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Assessing the current scenario of the Brazilian biojet market

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ABSTRACT

This study reviews the current scenario and the main uncertainties associated with the Brazilian biojet market. It also provides recommendations to mitigate the identified uncertainties. This study will enable the supply chain, research institutions, and policymakers to organize for better strategic action, identify research fields, and the need for R&D investment. As a global contribution, this assessment will share the Brazilian experience with other countries, thereby helping them to build a solid foundation for a new biofuels industry. Based on the evaluation, it is concluded that there are many technological and commercial uncertainties, such as lack of technical dominance in producing alternative feedstocks with higher energy density, lack of laboratory infrastructure for biojet certification, logistical issues, high cost of feedstocks and refining routes, and lack of public-private investment. On the other hand, organizational and social uncertainties are reduced. The following recommendations are made to reduce the uncertainties: greater operational planning between stakeholders and the government, integration with national and international agencies, and improving Brazil's regulations. It is also suggested that the best regional feedstocks, productive routes, and locations for establishing productive facilities should be analyzed based on technical evaluation such as multicriteria analysis. Besides, the study suggests incentives and investments in storage and mixing facilities, and in laboratories that already have infrastructure for certifying aviation fuels.

1. Introduction

Air transport accounts for approximately 2% of global greenhouse gas (GHG) emissions [1], and exponential growth in the sector can increase this share significantly [2–5]. Revenue passenger kilometers (RPKs) increased by 66.8% in ten years (2005–2015), up 7.4% only from 2014 to 2015 [1]. This growth increased the consumption of fossil jet fuel and, thereby, GHG emissions [6–8].

In 2009, the International Civil Aviation Organization (ICAO) adopted the target of achieving carbon neutral growth from 2020 onward and reducing net emissions by 50% by 2050 (compared to the 2005 levels) [9]. In addition, the ICAO approved the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [10], which compensates for any annual increase in international aviation carbon emissions above the 2020 levels.

In Brazil, the growth of jet fuel consumption also raises concerns. Therefore, national commitment to reduce GHG emissions was assumed through the Nationally Determined Contribution (NDC) during the 21st Conference on Climate Change (COP 21). Brazil pledged to reduce its emissions by 37% by 2030 and 43% by 2030 (compared to 2005) [11]. A transition in the use of fossil fuels by renewable energy sources is needed to honor the NDC. In this sense, the use of biojet produced from renewable feedstocks can contribute to achieving these ambitious goals [6,12–16] as these fuels have the potential to reduce emissions by up to 80% during their life cycle [1].

Brazil has already progressed in the use of renewable sources in its energy matrix [17–19]. Renewable sources in the Brazilian energy matrix comprise 42%, which is much higher than 13% of the world average and 9% in the Organization for Economic Cooperation and Development (OECD) countries [19]. Nonetheless, the use of biofuels in aviation is still negligible because they are considered to have low competitiveness with fossil jet fuels [2,13,16,20].

Some renewable energy sources are considered non-competitive with fossil energy fuels [21,22]. However, competitiveness must be observed from the social and environmental dimension and not only from the economic aspect [21,22]. The use of biojet fuels have many potential benefits, such as reducing GHG emissions, generating employment and income, reducing regional disparities, and encouraging research and innovation. Moreover, this new market can create opportunities for the diversification of the energy matrix, for the reduction

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of dependence on fossil jet fuel, and for the development of the national biojet industry. However, certain uncertainties need to be addressed to build a solid foundation for the biojet market in the country.

Studies have also investigated the major challenges of the biojet market in the world. This shows that the difficulties faced by emerging markets are not unique to Brazil. Connelly et al. [23] identified the most impacting actions in the global biojet industry from multicriteria analysis. Moraes et al. [24] pointed out the main challenges for sustainable production of biojet from sugar, starch, oil, lignocelluloses, and wastes. The evaluation was based after conducting workshops with the concerned stakeholders. Hari et al. [25] evaluated the main routes, opportunities, and challenges of the global biojet market based on literature reviews. Gegg et al. [2] studied the key drivers and constraints of the global biojet market based on interviews with stakeholders in Europe and North America. Smith et al. [16] evaluated the main drivers and barriers to the adoption and diffusion of biojet in the US Pacific Northwest region from stakeholder interviews. Kamali et al. [26] evaluated the social and governance issues for biojet supply chains using literature reviews and expert surveys. In the Brazilian context, Cortez et al. [13] identified the main technological, economic, and sustainability barriers of the Brazilian biojet market by holding stakeholder workshops.

To address these challenges, several biojet-related studies have been conducted worldwide. These studies seek to mitigate the challenges associated with feedstocks and routes. Kubátová et al. [27] proposed a new path in the thermal cracking of canola and soybean oils for biojet production. Mupondwa et al. [28] evaluated the techno-economic feasibility of commercial production of biojet from the hydrotreatment of camelina oil. Han and Wang [29] evaluated GHG emissions from ethanol-to-jet and sugar-to-jet, two biofuels produced from a biological route. Gómez-De la Cruz et al. [30] evaluated the economic and environmental dimensions of biojet production from microalgae oil. Tzanetis et al. [31] evaluated the impact of hydrothermal liquefaction reaction conditions on biojet production costs and the performance of GHG emissions. Ganguly et al. [32] made a life cycle assessment of biojet production from residual woody biomass. In Brazil, Klein et al. [33] made a comparative techno-economic evaluation and environmental feasibility study of biojet production from different routes integrated into the Brazilian sugarcane biorefineries. Silva et al. [34] made a technical evaluation of biojet production from the catalytic deoxygenation of macauba oils. Bailis and Baka [35] evaluated GHG emissions and any direct land use changes resulting from the production of biojet from jatropha. De Sousa et al. [36] studied biojet production from hydroprocessing of palm kernel oil.

To guide new studies and strategic investments in the Brazilian biojet market, it is necessary to identify the main uncertainties in the sector, the current market regulatory scenario, and the action plans implemented by stakeholders and the Brazilian government to mitigate these uncertainties. Identifying the current regulatory environment and developing initiatives helps to understand how policymakers and stakeholders are concerned with mitigating the challenges. This also enables to suggest improvements to the current regulatory acts in order to contribute to the biojet market. The identification of actions under progress clarifies how Brazil is attempting to overcome these barriers.

This study elucidates the current biojet regulation scenario in Brazil, identifies the actions taken by the Brazilian government and stakeholders to promote the biojet market in the country, and presents and discusses the technological, commercial, organizational, and social uncertainties associated with this market using the TCOS framework [37–39]. The TCOS framework is an analytical tool based on Technology Futures Analysis (TFA), and is presented in Section 2 (Theoretical Framework). Since the emerging biojet market falls within the definition of innovation [40], the TCOS framework is used as a guideline to evaluate the uncertainties present in this market.

The proposed assessment complements the study by Cortez et al. [13]. The authors [13] evaluated the main techno-economic and sustainability barriers in the Brazilian biojet market, but did not discuss the key initiatives that are underway to promote the production and use of biojet in Brazil. In addition, the authors did not present the current Brazilian regulatory scenario and the organizational aspects of the biojet production technology, which involves the assurance of intellectual protection.

Therefore, evaluating these important aspects will provide a better understanding of the current Brazilian biojet market. This study also proposes strategic recommendations to help advance a sustainable aviation biojet industry in the country. The study will enable supply chains, research institutions, and policymakers to organize for strategic action, identify fields of research, and the need for R&D investments. Besides, this assessment shares the Brazilian experience with other countries, thereby helping them build a solid foundation for a new biofuels industry.

2. Theoretical framework

The market is increasingly competitive and globalized, demanding quality and efficiency of products, services, and processes [41]. As a result, technological innovation has become central to economic development and to government policy [41]. Besides, innovation must be applicable, viable, and should be acceptable to both market and society [42,43]. In this context, Technology Future Analysis (TFA) comprises methodological tools that seek to analyze innovation and its future impact from different perspectives [44]. Therefore, TFA can be applied to assess the uncertainties involved in innovation and the results can be used to support strategic decision making [45].

The TFA methods are grouped into nine families [46–48]:

(1) Creativity Methods - These methods link innovation to creativity [49]. Thus, these methods assume that new products need to have perspicacity to become competitive in an increasingly demanding market. Two methods stand out: brainstorming and Theory of Inventive Problem Solving (TRIZ) [48].
(2) Expert Opinion Focus Groups - This family of methods is based on professionals' experience in relation to a certain subject [50]. By using these tools, it is possible to explore the most interesting futures and key impediments to achieving them, based on experience [48]. It fits into the panels and iterative survey method.
(3) Trend Analysis – These methods are based on the hypothesis that the patterns of the past are maintained in the future. Trend analysis uses techniques to extrapolate the time series into the future [49]. The differential of these methods is the ability to discard inconsistent scenarios from a logical trend assessment [46]. Long wave analysis and precursor analysis are the techniques used in this method.
(4) Monitoring and Intelligence Methods - These methods are based on acquiring information about individual choices [46]. That is, they are data acquisition tools, correlating with the prospective methods [46]. These methods seek to evaluate and interpret a compilation of information, such as scientific research and patents. From this evaluation, monitoring and intelligence methods can be associated with benchmarking in order to propose changes to future planning [48]. Demographics stand out in this family of methods.
(5) Statistical Methods - These methods analyze objective data [46]. They refer to models that seek to identify and measure the effect of one or more independent variables on the future behavior of a dependent variable. Correlation analysis and bibliometrics stands out in this family of methods.
(6) Scenarios - These methods are widely used in contemporary approaches to assist in the assessment of uncertainties involved in business environments [49]. The Field Anomaly Relaxation Method (FAR) is an important method in scenario assessment [48].
(7) Modeling and Simulation - These methods enable the understanding of phenomena from the creation of an artificial medium