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Creation of a Hybrid Biorefinery for the Manufacture of Jet Biofuel

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Abstract

It has been determined that jet biofuel (JBF) is an essential solution for reducing the aviation industry's carbon footprint. Since planes depend entirely on fluid powers, the improvement of pathways that creates JBF as a significant item has become pivotal. Over the past ten years, seven pathways for producing JBF have been developed and approved. Each of these pathways can handle a particular kind of biomass. However, there is still a problem with feedstocks' availability, sustainability, and feasibility to meet the growing demand for jet fuel. As a result, this study offers a comprehensive strategy for developing a cutting-edge hybrid biorefinery that can process a variety of biomass feedstocks, including energy crops (such as Jatropha energy crop), dry biomass (such as municipal solid waste), and wet biomass (such as livestock manure). A Qatari industrial-scale biorefinery was modeled in Aspen Plus with a pre-defined biomass geospatial distribution and the country's best biorefinery location in mind [1]. Hydroprocessing, Fischer-Tropsch, gasification, dry-reforming, and hydrothermal liquefaction were all incorporated into the hybrid system. While biomass ideal inclusion streams were assessed utilizing an expectation model. In addition, extensive integrations of materials, heat, water, and power were carried out in order to maximize JBF production, reduce its impact on the environment, and maintain cost control. 328, 94, and 44 million liters of JBF, gasoline, and diesel were produced by the system, respectively. Delivered JBF was described and found to agree with every single worldwide norm. Considering a maximum allowable jet biofuel blend of 50%, the generated JBF can power approximately one third of Qatar's fleet and replace 15.3% of the country's jet fuel requirements. In comparison to the current market price of conventional Jet-A fuel, the proposed model achieved a minimum selling price of JBF of 0.43 dollars per kilogram (2019). Additionally, the model's environmental analysis revealed that JBF reduced greenhouse gas emissions by 41% over the course of its lifecycle in comparison to Jet-A fuel [2].

Keywords: Jet biofuel; Hybrid biorefinery; Waste-to-Energy; QatarAspen PlusGIS

Introduction

As demand for energy resources rises and fossil fuel prices fluctuate as a result of global political and economic instability, biomass-to-energy technologies account for less than 70% of global gross renewable energy.

Technologies that can handle various kinds of biomass have come a long way in recent decades; pyrolysis and gasification of dry solid biomass, hydrothermal liquefaction (HTL) to liquify wet biomass, incineration for a direct conversion of biomass into energy, and anaerobic digestion to process putrescibles. While well-established technologies like the hydroprocess and the Fischer-Tropsch (FT) process have transformed intermediate products of these processes, such as syngas, biomethane, bioethanol, and biocrude, into liquid transportation fuels. However, in order to avoid requiring costly modifications to turbine jet engines, the only viable alternative fuel that should currently be considered for the aviation industry is a high-quality drop-in liquid fuel with a significant energy density [3, 4].

In light of this, the International Civil Aviation Organization (ICAO) launched a program in 2016 called "Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)" with the goal of compensating for all emissions that go above the baseline for 2019–2020. Where jet biofuel (JBF) has been deemed the most important alternative for the international aviation industry's ambitious plan. While the primary method for achieving CORSIA objectives has been identified as the cultivation of carbon-neutral energy crops [5, 6].

JBF, also known as aviation bio-kerosene, is a group of paraffins that adhere to the majority of the properties of fossil jet fuel, fall within the hydrocarbon length range of (C8-C16), and correspond to the boiling point range of kerosene. It can be made from a wide variety of renewable biomass, such as sugar, lignocellulosic waste, and oil triglycerides.

Methodology

Hybrid biorefinery design

The hybrid biorefinery in Qatar for the production of JBF from multiple biomass sources was designed using Aspen Plus (V.10). The majority of the system's components are two ASTM-certified JBF pathways: the hydroprocessing of fatty substances, and biomass gasification, trailed by FT [7]. In addition, a dry-reforming stage using CO2 was used to increase JBF yield and reduce the refinery's carbon footprint, and a third route includes HTL and upgrading. The system was designed to accommodate almost all types of local biomass in a single biorefinery, including whole-fruit Jatropha curcas and dry and wet solid wastes; while the process is in jet mode to get the most out of the JBF yield [8].

The system was modeled with steady-state reactions and isothermal system assumptions in mind. The thermodynamic properties were estimated using the non-random two-liquid model (NRTL) and the Redlich-Kwong-Soave (RK-SOAVE) models. The system utilized a variety of integration and intensification strategies, including waste valorisation, carbon capture and storage, and integration of power, water, and heat. The model allows for extensive utilization of by products

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within the system, resulting in green liquid fuels only in increased quantities. Additionally, power and water are produced on-site, making the system utility-self-sufficient. The accompanying subsections detail out the plan of each sub-framework [9].

Economic assessment

A thorough monetary plausibility of a huge scope half breed biorefinery alongside Jatropha curcas development in Qatar was assessed from "well to wheel". With a 2 km width and a 2 km length, the Jatropha-Greenbelt (GB) that was previously presented as part of this study was taken into consideration. The greenbelt was divided into 56 zones for management and cost estimation purposes (zone area: 2x4 kilometers), and each zone had eight sections (section area: 1x1 km), with 25 Jatropha fields in each section (field area: 4 ha). Each section contained a diesel generator, a key water storage tank, and a pumping station with a direct TSE supply from the source, while each zone had one fruit storage [10]. Additionally, a distinct water dripping system was installed in each field. Taking into account local prices and land status, key data for the economics of Jatropha cultivation were adapted from previous experiences in Taiwan and India. Due to the harsh structure of Qatar's lands, 25% of contingencies were considered for the plantation and land setup stage.

Fertilization, irrigation, machinery, and labor costs accounted for the majority of the cultivation project's operational costs. Suriharn et al's requirements for fertilizers were adapted for Jatropha's optimal growth and yield, whereas Neto et al. were used to adapt the machineries' energy requirements as well as Tongpun et al. In addition, it was believed that equipment maintenance accounted for 2% of the equipment's annual cost [11].

Lifecycle assessment

The hybrid biorefinery in Qatar's production of jet biofuel underwent a comprehensive lifecycle assessment (LCA) from the cradle to the grave. The LCA's impact categories were carbon, water, energy, and land footprints, which were measured in terms of gCO2-e, m3 of water, MJ of energy, and cm2 of land per MJ (JBF), respectively. The Intergovernmental Panel on Climate Change (IPCC)'s fifth assessment report on climate change was used in the evaluation of the carbon footprint [101]. The cultivation of jatropha, the transportation of biomass, the construction, processing, and use of fuel at the end of a refinery were all included in the scope of the analysis. Based on the cumulative energy content of the various products and by products, the various environmental footprints were distributed using energy [12].

Results and Discussion

A hybrid biorefinery's optimal location in Qatar has been determined using an ArcGIS approach, and the developed predictive model has been used to select its potential feedstocks. The findings are described in detail in the sections that follow.

Process outputs

The hybrid biorefinery's intensive stream integration maximized liquid fuel yields, with neither char nor gas products produced but instead utilized by the system. As shown in Figure, 5, the framework created around 466 million liters of fluid energizes each year, with stream fuel possessing 72 %, trailed by gas and diesel at 18 % and 10 %, individually. Around 24 % of the biomass feed (dry and debris free) has been changed over into fly fuel, which mirrors a great proficiency of the framework in stream fuel-mode activity.

Considering a maximum allowable jet biofuel blend of 50%, the generated jet biofuel can power approximately one third of Qatar's fleet and replace 15.3% of its conventional Jet-A. In addition, as depicted in Figure, the generated bio-gasoline and green diesel have the potential to replace 4 percent and 5 percent of conventional transportation fuels for the year 2016. 6 [13]. The year 2016 was chosen to reflect Qatar's typical fuel consumption prior to the Gulf crisis of 2017 and COVID-19. By which, the previously mentioned occasions have influenced the example of fuel utilization, particularly for air travel.

Characteristics of jet biofuel

The JBF produced by the proposed hybrid biorefinery was characterized to ensure compliance with international standards (ASTM D7566). According to Table 5, the generated JBF met all of the chemical and physical requirements set by Jet-A. The inclusion of the HTL stream into the refinery provided the fuel with the missing aromatics components, which is important to prevent tank leakage (with maximum JBF aromatics of 25 vol%). This is in contrast to the standalone Jatropha biorefinery that was presented in the author's previous study. The fuel's density has also been improved to fall within the acceptable range as a result [14]. Despite its slightly elevated flash point, the fuel still met the requirements. Storage and handling of fuels with higher flash points are safer, especially in hot areas like Qatar.

Performance in the economy Table 6 provides a summary of the project's finances. The total cost of the investment was $1,332,038,426, which was expected to be recouped in approximately 11 years with a 10.8% return on investment. The sub-CAPEX expected for the biorefinery foundation was higher than that of the Jatropha field, as opposed to OPEX, which was higher for the development part of the venture because of the labor necessity. The annual OPEX was estimated to total $215,696,583 [15].

Conclusion

A novel design for a hybrid biorefinery to produce jet biofuel from a variety of Qatari biomass resources has been proposed in this study. The model was created in Aspen Plus, which included hydroprocessing, Fischer-Tropsch, reforming, gasification, and hydrothermal liquefaction, all of which are key advanced and mostly well-established processes. To maximize JBF production and minimize solid and gaseous by-products, extensive stream integration was carried out. Additionally, the system was outfitted with units for carbon capture, power generation, and wastewater treatment to improve its environmental performance. The system produced 328, 94, and 44 million liters of JBF, gasoline, and diesel, which could replace 15.3%, 4%, and 6% of Qatar's conventional fuels, respectively. Delivered JBF was described and found to agree with every single worldwide norm. It is thought that the fuel can be used directly as a drop-in fuel without the need for any additives, blending with other fuel, or altering the jet engines that are already in use.

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