# Solid waste biomass as a potential feedstock for sustainable aviation fuel production

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**Abstract**
Aviation is one of the fastest growing transportation sectors that supports global economy and aviation fuels demand is going to be increased over the next years. Anthropogenic greenhouse gases emissions from aviation industry account approximately 2% of the total. In order to mitigate climate change policies have been put in place to achieve early and deep emissions reduction by 2030 and 2050, respectively. Towards this direction, utilization of sustainable aviation fuels (SAF) provide the most viable solution. Waste-biomass feedstocks such as municipal solid waste and lignocellulosic materials can contribute in near future to scale up the production of biojet fuels. Although, currently the majority of SAF is produced through fully commercialized hydrotreating of vegetable oils (HVO) route, research results indicate that there is a potential for solid waste residues to be converted in sustainable "drop-in" aviation fuels over alternative technologies such as pyrolysis, gasification-FT synthesis and alcohol-to-jet (ATJ) pathway. However, more research is needed as most of these technologies are still under demonstration scale.

**Introduction**
Decarbonization of aviation sector is an ongoing challenge and SAF are going to play a key role in order to achieve GHG emissions reduction in the next decades [1]. Due to high safety requirements and stringent emission standards, drop-in SAF with excellent performance can be only used in current aircraft engines [2]. Biojet fuels composition depends on biomass feedstock and refining processes. Since first generation (1G) biomass mainly includes edible crops and plants which rises food versus fuel controversies, second generation (2G) biomass consisting of non-edible crops and residues comprises a more attractive feedstock [3]. Biomass based waste materials include such municipal solid waste (MSW), agricultural and forestry residues [4].

To date, eight pathways for biojet fuels production have been certified by American Society for Testing and Materials (ASTM) D7566 standard allowing maximum a blend limit of 50% of biojet fuels with fossil aviation fuels [5]. Among them, hydroprocessed esters and fatty acids (HEFA) pathway that was certified in 2011 is based on a mature technology for converting oleochemical feedstocks to biojet fuels [6]. Moreover, Gasification-Fischer-Tropsch (FT) pathway that was certified in 2009 and involves catalytic syngas conversion over several catalysts such as iron or cobalt presents high potential for biojet fuels production derived from biomass waste materials [7, 8]. Also, alcohol-to-jet (ATJ) route that was certified in 2018 for ethanol and in 2016 for isobutanol, as alcohol intermediates, could be used in near future for starch-rich or lignocellulose-based biomass feedstocks. Challenges still involve feedstock availability, pretreatment cost and carbon intensity of produced biojet fuels [5, 8]. Biomass catalytic pyrolysis and hydrothermal liquefaction (HTL) have also been studied and in case of waste materials biojet fuels can be produced via bio-oil upgrading over heterogeneous and homogenous catalysts. However, thermochemical methods present limitations basically associated with high operational and pretreatment costs and still remain at pilot to demonstration scale [9, 10].

Food waste and plastic waste could serve as alternative feedstocks for SAF production. Instead of landfilling or burning, utilization of the organic fraction of these type of wastes could be used for biojet fuels production through several methods including pyrolysis, gasification, co-pyrolysis and HTL [11-13]. Moreover, catalytic hydrogenetion of waste cooking oils (WCOs) could be a promising method for biojet fuels production [14, 15]. Agricultural wastes also can be utilized for biofuels production through thermochemical conversion methods as they are generated in large amounts. Woody biomass-based biojet fuels can reduce global warming by 78% compared to their fossil fuels counterparts [16, 17]

**Methods**
The method that was used for this study was the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [18]. Searching databases were Scopus and Google Scholar and research took place between February and March 2022. Research criteria included the keywords: "solid AND waste AND aviation AND biofuels" between the years 2016 and 2022. From 1162 papers that were identified, 240 were further investigated after duplicates removal and screening. After the exclusion of 153 papers due to not fulfilling the research purpose, finally 87 papers were included in the review study.

**Results and discussion**

Utilization of waste-biomass based materials present high potential for biojet fuels production in order to meet the growing fuel demand needs in the future. Research results clearly indicated that obtained biofuels from these biomass sources can be used as blends with conventional jet fuels in aircraft engines with little or no modifications. Waste feedstocks such as WCOs, food and plastic waste as well as agricultural residues can be converted to biojet fuels through several waste-to-energy technologies [19, 20]. Catalytic hydrogenation or HEFA pathway is a promising conversion method for WCOs to biojet fuels. Chen et al. [21] investigated WCO conversion through hydroprocessing over Pd/C catalyst performed producing high concentrations of C15-C18 normal alkanes. Moreover, Xu et al. [22] used a two-step catalytic conversion and hydrogenation of waste triglycerides into aviation range hydrocarbons with a maximum yield of 60%. Main components of produced biojet fuel where found compatible to conventional aviation fuels. Hydrothermal catalytic cracking over zinc aluminate ($ZnAl_2O_4$) catalyst was performed by Araby et al. [23], where aviation carbon hydrocarbons ($C_8$-$C_{16}$) were produced by WCO reaching a yield of 49% and meeting ASTM standards. Asiedu et al. [24] investigated catalytic transfer hydrogenation of WCO over a fixed bed of granular activated carbon with biojet fuel fraction yield of approximately 52%. In addition, Shah et al. [25] studied catalytic pyrolysis hydrogenation over NiMo catalyst of agricultural wastes (Eucalyptus sawdust) and waste frying oil. Obtained upgraded bio-oil exhibited similar properties with conventional aviation fuels.

In regards to plastic waste valorization, several thermal processes can be applied to convert plastics into biofuels that have unlimited applications in airline industry, as well as in transportation and power generation industries [26, 27]. Among them, catalytic pyrolysis is a promising conversion method. Improvement of bio-oil quality under the most economic viable way is an ongoing concern for researchers [12]. Sarker et al. [28]., investigated the production of aviation range hydrocarbons from polystyrene (PS) waste plastics through thermal degradation and fractional distillation. Biofuel yield reached 23% having a carbon range $C_6$-$C_{16}$. Moreover, Ali et al. [29], proposed pyrolysis of waste plastic feedstock over graphite as catalyst and an output of 80% of biojet fuel was observed having similar chemical properties with conventional aviation hydrocarbons. In addition, according to Liu et al. [30], catalytic hydrocracking of polyethylene (PE) over bifunctional catalyst Pt/Al/MCM-48 produced biojet fuel range hydrocarbons with a yield of 85.9%. Co-gasification of plastic and biomass for biojet fuel production was modeled by López-Fernández et al. [31]. Hydrocarbons obtained by FT synthesis were further upgraded and the mass distribution for biojet fuel was found 41.08% meeting ASTM requirements in a blend of 50% with conventional jet fuel with a significant decrease of $CO_2$ emissions. Additionally, Park et al. [32] were investigated pyrolysis and co-pyrolysis of waste masks with food waste. Biojet fuel yield reached 18.4%, however, co-feeding with food waste increased char, hydrogen and pyrolysis gas production Recently, depolymerization of high-density polyethylene (HDPE) waste to biojet fuels through liquid phase hydrogenolysis over Ru/C catalyst was investigated by Jia et al. [33], where under mild reaction conditions and using n-hexane as solvent the highest yield of biojet fuel was 60.8 wt %.

**Conclusions**

Sustainable aviation fuels adoption is of great significance for aviation sector in order to mitigate climate change over next years and to meet the fast growing fuels demand needs. According to literature findings, HEFA pathway for oleochemical feedstocks will continue to dominate in near future. Thermochemical methods for lignocellulose-based waste materials present also high potential to contribute in global biojet fuel production. Solid waste materials could be promising alternative feedstocks for biofuels production including aviation range hydrocarbons; however, more research and development are required as most of these advanced technologies are not yet commercialized. Ongoing challenges are totally associated with feedstock availability, production costs and governments' support and incentives.

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