**Facing the Technical and Economic Challenges of the Energy Transition: Lessons from the Brazilian Experience**

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**Overview**

About 80% of the international energy matrix is based on fossil fuels (oil, natural gas and coal). Due to the impact of this participation in energy systems and CO2 emissions, there is a consensus to increase the share of renewable energies in the global energy mix. However, despite the increase in energy generation from renewable sources in recent years, opinions about the direction and speed of transformation of the energy mix vary significantly among stakeholders in the energy sector. These different views reflect the fact that major technological challenges are yet to be addressed in the transition toward a low-carbon energy matrix.

The successful introduction of solar and wind power generation entails significant challenges for the electricity industry in relation to supply security and reliability, as these are variable and non-dispatchable energy sources. To avoid using fossil fuel as a back-up for renewable energy sources, it is necessary to develop competitive solutions for energy storage, such as batteries water reservoirs or renewable liquid or gaseous fuels.

Decarbonizing the transportation sector presents no less important challenges. The diffusion of electric vehicles requires the improvement of battery technologies as well as the mobilization of a huge volume of resources to invest in new supply infrastructure. This challenge is particularly important in developing countries where the electricity transmission and distribution network has not yet reached an adequate level of development. The technological challenges and uncertainties surrounding the diffusion of renewable fuels in the cargo and air transport segment are even greater.

To face the challenges mentioned above, it will be necessary to build consensus on the direction of the energy transition, with the aim of reducing the degree of economic, technological and regulatory uncertainty to increase public and private investments in technological innovation and renewable energy production.

In this regard, Brazil has a successful experience in promoting renewable energies sources. Currently, they represent 44% of total energy consumption and 85% of electricity consumption. In the transportation segment, biofuels (ethanol and biodiesel) are responsible for 23% of total consumption. This level of diffusion of renewable energy sources was the result of the implementation of energy and technological policies that allowed the development of an innovation ecosystem in the Brazilian energy sector.

Considering the above, this article assesses the role of energy and innovation policies to face the technical and economic challenges of the energy transition, based on the Brazilian experience in the promotion of renewable energy sources.

**Methodology**

In order to achieve the objectives of the article, it was developed a bibliographic research with a qualitative and quantitative approach. To this end, the main studies with projections of demand for fossil fuels were reviewed, as well as projections of the investments necessary to enable the diffusion of new renewable energy sources in the world energy matrix, according to the goals established by the Paris agreement. Then, a review of the main prospects of clean energy technologies was carried out. In this regard, an analysis of the status of technologies for solar, wind and batteries in the electricity generation sector was highlighted. And, in the transportation sector, attention was focused on the diffusion status of electric cars and advanced biofuels.

Then, the Brazilian case of promoting renewable energy sources was analyzed, focusing on the instruments of innovation policy and energy policy in the electricity and biofuels sector. From the Brazilian experience, it was possible to establish a discussion based in some contributions of the innovation economy on innovation policies, highlighting the importance of the State in promoting technological solutions for the energy sector, as well as in the management of risks related with the development of R&D projects by the firms.

**Results**

Among the results, the study highlights the presence of a set of complementary technological solutions to lead the transition to a low carbon economy, with emphasis on the combination of wind energy, solar energy and batteries. However, the results show that there are still technologies bottlenecks and institutional barriers to be addressed by States and companies to allow the diffusion of new renewable sources complying with energy security requirements.

In the Brazilian case, the results show a long history of developing renewable sources to replace fossil sources, with emphasis on the use of hydroelectricity and biofuels, and, more recently, wind and solar energy. The country was able to structure an ecosystem of innovation and stable contracting mechanisms that supported the diffusion of these sources.

The Brazilian experience confirms that the energy transition requires robust innovation efforts, with the State playing a fundamental role in promoting business and innovation ecosystems, as well as managing the risks related to the generation of technological solutions in the energy industries.

In the other hand, the adoption of clean technologies implies the need to adapt the regulation and the design of the energy markets in each country. The Brazilian experience has highlighted the importance of coordination in the design of different public policy instruments in addition to innovation policy instruments.

**Conclusions**

The article concludes that despite the notable progress made in defining an international agenda for the decarbonization of the world energy mix, there are still great uncertainties regarding the speed of the energy transition. The decarbonization of the energy mix depends on facing important technological challenges in the energy markets increasingly dominated by private companies.

The article highlighted that the energy transition requires an intensification of investments in RD&I. Considering the scale of the challenge and the risk involved in the development of new energy technologies, government support through different public policy tools will be essential.

The current technological scenario in the energy sector presents a high risk for investors, with the possibility of diffusing disruptive energy technologies. In this context, industrial and technological policy contributes to reducing the perception of risk, by aligning investment visions and strategies. A good policy should include mechanisms to encourage investment in projects with high technological risk. Therefore, developing and disseminating alternative energy sources in a context of transformation of energy industries requires broad coordination between public policies and markets. It is necessary to establish transversal objectives in energy, innovation and industrial policies in a long-term horizon.

The analysis of the Brazilian experience made it clear that long-term efforts in the implementation of public policies were fundamental for the development of a cleaner and more reliable energy mix. This can be identified in the historical trajectory of hydroelectric development and in the recent process of wind and solar diffusion. The public sector played an important role in building an innovation ecosystem favorable to renewable energy sources.

More recently, public policies had to be adapted to technological changes and the configuration of the energy sector, which now has private companies as the main players. In this new context, the design of the markets for renewable energies through dedicated auctions and investments in RD&I through contractual clauses with investment targets in the concession contracts played a very important role in the diffusion of renewable sources. The development of new instruments to support innovation and investments in renewable energy sources allowed the country not only to absorb energy technologies developed in the international market but also to assume a leading role in the development of specific segments of the energy industry.

**References**

British Petroleum (BP) (2019a). World Energy Outlook: 2019 edition.

EDLER, Jakob and FAGERBERG, Jan (2017). Innovation policy: what, why, and how. Oxford Review of Economic Policy, Volume 33, Number 1, 2017, pp. 2–23.

FURTADO, A.; SCANDIFFIO, M.; CORTEZ, L. (2011). The Brazil sugarcane innovation system. Energy Policy, No. 39, pp. 156-166.

FURTADO, André (2015). Políticas de Inovação no Setor Elétrico Brasileiro. Edufes, Vitoria.

INTERNATIONAL ENERGY AGENCY (IEA) (2018a). World Energy Outlook 2018.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (2018b). Technology Innovation to Accelerate Energy Transitions.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (2019a). World Energy Investments.

INTERNATIONAL RENEWABLE ENERGY AGENGY (IRENA) (2016). Innovation Outlook : Advanced Liquid Biofuels. Available at <https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Innovation_Outlook_Advanced_Liquid_Biofuels_2016.pdf>. Accessed on September 09, 2019.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (IRENA) (2018). Global Energy Transformation: A Roadmap to 2050. Available at <https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf>. Accessed on September 09, 2019.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (IRENA) (2019). INNOVATION LANDSCAPE FOR A RENEWABLE-POWERED FUTURE: SOLUTIONS TO INTEGRATE VARIABLE RENEWABLES.

World Energy Council (2019). Designing for Disruptions: A New Era for Energy. London, United Kingdom.

World Economic Forum (2018). Fostering Effective Energy Transition: A Fact-Based Framework to Support Decision-Making.