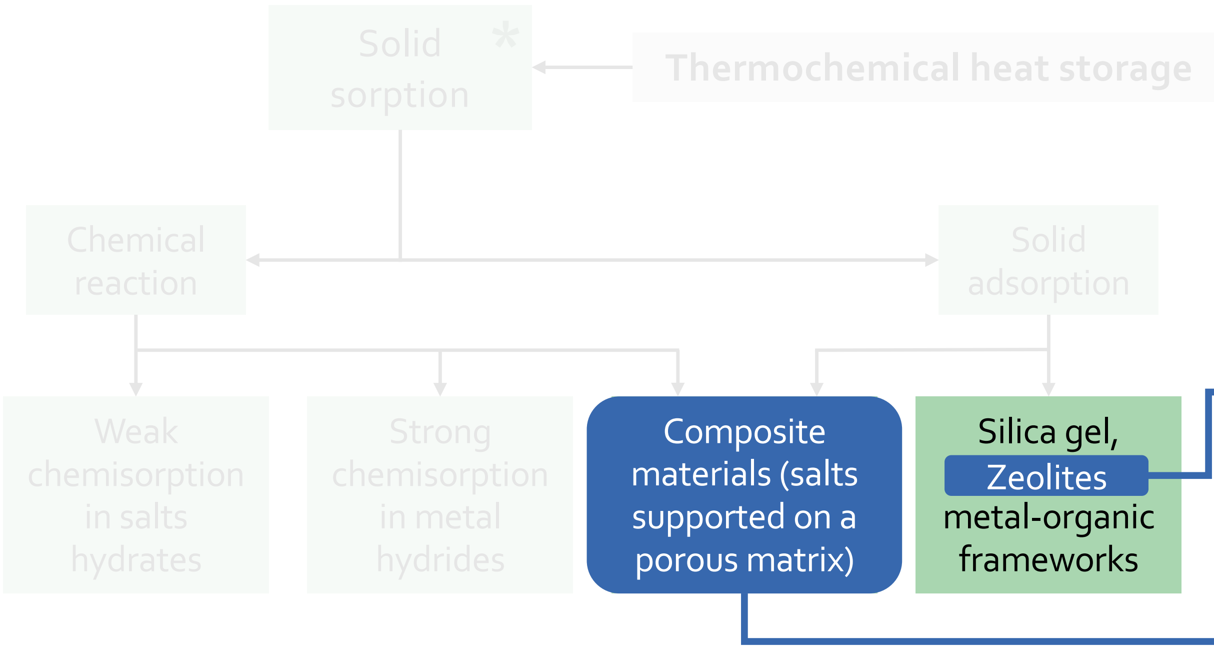
- High energy density → Reduction in storage volume
- Negligible thermal losses → Efficient seasonal thermal storage
- No other option for small-scale seasonal heat storage

Sarbu et al, A comprehensive review of thermal energy storage, Sustainability (2018)

BASICS OF THERMOCHEMICAL HEAT STORAGE

THERMOCHEMICAL HEAT STORAGE

Available technologies and research goals



GOALS AND CHALLENGES

Zeolites: cheap and durable. They are used to test the process and the system design.

– $E_{DENS} < 150$ kWh/m^3

$MgSO_4$ composites: very high theoretical energy density but require optimization.

Kant et al, Advances and opportunities in thermochemical heat storage systems for buildings applications (2022)

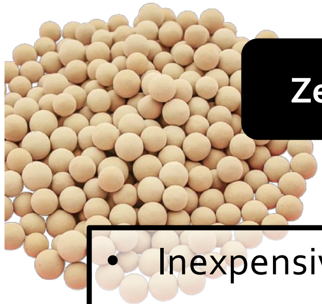
* H_2O is always the co-reactant

THERMOCHEMICAL HEAT STORAGE

Thermo-chemical materials (TCM)

RSE | 2025 EU goal

E_{DENS} kWh/m3 — 120 | 200 - 350 | 400 | 600



Zeolites

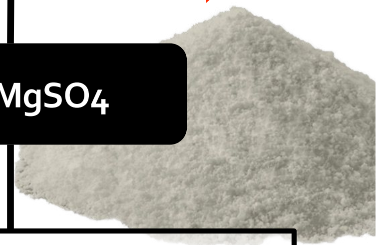
- Inexpensive
- Non-toxic
- High resistance

➖ Low E_{DENS}

$MgSO_4$ composites

- Better heat & mass transfer
- High E_{DENS} (with high salt loading)
- Good mechanical proprieties

Some candidates: alumina with optimal porosity, natural rocks, activated carbon



Pure $MgSO_4$

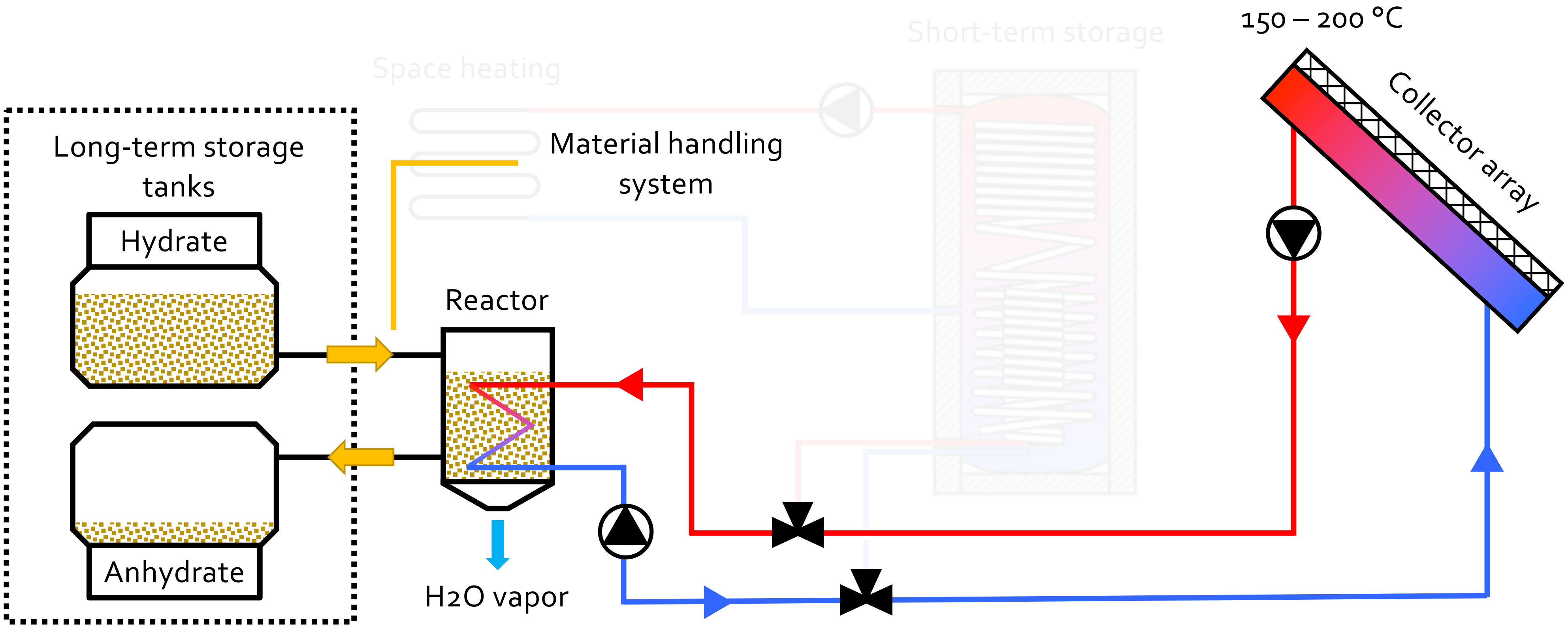
- Low cost (< 3 €/kg) and safe
- Chemically stable
- Extremely high E_{DENS}

➖ Mechanical proprieties

Zbair et al, Survey Summary on Salts Hydrates and Composites Used in Thermochemical Sorption Heat Storage: A Review (2021)

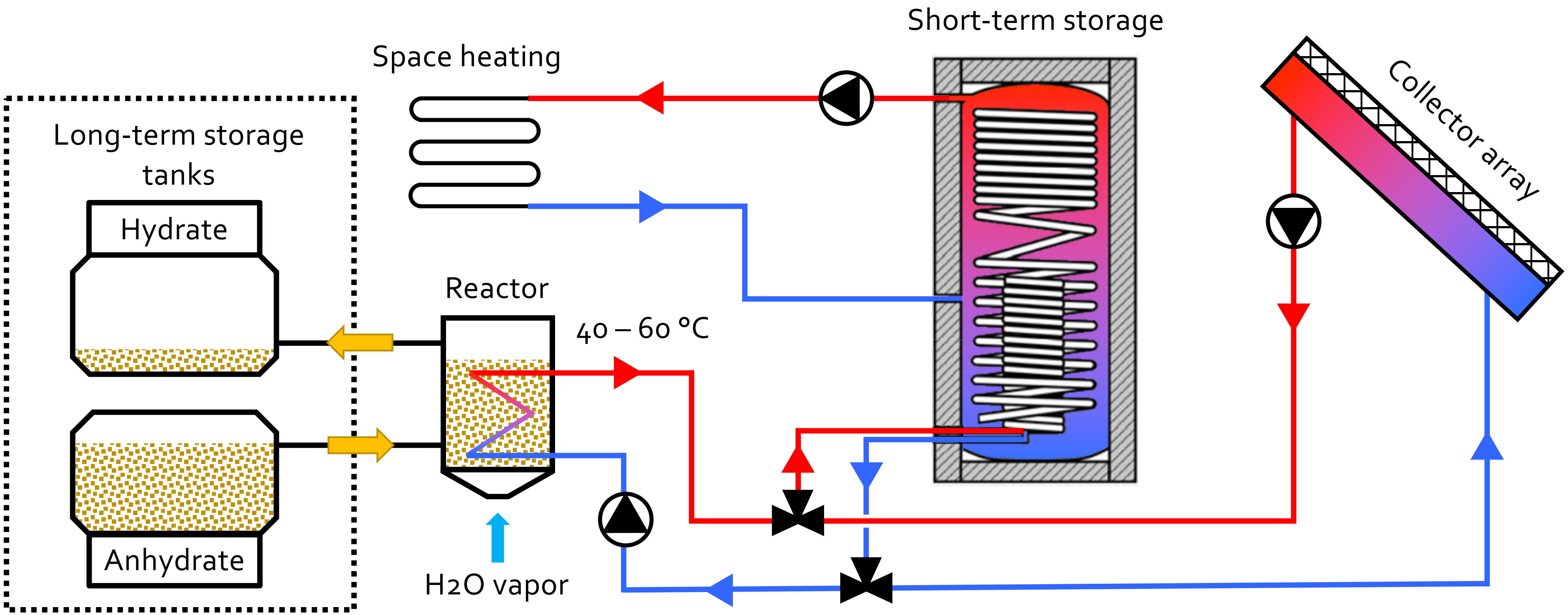
THERMOCHEMICAL HEAT STORAGE

Thermochemical storage system layout – summer operation (regeneration)



THERMOCHEMICAL HEAT STORAGE

Thermochemical storage system layout – winter operation (hydration)



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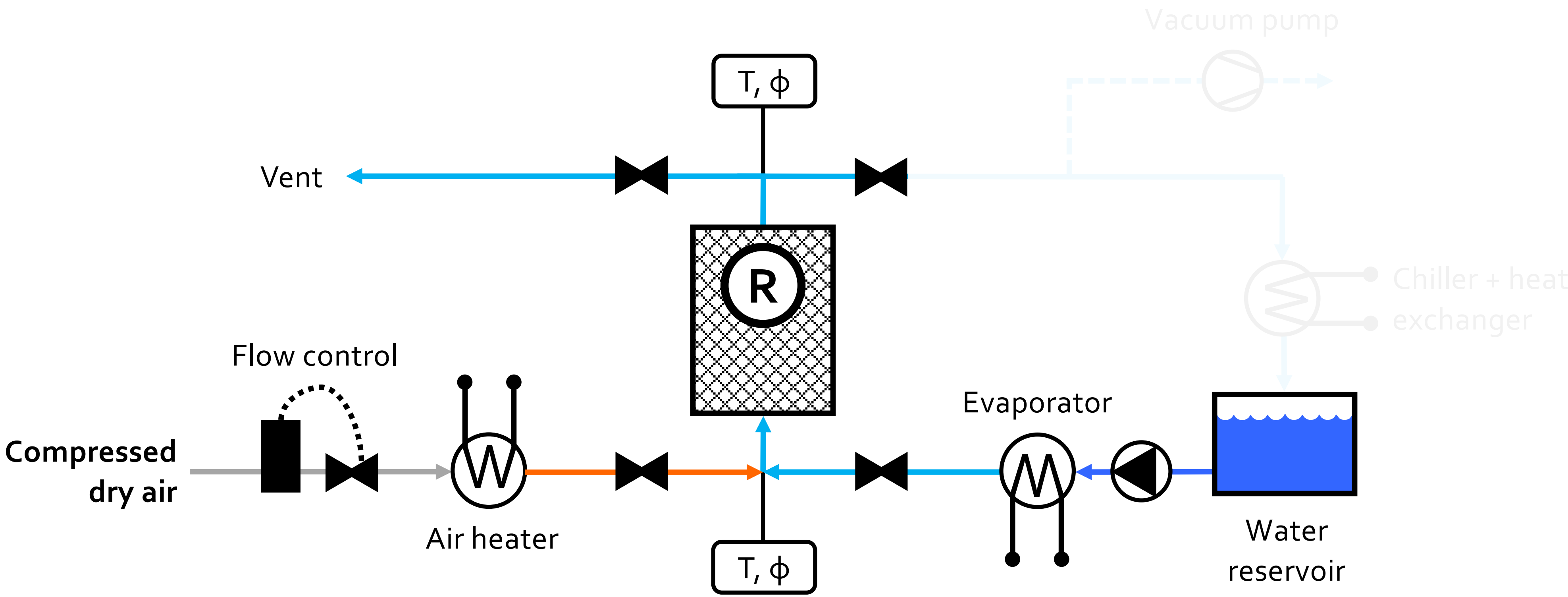
RSE TERMOCHEMICAL TEST FACILITY

RSE THERMOCHEMICAL TEST FACILITY

Open cycle operation



RSE THERMOCHEMICAL TEST FACILITY

Closed cycle operation

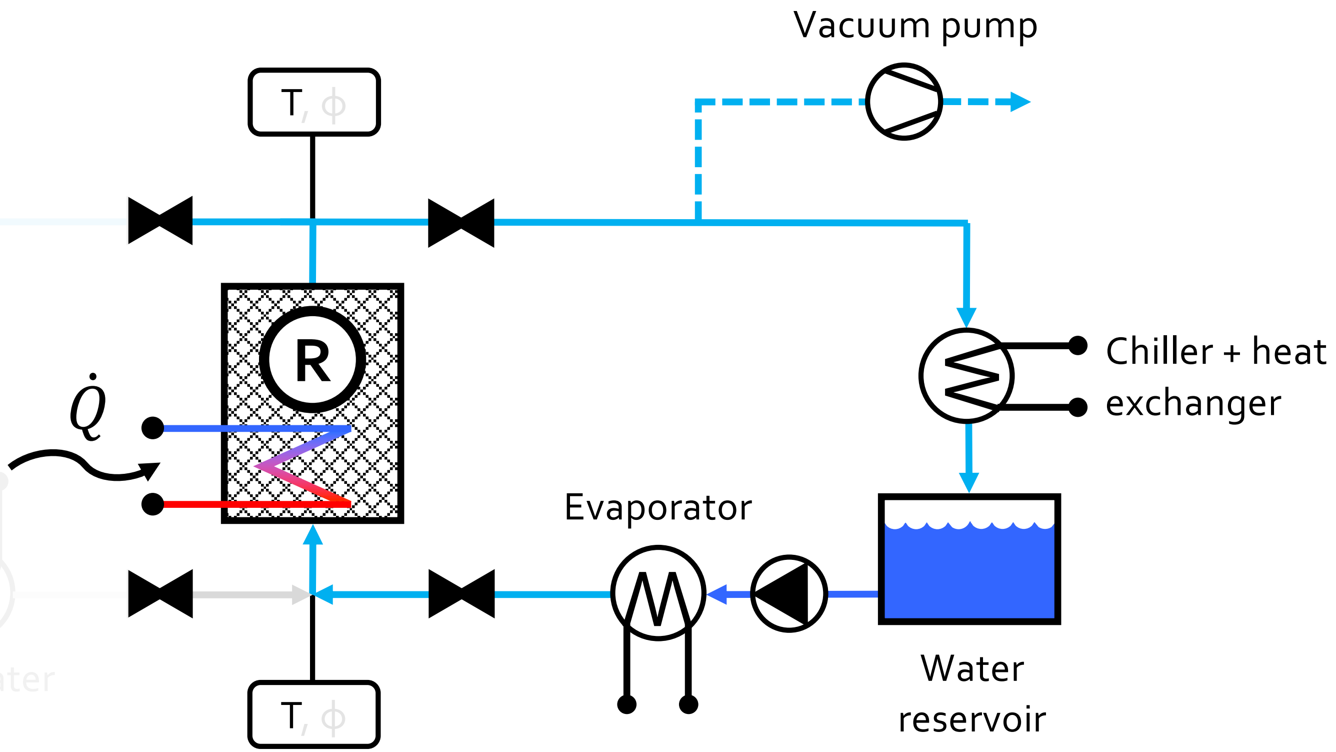
TLR: 1 - 2

TLR: 3 - 4

CLOSED vs OPEN

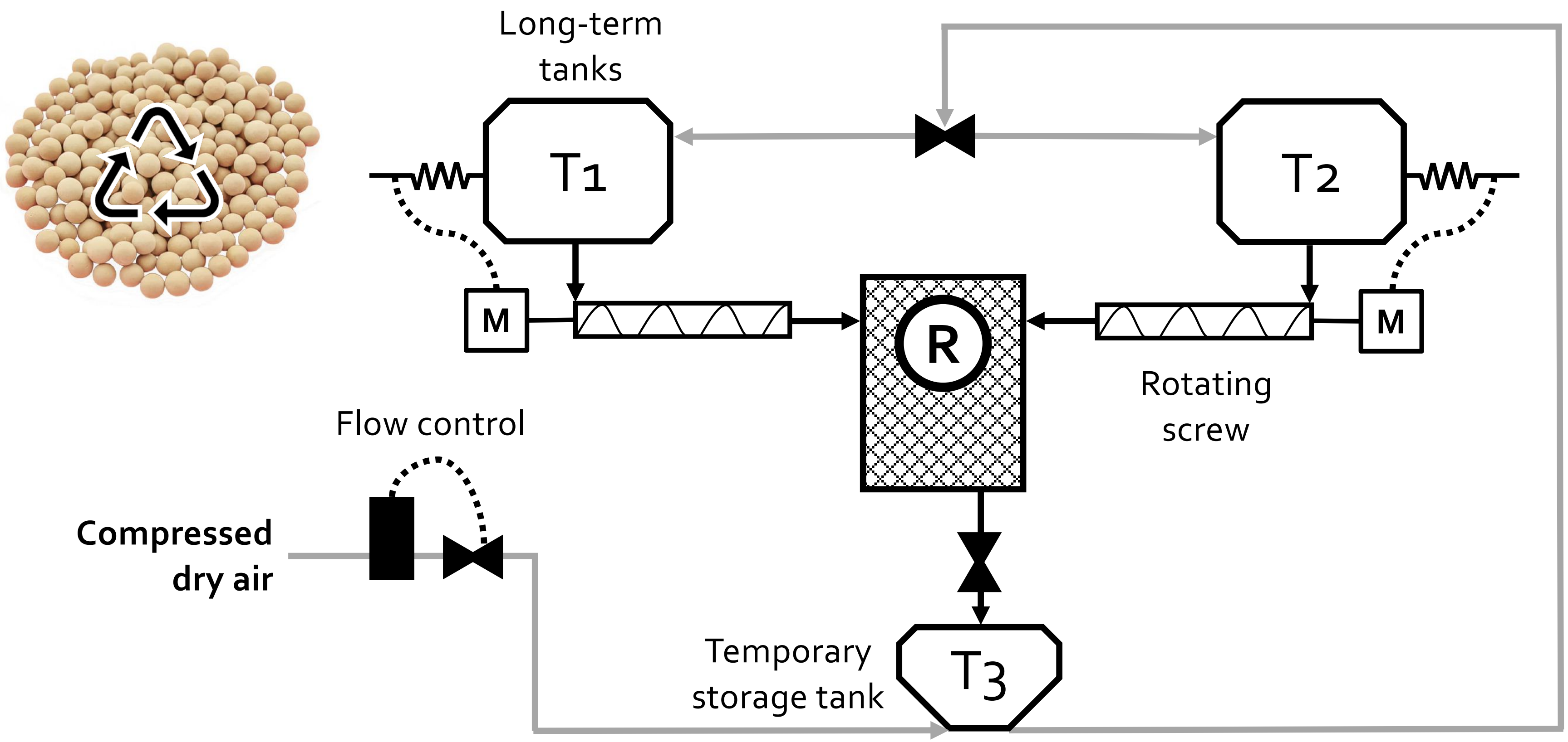
- Possibly more compact
- Less waste heat
- No ventilation consumptions

- Vacuum operation is critical



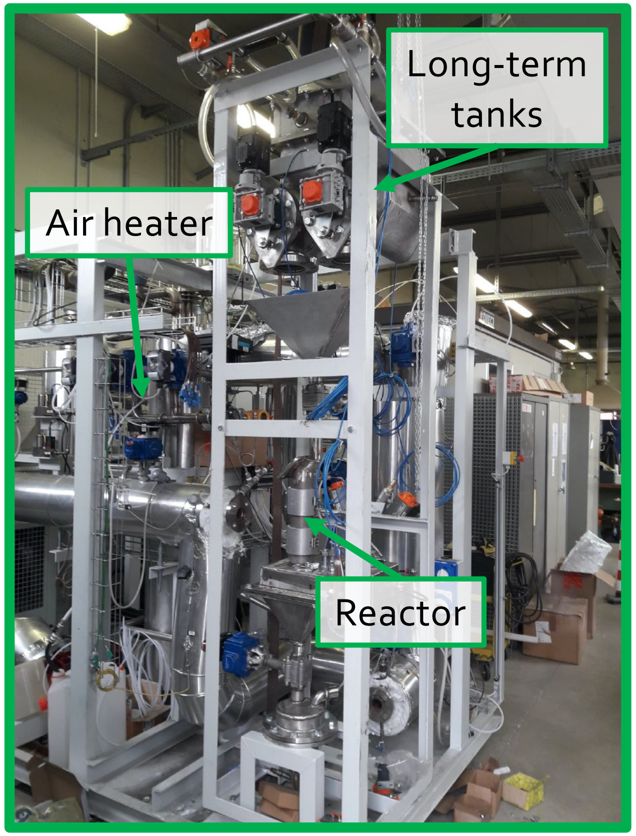
RSE THERMOCHEMICAL TEST FACILITY

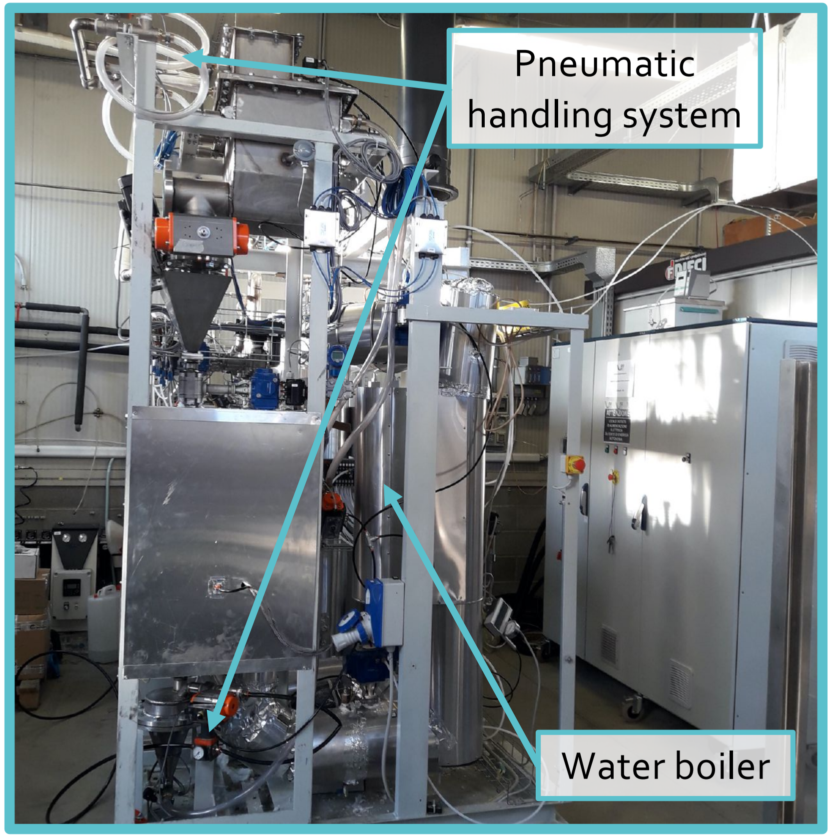
Material handling system – separate reactor concept



RSE THERMOCHEMICAL TEST FACILITY

Laboratory setup





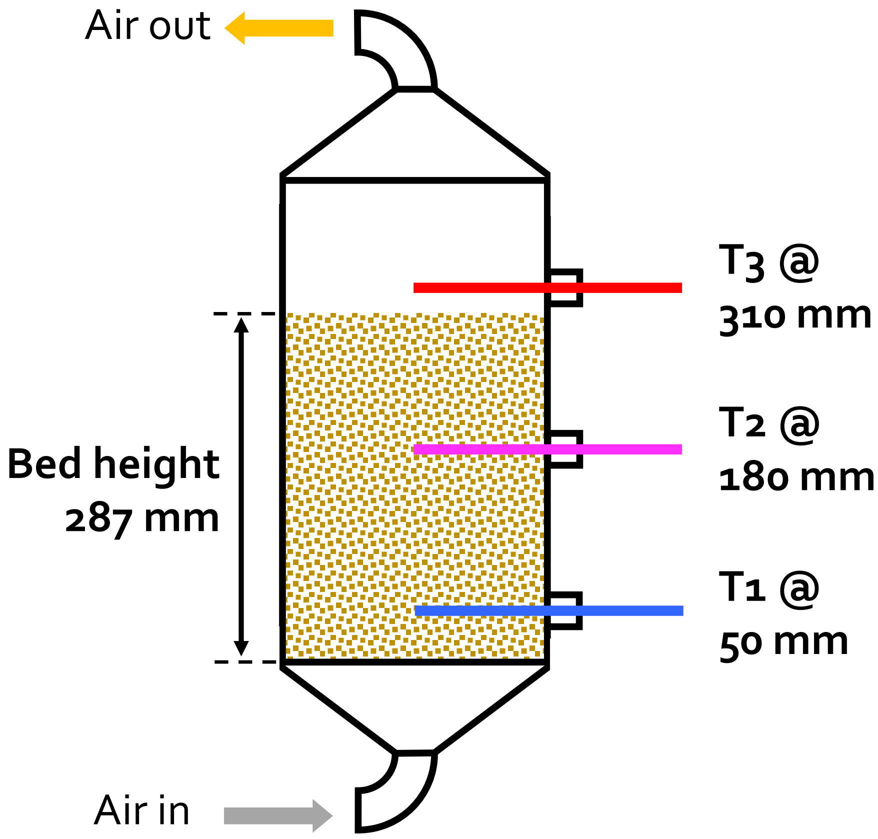
EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

Test conditions and parameters

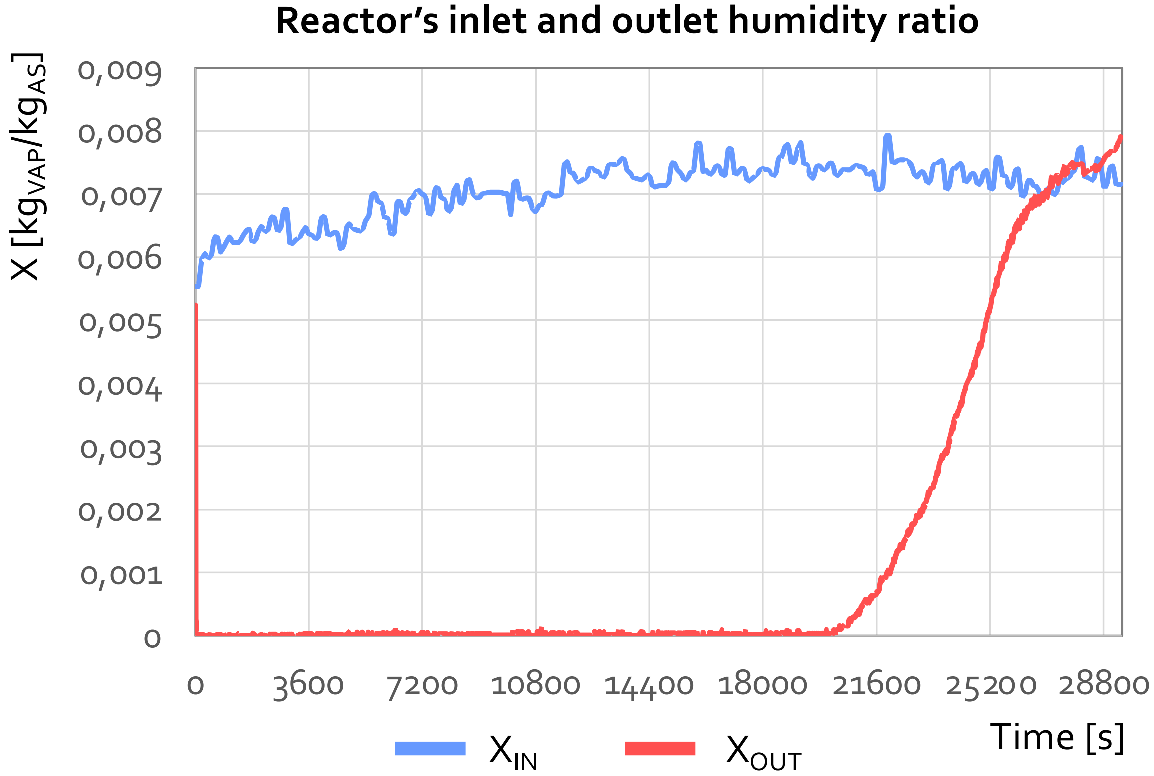
Goal: verify system performances when inlet conditions change (air flow rate, humidity rate, regeneration conditions)

Test conditions	Packed bed, 6 kg of Zeolite 13X (*Sylobead MSC544, Grace*) D_{BED} = 21,1 cm; h_{BED} = 28,7 cm
Adsorption	Q_a = 25 - 30 Nm^3/h X_{IN} = 5 - 10 g_{VAP}/kg_a T = 25 °C; p = 1 atm
Regeneration	Q_a = 28 Nm^3/h T = 190 °C; p = 1 atm Duration = 7 h



EXPERIMENTAL RESULTS

Open cycle adsorption test – inlet and outlet humidity



ADSORPTION

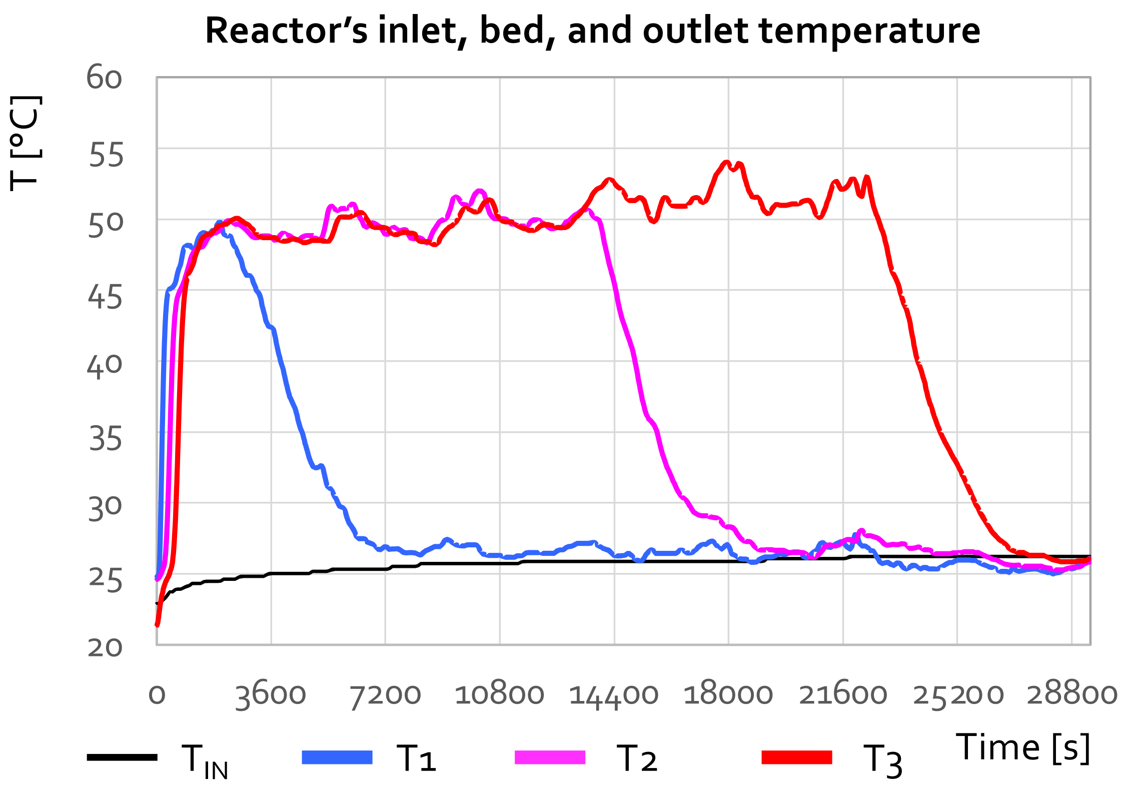
Adsorbed vapor: 1,73 kg_{VAP}

Zeolite vapor loading: 0,28 kg_{VAP}/kg_{ZEO}

Time of breakthrough: around 5,5 h

EXPERIMENTAL RESULTS

Open cycle adsorption test – inlet, bed, and outlet temperature



ADSORPTION

$\Delta T_{OUT,R}$: 25 °C for about 6 hours

Heating thermal power: 260 W_{th}

Bed energy density: 120 kWh/m^3

CONCLUSIONS

Why seasonal thermal energy storage with TCM?	Promising technology to help **phase-out fossil fuels** from the heating sector. Is expected to be **more efficient and economical** compared to other solutions.
Suitable technologies and materials?	Thermochemical storage using **$MgSO_4$ composite materials** is a promising technology. Zeolites are also compatible with **domestic heating** temperatures but show low energy density.
Results of the experimental campaign	**Experimental tests** in the RSE facility using Zeolites have shown that the performance of the system is compatible with the heating of buildings.

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THANK YOU FOR THE ATTENTION
QUESTIONS?

+39 3203713289

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