Exploring the flexibilities in the use of green hydrogen in the Northeast region of Brazil

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Abstract

The northeast region of Brazil is rich in wind and solar resources, making it an ideal location for wind and photovoltaic (PV) generation. However, there is a ubiquitous degree of uncertainty regarding the demand for the generated electricity. Therefore, any excess electrical energy produced by the wind and PV farms has the flexibility to be converted into green hydrogen to address this uncertainty.

Green hydrogen is a clean and renewable energy source that offers many flexibilities for efficiently using excess electric energy. This helps to manage the variability of the wind and solar resources and provides a long-term storage solution for the extra power. In addition, the converted green hydrogen can be used as fuel for transportation, heating, and back to electricity generation, or stored for further use, offering significant value maximisation to all stakeholders.

Keywords: real options, uncertainty, renewable energy, green hydrogen

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Introduction

The Paris Agreement, adopted under the United Nations Framework Convention on Climate Change in December 2015 ("The United Nations Paris Agreement | UNFCCC," 2015), aims to limit global warming and to achieve a carbon-neutral economy by mid-century. As part of this goal, the agreement calls for a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century. This implies achieving the often referred to as net-zero emissions by 2050 or sooner.

The northeast region of Brazil, also known as the Nordeste region, has abundant solar power potential. The area is known for its high solar radiation levels, averaging 5.5-6.5 kWh/m² per day (Kelman et al., 2020), and relatively low cloud cover, making it one of the best places in the world to place a photovoltaic (PV) power station (Figure1). Also, this same region, according to the Brazilian Ministry of Mines and Energy (Pereira de Lucena et al., 2010), has the largest wind energy capacity in the country due to trade winds (blowing from east to west), its long coastline and the usual high winds speeds, making it an ideal place for wind farms (Figure2). The demand for energy worldwide is increasing, and renewable energy is a promising solution to meet this demand while reducing dependence on fossil fuels.

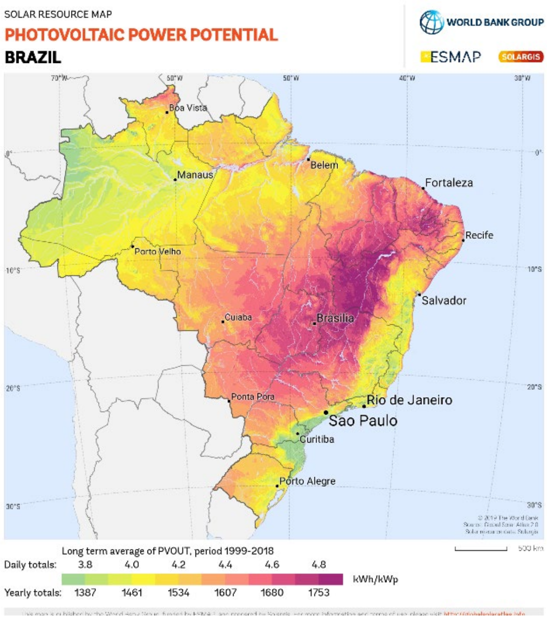

Figure 1 - Brazilian photovoltaic power potential

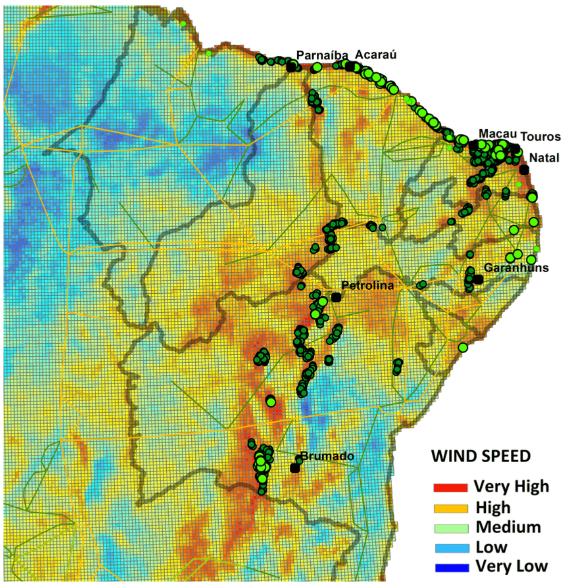

Figure 2 – Brazilian Northeast region wind power potential

As seen in (Figure 3), there are occasions when the wind and solar farms' outputs exceed the region's electricity demands, bringing the producers to a pervasive problem or uncertainty: should they continue providing and selling their electricity to the national grid or do something else? It is also important to remember that because their power is purely based on renewable sources, they can charge a premium for their energy, which is unlikely to be paid for when the electricity demand is low.

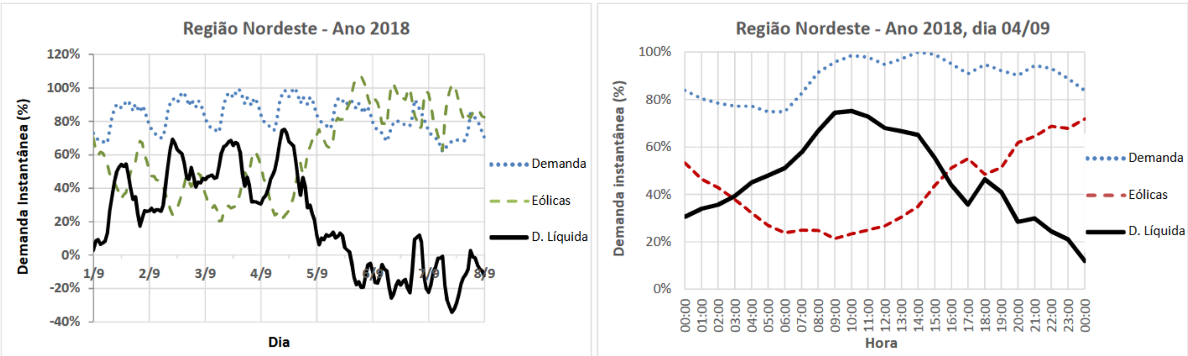

Figure 3 - Power demand and supply, with a surplus in a sample day from September 2018, accounting only for wind power.

This is where Power-to-X (PtX) framework takes place. It refers to the conceptual framework and approach of using surplus, renewable electricity to produce other forms of energy. This includes using PtX to balance the energy grid, store energy for later use, and provide power, heat, and feedstock for various industries. In addition, the PtX model is a critical enabler (Reuß et al., 2017) for a sustainable energy system, as it allows for the integration of variable renewable energy sources dependent on weather conditions.

For a PtX model to function correctly, one must also include energy storage systems to accumulate the electricity produced during the surplus for later use. Hydrogen is a source of energy that can be used for energy storage, transportation, and various industrial processes. For this article, we will focus on the generation of green hydrogen.

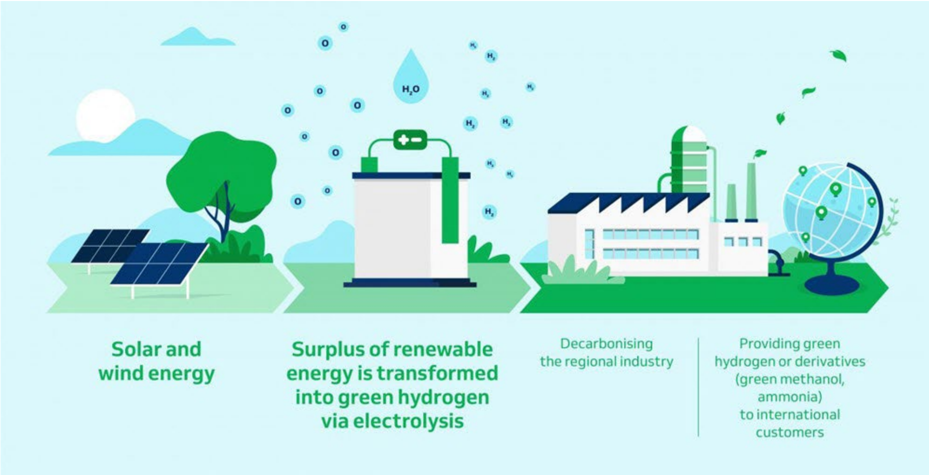

Figure 4 - A very simple drawing of how green hydrogen is produced

Green hydrogen, also known as renewable hydrogen, is a gas that can store energy in chemical form. It can be produced from water through electrolysis, which uses electricity to split water into hydrogen and oxygen (Figure 4). It is a clean and sustainable form of hydrogen using renewable energy sources such as solar and wind power. This form of hydrogen production has the potential to significantly reduce greenhouse gas emissions and contribute to the decarbonisation of various industries, thus contributing to the net-zero emissions mentioned in the Paris Agreement (Velazquez Abad & Dodds, 2020).

This article will model the uncertainty of electric energy prices, the investment to build wind and photovoltaic farms, the carbon credits and the premia for this type of energy generation, the option to switch the excess electricity output to green hydrogen production accumulating it in storage tanks similar to those used for storing natural gas and the further opportunities presented by the later use of green hydrogen, focusing but not limited to:

i. Energy storage: Green hydrogen can be produced and stored when renewable energy sources such as solar and wind power are abundant and then used as an energy source when demand is high or renewable energy sources are unavailable, offsetting the grid by providing energy during peak demand and absorbing excess energy from renewable sources.
ii. Transportation: Green hydrogen can be transported through pipelines, tankers, and other existing infrastructure, making it easily accessible to many industries.
iii. Feedstock: Green hydrogen can be used as a feedstock for various industrial processes, such as being transformed into green ammonia for producing fertilisers and for producing synthetic fuels for transportation or being a source of heat for chemicals and metals, making it a versatile option for multiple decarbonising industries.
iv. Long-term storage: Green hydrogen has a relatively long shelf life, allowing long-term storage and use as needed.

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