CREATE
Best Practices

The main aim of CREATE project is to develop and demonstrate a heat battery, i.e. an advanced thermal storage system based on Thermo-Chemical Materials (TCMs), that enables economically affordable, compact and loss-free storage of heat in existing buildings.

The CREATE concept is based on advanced compact thermal storage for existing dwellings using TCM. The heart of the system consists of a vessel that contains a salt that is hydrated and dehydrated, which generates an energy effect. In the time between de-hydration and hydration the energy is stored in the salt. There are two applications envisioned:

- Decentral thermal energy storage bridging supply and demand of renewable thermal energy
- Decentral grid-connected storage for increasing energy efficiency and introducing flexibility in the electricity grid, e.g. using a heat pump.

www.createproject.eu

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680450.

Development of the CREATE storage material

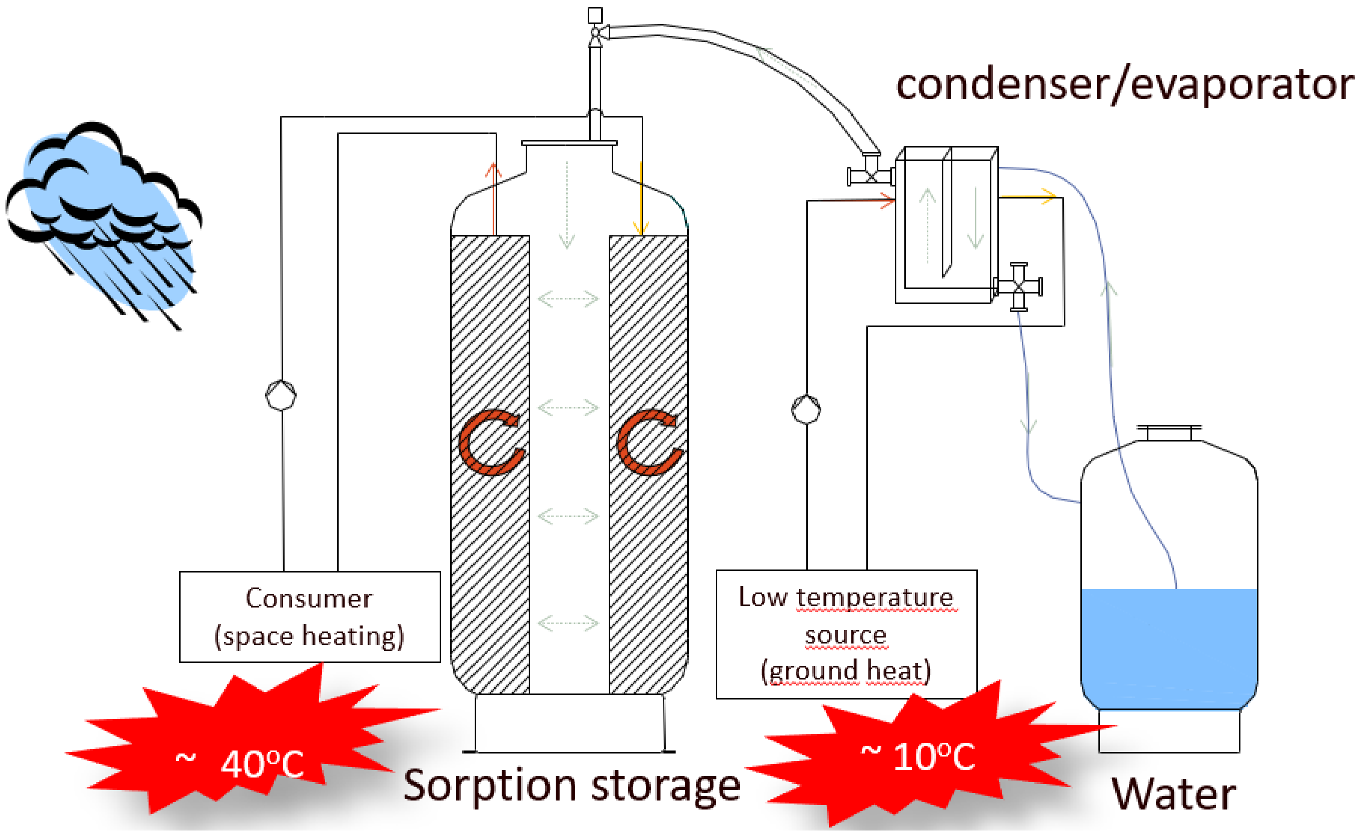
Stable and compact materials

Developing a compact and stable storage material that can be produced at industrial scale against low cost.

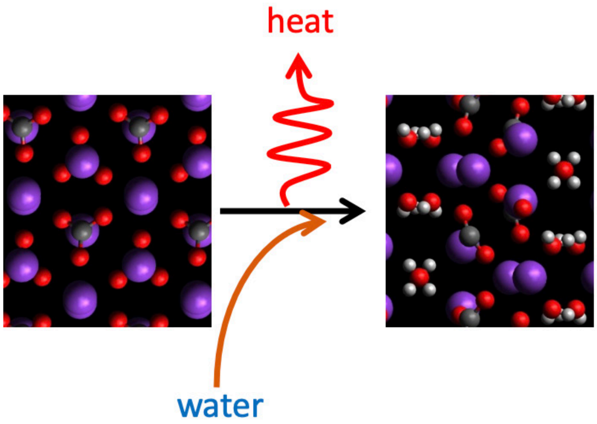
Tasks:

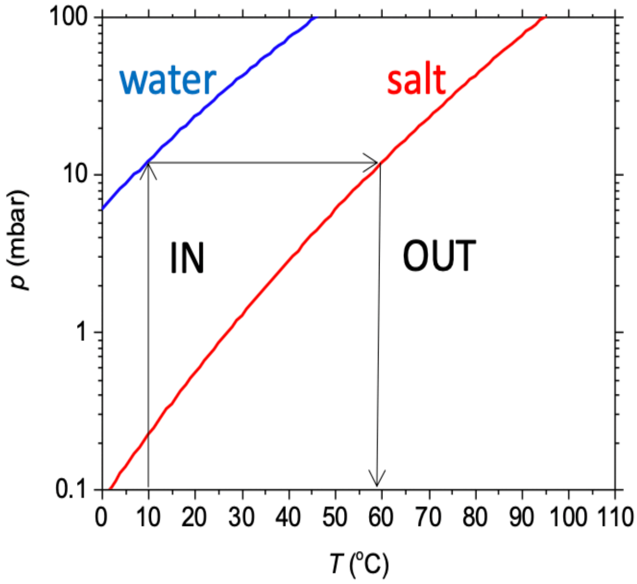
- Identify low cost base materials with a high energy density
- Develop and characterize stable materials (composites)
- Develop industrial scale production process
- Perform economic study of industrial scale process

Adsorption (Hydration)



Salt hydrates





Why salt hydrates?

- High energy density: > 1 GJ/m3, 280 kWh/m3
- Low cost: 0.2 – 1.0 €/kg
- Low temperature charging: < 100oC a

Material selection

Approach: 563 reactions have been screened

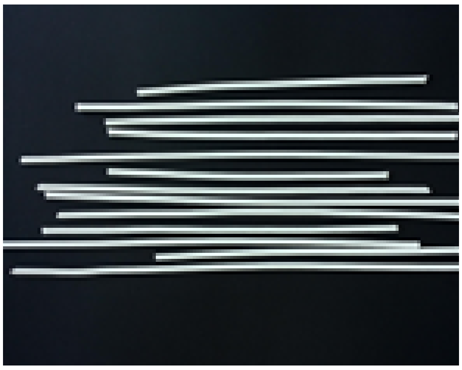
Selected candidate: Potassium carbonate – K2CO3

- Energy density @ material level: 1.3 GJ/m3, 3.6 kWh/m3
- Output temperature with: 60oC (with 10oC water)
- Health/safety issues: none
- Material costs: ~ 1 €/kg

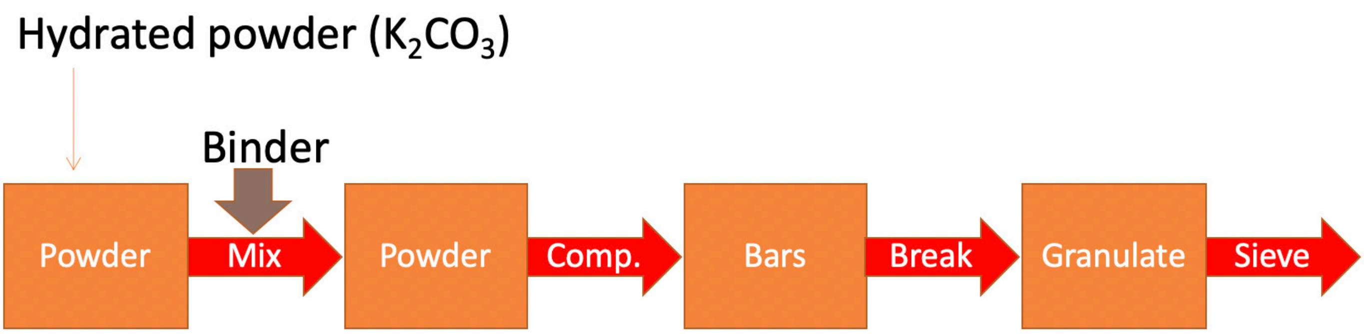
Composites

Type I: compaction

Type II: extrusion

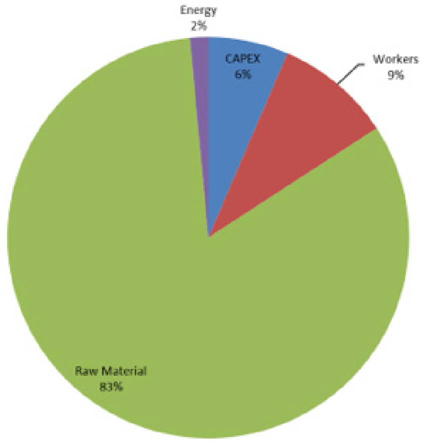


Industrial scale production



Cost analysis

	CREATE Salt Plant [€/kg]
Yearly CAPEX	0.09
Yearly workers OPEX	0.13
Yearly OPEX for materials	1.11
Yearly OPEX for energy	0.02
TOTAL	**1.3**
TOTAL (with profit margin)	**1.6**



Conclusions

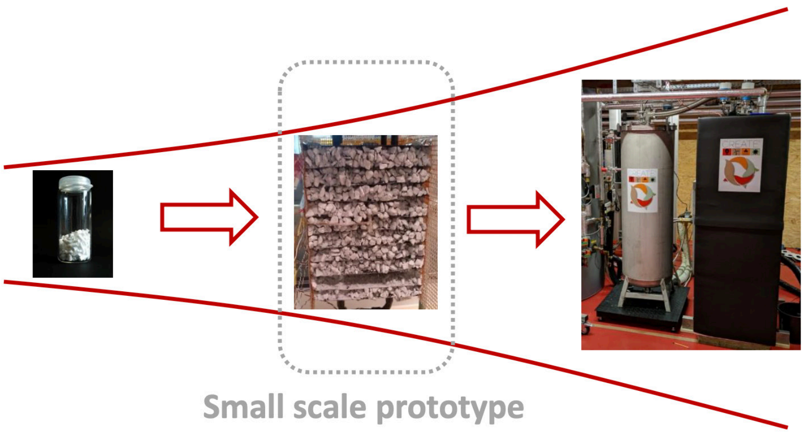
Original aim:

Develop a **compact** and **stable** storage material that can be produced at **industrial scale** against **low cost**.

- **Compact:** 1.3 GJ/m3, 3.6 kWh/m3 at particle level
- **Stable:** 100+ cycles
- **Industrial scale production:** yes
- **Material costs**: ~ 1.6 €/kg

Performance of a small-scale test reactor

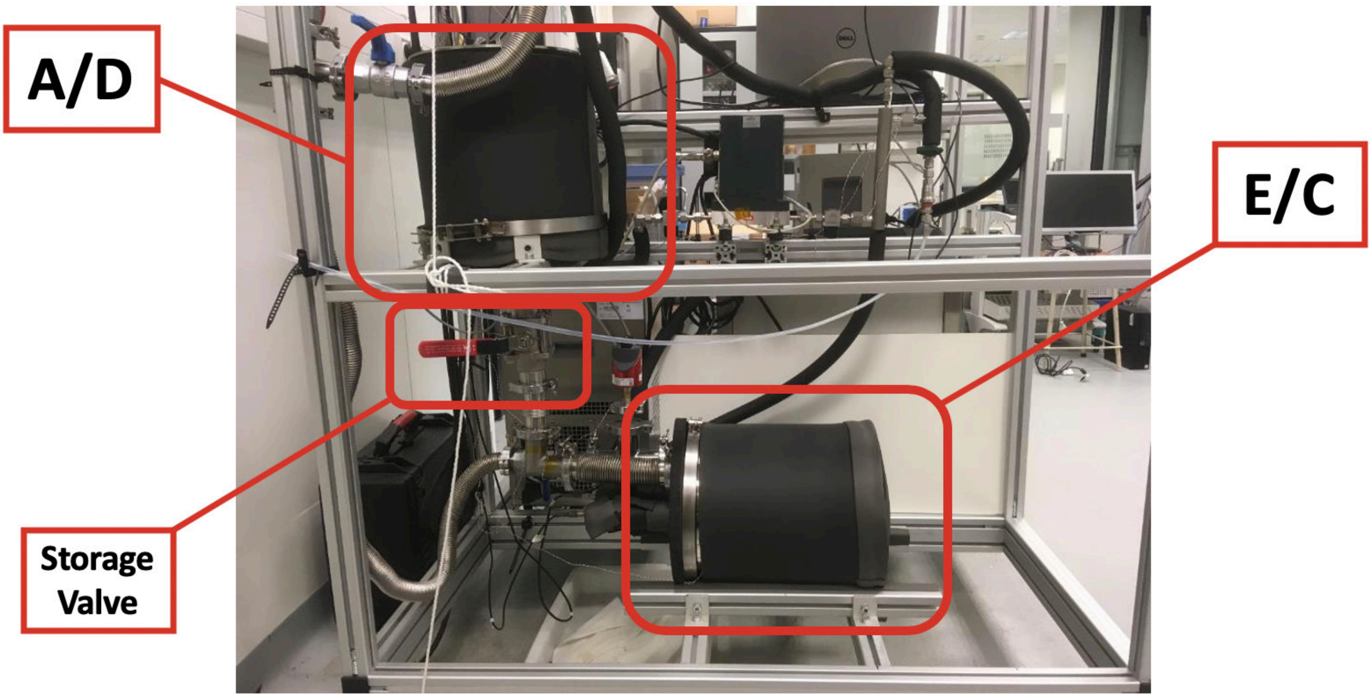
From material to prototype

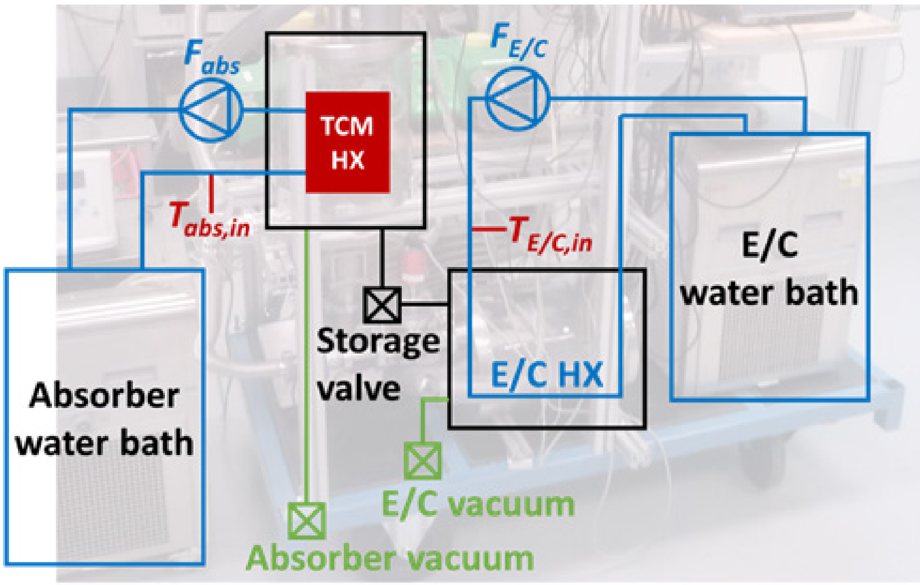


Key Performance Indicators (KPI)

	Material level	1-kg system	FSM
TCM mass [kg]	How much material fits inside the HX?		
Density TCM [g/cm^3]			
Average Power [W/dm^3]			
Charge @100°C	How quickly can I charge the battery?		
Discharge @40°C	How quickly can I discharge the battery?		
Total Energy density			
(based on HX volume) [GJ/m^3]	How much energy did I store inside 1m^3 HX?		
[kWh/m^3]			
(based on material volume) [GJ/m^3]	How much energy did I store inside 1m^3 of material?		
[kWh/m^3]			

Experimental - 1-kg setup

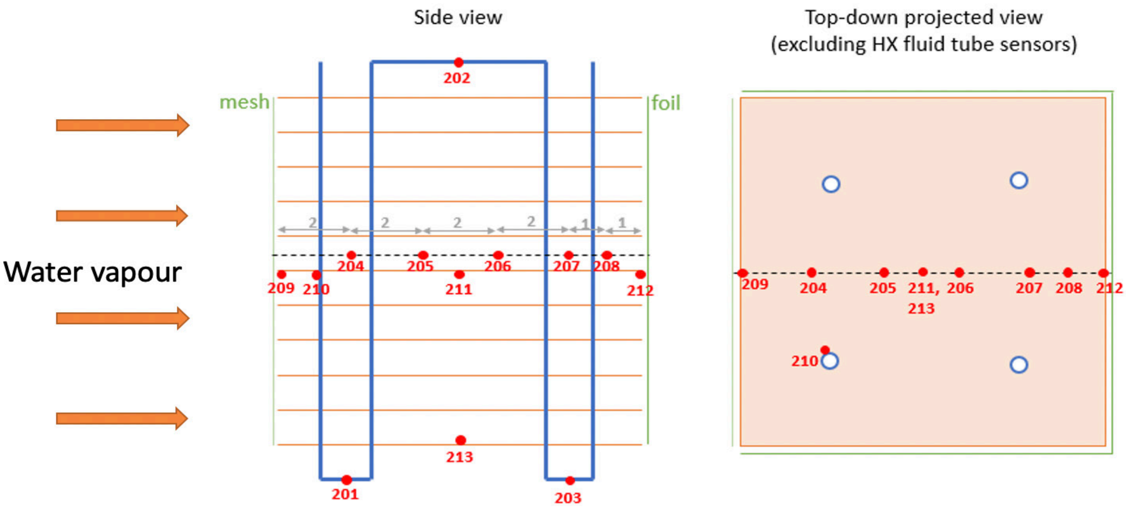




System schematic with controlled parameters

Filled HX for monomodal

Run #3/4- thermocouple layout



Typical experimental conditions

Hardware / materials:

- 96 wt% K2CO3, 3 wt% graphite, 1 w% silica
- Copper/copper fin/tube HX
- 10-mm spaced fins

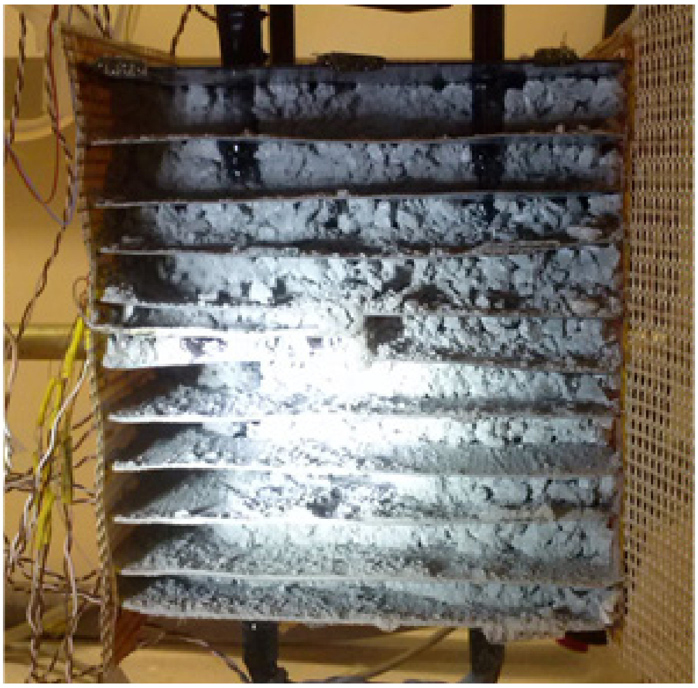
Software / Control conditions

- Charge: Tabs,in = 75; 80; 90; 100°C, TEC,in = 10°C
- Discharge: Tabs,in = 40; 55°C, TEC,in = 10°C

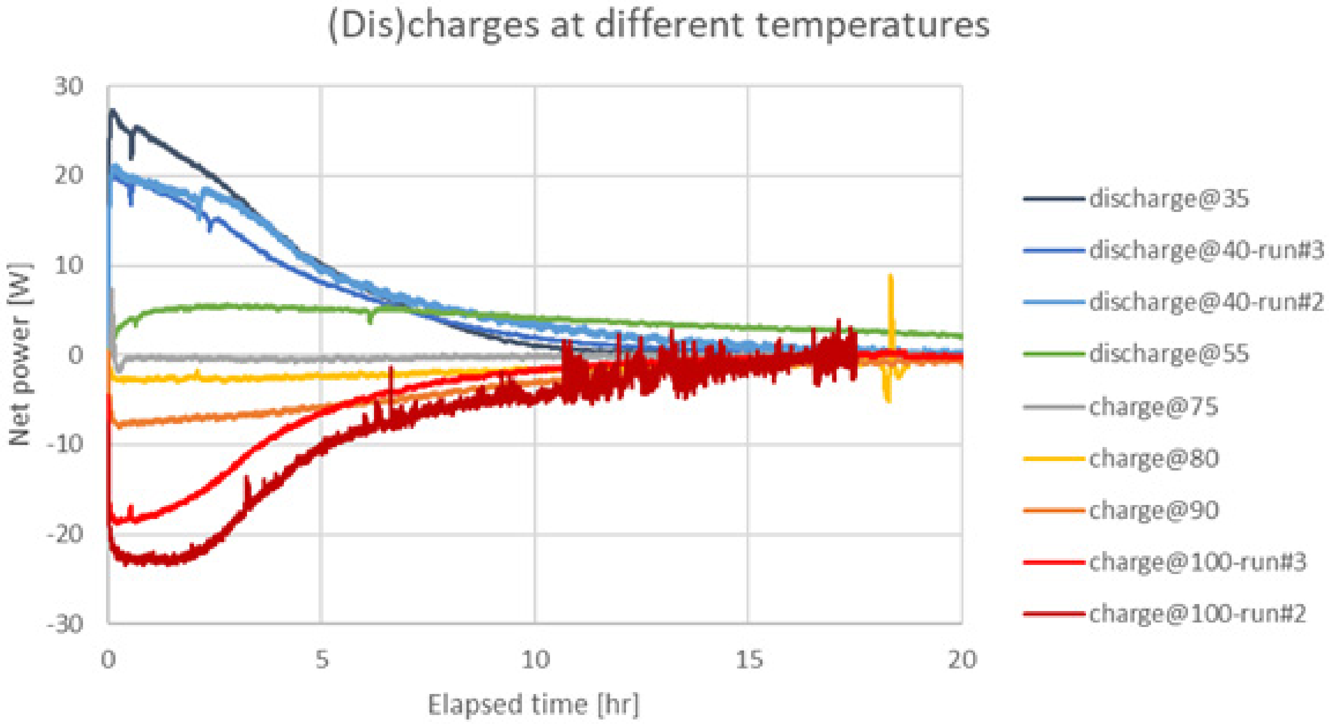
HX of the 1kg setup

Before

After



Power profiles



Key Performance Indicators (KPI)

	Material level	1-kg system	FSM
TCM mass [kg]	0.01-0.1	1.06	236
Density TCM [g/cm^3]	1.2 (tapped)	1.10	0.94
Average Power [W/dm^3]			
Charge @100°C	-	5	3.33
Discharge @40°C Discharge @35°C	-	5 7	1.43 1.66
Total Energy density			
(based on HX volume) [GJ/m^3]	-	0.53	
[kWh/m^3]	-	147	
(based on material volume) [GJ/m^3]	0.84	0.55	0.46
[kWh/m^3]	233	153	128

Conclusions

- Typical average discharge power is 5 W with 20 W peak at Tabs,in = 40°C
- Energy density of 0.56 GJ/m3 is achieved → translates into energy content of FSM (250 dm3) is 0.13 GJ (30kWh)
- Charging powers within the requirements occur at charging temperature above 90°C
- Best discharging powers occur at Tabs,in < 40°C

Development from storage module to storage system

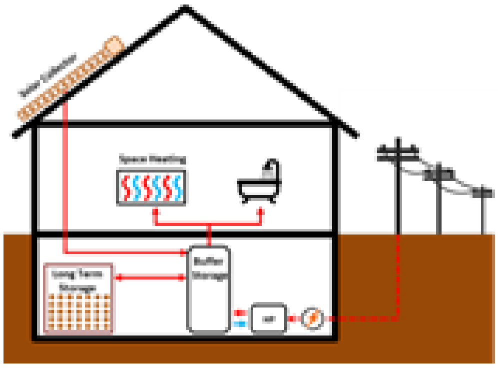
Aim

Development and demonstration of a **seasonal heat storage system** based on **salt hydrates** for single and multifamily houses with the following requirements:

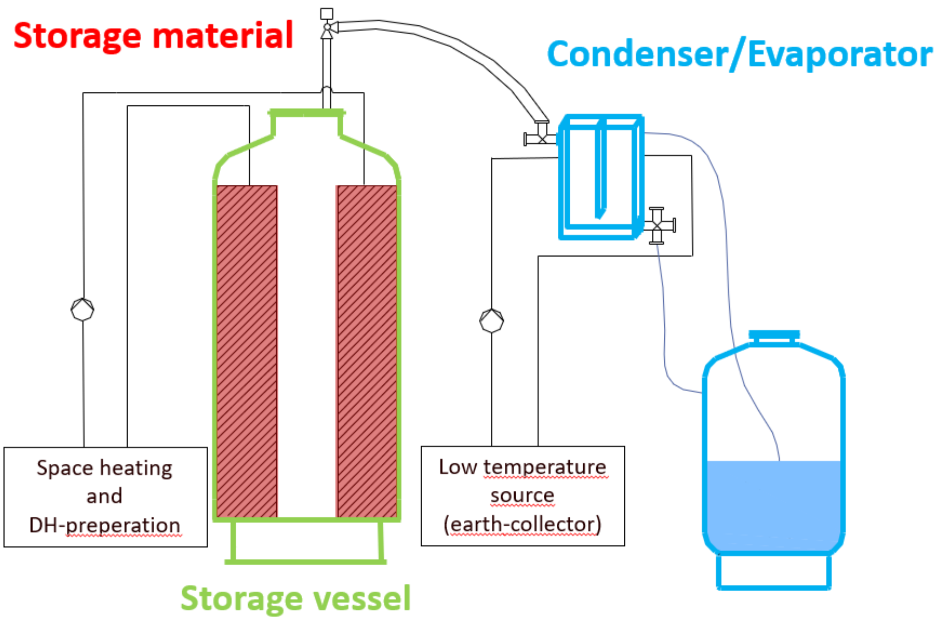
- Cost-effective
- Compact
- No heat loss during storage

Storage System Concept

- Long-term heat storage for hot water preparation and space heating
- Solar thermal collectors for loading the TCM storage
- Heat pump as a supplementary heating system



Technical development in CREATE



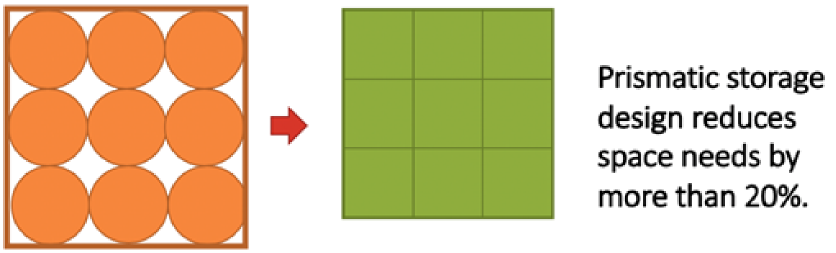
Storage Vessel

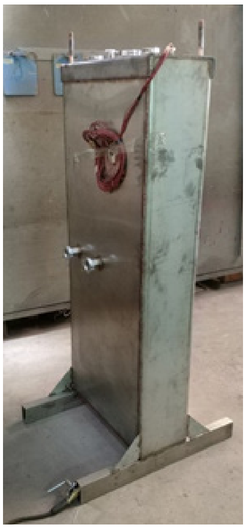
Aim: Increase the compactness of the storage system by reducing the total volume for:

- Insulation and auxiliary equipment
- Voids between the storage vessel and the building cubature

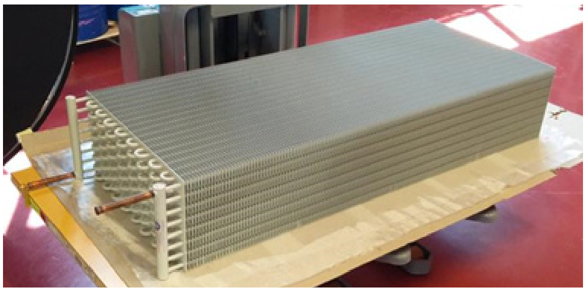
Method: Increased system storage density due to the development of prismatic and modular expandable storage modules.

Challenge: Working pressure range of ~10mbar



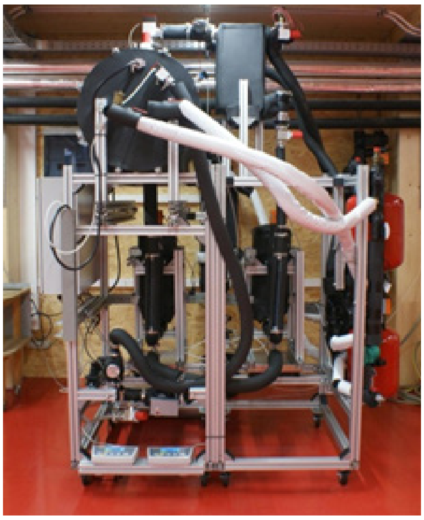


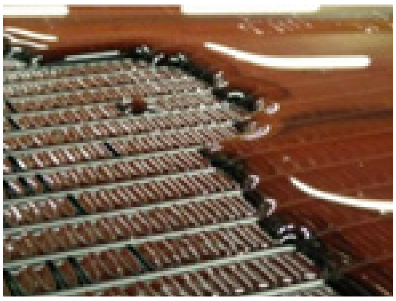
- Internal fin heat-exchanger as structural element
- Storage material filled into the fin heat-exchanger (10mm fin spacing)
- Welded stainless steel vessel and epoxy coating of the fin heat-exchanger
- Storage capacity: **200 liter resp. 400 liter pro module**
- Power requirement: 2.5kW
- Module size: 1.6m x 0.85m x 0.28m → 200 liter module
- 1.85m x 0.95 x 0.35m → 400 liter module
- **Working pressure: ~10mbar**



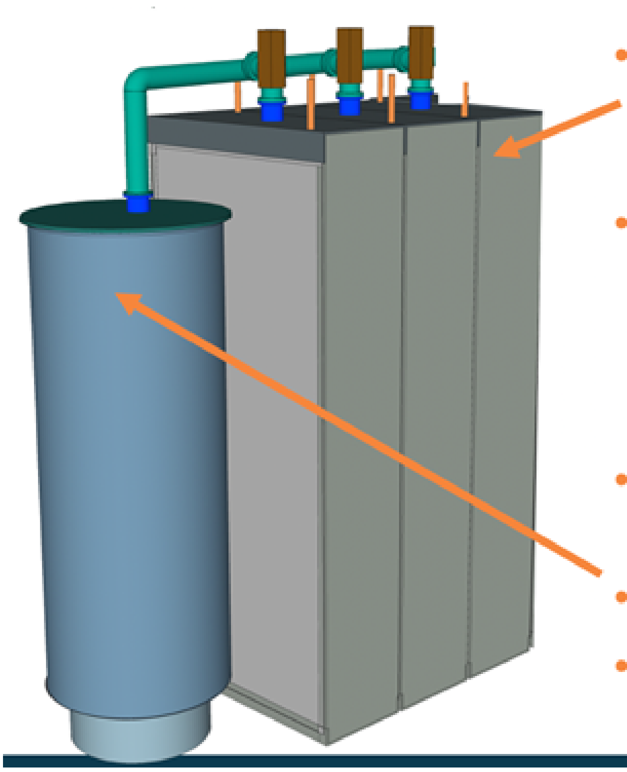
Evaporator/Condenser (E/C)

- Experimental investigation and evaluation of four different evaporator/condenser types (finned-E/C, microchannel- E/C, falling film- E/C, corrugated tube E/C)
- Corrugated tube E/C combines simple and powerful design:
  - 15m resp. 50m corrugated tube in 3 resp. 6 trays as E/C





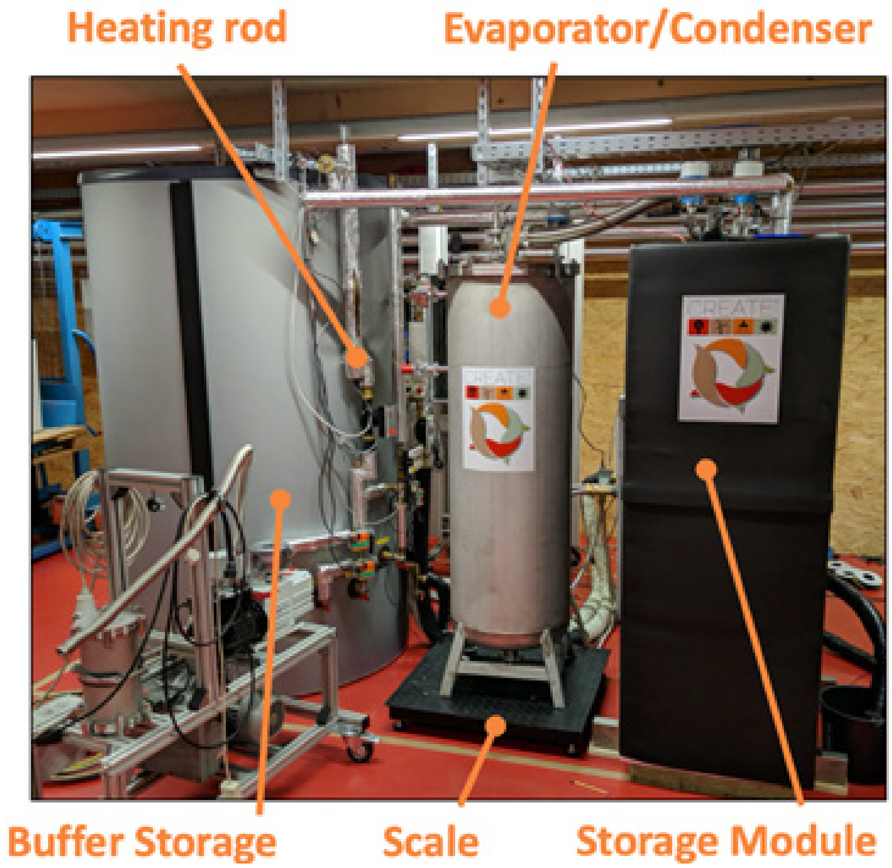
CREATE - System design



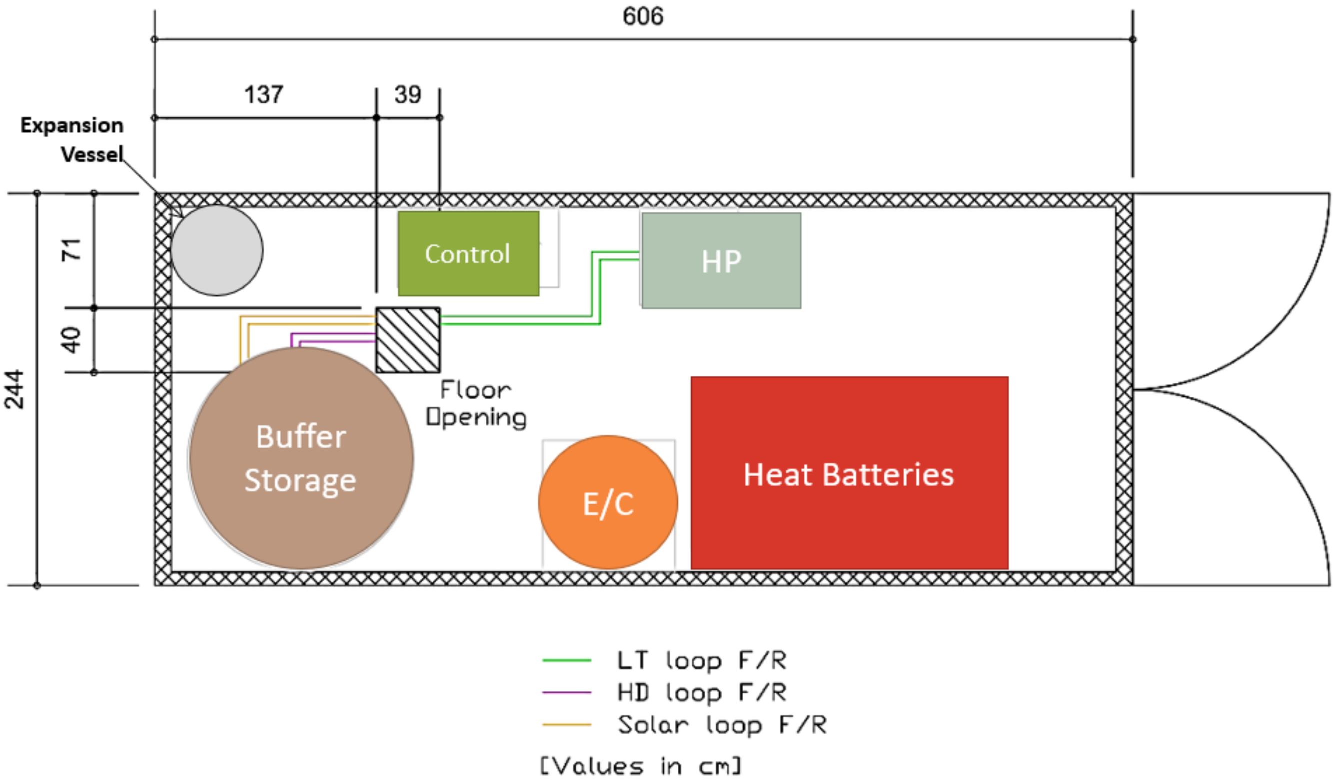
- Prismatic and modular expandable storage module design
- 3 modules with 400 litre K_2CO_3 storage material each
- Central "corrugated tube" - evaporator/ condenser design
- Pumped system
- Process water tank: ~200Liter

Storage system - laboratory experiments

- Experimental investigation of one storage module in 2018
- Multiple Dehydration und Hydration runs
- Charging temperature: 80°C-100°C
- Discharging temperature: <50°C
- Significant correlation between temperature and power
- No degradation of the material and performance after more than 20 runs



CREATE Container layout



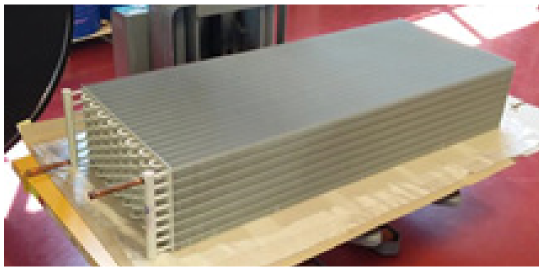
CREATE Storage system

- After single module tests, build up of a full CREATE storage system with 3 modules and a total of 1.200litres of K_2CO_3
- Hardware in the loop experiments in Gleisdorf until July 2019
- Integration of the CREATE storage system in an orphanage in Warsaw August 2019
- Demonstration of the storage system in Warsaw until April 2020

Key Facts

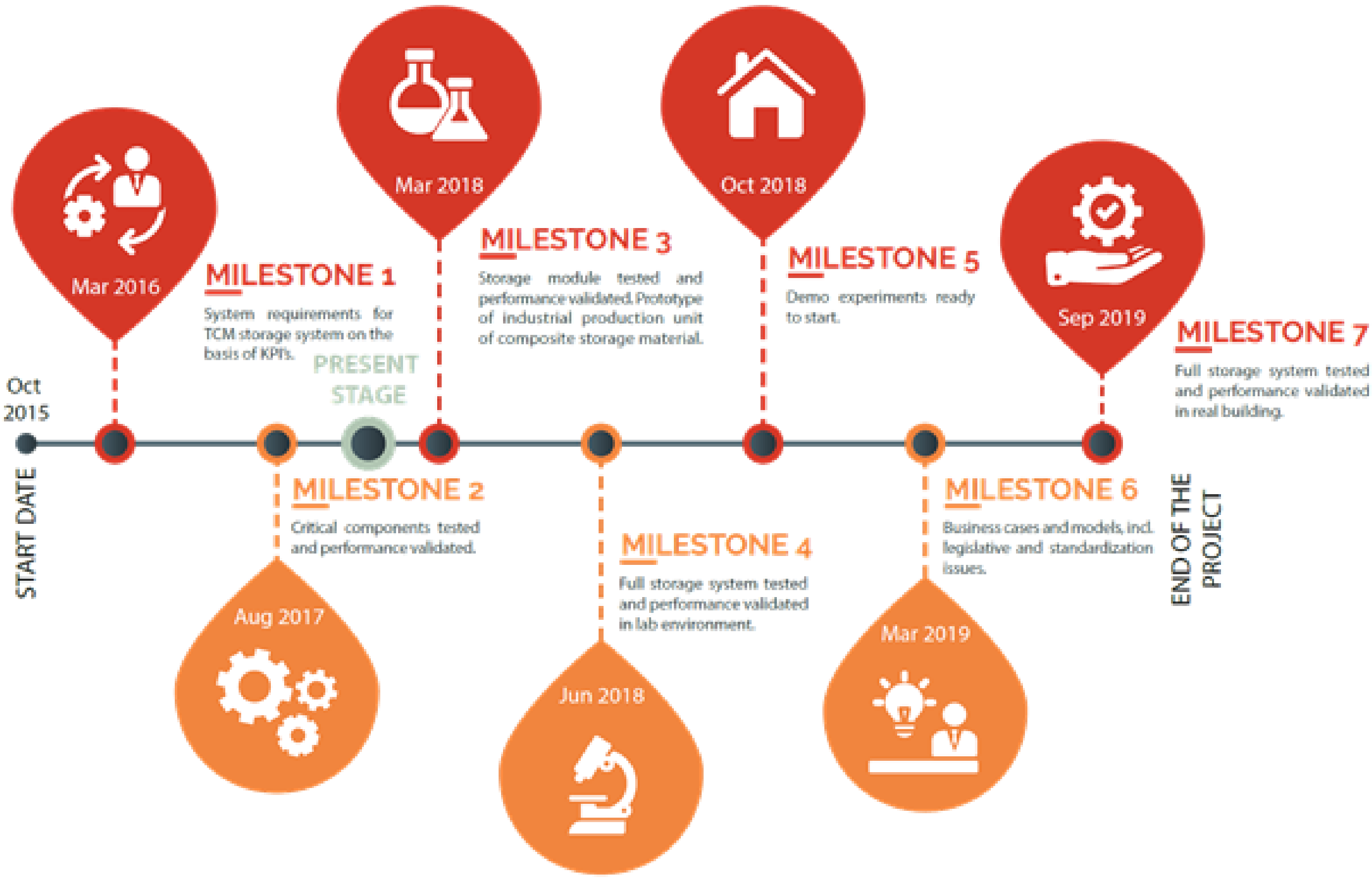
- **CREATE Storage System:**
  - Modular expandable storage module design
  - 3 modules with 400 litre K_2CO_3 storage material each
  - Capacity: ~145kWh*
  - Central “corrugated tube” - evaporator/ condenser design
  - Pumped system
- Significant correlation between temperature and power
- Maintenance-free operation, no material degradation
- Avg. heating power up to **2.766W***
- Storage density of **115kWh/m^3** *(HX-level)

** Hardware in the Loop experiments*



Technology solutions in practice

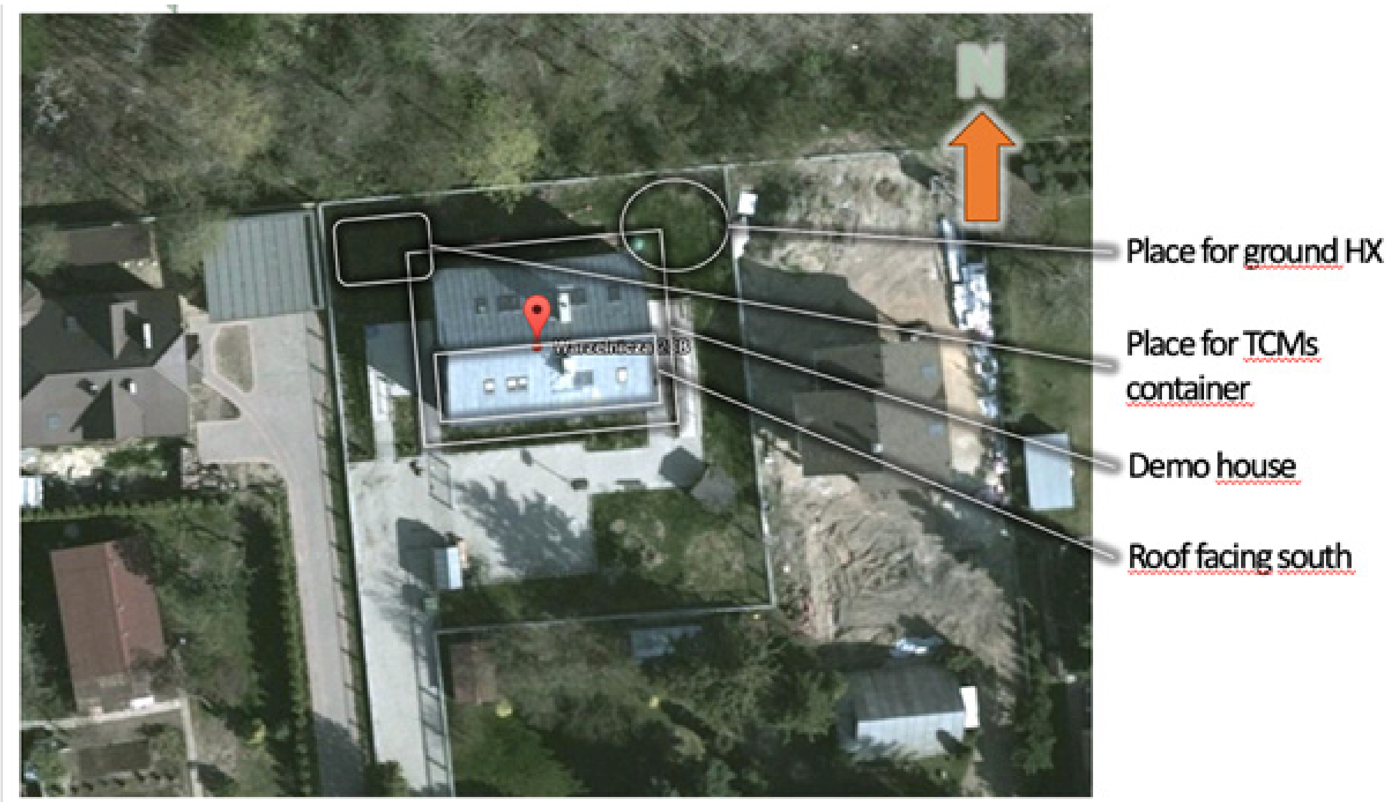
Demonstration is substantial



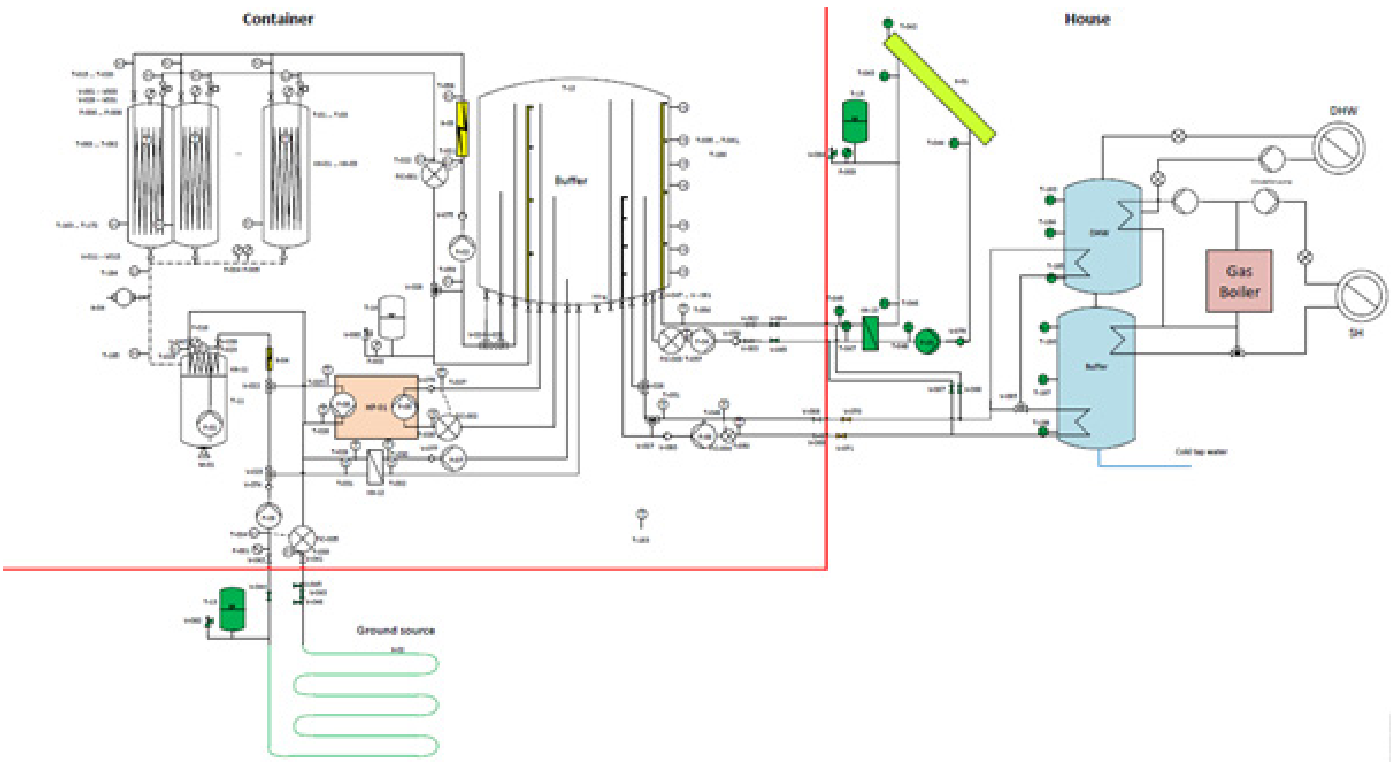
Demonstration house - Warsaw, Poland

Built year:	2009
Basement:	none
Overground storeys:	2 + attic
Useful space:	277,6 m^2
Building volume:	1258,5 m^3
External sidewalls:	plaster, aerated concrete 24 cm, mineral wool 12 cm, plaster
Roof:	gypsum-carton board, wooden structure, mineral wool 20 cm, wooden board, ventilation space, chipboard, galvanized steel sheet
Boiler room area:	7,1 m^2
Main heating source:	Bifunctional gas boiler 31 kW
Artificial heating source:	none
Heating system:	Conventional radiators; heating pipes placed in the floor
Mechanical ventilation:	none

Demosite layout

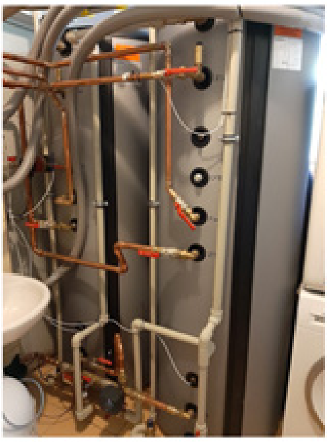


Demo system design



Scope of integration

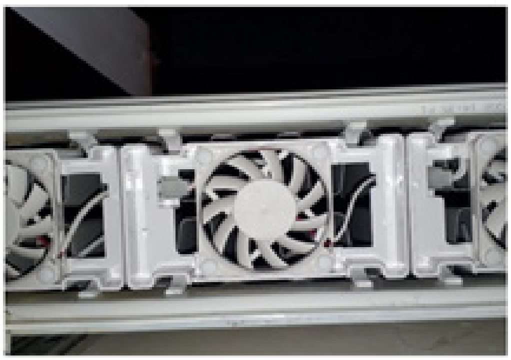
Ground heat exchangers



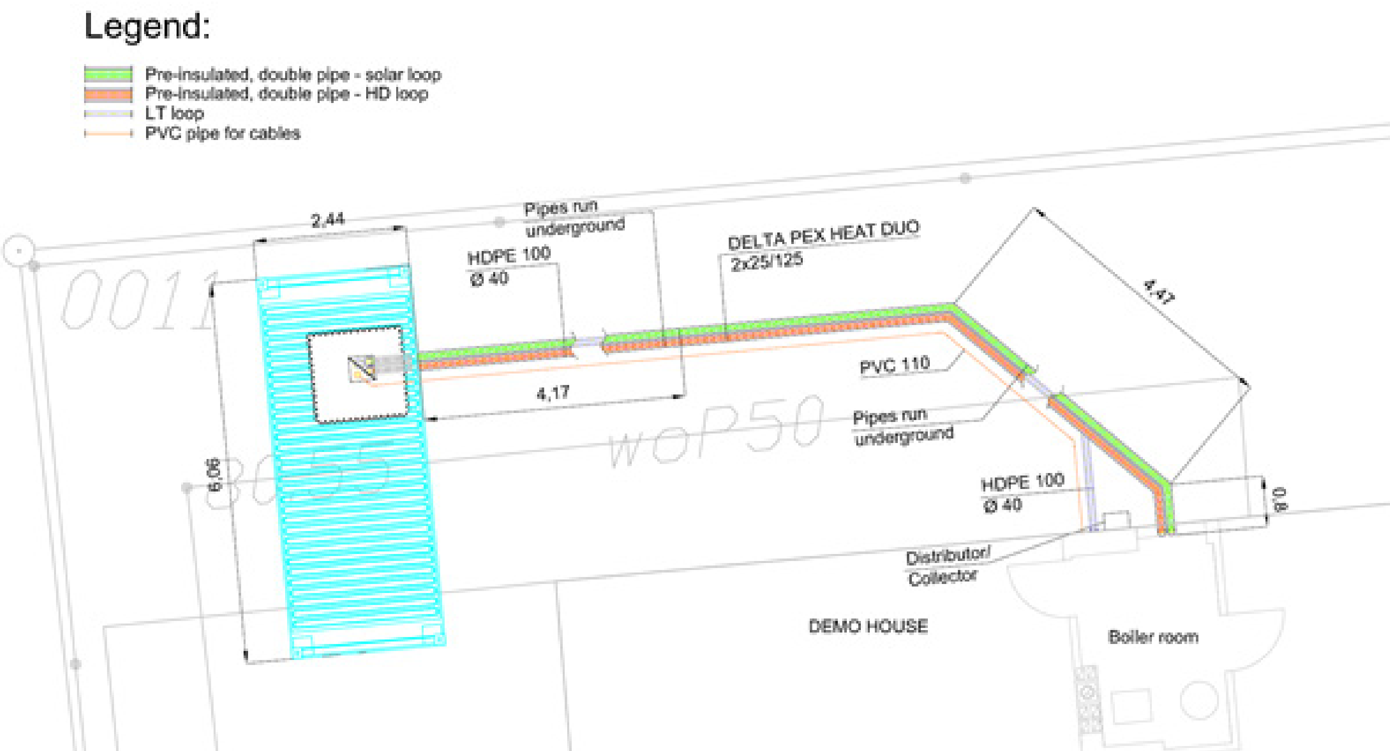
Buffers in boiler room

Measurement system

Solar collectors system



Fans on radiators



Container installation

Market potential

Background

- The building sector accounts for the largest share of energy consumption (approx. 40% in European Union).
- Energy storage is a key in providing flexibility and supporting renewable energy integration in the energy system and can efficiently contribute to the decarbonization of buildings.
- The EU 2030 climate and energy package calls for a substantial increase in renewable energy by 2030 (at least 32% share of final consumption for renewable energy).

Target market

- **European thermal energy storage market**
- Several countries were identified as the ones with the biggest potential: **Germany, Finland, Austria, Sweden, Belgium, Denmark and Cyprus**
- **Criteria:** Household energy consumption per dwelling by end-use, Newly installed solar thermal capacity in EU, Recent development of main solar thermal EU markets, General solar energy potential among the EU states, etc.)

Thermal storage market in 2020

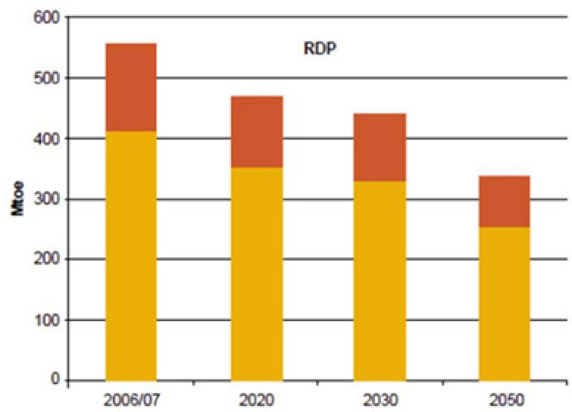
- Thermal storage in 2020 – **hot water storage tank** domination
- Other technologies (e.g. latent heat storage in PCMs) are not widely deployed
- The market for TES solutions associated with solar thermal and other renewable energy systems will significantly increase, partly driven by legislation and regulation

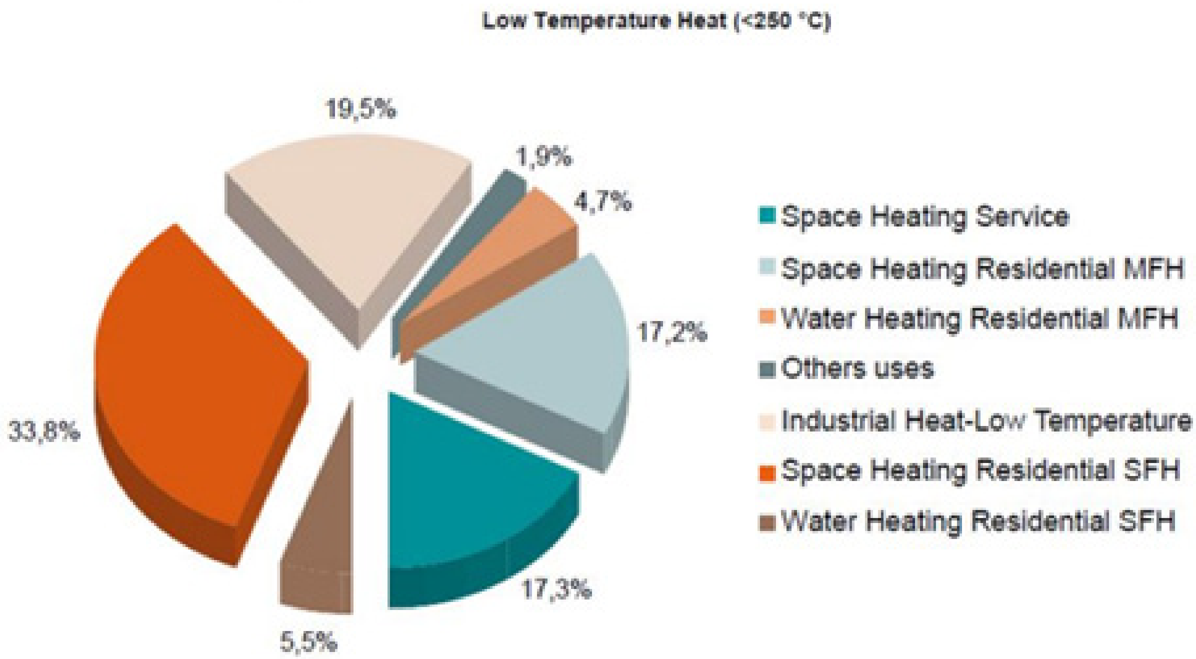
Thermal storage market potential

The heating demand under the ‘Full Research, Development and Policy (RDP) Scenario’ in the EU. The yellow bars indicate low-temperature heat (T < 250 °C) and the red bars indicate high temperature heat (T > 250 °C).

Source: 2020-2030-2050 Common Vision for the Renewable Heating and Cooling sector in Europe, European Technology Platform on Renewable Heating and Cooling

Heating demand and distribution of use in the EU.





The distribution of low-temperature heat by type of use in the EU (2006).26
MFH: Multi-family House, SFH: Single-family house.

Year [-]	2020	2030	2050
Total low-temperature heat demand [PJ][a]	14,700	13,650	10,500
Demand built environment [PJ][b]	11,760	10,920	8,400
Storage demand [PJ][c]	2,940	2,730	2,100
Market development [%][d]	4%	15%	47%
Total thermal storage market [PJ/year]	**118**	**410**	**987**
Energy price [€/GJ][e]	20	24	40
Total thermal storage market [10^6 €/year]	**2,360**	**9,840**	**39,480**

Estimation of the potential thermal energy storage market

a) Total low-temperature (T < 250 °C) heat demand in the EU under the RDP scenario 106 GJ = 277.7 GWh.

b) Heat demand in the built environment includes space heating and hot water.

c) The storage demand, 25% of the heat demand is assumed.

d) Market development for thermal storage is assumed to follow the solar thermal market.

e) The increase of the energy price is based on projections of the EU.

Year [-]	2020	2030	2050
Total thermal storage market [M€/year]	2,360	9,840	39,480
Number of heat batteries [-]	$0.47 \cdot 10^6$	$1.97 \cdot 10^6$	$7.90 \cdot 10^6$
Stabilizer [m³]	$0.24 \cdot 10^6$	$0.98 \cdot 10^6$	$3.95 \cdot 10^6$
Salt [m³]	$0.94 \cdot 10^6$	$3.94 \cdot 10^6$	$15.79 \cdot 10^6$
Market penetration			
Overall EU housing stock (%)	0.2%	0.9%	3.4%
EU social housing stock (%)	0.4%	1.9%	7.4%

Estimation of the potential market size in the EU for the individual elements of CREATE's heat battery.

When extrapolated to the potential global market for thermal energy storage to the current global population of around **7 billion people**, the overall market value for thermal energy storage systems in 2030 and 2050 might even grow to **multiple times this number.**

Market barriers

- Only short-term testing of standards for validation of reliability and safety currently exists
- Users confidence should be built up
- Limited experience regarding balancing the electricity grid by converting to heat storage
- Government acceptance of grid integration is growing slowly

Conclusion

- **Huge** market opportunity for integrated heat energy storage – expected market penetration of the building stock in 2030 and 2050 is **0,9 %** and **3,4 %** respectively
- EU legislation and strategies are **favourable** for the CREATE technology
- Several non-technical market barriers need to be addressed

CREATE project

Stable & compact materials

Efficient and high power energy discharge

Long lifetime

Safe and reliable operation

Affordable technology

Future value chain

Partners

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CALDIC

DOW

TNO innovation for life

POLAR

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FENIX.TNT

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