Puschnig, Oil Gas Res 2023, 9:3

Oil & Gas Research

Mini Review **Open Access**

Development of Biorefineries for the Production of Sustainable Aviation Fuel from Softwood Residues: Insights from Life Cycle Assessments and Energetic-Exergetic Analyses

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Abstract

Protein extraction and ethanol production from BSG and PKM can be combined in a conceptual biorefinery process. With 8000 production hours per year, the conceptual process is intended for an industrial-scale biorefinery that processes 20 kt DW of BSG and 50 kt DW of PKM. The performance is analyzed techno-economically with the help of the virtual biorefinery [1].

According to the techno-economic analysis, the biorefinery of BSG generates more revenue from protein powder than it does from ethanol when production costs are taken into account. With an internal rate of return of 24%, the BSG biorefinery has a significant economic potential. The protein powder's revenue in the PKM biorefinery is just higher than the costs of production. In any case, the income of the ethanol is a lot higher contrasted with the creation costs. The PKM biorefinery still has a positive internal rate of return of 12% despite the high costs of raw materials [2].

The economic potential of combining the production of a biofuel like ethanol from the remaining biomass with the production of a high-value product like protein powder for food applications was demonstrated by the virtual biorefineries that were presented. The biorefinery is profitable overall because the biorefining of a greater portion of the raw material's biomass into various products generates more revenue for the same amount of raw material.

Keywords: Lignocellulosic biomass; Biofuels; Exergy; Efficiency; Life cycle assessment; Aviation

Introduction

Over the past few decades, aviation has become a more prevalent trend. With the exception of the COVID-19 pandemic in 2020 and 2021, the number of flights around the world increased to 38.9 million in 2019. The aviation industry is anticipated to fully recover by 2024, according to the International Air Transport Association (IATA). Between 2019 and 2040, it is anticipated that the number of passengers traveling by air will rise to 7.8 billion at an annual rate of 3.3%. However, in the future, this will depend on airlines and the steps they take to make flying safe [3].

In 2019, aviation-related carbon emissions accounted for approximately 2.8% of global emissions. Since 2000, emissions have increased annually by 2%. Aviation accounts for 3.7% of carbon emissions in Europe. Around 20 percent of global aviation emissions came from Europe in 2015. In this context, the aviation industry wants to cut CO2 emissions by up to 50 percent from 2005 levels by 2050.

The EU and global levels structure the initiatives affecting the aviation industry's environmental footprint. Emission savings can be achieved through policies like Flightpath 2050, the EU Low Carbon Roadmap, Renewable Energy Targets, the EU ETS, and Biofuel Flightpath 2020 at the European level. Globally, the carbon-neutral growth strategy and the Carbon Offset and Reduction Scheme for International Aviation (CORSIA) are taken into consideration. Biojets would have a positive effect on the adoption of sustainable aviation fuels (SAF), despite the fact that policymakers are still not aware of them.

The renewal of engine technologies that are adaptable to sustainable fuels is the primary factor that will determine whether or not aviation will achieve carbon neutrality by 2050. The utilization of drop-in SAF, hydrogen-powered engine technology, hybrid kerosene, and electric-powered engine technologies, as well as enhanced projects for carbon removal and Air Traffic Management (ATM), constitute the majority of this [4]. When compared to emissions from fossil fuels, SAF emissions are up to 80% lower. The development of a biorefinery value chain that produces SAF and renewable fuels is made easier by current trends in the transportation industry on the road and in aviation [5]. Road transportation is gradually moving toward electrification, either through fuel cell or battery electric vehicles. However, due to the difficulty of electrification in his industry, the aviation industry is likely to demand SAF. However, hybrid and electric aircraft development is ongoing; particularly, because there are no other options, long-haul flights will rely more on SAF. The disposition of networks toward biorefinery offices was surveyed [6].

Materials and Methods

Over the past few decades, aviation has become a more prevalent trend. With the exception of the COVID-19 pandemic in 2020 and 2021, the number of flights around the world increased to 38.9 million in 2019. The aviation industry is anticipated to fully recover by 2024, according to the International Air Transport Association (IATA). Between 2019 and 2040, it is anticipated that the number of passengers traveling by air will rise to 7.8 billion at an annual rate of 3.3%. However, in the future, this will depend on airlines and the steps they take to make flying safe [7].

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Received: 1-Mar-2023, Manuscript No. ogr-23-93303; **Editor assigned:** 4-Mar-2023, PreQC No. ogr-23-93303(PQ); **Reviewed:** 18-Mar-2023, QC No. ogr-23-93303; **Revised:** 25-Mar-2023, Manuscript No. ogr-23-93303(R); **Published:** 31-Mar-2023, DOI: 10.4172/2472-0518.1000291

Citation: Puschnig S (2023) Development of Biorefineries for the Production of Sustainable Aviation Fuel from Softwood Residues: Insights from Life Cycle Assessments and Energetic-Exergetic Analyses. Oil Gas Res 9: 291.

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The renewal of engine technologies that are adaptable to sustainable fuels is the primary factor that will determine whether or not aviation will achieve carbon neutrality by 2050 [9]. The utilization of drop-in SAF, hydrogen-powered engine technology, hybrid kerosene, and electric-powered engine technologies, as well as enhanced projects for carbon removal and Air Traffic Management (ATM), constitute the majority of this. When compared to emissions from fossil fuels, SAF emissions are up to 80% lower. The development of a biorefinery value chain that produces SAF and renewable fuels is made easier by current trends in the transportation industry on the road and in aviation [10]. Road transportation is gradually moving toward electrification, either through fuel cell or battery electric vehicles. However, due to the difficulty of electrification in his industry, the aviation industry is likely to demand SAF. However, hybrid and electric aircraft development is ongoing; Particularly, because there are no other options, long-haul flights will rely more on SAF. The disposition of networks toward biorefinery offices was surveyed [11].

Results and Discussion

GHG mitigation potential

To better comprehend the locations where emissions occur throughout the biorefinery's value chain, LCA was carried out at the level of process units. As a result, the main process unit sections of saw dust (wood residues), transport, wood-to-sugars, fermentation, purification, conversion to SAF, and off-site (auxiliary) were used to calculate and organize emissions. This process unit approach permits an emission hot-spot analysis and provides detailed and significant insights for process development in comparison to an LCA conducted only at the biorefinery level. The assessment bolsters the identification of these process units, whose environmental footprint can be further reduced by increasing efficiency or developing new technology [12].

Primary energy demand

The biorefinery's 1 MJ SAF output was the focus of the PED analysis, which took into account either (i) a SAF allocation or (ii) no allocation at all. Examining just the designated results can prompt misdirecting translations. There are three types of PED: total, renewable, and non-renewable.

Biorefinery efficiency analysis

Considering SAF as the primary product and the entire system, including all by-products, a single energetic and exergetic efficiency analysis was carried out. According to the analysis, the energetic and exergetic SAF efficiencies varied slightly between scenarios [13]. The energetic efficiency was 11.7%–14.9%, while the exergetic efficiency was 11%–13.8%. The entire system saw significant improvements in efficiency. The efficiency of the energetic and exergetic systems lies somewhere between 40.4 percent and 54.9 percent, respectively. To improve the biorefinery's overall system efficiency, this demonstrates that all by-products must be utilized in addition to the primary product. The scenarios' energetic and exergetic efficiency evaluation yields comprehensive results [14].

Conclusion

The currently under construction biorefinery may present a promising route for the production of SAF or biofuels. The raw materials are saw dust and other softwood residues. As a result, a 2G biofuel is produced, and unlike 1G biofuels, there are no concerns about food safety. A potential for wood residues of 41,864 kt/a was estimated for EU-28. Valueable sugars (C6 and C5) are extracted from cellulose and hemicellulose and treated in subsequent processes through energy-intensive processes like pretreatment and enzymatic hydrolysis. By oligomerization and hydrogenation, the hydrolysate is eventually transformed into the chemical intermediate bio-isobutene, which is then fermented into SAF. Utilization is made of SAF value chain by-products. In the asphalt industry, lignin is used in place of bitumen, which reduces production's impact on the environment. It is also used in end-use applications like phenol-formaldehyde resins and bioplastics filler. Ethanol is made from the wood-to-sugar unit's C5 sugars that have been separated. Fertilizer that replaces potassium and calcium is made from the fermentation sludge. The created microbial biomass contains significant supplements that can be utilized as creature feed and in this way as a substitute for imported soybeans.

Acknowledgement

None

Conflict of Interest

None

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