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Sustainable Aviation Fuel: The Future of Aviation

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Abstract

Sustainable Aviation Fuel, sometimes known as SAF, is a biofuel that has been certified as Jet Fuel (Jet-A/A1). At present, only 0.1% of all flights, rely on Sustainable Aviation Fuel derived from feedstocks. Sustainable Aviation Fuel is exclusively produced from various renewable sources. Sustainable Aviation Fuel significantly reduces carbon emissions by an average of 80%. The aviation industry is responsible for 2.5% of the total global carbon dioxide (CO_2) emissions. However, it has thus far made a contribution of approximately 4% to the phenomenon of global warming. Although flying is considered a highly carbon-intensive activity, it only accounts for a mere 2.5% of global carbon emissions.

1. Production of Sustainable Aviation Fuels:

- The principal source for the manufacturing of Sustainable Aviation Fuel (SAF) is the hydrotreated esters and fatty acids (HEFA) pathway, which is favored due to its lower capital costs and the availability of feedstocks with energy density comparable to fossil fuels. The main raw materials for this conversion method consist of waste fats, oils, and greases, which can be treated in conventional hydrocracker units. Nevertheless, the availability of present feedstocks is restricted, which requires the urgent implementation of large-scale sustainable feedstock mobilization for commercial purposes. Algae, camelina, pennycress, tallow tree, and carinata are being tested or authorized as feedstocks for high energy crops, known as HEFA. It is anticipated that the production of SAF from alcohol to jet (AtJ), Municipal Solid Waste (MSW), and second generation (2G) biomass will experience a substantial increase after the year 2030. The first-generation alcohol to jet (AtJ) technology involves the conversion of sweet or starchy biomass, such as sugarcane and corn grain, into ethanol or other alcohols by fermentation. These alcohols can then be transported by shipping or piping and then turned into fuel. These feedstocks are readily cultivable and can be conveniently transported by train. However, it is imperative to convert sugarcane into ethanol within a strict timeframe of 48 hours after harvesting. In order to minimize logistical expenses, mitigate carbon emissions in transportation, and optimize infrastructure use, it is advantageous for ethanol facilities to be located in close proximity to feedstock producing mills and refineries.
- Currently, in certain locations, especially in the Americas, feedstock like as corn and sugarcane are commercially utilized for the generation of gasoline. Due to high demand from sectors like ground fuel and petrochemicals, there is a scarcity of feedstock for aviation. As a result, no commercial SK facilities are currently utilizing the AtJ production pathway. Timing is a crucial aspect to take into account when considering the AtJ pathway. As ground fuels become more electrified, there will be more availability of feedstock for the aviation industry. This, in turn, will enable the manufacture of sustainable aviation fuel (SAF) through this pathway.
- The carbon intensity reduction is relatively weaker in comparison to competing technologies. Therefore, the installation of solutions like carbon capture and storage technology will be crucial for

effectively reducing greenhouse gas emissions (GHG) with this technology. Additional alternatives to consider involve substituting biogas for natural gas in mills and changing agricultural machinery to operate on biofuels instead of fossil fuels.

- The Fischer-Tropsch (FT) process for converting municipal solid waste (MSW) into usable products has established paths for production. Currently, producers are prioritizing technological advancements aimed at mitigating the considerable initial investment required for this process. The primary environmental benefit of producing synthetic alternative fuels (SAF) from municipal solid waste (MSW) using Fischer-Tropsch (FT) technology is in the prevention of landfill decomposition of the trash. Within the European Union, bp is actively promoting the recognition of recycled carbon fuels derived from the non-organic fraction of municipal solid waste (MSW) as Sustainable Aviation Fuels (SAF) under the EU's forthcoming SAF blending mandate.
- The development of technologies for converting second-generation biomass is still in its early stages. However, effort is being made in collaboration with ASTM to explore the use of pyrolysis for biomass conversion, both as a standalone process and as a co-processing method in refineries. After a pathway is approved, it is necessary to develop demonstration plants in order to validate the technology on a large scale before it can be used commercially.
- Power-to-liquid (PtL) technology, also known as eSAF, is considered a highly promising method for creating sustainable aviation fuel (SAF) in the future. Electricity derived from renewable sources, such as solar, hydro, or wind, is employed in the process of electrolysis to separate hydrogen from water. The green hydrogen is initially utilized to convert carbon dioxide, sourced from the air, biogenic, or industrial sources, into carbon monoxide. The primary obstacle facing eSAF technology at present is its high cost, as well as the limited availability and high cost of renewable energy and carbon dioxide. These issues need to be resolved in order to satisfy the demands of the market.

2. Potential of Sustainable Aviation Fuel (SAF) :

- The SAF can seamlessly integrate into pre-existing infrastructure and aircraft. It has the capacity to achieve a carbon reduction of up to 80% during its lifecycle, in comparison to the conventional jet fuel it replaces.
- The SAF (Sustainable Aviation Fuel) will play a crucial part in achieving the aviation industry's carbon reduction targets. Nevertheless, it is imperative that we utilize all available choices to effectively minimize carbon emissions.
- There are multiple overarching possibilities for reducing carbon emissions in the business, including enhancing aircraft design for greater efficiency, implementing more intelligent operational practices, and advancing technology such as electrification.

3. Reducing the reliance on fossil fuels:

- The airline industry's dependence on fossil fuels exposes it to many changes, including volatility in the price of crude oil and issues related to supply and demand.
- SAF (Sustainable Aviation Fuel) is an appealing option because it can be produced in regions where fossil fuels cannot be extracted.
- This allows for a wider range of geographic sources and provides a certain level of energy security for states and airlines. Potentially, a variety of sustainable aviation fuel (SAF) feedstocks can be cultivated

or gathered under varying environmental circumstances worldwide, to meet the demands of the aviation sector.

- Similar to the petroleum business, it is probable that there will be significant manufacturers of SAF feedstock, which will be delivered to the necessary locations. Additionally, it is expected that smaller local supply chains will be created.

4. Economic Boon:

- The airline business often incurs the highest operational expenses from fuel. The volatile nature of crude oil prices poses significant challenges in forecasting and allocating long-term operating expenses. SAF (Sustainable Aviation Fuel) has the potential to address this issue by enabling global manufacturing and utilizing many feedstocks.
- This diversification reduces airlines' vulnerability to fluctuations in fuel costs that arise from relying on a single energy source. SAF can also yield economic advantages in regions with extensive marginal or unproductive land for food cultivation, but are suited for cultivating SAF crops, or have alternative sources of feedstock like municipal trash.
- Several of these nations are emerging economies that may considerably profit from the establishment of a new sector, such as the manufacturing of sustainable aviation fuel, without adversely affecting their local food production capacity.
- SAF has the potential to promote job creation and enhance waste management practices, particularly in underdeveloped nations where garbage often poses environmental challenges.
- Implementing Sustainable Aviation Fuel (SAF) could offer a mutually advantageous approach to managing waste, while concurrently mitigating carbon dioxide (CO2) emissions in the aviation industry.

5. Ways to increase the production of SAF:

- The aviation sector is genuinely dedicated to decreasing carbon emissions, but, governments must also establish appropriate legislation to expedite the expansion of Sustainable Aviation Fuel (SAF). In order to enhance production, it is crucial to have a stable and predictable policy framework that minimizes investment uncertainties. Additionally, there should be a strong emphasis on advancing research, development, and implementation of more efficient production methods and sustainable raw materials.
- At an individual level, certain airlines are currently offering passengers and corporate clients the choice to financially support the use of Sustainable Aviation Fuel (SAF) in order to decrease the emissions linked to their tickets. We consider these initiatives to be highly commendable.
- The primary factor that will lead to increased acceptance and implementation of SAF is the reduction in associated expenses. In the long run, it will be necessary to invest in cutting-edge technology to process raw materials more efficiently on a larger scale. Additionally, investment is needed to develop sustainable and expandable possibilities for raw materials. Nevertheless, in the immediate term, temporary assistance from governments and other stakeholders in the form of policy incentives is required. This assistance must be included into a comprehensive and enduring structure that instills confidence in investors, enabling them to make the investments necessary for expanding supply.

6. The ECLIF3 Study:

- The European Union intends to implement a compulsory requirement of 2% sustainable aviation fuel (SAF) by 2025, with the goal of reaching a minimum of 70% SAF by 2050. Utilizing SAF can decrease the overall carbon dioxide emissions during the whole life cycle and have a beneficial effect on particle emissions and contrail characteristics.
- The ECLIF3 aircraft campaign focused on studying the exhaust and contrail properties of an Airbus A350-941 aircraft that was equipped with Rolls-Royce Trent XWB-84 engines.
- The study discovered that while utilizing 100% HEFA-SPK fuel, there was a significant decrease in non-volatile particle number emissions of around 41% compared to the reference Jet A-1 fuel, specifically at low cruise engine power levels.
- The non-volatile particles in HEFA-SPK were somewhat smaller in size compared to those in Jet A-1. The study also demonstrated the influence of fuel mix, engine power settings, and the utilization of HEFA-SPK on particle emissions.

7. Applications of SAF:

- The United airline's objective is to achieve complete environmental sustainability by decreasing its greenhouse gas emissions by 2050. They are dedicated to reducing their environmental footprint and are striving for a more sustainable future in the aviation industry. The utilization of sustainable aviation fuel (SAF) is being employed to diminish lifecycle emissions, decrease carbon intensity by 50%, and attain net zero emissions by 2050. They are the pioneering airline to incorporate Sustainable Aviation Fuel (SAF) into their normal operations and have established a startup fund with a strong focus on sustainability.
- Air France-KLM, Total, Groupe ADP, and Airbus have accomplished the inaugural long-distance flight utilizing Sustainable Aviation Fuel (SAF) manufactured in France. The flight utilized a biofuel derived from waste and residue obtained from the circular economy. Total, a company, generated the Sustainable Aviation Fuel (SAF) from used cooking oil at its La Mède biorefinery in southern France and its Oudalle factory in Le Havre. The utilization of a 16% blend on this flight resulted in the prevention of the release of 20 tons of carbon dioxide (CO2) into the atmosphere. The objective of this partnership is to reduce carbon emissions in air transportation and establish a sustainable aviation fuel (SAF) supply chain in France. This initiative will enable France to take a leading role in driving innovation in the transition towards cleaner energy and a more sustainable environment. The Airbus A350 utilized for the flight exhibits a fuel efficiency that is 25% superior to its predecessor, while all ground support equipment employed by Air France operates exclusively on electric power.
- Emirates has begun using sustainable aviation fuel (SAF) as part of its fuel agreement with Neste on flights departing from Singapore Changi Airport. The airline has integrated 3.3 million litres of blended SAF into the fuelling system of Changi airport over the last few weeks. Neste provides SAF from sustainably sourced and 100% renewable waste, as well as residue raw materials, including used cooking oil and animal fat waste. The SAF used in this agreement can safely be used in existing Emirates aircraft and airport fuelling infrastructure and reduces lifecycle carbon emissions by up to 80% compared to conventional jet fuel. Emirates' multi-faceted SAF strategy focuses on exploring opportunities to use SAF operationally, sharing emissions reductions with corporate customers or freight forwarders, cooperating on longer-term SAF projects with reputable partners, and supporting SAF ventures in the UAE. The airline is also a member of the Solent Cluster in the UK, an initiative

focused on low carbon investments, and a founding participant of the UAE research consortium Air-CRAFT.

8. Infrastructure:

- Commercial airports possess comprehensive fuel management infrastructure, which encompasses gasoline tanks, pipelines, fuel pumps, flow meters, filters, and safety systems. Aircraft fuel is transported to fuel tanks using either hydrant systems or fuel trucks. Jet-A fuel is frequently utilized in the aviation industry, while SAF is exclusively carried through pipelines when it satisfies the ASTM specifications. Neste business carries Sustainable Aviation Fuel (SAF) to the West Coast, where it is mixed with traditional jet fuel. San Francisco International Airport receives refined fuel through a network of pipelines.
- World Energy employs distinct supply schedules for Jet-A fuel and Sustainable Aviation Fuel (SAF). Jet-A fuel is transported to the production site via trucks, where it is mixed with SAF (Sustainable Aviation Fuel), and thereafter transported to Los Angeles International Airport by truck. The delivery timetable is contingent upon variables such as the proximity of the airport to residential areas, the accessibility of Jet-A gasoline in the vicinity, and the limited quantity of fuel.
- There are two alternatives for SAF blending in the terminal: either storing them in distinct tanks that comply with ASTM D7655 criteria, or blending them with Jet-A fuel, which necessitates meticulous monitoring to determine the precise quantity of SAF added. SAF adheres to the same standards as regular jet fuel, thereby eliminating any compatibility difficulties that may arise from its use alongside conventional jet fuel.

9. SAF Producers:

- The primary manufacturers of SAF are World Energy and Neste. World Energy commenced production in 2016 in Paramount, California, and provides supplies to United Airlines and KLM. Neste, the largest producer of Sustainable Aviation Fuel (SAF) and renewable fuel in the world, supplies SAF to San Francisco International Airport. The SAF is produced at a refinery plant located in Rotterdam, Netherlands. Neste MY Renewable Jet Fuel TM is derived from sustainable waste and residual substances, such as recycled cooking oil or animal fats. Renewable items are manufactured in Finland, Netherlands, and Singapore.
- Fulcrum Bioenergy manufactures environmentally-friendly and affordable transportation fuel derived from domestic waste. Their objective is to transform 175 thousand tons of municipal solid waste into around 11 million gallons of synthetic crude, which will then be refined into sustainable aviation fuel, renewable diesel, and renewable gasoline (Fulcrum FuelTM). Fulcrum has formed strategic partnerships with BP, United Airlines, Cathay Pacific, Japan Airlines, World Fuel Services, and Marubeni.
- Red Rock Biofuels utilizes waste woody biomass as a raw material and intends to transform 130,000 tons of wood waste into 15 million gallons of Sustainable Aviation Fuel (SAF) and renewable diesel. The quantity of airports dispensing sustainable aviation fuel is steadily growing, either on a continuous basis or in periodic batches.

Summary:

Sustainable Aviation Fuel (SAF) is a type of biofuel that, on average, decreases carbon emissions by 80%. At present, SAF, which is made from renewable feedstocks, is only used in 0.1% of flights. The primary means of producing SAF is by the hydrotreated esters and fatty acids (HEFA) pathway, which involves the utilization of waste fats, oils, and greases. Nevertheless, the supply of feedstocks is restricted, requiring the mobilization of sustainable feedstocks on a wide scale. Anticipated growth in SAF production is projected to occur post-2030, as researchers investigate the potential of first-generation alcohol to jet (AtJ) technology, Fischer-Tropsch (FT) process, and power-to-liquid (PtL) technology. The SAF has the capability to be seamlessly incorporated into existing infrastructure and aircraft, resulting in a significant reduction of up to 80% in carbon emissions during its entire lifespan. Nevertheless, the obstacles encompass exorbitant expenses and restricted accessibility of sustainable energy and carbon dioxide. The aviation industry's dependence on fossil fuels makes it vulnerable to swings in crude oil prices and supply and demand challenges. Sustainable Aviation Fuel (SAF) provides an alternative source of energy that may be produced in areas where fossil fuels cannot be mined. This ensures energy security for both states and airlines. SAF can also tackle operating expenditures, stimulate employment generation, and improve waste management methodologies. In order to enhance output, governments should implement consistent policies, prioritize research and development, and offer temporary policy incentives. According to the ECLIF3 study conducted by the European Union, the utilization of SAF can effectively reduce carbon dioxide emissions and enhance particle emissions. United Airlines is committed to attaining environmental sustainability by decreasing greenhouse gas emissions by the year 2050. Air France-KLM, Total, Groupe ADP, and Airbus have successfully conducted the first long-distance flight utilizing Sustainable Aviation Fuel (SAF) from France, making them the pioneering airline to integrate SAF into their operations. Emirates has recently started utilizing Sustainable Aviation Fuel (SAF) in accordance with its fuel arrangement with Neste for flights departing from Singapore Changi Airport. Commercial airports possess a complete fuel management infrastructure, which includes the transportation of Sustainable Aviation Fuel (SAF) through pipes that fulfill the criteria set by the American Society for Testing and Materials (ASTM). Producers of sustainable aviation fuel (SAF) include World Energy and Neste. Fulcrum Bioenergy specializes in converting municipal solid waste into SAF, while Red Rock Biofuels focuses on converting wood waste into SAF. The number of airports utilizing Sustainable Aviation Fuel (SAF) is increasing.

Nomenclature:
1. IATA: International Air Transport Association
2. ASTM: American Society for testing and Materials
3. GHG: Greenhouse Gas
4. SAF: Sustainable Aviation Fuel

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