Hydrogen related perspectives in Brazil

Gustavo Henrique Romeu da Silva*, Andreas Nascimento, Nazem Nascimento

São Paulo State University, Faculty of Engineering, Guaratinguetá Campus, SP-12516-410, Brazil.

*Corresponding author

Abstract

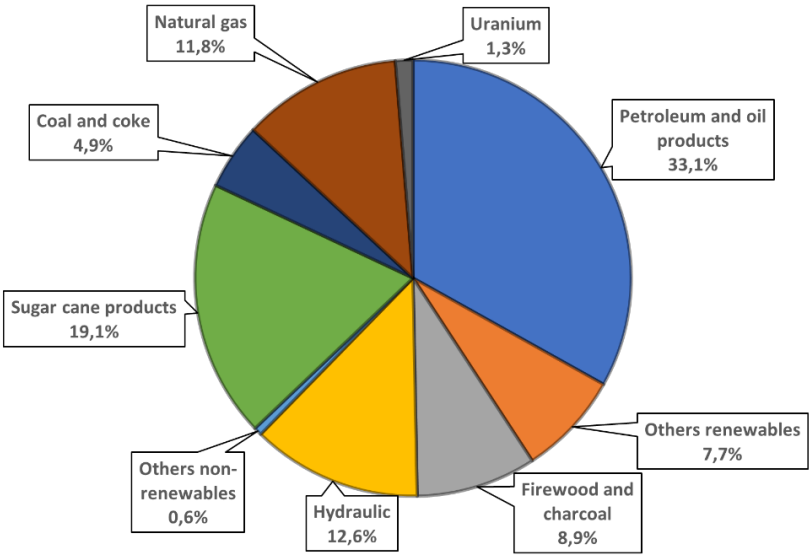
Due to the evolution of the global market and the progress of studies in the investigation for new renewable methods for obtaining energy and ways to minimize the emissions of gases produced by industrial activity, in the exploration for more efficient and sustainable resources for energy distribution and storage, hydrogen is an element of paramount importance to be studied and evaluated. Therefore, the reference work aims to evaluate the perspectives of hydrogen production in Brazil. Firstly, the current Brazilian scenario of hydrogen production was evaluated, which follows the global trend, having in its large part of hydrogen production from the reform of natural gas, also called gray hydrogen, focusing on the refining and fertilizer sectors that, in general, makes use of processes with high carbon dioxide emissions. Next, the prospects of hydrogen production in Brazil over the years will be analyzed. Thereby, it is concluded that Brazil has a prominent position to become an exporter of low-carbon hydrogen, since it presents excellent and favorable climatic conditions for electricity generation through wind, solar and hydro sources.

Keywords: Hydrogen, Low-carbon, Energy, Renewable.

1. Introduction

Currently, the Brazilian energy matrix is quite different from the world energy matrix. In the national scenario, although energy consumption from non-renewable sources is higher than renewable resource, we use more sustainable energy than in the rest of the world. Adding firewood and charcoal, hydraulics, sugar cane derivatives and other renewables, our total renewables energy amounts 48.3%, almost half of our energy matrix.

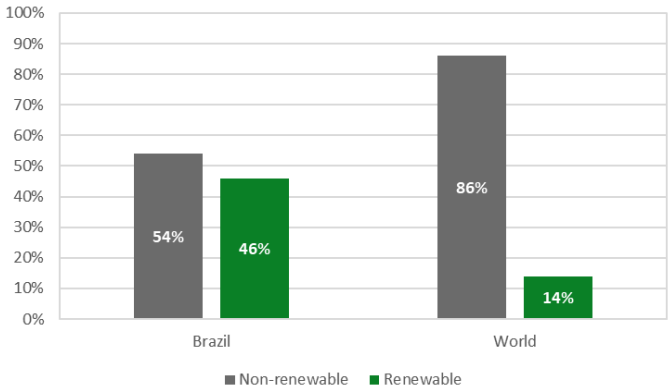
Figure 1: Brazilian Energy Supply in 2020



Source: EPE (2021).

Non-renewable energy sources are the largest responsible for greenhouse gas emissions. Analyzing Figure 2 and comparing the consumption of energy from renewable and non-renewable sources in Brazil and worldwide during 2019, it is noticeable that the Brazilian energy matrix is more renewable than in the rest of the world. Because our consumption is more renewable than in other countries, dividing greenhouse gas emissions by the total number of inhabitants in Brazil, we conclude that Brazil emits less greenhouse gas per inhabitant than most other countries.

Figure 2: Energy consumption in Brazil and in the rest of the world in 2019



Source: EPE (2021) & *IEA* (2021).

2. Methods

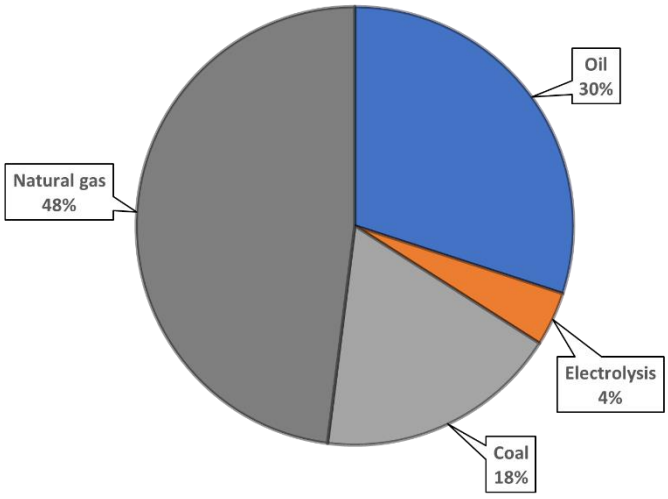
The work is developed from the analyzis of data obtained through the reading and collection of information in scientific articles and technical reports from funding agencies, like databases of the Brazilian Energy Balance on the current Brazilian scenario of hydrogen production and generation prospects over the years, International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA).

3. Results

3.1 Hydrogen in Brazil. At present

Currently, Brazil follows the global trend of hydrogen production through the reform of natural gas, also called gray hydrogen, focusing on the refining and fertilizer sectors that, in general, use processes with high emission of carbon dioxide. Most hydrogen production plants are found in coastal regions near the gas pipeline network of Brazil (Oliveira, 2022).

Figure 3: Raw material used in current global hydrogen production.



Source: EPE (2021).

In relation to the consumer market of hydrogen in Brazil, for the synthesis of products and various processes and insums, five main sectors are identified: petrochemical, for fuel refining; steel and metallurgical, for the reduction of crude iron and ovens of controlled atmospheres; hydrogenation of products, mainly margarines; of flat glass, for the process of inertization of the tin bath, in order to prevent the formation of defects in the glass and to protect the chambers and equipment in which the glass is conformed; and power generation (thermoelectric), for

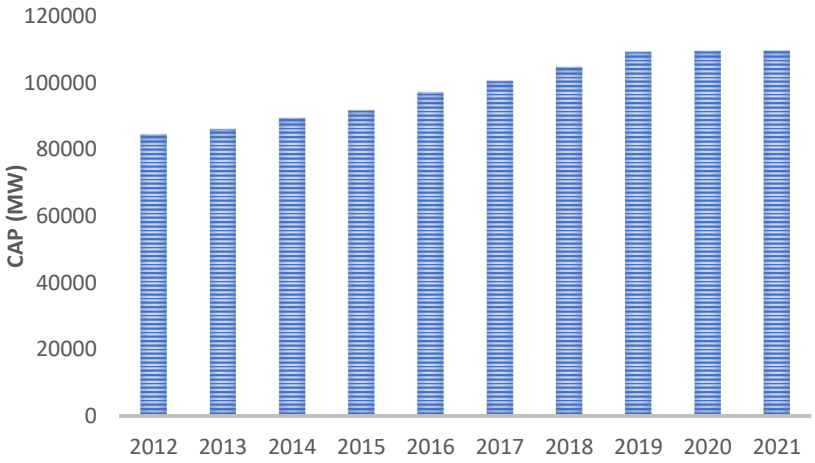
turbine cooling. In addition to these, the transport sector stands out, which includes cars, buses, ships, and airplanes (Oliveira, 2022).

3.2 Energy perspectives of hydrogen in Brazil

In recent years, hydrogen gas has attracted the attention of researchers and rulers, since it is pointed out as an alternative fuel, with the promise of significant contribution to the energy transition and substantial in the decarbonization process. In that regard, Brazil has a prominent position to become an exporter of low-carbon hydrogen, since it presents excellent and favorable climatic conditions for the generation of electricity through wind, solar and hydro sources (Oliveira, 2022).

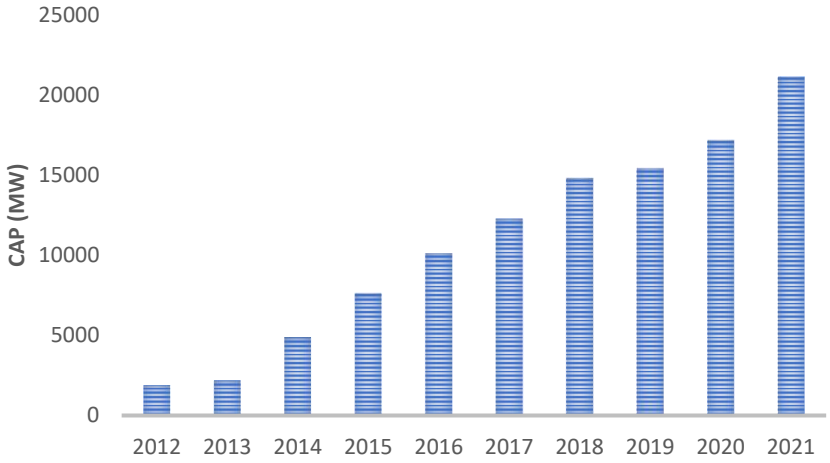
According to the renewable capacity statistics report for the year 2022 prepared by the International Renewable Energy Agency (IRENA), there is a considerable growth in the capacity of Brazilian hydroelectric plants (Figure 4), and a high increase in the evolution of solar and wind energy in the country (Figure 5 and Figure 6). In this sense, Brazil has very favorable conditions for the development of green hydrogen technology, from electrolysis.

Figure 4: Evolution of hydropower capacity in Brazil.



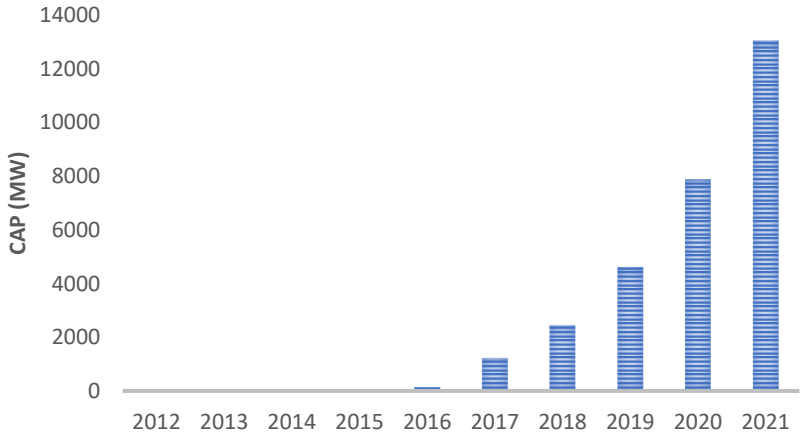
Source: Data collected from IRENA (2022).

Figure 5: Evolution of wind energy capacity in Brazil.



Source: Data collected from IRENA (2022).

Figure 6: Evolution of solar energy capacity in Brazil.



Source: Data collected from IRENA (2022).

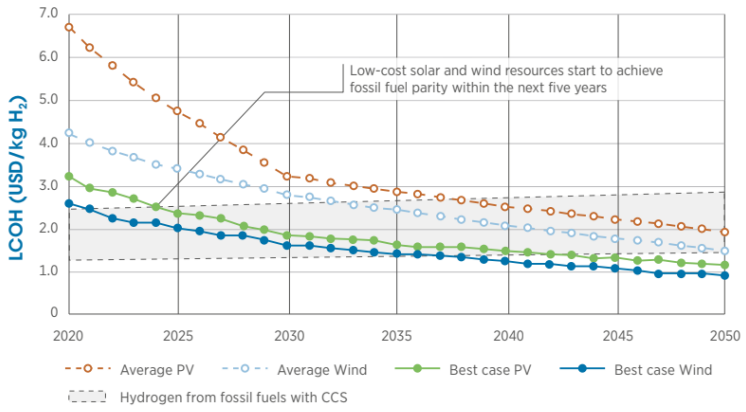
Although hydrogen is one of the best fuels for producing clean energy, its price is still expensive for Brazil compared to other fuels. With the creation of new technologies, its low production costs can make it competitive in relation to the others, increasing the level of security and diversification of the Brazilian energy matrix (Nadaleti et al., 2020).

In the literature, there are several studies on the technical-economic analysis of hydrogen production using other renewable sources, such as wind and solar (Moraes et al., 2019). Nadaleti, Santos and Lourenço (2020) reported a potential and economic viability of hydrogen production from the use of surplus energy from hydroelectric dams and wind farms in Brazil. They obtained the economic viability to produce hydrogen, at a cost of 0.303 USD. kWh^{-1}, a higher cost compared to that of wind and hydroelectric plants.

In Brazil, several technical-economic studies, and projects of significant importance in the compatibility of hydrogen with the natural gas infrastructure or with its reform are being developed. According to the annual report "Hydrogen: a Renewable Energy Perspective" conducted by International Renewable Energy Agency (2019), for the year 2019, the cost of producing green hydrogen was around 4 to 7 dollars per kilo (Figure 7). However, in one recent study named “Green hydrogen as an alternative fuel for the shipping industry” (Atilhan et al., 2021), the researchers point out that although the high cost of electrolysis hinders the implementation of the technique of producing green hydrogen, with the advance in materials and other technical issues it is possible to overcome the problems related to this approach.

Figure 7 shows the perspective of the cost of hydrogen production between the years 2020 and 2050, according to the study conducted by the International Renewable Energy Agency. In this illustration it is observed that, currently, the highest cost of producing hydrogen is from electrolysis, using photovoltaic energy, which is in the order of 7 dollars, followed using wind energy, which represents 4 dollars, and the most optimistic condition about solar energy, which is around 3 dollars. Finally, the most economical condition of hydrogen production is through the conventional route from fossil sources with carbon capture, being 2.5 dollars.

Figure 7: Hydrogen production costs.



Source: IRENA (2019).

In addition, it is observed in Figure 7 that the trend is that by the 2050s the costs of hydrogen production involving the use of hydro, wind and solar energy will be equivalent to the costs of production from fossil sources. This is because Brazil has high potential for the development of clean energy. According to EPE (2022) the country's hydraulic potential is in the order of 246.24 MW, with 44% of its total in operation. Today, wind is the second largest source of energy in the country, accounting for 11% of the electricity matrix, which has had a strong growth in the last decade, going from 1 GW in 2011 to 21 GW in January 2022 (Lee & Zhao, 2022). In addition, Brazil has large deposits of silicon, a material needed to produce solar energy, as well as a large territorial area and the contribution of sunlight, which reinforces the positive outlook, being able to generate tens of thousands of GWh only with this energy source (Denes & Kindl, 2019).

In this sense, several technical-economic studies are being developed. Shi, Qian e Yang (2020) reported a fluctuation analysis of a complementary wind−solar energy system and integration for large scale hydrogen production. They obtained that the operational cost of the coupling system is 3.59 \$/kg H_2, close to that of the coal gasification with carbon capture technology. Yadav and Banerjee (2018) reported an economic assessment of hydrogen production from solar driven high-temperature steam electrolysis process. For a photovoltaic plant, the researchers obtained the cost range of hydrogen production ranging from 16 to 22 US\$/kg H_2, depending on the operating conditions of the electrolyzer.

The costs related to the production of clean energy are still relatively expensive in Brazil. With the creation of new technologies, the cheapness to produce it can make it competitive with the others, increasing the levels of safety and diversification of the Brazilian energy matrix (Nadaleti et al., 2020). To decrease the costs of green hydrogen production, it is necessary to reduce the costs of generating the energy required for electrolysis.

The production of green hydrogen through electrolysis is currently a high-cost process, in this sense, a more economical alternative would be from the gasification of biomass, since it has acceptable costs and generates less environmental impact when compared to other raw materials, such as coal. In addition, it is a technology that allows blue hydrogen, since carbon dioxide produced from biomass is much cheaper to capture and store than carbon from fossil sources. The cost of biomass gasification ranges from 1.77 to 2.77 USD/kg H_2 (Ji & Wang, 2021).

4. Conclusion

With the analyzis of the Brazilian energy matrix, although Brazil follows the global trend of hydrogen production, focusing on the refining and fertilizer sectors that, in general, makes use of processes with high carbon dioxide emissions, it is a country that has high potential to become an exporter of low-carbon hydrogen, since it presents excellent and favorable climatic conditions for electricity generation through wind, solar and hydro sources.

Based on the analyzis of the information collected in the articles and the international development agencies, we can conclude that, in Brazil, several technical-economic studies, and projects of significant importance in the compatibility of hydrogen with the natural gas infrastructure or with its reform are being developed. In this sense, Brazil has very favorable conditions for the development of green hydrogen technology, from electrolysis. Nevertheless, the production of green hydrogen through electrolysis is currently a high-cost process, in this sense, a more economical alternative would be from the gasification of biomass, since it has acceptable costs and generates less environmental impact when compared.

Therefore, in the search for more efficient and sustainable energy distribution and storage resources, hydrogen is a choice of paramount importance to be studied and evaluated. Thus, investments in projects to analyze the cost-benefit of hydrogen production are essential, and a comparative evaluation of carbon dioxide emissions produced by these different hydrogen production processes proves to be an excellent way to look for ways to minimize gas emissions produced by industrial activity.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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