Editorial: Numerical and experimental analysis of conversion, storage and management of thermal energy

1. Introduction

According to the International Energy Agency's (IEA) net zero emissions forecast for 2050, the world is far from meeting the requirement to achieve net zero CO_2 emissions by 2050. How to improve the effective use of primary energy, increase the proportion of renewable energy and improve the utilization efficiency of new energy has important social significance. The thermal energy utilization technology represented by heat storage improves the effective utilization of renewable energy, helps to improve energy efficiency, and has important value to increase the proportion of renewable energy, and has been widely studied and applied in many fields such as air conditioning, refrigeration, solar energy and battery thermal management.

The current editorial provides an overview of the seven relevant research papers to be published in issue HFFF 35.3, summarizing the current frontiers of thermal energy research and its applications. Currently, these articles are in production and have all been cited in advance.

Li *et al.* (2025) proposed a novel lattice Boltzmann method coupled with pore scale and rev scale as a numerical tool to study the phase transition of porous materials. This approach allows for the capture of detail in the pores while processing a large range of calculations. This method solves the conjugate heat transfer problem between SLPCM and solid matrix in the enthalpy-based lattice Boltzmann model.

Oztop *et al.* (2025) performed experimental and numerical analyses of phase change material (PCM) with melting temperatures ranging from 22°C to 26°C under different conditions. Providing a novel perspective on efficient storage of waste heat with air transfer, and exploring the role of jet inclination and Reynolds number in optimizing the melting and energy storage performance of PCM.

Selimefendigil and Oztop (2025) studied the phase transition dynamics of multiple encapsulated PCMs installed in a U-shaped tube under inclined magnetic field. Facilitates the initial design and optimization of multiple PCMs in different energy system technologies such as solar energy, waste heat recovery, air conditioning, thermal management and drying.

VP *et al.* (2025) analyzed the conjugated heat transfer phenomenon in the developed region of a square pipe under constant temperature and constant flow boundary conditions. Combined with computational fluid dynamics and finite element analysis, the significant changes of heat transfer characteristics under constant temperature and constant flow boundary conditions are revealed.

Gnanasekaran and Mobedi (2025) highlighted a novel solution or approach to deal with pressure drop losses associated with metal-based multi-porous media. Through this study, considering the various requirements associated with any thermal management system, a novel method is provided to control the pumping power of the final cost while favoring increased heat transfer.

Li *et al.* (2025) proposed a lattice Boltzmann method coupled with pore scale and representative elementary volume scale, which is expected to be used for multi-scale calculation of latent heat

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storage devices with porous structures. The conjugate heat transfer between solid-liquid phase change material and solid matrix in lattice Boltzmann model based on enthalpy is solved.

Cui *et al*. (2025) proposed a novel composite metal fin structure to improve heat transfer efficiency during phase change energy storage in hot water displacement systems. The influence of fin structure on melt characteristics, energy storage performance and heat storage rate were analyzed and the non-uniform melting behavior was investigated.

The above mentioned seven papers focus on topics such as heat transfer, PCM, porous media, and nanofluids, focusing on numerical simulation of thermodynamic processes, experimental verification, and engineering applications of related technologies. It provides a full range of theoretical and practical support from material to system level, which lays an important foundation for the development of energy storage and heat transfer technology. They not only have guiding significance for the optimization of phase change materials themselves, but also provide scientific basis for future energy conservation, environmental protection and efficient energy utilization.

Possible future development direction: Multi-scale modeling can be further combined with experimental verification to improve the accuracy and engineering applicability of the model; Explore the application of novel materials to improve energy storage and heat transfer efficiency; Further integration of magnetohydrodynamic and complex geometric design to optimize industrial thermal management.

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