The Unfolding Potential of Green Hydrogen In Brazil

By **David Andrew Taylor** (November 6, 2024)

David Andrew Taylor

Hydrogen is increasingly gaining global recognition as critical in the quest for environmentally sustainable energy, particularly within the renewable energy sector.

Its role in electricity generation through fuel cell conversion not only produces energy that is free from carbon dioxide, but also yields pure water as the only byproduct, framing it as a true zero-emission solution.

In accordance with the Paris Agreement, there is an urgent need to scale up hydrogen production from renewable sources to combat the climate crisis, which poses a significant threat due to the catastrophic impacts of environmental pollution from human activities. Carbon emissions from fossil fuels have surged, contributing to global warming, rising sea levels and extreme weather events.

Addressing this problem — including significant methane emissions from human activities — is crucial, and transitioning to hydrogen as a clean fuel can play a vital role in mitigating carbon emissions and fostering global sustainability.

Brazil is strategically positioning itself to lead the charge in green hydrogen production, harnessing its vast renewable energy resources, including hydropower, solar energy and wind potential. The green hydrogen sector in Brazil is actively developing through several operational and planned projects.

Federal Law No. 14.948, enacted on Aug. 2, establishes a legal framework for hydrogen activities, designating the National Agency of Petroleum, Natural Gas and Biofuels, or ANP, as the regulatory body and introducing incentives for low-carbon hydrogen production. As such, it marks a significant regulatory step forward in creating the favorable environment for investment and growth in Brazil's green hydrogen industry essential for realizing its potential.

However, significant challenges remain — including high production costs, technological needs and infrastructure development — as shall be discussed below.

Historical Context

Brazil's energy strategy traces back to the early 2000s, coinciding with the global shift toward alternative energy to reduce dependence on fossil fuels and combat climate change.

In 2002, Federal Law No. 10.438 established the Alternative Electricity Sources Incentives Program, targeting an addition of 3,300 MW of renewable energy — primarily from wind, biomass and small hydroelectric sources — by the end of 2007. This initiative aimed to elevate renewable energy's share to 10% of total consumption within 20 years, supported by a certificate system based on clean energy output.

That same year marked the inception of the Brazilian Hydrogen and Fuel Cell Systems Program. Brazil joined the International Partnership for Hydrogen and Fuel Cells in the Economy in 2003, to promote hydrogen and fuel cell technology development. The establishment of the Brazilian Energy Planning Agency in 2004 further integrated hydrogen initiatives into long-term energy strategy.

In 2005, the Ministry of Mines and Energy published the "Roadmap for the Structuring of the Hydrogen Economy in Brazil," outlining foundational principles for national hydrogen development. In 2007, the Brazilian National Energy Plan 2030 emphasized Brazil's commitment to diversifying its energy matrix, prioritizing renewable sources.

The Brazilian National Plan on Climate Change, introduced in 2008, emphasized a "green growth" strategy, focusing on greenhouse gas reduction and clean energy technologies. In 2016, Brazil ratified the Paris Agreement, pledging to reduce greenhouse gas emissions by 37% below 2005 levels by 2025, with renewable resources targeted to constitute 45% of the energy mix by 2030.

The RENOVABIO policy, established by Federal Law No. 13.576 in 2017, required fossil fuel distributors to purchase decarbonization credits from biofuel producers, a support for renewable fuels facilitating the integration of other technologies, including hydrogen. Hosting the 2018 World Hydrogen Energy Conference in Rio de Janeiro further solidified Brazil's commitment to hydrogen.

In 2020, the Brazilian National Energy Plan 2050 recognized hydrogen as a disruptive technology with vast potential across industrial processes. It emphasized regulatory development, safety, infrastructure and international collaboration to incorporate hydrogen into Brazil's energy landscape.

The introduction of the National Hydrogen Program in August 2022 aimed to promote research, infrastructure development and international collaboration in hydrogen technologies. A three-year action plan launched in August 2023 sought to establish pilot hydrogen plants by 2025, and position Brazil as a leading global hydrogen producer by 2030.

The recent enactment of Federal Law No. 14.948 on Aug. 2 of this year established a comprehensive framework for low-carbon hydrogen within Brazil's National Energy Policy, marking a significant advancement toward implementing the country's hydrogen strategy.

Economic Potential

The economic potential of green hydrogen in Brazil is considerable. Projections indicate that by 2040, wind and solar could comprise approximately 47% of the country's electricity generation. It is estimated that Brazil's green hydrogen market could reach $5 billion by 2030, and expand to $11 billion by 2040.[1]

With approximately 85% of its energy sourced from renewables, Brazil is well-equipped for hydrogen production, with costs projected to decrease to below $1.50 per kilogram by 2030.[2]

Operational and Anticipated Projects

Brazil's green hydrogen sector has a diverse portfolio of projects at various stages of development. Key operational initiatives include the Federal University of Rio de Janeiro's green hydrogen pilot project and PTI/Furnas' certified green hydrogen production facility in Itumbiara, Goiás, both poised for advancement through 2025.

Launched in 2022, the Federal University of Rio de Janeiro's Solar Energy and Green Hydrogen Laboratory collaborates with the German Agency for International Cooperation to produce high-purity (99.999%) green hydrogen using nine anion exchange membrane electrolyzers.

This initiative aims to demonstrate hydrogen production from solar energy, with applications in urban mobility, and as a substitute component of natural gas, establishing a scalable model for clean energy solutions.

The Itumbiara renewable hydrogen plant, Brazil's first operational facility of its kind, is located near the Eletrobras Furnas hydroelectric station. It utilizes energy from an 800 kilowatt peak photovoltaic system. The facility comprises an electrolyzer with a maximum capacity of 51 normal cubic meters per hour, a pressurized reservoir storing up to 825 normal cubic meters of hydrogen and a fuel cell assembly that generates 300 kW of electricity.

Inaugurated in December 2021, the project focuses on hydrogen production, storage and conversion, with an ongoing emphasis on efficiency testing. Since its inception, it has produced over three tons of hydrogen, with a daily capacity of 100 kilograms, and received certification from the Brazilian Electric Energy Commercialization Chamber in November 2023.

Another notable initiative is the pilot project at Pecém Port in Ceará, led by the Portuguese EDP Group in collaboration with several partners. This project combines wind energy and a 3 megawatt solar photovoltaic unit to produce 250 Nm^3/h of hydrogen, contributing to the broader Pecém Thermal Complex's renewable hydrogen production goals.

The CH2V Green Hydrogen Center, developed by the Federal University of Itajubá in Minas Gerais, is also progressing. This facility features a 300 kW polymer exchange membrane electrolyzer, hydrogen storage vessels and a refueling dispenser, designed to produce green hydrogen at a rate of 60 Nm^3/h, supported by the German Agency for International Cooperation and the German Federal Ministry for Economic Cooperation and Development.

Looking ahead, significant future projects are in the feasibility and planning stages. A 2021 memorandum of understanding between Fortescue Future Industries and the state of Ceará aims to develop a large-scale green hydrogen production facility in the Pecém Industrial and Port Complex.

With a projected investment of $5 billion, the facility aims to produce 837 tons of green hydrogen daily by 2027, powered by 2,100 MW of renewable energy.

Similarly, in 2021, Qair Brasil, a subsidiary of the French company Qair International SAS, signed a memorandum of understanding to invest $6.95 billion in a green hydrogen initiative. This includes the development of the 1,216 MW Dragão do Mar offshore wind park, and a 2,240 MW electrolysis plant, together targeting an annual production of 296,000 tons of green hydrogen.

Additionally, in June 2023, Petrobras announced a nonbinding two-year confidentiality agreement with Unigel Participações SA to explore joint ventures in fertilizers, green hydrogen and low-carbon projects, in keeping with its strategic plan for 2024 through 2028.

Hydrogen Applications and Market Demand

The applications for hydrogen are extensive, spanning industries such as steel production, fertilizers and transportation decarbonization. Domestic hydrogen demand could reach approximately 9 million tons by 2040, potentially representing 5% to 10% of Brazil's energy mix should carbon pricing be implemented.

On the international front, Brazil could generate $1 billion to $2 billion from hydrogen exports to U.S. and EU markets by 2030, with projections increasing to $4 billion to $6 billion, or 2 million to 4 million tons, by 2040.[3]

Current Hydrogen Production Methods

This being said, current hydrogen production methods face significant technological challenges in reducing carbon emissions and improving efficiency.

Steam methane reforming, the most common method, uses high-temperature steam and methane, producing hydrogen but also carbon dioxide. Coal gasification converts coal into synthetic gas, but produces CO_2 emissions as well.

In contrast, electrolysis splits water into hydrogen and oxygen, producing energy that is free from CO_2. However, inefficiencies hinder effectiveness.

To improve efficiency, high-performance electrolyzers are in development, for example, utilizing alkaline electrolytes such as potassium hydroxide to facilitate ion transport. But these face drawbacks such as corrosiveness and low current density.

Stacking of electrolyzer cells can enhance capacity. The polymer exchange membrane electrolyzer, using solid polymer and distilled water, achieves around 80% efficiency, but relies on costly, rare metals like platinum and iridium.

Hysata's recent development-phase capillary-fed electrolyzers avoid these materials, and claim up to 95% efficiency. If successful, Hysata's 5 MW demonstration unit in Australia could significantly reduce electrolyzer costs and transform large-scale green hydrogen production.

Effective Energy Storage and Management

Brazil's favorable geography and seasonal wind and solar patterns have facilitated significant growth in its electrical matrix, with wind power reaching 14.4 gigawatts, and solar photovoltaic 2.3 GW. Some regions benefit from strong complementarity between wind, solar and water resources.

Linking green hydrogen production to these renewable energy sources is optimal. However, the intermittent nature of solar and wind complicates stable hydrogen production.

Fluctuations in energy availability require hybrid systems with energy storage solutions, such as batteries or hydrogen storage. Advanced power management systems will be crucial for synchronizing hydrogen production with renewable energy, to ensure a reliable supply.

Capital Investment for Infrastructure and Technology

One major impediment is the high initial capital investment for infrastructure and technology, particularly the cost of renewable electricity and electrolyzers, which are the largest expenses in green hydrogen production. Scaling from small pilot projects to industrial production requires overcoming these challenges.

Enhancing electrolyzer design for larger modules could reduce costs by over 30%. Additionally, addressing iridium, platinum and other critical material scarcity is vital. Projections suggest that technological improvements could reduce costs by up to 85% in the long term.[4]

Safe and reliable delivery infrastructure is essential for commercializing hydrogen. However, establishing an efficient transport network for hydrogen in Brazil is challenging, due to the country's vast geographic expanse.

Compressed gaseous hydrogen can potentially be transported via pipelines, rail or trucks. But there are high costs, and the requirement of high-pressure tanks and cryogenic storage to contend with.

As of 2021, Brazil's natural gas pipeline network spanned 9,409 km, and could potentially be retrofitted for hydrogen transport. However, hydrogen's small atomic size poses serious risks of embrittlement and leakage, necessitating specialized pipeline materials and reinforcement. Blending hydrogen with natural gas or transporting pure hydrogen each present their own unique technical challenges.

Industrial Transition

While hydrogen has a higher energy density by mass than methane or gasoline, its low volumetric energy density complicates the repurposing of existing infrastructure. Hydrogen must often be converted to higher-density forms, such as liquefied hydrogen or ammonia, for effective transport.

Transitioning to hydrogen requires extensive retrofitting of natural gas networks and new infrastructure, including specialized pipelines, storage solutions and refueling stations.

Automotive Industry Transition

The automotive sector in Brazil faces unique challenges in adopting hydrogen fuel cell technology.

As a case study example, in the U.S., hydrogen vehicles like the Toyota Mirai have limited presence due to a lack of fueling infrastructure, with only about 17,000 such vehicles on the road, mainly in California.

Despite their safety and quick fueling times, their high cost — the Mirai is priced at $57,500, mainly due to its fuel cell — and the scarcity of hydrogen refueling stations make them less appealing than battery electric vehicles, which have a more established electrical charging network.

Brazil´s automotive industry has an established ethanol infrastructure. And while Brazil is expanding its liquefied natural gas infrastructure, all the LNG flex-fuel vehicles still produce CO_2 emissions.

Liquid hydrogen suffers a challenge due to extreme cooling requirements, and hydrogen fuel cell electric vehicles, or HFCEVs, must also compete against the rising popularity of battery electric vehicles, which saw a 170% sales surge in Brazil in early 2024. That hydrogen refueling stations are, practically speaking, nonexistent in Brazil is, however, the most significant barrier to the adoption of HFCEVs.

This being said, HFCEVs offer the advantages of energy density and range. Existing trucking hubs in Brazil could serve as potential sites for hydrogen refueling stations, promoting a viable hydrogen infrastructure for road transport.

Regulatory Clarity for Green Hydrogen Production in Brazil

Regulatory clarity is essential for green hydrogen production in Brazil. Federal Law No. 14.948 designates the ANP as the primary regulatory authority, overseeing all aspects of hydrogen production and distribution, and requires that hydrogen production be conducted by companies under Brazilian law with ANP authorization.

Defining "low carbon hydrogen," "renewable hydrogen" and "green hydrogen," the law lays the groundwork for a National Low Carbon Hydrogen Policy, incorporating the National Hydrogen Program, and introducing the Brazilian Hydrogen Certification System, which promotes sustainable hydrogen use through voluntary certification.

It also introduces the Special Incentive Regime for Low Carbon Hydrogen Production, offering tax benefits for related infrastructure projects, and allowing for the issuance of incentivized debentures to facilitate capital access. Further regulatory decree will detail the law's provisions, and the ANP will provide clarity on how it will effectively fulfill its expanded regulatory responsibilities.

Conclusion

Currently, the prevailing discourse surrounding green hydrogen reflects a marked tendency toward overoptimism. While Brazil's green hydrogen sector stands poised for growth, buoyed by its abundant renewable resources, realizing its full potential will be no small feat.

Significant technological, financial and logistical real-world hurdles must be confronted head-on. That being said, the new legal framework regulating the production of green hydrogen in Brazil is a significant step toward fostering sustainable development, and attracting the investment that is essential to achieving its implementation within the country's energy transition goals.

David Andrew Taylor is a partner at Almeida Advogados.

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[1] McKinsey & Company, Website, Article, The Green Hidden Gem – Brazil's Opportunity to Become a Sustainability Powerhouse (Nov. 4, 2022), available at https://www.mckinsey.com/br/en/our-insights/all-insights/the-green-hidden-gem-brazils-opportunity-to-become-a-sustainability-powerhouse#/.

[2] McKinsey & Company, Website, Report, Green Hydrogen: An Opportunity to Create Sustainable Wealth in Brazil and the World (Nov. 25, 2021), available at https://www.mckinsey.com/br/en/our-insights/hidrogenio-verde-uma-oportunidade-de-geracao-de-riqueza-com-sustentabilidade-para-o-brasil-e-o-mundo.

[3] Id.

[4] International Renewable Energy Agency (IRENA), Website, Publication, Making the Breakthrough Green Hydrogen Policies and Technology Costs (Nov. 2020), available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Green_Hydrogen_breakthrough_2021.pdf.