SELF CONSUMPTION OF RENEWABLE ENERGY BY HYBRID STORAGE SYSTEMS

Training Course on Thermal Energy Storage for Heating, Cooling and DHW for Buildings

Different energy storage solutions and their importance for the decarbonization of buildings

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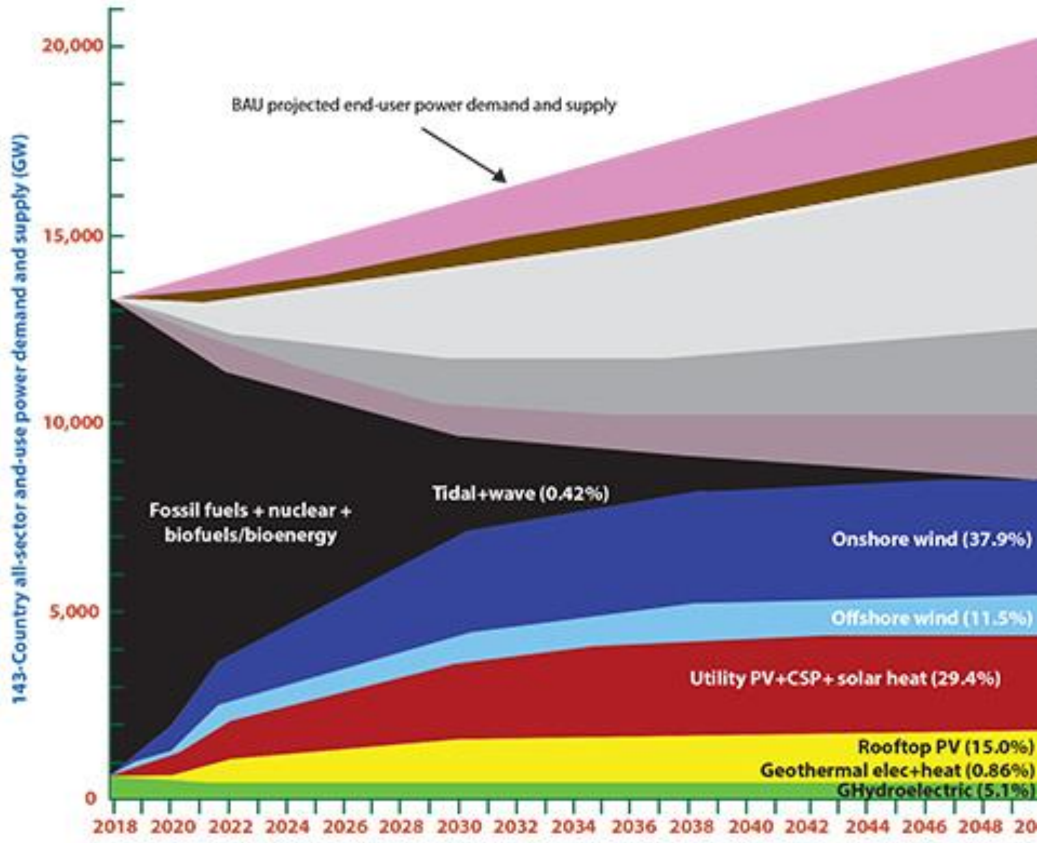
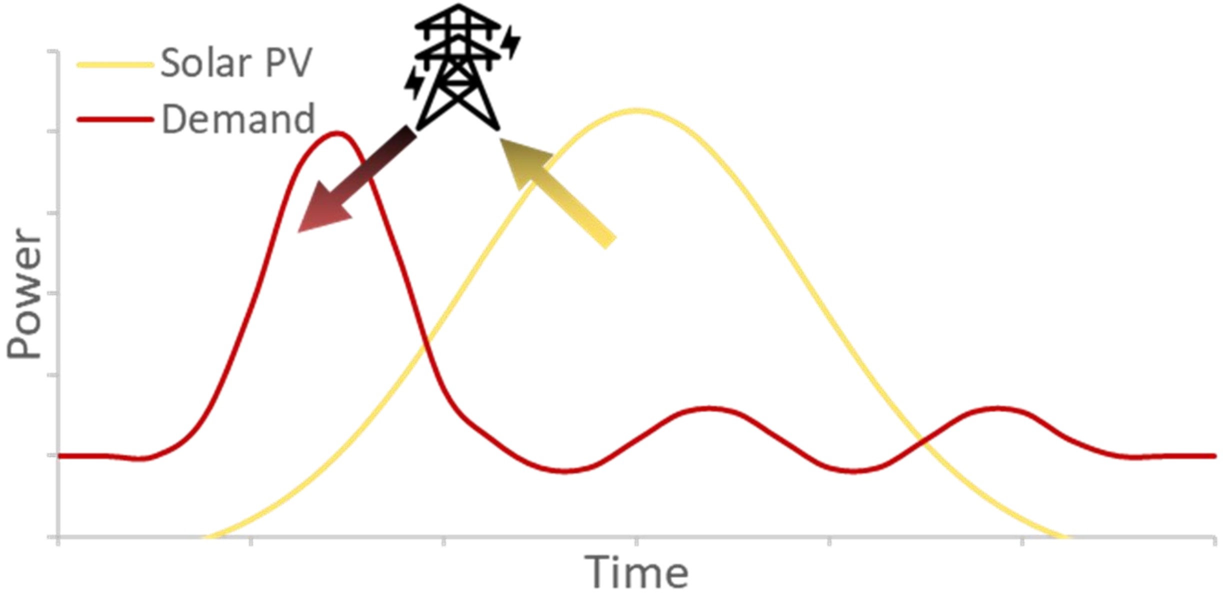
ADENE, Lisbon, Portugal, 1st of April 2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 766464.

What is going on? → Energy Transition





A Warmer World

Grid operators struggle with volume of connection requests from renewables

Sabri Ben-Achour | Feb 7, 2022

Heard on: MARKETPLACE

Watts up: Dutch electric grid is at capacity

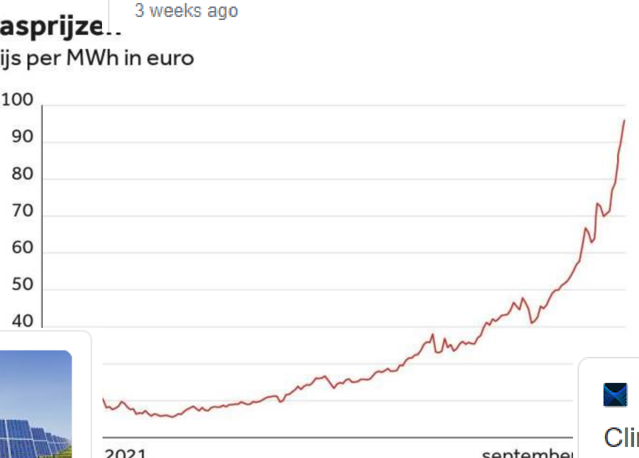
September 3, 2021

Reuters

Euro zone consumers in for a shock as power bills soar

But higher energy costs hitting households at home and at the petrol pump - with oil rising by half and wholesale prices for natural gas...

3 weeks ago



Reuters

Explainer: Why Europe faces climbing energy bills

Wholesale gas prices up over 300% last year · High prices expected to continue this year and next · Rising wholesale energy costs are passed on to...

5 days ago

The European Sting

Solar energy: how to start a rooftop revolution

The sluggish progress doesn't stem from lack of information or low public ... Energy consumption and production contribute to two-thirds of...

6 days ago

McKinsey

Climate change impact on real estate

Green buildings to attract more tenants. Developers and property managers can invest in developing green buildings or retrofitting older...

3 days ago

The Telegraph

Homes risk energy rating downgrade if they install a heat pump

A Whitehall source said: "We are aware of this problem and it is being reviewed." The Conservative MP Craig Mackinlay, the chairman of the Net...

1 day ago

Reuters

Analysis: Governments no match for markets in European ...

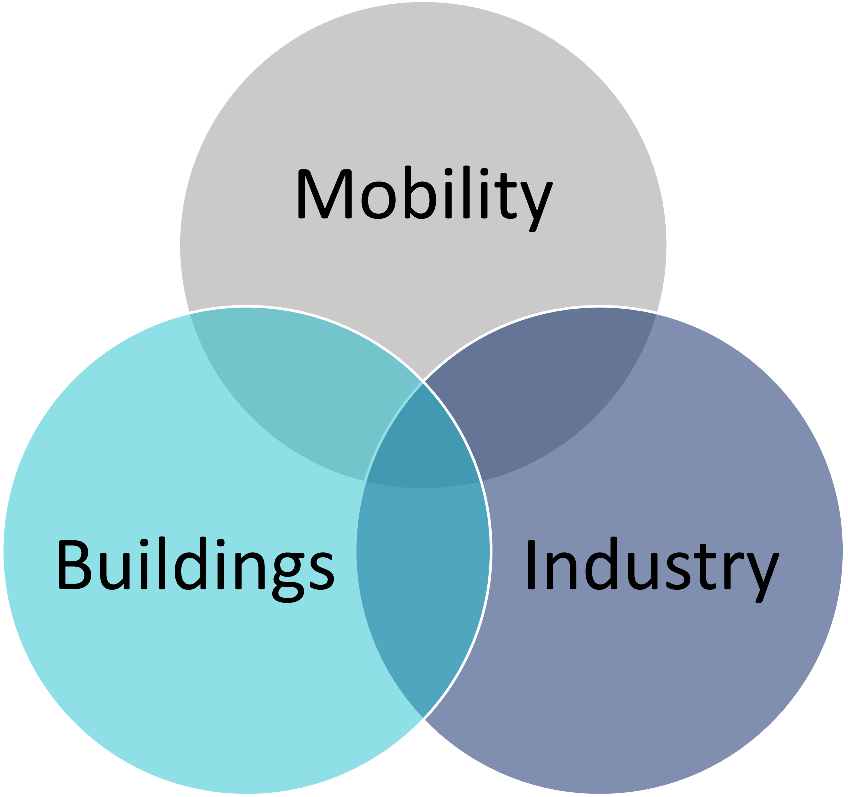
BofA analysts estimate the average western European households spent around 1,200 euros ($1,370) a year on gas and electricity in 2020. Based on...

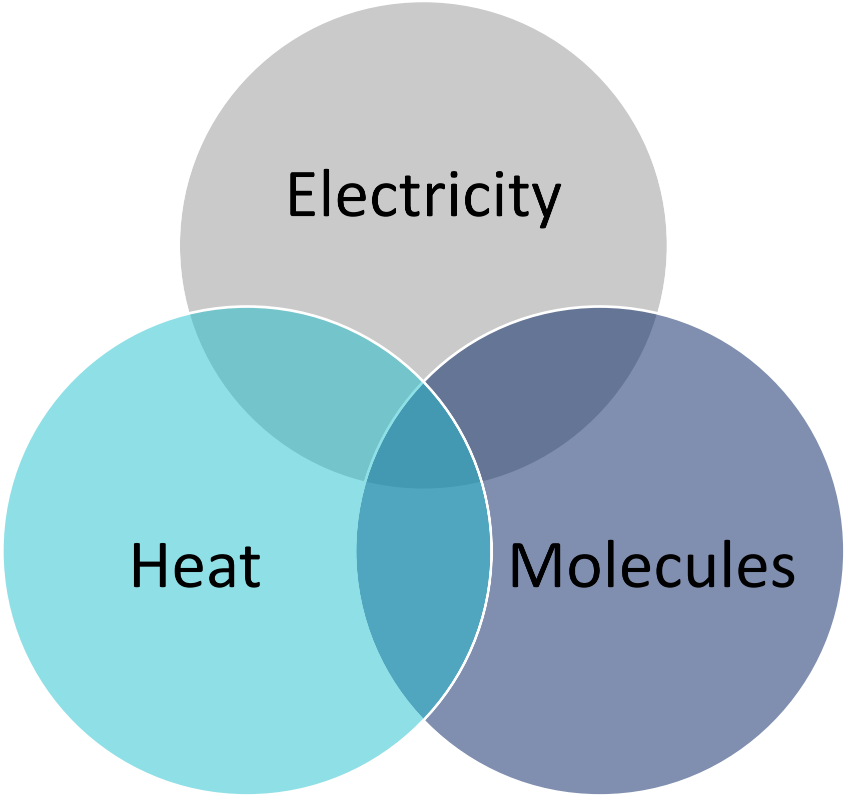
3 weeks ago

What could be the solution?

Limited grid capacity + Maximizing local production ➔ Maximizing self-consumption

Solutions fit for purpose

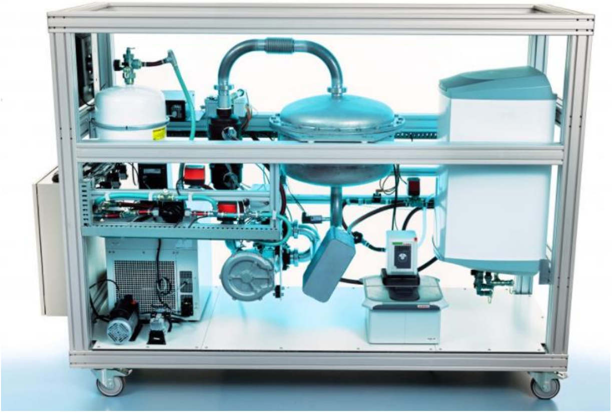




Different energy storage solutions

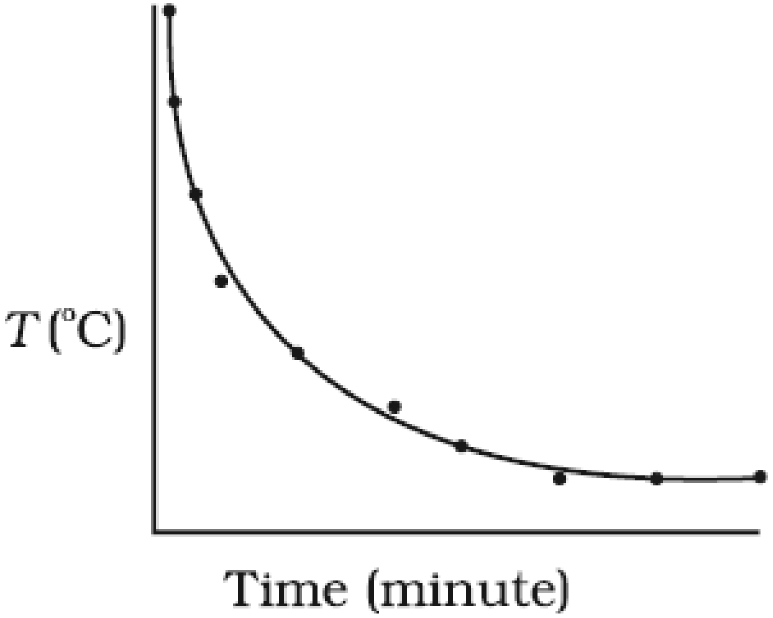
- Thermal energy storage solutions
  - Sensible thermal storage
  - Thermal storage based on Phase change materials
  - Thermochemical energy storage
  - Chemical looping energy storage

A lot of solutions are out there



Sensible thermal storage

Storage of heat in a form of warm liquid or solid



The main issue → stuff cools down

Newton Energy Solutions

+

+

=

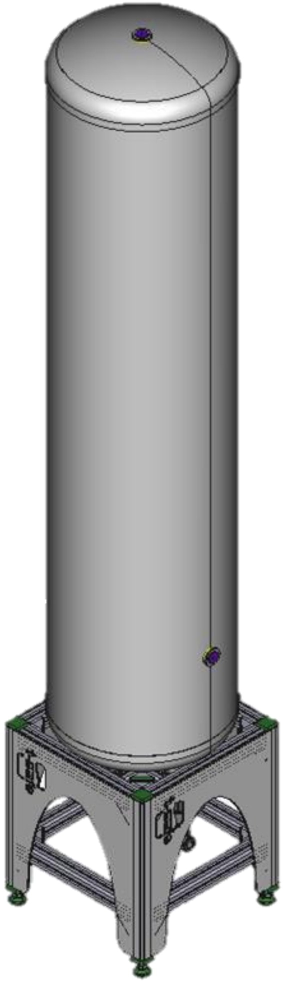
High energy density

Low energy losses

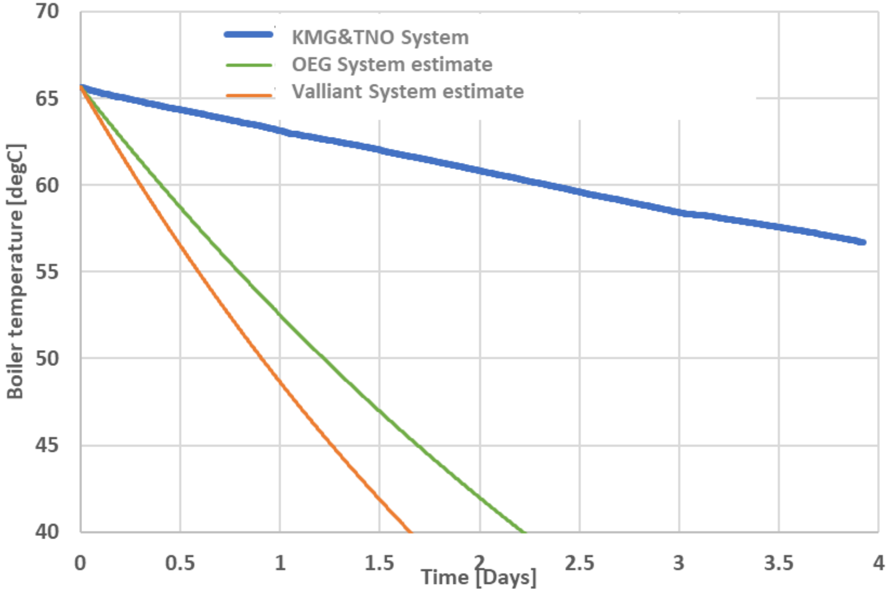
Low costs

NEStore

NEStore performance

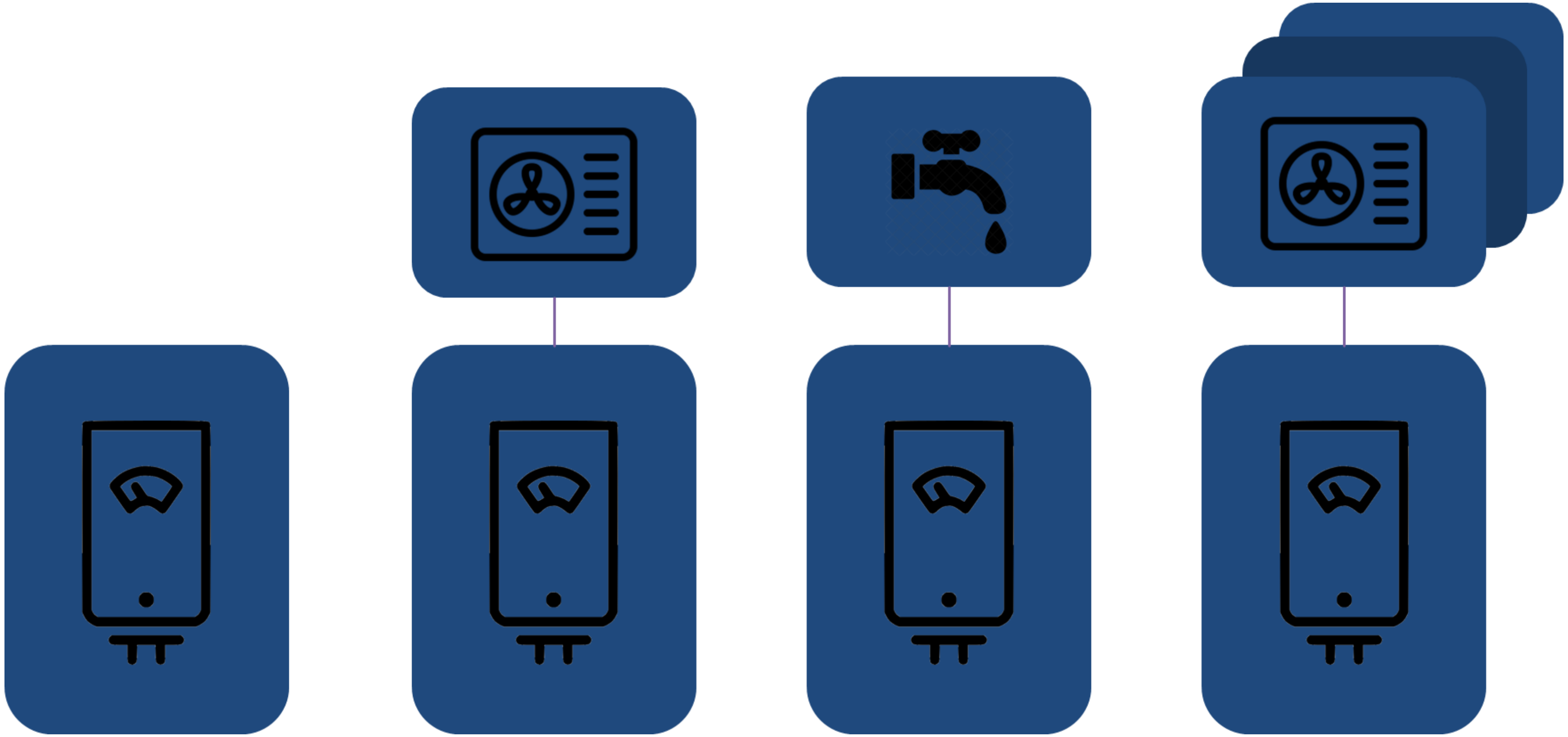


- Added value lies in:
  - System approach
  - Efficiency
  - Self reliance on energy
  - Energy grid decongestion
  - OPEX reduction and reduction of CO_2



Market and our entry

Our modular integration



Pathway to the market

#systems	10-20	100-1000	1000+
#designs			
Channel	direct to end-user →	through installers →	whole sales
Year	1	2	3

Production scale up and market introduction

Thermal storage using PCMs

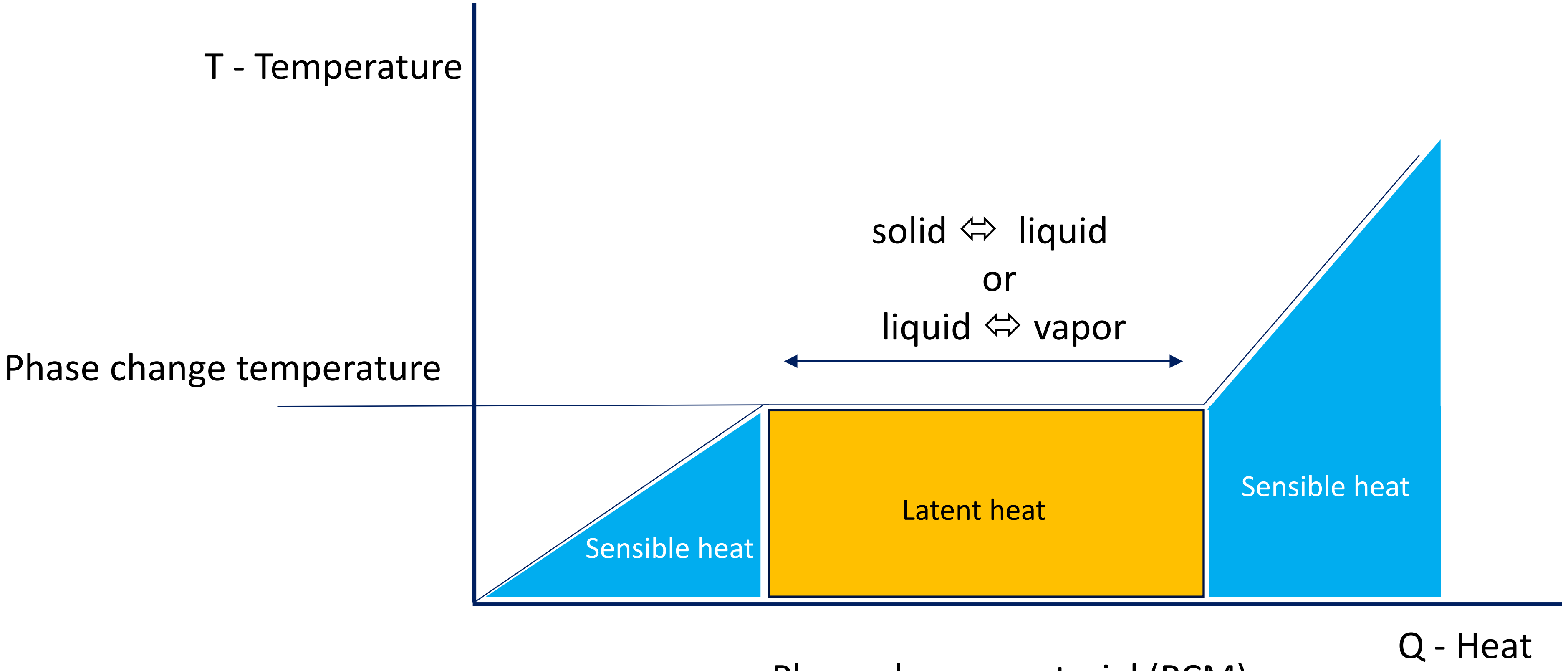
- The heat can be stored by **sensible** or **latent heat**.

- In **sensible heat**, the input and output of heat cause a **variation of the temperature** values of the substance, in which microscopic terms mean changes in its microscopic kinetic energy.

- In **latent heat**, the input and output of heat cause a **change of the phase** (solid↔liquid↔vapor). The **temperate remains constant** for a pure substance or occurs in a limited range of temperatures for a non-pure substance during this process.

Thermal storage using PCMs

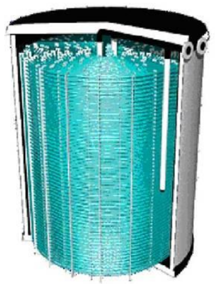
- Latent heat.



Phase change material (PCM)

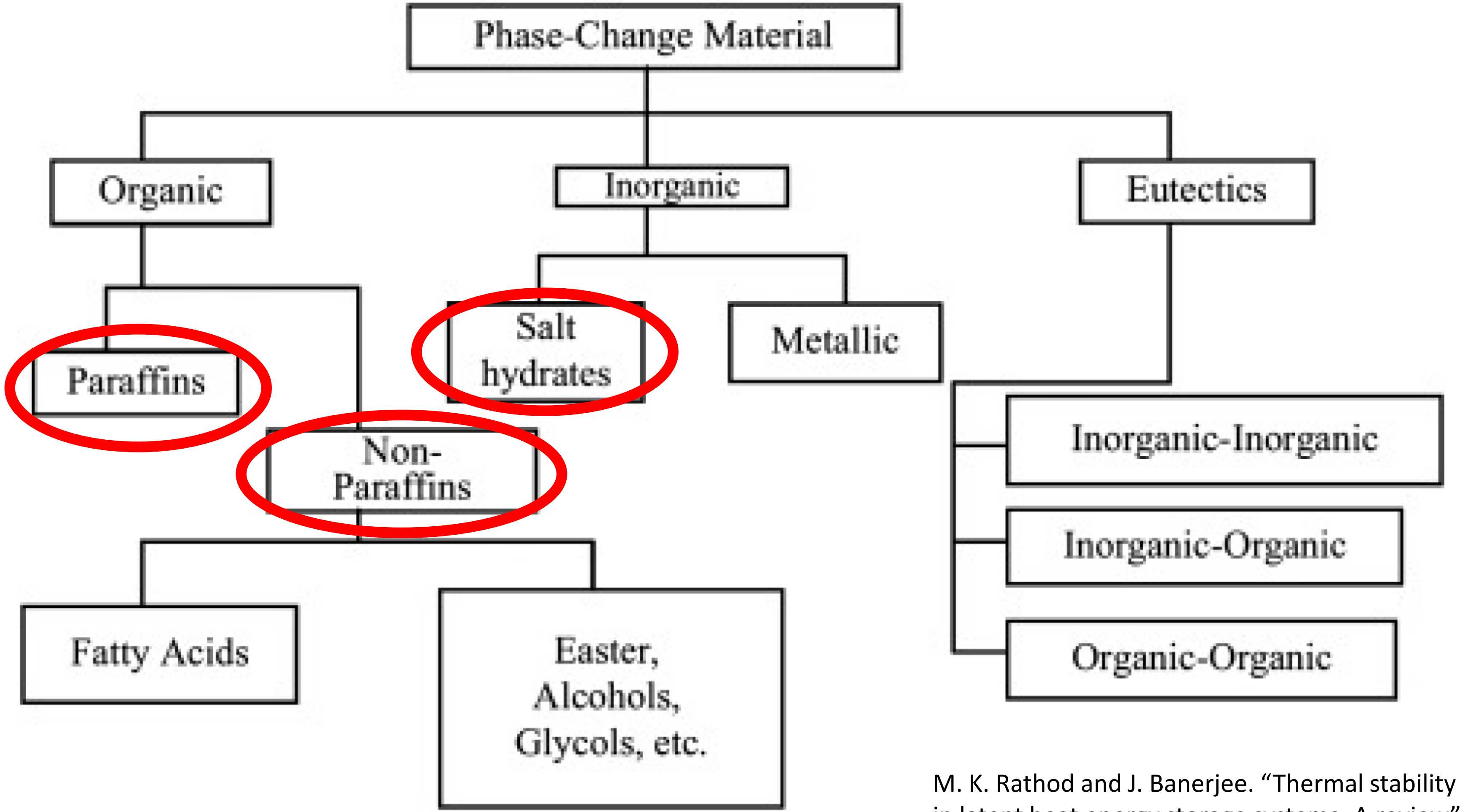
Thermal storage using PCMs

- The most know PCM (ice-water-steam)
- Classic thermal storage solution for cooling using PCM - **ice banks storage**
  - Two important limitations (due to its melting temperature, 0 ^oC)
    - Not applicable to space heating and DHW preparation;
    - Temperature too low for cooling affecting chiller efficiency.

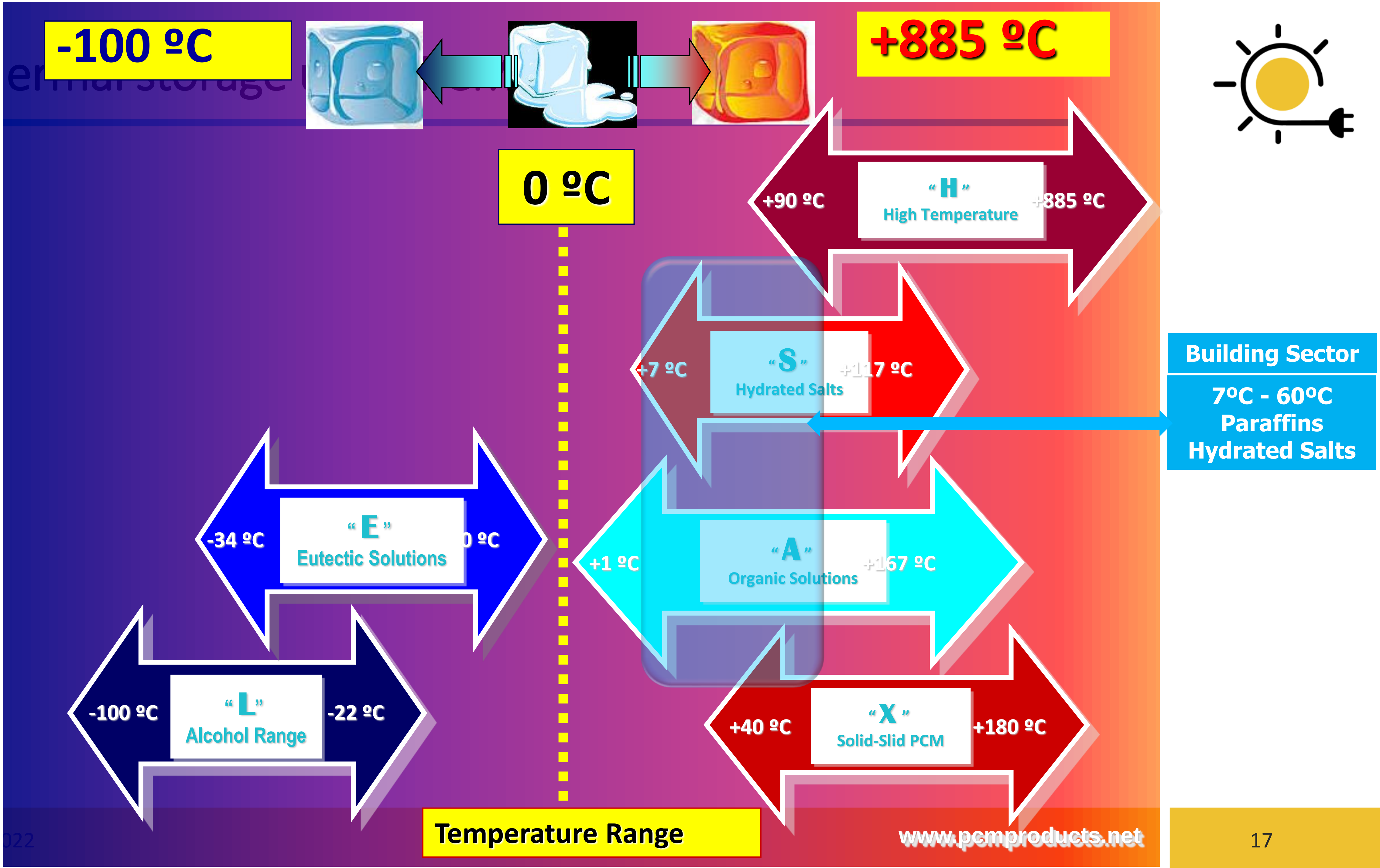


Need to find other PCMs with different melting/solidification temperature values

Thermal storage using PCMs



M. K. Rathod and J. Banerjee. "Thermal stability of phase change materials used in latent heat energy storage systems: A review". In: *Renewable and Sustainable Energy Reviews* 18 (2013). chp2.3, pp. 246–258



-100 ºC
+885 ºC
0 ºC
+90 ºC
"H"
High Temperature
+885 ºC
+7 ºC
"S"
Hydrated Salts
+117 ºC
-34 ºC
"E"
Eutectic Solutions
0 ºC
+1 ºC
"A"
Organic Solutions
+167 ºC
-100 ºC
"L"
Alcohol Range
-22 ºC
+40 ºC
"X"
Solid-Slid PCM
+180 ºC
Temperature Range
www.pcmproducts.net
Building Sector
7ºC - 60ºC
Paraffins
Hydrated Salts

Thermal storage using PCMs

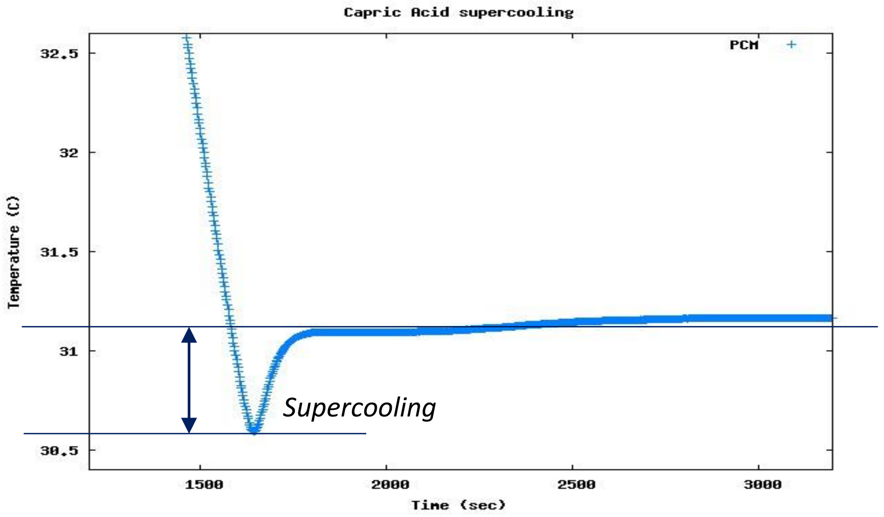
- Important thermophysical, kinetic and chemical properties:
  - **High energy density** (high latent heat per unit volume and high specific heat);
  - **Phase change temperature** suitably matched to the application;
  - **Low vapor pressure** at operational temperature. To avoid extra costs or danger of rupture due to vessel pressure, the vapor pressure should be as low as possible;
  - **Chemical stability**. Chemically stable materials will allow for PCMs to operate at the given temperature and with the given effect for a longer period, avoiding their degradation;

Thermal storage using PCMs

- Important thermophysical, kinetic and chemical properties:
  - **Low corrosion rate** to avoid degradation of the metals parts of the heat exchangers and containers that will shorten your life span;
  - **Not hazardous** and **not poisonous products**, to be allowed to be used in buildings;
  - **Low/No flammability**. Strict laws with regards to fire safety must also be fulfilled by PCMs;

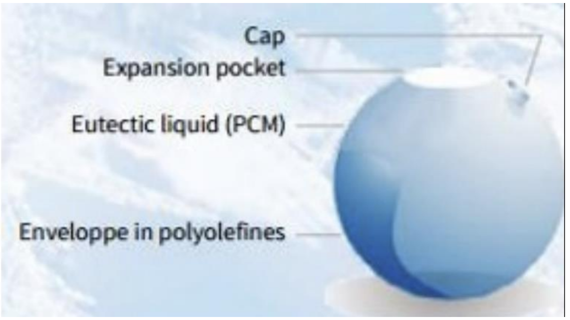
Thermal storage using PCMs

- Important thermophysical, kinetic and chemical properties:
  - **Small degree of supercooling** and a **high rate of crystal growth**. Supercooling will alter the temperature of the phase change at the beginning of the process. An attractive PCM should have an exact phase change temperature so that the phase change is predictable to allow a material to be selected correctly for optimal design;

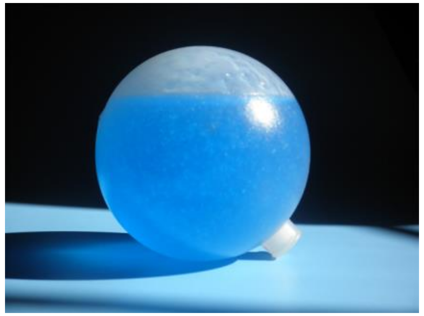


Thermal storage using PCMs

- Important thermophysical, kinetic and chemical properties:
  - **Low thermal expansion coefficient** throughout phase change. A large volume change will cause mechanical stress on container walls or reduce the effective volume of PCM inside;



CRISTOPIA Energy Systems

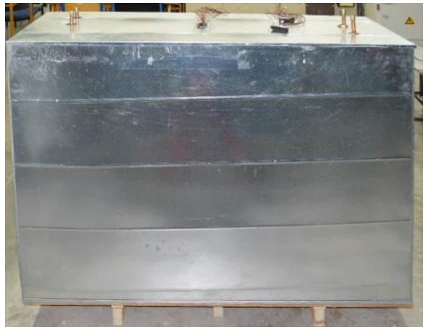


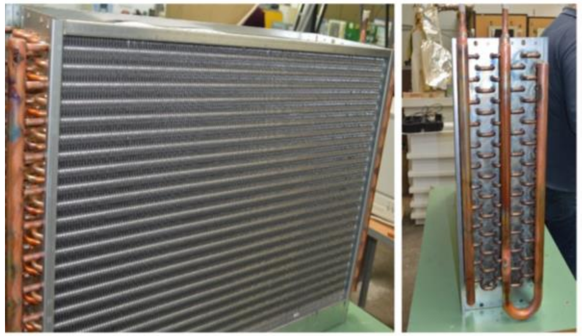
Dhruva Technologies Pvt. Ltd

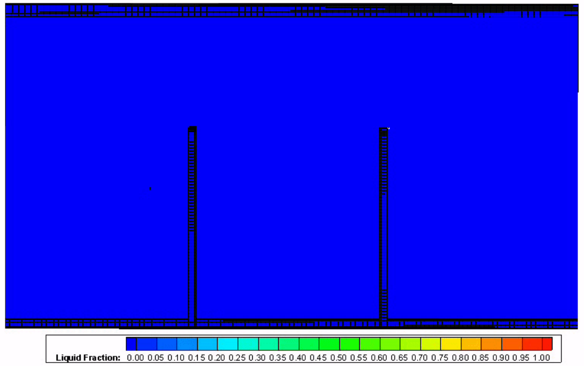
Thermal storage using PCMs

- Important thermophysical, kinetic and chemical properties:
  - **High thermal conductivity** to allow the PCM to absorb or release heat at a higher rate. This can be an important parameter that can limit the use of some PCMs, depending on the application.

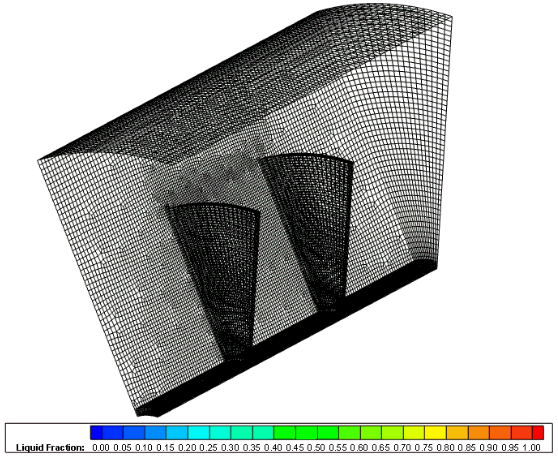
Values of heat storage (kWh) *versus* *values of heat transfer rate (kW)*







Melting 0-4188s (midplane slice)



3D time evolution of melting

Thermal storage using PCMs

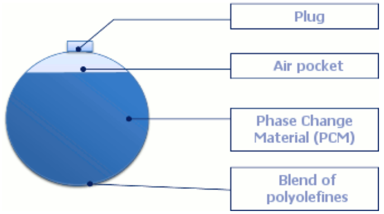
- Important thermophysical, kinetic and chemical properties:
  - **Use materials that are abundant and cheap**. To make the technology more attractive and possible to use at a large scale it is important that the materials to be used are abundant and cost-effective.

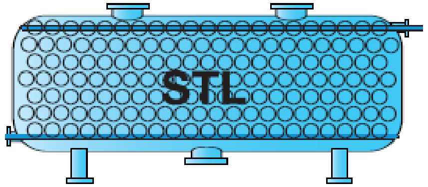
Thermal storage using PCMs

PCM's			Advantages	Disadvantages
Organic	Paraffins	Carbohydrates	Simple to use; Chemically inert; Stability for a high number of cycles; Low steam pressure; Low melting temperature; Low Corrosivity; Small volume variation in phase changes; No super-cooling; Non toxic; Recyclable;	Usually more expensive; Low density and latent heat capacity; Low thermal conductivity; Ill-defined phase shift temperature; Usually flammable; Often incompatible with plastic packages;
	Non Paraffins	Fatty acids, Alcohols and Glycols.		
Inorganic	Salt hydrates	$CaCL_2 6H_2O$, $LiClO3H_2O$, ...	Low cost and high availability; Good density and latent heat capacity; High thermal conductivity; Well-defined phase change temperature; Non flammable; Compatible with plastic containers; Usually recyclable;	Occurrence of segregation; Needs more preparation care; Low longevity, needs additives to prolong the life span; Prone to super-cooling phenomenon; Potentially corrosive to some metals; High steam pressure;
	Metallic	Mercury, Gallio, ...		
Eutectics	Organic-Organic		Strict melting temperature; High thermal storage capacity;	Usually little technical information is available on thermophysical properties;
	Inorganic-Organic			
	Inorganic-Inorganic			

Thermal storage using PCMs

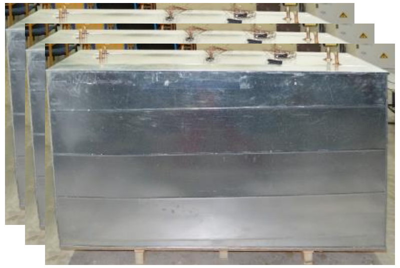
Encapsuleted PCM (www.pcmproducts.net)





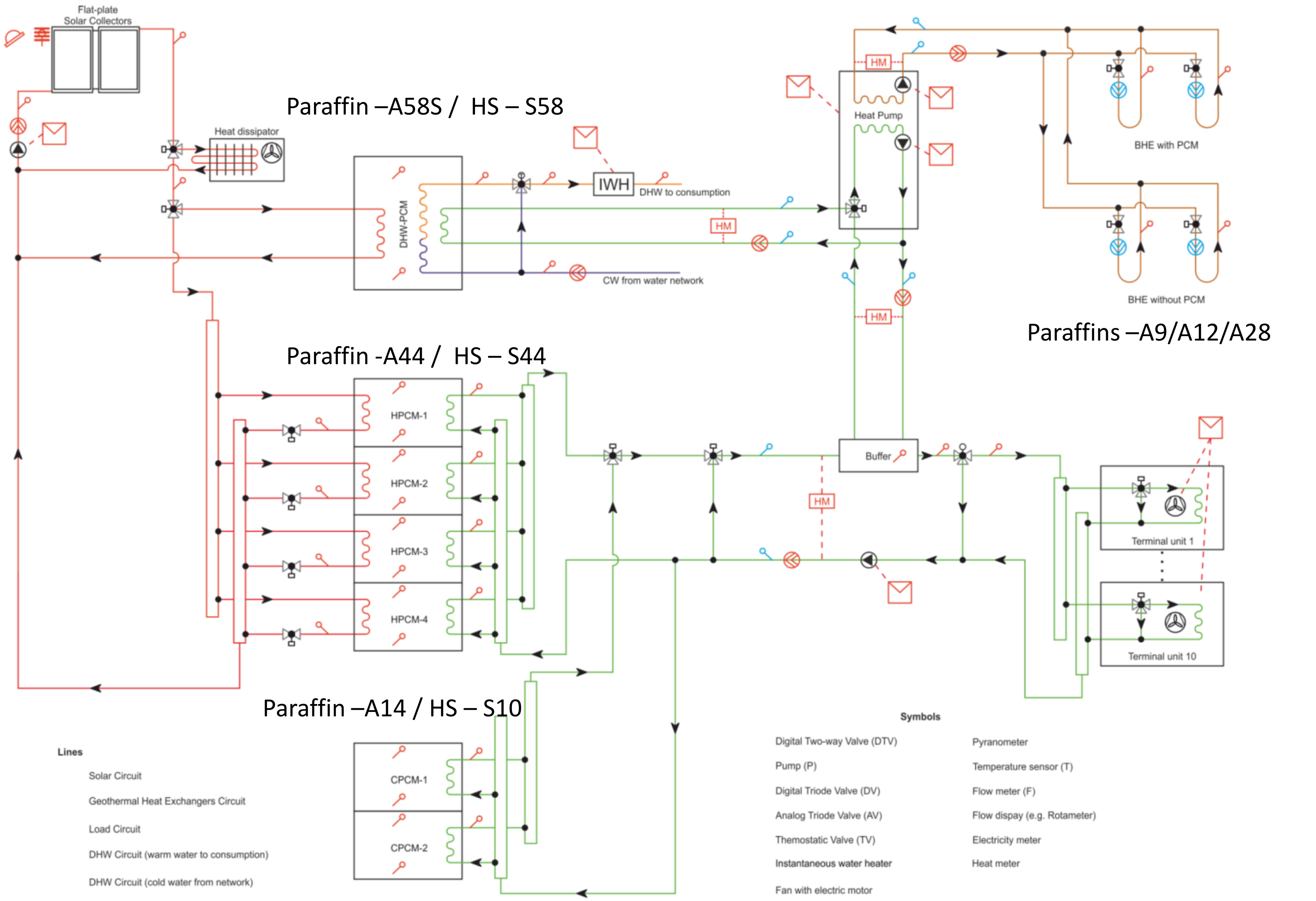
Source: Cristopia

Immersed PCMs in HEXs



Thermal storage using PCMs

- Examples of applications:
  - TESSe2b project



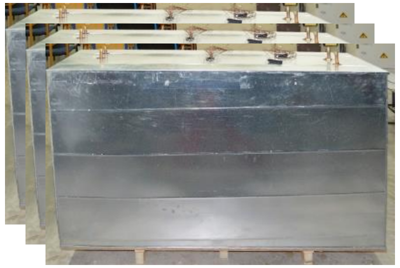
TESSE²B the smart energy storage

This project has received funding from the European Union's Horizon 2020 RIA under Grant Agreement No 680555.

Thermal storage using PCMs

- <u>TESSe2b project</u>

PCM Tanks (paraffins)

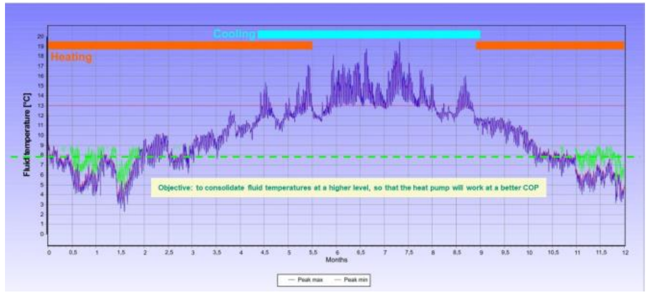


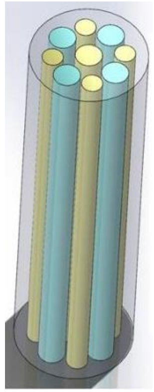
- Volume: 160 l (based in HEx volume).

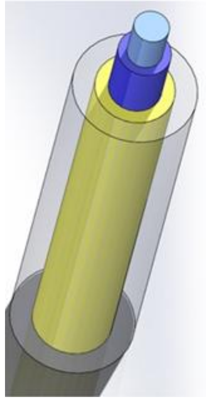
PCM Tanks (hydrated salts)

- Volume of each small tank: 17 l (based in HEx volume).

PCM Enhanced BHEs for Ground Source Heat Pump







Thermal storage using PCMs

- New developments:

  - For the thermal energy storage systems based on PCMs to be profitable, it is necessary to **reduce the costs** of the systems:

    - **Reducing the cost of the PCM**, based in new materials and in massive production;
    - **Integrate** into more **complex energy systems** with **advanced management systems**;
    - Develop **more efficient commercial equipment**, mainly based on **PCMs immersed in HEXs**;

  - It is necessary to **develop standards** that define methods for characterizing, manufacturing and evaluating the performance of PCMs and their systems to **give confidence to the market**;

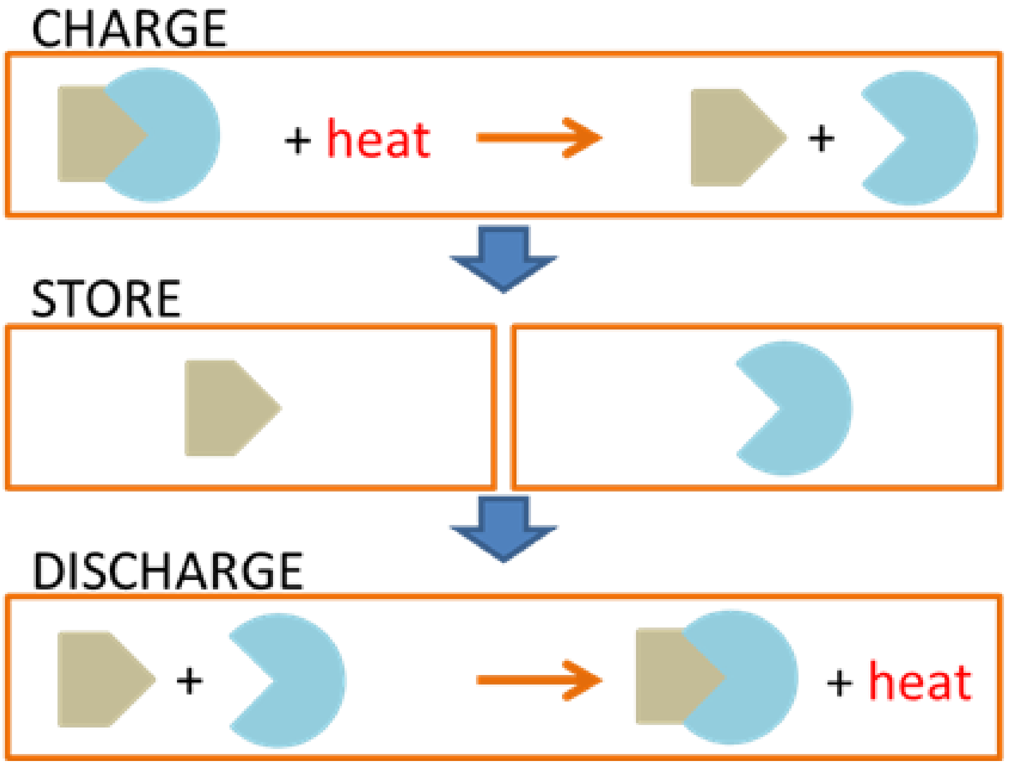
  - Some of the **results** of several recent **European projects** on the use of PCMs for thermal storage are expected to **come to market soon**.

BatterHeat
Store better heat.

Thermochemical thermal storage

- Chemical reaction: Absorption / Desorption
- Advantages
  - Loss-free heat storage
  - Very compact
  - Potentially cost-effective
  - No scarce materials
- Disadvantages
  - More complex than water storage
  - Low-temperature source required

- TNO: 2 concepts under development
  - Closed-loop (see www.cellcius.com)
  - Vacuum ("BatterHeat", current presentation)



Comparison to other solutions

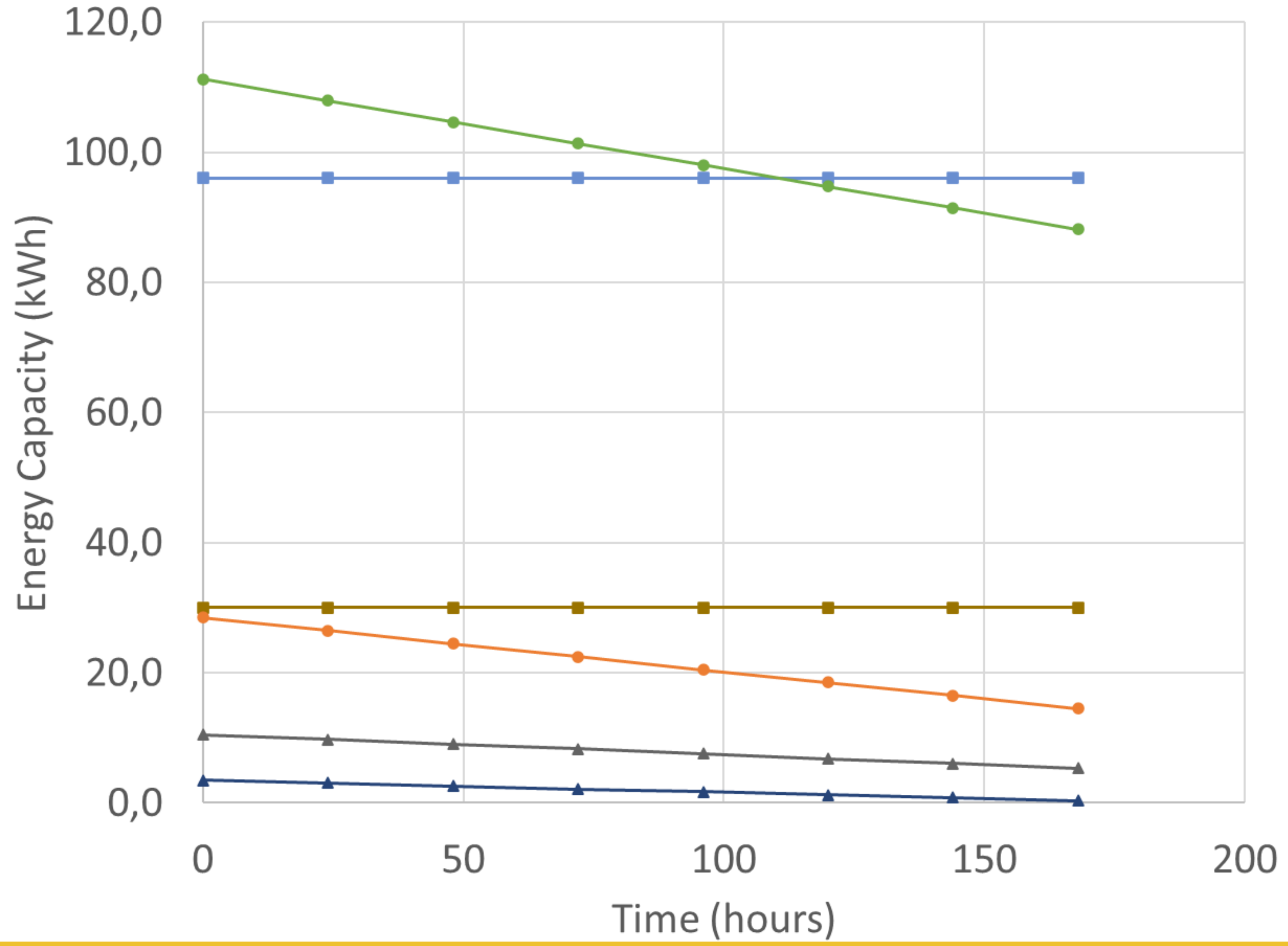
€ Q/V

€ Q/V

€ Q/V

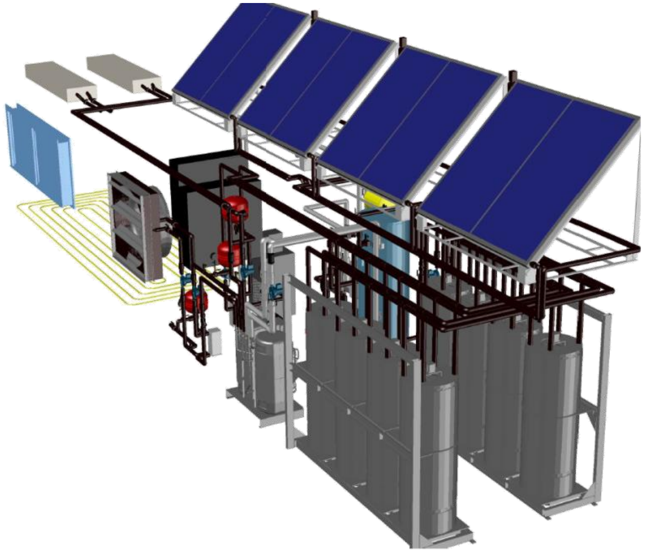
Loss-free!

Energy capacity in 1 week's time



- BatterHeat system: loss-free, so keeping its full capacity
- Commercial water buffers: large absolute losses (14 to 33 kWh (= 21 – 68%) losses after 1 week storage)
- PCM systems: large relative losses (3.5 to 5 kWh (= 49 - 90%) losses after 1 week storage)
- After 1 week a 300L BatterHeat heat battery has more capacity than an 800L boiler

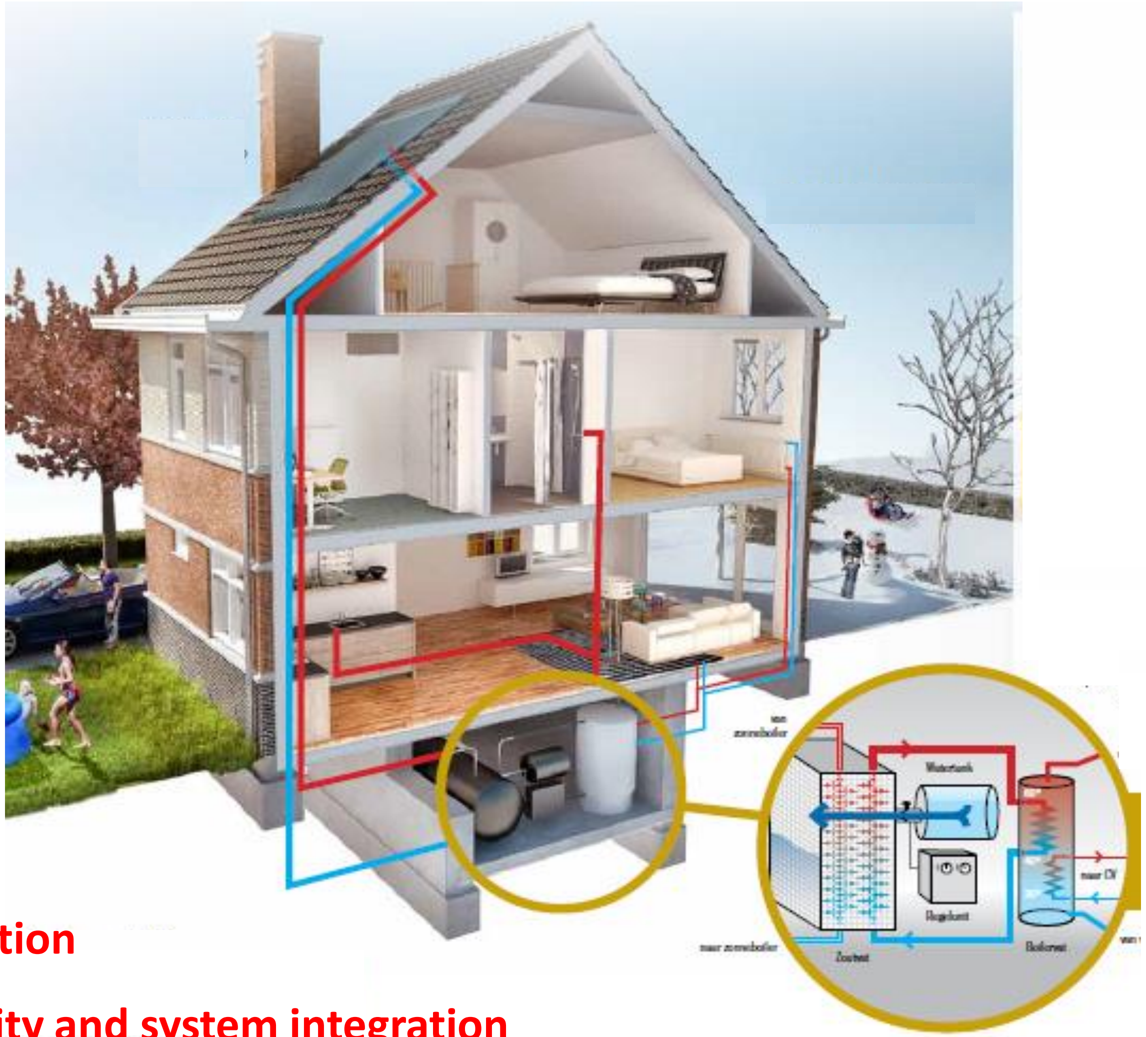
Examples of State-of-the-Art

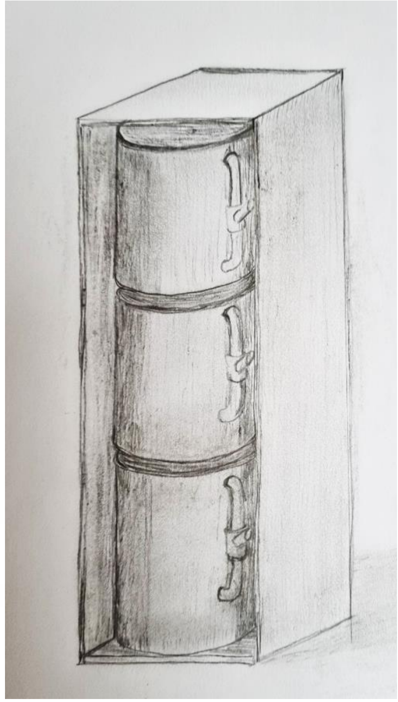


System concept (Early adopters)

Advantages:

- Better use of locally produced renewable energy
- Less network congestion
- Increased efficiency of HP





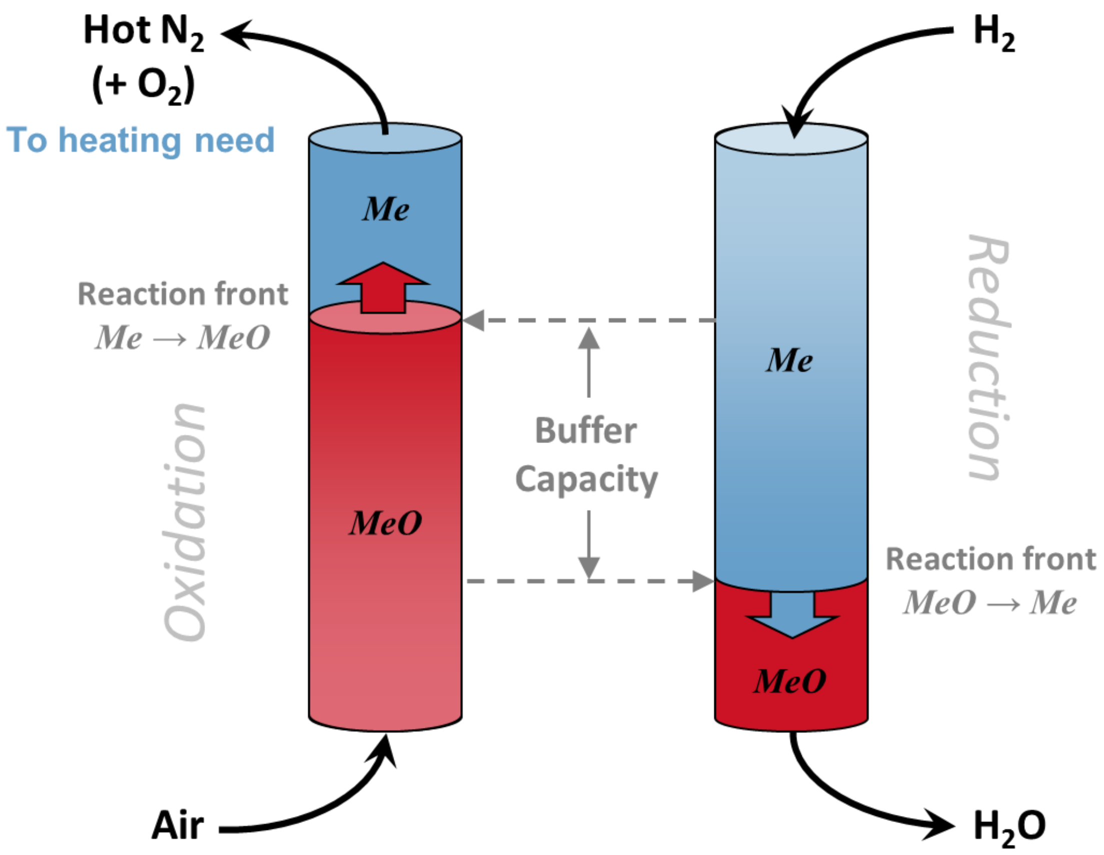
Battery with 3 modules
50x50x200cm^3
("Artist's Impression")

Cost reduction

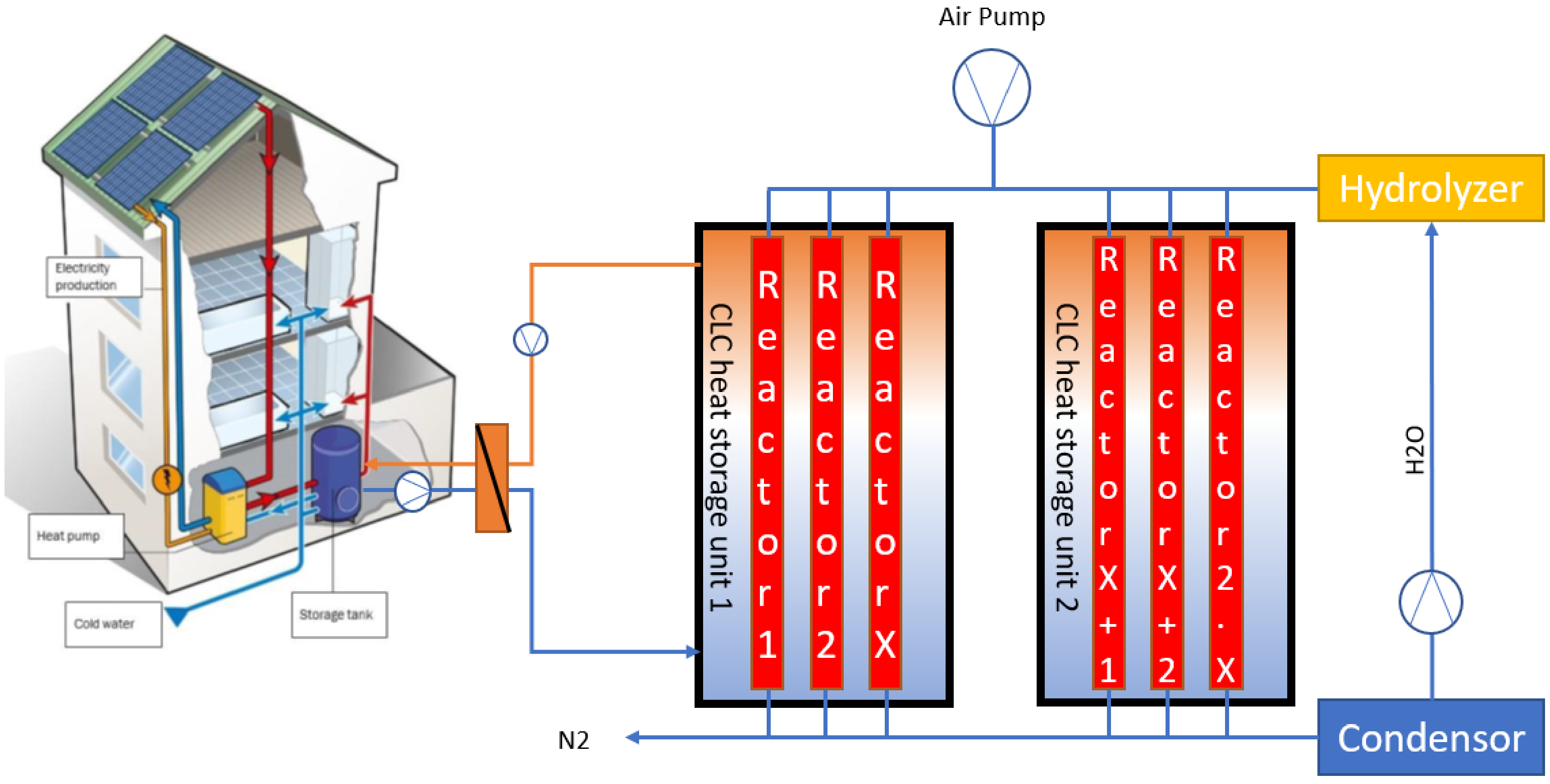
Further development → Reliability and system integration

Chemical looping energy storage (CLC)

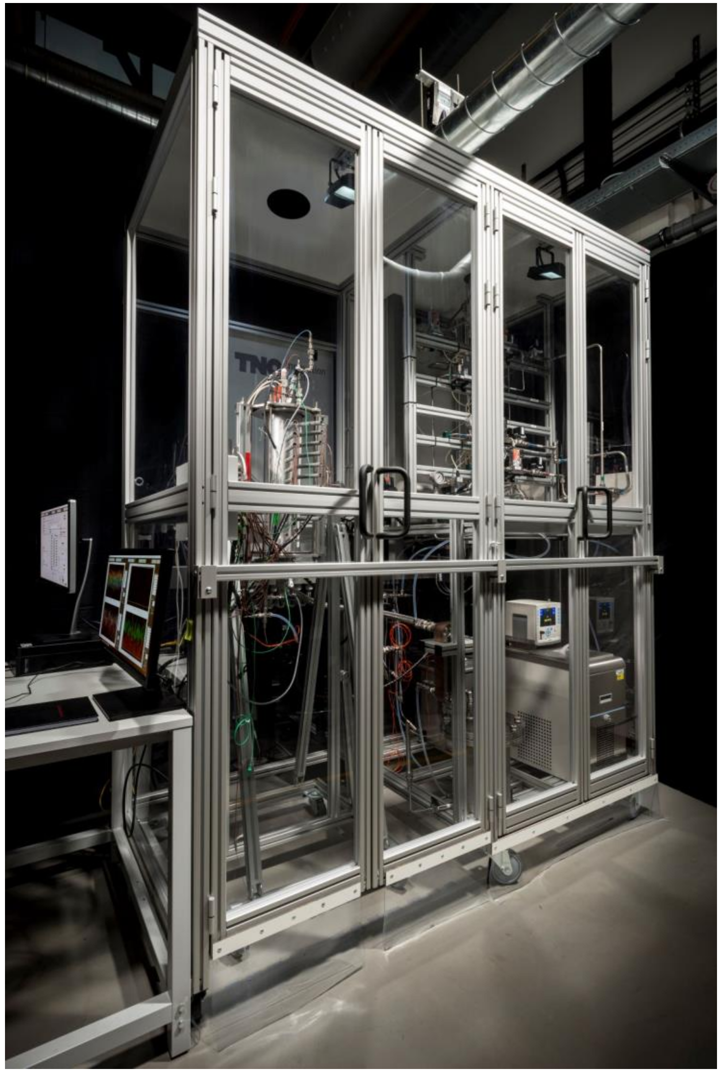
- CLC has been developed recently for power generation with inherent CO_2 separation
- A metal with specific characteristics is “looped” through oxidized and reduced states to release or store energy, respectively
- CLC technology has been adapted into Technology based on Redox reaction and thus we call it Redox Heat
- **Targeted energy storage density on system level of >1GJ/m³**

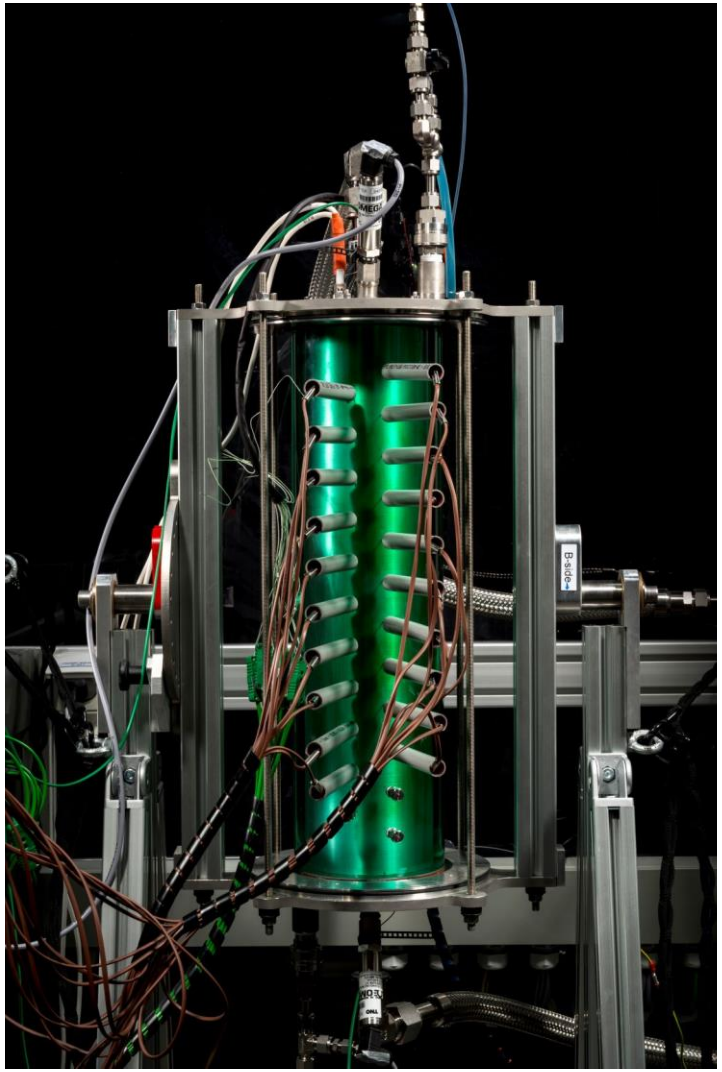


CLC and it’s interface with a building

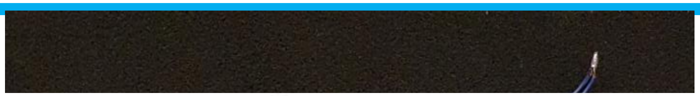


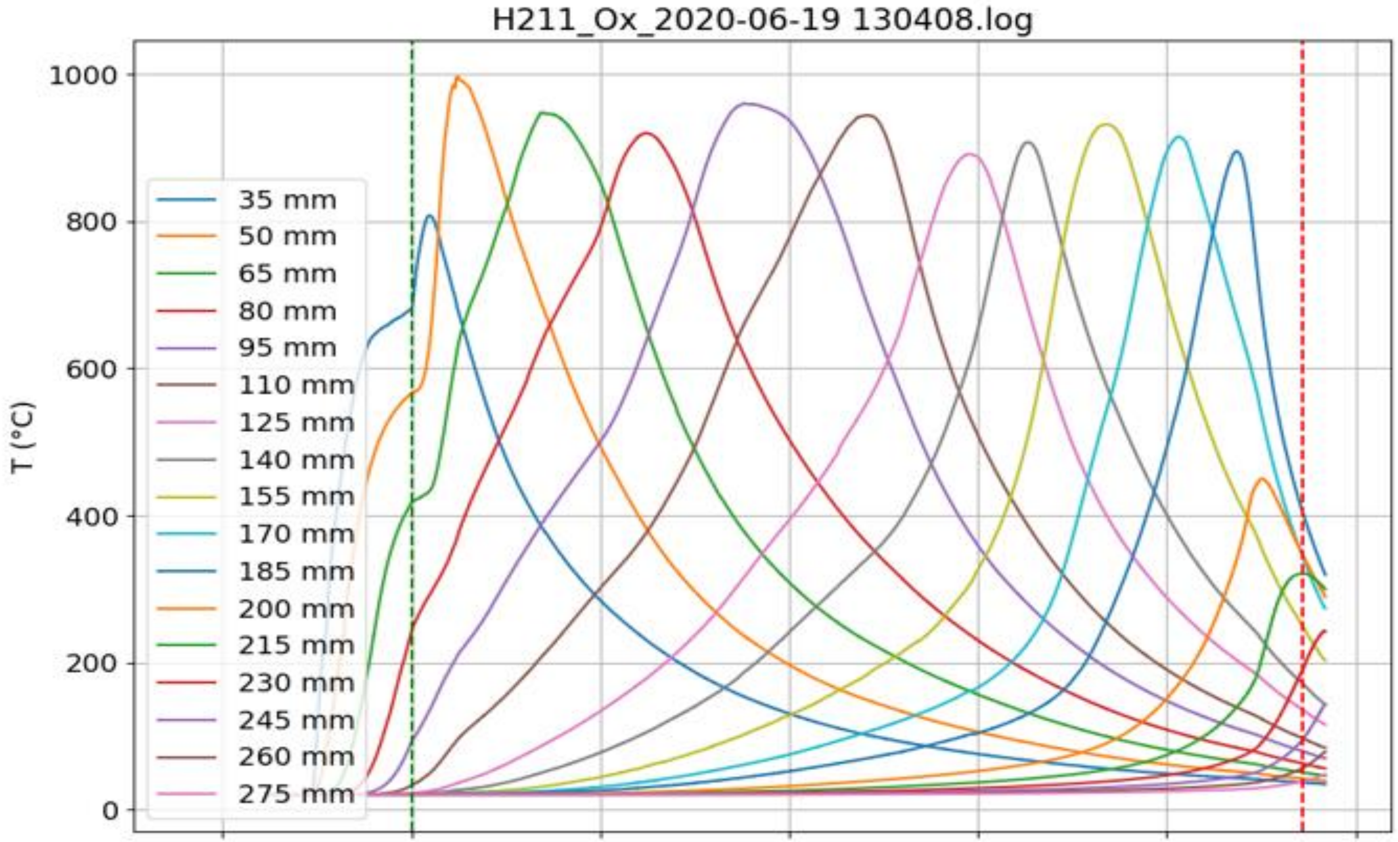
How does it look like in the laboratory?

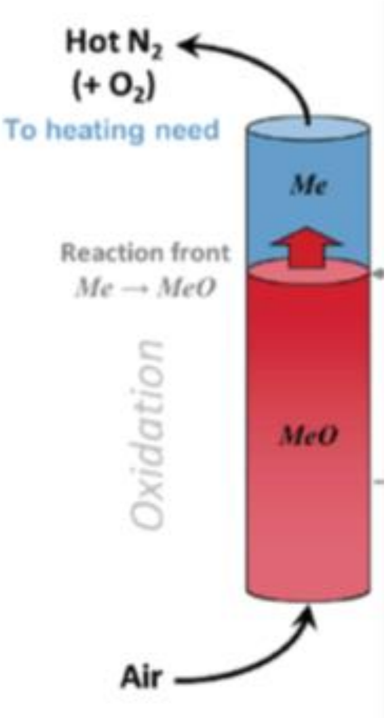




Experimental results







Further development → to increase number of cycles

Scale-up and Cost reduction are required

Conclusion and the way forward

- Sensible thermal storage (Newton Energy Solutions)
  - Production scale up
  - Market introduction
- Thermal storage using PCMs
  - Cost reduction
  - Implementation in the market of technological solutions already developed
- Thermochemical storage (Batterheat)
  - Cost reduction
  - Reliability and system integration
- Chemical looping energy storage
  - Scale-up and cost reduction
  - Performance boost → Increasing number of cycles

Thank you!

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