Business Implementation Study on the Use of Sustainable Aviation Fuels In Ghana

June 2026

This report is funded by the UK Department for Transport and developed using the ICAO ACT-SAF template for business implementation reports on Sustainable Aviation Fuels Version 1

Acknowledgement

ICF would like to express its gratitude to the UK Department for Transport for fully funding this study, and for providing support and guidance throughout its delivery.

ICF are also deeply grateful to the Ghana Civil Aviation Authority (GCAA) for its continued engagement throughout the study. The study would not have been possible without their coordination, insights and hosting of onsite workshops. In particular, ICF would like to thank William Gyamerah Agyare, Manager, Aerodrome Safety and Standards at the GCAA, for his valuable support and engagement.

Finally, ICF would also like to thank all stakeholders who contributed to the study through workshop participation, technical discussions, insightful feedback on the report, and support and warm welcome during site visits. The study would not have been possible without these contributions. A list of many of the stakeholders invited to participate is provided in Appendix A.

Executive summary

Aviation is an important enabler of Ghana's connectivity, trade, tourism, and wider economic development, and jet fuel demand is expected to grow as the sector expands over the coming decades. Building on the ICAO ACT-SAF Feasibility Study for Ghana, this study assesses viable feedstocks and pathways for SAF production. It concludes that the most credible near-term implementation opportunity, among the pathways assessed and excluding existing SAF project announcements, would be a standalone Alcohol-to-Jet (AtJ) facility in the Tema area supplied by decentralised second-generation ethanol from maize residues. The facility would produce approximately 92 kt of SAF per year, alongside renewable diesel and naphtha. Although the Hydroprocessed Esters and Fatty Acids (HEFA) pathway using waste oils has a lower modelled production cost, Ghana's waste lipid resource is uncertain, potentially more attractive for international trade, and may be difficult to aggregate at scale. Maize residue AtJ therefore offers a stronger strategic fit, greater domestic value creation, and a scalable residue-to-fuel platform. Cassava could also become more relevant for medium-term development, particularly if cassava processing expands and residue collection systems become more formalised.

Market analysis and pathway shortlisting

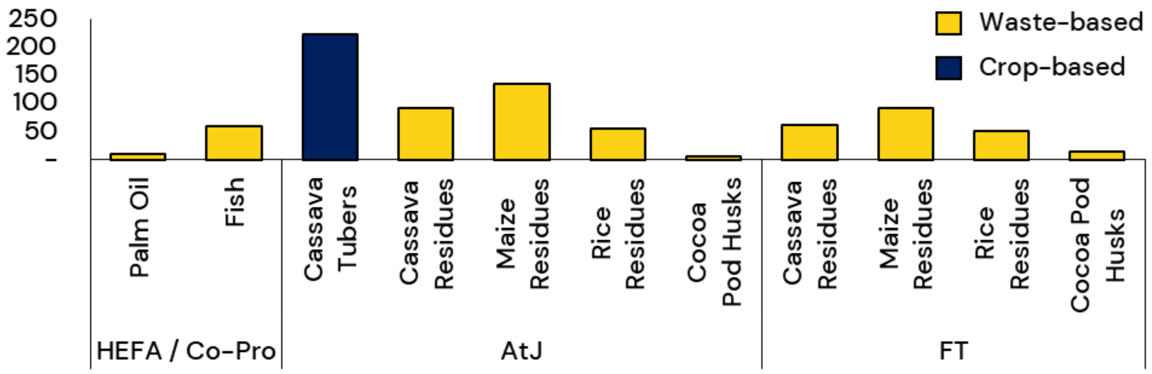
Ghana's aviation sector is expected to grow, increasing the importance of aviation decarbonisation over time. Jet fuel demand is forecast to rise from 233 kt in 2025 to 511 kt in 2055, despite improvements in aircraft technology and operations. This would increase well-to-wake aviation CO_2 emissions from around 0.9 Mt in 2025 to 1.9 Mt in 2055. Ghana's aviation market is also strongly shaped by international carriers, many of which already have SAF targets, offtake agreements, or exposure to SAF mandates in other jurisdictions.

Ghana's wider energy and investment context provides a more supportive backdrop for SAF development than in recent years. Ghana produces crude oil and has established fuel logistics infrastructure, but domestic refining activity declined sharply after the mid-2000s. Recent downstream activity suggests that Ghana's fuel infrastructure could become more relevant again over time, including for future SAF production, blending, and logistics. Ghana's investment environment has also improved since the 2022 macroeconomic crisis, supported by fiscal consolidation, debt restructuring, stronger reserves, falling inflation, and an improved sovereign credit rating. These developments provide a more stable basis for assessing SAF investment.

The feedstock assessment shows meaningful SAF potential, but practical recoverability is the main constraint. The Feasibility Study for Ghana quantified a range of potential feedstocks, which this study paired with suitable conversion technologies, including HEFA, co-processing, AtJ, and Fischer-Tropsch (FT), to form pathways. The figure below shows the estimated SAF potential of those pathways, derived from the feasibility study feedstock estimates. As discussed throughout this report, several of these values should be treated as indicative because practical availability will depend on collection, aggregation, competing uses, and other project-specific constraints.

There is potential to produce a meaningful amount of SAF in Ghana across several feedstock–technology combinations

Ghana's annual SAF potential by pathway, kt



Source: Ghana SAF Feasibility Study; ICF analysis. Note: MSW is excluded due to a planned facility

The pathway shortlist was designed to compare distinct SAF routes relevant to Ghana. The screening aimed to select pathways that were distinct in both feedstock and technology, with first-generation (1G) and second-generation (2G) AtJ considered separately. The selected pathways were: (i) co-processing of palm oil residues; (ii) standalone HEFA using fishery and livestock residues; (iii) AtJ using 2G ethanol from maize residues; (iv) integrated AtJ using 1G ethanol from cassava tubers; and (v) FT using cassava residues. These pathways are not mutually exclusive, but provide a representative basis for comparing Ghana's main SAF options before selecting one project-level business case. Other potentially viable pathways were not quantified in this study but may remain relevant for Ghana. MSW may have near-term potential but was excluded because existing projects are already targeting this feedstock, while sweet sorghum was treated as a longer-term option given that it is not yet cultivated at scale in Ghana.

Techno-economic assessment (TEA)

The techno-economic assessment applies a consistent modelling approach across the five shortlisted pathways, while reflecting pathway-specific differences in scale, feedstock availability, and facility configuration. Each pathway was modelled using a discounted cash flow approach, with the minimum fuel selling price (MFSP) used as the main economic indicator. The MFSP represents the SAF selling price required for the project to achieve a net present value of zero at the end of the project life. The table below summarises the key TEA parameters and results for each pathway.

Metric	**Co-Pro** ***Palm Oil Residues***	**HEFA** ***Fishery and Livestock Residues***	**AtJ** ***Maize Residues***	**AtJ** ***Cassava Tubers***	**FT** ***Cassava Residues***
Nameplate Fuel Capacity *(tonnes/year)*	10,130	83,800	134,000	171,300	71,000
Nameplate SAF Capacity *(tonnes/year)*	5,740	62,800	108,000	138,000	50,000
Steady-State Availability *(%)*	95	85	85	85	85
Total CAPEX *(Million USD)*	20.2	245	450	1,020	875

The financing structure used in the TEA is a representative approach to reflect Ghana's financing reality, not a confirmed funding package. The model applies a financing waterfall in which lower-cost concessional debt is used first, followed by grant funding and then higher-cost commercial debt and equity where required. For modelling purposes, the first USD 250 million of CAPEX is assumed to be financed through World Bank IDA debt, with a further USD 150 million available through the World Bank Scale-Up Window. Climate grant funding is then applied for the next USD 50 million, with any remaining capital financed through commercial debt and equity. These assumptions show how concessional and blended finance could affect project economics, recognising that SAF projects in Ghana would be difficult to finance on attractive terms if they relied heavily on domestic commercial debt and equity.

The co-processing pathway has an MFSP of USD 3,020 per tonne, with modelled SAF production of around 5.7 kt annually at nameplate capacity. Its main advantage is low incremental CAPEX, as the pathway would rely on modifying an existing refinery process rather than developing a standalone SAF plant. However, production potential is constrained by refinery configuration and blending limits. Co-processing could therefore be useful as a transitional option, but it does not provide the same basis for a scalable standalone SAF business case.

The standalone HEFA pathway has an MFSP of USD 2,165 per tonne, with modelled SAF production of around 62.8 kt annually at nameplate capacity. This is the lowest-cost pathway in the TEA, reflecting HEFA's commercial maturity and relatively low CAPEX. However, its suitability as the main business case is strongly limited by feedstock uncertainty, particularly around residue-to-oil conversion, collection logistics, competing uses, and aggregation. Waste lipid feedstocks are also energy-dense and globally traded, meaning that if collection increases in Ghana, exporting the feedstock may in some cases be more attractive than processing it domestically into SAF.

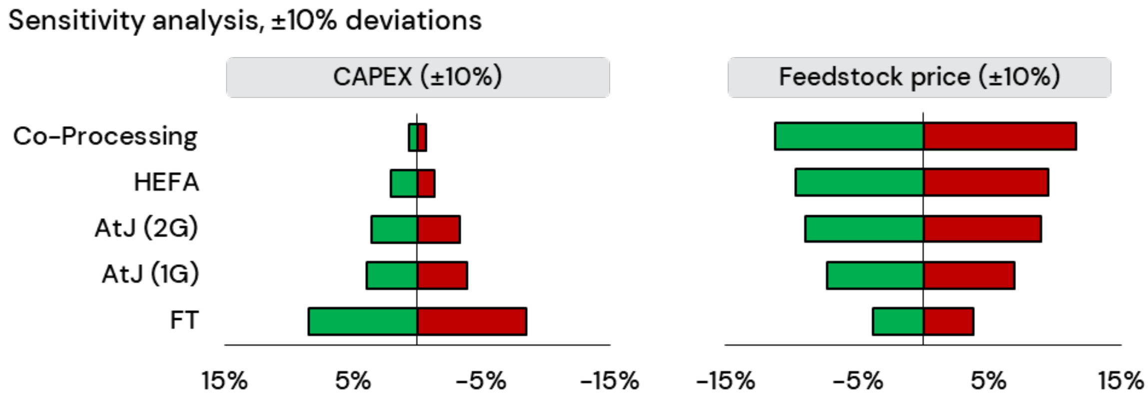
The AtJ pathway using 2G ethanol from maize residues has an MFSP of USD 4,980 per tonne, with modelled SAF production of 108 kt annually at nameplate capacity. Its main cost driver is 2G ethanol, which contributes an effective USD 3,550 per tonne of total fuel produced. A 10% decrease in the 2G ethanol price reduces the MFSP by 8.9%, meaning that global cost reductions in cellulosic ethanol could materially improve the pathway's economics over time. Although this pathway is not the lowest-cost option, it offers a stronger balance between domestic feedstock relevance, scalability, eligibility, and local value creation than the other pathways assessed.

The integrated AtJ pathway using 1G ethanol from cassava tubers has an MFSP of USD 6,880 per tonne, with modelled SAF production of 138 kt annually at nameplate capacity. Ghana has a large cassava resource base and existing interest in cassava ethanol, but cassava is a food crop. This creates eligibility constraints, particularly under the UK SAF Mandate and ReFuelEU Aviation. The pathway is therefore useful as a comparator, but its MFSP and limited access to regulated demand markets make it less suitable as the main business case.

The FT pathway using cassava residues has an MFSP of USD 7,540 per tonne, with modelled SAF production of 50 kt annually at nameplate capacity. Its main advantage is its strong carbon intensity profile, with agricultural residue FT pathways having a very low CORSIA default lifecycle emissions value. However, this is outweighed by the high CAPEX and financing burden associated with gasification and FT technology. Cassava residue availability also depends on cassava being processed, which is currently not widespread. FT may therefore be more relevant as a longer-term option than as the first SAF business case to take forward.

Feedstock price is the main cost driver for co-processing, HEFA, and both AtJ pathways, while FT is driven primarily by CAPEX. A sensitivity analysis considered changes to CAPEX, interest rates, feedstock prices, and plant availability. As shown in the figure below, all pathways except FT show a change of at least ±7% in MFSP from a ±10% change in feedstock price. FT is different because the capital intensity of gasification and Fischer-Tropsch conversion makes its MFSP more sensitive to CAPEX and financing terms.

Among the variables assessed, all pathways except FT were most sensitive to changes in feedstock price



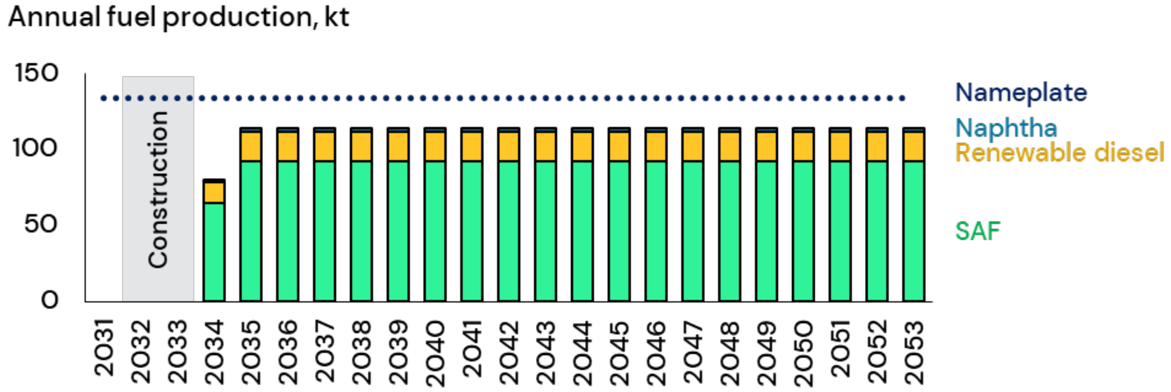
Source: ICF analysis

Financial and operational assessment

The selected business case is a standalone AtJ facility in the Tema area, supplied by decentralised 2G ethanol production near maize residue sources. The modelled AtJ facility has

CAPEX of USD 450 million and nameplate annual production of approximately 108 kt of SAF, alongside renewable diesel and naphtha. After applying the steady-state availability assumption, expected SAF output falls to around 91.8 kt annually, as shown in the figure below. The facility would be ethanol-agnostic, helping de-risk the AtJ project if domestic 2G ethanol production is delayed or develops more slowly than expected. Imported ethanol or alternative ethanol sources could be used as a contingency, although this would reduce the domestic value-creation, eligibility, and carbon-intensity benefits of the preferred maize residue pathway. Under the indicative timeline, FID is targeted for Q4 2029, with first commercial SAF production expected around 2034.

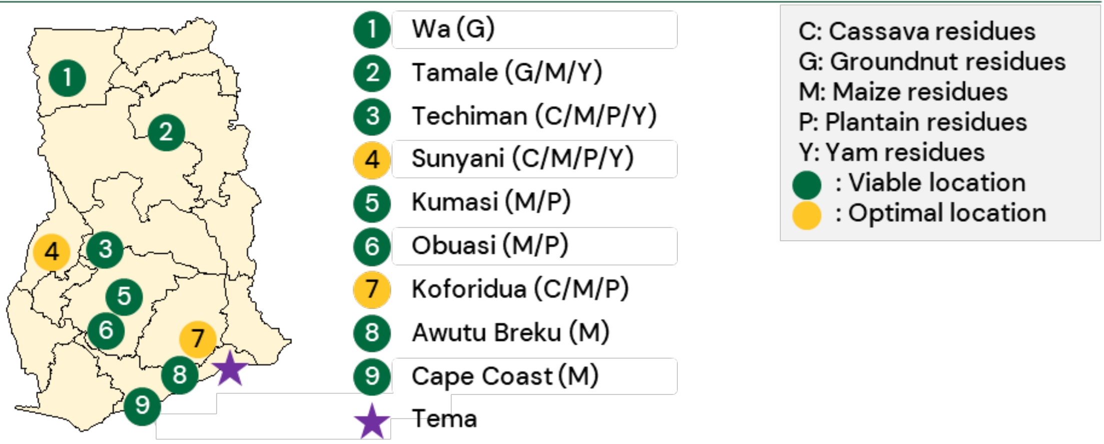
Once fully operational, the modelled AtJ facility would produce an estimated 91.8 kt of SAF, 19.6 kt of renewable diesel, and 2.6 kt of naphtha annually



Source: ICF analysis

The value chain is configured to keep bulky biomass movements short while locating fuel conversion close to Ghana's main downstream infrastructure. Maize stover is bulky, so 2G ethanol production is expected to be more practical near maize-producing regions and residue aggregation points. As shown in the figure below, a previous study identified candidate 2G ethanol production locations based on residue availability, highway access, and industrial activity, and then identified optimal locations based on minimising residue transport costs from source areas and ethanol transport costs to Tema[1]. AtJ conversion is then located in Tema to benefit from stronger electricity reliability, industrial energy infrastructure, LNG pipeline connections, port access, fuel-handling assets, storage and blending options, and potential Free Zone advantages.

A previous study identified nine viable locations for 2G ethanol production, two of which were considered optimal for minimising transportation costs to Tema



Source: Singh et Al (2018); ICF analysis

Commercialisation would need to combine domestic uplift with wider demand channels. The selected facility is expected to produce more SAF than Ghana is likely to absorb domestically at

[1] https://www.sciencedirect.com/science/article/abs/pii/S1364032118306658

low early blend levels, so domestic uplift at Kotoka International Airport would likely need to be complemented by regional exports, wider international demand, or book-and-claim sales. This is plausible because many of the international airlines serving Ghana already have SAF targets, offtake agreements, or exposure to SAF policy in other jurisdictions. Long-term offtake would be important not only for the AtJ facility, but also for the upstream 2G ethanol producers that would need confidence in future ethanol demand before investing.

The sustainability case depends on both lifecycle emissions performance and responsible residue management. Maize stover is a residue of existing maize production and does not directly compete with food use, but residue removal must be managed carefully to protect soil carbon, soil structure, water regulation, nutrient cycling, and existing local uses. To access target markets, the project would need certification evidence that traces maize stover from collection and aggregation through ethanol production, AtJ conversion, blending, and final fuel claims. Carbon intensity could also be improved through lower-carbon power, efficient logistics, process integration, or other emissions-reduction measures.

Risk assessment

The risk assessment identified 36 risks across the selected value chain, with each risk assessed by impact and likelihood using a traffic-light rating system and mitigation actions proposed for each. The table below focuses on the risks rated High for both impact and likelihood and summarises the corresponding mitigation priorities, as these are the issues most likely to affect project viability, bankability, or timing if not actively managed. A central risk is whether domestic 2G ethanol production can be financed and scaled in time to supply the AtJ facility. Imported ethanol could provide a contingency option, at least initially, but this would reduce the domestic value-creation benefits of the business case and may weaken the pathway's eligibility or carbon-intensity position. None of the risks identified rule out the selected business case, but they define the areas that require the most attention before the project can move towards FID.

High impact and high likelihood risk	Mitigation summary
Aggregation may be difficult and costly because maize production is concentrated in several regions but remains dominated by smallholder farms.	Build the collection model around existing maize aggregation channels and local aggregators, then use pilots to test collection costs, baling needs, farmer participation, and delivery reliability.
2G ethanol producers may struggle to secure financing.	Link ethanol financing to the AtJ project through long-term supply agreements, aligned development timelines, concessional lender engagement, and proven technology providers where possible.
Traceability may be difficult where maize stover is collected from many smallholder farms and passes through aggregators before reaching 2G ethanol production.	Require aggregators to record collection location, farmer or collection group, volume supplied, and delivery batch, with ethanol producers linking these records to incoming feedstock batches.
The SAF price may be too high for buyers to absorb.	Explore policy support, incentives, book-and-claim mechanisms, lifecycle emissions reductions, and 2G ethanol cost reductions to improve buyer affordability.
The project may not secure long-term SAF offtake agreements needed to support financing.	Engage airlines, fuel suppliers, and corporate buyers before FEED to test willingness to pay, contract structures, contract length, and sustainability requirements.

Business implementation recommendations

The implementation roadmap is structured around three phases that move the selected AtJ opportunity from study findings to investment readiness. Phase 1 focuses on mobilisation and validation from late 2026 through Q1 2028, with the key deliverable being a feasibility package. Phase 2 focuses on project definition from 2028 to Q1 2029, with substantially completed FEED as the key deliverable. Phase 3 focuses on investment readiness through 2029, with the key deliverable being an FID-ready project package by Q4 2029. The timeline below sets out the indicative sequencing of these phases and the priority actions required to advance the project.

Initiative	2026	2027	2028	2029	2030
Phase 1: Coordination and validation					
1.A Establish a SAF coordination committee or working group					
1.B Set Ghana's near-term SAF ambition and policy direction					
1.C Define the initial project partner landscape					
1.D Identify prospective SAF developer or development consortium					
1.E Validate practical maize stover availability					
1.F Run feedstock collection pilots					
1.G Assess other lignocellulosic biomass options					
1.H Complete a Ghana-specific 2G ethanol feasibility assessment					
1.I Complete AtJ facility feasibility / pre-FEED definition					
Phase 2: Project definition					
2.A Define the preferred project and contracting structure					
2.B Decide the appropriate ownership model					
2.C Agree funding responsibilities and preliminary risk allocation					
2.D Confirm technology access and procurement approach					
2.E Confirm preferred site pathway and utility basis					
2.F Undertake FEED and update the project cost estimate					
2.G Develop the certification and life cycle assessment (LCA) plan					
2.H Prepare preliminary commercial term sheets					
Phase 3: Investment readiness and FID preparation					
3.A Develop financing strategy for the AtJ and ethanol platform					
3.B Engage potential financial institutions					
3.C Advance SAF offtake and ethanol supply agreements					
3.D Prepare finance application materials					
3.E Develop and implement the permitting roadmap					
3.F Reduce exposure to high commercial financing costs					
3.G Finalise implementation responsibilities and FID package					

The selected pathway offers Ghana a credible starting point for SAF production, but investment readiness will depend on coordinated delivery. The immediate priority is to build the evidence base, partnerships, project structure, financing plan, offtake position, and permitting pathway needed for a first SAF project to become bankable. If these steps are progressed together, Ghana could position itself as an early SAF producer in West Africa while creating domestic value from agricultural residues, supporting rural supply chains, and reducing the emissions intensity of aviation fuel over time.

Contents

Abbreviations and Acronyms

AACE	Association for the Advancement of Cost Engineering
ANSP	Air navigation service provider
APRI	Airport Policy and Research Institute
ATJ	Alcohol-to-jet
ATK	Aviation turbine kerosene
CCS	Carbon capture and storage
CEPCI	Chemical Engineering Plant Cost Index
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DCF	Discounted cash flow
DFI	Development Finance Institute
EIA	Environmental Impact Assessment
EPC	Engineering, procurement and construction
ETJ	Ethanol-to-Jet
ETS	Emissions Trading System
FCC	Fluid catalytic cracking
FEED	Front-end engineering design
FEL	Front-end loading
FID	Final investment decision
FT	Fischer-Tropsch
GACL	Ghana Airports Company Limited
GPHA	Ghana Ports and Harbours Authority
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
GTL	Gas-to-Liquids
HDN	Hydrodenitrogenation
HDO	Heavy deoxygenation
HDS	Hydrodesulfurisation
HEFA	Hydroprocessed Esters and Fatty Acids
HPU	Hydroprocessing unit
IDA	International Development Association
IFC	International Finance Corporation
ILUC	Indirect land-use change
ISBL	Inside battery limits
KIA	Kotoka International Airport
KPI	Key performance indicator
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LTAG	Long-term aspirational goal
MDB	Multilateral development bank
MDEA	Methyldiethanolamine
MFSP	Minimum fuel selling price
MMBTU	One million British thermal units
MSW	Municipal solid waste
MVA	Megavolt-Amperes
NPV	Net present value
OCTP	Offshore Cape Three Points
OEM	Original equipment manufacturer
OMV	Oil market value
OSBL	Outside battery limits
PFAD	Palm fatty acid distillate
POME	Palm oil mill effluent
PPF	Palm Pressed Fiber
PPP	Public-Private Partnership

RD	Renewable Diesel
RIN	Renewable Identification Numbers
RTFO	Renewable Transport Fuel Obligation
SBCR	Slurry-phase bubble column reactors
SCS	Sustainability Certification Scheme
SPV	Special Purpose Vehicle
SUW	Scale-up window
TEA	Techno-economic assessment
TEN	Tweneboa, Enyenra, and Ntomme
UCO	Used cooking oil
UOP	Universal Oil Products
VGO	Vacuum gas oil
WGS	Water-gas shift reactor

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1 Market Analysis and Pathway Shortlisting

This chapter provides the market context for the rest of the study. While the feasibility study covers the wider market in detail, this chapter focuses on the parts of Ghana's energy landscape, investment environment, aviation sector, and SAF demand outlook that are most relevant to the business case. It then narrows the longlist of possible SAF options to a smaller set of pathways that could credibly be taken forward in Ghana. In doing so, it introduces the main factors that shape pathway selection at a high level, including feedstock availability, technology considerations, and broad eligibility and market factors. The more detailed technical, economic, and sustainability assessment of those shortlisted pathways is then undertaken in Chapter 2.

1.1 Energy landscape

Ghana's energy landscape offers both strengths and constraints for SAF development. The country has domestic crude oil production, established fuel infrastructure, and a policy direction that is broadly supportive of renewable energy and biofuels. At the same time, refining capacity remains limited, the power sector has faced reliability and financial pressures, and biofuel production has not yet developed at commercial scale.

1.1.1 Energy sector overview

Although Ghana possesses significant renewable energy potential, the contribution of modern renewable energy sources remains relatively limited, at around 6.3% of the country's total energy supply[2]. Additional demand from a growing population has instead been met largely by natural gas, as shown in the figure below, which became an integral part of Ghana's energy system following the discovery of offshore oil and gas in 2007. Renewable energy expansion has long been recognised as offering both energy security and emissions-reduction benefits, but the pace of development has been held back by a combination of limited technical capacity, weak market development, and wider institutional and human barriers[3,4].

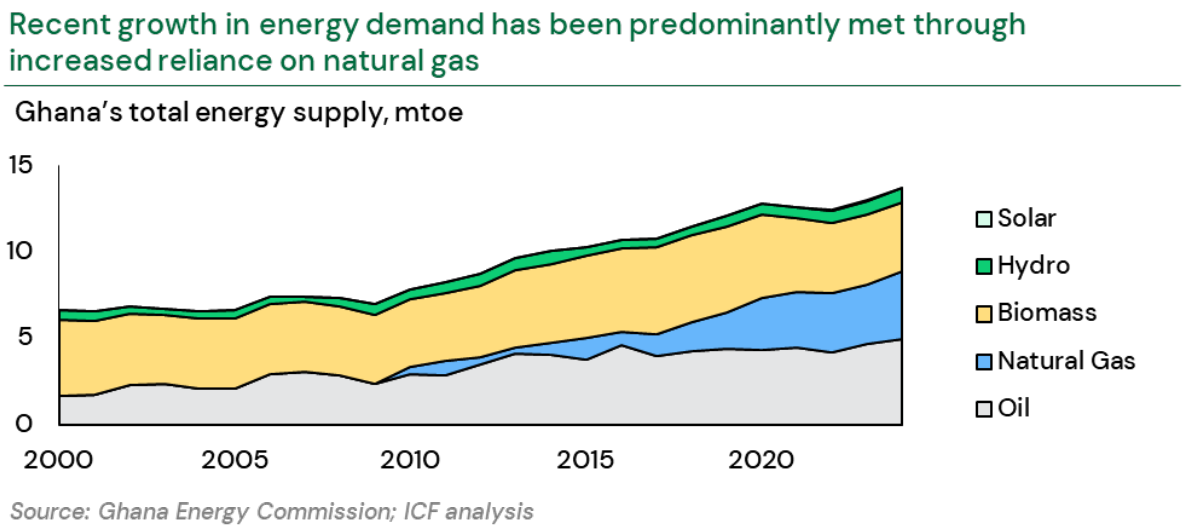

Figure 1: Ghana's total energy supply breakdown

Overall, Ghana was a net exporter of energy in 2023, driven by production of crude oil, natural gas, and wood-based energy, as shown in the figure below. However, as discussed later in this section, Ghana exports almost all crude oil produced, and imports refined petroleum products.

[2] https://energycom.gov.gh/planning/energy-statistics
[3] https://www.sciencedirect.com/science/article/pii/S2468227622001077
[4] https://link.springer.com/article/10.1007/s42452-024-06148-x

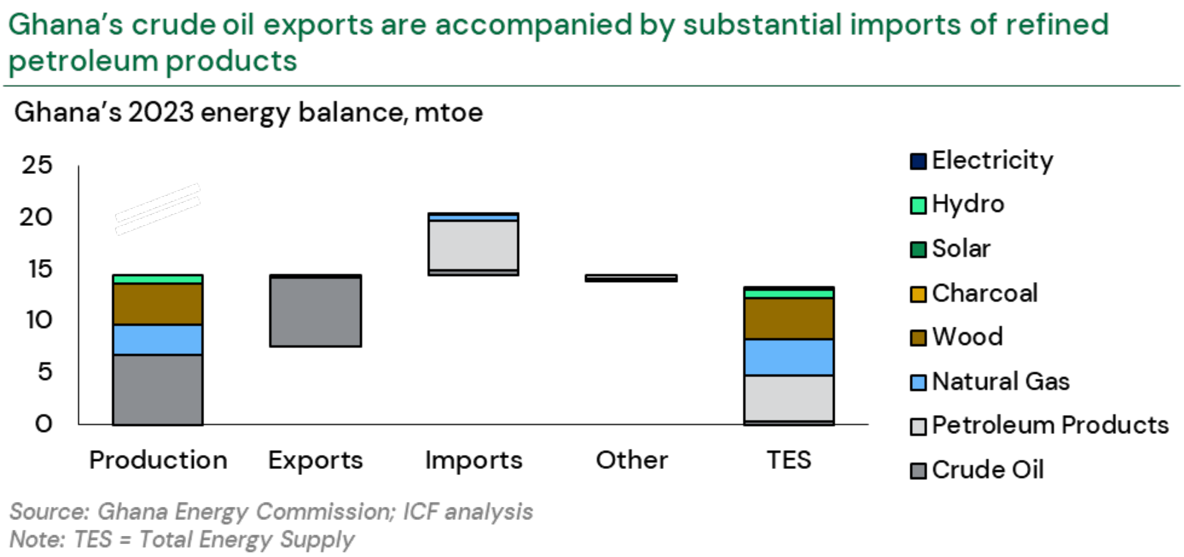

Figure 2: Ghana's energy balance

1.1.2 Electricity sector

Ghana has invested heavily in its electricity grid in recent years, increasing the share of the population with access to electricity from 43.7% in 2000 to 89.5% in 2023, with ambitions to reach 99.8% by 2030[5],[6]. Electricity generation in 2023 consisted primarily of thermal generation using natural gas at 14.4 TWh, or 59.2% of total generation, and hydropower at 9.2 TWh, or 37.9%[7]. When combined with the smaller but growing contribution from solar PV at 0.1 TWh, or 0.6%, the total renewable share reached 38.5% in 2023, placing Ghana around the middle of the range compared with other African countries, as shown in the figure below.

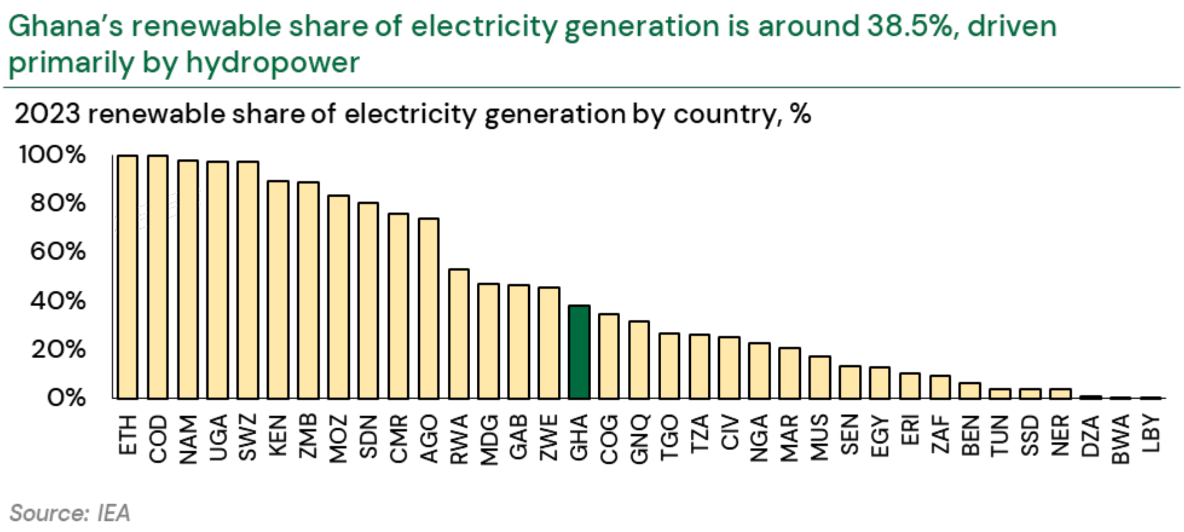

Figure 3: Renewable share of total electricity generation by country in 2023

Despite this progress, Ghana continues to face challenges with electricity reliability. Power outages remain common, driven by a combination of generation shortfalls, maintenance backlogs, and fuel supply constraints[8]. Reliable electricity generation has been reported at below 90% of capacity

[5] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=GH
[6] https://www.ghanaweb.com/blogs/michaeloberteye/Ghana-launches-Scaling-Up-Renewable-Energy-Programme-SREP-to-electrify-off-grid-communities-11832
[7] https://www.iea.org/countries/ghana/electricity
[8] https://www.mdpi.com/2071-1050/17/18/8266

due to maintenance issues and interruptions in fuel supply[9]. In particular, intermittent natural gas deliveries through the West African Gas Pipeline have periodically reduced output from gas-fired power stations and affected wider grid stability[10].

Power sector financial stability and investability

In 2015, a USD 500 million Partial Risk Guarantee (PRG) from the World Bank helped unlock around USD 8 billion in private investment into Ghana's energy sector, particularly through the Sankofa Gas Project[11]. The guarantee provided investment security under long-term take-or-pay gas agreements. Over time, the sector came under increasing financial strain due to a combination of structural and macroeconomic factors[12]. These included the rigidity of take-or-pay contracts, high generation costs, delays in government payments, and other macroeconomic pressures, particularly the mismatch between USD-denominated obligations and cedi-based revenues, alongside significant currency depreciation. As arrears accumulated, the Partial Risk Guarantee was fully depleted. This deterioration added to operational pressure in the sector, contributed to weaker system reliability, and affected wider perceptions of Ghana's energy-sector governance and creditworthiness.

Following the change in government in 2025, the new administration has reported a series of measures aimed at stabilising the sector. These include substantial payments to clear energy-sector arrears, settlement of the World Bank PRG exposure, and efforts to improve payment discipline going forward. These steps form part of a broader attempt to restore stability in the energy sector and improve Ghana's wider investment position.

1.1.3 Conventional petroleum sector

Ghana's petroleum sector is relevant to SAF because it combines domestic crude production with established, but currently limited, refining and fuel supply infrastructure. Commercial quantities of crude oil were first discovered offshore at the **Jubilee Field** in 2007, which began production in 2010. Operated by Tullow Oil, Jubilee remained the largest producer in 2023 with around 4.2 Mt of annual production, or over 63% of national production[13,14]. Additional wells are being drilled in the Jubilee Field and are expected to come online in the near term, increasing production further[15,16].

Tullow also operates the **Tweneboa, Enyenra, and Ntomme (TEN) Field**, which lies around 20 km from Jubilee and began commercial production in 2016. As of 2023, TEN produced 916 kt of crude oil annually, or 14% of national production. In December 2025, the government approved licence extensions for both the Jubilee and TEN fields for the period July 2036 to 2040. During this extension period, Ghana National Petroleum Corporation's share in the fields will increase by 10%, and 20 additional wells are expected to be developed.

The third major oil field in Ghana is **Offshore Cape Three Points (OCTP)**, operated by Eni. Eni has been active in exploration in Ghana since 2009, and the OCTP Field began commercial production in 2017. In 2023 it produced around 1.5 Mt annually, or 23% of national production[16,17]. A further significant oil discovery was made in 2021, and in September 2025 a memorandum of intent was

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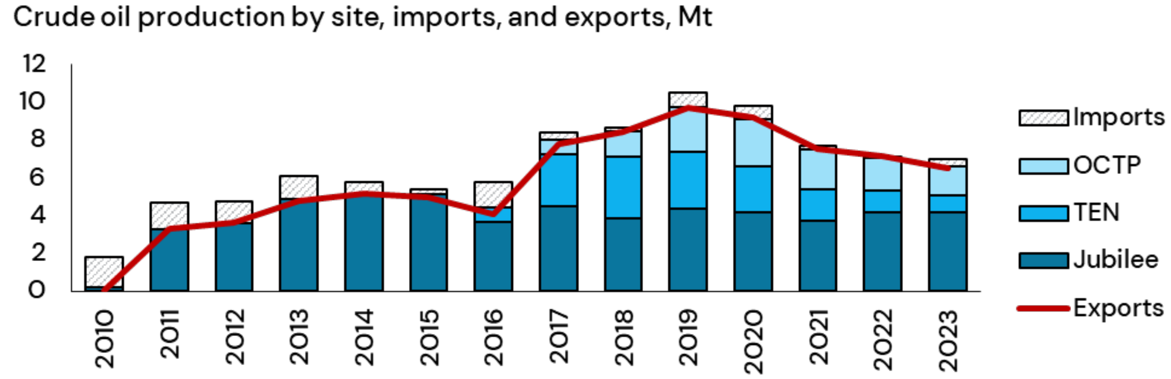
[9] https://gna.org.gh/2025/02/ghanas-24-hour-economy-are-the-ports-ready-for-non-stop-trade/
[10] https://www.myjoyonline.com/wapco-gas-pipeline-maintenance-triggers-power-supply-disruptions/
[11] https://www.mofep.gov.gh/news-and-events/2026-01-12/mahama-administration-pays-us1.470-billion-to-clear-energy-sector-debt-and-restore-world-bank-guarantee-within-first-year
[12] https://www.modernghana.com/news/1462889/how-ghana-slid-into-energy-sector-debt-and-the.html
[13] https://www.tullowoil.com/application/files/2115/7960/2357/tullow-ten-brochure.pdf
[14] https://energycom.gov.gh/index.php/planning/energy-statistics
[15] https://investors.kosmosenergy.com/news-releases/news-release-details/kosmos-energy-provides-operational-and-financial-update-2
[16] https://energycom.gov.gh/index.php/planning/energy-statistics
[17] https://www.eni.com/en-IT/actions/global-activities/ghana/octp.html

signed to increase oil and gas production and add sustainable initiatives to the OCTP Field, with the aim of meeting the country's growing domestic energy demand[18,19].

While Ghana's crude oil production peaked in 2019 at 9.7 Mt, the country still produced 6.6 Mt in 2023, with apparent plans for further expansion over the coming years. Nevertheless, almost all of this volume is exported, as shown in the figure below.

Since beginning production in 2010, Ghana has exported almost all of its crude oil output

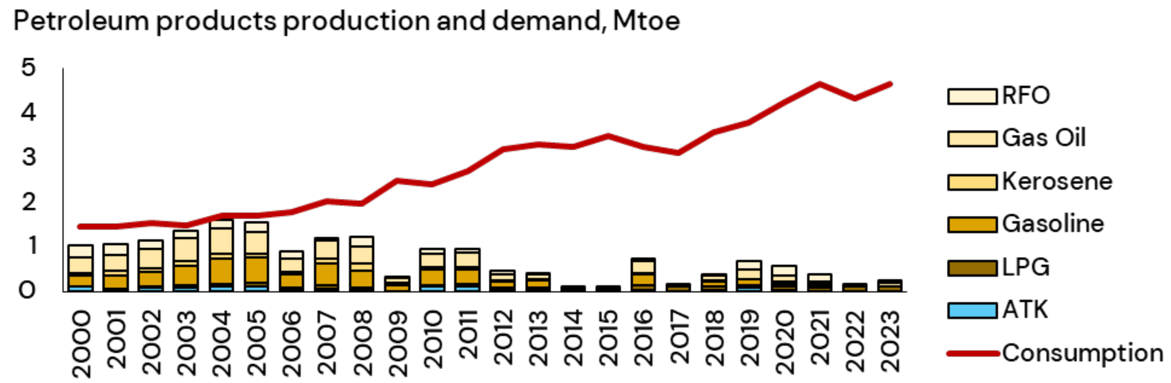


Source: Ghana Energy Commission; Petroleum Commission; Ghana National Petroleum Corporation; ICF analysis

Figure 4: Crude oil production site imports and exports since 2010

Ghana has had crude oil processing capacity since 1963, when the Tema Oil Refinery opened, initially relying on imported crude oil. Refining capacity was previously more significant. In 2004, approximately 1.6 Mt of finished fuels were produced, and domestic supply met 94% of consumption. Since then, as shown in the figure below, Ghana has experienced a marked decline, and considerable volatility, in refined petroleum product production. Despite the discovery of crude oil and a 5.4% CAGR in petroleum product consumption between 2004 and 2023, increasing from 1.7 Mt to 4.6 Mt, domestic production fell from 1.6 Mt to 264 kt.

The production of refined petroleum products has remained volatile and, in recent years, has been significantly below consumption



Source: Ghana Energy Commission; Tema Oil Refinery; Ghana National Gas Company; National Petroleum Authority; ICF analysis

Figure 5: Demand and production of petroleum products

[18] https://www.eni.com/en-IT/media/press-release/2021/07/eni-announces-significant-discovery-block-ghana.html
[19] https://www.eni.com/en-IT/actions/global-activities/ghana.html

A number of reasons have been identified for why Ghana exports its crude and imports refined products. Existing refineries require upgrades to process the available crude slate effectively, and Ghanaian crude is also understood to attract a premium in export markets[20]. A recent study found positive results for greater domestic refining, including a potential ROI of 29%, possible cost savings on refined products of USD 1.4 billion based on 2023 prices, and wider economic benefits[21].

There are, however, signs that Ghana's refining position may improve over time. Developments relevant to SAF include TOR, SOR, and PHDC, each of which could shape the infrastructure base available to future SAF production.

Tema Oil Refinery (TOR): Opened in 1963 as the Ghanaian Italian Petroleum (GHAIP) Company, TOR is Ghana's main crude oil processing facility. The Government of Ghana acquired full ownership in 1977, and the refinery was renamed Tema Oil Refinery Limited in 1990. TOR has the capability to produce liquefied petroleum gas (LPG), gasoline, diesel, kerosene, and aviation fuel (ATK)[22]. However, a period of operational inefficiencies gradually rendered it inactive, contributing to Ghana's dependence on imported petroleum products[23]. A turnaround maintenance project has since been undertaken and in December 2025, TOR announced the successful resumption of crude oil refining operations after several years of inactivity. The following months have been intended to stabilise systems, optimise performance, and ensure sustained operational reliability before the commissioning of a recently installed furnace. This new furnace will enable the refinery to return to its original capacity of 45,000 barrels per day, up from the current level of 28,000 barrels per day. There is a plan to expand capacity to 60,000 barrels per day following the installation of a new air-cooler[24]. The TOR regeneration plan suggests that imported crude will continue to feed the refinery, as much of Ghana's domestic crude remains tied up in contractual arrangements with joint venture partners and therefore continues to be exported[25].

Sentuo Oil Refinery (SOR): SOR was recently constructed in the Tema Industrial Zone with Chinese backing, becoming the first privately owned oil refinery in Ghana[26]. The refinery has a capacity of 5 Mt of crude oil processing per year, resulting in 3.2 Mt of refined products. It also has significant onshore and offshore storage capacity. Among the products produced are gasoline, gasoil, aviation fuel, fuel oil, and liquefied petroleum gas. Visual representations on the SOR website indicate that current aviation fuel production is at 7.2% of a 150 kt annual capacity, equivalent to 10.8 kt[27].

Petroleum Hub Development Corporation (PHDC): PHDC was established under the Petroleum Hub Development Corporation Act, 2020 (Act 1053) to promote and develop a petroleum and petrochemical hub for the West African sub-region and beyond[28]. It serves as the main point of contact for investors, suppliers, partners, and other stakeholders involved in the Petroleum Hub. Four strategic goals were identified in the Structure Plan published by PHDC in 2021, including improving the competitiveness of Ghana's oil and gas sector, developing coordinated infrastructure systems, supporting sustainable management of the natural and built environment, and promoting human resource development. Plans for an additional airport at the site did not materialise, partly because of the location's proximity to Côte d'Ivoire and the resulting airspace constraints. Even so, the site remains relevant in the SAF context because of its wider industrial ambition and its potential proximity to regional feedstock sources.

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[20] https://www.graphic.com.gh/news/general-news/energy-ministry-explains-why-tor-cannot-refine-ghanas-jubilee-crude.html

[21] https://www.researchgate.net/publication/393047204_An_Assessment_of_the_Potential_Benefits_of_Refining_Crude_Oil_in_Ghana

[22] https://torghana.gov.gh/about-us/

[23] https://thebftonline.com/2025/06/25/revamping-tor-the-challenge-of-depending-on-imported-crude/

[24] http://torghana.gov.gh/wp-content/uploads/2025/12/Update-on-Operations.pdf

[25] https://thebftonline.com/2025/06/25/revamping-tor-the-challenge-of-depending-on-imported-crude/

[26] https://www.ghanaweb.com/GhanaHomePage/business/Akufo-Addo-commissions-Ghana-s-first-privately-owned-oil-refinery-1913693

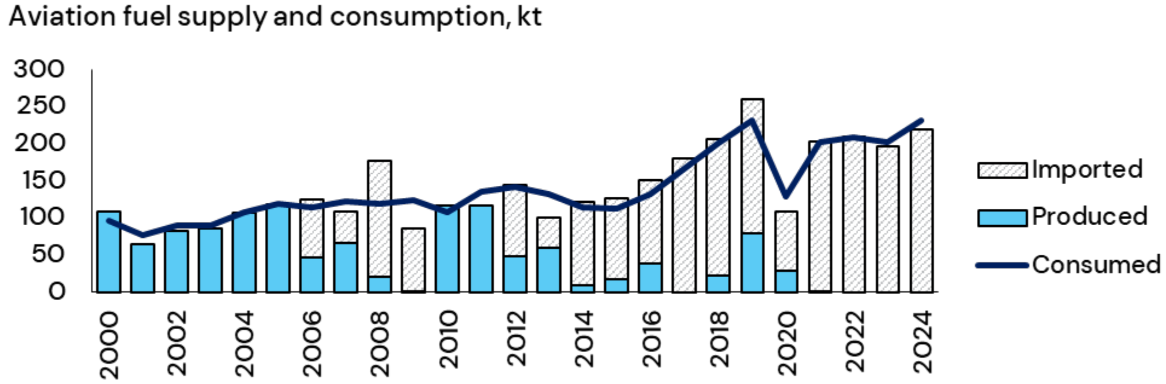
[27] https://sorlgh.com/

[28] https://phdc.gov.gh/

Aviation fuel

Aviation fuel supply reflects the downstream consequence of these broader petroleum dynamics. Domestic aviation fuel production was consistently sufficient to meet domestic demand in the 2000 to 2005 period, with peak domestic aviation fuel production reaching approximately 110 kt per year in 2004. Since then, imports have become increasingly important. The 2006 to 2020 period can be seen as a transition phase of declining domestic production and rising import volumes, and since 2021 all of Ghana's aviation fuel demand has been imported, as shown in the figure below.

While Ghana previously met its jet fuel demand through domestic production, it has relied solely on imports in recent years



Source: Ghana Energy Commission; Statsbank Ghana; ICF analysis

Figure 6: Ghana's aviation fuel supply and consumption

The feasibility study provides an overview of the logistical organisation of aviation fuel in Ghana. Most aviation fuel is currently imported via Tema port. Bulk Oil Storage and Transportation Company and private fuel companies manage storage depots, and tanker trucks are used to transport aviation fuel to airports. At Kotoka International Airport, an underground hydrant system is used to deliver aviation fuel to aircraft. TOR and SOR are both located close to Tema port and close to one another, which supports relatively efficient procurement of inputs and distribution of products. This existing infrastructure could create an advantage for future SAF facilities, particularly where co-location with existing refining or fuel logistics assets is feasible.

1.1.4 Biofuel and ethanol landscape in Ghana

Biofuels have been recognised in Ghana's policy framework for many years, but commercial deployment remains limited. Frameworks have been established for biofuel development, yet no enforceable blending mandates or clear commercialisation pathway have been established or identified. The main challenges to biofuel production in Ghana are the lack of a supportive policy environment and the complexity of the land tenure system. At the same time, gasoline and diesel prices are not subsidised, which could make the introduction of biofuels easier than in markets where fossil fuels are heavily protected[29].

Research has suggested that the use of 30% of cassava waste for ethanol production would be sufficient to fulfil an E10 mandate in Ghana[29]. There has also been considerable work on the potential for an ethanol industry more broadly. The University of Ghana Legon has studied the market potential of industrial alcohol since 2003 as part of wider work on industrial uses of cassava[30]. Other research has assessed possible locations for ethanol production and found that

[29] https://www.iese.edu/media/research/pdfs/OP-0320-E.pdf

[30] https://assets.publishing.service.gov.uk/media/57a08ce340f0b652dd001626/R8268h.pdf

the most economic configuration would involve three biorefineries of 50 million litres per year, each supplying separate demand centres, thereby reducing transportation costs[31].

Ghana currently imports around 60 million litres of ethanol per year, although, there have been some recent and notable announcements around domestic ethanol activity[32]. Caltech Ventures reported plans to begin ethanol production from cassava and is linked to Kasapreko Company Limited, an indigenous alcoholic beverage producer and major ethanol importer. Between June and December of 2016, the plant reportedly produced 150,000 litres of ethanol, with full-scale production originally expected by 2019[33]. Another ethanol plant was announced in the Volta Region in November 2023, with a capacity of 200,000 litres per day, although more recent reporting suggests this has been delayed[34,35].

Gulf Chemical Company Limited (GCCL) and Nungua Warehouse Ghana Limited (NWGL) have formed an alliance to support ethanol-gasoline blending in Ghana, using local feedstocks, primarily cassava and agricultural residues. The partnership combines GCCL's petrochemical and blending expertise with NWGL's 30 years of ethanol distribution experience, storage capacity exceeding 20 million litres, and 24 storage warehouses across Ghana and Togo. The partners have referenced a 45 million litre per year alcohol manufacturing plant in Ahinase, Eastern Region, and are open to future AtJ discussions. The feasibility study also states that six ethanol plants are currently operating in Ghana, though there is limited public information available on them. Ghana is not starting from zero on liquid biofuels, but neither does it yet have a mature ethanol sector.

1.1.5 Energy roadmaps

Ghana's policy framework is broadly supportive of renewable energy, bioenergy, and industrial development. A number of policies and roadmaps have been published over time, although they vary in their practical relevance and level of implementation.

The Bioenergy Policy for Ghana (2011) set an objective of substituting national petroleum fuel consumption with 10% biofuel by 2020, rising to 20% by 2030. This also aims to create a favourable regulatory climate for biofuels and position Ghana as a net exporter of biofuel in the medium to long term. However, it did not establish enforceable blending mandates.

The Ghana Renewable Energy Act (2011) provides the legal framework for the development, management, utilisation, sustainability, and supply of renewable energy. It also established the Renewable Energy Fund to provide financial resources for the development and utilization of renewable energy resources[36]. A 2020 amendment expanded the Fund to include renewable energy projects for non-electricity purposes, which could in principle support SAF-related investment.

The Ghana National Climate Change Policy (2013) provides a strategic framework for achieving a climate-resilient, low-carbon economy aligned with broader sustainable development goals. While it addresses transport emissions more broadly, aviation is not explicitly highlighted[37].

The Ghana Renewable Energy Master Plan (2019) provides an investment-focused framework for developing Ghana's renewable energy resources. It aims to increase the share of renewable energy in the national mix and reduce dependence on biomass for thermal energy generation, which could enable the diversion of biomass for higher value uses such as biofuel production. The Plan proposes incentives including tax reductions and exemptions on import duties and VAT for

[31] https://www.sciencedirect.com/science/article/abs/pii/S1364032118306658
[32] https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Ghana-s-first-ethanol-plant-to-begin-production-411854
[33] https://businessghana.com/site/news/business/140287/Caltech-produces-150-000-litres-of-ethanol-in-6-months
[34] https://www.graphic.com.gh/news/politics/im-starting-an-ethanol-plant-in-volta-central-regions-in-2024-as-reward-for-support-ken-agyapong.html
[35] https://metrotvonline.com/kennedy-agyapong-to-establish-ethanol-and-starch-factory-in-volta-region/
[36] https://ghalii.org/akn/gh/act/2011/832/eng@2020-12-29
[37] https://faolex.fao.org/docs/pdf/gha169292.pdf

renewable energy firms and sets a target of 20 kt per year of biofuel production by 2030[38]. At the same time, it recognises key barriers including the lack of clear policies and the absence of feedstock sourcing logistics. That target can also be seen as relatively modest in the context of fuel demand, as it represents less than 1% of 2017 consumption levels[29]. This plan is currently being updated[39].

Ghana Beyond Aid (2019) is a broader national transformation agenda, but it remains relevant because it highlights the need to build scientific and technological capability and specifically refers to ambitions in biofuel, green energy, and energy storage[40].

The National Energy Policy (2021) updates Ghana's broader energy strategy and identifies the blending of biofuels with petroleum products as a proposed policy direction. It also notes wider barriers to renewable energy development, including land access, weak regulatory support, and low public awareness, alongside limitations in downstream petroleum infrastructure[41].

The Coordinated Programme of Economic and Social Development Policies (2021-2025) includes an Aviation-Driven Development programme aimed at positioning Ghana as the leading aviation hub in West Africa. This signals continued aviation growth, even if sustainability is not yet explicitly stated[42].

The Ghana 5th National Action Plan (2023) is more governance-focused. It highlights the role of transparency, accountability, and data availability in supporting the energy transition, but does not set out specific energy transition commitments[43].

The Ghana Energy Transition & Investment Plan (2025) sets out an ambition to achieve net-zero CO_2 emissions by 2060 and identifies major investment needs across the energy system. In transport, electrification is expected to deliver a large share of emissions reduction, while aviation decarbonisation begins with efficiency improvements and only later introduces biofuels. The Plan also notes that limited biomass supplies are likely to need to be prioritised for sectors such as aviation and shipping, and identifies the high cost of SAF as a major barrier[44].

The Scaling-Up Renewable Energy Programme (2025) focuses on expanding electricity access to off-grid communities through mini-grids, solar home systems, and rooftop solar PV. Its direct relevance to SAF is limited, but it supports the broader transition towards a greener energy mix[6].

1.2 Investment attractiveness

Ghana's investment attractiveness matters to this study because SAF production is capital-intensive and highly sensitive to financing conditions. Even where feedstock and technology are viable, the ability to attract capital on acceptable terms will have a major influence on whether a project can move forward. This section therefore considers Ghana's broader macroeconomic and financing context, before examining the main policy and investment signals that are relevant to a potential SAF facility.

1.2.1 Macroeconomic and financing context

Since the discovery of oil in 2007, the petroleum sector has become an important contributor to Ghana's economy and supported a rapid increase in GDP[45]. However, much of that growth became concentrated in capital-intensive natural resource sectors, which contributed strongly to national output but created relatively few productive jobs. As a result, a large share of the labour force

[38] https://energycom.gov.gh/rett/documents-downloads/category/29-re-master-plan
[39] https://www.undp.org/ghana/press-releases/ghana-moves-finalize-updated-renewable-energy-masterplan-remp
[40] https://www.psrs.gov.gh/images/GBYA/ghana_beyond_aid_charter_new.pdf
[41] https://www.energymin.gov.gh/sites/default/files/2023-09/2021%20ENERGY%20POLICY.pdf
[42] https://faolex.fao.org/docs/pdf/gha218687.pdf
[43] https://www.opengovpartnership.org/wp-content/uploads/2024/01/Ghana_Action-Plan_2024-2028_December.pdf
[44] https://www.seforall.org/system/files/2025-05/Ghana-ETIP.pdf
[45] https://www.worldbank.org/en/news/press-release/2019/12/10/new-report-economic-diversification-can-create-more-and-better-jobs-in-ghana

remained concentrated in low-productivity agriculture, informal services, and self-employment, limiting the extent to which GDP growth translated into broader income growth and poverty reduction.

A period of elevated public spending and weak fiscal discipline then contributed to growing macroeconomic instability. This was compounded by external shocks, including the COVID-19 pandemic and the war in Ukraine, which together led to a macroeconomic crisis in 2022. During that period, Ghana defaulted on much of its international debt and lost access to international capital markets[46].

In 2023, Ghana entered into a USD 3 billion IMF-supported programme intended to help restore macroeconomic stability, support debt sustainability, and implement a wider programme of fiscal consolidation and debt restructuring. Since then, a number of the headline indicators have moved in a more positive direction. By the end of 2024, around 95% of pre-restructuring public debt had reportedly been restructured, helping to reduce debt-service pressure and improve confidence. This was supported by tighter monetary policy, fiscal consolidation, stronger reserves, and improved market sentiment. The government also introduced fiscal reforms, including amendments to the Public Financial Management Act, new fiscal rules targeting a primary surplus of at least 1.5% of GDP, and a debt ceiling of 45% of GDP by 2034, alongside measures to improve expenditure controls and revenue mobilisation.

The World Bank has noted that continued improvement depends on maintaining fiscal discipline, completing the remaining debt restructuring, and addressing structural weaknesses in areas such as energy, cocoa, and the financial sector[47]. Ghana's position is therefore materially stronger than it was at the height of the 2022 crisis.

The figure below highlights Ghana's public debt as a share of GDP, highlighting the steady build-up in debt pressure up to the 2022 crisis, followed by the debt restructuring and fiscal-consolidation measures introduced from 2023 onwards. These developments were also reflected in Ghana's sovereign credit rating. Following the events of 2022, S&P Global Ratings downgraded Ghana's foreign-currency debt rating to CC, indicating a distressed and highly vulnerable position[48]. In November 2025, that rating was upgraded to B-, reflecting improved fiscal discipline, stronger external balances, higher reserves, and progress with debt restructuring. While this still points to a vulnerable credit profile, it nevertheless represents a material improvement from the position reached during the crisis.

[46] https://www.reuters.com/world/africa/imf-ghana-reach-staff-level-deal-3-bln-loan-programme-review-2024-10-04/
[47] https://www.worldbank.org/ext/en/country/ghana
[48] https://www.spglobal.com/ratings/en/credit-ratings/about/understanding-credit-ratings

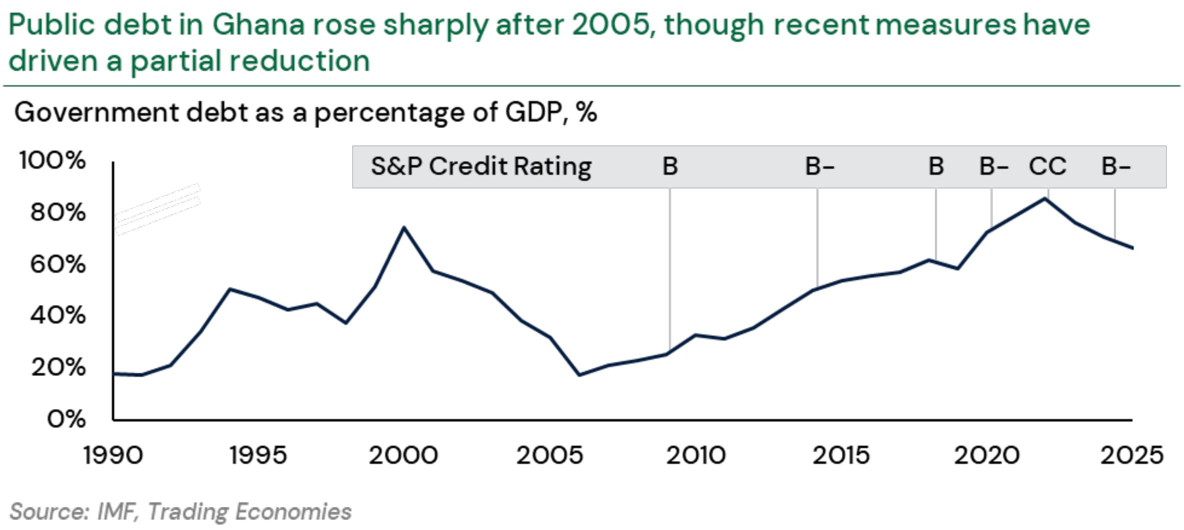


Figure 7: Historical government debt as a percentage of GDP and associates credit ratings

Ghana has therefore made notable progress since 2022. GDP growth rebounded from 2.9% in 2023 to 5.7% in 2024, inflation fell sharply from its December 2022 peak, and the government pursued reforms aimed at digitising public services, streamlining regulatory processes, and improving the business climate under the IMF-supported stabilisation programme launched in May 2023. Ghana remains one of sub-Saharan Africa's more attractive investment destinations because of its political stability and improving macroeconomic indicators, but sustained investor confidence will depend on continued debt management, more predictable policy implementation, and the delivery of structural reforms[49].

Inflation has been another important feature of the investment environment. Historical weaknesses in fiscal management, including VAT inefficiencies, expenditure-control problems, and fiscal risks from state-owned enterprises, particularly in the energy and cocoa sectors, helped keep inflation elevated even before the sharper crisis-driven spike after 2020. As shown in the figure below, inflation then rose sharply in 2022 and remained high in 2023, partly reflecting the fallout from the Russia-Ukraine war and Ghana's exposure to global commodity and import price volatility. In 2024, inflation began to fall as the IMF-supported stabilisation programme took effect, and by mid-2025 had declined further. The Bank of Ghana has set a target of reducing inflation to 8% by 2027[50].

[49] https://www.state.gov/wp-content/uploads/2025/09/638719_2025-Ghana-Investment-Climate-Statement.pdf

[50] https://documents1.worldbank.org/curated/en/099081225120527212/pdf/P181231-d65d2712-ab9a-46c3-ba22-ec2aa5f9f2c1.pdf

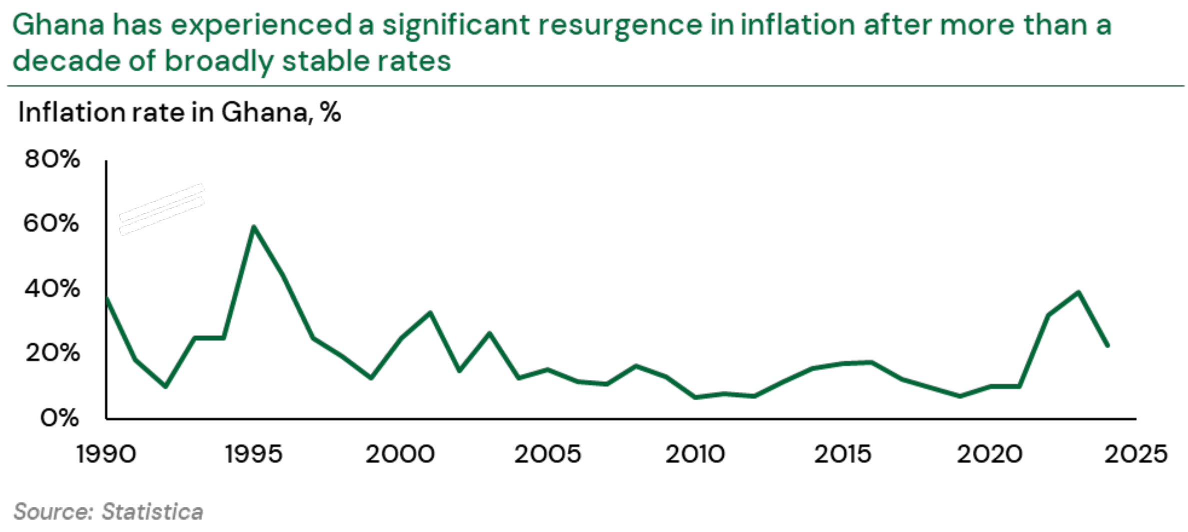


Figure 8: Historical inflation rates in Ghana, 1990-2024

Even with these constraints, Ghana compares relatively well within the region. The Rand Merchant Bank Where to Invest in Africa report for 2025/2026 ranks Ghana as the sixth most attractive country for investment in Africa, ahead of all neighbouring countries. Côte d'Ivoire also ranks relatively strongly, while Togo and Burkina Faso do not appear in the top tier. Nigeria, by contrast, has become less attractive in the near term because of weaker economic performance, inflation, and fuel-price pressures[51]. This does not mean Ghana is an easy market, but it does suggest that it remains comparatively well positioned in the West African context.

1.2.2 Policy support and investment signals

Among the most relevant policy support mechanisms for a SAF production facility in Ghana is the Ghana Free Zones Programme, established under the Free Zones Act, 1995[52]. The scheme formed part of Ghana's wider shift towards export-led industrialisation and was intended to attract foreign direct investment, promote non-traditional exports, generate foreign exchange, create jobs, support technology transfer, and accelerate structural transformation[53]. The scheme is private-sector driven, with government's role focused mainly on facilitation, regulation, and monitoring. It also allows qualifying businesses to locate across the country rather than only within a single industrial enclave, provided they meet the scheme's requirements[54].

The Free Zones Act provides a number of material fiscal incentives. These include a ten-year income tax exemption for licensed developers and enterprises, a maximum post-holiday tax rate of 8%, exemption from withholding tax on dividends, equal treatment of foreign and domestic investors, 100% foreign or domestic ownership, and permission to hold foreign currency accounts[55]. There are also a number of conditions attached. The business must be incorporated under Ghanaian law, and at least 70% of annual output must be exported. Only 30% may be sold on the domestic market, and those domestic sales attract the full duties and taxes that would otherwise apply. Records must also be maintained to demonstrate compliance with the reporting requirements of the Act[54].

Free Zones have proved successful in Ghana. By the end of 2016, as shown in the figure below, the scheme had resulted in 388 registered Free Zone companies, cumulative capital investment of USD 3.32 billion, cumulative exports of USD 30.31 billion, and 29,383 jobs created by licensed Free Zone

[51] https://brand.rmb.co.za/share/QSK82qW8MDvbZW8Sc55M/assets/402882
[52] https://gra.gov.gh/wp-content/uploads/2020/10/Free-Zones-Act-1995-Act-504.pdf
[53] https://thebftonline.com/2026/05/12/technical-brief-on-the-ghana-free-zones-programme-evidence-from-a-phd-research/
[54] https://gfza.gov.gh/ghana-free-zones-documents/
[55] https://gra.gov.gh/wp-content/uploads/2020/10/Free-Zones-Act-1995-Act-504.pdf

enterprises[56]. It should, however, be noted that the most recent annual report appears to be for 2016. More recent reporting suggests that total investment had increased to around USD 4.15 billion across about 495 companies by 2022, around 80% of which were in manufacturing[57].

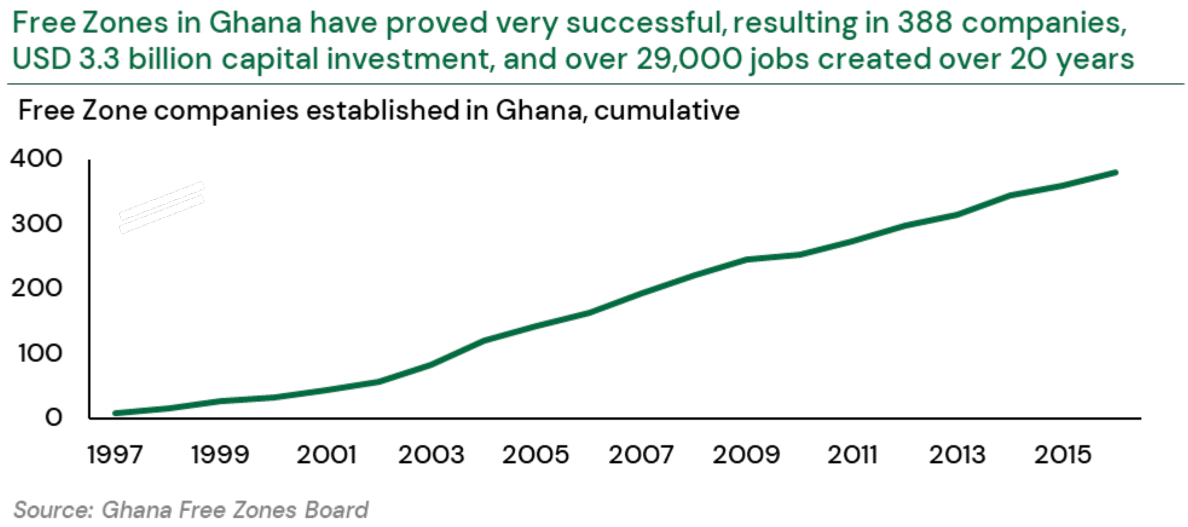


Figure 9: Number of companies established in Free Zones

There are clear points of alignment between the Ghana Free Zones regime and a potential SAF production facility. The regime already targets export-oriented manufacturing and agri-processing, and the wider investment climate remains oriented towards FDI-led industrialisation. At the same time, the investment case should still be framed with some caution. There are still important barriers, including infrastructure deficits, inconsistent utilities, high energy costs, bureaucratic inefficiencies, and land registration complexity[58].

1.3 SAF demand outlook

Understanding where SAF demand may come from is central to assessing the opportunity for production in Ghana. That demand could come from domestic uplift in Ghana itself, but it could also come from supplying regional or other international markets. This section looks at Ghana's aviation activity and expected jet fuel demand, before considering how SAF demand may emerge.

1.3.1 Aviation activity

There are currently three airlines based in Ghana. Africa World Airlines operates a fleet of eight Embraer ERJ-145LR aircraft on predominantly domestic flights, while also serving neighbouring countries. PassionAir operates only domestic flights within Ghana using a fleet of five Bombardier Dash 8 aircraft. The third airline based in Ghana is Air Ghana, a cargo airline operating two Boeing 737 aircraft, although it has recently announced plans to expand into passenger operations[59]. Ghana has not had a flag carrier since the collapse of Ghana International Airlines in 2010, although there has been more recent ambition to establish a new national airline[60,61].

While these Ghana-based carriers are important to the domestic aviation market, the airlines that serve Ghana most, when measured by available seat kilometres (ASKs), are international. Delta, British Airways, and Emirates are the top three, while Ethiopian Airlines, Kenya Airways, and

[56] https://gfza.gov.gh/ghana-free-zones-documents/
[57] https://thebftonline.com/2026/05/12/technical-brief-on-the-ghana-free-zones-programme-evidence-from-a-phd-research/
[58] https://www.state.gov/wp-content/uploads/2025/09/638719_2025-Ghana-Investment-Climate-Statement.pdf
[59] https://www.ch-aviation.com/news/156787-air-ghana-to-expand-into-pax-operations-by-late-4q25
[60] https://centreforaviation.com/news/ghana-international-airlines-collapses-49296
[61] https://atqnews.com/aviation-west-african-country-ghana-explores-flag-carrier-revival-through-potential-partnership-with-tap-air-portugal/

South African Airways are the only African carriers in the top 10. KLM, United, Turkish Airlines, and Brussels Airlines also feature in the top 10. Together, these carriers provide strong links between Ghana and major hubs in Africa, Europe, the Middle East, and North America. The figure below shows the number of ASKs originating in Ghana during 2025 by airline, which can be used as an approximate indicator of which airlines are the largest uplifters, and therefore which airlines would be most affected by the introduction of SAF into the Ghanaian jet fuel mix. Almost 90% of international arrivals to Ghana enter through Kotoka International Airport (ACC) [62].

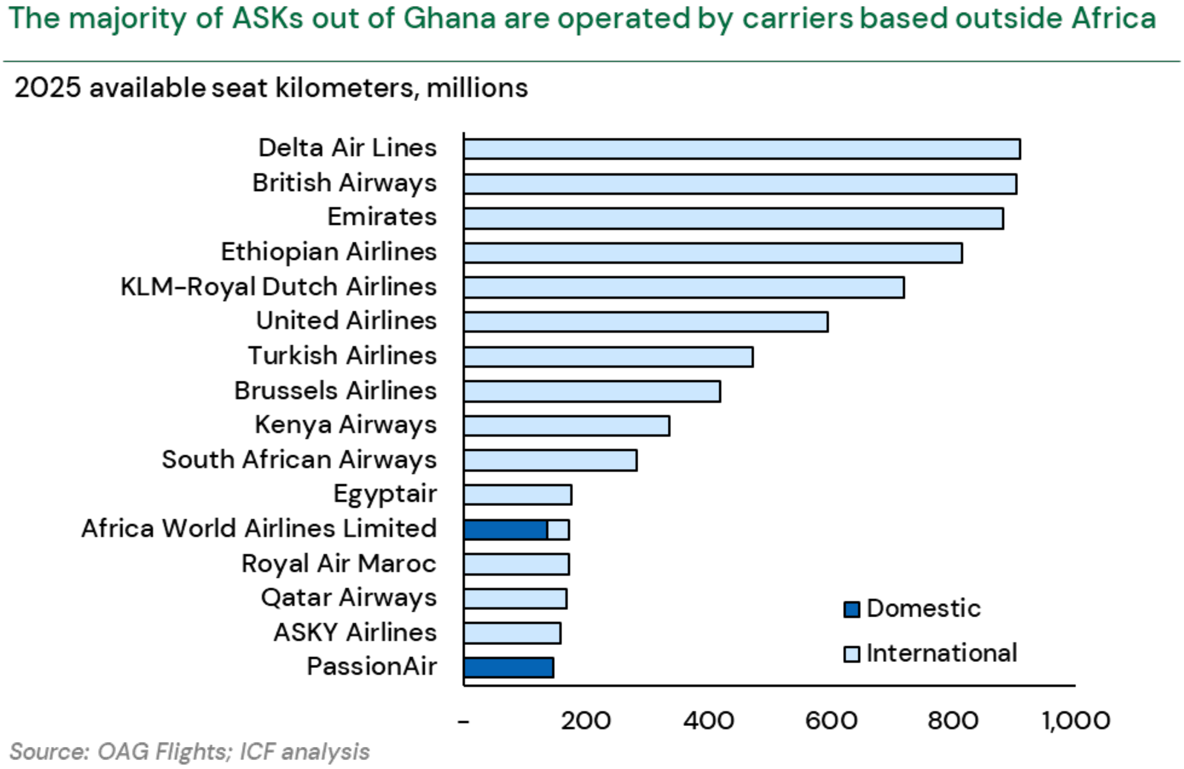


Figure 10: Share of available seat kilometers (ASK) originating in Ghana between airlines (2025)

Looking ahead, Ghana's aviation sector is expected to grow by around 4% annually between 2025 and 2050 in terms of both ASKs and revenue passenger kilometres (RPKs), based on ICF modelling. These figures are broadly in line with IATA's projections for Africa, which indicate annual growth of 4.1% between 2025 and 2044[63]. While this represents strong growth, Africa still accounts for only around 2% to 3% of global passenger traffic. As IATA has pointed out, part of the challenge is that aviation costs in the region are higher than in many other parts of the world. Fuel prices are around 17% above the global average and can account for 40% of operating costs, while taxes, ANSP charges, and maintenance costs can also be higher.

1.3.2 Conventional jet fuel forecast

Given the relatively high cost of jet fuel in the region, the expected growth in jet fuel demand is particularly important. Aviation fuel demand in Ghana increased rapidly before the COVID-19 pandemic, doubling between 2015 and 2019. By 2024, the market had recovered and demand had surpassed 2019 levels.

Despite the projected 3.8% annual growth in ASKs, jet fuel demand is expected to grow more slowly, at 2.7% per year, increasing from 233 kt in 2025 to 511 kt in 2055, as shown in the figure below. This difference reflects improvements in aircraft technology, including fleet renewal, as well as operational efficiency gains.

[62] https://www.motac.gov.gh/en/wp-content/uploads/2023-TOURISM-REPORT.pdf
[63] https://www.iata.org/globalassets/iata/pressroom/gmd/gmd-2025---africa-presentation.pdf

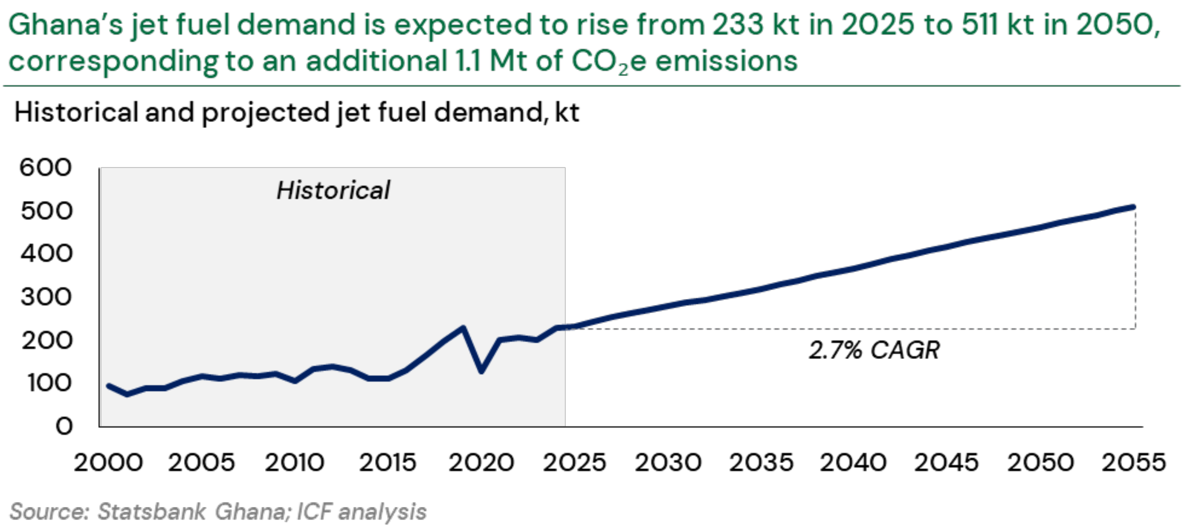


Figure 11: Forecasted growth of conventional jet fuel & SAF demand in Ghana from 2025-2055

While aviation growth is important to economic development, rising jet fuel consumption also means rising CO_2 emissions. Based on these projections, Ghana's well-to-wake CO_2 emissions from aviation are expected to increase from 0.9 Mt in 2025 to 1.9 Mt in 2055, despite expected improvements in aircraft technology and operations.

1.3.3 SAF demand

Overview

Against this backdrop, SAF is widely regarded as the most immediate and effective fuel-based option for reducing aviation emissions. SAF is a drop-in fuel that can significantly reduce life cycle emissions relative to conventional aviation fuel and is already being used in growing volumes in other parts of the world. In practice, SAF demand tends to come from two broad sources: mandated demand and voluntary demand.

Mandated demand arises where governments impose SAF obligations, either through blending requirements, as in the EU, or through emissions reduction requirements, as in jurisdictions such as the UK and Brazil. In the latter case, the value of SAF can also depend on the scale of the carbon intensity reduction. Eligibility also varies by jurisdiction. For example, in the UK and EU, food-based crops are not eligible, which affects which types of SAF can be supplied into those markets.

Voluntary demand may come from airlines, governments, airports, or other buyers setting their own SAF targets, or from the stacking of incentives that brings SAF closer to price parity with conventional aviation fuel. Given that SAF is expected to remain more expensive than conventional jet fuel for the foreseeable future, demand is likely to depend heavily on what enables buyers to meet compliance obligations or voluntary targets at the lowest cost. SAF demand may arise domestically as well as through export opportunities.

Domestic

As noted above, the two largest domestic airlines in Ghana by ASKs are Africa World Airlines and PassionAir. Both showed signs of interest in SAF during interviews conducted for the feasibility study. PassionAir described SAF as a key enabler of long-term sustainability in the aviation sector, while AWA suggested it could potentially play a role through book-and-claim. At the same time, both airlines identified the high price of SAF and its limited availability in Ghana, and in Africa more broadly, as key barriers.

Even so, these airlines account for only a fraction of total jet fuel demand in Ghana. They may still have an important role in supporting early SAF adoption, but the larger commercial opportunity is likely to depend more on the international carriers that account for a much greater share of ASKs and fuel uplift.

Among the airlines that fly most frequently to Ghana on an ASK basis, many are already active in SAF through targets, offtake agreements, or investments in production facilities, as shown on the table below. While many of these airlines are exposed to SAF mandates, a number have SAF commitments that go beyond their mandatory obligation. If SAF could be procured in Ghana at a lower cost than in other regions, whether in absolute terms or on a cost-of-abatement basis, there would likely be an incentive to do so. There may also be strategic and reputational value in supporting SAF production and uplift across a broader network of destinations.

Table 1: SAF initiatives across airlines frequently flying to Ghana

ASK Rank	Airline	SAF Initiative
1	Delta Airlines[64]	10% SAF target by 2030
2	British Airways[65]	10% SAF target by 2030 2.7% current SAF uplift
3	Emirates[66]	MoU to develop SAF initiatives
4	Ethiopian[67]	MoU for SAF uplift in Ethiopia
5	KLM Airlines[68]	10% SAF target by 2030 4.6% SAF uplift in 2025 Applies EU sustainability standards to worldwide uplift
6	United Airlines[69]	0.1% SAF uplift currently, including internationally Invested in over 15 Mt of future SAF

The most likely early source of SAF demand in Ghana is therefore voluntary uplift. However, the extent of that demand will still depend heavily on the policy and commercial environment created within Ghana. This includes whether there is sufficient support for production, whether barriers to project development can be reduced, and whether SAF can be supplied at a cost that buyers are willing to absorb.

To illustrate the scale of potential domestic uptake, the table below presents the volume of SAF that would be required at different blend levels between 2030 and 2055.

Table 2: Projected SAF demand in Ghana from 2030-2055 under varying blend levels

SAF Blend	kt of SAF required					
	2030	2035	2040	2045	2050	2055
1%	3	3	4	4	5	5
2%	6	6	7	8	9	10
5%	14	16	18	21	23	26
10%	28	32	37	42	46	51
20%	56	64	74	84	93	102

64 https://www.esgtoday.com/delta-confirms-commitment-to-10-saf-by-2030-countering-media-reports/
65 https://www.britishairways.com/content/information/about-ba/ba-better-world/planet?msockid=13bed362c30c6c5f25c2c614c2b76dc5
66 https://www.emirates.com/media-centre/emirates-and-enoc-group-sign-mou-to-explore-sustainable-aviation-fuel-supply-in-dubai/?msockid=13bed362c30c6c5f25c2c614c2b76dc5
67 https://corporate.ethiopianairlines.com/Press-release-open-page/sustainable-skies-ethiopian-airlines'-mou-with-satarem-marks-a-new-era-of-eco-friendly-travel
68 https://www.klm.co.uk/information/sustainability/saf?showredirectnotice=1
69 https://www.united.com/en/us/fly/company/responsibility/sustainable-aviation-fuel.html

50%	140	161	185	210	232	255

Source: ICF analysis

It is also worth being careful when comparing potential SAF uptake in Ghana with developed markets. Ghana forms part of a region where aviation demand is likely to be more price-sensitive, and high SAF costs could affect the affordability of air travel if passed through in ticket prices. At the same time, Ghana's international traffic mix includes a substantial share of flights to developed markets, which may make voluntary SAF uptake more plausible, particularly where passengers or corporate buyers are more willing to absorb a premium. Ghana's total jet fuel demand is also relatively modest in absolute terms, which may make initial SAF uptake more manageable from a volume perspective.

Export opportunity

In addition to domestic uplift, further SAF demand could emerge through exports to nearby regional markets or to wider international markets. Many neighbouring countries are also served by international airlines with SAF ambitions and may therefore represent future demand centres. As discussed later, Ghana already has some early momentum around SAF. If able to be an early mover, it could produce SAF not only for domestic use but also for export to neighbouring countries. That would allow Ghana to capture more of the economic value associated with SAF production and could also improve the trade balance.

Neighbouring countries in the wider West African region are projected to have aviation fuel demand of around 2 million tonnes per year by 2050, equivalent to approximately 200 kt of SAF demand at a 10% blend level. This includes Nigeria, Côte d'Ivoire, Angola, Cameroon, Togo, Burkina Faso, Benin, and Guinea. Much of that projected demand comes from Nigeria, which is by far the largest aviation fuel consumer in the region. At present, there are no announced SAF facilities in these nearby countries, which could create an opening for Ghana to establish itself as a regional supplier.

Beyond the region, there is also the possibility of exporting SAF to markets such as the EU and UK. Whether this is feasible will depend on how Ghanaian SAF aligns with those markets' sustainability criteria and how production costs in Ghana compare with production or import economics in those regions. This is particularly relevant for residue-based pathways. Dry feedstocks such as municipal solid waste or agricultural residues have low energy density, making them expensive to transport over long distances in raw form. For some pathways, it may therefore be more economic to convert those feedstocks into SAF in Ghana and transport the fuel instead.

Ghana's geography supports that possibility. Its position in West Africa, with direct access to deep-water ports along the Gulf of Guinea, gives it an advantage as a logistics and export hub. Tema and Takoradi are the country's two main ports and together handle around 85% of Ghana's trade[70]. Tema is the larger of the two, handling roughly twice the annual tonnage of Takoradi[71]. These ports are also important to the wider region, including for transit cargo to landlocked neighbours such as Burkina Faso, Mali, and Niger[72]. Significant investment has also been made in port infrastructure, including the expansion of Tema port from 2016 onwards and upgrades at Takoradi from around 2018. In the SAF context, this matters because it strengthens Ghana's ability to support production oriented not only to domestic uplift, but also to regional distribution and export.

1.3.4 Existing regional SAF activity

The ICAO ACT-SAF Feasibility Study for Ghana states that a SAF roadmap is in development. However, no source is provided for this and no supporting evidence could be identified. More broadly, Ghana's participation in the ICAO ACT-SAF initiative appears to be the first clear point at which SAF has entered the Ghana policy discussion in a visible way. In May 2025, Reverend Stephen

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[70] https://ghanaports.gov.gh/

[71] https://singlewindowcompany.azurewebsites.net/publications/ee8b88d3f70e4c4bb364aff767ca714a.pdf

[72] https://gna.org.gh/2025/02/ghanas-24-hour-economy-are-the-ports-ready-for-non-stop-trade/

Wilfred Arthur, Acting Director-General of the Ghana Civil Aviation Authority, and Joseph Bukari Nikpe, Minister of Transport, attended the ICAO ACT-SAF Project Kick-off meeting. Both acknowledged the potential role of SAF and Ghana's possible production potential[73].

A small amount of momentum is beginning to emerge in Ghana itself. Recent examples include the following:

F&B Bio Recyclage Ltd[74]**:** This registered special purpose entity in Ghana has the authority to build, develop, finance, construct, operate, and maintain waste recycling facilities at the Tema Industrial Enclave. As of October 2025, it had completed Phase 1 of a 2,000 tonnes per day municipal solid waste conversion facility intended to produce SAF and biodiesel using gasification and Fischer-Tropsch technology. Phase 1 involved technology selection, partner engagement, site identification, feedstock assessment, market assessment, and financial structuring. The project is now progressing into pre-FEED. The company has also reportedly received interest from international SAF offtakers, infrastructure investors, and development finance institutions. In December 2025, Saipem S.p.A. and ISS International S.p.A. were appointed as technical consultants.

Amaaba Bio-Refinery Complex[75]**:** In November 2025, Kambic Industrial Partners announced plans to develop the USD 1.3 billion Amaaba Bio-Refinery Complex, which is intended to become Africa's first industrial-scale bamboo biomass refinery and the world's largest biofuel facility based on bamboo feedstock. In collaboration with Honeywell and Chempolis, the refinery is intended to process bamboo into advanced biofuels and green chemicals, including SAF.

Portage Energy[76]**:** In November 2025, Ghana's Vice President Opoku-Agyemang met with Portage Energy to explore opportunities for collaboration to strengthen Ghana's waste management system and advance cleaner energy solutions, including SAF production. Portage Energy is a Canadian company developing municipal solid waste-to-SAF solutions using gasification and Fischer-Tropsch synthesis.

Tema Oil Refinery (TOR)[77]**.** In 2026, TOR indicated an interest in adding co-processing to its existing refinery process and exploring SAF production via the HEFA pathway. If developed, this could provide a refinery-based route for future SAF activity in Ghana.

More widely, the African SAF landscape remains at a very early stage compared with Europe and North America[78]. There are currently no operational commercial SAF production facilities on the continent, and African SAF demand remains weak in the absence of strong policy incentives or blending requirements. Even so, momentum is beginning to build, including the following initiatives:

- AFRAA has signed a memorandum of understanding with AfriSAF to support SAF deployment and production across Africa[79].
- Kenya Airways has worked with KLM to develop a regional policy and investment roadmap for SAF in Africa[80].

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[73] https://www.ghanaweb.com/GhanaHomePage/business/Ghana-poised-to-lead-in-Sustainable-Aviation-Fuel-adoption-GCAA-1984672
[74] https://fbrecyclage.com/category/news/
[75] https://www.ghanaweb.com/GhanaHomePage/africa/Ghana-to-host-world-s-largest-bamboo-biofuel-plant-in-1-3-billion-Kambic-project-2009549
[76] https://www.ghanaweb.com/GhanaHomePage/business/Ghana-explores-clean-energy-partnership-with-Portage-Energy-2010126
[77] https://onlinetimesgh.com/tor-targets-sustainable-aviation-fuel-production-in-major-strategic-shift/
[78] https://view.argusmedia.com/rs/584-BUW-606/images/PRO-SAF-Capacity-Map-17-Dec-2025.pdf?version=0
[79] https://www.afraa.org/press-release-afraa-and-afrisaf-sign-memorandum-of-understanding-to-accelerate-sustainable-aviation-fuel-development-across-africa/
[80] https://corporate.kenya-airways.com/en/news-press-release/2025/october/kenya-airways-and-klm-chart-first-regional-saf-policy-roadmap-to-power-sustainable-aviation-in-africa/

- The African Development Bank has signed a letter of intent to support decarbonisation of aviation fuel and wider SAF adoption across the continent[81].

Overall, SAF activity in Ghana and the wider region remains early-stage. However, the combination of emerging project announcements, growing institutional attention, and a still relatively open regional landscape suggests there may be a first-mover opportunity for Ghana if credible projects can be developed.

1.4 SAF pathway evaluation and selection

The purpose of this section is to identify which SAF pathways should be taken forward for detailed techno-economic assessment. It begins by summarising the feedstock findings from the ACT-SAF Feasibility Study for Ghana, before linking those feedstocks to the conversion pathways most relevant to the Ghanaian context. It then introduces the screening criteria used to compare pathways and narrows the longlist to five pathways for assessment in Chapter 2.

1.4.1 Summary of feasibility study findings

The ACT-SAF Feasibility Study for Ghana assessed a range of potential feedstocks for SAF production. Each feedstock was scored across five categories: availability, sustainability, collection, market viability, and spillover effects, as shown in the figure below. The feasibility study does not explain the scoring methodology in detail.

Table 3: Results of the feedstock assessment from the ACT-SAF Feasibility Study for Ghana

Feedstock	Availability	Sustainability	Collection	Market Viability	Spillover Effects
Cassava residues	◕	◕	◑	◕	◕
MSW	●	◕	◑	◕	◕
Palm oil residues	◕	◑	◕	◕	◑
Livestock & fisheries residues	◑	◕	◕	◑	◑
Sweet sorghum	◕	◕	◑	◑	◑
Maize residues	◕	◑	◑	◑	◑
Cocoa pod residues	◑	◕	◑	◑	◑
Rice residues	◑	◑	◑	◑	◑
Water hyacinth	◔	◕	◔	◔	◑

Source: Ghana Feasibility Study

Note: The scores achieved for sweet sorghum are potential, not current. The availability is assumed based on the hypothetical scaling of grain sorghum production in Ghana.

[81] https://www.jgc.com/en/news/2025/20250916

High-level takeaways from the feasibility study are summarised for each feedstock below. A consistent issue across the feedstocks is collection. Ghana has significant biomass potential, but much of it is dispersed across smallholder farms or informal supply chains. Limited mechanisation, weak aggregation infrastructure, seasonal availability, and competing uses all reduce the share of feedstock that can realistically be recovered for SAF production.

Cassava residues emerged as one of the strongest feedstock options in the feasibility study. Ghana produces over 20 Mt of cassava annually, generating substantial volumes of tubers and associated residues such as peels and bagasse. The main constraints are fragmented collection, smallholder production, high moisture content, and handling complexities. While cassava residues may be low-cost at source, significant investment would still be needed to create the collection, preprocessing, and logistics system required for SAF production. Cassava tubers, the primary cassava product, were also quantified in the feasibility study and are a staple food source in Ghana.

Municipal solid waste was assessed as a high-potential long-term feedstock. MSW scored strongly due to rapid urbanisation, growing waste volumes, and its generally favourable sustainability position under international frameworks. It also offers wider benefits through landfill diversion and methane emissions reduction. However, Ghana's waste system still faces practical barriers, including limited segregation, weak collection systems, contamination, and high preprocessing costs.

Palm oil residues were identified as one of the stronger feedstock options. Ghana's palm sector generates several relevant residue streams, including empty fruit bunches, palm kernel shells, palm oil mill effluent (POME), and palm fatty acid distillates (PFAD). A key advantage is that several of these streams are generated around mills, making collection more straightforward than for residues dispersed across farms. PFAD and POME oil are particularly relevant to HEFA and co-processing pathways.

Livestock and fisheries residues represent a smaller but relatively steady feedstock opportunity. Total volumes are lower than for crop-based residues, but these streams are more concentrated, which improves collection potential. They also have a strong sustainability position under frameworks such as CORSIA and the EU Renewable Energy Directive (RED), although their scalability is limited by overall supply and existing uses in other local markets.

Sorghum residues were treated as a more conditional opportunity. The feasibility study identified sorghum as a potential option, with potential linked to future production growth and regional concentration in northern Ghana. However, the availability score is based partly on the hypothetical scaling of sweet sorghum rather than an established SAF feedstock base today. Collection would also be constrained by bulkiness and rapid degradation.

Maize residues were recognised as abundant in gross terms, but difficult to recover efficiently. Maize stover, including stalks, cobs, leaves, and husks, is widely available due to Ghana's broad maize cultivation base. Challenges, however, include dispersed production, seasonal availability, and competition from other sectors.

Cocoa pod husks were identified as a high-potential but logistics-sensitive feedstock. Ghana's cocoa sector generates substantial volumes of husks, and concentration within the cocoa belt improves the potential for aggregation around processing areas. However, the dispersion of smallholder farms, as well as logistical and preprocessing barriers, still creates collection challenges.

Rice residues were considered technically possible, but more technically challenging than several other agricultural residues in the Ghana context. Rice cultivation generates meaningful volumes of straw and husks, but these are seasonal, exposed to climatic variability, and subject to competing uses such as bedding, soil incorporation, and local fuel. High silica and ash content also make rice residues more technically challenging than several other agricultural residues.

Water hyacinth scored weakest despite its abundance in some water bodies. It is generally regarded as an invasive nuisance and may offer environmental benefits if harvested, but it faces clear practical and eligibility constraints. Supply stability is uncertain, moisture content is very high, and the feedstock is not currently listed as eligible under CORSIA, EU, or UK frameworks.

1.4.2 SAF pathway options

Three of the feedstocks identified in the feasibility study are excluded from further consideration:

- **Sorghum residues** are excluded because Ghana does not currently cultivate sweet sorghum at scale, and the feasibility study analysis is therefore based on the assumption that this crop could be introduced or expanded in future. While it may become relevant over time, it is less suitable for a near-term business case.
- **Water hyacinth** is excluded because it is the weakest-scoring feedstock and faces clear practical and eligibility constraints. High water content, uncertain supply stability, and current absence from major eligibility frameworks make it less suitable for detailed TEA in this study.
- **Municipal solid waste** is also excluded, but not because it lacks potential. The F&B project discussed in Section 1.3 already aims to use a significant share of the MSW availability identified in the feasibility study. Given Ghana's current waste collection constraints and underdeveloped segregation infrastructure, it would not be reasonable to assume that a second MSW-to-SAF pathway could also be developed on a credible basis at this time[82,83].

The remaining feedstocks are then paired with the most relevant SAF conversion technologies to develop the pathway longlist. Palm oil residues and fishery/livestock residues fall within the fats, oils, and greases category, and are therefore suited to HEFA and co-processing. In the HEFA route, lipid feedstocks are hydroprocessed and upgraded into SAF and other fuels. In co-processing, renewable feedstocks are introduced into an existing refinery process alongside fossil feedstocks, producing a fuel pool that includes a renewable share.

Cassava tubers are considered under first generation Alcohol-to-Jet (AtJ). While AtJ facilities are ethanol-agnostic in technical terms, this study distinguishes between first and second-generation ethanol because the economics and sustainability position differ meaningfully by feedstock. In the first-generation case, starch-rich cassava tubers are converted into ethanol before being upgraded into SAF and co-products.

The remaining residue feedstocks, including cassava residues, maize residues, rice residues, and cocoa pod husks, are considered under second-generation AtJ and Fischer-Tropsch (FT). In the second-generation AtJ route, lignocellulosic residues are converted into ethanol before being upgraded into SAF. In the FT route, biomass is gasified to produce syngas, which is then converted into liquid hydrocarbon fuels.

The longlist consists of thirteen possible pathways, as shown below.

Table 4: Feedstock & conversion technology combinations for potential SAF pathways in Ghana

Conversion Technology	Feedstock
HEFA	Palm Oil Residue
	Fishery/Livestock Residue
Co-Processing	Palm Oil Residue
	Fishery/Livestock Residue
Alcohol-to-Jet (1G)	Cassava Tubers
Alcohol-to-Jet (2G)	Cassava Residue
	Maize Residue
	Rice Residue

[82] https://www.mdpi.com/2071-1050/17/18/8266
[83] https://www.theigc.org/sites/default/files/2024-09/Oteng-Ababio%20Policy%20Brief%20September%202024.pdf

Conversion Technology	Feedstock
	Cocoa Pod Husks
Fischer-Tropsch	Cassava Residue
	Maize Residue
	Rice Residue
	Cocoa Pod Husks

Source: ICF analysis

1.4.3 SAF pathway evaluation

This section introduces the main parameters used to compare the longlist of SAF pathway options. While one pathway within each technology grouping is ultimately selected for detailed techno-economic analysis (TEA), the assessment here remains high level. Its purpose is to support pathway screening and provide a general understanding of how the options compare, rather than to determine final project economics. Detailed technical design, production costs, minimum fuel selling prices (MFSPs), and pathway-specific assumptions are assessed in Chapter 2.

The screening considers feedstock viability, carbon intensity, eligibility, technical qualification under ASTM International specification, technology readiness, indicative CAPEX, and likely time to first production. These factors are not intended to replace detailed feasibility work, but they provide a structured basis for narrowing the pathway options before undertaking the TEA.

Feedstock viability

Feedstock could theoretically be imported for SAF production in Ghana, but there are clear disadvantages to that approach. Importing feedstock would increase logistics costs and could introduce taxes or other charges that raise the cost of production. It would also reduce some of the domestic economic benefit that could otherwise be captured through local feedstock collection, preprocessing, and conversion. In the case of second-generation ethanol from agricultural residues, for example, domestic value can be created not only through SAF production, but also through the residue collection system and ethanol production stage.

SAF availability depends on how much of the gross feedstock volume can be collected sustainably and at reasonable cost, after accounting for competing uses, recovery constraints, seasonality, and logistics. Moreover, the amount of SAF that can ultimately be produced from a given feedstock also varies by technology, and this is accounted for in the pathway comparison below.

To evaluate SAF production potential, a 1 to 4 score was applied. Pathways with more than 200 kt/year of SAF potential receive the highest score, while pathways below 50 kt/year receive the lowest score. The latter may still be relevant, particularly for co-processing, but are less likely to support a standalone SAF production facility. It should also be noted that several conversion technologies can use more than one feedstock type, meaning that feedstock-to-SAF conversion assumptions would vary on a facility-by-facility basis.

Table 5: SAF potential across varying conversion technologies and feedstock types

Conversion Technology	Feedstock	SAF Potential (Kt)	Score
HEFA	Palm Oil Residue	10	◔
	Fishery/Livestock Residue	60	◑
Co-Processing	Palm Oil Residue	10	◔

Conversion Technology	Feedstock	SAF Potential (Kt)	Score
	Fishery/Livestock Residue	60	◑
Alcohol-to-Jet (1G)	Cassava Tubers	223	●
Alcohol-to-Jet (2G)	Cassava Residue	92	◑
	Maize Residue	135	◕
	Rice Residue	55	◑
	Cocoa Pod Husks	6	◔
Fischer-Tropsch	Cassava Residue	62	◑
	Maize Residue	91	◑
	Rice Residue	52	◑
	Cocoa Pod Husks	14	◔

Caveats on feedstock availability from the feasibility study

The feedstock availability values used in this screening are adopted from the feasibility study and should be treated as indicative rather than definitive project assumptions.

- In most cases, the values represent theoretical or high-level technical potential. They are generally based on a single data point and do not change over time.
- Fish oil and fat availability appears to have been assessed using an assumed recovery rate of 20% of fish production. In practice, recoverable fish oil volumes will depend on fish species, processing methods, collection systems, existing uses, and whether the oil can be collected in suitable condition. Actual collectable volumes may therefore be materially lower.
- Cassava residue availability is also uncertain. The feasibility study assumes that only 25% of cassava processing residues are captured, but the theoretical potential appears to be based on all cassava being processed. In practice, only a limited share of cassava produced in Ghana is believed to be processed industrially, with much of it consumed or prepared through more informal channels.

These caveats do not undermine the usefulness of the screening exercise, but they do mean that any pathway taken forward would require more detailed feedstock due diligence before project development.

Carbon Intensity

The carbon intensity of SAF varies significantly by pathway and can affect both demand and value. One reason is that SAF must meet minimum life cycle emissions thresholds to qualify under different policy frameworks. Relative to conventional aviation fuel, these thresholds vary by jurisdiction. In the UK and US, SAF must achieve a 40% and 50% reduction respectively against a baseline of 89 gCO_2e/MJ. In the EU, the Renewable Energy Directive requires a 65% reduction for biofuels relative to a fossil comparator of 94 gCO_2e/MJ, while renewable fuels of non-biological origin must meet a 70% reduction.

Carbon intensity can also affect the value of SAF where policy frameworks reward deeper emissions reductions. In the UK, for example, SAF certificate value is linked to emissions performance. In Brazil, the obligation is framed around sectoral emissions reduction rather than a simple blend level. Even outside formal mandate systems, stronger carbon intensity performance can improve the monetisable environmental value of SAF, particularly where airlines or corporate buyers are seeking high-integrity emissions reductions.

For this screening, CORSIA default life cycle values are used as indicative carbon intensity values where available. These values are not Ghana-specific and do not replace a project-level life cycle assessment. They are, however, useful for comparing the relative emissions performance of pathways at this stage.

A 1 to 4 scoring scale was used. Pathways that achieve around a 90% reduction receive the highest score. Pathways meeting the EU RED 65% reduction threshold receive the next highest score, followed by pathways meeting the UK SAF Mandate 40% reduction threshold, and then the CORSIA 10% reduction threshold.

Table 6 Carbon intensity across varying conversion technologies and feedstock types

Conversion Technology	Feedstock	Carbon Intensity (gCO_2e/MJ)	Score
HEFA	Palm Oil Residue	POME: 18.1 PFAD: 20.7	◕
HEFA	Fishery/Livestock Residue	28.6	◕
Co-Processing	Palm Oil Residue	Assumed same as HEFA	◕
Co-Processing	Fishery/Livestock Residue	Assumed same as HEFA	◕
Alcohol-to-Jet (1G)	Cassava Tubers	N/A	
Alcohol-to-Jet (2G)	Cassava Residue	Standalone conversion design: 39.7 Integrated conversion design: 24.6	◑
Alcohol-to-Jet (2G)	Maize Residue	Standalone conversion design: 39.7 Integrated conversion design: 24.6	◑
Alcohol-to-Jet (2G)	Rice Residue	Standalone conversion design: 39.7 Integrated conversion design: 24.6	◑
Alcohol-to-Jet (2G)	Cocoa Pod Husks	Standalone conversion design: 39.7 Integrated conversion design: 24.6	◑
Fischer-Tropsch	Cassava Residue	7.7	●
Fischer-Tropsch	Maize Residue	7.7	●
Fischer-Tropsch	Rice Residue	7.7	●
Fischer-Tropsch	Cocoa Pod Husks	7.7	●

For co-processing, directly equivalent CORSIA values were not available for the specific pathway configuration considered in this study. The screening therefore assumes values broadly comparable to HEFA using the same feedstock, although actual co-processing values may be higher depending on refinery configuration, hydrogen source, allocation methodology, and the share of renewable feedstock. For agricultural residues, the same default values are applied across residue types for screening, but actual results would vary depending on feedstock logistics, preprocessing, power source, facility configuration, and whether the process is integrated. Additionally, there are no default life cycle values available for first-generation Alcohol-to-Jet derived from cassava tubers.

Eligibility

Alongside carbon intensity requirements, SAF must also meet broader eligibility requirements. Under CORSIA, this includes the principles captured in the table below.

Table 7 CORSIA sustainability criteria

Theme	Principle
Greenhouse Gases (GHG)	CORSIA SAF should generate lower carbon emissions on a life cycle basis. (10% reduction relative to 89 gCO_2e/MJ baseline required)
Carbon stock	CORSIA SAF should not be made from biomass obtained from land/aquatic systems with high biogenic carbon stock.
Greenhouse gas Emissions Reduction Permanence	Emissions reductions attributed to CORSIA SAF should be permanent.
Water	Production of CORSIA SAF should maintain or enhance water quality and availability.
Air	Production of CORSIA SAF should minimize negative effects on air quality.
Conservation	Production of CORSIA SAF should maintain biodiversity, conservation value, and ecosystem services.
Waste and Chemicals	Production of CORSIA SAF should promote responsible management of waste and use of chemicals.
Seismic and Vibrational Impacts	Production of CORSIA SAF should minimize seismic, acoustic, and vibrational impacts from CCS.
Human and labour rights	Production of CORSIA SAF should respect human and labour rights.
Land use rights and land use	CORSIA SAF production should respect land rights & land use rights including indigenous and/or customary rights.
Water use rights	Production of CORSIA SAF should respect prior formal or customary water use rights.
Local and social development	Production of CORSIA SAF should contribute to social and economic development in regions of poverty.
Food security	Production of CORSIA SAF should promote food security in food insecure regions.

New pathways can be added to the list of CORSIA Eligible Fuels with default LCA values by request of an ICAO Member State, observer organisation, or approved sustainability certification scheme. In practice, this requires:

- the pathway to use an ASTM-certified conversion process;
- the conversion process to be validated at sufficient scale to support commercial design and operating assumptions;
- sufficient data on the conversion process to perform LCA modelling;
- sufficient data on the feedstock to perform LCA modelling; and
- sufficient data on the region to perform ILUC modelling, where relevant.

There are currently three sustainability certification schemes approved by ICAO: ISCC, RSB, and ClassNK. These provide the basis through which sustainability compliance can be demonstrated under CORSIA.

Other jurisdictions impose additional requirements. The EU and UK treatment of food and feed crops is particularly important, as these frameworks do not accept food-competing crops as eligible SAF feedstocks. A pathway that appears viable in Ghana may therefore have limited access to some export markets if it does not meet those feedstock rules.

For this screening, eligibility is assessed using the available default life cycle values and the feedstock treatment under each framework. The classifications should therefore be treated as screening assumptions rather than final certification outcomes. The only pathway treated as ineligible under the UK SAF Mandate and ReFuelEU Aviation is AtJ using cassava tubers, because cassava is a food crop. Waste and residue pathways are treated as eligible in principle where the available default values and feedstock classifications support this, subject to project-specific carbon intensity performance, certification, and confirmation of feedstock classification.

A separate potentially eligible category is used where a pathway could meet the relevant framework requirements, but only if the project is designed to reduce life cycle emissions or provide further supporting evidence. This applies to AtJ using agricultural residues under ReFuelEU Aviation. Based on the standalone CORSIA default value, this pathway does not meet the EU emissions threshold, but measures such as renewable electricity use, process integration, improved logistics, or other emissions-reduction steps could reduce the life cycle carbon intensity below the required level. It is therefore treated as potentially eligible, recognising that a producer targeting EU markets would need to design the project accordingly.

Table 8 Pathway eligibility under various mandates

Metric	Score	Score Definition	Pathways
CORSIA Eligibility	●	Eligible	All Pathways
	◔	Not Eligible	N/A
UK SAF Mandate Eligibility	●	Eligible	Co-processing, HEFA, AtJ – Agricultural Residues, FT
	◔	Not Eligible	AtJ – Cassava Tubers
ReFuelEU Aviation Eligibility	●	Eligible	Co-processing, HEFA, FT
	◑	Potentially Eligible	AtJ – Agricultural Residues
	◔	Not Eligible	AtJ – Cassava Tubers

ASTM Qualification

The technical quality of conventional aviation fuel is defined primarily by ASTM D1655, while the specifications for synthetic aviation turbine fuels are defined in ASTM D7566. For a SAF pathway to be approved for use, it must pass through the ASTM D4054 evaluation process, which includes fuel property testing, engine testing, and OEM review. Once a pathway is approved, an annex is added to ASTM D7566 setting out the relevant property specifications. A producer using an already approved pathway does not need to repeat the full approval process but must demonstrate that its fuel meets the specifications under the relevant annex.

There are currently eleven approved conversion processes for SAF production. These include eight routes listed in ASTM D7566 for neat SAF production and three co-processing pathways listed in ASTM D1655. A further eleven conversion processes are currently under evaluation through ASTM

D4054 at the time of writing[84]. All pathways considered in this study use ASTM-approved conversion routes.

Table 9 ASTM qualification across varying pathways

Metric	Score	Score Definition	Pathways
ASTM Qualification	●	Approved	All Pathways
	◔	Not Approved	N/A

Project financing

Project financing is also an important screening factor. One of the clearest differences between pathways is CAPEX. Although CAPEX ultimately feeds into the production cost assessed in Chapter 2, it is useful to consider it separately at the screening stage because it is also a practical measure of how difficult a project may be to finance. Different SAF pathways require very different levels of upfront capital investment, and FT projects are generally more capital-intensive than pathways such as AtJ, HEFA, or co-processing.

High capital intensity is not the same as high fuel cost, since a lower-CAPEX pathway may still have higher operating costs. However, capital intensity affects the amount of funding required and the risk borne by lenders and equity investors. This is particularly relevant in markets where concessional finance is limited, or where only part of the capital stack can realistically be supported by public or blended finance.

Technology readiness is closely linked to this. HEFA and co-processing are established routes and therefore carry lower delivery risk than more advanced pathways. AtJ has reached early commercial operation but remains less widely deployed. FT is technically proven in other contexts, but biomass-to-liquids FT SAF has a more difficult commercial track record and is likely to be viewed as higher risk by investors.

Time to first production is also considered. Co-processing within an existing refinery is unlikely to require the same development timeline as a new FT facility, which would require more complex engineering, more extensive financing, and extended delivery arrangements.

Table 10 Project financing requirements across various conversion technologies

Metric	Score	Pathways
CAPEX Required	●	Co-processing
	◐	HEFA, AtJ
	◔	FT
Technical Readiness	●	Co-processing, HEFA
	◐	AtJ
	◔	FT
Time to First Production	●	Co-processing

[84] https://www.icao.int/SAF/saf-conversion-processes

Metric	Score	Pathways
	◕	HEFA
	◑	AtJ
	◔	FT

Note: AtJ is generally treated as between HEFA and FT for delivery risk and time to production. The exact position depends on technology provider, project scale, ethanol supply arrangements, and whether ethanol production is integrated or off-site.

1.4.4 SAF pathway selection

The decision matrix below shows how the longlisted SAF pathways compare across the screening categories described above. The results are broadly consistent with the feedstock rankings in the feasibility study, although there are important differences when pathways are evaluated rather than feedstocks alone. For example, a feedstock may score well in terms of availability but still be less attractive if it is linked to a high-CAPEX, less mature, or more difficult-to-finance conversion route.

Table 11 Results of the decision matrix

Feedstock	Fishery & Livestock Residue	Palm Oil Residue	Fishery & Livestock Residue	Palm Oil Residue	Cassava Tubers	Cassava Residues	Maize Residues	Rice Residues	Cocoa Pod Husks	Cassava Residues	Maize Residues	Rice Residues	Cocoa Pod Husks
Conversion Technology	HEFA		Co-Processing		Alcohol-to-Jet (1G)	Alcohol-to-Jet (2G)				Fischer-Tropsch			
Production Volumes	◑	◔	◑	◔	●	◑	◕	◑	◔	◑	◑	◑	◔
Carbon Intensity	◕	◕	◕	◕	○	◑	◑	◑	◑	●	●	●	●
CORSIA Eligibility	●	●	●	●	●	●	●	●	●	●	●	●	●
UK SAF Eligibility	●	●	●	●	◔	●	●	●	●	●	●	●	●
ReFuelEU Eligibility	●	●	●	●	◔	◑	◑	◑	◑	●	●	●	●
ASTM Qualification	●	●	●	●	●	●	●	●	●	●	●	●	●
CAPEX Required	◑	◑	●	●	◑	◑	◑	◑	◑	◔	◔	◔	◔
Technical Readiness	●	●	●	●	◑	◑	◑	◑	◑	◔	◔	◔	◔
Time to Production	◕	◕	●	●	◑	◑	◑	◑	◑	◔	◔	◔	◔

The pathways assessed in this study are not mutually exclusive options but represent a broader set of SAF opportunities that could support Ghana's aviation decarbonisation over time. Five pathways are taken forward because, together, they provide a representative cross-section of the main production routes relevant to Ghana, spanning different feedstocks, conversion technologies, maturity levels, eligibility considerations, and investment profiles. The purpose of the matrix is therefore not to provide a final judgement on pathway quality, but to identify a set of sufficiently strong and distinct options for detailed TEA analysis in Chapter 2. On this basis, one pathway was selected for each main technology grouping, with an additional split retained between first generation and second generation AtJ.

For co-processing, palm oil residues are selected. While available palm oil residue volumes would not be sufficient to support a large standalone HEFA facility, they are more plausibly suited to co-processing within an existing refinery context. Co-processing can accommodate smaller sustainable feedstock volumes because the renewable input is blended into a wider refinery stream rather than supplying a dedicated standalone SAF plant.

For standalone HEFA, fishery and livestock residues are selected. This provides a route based on waste-derived lipid feedstocks and allows comparison with co-processing in terms of scale, maturity, CAPEX, and likely economics. The main uncertainty is feedstock availability, particularly whether the volumes identified in the feasibility study can be collected in practice and in suitable condition.

For AtJ using first generation ethanol, cassava tubers are selected. This reflects the scale of cassava production in Ghana and the importance of understanding how a 1G ethanol route compares with waste- and residue-based alternatives. This pathway would not qualify under the UK SAF Mandate or ReFuelEU Aviation because cassava is a food crop. It is still useful as a comparator, given Ghana's cassava resource base and existing interest in cassava-derived ethanol.

For AtJ using second generation ethanol, maize residues are selected. Maize residues have the highest SAF potential among the residue-based AtJ pathways considered and are directly relevant to Ghana's agricultural base. This pathway also allows the study to assess whether domestic value could be created by converting bulky agricultural residues into 2G ethanol and then SAF, rather than relying on imported or globally traded feedstocks.

For FT, cassava residues are selected. Cassava residues scored strongly in the feasibility study and represent one of the larger residue opportunities identified in Ghana, although their practical availability depends heavily on processing assumptions. This pathway allows the TEA to assess a thermochemical route using an agricultural processing residue and compare it with the ethanol-based AtJ pathway using maize residues.

HEFA facilities can use a range of lipid feedstocks, including waste fats, oils, and greases, provided they meet the required technical specifications and sustainability criteria. Fishery and livestock residues are modelled in the TEA as the standalone HEFA case, but other eligible lipid feedstocks could also be relevant if sufficient volumes can be collected and certified. The practical limitation for Ghana is therefore less about HEFA technical compatibility and more about the scale, cost, competing uses, and traceability of suitable lipid feedstocks.

AtJ facilities are ethanol-agnostic and can accept ethanol from multiple sources, provided the ethanol meets the required technical, sustainability, and eligibility requirements. The AtJ pathway is therefore not tied to a single feedstock. Different ethanol sources will, however, have different yields, costs, carbon intensities, and eligibility positions. Maize residues, cassava residues, cassava tubers, and other ethanol sources could all support SAF production in principle, but the TEA models two specific AtJ cases: AtJ using 1G ethanol from cassava tubers and AtJ using 2G ethanol from maize residues.cFT facilities can also use a range of biomass feedstocks, although feedstock quality, moisture content, consistency, ash content, and logistics would affect facility design and performance. Maize residues and cocoa pod husks could therefore support FT-based SAF production in principle. The feasibility study suggests that maize residues are available in sufficient volume in theory, while cocoa pod husk potential could increase further through cooperation with Côte d'Ivoire. However, this study does not assume cross-border cocoa feedstock availability, given the added complexity of developing a cross-border SAF supply chain and the wider sustainability sensitivities around cocoa-linked land use in both countries.

The selected pathways therefore provide a balanced basis for the TEA. They cover near-term refinery integration, mature lipid-based SAF production, AtJ using first-generation ethanol, AtJ using second-generation ethanol, and thermochemical conversion of agricultural residues. This allows the following chapter to compare not only different feedstock types, but also the wider trade-offs between scale, maturity, carbon intensity, eligibility, CAPEX, and delivery risk.

2 Techno-economic Assessment

Following the pathway screening in Section 1.4, five pathways are taken forward for techno-economic assessment:

- Co-processing of palm oil residues;
- HEFA using fishery and livestock residues;
- AtJ using 2G ethanol derived from maize residues;
- AtJ using 1G ethanol derived from cassava tubers; and
- FT production using cassava residues.

The objective of this chapter is to compare the selected pathways on a consistent cost basis and identify the main drivers of production cost. It first sets out the common methodology and modelling assumptions used across the assessment. Each pathway is then assessed in turn, covering the feedstock, the conversion technology, the main sustainability considerations, the key inputs and assumptions and the resulting cost estimates.

A sensitivity analysis is then used to test the effect of key cost and financing assumptions on the minimum fuel selling price. The implications of the TEA results, and the rationale for selecting the preferred business case, are discussed at the beginning of Chapter 3.

2.1 Methodology

To evaluate the potential viability of commercial SAF production in Ghana, the production cost of SAF was assessed for each pathway using a discounted cash flow (DCF) model developed in Microsoft Excel. The minimum fuel selling price (MFSP) of SAF was used as the primary economic indicator. The MFSP represents the SAF selling price required for the project to achieve a net present value (NPV) of zero at the end of the project life, based on the assumed mix of concessional debt, commercial debt, grant funding, and equity.

The production cost of SAF is estimated using CAPEX, variable operating expenditure (variable OPEX), and fixed operating expenditure (fixed OPEX). These are calculated using a combination of publicly available CAPEX information, material and energy input requirements, and pricing inputs, as described below.

Financial structure

The financial model applies a financing waterfall, with concessional debt and grant funding assumed to be used before commercial debt and equity. This reflects the reality that capital-intensive SAF projects in Ghana, where domestic commercial debt and equity costs are relatively high, are likely to be difficult to finance without concessional support.

All pathway models first assume participation in the **World Bank's International Development Association (IDA)** loan programme for the first USD 250 million of CAPEX[85], with a five-year grace period and a 5% interest rate for the final 20 years of the 25-year term[86]. If CAPEX exceeds USD 250 million, up to a further USD 150 million is assumed to be financed through the **World Bank Scale-Up Window (SUW)**, at a 5.2% interest rate over a 20-year term[87]. The maximum capital outlay is assumed to be within Ghana's indicative SUW limits and IDA country allocation under the applicable replenishment cycle. For projects with CAPEX above USD 400 million, up to USD 50 million of **climate grant funding** is then applied. For projects with CAPEX above USD 450 million, the remaining funding requirement is split 60:40 between **commercial debt and equity**.

[85] https://treasury.worldbank.org/en/about/unit/treasury/ida-financial-products
[86] https://thedocs.worldbank.org/en/doc/5b9cc40a9dbfc95f546be3240e2d4c82-0410012025/original/IDA21-Terms-effective-01-01-2026-clean.pdf
[87] https://thedocs.worldbank.org/en/doc/6438005aba66b3ec6bb1c5b522da4ee0-0340012021/original/IDA19-Scale-Up-Window-Financing-Product-Note.pdf

Table 12 Financing sources and terms across different CAPEX requirements

CAPEX tranche	Financing source	Assumed terms
Up to USD 250 million	World Bank International Development Association (IDA)	25-year term; five-year grace period; 5% interest rate for the final 20 years; 1.3% service charge
USD 250–400 million	World Bank Scale-Up Window (SUW)	20-year term; 5.2% interest rate
USD 400–450 million	Climate grant funding	Grant funding; no repayment assumed
Above USD 450 million	Commercial debt and equity	Remaining funding requirement split 60:40 between commercial debt and equity; commercial debt assumed at 23% during construction and 20% during operations; equity return assumed at 28.5%

Note: *For projects with CAPEX below USD 450 million, 5% of total project cost is reserved for commercial debt and equity, split 60:40 between commercial debt and equity. The remaining 95% is allocated through the concessional financing waterfall up to the relevant CAPEX threshold.*

CAPEX

CAPEX represents the initial investment required for the equipment and infrastructure needed to deliver the project. It includes direct costs, such as equipment and labour required to construct the facility; indirect costs, such as construction support facilities and taxes; contingencies and EPC profit; and owner's costs, including project financing, engineering, and permitting-related expenses.

Equipment costs are categorised into two main types. Inside battery limits (ISBL) costs relate to the primary process equipment and technology vendor scope. Outside battery limits (OSBL) costs relate to ancillary and supporting equipment required for facility operation, such as cooling towers, feedstock dryers, storage tanks, wastewater treatment, and other utilities. ISBL costs used in this study are based on literature values. OSBL costs are included as a factor of ISBL costs, depending on the type of supporting equipment required for each pathway.

The equipment costs used in this study are based on US cost data. A location factor is therefore applied to reflect the cost of building the plant in Ghana rather than in the US. Differences in bulk material costs, labour rates, tariffs, taxes, and construction conditions can all affect equipment and installation costs by location. For this assessment, a location factor of 1.17 is applied, consistent with the factor used in the Zimbabwe Business Implementation Report[88]. The Zimbabwe location factor is used as a proxy.

The cost estimates presented in this report are at an AACE Class 5 level. Total CAPEX is then included in the financial model to estimate the MFSP for each SAF pathway. More precise cost estimates would require project-specific information, vendor quotes, and further engineering design. Costs in this study are presented in 2025 US dollars and are escalated where necessary using the Chemical Engineering Plant Cost Index (CEPCI) [89].

Variable OPEX

Variable OPEX includes expenses incurred during operation of the facility that vary with production. These include feedstock costs and utility costs, such as electricity, natural gas, process

[88] *Awaiting publication.* Business Implementation Study on the use of Sustainable Aviation Fuels - Zimbabwe, ICAO

[89] https://www.chemengonline.com/pci-home/

water, wastewater disposal, and chemical inputs. Variable costs are calculated using feedstock and utility pricing information, process energy and material requirements, and feedstock requirements for each pathway, as set out in the pathway-specific inputs.

Fixed OPEX

Fixed OPEX includes operating expenses that are incurred during facility operation but are not directly driven by production volume. These include maintenance expenses, labour costs, insurance, property tax, and major maintenance or capital-related expenses. Major maintenance expenses include larger and less frequent activities, such as catalyst replacement, refractory replacement, and capital improvements to the facility.

Common facility inputs

A number of inputs are common across all five pathway models, including material and energy inputs, utility prices, and financial assumptions. The financial investment decision (FID) year is assumed to be 2029 and the operational lifespan is assumed to be 20 years, which is a conservative assumption based on the 25-year life reported in the TEA analysis by Ahire et al. (2024) for SAF plants using forest residues.

Utility price inputs are Ghana-based where available. Electricity prices are based on GlobalPetrolPrices.com, while natural gas and water prices are based on information from the Ghana Public Utilities Regulatory Commission. Wastewater disposal costs are estimated using information from DeCarolis et al. (2007). Renewable diesel price is based on projections from Tan et al. (2021), while the naphtha price is based on historical prices prior to recent increases linked to Middle East conflicts.

The assumptions for maintenance, property tax, insurance, and working capital are based on ICF experience. Terms, rates, and grace periods for World Bank-related inputs, including IDA and SUW, are based on World Bank information. Commercial debt terms and rates are estimated using Ghana-based bank information and Ghana-specific information from Trading Economics. The equity rate is estimated using information from a 2024 economic report prepared by the Embassy of Switzerland for Ghana. Ghana's inflation rate is estimated using Statista. The percentage of project cost to depreciate and the blended corporate income tax rate are based on Ghana-specific corporate deductions and tax information from PwC. The common inputs used for each pathway are shown in the table below.

Table 13 List of inputs and assumptions used in the TEA

Input	Unit	Quantity
General facility inputs		
FID Year[90]	n/a	2029
Operational Lifespan[91]	Years	20
Process and energy/utility inputs		
Electricity Base Price[92]	USD/MWh	125
Natural Gas Price[93]	USD/MMBtu	7.63
Water Base Price[94]	USD/thousand gallon	3.3
Wastewater Disposal Costs[95]	USD/thousand gallon	3.5
Renewable Diesel Price[96]	USD/tonne	928
Naphtha Price[97]	USD/tonne	605

[90] ICF Assumption
[91] https://pubs.rsc.org/en/content/articlelanding/2024/se/d4se00749b
[92] https://GlobalPetrolPrices.com
[93] https://www.purc.com.gh/attachment/193147-20250508090515.pdf
[94] https://www.purc.com.gh/attachment/201729-20251202031237.pdf
[95] https://www.accesswater.org/?id=-293950
[96] https://www.nrel.gov/docs/fy21osti/78237.pdf
[97] https://tradingeconomics.com/commodity/naphtha

Input	Unit	Quantity
General Maintenance[90]	% of direct capital	1.5
Major Maintenance[90]	% of direct capital	1.0
Property Taxes[90]	% of direct capital	1.0
Insurance[90]	% of direct capital	0.8
Financial inputs		
Working Capital[90]	Days	90
IDA/World Bank Term[98]	Years	25
IDA/World Bank Rate[98]	%	5
World Bank Grace Period[98]	Years	5
IDA/World Bank Service Charge[98]	% of loan	1.3
SUW/World Bank Term[99]	Years	20
SUW/World Bank Rate[99]	%	5.2
Commercial Debt Term[100]	Years	10
Commercial Debt Interest Rate - Construction[101]	%	23
Commercial Debt Interest Rate – Operations[102]	%	20
Equity Rate[103]	%	28.5
Ghana Inflation Rate[104]	%	8.5
% of Project Cost to Depreciate[105]	%	30
Periods of Annual Debt Payments[90]	n/a	1
Blended Corp. Income Tax Rate[106]	%	25

2.2 Pathway 1: Co-processing of palm oil residue

2.2.1 Pathway description

Feedstock

When discussing palm oil residues as a SAF feedstock, it is important to distinguish between the different residue streams generated by palm oil production and refining. These streams differ in composition, availability, existing uses, and eligibility under international SAF frameworks. For the co-processing pathway considered in this study, the relevant palm oil residue streams are palm oil mill effluent oil (POME oil) and palm fatty acid distillate (PFAD).

POME is a nutrient-rich wastewater produced during the processing of palm oil. It is generated in large quantities and is one of the main environmental challenges associated with palm oil production. Direct discharge of POME into the environment can create toxicological and aesthetic

[98] https://thedocs.worldbank.org/en/doc/5b9cc40a9dbfc95f546be3240e2d4c82-0410012025/original/IDA21-Terms-effective-01-01-2026-clean.pdf
[99] https://thedocs.worldbank.org/en/doc/6438005aba66b3ec6bb1c5b522da4ee0-0340012021/original/IDA19-Scale-Up-Window-Financing-Product-Note.pdf
[100] https://republictt.com/commercial/commercial-property-loans
[101] https://www.absa.com.gh/personal/get-a-home-loan/
[102] https://tradingeconomics.com/ghana/interest-rate
[103] https://www.seco.admin.ch/dam/seco/en/dokumente/Aussenwirtschaft/Wirtschaftsbeziehungen/L%C3%A4nderinformationen/Mittlerer%20Osten%20und%20Afrika/wirtschaftsbericht_ghana.pdf.download.pdf/Wirtschaftsbericht%20Ghana%202025.pdf
[104] https://www.statista.com/statistics/447576/inflation-rate-in-ghana/?srsltid=AfmBOooyQZU99XkQiSl7cpdSuuO1Wg1k1DBZbwWj5fw6Gjs9hRuqspVc
[105] https://taxsummaries.pwc.com/ghana/corporate/deductions
[106] https://taxsummaries.pwc.com/ghana/corporate/taxes-on-corporate-income

concerns. POME oil, recovered from this wastewater stream, can be used as a lipid feedstock for hydroprocessing or co-processing[107].

PFAD is another by-product of palm oil refining. It is generated during the deodorisation stage of refining and consists mainly of free fatty acids, sterols, and minor impurities. PFAD has traditionally been used in animal feed and oleochemical production, but has also gained attention as a potential feedstock for biodiesel and SAF due to its high lipid content and widespread availability as a residue[108].

Other palm oil processing residues could also be relevant to SAF, although generally through different conversion routes. This distinction is important because the feasibility study identifies relatively high overall palm residue availability, but not all of that material is suitable for HEFA or co-processing. Much of the wider palm residue resource is lignocellulosic biomass, such as empty fruit bunches, fibres, shells, and fronds, which would be more relevant to pathways such as gasification/FT or potentially cellulosic ethanol production rather than lipid-based hydroprocessing.

Oil palm fresh fruit bunches (FFB) are the harvested clusters of oil-bearing fruits attached to a central stalk and represent the main raw material for palm oil production. During processing, FFBs are sterilised, threshed, and pressed to extract crude palm oil and palm kernel oil, generating a range of solid residues and waste streams[109].

Empty fruit bunches (EFB) are the fibrous remnants left after the fruits are removed from FFBs in palm oil mills, typically accounting for a significant proportion of fresh fruit weight. They are composed mainly of lignocellulosic biomass, including cellulose, hemicellulose, and lignin. Historically, EFBs have often been treated as low-value waste and landfilled or burned, although they are increasingly recognised as a potential biomass resource[110].

Pressed palm mesocarp fibres are the fibrous residues remaining after crude palm oil is mechanically extracted from the fruit mesocarp. These fibres are rich in lignocellulosic material and are generated in large quantities in palm oil mills. They have traditionally been used as boiler fuel for steam generation within mills, as animal bedding, or occasionally as a composting feedstock[111].

Crude palm oil production in Ghana decreased from approximately 360 kt in 2021 to around 300 kt in 2024. Palm oil production is concentrated in the southern half of the country, with around 42% located in the Eastern Region and most of the remaining production in the Western, Ashanti, and Brong Ahafo regions[112]. Oil-processing residues, including POME oil and PFAD, are estimated at approximately 21 kt/year in the feasibility study. These residues should be more straightforward to collect than dispersed agricultural residues because they are generated at palm oil processing hubs rather than across individual farms. For this pathway, it is therefore assumed that the full 21 kt/year of palm oil residues identified in the feasibility study is available for SAF production.

Technology

In the co-processing process, incoming renewable feedstocks are first subjected to pretreatment. This involves filtration and degumming to remove suspended solids and phospholipids, followed by dewatering to reduce free water content. The pretreated waste oil is then blended with conventional hydrocracker feed, most commonly vacuum gas oil (VGO) or straight-run distillate. Blending is carried out upstream of the reactor section, either at the feed surge drum or through an in-line static mixer.

107 https://www.mdpi.com/2227-9717/9/5/739
108 https://pubmed.ncbi.nlm.nih.gov/21687622/
109 https://www.sciencedirect.com/science/article/abs/pii/S0921344918301605
110 https://www.sciencedirect.com/science/article/abs/pii/S0961953414000038
111 https://onlinelibrary.wiley.com/doi/abs/10.1002/cjce.25595
112 https://www.fas.usda.gov/data/production/GH?source=ipad_redirect

The hydrocracker operates at elevated temperatures, typically 350°C to 420°C, and high hydrogen partial pressures, typically 80 to 180 bar. Under these conditions, triglyceride molecules in the waste oil feed undergo hydrodeoxygenation (HDO), in which oxygen present in the triglyceride structure is removed as water. Decarboxylation and decarbonylation reactions also occur, removing oxygen as carbon dioxide or carbon monoxide. In parallel, the co-fed petroleum fraction undergoes conventional hydrocracking chemistry, with long-chain paraffins and heavier hydrocarbons cracked into the diesel and jet boiling range. Hydroisomerisation also converts straight-chain hydrocarbons into branched paraffins, while hydrodesulfurisation (HDS) and hydrodenitrogenation (HDN) remove sulphur and nitrogen from both the petroleum and bio-derived fractions.

Reactor effluent from the distillate hydrocracker passes through a high-pressure separator before being routed to the fractionation section. This typically comprises a product stripper followed by a main fractionator. The fractionated product slate includes a paraffinic naphtha cut, a kerosene/jet fraction, and a diesel fraction. Any unconverted oil is recycled back to the reactor or routed to other refinery units, such as the fluid catalytic cracker (FCC).

A block-flow diagram of the pathway is presented in the figure below.

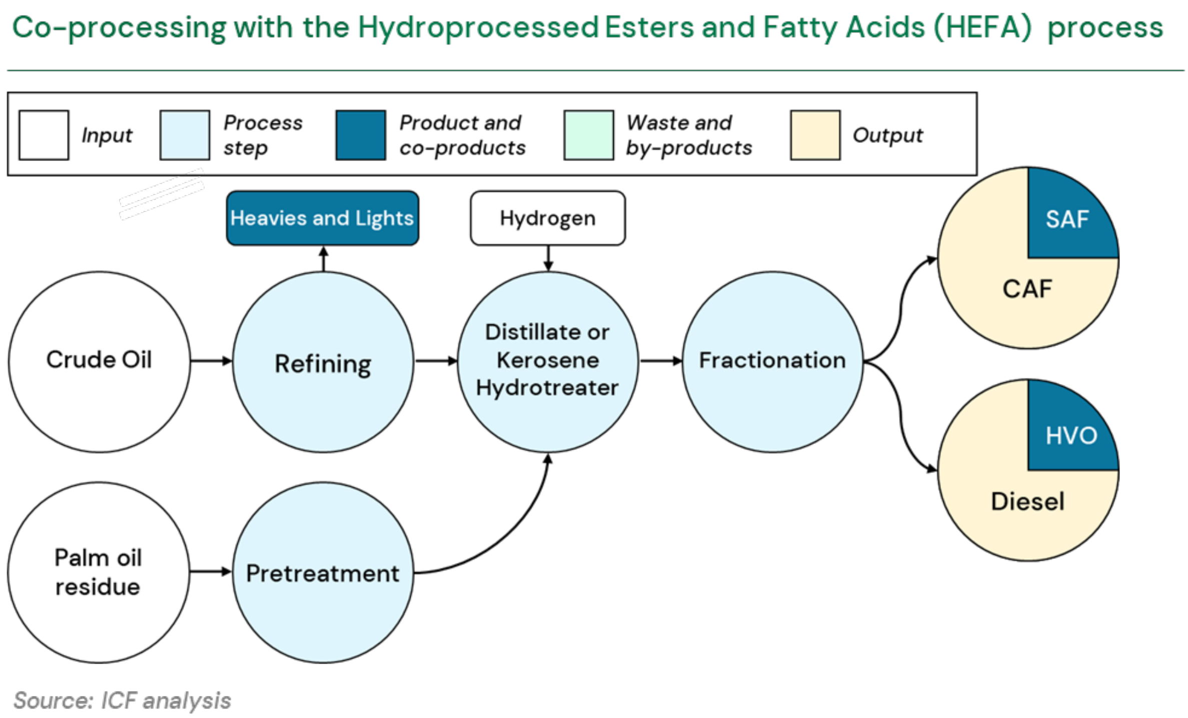

Figure 12 Production process for Co-processing with HEFA

While feedstocks can be co-processed in either a distillate hydrocracker or an FCC, the process modelled in this study assumes that the feedstock enters the distillate hydrocracker in order to maximise SAF production. In an FCC, the main product is gasoline, alongside light gases. According to the Argonne National Laboratory paper, *Carbon Intensities of Refining Products in Petroleum Refineries with Co-Processed Biofeedstocks,* dated February 2022[113], the products of the distillate hydrocracker include approximately 35% jet fuel, and adding 5 vol% oil does not significantly change the product split. For this reason, co-processing in the distillate hydrocracker is selected for modelling. This is also dependent on refinery capability. While a distillate hydrocracker is not part of TOR's current capabilities, it is expected to be included in the planned refinery expansion.

[113] U. Lee, Z. Lu, P. Sun, M. Wang, Carbon Intensities of Refining Products in Petroleum Refineries with Co-processed Biofeedstocks, *Argonne National Laboratory*, February 2022. Co-processing_ANL.pdf

While pretreatment of biogenic oil feedstocks is an important consideration for HEFA development which act as irreversible catalyst poisons at even low ppm concentrations, pretreatment is expected to be less significant in co-processing due to low concentration of oil entering the refinery system. These contaminantsinclude oxygen and inorganic elements, such as calcium, magnesium, sodium and phosphorus,

Co-processing is commercially proven, with 15 active sites globally at the end of 2025, as shown in the table below.

Table 14 Operational co-processing facilities worldwide

Region	Company	Location	Status/Note
Europe	bp	Lingen, Germany	Hydroprocessing
	bp	Castellón, Spain	Hydroprocessing
	Preem	Lysekil, Sweden	Hydrocracker / HPU
	OMV	Schwechat, Austria	Hydrotreating
	TotalEnergies	Normandy, France	Hydroprocessing
	Phillips 66	Humber, UK	Hydrotreating
	Eni	Taranto, Italy	Hydrotreating
North America	bp	Cherry Point, WA	Hydrotreating
	Phillips 66	Rodeo, CA	Hydrotreating (Pre-conversion)
	Par Pacific	Kapolei, HI	Hydrotreating
	Chevron	El Segundo, CA	FCC / Hydrotreating
Asia-Pacific	Pertamina	Cilacap, Indonesia	Hydroprocessing (TDHT)
	Petrobras	PGV, Brazil	Hydrotreating (Diesel R5)
	Sinopec	Zhenhai, China	Hydroprocessing
	bp	Kwinana, Australia	Hydroprocessing

It should be noted that the vast majority of the current sites in operation are focused on maximising diesel production, and thus feedstocks are processed through an FCC and not a distillate hydrocracker.

Sustainability and eligibility

The sustainability and eligibility of palm oil residues varies by residue type. This distinction is important because different palm-derived streams are treated differently under CORSIA, the UK SAF Mandate, and EU frameworks.

POME oil has a CORSIA default life cycle carbon intensity of 18.1 gCO_2e/MJ and is eligible under CORSIA, the UK SAF Mandate, and EU frameworks. PFAD has a higher default life cycle carbon intensity of 20.7 gCO_2e/MJ, but is not eligible under the UK SAF Mandate or EU framework, limiting its value for mandate-driven SAF markets. The eligibility position of other palm oil residues depends on the specific residue stream, its classification, and the evidence available to demonstrate that it is a genuine waste or residue rather than a co-product with competing food or feed uses.

Table 15 Eligibility of palm oil residue categories under CORSIA, UK, and EU frameworks

Palm Residue	Carbon Intensity (gCO_2e/MJ)	CORSIA Eligibility	UK Eligibility	EU Eligibility
Palm oil mill effluent (POME)[A]	18.1	Yes	Yes	Yes

Palm Residue	Carbon Intensity (gCO_2e/MJ)	CORSIA Eligibility	UK Eligibility	EU Eligibility
Palm fatty acids distillate (PFAD)	20.7	Yes	No	No

[A] In the CORSIA default life cycle emission values, this is listed under palm fresh fruit bunches. Source: CORSIA, ICF analysis

ISCC has issued guidance on the sustainability of residues from palm oil facilities, identifying which palm residue streams may be eligible as advanced biofuel feedstocks under the Renewable Energy Directive and therefore potentially eligible as SAF feedstocks under ReFuelEU Aviation[114]. ISCC guidance states that POME oil, EFB oil, and PPF oil have zero GHG emissions allocated to the point of origin because they are categorised as wastes. The guidance also highlights the need for audit and traceability arrangements for palm oil mill residues and collection points, which is particularly relevant where residues are to be certified as wastes or residues rather than products.

Palm-derived feedstocks carry heightened sustainability and traceability sensitivities. Transport & Environment has raised concerns that reported volumes of palm oil residues in some markets may exceed plausible physical availability, suggesting a risk of fraud or misclassification[115]. Germany has also announced the exclusion of palm oil-based biofuels from 2027 due to concerns that loopholes were being used to cross-subsidise unsustainable palm production. This exclusion includes feedstocks such as POME oil that are otherwise eligible under the Renewable Energy Directive[116]. These concerns do not exclude palm oil residues from consideration in Ghana, but they mean that any project using them would require strong traceability, certification, and audit procedures.

2.2.2 Pathway inputs and assumptions for TEA

For the co-processing pathway, the construction period was estimated based on information provided in ICAO's undated co-processing and revamping presentation titled *Co-processing and revamping: How to use existing refineries to produce SAF (ACT-SAF Series, No. 15)* (the 'ICAO Co-processing Presentation")[117]. Feedstock consumption is estimated at 16,400 tonnes per year of palm oil residue. This is based on the assumed TOR refinery capacity, after the planned staged expansion, of 120,000 barrels per day, and a blending limitation of 5 vol% oil feed to the distillate hydrocracker. This corresponds to approximately 78% of the palm oil residue feedstock available based on the Ghana Feasibility Study[118]. Feedstock costs were based on those estimated for similar feedstocks in the ICAO business implementation study for Kenya titled *Business Implementation Study on the use of Sustainable Aviation Fuels* – Kenya dated 2025 (the "Kenya Business Implementation Study")[119].

A majority of the utility and material inputs were based on co-processing modelling as provided in the ANL Co-processing Paper and the NREL report titled "*Sustainable Aviation Fuel: State of Industry Report: Hydroprocessed Esters and Fatty Acids Pathway*" dated July 2024 (the "NREL HEFA Paper")[120]. While it is possible that the existing labour pool within a refinery would be capable of taking on the demands of a co-processing unit, three new employees are conservatively included in the model: one engineer with co-processing experience, one operator, and one

[114] https://www.iscc-system.org/wp-content/uploads/2023/12/ISCC_Guidance_WR_from_Palm_Oil_Mills_V3.1.pdf
[115] https://uploads.transportenvironment.org/production/files/202504_POME_fraud_Report.pdf
[116] https://www.spglobal.com/energy/en/news-research/latest-news/agriculture/121025-german-cabinet-sets-59-ghg-quota-by-2040-bans-double-counting-adds-saf-mandate
[117] https://www.icao.int/sites/default/files/environmental-protection/Documents/ACT-SAF/ACT-SAF-Series-15-coprocessing-and-revamping.pdf
[118] D. Serafini, Feasibility Study on the use of Sustainable Aviation Fuels: Ghana, ICAO International, 2025.
[119] https://www.icao.int/sites/default/files/environmental-protection/Documents/ACT-SAF/Business_implementation_study_Kenya.pdf
[120] https://research-hub.nlr.gov/en/publications/sustainable-aviation-fuel-state-of-industry-report-hydroprocessed/

unskilled labourer. Salary estimates were based on Ghana-specific job sites, with an emphasis on engineering and plant operation. Availability estimates were based on the commercial track record of co-processing facilities and the low complexity of the pathway.

The material and energy inputs are shown in the table below.

Table 16 Material and energy inputs for the co-processing pathway

Input	Unit	Quantity
SAF Capacity[121]	Tonnes/year	5,740
RD Capacity[121]	Tonnes/year	4,390
Naphtha Capacity[121]	Tonnes/year	N/A
Construction[122]	Years	1
Electricity Requirement[121]	MWh/year	379
Natural Gas Requirement[121]	MMBTU/hour	3
Water Requirement[123]	Thousand gallon/day	21
Wastewater Generation[90]	Thousand gallon/day	4
Feedstock Requirements [124]	Tonnes/year	16,400
Feedstock Cost[125]	USD/tonne	1,200
Chemical and Catalyst Costs[123]	Million USD/year	0.16
Labor Costs[126] [127] [128]	% of total capital	0.32%
Average Salary[126] [127] [128]	USD/year	21,400
First Year Availability[90]	%	92
2nd Year+ Availability[90]	%	95

The CAPEX estimate is presented in million USD and is estimated based on the NREL HEFA Paper. An additional factor was applied to the equipment cost to include potential pretreatment requirements. The resulting estimated CAPEX, along with costs per tonne of annual fuel nameplate and an annual SAF nameplate, is shown in the table below.

Table 17 CAPEX inputs for the co-processing pathway

[121] U. Lee, Z. Lu, P. Sun, M. Wang, Carbon Intensities of Refining Products in Petroleum Refineries with Co-processed Biofeedstocks, *Argonne National Laboratory*, February 2022. Co-processing_ANL.pdf
[122] https://www.icao.int/sites/default/files/environmental-protection/Documents/ACT-SAF/ACT-SAF-Series-15-coprocessing-and-revamping.pdf
[123] https://docs.nrel.gov/docs/fy24osti/87803.pdf
[124] *Awaiting online publication.* Feasibility Study on the use of Sustainable Aviation Fuels: Ghana, ICAO
[125] https://www.icao.int/sites/default/files/environmental-protection/Documents/ACT-SAF/Business_implementation_study_Kenya.pdf
[126] https://africapay.org/ghana/career/role-pay/ghana-industrial-and-production-engineers
[127] https://www.paylab.com/gh/salaries-in-country
[128] https://www.glassdoor.com/Salaries/accra-ghana-plant-operator-salary-SRCH_IL.0,11_IM1421_KO12,26.htm

Input	Unit	Quantity
CAPEX (total)[123]	Million USD	20.2
CAPEX (per annual fuel nameplate capacity)	USD/tonne	1,995
CAPEX (per annual SAF nameplate capacity)	USD/tonne	3,520

For the co-processing pathway, only the additional cost associated with the inclusion of feedstock into the refinery is modelled. The model is therefore intended to represent an addition to an existing refinery rather than a standalone greenfield SAF production facility. A breakdown of the estimated CAPEX is shown in the table below.

Table 18 Capital cost line items for the co-processing facility

Capital Cost Line Item	Unit	Million USD
Direct Costs	Million USD	5.0
Indirect Costs	Million USD	3.0
Contingency	Million USD	3.5
Owners and Financing Costs	Million USD	3.5
Working Capital	Million USD	5.2
Total Costs	**Million USD**	**20.2**

Financial inputs were produced by applying the financing waterfall methodology described in Section 2.1. As the total CAPEX is below the USD 450 million threshold, 5% of total project cost is reserved for commercial debt and equity, split 60:40 between commercial debt and equity. Salvage value was calculated based on the common industry standard of 10%.

Table 19 Additional financial inputs for the co-processing pathway

Input	Unit	Quantity
World Bank Debt – IDA	Million USD	19.2
Total Traditional Debt	Million USD	0.6
Total Equity	Million USD	0.4
Salvage Value[129]	Million USD	2.02

2.2.3 Pathway results

The techno-economic model for the co-processing pathway yielded an MFSP for SAF of USD 3,020 per tonne in 2025 dollars. The pathway's main strength compared with the other pathways is its very low CAPEX, as it relies on modifications to an existing refinery rather than development of a standalone SAF plant. However, that same feature also limits the scale of production. The small size of the facility modification, due to limited refining capacity in Ghana and the blending limits for feedstock, reduces the opportunity for economies of scale. The pathway MFSP is also affected by the relatively low SAF yield compared with the other pathways examined.

[129] https://www.investopedia.com/terms/s/salvagevalue.asp

2.3 Pathway 2: Standalone HEFA using fishery and livestock residue

2.3.1 Pathway description

Feedstock

Waste fish oil is recovered from fish-processing by-products such as heads, viscera, frames, skins, tails, fins, scales, blood, and trimmings. These by-products can be rendered or reduced to separate an oil-rich fraction from the protein-rich meal fraction. Fishmeal and fish oil can be produced from whole fish, fish trimmings, or other processing by-products, with FAO noting that a growing share of production now comes from material that was previously discarded or used in lower-value applications[130]. It is estimated that approximately 11% of total fish weight can be extracted as oil[131]. Waste fish oil has also been actively researched as a biofuel feedstock, and its hydrogen-to-carbon content, heating value, density, and surface tension are similar to used cooking oil, making it suitable for HEFA SAF production[132,133].

Waste fish oil is already used as a SAF feedstock and is an approved feedstock for the Neste NExBTL HEFA process[134]. It has also been identified as a feedstock of interest by Atlas Air and Alaska Airlines[135]. Although waste fish oil is not always explicitly named under CORSIA, EU, or UK frameworks, it can fit within broader categories in each. Under CORSIA, it can be treated within the mixed animal fats category. Under the Renewable Energy Directive, it may fit within material from the agro-food, fish, and aquaculture industry, provided it is not suitable for use in the food or feed chain and meets the relevant animal by-product requirements. Under the UK RTFO and SAF Mandate, it may fit within relevant waste categories, subject to classification.

Fishing and aquaculture are important sectors in Ghana, contributing to employment, food supply, and economic activity. Approximately 70% of fish production comes from the artisanal sector, with most production from marine sources and the remainder from Lake Volta, aquaculture, and other inland sources. Moreover, aquaculture production has also grown significantly since 2015[136].

A study by Asiamah et al. assessed the fish-waste landscape in Ghana and found that only two of ten interviewed fish-processing companies processed fish waste, while the others disposed of it either on land or at sea[137]. The study identified several barriers to fish-waste recovery, including limited policy incentives, low awareness of the value of fish waste, limited environmental enforcement, and a lack of processing equipment[138].

For the standalone HEFA pathway, the modelled feedstock is fishery and livestock residues. Based on the Ghana Feasibility Study, 135,159 tonnes per year of fishery and livestock residues are available, although this should be treated as a high-level estimate given the ambitious residue-to-oil recovery assumption and the need to validate collection logistics, competing uses, and aggregation constraints. As some of these residues are already used in Ghana for products such as soap and animal feed, the modelled SAF facility capacity is limited to 80% of the available residues, equivalent to approximately 108,000 tonnes per year.

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[130] https://www.fao.org/flw-in-fish-value-chains/resources/articles/Fish-By-Products-Utilization-Getting-More-Benefits-from-Fish-Processing/en
[131] https://www.sciencedirect.com/science/article/abs/pii/S1364032112005266
[132] https://www.sciencedirect.com/science/article/abs/pii/S0016236109000672?via%3Dihub
[133] https://www.sciencedirect.com/science/article/pii/S0044848625001255?via%3Dihub
[134] https://www.neste.com/news/neste-oil-produces-premium-quality-n-ex-btl-renewable-diesel-from-waste-fat-sourced-from-the-fish-processing-industry
[135] https://www.spglobal.com/energy/en/news-research/blog/crude-oil/051425-fft-alaska-saf-sustainable-aviation-fuel-biomass-fish-oil-jet-fuel
[136] https://www.mofa.go.jp/mofaj/files/100866466.pdf
[137] https://ajfand.net/Volume22/No7/Asiamah21745.pdf
[138] https://mofaq.gov.gh/wp-content/uploads/2025/04/National-Fisheries-and-Aquaculture-Policy-2022-FINAL-1.pdf

Technology

The HEFA process begins with feedstock pre-treatment, where impurities such as free fatty acids, phospholipids, metals, and sulphur compounds are removed through degumming, bleaching, and filtration to protect downstream catalysts. The pretreated feedstock is then fed into a fixed-bed hydrodeoxygenation (HDO) reactor operating at elevated temperatures, typically 300°C to 450°C, and high hydrogen partial pressures, typically 40 to 100 bar, in the presence of a sulphided NiMo or CoMo catalyst supported on alumina.

In this stage, oxygen is removed from triglyceride and fatty acid molecules through two competing reaction pathways: hydrodeoxygenation, which produces water as a by-product, and decarboxylation/decarbonylation, which produces CO_2 or CO. This yields a mixture of straight-chain n-paraffins with carbon chain lengths broadly corresponding to the original fatty acid feedstock, predominantly C15 to C18.

The n-paraffin product stream from the HDO reactor is then routed to an isomerisation/hydrocracking reactor, another fixed-bed unit operating at moderate temperatures, typically 250°C to 380°C, and pressures of 30 to 70 bar over a bifunctional catalyst, typically a noble metal such as Pt or Pd on a molecular sieve or zeolite support. This stage, also known as catalytic dewaxing, converts straight-chain paraffins into iso-paraffins through skeletal isomerisation, while hydrocracking reactions selectively break longer chains into lighter fractions where required.

The reactor effluent is then processed through a gas-liquid separation system and routed to a fractionation column, where the product is separated into discrete cuts. The principal marketable products include a naphtha fraction, a jet fuel or SAF fraction, and a diesel/gasoil fraction. A small liquefied petroleum gas stream and process-generated CO_2/CO and water are also produced as by-products. The relative yields of each cut can be adjusted to some degree by changing isomerisation and hydrocracking severity, allowing refiners to shift production between SAF and renewable diesel depending on market demand.

A block-flow diagram of the pathway is presented in the figure below.

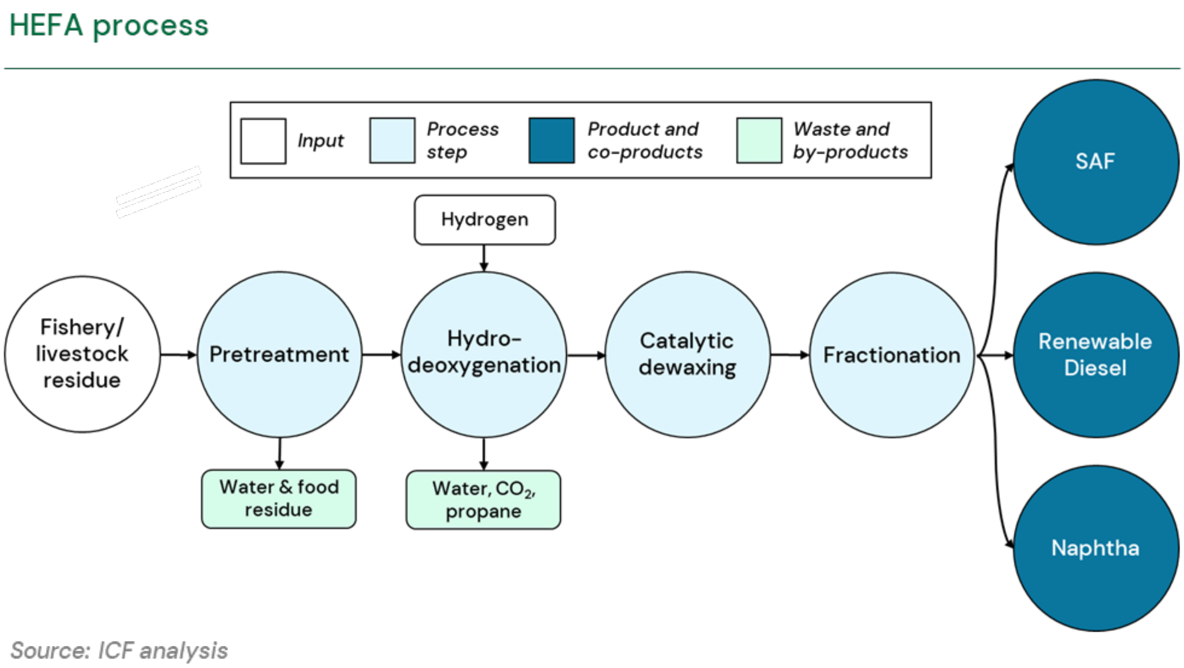


Figure 13 Process for HEFA SAF production

HEFA is the most commercially mature SAF and renewable diesel production pathway. As with co-processing, HEFA is commercially proven, with a number of active sites shown in the table below.

Table 20 Operational HEFA SAF facilities worldwide

Region	Company	Location	Status/Note
Europe	Neste	Porvoo, Finland	~100k tons/yr
	Neste	Rotterdam, Netherlands	~500k tons/yr
	TotalEnergies	La Mède, France	Converted biorefinery
	TotalEnergies	Grandpuits, France	Recently operational
	Eni (Enilive)	Venice/Gela, Italy	First biorefinery conversion
	bp	Castellón, Spain	Co-processing & dedicated
	OMV	Schwechat, Austria	Co-processing integration
North America	World Energy	Paramount, California, USA	Dedicated SAF pioneer
	Neste / Marathon	Martinez, California, USA	Joint Venture
	Montana Renewables	Great Falls, Montana, USA	High SAF yield focus
	New Rise Renewables	Reno, Nevada, USA	Recently active (2025)
	Phillips 66	Rodeo, California, USA	"Rodeo Renewed" project
Asia-Pacific	Neste	Singapore	World's Largest (1M tons/yr)
	Bangchak	Bangkok, Thailand	Strong focus on local UCO
	Pertamina	Cilacap, Indonesia	Co-processing specialist

Sustainability and eligibility

SAF derived from fishery and livestock residues, such as waste fish oil and other animal-derived waste fats, has a relatively strong sustainability and eligibility profile where the feedstock can be demonstrated to be a genuine waste or residue. The CORSIA default life cycle emission value for HEFA processing of mixed animal fats is 28.6 gCO_2e/MJ, which falls under CORSIA eligibility, subject to wider sustainability certification.

The feedstock is also expected to be eligible under the UK SAF Mandate and ReFuelEU Aviation where it meets the relevant waste or residue classification requirements. Under the UK SAF Mandate, eligible feedstocks include material originating from the slaughter process that has no other use than energy recovery and is not suitable for food or feed uses, or agricultural and horticultural purposes. In the EU, the Renewable Energy Directive includes relevant industrial waste streams from the agro-food, fish, and aquaculture industry, provided they are not fit for use in the food or feed chain and meet the applicable sustainability rules.

The main eligibility risk is therefore not the HEFA pathway itself, but the ability to demonstrate that the fishery and livestock residues are genuine waste or residue streams. This requires evidence that the feedstock has not been diverted from higher-value food or feed uses in a way that creates sustainability concerns, and that it can be traced through collection, aggregation, preprocessing, and conversion.

Table 21 Sustainability & eligibility of fishery residues under CORSIA, UK, EU frameworks

Feedstock	Carbon Intensity (gCO_2e/MJ)	CORSIA Eligibility	UK Eligibility	EU Eligibility
Livestock and fishery residue	28.6[A]	Yes	Yes	Yes

[A] In the CORSIA default life cycle emission values, this is listed under mixed animal fats.

Source: ICF Analysis, CORSIA

2.3.2 Pathway inputs and assumptions for TEA

For the modelled HEFA facility, the total feedstock quantity is 108,127 tonnes per year of fishery and livestock residues, equivalent to 80% of the fishery and livestock residue listed in the Ghana Feasibility Study. As with the co-processing pathway, feedstock costs were based on those estimated for similar feedstocks in the Kenya Business Implementation Study.

The majority of the remaining material and energy inputs for the standalone HEFA facility model, including all utility requirements, are based on the standalone HEFA facility modelled in the NREL HEFA Paper. Construction time was estimated based on the work by Pominville-Racette et al., 2025[29]. Labour demand for a HEFA plant was estimated based on information presented by Sustainable Aviation Futures[30]. A labour pool of 97 full-time employees was used in the model, with salary estimates based on the same Ghana-specific job sites referenced previously for the co-processing pathway. Availability estimates, which are slightly lower than those for the co-processing pathway, are based on the commercial track record of HEFA facilities and the higher complexity of the pathway facility.

The material and energy inputs are shown in the table below.

Table 22 Material and energy inputs of the HEFA SAF pathway

Input	Unit	Quantity
SAF Capacity[119]	Tonnes/year	62,800
RD Capacity[119]	Tonnes/year	16,800
Naphtha Capacity[119]	Tonnes/year	4,200
Construction[129]	Years	2
Electricity Requirement[119]	MWh/year	3,100
Natural Gas Requirement[119]	MMBTU/hour	20
Water Requirement[119]	Thousand gallon/day	50
Wastewater Generation[119]	Thousand gallon/day	43
Feedstock Requirements[117]	Tonnes/year	108,000
Feedstock Cost[118]	USD/tonne	1,200
Chemical and Catalyst Costs[119]	Million USD/year	1.70
Labor Costs[126 127 128]	% of total capital	0.95
Average Salary[126 127 128]	USD/year	23,600
First Year Availability[90]	%	60
2nd Year+ Availability[90]	%	85

The CAPEX estimate is presented in million US dollars and is estimated based on the NREL HEFA Paper. The modelled CAPEX is based on a greenfield standalone HEFA facility. CAPEX inputs are shown in the table below.

Table 23 CAPEX inputs for the HEFA pathway

Input	Unit	Quantity
CAPEX (total)[119]	Million USD	245

Input	Unit	Quantity
CAPEX (per annual fuel nameplate capacity)	USD/tonne	2,925
CAPEX (per annual SAF nameplate capacity)	USD/tonne	3,900

Similar to the co-processing CAPEX estimation, additional factors were included for indirect costs, contingencies, Owners' costs, financing costs and working capital. A breakdown of the estimated CAPEX can be found in the table below.

Table 24 Capital cost line items for the HEFA facility

Capital Cost Line Item	Unit	Million USD
Direct Costs	Million USD	71
Indirect Costs	Million USD	41
Contingency	Million USD	51
Owners and Financing Costs	Million USD	51
Working Capital	Million USD	31
Total Costs	**Million USD**	**245**

Financial inputs were produced by applying the financing waterfall methodology described in Section 2.1. As the total CAPEX for the HEFA facility is below the USD 450 million threshold, 5% of total project cost is reserved for commercial debt and equity, split 60:40 between commercial debt and equity. The remaining project cost is financed through the World Bank IDA allocation. Salvage value was calculated based on the common industry standard of 10%.

Table 25 Additional financial inputs for the HEFA pathway

Input	Unit	Quantity
World Bank Debt – IDA	Million USD	233
World Bank Debt – SUW	Million USD	0
Total Traditional Debt	Million USD	7.2
Total Equity	Million USD	4.8
Salvage Value	Million USD	24[139]

2.3.3 Pathway results

The techno-economic model for the HEFA pathway yielded an MFSP for SAF of USD 2,165 per tonne in 2025 dollars. HEFA is the only pathway examined in this report for which the model indicates an MFSP below the general SAF price in the EU of USD 2,465 per tonne. The relatively low MFSP for domestic SAF reflects the benefits of the World Bank IDA assumptions, including the five-year grace period, 5% interest rate, and 25-year term, compared with SUW loan terms and, more significantly, commercial debt and equity terms in Ghana. The pathway also has relatively low operating costs, at approximately USD 1,500 per tonne of total fuels produced, compared with the other pathways examined.

[139] Plant Operator in Ghana, *Glassdoor, LLC.* https://www.glassdoor.com/Salaries/accra-ghana-plant-operator-salary-SRCH_IL.0,11_IM1421_KO12,26.htm

2.4 Pathway 3: Maize Residue AtJ

2.4.1 Pathway description

Feedstock

The AtJ pathway modelled in this section uses 2G ethanol as the direct feedstock to the AtJ facility. However, that ethanol is assumed to be produced in Ghana from maize residues, primarily maize stover. The feedstock discussion is therefore split into two parts: first, the availability and suitability of maize stover as the upstream biomass resource; and second, the production of 2G ethanol as the intermediate feedstock for AtJ conversion.

Maize Stover:

Maize residues, often referred to as maize stover, are the non-grain parts of the maize plant left after harvest. These include stalks, leaves, husks, and cobs. The residue is generated in large volumes, often at a similar scale to the harvested grain, and can either be left on the field to decompose or collected for uses such as animal feed, soil conditioning, household fuel, bioenergy, or biofuel production.

Maize stover is an agricultural residue consisting of the non-grain parts of the maize plant remaining in the field after harvest

Source: Purdue University

Figure 14 Process of harvesting maize[140]

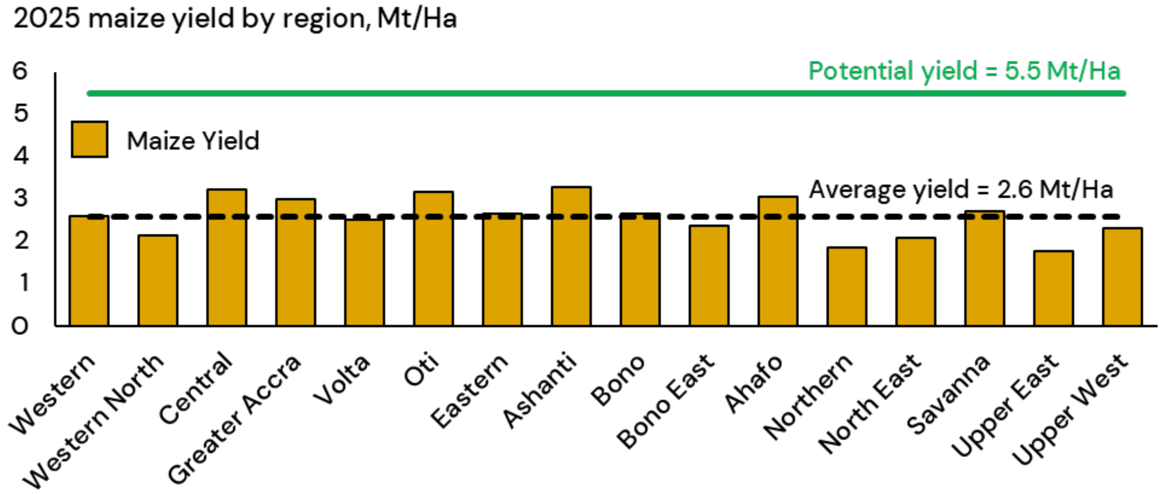
The Ghana Feasibility Study estimates that Ghana produces approximately 2.6 million tonnes of maize annually, with production increasing steadily over the past decade. Between 2013 and 2024, national maize output rose by around 94%. Production is concentrated in the Ashanti, Bono, Eastern, and Central regions, which represent the main cultivation zones. Maize residues are currently used mainly for livestock feed, animal bedding, soil nutrient recycling, and as a household fuel source.

The Ministry of Food and Agriculture has highlighted that crop yields in Ghana have scope to improve. In its November 2025 Facts and Figures publication, maize production is reported to yield around 2.6 tonnes per hectare on average, while the potential yield is estimated at 5.5 tonnes per hectare[141]. **This yield gap has been attributed to outdated agricultural practices, including limited use of modern technologies and fertilisers[142].** If this potential yield were realised, and assuming the cultivated area remains broadly unchanged, maize grain production could increase to 5.5 million tonnes per year. Using a commonly applied 1:1 ratio between maize grain and dry

[140] https://www.purdue.edu/newsroom/archive/releases/2015/Q4/purdue-study-shows-potential-for-growth-in-biofuels-from-corn-stover.html
[141] https://srid.mofa.gov.gh/sites/default/files/2025-12/AGRICULTURE%20IN%20GHANA%20%28Facts%20%26%20Figures%29%202024_0.pdf
[142] https://www.agricinafrica.com/2023/01/ghana-maize.html

maize residues, this would imply around 5.5 million tonnes per year of maize residues. If 75% of the potential yield were achieved, around 4.2 million tonnes per year of both maize grain and maize residues could be available. The 1:1 assumption may also be conservative, as Ghana-focused research has found that maize residues can reach up to 1.8 tonnes per tonne of maize grain[143].

Ghana's average maize yield is less than half of its potential, largely due to outdated agricultural practices



Source: Ghana Ministry of Food and Agriculture

Figure 15 Current and potential maize yield in Ghana

Maize residues therefore present a strong opportunity as a SAF feedstock in Ghana due to their large and growing availability, low cost as an agricultural by-product, and favourable sustainability profile as a non-food residue. There are, however, several practical challenges. Collection systems are fragmented because of the dominance of smallholder farming, and residues already have existing uses. Collection also needs to be managed carefully so that sufficient residue remains on the field to protect soil health and maintain nutrient cycles. Addressing these barriers would require robust aggregation systems, sustainability safeguards, farmer engagement, and clear end-use prioritisation.

2G Ethanol:

For this pathway, maize residues are not converted directly into SAF. They are first converted into second generation ethanol, which is then upgraded into SAF through the AtJ process. Second generation ethanol, also known as cellulosic ethanol, is produced from lignocellulosic biomass such as agricultural residues, forestry waste, and other non-food plant materials. Unlike first generation ethanol, which is produced from sugar or starch crops, 2G ethanol uses the inedible structural components of plants, including cellulose and hemicellulose. These materials are pretreated and broken down through hydrolysis into fermentable sugars, which are then converted into ethanol through microbial fermentation.

Starch- and sugar-based ethanol production facilities are well established globally, but their use in SAF production is being limited or excluded in several markets because of concerns around land use change, food competition, and carbon savings. Cellulosic ethanol facilities have been more difficult to commercialise, mainly because of cost, performance reliability, and scale-up challenges. Some success has been seen, particularly in Brazil, where companies such as Raízen and GranBio have developed commercial-scale production using sugarcane residues.

[143] https://www.fao.org/4/x5490e/x5490e0i.htm#results

As of late 2025, there were several operational, commissioning, planned, or idled cellulosic ethanol facilities globally, including those shown in the table below.

Table 26 Cellulosic ethanol facilities

Company	Location	Capacity	Status	Notes
South America (Brazil)				
Raízen	Costa Pinto, São Paulo	34 ML/yr	Operating	First commercial E2G plant; operating since 2015 on sugarcane bagasse. Now serves mainly as R&D reference facility.
Raízen	Bonfim Bioenergy Park, Guariba, São Paulo	82 ML/yr (~22 MMgy)	Operating	Inaugurated May 2024; world's largest cellulosic ethanol plant at time of opening. ~80% of output contracted; Shell is primary off-taker. Cost ~R$1.2 billion (~$230M USD). Sugarcane bagasse feedstock.
Raízen	Barra Bioenergy Park, São Paulo state	82 ML/yr (~22 MMgy)	Operating	Opened 2024 alongside Bonfim plant. Part of planned ramp to 4 operating units by 2025/26 harvest.
Raízen	Univalem Bioenergy Park, São Paulo state	82 ML/yr (~22 MMgy)	Commissioning/ 2025	One of two additional units expected to come online in 2025. Part of a 20-plant, 1.6 billion L/yr long-term plan.
Raízen	São Paulo state (4th unit)	82 ML/yr (~22 MMgy)	Commissioning/ 2025	4th commercial E2G unit; targeted for 2025/26 harvest. 11 further plants mapped in longer-term pipeline.
GranBio	São Miguel dos Campos, Alagoas	~82 ML/yr (~20 MMgy)	Operating	Operating since 2017 using sugarcane straw (Bioflex 1). Technology from GranBio's proprietary platform. Partnership with Honeywell UOP for future ATJ/SAF integration.
GranBio / Exygen consortium	Brazil (location TBC)	~150 ML/yr (~40 MMgy)	Planned	Announced Jan 2025 as "Exygen I" project. Partners include Impacto Bioenergia, Caete, and Central Açucareira Santo Antonio. Also includes 50 M m^3/yr biomethane facility. Total cost ~$250M USD.
Europe				
Sunliquid licensees (×5)	China (×2), Bulgaria, Poland, Slovakia	Combined ~254 ML/yr (planned)	Planned/ uncertain	Five licenses sold by Clariant prior to Podari closure. Status of individual projects unclear following Clariant's exit from direct operations. Combined planned capacity ~254 M L/yr if all proceed.
North America				

Company	Location	Capacity	Status	Notes
SAFFiRE Renewables (SW Airlines venture)	Liberal, Kansas, USA	Pilot scale (TBC)	Pilot, under construction	Groundbreaking Aug 2024. Located at Conestoga Energy's Arkalon corn ethanol facility. Goal is to produce cellulosic ethanol for onward conversion to SAF via ATJ pathway. Corn stover feedstock.
Various US corn ethanol plants (CKF)	Multiple, USA	Growing; ~43 MD RINs in 2024	Operating/ Growing	Corn kernel fiber (CKF) cellulosic ethanol co-produced at conventional corn ethanol plants. 2024 volumes grew ~3,000% following new EPA ASTM test method (E3417). Modest absolute volumes but steep growth trajectory.
Asia				
EcoCeres	Hebei, China	Not disclosed	Operating/ ramping	First shipment of cellulosic ethanol to Europe announced in May 2023. Backed by Bain Capital ($400M stake). Also operates HEFA renewable diesel / SAF facilities in Jiangsu (350 kt/yr) and Malaysia (420 kt/yr under construction).
Praj Industries	Maharashtra, India	Demo scale	Operating	Demonstration plant inaugurated Q2 2024. Technology showcase for agricultural residue conversion. This facility supports licensing business rather than commercial production.
India (PM JI-VAN / VGF program)	Multiple states, India	Up to 12 commercial plants planned	Planned	Government-backed program. Viability Gap Funding up to ~$20M USD per project. Odisha launched Interest Subvention Scheme in 2025 supporting 29 local projects. Straw and bagasse primary feedstocks. Commercial timelines unclear.

Note that ML/yr = million litres per year, MMgy = million US gallons per year, kt/yr = thousand metric tonnes per year, 1 MMgy ≈ 3.8 ML/yr.

The available maize residue is estimated in the Ghana Feasibility Study to be sufficient to produce 320,519 tonnes per year of cellulosic ethanol. This assessment assumes that 80% of the available maize residue is used to produce cellulosic ethanol, which is then transported to the AtJ facility. Based on this assumption, 256,000 tonnes per year of cellulosic ethanol is used in the pathway modelling.

Given the predominance of smallholder farms in Ghana, an 80% collection rate may be considered ambitious. However, maize production is expected to continue increasing in line with historical trends, and this study does not account for future growth in production. As production expands, the required feedstock volume could be met at a lower collection rate, meaning that the target quantity may not necessarily depend on collecting 80% of the current available residue.

The available volume of cellulosic ethanol would increase further if maize yields move closer to their stated potential. If the full potential yield discussed above were achieved, available cellulosic ethanol could rise to around 680 kt/year. If 75% of the potential yield were achieved, around 510 kt/year could be possible. This assumes that sufficient production capacity exists to convert maize residues into cellulosic ethanol.

Technology

For the maize residue-based AtJ pathway, maize residues are first converted into cellulosic ethanol off-site, and the ethanol is then transported to the AtJ facility. The process modelled in this section covers the conversion of ethanol into SAF and co-products. The shaded area in the block-flow diagram represents the cellulosic ethanol production stage, which is performed off-site and is not included in the AtJ facility CAPEX.

The AtJ process begins with ethanol dehydration to ethylene over a solid acid catalyst, typically an alumina- or zeolite-based catalyst. This occurs in a fixed-bed dehydration reactor operating at moderate temperatures of around 300°C to 500°C and near-atmospheric to modest pressures. The ethylene product stream is then purified to remove water and trace oxygenates before being fed into the oligomerisation section.

In the oligomerisation stage, ethylene molecules are catalytically coupled and grown into longer-chain olefin oligomers in a fixed-bed or tubular oligomerisation reactor. This typically operates at moderate temperatures and pressures, around 150°C to 350°C and 30 to 100 bar, depending on the catalyst system. Acid catalysts, such as zeolite or nickel-based systems, may be used. Oligomerisation can occur in one reactor or in a staged reactor system to build the desired C8 to C16 oligomers.

The resulting olefin mixture is then fed to a hydrogenation reactor, where unsaturated double bonds are saturated with hydrogen over a supported noble metal or nickel catalyst. This typically occurs at mild temperatures and pressures, around 100°C to 250°C and 20 to 60 bar, depending on the catalyst system. Lower temperatures and pressures can be used with noble metal catalysts, although they are generally more expensive and more susceptible to poisoning.

The hydrogenated product stream is then routed to a fractionation column, where distillation separates the material into discrete product cuts. The main marketable products are a SAF fraction and a renewable diesel/distillate fraction, with relative yields depending on oligomerisation severity and the carbon chain distribution achieved upstream. A lighter naphtha cut and LPG fraction are also recovered as by-products and are typically used in the facility fuel system.

A block-flow diagram of the modelled facility is provided below. The shaded area represents the cellulosic ethanol production to be performed off-site and is not included in the CAPEX.

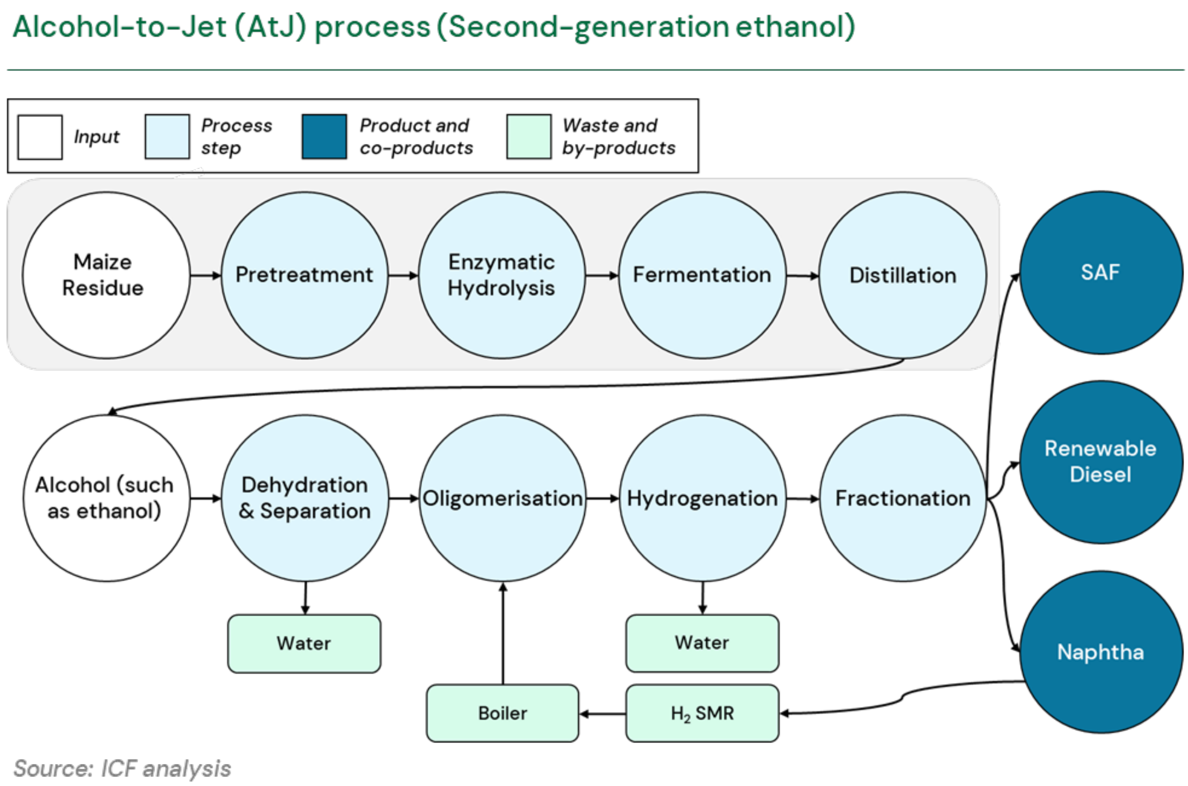


Figure 16 ATJ production process for second generation feedstocks

As of Q1 2026, the LanzaJet Freedom Pines facility, with a capacity of 10 million gallons per year, was the only operational integrated commercial-scale ethanol-to-jet facility in the world, although the extent of its operations, including availability and maximum capacity reached, was not being disclosed publicly. In Q4 2025, LanzaJet announced that it had operated the full facility and produced products, but it remains unclear whether the facility has operated at full capacity.

Several other companies have facilities in various stages of development. These include Summit Next Gen, which is developing a 250 million gallon per year ethanol-derived SAF facility in the US Gulf Coast region using Honeywell UOP's ETJ technology; Swedish Biofuels, which has three SAF production facilities planned in Sweden with a combined capacity of around 130 million gallons per year; and Axens, which is providing its Jetanol AtJ technology to five major projects with a total production pipeline approaching 1 billion gallons per year.

Sustainability and eligibility

Maize residues are an eligible SAF feedstock where they meet the relevant sustainability criteria. As an agricultural residue, maize stover does not directly compete with food production and has lower land-use change risk than purpose-grown energy crops or food/feed crops used as primary feedstocks. It can also deliver significant greenhouse gas savings, although the final carbon intensity depends on residue collection, transport distances, ethanol production, conversion energy, hydrogen source, and any process integration.

Under CORSIA, the default life cycle emission value for SAF produced from agricultural residues via the standalone AtJ pathway is 39.7 gCO_2e/MJ, representing a 55% reduction relative to the CORSIA baseline carbon intensity of conventional aviation fuel. An integrated conversion design has a lower default value of 24.6 gCO_2e/MJ, reflecting the benefit of integrating ethanol production and AtJ conversion. The pathway modelled in this section is a standalone AtJ facility supplied with externally produced cellulosic ethanol, and therefore the standalone value is the more relevant screening reference.

Maize residues are expected to be eligible under CORSIA and the UK SAF Mandate provided they are certified as agricultural residues and meet the relevant life cycle emissions and sustainability requirements. For EU markets, the standalone AtJ default value may not meet the applicable emissions reduction threshold without further measures. A producer targeting EU demand would therefore likely need to reduce life cycle emissions through measures such as renewable electricity, lower-carbon process heat, improved logistics, or process integration.

Table 27 Sustainability & eligibility of maize residue under CORSIA, UK, EU frameworks

Feedstock	Carbon Intensity (gCO_2e/MJ)	CORSIA Eligibility	UK Eligibility	EU Eligibility
Maize Residues	39.7[A]	Yes	Yes	No

[A] In the CORSIA default life cycle emission values, this is listed under agricultural residues.

Source: ICF Analysis, CORSIA

2.4.2 Pathway inputs and assumptions

For the cellulosic ethanol-to-jet fuel pathway, 256,000 tonnes per year of ethanol feedstock is estimated to produce 108,000 tonnes per year of SAF. The majority of the AtJ energy and material inputs included are based on the R&D GREET model developed by ANL (the "ANL GREET Model") using publicly available sources[144]. For this case, a standalone AtJ facility is modelled under the assumption that ethanol is transported to the facility. Additional factors are applied to natural gas and electricity use based on the inclusion of onsite hydrogen and OSBL electricity needs.

Construction time was based on an Air Cargo Week article focused on the timelines for various SAF production facilities, as well as the known time period required by LanzaJet to construct its Freedom Pines AtJ facility. Feedstock cost was based on information provided by Das et al. (2022) for cellulosic ethanol produced from corn stover[145]. Labour demand for an AtJ plant was estimated based on information presented by Sustainable Aviation Futures. As with the HEFA plant, a labour pool of 97 full-time employees was used in the model, with salary estimates based on the same Ghana-specific job sites referenced previously. Availability estimates were based on the similarity in size and complexity of the plant to the modelled HEFA facility.

The operating inputs and assumptions are shown in the table below.

Table 28 Material and energy inputs of the maize residue AtJ pathway

Input	Unit	Quantity
SAF Capacity[144]	Tonnes/year	108,000
RD Capacity[144]	Tonnes/year	23,000
Naphtha Capacity[144]	Tonnes/year	3,100
Construction[146]	Years	2
Electricity Requirement[144]	MWh/year	72,600
Natural Gas Requirement[144]	MMBTU/hour	35
Water Requirement[144]	Thousand gallon/day	195
Wastewater Generation[90]	Thousand gallon/day	230
Feedstock Requirements[118]	Tonnes/year	256,000

[144] https://greet.anl.gov/
[145] https://pubs.rsc.org/en/content/articlelanding/2022/se/d1se01881g
[146] https://aircargoweek.com/how-can-aviation-ramp-up-saf-production-fast-enough/#:~:text=By%202030%2C%20approximately%20140%20renewable,still%20be%20operational%20by%202030

Input	Unit	Quantity
Feedstock Cost[145]	USD/tonne	1860
Chemical and Catalyst Costs[147]	Million USD/year	12
Labor Costs[126] [127] [128]	% of total capital	0.51
Average Salary[126] [127] [128]	USD/year	23,590
First Year Availability[90]	%	60
2nd Year+ Availability[90]	%	85

The AtJ CAPEX estimate is based on a techno-economic assessment by Washington State University titled "Alcohol to jet techno-economic analysis, v. 3.1 - Washington State University" dated 2021 (the "WSU AtJ TEA") [34]. The ISBL costs available in the WSU AtJ TEA were scaled to 2024 using the CEPCI value and scaled to the facility capacity modelled for Ghana using the six-tenths rule. OSBL costs were included as a factor of ISBL costs. Assumed OSBL costs include equipment for onsite hydrogen generation, wastewater treatment, storage tanks and pumps, and truck loading for the product. The table below shows the CAPEX estimate for the AtJ facility.

Table 29 CAPEX inputs for the maize residue AtJ pathway

Input	Unit	Quantity
CAPEX (total)[148]	Million USD	450
CAPEX (per annual fuel nameplate capacity)	USD/tonne	3,360
CAPEX (per annual SAF nameplate capacity)	USD/tonne	4,180

Additional factors were included for indirect costs, contingencies, financing costs, and working capital. A breakdown of the CAPEX is shown in the table below.

Table 30 Capital cost line items for the maize residue AtJ facility

Capital Cost Line Item	Unit	Million USD
Direct Costs	Million USD	115
Indirect Costs	Million USD	65
Contingency	Million USD	80
Owners and Financing Costs	Million USD	80
Working Capital	Million USD	110
Total Costs	**Million USD**	**450**

The OPEX and CAPEX information was then used in the financial model to estimate the minimum fuel selling price of SAF in Ghana, based on the financing assumptions described in Section 2.1. In this case, total CAPEX reaches the upper end of the concessional and grant financing waterfall. The model therefore applies the World Bank IDA allocation, the World Bank SUW allocation, and climate

[147] https://rex.libraries.wsu.edu/esploro/outputs/model/Alcohol-to-jet-techno-economic-analysis-v/99900620482101842
[148] https://rex.libraries.wsu.edu/esploro/outputs/model/Alcohol-to-jet-techno-economic-analysis-v/99900620482101842

grant funding, with any remaining requirement treated according to the financing waterfall. Salvage value was calculated based on the common industry standard of 10%.

Table 31 Additional financial inputs for the maize residue AtJ pathway

Input	Unit	Quantity
World Bank Debt – IDA	Million USD	250
World Bank Debt – SUW	Million USD	150
Climate Grant Funding	Million USD	25
Total Traditional Debt	Million USD	15
Total Equity	Million USD	10
Salvage Value[139]	Million USD	45

2.4.3 Pathway results

The techno-economic model for the AtJ pathway using 2G ethanol from maize residues yielded an MFSP for SAF of USD 4,980 per tonne in 2025 dollars. This result reflects the high assumed cost of cellulosic, or 2G, ethanol at USD 1,860 per tonne, compared with first generation ethanol at around USD 1,000 per tonne. The pathway is also affected by the greater need for commercial debt and equity financing compared with the lower-CAPEX HEFA and co-processing pathways.

2.5 Pathway 4: Integrated Cassava ethanol and AtJ

2.5.1 Pathway description

Feedstock

Cassava (*Manihot esculenta*) is a tropical root crop grown for its starchy tuber and is a major source of carbohydrates in many diets. It is widely cultivated across Ghana, where it plays an important role in food security and rural livelihoods. Cassava is particularly important because it is resilient to adverse climate conditions, can grow in poor soils, and can withstand drought, making it well suited to smallholder farming systems[149]. Cassava is also of strong economic relevance to Ghana and has been estimated to contribute materially to national GDP[150].

[149] https://ghanaiantimes.com.gh/how-cassava-can-transform-ghanas-economy-unlocking-the-hidden-potential-of-a-humble-crop-to-drive-jobs-boost-exports-and-strengthen-ghanas-future/
[150] https://www.fao.org/4/a0154e/A0154E07.HTM

Cassava tubers are a root crop commonly consumed as a food source

Source: EOS

Figure 17 Cassava crop[151]

Ghana produces more than 20 million tonnes of cassava per year. Production has also increased over the past decade, rising by 66% between 2013 and 2024. While cassava is grown in most regions of Ghana, the largest volumes are produced in the Eastern Region, which accounts for approximately 25% to 30% of national production[152]. Significant production is also found in the Ashanti and Central regions.

In addition to its role as a food crop, cassava is increasingly used in Ghana for industrial applications, including starch, flour, and ethanol production[150,153]. In 2001, the Presidential Special Initiative on Cassava was introduced, aiming to increase export revenue through transformed smallholder production methods and the development of cassava-starch industries in Ghana[154]. Research has also assessed the potential for bioethanol production from cassava in Ghana, with some studies suggesting that operations can be profitable[155]. Domestic interest in cassava ethanol is also reflected in activity by Caltech Ventures Ltd.

The ethanol produced from cassava in this scenario is classified as first generation ethanol, as it is derived from a starch-based feedstock. This differs from the 2G ethanol discussed in Section 2.4, which is produced from lignocellulosic residues such as maize stover. This distinction is important because first generation ethanol is more commercially established, but faces greater sustainability and eligibility constraints in several SAF policy frameworks because cassava is a food crop.

The Ghana Feasibility Study estimates that around 25% of total cassava production is recoverable for SAF production. For the integrated cassava ethanol and AtJ pathway, the model assumes that 80% of this available cassava is used for the integrated facility. Based on this assumption, 4.16 million tonnes per year of cassava feedstock is used in the pathway modelling.

Technology

The production of ethanol from cassava begins with feedstock pretreatment. Harvested cassava roots are received at the facility, washed to remove soil and debris, and then chipped or rasped into smaller fragments to increase surface area. The chipped material is then milled, typically using a hammer mill or roller mill, to produce a fine cassava flour or slurry. At this stage, a key process

151 https://eos.com/blog/how-to-grow-cassava/
152 https://srid.mofa.gov.gh/sites/default/files/2025-12/AGRICULTURE%20IN%20GHANA%20%28Facts%20%26%20Figures%29%202024_0.pdf
153 https://ghanaiantimes.com.gh/how-cassava-can-transform-ghanas-economy-unlocking-the-hidden-potential-of-a-humble-crop-to-drive-jobs-boost-exports-and-strengthen-ghanas-future/
154 https://makhillpublications.co/files/published-files/mak-aj/2020/2-26-29.pdf
155 https://www.ajfand.net/Volume22/No3/Komlaga20720.pdf

decision is made between a dry mill approach, where dried cassava chips are milled to flour before slurrying with water, and a wet mill approach, where fresh cassava is directly slurried[156].

The cassava slurry is then fed into a liquefaction system, where it is mixed with water and thermostable alpha-amylase enzyme and heated in a jet cooker or continuous liquefaction vessel, typically at 85°C to 110°C. This gelatinises the starch granules and begins enzymatic hydrolysis of the long-chain starch polymers into shorter-chain dextrins. The liquefied mash is then cooled and transferred to saccharification tanks, where glucoamylase enzyme is added at lower temperatures, typically 55°C to 65°C, to complete hydrolysis of the dextrins into fermentable glucose.

The glucose-rich hydrolysate is then cooled further and pumped to fermentation vessels, typically large stirred-tank or fed-batch fermenters operating at 30°C to 35°C. Saccharomyces cerevisiae yeast converts the glucose to ethanol and CO_2 over a fermentation cycle of approximately 48 to 72 hours, achieving beer strengths of roughly 10% to 15% ethanol by volume. Nutrient supplementation, including nitrogen, phosphorus, and vitamins, is added to support yeast health, while temperature control is important throughout fermentation to prevent yeast stress and maintain conversion efficiency.

The fermented beer is then fed to a distillation train for product recovery and purification. The first column, the beer still or stripping column, operates at near-atmospheric pressure and removes the bulk of the ethanol from the fermentation solids and water, producing an overhead vapour stream of approximately 40% to 50% ethanol by volume. This is followed by a rectification column, which concentrates the ethanol to near the azeotropic limit of approximately 95% to 96% ethanol by volume.

To achieve the anhydrous specification required for fuel use, typically above 99.5% ethanol by volume, a molecular sieve dehydration unit is used downstream of the rectifier. This uses zeolite beds operating in pressure-swing adsorption mode to selectively adsorb water and break the ethanol-water azeotrope. The bottoms stream from the beer still, known as whole stillage, contains residual fibre, protein, and unfermented solids. This is typically processed through a decanter centrifuge and evaporator train to recover a concentrated distillers' dried grain or thin stillage syrup, which can be used as animal feed or returned to the process as a nutrient source[157]. The final product is fuel-grade anhydrous ethanol, suitable for use as a fuel, as a gasoline blendstock, or as feedstock for downstream conversion processes such as AtJ.

The AtJ portion of the process operates as described in Section 2.4.1.

A block-flow diagram of the modelled facility is provided below.

[156] The majority of dedicated cassava ethanol facilities, particularly in Southeast Asia (Thailand, China, Vietnam), use dried cassava chips as the primary feedstock form, which offers logistical advantages for storage and transport relative to the highly perishable fresh root. While not confirmed, it is assumed that the dry mill approach is currently taken by Caltech Ventures, Ltd., and that it will be used in any future facility.
[157] The distiller' dried grain is to be sold as animal feed at $130/tonne in our model.

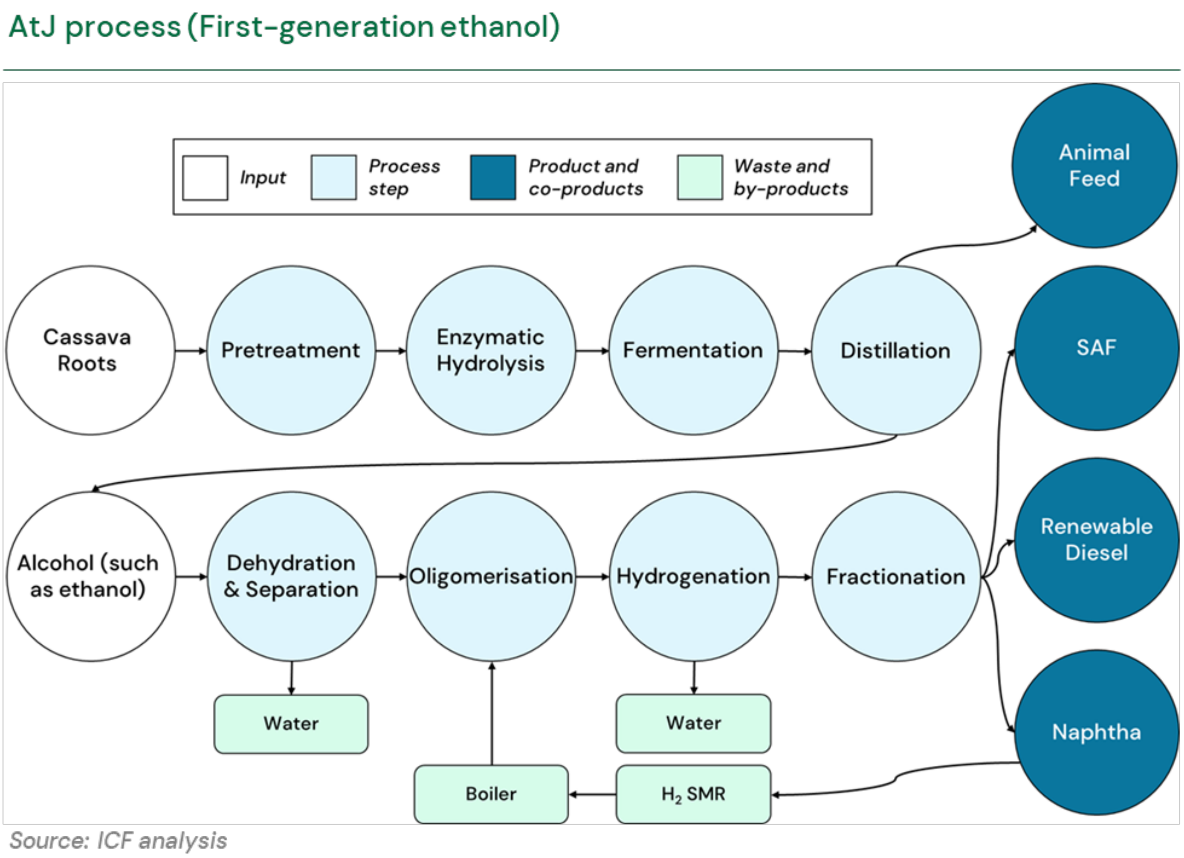


Figure 18 AtJ process for first generation feedstocks

Combining ethanol production and jet fuel production at one facility allows for energy integration, removes ethanol transport costs, and can lower some OSBL costs. However, the CAPEX for an integrated facility is much higher than for a standalone AtJ facility that purchases ethanol as an input.

First generation ethanol using cassava as a feedstock is a well-established industry, with much of the capacity concentrated in Southeast Asia, particularly Thailand, as shown in the table below.

Table 32 Locations of ethanol production facilities using cassava as a feedstock

Facility	Location	Capacity	Status	Notes
Asia				
Thai Agro Energy (TAE) / Lanna Resources	Central / West Thailand	350,000 L/day (~128 ML/yr)	Operating	Two production lines (150,000 + 200,000 L/day) using molasses and cassava as dual feedstocks. Produces anhydrous ethanol (99.5% v/v) for E10/E20/E85 gasohol blending.
KTIS Group	Central / Northeast Thailand	Not disclosed (major producer)	Operating	One of Thailand's top ethanol producers. Integrated sugar and cassava agribusiness. Uses both molasses and cassava feedstocks across multiple sites.
Mitr Phol Group (Mitr Phol Bio Fuel)	Central / Northeast Thailand	Not disclosed (major producer)	Operating	Asia's largest sugar and bioenergy producer. Cassava and molasses feedstocks.

KSL Group	Northeast Thailand	Not disclosed (major producer)	Operating	Major integrated sugar/ethanol group. Cassava and molasses feedstocks.
Various other producers (×23 additional plants)	Central and Northeast Thailand	Combined ~1.75 ML/day cassava capacity	Operating	Remaining Thai producers, most operating as downstream arms of major sugar or cassava starch groups.
Multiple producers (Guangxi, Guangdong)	Southern China	Substantial; not publicly disclosed per facility	Operating	China is major export market for Thai and Vietnamese cassava chips, primarily for industrial ethanol and animal feed. Production concentrated in southern provinces. Facility-level data not available in public sources.
MH Bioenergy Group (South Korea-backed)	Cambodia	36,000 t/yr (~45 ML/yr)	Operating	Opened 2008. Uses ~100,000 t/yr of dried cassava flour. Current operating status unclear.
Various producers	Vietnam	Multiple facilities; aggregate capacity not publicly reported	Operating	Vietnam is a major cassava grower and exporter (primarily to China). Domestic cassava ethanol facilities exist but are primarily oriented toward industrial-grade rather than fuel-grade ethanol.
Various / planned	Laos	Limited; expansion planned	Emerging	54,000 ha under cultivation in Xayaboury region alone. Processing infrastructure for ethanol remains limited.
Africa				
Allied Atlantic Distilleries Ltd (AADL)	Ogun State, Nigeria	30k liters/day (~9 ML/yr)	Operating	First and largest ethanol producer in Nigeria. Requires 250 t/day of fresh cassava roots.
CalTech Ventures Ltd	Ghana	30k liters/day (~9 ML/yr)	Unknown	Began producing cassava ethanol in 2016. Similar in size to the AADL plant in Nigeria. Markets product as extra neutral alcohol (ENA) which can be sold into the food and beverage industry.
Proposed Facility (UDC)	Gulu-Kitgum highway, Acholi, Uganda	Feasibility study completed; capacity TBD	Planned	Government-commissioned feasibility study completed (UDC / APRI, 2024). Proposed 25-acre site near Gulu; combined starch and ethanol production. Uganda has a surplus of ~9 M t/yr of cassava.

The Thai industry includes 27 operating plants with a combined cassava-based capacity of around 760 million litres per year, operating within a mature, policy-driven, commercially integrated industry. In 2024, the Thai industry produced around 340 million litres of cassava-based ethanol, equivalent to 57% of nameplate capacity. In Africa, despite the continent producing a large share of global cassava, the ethanol industry remains underdeveloped relative to the available resource base. This reflects feedstock logistics, infrastructure gaps, and capital constraints. Nigeria alone produces more than 59 million tonnes of cassava, yet AADL's 9 million litre per year facility has faced ongoing challenges around feedstock supply-chain reliability due to cassava's short postharvest shelf life and rural road infrastructure. The gap between agricultural production capacity and processing infrastructure is therefore a defining challenge across the African sector.

As noted in Section 2.4.1, LanzaJet's Freedom Pines facility is the first commercial-scale ethanol-to-jet facility of its kind. The facility went through a lengthy commissioning process and was delayed for more than a year before the company announced the facility had "fully operated and produced fuels". This adds risk to projects seeking to use AtJ for SAF production.

As of Q1 2026, there were only two major projects underway where onsite ethanol production was expected to be paired with an AtJ facility: Gevo's net-zero AtJ SAF plant in Richardton, North Dakota, located on the same site as a corn-fed ethanol plant previously operated by Red Trail Energy; and Project Speedbird, a partnership between LanzaJet, Nova Pangaea Technologies, and British Airways in Teesside, UK, intended to combine onsite cellulosic ethanol production with AtJ conversion.

Sustainability and eligibility

Cassava tubers are a food crop, which creates a different sustainability and eligibility position from residue-based pathways. This does not mean cassava ethanol cannot technically be converted into SAF, but it does limit the markets where that SAF would qualify for compliance or mandate purposes.

Cassava is not listed in Annex IX of the Renewable Energy Directive and would not be eligible as a SAF feedstock under ReFuelEU Aviation. It would also not qualify under the UK SAF Mandate, which restricts support for crop-based feedstocks. As a result, SAF produced from 1G ethanol from cassava tubers would have limited access to regulated SAF demand in the UK and EU.

Under CORSIA, the position is different. Food crops are not automatically excluded, and crop-based pathways can in principle be eligible if they meet the scheme's sustainability criteria and life cycle emissions requirements. However, there are currently no CORSIA default life cycle emission values for cassava-derived SAF. As a result, a project using cassava tubers would require project-specific life cycle assessment and sustainability evidence before it could be treated as a CORSIA Eligible Fuel.

There is a defined process for adding standalone pathways to the list of CORSIA default life cycle emission values, which could be used to insert cassava-derived ethanol as a feedstock for CORSIA Eligible Fuel production. ICAO Member States, Observer Organizations, or an approved SCS can request the ICAO Committee on Aviation Environmental Protection to consider an additional pathway by email (caep@icao.int), providing:

- The pathway uses an ASTM certified conversion process.
- The conversion process has been validated at sufficient scale to establish a basis for facility design and operating parameters at commercial scale.
- There is sufficient data on the conversion process of interest to perform LCA modelling.
- There is sufficient data on the feedstock of interest to perform LCA modelling.
- There is sufficient data on the region of interest to perform induced land use change (ILUC) modelling, where applicable to the pathway.

A list of data requirements is provided for the life cycle assessment calculation in the CORSIA LCA Methodology Document[158]. The Ghana Feasibility Study notes that cassava waste streams are not currently recognised as an approved feedstock for CORSIA Eligible Fuel, but that work is ongoing on the development of an LCA for consequent incorporation. However, no further information on the status of this work could be identified. While that statement relates specifically to cassava waste streams rather than cassava tubers, it highlights the broader point that cassava-based

[158] https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/CORSIA_Supporting_Document_CORSIA-Eligible-Fuels_LCA_Methodology_V7.pdf

pathways would need additional life cycle evidence before they could be relied on for CORSIA eligibility.

There is limited published life cycle evidence for cassava-derived ethanol and SAF. One study calculated the carbon intensity of ethanol produced from cassava in Vietnam at 35 gCO_2e/MJ[159]. This suggests that cassava ethanol may be capable of reducing life cycle emissions relative to conventional fuels. However, that study does not consider induced land use change emissions, which could be material for a food-crop feedstock. Cassava can grow on marginal and degraded land, which may reduce some land-use concerns, but eligibility and carbon intensity would still need to be demonstrated through project-specific assessment.

This is different from cassava residues, which are considered separately in the FT pathway in Section 2.6. Inedible residues from cassava processing may be capable of being treated as wastes or residues under relevant frameworks, subject to classification and certification. The pathway considered in this section, however, uses 1G ethanol from cassava tubers and therefore faces the food-crop eligibility constraints described above.

2.5.2 Pathway inputs and assumptions

For the integrated cassava ethanol and AtJ pathway, feedstock consumption is estimated at 4.16 million tonnes per year of cassava, based on the amount of feedstock available for SAF in the Ghana Feasibility Study. The feedstock quantity assumes that 80% of the cassava available for SAF production would be available for this facility. The modelled facility is estimated to produce approximately 138,000 tonnes per year of SAF.

Most utility and material inputs are based on the ANL GREET Model using publicly available sources. For this case, an integrated corn-to-ethanol and ethanol-to-jet fuel facility was modelled because no cassava starch pathway was available. This assumes that the starch-based feedstock is transported to the facility. Additional factors were applied to natural gas and electricity use based on the inclusion of onsite hydrogen and OSBL electricity needs.

Construction time was based on an Air Cargo Week article focused on the timelines for various SAF production facilities, the known time required by LanzaJet to construct its Freedom Pines AtJ facility, and the addition of an extra year for construction of the ethanol plant. Labour demand was estimated based on information presented by Sustainable Aviation Futures for SAF facilities and Low et al. (2008) for ethanol plants[160]. A combined labour pool of 131 full-time employees, comprising 34 for the ethanol plant and 97 for the AtJ plant, was used in the model, with salary estimates based on the same Ghana-specific job sites referenced previously.

Availability estimates were based on similarity to the AtJ facility modelled in Section 2.4, which is expected to be the key contributor to downtime within the integrated facility because of its complexity. The less complex ethanol plant is not considered a limiting factor. Feedstock costs were estimated based on information provided by Tridge.com and Procurementresource.com[161,162]. Cassava-based animal feed prices were estimated based on information provided by Project Assistance[163], while the ratio of ethanol production to animal feed by-product was based on information provided by Xu et al. (2025)[164].

The operating inputs and assumptions are shown in the table below.

Table 33 Material and energy inputs of the integrated cassava AtJ pathway

159 https://www.sciencedirect.com/science/article/abs/pii/S0961953413000263?via%3Dihub
160 https://www.researchgate.net/publication/23507192_Ethanol_Implications_for_Rural_Communities
161 https://Tridge.com
162 https://Procurementresource.com
163 https://www.projet-assistance.com/l/cassava-animal-feed-processing-line-turning-waste-into-wealth-for-livestock-aquaculture/
164 https://www.mdpi.com/2071-1050/17/17/8007

Input	Unit	Quantity
SAF Capacity[144]	Tonnes/year	138,000
RD Capacity[144]	Tonnes/year	30,000
Naphtha Capacity[144]	Tonnes/year	4,000
Construction[146]	Years	3
Electricity Requirement[144]	MWh/year	174,000
Natural Gas Requirement[144]	MMBTU/hour	310
Water Requirement[144]	Thousand gallon/day	1,100
Wastewater Generation[90]	Thousand gallon/day	1,400
Feedstock Requirements[118]	Tonnes/year	4,160,000
Feedstock Cost[165] [166]	USD/tonne	165
Animal Feed Co-Product Price[167]	USD/tonne	130
Chemical and Catalyst Costs[144]	Million USD/year	35
Labor Costs[126] [127] [128]	% of total capital	0.30
Average Salary[126] [127] [128]	USD/year	23,586
First Year Availability[90]	%	60
2nd Year+ Availability[90]	%	85

The integrated ethanol and jet fuel CAPEX estimate is based on the WSU AtJ TEA and a publicly available techno-economic assessment published by members of NREL and ANL titled "*Sustainable aviation fuel from ethanol: Techno-economic analysis and life cycle analysis*" dated November 15, 2025[168]. OSBL costs were included as a factor of ISBL costs. Assumed OSBL costs include equipment for onsite hydrogen generation, wastewater treatment, storage tanks and pumps, and truck loading of the product. The table below shows the CAPEX estimate for the integrated ethanol and jet fuel facility.

Table 34 CAPEX inputs for the integrated cassava AtJ pathway

Input	Unit	Quantity
CAPEX (total)[168]	Million USD	1,020
CAPEX (per annual fuel nameplate capacity)	USD/tonne	5,955
CAPEX (per annual SAF nameplate capacity)	USD/tonne	7,400

Additional factors for indirect costs, contingencies, owner's costs, financing costs, and working capital were applied to the direct costs. A breakdown of the CAPEX estimate for the integrated ethanol-to-jet pathway is shown below.

[165] https://www.tridge.com/
[166] https://www.procurementresource.com/
[167] https://www.projet-assistance.com/l/cassava-animal-feed-processing-line-turning-waste-into-wealth-for-livestock-aquaculture/
[168] https://doi.org/10.1016/j.apenergy.2025.126373

Table 35 Capital cost line items for the integrated cassava AtJ facility

Capital Cost Line Item	Unit	Million USD
Direct Costs	Million USD	302
Indirect Costs	Million USD	172
Contingency	Million USD	215
Owners and Financing Costs	Million USD	215
Working Capital	Million USD	116
Total Costs	**Million USD**	**1,020**

The OPEX and CAPEX information was then used in the financial model to estimate the minimum fuel selling price of SAF in Ghana, based on the financing assumptions described in Section 2.1. In this case, total CAPEX exceeds the World Bank IDA and SUW allocations as well as the USD 50 million maximum assumed for climate grant funding. As a result, the remaining funding requirement is financed through commercial debt and equity. Salvage value was calculated based on the common industry standard of 10%.

Table 36 Additional financial inputs for the integrated cassava AtJ pathway

Input	Unit	Quantity
World Bank Debt – IDA	Million USD	250
World Bank Debt – SUW	Million USD	150
Climate Grant Funding	Million USD	50
Total Traditional Debt	Million USD	342
Total Equity	Million USD	228
Salvage Value[139]	Million USD	102

2.5.3 Pathway results

The techno-economic model for the integrated cassava ethanol and AtJ pathway yielded an MFSP for SAF of approximately USD 6,900 per tonne in 2025 dollars. Although the facility uses 1G ethanol, the cost benefits are outweighed by the relatively low ethanol yield from cassava roots. Absolute alcohol yields from cassava roots are typically around 70 to 110 litres per tonne, depending on the variety and production method, compared with expected yields of around 350 to 400 litres per tonne from maize[169].

The ability to sell animal feed by-product from fermentation provides some support to the economics, but this benefit is limited relative to the high CAPEX of the integrated facility, the resulting exposure to commercial debt and equity, and the large recurring feedstock costs. These factors contribute to the highest operating cost of the pathways examined, at approximately USD 4,070 per tonne of total fuels produced.

2.6 Pathway 5: Gasification Fischer Tropsch of cassava residue

2.6.1 Pathway description

Feedstock

Cassava residues are generated during the processing of cassava tubers and include cassava peel residue, bagasse, and residual starch in wastewater. These residues differ fundamentally from whole cassava tubers. Cassava tubers are a primary food crop, whereas cassava residues are by-

[169] https://www.scribd.com/document/148037288/The-Alcohol-Textbook

products of food and industrial processing. This distinction is important because residues avoid the direct food-competition concerns associated with using cassava tubers as a dedicated fuel feedstock.

Cassava residues are therefore more attractive from a sustainability perspective than whole cassava tubers. Their use can create value from low-value processing by-products, reduce waste, and lower direct land-use change risk. At the same time, their practical availability depends heavily on how much cassava is processed industrially, where that processing takes place, and whether residues can be collected before they degrade.

Cassava bagasse and peels are waste products generated during cassava processing

Source: BioInnovate Africa; Technical Centre for Agricultural and Rural Cooperation

Figure 19 Cassava peels[170]

The geographic availability of cassava residues broadly follows the distribution of cassava production described in Section 2.5.1, with production concentrated in the Eastern, Ashanti, and Central regions. Cassava residues currently have low market value and limited formal markets, although they can be used as animal feed, compost, or for other local purposes.

Both cassava peel residue and bagasse are considered as potential feedstocks for the gasification/FT pathway. The Ghana Feasibility Study estimates that approximately 1,107,000 tonnes per year of cassava residues are recoverable for SAF production. This estimate is based on a conservative scenario in which 25% of cassava wastes and residues from industrial processing are recovered, reflecting practical limits on residue recovery. For this study, it is assumed that 80% of the recoverable volume is available for the modelled SAF plant.

This assumption should still be treated with caution. The 25% recovery rate applies to residues from industrial cassava processing, while only a fraction of Ghana's cassava production, estimated at around 0.5–10% in recent years, has been processed[171][172]. If most cassava continues to be consumed or prepared through informal channels, including boiling for household or local consumption, the practical availability of cassava peel residue and bagasse may be lower than the recoverable estimate. An FT facility would not necessarily need to rely only on cassava residues, however, and could use other lignocellulosic residues where technically compatible and certifiable.

Technology

The process begins with feedstock pretreatment, where the cassava residues are dried to a moisture content typically below 15–20 wt% and then size-reduced through chipping and milling to a particle size appropriate for the gasifier type selected. The dried, sized feedstock is then fed

[170] https://bioinnovate-africa.org/cassava-biowaste-could-be-a-gamechanger-in-the-development-of-bioplastics-as-eco-friendly-packaging-materials/
[171] https://www.newsghana.com.gh/ghana-cassava-processor-targets-billion-dollar-african-food-chain/
[172] https://citibusinessnews.com/2022/11/only-0-5-of-18m-tons-of-cassava-is-processed-dbg-girsal-forum-reveals/

to a gasification reactor, where it undergoes partial oxidation in the presence of a controlled supply of an oxidant (air, oxygen, or steam, depending on the gasifier configuration) at high temperatures (typically 700–1,400°C depending on gasifier type) and pressures ranging from near-atmospheric to 30–35 bar for pressurised systems (most systems use a slight amount of pressure to help drive gas through the system and prevent inflow of additional air). The principal gasifier configurations applicable to this feedstock include fixed-bed updraft or downdraft reactors (simpler and lower cost, but better suited to smaller scales and producing a relatively tar-laden syngas), fluidised-bed reactors (offering better temperature uniformity, higher throughput, and improved carbon conversion, well-suited to the variable particle size and moisture content typical of agricultural residues), and entrained-flow reactors (operating at the highest temperatures and producing a very clean, tar-free syngas, but requiring very fine, dry, and consistent feedstock and representing the highest capital cost option). The gasification reactions convert the biomass into a raw synthesis gas (syngas) composed primarily of hydrogen (H_2) and carbon monoxide (CO), along with carbon dioxide (CO_2), water vapour, methane, and a range of contaminants including tars, particulates, hydrogen sulphide (H_2S), ammonia (NH_3), hydrogen chloride (HCl), and alkali vapours, the relative proportions of which depend strongly on gasifier type and operating conditions.

The raw syngas exiting the gasifier requires extensive cleaning and conditioning before it can be fed to the FT synthesis reactor, and this gas cleanup train is one of the most technically and economically challenging aspects of the entire process. Hot syngas passes first through a cyclone and ceramic filter or wet scrubber system for particulate and coarse tar removal, followed by a tar reformer or catalytic tar cracker (in cases where fixed-bed or fluidised-bed gasification is used) to convert heavy tar molecules into additional CO and H_2. The gas then passes through a water-gas shift (WGS) reactor, where the H_2/CO ratio is adjusted to the value required by the FT catalyst (typically around 2:1 H_2:CO ratio for cobalt-based catalysts) via the reaction $CO + H_2O \rightarrow CO_2 + H_2$. Subsequent acid gas removal (AGR), typically using an amine scrubbing system such as MDEA or a physical solvent such as Selexol, removes H_2S, CO_2, and other acid gases to protect the downstream FT catalyst, which is highly sensitive to sulphur poisoning. Final polishing steps may include a zinc oxide guard bed for residual sulphur removal and, for pressurised systems, compression of the clean syngas to FT reactor operating pressure (typically 20–40 bar).

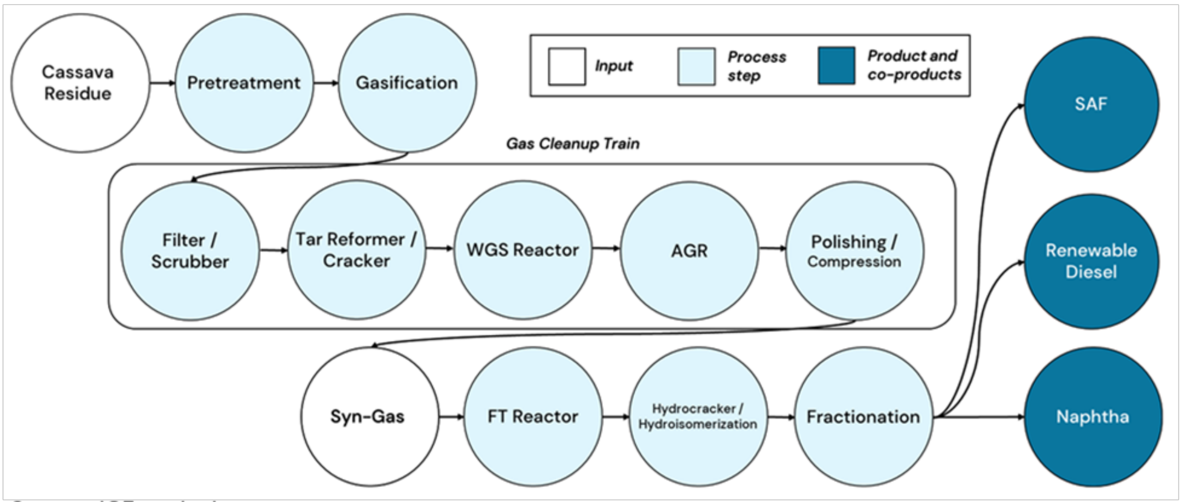
The clean syngas is then fed to the Fischer-Tropsch synthesis reactor, where it is converted over a cobalt or iron catalyst[173] at temperatures of 150–250°C and pressures of 20–40 bar. The FT reaction produces a broad distribution of straight-chain hydrocarbons (paraffins and olefins) ranging from methane to heavy waxes, according to the Anderson-Schulz-Flory (ASF) chain growth distribution. Reactor configurations include fixed-bed multitubular reactors and slurry-phase bubble column reactors (SBCR), the latter offering better heat management and catalyst handling flexibility at larger scales. The FT reactor effluent, a mixture of wax, liquid hydrocarbons, water, and light gases, is separated in a hot and cold separator train, with the aqueous phase (containing oxygenated co-products such as alcohols and organic acids) separated and treated, and the hydrocarbon phases routed forward to upgrading.

The FT wax and liquid hydrocarbon streams are then processed in a hydrocracking and hydroisomerisation unit, a fixed-bed catalytic reactor operating at 300–400°C and 35–70 bar over a bifunctional noble metal or base metal catalyst on a zeolite or amorphous silica-alumina support, where the heavy wax molecules are selectively cracked and isomerised into the target product boiling range. The upgraded product is subsequently fractionated in an atmospheric distillation column into discrete product cuts: a light naphtha fraction (C5–C8), a jet fuel cut (C9–C16), a diesel/gasoil fraction (C17-C30), and a residual heavy fraction recycled to the hydrocracker. Light hydrocarbon off-gases from the FT reactor and fractionation column, primarily methane and C2–C4 hydrocarbons, are typically recycled as fuel gas to the gasifier or used for process heat and power generation, improving overall process energy integration.

A block-flow diagram of the SAF plant is provided below.

[173] Cobalt being the preferred choice for biomass-derived syngas targeting wax and middle distillate production due to its higher activity and selectivity.

Gasification Fischer-Tropsch (FT) process



Source: ICF analysis

Figure 20 FT process flow

Gasification is one of the oldest industrial thermochemical processes, with origins in the early 19th century and major scale-up during the Second World War and the oil shocks of the 1970s. Modern commercial gasification is dominated by coal and petroleum coke feedstocks, primarily for integrated gasification combined cycle (IGCC) power generation and syngas production for ammonia, methanol, and hydrogen. The Global Syngas Technologies Council estimated total global gasification capacity at over 100 GW thermal in the early 2020s, making it a well-established technology at very large scale, although largely on fossil feedstocks.

Biomass gasification has a shorter and more mixed commercial history. Small and medium-scale biomass gasifiers for heat and power have been deployed for several decades, particularly in Scandinavia, Austria, and Southeast Asia. However, scaling biomass gasification to provide a high-quality and consistent syngas stream suitable for downstream chemical synthesis, rather than direct combustion for heat and power, has proved more difficult. The main challenges are tar management, feedstock variability, and the higher moisture and ash content of biomass compared with coal.

Notable large-scale biomass gasification examples include GoBiGas in Gothenburg, Sweden, a 20 MW biomass-to-biomethane plant operated between 2014 and 2018, and the Güssing plant in Austria, which operated as a research and demonstration facility. Both demonstrated technical capability, but neither achieved the economics required for sustained commercial operation without subsidy.

Fischer-Tropsch synthesis was developed in Germany in the 1920s and scaled during the 1930s and 1940s as part of Germany's synthetic fuels strategy. After the Second World War, South Africa's Sasol developed a large coal-to-liquids industry based on domestic coal reserves, and the Secunda complex remains the largest single FT plant in the world. Shell's Pearl GTL plant in Qatar, which began operations in 2011, represents another major commercial FT deployment, producing synthetic liquids from natural gas-derived syngas. A smaller Shell GTL plant has operated in Bintulu, Malaysia, since 1993.

Beyond Sasol and Shell, several smaller FT technology developers and licensors have emerged, including Velocys, CompactGTL, and Emerging Fuels Technology. Velocys in particular has targeted smaller-scale distributed biomass-to-liquids applications using microchannel FT reactor technology.

In the SAF context, biomass gasification coupled with FT synthesis remains pre-commercial to early-commercial. No large-scale commercial biomass-to-liquid FT SAF plant is currently operating, although several demonstration and early commercial projects have been under development.

Sustainability and eligibility

Cassava residues are not generally named explicitly under CORSIA, UK, or EU frameworks, but they may be capable of being classified as agricultural or processing residues where they are inedible by-products of cassava processing. This is different from using cassava tubers, which are a food crop. The sustainability position of cassava residues is therefore stronger than the 1G cassava ethanol pathway discussed in Section 2.5, provided that residue status, traceability, and collection practices can be demonstrated.

Under CORSIA, the default life cycle emission value for SAF derived from agricultural residues through the FT pathway is 7.7 gCO_2e/MJ, representing a reduction of more than 90% relative to the baseline carbon intensity of conventional aviation fuel. For the purposes of this assessment, cassava residues are treated as an agricultural residue pathway. However, because cassava residues are not explicitly listed as a standalone named feedstock, a project would need to confirm feedstock classification and sustainability treatment through the relevant certification scheme and, if needed, through the CORSIA process for adding or recognising additional pathways and default values.

The UK SAF Mandate allows wastes and residues of biological origin derived from agriculture, aquaculture, fisheries, or forestry. The Renewable Energy Directive Annex IX also includes relevant categories such as other lignocellulosic material, except saw logs and veneer logs, and the biomass fraction of industrial waste not fit for use in the food or feed chain, including material from the agro-food industry. On this basis, cassava residues will likely be eligible in principle under UK and EU frameworks, subject to feedstock classification, evidence of residue status, traceability, and life cycle emissions performance.

Table 37 Sustainability & eligibility of cassava residues under CORSIA, UK, EU frameworks

Feedstock	Carbon Intensity (gCO_2e/MJ)	CORSIA Eligibility	UK Eligibility	EU Eligibility
Cassava Residues	7.7[A]	Yes	Yes	Yes

[A] In the CORSIA default life cycle emission values, this is listed under agricultural residues.

Source: ICF Analysis, US dollars

Reasoning for the inclusion of cassava residues under the umbrella of agricultural residues is informed by the treatment of comparable waste and residue categories under the UK and EU frameworks. The UK SAF Mandate allows “wastes and residues of biological origin, which can be derived directly from agriculture, aquaculture, fisheries or forestry.” The Renewable Energy Directive Annex IX list of eligible feedstocks includes “other ligno-cellulosic material except saw logs and veneer logs” and the “biomass fraction of industrial waste not fit for use in the food or feed chain, including material from the agro-food industry.” On this basis, cassava residues are treated in this study as potentially eligible agricultural or processing residues, subject to confirmation of classification, traceability, and sustainability certification.

Cassava residues are not explicitly listed as an eligible feedstock under the UK Renewable Transport Fuel Obligation or SAF Mandate. However, new feedstocks can be added to the list of eligible materials. A form must be obtained from, completed, and returned to rtfo-compliance@dft.gov.uk or SAF-compliance@dft.gov.uk. Information must be provided on the process that generates the potential feedstock, its economic value, and its other uses. The Low Carbon Fuels Delivery Unit will then assess the appropriate classification and level of reward, with most new materials assessed within approximately eight weeks.

2.6.2 Pathway inputs and assumptions for TEA

For the gasification/FT pathway, feedstock consumption is estimated at approximately 885,600 tonnes per year of cassava residues. This is estimated to produce 50,000 tonnes per year of SAF, as well as 10,500 tonnes per year of renewable diesel and 10,500 tonnes per year of naphtha. SAF selectivity for the gasification/FT pathway is estimated based on the 2021 NREL paper titled "Jet Fuel Production at the Pittsburgh Airport: GTL via Fischer-Tropsch Synthesis" dated December 2, 2021 (the "NREL FT Paper")[174].

Utility and material inputs are based on the ANL GREET Model using publicly available sources. The gasification/FT facility is assumed to be fuel-balanced and not to require utility electricity or grid input during normal operation, although it is expected that the plant would be grid-connected. Feedstock input is based on information in the Ghana Feasibility Study. Water use, wastewater generation, and chemical and catalyst costs were based on information provided in an FT techno-economic analysis by Washington State University titled "Fischer Tropsch techno-economic analysis, v. 3.1" dated 2021 (the "WSU FT TEA")[175].

Construction time was based on an Air Cargo Week article focused on the timelines for various SAF production facilities. Labour demand for a combined gasification and FT plant was estimated based on information presented by Sustainable Aviation Futures for SAF facilities. A labour pool of 97 full-time employees was used in the model, with salary estimates based on the same Ghana-specific job sites referenced previously. Availability estimates were based on similarity to the integrated ethanol plant and AtJ facility modelled in Section 2.5, with facility complexity expected to be the key contributor to downtime. Feedstock costs were estimated based on information provided by Tridge.com and Procurementresource.com.

The material and energy inputs are shown in the table below.

Table 38 Material and energy inputs of the cassava residue gasification and FT pathway

Input	Unit	Quantity
SAF Capacity[174]	Tonnes/year	50,000
RD Capacity[174]	Tonnes/year	10,500
Naphtha Capacity[174]	Tonnes/year	10,500
Construction[146]	Years	3
Electricity Requirement[144]	MWh/year	114,000
Natural Gas Requirement[144]	MMBTU/hour	0
Water Requirement[175]	Thousand gallon/day	2,600
Wastewater Generation[175]	Thousand gallon/day	1,300
Feedstock Requirements[118]	Tonnes/year	885,000
Feedstock Cost[176,161]	USD/tonne	160
Chemical and Catalyst Costs[175]	Million USD/year	4
Labor Costs[126 127 128]	% of total capital	0.26
Average Salary[126 127 128]	USD/year	23,600
First Year Availability[90]	%	60

[174] https://netl.doe.gov/sites/default/files/2022-03/Jet%20Fuel%20Production%20at%20the%20Pittsburgh%20Airport%20GTL%20via%20FischerTropsch%20Synthesis.pdf
[175] https://rex.libraries.wsu.edu/esploro/outputs/model/99900620482301842
[176] https://www.researchgate.net/publication/23507192_Ethanol_Implications_for_Rural_Communities

Input	Unit	Quantity
2nd Year+ Availability[90]	%	85

The CAPEX estimate is based on the WSU FT TEA. The ISBL costs available in the WSU FT TEA were scaled to 2024 using the CEPCI value and scaled to the facility capacity modelled for Ghana using the six-tenths rule. OSBL costs were included as a factor of ISBL costs. Assumed OSBL costs include equipment for boiler and steam turbine systems, wastewater treatment, storage tanks and pumps, and truck loading for the product. The table below shows the CAPEX estimate for the FT facility.

Table 39 CAPEX inputs for the cassava residue gasification and Fischer Tropsch pathway

Input	Unit	Quantity
CAPEX (total)[175]	Million USD	875
CAPEX (per annual fuel nameplate capacity)	USD/tonne	12,320
CAPEX (per annual SAF nameplate capacity)	USD/tonne	17,500

A breakdown of the CAPEX costs is shown below.

Table 40 Capital cost line items for the cassava residue gasification and FT facility

Capital Cost Line Item	Unit	Million USD
Direct Costs	Million USD	283
Indirect Costs	Million USD	160
Contingency	Million USD	200
Owners and Financing Costs	Million USD	200
Working Capital	Million USD	32
Total Costs	**Million USD**	**875**

The OPEX and CAPEX information was then used in the financial model to estimate the minimum fuel selling price of SAF in Ghana, based on the financing assumptions described in Section 2.1. In this case, total CAPEX exceeds the World Bank IDA and SUW allocations as well as the USD 50 million maximum assumed for climate grant funding. As a result, the remaining funding requirement is financed through commercial debt and equity. Salvage value was calculated based on the common industry standard of 10%.

Table 41 Additional financial inputs for the cassava residue gasification and FT pathway

Input	Unit	Quantity
World Bank Debt – IDA	Million USD	250
World Bank Debt – SUW	Million USD	150
Climate Grant Funding	Million USD	50
Total Traditional Debt	Million USD	255
Total Equity	Million USD	170
Salvage Value[139]	Million USD	87.5

2.6.3 Pathway results

The techno-economic model for the gasification/FT pathway using cassava residues as a feedstock yielded an MFSP for SAF of approximately USD 7,540 per tonne in 2025 dollars. This is the highest MFSP of the pathways examined and is driven primarily by the high CAPEX associated with gasification and FT technology. The pathway has the highest CAPEX per tonne of total fuel production capacity, at approximately USD 12,320 per tonne per year of total fuels produced.

The high capital requirement also increases exposure to commercial debt and equity financing, which has a significant effect on the MFSP under the financing assumptions used in this study. However, the gasification/FT pathway has relatively low operating costs, at approximately USD 2,670 per tonne of total fuels produced, second only to the HEFA pathway. This partly offsets the high cost of facility development, but not enough to make the pathway competitive with the lower-CAPEX options assessed in this chapter.

2.7 Results of the TEA

The table below presents the operating costs, revenues, debt payments, and MFSP for each pathway. Values are shown for the first year of operation after the end of the World Bank IDA five-year grace period. All values are normalised to 2025 USD.

Table 42 Techno-economic analysis results for all pathways

Line Item	Unit	Co-Pro	HEFA	Maize AtJ	Cassava AtJ	Cassava FT
Fuel Nameplate Capacity	Tonnes/year	10,130	83,800	134,000	171,300	71,000
2nd Year+ Availability	%	95	85	85	85	85
Total CAPEX	Million USD	20.2	245	450	1,020	875
Variable OPEX	Million USD/year	19.2	113.6	427.4	655.3	144.0
Fixed OPEX	Million USD/year	0.75	10.5	18.0	41.3	33.0
Total OPEX	Million USD/year	19.9	124.1	445.4	696.6	176.9
OPEX	USD/tonne of annual fuel produced	2068	1,742	3,910	4,784	2,932
MFSP	USD/tonne of SAF	3,020	2,165	4,980	6,880	7,540

The results show a wide range of MFSPs across the pathways. HEFA has the lowest MFSP, at USD 2,165/tonne, followed by co-processing at USD 3,020/tonne. The AtJ pathways are higher, with maize residue AtJ at USD 4,980/tonne and integrated cassava ethanol and AtJ at USD 6,880/tonne. FT using cassava residues has the highest MFSP, at USD 7,540/tonne.

There are also clear differences in the cost structure of each pathway. Feedstock and other variable operating costs are a major component across all cases, although the relative importance of CAPEX and financing increases for the larger and more capital-intensive pathways. This is reflected in the higher commercial debt payments for the integrated cassava ethanol and AtJ pathway and the FT pathway, both of which exceed the concessional and grant funding thresholds assumed in the financing structure.

The following section tests the sensitivity of these results to changes in CAPEX, availability, financing costs, and feedstock prices.

2.8 Sensitivity analysis

A sensitivity analysis was carried out for each pathway to assess how changes in key variables affect the domestic MFSP for SAF. For each pathway, a single variable was changed positively and negatively, with all other variables held constant. The variables assessed were CAPEX, availability from year 2 onwards, commercial debt and equity rates, and feedstock price.

The same variables were assessed across all pathways to allow comparison. Most variables were changed by +/-10%. Availability and total commercial debt were capped at +/-5%, as larger changes were considered less realistic for those variables. The table below summarises the assumptions used for the sensitivity analysis.

Table 43 Sensitivity analysis inputs

Variable	Optimistic	Default	Pessimistic
CAPEX Deviation	-10%	0%	10%
Interest Rates	Commercial debt rate (construction): 21% Commercial debt rate (operations): 18% Equity: 26.5%	Commercial debt rate (construction): 23% Commercial debt rate (operations): 20% Equity: 28.5%	Commercial debt rate (construction): 25% Commercial debt rate (operations): 22% Equity: 30.5%
Year 2+ Availability	+5%	Varies with Pathway	-5%
Feedstock Price	-10%	Varies with Pathway	+10%

Results for each pathway can be seen in the figures below, along with related commentary.

2.8.1 Co-Processing

The co-processing pathway is most sensitive to feedstock cost. A +/-10% change in feedstock price has a +12/-11% impact on MFSP, a larger effect than the other variables tested. This reflects the small scale of the facility modification and the relatively low CAPEX associated with adding co-processing capability to an existing refinery.

Other variables have a more limited effect. CAPEX sensitivity is low because the absolute capital requirement is small. Availability also has limited impact because the assumed availability is already high, reflecting the commercial track record and low complexity of co-processing facilities. Changes in commercial debt and equity rates have little effect because the pathway requires only a small amount of commercial financing.

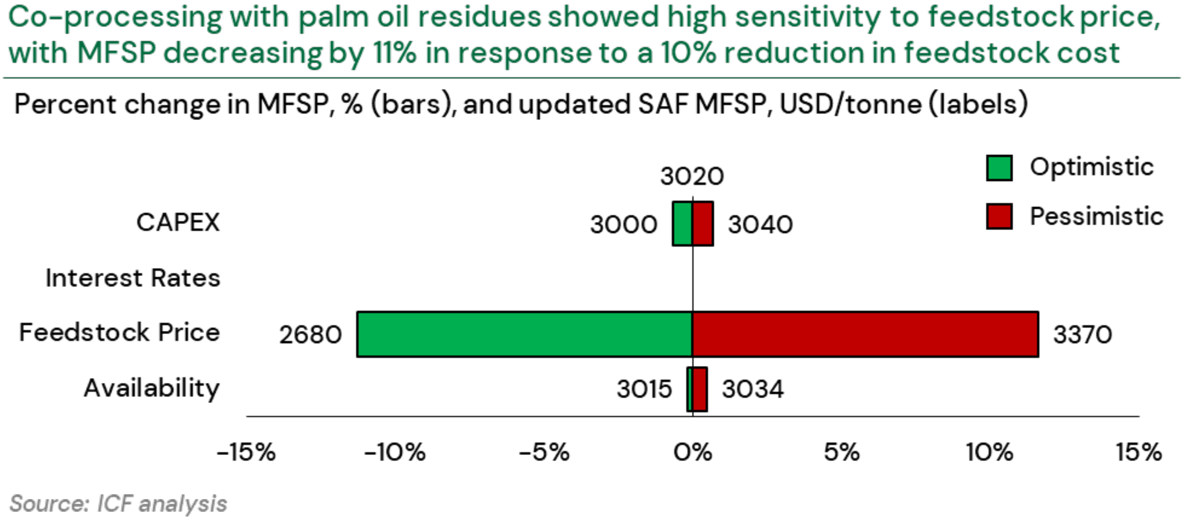


Figure 21 Pricing sensitivity of co-processing with palm oil

2.8.2 Standalone HEFA

Feedstock cost is also the dominant variable for the standalone HEFA pathway. A +/-10% change in feedstock price produces an MFSP spread of +9/-10%. This reflects the importance of lipid feedstock cost in HEFA economics, particularly where waste oil and fat feedstocks are already traded in competitive markets.

CAPEX has a larger effect than in the co-processing pathway because the HEFA facility is a standalone greenfield plant with a higher upfront capital requirement. However, changes in availability and financing rates have a smaller effect. This is because the assumed availability is based on a commercially mature pathway, and the facility remains largely within concessional financing assumptions, with only limited exposure to commercial debt and equity.

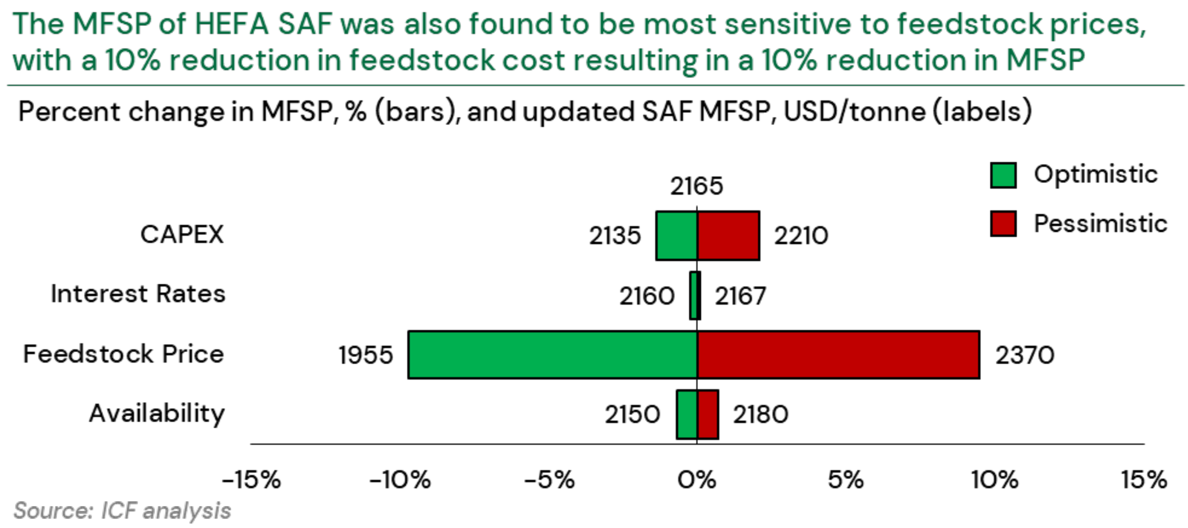


Figure 22 Pricing sensitivity of HEFA SAF

2.8.3 Maize Residue AtJ

For the maize residue AtJ pathway, feedstock price remains the most important variable. In this case, the feedstock entering the AtJ facility is 2G ethanol, which is assumed to cost USD 1,860/tonne. This is materially higher than the cost of 1G ethanol and drives a large share of the pathway's total OPEX. As a result, a +/-10% change in 2G ethanol price has a significant impact on MFSP of +9/-9%.

CAPEX is also relatively important, with a +/-10% CAPEX change leading to a +4/-3% change in MFSP. The pathway sits close to the upper end of the concessional and grant financing structure, meaning that changes in CAPEX can affect how much funding is exposed to higher-cost commercial debt and equity. Changes in availability and interest rates also affect MFSP, but their impact is smaller than the effects of feedstock price and CAPEX.

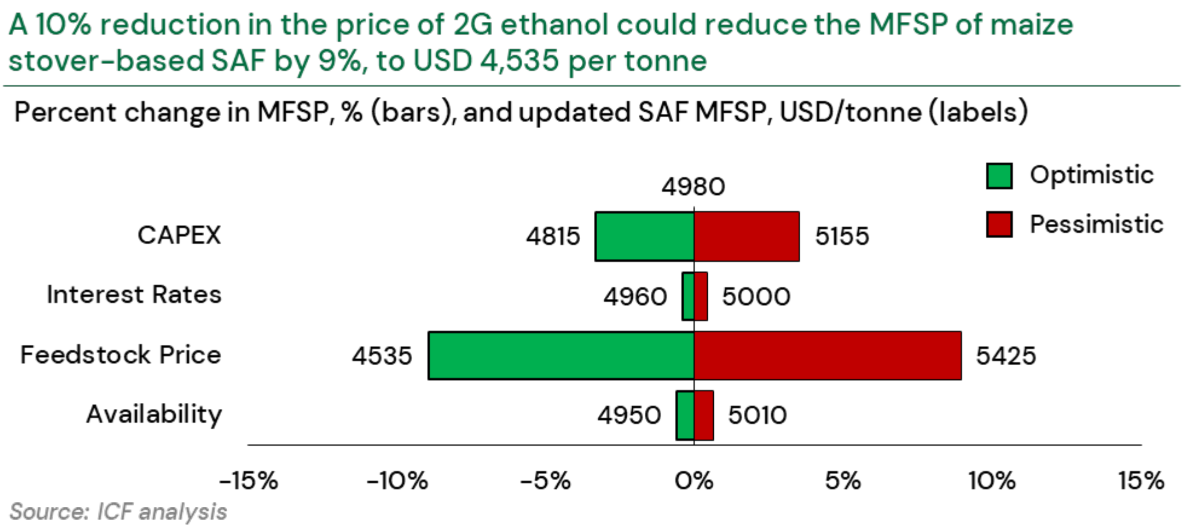


Figure 23 Pricing sensitivity of AtJ using maize stover

2.8.4 Integrated cassava ethanol and AtJ

For the integrated cassava ethanol and AtJ pathway, feedstock price is again a significant driver. A +/-10% change in cassava feedstock price changes the SAF price by +7/-7%. This reflects the large volume of cassava required by the facility and the importance of recurring feedstock costs to the overall economics.

CAPEX also has a more significant effect because the integrated facility is substantially more expensive than the standalone maize residue AtJ pathway. Interest rates become more important for this pathway than for the lower-CAPEX pathways, reflecting the much larger share of funding that must be provided through commercial debt and equity. Availability also has a more visible effect than in the earlier pathways because of the larger scale of daily output and the economic impact of operating above or below assumed utilisation.

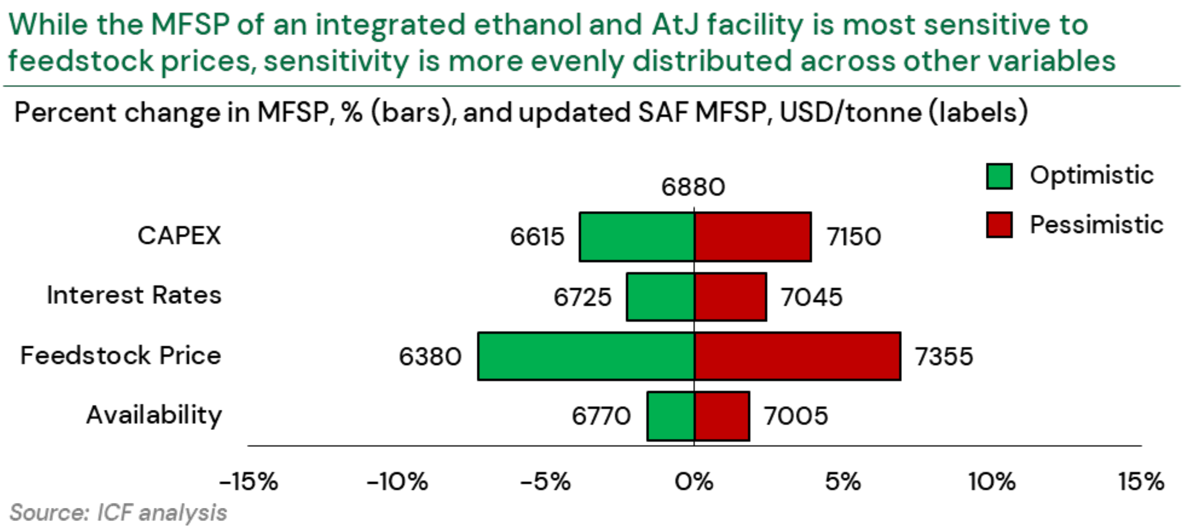


Figure 24 Pricing sensitivity of integrated cassava ethanol and AtJ

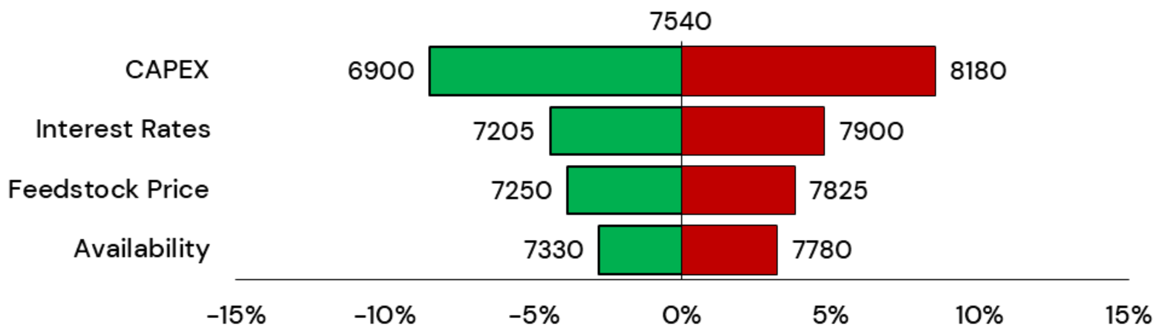
2.8.5 Gasification and FT using cassava residue

The FT pathway is the only pathway where feedstock price is not the dominant sensitivity. Instead, CAPEX has the largest effect on MFSP. This reflects the high capital intensity of gasification and FT technology, with even a +/-10% change in CAPEX producing a significant +8/-8% change in SAF price.

Interest rates also have a larger effect than feedstock price, because the pathway requires substantial commercial debt and equity once concessional and grant funding have been exhausted. Feedstock price remains relevant, but the pathway's relatively low OPEX means that feedstock cost changes have a smaller effect than in HEFA, co-processing, or AtJ. Availability is also important, as changes in utilisation have a material effect on project economics for a large and capital-intensive facility.

The FT pathway is most sensitive to CAPEX, and by extension, to interest rates

Percent change in MFSP, % (bars), and updated SAF MFSP, USD/tonne (labels)



Source: ICF analysis

Figure 25 Pricing sensitivity of gasification and FT using cassava residue

3 Financial and Operational Assessment

Chapter 2 compared the five selected pathways on a consistent techno-economic basis. This chapter uses those results to define the preferred business case and assess how it could be developed in practice. Alongside the modelled production cost, the chapter focuses on the wider operational, commercial, sustainability, policy, and financing conditions that would affect project delivery in Ghana.

Chapter 3 therefore focuses on AtJ using 2G ethanol from maize residues, which is selected as the preferred pathway for the project-level business case based on the TEA results and the wider considerations discussed in this chapter. The focus on one pathway is intended to develop a practical business implementation case, not to exclude other SAF routes from Ghana's longer-term decarbonisation pathway. Other options assessed in Chapter 1 may still be relevant for Ghana as feedstock markets, technology costs, certification pathways, and policy support develop.

The chapter is structured as follows:

Section 3.1 uses the TEA results to select the pathway taken forward into the business case and summarises the proposed SAF facility concept;

Section 3.2 assesses the facility configuration, site requirements, infrastructure needs, logistics interfaces, and development timeline;

Section 3.3 considers the main sustainability and certification requirements for the selected pathway;

Section 3.4 discusses commercialisation, including offtake, domestic uplift, export potential, and book-and-claim;

Section 3.5 reviews the policy and permitting considerations relevant to project development;

Section 3.6 considers financing requirements, potential investment sources, and ownership structures; and

Section 3.7 discusses the wider economic, social, industrial, and environmental impacts that could arise if the selected pathway is developed in Ghana.

Together, these sections provide the basis for assessing whether the selected pathway can move from a modelled TEA case towards a practical SAF business case for Ghana.

3.1 Business case selection

This subsection uses the TEA results from Chapter 2 to identify which pathway should be taken forward into a project-level business case. It first summarises the main results and cost drivers across the five pathways, before explaining why the lowest-cost pathway is not necessarily the most suitable option for a Ghanaian SAF business case. It then introduces the selected pathway and the main assumptions that shape the rest of this chapter.

3.1.1 Recap and discussion on TEA results

The TEA in Chapter 2 assessed five pathways selected through the screening process in Section 1.4. These were co-processing of palm oil residues, standalone HEFA using fishery and livestock residues, AtJ using 2G ethanol from maize residues, integrated AtJ using 1G ethanol from cassava tubers, and FT using cassava residues.

The two AtJ pathways represent different project configurations. The maize residue AtJ pathway is modelled as a standalone AtJ facility that purchases 2G ethanol produced off-site from maize residues. By contrast, the cassava pathway is modelled as an integrated facility, with 1G ethanol produced on site from cassava tubers and then upgraded into SAF. This distinction is important because the standalone AtJ case excludes the CAPEX of upstream ethanol production, while the integrated cassava case includes both ethanol production and AtJ conversion within the facility boundary.

The pathways also differ significantly in nameplate capacity. These capacities are based on the feedstock availability estimates adopted from the feasibility study, adjusted for pathway-specific assumptions. AtJ using 1G ethanol from cassava tubers has the largest modelled production potential, reflecting the scale of cassava production in Ghana. At the other end of the range, co-processing of palm oil residues has the smallest production volume, reflecting the limited availability of lipid-based palm oil residues suitable for the pathway and the blending limits that apply to co-processing.

These feedstock availability values should be validated through pathway-specific assessments before project development, including recoverable volumes, collection logistics, processing routes, and competing uses. Where compatible with the selected technology and certification requirements, other eligible residues can also be used to improve supply resilience.

The modelled output from each facility is lower than nameplate capacity once availability, ramp-up, and downtime are accounted for. Availability assumptions vary by pathway, reflecting differences in commercial maturity and expected operating complexity. Co-processing has the highest assumed steady-state availability at 95%, reflecting its lower complexity and stronger commercial track record. HEFA, AtJ and FT are assumed to operate at 85% availability from year 2 onwards in the TEA. Across the pathways, the share of total fuel output that is SAF also varies. The AtJ pathways have the highest SAF share, at around 80% of total fuel production. HEFA and FT follow, with SAF shares of around 75% and 70%, respectively, while co-processing has the lowest SAF share at around 57%.

This product split is commercially important because SAF is expected to have a higher market value than renewable diesel and naphtha. In the TEA, renewable diesel is valued at USD 928/tonne and naphtha at USD 605/tonne, while SAF value is solved through the MFSP. If producers are able to increase the SAF share through technology configuration or operating optimisation, the MFSP could fall, although this may require additional investment or affect other operating assumptions. The figure below shows the fuel volumes produced by the modelled facilities, with the labelled values indicating the quantity of SAF produced under steady-state operating conditions.

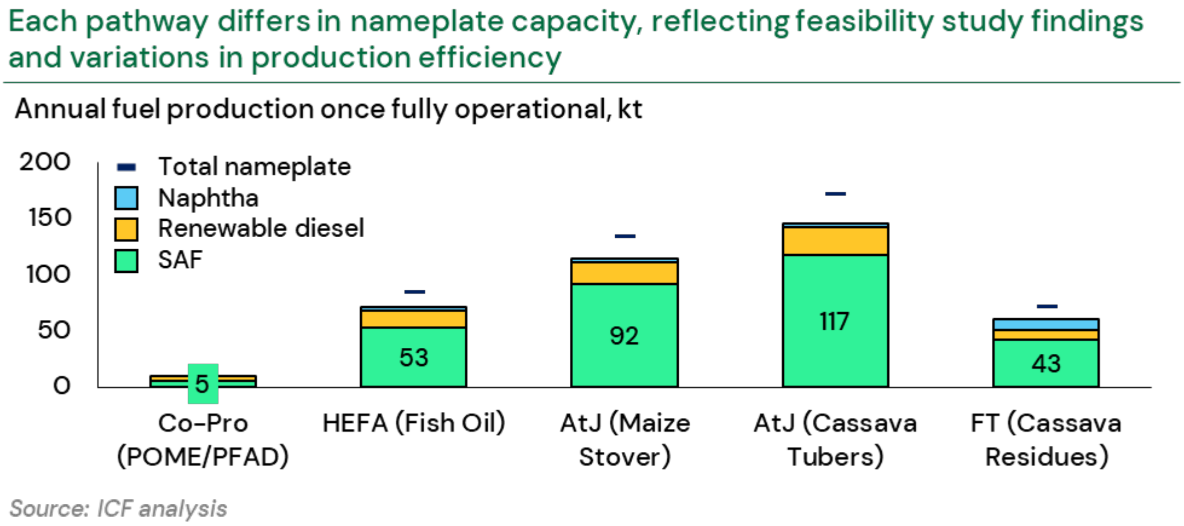


Figure 26 Annual fuel production of different production pathways

The main economic output from the TEA is the minimum fuel selling price, which represents the SAF price required for each pathway to achieve a net present value of zero under the financing assumptions used. HEFA has the lowest MFSP at USD 2,165/tonne, followed by co-processing at USD 3,020/tonne. These are the two most commercially mature pathways assessed and have the lowest overall financing burden. However, as discussed below, both have important drawbacks. AtJ using 2G ethanol from maize residues has a higher MFSP at USD 4,980/tonne, driven primarily by the assumed cost of 2G ethanol. Integrated AtJ using 1G ethanol from cassava tubers has a higher MFSP again, at USD 6,880/tonne, while FT using cassava residues has the highest MFSP at USD 7,540/tonne, as shown in the figure below.

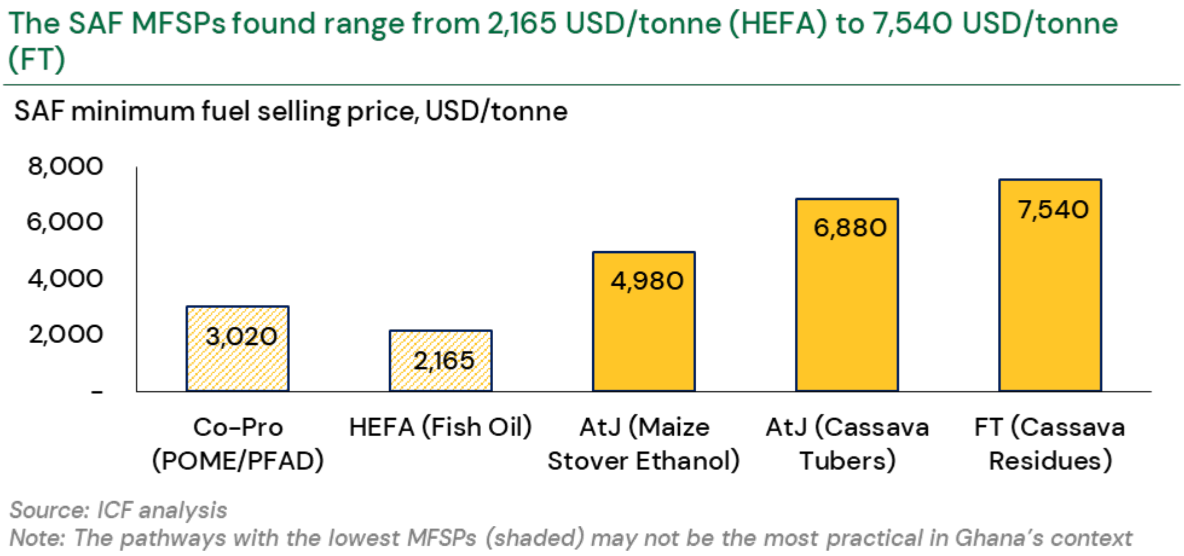


Figure 27 Minimum fuel selling price across varying pathways

These differences are particularly important under the financing assumptions applied in Chapter 2. The model assumes concessional finance through the World Bank IDA loan programme for the first USD 250 million of CAPEX, the World Bank Scale-Up Window for a further USD 150 million, and climate grant funding for the next USD 50 million where applicable. For projects with CAPEX above USD 450 million, the remaining funding requirement is split between commercial debt and equity, both of which carry much higher assumed costs in Ghana. As a result, pathways that exceed the concessional and grant thresholds face a much larger financing burden. This is most visible for the integrated cassava ethanol and AtJ pathway and the FT pathway, both of which require substantial commercial debt and equity.

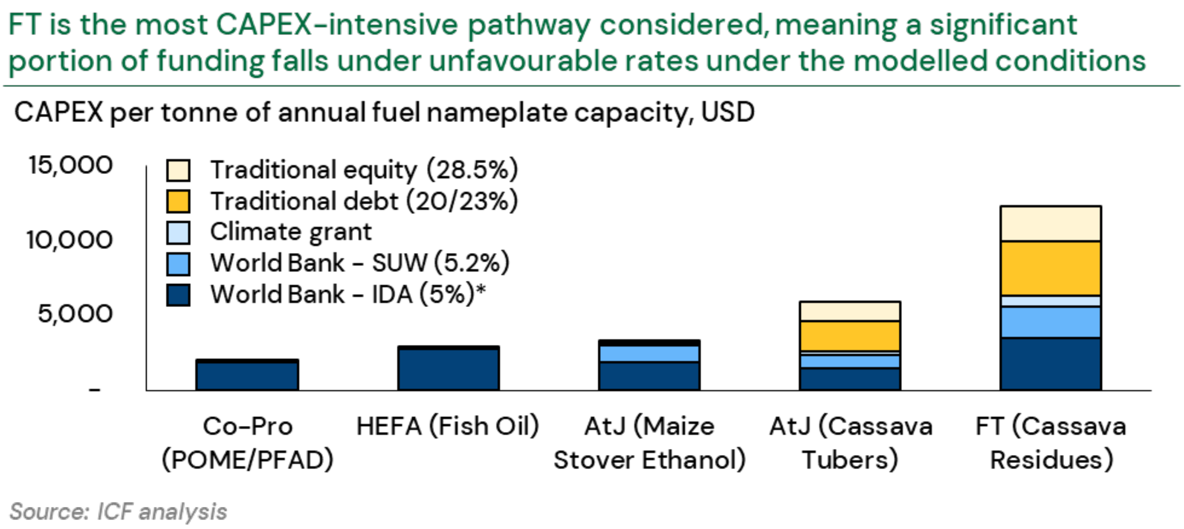


Figure 28 CAPEX per fuel capacity across varying pathways

OPEX is the other major driver of the MFSP. On a per-tonne-of-total-fuel-produced basis, HEFA has the lowest operating cost, followed by co-processing and FT. The lower OPEX for FT partly reflects the relatively low assumed cost of cassava residues, although this is offset by the pathway's very high CAPEX. By contrast, the maize residue AtJ pathway has a higher operating cost because the AtJ facility purchases 2G ethanol at an assumed price of USD 1,860/tonne. The integrated cassava ethanol and AtJ pathway has the highest operating cost, reflecting the large quantity of cassava feedstock required and the lower alcohol yield from cassava roots compared with other starch-based feedstocks.

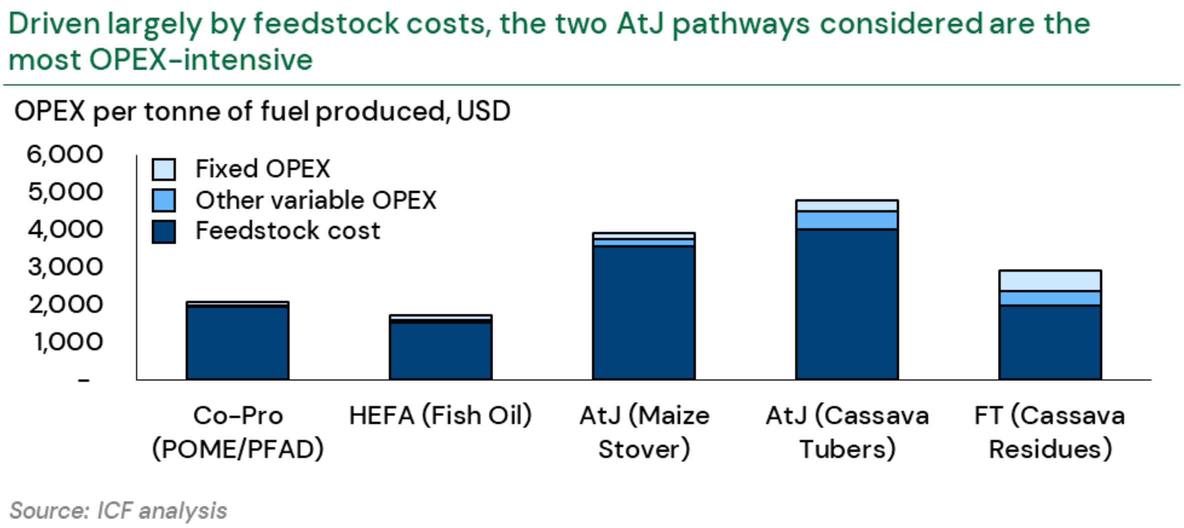


Figure 29 OPEX per fuel capacity across varying pathways

The sensitivity analysis reinforces these findings. Co-processing and HEFA are most sensitive to feedstock cost, reflecting the importance of lipid feedstock prices in their economics. Maize residue AtJ is also highly sensitive to feedstock cost, but in this case the relevant feedstock is 2G ethanol rather than raw maize residue. For the integrated cassava ethanol and AtJ pathway, feedstock cost, CAPEX, and financing all have material effects. For FT, CAPEX is the dominant sensitivity, followed by financing costs, reflecting the pathway's capital intensity.

3.1.2 Pathway evaluation and selection

Although HEFA and co-processing have the lowest MFSPs in the TEA, neither is selected as the central business case for this study. Both remain relevant to Ghana and could form part of a wider SAF development pathway, but they are less suitable as the main project-level case considered in this chapter.

Co-processing of palm oil residues has a relatively low MFSP and could provide a useful near-term route to introducing SAF into Ghana's fuel system. It also benefits from low incremental CAPEX, particularly if refinery infrastructure is available. However, its production potential is limited by refinery configuration and blending limits, as well as the availability of suitable palm oil residues if no other compatible feedstocks are available. It may therefore be useful as a transitional or proof-of-concept option, but it does not provide the same basis for a scalable domestic SAF production case.

Standalone HEFA using fishery and livestock residues performs best in the TEA, with the lowest MFSP of the pathways assessed. However, there are two reasons why it is not selected as the central business case. First, waste fats, oils, and greases, including fish oil and animal fats, are globally traded commodities. Their high energy density makes them economically viable to transport internationally before processing into fuel. As demand for these feedstocks grows, their value is also likely to increase. If collection of these residues were to increase materially in Ghana, there is a reasonable possibility that exporting the feedstock could be more commercially attractive than processing it domestically into SAF. Second, the practical availability of fish oil remains uncertain. The fish oil availability figures adopted from the feasibility study appear to rely on ambitious assumptions around residue-to-oil conversion as well as collection and actual collectable volumes may be lower in practice. This weakens the case for selecting HEFA as the main business case without further feedstock validation.

AtJ using 1G ethanol from cassava tubers also faces important limitations. Although Ghana has a large cassava resource base and there is existing interest in cassava ethanol, the pathway has a high MFSP of USD 6,880/tonne. Its demand potential is also constrained by eligibility. Cassava is a food crop and therefore SAF produced from 1G ethanol from cassava tubers would not qualify under the UK SAF Mandate or ReFuelEU Aviation. That limits access to two important regulated demand markets. In markets without those restrictions, Ghana would still need to compete with countries that already have large-scale, lower-cost ethanol sectors. This pathway therefore remains useful as a comparator, but is less suitable as the main business case.

FT using cassava residues has the highest MFSP of the pathways assessed, at USD 7,540/tonne. Its main advantage is its strong carbon intensity profile, with agricultural residue FT pathways having a very low CORSIA default life cycle emissions value. However, this is outweighed by high CAPEX and financing requirements. The pathway is also exposed to practical feedstock uncertainty, as cassava residue availability depends on processing assumptions and collection systems that are not yet fully developed. FT facilities can in principle use a broader mix of lignocellulosic residues, but doing so would require feedstock testing, plant design work, and a more complex aggregation system. For Ghana, FT may therefore be more relevant as a longer-term option than as the first business case to take forward.

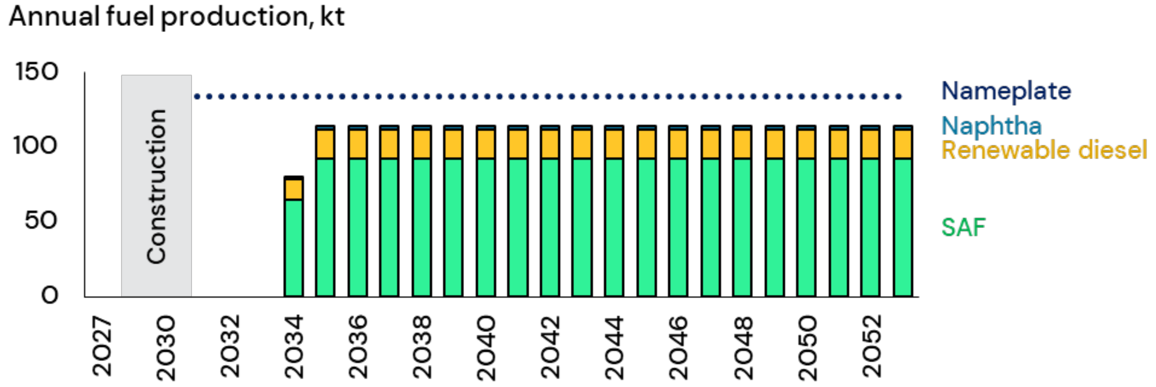
AtJ using 2G ethanol from maize residues is selected as the most suitable pathway for the project-level business case. It does not have the lowest MFSP, but it offers the strongest overall balance across scalability, feedstock suitability, eligibility, domestic value creation, and financing practicality. Waste lipid feedstocks such as fish oil and animal fats are energy-dense and can be traded internationally, meaning Ghana may not always capture the highest value by processing them domestically. Maize residues are different. They are bulky, lower-value materials that are much less likely to be exported in raw form, creating a clearer case for domestic collection, preprocessing, and conversion into 2G ethanol. While ethanol itself can be traded, producing it in Ghana would allow more value to be retained locally before the AtJ conversion step. Maize residues are also directly relevant to Ghana's agricultural base, and production has grown significantly over the past decade.

The pathway is also better aligned with international demand than 1G cassava ethanol. As a residue-based pathway, AtJ using 2G ethanol from maize residues is better positioned for eligibility under CORSIA, the UK SAF Mandate, and ReFuelEU Aviation, subject to certification and carbon intensity requirements. It also avoids the direct food-crop concerns associated with cassava tubers. Finally, the standalone AtJ facility is significantly less capital-intensive than FT or the integrated cassava ethanol and AtJ facility, reducing exposure to higher-cost commercial debt and equity under Ghana's financing conditions.

3.1.3 Business case introduction

The selected business case is a standalone AtJ facility supplied by 2G ethanol produced in Ghana from maize residues. At nameplate capacity, the modelled facility produces approximately 108 kt/year of SAF, 23 kt/year of renewable diesel, and 3.1 kt/year of naphtha. In practice, production is lower once the steady-state availability assumption used in the TEA is applied, with annual output estimated at approximately 91.8 kt/year of SAF, 19.6 kt/year of renewable diesel, and 2.6 kt/year of naphtha, as shown in the figure below.

Once fully operational, the AtJ facility will annually produce 91.8 kt of SAF, 19.6 kt of renewable diesel, and 2.6 kt of naphtha



Source; ICF analysis

Figure 30 Annual fuel production of the AtJ facility

The techno-economic model assumes that just under 220,000 tonnes of 2G ethanol is produced in Ghana and transported to a standalone AtJ facility each year. This requires just over 1.1 million tonnes of maize stover to be collected and converted into ethanol. The modelled AtJ facility has total CAPEX of USD 450 million and an MFSP of USD 4,980 per tonne of SAF.

Note: Chapter 2 presents a 2G ethanol feedstock requirement of 256,000 tonnes per year for the AtJ facility. This reflects the modelled ethanol input at nameplate capacity. The "just under 220,000 tonnes" figure used here reflects the effective annual ethanol requirement after applying the steady-state availability assumption used in the TEA. The same distinction applies to SAF output: the facility has a nameplate SAF capacity of 108 kt/year, while steady-state annual SAF production is approximately 91.8 kt/year after availability is applied.

It is important to distinguish between the TEA boundary and the wider business case. The TEA assesses the AtJ facility itself and treats 2G ethanol as a purchased input. However, the pathway only works in practice if Ghana can also develop the upstream system needed to collect maize residues, convert them into 2G ethanol, and deliver that ethanol reliably to the AtJ facility. The business case is therefore not only an AtJ facility, but a maize residue-to-ethanol-to-SAF value chain.

The viability of this business case depends on several linked conditions. On the supply side, Ghana would need to establish a credible maize residue collection system, develop 2G ethanol production capacity, secure reliable utilities, and ensure that ethanol can be transported to the AtJ facility at the required quality and cost. On the demand side, the project would need access to buyers that value residue-based SAF, including domestic, regional, and export markets. These elements are considered in more detail in the facility concept, sustainability, and commercialisation sections that follow.

The price of 2G ethanol is the main cost driver for this pathway, with the model assuming a cost of USD 1,860 per tonne. The sensitivity analysis shows that a 10% reduction in CAPEX reduces MFSP by 3.3% while, by contrast, a 10% decrease in 2G ethanol price reduces MFSP by 8.9%. Reducing the cost of cellulosic ethanol is therefore the most important lever for lowering SAF production cost in Ghana.

While the TEA model assesses the AtJ facility in isolation, the full maize residue-to-ethanol-to-SAF value chain must be understood as part of the business case. This chapter therefore gives greater attention to the AtJ facility itself, while also assessing the upstream requirements needed to make the modelled ethanol supply credible. It should also be reiterated that AtJ is ethanol-agnostic. 2G ethanol is not limited to maize residues, and other lignocellulosic biomass sources, including cassava residues, could potentially be used. Similarly, 1G ethanol from crops such as cassava tubers could technically be used, although its eligibility, carbon intensity, and market value would differ.

3.2 Facility concept and integration

The project configuration is based on distributed 2G ethanol production and a central AtJ facility. This follows the TEA structure, where ethanol is produced off-site and transported to the AtJ facility, and also reflects the different transport characteristics of each stage of the value chain. Maize residues are bulky and low-density materials and become expensive to move over long distances. Ethanol is easier to transport than raw biomass, while SAF is better suited to established fuel logistics infrastructure once produced. It is therefore more practical for 2G ethanol production to be located closer to feedstock sources, with the AtJ facility located in an industrial area with stronger access to utilities, hydrogen generation, storage, fuel logistics, and export infrastructure.

The project configuration can therefore be summarised as follows:

- **2G ethanol production**: located near maize-producing regions and residue aggregation points.
- **AtJ facility:** located in the Tema Free Zone or wider Tema industrial area.

This structure allows the project to reduce raw biomass transport costs while still locating the AtJ facility where industrial and downstream fuel infrastructure is strongest.

3.2.1 Project configuration and location

2G ethanol production

The location of 2G ethanol production is primarily driven by feedstock origin. Maize residues are generated in agricultural regions rather than industrial clusters, and production is relatively concentrated across a number of key regions. Since maize stover is low-density, transporting residues over long distances would increase cost and complexity.

For this reason, 2G ethanol plants should be located close to the main maize residue-producing areas. These plants could be smaller and more distributed than the central AtJ facility, allowing residues to be aggregated, pretreated, and converted into ethanol nearer to source. This would reduce the cost of transporting raw biomass and create a more resilient supply chain.

The key location criteria for 2G ethanol plants are:

- proximity to maize residue production;
- ability to aggregate residues from surrounding farms;
- road access and local logistics capacity;
- land availability for storage, preprocessing, and ethanol production;
- water and process utility access; and
- potential to incorporate other lignocellulosic residues where available.

A previous study evaluated suitable locations for producing 150 million litres per year of cellulosic ethanol in Ghana[177]. The study filtered locations based on sufficient residue generation, existing industrial activity, and access to highways. This narrowed the list to nine locations, shown in the table below, alongside the number of existing industrial companies, the nearest highway, and residue sources that could locally yield at least 50 million litres of cellulosic ethanol per year.

Table 44 Shortlisted locations for ethanol production in Ghana

City	Region	Number of industrial companies	Nearest highway	Residue sources
Obuasi	Ashanti	787	N8: 22.1 km	Maize/Plantain

[177] https://www.sciencedirect.com/science/article/abs/pii/S1364032118306658

City	Region	Number of industrial companies	Nearest highway	Residue sources
Kumasi	Ashanti	5895	N6/N8/N10: 0 km	Maize/Plantain
Sunyani	Brong Ahafo	749	N12: 0 km	Cassava/Maize/Plantain/Yam
Techiman	Brong Ahafo	637	N10/N12: 0 km	Cassava/Maize/Plantain/Yam
Cape Coast	Central	608	N1/N8/ 0 km	Maize
Awutu Breku	Central	603	N1: 0 km	Maize
Koforidua	Eastern	833	N4: 0 km	Cassava/Maize/Plantain
Tamale	Northern	1351	N9/N10: 0 km	Groundnutes/Maize/Yam
Wa	Upper West	600	N12: 0 km	Groundnuts

The study then identified the most suitable locations by considering both the cost of transporting residues to the ethanol facility and the cost of transporting ethanol onward to the Tema area. It found that three 50 million litre per year facilities were more economically attractive than one 100 million litre facility and one 50 million litre facility. Koforidua in the Eastern Region and Sunyani in Brong Ahafo were identified as particularly suitable locations under the minimised transport-cost scenario, as shown on the map below alongside the other shortlisted locations from the table above. The study also noted that other factors would need to be considered before project development, including labour availability and environmental constraints.

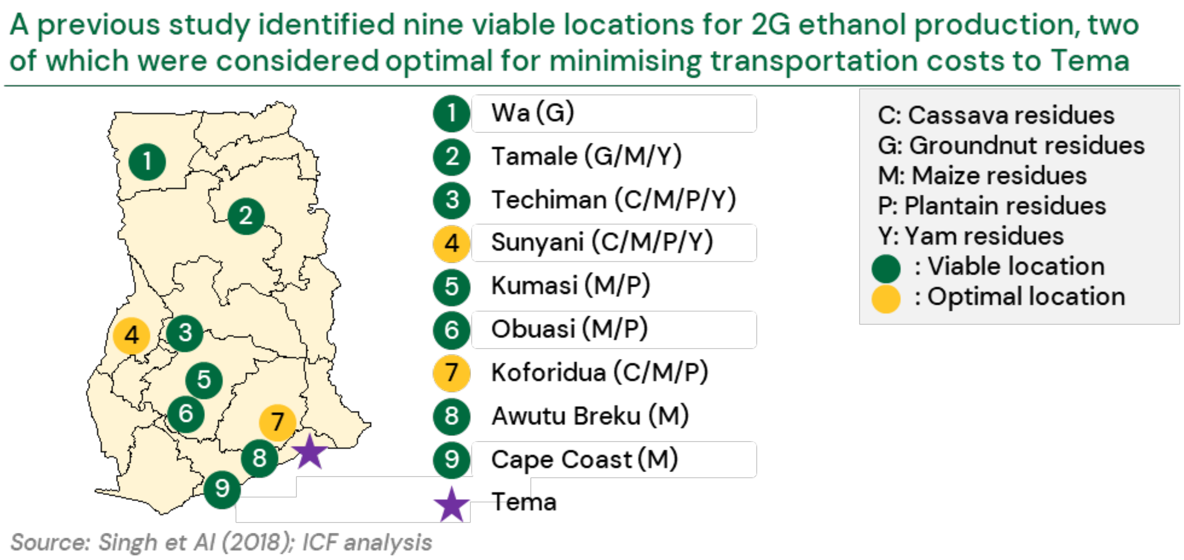


Figure 31 Map of viable locations identified for 2G ethanol production

There is also an alternative configuration in which 2G ethanol production and AtJ conversion are co-located in a single integrated facility. This is not the configuration modelled in the TEA for the maize residue pathway, but it is worth noting because it can affect both economics and carbon intensity[178]. A standalone AtJ facility utilising agricultural residues has a CORSIA default LCA of 39.7 gCO_2e/MJ compared to 24.6 gCO2e/MJ for an integrated facility, partly because a co-located facility can share heat and utility systems. An integrated facility could therefore increase

[178] https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/ICAO-document-06-Default-Life-Cycle-Emissions-June-2025.pdf

the value of the SAF produced in markets where emissions performance affects certificate value or demand.

However, integration also has drawbacks. It would increase overall project CAPEX and concentrate more risk in a single facility. It would also reduce some flexibility, because the AtJ facility would be tied more closely to one ethanol production asset. By contrast, a standalone AtJ facility supplied by multiple 2G ethanol plants could provide more resilience if one ethanol source underperforms. It may also be easier to finance several medium-sized ethanol facilities near residue supply than one large integrated project attached to a single SAF demand source. For this study, the standalone AtJ configuration remains the base case.

AtJ facility

The AtJ facility has a different set of location drivers from the 2G ethanol plants. For the AtJ facility, the feedstock entering the plant is ethanol rather than maize residue. This shifts the siting priority away from feedstock proximity and towards industrial infrastructure, utilities, fuel logistics, and market access.

The key location requirements for the AtJ facility are:

- reliable electricity supply;
- access to natural gas or other process energy;
- water supply and wastewater treatment infrastructure;
- sufficient land for a large industrial processing facility;
- access to storage, pumps, and truck-loading infrastructure;
- proximity to blending and fuel-handling assets;
- access to port infrastructure for export;
- connection to the aviation fuel supply chain serving Kotoka International Airport; and
- access to Free Zone or other investment incentives.

On this basis, the preferred location for the AtJ facility is the Tema Free Zone or wider Tema industrial area. Tema is the strongest candidate because it combines Ghana's main industrial cluster with port access, fuel infrastructure, logistics links to domestic and export markets, and potential administrative and commercial advantages through Free Zone arrangements.

3.2.2 Upstream characteristics and infrastructure integration

The upstream part of the value chain covers maize residue collection, aggregation, storage and preprocessing, 2G ethanol production, and transport of ethanol to the AtJ facility in Tema. While the TEA models the AtJ facility only, the upstream system remains central to whether the business case can operate at the scale assumed.

Maize stover is treated as the base-case feedstock for 2G ethanol production. However, the AtJ facility itself is ethanol-agnostic, meaning that ethanol from other sources could theoretically be used if it meets the required technical, sustainability, and eligibility requirements. Maize residue is therefore the central supply case, rather than the only possible ethanol source.

Feedstock collection and aggregation

Maize stover is attractive because of its abundant supply and lack of direct trade-off with food uses. However, its key challenge in Ghana will be aggregation. While around 80% of maize production is concentrated in a number of regions, around 70% of production takes place on smallholder farms[179]. This means that, even where the feedstock exists in sufficient quantity, collecting it at scale would require a structured and reliable aggregation system.

[179] https://www.agricinafrica.com/2023/01/ghana-maize.html

There are several ways to collect maize stover[180]. A two-pass system would involve farmers harvesting the maize grain first, which leaves the residues in the field, followed by a second pass to collect the stover, either manually or using baling equipment. Another option is a one-pass system, where maize grain and stover are collected during the same harvest operation. This can reduce field operations, but generally requires more specialised equipment and may be harder to implement in a smallholder farming context.

The main driver for collection will be the market value of maize stover. Farmers and aggregators would need a clear commercial reason to collect, store, and sell the residue rather than leave it in the field or use it for other purposes. Training would also be needed so that residues are collected efficiently and sustainably. This is important because not all stover should be removed: a share should remain on the field to protect soil structure, reduce erosion, and maintain nutrient cycling[181]. If the market value of maize stover increases, there is a risk that too much residue could be removed unless sustainable harvesting thresholds are clearly communicated and monitored.

Policy support could help establish the collection system. This could include support for baling equipment, concessional finance for aggregators, farmer training, extension services, or support for cooperatives. These measures could be aligned with broader agricultural objectives, including efforts to increase maize yields and strengthen rural value chains. Maize stover collection could create additional income for farmers and new employment in collection, baling, aggregation, storage, and transport.

Existing maize aggregation networks may provide a useful starting point. Local aggregators already play a role in financing smallholder farmers before production, collecting bags of maize from farmers after harvest, and reselling to larger wholesalers. A similar model could potentially be adapted for maize stover, with aggregators collecting residues and selling them to ethanol producers. To maximise logistics efficiency, maize stover would ideally be baled before transport, although this may not always be possible in early stages. Where baling is not available at farm level, aggregation points could provide a location for drying, baling, and quality checks before the material is moved to ethanol production facilities.

Biomass storage and preprocessing

Maize production is seasonal, while 2G ethanol production and AtJ conversion would need to operate more consistently through the year. In northern Ghana, maize generally has one harvest season, typically between August and October[182]. In southern Ghana, there are usually two harvest seasons: a major season around August and September, and a minor season around December and January. This creates a feedstock management challenge, because residues would need to be stored, preserved, or supplemented with other eligible biomass streams to support continuous ethanol production.

One way to manage seasonality would be to supplement maize stover with other lignocellulosic residues during periods when maize residues are less available. This could include residues such as cassava residues, rice residues, cocoa pod husks, or other agricultural processing residues, subject to feedstock testing, sustainability requirements, and ethanol production compatibility. However, even with a mixed biomass supply, the upstream system would still need storage and preprocessing infrastructure.

Storage and preprocessing would need to address several issues. Maize stover would need to be checked for quality, dried or managed for moisture where needed, size-reduced, and stored in a way that prevents degradation. The material would also ideally be densified, for example through baling, to improve transport efficiency. Without densification, the low bulk density of maize stover would increase truck movements and logistics costs.

[180] https://www.mdpi.com/2311-5637/11/6/338#B37-fermentation-11-00338
[181] https://www.ars.usda.gov/research/publications/publication/?seqNo115=354236
[182] https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Ghana%20Grain%20and%20Feed%20-%20Update%20-%202024_Accra_Ghana_GH2024-0015.pdf

The location of storage and preprocessing will need to be defined during project development. Storage could take place closer to farms, at aggregation points, or at the ethanol facility itself. Local storage and preprocessing would reduce the need to move all residues immediately after harvest and could allow baling to occur before long-distance transport. However, it would require more distributed equipment, storage sites, and quality-control procedures, which may increase cost and operational complexity. Storage at the ethanol facility would benefit from economies of scale and stronger control over feedstock quality, but may require less efficient transport if residues are moved before baling or densification. The preferred configuration is therefore likely to depend on farm size, road access, mechanisation, residue moisture, and the distance between production areas and ethanol facilities.

2G ethanol production infrastructure

Although this study focuses on the AtJ facility, 2G ethanol production is one of the most important prerequisites for the selected business case. For the base case of ethanol from maize stover, this means producing ethanol from lignocellulosic residues rather than from starch or sugar crops. This is a more challenging route than first generation ethanol production and remains an evolving technology globally.

The TEA assumes that just under 220,000 tonnes of 2G ethanol is supplied to the AtJ facility each year after applying steady-state availability assumptions. The ethanol production facilities themselves are outside the AtJ CAPEX, but the cost of ethanol is included in OPEX through the assumed 2G ethanol price. This means the AtJ economics depend heavily on the cost and reliability of the upstream ethanol platform, even though that platform is not included within the AtJ facility CAPEX.

Global examples show that 2G ethanol production can require substantial capital investment. A 2G ethanol plant in Brazil with annual capacity of around 64.7 kt required approximately USD 230 million of investment[183]. Similarly, a facility in India with capacity of 100 thousand litres per day, equivalent to around 28.8 kt per year, has been reported with CAPEX of around USD 90 million[184]. A Ghana-specific TEA would be required to estimate costs properly, but these examples suggest that the upstream 2G ethanol platform could require significant investment, potentially exceeding the USD 450 million CAPEX of the AtJ facility depending on the number, scale, and configuration of ethanol plants required. While these examples point to a high capital requirement, costs may fall as more 2G ethanol facilities are developed and technology providers gain further commercial experience.

There are nevertheless reasons to be optimistic about the ability of 2G ethanol production to attract investment if it is developed alongside the AtJ facility. A long-term supply agreement between the ethanol producer and AtJ facility could provide revenue certainty for the ethanol plant and feedstock certainty for the AtJ developer. This could support financing for both parts of the value chain. In addition, 2G ethanol is not limited to SAF production. If the AtJ facility were delayed or underperformed, 2G ethanol could potentially serve other markets, including road fuel blending, industrial ethanol, or AtJ facilities outside Ghana, depending on eligibility and commercial terms. This gives the upstream ethanol platform some value beyond the SAF project alone.

Ethanol transport to Tema

Once the 2G ethanol is produced, it must be transported to the AtJ facility in Tema. Ethanol is more practical to transport than maize stover because it is a liquid and has a higher energy density than raw biomass. However, it still requires appropriate handling, storage, safety procedures, and tanker equipment. In the near term, road transport is likely to be the most practical option.

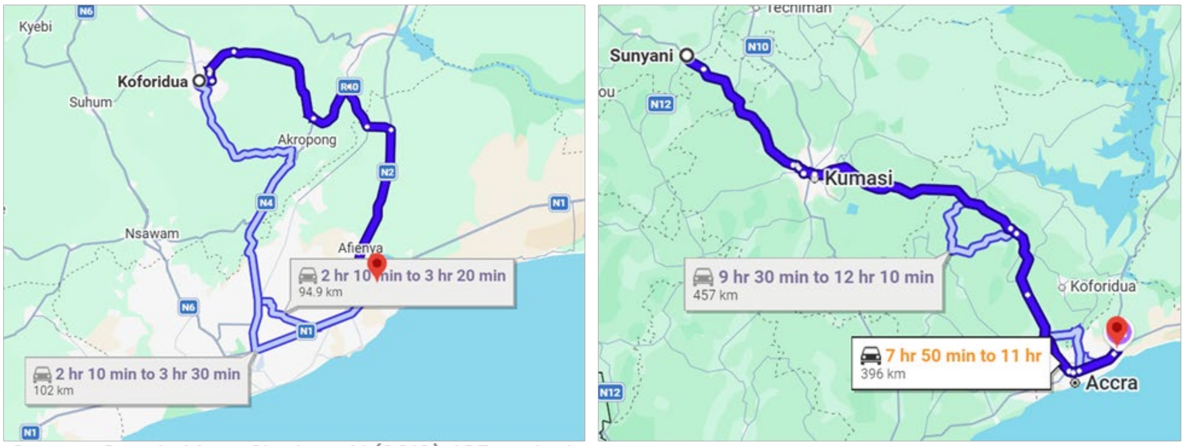
Ghana already has companies involved in ethanol transport, including Midland International GH Ltd, which provides ethanol haulage services using tankers of 30,000 litres and above[185]. This suggests that some of the required transport capability already exists domestically, although a project of this scale would still need to confirm fleet availability, route reliability, safety standards, loading

[183] https://www.fuelsandlubes.com/raizen-opens-worlds-largest-second-generation-ethanol-plant/
[184] https://iocl.com/Talktous/PDF/EthanolBrochure3102023.pdf
[185] https://www.midlandghana.com/services/

and unloading arrangements, and storage interfaces at both the ethanol production sites and the AtJ facility.

The previous location study described in Section 3.2.1 identified suitable ethanol production locations partly by minimising the combined cost of transporting residues to the ethanol facility and transporting ethanol onward to Tema, and determined Koforidua and Sunyani to be most optimal[186]. As shown in the figure below, the road transport time between Koforidua and Tema takes around two to three hours, whereas that between Sunyani takes eight to eleven hours. However, the maize residue transportation costs in Sunyani were found to be less than in Koforidua. The study also found that three 50 million litre per year facilities were more economically attractive than one 100 million litre facility and one 50 million litre facility, and identified Koforidua and Sunyani as strong candidate locations.

Road transport is likely the most viable transport mode from the sites previously identified as optimal for ethanol production: Koforidua (left) and Sunyani (right)



Source: Google Maps Singh et Al (2018); ICF analysis
Note: Normalised to departing at 10:00

Figure 32 Journey length by road from optimal ethanol production sites to Tema

3.2.3 Midstream characteristics and infrastructure integration

The midstream part of the value chain is the Tema-based AtJ facility, where ethanol is delivered and upgraded into SAF and co-products. This was the focus of the TEA analysis. The practical assessment therefore focuses on what the AtJ facility would require in the Tema area, including utilities, hydrogen, water, wastewater, product handling, and integration with existing industrial infrastructure.

AtJ facility scope and configuration

The modelled AtJ facility has nameplate production capacity of 108 kt/year of SAF, 23 kt/year of renewable diesel, and 3.1 kt/year of naphtha. Actual annual output is lower once availability assumptions are applied, as set out in Section 3.1.3. The facility is based on a standalone AtJ configuration, with ethanol transported to the site rather than produced on site. The model includes a CAPEX estimate of USD 450 million, with OSBL costs included as a factor of ISBL costs.

The OSBL scope is important because it includes the supporting systems required to operate the facility, not only the core AtJ process units. These include onsite hydrogen generation, wastewater treatment, storage tanks, pumps, and truck-loading infrastructure. The Tema site would therefore need to accommodate a broader industrial footprint, including process units, utility systems, product handling, safety systems, and logistics infrastructure.

[186] https://www.sciencedirect.com/science/article/abs/pii/S1364032118306658

Electricity

The modelled AtJ facility requires 72,600 MWh/year of electricity at nameplate capacity. Ghana has faced electricity reliability challenges in the past, although the Tema area is better positioned than many other locations because of its industrial power infrastructure. Enclave Power Company supplies power to companies within the Tema Free Zone and has a 130 MVA substation, serving more than 80 companies with reported uptime of 99%[187].

Tema also hosts large-scale power infrastructure and projects under development, including the Bridge Power Project, a 424 MW power plant[188]. Renewable electricity projects are also gaining momentum in the area, including rooftop solar installations at Tema Port and a 150 MW solar project supported by a USD 100 million IFC loan, part of the World Bank Group[189,190]. Not all of these projects would be directly relevant to the SAF facility, but they indicate that the Tema area has both existing power infrastructure and experience in developing large industrial energy projects.

Natural gas and process energy

The modelled AtJ facility requires 35 MMBtu/hour of natural gas at nameplate capacity, primarily for onsite hydrogen production and process energy needs. Tema benefits from the Tema LNG Terminal Company, which commenced operations in 2021 and is the first LNG import terminal in West Africa[191]. The project comprises a 600 m subsea pipeline and a 6.5 km onshore pipeline, with annual capacity of 1.7 million tonnes. It was privately financed, with debt support from international banks. This provides a relevant reference point for industrial gas supply in the Tema area.

Water and wastewater

At nameplate capacity, the modelled AtJ facility is expected to require 195,000 gallons of water per day and generate 230,000 gallons of wastewater per day. Wastewater treatment costs are included in the OSBL costs of the facility, but the wider wastewater context in Tema remains relevant.

Across Ghana, over 95% of wastewater remains untreated, creating environmental and health concerns[192]. In the Tema Free Zone, wastewater has historically been managed through a central pond system, which has experienced issues including backflows into factories and spillovers[193]. However, recent investments in wastewater treatment have been made in the area. These include a USD 2.6 million treatment plant at Cargill's cocoa processing facility and a USD 1 million plant for Nutrifood, supported by the Royal Danish Embassy[194]. These projects, commissioned in 2025 and 2026 respectively, provide recent examples of industrial wastewater treatment investments in the Tema Free Zone and may offer useful precedents for an AtJ facility.

Product slate

At nameplate capacity for the modelled facility, SAF accounts for around 81% of total fuel output, with renewable diesel accounting for around 17% and naphtha for around 2%. Renewable diesel is valued in the TEA at USD 928/tonne, while naphtha is valued at USD 605/tonne. Although these co-products are lower value than SAF, they provide meaningful revenue streams and help support the overall economics of the facility.

There may be some flexibility to optimise product yields, depending on technology configuration and operating conditions. A higher SAF share may be possible in some cases, which could reduce

[187] https://enclavepower.lmi-utilities.com/
[188] https://www.nsenergybusiness.com/projects/bridge-power-project-ghana/
[189] https://energyinafrica.com/news/ghanas-tema-port-solar-installation/
[190] https://www.ifc.org/en/pressroom/2025/ifc-deepens-partnership-with-lmi-holdings-to-expand-clean-energy-to-industrial-zon
[191] https://www.aiimafrica.com/media/case-study-detail/case-study-tema-lng-terminal-company/
[192] https://www.businessghana.com/site/news/general/346541/Tema-gets-new-wastewater-treatment-plant-for-sustainable-water-management
[193] https://thebftonline.com/2025/10/22/cargill-inaugurates-us2-6m-wastewater-treatment-plant/
[194] https://thebftonline.com/2025/10/22/cargill-inaugurates-us2-6m-wastewater-treatment-plant/; https://managingghana.com/2026/04/04/nutrifoods-commissions-us1-million-wastewater-treatment-plant/

the MFSP if overall costs remain similar. In practice, however, increasing SAF yield may require additional investment, changes to operating severity, or trade-offs with co-product output. The producer would therefore need to optimise the product slate based on SAF demand, co-product markets, and technical constraints.

3.2.4 Downstream characteristics and infrastructure integration

The downstream part of the value chain covers storage, blending, testing, certification, and the movement of SAF and co-products to domestic or export markets. Ghana already has aviation fuel infrastructure centred around Tema and Kotoka International Airport, which provides a useful starting point for downstream integration.

Storage and handling

The TEA accounts for minimum storage requirements at the AtJ facility. In practice, a producer may choose to hold additional storage capacity for commercial or operational reasons. Onsite storage would provide greater control over inventory and timing of sales, although it would increase costs. Alternatively, the producer could use existing fuel terminal infrastructure.

As discussed in the feasibility study, Ghana's primary terminals for aviation turbine kerosene storage are TOR and Tema Multi-Purpose Terminal, with secondary facilities, including Puma Energy and GOIL PLC Aviation, located at the airport. These facilities may be adaptable for SAF, subject to technical and commercial requirements.

BOST Energies, previously the Bulk Oil Storage and Transportation Company, may also play a role in storage, handling, or wider logistics. BOST operates a network of depots, pipelines, and barge infrastructure[195]. Its 209 million litre Accra Plains Depot has pipelines to Tema and an aviation fuel pipeline to the hydrant facility at Accra Airport[196]. For the selected business case, the most practical storage model is likely to be a hybrid approach, with minimum operational storage at the AtJ facility supplemented by access to existing terminal infrastructure at TOR, Tema Multi-Purpose Terminal, or potentially BOST's Accra Plains Depot where technically and commercially feasible.

Blending

Neat SAF must be blended with conventional aviation fuel before it can be supplied for aircraft uplift. As noted by NREL and adapted to Ghana's context, the most likely blending options are terminal-based[197].

- **Separate SAF and conventional aviation fuel storage, with blending into a third tank.** Under this option, neat SAF would be delivered to a primary terminal, such as TOR or Tema Multi-Purpose Terminal, and stored separately from conventional jet fuel. SAF and conventional fuel would then be blended into a third tank at the required blend ratio. This option provides the clearest physical segregation up to the point of blending and allows the blended batch to be sampled and certified before onward delivery to the airport. Once blended, the specific SAF molecules would no longer be tracked through the downstream system; instead, the SAF share would be managed through batch records, certification, and chain-of-custody documentation.
- **Direct injection of SAF into conventional aviation fuel storage.** Under this option, neat SAF would be delivered directly into an existing conventional jet fuel storage tank at the terminal. This would reduce the need for separate SAF storage and a dedicated blending tank, but would require strong metering, inventory control, and mass-balance procedures to confirm the SAF blend percentage and ensure it remains within the allowable limit. Once SAF is co-mingled in the storage tank, the physical SAF molecules are no longer separately traceable.

Other options include blending at a refinery or at the airport, although these are likely to be less attractive in the Ghanaian context. Refinery blending may be difficult where fuel is produced by a separate company and there are no clear commercial, operational, or certification arrangements for introducing third-party product into refinery systems. Airport blending would move fuel-quality

[195] https://bostenergies.com.gh/who-we-are#depot-network
[196] https://epcmholdings.com/project/accra-airport-aviation-refuel-system/
[197] https://docs.nlr.gov/docs/fy21osti/78368.pdf

risk closer to aircraft operations and may require additional storage, blending equipment, safety systems, laboratory testing capability, staff procedures, and insurance coverage.

For this business case, the preferred option is therefore likely to be terminal-based blending in Tema, either through separate SAF and conventional jet fuel storage with blending into a third tank, or through controlled direct injection into conventional jet fuel storage where tank availability is limited.

Testing and certification

Testing and certification will be required for both fuel quality and sustainability purposes. Fuel quality testing could potentially use resources at existing refineries or fuel terminals, as suggested in the feasibility study. Testing could also be carried out abroad for certain volumes if full domestic testing infrastructure is not available in the early stages. However, any long-term SAF supply chain would benefit from domestic or regional testing capability to avoid delays and reduce operational complexity.

Sustainability verification must also be maintained across the supply chain. This includes evidence on feedstock origin, residue classification, ethanol production, AtJ conversion, blending, and final fuel claims. These requirements are discussed further in Section 3.3.

SAF supply logistics

The final logistics step depends on whether the SAF is uplifted domestically or exported. For domestic uplift at Kotoka International Airport, SAF would be produced near existing refineries and Ghana's main fuel terminals, meaning the logistics are likely to resemble those used for conventional aviation fuel. Depending on where blending occurs, fuel could be moved by road tanker or potentially through existing pipeline infrastructure.

For exports, the Tema area already has established logistics links between industrial zones and Ghana's largest port. Existing trucking networks, storage infrastructure, and potential pipeline links could be used to move SAF from the production or storage site to export points, subject to commercial arrangements and fuel-handling requirements[198].

3.2.5 Development timelines

Developing a SAF facility involves multiple stages and requires significant time as well as capital investment, beginning with project conception and moving through feasibility, engineering, financing, procurement, construction, and commissioning.

The feasibility study is the first stage of the process, typically requiring around 6–12 months to confirm technical, commercial, and market viability. For a SAF project, this would assess feedstock availability, technology suitability, production scale, infrastructure requirements, indicative capital and operating costs, potential offtake markets, and major regulatory or sustainability constraints. The feasibility study provides the evidence base needed to decide whether the project should progress to more detailed engineering and investment planning.

Front-end engineering design (FEED) follows a positive feasibility study and typically lasts around 9–12 months. During this stage, the project concept is developed in greater technical detail, including confirmation of the preferred technology pathway, facility configuration, site layout, utility requirements, logistics interfaces, and major equipment needs. FEED also refines the project scope, schedule, risk profile, and capital cost estimate to a level suitable for commercial assessment.

A financial investment decision represents a critical project milestone, marking the point at which sponsors commit the capital required to move from development into execution. This decision is typically supported by a sufficiently mature technical design, robust cost estimates, credible or secured offtake arrangements, and a clear financing plan. Funding would usually be drawn from a combination of equity investment, debt financing, public support mechanisms, or other commercial funding sources.

[198] https://channelonenewsonline.com/2025/07/24/no-shortage-of-aviation-fuel-in-ghana-npa/

Equipment procurement often involves long lead times, typically 18–30 months, reflecting the specialist nature of process equipment. This phase may involve custom design, fabrication, factory testing, and delivery of major components. Equipment may only be available from a limited number of qualified vendors, meaning procurement can become a key schedule constraint if not started early enough.

Detailed engineering design overlaps with equipment procurement to reduce overall schedule duration. During this stage, the technical design is developed in greater detail, including finalisation of process layouts, equipment specifications, piping and instrumentation, civil and structural requirements, and integration with utilities and supporting infrastructure.

Permitting is required to obtain formal regulatory approval for the project and ensure compliance with applicable laws and standards. This typically includes demonstrating that the facility meets environmental, safety, and land-use requirements, including control of emissions, protection of water and land resources, and compliance with construction and zoning regulations.

Construction can begin once the required approvals are in place and equipment has been secured. This typically lasts around 18–36 months, depending on facility scale, technology pathway, site complexity, and supporting infrastructure requirements. Construction generally begins with site preparation and civil works, followed by installation of structural, mechanical, electrical, and control systems.

Commissioning is the final stage before steady-state operation, typically requiring 6–12 months. During this period, individual systems are tested, integrated operations are verified, and plant performance is demonstrated before the facility transitions into stable operation.

The table below summarises the expected duration of each development stage and provides an indicative timeline for the AtJ business case in Ghana.

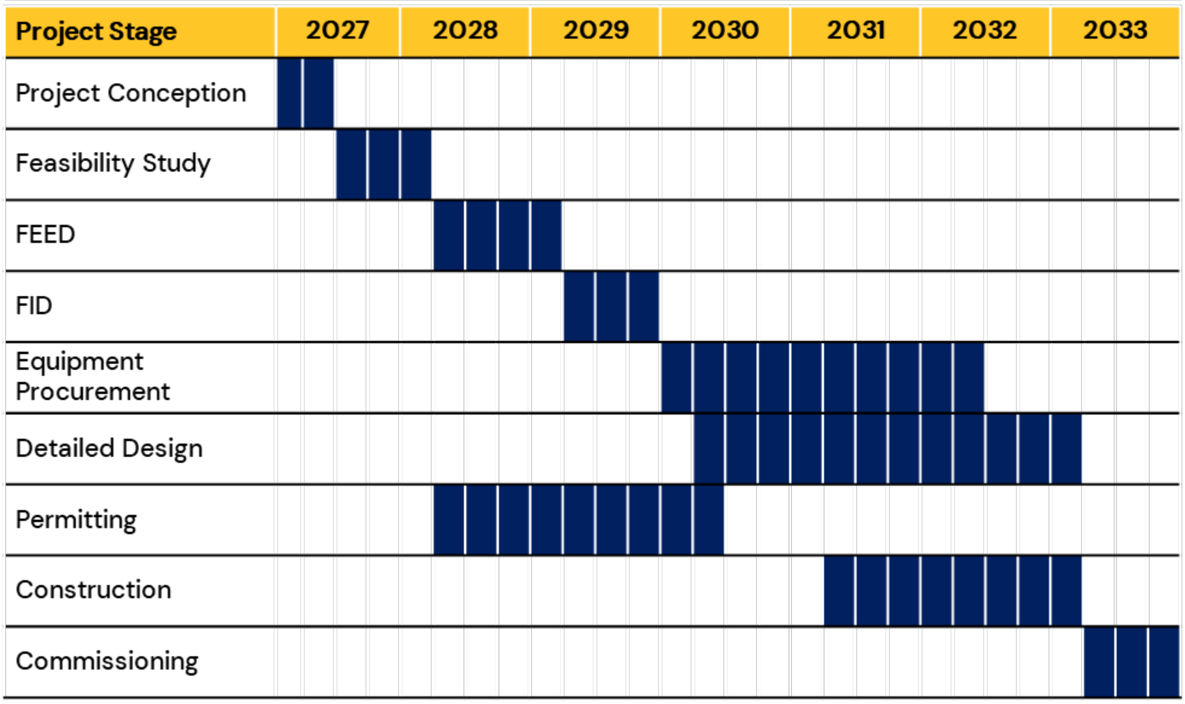
Table 45 Estimated timelines for SAF facility development

Project Stage	Estimated Time Required	Indicative Timeline
Project Conception	6-12 months	Q1–Q2 2027
Feasibility Study	6-12 months	Q3 2027–Q1 2028
Front-End Engineering Design	9-12 months[199]	Q2 2028–Q1 2029
Financial Investment Decision	6-9 months	Q2 2029-Q4 2029
Equipment Procurement	18-30 months	Q1 2030–Q2 2032
Detailed Design	9-12 months[200]	Q2 2030–Q4 2032
Permitting	18-24 months	Q2 2028–Q1 2030
Construction Phase	18-36 months	Q2 2031 – Q2 2033
Commissioning	6-12 months	Q2 2033 – Q4 2033

Several project stages can be delivered in parallel rather than as a strictly sequential process. Equipment procurement may begin while detailed design is still being finalised, and permitting activities can run alongside engineering and procurement to reduce overall schedule duration. This overlap is important for managing long-lead items, regulatory review periods, and construction readiness. However, even with parallel workstreams, the full project life cycle from initial conception through feasibility, design, financing, procurement, construction, and commissioning may still be expected to take around seven years, as illustrated on the figure below.

[199] Assumes equity is attained around the end of FEED
[200] Plus the duration of construction

Indicatively, the proposed AtJ facility could complete development by the end of 2033, although project timelines may vary



Source: ICF analysis

Figure 33 Proposed project timeline

Additional time may also be required for the 2G ethanol production facilities needed to supply the AtJ plant. These projects have also demonstrated multi-year engineering, construction, and start-up periods. For example, Nippon Steel Engineering's cellulosic ethanol pilot began engineering and construction in 2015 and completed pilot testing in 2019[201]. While the technology has since matured, this reinforces the need to develop the ethanol supply platform in parallel with the AtJ facility rather than treating it as a later add-on.

3.2.6 Exploring a potential demo facility

Pilot and demonstration-scale facilities are used globally to prove and de-risk technologies before full commercial deployment. They can help test whether feedstock logistics, technology performance, product quality, and operating assumptions hold up outside a modelling environment. However, fuel produced at small scale is usually not cost-competitive, as demonstration facilities do not benefit from the economies of scale available to commercial plants.

For this business case, the value of demonstration will differ across the value chain. For 2G ethanol, some technologies have been demonstrated or deployed globally, but commercial scale-up remains challenging and no equivalent supply chain has been developed in Ghana. A demonstration or pilot facility could therefore be useful for testing how maize residues are collected, preprocessed, and converted into ethanol under Ghanaian conditions. This would help validate the local operating model before larger-scale investment is committed.

AtJ demonstration could also be useful where the selected technology provider requires feedstock testing, pilot-scale validation, or project-specific evidence before committing to performance guarantees or FEED assumptions. While some ethanol-to-jet technologies have been demonstrated, not all AtJ technologies or project configurations are at the same level of maturity. Planned facilities should provide further evidence on how these technologies perform at

[201] https://www.eng.nipponsteel.com/files_publish/page/155/vol11_07_en.pdf

commercial scale, but a Ghana-based AtJ demonstration facility would likely be expensive relative to the volume of fuel produced.

Demonstration activity should therefore be targeted at the parts of the value chain where it would reduce the most project risk. In Ghana, this is likely to mean prioritising maize residue collection, preprocessing, and 2G ethanol production, while using technology-provider evidence, feedstock testing, and international AtJ project experience to de-risk the AtJ conversion step where possible.

3.3 Environment and sustainability

3.3.1 Sustainability considerations

Maize stover is one of the stronger SAF feedstock options from a sustainability perspective because it is a residue of existing maize production rather than a food crop grown specifically for fuel. Its use therefore avoids the direct food-competition and land-conversion concerns associated with many first generation biofuel feedstocks. However, the sustainability case depends on how the residue is collected, how much is removed, how nutrients are replaced, and whether soil carbon and wider farming-system functions are protected.

This section assesses maize stover in the context of CORSIA's sustainability criteria. Several of these considerations, particularly soil carbon, water, food security, labour conditions, and traceability, are also relevant to the risk assessment in Chapter 4.

Greenhouse Gases (GHG)

Under CORSIA default life cycle values, SAF produced from agricultural residues through a standalone AtJ pathway has a carbon intensity of 39.7 gCO_2e/MJ. This is materially below the CORSIA baseline for conventional aviation fuel, although the actual life cycle emissions of a Ghanaian project would depend on project-specific factors, including residue collection, transport distance, ethanol production, energy use, hydrogen source, and facility configuration. Studies focused on maize stover-based SAF have found that emissions reductions can be improved further where lower-carbon electricity, efficient logistics, or carbon capture are applied[202].

There are several emissions sources to consider across the value chain. At the farm level, field operations to collect, bale, and move maize stover may rely on diesel-powered machinery. These emissions can be reduced by using efficient collection routes, avoiding unnecessary field passes, increasing bale density, and, over time, shifting to lower-emission machinery where available. The aim should be to collect only the residue that can be moved efficiently and sustainably, rather than creating a highly dispersed supply chain with excessive vehicle movements.

Transport emissions will also depend on where 2G ethanol production is located[203]. Moving raw maize stover over long distances would be inefficient because the material is bulky and low-density. For that reason, the project configuration in Section 3.2 places 2G ethanol production closer to maize-producing areas, so that residues are transported shorter distances before conversion. Ethanol is then transported to the AtJ facility in Tema. This does not remove transport emissions, but it shifts the longer-distance movement from raw biomass to a higher-density liquid intermediate, which is more practical to move by road tanker.

The life cycle performance of the pathway will also depend on the energy used for drying, shredding, densification, ethanol production, and AtJ conversion. Using renewable electricity or lower-carbon process energy would reduce upstream emissions. This could include grid-connected renewable power where available, onsite solar for parts of preprocessing, or the use of process residues and lignin-rich fractions to provide heat and steam within ethanol production[204]. These measures are particularly relevant because maize stover may require drying and size reduction before conversion, and these steps can become emissions-intensive if powered mainly by fossil fuels.

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202 https://www.mdpi.com/1996-1073/18/13/3418

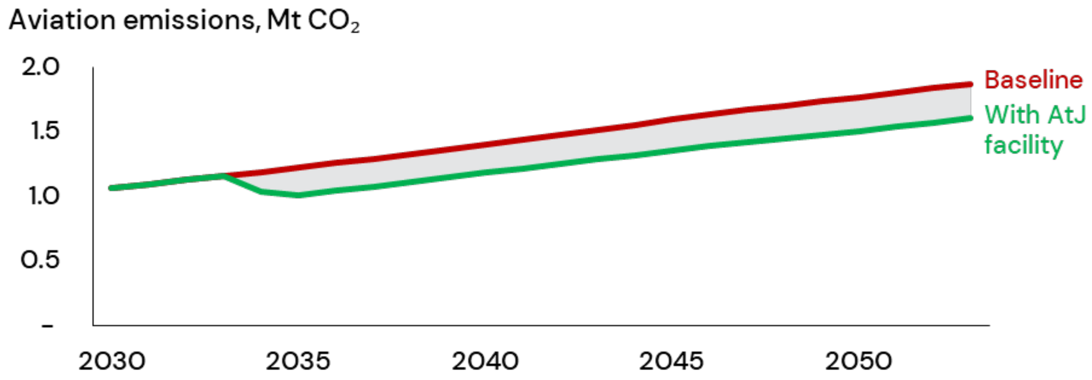
203 https://ageconsearch.umn.edu/record/91342/?v=pdf

204 https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2018.00090/full

Soil carbon is another important factor. Removing residues from the field can reduce organic matter inputs, releasing soil carbon over time[205]. Nitrous oxide emissions should also be considered, as reduced residue cover can alter soil nitrogen cycling and increase fertiliser needs. These impacts can be limited through low-carbon farm machinery, precision nutrient replacement rather than blanket fertiliser application, reduced tillage, cover crops, and regular monitoring of soil condition.

While many emissions reduction measures could be implemented from the start of production, this study assumes a gradual reduction in life cycle emissions, reaching 23.0 gCO_2e/MJ by 2050, equivalent to a 74% reduction relative to the CORSIA baseline for conventional aviation fuel. This could be reduced further through measures such as renewable electricity, lower-carbon hydrogen, process integration, or carbon capture. Using the study's assumptions, SAF produced from the proposed AtJ facility could reduce Ghana's well-to-wake aviation emissions by around 17% in the first year of full operation if all SAF produced were uplifted in Ghana. By 2053, the final year of the facility's production, the reduction would be around 14%, despite the lower carbon intensity, because Ghana's aviation activity and fuel demand are expected to grow over time.

If all SAF from the proposed AtJ facility is uplifted in Ghana, 4.6 Mt CO_2 of aviation emissions could be avoided between 2030 and 2050



Source; ICF analysis

Figure 34 Emissions avoidance from SAF production

Carbon stock

As noted above, maize stover plays an important role in maintaining soil organic carbon, and any removal of these residues would need close and regular monitoring. This is likely to be particularly important in Ghana, where many maize-growing areas already face low soil organic carbon, weak soil structure, and erosion risk. In these conditions, maize residues are not simply a by-product. They provide organic matter, ground cover, and protection against erosion, and excessive removal could reduce carbon inputs to soil and accelerate soil organic carbon loss[206].

Sustainable harvesting techniques would therefore be needed so that only surplus residue is removed, while enough biomass remains on the field to maintain soil organic matter and protect the soil surface[207]. The appropriate removal rate would vary by soil type, slope, rainfall intensity, existing soil carbon levels, crop rotation, and current residue uses, with more residue likely needing to remain on fragile or carbon-poor soils[208]. Cover crops, biochar, and other soil amendments could

[205] https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12631
[206] https://www.researchgate.net/publication/357971447_Influence_of_Tillage_Crop_Rotation_and_Crop_Residue_Management_on_Soil_Erosion_and_Maize_Yield
[207] https://www.osti.gov/pages/biblio/1559351
[208] https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2023.1094290/full

also help replace lost biomass, support more stable soil carbon storage, and improve nutrient retention where residue removal is taking place[209].

Water and water use rights

Maize stover affects water primarily through indirect rather than direct water demand. Maize itself can be water-intensive, but maize stover is a residue of existing maize production rather than a purpose-grown energy crop. Its use as a SAF feedstock therefore does not in itself require additional irrigation[210]. By contrast, if dedicated energy crops were introduced to supplement residue supply, irrigation demand could increase, particularly in water-constrained areas. In those cases, more efficient irrigation systems such as drip irrigation can help reduce water withdrawals, and water recycling within ethanol or biofuel production processes can also lower net freshwater demand.

The more immediate water-related issue is the effect of residue removal on soil water regulation. Retaining residues on the field helps protect the soil surface, reduce evaporation, improve infiltration, and support moisture storage[211]. If too much stover is removed, soils can become more exposed to raindrop impact, crusting, runoff, and erosion, which can reduce infiltration and weaken drought resilience[212]. This means that even if maize stover does not increase irrigation demand directly, excessive residue harvesting could still worsen field-level water stress by reducing the soil's ability to capture and retain rainfall.

There are also implications for water quality and wider water competition. If residue removal increases erosion and nutrient loss, nearby water bodies may experience higher sedimentation, nitrate contamination, and phosphorus loading[213]. This can reduce water quality for downstream agricultural, municipal, and ecological uses. Any use of maize stover for SAF should therefore be accompanied by monitoring of local water availability and water quality, alongside site-specific residue retention thresholds and soil management practices that maintain infiltration, ground cover, and nutrient retention.

Air

Using maize stover as a feedstock can improve local air quality where it displaces open-field burning of agricultural residues, which is a source of particulate matter and other harmful air pollutants[214]. Avoiding open burning can therefore reduce emissions that affect human health and local air quality, while also creating a more controlled residue management system.

However, residue collection and logistics can introduce other air-quality impacts. Baling, handling, and transporting dry biomass can generate dust, while harvesting and hauling equipment powered by diesel can contribute exhaust emissions, particularly particulate matter and nitrogen oxides. These impacts are typically smaller and more localised than emissions from open burning, but they should still be managed through dust suppression techniques, efficient logistics, and, where feasible, cleaner or lower-emission transport and collection equipment.

Conservation

Revenue from maize stover can support better conservation outcomes if it creates an incentive for farmers to improve residue management, monitor soil condition more closely, and adopt conservation technologies that protect long-term land productivity. However, residues left on fields also perform ecological functions in their own right. They provide ground cover, support soil organisms and other farmland biodiversity, and help maintain broader agroecosystem resilience. If too much residue is removed, these functions can be weakened, increasing the risk of lower biological activity and reduced resilience of the farming system over time.

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[209] https://www.energy.gov/sites/default/files/2023-05/beto-12-project-peer-review-feed-apr-2023-smith.pdf
[210] https://pubs.acs.org/doi/10.1021/es104145m
[211] https://link.springer.com/article/10.1007/s40518-013-0001-2
[212] https://cropsandsoils.extension.wisc.edu/articles/harvesting-corn-stover/
[213] https://www.tandfonline.com/doi/abs/10.1080/07352680902776507
[214] https://www.sciencedirect.com/science/article/abs/pii/S0959652620312385

Mapping conservation considerations into sustainable harvesting plans would help protect soil biodiversity and field-level ecosystem services. More broadly, landscape-level ecological screening, biodiversity planning, and integration with regenerative agriculture practices can help ensure that residue recovery does not undermine conservation priorities and is instead aligned with habitat connectivity and ecosystem resilience[215].

Waste and Chemicals

Maize stover can support positive outcomes for waste and chemicals management because it is itself an agricultural residue. Using it as a SAF feedstock supports circular bioeconomy objectives and valorises a by-product that might otherwise be left to decompose, burned in the field, or used only in lower-value applications[216].

At the same time, maize stover contains nutrients including nitrogen, phosphorus, and potassium, so its removal can create a nutrient deficit in the field and increase reliance on replacement fertiliser[217]. Additional waste streams may also arise during processing, since maize stover pretreatment and refining can generate wastewater, inhibitory compounds, and chemical residues that need to be managed carefully. Opportunities for improvement include returning nutrients to soils through suitable by-products, adopting lower-impact pretreatment methods, using closed-loop water systems, and applying biological fertilisers or soil amendments to reduce the chemical burden of replacement fertilisation[218,219].

Human and labour rights

Maize stover can support positive human and labour rights outcomes where it creates additional rural income opportunities, supports more formalised supply chains, and encourages investment in safer and more organised agricultural logistics. However, these benefits are not automatic. Residue collection, baling, transport, and handling can involve seasonal and informal labour, and without clear standards there may be risks around worker safety, insecure employment conditions, and uneven benefit-sharing across the supply chain[220]. These issues may be particularly relevant where smallholders and contract labourers have limited bargaining power.

Opportunities for mitigating these issues include embedding labour standards into feedstock procurement, supporting safe machinery use and training, and ensuring that worker protections extend across contractors and seasonal labour arrangements. Greater supply-chain formalisation, transparent contracting, and producer aggregation models can also help improve working conditions and reduce the risk that the economic value of maize stover is captured mainly by intermediaries. In practice, the human and labour rights case for maize stover is strongest where projects are paired with occupational safety measures, fair contracting, and clear mechanisms to include smallholders and local workers in the benefits of SAF development.

Land use rights and land use

Because maize stover is a residue of existing maize production, its use as a SAF feedstock generally creates lower direct land-use change pressure than dedicated energy crops, which can require new land conversion or displace other land uses. This means residue-based pathways can avoid many of the direct and indirect land conversion risks associated with purpose-grown bioenergy feedstocks.

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[215] https://link.springer.com/article/10.1007/s12155-014-9423-y

[216] https://books.rsc.org/books/edited-volume/2131/chapter-abstract/7758524/Valorization-of-Agricultural-Residues-Generated?redirectedFrom=fulltext

[217] https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/SCS-Evaluation/CORSIA_Supporting_Document_CORSIA-Eligible-Fuels_LCA_Methodology_V6.pdf

[218] https://biochar-international.org/wp-content/uploads/2018/11/prelim_ch1_2015biocharforenvironmentalmanagement_text.pdf

[219] https://www.researchgate.net/publication/221916719_Detoxification_of_Lignocellulosic_Hydrolysates_for_Improved_Bioethanol_Production

[220] https://www.ecologyandsociety.org/vol16/iss4/art29/

Land-use rights still need to be considered carefully, particularly where tenant farmers or short-term leaseholders may have limited control over residue management decisions or reduced incentives to adopt long-term conservation practices. In these cases, decisions about whether residues are left on fields, removed, or managed through rotations may depend as much on lease structures and tenure arrangements as on agronomy. Opportunities for improvement therefore include clearer lease arrangements that support conservation practices, farmer guidance on residue removal, and land stewardship measures that improve resilience over time.

Local and social development

Maize stover could contribute positively to local and social development if it creates new revenue streams for farmers, supports rural service industries such as collection and transport, and helps anchor wider investment in agricultural value chains. Because stover is a by-product of existing maize production, its use may allow additional value to be generated from current farming systems without requiring new crop areas.

If linked to domestic 2G ethanol production and SAF conversion, the pathway could also support job creation, local infrastructure improvements, and broader economic multipliers in rural areas. Rural communities participating in biomass supply chains may benefit from improved storage, logistics, roads, electricity access, or digital tracking systems established to support feedstock aggregation. Increased household income from residue sales could also support spending on education, healthcare, and local businesses. These benefits would be strongest where the supply chain is structured inclusively through cooperatives, outgrower systems, or transparent contracts.

Food security

As maize stover is a residue of existing maize production rather than a food crop grown specifically for fuel, its use as a SAF feedstock generally creates lower direct food security risks than dedicated bioenergy crops. It does not directly divert grain away from food or feed markets, and it avoids some of the land-competition risks associated with purpose-grown feedstocks.

However, maize stover still plays an important role within farming systems. It can be used as livestock feed, household fuel, bedding, mulch, and a source of nutrients and organic matter when left on the field. Removing too much residue can therefore affect food security indirectly by increasing fertiliser needs, weakening soil health, reducing livestock feed availability, or increasing costs for households that already rely on it. The food security position of the pathway therefore depends on sustainable removal rates, protection of existing essential uses, and monitoring of local impacts.

3.3.2 Eligibility

As previously discussed, the carbon intensity of SAF will depend on a facility-by-facility assessment, with several measures available to reduce it. Using the baseline figures applied in this study, alongside the modelled decrease over time, SAF produced from the business case facility is expected to be eligible under CORSIA and the UK SAF Mandate from the time of production. Under the more stringent EU rules, the baseline standalone AtJ value may not meet the required threshold until later in the project period, as shown on the figure below. However, if the producer intends to sell into the EU market, it would likely take measures from the outset to reduce life cycle emissions below the required threshold.

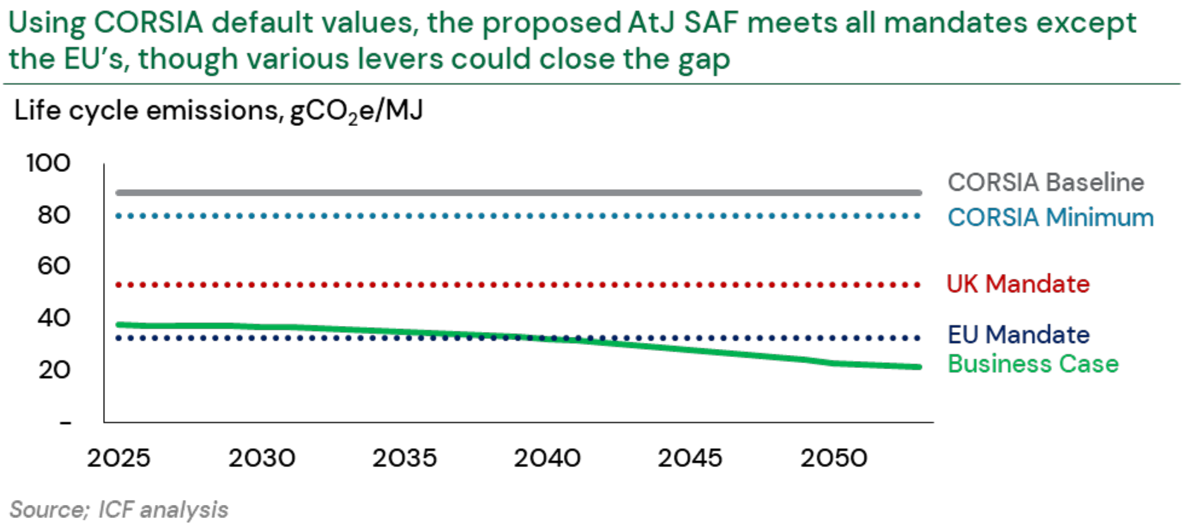

Figure 35 Lifecycle emissions compared to mandates

Aside from carbon intensity criteria, SAF produced from maize stover would in principle be capable of qualifying under both the UK and EU SAF compliance frameworks because maize stover is an agricultural residue rather than a food or feed crop used as the primary fuel feedstock. Under the UK SAF Mandate, SAF derived from crops or products is not eligible, whereas wastes and residues can qualify, subject to the detailed feedstock classification rules in the UK technical guidance and compliance with the mandate's carbon and sustainability requirements[221].

Under the EU's ReFuelEU Aviation framework, eligible aviation biofuels are those produced from sustainable biomass feedstocks, particularly the waste and residue categories recognised under Annex IX of the Renewable Energy Directive. Agricultural residues are part of the residue-based feedstock categories recognised under that framework, while food and feed crops are excluded from the SAF obligation[222]. Although feedstock eligibility in practice depends on the precise legal classification and certification evidence submitted for the material, maize stover is generally understood to fall within the agricultural residue concept rather than the excluded crop category.

Under ICAO CORSIA, maize stover-based SAF could also be eligible in principle, provided it is produced through an approved pathway, meets the scheme's sustainability criteria, and achieves the required life cycle emissions reduction. As an agricultural residue, maize stover is better aligned with CORSIA eligibility than food-competing crops, but qualification would still depend on certification of the feedstock as a residue, use of an approved life cycle assessment methodology, and compliance with the applicable environmental and social safeguards.

Accordingly, the key issue for maize stover-based SAF is less whether the feedstock is conceptually admissible under the relevant schemes, and more whether the specific production pathway can demonstrate full regulatory compliance, including verified residue status, traceability, sustainability assurance, and the required life cycle emissions reduction. This is discussed further in the next section.

3.3.3 Certification

CORSIA sets out sustainability requirements which must be achieved for fuels to qualify as CORSIA Eligible Fuels. These requirements must be met by all operators within the fuel supply chain on a

[221] https://www.gov.uk/government/publications/rtfo-and-saf-mandate-feedstock-materials-used-for-creating-low-carbon-fuels/rtfo-and-saf-mandate-list-of-feedstocks-including-wastes-and-residues
[222] https://eur-lex.europa.eu/eli/reg/2023/2405/oj/eng

well-to-wake basis, making traceability essential for verification[223]. This process places emphasis on the upstream supply chain rather than emissions from SAF combustion itself, with combustion emissions treated as biogenic within life cycle accounting.

In practice, all relevant operators in the supply chain must demonstrate compliance with the sustainability criteria set out by ICAO. This is carried out through approved Sustainability Certification Schemes. These schemes assess, verify, and certify compliance with CORSIA sustainability requirements. Approved schemes currently include ISCC, RSB, and ClassNK. The certification schemes set the criteria and requirements that must be followed at each stage, while certification is undertaken by accredited third-party auditors through documentation reviews, onsite inspections, and data verification.

Once certified, an economic operator is required to issue a Proof of Sustainability for each batch of sustainable material produced. This Proof of Sustainability is passed along the value chain and provides evidence at the end of the chain that the final fuel is CORSIA-eligible[224]. For the selected business case, this means documentation would need to cover maize residue collection, aggregation and storage, 2G ethanol production, ethanol transport, AtJ conversion, blending, and the final fuel claim.

The figure below illustrates the stages in the supply chain where a Proof of Sustainability must be supported by documented evidence.

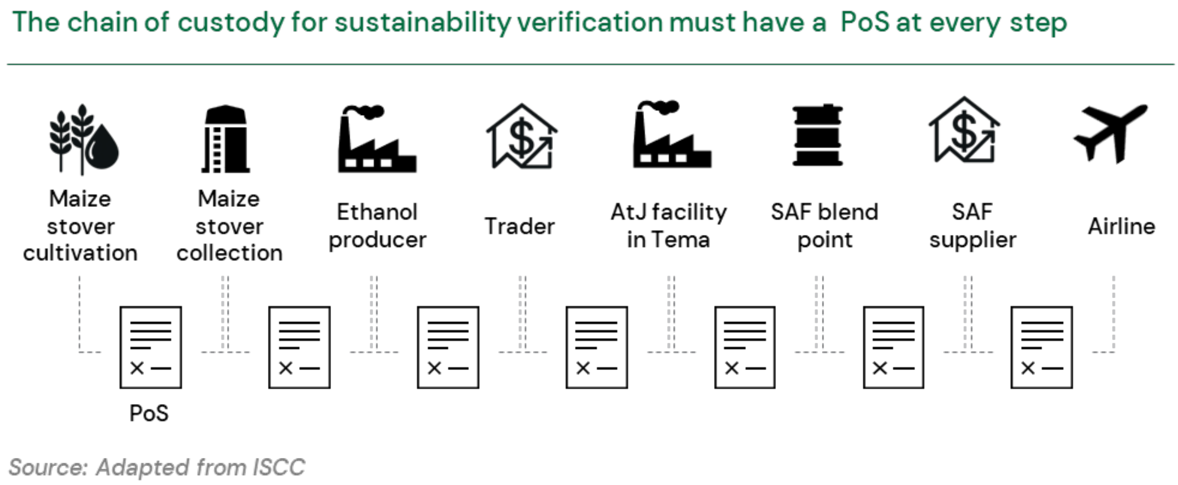

Figure 36 Chain of custody for sustainability verification (adapted from ISCC)[225]

While CORSIA remains at the voluntary stage for some States, it is recommended for States developing SAF production to embed CORSIA requirements into national policies. This creates greater certainty and clarity of requirements across the market and helps ensure that any SAF produced in Ghana can be recognised as CORSIA-eligible.

3.4 Commercialisation and offtake considerations

Chapter 1 set out the potential sources of SAF demand in Ghana, including domestic uplift, international airlines serving Kotoka International Airport, regional export opportunities, and wider voluntary or regulated markets. For the selected business case, the main issue is how that demand can be converted into bankable revenue. This is particularly important because the AtJ facility requires significant upfront capital, depends on a reliable 2G ethanol supply chain, and is expected to produce more SAF than Ghana is likely to absorb domestically in the early years.

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[223] https://www.icao.int/CORSIA/corsia-eligible-fuels
[224] https://www.iata.org/contentassets/0bf212bfcb0548f2b6ad4c1e229f7e94/guidance-document-on-saf-sustainability-certification-v0.41_rm-indepth.pdf
[225] https://www.iscc-system.org/wp-content/uploads/2024/01/ISCC_EU_203_Traceability_and_Chain-of-Custody_v4.1_January2024-1.pdf

3.4.1 Offtake requirements

Unlike conventional jet fuel, which is often purchased through shorter-term or spot-market arrangements, SAF projects usually require stronger revenue certainty. This is especially true for less mature pathways and projects with high capital requirements. For the selected business case, long-term offtake agreements are likely to be needed before financial investment decision, both to support the AtJ facility and to give confidence to upstream 2G ethanol producers.

Potential offtakers include international airlines operating from Ghana, airline groups with SAF targets, fuel suppliers, corporate travel buyers using book-and-claim systems, and potentially public-sector buyers seeking to support early SAF adoption. The strongest structure would likely involve one or more creditworthy buyers committing to defined volumes over several years, either at a fixed price, an indexed price, or a price linked to SAF certificates or emissions reductions.

3.4.2 Domestic uplift, exports, and book-and-claim

The selected facility is expected to produce around 91.8 kt/year of SAF after applying the steady-state availability assumption. This is larger than the volume Ghana would need under low early blend levels. As shown in Chapter 1, a 10% SAF blend would require 28 kt in 2030 and 46 kt in 2050, while a 20% blend would require 56 kt in 2030 and 93 kt in 2050. Domestic uplift could therefore absorb a meaningful share of production over time, but is unlikely to provide the full demand base in the early years unless blend levels are high.

The business case should therefore be treated as partly domestic and partly export-oriented. Domestic uplift at Kotoka International Airport could provide an important anchor market, particularly if international airlines are willing to purchase SAF in Ghana for voluntary commitments or CORSIA-related purposes. However, the facility would likely also need access to regional, international, or book-and-claim demand to support full utilisation and financing.

Book-and-claim could be particularly useful in this context. It allows the environmental attributes of SAF to be separated from the physical fuel, meaning SAF could be produced and uplifted in Ghana while a buyer elsewhere purchases the associated emissions benefit. This could reduce the need to physically export fuel while still allowing Ghanaian SAF to access international voluntary demand. Its value would depend on buyer acceptance, robust certification, and use of recognised registries such as RSB, ISCC, IATA, or

to prevent double counting.

Book-and-claim is not a complete substitute for physical demand, as some regulatory schemes require physical supply or apply specific accounting rules. However, it could provide an important early route to demand while Ghana's domestic SAF market is still developing.

3.4.3 Commercial priorities

Commercialisation should begin well before construction. The project developer would need to test willingness to pay, preferred contract structures, sustainability requirements, book-and-claim acceptance, and the value buyers place on Ghana-produced residue-based SAF. Engagement should include airlines serving Ghana, international airline groups with SAF commitments, fuel suppliers, corporate travel buyers, and book-and-claim market participants.

The SAF offtake strategy also needs to be linked to the upstream ethanol strategy. If 2G ethanol producers are expected to invest in new capacity, they will need confidence that there is a stable buyer for their ethanol. Similarly, the AtJ facility will need confidence that ethanol can be supplied at the required volume, quality, sustainability standard, and price. Commercialisation is therefore not only about selling SAF, but about creating linked contracts across the value chain.

The main early priorities are to:

- engage airlines and fuel suppliers serving Ghana on physical uplift potential;
- test international demand for Ghana-produced SAF through voluntary or compliance markets;
- explore book-and-claim routes with recognised registries and buyers;

- develop preliminary offtake terms for SAF and co-products;
- assess whether SAF offtake can support financing for both the AtJ facility and upstream 2G ethanol production; and
- confirm the sustainability, traceability, and carbon intensity requirements expected by buyers.

3.5 Policy and permitting considerations

3.5.1 Policy considerations

A supportive policy framework will be central to the development of a prospective SAF industry in Ghana. ICAO guidance on policy measures for SAF development and deployment highlights that there is no single model for successful SAF policy implementation. Instead, policy packages should be tailored to each State's resources, economic conditions, regulatory context, and development priorities.

The following table presents a toolkit of potential policy options outlined by ICAO, grouped around three core objectives: stimulating SAF supply, creating demand, and enabling the wider SAF marketplace[226].

Table 46 Policy toolkit options for SAF development and deployment in the Ghana context [227]

Policy Measure	Description
Stimulating growth of SAF supply	
Public funding for SAF	Public funding for SAF research, development, demonstration and deployment can help accelerate learning and reduce early-stage project risk across the SAF supply chain. This includes support for targeted R&D to improve feedstock yields, conversion efficiency, logistics and production costs, as well as demonstration funding to help scale up promising feedstocks and technologies. Such funding can be channelled through dedicated government programmes, universities, research institutions or private-sector partnerships. **Ghana Relevance:** Public funding could support Ghana's SAF development by addressing gaps in feedstock aggregation, biofuel scale-up, SAF certification, and technical capacity. However, given Ghana's wider fiscal constraints and competing development priorities, direct public funding would likely be targeted and limited, with preference given to donor-funded pilots, university partnerships, and private-sector co-funding rather than large-scale government expenditure. This would allow Ghana to build the evidence base for SAF investment without placing significant pressure on public finances.
Targeted incentives and tax relief to expand SAF supply infrastructure	Targeted incentives and tax relief can help expand SAF supply infrastructure by reducing upfront capital costs, lowering financing risk, and improving project economics for early SAF producers. These measures may include capital grants, loan guarantees, tax credits, accelerated depreciation, green bonds, streamlined approval processes and other de-risking tools for production, blending, refuelling and feedstock infrastructure. **Ghana Relevance:** Targeted incentives could help improve SAF project bankability in Ghana. Ghana already has some relevant

[226] https://www.icao.int/sites/default/files/environmental-protection/Documents/Guidance-on-SAF-policies-Version-4.pdf

[227] https://www.icao.int/sites/default/files/environmental-protection/Documents/Guidance-on-SAF-policies-Version-4.pdf

	investment mechanisms, including tax/customs incentives, Free Zones eligibility, concessional lending and potential risk-sharing tools, but the SAF feasibility study notes that these are not yet tailored to SAF's specific risk profile.
Targeted incentives and tax relief to assist SAF facility operation	Targeted incentives and tax relief for SAF facility operations are designed to reduce the ongoing cost gap between SAF and fossil jet fuel once production begins. These can include blender or producer tax credits, excise tax relief, feedstock production support, and direct incentives for airlines or fuel users to purchase SAF. Such mechanisms are usually linked to the volume of SAF produced, blended or consumed, helping improve operational economics and stimulate market uptake. **Ghana Relevance:** These operational incentives may be more practical for Ghana than upfront capital grants, as support can be linked to SAF that is produced, blended, or consumed rather than requiring major public expenditure before project delivery.
Recognition and valorisation of SAF environmental benefits	Recognition and valorisation of SAF environmental benefits means giving financial or regulatory value to the emissions and wider environmental benefits delivered by SAF. This can include reduced carbon tax exposure, lower obligations under cap-and-trade schemes, recognition of CORSIA or EU ETS benefits, and potential future credit for non-CO_2 benefits such as improved air quality or reduced contrail impacts. These mechanisms help improve SAF economics by monetising its environmental value, rather than relying only on fuel sales or direct subsidies. **Ghana Relevance:** This is likely to be a longer-term policy option rather than a near-term priority for Ghana. In the near term, effort should be focused on establishing CORSIA-aligned sustainability standards and certification systems, which would create the foundation for future recognition of SAF's environmental value.
Creating demand for SAF	
Creation of SAF Mandates	SAF mandates require a defined share of SAF, or a reduction in fuel carbon intensity, within the aviation fuel supply or airline fuel use over time. These policies create demand certainty by obligating fuel suppliers, airlines or end users to support SAF uptake, and may generate tradeable or bankable credits that help bridge the cost gap with fossil jet fuel. Mandates can be volume-based, carbon-intensity based, or supported through levies on users, but they are generally most effective where supply availability, compliance systems and market readiness are sufficiently developed. **Ghana Relevance:** A SAF mandate could provide long-term demand certainty, but is not a suitable near-term priority. Domestic SAF production does not yet exist, and imposing a mandate too early could create cost and compliance pressure for fuel suppliers or airlines before supply chains are ready. A future mandate could be considered once domestic production, blending, and certification systems are more developed.
Update existing policies to incorporate SAF	Updating existing policies to incorporate SAF involves adapting current alternative fuel, biofuel or low-carbon fuel frameworks so that SAF qualifies for support alongside road-transport fuels. This can be

	done at national, regional, or local level and may allow SAF producers or users to access existing incentives, credits, or compliance mechanisms without creating an entirely new policy system. **Ghana Relevance:** This is highly relevant for Ghana because it would be a practical and low-complexity way to support SAF without creating a new standalone SAF policy. Ghana already has bioenergy and renewable energy frameworks, but the SAF feasibility study notes that aviation is not explicitly addressed and that incorporating SAF and renewable diesel into the bioenergy policy framework and forthcoming action plans would strengthen regulatory clarity, planning certainty, and investor confidence.
Demonstrate government leadership	Government leadership can support SAF market development by setting clear policy direction and creating early demand signals. This may include aspirational production, use, or emissions-reduction targets, such as the U.S. SAF Grand Challenge, ReFuelEU Aviation's progressive SAF supply targets, or ICAO's global cleaner aviation energy vision, as well as direct government or public-sector SAF procurement for official travel and aircraft operations. **Ghana Relevance:** Government leadership is a relatively low-cost early-stage enabler. A clear policy statement, or inclusion of SAF in national aviation, climate, or energy transition strategies, could reduce perceived investor risk. Public-sector SAF procurement, including through book-and-claim, could also signal commitment without requiring immediate physical SAF uplift in Ghana.
Enabling SAF Markets	
Market-enabling activities	Market-enabling activities support SAF deployment by establishing the systems and coordination needed for a functioning market. This includes adopting recognised sustainability certification and life cycle GHG methods (e.g. CORSIA-aligned) to ensure integrity, developing "book-and-claim" systems to enable trading of environmental attributes, supporting stakeholder initiatives to align actors and improve transparency, and facilitating qualification of new SAF pathways (e.g. clearing houses) to expand supply and reduce deployment risk. **Ghana Relevance:** Market-enabling activities in Ghana would establish credibility and access to international SAF markets. Aligning with recognised sustainability standards (e.g. CORSIA) would allow any future SAF production or use to meet global eligibility requirements, while early adoption of compatible accounting and certification systems could enable participation in international demand (including book-and-claim markets) even without domestic infrastructure.

For the selected business case, the most relevant near-term policy actions are enabling rather than compulsory. Ghana could incorporate SAF into existing bioenergy and renewable energy planning, support maize residue and 2G ethanol development, establish CORSIA-aligned certification processes, and begin structured engagement with airlines, fuel suppliers, airport operators, and potential developers. These steps would help build the conditions for investment without placing immediate cost obligations on the aviation sector.

3.5.2 Permitting landscape

The permitting landscape for a SAF facility in Ghana would involve several interlinked approval processes, including environmental permitting, spatial planning, construction consent, petroleum-sector authorisations and operational licensing. This section focuses on the main permitting requirements likely to apply to the AtJ facility, while recognising that the wider value chain would have additional site-specific requirements.

Environmental Protection Agency Act, 1994

The Environmental Protection Agency Act, 1994 (Act 490) establishes the Environmental Protection Agency (EPA) as the central authority responsible for regulating environmental impacts and issuing environmental permits in Ghana[228]. For a prospective SAF facility, this creates a mandatory requirement to undertake Environmental Impact Assessment (EIA) where the project is likely to have adverse environmental effects. EPA approval would also be a prerequisite for other licences, permits, or consents.

The EPA has broad powers to set and enforce standards relating to emissions, discharges, waste management, and the handling of hazardous substances. A SAF developer would therefore need to demonstrate compliance across the facility life cycle , including feedstock handling, fuel production, wastewater treatment, storage, and product handling. The EPA can also conduct inspections, require monitoring and reporting, issue enforcement notices, and require corrective action where activities pose environmental or public health risks. Compliance would therefore be both a pre-condition for project approval and an ongoing operational obligation.

Environmental Assessment Regulations, 1999

The Environmental Assessment Regulations of 1999 establish the detailed process for obtaining environmental approval under Ghana's EPA regime[229]. A SAF facility would likely be treated as an industrial undertaking with potential environmental and public health impacts, requiring registration with the EPA and an environmental permit before construction or operation. The Netherlands Commission for Environmental Assessment provides a detailed overview of this procedure[230].

The screening process is the first mandatory step and determines whether a proposed project can proceed directly to permitting or must undergo further environmental assessment. A SAF facility falls under the Schedule 2 category, which requires an Environmental Impact Assessment. The screening submission would need to describe the proposed activity, location, technology, infrastructure and utility requirements, likely waste generation, potential environmental and health and safety impacts, mitigation measures, alternatives, and evidence of stakeholder consultation.

The scoping stage then defines the scope and terms of reference for the EIA. This includes explaining the need for the project, assessing alternatives, justifying site selection, describing the environmental, social, and economic baseline, identifying likely impacts, setting out mitigation measures, and proposing monitoring arrangements. Public and institutional engagement is built into the process, including consultation with affected parties, relevant ministries, government departments, organisations, and the relevant Metropolitan, Municipal or District Assembly.

The assessment process requires the developer to prepare a draft Environmental Impact Statement. This assesses the direct and indirect impacts of the proposed undertaking across pre-construction, construction, operation, decommissioning, and post-decommissioning. The assessment must cover potential positive and negative impacts on environmental, social,

228 https://www.epa.gov.gh/ghanalex/acts/Acts/ENVIRONMENTAL%20PROTECTION%20AGENCY%20ACT%201994.pdf

229 https://www.epa.gov.gh/ghanalex/acts/Acts/ENVIRONMENTAL%20ASSESSMENT%20REGULATION,1999.pdf

230 https://www.eia.nl/en/wp-content/uploads/2025/01/2019-08-20-Ghana-Legislation-at-project-level.pdf

economic, and cultural aspects, including air, water, land, ecology, noise and vibration, odour, traffic, road safety, and local social and economic conditions.

The review process is supported by cross-sectoral technical committees at regional and national level. It considers the strengths and weaknesses of the assessment, whether further studies are needed, what monitoring obligations should apply, and what conditions should be attached if approval is granted. When the Environmental Impact Statement is accepted, a written notice will be issued, and the environmental permit is issued once the developer submits the final approved copies.

Once approved, developers must comply with ongoing obligations, including submission of an environmental management plan, annual environmental reporting, and obtaining an environmental certificate within 24 months of commencing operations. Permits are subject to conditions and may be suspended or revoked if requirements are not met.

Guidelines of development permitting

A prospective SAF facility in Ghana would require planning and development approval before physical development begins[231]. This would require a permit under the Land Use and Spatial Planning Act, 2016 (Act 925) [232]. For an AtJ facility, this would cover site development, process units, storage areas, utilities, access roads, safety zones, and supporting infrastructure.

Applications are submitted to the Physical Planning Department of the relevant District Assembly. The Secretariat acknowledges receipt, the Technical Sub-Committee reviews the application and conducts a site inspection, and the District Spatial Planning Committee may grant, refuse, or defer the application. Where requirements are met, permit processing should take around 30 days. Development permits are valid for five years and must be renewed if the development is not completed within that period. After construction, the developer must obtain a Certificate of Habitation before occupying the building.

Refinery permitting

The National Petroleum Authority Public Notice 017[233] on the construction of petroleum refineries or petrochemical plants may also be relevant to a SAF facility, particularly where the facility produces aviation fuel blending components, renewable diesel, naphtha, or other liquid fuels. The approval process is structured in three sequential stages: a licence to establish, a permit to construct, and a licence to operate.

Obtaining the **licence to establish** requires developers to provide corporate documentation, land title evidence, feasibility studies, preliminary marketing and product plans, feedstock details, proposed site information, process configuration, technology or licensor information, safety provisions, preliminary environmental information, an implementation schedule, a financial plan, and hazard review information.

The **permit to construct** requires evidence of wider statutory compliance, including development and building permits, fire safety review, geotechnical assessment, and an Environmental Impact Assessment leading to an EPA environmental permit.

The **licence to operate** requires physical inspection of the plant by the National Petroleum Authority's engineers to confirm conformity with the approved design. If satisfactory, approval for plant commissioning and a licence to operate may then be granted.

Permitting challenges and recommendations

Permitting for a first SAF facility in Ghana would require careful coordination because several approvals are likely to be interdependent. EPA environmental approval is expected to be needed before some other consents can be granted, while NPA construction approval may also require evidence of development and building permits, fire safety review, geotechnical assessment, and

[231] https://www.luspa.gov.gh/wp-content/uploads/2023/12/LUSPA-GUIDELINES.pdf
[232] https://faolex.fao.org/docs/pdf/gha180045.pdf
[233] https://npa.gov.gh/wp-content/uploads/notices/NPA.N%20017%20Refinery%20Construction%20New.pdf

an EPA environmental permit. Clear sequencing will therefore be important so that one approval process does not unnecessarily delay the wider project timeline.

As Ghana does not yet have an operational SAF facility, the first project would also help establish how existing environmental, planning, petroleum-sector, fuel-quality, and safety requirements apply in the SAF context. This should be manageable if developers engage early with the EPA, NPA, the relevant District Assembly, fire authorities, fuel-quality bodies, airport and terminal operators, and other permitting stakeholders. A permitting roadmap should be developed before FEED so that approval requirements, sequencing, responsible authorities, and expected timelines are clear.

3.6 Financing and ownership considerations

3.6.1 Financing considerations

Given the scale of investment required for SAF production, securing finance will be one of the main challenges for the selected business case. Financing terms have a material impact on the cost of producing SAF because the minimum selling price is driven not only by upfront CAPEX, but also by the cost, availability, and structure of capital.

The balance between debt and equity will depend on how lenders and investors assess the project's risk profile, including technology maturity, construction risk, offtake certainty, country risk, and the availability of concessional or public support. Projects with stronger offtake arrangements and more proven technologies can usually support a higher share of debt, while higher-risk projects often require more equity or risk-sharing support.

The World Economic Forum identifies several financing levers for SAF production, including strategic industry investment, private equity, infrastructure investors, long-term offtake agreements, multilateral development bank support, guarantees, and insurance instruments[234]. These mechanisms can help mobilise capital and improve project bankability. The World Bank similarly highlights that SAF production in African markets is shaped by cost and risk factors, including elevated risk premiums and green premiums, reinforcing the importance of de-risking instruments and supportive financing structures[235].

Reducing financing costs will therefore be central to the competitiveness of the selected pathway. Blended finance, concessional debt, guarantees, export-credit support, and credible offtake arrangements could reduce reliance on expensive equity and lower the cost of capital, reducing the SAF selling price required for the project to be commercially viable[236]. Section 1.2 shows that Ghana's investment environment is improving, with stronger growth, improved reserves, cedi appreciation, and falling inflation. This creates a more supportive backdrop for SAF investment.

As discussed in Chapter 2, the TEA applies a financing waterfall in which concessional finance is used first, followed by grant funding and then higher-cost commercial debt and equity where needed. For the selected AtJ case, the model assumes USD 250 million of World Bank IDA debt, USD 150 million of World Bank SUW debt, USD 25 million of climate grant funding, and a remaining USD 25 million split between commercial debt and equity at a 60:40 ratio. This leaves USD 15 million of commercial debt and USD 10 million of equity in the capital structure for the AtJ facility. Although most of the AtJ facility funding is assumed to come from concessional sources, the residual commercial debt and equity still increase the overall cost of capital and therefore the MFSP.

The wider financing requirement is higher than the AtJ CAPEX alone, because upstream 2G ethanol production capacity is not included in the AtJ facility cost. This investment could be substantial, depending on whether Ghana develops several distributed ethanol facilities, one larger facility, or an integrated model. Financing for 2G ethanol could be structured separately from the AtJ facility and supported by long-term ethanol supply agreements, concessional finance, climate funds, or

[234] https://www.weforum.org/publications/financing-sustainable-aviation-fuels-case-studies-and-implications-for-investment/
[235] https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099060225114591835
[236] https://thedocs.worldbank.org/en/doc/bae48ff2fefc5a869546775b3f010735-0500062021/related/mpo-gha.pdf

industrial development finance. This may make the overall value chain more financeable than attempting to fund the AtJ facility and all upstream ethanol capacity as one large integrated project from the outset.

Additional Investment Sources

In addition to the World Bank, several other funding sources may be relevant to capital-intensive projects in Africa.

The **African Development Fund** was established by the African Development Bank (AfDB) in 1972 and provides concessional funding for public-sector projects and programmes, along with technical assistance for studies and capacity-building initiatives[237]. The fund has invested approximately USD 58 billion across Africa, with 74 completed projects located in Ghana. Ghana is currently listed as a Category A country by the ADF, meaning it is not creditworthy for non-concessional financing and is only eligible to receive ADF resources. The AfDB has also supported aviation infrastructure in Ghana, including the construction of a new terminal at Kotoka International Airport (KIA) in Accra through a USD 120 million corporate loan to Ghana Airports Company Limited's (GACL) capital investment programme[238].

The **African Infrastructure Investment Fund (AIIF)[239]** was established in 2004 by Africa Infrastructure Investment Managers and is now in its fourth iteration. Total commitments to the fund amount to USD 954 million. AIIF focuses on three investment themes across Africa: digital infrastructure, energy transition, and mobility and logistics. Its strategy is to invest in market-leading companies with primarily private-sector counterparties. The fund also includes a climate-focused sidecar, AIIF4 Climate Investment L.P. (ACI), which was established to invest alongside the main fund in climate and environmentally focused infrastructure assets in Africa.

The **Emerging Africa Infrastructure Fund** was established over 20 years ago to raise and deploy public and private debt capital for infrastructure projects across sub-Saharan Africa[240]. It has supported more than USD 27 billion of total investment across 96 completed projects, creating over 23,000 permanent jobs. Renewable energy is a key sector focus for the fund, and completed projects include a biomass power plant in Côte d'Ivoire and a hydropower plant in Gabon.

The **Fund for Export Development in Africa** was established as the impact investment arm of the African Export-Import Bank to support intra-African trade growth, value-added export development, and industrialisation[241]. In 2022, its first close of USD 670 million was announced, with a target to raise USD 1.3 billion by 2024.

3.6.2 Ownership models

There are several ownership models that could be used for a SAF facility in Ghana. The most relevant options are a private single-entity model and a public-private partnership model. Each has advantages and disadvantages, and the preferred structure would need to be tested during project development against investor appetite, fiscal exposure, procurement requirements, and the role government is expected to play.

Under a **single-entity model**, the project is owned and developed by one sponsor-led project company, often structured as a dedicated project entity or Special Purpose Vehicle (SPV). The project company raises finance, contracts the procurement and construction phase, and manages delivery and operation through a network of commercial agreements. This can provide clear commercial control and faster decision-making, but it also places the full capital burden and risk exposure on the project sponsor.

[237] https://adf.afdb.org/
[238] https://www.afdb.org/en/news-and-events/afdb-approves-us-120-million-corporate-loan-to-ghana-airports-company-first-private-sector-investment-in-ghanas-transport-sector-14766
[239] https://aiimafrica.com/our-funds/funds_aiif/
[240] https://www.eaif.com/
[241] https://www.afreximbank.com/the-fund-for-export-development-in-africa-feda-announces-its-first-close-of-us670-million-across-four-fund-strategies/

A **public-private partnership** (PPP) differs from a single-entity model because it is a long-term arrangement between public and private institutions to deliver an asset or service. The private partner typically delivers and funds the project using a capital asset and shares the associated risks[242]. PPP agreements can take several forms, including Build-Own-Operate, Build-Own-Operate-Transfer, and Build-Operate-Transfer. Under a Build-Own-Operate model, the private party builds, owns, and operates the asset with no requirement to transfer ownership back to the public sector. Under a Build-Own-Operate-Transfer model, the private party builds, owns, and operates the asset for a defined concession period before transferring it to the public sector. Under a Build-Operate-Transfer model, the private party builds and operates the asset for a defined period before transferring ownership.

Table 47 Advantages and disadvantages of single-entity and PPP ownership models

Ownership Model	**Advantages**	**Disadvantages**
Single Entity	- The single entity holds full control over the project strategy and management, allowing for faster decision making. - The project can be structured around a clear commercial strategy rather than balancing wider public-sector objectives. - The single entity retains all financial benefits. - Governance structure is relatively simple.	- The single entity is responsible for the full capital burden. - The single entity is responsible for the full risk burden. - Potentially weaker access to government coordination and support for permitting and regulatory requirements. - Uncertain strategic alignment with national SAF policy objectives.
Public-Private Partnership (PPP)	- Private sector capital and delivery expertise can still be mobilised. - There is a structured allocation of risk across multiple entities. - Supports strategic public-sector involvement without full public ownership. - Allows for easier alignment with emerging SAF policies, incentives, or frameworks. - Improves coordination across public bodies involved across the life cycle of a SAF facility.	- Project structure and preparation are typically more complex than a single entity venture. - Risk allocation can become difficult for first-of-a-kind projects. - Government support can create fiscal exposure to the state which may impact the economy. - Commercial flexibility may be reduced for the project developer. - Potential project exposure to political shocks.

A PPP-style model may be appropriate for an early SAF project in Ghana, particularly where government support is needed for land, permitting coordination, infrastructure interfaces, policy alignment, local content, or de-risking. The private sector would still be expected to lead project

242 https://legalinstruments.oecd.org/public/doc/275/275.en.pdf

delivery and operations, but public-sector participation could help coordinate the wider enabling environment. This may be especially relevant where the project depends on multiple public interfaces, including energy, aviation, environmental regulation, fuel standards, ports, and potentially Free Zone arrangements.

However, PPP should not be assumed automatically. If a credible private sponsor can secure land, offtake, finance, and permits without material government support, a single-entity project structure may be simpler. The best model will depend on the role government wants to play, the availability of public support mechanisms, investor appetite, and whether the project seeks access to viability gap funding or other PPP-specific support.

Public Private Partnership Act, 2020

Ghana's Public Private Partnership Act, 2020 provides the legal framework for PPP arrangements between public contracting authorities and private parties for infrastructure and services[243]. The Act is intended to mobilise private-sector resources for infrastructure delivery, improve service quality, establish clear processes for PPP identification, structuring, procurement, and monitoring, and manage government financial commitments.

The Act sets out a three-stage PPP process covering project preparation, procurement, and contract/post-contract award management. For a SAF facility, this means a PPP would not simply be a negotiated financing arrangement between government and a developer. It would likely need to move through formal project preparation, appraisal, approval, and procurement before contract award. The feasibility study would need to assess the technical and legal requirements, risk transfer, contingent liabilities, PPP structure options, financial viability, fiscal affordability, end-user affordability, value for money, and wider social, economic, and environmental impacts.

The Act also establishes a Project Development Facility to support project preparation, structuring, procurement, monitoring, capacity building, and transaction advisory services. In addition, it establishes a Viability Gap Facility for projects that are technically feasible but not financially viable. Viability gap support can include construction grants, capital grants, operating grants, availability payments, service payments, annuity payments, and minimum revenue guarantees.

One important limitation is that viability gap support cannot be applied to unsolicited proposals or private-sector-led proposals. This could be relevant if a SAF developer approaches government with its own project concept. If the project is treated as an unsolicited or private-sector-led proposal, it may not be eligible for viability gap funding under the Act. This should therefore be clarified early if PPP support is being considered.

The Act also requires PPP agreements to specify which assets are public property and which are private property. The agreement must identify assets to be returned or transferred to the contracting authority, assets the contracting authority may purchase, and assets the private party may retain or dispose of at expiry or termination. If the agreement does not address asset treatment, the asset is considered public property. For a SAF project, this would make asset ownership an important structuring issue, particularly if public land, port infrastructure, storage assets, or other public interfaces are involved.

Previous Public-Private Partnerships in Ghana

Ghana has experience using PPPs for large and technically complex infrastructure projects. According to the 2024 Annual Report on Public-Private Partnership Projects, Ghana's PPP portfolio included 36 projects at the end of 2024, with 17 in the pre-investment stage and 19 in the investment phase[244]. These projects span infrastructure, administration, economic, and social sectors.

The **Tema LNG project** is a USD 350 million, 25-year Build-Operate-Transfer PPP involving Tema LNG Terminal Ltd. and the Ghana Ports and Harbours Authority. The project is designed to import,

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[243] https://mofep.gov.gh/sites/default/files/acts/PPP-ACT-1039.pdf

[244] https://www.mofep.gov.gh/sites/default/files/reports/economic/2024-Annual-Report-on-PPP-Projects_v2.pdf

store, and supply LNG for Ghana's power and industrial sectors. By the end of 2024, it was reported to be 98% complete, although not yet operational.

Another major PPP example is the development of **Terminal 3 at Tema Port**, with a total estimated cost of USD 1.5 billion. This is a 35-year Build-Operate-Transfer concession between Meridian Port Services and the Ghana Ports and Harbours Authority, with GPHA holding a 30% equity stake. Phase 1 began operations in 2019, with completion targeted in 2025. Over the concession period, gross revenue is estimated at USD 22.9 billion, with GPHA expected to receive USD 4.5 billion in variable concession fees. The project has modernised Tema Port, created direct jobs, and provided GPHA with revenue through dividends and concession fees without requiring direct capital investment.

These examples show that PPP structures can be used in Ghana for large infrastructure projects with significant private-sector participation. For SAF, the relevance is not that either structure should be copied directly, but that Ghana has an established PPP framework and experience with complex infrastructure concessions. A SAF project would still need to test whether a PPP offers better value than a private project structure, particularly given the first-of-a-kind nature of SAF production, the need to allocate risk carefully, and the potential fiscal exposure for government.

3.7 Economic and wider development impacts

Developing maize stover as a feedstock for SAF in Ghana could generate economic, social, and environmental benefits beyond the production of aviation fuel itself. These benefits would come mainly from feedstock collection, aggregation, transport, preprocessing, 2G ethanol production, and operation of the AtJ facility.

One of the most significant impacts would be rural employment creation across the agricultural and industrial supply chain. SAF production from maize stover would require collection, aggregation, transportation, storage, preprocessing, conversion into 2G ethanol, and distribution of the final fuel. Each stage could create employment opportunities, particularly in maize-producing regions, with one estimate suggested that development of the ethanol industry in Ghana could create more than 500,000 direct and indirect jobs[245][246]. This should be treated as a wider ethanol-sector estimate rather than a project-specific employment figure, but it indicates the scale of economic activity that could be linked to a domestic ethanol value chain.

Farmers and local cooperatives could also earn supplementary income by selling residues that are currently underutilised, burned, or used in lower-value applications[247]. This could be particularly important in rural areas where agricultural incomes are often seasonal and volatile. However, the distribution of benefits would depend on how the supply chain is structured. Transparent contracts, cooperatives, and aggregator models could help ensure that smallholders retain a meaningful share of the value created.

The development of a maize stover SAF industry could also support diversification within Ghana's agricultural economy. Ghana's economy remains strongly linked to primary production and a relatively narrow set of major commodities, namely cocoa and gold-related activities[248]. Developing a domestic bioeconomy around agricultural residues would create additional value from existing farming activity, while increasing processing and industrial activity within the country. There may also be opportunities to use by-products from the ethanol production process for heat, power, soil amendments, nutrient recycling, or potentially animal feed, depending on the technology and facility configuration.

A maize stover SAF sector could also support industrial development and technology upgrading in Ghana. SAF production would require investment in advanced biorefineries, logistics systems, biomass preprocessing infrastructure, ethanol production, AtJ conversion, hydrogen generation,

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[245] https://www.mdpi.com/1996-1073/15/16/5800
[246] https://www.myjoyonline.com/unlocking-ghanas-biofuel-potential-the-case-for-corn-and-cassava-ethanol-production/
[247] https://www.mdpi.com/2071-1050/13/1/381
[248] https://www.britannica.com/place/Ghana/Economy

storage, blending, testing, and certification[249]. These investments could create demand for skilled technicians, chemical engineers, environmental specialists, logistics operators, equipment suppliers, and certification professionals. Over time, this could support knowledge transfer and contribute to the development of a broader low-carbon industrial base.

Community-level benefits may also arise in maize-producing regions[250]. Rural communities participating in the biomass supply chain could benefit from improved storage facilities, aggregation centres, roads, logistics systems, and digital tracking tools. Increased household income from residue sales could support spending on education, healthcare, and local businesses. If structured through cooperatives or outgrower models, the supply chain could also strengthen farmer participation in formal markets.

Environmental co-benefits are also possible. Where maize residues are currently burned or poorly managed, organised biomass collection could support more controlled residue management, improve local air quality, and reduce health impacts in nearby communities[251]. These benefits would depend on sustainable collection practices, as excessive residue removal could weaken soil health, reduce soil carbon, and affect long-term agricultural productivity.

The selected pathway could also support Ghana's trade and energy objectives. Ghana currently imports all of its aviation fuel, so domestic SAF production could allow more value to be retained in the local fuel supply chain. If production exceeds domestic uplift demand, exports or book-and-claim sales could create additional revenue opportunities. Co-products such as renewable diesel and naphtha could also provide supporting revenue, although SAF remains the main product of the business case.

The wider development case for the proposed AtJ facility is strongest where the project is treated as part of a broader agricultural and industrial value chain, rather than only as a fuel-production facility. The main benefits would come from building domestic capacity in residue collection, 2G ethanol production, fuel conversion, certification, and logistics. These benefits would depend on project design, farmer participation, local content, sustainability safeguards, and access to finance.

[249] https://www.mdpi.com/1996-1073/18/13/3418
[250] https://www.irena.org/-/media/files/irena/agency/events/2018/jan/irena8a-bioenergy/bioenergy-and-sustainable-development.pdf?la=en&hash=925cce24475c34c53d3dabdc458612167166f74d
[251] https://www.unep.org/news-and-stories/story/toxic-blaze-true-cost-crop-burning#:~:text=Many%20farmers%20consider%20agricultural%20burning,to%20human%20and%20environmental%20health

4 Risk Assessment

The selected business case depends on several parts of the value chain developing in parallel, including maize stover collection, 2G ethanol production, AtJ conversion, downstream fuel logistics, certification, offtake, financing, and permitting. The risks below are grouped around these main dependencies.

Each risk is assessed by impact and likelihood. Impact reflects the potential effect on project viability if the risk occurs, while likelihood reflects the probability that the risk could affect development without mitigation. Both are rated as High, Medium, or Low, using the definitions in the table below.

Table 48 Risk rating definitions

Rating	Impact Definition	Likelihood Definition
Low	Would have limited effect on project viability or delivery and can likely be managed through normal project controls.	Only expected under specific conditions that can be monitored and managed.
Medium	Could affect project cost, timing, operational performance, or sustainability, but is unlikely to stop the project if managed early.	Plausible and should be planned for, but not certain to occur if early mitigation and validation are completed.
High	Could materially affect project viability, cost, delivery timeline, sustainability, certification, financing, or ability to reach FID.	Likely to occur or affect the project unless actively managed, based on current uncertainty, market conditions, or lack of established systems.

4.1 Feedstock and upstream supply risks

A reliable biomass supply is essential for domestic 2G ethanol production. If maize stover cannot be collected sustainably and at sufficient scale, the project would either need to rely more heavily on other eligible residues or consider imported ethanol. While imported ethanol could help the AtJ facility operate, it would reduce many of the domestic benefits of the business case, including rural income, residue valorisation, and local value creation.

Table 49 Ratings and mitigations for feedstock and upstream supply risks

Feedstock and upstream supply risks
Risk: Maize stover availability may be lower than assumed once additional loss factors are accounted for. **Impact:** Medium **Likelihood:** Medium **Mitigation 1:** Complete a regional feedstock assessment before FEED to confirm practical rather than theoretical maize stover availability. **Mitigation 2:** Design the upstream ethanol supply system so that other eligible lignocellulosic residues can supplement maize stover where technically compatible and certifiable.
Risk: Aggregation may be difficult and costly because maize production is concentrated in several regions but remains dominated by smallholder farms. **Impact:** Low **Likelihood:** Low

Feedstock and upstream supply risks
Mitigation 1: Build the collection model around existing maize aggregation channels, cooperatives, and local aggregators. **Mitigation 2:** Use pilot schemes to test collection costs, baling needs, farmer participation, and delivery reliability before commercial scale-up.
Risk: Excessive residue removal could weaken soil health, reduce soil organic carbon, and affect long-term maize productivity. **Impact:** Low **Likelihood:** Medium **Mitigation:** Set site-specific residue removal thresholds based on soil and agronomic factors, with farmer training, soil monitoring, and nutrient replacement included in procurement requirements.
Risk: Seasonal maize production could make it difficult to supply upstream ethanol facilities consistently throughout the year. **Impact:** High **Likelihood:** Medium **Mitigation 1:** Develop storage and preprocessing capacity to manage seasonal feedstock flows. **Mitigation 2:** Allow other eligible residues to smooth supply where maize stover availability is lower.
Risk: Poor storage or high moisture content could reduce maize stover quality before it reaches ethanol production. **Impact:** Low **Likelihood:** Medium **Mitigation:** Set feedstock quality standards for moisture, contamination, storage, and handling, with inspection and rejection procedures for off-spec material.
Risk: Feedstock collection systems may not scale at the same pace as ethanol production capacity. **Impact:** Low **Likelihood:** Medium **Mitigation:** Develop feedstock pilots, ethanol plant siting, storage planning, and AtJ offtake discussions in parallel, supported by contracts linking aggregators, ethanol producers, and the AtJ facility.

4.2 2G ethanol production risks

The next set of risks relates to the conversion of biomass into 2G ethanol. This is a critical step because the AtJ facility depends on ethanol supply, but the ethanol production sits outside the AtJ CAPEX boundary in this study. The project therefore needs the upstream ethanol platform to be technically credible, financeable, and aligned with the AtJ development timeline.

Table 50 Ratings and mitigations for 2G ethanol production risks

2G ethanol production risks
Risk: 2G ethanol producers may struggle to secure financing.

2G ethanol production risks
Impact: Low **Likelihood:** Low **Mitigation 1:** Coordinate financing for the AtJ facility and upstream 2G ethanol platform through linked supply agreements, aligned development timelines, and shared engagement with concessional lenders. **Mitigation 2:** Support ethanol financing through long-term AtJ supply agreements while preserving optionality to serve other ethanol markets where commercially and sustainably viable. **Mitigation 3:** Use proven 2G ethanol technology providers where possible to reduce perceived technology and delivery risk for lenders.
Risk: The cost of 2G ethanol may be higher than the USD 1,860/tonne assumed in the TEA. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Complete a Ghana-specific 2G ethanol feasibility assessment before FEED and use ethanol supply contracts that manage price escalation while still giving ethanol producers enough incentive to invest. **Mitigation 2:** Test alternative ethanol supply options as a contingency, recognising that these may have weaker eligibility, carbon intensity, and domestic value-creation benefits.
Risk: 2G ethanol technology may underperform if yields, uptime, or pretreatment performance are lower than expected. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Select technology providers with relevant commercial or near-commercial experience, require feedstock testing, and use conservative ramp-up assumptions before committing to full-scale ethanol supply. **Mitigation 2:** Test alternative ethanol supply options as a contingency, recognising that these may have weaker eligibility, carbon intensity, and domestic value-creation benefits.
Risk: Using multiple lignocellulosic residues could create variability in ethanol yield, handling requirements, and process performance. **Impact:** Low **Likelihood:** High **Mitigation:** Build feedstock flexibility only around residues that have been tested for technical compatibility, ethanol yield, handling requirements, and certification.
Risk: Ethanol supplied to the AtJ facility may not consistently meet required quality, sustainability, or documentation standards. **Impact:** Low **Likelihood:** High **Mitigation:** Set clear ethanol specifications and sustainability documentation requirements in supply contracts, with testing, batch records, and rejection rights for off-spec material.

4.3 AtJ facility, infrastructure, and logistics risks

These risks relate to the AtJ facility itself and its physical integration with the wider fuel system. Even with ethanol supply secured, the project would still need the facility to be delivered on time, connected to reliable utilities, supplied with ethanol, and integrated with storage, blending, testing, and distribution infrastructure in Tema.

Table 51 Ratings and mitigations for AtJ facility, infrastructure and logistics risks

AtJ facility, infrastructure, and logistics risks
Risk: The AtJ facility may become operational before domestic 2G ethanol supply is fully available. **Impact:** Medium **Likelihood:** Low **Mitigation 1:** Develop the AtJ facility and domestic 2G ethanol supply plan in parallel, with aligned commissioning timelines and supply agreements. **Mitigation 2:** Consider the potential use of imported ethanol or 1G ethanol, while recognising that these options may have weaker eligibility, carbon intensity, and domestic value-creation benefits.
Risk: Commissioning or early operational challenges could delay the AtJ facility reaching stable production. **Impact:** Low **Likelihood:** Medium **Mitigation:** Select a proven AtJ technology provider and include clear commissioning milestones, delay responsibilities, and handover requirements in project contracts.
Risk: The AtJ facility CAPEX may exceed the USD 450 million estimate used in the TEA. **Impact:** Medium **Likelihood:** Medium **Mitigation:** Refresh the TEA through a pre-FEED study based on vendor quotes, then refine the cost estimate through FEED and vendor engagement, including major equipment, utility requirements, contingency, and cost-control processes.
Risk: Electricity, natural gas, water, hydrogen production, or wastewater interfaces may not be available at the reliability, cost, or permitting conditions assumed. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Confirm utility requirements and connection options during FEED, noting that onsite hydrogen generation and wastewater treatment are already included in the modelled facility scope. **Mitigation 2:** Build resilience into the facility design through backup power, onsite renewable generation where feasible, water storage or recycling, and contingency plans for natural gas supply interruptions.
Risk: Transporting ethanol from distributed 2G ethanol facilities to Tema may be more costly or operationally complex than assumed. **Impact:** Medium **Likelihood:** High **Mitigation:** Confirm ethanol transport routes, tanker availability, loading and unloading requirements, storage interfaces, and safety procedures during project development, with ethanol facility siting assessed alongside transport cost to Tema.

AtJ facility, infrastructure, and logistics risks
Risk: Storage, blending, testing, or terminal access may be more difficult than assumed. **Impact:** Low **Likelihood:** High **Mitigation 1:** Engage early with TOR and other stakeholders to confirm storage, blending, and testing options. **Mitigation 2:** Prioritise terminal-based blending in Tema, with clear procedures for batch testing, chain-of-custody documentation, and onward delivery to domestic or export markets.
Risk: The AtJ facility may produce a lower SAF yield than assumed in the TEA, reducing SAF output and increasing reliance on co-product revenues. **Impact:** Medium **Likelihood:** High **Mitigation:** Confirm expected product yields with the technology provider and assess whether the facility can optimise SAF output without undermining co-product revenues or increasing costs.

4.4 Sustainability, eligibility, and certification risks

The selected pathway only has value as SAF if it can meet the sustainability, carbon intensity, traceability, and certification requirements of target markets. These risks therefore cover both environmental performance and the practical evidence needed to support claims across the maize stover-to-ethanol-to-SAF value chain.

Table 52 Ratings and mitigations for sustainability, eligibility and certification risks

Sustainability, eligibility, and certification risks
Risk: The SAF produced may not meet the carbon intensity thresholds required for target markets, particularly under more stringent EU requirements. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Reduce life cycle emissions through measures such as renewable electricity, lower-carbon process energy, efficient logistics, lower-emission farm equipment, process integration, or carbon capture where feasible. **Mitigation 2:** Complete a project-specific LCA before FID.
Risk: Maize stover collection could reduce soil carbon, weaken soil structure, and affect long-term maize productivity if residue removal is not managed properly. **Impact:** Low **Likelihood:** Medium **Mitigation:** Apply established corn stover recovery guidance, then set Ghana-specific residue retention requirements supported by soil monitoring, nutrient replacement, reduced tillage, cover crops, and soil amendments where appropriate.
Risk: Traceability may be difficult to demonstrate where maize stover is collected from many smallholder farms and passes through aggregators before reaching 2G ethanol production. **Impact:** Low

Sustainability, eligibility, and certification risks
Likelihood: Low **Mitigation:** Require each aggregator to keep supplier records showing where maize stover was collected, the farmer or collection group involved, the volume supplied, and the delivery batch. Ethanol producers should then link these records to incoming feedstock batches and retain the documentation needed to support Proof of Sustainability claims.
Risk: Residue removal could worsen field-level water stress or water quality if it increases runoff, erosion, or nutrient loss. **Impact:** Medium **Likelihood:** Medium **Mitigation:** Apply established corn stover recovery guidance alongside local water monitoring, erosion controls, nutrient management, and soil practices that maintain infiltration and ground cover.
Risk: Maize stover collection could affect existing local uses, including livestock feed, household fuel, bedding, mulch, and soil nutrient recycling. **Impact:** Medium **Likelihood:** Medium **Mitigation:** Map existing residue uses by region before procurement begins.
Risk: Labour, land-use, water-use, and community safeguards may be difficult to document across a smallholder-based supply chain. **Impact:** Medium **Likelihood:** Medium **Mitigation:** Include worker safety standards, safe machinery training, fair contracting, land and water-use requirements, and written terms on payment timing, residue ownership, and land access in feedstock procurement.

4.5 Market and offtake risks

The demand analysis in Chapter 1 shows that SAF demand may exist domestically, regionally, and internationally. The commercial risk is whether that demand can be converted into long-term offtake agreements at prices and terms that support the project. This is especially important because domestic uplift alone is unlikely to absorb the facility’s full output in the early years.

Table 53 Ratings and mitigations for market and offtake risks

Market and offtake risks
Risk: The SAF price may be too high for buyers to absorb. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Explore SAF policy support, incentives, or book-and-claim mechanisms to help close the price gap with conventional jet fuel. **Mitigation 2:** Reduce life cycle emissions where feasible, as a lower carbon intensity can reduce the cost of abatement for buyers in markets where SAF value is linked to emissions performance.

Market and offtake risks
Mitigation 3: Reduce the underlying cost of 2G ethanol through feedstock logistics optimisation, technology-provider selection, and long-term supply agreements that support scale-up and cost reduction.
Risk: Export demand may be limited if Ghana-produced SAF does not meet the sustainability, carbon intensity, or documentation requirements of target markets. **Impact:** Low **Likelihood:** Medium **Mitigation:** Align certification, life cycle assessment, and chain-of-custody documentation with target market requirements before offtake agreements are finalised.
Risk: The project may not secure long-term SAF offtake agreements needed to support financing. **Impact:** Low **Likelihood:** Low **Mitigation:** Engage airlines, fuel suppliers, and corporate buyers before FEED to test willingness to pay, preferred contract structures, contract length, and required sustainability attributes.
Risk: Domestic SAF demand may be too small to absorb the facility's full output in the early years. **Impact:** Medium **Likelihood:** Low **Mitigation:** Develop the commercial strategy around a mix of domestic uplift, regional exports, wider international sales, and book-and-claim demand rather than relying only on Ghanaian uplift.

4.6 Financing risks

Financing risks are central because the MFSP is sensitive to both the cost and structure of capital. The AtJ facility is capital-intensive, and the upstream 2G ethanol platform would require additional investment beyond the AtJ facility itself. The project will therefore need financing structures that reduce exposure to high commercial debt and equity costs while supporting both parts of the value chain.

Table 54 Ratings and mitigations for financing risks

Financing risks
Risk: Concessional finance may not be available at the scale or terms assumed in the TEA. **Impact:** Low **Likelihood:** Medium **Mitigation:** Engage DFIs, MDBs, climate funds, and export-credit providers early, and test alternative capital structures before FEED so the project is not dependent on one financing source.
Risk: Lenders may require an EPC wrap or equivalent construction-risk protection, which could be difficult to secure for a first-of-a-kind biofuels project. **Impact:** Low

Financing risks
Likelihood: Medium **Mitigation:** Engage EPC contractors and technology providers early to test whether an EPC wrap, performance guarantees, delay protections, or equivalent lender protections are available. If a full EPC wrap is not available, develop an alternative bankability package using technology warranties, contingency, independent technical due diligence, staged drawdowns, and clear allocation of construction and commissioning risk.
Risk: Commercial debt, equity, interest-rate, or exchange-rate conditions may be less favourable than assumed, increasing the MFSP. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Align revenue with financing risks, for example through long-term offtake contracts with price indexation, hard-currency revenues, or pass-through mechanisms for fuel price and exchange-rate movements. **Mitigation 2:** Structure financing to reduce exposure, including maximising concessional debt, using local-currency financing where feasible, and securing guarantees or export credit support.

4.7 Policy and regulatory risks

Policy and regulatory risks relate to whether Ghana's enabling environment can support a SAF project. This includes SAF policy clarity, certification systems, tax and Free Zone treatment, and the sequencing of environmental, planning, petroleum-sector, and fuel-quality approvals. These issues do not replace the commercial case, but they can affect whether the project can move from concept to delivery.

Table 55 Ratings and mitigations for policy and regulatory risks

Policy and regulatory risks
Risk: Ghana may not have SAF-specific policy, certification, or support frameworks in place during project development. **Impact:** Medium **Likelihood:** Medium **Mitigation**: Incorporate SAF into existing bioenergy, renewable energy, and aviation policy frameworks, with early focus on certification, life cycle emissions accounting, and market-enabling measures.
Risk: Policy support or incentives may not be implemented in time to support SAF demand or improve project economics. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Engage government early to confirm required policy, certification, and market conditions. **Mitigation 2:** Avoid making the base case dependent on new policy support unless there is a clear route to implementation.
Risk: Free Zone, tax, or export treatment may be unclear for SAF supplied to domestic uplift, exports, or book-and-claim buyers. **Impact:** Low

Likelihood: Medium **Mitigation:** Clarify tax, Free Zone, and export treatment early in project development, including how domestic sales and international claims are treated.
Risk: Permitting approvals may be delayed if environmental, planning, fuel-sector, and operational requirements are unclear or not well coordinated. **Impact:** Low **Likelihood:** Medium **Mitigation 1:** Develop a permitting roadmap before or at the start of FEED that identifies the approvals required, responsible authorities, sequencing, and expected timelines. **Mitigation 2:** Engage early with EPA, NPA, the relevant District Assembly, and other permitting authorities to coordinate environmental approval, development permits, fuel-sector licences, and operational requirements.
Risk: Approval timelines may extend if reviews, consultations, or additional assessments take longer than expected. **Impact:** Medium **Likelihood:** Medium **Mitigation:** Allow sufficient time in the project schedule for permitting and consultation processes, and maintain regular engagement with regulators throughout development.

5 Business Implementation Recommendations

This section sets out the recommended actions to move the selected business case towards investment readiness. The preferred pathway is AtJ using 2G ethanol from maize residues, but it should not be treated as a standalone AtJ facility. The project will only be credible if the upstream biomass and ethanol supply, the AtJ facility, certification, offtake, financing, permitting, and fuel logistics are developed as part of one coordinated value chain.

The recommendations below are based on the findings of this study and the risks identified in Chapter 4. They focus on the actions, partner roles, financing routes, and structuring decisions that need to be addressed before the project can move towards FID.

5.1 Implementation recommendations

The implementation recommendations are structured as a phased action plan. Each initiative includes a timeline, lead, and key stakeholders. The timeline assumes formal project conception begins in Q1 2027, although two early coordination and policy-alignment actions, 1.A and 1.B, could begin in Q4 2026 if stakeholders are ready. The sequencing is aligned with Section 3.2.5, with project conception during Q1–Q2 2027, feasibility and validation during Q3 2027–Q1 2028, FEED during Q2 2028–Q1 2029, and FID targeted for Q4 2029.

The schedule depends on early coordination and the progression of several activities in parallel. If a major workstream takes longer than expected, later milestones would need to move accordingly.

The phases are as follows:

- **Phase 1**: Coordination and validation
- **Phase 2**: Project definition
- **Phase 3**: Investment readiness and FID preparation

The phases are made up of initiatives, each of which includes a description, an indicative timeline shown in months and calendar quarters, a lead stakeholder or institution, and other key stakeholders. Timelines are measured from Q1 2027 unless an initiative is explicitly shown as starting in Q4 2026.

5.1.1 Phase 1: Coordination and validation

Objective: Put in place the governance, policy direction, project leadership, and feasibility evidence needed to decide whether the project should move into detailed project definition.

This phase should establish whether the opportunity is practical enough to develop further. The early actions focus on coordination, policy direction, and identifying a prospective developer. The remaining actions test the core technical and commercial assumptions, particularly biomass availability, 2G ethanol production, and the AtJ facility concept.

1.A Establish a SAF coordination committee or working group

Ghana should establish a SAF coordination mechanism under the wider policy and oversight function. Its role should be to keep the main workstreams moving together, not to create another approval layer. The committee should provide a clear coordination point for government, regulators, agriculture, fuel supply, certification, and early investor engagement. It should also link SAF development to national policy processes and to Ghana's ICAO State Action Plan and LTAG monitoring.

Timeline: Months 0–3 / Q1 2027, *with possible early start in Q4 2026*

Lead: Ministry of Transport and Ghana Civil Aviation Authority

Key stakeholders: Government Ministries, regulators, feedstock collectors, technology providers, airlines, fuel producers

1.B Set Ghana's near-term SAF ambition and policy direction

Following the formation of the SAF coordination committee, Ghana should set a clear near-term SAF ambition. This does not need to be a mandate or financial support commitment at this stage.

The aim is to make SAF part of Ghana's aviation, energy transition, and industrial development agenda, including through relevant national strategies and a possible SAF roadmap.

This step should also cover early clarification of tax, Free Zone, export, and domestic sales treatment. These issues may affect site selection, project structure, offtake, and financing, so they should be addressed from the beginning rather than left until FID.

Timeline: Months 0–6 / Q1–Q2 2027*, with possible early start in Q4 2026*

Lead: Ministry of Transport and Ghana Civil Aviation Authority

Key stakeholders: Ghana's SAF committee

1.C Define the initial project partner landscape

The coordination group should identify the stakeholders likely to be needed for a first project and define their possible roles early. This should include prospective SAF developers, prospective ethanol developers, feedstock aggregators, AtJ technology providers, fuel infrastructure partners, offtakers, and financiers.

Timeline: Months 0–6 / Q1–Q2 2027

Lead: Ghana's SAF committee

Key stakeholders: Prospective SAF developers, prospective ethanol developers, feedstock aggregators, technology providers, fuel suppliers

1.D Identify prospective SAF developer or development consortium

A prospective SAF developer or development consortium should be identified before detailed AtJ project definition begins. This entity would be expected to lead commercial development of the AtJ facility, commission technical studies, engage technology providers, and take forward buyer and finance discussions. Until this point, the SAF coordination committee can support enabling work, but it should not substitute for a project sponsor.

Timeline: Months 3–6 / Q2 2027

Lead: Ghana's SAF committee

Key stakeholders: Prospective SAF developers, fuel suppliers, AtJ technology providers, infrastructure investors, Ministry of Finance

1.E Validate practical maize stover availability

A regional feedstock assessment should focus on the practical supply case for maize stover. It should assess expected growth in maize production, sustainable removal rates in Ghana's context, realistic collectable volumes, collection methods, and competing uses. The aim is to move from theoretical residue potential to a practical feedstock supply case.

Timeline: Months 6–15 / Q3 2027–Q1 2028

Lead: Prospective ethanol developers / Ministry of Food and Agriculture

Key stakeholders: Maize producers, aggregators, academia

1.F Run feedstock collection pilots

Pilot schemes should be developed in priority maize-producing regions to test collection costs, baling needs, farmer participation, storage requirements, feedstock quality, and delivery reliability. These pilots should use existing maize aggregation channels and local aggregators where possible, rather than creating a new supply chain from scratch.

Timeline: Months 6–15 / Q3 2027–Q1 2028

Lead: Prospective ethanol developers / Ministry of Food and Agriculture

Key stakeholders: Maize producers, aggregators, academia

1.G Assess other lignocellulosic biomass options

Maize stover should remain the base-case feedstock, but the upstream ethanol system should not be designed around one residue stream only. The project should assess which other lignocellulosic biomass sources could supplement maize stover, including cassava residues, rice residues, cocoa pod husks, and other agricultural processing residues. These should be tested for availability, handling requirements, ethanol yield, sustainability, and compatibility with the selected 2G ethanol technology.

Timeline: Months 6–15 / Q3 2027–Q1 2028

Lead: Prospective ethanol developers

Key stakeholders: Maize producers, aggregators, ethanol technology providers, academia

1.H Complete a Ghana-specific 2G ethanol feasibility assessment

A Ghana-specific 2G ethanol feasibility assessment should go beyond a cost model. It should assess technology options, feedstock suitability, ethanol yields, plant siting, CAPEX, OPEX, delivered ethanol cost, utility needs, permitting requirements, and financing implications. It should also test whether distributed ethanol plants near feedstock supply are more practical than fewer larger plants.

Timeline: Months 6–15 / Q3 2027–Q1 2028

Lead: Prospective ethanol developer

Key stakeholders: 2G ethanol technology provider, regulators

1.I Complete AtJ facility feasibility / pre-FEED definition

The prospective SAF developer should complete an AtJ facility feasibility or pre-FEED definition before full engineering begins. This should confirm the facility configuration, major equipment needs, hydrogen production approach, utility requirements, storage needs, product slate, cost estimate basis, and key interfaces with ethanol supply and downstream fuel logistics. This work should provide enough definition to decide whether full FEED is justified.

Timeline: Months 6–15 / Q3 2027–Q1 2028

Lead: Prospective SAF developer

Key stakeholders: AtJ technology provider, prospective ethanol developer, fuel infrastructure partners

Phase 1 summary and KPIs:

By the end of Phase 1, the project should have enough evidence to decide whether it is credible enough to move into full project definition.

Key indicators for staying on track include:

- SAF coordination committee established by Q1 2027.
- Near-term SAF ambition or roadmap process agreed by Q2 2027.
- Initial project partner landscape defined by Q2 2027.
- Prospective SAF developer or development consortium identified by Q2 2027.
- Regional maize stover assessment completed by Q1 2028.
- Feedstock collection pilots launched by Q3 2027, with initial results available by Q1 2028.
- Ghana-specific 2G ethanol feasibility assessment completed by Q1 2028.
- AtJ facility feasibility / pre-FEED definition completed by Q1 2028.

5.1.2 Phase 2: Project definition

Objective: Move from feasibility-level definition into detailed project definition, while confirming the project structure, site basis, technology route, certification plan, and commercial interfaces.

This phase should turn the preferred pathway into a defined project. By the end of Phase 2, the project should have undertaken FEED and have enough technical and commercial definition to support financing and FID preparation.

2.A Define the preferred project and contracting structure

The most practical structure is likely to be a central AtJ project company linked by long-term contracts to one or more 2G ethanol producers. This would allow the AtJ facility and ethanol assets to be financed separately, while still aligning supply, commissioning, certification, and offtake. This step should also clarify the main commercial interfaces, including ethanol supply, SAF offtake, terminal access, and co-product sales.

Timeline: Months 15–18 / Q2 2028

Lead: Prospective SAF developer

Key stakeholders: Prospective ethanol producers

2.B Decide the appropriate ownership model

The project should decide whether a private SPV, PPP-style structure, joint venture, or hybrid model is most appropriate. A private SPV may be simplest if the public sector's role is limited to enabling support. A PPP-style structure may be relevant if government support is needed for land, infrastructure interfaces, viability gap support, or coordinated permitting. A joint venture could be appropriate where a technology provider, fuel supplier, airline, or infrastructure investor wants to take an equity role.

Timeline: Months 15–21 / Q2–Q3 2028

Lead: Prospective SAF developer

Key stakeholders: Ministry of Finance, equity investors, concessionary finance institutions

2.C Agree development funding responsibilities and preliminary risk allocation

Before major project-development expenditure is committed, the parties should agree who funds the next stage of work, who owns the outputs, and how early development costs are treated if the project does not proceed. This is particularly important for FEED, but the same principle applies to site studies, permitting work, certification preparation, legal structuring, and commercial negotiations. The parties should also set out a preliminary allocation of risks across the AtJ facility, ethanol supply, feedstock procurement, site access, utilities, offtake, and permitting. This does not need to be the final FID risk allocation, but it should be clear enough to justify continued project-development spend.

Timeline: Months 15–18 / Q2 2028

Lead: Prospective SAF developer

Key stakeholders: Prospective ethanol producers, equity investors, lenders, concessionary finance institutions

2.D Confirm technology access and procurement approach

Technology providers should be engaged through a structured process before and during detailed project definition. Procurement should prioritise proven AtJ and 2G ethanol providers where possible. The process should also confirm feedstock testing needs, performance assumptions, commissioning requirements, technology guarantees, and local training.

Timeline: Months 15–27 / Q2 2028–Q1 2029

Lead: Prospective SAF developer

Key stakeholders: AtJ technology provider, 2G ethanol technology provider, EPC contractor

2.E Confirm preferred site pathway and utility basis

The project should confirm the preferred Tema site pathway and utility basis early enough to inform engineering. This should include land access, power and gas connections, water and wastewater arrangements, hydrogen production requirements, and the route to storage, blending, testing, and terminal access. Full contracts may come later, but the project should not proceed without a credible site and utility basis.

Timeline: Months 15–21 / Q2–Q3 2028

Lead: Prospective SAF developer

Key stakeholders: Ghana Free Zones Authority, Tema site owner, utility providers, fuel infrastructure partners

2.F Undertake FEED and update the project cost estimate

Full FEED should begin once the Phase 1 evidence is sufficient and the early Phase 2 structuring decisions are in place. It should refine the AtJ facility design, cost estimate, utility needs, site layout, storage requirements, safety systems, and interfaces with ethanol supply and downstream fuel logistics. This should give the project a stronger basis for financing, permitting, EPC procurement, and FID.

Timeline: Months 15–27 / Q2 2028–Q1 2029

Lead: Prospective SAF developer

Key stakeholders: AtJ technology provider, EPC contractor, prospective ethanol producer, fuel infrastructure partners

2.G Develop the certification and LCA plan

A project-specific LCA should be developed alongside a certification plan covering the full chain from maize stover collection through to final fuel claims. This should be tested with certification schemes and target buyers before offtake agreements are finalised.

Timeline: Months 15–27 / Q2 2028–Q1 2029

Lead: Prospective SAF developer

Key stakeholders: Certification scheme, LCA advisor, feedstock collectors, prospective ethanol producer, fuel supplier, target offtaker

2.H Prepare preliminary commercial term sheets

Preliminary term sheets should be prepared for the main commercial agreements, including SAF offtake, ethanol supply, terminal access, and book-and-claim where relevant. These should focus on the terms that affect bankability, especially pricing, contract length, sustainability requirements, and allocation of delivery risk. They should also consider whether policy support or lower carbon intensity could reduce the effective price gap for buyers.

Timeline: Months 18–27 / Q3 2028–Q1 2029

Lead: Prospective SAF developer

Key stakeholders: Airlines, fuel suppliers, airports, fuel terminal operators, lenders

Phase 2 summary and KPIs:

By the end of Phase 2, the project should have moved from feasibility-level definition to a FEED-supported project concept.

Key indicators for staying on track include:

- Preferred project and contracting structure agreed by Q2 2028.
- Development funding responsibilities and preliminary risk allocation agreed by Q2 2028.
- Ownership model selected or narrowed by Q3 2028.

- Preferred site and utility basis confirmed by Q3 2028.
- Technology-provider shortlist prepared by Q4 2028.
- FEED completed or substantially completed by Q1 2029.
- Certification and LCA plan prepared by Q1 2029.
- Preliminary SAF offtake and ethanol supply term sheets prepared by Q1 2029.

5.1.3 Phase 3: Investment readiness and FID preparation

Objective: Prepare the project for FID by confirming financing, approvals, contracts, and implementation responsibilities.

This phase should begin while project definition is underway, not after it is complete. The aim is to ensure that financing, permitting, offtake, and partner responsibilities are sufficiently mature for a Q4 2029 FID decision.

3.A Develop a financing strategy for both the AtJ facility and ethanol platform

Financing should cover the AtJ facility and upstream 2G ethanol production, even if they are financed separately. The AtJ facility has modelled CAPEX of USD 450 million, while ethanol production would require additional investment outside the AtJ CAPEX boundary.

Timeline: Months 18–30 / Q3 2028–Q2 2029

Lead: Prospective SAF developer

Key stakeholders: Prospective ethanol producers, potential lenders

3.B Engage potential financial institutions

Financing discussions should focus on institutions that can provide concessional debt, blended finance, guarantees, or infrastructure capital. The most relevant candidates include MDBs, DFIs, climate funds, infrastructure funds, export-credit providers, commercial lenders, strategic investors, and equity investors.

Timeline: Months 15–30 / Q2 2028–Q2 2029

Lead: Prospective SAF developer

Key stakeholders: Ministry of Finance, potential lenders, concessionary finance institutions, equity investors

3.C Advance SAF offtake and ethanol supply agreements

SAF offtake agreements and ethanol supply agreements should move from preliminary terms towards bankable agreements. The most important issues to settle are volume commitments, pricing structure, sustainability requirements, delivery obligations, and remedies if either party underperforms.

Timeline: Months 18–33 / Q3 2028–Q3 2029

Lead: Prospective SAF developer

Key stakeholders: Airlines, fuel suppliers, prospective ethanol producers, lenders

3.D Prepare finance application materials

Finance preparation should include the core materials lenders and investors need to assess the project. This should include FEED outputs or updated cost estimates, feedstock assessment, 2G ethanol feasibility assessment, site concept, project-specific LCA, offtake strategy, permitting roadmap, risk register, proposed capital structure, and evidence of government support or policy alignment.

Timeline: Months 24–33 / Q1–Q3 2029

Lead: Prospective SAF developer

Key stakeholders: LCA advisor, SAF coordination committee, potential offtakers

3.E Develop and implement the permitting roadmap

The permitting roadmap should be developed before or at the start of detailed engineering, with key approval processes beginning during project definition where possible. It should cover the AtJ facility, ethanol production sites, feedstock aggregation locations, storage, blending, and downstream logistics. The purpose is to confirm the approvals required, the order in which they need to be obtained, and which approvals must be sufficiently advanced before FID.

Timeline: Months 15–42 / Q2 2028–Q2 2030

Lead: Prospective SAF developer

Key stakeholders: EPA, NPA, relevant local planning authority, fuel terminal operators

3.F Reduce exposure to high commercial financing costs

The project should maximise concessional debt and blended finance where available, while exploring guarantees, export-credit support, local-currency financing where feasible, and revenue structures that reduce currency and interest-rate exposure.

Timeline: Months 18–33 / Q3 2028–Q3 2029

Lead: Prospective SAF developer / financial advisor

Key stakeholders: Potential lenders, concessionary finance institutions, offtakers, commercial lenders

3.G Finalise implementation responsibilities and FID package

Before FID, the project should confirm the lead developer, public-sector coordination role, ethanol suppliers, technology providers, EPC route, offtakers, terminal partners, financiers, certification bodies, and permitting responsibilities. By this stage, the equity position should already have been resolved, or supported by a credible funding plan, so that unresolved equity does not delay the FID package. The final FID package should bring these elements together with the FEED outputs, financing plan, offtake position, permitting status, and project governance structure.

Timeline: Months 30–36 / Q3–Q4 2029

Lead: Prospective SAF developer

Key stakeholders: SAF coordination committee, prospective ethanol producers, technology providers, EPC contractor, offtakers, financiers

Phase 3 summary and KPIs:

By the end of Phase 3, the project should have the materials, agreements, and approvals pathway needed to support an FID decision.

Key indicators for staying on track include:

- Initial lender engagement completed by Q3 2028, with preferred financing routes narrowed during 2029.
- Financing strategy agreed by Q1 2029, with further refinement through Q2 2029 as FEED outputs and offtake terms mature.
- Equity commitments or a credible equity funding plan confirmed by Q1 2029, before FEED is completed.
- Permitting roadmap active by Q2 2028, with key approvals sufficiently advanced by FID and remaining approval processes progressing through Q1/Q2 2030.
- SAF offtake and ethanol supply agreements advanced during 2029.
- Finance application materials prepared by Q2–Q3 2029.
- Implementation responsibilities and FID package prepared by Q4 2029.

- FID targeted for Q4 2029, subject to finance, offtake, permitting, ethanol supply, and partner commitments being sufficiently mature.

Actions after FID would include equipment procurement, detailed design, construction, commissioning, and ramp-up. These activities are not treated as separate recommendations in this chapter because the immediate priority is to resolve the pre-FID issues that determine whether the project can become investable.

5.2 Indicative project partner structure

The selected business case is best treated as a coordinated value-chain project rather than a single integrated asset. A fully integrated project, covering feedstock collection, 2G ethanol production, AtJ conversion, storage, blending, and marketing, could provide control over the full supply chain, but it would also concentrate a large amount of capital and delivery risk in one entity. A more practical structure is likely to be a private-led AtJ project company, supported by public-sector coordination and linked contractually to upstream ethanol producers and downstream fuel infrastructure partners.

Under this structure, the AtJ facility would be developed by a project company or SPV. The upstream 2G ethanol platform could be developed by one or more separate ethanol producers, with long-term supply agreements used to link ethanol production to the AtJ facility. This would allow the AtJ facility and ethanol assets to be financed separately while still aligning commissioning timelines, sustainability documentation, product specifications, and commercial incentives.

Public-sector involvement would still be important, but it does not necessarily require public ownership of the project. Government's role would be strongest where it can reduce coordination risk, clarify policy and fiscal treatment, support permitting alignment, and help connect the project with concessional finance or climate finance. If a PPP structure is used, it should be limited to areas where public participation adds clear value, such as land access, infrastructure interfaces, viability gap support, or coordinated permitting. If those needs can be addressed through enabling support rather than formal public ownership, a private SPV or joint venture may be simpler.

The table below sets out an indicative division of roles. This should be refined during Phase 2 once prospective developers and partners are identified.

Table 56 Indicative stakeholder roles

Stakeholder group	Indicative role in project development
Government and regulators	Provide policy direction, coordinate the SAF committee, clarify certification, tax, Free Zone, and export treatment, and support permitting alignment. Government would also link the project to Ghana's aviation decarbonisation planning and ICAO-related reporting where relevant.
Prospective SAF developer / AtJ project company	Lead development of the AtJ facility, commission feasibility and FEED work, procure technology, coordinate financing, negotiate offtake, and manage integration with ethanol supply and fuel logistics.
2G ethanol producers	Develop and finance ethanol production assets, procure sustainable biomass, operate ethanol facilities, meet ethanol quality requirements, and provide sustainability documentation to the AtJ project company.
Feedstock aggregators and maize producers	Supply maize stover and other eligible residues, support aggregation and quality control, participate in collection pilots, and comply with residue removal and sustainability requirements.

Stakeholder group	Indicative role in project development
Technology providers and EPC contractors	Provide process design, technology licensing, equipment supply, FEED support, construction, commissioning, performance support, and training.
Fuel infrastructure partners	Provide or support access to storage, blending, testing, terminal infrastructure, and onward delivery to domestic or export markets.
Offtakers	Provide long-term SAF purchase commitments, define sustainability and documentation requirements, and participate in physical uplift or book-and-claim arrangements where relevant.
Financial institutions	Provide concessional debt, commercial debt, equity, guarantees, export-credit support, or climate finance. Their role should be tested early so that financing assumptions are reflected in project structure and offtake negotiations.

This structure would keep delivery primarily private-sector led while recognising that a first SAF project in Ghana will still require active coordination across government, regulators, fuel infrastructure owners, financiers, and project developers. The main structuring decision is therefore how risks, costs, and delivery responsibilities are allocated across the value chain, rather than whether the project is simply public or private.

5.3 Moving from recommendations to investment readiness

The recommendations above should be treated as the workplan for moving from the current BIS stage towards investment readiness. The sequence is structured around three decision points. Phase 1 should confirm whether the selected pathway is credible enough to justify detailed project definition. Phase 2 should convert the pathway into a defined project, supported by FEED outputs, site and utility assumptions, technology engagement, and preliminary commercial terms. Phase 3 should then bring together the financing, offtake, permitting, equity, and implementation package needed to support FID.

This sequencing is important because the AtJ business case depends on the parallel development of maize stover collection, 2G ethanol production, ethanol transport, AtJ conversion, fuel logistics, certification, and bankable demand. Progress in one part of the value chain will not be sufficient if the other elements are not developed at the same pace. The main purpose of the action plan is therefore to ensure that technical definition, commercial structuring, financing, permitting, and partner responsibilities move forward together rather than sequentially.

Under the indicative timeline, feasibility and validation work would be completed by Q1 2028, FEED would run from Q2 2028 to Q1 2029, and FID would be targeted for Q4 2029. To meet this timeline, lender and equity engagement, offtake discussions, permitting, certification planning, and ethanol supply structuring would need to begin before FEED is complete. In particular, unresolved equity commitments, unclear ethanol supply arrangements, or delayed permitting could prevent the project from moving from technical definition into an investable FID package.

If FID is reached in Q4 2029, post-FID activities would include equipment procurement, detailed design, construction, commissioning, and ramp-up through the early 2030s. First commercial SAF production could begin around 2034, subject to successful commissioning and the availability of domestic 2G ethanol supply. The upstream ethanol platform would therefore need to follow a parallel development path so that ethanol production is available before, or at least during, AtJ facility ramp-up.

Appendix A: Stakeholder Engagements

As part of this business implementation study, an in-person workshop was held in Accra, Ghana on 24–25 February. During the workshop, preliminary results were presented and discussed with a wide range of stakeholders spanning government, the private sector, research institutions, and international organisations. A survey was also sent to stakeholders following the workshop. A second in-person engagement was held on 9 June, in which the final results of the study were presented to stakeholders. The table below presents a number of the invited organisations and their organisation type.

Organisation name	Organisation type
Africa World Airlines (AWA)	Airline
BOST Energies	Energy infrastructure
Circular Bioeconomy Hub / International Water Management Institute (CBEH-IWMI)	Research institution
Council for Scientific and Industrial Research (CSIR)	Research institution
F&B Bio Recyclage	SAF Producer
EcoLinks	Renewable energy developer
Environmental Protection Authority (EPA)	Government
Ghana Airports Company Limited (GACL)	Airport operator
Ghana Civil Aviation Authority (GCAA)	Government
GOIL PLC	Fuel supplier
Gulf Chemical Company Limited (GCCL)	Ethanol logistics
International Civil Aviation Organization (ICAO)	International organisation
Joint User Hydrant Installation – TotalEnergies (JUHI-Total)	Fuel infrastructure / supplier
Koforidua Technical University	Academic institution
Ministry of Energy and Green Transition (MoEnGT)	Government
Ministry of Transport (MoT)	Government
Petroleum Hub Development Corporation (PHDC)	Government
Puma Energy	Fuel supplier
SO Energy	Fuel supplier
Tema Oil Refinery (TOR)	Fuel producer
Zoomlion	Waste management

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Yasar Yetiskin
Senior Sustainable Aviation Manager
yasar.yetiskin@icf.com

Mark Penshorn
Director, Fuels Engineering
mark.penshorn@icf.com

Aron Bell, PhD
Sustainable Aviation Consultant

Andre J Couture
Aviation Consultant

Kelly Gibson
Senior Sustainable Aviation Consultant

Erick Schutte, PhD
Catalysis Expert

Jessica Lyons
Technical Advisory Consultant

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