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Analysis of techno-economic potential of green ammonia upscaling and export in South America with a focus on Brazil

Summary

Ammonia is a viable storage and transport option for renewable hydrogen, as well as a highly sought after chemical in various industries. Brazil possesses a natural wealth of renewable energy sources, but an overall assessment of its potential regarding renewable ammonia production is missing in literature. This analysis includes various techno-economic aspects, in particular policies and regulations, availability of resources, economic and financial viability including capital and operational costs (CAPEX and OPEX) and Levelized Cost of Ammonia (LCOA), infrastructure and logistics and the market demand. It aims to support informed decisions regarding future investments in the sector and to provide an overview of Brazil's potential in green ammonia production and export.

Keywords: renewable hydrogen; chemical hydrogen storage; hydrogen derivatives; hydrogen economy; hydrogen transportation; renewable ammonia transportation

Field of application for the findings: utilization of green hydrogen

Addressed audience: researchers, academics, or professionals in renewable energies

1. Introduction

Because renewable energy production is inherently connected to the availability of sunlight or wind, the amount of generated electricity fluctuates over time. This often does not match the demand, causing a deficit or oversupply. (The Royal Society 2020) To balance out the fluctuations, an energy storage is necessary. Even though batteries have the lowest loss of energy through conversion rates, the materials needed for their production are hard to obtain and limited in amount. (European commission) Energy storage in chemical form is possible by generating hydrogen through electrolysis. But hydrogen has disadvantages in comparison to conventional fuels, like the physical properties of the molecule with a lower energy density and a very low melting point, making storage more complicated. (Menefee and Schwartz 2024) To avoid these issues is one of the reasons, why another conversion into ammonia, having more convenient physical attributes, is considered. Ammonia is also the second most produced chemical product in the world, being responsible for up to 1.8 percent of the global carbon dioxide emissions. (The Royal Society 2020) Therefore green ammonia should not only be considered as a hydrogen carrier, but also as the desired end product to help decarbonize the chemical industry.

2. Techno-economic analysis

Because of Brazil's natural wealth of renewable energy resources and Germany's interest in future trade relations to meet its own demand, the focus of this study lies on these two countries. Current literature is mainly focused on specific projects linked to non-universal parameters or is giving a global overview. An analysis of the production potential of Brazil is not yet available. To fill this gap, a detailed techno-economic analysis, including policies and regulations, availability of resources, economic and financial viability including capital and operational costs (CAPEX and OPEX) and Levelized Cost of Ammonia (LCOA), infrastructure and logistics and the market demand is conducted. Data and literature will be used to predict the potential for scaling up ammonia production in Brazil and to evaluate export feasibility to Germany, considering transport

options and projected prices. The data is taken from secondary literature, including journal articles, books, publications and regulations from governmental, international and academic institutions and international agencies as well as online sources.

2.1 Policies and regulations

The direction of the Brazilian government can be clearly seen through its strategies towards renewable energy and hydrogen like the Programa Nacional de Hidrogênio (PNH2) and the Combustıvel do Futuro Program. (Ministério de Minas e Energia 2023) There is a special focus on research and development, which demonstrates a legitimate interest in the field. Implementation and trading policies are currently in development through the PNH2. The missing legal framework for green hydrogen production and especially green ammonia production is a clear obstacle for real life investments into the sectors.

The support of the German government regarding not only renewables, but in specific hydrogen and its derivates, appears solid, due to the vast number of regulations already existing, for example the National Hydrogen Strategy. (BMWK 2023) They also include precise action plans for short- and medium-term measures. It is still important to note, that, especially the directly with green ammonia correlating strategies, have been issued very recently. The timeframe since it was implemented is not long enough to verify the feasibility through real life application.

2.2 Availability of resources

The geographical location of Brazil indicates potential for several renewable energy sources. The geographical conditions are often highlighted as favorable in literature and as a starting point of interest in the country. It is also notable that the vast coastline of the country enables easy access to the sea for energy generation and for transport. The availability of resources in Brazil is classified as exceptionally well during the analysis and will most likely not pose a risk for the implementation of a green ammonia industry in the country.

2.3 Economic and financial viability

There is little literature available, that calculates the LCOA with a universal applicable method. Most of them include a multitude of application specific parameters, for example a salt cavern being used as a storage or a heavy reliance on the grid for electricity supply. Some of the authors do not specify how the variability of the power supply is included in their estimations and some subsidies the LCOA by selling other produce of the process, like excess electricity or hydrogen. Nevertheless, the analysis concluded that predictions are already close to a competitive range and some of them can already compete with higher price locations, like Europe.

2.4 Infrastructure and logistics

The transport of ammonia is already highly established worldwide due to its significant role in the agricultural economy. For example, ammonia pipelines including the safety standards and regulations are already in use. They are especially preferable over long distances and for large quantities. (Menefee and Schwartz 2024, p. 2) For distribution over short to medium distances trucking is considered a useful option, especially as the infrastructure already exists and ammonia can be used as a direct fuel. (Salmon and Bañares-Alcántara 2021, p. 2817) In regards of distributing the ammonia after production the Brazil's vast coastline and its multiple ports precedents the transport via shipping considering long distances. (Bisognin Garlet et al. 2024, p. 563)

2.5 Market demand

Brazil cannot supply its demand by itself, while Germany exported more than it imported. This indicates a solid domestic production and participation in trade for Germany. Brazil on the other hand is dependent on imports to meet its ammonia demand. Assessments for the future predict a shift in demand, especially in Europe, which results in higher imports and a possible export market for Brazil.

2.6 Upscaling

This chapter focuses on the study called “Wind and solar hydrogen for the potential production of ammonia in the state of Ceara - Brazil” , in which the data of the solar radiation and the wind average were used to map the entire state of Ceara. (Esteves et al. 2015) It concluded a very high potential for green ammonia production in the state. Future assessments can use the methodology of this study and apply it onto other states by using the respective wind and solar data.

2.7 Export possibilities

A rough estimation of the production capacity of Brazil was made based on the potential production results of the study in Chapter 2.6. Brazil could not only supply their own demand with ease; they can also supply a multitude of other countries. This even applies, if the most conservative estimate is assumed.

3. Conclusion

The analysis concluded, that the Brazilian government is solidifying their interest in green ammonia, but the legal framework is still insufficient for investors. Calculations of green ammonia production costs in Brazil are already close to competitiveness with the current prices on the market. The national infrastructure is not sufficient for transportation at this point. International trade can be conducted via shipping by utilizing existing ports. The demand for ammonia is high and expected to rise in the predictable future, with a focus on the renewable production route. Brazil's production potential is very high and can additionally supply other countries demands. To implement an international ammonia economy, the stakeholders wish for a clear political stance by the government. Strengthening the partnership between Brazil and Germany could be further achieved through joint investments in research and development.

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