**PROMOTING INDUSTRIAL DEVELOPMENT FOR THE ENERGY TRANSITION IN LATIN AMERICA: LESSONS FROM THE WIND ENERGY AND THE GREEN HYDROGEN SECTORS IN ARGENTINA**

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**Overview**

For some decades now, the energy transition has emerged as a global trend that demands an active strategy from States to transform the challenges of this process into opportunities for development in emerging countries. This trend demands a profound transformation of the energy matrix, that implies the gradual elimination of fossil fuels (United Nations, 2023) and the incorporation of diverse technologies for energy generation from renewable sources (EFR). These technologies are in different stages of development and, even though their adoption and diffusion can enhance the comparative advantages of the energy sector, their impact on the technological dynamism of its associated industries is not clear. For example, wind energy has a high penetration rate in South American energy markets (IRENA, 2023) and its diffusion, within an appropriate institutional and economic framework, has facilitated the installation of factories for blade production in Brazil and tower production in Argentina. At the same time, green hydrogen is in a phase of feedback between technology development and demonstration on a global scale, but countries in the region continue to outline their institutional frameworks without achieving significant technological advances, except in Chile where the country's first hydrogen fuel cell vehicle was homologated (OLADE, 2023).

In the last decade, within the framework of neo-Schumpeterian and Evolutionist theories, various academic studies suggest that the processes of learning and innovation around industries based on the exploitation of natural resources (IBRN), such as those dedicated to the generation of EFR, are relevant for economic development, although these processes qualitatively differ from those in other segments of the economy. These works highlight the role IBRN have in the technological dynamism of the network of actors that supplies them with equipment, services and knowledge and their economic and technological relevance in South American economies. However, they also point out that there are conditions that enable these processes, which are expressed in the demand configuration, the industrial organization, the technology cycles, and the institutional (Andersen, Marín & Simensen, 2018; Crespi, Katz & Olivari, 2018; Katz & Pietrobelli, 2018). This work analyzes the innovation trajectory of the wind energy industry in Argentina and, after comparing its similarities and differences with the green hydrogen path, it draws lessons on the processes of learning and innovation around IBRN and the opportunities and challenges the green hydrogen industry pose to lever economic development in the region.

**Methods**

The research is based on the analysis of one case study: the wind energy industry in Argentina and its evolution over the past two decades, including the global context in which it has been embedded. Following Perez, Marín, and Navas-Aleman (2014), this case study is not limited to firms that produce wind energy but encompass the entire range of actors, both public and private, involved in the transformation of a renewable natural resources, such as wind, into energy. Although this case study does not adopt a comprehensive historical approach, it analyzes the institutional trajectory and the strategies and technological capabilities built along the years by the main local actors that comprise this industry in Argentina. Additionally, the research analyses the economic, technological, and political frameworks that surround the emergence of a green hydrogen industry, globally and nationally.

These industries were selected for their relevance to the agenda of energy transition in South American countries and for their technological, market, institutional, and organizational differences up to the present moment. The construction of the case study and the analysis of the green hydrogen nascent industry were carried out through the collection of information from multiple secondary sources and semi-structured interviews with representatives from both industries. Their analysis is based on the coding and recording of information in matrices to identify common patterns and differences.

# Results

In Argentina, the wind energy industry emerged in the late 2000s, when at least three companies with different strategies and technological capabilities developed and, in some cases, installed wind turbines produced in the country. These developments were motivated by the global growth of renewable energy demand and the internationalization of this technology at a time when its costs continued to be higher than non-renewable energy, as is currently happening with hydrogen. The existence of technological and demand-oriented public policies at the national level, albeit with limited resources and politically unstable, accelerated the development of local technological capacities within these firms, but also among their domestic suppliers. However, the small and unstable market scale offered by the public sector in Argentina, in a highly competitive global environment, forced the firm that managed to stay in that market to internationalize, for which the economic integration of Mercosur proved to be key.

The analysis of the trajectory of the wind energy industry in Argentina and its comparison with the dynamic of the green hydrogen nascent industry shows different enabling conditions acquire different degrees of importance along the technological cycle to give rise to processes of learning and innovation in networks of domestic firms. Wind energy is solely destined for electricity production, but green hydrogen has a variety of applications that go beyond the energy sector and involve a variety of domestic and external actors, both public and private. This diversity can inject greater dynamism into the demand, but its speed and scope may be partially affected by the national institutional framework and to some extent by international norms and agreements.

On the other hand, long-term patterns of innovation in energy technologies are crucial for public policy planning around their development in the context of climate change. While wind turbine technology resembles the life cycle of complex products and systems –the focus of innovative activity shifts over time through different parts of the product- (Huenteler, Schmidt, Ossenbrink, & Hoffmann, 2016), the life cycle of hydrogen is not yet clear though it may follow mass-produced goods, where early product innovations are followed by a surge of process innovations in green hydrogen production. This innovation pattern affects industry configuration.

Today, the global value chain of the wind industry is led by companies that manufacture wind turbines. This link in the chain has become concentrated in a few companies with the internationalization of the market and the emergence of entry barriers due, first, to the vertical integration of firms and, subsequently, to the control of a knowledge and capital-intensive technology with O&M contracts for the life cycle of wind farms. Hydrogen technology, on the other hand, is in transition between demonstration and diffusion stages. This has led European Union countries and the USA to implement policies to incentivize the localization of new factories to produce electrolyzer in their territories, even though in China there already exists a local supply chain that allows to produce alkaline electrolyzers at a competitive price. In parallel, the strategies of South American countries aim to incentivize, with some exceptions, the installation of hydrogen production plants.

**Conclusions**

At a global level, the energy transition is a response to climate change, but also an opportunity to enhance innovation income and exploit new sources of capital accumulation based on natural resources. In developed countries, the States have implemented demand, industrial, and technological policies to strengthen learning and innovation of the firms in the renewable energy sector. Many of them now control technology and, in the case of the wind sector, lead global value chains. The trajectory of the wind sector in Argentina shows that, in the early stages of technology diffusion, firms with frontier technological capabilities can develop strategies to integrate themselves into production processes with high value-added and knowledge-intensive impacts on the development of local suppliers. However, as wind energy is a complex and capital-intensive technology, its diffusion led to a process of global concentration. While the specificity of natural resources and the national regulatory framework can counterbalance the centrality of global firms, weighing the participation of local companies, financial logic, global certifications, and ICTs can counteract this trend. This raises questions about the degree of relevance that the specificity of renewable energy sources and institutional frameworks have compared to other factors such as industry organization and the market. Besides, the innovation pattern of electrolyzers and the complexity of the knowledge embedded in these devices could be a constraint for the development of innovations around the product and the hydrogen production process.

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