

RF heating for an energy storage system developed in the Horizon Europe Project Hystore

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ABSTRACT. —Within the framework of the EU Horizon project HYSTORE (grant agreement N. 101096789) a thermochemical (TCM) prototype has been developed. The innovation in the TCM system involves using radiofrequency (RF) dielectric heating on Zeolite 13X instead of conventional microwave heating and use ground electrodes also as heat exchanger in the chamber.

Keywords— energy storage, radiofrequency, zeolite.

INTRODUCTION

Power-to-heat strategies are being utilized to mitigate grid stability issues caused by renewable energy integration by converting surplus electricity into manageable thermal energy. Within the Horizon Europe HYSTORE project, an innovative thermochemical energy storage (TCM) system is being developed, utilizing a high-density, reversible solid-gas adsorption cycle based on Zeolite 13X and water.

During the endothermic charging phase, input electromagnetic energy breaks the water-zeolite molecular bonds via desorption, condensing the released vapor into a liquid state. Since the dry zeolite and liquid water are stored separately, the system avoids continuous temperature maintenance, achieving loss-free energy conservation over several months. During discharging, the water is re-vaporized and reintroduced into the bed, triggering an exothermic adsorption reaction that releases the stored heat for domestic applications.

PROBLEM DESCRIPTION

The primary obstacle in scaling conventional thermochemical reactors is the low thermal conductivity of porous zeolite pellet beds. Traditional conductive or convective heating methods rely on external heat transfer through the boundaries, creating severe internal thermal gradients and slowing down the process.

To overcome this, the Hystore TCM project utilizes radiofrequency (RF) heating operating at 27.125 MHz. At this frequency, the longer electromagnetic wavelength ensures deep penetration and a highly uniform field distribution in the chamber.

This method achieves direct volumetric heating from within the material, completely eliminating localized hotspots and power peaks that could damage the zeolite structure over thousands of cycles.[1] Furthermore, RF heating allows for highly efficient low-temperature desorption (120°C–200°C) under vacuum conditions. By pairing solid-state RF generators with automated impedance matching units, the system continuously maximizes real power delivery during the endothermic cycle.

System Engineering, Simulation, and Prototyping

The developed system features a cylindrical vacuum chamber geometry specifically designed to maintain strict axial symmetry and ensure a uniform electromagnetic field distribution throughout the material bed.

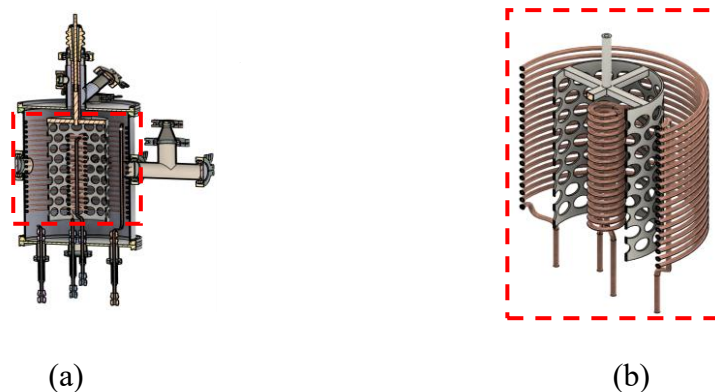


Figure 2. System design. (a) complete system design and (b) HV and ground electrodes.

As illustrated in Figure 2, the system architecture integrates several components engineered to balance electromagnetic performance with optimal thermodynamic control. At the core of this configuration, a top-fed high-voltage electrode (Figure 2b) guarantees uniform electromagnetic field coupling into the chamber; the electrode structure consists of an internal perforated sheet metal cage immersed in the granular zeolite pellets to facilitate efficient moisture transport. Electrical grounding and thermal management are handled simultaneously by a network of internal copper coils, which function as both the radiofrequency ground electrodes and internal cooling heat exchangers. This internal assembly is supplemented by external coils welded directly onto the outer wall of the chamber, which rapidly extract heat to accelerate cooling and enable fast cycle repeatability (Figure 2b).

Following a rigorous virtual validation, a physical prototype was fabricated and installed at the CNR ITAE facility in Messina, where experimental testing is currently ongoing.

CONCLUSIONS

The RF-heated thermochemical reactor developed under the HYSTORE project offers a breakthrough solution for Power-to-Heat sector coupling. By shifting from boundary conduction to volumetric radiofrequency dissipation at 27.125 MHz, the system successfully bypasses the heat transfer limitations of porous zeolite beds. The combination of 3D numerical modeling and optimized vacuum chamber engineering ensures uniform thermal distribution and exceptional lifecycle stability. This advanced thermal battery represents a highly scalable, loss-free energy storage option designed to provide vital flexibility to future decarbonized energy grids.

REFERENCES

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