TES Cluster

Thermal Energy Storage

ECHO
EFFICIENT COMPACT MODULAR
THERMAL ENERGY STORAGE SYSTEM

ThumbsUp

HYSTORE
Hybrid Services from Advanced
Thermal Energy Storage Systems

BEST-Storage

Compact TES of the Future:

from Challenges to Opportunities

24 June 2025 | 14:00 - 16:00

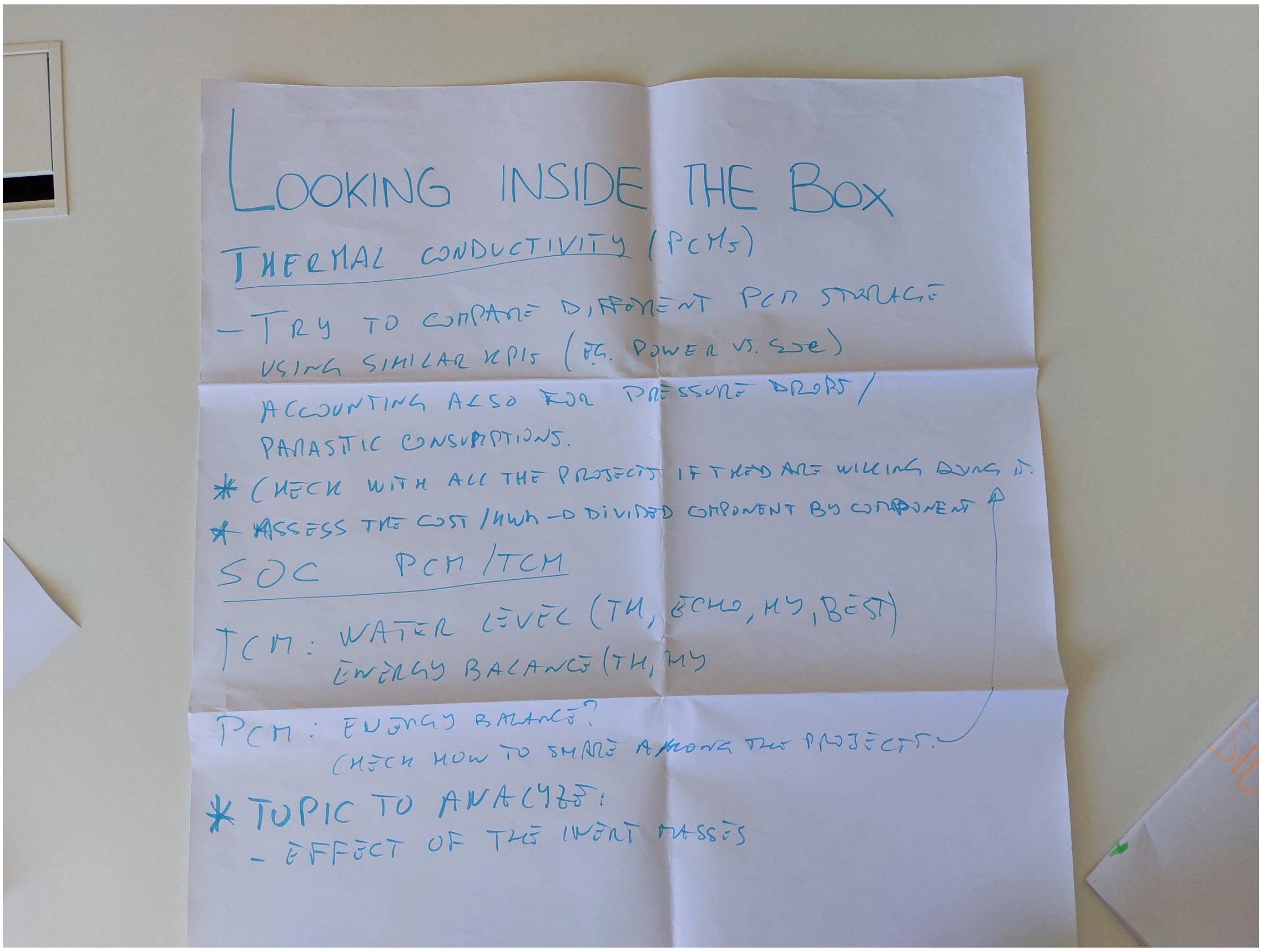
ICSET 2025 | Doride room

BEST-Storage | ECHO – Efficient Compact Modular Thermal Energy Storage System | HYSTORE – Hybrid Services from Advanced Thermal Energy Storage Systems | ThumbsUp

Looking inside the box: Power-to-X possibilities unlocked by compact TES

1. Thermal Energy Storage: Size of the internal equipment and installed power vs energy density reached/required for its application.
2. Thermal Energy Storage: Source/sink and temperature lift for the technology to optimally work.
3. Thermal Energy Storage: Material degradation, low conductivity, state of charge estimation, cost reduction.

CHAIRS: *Sergio Bobbo (CNR-ITC), Dani Carbonell (OST), Andrea Frazzica (CNR-ITAE), Ilaria Marotta (CNR-ITAE)*



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ECHO - GA n.101096368, BEST-STORAGE - GA. n.101096516, HYSTORE - GA n. 101096789, THUMBSUP - GA n.101096921.

HIGHLIGHTS:

The event began with a brief presentation of the four projects, outlining their progress and setting the stage for the main discussion points of the Inside the Box and Outside the Box sessions. Each project shared how they are addressing the challenges of thermal energy storage (TES) deployment, highlighting the advantages and limitations of each approach across different application environments. It became clear that while each project offers specific solutions to targeted needs, working together within the TES Cluster enables complementary and robust conclusions, providing comprehensive solutions for various sectors (residential, tertiary, industrial) and contexts (district heating, self-consumption, grid flexibility, renewable integration).

Thermal Energy Storage: Size of the internal equipment and installed power vs energy density reached/required for its application.

The ECHO system uses a closed-loop solution, which offers the advantage of being independent from external conditions. The thermal energy storage (TES) material is a thermochemical material (TCM) composed of hydrated salts impregnated into vermiculite. This vacuum impregnation process enables an energy density of up to 2.1 GJ/m^3, equivalent to a maximum storage capacity of 270 kWh/m^3—exceeding the target of 210 kWh/m^3. However, processing airflow rates of around 1000 m^3/h requires a relatively large air handling unit (AHU), with a volume approximately ten times greater than that of the TCM reactor itself. As a result, the system is currently not suitable for use in apartments or single-family homes, but it shows potential for scalability in district heating networks or industrial applications.

Thermal Energy Storage: Source/sink and temperature lift for the technology to optimally work.

The ECHO TESS employs an R515B heat pump to supply 80 °C dry air during the charging phase, temperature level necessary to optimise the thermal energy storage in the TCM. The heat source is a water reservoir at 15 °C, which also serves to dehumidify the air exiting the reactor. This results in a temperature lift of approximately 80 °C (evaporation at 5 °C, condensation at 85 °C). For cooling, the same heat pump operates between a -3 °C water/glycol tank with eutectic salt accumulators (evaporation at -10 °C) and a 50 °C user-side reservoir (condensation at 60 °C), yielding a temperature lift of about 70 °C. During discharging (hydration), the air temperature in the reactor increases due to the exothermic reaction. Lab tests with the optimized VCM-vac TCM showed a 20 °C temperature rise. The current prototype in Ferrara uses a different, non-optimized TCM, achieving a 10 °C rise. Tests with VCM-vac are planned to validate performance improvements.

Thermal Energy Storage: Material degradation, low conductivity, state of charge estimation, cost reduction.

<u>Material Degradation</u>. The VCM-vac TCM has shown good stability over 20 charge/discharge cycles. PCMs used across the system (ethyl palmitate for insulation, A32 for accumulators, eutectic H_2O+Na_2CO_3+graphite for cooling) demonstrate high stability, though long-term degradation in the cooling unit remains a concern despite the addition of fumed silica.

<u>Low Thermal Conductivity.</u> To address low conductivity, various enhancements are used: In insulation, hybrid PU layers combine neat PU with PCM composites (e.g., ethyl palmitate) to buffer heat at target temperatures. In accumulators, aluminium foam embedded in A32 PCM significantly reduces solidification time. In the cooling unit, adding 10% graphite flakes to the eutectic mixture improves conductivity by 78% (liquid phase) and 55% (solid phase). However, the last two solutions induce some problems of stability, thus their actual implementation is under discussion.

<u>State of Charge Estimation</u>. SoC is inferred by monitoring water levels in the humidification tank of the closed-loop circuit. The amount of water absorbed by the TCM is estimated as the difference between total system water and the tank content.

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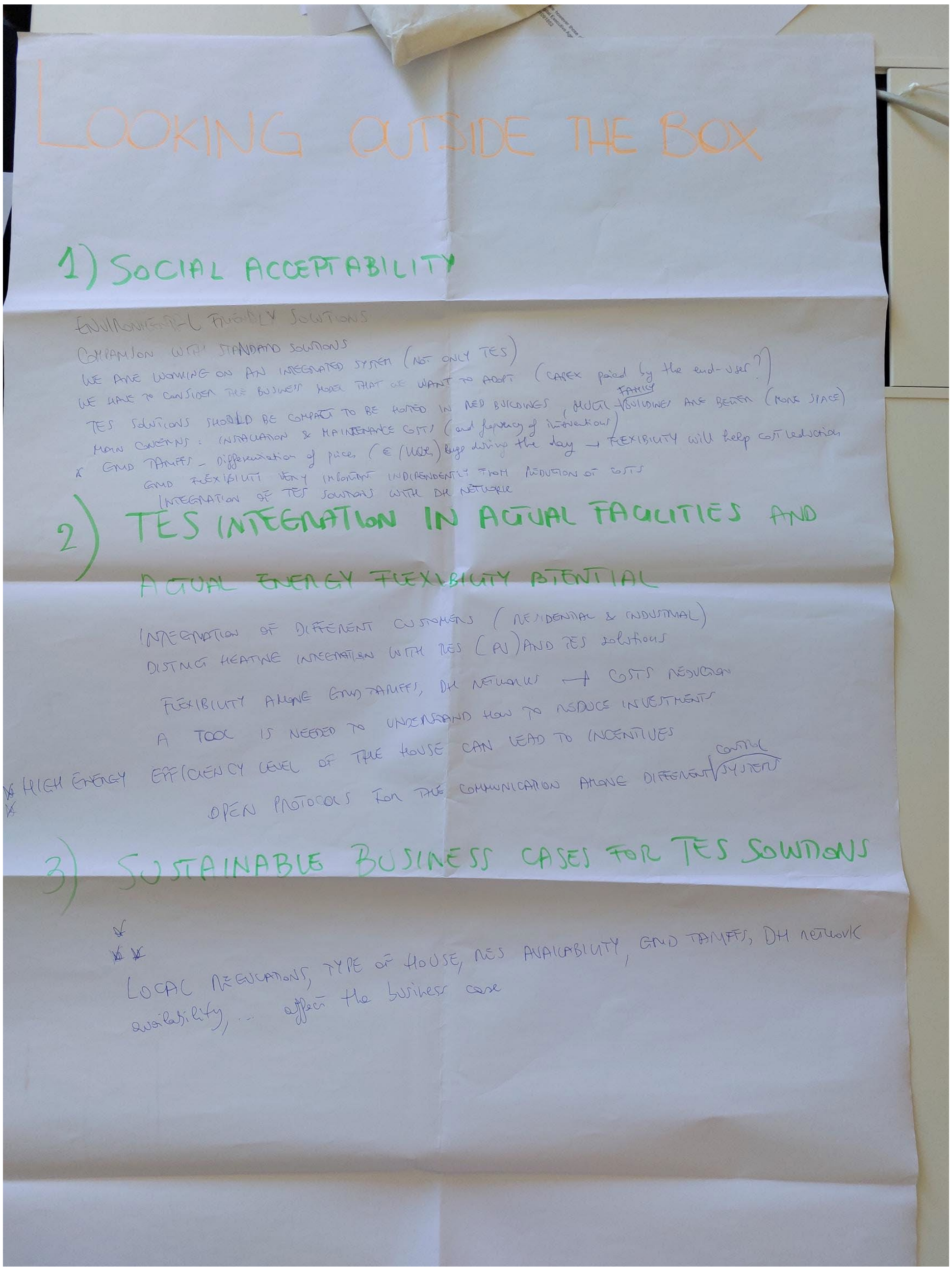
Looking outside the box: TES for easy integration

1. Social acceptability in residential buildings & TES application feasibility in residential vs industrial sector. Affection of local RES availability, DHNs and grid tariffs.
2. TES integration in actual facilities and actual energy flexibility potential. PtH & TES solutions vs electrical batteries.
3. Suitable business cases for TES solutions: Prices, market applications, offered value.

CHAIRS: *Guillermo Andrés Nieto (Veolia), Juan Carlos del Castillo Garcia (CARTIF), Maria Chiesa (beWarrant – Tinexta Innovation Hub), Marco Rocchetti (R2M Solution)*



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HIGHLIGHTS:

From the ThumbsUp perspective, the discussion emphasized that convincing future users of TES benefits is essential, particularly in residential buildings where social acceptance requires clear communication, demonstration of benefits, and concrete case studies. ThumbsUp highlighted the importance of creating synergies with the PV industry, offering TES as part of self-consumption packages to optimize local renewable generation, avoid low feed-in tariffs, and increase the perceived value for end-users. This approach not only supports social acceptance but also accelerates TES adoption in combination with distributed generation.

The flexibility potential of TES was discussed, an aspect actively explored within ThumbsUp, especially when combined with Power-to-Heat (PtH) and dynamic price signals. TES enables load shifting to periods of high renewable generation or low demand, reducing emissions and facilitating renewable integration.

Compared to batteries, TES systems, as evaluated in ThumbsUp, are more cost-effective, with lower investment and operating costs per kWh stored, longer lifespan, and higher sustainability by avoiding critical raw materials. TES also supports thermal flexibility and peak shaving through PtH, enhancing energy demand management while supporting renewable integration.

In buildings with District Heating Networks (DHN), ThumbsUp underlined that TES can smooth thermal demand peaks, helping avoid high power penalties and improving network efficiency while reducing costs.

A key point raised by ThumbsUp was the need for an optimized and user-friendly BEMS to manage batteries, TES, and building operations in an integrated way. Without it, TES may lose efficiency despite their potential, highlighting the importance of digital tools enabling automated operation, monitoring, and integration of price signals and renewable generation to fully leverage TES within energy systems.

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More info

BEST STORAGE

best-storage.eu

ECHO:

echo-euproject.eu

HYSTORE:

www.hystore-project.eu

THUMBS UP:

www.thumbsupstorage.eu

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