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Editorial: 10 Years of frontiers in energy research

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Editorial on the Research Topic

10 Years of frontiers in energy research

As Frontiers in Energy Research marks its 10th anniversary, we reflect on a transformative decade defined by groundbreaking discoveries, interdisciplinary collaboration, and global efforts to address humanity's most pressing energy challenges. Since its inception, this journal has served as a beacon for cutting-edge research, bridging the gaps challenging the sustainable developments and technological advances of energy. This commemorative issue not only celebrates our shared achievements but also underscores the urgency of accelerating the energy transition in an era of climate imperatives and technological revolutions. In the following pages, we invite readers to explore visionary contributions that redefine possibilities for a sustainable future.

From theoretical frameworks to practical applications, this issue exemplifies the multi-scale approach required for energy innovation. [Campbell et al.](#) comprehensively examined the concept of energy as a thermodynamic metric for evaluating ecological and social systems, emphasizing its role in quantifying evolutionary competitiveness through the principle of 'maximum empower'. Their white-box Geobiosphere model refines energy accounting through spatiotemporal boundary expansion, proposing blockchain-enhanced platforms to improve global ecosystem management via standardized thermodynamic benchmarking. Complementing this systems-level perspective, [Kowalski et al.](#) addressed electronic correlation challenges in energy materials through advanced computational methods. Their work demonstrates how DFT + U approaches with Hubbard U parameters enable accurate predictions of metal oxide properties, bridging theoretical simulations with electrochemical energy storage design.

The transition from theoretical foundations to material innovation finds expression in [Sankarasubramanian et al.](#) analysis of titanium-based redox flow batteries. With 50-fold greater crustal abundance and 90% lower cost than vanadium, titanium systems emerge as high-potential alternatives for grid-scale storage ([Sankarasubramanian et al.](#)), contingent upon advancements in catalyst development. Expanding the electrocatalyst frontier, [Santos et al.](#) reviewed transition metal-based alternatives to precious metal catalysts. Their analysis highlights how polyoxometalates and metal-organic frameworks enhance catalytic activity while reducing reliance on scarce materials, accelerating sustainable energy conversion.

Bioenergy innovations demonstrate nature-inspired solutions across multiple scales. [Igathinathane et al.](#) quantified break-even transportation distances for 14 biomass

feedstocks, revealing ship transport's superiority through large cargo capacities and steady operations. Building on biomass logistics, Chundawat et al. engineered supercharged enzymes to overcome lignin inhibition in bioethanol production. Their work on ammonia-pretreated corn stover reveals strategic protein modification as key to high-temperature biorefining. Ieropoulos et al. further extended biomass applications through microbial fuel cells that convert organic matter to electricity, showcasing microalgae's potential for carbon-neutral energy cycles despite persistent cultivation challenges.

Dynamic energy management emerges as critical in evolving consumption landscapes. Ali et al.'s ANFIS2 model demonstrated 45% error reduction in pandemic-era residential energy use forecasting, providing adaptive frameworks for uncertain environments. Zhang et al. further addressed pandemic impacts through EV charging load models responsive to public health crises, capturing load shifts between outbreak/non-outbreak periods via dynamic feature integration. For grid-scale optimization, Lai et al. developed storage dispatch strategies for China's deregulated power markets, balancing renewable integration with multi-market revenue streams. Pahwa et al. reinforced the economic imperative for PV-battery hybrids, showing how integrated systems offset efficiency losses through peak demand reduction.

Converging technological and policy dimensions, Naqvi et al. synthesized the evolution of net-zero emissions and circular economy paradigms. Their analysis of carbon capture innovations and policy frameworks like the EU Green Deal underscores the need for context-specific solutions to bridge technical potential with socio-economic realities.

In summary, the Research Topic of 10 Years of Frontiers in Energy Research highlights scientific and technological advancements of energy conversion, use, and management. We sincerely thank authors, reviewers, and readers. Together, we will continue pioneering sustainable solutions to global energy challenges.

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