Multi-scale experimental characterization and management of the supercooling of Isosorbide as Phase Change Material for thermal energy storage

Arnaud Bruch, Fabrice Bentivoglio, Baptiste Boit, Awa Sy

COMBIOTES Project

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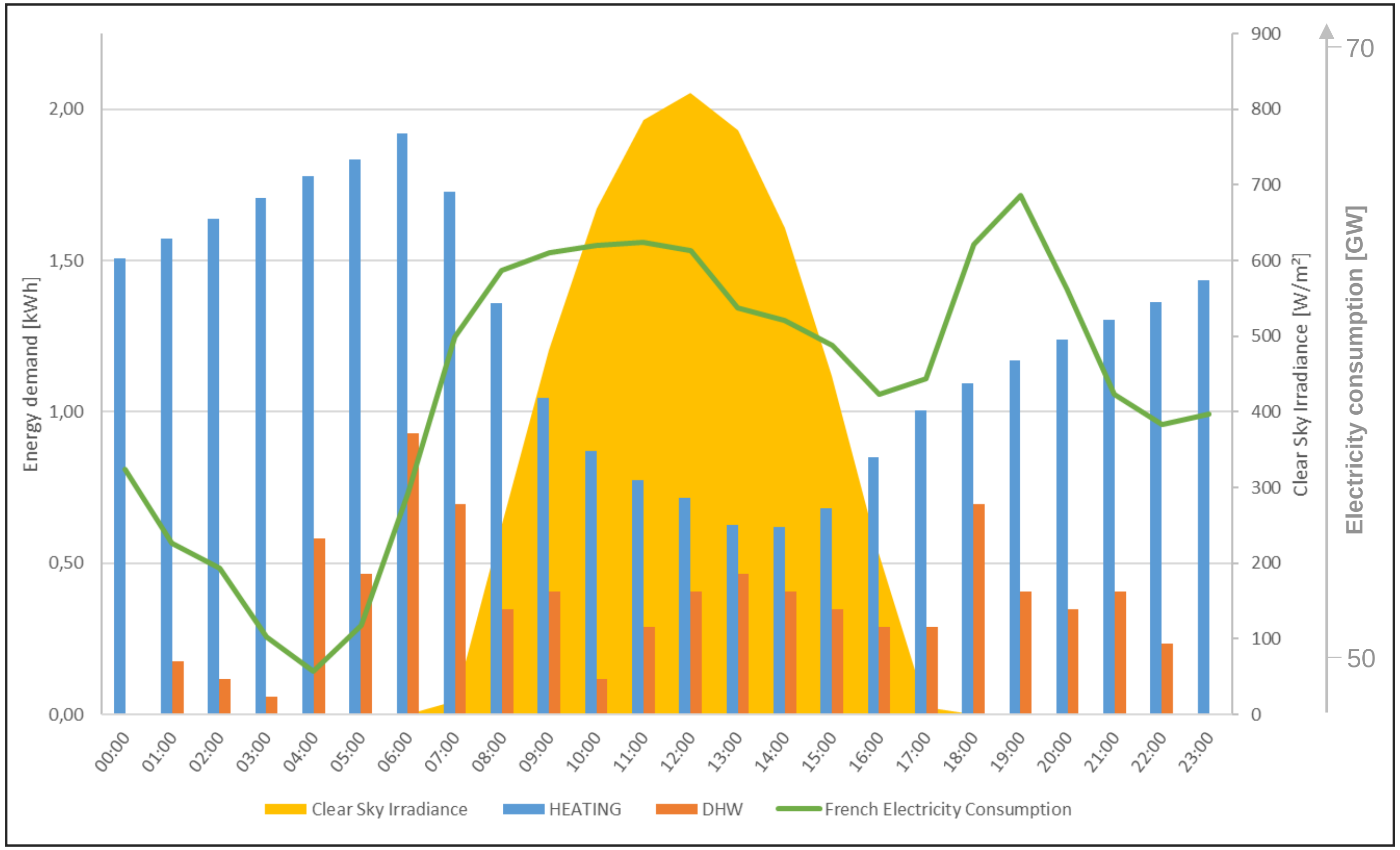
Context of the COMBIOTES project



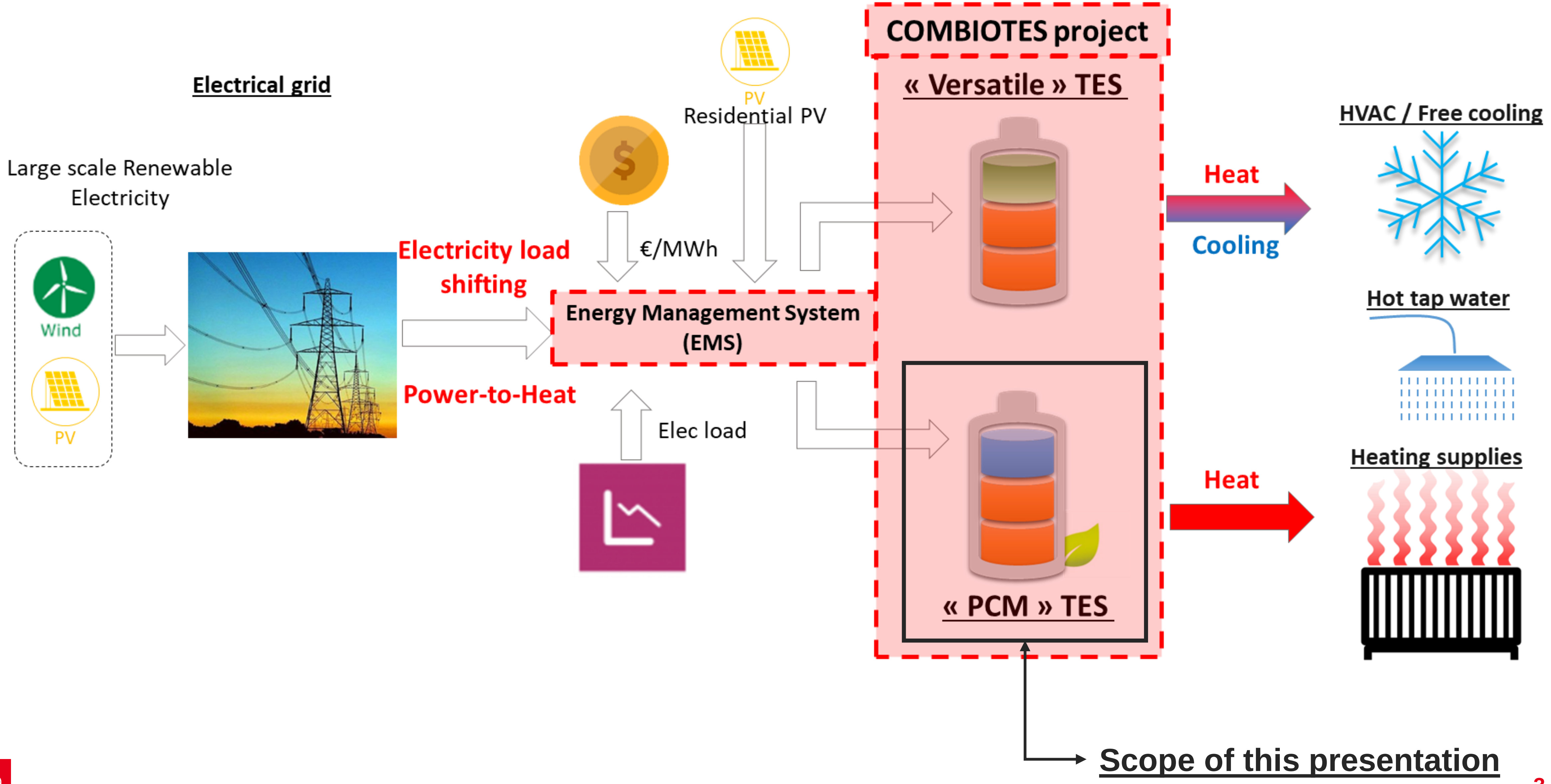
Own calculations based on data from PVGIS, DHWcalc and RTE

- Peaks of Domestic Hot Water (DHW) and Heating consumptions in the morning and in the evening
  - Concomittant with peak of electricity demand
  - In opposite phase with solar profile

Thermal storage at residential scale

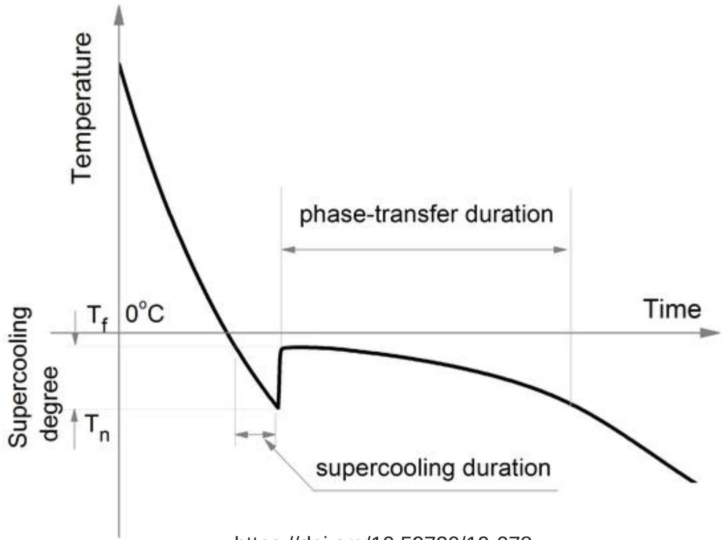
- Facilitation of solar thermal integration
- Shift of demand on electrical grid by time-decoupling between heat production and consumption

Scope of the COMBIOTES project



Context of PCM TES

- **Specifications for PCM for PCM TES for residential applications (DHW, SH)**
    - **Melting T**: in the range 50-80 °C
    - High **melting enthalpy**
    - Preferentially **bio-based** PCM
    - Low **cost**
    - **Safety** consideration
        - Non flammable
        - Non toxic
        - Non corrosive
        - etc.
- **Isosorbide** is a promising candidate, fulfilling all the criterion, except its **supercooling behaviour**



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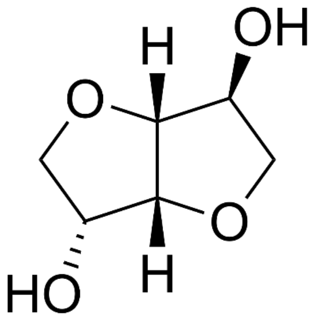


Objectives of the study

- **Experimental characterization** of Isosorbide **supercooling** and ways to **manage** it
- **Influence of the set-up size** on supercooling and its management

DSC analysis

mg
Material scale

Breaker

Hundreds of g
Phenomenological scale

PCM TES

Dozen of kg
Prototype scale

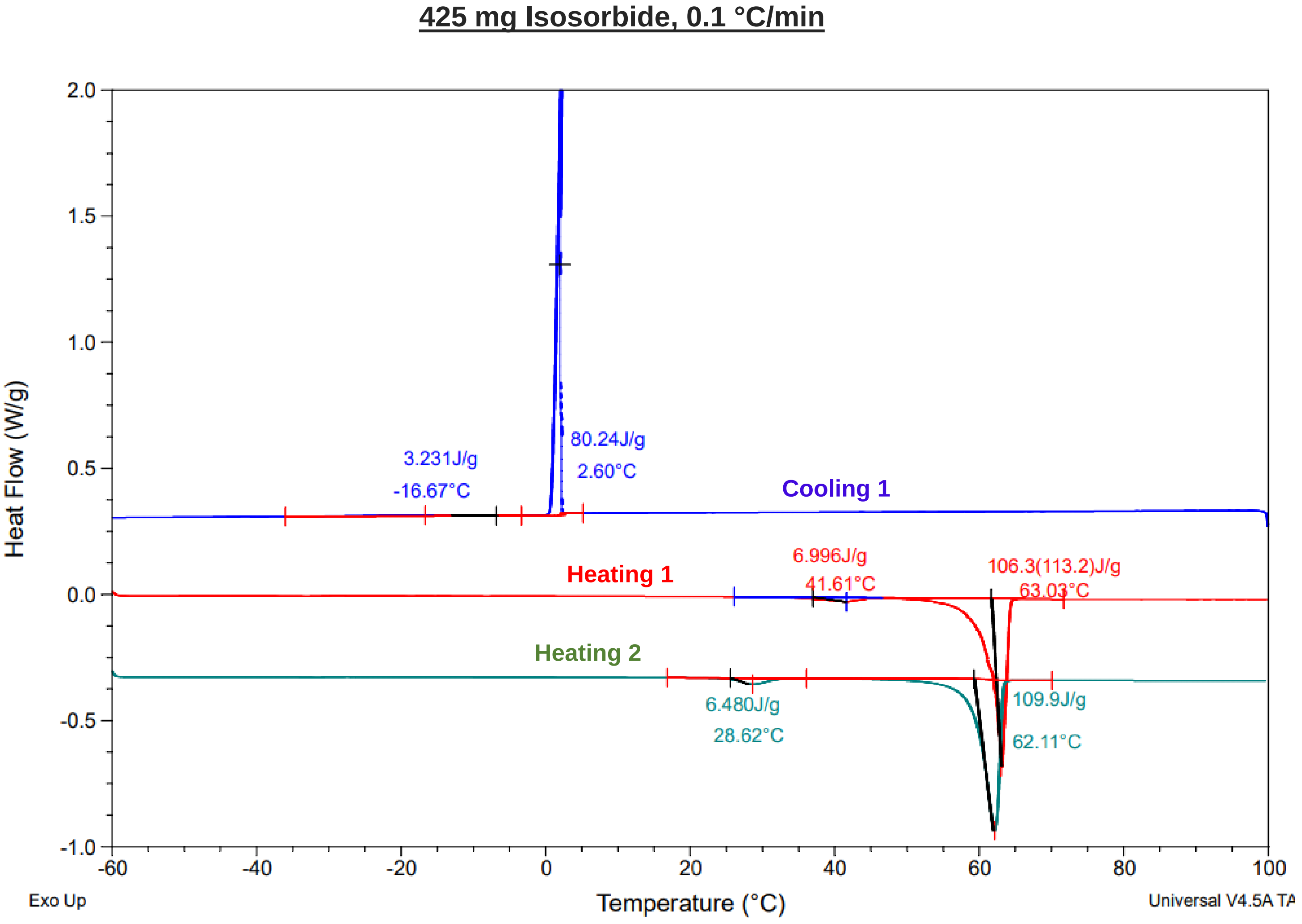
Multi-scale study
From sample to component

DSC scale

(QA20, TA instruments)

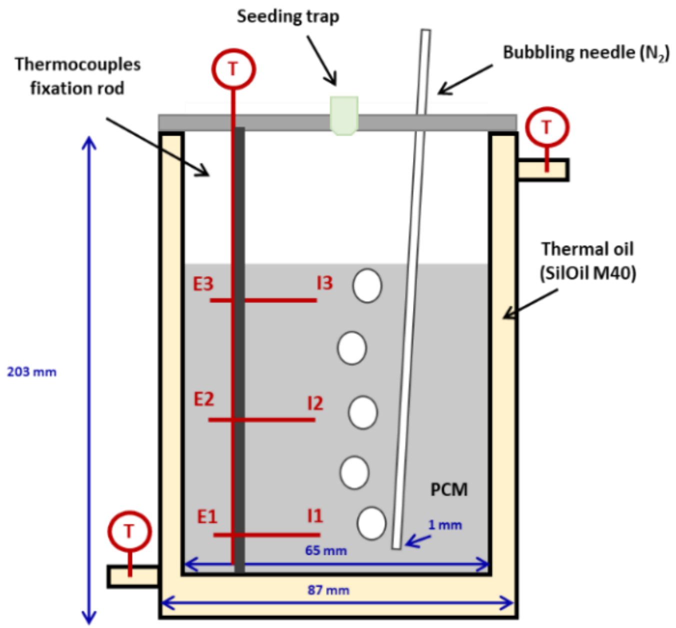
- **<u>Consistent measurements in heating</u>**
  - T_m=60-65°C
  - H_lv=110 J/g
  - Small effect of successive cycling

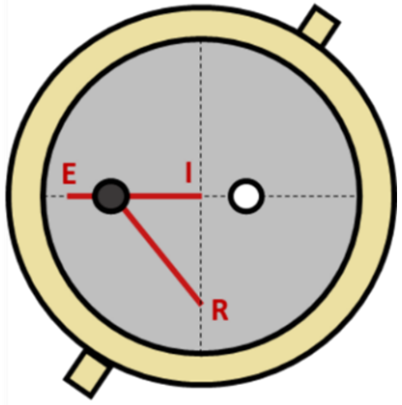
- **<u>Cristallization</u>** around 5°C, with a very sharp peak (relevancy of the measurement in such condition?)



Breaker scale

CRYSTAL set-up, 400 mL Isosorbide



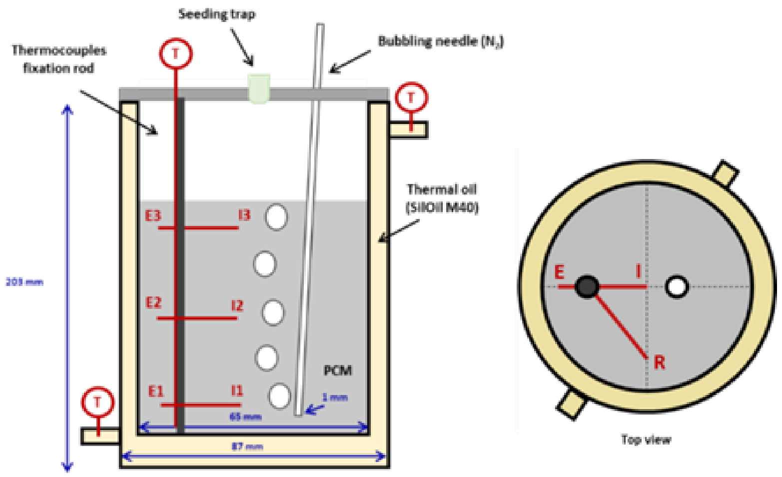


Top view

- Double wall metallic cylindrical critallizer
- 400 mL of Isosorbide
- Connection to thermal bath using thermal oil HTF for heating and cooling
- No direct control of the heating and cooling rates
- Inlet/outlet TC + 9 immersed TC in the breaker
- Needle for N2 bubbling as supercooling breaker

Breaker scale

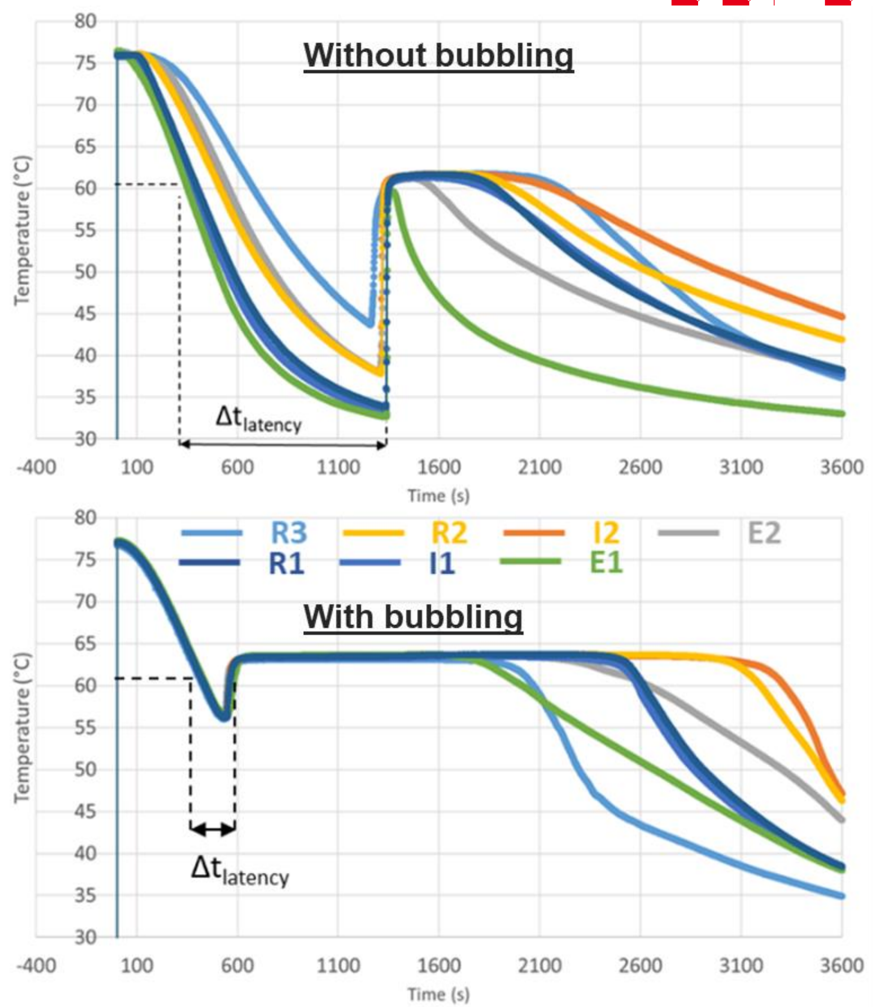
CRYSTAL set-up, 400 mL Isosorbide



- **Without bubbling:**
  - Natural break of supercooling → homogeneous primary nucleation
  - High level of supercooling (> 30°C)
  - Non repeatable results → stochastic nature of supercooling

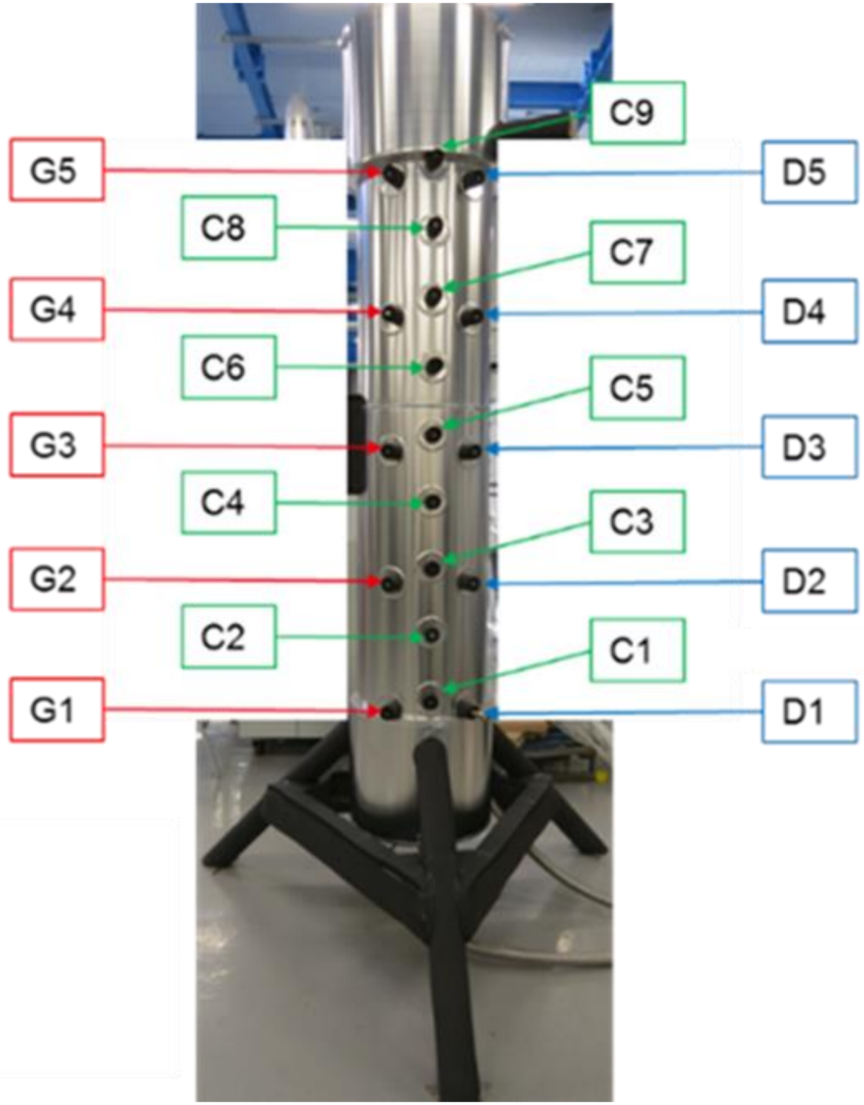
- **With bubbling:**
  - Supercooling temperature and latency times ↘↘
  - More repeatable behaviours
  - Global T homogenization

Effect on performances of PCM TES component?



	Latency time (s)	Triggering T (°C)
Without bubbling Test 1	477	38.8
Without bubbling Test 2	1014	32.6
With bubbling Test1	133	56.5
With bubbling Test2	139	56

PCM TES prototype scale



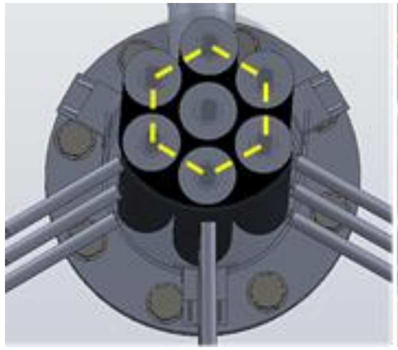
- Based on **Shell-and-tube** Heat Exchanger concept

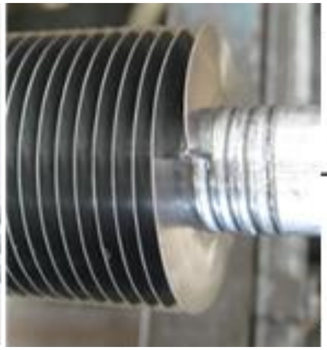
- Heat Transfer Fluid (HTF, water) flows inside **finned tubes**
- **Tube bundle** (7 tubes) is surrounded by Phase Change Material (PCM) embedded in the shell
- **Inserts** are placed inside the tubes to increase the tube internal HTC

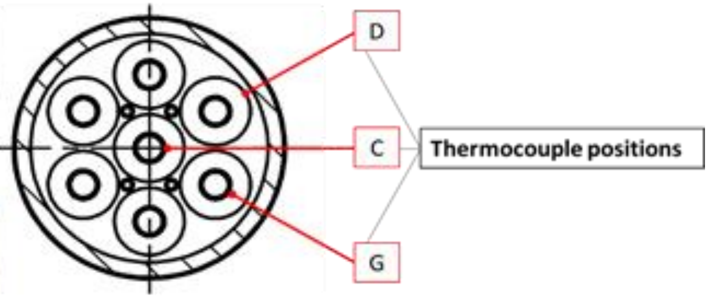
- (D, H)=(0.22 m, 2.15 m, 53.5kg of Isosorbide

- Neddle + N2 for **bubbling** at the bottom of TES tank

- **Thermocouples** (TC) placed on TES tank height to follow the thermal beahviour, melting process etc.





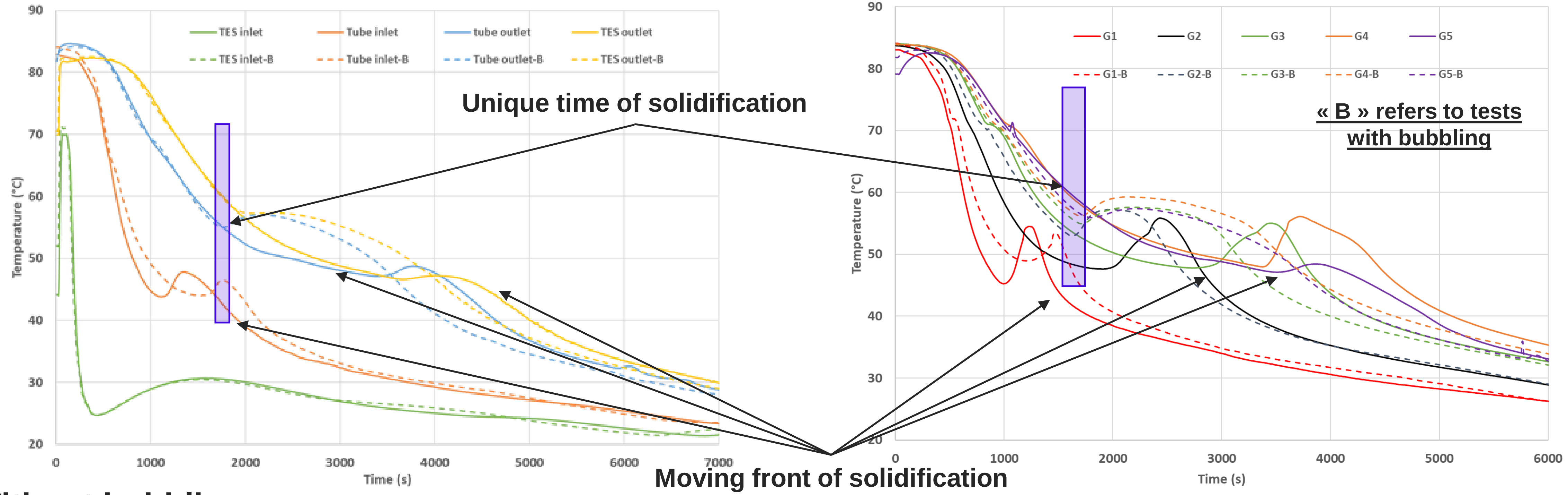


PCM TES prototype scale

TES Inlet/Outlet

TES internal behaviour

Water 100 kg/h, N2 5NL/min

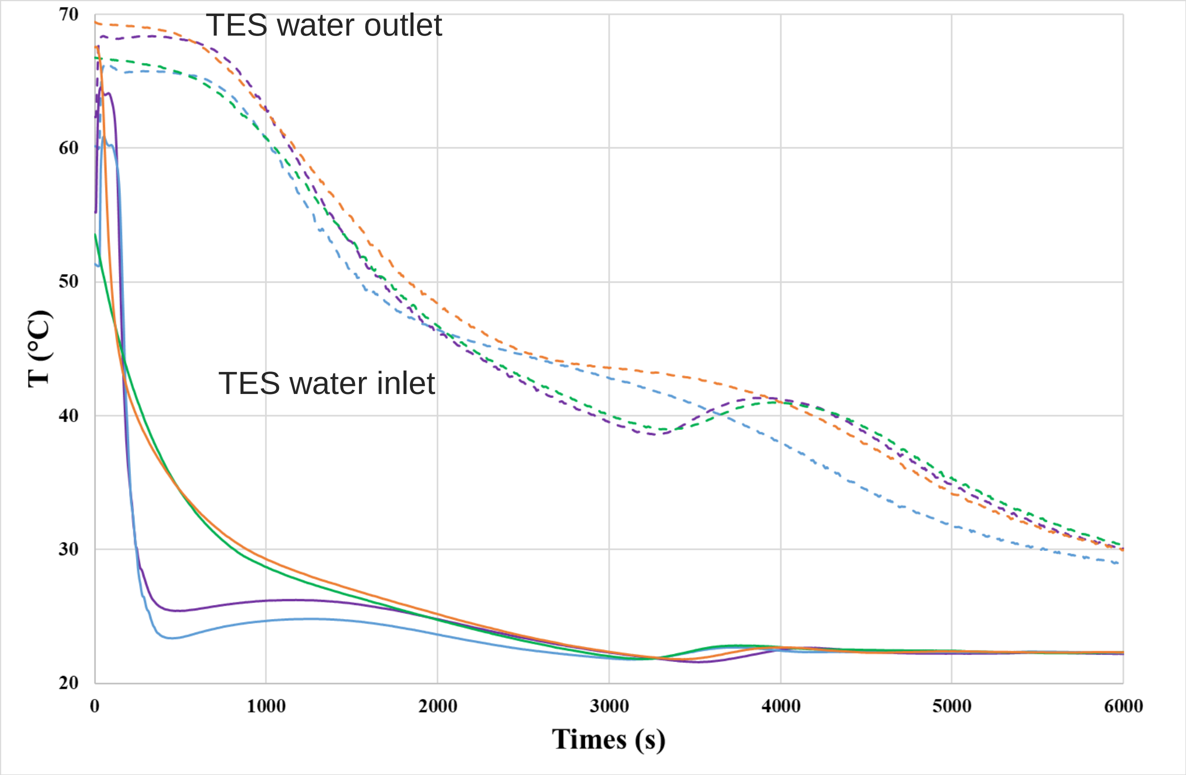


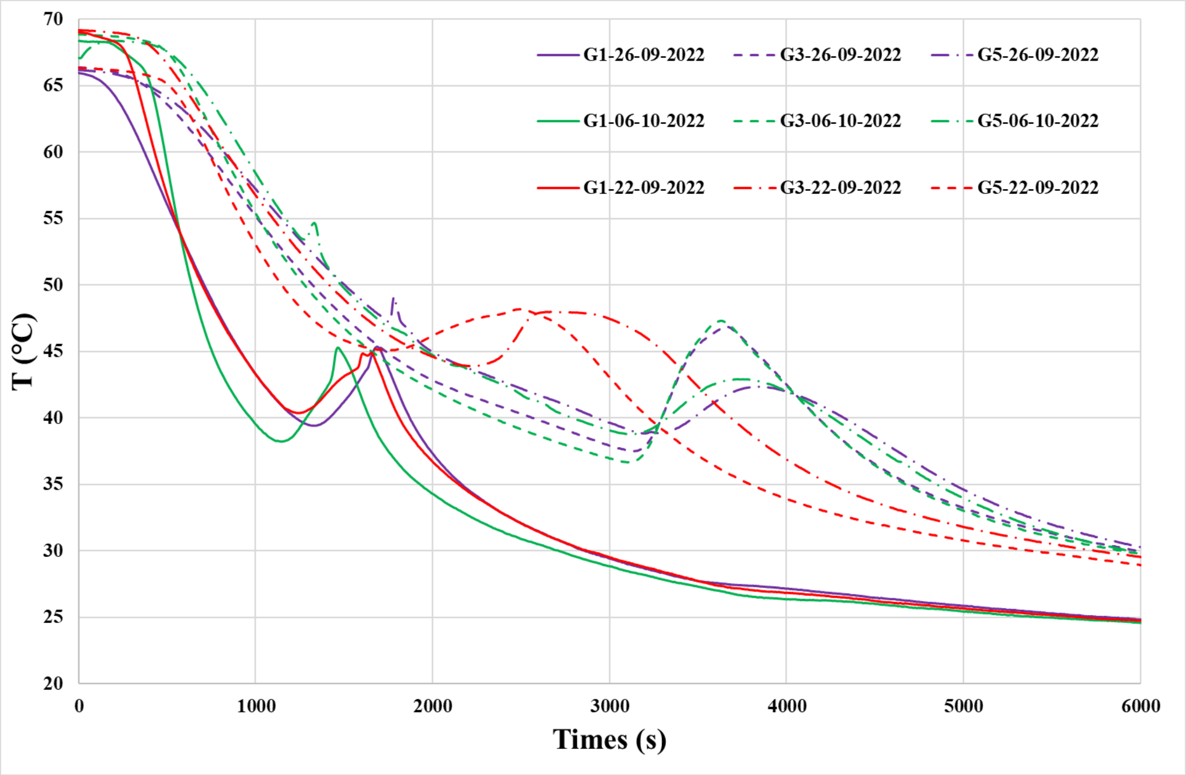
- **Without bubbling**
  - Bottom to top moving solidification front, with T increase close to melting T (on PCM side)
  - No temperature plateau linked with solidification
  - Significant supercooling

- **With bubbling**
  - Reduction of observed supercooling
  - No more moving solidification front. Cristallization is triggered in all the PCM at the same time
  - Observable effects on both PCM and global inlet/outlet sides

PCM TES prototype scale – Reproducibility tests

Water 360 kg/h, N2 5NL/min





- Reproducibility, even with bubbling, is not fully assessed
- Different behaviours (triggering temperature, latency time) are observed, even with identical inlet conditions
- Unpredictible behaviour of the TES component, even with bubbling
- Influence on the global TES performances, even more in case of treshold on usefull water outlet T

Conclusion

- **Isosorbide** is a good candidate for **PCM TES for residential applications**
- Isosorbide has drawback of significant **supercooling**
- Study of Isosorbide from sample to PCM TES prototype highlights that **supercooling** exists and impacts behaviour **at all scales**
- **N2 bubbling** is an effective way to **trigger supercooling** and initiate cristallization
- **N2 bubbling** is also linked with global change of behaviour of the PCM TES, with **single thermal behaviour** on the entire height of the PCM TES
- **N2 bubbling reduces stochastic** behaviour linked with supercooling, without eliminates it
- Additional study is needed to finely evaluate the influence on the performances of the supercooling and the supercooling triggering system, as well as the influence of the operating parameters.

Any question?

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CEA-Liten, Grenoble, France

liten.cea.fr

Arnaud.bruch@cea.fr