Industrial waste heat recovery based on thermochemical heat storage: the case of a district heating network

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France has set as key target to increase the effective use of renewable and excess energy resources up to 38% of its end-user heat consumption, by 2030. To reach these requirements, it is necessary to enhance the utilization of under-exploited thermal energy resources (solar, waste heat in industry, biomass-based boilers …). A key point is the integration of such recovered energy sources in urban heat distribution networks. Whether they are district heating networks or not, their production timing, power, temperature level, or even their location, often do not match the requirements of grids that are driven on-demand (Bühler et al. 2018). Thermochemical heat storage systems are among the most promising candidates to achieve a sustainable management of renewable and waste energy sources (European Association for Storage of Energy 2013). In this project, we investigate the integration potential of a thermochemical heat storage unit into an existing district heating network. The aim is to increase the utilization ratio of energy from renewable and waste heat sources while reducing the consumption of fossil fuels in auxiliary boilers. Even though such integration has been shown to be theoretically possible since a long time ago, only few realizations already exist at an industrial scale, and none of the existing thermochemical storage technologies (mainly divided into open or closed systems) seem to have reached a market-ready stage of development (Miró, Gasia, et Cabeza 2016).

To appreciate the orders of magnitude involved in that project, Fig. 1 shows the heating power demand profile of the use-case network as a function of the corresponding time, over a five-month-long heating season. Three areas are identified: first, the low-grade heat from waste or renewable sources, available for recovery through regeneration of the storage material (in blue); second, the stored heat that can be eventually utilized through its release into the network (green); third, the residual energy demand that is still fulfilled with conventional fossil fuels.

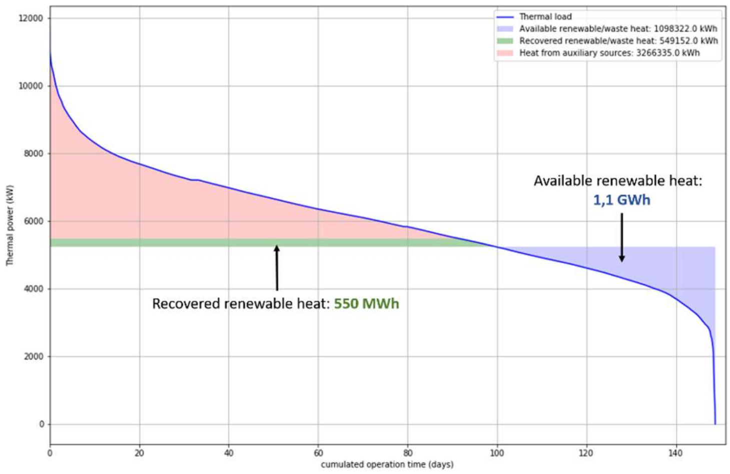

Fig. 1: Heating power as a function of corresponding operation time in the use-case district heating network.

The analysis shows that 1.1 GWh of waste or renewable heat are available to regenerate the heat storage unit. With a theoretical yield as low as 50%, 550 MWh would be available for utilization. For the record, the storage capacity integrated in this facility is currently limited to 2.3 MWh thanks to a 100 m^3 thermocline-type hot water buffer. A similar volume of thermochemical heat storage material would allow to store 9 MWh, based on the material investigations performed with a combined thermogravimetric and differential scanning calorimetry apparatus. Indeed, Zeolite 13X is identified as the storage material, because its regeneration was proved feasible at temperature grades as low as 70-90°C, along with a heat storage density in the order of 623 kJ/kg (see fig. 2). Moreover, this material is commercially available in large quantities. This input leads to about 60 loading/unloading cycles to recover the 550 MWh.

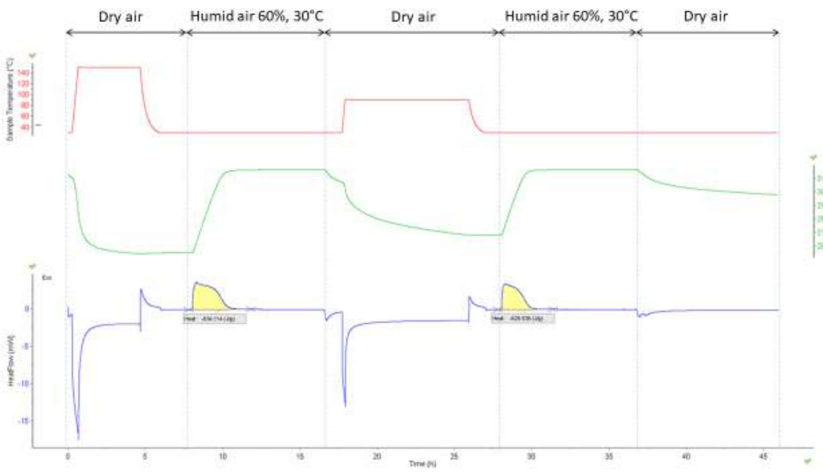

Fig. 2: temporal outputs during a TG-DSC zeolite 13X analysis (red: sample temperature, °C; green: sample mass, mg; blue: heat flow exchanged by the sample, mW).

The integration of a thermochemical storage unit within an existing grid firstly consists in an analysis of the grid to target the best integration scheme and to define the input conditions for real application testing. Requirements in terms of charging and discharging of the thermal power, storage capacity, volumetric energy storage density and transient characteristic time needs to be identified.
In parallel, an advanced physico-chemical characterization of the material (Zeolite 13X) is carried out to validate the heat storage capacity that is expected with the previously defined cycling conditions.

The gathered data provides inputs to develop heat and mass transfers models, in addition to a lab-scale experimental setup used for validation of the simulation results. This combined numerical and experimental approach aims to identify the thermo-fluidic behavior of the reactor, which will be at the basis of the upscaling process and its integration into an existing district heating network.

Acknowledgments

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