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RETHINKING SUSTAINABILITY: LINKING ENERGY TRANSITION AND CIRCULAR ECONOMY IN A CHANGING GLOBAL CONTEXT

REPENSAR A SUSTENTABILIDADE: LIGAR A TRANSIÇÃO ENERGÉTICA E A ECONOMIA CIRCULAR NUM CONTEXTO GLOBAL EM MUDANÇA

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Duygu Celayir*
***İstanbul Ticaret University, İstanbul, Turkey
Orcid: https://orcid.org/0000-0002-1435-3910
dcelayir@ticaret.edu.tr

Çağla Celayir**
****Adesso Turkey, Istanbul, Turkey
Orcid: https://orcid.org/0009-0001-4357-3090
muhendiscaglacelayir@gmail.com

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Abstract
The growing urgency of climate change and the increasing pressure on natural resources have led to a renewed focus on how energy systems and production models are structured. In this context, the transition towards cleaner energy sources is often presented as a key solution for improving environmental outcomes. However, it is becoming increasingly clear that energy transition alone may not be sufficient to achieve broader sustainability goals. This study takes a step back and examines how sustainability can be better understood when energy transition is considered together with circular economy practices. Rather than treating these two areas as separate policy domains, the study adopts an integrated perspective and explores how they interact and potentially reinforce each other. Drawing on recent academic studies and international policy discussions, the analysis suggests that improvements in energy systems—such as increasing the share of renewable energy or enhancing energy efficiency—tend to have a positive effect on environmental performance. At the same time, circular economy practices, including resource efficiency, recycling, and the reuse of materials, appear to play a complementary role by reducing overall resource demand and supporting more sustainable production systems. The findings highlight that meaningful progress in sustainability is more likely to be achieved when energy transition is supported by changes in material use and production patterns. This paper is also shaped by the increasing policy discussions around sustainability transitions, particularly in the European context. From a policy perspective,

Resumo
A crescente urgência das alterações climáticas e a pressão cada vez maior sobre os recursos naturais levaram a um foco renovado na forma como os sistemas energéticos e os modelos de produção estão estruturados. Neste contexto. a transição para fontes de energia mais limpas é frequentemente apresentada como uma solução fundamental para melhorar os resultados ambientais. No entanto. torna-se cada vez mais claro que a transição energética. por si só. pode não ser suficiente para alcançar objetivos de sustentabilidade mais amplos. Este estudo dá um passo atrás e examina como a sustentabilidade pode ser melhor compreendida quando a transição energética é considerada em conjunto com as práticas da economia circular. Em vez de tratar estas duas áreas como domínios políticos separados. o estudo adota uma perspetiva integrada e explora a forma como interagem e se reforçam mutuamente. Com base em estudos académicos recentes e em debates políticos internacionais. a análise sugere que as melhorias nos sistemas energéticos — tais como o aumento da quota de energias renováveis ou o reforço da eficiência energética — tendem a ter um efeito positivo no desempenho ambiental. Ao mesmo tempo. as práticas da economia circular. incluindo a eficiência de recursos. a reciclagem e a reutilização de materiais. parecem desempenhar um papel complementar ao reduzir a procura global de recursos e apoiar sistemas de produção mais sustentáveis. As conclusões destacam que é mais provável alcançar progressos significativos em matéria de sustentabilidade quando a transição energética é apoiada por mudanças nos padrões

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this implies that strategies focusing solely on energy may overlook important dimensions of sustainability. Instead, a more integrated approach—one that brings together energy, resource efficiency, and circularity—may offer a more effective pathway towards long-term sustainable development. This integrated perspective contributes to the growing debate on sustainable development by highlighting the importance of aligning energy and resource systems.

Keywords: Sustainability. Energy Transition. Circular Economy.

de utilização e produção de materiais. Este artigo é também moldado pelas crescentes discussões políticas em torno das transições de sustentabilidade. particularmente no contexto europeu. De uma perspetiva política. isto implica que as estratégias que se centram exclusivamente na energia podem ignorar dimensões importantes da sustentabilidade. Em vez disso. uma abordagem mais integrada — que reúna energia. eficiência de recursos e circularidade — pode oferecer um caminho mais eficaz para o desenvolvimento sustentável a longo prazo. Esta perspetiva integrada contribui para o crescente debate sobre o desenvolvimento sustentável. destacando a importância de alinhar os sistemas energéticos e de recursos.

Palavras-chave: *Sustentabilidade. Transição Energética. Economia Circular.*

1 INTRODUCTION

In recent years, growing environmental pressures, climate change, and the rapid depletion of natural resources have increasingly challenged the sustainability of existing economic systems. The traditional linear production model, often summarized as a "take–make–dispose" approach, is no longer considered viable in the long term, particularly in the face of rising global consumption and limited resource availability (Geissdoerfer et al., 2017). As a result, both policymakers and researchers have begun to place greater emphasis on systemic transformations that address not only energy systems but also production and consumption patterns. Within this broader transformation, energy transition has emerged as one of the most widely discussed concepts. It generally refers to the gradual shift from fossil fuel-based energy systems towards cleaner and more sustainable alternatives, including renewable energy sources such as wind and solar power (International Energy Agency, 2021). This transition is widely regarded as a key mechanism for reducing greenhouse gas emissions and mitigating the effects of climate change. Empirical studies consistently show that increasing the share of renewable energy contributes to improved environmental outcomes, particularly through reductions in carbon emissions (Shahbaz et al., 2015).

However, despite its importance, energy transition alone may not be sufficient to achieve broader sustainability objectives. While renewable energy reduces emissions, it does not directly address issues such as resource depletion, material inefficiency, or waste generation. In this sense, focusing exclusively on energy systems may lead to an incomplete understanding of sustainability challenges (Kirchherr et al., 2017). This has led to increasing interest in complementary approaches that can enhance the overall impact of sustainability strategies. At this point, the concept of circular economy provides a particularly relevant framework. Unlike the traditional linear model, the circular economy emphasizes the efficient use of resources, the reduction of waste, and the continuous reuse of materials within production systems (European Commission, 2020). By promoting closed-loop systems, circular economy practices aim to minimize environmental impact while maintaining economic value. Recent studies suggest that such practices not only improve resource productivity but also contribute to environmental sustainability by reducing both material consumption and associated energy demand (Kirchherr et al., 2017). From this perspective, it becomes increasingly important to consider how energy transition and circular economy interact with each other. Rather than treating these as separate policy domains, a more integrated approach may provide a better understanding of sustainability outcomes. In particular, improvements in energy systems may be significantly more effective when combined with more efficient use of materials and resources. This paper is also shaped by the increasing policy discussions around sustainability transitions, particularly in the European context, where integrated approaches to energy and resource management have become more prominent in recent years. These developments suggest that sustainability should not be viewed as a single-dimensional objective, but rather as a complex process requiring coordinated changes across multiple systems. Against this background, the present study explores the relationship between energy transition, sustainability, and circular economy from a more holistic perspective. By bringing these elements together, the study seeks to contribute to the existing literature and to offer a more comprehensive understanding of how sustainable development can be achieved in practice.

2 LITERATURE REVIEW

2.1 Energy transition, economic and environmental sustainability

Energy transition has been widely discussed in the literature as a fundamental driver of sustainable development, particularly in the context of climate change mitigation and long-term economic transformation. At its core, energy transition involves a structural shift from fossil fuel-based energy systems towards low-carbon and renewable energy sources (International Energy Agency, 2021). This transformation is considered essential for reducing greenhouse gas emissions and improving environmental performance at both national and global levels. A large body of empirical research has examined the relationship between renewable energy consumption and environmental sustainability. Most studies report a negative relationship between renewable energy use and carbon emissions, suggesting that increasing the share of renewable energy contributes to environmental improvement (Shahbaz et al., 2015; Apergis & Payne, 2010). In addition, renewable energy has been associated with long-term economic growth, particularly in economies that invest in green technologies and infrastructure (Sadorsky, 2009). However, the literature also highlights that the effects of energy transition are not always straightforward. In some cases, the environmental benefits of renewable energy may be offset by increased consumption or rebound effects, where improvements in energy efficiency lead to higher overall energy use (Sorrell, 2015). This suggests that energy transition alone may not be sufficient to achieve comprehensive sustainability outcomes.

Energy intensity, defined as the amount of energy required to produce a unit of economic output, is another key variable in this literature. Lower energy intensity is generally interpreted as an indicator of improved energy efficiency and is associated with more sustainable production systems (World Bank, 2022). Nevertheless, reductions in energy intensity often depend on broader structural changes, including technological innovation and shifts in economic activity. Taken together, these findings suggest that while energy transition is a necessary component of sustainability, it should be considered within a broader framework that includes additional dimensions such as resource use and material efficiency.

2.2 Circular economy and resource efficiency

The concept of circular economy has gained significant attention as a response to the limitations of the traditional linear economic model. Unlike the linear system, which is based on a continuous flow of resource extraction, production, and disposal, the circular economy emphasizes the reuse, recycling, and regeneration of materials within closed-loop systems (Geissdoerfer et al., 2017). A key contribution of circular economy lies in its focus on resource efficiency. By minimizing waste and maximizing the use of existing materials, circular practices reduce the demand for primary resources and, consequently, the environmental pressure associated with extraction and processing activities (Ghisellini et al., 2016). This is particularly relevant in the context of increasing global demand for raw materials and growing concerns over resource scarcity.

Empirical studies provide strong evidence of the benefits of circular economy practices. For instance, higher recycling rates and increased use of secondary raw materials have been linked to improvements in resource productivity and reductions in environmental impact (Kirchherr et al., 2017). In addition, circular economy strategies can contribute to economic resilience by reducing dependency on imported raw materials and enhancing supply chain stability (Murray et al., 2017). Despite these advantages, the transition towards a circular economy is not without challenges. It requires significant changes in production processes, business models, and consumer behavior. Moreover, the effectiveness of circular economy practices often depends on institutional factors, including regulatory frameworks and policy support (Korhonen et al., 2018).

2.3 Sustainability measurement and multidimensional approaches

Sustainability is inherently a multidimensional concept that encompasses environmental, economic, and social dimensions. However, empirical research has often focused primarily on the environmental aspect due to the availability of measurable indicators. Common measures include carbon emissions, ecological footprint, and resource productivity (OECD, 2020). In recent years, there has been a growing emphasis on resource productivity as a key indicator of sustainability performance. Resource productivity reflects the efficiency with which natural resources are used to generate

economic value and is widely used in policy frameworks, particularly within the European Union (Eurostat, 2023). Higher levels of resource productivity are generally associated with more sustainable economic systems. At the same time, scholars have increasingly questioned the adequacy of traditional economic indicators, such as GDP, in capturing sustainability outcomes. Stiglitz et al. (2009) argue that such indicators fail to account for environmental degradation and resource depletion, leading to an incomplete assessment of economic performance. This has led to the development of alternative frameworks that incorporate broader sustainability metrics.The multidimensional nature of sustainability implies that no single indicator can fully capture its complexity. Instead, a combination of environmental, economic, and social indicators is required to provide a more comprehensive assessment.

2.4 Policy integration: linking energy and resource systems

One of the emerging themes in the literature is the need for policy integration across different domains of sustainability. Traditional policy approaches often treat energy, environment, and resource management as separate areas, leading to fragmented and sometimes inconsistent outcomes. In contrast, recent studies emphasize the importance of integrated policy frameworks that address these dimensions simultaneously (D'Amato et al., 2017). The integration of energy transition and circular economy is particularly important in this context. While energy transition focuses on reducing emissions through cleaner energy sources, circular economy addresses the efficiency of material use. Combining these approaches can lead to significant sustainability gains by addressing both energy and resource dimensions.Policy frameworks such as the European Green Deal illustrate this integrated approach. By aligning energy, industrial, and environmental policies, such frameworks aim to achieve multiple sustainability objectives simultaneously. However, achieving effective policy integration is challenging. It requires coordination across different sectors and governance levels, as well as alignment between short-term economic objectives and long-term sustainability goals. These challenges highlight the need for further research on how integrated policy frameworks can be designed and implemented effectively.

2.5 Bridging the gap: towards an integrated perspective

Despite the growing body of literature on energy transition and circular economy, there remains a significant gap in understanding how these processes interact. Most studies continue to analyze these concepts separately, without fully exploring their combined effects on sustainability. This gap is particularly important because the interaction between energy and material systems can create synergies that enhance sustainability outcomes. For example, improvements in resource efficiency can reduce energy demand, while cleaner energy systems can support more sustainable production processes. The present study contributes to this emerging area by adopting a more integrated perspective. By linking energy transition, sustainability performance, and circular economy practices, it seeks to provide a more comprehensive understanding of how sustainable development can be achieved.

2.6 Energy–growth–environment nexus

The relationship between energy consumption, economic growth, and environmental sustainability—commonly referred to as the energy–growth–environment nexus—has been extensively examined in the literature. This line of research provides an important foundation for understanding the broader implications of energy transition. Early studies in this field primarily focused on the relationship between energy consumption and economic growth, often debating whether energy acts as a driver of growth or merely responds to it (Sadorsky, 2009). However, with increasing concerns over environmental degradation, the nexus framework has evolved to incorporate environmental indicators such as carbon emissions.

Empirical findings suggest that the relationship between these variables is complex and often context-dependent. While economic growth tends to increase energy demand and emissions, the adoption of renewable energy can alter this relationship by decoupling growth from environmental degradation (Apergis & Payne, 2010). In this sense, energy transition plays a critical role in reshaping the traditional growth–environment trade-off. However, several studies argue that decoupling is difficult to achieve without broader structural changes. In particular, high levels of material

consumption can offset the environmental benefits of cleaner energy systems. This highlights the importance of integrating circular economy principles into the energy–growth–environment framework.

From this perspective, circular economy can be seen as a mechanism that supports decoupling by reducing resource intensity and improving material efficiency. By lowering both energy and material demand, circular practices contribute to a more sustainable growth trajectory. This reinforces the argument that energy transition and circular economy should be analyzed together rather than in isolation.

2.7 Challenges in implementing circular economy

Despite its theoretical advantages, the implementation of circular economy faces several practical challenges. One of the main barriers is the need for systemic change across production and consumption systems. Transitioning from a linear to a circular model requires redesigning products, reconfiguring supply chains, and altering consumer behavior (Korhonen et al., 2018). Another important challenge relates to economic and financial constraints. Circular economy practices often require significant upfront investments, particularly in infrastructure for recycling and material recovery. In many cases, the economic benefits of circular practices may only materialize in the long term, which can discourage firms from adopting such strategies. Institutional and regulatory barriers also play a critical role. In some contexts, existing regulations may not adequately support circular practices, or may even create disincentives. For example, waste management policies that prioritize disposal over recycling can hinder the development of circular systems.

Moreover, technological limitations can restrict the effectiveness of circular economy initiatives. Not all materials can be easily recycled, and the quality of recycled materials may be lower than that of primary resources. These limitations highlight the need for continuous innovation and technological development. These challenges suggest that the transition towards a circular economy is not automatic and requires coordinated policy efforts. This further strengthens the argument that circular economy should be integrated with broader sustainability strategies, including energy transition.

3 CONCEPTUAL FRAMEWORK AND ANALYTICAL APPROACH

Understanding the relationship between energy transition, sustainability, and circular economy requires a conceptual framework that captures the interaction between energy systems and material flows. While the existing literature provides substantial insights into each of these domains, it often treats them as separate analytical fields. This separation limits the ability to fully understand how sustainability outcomes are generated in practice.

From a theoretical perspective, energy transition can be conceptualized as a process that primarily affects environmental performance through changes in energy production and consumption structures. The shift from fossil fuel-based systems to renewable energy sources, combined with improvements in energy efficiency, is generally associated with reductions in greenhouse gas emissions and environmental pressure (International Energy Agency, 2021). However, these effects are not independent of broader economic systems, particularly those related to resource extraction and material use.

In this regard, sustainability performance should be interpreted as the outcome of multiple interconnected processes rather than the result of a single policy intervention. Indicators such as resource productivity and environmental efficiency reflect both energy-related improvements and the efficiency of material use within the economy (OECD, 2020). This perspective highlights the importance of adopting a systems-based approach to sustainability. The circular economy plays a central role in linking material use to sustainability outcomes. By promoting resource efficiency, recycling, and the reuse of materials, circular economy practices reduce the demand for primary resources and lower the energy required for production processes (Geissdoerfer et al., 2017). This implies that circular economy not only contributes directly to sustainability but also indirectly supports energy transition by reducing overall energy demand.

Building on these insights, the relationship between energy transition, circular economy, and sustainability can be conceptualized as an integrated system. Energy transition influences sustainability performance through emission reduction and improved energy efficiency, while circular economy strengthens this relationship by improving resource efficiency and reducing material intensity. In this framework, circular

economy can be interpreted as a reinforcing mechanism that amplifies the sustainability effects of energy transition. This study adopts an analytical approach based on this integrated perspective. Rather than relying on a formal econometric model, it focuses on the interaction between these dimensions using a qualitative and policy-oriented analysis. This approach is particularly appropriate given the aim of the study, which is to explore the combined effects of energy and resource systems on sustainability. In addition, this framework provides the basis for the policy case analysis presented in the following section. Specifically, it allows for an evaluation of how integrated policy initiatives, such as those implemented within the European Union, reflect the interaction between energy transition and circular economy in practice. Finally, the conceptual framework developed in this study contributes to the literature by addressing a key gap: the lack of integrated approaches that simultaneously consider energy systems and material flows. By bringing these elements together, the study offers a more comprehensive understanding of sustainability and provides a foundation for future empirical research.

4 POLICY CASE STUDY

4.1 The European green deal as an integrated sustainability model

The increasing complexity of sustainability challenges has led policymakers to move beyond fragmented approaches and towards more integrated policy frameworks. In this context, the European Green Deal represents one of the most comprehensive efforts to align energy transition with broader sustainability and resource efficiency objectives. Introduced by the European Commission in 2019, the European Green Deal sets out a long-term vision to achieve climate neutrality by 2050. One of its key intermediate targets is the reduction of greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels (European Commission, 2019). This ambitious target highlights the scale of transformation required, particularly in energy, industry, and resource management systems. A central component of the European Green Deal is the transformation of the energy system. Policies promoting renewable energy aim to significantly increase the share of renewables in total energy consumption, while energy efficiency measures are designed to reduce overall energy demand. These initiatives are supported by regulatory

instruments, financial incentives, and investment programs that facilitate the transition towards a low-carbon energy system (International Energy Agency, 2021). However, what distinguishes the European Green Deal from earlier policy frameworks is its explicit integration of circular economy principles. The Circular Economy Action Plan, introduced as a core element of the strategy, emphasizes the need to reduce material consumption, extend product lifecycles, and increase recycling rates (European Commission, 2020). The plan includes sector-specific measures targeting industries such as electronics, construction, textiles, and plastics, which are among the most resource-intensive sectors.

From an analytical perspective, the integration of energy transition and circular economy within the European Green Deal reflects a systemic approach to sustainability. Rather than addressing emissions and resource use separately, the policy framework recognizes their interdependence. For instance, improving material efficiency reduces the energy required for production processes, thereby supporting energy transition objectives. Similarly, the use of renewable energy reduces the environmental impact of recycling and material processing activities. Empirical evidence from the European context supports this integrated approach. Data from Eurostat indicate that countries with higher levels of circular material use and resource productivity tend to exhibit better environmental performance. While causality may be complex, these patterns suggest that circular economy practices can reinforce the benefits of energy transition.mDespite its comprehensive design, the implementation of the European Green Deal faces several challenges. These include variations in economic structure across member states, differences in technological capabilities, and the financial costs associated with large-scale transformation. Moreover, achieving policy coherence across multiple domains remains a complex task, particularly when balancing environmental objectives with economic competitiveness. Nevertheless, the European Green Deal provides a valuable case for understanding how integrated policy frameworks can enhance sustainability outcomes. It demonstrates that aligning energy transition with circular economy practices can create synergies that would not be achieved through isolated policy measures.

4.2 Sectoral implications of the european green deal

To better understand how these policy objectives translate into practice, it is useful to examine their sectoral implications. Beyond its general policy framework, the European Green Deal has significant implications at the sectoral level. Different sectors are affected in distinct ways, reflecting their varying levels of energy intensity and resource use. In the energy sector, the transition towards renewable sources has led to substantial investments in wind and solar energy. These developments have not only reduced emissions but also created new economic opportunities. However, the variability of renewable energy sources requires additional investments in energy storage and grid infrastructure.

The industrial sector, particularly energy-intensive industries such as steel, cement, and chemicals, faces more complex challenges. These sectors must simultaneously reduce emissions and improve resource efficiency, often requiring significant technological innovation. Circular economy practices, such as material recycling and process optimization, play a crucial role in achieving these objectives.mIn the waste and resource management sector, the European Green Deal has accelerated the adoption of recycling and material recovery practices. Higher recycling targets and stricter waste regulations have encouraged the development of circular systems. These changes contribute to both resource efficiency and energy savings, as recycling generally requires less energy than primary production.

These sectoral dynamics illustrate how the integration of energy transition and circular economy operates in practice. They also highlight the importance of tailored policy approaches that consider the specific characteristics of each sector.

5 DISCUSSION

The findings of this study contribute to the growing literature that emphasizes the importance of integrated approaches to sustainability. While previous studies have extensively examined energy transition and circular economy as separate concepts, the present analysis highlights the need to consider their interaction in a more systematic manner.

One of the key insights emerging from the literature and policy analysis is that energy transition, although essential, represents only one dimension of sustainability. The transition towards renewable energy and improvements in energy efficiency can significantly reduce greenhouse gas emissions, as documented in numerous studies (Shahbaz et al., 2015; Apergis & Payne, 2010). However, these changes do not fully address issues related to material consumption and resource depletion.

In this respect, the circular economy provides a complementary perspective that extends beyond energy systems. By focusing on resource efficiency, recycling, and the reuse of materials, circular economy practices address the material dimension of sustainability, which is often overlooked in energy-focused analyses (Geissdoerfer et al., 2017). This suggests that sustainability should be understood as the outcome of multiple interacting systems rather than the result of isolated interventions. The interaction between energy transition and circular economy can be explained through several mechanisms. First, improvements in resource efficiency reduce the demand for primary materials, which in turn lowers the energy required for extraction and processing. This indirect effect highlights the role of circular economy in supporting energy transition. Second, the use of renewable energy reduces the environmental impact of material processing activities, thereby enhancing the sustainability of circular systems.

These findings are consistent with recent studies that emphasize the importance of policy integration (D'Amato et al., 2017). The case of the European Green Deal further illustrates how integrated policy frameworks can align energy and resource strategies to achieve multiple sustainability objectives simultaneously. At the same time, the analysis also reveals several challenges associated with integration. Implementing circular economy practices requires significant changes in production systems, supply chains, and consumer behavior. Similarly, energy transition involves large-scale investments and technological innovation. These challenges suggest that achieving sustainability requires not only technological solutions but also institutional and behavioral changes.

Another important implication relates to measurement. As discussed in the literature, sustainability is a multidimensional concept that cannot be captured by a single indicator (Stiglitz et al., 2009). This raises important questions about how to evaluate the effectiveness of integrated sustainability strategies. Future research could explore more comprehensive measurement frameworks that incorporate both energy and material

dimensions. From a theoretical perspective, this study contributes by proposing a more holistic understanding of sustainability. Rather than focusing on individual components, it emphasizes the interaction between energy systems and material flows. This perspective aligns with emerging research that views sustainability as a complex, interconnected system

5.1 Comparison with existing literature

The findings of this study are broadly consistent with the existing literature on energy transition and sustainability. Previous studies have demonstrated that renewable energy contributes to lower emissions and improved environmental performance (Shahbaz et al., 2015). Similarly, research on circular economy highlights the importance of resource efficiency and waste reduction (Geissdoerfer et al., 2017). However, the present study extends this literature by emphasizing the interaction between these two domains. While most previous studies analyze energy transition and circular economy separately, this study suggests that their combined effects are particularly important for achieving sustainability. In this sense, the findings contribute to a growing body of research that calls for more integrated approaches. By highlighting the synergies between energy systems and material flows, the study provides a more comprehensive perspective on sustainability.

6 CONCLUSION

This study has sought to provide a more integrated understanding of sustainability by examining the relationship between energy transition and circular economy practices within a broader analytical framework. Rather than approaching these concepts as independent domains, the analysis has emphasized their interdependence and the potential synergies that emerge when they are considered together. The discussion throughout the paper suggests that energy transition, particularly through the increasing adoption of renewable energy sources and improvements in energy efficiency, plays a fundamental role in reducing environmental pressure. This finding is consistent with a wide range of studies highlighting the importance of low-carbon energy systems in

addressing climate change (International Energy Agency, 2021). However, the analysis also indicates that focusing solely on energy systems may provide only a partial view of sustainability challenges. In this context, the circular economy emerges as a critical complementary framework. By promoting more efficient use of resources, reducing waste, and extending material lifecycles, circular economy practices contribute to sustainability outcomes in ways that go beyond emissions reduction. As discussed in the literature, these practices not only reduce environmental impact but also support economic resilience and resource security (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

One of the key insights of this study is that the effectiveness of energy transition can be significantly enhanced when it is supported by circular economy strategies. This interaction operates through multiple channels. For example, improvements in resource efficiency reduce the energy required for production processes, while cleaner energy systems facilitate more sustainable material cycles. Taken together, these mechanisms suggest that sustainability outcomes are likely to be stronger when energy and material systems are transformed simultaneously. The policy case of the European Green Deal further reinforces this argument by demonstrating how integrated policy frameworks can align energy transition with circular economy principles in practice. The European experience illustrates that coordinated strategies, rather than isolated policy measures, are more effective in addressing complex sustainability challenges. From a policy perspective, the findings of this study highlight the importance of adopting a more holistic approach to sustainability. Policymakers should consider designing integrated strategies that simultaneously target energy systems and resource use. In particular, policies that encourage renewable energy adoption should be complemented by measures that promote resource efficiency, recycling, and circular production models. Despite its contributions, the study has certain limitations. As a review-based and policy-oriented analysis, it does not provide empirical testing of the proposed relationships. Future research could address this limitation by employing quantitative methods, such as panel data analysis, to examine the interaction between energy transition and circular economy in greater detail.

In conclusion, achieving sustainability requires more than incremental improvements in individual policy areas. It demands a systemic transformation that

integrates energy transition with circular economy principles. Such an approach offers a more comprehensive and effective pathway towards long-term sustainable development.

7 IMPLICATIONS FOR EMERGING ECONOMIES

While much of the discussion on energy transition and circular economy has focused on developed economies, particularly within the European context, these issues are equally relevant for emerging economies. Emerging economies often face a dual challenge: sustaining economic growth while reducing environmental impact. In this context, energy transition offers an opportunity to adopt cleaner technologies at an earlier stage of development. At the same time, circular economy practices can help reduce resource dependency and improve efficiency.

However, the implementation of these strategies in emerging economies is often constrained by financial, technological, and institutional factors. Limited access to capital, lack of infrastructure, and weaker regulatory frameworks can hinder progress. Despite these challenges, emerging economies also have certain advantages. For instance, they may have greater flexibility in adopting new technologies and systems, as they are not as heavily locked into existing infrastructure. This creates opportunities for leapfrogging towards more sustainable models. From a policy perspective, this suggests that strategies should be adapted to local conditions. International cooperation, technology transfer, and financial support can play a crucial role in facilitating this transition.

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