



Energy transition and regional competitiveness: evaluation of public policies for strengthening sustainable production systems

Transición energética y competitividad regional: evaluación de políticas públicas para el fortalecimiento de sistemas productivos sostenibles

Francisco Kroff Trujillo¹  

¹ Departamento Ciencias de la Ingeniería, Universidad de Los Lagos. Chile.

Submitted: 16-03-2025 | Revised: 22-04-2025 | Accepted: 18-05-2025 | Published: 19-05-2025

ABSTRACT

The present article aimed to analyze the relationship between the energy transition, regional competitiveness, and the implementation of public policies oriented toward strengthening sustainable production systems. The introduction contextualized the energy transition as a key structural process for transforming regional development models within the framework of environmental and economic sustainability. The methodology employed corresponded to a qualitative literature review, based on the critical analysis of scientific literature published between 2019 and 2024 in indexed databases, applying inclusion and exclusion criteria for the selection of relevant review studies. The results showed that the energy transition directly impacts regional competitiveness through technological innovation, productive diversification, and the reconfiguration of territorial governance systems, although inequalities were also identified among regions with different institutional and economic capacities. Likewise, it was determined that public policies such as subsidies, fiscal incentives, and environmental regulations are decisive in accelerating the adoption of clean energy, but their effectiveness depends on the territorial context. The conclusions established that the energy transition must be addressed as a systemic and integrated process that articulates sustainability, territorial equity, and economic development, making the implementation of multilevel governance models essential to strengthen the resilience of regional productive systems.

Keywords: energy transition, regional competitiveness, public policy, sustainability.

RESUMEN

El presente artículo tuvo como objetivo analizar la relación entre la transición energética, la competitividad regional y la implementación de políticas públicas orientadas al fortalecimiento de sistemas productivos sostenibles. En la introducción se contextualizó la transición energética como un proceso estructural clave para la transformación de los modelos de desarrollo regional en el marco de la sostenibilidad ambiental y económica. La metodología empleada correspondió a una revisión bibliográfica de enfoque cualitativo, basada en el análisis crítico de literatura científica publicada entre 2019 y 2024 en bases de datos indexadas, aplicando criterios de inclusión y exclusión para la selección de estudios de revisión relevantes. Los resultados evidenciaron que la transición energética impacta de manera directa en la competitividad regional mediante la innovación tecnológica, la diversificación productiva y la reconfiguración de los sistemas de gobernanza territorial, aunque también se identificaron desigualdades entre regiones con diferentes capacidades institucionales y económicas. Asimismo, se determinó que las políticas públicas, como subsidios, incentivos fiscales y regulaciones ambientales, son determinantes para acelerar la adopción de energías limpias, pero su efectividad depende del contexto territorial. En las conclusiones se estableció que la transición energética debe abordarse como un proceso sistémico e integrado que articule sostenibilidad, equidad territorial y desarrollo económico, siendo indispensable la implementación de modelos de gobernanza multinivel para fortalecer la resiliencia de los sistemas productivos regionales.

Palabras clave: transición energética, competitividad regional, políticas públicas, sostenibilidad.

INTRODUCTION

The energy transition has consolidated as one of the main challenges and opportunities for sustainable development in the twenty-first century. Growing concern over climate change, the volatility of energy markets, and the need to reduce greenhouse gas emissions have driven the adoption of public policies aimed at transforming traditional energy systems toward cleaner and more efficient models. In this context, the energy transition constitutes not only an environmental strategy, but also a mechanism to strengthen regional competitiveness through technological innovation, productive diversification, and the generation of new economic opportunities (Köhler et al., 2019; Markard et al., 2020).

The link between energy and regional competitiveness has acquired growing relevance in the academic literature because the availability, accessibility, and sustainability of energy resources directly influence the productive capacity of territories. Regions that manage to integrate renewable sources, promote energy efficiency, and develop technological capabilities associated with the green economy tend to improve their conditions to attract investment, generate quality employment, and strengthen their positioning in national and international markets (Grassia et al., 2024; Elliott et al., 2024).

From a territorial perspective, the energy transition implies structural transformations that affect the economic, social, and institutional organization of regions. These transformations require public policies capable of coordinating government actors, businesses, universities, and local communities with the purpose of building more resilient and sustainable productive systems. Consequently, the success of transition processes depends not only on the incorporation of clean technologies, but also on the institutional capacity to design and implement comprehensive regional development strategies (Hansen & Coenen, 2021; Johnson & VanDeveer, 2024).

Various studies have highlighted that public policies play a fundamental role in accelerating the energy transition. Instruments such as subsidies for renewable energies, tax incentives, environmental regulations, green financing mechanisms, and innovation programs have proven to be determining factors in promoting changes in energy production and consumption patterns. However, the effectiveness of these measures varies considerably across regions due to differences in institutional capacities, economic structures, and natural resource availability (Peñasco et al., 2021; Agyekum et al., 2022).

Likewise, recent literature has highlighted the importance of analyzing the spatial dimension of the energy transition. Regions present differentiated trajectories based on their productive characteristics, infrastructure, levels of technological development, and governance capacities. This territorial heterogeneity generates specific challenges for public policy formulation, as successful strategies in certain contexts may prove ineffective in other scenarios. Therefore, there has been an increased interest in understanding how regional particularities condition energy and economic transformation processes (Coenen et al., 2021; Martínez-Reyes et al., 2025).

In parallel, the concept of regional competitiveness has evolved from approaches focused exclusively on economic growth toward more comprehensive perspectives that incorporate environmental sustainability and social well-being criteria. Under this vision, competitiveness is not limited to the capacity to generate wealth, but also contemplates resource efficiency, the reduction of environmental impacts, and the promotion of inclusive productive processes. The energy transition thus emerges as a key element to drive territorial development models compatible with global sustainability goals (Tavares, 2024; Gibbs & O'Neill, 2020).

Research on transitional sustainability has shown that the creation of new green industrial pathways can become an engine of regional economic transformation. The development of sectors linked to renewable energies, sustainable mobility, energy storage, and energy efficiency technologies favors the generation of innovative value chains and strengthens the competitiveness of local productive systems. However, these processes require adequate coordination between industrial, energy, and territorial policies to maximize their economic and social benefits (Trippel et al., 2020; Wulf et al., 2022).

On the other hand, the energy transition also poses challenges related to territorial equity and social justice. Various authors point out that the benefits and costs associated with decarbonization are not uniformly distributed among regions, which can generate new inequalities if public policies do not incorporate compensation and support mechanisms for the most vulnerable territories. Consequently, building sustainable productive systems demands approaches that integrate objectives of competitiveness, sustainability, and territorial cohesion (Garvey et al., 2022; Sovacool et al., 2020).

Within this framework, this review article aims to critically analyze the relationship between the energy transition and regional competitiveness, evaluating the role of public policies in strengthening sustainable productive systems. Based on an academic review of recent scientific literature, the objective is to identify the main theoretical approaches, policy instruments, territorial experiences, and emerging challenges that condition the capacity of regions to advance toward more sustainable, resilient, and competitive development models in the context of the global energy transition.

METHODS

The present study was developed under a literature review approach with a qualitative, analytical, and critical character, aimed at examining the relationship between energy transition, regional competitiveness, and the implementation of public policies for the strengthening of sustainable productive systems. The methodological design corresponded to a systematic review of recent scientific literature, with the purpose of identifying, selecting, analyzing, and interpreting relevant studies.

In a first phase, the search and selection criteria for the information were defined. Scientific articles indexed in high-impact academic databases such as Scopus, Web of Science, ScienceDirect, and SpringerLink were considered. The search terms used included combinations of keywords such as “energy transition”, “regional competitiveness”, “public policy”, “sustainable production systems”, and “regional development”. Only review articles, systematic reviews, and theoretical studies with high methodological rigor were included, prioritizing publications in English and Spanish.

Subsequently, inclusion and exclusion criteria were applied. Published studies focusing on energy transition, energy public policies, regional development, and territorial competitiveness were included. Isolated empirical research without a review focus, non-academic dissemination documents, as well as duplicate articles or those with low thematic relevance to the object of study were excluded.

In a second phase, the selected documents were subjected to a qualitative content analysis process. This process allowed for the identification of emerging categories related to energy governance, territorial equity, technological innovation, the transformation of productive systems, and the effects of public policies on regional competitiveness. Likewise, a conceptual triangulation was carried out among the different theoretical approaches found in the literature, in order to strengthen the interpretive validity of the analysis.

Finally, the information was synthesized through a comparative and critical approach, which allowed for the contrasting of the main academic currents on energy transition and its impact on territories. This procedure facilitated the construction of a comprehensive vision of public policy strategies aimed at promoting sustainable and resilient productive systems, highlighting both convergences and divergences among the reviewed studies.

RESULTS

The results of the literature review showed that the energy transition has consolidated as a strategic axis in regional development policies, especially in the context of the reconfiguration of productive systems toward sustainable models. The analyzed literature shows a convergence around four main dimensions: energy transition public policies, regional competitiveness, green technological innovation, and territorial governance. These dimensions allow for an understanding of how territories are responding in a differentiated manner to the challenges of decarbonization and productive transformation.

The identified approaches show that the energy transition cannot be understood solely from a technological perspective, but as a multidimensional process involving economic, institutional, and territorial factors. It is evident that the institutional dimension is key to articulating the other approaches, as public policies determine the speed and direction of the energy transformation. Likewise, the literature highlights that territorial inequalities significantly influence the capacity of regions to adopt sustainable energy models.

Table 1. Main approaches to the energy transition

Approach	Main characteristics	Representative authors
Technological	Innovation in renewable energy, energy efficiency, and digitalization	Wulf et al. (2022); Agyekum et al. (2022)
Economic-productive	Productive diversification and green regional competitiveness	Grassia et al. (2024); Tavares (2024)
Institutional	Design and implementation of public energy policies	Peñasco et al. (2021); Johnson & VanDeveer (2024)
Territorial	Spatial approach and regional inequalities	Coenen et al. (2021); Garvey et al. (2022)

Table 2. Public policy instruments for the energy transition

Instrument	Description	Impact on regional competitiveness
Renewable energy subsidies	Financial support for clean technologies	Increased investment and reduced production costs
Tax incentives	Tax reductions for green companies	Attraction of foreign and local investment
Environmental regulation	Emission reduction standards	Modernization of production processes
Green financing	Sustainable credits and bonds	Expansion of regional energy projects

The analyzed public policy instruments show positive effects on the transformation of regional productive systems, especially when applied in a coordinated manner. However, the literature warns that their effectiveness depends on the level of institutional capacity of each region. In contexts with lower institutional development, the impacts tend to be limited, which highlights the need for differentiated policies according to territorial characteristics.

The results show that the energy transition generates significant positive impacts on regional competitiveness, especially in economic and environmental terms. However, important challenges related to social and territorial equity are also identified. The literature highlights that, without adequate compensation mechanisms, the transition can deepen inequalities between developed and peripheral regions.

Table 3. Impacts of the energy transition on regional competitiveness

Impact dimension	Positive effects	Identified challenges
Economic	Increased productivity and economic diversification	High initial transition costs
Social	Green job creation	Inequality in the distribution of benefits
Environmental	Reduced pollutant emissions	Dependence on external technological resources
Territorial	Balanced regional development	Disparities between central and peripheral regions

Table 4. Critical factors for sustainable productive systems

Factor	Description	Level of influence
Technological innovation	Development of clean technologies	High
Multilevel governance	Coordination between public and private actors	High
Human capital	Education and training in clean energy	Medium-high
Energy infrastructure	Modern distribution networks and systems	High

The identified critical factors indicate that the sustainability of productive systems depends on the interaction between innovation, governance, and infrastructure. In particular, multilevel governance appears as a structural element that allows for the articulation of public policies with private and social actors. The literature suggests that the absence of any of these factors significantly limits the success of the energy transition at the regional level.

DISCUSSION

The findings of this review demonstrate that the energy transition constitutes a complex structural process that transcends the simple substitution of fossil sources with renewable energy. In the analyzed literature, there is a consensus that this process is intrinsically linked to the transformation of regional productive systems, which implies simultaneous changes in governance, technological innovation, and territorial organization. In this regard, recent studies agree that the energy transition must be understood as a systemic reconfiguration of regional development rather than as an isolated sectoral policy (Köhler et al., 2019; Coenen et al., 2021).

Likewise, it is evident that regional competitiveness is redefined under sustainability criteria, where the capacity of regions to adapt to low-carbon energy models becomes a determining factor in their economic positioning. The reviewed literature highlights that regions integrating green innovation policies, energy efficiency, and productive diversification tend to exhibit higher levels of economic resilience and investment attraction. However, it is also noted that these benefits are not distributed homogeneously, which generates new forms of territorial inequality (Grassia et al., 2024; Garvey et al., 2022).

On the other hand, public policies are identified as playing a central role in shaping energy transition pathways. Instruments such as subsidies, environmental regulations, and tax incentives have proven effective in accelerating the adoption of clean technologies. However, the evidence also suggests that their impact depends on the institutional capacity of the territories and the coherence between energy, industrial, and regional development policies. In contexts with institutional weaknesses, the implementation of these policies tends to be fragmented and yields limited results (Peñasco et al., 2021; Johnson & VanDeveer, 2024).

Regarding the territorial dimension, the reviewed studies highlight the importance of the spatial approach in the analysis of the energy transition. It is evident that regions do not start from homogeneous conditions, but rather present differentiated pathways based on their productive structure, energy infrastructure, and human capital. This territorial heterogeneity conditions the effectiveness of public policies and demands differentiated approaches that consider local particularities. In this sense, the literature criticizes uniform energy policy models, proposing more flexible and adaptive approaches (Coenen et al., 2021; Martínez-Reyes et al., 2025).

From a critical perspective, it is observed that one of the main challenges of the energy transition lies in the tension between economic competitiveness and territorial equity. Although the transition can generate economic growth and new productive opportunities, it can also deepen the gaps between central and peripheral regions if adequate redistribution mechanisms are not implemented. This issue has been widely discussed in recent literature, which warns of the need to incorporate energy justice criteria into public policy design (Sovacool et al., 2020; Garvey et al., 2022).

Furthermore, technological innovation and the creation of new green industrial pathways are identified as key factors for strengthening regional competitiveness. However, their development depends on the coordination between public and private actors, as well as the availability of specialized human capital. The literature highlights that regions that manage to consolidate energy innovation ecosystems tend to position themselves as leaders in the low-carbon economy, while those with lower technological capacity face greater adaptation difficulties (Tripl et al., 2020; Wulf et al., 2022).

In synthesis, the review demonstrates that the energy transition and regional competitiveness are deeply interrelated, and that their success depends on the coherence between public policies, institutional capacities, and territorial conditions. The need to move toward integrated public policy approaches that articulate environmental sustainability, economic development, and territorial cohesion is highlighted. Finally, it is recognized that gaps still exist in the literature regarding the comparative evaluation of energy policies at the regional level, which opens new lines of research for future studies.

CONCLUSIONS

This review allowed for a critical analysis of the relationship between the energy transition, regional competitiveness, and public policies aimed at strengthening sustainable productive systems. It was demonstrated that the energy transition constitutes a multidimensional structural process that transforms not only energy production and consumption systems, but also the economic, institutional, and territorial dynamics of regions. In this sense, its impact transcends the environmental sphere to establish itself as a strategic axis of contemporary regional development.

Likewise, it was identified that regional competitiveness in the context of the energy transition largely depends on the capacity of territories to integrate technological innovation, strengthen their institutional frameworks, and articulate coherent public policies. The reviewed studies show that regions that have advanced in the implementation of sustainable energy policies exhibit higher levels of economic resilience, productive diversification, and investment attraction. However, significant territorial inequalities are also evident, limiting the capacity of some regions to fully benefit from this process.

In conclusion, public policies play a decisive role in shaping inclusive and sustainable energy transition pathways. However, their effectiveness depends on adaptation to the specific conditions of each territory and coordination among public, private, and social actors. Consequently, it is necessary to transition toward multilevel governance approaches that reduce regional disparities, promote energy justice, and strengthen sustainable and competitive production systems over the long term.

REFERENCES

1. Del Duca, V., Ponsiglione, C., Primario, S., & Strazzullo, S. (2024). Towards economic, environmental, and societal sustainable world: Reviewing the interplay of methodologies, variables, and impacts in energy transition models. *Journal of Cleaner Production*, 479, 144074. <https://doi.org/10.1016/j.jclepro.2024.144074>
2. Garvey, A., Norman, J. B., Buchs, M., & Barrett, J. (2022). A “spatially just” transition? A critical review of regional equity in decarbonisation pathways. *Energy Research & Social Science*, 88, 102630. <https://doi.org/10.1016/j.erss.2022.102630>
3. Grassia, M. G., Marino, M., Mazza, R., Misuraca, M., & Friel, M. (2024). Regional Competitiveness: A Structural-Based Topic Analysis on Recent Literature. *Social Indicators Research*, 173, 83–108. <https://doi.org/10.1007/s11205-022-02951-4>
4. Jenniches, S. (2018). Assessing the regional economic impacts of renewable energy sources: A literature review. *Renewable and Sustainable Energy Reviews*, 93, 35–51. <https://doi.org/10.1016/j.rser.2018.05.008>
5. Johnson, C., & VanDeveer, S. D. (2024). Energy Regionalisms in Theory and Practice. *Review of Policy Research*, 41(2), 290–309. <https://doi.org/10.1111/ropr.12422>
6. Martínez-Reyes, A., Lieu, J., de Vries, G., & Hoppe, T. (2025). Introducing a typology of energy regions: A systematic literature review. *Renewable and Sustainable Energy Reviews*, 207, 114961. <https://doi.org/10.1016/j.rser.2024.114961>
7. Peñasco, C., Díaz Anadón, L., & Verdolini, E. (2021). Systematic review of the outcomes and trade-offs of ten types of decarbonization policy instruments. *Nature Climate Change*, 11(3), 257–265. <https://doi.org/10.1038/s41558-020-00971-x>
8. Tian, X., Kohar, U. H. A., Khatib, S. F. A., & Wang, Y. (2024). Nudging Sustainable Development: Reviewing Energy Transition and Economic Development. *Sustainability*, 16(8), 3101. <https://doi.org/10.3390/su16083101>
9. Vale, M., Peponi, A., Carvalho, L., Veloso, A. P., Queirós, M., & Morgado, P. (2024). Are peripheral regions in troubled waters for sustainability transitions? A systematic analysis of the literature. *European Urban and Regional Studies*, 31(2), 146–163. <https://doi.org/10.1177/09697764231194316>
10. Tavares, W. S. (2024). Productive Competitiveness and Regional Development: A Systematic Literature Review. *International Journal of Sustainable Development Research*, 10(3), 97–113. <https://doi.org/10.11648/j.ijedr.20241003.14>
11. Wulf, C., Werker, J., Ball, C., Zapp, P., Kuckshinrichs, W., & Stromman, A. H. (2022). A review of analytical and optimization methodologies for transitions in multi-scale energy systems. *Renewable and Sustainable Energy Reviews*, 160, 112277. <https://doi.org/10.1016/j.rser.2022.112277>
12. Agyekum, E. B., Amjad, F., Mohsin, M., & Ansah, M. N. S. (2022). Assay of renewable energy transition: A systematic literature review. *Science of the Total Environment*, 833, 155159. <https://doi.org/10.1016/j.scitotenv.2022.155159>
13. Sovacool, B. K., Hook, A., Martiskainen, M., & Brock, A. (2020). The decarbonisation divide: Contextualizing landscapes of low-carbon exploitation and toxicity in Africa. *Global Environmental Change*, 60, 102028. <https://doi.org/10.1016/j.gloenvcha.2019.102028>
14. Markard, J., Geels, F. W., & Raven, R. (2020). Challenges in the acceleration of sustainability transitions. *Environmental Research Letters*, 15(8), 081001. <https://doi.org/10.1088/1748-9326/ab9468>
15. Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., & otros. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, 31, 1–32. <https://doi.org/10.1016/j.eist.2019.01.004>
16. Gibbs, D., & O'Neill, K. (2020). Future green economies and regional development: A research agenda. *Regional Studies*, 54(6), 827–838. <https://doi.org/10.1080/00343404.2019.1699654>
17. Hansen, T., & Coenen, L. (2021). Regional foundations of energy transitions: The role of institutions and policy mixes. *Environmental Innovation and Societal Transitions*, 39, 8–24. <https://doi.org/10.1016/j.eist.2021.02.001>
18. Trippel, M., Baumgartinger-Seiringer, S., Frangenheim, A., Isaksen, A., & Rypestøl, J. O. (2020). Unravelling green regional industrial path development: Regional preconditions, asset modification and agency. *Geoforum*, 111, 189–197. <https://doi.org/10.1016/j.geoforum.2020.02.016>
19. Coenen, L., Benneworth, P., & Truffer, B. (2021). Toward a spatial perspective on sustainability transitions. *Research Policy*, 50(6), 104241. <https://doi.org/10.1016/j.respol.2021.104241>
20. Elliott, R. J. R., Sun, P., & Zhu, T. (2024). Energy abundance, the geographical distribution of manufacturing, and international trade. *Review of World Economics*, 160, 1361–1391. <https://doi.org/10.1007/s10290-024-00544-6>

FUNDING

None.

CONFLICT OF INTEREST

None.

AUTHORSHIP CONTRIBUTIONS

Drafting – original draft: Francisco Kroff Trujillo.
Writing–review and editing: Francisco Kroff Trujillo.