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Mini Review

A Project Proposal for Brazil: Low-Carbon Hydrogen Potential from Sucrenergetic Sector for the Sustainable Aviation Fuel Production

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Abstract

In 2022, Brazil's aviation sector faced a fuel imbalance, consuming 6 billion liters of jet fuel while producing around 4.9 billion, resulting in an import exceeding 20%. Besides, the aviation industry seeks to reduce emissions to achieve net-zero by 2050. To address environmental concerns and jet fuel demand, Sustainable Aviation Fuel (SAF) plays a crucial role. Current technology enables the production of SAF from a variety of biomass. Low-carbon hydrogen is crucial for producing SAF, but currently, over 96% of hydrogen is derived from fossil fuels. Alternative technologies for low-carbon hydrogen production include electrolysis, steam reforming of biomethane, and biomass gasification. In this context, considering the low-carbon hydrogen necessity for SAF production in Brazil, this research seeks to estimate the production technical potential from the sucrenergetic sector studying different routes. Water electrolysis and steam reforming of biomethane and ethanol at the national level will be studied. Residues, such as vinasse and filter cake, will be used for biomethane production, and the excess electricity from burning bagasse will be used in the water electrolysis. This research aims to provide a database and georeferenced maps of the hydrogen potential available from the sucrenergetic sector for use in SAF production in Brazil.

Introduction

The aviation industry aimed for net-zero carbon emissions by 2050, given that in 2019, 46.8 million flights emitted 2% of global carbon (914 million tons). With projected passenger numbers hitting 7.2 billion by 2035 [1], urgent measures are vital for sustainability. Sustainable Aviation Fuel (SAF) offers a safe alternative, currently blended up to 50% with kerosene, with plans for 100% SAF in the future [2]. Large-scale SAF production faces challenges due to securing high-quality feedstocks, particularly as land use changes can have significant environmental impacts. Hydrogen, essential for SAF production, needs sustainable expansion, considering over 96% is currently derived from fossil fuels. Brazil is set to join CORSIA from 2027, targeting a 1.5 million-ton CO₂ reduction by 2030, aligning with ambitious goals outlined in the Nationally Determined Contribution (NDC) as a signatory to the Paris Agreement. The aviation sector in Brazil aims for carbon-neutral growth, necessitating a reduction of 8.3 to 12.4 million tons of CO₂ by 2030 (Klein et al., 2018).

Justificative

The Brazilian jet fuel consumption by the aviation sector, in 2022, reached 6 billion liters per year, while its production was around 4.9 billion, generating the need for import of more than 20% [3]. The aviation sector consumption represents 2% of global energy-related CO₂ emissions, which reached almost 800 Mt CO₂ worldwide. The worldwide emissions are expected to proliferate and surpass their 2019 level (1,000 Mt CO₂) around 2025 [4]. Sustainable Aviation Fuel (SAF) is vital for powering aircraft with cleaner energy, and SAF could contribute between 53 and 71% of the emissions reductions needed to achieve net zero by 2050 [2].

Currently, SAF is blended with conventional fuel, but the industry aims to have commercial flights powered by 100% SAF in the future [2]. In addition, the Net Zero Emissions by 2050 (NZE) Scenario predicts the commercialization of hydrogen aircraft by 2035, and it is estimated that aviation might need between 412 and 556 billion liters of SAF per year by 2050 to achieve net-zero 2050 goal [5]. Current technology enables the production of SAF from various feedstocks such as waste oils and fats, municipal solid waste, cellulosic waste, cover crops, and non-biogenic alternative fuels. It can be blended with conventional fuel, certified to the same standard, and used without requiring aircraft or engine modifications. These "drop-in fuels" can seamlessly integrate into airport fueling systems and aircraft (Forsberg, 2009).

The primary difficulty in converting biomass into drop-in biofuels is eliminating oxygen, which may lead to compatibility issues with existing petroleum infrastructure and introducing impurities. The deoxygenation process involves three essential chemical reduction methods: Hydrodeoxygenation (HDO), Decarboxylation (DCO), and decarbonylation (resulting in CO and H₂O). Hydrodeoxygenation involves hydrogen oxidation in biomass, removing oxygen as water (H₂O) and potentially enhancing hydrocarbon yields [6]. Nevertheless, the cost and sustainability of imported hydrogen must be considered. Although hydrogen is crucial for producing SAF, over 96% is currently derived from fossil fuels, primarily Steam Reforming of Methane (SMR). Thus, developing and expanding sustainable hydrogen production methods is necessary to decrease life cycle emissions [7]. Alternative low-carbon technologies for hydrogen production include electrolysis, steam reforming of biomethane, and biomass gasification.



Brazil holds promising potential for jet biofuel production, as identified by the geospatial database SAFmaps developed by the University of Campinas (Unicamp), Boeing-Embraer, Roundtable on Sustainable Biomaterials Association (RSBA), and Agroicone. The country's diverse feedstocks include eucalyptus/residues, soybean, macaw oil, palm oil, corn, sugarcane/residues, and tallow, with multiple conversion pathways [8]. In the sucroenergetic sector, over 400 biorefineries, in the 2023/24 harvest, produce 637.1 million tons of sugarcane, 27.53 billion liters of ethanol, and 38.77 million tons of sugar. Notably, the industry generates significant residues, such as vinasse and filter cake, rich in organic matter and nutrients. Approximately 10-13 liters of vinasse are produced for every liter of alcohol, while filter cake accounts for 2.5 to 3.5% of crushed sugarcane with high moisture content [9]. These residues are currently used for fertilizing sugarcane fields and producing biogas for electricity or biomethane. Bagasse, another sugarcane residue, is employed in cogeneration systems for thermal and electromechanical energy in mills, with excess electricity sold to the commercial grid [10]. The sugarcane industry has increasingly focused on valorizing these residues to reduce environmental impacts, contribute to the circular economy, and minimize the carbon footprint.

In the previous context and considering the hydrogen necessity for SAF production with low carbon in Brazil, this research seeks to study the routes for obtaining hydrogen: water electrolysis and steam reforming of biomethane and ethanol at the national level, initially from the resources available in the sucroenergetic sector. It is expected to map the potential availability of hydrogen from other feedstocks in the future. This research is in the initial stage, being developed by the Research Group on Bioenergy at the Institute of Energy and Environment at the University of São Paulo (GBIO/IEE/USP) in partnership with the National Institute of Bioethanol Science and Technology (INCT do Bioetanol) and the Research Centre for Greenhouse Gas Innovation (RCGI) [11].

Expected Results

At the end of this research project, it is expected that an in-depth diagnosis of the potential for hydrogen production from the technologies proposed at the national level can be elaborated. It is intended that these technologies can be used in the country satisfactorily for hydrogen production and that it will be possible to contribute significantly to the National Hydrogen Program (PNH2) in Brazil. This project aims to provide a database and georeferenced maps of the hydrogen potential from the sucroenergetic sector for SAF production.

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