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Editorial

Special Issue on "Modeling, Design and Engineering Optimization of Energy Systems"

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The global energy landscape is undergoing a transformative shift, driven by the urgent need to address climate change, enhance energy efficiency, and integrate renewable energy sources [1–3]. Advanced modeling, innovative design, and engineering optimization are pivotal to achieving these goals [4]. This Special Issue of *Processes* on "Modeling, Design, and Engineering Optimization of Energy Systems" presents cutting-edge research that explores novel methodologies, computational tools, and optimization strategies to tackle the complexities of modern energy systems.

1. Innovations in Energy Storage and Conversion

Energy storage systems are critical for balancing supply and demand, especially with the increasing penetration of intermittent renewable energy sources [5]. This Special Issue features several studies focused on optimizing energy storage technologies. One article [6] proposed a framework to quantify the environmental benefits of electrochemical storage systems, providing policymakers and industry stakeholders with data-driven insights to support sustainable deployment. Meanwhile, another article [7] addressed the challenges of wind power variability by integrating hybrid storage solutions. This not only enhanced grid reliability but also reduced the need for fossil-fuel-based balancing reserves. Collectively, the study underscored how technological advancements in energy storage can bolster system resilience, support higher renewable penetration, and accelerate progress toward a sustainable energy future.

2. Hydrogen and Fuel Cell Technologies

Hydrogen energy and fuel cell technologies are rapidly emerging as critical enablers of a sustainable and decarbonized energy future [8]. As nations worldwide strive to meet ambitious climate targets, hydrogen—particularly when produced via renewable-powered electrolysis ("green hydrogen")—offers a versatile solution for sectors that are challenging to electrify directly, such as heavy industry, long-haul transportation, and seasonal energy storage [9]. Fuel cells, which convert hydrogen into electricity with high efficiency and zero emissions, further enhance this potential, making hydrogen a cornerstone of the future energy mix [10]. In this Special Issue, cutting-edge research highlights the multifaceted advancements in hydrogen-based systems. One standout article [11] introduced an innovative Integrated Energy System approach by enhancing conventional Power-to-Gas (P2G) systems. To overcome the operational dependency of existing P2G, hydrogen fuel cells (HFCs) were integrated, enabling autonomous dual-phase operation that strengthened renewable energy integration. A tiered penalty–reward

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carbon trading mechanism, with differentiated emission pricing, incentivized energy suppliers to reduce emissions. Further, flexible heat-to-power ratio adjustment in cogeneration significantly boosted energy efficiency. The proposed P2G-HFC co-optimization model minimizes total costs—including carbon trading and renewable integration expenses—across the combined system.

3. Computational and AI-Driven Optimization

Artificial intelligence (AI) and computational modeling are fundamentally transforming the design, operation, and optimization of modern energy systems [12]. One article [13] synthesized the current AI-CDR integration research, articulating the following four principal implementation dimensions: precision carbon quantification, adaptive energy system reconfiguration, the dynamic spatiotemporal orchestration of CDR infrastructure, and symbiotic mechanism design—collectively demonstrating AI's tripartite value proposition in environmental mitigation, economic optimization, and efficiency augmentation. Future advancement necessitates next-generation computational frameworks for optimization, unified cross-domain data fusion architectures, robust decision-risk analytics under uncertainty, and policy-informed interdisciplinary collaboration.

4. Renewable Energy Integration and Smart Systems

The seamless integration of intermittent renewable energy sources into legacy power grids demands increasingly sophisticated optimization techniques [14], particularly as global renewable penetration targets exceed 60% by 2040. One article [15] in this Special Issue addressed the challenges of variability and demand-side management. This study employed a coordinated charging–discharging strategy for balancing user mobility patterns and charger operational efficiency. A spatiotemporal probability model with Monte Carlo simulations generates EV mobility trajectories, informing a linear programming framework that minimizes the dual costs of charger operation expenses and user charging fees. Empirical validation shows that corporate costs reach a minimum at specific charger deployment levels under routine travel patterns. Crucially, user-centric optimization objectives heighten sensitivity to battery degradation, drastically reducing discharge participation willingness.

5. Conclusions

The research presented in this Special Issue reflects the diverse and dynamic nature of energy system optimization. From hydrogen technologies to AI-driven solutions, these contributions pave the way for a more sustainable and efficient energy future. We hope this collection inspires further innovation and collaboration in the field, ultimately accelerating the transition to a low-carbon economy.

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