Calorimetry and Thermal Analysis days
53rd edition

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Corn cobs' biochar as a host support of salt hydrates for heat storage applications

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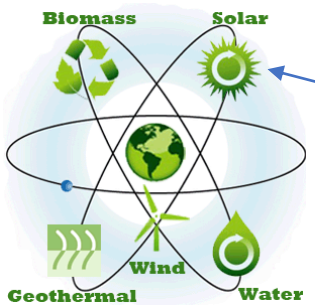
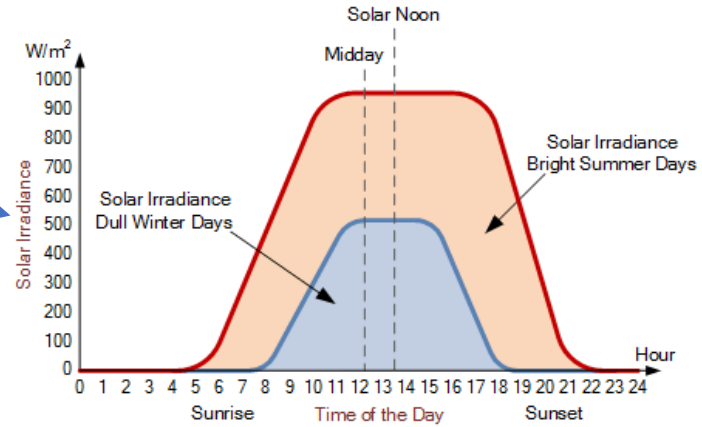
Increasing demand for energy consumption

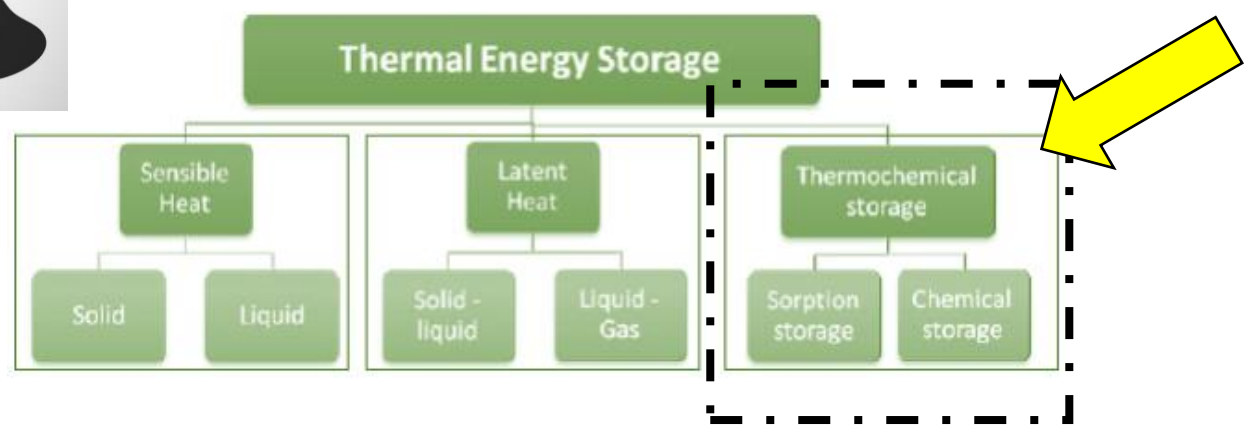
Transition

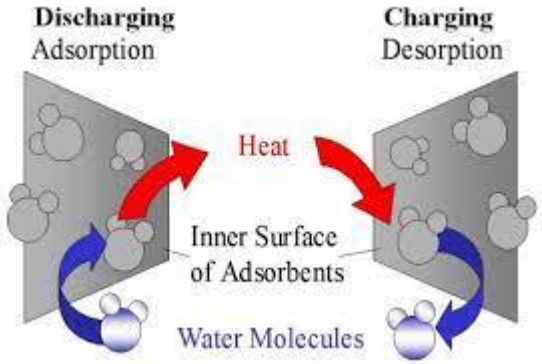


Renewable energies



Problem of intermittence



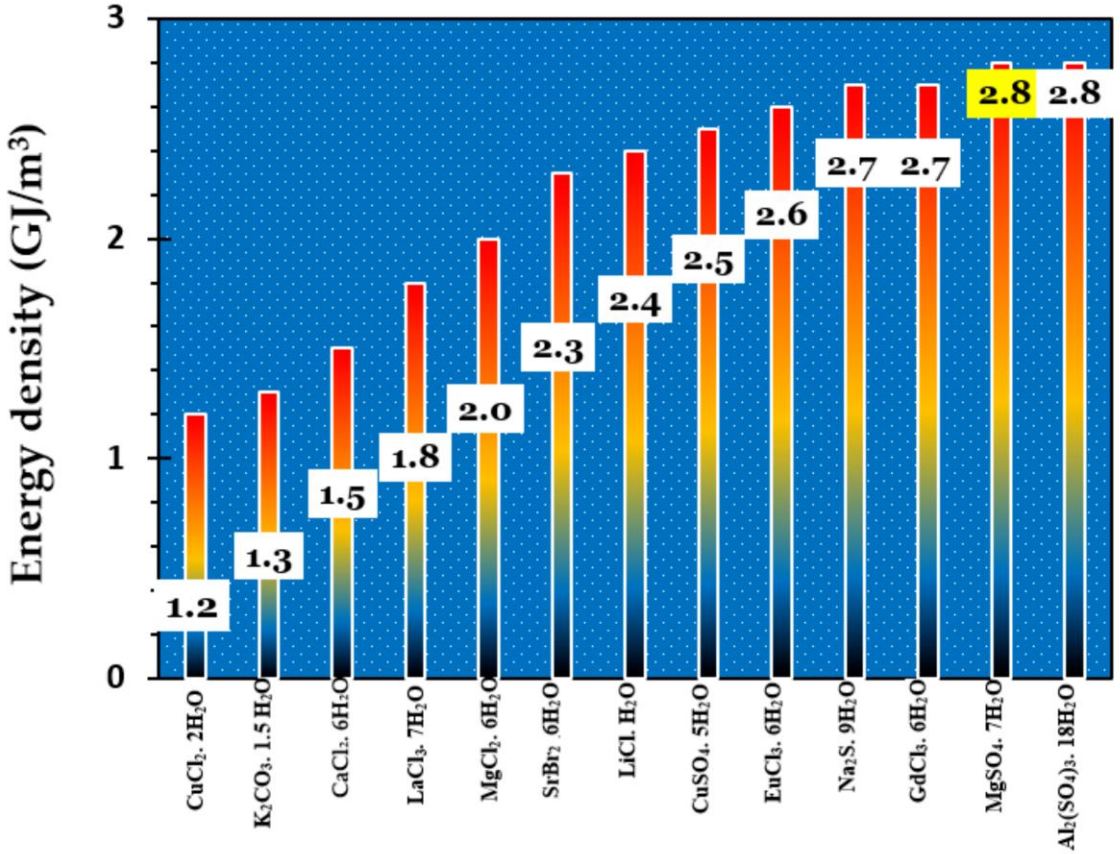


How it works

Materials

Salt hydrates : high theory heat storage density and non-toxic

Low Charging temperature (150 °C) → *Suitable for domestic applications*



Zbair, M.; Bennici, S. ENERGIES ***2021****, 14, doi:10.3390/en14113105*

$MgSO_4$ = best candidate

High cost	Low-cost (3.8 €/kg)
Toxic and corrosive	Non-corrosive nor toxic
Deliquescence	High DRH : 90 % at 30 °C
Slow kinetic	High theory ESD : 2.8 GJ/m³
Limited mass transfer	Low charging temperature

Dispersion of $MgSO_4$ onto a porous support

Composites $MgSO_4$/biochar CC

- Pore size
- High surface area and High thermal conductivity

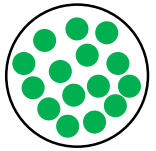
Corncob collected-pyrolyzed in Alsace region

Sieving

2.5 – 4 mm

Biochar CC

Impregnation



$MgSO_{4\ (aq)}$

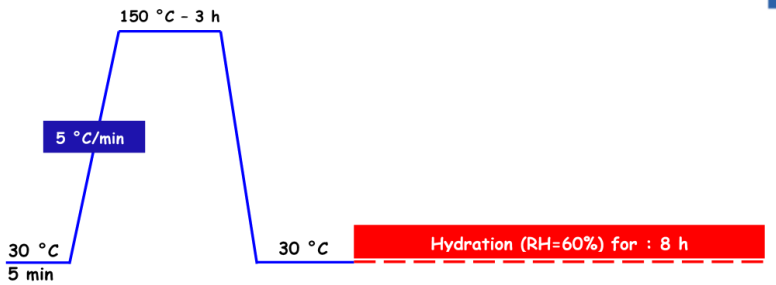
Drying

Composite xMgCC

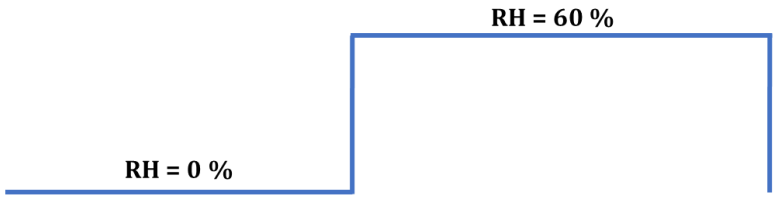
x : wt.% of $MgSO_4$

- Valorization of agriculture co-product
- Answer to circular economy issues

- X-Ray Fluorescence : determine the chemical composition of the sample
- X-Ray Diffraction : analysis of the present crystalline phases
- SEM coupling with EDX : analysis sample morphology and perform elemental composition mapping
- CO_2 isotherm adsorption : analysis of the porosity, pore size distribution and surface area
- Hg intrusion porosimetry : analysis of the macroporosity
- **Water adsorption experiments**

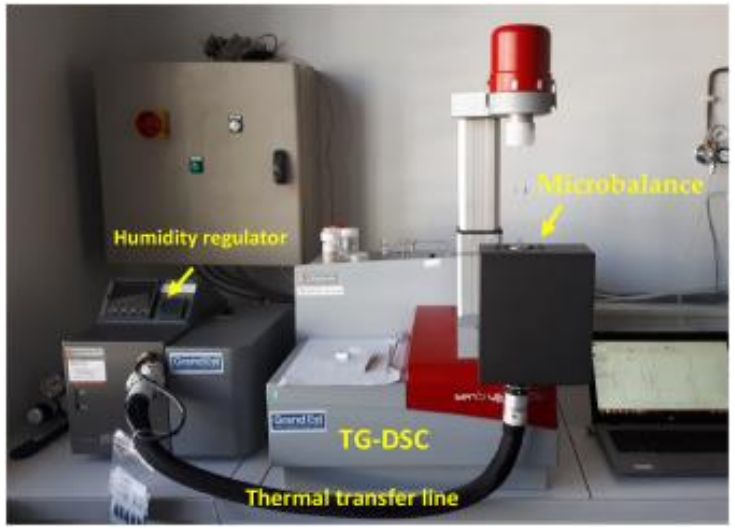


Dehydration/hydration cycle conditions

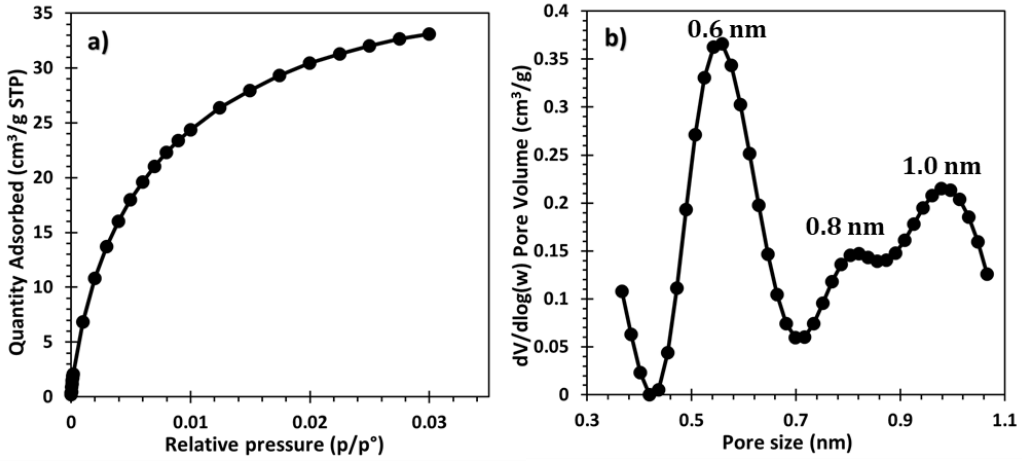


Wetsys program

A Sensys TG-DSC apparatus, equipped with a Wetsys flow humidity generator

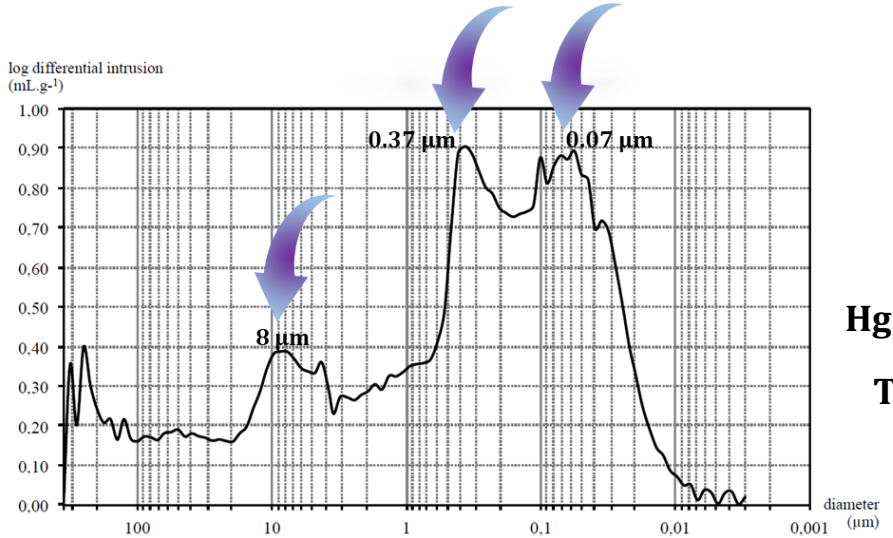


Discussion



CO_2 adsorption isotherm and PSD of the CC

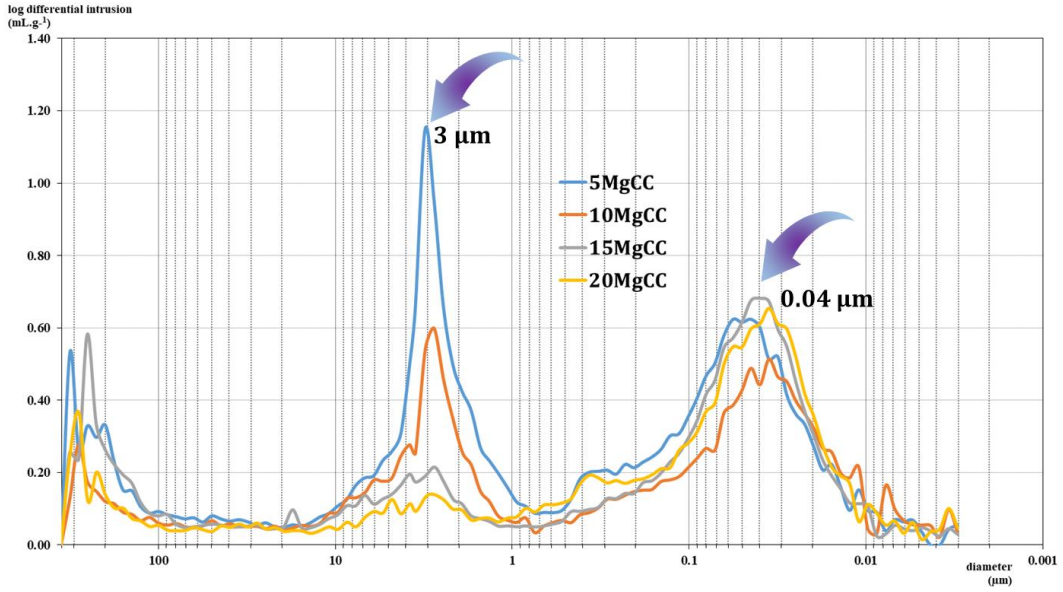
S_{BET} = 175 m^2/g



Hg intrusion analysis of CC

Total porosity = 70.4 %

V_p = 1.89 cm^3/g

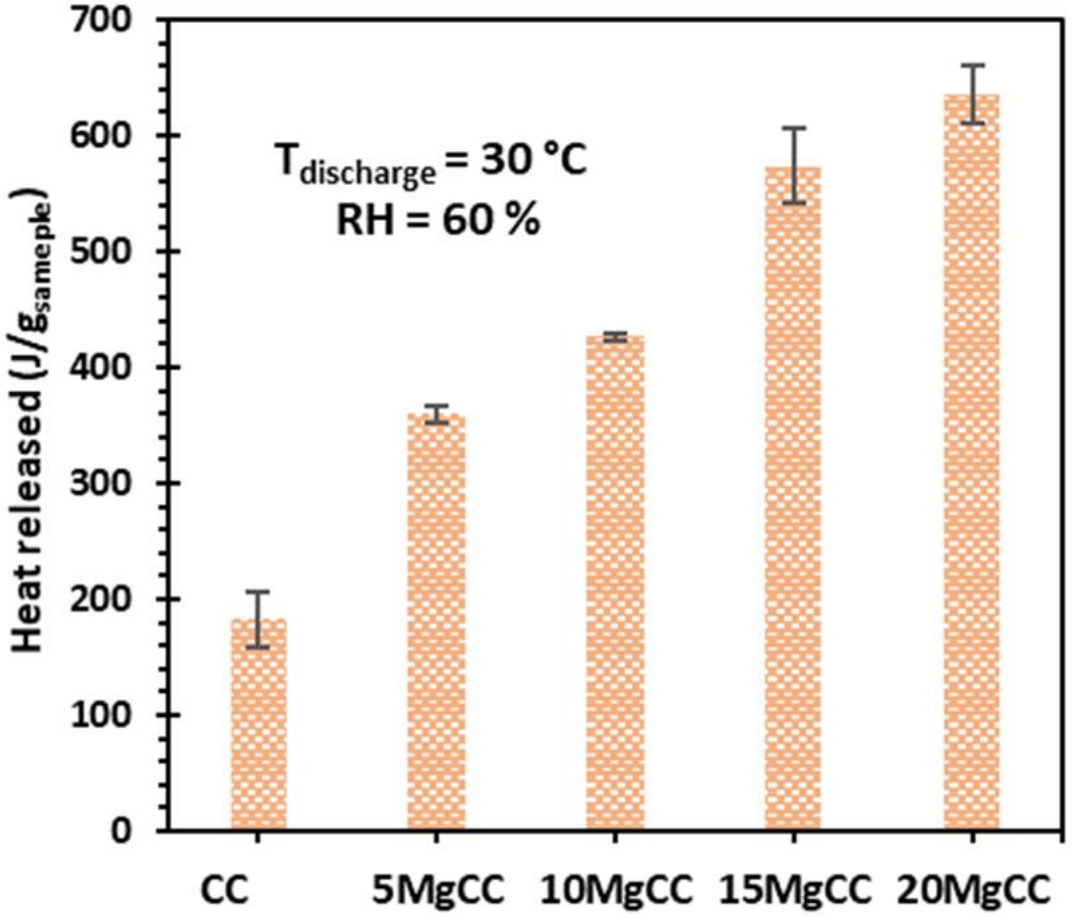


Total porosity ↘

70.4 % to 54.8 %

V_p ↘

1.89 to 0.81 cm^3/g



Sample	Heat released (J/g_{comp})	Water adsorption (g/g)
CC	183	0.070
5MgCC	360	0.126
10MgCC	426	0.157
15MgCC	574	0.207
20MgCC	635	0.235

The heat released increases with the salt content

Composites $MgSO_4$/biochar CC – Heat released

Sample	Heat released (J/g_{comp})	Heat released (J/g_{H2O})
CC	183	2607
5MgCC	360	2854
10MgCC	426	2940
15MgCC	574	3031
20MgCC	635	3100

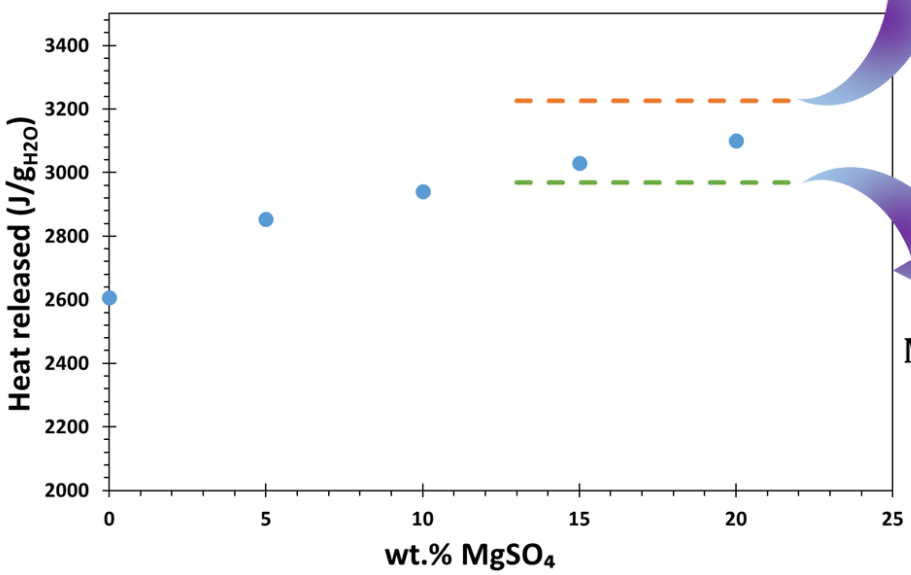
Case of biochar CC

Heat released of the support biochar : Q_{sup} = 2607 J/g_{H2O}

Latent heat of water at 30 °C : L_v = 2406 J/g_{H2O}

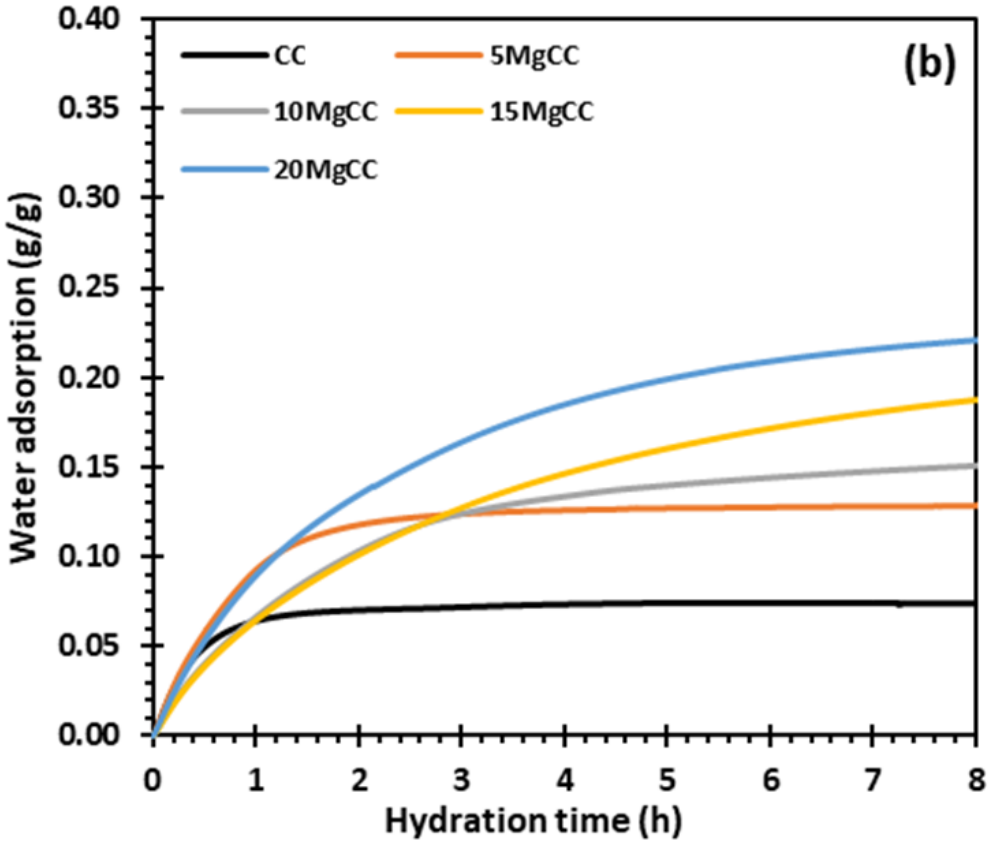
$Q_{sup} \approx L_v$

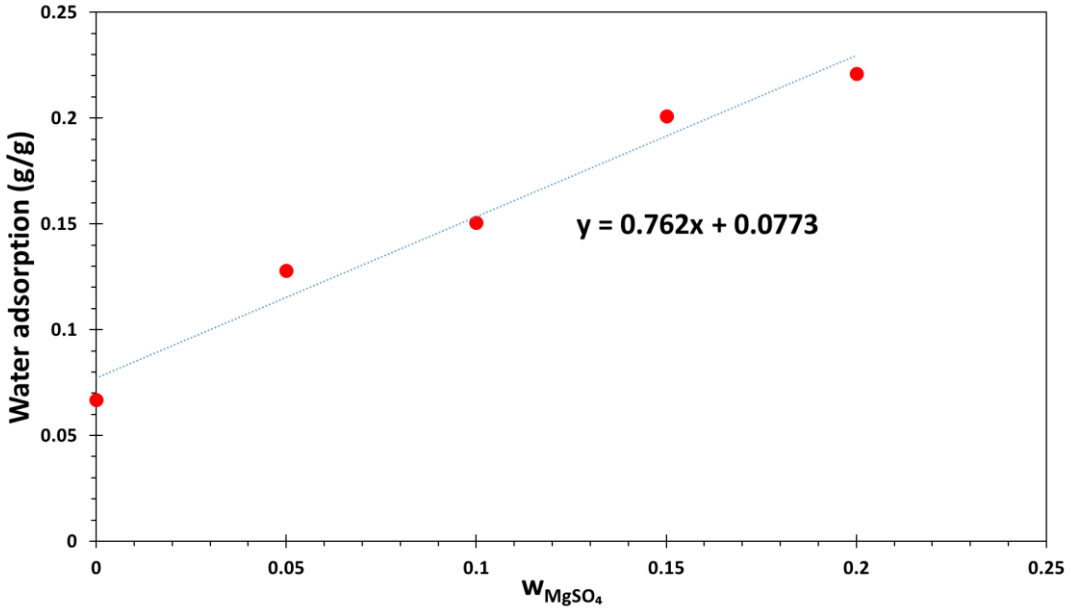
$MgSO_4.1H_2O \rightarrow MgSO_4.7H_2O$



$MgSO_4.1H_2O \rightarrow MgSO_4.6H_2O$

Composites $MgSO_4$/biochar CC – Water adsorption

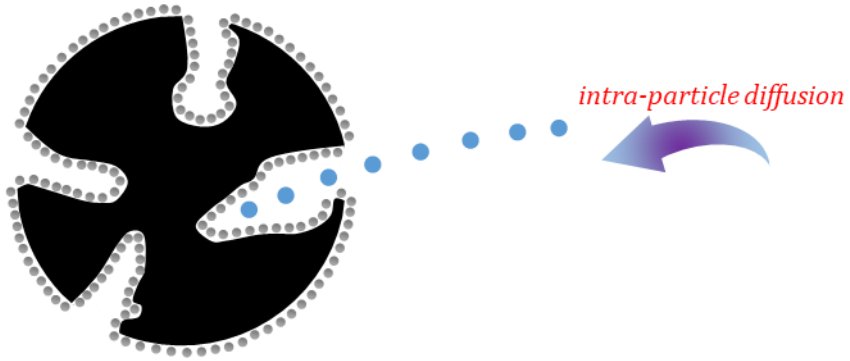




$$w_e = 0.762 * \omega_{MgSO_4} + 0.077\ g_{H_2O}/g_{comp}$$

The hydration behavior is similar for all composites

Composites $MgSO_4$/biochar CC – Kinetic

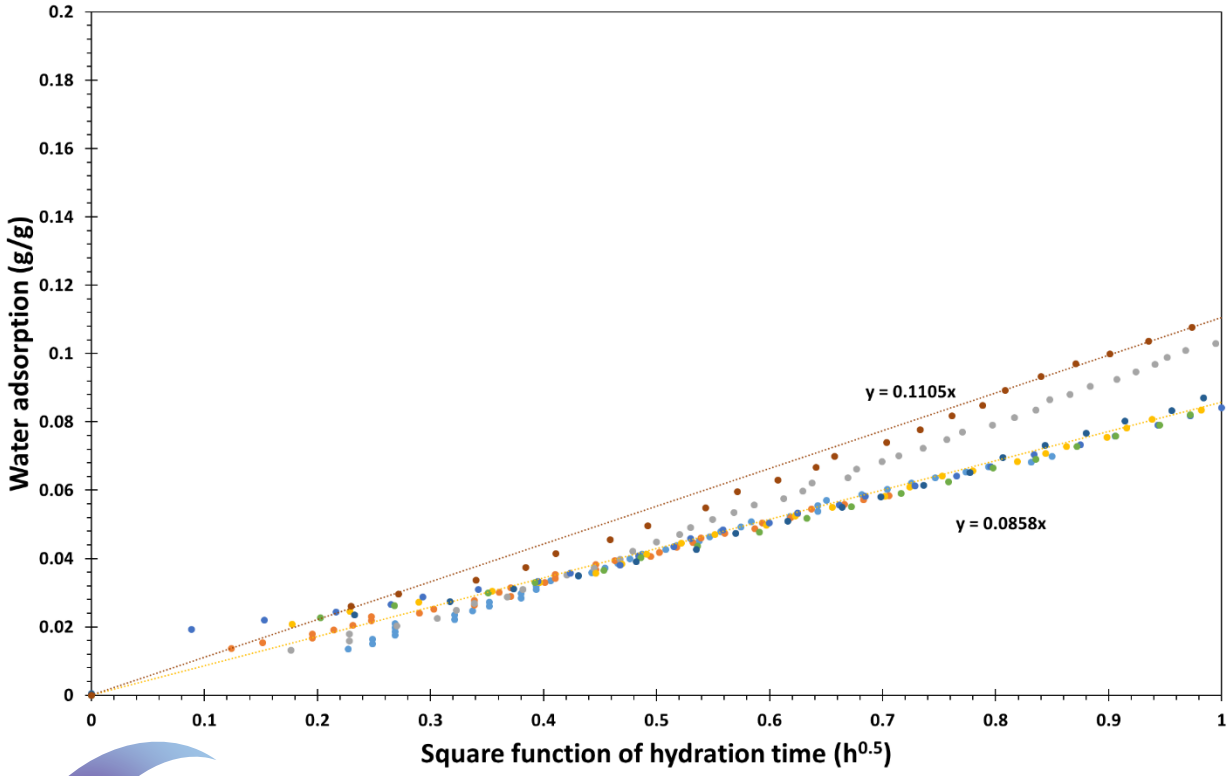


Intra-particle diffusion model (Weber-Morris)

$$q_t = k_i * t^{0.5} + C$$

with k_i intra-particle diffusion rate constant ($g.g^{-1}.h^{-0.5}$)

C represents the material transfer resistance (g/g)



$$0.09 \leq k_i \leq 0.11$$

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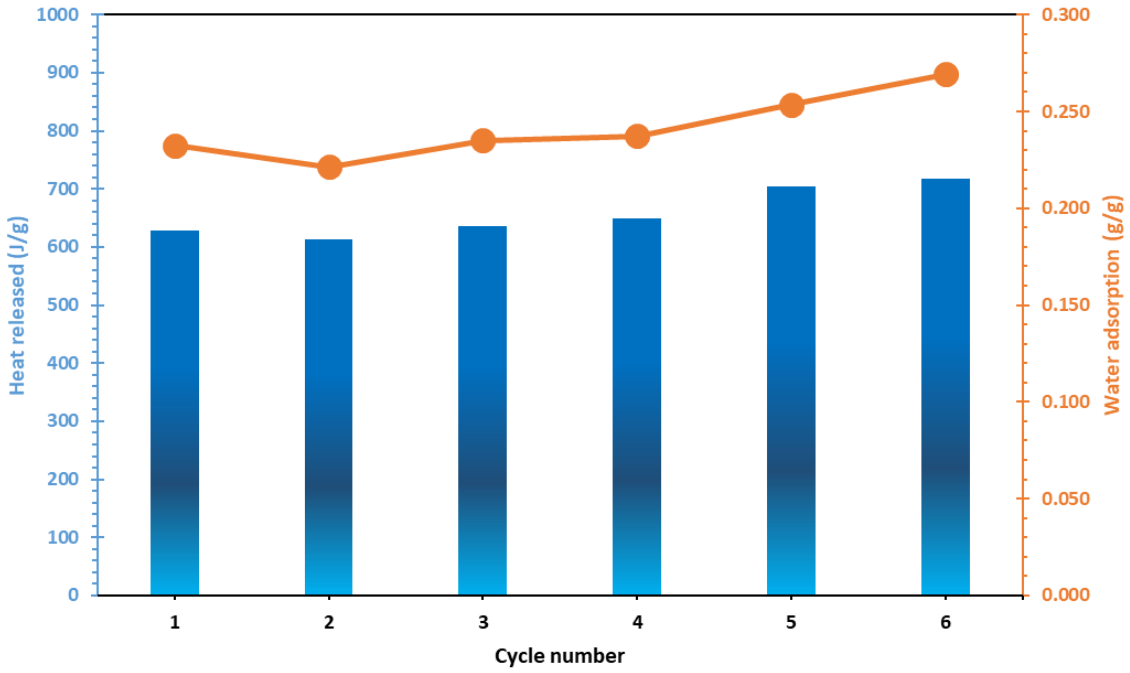
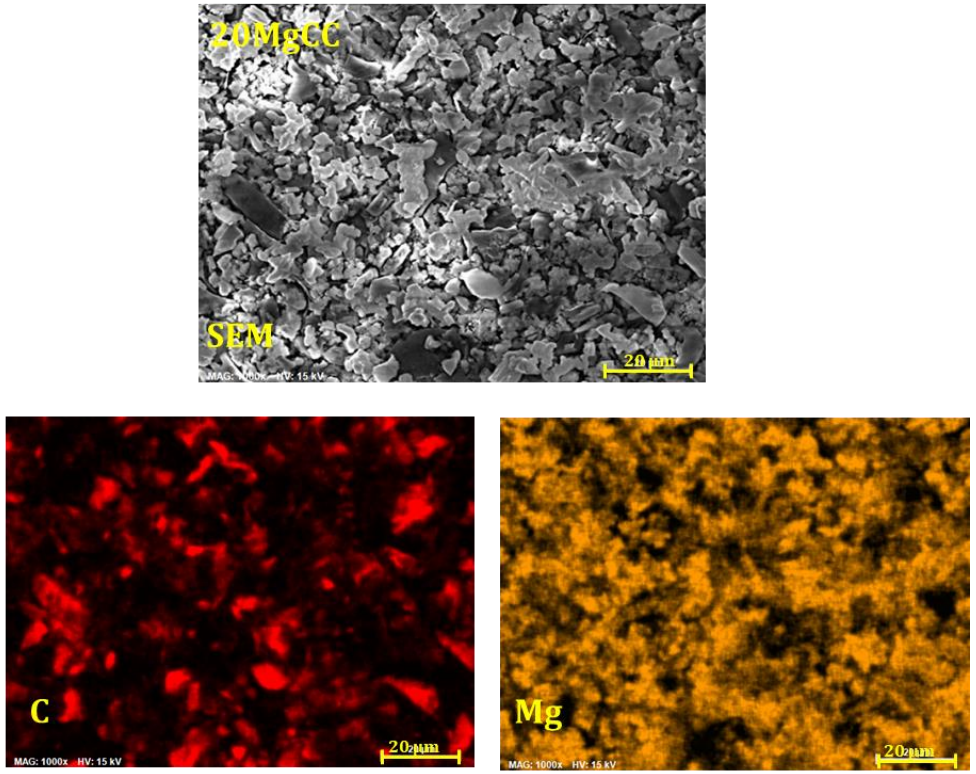
Composites $MgSO_4$/biochar CC-cyclability



Composite 20MgCC after 6 cycles dehydration/hydration



SEM/EDX after 6 cycles

- Corn-cobs biochar is a promising host for salt hydrates for TES materials.
- Calorimetry coupled with TG is fundamental for the study of heat storage materials.
- Salt composites have a good stability over multiple hydration/dehydration cycles.


THANK YOU