Low Temperature Heat Recovery and Distribution Network Technologies

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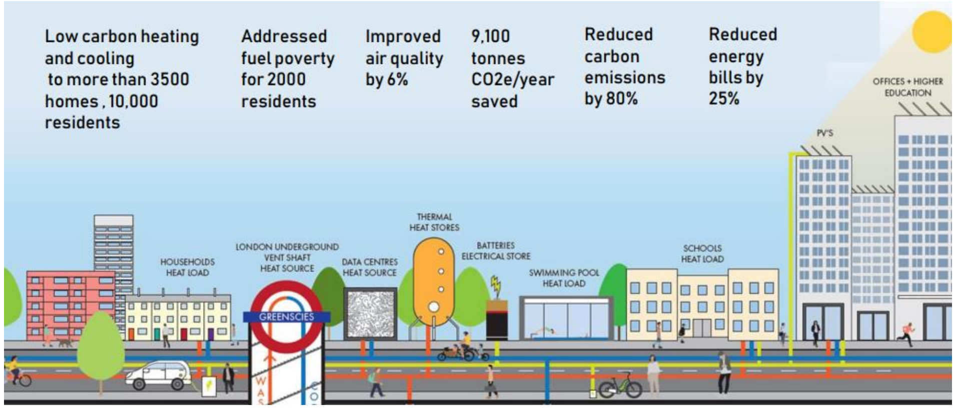
Research Challenge

LoT-NET research focuses on the integration of low temperature (LT) networks with heat pumps and thermal storage technologies to maximise waste and ambient heat utilisation in low or zero-carbon heating and cooling solutions.

Research Challenge 2: To advance performance of novel thermal storage, heat distribution and capture systems.

- WP2.1 Distribution medium or method: Thermochemical systems;
- WP2.2 Storage: New composite thermochemical heat storage materials will be developed.



LoT-NET

Loughborough University

Thermal Energy Storage

Sensible Heat Storage	• Temperature changes • Water, Oil, Rocks etc. • $Q = V\rho C_p \Delta T$	• Low cost • Reliable • Low storage density • Large volumes • Heat losses
Latent Heat Storage	• Phase changes • Salts, Paraffins, Eutectic etc. • $Q = m h_m$	• Medium storage density • Small volumes • Corrosion • Low heat transfer • Heat Losses
Thermochemical Storage	• Chemical reactions • Solid/Liquid-Gas, Gas-Gas • $Q = X n_B \Delta H_r$	• Medium/Long term storage • High storage density • Technical complexity • High costs

Thermal Energy Storage

Thermochemical Storage

Latent Heat Storage

Sensible Heat Storage

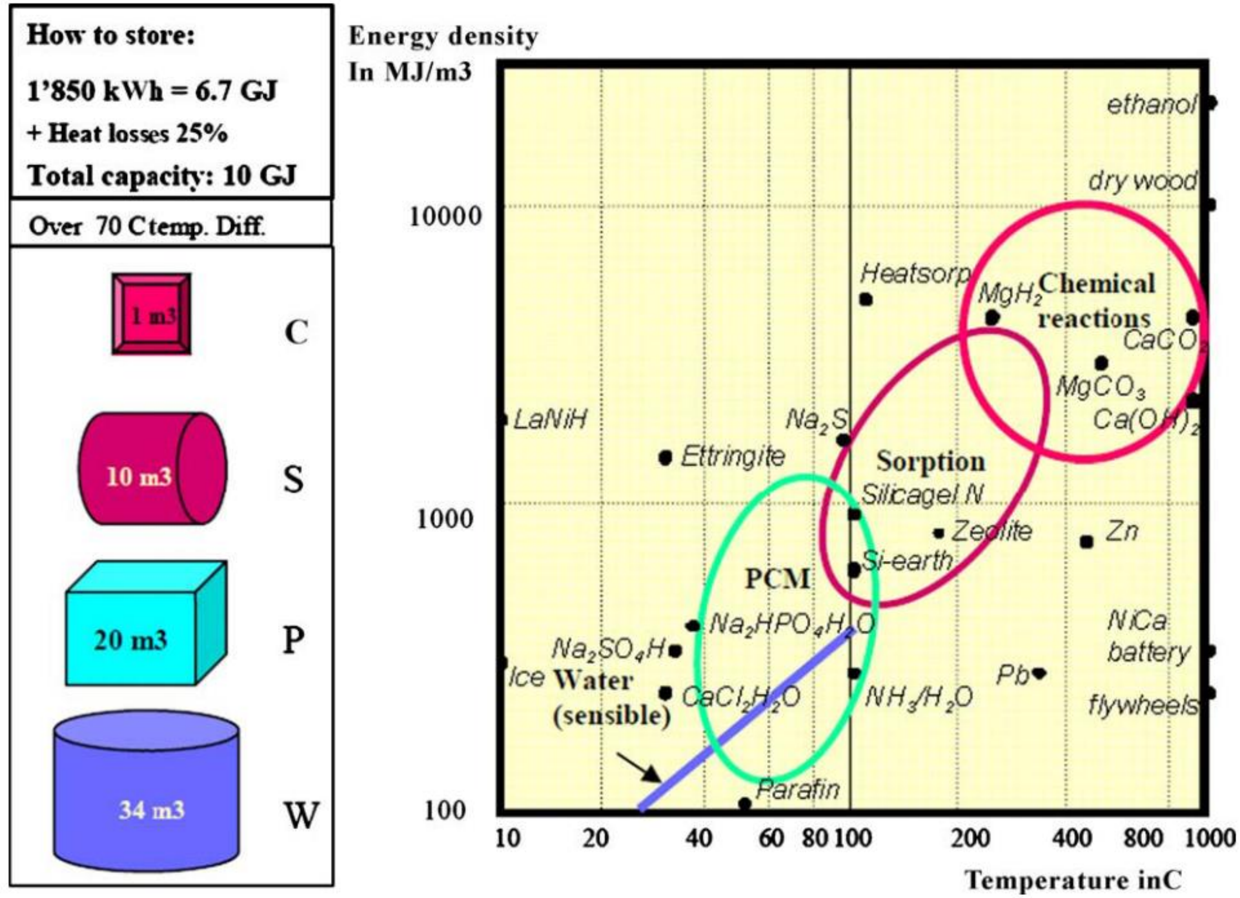


Fig.1. Energy density of high energy storage methods. [1]

[1] N'Tsoukpoe KE, Liu H, Pierres NL, Luo LG. A review on long-term sorption solar energy storage. Renewable and Sustainable Energy Reviews, 2009, 13, 2385-2396.

Thermochemical Heat Storage

$$A \cdot (m+n)B + Heat \underset{\text{discharging}}{\overset{\text{charging}}{\rightleftharpoons}} A \cdot mB + nB$$

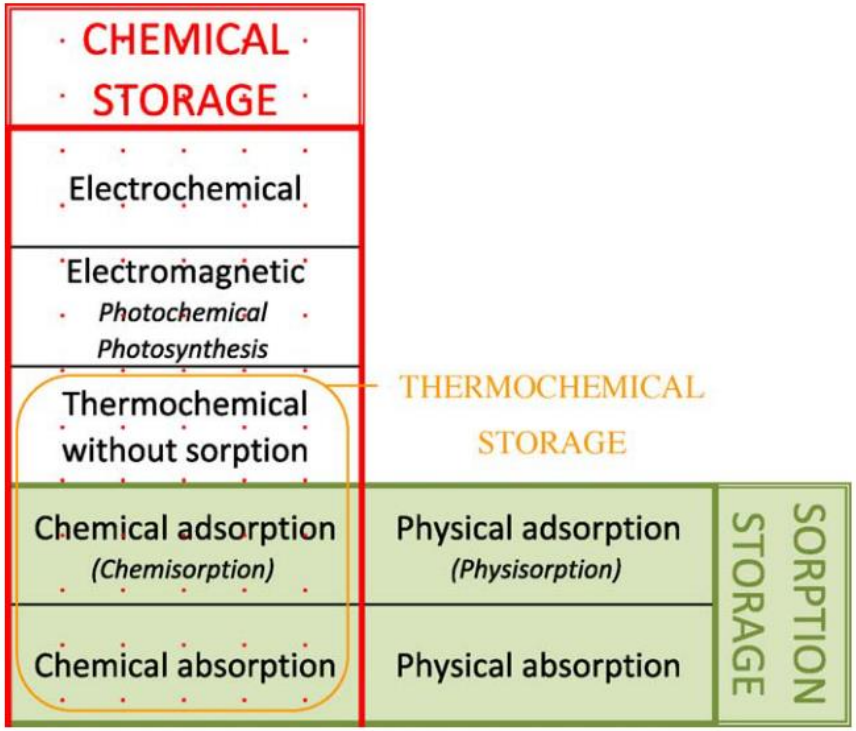


Fig.2. Chemical storage and sorption storage classification. [1]

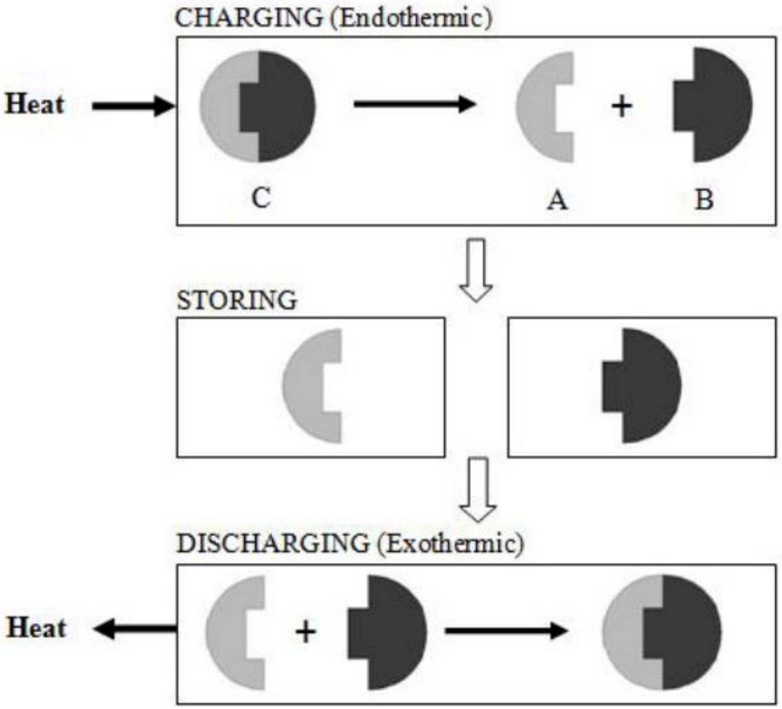


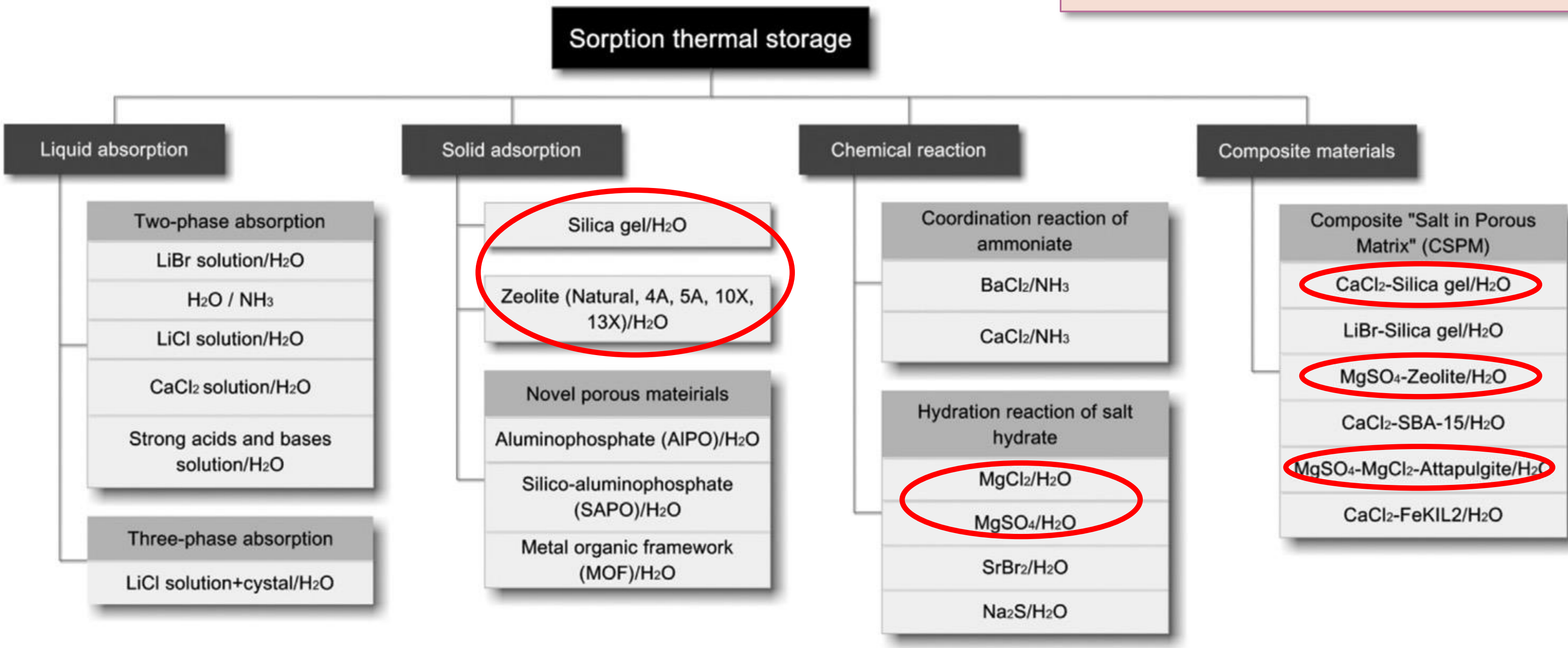
Fig.3. Charging, storing and discharging processes involved in a thermochemical energy storage cycle. [2]

[2] Abedin AH, Rosen MA. A critical review of thermochemical energy storage systems. The Open Renewable Energy Journal, 2011, 4, 42-46.

Thermochemical Heat Storage

Sorption thermal storage classification [3]

Waste Heat Source: 120°C



[3] Yu N, Wang RZ, Wang LW. Sorption thermal storage for solar energy. Progress in Energy and Combustion Science, 2013, 39, 489-514.

Example: $MgCl_2 \cdot 6H_2O$

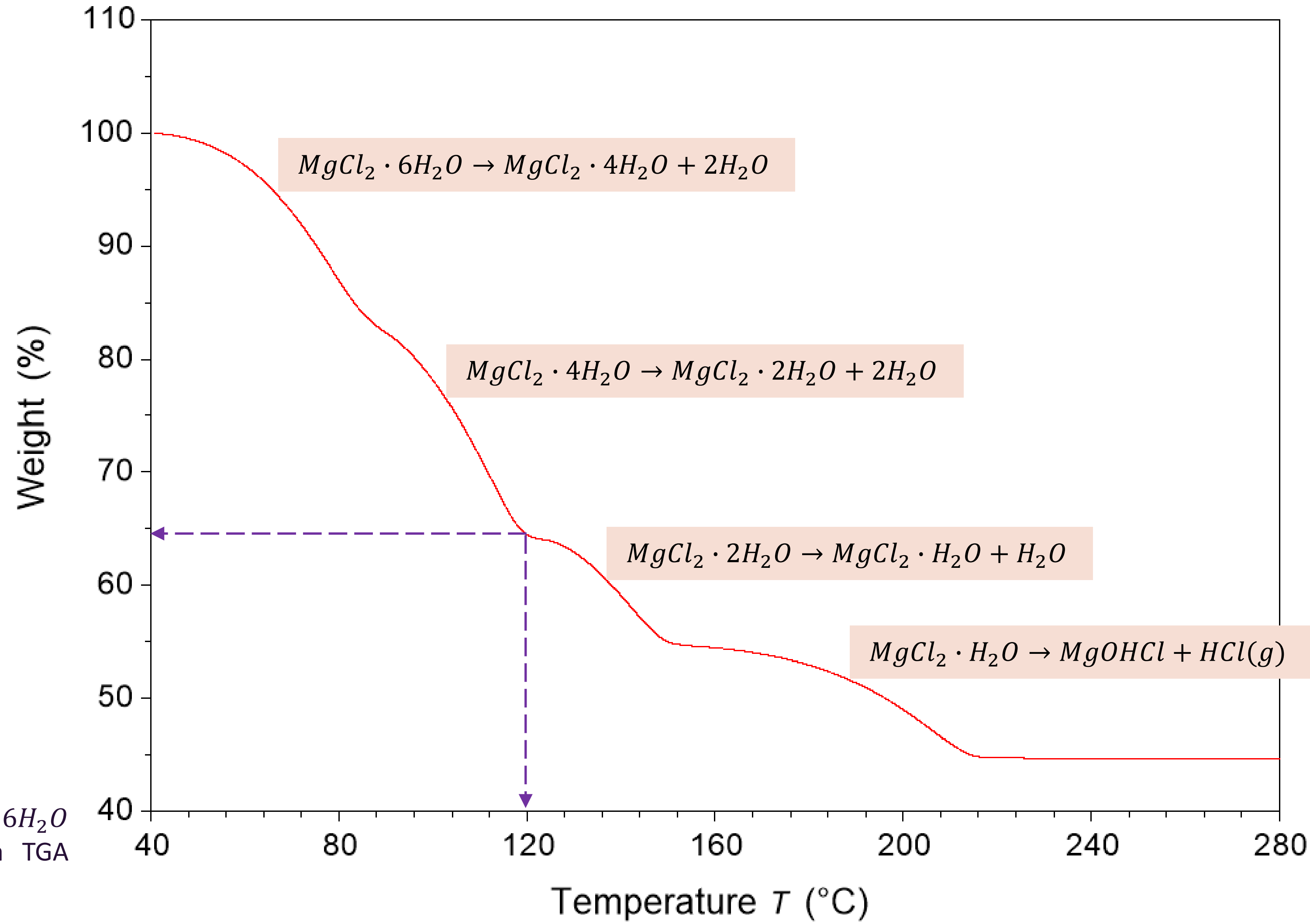


Fig.4. Weight loss of $MgCl_2 \cdot 6H_2O$ versus temperature using a TGA with heating rate 2°C/min.

Example: $MgCl_2 \cdot 6H_2O$

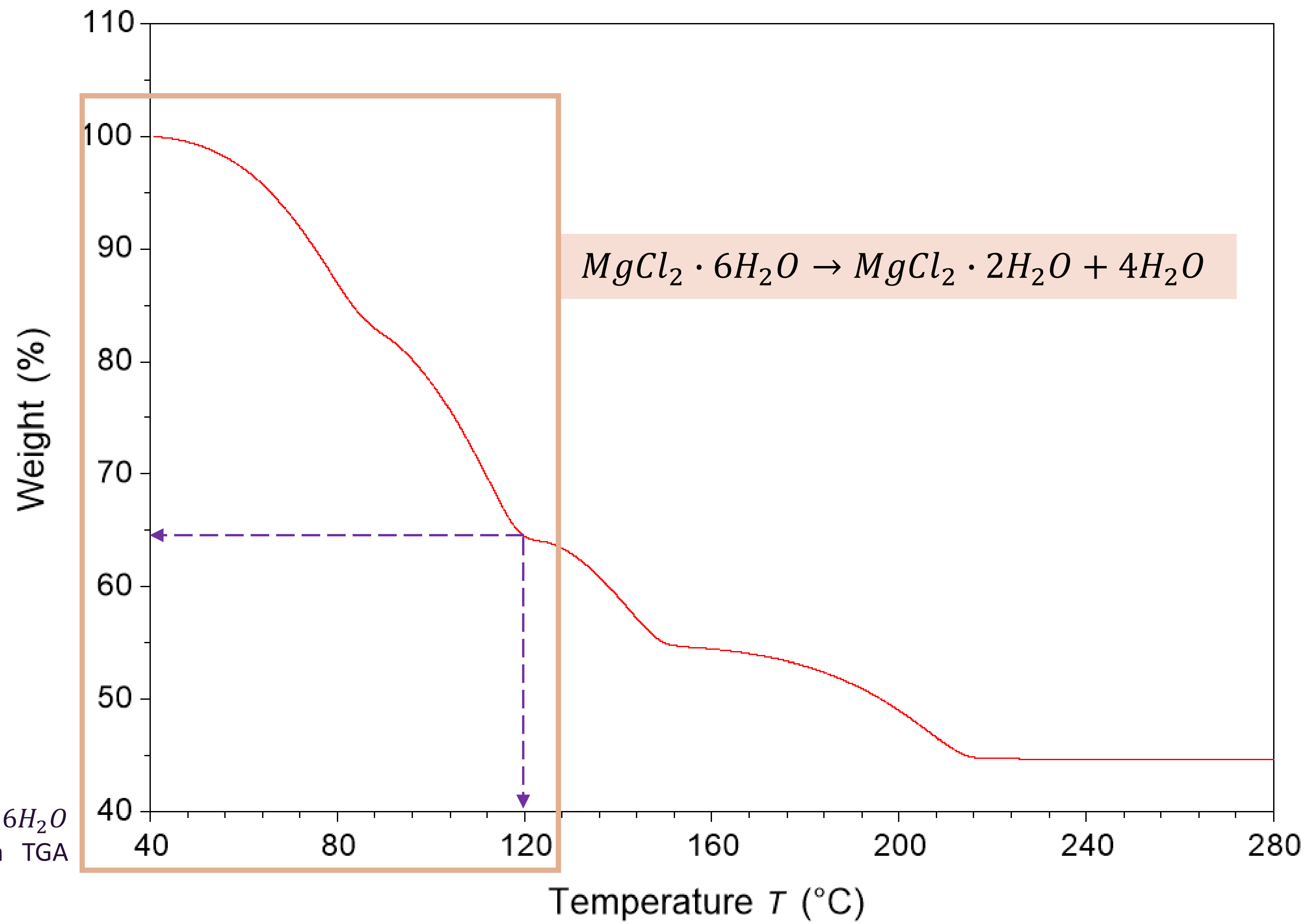
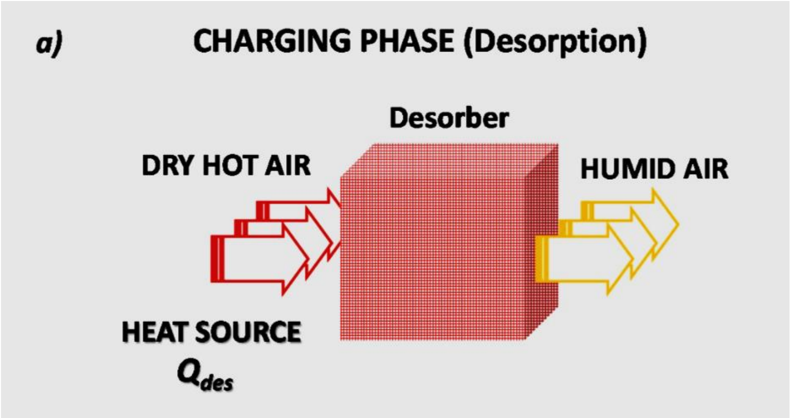


Fig.4. Weight loss of $MgCl_2 \cdot 6H_2O$ versus temperature using a TGA with heating rate 2°C/min.

Example: $MgCl_2 \cdot 6H_2O$



$$MgCl_2 \cdot 6H_2O + \text{Heat} \rightarrow MgCl_2 \cdot 2H_2O + 4H_2O$$

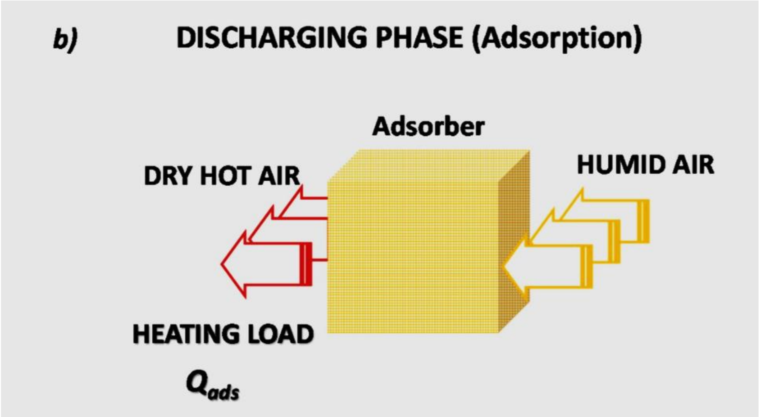


Fig.5. An adsorption heat storage cycle. [4]

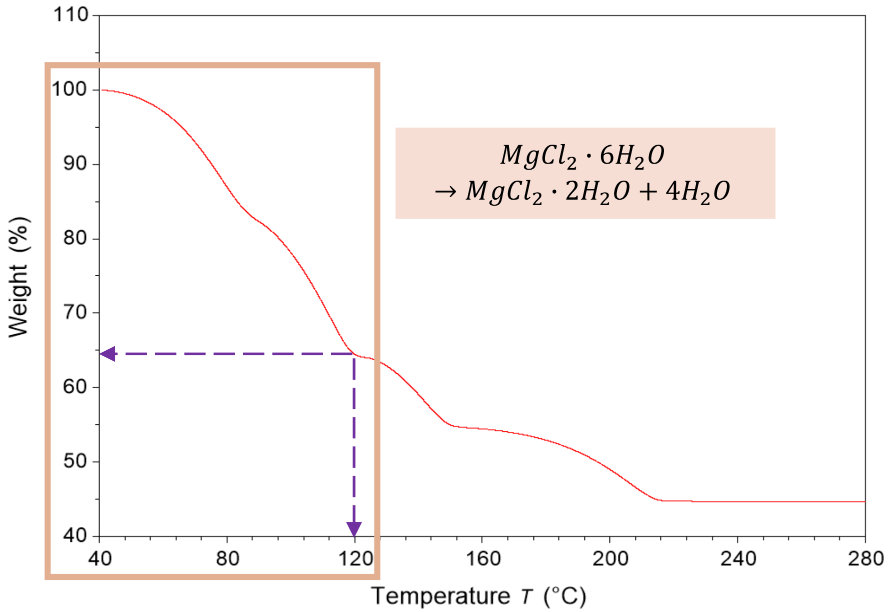


Fig.4. Weight loss of $MgCl_2 \cdot 6H_2O$ versus temperature using a TGA with heating rate 2°C/min.

$$MgCl_2 \cdot 2H_2O + 4H_2O \rightarrow MgCl_2 \cdot 6H_2O + \text{Heat}$$

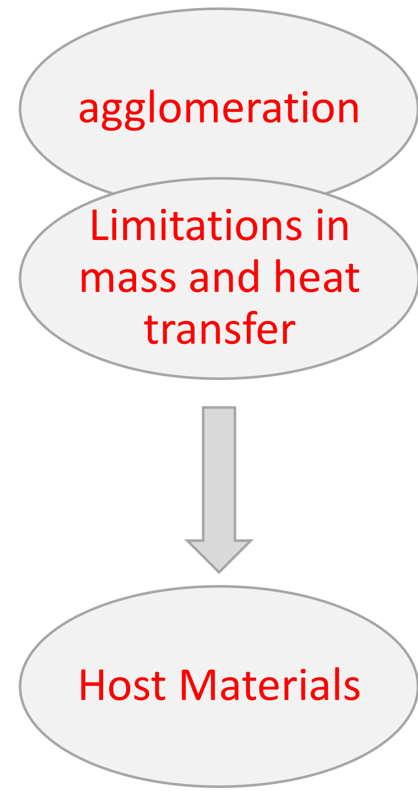
[4] Vasta S, Brancato V, Rosa DL, Palomba V, Restuccia G, Sapienza A, Frazzica A. Adsorption Heat Storage: State-of-the-Art and Future Perspectives. Nanomaterials, 2018, 8, 522.

Potential Materials for TCES

Table 1: Details of Potential Materials

Materials	Charging Temperature	Storage Density (Wh/kg)	Supplier	Price
$MgCl_2$	130°C	477	Fisher Scientific	1KG/£99.20
$MgSO_4$	150°C	442	Fisher Scientific	1KG/£106.00
$CaCl_2$	100°C	623	Fisher Scientific	1KG/£46.00
$SrCl_2$	100°C		Fisher Scientific	
AlPO-18	95°C	243		
SAPO-34	95°C	203		

Materials	Charging Temperature	Storage Density (Wh/kg)	Supplier	Price
Zeolite 13X			Fisher Scientific	1KG/£38.08
Silica Gel			Fisher Scientific	1KG/£58.20
Activated Carbon			Sigma Aldrich	1KG/£51.10



Research Plan

Materials → Small Scale → Medium Scale

Step 1: Materials

$MgCl_2$

- Mixture Salts: $MgCl_2 + MgSO_4/CaCl_2/SrCl_2$
- Host Materials: Zeolite 13X/Silica Gel/Activated Carbon + Salts
- Additives: Nanoparticles

Wetness Impregnation

Research Plan

Materials → Small Scale → Medium Scale

Step 1: Materials

$MgCl_2$

- Mixture Salts
- Host Materials
- Additives

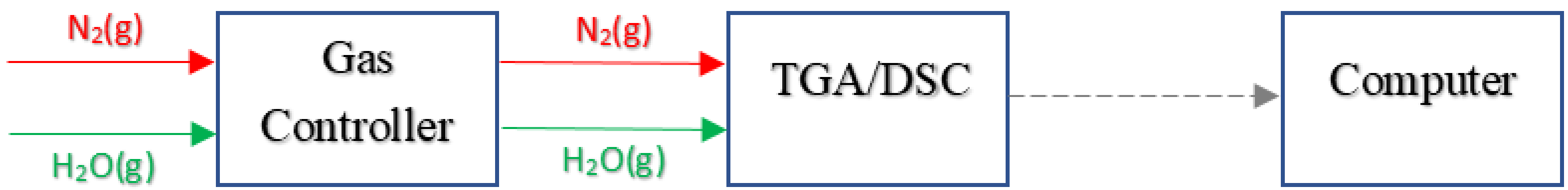
Thermophysical Properties

Theoretical Storage Density

Research Plan

Materials → Small Scale → Medium Scale

Step 2: Hydration and dehydration cycle tests in small scale (~10mg).



Dehydration (charging)

Hydration (discharge)

Cycle Tests →

- ✓ Cycle Stability
- ✓ System Energy Storage Density $W = \frac{Q_{discharge}}{Volume}$
- ✓ Energy Storage Efficiency $\eta = \frac{Q_{discharge}}{Q_{charge}}$

Research Plan

Materials → Small Scale → Medium Scale

Step 3: Experimental Reactor and System Design in medium scale (~50g).

- ✓ System: Open/Closed
- ✓ Reactor: Particles
  - Beads
  - Pellets
  - Honeycombs

Things To Do

- Making materials for hydration/dehydration cycle tests;
  - Lab training (TGA/DSC done);
- Conducting thermophysical analysis of materials;
- Conducting hydration/dehydration cycle tests;
- Designing rig for medium scale experiments.

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THANK YOU!

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