

ENERGY TRANSITION AND TECHNOLOGICAL DEVELOPMENT: INTERFACES BETWEEN RENEWABLE ENERGY, INNOVATION, AND INDUSTRIAL INTELLECTUAL PROPERTY

**TRANSIÇÃO ENERGÉTICA E DESENVOLVIMENTO TECNOLÓGICO:
INTERFACES ENTRE ENERGIAS RENOVÁVEIS, INOVAÇÃO E PROPRIEDADE
INTELLECTUAL INDUSTRIAL**

Engenharias, Ciências Sociais Aplicadas • 13/07/2026

REGISTRO DOI: [10.70773/revistatopicos/783479239](https://doi.org/10.70773/revistatopicos/783479239)

Ana Katherine Silveira Pereira Caracas¹

Antonio Werbiton Marinho Almeida²

Carlos Riedel Porto Carreiro³

Emanuel Lopes Frate⁴

Esaú Aguiar Carvalho⁵

Francisco Jeandson Rodrigues da Silva⁶

Francisco José Lopes Cajado⁷

Givanildo Ximenes Santana⁸

Irene Mendes Fontes⁹

João Guilherme de Oliveira Duarte¹⁰

José Nabuco Ribamar Neto¹¹

Márcio Carneiro Barbosa¹²

Michele Aragão Fernandes¹³

Rickardo Léo Ramos Gomes¹⁴

Roberto Augusto Caracas Neto¹⁵

Ronara Marques Ribeiro de Sousa¹⁶

Tadeu Dote Sá¹⁷

ABSTRACT

The energy transition has assumed a prominent position in socio-economic and environmental debates due to three key factors: the urgent need to reduce greenhouse gas emissions, the promotion of sustainable development, and the strengthening of energy security. In this context, the general objective of this study is to analyze the interfaces between renewable energy, technological innovation, and industrial intellectual property within the framework of the energy transition, examining their contribution to technological development, competitiveness, and sustainability. The research adopted a qualitative approach, employing the following investigative procedures: a literature review and documentary research. Scientific sources, legislation, and institutional documents related to the energy transition, technological innovation, and industrial intellectual property were examined, enabling a comprehensive and integrated understanding of the subject under investigation. The findings revealed that the energy transition is a multidimensional process grounded in the consolidated expansion of renewable energy sources, the advancement of technological innovation, and the strategic use of industrial intellectual property instruments. The results also demonstrated that renewable energy sources contribute to sustainability and energy security, while technological innovation supports the development and implementation of more efficient energy solutions. Furthermore, industrial intellectual property was found to play a significant role in the protection, valorization, and dissemination of innovations, thereby strengthening competitiveness and encouraging investments in research and development. It is concluded that the integration of these elements contributes to the establishment of development models aligned with the demands of decarbonization, sustainability, and technological competitiveness.

Keywords: Energy transition; Renewable energy; Technological innovation; Industrial intellectual property.

RESUMO

A transição energética assumiu, nos debates socioeconômico-ambientais, uma posição de destaque por conta de três fatores: a necessidade premente da redução das emissões de gases de efeito estufa, a promoção do desenvolvimento sustentável e o fortalecimento da segurança energética. Nesse contexto, esta pesquisa tem como objetivo geral analisar as interfaces entre energias renováveis, inovação tecnológica e propriedade intelectual industrial no contexto da transição energética, compreendendo sua contribuição para o desenvolvimento tecnológico, a competitividade e a sustentabilidade. A pesquisa adotou uma abordagem qualitativa, empregando os seguintes procedimentos investigativos: a revisão bibliográfica e a pesquisa documental. Foram consideradas fontes científicas, legislações e documentos institucionais relacionados à transição energética, à inovação tecnológica e à propriedade intelectual industrial, permitindo um entendimento pleno e integrado da temática investigada. Os resultados evidenciaram que a transição energética caracteriza-se por ser um processo multidimensional fundamentado pela consolidada expansão das energias renováveis, pelo avanço da inovação tecnológica e pela utilização estratégica dos instrumentos de propriedade intelectual industrial. Verificou-se também que as fontes renováveis colaboram para a sustentabilidade e a segurança energética, enquanto a inovação tecnológica beneficia o desenvolvimento e a implementação de soluções energéticas mais eficientes. Constatou-se, ainda, que a propriedade intelectual industrial cumpre papel relevante na proteção, valorização e disseminação das inovações, fortalecendo a competitividade e incentivando investimentos em

pesquisa e desenvolvimento. Conclui-se que a integração entre esses elementos contribui para a edificação de modelos de desenvolvimento alinhados às demandas da descarbonização, da sustentabilidade e da competitividade tecnológica.

Palavras-chave: Transição energética; Energias renováveis; Inovação tecnológica; Propriedade intelectual industrial.

1. INTRODUCTION

The energy transition has increasingly emerged as one of the most relevant and strategic issues of the contemporary era, driven primarily by the urgent need to reduce greenhouse gas emissions. It is important to emphasize that this transition is also shaped by the growing demand for enhanced energy security and by the international commitment to development models aligned with sustainability principles. This scenario highlights the magnitude of the challenge facing humanity and underscores the need for actions that integrate climate and energy concerns in support of a more responsible future. Within this context, renewable energy sources have gained significant prominence, as they provide viable alternatives for reducing dependence on fossil fuels. These alternatives contribute to the diversification of energy matrices and, consequently, to the mitigation of the adverse impacts associated with climate change. Simultaneously, advances in technologies related to energy generation, storage, and management have substantially expanded the possibilities for consolidating energy systems on a global scale.

In turn, the energy transition is closely linked not only to the expansion of renewable energy sources but also to a society's capacity for technological innovation. It constitutes an ongoing

process that requires the development of effective mechanisms capable of promoting strategic research activities, as well as fostering the advancement and dissemination of innovative solutions applicable across multiple sectors. In this regard, ensuring synergy between innovation and research incentives is of paramount importance, as this convergence is essential for achieving an effective and sustainable energy transition. From this perspective, industrial intellectual property emerges as a crucial instrument for safeguarding technological assets, contributing significantly to the valorization of generated knowledge and serving as an effective mechanism for strengthening the competitiveness of companies, research institutions, and nations alike. The relationship established among renewable energy sources, technological innovation, and industrial intellectual property therefore represents a significant field of inquiry that is essential for a comprehensive understanding of both the challenges and opportunities associated with the energy transition. Furthermore, this area of research enables reflection on the interconnections among these elements and on the role, each plays in the transition toward a more sustainable future.

Given this broad context, the general objective of the present study is to analyze the interfaces among renewable energy, technological innovation, and industrial intellectual property within the framework of the energy transition, examining their contributions to technological development, competitiveness, and sustainability. Specifically, the study seeks to: (i) understand the foundations of the energy transition and the relevance of renewable energy sources for sustainable development and energy security; (ii) investigate the role of technological innovation in the development and diffusion of technologies related to renewable energy; and (iii) analyze the

contribution of industrial intellectual property to the protection, valorization, and dissemination of innovations associated with the renewable energy sector.

The study adopted a qualitative approach, as it enables a comprehensive understanding of the relationships among the themes investigated. Regarding methodological procedures, a literature review was conducted based on the analysis of thirty-two scientific sources, complemented by documentary research grounded in the critical examination of legislation, institutional documents, and national and international reports related to renewable energy, innovation, and the protection of intellectual property. The combined use of these procedures facilitated an integrated, consistent, and objective-oriented analysis.

To achieve the proposed objectives and ensure the logical organization of the discussion, the article was structured into four main sections. The first section consists of this introduction, presenting the research theme, contextual background, objectives, and methodological aspects. The second section provides the theoretical framework, encompassing the principal references related to the energy transition, technological innovation, and industrial intellectual property. The third section describes the adopted methodology. Finally, the fourth section presents the final considerations, highlighting the main conclusions of the study and suggesting directions for future research.

2. THEORETICAL FRAMEWORK

This theoretical framework was organized around three interrelated and complementary topics. This structure was designed to fully

address the research objectives, enabling a logical and articulated approach to the central elements that constitute the object of investigation of this study. Each of these topics was developed to facilitate and ensure a comprehensive understanding of the subject under examination. The first topic focused on the foundations, current challenges, and future opportunities of the energy transition, considering the role played by various renewable energy sources. The second topic emphasized technological innovation and the advancement of technologies directly related to the responsible use of renewable energy. The third topic provided a detailed analysis of industrial intellectual property, particularly concerning the role this field has effectively played in the protection, valorization, and dissemination of innovations associated with the renewable energy sector.

2.1. Energy Transition And Renewable Energy: Foundations, Challenges, And Perspectives

The energy transition is a process of structural transformation in energy production, distribution, and consumption systems, aimed at gradually replacing fossil fuels with renewable and low-carbon energy sources. This transformation is driven by the urgency of addressing the impacts of the climate crisis, reducing greenhouse gas emissions, and establishing development models that respect the planet's environmental limits. This global perspective was reinforced by the Paris Agreement, which intensified international awareness regarding the need to pursue renewable, environmentally cleaner, and ecologically sustainable energy generation alternatives in contrast to petroleum-derived fuels (WEF, 2024).

Santos (2019) emphasizes that the energy transition, in addition to requiring transformations in technological research, also encompasses economic, political, regulatory, and social changes that affect current development models. From this perspective, the reconfiguration of national energy matrices has emerged as one of the principal development strategies for promoting sustainability and energy security.

The intensification of extreme climate events and the increasing concentration of CO₂ in the atmosphere have led to the implementation of global strategies aimed at promoting economic decarbonization. The transition toward cleaner and more sustainable energy sources has become a priority for governments, international organizations, and industry, particularly as commitments established through international climate agreements have gained greater momentum. According to Gutierrez (2025), the energy transition in Brazil is, above all, a complex challenge that seeks to reconcile economic growth, social inclusion, and environmental preservation. This challenge is closely associated with a substantial demand for investments in innovation, infrastructure, and governance, while also being grounded in the principles of a low-carbon economy.

At the international level, a geoeconomic reconfiguration is already underway, driven by the rise of renewable energy sources and the growing strategic value of resources essential for the production and implementation of clean technologies. According to Gomes et al. (2026a), the energy transition is transforming economic relations among countries while simultaneously generating new geopolitical tensions related to critical minerals, green hydrogen, energy storage, and the supply chains of sustainable technologies. This scenario

demonstrates that contemporary energy security extends beyond the mere availability of resources, encompassing the technological capabilities, industrial innovation capacity, and international competitiveness of nations.

Currently, Brazil's energy matrix differs significantly from the global average, particularly due to the substantial contribution of renewable energy sources. The combination of already-developed hydropower resources with the growing incorporation of wind, solar, and biomass energy places the country in a favorable position to lead key sectors of the low-carbon economy. However, as highlighted by Barbosa and Gomes (2026), the continued expansion of this competitive advantage requires the consolidation of stable public policies. Such policies should focus on modernizing energy infrastructure and increasing investments in research, technological development, and innovation aimed at the production of sustainable fuels, particularly green hydrogen.

In this context, renewable energy sources have assumed increasing importance in diversifying energy matrices and reducing dependence on fossil fuels. The integration of artificial intelligence, digital monitoring systems, and energy storage technologies has enhanced the operational efficiency of renewable energy systems, promoting greater stability, predictability, and utilization of available energy resources, as noted by Gomes et al. (2026b).

The connection between the energy transition and technological innovation is also evident in processes of sustainable urbanization. In this regard, Mendes and Porto (2025, p. 3) state:

Smart cities function as sociotechnical ecosystems that integrate data, sensors, and automation to improve public services and optimize resources. The energy transition, in turn, involves the reconfiguration of energy provision systems through the replacement of fossil-based matrices with renewable sources and efficiency gains. This same process depends on innovation pathways, stable policies, and institutional learning, generating impacts on physical infrastructure and energy markets.

The authors’ analysis reveals that the modernization of urban systems is directly associated with the adoption of sustainable energy technologies, resulting in environmental, economic, and operational benefits across multiple territorial dimensions.

Table 1 is presented below, summarizing the principal concepts that structure the energy transition and illustrating how they relate to sustainable development and energy security.

Table 1 – Structural Elements of the Energy Transition and Their Implications for Sustainable Development.

Dimension	Main Characteristics	Implications for Sustainable Development
-----------	----------------------	--

Energy transition	Gradual replacement of fossil fuel sources with renewable energy sources and low-carbon technologies	Reduction of greenhouse gas emissions and strengthening of sustainability
Decarbonization	Strategies aimed at carbon neutrality and climate change mitigation	Fulfillment of international climate commitments
Energy matrix	Diversification of energy generation sources and increased participation of renewable energy	Greater resilience of energy systems
Renewable energy	Utilization of renewable natural resources such as solar, wind, biomass, and green hydrogen	Expansion of clean energy generation and reduction of dependence on fossil fuels
Energy security	Assurance of a stable, accessible, and sustainable energy supply	Reduction of economic and geopolitical vulnerabilities
Technological innovation	Development of technologies for energy generation, storage, and management	Increased efficiency and industrial competitiveness
2030 Agenda	Integration of energy, social, and environmental policies	Contribution to the Sustainable Development Goals (SDGs)
Governance and regulation	Regulatory framework guiding investments and project implementation	Institutional stability and legal certainty

Source: Prepared by the authors based on Santos (2019), Cataia and Duarte (2022), Gutierrez (2025), Barbosa and Gomes (2026), Gomes et

al. (2026a), Sá et al. (2026), Mendes and Porto (2025), and Gomes et al. (2026b).

The geographical dimension of the energy transition is equally significant; however, its effects manifest differently across regions and nations. Cataia and Duarte (2022) emphasize that, although discussions surrounding the energy transition frequently highlight its environmental and technological benefits, it is equally important to critically examine the territorial inequalities arising from the uneven distribution of natural resources, infrastructure, and investments. Consequently, energy sustainability should not be understood solely as a technological challenge but also as an issue of social justice, land-use planning, and the democratic governance of energy resources. Furthermore, it is important to recognize that, in certain countries, such as the United States, the energy transition and the expansion of renewable energy sources have not always been treated as policy priorities. In this regard, recent policy orientations have demonstrated greater support for the exploitation of fossil fuels than for the strengthening of initiatives aimed at expanding the use of renewable energy sources (Gilliver, 2026).

Considering this scenario, sustainability should not be interpreted exclusively from an environmental perspective but rather through an integrated approach encompassing economic and social dimensions. Within this framework, the concept of the Triple Bottom Line, developed by John Elkington, became widely established. According to this approach, sustainability is based on the integration of three fundamental pillars: People, Planet, and Profit. In the context of corporate responsibility, an organization can be considered sustainable only if it is economically viable, socially equitable, and environmentally responsible (SEBRAE, 2022).

At the same time, the realization of a low-carbon economy requires regulatory frameworks capable of providing legal certainty and predictability for investors. From this perspective, Sá et al. (2026, p. 3) argue that:

The energy transition has become one of the central pillars of the reconfiguration of contemporary economies, requiring governments to develop legal responses capable of harmonizing economic growth, technological innovation, and socio-environmental responsibility. In Brazil, this movement has acquired distinctive characteristics due to the strategic importance of renewable energy sources within the national electricity matrix and the country's growing participation in global low-emission energy value chains. In this context, discussions surrounding environmental licensing become crucial, as it constitutes a structuring instrument of environmental policy and directly influences the implementation of large-scale projects.

In a similar vein, the United Nations 2030 Agenda reinforces the connection between clean energy, innovation, sustainable economic growth, and climate action, particularly through the Sustainable Development Goals (SDGs), which address, among other issues, affordable and clean energy, industry, innovation and infrastructure, and the promotion of actions to combat climate change (United Nations, 2015).

2.2. Technological Innovation And The Development Of Renewable Energy Technologies

Technological innovation is undoubtedly one of the principal drivers of the contemporary energy transition, fostering the development of solutions that enhance the efficiency, competitiveness, and sustainability of energy systems. In this context, the expansion of renewable energy sources is directly linked to the generation, absorption, and dissemination of scientific and technological knowledge, enabling the incorporation of new technologies into production processes and industrial value chains. As highlighted by Paixão and Abaide (2026), the intersection between the energy transition and technological innovation constitutes one of the most significant drivers of economic transformation, creating new opportunities for industrial development while simultaneously promoting the reconfiguration of global energy markets.

According to the specialized literature, innovation processes do not occur in isolation but rather emerge from national innovation systems involving universities, research centers, companies, government institutions, and funding mechanisms. Within these environments, interactions among multiple stakeholders stimulate knowledge generation, the development of technological capabilities, and the creation of conditions that foster industrial competitiveness (Paixão; Abaide, 2026; Corrêa, 2021; Cardoso, Camilo; Pico, 2024). The Economic Commission for Latin America and the Caribbean (ECLAC) (2020) indicates that countries capable of establishing robust innovation systems are better positioned to adapt more rapidly to the demands of the energy transition. Furthermore, such countries tend to achieve stronger integration into global clean technology value chains.

According to Paixão and Abaide (2026, p. 2), the relationship between energy, innovation, and economic growth is emphasized when they state:

The relationship between energy and economic development constitutes one of the central axes of the structural transformations shaping contemporary societies. Historically, economic growth has been associated with increasing energy consumption, primarily derived from fossil fuels such as coal, oil, and natural gas. Although this model has promoted substantial industrial and technological advances, it has become increasingly unsustainable in light of accelerating climate change, environmental degradation, and instability in energy markets. Renewable energy sources therefore emerge as a strategic alternative, not only from an environmental perspective but also as a potential instrument for the reconfiguration of economic development models.

It is important to note that, within research, development, and innovation (R&D&I) activities aimed at fostering industrial development, increasing financial resources are being directed toward technologies designed to reduce costs, improve energy efficiency, and enhance the integration of renewable energy sources, thereby making them more accessible. According to Acemoglu et al. (2019), directed innovation policies are essential for driving technological change capable of mitigating climate change, counteracting environmental denialism, and encouraging the

reallocation of investments from carbon-intensive technologies to those characterized by lower environmental impacts. Once again, this process of technological evolution demonstrates that the energy transition is not a spontaneous phenomenon but rather one shaped by institutional incentives, public policies, and industrial strategies.

Another important aspect deserving attention is the fact that ongoing transformations within the energy sector have stimulated and accelerated the development of new technologies focused on energy generation, storage, and intelligent management. Among these innovations are advanced electrochemical storage systems, smart grids, the digitalization of energy systems, renewable hydrogen, and artificial intelligence applications for managing energy supply and demand. As noted by Cardoso, Camilo, and Picolo (2024), technological innovation in the electricity sector has been intensified by the convergence of digitalization, automation, and sustainability, resulting in profound transformations in both corporate operational models and energy systems.

Table 2 is presented below and summarizes the principal dimensions of technological innovation in the development of renewable energy technologies, as well as their impacts on industrial competitiveness and the energy transition.

Table 2 – Dimensions of Technological Innovation and Their Contribution to the Development of Renewable Energy Sources

Dimension	Characteristics	Contributions to the Energy Transition
-----------	-----------------	--

Scientific research	Production of basic and applied knowledge	Generation of new technological solutions
Technological development	Transformation of knowledge into products and processes	Enhancement of energy efficiency
Industrial innovation	Introduction of technologies into the market	Increased business competitiveness
Technology transfer	Sharing of knowledge among institutions and companies	Accelerated diffusion of renewable energy technologies
Energy digitalization	Use of artificial intelligence, sensors, and automation	Optimization of energy generation and consumption
Energy storage	Development of batteries and energy storage systems	Greater stability of renewable energy systems
National innovation systems	Integration among government, universities, and the productive sector	Strengthening of national technological capabilities
Sustainable development	Articulation among innovation, economic growth, and environmental protection	Promotion of a low-carbon economy

Source: Prepared by the authors based on Acemoglu et al. (2019), ECLAC (2020), IRENA (2022), Corrêa (2021), Cardoso et al. (2024), UNRISD (2022), Lima (2022), Mendonça et al. (2025), and Paixão and Abaide (2026).

Corrêa (2021) explains that the establishment of innovation-friendly environments is also dependent upon the existence of effective technology transfer mechanisms. In this regard, such mechanisms enable knowledge generated by universities, research centers, and

scientific institutions to be translated into practical applications capable of creating economic value and generating social benefits. Expanding upon this perspective, Corrêa (2021) demonstrates that the growth of the wind and solar energy sectors in Brazil is associated not only with the availability of natural resources but also with the continuous incorporation of technological knowledge, the attraction of investments, and the development of local productive capacities.

From the perspective of sustainable development, technological innovation should be understood as a mechanism capable of promoting economic growth while fostering social inclusion and environmental responsibility. This understanding emerged as socio-environmental challenges intensified and governments encountered increasing difficulties in addressing them effectively. Consequently, companies began adopting socially responsible approaches in the management of their operations. As a result, the concepts of socio-environmental responsibility and sustainable development have increasingly been incorporated into corporate strategies as instruments for organizational growth and long-term competitiveness (Chaves; Castello, 2013).

According to the United Nations Research Institute for Social Development (UNRISD) (2022), a socially just energy transition requires that the benefits derived from new technologies be distributed equitably among different social groups and regions. Consistent with this perspective, Mendonça, Barbosa, and Sousa (2025) argue that technological innovation can be associated with low-cost social technology strategies, significantly expanding access to energy solutions and promoting local development initiatives.

Understanding innovation processes also requires an integrated analysis of the economic, institutional, and technological factors that shape the generation and diffusion of knowledge. In this regard, Lima (2022, p. 3) defines technological innovation as:

[...] the incorporation of knowledge and technologies into productive processes as a means of improving performance and generating social and economic development. Its principal actors include society, with its objectives, values, and social systems that define socioeconomic sectors, needs, problems, and priorities, as well as the scientific community, which develops projects, proposals, products, and services aimed at addressing the needs and priorities of social systems. Innovation occurs when these environments are integrated, making it necessary to apply knowledge to identified problems and opportunities, generate technology in the form of products, processes, services, systems, and business models, and achieve economic and social benefits that contribute to human well-being.

Considering the issues and arguments discussed throughout this section, it becomes evident that technological innovation plays a fundamental role in the transition toward a cleaner and more sustainable energy matrix. It enables the development and continuous improvement of renewable energy sources, enhances competitiveness within the industrial sector, increases the efficiency of energy systems, and contributes to the construction of

development models that are consistent with economic, social, and environmental sustainability.

2.3. Industrial Intellectual Property And Innovation In The Renewable Energy Sector

Industrial intellectual property is one of the most important institutional mechanisms for fostering technological innovation and plays an essential role in protecting the intangible assets generated through research, development, and innovation activities. Within the context of the energy transition, its relevance becomes even more evident due to the growing demand for technologies focused on the generation, storage, distribution, and efficient management of energy derived from renewable sources. As discussed by Buainain et al. (2019), the legal protection of innovations is based on a threefold objective: generating economic returns from developed knowledge, attracting investments in research and development, and contributing to the creation of environments that are more conducive to technological advancement.

The specialized literature demonstrates that industrial intellectual property extends beyond a merely protective function, establishing itself as a strategic instrument for business competitiveness and for strengthening national innovation systems (Vieira et al., 2023; Simionato; Silva; Peres, 2024). From this perspective, Vieira et al. (2023) argue that the interaction among intellectual property, economic development, and technological innovation has acquired increasing importance within knowledge-based economies, particularly in sectors characterized by high technological intensity, such as the energy sector. The protection of intellectual assets contributes to attracting investments, establishing technological

partnerships, and expanding the innovative capabilities of organizations.

Within the renewable energy sector, invention patents and utility models are among the most frequently employed instruments for protecting novel technological solutions and functional improvements capable of generating competitive advantages. According to the Brazilian National Institute of Industrial Property (INPI) (2021), patents grant their holders the temporary right to commercially exploit an invention in exchange for the public disclosure of the technical knowledge contained within the patent document. Consequently, this mechanism simultaneously protects innovation and promotes the dissemination of technological knowledge, ensuring that technical information becomes more accessible to the scientific community, policymakers, and the productive sector.

The strategic relevance of intellectual property to the energy sector is highlighted by Bez and Almeida Júnior (2024, p. 8), who state that:

The energy sector continues to evolve and expand, and the role of intellectual property (IP) as a strategic asset becomes increasingly critical. Companies that invest in adequate IP protection are better equipped to safeguard their innovations, maximize their market potential, optimize the monetization of their assets, and position themselves as leaders at the forefront of energy technology. For these companies, IP is not merely a form of protection; it is an essential tool for growth and sustainable competitiveness in the global energy market.

This perspective demonstrates that intellectual property is not limited to the legal protection of inventions. Rather, it constitutes a fundamental component of value creation, business competitiveness, and the consolidation of productive value chains associated with the low-carbon economy. To illustrate the diversity of legal instruments applicable to the protection of innovations in the renewable energy sector, Table 3 presents a synthesis of the principal intellectual property mechanisms provided for under the Brazilian legal framework and their respective technological applications.

Table 3 – Intellectual Property Instruments Applicable to Renewable Energy Innovations and Their Terms of Protection in Brazil

Intellectual Property Instrument	Subject Matter of Protection	Example in Renewable Energy	Protection Term in Brazil
----------------------------------	------------------------------	-----------------------------	---------------------------

Invention Patent (IP)	Novel technical solution involving an inventive step and industrial applicability	New electrolyzer for green hydrogen production; novel photovoltaic cell	20 years from the filing date
Utility Model (UM)	Functional improvement in an object of practical use	Structural improvement in wind turbines or solar panels	15 years from the filing date
Industrial Design (ID)	Ornamental appearance of a product	Innovative design of solar or wind energy equipment	10 years, renewable for three successive periods of 5 years each (up to 25 years)
Trademark	Identification of products or services	Brand of a green hydrogen producer or solar energy company	10 years, renewable indefinitely
Computer Program	Software and algorithms	Microgrid management systems, smart grids, and energy storage solutions	50 years, counted from January 1 of the year following publication or creation
Trade Secret	Strategic confidential knowledge	Production processes for green hydrogen or energy storage technologies	As long as confidentiality is maintained

Plant Variety Protection (when applicable to bioenergy)	New plant varieties	Energy sugarcane or biomass crop developed for biofuel production	15 years (18 years for vines, trees, and perennial species)
--	---------------------	---	---

Source: Prepared by the author based on Law No. 9,279/1996 (Industrial Property Law), Law No. 9,609/1998 (Software Law), Law No. 9,456/1997 (Plant Variety Protection Law), and information provided by the Brazilian National Institute of Industrial Property (INPI).

At this point, it is important to discuss the concept of green patents. Beyond conventional protection mechanisms, so-called green patents have attracted increasing international attention because they encourage the development of environmentally sustainable technologies. It is important to note that, although green patents do not constitute a distinct legal category separate from traditional patents, many countries have established administrative procedures designed to accelerate the examination of patent applications related to clean technologies. In this regard, Gomes (2025) points out that the growing expansion of renewable energy sources has occurred concurrently with a significant increase in technological development aimed at energy efficiency, energy storage, and industrial decarbonization, thereby enhancing the importance of intellectual property protection instruments.

In May 2026, the World Intellectual Property Organization (WIPO) and the International Renewable Energy Agency (IRENA) released a report on the patent landscape associated with the decarbonization of road transport during an event held in Leipzig, Germany. Among its principal findings, the report highlighted electric batteries as the

leading technological pathway for the decarbonization of heavy-duty vehicles. To illustrate, the share of patents related to decarbonization technologies increased from only 7% of all heavy transport patents in 2000 to approximately 20% in 2024, with batteries accounting for 73% of all low-emission energy source patents. Furthermore, patents related to energy infrastructure recorded growth exceeding 2,200% during the same period (WIPO, 2026).

Another important aspect concerns the use of patent documents for technological prospecting and intelligence activities. Beyond their legal protection function, patent databases serve as important sources of scientific and technological information. As such, they enable the identification of market trends, emerging technological trajectories, collaboration opportunities, and research gaps. According to Simionato, Silva, and Peres (2024), the strategic management of intellectual property is increasingly associated with the institutional capacity to monitor technological information and transform protected knowledge into innovations that can be effectively integrated into productive processes and technology transfer mechanisms.

The complexity of intellectual property within the context of the energy transition underscores the urgent need to reconcile innovation protection, knowledge dissemination, and access to sustainable technologies. In highly innovative fields such as solar energy, wind energy, green hydrogen, energy storage, and smart grids, it is essential to establish regulatory mechanisms capable of stimulating innovation without hindering the rapid adoption of technologies that are critical for mitigating climate change. In this regard, Pompermayer, De Negri, and Cavalcante (2011) emphasize

that policies designed to promote technological research and innovation within the electricity sector are fundamental for building national capabilities, as they enhance industrial competitiveness and consolidate a development model aligned with the objectives of a sustainable energy transition.

3. METHODOLOGY

This study addresses the themes of energy transition, technological innovation, and industrial intellectual property. These topics have gained increasing relevance in contemporary society due to the challenges associated with reducing environmental pollution, ensuring secure and renewable energy supplies, and supporting sustainable economic development. Understanding the relationships among renewable energy sources, technological innovation, and intellectual property protection is of fundamental importance, as these elements contribute to knowledge creation, enhanced industrial competitiveness, and the dissemination of technologies capable of promoting environmentally sustainable energy systems. Within this context, scientific research on these phenomena contributes to the generation of new knowledge that can support academic discussions, institutional decision-making processes, and the formulation of regulations and public policies related to the energy transition.

With regard to its methodological orientation, this study adopted a qualitative research approach. According to Creswell and Creswell (2018), qualitative research enables a deeper understanding of social, institutional, and technological contexts through the interpretation of meanings, relationships, and contextual dynamics. This approach extends beyond the mere application of statistical analyses, allowing

researchers to explore the complexity of the phenomena under investigation. Gil (2019) argues that qualitative research facilitates a comprehensive and objective understanding of complex realities, supporting the formulation of explanations grounded in the context being examined. Widely employed across diverse fields of inquiry, the qualitative approach has proven particularly valuable for investigating legal frameworks, technological innovation, environmental sustainability, and the societal transformations associated with the expansion of human knowledge. In each of these contexts, understanding how processes unfold and how different factors interact is essential for advancing scientific knowledge.

To achieve the proposed objectives, two complementary research procedures were employed: a literature review and documentary research. The literature review represents one of the most widely used procedures in scientific research, as it facilitates the organization and critical analysis of existing knowledge on a given topic. Through this process, researchers can identify conceptual definitions, research gaps, and major trends within the scholarly literature (Arantes, 2025; Gil, 2019). In the present study, the literature review was based on the examination of thirty-two academic sources, including dissertations, peer-reviewed journal articles, book chapters, and scholarly books addressing topics related to the energy transition, renewable energy sources, technological innovation, and intellectual property. This procedure provided the theoretical foundation of the study and supported the analytical discussions developed throughout the research.

Documentary research, in turn, was employed to examine normative, institutional, and technical documents directly related to

the research object. As emphasized by Arantes (2025) and Gil (2019), this procedure enables access to primary sources containing information, guidelines, regulations, and institutional positions relevant to understanding the phenomena under investigation. Accordingly, the following documents were analyzed: Law No. 9,279/1996, which regulates rights and obligations related to industrial property; Law No. 9,456/1997, concerning plant variety protection; Law No. 9,609/1998, which governs the intellectual property protection of computer programs; The Energy Transition and Sustainable Development in Latin America (ECLAC, 2020); Basic Manual for the Protection of Invention Patents, Utility Models, and Certificates of Addition (INPI, 2021); the legislation concerning computer programs made available by INPI (2020); the report World Energy Transitions Outlook 2022 (IRENA, 2022); Transforming Our World: The 2030 Agenda for Sustainable Development (United Nations, 2015); and the report Leaving No One Behind in the Energy Transition (UNRISD, 2022). The analysis of these documents enabled the examination of the legal, regulatory, and institutional foundations associated with energy technologies, innovation, and intellectual property.

The methodological strategy based on the integration of literature review and documentary research proved particularly appropriate, as it enabled the combination of diverse forms of scientific, normative, and institutional evidence. While the literature review provided a robust theoretical foundation for understanding the concepts, trends, and academic debates related to the topics addressed, documentary research facilitated the examination of legal frameworks and strategic documents guiding the implementation of policies and regulatory instruments at both national and international levels aimed at promoting a just energy

transition. Through the complementary use of these procedures, the study achieved a comprehensive and integrated analysis of the relationships among renewable energy, technological innovation, and industrial intellectual property within the broader context of sustainable development.

4. FINAL CONSIDERATIONS

The energy transition has emerged as one of the defining issues of the twenty-first century, particularly due to its relevance in addressing climate change, promoting sustainable development, and restructuring global production systems. In this context, the intersection among renewable energy sources, technological innovation, and industrial intellectual property becomes essential for the development of low-carbon economies capable of balancing economic growth, industrial competitiveness, and socio-environmental responsibility. It is precisely this interconnection among these three thematic axes that underscores the relevance of the present study, as it provides a framework for understanding how knowledge generation, technological advancement, and innovation protection systems contribute to fostering energy transition processes at both national and international levels.

The findings of this study indicate that the general research objective was successfully achieved, as the interfaces among renewable energy, technological innovation, and industrial intellectual property within the context of the energy transition were thoroughly analyzed, highlighting their contributions to technological development, competitiveness, and sustainability. Likewise, all specific objectives were fully accomplished. First, the study examined the fundamental concepts of the energy transition

and the importance of renewable energy sources for sustainable development and energy security. Subsequently, it investigated the role of technological innovation in the development and diffusion of renewable energy technologies. Finally, it analyzed the ways in which industrial intellectual property contributes to the protection, valorization, and dissemination of innovations within the energy sector.

The first topic of the theoretical framework demonstrated that the energy transition is a multidimensional process encompassing technological, economic, environmental, and institutional transformations aimed at the gradual replacement of fossil fuels with renewable energy sources. The findings revealed that increasing the share of clean energy contributes to reducing greenhouse gas emissions, diversifying energy matrices, and strengthening energy security, all of which are closely aligned with global sustainability commitments and the objectives established under the 2030 Agenda.

The second topic highlighted technological innovation as one of the principal drivers of the energy transition. The study demonstrated that research, development, and innovation activities generate new technologies capable of improving the efficiency of energy systems, reducing production costs, increasing the integration of renewable energy sources, and enhancing industrial competitiveness. Furthermore, the analysis underscored the importance of national innovation systems, technology transfer mechanisms, and cooperation among universities, research centers, companies, and governments in the creation of technological ecosystems oriented toward sustainable energy development.

Moreover, the third topic of the theoretical framework confirmed that industrial intellectual property plays a crucial role in the protection and valorization of innovation outcomes. The findings demonstrated that protection mechanisms such as invention patents, utility models, software protection, and other legal instruments encourage investment in research, facilitate the dissemination of technological knowledge, and strengthen the competitiveness of organizations operating within the renewable energy sector. The study also revealed that patent documents constitute valuable sources of technological intelligence, enabling the identification of trends, innovation opportunities, and emerging pathways for technological development within the broader context of the energy transition.

Overall, the research considered these interconnected dimensions and demonstrated that the energy transition extends far beyond the mere availability of renewable resources. Rather, it encompasses the creation, dissemination, and absorption of relevant knowledge, the promotion of innovation-friendly environments, and the adoption of effective intellectual property protection mechanisms. Within this contemporary landscape, renewable energy sources, innovation, technological advancement, and industrial intellectual property emerge as mutually reinforcing factors that collectively support the sustainable development trajectories of countries pursuing a low-carbon future.

For future research, it is recommended that comparative studies be conducted on intellectual property policies specifically designed for renewable energy technologies across different countries. Further investigation into the economic impacts of green patents on the dissemination and diffusion of technological innovations would also

be valuable. Additionally, future studies should explore the interrelationships among artificial intelligence, the digitalization of energy systems, and intellectual property protection in order to better understand how these phenomena interact and influence one another within the evolving landscape of the energy transition.

REFERENCES

ACEMOGLU, D. et al. **Climate Change, Directed Innovation, and Energy Transition**. Cambridge: MIT Press, 2019.

ARANTES, T. R. de R. Documentary research, bibliographic research, and systematic review: defining aspects and brief considerations. **Interdisciplinary Studies Notebooks**, v. 7, n. 2, e722501, 2025. ISSN 2764-394X. <https://doi.org/10.5281/zenodo.15799019>.

BARBOSA, M. C.; GOMES, R. L. R. **The Energy Transition and the Global Decarbonization of the Economy [electronic resource]**: The Contribution and Strategic Role of Ceará in the Production and Export of Green Hydrogen to Europe. São José dos Pinhais: Seven Editora, 2026. ISBN 978-65-6109-324-8. <https://doi.org/10.56238/livrosindi202635-001>.

BEZ, B.; ALMEIDA JUNIOR, J. R. de. **The Importance of Intellectual Property in the Energy Sector**. São Paulo: Estúdio JOTA, 2024. Available at: <https://www.jota.info/opiniao-e-analise/artigos/a-importancia-da-propriedade-intelectual-no-setor-de-energia>. Accessed on: Jun. 2026.

BRAZIL. Law No. 9,279, of May 14, 1996. **Regulates rights and obligations related to industrial property**. Brasília, DF: Presidency of the Republic, 1996. Available at:

https://www.planalto.gov.br/ccivil_03/leis/l9279.htm. Accessed on: Jun. 2026.

BRAZIL. Law No. 9,456, of April 25, 1997. **Plant Variety Protection Law**. Brasília, DF: Presidency of the Republic, 1997.

BRAZIL. Law No. 9,609, of February 19, 1998. **Provides for the protection of intellectual property rights in computer software**. Brasília, DF: Presidency of the Republic, 1998. Available at: https://www.planalto.gov.br/ccivil_03/leis/l9609.htm. Accessed on: Jun. 2026.

BUAINAIN, A. M. et al. **Intellectual Property and Development in Brazil**. Rio de Janeiro: Ideia D; ABPI, 2019. 204 p. ISBN 978-85-5731-005-6.

CARDOSO, J. V. M.; CAMILO, S. P. O.; PICOLO, J. D. Technological innovations in the electric power sector: a systematic review and meta-synthesis. **Journal of Management and Secretariat**, v. 15, n. 7, e4028, 2024. ISSN 2178-9010. <https://doi.org/10.7769/gesec.v15i7.4028>.

CATAIA, M.; DUARTE, L. Territory and energy: a critique of the energy transition. **ANPEGE Journal**, v. 18, n. 36, 2022. ISSN 1679-768X. <https://doi.org/10.5418/ra2022.v18i36.16356>.

CHAVES, D. A.; CASTELLO, R. do N. Sustainable development and corporate socio-environmental responsibility. In: SYMPOSIUM OF EXCELLENCE IN MANAGEMENT AND TECHNOLOGY, 2013, Resende. **Proceedings [...]**. Resende: AEDB, 2013.

CORRÊA, L. **Energy Transition, Innovation Policies and Economic Development: An Analysis of Wind and Solar Photovoltaic Energy**

Initiatives in Brazil. Dissertation (Master's in Economics) – Federal University of Santa Catarina, Florianópolis, 2021.

CRESWELL, J. W.; CRESWELL, J. D. **Research Design:** Qualitative, Quantitative, and Mixed Methods Approaches. 5th ed. Thousand Oaks: Sage Publications, 2018. ISBN 978-1506386706.

ECLAC - ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN. **Energy Transition and Sustainable Development in Latin America.** Santiago: CEPAL, 2020.

GIL, A. C. **Methods and Techniques of Social Research.** 7th ed. São Paulo: Atlas, 2019.

GILLIVER, L. United States: Trump is losing the war against renewables. **Euronews**, 28 Jun. 2026. Available at: <https://pt.euronews.com/2026/06/28/estados-unidos-trump-esta-a-perder-a-guerra-contra-as-renovaveis>. Accessed on: 2 Jul. 2026.

GOMES, R. L. R. (Org.). **Innovation and Trends in Renewable Energy:** Collection of Scientific Production. Fortaleza: FB Editora; IEL, 2025. ISBN 978-85-8420-299-7. <https://doi.org/10.5281/zenodo.17584494>.

GOMES, R. L. R. et al. Geoeconomics of the energy transition and the geopolitics of strategic resources: implications for sustainable development in Brazil. **IOSR Journal of Research & Method in Education**, v. 16, n. 3, ser. 4, p. 50-60, 2026. ISSN 2320-737X. <https://doi.org/10.9790/7388-1603045060>.

GOMES, R. L. R. et al. Intelligent architectures for sustainable housing: use of AI in the management and storage of renewable

energy. In: CARVALHO, I. de S.; VALENTE, N. A. (Ed.). **Horizons of Insight: Exploring the Frontiers of Multidisciplinary Science**. 2nd ed. São José dos Pinhais: Seven Editora, 2026. p. 1-17. ISBN 978-65-6109-315-6. <https://doi.org/10.56238/sevened2026.019-022>.

GUTIERREZ, M. B. G. P. S. **Energy and Sustainability in Brazil: Challenges and Perspectives in a Context of Energy Transition**. Brasília, DF: Ipea, 2025. 28 p. (Discussion Paper, n. 3130). <https://doi.org/10.38116/td3130-port>.

INPI. National Institute of Industrial Property. **Basic Manual for the Protection of Inventions, Utility Models and Addition Certificates**. Rio de Janeiro: INPI, 2021. Available at: <https://www.gov.br/inpi/pt-br/servicos/patentes/guia-basico/ManualdePatentes20210706.pdf>. Accessed on: 2 Jul. 2026.

INPI. National Institute of Industrial Property. **Legislation on Computer Programs**. Rio de Janeiro: INPI, 2020. Available at: <https://www.gov.br/inpi/pt-br/servicos/programas-de-computador/legislacao-programa-de-computador>. Accessed on: 2 Jul. 2026.

IRENA - INTERNATIONAL RENEWABLE ENERGY AGENCY. **World Energy Transitions Outlook 2022**. Abu Dhabi: IRENA, 2022.

LIMA, S. M. V. Private subsystem of agricultural technological innovation and the provision of inputs for Brazilian agribusiness. **Notebooks of Science & Technology**, Brasília, DF, v. 39, n. 2, e26833, 2022. ISSN 1678-0892. <https://doi.org/10.35977/0104-1096.cct2022.v39.26833>.

MENDES, C. S.; PORTO, R. M. A. B. Sustainability and urban innovation: obstacles and perspectives in the energy transition of smart cities. **Research, Society and Development**, v. 14, n. 10, e120141049748, 2025. ISSN 2525-3409. <https://doi.org/10.33448/rsd-v14i10.49748>.

MENDONÇA, M. de S.; BARBOSA, M. J. de S.; SOUSA, R. da P. Technological innovation and low-cost social technology: potential solidarity economic strategies. **Pedagogical Notebook**, v. 22, n. 12, e20730, 2025. ISSN 1983-0882. <https://doi.org/10.54033/cadpedv22n12-142>.

ONU – UNITED NATIONS ORGANIZATION. **Transforming Our World: The 2030 Agenda for Sustainable Development**. New York: United Nations, 2015. Available at: <https://brasil.un.org/sites/default/files/2020-09/agenda2030-pt-br.pdf>. Accessed on: 30 Jun. 2026.

PAIXÃO, J. L.; ABAIDE, A. R. Renewable energy and economic development: energy transition and technological innovation. **Revista Tópicos**, Rio de Janeiro, v. 4, n. 29, p. 1-20, 2026. ISSN 2965-6672. <https://doi.org/10.5281/zenodo.18142545>.

POMPERMAYER, F. M.; NEGRI, F. de; CAVALCANTE, L. R. (Orgs.). **Technological Innovation in the Brazilian Electric Sector: An Evaluation of the R&D Program Regulated by ANEEL**. Brasília, DF: Ipea, 2011. 168 p. ISBN 978-85-7811-120-5.

SÁ, T. D.; SANTANA, G. X.; DUARTE, J. G. de O.; GOMES, R. L. R. Energy transition, legal certainty, and the new environmental licensing framework: perspectives for the green hydrogen and ammonia industry in Brazil. In: **Scientific Collection of Seven Editora**. São José

dos Pinhais: Seven Editora, 2026. p. 4047-4058.
<https://doi.org/10.56238/sevened2026.008-222>.

SANTOS, F. M. Energy transition: framework and challenges. **Revista Videre**, Dourados, v. 11, n. 22, 2019. ISSN 2177-7837.
<https://doi.org/10.30612/videre.v11i22.11217>.

SEBRAE. **Sustainability: Healthy Practices that Drive Your Business**. Brasília, DF: SEBRAE, 2022.

SIMIONATO, R.; SILVA, F. G. da; PERES, L. Innovation and intellectual property: challenges and strategies in the management and transfer of institutional technologies. **Contributions to Social Sciences**, v. 17, n. 7, e8940, 2024. ISSN 1988-7833.
<https://doi.org/10.55905/revconv.17n.7-447>.

UNRISD – UNITED NATIONS RESEARCH INSTITUTE FOR SOCIAL DEVELOPMENT. **Leaving No One Behind in the Energy Transition**. Geneva: UNRISD, 2022.

VIEIRA, A. C. P. (Org.) et al. **Intellectual Property, Development and Innovation: Future Perspectives** [electronic resource]. Ponta Grossa: Aya Editora, 2023. 244 p. ISBN 978-65-5379-272-2.
<https://doi.org/10.47573/aya.5379.2.197>.

WEF – WORLD ECONOMIC FORUM. **The Global Risks Report 2024**. Geneva: World Economic Forum, 2024. Available at:
https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2024.pdf. Accessed on: 2 Jul. 2026.

WIPO – WORLD INTELLECTUAL PROPERTY ORGANIZATION. **WIPO and IRENA Launch Patent Landscape Report on Decarbonizing**

Heavy-Duty Road Transport. Geneva: WIPO, 2026. Available at: <https://www.wipo.int/en/web/patent-analytics/w/news/2026/wipo-and-irena-launch-patent-landscape-report-on-decarbonizing-heavy-duty-road-transport>. Accessed on: 2 Jul. 2026.

¹ Undergraduate Student in Chemical Engineering - USP

² Master's degree in Administration and Controllershship - UFC

³ Ph.D. in Fisheries Engineering - UFC

⁴ MBA in Business Analytics - IEL

⁵ Dr. in Biotechnology - Federal University of Amazonas

⁶ Dr. in Electrical Engineering - UFC

⁷ Prof. Dr. in Agricultural Biotechnology - RENORBIO – UFC

⁸ Ph.D. in Genetics, Conservation, and Evolutionary Biology National
Institute of Amazonian Research

⁹ Postgraduate Degree in Criminal Law - Uniateneu University
Center

¹⁰ Postgraduate MBA in Renewable Energy Management –
Fbuni/IEL

¹¹ Postgraduate MBA in Renewable Energy Management – Fbuni/IEL

¹² M.Sc. in Military Sciences – Brazilian Army Command and General Staff School

¹³ Master's Degree in Administration and Controllershship - UFC

¹⁴ Dr. in Biological Sciences (Cultural Title) – FICL; Master's degree in Crop Science – UFC – e-mail: [acesse o artigo original para visualizar o e-mail](#)

¹⁵ Doctoral Student at the Academy of the National Institute of Industrial Property

¹⁶ Masters in Intellectual Property and Technology Transfer for Innovation - IFCE

¹⁷ Prof. Dr. in Regional Development from the University of Barcelona