Decarbonising UK domestic heating: Disruptive approaches
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ENERGY RESEARCH ACCELERATOR

Investigation of Low-temperature Thermochemical Energy Storage for Water Heating in Residential Application

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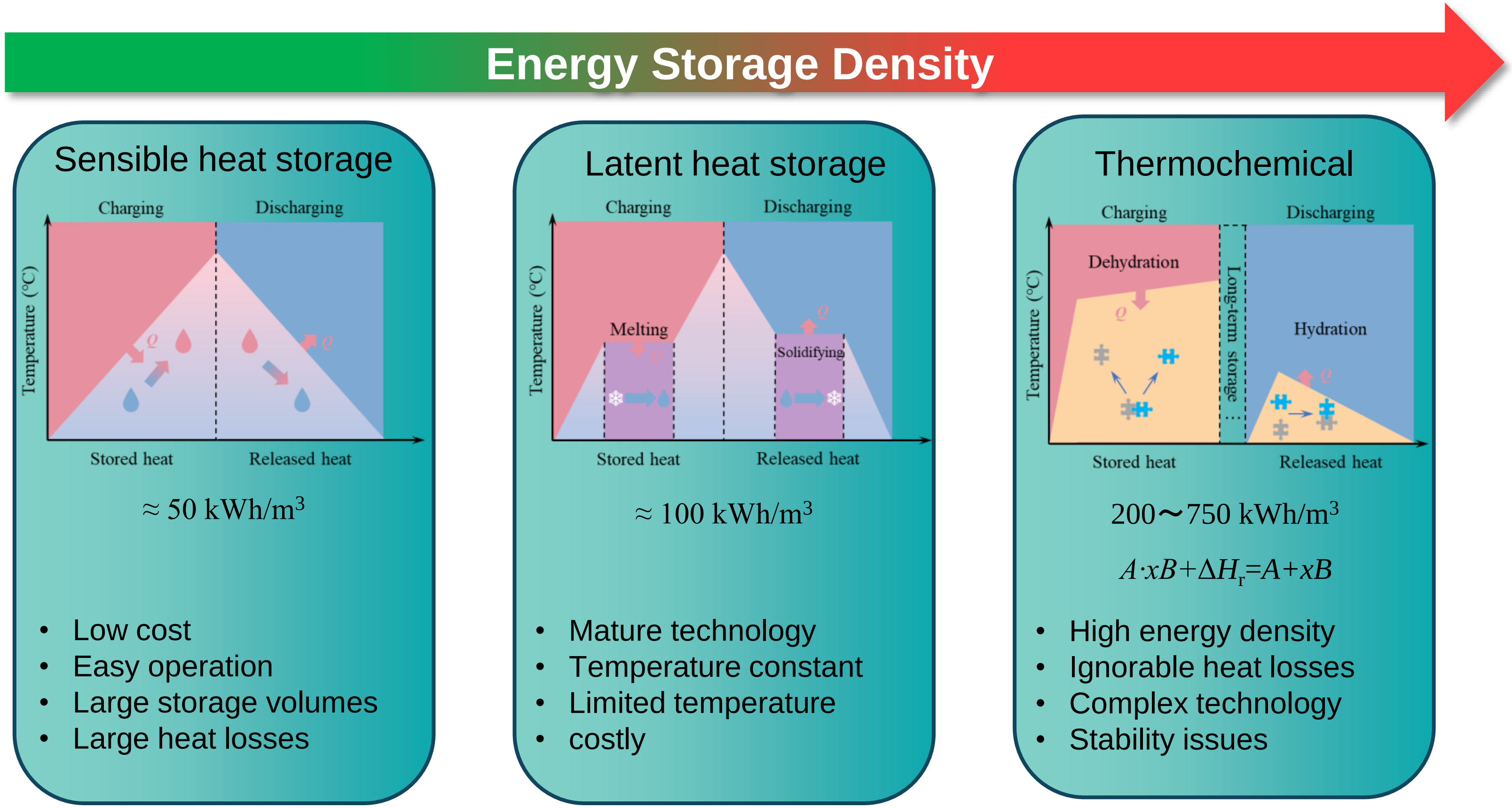
Contents

Solar energy and thermal energy storage

- Thermal energy storage (TES) is considered to solve the problem of supply and demand dismatch.



Comparison the characteristic of three main TES methods.

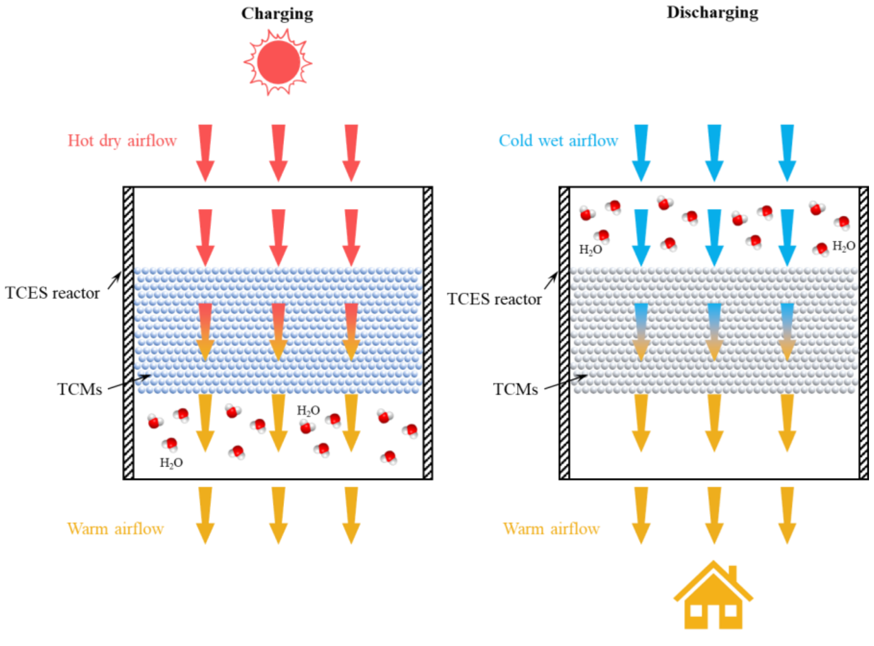
Open system and closed vacuum system

Open system

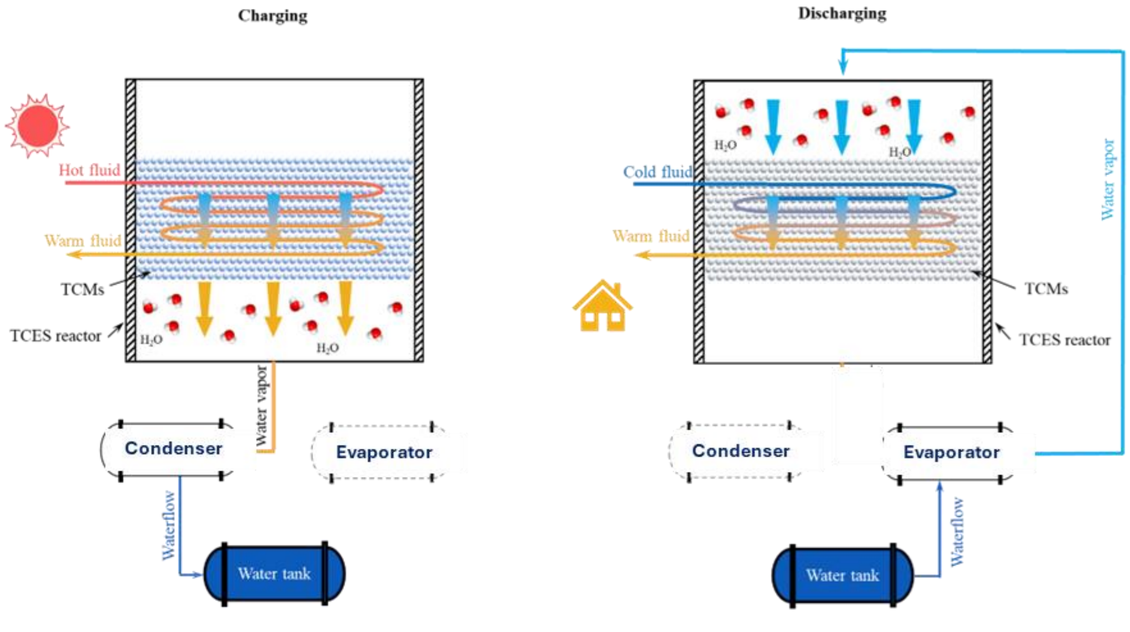
- Simple structure
- Low cost
- Salt hydrate as energy storage media
- Moist air as energy carrier
- Cannot be directly integrated into existing central heating systems

Closed vacuum system

- Can be directly connected to existing central heating systems
- Environmentally friendly
- Complex structure
- Difficulty to maintain vacuum
- High cost



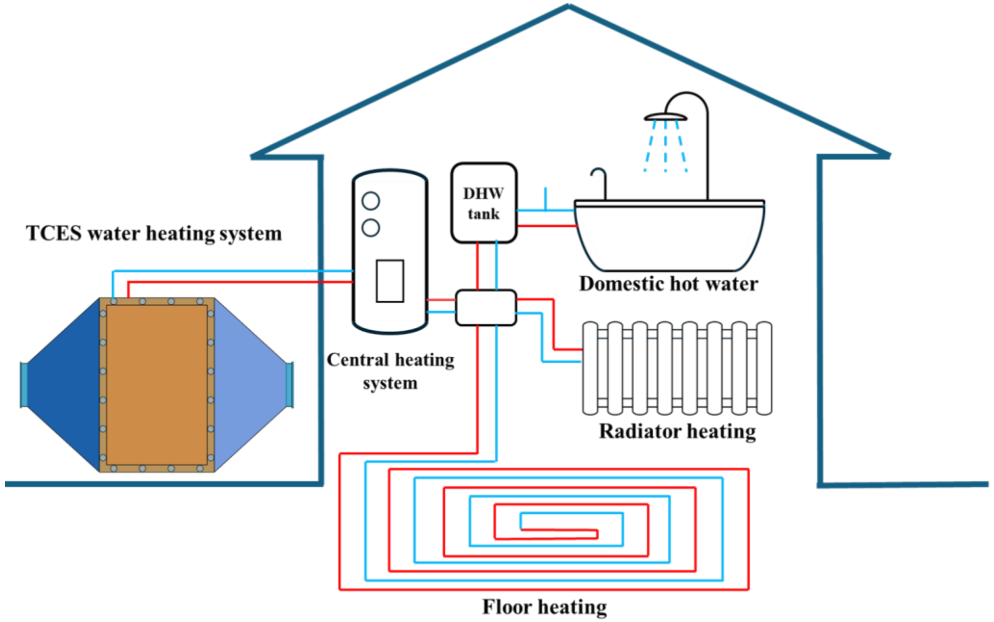
Open TCES system



Closed TCES system

TCES water heating system

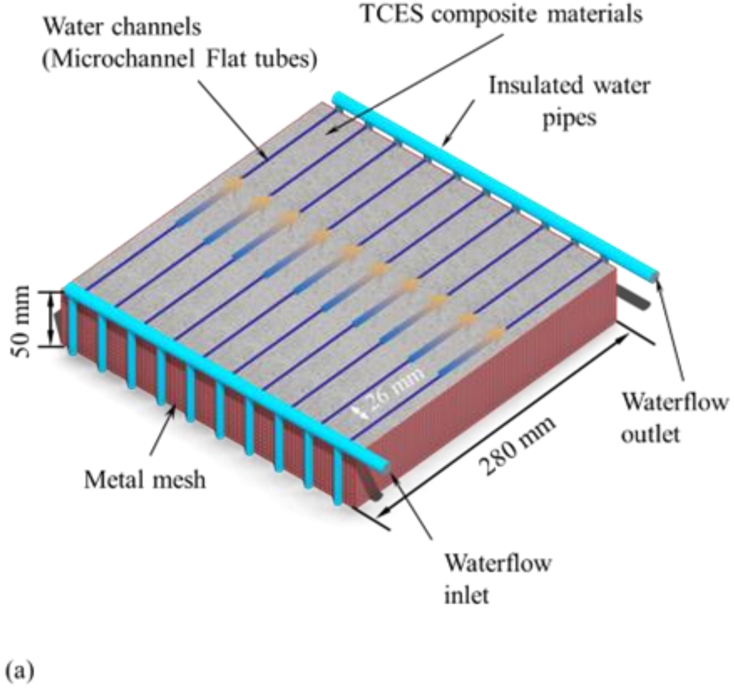
- Central heating systems (water + radiator) are prevalent in most households today
- Research on TCES system for air heating is dominant
- It would be attractive to incorporate a TCES system directly into existing domestic central heating systems

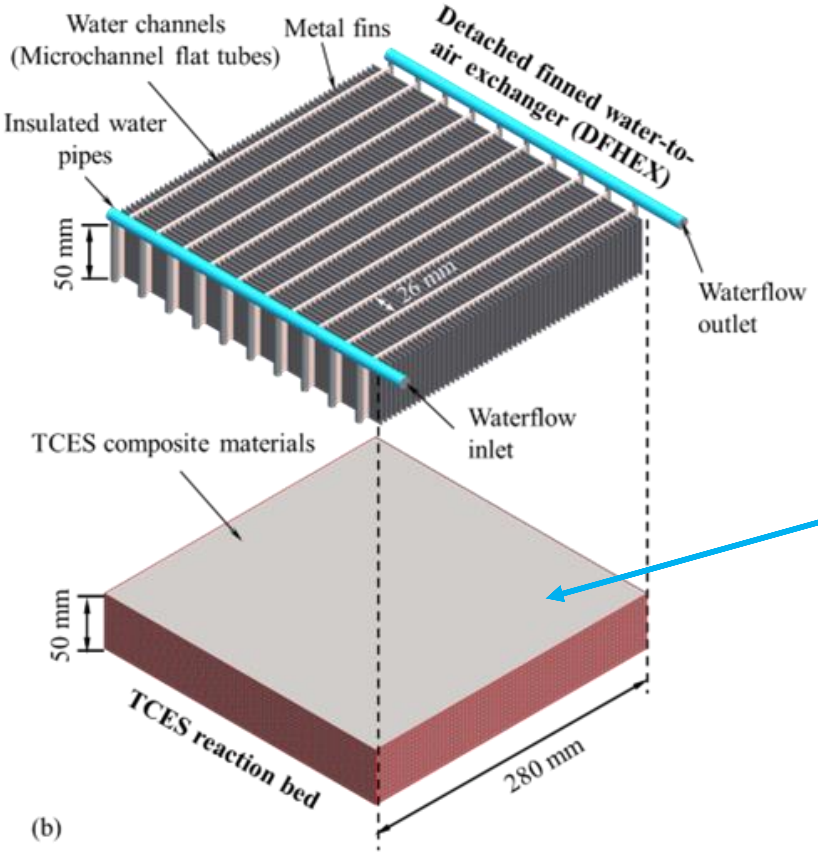


Schematic diagram of the TCES water heating system integrated into the domestic central heating system..

TCES water heating system

Two options of positioning air-to-water heat exchanger in TCES reaction bed:





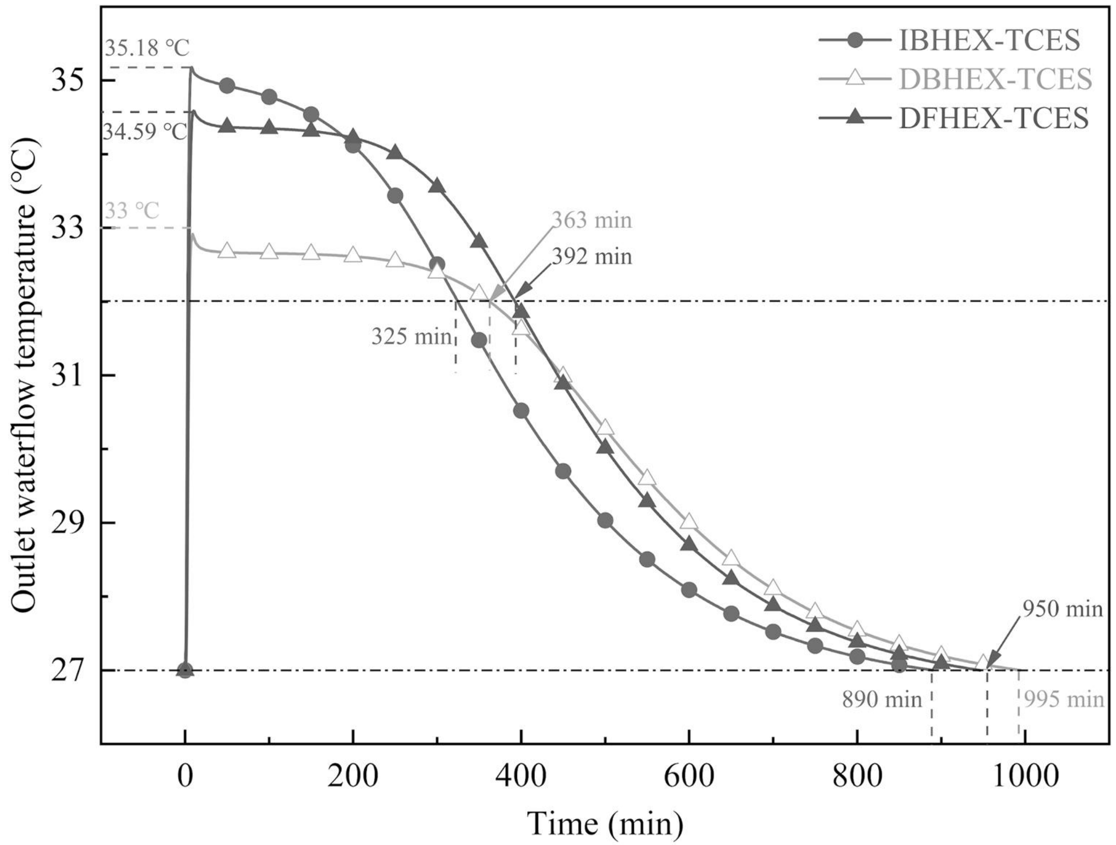
TCES composite materials

Internal (embedded) bare microchannel heat exchanger

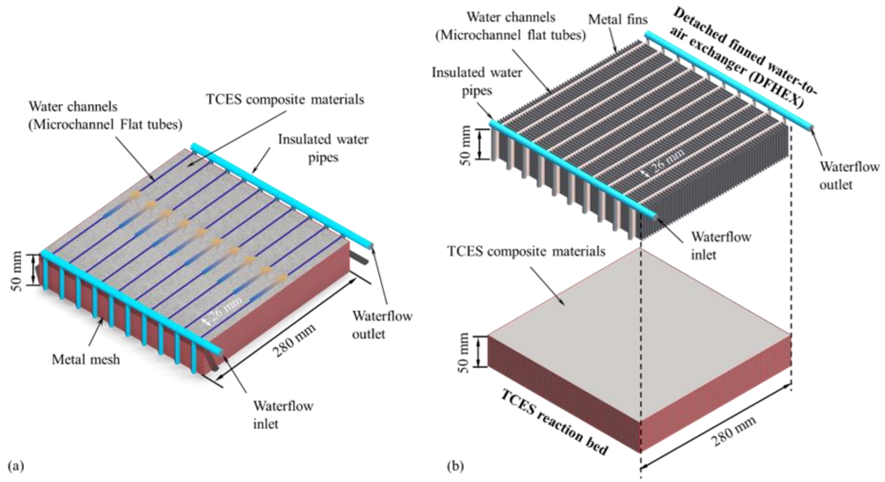
Detached finned microchannel heat exchanger

TCES water heating system

Simulation comparison of 3 combinations (IBHEX-TCES, DBHEX-TCES and DFHEX-TCES):



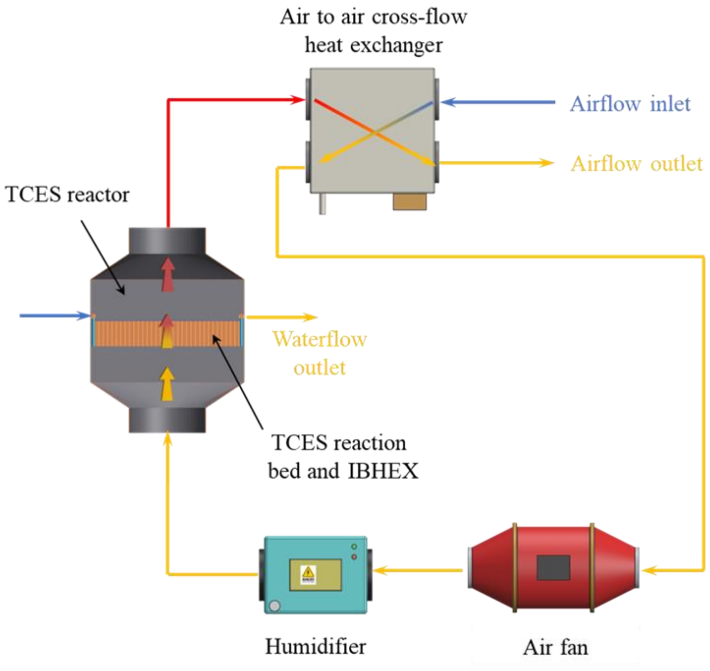
	IBHEX-TCES	DBHEX-TCES	DFHEX-TCES
HEX Configuration	Internal bare air-to-water HEX	Detached finned air-to-water HEX	Detached bare air-to-water HEX
HEX Position	Embedded in reaction bed	After the reaction bed (detached from the reaction bed)	After the reaction bed (detached from the reaction bed)
*Q*reaction	1559	1546	1554
$Q_{w,ab}$ (kJ)	1272	1252	1430
η_{th} (%)	82	81	92



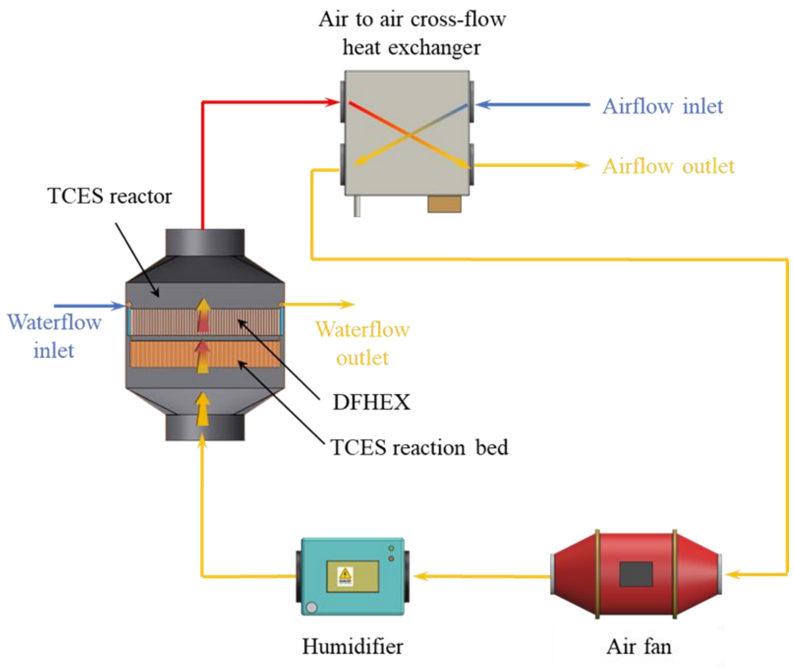
- **The peak temperature of the internal heat exchanger is 2 °C higher than the detached one.**
- **Detached finned heat exchanger matches peak temperatures of internal bare structure.**
- **Finned structure enhances discharging thermal efficiency over bare configurations.**

TCES water heating system

- **Two TCES water heating system schemes are proposed.**
- **These two TCES water heating systems can be integrated directly into domestic central heating systems.**



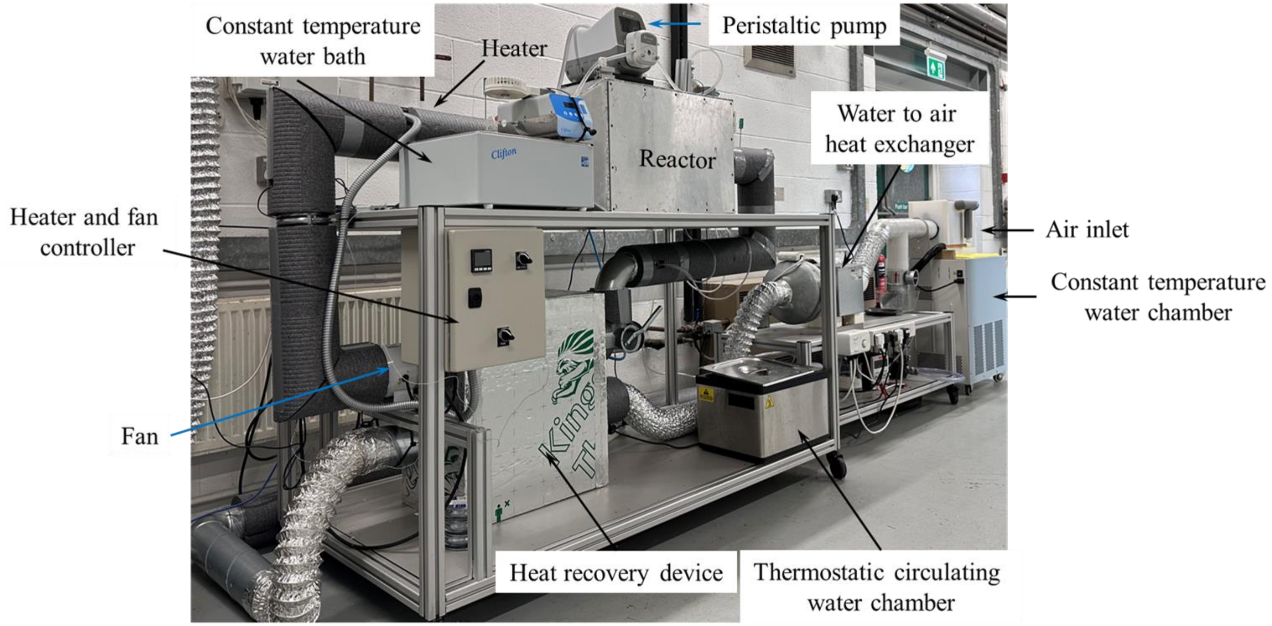
TCES water heating system with integrated an internal bare microchannel heat exchanger (IBHEX-TCES)

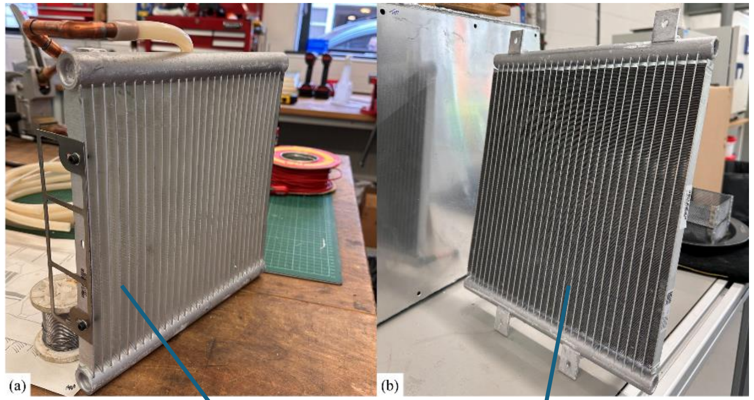


TCES water heating system with integrated a detached finned microchannel heat exchanger (DFHEX-TCES)

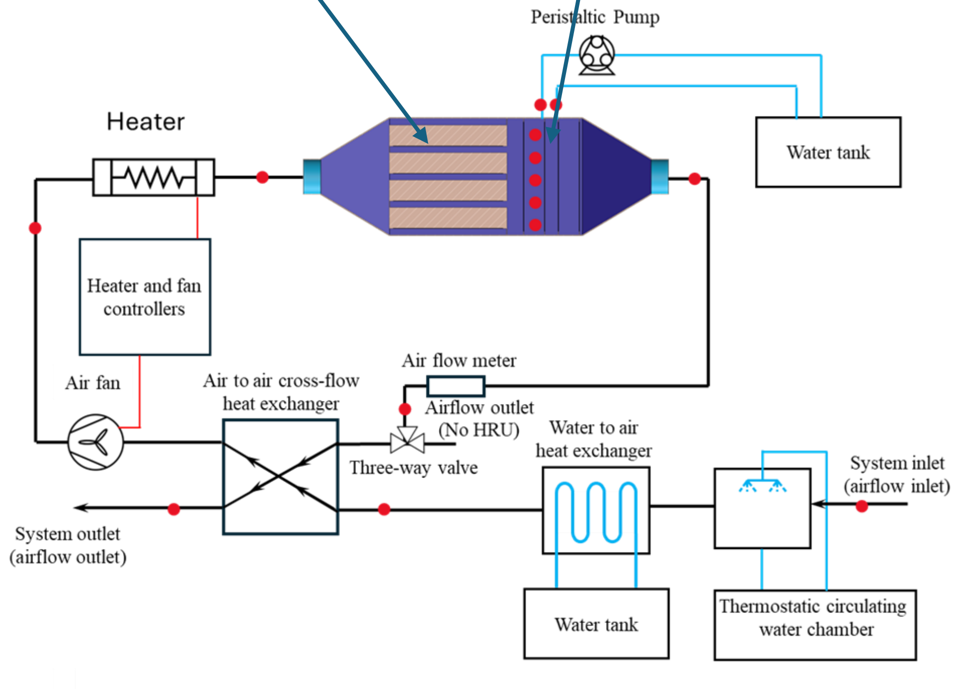
TCES water heating system

Experimental work – a versatile test rig





IBHEX and DFHEX were sourced from Sanhua

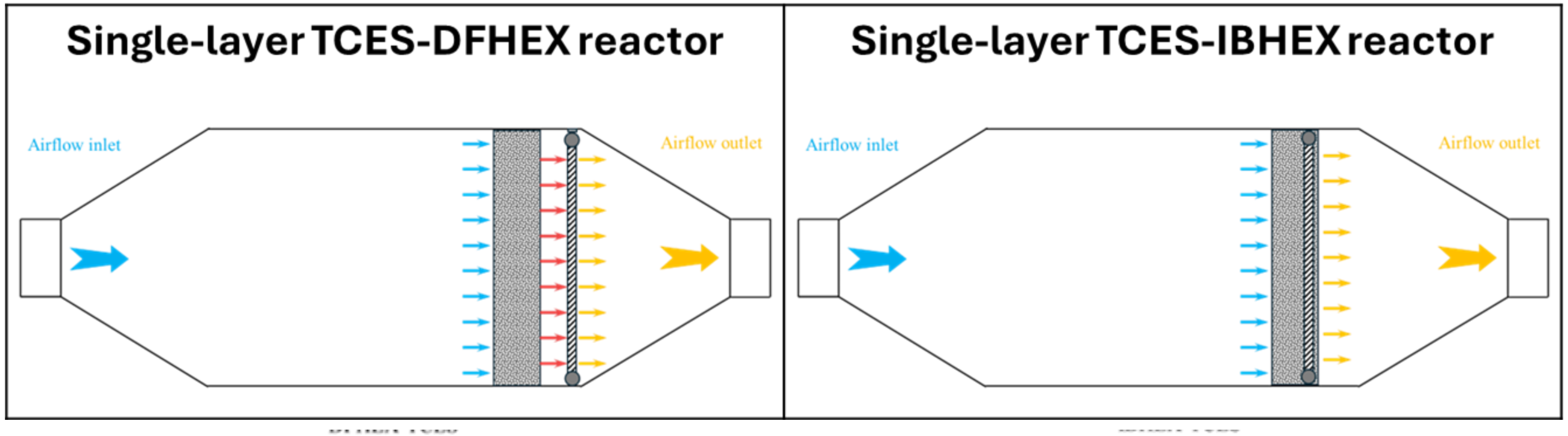


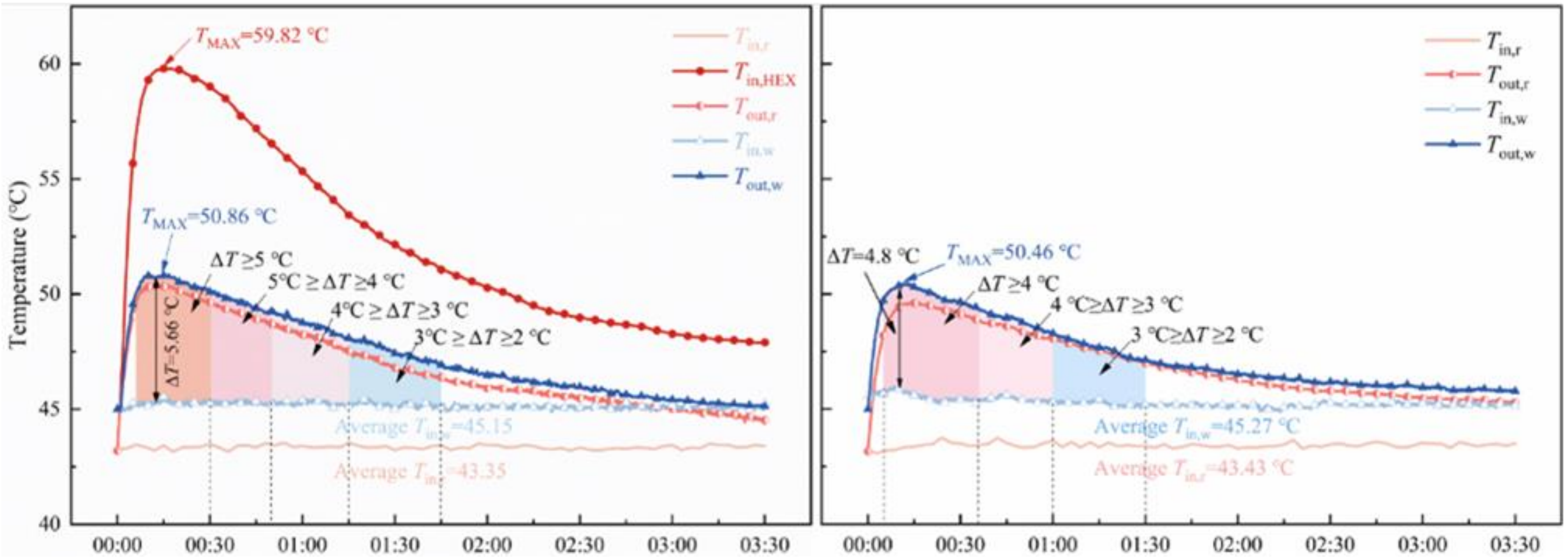
Note: The red dot ● represents the relative humidity & temperature sensor (RH&T sensor) and thermocouple

TCES water heating system

Single-layer TCES reactor discharging performance comparison (High inlet temperature)

Air and water inlet temperature: ~ 45 ℃
Air flow rate:17 m^3/h
Water flow rate: 9 L/h





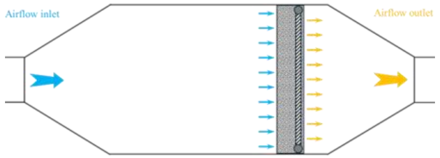
TCES water heating system

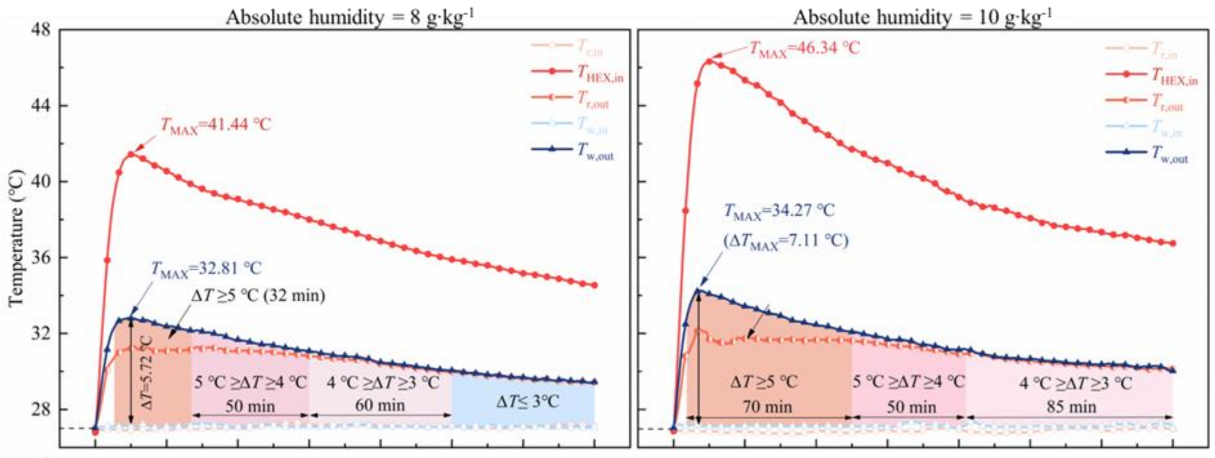
Single-layer TCES reactor discharging performance comparison (Low inlet temperature)

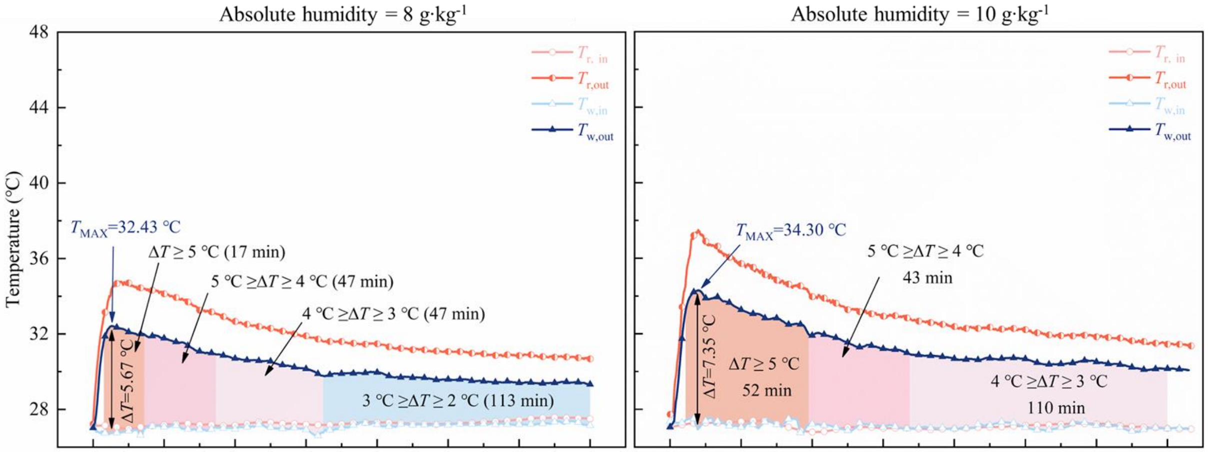
Air and water inlet temperature: 27 ℃
Air flow rate:17 m^3/h
Water flow rate: 9L/h

Single-layer DFHEX-TCES reactor

Single-layer IBHEX-TCES reactor





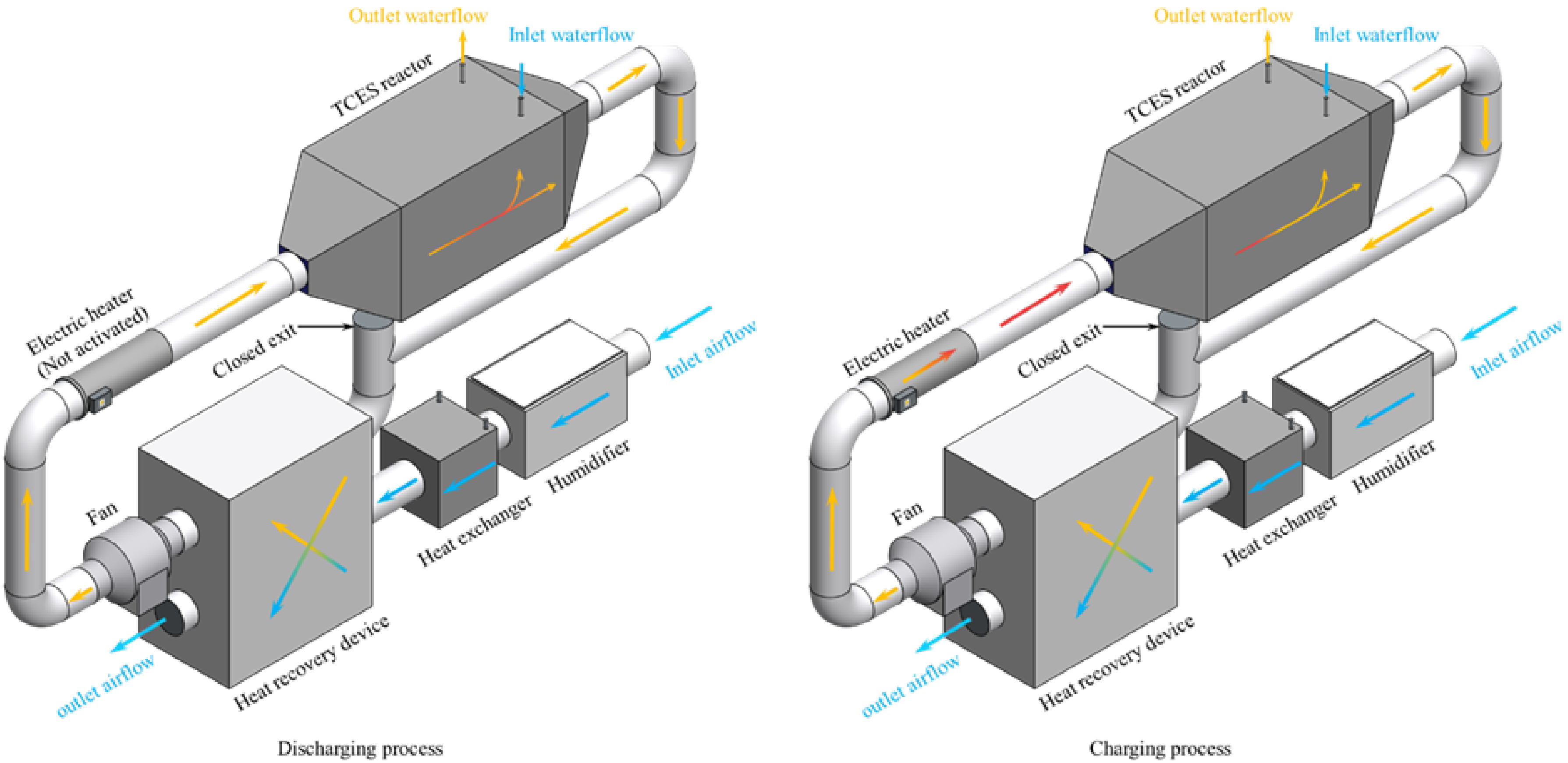


	Single-layer DFHEX-TCES		Single-layer IBHEX-TCES	
	$8\ g \cdot kg^{-1}$	$10\ g \cdot kg^{-1}$	$8\ g \cdot kg^{-1}$	$10\ g \cdot kg^{-1}$
Start mass (g)	1557	1527	1091	1270
Increase weight (g)	280	350	281	367
Heat released from TCMs (kJ)	735	962	752	996
Heat absorbed by water (kJ)	493	623	416	561
Heat Transfer Effectiveness (%)	67	65	55	56

- **Both reactors achieved similar peak water temperature lifts.**
- **The IBHEX-TCES reactor loads and replaces TCMs slowly.**
- **Internal heat exchangers in the IBHEX-TCES are in direct contact with TCMs and are at risk of corrosion.**

TCES water heating system

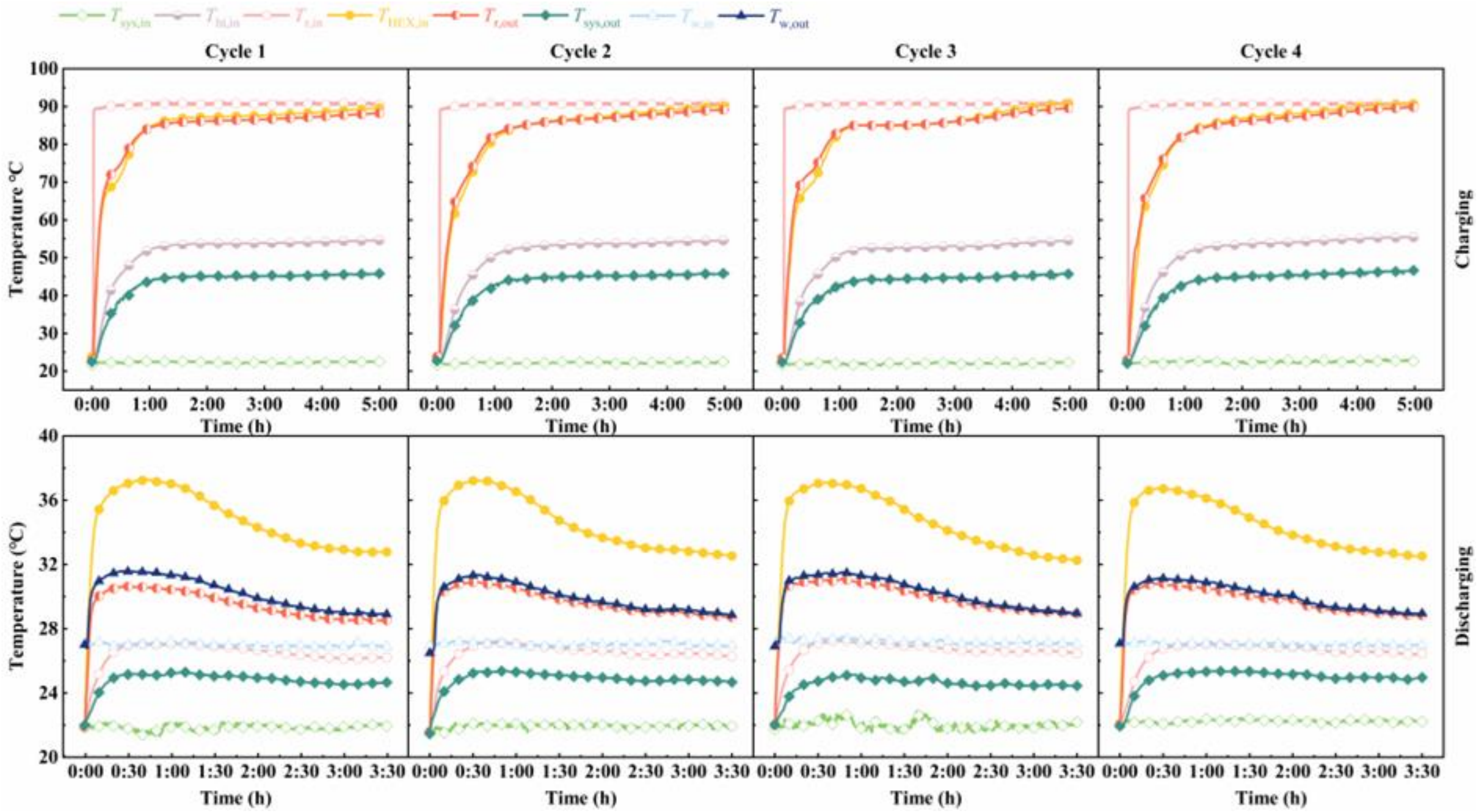
Cyclic performance of the complete single-layer TCES water heating system

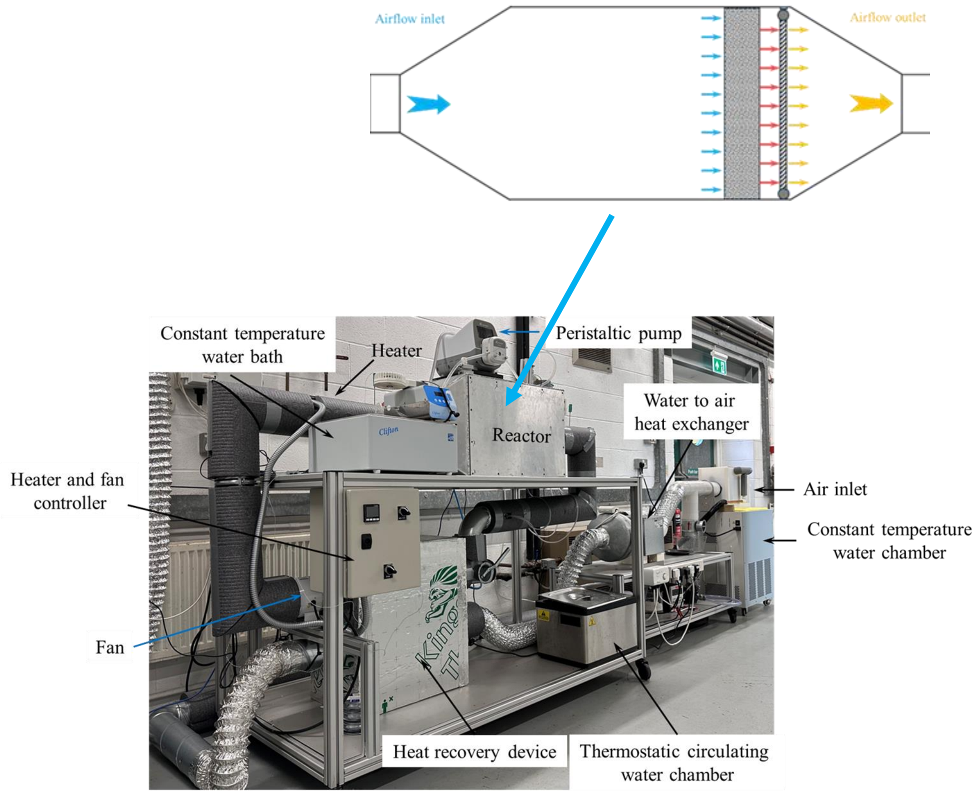


Discharging: air and water inlet temperatures set at 22 °C and 27 °C, respectively. The inlet absolute humidity is 8 g·kg^{-1} (50% RH).
Charging: 90 °C by electric heater

TCES water heating system

Cyclic performance of the complete single-layer TCES water heating system

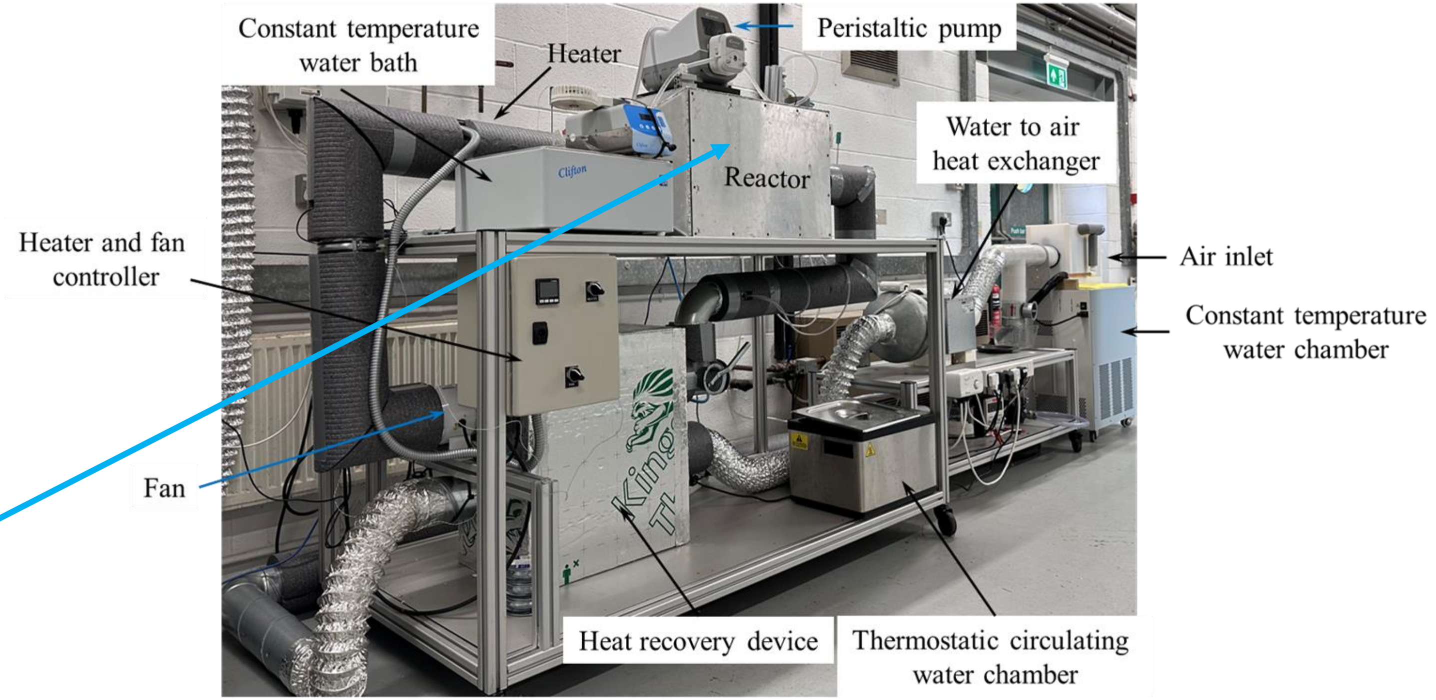


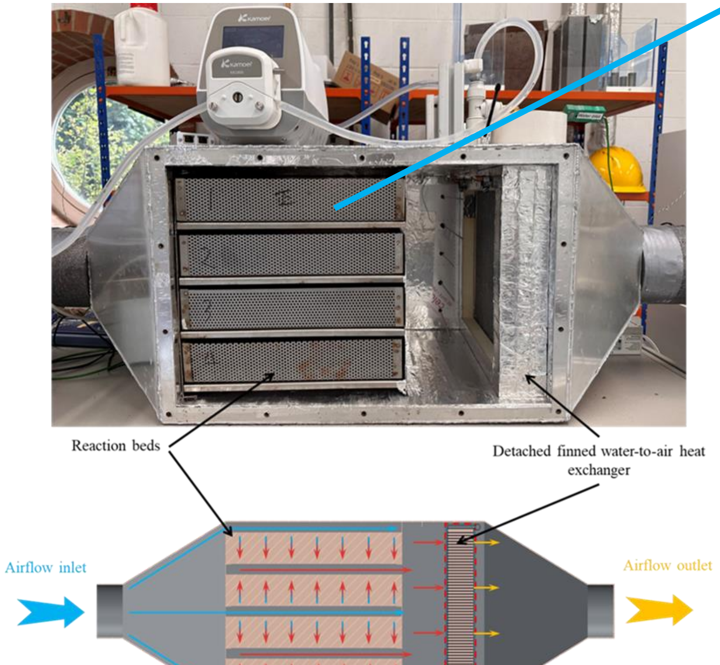


Discharging: air and water inlet temperatures set at 22 °C and 27 °C, respectively. The inlet absolute humidity is 8 g·kg^{-1} (50% RH).
Charging: 90 °C by electric heater

TCES water heating system

Multilayer TCES reactor

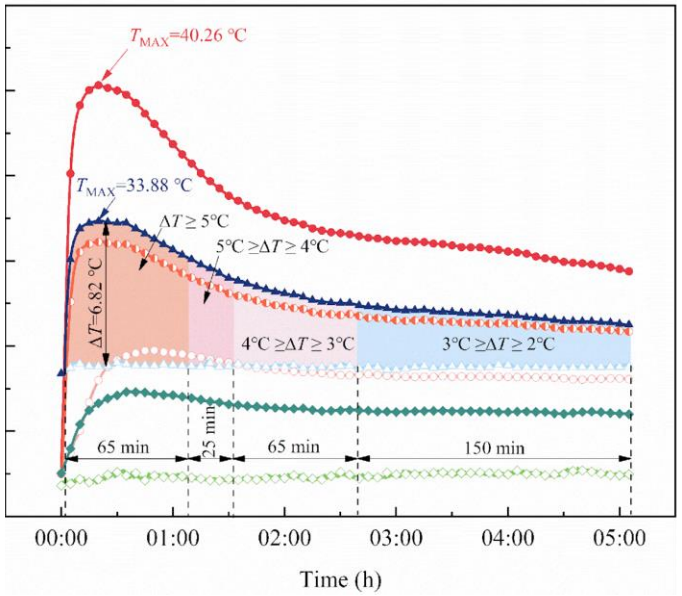




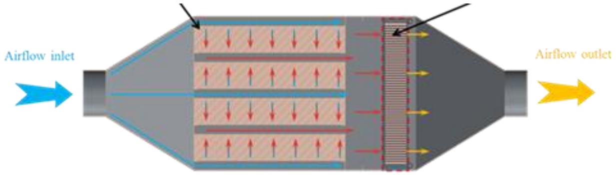
TCES water heating system

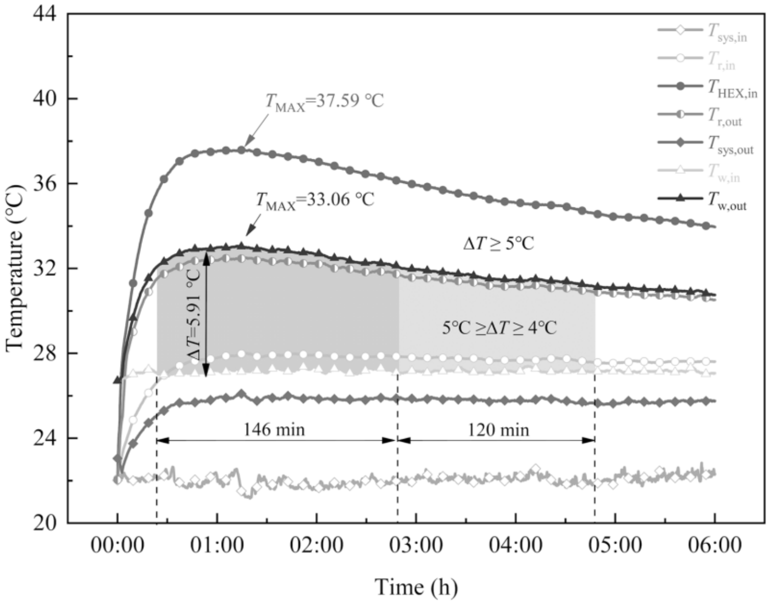
Discharging performance evaluation of single-layer and multilayer DFHEX-TCES system

Single-layer DFHEX-TCES with HRU



multilayer DFHEX-TCES with HRU

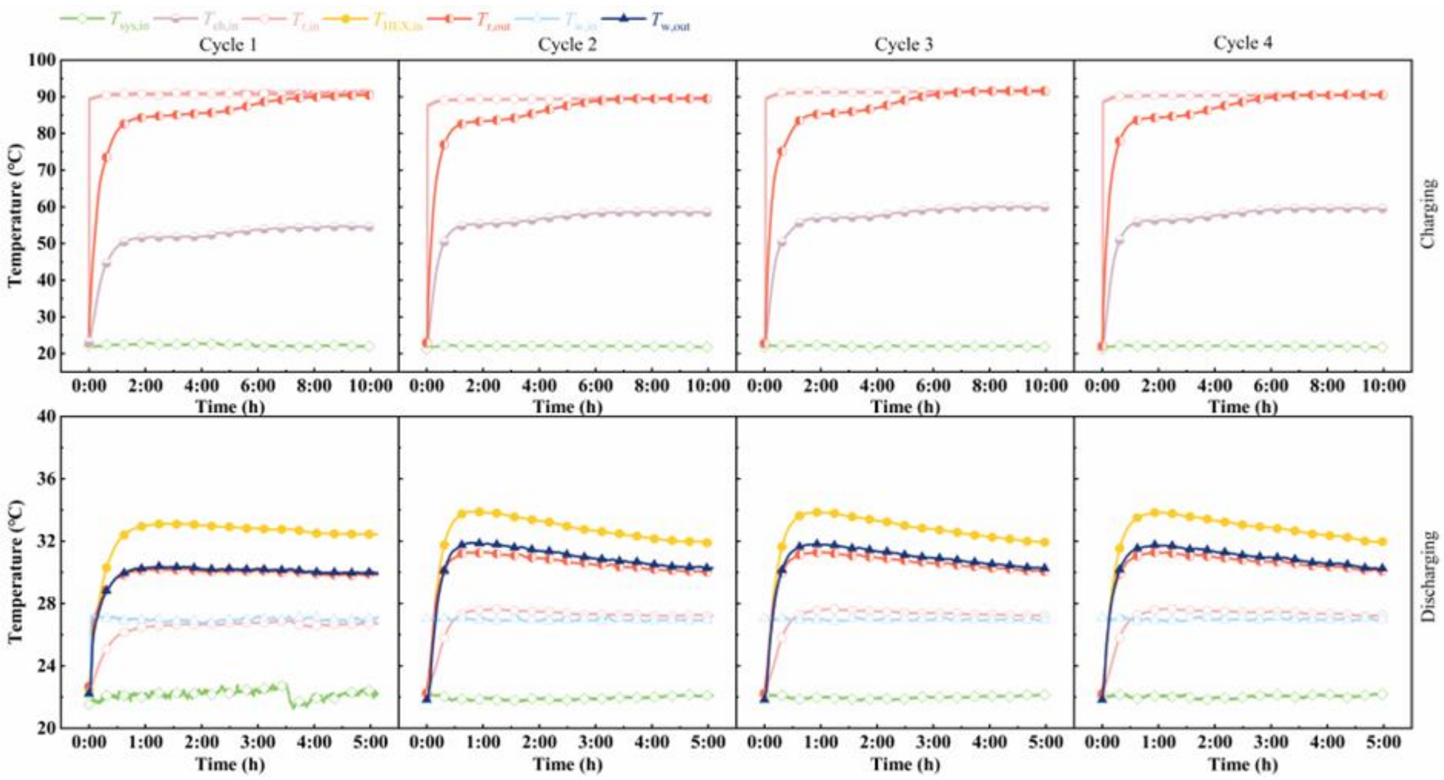


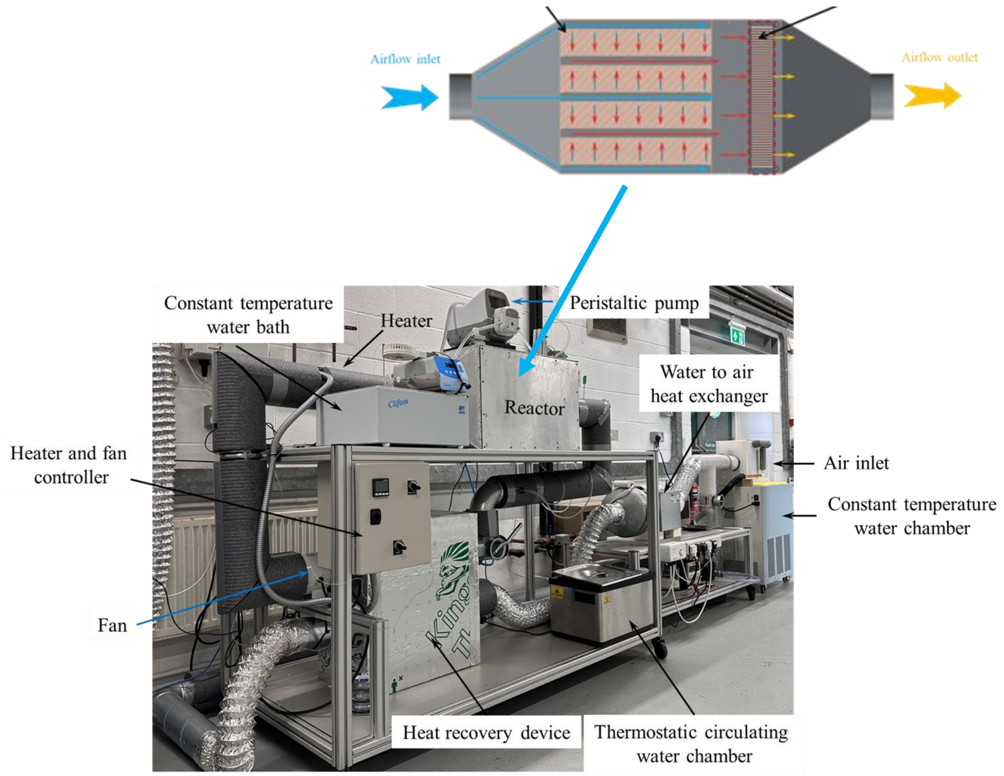


Reactor bed: 6 cm thickness
Testing conditions: air and water inlet temperatures set at 22 °C and 27 °C, respectively.
The absolute humidity of the system inlet air is 8 g·kg^{-1} (the relative humidity is about 50%).

TCES water heating system

Cyclic performance of the complete multi-layer TCES water heating system





Discharging: air and water inlet temperatures set at 22 °C and 27 °C, respectively. The inlet absolute humidity is 8 g·kg-1 (50% RH).
Charging: 90 °C by electric heater

Summary

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- Use of a **detached heat exchanger** is more advantageous for thermochemical energy storage integrated water heating, owing to an easier sourcing, installation and maintenance of heat exchangers and as well as less corrosion risk.
- Use of **heat recovery** is essential in thermochemical energy storage integrated water heating to achieve a high efficiency.
- Both high and low **water outlet temperatures** were demonstrated experimentally.
- Onsite demonstration in 3 locations is being prepared in the ECHO project

(https://echo-euproject.eu/)

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Thank you

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