Loughborough University

$MgSO_4$ + Zeolite based composite thermo-chemical energy stores (TCES) integrated with vacuum flat plate solar thermal collectors (VFPC) for seasonal thermal energy storage

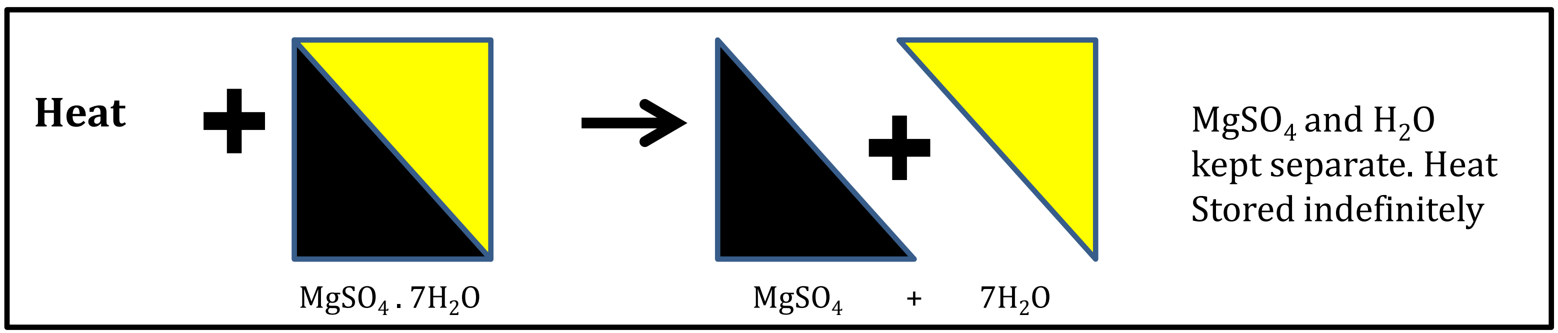
Daniel Mahon, Paul Henshall & Philip Eames

CREST
Loughborough University

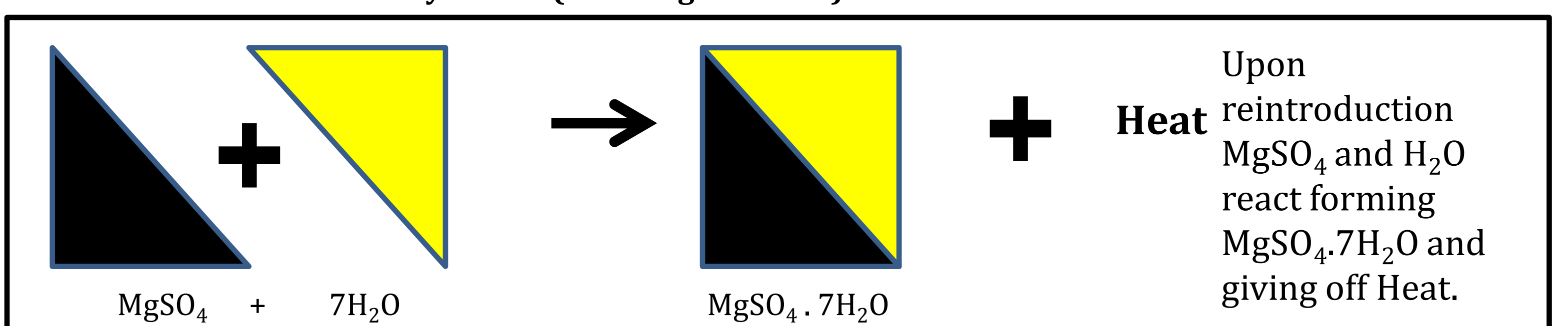
Introduction

- Thermochemical Energy Storage offers a solution for storing heat indefinitely almost loss free.
- $MgSO_4$ is a prime candidate
    - Cost effective (£61/Ton), Widely available, High energy density 2.8GJ/m^3 (778kWh/m^3), Non-Toxic.
    - Problems – Material difficult to work with in powder form, agglomeration occurs reducing cycle stability, permeability and power output.

Dehydration (Charging Process)

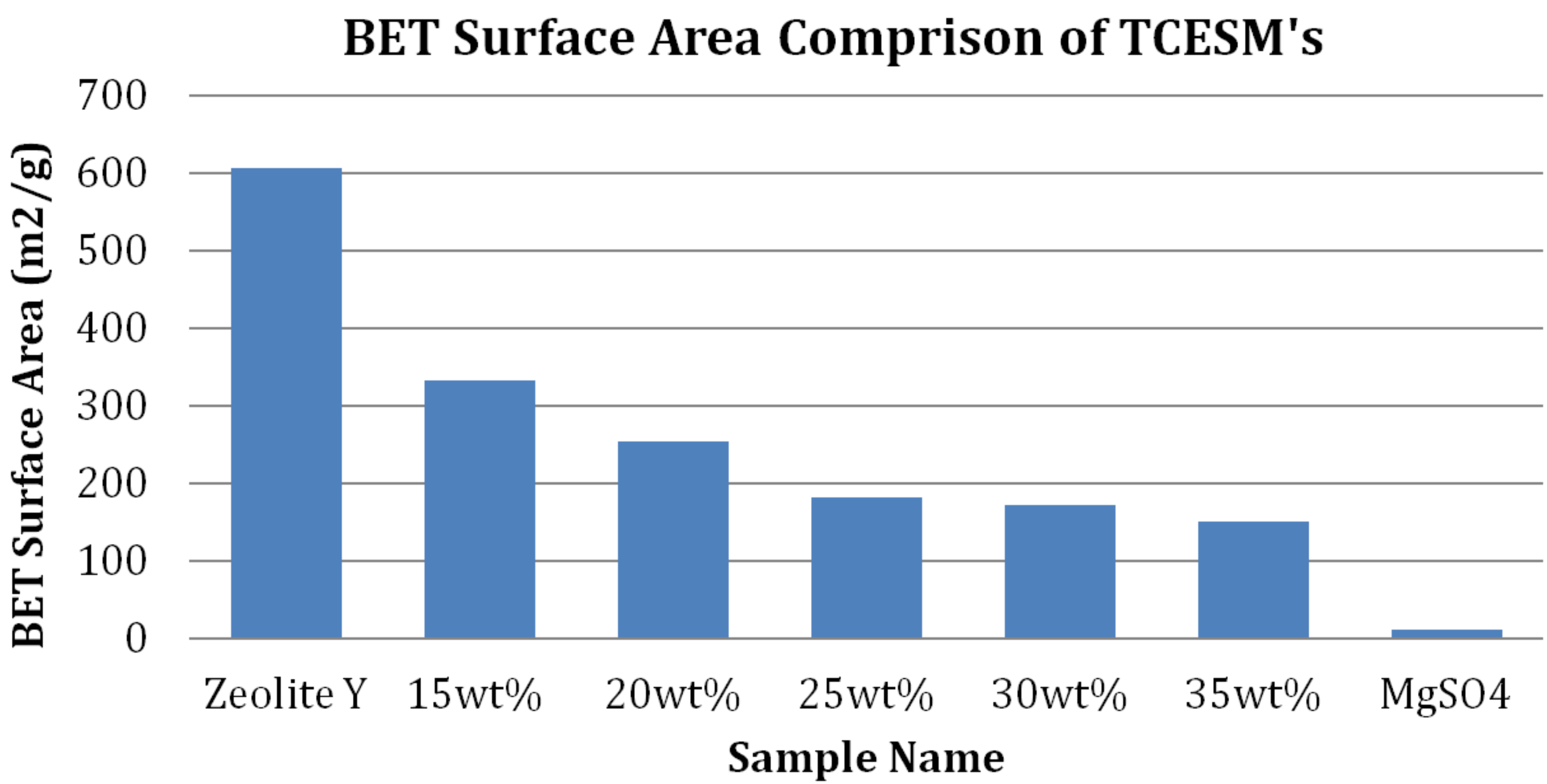


Re-hydration(Discharge Process)



Creation of Zeolite + $MgSO_4$ Composites

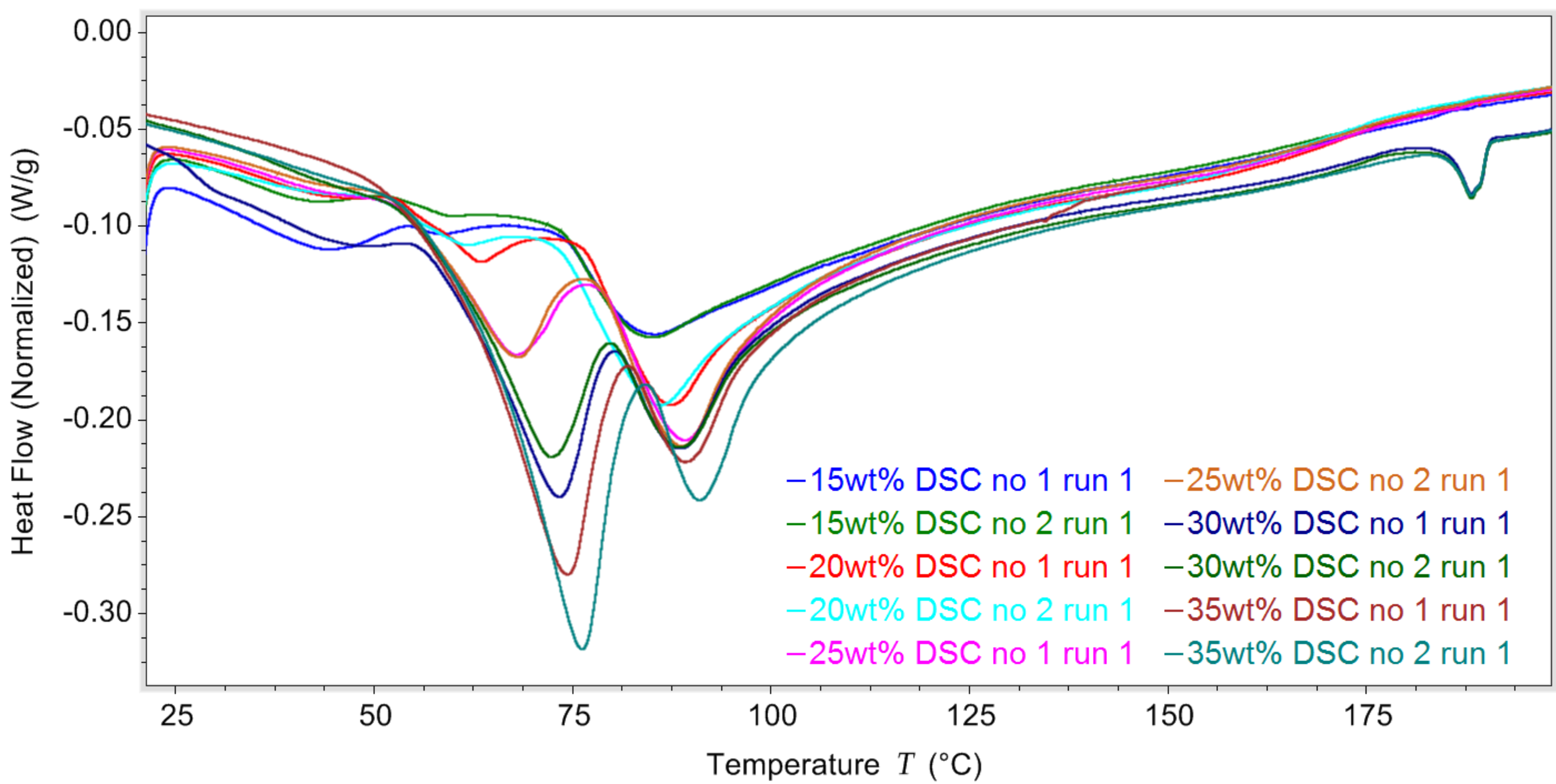
- In order to alleviate $MgSO_4$ issues a composite material is created using Zeolite
- Zeolite – Can be used as a sorption heat store
    - Typically highly porous, high surface area and very absorbent
    - Around 750J/g energy density.
- Higher surface are = larger reaction area = should result in higher power output



Loughborough University

Creation of Zeolite + $MgSO_4$ Composites

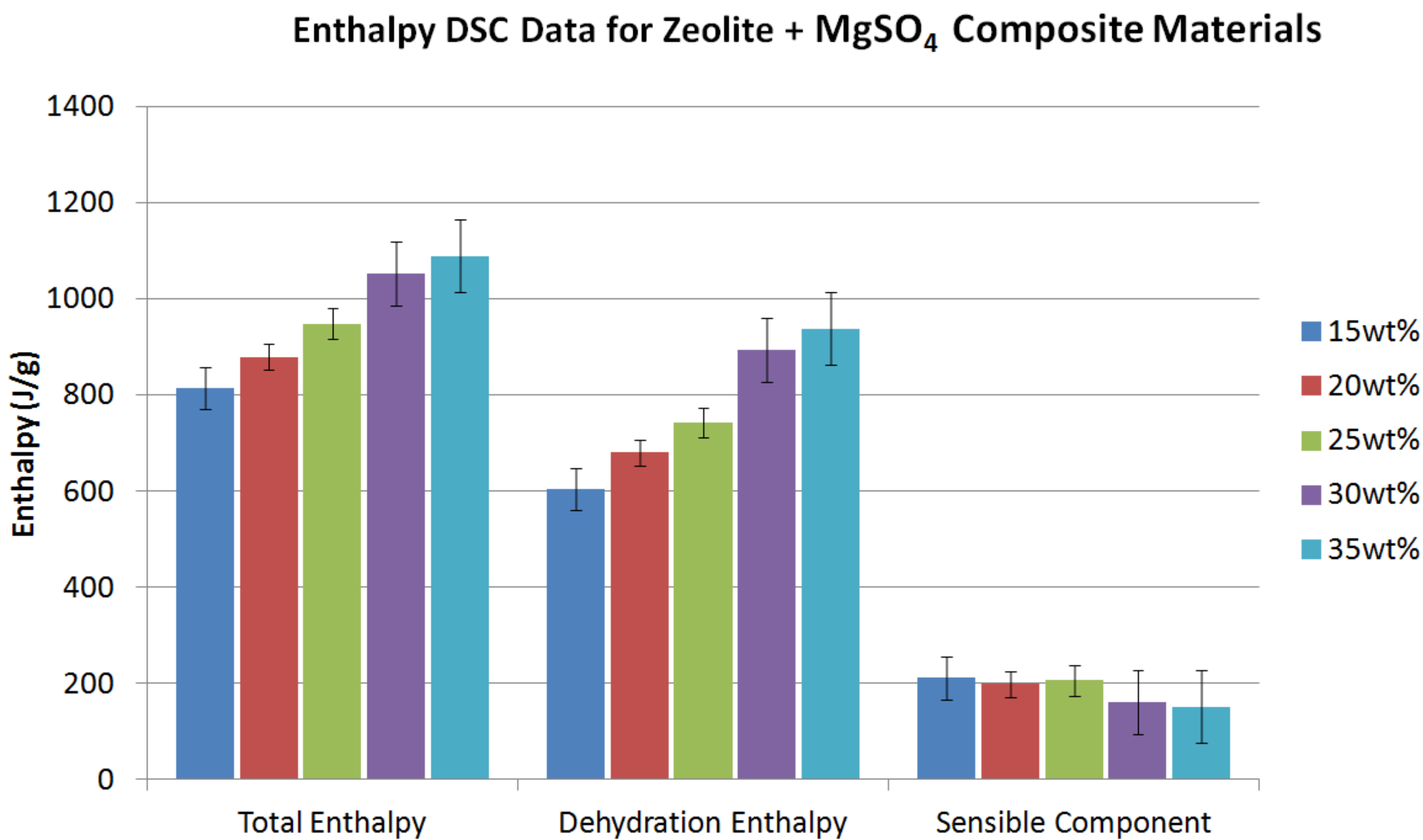
- Composite materials do not suffer from agglomeration after hydration.
- Graph shows DSC dehydration of composite materials (hydrated at 56%RH & 20˚C)
- Majority of endothermic heat flow below 150˚C = Ideal for VFPC



Loughborough University

Composites Enthalpy

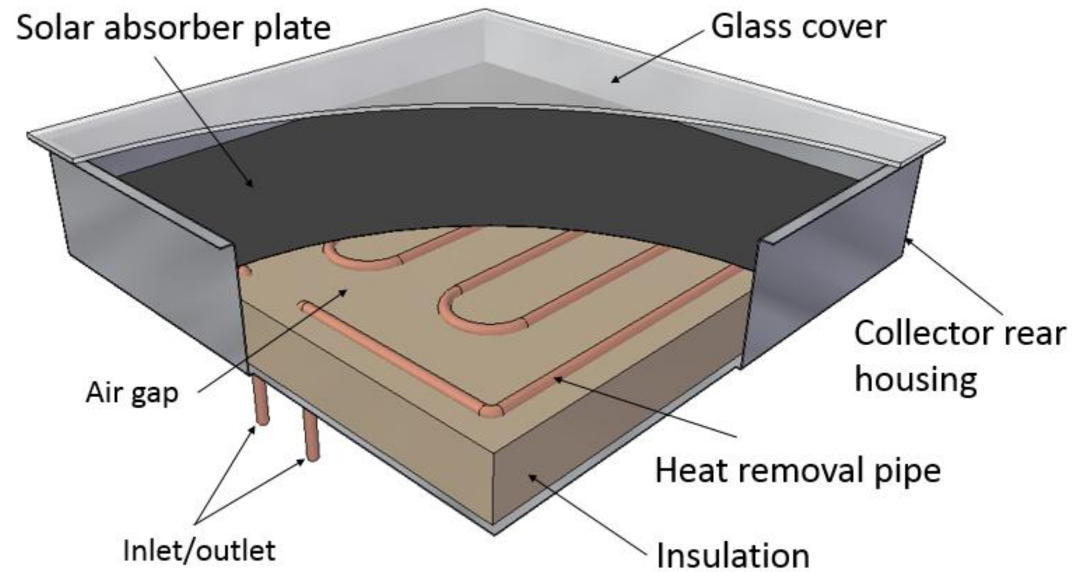
- 35wt% composite has a dehydration enthalpy, taking sensible losses into account, of ~950J/g using only 56% RH at 20 °C
- Increasing wt% results in decreasing sensible component %. I.e. less wasted energy (~14% for 35wt%)



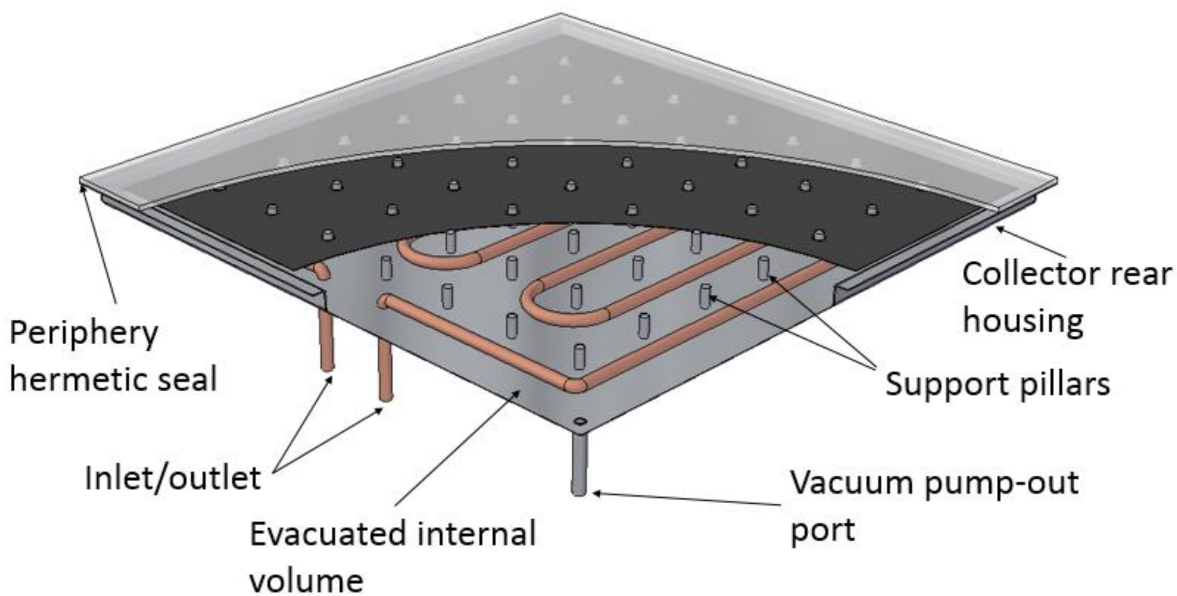
Loughborough University

Vacuum Flat Plate Solar Thermal Collectors

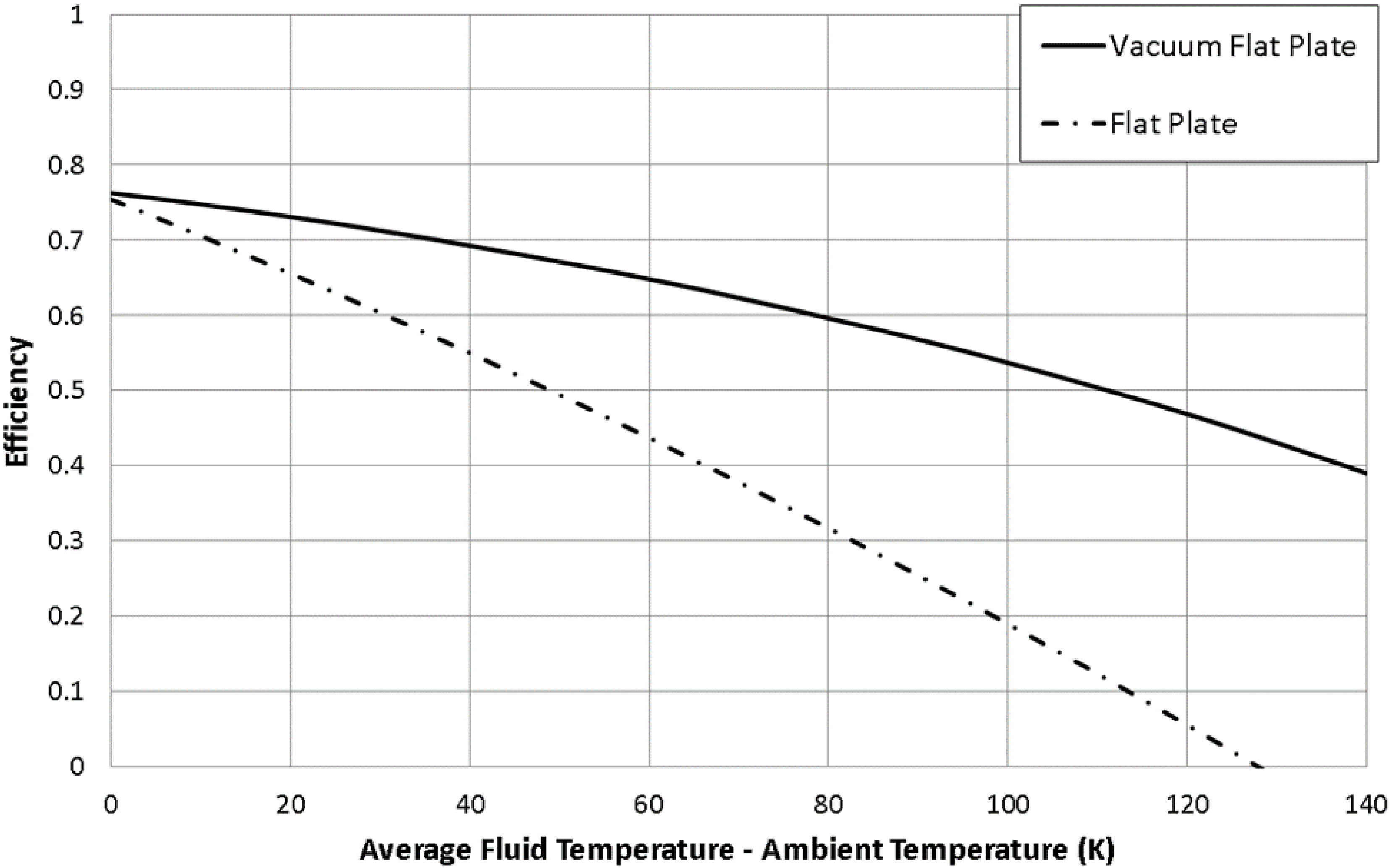
- Conventional flat plate solar thermal collectors



- Vacuum flat plate solar thermal collector.
  - Absorber fills up more of the installed collector area in comparison to evacuated tube solar thermal collectors
  - Vacuum provides greater insulation in comparison to convectional flat plate collectors



Vacuum Flat Plate Solar Thermal Collectors

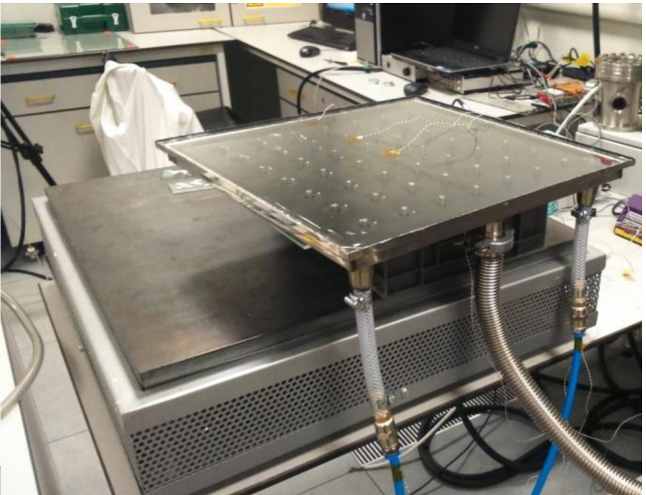


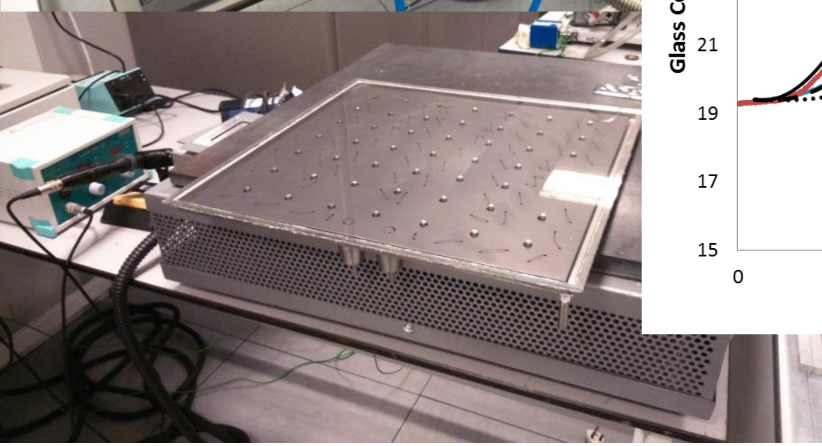
(EN12975-2:2006) (800 W/m^2, Ambient temperature is 20°C)

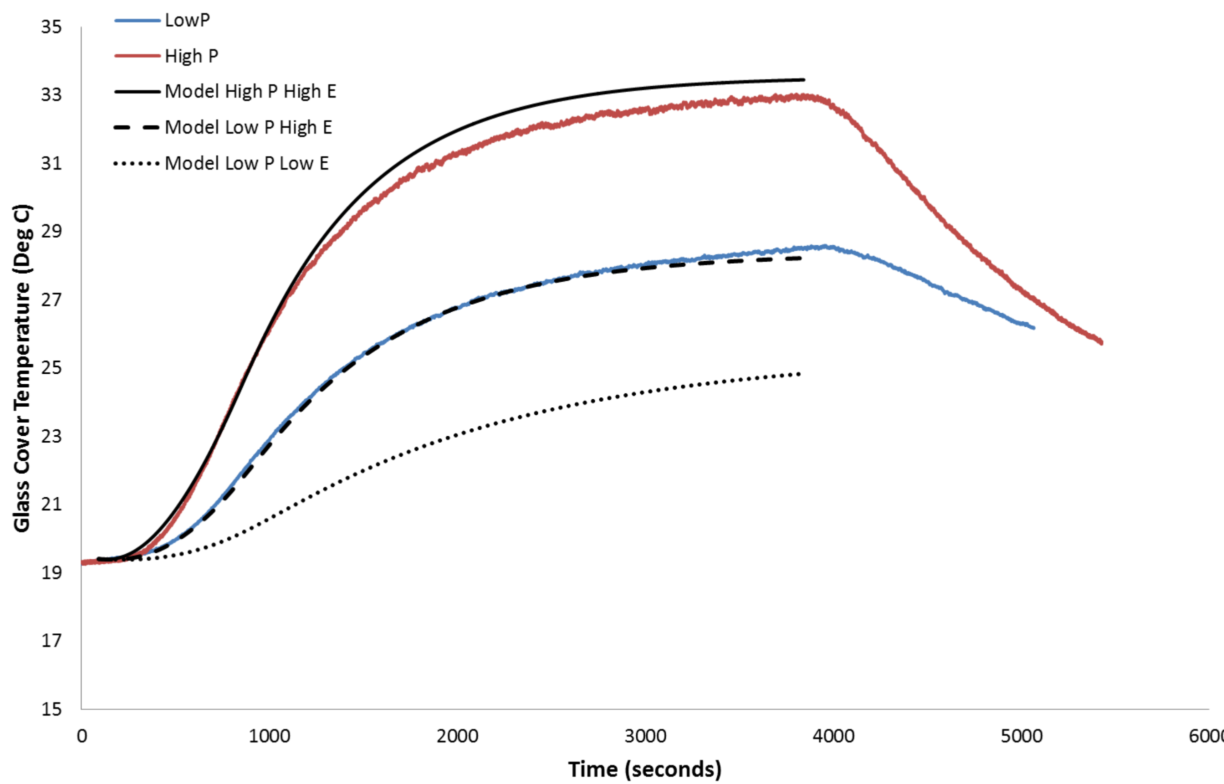
Efficiencies based on aperture area

Loughborough University

Vacuum Flat Plate Solar Thermal Collectors







Experimental testing has verified level of insulation attainable

Vacuum flat plate solar thermal collectors can operate efficiently at temperatures (100°C - 150°C) compatible with the dehydration of $MgSO_4$

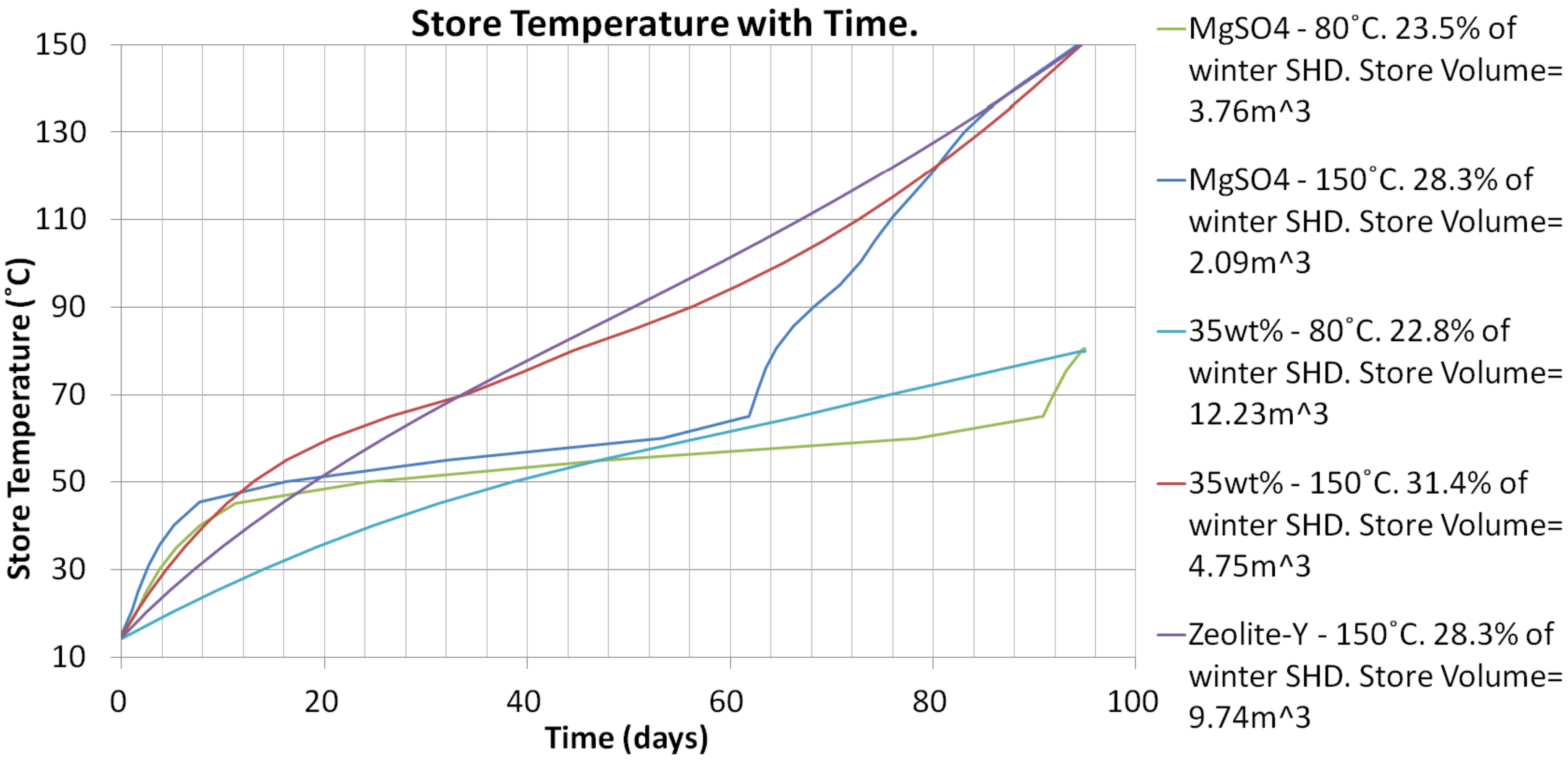
Loughborough University

Feasibility Study

- Feasibility of VFPC+TCES system calculated.
- Solar irradiance + ambient temperature calculated using CREST Integrated Electrical and Thermal Energy Demand model - Data generated stochastically
- All systems modelled with $8m^2$ of VFPC
- Energy density (J/g) and *effective* heat capacity calculated from DSC tests.
- Main Assumptions:
  - 3 months (summer) charge time.
  - Remaining 9 months the VFPC solar gains are utilised.
  - Inflation and £/kWh rise calculated from historic data.
  - TCES only used throughout winter months.

Feasibility Study

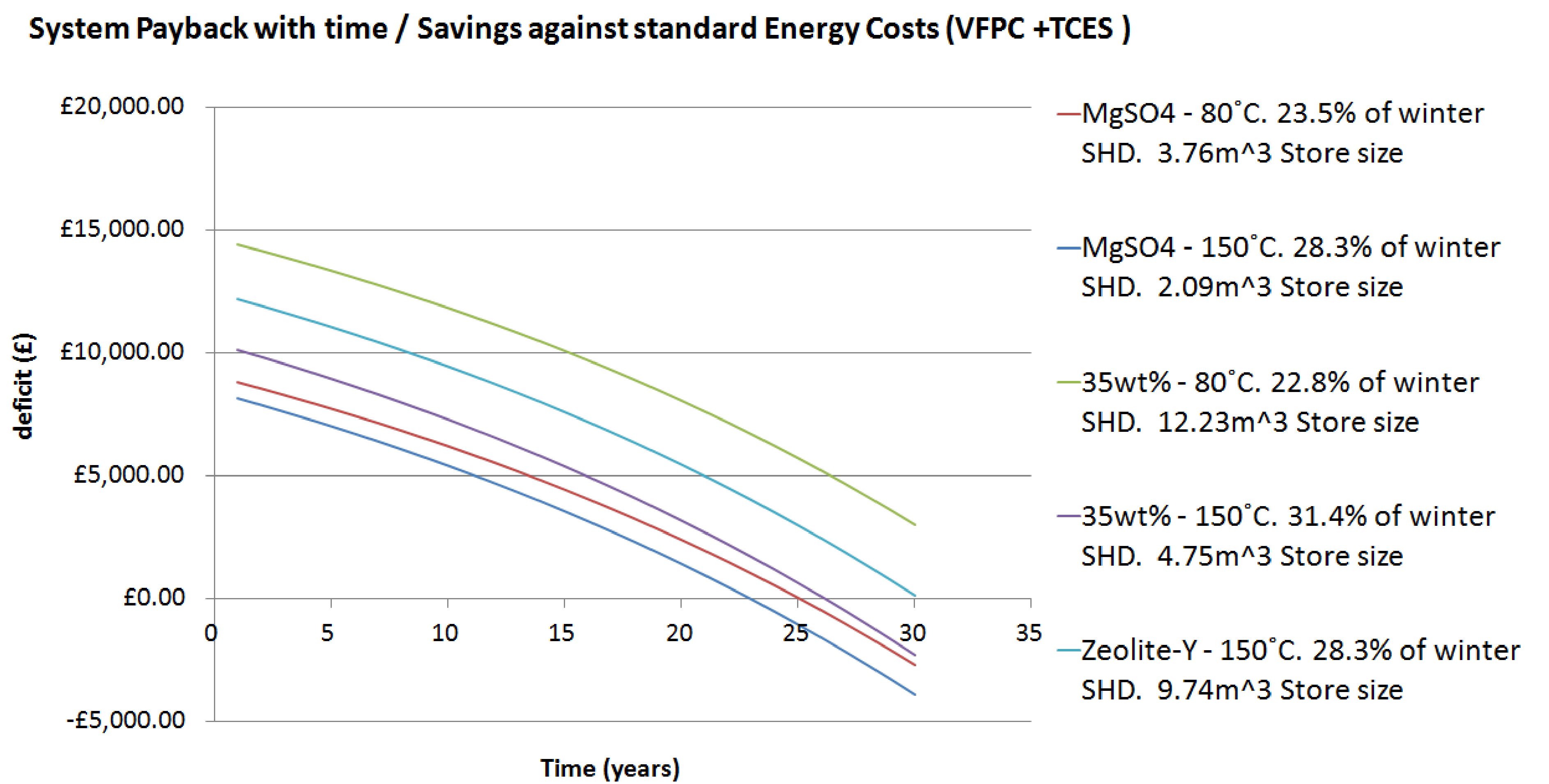
- $MgSO_4$ and 35wt% composite dehydrated to 150 ˚C – able to store ~30% of winter space heating demand.
- Store size of $MgSO_4$ and 35wt% composite = 2.09 and 4.75m^3 , respectively.



Loughborough University

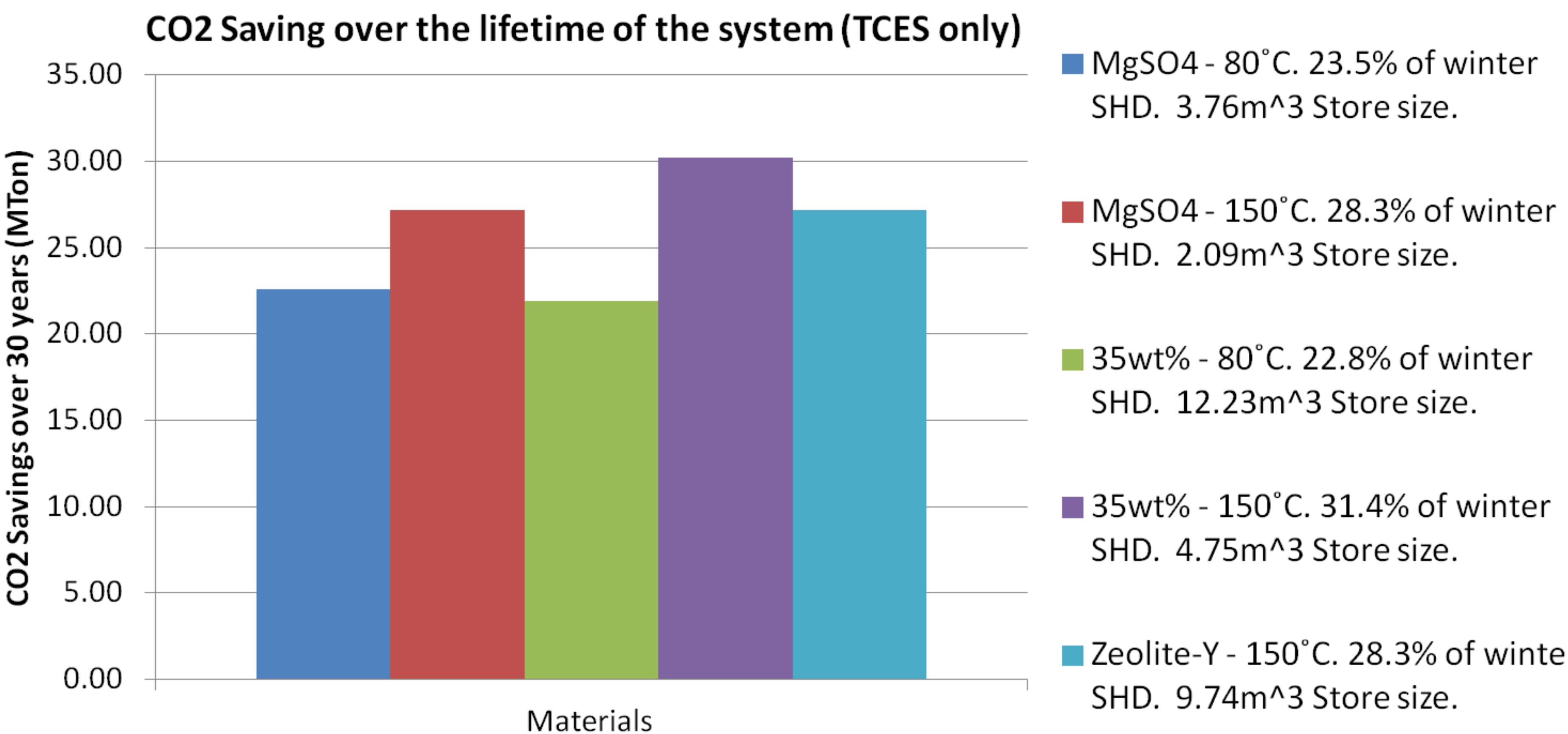
System Payback

- Graph shows the system payback with time.
- $MgSO_4$ dehydrated to 80˚C and 150˚C as well as 35wt% dehydrated to 150˚C are viable.



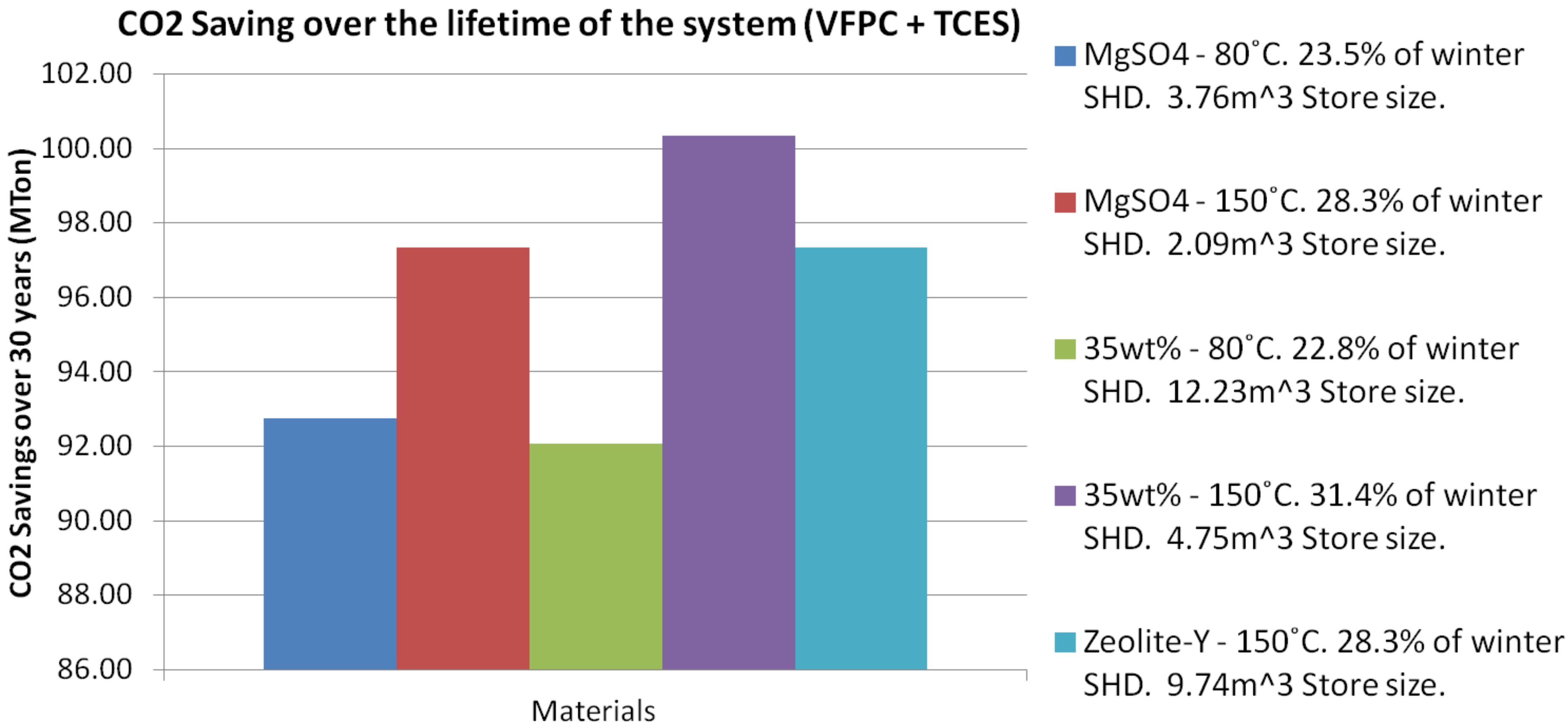
UK CO_2 Savings

- Graph shows the amount of CO_2 saved, in the UK, using each of the different systems over a 30 year lifetime.
- It assumes the systems are completely 0 carbon and 10% of all UK households have a system.



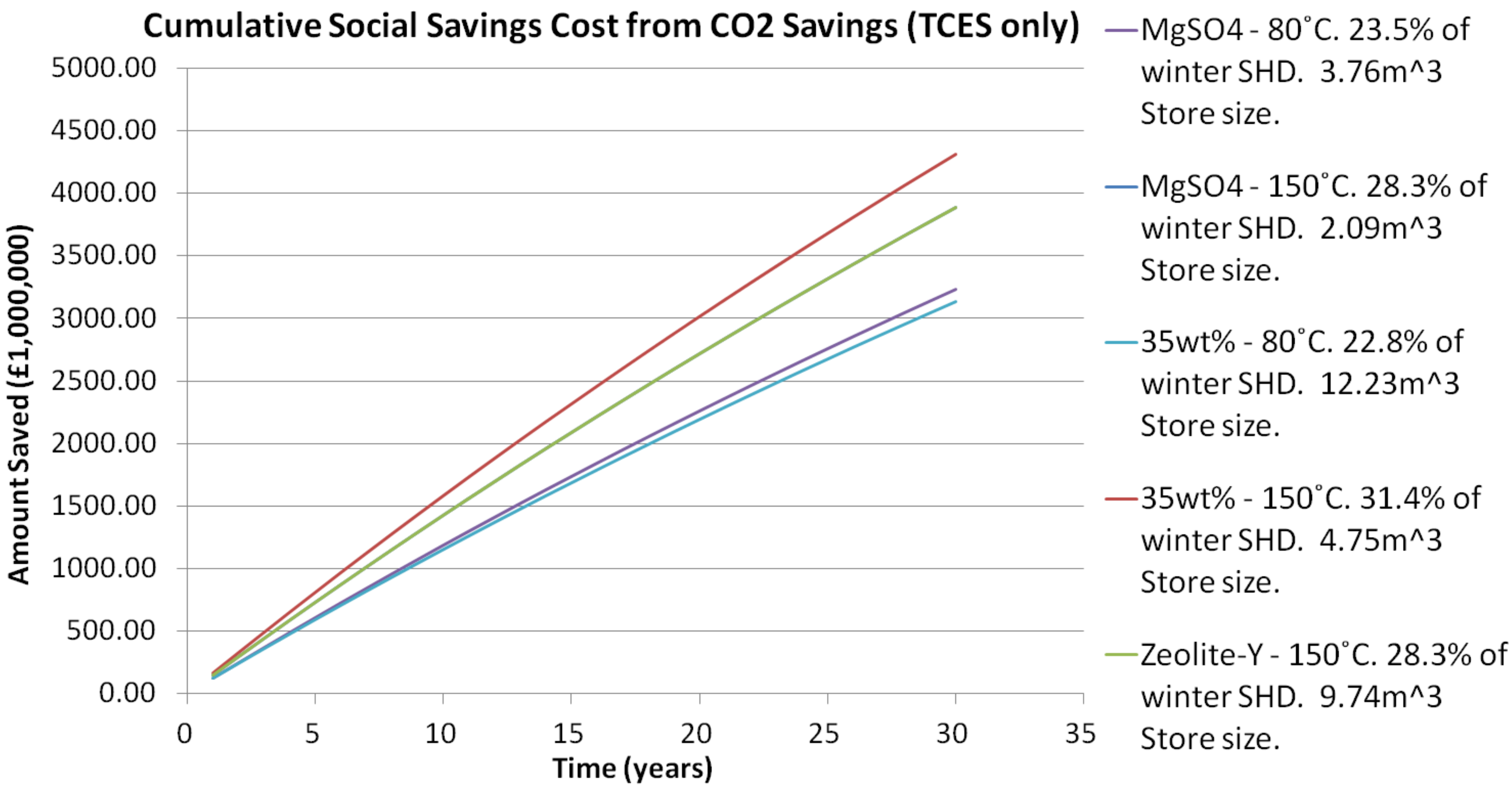
UK CO_2 Savings

- Graph shows the amount of CO_2 saved, in the UK, using each of the different systems over a 30 year lifetime.
- It assumes the systems are completely 0 carbon and 10% of all UK households have a system.



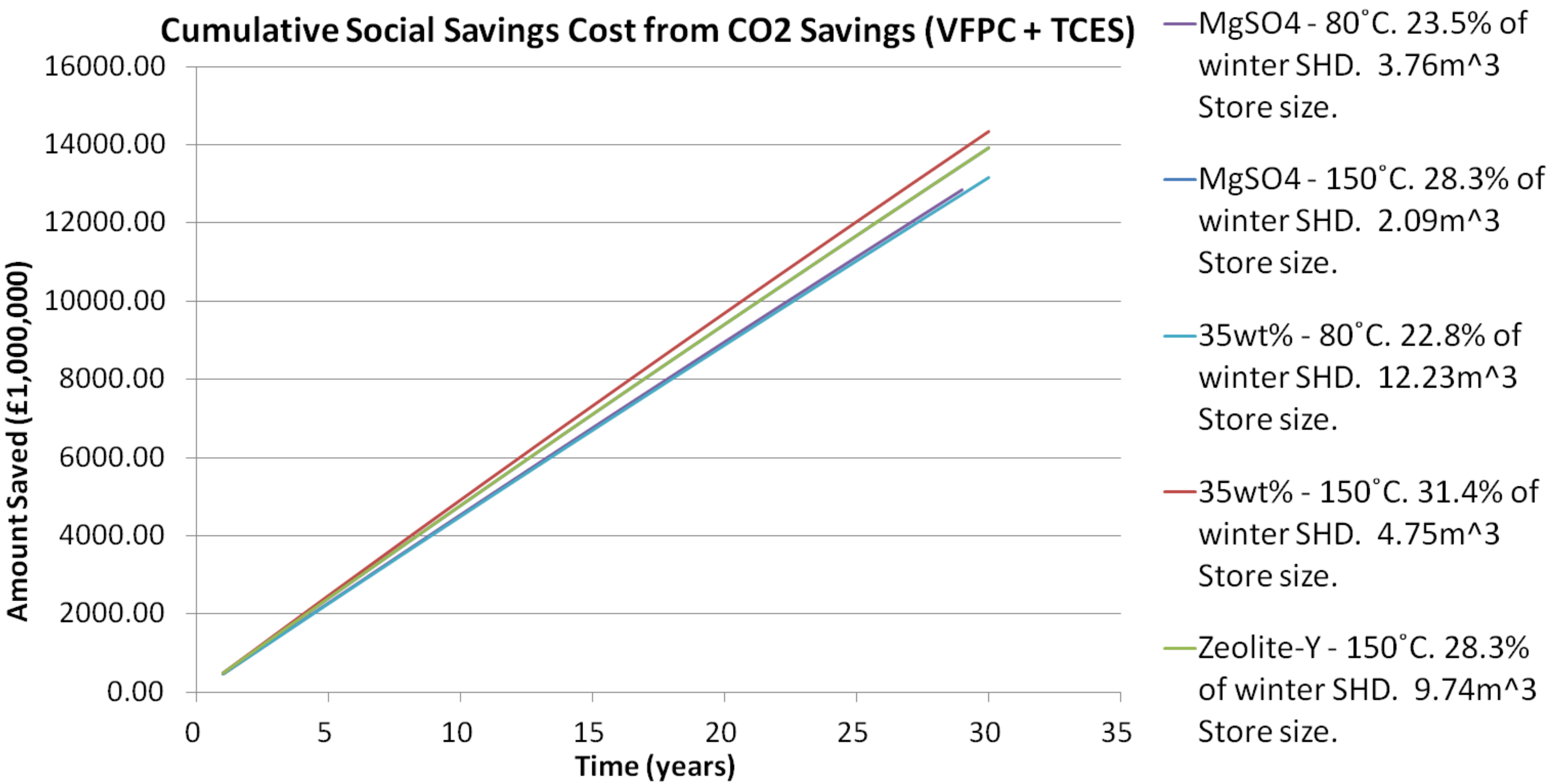
Social Savings

- The graph shows the "social savings" from the reduction in the CO_2 emissions.
- Assuming the systems are completely carbon free and 10% of all UK households have a system.
- ~£4 250 million savings over 30 years



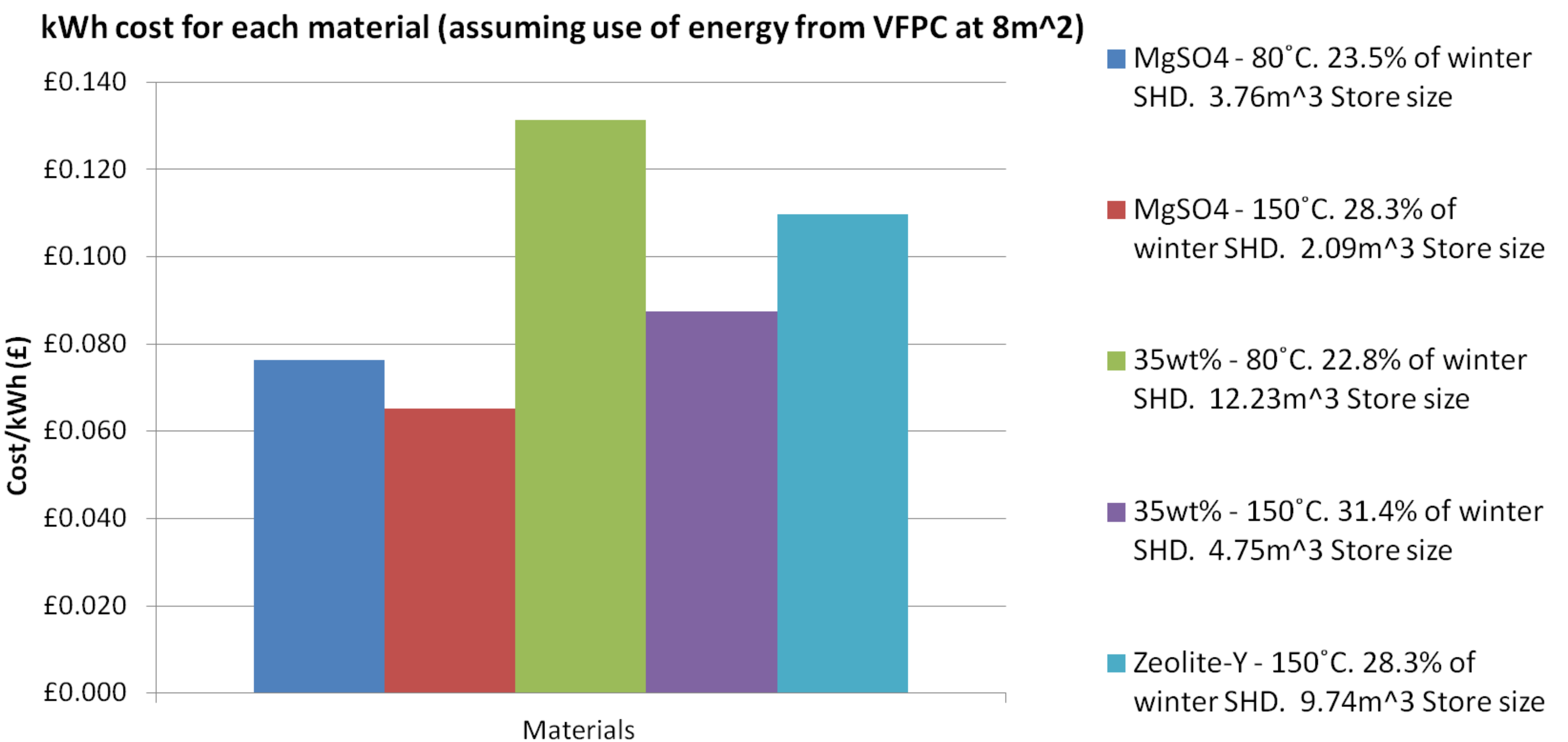
Social Savings

- The graph shows the "social savings" from the reduction in the CO_2 emissions.
- Assuming the systems are completely carbon free and 10% of all UK households have a system.
- ~£14 000 million savings over 30 years

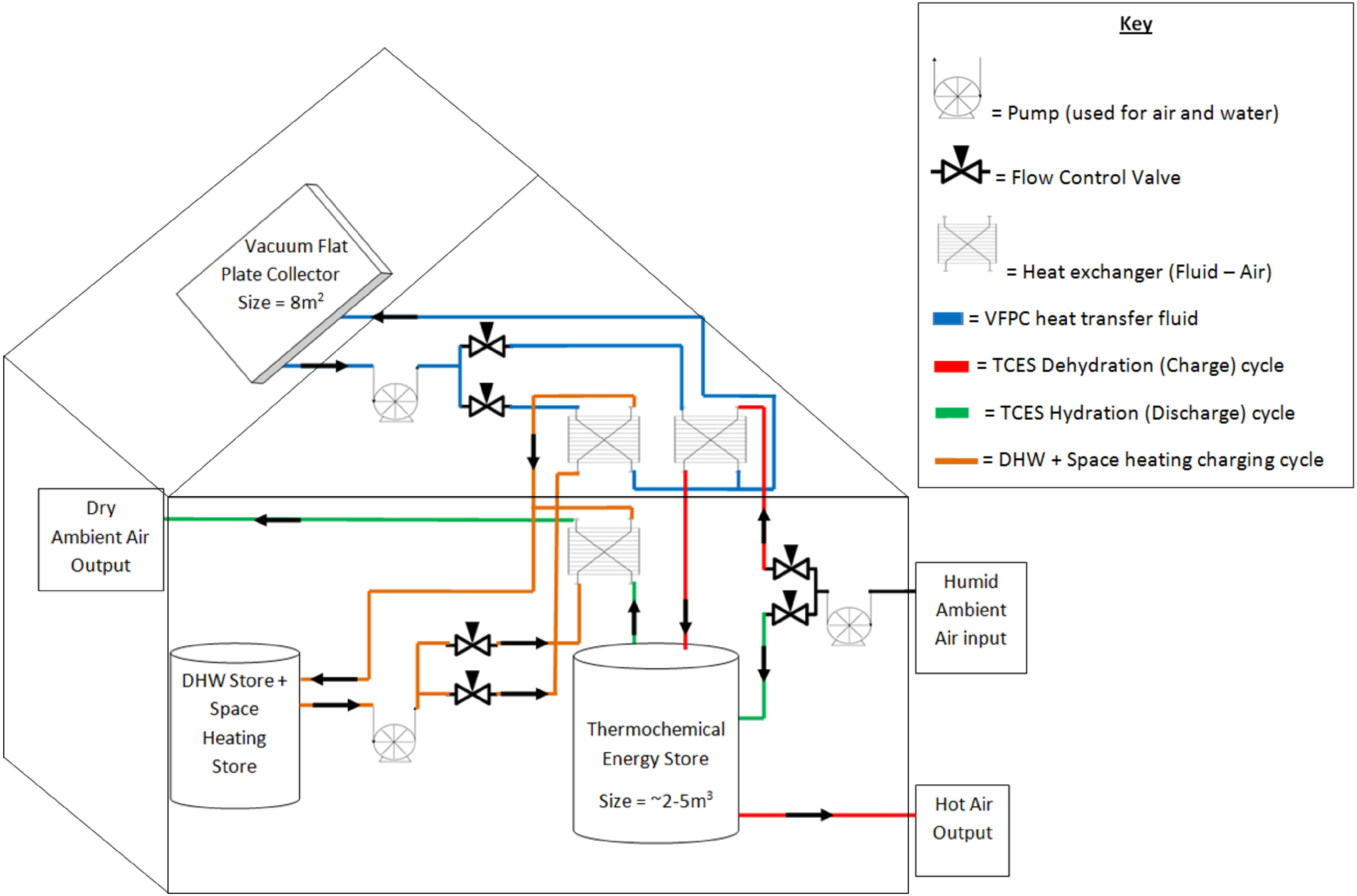


Cost/kWh

- Graph shows the Cost/kWh of energy produced from the VFPC+TCES systems.
- 14p/kWh = current electricity cost
- 5p/kWh = current average space heating cost
- £/kWh will only increase over time from traditional source's



Integration of VFPC+TCES



Loughborough University

Conclusion

- Huge potential for a VFPC + TCES system along side existing DHW and space heating solutions.
- Potential to dramatically reduce energy consumption from typical (dirty) sources.
- Feasibility study suggests the $MgSO_4$ and 35wt% (dehydrated to 150˚C) pay for themselves after around 25 years of use.
- Potential to make huge social savings for the UK economy (in the order of +£460 million/year)

EPSRC funded project: High Performance Vacuum Flat Plate Solar Thermal Collectors for Hot Water and Process Heat (EP/K009915/1)

This Research is funded by: i-STUTE EPSRC Engineering and Physical Sciences Research Council