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Editorial

Sustainable Industrial Investment in the Energy Sector: Aligning Capital, Risk, and the Low-Carbon Transition

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1. Introduction

In recent decades, the global economy has been increasingly defined by the demand to balance industrial growth with environmental limits. Energy systems represent a critical technology in this transformation pathway, as they can be considered both as the primary source of greenhouse gases emissions and as the main strategy for decarbonization. Therefore, the sustainability of industrial investments in the energy sector is crucial for the success of the low-carbon transition and the spread of a renewed concept of industry [1].

Conventional approaches to project evaluation often prioritize profitability over Environmental, Social, and Governance (ESG) outcomes. We argue that this perspective is no longer viable in a world facing new challenges, such as climate instability, increasingly limited resources and social inequality. In our view, to embrace a redefined and sustainable industrial paradigm, an investment analysis in the energy sector should evolve beyond the conventional approach of technical and economic-financial feasibility. These investments should be evaluated within the context of broader sustainability frameworks and capable of generating systemic value that goes beyond mere economic return [2,3]. This strategic realignment requires an innovative approach that harmonizes capital allocation, risk management and technological innovation with Sustainable Development Goals (SDGs). The challenge is not only to finance cleaner technologies but also to reconfigure the institutional foundations of investment decision-making [4].

We believe that engineering design, corporate strategy and financial governance must be integrated to deliver sustainable industrial projects that are resilient, inclusive and regenerative.

This editorial discusses key challenges, emerging frameworks and practical pathways for integrating sustainability into the core logic of industrial energy investment, investigating how ESG criteria, circular economy models and financial innovation can collectively reshape the industrial landscape and accelerate the global energy transition [5,6].

2. A New Paradigm for the Sustainability of the Industrial Investment in the Energy Sector

Energy transition is not only a matter of technological transformation; it is a multifaceted phenomenon that includes financial, social and institutional implications. Industrial investment plays a key role in determining the speed and equity of this process [7]. In this regard, the present capital allocation will inevitably shape the future path towards decarbonization. However, current financial evaluation models, such as Net Present Value (NPV) and Internal Rate of Return (IRR), are inadequate in capturing the long-term benefits and inherent risks associated with sustainability [4,8].

Received: 23 May 2026
Accepted: 4 June 2026
Published: 16 June 2026

To address the future challenges, it will be necessary to rethink the conventional concept of value, integrating sustainability into investment decision-making and supplementing traditional metrics with indicators that account for externalities, life-cycle impacts and resilience. For instance, a renewable hydrogen plant should be evaluated not only on its expected returns but also on its contribution to decarbonization pathways, local employment and technological learning. This broader concept of value aligns with emerging ESG frameworks, which emphasize transparency, accountability and stakeholder engagement [9–11]. This ESG integration in the industrial sector is no longer optional for credibility and competitiveness in global markets [11].

Alongside the updating of investment analysis instruments, due consideration must be given to the impact of technological innovation. The rapid evolution of energy technologies, ranging from advanced photovoltaics and green hydrogen production to energy storage and carbon capture, introduces both uncertainty and opportunity. Managing technological risk requires advanced and flexible investment portfolios and adaptive governance mechanisms. In this context, scenario and real options analysis can provide a more solid basis for decision-making in conditions of uncertainty [12]. Digitalization allows for data-driven sustainability assessments and continuous performance monitoring, closing the gap between engineering optimization and financial accountability.

From a systemic perspective, sustainability-oriented investments must incorporate the social dimension into the energy transition; costs and benefits distribution across communities determine whether industrial projects will exacerbate or mitigate inequalities. The concept of a 'just transition' highlights the moral and economic imperative to ensure that workers, suppliers and local ecosystems are not marginalized in the transition toward clean energy. This inclusivity can be achieved through the implementation of participatory governance models, appropriately designed funding mechanisms and transparent dialog with stakeholders [13]. We believe that social legitimacy can be considered as important to project success as technological excellence.

In this intricate landscape, the circular economy is another critical factor. Industrial energy projects are increasingly evaluated not only by their output but also by their material efficiency and waste minimization [3,7,8]. The integration of circular economy principles into investment design allows for resource recovery, product-life extension and reduction in associated carbon emissions [5]. For instance, repurposing decommissioned wind turbine blades into composite materials for new structures can create both environmental and economic value [14]. In this sense, circularity is not merely a sustainability add-on but a competitiveness driver [7,12].

Sustainable investments necessitate financial innovation that can serve as a foundational element to support technological progress. Financial instruments such as green bonds, sustainability-linked loans and transition finance mechanisms have attracted significant capital toward decarbonization [6,8]. Their effectiveness depends on the credibility of underlying standards and the integrity of reporting frameworks [10,15].

At the policy level, coherence and predictability are essential for investors to commit to long-term projects, as they provide a stable regulatory environment. Governments should therefore design policy instruments that reward sustainability performance, penalize carbon intensity and reduce bureaucratic barriers for green innovation [16]. The implementation of coordinated industrial and energy policies, supported by public–private partnerships, could accelerate the diffusion of sustainable technologies and foster regional industrial ecosystems that generate shared prosperity [8].

Considering the factors just discussed, industrial investments in the energy sector are undergoing a paradigm shift. At a global level, emerging economies face the dual challenge of expanding access to energy while reducing carbon emissions. International collaboration

and technology transfer are essential to overcome techno-financial barriers and to avoid a 'two-speed transition', where advanced economies decarbonize while developing regions remain locked in fossil fuel dependence [4]. Considering these factors, the development of public–private partnerships and a joint effort among key institutional stakeholders is a promising step toward a more equitable energy future [7].

In such a complex context, universities and research institutions play a decisive role. Research should provide actionable frameworks that integrate science, finance and policy. Interdisciplinary cooperation is essential for the development of methodologies and indicators that enable sustainability-driven investment appraisal [6,8]. With a view to future projects, it is important to establish a new research agenda focused on integrating life-cycle sustainability assessment, system thinking, and financial modeling into decision-support instruments for industrial investors [6,12].

3. Conclusions

In the energy industry, sustainable industrial investments are a social necessity that constitutes an effective financial strategy [2,9]. The future of the low-carbon transition will depend on our ability to combine capital allocation, technological progress and social inclusion. Sustainability must be integrated into every stage of the investment process, encompassing the feasibility analysis, operational management and decommissioning. The integration of ESG criteria, the adoption of circular economy principles and the management of transition risks should not be viewed as isolated activities, but rather as interdependent aspects of a systemic transformation [3,7].

To institutionalize sustainability as a resilient source of innovation and to shape the future of the low-carbon transition, a collective effort must be made across academia, industry and government. In this direction, sustainable investments are not merely a response to potential harm; instead, they yield shared value for both human prosperity and planet preservation [5,8].

Looking ahead, research and practice should converge toward a common goal: the design of industrial ecosystems that are both economically viable and socially inclusive. The alignment of industrial capital with sustainability objectives is not an abstract concept but an operational necessity for a stable, just and competitive low-carbon transition [11,16].

Author Contributions: Conceptualization, D.M.; writing—original draft preparation, D.M. and G.P.; supervision, D.M. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

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