Perspectives for the Production of Green Hydrogen in Brazil

Juliane Taise Piovani[1]; Victoria Alejandra Salazar Herrera[2]; Adriano Gomes de Freitas[3]; Federico Bernardino Morante Trigoso[4].

[1, 3, 4] *Graduate Program on Energy, The Federal University of ABC - UFABC, Santo André, SP, Brazil, juliane.piovani@ufabc.edu.br; adriano.gomes@ufabc.edu.br; federico.trigoso@ufabc.edu.br.*
[2] *Graduate Program on Information Engineering, The Federal University of ABC - UFABC, Santo André, SP, Brazil, victoria.herrera@ufabc.edu.br.*

ABSTRACT

Brazil has great potential to become a world leader in the production of green hydrogen (H2V), but it still does not take advantage of it, mainly due to lack of investment. The country has a mostly renewable energy matrix, with emphasis on hydroelectric, wind and solar energy. Brazil has a large territory with favorable geographic and climatic conditions for the production of H2V. The Brazilian territorial sea has an immense potential for renewable energy generation that is totally unexplored. Brazil needs to invest more in research and development to take advantage of its full potential. It is also necessary to create public policies to encourage the H2V production. This article discusses the theme and evaluates regions that have vocation and potential for the production of H2V. The article argues that, with investments and research, Brazil can become a leader in the production of this clean and renewable fuel.

Keywords: Brazil, Green Hydrogen, Photovoltaic Energy, Renewable Energy, Wind Energy.

Introduction

The recent global crises climate highlight the need to reduce the burning of fossil fuels across the planet. The impacts of climate change are becoming increasingly visible. Extreme heat and/or cold weather, intense droughts, forest fires and storms have been spreading around the world, resulting in impacts to the ecosystem and the population [1].

"Paris Agreement", signed in 2015, forces countries to seek alternatives to reduce the consumption of fossil fuels in the global energy matrix, increasing the use of renewable sources, in an attempt to keep the increase in the global average temperature below 2 °C, above pre-industrial levels, reaching 1.5 °C by the year 2050 [1].

Among the renewable fuel options, there is a non-primary energy source called hydrogen, which is defined as an energy vector capable to storage energy to be used later [2]. Hydrogen is obtained by means of electrolysis using primary energy sources, when renewable sources are used for it obtention it is called green hydrogen (H2V). The H2V is seen as a viable alternative to face several energy challenges in the decarbonization of the planet, mainly in *"hard-to-abate sectors"*. The transport sector, including the air and maritime segments, chemical and steel industries are some examples. Currently, hydrogen production in Brazil is centered on the oil sector (refining and industry) and fertilizers (ammonia) [3].

Countries that use renewable resources in greater quantities in their energy matrix, which have favorable conditions for generating solar and wind energy and have access to water, alongside with the ability to export, are seen as ideal for the development of an H2V infrastructure with costs reduced. In this regard, countries such as Brazil, Argentina, Chile, Australia and South Africa stand out for investments [4].

The potential of hydroelectric, photovoltaic and wind energy, in addition to biomass, is part of Brazil's strategies to satisfy the electric energy demand of the population and contribute to the reduction of global warming in the context of climate change. However, the production of H2V, combining wind and solar energy with electrolysis of water, was not initially Brazil's proposal. Projects related to the development of hydrogen (H_2) were linked to other technologies, such as natural gas reforming, gasification, pyrolysis, fuel cells, etc. processes that, despite being less polluting, emit carbon dioxide (CO_2) into the atmosphere [5].

In this sense, the purpose of this article, the purpose of this article is to discuss the project possibilities related to H2V and some points that hold back the advancement of technology H2V production in Brazil.

DOI: 10.55592/ISE.2023.2270049

Global projections for the future of Green Hydrogen

Projections made by International Renewable Energy Agency (IRENA, 2023), to reduce greenhouse gas (GHG) emissions satisfactorily by 2050, evince that abundant production of H2V is required, only by electrolysis. For other sources of obtaining hydrogen, it is necessary to adopt the capture of CO_2 emissions that make the process more expensive for investment [1]. Fig. 1 shows the H2V projection required until 2050.

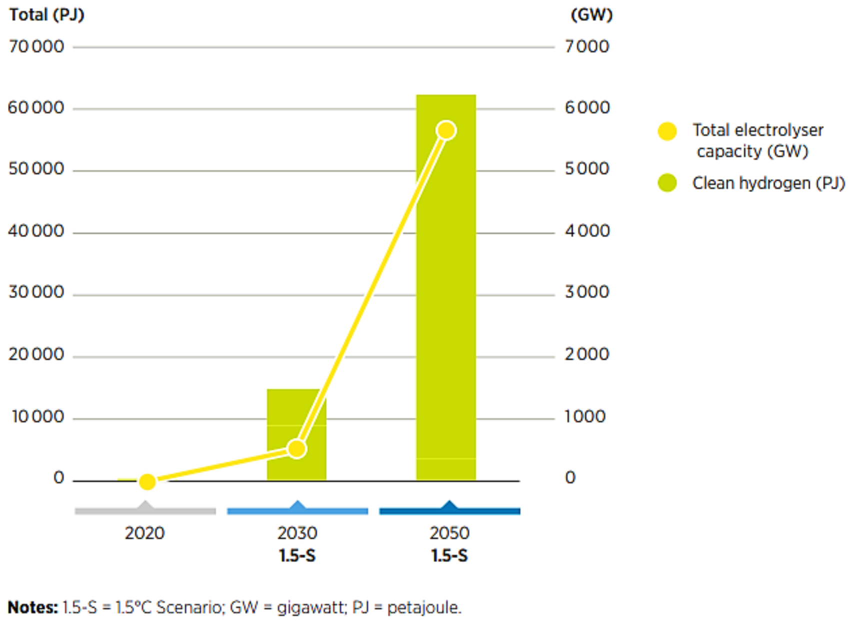

Figure 1. H2V required in 2020, 2030 e 2050 in a 1.5 °C increase scenario [1].

A relevant issue that could be an obstacle to commercialization is that H_2, in general, will probably be less competitive and less profitable than oil and natural gas (O&G), as it is a secondary source of energy conversion. As a result, H_2 may not return compatible profits, compared to the profits obtained by the O&G sector, which represent an average of 2% of world Gross Domestic Product (GDP) [6].

Another problem is the higher cost of producing H2V. According to REPowerEU Program (2022), the cost of fossil-based H_2 is close to US$ 1.4/kg H_2. Green hydrogen, on the other hand, which is produced from water electrolysis, has a production cost that ranges from US$ 5 to US$ 7/kg H_2 [7]. This value reflects the 60% reduction in the capital expenditure (CAPEX) of the electrolysis process since 2010 [8]. Therefore, without government policies to reduce costs, investment interest will decline, making it difficult to commercialize H_2. Fig. 2 shows the participation of H_2 and its derivatives in the global fuel market by 2050.

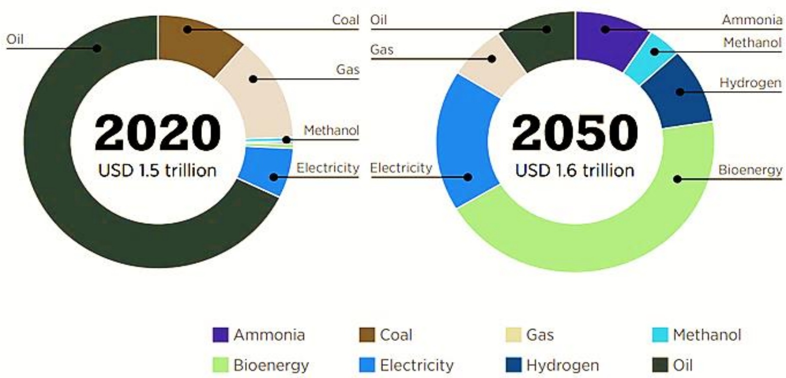

Figure 2. Predicted value of commodities in the energy sector between 2020 and 2050 [5].

DOI: 10.55592/ISE.2023.2270049

Issues such as high production costs, lack of infrastructure, tax regimes, deployment policies, trade agreements and financial regulation also hamper the energy transition [9].

A. *Investments in Brazil*

In 2002, investments in R&DI began in Brazil, focused on the development of fuel cells. Since then, government agencies have financed projects to obtain renewable hydrogen (ethanol, hydro, wind and solar). The total invested between 1999 and 2018 is close to BRL 200 million [10].

Even with these investments, the country's objective initially is to invest in the development and improvement of fuel cells that use as source reformers of ethanol, methanol, natural gas and syngas, which, despite being less polluting, produce CO_2. These investments are medium term (2020 to 2030). Technologies to produce H2V are strategic projects with longer terms (between 2030 and 2050) [5].

In 2021, the Ministry of Science, Technology and Innovation and Ministry of Mines and Energy; in partnership with Germany, the H2Brasil project for developing scenarios and actions for the implementation of H2V began [11]. According to Institute of Applied Economic Research (IPEA, 2022 – in Portuguese), Brazil will invest, on average, US$ 27 billion in the construction of H2V plants. The investments are close to ports; however, they are announced investments, without schedules prediction, that are in the R&D stage or MoU (Memorandum of understanding) stage [10].

B. *Promising technologies in Brazil*

Brazil has a promising potential for the installation of floating solar plants Floating Photovoltaic Systems (FPV) due to the variety and quantity of water bodies in its territory. There are about 241,000 water bodies in Brazil [12].

Table 1 shows the technical potential available for offshore H2V production. Solar energy represents almost 79% of the potential. In this evaluation, ocean energy was considered, which unfortunately is in the distant future in Brazil, while countries in Europe and Asia seek to implement the production of H2V by tidal converters, coupled to other energy systems. Table 2 shows an estimate of the technical potential for hydrogen production from the balance of energy resources until 2050 [10].

Table 1. Technical potential for hydrogen production from offshore renewable offshore [10].

Offshore Renewable Energy Resource	**Hydrogen Potential (Mt/year)**
Offshore wind energy – up to 10 km distance (dist.) from shore	11.2
Offshore wind energy – 50 km (exc. 10 km dist.)	39.8
Offshore wind energy – 100 km (exc. 50 km dist.)	50.2
Offshore wind energy – EEZ* (exc. 100 km dist)	249.2
Ocean energy	8.8
Offshore PV	1356.1
Total	**1715.3**

* Exclusive Economic Zone (EEZ).

Table 2. Energy resources available until 2050 [10].

Energy Resource	**Hydrogen Potential (Mt/year)**
Renewable – Offshore*	1715.2
Renewable – Onshore*	** 18.1
Biomass	50.5
Nuclear	6.9
Fossil	60.2
Total	**1851.0**

Notes:
* The onshore and offshore renewable resources considered are hydro, solar and wind.
** The potential may prove to be much higher.

Three FPVs are in the testing phase at Brazil’s hydroelectric dams. The Balbina hydroelectric power plant, in Amazonas, was designed to generate 250 MW, but since 2016 it has generated 50 MW [13]. Balbina has a pilot-scale FPV with a capacity of 1 MWp. The Sobradinho hydroelectric reservoir, in Bahia, has pilot-scale FPV with a capacity of 1 MWp [14]. The São Paulo Energy Company (CESP) has two 25 kWp PV installations at the Rosana hydropower plant, in São Paulo, operating since 2014 [15]. Rosana also installed in 2017 two wind generators that together produce around 100 kW.

These three projects were developed to increase capacity; however, even tought they have potential to produce H2V they were not adapted for such purpose until 2023. These projects are ongoing, however, not yet operational.

C. *Favorable places for H2V production*

Renewable sources are responsible for 44.7% of the total domestic energy supply in Brazil [16]. Most of the electricity produced by Brazil (53.4%) comes from hydroelectric plants. Moreover, Brazil has large amounts of water to obtain hydrogen by electrolysis, a resource not available in many countries in the world where water is a scarce resource.

The South region has the second greatest potential for H2V production, considering wind and hydroelectric facilities in operation. The State of Paraná has the greatest potential for H2V production, using surplus energy from hydroelectric plants. The State of Paraná is bathed by 16 basins, among which the Paraná, South Atlantic and Uruguay basins stands out. This region favors FPV installations. In 2021, an R&D project was developed at the Itaipu Binational Power Plant for energy generation and storage, considering hydroelectric and solar sources, associated with the production of H2V [10]. Then there is the State of Rio Grande do Sul (RS), which has several competitive advantages in this segment, due to the extensive coastline and the occurrence of lakes. RS is one of the largest onshore wind power generators in Brazil and have projects for wind offshore analysed for Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA, in Portuguese). The state of Santa Catarina also has favorable conditions to a lesser extent [4] [17].

According to M. P. C. Lopes, *et al.* (2022), if only 1% of the surface of artificial water bodies in Brazil were occupied by FPVs, it would be possible to generate 79,377 GWh/year of electricity with a potential capacity of 43,276 MWp [12].

Brazilian states in the Northeast region (Rio Grande do Norte, Piaui, Pernambuco, Bahia) and the Southeast region (Minas Gerais and Rio de Janeiro) also invest in H2V generation. The projects are concentrated near port regions to facilitate exports and by proximity to future installations of offshore wind energy projects, announced in Brazil, with huge H2V production capacity [18] [19].

D. *Possibilities and impacts of H2V production*

According J.A. Prieto, *et al.* (2021), less than 1% of H2V in the world is produced by means of renewable resources, the rest is obtained by process involving coil, lignite or natural gas and its production has efficiency between 20 to 40%, showing a necessity of combining which another sources in order to avoid losses.

If H2V were considered as a green energy to be included on Brazilian electric matrix, J.A. Prieto, *et al.* (2021) suggest taking into account: substitution of material consume of H_2, improve efficiency, substitute demand of some minerals among other. It is important to have in mind the impacts of H2V too, for example, the fact of using renewable sources to produce H_2 do not exempt impacts related to transportation and power plants required areas. Infrastructure and needing of resources to produce H_2 and guarantee to avoid substituting the dependency of some non-renewable sources for only this resource.

Conclusions

Brazil has already an electric matrix based on renewable energy, mainly based on hydroelectric, but solar and wind sources are increasing exponentially last decade as decentralized generation and it has potential for producing energy by means of tidal energy and H2V even though it is not a primary source, so it need the above mentioned sources to be produced. This evinced that Brazil has many resources available for use, however, there is a slow progress in terms of public policies, tax incentives and broader research development in relation to the production of H2V in cycles combined with wind, solar and hydroelectric sources. The onshore and offshore wind and FPV energy sources are at first promising, consistent with the desirable characteristics for the development of H2V production in a country, cited by the literature and by relevant reports such as IRENA.

DOI: 10.55592/ISE.2023.2270049

More studies are necessary, as Brazil has a wide range of resources, an extensive coastline and a large number of water bodies, and may occupy a prominent position in world production. That is why it is necessary to carry out mapping and bathymetry to obtain details of the physical characteristics, in addition to studies on the bottom of the sea or bodies of water, for analysis of the region, seeking to preserve the marine habitat and detect other Brazilian regions with potential for H2V production. There are many uncertainties regarding the environmental impacts caused by offshore systems, including studies on environmental impacts related to the installation of FPV are even more unknown. However, H2V production must be analyzed to remain the renewable electric Brazilian matrix, not becoming technologically dependent and keeping the diversity of resources.

Acknowledgments

The authors acknowledge the support received from Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 001 and the Federal University of ABC.

References

[1] IRENA, "World Energy Transitions Outlook 2023: 1.5°C Pathway," IRENA, Abu Dhabi, 2023.

[2] J. A. Prieto, S. M. López, J. N. Corpas, "Hidrógeno: la nueva panacea? Mitos y realidades de las expectativas del hidrógeno en España," Ecologistas en Acción y el Observatorio del Deute en la Globalitzacion, Barcelona, 2021.

[3] Rosana Cavalcanti de Oliveira, "PANORAMA DO HIDROGÊNIO NO BRASIL," IPEA, Rio de Janeiro, 2022.

[4] Daniela Mueller de Lara and Marc François Richter, "Hidrogênio verde: a fonte de energia do futuro," *Novos Cadernos NAEA*, v. 26, pp. 413-436, 2023.

[5] CGEE, "Prospecção tecnológica no setor elétrico brasileiro," CGEE, Brasília, 2017.

[6] IRENA, "IRENA," 2023. Available: https://www.irena.org/.

[7] Fernandes *et al.*, "Fundação Getúlio Vargas," 27 jan. 2023. Available: https://portal.fgv.br/artigos.

[8] SAINI, "GEP," 12 jan. 2023. [Online]. Available: https://www.gep.com/.

[9] Sabrina Fernandes Macedo; Drielli Peyerl, "Prospects and economic feasibility analysis of wind and solar photovoltaic hybrid systems for hydrogen production and storage: A case study of the Brazilian electric power sector," *International Journal of Hydrogen Energy*, v. 47, nº 19, pp. 10460-10473, 2022.

[10] BRASIL, "Plano Decenal de Expansão de Energia 2031," MME/EPE, Brasília, 2022.

[11] BRASIL, "Ministério de Minas e Energia," 2021. Available: https://www.gov.br/mme/pt-br.

[12] Mariana Padilha Campos Lopes et al., "Technical potential of floating photovoltaic systems on artificial water bodies in Brazil," *Renewable Energy*, vol. 181, pp. 1023-1033, 2022.

[13] Blanca Palva, "Agência Brasil," 2016. Available: https://agenciabrasil.ebc.com.br/.

[14] Andreia Verdélio, "Agência Brasil," 2019. Available: https://agenciabrasil.ebc.com.br/.

[15] Blue Sol, "Blue Sol," 2020. Available: https://bluesol.com.br/.

[16] BRASIL, "Relatório Síntese 2022: ano base 2021," MME/EPE, Brasília, 2022.

[17] W. C. Nadaleti; G. B. Santos; V. A. Lourenço, "The potential and economic viability of hydrogen production from the use of hydroelectric and wind farms surplus energy in Brazil: A national and pioneering analysis," *International Journal of Hydrogen Energy*, vol. 45, nº 3, pp. 1373-1384, 2020.

[18] G. Chiappini, "epbr Agency", 26 abr. 2023. Available: https://epbr.com.br/.

[19] D. Zaparolli, "Pesquisa FAPESP", abr. 2022. Available: https://revistapesquisa.fapesp.br/.