COMSOL/Simulink-Coupling For Optimization Of Sorption Heat Storage In Residential Buildings

Ria Maria Mathew[1], Elham Abohamzeh[1], Georg Frey[1]

[1]Saarland University, Chair of Automation and Energy Systems, D-66123 Saarbrücken, Germany

Abstract

Problem Description
Sorption heat storage systems are attracting growing interest due to their high energy density and loss-free heat storage capability, making them a promising solution for storing surplus solar energy in summer for use in winter in residential buildings. However, these systems are still in the research and development stage. In the absence of validated pre-existing models within building simulation environments such as Simulink, the use of an experimentally validated COMSOL Multiphysics® model provides a valuable means to evaluate system performance under realistic operating conditions when integrated with other building energy components. CFD based models offer high spatial and temporal resolution, enabling accurate prediction of outlet temperatures and output power. Coupling the models creates a powerful analysis and optimization framework.
Use of COMSOL Multiphysics®
User-defined functions were developed to implement the sorption reaction kinetics and the temperature and moisture-dependent thermophysical property correlations. The vapor flow through the porous domain was modelled using Darcy's Law interface. Coupled heat and mass transfer in the sorbent bed were resolved using the Heat Transfer in Porous Media and Transport of Diluted Species in Porous Media interfaces. The heat transfer fluid (HTF) flow field was computed separately using the Laminar Flow interface.
The integration between the CFD-based sorption unit model and the building energy system model was implemented using COMSOL LiveLink™ for Simulink. Building energy components in Simulink were either imported from the Carnot Toolbox library or developed directly in MATLAB/Simulink. In this coupled setup, the heat transfer fluid (HTF) inlet temperature and mass flow rate, calculated within Simulink, were dynamically transferred to COMSOL as time-dependent boundary conditions. COMSOL then performed transient CFD simulations of the sorption storage unit to resolve coupled heat and mass transfer phenomena. The simulated outlet temperature and the corresponding useful thermal power were subsequently exported back to Simulink, where they were incorporated into the building energy model for control strategy implementation and for determining the thermal energy flow distribution to downstream system components.
Results
Several control strategies were developed to optimize the operation of the integrated system, enabling adaptive management of heat generation, storage, and delivery. Representative days from all four seasons were simulated to capture seasonal performance variation under diverse climatic and operational conditions.
Conclusions
The developed framework enables seasonal and dynamic performance assessment of sorption-based heat storage systems and supports optimal integration with other energy components—such as heat pumps, sensible heat storage, photovoltaics, and electric heaters—to ensure the required supply temperature for various locations and building sizes. Simulation results for representative winter days in Athens indicate that the system effectively heats the room using the heat stored during the summer desorption mode simulations. During periods of low solar radiation, the collector temperature drops, triggering the reactor to operate in adsorption mode. In combination with the collector, reactor, and a backup electric heater, the system maintains the required indoor temperature. The simulation also monitors other performance parameters, including domestic hot water production, which consistently reaches a temperature suitable for human use.

Reference

Daborer-Prado, N. Modeling and Simulation of an Innovative Domestic Sorption Storage System. Diss. MS Thesis, University of Applied Sciences Upper Austria, Wels, Austria, 2019.

Abohamzeh, Elham, Seyed Ehsan Hosseinizadeh, and Georg Frey. "Numerical investigation and response surface optimization of a sorption heat storage systems performance using Y-shaped fins." Journal of Energy Storage 84 (2024): 110803.

Figures used in the abstract

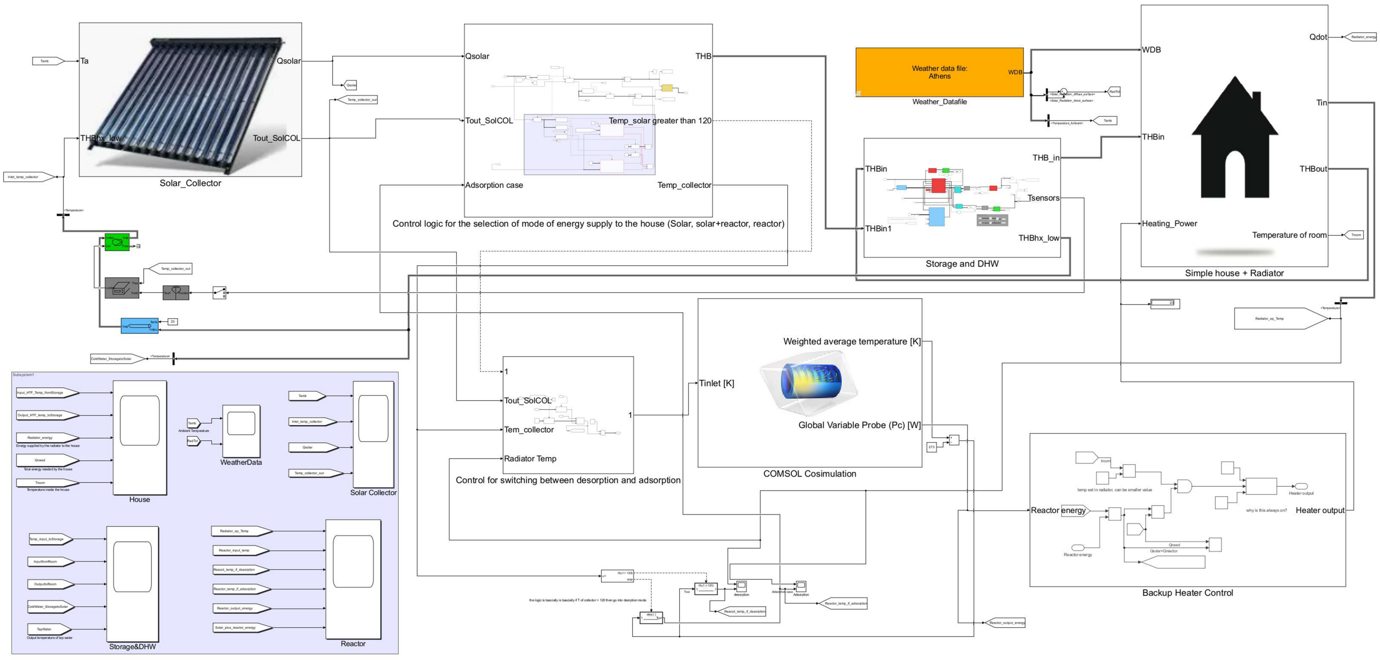
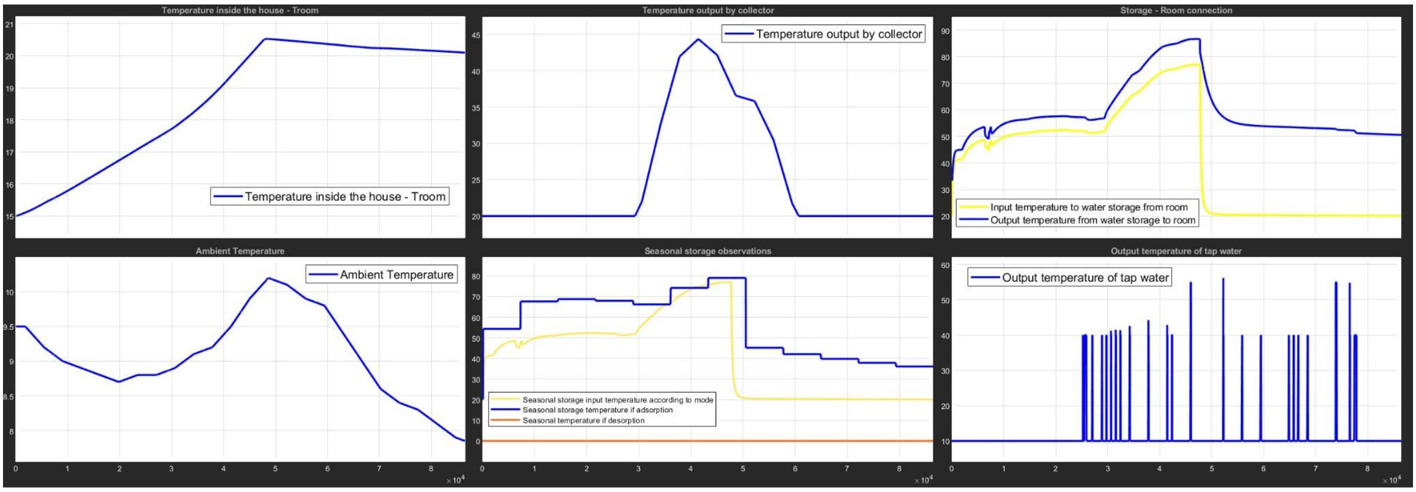
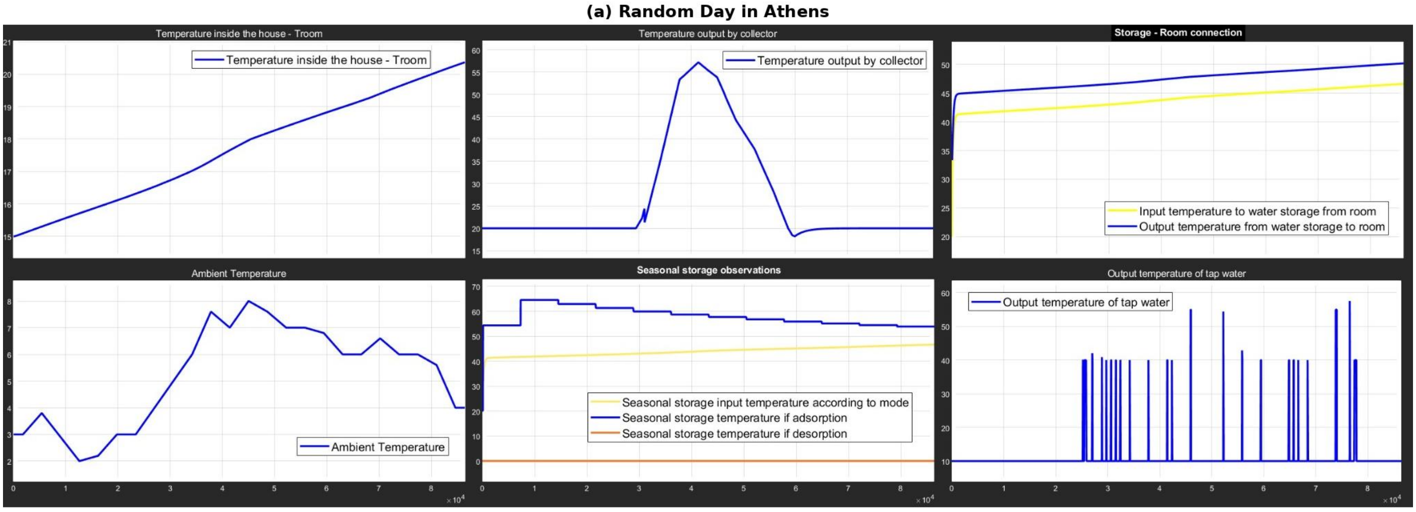


Figure 1 : A schematic of System-Level Co-Simulation



(a) Random Day in Athens



(b) Coldest day in Athens

Figure 2 : System Analysis for a Representative Winter Day

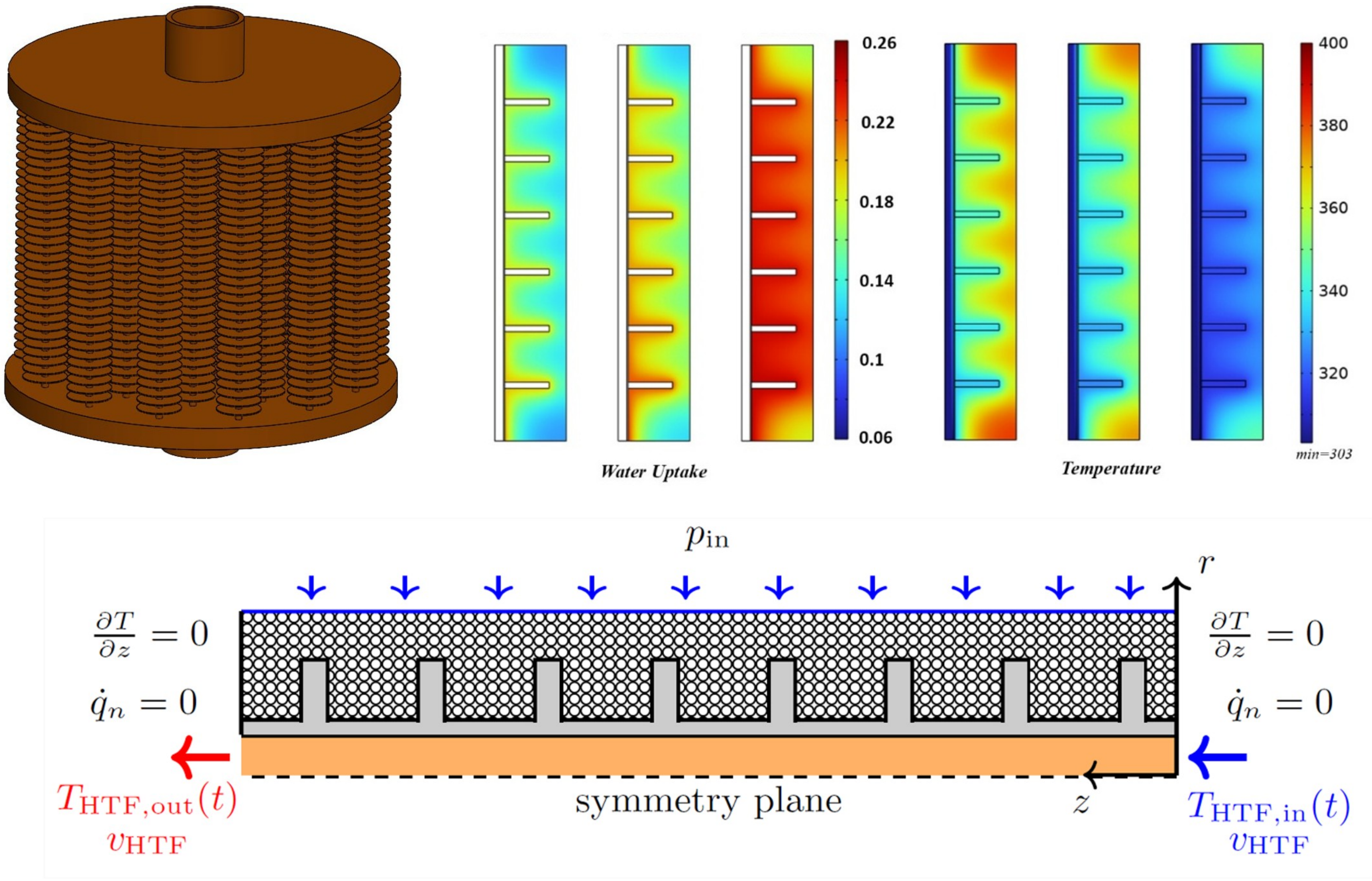


Figure 3 : Schematic of the Developed Reactor Model in COMSOL Multiphysics®