24/03/2025

Municipal Solid Waste to Sustainable Aviation Fuel

A Houston, Texas Case Study

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I. Introduction

The aviation industry accounts for nearly 10% of global transport-related CO_2 emissions as of 2023, and this percentage is expected to grow due to the sector's strict regulatory environment and few low-carbon alternatives. [1] A recent study by the International Energy Agency found that Sustainable Aviation Fuel is the most promising near-term pathway to net zero emissions by 2050, with hydrogen and electric airplanes only playing a role on regional and short-haul flights. [2] As of 2024, SAF only comprises 0.53% of global jet fuel usage, but the International Air Transport Association has identified SAF uptake as the means for 65% reduction in aviation emissions by 2050. [3] Thus, to achieve net-zero goals, the aviation industry must rapidly scale up SAF production in a way that is both environmentally sustainable and economically feasible.

II. Context

Sustainable Aviation Fuel (SAF) can be produced through eight approved methods under ASTM D7566. [3] Hydroprocessed Esters and Fatty Acids (HEFA) is the only form of SAF that is commercially produced at scale in 2025, with a Technological Readiness Level (TRL) of 9. [6] However, HEFA alone will not be sufficient to meet 2030 global demand, according to the National Renewable Energy Laboratory's SAF State-of-Industry report. [6] There are several promising alternatives to HEFA, chief among which are the Gasification Fischer Tropsch (GFT) process, the Alcohol-to-Jet (ATJ) method, and the Power-to-Liquid approach. GFT SAF uses gasified cellulosic biomass or organic waste feedstock to produce syngas, which is then chemically converted to synthetic kerosene via the Fischer Tropsch process. The ATJ pathway utilises alcoholic feedstocks which undergo a series of reactions including dehydration, oligomerization, and hydrogenation to yield jet fuel. The Power-to-Liquid approach uses captured CO_2 and renewable hydrogen to synthesise jet fuel.

This paper will focus on the Fischer Tropsch (FT) process with Municipal Solid Waste (MSW) as a feedstock. This technology is approaching commercialisation, with a TRL of 7-8. [5] In this process, Municipal Solid Waste is first sorted and dried before the portion with a high carbon content is partially combusted at high temperatures to produce syngas. The syngas (a mixture of hydrogen and carbon monoxide) is then purified before entering the Fischer Tropsch synthesizer to create straight-chain hydrocarbons. Finally, these hydrocarbons are refined into SAF through an isomerization and cracking process. [13] The resulting fuel, known as FT-SPK (Fischer Tropsch Synthetic Parrafin Kerosene), has the advantage of lower lifecycle emissions than HEFA or ATJ fuels, and lower prices than the synthetic Power-to-Liquid approach (Figure 1). Using municipal waste as feedstock has additional advantages of availability in high concentrations, limited land-use conflict, and low (or negative) feedstock costs. Amidst the growing demand for SAF and the increasing trends in population and urbanization, a symbiotic Waste-to-SAF scheme could become economically viable.

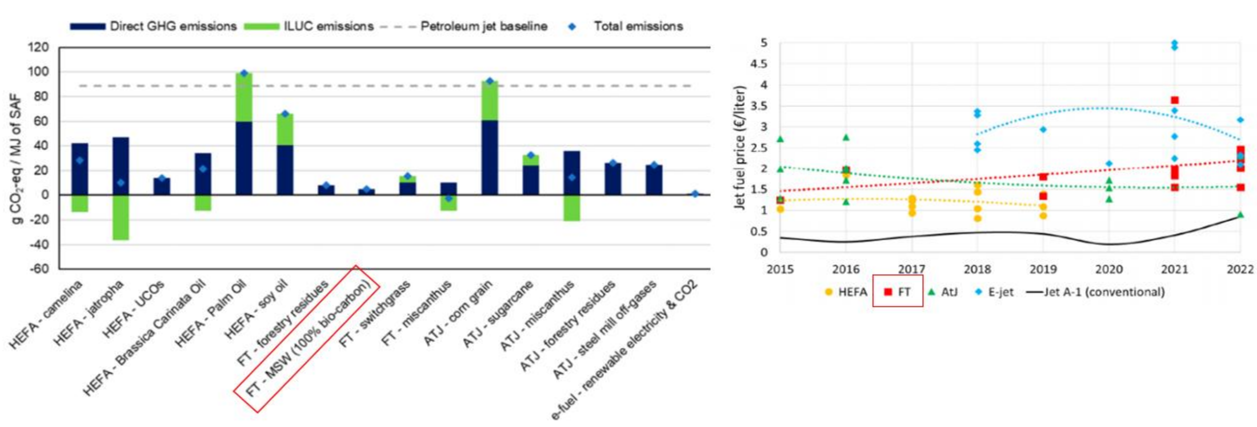

Figure 1: Lifecycle Emissions and Cost Comparison of SAF Production by Method. Detsios, 2023 [5]

III. Mass and Energy Balance

A 2023 study by Seiple et al predicts that the US could cost-effectively produce up to 5.44billion gallons of SAF per year from MSW, which would account for 25% of total U.S. jet fuel demand. After reviewing multiple feasibility studies, Houston Texas was chosen as an optimal location for a Waste-to-SAF pilot plant due to its ample waste supply, aging landfills, and proximity to airports, rail, and industrial clusters. The McCarty Road Landfill northeast of Houston receives 1.5 to 2 million tons of MSW annually at a fee of $26.50 per ton. [7] The Republic Services-owned landfill has only 9 years of capacity left and has burned off its methane byproducts until recently. In 2021, Republic Services in partnership with Ameresco began to export biomethane (RNG) from the landfill to gas distributors. Instead of ending this mature revenue stream, a hybrid solution is proposed with the co-production of RNG and SAF. If a mere 15% of MSW were to be diverted from the landfill to a new waste-to-SAF facility (dubbed the McCarty Road SAF Plant), this would still be the largest operational SAF plant of its kind. It would also extend the McCarty Road landfill's lifespan by an estimated 19 months. Assuming a throughput yield of 14% [4], this would result in nearly 40,000 tons of SAF production per year.

The Capital Expense (CAPEX) of a Fischer Tropsch waste-to-SAF plant is driven mainly by the bioconversion or gasification processing infrastructure. [13] Table 2 shows a compendium of Capital Expenses for similar waste-to-biofuel plants in the last 10 years, both real and conceptual. The CAPEX for each plant was then scaled to account for inflation and plant size in order to predict the McCarty Road SAF Plant's upfront cost, which was found to be approximately $270 million (see Appendix I for the full calculation).

Plant	Year Comissioned	Technology	Capacity (gge/day)	CAPEX (MM$)	Status	Scaled CAPEX
Enerkem Alberta CN	2016	MSW to Methanol	27,397	100-120	Closed 2024	$171,000,000
Red Rock Biofuels OR	-	Woody Biomass to SAF	41,096	356	Halted Work 2023	$328,000,000
Fulcrum BioEnergy NV	2022	MSW to Renewable Diesel	30,137	180	Closed 2024	$200,000,000
Velocys UK	Concept	MSW to SAF	54,795	438	-	$339,000,000
WA State University, Tanzil et al	Concept	Woody Biomass to SAF	43,430	342	-	$305,000,000
UT Tyler, Shahriar et al	Concept	MSW to Renewable Diesel	164,384	685	-	$275,000,000
McCarty Rd SAF Plant	**Concept**	**GFT waste to SAF**	**35,890**	**270**	-	**$270,000,000**

Table 2: Comparison of GFT Facility CAPEX and Scale

High CAPEX and low TRL increase the investment risk and the cost of borrowing, as similar ventures have shown. The most successful waste-to-fuel plants to date (Enerkem Alberta and Fulcrum Bioenergy) both prematurely halted operations due to unforeseen losses and low SAF yields. [9], [10] Fulcrum was plagued by nitric acid corrosion issues and tar buildup during gasification, while Enerkem Alberta suffered from construction delays and disappointing fuel production rates. [9], [10] Additionally, Red Rock Biofuels halted work on a MSW to SAF plant in 2023 after spending approximately $356 million in capital and interest. It has since sold the plant to NEXT Renewable Fuels, which will pivot towards RNG and hydrogen production. [11] This highlights the need to incorporate substantial contingencies to mitigate technical and programmatic risks of such projects. Another factor to consider is plant scale, and balancing the conflicting interests of low capital expenditure (CAPEX) and competitive per-unit fuel prices.

IV. Policy Interventions

Several policy mechanisms exist to incentivise SAF usage in the United States. The Inflation Reduction Act offers a base tax credit of $1.25 per gallon of SAF with over 50% lifecycle emissions reductions. Additionally, the Fueling Aviation's Sustainable Transition (FAST) program offers grants of up to $50million for qualifying SAF projects. [8] These benefits could compound with the US federal RIN credits, which typically subsidise a D3 fuel such as GTF SAF by between $0.74 and $2.32 per gallon. [4]

The economic feasibility of the McCarty Road SAF Plant was assessed for three different policy scenarios: a maximum subsidy scenario (with a $50million FAST grant plus RIN and tax credits), a realistic subsidy scenario (just RIN and tax credits), and an unsubsidised scenario. All but the fully unsubsidised scenario appear to have financial viability, as seen in Figure 3.

V. Results

The proposed McCarty Road SAF facility could yield a Min Fuel Sell Price (MFSP) of as low as $4.86 per gallon, with the key assumptions outlined in Table 4. A competitive SAF price of $6/gallon with a D3 RIN Credit of $1.50/gallon would result in a payback period of 11-25 years, depending on the level of subsidy. This preliminary analysis assumes a construction time of 4 years, a constant SAF market price, and uninterrupted subsidies— negative changes to any of these conditions could result in a negative Net Present Value (NPV).

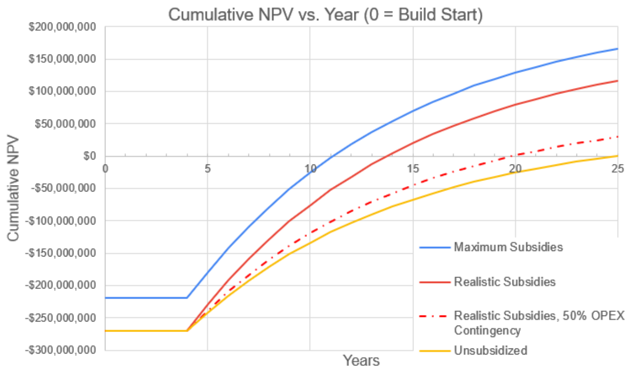

Figure 3: Cumulative NPV over Time by Subsidy Scheme

CAPEX	$270,000,000
CAPEX Contingency	10%
Discount Rate	10%
Build TIme	4
Project Life	20
SAF Production (t/y)	39,900
SAF Revenue	$78,492,000
Waste Fees	$7,500,000
RIN Dredits Revenue	$19,623,000
OPEX (electricity)	$2,476,000
OPEX (water)	$159,000
OPEX (labor + maintenance)	$34,000,000
OPEX contingency	$3,663,500

Table 4: Key Financial Metrics and Assumptions

VI. Conclusions

The conversion of Municipal Solid Waste to Sustainable Aviation Fuel via the McCarty Road SAF Plant helps to augment Houston's limited landfill capacity while providing Houston airport with nearly 40,000 tons of SAF per year. This project shows reasonable financial viability with RIN subsidies and tax credits, but it carries notable risks, including a lengthy construction period, substantial capital expenditure, and limited SAF yield per unit of waste. New waste-to-fuel endeavors should build on past lessons learned to optimally supply the growing demand for clean aviation fuels. In the future, Carbon Capture could be implemented to reduce the fuel's carbon footprint while creating an additional revenue stream.

VII. References

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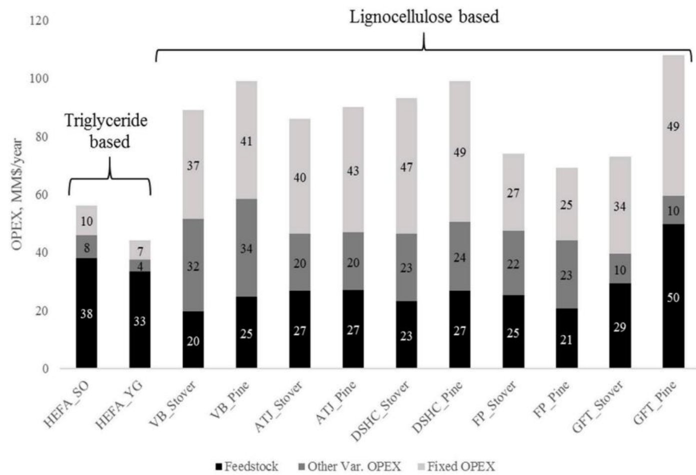
VIII. Appendix

A. CAPEX scaling methodology: The following equation was used to scale Capital Cost (C) from Plant Capacity (V) per Seiple et al, 2023.

$$C/C_{ref} = (V/V_{ref})\text{^}0.6 * (\text{Inflation Factor})$$

B. OPEX scaling methodology: The OPEX was determined by scaling the per gallon gasoline equivalent (GGE) utility usage from Seiple at al and cross referencing with Houston, TX average industrial utility rates. The fixed OPEX was derived from a similar scale plant outlined in Tanzil et al, 2023. [12]



Tanzil et al, 2023 [12]

C. Min Fuel Sel Cost in $/gallon was calculated using the equation below, where "Io" represents the initial CAPEX of 270million, "At" is the yearly cash flows, "i" is the discount rate, and Mt is the yearly production of SAF in gallons.

$$\text{MFSP} = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}}$$

Full Table of Assumptions for Cost Analysis:

Tons MSW/Gal SAF	0.0212
Tons SAF/Gal SAF	0.00305
Tons SAF/tons MSW	0.1439
% yield	14.3868
$/Gal, RIN credit	1.5
$/Gal, SAF sell cost	6
Yearly tons MSW	300000
Yearly tons SAF	39900
CAPEX	$270,000,000
CAPEX Contingency	0.1
Discount Rate	0.1
TX electricity price ($/kWh)	0.15
TX water price ($/ton)	1.5
Build TIme	4
Project Life	20
SAF Revenue	$78,492,000
Waste Fees	$7,500,000
RIN Dredits Revenue	$19,623,000
OPEX (electricity)	$2,476,000
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