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# Editorial: Assessment of renewable energy systems for energy conversion and storage

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Editorial on the Research Topic
Assessment of renewable energy systems for energy conversion and storage

The global pursuit of decarbonizing power systems has driven the transition from fossil fuels to renewable energy systems which is critical for achieving sustainable development. Renewable sources offer virtually inexhaustible energy; however, their variable nature poses challenges for a reliable supply of electricity (Hemeida et al., 2022). Harnessing energy from these sources requires advanced energy conversion systems, such as photovoltaic cells, wind turbines, and gasification plants. Under optimal conditions, these systems may offer efficiencies of 20%–45%; however, it is worth noting that the intermittency of solar and wind power requires energy storage solutions to balance supply and demand (Hemeida et al., 2022). Energy storage and advanced conversion technologies have emerged as key drivers of renewable energy penetration, offering flexibility, risk mitigation, and multi-service value. It is also essential to innovate to meet current energy demands, improve the operation of conversion systems and optimize future designs. In order to address challenges related to extreme environments and the nature of produced energy, the team of editors proposed the Research Topic "Assessment of Renewable Energy Systems for Energy Conversion and Storage" in the journal Frontiers in Energy Research. Four articles were contributed, which cover the numerical and experimental studies on renewable energy, materials and systems under extreme environments.

Accurate modeling of individual renewable sources is essential, but real-world energy systems require coordination of multiple sources. To this end, a novel algorithmic approach for the precise extraction of unknown parameters of solar photovoltaic cell models was utilized by Hussain et al., who introduced the Archimedes Optimization Algorithm (AOA) in their study for the extraction of unknown parameters of solar photovoltaic (PV) cell models using both the Single Diode Model (SDM) and Double Diode Model (DDM) (Hussain et al.). Manufacturers typically omit essential model parameters, hindering accurate performance prediction. A novel formulation of the root mean square error (RMSE) was introduced that computes the error between the estimated and experimental currents at each I–V point. The results suggest that AOA outperforms other metaheuristic methods in the extraction of parameters, offering strong, accurate modeling for PV system design and control. AOA-based PV parameter extraction offers a future-ready approach that enhances simulation accuracy, enabling efficient, scalable integration of renewable energy systems into the grid by providing reliable renewable energy modeling and precise solar performance prediction.

The research submitted by Cai et al. presented an advancement in the field by improving energy systems integration via a two-tier coordinated optimal scheduling framework that manages wind, PV, hydropower, and energy storage systems more efficiently. Their work used an elevated Generative Adversarial Network (GAN) for the creation of scenarios, and an improved Coati Optimization Algorithm (COA) to compute solutions. This method addresses the uncertainty and variability of renewable sources. Using the studied model, the authors were able to minimize load fluctuations and optimize energy dispatch thus achieving a 51.7% reduction in active network losses. The study was validated on a modified IEEE 30-bus system and provides solutions that are relevant for future smart grid development, in which multi-source integration is essential to sustaining the transition toward low-carbon, resilient energy infrastructure (Cai et al.).

A multitude of integration challenges are revealed through multi-energy coordination, directly highlighting the critical importance of intelligent energy storage configuration strategies. A bi-level programming optimization model addressed these needs by simultaneously considering flexible requirements and operational risk through the conditional value-at-risk methodology presented by Hui et al.. The upper level of the model optimizes the energy storage system, does planning and makes decisions, while the lower level of the model simulates daily operations under a typical scenario to incorporate flexibility requirements and constraints to characterize the required flexibility of the power system. This approach transforms the original bi-level programming model into a single-level, directly solvable, mixed Integer Linear Programming model through the association of constraints, providing an efficient solution while maintaining planning accuracy. The results effectively demonstrate how an optimized storage system provides the flexible backbone necessary for future development while reducing operational risk in the power system (Hui et al.).

Some studies suggest advancement beyond traditional storage solutions. Cozzolino and Bella reviewed electrolyzer-based systems with evolutionary grid support technologies, enabling dual-purpose capabilities. Being based on electrolyzers, these systems can produce hydrogen for the end user while providing ancillary services. These innovative systems deliver frequency control, voltage control, congestion management, and black-start capabilities, leveraging rapid response measures in milliseconds, enabling ultrafast grid support that surpasses conventional generation units (Cozzolino and Bella).

Progress in the field of renewable energy, from precise renewable energy modeling to multi-source energy coordination, and intelligent storage units to advanced electrolyzer-based grid services has created a comprehensive ecosystem for a sustainable energy transition. The submitted articles demonstrate innovative optimization and modeling approaches for renewable energy conversion and storage. A review of the electrolyzer-based system has underscored how power-to-hydrogen conversion can provide both hydrogen and grid balancing services. Each article contributes to advances in scenario-based optimization, offering flexibility and informed planning. Together, they illustrate how coordinated multi-source operation and advanced conversion technology can be integrated to improve energy conversion and storage utilization. These articles critically assess the performance, environmental impacts, and techno-economic viability of leading renewable energy conversion and storage systems, providing insights to guide future research, deployment strategies, and policy measures.

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## Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. ChatGPT is used to improve the language.

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