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BUSINESS IMPLEMENTATION STUDY ON THE USE OF SUSTAINABLE AVIATION FUELS

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FOREWORD

In June 2022, on the 50th anniversary of the Stockholm Convention, the International Civil Aviation Organisation (ICAO) launched the Assistance, Capacity Building, and Training for Sustainable Aviation Fuels (ACT-SAF) program to aid developing states in their transition to cleaner aviation energy.

Later in 2022, the 41st ICAO Assembly adopted a long-term global aspirational goal (LTAG) for international civil aviation: collectively targeting net-zero carbon emissions by 2050, as a contribution to global climate action in line with the objectives of the UNFCCC Paris Agreement. The ICAO Assembly, through Resolution A41-21, emphasized the need for targeted support to developing states, including enhanced access to financial resources, technology transfer, and capacity-building initiatives.

With the adoption at the 3rd ICAO Conference on Aviation Alternative Fuels (CAAF/3) in November 2023 of the ICAO Global Framework for Sustainable Aviation Fuels (SAF), Lower Carbon Aviation Fuels (LCAF) and other Aviation Cleaner Energies, ICAO and its Member States have agreed to strive to achieve a collective global aspirational Vision to reduce CO_2 emissions in international aviation by 5 per cent by 2030 through the use of SAF, LCAF and other aviation cleaner energies (compared to zero cleaner energy use).

The Vision has four building blocks, the third of which is implementation support. It expresses the importance of support for developing countries and states with particular needs, to be addressed through the ACT-SAF programme. This should be a robust and substantial capacity-building and implementation support programme designed to assist states, to foster partnerships and collaboration on SAF initiatives under ICAO's coordination and to serve as a global platform for knowledge exchange. In Resolution A42-21, the 42nd ICAO Assembly resolves to achieve this Vision and requests the ICAO Council to continue to implement the ACTSAF Programme to support the global scale-up in development and deployment of SAF, LCAF and other aviation cleaner energies.

In 2022, the Netherlands made a voluntary financial contribution to the ICAO Environment Fund to fund three feasibility studies. In 2023, an additional contribution was made, intended to support a business implementation study in Kenya, which had previously received a feasibility study funded by the EU in 2018. This business implementation study focuses on the technical assessment and techno-economic analysis of repurposing the Kenya Petroleum Refinery located in Mombasa for SAF production. Due to this specific scope, the structure deviates partially from *the ICAO Template for Business Implementation Reports on Sustainable Aviation Fuels* (Version 1, July 2024) while adhering to its principles.[1]

[1] www.icao.int/ACT-SAF

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This study is therefore considered a joint effort, and we extend our sincere gratitude to all who contributed to its success. *Asante Sana!*

EXECUTIVE SUMMARY

KEY FINDINGS

Kenya is well-positioned to become a regional hub for the production of sustainable aviation fuels (SAF), capitalizing on its strategic location, diverse feedstock potential and capacity to scale renewable energy resources. Building on the findings of a preceding SAF feasibility study (ICAO, 2018), this report provides techno-economic insights, identifies project risks, and outlines business implementation recommendations to support successful SAF deployment in Kenya. This study evaluates the readiness for SAF development and analyzes two main production pathways: Hydroprocessed Esters and Fatty Acids (HEFA) and Power-to-Liquid (PtL). It further assesses opportunities and challenges, financing options, project risks, and the need for a SAF roadmap and policies required to enable and fast-track market adoption. Overall, the findings highlight the strong potential for HEFA-based SAF production in Kenya, with detailed results, challenges to be overcome, and recommendations presented throughout this report.

READINESS AND RESOURCES TO SUPPORT SAF DEVELOPMENT IN KENYA

Kenya currently imports approximately 1.2 million m³ of jet fuel annually, which is distributed from the port of Mombasa through an existing pipeline network that serves not only the domestic market but also the broader East African region, including Uganda, South Sudan, the Democratic Republic of Congo (DRC), Rwanda, and Burundi. Of this volume, around 926 000 m³ is allocated for domestic consumption.

In alignment with the international aviation climate vision to achieve a 5% GHG emission reduction target by 2030, as outlined under the CAAF/3 (Third Conference on Aviation and Alternative Fuels) framework, discussions are underway regarding the integration of SAF/LCAF and other cleaner energy sources in aviation. To advance this agenda, the *Kenya SAF National Steering Committee on the Acceleration of Development and Deployment of Sustainable Aviation Fuels* was established to fast-track this agenda. The committee fosters coordination among key stakeholders, aiming to accelerate policy formulation, infrastructure development, and market readiness for SAF adoption. Notably, Kenya Airways conducted its first SAF-powered flight in 2023 between Nairobi and Amsterdam, demonstrating the nation's growing commitment and interest in this emerging field.

With a renewable energy share exceeding 90%, Kenya is increasingly attracting attention for potential projects in green hydrogen and green ammonia production. This strong renewable energy base also provides a competitive advantage in pursuing low-carbon SAF production. The country benefits from a diverse range of potential feedstocks that can be cultivated on marginal lands, thereby minimizing competition with food crops. Promising options include croton, castor, cottonseed, Brassica carinata, yellow oleander and jatropha (subject to local feasibility), which can be produced domestically or sourced via regional partnerships. Moreover, used cooking oil represents an immediately available and sustainable feedstock for SAF production. Ongoing initiatives, such as the early development of feedstock supply chains through projects like the Eni Agri-hub and the Bleriot SAF aspiration, show promising potential for the biofuel sector. Although considerable potential exists, the current feedstock supply chain and availability are insufficient to support a commercial-scale plant, making substantial development and reinforcement of these systems necessary.

These initiatives and resources can potentially position Kenya to establish a resilient SAF ecosystem, which can cover national aspirations and potentially create a hub for East Africa. However, despite significant progress, considerable efforts are still needed, particularly to develop adequate feedstock volumes, mobilize capital for investments in infrastructure, and establish effective SAF policies to ensure the viability and efficiency of biorefineries.

TECHNICAL ASSESSMENT OF THE MOMBASA REFINERY

The decommissioned Kenya Petroleum Refinery in Mombasa presents an opportunity for conversion into a SAF production facility, leveraging its strategic coastal location with direct access to the harbour for both loading and offloading and connection with the KPC pipeline, rail, road networks, and nearby airports. Since the KPC pipeline is restricted to petroleum products, SAF blended and requalified as Jet A-1 could be distributed through the existing system, minimizing reliance on rail and road transport except for special deliveries (e.g., remote airports). Feedstock, however, cannot be conveyed through the multiproduct pipeline; instead, decommissioned or dedicated pipelines may be repurposed for this purpose, provided the feedstock's fluid dynamic properties are compatible. Rail and tanker truck transport will remain important due to the dispersed distribution of feedstock across the country, while maritime transport will play a key role in the potential import of feedstock and export of SAF. In the refinery, the large tank farm (and its potential for expansion), operational pump stations, and existing pipelines offer significant logistical and cost advantages compared to a greenfield development.

However, the refinery's processing units were built in the 1960s and have been inactive for over a decade, showing extensive corrosion and structural degradation. Most existing units, including hydrotreaters, are not suitable for reuse, with only a few components potentially salvageable after further detailed assessment. To ensure technological reliability and operational flexibility, constructing a new HEFA unit is likely the preferred option. Additional infrastructure, such as hydrogen production, feedstock pretreatment, acid gas treatment, and sulphur recovery systems, would be required (Figure S1).

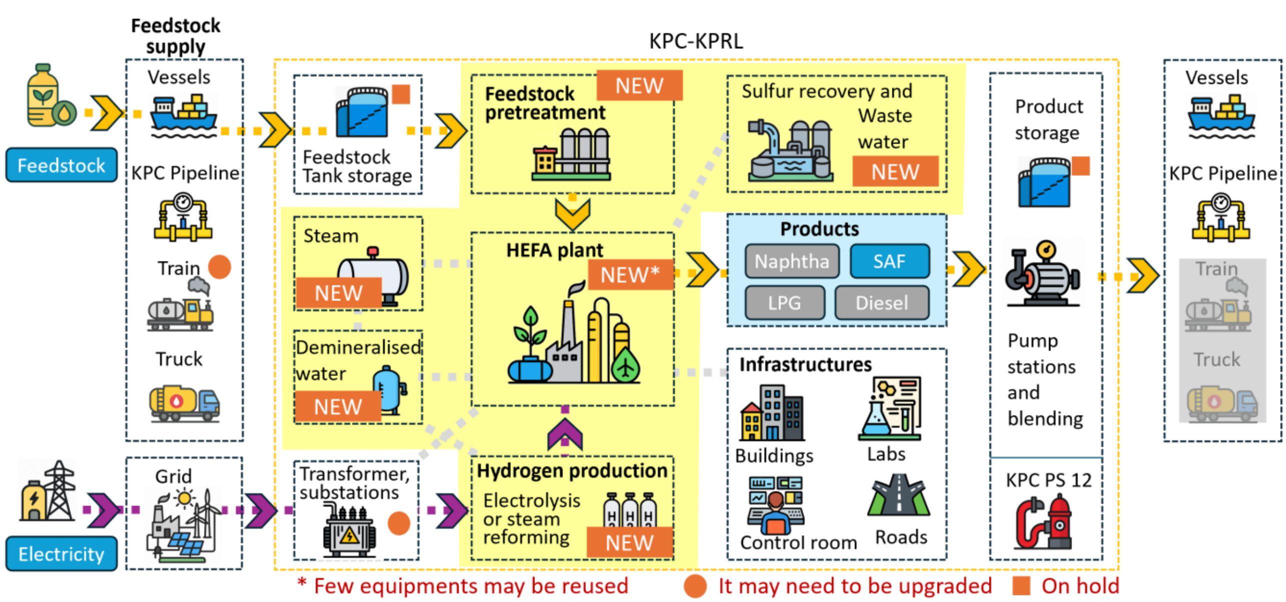

Figure S1. Overview of the refinery assessment and the new units to be installed (see SECTION 2).

Despite the majority of the refinery assets being no longer usable, the site continues to offer advantages over a greenfield development: it is already zoned for industrial use, which may expedite the permitting process, and it benefits from established distribution and logistics infrastructures. A comprehensive engineering feasibility study will be needed to refine the project scope, assess costs, and evaluate feedstock supply and supporting infrastructure.

TECHNO-ECONOMIC ASSESSMENT OF THE HEFA PATHWAY FOR SAF PRODUCTION

This study proposes the development of a HEFA-based SAF production facility with a capacity of 255 000 t/year of feedstock input, enabling flexible production of both SAF and HVO diesel based on market dynamics (Figure S2). Diesel yields in a maximised HVO diesel scenario are generally higher than the SAF yields obtained in a maximised SAF scenario. Internal estimates suggest an approximate production of up to 215 000 t/year of diesel or 180 000 t/year of SAF. These figures depend on the feedstock mix and should be validated against technology provider data in the next phase, as well as considering losses due to pretreatment. Under optimal conditions, SAF production could supply up to 25% of current national jet fuel consumption, although this share may decrease depending on the operational mode defining the product slate and the projected year of operation (aviation growth is projected at an annual rate of 5%).

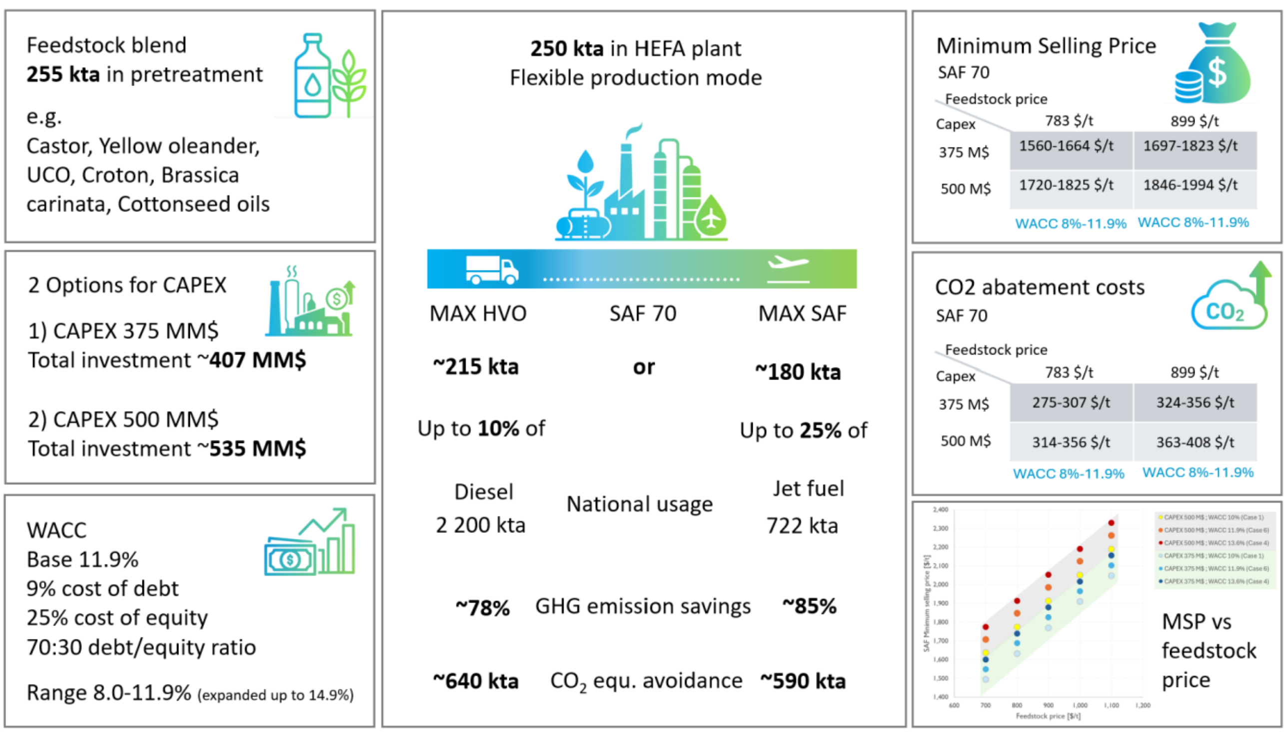

Figure S2. Preliminary estimation derived from the techno-economic analysis of a HEFA plant in the Mombasa refinery for the examples presented in (see SECTION 3). kta stands for thousand t/year.

To account for the uncertainty of the CAPEX estimates at this stage of the study and verify its sensitivity to the SAF price, we consider two scenarios: (i) a lower-CAPEX case, representing optimistic assumptions with a certain degree of integration and a potential favourable regional cost factor; and (ii) a higher-CAPEX case, reflecting a more conservative approach. In this study, we adopted a lower bound CAPEX of USD 375 million (with a total investment of USD 407 million) and an upper bound CAPEX of USD 500 million (with a total investment of USD 535 million), based on AACE Class V estimation. Given the early stage of development, these figures remain preliminary and subject to further refinement.

The analysis considered multiple feedstock options, with a focus on locally available and regionally accessible resources, including castor, yellow oleander, croton, used cooking oil, jatropha, Brassica carinata, cottonseed, canola, and coconut. Among the critical success factors, feedstock price and availability are paramount, as they may account for over 60% of SAF production costs and therefore exert significant influence on project viability and economic competitiveness. Feedstock sustainability is equally crucial, since greenhouse gas (GHG) emissions generated during cultivation, harvesting, and transportation directly affect the overall life-cycle emissions of SAF. Based on these three criteria, most of the analyzed feedstocks are technically viable; however, canola and conventional (edible-grade) coconut oil may be avoided due to their higher risk of food-fuel competition, limited sustainability, and less favourable economic profile resulting from premium market prices. Their utilization remains feasible only provided that these limitations are overcome. Jatropha may be among the most promising feedstocks due to its low cost; however, its cultivation feasibility in Kenya should be carefully assessed to avoid repeating the challenges experienced during the biodiesel initiatives of the early 2000–2010 period. Moreover, alternative feedstocks that meet sustainability criteria and demonstrate cost-competitiveness and availability can also be considered.

Feedstock selection is not merely a logistical consideration; it is a core technical and environmental decision that shapes the entire SAF value chain. Defining the feedstock mix early in the project is essential to have time to secure CORSIA eligibility (if not already granted), develop supply chains, assess cost viability, and optimize plant design with technology providers. Feedstocks such as castor, yellow oleander, croton, and cottonseed oil are not yet explicitly referenced in CORSIA, but applications can be submitted to ICAO for their inclusion in the CORSIA framework. The possibility of using such feedstocks without going through the ICAO evaluation process (e.g., use of CORSIA actual life cycle emissions calculations and low LUC risk practices for feedstock production) should also be considered. Feedstock development should be aligned with the company's strategy to target specific markets (e.g., CORSIA, EU, UK, US, or other regional schemes), since each market has specific regulations regarding feedstock eligibility and minimum GHG emission savings. According to a survey conducted in this study, sufficient feedstock is not yet readily available for biofuel production in Kenya; however, the establishment of a dedicated supply chain appears feasible. A relevant reference is the Agri-Hub model developed by Eni, which promotes feedstocks with low LUC risk. Further studies are required to advance the development of such supply chains and feedstock logistics (whether at the national or regional level), along with clearer insights into current and projected prices for both feedstocks and SAF. Strategically employing a few feedstocks (e.g., 4-6) can mitigate reliance on any single source, thereby stabilizing supply and reducing exposure to price volatility. At the same time, potential technical constraints of the plant's processing capacity should be taken into account. Although the chemical composition of the vegetable oils, waste fats, oils and grease impacts pretreatment requirements, it has only a minor influence compared to the feedstock price on the overall cost of SAF production.

Various hydrogen production technologies were evaluated. Steam reforming of off-gases, LPG, and naphtha (co- and by-products of the process) offers the highest level of plant self-sufficiency, ensuring the lowest dependency on external sources and higher GHG emission savings.

Among the processing modes, MAX HVO achieves the lowest production costs but yields relatively little SAF, whereas MAX SAF maximizes SAF output but also generates large volumes of naphtha and LPG, reducing distillate yield and raising unit costs. Yield estimates were calculated in-house and may differ from figures provided by technology suppliers, who should be consulted in the next project phase. Due to missing data, GHG emissions were assumed to align with low LUC feedstocks. In MAX HVO mode, production reaches ~215 000 t/year (~10% of national diesel demand), with ~78% GHG savings and ~640 000 t/year CO_2 avoidance. In MAX SAF mode, output is ~180 000 t/year (~25% of national jet fuel volume demand), with ~85% GHG savings and ~590 000 t/year CO_2 avoidance. SAF70 (70% conversion of the diesel fraction in the hydrocracking to SAF) represents an intermediate, flexible configuration with balanced yield and cost. In practice, the plant is expected to operate flexibly among the three modes depending on market demand between SAF and HVO diesel and relative prices. Maximum profitability from SAF production is achieved when its selling price exceeds 1.2 times that of HVO diesel. SAF and HVO prices are interrelated, and a fall in HVO prices could theoretically raise SAF prices.

At this early stage, determining the exact Weighted Average Cost of Capital (WACC) remains challenging due to the variety of financing options available. A base case WACC of 11.9% (real terms after taxes) is assumed, based on a 9% cost of debt (potentially achievable through international development banks) and a 25% cost of equity (minimum required equity IRR). Alternative scenarios with higher and lower WACC values were also assessed, including a concessional loan case at 8% WACC, which represents an optimistic scenario with potentially the best conditions achievable. The WACC needs to be refined with discussions with potential lenders during and after the engineering feasibility study, at which stage CAPEX estimates can be determined with greater accuracy and the business case should be better defined. In general, plants in Africa tend to face higher WACC levels compared to those in developed countries. This should be carefully assessed to evaluate its impact on market competitiveness.

The minimum selling price (MSP) of SAF for an HEFA plant in Kenya will be primarily determined by factors such as feedstock price, operational configuration, capital expenditure, and financing conditions. Feedstock costs, typically accounting for more than 60% of production costs, primarily influence the SAF minimum selling price (MSP). CAPEX plays a smaller role in MSP determination but remains critical in financing, as excessively high investment requirements may be difficult to secure. WACC influences overall costs and scales proportionally with CAPEX; therefore, the two should be evaluated together. While a high WACC may be manageable with low CAPEX, it becomes less tolerable in high-CAPEX scenarios. It is important to recognize that elevated WACC values can significantly undermine project viability, as excessively high financing costs may render an otherwise technically feasible project economically uncompetitive.

For single feedstocks, the minimum selling price without incentives generally remained below 2 000 USD/t, except in the case of wholesale pricing combined with a higher WACC and higher CAPEX, where it rose but remained under 2 250 USD/t. The study provided an example for a defined feedstock mix, which constitutes equal shares of castor, yellow oleander, croton, Brassica carinata, cottonseed, and used cooking oil. The minimum selling price was calculated using the SAF 70 operational mode and under the assumption of fiscal incentives, including a reduced corporate tax rate (15% for the first 10 years and 20% for the subsequent 10 years for starting businesses according to Finance Bill 2025) and accelerated depreciation (maximum reduction effect of both 50-90 USD/t). Two pricing benchmarks were applied: (i) a consortium-sourced feedstock price, treated as a lower-bound scenario since prices below this level would not realistically cover cultivation, harvesting, and pre-processing costs; and (ii) the average wholesale feedstock price. This preliminary analysis indicates that for a WACC of 8-11.9% and with a consortium-source feedstock price at 783 USD/t, MSP ranges from 1 560–1 664 USD/t for USD 375 million CAPEX to 1 720–1 825 USD/t for USD 500 million CAPEX (Figure S2). At an average wholesale price of 899 USD/t, MSP increases to 1 697–1 823 USD/t (USD 375 million CAPEX) and 1 846–1 994 USD/t (USD 500 million CAPEX). When feedstock prices are around 1 000 USD/t in the high-CAPEX scenario, the MSP surpasses 2 000 USD/t, whereas for the low-CAPEX case it remains below this threshold. Feedstock prices can exhibit significant variability, necessitating the identification of appropriate de-risking mechanisms. Furthermore, while higher feedstock prices may not necessarily impede market development, a correspondingly greater willingness to pay must be ensured to maintain the viability of the business case. Securing this condition is therefore essential. SAF production at competitive prices within the SAF market is achievable under favourable conditions; while achieving full cost parity with conventional fossil jet fuel is unlikely through incentives alone (the effect of tax reduction was~44-65 USD/t and accelerated depreciation 7-24 USD/t price reduction). Mandates or other forms of policies should be implemented to support the market.

A SAF price of 2 000–2 250 USD/t is taken as a market reference for this study; however, prices have shown considerable volatility over the past two years, ranging from 1 750 to 2 800 USD/t for RED-compliant HEFA-SPK prices in Western Europe. In August 2025 this indicator averaged 2 372 USD/t. The SAF market remains relatively opaque, and bilateral agreements may have contract prices different from publicly reported levels. In future analyses, it is essential to account for price variability in both feedstocks and SAF, as well as to incorporate forecasts of potential volatility when developing the business case and designing appropriate de-risking measures. Feedstock prices may also rise sharply over time due to market demand; however, implementing consortium-based sourcing strategies can enhance price stability and reduce exposure to global market fluctuations. The SAF market should be carefully assessed, and SAF offtake agreements with indexed price formulas will help secure the business case. Feedstock prices require additional studies to better capture both current and future trends, including potential increases linked to global market dynamics.

The projected GHG emissions savings may range between 78% and 85% for low LUC feedstock (to be refined in further studies), consistent with CORSIA certification requirements. CO_2 abatement costs are estimated at 275–410 USD/t, with potential for further reductions through biogenic CO_2 capture from steam reforming.

Overall, the initial results from the techno-economic analysis suggest that SAF production in Mombasa could be priced competitively, or at least not far from prevailing SAF market levels. This suggests that further investigation is warranted, particularly to refine estimates for SAF prices, financing conditions, CAPEX, OPEX, and feedstock costs and logistics in relation to both current conditions and potential future developments, while considering market volatility.

TECHNO-ECONOMIC ASSESSMENT OF ALTERNATIVE PATHWAYS FOR SAF PRODUCTION

While the HEFA pathway currently offers the most practical and cost-effective solution, several alternative technologies have been assessed for possible deployment in the repurposing of the Kenya Petroleum Refinery in Mombasa.

Alcohol-to-Jet (AtJ) presents an interesting opportunity given Kenya's well-established sugarcane industry. However, as sugarcane production is largely concentrated in Western Kenya and around Kisumu, this pathway would be more viable if processing facilities were developed closer to the feedstock to avoid costly long-distance transport. AtJ has a lower technology readiness level compared to HEFA and is therefore considered more suitable for medium- to long-term deployment.

The conversion of Kenya's substantial waste streams into low-carbon fuels through gasification of municipal solid waste (MSW) or biomass presents significant potential. Nevertheless, the technology remains at a relatively low maturity level and carries higher operational and investment risks at this stage.

The Power-to-Methanol-to-Jet pathway offers flexibility through decentralized methanol production and alternative market options but remains at a low technology readiness level and currently lacks ASTM certification, making it a long-term opportunity.

Power-to-Liquids (PtL) through Fischer-Tropsch synthesis has attracted significant attention globally and could be relevant for Kenya in the longer term, especially given the country's high renewable power penetration and national initiatives around green hydrogen development. However, the pathway remains capital and energy-intensive. Current estimates suggest production costs of around 5 500 USD/t of SAF compared to below 2 000 USD/t for HEFA. A 200 000 t/year SAF PtL facility would require over USD 4 billion in total investment, including renewable power generation, direct air capture systems, and refinery integration, making it less feasible in the short term.

BUSINESS IMPLEMENTATION RECOMMENDATIONS

SAF production in Mombasa through repurposing Kenya Petroleum Refinery's site can be feasible and profitable, benefiting from its strategic location and existing infrastructure, though several factors must be carefully assessed and implemented for successful deployment. Beyond its environmental benefits, the project also offers significant socio-economic potential by creating jobs across the value chain, ranging from feedstock farming to refinery operations and construction activities, while also reducing reliance on fossil fuel imports and potentially stimulating economic growth through SAF exports. The proposed SAF project at the Mombasa refinery is currently in the concept phase and would require completion of feasibility studies, basic engineering design, and a final investment decision before construction. With immediate action, commercial operations could begin within five years, but achieving production before 2031 will require a lot of coordinated effort and alignment with various institutions.

As a first step, the company must establish a clear strategy that defines the SAF target market (Figure S3) and the indicative production split between SAF and diesel. The selected market (e.g., domestic, CORSIA, EU, US) will dictate the applicable feedstock eligibility requirements and minimum GHG emission savings thresholds. These considerations may, in turn, shape both the plant design and the development of the feedstock supply chain.

To realize the SAF opportunity and avoid project delays, several key challenges (common to most of HEFA projects) must be addressed in the next phase, requiring actions at both the company and government levels:

1. Sustainable feedstock security and SAF target market compliance

Project success will depend on securing sustainable feedstock at competitive prices. A comprehensive feedstock study is recommended to map cultivation potential, assess logistics and ensure compliance with international sustainability criteria. It is important to examine projections for the volatility of feedstock prices and the SAF market and evaluate their potential implications for the overall business case. To meet global market requirements, the project needs to consider sustainability frameworks, such as CORSIA (or others if other markets are targeted), and implement a robust methodology for life-cycle emissions accounting to ensure certification for CORSIA-eligible fuels. The success of existing agri-hub businesses in feedstock cultivation and processing needs to be highlighted, drawing on their experience for learning opportunities and exploring potential partnership agreements to support project implementation.

2. Securing long-term offtake agreements with airlines

Establishing long-term offtake agreements with airlines is essential to ensure market stability and project bankability. Such contracts provide predictable revenue streams and reduce investment risk, which is critical for attracting financing for capital-intensive SAF production facilities. In addition, binding offtake arrangements demonstrate a committed demand base, facilitating compliance with lenders' due diligence requirements and supporting the overall financial viability of the project. These agreements can also align with airlines' decarbonization strategies and regulatory mandates for SAF adoption. These agreements are characterised by a high upfront capital investment and a high level of financing complexity. Given the large scale of the proposed SAF project and its estimated USD 407–535 million total investments, defining an early financing structure and partnership framework will be critical to successful implementation. The recommended approach is to establish a Special Purpose Vehicle (SPV) to manage financial exposure and attract strategic partners. Partnering with experienced technology providers, feedstock suppliers, and investors with experience in the SAF market can derisk the project, improve access to favourable financing terms, and accelerate time-to-market. Integrating large agri-hubs within the consortium or securing long-term feedstock contracts will help stabilize costs and ensure supply security. Engaging airlines as potential minority investors can enhance project bankability and investor confidence through long-term offtake agreements. Given the scale of the project, a carefully designed financing structure, likely combining multiple instruments to reduce the debt interest rate, will be essential to ensure successful implementation. It is also advisable to reach out to agencies that can assist with financial structuring, such as the ICAO Finvest Hub. KPC's legal structure will significantly influence the types of funding the company can access.

3. Regulatory certainty to guarantee SAF market competitiveness against lower-priced fossil jet fuel

While Kenya's policy environment is evolving, a national SAF roadmap is still under development. Clear policies and regulations will be essential to bridge the cost gap with fossil jet fuel and encourage investment. The national SAF roadmap and the derived policy must provide clear targets, mandates, and/or incentives to attract investors and increase the willingness-to-pay for SAF compared to fossil jet fuel. Regulations in the renewable diesel field will be useful. Mandates or levies generally do not impose a fiscal burden on taxpayers, whereas incentives may, highlighting the need to establish an appropriate policy balance for the country. Aligning policies with international sustainability frameworks, such as CORSIA, would also facilitate integration between domestic, regional, and international markets. Incentivizing the sector is critical to achieving a balance between the adoption of SAF and the growth of air transport in the country and region.

Mitigation strategies include establishing long-term feedstock contracts, securing SAF offtake agreements with airlines, accessing concessional financing and green bonds, adopting risk-sharing partnership models, ensuring clear policy frameworks before the final investment decision, and aligning with international sustainability standards to unlock SAF market access.

At the company level, clear strategies are required for technology selection, feedstock sourcing, financing, potential partnerships and stakeholder engagement. The next steps should focus on defining the project scope and market positioning, as well as developing an internal roadmap outlining the necessary engineering studies, permitting requirements, and other pre-FID and pre-operations actions. Stakeholder engagement is central to project success, requiring active participation from farmers, feedstock aggregators, refiners, regulators, certification bodies, financiers, airlines, and local communities, ensuring broad alignment across the supply chain.

Kenya has the resource potential and basic infrastructure to develop a competitive SAF industry; however, substantial efforts are still required to build the supply chain, and further studies are needed to verify the existence of favourable conditions with respect to feedstock, financial terms, and total investment. Through support of the National Steering SAF Committee, coordinated action, clear policy frameworks, and sustained commitment, the country has the potential to become a regional leader in SAF production, fostering economic growth, job creation, and substantial emissions reductions in the aviation sector.

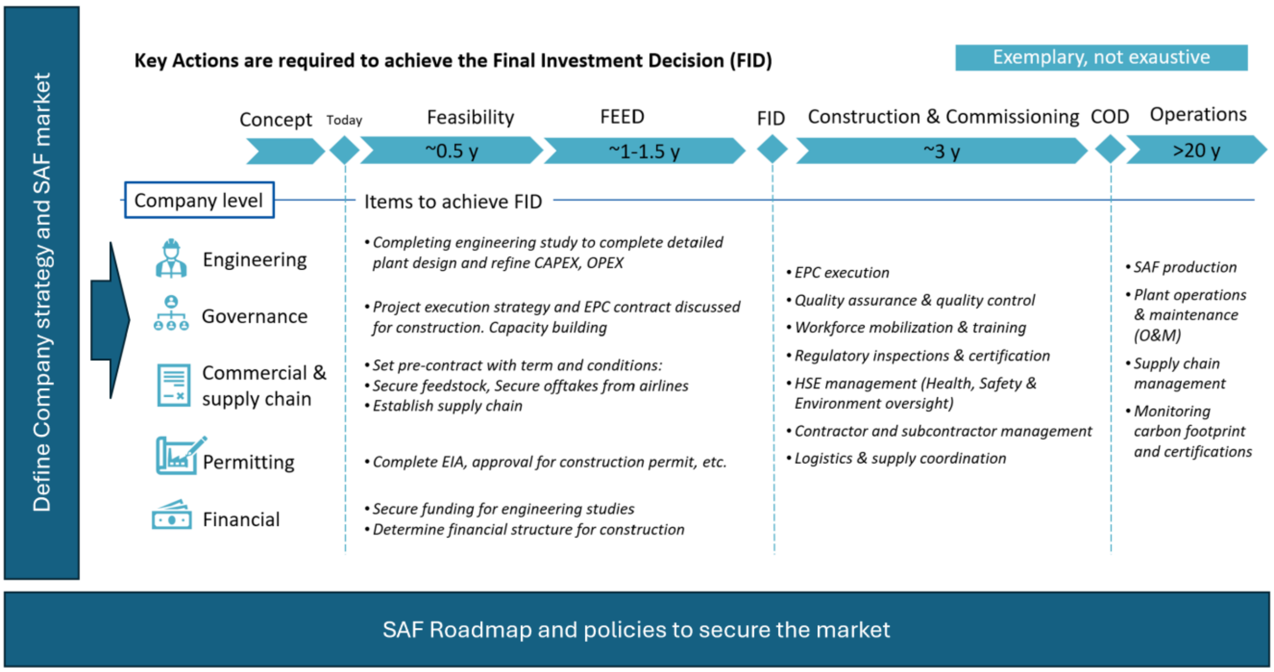

Figure S3. Definition of the company strategy and SAF market and roadmap at the company level, supported by policies to stabilize the market.

POLICY RECOMMENDATIONS

In developing a SAF roadmap and policies, it is essential to establish quantifiable targets and a clear implementation timeline across short- (0–5 years), medium- (5–10 years), and long-term (>10 years) horizons. Targets should be realistic and sustainable in order to effectively secure the market. Based on this study, MAX SAF production at the Mombasa refinery could supply approximately 25% of Kenya's 2024/2025 jet fuel demand, corresponding to a 21% reduction in total sectoral GHG emissions. By 2030, this would represent about 20% of jet fuel volume or roughly 17% of the GHG emission reductions. These figures should be interpreted with caution, as they are based on theoretical calculations and may vary depending on the technology provider, feedstock characteristics, and the refinery's market strategy (HVO diesel vs SAF).

Kenya may consider mandates, incentives, levies, or a combination thereof as key policy instruments to promote the deployment of SAF. While incentives can play an important role in accelerating SAF adoption, they alone cannot eliminate the green premium relative to fossil fuels; however, they can contribute to making SAF competitive within its own market. Mandates, levies or other forms should be applied to guarantee the market. Preferably, any fiscal incentives should be carefully targeted to ensure maximum effectiveness, time-bound, and explicitly linked to verified lifecycle GHG emissions performance to ensure environmental integrity and cost-effectiveness. If fiscal resources are limited or must be prioritized for other strategic sectors, incentives should be minimized. Similar concepts can be applied, such as the proposed incentives for green hydrogen projects in Kenya, such as tax reductions/holidays for specific years, duty and VAT exemptions, and investment deductions. In addition, the government can support more favourable debt conditions by providing loan guarantees or facilitating the issuance of green bonds and having access to other potential green finance tools. Streamlining permitting procedures can also help reduce administrative barriers and strengthen investor confidence.

Especially in contexts where fiscal space is constrained, establishing a SAF mandate or introducing a calibrated levy (and potentially putting higher taxation on fossil fuels and installing a carbon credit market) can help to stimulate the use of SAF over the conventional jet fuel. Moreover, if a SAF blending mandate is introduced, it should clearly define the obligated parties, e.g., whether compliance lies with fuel suppliers, airlines, or other actors within the aviation fuel value chain, ensuring regulatory clarity and effective implementation. Alternatively, a dedicated SAF levy on flights could be introduced to finance SAF procurement, with potential variations based on flight distance and SAF blending targets. As an example, for a USD 500 flight ticket, the additional cost of a 10% HEFA blend that could impact the ticket price is around USD 30 (~6%).

In addition, mechanisms such as book-and-claim systems can be considered when permitted, and participation in carbon markets and penalties or higher pricing for fossil jet fuels could help narrow the green premium by enhancing SAF's competitiveness. The policy framework should also include periodic reviews with robust measurement, reporting, and verification (MRV) protocols to track progress, adjust measures, and ensure alignment with evolving technological and market conditions.

Moreover, harmonizing SAF certifications and sustainability standards at the domestic, regional (East African Community, EAC), and international levels, while simplifying cross-border procedures for certified feedstocks and fuels, would significantly enhance supply chain efficiency. In addition, aligning national policies with international frameworks such as CORSIA would promote regulatory consistency, which is particularly important given that the majority of flights in Kenya are international.

Kenya can benefit by reviewing existing international policies and adapting them to develop a framework suited to its context. Regardless of the approach Kenya chooses to pursue, the policy must provide a clear and consistent signal to attract investment and ensure long-term market stability.

To drive the effective deployment of SAF, governments should set ambitious and achievable national targets while working closely with the private sector and international partners to ensure alignment. Such coordination is essential to avoid fragmented policy approaches, misaligned incentives, and risks such as feedstock diversion and price volatility, thereby ensuring that public resources are used efficiently and sustainably.

CONTENTS

ABBREVIATIONS AND ACRONYMS

AACE Association for the Advancement of Cost Engineering
ADF African Development Fund
AEL Alkaline Electrolyzer
AFA Agriculture and Food Authority (Kenya)
AfDB African Development Bank
AGO Automotive Gas Oil (diesel)
AI Artificial Intelligence
API American Petroleum Institute
ARA Applied Research Associates
ASAL Arid and Semi-Arid Lands (Kenya)
ASTM American Society for Testing and Materials
AtJ Alcohol-to-Jet
BLT Build–Lease–Transfer
BOD Biochemical Oxygen Demand
BOO Build–Own–Operate
BOOR Build–Own–Operate–Remove
BOT Build–Operate–Transfer
BP British Petroleum
CAAF/3 Third Conference on Aviation and Alternative Fuels
CAPEX Capital Expenditure
CBK Central Bank of Kenya
CBR Central Bank Rate (Kenya)
CCS Carbon Capture and Storage
CCU Carbon Capture and Utilization
CDB China Development Bank (likely)
CDU Crude Distillation Unit
CEF CORSIA-Eligible Fuel
COA Certificate of Analysis
COD Chemical Oxygen Demand
COQ Certificate of Quality
CORSIA Carbon Offsetting and Reduction Scheme for International Aviation
CUI Corrosion Under Insulation
DAC Direct Air Capture
DCMF Design-Construct-Manage-Finance
DCO Decarbonylation
DCO2 Decarboxylation
DCS Distributed Control System
DDB Double-Declining Balance (depreciation)
DEA Diethanolamine (for gas treating)
DFI Development Finance Institution
DPK Dual-purpose kerosene (household/jet)
DRC Democratic Republic of the Congo
EAC Energy Attribute Certificates
EAC East African Community,
EASA European Union Aviation Safety Agency
EBRD European Bank for Reconstruction and Development
EEMUA Engineering Equipment and Materials Users Association
EHS Environment, Health and Safety
EIA Environmental Impact Assessment
EMCA Environmental Management and Coordination Act
ENOC Emirates National Oil Company
EOPS Early Oil Pilot Scheme
EPC Engineering, Procurement, and Construction
EPCM Engineering, Procurement, and Construction Management
EPRA Energy and Petroleum Regulatory Authority (Kenya)
EPZ Export Processing Zone (Kenya)
ERP Enterprise Resource Planning
ESG Environmental, Social, and Governance
ETS Emissions Trading System (EU ETS)
EU European Union
EUR Euro (currency)
EURIBOR Euro Interbank Offered Rate
FAME Fatty Acid Methyl Esters (biodiesel)
FCI Fixed Capital Investment
FDP Field Development Plan
FEED Front-End Engineering Design
FEL Front-End Loading
FFA Free Fatty Acids
FFI Fortescue Future Industries
FID Final Investment Decision
FOAK First-of-a-Kind (for plants)
FOB Free On Board (incoterm)
FOG Fats, Oils and Grease
FT Fischer–Tropsch
GBP Pound Sterling (currency)
GHG Greenhouse Gas
GHI Global Horizontal Irradiance (solar)
GIS Geographic Information System
GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit
HDO Hydrodeoxygenation
HEFA Hydroprocessed Esters and Fatty Acids
HFO Heavy Fuel Oil
HGO Heavy Gas Oil
HP High Profit
HTHA High-Temperature Hydrogen Attack
HVAC Heating, Ventilation and Air Conditioning
HVO Hydrotreated Vegetable Oil (renewable diesel)
IATA International Air Transport Association
IBRD International Bank for Reconstruction and Development (World Bank)
ICAO International Civil Aviation Organization
ICBC Industrial and Commercial Bank of China
IDA International Development Association (World Bank Group)
IEA International Energy Agency
IFAD International Fund for Agricultural Development

IFC	International Finance Corporation
IFP	IFP Energies nouvelles (Institut Français du Pétrole)
ILUC	Indirect Land Use Change
IP	Innovation premium
IPO	Initial Public Offering
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ISBL	Inside Battery Limits (process plant)
ISCC	International Sustainability & Carbon Certification
ISO	International Organization for Standardization
JFTOT	Jet Fuel Thermal Oxidation Tester (ASTM D3241)
JIG	Joint Inspection Group (aviation fuel)
JPY	Japanese Yen
JV	Joint Venture
KAA	Kenya Airports Authority
KCAA	Kenya Civil Aviation Authority
KEBS	Kenya Bureau of Standards
KENAS	Kenya Accreditation Service
KES	Kenyan Shilling (currency)
KETRACO	Kenya Electricity Transmission Company
KOT	Kenya Oil Terminals (Mombasa)
KPC	Kenya Pipeline Company
KPI	Key Performance Indicator
KPLC	Kenya Power and Lighting Company
KPRL	Kenya Petroleum Refineries Limited
KRC	Kenya Railways Corporation
LAPSSET	Lamu Port–South Sudan–Ethiopia Transport Corridor
LCA	Life Cycle Assessment
LCAF	Lower Carbon Aviation Fuels
LCEF	Life-cycle Carbon Emissions of CORSIA-Eligible Fuels
LCOE	Levelized Cost of Electricity
LCOH	Levelized Cost of Hydrogen
LCOP	Levelized Cost of Production (e-fuels/chemicals)
LCPDP	Least Cost Power Development Plan (Kenya)
LT-LEDS	Long-Term Low Emission Development Strategy
LGO	Light Gas Oil
LHV	Lower Heating Value
LP	Low Profit
LPG	Liquefied Petroleum Gas
LROT	Lease-Renovate-Operate-Transfer
LTAG	Long-Term Aspirational Goal (ICAO net-zero 2050)
MEA	Monoethanolamine (for gas treating)
MGR	Metre Gauge System (railways)
MIC	Microbiologically Influenced Corrosion
MIGA	Multilateral Investment Guarantee Agency (World Bank Group)
MIOG	Morendat Institute of Oil and Gas
MMUST	Masinde Muliro University of Science & Technology
MRV	Measurement, Reporting, and Verification
MSP	Minimum Selling Price
MSW	Municipal Solid Waste
MTP4	Fourth Medium-Term Plan
MUFA	Monounsaturated Fatty Acids
MW	Molecular Weight
NCCAP	National Climate Change Action Plan (Kenya)
NDA	Non-Disclosure Agreement
NDC	Nationally Determined Contribution
NDT	Non-Destructive Testing
NEMA	National Environment Management Authority (Kenya)
NEXBTL	Neste Renewable Diesel/Jet brand (NExBTL)
NG	Natural Gas
NIFC	Nairobi International Financial Centre
NOOC	North Oil Company (Qatar)
NPV	Net Present Value
NREL	National Renewable Energy Laboratory (US)
NSE	Nairobi Securities Exchange
OMC	Oil Marketing Company (Kenya)
OMV	Österreichische Mineralölverwaltung (OMV Group)
OPEC	Organization of the Petroleum Exporting Countries
OSBL	Outside Battery Limits (process plant)
PLC	Programmable Logic Controller
PMS	Premium Motor Spirit (gasoline)
POME	Palm Oil Mill Effluent
PPA	Power Purchase Agreement
PPP	Public–Private Partnership
PtX	Power-to-X (e-fuels, e-chemicals)
PUFA	Polyunsaturated Fatty Acids
PV	Photovoltaic
QA	Quality Assurance
QC	Quality Control
RCQ	Refinery Certificate of Quality
RD	Renewable Diesel
REC	Renewable Energy Certificate
RED	Renewable Energy Directive (EU)
REREC	Rural Electrification and Renewable Energy Corporation (Kenya)
ROE	Return on Equity
ROI	Return on Investment
RSB	Roundtable on Sustainable Biomaterials
RSBI	Risk-Based Inspection
RWGS	Reverse Water-Gas Shift (reaction)
SAF	Sustainable Aviation Fuel
SEZ	Special Economic Zone
SGR	Standard Gauge Railway (Kenya)
SMR	Steam Methane Reforming (hydrogen)
SOEC	Solid Oxide Electrolysis Cell
SOFR	Secured Overnight Financing Rate (USD)
SONIA	Sterling Overnight Index Average (GBP)
SOT	Shimanzi Oil Terminal
SPK	Synthetic Paraffinic Kerosene (SAF)
SPV	Special Purpose Vehicle (project company)
STD	Standard
SWOT	Strengths, Weaknesses, Opportunities, Threats
TDS	Total Dissolved Solids
TONA	Tokyo Overnight Average Rate (JPY)
TRL	Technology Readiness Level
TSS	Total Suspended Solids
TTF	Title Transfer Facility (Dutch gas hub)
TWG	Technical Working Group
UCO	Used Cooking Oil

UNFCCC United Nations Framework Convention on Climate Change
UPS Uninterruptible Power Supply
USA United States of America
USD United States Dollar
VAT Value-Added Tax
VOC Volatile Organic Compounds
WACC Weighted Average Cost of Capital
WEF World Economic Forum
WGS Water-Gas Shift (reaction)
WHRC Waste Heat Recovery Capacity
WHSV Weight Hourly Space Velocity (catalysis)

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SECTION 1. INTRODUCTION

This section sets out the structure of the study and the broader Kenyan context. It outlines national fuel consumption, potential feedstocks and the current state of relevant SAF technologies. As Kenya positions itself as a regional leader in renewable energy, with over 90% of its grid powered by clean sources, the potential for integrating SAF into its broader green transition becomes increasingly tangible. Emerging opportunities include green hydrogen and SAF initiatives, with existing infrastructure like the Kenya Petroleum Refinery in Mombasa considered key enablers of this energy shift. Together, these elements provide the basis for assessing Kenya's readiness to adopt SAF technologies and scale production sustainably.

1.1 READING GUIDE

This study aims to provide an overview of the current landscape for developing a SAF supply chain in Kenya, with a particular focus on the potential repurposing of the Kenya Petroleum Refinery in Mombasa. This study is not intended as a substitute for an engineering study. It is presented as a conceptual assessment, which can be positioned before a full technical assessment. The results presented herein have been calculated in-house using publicly available data and professional judgement. They are intended for preliminary estimation purposes only and should not be relied upon as a definitive assessment without further analysis.

The study is structured to serve a wide range of stakeholders, each with different interests and priorities. The following guide will help the reader navigate the chapters and focus on the sections most relevant to you. To support rapid reading each section ends with a concise summary of the key outcomes. Table 1 provides an overview of all the sections and their audience, while Figure 1 provides a graphical schematic.

Table 1. Overview of report sections with topics and target audience.

Section 1	INTRODUCTION • Topic: overview of renewable resources in Kenya and introduction to SAF technologies • Target readers: general public interested in SAF
Section 2	TECHNICAL ASSESSMENT OF EXISTING INFRASTRUCTURE • Topic: preliminary considerations about the reusability of equipment and potential for repurposing of the refinery • Target readers: technical stakeholders
Section 3	TECHNO-ECONOMIC ASSESSMENT OF A BROWNFIELD HEFA REFINERY • Topic: estimation of minimum selling price considering different scenarios for a HEFA pathway • Target readers: technical stakeholders, investors, project developers
Section 4	TECHNO-ECONOMIC ANALYSIS OF AN ALTERNATIVE PATHWAY TO HEFA • Topic: estimation of minimum selling price for PtL pathway • Target readers: technical stakeholders, investors, project developers
Section 5	PROJECT FINANCING AND RECOMMENDATIONS • Topic: an overview of potential sources of finance • Target readers: project developers

Section 6	EVALUATION OF THE PROJECT • Topic: reflections on the techno-economic analysis results and insights on project structuring • Target readers: policymakers, investors, project developers, industry stakeholders, technical stakeholders, and the public interested in SAF
Section 7	ROADMAP AND POLICY RECOMMENDATIONS • Topic: an overview about next steps for the company and potential policies at the state level • Target readers: policymakers and project developers

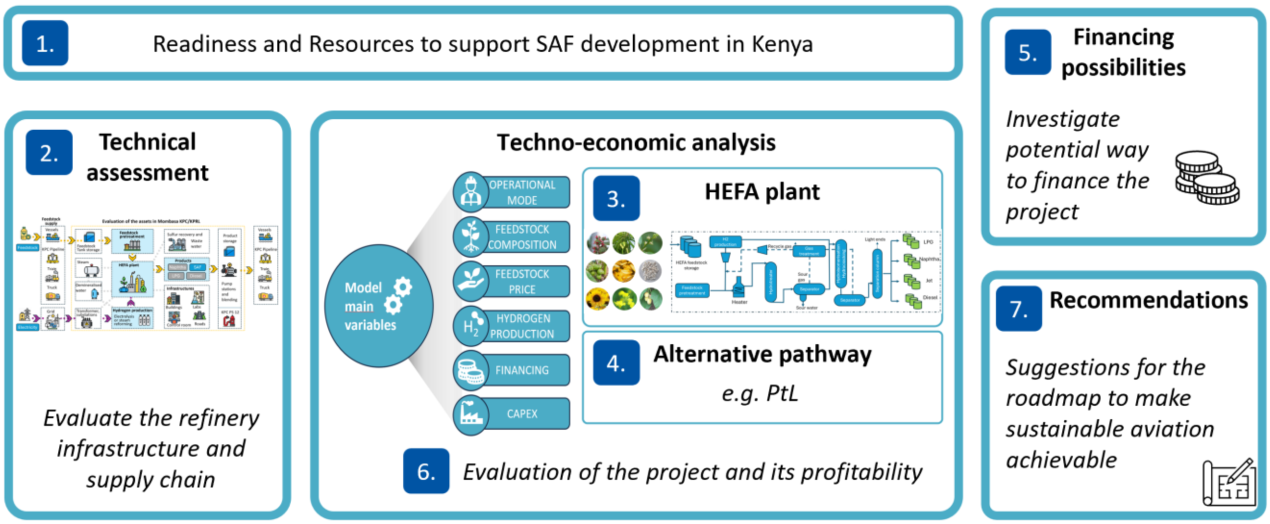


Figure 1. Overview of the study structure. The numbers refer to the sections of this report.

1.2 MAIN OBJECTIVES AND RATIONALE

This study evaluates the feasibility of converting the existing refinery infrastructure into a SAF production facility. The study specifically examines how the decommissioned refinery in Mombasa could be retrofitted to support the HEFA process using renewable feedstocks such as vegetable oils, waste fats, oils, and greases (FOG), and compares this approach with an alternative SAF production pathway as a benchmark. Based on these results, the study additionally emphasizes that focusing solely on the refinery is insufficient; rather, the establishment of a complete ecosystem is required. Effective SAF deployment depends on supportive policies, appropriate financing mechanisms, and collaboration among stakeholders across the supply chain. The analysis therefore aims to provide a preliminary estimate of key values for the SAF business case and a basis for understanding how the different components must interact to enable the development of a functioning SAF supply chain.

In 2013, the Mombasa refinery ceased all refining activities for fuel production due to production inefficiency attributed to ageing process technology. However, the facility's storage and distribution infrastructure for refined products has remained in utilization after decommissioning. In an effort to revamp the facility and enhance the country's petroleum storage capacity and streamline the management of oil and gas infrastructure, the government transferred the shareholding of the refinery on 27 October 2023 to Kenya Pipeline Company Ltd (KPC) following the signing of a 100% share transfer agreement by the National Treasury. Currently, the Kenya Petroleum Refineries Limited (KPRL) has the mandate to process, store, transport, and distribute petroleum products, and it has been integrated into KPC operations. KPC, a wholly government-owned entity, operates multiple multi-product pipelines for nationwide fuel distribution and also supplies jet fuel via hydrant systems to both Moi International Airport in Mombasa and Jomo Kenyatta International Airport in Nairobi. As the lead agency responsible for SAF policy and implementation in Kenya, KCAA plays a central coordinating role in advancing national efforts toward cleaner aviation energy. It is closely collaborating with key stakeholders, including the Kenya Airports Authority (KAA), which operates the country's major airports, and KPC, which manages aviation fuel distribution in coordination with different fuel marketers.

1.3 NATIONAL JET FUEL CONSUMPTION AND PETROLEUM PRODUCT MARKET

Kenya occupies a strategically significant position within East Africa's aviation landscape, supported by a well-established jet fuel logistics and distribution infrastructure, alongside advancing sustainability initiatives. Following the decommissioning of its sole domestic refinery in 2013, Kenya has continued to ensure an uninterrupted jet fuel supply and other refined petroleum products through importation, with volumes offloaded at the Port of Mombasa and conveyed inland via an integrated multi-product pipeline network servicing the country's primary international airports.

In the financial year 2024/2025 Kenya imported approximately 1.208 million m^3 of jet fuel (KPC data), of which around 926 000 m^3 were consumed domestically (equivalent to roughly 15 860 barrels per day or 722 000 t/year) while the remaining 282 000 m^3 were re-exported to neighbouring countries. The growth in aviation fuel demand has been driven by both domestic and international air traffic, primarily localized in key aviation hubs such as Jomo Kenyatta International Airport (HKJK), Moi International Airport (HKMO), and Eldoret International Airport (HKEL). The majority of Jet A-1 consumption is concentrated at Nairobi's main airport, accounting for over 90% of total usage, while Mombasa contributes approximately 8% (ICAO, 2018). Aviation activity is projected to grow steadily, leading to an estimated annual increase of approximately 5% in kerosene consumption (KCAA, 2022).

SAF production, particularly via the HEFA pathway, often involves the co-production of renewable diesel. As such, consideration of the diesel market is also relevant. In the financial year 2024/2025, diesel (Automotive Gas Oil, AGO) import through the port of Mombasa was 4.6 million m^3, where the national consumption was approximately 2.7 million m^3 (KPC data). Although there is a national policy that proposes a biodiesel blending mandate, its implementation has not yet been effectively realized.

During 2024, 9.374 million m^3 of petroleum products (AGO, PMS, Jet-A1) were imported in Kenya for local consumption and export to neighbouring countries, such as Uganda, South Sudan, DRC, Rwanda and Burundi (EPRA, 2025a). Overall, the volumes designated for the local market accounted for 54.16% of the total import and an overview of Kenyan domestic consumption for 2022-2024 is reported in Figure 2.

The Kenyan oil market is a price-controlled market through the Energy and Petroleum Regulatory Authority (EPRA), which is responsible for setting and regulating the retail and wholesale prices of petroleum products in Kenya. This is to ensure price stability, transparency, and consumer protection through monthly price reviews based on global market trends, exchange rates, and supply chain costs. The retail pump prices are published on the EPRA website (EPRA, 2025b).

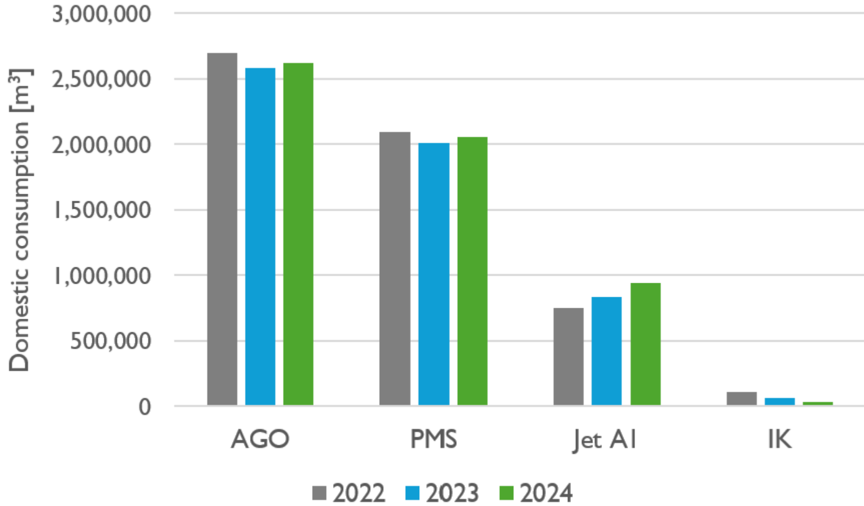


Figure 2. Annual petroleum product consumption in Kenya (EPRA, 2025a). AGO is Automotive Gas oil or Diesel; PMS is Premium Motor Spirit or Gasoline; Jet-A1 is Aviation fuel; IK is Illuminating Kerosene.

1.3.1 Prospective developments in Kenya's fossil fuel industry: LAPSSET and Turkana oil project

The Lamu Port-South Sudan-Ethiopia Transport (LAPSSET) Corridor is one of East Africa's most ambitious infrastructure programs. Its core objective is to open up northern Kenya and connect it to South Sudan and Ethiopia through a multi-modal transportation and energy corridor. The project (Kenya Vision 2030, 2025) includes the construction of:

- A standard gauge railway line and an extensive road network;
- Multiple oil pipelines (including refined and crude oil) connecting Lamu to Juba and Ethiopia;
- A new oil refinery in Lamu with a processing capacity of 120 000 barrels per day, intended to reduce dependency on imported refined fuels;
- A modern oil terminal at Lamu Port to support fuel exports and imports;
- Additional petroleum pipeline links to the Mombasa-Kampala network;
- New international airports in Lamu, Isiolo, and Lokichoggio;
- Energy and utility infrastructure, including a 1 420 km high-voltage electricity transmission line.

These developments not only support Kenya's domestic energy security and trade competitiveness but also enhance the logistical and supply chain backbone for SAF production and distribution. In particular, the Lamu refinery and port facilities will offer future opportunities for processing and exporting SAF and its feedstocks, while improved road and rail links make upstream agricultural zones more accessible for feedstock collection. As of July 2025, the LAPSSET project is partially operational. Lamu Port is active (Business Daily, 2020), Isiolo Airport is completed and operational while further upgrading is ongoing, and major highways are nearing completion (Kenya News, 2024). However, large portions (rail, pipeline, resort cities) await further investment and resolution of security and political challenges (Rift Valley Institute, 2018; The Coast Media Group, 2025).

The Turkana Oil Basin, located in northwestern Kenya, is part of the broader South Lokichar Basin, where commercially viable oil reserves were first discovered in 2012 by Tullow Oil in partnership with Africa Oil Corp and Maersk (Ej Atlas, 2021). The basin is estimated to hold over 560 million barrels of recoverable oil, making it Kenya's most significant onshore oil reserve to date. Despite successful exploration and appraisal phases, full-scale development has faced delays due to infrastructure constraints, particularly the need for pipeline and export facilities, and shifting investment priorities. The basin remains a key component of Kenya's long-term energy strategy, with potential integration into the LAPSSET Corridor for eventual crude export via Lamu Port, which the government plans to export in 2026 (Bolding, 2025).

1.4 KENYA'S RENEWABLE ENERGY LANDSCAPE: KEY FACTS AND INITIATIVES

This section provides an overview of Kenya's renewable energy landscape and national initiatives that are paving the way for cleaner fuel alternatives. Recent developments, such as the formation of a SAF National Steering Committee led by the Kenya Civil Aviation Authority (KCAA), signal growing momentum behind SAFs. In May 2023, Kenya Airways made headlines by operating the first flight from Africa using imported SAF (Musalia, 2023). Additionally, feasibility studies on SAF are done, such as the study by ICAO in 2018 and the World Bank in 2025, emerging projects in green hydrogen and green ammonia, along with strategic investments such as the establishment of agri-hubs by Eni and efforts from developers like Bleriot, highlight the synergies between renewable energy, agriculture, and future SAF production.

Public institutions, including KenGen, continue to play a central role in scaling up green energy infrastructure, while government policies underscore Kenya's ambition to position itself as a regional hub for clean energy innovation. Together, these elements create a favourable ecosystem for integrating SAFs into the country's broader energy and climate strategy.

1.4.1 Kenya SAF National Steering Committee

In its effort to transition toward low-carbon aviation, Kenya has taken a significant institutional step with the formation of the Kenya SAF National Steering Committee on the acceleration of development and deployment of sustainable aviation fuels (SAF). This committee plays a central role in shaping the country's SAF future by bringing together key aviation stakeholders, jet fuel suppliers, regulators, and policy experts under a unified framework.

The primary mission of the Steering Committee is to guide the development of a comprehensive SAF roadmap tailored to Kenya's needs and capabilities, while fostering an environment that supports the growth of a sustainable SAF supply chain. This involves technical and economic discussion, fostering stakeholder engagement across the aviation fuel value chain. The aim is to ensure that SAF deployment aligns with Kenya's national climate goals while also generating local socio-economic benefits.

To operationalize this mission, the Steering Committee established a structured coordination mechanism through six Technical Working Groups (TWGs). Each working group focuses on a specific pillar critical to the SAF transition:

1. **SAF finance case for Kenya**: tasked with modelling investment flows, cost structures, and financing opportunities.
2. **Socio-economic benefits:** responsible for quantifying the employment, health, and rural development impacts of SAF.
3. **SAF policies**: focused on identifying legal and regulatory gaps and proposing policy instruments specific to SAF.
4. **Mombasa refinery, jet fuel blending, and certification**: addressing infrastructure needs and compatibility with international SAF certification standards.

5. **Feedstock sourcing:** mapping and assessing the availability, sustainability, and logistics of potential feedstocks across Kenya.
6. **SAF roadmap:** responsible for synthesizing all technical, policy, and financial inputs into an actionable national deployment plan.

Starting in August 2022, SAF workshops have been held, followed by technical assessments and stakeholder consultations, leading to the formal invitation of Steering Committee members in early 2024. The first official committee meeting took place on 29 May 2024, with the second one held in October 2024, and the third in May 2025, marking key points of consolidation and coordination.

Looking ahead, one of the top priorities for the Steering Committee is to strengthen the policy framework, which currently lacks SAF-specific provisions. By embedding these into Kenya's broader environmental and energy legislation, the committee aims to ensure that regulatory systems support rather than hinder SAF deployment. This work is essential to unlocking investment and guiding infrastructure development.

1.4.2 Kenya's green grid with more than 90% renewable electricity

Kenya has emerged as a continental leader in clean energy, with an impressive 92% of its national electricity generation coming from renewable sources (Oyemike, 2023). According to the EPRA Biannual Energy and Petroleum Statistics report (EPRA, 2025a) at the end of 2024 Kenya's national electricity grid had a total installed capacity of approximately 3 812 MW (including captive capacity). Peak demand at the time stood at around 2 300 MW, leaving sufficient headroom for future industrial expansion. As of December 2024, geothermal energy represents the largest share of Kenya's total installed power capacity at 26.13%, followed by hydro at 24.16% and thermal at 17.36%. Solar photovoltaic and wind technologies contribute 13.43% and 12.07%, respectively (Table 2).

Captive power capacity reached 574.6 MW, representing 15.04% of the total installed capacity. This segment, primarily comprising biomass, solar, and small-scale hydro, continues to expand, driven by commercial and industrial users seeking cost-effective, flexible energy solutions and benefiting from favourable policy frameworks. In particular, captive solar PV capacity rose to 271.3 MW over the review period.

Table 2. Installed, effective and captive power capacity as at 31 December 2024 (EPRA, 2025a). WHRC is Waste Heat Recovery Capacity.

Technology	Interconnected capacity		Captive capacity (MW)	Off-grid capacity (MW)	Total installed capacity (MW)	Share of total installed
	Installed (MW)	Effective (MW)				
Hydro	839.5	809.7	33.0	0.1	872.5	24.16%
Geothermal	940.0	876.1	3.7	-	943.7	26.13%
Thermal	564.8	558.4	21.3	41.0	627.1	17.36%
Wind	435.5	425.5	-	0.6	436.1	12.07%
Solar	210.3	210.3	271.3	3.4	484.9	13.43%
Bioenergy	2.0	2.0	161.8	-	163.8	4.54%
Imports	200.0	200.0	-	-	200.0	-
WHRC	-	-	83.5	-	83.5	2.31%
Total	**3 192.1**	**3 082.0**	**574.6**	**45.1**	**3 811.6**	**100.00%**

Figure 3 reports the electrical energy mix generated in Kenya, representing the total electricity delivered to the national grid and public off-grid systems at designated delivery points, representing the net output from power producers under power purchase agreements (PPAs), excluding auxiliary consumption. During 2024 approximately 14 000 GWh were generated with a renewable component higher than 90% (EPRA, 2025a). In the financial year 2024/2025, industrial users consumed 51% of total electricity demand (EPRA, 2025a).

Geothermal energy remains the dominant source of electricity generation in Kenya, accounting for 39.81% of the total national generation. Hydropower ranks as the second-largest source of generation, with 24.74% of the electricity mix. Wind energy contributes 13.46% of total generation. Electricity imports increased significantly in 2024, totalling 10.41% of total electricity supply, compared to 6.16% in 2023. The increase is mainly due to the full commercial operation of power imports from Ethiopia. Additionally, cross-border energy exchange with Tanzania commenced on 13 December 2024 to support the commissioning of the Isinya–Arusha–Singida 400 kV transmission line, although full commercial operations under this agreement are yet to begin.

Thermal generation represented 8.42% of the electricity mix. This is mainly localized in the coastal regions, mainly in Mombasa, with two thermal plants of 120 MW capacity. Despite its modest contribution, thermal power remains essential for grid reliability, particularly in maintaining voltage stability in coastal regions and providing peaking capacity.

KenGen (Kenya Electricity Generating Company PLC, majority-owned by the government) is the largest power producer in Kenya, contributing to over 60% of the country's total electricity installed capacity (KenGen, 2025b) and generation (EPRA, 2025a). The electricity is distributed by Kenya Power. Transmission lines in Kenya are operated at 132 kV, 220 kV, 400 kV and 500 kV. These lines are owned either by the Kenya Electricity Transmission Company (KETRACO) or by the Kenya Power and Lighting Company (KPLC). KenGen operates a diverse generation mix, with major contributions from geothermal (754 MW), hydropower (826 MW), wind (26 MW) and thermal (120 MW) sources (KenGen, 2025a). Its geothermal plants, primarily located in the Olkaria region (in the Rift Valley), make Kenya a continental leader in renewable base-load generation, with the lowest tariffs in the regions. Hydropower along Tana River and at Turkwel Gorge Dam remains important, though power generation amount is bound to the season, while thermal plants support peak demand and grid stability (located mainly in Mombasa region, and Embakasi, Muhoroni and Thika and Athi river). KenGen is also piloting solar energy and exploring green hydrogen and battery storage. Its operations align with Kenya's Vision 2030 and energy transition targets, with a strong focus on expanding clean, reliable power generation.

Kenya's energy transition demonstrates the feasibility of integrating high shares of renewable electricity into the national grid, being also a potential for green industry and potentially for SAF production with a higher share of renewables.

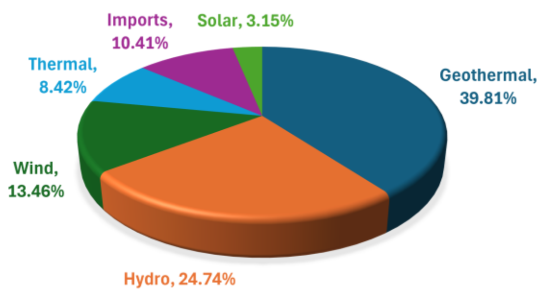


Figure 3. Electricity generation mix by source as of 31 December 2024. (EPRA, 2025a)

1.4.3 Kenya's growing momentum on green hydrogen and ammonia

Kenya is emerging as a key player for the green hydrogen economy, supported by national strategies and feasibility studies. Current initiatives focus on evaluating production potential, cost competitiveness, and the role of green hydrogen and ammonia in decarbonizing transport, industry, agriculture, and energy systems.

Several studies have been conducted, and this section highlights a selection of key publications, including the *Green Hydrogen Strategy and Roadmap for Kenya* (Ministry of Energy and Petroleum, 2023), *Towards a Green H2 Economy: Kenya Country Report* (Oyan and Kantel, 2024) (Fraunhofer ISI), *Kenya's Guidelines on Green Hydrogen and Its Derivatives* (EPRA, 2024a), *Sector Analysis Kenya: Green Hydrogen for C&I sector* (GIZ, 2023) and as a global reference *Green Hydrogen Cost Reduction* (IRENA, 2020). These documents highlight Kenya's vast potential in leveraging its abundant renewable energy resources, especially geothermal, hydro, solar and wind, to drive cost-competitive hydrogen production. In the *Green Hydrogen Strategy and Roadmap for Kenya* an estimate of the Levelized Cost of Hydrogen (LCOH) is provided considering different renewable power generation sources (see Table 3).

Table 3. LCOH for green hydrogen from different sources in Kenya (Ministry of Energy and Petroleum, 2023).

Technology	Electricity cost (USD/MWh)	Load factor (%)	Hydrogen cost (USD/kg)
CI5[a] grid tariff	203	98	12-13
Solar	58	20	8-9
Wind	60	60	5-6
Geothermal	65	90	4-5

[a] *CI5: extra-large industrial users*

In Kenya, geothermal energy stands out as the most promising option for green hydrogen production, owing to its relatively low cost and high-capacity factor (above 90%). This enables a LCOH in the range of 4–5 USD/kg. However, to achieve cost parity with conventional fossil-based hydrogen (approximately 2 USD/kg), the cost of geothermal electricity would need to decrease to around 25–30 USD/MWh, assuming no policy incentives or subsidies. Reducing geothermal power costs may be feasible in the future through process optimizations. While solar PV can deliver a low levelized cost of electricity (LCOE) in optimal locations, its limited capacity factor (~20%) results in higher hydrogen production costs when used in captive systems. A hybrid configuration combining solar and wind, whose diurnal profiles are often complementary, could enhance overall system utilization. This could improve the aggregate capacity factor and subsequently lower the LCOH, enhancing the competitiveness of green hydrogen.

In a GIS analysis performed in the GIZ study (GIZ, 2023), a large portions of northern-western and western regions have favourable conditions for low-cost hydrogen production, thanks to high solar irradiance and land availability, with a potential LCOH lower than 6.6 EUR/kg.

The Kenyan government, through agencies like the EPRA and in collaboration with development partners, is now working to create enabling policies and investment frameworks to attract both local and foreign investment, such as the measurement proposed in *Kenya's Guidelines on Green Hydrogen and Its Derivatives.* A recent sector analysis led by GIZ further outlines the regulatory needs, market design, and financing models required to support a viable green hydrogen market in Kenya.

Beyond hydrogen, attention is also turning to green ammonia, which is produced by reacting green hydrogen and nitrogen. Green ammonia has significant potential for Kenya's export ambitions, particularly as a carbon-free maritime fuel and a green fertilizer substitute that could enhance food security while reducing emissions from the agricultural sector.

Three pioneering projects, currently underway or in advanced planning stages, are leading this transition.

1. **Talus Renewables & Kenya Nut Company – Naivasha (Jayarai, 2023)**
In Naivasha, a modular green ammonia facility powered by on-site solar photovoltaic systems is already operational. Developed in partnership between Talus Renewables and the Kenya Nut Company, the plant currently produces 1 ton of fertilizer per day, with plans to scale up production to 200 tons daily. This initiative not only demonstrates the technical feasibility of localized, renewable-powered ammonia production but also aims to reduce Kenya's reliance on imported fertilizers.

2. **Fortescue Future Industries (FFI) – Olkaria Project (Cariaga, 2023)**
Australian-based Fortescue Future Industries (FFI) has signed an agreement to develop a 300 MW green ammonia and fertilizer facility in the Olkaria region, one of Kenya's most prominent geothermal fields. The project will be powered entirely by geothermal energy. Once operational, it is expected to deliver affordable, sustainable fertilizers and contribute significantly to Kenya's ambitions as a green energy exporter.

3. **Tarita Green Energy – Kaptagat Hydrogen and Ammonia Hub (Njovu, 2025; Wachira, 2025)**
In Kaptagat, an area located near Eldoret in western Kenya, Tarita Green Energy is leading the development of a large-scale solar-powered green ammonia facility. The planned plant will have a production capacity of 40 000 t/y, and is aimed at serving the local agricultural sector, which is heavily fertilizer-dependent. The project includes a dedicated captive power installation of approximately 250 MW, ensuring a stable and independent energy supply.

These initiatives highlight the synergy between renewable electricity, agriculture, and emerging green fuels. With strong solar irradiation in the Rift Valley and established geothermal infrastructure in Olkaria, Kenya has a comparative advantage in producing low-cost, clean ammonia and hydrogen.

In addition to serving domestic needs, these projects could eventually supply green ammonia to global markets, particularly in Europe and Asia, where demand for low-carbon maritime fuel and fertilizer inputs is expected to rise sharply.

1.4.4 Eni presence in Kenya and agri-feedstock initiatives

The Italian energy company Eni has launched an ambitious and multifaceted initiative in Kenya, aimed at establishing a sustainable supply chain supply chain for agri-feedstock production to be used in biorefining. As part of its broader global decarbonization strategy, Eni is positioning Kenya as a key platform for agricultural-based feedstock sourcing, vegetable oil (non-edible) processing, anchored in a model that combines renewable energy, local development, and environmental safeguards.

At the heart of Eni's operations in Kenya is the Agri-feedstock Program, an integrated system for sourcing, processing, and transporting non-edible vegetable oil feedstocks intended for conversion into biodiesel (HVO) and SAF. Currently, these vegetable oils are shipped to Italy, where they are processed into biofuels at ENI's biorefineries. Since 2021, Eni has established two oilseed pressing plants (agri-hubs) for the extraction of non-edible vegetable oil used in biofuel production. The first agri-hub, in Wote, Makueni County, has a capacity of

15 000 t/y and became operational in 2022. The second, in Bonje, Kwale County, has a capacity of 55 000 t/y and became operational in 2023.

To date, Eni has worked with and supported over 100 000 small-scale farmers in 11 counties, in arid and degraded lands, with a goal to improve agricultural production and promote soil regeneration through the adoption of sustainable farming practices and the enhancement of food security in the region.

In March 2025, Eni and its local partner Janari Farms achieved a major milestone: the first Low Indirect Land Use Change (ILUC) certification in Kenya, awarded under the International Sustainability & Carbon Certification (ISCC) scheme (Eni, 2025a). This certification confirms that the castor-based vegetable oil supply chain complies with EU regulations and does not lead to the indirect displacement of food or feed production.

Beyond agri-hubs, Eni is also investing in collection of used cooking oil (UCO) in Kenya (Eni, 2023) for conversion into biofuels, supporting circular economy principles by reusing and safely disposing of used cooking oil. Once collected, the oil is shipped to Eni's Venice and Gela bio-refineries in Italy.

Eni's agri-hub model in Kenya represents a structured approach to biofuel feedstock production, with potential for scalability in similar contexts across Africa. The initiative integrates local development objectives with international sustainability criteria, contributing to Kenya's efforts in low-carbon fuel development within the broader energy transition framework. In addition, Eni's operations in Kenya contribute meaningfully to local economic development and job creation.

1.4.5 Fueling Africa's Flight: A Techno-Economic Assessment of SAFs in Africa, a study by the World Bank

Among various studies conducted in Kenya, such as the ICAO feasibility study in 2018 (ICAO, 2018) (see 1.5), a recent World Bank analysis examines multiple scenarios across Africa, including Kenya, to evaluate the economic viability of SAF production and utilization (World Bank, 2025a). Two feedstocks, used cooking oil (UCO) and castor oil, were evaluated for their performance in the Kenyan context. Each offers distinct advantages and limitations that affect scalability, sustainability, and market competitiveness. UCO is eligible in CORSIA, can achieve up to 85% emission savings, generating a fuel with a price of ~2 USD/L (~2 600 USD/t). However, scalability remains a major challenge due to limited supply amount and the market volatility.

On the other hand, castor oil offers a more reliable supply potential through dedicated cultivation but comes with higher production costs (~2.6 USD/L equivalent to ~3 400 USD/t) and lower GHG emission savings without counting the ILUC (induced land-use change) contribution, approximately 61% below conventional fuel.

An economic simulation based on a 4 000-barrels-per-day (~200 000 t/year) HEFA facility using castor oil illustrates how different policy interventions could mitigate green premiums (the cost difference between SAF and conventional jet fuel). Policy tools such as tax breaks, concessional loans, loan guarantees, and carbon incentives all contribute to reducing the Minimum Selling Price (MSP) of SAF. Under a favourable scenario that includes high carbon incentives and reduced selling price, the MSP can be brought closer to global market averages. This highlights the pivotal role of government policy and financial mechanisms in enabling SAF scale-up.

1.4.6 Bleriot SAF: SAF production ambition and local feedstock research

Bleriot Group, through its SAF for Africa initiative, aims to start producing SAF in Kenya. Operating from its SAF Centre in Ukunda, Kwale County, the company focuses on creating locally sourced SAF to support Africa's transition to cleaner aviation (Bleriot, 2025). Its work integrates biotechnology research, feedstock innovation, and community engagement. The company operates through three specialized divisions:

- Bleriot SAF, a company dedicated to the production of Sustainable Aviation Fuel (SAF) in Africa,
- Bleriot biotech is committed to research and development in SAF seed engineering and feedstock innovation, thereby ensuring a consistent, sustainable, and efficient supply chain for bio-based fuels.
- Bleriot Foundation, responsible for corporate social responsibility, environmental projects, and community development, empowers local farmers while promoting environmental sustainability.

The company also supports on-the-ground feedstock cultivation and crop research, reinforcing the entire SAF value chain, from seed to fuel. In a strategic development, Kenya Airways has signed a memorandum of understanding (MOU) with Bleriot Group (Jones, 2024).

To date, production has been conducted in 100-litre test batches primarily for research and development and certification purposes. These batches are designed to validate process stability and quality compliance using various feedstocks. The nominal production capacity of the modular Pilot HEFA-SPK plant is one metric ton per day under continuous operation. Bleriot Group envisions producing SAF at an annual capacity of 5 000 tons, with the aim of doubling this volume in the next years, using non-food feedstocks, such as castor oil and yellow oleander. The current production of vegetable oil is 7 000-8 000 t/y.

1.4.7 Emoru Project: green hydrogen and SAF

The Emoru Power-to-X (PtX) project (AEC, 2025), proposed by Galetech Energy Developments, seeks to establish large-scale production of SAF in Kenya by integrating multiple renewable energy resources. The project idea is to combine wind, solar, and geothermal power to provide the electricity and thermal energy required for electrolysis and carbon capture, thereby enabling a fully renewable production pathway.

The planned configuration includes a wind farm of up to 2 GW capacity at Moru Ang'akirim, developed in three phases; a solar photovoltaic (PV) installation of up to 1 GW at Siguta; and a geothermal plant of 140 MW, which will supply both baseload electricity and waste heat for carbon capture. The PtX facility is designed with an electrolyzer capacity of 2 GW and will be coupled with a direct air capture (DAC) system to secure the CO_2 feedstock. At full scale, the plant is expected to produce up to 500 million L of SAF per year. This project is at idea/concept stage, and no information has been provided regarding its potential development timeline or expected date of operation.

1.5 FEEDSTOCK POTENTIAL FOR SAF IN KENYA

The previous feasibility study conducted under the ICAO-EU assistance programme (ICAO, 2018) has identified strong potential for the development of a national SAF industry in Kenya, while also identifying several key challenges to be addressed. The findings indicated the potential availability of suitable feedstocks, favourable environmental conditions, and a positive outlook for the implementation of supportive policies.

The study recommends prioritizing waste-based feedstocks, particularly used cooking oil (UCO), in the short to medium term. UCO does not compete with food resources, and its collection and reuse align well with

Kenya's evolving waste management regulations. The National Environment Management Authority (NEMA) is the designated regulatory body responsible for issuing licenses for the collection of UCO and in general for waste materials. UCO is a CORSIA-eligible feedstock for SAF, and it is a highly attractive feedstock for HEFA-based SAF production. While its volume is currently limited, especially outside urban areas, UCO remains one of the most viable feedstocks for SAF production in Kenya in the short term. Preliminary estimates suggest that by 2030, UCO alone could enable the production of up to 200 million litres of SAF annually (ICAO, 2018). According to an internal survey, the current collection of waste oil in Kenya is around 8 000 tons.

In the long term, additional feedstocks such as municipal solid waste (MSW), sugarcane by-products (cane tops and bagasse), and water hyacinth can offer significant potential for other type of process, such as gasification followed by Fischer-Tropsch synthesis. Other feedstocks that can be implemented for Alcohol-to-Jet pathway are sugarcane, molasses, cassava, sweet sorghum and bagasse. These sources are either regionally concentrated or aggregated in large volumes in localized specific areas, and they can be used for industrial purposes.

For the scenario related to HEFA pathway, other feedstocks native to East Africa were identified from the study. These are vegetable oils derived from castor, coconut, croton, jatropha, rapeseed, sunflower seeds (Table 4). The following is a summary of the key advantages and disadvantages of each plantation.

- **Castor** is a shrub and is considered a promising feedstock due to its adaptability to agroforestry systems, ease of cultivation also in marginal lands, non-food competition, and potential competitive production costs. Its high oil content (45-55% by weight of the seed) makes it efficient for fuel conversion. However, castor is an invasive species that thrives in fertile, well-drained soils, land that often overlaps with food production areas, which may result in land-use conflicts. Additionally, castor cultivation is decentralized and largely non-mechanized in Kenya, making large-scale harvesting and oil aggregation logistically complex. With adequate structural investment, castor cultivation can be developed in marginal lands, as is currently being implemented in Eni's Agri-hub (Eni, 2022).
- **Coconut** presents moderate potential, particularly in coastal regions of Mombasa, Kilifi, Kwale, Taita Taveta, Tana River and Lamu, where it is traditionally grown. It is non-invasive and reasonably drought-tolerant, but its primary weakness lies in its high susceptibility to pests and its dependence on manual harvesting. These challenges limit its scalability and efficiency as a SAF feedstock, especially for their competition with food. As a result, its viability for SAF remains limited unless non-standard coconut, which cannot be used for food purposes and is already CORSIA-eligible, can be considered.
- **Croton** is a tree resilient to harsh conditions, thanks to its deep-root system, and it provides multiple co-benefits such as erosion control and shade, and it is not in competition with food. The tree produces seeds for many years, which can be used for oil extraction without the need for annual replanting. However, current harvesting practices are entirely manual, and infrastructure for seed collection is minimal. This plant has also being implemented in the Eni's Agri-hub (Eni, 2022).
- **Jatropha** is a tree that has long been studied for biofuel use, especially for local biodiesel, and is already recognized under the CORSIA framework. It is not native of east Africa, but other tropical regions. It grows well in semi-arid regions, helps control soil erosion, and has seeds rich in nitrogen that can improve soil health. Despite these advantages, jatropha poses several serious challenges. It requires two to three years to reach full productivity, contains toxic compounds (curcasin), and is susceptible to numerous pests and diseases. Kenya's efforts to cultivate jatropha (Jatropha curcas) as a biofuel crop in 2000s-2010s faced numerous challenges that ultimately limited its success. Among the primary issues there

were the selection of a not-particularly resistant seed strain in the Kenyan environment and the overestimation of its yield potential (Langford, 2014); while early projections suggested high oil productivity, actual yields under Kenyan conditions, particularly in arid and semi-arid areas, were often low and inconsistent. The assumption that jatropha could thrive on marginal land proved problematic, as the crop performed poorly without sufficient water and nutrients, often requiring more fertile land and agricultural inputs than initially anticipated. Compounding these agronomic issues was a lack of localized research and technical guidance, leaving many farmers without the necessary knowledge to manage the crop effectively. Furthermore, the market structure (e.g., for biodiesel) for jatropha never fully materialized. There was no stable or guaranteed demand for jatropha seeds or oil, leading to uncertainty and discouraging continued investment by farmers and stakeholders. The crop also proved to be labour-intensive, particularly during harvesting and seed processing. At the institutional level, the absence of a coherent national biofuel policy and a fragmented project landscape, often driven by short-term donor funding, further undermined long-term development. As a result, large-scale jatropha cultivation in Kenya was largely abandoned, though it could be reconsidered if evidence emerges about its feasibility.

- **Rapeseed (canola)** is another CORSIA-eligible feedstock with a high oil yield and established biodiesel use. It is a good rotational crop and is typically grown on a large scale using mechanized farming methods. However, rapeseed production is energy- and chemical-intensive, often relying on fertilizers, herbicides, and pesticides. These inputs can lead to environmental degradation and make the crop less attractive from a sustainability standpoint (e.g., GHG emission saving). Additionally, rapeseed oil is widely used in human and animal nutrition, creating competition with the food sector. These factors make its viability in Kenya relatively low.
- **Sunflower**, a common oilseed crop, offers high oil yields and performs well under Kenyan conditions. However, it requires a substantial amount of water and is susceptible to pests, birds, diseases, and weeds, factors that limit its reliability and scalability. While technically feasible, its high-risk profile and strong food market demand reduce its attractiveness as a long-term SAF feedstock.

Summarizing, among the CORSIA feedstock status, UCO, jatropha, rapeseed and non-standard coconut have been already evaluated and included in the CORSIA framework. In contrast, castor and croton need to be evaluated by ICAO if they are expected to be certified without low LUC risk certification. Other feedstock such as yellow oleander (no land competition, Brassica carinata (no land competition), cottonseed (potential land competition), crambe (no land competition) and safflower (potential land competition) may be considered as well for potential production. Also, a variety of animal-based waste feedstocks can be used due to their high lipid content, such as waste tallow, lard, poultry fat, fish oil, used cooking grease and mixed rendering waste.

Table 4. Productivity of several feedstocks identified in the Kenya feasibility study (ICAO, 2018).

Feedstock	Yield (t/ha/year)	Oil content (L/t)	Oil yield (L/ha/year)	Land required for 50 million t SAF (ha)
Castor oil seed	0.23 (rainfed)	448	64	780 000
Coconut	1.64 (Kenya)	364	300	170 000
Croton	2.5 (rainfed)	336	420	120 000
Jatropha	2.5 (rainfed)	336	420	120 000
Rapeseed (canola)	2 (rainfed)	392	390	130 000
Sunflower	0.92 (current)	414	190	260 000

In addition, 43 potential energy plants and trees have been actively mapped and analyzed, including native and cultivated biomass suitable for SAF feedstock production, during engagement with various stakeholders in the SAF National Steering Committee. These feedstocks need to be verified in terms of sustainability against CORSIA guidelines. Another biofuel study was conducted by Rural Electrification and Renewable Energy Corporation (REREC, government agency under the Ministry of Energy and Petroleum) and is expected to be published online in the second half of 2025.

While current feedstock availability may be insufficient to meet projected demand, there is potential for expansion through targeted cultivation and organised collection of lipid waste material. Further studies are required to develop a comprehensive report and strategy for sustainable feedstock scale-up and which land can be used for the purpose.

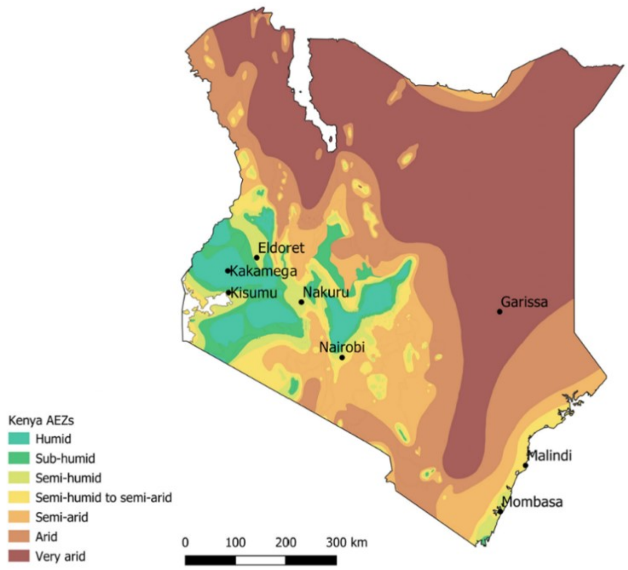


Figure 4. Agro-ecological map of Kenya. Adapted from Constantine *et al.*, 2020.

A previous study in 2011 (Ndegwa *et al.*, 2011) evaluated Kenya's potential to supply biofuel feedstocks for domestic use and export. Key bioethanol and biodiesel feedstocks were identified and assessed based on environmental suitability, production yield, and economic viability. For biodiesel, castor and jatropha showed the largest suitable areas (28% and 26.2% of Kenya's land, respectively), though agronomic data remains limited, followed by croton and sunflower. Sweet sorghum emerged as the most promising bioethanol crop with 30.6% of the national land suitable and the highest gross margin. Cassava and sugarcane followed in suitability and profitability. Figure 4 and Table 5 present a profile of the various climatic and agricultural zones across Kenya (GMES, 2025), showing the western region to be the one more favourable for agriculture and the northern-eastern region characterized by a very arid climate. Castor and croton can be cultivated in arid and semi-arid regions (ASAL), while jatropha and sunflower are more suited for semi-arid areas. Utilizing ASAL regions for growing these crops is ideal, as it minimizes competition with food crops for fertile land.

Selecting and characterizing the appropriate feedstock is a foundational step in the production of SAF. Feedstock plays a critical role in the success of the business case, as it directly influences factors such as:

1. The production capacity, which is dependent on the availability of feedstock
2. The sustainability profile and the level of greenhouse gas (GHG) emission reductions achieved
3. The final selling price of the jet fuel

Table 5. Kenya's agro-ecological zone and agriculture potential (Ndegwa *et al.*, 2011).

Agro-ecological Zone	Potential land use	Area (thousand ha)	% of land
I-III (humid, sub-humid, semi-humid)	Medium to high: agriculture, livestock (intensive), forestry	860	15
IV-V (semi-humid to semi-arid, semi-arid)	Marginal to medium: agriculture (drought-resistant crops), livestock (ranching)	11 500	20
VI-VII (arid-very arid)	Marginal: livestock (extensive pastoralism)	37 400	65
Total		**57 500**	**100**

The quality, composition, and environmental impact of a given feedstock directly influence both the technical design of the plant, especially the pretreatment system, and the overall greenhouse gas (GHG) emissions associated with the final fuel. The pretreatment of the feedstock aims to remove impurities and to meet the requirement for the HEFA plant (see 1.7).

For the lifecycle analysis (LCA) of feedstock, the core LCA and indirect land-use change (ILUC) should be considered to calculate the total carbon intensity (LCEF, in g_{CO_2e}/MJ). These values are crucial for determining the environmental sustainability of SAF pathways under international schemes such as CORSIA. Some standard values are provided in the CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels (ICAO, 2025f) and in Table 6.

Notably, feedstocks like UCO, waste FOGs exhibit relatively low LCA values, making them highly attractive for SAF production from a climate perspective. In contrast, some virgin oils, such as palm fatty acid distillates or soybean oil from direct land use, have much higher total emissions, especially when ILUC effects are included. However, some feedstocks like Brassica carinata and camelina oil are grown as secondary crops and can even demonstrate negative ILUC values due to avoided land-use competition, significantly improving their sustainability profile.

Given the significant variation in feedstock characteristics, it is essential to define the feedstock type early in the project development phase. Doing so, the design of pretreatment units can be optimised, it allows for accurate projections of GHG performance and the effect of feedstock costs on the final SAF price can be assessed. Regulatory compliance under international aviation sustainability frameworks can be already verified at earlier stage. In conclusion, feedstock selection is not merely a logistical consideration, it is a core technical and environmental decision that shapes the entire SAF value chain.

Table 6. Illustrative values for Core LCA, ILUC and LCEF of feedstocks in CORSIA (ICAO, 2025f).

Region	Feedstock	Core LCA value (g_{CO2e}/MJ)	ILUC LCA value (g_{CO2e}/MJ)	Total value LCEF (g_{CO2e}/MJ)
Global	Tallow	22.5	0	22.5
Global	Used cooking oil	13.9	0	13.9
Global	Palm fatty acid distillate	20.7	0	20.7
Global	Corn oil (from dry mill ethanol plant)	17.2	0	17.2
Global	Soybean oilseed	40.4	25.8	66.2
Global	Rapeseed/Canola oilseed	47.4	26	73.4

Region	Feedstock	Core LCA value (g_{CO2e}/MJ)	ILUC LCA value (g_{CO2e}/MJ)	Total value LCEF (g_{CO2e}/MJ)
Global	Brassica carinata oilseed (secondary crop)	34.4	-12.7	21.7
Global	Camelina oilseed (secondary crop)	42.0	-13.4	28.6
Malaysia & Indonesia	Palm fresh fruit bunches (POME treated, >85% biogas captured)	37.4	39.1	76.5
Malaysia & Indonesia	Palm fresh fruit bunches (POME treated, <85% biogas captured)	60.0	39.1	99.1
India	Jatropha oilseed (meal used as fertilizer or electricity input)	46.9	-24.8	22.1
India	Jatropha oilseed (meal used as animal feed after detox)	46.8	-48.1	-1.3

1.6 EMERGING TECHNOLOGIES IN SAF: A GLOBAL SNAPSHOT

SAFs are renewable, drop-in fuels designed to replace or supplement conventional jet fuel, offering a viable solution for decarbonizing the aviation sector. SAF can be produced via several technological pathways, with 11 ASTM-approved methods currently recognized under standards D7566 and D1655. Among these, three main standalone synthesis routes are commonly employed: HEFA (Hydrotreated Esters and Fatty Acids), FT (Fischer-Tropsch Synthesis), and AtJ (Alcohol-to-Jet). Each of these pathways begins with a specific type of feedstock and involves a unique conversion process to yield SAF that must be blended before commercial use (Figure 5). An overview about the main characteristics of the SAF pathway is given in Table 7.

The **HEFA** pathway is the most commercially mature and involves processing vegetable oils or waste fats, oils, and greases through hydrotreaters and hydrocrackers. These units use hydrogen to remove oxygen and other impurities, and to convert longer chains in a product fraction with physical and chemical properties that serve as SAF output.

The **Fischer-Tropsch** synthesis pathway starts from syngas produced via the gasification of biomass or waste materials or by reverse water gas shift of CO_2 and green hydrogen. This syngas, composed mainly of carbon monoxide and hydrogen (e.g., green hydrogen) enters an FT reactor where it is catalytically converted into longer-chain hydrocarbons.

The **Alcohol-to-Jet** pathway uses feedstocks such as ethanol or butanol. The process includes dehydration, oligomerization, and further refining steps to convert the alcohol into hydrocarbon molecules suitable for aviation use.

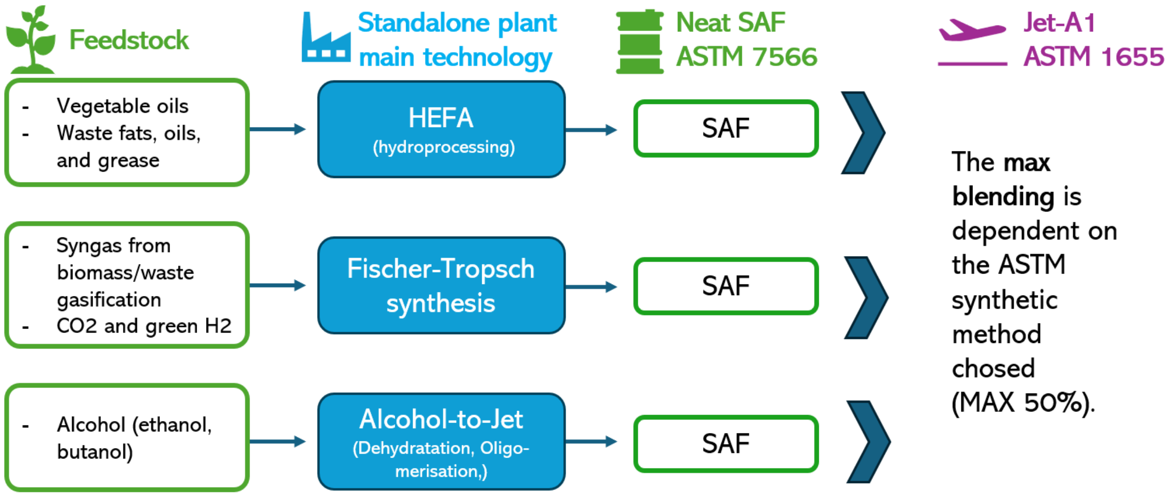


Figure 5. Main SAF production pathways.

Table 7. Characteristics of the main SAF pathways.

Parameter	HEFA	Alcohol-to-Jet	Fischer–Tropsch via gasification	Fischer–Tropsch via Power-to-Liquid
Feedstocks	Lipids (used cooking oil, tallow, vegetable oils)	Alcohols (ethanol, isobutanol) from sugar or second generation	Syngas from biomass, residues, MSW	CO_2 capture + green H_2 (PtL)
Technology maturity	TRL 9	TRL 7-8	TRL 6-8	TRL5-8
CAPEX (relative)	Low–moderate	Moderate-High	High	High
Main OPEX drivers	Feedstock price, H_2	Alcohol price, H_2	Energy, electricity	H_2, electricity, CO_2 capture
GHG emission	Very low with waste oils; higher with virgin oils (ILUC risk)	Potentially low with cellulosic alcohol; varies with alcohol source	Very low with biomass/MSW + renewable power; excellent with CCS	Very low if renewable energy is used
Potential co-products	Diesel, naphtha, LPG	Diesel, naphtha	Diesel, naphtha, LPG, waxes (optionally valuable)	Diesel, naphtha, LPG, waxes (optionally valuable)
Key advantages	Fastest to market, uses existing refinery; several plants already active at commercial scale	Broad feedstock pathway via existing ethanol industry; use of cellulosic material	Huge feedstock flexibility and low feedstock cost; long-run decarbonization potential	Potential for near-total GHG elimination, no feedstock land-use impacts
Key challenges	Feedstock availability & sustainability (ILUC for virgin oils); high carbon intensity if fossil H_2 is used	Economics hinge on cheap, low-carbon alcohol; fewer large-scale references	Capital intensity, integration complexity, development timelines, robust feedstock supply chains needed	Very high upfront cost, needs affordable renewable power and CO_2

Regardless of the pathway, all SAF produced in a standalone and dedicated plant must comply with ASTM D7566 and be blended with conventional jet fuel to meet the specification in ASTM D1655, which governs the final specification for aviation turbine fuel. The maximum allowable blending ratio is determined by the synthetic pathway used, with a general cap of up to 50%. For HEFA this limit is 50%. SAF produced through co-processing in fossil refineries must meet the specifications outlined in ASTM D1655 (max 5% renewable content).

To be eligible under the CORSIA, SAF must also meet specific sustainability criteria. This includes compliance in biomass selection, a minimum greenhouse gas (GHG) emissions reduction of more than 10%, and sustainable resource utilization (ICAO, 2025c). Fuels that meet these requirements are eligible for certification and contribute to international aviation's climate goals.

1.7 GLOBAL LANDSCAPE OF HEFA TECHNOLOGY AND REFINERY REPURPOSING

The HEFA pathway's commercial maturity, adaptability, and compatibility with existing refinery infrastructure make it the backbone of current SAF production. While other emerging pathways such as alcohol-to-jet (ATJ) and power-to-liquid (PtL) are being developed, HEFA remains the most immediately deployable technology to decarbonize aviation fuels at scale in the short to medium term.

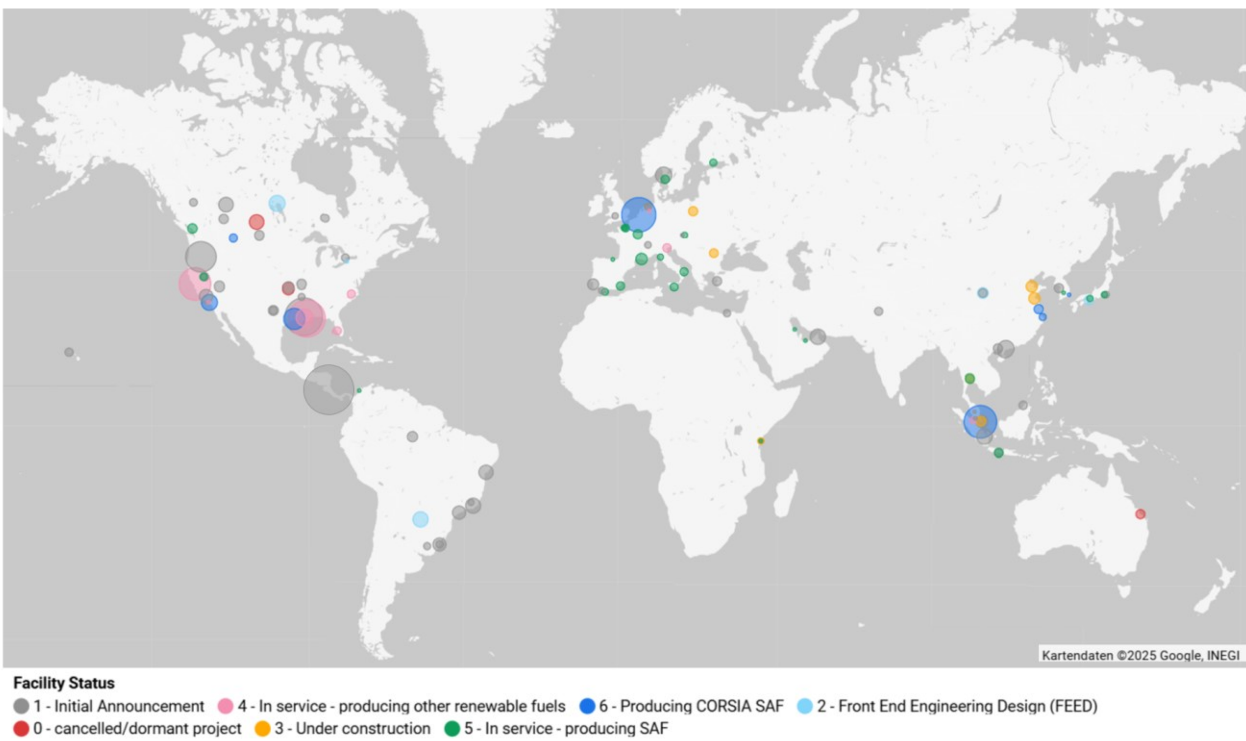


Figure 6. HEFA standalone and coprocessing facilities announced in the world for renewable diesel and SAF production (ICAO, 2025e).

The global SAF landscape today is characterized by the deployment of SAF and HVO diesel standalone plants, including both greenfield projects (new builds) and retrofitted conventional refineries. In some cases, co-processing of SAF in existing fossil fuel facilities is also being utilized as a transitional approach. These pathways provide flexibility in production scale and location, making them well-suited for integration with existing refining infrastructure or for establishment in strategic renewable energy zones.

There are already several HEFA production plants in the world in operation (Figure 6). For insights on some success stories we refer to the article (Shiflett, 2025). Facility sizes vary widely, ranging from small modular units to large-scale facilities with few capacities exceeding the million tonnes per year. Typically, the size of a plant is determined by the availability of sustainable feedstock at competitive price. For HEFA technology, feedstock availability remains a significant limitation. This constraint is expected to hinder the ability to rely solely on HEFA to meet future demand for SAF. As a result, a combination of different production pathways will be necessary to fulfil global SAF requirements. In some regions, such as Europe, restrictions have been placed on the use of certain feedstocks, like used cooking oil, to prevent fraudulent practices, such as artificially inflating supply and undermining sustainability goals.

The development of HEFA has been particularly concentrated in regions where strong policy support for SAF exists. These regions include North America, Europe, and the Asia-Pacific, where clear regulatory frameworks, with mandates and/or incentives have driven investment and growth in SAF production. The primary chemical reactions occurring within a HEFA plant are illustrated in Figure 7. The key components of a HEFA plant are the hydrotreater and the hydroisomerization/hydrocracking units, detailed below.

Hydrotreatment

The primary objective of the hydrotreatment stage is the removal of heteroatoms, primarily oxygen, sulphur, and nitrogen, from HEFA feedstocks using hydrogen. Unlike conventional fossil fuels, HEFA feedstocks typically contain approximately 10 wt.% oxygen, presenting additional challenges that require tailored process adaptations. This stage is conducted in hydrodeoxygenation reactors equipped with multiple fixed catalyst beds, operating under conditions typically ranging between 300 °C and 400 °C and pressures of 35 to 50 bar (NREL *et al.*, 2024).

Hydroisomerization and hydrocracking

Hydroisomerization focuses on “restructuring” hydrocarbon chains to enhance fuel cold flow properties, which is critical for aviation fuel performance. In parallel, hydrocracking involves breaking down long-chain hydrocarbons, converting heavier diesel fractions into lighter products such as jet fuel and naphtha. Process severity is adjusted based on feedstock type and desired product output, with typical operational ranges from 300 °C to 400 °C and pressures between 35 and 75 bar (NREL *et al.*, 2024).

Some technologies can be designed for variable yields to optimize between maximum RD and SAF depending on market conditions. HEFA plants which focus on maximizing RD production typically omit the more expensive hydrocracking reactors and catalysts, experiencing less yield loss to fuel gas, LPG (Liquefied Petroleum Gas), and naphtha, and consuming less hydrogen. However, they still need hydroisomerization after the hydrodeoxygenation step. With appropriate fractionation equipment, these plants can still extract a portion of the liquid fuel produced as a lighter SAF cut (typically <20% by volume) (Robertson, 2024). To optimize SAF yield, a hydrocracker is typically required. These facilities generally operate under more intense conditions and demand greater hydrogen input to maximize SAF production.

While it is feasible to design for 100% SAF production and lighter products (no diesel as sale product, e.g., (Andersson, Alkilde and Duong, 2020), (Axens, 2025)), most HEFA plants are configured for a mix of jet and diesel production (typically <80% SAF) (Robertson, 2024) for economical/market reasons. In recent years, there is a growing trend toward maximizing SAF yield (IEA Bioenergy, 2024). For example, refineries like Montana are developing projects specifically aimed at upgrading their facilities to increase SAF output (Montana Renewables, 2025). Additionally, some initiatives are being designed from the outset to produce solely SAF (no diesel) with LPG and naphtha as byproducts, such as Bangchak in Thailand (Bangchak Corp, 2025) and the SkyNRG project in the Netherlands (SkyNRG, 2025).

The plant configuration is highly dependent on the technology providers (Seibel, Cabral Wancura and Dias Mayer, 2024). Some examples of HEFA technology and technology providers/owners are Hydroflex by Topsoe, Ecofining by Honeywell UOP, Vegan by Axens and NEXBTL by Neste.

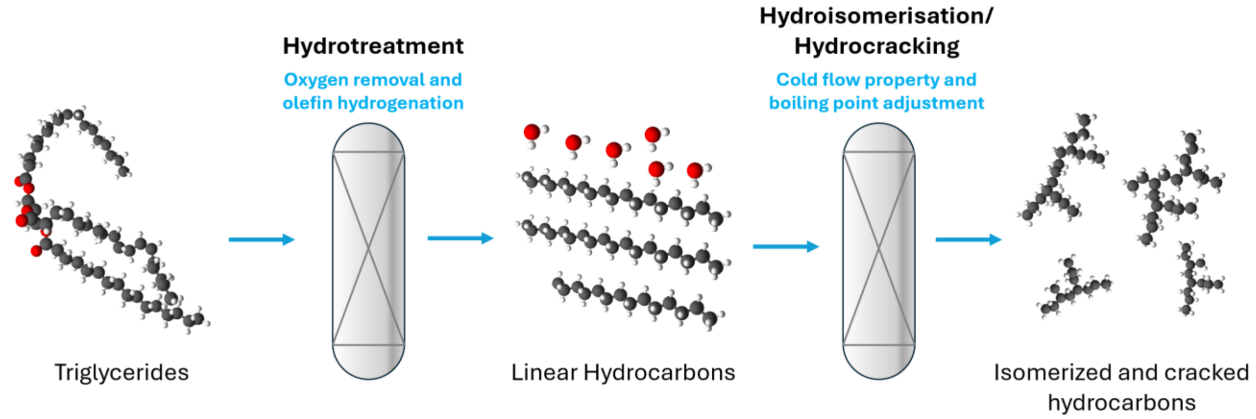


Figure 7. Main reactions during HEFA conversion to SAF.

HEFA technologies are feedstock-flexible and process conditions can be adjusted to accommodate a range of lipids (oils and fats) with different chemical compositions (CBSCI, 2019). The ability to switch between feedstock compositions depends on their quality and the facility's pre-treatment capacity to remove impurities (CBSCI, 2019).

Other key units in a HEFA plant include the pretreatment system and the hydrogen production unit. Pre-treating raw materials is an essential first step in the HEFA process, since it removes contaminants and prepares waste oils, fats, or vegetable oils for conversion into SAF (Advanced Biofuels USA, 2025; Alfa Laval, 2025; Desmet, 2025). This stage is vital for removing contaminants to protect catalyst performance and prevent reactor fouling. Selection of feedstock for HEFA should be done understanding their compatibility with the pretreatment units. Several companies are prominent in this domain, such as Alfa Laval and Desmet Balestra (in 2022 acquired by Alfa Laval), Crown Iron Works, Applied Research Associates (ARA), Alden Group Renewable Energy and Sulzer.

Table 8 highlights the wide range of impurity levels present in different feedstocks such as crude and refined vegetable oils, animal fats, UCO, yellow and brown grease, and algae oil. Parameters like free fatty acids, moisture content, insoluble impurities, phosphorus, metals, and nitrogen are critical because they affect catalyst performance and downstream processing efficiency.

Different feedstocks exhibit varying levels of impurities, which may require different processing approaches or intensities. For example, brown grease and yellow grease/used cooking oil (UCO) often contain high concentrations of free fatty acids and phosphorus, demanding more intensive pretreatment. Chlorine and polyethylene are typically found in waste animal fats, greases, and UCO, feedstocks that also tend to have elevated levels of sulphur and nitrogen. In contrast, refined vegetable oils generally fall within acceptable limits for free fatty acids in hydroprocessing but still require reductions in phosphorus, minerals, and unsaponifiable matter (such as gums).

The pretreatment process typically begins with filtration and heating, where insoluble impurities such as seed fragments, waxes, and water are removed. The oil is heated to around 70 °C to enhance the efficiency of the following degumming step.

Table 8. Example of impurities present in feedstock and the maximum allowable value for hydroprocessing equipment (NREL *et al.*, 2024).

Parameter	Units	Vegetable oil (crude)	Vegetable oil (refined)	Animal fats	UCO / yellow grease	Brown grease	Algae oil	Max. value for hydro-processing
Free fatty acids	wt. %	0.3-12.22	<0.05-0.07	0.61-20	2.72-7.38	>15	0.45-1.75	15-25
Moisture and volatile matter	wt. %	<0.3-0.5	0.1-0.41	0.02-1.5	0.16-1	-	-	0.05-0.07
Insoluble impurities	wt. %	0.02-0.25	0.006-0.1	0.01-0.5	0.04-0.5	-	0.128-0.474	0.01-0.05
Unsaponifiable	wt. %	0.85-1.7	0.3-0.99	0.02-1	0.05-1.5	0.5	0.44-0.6	<1
Phosphorus	ppm	17-642	1.0-3.7	43-643	5-132	23.5-301.2	287-340	<1-3
Total metals (Mg, B, Na, Fe, Zn, K, Ca, Si)	ppm	150	-	300	150	-	-	5-10
Nitrogen	ppm	50	-	700	60	-	-	200-350
Sulphur	ppm	2-15	<1	80-100	3-31	640	15-28	10-250
Chlorides (total)	ppm	10	<2	200	50	-	-	<5-50
Polyethylene	ppm	0	-	200	50	-	-	20-50

Degumming targets the removal of phospholipids, commonly referred to as "gums", and of metals. Water or acid degumming, using agents like citric acid, hydrates the gums, allowing their separation through centrifugation. For non-hydratable gums containing metals such as calcium, magnesium, or iron, acidulation followed by neutralization is necessary. This step is crucial, as it significantly reduces phosphorus content helping to prevent catalyst poisoning in downstream units. Enzymatic degumming is often used for high-quality vegetable oils to improve overall yield.

Following degumming, neutralization (or deacidification) is carried out to remove free fatty acids (FFAs). This involves reacting the FFAs with sodium or potassium hydroxide to form soapstock, which is then separated by centrifugation. Although effective, this step results in a loss of neutral oil, approximately one kilogram of neutral oil is lost per kilogram of soapstock, and it also generates wastewater.

The final key step is bleaching, which eliminates residual phosphorus, metals, pigments, and peroxides. This is done using adsorbents such as bleaching clays, silica, or activated carbon. After treatment, the mixture is filtered to remove spent bleaching earth, which typically accounts for 0.5–2% of the oil feed. This waste material poses challenges due to its high residual oil content (25–30%), risk of self-ignition, and potential to emit methane if landfilled. Alternative uses for spent bleaching earth include fuel, wastewater treatment, and fertilizer production.

Hydrogen is a key input in the HEFA process. Various production methods exist, each with different cost, carbon intensity, and integration implications. The most common method is Steam Methane Reforming

(SMR), which reacts natural gas with steam to produce hydrogen. While traditional SMR is cost-effective, it has high CO_2 emissions. Adding partial or full carbon capture (via CCU or CCS) can significantly reduce its carbon footprint, aligning with decarbonization targets, though at higher capital cost.

Electrolysis, particularly when powered by renewable electricity, produces green hydrogen with near-zero emissions but remains more expensive. Grid-connected electrolysis offers flexibility, but its environmental benefit depends on the local electricity mix.

Hydrogen can also be produced through steam reforming of other hydrocarbons, such as naphtha or LPG, often using refinery bio-byproducts (off-gases, LPG, naphtha). The latter generates bio-hydrogen with reduced GHG emission reduction. Steam integration is another key aspect. In a steam export configuration, excess steam from hydrogen production is used in other refinery processes, improving energy efficiency. Alternatively, a zero-steam export setup consumes all generated steam internally, simplifying operations but possibly increasing external steam needs. More information about hydrogen production is reported in 2.5.3.

1.8 MOMBASA REFINERY: BROWNFIELD ADVANTAGES, OPPORTUNITIES AND BENEFITS

The potential repurposing of the decommissioned Mombasa oil refinery for SAF production presents both strategic opportunities and some challenges. As Kenya works to scale up domestic SAF production, leveraging existing infrastructure such as the Mombasa refinery is seen as a cost-effective and time-efficient alternative to greenfield development. HEFA technology also offers a level of maturity and compatibility with existing refinery operations, thereby reducing overall project risk.

The refinery's coastal location is logistically strategic, providing direct access to the harbour, jetty facilities, KPC infrastructure, rail networks and road transport thus supporting feedstock import and product distribution. On-site utilities like water and electricity, as well as infrastructure for storage and blending, further contribute to the site's retrofit potential. However, some technical and economic challenges must be addressed. The refinery was originally built in the 1960s and has been inactive for over a decade, with visible signs of corrosion and deterioration. An in-depth assessment of the refinery's condition is provided in SECTION 2.

Repurposing the Mombasa refinery for HEFA fuel production will represent a milestone in Kenya's SAF strategy and it will offer several potential benefits, which span in the economic, energy, and environmental dimensions:

- **Economic development**: creating new jobs, stimulating industrial activity, and fostering innovation in clean technologies.
- **Energy security and diversification**: reducing dependency on imported petroleum products and creating a more resilient energy system.
- **Environmental impact**: reducing lifecycle greenhouse gas emissions and promoting the circular use of waste and developing agriculture.
- **Local resource utilization**: maximizing the use of locally available feedstocks to ensure a low-carbon and cost-effective SAF value chain.
- **Export potential**: positioning Kenya as a potential exporter of SAF to international markets, especially to airlines and countries with blending mandates.

- **Local infrastructure**: building modern infrastructure.

The SAF initiative aligns closely with the country's broader climate, energy, and industrial development goals. It not only supports the decarbonization efforts of both domestic and international airlines but also enhances Kenya's competitiveness and leadership in Africa's transition to cleaner aviation fuels.

1.9 SUMMARY

Kenya imports approximately 1.25 million m³ of jet fuel annually, distributed from the port of Mombasa via an established pipeline network that supplies both the domestic market and the wider East African region, including Uganda, South Sudan, the Democratic Republic of Congo (DRC), Rwanda, and Burundi. Of this total, an estimated 926 000 m³ is consumed domestically. In line with the international aviation climate objective of achieving a 5% reduction in greenhouse gas (GHG) emissions by 2030, as set out under the CAAF/3 (Third Conference on Aviation and Alternative Fuels) framework, Kenya has initiated discussions on the integration of SAF/LCAF and other cleaner energy solutions into the aviation sector. To advance this agenda, the *Kenya SAF National Steering Committee on the Acceleration of Development and Deployment of Sustainable Aviation Fuels* was established to enhance coordination among stakeholders and to facilitate progress in policy development, infrastructure investment, and market preparedness. As a demonstration of this commitment, Kenya Airways undertook its first SAF-powered flight in 2023, operating between Nairobi and Amsterdam.

With a renewable energy share exceeding 90%, Kenya has emerged as an attractive location for prospective green hydrogen and green ammonia projects. This strong renewable base also provides a competitive advantage for the development of low-carbon SAF. The country possesses a diverse portfolio of potential feedstocks that can be cultivated on marginal lands, thereby reducing competition with food crops. Promising options include croton, castor, cottonseed, Brassica carinata, yellow oleander, and jatropha (subject to local feasibility), which could be produced domestically or through regional partnerships. In addition, used cooking oil offers an immediately available and sustainable feedstock source. Early initiatives such as the Eni Agri-hub and Bleriot's SAF program illustrate the emerging potential of feedstock supply chain development. Nevertheless, current feedstock availability remains insufficient to sustain a commercial-scale facility, underscoring the need of further developing a feedstock supply chain. If adequately developed, these resources could allow Kenya to establish a resilient SAF ecosystem.

In addition, this section presented a global overview of emerging SAF technologies, with particular emphasis on HEFA as the most commercially mature pathway, alongside Fischer–Tropsch synthesis and Alcohol-to-Jet. The deployment of HEFA in the world has been most pronounced in regions supported by robust policy frameworks, underscoring the critical role of regulation in advancing SAF adoption. In the Kenyan context, the decommissioned Mombasa refinery presents a brownfield opportunity. Its strategic coastal location, access to logistics and utilities, and integration potential make it a viable candidate for retrofitting into a HEFA facility. Challenges include the age and condition of the infrastructure with need for substantial upgrades. If successfully repurposed, the Mombasa refinery could deliver multiple benefits: supporting economic growth, enhancing energy security, reducing emissions, strengthening local feedstock utilization, and positioning Kenya as a potential exporter of SAF. This opportunity aligns with Kenya's broader industrial, energy, and climate strategies and could establish the country as a regional pioneer in clean aviation fuels.

SECTION 2. TECHNICAL ASSESSMENT OF EXISTING INFRASTRUCTURE

This chapter presents a technical evaluation of the existing infrastructure at the Mombasa KPRL refinery, with a focus on its potential repurpose as a SAF production and blending facility. With several decades in operations, the refinery was a key component of Kenya's energy infrastructure until its decommissioning. Today, it is a fully government-owned entity operating as a subsidiary of KPC, primarily tasked with the storage and distribution of petroleum products across the country.

The site includes a broad range of assets such as refining units, pipelines, storage tanks, and product distribution facilities for both oil and gas. This assessment reviews the current condition and technical suitability of these infrastructures, evaluating whether they can be used in their existing form, require modifications, or need complete replacement to support SAF production. The analysis considers the entire supply chain, from feedstock handling and pre-treatment to blending and delivery, highlighting the main technical and logistical factors relevant to integrating SAF into the national fuel system.

2.1 HISTORY OF THE KPRL REFINERY

The Mombasa Refinery has historically served as a key processing and logistics hub within East Africa's petroleum supply chain. Originally established through a colonial government agreement in 1959 (Table 9) with equal ownership by Shell and BP, the refinery was designed to meet regional fuel demands through local processing of imported crude. Incorporated in 1960, the facility expanded significantly in the decades that followed, with Complex I commissioned in 1963 and Complex II coming online in 1974.

Over time, additional stakeholders such as Esso, Caltex, and eventually the Kenyan Government took part in KPRL's evolution. In 1983, the facility was renamed Kenya Petroleum Refineries Limited (KPRL), the name it retains today. Over the years, it underwent several modernization efforts, and in 2009, Essar Oil & Gas (India) acquired the shareholding previously held by BP, Shell, and Chevron. On 1 July 2012 the refinery transitioned from a toll refinery to a merchant refinery (Kenya Engineer, 2012). In a toll refinery model, the facility processes crude oil on behalf of oil marketers for a fee, whereas in a merchant refinery model, the refinery purchases crude oil, processes it, and sells the refined products independently. Despite these advancements, KPRL ceased crude oil processing on 4 September 2013 after efforts to secure USD 1.2 billion for modernization failed (The EastAfrican, 2020). The modernization would have been essential to remain competitive under increasingly stringent environmental standards, such as regulations mandating low-sulphur diesel. This would include the installation of a desulphurization unit to enable the production of environmentally compliant low-sulphur diesel. Additionally, a hydrocracking unit would be required to upgrade low-value heavy fuel oil into higher-value products such as diesel and gasoline. Since then, KPRL has functioned primarily as a storage and product distribution hub and is now a fully owned subsidiary of KPC and considered a 100% Government of Kenya owned entity since 2023.

Table 9. Historical milestones of Mombasa refinery (KPRL, 2025).

1959	Colonial government agreement with 'Consolidated' (50% Shell, 50% BP)
1960	East African Oil Refineries Limited Incorporated
1963	Complex I completed and commissioned
1963	Esso and Caltex become shareholders
1970	Grease plant constructed
1971	Government acquires 50% shareholding
1974	Complex II completed and commissioned
1983	Change of name to Kenya Petroleum Refineries Limited
1994	Deregulation leading to the introduction of base load and processing fees changes
1996	New Distributed Control System (DCS) commissioned
1997	Esso sold their shares
1998	KPRL laboratory ISO 9002 certified
2005	Commencement of production of unleaded mogas
2007	New laboratory completed and commissioned
2009	Essar acquired 50% of shares from Shell, BP and Chevron
2016	Essar exits from the shareholding of KPRL and shares 100% acquired by government
2017	KPRL signed an agreement with KPC for lease of its storage facilities
2023	KPRL became a wholly owned subsidiary of KPC with effect from 27 October, 2023

At its operational peak, the refinery had a capacity of 4.0 million tonnes per year, equivalent to 80 000 barrels per day (Abarellfull.co.uk, 2020) (~11 000 t/day), and a Nelson Complexity Index of 2.64, suggesting a moderate level of refining sophistication. The facility processed Murban and Arab Medium crude oils, producing a range of petroleum products including LPG, unleaded gasoline, regular petrol, dual purpose kerosene, diesel (automotive and industrial), fuel oil, and specialities like bitumen and grease. The refinery's processing assets were divided into two main complexes (Figure 8, Figure 9):

Complex I housed an atmospheric distillation unit that processes crude oil to separate it into various fractions, including kerosene minus, light gas oil (LGO), heavy gas oil (HGO), and residues. It also included a hydrotreating unit for kerosene to remove impurities such as sulphur and nitrogen, a catalytic reforming unit to upgrade naphtha into high-octane reformate for gasoline blending, and a three-cut splitter to isolate LPG, PMS, and naphtha.

Complex II also contains an atmospheric distillation unit, along with hydrotreating units for naphtha minus and kerosene/LGO fractions, a catalytic reforming unit, and fractionation facilities such as a debutanizer, two-cut splitter, and depropanizer to separate lighter hydrocarbons. The site includes a bitumen production unit integrated within the refinery, with a design capacity of 150 t/day. However, the grease plant last operated in the year 2000, with a capacity of 8 t/day.

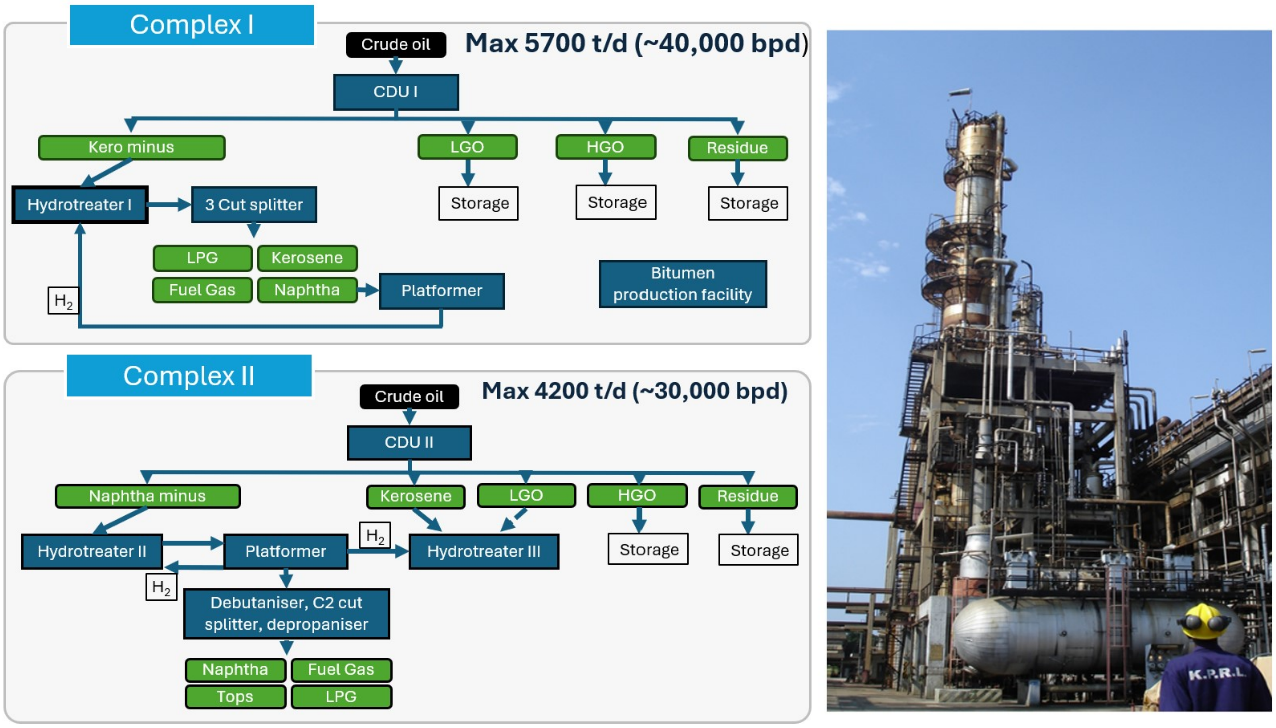


Figure 8. Configuration of Complex I and II at the refinery of Mombasa (right); part of Complex II (left) (used with permission from KPRL).

Although refining stopped, the facility retained significant strategic value through its infrastructure. The Mombasa refinery's strategic position along the coast with reliable access routes has enabled its involvement in several additional projects. In 2018, the Government of Kenya launched a pilot scheme under the Early Oil Pilot Scheme to assess the commercial viability of producing and exporting crude oil from the Turkana region (Mwanza, 2020; CGTN Africa, 2023; Bolding, 2025). The project aimed to test the logistics, infrastructure, and market reception for Kenya's nascent oil resources, prior to full-scale production. The Turkana oil reserves in South Lokichar Basin hold significant potential, with estimates indicating approximately 560 million barrels of recoverable oil. The Field Development Plan (FDP) aims to exploit around 433 million barrels over a 25-year period, targeting an initial production capacity of 60 000 to 100 000 barrels per day (Bolding, 2025). In the pilot scheme, crude oil was transported by road from the oil fields in Lokichar to KPRL facility in Mombasa, where it was stored before being shipped for export. The Early Oil Pilot Scheme (EOPS) concluded in 2020, and recent announcements indicate that commercial exports are now targeted to begin by the end of 2026 (Bolding, 2025).

In November 2024, KPRL launched a project to expand its liquefied petroleum gas (LPG) handling capacity. The refinery now has a storage capacity of 1 200 t of LPG and aims to improve its role in meeting regional energy demands (KPRL, 2024), by expanding to 30 000 t with a project under PPP agreement (Mwambingu, 2025).

Figure 9. View of the refinery complexes from the KPRL tank farm in Changamwe (used with permission from KPRL).

2.2 TECHNICAL ASSESSMENT METHODOLOGY

The primary objective of the technical assessment is to determine which units from the decommissioned refinery complex can be repurposed, identify the new processing units required for SAF production, and evaluate how existing infrastructure, such as storage facilities and pipelines, can be utilized to support an efficient and integrated SAF supply chain. The assessment comprises two core domains:

- **Refining Units:** This involves a thorough evaluation of the current condition of existing processing units, such as hydrotreaters, to determine their potential for repurposing, alongside the identification of new units required, including hydrogen production systems and vegetable oil pre-treatment facilities. The assessment also reviews the availability of site utilities, buildings, and support services. Additionally, the study considers risks associated with aging infrastructure and the operational limitations of existing units.
- **Logistics and Supply Chain**: The assessment considers feedstock logistics, especially related to the receiving capacity in the refinery, as well as the adequacy of storage and blending infrastructure for final products. It also evaluates the readiness of distribution systems, such as pipelines, railways, seaport jetty and truck loading stations. Certification and testing capabilities, particularly laboratory facilities, are examined to ensure quality assurance and compliance with aviation fuel specifications.

To support a comprehensive technical assessment of the Mombasa refinery, a multidisciplinary team of local experts across various engineering and operational domains was consulted. Chemical, process engineers and operations specialists provided detailed insights into the status and performance of the idle existing processing units, utility systems (including steam, water, compressed air, and nitrogen), and current blending and pumping operations. The inspection and integrity engineering team evaluated the condition of static equipment, such as reactors, columns, vessels, and heat exchangers, focusing on corrosion and structural integrity. The mechanical engineering team assessed the condition of rotating machinery, including pumps and compressors, while the electrical engineering team reviewed the power distribution infrastructure, including transformers, substations, and switchgears, and assessed its capacity to accommodate additional electrical loads in the case an electrolyzer is used for hydrogen production. The civil and structural engineering team gave indications about the space availability within the refinery and the zoning classification, the permitting requirements for new unit construction, and reviewed the structural integrity of existing steel frameworks of the process units. Though not included in this report, discussions with technology providers for HEFA plants and feedstock pretreatment were also held to explore the newest commercial solutions for the SAF facility.

Instrumentation and automation professionals were consulted to evaluate the existing Distributed Control System (DCS) used for managing product movement in storage and pumping stations. Environmental, Health, and Safety (EHS) experts contributed input on environmental permitting procedures, emission and effluent standards, and regulatory compliance. The laboratory team was engaged to assess current testing capabilities for petroleum product certification and identify additional analytical requirements needed to certify SAF in accordance with ASTM D7566, including the analysis of incoming feedstocks.

The supply chain and logistics experts illustrated the infrastructure (pipeline, railways, truck loading stations, seaport terminal jetties) supporting the movement of imported materials and distributed products, with a focus on connectivity between pump stations on different parts of the city and in the country. In addition, consultations with Kenya Railways Corporation (KRC) and site visits to seaport terminal jetties, pump stations, tank farms, and airport fuel storage facilities were done to evaluate their current condition and potential role in a SAF supply chain. This collaborative and interdisciplinary process provided a holistic understanding of the refinery's current state and the technical requirements necessary to transition it into a viable platform for SAF production.

The initial phase of the technical assessment methodology consists of systematically addressing a series of engineering criteria aimed at evaluating the viability of repurposing existing refinery infrastructure for SAF production:

1. **Identification of suitable units**: an evaluation is undertaken to select existing process units which can be reused for their functions in HEFA-based hydrotreatment processes.
2. **Process condition compatibility**: each identified unit is evaluated against the operating pressures and temperatures required for SAF process units.
3. **Feedstock throughput**: the nominal capacity of the existing process units is assessed in relation to the expected availability of feedstocks in Kenya and the reaction conditions.
4. **Materials compatibility**: the metallurgy and material properties of critical components are reviewed to assess their chemical compatibility with renewable feedstocks and hydrogen-rich process environments.
5. **Preservation and mechanical integrity assessment**: the integrity against corrosion and usability of pre-existing assets, such as reactors, columns, strippers, vessels and utilities are estimated.
6. **CAPEX vs. OPEX trade-off**: if necessary, potential capital expenditure (CAPEX) savings resulting from asset reuse will be compared to potential associated increases in operational expenditure (OPEX), maintenance costs, and reliability risks, due to the use of older and potential less efficient technology. This trade-off informs whether upgrading or replacing key units is a more economical approach.

By taking all these factors into consideration, the assessment helps determine the site's overall potential and the suitability of its existing infrastructure, while also identifying the additional developments or modifications required to support future operations. In addition to these factors, further elements related to sustainability will be considered to ensure compliance with the CORSIA SAF criteria.

2.3 KPC/KPRL ASSETS: REFINERY, PIPELINES AND TANK FARMS

KPRL operates two main sites: the Changamwe Site and the Port Reitz Site, covering a combined area of approximately 152.6 ha (KPC, 2025a) (see Figure 10). These assets now form part of the broader infrastructure managed by the KPC, which owns the pipeline and pump stations responsible for the nationwide distribution of refined petroleum products.

Figure 10. Overview of KPRL and KPC assets in Mombasa and distribution hubs.

The Changamwe Site houses the decommissioned refinery complex, which was originally designed for a throughput capacity of 80 000 barrels per day. In Figure 11 the position of Complex I and Complex II are highlighted, as well as the tank farm, which consist of several tanks, with specific features per product (fixed or floating roof, isolated/heated, with mixers). Currently only white oil products are stored in the facility.

Figure 11. Overview of Complex I and II and the tank farm on the KPRL Changamwe site.

Although the refinery is no longer operational, the site continues to support critical logistics functions. It is equipped with truck loading facilities capable of handling volumes of approximately 2 000 m^3/d of Premium Motor Spirit (PMS), 2 000 m^3/d of Automotive Gas Oil (AGO), and 500 m^3/d of Heavy Fuel Oil (HFO).

A standard gauge railway line is also connected to the site, although it has fallen into disuse following the commissioning of the petroleum pipeline system, and its current condition reflects this inactivity. Additionally, a 9.2 MW power generation plant, commissioned in 2012, remains on-site but is presently idle since 2013.

The Port Reitz Site hosts the Kipevu tank farm, a storage facility within the KPRL infrastructure. This site is connected to two operational marine terminals: Jetty 2 (KOT-2) and Shimanzi Jetty, which serve as the primary import points for petroleum products. In addition, the tank farm is linked via underground pipeline to the Changamwe Site, enabling integrated product transfer and distribution.

As of the latest available data, KPRL's total storage capacity is approximately 284 111 m^3, with planned expansions targeting a future capacity of up to 484 209 m^3 (KPC, 2025a). The facility handles a range of petroleum products (Table 10), including PMS, AGO, Dual Purpose Kerosene (DPK), HFO, and LPG (LPG storage in Figure 12).

Table 10. Storage capacity at KPRL (KPC, 2025a).

Product	Currently in use (m^3)	Future plan (m^3)
PMS (Super)	105 989	111 399
AGO (Diesel)	127 820	338 080
DPK (Dual purpose kerosene)	30 629	-
HFO (Heavy fuel oil)	19 673	34 730
Total	**284 111**	**484 209**

Figure 12 LPG storage in Changamwe site (used with permission from KPRL).

KPC operates a robust and extensive petroleum distribution network that forms the backbone of fuel transportation across Kenya. The pipeline system stretches 1 342 kilometres, running from the coastal city of Mombasa through Nairobi and extending westward to key towns including Nakuru, Eldoret, and Kisumu (KPC, 2025b) (Figure 13). KPC's pipeline network is designed to transport multiple refined petroleum products, including AGO, PMS, Illuminating Kerosene (IK), and Jet A-1 (aviation turbine fuel). These products are transported in sequential batches through the same pipeline system, with careful scheduling and quality control measures to prevent cross-contamination (KPC, 2025c).

The primary pipeline corridor between Mombasa and Nairobi (450 km) includes two main lines:

Line 1: Commissioned in 1978, this 14-inch diameter pipeline had a capacity of approximately 125 000 barrels per day. It is currently decommissioned and slated for removal. Alternative use for this dismissed pipeline can be explored in the context of the SAF project. The decommissioned section of KPC's Line 1 pipeline was repurposed for water transportation from Mzima Springs to Mombasa. This project can be utilized in hydrogen generation through electrolysis of water as part of the alternative feedstock for both HEFA and PtL pathways.

Line 5: Commissioned in 2018, this 20-inch diameter pipeline was constructed to replace Line 1. It has a capacity of up to 287 000 barrels per day and is designed as a multi-product pipeline.

Lines 2, 3, 4 and 6 connect Nairobi to Nakuru, Eldoret, and Kisumu with varying diameters and capacities (Figure 13). This integrated pipeline infrastructure significantly reduces dependency on road transport, cutting logistics costs and improving delivery timelines. It should be noted that the pipeline system operates unidirectionally, transporting products exclusively from Mombasa to Nairobi. Reversing the flow direction would be technically complex and could significantly disrupt the established logistics and supply chain operations.

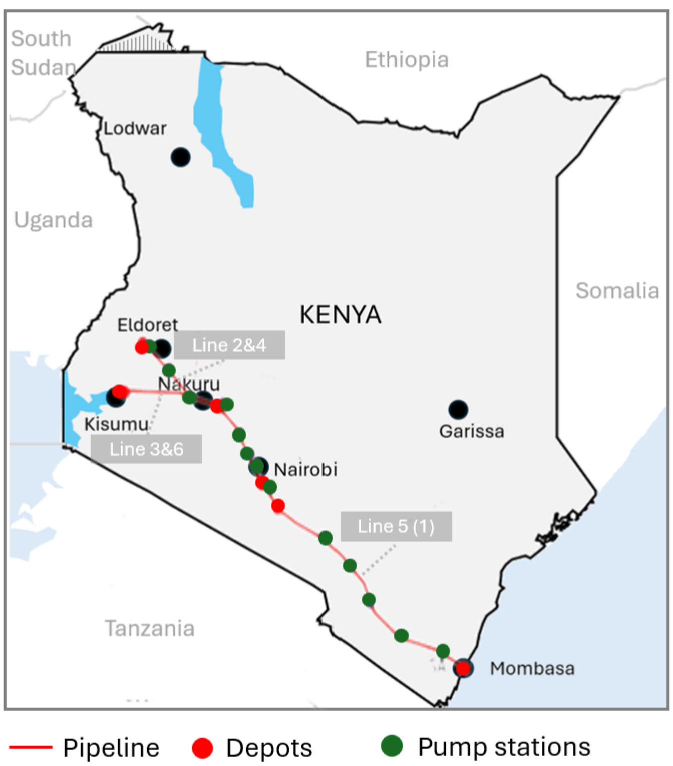


Figure 13. KPC pipeline profile adapted (KPC, 2025b).

KPC also operates 14 pumping stations and 7 loading depots along the pipeline route to facilitate distribution. Its infrastructure includes a series of storage facilities located in Mombasa (Kipevu and Moi Airport), Nairobi (JKIA and Nairobi Terminal), Nakuru, Eldoret, and Kisumu. The largest facility is at Kipevu (Mombasa), with a storage capacity of 326 000 m^3, followed by the Nairobi Terminal with 233 000 m^3, and KPRL Changamwe with 140 000 m^3. The Kipevu facility serves as the primary receiving point for petroleum products discharged from the marine jetties. The combined national storage capacity managed by KPC totals approximately 884 000 m^3 (Table 11). In addition, KPC supports the aviation sector with two hydrant refuelling facilities located at Jomo Kenyatta International Airport (JKIA) and Moi International Airport in Mombasa. For ground and rail transport, there are truck and rail loading facilities distributed throughout the network. The company also operates two key oil and gas marine terminals, one at the coastal port of Mombasa and another at Kisumu on Lake Victoria, to facilitate import and export logistics.

Table 11. KPC storage facilities (KPC, 2025b).

	KPC facility	Storage capacity (thousand m^3)
1	Kipevu (Mombasa)	326
2	Nairobi Terminal	233
3	KPRL (Changamwe)	140
4	JKIA (Nairobi)	54
5	Eldoret	48
6	Kisumu	45
7	Nakuru	31
8	Moi International Airport (Mombasa)	7
	Total	**884**

2.4 POTENTIAL CONVERSION OF THE REFINERY COMPLEXES: REVIEW OF THE UNITS FOR HEFA CONVERSION AND PRELIMINARY CONSIDERATIONS

In typical refinery conversions to HEFA operations, existing hydrotreaters or hydrocrackers are the most likely candidates for reuse due to their compatibility with the hydrogenation conditions required in renewable fuel processing. At the Mombasa refinery, three hydrotreaters are available and are being evaluated in this study for potential suitability under HEFA operating conditions. Their configuration is outlined in Figure 8, and a summary of their key characteristics and current functions is provided below:

<u>Complex I – Kero-Minus Hydrotreater</u>

This unit processes the kerosene and lighter fractions recovered from CDU I (Crude Distillation Unit I). With a maximum capacity of 2 200 t/day (~15 400 barrels per day), it operates to remove heteroatoms such as sulphur, nitrogen, and oxygen. The unit is designed for a maximum pressure of 34.1 kg/cm² and a maximum temperature of 410 °C. Hydrogen is supplied from the catalytic reforming (platforming) unit (0.1-0.25 % by weight of the feed). The treated stream is subsequently routed to the three-cut splitter for further fractionation.

<u>Complex II – Naphtha-Minus Hydrotreater</u>

This hydrotreater treats the naphtha-range and lighter fractions drawn from CDU II, with a design capacity of maximum 600 t/day (~4 200 barrels per day). Operating in the gas phase, the unit targets the removal of heteroatoms under mild conditions. Operating limits include a pressure of 23 kg/cm² and temperature of 390°C, with hydrogen sourced from the platformer. The treated stream is processed downstream in a debutanizer, two-cut splitter, and subsequently a depropanizer for product separation.

Complex II – Kerosene and LGO Hydrotreater

Designed for more severe conditions, this unit handles kerosene and light gas oil (LGO) fractions recovered from CDU II, at a maximum capacity of 800 t/day (~5 600 barrels per day). The unit is a trickle-bed reactor, operating under higher pressure and temperature conditions (45 kg/cm², 360°C) necessary to break stronger heteroatom bonds and to saturate olefins. The hydrogen is provided by the platformer (requirement ~0.6 % H_2 by weight compared to the feed). Post-treatment, the product is routed to a stripper/dryer section for further purification.

Other sections of the refinery are not relevant for HEFA operations, and the existing distillation units are significantly oversized relative to the capacity requirements of a typical HEFA plant.

It is important to recognize that the configuration and operating conditions of a standalone HEFA production facility differ substantially from those of a conventional petroleum refinery. These differences have direct implications on process integration, equipment design, and overall plant layout. As such, the reuse of existing refinery assets must be approached with caution, and careful technical evaluation is required to determine suitability. The following section outlines the key distinctions between conventional fossil-based refining and HEFA operations, highlighting the process units and system modifications that would be necessary to support the conversion to SAF production. It is important to note that within these two categories, units may differ significantly depending on their specific function, type of feedstock, and the configuration defined by the technology provider. As a result, no two refineries or biorefineries are exactly alike, and the following should be viewed as general guidance rather than a definitive description (Figure 14).

In a standalone HEFA facility, the feedstock used is derived from renewable lipid-based sources such as vegetable oils, used cooking oil (UCO), waste animal fats, and other bio-based materials. These feedstocks differ fundamentally from crude oil in their chemical composition, typically containing higher levels of oxygen, trace metals, solids, and other impurities. As a result, a dedicated pretreatment unit is essential to remove contaminants and condition the feed to meet the specifications required for the hydrotreater unit to avoid catalyst poisoning.

The central process units of a HEFA plant comprises a hydrotreating unit for deoxygenation, followed by hydroisomerization and hydrocracking steps to modify the hydrocarbon structure to enhance fuel properties, particularly cold flow behaviour. Units for hydrogen generation and gas recovery need to be integrated. Product separation is achieved through downstream units, typically involving a stripper in case only HVO diesel is produced or a distillation column or other type of separation units for mix of SAF and HVO diesel. The final product slate generally includes LPG, naphtha, SAF, and diesel. In addition, the facility must be equipped with essential utility systems, including steam generation, electrical power supply, water provision, and cooling infrastructure, alongside storage tanks, blending facility, pumping stations, and pipeline connections to enable effective product handling and distribution.

Conversely, a refinery hydrotreating unit, such as a kerosene hydrotreater, is integrated within a broader refinery system. The process begins with crude oil desalination, followed by atmospheric distillation via the Crude Distillation Unit (CDU), where kerosene is separated as one of the distillates. This kerosene stream is then treated in a hydrotreating unit to remove sulphur and other impurities. The hydrotreater is supported by hydrogen derived from the catalytic reformer of naphtha and gas recycling, and its output is routed through a separator, typically a stripper column, to purify jet fuel. In addition, it requires the aforementioned utilities for a HEFA plant, as well as product distribution facilities.

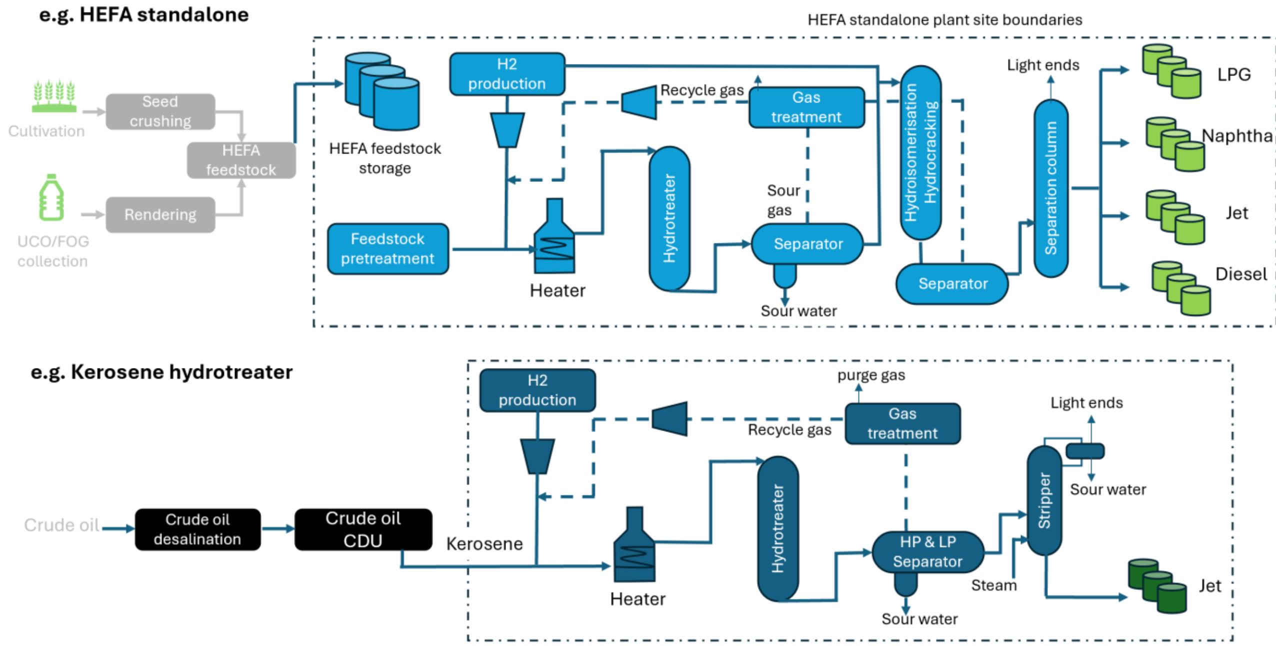


Figure 14. Typical plant configurations at comparison: HEFA plant versus fossil kerosene hydrotreater.

While the HEFA standalone plant and the hydrotreater complex in a crude oil refinery share certain similarities, they also exhibit key differences. Transitioning a refinery to process HEFA feedstocks would therefore require modifications to accommodate the process needs of renewable inputs and products, involving a set of technical, operational, and economic considerations. One of the fundamental differences lies in the feedstock type and pretreatment requirements. HEFA plants are designed to process bio-based, highly oxygenated materials (typically 10–12% O_2 by weight in vegetable oil against <1% in crude oil) in presence of sulphur, nitrogen, phosphor and other minerals, as well as insoluble materials. Therefore lipid-based feedstocks necessitate pretreatment in a dedicated unit and specific hydrotreating/hydrocracking catalysts. In contrast, refinery hydrotreaters process hydrocarbon streams derived from crude oil, which require simpler treatment for impurity removal. Specifically, achieving the cold flow properties necessary for jet fuel entails more intensive hydroprocessing, including hydrodeoxygenation, hydroisomerization and hydrocracking in the case of a HEFA plant. This often necessitates a dual-reactor configuration with interstage cooling (NREL *et al.*, 2024).

Due to the higher presence of heteroatoms, usually HEFA reactors operate at lower weight hourly space velocities (WHSV), resulting in a derating of nameplate capacity (maintaining only 25%–50% of the original unit capacity, or lower). Another parameter that could contribute to the derating if the availability of hydrogen on site. Hydrogen requirements for HEFA processing are substantially higher than those for fossil fuel refining, with consumption rates ranging between 2 and 20 times more hydrogen per ton of fuel produced. This is primarily due to the higher oxygen content, which usually required 4-5% H_2 by weight in relation to the feedstock.

The exothermic nature of hydroprocessing reactions presents another design constraint. The energy released during heteroatom removal reactions necessitates efficient thermal management strategies for the control of the temperature, such as recycling gas and liquid streams to serve as heat sinks, if intermediate cooling is not present. However, this recycled liquid displaces fresh feed, effectively reducing reactor throughput and overall plant capacity. Moreover, high recycle ratios increase energy demand, leading to higher production costs and carbon intensity (NREL *et al.*, 2024).

Corrosion is another critical issue in SAF production. Key corrosion concerns include acidic corrosion from free fatty acids in the feedstock, high-temperature hydrogen attack (HTHA) and hydrogen sulphide (H_2/H_2S) corrosion in hydrotreating reactors, and various salt-related corrosions such as ammonium bisulfide and ammonium chloride, particularly in exchangers and separation units (Fazackerley, 2025). Additional risks include amine-induced corrosion in the gas treating section and erosion-corrosion in sour water and low-pressure separator systems. Effective mitigation requires appropriate material selection (upgraded metallurgy), temperature and pressure control, water wash systems, and corrosion monitoring throughout the process.

Additionally, product versatility is greater in a HEFA plant, which can yield multiple renewable fractions, including SAF, renewable diesel, naphtha and LPG (Shiflett, 2025). A certain plant configuration can provide flexibility in producing a mix of HVO diesel and SAF, depending on the severity of the hydrocracking step, the catalyst type, fractionation design and recycles (Andersson, Alkilde and Duong, 2020; NREL *et al.*, 2024; Robertson, 2024; Seibel, Cabral Wancura and Dias Mayer, 2024; Axens, 2025). However, it should be noted that targeting a higher SAF yield typically results in a lower overall distillate product yield compared to producing only HVO diesel. To separate the resulting product mix, a distillation column is required. In contrast, conventional refineries operate with dedicated hydrotreating units for single crude oil fractions (e.g., kerosene), which are separated upstream by distillation. As a result, the downstream separation is generally limited to a simple stripper.

The implementation timeline for constructing new HEFA units or retrofitting existing facilities typically spans from two to five years, which is significantly longer compared to co-processing solutions that can become operational within one to two years.

Some preliminary considerations can be made based on the existing assets in Mombasa. For example, Hydrotreater III (Kero hydrotreater Complex II), originally designed for a nominal capacity of 800 t/day, may experience significant derating, resulting in a substantial reduction in throughput. One major constraint is the hydrogen compressor, which currently supplies a maximum of 0.6 % H_2 by weight, which is far below the 4–5% by weight typically required for vegetable oil hydrotreating. Additionally, the unit operated at a WHSV of 4 (typical for kerosene hydrotreater), and its limited catalyst volume restricts the ability to reduce the flow rate. Under such limitations, a derating to 10–25% of the original capacity would result in a throughput of only 80-200 t/day, well below the target of 750 t/day for a 250 000 t/year HEFA plant.

Hydrotreater I (Kero minus) may also face performance limitations, primarily due to its maximum allowable operating pressure. However, with an original capacity of 2 200 t/day, a 10–25% derating would still yield 220-550 t/day, which is more feasible within the HEFA production framework. Further technical details and considerations regarding the potential reuse of these reactors are provided in 2.5.5.

These figures underscore the need for careful evaluation of hydrogen system capacity, reactor volume, and pressure limitations when assessing the feasibility of adapting existing hydrotreaters for SAF production. Revamping or supplementing existing infrastructure may be necessary to accommodate the more severe operating conditions associated with renewable feedstock processing.

2.5 INTEGRATION OF A SAF PRODUCTION FACILITY WITHIN THE MOMBASA REFINERY: OPPORTUNITIES FOR ASSET REUSE AND LOGISTICAL SYNERGIES

This preliminary analysis for SAF production at KPRL outlines a potential configuration for integrating a HEFA plant within the existing infrastructure. The proposed system is designed to handle the full value chain, from feedstock supply to final product distribution, and is built around the KPC-KPRL operational boundary (Figure 15). The supply of a lipid-based feedstock, such as used cooking oil or vegetable oils, is envisaged through multiple logistical channels, including maritime vessels, trucks, railways, and the KPC pipeline. Upon arrival at the site, the feedstock is directed to tank storage facilities and subjected to a pretreatment process to remove impurities. Parallel to this, a dedicated hydrogen production unit will be established, utilizing either electrolysis or steam reforming technologies. In the eventuality that an electrolyzer is chosen, electricity will be sourced from the national grid and routed through transformers and substations, and a continuous supply of demineralized water is needed. Additional utilities, including a steam boiler, are incorporated to support plant operations. In the case of steam reformer, water and a light gas (natural gas, LPG or naphtha) is needed as feedstock to produce hydrogen, as well as provide heat for the reaction.

At the core of the facility lies the HEFA plant, where the pretreated feedstock is catalytically converted into a range of hydrocarbon fuels using the supplied hydrogen. The main products include SAF, naphtha, diesel, and liquefied petroleum gas (LPG). Supporting infrastructure such as sulphur recovery and wastewater treatment units are included to manage by-products and ensure environmental compliance. Finished products are stored in dedicated tanks and prepared for dispatch through blending and pump stations (e.g., KPC PS 12 for displacement to the hydrant system of the Moi international airport). Distribution of the final fuels mirrors the supply chain, utilizing vessels, pipelines, trains, and trucks for outbound logistics.

The overall system configuration also includes essential infrastructure such as administrative and operational buildings, laboratories, control rooms, and internal road networks. In the following sections, each step of the process will be examined in detail, based on the described system configuration. This integrated and holistic approach allows for a comprehensive analysis of the entire supply chain, highlighting areas that require further development. Additionally, attention should be given to ensuring compliance with sustainability criteria throughout the value chain, including chain of custody requirements.

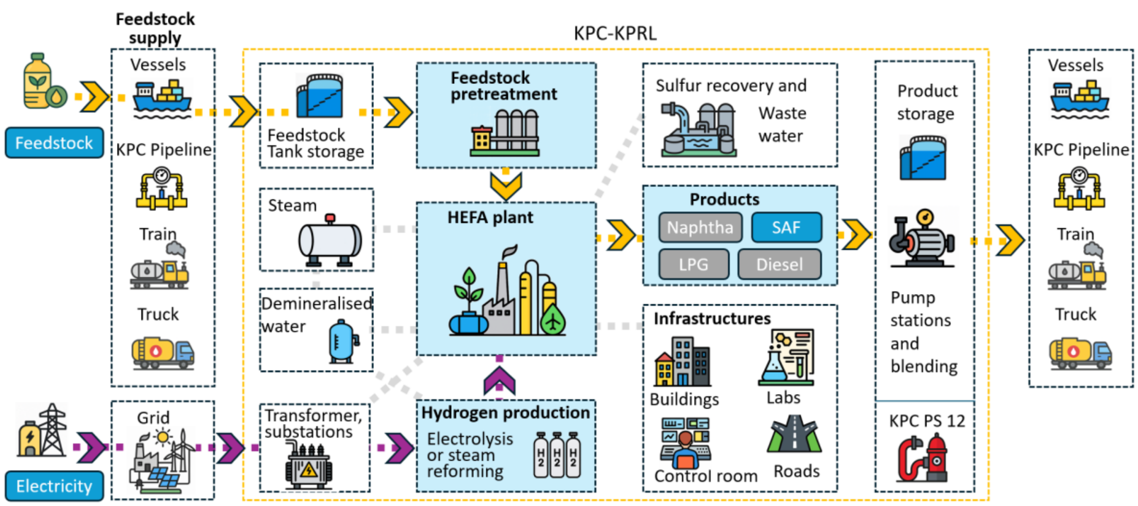


Figure 15. Example of supply chain using existing assets of KPC/KPRL.

2.5.1 Feedstock sourcing and logistics

Feedstock availability plays a critical role in the viability of the business case for SAF production. It directly influences the plant's production capacity, based on availability of the feedstock in the region, and impacts the sustainability credentials in term of greenhouse gas (GHG) emission reductions, and ultimately it determines the market value of the produced jet fuel.

For a HEFA plant, the intended feedstock will consist of vegetable oils, used cooking oil, or other lipid-based materials, preferably in liquid form to allow for easier handling and pumping. Several logistical options are under consideration for the transport and delivery of this feedstock:

1. **Inland pipeline -** If the vegetable oil is sourced from within Kenya, the decommissioned 14-inch pipeline (Line 1), managed by KPC and connecting Nairobi to Mombasa, could potentially be repurposed for this use. This would be subject to a technical assessment confirming that the physical properties of the vegetable oil, such as viscosity and density, are compatible with the pipeline's operational specifications.
2. **Terminal jetties -** If the feedstock is imported by sea (e.g., coastal region or neighbouring countries), it could be received at the terminal jetties, specifically Jetty II or Shimanzi, as Jetty I is currently being decommissioned. In this scenario, a dedicated pipeline from the jetty to the refinery would be required for the handling of vegetable oils. One possibility is to repurpose an existing but unused multiproduct or crude oil line, such as one connected to the Shimanzi terminal.
3. **Railways -** If the vegetable oil is sourced within Kenya or connected neighbouring countries, an option involves rail transport, particularly if pipeline use is not feasible. This will connect Mombasa and the western region of the country. The KPRL site is already equipped with a rail connection using meter gauge infrastructure. However, this rail line has been inactive since the pipeline became the dominant transport method, and it would require rehabilitation before being reactivated for feedstock delivery.
4. **Trucks -** road transport by truck may be suitable for short-distance haulage, especially for decentralized feedstock collection. Vegetable oils could be gathered from various sources and delivered to a centralized depot for further handling. KPRL is already equipped with truck loading and unloading facilities that could support this mode of transport.

A more detailed and sophisticated logistics system for feedstock collection must be established, enabling aggregation at various centralized locations before further transportation. Proposed solutions should consider material compatibility, viscosity, and fluidity, as these properties differ from those of crude oil. Each option and the status of the associated infrastructure need to be examined in detail.

<u>Inland pipeline</u>

Since 2016, a 20-inch pipeline has been operating between Mombasa and Nairobi. This pipeline is a unidirectional, multi-product system specifically designed for the transport of refined petroleum products, including PMS (petrol), AGO (diesel), jet fuel, and kerosene. It is dedicated solely to these fuels and is not suitable for transporting other types of products.

While vegetable oils cannot be transported through this multi-product line due to contamination risks and incompatibility, it could potentially be handled through an older decommissioned 14-inch pipeline (Line 1).

Line 1 was commissioned in 1978 and decommissioned in 2022. It operates along the same corridor than Line 5 connecting Mombasa and Nairobi, and it could potentially be repurposed for transporting non-petroleum liquids, such as vegetable oil, provided that the flow characteristics, including viscosity, density, and temperature behaviour, are compatible with the pipeline's design and operational parameters. Alternatively, it can be used for the transport of water if an electrolyzer for green hydrogen is operated.

This would enable the collection of oil from inland sources and transport to Mombasa at economical prices. However, further studies are required to assess the feasibility and technical requirements for repurposing the existing infrastructure and compatibility with vegetable oils.

Jetty infrastructure at the port terminal

Specialized jetties, such as the Kipevu Oil Terminal (KOT) and the Shimanzi Oil Terminal (SOT), are dedicated to the import and export of petroleum products. These facilities are equipped with pipelines and storage tanks to manage the flow of refined fuels (PMS, AGO, DPK) and LPG. Previously also crude oil was imported but this is no longer the case since the refinery processing was shut down.

Kipevu Oil Terminal is the primary facility for handling imported petroleum products. In 2022, a major upgrade was completed with the commissioning of a new offshore terminal (Figure 10), often referred to as KOT 2, while the old infrastructure KOT 1 are being decommissioned. KOT 2 is owned by the Kenya Ports Authority and operated by KPC. These modern terminal features expanded capacity, with four berths capable of accommodating large vessels of up to 200 000 deadweight tons, allowing simultaneous unloading of up to three vessels for petroleum products and one dedicated to LPG. The new jetty has a loading capacity of approximately 4 000 m^3/h, a significant increase compared to the previous jetty's capacity of 1 000 m^3/h. This development significantly improved the efficiency and reliability of Mombasa's fuel handling capabilities.

Alongside Kipevu, the older Shimanzi Oil Terminal continues to operate (Figure 10), though on a smaller scale. It primarily serves coastal shipping and local fuel distribution, handling smaller vessels (15 000-20 000 t) compared to the more advanced offshore facility (typically 85 000–100 000 t). Despite its age and limited capacity, Shimanzi remains an important part of the port's infrastructure, especially for domestic supply needs.

Once petroleum products are offloaded at the terminals, they are transferred via undersea or underground pipelines to onshore storage depots in the Kipevu area. These storage facilities, one operated by KPC (PS14) and one by KPRL (Figure 10) hold the fuel before it is pumped inland. The national pipeline system transports these products to major consumption and distribution centres across the country, including Nairobi, Eldoret, and Kisumu.

Since we are dealing with volumes in the range of 250 000 t/year, Jetty 2 (typically used for handling much larger quantities) may be oversized for our needs. In comparison, the Shimanzi terminal appears to be a more suitable option for the scale of operations.

Vegetable oil storage tanks (for food) are already in operation at the Shimanzi terminal, although they are currently managed by other private companies. The terminal is connected to the refinery through three pipelines: an 8-inch multiproduct line, an 8-inch LPG line, and a 12-inch fuel oil line. Vegetable oils require a dedicated pipeline to avoid contamination with other products. One possible solution would be to repurpose an existing but unused crude oil or multiproduct line, such as one of those at Shimanzi, or to construct a new pipeline specifically designed for vegetable oil transport.

Railway

Kenya's railway network has experienced a major transformation, shifting from its historical meter gauge system (MGR) to the more modern standard gauge railway (SGR), (Figure 16). The meter gauge railway, built during the colonial era with tracks one meter apart, once formed the backbone of regional transport with over 2 000 km network. It connects the Port of Mombasa to Nairobi, Kisumu, and onward to Uganda, facilitating trade and movement across East Africa. However, over time, this system became inefficient due to outdated infrastructure, slow speeds, and limited capacity.

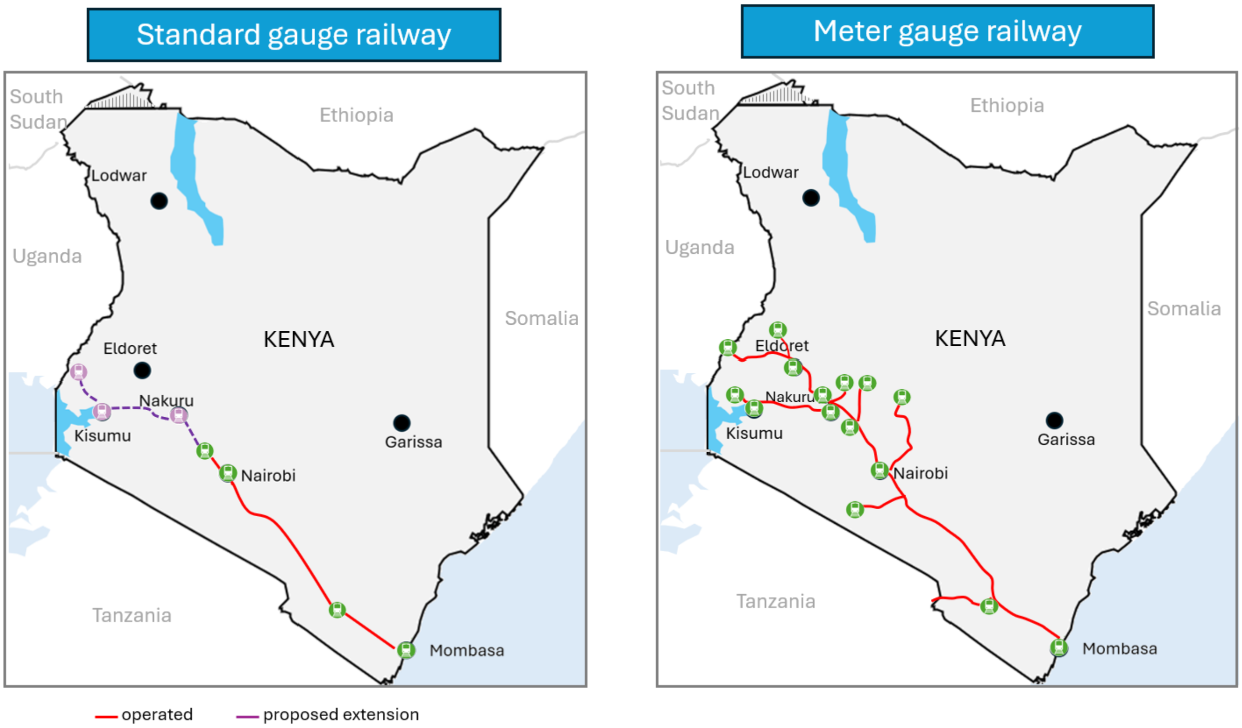


Figure 16. Standard gauge and meter gauge railway network adapted (Olander, 2023; KRC, 2025).

To address these challenges, the Kenyan government introduced the standard gauge railway, constructed with wider 1.435-meter tracks to allow for faster and heavier trains. The first phase, linking Mombasa to Nairobi, was completed in 2017. This new line significantly improved transport efficiency reduced pressure on highways and marked a major step in modernizing the country's logistics network. The SGR has since been extended to Naivasha, with long-term ambitions to reach the Ugandan border and integrate with a regional rail corridor. Funding has now been obtained for extension to Malaba, near the Uganda boarder. However, due to funding delays, construction beyond Naivasha has not progressed as quickly as planned. Today, both systems operate in tandem. While the standard gauge railway represents the future of high-capacity rail transport in Kenya and the region, the meter gauge network remains essential for cross-border trade and local connectivity.

Rail remains a viable alternative for transporting vegetable oil, especially if pipeline options are unavailable or impractical. Kenya Railways Corporation (KRC) already has experience transporting liquid cargo, including vegetable oils, using ISO tank containers, each with a capacity of approximately 24 000 L. The metre-gauge railway provides a logistical advantage as it enters directly into the Mombasa refinery site, where a loading and unloading station is already in place. This facility was previously used before all fuel distribution was shifted to pipeline transport, which remains the most economical transportation system. However, the existing rail infrastructure within KPRL is in poor condition and would require significant rehabilitation, including restoration of the track and of unloading stations, to support feedstock logistics.

From inland regions, it will be essential to develop an efficient feedstock collection strategy to minimize transportation costs. This would involve identifying cultivation areas and determining suitable locations for centralized aggregation points. A central depot could be established to collect vegetable oil from multiple sources, with onward transport to the terminal carried out either by rail or pipeline, depending on the most practical and cost-effective solution.

<u>Trucks</u>

Currently, vegetable oils (e.g., for food) are typically transported mainly by tanker truck or by rail. Trucks can be considered a suitable option for short-distance transport of vegetable oil, particularly as a first step in moving the product to centralized depots for further distribution. They are also a practical alternative in regions where neither pipeline nor railway infrastructure is available, but it should be noted that road transport is likely to be the most expensive mode of transportation. KPRL is equipped with truck loading (8 permanent bays) and unloading (2 permanent bays) stations (Figure 17), which have supported both regular operations and previous pilot schemes. The unloading stations were designed for the unloading of the waxy crude oil of Turkana, therefore they have also the possibility to handle viscous material, like vegetable oil. These systems were designed to handle waxy oils requiring heating, a feature that may also be beneficial for reducing the viscosity of certain types of vegetable oils.

For future operations, it will be important to assess whether the existing unloading facilities at KPRL, especially those installed during earlier pilot programs, are adequate in number and in status. It should be considered that only trucks for transporting vegetable oil may not be feasible. Considering that a tanker truck can transport ~23 tons per loading, moving large volumes such as 255 000 t/year will require 765 t/day of vegetables, which means 33 trucks per day. This presents logistical and economic challenges (considering also that one unloading operation can last more than 30 min). For this reason, an integrated approach that incorporates multiple transport modes, including pipelines and rail, is recommended, as these options are generally more practical and cost-effective for sustained for high-volume operations.

Figure 17. Loading station for tanker trucks at KPRL (used with permission from KPRL).

This section explored the various transport options available, with pipelines offering the lowest cost, followed by rail and then road transport. However, a dedicated and comprehensive logistics study should be conducted to optimize the supply chain and ensure reliable and efficient delivery of the feedstock.

2.5.2 Electrical supply and substations

Kenya's national electricity grid is composed of over 90% renewable energy sources, primarily driven by geothermal and hydropower generation. The total installed capacity of the grid is approximately 3.8 GW, with an average utilization of around 2.3 GW. Although Mombasa County primarily relies on thermal power generation from fossil fuels, it remains fully integrated into the national grid, thereby benefiting from the high share of renewable electricity in the overall energy mix.

Kenya Power serves as the national grid distributor, from which KPRL currently sources its electricity. The facility operates with two 15 MW transformers (configured with one as a standby in an exclusionary operation mode), stepping down voltage from 33 kV to 6.6 kV (used for high-power motors), and further reduced to 415 V for general equipment use. The current use of this capacity is less than 1 MW since the process plants are not in operations. There was also a project which developed an independent 9.2 MW power plant to ensure energy autonomy (fossil HGO); although it was commissioned, it was never brought online due to the refinery's shutdown in 2013.

The Mombasa County grid is sufficiently stable to support existing operations and could feasibly accommodate additional loads, including a 50–70 MW electrolyzer. A grid study conducted for a past project (KPRL internal study) confirmed this potential, though transformer upgrades would be required to handle increased capacity. The investment for upgrading the transformers should be considered in the case of electrolyzers, while in the case of steam reforming the current transformer capacity should be sufficient. Although Kenya presently experiences no routine load shedding, during its operational period the refinery recorded some short power outages per month, which should be considered for the plant design to avoid operations interruptions.

Within the KPRL site, electricity is routed through a central substation (Substation 1), which feeds a total of nine substations across the facility. The substation infrastructure is in good condition, with regular inspection and maintenance routines. The medium-voltage switchgear has over 30% available capacity, which can accommodate further loadings. The system maintains a power factor of 0.97. For critical loads, the site includes UPS-supported switchgear, battery chargers, and standby diesel generators rated at 360 kVA and 2×250 kVA, all maintained with weekly routines. Grounding systems are in place for tanks, buildings, and other critical infrastructure, while lightning protection systems are installed at the main substation to ensure safety and compliance with electrical standards.

Overall, the electrical system is in good condition and appears suitable for integration with a new HEFA production facility in the case hydrogen will be produced by the steam reformer, while major upgrades will be required for the electrolyzer.

2.5.3 Hydrogen production

No dedicated hydrogen production unit currently exists at the Mombasa refinery and there is no hydrogen producer nearby in the region that can provide the amount envisaged for HEFA or PtL plants. Historically, hydrogen was supplied via catalytic reforming of naphtha within the refinery, but the system is no longer viable and not feasible to reactivate, due to its current condition and the mismatch in design capacity for the naphtha volume produced in HEFA processes.

For SAF production, a new hydrogen production facility will be required. Several options are available:

1. **Water electrolysis –** This process involves splitting water into hydrogen and oxygen using electricity. To support a HEFA plant with a capacity of approximately 750 t/day, an electrolyzer in the range of 50–70 MW would be necessary. From a sustainability point of view, this option produces green hydrogen if the electricity is sourced from the grid (> 90% renewables) or other captive renewable plants, resulting in high GHG emissions saving. The decommissioned Line 1 pipeline where a section of the pipeline was repurposed for water transport from Mzima springs to Mombasa might need to be considered for revival for water delivery for use in the hydrogen production process.
2. **Steam reforming of renewable byproducts (e.g., naphtha or LPG) –** The naphtha generated in the process needs further refining and it does not have fuel grade quality for direct commercialization, and the limited volume may not justify investment in a new catalytic reformer. Bio-LPG and Bio-naphtha generated can be reformed to produce hydrogen. This pathway allows the use of renewable feedstocks to generate renewable hydrogen and offers the advantage of creating a more self-sufficient (autarkic) plant, reducing dependency on imported fuel. As the process utilizes biogenic feedstocks, the CO_2 emissions generated are considered climate-neutral. Moreover, incorporating carbon capture and sequestration (CCS) technologies could enable additional reductions in overall greenhouse gas (GHG) emissions.
3. **Steam reforming of fossil natural gas –** This route would require importing natural gas from neighbouring countries such as Tanzania or Uganda. Although infrastructure is currently lacking, it may become available in the future. However, using fossil-based natural gas would reduce the overall greenhouse gas (GHG) savings of the SAF plant and could affect compliance with sustainability criteria.
4. **Steam reforming of fossil-based LPG or naphtha –** In the absence of natural gas and insufficient availability of bio-based naphtha or LPG, fossil-derived LPG or naphtha may be used as feedstock for hydrogen production. However, this approach does not offer any greenhouse gas (GHG) emission reduction benefits and therefore does not contribute to the sustainability performance of the SAF pathway.

All hydrogen production routes require significant water input. Currently, municipal water is used to support the refinery's operational needs. To ensure a reliable and scalable water supply, the installation of a dedicated desalination plant may be considered as a supplementary or alternative option. The revival of the Mzima Springs water project using the decommissioned Line 1 pipeline.

2.5.4 Pretreatment of the feedstock

This type of unit is not commonly found in conventional crude oil refineries and as such, no feedstock pretreatment facilities currently exist on site. A completely new installation will be required, tailored to the specific characteristics of the feedstock to be processed. They can generally offer a degree of flexibility and can accommodate multiple feedstocks with similar physical properties. For vegetable oils, pretreatment typically includes degumming, water washing, and bleaching steps. Further details are provided in 1.7.

2.5.5 Condition of hydrotreater technology islands: status of static and rotating equipment

The refinery complexes were shut down on 4 September 2013. The shutdown was driven largely by political considerations and did not follow a structured, conventional procedure. Instead, it was executed as a temporary suspension, with the intention of potentially restarting operations within a short timeframe. As a result, the shutdown was not fully executed in accordance with standard decommissioning protocols. Several units were not completely drained or cleaned, and residual quantities of crude oil or intermediate products remain within the system. Additionally, some sections of the plant that contain catalysts, such as the hydrotreaters and platformers island, have been maintained under inert gas purging conditions. However, the long-term effectiveness of this preservation method remains uncertain, primarily due to difficulties in maintaining consistent positive pressure, likely caused by potential system leaks.

The last major inspections and shutdowns were conducted in 2009 for Complex I and in 2011 for Complex II. These inspections followed Shell's protocol (RSBI), which involves categorizing each unit within defined corrosion loops. This approach is used to assess corrosion rates and evaluate the likelihood and potential consequence of equipment failure. Under standard practice, the plant undergoes a full shutdown approximately every five years to carry out inspections and maintenance. Based on the corrosion assessments, a risk matrix is developed to rank equipment by criticality. If an asset is classified as high risk, corrective actions must be taken during the scheduled shutdown period. Non-destructive testing (NDT) was conducted at the time using wall thickness measurements to assess equipment condition.

In the years following the shutdown, maintenance budgets were significantly reduced and eventually unavailable for the refining complexes, making it impossible to fully preserve the units. Initially, the limited budget was prioritized for the most critical components, such as heat exchangers and furnaces; however, even these have experienced notable corrosion in recent years. No maintenance activities were carried out on the crude distillation units (CDUs), whose condition has since deteriorated severely.

In some cases, the external cladding of equipment has begun to detach, exposing underlying surfaces to further degradation. A particular concern is Corrosion Under Insulation (CUI), which poses a significant risk due to water ingress into thermal insulation systems. CUI is a form of localized external corrosion that occurs when moisture from rain, leaks, or condensation becomes trapped under insulation, remaining in contact with metal surfaces for extended periods. This creates a highly corrosive environment that often goes undetected. Carbon steel, which is widely used throughout the plant, is especially vulnerable, particularly in warm, humid coastal regions such as Mombasa, where the presence of airborne salts exacerbates the risk and severity of corrosion.

The furnaces had experienced severe corrosion, primarily due to prolonged use of heavy fuel oil and hydrogen sulphide (H_2S) as byproducts of the hydrotreaters, combined with condensation on the external surfaces of the furnace tubes. These conditions contributed to accelerated degradation of the metal.

Regarding the heat exchangers, some were externally coated for preservation purposes and appear to be in relatively good condition from the outside. However, stagnant water remains inside several units, creating an environment conducive to microbial activity. This has led to observed pitting corrosion for some units in the past, which is likely associated with Microbiologically Influenced Corrosion (MIC). Internal inspection is necessary to accurately assess the extent of damage in each unit. In general, wherever standing water is present within the system, there is a high likelihood of internal pitting and MIC. All insulated piping, reactors, and columns have the risk to be subject to active corrosion under insulation (CUI), which poses a significant risk to their structural integrity.

The two flare stacks, each approximately 60 m in height, were dismantled due to severe corrosion at their bases. The degradation was primarily caused by prolonged exposure to hydrogen sulphide (H_2S), which had led to extensive structural weakening and compromised their integrity, making removal necessary for safety reasons.

While the hydrotreater reactors have been kept under inert conditions, suggesting some level of internal preservation, their actual condition cannot be verified without thorough internal inspection. Additionally, there are some signs that suggest possible external corrosion under insulation, which may further affect their suitability for reuse. Based on current knowledge, the following considerations apply:

- Complex II Naphtha Hydrotreater: The reactor is not compatible with the process conditions or required metallurgy for HEFA operations and is therefore excluded from consideration.
- Complex I Kero Minus Hydrotreater: Like the naphtha unit, this reactor does not meet the necessary operating conditions or metallurgical requirements and is also excluded.
- Complex II Kerosene Hydrotreater: While the reactor may have originally been compatible with the required process conditions, the metallurgy is not adequate. Historical issues with hydrogen embrittlement were addressed through repairs; however, the equipment no longer meets modern safety and performance standards and is not recommended for reuse.

Regarding the remaining equipment in the Complex II Kerosene Hydrotreater area, assuming the sizing is compatible with the new HEFA plant, the following considerations can be made for each equipment.

Most of the heat exchangers in this section are in poor condition and not considered suitable for reuse. Internal inspection is particularly necessary at the return elbows, where lack of cleaning may have caused localized damage. Additionally, deterioration of internal elements such as baffles and refractory lining is a concern. The air coolers are assessed as non-recoverable and are not recommended for reuse.

The high-pressure and low-pressure separators, which are not insulated and have been maintained under a nitrogen blanket, are likely to have experienced minimal corrosion. These vessels were equipped with cathodic protection, which should be still active. However, it is important to note that they were previously exposed to acidic environments, including hydrogen sulphide (H_2S, sour water), which could have contributed to internal material degradation and should be carefully evaluated.

The stripper column was likely maintained under positive pressure, which may have helped preserve the internal trays. However, the external shell poses a high risk of corrosion under insulation (CUI) and requires detailed evaluation. This assessment can only be carried out by removing the insulation and performing internal inspections.

As for rotating equipment, the compressors may still be operable, but their flow capacity and operating pressure are inadequate for a new HEFA plant, rendering them not recommended for integration. The pumps appear to be potentially functional and could be reused, subject to detailed mechanical inspection. However, considering that pumps represent a relatively minor share of overall capital expenditure (CAPEX), it may be more prudent to install new items to mitigate the risk of future failure and improve operational reliability and efficiency.

Overall, some marginal components within the unit, such as non-insulated vessels, may be suitable for reuse, while others will require detailed inspection, refurbishment, or replacement. A comprehensive assessment should be conducted in collaboration with the selected HEFA technology provider to determine which units can be feasibly repurposed within the framework of their specific process requirements. As part of this evaluation, equipment with appropriate sizing should undergo thorough internal and external inspections, following a proper cleaning procedure prior to opening, to accurately assess their condition and suitability for integration.

2.5.6 Civil engineering and area available for construction

The KPRL refinery site covers a total area of approximately 153 ha. Currently, Complexes I and II occupy less than 5 ha, while the tank farm utilizes about 17 ha. More than 120 ha remains available for future industrial development. The land is fully zoned for industrial use, which allows for the construction of new facilities without major legal or zoning constraints. A site master plan outlines several potential future developments, including:

- 6 ha allocated for a new biodiesel or biorefinery plant,
- 9 ha proposed for LPG terminal expansions (under 31-year public private partnership agreement), (Mwambingu, 2025)
- 24 ha considered for a 33 MW photovoltaic plant.

The assessment revealed that the structure of main processing units, Complex I and Complex II, show significant deterioration and corrosion. Complex I is a single-level structure with all equipment located on the ground floor, while Complex II is built on a reinforced steel framework spanning multiple floors. Although Complex II is more recent than Complex I, it is in worse structural shape due to a lack of maintenance following the 2013 shutdown. Structural degradation includes degradation of concrete reinforcements and damage to substructures. Evidence of settlement, cracking, and spalling is visible in many concrete elements for the steel structure.

In addition, structural steel elements, including pipe racks, platforms, staircases, and walkways, are severely corroded and exhibit signs of buckling and joint fatigue. These structures lack the capacity for additional loads and offer no flexibility for expansion or integration with the new HEFA plant. Although some individual equipment could potentially be reused, relocation and installation in new foundations would be required.

Geotechnical investigations have revealed moderately weak soil conditions, leading to the use of pile foundations in past projects. Future projects will likely continue likely this practice after being confirmed with a soil load bearing study.

The tanks and pipelines are reported to be in good condition. Buildings on-site such as control rooms, substations, and warehouses are in good condition, compliant with current regulations, and have sufficient structural and space capacity for additional control systems or lab facilities. The existing buildings are in good condition and provide adequate space to accommodate a workforce of around 250 people, including the additional 100 personnel anticipated for the SAF facility. Previously, the refinery supported a staff of 350 before its shutdown, and with only 100 currently on site, there is sufficient capacity available.

Site grading and the stormwater drainage system are functional, with roadways and access routes suitable for transporting and installing new process equipment. No known flood risk zones or poor drainage areas were identified.

The existing power plant, originally designed to run on heavy fuel oil (HFO), remains structurally sound and it can be evaluated for reactivation. It should be note that the plant is running with fossil source, therefore the captive use of that will negatively affect the carbon footprint of SAF production. If power generated by the HVO plant is supplied to the grid and the plant connected as well to the grid, the renewable energy share of the grid can be accounted for in SAF production.

On permitting, Kenya's permitting process is relatively streamlined, particularly for government-supported investments. Approvals must be obtained from the Ministry of Energy and Petroleum and the National Environment Management Authority (NEMA), along with the local county government and Energy and Petroleum Regulatory Authority (EPRA) for construction permits. These processes typically take a year. There should be no major land-use restrictions that would impact new construction, but it should be considered that the site's proximity to Moi International Airport introduces height restrictions, though experience with flares up to 60 m in height has been permitted.

Regarding construction logistics, the existing infrastructure, such as the seaport and road networks, are well-developed and capable of supporting the transport of large, prefabricated units. Similar projects involving large equipment have previously been executed using modular transport, with Kenya's national highways successfully accommodating comparable loads. As a result, the site can be well-suited for a modular plant construction approach, with sufficient space available for a construction yard and material storage. A study on the transportation of large equipment is recommended during the basic engineering phase.

The existing complexes are not currently scheduled for dismantling, and there is no legal obligation to remove them in the near term; this will depend on future policy decisions. If dismantling is required, a formal proposal from KPC and KPRL must be submitted to the Treasury or other relevant government authorities for approval. Their removal can be planned separately and does not need to be integrated into the SAF project.

2.5.7 Environmental, Health & Safety (EHS)

The EHS (Environment, Health, and Safety) team is engaged in standard procedures related to waste management, air and water emissions, and overall safety and environmental compliance for the current site (without the refining operations). Additionally, EHS plays a key role in conducting Environmental Impact Assessments (EIA) required for the development of new processing facilities. This section addresses both aspects. Waste management follows a clear system, with separate procedures for hazardous and non-hazardous materials. Certified third-party contractors are used to ensure proper tracking and disposal.

Table 12. EMC (Air Quality Regulations) 2014 ambient air quality tolerance limits.

Pollutant	Time weighted average	Industrial area	Residential, rural & other
Sulphur oxides (SO_x)	Annual average	80 µg/m³	60 µg/m³
	24 hours	125 µg/m³	80 µg/m³
Oxides of nitrogen (NO_x)	Annual average	80 µg/m³	60 µg/m³
	24 hours	150 µg/m³	80 µg/m³
PM10	Annual average	70 µg/m³	50 µg/m³

Pollutant	Time weighted average	Industrial area	Residential, rural & other
	24 hours	150 µg/m³	100 µg/m³
PM2.5	Annual average	35 µg/m³	-
	24 hours	75 µg/m³	-
Carbon monoxide (CO)	8 hours	5.0 mg/m³	2.0 mg/m³
	1 hour	10.0 mg/m³	4.0 mg/m³
Volatile organic compounds (VOC)	24 hours	600 µg/m³	-

Regarding air and effluent emissions, the facility currently performs annual stack emission monitoring and quarterly effluent testing. Currently air emissions primarily originate from diesel generators and compressors. At present, wastewater treatment is minimal and relies on a skimming process to separate oil from water before discharge. The oil is collected in a slop tank, while the effluent is discharged in the municipal network if the water quality analysis is compliant. An annual discharge license is required for this operation. Emission limits for both air and water are regulated according to the limits shown in Table 12 and Table 13.

Table 13. Limits for a composite effluent sample.

Parameters	Methods	Standard limit
pH	CSITP 002	6.0 - 9.0
Colour in Hazen units	CSITP 009	40
Biological oxygen demand - (BOD5 at 20°C), mg/L	KS ISO 5815	500
Chemical oxygen demand (COD), mg/L	KS ISO 6060	1000
Total dissolved solids (TDS), mg/L	CSITP 012	2000
Total suspended solids (TSS), mg/L	CSITP 007	250
Oil and grease, mg/L	CSITP 014	5
Trivalent chromium as Cr3+, mg/L	CSITP 003	2
Hexavalent chromium as Cr6+, mg/L	CSITP 003	2
Phenols, mg/L	KS ISO 14402	10
Ammonia nitrogen as NH3-N, mg/L	KS ISO 11905	20
Sulfide as S_2-, mg/L	KS ISO 10530	2
Toluene, µg/L	ISO 16265	Np
Ethylbenzene, µg/L	ISO 16266	Np
Xylene, µg/L	ISO 16265	Np
Benzene, µg/L	ISO 11423	500

Existing safety infrastructure includes fire suppression systems, gas detection, and emergency exits. These systems are already in place and will be upgraded as necessary based on the specifications of the new SAF plant. EHS training for personnel is well established. The EHS team is responsible for organizing these trainings and ensuring operational readiness.

Regarding new plant installation, environmental assessments are mandatory for any new project at the facility. To initiate a new project, an Environmental Impact Assessment (EIA) must be conducted as part of the regulatory approval process. The EIA evaluates the potential environmental and social impacts of the proposed development. It typically includes assessments of air and water quality, waste generation, noise, biodiversity, and land use, along with health and safety risks. The process also involves public participation and stakeholder engagement, especially with affected local communities, to ensure transparency and incorporate local concerns.

Once the assessment is completed, it is submitted to the National Environment Management Authority (NEMA) for approval. In parallel, any changes to the plant's design must be submitted to the Energy and Petroleum Regulatory Authority (EPRA), which coordinates further consultation with industry stakeholders. This dual process ensures that both environmental and technical compliance need to be achieved before work begins. EPRA plays a vital role in the regulation of petroleum and energy infrastructure. It is responsible for issuing licenses, approving design changes, regulating tariffs for electricity and fuel, and monitoring compliance across the sector. NEMA, on the other hand, oversees environmental compliance and the EIA process. In any new project, approvals must be obtained from both bodies.

No significant existing contamination has been identified, and soil remediation is not expected to be necessary; however, this will ultimately depend on the results of the formal Environmental Impact Assessment (EIA).

Community and stakeholder engagement is considered essential. Since the site is already industrialized and the project does not affect community land, the local response is expected to be positive. The conversion project is also likely to generate local employment opportunities. Engagement with the community is integrated into the EIA process and is viewed as a necessary part of regulatory compliance.

2.5.8 Ancillary units and utilities

The plant also requires the integration of several utility and support systems, including:

- A unit for acid gas removal and hydrogen recovery and purification
- Facilities for sour water and wastewater treatment
- A sulphur recovery unit
- A cooling water system
- A demineralized water production unit
- Boilers for steam
- A flare system

The Acid Gas Removal Unit removed hydrogen sulphide (H_2S) and carbon dioxide (CO_2), from the hydrogen-rich gas stream, which will be recycled. H_2S and CO_2 are present or formed during the hydrodeoxygenation reaction. This is to ensure that downstream equipment and catalysts are protected and to prevent the release of harmful sulphur compounds into the environment, ensuring compliance with strict air quality and emissions regulations.

Typically, the Acid Gas Removal Unit in a HEFA facility uses an amine-based solvent system, such as monoethanolamine (MEA) or diethanolamine (DEA), to absorb hydrogen sulphide and carbon dioxide. The gas stream is passed through an absorber column where it comes into contact with the amine solution, which selectively absorbs the acid gases. The resulting "rich" amine is then directed to a regeneration unit, where heat is applied to strip out the absorbed gases, producing a "lean" amine that can be recycled back into the system. The stripped acid gases, primarily hydrogen sulphide, are usually sent to a sulphur recovery unit or a thermal oxidizer, depending on the scale and configuration of the plant. The Acid Gas Removal Unit is not currently available at the refinery and will need to be installed as a completely new system.

In a HEFA plant, both sour water treatment and wastewater treatment are also units that are needs to be installed. Sour water is typically generated during the hydrotreating. This water becomes contaminated with hydrogen sulphide (H_2S), ammonia (NH_3), and other volatile compounds, making it corrosive and environmentally hazardous if untreated. To manage this, the sour water is collected from various units in the plant and directed to a sour water stripper. In this unit, the water is heated, usually with steam, and volatile components such as hydrogen sulphide and ammonia are removed through a stripping process. The resulting gas stream is then typically routed to a sulphur recovery unit or an ammonia handling system, depending on the specific plant configuration. Once the sour components are removed, the treated water is either sent to the wastewater treatment system for further purification or reused within the facility where applicable.

Wastewater treatment in a HEFA plant covers all other aqueous effluents generated across the site, such as the pretreatment facility, the hydrotreaters and other eventual units. The treatment process typically begins with pre-treatment, where oil, grease, and suspended solids are removed through physical separation methods such as API separators or dissolved air flotation units. Subsequent treatment steps include biological processes that use aerobic or anaerobic systems to degrade organic contaminants, followed by chemical treatments such as pH adjustment, coagulation, and flocculation to remove remaining impurities and heavy metals. In many cases, the treated water undergoes final polishing through filtration or disinfection to meet regulatory standards for discharge or to enable reuse within the plant. There is a possibility that some of the existing sour water strippers on site could be reused, but this would need to be verified through further assessment. The wastewater treatment facility is currently non-operational, and it may be not sized to handle the expected volume of effluent, probably making the installation of a new treatment unit necessary.

The separated H_2S must be converted into a stable form, such as elemental sulphur or a sulphur salt, or adsorbed in a filter, to ensure safe handling and storage. Several methods are available for this conversion, and the most economically viable approach will depend on the quantity of sulphur to be recovered. It is essential to include a dedicated recovery unit for sulphur in the plant design.

A cooling water facility is required for the plant. There is an existing cooling tower on-site that may still be operational, but its condition must be assessed to determine whether it can be reused. This tower forms part of the cooling water system previously in use at the refinery.

Currently, municipal fresh water is supplied to meet the refinery's operational needs. However, KPRL have access to seawater, and this could potentially be used for specific purposes, such as system testing. For example, seawater is used for hydrotesting storage tanks following maintenance activities, after which the water is typically discharged and the system switched back to fresh water. The existing demineralized water plant, which uses ion exchange resins, is no longer functional and is not in a condition suitable for refurbishment. A new demineralized water unit will need to be installed. At the time of shutdown, the system had not been emptied and still contains residual acids and bases, and the external parts of the equipment are visibly corroded.

The large boilers previously used for the refining complexes are no longer available, and only two small units remain, which produce saturated steam. The existing small boilers are operational but may be undersized for the plant's full steam demand. However, a detailed heat integration study should be carried out before determining the required boiler capacity, as steam can also be exported from units such as the steam reformer and the hydrotreater and it could cover the overall steam requirements.

A functioning air compressor is currently in place and operational. The facility uses compressed air at an operating pressure of 4 bar for instrumentation, which aligns with standard industry practices. Additionally, a nitrogen tank is available on-site and is regularly refilled to ensure continuous supply.

The original flare units were dismantled due to structural stability concerns. As a result, a new flare system will need to be designed and installed to meet safety and regulatory requirements.

In terms of fire protection, the existing fresh water supply may be insufficient to handle large-scale firefighting needs, particularly in emergency situations, but they can have access to sea water.

Regarding energy and fuel utilities, Kenya currently neither produces nor imports natural gas for industrial use. Liquefied Petroleum Gas (LPG) is mainly used for domestic cooking. Although Tanzania has established natural gas production, the primary constraint to its availability in Kenya is the lack of cross-border transport infrastructure. However, there is potential for future projects focused on developing the necessary infrastructure to facilitate natural gas imports. To meet high-energy demands, most industrial facilities rely on heating fuel oil. This is also the case for the two power plants operating in Mombasa. Heavy fuel oil is predominantly imported into the country to support these industrial and power generation needs.

2.5.9 Control room and instrumentation & automation

The control room is located outside the main process complexes, in a designated area considered safe from operational hazards. It is housed in a well-maintained explosion-proof building and provides centralized control over the refinery's processing units (currently non-operational) as well as the active pump station and tank farm.

The existing control system is based on Yokogawa technology. While it remains functional for basic process monitoring and control, it is outdated and lacks the capabilities required for a modern HEFA-based SAF facility. A complete system upgrade will be necessary to meet current industrial standards, including integration with Enterprise Resource Planning (ERP) systems for real-time data and operational efficiency. In recent years, there were plans to modernize the truck loading and unloading stations using a new control system. However, this initiative was halted following the suspension of the pilot scheme project.

Within the tank farm and blending areas, instrumentation is installed to monitor critical parameters such as pressure, temperature, and liquid levels. Operators can currently start and stop pumps remotely, but many valves, particularly those in the blending area, are still operated manually. A previous automation upgrade project, which included the installation of automated valve actuators, was initiated but not completed. The facility employs compressed air at 4 bar operating pressure for instrumentation purposes, a practice consistent with industry standards.

An upgraded control system will be developed for the HEFA plant, incorporating the latest technological standards. Although the existing instrumentation and automation systems for the tank farm and pump stations are still functional, a comprehensive modernization may be necessary to ensure improved reliability and seamless integration with the new SAF production unit.

2.5.10 Tank farm

The storage infrastructure in the Changamwe comprises a total of 73 tanks (including small tanks for utilities) of diverse types and configurations, including fixed cone roofs, floating roofs, and combi tanks (tanks with a fixed roof and internal floating roof, and in some cases, an external geodesic dome). These tanks are primarily constructed from carbon steel and have been designed following international standards such as API 650. For inspection and maintenance, the facility adheres to EEMUA 159 guidelines, which cover tank condition assessment, integrity management, and routine monitoring using non-destructive testing (NDT).

A protective coating system is rigorously applied to both the internal and external surfaces of the tanks. Internal coatings are selected based on chemical compatibility, using materials such as epoxy, depending on the product stored. Some of the tanks are also insulated and jacketed, with thermal systems in place to accommodate products that require heating, such as Kenyan crude oil or heavy fuel oil. Corrosion prevention is managed using high-quality coatings and slightly elevated tank foundations to prevent water percolation and bottom plate corrosion.

The overall condition of the tanks is very good, as they are well-preserved through regular maintenance and monitoring. The site includes various types of storage tanks, each designed to accommodate products with different hazard classifications (Table 14).

Table 14. Storage tank categories by product hazard level.

Category	Description	Examples of stored products	Typical tank features
Category 0	Non-hazardous or very low hazard	Water, inert materials	Basic atmospheric tanks
Category 1	Low hazard – flammable liquids with high flash point	Diesel (AGO), HFO	Fixed-roof tanks, minimal safety instrumentation
Category 2	Medium to high hazard – flammable, volatile or toxic	PMS (gasoline), Kerosene (DPK), LPG, crude oil	Floating roof or pressurized tanks, vapor recovery, extensive safety systems

Currently, most of the tanks in Changamwe are used for storing Premium Motor Spirit (PMS) and Automotive Gas Oil (AGO), with individual capacities ranging from approximately 3 000 m³ to 18 000 m³. Additionally, three tanks are dedicated to Dual Purpose Kerosene (DPK), two are allocated for Heavy Fuel Oil (HFO) and two spherical tanks for LPG. Previously, six tanks had been designated for the storage of Kenyan crude oil, which requires preheating to 60–80°C. These tanks are equipped with heating systems and insulating jackets. Following the conclusion of the pilot scheme, these tanks were either converted for HFO storage or repurposed for PMS, depending on operational needs. It is important to note that additional tank structures are also located in the Kipevu area, complementing the main storage facilities at the refinery. In the Kipevu oil terminal tanks (KOT-Port Reitz) five former crude tanks were recently converted to AGO storage.

Several tanks are available and in good condition for potential allocation to SAF storage. For 100% neat SAF, intermediate storage tanks will be required, along with dedicated tanks for blended SAF, which, once certified, can be classified as Jet-A or Jet-A1. Since certified SAF is chemically compatible with kerosene, existing tanks approved for jet fuel can likely be used without modifications. However, additional material compatibility checks should be conducted in the case of neat SAF, especially considering that it contains no aromatics, which may affect certain sealing materials or coatings.

In addition, consideration should be given to storage requirements for HVO diesel, bio-naphtha, and bio-LPG/off-gas as part of the overall infrastructure planning. HVO diesel and bio-naphtha can likely be accommodated within the existing tank infrastructure. For example, there are two old, decommissioned naphtha tanks that could be reused after inspection and maintenance rehabilitation. However, it may be necessary to consider installing a small tank to serve as buffer storage for LPG and off-gas. Tanks will be also necessary to store vegetable oils.

Although KPRL possesses a range of storage tanks, some of which may be technically suitable for the project, in the final phase of this study, we were informed that competing demands from other initiatives could limit their availability. Consequently, the potential requirement for constructing new, dedicated tanks to support SAF development should be carefully considered.

2.5.11 Blending facilities and pump equipment

Blending of SAF must take place at facilities equipped to handle aviation fuels, typically at the refinery and specialized fuel terminals. Neat SAF must comply with ASTM D7566, which specifies the technical requirements for synthetic aviation fuels. However, the use of neat SAF in commercial aviation has not yet been approved. Instead, SAF must be blended with conventional fossil-based Jet A or Jet A-1 fuel before use. Once blended, the resulting fuel mixture is re-certified according to ASTM D1655, the standard specification for conventional jet fuel. This certification ensures that the blended fuel meets all necessary safety and performance standards required for commercial aviation. For the HEFA production pathway, SAF can be blended with fossil jet fuel at ratios of up to 50% by volume. This blending ratio necessitates adequate tank capacity and pumping infrastructure to manage the combined fuels effectively.

Currently, the facility is already set up to perform blending operations. Piping, product lines, and pump stations are strategically concentrated in a central area of the tank farm, providing flexibility for rerouting, blending, and distribution. The site is equipped with high-capacity pumps operating at 6.6 kV, ensuring efficient handling of large volumes of fuel. Blending activities are performed in selected tanks equipped with mixer, to guarantee homogeneity. At present, blending is primarily used to adjust product specifications and is conducted in batch mode by monitoring tank levels.

While metering systems are installed across various areas of the refinery, for monitoring both incoming and outgoing product volumes, particularly for truck and pipeline operations, blending tanks themselves are monitored solely by level measurement. The blending of SAF with Jet-A1 is expected to take place in batch mode, using tank-level monitoring to verify the blend ratios. While the current systems are suitable for this approach, it will be necessary to assess the required accuracy and compliance standards to ensure the blending process meets SAF certification criteria (e.g., whether metering is required).

Blending within the refinery is strongly recommended, while blending at the airport terminal is excluded according to JIG 2: 2.3.2(b)(JIG, 2022), where only certified ASTM D1655 and Def Stan 91-091 jet fuel can enter, to avoid not conform batches at the facility. Alternatively blending at intermediate fuel depots would be allowed, but logistically it will be favourable to perform inside the refinery. The refinery site has ample tank capacity and a well-equipped laboratory capable of supporting the certification process. Additionally, blending on-site avoids the challenges associated with transporting neat SAF, which is generally not allowed in multiproduct pipelines. In contrast, certified SAF blends are compatible with the existing jet fuel infrastructure and can be distributed through systems such as KPC Line 5 to Nairobi or via the multiproduct pipeline to the marine jetties. However, depending on the destination, neat SAF may be considered a better option for export.

Information regarding blending methods and accuracy is limited, even though these aspects should be subject to regulation (Buxton, 2025). The blending process must be properly certified, and product homogeneity must be ensured to avoid issues such as stratification or layering within the tank. For this reason, it is generally recommended to use parallel blending, where two separate batches are transferred simultaneously into a third tank (Moriarty and McCormick, 2024). This method is preferred over sequential blending, as it provides better mixing and more consistent product quality.

These operations need to be documented according to a rigorous certification framework to ensure traceability, quality and compliance throughout the SAF supply chain (Figure 18). Each batch of petroleum jet fuel produced at a refinery is assigned a unique batch number and undergoes a full conformity test, resulting in the issuance of a Refinery Certificate of Quality (RCQ). As the fuel moves through the supply chain, a Certificate of Analysis (COA) is generated for each transfer point, requiring the retesting of key fuel properties to ensure ongoing compliance. At SAF production facilities, a Certificate of Quality is issued to verify conformance with the relevant annex of ASTM D7566. Additionally, a COA is produced at the point where Jet A and SAF are blended, and at every subsequent stage in the supply chain, since blended fuel may be transferred between multiple terminals. Laboratories are required to issue Certificates of Quality (COQs) or Refinery Certificates of Quality (RCQs) to confirm that the blended fuel meets all applicable specifications (see 2.5.13).

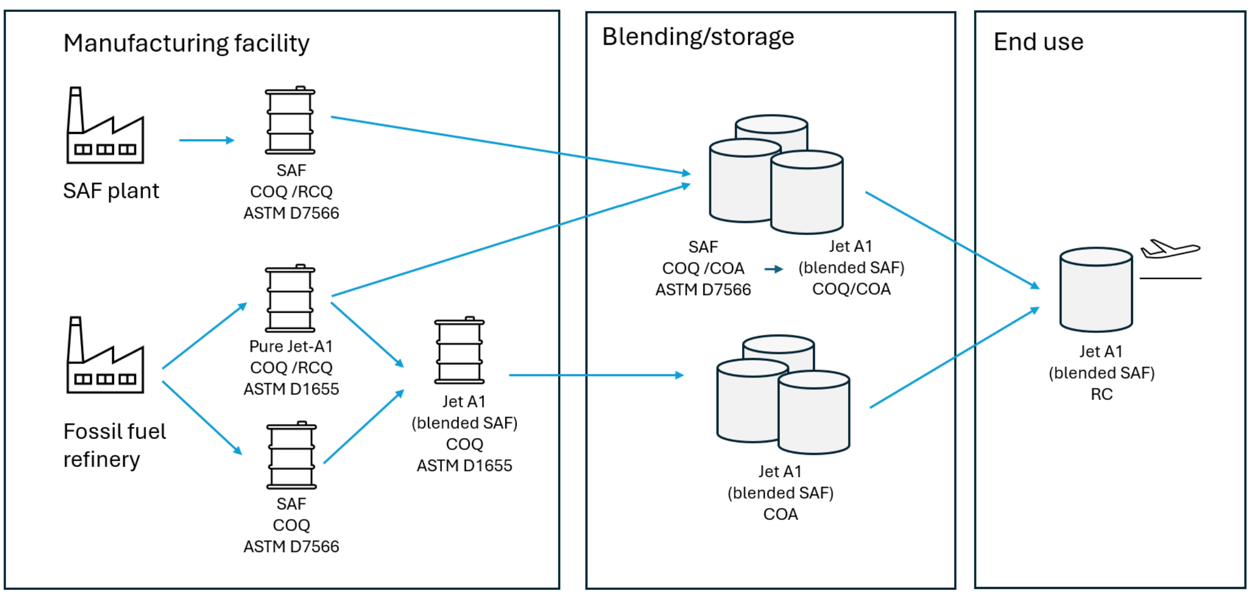


Figure 18. Blending and certification of SAF (JIG, 2022).

2.5.12 Fossil product sourcing for blending

The Kenyan government has used different models over time to manage the importation and distribution of petroleum products across the country. Historically, the country relied on an open tender system, where each month a single importer was selected through a competitive tendering process overseen by the Ministry of Energy and the Energy and Petroleum Regulatory Authority (EPRA). The winning importer would then be responsible for bringing in fuel for the entire country, which was subsequently allocated to various Oil Marketing Companies (OMCs) for local distribution.

However, in response to foreign currency shortages and economic pressure, Kenya adopted a new procurement model in 2023 known as the government-to-government (G-to-G) fuel import arrangement (Hafsah, 2024). Under this framework, Kenya entered into supply agreements with three state-backed entities from Gulf countries: Saudi Aramco from Saudi Arabia, ENOC from the United Arab Emirates, and NOOC from Qatar. These companies agreed to deliver petroleum products to Kenya on a deferred payment basis, allowing the country up to six months to settle the invoices in an effort to ease pressure on the local dollar reserves. To manage the actual importation of fuel, the government appointed three local firms (Gulf Energy, Oryx, and Galana Oil) to act as the exclusive importers under the G-to-G framework.

Oil Marketing Companies such as TotalEnergies, Vivo Energy (Shell), Rubis, and a host of smaller players continue to play a central role in the distribution chain. They purchase fuel from the appointed importers and then distribute it to retail service stations, industrial clients, and public institutions. The allocation of fuel among OMCs is done proportionally based on each company's market share. These companies operate under price controls, with pump prices being set by EPRA through a regulatory framework designed to stabilize consumer costs. The KPC is responsible for transporting and storing the petroleum products, using its extensive network of pipelines and inland depots. KPRL, as a subsidiary of KPC, also shares its storage facilities for the oil marketer products. To prevent long-term tank occupancy, a 30-day product removal policy is enforced and marketers who fail to clear their product within this period are subject to penalties.

Overall, the government continues to oversee the import and policy direction of the petroleum sector, with EPRA playing a regulatory role in pricing and licensing. Appointed importers handle the fuel inflows, while OMCs ensure that petroleum products reach consumers across the country. The KPC remains a key logistical operator in maintaining fuel movement and storage across the national network. Fossil fuels continue to play a key role in SAF blending, and it is essential for stakeholders involved in the jet fuel market to coordinate with SAF producers to ensure seamless integration within the supply chain, especially when distributing blended SAF.

2.5.13 Laboratory infrastructure

To ensure compliance and traceability (JIG, 2022; Moriarty and McCormick, 2024), several types of certification documents are used between producers, distributors, and buyers:

- A Refinery Certificate of Quality (RCQ) is issued for each batch of petroleum jet fuel produced at a refinery. It includes the batch number, quantity, refinery name, date, confirmation of compliance with ASTM D1655 (Jet A), and the type and amount of any additives used.
- A Certificate of Quality (COQ) is produced at SAF facilities and contains similar data than an RCQ, but testing is performed according to the relevant annex of ASTM D7566.
- A Certificate of Analysis (COA) is generated at key transition points in the supply chain by certified, third-party laboratories. It confirms that the fuel meets ASTM D1655 or D7566 specifications and the standard for jet fuel quality control at airports. A COA is also issued when SAF is blended with Jet A, serving as proof that the final fuel meets ASTM D1655 requirements.
- A Recertification Test Certificate is used when there's a potential risk of contamination, such as after transport through a multiproduct pipeline or marine vessel. Though it covers fewer parameters than an RCQ, it ensures that the fuel remains within specification and that no significant deviations are detected.

SAF is blended with Jet A either according to end-user requirements or up to the maximum permitted by the fuel's technology pathway. Once testing confirms compliance with ASTM D7566 Annex 1, the fuel is reclassified as ASTM D1655.

Three laboratories are present between KPC and KPRL: PS14 (KPC at Kipevu), PS1 (KPC in Changamwe), PS15 (KPRL at Changamwe). The three labs support and complement each other for the QC analysis. The labs generally conduct analysis on all the petroleum product they receive (Jet-A1, AGO, PMS, HFO, residual oil and LPG). They also participate in proficiency tests in local-interlaboratory cross check program and ASTM-proficiency testing-renewed-product analysed.

A high-level evaluation was conducted on the testing capabilities of KPRL PS14 and PS15 for SAF and Jet A-1 analysis, referencing applicable standards such as ASTM D1655, ASTM D7566, Def Stan 91-091, JIG/152, and JIG/1530. The review identifies current capabilities, gaps, and potential areas for upgrading.

PS14 lab is ISO 17025:2017 accredited by KENAS (Kenya Accreditation Service) and PS15 lab is accredited to ISO 17025:2017, with renewal in progress. KEBS (Kenya Bureau of Standards) is responsible for developing and publishing national standards and certifying that products comply with these established requirements. It also conducts audits and inspections to verify adherence to the relevant Kenyan standards. It is also likely that ASTM D7566 will need to be adopted or harmonized as a Kenyan standard to be recognized at the national level.

While the laboratories are already equipped to perform analyses according to ASTM D1655, certain gaps remain in meeting the full testing requirements of ASTM D7566. Table 15 outlines the tests commonly conducted at both facilities, those performed at only one lab but not the other (and thus complementary), and the specific testing gaps that would need to be addressed to fully support ASTM D7566 compliance.

Table 15. Overview of the analysis performed in PS14 and PS15 with gap analysis for D7566.

Common tests done at PS14 and PS15	Tests not done at PS14	Tests not done at PS15	Gaps in analysis
Distillation	Aromatics content	FAME content	Viscosity at -40 °C D445
Density	Viscosity at 20 °C	Electrical conductivity	Lubricity D5001
Visual appearance	Specific energy	Sulphur content	Naphthalenes D1840
Acid appearance	Total acidity	JFTOT	Mercaptan sulphur D3227
Color saybolt	Existent gum	MSEP	-
-	Particulate contamination	Particle count	-
-	-	Auto freezing point D5972	-
-	-	Auto smoke point	-

In parallel, it will be important to extend analytical capabilities to cover the characterization of vegetable oils and other feedstocks. This may involve testing for parameters such as free fatty acids, moisture and volatile matter, insoluble impurities, unsaponifiable content, phosphorus, total metals (including Mg, B, Na, Fe, Zn, K, Ca, and Si), nitrogen, sulphur, chlorides, and polyethylene (NREL *et al.*, 2024). Some equipment, such as an atomic absorption spectrometer for metal analysis, is already available, though alignment with specific analytical standards may be necessary. Additional instruments might also be required to meet the full range of testing needs.

Furthermore, it should be evaluated whether Carbon-14 (C^{14}) analysis will be necessary to verify the biogenic content of the fuel. This requirement will depend on the regulatory framework under which the SAF is certified and marketed (SGS, 2021; Turner, 2024).

Overall, the laboratory has adequate space and is well-maintained, making it suitable for the installation of new equipment. As analytical demands increase, particularly with the introduction of SAF production, staffing levels may need to be expanded to support the additional workload.

2.5.14 Product logistics

Since the recommendation is for SAF to leave the refinery already blended and certified as Jet A-1, it can utilize the existing jet fuel distribution infrastructure without the need for major adjustments. Once blended and certified, SAF becomes fully compatible with current systems and can be transported via the multiproduct pipeline and reach the port for export through vessels or Nairobi through Line 5.

This approach offers a clear logistical advantage, as neat SAF, being unblended, is typically not permitted in shared pipelines due to contamination risks. Blending at the refinery allows for certification at the source and seamless integration into the national distribution network. Railway for product distribution is not foreseen, since the blended jet fuel can reach the same destinations by pipeline (unless required for special deliveries, e.g., neat SAF). Tanker trucks will be useful in supplying remote airports that are not served by the pipeline.

If neat SAF is exported, it should be considered a dedicated pipeline to the port or transported by tanker trucks as second option. In all cases, certification requirements and distribution modalities should be further coordinated with EPRA to ensure regulatory compliance.

One specific method of jet fuel distribution is via a hydrant system directly to the airport. Moi International Airport serves as an example of this approach. Fuel distribution to the airport involves an intermediary step: KPRL supplies the fuel to PS-12, a station operated by KPC in the airport depot, from where it is then transferred to the airport hydrant system. PS-12 infrastructure at Moi International Airport is composed of a total of four storage tanks, each with a capacity of 1 500 m^3. Two tanks are designated for receiving fuel from KPRL, while the remaining two are used for issuing fuel to aircraft.

Upon receipt from KPRL, the Jet A-1 fuel is transferred into the receiving tanks, where it is allowed to settle for 24 hours and samples are submitted for quality analysis, described in the Joint Inspection Group (JIG) procedure. The most critical parameter assessed at this stage is the fuel's electrical conductivity, which must conform to the JIG specification range of 60–600 pS/m (picosiemens/metre). If the conductivity falls below this threshold, an additive known as Stadis 450 is introduced to increase conductivity and ensure proper electrostatic discharge during aircraft operations. Once the certification from the laboratory is released, the fuel can be transferred from the receiving to the issuing tanks and settle for 24 hours before some parameters are checked again and the fuel sent over the fence. Prior to distribution, the fuel passes through a system of filters and coalescers designed to remove water and particulates. Fuel delivery to aircraft is facilitated via a network of 20 hydrant valves located across the airport. For smaller regional airports, fuel delivery is conducted using tanker trucks leaving from PS-12. The fuel distribution chain operates through licensed marketers who purchase specified volumes of Jet A-1. All handling, quality assurance, and operational procedures strictly adhere to JIG guidelines, ensuring compliance with international aviation fuel standards.

A similar type of hydrant facility exists at Jomo Kenyatta International Airport (JKIA) in Nairobi. However, these facilities are too small to support fuel blending operations. The only additive typically introduced is Stadis 450, dosed in minimal quantities. These facilities lack the required pump capacity, sufficient tank storage, and laboratory capabilities for certification, making them unsuitable for on-site blending. This reinforces the conclusion that blending is best carried out at the refinery.

2.5.15 Traceability and sustainability certification management system

The blending of SAF with conventional jet fuel is subject to strict certification and traceability requirements to ensure fuel quality, compliance with aviation standards, and the accurate accounting of renewable content for environmental and regulatory purposes. In 2.5.13, we examined the importance of the certificate of analysis to confirm the fuel composition and the SAF percentage. In parallel, sustainability certification schemes play a key role in verifying the renewable nature of the SAF, the feedstock source, and the lifecycle greenhouse gas emissions reductions achieved.

Although the final product is chemically indistinguishable from traditional jet fuel, the renewable portion is carefully tracked and documented to verify its origin and sustainability. Looking ahead, it will be essential to implement a robust traceability system that ensures compliance with sustainability frameworks such as CORSIA or for other regional market. This system should maintain comprehensive records across the entire value chain, from feedstock sourcing to delivery at the airport, and be verifiable under certification schemes such as the International Sustainability and Carbon Certification (ISCC), the Roundtable on Sustainable Biomaterials (RSB). It must include the documentation of emission reductions, the monitoring of upstream (Scope 3) emissions, and the application of chain-of-custody mechanisms for renewable content.

These certification and documentation processes are essential not only to ensure that SAF is safely used in aircraft but also to validate its environmental benefits and support its recognition in emissions accounting and incentive programs.

2.6 CONCLUSIONS ON EVALUATION OF EXISTING INFRASTRUCTURE AND BROWNFIELD REPURPOSING POTENTIAL

The potential conversion of the decommissioned Mombasa oil refinery into a SAF production facility offers significant strategic advantages. Its coastal location provides direct access to the harbour, existing KPC infrastructure, railway lines, road networks, and nearby airports, making it highly favourable for both feedstock supply and product distribution. The site also features a large tank farm, which could be used to store both feedstocks and finished products provided it is not required for other initiatives, along with fully operational pump stations and pipelines. This existing infrastructure can lead to cost savings on off-site and utility systems (OSBL) compared to developing a greenfield facility.

However, several technical challenges must be overcome when considering the reuse of the existing refinery units. Originally constructed in the 1960s, the refinery has been inactive for more than a decade and shows clear signs of corrosion and structural degradation. Unfortunately, the existing processing units, including the hydrotreaters, are unlikely to be reusable, aside from a few individual pieces of equipment that may still be serviceable, but they require further studies for detailed condition assessment. Given these limitations, constructing a new HEFA unit may be the preferred option to ensure technological reliability and operational flexibility. Additionally, critical infrastructure such as a hydrogen production unit, SAF feedstock pretreatment facilities, acid gas treatment, and sulphur recovery systems are currently lacking. While the electrical infrastructure appears to be in reasonably good condition, only a portion of the utility systems remains operational. Table 16 and Figure 19 provide a summary of the existing assets, identifying which components are in place, which require upgrades, and which would need to be newly installed.

Table 16. Overview of units required for HEFA SAF production and their condition.

#	Units	Asset condition	Comment
1	Pipeline for feedstock transportation	Needs upgrading / modernization	1. From inland Line 1 can be used and it needs modernization. 2. From Shimanzi jetty a line not in use can be converted.
2	Rail for feedstock transportation	Needs upgrading / modernization	The loading/unloading station inside KPRL needs to be renewed.
3	Shimanzi jetty	Adequate / operational as-is	Should be functional, some modernizations may be needed for the pipeline.
4	Tank storage for feedstock	Adequate / operational as-is	There are enough tanks, but a check about material compatibility should be done. As risks, potential parallel projects, which may materialise, may limit their availability
5	Grid	Adequate / operational as-is	The grid has enough capacity but may present some outages. This should be considered in the plant design.
6	Transformer/substatio ns	Adequate / operational as-is	Status is good and their capacity is sufficient if H_2 is produced by steam reforming. Upgrade is needed in the case an electrolyzer is used.
7	Hydrogen production unit	Requires new installation	No hydrogen plant is present, new installation is required.
8	Feedstock pretreatment	Requires new installation	No feedstock pretreatment is present, new installation is required.
9	HEFA plant	Requires new installation	The existing hydrotreaters may offer only few equipment that can be reused. This needs to be further validated. A completely new installation may be necessary.
10	Acid gas treatment	Requires new installation	No acid gas treatment in place. New installation is necessary.
11	Sulphur recovery	Requires new installation	No sulphur recovery in place. New installation required.
12	Demineralized water	Requires new installation	The status is degraded. New installation required
13	Sour water stripper	Requires new installation	New installation is necessary. Maybe an existing stripper may be used after further verification
14	Waste water treatment	Requires new installation	The existing plant is small and probably not functional. New installation is needed.
15	Cooling tower	Needs upgrade / modernization	A cooling tower is present. It may be feasible to operate, but further analysis should be done.
16	Flare stacks	Requires new installation	No flare stacks on the site. New installation is required.
17	Firefighting system	Adequate / operational as-is	This should be adequate, but upgrade may be needed.
18	Boilers	On hold	Boilers are not functional, however enough steam should be generated by steam reforming and hydroprocessing.
19	Buildings, office, warehouse, mechanical workshop, control room	Adequate / operational as-is	The buildings are adequate.
20	Laboratory	Needs upgrade / modernization	The laboratory structure and more of the analytics are available for Jet-A1. An expansion for SAF analysis and feedstock is required.

#	Units	Asset condition	Comment
21	Road	Adequate / operational as-is	Further roads for the new plants need to be considered.
22	Control room	Needs upgrade / modernization	New software integration necessary. Building is adequate.
23	Blending system	Adequate / operational as-is	Blending is adequate. However, special requirements for certification should be checked in case metering is required.
24	Pump stations	Adequate / operational as-is	Pump stations are adequate.
25	Tank storage for product ad intermediate	Adequate / operational as-is	Tank storage is adequate for Jet, diesel, naphtha. As risks, potential parallel projects, which may materialise, may limit their availability. Tanks for off-gas & intermediate LPG should be planned.
26	Pipeline for product	Adequate / operational as-is	Multi-product pipeline is adequate.
27	Airport depot	Adequate / operational as-is	Airport depots are adequate to handle Jet-A1.
28	Power plant	Needs upgrade / modernization	The plant may be operational, but inspection is needed.

Despite the majority of the refinery's assets no longer being usable, the site continues to offer advantages over a greenfield development: it is already zoned for industrial use, which may expedite the permitting process, and it benefits from established distribution and logistics infrastructures, which are economically valuable. However, the overall cost advantage is less substantial than it would be if the existing refining assets could be reused. The site offers adequate land availability, opportunities for modular construction, integrated logistics, and partially operable utilities, which mainly provide a logistical advantage. Further assessments, such as an engineering feasibility study, will be required to better define project scope and costs, including evaluations of feedstock supply and logistics, and other studies detailed for each engineering discipline.

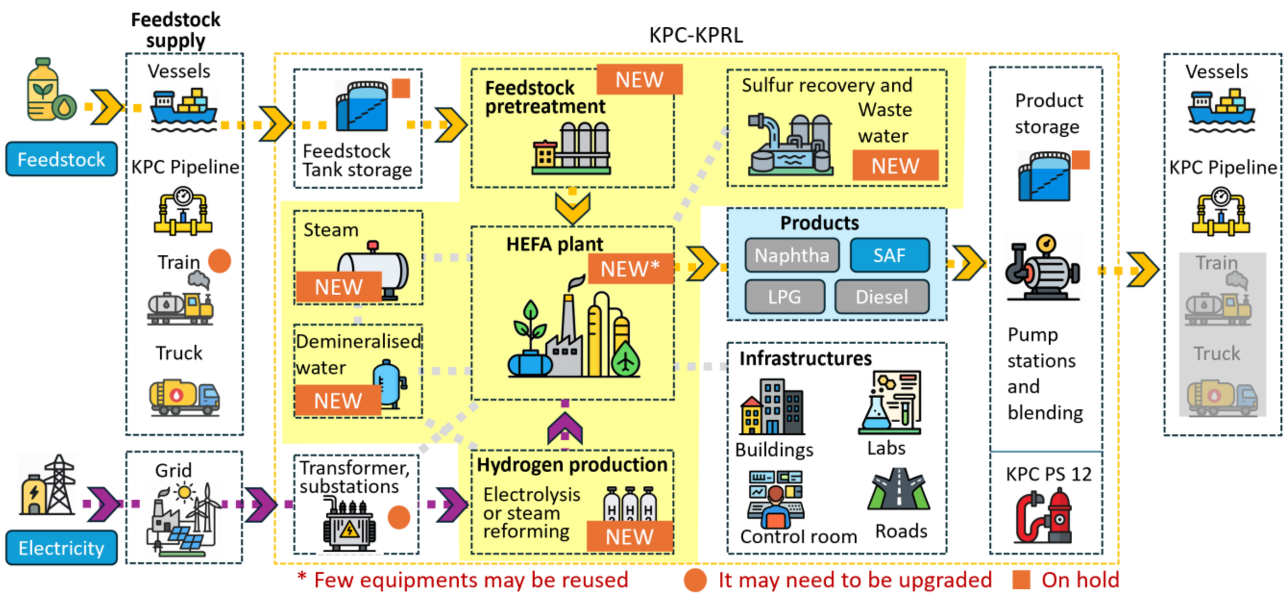


Figure 19. Overview of the need of the installation of new units at the KPRL site.

SECTION 3. TECHNO-ECONOMIC ASSESSMENT OF A BROWNFIELD HEFA REFINERY

This section explores the potential of developing a HEFA plant co-located with an existing refinery. It begins by outlining the core assumptions and methodological framework guiding the analysis. From there, it delves into the yield and selectivity profiles of various biomass feedstocks, examining the distribution of major products. The economic assessment follows, including the calculation of the Levelized Cost of Production (LCOP), structured to enable meaningful comparison with other studies. To evaluate the financial viability from an investor's perspective, the minimum selling price required for profitability was determined. Finally, the environmental dimension is addressed through an analysis of greenhouse gas (GHG) emission savings and the corresponding cost of CO_2 abatement.

3.1 SCENARIOS AND ASSUMPTIONS

Based on previous World Bank study (World Bank, 2025a) that evaluated various plant sizes, we chose to adopt a scale aligned with those analyses. The goal is to strike a balance between a moderate CAPEX investment, a minimum level of economy of scale, and realistic feedstock availability, considering that a feedstock supply chain is at an early stage of development in the region. The HEFA facility was therefore designed to process 250 000 t/year of feedstock (~5 275 barrels per day) in the hydrotreater. Assuming an average 2% loss (Hamelinck *et al.*, 2021) during pretreatment for vegetable oil, approximately 255 000 t/year (~5 380 barrels per day) of feedstock is required at the facility's inlet. This estimate should, however, be verified for each specific feedstock in consultation with the pretreatment technology provider, as actual losses may be higher. The final product yield depends on the operating conditions of the hydrotreating unit. Under maximum HVO production conditions, the average middle distillate yield is projected to be around 215 000 t/year, compared to approximately 180 000 t/year when operated under maximum SAF conditions.

3.1.1 Configuration for the HEFA plant and assumptions

Figure 20 presents the process flow diagram of a typical HEFA plant configuration used as a reference in this study. The layout indicates the main units needed in the Mombasa refinery. This section outlines the key process units and the assumptions underpinned in the techno-economic analysis.

<u>Feedstock unloading, storage and pretreatment</u>

The process begins with the unloading and storage of the feedstock, where raw materials are received and temporarily held before entering the processing line. As mentioned in SECTION 2, the feedstock can potentially arrive at the refinery of Mombasa by train, tanker trucks or pipeline. For transport by train or tanker truck, the product is unloaded at designated refinery bays and transferred to storage tanks, preferably equipped with heating. The raw materials can consist of vegetable oils and waste fats, oils, and grease (FOG), which are assumed to arrive at the facility pre-processed, meaning that seed crushing or rendering processes occur off-site. As this study does not include a logistics assessment, transportation costs must be carefully evaluated in a separate, dedicated analysis. The feedstock storage tanks are designed to hold a 23-day supply (~20 000 m^3) to ensure continuous operation. If needed, different feedstocks may be blended in these tanks before being pumped to the pretreatment unit (Robertson, 2024).

The feedstock is then directed to the pretreatment unit, where impurities such as metals, gums, and particulates are removed. The feedstock oil usually undergoes degumming and drying, with optional steps such as chloride removal, polyethylene removal, clay adsorption, or bleaching. It is assumed that an average 2% weight loss (Hamelinck *et al.*, 2021) may occur during the pretreatment process, particularly during degumming and bleaching, but this can be very variable depending on the feedstock and the pretreatment technology. In addition, the pretreatment unit can be slightly oversized to compensate for downtime and maintain overall throughput. Once pretreated, the feedstock is typically stored in dedicated tanks prior to further downstream processing. Several information were collected to calculate the amount of chemical needed (Brandt *et al.*, 2021; Alfa Laval, 2024), the cost of the chemicals (Brandt *et al.*, 2021), the electricity and steam needed (Hamelinck *et al.*, 2021). Once pretreated, the clean feedstock is stored in an intermediate tank before being routed to the hydroprocessing section.

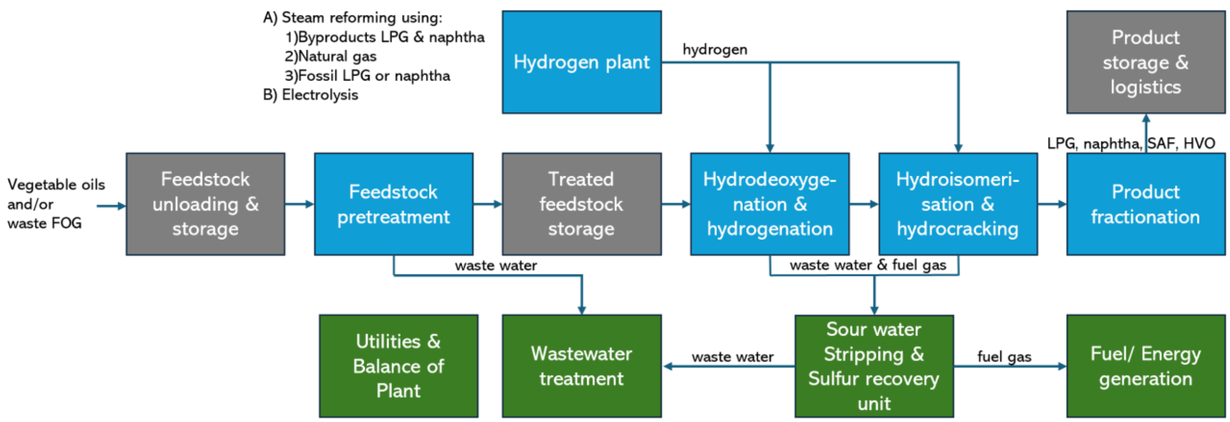


Figure 20. Indicative HEFA plant configuration used for this study (ISBL: main unit in blue, OSBL: storage in grey and auxiliary unit in green). Adapted from Robertson, 2024.

<u>Hydroprocessing and product flexibility for SAF and renewable diesel</u>

At the heart of the process are two sequential hydroprocessing stages. The first is hydrodeoxygenation and hydrogenation, where the feedstock reacts with hydrogen to remove oxygen and saturate the hydrocarbon chains. The second stage, hydroisomerization and hydrocracking, is used to enhance fuel quality and adjust the product slate by breaking down heavier molecules into lighter, to produce SAF.

Using a specific plant configuration that offers full flexibility for the product slate, we simulated three potential operational modes:

1. MAX HVO: *Maximum diesel-range output with optional SAF recovery.* The process is optimized for maximum production of the HVO diesel-range fraction, with the flexibility to extract a SAF fraction if required.
2. SAF 70: *SAF as main product.* It operates at approximately 70% hydrocracking conversion, offering a balanced approach that ensures good yield in SAF and diesel, while maintaining favourable economics. This mode is commonly adopted by refineries aiming to optimize for SAF.

3. MAX SAF: *Maximization to 100% SAF and lighter product.* This mode targets complete conversion to SAF (no diesel, but naphtha and LPG as coproducts). While not widely adopted today due to market constraints, it represents a growing trend, with pioneers (Section 1.6) moving toward dedicated SAF production (Andersson, Alkilde and Duong, 2020).

The mass balance was calculated based on the composition of each feedstock, incorporating the hydrodeoxygenation and hydrogenation reactions outlined in Figure 21. Catalysts used at this stage often promote parallel reactions such as decarbonylation (DCO) and decarboxylation (DCO_2), which produce CO and CO_2, which can potentially be further converted into methane. The selectivity for DCO/DCO_2 reactions varies significantly depending on the catalyst, but there is a general trend toward developing catalysts that minimize carbon loss (Bergwerff, 2025). Literature reports a lower selectivity of approximately 10% for DCO/DCO_2 (Seibel, Cabral Wancura and Dias Mayer, 2024) or even lower (Shiflett, 2025). Since assuming a hydrodeoxygenation (HDO) selectivity greater than 90% results in an estimated carbon balance error of only ~1%, these reactions were omitted from this study. However, they remain important to consider when addressing gas recycle treatment.

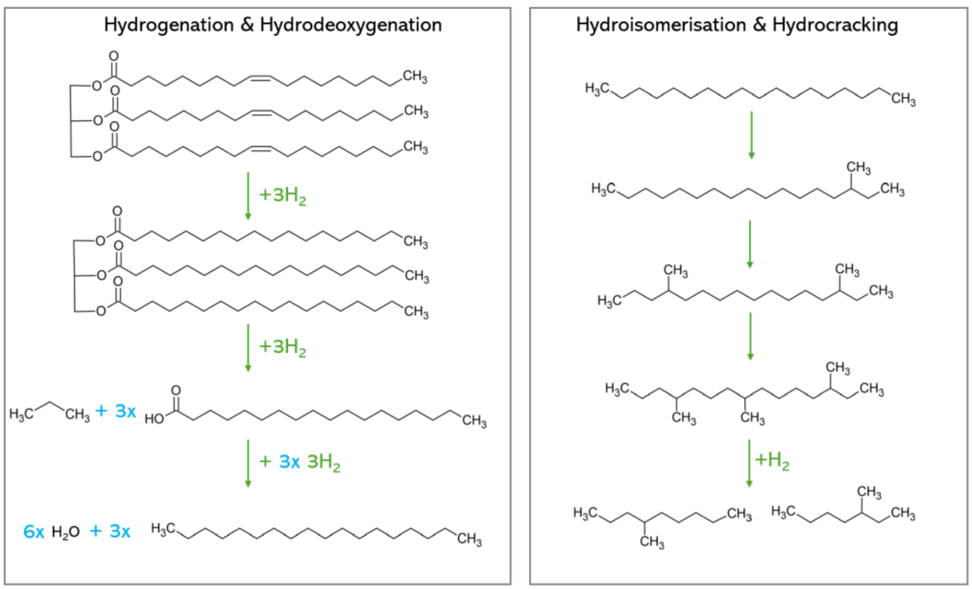


Figure 21. Stoichiometry and simplified mechanism of hydrogenation and hydrodeoxygenation for triolein, hydroisomerization and hydrocracking for octadecane.

For hydroisomerization, an average of 3–4 isomerization steps were considered before cracking occurred. For hydrocracking, the distribution of products was estimated using a simplified ideal hydrocracking mechanism, as described in the referenced paper (Bouchy *et al.*, 2009). Please note that all calculations presented above were performed in-house and may differ from the yields observed in commercial processes.

Hydrogen production

Hydrogen required for these reactions is supplied by a dedicated hydrogen production plant. Various production pathways are considered in the techno-economic analysis to determine the most suitable option for the specific setup and location. The following alternatives are evaluated:

1. Steam reforming of process co-/byproducts (e.g., naphtha, LPG/off-gases): Since the amount of LPG and naphtha is not enough to justify extra purification or refining, they can be used in steam reforming to produce bio-hydrogen. This approach offers the advantage of creating a largely self-sufficient (autarkic) system, with limited reliance on external fuel imports. Data for this scenario were calculated in-house (using minimization of the Gibbs-energy with Peng-Robinson equation) and validated by comparison with standard steam reforming (Spath and Mann, 2000; European Hydrogen Observatory, 2023).
2. Steam reforming of fossil-based LPG or naphtha: Since Kenya lacks domestic natural gas resources and import infrastructure, steam reforming in this study was based on LPG as the feedstock. While naphtha could also be used, its values would differ slightly from those of LPG but still be comparable. Data for this scenario were calculated in-house (using minimization of the Gibbs-energy with Peng-Robinson equation) and validated by comparison with standard steam reforming.
3. Alkaline electrolysis: Electrolyzers were assumed to be connected directly to the electrical grid due to their scale. Electricity prices from the grid were used in the analysis. While this study focuses on grid-connected electrolysis, future models may consider integration with captive renewable energy sources. Data about alkaline electrolysis were taken from the reference (European Hydrogen Observatory, 2024).
4. Steam reforming of natural gas: In this scenario, natural gas would need to be imported from Tanzania or Uganda. Infrastructure development costs were not included; only the natural gas pricing from Tanzania was considered. Data were calculated (using minimization of the Gibbs-energy with Peng-Robinson equation) and compared against the reference scenario (Spath and Mann, 2000). Biogas can be considered as an alternative; however, the current market is not yet developed enough to supply the required amount of hydrogen.

Carbon capture was not included in any of the steam reforming cases analyzed. However, future models may incorporate carbon capture technologies to reduce emissions, though this would require additional capital investment (on average 0.82 EUR/kg_{H2}, (European Hydrogen Observatory, 2023)). In addition, a traditional steam export configuration was assumed for the steam reforming process. However, future studies should further investigate heat integration to assess whether a zero steam export configuration (Schlichting *et al.*, 2016) could be more advantageous.

The upgraded hydrocarbon mixture is then sent to the product fractionation unit, where it is separated into individual fuel products such as SAF (C8-C16), HVO (C10-C24), naphtha (C5-C7), and LPG (C3-C4).

<u>Product logistics and distribution system</u>

The final products are subsequently routed to the storage and logistics section for distribution or export. For product storage, a 30-day tank capacity was assumed for SAF and HVO respectively (probably 2 tanks -one as receiver and one as issuer- for each product, total volume <23 000 m^3), according to existing arrangements where the client should evacuate the product from the storage facilities withing 30 days after purchase. In the case of steam reforming, naphtha and LPG/off-gas can be stored in dedicated vessels with a short capacity such 1-2 days (to be determined during next study phase).

Logistics and distribution costs were not included in the calculation of the Levelized Cost of Production (LCOP) or the minimum selling price. These costs should be incorporated once there is greater clarity on the proportion of products intended for local use versus export, and the specific regions targeted for export. However, logistics costs for transporting liquid fuels or feedstock are generally expected to have a relatively minor impact, typically accounting less than 1% of the total fuel cost.

OSBL

The plant is supported by several essential utility and environmental systems. Utilities and balance of plant infrastructure provide services such as steam, electricity (transformers, switchgear), cooling water, compressed air and nitrogen required for operation. Wastewater generated during pretreatment and hydroprocessing is treated in a dedicated wastewater treatment unit. Demineralized water unit is needed for the processes. Additionally, a sour water stripping and sulphur recovery unit are needed to process sulphur-containing wastewater and off-gases, capturing usable fuel gas and minimizing emissions. Recovered fuel gas is directed to the plant's energy generation system or to the steam reforming, improving overall energy efficiency.

Other supporting systems part of the Balance of Plant (BoP) include also control systems (DCS/PLC, instrumentation), piping and valves, storage and handling (tanks, loading/unloading), fire safety (firewater, extinguishers), HVAC, and auxiliary buildings (control rooms, workshops, labs).

Methodology for CAPEX estimation

Given the proprietary nature of technology-specific cost data, a precise CAPEX estimate requires detailed feasibility studies in collaboration with technology providers and engineering firms, typically under confidentiality agreements. As this was beyond the scope of the current study, we aimed to provide a realistic approximation based on market analysis and publicly available information from comparable projects of similar scale. These values have been reviewed and are supported by internal assumptions and modelling. It is evident that the accuracy of this estimate cannot be higher than AACE Class 5 (from -50% to 100%), reflecting a high degree of uncertainty, typical and acceptable for this early stage of project development (see 6.2).

As established in SECTION 2, the Mombasa refinery will require the addition of a new HEFA unit, a hydrogen production plant, and a feedstock pretreatment facility. However, it will benefit from the existing distribution infrastructure and buildings already available at the site. Accordingly, Table 17 presents a selection of HEFA plants that involve new unit installations while being integrated within existing refinery complexes.

The differences in the investment costs are also influenced by several factors, including the prevailing economic conditions at the time of investment, location-specific cost variations, and the actual level of integration with the refinery's existing infrastructure. As a result, various estimates are provided, ranging approximately from USD 300 to 600 million. The investments for Repsol and Bangchak appear lower in comparison, probably due to a high synergy with the site and both should use existing facilities for the hydrogen production (Collins, 2021; Advanced BioFuels USA, 2022; Laity, 2025; Martin, 2025; Repsol, 2025). At the higher end of the investment scale is OMV, whose facility is designed for high operational flexibility, allowing it to adjust the product mix (SAF vs HVO diesel) (OMV, 2024). This level of flexibility usually contributes to increased capital and engineering costs. In addition, an extra EUR 190 million has been allocated on top of the EUR 560 million for two electrolyzers with a hydrogen production capacity of 11 000 t/year (55 MW). Similarly, Holborn emphasizes the flexible design of its plant, which is also expected to impact overall investment levels.

Table 17. Overview of similar size HEFA plants with disclosed investment in press releases.

Company	Year operation	Country	Product volume [t/year]	Plant integration	Product	Costs in million USD[h]
SkyNRG[a]	2028	Netherlands	100 000	Greenfield	SAF	340[i]
Tidewater Midstream[b]	2023	Canada	130 000	New plant within existing refinery	diesel + SAF	342
St1 Nordic[c]	2024	Sweden	200 000	New plant within existing refinery	diesel + SAF	407
Holborn[d]	2027	Germany	220 000	New plant within existing refinery	diesel + SAF	540
OMV[e]	2028	Romania	250 000	New plant within existing refinery	diesel + SAF	640
Repsol Cartagena[f]	2024	Spain	250 000	New plant within existing refinery	diesel + SAF	285
Bangchak[g]	2025	Thailand	280 000	New plant within existing refinery	SAF	310

Sources: [a] (Segal, 2025; SkyNRG, 2025), [b] (Von Kursk, 2023), [c] (Bioenergy International, 2017; Hussain, 2024), [d] (Hamburg News, 2024; Holborn, 2024), [e] (OMV, 2024), [f] (Argus, 2024; Repsol, 2024), [g] (Bangchak, 2024, 2025; Praiwan, 2025).
[h] These costs can vary significantly depending on the level and type of integration required within the existing refinery infrastructure. These figures should be considered only as reference. Exchange rate of 0.88 USD/EUR as of 31 July 2025.
[i] Capital raised to date has been reported, not total investment.

A recent World Economic Forum (WEF) study, based on a survey of project developers (WEF, 2025), indicated that a 500 000 t/year SAF/HVO facility could require an investment of approximately USD 700 million. On average, capital expenditure was reported at around 1 500 USD/t of installed capacity, with a broad range spanning from as low as 400 USD/t to as high as 3 600 USD/t, depending on project-specific factors. As a reference, when estimating Inside Battery Limits (ISBL) costs for different plant scales, a scaling factor (Lange factor) in the range of 0.6 to 0.7 is commonly applied.

To account for the uncertainty of the CAPEX estimates at this stage of the study and verify its sensitivity on the SAF price, we consider two scenarios: (i) a lower-CAPEX case, representing optimistic assumptions with a high degree of integration and a potential favourable regional cost factor; and (ii) a higher-CAPEX case, reflecting a more conservative approach. Considering the CAPEX values referenced above, combined with an internal assessment and recent market price trends, we adopt USD 375 million as the lower-bound estimate and USD 500 million as the upper-bound one. This represents a preliminary assessment, and additional engineering studies are necessary to further refine the CAPEX value. It is important to note that costs may also increase if a significant portion of the existing infrastructure is proved to be not adequate, requiring additional investment in off-site infrastructure. This cost estimate is supposed to include ISBL and OSBL components (equipment and installation), engineering costs and supervision, owner's costs, as well as a 15% contingency allowance (AACE Class 5). Together they represent the Fixed Capital Investment (FCI).

As no HEFA plants have yet been built in Africa, regional cost factors remain uncertain and will depend on future decisions regarding project execution strategies as well as the availability of local expertise, specialized skills, and manufacturing capabilities. These factors could either have an effective reduction on the CAPEX or increase it if key technologies need to be imported. Key variables such as local fabrication capacity, labour availability and costs, equipment transport and logistics, import duties, and currency exchange rates will need to be assessed once a more defined project framework is in place. According to East Africa Community

Common External Tariff (EAC Customs Union, 2022), import duties may not be applicable to production equipment and machinery, and special conditions may apply to projects in the renewable sector. Additional fees, VAT, and levies are not implicitly included in this analysis. Since other types of renewable projects (e.g., in Green Hydrogen) often benefit from exemptions, this aspect should be further investigated, as it could significantly affect the final cost (KRA, 2025).

Tank storage

Several storage tanks are available on site for the use of SAF project, but their utilization may be constrained by parallel initiatives at KPRL. In the absence of available free storage, additional tank capacity will be required. For each product stream, a dual-tank configuration is proposed, with one tank dedicated to the reception of material (receiver) and the other to product dispatch (issuer). Furthermore, two supplementary tanks will be allocated for blending operations (Table 18).

With respect to technical design, tanks designated for neat SAF and blended Jet A1 will require floating roofs, whereas feedstock and HVO diesel are suitably stored in fixed-roof tanks. Drawing on cost benchmarks established in comparable projects at KPRL, the provision of eight extra-large storage tanks is projected to require a capital investment of approximately USD 17.5 million (10-15 USD/t influence on SAF production cost).

In parallel, smaller-scale storage facilities will be necessary for water, pretreated feedstock, intermediate products (e.g., naphtha), and liquefied petroleum gas (LPG). It is possible that these smaller tanks are available for use on site. Imported LPG could be accommodated in the new LPG facility expansion. As reference, a 15-days of LPG storage capacity, corresponding to roughly 3 300 m³. As an alternative pathway, naphtha imports may be considered in place of LPG, if this is economically more convenient. Two naphtha tanks are on site and currently decommissioned. They may be retrofitted for the project, but this is subject to further technical evaluation.

The present section is intended only to provide an initial indication. The detailed planning and calculation of storage tanks should be addressed in a future study with an engineering company.

Table 18 Proposed ultra-large storage tanks needed.

Tank storage use	Storage time [day]	Tank number	Volume per tank [m³]	Total volume [m³]
Feedstock	23	2	10 000	20 000
Neat SAF	30	2	10 000	20 000
Jet A-1 blended	Only for blending	2	10 000	20 000
Neat HVO diesel	30	2	11 000	22 000
Fossil kerosene	-	3 available	-	-

Evaluation of existing KPC/KPRL assets to share within the project

Part of the KPC/KPRL existing assets could be treated as shared capital contributions for the project. While the inclusion in the project will not change the external capital to be raised, they can affect the cost of production and as well the equity/debt financing. Since the evaluation of their current value is out of the scope of this study, only direct CAPEX of new installed units has been considered in this analysis. Future analyses should also consider incorporating this aspect.

Total project cost

The total project cost includes both the fixed capital investment and the working capital required to support initial operations. The costs presented do not include expenses related to the project development phase studies, which should be accounted for separately.

Estimated time for development, construction, commissioning and production ramp-up

As a high-level estimation, the overall project timeline typically includes a 1.5 to 2-year period for feasibility studies and basic engineering. During this phase, activities such as consortium formation, stakeholder engagement, and preliminary contract negotiations are usually carried out in parallel, culminating in a Financial Investment Decision (FID) once alignment is achieved among all parties, and financing institutions and the operator commit to funding. Following FID, the construction and commissioning phase is expected to span approximately three years. Capital expenditures during construction are generally distributed following an S-curve, with an assumed 20% incurred in the first year, 55% in the second, and the remaining 25% in the third year. Operational ramp-up is anticipated to follow a staged approach: reaching 50% capacity in the first operational year, 90% in the second, and full capacity by the third year.

The timeline and cost assumptions presented here are indicative and intended for preliminary planning purposes only. The detailed schedule, construction phasing, and performance expectations should ultimately be defined by the selected engineering contractors and technology licensors, based on their specific design, proprietary process, and operational experience.

3.1.2 Operations: assumptions on process and energy/utility inputs

Availability (national/regional supply) of feedstock and composition

Given Kenya's favourable agro-climatic conditions, several locally adaptable feedstocks have been identified as promising candidates for SAF production via the HEFA pathway. The selection of these feedstocks is based on previous feasibility assessments (ICAO, 2018) and local studies (Ndegwa *et al.*, 2011).

Currently, the most significant source of vegetable oil for biofuels in the country is the Eni Agri-hub, which will plan to produce approximately 70 000 t/year (Eni, 2025b). As of July 2025, Eni's main cultivation efforts focus on low ILUC feedstock, such as castor, croton and cottonseed (Eni, 2022, 2025c). Bleriot is producing currently 7 000-8 000 t/year of vegetable oil and envisions production of SAF using castor and yellow oleander. To the best of our knowledge, the vegetable oils (without counting the ones in competition with food) and waste FOG collected currently in Kenya for biofuel could supply nowadays only a marginal part of the feedstock required for the 255 000 t/year HEFA plant, suggesting that a stronger supply chain will need to be developed in the coming years.

According to the analysis of Masinde Muliro University of Science & Technology (MMUST), yellow oleander shows considerable promise. It has an estimated oil content of 60-70% (Odhiambo, 2005) and a seed yield of roughly one tonne per hectare. With up to five million hectares potentially suitable for cultivation, and approximately 900 000 hectares in fragmented allotments potentially cultivated in 2025 (data estimated by MMUST), yellow oleander could play a significant role in future SAF production, thank also to its resistance in ASAL region. The suitability of yellow oleander should be subject to further agronomic validation and sustainability assessments.

The Agriculture and Food Authority (AFA) track domestic vegetable oil output for food, and it indicated that coconut, cotton seed, and canola are the most relevant in Kenya. In 2024 coconut is the most extensively grown, with 75 012 hectares under cultivation and a seed yield of 1.2 t/hectare (~90 000 t/y seed). Cotton seed is grown on 16 477 hectares, though it delivers a lower yield of 0.38 t/hectare (~4 000 t/y seed). Canola, though limited to 4 309 hectares, shows the highest productivity, with a seed yield of 3.3 t/hectare (~14 000 t/y seed).

In terms of edible oil consumption, Kenya's domestic production is limited to around 80 000 t/y, falling significantly short of the estimated national demand of 900,000 tonnes (The Star, 2024). To meet this gap, the country imported approximately 784 000 tonnes of palm oil in 2023 (WITS, 2023), primarily from Malaysia, at prices ranging between 900 and 1 000 USD/t. Consequently, when assessing used cooking oil (UCO) as a feedstock in this techno-economic study, its composition is assumed to reflect the characteristics of waste palm oil.

In addition, a regional approach could be considered, involving neighbouring countries such as Ethiopia, Uganda, Tanzania, and extend it to the Democratic Republic of Congo for feedstock supply and potential SAF distribution. For instance, Ethiopia is currently evaluating the cultivation of Brassica carinata for oil production, which may contribute to a broader regional feedstock strategy. Known also as Ethiopian mustard, Brassica carinata is a resilient, non-edible oilseed crop well-suited for intercropping and crop rotation with cereals and legumes. It offers agronomic benefits such as soil enhancement, erosion control, and performs reliably under minimal tillage and low-input conditions without notable yield reductions. Its adaptability to marginal lands and contribution to sustainable farming systems make it a promising feedstock for renewable fuels. Although more commonly cultivated in Ethiopia, it shows potential for adaptation to Kenyan agro-climatic conditions.

These feedstocks represent varying levels of potential for SAF production through the HEFA pathway, influenced by oil yield, conversion efficiency, and overall market availability. A preliminary survey and research were conducted in this study to assess current feedstock availability and pricing. However, data remains limited, and a deeper study will be necessary to clearly define the landscape, their potential for the business case, the long-term viability and supply chain readiness. Establishing a well-defined plan on how to expand the cultivation and on logistics will be essential to ensure sufficient supply for the 255 000 t/year HEFA plant. The chemical composition of the vegetable oils and their key fatty acid profiles are important for both processing performance and pricing considerations.

For the techno-economic study we will focus on nine feedstocks (see Table 19Table 18):

1. Castor oil: it derives from the seeds of the *Ricinus communis* plant, castor oil is known for its high viscosity (which may require special considerations for the pretreatment compared to other oils) and unique composition. It is not typically used for edible purposes and is considered non-edible. Its main component is ricinoleic acid (approximately 85–90%), followed by oleic and linoleic acids.
2. Yellow oleander oil: it is extracted from the seeds of *Thevetia peruviana*, this oil is non-edible and toxic, making it suitable for industrial uses. It is composed mainly of oleic, linoleic, and palmitic acids.
3. Croton oil: sourced from *Croton megalocarpus*, an indigenous tree in East Africa, croton oil is non-edible and contains a high proportion of unsaturated fatty acids. Its primary components are linoleic acid (~44%), oleic acid (~32%), and palmitic acid (~20%).
4. Used Cooking Oil (UCO): A waste product from food processing and households, UCO is an economically and environmentally advantageous feedstock. Its fatty acid profile varies depending on the original oil and cooking conditions; therefore, each batch can be different. For this study we focus on waste palm

oil, since it is Kenya's main edible oil. UCO is already being used in HEFA-based SAF production globally. Under CORSIA default LCA values are available and it is classified as a waste with zero ILUC.

5. Cottonseed oil: it is obtained as a co-product of cotton production, cottonseed oil contains gossypol, which must be removed for safe use. The oil comprises primarily linoleic acid (~50%), palmitic acid (~22–25%), and oleic acid (~18%). It can be used for food.

6. Coconut oil: this oil is abundant in Kenya's coastal areas and extracted from the dried meat of coconuts (copra). It is rich in saturated fats, especially lauric acid (~45–53%), followed by myristic, capric, and caprylic acids, making it a suitable candidate for biofuel applications due to high oxidative stability. Non-standard coconuts have a default LCA value under CORSIA and are classified as a by-product, giving them an ILUC value of zero.

7. Brassica carinata oil: the oil typically contains around 40% erucic acid among its fatty acids; however, this level can potentially be reduced to near zero through genetic breeding and modification. For this study the oil composition of the non-genetic modified strain is used. Under CORSIA default LCA and ILUC values are available.

8. Canola oil: a low-erucic acid variety of rapeseed oil, canola is valued for its favourable fatty acid profile. it contains mostly oleic acid (~60%), linoleic acid (~20%), and alpha-linolenic acid (~10%). Its low saturated fat content. It is used also for food. Under CORSIA default LCA and ILUC values are available.

9. Jatropha oil: it is extracted from the seeds of *Jatropha curcas*, this non-edible oil is known for its adaptability to arid climates, making it a promising candidate in Kenya. The main fatty acids include oleic acid (~42%), linoleic acid (~34%), and palmitic acid (~14%). Under CORSIA default LCA and ILUC values are available.

It is important to acknowledge that Table 19 provides a single representative oil composition for each feedstock used in this study. In practice, these values can vary, typically by ±5%, due to differences in geographic location, cultivation practices, and plant variety.

Table 19. Fatty acid content in the oil feedstocks used in this study.

	# carbon atoms	Insaturation	MW (g/mol)	Castor oil[a]	Yellow oleander oil[b]	Croton oil[c]	UCO[d]	Cotton oil[e]	Coconut oil[f]	Brassica carinata oil[g]	Canola oil[h]	Jatropha oil[h]
Caprilic acid	8	0	144						10%			
Capric acid	10	0	172						5%		1%	
Lauric acid	12	0	200			1%			51%			
Myristic acid	14	0	228		1%	7%		1%	19%			
Palmitic acid	16	0	256	2%	21%	6%	41%	24%	8%	5%	5%	16%
Palmitoleic acid	16	1	254					1%				1%
Stearic acid	18	0	284	1%	8%	3%	4%	3%	3%	1%	2%	7%
Oleic acid	18	1	282	7%	52%	21%	45%	19%	5%	14%	58%	41%
Ricinoleic acid	18	1	298	87%								
Linoleic acid	18	2	280	3%	18%	51%	8%	53%	1%	21%	25%	35%
a-Linolenic acid	18	3	278				3%	1%		14%	8%	
Arachidic acid	20	0	313			2%				1%		
Gadoleic acid	20	1	311			10%						
Erucic acid	22	1	339							46%		

Sources: [a] (Baker and Grant, 2015), [b] (Odhiambo et al., 2012), [c] (Usman, Cheng and Cross, 2022), [d] (Mannion et al., 2024), [e] (Djomdi et al., 2020), [f] (Ogugua, Joshua and Ukegbu, 2014), [g] (Paula et al., 2019), [h] (Béalu, 2017)

Cost of feedstock

Determining accurate regional feedstock prices was challenging due to limited publicly available information and the sensitivity surrounding the disclosure of such data. Therefore, the prices presented in this study should be considered indicative estimates. For more robust evaluations, it is recommended that future studies engage with feedstock suppliers under Non-Disclosure Agreements (NDAs) to obtain more reliable and project-specific pricing.

Where possible, local pricing data were incorporated (Table 20). For example, some indicative values were obtained from the public website of Selina Wamucii, which is a Kenyan-based agri-tech platform that connects smallholder farmers and cooperatives to global markets and regularly publishes market data, including the wholesale market for 2025**.** For feedstocks such as croton and yellow oleander, prices were estimated based on seed costs, as markets for these non-edible feedstocks are not yet fully established.

In the techno-economic model, two scenarios were examined: one in which the feedstock is procured externally (wholesale price), and another in which it is supplied internally within a consortium dedicated to SAF production. In the latter case, a 10% reduction from the lower wholesale price was assumed (unless otherwise specified), reflecting potential integration and supply chain efficiencies. The consortium-sourced feedstock price represents a lower-bound scenario, as further reductions in SAF cost through feedstock price decreases are considered unlikely, given that prices below this level would not realistically cover cultivation, harvest and pre-processing costs. These values should be considered indicative (based on public data), as actual commercial costs may vary and warrant further investigation. Feedstock prices require additional analysis to better capture both current and future trends, including potential increases linked to global market dynamics. NREL noted that vegetable oil prices may escalate over the years in response to rising demand, as it happened between 2020 and 2021 from value below 1 000 USD/t to over 1 500 USD/t (e.g., Table G-5 in (NREL *et al.*, 2024)). As global reference for common traded vegetable oils, the International Monetary Fund report for July-August 2025 average prices ranges such as 931-1 026 USD/t for palm oil, 1 151-1 179 USD/t for soybean oil, 1 215-1 241 USD/t for rapeseed oil, and 1 486-1 538 USD/t for sunflower oil (IMF, 2025). Regular quarterly or monthly fluctuations of around ±100 USD/t, and occasionally more, are typical and should be carefully considered in future techno-economic assessments, as well as strategies to derisk price volatility.

Table 20. Estimated feedstock price of vegetable oils and used cooking oil.

USD/kg	Castor oil	Yellow ol. oil	Croton oil	UCO	Cotton oil	Coconut oil	Brassica c. oil	Canola oil	Jatropha oil
Wholesale low price	0.82[a]	0.76	0.91	0.9	0.66[a]	1.48[a]	1.05	1.35[a]	0.35[b]
Wholesale high price	1.02[a]	0.86	1.01	1.1	0.74[a]	2.64[a]	0.95	1.69[a]	0.5[b]
Average wholesale price	0.93[c]	0.81[d]	0.96[e]	1.0[f]	0.7[c]	2.06[c]	1.0[g]	1.52[c]	0.43
Consortium-sourced feedstock[h]	0.74	0.72[d]	0.85[e]	0.9	0.59	1.33	0.9[g]	1.22	0.32

Sources: [a] (Selina Wamucii, 2025), [b] (Tao et al., 2017; TradeIndia, 2025)

[c] Wholesale price average calculated from the average of Wholesale price low and high,

d: Estimated by MMUST (Masinde Muliro University of Science and Technology),

e: Estimated from the nut price and yield from source (10 KHS/kg, 10 kg nuts for 1 L oil yield (Kenya News Agency, 2023)),
f: (Fastmarkets, 2025),
g: Estimated in the feasibility study under ACT-SAF support to Ethiopia,
h: Calculated as 10% reduction from the lower wholesale price, unless explicitly reported.

Additionally, by-products such as oilseed cake, such as croton and potentially other sources after detoxification if required, can be used as animal feed, which could improve the overall business case by offsetting feedstock costs. While this potential revenue stream was not quantified in the current analysis, it should be considered in future studies for a more comprehensive economic assessment.

Sourcing of electricity and costs

Electricity is assumed to be sourced from the national grid. The reference price structure is well illustrated in the website (Stimatracker, 2025), where additional surcharges for demand charge and fixed costs should be added. For the purposes of this study, a rate of 0.22 USD/kWh was used for the HEFA plant, reflecting current industrial electricity pricing conditions. As a reference, we use the electricity price from a captive geothermal plant in Olkaria, which is 0.07 USD/kWh.

Heating fuel and steam generation

Hydrogen production requires high temperatures and significant heat input. Ideally, renewable energy sources, such as process by-products or co-products, would be used to meet this demand. In the event of insufficient renewable options, conventional fuels such as heating fuel oil, naphtha, LPG or natural gas may be required for thermal energy supply. It is likely that the necessary steam for the whole complex can be generated by recovering heat from the steam reforming and hydroprocessing units. However, a detailed heat integration study is essential to determine the most efficient and cost-effective configuration.

Byproduct use and valorization

The study will assess whether it is more beneficial to use co-products such as naphtha and off-gases/LPG for hydrogen production, or to sell these streams and instead produce hydrogen through fossil-based resources or electrolysis.

Operating hours per year and operational lifespan

The plant is designed to operate for 8 000 hours per year, and the project consider 20-year operations. However, the facility may continue to be utilized beyond this period, depending on its condition and future operational requirements.

Working capital

In this model, working capital is calculated based on 7 weeks of total production costs, minus 2 weeks of feedstock costs, and includes an additional 1.5% of ISBL and OSBL capital expenditures (Towler and Sinnott, 2022).

Waste management

The site must include provisions for the disposal of bleached earth and degumming residues. Wastewater will be managed through a dedicated treatment facility, and sulphur recovery systems will be incorporated. Off-gases may also be recovered and utilized for energy purposes, enhancing overall process efficiency.

Other operation expenses

Other operating expenses for the HEFA plant include the consumption of fresh water and chemicals such as citric acid, sodium hydroxide (NaOH), and bleaching earth, as well as the cost of catalyst replacement. Annual maintenance costs are estimated at 5% of the total capital expenditure (CAPEX), while insurance and royalties are projected at 1.5% of the total CAPEX. Labor costs are based on locally established salaries, consistent with those already in place at KPRL. The plant design considers three main technology areas: feedstock unloading and pretreatment, hydrogen production and utilities, and the hydroprocessing unit. For each technology island, a 24/7 operation is planned to use a three-shift system, with five shift supervisors included to ensure continuous supervisory coverage.

Regarding staffing, the number of full-time employees required to operate a liquid fuels production facility with a capacity of 255 000 t/year can vary depending on the level of automation, integration with existing infrastructure, and regulatory conditions. Typically, a standalone facility would require between 80 and 150 employees. If integrated within an existing refinery, staffing needs may be reduced due to shared services and operational efficiencies. We estimate in this study around 100 employees will be necessary (Table 21). Additionally, indirect labour demand will arise in areas such as logistics, maintenance, utilities, and administrative support. A detailed staffing plan tailored to the specific configuration of the facility should be developed during the basic engineering phase.

Table 21. Estimation of staffing in a HEFA plant (illustrative).

Type of worker	Amount
Plant manager	1
Plant engineer	5
Maintenance supervisor	2
Lab manager	1
Lab technician	5
Shift supervisor	15
Shift operators	60
Yard employees	4
Clerks and secretaries	3
Total	**96**

3.1.3 Financial inputs

Tax rates

The standard corporate tax rate is 30%. However, tax relief is available under certain conditions. Companies registered with the Nairobi International Financial Centre (NIFC) may benefit from preferential tax treatment. According to the Finance Bill 2025, startups are eligible for a reduced corporate tax rate of 15% for the first three years, followed by 20% for the next four years. Large investors committing at least KES 3 billion may qualify for a 15% corporate tax rate for the first 10 years and 20% for the subsequent 10 years, offering significant long-term fiscal incentives (Kenyan Parlament, 2025).

Inflation rate

The average inflation rate over the past five years has been approximately 6% (CBK, 2025), and this value will be used for the techno-economic analysis. However, it should be mentioned that inflation is in a decreasing phase, with the current inflation rate stands at 3.8% as of July 2025 (CBK, 2025). The economic growth rate is foreseen as 4.7% (KNBS, 2025).

Financing: debt vs equity

The proposed financing structure for the project is based on a debt-to-equity ratio of 70:30, with flexibility to adjust within a range of 65:35 to 85:25, depending on financing terms and investor preferences.

<u>Depreciation length and type of depreciation</u>

Depreciation is calculated using the straight-line (linear) method over a period of 20 years, reflecting the expected useful life of the plant and its assets. The impact of adopting a double-declining balance (DDB) depreciation method over 10 years was also assessed.

<u>Weighted Average Cost of Capital (WACC)</u>

The weighted average cost of capital (WACC) in the region exhibits significant variability, reflecting the wide range of financing structures available. The cost of debt may vary from approximately 1% under concessional financing arrangements to around 15% in more conventional market-based structures (detailed interest rate assumptions are provided in 5.2). Similarly, the cost of equity is highly context-dependent, though it is generally expected to exceed 20%. Reported benchmark values also differ by sector: for renewable energy projects in Kenya, WACC estimates are typically in the range of 8.5–9% (nominal terms with concessional financing) (Global Renewable News, 2025; IEA, 2025), while the national green hydrogen strategy adopts a reference value of 13% (real terms) (Ministry of Energy and Petroleum, 2023) for hydrogen-related investments.

Given that the project aims to avoid high interest rates, the preferred approach is to seek international financing through Development Finance Institutions (DFIs). Therefore, our base scenario focuses on this assumption. In this study, we examine 11 distinct financial scenarios (Table 22) to understand the potential range of outcomes for the project, particularly focusing on the impact of financing structures on the Levelized Cost of Production (LCOP). These scenarios reflect variations in key financial parameters such as the Weighted Average Cost of Capital (WACC), cost of debt, cost of equity, and debt-to-equity ratios.

- Case 1 serves as the base case, assuming an average cost of debt of 9% and a cost of equity of 25%, resulting in a WACC of 11.9%.
- Cases 2 through 5 explore the sensitivity of WACC and LCOP to different debt interest rates, analyzing how fluctuations in borrowing costs affect overall project viability.
- Case 6 presents a scenario with a particularly low cost of debt, achieved through a blended financing structure that includes both concessional and non-concessional loans.
- Case 7 represents a best-case stretch scenario, examining the lowest possible WACC achievable under highly favourable conditions. This includes financing composed of 50% concessional loans at 1%, the remainder at 7.5%, and a reduced cost of equity of 22%.
- Cases 8 and 9 investigate the impact of varying the debt-to-equity ratio, evaluating how changes in capital structure influence the WACC and, consequently, the cost of production.
- Cases 10 and 11 focus on the sensitivity of the model to changes in the cost of equity (as minimum IRR on equity), with scenarios tested at 22% and 28%, in addition to the baseline of 25%.

Overall, the WACC values across these scenarios range from 8% to 14.85%, offering a comprehensive view of how financing conditions can shape project outcomes. The objective is to structure the project in a way that it is attractive for investors, but still profitable and financially viable. It is important to recognize that elevated

WACC values can significantly undermine project viability, as excessively high financing costs may render an otherwise technically feasible project economically uncompetitive.

Table 22. WACC (real terms) for different financing scenarios.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
WACC (IRR)	11.9%	11.2%	12.4%	13.6%	14.9%	10.0%	8.0%	11.0%	12.9%	11.0%	12.8%
Equity/debt ratio	30%	30%	30%	30%	30%	30%	30%	25%	35%	30%	30%
Cost of equity	25%	25%	25%	25%	25%	25%	22%	25%	25%	22%	28%
Cost of debt	9%	7.5%	10%	12.5%	15%	5%	3%	9%	9%	9%	9%

3.1.4 Other inputs

Reference price of jet fuel and SAF

Jet fuel costs are clearly specified for use at both Mombasa and Nairobi airports (JET-A1-Fuel, 2025). As of August 2025, the price was 661.2 USD/ton (0.53 USD/L). As reference IATA published a price for jet-fuel in Africa of 703 USD/t and Middle East at 654 USD/t (IATA, 2025) as average of August 2025. In addition to the base fuel price, a fuel charge of 0.35 USD/L (436.64 USD/t) is applied (Nairobi international airport, 2025). For domestic flights, additional fees may be included. However, for international flights, certain tariffs (e.g., fees, levies and excise duty) are waived under existing international aviation agreements (ICAO, 2000). Therefore, the final cost of Jet-A1 fuel for airlines also depends on whether the flight is international or domestic.

The SAF market continues to show limited price transparency, with available indications mainly for the ARA region (Amsterdam–Rotterdam–Antwerp). According to Argus Media (Argus Media, 2025b), RED-compliant HEFA-SPK prices on an FOB ARA basis fell from an average of 2 800 USD/t in January 2024 to a minimum of 1 747.90 USD/t on 11 September 2024 (methodology reported in (Argus Media, 2025a)). Prices then recovered through 2025, surpassing 2 000 USD/t in the second half of the year and reaching an average of 2 372.50 USD/t in August 2025 (Argus Media, 2025b), with the upward trend continuing into September 2025.

General index published in November 2024 some indicative trends, where the SAF price (RED SAF Neat HEFA NEW FOB Barges) for the barge market in and around Amsterdam-Rotterdam-Antwerp trading hub was around 2 000 USD/t (General Index, 2024). It is interesting to note that for the period shown, the SAF premium compared to fossil fuel was ~1 300 USD/t. A SAF margin of ~400 USD/t was applied compared to the cost of production. EASA (EASA, 2025) reported for 2024 an average aviation biofuel price of 2 085 EUR/t (~2 350 USD/t) with an average production of 1 461 EUR/t (~1 660 USD/t). The price of 2023 was reported at 2 768 EUR/t. It is important to note that SAF price is subject to variability and that SAF prices in bilateral offtake agreements may deviate from these benchmarks, particularly in the context of countries with mandates, which can drive a higher willingness to pay due to regulatory compliance and sustainability commitments.

Prices of co-products, fuels and utilities

As of 1 August 2025, the naphtha price was approximated to be 600 USD/t based on global market data, due to the absence of local reference prices (Business Insider, 2025). Heating oil is at 2.30 USD/gallon (Trading Economics, 2025b), indicating that naphtha is cheaper at the moment.

LPG prices are typically reported for 13-kg cylinders (~1.88 USD/kg), which are noticeably higher due to retail and distribution costs (price without oil marketer margin <0.75 USD/kg) (Omondi, 2025). Since Kenya imports most of its LPG (International Trade Administration, 2023), we took a reference value for the global market of 500 USD/t (Chemanalyst, 2025; Echemi, 2025).

In this study natural gas prices are based on Tanzanian rates, at 161 USD/t (Africa Press, 2022), which is significantly cheaper than the European market price of 33.50 EUR/MWh (Trading Economics, 2025a). Fresh water is priced at 3.40 USD/m^3 in Mombasa.

For gasoline, diesel, and kerosene, pump prices are published on the EPRA website (EPRA, 2025d). In the period 15 November 2024 to 14 September 2025, the average pump prices in Kenya were: 181 KES/L for Super Petrol (PMS), 169 KES/L for Diesel (AGO), and 153 KES/L for Kerosene (IK). Converted to USD, these are approximately 1.39 USD/L for Super, 1.30 USD/L for Diesel, and 1.18 USD/L for Kerosene. However, the landed costs (at the country entry) are typically below 800 USD/t, as pump prices include levies, fees, excise duties, and various taxes (EPRA, 2024b, 2025c). For international flights, the Jet A-1 reference price of 661.2 USD/t is considered.

In Europe, HVO diesel is typically sold at a slightly lower price than SAF. For instance, if SAF is priced at 2 000 USD/t, HVO diesel is usually around 1 900 USD/t (General Index, 2024; Argus, 2025). This price difference is likely due to HVO requiring fewer processing steps and less energy during conversion. However, HVO price are as well subject to variability, and they also not follow the same trends of SAF. There were also periods when the two prices moved independently.

3.1.5 Outputs

In the first part of the study, the results are presented as the Levelized Cost of Production (LCOP), providing insight into the effective cost of producing SAF and allowing for comparison with other projects. The second part focuses on determining the Minimum Selling Price (MSP) at a given discount rate to assess the project's profitability for investors. Key financial indicators such as NPV, IRR, ROI, and payback period are provided. Finally, the cost of CO_2 abatement is calculated.

Levelized Cost of Production (LCOP)

The Levelized Cost of Production (LCOP) is a key metric used to assess the most suitable technology option and the financial viability of a project. It is calculated as the net present value of capital and operating costs, adjusted for any operational benefits, divided by the discounted total output over the project’s lifetime. For simplicity, in this context, the cost of SAF is assumed to be equal to the cost of HVO diesel.

$$LCOP = \frac{CAPEX \; + \; \sum_{n=1}^{N} \frac{OPEX_n}{(1+WACC)^n} \; - \; \sum_{n=1}^{N} \frac{OperationalBenefits_n}{(1+WACC)^n}}{\sum_{n=1}^{N} \frac{\text{product amount}_n}{(1+WACC)^n}}$$

Where:

- CAPEX = Capital expenditure
- OPEX = All operational expenditure (including fuel and maintenance CAPEX)
- WACC = WACC of the project:
- n = The year
- N = Project lifetime
- Product amount = e.g., tonnes of SAF and/or HVO diesel

WACC is defined as:

$$\text{WACC} = \frac{E}{V} \cdot r_e + \frac{D}{V} \cdot r_d \cdot (1 - T_c)$$

Where:

- E = equity value
- D = debt value
- V=E+D total firm value
- r_e = cost of equity
- r_d = cost of debt
- T_c = corporate tax rate

This analysis does not account for depreciation or inflation. For simplicity, the production cost of SAF and HVO diesel are assumed to be equal at this stage. A production ramp-up is considered during the first two years, with operations at 50% capacity in year 1 and 90% in year 2. In certain cases, potential revenue from co-product sales is included, specifically when the co-products are not utilized for hydrogen generation.

Minimum Selling Price of SAF (MSP)

The minimum selling price (MSP) is calculated by ensuring that the project's cash flows cover all capital and operating costs. In essence, the MSP is the price at which the project reaches a Net Present Value (NPV) of zero when discounted at WACC, ensuring that the investment meets the minimum acceptable return threshold. This analysis is done using an unlevered cash flow and it includes depreciation, inflation and corporate taxes. At this stage, SAF and diesel price can be varied independently. For this analysis HVO diesel price is 95% of the SAF price. Additionally, the potential margin from selling SAF at market prices of 2 000 USD/t and 2 250 USD/t will be assessed compared to the MSP. This analysis will use IRR and NPV as key evaluation metrics.

Internal Rate of Return (IRR)

The IRR is the discount rate that makes the Net Present Value (NPV) of a project equal to zero.

Net Present Value (NPV)

Net Present Value (NPV) is the sum of all expected future cash flows from a project, discounted back to their present value using a chosen discount rate. It shows the project's profitability. A positive NPV means the project is financially viable. For this study, the NPV is discounted by the value of the WACC.

Return on Investment (ROI)

In this study, the return on investment (ROI) is calculated according to the formula:

$$ROI = \frac{net\ annual\ profit}{total\ investment} * 100\%$$

Payback period

Non discounted and non-inflated payback period will be calculated in reference to the total investment (fixed capital costs + working capital).

CO_2 abatement cost

Abatement cost represents the economic cost of reducing greenhouse gas (GHG) emissions by one metric ton of CO_2-equivalent (tCO_2e). It helps measure how cost-effective a low-carbon fuel or technology is compared to a conventional one.

$$\text{Abatement Cost}\left(\frac{\$}{tCO_2e}\right) = \frac{MSP_{SAF} - P_{jet}}{LSf_{jet} - LSf_{SAF}}$$

Where:

- P_{jet} is the price of fossil jet fuel
- LSf is the emission in t_{CO2eq}/MJ (to consider 89 g/MJ for fossil jet fuel)
- 43.2 MJ/kg to be used as LHV of jet fuel

3.1.6 Model scenario simulation for HEFA in Kenya

In the following section, the model is used to explore a range of scenarios by adjusting six key variables that influence both the technical and financial performance of the project as shown below in Figure 22.

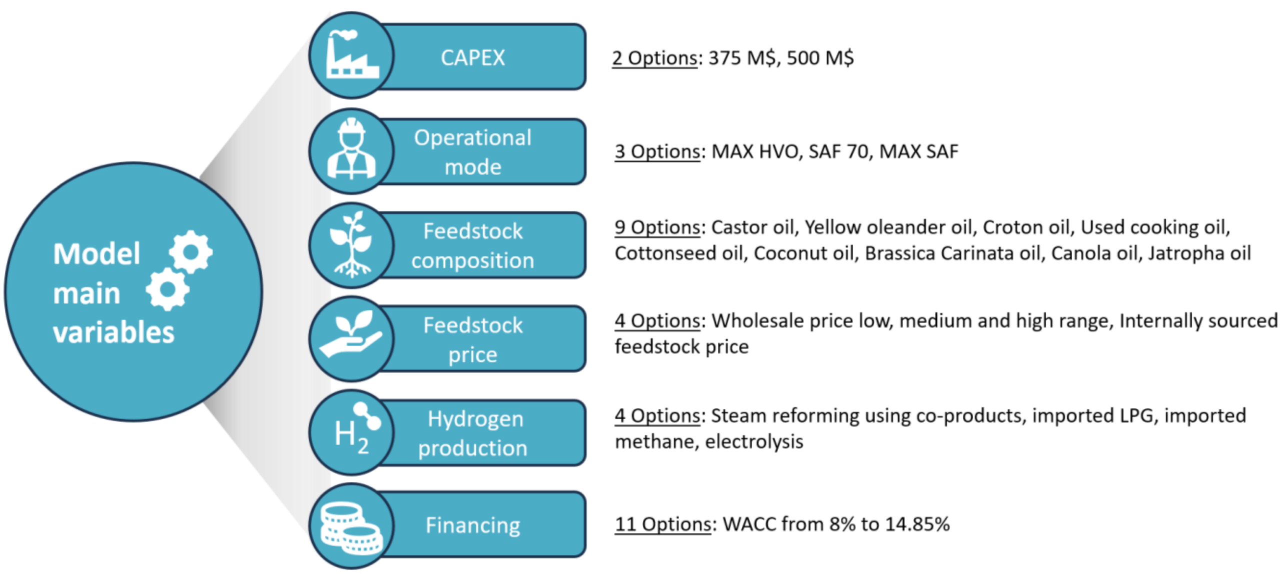


Figure 22. Main variables for the techno-economic model for HEFA technology.

In the analysis, two capital expenditure levels, USD 375 million and USD 500 million, are considered to capture potential variations in investment requirements. The analysis considers three operational modes (MAX HVO, SAF 70, and MAX SAF) representing different production configurations. Nine feedstock options are examined, and feedstock prices are varied across four levels, from wholesale market rates to internally sourced pricing. Hydrogen supply is evaluated through four production pathways: steam reforming with co-products, imported LPG, imported methane, and electrolysis. Financing scenarios are assessed under eleven different WACC conditions, ranging from 8% to 14.85%, to reflect varying capital structures and lending costs. This approach allows for a comprehensive assessment of the model's sensitivity to a broad spectrum of technical and financial inputs.

3.2 YIELD AND SELECTIVITY

The chemical composition of the feedstock plays a critical role in determining process yield, selectivity, and overall energy requirements. This section examines how variations in feedstock characteristics influence these factors, providing a foundation for understanding their impact on process performance and efficiency.

3.2.1 Feedstock composition

The chemical composition and molecular characteristics of various vegetable oils can be examined across four key dimensions: fatty acid chain length, functional groups, degree of saturation, and elemental content (Figure 23). These properties can be derived from the analysis of the data reported in Table 19.

Fatty acid length chain

The carbon chain length of fatty acids influences the distribution of fuel fractions produced during hydrotreatment, particularly the proportions of SAF and diesel (Figure 23, Vegetable oil composition). Since SAF typically consists of hydrocarbons in the C8–C16 range, fatty acid chains within this range need isomerization without strictly requiring hydrocracking to fulfil the specification for SAF. This avoids additional hydrogen consumption and simplifies the process.

The chain length distribution of fatty acids varies significantly across different types of vegetable oils. Among the most favourable compositions for SAF production is coconut oil, with over 90% of its fatty acid chains falling within the SAF-relevant range (C8–C16), which theoretically do not require necessarily hydrocracking. Used cooking oil, usually derived from palm oil in Kenya, contains significant amounts of both C16 and C18 chains, making also a quite attractive feedstock. However, its composition can vary considerably depending on the types of culinary oils commonly used.

On the opposite end of the spectrum, Brassica carinata contains longer-chain fatty acids, extending up to C22, making it more suitable for diesel production and requiring hydrocracking for SAF use. Croton oil also includes a portion of C20 chains. Most other vegetable oils are primarily composed of C18 fatty acids, with minor components as short as C16. This type of oil usually requires hydroisomerization and hydrocracking to optimize SAF production.

Chemical functional groups in vegetable oils

The presence of specific chemical functional groups in vegetable oils directly influences hydrogen consumption during processing (Figure 23, Vegetable oil functional groups). These functional groups include esters (- COOR), hydroxyls (-OH), and carbon-carbon double bonds (-C=C-), all of which must be removed or transformed to produce hydrocarbons suitable for fuel. Among the feedstocks, castor oil is unique due to the presence of hydroxyl groups within the ricinoleic acid chain. This additional oxygen content increases the hydrogen demand and slightly reduces the overall liquid fuel yield compared to other oils.

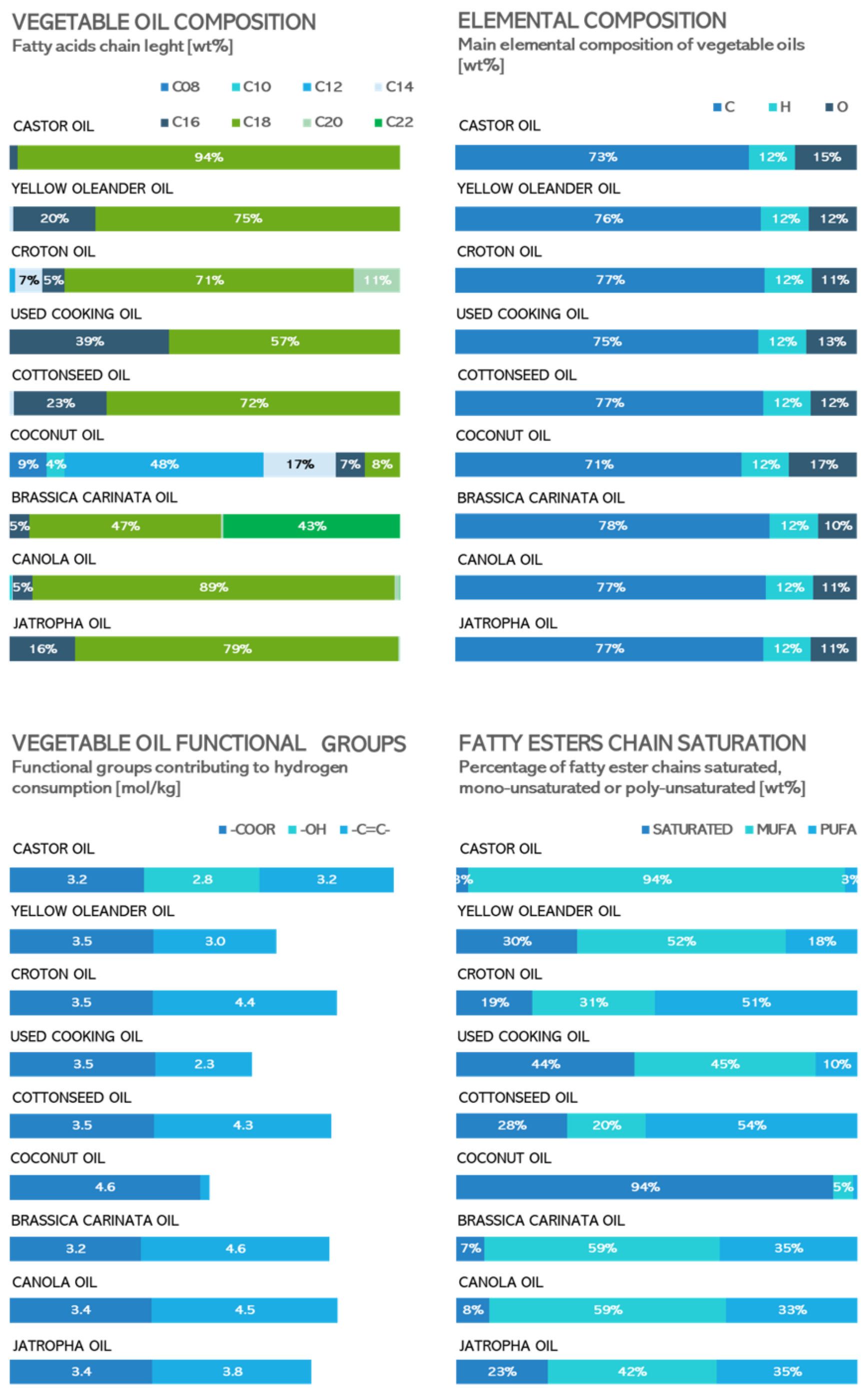


Figure 23. Main characteristics of vegetable oils influencing the reaction yield and hydrogen requirements.

Coconut oil contains no unsaturated bonds, which lowers hydrogenation requirements; however, its shorter carbon chains result in a relatively higher number of ester groups per unit of mass. Yellow oleander and used cooking oil (in this case from palm) generally exhibit lower degrees of unsaturation than other vegetable oils, meaning they require less hydrogen for saturation, making them slightly more efficient in terms of hydrogen consumption during the upgrading process.

Saturation of the fatty acid chains

The saturation level of fatty acid esters is typically represented by the relative proportions of saturated, monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids (Figure 23, Fatty ester chain saturation). This composition significantly impacts the hydrogen demand during processing, as higher degrees of unsaturation require more hydrogen for saturation. At one end of the spectrum, coconut oil consists almost entirely of saturated fatty acids, resulting in minimal hydrogenation requirements. In contrast, croton and cottonseed oils contain over 50% polyunsaturated fatty acids, leading to substantially higher hydrogen consumption during conversion.

Oil elemental composition

The elemental composition of the oils is reported in terms of carbon (C), hydrogen (H), and oxygen (O) content by weight percentage (Figure 23, Elemental composition).

During hydrotreatment, heteroatoms such as oxygen are removed from the feedstock, resulting in a reduction in final product yield relative to the original oil weight. Oils like coconut and castor oil are particularly affected due to their higher oxygen content. As previously noted, coconut oil contains a greater number of ester (COOR) groups per unit mass because of its shorter fatty acid chains, while castor oil has an elevated oxygen content due to the hydroxylated fatty acids. In contrast, the other feedstocks, such as yellow oleander, croton, used cooking oil, cottonseed, Brassica carinata, canola, and jatropha, have more uniform elemental compositions, typically consisting of approximately 76–77% carbon, 12% hydrogen, and 11–13% oxygen.

3.2.2 Product yields under different process scenarios

Figure 24 illustrates the product distribution resulting from different operational conditions.

MAX HVO

The MAX HVO mode refers to a process configuration involving hydrotreatment and isomerization, but without hydrocracking the molecules. Under this mode, most feedstocks predominantly yield diesel (~C10-C24), as longer-chain hydrocarbons are preserved (Table 23). However, depending on the proportion of components with carbon chain lengths below C16, a portion of the product can be separated and qualified as SAF. Among the feedstocks, coconut oil exhibits the highest SAF yield under MAX HVO conditions, due to its high concentration of medium-chain fatty acids. This is followed by used cooking oil derived from palm oil, which also shows a relatively high SAF fraction. For the other feedstocks, the SAF-yielding fraction typically remains below 20%. During the hydrotreatment process, water formation accounts for a weight loss of approximately 11–17%, resulting from deoxygenation reactions. Additionally, propane is produced through hydrogenation of glycerol, contributing around 5–7% of the product mass. In practice, minor amounts of CO_2, CO, and methane may also form due to parallel decarbonylation, decarboxylation, and methanation reactions. These byproducts are not explicitly modelled but could introduce a carbon balance error of roughly 1%, assuming hydrodeoxygenation (HDO) selectivity exceeds 90%.

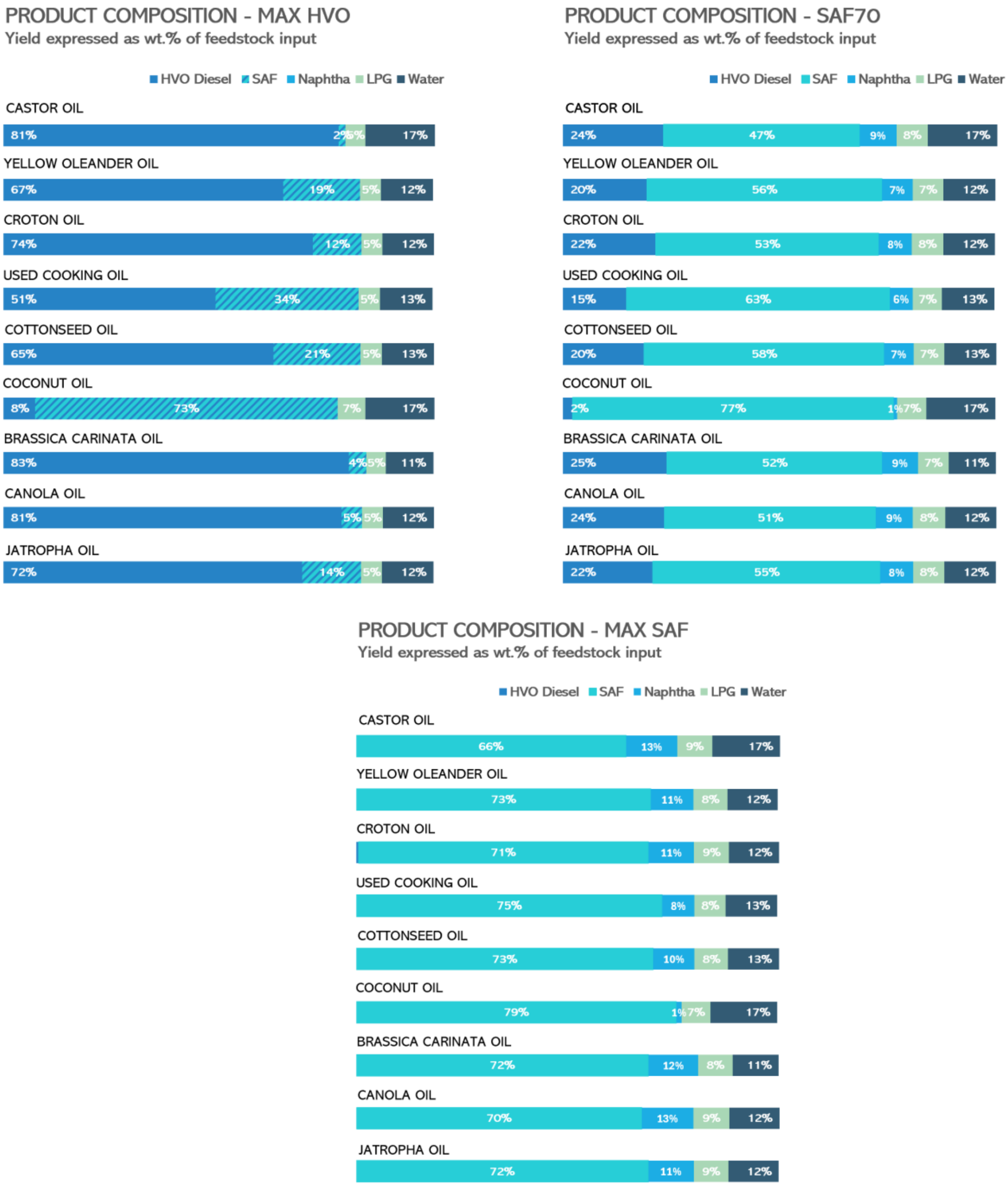


Figure 24. Product slate for three operational modes (in-house calculations).

Table 23. Product distribution of MAX HVO process configuration (in-house calculations).

	Castor oil	Yellow ol. oil	Croton oil	UCO	Cotton oil	Coconut oil	Brassica c. oil	Canola oil	Jatropha oil
Vegetable oil input [thousand t/year]	250	250	250	250	250	250	250	250	250
Total distillates [thou-sand t/year]	206	215	215	214	215	201	216	216	215
SAF + HVO diesel [mass/mass]	82%	86%	86%	85%	86%	80%	86%	86%	86%
SAF [thousand t/year]	4	46	29	86	52	182	14	12	35
HVO diesel [thousand t/year]	202	168	186	128	163	19	201	204	180
Naphtha [mass/mass]	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%
LPG output [thousand t/year]	12	13	13	13	13	17	13	13	13
Water produced [thousand t/year][a]	42	31	31	32	31	41	31	31	31
Hydrogen consumed [thousand t/year]	9.5	8.4	9.1	8.2	9.1	9.3	9.4	9.1	8.8
Extra LPG import [thousand t/year][b]	37	32	35	31	35	32	36	35	34
Power required [GWh/year][c]	29	28	29	27	29	28	29	29	28

Note: A net export of steam is expected; however, as this also depends on the type of steam reformer used, it is not reported here. In this scenario naphtha production

[a] CO and CO_2 formation are considering negligible for HDO >90%, giving (error ~1 % by weight)

[b] Only estimation. More accurate value needs heat integration calculations

[c] The estimate only accounts for major consumers, such as compressors, and therefore underestimates the total demand. However, with a requirement of approximately 4 MW, this suggests that the 15 MW transformer will be sufficient.

<u>SAF 70</u>

The SAF70 scenario reflects a hydrocracking-based approach in which approximately 70% of the diesel fraction is converted to SAF. Operation with 70-80% conversion is commonly regarded as a practical compromise between maximizing SAF output and maintaining overall process efficiency and economic viability. Under these conditions, around 50–60% of the feedstock's weight is typically converted into SAF, while 15–25% remains as diesel (Table 24). An exception to this trend is coconut oil, which, due to its unique fatty acid composition, behaves differently without a need for the hydrocracking process.

Hydrocracking also leads to the formation of additional byproducts such as naphtha and LPG, contributing to the overall product slate for a total of 8-17%. However, as the extent of conversion in the hydrocracker increases, the combined yield of middle distillates (SAF + diesel) tends to decline. This is because longer diesel-range molecules are increasingly broken down into lighter fractions, including SAF, naphtha, and LPG.

Table 24. Product distribution of the SAF 70 process configuration (in-house calculations).

	Castor oil	Yellow ol. oil	Croton oil	UCO	Cotton oil	Coconut oil	Brassica c. oil	Canola oil	Jatropha oil
Vegetable oil input [thousand t/year]	250	250	250	250	250	250	250	250	250
Total distillates [thousand t/year]	178	191	190	196	193	198	189	188	190
SAF + HVO diesel [mass/mass]	71%	77%	76%	78%	77%	79%	76%	75%	76%
SAF [thousand t/year]	118	141	134	158	144	193	128	127	136
HVO diesel [thousand t/year]	60	50	56	38	49	6	61	61	54
Naphtha [thousand t/year]	22	18	20	14	18	2	22	22	20
LPG output [thousand t/year]	19	18	19	17	18	18	19	19	19
Water produced [thousand t/year]	42	31	31	32	31	41	31	31	31
Hydrogen consumed [thousand t/year]	10.6	9.3	10.1	8.9	10.0	9.4	10.4	10.2	9.8
Extra LPG import [thousand t/year]	8	7	7	8	8	27	7	7	7
Power required [GWh/year]	36	29	30	28	30	28	31	30	30

Note: see notes for Table 23.

MAX SAF

In the MAX SAF configuration, the process is optimized to maximize the conversion of feedstock into SAF, effectively minimising diesel production from the product slate. Under this setup, SAF becomes the predominant output, with yields ranging from 66% for castor oil to up to 79% for coconut oil (Table 25). Most feedstocks, including yellow oleander, croton, used cooking oil, cottonseed, Brassica carinata, canola, and jatropha, produce SAF in the range of 70–75%.

Byproducts such as naphtha and LPG are also generated, typically accounting for 8% to 22% of the total product yield, depending on the feedstock and its composition. The amount of water produced remains consistent with other process configurations, as water formation is primarily tied to the hydrodeoxygenation (HDO) reactions.

Table 25. Product distribution of MAX SAF process configuration (in-house calculations).

	Castor oil	Yellow ol. oil	Croton oil	UCO	Cotton oil	Coconut oil	Brassica c. oil	Canola oil	Jatropha oil
Vegetable oil input [thousand t/year]	250	250	250	250	250	250	250	250	250
Total distillates [thousand t/year]	166	181	180	188	183	197	176	176	180
SAF + HVO diesel [mass/mass]	66%	72%	71%	75%	73%	79%	70%	70%	72%
SAF [thousand t/year]	166	181	178	188	183	197	176	176	180
HVO diesel [thousand t/year]	-	-	-	-	-	-	-	-	-

	Castor oil	Yellow ol. oil	Croton oil	UCO	Cotton oil	Coconut oil	Brassica c. oil	Canola oil	Jatropha oil
Naphtha [thousand t/year]	32	26	28	20	25	3	32	32	28
LPG output [thousand t/year]	22	21	21	19	21	18	22	22	21
Water produced [thousand t/year]	42	31	31	32	31	41	31	31	31
Hydrogen consumed [thousand t/year]	11.1	9.7	10.6	9.2	10.4	9.5	10.9	10.7	10.2
Extra LPG import [thousand t/year]	6	6	8	12	10	31	5	4	6
Power required [GWh/year]	39	36	38	35	38	34	39	39	37

Note: see notes for Table 23.

These three processing configurations represent potential operational modes for a flexible HEFA facility. The yield values presented are based on theoretical calculations and may differ from actual results under commercial operating conditions; the purpose here is to illustrate general trends rather than predict precise outcomes.

The MAX HVO mode is optimized for diesel production, making it suitable for applications where maximizing middle distillates is a priority. The SAF70 scenario offers a balanced strategy, producing both SAF and diesel in significant quantities while maintaining moderate levels of byproducts. In contrast, the MAX SAF configuration is designed to maximize aviation fuel output, with minimal diesel production.

This comparative analysis is valuable for understanding how feedstock composition influences product distribution, and it highlights the importance of aligning process design with fuel targets. In selecting suitable feedstocks for a HEFA plant, additional factors such as sustainability, pretreatment requirements, and feedstock cost must also be carefully considered.

3.2.3 Hydrogen consumption and potential cost

Figure 25 illustrates hydrogen consumption across three distinct operational scenarios: MAX HVO (focused on maximizing diesel yield), SAF70 (partial conversion to SAF), and MAX SAF (optimized for maximum SAF production). Hydrogen usage is expressed as a percentage by weight relative to the original feedstock mass and varies between 3.2% and 4.5% by weight, depending on both the feedstock type and the processing configuration.

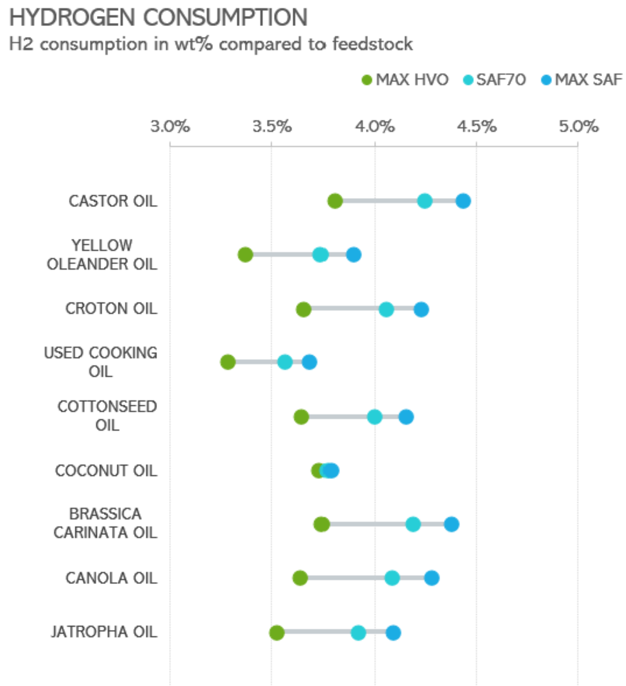


Figure 25. Hydrogen consumption for different feedstocks and operation mode (in-house calculations).

Hydrogen consumption is generally lowest in the MAX HVO mode, where minimal hydrocracking occurs and diesel remains the primary product. In this configuration, hydrogen demand typically ranges from 3.2% to 3.8% by weight. Feedstocks such as yellow oleander and used cooking oil derived from palm oil fall within this lower range, reflecting their lower degree of unsaturation and simpler hydrogenation requirements.

As the degree of hydrocracking increases in the SAF70 scenario, hydrogen demand rises accordingly. Most feedstocks in this mode require between 3.7% and 4.3% hydrogen by weight, due to the additional processing steps involved in converting diesel fractions into SAF.

The highest hydrogen consumption is observed in the MAX SAF scenario, where extensive hydrocracking is necessary to maximize SAF yield. In this case, hydrogen use reaches up to 4.5% of the feedstock weight. While most of the hydrogen is consumed during the hydrodeoxygenation (HDO) step across all scenarios, total demand clearly scales with the intensity of conversion.

3.3 LEVELIZED COST OF PRODUCTION FOR SAF PRODUCTION

In this chapter, two main scenarios are analyzed, based on the capital expenditure (CAPEX) assumptions outlined previously. These scenarios reflect investment levels of USD 375 million and USD 500 million, corresponding to an optimistic case and a more conservative case. Building on these scenarios, a range of key variables is examined to assess their influence on the Levelized Cost of Production (LCOP). These variables include the operational model feedstock composition and price, hydrogen production strategy, co-product utilization, and the Weighted Average Cost of Capital (WACC).

The chapter concludes with a sensitivity analysis, aimed at evaluating the impact of each parameter on the overall economic performance of the project.

3.3.1 Influence of CAPEX, operational mode and feedstock composition

In this section, the impact of CAPEX, operational mode, and feedstock composition on the Levelized Cost of Production (LCOP) is assessed. The LCOPs are presented on a per-tonne-of-middle-distillate (SAF + HVO diesel) basis, and at this stage, SAF and HVO diesel are assumed to have the same selling price. Naphtha and LPG are internally used to generate green hydrogen, rather than being sold. For comparison, all feedstocks are evaluated at a fixed price of 1 000 USD/t. This standardization allows for a clearer understanding of how feedstock composition influences the cost of producing one tonne of middle distillate (SAF + HVO diesel).

For instance, under the MAX HVO operational mode (Figure 26), a feedstock cost of 1 239 USD/t directly reflects the requirement of 1.239 tonnes of castor oil to produce 1 tonne of middle distillate. The remaining mass is converted into by-products such as water, LPG, naphtha, and other off-gases. This illustrates the impact of feedstock chemical composition, particularly the oxygen content, on the product yield. Feedstocks with higher oxygen content, such as castor oil and coconut oil, tend to yield lower amounts of middle distillates due to increased formation of water. Feedstock composition has an influence on the LCOP since it influences both product yields and hydrogen demand, but the variability is usually confined in 100-200 USD/t (Figure 26), depending on the operation mode. In contrast, feedstock price has the most substantial effect, contributing approximately 60–70% of the total LCOP. This will be examined in further detail in Section 3.3.2.

With respect to capital costs, the comparison between the USD 375 million and USD 500 million CAPEX scenarios indicates that the direct impact on the final SAF price is relatively modest, typically contributing less than 100 USD/t. However, having a lower investment requirement may facilitate easier access to financing.

The three operational modes analyzed, MAX HVO, SAF 70 and MAX SAF, represent distinct strategies in terms of production focus and economic performance. The MAX HVO configuration offers the lowest production cost, but results in a limited yield of SAF, as it prioritizes the production of HVO diesel (see 3.2.2).

Conversely, the MAX SAF mode is designed to maximize SAF output but does so at a higher cost due to increased generation of naphtha, LPG, and other by-products. The SAF 70 scenario provides a balanced compromise, delivering a moderate SAF yield with intermediate production costs, making it potentially attractive under certain market conditions. In real-world operation, the facility is expected to adopt a flexible approach, shifting between MAX HVO, SAF 70, and MAX SAF modes depending on market demand for SAF and HVO.

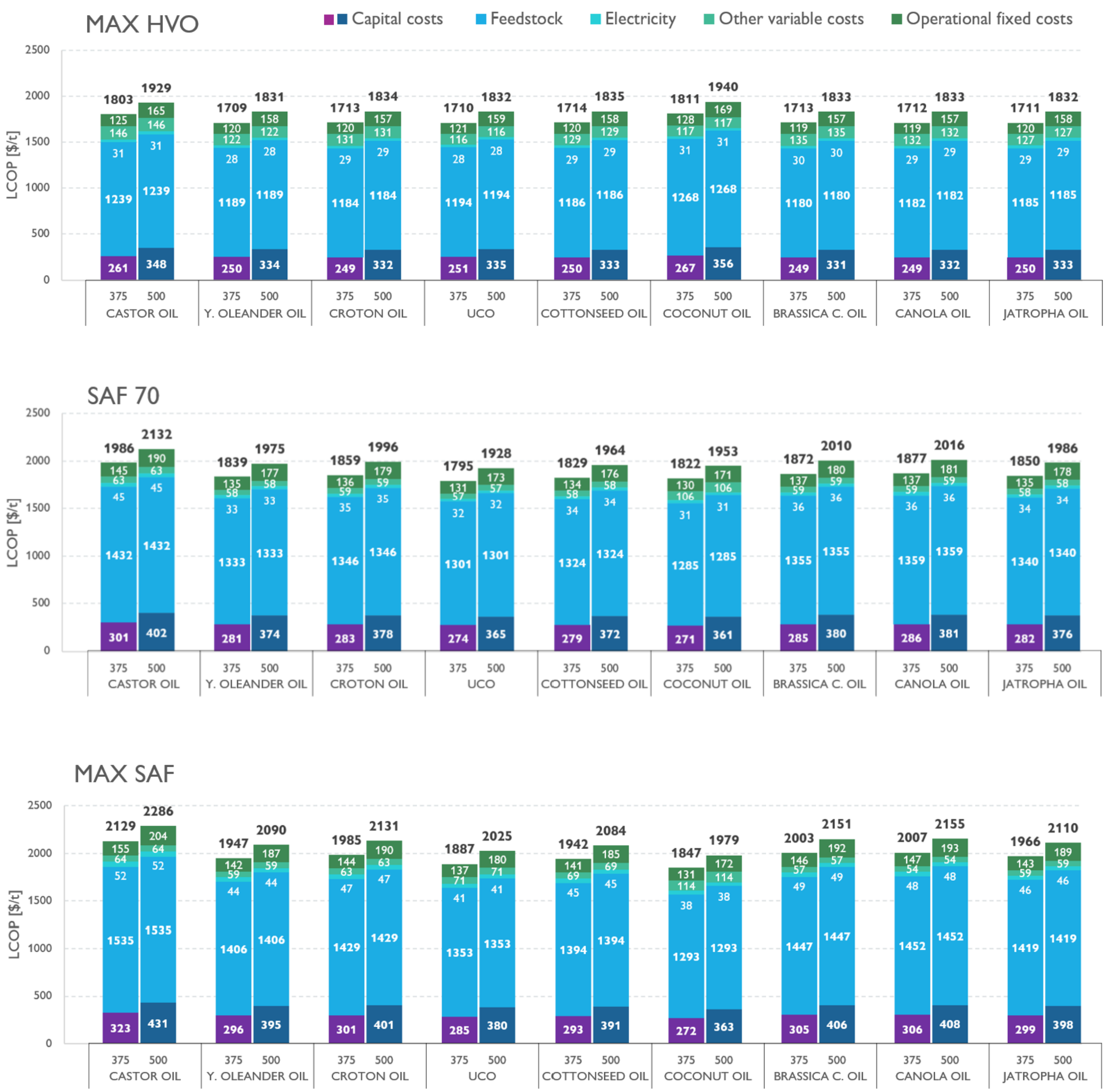


Figure 26. LCOP for SAF and HVO diesel calculated with the following assumptions: WACC 11.9%, CAPEX USD 375-500 million, feedstock price equalised at 1 000 USD/t, H_2 production by steam reforming of co/by-products.

Overall, the production cost of middle distillates varies depending on the operational mode. For instance, assuming a feedstock price of 1 000 USD/t, the LCOP is below 2 000 USD/t for the MAX HVO and SAF 70 scenarios, and below 2 300 USD/t for the MAX SAF case. It is important to note that these results reflect general trends, and actual yields may differ with commercial-scale catalysts and process optimizations.

3.3.2 Influence of feedstock price

In practice, the cultivation and sourcing of feedstocks can vary significantly, leading to differences in production costs. These variations may stem from agronomic factors, supply chain complexity, or simply market-driven demand that drives up prices. In this section, we examine how fluctuations in feedstock market prices influence the Levelized Cost of Production (LCOP) of SAF (Figure 27).

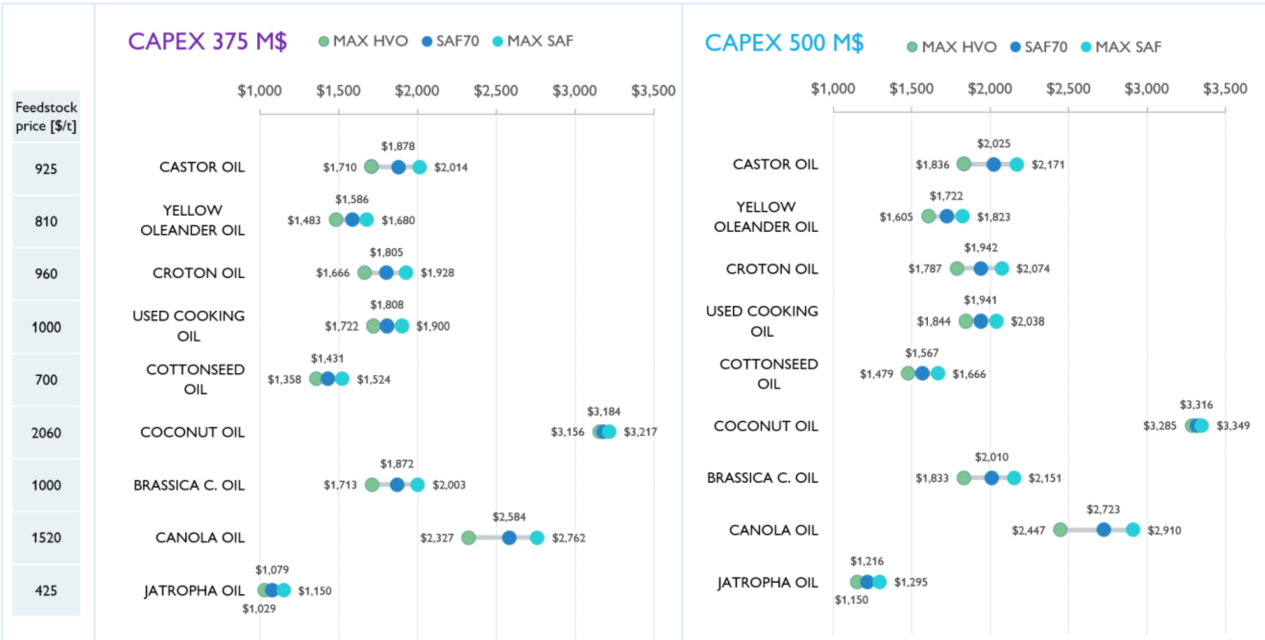


Figure 27. LCOPs calculated using the average feedstock wholesale prices reported in Table 20. Calculation assumptions: WACC 11.9%, CAPEX USD 375-500 million, H_2 production by steam reforming of co/by-products.

Feedstock cost represents the most critical factor influencing the economics of SAF production. When feedstock is priced at 700 USD/t, the Levelized Cost of Production (LCOP) remains below 1 600 USD/t. Feedstock prices below 1 000 USD/t generally allow the LCOP to stay under 2 000 USD/t, highlighting the strong sensitivity of production economics to feedstock pricing.

In the current market context, feedstocks such as coconut oil and canola oil are priced above profitable thresholds in the local wholesale market, rendering them less viable. By contrast, jatropha oil offers a very low wholesale price, which could enable cost-competitive SAF production. However, the scalability and commercial availability of jatropha still require further technical validation and market assessment before being considered a reliable feedstock option at scale. The most recent biodiesel experiment in Kenya, which focused on jatropha, did not conclude successfully due to various factors, including unsuitable seed material and limited locally knowledge for its cultivation (Langford, 2014).

In Figure 28 a range of market prices was assessed for the sensitivity of SAF production costs to feedstock prices. For some feedstocks, such as yellow oleander, croton, and Brassica carinata, the upper and lower price limits were only estimated, due to limited published data for the region. The results show that a price fluctuation of just 100 USD/t in feedstock can lead to a change of more than 100 USD/t in the final SAF price. Such volatility can significantly affect the project's profitability, potentially shifting it from a highly competitive to a non-competitive position. It should be noted that feedstock prices may rise significantly in the future due to increasing demand or other influencing factors. Such developments could alter the allocation of feedstock to different markets and potentially drive up the price of sustainable aviation fuel (SAF). Therefore, future studies should carefully assess not only variations in the current market but also potential future dynamics, with particular attention to comparisons across the global market.

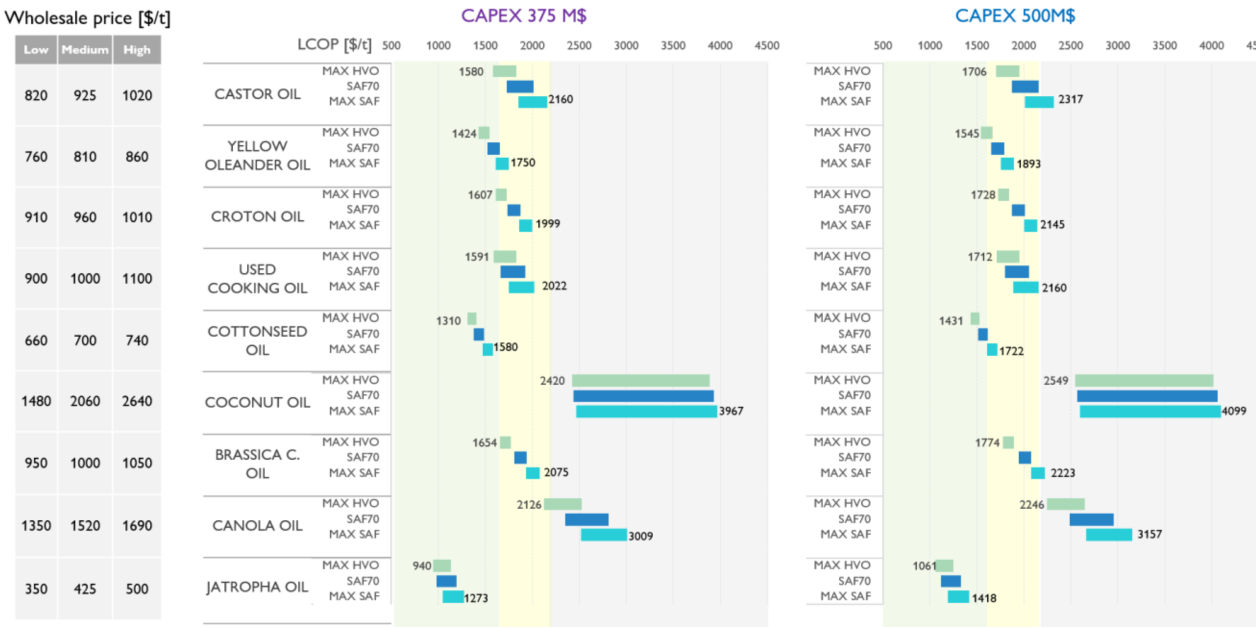


Figure 28. LCOP variation in dependence of feedstock price. Assumption for the calculation: WACC 11.9%, CAPEX USD 375-500 million, H_2 production by steam reforming of co/by-products. Green indicates feedstocks with high cost-competitiveness, yellow represents those with moderate economic viability, and grey denotes feedstocks that currently may be too expensive to be considered viable.

To mitigate exposure to volatile market prices, one promising strategy is to secure feedstock supply internally, either within the project scope or through a consortium-based model. This approach has the potential to lower procurement costs and improve overall cost stability. Due to limited data availability and time constraints, a more detailed breakdown of actual cultivation costs for the various feedstocks could not be developed at this stage. For this assessment, internal production costs were estimated by applying a 10% reduction to the lower bound of the wholesale price range, in cases where specific production cost data were not available. An exception was made for used cooking oil (UCO), where no reduction was applied as it is not affected by margin reductions for cultivation. Additionally, production costs could potentially be lower if co-products of the oil extraction can be sold and generate revenue. For instance, protein isolates or seed cake for animal feed can add value and offset overall costs.

In Figure 29 the influence on the SAF LCOP is illustrated in comparison to Figure 27, highlighting some trends in cost reduction. For most feedstocks, the SAF LCOP remains below 1 800 USD/t with a CAPEX of USD 375 million, and below 1 900 USD/t with a CAPEX of USD 500 million. For certain feedstocks, particularly coconut and canola oil, even after adjusting for internal production costs, the resulting LCOP remains relatively high, indicating limited economic benefit under current market conditions. However, this does not rule out that their real production costs are much lower than the market price and these feedstocks may be potentially used profitably. It is important to note that they are also in competition with the food market, where they can generate more profit, making their diversion to fuel production less attractive. Recently, however, non-standard coconut oil, which does not meet food-grade requirements, was approved under CORSIA as eligible feedstock for SAF with an ILUC value of zero. This category of feedstock may be available at significantly lower prices, potentially improving its viability for SAF production.

A more comprehensive analysis of the cost structure for feedstock cultivation and their effective cultivation and oil production costs, as well as potential supply chain efficiencies would be valuable in future studies. Such analysis could help determine realistic cost reduction potential and identify areas for process or logistical optimization.

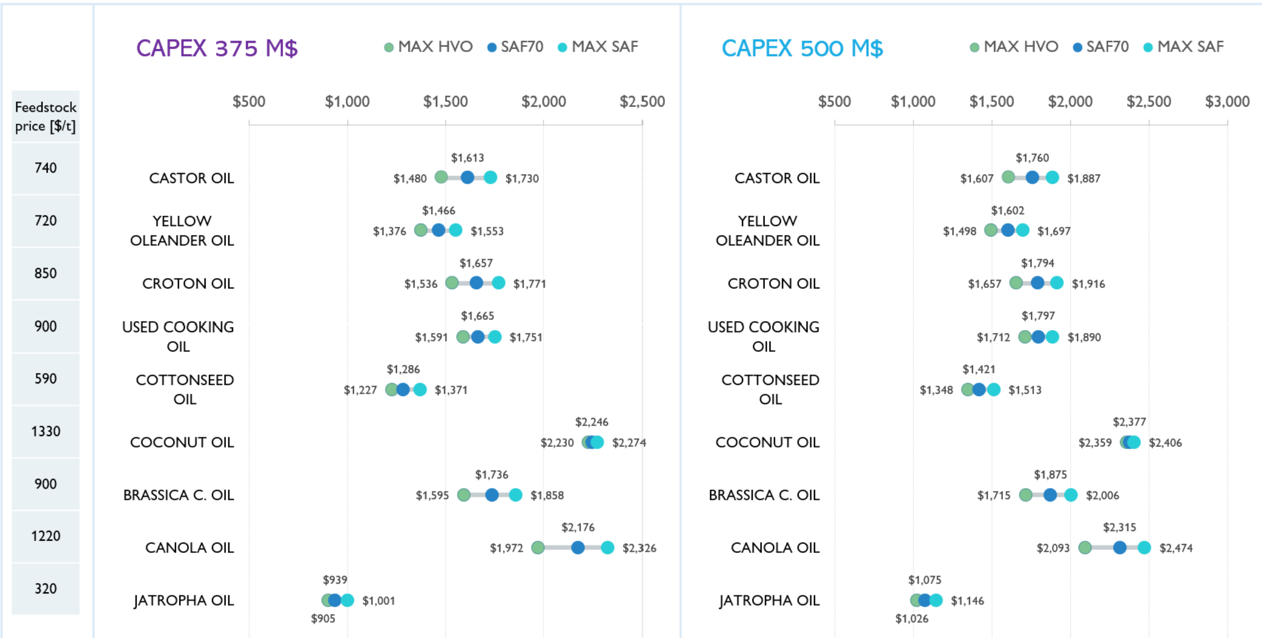


Figure 29. LCOP calculated using internally sourced feedstock prices reported in Table 20. Assumption for the calculation: WACC 11.9%, CAPEX USD 375-500 million, H_2 production by steam reforming of co/by-products.

3.3.3 Hydrogen production and co-product utilization

The choice of hydrogen supply strategy is a key factor influencing the overall economic viability of SAF production. The HEFA pathway requires on-site hydrogen supply, necessitating the construction of a new production unit. Accordingly, two main technologies are considered (steam reforming and electrolysis) and four hydrogen supply scenarios are analyzed (Figure 30), assessing their impact on the LCOP and examining their feasibility within the local context of the Mombasa refinery.

Steam reforming is the dominant and economically favourable hydrogen generation route. For this case study three feedstock options can be considered: natural gas, LPG, and naphtha/LPG/off-gases co-/byproduct streams. Steam reforming of natural gas typically produces hydrogen at a cost of approximately 1.30–3.20 USD/kg, depending primarily on natural gas prices. The incorporation of carbon capture and storage (CCS) technologies to mitigate associated emissions generally increases production costs by about 0.80 USD/kg. Steam reforming using LPG is on average more expensive, averaging 2.70-3.30 USD/kg plus the same CCS cost if implemented. Steam reforming of co-/byproducts is similar to using LPG if the cost of the feedstock is considered.

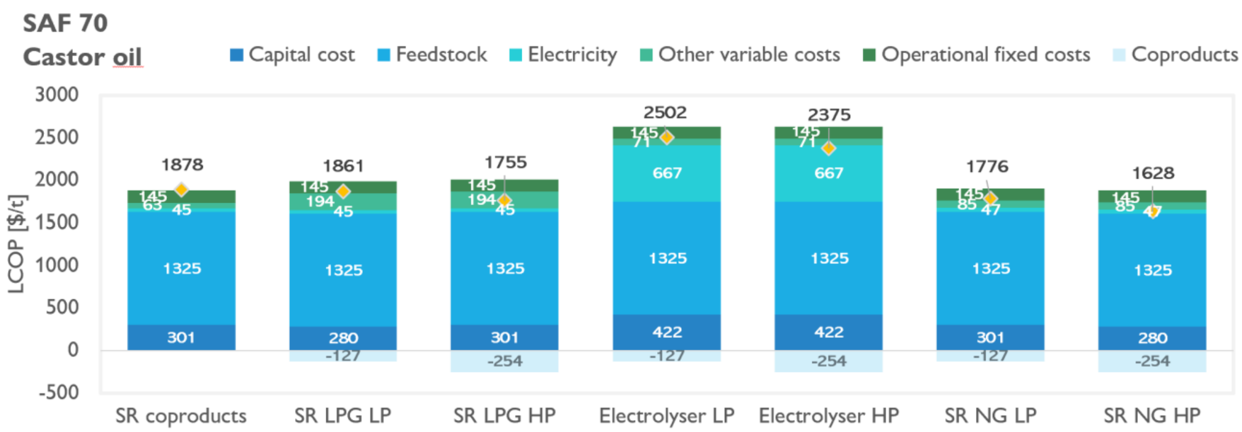


Figure 30. Comparison on LCOP of different hydrogen production modes. Assumption for the calculation: WACC 11.9%, CAPEX USD 375 million, Castor oil for SAF 70 operation mode. Legend: SR= steam reformer; LP= low profit; HP= high profit; NG= natural gas.

Option 1. Steam reforming of co/by-products (SR coproducts)

Steam reforming of internally generated co- and by-products, such as naphtha, LPG and off-gases, presents the most suitable solution for the Mombasa refinery, both logistically and economically. This option offers three main advantages:

- It produces renewable hydrogen, since the co/by-products have biogenic origins
- It enhances GHG savings, thereby improving the sustainability profile of the SAF
- It increases the economic value of SAF under carbon accounting mechanisms

Although this approach may still require additional fossil fuel input, particularly under MAX HVO operations where fewer co-products are formed, it delivers a competitive LCOP of 1 878 USD/t. This makes it the most viable option among those evaluated, particularly when accounting for the degree of plant autonomy from external imports.

Option 2. Steam reforming of fossil LPG (SR LPG)

In the absence of a natural gas connection from neighbouring countries, steam reforming of fossil-based LPG (or alternatively fossil naphtha) emerges as a viable alternative for hydrogen production. Utilizing fossil products for hydrogen generation also allows bio-naphtha and bio-LPG to be sold, generating additional revenue and helping to reduce the SAF production cost.

Two pricing scenarios were considered:

- Low Profit (LP): Co-products are sold at standard fossil market prices (naphtha at 600 USD/t, LPG at 500 USD/t). Under this scenario, resulting in an LCOP of 1 861 USD/t, there is no significant economic advantage compared to using co-/by-products for steam reforming.
- High Profit (HP): Co-products are assumed to benefit from green market premiums (assumption: naphtha at 1 200 USD/t, LPG at 1 000 USD/t). This improves the LCOP to 1 755 USD/t. However, the feasibility of this scenario is uncertain, as there is currently no policy framework or market mechanism in the region that incentivizes or supports green co-product pricing.

This scenario offers limited advantages compared to steam reforming of co-/by-products and provides fewer environmental benefits, including lower greenhouse gas (GHG) emissions savings, making it a less preferable option.

Option 3. Electrolysis using grid electricity

Hydrogen production via alkaline electrolysis using grid electricity results in the highest LCOPs, ranging from 2 375 USD/t to 2 502 USD/t, depending on co-product pricing assumptions (low and high profit respectively). Despite its renewable nature, the high cost of electricity from the grid in Mombasa makes this pathway economically uncompetitive at present. For example, at an electricity cost of 0.22 USD/kWh, hydrogen production would reach approximately 12 USD/kg. In contrast, captive power plants using lower-cost energy sources can significantly reduce this cost. For instance, geothermal power in Olkaria can provide electricity at around 0.07 USD/kWh, potentially lowering hydrogen production costs to approximately 5 USD/kg. For this reduced price, SAF production cost will be between 1 920-2 047 USD/t considering high and low product profits.

Option 4. Steam reforming of fossil natural gas (SR NG)

While conventional natural gas steam reforming is typically the most cost-effective method for hydrogen production, the lack of internal resource and of pipeline infrastructure connecting Tanzania makes this option not feasible in the short term for the Mombasa site. This pathway can offer competitive economics, with LCOPs ranging from 1 628 USD/t to 1 776 USD/t, but it will not offer the advantage of further reduction in GHG emissions. In conclusion, steam reforming of co-/by-products emerges as the most cost-effective and sustainable hydrogen supply strategy for the Mombasa refinery under current conditions.

Consideration about selling co-products such as bio-naphtha and bio-LPG

While steam reforming of co-products provides a reliable internal hydrogen source, it also eliminates the opportunity to sell these valuable by-products. Conversely, opting for external fossil fuel for hydrogen production preserves these saleable co-product streams, potentially improving the plant's economic return. However, this benefit must be weighed against increased expenses for sourcing fossil fuels, as well as logistical complexity related to transporting and marketing the co-products. For a meaningful economic contribution, co-products must reach market prices of at least 500-600 USD/t. Below this threshold, the added complexity of managing importing fuel and co-product sale logistics may outweigh the benefits. However, while bio-naphtha and bio-LPG can be sold at prices comparable to their fossil-based counterparts, it remains uncertain whether the local market will be willing to pay a premium for these bio-based alternatives.

Further challenges arise with naphtha utilization. Although naphtha produced via HEFA could technically be upgraded to gasoline via catalytic reforming, the existing platforming units at the site are outdated and oversized. Given the relatively low production volume (<30 000 t/year), investment in a new reforming unit is not considered economically viable. As a result, naphtha would either need to be sold as-is or transported to an external facility for further processing to be upgraded to gasoline.

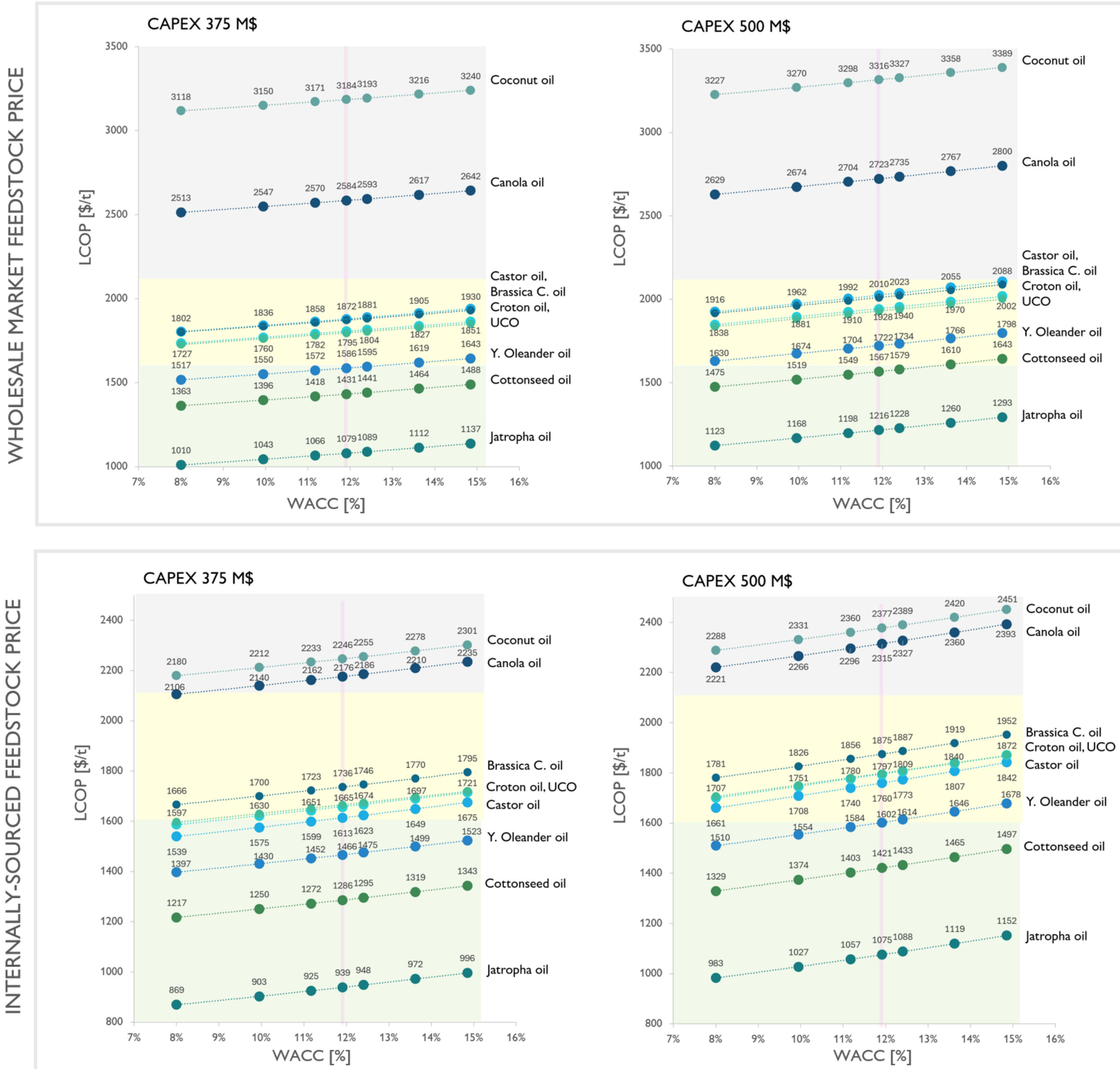


Figure 31. Influence on LCOP by varying WACC for several feedstock under SAF 70 operational mode.

In addition, green LPG currently lacks a well-established market and may not command a price premium over fossil LPG. Given this, its internal use for hydrogen production offers greater value under current market and infrastructure conditions. Considering both the quantity of co-products generated and the regional market, utilizing LPG and naphtha internally for hydrogen production may yield better overall economic performance and higher environmental benefits.

3.3.4 WACC (Weighted Average Cost of Capital)

Figure 31 presents a comparative analysis of various scenarios based on different WACC values, as outlined in Table 22. The baseline scenario assumes a WACC of 11.9%, corresponding to a capital structure comprising 9% debt interest rate and an equity internal rate of return (IRR) of 25%. As expected, higher WACC values lead to an increase in the LCOP. For instance, in Case 5, a WACC of 14.9%, based on a debt interest rate of 15% and equity IRR of 25%, results in an increase of approximately 50-90 USD/t, depending on the feedstock and specific project conditions. However, we believe that the prevailing local bank interest rates are too high to support the financial viability of the project. Therefore, more favourable financing terms, particularly lower interest rates, should be sought through international financing to keep debt interest rate lower than 9%.

A noteworthy exception is presented in Case 7, which models a WACC of 8% under a financing structure that includes 50% concessional loans. This scenario represents a favourable, albeit optimistic, best-case reference point, underling that it will be difficult to further reduce costs beyond this level.

To aid interpretation, the background of the graphs is color-coded to reflect the relative profitability of each scenario. Assuming a reference SAF market price in the range of 2 000-2 200 USD/t:

- The **green zone** indicates highly competitive LCOPs, well-positioned in the market, allowing significant additional profit margins.
- The **yellow zone** represents economically viable outcomes that may allow for additional profit margins. The profitability is highly dependent on the current market price.
- The **grey zone** reflects cost levels that exceed the expected market price range, signalling limited competitiveness.

Nonetheless, the use of feedstock blending strategies may enhance the economic viability of certain high-cost feedstocks by balancing them with lower-cost alternatives, potentially making otherwise uncompetitive options more attractive. Figure 31 also highlights how costs can be significantly reduced by utilizing lower-priced feedstocks, particularly those sourced internally.

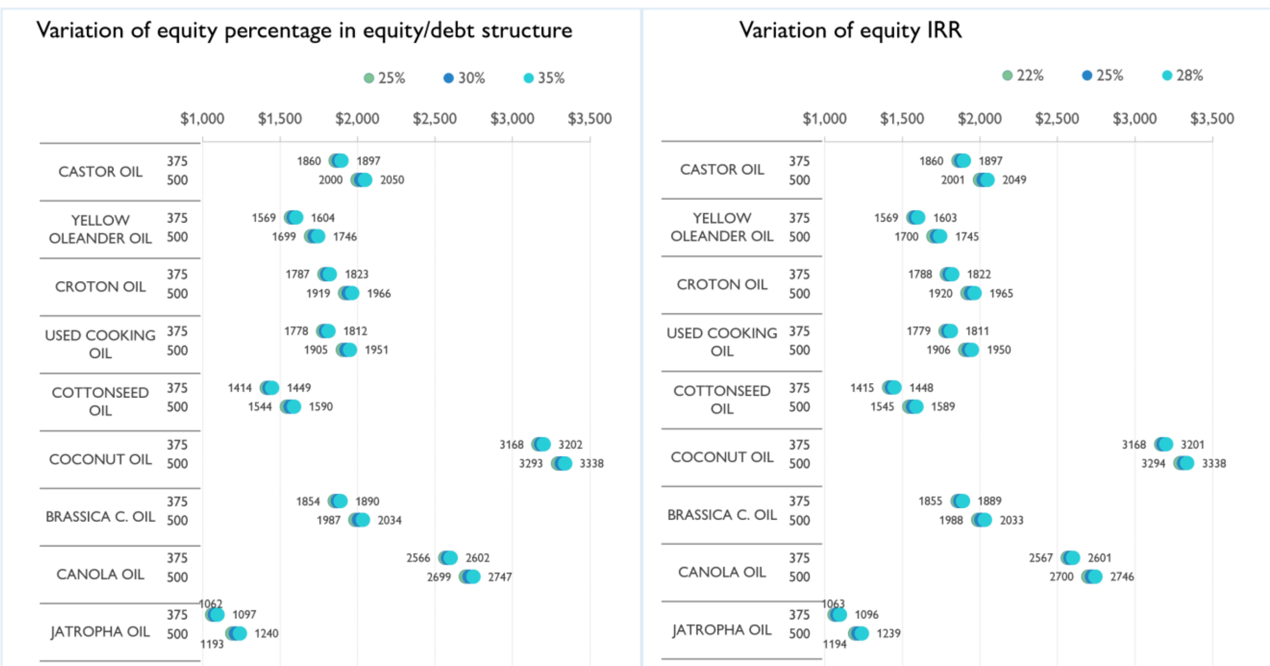


Figure 32. Influence on LCOP due to equity/debt ratio and equity IRR variations (SAF70; right Case 8-9 Table 21 and Case 10-11 Table 21).

In general, the SAF LCOP remains lower than 2 000 USD/t when the WACC is below 11.9%, particularly for feedstocks such as vegetable oil from jatropha, cottonseed oil, yellow oleander, castor, croton, used cooking oil (UCO), and Brassica carinata.

Figure 32 illustrates the impact of varying the equity-to-debt ratio (Case 8-9 Table 22) and the equity internal rate of return (Case 10-11 Table 22). In both scenarios, the resulting cost variation remained within approximately 50 USD/t, likely due to the relatively moderate changes applied. Specifically, the equity share was adjusted from 25% to 35%, while the equity IRR was varied between 22% and 28%.

3.3.5 Feedstock breakeven price for target LCOP

To provide an indication of economically viable feedstock pricing under different financing conditions, Table 26 and Table 27 present a model based on croton oil (having an average chemical composition among the vegetable oil in consideration) within the SAF 70 configuration. While the analysis is specific to croton, the results are generally applicable to other feedstocks, with only some small deviations expected. Higher deviations are expected for castor and coconut oil, which have higher oxygen content and therefore experience greater yield losses.

Assuming different LCOP targets, the maximum average feedstock price that would make economic sense under two capital expenditure scenarios (USD 375 million and USD 500 million) is as follows:

- For an LCOP target of 1 600 USD/t:
    - Max averaged feedstock price: 810 USD/t (CAPEX USD 375 million), 710 USD/t (CAPEX USD 500 million)
- For an LCOP target of 1 800 USD/t:
    - Max averaged feedstock price: 960 USD/t (CAPEX USD 375 million), 860 USD/t (CAPEX USD 500 million)
- For an LCOP target of 2 000 USD/t:
    - Max averaged feedstock price: 1 100 USD/t (CAPEX USD 375 million), 1 000 USD/t (CAPEX USD 500 million)

These thresholds provide a useful benchmark for evaluating the feasibility of feedstock procurement under varying financial assumptions.

Table 26. Feedstock price in USD/t for targeted LCOP (SAF 70, model for croton oil) for CAPEX of USD 375 million.

CAPEX USD 375 million	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
WACC	11.91%	11.18%	12.40%	13.63%	14.85%	9.95%	8.00%
LCOP 1 600	808	818	801	783	765	835	860
LCOP 1 800	957	967	950	932	914	983	1 008
LCOP 2 000	1 105	1 115	1 098	1 080	1 062	1 132	1 157

Table 27. Feedstock price in USD/t for targeted LCOP (SAF 70, model for croton oil) for CAPEX of USD 500 million.

CAPEX USD 500 million	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
WACC	11.91%	11.18%	12.40%	13.63%	14.85%	9.95%	8.00%
LCOP 1 600	706	719	697	673	649	742	775
LCOP 1 800	854	868	845	822	797	890	924
LCOP 2 000	1 003	1 017	994	970	946	1 039	1 072

3.3.6 Ratio SAF/diesel price

In this analysis, HVO diesel production costs were assumed to be equal to those of SAF for simplicity, as both are produced within the same flexible units and share the same CAPEX. In practice, HVO diesel requires less process steps and energy. It is typically sold at a slightly lower price, often around 0.95 times the SAF price (General Index, 2024). Under such conditions, producing HVO diesel would generally be more advantageous for the HEFA plant in term of economic profitability. This is why usually MAX HVO and SAF 70 configuration can give lower production costs than MAX SAF. However, according to the yields in this model, the MAX SAF configuration becomes the most profitable option when SAF is valued at 1.2 times the price of HVO diesel. For instance, if HVO diesel sells for 1 900 USD/t, securing a SAF price above 2 300 USD/t would make SAF production more profitable than producing HVO diesel. This is proportional to the maximum achievable yields of diesel and SAF, as illustrated in Table 28.

The willingness-to-pay for HVO diesel directly affects the SAF price, as lower revenues from this co-product would raise the required SAF selling price. Currently HVO diesel and SAF prices are relatively similar in Europe (General Index, 2024; Argus Media, 2025b), but their market price could develop differently in certain timeframe. This relationship should be carefully evaluated in other markets, and incorporating future price forecasts would also be valuable.

Table 28. Maximum HVO diesel and SAF yields used to establish the price ratio breakeven.

	Castor oil	Y. oleander oil	Croton oil	UCO	Cottonseed oil	Coconut oil	Sunflower oil	Canola oil	Jatropha oil
HVO yield [thousand t/year]	206	215	215	214	215	201	216	216	215
SAF yield [thousand t/year]	166	181	178	188	183	197	176	176	180
Price ratio	1.2	1.2	1.2	1.1	1.2	1.0	1.2	1.2	1.2

3.3.7 Sensitivity analysis

The sensitivity analysis aims to examine the impact of identical percentage variations in individual variables on the overall cost. Figure 33 presents a tornado chart illustrating the sensitivity of the Levelized Cost of Production of SAF to key input parameters. The chart clearly shows that feedstock price is the most influential variable, with a ±15% change in LCOP resulting by a ±20% variation in the feedstock price. This underscores the critical importance of securing low-cost, stable feedstock supplies to ensure economic viability.

The CAPEX is the second most significant factor, with moderate influence on LCOP when varied within the tested range. Following that, WACC also has a notable impact, reflecting the role of financing structure in project economics.

Other financial variables, such as cost of equity, equity share (%), and cost of debt, have a smaller but still relevant effect on LCOP. These elements contribute to the financing cost and risk profile of the project.

On the other hand, electricity price and fuel price (for energy use in the refinery) show only minimal sensitivity in this analysis, suggesting that fluctuations in these factors have a relatively minor effect on the LCOP within the assumed conditions. Overall, this sensitivity analysis highlights the need to prioritize cost control strategies focused on feedstock procurement and financing conditions to ensure a competitive SAF production cost. While these results reflect a selected variation of ±20% in the parameter value, actual fluctuations may be greater or smaller and should be carefully assessed.

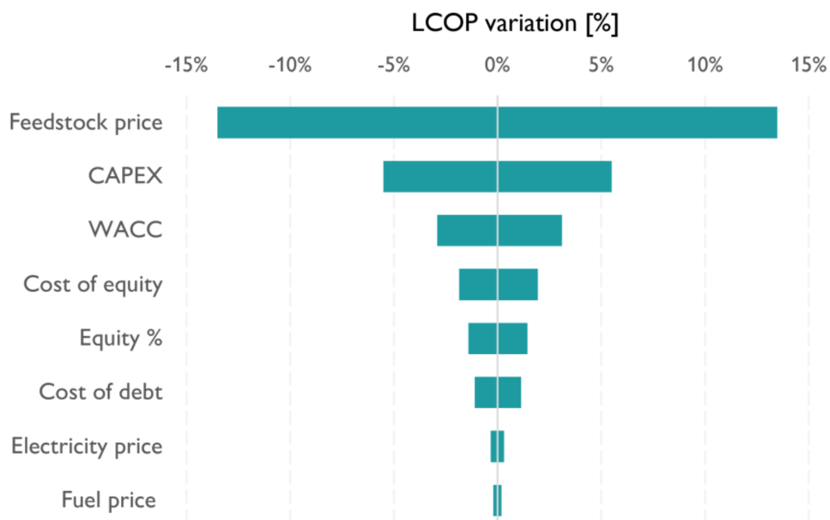


Figure 33. Sensitivity analysis for ±20% variation of each variable on SAF LCOP. Operational Mode SAF 70 with steam reforming of co-/by-products.

3.4 GHG EMISSIONS SAVINGS

Calculations of GHG emissions for the HEFA process are reported in CORSIA for SAF-eligible feedstocks, with base values provided in Table 29. As noted, some feedstocks, such as castor, yellow oleander, croton and cottonseed, have not yet been submitted for eligibility under CORSIA. However, it will be important to submit these feedstocks for CORSIA approval, as they represent major and potential sustainable sources for SAF production in Kenya. This section is intended to provide only a general indication of the potential GHG emissions. Default values provided by CORSIA methodology were mainly used as base for this analysis and dedicated future studies should be addressed to calculate LCA core from cultivation to end-use as fuel for the specific case, as well ILUC values (out of the scope of this study).

Used cooking oil has the lowest GHG emissions, as it is a waste product and does not require cultivation resources like other feedstocks (Table 29). Crops, shrubs, or trees that can be cultivated on marginal land also tend to have low ILUC, for example, jatropha, castor, and brassica grown on marginal land. In contrast, crops such as canola typically have higher ILUC.

The LCA core value can be reduced by showing improved process efficiency. ILUC can be reduced by obtaining low-ILUC certification when applicable (e.g., cultivation in marginal land, enhancement of the yield per hectare, etc.). For the proposed HEFA process in this study, additional reductions can be achieved by using biogenic feedstock in steam reforming for hydrogen production (Table 30). In this case, SAF 70 and MAX SAF configurations show an additional GHG emission reduction up to 9%, as they are largely self-sufficient, meeting most of their energy demand through internal bio-coproducts (naphtha, LPG, off-gases) and requiring only minimal external fuel. In contrast, MAX HVO still requires fossil fuel imports due to the lower production of naphtha and LPG, therefore it shows marginal improvements.

Table 29. GHG emission values reported in CORSIA documents or other sources.

	Source LCA, ILUC	Core LCA [g_{CO2eq}/MJ]	ILUC [g_{CO2eq}/MJ]	Total GHG [g_{CO2eq}/MJ]	Base GHG emission savings
Castor oil[a]	(Risi, 2024);	25	0	25	72%
Y. Oleander oil	not available	-	-	-	-
Croton Oil	not available	-	-	-	-
Used Cooking Oil	CORSIA	13.9	0	13.9	84%
Cottonseed oil	not available	-	-	-	-
Non-standard coconut oil	CORSIA	26.9	0	26.9	70%
Brassica C. oil	CORSIA	34.4	-12.7	21.7	76%
Canola oil	CORSIA	47.4	24.1	71.5	20%
Jatropha oil	CORSIA	46.9	-24.8	22.1	75%

[a] *Values only an indicative approximation based on RED-EU, feedstock does not have CORSIA default value yet.*

Excluding canola, whose emissions remain too high without a zero-ILUC certificate, the other feedstocks deliver substantial CO_2 emission reductions when steam reforming is powered by internal coproducts. On average, MAX HVO achieves 78% GHG savings, while SAF 70 and MAX SAF reach around 85%. Furthermore, capturing and sequestering the biogenic CO_2 from steam reforming (SR) can significantly enhance these savings. In the latter case, average GHG reductions (canola and coconut are excluded) increase to about 84% for MAX HVO, and up to 103% and 105% for SAF 70 and MAX SAF, respectively.

Table 30, also illustrates the potential CO_2 savings achievable through the process, reaching 700 000 t/year annually (HVO diesel + SAF). The allocation between SAF and diesel will be market-dependent; however, it is estimated that the MAX SAF configuration (excluding canola) could achieve an average maximum of approximately 590 000 t/year of CO_2 savings in aviation.

Table 30. Further GHG emission reduction and overview of tonnes of CO_2 avoided per year for MAX HVO.

Scenario: MAX HVO	CO_2 avoided by SR [g_{CO2eq}/MJ]	Total GHG [g_{CO2eq}/MJ]	% GHG emission savings	SAF + HVO production [thousand t/year]	Total t_{CO2eq} saved in 1 year [thousand]	t_{CO2eq} saved in 1 year in aviation [thousand]
Castor oil	-2.0	23.0	74%	206	587	11
Used Cooking Oil	-2.5	11.4	87%	214	716	288
Non-standard coconut oil	-3.7	23.2	74%	201	571	517
Brassica C. oil	-2.1	19.6	78%	216	648	42
Canola oil	-2.2	69.3	22%	216	184	10
Jatropha oil	-2.3	19.8	78%	215	643	105

Table 31. Further GHG emission reduction and overview of tonnes of CO_2 avoided per year for SAF 70.

Scenario: SAF 70	CO_2 avoided by SR + Δ process emis. SAF70-MAX HVO[2] [g_{CO2eq}/MJ]	Total GHG [g_{CO2eq}/MJ]	% GHG emission savings	SAF + HVO production [thousand t/year]	Total t_{CO2eq} saved in 1 year [thousand]	t_{CO2eq} saved in 1 year in aviation [thousand]
Castor oil	-13.5 + 3.0	14.5	84%	178	573	380
Used Cooking oil	-10.3 + 1.6	5.2	94%	196	710	572
Non-standard coconut oil	-3.9 + 0.3	23.2	74%	198	563	548
Brassica C. oil	-12.6 + 2.8	11.9	87%	189	630	426
Canola oil	-12.3 + 2.8	62.0	30%	188	220	148
Jatropha oil	-11.7 + 2.4	12.8	86%	190	627	448

Table 32. Further GHG emission reduction and overview of tonnes of CO_2 avoided per year for MAX SAF.

Scenario: MAX SAF	CO_2 avoided by SR + Δ process emis. MAXSAF-MAXHVO [g_{CO2eq}/MJ]	TOTAL GHG [g_{CO2eq}/MJ]	% GHG emission savings	SAF + HVO production [thousand t/year]	Total t_{CO2eq} saved in 1 year [thousand]	t_{CO2eq} saved in 1 year in aviation [thousand]
Castor oil	-15.1 + 4.6	14.5	84%	166	534	534
Used Cooking oil	-11.1 + 2.4	5.2	94%	188	682	682
Non-standard coconut oil	-4.0 + 0.4	23.3	74%	197	559	559
Brassica C. oil	-14.0 + 4.2	11.9	87%	176	586	586
Canola oil	-13.8 + 4.2	61.9	30%	176	206	206
Jatropha oil	-12.9 + 3.6	12.8	86%	180	592	592

It is important to note that SAF GHG emissions savings are strongly influenced by feedstock cultivation practise (ICAO, 2025b; World Bank, 2025a). A careful selection of feedstocks is therefore essential to ensure that SAF delivers relevant emission reductions. Even the most efficient HEFA conversion technology cannot compensate for feedstocks with inherently high carbon footprints. In addition, GHG emission calculation methodology varies depending on the regulatory framework applied (e.g., CORSIA, RED, GREET), as does the eligibility of certain feedstocks. As a result, the indicative values presented here may differ under other

[2] Estimated difference between process emissions produced in SAF 70 and MAX HVO

methodologies. For this reason, it is also crucial to clearly define the target market in which SAF will be deployed.

3.5 MINIMUM SELLING PRICE

In 3.3 the most promising configurations were identified, as were the key variables influencing the SAF production cost. The analysis shows that the optimal setup involves steam reforming of coproducts, which supports plant self-sufficiency while minimizing GHG emissions. For the LCOP assessment, production costs are assumed to be evenly allocated between HVO and SAF, although their market values may differ. To reflect this, the minimum selling price is calculated considering that SAF can command a higher market price than HVO diesel, applying a diesel-to-SAF price ratio of 0.95 (as reference see Section 3.1.4). For simplicity for the calculation of the MSP, the operational mode SAF 70 is used as an intermediate reference between MAX HVO and MAX SAF, assuming the plant continues to operate with production flexibility.

3.5.1 Minimum Selling Price for individual feedstocks

In this section, the MSP represents the minimum price required to cover debt (variable) and provide the investor with the targeted return (25% IRR on equity). This section applies an unlevered cash flow analysis, incorporating taxes and depreciation, which results in an MSP that is, on average, slightly higher than the LCOP reported earlier. Table 33 presents the MSP under varying CAPEX scenarios, considering whether feedstock is sourced internally at a reduced price or purchased on the wholesale market (Table 20), and evaluating two WACC values. Case 1 (Table 22), with a WACC of 11.9%, is treated as the base case, while Case 7 (Table 22), with a WACC of 8%, represents a highly optimistic scenario, indicating a lower bound that would be difficult to reduce further.

In Table 33, minimum selling price over 2 000 USD/t (as reference value) are highlighted. Under most conditions, most feedstocks can be sold below this threshold. However, higher CAPEX and WACC values reduce the potential margin above production cost, limiting profitability. Prices above the reference do not necessarily indicate that sales are unfeasible, but they suggest that they can be sold for higher prices if there is willingness-to-pay and the margin potential may be reduced. It should also be recognized that the SAF market price is inherently volatile, with potential increases or decreases depending on market conditions, which are in turn strongly influenced by feedstock prices and availability. For instance, between 2024 and August 2025, prices ranged from a minimum of 1 750 USD/t to a maximum of 2 800 USD/t, with the current price reported at 2 372.50 USD/t.

SAF market conditions are critical in determining the viability of each case, as they define the willingness to pay for the products. For instance, in Europe, a 2% SAF mandate is set for 2025, with a non-compliance penalty approximately twice the cost difference between SAF and conventional jet fuel. For 2025, the non-compliance penalty is estimated at around 2 701 EUR/t (Watts, 2025). This implies that SAF priced below this threshold could be competitive. However, the actual attractiveness will ultimately be influenced by the level of competition in the market or by bilateral offtake agreements.

To illustrate the cash flow magnitude, Table 34 presents typical values for an unlevered, non-discounted, and non-inflated annual cash flow before taxes, based on 100% capacity production for yellow oleander. The data show that a substantial portion of capital is allocated to feedstock costs.

Table 33. Minimum selling price in USD/t for various feedstocks, with prices exceeding 2 000 USD/t highlighted in red/italic. Assumption SAF 70, prices from Table 19.

CAPEX [million USD]	375				500			
	Internally-sourced feedstock price [USD/t]		Market wholesale price [USD/t]		Internally-sourced feedstock price [USD/t]		Market wholesale price [USD/t]	
	WACC 8%	WACC 11.9%	WACC 8%	WACC 11.9%	WACC 8%	WACC 11.9%	WACC 8%	WACC 11.9%
Castor oil	1 661	1 797	1 933	*2 071*	1 812	1 991	*2 084*	*2 265*
Y. Oleander oil	1 502	1 628	1 625	1 752	1 642	1 808	1 765	1 931
Croton Oil	1 700	1 828	1 851	1 981	1 841	*2 010*	1 993	*2 163*
Used Cooking Oil	1 699	1 823	1 832	1 957	1 835	1 998	1 968	*2 132*
Cottonseed oil	1 317	1 441	1 466	1 591	1 456	1 619	1 605	1 769
Non-standard coconut oil	*2 276*	*2 402*	*3 224*	*3 357*	*2 409*	*2 573*	*3 358*	*3 528*
Brassica c. oil	1 784	1 914	1 923	*2 054*	1 927	*2 097*	*2 066*	*2 237*
Canola oil	*2 236*	*2 369*	*2 654*	*2 791*	*2 379*	*2 553*	*2 797*	*2 974*
Jatropha oil	963	1 087	1 108	1 232	1 104	1 267	1 248	1 412

Table 34. Example of costs and revenues for Yellow Oleander (SAF 70), assuming an internal feedstock price of 720 USD/t, a wholesale price of 810 USD/t, and revenues calculated using the MSP.

CAPEX [million USD]	375		500	
	Internally-sourced feedstock price [million USD per year]	Market wholesale price [million USD per year]	Internally-sourced feedstock price [million USD per year]	Market wholesale price [million USD per year]
Working capital	*29*	*32*	*33*	*35*
Total investment	***404***	***407***	***533***	***535***
Total OPEX	***227***	***250***	***235***	***257***
Feedstock	*184*	*207*	*184*	*206*
Electricity	*6*	*6*	*6*	*6*
Other variable costs	*11*	*11*	*11*	*11*
Fixed operating costs	*26*	*26*	*34*	*34*
Revenue total	***297***	***320***	***327***	***350***
SAF [140 000 t/year]	*222*	*239*	*244*	*262*
Diesel [50 000 t/year]	*75*	*81*	*83*	*89*
Profit before tax	***70***	***71***	***93***	***93***

3.5.2 Minimum Selling Price for blended oils including incentives

In practice, the plant is expected to operate with more than one feedstock. These feedstocks may be processed individually at different times of the year or utilized as homogeneous blends. The strategy to adopt may vary depending on potential seasonal variations in feedstock availability. This requires careful evaluation with pretreatment technology providers to ensure that the blended feedstock can be processed efficiently, as variations in viscosity, density, and contaminant levels can significantly influence operating conditions.

In this section, we evaluate as example a feedstock oil mix equally composed of castor, yellow oleander, croton, UCO, cottonseed, and Brassica carinata. The optimal feedstock selection and proportion should be determined based on availability, price, and sustainability criteria. As the feedstock supply chain is not yet established to cover the volume required by the HEFA plant, an equal composition was assumed here for illustrative purposes. However, further analyses are required to identify effective strategies for feedstock production and supply chain management. Coconut and canola are excluded due to food competition, high market prices and lower benefits for GHG emission savings, while jatropha is excluded because its assumed price may be overly optimistic and its cultivation in Kenya may present challenges that were identified in the past. However, if it can be demonstrated that jatropha can maintain this price level and be cultivated feasibly in Kenya, it could become a highly attractive feedstock option. Additional feedstocks beyond those listed may also be considered, provided they meet the general criteria of availability, price, and sustainability.

For the proposed blended feedstock mix, the average feedstock cost was estimated at 783 USD/t when sourced internally and 899 USD/t when purchased from the market with the wholesale price.

Without incentives, the calculated minimum selling price (MSP) for a CAPEX of USD 375 million ranges between 1 610 USD/t and 1 900 USD/t, while for a CAPEX of USD 500 million the range increases to 1 750–2 080 USD/t, indicating potential market competitiveness.

Fiscal incentives can further improve these economics. The above values were calculated assuming a 30% corporate tax rate and straight-line depreciation over 20 years. However, under Kenya's Finance Bill 2025, large investors committing at least KES 3 billion may qualify for a reduced corporate tax rate of 15% for the first 10 years, followed by 20% for the subsequent 10 years, representing a substantial long-term tax advantage.

The impact of adopting a double-declining balance (DDB) depreciation method over 10 years was also assessed; the results showed a relatively minor benefit compared to the corporate tax reduction. When both the preferential tax rate and DDB depreciation are applied, the MSP improves: for a CAPEX of USD 375 million, the range decreases to 1 560 – 1 825 USD/t, and for a CAPEX of USD 500 million, to 1 700–2 000 USD/t.

Overall, these results demonstrate that lower CAPEX and reduced WACC significantly enhance competitiveness. Furthermore, if market conditions allow for higher selling prices, margins can be further increased, providing additional financial resilience.

Table 35. Minimum Selling Price (MSP) for a Blended Feedstocks – SAF 70 Configuration

CAPEX [million USD]	375				500			
	Internally-sourced feedstock price [USD/t]		Market wholesale price [USD/t]		Internally-sourced feedstock price [USD/t]		Market wholesale price [USD/t]	
	WACC 8%	WACC 11.9%	WACC 8%	WACC 11.9%	WACC 8%	WACC 11.9%	WACC 8%	WACC 11.9%
Feedstock price	783	783	899	899	783	783	899	899
MSP SAF	1 611	1 739	1 772	1 901	1 752	1 921	1914	2 083
MSP after reduced taxes	1 567	1 674	1 726	1 835	1 696	1 837	1 856	2 018
MSP after reduced taxes and DDB	1 560	1 664	1 720	1 825	1 697	1 823	1 846	1 994

Furthermore, carbon credits have the potential to further reduce these values, thereby enhancing the competitiveness of SAF relative to fossil jet fuel, although they do not provide an advantage when compared with prevailing SAF market prices (since other SAFs also benefit from carbon credit). Carbon credit were not included in the current calculations, as their value can vary significantly depending on the market in which they are traded (Carbon Credits, 2025). For instance, CORSIA credits are currently projected to reach 25–36 USD/t by 2027 (Sylvera, 2025), with expectations of further increases, while EU ETS prices are approximately 72 EUR/t of CO_2. Considering that the production of 1 ton of 100% renewable jet fuel avoids approximately 3.15 tons of CO_2 and specifically 3.8 tons of CO_2 equivalent emissions, carbon credits could represent a substantial additional incentive, further lowering the effective MSP compared to fossil jet fuel. In this context, improving GHG emission savings per ton of fuel will increase total CO_2 reductions, thereby enhancing the volume of carbon credits for which the project is eligible. It is worth noting that the current price outlook in Table 35 may have room for further improvement through such mechanisms, however, parity with fossil jet fuel prices cannot be achieved only with current carbon credit price.

Given the significant influence of feedstock on production costs, Figure 34 illustrates how the MSP varies with the price of the blended feedstock. The analysis demonstrates a strong sensitivity of the Minimum Selling Price to feedstock cost, with MSP increasing linearly across all scenarios and influencing as key driver SAF production economics. As mentioned previously, feedstock prices can exhibit significant variability, necessitating the identification of appropriate de-risking mechanisms. Furthermore, while higher feedstock prices may not necessarily impede market development, a correspondingly greater willingness to pay must be ensured to maintain the viability of the business case. Securing this condition is therefore essential.

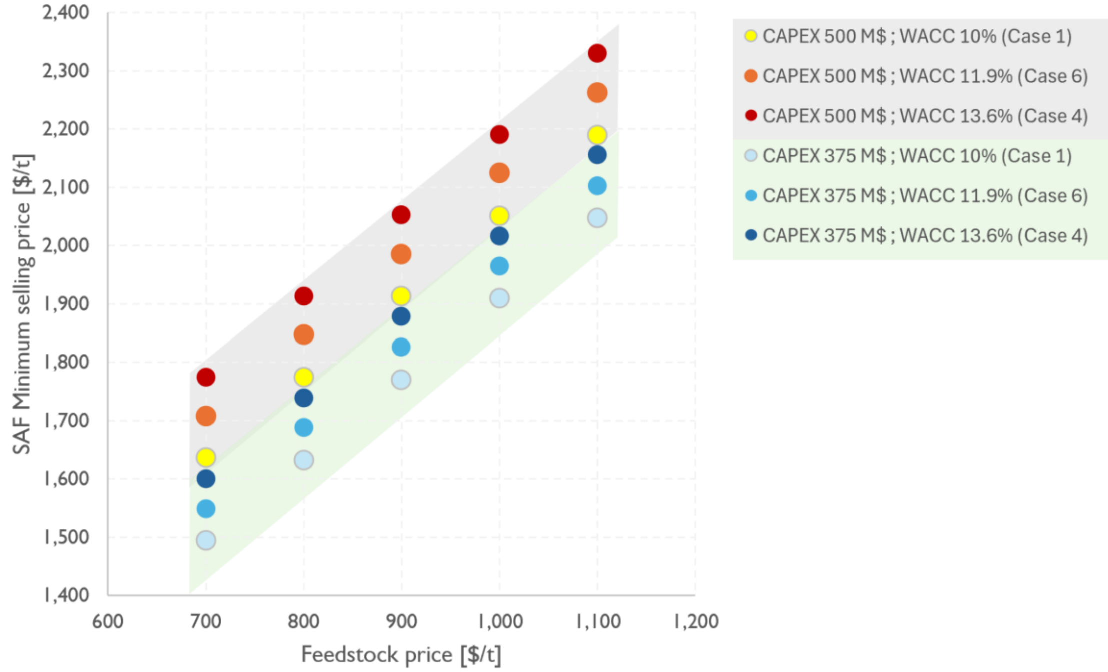


Figure 34. Influence of blended feedstock price volatility in relation to WACC and CAPEX on MSP (SAF 70 configuration).

Notably, when feedstock prices are around 1 000 USD/t in the high-CAPEX scenario, the MSP surpasses 2 000 USD/t, whereas for the low-CAPEX case it remains below this threshold. For feedstock price at 1 100 USD/t, MSP is over 2 000 USD/t for every CAPEX and WACC conditions. From a competitiveness perspective, minimizing both CAPEX and WACC substantially enhances price competitiveness, improving the likelihood of meeting lower market price points and increasing the economic feasibility of SAF production.

3.5.3 Assessment of profit generation potential

The determination of the final market price must consider multiple factors, particularly the characteristics of the target market. As noted earlier, the MSP typically reflects the minimum price required to meet debt obligations and equity return expectations; in practice, the actual selling price is often set higher to ensure project profitability.

For this analysis, two potential sales price scenarios are considered: 2 000 USD/t and 2 250 USD/t. It is important to emphasize the need for a comprehensive market assessment involving key stakeholders, as the SAF market remains relatively not transparent, with the potential for bilateral agreements at different prices compared to the publicly reported levels. In addition, consideration should be given to potential market outcomes in scenarios where prices fall below the reference value of 2 000 USD/t, or conversely, where feedstock prices rise substantially in the future. Such forecasts require careful and systematic assessment.

The MSP already incorporates a minimum equity IRR of 25%; therefore, any additional profit would be accrued on top of this baseline return. The project remains profitable at both CAPEX levels; however, at USD 500 million, margins are significantly reduced when the selling price is 2 000 USD/t, primarily due to the high WACC (Table 36). Since the NPV is driven by the spread between the selling price and the MSP, Figure 35 illustrates the required margin to achieve a given NPV under WACC values of 11.9% and 8%. In comparable projects, the typical payback period ranges from 4 to 7 years of operation, with annual ROI generally between 10% and 35%.

Table 36. Evaluation of NPV, IRR, payback period and ROI for two feedstock blends.

Feedstock blend [USD/t]	783				899			
CAPEX [million USD]	**375**		**500**		**375**		**500**	
WACC (real)	**Case 7: 8.0%**	**Case 1: 11.9%**	**Case 7: 8.0%**	**Case 1: 11.9%**	**Case 7: 8.0%**	**Case 1: 11.9%**	**Case 7: 8.0%**	**Case 1: 11.9%**
MSP [USD/t]	1 560	1 664	1 687	1 823	1 720	1 825	1 846	1 984
Selling price 1	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
NPV [million USD]	504	261	359	138	321	136	176	13
Real Project IRR	22%	22%	16%	16%	17%	17%	12%	12%
Nominal Project IRR	29%	29%	23%	23%	24%	24%	19%	19%
Payback period [year][a]	5.0	5.0	6.2	6.2	5.9	5.9	7.7	7.7
ROI	27%	27%	19%	19%	21%	21%	15%	15%
Selling price 2	2 250	2 250	2 250	2 250	2 250	2 250	2 250	2 250
NPV [million USD]	790	456	645	332	607	331	462	207
Real Project IRR	28%	28%	21%	21%	24%	24%	18%	18%
Nominal Project IRR	35%	35%	29%	29%	31%	31%	25%	25%
Payback period [year][a]	4.1	4.1	5.0	5.0	4.6	4.6	5.7	5.7
ROI	36%	36%	26%	26%	30%	30%	22%	22%

[a] *From start of operations.*

These findings reinforce that controlling both feedstock price, capital investment and financing costs is essential to maintaining strong market positioning. By reducing feedstock price, CAPEX and WACC, the project can operate profitably at more competitive price levels, thereby strengthening its commercial viability in the SAF sector.

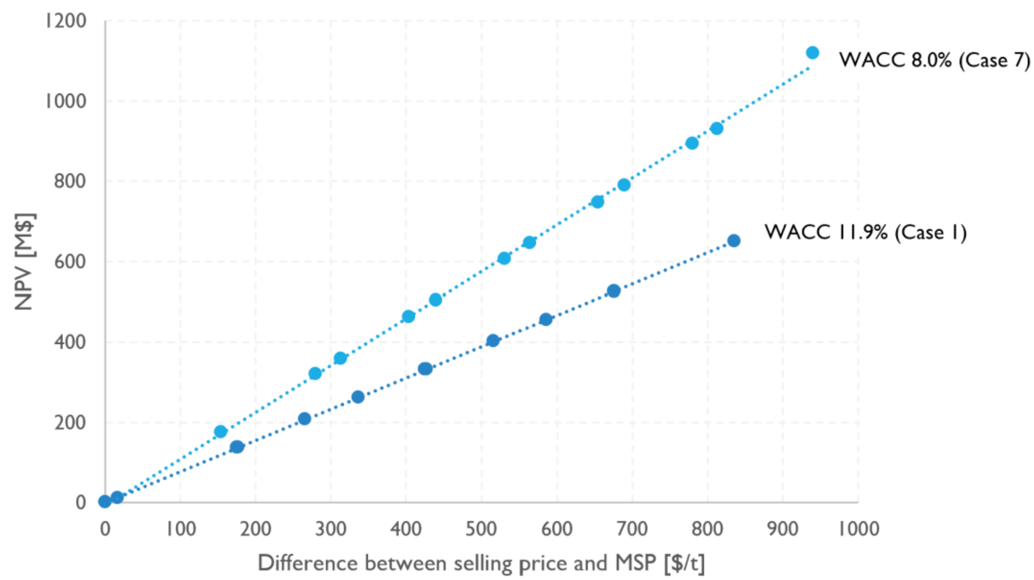


Figure 35. NPV dependency on the margin between effective selling price and MSP for the HEFA case study.

3.5.4 Price formula for SAF price in real offtake practice

In practice, SAF sales or other commodities are rarely based on a fixed price; instead, transactions are typically structured around an indexed pricing formula. Establishing a robust price formula for SAF in offtake agreements is essential to ensure long-term commercial viability. Feedstock prices, energy costs, and other parameters affecting SAF price can fluctuate significantly over the project lifetime, directly impacting production costs and the minimum selling price. A well-defined pricing formula, indexed to key market variables, allows both producer and buyer to share price risks more equitably, maintain competitiveness in changing market conditions, and provide the financial predictability needed to secure investment and operational stability. Likewise, contracts designed to secure feedstock within a defined price range would be beneficial.

3.6 CO_2 ABATEMENT COSTS

For some feedstocks, official GHG emissions data are unavailable, therefore, the following represents an estimated value for a blended feedstock scenario. The assessment assumes a SAF 70 configuration in which the selected feedstock blend achieves an average GHG emissions reduction of approximately 85%. Under these conditions, the CO_2 abatement cost is estimated to fall within the range of 275 USD/t to 410 USD/t.

Consistent with other economic performance metrics, the abatement cost is highly sensitive to the Minimum Selling Price, which is itself primarily governed by feedstock cost. While the minimum selling price is used here to calculate the CO_2 abatement costs, for airlines this value should ideally be derived from the actual market selling price.

Although the SAF abatement costs are higher than those observed in the current conventional carbon markets, such as the EU ETS (60–90 EUR/t), CORSIA (3–25 USD/t), or nature-based solutions like reforestation, they remain well below the costs associated with high-expense mitigation technologies, including Direct Air Capture (DAC) or other SAF production pathways. It is also worth noting that carbon market prices are expected to rise over time, which would further enhance the competitiveness of SAF.

Overall, HEFA-based SAF production remains an attractive option, particularly in markets with blending mandates and a demonstrated willingness to pay a green premium. In addition, an upward trend in global carbon prices would make HEFA-based SAF increasingly competitive over time.

Table 37. Estimation of the CO_2 abatement costs for blended feedstock - SAF 70 configuration

Feedstock blend price [USD/t]	**783**				**899**			
CAPEX [million USD]	**375**		**500**		**375**		**500**	
WACC	**Case 7: 8.0%**	**Case 1: 11.9%**	**Case 7: 8.0%**	**Case 1: 11.9%**	**Case 7: 8.0%**	**Case 1: 11.9%**	**Case 7: 8.0%**	**Case 1: 11.9%**
MSP [USD/t]	1 560	1 664	1 687	1 823	1 720	1 825	1 846	1 984
CO_2 abatement cost [USD/t_{CO2}]	275	307	314	356	324	356	363	408

3.7 SUMMARY

A HEFA plant with a production capacity of 250 000 t/year (approximately 5 275 barrels per day) demonstrates the potential to produce SAF at competitive prices below 2 000 USD/t for certain conditions (Figure 36) aligning with SAF market price. The pretreatment unit was design for an average of 255 000 t/year of feedstock; however, actual losses should be verified for each specific feedstock in consultation with the pretreatment technology provider, as these may be higher than assumed. The minimum selling price of SAF for an HEFA plant in Kenya will be primarily determined by factors such as feedstock selection, operational configuration, capital expenditure, and financing conditions.

<u>Feedstock selection</u>

The optimal feedstock selection should be determined based on availability, price, and sustainability criteria. While feedstock flexibility is technically achievable, it depends heavily on the effectiveness of the pretreatment system to manage impurities and contaminants. Excessive variation in feedstock types, however, may be constrained by the plant's design and operational limitations (to be clarified with technology providers). Strategically using a mix of 4 to 6 feedstocks can mitigate dependence on any single source, helping to stabilize supply and reduce exposure to price volatility. Additionally, combining higher-cost and lower-cost feedstocks can help keep SAF prices within the target market range, increasing in any case the volume sold (in cases where the availability of the low-cost feedstock is limited). The survey conducted in this study indicates that sufficient feedstock is not yet readily available for biofuel production in Kenya; however, it appears potentially feasible to establish a dedicated supply chain. A relevant example can be found in the Agri-Hub model developed by Eni, where feedstocks with low ILUC are promoted. Further research is required on the development of feedstock supply chains, which may be structured at either the national or regional level.

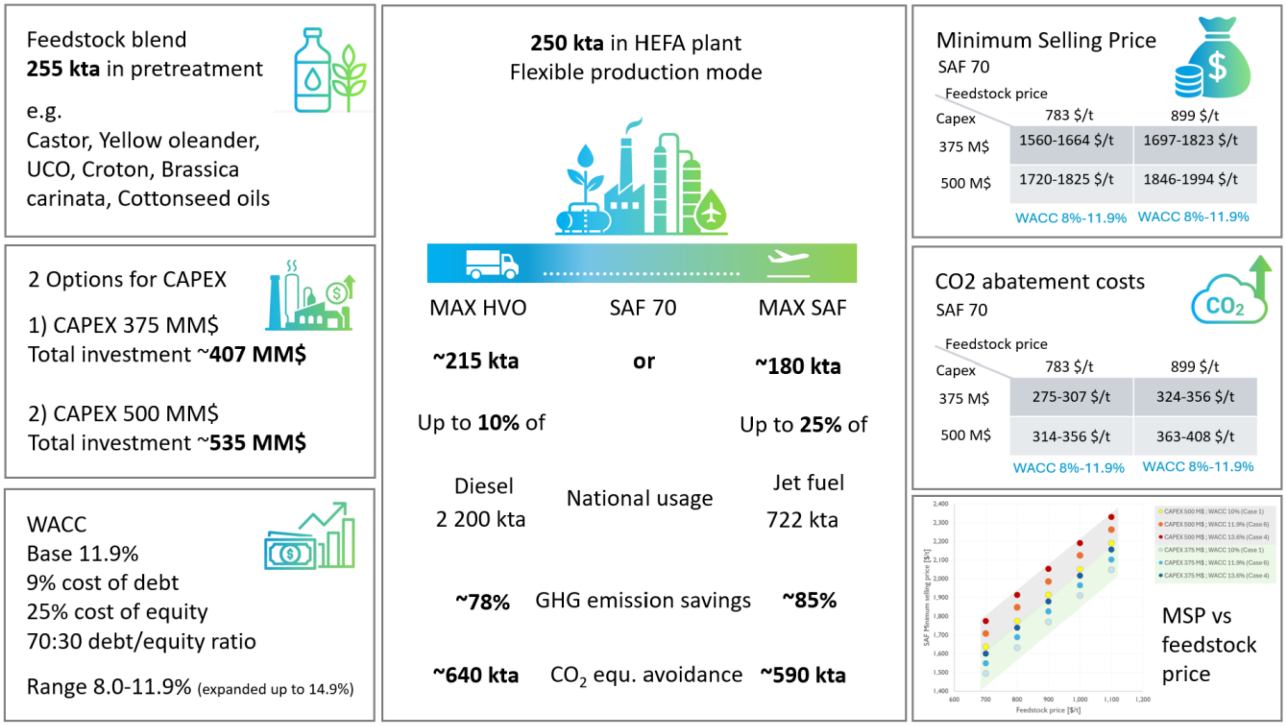


Figure 36. Preliminary estimation derived from the techno-economic analysis of a HEFA plant in the Mombasa refinery.

Although chemical composition of the vegetable oil/used cooking oils impacts pretreatment requirements, it has only a minor influence compared to the feedstock price on the overall cost of SAF production. Feedstock cost remains the most influential factor, typically accounting for more than 60% of total production costs. Implementing consortium-based sourcing strategies can help improve pricing stability and reduce exposure to global market fluctuations. Feedstocks such as cottonseed oil, croton, Brassica carinata, used cooking oil, yellow oleander, and castor oil show promising cost-competitiveness, especially if the prices remain below 900 USD/t or up to 1 000 USD/t under specific conditions. Higher feedstock costs may still be acceptable, particularly when CAPEX and financing costs are limited and market conditions support a sufficient willingness to pay. Nevertheless, it is essential to account for price variability in both feedstocks and SAF, as well as to incorporate forecasts of potential volatility when developing the business case and designing appropriate de-risking measures.

These feedstocks should also meet sustainability requirements under the CORSIA certification scheme to qualify for SAF production under international standards. While used cooking oil, Brassica carinata, jatropha, canola and non-standard (non-food-grade) coconut oil are already recognized as CORSIA-eligible feedstocks, castor, croton, cottonseed, and yellow oleander oil would still need to be submitted for CORSIA approval if they aren’t produced with the use of low LUC risk practices. Among them, yellow oleander oil is a relatively new feedstock with strong potential for SAF production, and further research could help unlock and optimize its application. Jatropha may be among the most promising feedstocks due to its low cost; however, its cultivation feasibility in Kenya should be carefully assessed to avoid repeating the challenges experienced during the biodiesel initiatives of the early 2000–2010 period. In contrast, feedstocks like coconut and canola oil are generally more expensive due to competition with food markets. According to CORSIA, if the ILUC contribution of canola oil cannot be reduced, the resulting GHG emission savings remain relatively limited. Their utilization remains feasible provided that these limitations are overcome. Moreover, alternative feedstocks that meet sustainability criteria, are potentially available, and demonstrate cost-competitiveness can also be considered.

One of the most important next steps for the company is to clearly define the target market for the SAF produced in Kenya, as regulatory frameworks play a decisive role in determining feedstock eligibility. Base on this also a strategy on feedstock supply can be developed. In this context, the study emphasizes the need to further analyze potential markets for the produced SAF, with particular attention to how feedstock types align with different regulatory schemes (e.g., CORSIA, EU, UK, US and other regional markets). Such an assessment of market access and related challenges is essential for evaluating the business case and determining the potential margins over the minimum selling price. In addition, future feedstock prices will be shaped by global competition, and awareness of current and projected prices in other regions can help strengthen the business case. Likewise, monitoring regional SAF prices and associated willingness to pay is essential.

<u>Operational mode</u>

Among the processing modes, MAX HVO generally results in the lowest production costs, but it yields relatively little SAF. MAX SAF, by contrast, maximizes SAF output but also produces significant volumes of naphtha and LPG, lowering the distillate yield and raising unit production costs. The yield calculations for the processing modes were conducted in-house and may differ from the figures provided by technology suppliers, which should be contacted for the next phase of the project. Moreover, since GHG emission data were unavailable for certain feedstocks, we assumed values consistent with low-ILUC feedstocks, as reported in Section 3.4. In MAX HVO mode, production reaches ~215 000 t/year, equivalent to ~10% of the current national diesel demand (1.647 million m^3/year = ~1 367 000 t/year), delivering ~78% GHG emissions savings and avoiding ~640 000 t/year of CO_2. In MAX SAF mode, output is ~180 000 t/year, equal to ~25% of the current national jet fuel demand (926 000 m^3/year = ~722 000 t/year), with ~85% GHG emissions savings and ~590 000 t/year of CO_2 avoidance. SAF 70 represents an intermediate flexible configuration. The SAF70 configuration represents a balanced approach, offering moderate SAF yield at a manageable cost. In real-world operations, it is expected that the plant will flexibly operate between MAX HVO, SAF 70 and MAX SAF as needed based on market demand for HVO and SAF products and their selling price. For example, if SAF can be sold at more than 1.2 times the price of HVO diesel, the plant achieves maximum profitability from SAF production. It is important to recognize that SAF and HVO diesel prices are interrelated. In theory, a decline in HVO diesel prices could lead to an increase in SAF prices. In the configuration suggested, co-products and by-products such as naphtha and LPG off-gases are used internally to produce hydrogen through steam reforming and as an energy source.

<u>Financial terms</u>

Securing low-cost financing is also critical, as both interest rates and capital structure have a significant impact on the economic viability of SAF projects. In this analysis, a base WACC of 11.9% (real term after taxes) is considered alongside alternative scenarios. The financial structure assumes a 70:30 debt-to-equity ratio, with a cost of debt of 9% (potentially attainable through international development banks) and a cost of equity of 25%, representing the minimum IRR required by investors. In an optimistic scenario (used here as the lower bound for SAF pricing) a WACC of 8% is assumed, corresponding to financing through a 50% concessional loan. This implies that SAF prices below this threshold are unlikely to be achieved solely by adjusting financing terms. WACC influences overall costs and scales proportionally with CAPEX; therefore, the two should be evaluated together. While a high WACC may be manageable with low CAPEX, it becomes less tolerable in high-CAPEX scenarios. Higher WACC values up to 14.9% were also analysed in the study. It is important to recognize that elevated WACC values can significantly undermine project viability, as excessively high financing costs may render an otherwise technically feasible project economically uncompetitive.

<u>Capital expenditure</u>

To account for the uncertainty of the CAPEX estimates at this stage of the study and verify its sensitivity on the SAF price, we consider two scenarios: (i) a lower-CAPEX case, representing optimistic assumptions with a high degree of integration and a potential favourable regional cost factor; and (ii) a higher-CAPEX case, reflecting a more conservative approach. For this study we adopted as CAPEX USD 375 million (total investment USD 407 million) as the lower-bound estimate and USD 500 million (total investment USD 535 million) as the upper-bound one. This represents a preliminary assessment (indicatively AACE Classe V, -50% to 100%), and accurate CAPEX estimation will require more detailed studies, including an engineering feasibility study followed by basic engineering. While CAPEX has a direct impact on total costs, it becomes largely fixed once project specifications are defined, making significant reductions difficult to achieve. While CAPEX has a smaller impact on the SAF minimum selling price compared to feedstock costs, it plays a critical role in financing, as excessively high capital requirements may be difficult to secure.

<u>Minimum selling price</u>

While achieving full cost parity with conventional fossil jet fuel is unlikely through incentives alone, SAF production at competitive prices within the SAF market is achievable under favourable conditions. Some measurements, such as tax reduction (under the Kenya Finance Bill 2025, startups investing at least KES 3 billion may qualify for a reduced corporate tax rate of 15% for the first ten years and 20% for the subsequent ten years) and accelerated depreciation were applied and both together could lower the SAF price by approximately 50–90 USD/t, depending on the specific case. Additional measures to promote SAF, such as implementation of blending mandates, should be considered.

Nonetheless, the minimum selling price remains highly sensitive to feedstock costs. In this study, both single feedstocks and a blended feedstock oil composed equally of castor, yellow oleander, croton, UCO, cottonseed, and Brassica carinata oil were evaluated. For single feedstocks, the minimum selling price without incentives generally remained below 2 000 USD/t, except in the case of wholesale pricing combined with a higher WACC and higher CAPEX, where it rose but remained under 2 250 USD/t.

The optimal feedstock mixes and proportions should ultimately be determined by availability, price, and sustainability considerations, which should be further investigated. The consortium-sourced feedstock price is treated as a lower-bound scenario, as further reductions in SAF cost through lower feedstock prices are unlikely. A second benchmark is represented by the average wholesale feedstock price. For example (Figure 36), in the SAF 70 configuration with WACC 8%-11.9% and with a consortium-source feedstock price at 783 USD/t, MSP ranges from 1 560–1 664 USD/t for USD 375 million CAPEX to 1 720–1 825 USD/t for USD 500 million CAPEX. At an average wholesale price of 899 USD/t, MSP increases to 1 697–1 823 USD/t (USD 375 million CAPEX) and 1 846–1 994 USD/t (USD 500 million CAPEX).

Notably, when feedstock prices are around 1 000 USD/t in the high-CAPEX scenario, the MSP surpasses 2 000 USD/t, whereas for the low-CAPEX case it remains below this threshold. Feedstock prices can exhibit significant variability, necessitating the identification of appropriate de-risking mechanisms. Furthermore, while higher feedstock prices may not necessarily impede market development, a correspondingly greater willingness to pay must be ensured to maintain the viability of the business case. Securing this condition is therefore essential. At present, a SAF price of 2 000–2 250 USD/t is taken as a market reference for this study;

however, prices have shown considerable volatility over the past two years, ranging from 1 750 to 2 800 USD/t for RED-compliant HEFA-SPK prices on an FOB ARA, with August 2025 averaging 2 372 USD/t. SAF market remains relatively opaque and bilateral agreements may have contract prices different from the reported traded market price. In this regard, the SAF market should be carefully assess and SAF offtake agreements with indexed price formula will help securing the business case. Feedstock prices require additional analysis to better capture both current and future trends, including potential increases linked to global market dynamics.

These findings reinforce that controlling both feedstock price, capital investment and low financing costs is essential to maintaining strong market positioning. By reducing feedstock price, CAPEX and WACC, the project can operate profitably at more competitive price levels, thereby strengthening its commercial viability in the SAF sector.

<u>GHG emission savings</u>

In terms of environmental performance, GHG emission savings generally exceed 70% when low ILUC feedstocks and steam reforming of bio- co/by-product are considered, making the fuels compliant with sustainability thresholds for CORSIA and potentially in EU and US markets (to be cross-checked for GHG emission methodology and feedstock eligibility). However, CO_2 abatement costs vary widely, ranging in average for feedstock blend from 275 to 410 USD/t_{CO2}, with feedstock selection playing a decisive role in determining both climate impact and cost efficiency. A careful selection of feedstocks is therefore essential to ensure that SAF delivers relevant emission reductions. Even the most efficient HEFA conversion technology cannot compensate for feedstocks with inherently high carbon footprints.

<u>Next steps</u>

Overall, the initial results from the techno-economic analysis suggest that SAF production in Mombasa could be priced competitively, or at least not far from prevailing SAF market levels. This indicates a case worth further investigation, with a focus on refining estimates for SAF prices, financing conditions, CAPEX, OPEX and feedstock costs and logistics, both in relation to current conditions and potential future developments, while accounting for market volatility.

The company must first develop a clear strategy to identify the target markets for SAF and which percentage to dedicate to SAF and HVO diesel market. Based on it, further analysis is needed to assess feedstock availability, effective market feedstock and SAF price (current and forecast), and ensure alignment with sustainability standards, particularly by favouring feedstock cultivation on marginal or non-arable lands to avoid competition with food crops. In addition, it is essential to submit the proposed feedstock list to ICAO for approval and verify that all selected feedstocks meet the eligibility requirements for sale in targeted regulatory markets. CAPEX and OPEX should be refined through detailed engineering studies, while financial conditions must be assessed to determine potential financing source and the applicable range of interest rates. Overall, a flexible HEFA plant supported by a strategic feedstock sourcing plan and aligned with regulatory sustainability criteria can achieve both cost-effective and environmentally compliant SAF production.

SECTION 4. TECHNO-ECONOMIC ANALYSIS OF AN ALTERNATIVE PATHWAY

To provide a reference point, this chapter examines a benchmark scenario. Unlike the HEFA pathway, the focus here shifts to alternative technologies that offer diverse implementation opportunities for the country. We will explore at high-level multiple conversion routes, having a look on Alcohol-to-Jet (AtJ) and Fischer–Tropsch (FT) synthesis and highlighting their technical characteristics, feedstock requirements, and feasibility for the country and for the Mombasa site. The chapter will then concentrate on Power-to-Liquid (PtL) technology, a pathway of growing interest due to its independence from biomass feedstocks and its compatibility with renewable electricity and captured CO_2. This section aims to provide a comparative perspective on these advanced pathways as part of a broader strategy for SAF deployment.

4.1 OVERVIEW OF ALTERNATIVE PATHWAYS FOR SAF PRODUCTION

It is important to note that the HEFA pathway is currently the most commercially mature SAF technology, having reached Technology Readiness Level 9 (TRL 9).

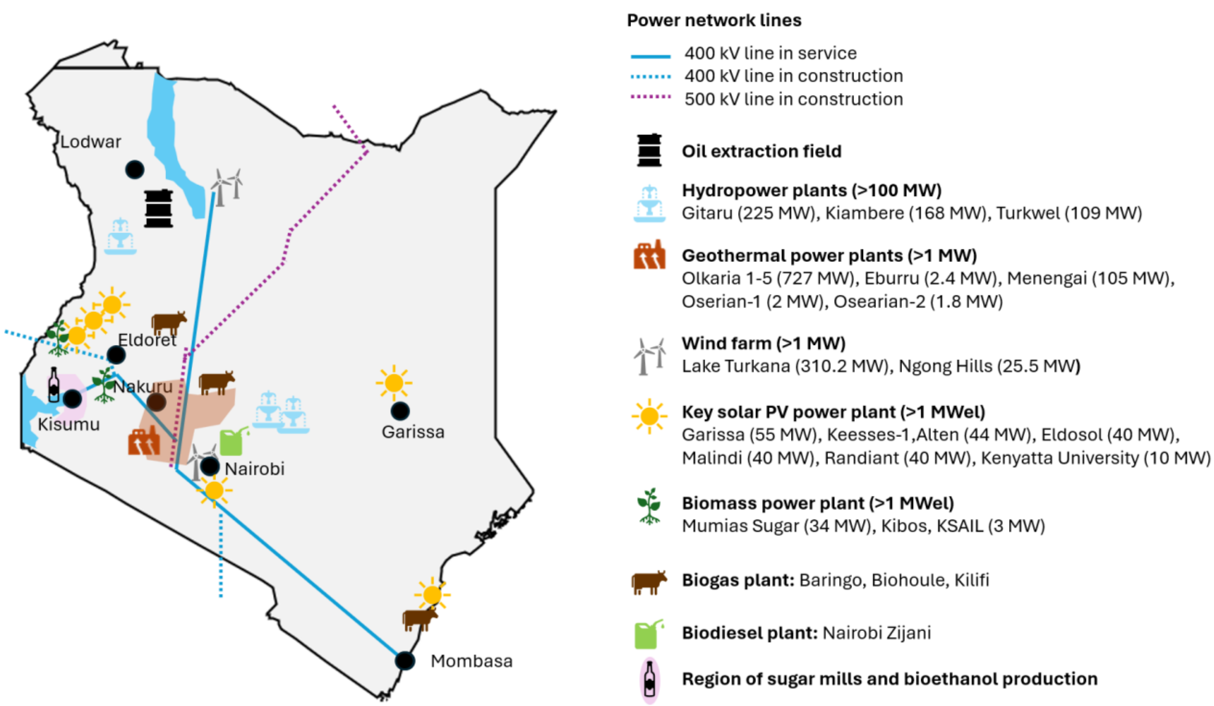


Figure 37. Overview of renewable resources in Kenya (Aenert, 2025).

Emerging technologies such as AtJ, PtL or gasification conversion are associated with higher investment risks and significantly elevated production costs. This is largely due to the greater process complexity required to convert feedstocks with significantly different chemical compositions into SAF.

To identify the most suitable alternative pathway for SAF production, it is essential to understand the availability and geographic distribution of the country's natural resources (Figure 37).

Alcohol-to-Jet scenario

The region surrounding Kisumu is widely recognized for its extensive sugarcane cultivation and numerous sugar mills. In this context, sugarcane and molasses can serve as feedstocks for ethanol production, which in turn can be utilized in the Alcohol-to-Jet (AtJ) pathway. These feedstocks are compliant with the CORSIA framework, though they are not eligible under the EU's RED III directive, and they directly compete with food resources.

Bagasse, a by-product of sugarcane processing, offers an opportunity for second-generation ethanol production through enzymatic hydrolysis of its cellulosic content, providing a non-food-based alternative for AtJ fuel (Vasconcelos, 2002). Alternatively, bagasse can be gasified to produce syngas, which may then be converted into SAF via the Fischer–Tropsch synthesis pathway. Other regionally available crops such as cassava and sweet sorghum could also be used for AtJ production, though they similarly raise concerns regarding food competition. An additional resource, water hyacinth, which is considered an invasive species in Lake Victoria, has shown promising potential for bioethanol production (Farmers Review Africa, 2023).

As a rough estimate, producing 200 000 t/year of SAF would require approximately 385 000 t/year of ethanol. Assuming an optimistic 15-22% conversion yield from bagasse to ethanol—based on a 30–45% fermentable sugar content and a 50% sugar-to-ethanol conversion efficiency—this would equate to a demand of roughly 1 750 000 - 2 570 000 t/year of dry bagasse.

In terms of cost, the Alcohol-to-Jet (AtJ) process yields approximately 65% distillate from ethanol, and assuming 80% selectivity for SAF, only about 52% of the ethanol is effectively converted into SAF. Given a typical ethanol price of 100 KES/L (Farmers Review Africa, 2023), or approximately 0.98 USD/kg, the ethanol feedstock alone would contribute an estimated 1.50 USD/kg of SAF to the production cost. Furthermore, the AtJ pathway is highly CAPEX-intensive, requiring multiple processing stages including ethanol fermentation, dehydration, oligomerization, and product upgrading. For instance, the World Economic Forum report (WEF, 2025) estimates that a 500 000 t/year SAF/HVO facility would require on average around USD 0.7 billion for HEFA, compared to about USD 2.2 billion for AtJ. This makes AtJ economically less attractive when compared to the more mature and cost-effective HEFA pathway.

Although substantial quantities of bagasse are available in Western Kenya and near Kisumu, it is primarily utilized to meet the energy requirements of the sugar mills. The unutilized fraction—estimated at approximately 300 000 t/year (ICAO, 2018), or potentially exceeding 600 000 t/year according to our survey (MMUST, Kabras), pending validation with all sugar industry stakeholders—would only be sufficient to supply a portion of the feedstock required to support a 200 000 t/year SAF production facility. If a second-generation ethanol plant and an Alcohol-to-Jet (AtJ) facility were to be developed, the most suitable location would be in Western Kenya and Kisumu area, close to the sugar mills that supply bagasse (alternatively sugarcane). In this scenario, the Mombasa site would be too distant for the cost-effective transport of bagasse or other solid feedstock (especially given the need to transport large volumes of biomass to achieve ethanol yields of less than 25%). The only feasible way to involve Mombasa would be to produce ethanol in Kisumu and transport it to Mombasa for further processing. While this is logistically possible, it raises concerns regarding operational efficiency and system integration. Additionally, since there is only limited synergy between HEFA and AtJ technologies, co-locating these processes would offer no strategic or economic benefit. Currently AtJ has a TRL of 7-8.

In summary, while AtJ represents a viable medium/long-term SAF option for Kenya, it may not be the most practical solution for near-term deployment, particularly in the context of the Mombasa refinery.

Gasification and Fischer-Tropsch synthesis

The previous feasibility study supported by ICAO (ICAO, 2018) recommended prioritizing waste-based feedstocks for SAF production. In the short to medium term, the focus should be on used cooking oil (which was analysed as feedstock for HEFA in Section 3), while in the longer term, attention can shift to municipal solid waste (MSW), sugarcane field residues such as cane tops (Kisumu area), and invasive species like water hyacinth (Lake Victoria). It is also worthwhile to consider agricultural and forestry residues as potential feedstocks (e.g., bagasse, water hyacinth, etc.).

MSW is a chemically complex and highly variable feedstock, which poses significant challenges for conversion processes. One of the primary difficulties lies in handling an inhomogeneous solid feedstock, that contains numerous contaminants, during gasification and in the subsequent Fischer–Tropsch synthesis. These impurities can negatively impact both equipment, reaction performance and product quality. Additionally, caution is needed when evaluating MSW from a regulatory standpoint. While many legislative frameworks consider MSW to be an eligible feedstock for renewable fuel production, only the organic fraction typically qualifies as renewable, thus contributes to SAF targets.

From a technical perspective, biomass feedstocks, such as agricultural and forestry residues, are generally preferred over MSW due to their more consistent composition (although as well variable). Although these feedstocks have low costs, the associated conversion technologies are capital- and energy-intensive.

For instance, the World Economic Forum report (WEF, 2025) estimates that a 500 000 t/year SAF/HVO facility would require on average around USD 0.7 billion for HEFA, compared to about USD 3.6 billion for processes composed by gasification followed by Fischer-Tropsch synthesis.

Given the current technology readiness levels (TRL=6-8) and the degree of maturity of gasification-based pathways, it is not advisable to pursue MSW or biomass gasification for SAF production in the short term. However, these pathways hold significant potential and should be seriously considered as part of a long-term strategy, especially MSW conversion can target the problem of waste management.

Power-to-Liquid

The most common Power-to-Liquid (PtL) pathway involves combining CO_2 and hydrogen, followed by a Reverse Water-Gas Shift (r-WGS) reaction to produce syngas, which is then processed via Fischer–Tropsch synthesis to generate SAF. An alternative, though not yet ASTM-certified (approval expected soon), involves converting CO_2 and hydrogen into methanol, and subsequently upgrading it through the Methanol-to-Jet (MtJ) process.

The Fischer–Tropsch route is currently more advanced in terms of technological readiness and commercial development, therefore this section will focus on this pathway. However, the MtJ route presents an interesting future alternative due to its potential for greater flexibility and decentralization. In such a model, methanol could be produced at multiple smaller sites, leveraging local renewable resources, and then transported to a centralized facility for SAF conversion. Additionally, methanol has broader market applications, such as use in the chemical industry or as a marine fuel, which could improve project viability and integration across sectors.

Regarding way to produce green electricity (Figure 37), Kenya benefits from abundant renewable energy resources, with a grid provided by more than 90% renewables. Geothermal and hydropower can provide a stable electricity supply suitable for electrolyzer operation, essential for Power-to-Liquid (PtL) fuel production. Geothermal is mainly concentrated in the Rift Valley, with the biggest plant aggregation around Olkaria. Although today has an installation of 0.94 GW (Aenert, 2025), it may have a potential expansion up to 10 GW. Hydropower has an installation of 0.86 GW, with more than 10 plants operating. However, hydropower reliability is vulnerable to climate variability in Kenya. Dry spells reduce water levels, and this may lead to increased reliance on fossil-fuel-based thermal generation. In addition, solar and wind energy show strong potential, particularly in the northwestern regions, where a 0.31 GW wind farm in Turkana is installed. The most common solar Global Horizontal Irradiance (GHI) intensity ranges between 6.5 and 6.8 kWh/m^2 per day, notably present in parts of North-Western, the Eastern and Rift Valley provinces. Similarly, average wind speeds exceed 7.5 m/s at 50 meters in the northwestern part of the country, especially in the Eastern province and along the Lake Turkana coastline, making these areas highly suitable for renewable energy generation and Power-to-liquid plants (Aenert, 2025).

Most renewable energy resources in Kenya, particularly those capable of providing stable, 24/7 generation such as geothermal and hydropower, are not located near Mombasa. Although Mombasa is connected to the national grid and therefore able to exploit them, the grid's total capacity is only around 3.3 GW and the electricity cost from the grid can be more than three times higher than that of power generated from a dedicated (captive) plant.

Given the high electricity demand of Power-to-Liquid (PtL) processes, especially for hydrogen production, a dedicated (captive) power plant may still be necessary to ensure a reliable supply and to benefit from lower electricity costs. Given the equation to describe the combination of reverse water gas shift (r-WGS) and Fischer-Tropsch synthesis, $n[CO_2 + 3\ H_2] \text{->} -(CH_2)_n- + 2n\ H_2O,$ a first estimation about the electrolyzer installation to produce 200 000 t/year SAF can be calculated. Considering a selectivity of FT of 60-80% for SAF (WEF, 2022), a 108 000 t/year H_2 production would be required and this translate to a 660 MW electrolyzer assuming 68% efficiency. This capacity alone represents more than 20% of the whole installed capacity of Kenya, indicating how energy intensive this process can be. It is also important to note that PtL remains a relatively immature technology and is currently among the most expensive SAF production pathways. Currently, there are no commercial PtL plants operating at TRL 9 (usually TRL 6-7 is attributed (S&P Global, 2024)), and the facilities that are planned typically have production capacities below 100 000 t/year of SAF. One example of a commercial project is Arcadia eFuels. Its most advanced initiative, Project Endor, is a EUR 2 billion investment in Vordingborg. The project completed FEED (Front-End Engineering Design) and was granted the environmental permit and is approaching the stage for FID (Financial Investment Decision). The plant is a fully electrified refinery designed to produce about 70 000 tonnes of e-SAF and 10 000 tonnes of e-naphtha annually and after FID is obtained it will required 3.5 years for construction (Kold, 2025b, 2025a; Markosyan, 2025).

In contrast to the HEFA pathway, which has reached full commercial maturity and can scale to millions of tonnes annually (e.g., Neste's plant in Singapore), PtL projects remain limited in scale. This is primarily due to technological maturity limitations, the substantial investment to be raised, the significant renewable energy input required for hydrogen production and an electrolyzer still-developing market. In terms of investment, Power-to-Liquid (PtL) projects are typically an order of magnitude more expensive than HEFA. For instance, the World Economic Forum report (WEF, 2025) estimates that a 500 000 t/year SAF/HVO facility would require on average around USD 0.7 billion for HEFA, compared to about USD 6.3 billion for PtL. This significant difference in capital costs directly impacts the production cost of SAF.

Although other regions in Kenya may be more favourable than Mombasa for renewable energy generation, this scenario will be modelled based on a Mombasa location, with the understanding that it can be extrapolated to other sites. While the CAPEX for the plant is expected to remain broadly similar across regions, the key variable will be the cost of electricity, which will depend on regional resource availability, generation efficiency, and the specific mix of technologies used (e.g., wind, solar, geothermal, or hydropower).

4.2 POWER-TO-LIQUID

The Power-to-Liquid (PtL) pathway was selected given the significant attention it has received in relation to Kenya, owing to the country's unique position where over 90% of its electricity is generated from renewable sources. In this section, we present a high-level analysis to develop a rough estimate of the PtL production cost and compare it against the corresponding estimate for HEFA.

4.2.1 Scenario and assumptions

Since the study aims to utilize the Mombasa refinery site, the proposed PtL plant is assumed to be in Mombasa, but the results can be abstracted for other location. For reference and comparison with the HEFA case analysed in SECTION 3, the facility is designed to produce approximately 200 000 t/year of SAF and HVO diesel. It should be noted, however, that this capacity is significantly above the current state of the art, and a more realistic assumption would be a plant with a capacity of around 100 000 t/year. The feedstock will consist exclusively of water, CO_2, and renewable electricity. In the absence of suitable point sources, CO_2 will likely be captured directly from the air. Water may be sourced through desalination, as electrolyzers generally require ASTM Type II/III deionized water to ensure low conductivity and minimal organic or ionic contamination. Renewable power could be supplied through a hybrid system, supplemented by grid electricity as backup (see later section). The logistical distribution of the products will follow the framework outlined in Sections 2 and 3.

4.2.2 Power to Liquid requirements

Kenya has developed a strategy addressing both hydrogen and its derivatives (PtL). Two key national documents define the PtL sector: the *Green Hydrogen Strategy and roadmap for Kenya* issued by the Ministry of Energy and Petroleum (Ministry of Energy and Petroleum, 2023) and the *Kenyan's guidelines on green hydrogen and its derivates* published by EPRA (EPRA, 2024a). Both documents are relevant to defining this business case. In addition, the recent *CORSIA Methodology for Calculating Actual Life Cycle Emissions Values, Sixth Edition (June 2025)* (ICAO, 2025f) introduces important updates on the electricity source and CO_2 supply for CORSIA eligible fuels. This section provides an analysis of the requirements established under both Kenyan guidelines and the CORSIA framework.

Electricity sourcing

According to EPRA guidelines, the electricity for green hydrogen production may be sourced through one or more of the following options:

- **Option 1 – Captive Renewable Energy Plant:** A dedicated renewable energy plant (off-grid or grid-tied) built solely for electrolysis.
- **Option 2 – Renewable Energy Supply from the Grid**
  Electricity supply must 1) contain at least 80% renewable energy (based on previous year's grid mix); 2) have grid emission intensity below 64.8 g_{CO_2eq}/kWh; 3) demonstrate that supply to the electrolyzer does not compromise grid reliability for other users.
- **Option 3 – Power Wheeling via the Grid**
  Applicable where the electrolyzer operator owns or contracts renewable energy (via PPA) located off-site. The renewable plant must not have been committed to the grid at electrolyzer commissioning. Electricity used must coincide with the renewable plant's generation period.

For options 1 and 3, the energy use must be validated by the Authority through measurements and/or RECs from recognized bodies.

According to CORSIA, for CORSIA eligible fuels (CEF) production facilities that begin operation before 1 January 2033, the following power requirements will remain in effect until the conclusion of CORSIA's Second Phase on 31 December 2035. The electricity used for CEF production must be fully (i.e., 100%) sourced through one or more of the following options:

- The CEF producer's own dedicated electricity generation facility;
- Energy Attribute Certificates (EACs), which represent the legal rights to the environmental attributes of electricity generation; or
- Contractual arrangements under which the producer takes ownership of the electricity (e.g., through a Power Purchase Agreement, PPA) and, where applicable, any EACs associated with that electricity.

For CEF production facilities commencing operation on or after 1 January 2033, 100% of the electricity must be sourced through two specified arrangements.

- **Type 1 (minimum 70%)** – Electricity sourced from the producer's own generation facility or contractual mechanisms (e.g., PPAs), including any associated Energy Attribute Certificates (EACs). To claim this electricity, the EAC must be owned and retired by or on behalf of the producer.
- **Type 2 (maximum 30%)** – Electricity sourced through EACs, representing the environmental attributes of electricity generation. These EACs must also be owned and retired with CEF production. Unbundled EACs (i.e., without ownership of the underlying electricity) are permitted only if they meet specific requirements.

The electricity must also meet the criteria of deliverability, temporal matching, additionality, and sustainability.

To demonstrate deliverability, CEF producers are required to show that the electricity generation facility and the CEF production facility (or an intermediate facility such as hydrogen production) are located within the same network, defined as an integrated grid managed by a single Transmission System Operator. Alternatively, if electricity market regions with zonal pricing are in place, the generation facility must be situated either in the same market region as the CEF production facility, in an interconnected offshore region, or in a neighbouring interconnected region with equal or higher electricity costs. There are also some exceptions, and we refer to the document for further details.

Temporal matching refers to the timescale over which electricity consumption by a CEF producer (or by an intermediate facility such as hydrogen production) must correspond to electricity obtained under approved sourcing arrangements. Until 31 December 2029, or later if the grid is not considered “ready,” compliance is based on annual matching. This means that the total electricity consumed within a calendar year must equal the amount of electricity sourced in that same year. If energy storage is used, evidence must demonstrate that the storage asset was charged with sourced electricity within the calendar year and that the electricity discharged from storage and used in CEF production also occurred within the same year. Starting from 1 January 2030, provided the grid is assessed as “ready,” the requirement shifts to hourly matching. In this case, electricity consumed must correspond to electricity sourced within the same one-hour period. Where storage is involved, it must be shown that the storage asset was charged with sourced electricity in the same one-hour period and that its discharge aligned with electricity use for CEF production within that period.

Additionality refers to the requirement that electricity generation and storage used for CEF production, or for intermediates such as hydrogen, represent new capacity rather than diverting resources already needed to decarbonize the grid or other sectors. To demonstrate additionality, CEF producers must show that the generation or storage facility began operating no earlier than thirty-six months before the CEF facility itself entered operation. Expanded capacity can also be considered additional, provided it meets the same timeframe. There are also situations where electricity use is exempt from additionality requirements. These include existing power plants with expired offtake agreements that would otherwise retire, the use of curtailed electricity with the eligible share calculated based on the ratio of curtailed to total generation over the past one to three years, cases where electricity use is less than 30% of total input energy and grid-average emissions are claimed, and cases where electricity use is less than 7.5% of total input energy.

CEF facilities that begin operating before 2028 are not required to comply with the additionality provisions until the end of CORSIA’s Second Phase on 31 December 2035. It is also noted that current rules do not exempt electricity sourced from highly decarbonized grids or underutilized assets, though such exemptions may be considered in future updates.

CEF producers must provide a valid sustainability declaration for all electricity used. This declaration must show that electricity is not sourced from land or aquatic ecosystems with high carbon stocks (such as primary forests, wetlands, peatlands, coral reefs, or mangroves) that were converted after 1 January 2008, nor from activities that degrade such ecosystems.

For solar electricity, providers must demonstrate that systems are located either on land not used for crops after 1 January 2016 or on marginal land (until 31 December 2029), defined as parcels unused for agriculture for at least 36 months and performing in the lowest tercile of agricultural norms. Further rules will be developed for cases such as dual-purpose land (e.g., agrivoltaics). Electricity must also not come from areas protected for biodiversity, conservation, or ecosystem services, unless it can be shown that generation does not interfere with protection purposes. As exemption, sustainability requirements do not apply if the electricity facility is already certified under CORSIA sustainability criteria by an approved certification scheme, or if electricity accounts for less than 30% of input energy.

Water resource and land use

Following the EPRA guidelines, which are broadly aligned with CORSIA, developers shall optimize water use, avoid freshwater consumption in water-stressed areas, and minimize risks related to water access. A water resource assessment must be conducted to determine the availability, quantity, and quality of water. The assessment report shall be publicly accessible and outline potential co-benefits for local communities, such as providing water for drinking, irrigation, and/or treatment.

Developers should prioritize suitable non-arable land or areas with minimal environmental impact for green hydrogen projects. They must engage local communities, seek acceptance, improve living standards, and respect rights, culture, equity, and livelihoods, obtaining consent where resettlement is required.

CO_2 sourcing

EPRA and ICAO do not make specific reference to the CO_2 source for PtL; instead, ICAO refers to waste and residue gases. According to CORSIA, specific conditions must be met for CO_2 sourcing when derived from waste or residue gases. For a gas stream to qualify as a waste and residue gas stream, three specifications must be satisfied. First, the gas stream must be unavoidably generated during the production of a primary product other than the gas stream itself. Second, its generation must be fundamentally tied, both causally and in intensity, to the production process of the primary product and any co-products, meaning that the production of the gas stream is unintentional. For waste gases the third point requires that the gas stream would have been discarded in the absence of use or there must be a legal obligation to discard it. For the residue gases, the third point requires that the economic value of the gas stream must be insignificant at the point of origin, defined as less than ten percent of the value of all products, including intermediates, resulting from the process in which the gas stream is captured. A methodology for GHG emission calculation is reported to calculate their emission impact.

In general, for the PtL process, carbon can be sourced either directly from the air through direct air capture (DAC) or from point sources from industrial plants such as flue gases or by biogenic sources such biogas, and bio-based ethanol production. Capturing carbon emissions from industrial sources can serve as a practical interim solution until direct air capture technology is deployed at scale. In the near term, facilities such as steel mills, cement kilns, and coal-fired power plants, where CO_2 is produced from fossil fuels, can play an important role in advancing and scaling the carbon capture industry.

However, since the CO_2 comes from fossil sources, it cannot achieve full decarbonization of the fuel. There is also a risk that PtL produced using CO_2 from fossil-based industrial processes may fail to meet future sustainability standards or align with energy accounting frameworks. In addition, as steel and other major industries reduce their emissions, the availability of such CO_2 sources will decline, an important factor to weigh before investing in capture equipment that relies solely on fossil-based emissions.

Biogenic point sources, such as pulp and paper mills, biogas plants, waste incinerators, and bio-based heat and power facilities, can provide biogenic CO_2 for use, at least until their supply limits are reached. However, CO_2 concentrations vary significantly among these sources: air contains only about 0.04% CO_2 by volume compared to e.g., cement kiln flue gas with ~22% CO_2 (Schmidt *et al.*, 2023). This has a direct impact on the cost of CO_2.

In Kenya, two companies are active in the DAC space: Octavia Carbon (Octavia Carbon, 2025) and Sirona Technologies (Sirona Technologies, 2025). At present, their focus is more on CCS, but they could also serve as potential technology providers for CO_2 sourcing in PtL projects.

Green hydrogen and PtL production: conformity to Kenyan guidelines

According to the EPRA guidelines, green hydrogen and its derivatives (e.g., synthetic fuels) producers are required to submit the following information to the Authority on an annual basis:

- an accounting framework covering all hydrogen produced and its offtakers;
- an annual compliance certificate issued by the National Environmental Management Authority after audits;
- a list of dispensing outlets (where applicable);
- a certificate of product conformity issued by the Kenya Bureau of Standards.

The requirements, approvals and involvement of the stakeholders for green hydrogen and PtL projects are outlined in the *Kenyan's guidelines on green hydrogen and its derivates* published by EPRA (EPRA, 2024a). Synthetic fuels may be transported by pipeline, road tanker, ship or any other method approved by the Authority.

Incentives for PtL producers

The Kenyan government has set up three public Special Economic Zones (SEZs) and licensed more than fifteen private SEZs, offering the following incentives to companies operating within them:

1. Imported goods fully exempt from VAT, excise duty, import duty and import declaration fee;
2. Zero-rated VAT for local supplies;
3. 10-year tax holiday;
4. 10% corporate tax for the first 10 years, 15% corporate tax for the next 10 years and 30% corporate tax for subsequent years;
5. Operation under a single license;
6. Perpetual exemption of stamp duty;
7. Preferential rates for withholding tax at 5% on interest, management and royalties;
8. 100% investment deduction allowance over 20 years; and
9. Access to special electricity tariffs.

Investors in green hydrogen and its derivatives may apply to have the areas where their projects are being developed designated as Special Economic Zones (SEZs). The guideline came into effect on 1 May 2024.

4.2.3 General facility design and inputs for PtL plant

Plant configuration proposed

The plant under consideration is a PtL facility, fully running on renewable power and sourcing CO_2 (Figure 38). For the purposes of modelling, the renewable energy source and the DAC unit are assumed to be external to the plant boundary. This assumption facilitates the adjustment of power and CO_2 costs according to their respective sources and enables a straightforward sensitivity analysis. In practice, however, KPC would need to determine whether these inputs can be secured through external contracting or whether they should be integrated into its own investment portfolio.

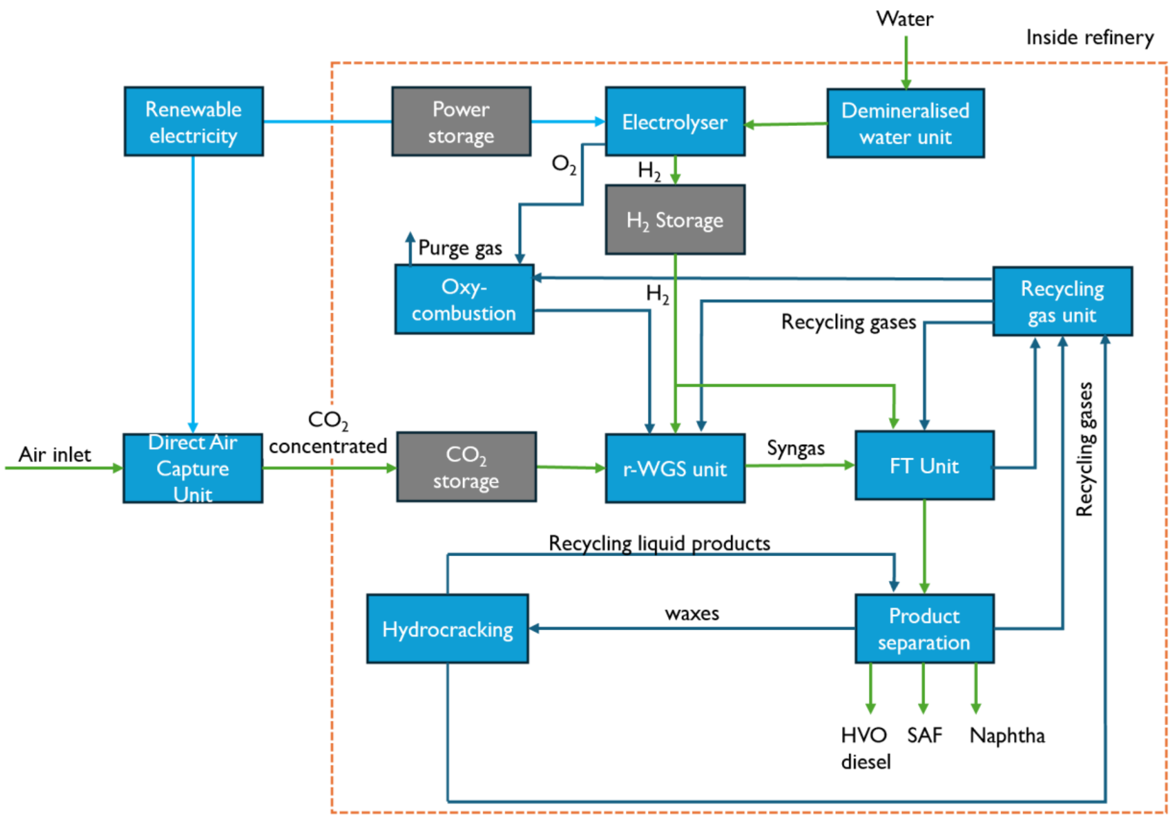


Figure 38. Example of PtL plant used for the study calculations, adapted from (Rojas-Michaga *et al.*, 2023).

The renewable electricity powers an electrolyzer, which splits demineralized water into hydrogen and oxygen. An alkaline electrolyzer (AEL) was selected for this purpose, as it represents the most advanced and commercially mature technology currently available. Solid oxide electrolysis cells (SOECs) may become relevant in the future, particularly if co-electrolysis (the simultaneous conversion of CO_2 to CO) can be effectively implemented, thereby eliminating the need for a reverse water–gas shift (r-WGS) step. Moreover, SOECs have the potential to become highly cost-competitive; however, at present, the technology is not yet sufficiently developed for large-scale commercial deployment.

The hydrogen produced can be stored for short time to ensure flexible operation, while the oxygen can be used in oxy-combustion to generate heat and manage purge gases. At the same time, carbon dioxide is captured directly from the air using a Direct Air Capture (DAC) unit, with the option of temporary storage in a CO_2 buffer system. Alternatively, CO_2 can be sourced from a single point emitter, preferably of biogenic origin.

The hydrogen from electrolysis and the CO_2 are combined in a reverse Water-Gas Shift (r-WGS) unit to form CO and water. Downstream, hydrogen is added to adjust the syngas to the correct stoichiometry for the Fischer–Tropsch reaction, where it undergoes catalytic conversion into a spectrum of long-chain hydrocarbons (using a low temperature catalyst to maximize wax formation). To enhance overall efficiency, a portion of the unconverted gases is recycled through a dedicated recovery unit (Rojas-Michaga *et al.*, 2023).

The hydrocarbons leaving the FT reactor are separated into different fractions in a distillation unit. This step yields hydrocarbons such as HVO diesel, SAF, and naphtha. Heavy waxes formed during the process are directed to a hydrocracking unit, where they are cracked into lighter products that can be fed back into the separation stage, increasing the share of SAF and other usable fuels. Throughout the process, both gases and liquids are recycled wherever possible, ensuring high efficiency and maximum fuel output. Overall, the PtL pathway enables the transformation of renewable electricity, water, and carbon dioxide into drop-in liquid fuels.

Product flexibility for SAF and green diesel

The product distribution from Fischer–Tropsch (FT) synthesis differs significantly from that of HEFA. Typically, dependently from the hydrocracking conditions, the product slate consists of approximately 60% e-SAF , 20% e-diesel, and 20% e-naphtha (WEF, 2022), while the lighter gases generated are internally utilized to meet the facility's energy demand. Recent developments, however, indicate the potential to shift production towards a distribution of 80% e-SAF and 20% e-naphtha (WEF, 2022), reflecting an emerging trend in the sector. In general, FT processes yield about 80% jet and/or diesel fuel with around 20% naphtha. For the purposes of this study, the 80% SAF and 20% naphtha scenario will be considered.

Renewable power generation

Based on the power capacity required solely for the electrolyzer (660 MW) and the requirement for green hydrogen power outlined above, the development of a dedicated power plant will be necessary to supply the PtL facility. Electricity could either be generated by KPC itself in a dedicated captive plant or procured through a power purchase agreement (PPA). Renewable power can be produced by a hybrid solar/wind installation, e.g., located directly in Mombasa, or alternatively via power wheeling through the national grid. In the latter case, geothermal power generated in Olkaria connected to the grid, for instance, could also be utilized in Mombasa for a reduced price compared to the grid fees. It should be noted that once a renewable plant of this scale is connected to the grid, modernization of the grid infrastructure may be required to accommodate the additional capacity and to prevent congestion. A grid connection is likely to be advantageous, as it would allow the PtL facility to inject electricity into the network when excess renewable power is generated and to draw electricity from the grid as a backup during periods of low renewable availability. In this way, the grid would effectively function as a "virtual" storage system, helping to mitigate fluctuations in renewable energy production.

Since the structuring of power supply from renewable resources (e.g., defining the percentage of wind, solar and geothermal to provide a stable power supply) would require a dedicated study in its own right, this analysis considers only the cost of electricity as variable (Table 38). However, to give an estimation of the CAPEX required for renewable energy, a rough estimation will be calculated using the value in Table 39. The size of the investment required for renewable energy deployment may represent a potential constraint for the project.

The Energy and Petroleum Regulatory Authority (EPRA) sets electricity tariffs in Kenya. For the largest consumers, tariffs now exceed 200 USD/MWh. The energy charge, covering generation, transmission, and distribution, accounts for 93 USD/MWh, or roughly half of the total tariff, with additional charges, taxes, and fees applied on top (Table 38). Kenya has established industrial clusters and Special Economic Zones (SEZs) to promote industrialization, improve competitiveness, and attract investment through incentives and government support. According to EPRA's 2023 tariff review, a special SEZ tariff category has been introduced:

investors in the 15 designated SEZs pay a harmonized energy charge of 10 KES/kWh (77 USD/MWh), though standard additional fees and taxes still apply.

Table 38. Reference price for renewable electricity in Kenya (Ministry of Energy and Petroleum, 2023).

	Energy charges [USD/MWh]	Fees, charges [USD/MWh]
Retail tariff domestic (03/2023)	161	118
Retail tariff business CI5 (03/2023)	93	110
Retail tariff business SEZ (03/2023)	77	110
Geothermal[a]	65.0	-
Solar[a]	57.5	-
Wind[a]	59.7	-

[a] *Benchmark tariffs for renewable energy auctions.*

Overall, grid electricity tariffs in Kenya are high and can significantly undermine the viability and competitiveness of green hydrogen projects. By comparison, benchmark tariffs from renewable energy auctions—used here as a proxy for the levelized cost of electricity (LCOE) for geothermal, solar, and wind—range between 57 USD/MWh and 65 USD/MWh (Table 38). Green hydrogen developers may, however, opt to build captive renewable plants at potentially lower costs. Other options worth exploring include corporate PPAs, creating SEZs dedicated to hydrogen production, or implementing tax and fee waivers to reduce electricity costs for hydrogen projects.

Table 39. CAPEX, OPEX estimation and capacity coverage of different renewable energy plants.

Power source	CAPEX [USD/kW installed]	OPEX as % of CAPEX	Capacity factor	Lifecycle carbon footprint [g_{CO2eq}/kWh][f]
Geothermal[f]	1 870 - 5 050[a] 4 589[b]	2.0%[c]	90%[a]	37[d]
Solar[f]	676[e] 758[b]	2.0%[e]	20%[a]	43[d]
Wind[f] **(onshore-offshore)**	1 040 - 4 540[e] 1 160 - 2 080[b]	2.5%[e]	60%[a]	13[d]

Sources: [a] *(Ministry of Energy and Petroleum, 2023),* [b] *(IRENA, 2024),* [c] *(Scarlat et al., 2020),* [d] *(NREL, 2021)* [e] *(Seymour et al., 2024);*

[f] *Average among studies of several plants. Emissions are specific to each plant.*

CO_2 sourcing

CO_2 sourcing is associated with a wide range of costs, which vary depending on the capture pathway—whether from a concentrated point source or through direct air capture (DAC). These costs are not only influenced by the scale of capital investment but are also strongly affected by the substantial power and heat requirements of the respective technologies.

In certain sectors, such as bioethanol production, CO_2 can be captured from industrial point sources at relatively low cost, estimated at approximately 25 USD/t. In contrast, capture from more challenging industries, such as cement manufacturing, may exceed 100 USD/t (WEF, 2022).

In the longer term, direct air capture (DAC) offers the potential to provide an effectively unlimited source of CO_2 and thereby fully close the carbon cycle. At present, however, DAC technologies remain costly, with current estimates ranging from 250 to 600 USD/t of CO_2. Globally, 19 DAC plants are in operation, collectively capturing more than 9 000 tonnes of CO_2 annually, though no existing facility has yet demonstrated scalability beyond a few thousand tonnes per year (WEF, 2022). The cost of DAC varies by technology type. Projections for 2030 suggest that liquid solvent–based DAC could achieve capture costs of 170–260 USD/t, while solid sorbent–based DAC may range from 270–500 USD/t. With technological advancement, economies of scale, and declining renewable electricity costs, capture costs for both approaches are expected to fall to approximately 90–240 USD/t. By 2050, DAC costs could decrease by 50–80% compared to current levels, reflecting technological maturation and continued reductions in capital and operational expenditures (WEF, 2022).

Given the limited availability of operational data, cost estimates for CO_2 sourcing are subject to considerable uncertainty. For the purposes of this study, two reference values are therefore applied: 100 USD/t to represent capture from a concentrated point source, and 400 USD/t to represent direct air capture (DAC). For the GHG calculation with CORSIA methodology it was assumed that CO_2 from fossil CO_2 sources is accounted as in RED II (0 g_{CO_2eq}/g_{CO_2} before 2041).

Water sourcing

For the purposes of this study, the price of freshwater is assumed to be 3.4 USD/m^3. However, given the potential scarcity of freshwater in Mombasa, the installation of a seawater desalination system may be required. In general, the integration of a desalination unit has only a marginal impact on the overall costs of a PtL facility (Fasihi, Bogdanov and Breyer, 2016a) (<<1%). Additionally, part of the process water can be recovered either from the Fischer–Tropsch (FT) synthesis or from moisture captured during DAC operations. Nevertheless, FT wastewater often contains dissolved gases (CO, CO_2, and unreacted H_2) as well as organic oxygenates (e.g., alcohols, acids, aldehydes). Therefore, the potential costs associated with purifying this water to ASTM Type II/III deionized standards (suitable for electrolysis) must be carefully evaluated to determine whether such reuse is economically and technically viable.

Co-/by-product use and valorization

As co-products, both naphtha and oxygen are generated. A portion of the oxygen can be utilized for oxy-combustion, while the remainder may be sold. We assumed that naphtha can be marketed in the range of approximately 600-1 200 USD/t; however, it should be noted that Fischer–Tropsch-derived naphtha is not directly suitable for use as gasoline and requires further upgrading in a catalytic reformer. Given that the volumes produced are insufficient to justify reactivating a reforming unit on-site, it is recommended to sell naphtha to externals.

The light gases and off-gases generated are combusted on-site to produce energy. For the purposes of this study, only the sale of naphtha is considered, while the valorization of oxygen is not taken into account.

Utilities and infrastructure

The infrastructure outlined in 3.1.2, such as the existing tanks for liquid products, pipelines for distribution, buildings may be utilized if available also in the case of PtL. In addition, dedicated gas storage is required. For this study, storage capacity equivalent to 24 hours of operation is assumed for both hydrogen and CO_2. Such storage serves primarily as a buffer for plant operations and is generally limited to short durations (24–48 hours) due to the high associated costs.

Operating hours per year and operational lifespan

The same assumptions as outlined in 3.1.1 are applied for operating hours and plant lifetime.

Estimated time for development, construction, commissioning and production ramp-up

The same assumptions as presented in 3.1.1 are adopted.

Methodology for CAPEX and OPEX estimation

The simulation of PtL systems involves substantial complexity. In order to provide a first-order assessment within the scope of this study, we adopt a pragmatic approach by drawing on data reported in the literature and studies, which specify quantities on a per-unit-installed basis or similar plant dimensions (Table 40).

Table 40. Estimated CAPEX and OPEX costs for PtL. (Source: Seymour *et al.*, 2024)

Element	CAPEX[e]	CAPEX Unit	OPEX [% of CAPEX per year]	Lifetime [year]
Electrolyzer	2625[a]	USD/kW_{el}	2.0%[a]	30 (stack 10)
DAC	260[b]-830[c]	USD/t	4.0%	12
Fuel synthesis	1792[d]	USD/kW_{CH}	2.5%	30
Li-ion battery	368	USD/kWh_{el}	2.5%	15
H_2 storage	24	USD/kWh_{H2}	1.0%	30
CO_2 storage	1705	USD/t_{CO2}	2.5%	30

[a] *Data from the European Hydrogen Observatory (European Hydrogen Observatory, 2024). The estimates of 2 310 EUR/kW_{el} for 100 MW_{el} are based on annual industry surveys of European project developers and highlight that actual CAPEX values vary considerably depending on project scope and equipment specifications. The costs assumptions are explained in the website (European Hydrogen Observatory, 2024), which consists of stack costs, balance of plant, other utilities costs, other CAPEX costs. The stack cost covers the equipment, engineering, procurement, and installation of the electrolyzer stack. The balance of plant cost includes the equipment, engineering, procurement, and installation of the rectifier, the transformer directly connected to the rectifier, gas and liquid separation units, water/lye feeding systems, and gas purification equipment. The other utilities costs comprise the equipment, engineering, procurement, and installation of high-voltage transformers, water treatment equipment, cooling systems, hydrogen compression (if required for the system), the control system, and other auxiliary services. The other CAPEX costs consist of land and grid fees, insurance, permitting, feasibility studies, contingency, and EPC (Engineering, Procurement, and Construction) management. The OPEX was reported as 46.20 EUR/kW/y, representing 2% of the capex p.a. Electricity is excluded from the OPEX. A Lange factor of 0.88 was applied for further calculation*

[b] *Calculated from data given in Source (Fasihi, Bogdanov and Breyer, 2016b)*

[c] *Source: (Seymour et al., 2024)*

[d] *Calculated from data given in Source (Schmidt et al., 2023) for a reference plant of 200 000 t/year PtL fuel*

**Conversion dollar to euro 0.88*

For the electrolyzer, the value provided by the European Hydrogen Observatory (European Hydrogen Observatory, 2024) was used. Although this figure is typically higher than those reported in other studies (Fasihi, Bogdanov and Breyer, 2016b; Rojas-Michaga *et al.*, 2023; Howe *et al.*, 2024; Seymour *et al.*, 2024; Frąckiewicz, 2025), it has been validated through interviews with various European project developers and should provide a reliable estimate of all the components required to establish a fully functioning system. In addition, it should be noted that for alkaline electrolyzers (AELs), the stack lifetime is typically estimated at 60 000–90 000 operating hours, corresponding to approximately 7–10 years of continuous operation, after which they require replacement (Frąckiewicz, 2025). However, costs are projected to decline over the next few years, improving the feasibility of the PtL business. A Lange factor of 0.88 was used for electrolysis. Water preparation is already included in the cost of the electrolyzer; however, even when desalination is required, the associated costs are relatively low compared to the overall project CAPEX. The cost of desalinated water is estimated at approximately 0.59 USD/m³ (Fasihi, Bogdanov and Breyer, 2016b). The efficiency of the AEL electrolyzer was assumed to be 68% (Schmidt *et al.*, 2023). For electrolysis, a water demand of 8.94 kg per kg of hydrogen was considered, accounting for losses as reported in source (Schmidt *et al.*, 2023).

For simplicity for the sensitivity analysis, CO_2 supply is treated as an OPEX costs. However, to give an estimate of the capital investment required, Table 40 provides indicative CAPEX estimates for DAC. Owing to its low technology readiness level (TRL), direct air capture (DAC) is associated with significant uncertainty regarding commercial costs and is therefore subject to a high margin of error. Moreover, CAPEX and OPEX for carbon capture strongly depend on the CO_2 concentration in the input stream. For example, flue gas from a cement kiln (~22% CO_2) requires considerably less energy and lower CAPEX (e.g., process with liquid absorption) compared to ambient air capture (~0.04% CO_2)(Schmidt *et al.*, 2023), which often relies on solid adsorbents that are not yet sufficiently mature to ensure higher efficiency. Reported values in the literature therefore vary substantially.

In Table 40 the lower CAPEX limit may be interpreted as representing high-concentration streams, while the upper limit corresponds to low-concentration streams. A scale factor of 1 was used for DAC. Direct air capture (DAC) is assumed to operate at 90% efficiency (Rojas-Michaga *et al.*, 2023), with electricity and heat consumption data taken from LBST (Schmidt *et al.*, 2023). For the synthesis, which is composed by a r-WGS, FT synthesis, product upgrading (hydrocracker) and separation, the data were taken for a 200 000 t/year plant analysed in the source (Schmidt *et al.*, 2023). For the storage system, the primary strategy is to prioritize hydrogen storage over Li-ion batteries, as batteries are suitable only for short-term use and are more than ten times as costly as hydrogen storage. In addition, provisions are considered for CO_2 storage. A scale factor of 1 is considered for storing facilities.

In terms of fixed costs, the same assumptions outlined in 3.1.1 are applied, including the staffing requirements. Working capital is estimated at 5% of the fixed capital investment (FCI)

Financial inputs, other inputs and outputs

In term of financial inputs and other input and output, we refer to the same parameters and values described in 3.1.3, 3.1.4 and 3.1.5. In terms of WACC, also Kenyan LCPDP applies a weighted average cost of capital (WACC) of 13% (in real terms) for the calculation of the levelized cost of electricity (LCOE) across various power generation technologies. Considering the higher intrinsic risks associated with green hydrogen, it is reasonable to assume the same WACC for hydrogen projects in Kenya (Ministry of Energy and Petroleum, 2023).

4.2.4 Results of the Techno-Economic Assessment

Plant design: input requirements and output products

The plant is designed to produce approximately 200 000 t/year of SAF (Table 41). Within this configuration, renewable diesel has not been included; nevertheless, a similar level of operational flexibility is achievable, as demonstrated in the HEFA pathway, allowing flexible production of renewable diesel and SAF. The principal co-product is naphtha, with an estimated annual output of 50 000 t/year. As Fischer–Tropsch naphtha, this fraction does not inherently meet gasoline specifications and therefore requires additional upgrading in a catalytic reformer. Considering the production volume, direct commercialization of the naphtha to available off-takers may represent a more economically viable option than establishing a new processing facility in Mombasa.

In addition to liquid products, oxygen is also generated as a co-product of the electrolysis. A portion of this oxygen can be employed within the plant for oxy-combustion processes, while the surplus has the potential to be marketed externally, subject to demand. Furthermore, significant amounts of wastewater are expected to be produced (approximately 650 000 t/year), necessitating the integration of a dedicated wastewater treatment plant within the overall facility design.

Table 41. PtL plant characteristics including feedstock, energy, and products.

Plant characteristics	Value
Products	
Final product middle distillate [thousand t/year]	200
Of which SAF [thousand t/year]	200
Naphtha [thousand t/year]	50
Oxygen produced by electrolysis [thousand t/year]	863
Wastewater produced during FT and r-WGS [thousand t/year]	647
Efficiency	
Carbon efficiency of the synthesis plant	98%
Power to liquid plant efficiency to fuel	34%
Inputs	
CO_2 supply counting carbon efficiency [thousand t/year]	791
H_2 supply [thousand t/year]	108
Electricity need for electrolyzer [TWh/year]	5.3
Electrolyzer capacity needed [MW_{el}]	660
Water needed for electrolysis [thousand t/year]	1 085
Outside refinery	
CO_2 entering DAC (efficiency 90%) [thousand t/year]	879
Electricity required for DAC from air [MW_{el}]	44
Electricity required for DAC from concentrated sources [MW_{el}]	16
Heat required for DAC from air [MW_{therm}]	176
Heat required for DAC from concentrated sources [MW_{therm}]	115

The carbon efficiency of the plant has been assumed at 98%, reflecting near-complete utilization of carbon inputs. The energy efficiency associated with the storage of energy in middle-distillate hydrocarbons is estimated at 34%, consistent with values reported in comparable process configurations.

The PtL plant requires approximately 791 000 t/year of CO_2 and 108 000 t/year of H_2 as inputs. The associated energy demand is substantial, with electrolysis alone requiring 5.2 TWh annually, corresponding to an installed electrolyzer capacity of 660 MW. Water demand for electrolysis exceeds 1 million tonnes per year.

Direct air capture (DAC) is not considered within the refinery boundary; however, for the overall process it must be acknowledged as a major consumer of both electricity and heat. Its operation is estimated to require an additional 16–44 MW of renewable power capacity. In total, the project would demand more than 700 MW of effective renewable power generation. To put this in context, Kenya’s current electricity production is approximately 2.3 GW from a total installed capacity of 3.8 GW (incl. captive plants). Consequently, the implementation of this project would necessitate a significant expansion of generation capacity, equivalent to around 30% of the country’s present electricity production. Moreover, if the renewable power plant were to be connected to the national grid, grid infrastructure upgrades would likely be required. Connecting to the grid could be advantageous, as it would allow the grid to serve as virtual storage and thereby avoid the need for batteries. However, further studies are required to assess the feasibility of this approach.

CAPEX and OPEX

In terms of investment, the total CAPEX is estimated at approximately USD 2.3 billion (Table 42). The largest share of this cost is attributed to the electrolyzer, which represents the dominant capital expenditure, followed by the fuel synthesis unit and the hydrogen storage system. The latter contributes significantly to overall costs due to the technical requirements and expenses associated with storing hydrogen.

Table 42. CAPEX and OPEX for process units for a 200 000 t/year SAF PtL plant.

Element	CAPEX [million USD]	OPEX [million USD/year]
Electrolyzer	1 382	27.6[a]
Fuel synthesis	672	16.8
H_2 storage [24 hrs]	259	2.6
CO_2 storage [24 hrs]	4	0.1
Total	2 316	47.1

[a] *electricity, water, CO_2 supply costs not included.*

Operating expenditures for the plant are presented in Table 42. By comparison, Table 43 highlights the portion of OPEX associated with externally purchased inputs, providing an overview of the recurring costs required for plant operation. The overall costs are highly dependent on the price of individual components; however, it is evident that electricity and CO_2 supply represent the most significant cost drivers. Especially, CO_2 supply is characterized by considerable variability, which further influences the economic performance of the system.

It should be noted that operating a PtL facility requires the installation of new renewable power generation capacity as well as a DAC system. Depending on the chosen strategy, these components could either be built and operated by KPC or by third-party.

Table 43. Input cost per year for a 200 000 t/year SAF PtL plant.

Feedstock	Cost per year [million USD]
Electricity at 60 USD/MWh	317
CO_2 supply at 100-400 USD/year	79-316
Water at 3.2 USD/t	3.7

Table 44. Additional CAPEX for DAC and renewable energy required to operate a 200 000 t/year SAF PtL plant.

Outside refinery unit CAPEX	Low range[a] [million USD]	High range[a] [million USD]
DAC	205	730
Option: Hybrid photovoltaic (850 MWp) + wind (850 kW) power generator	1 460	4 500
Option: Geothermal (730 MW)	1 365	3 685

[a] Based on Table 39 and Table 40

In any case, the required capital must be raised, and such funds should be regarded as essential investments to enable the implementation of PtL.

Based on the capacity factor outlined in Table 39 and the assumptions reported in Fasihi, Bogdanov and Breyer, 2016b, a rough estimate can be made. Considering the refinery-related investment of USD 2 316 million, the additional capital requirement for renewable power and DAC is expected to range between USD 1 570 million and USD 5 230 million, depending on the selected technology pathway and associated costs of the technology (Table 44). This implies that establishing a PtL plant with a SAF production capacity of 200 000 t/year would likely require a total investment exceeding USD 4 billion.

Item	Base scenario
Electricity	60 $/MWh
CO2 supply	400 $/t
Electrolyser system costs	2 625 $/kW
CAPEX (electrolyser+FT)	$ 2.3 billion
Operational hours	8 000 h/y
WACC	11.91%
Selling price Naphtha	1 200 $/t

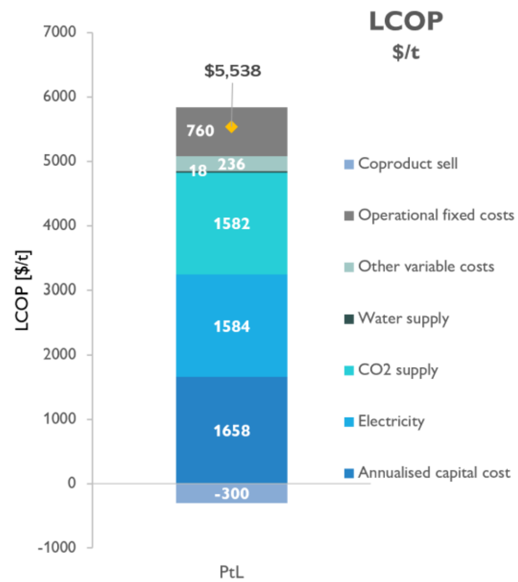


Figure 39. Levelized cost of production of SAF for PtL using direct air capture.

<u>LCOP cost structure: base case assumptions</u>

In this section, the key cost drivers influencing the Levelized Cost of Production (LCOP) are examined (Figure 39). The analysis is based on a reference scenario in which CO_2 is captured from ambient air and electricity is sourced at a price of 60 USD/MWh. For comparability, the weighted average cost of capital (WACC) applied is the same as that used in the HEFA project. Bio-naphtha is assumed to be sold at 1 200 USD/t.

Within this configuration, the estimated CAPEX amounts to USD 2 316 million, while the working capital is approximately USD 113 million. Accordingly, the total investment requirement is USD 2 429 million.

The LCOP for SAF in the base case is estimated at 5 538 USD/t. In this case scenario, electricity price, CO_2 supply cost, and CAPEX exert comparable levels of influence, together constituting the dominant cost drivers. Variations in these parameters therefore have the greatest potential impact on the overall economic viability of the PtL pathway.

<u>Parameter variation analysis and influence on LCOP</u>

To assess the sensitivity of the LCOP to different parameters, each parameter was systematically varied, and the corresponding results are presented in Figure 40.

Item	Base scenario
Electricity	60 $/MWh
CO2 supply	400 $/t
Electrolyser system CAPEX	2 625 $/kW
CAPEX (electrolyser + FT)	$ 2.3 billion
Operation hours	8 000 h/y
WACC	11.91%
Selling price Naphtha	1 200 $/t

SAF 5538 $/t

Parameter variation analysis

Electricity price [$/MWh]	20	40	**60**	80
SAF LCOP [$/t]	4481	5010	5538	6066

CO2 supply [$/$t_{CO2}$]	25	100	250	**400**
SAF LCOP [$/t]	4055	4351	4945	5538

Electrolyser CAPEX [$/kW]	1300	1800	2200	**2625**
SAF LCOP [$/t]	4742	5042	5282	5538

CAPEX [B$]	1.8	**2.3**	2.8
SAF LCOP [$/t]	5000	5538	6041

Operation hour [h/y]	7000	**8000**
SAF LCOP [$/t]	6113	5538

WACC	8.0%	10.0%	**11.9%**	13.6%
SAF LCOP [$/t]	5129	5332	5538	5729

Selling price naphtha [$/t]	600	**1200**
SAF LCOP [$/t]	5687	5538

Figure 40. Parameter variation analysis on LCOP price for PtL SAF.

With respect to electricity price, the base case assumes a cost of 60 USD/MWh, which results in a SAF price of 5 538 USD/t; however, this value could increase if tariffs or grid usage fees are applied. For instance, at 80 USD/MWh, the LCOP rises to more than 6 000 USD/t. While the current cost of electricity in Kenya is approximately 60-70 USD/MWh (Ministry of Energy and Petroleum, 2023), general trends suggest that power prices are likely to decline in the long term. To capture this possibility, additional scenarios were evaluated at 40 USD/MWh and 20 USD/MWh. Under these conditions, and assuming no other parameters are modified, the LCOP decreases to as low as 4 481 USD/t.

The cost of CO_2 supply is subject to significant variability and uncertainty. For concentrated flue gas from point sources, costs are typically reported in the range of 25–200 USD/t, whereas direct air capture (DAC) is considerably more expensive. In the base scenario, a CO_2 supply cost of 400 USD/t_{CO2} was assumed for direct air capture. Under more optimistic future assumptions, the cost for point sources could decrease to as low as 25 USD/t_{CO2}, which would correspondingly reduce the LCOP of SAF to approximately 4 055 USD/t. An analysis of potential CO_2 point sources in the vicinity of Mombasa should be conducted.

As noted earlier, the electrolyzer system cost assumed in this study is relatively high, as it is intended to encompass all necessary installations required and costs for a fully operating system. However, electrolyzer CAPEX costs are expected to decrease in the future; therefore, scenarios with lower electrolyzer-system CAPEX values were also assessed. For an installed electrolyzer-system CAPEX of 1 300 USD/kW, the LCOP of SAF could decline to approximately 4 742 USD/t.

The total CAPEX is also subject to considerable uncertainty at this stage. To assess its impact, a sensitivity analysis was performed by varying the investment by ±500 million USD. The results indicate that such a variation in CAPEX translates into an approximate change of ±500 USD/t in the LCOP.

For renewable energy resources, reduced annual operating hours may necessitate oversizing the PtL plant to maintain the same SAF output. For instance, decreasing the operating time from 8 000 to 7 000 hours per year increases the LCOP from 5 338 USD/t to 6 113 USD/t.

For the WACC, assumptions consistent with the HEFA case are applied. In an optimistic scenario with concessional financing, a WACC of 8% is assumed, resulting in an LCOP of 5 129 USD/t. Conversely, in a high-cost scenario with a debt cost of 12.5% (corresponding to a WACC of 13.6%), the LCOP increases to the upper bound of 5 729 USD/t.

The sale of co-products such as e-naphtha has only a minor effect on the LCOP. For instance, varying the naphtha price by 600 USD/t results in a change of approximately ±150 USD/t in the LCOP. Even if naphtha is purchased at a premium price, for example 1 200 USD/t, the impact on cost reduction remains moderate.

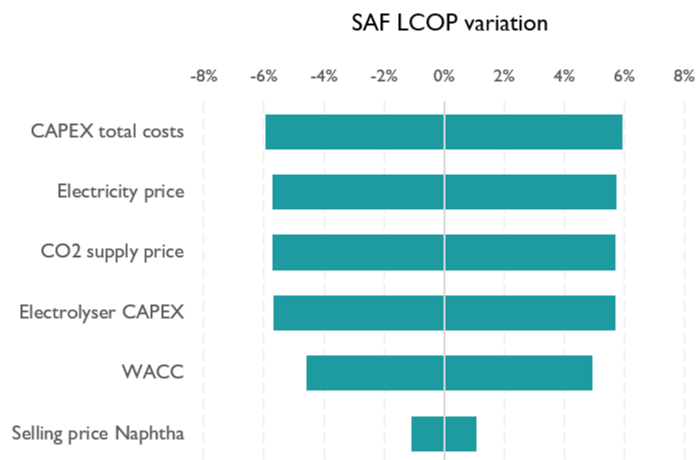


Figure 41. Sensitivity analysis of the PtL case (effect of ±20% variation of key variables on LCOP).

As shown, the LCOP of PtL SAF is considerably higher than that of HEFA. In this study, the average LCOP is estimated at approximately 5 500 USD/t, compared with HEFA SAF prices that typically remain below 2 000 USD/t. Achieving cost levels comparable to HEFA would require the simultaneous fulfilment of several favourable conditions. For example, assuming a CAPEX of USD 1.8 billion with a WACC of 8%, an electricity price of 20 USD/MWh, a CO_2 cost of 25 USD/t, 8 000 operating hours per year, and a naphtha selling price of 1 200 USD/t, the resulting LCOP would decline to 2 312 USD/t. However, these assumptions do not reflect the current state of the art and are unlikely to be realized in the short term, though they may become feasible in the longer term with technological advancements and cost reductions.

Sensitivity analysis

In the base case scenario, a ±20% variation of key variables was analyzed (Figure 41). As previously noted, CAPEX (including electrolyzer CAPEX), electricity price, and CO_2 supply cost represent the main components influencing the LCOP, each exerting a comparable impact under this sensitivity analysis. The WACC also has a significant effect, whereas the contribution of co-product revenues remains marginal.

Economic and environmental indicators: MSP, CO_2 savings, and abatement costs

At present, there is no commercial-scale plants are in operation, therefore no market reference for PtL SAF, making it difficult to estimate the price that the market would be willing to pay. For this reason, a hurdle rate (expressed as project IRR) is applied to assess the variation in price under different margin assumptions. It should be emphasized that the baseline WACC of 11.9% already accounts for investors requiring a minimum equity return of 25%.

In the base scenario, this corresponds to a minimum selling price of 5 900 USD/t at a WACC of 11.9%. When applying a hurdle rate of 15%, the SAF price increases to 6 428 USD/t, while at a 20% hurdle rate it reaches 7 400 USD/t (Table 45).

Table 45. Overview of MSP in dependence of hurdle rates.

	WACC 11.9%	Project IRR 15%	Project IRR 20%
SAF MSP [USD/t]	5900	6428	7400

When accounting for GHG emissions, the overall impact depends primarily on the electricity source. For estimation purposes, a configuration consisting of 850 MW photovoltaic and 850 MW wind capacity results in an emission intensity of approximately 10 g_{CO_2}/MJ of SAF, corresponding to an 89% GHG reduction. Alternatively, a configuration with 730 MW of geothermal capacity yields an emission intensity of around 18 g_{CO_2}/MJ, corresponding to an 80% reduction.

Based on these values, the abatement cost is estimated at 1 531 USD/t_{CO_2} for the 10 g_{CO_2}/MJ case, and 1 703 USD/t_{CO_2} for the 18 g_{CO_2}/MJ case. Assuming a minimum selling price of 5 900 USD/t of SAF, the resulting CO_2 abatement cost therefore falls within the range of 1 500–1 700 USD/t_{CO_2}. These values are significantly higher than those observed in the HEFA scenario, where the average abatement cost for the same WACC and for a feedstock mix range between 307 and 408 USD/t_{CO_2}.

4.3 SUMMARY

Kenya is a resource-rich country with significant renewable energy availability and potential. In this chapter, alternative pathways for the Mombasa refinery, beyond HEFA, have been assessed. Alcohol-to-Jet (AtJ) appears to be a promising option given the established sugarcane industry. However, as sugarcane production is concentrated near Kisumu, the option may be more viable if the processing facility were located closer to the feedstock source rather than transporting biomass or ethanol across the country. In addition, AtJ has a lower technology readiness level compared to HEFA and is therefore considered more suitable for medium- to long-term deployment.

Gasification of municipal solid waste (MSW) or biomass also presents potential opportunities, though the technology is still at a relatively low technology readiness level and therefore carries higher risk. Power-to-Liquids (PtL) is likewise an emerging pathway, and while it is not yet mature, Kenya has been increasingly highlighted as a promising location for PtL development, particularly in the context of national programs aimed at advancing green hydrogen.

Nevertheless, SAF production through PtL with direct air capture remains highly capital-intensive and costly. Current estimates indicate production costs of approximately 5 500 USD/t, compared to below 2 000 USD/t for the HEFA pathway. Moreover, PtL requires substantial investment: in addition to refinery-related CAPEX of 2.3 billion USD and 110 million USD in working capital, the installation of renewable power generation and DAC facilities would be necessary. In total, this could amount to an investment exceeding USD 4 billion for a

200 000 t/year SAF plant. By comparison, HEFA is estimated to require between USD 407 and 535 million in total investment costs.

Although PtL costs are expected to decline in the future, potentially enabling cost parity with HEFA in the longer term, this is unlikely to be achieved in the short term. An additional pathway worth consideration is Power-to-Methanol followed by methanol-to-jet conversion. This route is reported to yield SAF costs similar to PtL-FT (Eyberg *et al.*, 2024) while offering greater flexibility, as methanol can be produced in decentralized locations, transported to a central refinery for conversion, and also sold into alternative markets. However, this pathway is not yet ASTM-certified and remains at a lower TRL; it should therefore be regarded primarily as a long-term option.

In conclusion, while PtL holds promise as a long-term option, HEFA currently remains the more viable pathway for SAF production at the Mombasa refinery, if feedstock availability, cost, and sustainability criteria can be sufficiently addressed.

SECTION 5. PROJECT FINANCING AND RECOMMENDATIONS

During the course of this study KPC underwent a transformation process. KPC is a wholly government-owned entity, with 99.9% of its shares held by the National Treasury and 0.1% by the Ministry of Petroleum and Mining. However, on July 23, 2025, news emerged that President Ruto had set a September 2025 deadline for the company's listing on the Nairobi Securities Exchange (NSE) stock exchange (Ngigi, 2025a).

In the initial public offering (IPO), the company will raise capital from new investors and part of its shares are made available for trading on the exchange. The Privatization Commission needs to finalize the structure and the details of the IPO. The listing of KPC is the first privatization of a government entity since 2008.

The upcoming KPC listing is anticipated to generate strong investor interest due to its substantial asset base of KES 120 billion (USD 930 million) and solid profitability. For the financial year ending June 2024, the petroleum distributor posted a profit after tax of KES 6.86 billion (USD 53 million), up from KES 4.5 billion (USD 35 million) the previous year. KPC had a net book value of KES 83.3 billion (USD 640 million) with pipeline pumps and tanks being its prime assets valued at KES 58.2 billion (USD 450 million) in the period.

Government entities that have been partly privatized through listings include Kenya Commercial Bank in 1988, national air carrier Kenya Airways in 1996, power generating company Kengen in 2006, Kenya Re-Insurance Corporation and Safaricom.

While the government has indicated a requirement for public entities to list at least 20% of their equity on the NSE within a year of initial disclosure, it remains unclear the future financial structure of KPC and whether the government will retain only 35% stake post-listing as announced in the disclosure to the Parliament (Hinda, 2025b). In summary, while the government will divest part of its ownership in KPC through the upcoming IPO, the precise shareholding structure after the listing has yet to be specified. This move is part of the government's broader strategy to privatize state-owned enterprises and attract private investment to boost economic growth.

The decision on whether the government retains 35% ownership or another percentage will impact the company's funding options, as ownership structure plays a key role in determining investor interest and the suitability of different financing models. In the following sections, we will explore various possibilities in terms of sponsors and financing options; however, not all of them may be accessible or applicable in practice, depending on the future KPC legal form.

5.1 PROJECT SPONSORS

5.1.1 Types of project sponsors

In project finance, sponsors are the key stakeholders who initiate, invest in, and take responsibility for the successful execution of a project. They can be individuals, companies, or public institutions, and their role is to provide capital, expertise, and credibility to the project.

Project sponsors usually play key roles, including:

- Provide equity investment (capital at risk)
- Set up the Special Purpose Vehicle (SPV) to develop and manage the project
- Oversee project development, approvals, and financing
- May offer guarantees or be involved in operations or supply agreements
- Share in profits/losses and sometimes participate in management

When engaging in a project finance venture, each sponsor typically has a specific goal, which varies depending on the type of sponsor. Generally, there are four common categories of sponsors involved:

- **Industrial sponsors**: These are companies that view the project as directly connected to their core operations, whether upstream or downstream in the supply chain.
- **Public sponsors**: These include central or local governments, municipalities, or state-owned entities, and their motivation is usually tied to achieving social welfare objectives.
- **Contractor/ sponsors**: These are entities involved in the development, construction, or operation of the project. They often invest equity or provide subordinated debt to support the initiative.
- **Financial investors**: These are private equity firms, banks, or other institutional investors that contribute capital with the expectation of financial returns.

Until the mid-2000s, most project finance structures were dominated by industrial developers, who owned the Special Purpose Vehicles (SPVs) used to implement projects. However, since then, the financing landscape has evolved. Financial investors have emerged as a key group of funders for infrastructure projects. Today, it is common for SPVs to be established through a partnership between industrial sponsors, who bring technical expertise, and financial sponsors, who contribute the majority of the equity needed to support project development and implementation (Gatti, 2024).

5.1.2 Corporate financing versus project financing

When financing a new project, sponsors typically choose between two main approaches (Gatti, 2024):

1. Corporate Financing – The project is funded directly through the company's existing balance sheet.
2. Project Financing – A new entity, known as a Special Purpose Vehicle (SPV), is created specifically for the project and is financed off the sponsor's balance sheet.

In the first option (corporate financing), the sponsor relies on the company's total assets and cash flows to secure additional credit from lenders. If the project fails, the company's remaining assets and income streams can still be used to repay both existing and new creditors, since the project and company are financially linked.

Alternatively, project financing means that the new project is kept entirely separate from the sponsoring company. If the project fails, creditors typically have no (or only limited) claim on the sponsor's other assets and cash flows. This separation allows the parent company's shareholders to protect their other investments through the creation of a SPV.

However, a key disadvantage of this approach is the higher cost. Structuring and setting up a project finance deal is generally more expensive than corporate financing. Available data indicates that transaction costs can amount to 5%–10% of the total investment. This is due to several factors, including:

- The need for extensive involvement from legal, technical, and insurance experts, as well as loan arrangers, to assess the project and draft detailed contracts.
- High costs associated with ongoing project monitoring.
- Lenders take higher risk and the due diligence to be more complex, requiring more money and time.

Despite these higher costs, project finance offers significant advantages over corporate finance:
- It enables a greater distribution of risk among all parties involved, which can result in a higher debt-to-equity ratio and improve the sponsor's return on equity (measured by internal rate of return, IRR).
- From an accounting perspective, contracts between the SPV and the sponsor can function like commercial guarantees, but they often do not appear on the sponsor's balance sheet or in financial disclosures.
- Unlike corporate financing, which may rely on the sponsor's personal assets for loan guarantees, project finance loans are backed only by the project's assets. This protects the sponsor's other assets and makes it easier to seek additional financing if needed.
- Establishing an SPV provides legal and financial separation, isolating sponsors from project-specific risks. When structured on a no-recourse or limited-recourse basis, sponsors are not liable for the project's failure, an important benefit not offered under corporate finance, where failure can impact the overall risk profile and cost of capital for the entire firm.

Nowadays, most projects related to SAF, particularly those involving first-of-a-kind plants, are typically structured through a SPV.

5.1.3 Ownership and operational models for the project

<u>Single entity</u>

In the context of project development, a "single entity" approach refers to a company undertaking the entire project independently, without involving external equity partners or forming joint ventures. When evaluating whether KPC should develop the SAF project independently, it is essential to consider both the benefits and challenges of this approach. The key advantages and disadvantages of pursuing a single-entity SPV model are highlighted below.

Advantages:
- **Full control**: KPC would retain complete decision-making authority over strategy, operations, technology, and profits.
- **All returns go to KPC:** If the SAF project is successful, all financial benefits (dividends, asset appreciation) remain with KPC.
- **Brand alignment:** KPC can ensure the SAF plant aligns with national or company sustainability goals and its strategic image.
- **Internal knowledge gain:** KPC builds in-house experience in SAF technology, operations, and project finance.

Disadvantages:
- **High capital burden**: KPC must raise the full USD 400-500 million, either through borrowing (which affects its debt profile) or equity.
- **Higher financial risk**: If the project underperforms or fails, KPC bears the full loss. In project finance, this risk is usually shared.

- **Limited risk sharing**: No private investor or co-sponsor to absorb part of the construction, market, or technology risks.
- **Lower leverage potential**: Lenders may require stronger guarantees or reduce available financing.
- **Complexity of SAF**: Having technology or industrial partners would reduce risk.
- **Opportunity cost**: Tying up large internal capital may prevent KPC from investing in other strategic or core infrastructure.

There are several examples of companies developing SAF projects as single entities, particularly when they possess the necessary capital, expertise, and strategic alignment. These are usually refineries with high annual net profit, that are developing a renewable strategy, but they can also be emerging companies.

Public-Private Partnership (PPP)

A Public-Private Partnership (PPP) is a collaborative agreement between a public body (such as a government agency) and one or more private firms, where the parties share both risks and rewards through the joint delivery of public infrastructure or services. A PPP involves not only the design and construction of infrastructure but also its financing, maintenance, and in some cases, long-term management by the private sector, based on a binding contractual arrangement.

There are mainly two types of PPP (Gatti, 2024):

- **Institutional PPP**: in institutional PPPs, a SPV is created in which both public and private entities are shareholders. This form of partnership often implies shared ownership and governance of the project. The public partner can hold either a majority or minority stake, depending on the structure agreed upon. The joint participation in the SPV allows for aligned decision-making and long-term commitment from both sides.
- **Contractual PPPs**: they are based on formal agreements, typically concession contracts, where the public partner grants the private party the right to develop and operate a public asset for a specified period. In this model, there is no requirement for shared ownership, making it more common in projects like highways, airports, and utilities.

The Public Private Partnerships (PPP) Act of 2021 in Kenya defines various models for structuring PPP projects (Musalia, 2024). These models guide the roles of public and private sectors in developing and operating infrastructure. The main frameworks include:

- **Build-Operate-Transfer (BOT)**: The private partner is responsible for constructing and operating the project for a predetermined period, after which the asset is transferred back to the government.
- **Build-Own-Operate (BOO)**: The private entity designs, builds, owns, and operates the infrastructure indefinitely without transfer of ownership to the public sector.
- **Lease-Renovate-Operate-Transfer (LROT)**: The private partner leases an existing government facility, renovates it, operates it, and eventually returns it to the government.
- **Build-Lease-Transfer (BLT)**: Under this model, the private entity constructs the facility, leases it to the government for use, and then transfers ownership after the lease expires.
- **Design-Construct-Manage-Finance (DCMF)**: Commonly applied in complex infrastructure projects, this model involves the private sector designing, building, financing, and managing the facility.
- **Build-Own-Operate-Remove (BOOR)**: The private entity develops, owns, and operates the project, and is required to dismantle or remove the infrastructure at the end of the agreement.

PPPs are now a key component of Kenya's infrastructure development strategy, allowing the government to work with private sector players to finance, construct, and operate major projects without placing excessive strain on public resources (Musalia, 2024). The Kenyan government has increasingly turned to PPPs as a strategic tool for achieving infrastructure development without further inflating public debt. With the national debt nearing KES 11 trillion (as of March 2025), PPPs offer a practical alternative to traditional public financing by enabling large-scale projects to proceed without direct reliance on taxpayer funds or external borrowing.

Kenya has undertaken several major infrastructure projects through PPPs, demonstrating the model's potential in sectors such as transport and energy:

- **Nairobi Expressway**: A 27-kilometer toll road linking Jomo Kenyatta International Airport with Nairobi's Westlands area. The project was implemented through a PPP with China Road and Bridge Corporation.
- **Geothermal Power Plants**: Notably, the Menengai III Geothermal Power Station (35 MW), developed by Sosian Energy Limited, is part of Kenya's push for renewable energy through private sector collaboration.
- **Lamu Port-South Sudan-Ethiopia Transport (LAPSSET) Corridor**: This large-scale regional integration project includes construction of a new port in Lamu and related infrastructure to boost trade and connectivity across East Africa.

KPC, in the current form as a government-owned entity, can represent the public sector's interest by contributing existing infrastructure and seeking a private partner to finance, construct, and/or operate the new plant. However, this form of public-private collaboration may no longer be viable if KPC undergoes full privatization. Below we analyse the Advantages and Disadvantages of PPP for KPC.

Advantages

- **Risk sharing:** The extent of risk transfer depends on the specific structure and terms of the PPP agreement. Typically, construction, financing, and in some cases operational risks are transferred to the private sector.
- **Access to private capital and expertise:** It reduces the need for public borrowing or upfront budget allocation. Enables large infrastructure projects without straining public finances.
- **Faster implementation:** Private sector efficiency and experience may accelerate project delivery.
- **Focus on core activities:** KPC can concentrate on regulatory and oversight roles while the private partner handles day-to-day project execution.

Disadvantages:

- **Reduced control:** KPC may have limited influence over some aspects of design, operations, or pricing policies.
- **Higher long-term costs:** While initial public spending is lower, long-term payments (including private profit margins) can be higher than traditional procurement.
- **Profit sharing:** In most PPP structures, profits generated during the initial years are allocated primarily to the private partner to recover their investment and service debt obligations. Only after full repayment and, in some cases, transfer of the asset or service, does the government begin to realize financial returns.
- **Complex contractual arrangements:** PPP agreements can be legally and administratively complex, requiring significant negotiation and monitoring.

These pros and cons highlight the need for careful project structuring, due diligence, and balanced risk allocation to ensure mutual benefit in PPP arrangements.

Joint Venture (JV)

A Joint Venture (JV) is a business arrangement where two or more parties, usually companies, collaborate to undertake a specific project or business activity. Each party contributes resources, such as capital, expertise, or assets, and shares the risks, costs, profits, and control according to a pre-agreed structure.

Advantages:

- **Shared risk:** Costs and risks are distributed among the partners. No single party bears the full burden.
- **Access to new markets:** Local partners can help foreign companies enter new regions (e.g., new markets).
- **Combined strengths:** Partners bring complementary skills, assets, technology, or networks.
- **Flexibility:** Joint ventures can be limited to specific projects or timeframes, making them less permanent than mergers.
- **Resource pooling:** Sharing financial, technical, or human resources enables larger or more complex projects, as well as capacity building can be favoured by the knowledge of a partner.

Disadvantages:

- **Shared Control:** Decision-making can be slower or more complex due to differing interests or management styles.
- **Unequal commitment:** One partner may contribute more effort, capital, or risk than the other, leading to tension.
- **Cultural clashes:** Differences in corporate culture or national practices can affect collaboration.
- **Profit sharing:** Profits must be split, which may reduce each partner's return compared to going solo.

A joint venture is particularly beneficial in situations where the scale, complexity, or strategic nature of a project demands collaboration. It is often a good choice for large infrastructure or energy projects, where sharing capital investment and operational risk is essential. JVs are also ideal when a company is entering new or foreign markets, as local partners can offer regulatory knowledge, networks, and market access. Additionally, when a project requires specialized technical expertise or proprietary technology, forming a joint venture with a more experienced partner can enhance project success. Finally, JVs are well-suited for resource-intensive ventures that require pooling significant financial, technical, or operational resources that may be beyond the reach of a single entity.

Table 46. Main differences between PPP and JV structure.

Aspect	Public-Private Partnership (PPP)	Joint Venture (JV)
Nature of relationship	Contractual agreement to deliver public service or infrastructure on behalf of the government	Separate legal entity jointly owned by two or more parties for mutual benefit
Legal structure	Not a jointly owned entity; governed by a project agreement	New co-owned company (SPV) formed with shared governance
Ownership and control	Public entity retains ownership; private partner operates temporarily	Ownership and control are shared among partners
Objective	Deliver public infrastructure efficiently while reducing government spending	Achieve commercial objectives and share profits, risks, and expertise
Risk allocation	Risks allocated based on party best able to manage (e.g., construction, financial)	Risks and rewards typically shared based on equity stakes
Revenue model	Revenue from user fees or government payments (e.g., tolls, availability payments)	Revenue distributed according to equity and profit-sharing terms
Flexibility	More rigid due to predefined contractual terms and regulations	Greater flexibility in decision-making and operations

Joint venture arrangements are typically more attractive to private parties due to the shared risk and defined project scope than PPPs**.** This may be the only collaboration option if KPC is fully privatized.

As a summary, we highlight in Table 46 the main differences between Public-Private Partnerships (PPPs) and Joint Ventures (JVs). However, it is important to note that variations may arise depending on the specific terms and structure of the agreement established between the parties.

5.2 FINANCING THE PROJECT

Financing a large-scale infrastructure project presents a high level of complexity, both in structure and execution. Whether pursued through traditional bank lending or via the capital markets through a bond issuance, the scale of investment required demands the involvement of a broad base of financial participants.

Financing projects of this magnitude typically involves the engagement of specialized financial institutions that take on advisory and arranging roles. These institutions are responsible for designing a financing structure that addresses the specific risks and requirements of the project, with the ultimate goal of ensuring its bankability, which means attractive and acceptable to lenders and investors. Their tasks often include conducting financial due diligence, structuring debt and equity components, coordinating with potential financiers, and aligning the financial terms with the project's risk profile and cash flow projections. This structured approach is essential to secure funding from a broad base of stakeholders and to ensure the long-term viability of the investment. The following section outlines potential financing approaches, recognizing that further in-depth analysis and engagement with relevant stakeholders will be necessary to refine and validate the options.

It is advisable to structure the project with a high debt-to-equity ratio, such as 70:30 (or if allowed even higher), particularly in capital-intensive developments. As a reference point for financing, it is important to note that as of July 2025, the Central Bank Rate (CBR) in Kenya stands at 9.75% (CBK, 2025), while the yield on the reference 10-year Treasury bonds is 13.5% (World Government Bonds, 2025).

5.2.1 Loans and guarantees from international financial institutions and multilateral banks

A recent study offers an in-depth analysis of Africa's sovereign debt system, introducing the Africa Debt Database (ADD), the most detailed dataset to date on external borrowing by African governments (Trebesch, 2023)**.** Covering over 7 000 loans and bonds between 2000 and 2020, the study provides valuable insights into the structure, terms, and dynamics of Africa's debt landscape. The micro data also reveal a large variation in lending terms across countries, time, and creditors. In Kenya Sovereign external bonds have interest rates of 6-9%, Exim banks and private charge 2-9%, and multilateral organizations concessional loan just 1-3%.

If KPC retains a majority sovereign component, the debt financing could be channelled through the Government of Kenya, specifically via the National Treasury and Planning, by requesting a financing institution to provide the required debt. However, this approach also depends on national priorities, for instance, the extent to which the government views the aviation sector and general transport sector as a strategic priority compared to other critical areas (e.g., Food Security, Manufacturing, affordable Housing and Universal Healthcare).

Financing institutions may include multilateral, bilateral, or private lenders. A comprehensive list of such institutions that provided funding from 2000 to 2020 is available in Table 47 which indicates the sum and the interest rate range (Trebesch, 2023).

Key institutions to consider include the World Bank, the African Development Bank (AfDB), as well as various bilateral financing agencies. Additionally, regional institutions such as the European Bank for Reconstruction and Development (EBRD) started operations in Kenya in 2025.

The World Bank Group is the largest multilateral donor to Kenya, primarily through the International Development Association (IDA), International Bank for Reconstruction and Development (IBRD), International Finance Corporation (IFC), and the Multilateral Investment Guarantee Agency (MIGA). The World Bank provides a wide range of financing instruments to support development across the globe, including in Kenya, through its key institutions:

- **IDA (International Development Association):** Offers concessional loans and grants to the world's in-need countries, including Kenya, often used for infrastructure, health, and education projects.
- **IBRD (International Bank for Reconstruction and Development):** Provides non-concessional loans to middle-income countries or creditworthy low-income countries for large-scale development initiatives.
- **IFC (International Finance Corporation):** Supports the private sector by offering direct investments, loans at market rate, and advisory services, particularly in infrastructure, agribusiness, and financial markets.
- **MIGA (Multilateral Investment Guarantee Agency):** Offers political risk insurance and credit enhancement to attract foreign investment into developing countries by protecting against risks like expropriation or breach of contract.

According to the World Bank country classification, Kenya is eligible for financing from both IDA and IBRD (group A), allowing the country to access blended financing (a combination of concessional and non-concessional loans). However, both institutions provide funding exclusively to sovereign entities, such as national governments or government-guaranteed projects and KPC may be not any more eligible if fully privatized.

Both financing conditions are reported on the World Bank website:

1. IDA (World Bank, 2025c) development finance support is in the form of very long-term loans (35–40 years), with long grace periods (up to 40 years) and no interest payment, which is replaced by an annual commitment fee of 0.75%. It offers also guarantees.
2. IBRD (World Bank, 2025b) offers loans based on a floating reference rate (e.g., SOFR, EURIBOR, TONA, or SONIA) plus a fixed spread that increases with loan maturity. For USD loans, the spread ranges from SOFR + 0.74% for short maturities to SOFR + 1.44% for 18–20 years. Similar structures apply to EUR, JPY, and GBP, with adjusted spreads based on the respective benchmark rates. It offers also guarantees.

IFC focuses on promoting private sector growth in developing countries. It can finance fully local or joint ventures, JV with foreign entities or with public-sector partner without needing direct government involvement for the approval. IFC finances only profitable projects that comply with social, environmental, and economic guidelines. Its services include loans, equity investments, hedging solutions, and guarantees. Financing is provided at market conditions and without subsidies. IFC loans are usually for 7-12 years (IFC, 2025). Projects may benefit from IFC's reputation and standards, enhancing investor confidence and risk mitigation.

The African Development Bank (AfDB) is a regional multilateral development finance institution established to promote economic and social development across African countries. It provides funding through loans, grants, equity investments, and technical assistance for both public and private sector projects. AfDB supports infrastructure, energy, agriculture, water, education, and health initiatives, with a strong focus on inclusive and sustainable growth.

It also offers concessional financing through its African Development Fund (AfDF) for low-income countries. Lending rates are published in the website (African Development Bank, 2025) and updated every quarter. They are currency specific. For example, for USD dollar, the rate is 1.45% + 1% for administrative fee.

The European Bank for Reconstruction and Development (EBRD) is a multilateral development bank that supports projects aimed at building market-oriented economies. Originally focused on post-communist countries in Europe, it has since expanded to parts of Africa, Asia, and the Middle East. EBRD invests primarily in private sector projects through loans, equity investments, and guarantees, while also providing policy advice and technical assistance. Its priorities include promoting green energy, sustainable infrastructure, private enterprise, and good governance. In 2025, EBRD began operations in Kenya (EBRD, 22025), offering new financing opportunities for the region. Loans typically ranging from EUR 5 million to EUR 250 million and loan pricing is determined by market conditions and includes a base rate (like SOFR or EURIBOR) plus a margin reflecting project risk. Loan terms are flexible, generally between 1 and 15 years, and tailored to the project's needs and creditworthiness.

Other institutions, including bilateral agencies, can also be considered. It is worth noting that some major projects, such as the Mombasa–Nairobi Standard Gauge Railway, were financed by bilateral lenders like the China Eximbank (AIDDATA, 2025). An Export-Import (Ex-Im) Bank is a government-backed financial institution that supports and promotes the international trade of goods and services by providing export credit and investment guarantees. Its primary objective is to assist domestic companies in accessing foreign markets by offering financial products that reduce the risk of cross-border transactions.

Table 47. List of major sovereign loans in 2000-2020 (Trebesch, 2023).

Institution	Sum of loans [million USD]	Min-max interest rate
Bilateral (excl. China)	7 119	0%-5.4%
Artigiancassa	59	0% - 1.5%
Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung	199	0% - 0.8%
Directorate General for Co-operation and Development	147	0% - 0%
Export-Import Bank of Korea	329	0.1% - 1%
Export-Import Bank of the United States	7	0% - 0%
French Development Agency	2 193	0% - 4.4%
Japan Bank for International Co-operation	454	0% - 0.8%
Japanese International Co-operation Agency	2 754	0% - 1.2%
Kreditanstalt für Wiederaufbau	500	0% - 3.2%
MINEFI/NATEXIS	257	0% - 0%
Ministry of Economy and Business	44	0.3% - 1.1%
Ministry of Economy, Finance and Industry	108	0% - 0.7%

Institution	Sum of loans [million USD]	Min-max interest rate
Other	68	0% - 5.4%
Bilateral China	9 458	2% - 5.9%
China Development Bank (CDB)	723	3.7% - 5.9%
Export-Import Bank of China	8 735	2% - 3.9%
Multilateral	23 901	0% - 5.4%
AfDB Ordinary Capital	2 010	0.2% - 0.2%
AfDF	2 318	0.5% - 1.8%
Arab Bank for Economic Development in Africa	20	1% - 1%
Exogenous Shocks Facility	210	0% - 0%
Extended Credit Facility	763	0.3% - 0.3%
IBRD	500	-
IDA	12 826	0% - 2.8%
IFAD	309	0.8% - 0.8%
International Finance Corporation	510	-
Islamic Development Bank	45	-
OPEC Fund	224	1.5% - 5.4%
Poverty Reduction and Growth Facility	574	0.5% - 0.5%
Rapid Credit Facility	738	0% - 0%
Stand-By Arrangement-Standby Credit Facility	2 846	-
Other	8	-
Private	6 191	0% - 8.4%
Bondholders	6 100	5.9% - 8.3%
China Ministry of Commerce	24	0% - 0%
China Wuyi Co., Ltd.	14	-
Industrial and Commercial Bank of China (ICBC)	13	8.4% - 8.4%
Unspecified Chinese Government Institution	40	-
Grand total	**46 669**	

5.2.2 Commercial loans from local banks

There are more than 40 official banks in Kenya. To give an impression the Central Bank of Kenya (CBK) lending rate for KES is 15.44% as July 2025 (CBK, 2025). According to the most recent data published by the Central Bank of Kenya (CBK) covering other Kenyan banks (Hinda, 2025a), lending rates vary widely across the sector. The average lending rate across banks was 14.8%, with a median of 15.1%, spreading from minimum value of 10.4% to a maximum value of 16.4% (Hinda, 2025b). This spread reflects the prevailing cost of borrowing for businesses and individuals in the local market, and these values may differ from project financing.

Among them, KCB Bank, which is a Pan-African banking institution focused on green growth, has set a precedent as a critical player in resource mobilization guided by the ambition to invest 25% of the group loan portfolio in green initiatives by the end of this year 2025. Additionally, as an accredited entity of the Green Climate Fund (GCF) under category B, this means the bank can access between USD 50 million and USD 250 million per project that can be tapped to finance the refinery.

The cost of debt (Rd) is generally calculated as the sum of a base rate and a credit spread (European Commission, 2022).

$$Rd = \text{base rate} + \text{credit spread}$$

Where:

- **Rd** is the cost of debt
- **Base rate**, e.g., central bank rate (9.75% in July 2025) or SOFR for USD currency
- **Credit spread** is the risk premium added on top of a base rate. Several factors influence the determination of a credit spread, including the creditworthiness of the borrower, loan/project size and term, country risk, type of project, collateral and guarantees, and market conditions.

A few banks can offer loans in USD, which may be a suitable option for KPC since usually the interest rate is usually lower and given that KPC revenues are primarily in U.S. dollars. However, caution is needed when dealing with local obligations or expenses in Kenyan Shillings (KES), as currency risk may arise. In such cases, currency hedging, often structured as financial insurance, can help mitigate the risk of exchange rate fluctuations by stabilizing repayment costs over time.

5.2.3 Capital market: project bonds

Kenya's Sovereign Green Bond Framework (The National Treasury and Planning, 2021), developed by the National Treasury and Planning, serves as a strategic tool to mobilize capital for environmentally sustainable projects, in line with the country's Vision 2030 and commitments under the Paris Agreement (Green Bonds Programme Kenya, 2017, 2025). These green bonds are intended to finance or refinance projects in key sectors such as renewable energy, energy efficiency, clean transportation, sustainable water and waste management, and natural resource conservation (APRI, 2024). The framework includes a strong governance structure, with a dedicated committee for project selection, strict tracking of proceeds, and regular public reporting on both fund allocation and environmental impact. For example, green bonds often come with incentives, such as tax exemptions for investors, which enhance their attractiveness and allow them to be issued at lower interest rates compared to conventional bonds. One example is the inaugural green bond issuance for student housing project by Acorn Holdings, which raised KES 4.3 billion (approximately USD 41.45 million) with a coupon of 12.25% (Miriri, 2019; NSE, 2025b). Depending on the circumstances, green bond may be issued also at a lower interest rate.

The green bond market in Kenya is still at an early stage of development. Another key financing instrument is the infrastructure bond, which has seen a range of issuances. These bonds typically offer coupon rates lower to the market average, e.g., 12.5% and 12.96% (tax-exempt) (Ntongai, 2025), providing attractive returns for investors while supporting large-scale public projects. A recent infrastructure bond was issued by the Government of Kenya to support the development of the Talanta Sports City Stadium in Nairobi. Launched in July 2025, the bond is listed in NSE and raised KES 44.79 billion (approximately USD 347.5 million) and has a 15-year maturity (Ngigi, 2025b). It offers investors an internal rate of return (IRR) of 15.04% per annum, and benefits from a suite of tax exemptions, making it an attractive investment vehicle. Usually, infrastructure bonds are allocated for road and highway construction and maintenance, energy generation and distribution projects, water supply and sanitation systems, public transportation infrastructure and educational and healthcare facilities.

Corporate bonds in Kenya are debt instruments issued by private companies or state-owned enterprises to raise capital from investors, typically through the Nairobi Securities Exchange (NSE). These bonds allow firms to access long-term funding for expansion, refinancing, or project development, without diluting ownership through equity. Some corporate bonds in Kenya have offered coupon rates ranging between 12% and 13.75%, though many of these issuances have had tenors of less than 7 years (NSE, 2025a).

Eurobonds in Kenya are mainly sovereign bonds issued by the Government of Kenya in international markets, typically denominated in USD. These instruments are primarily used to raise capital for budgetary support and debt refinancing (Kenya Eurobonds coupon 6.3-9.75%), rather than for funding specific infrastructure projects (The National Treasury and Economic Planning, 2023; The National Treasury and Economic Planning, 2024b).

A Eurobond makes sense for a project when it requires large-scale funding in foreign currency and generates revenue in U.S. dollars, reducing exchange rate risk. It is suitable for export-oriented ventures, infrastructure with international users, or sectors like aviation and energy. One advantage is that it provides access to international capital markets. However, while issuing debt in a foreign currency can be advantageous, it also exposes the issuer to currency risk (e.g., if the issuer's local currency depreciates against the bond's currency, the cost of servicing the debt can increase significantly). Eurobonds could be a feasible option for KPC, as its core operations are primarily conducted in USD and part of the SAF may be exported.

5.2.4 Equity

Equity financing refers to the capital invested in a project or company in exchange for ownership shares, typically contributed by project sponsors, private investors, or strategic partners. In the context of large-scale infrastructure or energy projects, this equity is often critical to unlocking additional debt financing and ensuring risk-sharing among stakeholders. A commonly applied rule of thumb is to target a 30:70 equity-to-debt ratio. This structure is generally seen as a balanced approach to ensure investor commitment while maximizing leverage. Usually, majority of the equity is provided by the sponsor(s), which can be KPC as single entity or with one or more partners.

Equity can be provided also in form of assets (e.g., KPC existing infrastructure for the project) or it can be raised through IPO (Initial Public Offering), as in the current case of KPC.

Institutions such as the International Finance Corporation (IFC) and the European Bank for Reconstruction and Development (EBRD) not only provide debt but can also act as equity investors, taking minority stakes in projects, they consider commercially viable and developmentally impactful. Their involvement brings not only capital but also credibility, environmental and governance standards, and support in attracting co-investors. Equity investors typically take on higher risk but also expect higher returns, and their participation is key in capital-intensive, long-horizon ventures such as sustainable fuels, renewable energy, or logistics infrastructure.

The cost of equity can be indicatively calculated by some guidelines (European Commission, 2022), using the formula:

$$Re = Rf + (\beta \cdot ERP) + IP$$

Where:

- **Rf** is the risk-free rate
- **β** is the beta of the project (measures project risk relative to the market)
- **ERP** is the equity risk premium (compensation for market risk)

- **IP** is the innovation premium (optional, reflects added risk from novel technologies or models)

For Kenya, the cost of equity can be estimated as follows:

- **Rf:** 13.5% (based on the Kenya 10-year government bond yield)
- **β:** 1.0 (typical value for the chemical industry)
- **ERP:** 6.55% to 14.11% (Damodaran, 2024) (value without and with country risk premium)
- **IP:** 0% (assumed for this case, since HEFA plant are already at TRL 9)

This results in a range from 20 to 28%. However, local investors are generally attracted to projects with an equity internal rate of return (IRR) exceeding 20%, typically in the range of 22.5% to 25%. Depending on the sector also lower equity rate can be found. For example for the geothermal sector equity IRR between 15% and 23% are expected (Micale, Trabacchi and Boni, 2015).

5.2.5 Grants

Securing a grant as part of KPC's financing strategy could offer several key advantages. One of the most significant benefits is that grants are non-repayable, meaning they do not add to the company's debt burden or affect its cash flow in the way loans do. This helps reduce the overall financial risk of the project and can make it more attractive to other investors or lenders. In fact, having grant funding in place can improve KPC's credit profile and serve as a form of leverage to unlock additional financing, whether through debt or equity.

Many grant providers, especially international donors and development agencies, prioritize projects that deliver broad social, economic, or environmental benefits. In addition to funding, some grants come with technical assistance, capacity building, or advisory services that can enhance the quality and execution of the project. KPC can research them in the regional and international context and proof its eligibility for example for the World Bank's International Development Association (IDA), the African Development Fund (ADF), or the European Union's development instruments. Usually, grants can finance only small percentages of the project.

5.2.6 Overview of financial possibilities and indicative interest rates

Table 48 provides a summary of the various financing options analyzed, along with indicative interest rates. It is important to note that these rates can vary significantly, as they depend on several project-specific risk factors, such as the choice of partners, total investment size, loan maturity, and other conditions. Final rates are typically subject to change during negotiations with the financing institutions.

It is essential to define a well-structured financing strategy for this type of project, likely considering a combination of financing sources. Financial support, guidance, and connectivity can be provided by a variety of organizations and entities. The Finvest Hub (ICAO, 2025d), launched by the International Civil Aviation Organization (ICAO) in collaboration with the International Renewable Energy Agency (IRENA) through the Finvest@ETAF initiative, serves as a strategic mechanism to mobilize financing for low-carbon aviation projects, particularly those focused on Sustainable Aviation Fuel (SAF). Rather than acting as a direct source of capital through loans or equity, Finvest functions as an investment facilitation platform, linking eligible projects with a global network of public and private financiers, including development banks, institutional investors, and climate funds. Through its partnership with IRENA's Energy Transition Accelerator Financing (ETAF) platform, Finvest enhances project investment readiness by supporting technical, financial, and sustainability assessments; strengthening due diligence processes; and assisting developers in identifying appropriate funding mechanisms such as equity participation, concessional and commercial loans, blended finance, and grant-based support. The initiative also contributes to de-risking SAF and renewable energy projects, particularly in emerging economies, by aligning them with recognized sustainability standards, promoting transparent evaluation, and providing capacity-building for project proponents and policymakers. By fostering stronger collaboration among governments, financial institutions, and the private sector, Finvest improves the visibility, credibility, and bankability of SAF initiatives, facilitating access to capital and accelerating investment flows. Overall, Finvest represents a catalytic enabler within the global aviation finance ecosystem, supporting the large-scale deployment of sustainable aviation fuels and other clean energy technologies necessary to achieve the sector's long-term decarbonization goals.

Table 48. Overview of potential interest rates for projects in Kenya

Source of financing	Estimated interest rate
Concessional loan	0-3%
Blended concessional and non-concessional loans	2-6%
DFI commercial loan or international banks	5-10%
Local Commercial bank loan in KES	10-16%
Project green bond	10-15%
Eurobond (USD)	7-10%
Equity	20-28%
Grant	No repayment, no interest

5.3 RECOMMENDATIONS AND NEXT STEPS

Given the large scale of a HEFA project and its estimated cost of USD 407–535 million, it will be crucial to define the financing structure and partnership framework at an early stage to ensure successful implementation. The easiest solution would be to identify financial partners to help de-risk the investment. Engaging external investors offers both advantages and disadvantages, particularly for a capital-intensive undertaking of this nature.

The most suitable approach would be to establish a Special Purpose Vehicle (SPV), regardless of whether KPC proceeds independently or chooses to bring a strategic investor on board. This approach is especially important because, in the event of project failure, the financial implications could directly impact KPC's balance sheet. Furthermore, partnering with one or more credible and experienced entities in the SAF market could enhance investor confidence and potentially lead to more favourable interest rates when securing project financing.

Ideally, the selected partner(s) should bring technical expertise and have a proven track record of successfully executing similar projects. This would significantly reduce the technology and operational risks and improve the likelihood of project success, as well as the time to market. KPC should also clearly define its strategic interests in the jet fuel market and renewable diesel production. If the project includes an export component, it would be beneficial to partner with an entity familiar with international and foreign fuel markets, preferably one with existing customers or established distribution networks in target regions.

Additionally, large agri-hubs could serve as valuable partners in the project, particularly by supplying feedstock at more stable and predictable prices. Integrating feedstock suppliers within the ownership or set solid supply contracts structure would help reduce price volatility. The first arrangement would represent a case where the feedstock supply chain is internalized within the consortium, further enhancing project stability. Furthermore, airlines could be considered as minority investors, as they have a vested interest in securing SAF supplies. Long-term offtake agreements with airlines will be essential to secure finance and make the project bankable.

If KPC has strong internal financial capacity or can access concessional financing, the company may be able to undertake the project alone. However, the overall investment required for the project is substantial and may represent a significant financial commitment relative to the company's scale. Proceeding without partners may carry more risks, especially for a project outside the KPC core business. KPRL has knowledge about refinery, but biofuels have usually different challenges and different markets, and this may expose KPC to higher technical, operational, and market risks. Therefore, partnering with expert players in the SAF market would have advantages.

As a next step, KPC should define or further refine the project scope and market positioning and decide whether to pursue the initiative independently or in partnership with other entities. If a partnership approach is chosen, KPC should identify and engage potential partners to jointly define the collaboration framework and project organizational structure.

In parallel, it will be important to advance the project's technical and engineering details, and to explore financing opportunities. Additionally, KPC should begin identifying potential offtakers, with the aim of securing long-term offtake agreements to enhance project bankability and reduce market risk. One of the biggest challenges, and arguably the most critical, is securing a reliable supply of vegetable oils/UCO at a competitive price. KPC should assess early as next step the availability of feedstock within Kenya, as well as potential import options from neighbouring countries such as Tanzania, Uganda, Somalia and Ethiopia. This assessment should ensure that the feedstock is not only available, but also compliant with sustainability standards required by the target SAF markets and priced at a level that allows for viable profit margins.

In terms of financing, KPC should aim to maximize the debt portion. Given the scale of the project, a well-structured financing plan will be essential, likely involving a combination of multiple financing instruments to support its successful implementation. If possible, securing concessional loans and grants would be advantageous. Additionally, diversifying the financing structure could help manage risk and improve the terms. Since the company's operating currency will be in KES/USD, it may be beneficial to consider loans denominated in USD by DFIs or issuing Eurobonds, which may offer lower interest rates. Exploring the possibility of green bonds could also be worthwhile, particularly if the project has environmentally sustainable components. It is important to recognize that elevated WACC values can significantly undermine project viability, as excessively high financing costs may render an otherwise technically feasible project economically uncompetitive. Therefore, it is recommended to contact agencies that can support financial structuring and facilitate connections with financiers, such as ICAO's Finvest.

Understanding KPC's legal structure in the coming months will be crucial, as it will significantly influence the types of funding the company can access.

SECTION 6. EVALUATION OF THE PROJECT

6.1 SCENARIO EVALUATION AND INDENTIFICATION OF THE BEST BUSINESS CASE

This study examines three principal scenarios for SAF production. Two scenarios are based on the HEFA pathway: one with lower investment requirements and another one with higher CAPEX. As a benchmark, a third scenario considers the PtL pathway with direct air capture.

It is important to note that the results presented in this study are based on our best available knowledge, combining assumptions derived from public domain sources with information that stakeholders were able to share. Consequently, the outcomes are valid within the scope of the assumptions defined in this analysis. Any deviation from these assumptions in real-world conditions would naturally affect the assessment presented here. Such limitations are inherent to analyses conducted at this preliminary stage of project development. Therefore, the data and assumptions applied in this study should be revisited and progressively refined as the project advances, to improve the accuracy and robustness of the evaluation.

When comparing the three scenarios for SAF production, the HEFA pathways (Scenarios I and II) emerge as the most favourable options under current conditions (Figure 42). A key advantage lies in the substantially lower total investment required: while HEFA plants necessitate capital expenditures of 407–530 million USD, the PtL pathway (Scenario III) requires investments on the order of 2 400 million USD, in addition to renewable power and direct air capture (DAC) installation cost. This considerable difference highlights that HEFA entails significantly reduced financing risks, rendering it more attractive for near-term deployment. Furthermore, the minimum selling price of SAF produced via HEFA remains below 2 000 USD/t for the conditions analysed (1 664–1 823 USD/t in Scenario I and 1 825–1 994 USD/t in Scenario II). In contrast, PtL SAF reaches approximately 5 900 USD/t, which at the moment is not competitive outside of specific policy requirements.

	HEFA		PtL
	Scenario I	Scenario II	Scenario III
Total Investment	407 M$	535 M$	~ 2400 M$ + renewable power and DAC installation required
SAF Minimum selling price	1664-1825 $/t	1823-1994 $/t	~5900 $/t
CO2 abatement costs	307-356 $/t	356-408 $/t	1500-1700 $/t

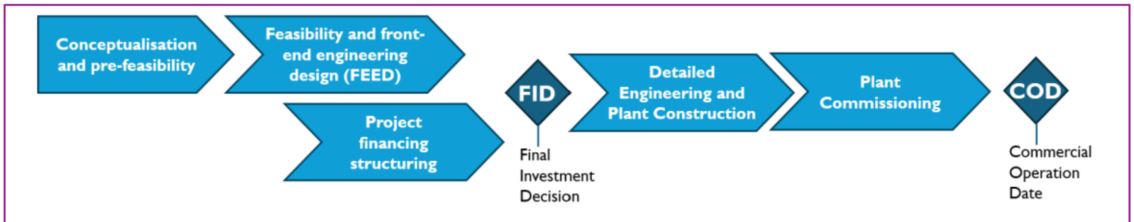
Figure 42. Overview of the scenarios analyzed in this study for SAF production under 11.9% WACC. M$ means millions of USD.

As comparison, ICAO "rules of thumb" (ICAO, 2025g) reports a MSP of 0.8–1.0 USD/L for a 1-billion-litre-per-year HEFA facility and a MSP of 4.4 USD/L for PtL of the same dimension using DAC. In this study, the calculated MSPs are higher, primarily due to different assumptions regarding feedstock prices and capital expenditures (CAPEX), but the relative cost trends between HEFA and PtL technologies remain consistent. It is important to note that feedstock prices can vary significantly depending on the region and time period and can even increase sharply due to supply/demand dynamics (e.g., as observed from average vegetable oil prices between 2009 and 2022 in Table 5G in (NREL *et al.*, 2024)). Therefore, we recommend treating such models and benchmarks as initial feasibility indicators only. For a more robust and reliable assessment, it is advisable to engage directly with feedstock suppliers, technology providers, and engineering companies, ideally under a non-disclosure agreement (NDA), to refine assumptions using the latest market data and technical inputs.

In terms of environmental performance, HEFA also demonstrates superior cost efficiency in carbon abatement. The CO_2 abatement costs for HEFA range between 278–375 USD/t, depending on the scenario, while PtL shows markedly higher values of 1 500–1 700 USD/t. This further emphasizes that HEFA offers a more efficient pathway for achieving climate mitigation objectives at present. Taken together, these factors suggest that, under current techno-economic conditions, HEFA represents the most viable and scalable route for SAF production, balancing financial feasibility with effective CO_2 emissions reduction. The analysis further suggests that the SAF price achieved is aligned with market competitiveness.

6.2 PROJECT TIMELINE AND NEXT STEPS

The present study represents an initial scoping and conceptual assessment, providing a preliminary evaluation of the technical and economic feasibility of SAF production in Kenya. While this work establishes a foundation and identifies promising scenarios, several additional stages must be undertaken before a facility can reach the commissioning and operational phase. As illustrated in Figure 43, the project lifecycle of a greenfield SAF facility typically spans multiple phases, each requiring significant investment, stakeholder engagement, and regulatory approvals.



	1. Conceptualisation and pre-feasibility	2. Feasibility and front-end enginerring design (FEED)	3. Project financing structuring	4. Plant construction	5. Plant Commissioning
Activities	Initial engineering cost estimation, market analysis, concept development	Comprehensive analysis of the project's technical, financial, environmental and social aspects	Structure of commercial and financing terms and conditions. Financing secured through investor and lender commitments.	Final engineering study and construction of the plant	Commisioning of the plant
Duration	6-12 months	12-18 months	12-18 months	24-36 months	6-12 months
Costs*	0.5-2 M$	10-15 M$, up to 100 M$	15-30 M$	Size and design dependent. e.g HEFA 400-500 M$	Included in Construction budget
CAPEX estimation accuracy	AACE Class V	AACE Class IV: Feasibility AACE Class III: FEED	-	AACE Class II/I Detailed Engineering	-

Figure 43. Overview of the project phases for the construction of a HEFA plant. Costs from (WEF, 2025).

The project phases from initial concept to full commercial operation are (WEF, 2025):

1. **Conceptualization and pre-feasibility (6–12 months)**
   This first stage involves early identification of opportunities, preliminary market and feedstock assessments, and alignment with strategic objectives. The current study falls within this phase, serving as a scoping exercise.
2. **Feasibility and Front-End Engineering Design (FEED) (12–18 months)**
   A comprehensive analysis of technical, financial, environmental, and social aspects will follow. This stage is usually divided in two steps: feasibility study and FEED. While feasibility study costs usually USD 0.5-2 million, FEED typically requires USD 10–15 million, but costs may exceed USD 100 million for first-of-a-kind (FOAK) facilities (the costs vary highly from the project). It includes feedstock validation, engineering design, permitting and environmental impact assessment.
3. **Project financing and Final Investment Decision (12–18 months, which can partially occur in parallel with basic engineering)**
   Lenders and investors must be engaged to secure capital commitments. Legal, financial advisory, and offtake agreements are negotiated, and terms and conditions of financing and commercial contracts are established. The expected transaction costs for legal fees, financial advisory and support to negotiate and finalize financing and offtake agreement may be USD 15–30 million. This phase concludes with the final investment decision by the plant owner.
4. **Detailed engineering, construction and implementation (24–36 months)**
   Once financing is secured, contractors are engaged, and equipment is procured. The last engineering study (detailed engineering) is done in this phase. Construction costs vary significantly depending on the technology pathway and the plant size. For example, in this study the HEFA plant was estimated to be USD 375 and 500 million for the two scenarios.
5. **Commissioning and operation (6–12 months).**
   Initial operations begin, with testing, certification, and ramp-up of production. Debt repayments commence as revenue generation starts. Operational performance and sustainability certification are critical at this stage to ensure compliance with both domestic and international markets.

The overall timeline for SAF project development can vary considerably, depending on several critical factors that also influence capital expenditure. First, the technology readiness level is decisive: HEFA has been proven at commercial scale, while Alcohol-to-Jet is emerging, and pathways such as Gasification Fischer–Tropsch or Power-to-Liquid typically entail much longer development cycles. Second, the location of the facility affects access to renewable power, hydrogen, feedstocks, and distribution infrastructure; projects in regions with weaker logistics or regulatory systems are more vulnerable to delays. Third, the experience of the operator can shorten timelines, as developers with prior projects are able to streamline processes and manage risks more effectively. Fourth, financing requirements are often complex and time-consuming, especially when multiple investors and institutions are involved; projects with strong equity contributions are generally faster to advance. Finally, if the chosen pathway is not yet ASTM-certified, the certification process can add years and significant costs, as investors require assurance of fuel safety and compatibility before committing capital.

Table 49. Overview of capital cost estimate classes. (AACE, 2020; Possession Planning, 2025)

	Class 5	Class 4	Class 3	Class 2	Class 1
Project phase	Concept	Feasibility	FEED	Detailed Eng.	Detailed Eng
Purpose	Screening and feasibility	Conceptual study	Budget authorization	Control or Bid/Tender	Check estimate or Bid/Tender
Methodology	Stochastic and judgment, project analogy	Equipment factored or parametric model	Semi-detailed unit costs with assembly level line items	Detailed unit cost with forced detailed take-off	Detailed unit cost with forced detailed take-off
Level of project definition/ engineering	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
Expected accuracy range	-20% to -50% / +30% to +100%	-15% to -30% / +20% to +50%	-10% to -20% / +10% to +30%	-5% to -15% / +5% to +20%	-3% to -10% / +3% to +15%
Documentation requirement	- Basic scope definition - Rough capacity data - Location indicators - Historical similar projects	-Preliminary scope - Equipment lists - Rough quantities - Preliminary schedule	- Detailed scope - Preliminary P&IDs - Equipment specifications - Vendor quotes	- Detailed drawings - Specifications - Vendor quotes - Detailed schedule	- Final drawings - Specifications - Firm quotes - Detailed schedule

In terms of cost estimation, the level of accuracy evolves as the project advances. At the concept phase, capital expenditure (CAPEX) estimates are subject to considerable uncertainty, as limited technical definition is available. At this early stage, variations of approximately –50% to +100% around the estimated value are common. As the project progresses through subsequent phases and more detailed engineering information becomes available, the accuracy of estimates improves significantly, as summarized in Table 49. Overall, the transition from feasibility to operation is expected to require a minimum of 4.5 to 5 years at an efficient pace, with the exact duration influenced by the chosen technology pathway, the availability of financing, and the level of regulatory preparedness. Delays in these sectors may postpone the commercial operation date by several months or even years. The scoping study presented here provides an essential first step, but sustained effort across technical, financial, and policy domains will be required to bring SAF production in Kenya from concept to reality.

During the development phase up to the Final Investment Decision (FID), several critical actions are important:

- **Develop a roadmap for the feasibility study (FEL-2) and FEED/basic engineering (FEL-3)** (including preliminary terms of reference, indicative budgets, timelines) and complete both studies before FID.
- **Stakeholder & community engagement:** Establish engagement plan, identify, inform and consult stakeholders in the SAF supply chain
- **Assess feedstock availability** through detailed field studies and supply chain mapping.
- **Sustainability & certification:** Submit remaining potential feedstocks for approval under CORSIA, and/or consider the possibility of low LUC risk certification, implement system for traceability and chain-of-custody, and comply with sustainability criteria

- **Feedstock strategy:** Secure multi-year volumes via MoUs/term sheets with aggregators/co-ops; define pretreatment specs; plan hubs/logistics and storage
- **Define the market:** SAF vs HVO diesel
- **Offtake agreements:** Advance airline (and/or trader) offtake to term-sheet stage with price/indexation, volume ramps, and sustainability clauses.
- **Regulatory & permitting (Kenya):** Map and initiate approvals (e.g., NEMA EIA, EPRA licensing, KEBS quality standards), etc.
- **Governance & readiness for FID:** Define project governance, decision gates, reporting, and FID prerequisites (bankability, permits, FEED, offtake/feedstock terms).
- **Initiating dialogue with potential project partners** (e.g., investors, airlines, oil marketers) to define operations structure.
- **Commercial model & policy alignment:** Build a detailed financial model, reflecting taxes, incentives, and mandates; align with national policy and CORSIA.
- **Financing & de-risking:** Structure capital stack (equity, concessional/blended finance, debt), collateral, guarantees, insurance (performance, construction, political risk).
- **Procurement & delivery strategy**: Decide EPC/EPCM approach, contracting packages, and execution plan; develop project controls and QA/QC.
- **Risk management:** Maintain a live risk register with mitigations (technology, feedstock, market, schedule); run sensitivity/scenario analyses.

A brief introduction to these topics is provided in the following sections.

6.3 STAKEHOLDER ENGAGEMENT IN THE SUPPLY CHAIN FOR THE BEST SCENARIO

The successful development of a SAF industry in Kenya requires coordinated engagement of stakeholders across the entire supply chain. From feedstock producers to regulators and end-users, each actor plays a critical role in shaping a robust, transparent, and economically viable SAF ecosystem (Figure 44). This section examines stakeholder engagement of the HEFA pathway.

<u>Feedstock producers and farmers</u>

Farmers producing feedstock for vegetable oil production, waste fat, oil and grease collectors are at the foundation of the SAF supply chain. Effective engagement includes capacity building, access to training on sustainable practices and certifications, and integration into cooperatives or feedstock aggregation schemes. Ensuring that smallholder farmers benefit directly from SAF markets strengthens both feedstock security and social acceptance of the project.

<u>Feedstock aggregators and agri-hubs</u>

Feedstock aggregators and agri-hubs serve as intermediaries, providing logistics, pre-processing, and quality control. Their engagement is crucial for stabilising costs, ensuring traceability, and achieving compliance with sustainability certification schemes (e.g., ISCC, RSB). They function as coordination hubs where farmers, processors, service providers, and buyers converge. At these sites, agricultural products are aggregated and undergo initial processing, such as collecting oilseeds, residues, and seed-pressing to produce vegetable oils, before being delivered to industrial facilities. Stakeholder involvement at this level should emphasize transparency and digital traceability systems to maintain confidence in the supply chain.

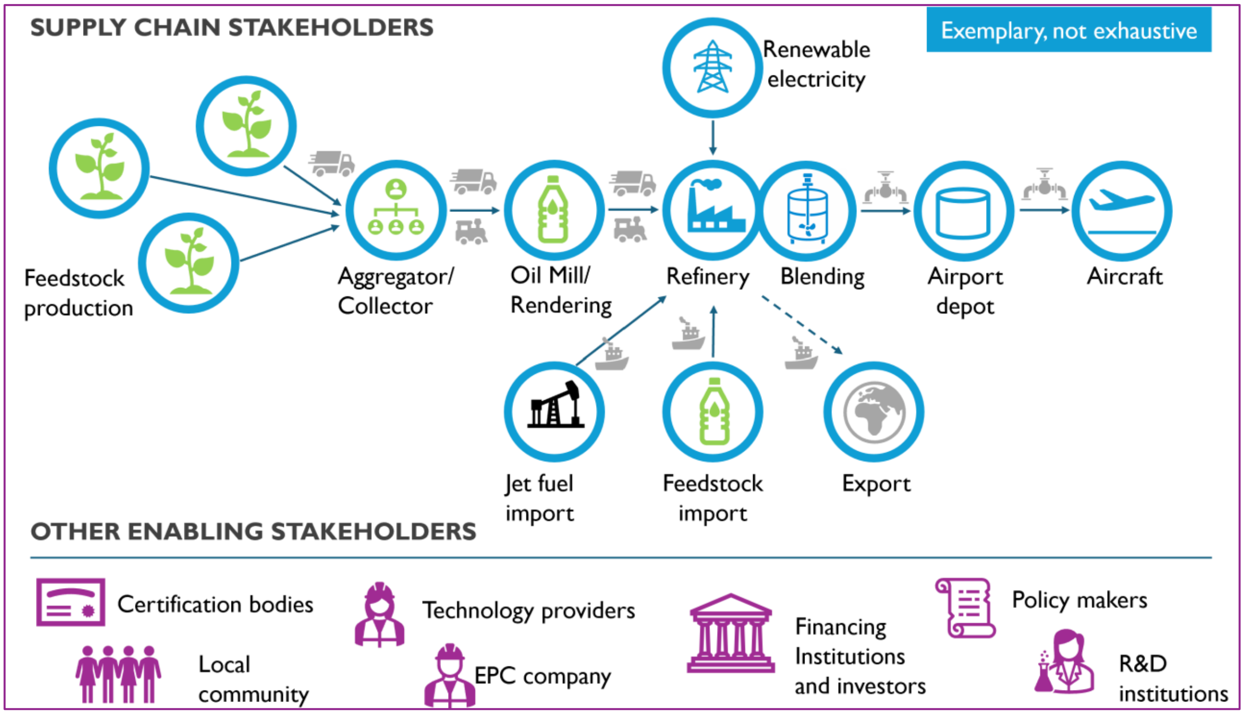


Figure 44. Stakeholders involved in the development of SAF supply chain.

Refinery: SAF production and blending

The refinery serves as the central facility for converting feedstock into SAF and/or HVO diesel. In the case of the Mombasa refinery, blending can be carried out internally, allowing the production of certified Jet A-1, which could in principle be distributed through the existing pipeline network. In this configuration, interactions are primarily contained within KPRL and KPC, thereby facilitating coordination. What remains external, however, is the ownership of the fossil jet fuel, which lies with the oil marketers and is distributed by KPC. Early engagement with feedstock suppliers is essential to secure sufficient volumes of sustainable feedstock at competitive prices. Similarly, early collaboration with international technology partners is critical to ensure access to proven process technologies and to adapt plant design to the characteristics of local feedstocks.

Policymakers, regulators and standards bodies

Supportive policy frameworks are essential to facilitate the development of the SAF sector, providing regulatory certainty and investment security necessary to attract and sustain financing. Active engagement with government institutions is critical for setting clear national ambitions for SAF, as policy direction and regulatory alignment provide the foundation for market development, investment mobilization, and long-term sectoral growth.

Institutions such as the Energy and Petroleum Regulatory Authority (EPRA) and the Kenya Bureau of Standards (KEBS) are relevant for licensing and fuel quality certification. Their involvement from the project's inception is critical to avoid regulatory bottlenecks and to integrate international sustainability requirements into national frameworks. The National Environment Management Authority (NEMA) must also be engaged early for environmental permitting and impact assessments.

Fuel suppliers and airlines

Airlines are the principal end-users of SAF. Their involvement in long-term offtake agreements provides demand certainty, which is critical for securing project finance. It is important to engage with the local airlines, (e.g., Kenya Airways, 748 and Astral), but also with the over 50 international carriers operating flights to Kenya, as these may represent potential off-takers of SAF even in the absence of an international book-and-claim system. Fuel marketers must also be included to ensure seamless integration of SAF into existing aviation logistics. Traceability and custody of chain is required to prove sustainability along all the gates in the supply chain.

Alternatively, the export of SAF to countries with established markets and blending mandates may be considered, offering an additional pathway to secure demand and enhance project viability.

Financial institutions and development partners

Banks, multilateral development banks, development finance institutions and climate funds (e.g., Green Climate Fund) and investors are key stakeholders in financing SAF projects. Structured engagement with financiers should focus on risk mitigation strategies, such as blended finance, guarantees, and carbon credit revenues. Development partners can also provide technical assistance and capacity building. In addition, the involvement of a specialized financial advisor can be highly valuable to design and structure the financing package in the most effective way, ensuring optimal allocation of risks and alignment with both investor expectations and project objectives.

Local communities and R&D activities

Local communities and civil society organizations are essential stakeholders in securing acceptance to the project. Meaningful engagement should emphasize transparent communication of project benefits, the establishment of accessible grievance redress mechanisms, and the inclusion of communities in participatory monitoring of environmental and social impacts. In parallel, research and development institutions, including universities and specialized research centres, play a critical role in advancing technological innovation, adapting SAF production pathways to local conditions, and building long-term human and institutional capacity. For example, they can be involved in testing new types of feedstocks or to map potential cultivation for feedstock or for simulations.

Logistics and transport

Logistics and transport are essential components of SAF value chain development, particularly concerning feedstock mobilization. A well-structured plan for the efficient collection, aggregation, and movement of feedstock is critical to ensure a reliable and cost-effective supply to the refinery. By contrast, the distribution of finished fuel is comparatively less challenging in this context, as established pipeline infrastructure already provides the primary means of delivery. Stakeholder engagement across the SAF supply chain is fundamental to realizing a HEFA SAF plant. By building inclusive partnerships among farmers, aggregators, refiners, regulators, airlines, financiers, and communities, Kenya can establish a resilient SAF value chain that balances economic viability with environmental integrity and social benefits.

6.4 FEEDSTOCK AGGREGATOR AND AGRI-HUB AS MODEL FOR FEEDSTOCK PRODUCTION

The availability of sustainable and reliable feedstocks is a cornerstone for the development of a viable SAF industry in Kenya. However, smallholder-based agricultural systems, dispersed residues, and fragmented supply chains pose challenges to feedstock collection and consistency. To address these barriers, the feedstock aggregator and agri-hub models offer an effective organizational and logistical solution for scaling biomass supply in a structured and sustainable manner.

Aggregators serve as intermediaries between smallholder farmers and waste oil collectors and the SAF refinery. Their role includes organizing farmer cooperatives, consolidating biomass from multiple sources, ensuring quality control, and managing traceability documentation. By pooling feedstock supply, aggregators reduce transaction costs, provide economies of scale, and enable smallholders to participate in higher-value SAF markets. Importantly, aggregators can also facilitate compliance with international sustainability certification schemes required for CORSIA eligibility, by ensuring documentation of land-use practices, waste sourcing, and chain of custody.

An agri-hub functions as a regional hub where feedstock is collected, pre-processed, and stored before delivery to the refinery. Such hubs can include facilities for oil extraction or fat rendering, to process the feedstock in a form that can be accepted by the refinery. In the Kenyan context, agri-hubs could be strategically located near agricultural clusters (e.g., cultivation regions for oilseeds, or urban centres for waste oil collection). By centralizing pre-processing, agri-hubs increase efficiency, reduce logistics costs, and enhance the reliability of feedstock flows to SAF producers. Among the agri-hubs present in Kenya targeting biofuel feedstock, the biggest in capacity are the agri-hubs currently operated by Eni and Bleriot. The aggregator/agri-hub model also delivers significant social benefits for farmers, who can gain stable income from supplying agriculture products, and they can have access to training on sustainable agricultural practices.

To ensure stable and competitive feedstock prices, agri-hubs can be integrated into a consortium model for SAF production. Such an approach would align farmers, aggregators, and refiners under a coordinated governance framework, facilitating long-term contracts, fair pricing mechanisms, and improved supply security. This integration also strengthens traceability and compliance with sustainability standards, which are essential for international certification schemes such as CORSIA. While the specific structure may vary, ranging from direct ownership to strategic partnerships or farmer cooperatives, the consortium model offers a practical pathway to reduce transaction costs, mitigate market volatility, and enhance the competitiveness of SAF production in Kenya.

In addition to the development of a national market, the creation of a regional feedstock market could be envisaged, whereby neighbouring countries contribute to feedstock supply and benefit also from SAF distribution. For instance, Ethiopia shows potential for the cultivation of Brassica carinata as oilseed crop, which can be explored further and can be aggregated for refining in Mombasa refinery. Similar opportunities could be explored with other neighbouring countries such as Uganda, Somalia, Rwanda, South Sudan and Tanzania, with the potential to extend cooperation further to the Democratic Republic of Congo and beyond.

The feedstock aggregator and agri-hub model provide a scalable and inclusive framework for securing sustainable biomass supply for SAF production in Kenya. By consolidating dispersed feedstocks, ensuring compliance with certification standards, and creating rural development benefits, this approach can mitigate supply chain risks while simultaneously strengthening social and economic co-benefits.

6.5 REFINERY OPERATIONAL STRUCTURE

The choice of operational and ownership structure for a SAF refinery in Kenya is a critical determinant of project feasibility, risk-sharing, and long-term success. Several models can be considered, ranging from full state ownership to collaborative partnerships with private or international stakeholders. Each model carries implications for procurement strategies, and financing structures.

As examined in detail in SECTION 5, one option is to have 100% KPC ownership, which would ensure direct control and alignment with national energy and climate objectives. However, this model places the full financial burden on the state and exposes the project to fiscal risks.

A second option is through a Public-Private Partnership (PPP), where risk-sharing between government and private entities is explicitly structured. Under this model, the government can contribute land, regulatory support, or initial equity, while private partners bring technology, operational expertise, and co-financing. Specific PPP arrangements such as Build-Operate-Transfer (BOT) or Build-Own-Operate (BOO) models can be applied, with contractual timelines for transfer or continued private operation defined at the outset.

A more flexible approach is a Joint Venture (JV) between KPC and a private or international partner. Such a structure allows for the division of expenditures, access to proven SAF technologies through the private partner, and shared responsibility for procurement and operations. JVs can also attract foreign direct investment and provide opportunities for knowledge transfer, especially if the partner has already experience in SAF markets and technologies.

KPC should assess the advantages and disadvantages of each ownership model, particularly once its legal structure is clarified, given that it is currently transitioning from full government ownership towards potential private equity participation through the ongoing IPO process, which is expected to be listed in the Nairobi Securities Exchange by the end of the year 2025**.** For further details on operational structures, ownership models, and financing considerations, reference is made to SECTION 5.

6.6 PRODUCT DISTRIBUTION: SAF VS HVO DIESEL MARKET

A key question for facilities producing hydroprocessed biofuels is the output balance in terms of product distribution between SAF and HVO diesel. Both products can be produced from the same feedstocks in the same plant using a flexible process, but market dynamics, regulatory frameworks, and policy incentives will strongly influence which fuel is prioritized.

The National Energy Policy (2025–2034) (Ministry of Energy & Petroleum, 2025) has proposed to keep in consideration a 10% blending for ethanol in gasoline and the potential for biodiesel production. However, no specific legislation has yet been enacted to make biofuel blending in transport fuels mandatory (IEA, 2024). In addition, Kenya is participating in the ICAO CORSIA scheme and has submitted a State Action Plan outlining several measures to reduce aviation emissions, with a national target of reducing CO_2 emission by 5% by 2030 and SAF is one of the key measures listed in the action plan (KCAA, 2022).

Renewable diesel (FAME and HVO), as well SAF policy-specific support is still emerging in Kenya. Nonetheless, SAF offers strategic advantages, since it can access international markets where blending mandates and willingness to pay a green premium are present. By contrast, HVO addresses immediate domestic and regional energy demand.

From a refinery perspective, maximum SAF yields are generally lower than maximum diesel yields from the same feedstock, therefore it tends to have higher production costs. If SAF can be sold at higher price than HVO diesel to compensate higher production costs, then SAF sale can generate more profit than diesel. SAF may be interesting for domestic and international markets where airlines seek long-term offtake agreements to meet decarbonization commitments.

Since there is no policy that favours one of the two products at the moment, there is no single “better” product choice between SAF and HVO diesel. Instead, producers must evaluate a dynamic balance between HVO diesel and SAF to meet immediate domestic, regional and/or international demand. The optimal distribution will depend on policy incentives/mandates and offtake agreements.

Flexibility in refinery operations, enabled by the latest available technologies, will be a key advantage in adjusting production to market dynamics. Robust policy frameworks will be essential to securing a viable business case for SAF production.

6.7 OFFTAKES FOR THE PRODUCTS: IMPORT VS EXPORT AND OIL MAJORS VS AIRLINES

The commercialization of SAF in Kenya will depend strongly on the establishment of secure and credible offtake agreements. Offtakes determine whether the fuel produced is consumed locally by airlines, exported to international markets, or distributed through oil marketing companies. They also define the commercial counterparties for refineries and are thus central to the bankability of SAF projects.

In Kenya, aviation fuel demand is distributed across international (88%), domestic (7%), and regional (5%) operations (Ministry of Energy & Petroleum, 2025). Current jet fuel consumption in aviation is expecting to increase at an estimated annual rate of 5% (KCAA, 2022) based on annual traffic demand from Kenya. Kenya is currently a net importer of petroleum fuels, including jet fuel. The introduction of domestic SAF production would therefore primarily aim to substitute imports, enhancing national energy security and reducing exposure to global price volatility. In this sense, domestic offtake by local airlines and over 50 international carriers flying in Kenya represents the most direct and strategic initial market, provided sufficient interest in offtake agreements is secured. At the same time, opportunities may arise to export SAF to neighbouring countries or to the international market, particularly if Kenya can establish certification under international schemes such as CORSIA or other regulatory frameworks. Export markets could be especially relevant if securing local offtake agreements proves challenging.

In practice, in the context of the current fossil market, airlines do not purchase fuel directly from refineries. Instead, oil marketers act as intermediaries. In Kenya, these entities purchase bulk volumes through the Open Tender System from the government. Products are stored and transported through KPC/KPRL infrastructure, with oil marketers retaining ownership and responsibility to consumers, including airlines.

In the case of blended fuels, the structure of the market will need to be clearly defined. One option would be for the refinery to sell SAF directly to airlines, with oil marketers continuing to supply the remaining fossil kerosene, and the final product delivered as a certified blend. Alternatively, the refinery could sell neat SAF to oil marketers, who would subsequently engage KPC/KPRL for blending and distribution through the pipeline system and airport depots. Regardless of the model adopted, a critical requirement is the establishment of robust mechanisms for sustainability documentation, custody chain management, and accurate tracking of certified volumes under CORSIA. In all cases, long-term offtake agreements will be essential to ensure the bankability of the project. Ideally, the duration of such agreements should exceed the loan repayment period and thereby provide revenue certainty and reduce financing risks.

6.8 EFFECT ON TICKET PRICE

Fuel represents the single largest cost component for airlines, accounting for approximately 30% of total operating costs according to IATA (IATA, 2022). It should be noted that, unlike domestic flights, fuel for international aviation is exempt from taxation. Considering the capacity of the refinery, if the plant is used exclusively to produce SAF for the Kenyan internal use, it can provide a theoretical maximum of approx. 25% blend (this number will also depend on the specific plant performance of the technology provider and on the effective market volume of jet fuel for the specific operation year). However, it would be more realistic that the plant is used also to produce HVO and maybe some SAF for export, therefore the effective blending should be calculated once the above points are defined.

As an assumption, the introduction of a 10% SAF blend at an assumed cost of 2 000 USD/t_{SAF} has a measurable effect on ticket prices when compared with conventional jet fuel. With current jet fuel prices averaging around 661 USD/t in Kenya (August 2025), SAF is more than three times as expensive.

A weighted cost calculation shows that a 10% blend increases the effective fuel cost from 661 USD/t to about 795 USD/t, corresponding to a 20% rise in fuel expenditure. Given that fuel-related costs accounts for roughly 30% of overall airline costs, this translates into an estimated ~6% increase in total operating costs. If fully transferred to consumers, ticket prices would rise by a similar proportion; for instance, a 500 USD ticket could increase by around 30 USD.

The analysis highlights that SAF blending (for low percentages) has a non-negligible but manageable effect on ticket prices at current cost differentials.

6.9 CERTIFICATION AND REGULATORS FOR RENEWABLE FUELS AND PETROLEUM PRODUCTS

The deployment of SAF requires not only technical feasibility but also compliance with sustainability certification, and regulatory oversight. Certification processes are essential to ensure that SAF can be safely blended with conventional jet fuel, that its environmental attributes are recognized in international climate frameworks such as CORSIA, and that its production pathways comply with both regional and international sustainability requirements.

<u>ASTM approval</u>
From a technical perspective, SAF must comply with the ASTM D7566 standard, which defines the specifications for aviation turbine fuels containing synthesized hydrocarbons. Each production pathway, such as HEFA or PtL, requires separate approval through a rigorous process of testing and validation. Once a pathway is approved, SAF produced under ASTM D7566 can be blended up to 50% with conventional Jet A-1 fuel, after which it is re-certified as ASTM D1655 jet fuel. This ensures that SAF can be safely used in existing aircraft engines and fuel distribution infrastructure without requiring modifications.

CORSIA Eligible Fuel certification

On the sustainability side, CORSIA defines eligibility criteria for sustainability for SAF. To qualify as a CORSIA-eligible fuel, SAF must achieve a minimum 10% reduction in life-cycle greenhouse gas (GHG) emissions compared to the reference value for fossil jet fuel of 89 g/MJ. Additionally, it must be produced from feedstocks that are not associated with deforestation, high indirect land-use change risks, or other environmental and social harms. CORSIA requires that fuels be certified by an approved sustainability certification scheme, ensuring traceability and credibility of the claimed emission reductions.

The verification of feedstock eligibility is a critical component of CORSIA compliance. Certification schemes accredited under CORSIA, such as the Roundtable on Sustainable Biomaterials (RSB) or the International Sustainability and Carbon Certification (ISCC), play a key role in auditing feedstock sourcing, land-use impacts, and supply chain practices. In addition, feedstocks that are not currently listed as CORSIA-eligible but meet the required sustainability criteria need to be submitted for approval to ICAO or go through the CORSIA low LUC risk certification process. For Kenya, this process would be particularly relevant for locally available feedstocks such as castor, yellow oleander, croton, and cottonseed.

To maintain integrity across the supply chain, CORSIA requires the establishment of a robust chain of custody system. This involves the documentation and verification of SAF volumes from feedstock production, through conversion and blending, to delivery at the airport. Chain of custody systems, typically based on "mass balance" approaches (maybe in future also "book-and-claim"), allow for accurate tracking of sustainability attributes and will prevent issue of double counting. Proper custody chain management ensures that emission reduction claims made by airlines can be transparently linked to certified SAF production.

It should be noted that while CORSIA certification covers the international aviation market, other regional markets may also be relevant, but they may have different sustainability criteria (e.g., EU RED III). In this context, it is crucial to establish a clear national strategy for the SAF percentage that will be used under CORSIA or for export to other regional markets, to guide the development of an appropriate and resilient feedstock supply chain.

The Role of EPRA and National Standards Bodies.

In Kenya, the Energy and Petroleum Regulatory Authority (EPRA) serve as the central regulator for both petroleum and renewable energy sectors. EPRA's role encompasses licensing, compliance monitoring, and the integration of renewable fuels, including SAF, within the national energy framework. By establishing clear technical and economic regulations, EPRA can ensure that SAF production, blending, and distribution are aligned with international certifications, while also reflecting Kenya's specific market and policy context. Complementing this, the Kenya Bureau of Standards (KEBS) is responsible for developing and enforcing national quality and safety standards, including the adoption of global certification requirements for fuel products. KEBS may play a critical role in ensuring that SAF entering the Kenyan supply chain meets both technical specifications and sustainability criteria. Together, EPRA and KEBS provide robust national oversight that complements international certification schemes, therefore, the SAF National Committee should continue engaging them during the development phase of SAF projects.

6.10 HUMAN RESOURCE DEVELOPMENT AND CAPACITY BUILDING FOR THE REGION

The successful deployment of SAF in Kenya depends not only on technological readiness and regulatory alignment but also on the development of robust human resource capacity across the entire value chain.

Capacity building is essential for farmers, feedstock suppliers, technology operators, financiers, and policymakers, ensuring that all actors are adequately equipped to participate in and sustain the SAF sector.

Knowledge Transfer to Farmers and Feedstock Suppliers

As Kenya considers the large-scale mobilization of oilseed crops and shrubs and trees, waste FOGs, and other feedstocks for SAF production, farmers and collectors must receive targeted training in sustainable agricultural practices, residue collection, and quality assurance. Knowledge transfer should emphasize the importance of maintaining soil health, avoiding indirect land-use change, and ensuring traceability of biomass in line with international sustainability standards such as CORSIA. Training for farmers can be organized inside the Agri-hub, technical schools or in partnerships with both local and foreign universities and agricultural institutes.

Capacity for technology operators and industry professionals

SAF production facilities require a highly skilled workforce with competencies in process engineering, HEFA refinery operations, quality assurance, and environmental management. Capacity-building initiatives should also extend beyond plant operations to encompass expertise in logistics, feedstock management, SAF market dynamics, chain of custody, as well as storage and blending, to ensure effective integration into the aviation fuel supply chain. Basic training for engineers could be incorporated into curricula at universities and specialized institutions, such as the Morendat Institute of Oil and Gas (MIOG, 2025), which has historically provided specialized training in petroleum, gas, and energy-related fields for KPC. In an interview, the Morendat Institute of Oil & Gas confirmed that they could be mobilized to design and deliver new courses tailored to the specific competencies required for SAF development. The East African School of Aviation (EASA), which is an ICAO TRAINAIR PLUS Programme member, can also be considered to provide SAF courses to aviation stakeholders and other interested parties. Potential partner(s) to the project can provide technical knowledge transfer through exchange programs and long-term training placements in other operating refineries. Technology licensors typically also provide specialized training on their systems. Study tours or site visits to operating SAF refineries may serve as an additional means of experiential learning and capacity enhancement.

Financial institutions and project developers

For financiers and project developers, capacity building is needed to improve understanding of SAF project economics, risk assessment, and the regulatory frameworks governing renewable fuels. Training on blended finance, green bonds, and carbon credit markets can strengthen the ability of investors to participate in SAF financing.

Policymakers and regulators

Policymakers and regulators play a pivotal role in establishing enabling frameworks for SAF development. Capacity building at this level should focus on strengthening knowledge of international best practices, sustainability certification systems, and compliance requirements under frameworks such as CORSIA. Government ministries have the role of designing effective incentives/mandates, targets, monitor compliance, and align policies with Kenya’s broader energy transition and climate commitments. Exchanges with countries that have already established a SAF roadmap and policies could provide valuable insights for defining Kenya’s own SAF roadmap. While some exchanges have already taken place during this study, these collaborations could be further intensified in the future to strengthen knowledge transfer and strategic planning.

Regional knowledge networks and collaboration

Given the cross-sectoral nature of SAF development, regional collaboration and knowledge sharing are also critical. Establishing platforms for dialogue between universities, industry, government, airlines, airport operator and civil society can promote coordinated capacity building. Kenya, with its strong regional role in aviation and bioenergy, is well-positioned to lead such initiatives in East Africa, fostering a regional ecosystem of expertise in sustainable fuel production.

Human resource development is a cornerstone for the successful rollout of SAF in Kenya. Targeted training and knowledge transfer for farmers, operators, financiers, and policymakers will ensure that the emerging industry is grounded in local expertise while benefiting from international best practices. Investing in capacity building will not only facilitate the uptake of SAF but also generate wider socio-economic benefits, including job creation, enhanced agricultural productivity, and strengthened institutional frameworks.

6.11 ENVIRONMENTAL AND BUILDING PERMITS

The development of SAF facilities in Kenya requires compliance with a robust framework of environmental permitting and regulatory approvals at both national and local levels. These permits are essential for ensuring that projects meet Kenya's environmental protection objectives, align with international sustainability standards, and safeguard local communities and ecosystems.

Under the Environmental Management and Coordination Act (EMCA, 1999, revised 2015), all large-scale energy and industrial projects in Kenya are subject to Environmental Impact Assessments (EIAs). These are overseen by the National Environment Management Authority (NEMA), which issues approvals and licenses for project implementation. Such studies assess potential impacts on air and water quality, biodiversity, land use, and socio-economic conditions, and propose mitigation measures. Public consultation is a mandatory part of this process. Approval timelines for comprehensive EIAs typically range between 6–12 months, depending on the complexity of the project and the adequacy of submitted documentation. Beyond the EIA license, SAF projects will require a series of permits and approvals, including:

- **Air Emission and Effluent Discharge Permits** (NEMA), ensuring compliance with air quality and water regulations.
- **Waste Management Licenses** for handling, storage, and disposal of industrial by-products. NEMA also releases licenses for collecting waste oils and FOG.
- **Land Use Permits and Zoning Approvals,** which are already in place since KPRL land is already zoned as industrial.
- **Water Abstraction Permits** from the Water Resources Authority (WRA), in cases where SAF feedstock or conversion processes involve significant water use.

The Energy and Petroleum Regulatory Authority (EPRA) is mandated to license facilities for the production, storage, and distribution of petroleum products, including renewable fuels. SAF producers will require EPRA licensing to ensure compliance with national fuel standards, blending practices, and safety protocols. Construction permit must be also obtained from the Ministry of Energy and Petroleum and the National Construction Authority.

Approval timelines depend on the scale of the project and the level of inter-agency coordination required. For a greenfield SAF facility, the combined process of obtaining EIA approvals, NEMA permits and EPRA licensing could reasonably be expected to take 12 months or more before project implementation, if applications are complete and stakeholder consultations are properly conducted. Early engagement with regulators, transparent disclosure of project information, and phased permitting (e.g., securing feedstock collection permits in parallel with EIA approval) can help accelerate the process.

Product conformity assessments fall under the mandate of the Kenya Bureau of Standards (KEBS), which is responsible for ensuring that fuels meet established technical and quality standards before entering the market.

6.12 POLICY IMPLEMENTATION FOR THE REGION AND GOVERNMENT INTEREST

Kenya has taken steps towards establishing an enabling policy environment for the development and deployment of SAF. Several national strategies, sectoral policies (e.g., biofuel, bio-energy, green hydrogen), and institutional initiatives provide a framework within which SAF can be integrated into the country's energy and aviation sectors, though further refinement and dedicated measures remain necessary.

Aviation and climate policies

With the adoption in November 2023 of the ICAO Global Framework for SAFs , Lower Carbon Aviation Fuels (LCAF), and other Cleaner Aviation Energies, ICAO and its Member States, included Kenya, committed to a collective aspirational Vision during the third ICAO Conference on Aviation and Alternative Fuels (CAAF/3): reducing CO_2 emissions from international aviation by 5% by 2030 compared to a baseline of zero cleaner energy use.

A dedicated policy framework for SAF has yet to be established. However, a Kenyan SAF roadmap is currently under development, and specific national targets for SAF production and utilization are expected to be defined as part of this process. The National Aviation Policy (Sessional Paper No. 6 of 2024 (Ministry of Roads and Transport, 2024)) represents a landmark development by explicitly stating that the country needs to revise the current legal, fiscal, regulatory, and institutional framework to provide sufficient incentives for SAF production and consumption to encourage their development. Complementing this, the draft National Energy Policy (2025–2034)(Ministry of Energy & Petroleum, 2025) includes biofuels and SAF among priority renewables to address climate change and energy security. Broader strategic alignment is also provided by Kenya Vision 2030 (Kenya Vision 2030, 2008) and the country's climate governance framework. Kenya Vision 2030 emphasizes a transition to green energy, universal energy access, and increased renewable integration, all of which provide an enabling backdrop for SAF development. The Climate Change Act (Republic of Kenya, 2016), amended (Republic of Kenya, 2024), together with the National Climate Change Response Strategy and Action Plans (Ministry of Environment, Climate Change and Forestry, 2023), reinforces Kenya's commitment to low-carbon, climate-resilient development.

Biofuel policies

Since diesel production competes for the same feedstock than SAF, it is important to also consider the policies aimed at promoting biofuels. The Bioenergy strategy 2020-2027 (Ministry of Energy, 2020) provides further recommendations on revival and implementation of the E10 mandate for the transport sector. Compared to bioethanol, the biodiesel sector in Kenya is at its infant stage and there is currently no blending mandate in Kenya. The National Energy Policy (2025–2034) confirmed the potential of 10% blending for ethanol in gasoline and potential for biodiesel production (without citing a blending percentage). The EPRA Biofuels Guidelines of 2022 (EPRA, 2022) further refine the regulatory landscape by introducing technical standards and licensing requirements for biofuel production and blending, but they do not prescribe mandatory blending percentages. Most recently, the Draft Energy Biofuels Regulation of 2025 (EPRA, 2025e) provides a comprehensive framework for biofuel operations, including conditions for blending, quality control, and compliance. The Fourth Medium Term Plan (The National Treasury and Economic Planning, 2024a) (MTP4) of Kenya, covering 2023–2027, specifically includes a target to set up two biorefineries in the country by 2028. This is part of the plan's broader push for value addition in the manufacturing sector, green transition, and fostering a formal bioenergy industry. These biorefineries are intended to support the local production of biofuels, including SAF and other bio-based products, promote Kenya's green industrialization, and diversify energy sources to enhance energy security and sustainability.

Renewable energy and green hydrogen policies

Kenya's policy framework supports for renewable energies and the integration of green hydrogen through several strategic documents. The National Energy Policy (2018 and 2025–2034) served as the umbrella policy for the energy sector, promoting renewable energy uptake, private sector participation, and incentives while mandating the development of an Integrated National Energy Plan and improved transmission infrastructure. The Least Cost Power Development Plan (LCPDP) 2022–2041 provides a long-term roadmap for optimal power sector development, updated biennially, and offers opportunities to integrate green hydrogen into future energy planning. The National Energy Efficiency and Conservation Strategy (2020) sets targets to reduce fossil fuel demand and GHG emissions, stimulating renewable energy adoption and potential hydrogen demand. Ongoing policy developments also shape the landscape: the draft Captive Power Policy will allow industries to generate their own electricity; the Energy Sector Roadmap 2040 (Kenya Energy White Paper) aims to accelerate the growth of new technologies, including industrial applications for hydrogen. The Renewable Energy Auctions Policy (2021), approved and in force, seeks to procure renewable capacity at competitive prices, reducing electricity costs for hydrogen production.

Kenya's Updated First Nationally Determined Contribution (NDC, 2020) commits to a 32% reduction in GHG emissions by 2030, emphasizing renewables and clean energy technologies. The National Climate Change Action Plans (NCCAPs) prepared every five years, guide climate-resilient energy planning. Finally, the National Long-Term Low Emission Development Strategy (LT-LEDS), sets a pathway to net zero by 2050, calling for hydrogen-fuelled transport, hydrogen use in cement (40% replacement), manufacturing (15% replacement), and wider industrial applications. Kenya's Green Hydrogen Strategy (2023) outlines the country's vision to position itself as a regional leader in green hydrogen production by leveraging its abundant renewable energy resources to drive industrial decarbonization, energy security, and sustainable economic growth. Meanwhile, the EPRA Guidelines on Green Hydrogen and Its Derivatives (2024) defines sustainability criteria (for renewable energy, water and land use), project approval and monitoring processes, health and safety provisions, and local content requirements. Kenya offers extensive incentives for green hydrogen investors through Export Processing Zones (EPZs) and Special Economic Zones (SEZs), including multi-year tax holidays, duty and VAT exemptions, investment deductions, preferential corporate tax rates, and access to special electricity tariffs (EPRA, 2024a).

Taken together, Kenya's policy provides a strong foundation for SAF development, but a dedicated and specific policy for SAF should be implemented to consolidate and stabilize this new market.

6.13 SOCIAL AND ENVIRONMENTAL BENEFITS

The development of a SAF sector in Kenya offers not only climate mitigation opportunities but also significant social and economic co-benefits. SAF production can generate new employment opportunities, enhance local value chains, and reduce dependency on imported fossil fuels, while simultaneously contributing to Kenya's commitments under international climate frameworks.

Job creation

The establishment of SAF production value chains has strong potential to create local employment across multiple sectors. At the agricultural level, farmers engaged in the supply of biomass feedstocks (e.g., oilseed crops) can access new income streams, thereby improving rural livelihoods. Feedstock aggregation, logistics, and pre-processing activities are labour-intensive and can stimulate job creation in rural areas. On the industrial side, the construction, operation, and maintenance of SAF production facilities will require skilled workers. Capacity building and skills transfer programs further amplify these social benefits by ensuring long-term employability and technological expertise among the local workforce.

Environmental sustainability and co-products

When designed in accordance with international sustainability standards, SAF production can also deliver environmental co-benefits beyond GHG reduction. The use of waste oils and agricultural residues can help reduce environmental burdens associated with waste management, while sustainable cultivation of energy crops can promote soil restoration and rural landscape management when properly regulated. Additionally, SAF production processes often generate co-products such as animal feed or bio-chemicals, which can support circular economy practices and reduce environmental pressures in related sectors.

Energy security and import reduction

Kenya currently depends on imported petroleum products to meet its aviation fuel demand, which exposes the sector to international price volatility and supply chain disruptions. Local production of SAF can partially substitute fossil jet fuel imports, thereby enhancing national energy security and reducing foreign exchange expenditures.

6.14 OPPORTUNITIES AND CHALLENGES FOR THE DEVELOPMENT, DEPLOYMENT AND COMMERCIALIZATION OF SAF

The large-scale deployment of SAF in Kenya presents a unique set of opportunities and challenges. While the country possesses favourable conditions for the development of a domestic SAF industry, commercialization requires coordinated action across technology, policy, finance, and market ecosystems. Table 50 provides a SWOT assessment of a HEFA refinery in Mombasa, detailing its strengths, weaknesses, opportunities, and threats under prevailing market, political, financial, and technological conditions.

The development of SAF in Kenya represents a strategic opportunity to align economic growth with climate action, enhance energy independence, and create new industrial and agricultural value chains. However, realizing this potential will require overcoming challenges related to financing, feedstock logistics, regulatory development, and market incentives/mandates. Coordinated action among government, industry, financiers, and international partners will be essential to bridge these gaps and establish Kenya as a leader in SAF production in Africa.

Table 50. SWOT analysis for the development of HEFA plant in Mombasa.

STRENGTHS	WEAKNESSES
• Sustainable feedstock potential to be developed (oil seeds, waste oils, FOG residues) • Strong renewable energy base (>90% electricity from renewables) • Supportive policy framework (National Aviation Policy 2024, Energy Policy 2025–2034) to produce biofuels • Established national SAF committee, demonstrating interest and commitment • Proactive steps and preliminary sustainability commitment of Kenyan airlines to SAF (e.g., KQ test flights with SAF blends and SAF target for 2030) • Alignment with global schemes (CORSIA, ICAO, Paris Agreement). • HEFA is an already established commercial technology, with low technological risks • First ICAO feasibility study in place (it suggests HEFA as short-term implementation technology) • Leveraging of the existing infrastructure at the Mombasa refinery • Mombasa is a strategic location for both domestic supply and exports	• Although HEFA is one of the cheapest SAF technology, it requires high upfront capital costs • SAF production costs remain above fossil jet fuel prices • Limited local technical expertise in SAF production and certification. • Supply chain for HEFA needs to be set in place, especially regarding feedstock production • Current feedstock availability is not sufficient for plant scale and a strategy for feedstock cultivation should be set, together with feedstock logistics and aggregation systems. • Several promising feedstocks lack CORSIA approval at present • Limit awareness about SAF and need for local capacity building • Current lack of clear policies promoting SAF (e.g., mandates, incentives) • Perceived investment risks may be high • Financing source to be defined • No binding mandates for HVO diesel as co-product, reducing demand certainty • Market uptake and price competitiveness remain uncertain at the current stage
OPPORTUNITIES	**THREATS**
• First mover advantage in Africa and positioning Kenya as a regional SAF hub in East Africa. • Growing global and regional demand for SAF • Potential to reduce import dependency and improve energy security • Access to international climate finance and carbon markets • Job creation and rural development through feedstock supply chains and in the refinery • Skills development and knowledge transfer in refinery operations, logistics, and certification • SAF offers significant GHG reductions • Potential co-benefits: waste management, soil improvement, circular economy • Serve both biodiesel and SAF market keeping production flexibility • Finding potential partner(s) contributing to project financing	• Competition for feedstocks with food, feed, or other bioenergy uses if not properly planned and managed • Policy uncertainty or slow implementation of SAF-specific regulations. • Financing risk • Feedstock volatility price • Without efficient supply chain systems (e.g., costs of aggregation and transportation in rural areas), feedstock costs may undermine SAF competitiveness • International competition from countries with stronger subsidies or established SAF industries • Market uptake challenges without clear policy. • High capital cost can discourage financing • New entrants face competition from established energy companies and other experienced actors with significant resources and market influence.

6.15 PROJECT RISKS AND MITIGATION

The commercialization of SAF in Kenya entails a range of risks that must be carefully identified, assessed, and mitigated. These risks span financial, technical, regulatory, feedstock, and social dimensions, with implications for project bankability, competitiveness of the aviation sector, and the broader energy transition. Table 51 highlights only the principal risks; a more detailed assessment should be conducted during project development.

Table 51. Potential risks in implementing a HEFA SAF plant in Kenya

Risk category	Specific risks	Potential mitigation measures
Financial & Market Risks	• High capital expenditure may deter investment. • Bankability thresholds may not be achieved. • The SAF price premium over fossil jet fuel may constrain demand uptake.	• Employ blended finance, concessional loans, and performance-guarantee insurance. • Secure long-term offtake agreements with airlines • Introduce or strengthen SAF blending mandates to stabilize demand and/or other form of policy support
Feedstock Supply & Logistics Risks	• Seasonal variability and uneven regional distribution, plus force majeure events (e.g., drought), may disrupt supply. • High logistics costs from rural sourcing to the refinery may erode project economics. • Competition with food/feed markets and other bioenergy uses (e.g., biodiesel) may constrain availability. • Feedstock price volatility may increase procurement risk. • Sustainability criteria and chain-of-custody/traceability requirements are not met	• Diversify feedstock types • Use forward contracts with growers/co-ops and require sustainability certification to lock quality and eligibility. • Establish regional feedstock hubs and farmer cooperatives to aggregate supply. • Maintain buffer inventories and secure import options for poor seasons. • Conduct a detailed study on feedstock availability, cultivation zones and logistics corridors. • Deploy digital tracking systems to enable traceability and lower transaction costs. • Provide capacity building in terms of sustainability and certification.
Technological & Operational Risks	• Technology maturity varies across providers, some may have limited commercial experience • For certain feedstocks, pretreatment may not reach the required purity, or only under restrictive conditions • Potential for disruptive technological shifts may render chosen pathways/ equipment obsolete • Local operating expertise may be limited	• Partner with proven international technology providers and secure performance guarantees. • Invest in technical training for operators, engineers, and regulators. • Collaborate with pretreatment technology providers and run tests to validate feedstock purity and performance.
Policy & Regulatory Risks	• SAF-specific regulations, certification systems, and blending mandates are still under development. • Slow or inconsistent implementation may weaken investor confidence. • Policy prioritization and incentives under the Big Four Agenda (Food & Nutrition Security, Affordable Housing, Universal Health Coverage, Manufacturing) is favoured instead of SAF incentives. • Competing incentives in other sectors (e-mobility, renewable diesel) may divert resources and attention.	• Enact clear SAF Policy (e.g., targets, mandates, incentives) • Set technical regulation and standards also from EPRA/KEBS, and as well as capacity for certification, monitoring, and quality compliance. • Coordinate across energy, transport, agriculture, and environment ministries to write policies • Use incentives judiciously given competing national priorities; where fiscal space is limited, rely on non-fiscal instruments (e.g., blending mandates, ticket levies, supplier

Risk category	Specific risks	Potential mitigation measures
		obligations) to secure demand and bankability.
Social & Environmental Risks	• Land-use change, biodiversity loss, and water stress may arise if feedstock expansion is not carefully managed. • Food-security concerns and community acceptance risks may emerge	• Conduct rigorous EIAs, engage early with communities, and implement benefit-sharing mechanisms. • Prioritize feedstock not in competition with food and in marginal lands • Ensure transparent sustainability certification aligned with CORSIA and/or other frameworks.
Impacts on Aviation Competitiveness	• Near-term increases in fuel prices may raise air-transport costs and pressure competitiveness. • In the absence of adequate policy support, airlines may face higher operating costs.	• Adopt phased blending targets to smooth cost pass-through (starting from low targets). • Leverage carbon-credit revenues under CORSIA or other frameworks. • Harmonize SAF policies across East Africa to avoid competitive distortions.

A structured risk monitoring and review plan is necessary to update risk assessments regularly during the project development considering technological, policy, and market developments. This should include:

- **Periodic risk reviews** during project development and operation.
- **Scenario analysis** to assess robustness under different conditions (e.g., varying feedstock costs, carbon pricing levels, oil price volatility).

Risks facing SAF deployment in Kenya are present, but manageable with proactive mitigation strategies and structured planning. Strong regulatory frameworks and stakeholder engagement will be essential.

6.16 SUMMARY AND NEXT STEPS

This chapter has examined the techno-economic, regulatory, and institutional dimensions of developing SAF in Kenya, identifying both opportunities, challenges and risks along the supply chain. Our assessment indicates that HEFA process constitutes the most viable near-term pathway owing to their higher technological maturity and comparatively lower capital intensity. In specific conditions, the minimum selling price of HEFA-derived SAF could fall below 2 000 USD/t. By contrast, PtL currently entails substantially higher technology and financing costs; although unit costs are expected to decline with learning and scale, PtL is unlikely to be competitive with HEFA in the short term.

To reach commercial operation, the HEFA project at the Mombasa refinery (currently it can be considered in the concept phase) must define the company strategy and market, and progress through the standard Front-End Loading stages.

The company must first develop a clear strategy to identify the target markets for SAF and which percentage to dedicate to HVO diesel market. Based on it, further analysis is needed to assess feedstock availability, effective market feedstock and SAF price (current and forecast), and ensure alignment with sustainability standards. CAPEX and OPEX should be refined through detailed engineering studies, while financial conditions must be assessed to determine potential financing source and the applicable range of interest rates. Before construction, an engineering feasibility study and basic engineering should be completed, culminating in a Final Investment Decision (FID). If the feasibility study begins immediately, start-up could be achieved in approximately 5 years; any delays in these stages would proportionally extend the schedule. Accordingly, achieving SAF production prior to 2030 will be challenging.

For project success, robust communication and coordination across all supply-chain stakeholders are essential, such as farmers, aggregators, refiners, regulators, airlines, marketers, financiers, and local communities. A central priority is to establish a strategy to secure sufficient sustainable feedstock at competitive prices. Developing aggregators and agri-hubs can strengthen logistics and coordination, while long-term offtake agreements will be important to reduce volatility price risks.

We also recommend a comprehensive feedstock feasibility study that

(i) maps potential cultivation areas of different feedstocks,
(ii) defines a strategy for expanding biofuel feedstock cultivation and that supports sustainability criteria,
(iii) assesses logistics, supply-chain design, and cost implications,
(iv) evaluates current and projected feedstock price

In addition, the refinery should define its strategic approach (solo or partnered), specify the target market (e.g., SAF vs. HVO biodiesel), and identify priority customers to initiate early offtake agreements, which are critical for bankability.

Several policy documents reference SAF within broader biofuel frameworks, but operational details remain to be defined; a national SAF roadmap is presently in preparation. Policy design should balance targets, mandates and incentives, acknowledging that incentives alone are unlikely to narrow the cost gap with fossil jet fuel in a durable way, and render SAF price to the same level of Jet-A1. For illustration, a vegetable-oil feedstock priced at USD 800–1 000/t already exceeds the current market price of Jet A-1 (≈USD 600–700/t). As reference, a 10% SAF blending mandate is estimated to raise airlines' total operating costs by approximately 6–7%, with a broadly similar pass-through to ticket prices.

A SWOT assessment and an analysis of risks alongside the social and environmental benefits of SAF were performed. When implemented in a sustainable context, SAF can provide meaningful emissions abatement and inclusive socio-economic benefits. In conclusion, Kenya has strong foundations for advancing SAF, such as feedstock potential, renewable energy resources, and supportive policy frameworks. However, successful commercialization will require coordinated action:

- building robust feedstock supply chains,
- engaging stakeholders across the value chain,
- aligning domestic policies with international frameworks, and
- de-risking investment.

SECTION 7. ROADMAP AND POLICY RECOMMENDATIONS

A roadmap is a strategic planning tool that outlines the sequence of actions, milestones, and enabling conditions required to achieve a defined objective within a specific timeframe. In the context of SAF, roadmaps provide a structured framework for aligning technical, financial, regulatory, and market developments to facilitate the successful deployment of SAF at scale.

For this study, two complementary roadmaps are proposed:

1. **Company-level roadmap**

   This roadmap should focus on the internal strategy of the company aiming to produce SAF in Kenya. It defines the technological pathway, investment requirements, capacity-building needs, feedstock mobilization strategies, and operational milestones necessary to achieve commercial production. It serves as a guiding tool for the company's management and investors, ensuring decisions are evidence-based and synchronized with market dynamics.

2. **State-level roadmap**

   A national roadmap is designed to outline the policy, regulations, and infrastructural enablers required to create a favourable environment for SAF development in Kenya. It provides government institutions with a strategic vision for supporting SAF investments, including policies, sustainability standards, certification frameworks, and stakeholder coordination. By providing a clear and consistent policy signal, the state-level roadmap strengthens the business case for SAF producers and facilitates investor confidence.

Together, these two roadmaps create a synergistic planning framework: the company roadmap defines what needs to be done internally, while the state roadmap addresses the external enabling conditions. This dual approach will ensure that SAF development in Kenya is not only technologically and financially viable but also aligned with national energy transition goals and international sustainability commitments.

7.1 RECOMMENDATIONS FOR INDUSTRIAL IMPLEMENTATION AT THE COMPANY LEVEL

The development of a SAF project requires a structured, phased roadmap covering the short, medium, and long term, starting from concept definition to the Final Investment Decision (FID), followed by construction, commissioning, and full-scale operations. At the company level, this roadmap outlines the technical, commercial, financial, and governance actions needed to ensure project viability, secure stakeholder alignment, and de-risk investments.

In the short term, the priority is to organize and execute all critical steps required to reach FID, while maintaining a high-level perspective on the subsequent construction, commissioning, and operational phases. The following key actions described in the next sections should be addressed and structured to achieve FID effectively (Figure 45). The list provided is an example and not exhaustive.

Before undertaking these activities, it is crucial for the company to establish a clear strategy, defining the target market and the indicative share of SAF and diesel to be produced. The choice of market (e.g., domestic, CORSIA, EU, US) will determine the applicable feedstock eligibility criteria and the minimum GHG emission savings required. These factors, in turn, influence the development of the feedstock supply chain, the chain-of-custody mechanism, product logistics, plant design and other factors.

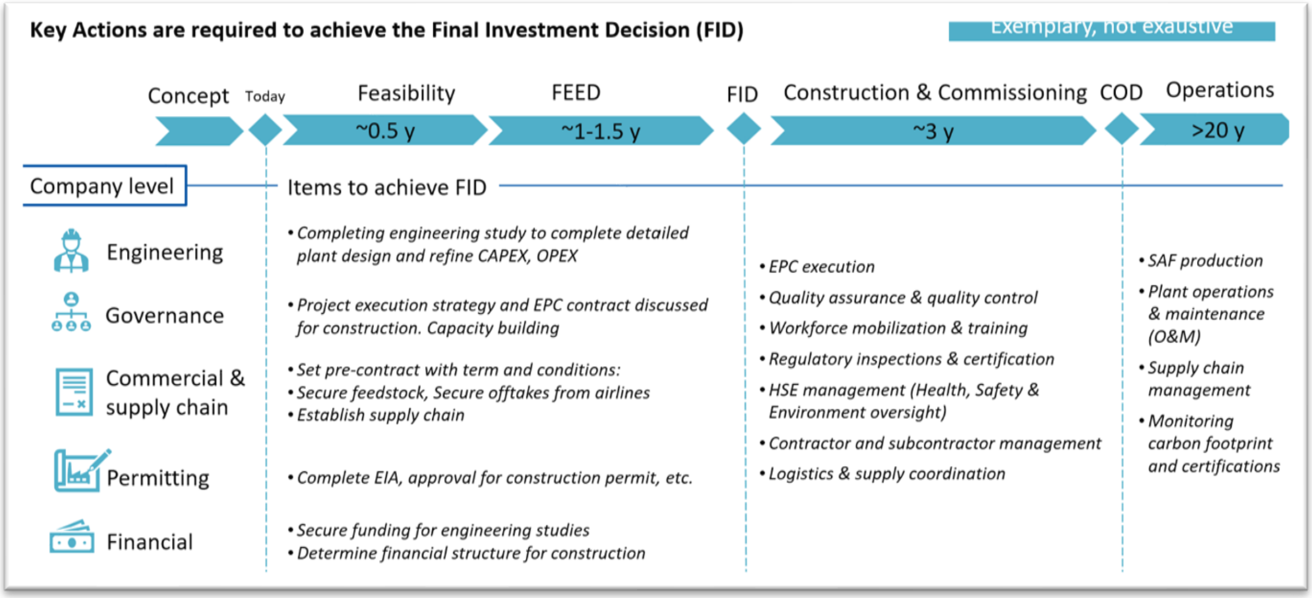


Figure 45. Key actions required to achieve FID for SAF-HEFA project and following phases

7.1.1 Recommendations for the technical and sustainability domain

Within the technical domain, several actions are required to advance the project towards the Final Investment Decision (FID) and ensure readiness for subsequent phases:

- **Roadmap for engineering studies**: Develop detailed terms of reference, allocate indicative budgets, and establish milestones for completing both the Feasibility Study (FEL-2) and the Front-End Engineering Design (FEED / FEL-3) ahead of FID.
- **Sustainability and certification**: Select feedstocks according to sustainability criteria (depending on the market), availability potential and price to optimize and submit any remaining potential feedstocks for approval under CORSIA. Establish systems for traceability, chain-of-custody, and compliance with international sustainability criteria.
- **Technology selection**: Evaluate and select the most suitable HEFA-based SAF production technology and associated licensors. This can be done during the engineering feasibility study.
- **Feasibility Study (FEL-2)**: Conduct a comprehensive evaluation of feedstock availability, production pathways, technology licensors, preliminary cost estimates, and indicative project timelines.
- **Front-End Engineering Design (FEL-3 / FEED)**: Advance engineering designs to achieve the level of detail required for accurate cost forecasting and procurement planning.
- **Regulatory and permitting**: Map all relevant permitting and licensing requirements, e.g., including Environmental Impact Assessment (EIA), NEMA environmental approvals, EPRA licensing, and KEBS fuel quality certification, construction approval and initiate applications early to align with project timelines and regulatory lead times.

Typically, engineering studies are conducted by a specialized engineering firm responsible, which also coordinates with the different technology suppliers (e.g., HEFA production units, pretreatment facilities, etc.) and integrates their technological components. In parallel, KPC should establish an internal team of owner's engineers to oversee and supervise the progress of these studies.

At this stage, the critical priority is not to secure financing for the entire plant, but rather to obtain funding for the next engineering study itself (usually financed internally, by equity sponsors, grants, development banks or combination of the previous) and develop a strategy. Such a study will progressively refine the estimates of capital (CAPEX) and operating expenditures (OPEX), which improves the reliability of the projections and strengthens confidence in the profitability of the overall business case.

7.1.2 Recommendations for the commercial domain

In the commercial domain, a coordinated strategy is required to define market positioning, secure reliable offtake agreements, ensure feedstock availability, and align financial and contractual frameworks with both national policies and international decarbonization commitments. The following actions are recommended:

1. **Market definition and offtake agreements**
    - Market analysis: Evaluate competing markets, particularly SAF versus HVO diesel, to optimize production allocation and maximize revenue potential.
    - Offtake agreements: Advance negotiations with airlines, fuel traders, and other potential buyers to the term-sheet stage, specifying price indexation mechanisms, volume ramp-up schedules, and sustainability clauses. Clarify the strategy outlining the share of SAF for domestic use versus export.
    - Alignment with global frameworks: Ensure commercial terms are consistent with the market needs. Align on sustainability criteria and schemes depending on the market served (e.g., CORSIA for international markets, or others for regional markets).
2. **Feedstock strategy and sustainability compliance**
    - Feedstock assessment: Conduct detailed field studies and supply chain mapping to quantify available volumes, evaluate seasonal variability, and identify logistics constraints.
    - Feedstock price: assess current and projected feedstock price and identify measure on how to derisk on its volatility.
    - Strategic procurement: Secure multi-year feedstock supply via MoUs or term sheets with aggregators and cooperatives or evaluate how a consortium for feedstock production can be assembled. Define pretreatment specifications and plan for logistics hubs, storage facilities, and transport routes.
    - Sustainability certification: Submit all relevant feedstocks for approval under CORSIA and establish robust systems for traceability, chain-of-custody, and measurement, reporting, and verification (MRV).
3. **Supply chain and logistics:** validate its reliability, identify potential bottlenecks, and ensure readiness for commercial-scale SAF production
4. **Procurement and delivery strategy**

- Contracting approach: Decide between EPC (Engineering, Procurement, and Construction) and EPCM (Engineering, Procurement, and Construction Management) models based on project complexity, risk allocation, and delivery timelines.

- Execution planning: Prepare procurement packages, detailed execution schedules, and QA/QC frameworks to ensure efficient delivery, cost control, and timely commissioning.

7.1.3 Recommendations for the financial domain

Establishing a bankable financial model is critical for the successful development of a SAF project. A robust financial strategy should integrate project economics, funding structures, and policy alignment to ensure investment attractiveness and long-term viability. The following actions are recommended:

1. **Financial modelling**

   - Detailed financial model: Develop a comprehensive financial model capturing capital expenditures (CAPEX), operating costs (OPEX), taxes, subsidies, and potential carbon pricing mechanisms.

   - Sensitivity and scenario analysis: Incorporate multiple scenarios to evaluate the impacts of feedstock prices in the long-term, policy shifts, and market volatility on project economics.

2. **Financing strategy and capital structuring**

   - Funding opportunities: Explore diverse financing sources, including multilateral development banks, climate funds, green bonds, and other sustainable finance mechanisms.

   - Capital stack design: Structure a balanced financing mix combining equity and debt to optimize project bankability.

   - Risk mitigation tools: Secure guarantees, insurance instruments (e.g., performance, construction, and political risk), and other de-risking mechanisms to attract private investment.

3. **Policy and incentive alignment**

   - Policy integration: Align financial assumptions and pricing strategies with national energy transition policies and international sustainability frameworks (e.g., CORSIA) to ensure compliance.

   - Regulatory Engagement: Collaborate with policymakers to be informed about supportive mechanisms, that can improve the project's financial viability.

7.1.4 Recommendations for the governance domain

Effective governance is essential for coordinating stakeholders, ensuring regulatory alignment, managing risks, and achieving Final Investment Decision (FID) readiness. A robust governance framework integrates decision-making structures, reporting mechanisms, and strategic partnerships while maintaining alignment with national and international sustainability objectives. The following actions are recommended:

1. **Stakeholder engagement and partnerships**

   - Strategic partnerships: Initiate dialogue with investors and potential project partners to define operational structures, roles, and collaboration mechanisms.

   - Stakeholder engagement plan: Develop a structured plan to identify and engage all key actors across the value chain, including farmers, aggregators, airlines, regulators, policy makers, fuel suppliers, financiers, and local communities.

- Community consultations: Conduct early and transparent discussions with local communities for social acceptance, e.g., through Strategic Environmental and Social Assessment (SESA) on the sustainability and social impacts of the SAF development in Kenya.

2. **Project governance and FID readiness**
    - Governance framework: Define decision gates, reporting mechanisms, and management responsibilities to ensure effective oversight throughout project development.
    - FID prerequisites: Establish clear requirements for advancing to FID, including e.g.,
        - Completion of FEED study
        - Secured regulatory permits
        - Signed feedstock agreements
        - Finalized offtake contracts
        - Bankability of the project
    - Readiness to invest: Ensure key technical, financial, and contractual conditions are met to de-risk FID approval.
3. **Policy alignment and compliance**
    - National policy and international frameworks: Ensure compliance with national and international policy for aviation markets, especially keeping in mind the developing economy challenges and opportunities.
4. **Risk management**
    - Risk register: Maintain a live risk register identifying technical, market, feedstock, financial, and schedule-related risks. Use standardised template documenting risks, causes, impact, likelihood and mitigation measurements.
    - Testing scenarios: Conduct sensitivity analyses and scenario modelling to evaluate project resilience under different market and policy conditions.
    - Mitigation measures: Implement proactive risk mitigation strategies to strengthen project robustness.
    - Derisking strategies: e.g., insurances. Technology Performance Insurance is an insurance product designed to cover the risk that a new or innovative technology underperforms versus the guarantees of the technology provider. If the SAF plant does not achieve certain output, efficiency, or quality targets, the insurer compensates the project owner and/or lenders for part of the financial shortfall. By transferring this risk to an insurer, the project looks less risky to banks and investors. This can lower financing costs (cheaper debt, more equity interest), improve chances of financial close, and accelerate deployment of SAF capacity.

It is essential for the company to define a clear strategy and vision, along with the pathway to achieve it. Projects of this scale require significant human resources, dedicated teams, and time investment. Aligning the project with the national SAF roadmap ensures regulatory certainty and enhances the project bankability, making it more attractive to investors.

7.2 RECOMMENDATIONS FOR THE SAF STATE ROADMAP TO HELP THE SAF BUSINESS CASE

A SAF roadmap sets out a coherent pathway for developing SAFs. Its purpose should translate national climate and industrial objectives into an actionable sequence to favour projects, enable infrastructures and build human capital across the entire value chain, such as feedstock, technology pathways, logistics, certification, airport interface, and offtake.

Establishing a clear vision and strategy in the roadmap before issuing policies is essential. A shared vision anchors priorities (e.g., which pathways to deploy, when, and where) and defines success metrics (cost, GHG intensity, local value creation). Strategy defines how to reach the target, identifying resources, technology choices, infrastructure needs, financing structures, and governance roles. The roadmap provides the design brief for policy. It specifies which instruments are needed (mandates, certification, registry/MRV, fiscal or levy mechanisms), when they should take effect and how they will be reviewed and sunset as markets mature. In short, policies are the tools; the vision and strategy ensure those tools are applied in the right order, at the right scale, and for the right outcomes in terms of GHG emissions reductions, competitive costs, and durable socio-economic benefits.

In this section, we present a set of recommendations for key elements of the roadmap considering the outcome of this study.

7.2.1 Recommendations for vision for the short- and medium/long-term plan

In several regions worldwide, roadmaps and policy frameworks supporting SAF development have already been established, providing valuable insights and best practices. These existing strategies can serve as inspiration and a reference point for Kenya, offering lessons on how to design effective measures that stimulate investment, support technology deployment, and enable market uptake. By critically reflecting on these international experiences and adapting them to the local context, Kenya should define and implement a tailored SAF roadmap and policy framework that aligns with its unique resource potential, infrastructure, and economic priorities.

A comprehensive and forward-looking vision for the development of a SAF roadmap can be structured around three strategic pillars, in line with approaches already being adopted by other countries.

- First, the roadmap should aim to expand SAF supply and market uptake by fostering regional feedstock and fuel production capabilities, strengthening outreach and workforce capacity, and providing robust commercialization and infrastructure support. This also requires the implementation of enabling policies, streamlining of regulatory approvals for diverse SAF production pathways, and ensuring close coordination with key stakeholders.
- Second, minimizing the cost of SAF production is critical for achieving large-scale deployment. This entails driving down costs across the entire value chain by diversifying feedstock availability, advancing a wider portfolio of conversion technologies, and, where possible, repurposing existing production assets. Additionally, creating policy mechanisms to de-risk investments.
- Third, the roadmap must prioritize sustainability criteria and environmental/social benefits and capacity building. This involves maximizing environmental and social co-benefits, reducing lifecycle carbon intensity across the entire supply chain, and enforcing rigorous sustainability standards to ensure high environmental performance.

Together, these three pillars provide a coherent strategic framework to guide policy development, technology deployment, and market transformation, ultimately supporting the large-scale adoption of SAF and contributing to the decarbonization of the aviation sector.

It is beneficial for a SAF roadmap to include quantifiable targets and a clear implementation timeline to guide market development and policy action. Typically, such targets are defined across three-time horizons: short term (0–5 years), medium term (5–10 years), and long term (>10 years). Short-term targets are essential to stimulate initial market uptake and encourage investment, while long-term objectives are equally important to ensure market stability, policy continuity, and energy security.

Targets can be formulated in different ways, such as setting a blending target (specifying as volume percentage of SAF in the jet fuel) or establishing a lifecycle GHG emissions reduction target. These two approaches are not directly equivalent. The use of one tonne of conventional jet fuel corresponds to the emission of 3.8 t of CO_2 equivalent, yet the lifecycle greenhouse gas savings achieved by SAF are generally below 100% (<89 g_{CO2eq}/MJ). For example, HEFA-based SAF produced using biogenic hydrogen can achieve around 78–85% reductions in lifecycle emissions (further deviation can depend on the feedstock as well). According to CORSIA regulations, SAF can currently be certified if it achieves a minimum GHG emissions reduction of 10% compared to conventional jet fuel. Therefore, the same volume of jet fuel can have different environmental impact.

The choice of policy framework (whether based on a blending mandate or a GHG emissions savings target) has significant implications for producers, overall system design and on the market criteria. A blending target incentivizes producers to minimize the cost per unit volume of SAF, potentially favouring lower-cost pathways even if their GHG reductions are limited. In contrast, a GHG emissions savings target encourages strategies aimed at maximizing emissions reductions per unit volume and minimizing CO_2-equivalent abatement costs. Consequently, the selected policy approach strongly influences the key drivers of SAF deployment and may also affect decisions regarding the design and configuration of production facilities. Furthermore, a generic GHG emissions savings target should ideally specify whether a defined share of these reductions must be achieved directly through SAF or whether alternative mitigation measures can also contribute toward meeting the target.

This study indicated that, under the HEFA production pathway, it would be technically possible to produce approximately 180 000 t/year, which corresponds to around 25% of Kenya's estimated 2024/2025 jet fuel consumption and an approximative GHG emission savings compared to the whole annual jet fuel consumption of 21%. However, these figures should be considered indicative. Accurate yield estimates will require engagement with technology providers to account for the specific performance of their processes and the influence of the selected feedstock mix. It should be considered that, depending on market conditions, the refinery may choose to operate the facility in a flexible production mode, allocating a portion of its output to HVO diesel, which would consequently reduce the available volume of SAF.

Furthermore, clarifying the market strategy of the refinery is essential, determining the intended balance between serving domestic aviation demand and exporting SAF. In addition, when setting any production target, it is important to consider that Kenya's aviation market is forecasted to grow, with jet fuel demand projected to increase by roughly 5% per year. If production capacity remains constant at MAX SAF production, the plant's relative contribution to national demand is expected to decline over time. After five years (in 2030), it may cover only about 20% of the blending target or approximately 17% of the required GHG emissions reduction, while after ten years, its contribution could drop to around 15% of the blending target or roughly 13% of the GHG emissions reduction.

Additionally, Kenya's current jet fuel imports are approximately 1.208 million m³/year, a portion of which is re-exported to neighbouring countries. It is recommended to assess whether these neighbouring countries will participate in the SAF initiative under the regional framework.

Therefore, when establishing SAF targets, it is essential to adopt an evidence-based approach that accounts for all technical, economic, and environmental considerations. This ensures that the defined objectives are not only ambitious but also realistic, achievable, and aligned with national capabilities and market conditions.

7.2.2 Recommendations for feedstock and conversion technologies

Feedstock availability and the associated conversion technologies play a critical role in shaping a sustainable and economically viable SAF supply chain. These two factors must be assessed together to define an optimal strategy for both short-term deployment and long-term development.

<u>SAF pathways</u>

The findings of this study indicate that, at present, HEFA represents the most cost-effective and commercially mature technology for SAF production. In Kenya, as in many other regions globally, the deployment of HEFA could enable the lowest production costs among the currently available pathways. Therefore, HEFA is recommended as the preferred short-term strategy for SAF production over the next five years. From a technological perspective, it is advantageous to minimize capital investment by leveraging existing infrastructure, such as the facilities available at the Mombasa refinery. It is also important to prioritize the implementation of technologies that reduce GHG emissions per unit of fuel produced, thereby improving the overall environmental performance of SAF production.

For the longer term, other advanced technologies, such as Power-to-Liquids (PtL), Alcohol-to-Jet (AtJ), and gasification of municipal solid waste (MSW), should be further explored and considered as part of Kenya's SAF roadmap. As these technologies mature and their associated technical and financial risks decrease, they could play a key role in diversifying SAF supply and supporting deep decarbonization targets.

Furthermore, it would be optimal if supportive policy frameworks were established prior to the final investment decision (FID) for any large-scale SAF facility. Such policies would help secure financing, reduce investor risk, and provide clear market signals.

Finally, given Kenya's significant renewable energy potential and strategic location, there is an opportunity to establish multiple SAF production facilities across the country, leveraging different technological pathways. Considering the broader context, it may also be beneficial to design this strategy within a regional framework, enabling East African cooperation to maximize feedstock utilization, infrastructure efficiency, and market integration.

<u>Comprehensive feedstock assessment and supply chain</u>

Improving feedstock supply logistics is essential to enhance the efficiency, cost-effectiveness, and environmental sustainability of SAF production. Developing robust supply chain systems, including transportation, storage, and preprocessing infrastructure, can significantly reduce both operational costs and the carbon intensity associated with delivering feedstocks from the producer's field to the conversion facility.

In the short term, for a HEFA-based SAF production facility, it will be crucial to maximize the sustainable supply of lipid-based feedstocks to support stable and cost-effective operations. This can be achieved by enhancing the collection and recovery of fats, oils, tallow, and greases waste and by strategically leveraging vegetable oil production within Kenya's agricultural systems. To achieve this, a comprehensive approach to feedstock innovation is required. First, it is important to assess resource markets and accurately quantify the sustainable availability of different feedstocks. Secondly, it is important to strategically plan the expansion of vegetable oil production, particularly by targeting marginal lands that are less suitable for food crops to avoid competition with food production. Intercropping and multi-cropping is encouraged to ensure there is no interference with food sustainability. Diversification of the feedstocks for HEFA will be important because it enhances supply chain resilience, mitigates risks associated with feedstock price volatility and availability, and ensures a more stable and sustainable SAF production capacity over the long term. However, feedstock selection should be carried out carefully, considering not only sustainability and availability but also the technical feasibility and costs of the pre-treatment. Such planning should not focus solely on cultivation areas but must also consider the logistics and overall sustainability of the supply chain, including harvesting, collection, storage, and transportation. Given that feedstock sourcing has a major influence on the overall carbon footprint of SAF, a holistic approach is essential to ensure that expanding production capacity does not compromise environmental integrity or social sustainability.

At the same time, greater attention should be given to traceability, chain of custody, and feedstock certification, as these elements are essential for ensuring transparency and sustainability throughout the supply chain. Regarding feedstock sustainability criteria, it is important to ensure alignment with the requirements of the target markets that the produced SAF will serve. As a recommendation, applying the CORSIA sustainability criteria not only to international flights but also to domestic operations would simplify regulatory compliance and help avoid policy fragmentation across different market segments.

In the short term, the Mombasa refinery represents a suitable location for SAF production due to its existing infrastructure and proximity to fuel distribution networks. However, in the long term, the relationship between feedstock availability, conversion technology, and logistics must be carefully evaluated to choose the optimal site for the plant. For example, production pathways with low feedstock-to-fuel conversion efficiencies, such as Alcohol-to-Jet or gasification-based processes, would benefit from being co-located near the feedstock source to reduce transportation costs and improve overall supply chain efficiency.

For the SAF roadmap, Kenya should strategically define the preferred feedstocks for the short and long term, establish clear sustainability criteria, and identify the policy and infrastructural measures needed to enable the development of this sector.

7.2.3 Recommendations for enabling end use

To facilitate the seamless integration of certified SAF into Kenya's aviation sector by making its uptake at Kenyan airports easy, safe, and commercially viable. Achieving this objective requires the development of a robust supply chain and fuel distribution infrastructure that ensures SAF can be delivered, stored, and blended in compliance with international certification standards (e.g., ASTM D7566, D1655, JIG procedures). Furthermore, regulatory frameworks and operational guidelines should guarantee safety and quality assurance across the entire value chain, from production to aircraft refuelling. In this case, it is important to assess which aspects require nationalization and determine whether approvals from EPRA or KEBS may be necessary.

From a commercial perspective, creating economically viable business models is essential to make SAF adoption attractive for airlines. This may involve introducing policy incentives, such as tax exemptions, subsidies, or blending mandates, and fostering partnerships between fuel producers, airports, and airlines to reduce costs and improve supply security. Similar concepts to the green hydrogen projects can be elaborated, such as a range of incentives which could include full exemptions from VAT, excise duty, import duty, and import declaration fees on imported goods, zero-rated VAT on local supplies, as well as tax holidays and reductions in corporate tax rates.

The roadmap and policies should also clearly define the roles and responsibilities of all stakeholders across the SAF value chain, including producers, fuel suppliers, and offtakers such as airlines, to ensure effective coordination and accountability. Ensuring alignment with global sustainability certification schemes will also be critical to enable Kenyan airports to serve as regional SAF hubs, supporting both domestic and international carriers.

7.2.4 Recommendations for building a supply chain

Building a refinery alone will not be sufficient to enable large-scale SAF deployment; rather, the entire supply chain must be carefully designed and coordinated to ensure success.

The SAF supply chain encompasses multiple stages, including feedstock production, collection, pre-elaboration and distribution to SAF production facilities; the conversion of feedstock into fuel; and the transport of the finished product to the airport for aircraft refuelling. Because current fuel certification standards mandate that SAF be blended with conventional jet fuels, the SAF supply chain must also be closely integrated and coordinated with the existing fossil-based aviation fuel industry. For the HEFA plant in Mombasa, these processes can be integrated within the same facility; however, similar considerations should also be applied when planning future SAF plants in the long term.

As SAF production remains a nascent industry, supply chains are still immature and will require significant investment and resources to establish. In this context, stakeholder coalitions play a pivotal role by creating platforms for collaboration and engagement among diverse actors across the value chain, including feedstock providers, producers, fuel suppliers, policymakers, and airlines. Such coalitions are critical for developing effective strategies that drive both the scalability and sustainability of SAF deployment. By fostering collaboration, they help stakeholders identify common objectives, mitigate financing and investment risks, navigate regulatory challenges, and overcome infrastructure constraints. Moreover, these coalitions enable the alignment of industry efforts with policy frameworks, which is essential for attracting investment, promoting market growth, and strengthening the resilience of the aviation sector.

The Kenya National Steering Committee on Acceleration of Development and Deployment of SAFs has already been established to facilitate exchange and coordination among the different stakeholders involved in SAF development. This represents an important first step toward the establishment of a robust SAF supply chain. The success of existing SAF stakeholder coalitions largely depends on several interrelated factors. Three critical elements are the active support and engagement of experienced key members, inclusivity among partners, clear and consistent communication both among members and with external stakeholders. To ensure effectiveness, clear objectives, defined targets, deliverables, and realistic timeframes should be agreed upon by all partners. Moreover, dedicated time and resources must be invested to advance this initiative and ensure its successful implementation. Effective collaboration among stakeholders is essential to overcome challenges and achieve the milestones required for developing a mature SAF supply chain. However, a lack of alignment in vision and objectives may lead to conflicting efforts, which can ultimately slow or hinder progress.

The roadmap can also specify the objectives of the steering committee and establish a clear timeframe for achieving them. The government can play a key role by providing a clear strategic vision, facilitating coordination among stakeholders, and stimulating access to the necessary resources to support SAF development. It should be noted that different feedstocks and conversion technologies are associated with distinct supply chain structures, which may therefore require specific optimization strategies tailored to each pathway.

It would be advisable to designate a driving partner or central coordinating entity responsible for overseeing the development of the SAF supply chain and modelling/assessing its feasibility. Having a single, accountable body to monitor, evaluate, and guide supply chain planning would help ensure consistency, reduce risks, and improve overall project coordination. For the single project, this responsibility could be best entrusted to the SAF producer, as this would allow the supply chain to be optimized in alignment with production plans and operational requirements.

7.2.5 Recommendations for regulatory framework and support policies

Policies play a central role in de-risking SAF projects by providing long-term regulatory certainty and creating stable market demand. A consistent and supportive policy framework is essential to mitigate financial risks, thereby unlocking investment, driving technological innovation, and enabling the development of efficient SAF supply chains. Policies must ensure that production relies on sustainable feedstocks capable of delivering significant lifecycle GHG emissions reductions and define clear sustainability criteria accordingly.

The development of a scaled SAF market requires a coordinated mix of policy instruments addressing supply, demand, and enabling measures, tailored to each country's feedstock availability, supply chain maturity, energy dependency, and climate objectives. A balanced approach of policies is needed to stimulate growth while maintaining market equilibrium.

While the existing policy framework provides an initial foundation, further measures are needed to enable the successful deployment of SAF in Kenya. Although various strategic documents and policies reference the potential use of biofuels, no binding mechanisms are currently in place to translate these ambitions into implementation.

A coherent policy framework for SAF in Kenya can be drawn on proven elements from recent international practice while remaining tailored to domestic constraints. According to *Clean Skies for Tomorrow: SAF Policy Toolkit* (WEF, 2021), the roadmap for scaling up SAF deployment can be structured around three strategic pillars: (1) growing SAF supply, (2) stimulating SAF demand, and (3) enabling the connection between supply and demand through trade facilitation and certification harmonization:

1. **Growing SAF supply examples:**

- Increase production capacity by supporting the scale-up of SAF facilities and bringing new pathways to market.
- Fund and promote research and development (R&D) to advance emerging technologies and de-risk first-of-a-kind SAF plants.

- Support the deployment of higher-TRL technologies by facilitating investments
- Improving production efficiency and optimizing product slate
- Increase sustainable feedstock availability through improved production, collection, logistics, and processing, while prioritizing feedstocks with low carbon intensity.

2. **Stimulating SAF demand examples:**

- Mandatory mechanisms: Introduce SAF blending mandates to ensure a minimum share of SAF in total jet fuel consumption. The mandate should place a clear obligation on relevant actors in the value chain, such as fuel suppliers, blenders, airports, or airlines, to raise SAF's share in jet fuel over time, thereby sending a strong demand signal to the market. This measure does not impose direct burden on taxpayers.
- Market-based mechanisms:
  - Reduce SAF prices for users through direct and indirect subsidies. For example, incentives can be provided to SAF producers either as general benefits, such as tax holidays, or linked proportionally to the volume of the SAF produced or to the verified GHG emissions reductions. Such measures can help enhance plant competitiveness and stimulate investment in SAF production.
  - Improve SAF competitiveness by increasing the relative cost of conventional jet fuels.
- Voluntary mechanisms: Integrate SAF into public procurement policies and promote industry-led commitments to SAF adoption.

3. **Enabling SAF supply-demand connection examples:**

- Facilitate SAF trade by creating dedicated marketplaces and streamlining import and export procedures. An example can be to implement a domestic carbon pricing scheme or an aviation-specific cap-and-trade mechanism to internalize the cost of GHG emissions associated with fossil jet fuels.
- Harmonize SAF certification frameworks to guarantee compatibility across jurisdictions and simplify compliance with ASTM and CORSIA standards.

Globally, a variety of policy frameworks and support mechanisms have been implemented to promote SAF deployment. There is no single universally optimal approach; rather, it is essential to design a strategy tailored to the country's specific context, taking into account its resources, market dynamics, and policy priorities.

In the United States, early supply has been catalysed by time-limited federal tax credits tied to lifecycle carbon performance: the SAF credit pays 1.25 USD/gallon for fuels achieving at least a 50% lifecycle GHG reduction, plus up to 0.50 USD/gallon for deeper reductions in 2023–2024; from 2025, the tech-neutral Clean Fuel Production Credit continues support based on carbon intensity rather than a fixed pathway, offering a template for rewarding verified performance rather than volumes alone.

The European Union has taken a mandate mixed with incentives approach through ReFuelEU Aviation, applying to all flights departing EU airports and requiring a minimum 2% SAF share in 2025, 6% in 2030, and a continued ramp reaching 70% in 2050, with a defined sub-target for synthetic e-fuels; this creates a single regional market signal across airports and suppliers. By reducing lifecycle emissions, SAF can lower compliance costs under the EU Emissions Trading System (ETS), which plays as incentive. The United Kingdom is implementing a similar obligation from 2025, starting at 2% and rising to 10% by 2030 and 22% by 2040. In the United Kingdom, Contracts for Difference (CfDs) are used to support SAF deployment by guaranteeing producers a fixed strike price for their fuel.

Singapore has introduced a national SAF target and a SAF levy. Starting in 2026, all flights departing from Singapore will be required to use SAF, beginning with a 1% blending target. This initial target aims to encourage investment in SAF production and support the development of a resilient and cost-effective SAF ecosystem. Subject to global market developments and the wider availability of SAF, the target is planned to increase to 3–5% by 2030. Additionally, centralized SAF procurement will be implemented to aggregate demand and achieve economies of scale.

Brazil's "Fuel of the Future" law offers an outcome-based variant: ProBioQAV mandates airlines to achieve gradual emissions reductions on domestic flights, beginning with 1% in 2027 and scaling to 10% by 2037, allowing compliance through SAF use or other approved measures, supporting book & claim to avoid transportation of the physical fuel in remote destinations, which can reduce the environmental benefit.

Kenya may consider incentives, mandates, levies, or a combination thereof as key policy instruments to promote the deployment of SAF. While incentives can play an important role in accelerating SAF adoption, they are not a must and should be carefully targeted to ensure maximum effectiveness. Their use should be minimized or avoided if fiscal resources are limited or must be prioritized for other strategic sectors. In the case of green hydrogen, Kenya provides incentives such as multi-year tax holidays, duty and VAT exemptions, investment deductions, preferential corporate tax rates, and access to special electricity tariffs. Preferably, any fiscal incentives should be carefully targeted, time-bound, and explicitly linked to verified lifecycle GHG emissions performance to ensure environmental integrity and cost-effectiveness. It should be recognized that using incentives alone to make SAF fully price-competitive with conventional jet fuel is not financially practical.

Especially in contexts where fiscal space is constrained, establishing a SAF mandate or introducing a calibrated levy (and potentially putting higher taxation of fossil fuels) can help narrow the price gap between SAF and conventional Jet A-1. Moreover, if a SAF blending mandate is introduced, it should clearly define the obligated parties, e.g., whether compliance lies with fuel suppliers, airlines, or other actors within the aviation value chain, ensuring regulatory clarity and effective implementation. Alternatively, a dedicated SAF levy on flights could be introduced to finance SAF procurement, with potential variations based on flight distance and SAF blending targets. This would help bridge the cost gap between SAF and conventional jet fuel, splitting proportionally to the jet use the levy across airlines, which can pass the levy on to passengers through ticket prices. A centralized institution, which could be also part of the government, could manage SAF procurement.

Looking ahead to 2030, it is likely that only one big SAF production facility may be operational in Kenya, and even this is not guaranteed. Since no large-scale SAF production facilities exist in Africa, importing SAF would be challenging and costly. Therefore, a fair policy with feasible targets needs to be in place to avoid penalizing airlines or fuel suppliers if domestic production does not materialize as expected.

Given this context, to bridge the green premium and provide stability to the business case, Kenya could consider adopting a phased approach, where achievable targets are set for different years. It could be implemented as a mandate or a levy mechanism, potentially valid from the entry in operation of a certified domestic refinery approved by the relevant authority. Regardless of the approach Kenya chooses to pursue, it is essential that the policy provides a clear and consistent signal to attract investment and ensure long-term market stability.

Additionally, the adoption of innovative mechanisms, such as book-and-claim systems, which enable airlines to claim the environmental benefits of SAF produced elsewhere, could provide Kenya with greater flexibility in meeting its aviation decarbonization targets while stimulating early market development. Establishing or participating in carbon markets and introducing penalties or higher pricing for fossil jet fuels could help reduce the green premium by improving the relative competitiveness of SAF.

Furthermore, the policy framework should incorporate periodic reviews to assess progress, adjust measures as needed, and ensure alignment with evolving technological and market conditions (Measurement, Reporting, and Verification protocols).

Additional measures could also be considered to facilitate the establishment of SAF production in Kenya. These include streamlining permitting procedures to reduce administrative barriers and improve investor confidence, as well as ensuring a reliable supply of sustainable feedstocks by adopting structured policies for the collection and traceability of used cooking oil, tallow and other waste. To further stimulate investment, financial de-risking mechanisms, such as public guarantees, insurance instruments, and access to green finance tools like green bonds and low-interest sustainability-linked loans, can play a critical role.

Moreover, harmonizing SAF certifications and sustainability standards at the domestic, regional (East African Community, EAC), and international levels, while simplifying cross-border procedures for certified feedstocks and fuels, would significantly enhance supply chain efficiency. In addition, aligning national policies with international frameworks such as CORSIA would promote regulatory consistency, which is particularly important given that most flights in Kenya are international.

To drive the effective deployment of SAF, governments should set ambitious and achievable national targets, while working closely with the private sector and international partners to ensure alignment. Such coordination is essential to avoid fragmented policy approaches, misaligned incentives, and risks such as feedstock diversion, price volatility, thereby ensuring that public resources are used efficiently and sustainably.

7.2.6 Recommendations for capacity building and communication

The roadmap should define clear strategies for strengthening human capacity and establishing effective communication mechanisms throughout the development of the SAF sector. The successful deployment of SAF in Kenya depends not only on technological readiness and regulatory alignment but also on robust human resource capacity across the value chain (for more details Section 6.10). Targeted training is required for farmers and feedstock suppliers on sustainable practices, residue collection, and traceability to meet international sustainability standards such as CORSIA. Technology operators and industry professionals need competencies in refinery operations, quality assurance, logistics, and SAF market integration, supported by universities, specialized institutes, and exchange programs. Financiers and project developers require capacity building on SAF economics, risk assessment, and financing mechanisms, while policymakers and regulators must strengthen knowledge of global best practices, certification systems, and policy design. Finally, regional collaboration and knowledge-sharing platforms can foster coordinated capacity building across stakeholders. Investing in human capital will not only accelerate SAF adoption but also generate broader socio-economic benefits, including job creation, agricultural productivity, and institutional strengthening.

The roadmap should establish a national SAF registry and data platform to track batch attributes, greenhouse gas (GHG) intensity, and certificate issuance and retirement. Training for operators and verifiers on data capture, assurance, and audit trails will be essential to ensure accuracy and credibility. To enhance transparency, an annual SAF market report should be published, summarizing production volumes, feedstocks used, GHG performance, and audit outcomes.

A comprehensive communications strategy should be developed to engage communities, farmers, collectors, airlines, and investors throughout SAF deployment. Communication efforts should highlight environmental safeguards on land, water, and biodiversity, as well as local livelihood benefits and available grievance mechanisms. Book-and-claim systems and safeguards against double counting can be implemented. Additionally, standardized claims guidance should be offered to airlines and corporate customers to prevent greenwashing and ensure alignment with CORSIA reporting requirements.

7.3 CONCLUSIONS AND OUTLOOK

This study provides an initial proof of concept of the techno-economic potential of implementing SAF production in Kenya. The findings suggest that the country, and particularly in the location of Mombasa, has potential to develop into a regional hub for SAF production and distribution; however, several key considerations must be addressed to establish a robust and sustainable SAF supply chain.

The Mombasa refinery has been decommissioned for over a decade, and only a portion of its infrastructure is still operational, such as the storage facilities (to be confirmed), distribution networks, and blending capabilities. To enable commercial-scale SAF production, substantial investments will be required, especially for a new HEFA unit, dedicated pretreatment facilities, a hydrogen production unit and the modernization of utilities.

From an economic perspective, HEFA-based SAF currently appears to be the most promising short-term option. Under favourable conditions, production costs could remain below 2 000 USD/t, a price broadly aligned with potential SAF market benchmarks. However, the financial viability of such a project depends on refining several critical variables during the next stages of project development:

- Feedstock price and availability: Given the sensitivity of SAF production economics to raw material costs, detailed supply chain assessments and long-term procurement strategies are essential.
- SAF offtake agreements with airlines or fuel suppliers: to increase bankability
- Final investment costs (CAPEX): More accurate cost estimates will emerge during feasibility studies (FEL-2) and front-end engineering design (FEL-3) phases.
- Financing structure and interest rates: Access to concessional finance, green bonds, and climate funds could significantly improve project bankability and overall competitiveness. It is advisable to reach out to agencies that can assist with financial structuring (e.g., ICAO Finvest Hub).

Preliminary findings indicate that, with the right technical choices, feedstock strategies, and financing structures, SAF production in Kenya can be economically viable. Given Mombasa's infrastructure, strategic location, and regional importance, the development of a SAF production facility is technically and commercially feasible.

This study concludes that the SAF business case merits to be analyzed in further development studies (e.g., feasibility study FEL-2). Subsequent phases should focus on feedstock supply chain, engineering feasibility studies, stakeholder engagement (e.g., through the SAF Steering Committee), financial modelling, and policy alignment to refine assumptions and ensure successful implementation. If properly structured, SAF development and deployment in Kenya could not only support domestic aviation decarbonization but also position the country as a regional leader in sustainable fuel production.

In the mid-term and long term, other SAF production pathways, such as Alcohol-to-Jet (AtJ), gasification of MSW, and Power-to-Liquid (PtL) technologies, may also hold significant potential for Kenya. However, at present, their production costs remain uncompetitive compared to HEFA unless strong policy frameworks are introduced to mandate or incentivize their adoption.

For the successful deployment of SAF, it is essential that national policies provide a clear and consistent commitment to support investment decisions, which at the moment is lacking. In addition, ensuring full compliance with international certification systems such as CORSIA will be critical to accessing global markets and maintaining credibility.

Furthermore, SAF development must be approached at two interconnected levels. At the company level, a clear strategy is required to manage technology selection, feedstock sourcing, financing, and stakeholder engagement. At the State level, a coordinated policy framework is needed to ensure regulatory stability and demonstrate long-term commitment to the energy transition. This dual approach is essential to develop the project, de-risk investments, attract capital, and enable Kenya to position itself as a competitive regional hub for SAF production in the coming years.

While this study represents an initial step in assessing the feasibility of SAF production in Kenya in the location of Mombasa, much more work remains to be done. Developing SAF at scale requires the mobilization and coordination of multiple sectors, given the cross-sectoral nature of the HEFA pathway and other SAF technologies.

The successful realization of such a project demands persistence and long-term dedication. On the one hand, SAF project developers must strategically mature their business cases and secure financing. On the other hand, the government must establish a supportive policy and regulatory environment that enables SAF projects to flourish. This requires a holistic approach combining capacity building, stakeholder engagement, and policy coherence to create the right conditions for investment and operational success. The SAF national steering committee could play a pivotal role in coordinating these efforts. However, its success will depend on setting clear timelines, defined deliverables, and ensuring active collaboration among all stakeholders. Ultimately, communication, engagement, and partnership will be the key drivers of success for SAF deployment in Kenya.

Importantly, clear and supportive policies should ideally be in place before the Final Investment Decision (FID) to provide security and investor confidence. Considering the expected project timeline, with feasibility studies and FEED likely taking 1.5 to 2 years (~ time to FID) and construction and commissioning requiring an additional 3 years, it is unlikely that full-scale operations could commence before 2030. In parallel, dedicated working groups or teams should be established within the company to address the technical and operational aspects required for the successful development and construction of the project.

Although a considerable amount of work is still required, this study demonstrates that Kenya possesses the strategic location, infrastructure potential, and resource availability potential needed to develop a competitive SAF industry. With coordinated actions, clear policies, and sustained commitment, Kenya has the potential to become a regional leader in SAF production, driving both economic growth and climate progress.

APPENDIX - CONTRIBUTIONS

We would like to express our sincere gratitude to the institutions that engaged us in insightful discussions on Sustainable Aviation Fuel (SAF) in Kenya. We acknowledge the institutions listed below in alphabetical order.

Institution	Efforts to acknowledge
748 Air Services	Perspectives from airlines on SAF adoption
Agriculture and Food Authority Kenya	Exchange on current oilseed feedstock cultivation in Kenya
Alfa Laval	Discussions on pretreatment processes for the HEFA pathway (no proprietary data reported in this study)
Agência Nacional de Aviação Civil - Brazil	Discussions on approaches to policy development
Astral Aviation Airline	Perspectives from airlines on SAF adoption
Bleriot	Exchange about current activities in Kenya
Civil Aviation Authority of Singapore	Discussions on approaches to policy development
European Bank for Reconstruction and Development (EBRD)	Exchanges on financial opportunities and investment possibilities
Eni Kenya	Exchange on Eni activities in Kenya, Agri Feedstock Program
GET.invest	Exchanges on financial opportunities and investment possibilities
Honeywell UOP	Preliminary exchanges and discussions on the HEFA pathway (no proprietary data reported in this study)
ICAO Consultants - Ethiopia	Discussion about feedstock and regional synergies
Kenya Airports Authority (KAA)	Insights into airport operations and infrastructure
Kabras	Insights on sugarcane and ethanol industry by-products in the context of AtJ pathways
KenGen	Discussions on renewable energy, green hydrogen, and insights on Olkaria geothermal plants
Kenya Airways	Perspectives from airlines on SAF adoption
Kenya Railways Corporation (KRC)	Discussion on railway network and logistics
Ministry of Energy and Petroleum - Kenya	Exchange on policies and the current regulatory status
Ministry of Transport - Kenya	Insights on renewable fuels for transportation
Ministry of Transport of Singapore	Discussions on approaches to policy development
Morendat Institute of Oil & Gas (MIOG)	Exchange on capacity building for emerging sectors such as SAF
Masinde Muliro University of Science and Technology (MMUST)	Exchange of data on feedstock options, specifically yellow oleander and sugar-based feedstock.
National Treasury of Kenya	Exchanges on financial opportunities and investment possibilities
National Environment Management Authority of Kenya (NEMA)	Insights on used cooking oil collection in Kenya
Netherlands Ministry of Infrastructure and Water Management	Discussions on approaches to policy development
Rural Electrification and Renewable Energy Corporation (REREC)	Preliminary exchanges on feedstock availability and potential
The Top Energy	Discussions around potential feedstocks
Topsoe	Preliminary exchanges and discussions on the HEFA pathway (no proprietary data reported in this study)
Transport Styrelsen - Sweden	Discussions on approaches to policy development
World Bank	Exchanges on financial opportunities and investment possibilities
Zijani	Exchange about feedstock collection

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