UNIVERSITY OF BIRMINGHAM

SOWHAT

Kinetic modelling of thermochemical energy storage reactions for storage of solar heat and waste heat

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Outline and Objectives

- Specific Challenge Introduce H2020 project: Supporting new opportunities for waste heat and cold valorisation toward EU decarbonisation

- Address the role waste heat recovery and thermal/thermochemical energy storage within the context of WH/C valorisation strategies

- Present selection strategy for best integration of thermal/thermochemical storage strategy to support WH/C valorisation

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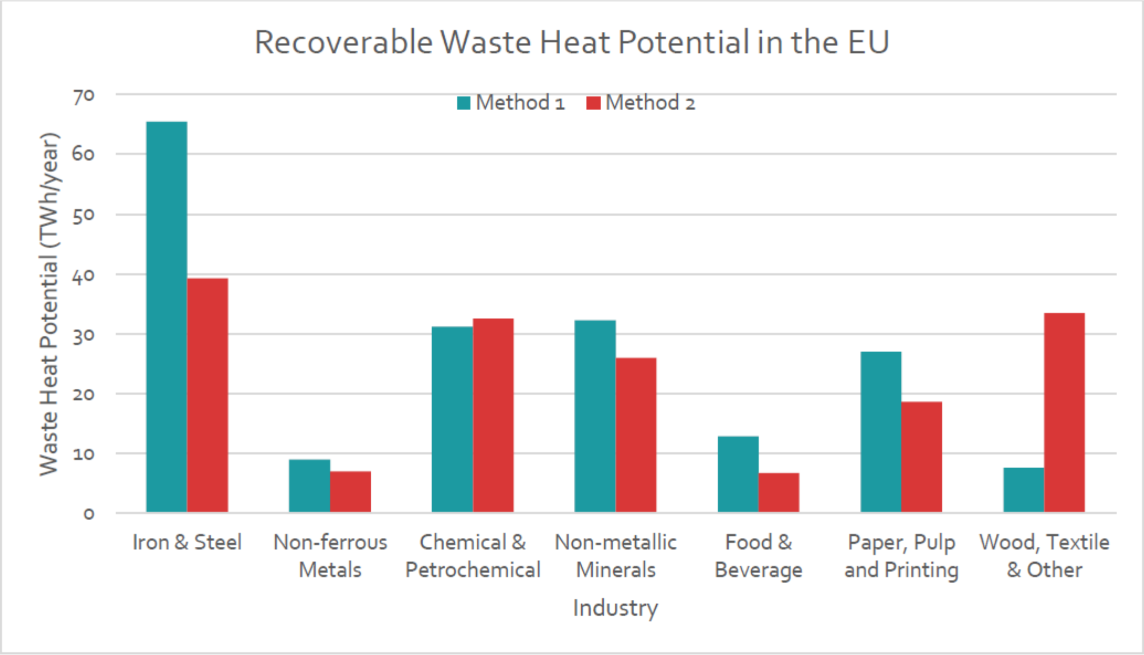
The Challenge

Current studies on the quantification of available industrial waste heat volumes showed that, in the EU, the amount of heat wasted by industries in the form of hot water or flue gases would be sufficient to cover a significant portion of EU's heating needs



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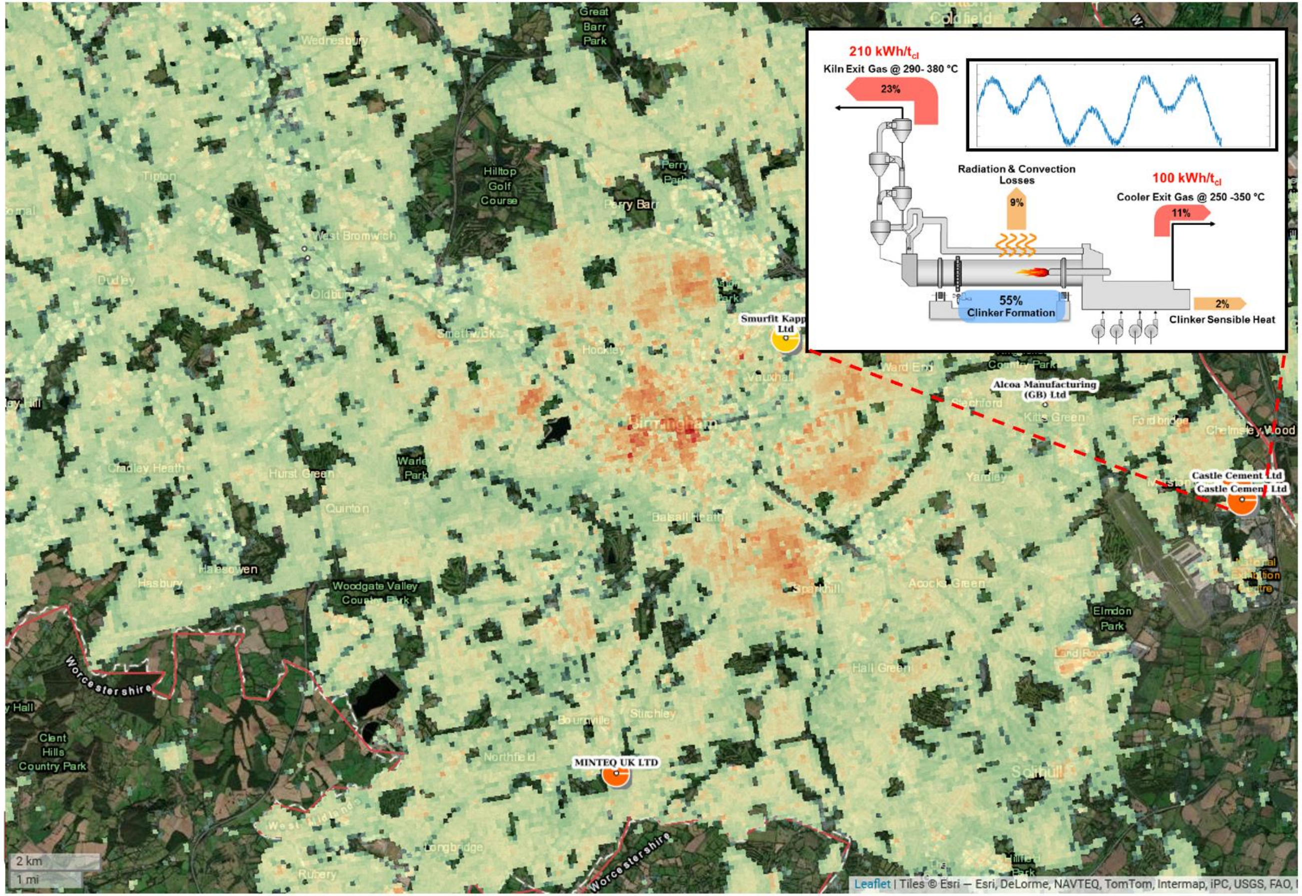
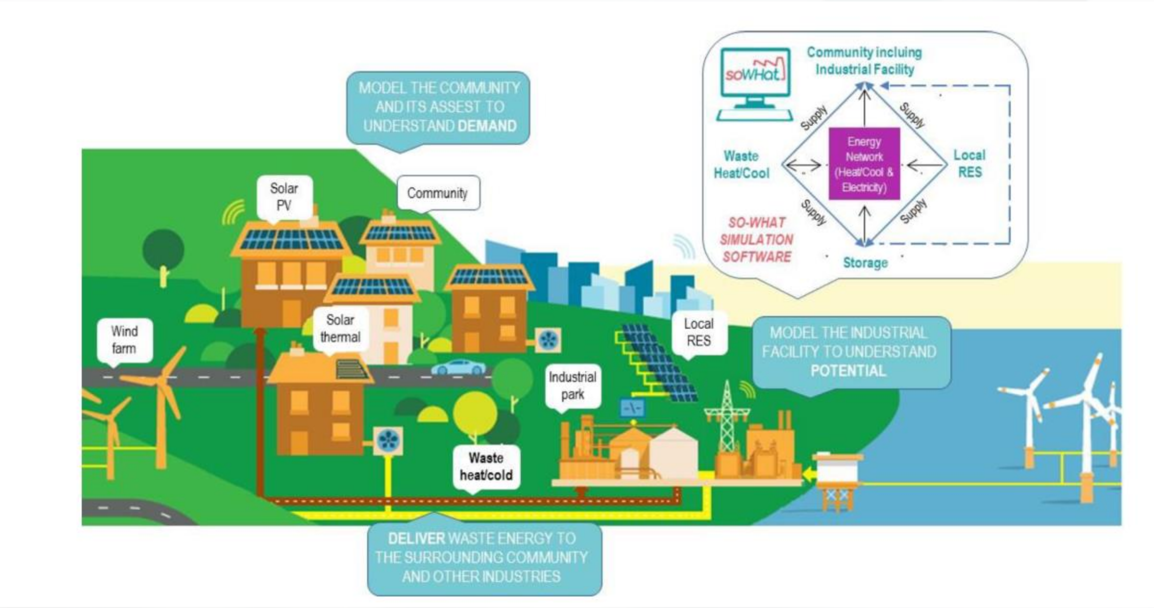
From Monitoring-to-Design-to-Technologies-to-Maintenance aspects

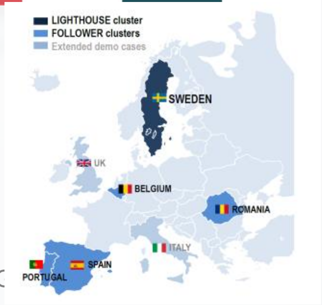


Supporting new Opportunities for Waste Heat And cold valorisation Towards EU decarbonization

- Develop and validate, through different sector and countries real industrial test cases, an **integrated software for auditing industrial process, planning and simulation of waste heat and cold (WH/C) valorisation systems towards the identification of economically viable scenarios** where WH/C and renewable energy sources (RES) cooperate to match local demand



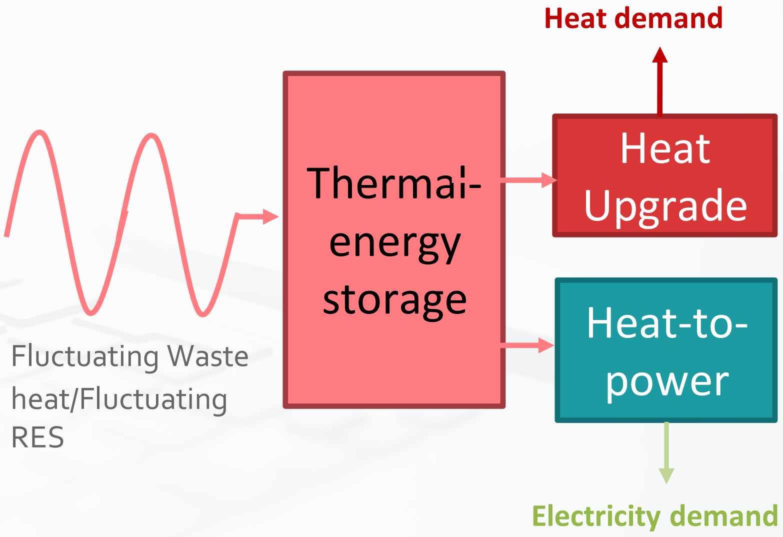
Consortium



Role of WH/C and TES technologies in SO-WHAT Project

Barriers SO-WHAT aims to overcome:

- **Uncertainties prevents investors to go ahead to realization of these WH/C investments** – a dedicated framework (technical, economic and environmental) tailored to assess and reduce such uncertaintie
- **Deployment of WH/C solutions is a complex process involving a number of actors along the value chain**: industrial facilities (owner of WH/C), investors, heating provides, DH managers, tech providers, energy-companies and end users
- **Perception of technological reliability of the solutions needs to be improved, especially with reference to the WH/C capture systems with the aim of increasing the overall efficiency and the operating time system, also thanks to the Thermal Energy Storage Integration**



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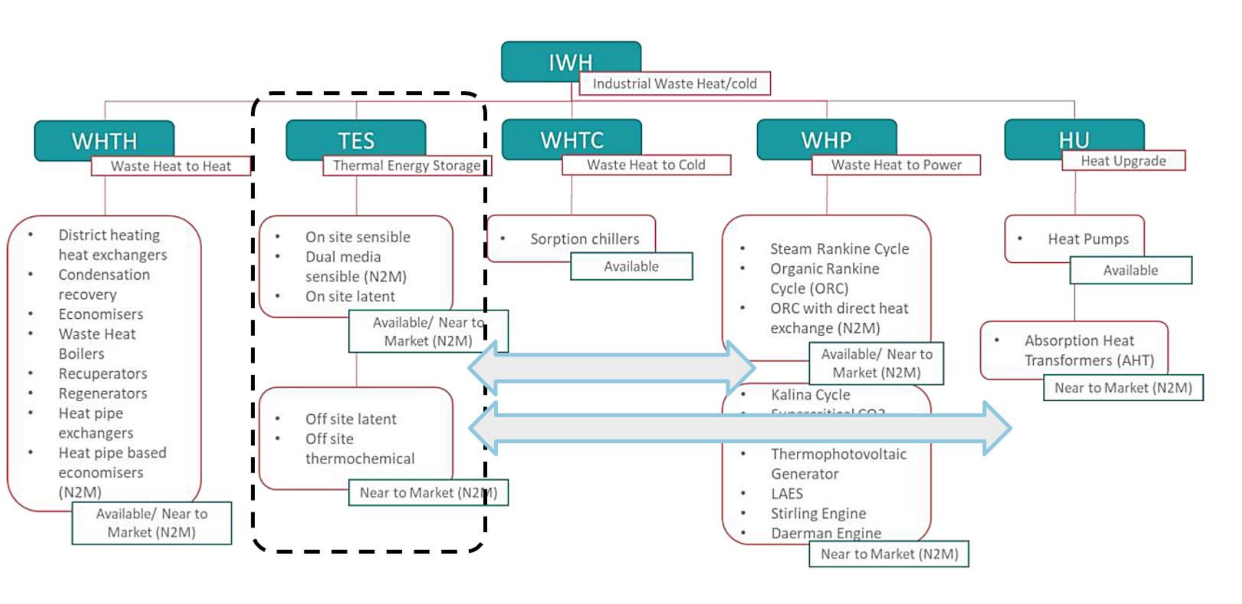

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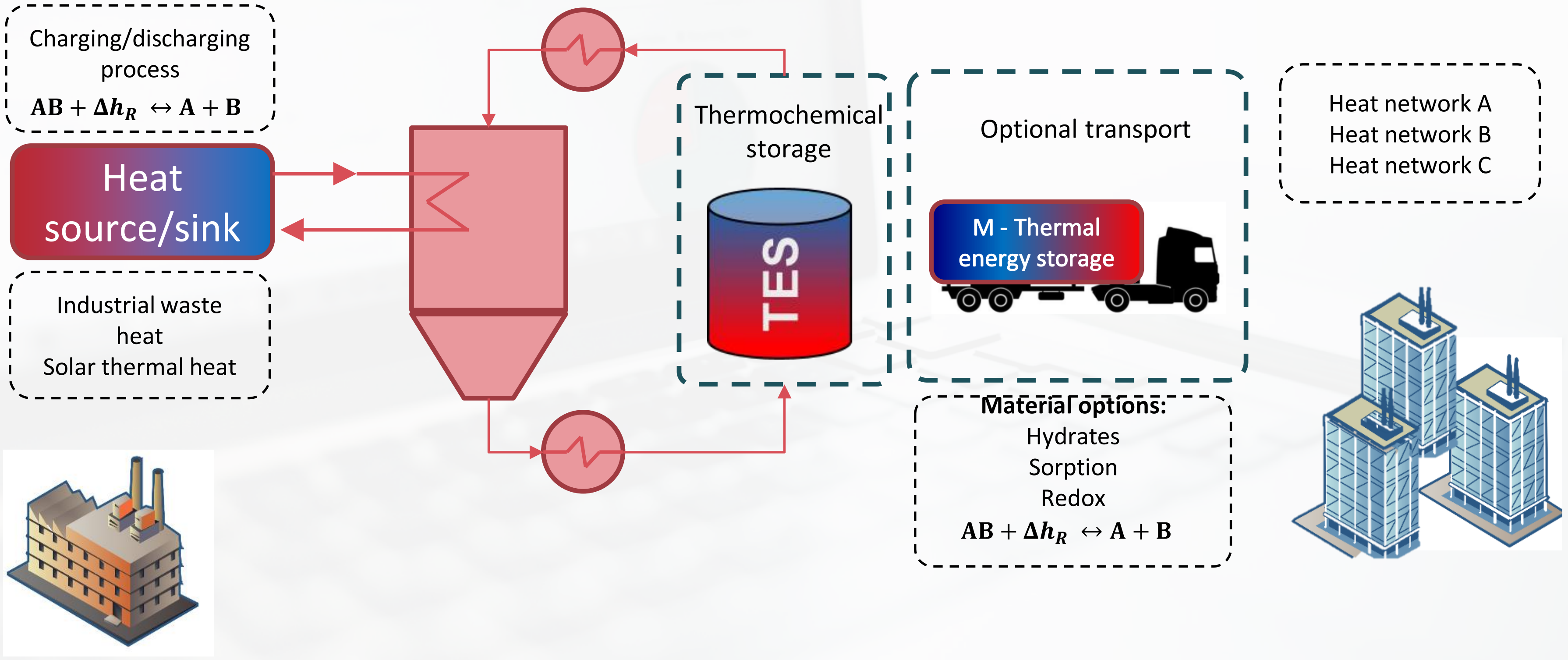
Role of Thermochemical energy storage



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SO-WHAT selection and Integration strategy for TcES

1 - Calculation of heat available from WH/C sources or RES sources

2 - Selection of functional parameters of TES (operational envelop)

3 - Shortlisting TES material options on the basis of MCDA

4 - Techno-economic sizing and costing

5 - Simulated in-operando performance

Experimental data on materials

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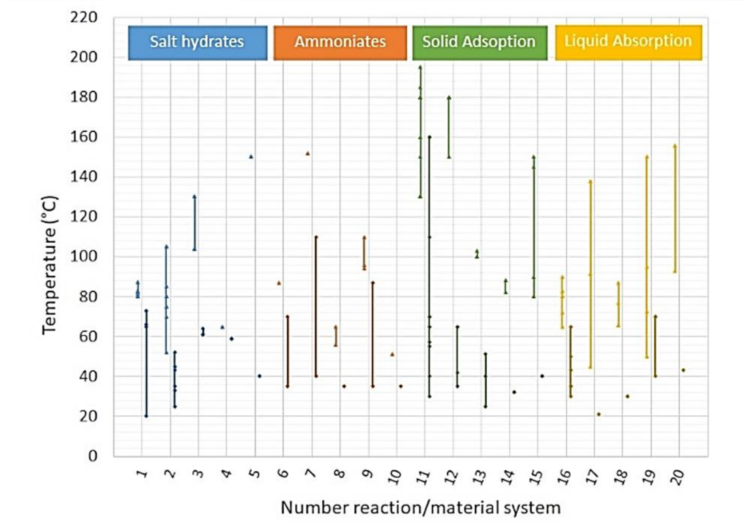
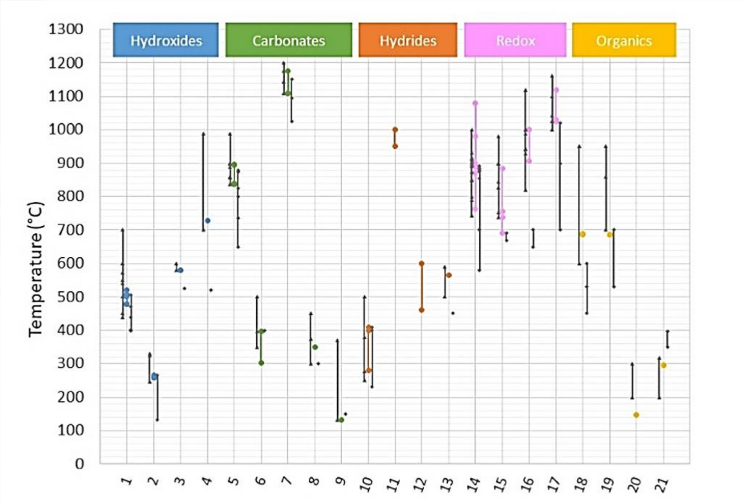
Shortlisting of TcES material options

Systematic screening of TcES options and devices suitable for the WHTP and HU sink/sources at multiple temperatures:

- 50 candidates from 100+ studies
- TRL <5-6 in the vast majority the cases although potentially attractive for WH/C recovery





Charge/discharge temperature of selected TcES: left) Low-temperature; right) Medium-High Temperature

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Shortlisting of TcES material options

- TcES options have been identified by comparing the operating temperature envelope of other WH/C technologies
- Example 1 - Only a few LT TCMs and/or favorable operating conditions can drive a LT-ORC. E.g. discharging temperatures higher than 90°C were reported only for zeolite 13X
- Example 2 - the temperature mismatch between charging and discharging discloses a variety of opportunities for LT TCES integration with VCHP

N.	Chemical reaction / Material	Category	HTP/HU Technology														
			LT-ORC		LT-KC		VCHP		HT/VHT-VCHP		AHP			AHT	
			so	si	so	si	so	si	so	si	so1	so2	si	so	si
1	$Na_2S \cdot 5H_2O \leftrightarrow Na_2S \cdot 0.5H_2O$	SALT HYDRATES													
2	$SrBr_2 \cdot 6H_2O \leftrightarrow SrBr_2 \cdot 1H_2O$														
3	$MgCl_2 \cdot 6H_2O \leftrightarrow MgCl_2 \cdot 2H_2O$														
4	$K_2CO_3 \cdot 1.5H_2O \leftrightarrow K_2CO_3$														
5	$MgSO_4 \cdot 6H_2O \leftrightarrow MgSO_4$														
6	$CaCl_2 \cdot 8NH_3 \leftrightarrow CaCl_2 \cdot 4NH_3$	AMMONIATES													
7	$MnCl_2 \cdot 6NH_3 \leftrightarrow MnCl_2 \cdot 2NH_3$														
8	$BaCl_2 \cdot 8NH_3 \leftrightarrow BaCl_2$														
9	$SrCl_2 \cdot 8NH_3 \leftrightarrow SrCl_2 \cdot NH_3$														
10	$NaBr \cdot 5.25NH_3 \leftrightarrow NaBr$														
11	Zeolite 13X/H_2O	SOLID ADSORPTION													
12	Zeolite 4A/H_2O														
13	Zeolite 5A/H_2O														
14	Microporous silica gel/H_2O														
15	Composite with CaCl2/H_2O														
16	LiBr(solution)/H_2O	LIQUID ABSORPTION													
17	$CaCl_2$(solution)/H_2O														
18	LiCl(solution)/H_2O														
19	NaOH(solution)/H_2O														
20	H_2O/NH_3														

Temperature legend LT TCES (Table 3)

	T<20°C
	20<T<40°C
	40<T<100°C
	100<T<150°C
	150<T<200°C

The diagonal in a cell means that the temperature range extends to two intervals

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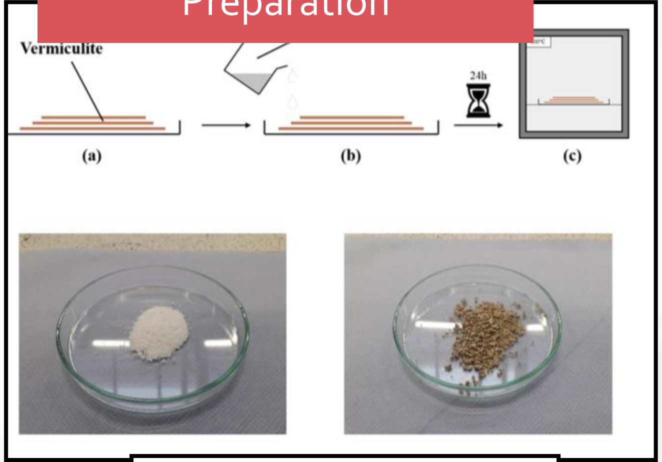
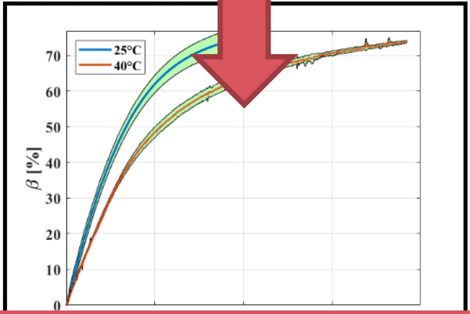
$MgCl_2$ as a case study

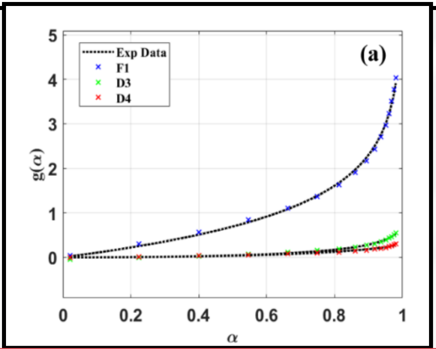
Preparation



Thermo-physical characterization

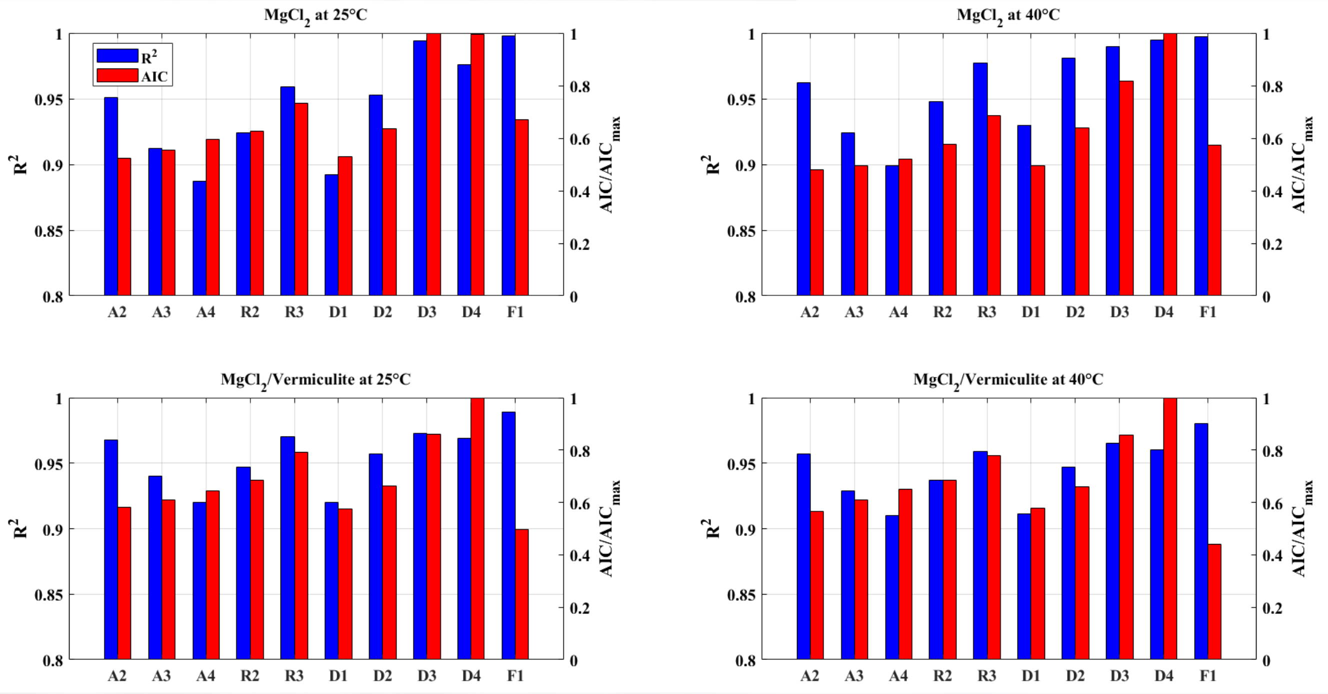


Experimental data



Reconstructed kinetics for assessment

Shortlisting of TcES material options



Quality of reconstructed kinetics measured by statistical indicators

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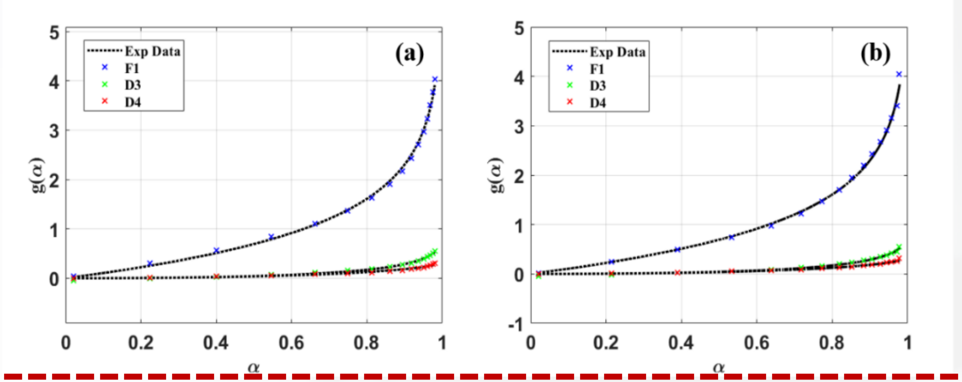
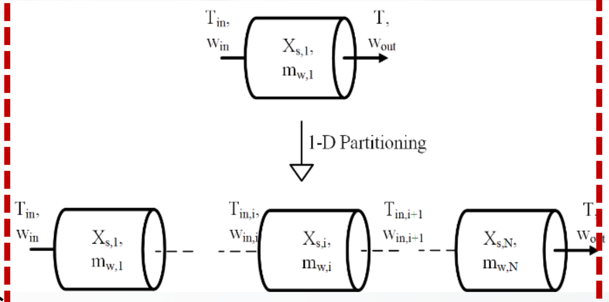
$MgCl_2$ as a case study: kinetics to UXI

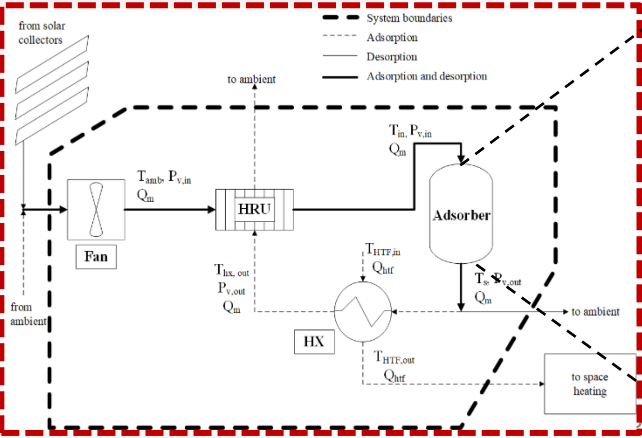


- Reconstructed kinetics for MgCl2 hydration at 25°C and (b) 40°C with best fitting models

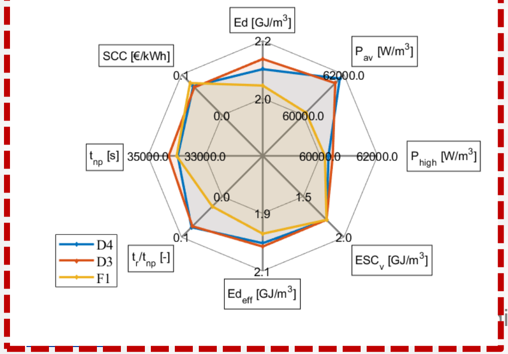
k(T), f(α)

sample scale kinetic parameters into reactor model





UXI for assessment



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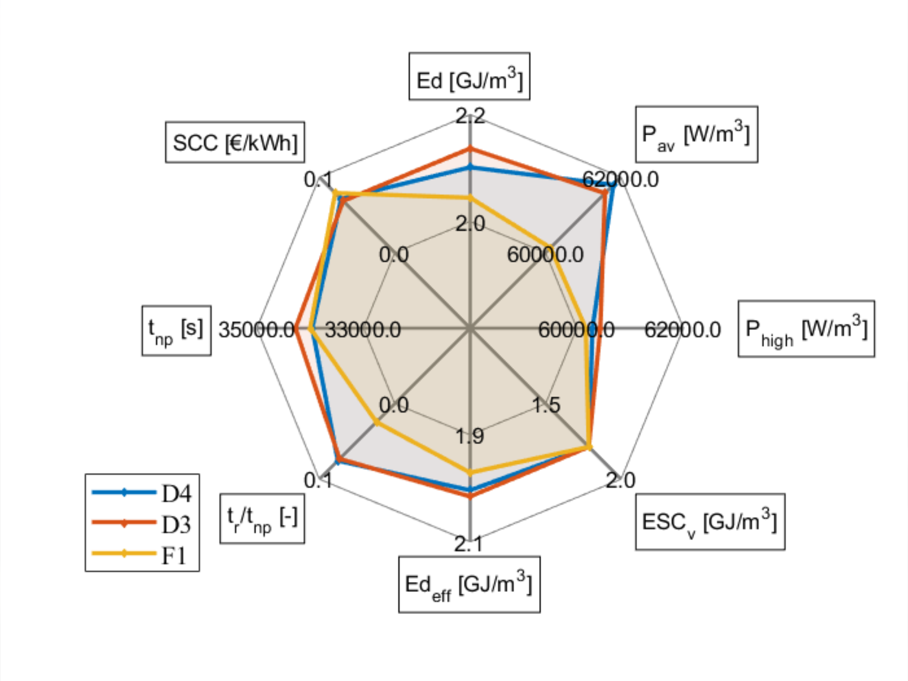
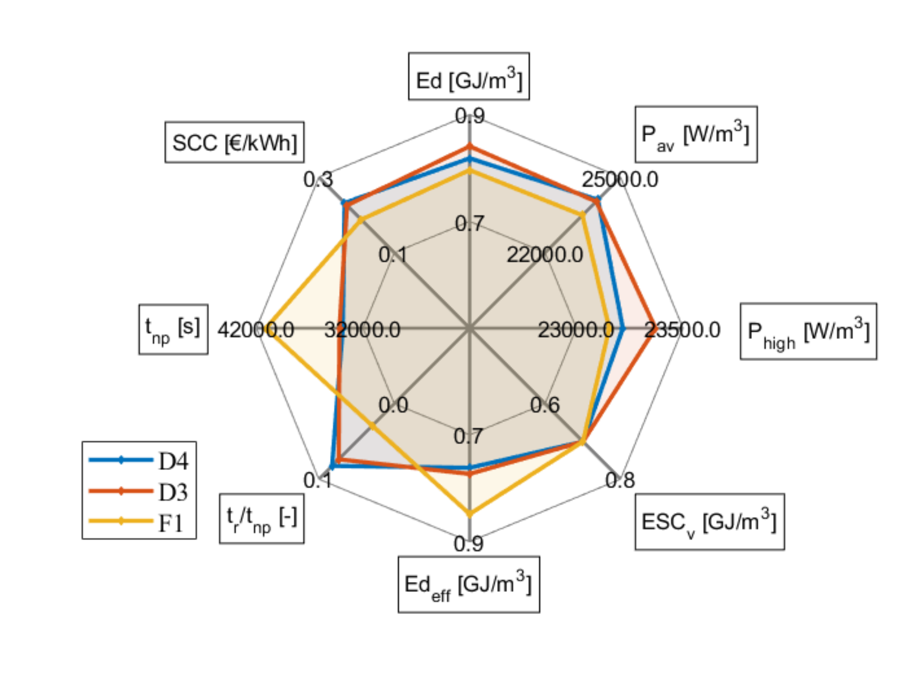
$MgCl_2$ as a case study: Final assessment stage





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Contributions

- A rigorous framework for assessing the role of TcES in storing and valorizing fluctuating heat (solar, waste heat) has been introduced
- A six step procedure to guide the user/stakeholder has been developed to support decision making, including the effect of kinetic behaviour and kinetic models
- Generalization of the procedure has been implemented to cover 50+ TcES materials and devices

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THANK YOU FOR YOUR ATTENTION

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