Proceedings of the 11th World Congress on Mechanical, Chemical, and Material Engineering (MCM'25)
Barcelona, Spain –Paris, France - August, 2025
DOI: 10.11159/htff25.005

From Thermal Phenomena to Scalable Devices: The Thermo-Mechanical Foundations of Long-Duration Energy Storage for Flexible Heat

Dr. Adriano Sciacovelli
The Technical University of Denmark (DTU), Denmark

Abstract

Decarbonizing thermal energy is critical for achieving climate neutrality, yet industries, cities, and the transport sector still heavily rely on high-CO_2, fossil-fuel-based systems due to limited thermal energy flexibility. This dependency hinders the transition to electrified and renewable energy sources, posing a significant challenge to heat decarbonization.

To address this, advanced thermal energy storage (TES) and thermo-mechanical energy storage (TMES) solutions must evolve with compact, modular, and cost-effective solutions. Such innovations are essential to achieve a step-change in performance, enhance technology adoption, and improve value. Conventional TES and TMES systems, dominated by bulky, standardized designs, often fail to meet such spatial, economic, and performance needs.

This keynote presents advancements in TMES concepts combining fundamental insights into phase-change phenomena, topological optimization, and thermo-fluid engineering. These strategies unlock enhanced performance, overcoming limitations inherent in traditional systems. The talk will explore the distinct characteristics of latent heat TES, thermochemical energy storage, and TMES, emphasizing engineered structures that intensify heat and mass transfer to improve charge/discharge rates and economic feasibility.

The presentation will highlight future research directions, unresolved challenges, and the potential role of emerging thermo-fluid techniques in driving innovation in TES solutions.