Work Packages 3.1,3.2,4.3

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Work Package 3.1
Compact Chemical Heat Storage
MgSO$_4$(s) + 7H$_2$O(g) $\leftrightarrow$ MgSO$_4$ $\cdot$ 7H$_2$O(s) + heat

A reversible chemical reaction that stores heat;

**Potential of MgSO$_4$·7H$_2$O.**
- High energy density – Theoretically 2.8GJ/m$^3$ (778kWh/m$^3$)
- Sensible heat losses are small
- Stores heat for an indefinite amount of time
- Relatively cheap - $\sim$£61/1000kg [2]

**Problems with MgSO$_4$·7H$_2$O.**
- Cycle stability – material degrades & cracks after cycles
- Vapour transportation – difficulty achieving the theoretical energy density.
Cycle stability of pure MgSO$_4$ is problematic, using a host material may address this
e.g. Zeolites may be used as a host material
- large surface area & pore volume,
- composites may allow lower desorption temperatures
- Enhanced vapour transportation = Increased power output

Investigate the potential of a selection of porous materials to determine a suitable candidate to produce a range of composites for characterisation. When a suitable composite combination is developed cycle stability tests will be performed.

Using DSC, TGA, RGA & SEM along with lab scale (~100g) hydration chambers promising composites will be tested to assess:
- Desorption temperature
- Power output/cycles
- Optimal hydration conditions
- Energy storage density kWh/m$^3$

A prototype storage system will be developed.
DSC, TGA & RGA Data for the dehydration of \( \text{MgSO}_4 \cdot 7\text{H}_2\text{O} \)

As mass is lost (due to water loss) endothermic peaks are observed. This can be confirmed with the RGA data.

<table>
<thead>
<tr>
<th>Heating Rate (°C/min)</th>
<th>Max Temperature °C</th>
<th>Enthalpy (normalized) J/g</th>
<th>Peak Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110</td>
<td>1224.3</td>
<td>87.045</td>
</tr>
<tr>
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<td>110</td>
<td>806.53</td>
<td>100.389</td>
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<tr>
<td>10</td>
<td>110</td>
<td>866.68</td>
<td>101.764</td>
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<tr>
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</table>
Work Package 3.2
Compact Latent Heat Energy Storage
A range of organic and inorganic materials are being characterised to determine their latent heat and phase change temperature.

- Repeatability and Subcooling may be an issue for some materials tested.
- Corrosion tests are being performed for salts to determine material compatibility.
- A laboratory storage system of 1 kWh will be constructed when the most suitable material is selected and corrosion tests have been completed.
- Modelling of phase change for melting and solidification will be informed by materials characterisation.
Prediction of charging of a PCM store
Prediction of store discharging
Initial Temperature = 61°C, volume flow = 0.08 l/s$^{-1}$
Work Package 4.3
Process Heat Storage
Material Preparation

- A mixture of Lithium Nitrate and Sodium Chloride (mole fraction of 0.87 :0.13) was selected as the heat storage material for industrial process heating.
- To get a uniform mixture, the two salts with right mass proportions were dissolved in water. The mixture was then placed in the oven at 150 °C until all the water evaporated. The solid remaining was ground into a fine powder.
Thermal properties

- A DSC was used to determine phase change enthalpy and thermal stability/repeatability. The heating and cooling rates used were both 10 °C/min.

![Graph showing thermal properties](image-url)
Thermal stability

The mixture was heated up and cooled down at the same rate 11 times.
## Thermal stability

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Onset melting temperature (°C)</th>
<th>Peak melting temperature (°C)</th>
<th>Enthalpy (Melting) (kJ/kg)</th>
<th>Onset solidification temperature (°C)</th>
<th>Peak solidification temperature (°C)</th>
<th>Enthalpy (Solidification) (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle 1</td>
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<td>235.5</td>
<td>292.8</td>
<td>221.7</td>
<td>214.1</td>
<td>316.3</td>
</tr>
<tr>
<td>Cycle 2</td>
<td>221.9</td>
<td>235.9</td>
<td>302.7</td>
<td>221.7</td>
<td>214.1</td>
<td>319.1</td>
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<td>299.4</td>
<td>222.4</td>
<td>214.3</td>
<td>320.5</td>
</tr>
</tbody>
</table>
Thermal stability

The mixture was also tested in a TGA at a heating rate of 10 °C/min from 50 °C to 250 °C, repeated 5 times. The weight loss in the first cycle is about 10.6% due to desorption of water. The weight loss in the following four cycles was low, between 0.1% to 0.2%. (Not visible on the graph.)
Future work

1. Test the long-term thermal stability of the material.
2. Measure the other properties of the material, such as thermal conductivity, viscosity, and assess corrosion issues.
3. Identify other suitable, reliable and cheap materials for industrial process heat storage applications.
4. Design an experimental test system and analyse the thermal performance of a control system and identify mechanisms for heat transfer enhancement.
Conclusions

Progress is being made in all 3 work packages.
Materials selection and characterisation is ongoing.
Designs for laboratory scale systems are being developed.
Models of phase change systems are being developed.