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

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Presentation Outline

- Introduction
- Purpose
- Research method
- Results and discussion
- Conclusions

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Introduction

Aviation sector:

- Contributes approximately 2% of total CO_2 emissions.

- **Sustainable Aviation Fuels (SAF)** will play a key role for early reductions of CO_2 emissions by 2030 and deeper reductions by 2050.

- **Non-edible** feedstocks comprise favorable choice and include municipal solid waste (MSW) and forestry residues.

- The **price** of biojet fuel depends on feedstock cost, availability, conventional jet fuels' price volatility and commercialization feasibility of production technologies.

Introduction

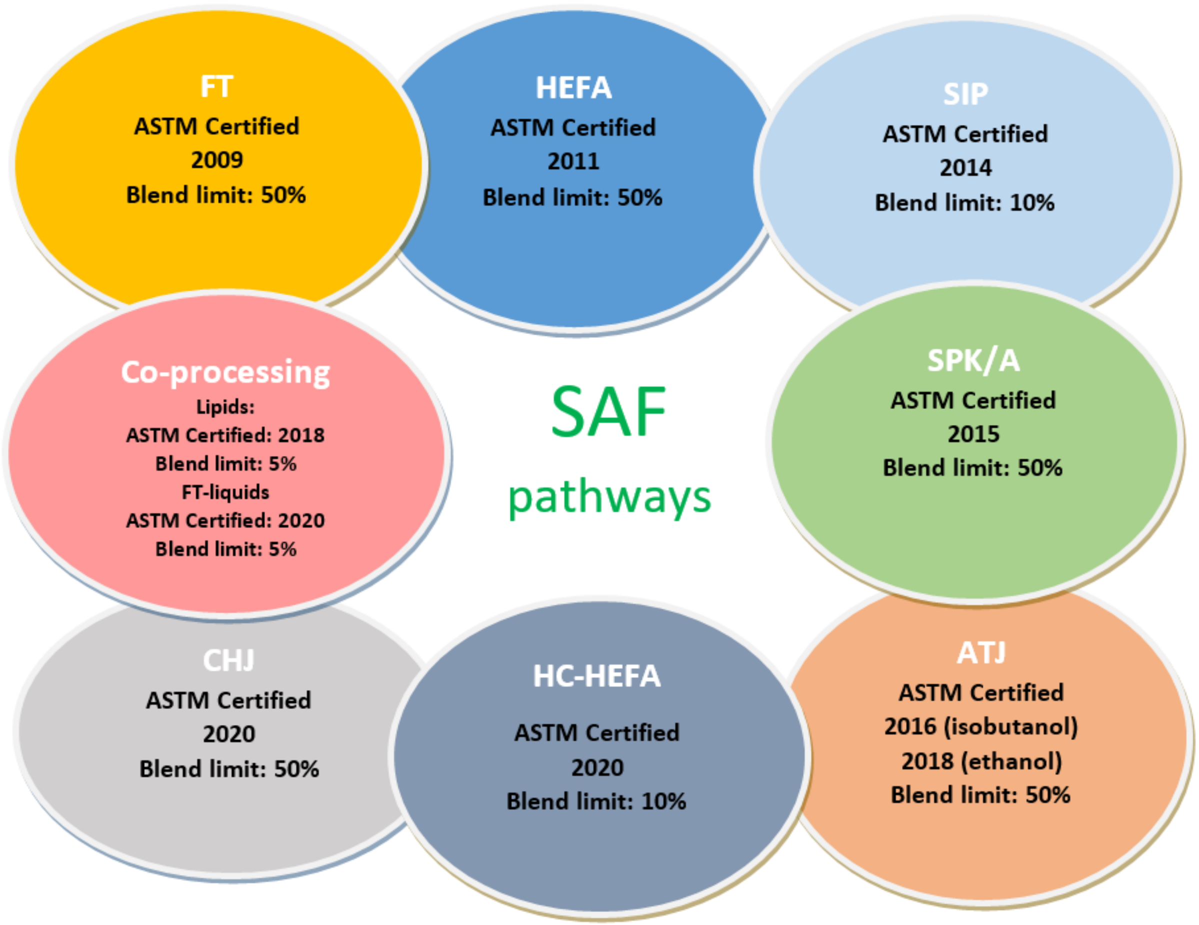

Figure 1. ASTM approved pathways for SAF production
(IRENA, Reaching Zero with Renweables: Biojet fuels, 2021).

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Purpose

- Investigation of the potential of SAF production from waste materials.
- Waste materials: MSW including food waste and waste cooking oils, plastic waste as well as agricultural and forestry residues.
- Current conversion technologies based on recent literature data.

Research method

- Systematic review by using PRISMA analysis.

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Results

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Table 1. Various waste materials as feedstock for biofuel and biojet fuel production [3-10].

Feedstock	Conversion method	Reaction conditions	Obtained biofuels	Highlights
Food waste/WCO				
Chicken fat oil from chicken waste	**Hydroprocessing**	Hydroprocessing reactor Temperature: 400 °C Pressure: 6.07 MPa H_2/oil molar ratio: 450 v/v Catalyst: DHC-8 commercial Hydroisomerization reactor Pressure: 8.1 MPa Temperature: 480 °C Catalyst: Pt/amorphous SiO_2-Al_2O_3	**Biojet** **Yield: 47.46%**	Thermally coupled distillation columns resulted in 22% of CO_2 emissions and 33% of utilities cost reduction.
Hydrotreated paraffins from WCO	**Hydrocracking/ Hydro-isomerization**	Temperature: 380 °C Pressure: 4 MPa H_2/alkane molar ratio: 13.6 Catalyst: NiAg/SAPO-11 (5 g) Time: 2.5 h	**Biojet** **Yield: 54%** Selectivity: 67% Main components: C_{15}-C_{18} alkanes	Relative poor cold flow properties. Catalyst performed excellent isomerization and medium cracking properties.
Waste oil with high viscosity	**Catalytic cracking and hydrogenation/aromatization**	Catalytic cracking Base catalyst: Na_2CO_3 (100 g) Amount of feedstock: 2 kg Temperature increasing rate: 10°C/min Column temperature: 280 °C Hydrogenation Catalyst: Ni/ZSM-5	**Biojet** **Yield: up to 60%** Biodiesel Yield: 15-30%	Two-step conversion is efficient for low quality triglycerides. Diesel fraction can also be obtained by adjusting operating parameters.

Results

Table 1. Various waste materials as feedstock for biofuel and biojet fuel production [3-11].

Feedstock	Conversion method	Reaction conditions	Obtained biofuels	Highlights
Food waste/WCO				
Waste cooking oil	**Catalytic cracking and aromatization and hydrogenation**	*Catalytic cracking* Base catalyst: Na_2CO_3 (5 wt. %) Amount of feedstock: 1500 g Pyrolysis temperature: 350 – 450 °C *Aromatization* 80 g distilled aviation fuel Catalyst: HZSM-5 (5 wt. %) Temperature: 350 °C Time: 6 h *Hydrogenation* Catalyst: Pd/AC (5 wt. %)	*Liquid hydrocarbons* Yield: 76 ± 1.0% ***Biojet*** **Yield: 29.5 ± 1.9 %**	Biojet fuel presented **similar properties** to fossil based aviation fuels. The freezing point was found -48 °C indicating good fluidity in low temperature. During catalytic cracking biodiesel can also be produced.
Food waste, sewage sludge, blend of food waste and fats	**Hydrothermal liquefaction and hydrotreatment**	*Hydrotreatment of bio-crude* Catalysts: sulfided NiMo and CoMo	***Biojet*** **Yield: 65%** Average carbon distribution: 11.2	Carbon content increased >11%. Oxygen content of bio-crude reduced >90% **Drawback**: High nitrogen content after upgrading.
Agricultural wastes and waste frying oil	**Pyrolysis and catalytic hydrogenation**	Amount of feedstock: 300 g Heating rate: 20 °C min^{-1} Temperature: 850 °C Catalyst: NiMo (200 g) 1Hydrogen pumping rate: 10 mL min^{-1} Hydrogenation temperature: 450 °C	***Pyrolysis oil*** Yield: 54% *Hydrogenated bio-oil* aliphatic hydrocarbons: 21% aromatics: 25% cyclic hydrocarbons: 16%	After hydrogenation, more than 60% of oxygenates and 12% of nitrogen compounds were removed. Hydrogenated bio-oil exhibited **similar properties** with conventional jet fuel.

Results

Table 1. Various waste materials as feedstock for biofuel and biojet fuel production [3-12].

Feedstock	Conversion method	Reaction conditions	Obtained biofuels	Highlights
Plastic/Lignocellulosic wastes				
Polystyrene (PS) waste	**Thermal liquefaction and fractional distillation**	Amount of feedstock: 750 mg Temperature: 100 – 400 °C	***Biojet*** **Yield: 23%** Main components C_6 to C_{16}	Aromatic and aliphatic compounds in produced fuels. Further **modification** is required for commercial use.
Waste plastics (PE,PP,PS,PET)	**Catalytic pyrolysis and fractional distillation**	Catalyst: graphite Temperature: 350 °C – 450 °C	***Biojet*** **Yield: 80%**	Chemical properties of biojet fuel were **comparable** to aviation jet fuel.
Waste plastic LDPE	**Catalytic hydrocracking**	Catalyst: Pt/Al/MCM-48 (1 wt. %) Hydrogen pressure: 4 MPa Temperature: 573 K Time: 4 h	Main components C_9–C_{15} ***Biojet*** **Yield: 85.9%**	Catalytic performance was not reduced after **four cycles**.
Plastic waste (PE,PP) and agricultural biomass	**Co-gasification-FT synthesis and upgrading**	Overall process included 6 units.	*Biofuels yield* 13.06% ***Biojet*** **Mass distribution: 41.8%** Output: 1697.45 kg/h	Plastic addition to biomass **improved** the volatility of mixture. Biojet fuel emissions: 20.14 g CO_2eq/MJ Minimum selling price: 1.37 €/L. Heat exchanger network reduced total cost of GFT synthesis.

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Discussion

- **Utilization of biomass waste materials** as feedstocks for SAF production is of great significance for future demands as well as for cost minimization and environmental protection.

- **To date**, the majority of aviation biofuels is produced from **oleochemical/lipid feedstocks** such as vegetable oils and bio-wastes.

- Obtained biofuels have the **potential** to be considered as drop-in jet fuels and used as blends with conventional jet fuels in aircraft engines without any further modification.

- Catalytic hydrogenation or **HEFA pathway** is a promising method for WCOs conversion into SAF, nonetheless pretreatment, including filtration and cleaning are still required.

Discussion

- **Agricultural wastes** are still **underutilized** as an alternative feedstock for biofuels and value added chemicals production.

- **Lignocellulosic residues** could contribute to sustainable biojet fuel production.

- **Thermal processes** can be used to convert plastics into hydrocarbon fuels which have unlimited applications in airline industries, as well as in transportation and power generation industries.

- **Co-pyrolysis** of plastic waste and biomass-based materials serves as a **promising way** to convert wastes into value added products and biofuels with high product yields and quality.

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Conclusions

- **HEFA pathway** for oleochemical feedstocks will continue to dominate in near future.
- **Waste-biomass feedstocks** can contribute to scale up the production of biojet fuels.
- **Thermochemical methods** for lignocellulose-based waste materials present also high potential to contribute in global biojet fuel production.
- **Ongoing challenges** for SAF production through advanced methods are closely related to feedstock availability, high production cost and lack of policy support.

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Indicative Bibliography

1. Abrantes, I., et al., Sustainable aviation fuels and imminent technologies - CO2 emissions evolution towards 2050. Journal of Cleaner Production, 2021. 313.
2. IRENA, *Reaching Zero with Renweables: Biojet fuels*, 2021, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Sep/IRENA_Reaching_zero_2020.pdf. (Accessed 10/02/2022)
3. Moreno-Gómez, A.L., et al., *Modelling, simulation and intensification of the hydroprocessing of chicken fat to produce renewable aviation fuel.* Chemical Engineering and Processing - Process Intensification, 2021. **159**.
4. Chen, R.-X. and W.-C. Wang, The production of renewable aviation fuel from waste cooking oil. Part I: Bio-alkane conversion through hydro-processing of oil. Renewable Energy, 2019. 135: p. 819-835.
5. Chen, Y.-K., C.-H. Hsieh, and W.-C. Wang, The production of renewable aviation fuel from waste cooking oil. Part II: Catalytic hydro-cracking/isomerization of hydro-processed alkanes into jet fuel range products. Renewable Energy, 2020. 157: p. 731-740.
6. Li, F., et al., *Catalytic cracking of triglycerides with a base catalyst and modification of pyrolytic oils for production of aviation fuels.* Sustainable Energy & Fuels, 2018. **2**(6): p. 1206-1215.
7. Cronin, D.J., et al., *Sustainable Aviation Fuel from Hydrothermal Liquefaction of Wet Wastes.* Energies, 2022. **15**(4).
8. Shah, Z., et al., *Preparation of jet engine range fuel from biomass pyrolysis oil through hydrogenation and its comparison with aviation kerosene.* International Journal of Green Energy, 2019. **16**(4): p. 350-360.
9. Xu, J., et al., Integrated catalytic conversion of waste triglycerides to liquid hydrocarbons for aviation biofuels. Journal of Cleaner Production, 2019. 222: p. 784-792.
10. Ali, Z., et al., Jet fuel produced from waste plastic with graphite as a catalyst. Materials Today: Proceedings, 2021.
11. Liu, Y., Hydrocracking of Polyethylene to Jet Fuel Range Hydrocarbons over Bifunctional Catalysts Containing Pt- and Al-Modified MCM-48. Reactions, 2020. 1(2): p. 195-209.
12. López-Fernández, A., et al., Design and Pinch Analysis of a GFT Process for Production of Biojet Fuel from Biomass and Plastics. Energies, 2021. 14(19).
13. Panoutsou, C., et al., Advanced biofuels to decarbonise European transport by 2030: Markets, challenges, and policies that impact their successful market uptake. Energy Strategy Reviews, 2021. 34: p. 100633.

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