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Editorial: Energy management, energy efficiency policies, and energy system studies

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Editorial on the Research Topic
Energy management, energy efficiency policies, and energy system studies

Global energy use and greenhouse gas emissions continue to rise, placing the industrial sector—along with transport and the built environment—at the centre of today's sustainability challenges. Strengthening energy management and advancing energy efficiency policies are critical, as they reduce costs, enhance competitiveness, and support key Sustainable Developments Goals. Meanwhile, energy systems are becoming more complex with the rise of Industry 4.0 technologies such as Artificial Intelligence, Internet of Things, and digital twins. These innovations offer strong potential for real-time monitoring and optimisation, yet a comprehensive understanding of how energy resources interact with other industrial resources—and how firms can adopt these technologies effectively—remains insufficient. To address these Research Topic, the editorial team proposed the Research Topic "*Energy Management, Energy Efficiency Policies, and Energy System Studies*" in *Frontiers in Energy Research*. A total of twelve articles were contributed, covering diverse themes across this important area and offering valuable insights for advancing sustainable energy systems.

Green innovation and improved energy efficiency are essential for advancing sustainable industrial development. In this context, Zhou and Ning research offers valuable insights by examining how innovative industrial cluster policies influence urban green technological innovation in China. The results show that the investigated pilot policy significantly promotes urban green technological innovation, a finding that remains consistent across multiple robustness checks.

The article by Sun and Wang presents a compelling argument that coordinated reductions in Sulfur dioxide, Nitrogen oxides, and Carbon dioxide can be achieved when energy use patterns and governance investments are optimized under constrained financial resources. In their analysis, causal relationships

between air quality and pollutant emissions are first identified using the Granger causality test, establishing an evidence-based foundation for further modelling.

Given the growing recognition that supply chains can significantly influence industrial sustainability outcomes, Hilmola et al. argue that understanding manufacturers' collaboration with suppliers on energy efficiency is both timely and essential. Their study critically assesses how extensively manufacturers pursue energy efficiency initiatives with their suppliers and to identify the underlying drivers that compel firms to prioritise such collaborative efforts. By examining these dynamics, the research underscores the strategic importance of supplier engagement in achieving system-wide efficiency improvements.

As the built environment moves through rapid technological and sustainability transitions, Lane et al. highlight the barriers, drivers and motivational factors particularly integrating Building Management Systems. The study shows that improved energy efficiency is a key motivation for users and decision makers, while technology providers emphasise easier workflow. Furthermore, the study underscores the need for a facilitator to support organisations in making informed decisions and argues that such facilitation should be integrated into future twin-transition policies.

Functional data analysis is increasingly recognised for its potential in electricity price forecasting, Jan et al. position it as a particularly effective approach for the complexities of deregulated power markets. Electricity prices exhibit challenging features—high-frequency fluctuations, long-term trends, multiple seasonal patterns, sudden spikes, and holiday effects—making accurate forecasting essential yet difficult. The authors apply functional data analysis to the day-ahead price forecasting problem, arguing that, unlike traditional time-series models, it captures the full daily price profile and thereby offers a more robust foundation for short-term predictions.

Whilst decision-making plays a central role in the uptake of energy-efficient solutions, a clear understanding of how individuals make these choices is essential. Building on this premise, Niknafs et al. examine the perspectives of single-family house owners and the factors that shape their renovation decisions. The study highlights the importance of assessing both the barriers and the drivers behind these decisions, incorporating socio-economic considerations as well as the role of financial instruments such as green loans.

While Hydrogen is regarded as a critical element for decarbonization, Marnate provides valuable insights into why its uptake has remained inconsistent. Drawing on historical trends, the study highlights that only by integrating technical, economic, policy, and social perspectives across the full hydrogen value chain can the sector break its recurring boom-and-bust cycles and secure a stable, long-term role in future decarbonization pathways.

Similarly, CO_2 capture is increasingly recognised as a critical pillar of global decarbonization strategies. In this space, Milic et al. investigate the potential of integrating small-scale direct air capture technology into building ventilation systems, focusing on its application within a gym environment. The study discusses the technical configuration, operational considerations, and economic implications of deploying building-integrated direct air capture, offering valuable insights into how indoor environments can contribute to distributed CO_2 removal efforts.

Data-driven decision-making is very critical, particularly for monitoring and improving energy efficiency. Responding to this, Milic presents a structured approach for data centres by introducing a decision-making framework. Drawing on insights from an Ericsson-operated data centre in Sweden, the study outlines how large datasets generated by building management systems can be systematically used to guide operational decisions. By incorporating AI techniques—the framework demonstrates how advanced analytics can strengthen operational efficiency within data centre environments.

With regard to energy management, a precise understanding of how coal-fired units operate under low-load conditions is essential for achieving meaningful flexibility improvements. Xu et al. address this need by developing an integrated simulation model that couples key boiler and turbine processes—including flue gas and air flows, the steam–water cycle, and heat-recovery systems. Tailored specifically for low-load scenarios, their model is applied to a 350 MW supercritical unit and shows strong agreement with operational data, demonstrating its reliability as a decision-support tool for guiding future flexibility upgrades and performance optimisation.

While such advanced modelling tools support energy optimisation in large-scale industrial systems, energy management and efficiency challenges persist in many developing economies at the grassroots level. Reflecting this broader disparity, Lutfi et al. examine smallholder rice farming in Indonesia, revealing how entrenched practices lead to excessive energy use and elevated greenhouse gas emissions. The study argues that meaningful improvement will require more than incremental adjustments—calling for targeted mechanisation, and the adoption of sustainable energy solutions to strengthen the resilience of low carbon farming systems.

Finally, Xavier et al. draw attention to a significant gap in the scientific literature: energy efficiency is rarely explored within supply chain management (SCM), and existing studies tend to focus only on total energy use rather than examining opportunities to reduce consumption among upstream suppliers. The lack of standardised methods for assessing suppliers' energy use further restricts progress, particularly for small and medium-sized enterprises facing barriers to implementing energy management practices. Consequently, although energy efficiency is one of the most cost-effective strategies for reducing CO_2 emissions, its integration into SCM research remains limited, highlighting a substantial and enduring knowledge gap in this area.

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