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ABSTRACT

This editorial article introduces a Special Issue of *Applied Thermal Engineering* dedicated to the 36th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems (ECOS 2023), held from 25 to 30 June 2023 in Las Palmas de Gran Canaria, Spain. The conference welcomed 413 participants from 38 countries and featured a rich scientific programme, including 17 plenary and keynote lectures, 2 special sessions, and 425 articles published in the conference proceedings. The 18 articles selected for this Special Issue focus on topics such as solar energy and thermal energy storage, heat pumps and industrial process optimization, hydrogen technologies and sustainable fuels and energy networks and building energy management, reflecting a curated sample of the high-quality research presented at the event. These contributions showcase ongoing advances in specific areas of applied thermal engineering and highlight the strong experimental and modelling capabilities within the scientific community.

1. Introduction

The global shift towards sustainable energy systems necessitates the development and implementation of innovative solutions aimed at enhancing efficiency, reducing environmental impacts, and effectively integrating renewable energy sources into existing infrastructures. In this regard, the 36th International Conference on Efficiency, Cost, Optimization, Simulation, and Environmental Impact of Energy Systems (ECOS 2023), held in Las Palmas de Gran Canaria, Spain, served as a vibrant and influential forum where leading researchers, academics, and industry professionals convened to share and discuss the latest advancements in the design, optimization, and sustainable management of modern energy systems.

In accordance with the recommendations provided by the Chairpersons and Session Monitors, the Selection Committee conducted an evaluation process to identify a collection of high-calibre papers suitable for archival publication in this Special Issue of *Applied Thermal Engineering*. Following an extensive peer-review procedure, a total of 18 papers were selected, each representing a substantial contribution emerging from the ECOS 2023 conference. The selected studies encompass critical topics such as solar energy and thermal storage, heat pumps, hydrogen technologies, sustainable fuels, energy networks, and building energy management.

Presented below is a concise overview of the selected articles included in this Special Issue. Each one is briefly introduced and examined to highlight its primary contributions to the field, while demonstrating the excellent scientific and academic research presented at the 36th ECOS Conference.

2. Solar energy and thermal energy storage

In the research reported in Ref. [1], three storage materials, namely molten salts, cascade phase change materials (PCM), and concrete, integrated into concentrated solar power (CSP) plants are compared. While annual energy output is similar across all cases, the PCM system achieves the lowest levelized cost of electricity ($14.35/kWh) due to its high energy density despite a lower efficiency (93 %). Concrete allows longer discharge but with higher losses and costs ($16.16/kWh). PCM stands out as the most competitive option.

An innovative solar chimney design with integrated sensible heat storage is presented by Sornek et al. [2] to reduce energy consumption in residential buildings under Polish climate conditions. The system, built with an innovative heat-accumulating material, captures solar radiation during the day to preheat ventilation air. Its performance was evaluated through laboratory experiments and dynamic simulations using TRNSYS software. Results indicate that factors such as airflow direction, airflow volume, and the number of heated walls strongly influence the heat transfer from the chimney walls to the air, with significant variations in power output per unit surface.

The study by Sandos et al. [3] develops a transient model of a sensible thermal storage system integrated with a pumped thermal energy storage configuration, including a vapour compression heat pump, an organic Rankine cycle (ORC) system, and a storage tank using R1233ZD (E). Seven parameters were varied to optimize roundtrip efficiency and

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levelized cost of energy storage (LCOS). Wider storage spreads and higher pinch points reduce costs by minimizing tank and exchanger sizes but lower efficiency due to unfavourable temperature gradients. A Pareto front identifies trade-offs between cost and performance, with the optimized system achieving 1.746 roundtrip efficiency and 0.348 €/kWh LCOS.

3. Heat pumps and industrial process optimization

Several studies in this Special Issue focus on heat pumps and optimization. For example, in Padullés et al. [4], a heat pump coupled with thermal storage is optimized to reduce costs and emissions, accounting for electricity price and solar variations. Linear programming shows reductions of up to 17.3 % in costs and 15.4 % in emissions under ideal forecasts, and 15.5 %/14.2 % even with limited predictions. Cost optimization inherently reduces emissions and improves system sizing.

In de Raad et al. [5] energy and exergy-based approaches are compared for optimizing subcritical steam heat pumps. Incorporating internal heat exchangers or flash vessels, suggested by exergy analysis, boosts efficiency (COP from 2.3 to 2.8) and reduces costs (from €10.3 M to €8.7 M over 5 years). Exergy-based methods prove superior for effective design improvements.

Höges et al. assess [6] how different evaluation methods affect the optimal selection of refrigerants for heat pumps, analysing ten options using SCOP, TEWI, LCCP, and LCA. Results show minimal differences in refrigerant rankings across SCOP, TEWI, and LCCP, as indirect emissions dominate and depend on SCOP. With current regulations (zero ODP, GWP < 150), SCOP alone is sufficient for selection, with R436A showing the best ecological performance.

4. Hydrogen technologies and sustainable fuels

A four-parameter semi-empirical model for alkaline water electrolysis (AWE) is introduced by Jin et al. [7], designed to minimize empirical fitting while ensuring reliable extrapolation. The model, tested in 0-D, ½-D, and 1-D configurations, accurately reproduces literature and experimental data for system optimization. Results show that maintaining small temperature differences in AWE stacks (76–80 °C) improves efficiency and lowers hydrogen production costs, aiding the design of decarbonization and energy storage systems.

Dossow et al. [8] integrates solid oxide electrolysis (SOEL) into a biomass-to-liquid (BtL) process to produce sustainable aviation fuel via gasification, co-electrolysis, and Fischer-Tropsch synthesis. Two configurations—electrified BtL (eBtL) and power-and-biomass-to-liquid (PBtL)—are assessed, achieving carbon efficiencies of 61–94 % with reduced electricity demand compared to conventional methods. Up to 17 % of SOEL's energy can be supplied by syngas heat, boosting overall energy yield and efficiency, though renewable electricity and further SOEL development are essential for feasibility.

5. Energy networks and building energy management

In their work, Elhafaia et al. [9] present a non-linear programming (NLP) optimization for district heating networks, optimizing pipe sizing and operation with accurate network modelling. Using orthogonal collocation on finite elements to solve temperature partial differential equations (PDEs) and Darcy–Weisbach for pressure drops, the study minimizes investment, operational, and total costs. The results identify optimal pipe diameters and demonstrate robustness across different initial conditions and heat production costs.

The study of Ubachukwu et al. [10] presents web-based applications developed under the Living Lab Energy Campus initiative to promote energy-efficient behaviour among office occupants at Forschungszentrum Jülich. The tools provide real-time feedback, gamification, and automated heating control to influence ventilation and temperature habits. Field experiments showed significant reductions in energy penalties of up to 65 % in ventilation-focused interventions—and annual thermal energy savings of 18 % (11.8 MWh) in a pilot building.

A two-stage optimization framework is proposed by Fuchs et al. [11], which can be used to design cost-effective subsidy strategies that support building-sector decarbonization. By integrating government-level funding decisions with individual building cost-optimization models, the approach identifies minimum subsidy rates needed to make low-emission technologies and insulation upgrades viable. Results show that targeted subsidies up to 40 % for heat pumps combined with building insulation—significantly drive emission reductions, reinforcing their role in meeting climate targets alongside renewable energy expansion.

Zabala Urrutia et al. [12] introduce Building Optimizer, an adaptive model predictive control (MPC) system with self-learning capabilities for managing HVAC in buildings. It optimizes energy use and supports community demand response by adjusting consumption based on thermal inertia and real-time data. Compared to traditional controllers, Building Optimizer improves thermal comfort and shifts peak loads by over 13 %, effectively providing power flexibility without occupant discomfort.

6. Other thermal energy and optimization applications

Dzido and Krawczyk [13] analyse dry ice blasting, which is an industrial cleaning method based on high-speed air and CO_2 particles. The cleaning effect results from cooling, abrasion, and sublimation forces, influenced by air pressure, particle velocity, and nozzle geometry. A mathematical model of supersonic two-phase flow was developed in Ansys CFX to study particle behaviour, including collisions and mass loss. Results show nozzle geometry, inlet pressure, and particle size strongly affect transport efficiency, which reached up to 91.1 % with Nozzle A at 4 bar. The model provides a valuable tool for optimizing nozzle designs and improving cleaning performance.

The study proposed by Satasiak et al. [14] conducts an exergy analysis of a negative CO_2 emission gas power plant (nCO2PP) integrating fuel preparation, power generation, and carbon capture. The cycle is modelled in Aspen Plus with REFPROP, combining deterministic and Monte Carlo approaches, the latter simulating sewage sludge composition for greater accuracy. Results identify major exergy losses in the wet combustion chamber, gasification, and gas scrubber, with efficiencies ranging from 62 % to 89 % in key components.

In their study, Sosnowski et al. [15] present several sorption reactor concepts designed to address specific operational challenges. Heat and mass transfer parameters for each design were calculated using a customized computational fluid dynamics (CFD) code. A novel model combining CFD and discrete element modelling was developed to accurately represent fluidized sorption reactor behaviour. The numerical model was validated using experimental data from a dedicated test stand. The study provides insights for advancing innovative sorption reactor designs.

Buchalik and Nowak [16] study thermoelectric cooling under pulsed quasi-steady conditions, relevant for intermittently operating electronics. By optimizing heat reservoirs and electrical current profiles in a two-stage system, it achieves lower cooling temperatures than steady-state operation for limited times. The analysis reveals how supercooling levels, duration and thermal resistances interact, providing detailed insights into performance limits and optimization strategies.

In their study, Ghazale et al. [17] present a hybrid thermochemical cycle designed to recover medium-grade waste heat (150–250 °C) for simultaneous cooling production and mechanical work via an integrated expander. The two-step, discontinuous sorption process also enables thermal storage. Experimental tests reveal how electrical load influences the coupling between expander and reactor, while highlighting limitations such as internal leaks and heat transfer inefficiencies. A parametric study suggests the potential to generate 125 W of mechanical power and 2.3 kW of cooling, paving the way for a detailed exergy analysis to reduce irreversibilities and improve cycle efficiency.

Finally, Amiri et al. [18] analyse an innovative system combining a spray ejector condenser and a cyclone separator for steam condensation and CO2 purification in power plants. It investigates the effects of CO2 flow rate, cyclone cone size and droplet breakup on separation efficiency and energy consumption. Results show that increasing cone size and droplet breakup enhances efficiency but also raises pressure drop, highlighting a trade-off between purification and energy use.

7. Conclusion

The original research articles included in this Special Issue reflect not only the diversity but also the quality of research presented at ECOS 2023, emphasizing the growing relevance of innovative methodologies and emerging technologies in advancing the global energy transition. This collection of articles illustrates how the convergence of theoretical advancements, sophisticated numerical modelling, and meticulous experimental validation can generate concrete solutions to some of the most pressing challenges in modern energy systems. By addressing topics ranging from thermal energy storage and heat pump optimization to renewable fuel production and energy management in buildings and networks, these studies collectively serve as a roadmap for the development of cleaner, more efficient, and economically viable energy infrastructures. We strongly believe that this collection will not only inform and inspire future research, but also encourage collaboration among scientists, engineers, industry leaders, and policymakers as we work together to accelerate the transition toward a sustainable, resilient, and low-carbon energy future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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