



Compact High-Performance Thermal Energy Storage System for Buildings

Introduction

Buildings account for 30% of global final energy demand (123 EJ), with space heating and domestic hot water responsible for 15% (63 EJ) and 2.2 Gt of CO₂ emissions annually¹. Without additional means, renewable energy sources (RES) alone struggle to replace fossil fuels due to the mismatch between intermittent RES availability (e.g., solar PV) and peak thermal demand. Ministor with the Thermal Energy Storage (TES) helps to bridge supply and demand gap and thereby helps to increase the share of renewable energy used for space heating and Domestic Hot Water (DHW). TES is a flexible decentralised system overcoming the challenges of installation of large scale heat transfer system such as district heating and cooling systems.

Currently most widespread TES is water storage based system with limitation of operating temperature difference. Complementary technologies such as latent or thermochemical storage often suffer from problems with long-term stability, non-suitable temperature ranges or dangerous materials involved. The ministor system combines the high energy density of TCMs

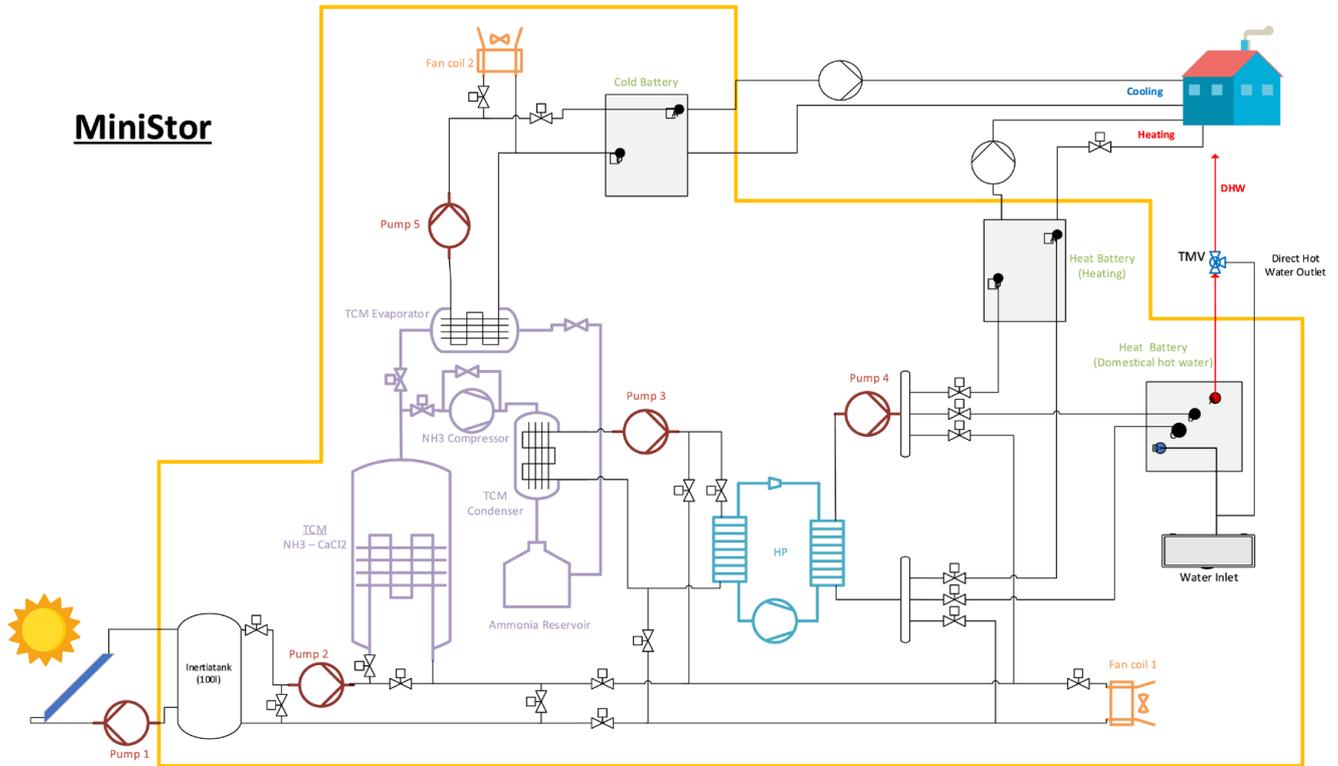
with the compactness of the PCM storage. Ministor TES contributes toward a larger share of renewable heating, cooling and electricity storage through a novel technology which can be used in new and existing residential buildings. The novel compact and flexible TES based MiniStor system combines CaCl₂/NH₃ thermochemical storage (TCM), hot and latent heat storage based phase-change materials (PCM), and Li-ion batteries into a resilient unit that delivers:

- 🏠 10.6 times higher energy density (182 kWh/m³) than water based TES.
- 🏠 Better flexibility and a higher storage density with higher operating temperature differences.
- 🏠 Scalability for diverse home configurations (e.g., home energy management system to manage overall supply and demand of household having boilers, solar thermal, or hybrid PVT systems).
- 🏠 Fast supply of cold through ammonia absorption process.

MiniStor TES energy management and storage solution **decarbonizes residential energy** by storing renewable heat and electricity for on-demand use. **With 182 kWh/m³ density (10.6× water-based TES)**, it ensures **20+ years of stable performance (COP 1.8)**. Its modular design adapts to homes with boilers, solar fields, or heat pumps, enabling **resilient, grid-independent heating/cooling in any climate**.



Approach and results



Conventional technologies for thermal energy storage include Sensible Heat Storage (SHS) and Latent Heat Storage (LHS) using Phase Change Materials (PCMs). With SHS thermal energy is stored by heating or cooling a liquid or solid such as water, sand, rocks or molten salts. LHS consists in storing heat exploiting the phase-change process of a material which occurs at a nearly constant temperature. On the other hand, MiniStor uses thermochemical heat storage (TCM) technology, which uses sorption and chemical reactions to generate heat. The thermal part of the MiniStor system comprises various components, a PVT, a TCM, an HP and a PCM. The PVT is used to supply heat to the TCM thereby charging the storage device. This configuration can achieve a COP of 1.8, thus increasing RES-generated heat of the PVT by 80%. When the TCM unit operates in charging

mode, an endothermic decomposition reaction takes place absorbing the solar heat from the PVT and producing a gaseous ammonia stream at 3 bar and -7°C . The liquid ammonia is collected and stored in a tank at a pressure of 11 bar. A significant amount of heat is generated from the condensation of the produced ammonia at $\sim 28^{\circ}\text{C}$. On the other hand, when the TCM unit operates in discharging mode, an exothermic reaction between the gaseous ammonia and the CaCl_2 -based salt occurs. A small HP is used to match operating temperature of modern heating systems elevating the temperature of the released heat at the ammonia condenser from 28°C up to $60\text{--}65^{\circ}\text{C}$. During the summer period, the HP can be operated in reverse mode providing chilled water at $5\text{--}7^{\circ}\text{C}$. Moreover, two Phase Change Material (PCM) tanks, called respectively the hot PCM and cold PCM,

are used to store heat at 60°C and cold at 5°C. The Hot PCM is connected through two independent circuits with the TCM reactor to charge the surplus of produced heat and with the heat pump to discharge it. The Hot PCM is connected with both the water circuit of the space heating system and the DHW tank. The Cold PCM storage is used to store the cold that is produced at the evaporator at about 0-5 °C during the night phase. The Cold PCM storage is filled with a wax that solidifies at 5 °C. The HP is also connected with the Cold PCM as it is operated in reverse mode during summer.

In addition to the thermal energy storage solution, the MiniStor unit uses off-the-shelf battery systems to provide an integrated home-scale energy solution which allows to implement peak-shaving and optimal operational strategies to meet both electricity demand of home appliances as well as heating and cooling demands. Furthermore, the Ministor solution includes a Smart Home energy management system comprising a cloud-based monitoring tool, an IoT platform for user interaction, a model predictive controller, a Distributed Energy Resource (DER) forecasting and demand profiling service.

Conclusion

MiniStor is an innovative concept for TES based on solid/gas thermochemical reaction taking place in a TCM/ammonia reactor which enables to store heat and cold with high energy densities. The MiniStor unit can store large quantities of thermal energy and can generate cold and heat rapidly through a thermochemical reaction between ammonia and salts. When a valve opens, the ammonia vapour is absorbed by the salt generating heat. On the other hand, the evaporation of ammonia in the evaporator produces cold. Ministor is a flexible, modular and scalable system that offers an energy storage capacity which does not degrade over time. The Ministor unit is silent and does not produce noise or vibration when supplying cooling or heating. It can be used to reduce CO₂ emissions of buildings improving the exploitation of renewable energy under any conditions and climate.



Implications and recommendations

Policy implications

- 🏠 Demonstration of the Ministor compact TES system for buildings convinces potential investors that the overall efficiency, energy storage density and reliability offer superior performances compared to state-of-the-art compact TES for buildings, whereas investment and operational costs are reduced, along with CO₂ emissions and pollution of the environment. An industrialisation and commercialisation pathway is undertaken to bring a product based on the Ministor technology to the market.
- 🏠 Ministor may become a commercial product with a potentially high market uptake if the cost of energy storage per MWh will be sufficiently low, e.g., below €15/MWh

Policy recommendations

- 🏠 **Incentivise** the adoption of TES in buildings establishing a financial support mechanism for investments in TES systems or the increased share of renewable energy usage. Furthermore, any policy that would penalise CO₂ emissions harder than current policies would indirectly incentivise the adoption of TES in buildings.
- 🏠 **Incentivise** the installation of home energy management systems which enable to control TES units such that renewable energy available can be stored when there is no significant residential building demand and used at a later time, e.g., to supply the building peak demand.
- 🏠 **Encourage** customers to install TES by offering lease-to-own deals in cooperation with national, regional and local authorities (recommendation for manufacturers/vendors of TES systems)². This approach would reduce the risks and concerns that come with an upfront investment in TES technologies.
- 🏠 **Establish** appropriate incentives for the recovery of waste heat in buildings from exhaust air and hot water. Heat can be recovered from activities like showering, bathing, and washing, and stored using TES systems to be used for space and water heating when needed.
- 🏠 **Incentivise** decarbonisation of buildings using TES systems properly rewarding reduction in carbon emissions associated with installation of a TES system.
- 🏠 **Incentivise** installation of TES systems in conjunction with renewable energy systems as they can increase the self-consumption of renewable energy in buildings and reduce wastes of free and clean energy available from renewable sources.

References

- 1 [MISSION POSSIBLE – REACHING NET-ZERO CARBON EMISSIONS FROM HARDER-TO-ABATE SECTORS BY MID-CENTURY.](#)
- 2 European Association for Storage of Energy. [Thermal Energy Storage](#). Brussels, September 2023.

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