Baseline Assessment for De-fossilising the Cut Flower Value Chain: Opportunities for Power-to-X and Green Hydrogen

International PtX Hub

On behalf of:
Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

IKI INTERNATIONAL CLIMATE INITIATIVE

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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The International PtX Hub is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Environment, Climate Action, Nature Conservation and Nuclear Safety (BMKUN). Financed by the International Climate Initiative (Internationale Klimaschutzinitiative, IKI), the International PtX Hub is a contribution to the German National Hydrogen Strategy of 2020 and represents one of the four pillars of the BMUV's PtX action programmes initiated in 2019.

As at November 2025

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Executive Summary

Kenya's cut flower industry, a leading foreign-exchange earner and major rural employer, is at a critical juncture: rising global demand for low-carbon products converges with mounting climate imperatives to decarbonise agriculture. Currently, the production of cut flowers in Kenya leads to Greenhouse gas (GHG) emissions across the whole value chain from production to market. The main emission sources are from fertiliser use-, energy consumption for heating and equipment (pumps and lighting) operation, transportation - both aviation for export markets and ground transport-and cold chain logistics that include refrigeration of the cut flowers during storage and transportation.

This baseline assessment was undertaken using stakeholder engagement through key informant interviews, survey questionnaires, field visits and desktop literature review. The assessment outlines how Power-to-X (PtX) technologies—including green ammonia for fertiliser, sustainable aviation fuels from floral residues, bio-methanol for maritime logistics, and ammonia-based refrigeration can be leveraged to reduce the cut flower value chain GHG emissions.

Presently, the cut flower sector consumes an estimated 425.6 metric tonnes annually of nitrogenous fertiliser[1]. The farms' cold storage and refrigerated transport systems mainly use Hydrofluorocarbon (HFC)such as R-410A and R-134a and Hydrochlorofluorocarbon (HCFC) such as R-22 refrigerants. They also use diesel as the main source of energy for road transport and airport ground handling equipment. Cut flower farms consume approximately 297.7 million litres[1] annually of diesel on cut flower transportation. Air freight operations, on the other hand, are powered by petroleum-based jet fuel.

> Consumption of the nitrogenous fertiliser, electricity and diesel by cut flower farms' fleets emit about 97.9 to 1,476.99 tCO_2e, 68.5 tCO_2e and 3,593 tCO_2e annually respectively. Air transport on the other hand emits an estimated 1.16 million tCO_2e per year

To defossilise hard-to-defossilise segments such as fertiliser production, air transport and refrigerant, PtX pathways such as green hydrogen, synthetic fuels, and e-ammonia are required. In addition to use of synthetic fuels such as sustainable aviation fuel (SAF), strategic modal shift of some exports to marine transport which has lower emissions compared to air freight.

The use of SAF and sustainable marine fuels (SMF) can also reduce emissions related to air freight and maritime shipping. Since production of SAF and SMF does not exist locally, pilot production can leverage cut flower bio-residues in the short term. Long term, however, Power-to-Liquid (PtL) pathways will be the most viable due to their production scaling ability and maturity of the technology.

> From field data collection, these bio residues can support the annual production of about 16,995 to 22,660 metric tonnes of SAF or approximately 14,840 metric tonnes of SMF (bio-methanol). The cost of such fuels, however, will be beyond the current conventional fuels requiring significant subsidies for potential off-takers to transition.

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[1] From primary data collection

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For the actualisation of the proposed PtX pathways implementation, the following strategic enablers have been recommended:

Current Strategic Enablers

Policy and Regulatory Frameworks

The Energy and Petroleum Regulatory Authority (EPRA) has introduced Green Hydrogen Guidelines covering sustainability criteria, licensing, and potential incentives within special economic zones. These measures reduce regulatory risk and enhance investor confidence in PtX projects, particularly for electrolysis, methanol synthesis, and SAF production near flower clusters.

Innovative Finance and De-risking Instruments

Kenya leverages the Public-Private Partnerships Act (2013) and collaborates with development banks to offer Partial Risk Guarantees (PRGs) and concessional loans—evident in projects like the Lake Turkana Wind Farm and Kopere Solar

Anchor Off-taker Agreements

Long-term offtake contracts reduce market risk and support project bankability. Kenya Airways' SAF-powered flight demonstrated the role of national carriers as anchor off takers. Similarly, the 15-year green ammonia supply agreement between TalusAg and Kenya Nut Company illustrates how fixed-price contracts can secure demand and stabilise e-fertiliser costs for farmers.

Value Chain Aggregation and Cooperative Models

The Kenya Flower Council (KFC), representing over 80% of growers, offers a platform for aggregating bio-residues, sharing logistics, and negotiating collective investment terms. This coordination will enhance economies of scale and lower transaction costs for small and medium-sized farms.

Technical Partnerships and R&D

Collaborations between local universities, technology providers, and international research institutions will accelerate the localisation of PtX technologies. The Hub's support in policy advisory, feasibility studies, and certification will help tailor modular PtX systems to Kenya's renewable and agricultural context.

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Capacity Building and Stakeholder Engagement:

Scaling PtX requires training for farms, financiers, and regulators. KFC has previously held capacity building with flower farms and other stakeholders. For instance, in 2013, it partnered with Horticultural Crops Directorate (HCD), then Horticultural Crops Development Authority (HCDA) and the Climate & Development Knowledge Network (CDKN) and KFC to develop the Carbon Reduction, Resources and Opportunities Toolkit (CaRROT), a sectoral spreadsheet tool integrating energy and water trackers with a carbon calculator.

These systematic barriers can be effectively addressed through the implementation of the following recommendations.

Current Systematic Barriers

Technology Maturity and Scale-Up

PtX technologies such as green hydrogen and ammonia production via electrolysis remain at the pilot stage in Kenya, limiting immediate scalability and commercial deployment.

Feedstock Competition

While flower farms generate significant bio-residues suitable for SAF and bio-methanol production, these are currently used for low-cost composting. Without compensation mechanisms for lost compost value and additional handling, redirecting residues to PtX applications will likely face economic resistance.

Grid Reliability and Renewable Integration

Despite Kenya's high renewable energy share, grid instability—including outages and voltage fluctuations—poses risks to some sensitive PtX equipment. Moreover, integrating solar and wind remains complex due to off-grid setups and regulatory hurdles, undermining the viability of energy-intensive electrolysers.

Logistics Inertia and Modal Shift Challenges

Transitioning from air to sea freight for cut flowers requires substantial infrastructure investment. Concerns over product quality, longer transit times, and lack of demonstrated commercial benefits will likely hinder adoption by logistics providers and exporters.

Policy Gaps and Incentive Misalignment

Kenya lacks clear PtX technologies adoption mandates and feed-in tariffs for green hydrogen. This regulatory uncertainty could likely deter investment. The gaps also will prevent long-term price signals for potential off takers.

Stakeholder Misalignment

Diverse actors across the value chain—producers, consolidators, logistics providers, and carriers—have differing priorities and risk appetites. The absence of coordination platforms, shared vision, or a lead institution hampers collective action and risks isolating pilot projects from broader systemic transformation.

Recommendations

Policy Support

The policy support needed include introduction of a National SAF Blending Mandate, SAF consumption Incentives, development of PtX Regulatory Sandbox, provision of performance-based incentives, PtX integration into the National Policies and development of dedicated Special PtX Economic Zones

Strategic Partnerships

The proposed strategic partnerships are Kenya Airways × Local SAF Producers, Green Ammonia Producers × Cold-Chain Vendors, Development Banks × Local Financial Institutions, Private Equity × Sector Incubators and Local × International Research Institutions.

Funding Opportunities

Some of the fundings and funding opportunities for PtX projects include German BMZ / KfW PtX Development Fund, EU Global Gateway & Innovation Fund, Kenya Green Bond Programme, Export Credit Agencies (ECAs), Afreximbank Country Programme, GET.invest & GET.prospect program, Acumen Resilient Agriculture Fund (ARAF) equity fund, Green Climate Fund (GCF) and European Green Deal Fund (EGDF)

List of Acronyms & Abbreviations

CAP	Common Agricultural Policy
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EGDF	European Green Deal Fund
EPRA	Energy and Petroleum Regulatory Authority
EPZ	Export Processing Zones
ETS	Emissions Trading Scheme
EU ETS	European Union Emissions Trading System
EXIM	Export-Import Bank
F.O.S.S	Flowers and Ornamental Sustainability Standard
FiT	Feed in Tariff
FT-SPK	Fischer-Tropsch Synthetic Paraffinic Kerosene
GCF	Green Climate Fund
GDP	Gross Domestic Product
GH_2-PCC	Green Hydrogen Coordination Committee
GHGs	Greenhouse Gases
GRASP	Risk Assessment on Social Practice
GWP	Global Warming Potential
HCD	Horticultural Crops Directorate
PtX	Power-to-X
SAF	Sustainable Aviation Fuels
SEZ	Special Economic Zones
SGR	Standard Gauge Railway
WTO	World Trade Organization
HCDA	Horticultural Crops Development Authority
HCFC	hydrochlorofluorocarbons
HFC	Hydrofluorocarbon
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IFC	International Finance Corporation
JKIA	Jomo Kenyatta International Airport
KCAA	Kenya Civil Aviation Authority
KEBS	Kenya Bureau of Standards
KFC	Kenya Flower Council
KQ	Kenya Airways
KRC	Kenya Railway Corporation
MW	Megawatts
NCCAP	National Climate Change Action Plan
NDCs	Nationally Determined Contributions
NEMA	National Environment Management Authority
NICD	Naivasha Inland Container Depot
PES	Payment for Ecosystem Services
PoM	Port of Mombasa
WITS	World Integrated Trade Solution)

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Definition of Terms

Term	Definition
Bio-Methanol	This is methanol produced from biomass or organic waste through thermochemical processes like gasification followed by synthesis. It is a renewable and low-emission alternative to fossil-derived methanol and is gaining traction as a sustainable marine fuel.
e-Fertiliser	These are synthetic fertilisers produced using renewable electricity, typically through Power-to-X (PtX) processes. A common example is green ammonia, where hydrogen is generated via electrolysis using renewable energy and then combined with nitrogen to form ammonia. These fertilisers are considered low-carbon alternatives to conventional (fossil-based) fertilisers
E-Methanol (Electro-methanol)	This is methanol produced by combining green hydrogen (from renewable electricity) with captured CO_2. It is a synthetic fuel with near-zero lifecycle emissions when both inputs are sustainably sourced. E-methanol is used in shipping, chemicals, and potentially aviation
Green Ammonia	This is ammonia produced using green hydrogen (from water electrolysis powered by renewable energy) and nitrogen from the air. Unlike grey ammonia, it is a carbon-free alternative used in fertilisers, refrigeration, and as a potential fuel for shipping and power generation.
Grey Nitrogenous Fertilisers	These are conventional fertilisers (e.g., urea, ammonium nitrate) produced using fossil fuels, particularly natural gas, in energy-intensive processes like the Haber-Bosch process. Their production emits large amounts of CO_2, making them a major contributor to agricultural emissions.
Pack Animals	Animals specifically trained or used to carry loads, typically by transporting goods, supplies, or equipment on their backs.
Power to X	Refers to a set of technologies that convert renewable electricity ("Power") into other forms of energy or products ("X"), enabling the de-fossilisation of sectors that are hard to electrify directly.
Refrigerants	This is a substance used in cooling systems—such as refrigerators, air conditioners, and cold storage units—to absorb and release heat, enabling temperature regulation.
Sustainable Aviation Fuel	Sustainable Aviation Fuels are alternative jet fuels produced from renewable or waste-derived sources rather than fossil fuels. They can be made from feedstocks such as used cooking oil, non-food crops, agricultural residues, or even captured carbon via synthetic routes.
Sustainable Fuels	Sustainable fuels are energy carriers derived from renewable or waste-based sources that have a significantly lower carbon footprint than fossil fuels. They include Sustainable Aviation Fuel (SAF), Bio-methanol, green ammonia.

1. Introduction

Kenya's floriculture sector is a key pillar of the national economy and a global leader in cut flower exports. The country's share of the global cut flower market has grown from 8.6% in 2003 to approximately 16.1% in 2024[2], earning it the nickname "the flower garden of Europe."[3] Kenya now supplies around 38% of the European Union's cut flower imports, with major markets including the Netherlands, United Kingdom, Germany, France, and Switzerland. The sector contributes about 1.3% to GDP (approximately US $900 million annually) and supports over 150,000 direct and two million indirect jobs[4].

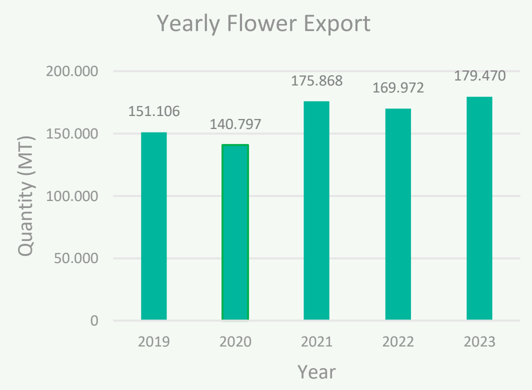
Between 2019 and 2024, Kenya's cut flower exports grew by approximately 18.8%, as shown in Figure 0-1[5]. This growth was driven by increased demand from key markets, including the United Kingdom, Saudi Arabia, and Kazakhstan, as illustrated in

As global supply chains increasingly prioritize carbon footprint reduction, transitioning to low-emission production methods is essential to maintain the sector's competitiveness and environmental integrity.

Figure 0-2.

Despite its economic importance, the cut-flower value chain has significant environmental impacts across production, post-harvest handling, and logistics. Life-cycle assessments of Kenyan roses reveal that intensive agrochemical use, diesel-powered irrigation, and air freight contribute substantially to greenhouse gas emissions, freshwater eutrophication, and high energy demand[6].

Figure 0-1: Reported Kenya Flower Export



Source: World Integrated Trade Solution (WITS)

As global supply chains increasingly prioritize carbon footprint reduction, transitioning to low-emission production methods is essential to maintain the sector's competitiveness and environmental integrity.

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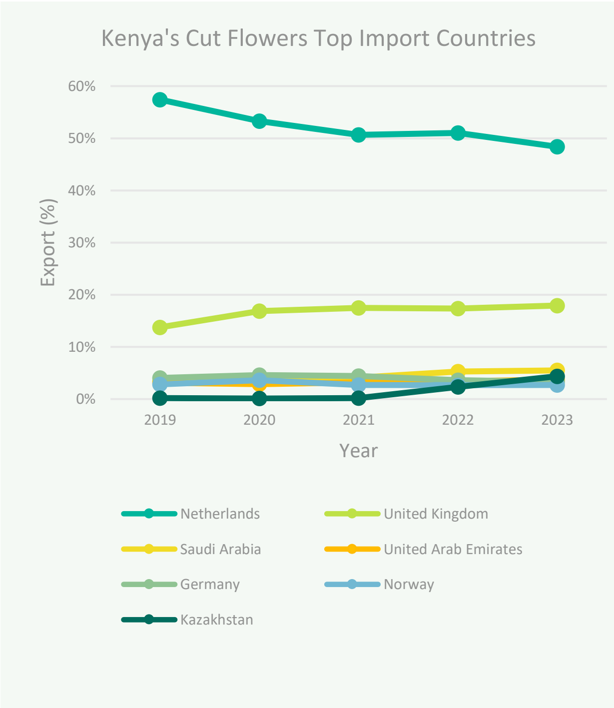
[2] How Kenya is fuelling global romance with fresh flower exports
[3] List of flower farms in Kenya - Tuko.co.ke
[4] Kenya's Flower Farms Are All Going Solar - Miale Solar
[5] WITS: Kenya Fesh cut flowers and buds export by country 2019, 2020 , 2021, 2022, 2023
[6] New study confirms Fairtrade roses from Kenya have smaller environmental footprint - Fairtrade

Figure 0-2: Major Kenya's Cut Flower Markets



Source: Analysis from WITS

Kenya has reaffirmed its commitment to deep decarbonization through its Nationally Determined Contribution (NDC) under the Paris Agreement and the launch of its Green Hydrogen Strategy and Roadmap at the Africa Climate Summit in September 2023. The country is well-positioned to lead in low-carbon energy transitions, with over 90% of its electricity already

Kenya aims to scale up green hydrogen production without compromising domestic energy access[7,8], aligning with the sustainable development goals outlined in Vision 2030. This strategic direction positions the country to capitalize on emerging Power-to-X (PtX) opportunities across agriculture, industry, and transport.

Green hydrogen—produced via renewable-powered electrolysis—and its derivatives, such as green ammonia and green methanol, offer viable pathways to defossilise the cut-flower value chain. In agriculture, green ammonia can replace fossil-based fertilizer imports. Preliminary assessments indicate that integrating PtX technologies could reduce the sector's life-cycle GHG emissions by up to 30%, enhance energy resilience, and foster new local value chains for renewable-based commodities[9].

This baseline assessment evaluates the current state of decarbonization within Kenya's cut-flower value chain, identifying key emissions hotspots and exploring practical opportunities for deploying Power-to-X and green hydrogen solutions. By analyzing technological feasibility, economic viability, and policy enablers, the study aims to

[7] Kenya | Green Hydrogen Organisation

[9] Green Hydrogen Strategy and Roadmap for Kenya (2023 - 2032)

2. Policy and Regulatory Landscapes

Kenya's floriculture sector operates under a comprehensive regulatory framework encompassing domestic climate policies, energy and environmental legislation, and international trade and safety standards. These frameworks collectively define compliance obligations and provide incentives for defossilisation across the cut-flower value chain.

The regulatory landscape has been structured into three key categories:

- National Policies and Strategies
- International Policies and Regulations
- Local and Global Standards

2.1 National Policies and Strategies

The local regulatory framework and strategies aimed at shifting the agricultural sector towards sustainability are highlighted.

Strategy Name	Description	Implications to Kenya's Floriculture Sector
National Climate Change Response Strategy (NCCRS, 2010)	The NCCRS laid out Kenya's first comprehensive framework for both adaptation and mitigation, identifying agriculture as a priority sector for low-carbon interventions. It recommended promoting renewable energy, sustainable land management, and climate-smart practices to reduce greenhouse-gas (GHG) emissions and build resilience in cropping systems.	For cut-flower producers, the NCCRS's call for decentralised renewables and energy efficiency. It creates a policy precedent for deploying PtX-powered cold-storage, replacing HFC chillers with green ammonia.
National Climate Change Action Plan (NCCAP, 2011–2028)	The NCCAP translates high-level goals into concrete sectoral actions—including targets for sustainable agriculture, renewable energy uptake, and transport decarbonisation. It explicitly mandates development of clean-energy projects in agro-processing and calls for incentive schemes to spur private investment.	In the cut-flower context, NCCAP's renewable-energy targets and transport-sector measures provide the regulatory basis for blended-finance mechanisms and feed-in tariffs that improve the business case for PtX electrolysers, methanol synthesis, and SAF production.
Climate Change Act 2016 and its 2023 Amendment	Form a unified legal framework that mandates low-carbon, climate-resilient development and creates carbon market mechanisms.	The Amendment transforms decarbonisation measures such as PtX projects into monetisable assets, significantly enhancing their bankability and scaling potential.

Climate-Smart Agriculture (CSA) Strategy, 2017–2026	The CSA Strategy integrates productivity, resilience, and mitigation goals into one roadmap for Kenya's farming systems. It explicitly targets "minimisation of GHG emissions from key and minor sources in the agriculture sector" while enhancing adaptation and livelihoods.	For floriculture, CSA's mitigation pillar underscores the value of replacing diesel- and HFC-based cold chains with PtX-enabled refrigeration, as well as valorising floral biomass into bio-methanol or green ammonia, thereby cutting Scope 1 & 2 emissions and strengthening farm-gate resilience.
National Environment Management Authority (NEMA) Guidelines	Under the Environmental Management and Coordination Act, NEMA requires Environmental Impact Assessments (EIAs) for new or expanded energy and industrial facilities.	PtX projects must demonstrate minimal ecological disturbance, sustainable water use, and proper waste handling before receiving permits.
National Adaptation Plan (NAP, 2015–2030)	The NAP concretises Kenya's adaptation priorities through 2030, consolidating actions across water management, infrastructure resilience, and climate-smart agriculture. It specifies that agricultural value chains—including high-value exports like cut flowers—must integrate renewable energy for both resilience and mitigation.	It opens pathways for farmers and exporters to access NAP-linked financing for PtX-powered projects and backup power systems that both adapt to and mitigate climate change.
Green Economy Strategy and Implementation Plan (GESIP, 2016–2030)	GESIP articulates Kenya's long-term blueprint for a "low-carbon, resource-efficient, equitable and inclusive" economy. It identifies sustainable agriculture, clean transport, and green infrastructure as five pillars, and calls for public–private partnerships to drive investment in renewable-energy clusters.	The cut-flower sector stands to benefit from GESIP's proposed green-industrial parks—ideal hosts for PtX hubs—where co-located electrolyser, methanol/SAF synthesis, and green ammonia refrigerants can leverage shared infrastructure and regulatory incentives
Energy Act, 2019	Unifies regulation of electricity, petroleum, and renewable energy under EPRA and establishes a mandate to promote the utilisation of renewable energy sources for either power generation or transportation.	Provides the regulatory basis for feed-in tariffs, licensing of novel fuel imports (e.g., green methanol, SAF) and special economic-zone incentives—mechanisms that can lower energy costs for electrolyser operation and SAF production in export zones.
EPRA Fuel and Licensing Regulations	Through subsidiary regulations under the Energy Act, EPRA sets technical specifications and import-licensing requirements for all transport and industrial fuels. Any introduction of PtX-derived fuels—green methanol for reefers, SAF for cargo flights, or green ammonia for refrigeration—must clear EPRA's approval process, conform to blending limits, and meet the authority's safety and quality standards.	These regulatory gates ensure that PtX fuels entering Kenya's value chains are consistent, reliable, and legally recognised, providing confidence to both technology investors and end-users.
Green Hydrogen and derivatives Guidelines	Set out the sustainability criteria, licensing procedures, and fiscal incentives for electrolytic hydrogen and its derivatives and establish a single-window licensing process to fast-track approvals. To spur investment, they offer a ten-year corporate-tax holiday, VAT and import-duty exemptions on equipment and inputs, and stamp-duty	By clarifying technical standards and bundling financial breaks, these Guidelines lower barriers for siting electrolysers and green hydrogen and derivatives directly enabling PtX solutions that decarbonise Kenya's floriculture cold-chain and freight operations.

	waivers—particularly for facilities located in SEZs or EPZs.	
Draft National Energy Policy (2025–2034)	It positions Power-to-X (PtX) and low-carbon fuels at the heart of its decarbonisation strategy. It commits to scaling up renewable electricity—geothermal, solar, wind and bioenergy—as the primary feedstock for green-hydrogen production and PtX derivatives, while minimising thermal-plant dispatch and avoiding new fossil projects.	It explicitly highlights the development of e-fertiliser to replace imported nitrogenous inputs and promotes Sustainable Aviation Fuels (SAF) and Sustainable Maritime Fuels (SMF) derived from local biomass or CO_2 capture to reduce reliance on imported kerosene and bunker fuels, secure premium export markets (e.g., cut flowers), and meet Kenya's international climate commitments.

2.2 International Policies and Regulations

Policy/Regulation	Description	Implications to Kenya's Floriculture Sector
ICAO CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation)	Under CORSIA, international flights must offset any CO_2 emissions above a set baseline—originally the 2019–20 average but revised to 2019 only for the pilot phase (2021–23) and 85 percent of 2019 thereafter[10].	For Kenya's flower exporters, this means cargo carriers flying blooms abroad face growing offset liabilities unless they adopt approved low-carbon fuels.
EU Emissions Trading System (EU ETS) – Aviation	Flights to, from, or over EU airspace are incorporated into the EU Emissions Trading System's aviation sector. Each ton of CO_2 emitted requires surrendering an allowance, effectively placing a carbon price on air-freight services	Kenyan exporters reliant on air transport thus face higher shipping costs in EU markets, strengthening the business case for PtX-based SAF that lowers carbon intensity and potentially earns exemption or reduced allowance requirements.
ICAO Annex 16, Volume II (Aircraft Engine Emissions Standards)	This standard sets global certification limits for engine CO_2 and NO_x emissions. As carriers phase out older, less efficient engines, demand for cleaner fuels grows.	By supporting PtX-SAF blending and drop-in fuels, Kenya's floriculture logistics can align with emerging engine-efficiency regimes and secure cargo capacity on greener aircraft.
IMO MARPOL Annex VI (Air Pollution from Ships)	MARPOL Annex VI caps sulphur in marine fuels at 0.50 percent and enforces NO_x tiers in designated Emission Control Areas. Vessels must also begin reporting fuel consumption under the IMO Data Collection System and meet the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII) by 2023.	For refrigerated container services ("reefers") carrying cut flowers, switching from heavy fuel oil to green methanol or ammonia—both PtX derivatives—helps ship operators comply with sulphur and efficiency rules while reducing lifecycle GHG emissions.

[10] IATA CORSIA Handbook (IATA - CORSIA)

EU MRV & EU ETS – Maritime	Ships above 5 000 GT calling at EU ports must monitor, report, and verify CO_2 emissions (EU MRV), and from 2024 intra-EU voyages are covered by the EU ETS. These measures put a price on vessel emissions, incentivising shipowners and charterers to use low-carbon bunker fuels.	Kenyan exporters contracting reefer vessels to Europe can request PtX-fuelled shipping options to minimise ETS costs and demonstrate greener supply-chain credentials.
Kigali Amendment to the Montreal Protocol	The Kigali Amendment mandates an 80–85 percent phase-down of hydrofluorocarbon (HFC) refrigerants by 2047. Cold-storage facilities and reefer containers must transition away from high-GWP HFCs such as R404A	Ammonia-based refrigeration systems emerge as compliant, low-carbon alternative refrigerant.
EU F-Gas Regulation (EU 517/2014)	This regulation enforces HFC phase-down quotas, leak-testing, technician training, and end-of-life recovery for refrigerants.	Exporters using EU-certified cold-chain assets must adhere, making PtX-powered ammonia-retrofit options in Kenyan pack-houses and reefers a strategic pathway to compliance and emissions reduction.
WTO Technical Barriers to Trade (TBT) Agreement	The TBT Agreement requires that technical regulations (e.g., for labelling, quality marks, sustainability claims) be non-discriminatory and science-based.	As Kenyan exporters adopt PtX-enabled “low-carbon” or “green” labels, they must ensure these claims are backed by transparent methodologies and recognised across markets—avoiding potential TBT disputes over unverified carbon credentials.

2.3 Local and International Standards

Based on survey questionnaires and KFC membership records[11], Kenya cut flower farms have mainly adopted the following local and international standards.

Standard	Core Focus
KFC Flowers & Ornamentals Sustainability Standard (KFC F.O.S.S) Silver	Advocates a baseline sustainability framework for Kenyan floriculture, emphasising responsible environmental management (pesticide use, water conservation), worker welfare (legal compliance, basic health & safety), and basic traceability through grower self-assessment and internal audits.
KFC F.O.S.S Gold	Builds on FOSS Silver by adding stricter environmental controls (soil-health monitoring, biodiversity offsets), enhanced social requirements

[11] Kenya Flower Council certified members: Growers / Producers

	(living-wage guidance, grievance mechanisms), and third-party verification—aimed at moving farms toward international market expectations.
GlobalG.A.P. Integrated Farm Assurance – Fruit & Vegetables (GlobalG.A.P. F.O.) Option 3	Promotes an Integrated Farm Assurance model covering the full spectrum: Good Agricultural Practices, traceability, product safety, environmental protection (soil, water, biodiversity), and robust quality-management systems, with mandatory independent audits.
KS 1758-1:2015 (Kenya Standard for Cut Flowers)	Focuses on product quality and safety, prescribing specifications for sizing, grading, post-harvest handling, and packaging. It also includes basic hygiene and labelling requirements to meet both local and export market standards.
GLOBALG.A.P. Risk Assessment on Social Practice (GRASP)	Aimed solely at the social pillar, GRASP adds a layer of labour-rights assurance—covering fair pay, working hours, forced-labour prevention, and worker representation—complementing any existing GAP certification.
MPS (Milieuprogramma Sierteelt)	A Dutch environmental standard that encourages continuous improvement in pesticide reduction, nutrient management, and energy efficiency through annual scoring, but allows entry-level participation with minimal thresholds.
MPS-ABC	The top tiers of the MPS scheme—A, B, and C—award farms based on quantitative environmental performance: • A (best) for very low pesticide use and resource intensity • B for moderate improvements • C for entry-level compliance Farms with MPS-ABC certification publicly report their aggregate environmental scores.
Fairtrade	Centres on social equity and economic justice, ensuring fair pricing, pre-finance provisions, community development premiums, democratic producer organisation, and strict worker-rights protections (child labour prohibition, safe working conditions).
B Corp	Advances a holistic stakeholder model, scoring companies across Governance, Workers, Community, Environment, and Customers to ensure that business purpose, ethical leadership, social impact, and environmental stewardship are legally embedded.
Carbon Neutral (PAS 2060)	Requires organisations to measure, reduce, and offset their full greenhouse-gas footprint (Scopes 1–3), and to publicly document and verify their carbon-neutrality claims through independent validation and a Qualifying Explanatory Statement.

3. The Cut Flower Value Chain and Emissions Landscape

3.1 Cut Flower Stakeholders

The cut flower value chain in Kenya is comprised of different players ranging from agrochemical suppliers to membership bodies. These stakeholders play different roles in the cut flower value chain as highlighted in Table 3-1.

Table 3-1:Stakeholders Across the Cut Flower Chain

Stakeholder	Role
Agrochemical Suppliers	• Key agrochemical suppliers to Kenya's cut-flower farms include companies such as Syngenta Kenya, BASF East Africa, ADAMA East Africa, UPL Kenya, Osho Chemical Industries, Elgon Kenya, Kenagro Suppliers, Twiga Chemical Industries, Lachlan Kenya, East African Agri-Business PLC, Amiran Kenya, Manuchar Kenya, and Chrystal Africa. • These suppliers offer a range of specialised and general agrochemical products, including pesticides, inorganic fertilizers, flower nutrients, and farm acid.
Seedling Propagators	• While many cut-flower farms propagate their own seedlings, others source them from specialized propagators such as Murara Plants Kenya Ltd, Stokman Rozen Kenya Ltd, Sian Flowers (Maasai Flowers Propagation), Longonot Farm Ltd, Seedlings Paradise Delamere, and Savanna Flowers.
Flower farms	• Kenya hosts approximately 220 flower farms[12] covering an estimated 4,300 hectares[13]. The sector is dominated by roses, which account for over 70% of export volume, followed by carnations and a variety of specialty and summer flowers such as Alstroemeria, lilies, gypsophila, and chrysanthemums. • While large farms often operate their own cold storage facilities at Jomo Kenyatta International Airport (JKIA) and manage in-house logistics, most rely on third-party transport and forwarding companies that also maintain cold storage at JKIA. Additionally, some farms focus solely on cultivation, selling their flowers to consolidators for export.

[12]The Kenyan Floriculture Sector 2024: A Review of Floriculture Sector in Kenya by Kenya Flower Council
[13] Kenya's flower exports to rise 10 pct in 2023-Xinhua

Cut Flower Consolidators	• Key flower consolidators in Kenya include Dutch Flower Group Africa, Rhema Flowers Ltd, Flora Times Group, The Flower Hub, and Caly Flora. These firms collect harvested flowers from multiple farms, conduct quality inspections, and prepare unified consignments for packaging, cold storage, and export. Most operate their own cold storage facilities at Jomo Kenyatta International Airport (JKIA).
Land Transport Logistic Companies	• Road transport providers such as FlowerLink Kenya, Kisanji Enterprises, Pickit Reefer Logistics, and Bamm Tours & Safaris (Reefer Division) manage the land leg of the flower export cold chain. They transport flowers directly from farm packhouses to the cargo apron at Jomo Kenyatta International Airport (JKIA), where licensed ground-handling agents assume responsibility for cold storage, customs clearance, and airside loading.
Logistics companies & forwarding and clearing companies	• Companies such as Floral Chain, Flora Times Group, Kuehne + Nagel, Garden Freight Logistics, and DHL Global Forwarding provide integrated cold-chain logistics for flower exports. Their services include temperature and humidity control throughout transit, documentation management, phytosanitary compliance, customs clearance, and value-added offerings such as pre-cooling and inventory management to meet stringent export standards.
JKIA Ground Handlers	• Ground-handling agents such as Siginon Aviation, Swissport Kenya, and Fresh Handling Kenya Ltd support air freight operations by transferring flower pallets between cold storage and aircraft. They also manage export documentation, customs and phytosanitary clearance, and conduct quality checks—including temperature, humidity, and packaging integrity verification.
Air freight carriers	• Major airlines supporting Kenya's flower exports include Qatar Airways Cargo, which operates the Nairobi–Doha–Liège route and transports approximately 18,750 tonnes of flowers annually[14]. Network Airline Management (NAM) runs daily freighter services from Nairobi to its European hub in Liège[15], while Kenya Airways Cargo, in partnership with Qantas, has established routes to Sydney and Melbourne, moving over 30 tonnes of flowers monthly to Australia via interline connections.[16] • These carriers offer both dedicated freighter and belly-hold capacity from JKIA, ensuring pre-cooling, cold-chain integrity, and compliance with phytosanitary standards[17].
Flower Sale	• Internationally, cut flowers are sold either directly to retailers and wholesalers or through Dutch auction systems.

[14] Qatar Airways Cargo Transports 25 Million Red Roses from Kenya for Valentine's Day

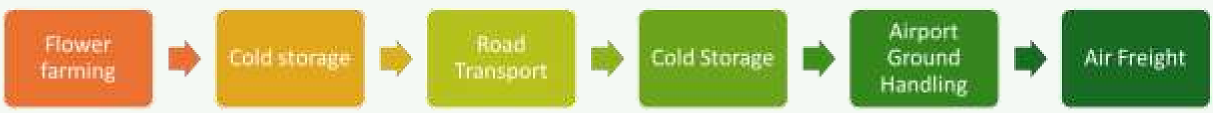
[15] What is Network Aviation's strategy to boost Kenya's flower trade?
[16] Boost for Kenyan farmers after KQ deal to export flowers to Australia - Business Daily
[17] Cargo Infrastructure – Kenya Airports Authority

Agriculture & Food Authority Horticultural Crops Directorate (HCD)	• Regulates production, post-harvest handling and marketing of horticultural crops under the Agriculture & Food Authority
Kenya Plant Health Inspectorate Service (KEPHIS)	• Oversees seed certification, phytosanitary compliance and plant variety registration for exports.
Kenya Flower Council (a membership organisation)	• Acts as the collective voice of the flower industry in Kenya. • Establishes and implements quality and sustainability standards that are internationally recognized. • Advocates beneficial trade policies, aids in phytosanitary compliance through partnerships with governmental bodies, and offers training in best agricultural practices, integrated pest management amongst others

3.2 Cut Flower Value Chain Energy and Materials flow

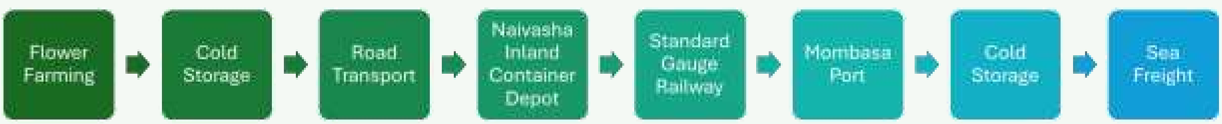
The cut-flower sector's value chain is underpinned by a complex interplay of energy sources and agro-materials that support every stage—from propagation to export. Seedling propagators rely predominantly on thermal energy, while farms, consolidators and logistics providers draw on grid electricity, captive solar PV installations and diesel generators to power irrigation, packing and handling operations. Diesel-fuelled vehicles facilitate on-farm mobility and transport, and hydrofluorocarbon (HFC)–based refrigeration systems in cold rooms and refrigerated trucks ensure product quality during storage and shipment. Together, these inputs generate both bio-residues (e.g. discarded stems, spent media) and non-biodegradable waste (e.g. plastic films, refrigerant gases), shaping the sector's environmental footprint. The current value is illustrated in Figure 3-1 with piloted alternative/complementary value chain shown in Figure 3-2.

Figure 3-1: Current Flower Production & Export Value Chain



Source: From primary Data Collection

Figure 3-2: Piloted Alternative/Complementary Flower Production & Export Value Chain



Source: From primary Data Collection

The different forms of energy and agro materials utilised across its value chain outlined in the following table.

Fertiliser s	Both seedling propagators and flower farms in Kenya use a mix of organic (compost) and inorganic fertilizers. Common inorganic fertilizers include potassium nitrate, calcium nitrate, magnesium nitrate, monoammonium phosphate, and monopotassium phosphate. Micronutrient supplements such as manganese sulphate, zinc chelate, solubor, copper sulphate, sodium molybdate, and chelated blends like Librel and 3% Fe-DTPA are also widely used. *The estimated total annual nitrogenous fertilizer consumption across Kenya's cut flower farms is approximately 425.7 metric tonnes, based on an average of 99 kg per hectare over 4,300 hectares.*
Pesticides	Both seedling propagators and flower farms in Kenya use a range of pesticides, including fungicides, insecticides, acaricides, nematicides, and herbicides. Additional inputs include florissants and biological control agents to manage pests and enhance plant health.
Acids	Flower farms also use inorganic acids such as phosphoric, sulfuric, and nitric acid to regulate pH levels
HFC Refrigerant s (Cooling agents)	Cold storage systems used by flower farms, consolidation centres, logistics providers, and reefer trucks primarily utilize refrigerants such as R404A and R407C.
Petroleum Diesel	This fuel is used by flower farms for intra-farm transport, land logistics, and backup power systems. Consolidation centres and logistics companies rely on it for power backup, while land transport operators use it to run reefer trucks. Airport ground handling agents use it to power tractors towing ULD trailers *Based on a sample of 90 cut flower farms, each consuming approximately 1,353,024 litres of diesel monthly, the projected annual diesel consumption for the estimated 220 flower farms is approximately 297.7 million litre per*
PPetroleum J Jet fuel	This is used by air freight carriers to power the cargo planes.
EElectricity	Electricity consumed by flower farms is sourced from the national grid, captive solar PV systems, and backup diesel generators. Additionally, some farms generate electricity from biogas plants for internal use. Based on data from 94 sampled flower farms, each farm consumes approximately: 736,800 kWh annually from the national grid,237,600 kWh from solar PV systems, and 42,360 kWh from diesel-powered backup systems. When extrapolated to the estimated 220 flower farms in the sector, the total annual electricity consumption is projected to be: 162.1 million kWh from the national grid, 52.3 million kWh from solar PV systems, and 9.3 million kWh from diesel backup systems. *This analysis highlights the national grid as the primary electricity source for flower farms, with solar PV systems playing a significant supplementary role. Diesel generators are used to a much lesser extent, likely reserved for backup during outages or peak demand periods. The growing contribution of solar PV suggests a shift toward more sustainable energy*
TThermal eEnergy	Seedling propagation farms consume thermal energy in the form of hot water, primarily generated from wood biomass. Some farms also report using petroleum-based kerosene as an alternative heat source.

Bio resi-dues	Flower farms generate bio-residues, which are primarily used for compost production. In some cases, these residues are also utilized for biogas generation, supplying cooking gas for onsite farm kitchens.

Based on data from 220 flower farms, each producing approximately 515 metric tonnes of bio-residues annually, the total annual bio-residue production is estimated to be around 113,300 metric tonnes. 83.3% use their bio-residues entirely for compost manure production. While the remaining 16.7% utilise the residues for both composting and biogas production, with the biogas typically used for internal purposes such as

.

3.3 Major Emissions Hotspot

3.3.1 Inorganic Fertiliser Consumption

Under Scope 3, Category 2 (Capital Goods) of the GHG Protocol – Corporate Value Chain (Scope 3) Accounting and Reporting Standard, projected annual emissions from nitrogenous fertiliser consumption by flower farms range from approximately 97.9 to 1,476.99 tCO_2e, depending on the fertiliser's origin[18].

When emissions from Scope 3, Category 4 (Upstream Transportation and Distribution) are included, the overall carbon footprint associated with nitrogenous fertiliser use increases further, highlighting the significant impact of supply chain logistics on total emissions.

[18] F. Brentrup, A. Hoxha, and B. Christensen, "Carbon footprint analysis of mineral fertilizer production in Europe and other world regions," 2016. [Online]. Available: https://www.researchgate.net/publication/312553933

3.3.2 Electricity Consumption

Electricity consumption in cut flower farms contributes to both Scope 1 and Scope 2 greenhouse gas emissions:

- Scope 1 emissions arise from the use of diesel-powered backup systems.
- Scope 2 emissions result from grid electricity consumption.

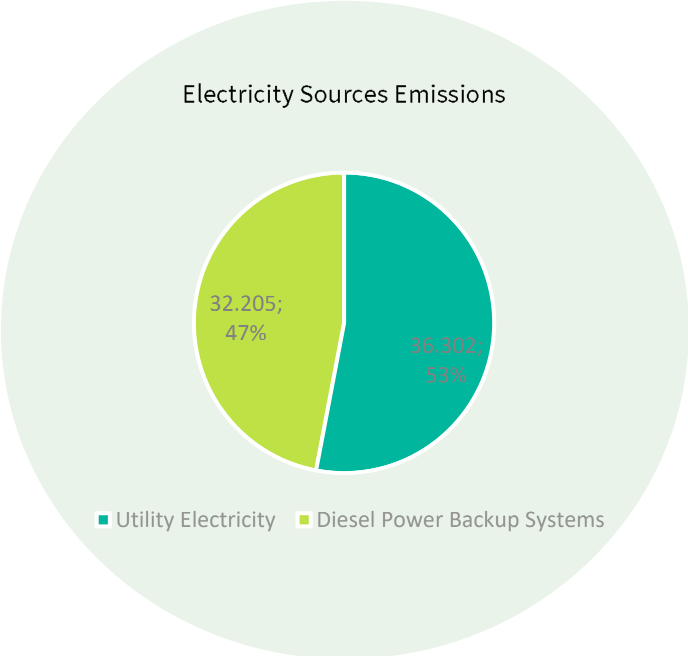
Using Kenya's emission factors—0.04927 $kgCO_2e/kWh$ for grid electricity[19] and 2.66155 $kgCO_2e/litre$ for diesel[20]—the total GHG emissions per flower farm from electricity use are estimated at 68,507 $kgCO_2e$ annually.

Despite diesel backup systems supplying only 4% of the electricity and the national grid supplying 73%, Scope 1 emissions account for 47% of the total, while Scope 2 emissions contribute 53%. This disparity highlights the high carbon intensity of diesel compared to grid electricity as illustrated Figure 3-3.

[19] Energy and Petroleum Regulatory Authority Biannual Energy & Petroleum Statistics Report Financial Year 2024/2025

[20] DEFRA GHG emission factors for 2024

Figure 3-3: Average Cut Flower Farm Electricity Use GHGs Emissions



Source: From primary Data Collection

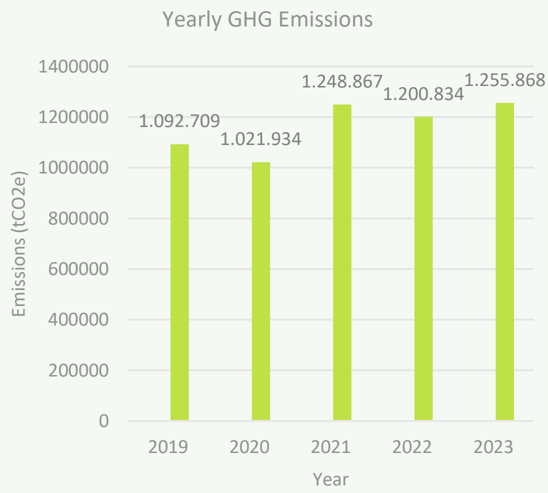
3.3.3 Flower Transportation

Emissions from cut flower transportation contribute to both Scope 1 and Scope 3 greenhouse gas (GHG) emissions:

- Scope 1 emissions, resulting from mobile combustion equipment, are estimated at approximately 3,593,386 $kgCO_2e$ per year from farm-owned transport vehicles.
- Scope 3 emissions, specifically from air freight flower exports, are significantly high. Between 2019 and 2023, air freight contributed an estimated 1,164,042 tCO_2e annually (using the assumptions[21]) as shown in Figure 3-4

This comparison highlights the disproportionate impact of international air transport on the sector's carbon footprint.

Figure 3-4: Yearly Projected Air Freight GHGs Emissions



Source: Estimations from Average Export Market Distances from JKIA

[21] Assumptions:

- It is assumed that Cut flower exported to a given country were flown directly from JKIA to the individual country.
- DEFRA GHGs emission factors for 2024 for freight flights were used.
- The flight types were grouped into short haul (within Eastern and Central Africa region), long haul (within Africa) and international (outside Africa).
- Flight distance between JKIA and countries that imported flowers were estimated using https://www.distance.to website.
- The exports were made via air freight

3.4 Cut Flower Bio Residue Resource Recovery

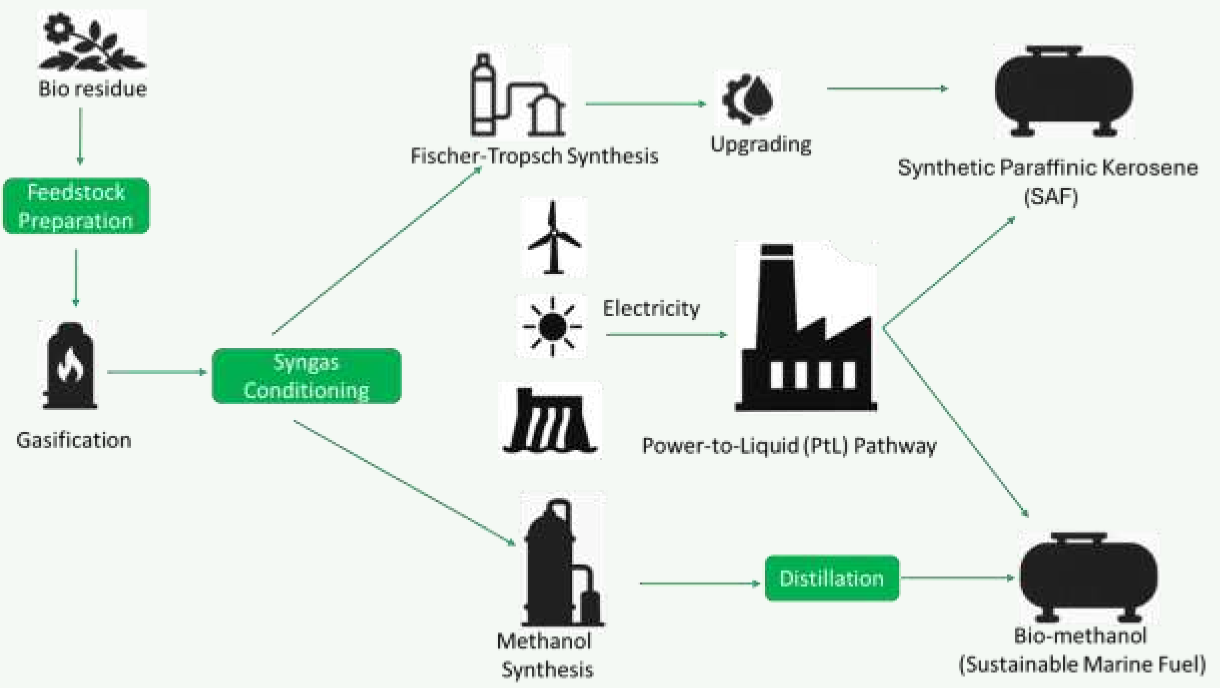
Flower farms generate approximately 113,000 metric tonnes of bio-residues annually[22]. These bio residues can be collected through "milk run" operations and transported to a central syngas production facility. The syngas can then be processed via:

- Fischer-Tropsch synthesis to produce sustainable aviation fuel, or
- Bio-methanol production for use as a sustainable marine fuel as illustrated in Figure 3-5

This approach significantly enhances the value of bio-residues while contributing to defossilisation in the aviation and maritime sectors in the short term due to its possible low production cost. In the long term, Power-to-Liquid (PtL) pathways will be the most viable due to their production scaling ability and maturity of the technology as shown in Figure 3-5 (PtL pathway).

Figure 3-5: PtX Ecosystem for Production Sustainable Marine & Aviation Fuels

Source: Expert Illustration



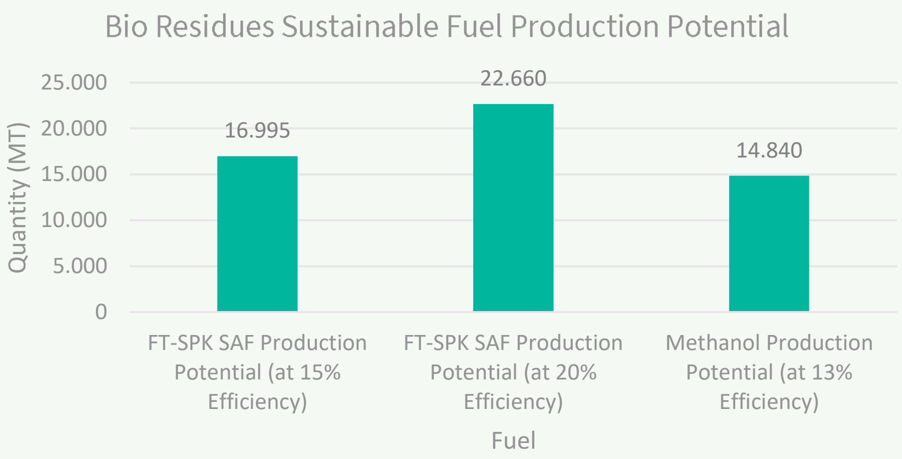
22 Each surveyed farm produces about 515 MT of bio residues on average.

3.4.1 E-fuels Production Potential from Cut Flower Bio Residues

Considering FT-SPK SAF conversion efficiencies of between 15% and 20%[23] and bio-methanol conversion efficiency of 13%[24], the 113,000 metric tonnes of bio-residues can support the production of 16,950 - 22,600 metric tonnes of FT-SPK SAF or 14,816 metric tonnes of bio-methanol, a sustainable marine fuel as shown in

Figure 3-6.

Figure 3-6: Cut Flower Bio Residues SAF & Bio-Methanol Production Potential



Source: Inhouse Assessment

23 Sustainable Aviation Fuel: Part 3 | by Mike Blaisse | Prime Movers Lab | Medium

24 A metric tonne of dry bio residue has the potential to produce about 0.59 MT of methanol production . Studies report that cutflower bio residues have an initial moisture content around 80% by weight on a wet basis, with drying down to about 10% by weight moisture required before further processing. 77.8 % of the original mass is removed as water during drying. This lowers the conversion efficiency to 13%

4. Opportunities for PtX

The cut flower value chain can be broadly categorised into two segments based on their defossilisation potential as shown in

Figure 4-1.

Hard-to-Defossilise Components

- Inorganic fertiliser production
- Cold storage systems using green refrigerants
- Air and sea freight logistics

These segments are challenging to defossilise due to their reliance on high-emission industrial processes and fossil-based transport systems. Achieving meaningful reductions in these areas will likely require the adoption of PtX technologies, such as green hydrogen and synthetic fuels.

Easier-to-Defossilise Components

- On-farm energy consumption
- Intra-farm transportation
- Road transport of cut flowers to exit ports

These areas can be defossilised more competitively using currently available technologies, such as:

- Solar PV systems with battery storage
- Light electric vehicles
- Use of biodiesel
- Pack animals for intra-farm transport

This division highlights the importance of targeted investment and innovation, focusing on deploying existing clean technologies where feasible, while supporting research and infrastructure for harder-to-abate sectors.

The PtX pathways for decarbonising the hard-to-abate segments of the cut flower value chain include:

- Green Hydrogen
- Synthetic Fuels – particularly effective for decarbonising air and sea freight.
- E-Ammonia – especially relevant for fertiliser production and as a low-carbon refrigerant.

These PtX pathways represent the next frontier in deep defossilisation, enabling emissions reductions where traditional renewable technologies fall short. The utilisation of these pathways in de-fossilising the cut flower value chain in discussed in detail in the ensuing sections.

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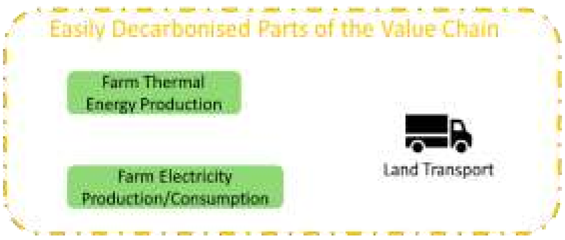


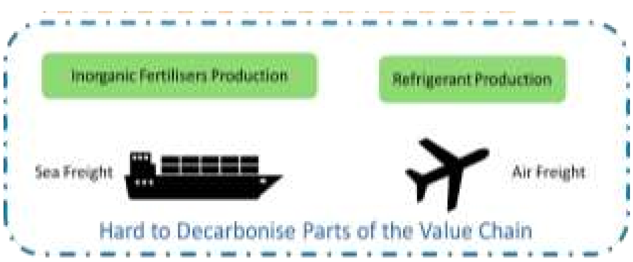


Figure 4-1: Comparative Assessment of Defossilisation Feasibility Across the Cut-Flower Value Chain

Source: Expert Illustration

4.1 Green Ammonia as a Defossilisation Pathway for Fertiliser Use in Kenya's Cut Flower Sector

The 425.7 tonnes (annual consumption) grey nitrogenous fertilisers currently used in Kenya's cut flower farms can be directly replaced by green ammonia (an e-fertiliser), a low-carbon e-fertiliser, to significantly reduce GHG emissions associated with conventional fertiliser production and use.

While green ammonia can supply the nitrogen component, other essential nutrients—such as calcium, potassium, and magnesium—can be delivered through secondary salts and liming materials, including:

- Mono potassium phosphate (MKP)
- Magnesium sulphate
- Potassium sulphate
- Calcium carbonate, quicklime, or slaked lime

According to the PESTEL analysis shown in Annex C, the adoption of green ammonia is supported by:

- Strong political will and sufficient technological readiness
- Satisfactory economic, social, environmental, and legal conditions

This positions green ammonia as a strategically viable and environmentally responsible alternative to grey nitrogenous fertilisers in the transition toward a low-carbon flower industry.

Annex A shows a comparative analysis of e-fertilisers versus grey nitrogenous fertilisers in terms of cost-effectiveness and environmental impact.

The produced e-fertilisers can be procured by flower farms through leveraging the different procurement models. The main models appropriate for cut flower farms are:

Producer-Farm Contracts Model: This model involves long-term periods (such as 15 years) and fixed-price supply agreement contracts. The model would be appropriate where the farm provides a site within the flower farm for installation of a renewable energy captive power plant and ammonia production equipment. The produced ammonia is then supplied directly to the farm where it can be integrated into irrigation systems (drip or sprinkler).

Producer-Cluster Contract Model: In this model a central modular electrolyser would be developed in a flower cluster to target smaller farms or those without on-site production capacity/installation space. The produced green ammonia would then be delivered to the farms in anhydrous or any other appropriate form. This model would also involve contract where a long-term (such as 15 years) and fixed-price supply agreement or any appropriate agreements/contracts.

4.2 Sustainable Cooling and Storage Using Green Ammonia (R-717)

Cut flowers require precise temperature control (1–5 °C) and high relative humidity (90–95%) to maintain quality. Green ammonia (R-717) offers a technically and environmentally superior solution for meeting these conditions to conventional HFC refrigerants.

4.2.1 Technical Feasibility of Ammonia-Based Refrigeration Retrofits

Ammonia has long been used in industrial refrigeration due to its high thermal capacity, low flammability, distinct odour for leak detection, and cost-effectiveness. It also offers a high coefficient of performance (COP), reducing electricity consumption by up to 10% compared to HFC-based systems[25].

However, retrofitting existing HFC systems with ammonia presents challenges. Some of these challenges include:

- Ammonia is corrosive to copper and brass, necessitating steel or aluminium components.
- Retrofitting often requires replacement of piping, compressors, and heat exchangers.
- Ammonia operates under different pressure conditions and requires compatible lubricants, making full system redesigns more likely than simple retrofits

4.2.2 Safety Protocols for Ammonia Use

Classified by the EPA as an extremely hazardous substance, anhydrous ammonia requires stringent safety measures[26]: Some of the measures include:

- Systems must be sealed, ventilated, and equipped with pressure relief valves and ammonia detectors.
- Only compatible materials (e.g., steel) should be used to prevent corrosion.
- Personnel must use PPE (gloves, goggles, respirators) and undergo training in ammonia safety and emergency response.
- Facilities must comply with OSHA, EPA, and IIAR standards, and maintain emergency equipment such as spill kits and eyewash stations.

While these requirements may limit use in smaller or enclosed environments, they are well-established and manageable in industrial settings.

4.2.3 Lifecycle Emissions Reduction

Ammonia offers substantial lifecycle emissions benefits:

- When produced using green hydrogen, it avoids the high embedded emissions of synthetic refrigerants.

It has a Global Warming Potential (GWP) of 27[27], compared to R-32 (a hydrochlorofluorocarbon (HCFC)) and R-410A with GWP of 1,960 and 2,2256 respectively[28].

This makes ammonia a highly sustainable alternative for cold storage in the cut flower industry.

4.2.4 Certifications

In Kenya, the Refrigerating Engineers and Technicians Association (RETA)[29] provides internationally recognized certifications for ammonia refrigeration professionals. These certifications include CARO (Certified Assistant Refrigeration Operator), CIRO (Certified Industrial Refrigeration Operator) and CRST (Certified Refrigeration Service Technician).

The certifications are accredited by ANSI under the ANSI/ISO/IEC 17024 standard and ensure that technicians are qualified to handle ammonia's unique properties safely and competently.

According to the PESTEL analysis shown in Annex C the adoption of ammonia as refrigerants enjoys:

- Strong political and environmental support
- Satisfactory economic, social, technological, and legal backing

As shown in Annex A, ammonia outperforms conventional HFC refrigerants in terms of cost-effectiveness and environmental impact. It is also feasible. These factors, therefore, reinforce its role as a sustainable cooling solution.

4.3 Adoption of E-Fuels

The cut flower export sector can significantly reduce emissions by partnering with air freight carriers that use Sustainable Aviation Fuel (SAF) and shifting a portion of exports to maritime shipping through the green logistics

25 Ammonia Vs HFC/HCFC- The guide to finding a better refrigerant | Danfoss

26 J. Buhari, M. N. Jaafar, and M. I. Rosli, "Optimising Ammonia Safety in Industrial Refrigeration Applications: A Review of Risk Assessment Practices and Regulations," Sep. 27, 2024, *Social Science Research Network, Rochester, NY*: 4966723. doi: 10.2139/ssrn.4966723.

27 IPPC Global Warming Potential Values (Sixth Assessment Report (AR6))

28 IPPC Global Warming Potential Values (Sixth Assessment Report (AR6))

29 "Certification Overview - RETA."

corridor developed by Maersk and the Kenya Railways Corporation (KRC).

4.3.1 Use of SAF in Air Freight

Adoption of SAF will reduce air freight emissions by up 80%[30]. These emission reductions have accelerated SAF adoption with over 360,000 commercial flights reported, in 2023, to have used SAF across 46 airports primarily in the U.S. and Europe[31]. IATA factsheet states that SAF production reached 1.250 billion litres which doubled the amounts produced in 2023 and expects the production to reach 2.5 billion litres in 2025[32].

According to the PESTEL analysis highlighted in Annex C, SAF-powered cargo flights for flower exports enjoy strong political, economic, social, technological, environmental, and legal support.

This positions utilisation of SAF fuelled carriers as a strategically viable and environmentally responsible alternative to fossil fuels in the transition toward a low-carbon air transport is illustrated in Annex A.

4.3.2 Green Methanol for Maritime Shipping

Green methanol, produced from renewable sources like biomass or captured CO_2 with green hydrogen, is emerging as a viable low-emission marine fuel. While not yet adopted in Kenya, global leaders such as Maersk and X-Press Feeders[33] are pioneering its use, with Maersk planning fleet expansion by 2028[34].

Methanol is compatible with existing marine engines, and manufacturers like Wartsila and MAN offer dual-fuel engines, enabling a smooth transition[35].

According to the PESTEL analysis highlighted in Annex C, the use of green methanol fuelled sea vessels enjoys:

- Strong political and environmental support
- Satisfactory economic, social and technological backing.
- Sufficient legal support

This positions green methanol as a strategically viable and environmentally responsible alternative to fossil fuels in the transition toward a low-carbon sea transport as detailed in Annex A.

4.4 Adoption of Maersk and KRC Green Logistics Initiatives

A pilot project by Maersk and KRC tested a rail-sea logistics model for flower exports. Flowers were transported via the Standard Gauge Railway (SGR) from Naivasha Inland Container Depot (NICD) to the Port of Mombasa (PoM), then shipped to Rotterdam.

This model is widely regarded by key stakeholders in the logistics sector—particularly Maersk and Kenya Railways Corporation (KRC)—as a low-carbon logistics solution, as demonstrated by KRC's deployment of 50 refrigerated wagons, with plans to add 500 more[36,37]. These wagons intend to connect inland consolidation centres to PoM's 1,300 reefer plug-in points, streamlining customs and enhancing cold chain efficiency for perishable exports[38,39].

According to the PESTEL analysis shown in Annex C the use of green methanol fuelled sea vessels enjoys:

[30] IATA - Sustainable Aviation Fuel (SAF)
[31] https://www.carbonclick.com/news-views/the-benefits-of-sustainable-aviation-fuel-explained?

[32] https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet-sustainable-aviation-fuels/
[33] "X-Press Feeders Starts Europe's First Feeder Network Powered by Green Methanol, Ushering in New Era of Sustainable Shipping."

[34] Shippers bet on green methanol to cut emissions, supply lags," *The Straits Times*, Singapore, Aug. 22, 2023.
[35] Wärtsilä and MAN in new research collaboration." Accessed: Jun. 11, 2025. [Online]. Available: https://shippingwatch.com/suppliers/article7044558.ece

[36] Kenya Railways to Transport Perishables with New Reefer Wagons – Floriculture

[37] Kenya Railways Commences Transportation of Fresh Produce/Perishables Via Reefer Wagons – Kenya Railways
[38] Kenya Railways to Transport Perishables with New Reefer Wagons – Floriculture
[39] Cool transportation solutions for boosting Kenya's flower exports | Maersk

- Strong political, economic and technological support
- Satisfactory social, technological and legal backing.

This positions utilisation of the initiative as a strategically viable and environmentally responsible alternative to the current road and air logistics in the transition toward a low carbon multi modal transport logistics as highlighted in Annex A.

5. Business Case for a Defossilised Flower Sector

To accelerate the uptake of low-carbon inputs and reward sustainable practices across geographically dispersed cut-flower farms, Kenya's cut flower sector can adopt a "Book-and-Claim" (B&C) system tailored to its cold-chain and biofuel value streams. Under this mechanism, a centralised registry issues digital sustainability certificates—each representing a verified unit of green input (e.g., 1 kg of green ammonia, 1 L of PtX-SAF, or 1 kg of biomass-derived methanol) produced or deployed by participating farms and service providers. Rather than requiring every farm to physically receive these inputs, flower farms "book" their certified volume at source, and downstream actors or international buyers "claim" the same volume on their sustainability reports. This decouples the physical supply chain from the environmental attributes, allowing smallholder farms lacking direct access to PtX installations to monetise their feedstock or off-take rights while buyers—including exporters, airlines, maritime vessels, and cold-chain operators—demonstrate their green procurement commitments.

This section also focuses on the **business case** that includes required investments, which investments are (un)viable under the given assumptions, the key sensitivities that drive outcomes, and recommendations to make the investments attractive to developers and financiers.

5.1.1 Green Ammonia Production

A green ammonia plant installation and operation costs include CAPEX and OPEX. CAPEX Components include:

- Solar PV farm
- Electrolyser
- Air Separation Unit (ASU)
- Haber–Bosch synthesis unit

The cumulative cash flow analysis of this investment was made under four scenarios as shown in

Figure 5-1. These scenarios are:

- Scenario 1: Lower Limit investment cost (USD 1300/tonne) and lower limit green ammonia unit cost (USD 900/tonne)
- Scenario 2: Lower Limit investment cost (USD 1300/tonne) and upper limit green ammonia unit cost (USD 2,700/tonne)
- Scenario3: Higher Limit investment cost (USD 2,000/tonne) and lower limit green ammonia unit cost (USD 900/tonne)
- Scenario 4: Higher Limit investment cost (USD 2,000/tonne) and upper limit green ammonia unit cost (USD 2,700/tonne)

From the economic analysis, initial investment cost for a plant producing about 1.2 tonnes per day is about USD 2.297 million – USD -2.604 million depending on the Greenfield CAPEX limit used as outlined in Annex D section 10.4.1

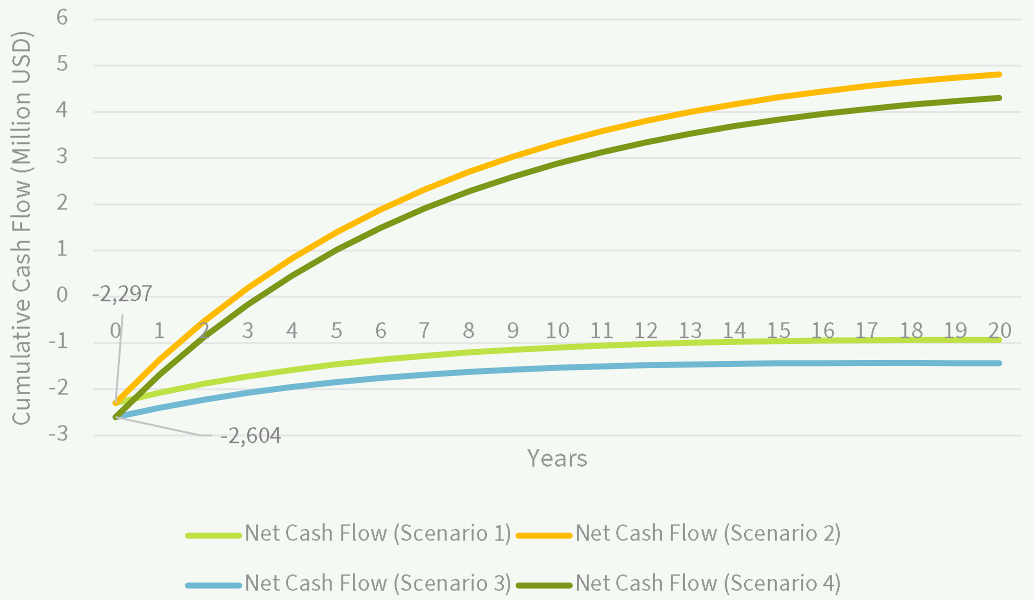
5.1.1.1 Cost Competitiveness

Green ammonia is projected to cost USD 900–2,700 per metric tonne[40], versus USD 580–930/t for grey ammonia[41] and USD 380-736 per metric tonne for fossil-based nitrogenous fertilizers[42,43]. At these price points, green ammonia cannot compete without incentives.

5.1.1.1 Investment Viability

Scenarios 1 and 3 are unviable, as their discounted payback periods exceed the 20-year evaluation horizon. Scenarios 2 and 4 are viable, with internal rate of returns (IRRs) of 28% and 22%, respectively. Since the recommended/projected price point (USD 2,700/tonne) for green ammonia are higher than that of grey ammonia and conventional grey nitrogenous fertilisers, green ammonia will still need incentives for it to compete favourably.

Figure 5-1: Green Ammonia Plant Development and Operation Cumulative Cash Flows Under Different Scenarios



[40] OECD (2025), The Role of Shipbuilding in Maritime Decarbonisation: Impacts of Technology Developments and Policy Measures, OECD Publishing, Paris, https://doi.org/10.1787/0c8362c0-en

[41] Ammonia price index - businessanalytiq

[42] Diammonium phosphate prices, July, 2025 - data, chart | TheGlobalEconomy.com

[43] Urea prices, July, 2025 - data, chart | TheGlobalEconomy.com

5.1.2 Refrigeration Retrofit

The cost of retrofitting existing Hydrofluorocarbon (HFC) / Hydrochlorofluorocarbon (HCFC) -based industrial cold storage systems to ammonia refrigerated systems is estimated at USD 7,000 per refrigeration ton (TR)[44]. In this assessment, retrofitting a 100-kW rated HFC refrigeration system to ammonia refrigerant was considered under three scenarios.

- Scenario 1: The system has a daily duty cycle of 8 hours, translating to 2,920 hours/year.
- Scenario 2: The system has a daily duty cycle of 16 hours, translating to 5,840 hours/year.
- Scenario 3: The system has a daily duty cycle of 24 hours, translating to 8,760 hours/year.

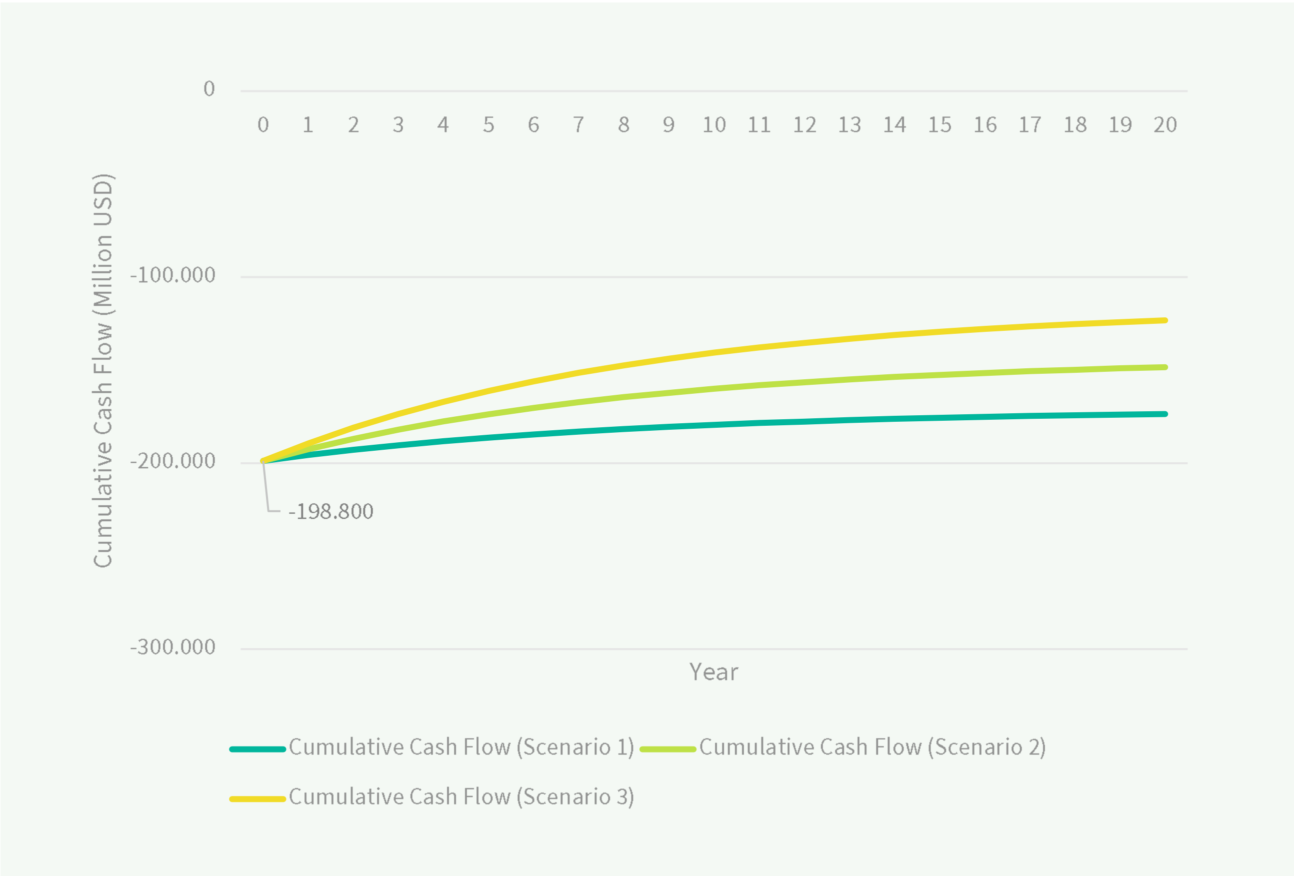
The cash flow for each of these scenarios is as shown in

Figure 5-2.

Investment Viability

Retrofitting existing refrigeration systems is economically unviable since the discounted payback period exceed the 20-year evaluation horizon. To pursue HFC/HCFC refrigeration system retrofits, therefore, cut flower farms will require funding support—such as grants or any other financing model.

Figure 5-2: HFC/HCFC Refrigeration System Retrofit with Ammonia Refrigerant Cumulative Cash Flows Under Different Scenarios



[44] International Association of Refrigeration Warehouses (2014): Low Ammonia Charge Refrigeration Systems for Cold Storage White Paper

5.1.3 SAF (FT-SPK) Production

Kenya Airways (KQ) has shown an interest to incorporate SAF into its consumption[45]. At the beginning, the proposed SAF production should target KQ as the main off taker. Considering KQ's 2024 annual non-renewable jet fuel consumption of 436,894 tonnes, if it was to adopt 2% SAF consumption, about 8,738 tonnes (10,868,013 litres) of SAF would have been demanded. In this analysis, two cases have been considered. CASE 1 entails producing half of this demand and CASE 2 producing 100% of the SAF demand.

Depending on the adopted technology maturity level (nth facility vs pioneer facility), the plants have different estimated capital investment as follows.

CASE 1: PRODUCTION OF 4,369 TONNES/YEAR OF SAF

The estimated CAPEX is USD 235,641,942 and 382,483,514 for nth and pioneer facility respectively based on ICAO "Rules of Thumb"[46]

CASE 2: PRODUCTION OF 8,738 TONNES/YEAR OF SAF

The estimated CAPEX is USD 357,166,395 and 579,736,599 for nth and pioneer facility respectively based on ICAO "Rules of Thumb"[46]

The plant cash flows assessed under different scenarios for both cases are shown in

Figure 5-3 and Figure 5-4 under following four scenarios.

Scenario	Case 1: Production of 4,369 Tonnes/Year of SAF	Case 2: Production of 8,738 Tonnes/Year of SAF
Scenario 1 (nth facility) Recommended MSP	2.00 USD/L[46]	
Scenario 2 (nth facility) Proposed MSP	USD 16.25 /L	USD 26.20/L
Scenario 3 (Pioneer facility) Recommended MSP	USD 3.80 /L[46]	
Scenario 4 (Pioneer facility) Proposed MSP	USD 12.40 /L	USD 19.92 /L

[45] Kenya Airways PLC (2024): Sustainability Report
[46] ICAO SAF rules of thumb

Figure 5-3: CASE 1- SAF Plant Development and Operation Cumulative Cash Flows Under Different Scenarios

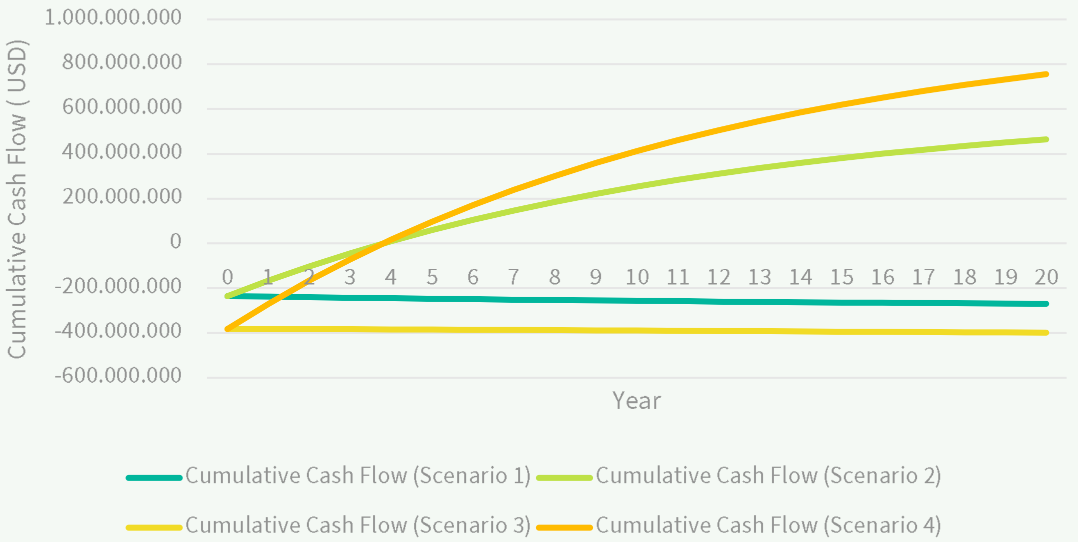
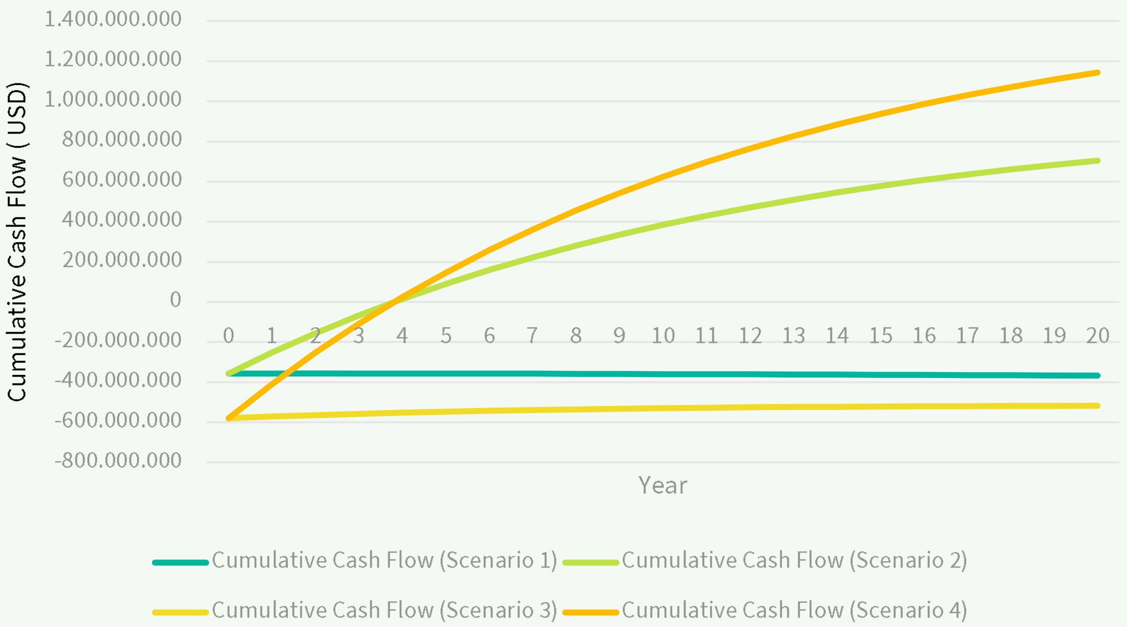


Figure 5-4: CASE 2 - SAF Plant Development and Operation Cumulative Cash Flows Under Different Scenarios



5.1.3.1 Investment Viability

The investment is unviable, under both scenarios 1 and 3 are unviable, since the investment never breaks even as annual OPEX exceeds revenues. However, the investment is viable under scenarios 3 and 4 in both cases with the proposed minimum selling price (MSP) to achieve an IRR at least 20% as preferred by investors for this kind of projects[47].

Under the proposed MSP, CASE 1 would require subsides amounting to USD 12.40 - 19.92 per litre of SAF while CADE 2 would require subsides amounting to USD 14.25 - 26.20 per litre of SAF.

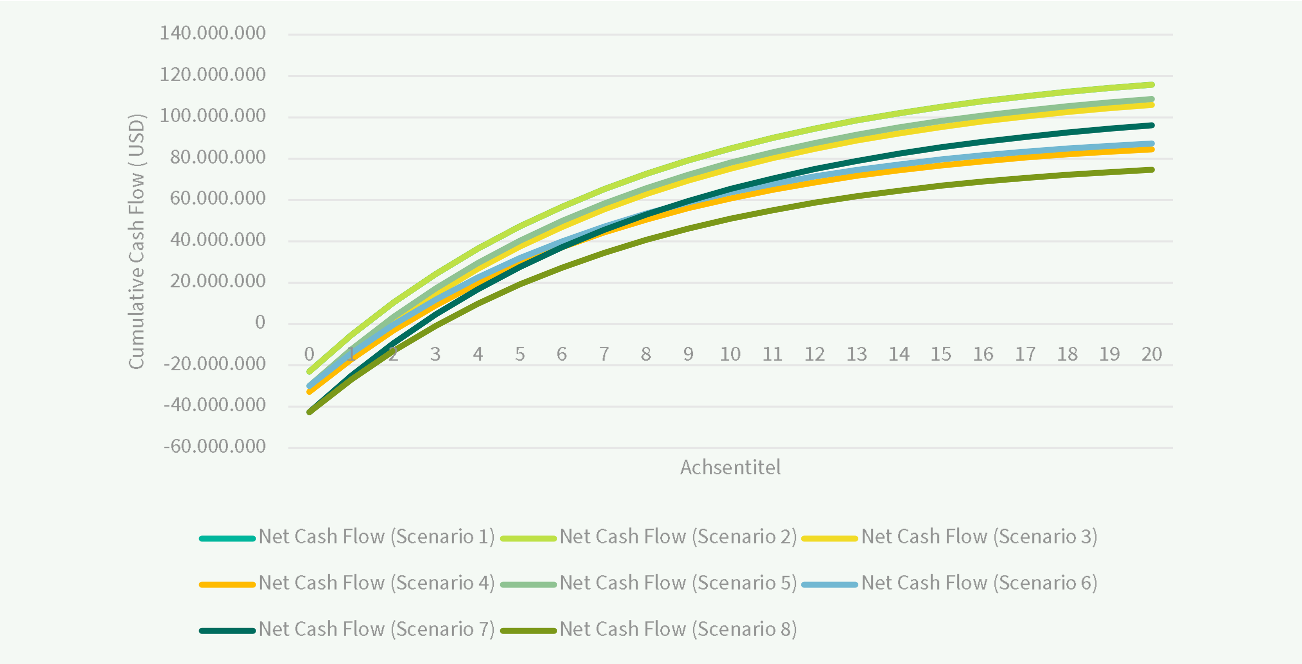
Additionally, as the production capacity of the plant reduces, the subsidy requirement increases significantly. For this assessment, the proposed 8,738 tonnes annual production capacity would require the least subsidies.

5.1.4 Bio Methanol (MeOH)

A smaller biomass-to-methanol facility, as outlined in the of Business Case Report (Annex 3), shows that a mature (nth-of-a-kind) 14.8 kt/year plant would require a capital investment of approximately USD 23.2–32.95 million. For a first-of-a-kind (FOAK) facility, CAPEX increases to USD 30.1–49.4 million due to additional risk and development factors. The cash flow under the 8 scenarios considered is shown in Figure 5-5:

- nth Facility - Low CAPEX and Low OPEX Case[48]
- nth Facility - Low CAPEX and High OPEX Case[48]
- nth Facility - High CAPEX and Low OPEX Case[48]
- nth Facility - High CAPEX and High OPEX Case[48]
- Pioneer Facility - Low CAPEX and Low OPEX Case[48]
- Pioneer Facility - Low CAPEX and High OPEX Case[48]
- Pioneer Facility - High CAPEX and Low OPEX Case[48]
- Pioneer Facility - High CAPEX and High OPEX Case[48].

Figure 5-5: Bio-methanol Plant Development and Operation Cumulative Cash Flows Under Different Scenarios



[47] Office of Clean Energy Demonstrations (OCED) (2024): PORTFOLIO INSIGHTS: Learning from Case Studies: Financing and Development Approaches from Recent First-of-a-Kind Projects

[48] IRENA AND METHANOL INSTITUTE (2021), Innovation Outlook : Renewable Methanol, International Renewable Energy Agency, Abu Dhabi

5.1.4.1 Cost Competitiveness and Investment Viability

The investment is only viable at premium methanol prices such as €1,193/tonne [USD 1,395][49]. At current fossil-based methanol prices (USD 400–500/tonne)[50], the discounted payback period exceeds the 20-year horizon, and the IRR falls below acceptable developer thresholds.

[49] Methanol Institute (n.a), Economic Value of Methanol for Shipping Under FuelEU Maritime and EU ETS (https://www.methanol.org/wp-content/uploads/2024/09/ECONOMIC-VALUE-OF-METHANOL-FOR-SHIPPING-PAPER_final.pdf)
[50] https://www.methanex.com/wp-content/uploads/Mx-Price-Sheet-July-30-2025.pdf?

6. PtX Pathways Development: Systemic Barriers and Strategic Enablers

While PtX technologies present opportunities to defossilise the cut-flower value chain, several systemic barriers—such as the early-stage development of PtX processes, competing agricultural uses for bio-residues, regulatory gaps, and entrenched logistics—may hinder their adoption. However, targeted policy incentives, blended financing models, anchor off-take agreements, value-chain aggregation, and technical partnerships offer viable strategies to overcome these challenges. The following discussion explores these barriers and enabling mechanisms in detail.

6.1 Systematic Barriers

6.1.1 Technology Maturity and Scale-Up Challenges

Although Kenya possesses abundant renewable resources—geothermal, wind, and solar—PtX pathways such as green hydrogen (ammonia) production via electrolysis remain largely at the pilot stage. In 2021, a baseline study on green hydrogen production was completed, and small pilots were planned, but no large-scale commercial plants have yet been commissioned. The high capital expenditure for electrolysers, coupled with limited local expertise in operating and maintaining these systems, will constrain the rapid deployment of PtX facilities near flower clusters. Until electrolysis and downstream conversion technologies such as green methanol synthesis and SAF production and upgrading demonstrate reliable performance at scale in Kenya's context—where grid stability and supply chain logistics differ from more developed European or North American settings—investors and off-takers will remain cautious.

6.1.2 Feedstock Competition with on-Farm Composting

Cut-flower farms in Kenya generate significant amounts of bio-residue, but these residues currently serve as a critical on-farm input for compost, soil amendment and to some extent biogas production for captive use. Redirecting this material to PtX conversion to synthesis green methanol and SAF would displace a low-cost source of organic fertiliser that supports yield and quality. Moreover, the decentralized nature of small and medium-scale flower farms makes aggregation of residues logistically complex and costly. Without mechanisms to compensate farms for both the lost compost value and the additional handling effort, bio-residue valorisation for PtX will struggle to compete with farms' entrenched circular practices.

6.1.3 Grid Reliability and Renewable Integration

Kenya's electricity grid—while increasingly renewable—is prone to occasional outages and voltage fluctuations that can trip sensitive PtX equipment. The 2023 nationwide blackout, which knocked out power for nearly 24 hours[51] and disrupted key economic activities, underscored vulnerabilities in transmission and system resilience. Furthermore, solar and wind generation in Kenya is still largely off-grid or connected via complex licensing processes, making it difficult to secure a stable, low-cost power supply for energy-intensive electrolysers. Without co-located storage or dedicated feed-in arrangements, PtX plants for green hydrogen production may face variable electricity availability and prohibitively high costs, undermining commercial viability.

6.1.4 Logistics Inertia and Cold-Chain Modal Shift

Shifting from air freight to sea transport for cut flowers will demand extensive new infrastructure - temperature-controlled containers, upgraded port cold-rooms at PoM, and revised insurance and contractual terms. Many exporters lack access to refrigerated shipping services or are unfamiliar with maritime perishables handling. As a result, the perceived risk of product spoilage and extended transit times will likely keep most volumes on air routes. Convincing logistics providers and flower exporters to invest in new equipment and processes—without first demonstrating consistent quality and margin benefits—will remain a major hurdle.

6.1.5 Policy Gaps and Incentive Misalignment

Kenya's existing legal framework promotes general renewable energy uptake, but specific PtX targets, subsidies, or carbon pricing mechanisms for green hydrogen, bio-methanol, or SAF are absent. Although

VAT exemptions apply to renewable equipment imports, there are no feed-in tariffs or direct support schemes for PtX outputs. This policy vacuum makes it difficult to build bankable business cases. Potential investors must assume unquantified regulatory risk, and off takers see no long-term price signals to absorb potential cost premiums.

6.1.6 Stakeholder Misalignment Across the Value Chain

The cut-flower ecosystem encompasses flower producers, freight forwarders, consolidators, port authorities, airlines, and government regulators—each with different priorities, risk tolerances, and time horizons. Producers may focus on yield and activities around flower production, consolidators and freight forwarders on logistics throughput, and airlines on fuel availability and cost. Coordinating these actors to adopt novel PtX-enabled practices such as bio residue sourcing contracts, and SAF supply agreements requires facilitation platforms, trust-building forums, and often third-party convenors. Without a shared vision or lead institution to align incentives and mediate trade-offs, pilot projects risk remaining isolated demonstrations rather than system-wide transformations.

6.2 Strategic Enablers

6.2.1 Policy & Regulatory Frameworks

Kenya's Energy Act of 2019 established a comprehensive Feed-in-Tariff (FiT) system for renewable electricity, and, in May 2024, the Energy and Petroleum Regulatory Authority (EPRA) issued the Green Hydrogen Guidelines to govern sustainability criteria, licensing, and potential special economic zone incentives for hydrogen and derivative projects[52]. These measures provide predictable revenue streams for PtX producers and allow projects to access tax breaks and streamlined permitting

[51] Kenya Hit With Third Nationwide Blackout in 3 Months

[52] The legal landscape of renewable energy in Kenya: opportunities & challenges for global investors : Clyde & Co

when designated as PtX zones—critical signals that reduce regulatory risk and attract investors to develop electrolysis, methanol synthesis, and SAF upgrading facilities near flower clusters.

6.2.2 Innovative Finance & De-risking Mechanisms

Blended finance structures—combining concessional loans, guarantees, grants, and equity—are essential to bridge the gap between pilot-scale PtX demonstrations and commercial roll-out in Kenya. In practice, the Government of Kenya has leveraged the Public-Private Partnerships Act (2013) and collaborated with development banks to offer Partial Risk Guarantees (PRGs) that shield investors from government defaults—most notably the AfDB's PRG for the 300 MW Lake Turkana Wind Project—and concessional loans for the Kopere Solar Park Project to improve debt service coverage and reduce capital costs[53]. At the same time, blended-finance vehicles like the EU-Africa Infrastructure Trust Fund have filled critical equity gaps by combining grant resources with development-finance institution funding.

The Green Bond Programme–Kenya, spearheaded by the Kenya Bankers Association, Nairobi Securities Exchange, and the Climate Bonds Initiative, is developing a domestic green bond market to mobilize capital for sustainable infrastructure, including biofuel and renewable energy projects[54].

Applying these de-risking mechanisms to PtX facilities—by pairing low-interest credit lines, partial guarantees, and targeted grants— and leveraging the Green Bond

Programmed can make electrolysis and downstream fuel-synthesis plants near flower clusters financially viable and attractive to private investors.

6.2.3 Anchor Off-taker Agreements

Securing long-term offtake commitments from major buyers de-risks PtX ventures by guaranteeing demand and pricing stability. Kenya Airways' pioneering flights using SAF—notably its first Africa-to-Europe Eni biojet flight in May 2023[55]—and its 2024 SkyTeam award for scaling SAF[56] exemplify how national carriers can serve as anchor off-takers, creating initial commercial volumes and cost benchmarks for bio-SAF producers.

In the agricultural sector, the 15-year supply agreement between TalusAg and Kenya Nut Company to deliver carbon-free green ammonia fertilizer at a fixed price further exemplifies how off-taker contracts can underpin PtX investments, providing farmers with reliable, low-cost inputs while securing a stable market for modular PtX systems in flower clusters[57].

6.2.4 Value-Chain Aggregation & Cooperative Models

The Kenya Flower Council (KFC), representing over 80 percent of growers and exporters across more than 130 farms, can offer a platform for clustering producers to pool bio-residues, share logistics costs, and negotiate collective investment terms. By leveraging KFC's advocacy and partnership mechanisms, PtX developers can tap into aggregated feedstock supplies and coordinated residue-sales contracts, enhancing economies of scale and reducing transaction costs for small and medium-sized farms.

[53] Innovative green financing for energy access: Insights from Kenya - REGlobal - Finance
[54] About | greenbondskenya
[55] Kenya Airways operating the first flight from Africa using Eni Sustainable Mobility's aviation biofuel
[56] https://corporate.kenya-airways.com/en/news-press-release/2023/october/hero/
[57] Kenya Nut Company Installs First Commercial On-Site Green Ammonia System for Carbon-Free Fertilizer Production

6.2.5 Technical Partnerships & Local Research & Development

Collaborations between the PtX Hub in Kenya, local universities, technology providers, and international research institutions can fast-track the localisation of electrolysis and sustainable fuels production and upgrading technologies. The PtX Hub's policy advisory, feasibility studies, and sustainability-certification[58] support demonstrate how multi-stakeholder consortia can co-design modular PtX plants tailored to Kenya's renewable resource profile and agronomic context.

6.2.6 Capacity-Building & Stakeholder Outreach

Effective scaling necessitates training growers, financiers, and regulators on PtX value propositions. Stockholm Environment Institute (SEI) underscores the role of strategic communication and engagement—particularly with research institutions and community organizations—in refining policy instruments and de-risking mechanisms[59]. Similarly, the Kenya Bankers Association's Sustainable Finance Guidelines, developed with International Finance Corporation (IFC) and GIZ, equip financial institutions to evaluate and underwrite renewable energy and sustainable agriculture projects, ensuring that bankers can structure PtX financing aligned with environmental and social risk management best practices[60].

In 2013, in partnership with HCDA and the Climate & Development Knowledge Network, KFC co-developed the Carbon Reduction, Resources and Opportunities Toolkit (CaRROT), a sectoral spreadsheet tool integrating energy and water trackers with a carbon calculator[61]. In 2025, in collaboration with the Embassy of the Netherlands, KFC delivered a capacity-building programme for member farms focused on "Balancing Growth and Sustainability". Through this capacity building programmes, farms and on the stakeholders are trained on renewable energy, energy efficiency, logistics decarbonization and best practices in resource management[62].

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[58] Kenya - PtX Hub

[59] Stakeholders' perspectives on the effectiveness of the feed-in tariff and renewable energy auction policies in Kenya | SEI

[60] https://www.kba.co.ke/partners-unveil-sustainable-finance-guidelines-and-report-as-banks-shine-in-sustainability

[61] Project: Developing a carbon reduction, resources and opportunities toolkit for Kenya's flower sector | Climate & Development Knowledge Network

[62] Balancing growth and sustainability for the long-term success of Kenya's flower industry | Nieuwsbericht | Agroberichten Buitenland

7. PtX Pathways Development Enablers Recommendations

To unlock the full potential of PtX technologies, sustainable aviation and marine fuels and in Kenya, a coordinated and forward-looking strategy is essential. This section outlines a comprehensive set of recommendations across three critical pillars: Policy Support, Strategic Partnerships, and Funding Opportunities. These measures aim to create an enabling environment for PtX technologies innovation, investment, and industrial growth. From establishing a national SAF blending mandate and integrating PtX into national climate frameworks, to fostering cross-sectoral collaborations and tapping into global green finance instruments, these recommendations are designed to catalyse the Kenya cut flower sector's transition to a low-carbon, climate-resilient economy. Together, they form a roadmap for aligning national ambition with international momentum in the green energy transition

7.1 Policy Support

7.1.1 Development of a National SAF Blending Mandate

The Ministry of Energy and Petroleum in collaboration with the Ministry of Roads and Transports, EPRA, KCAA amongst other players should work together to introduce a phased mandate requiring airlines to blend SAF with conventional jet fuel. Such a mandate could for instance have targets of 2% by 2030, 10% by 2040 et cetera. This creates guaranteed demand, incentivises investment, and aligns with global targets like ICAO's CORSIA and EU ETS. Additionally, the mandate could mirror the EU's ReFuelEU Aviation regulation but adapt thresholds to Kenya's production capacity.

7.1.2 Carbon Pricing Mechanisms

Carbon pricing mechanisms could be set to allow SAF credits to offset obligations under Kenya's voluntary carbon registry, enhancing project bankability under the Climate Change Act.

7.1.3 Performance-Based Grants & Subsidies

There should be a low-carbon fertiliser subsidy. Such a subsidy could target fertilisers that achieve at least a 30% reduction in cradle-to-farm greenhouse gas emissions compared to conventional products. To accelerate market adoption, an initial flat-rate subsidy per qualifying fertiliser tonne or unit could be offered, with the rate gradually decreasing after a certain threshold, say 500 units, to encourage early uptake while managing long-term fiscal exposure.

7.1.4 Creation of a PtX Regulatory Sandbox

EPRA and the Green Hydrogen Coordination Committee (GH_2-PCC) Secretariat can be empowered to grant temporary waivers or streamlined approvals for pilot PtX projects—covering licensing, environmental permitting, and product certification—so that innovators can test new business models without full compliance burdens.

7.1.5 PtX integration into the NCCAP

Explicitly include PtX pathways in the upcoming NCCAP cycle, ensuring alignment with Kenya's NDCs and unlocking climate-finance channels. This integration will also guide sectoral ministries (Energy, Agriculture, Transport) to embed PtX in their budgets and programs.

7.1.6 Institutional Coordination Strengthening via the Green Hydrogen Coordination Committee (GH_2-PCC)

The GH_2-PCC should be elevated into a cross-ministerial PtX Council, with clear mandates for stakeholder engagement, policy review, and investment facilitation. A centralized body will reduce inter-agency delays and maintain momentum across pilots and scale-ups.

7.1.7 Allocation of Dedicated PtX Zones in Industrial Parks

Specific areas within existing SEZs or new PtX-focused parks—preferably near flower clusters should be dedicated for PtX solutions production—with pre-approved land use, grid interconnection, water access, and environmental authorizations. Such "plug-and-play" sites will drastically cut lead times for PtX developers.

7.2 Partnerships

7.2.1 Kenya Airways (KQ) x Local SAF Producers and Maersk x Local Bio-methanol Producers

KQ can anchor early-volume demand for bio-SAF to validate commercial viability and drive scale. This partnership can involve multi-year SAF offtake agreements for blended SAF such as 10% drop-in with contractual price review clauses. It can also involve co-funded demonstration flights and carbon-emissions monitoring to build operational know-how. Additionally, it can support collaborative marketing to showcase "Kenyan-made SAF" on international routes.

Given Maersk's strategic commitment to transitioning its maritime fleet to sustainable marine fuels, there exists a significant opportunity for local producers—particularly those manufacturing bio-methanol—to establish long-term partnerships with Maersk, positioning the company as an anchor off-taker and thereby enhancing market stability and investment confidence.

This partnership can lead to market certainty for SAF producers, accelerated regulatory certification, and enhanced brand equity for KQ.

7.2.2 Green Ammonia Producers × Cold-Chain Equipment Vendors

These partnerships will avail green ammonia to be utilised by vendors to offer turnkey retrofit packages—equipment, installation, commissioning, and operator training—under a single agreement. Availability of the refrigerant will lead to roll out of pilot retrofits at high-volume pack-houses in Naivasha to validate cost savings.

7.2.3 Development Banks × Local Financial Institutions

The partnerships between development banks such as AfDB and EIB and local banks such as Equity Bank can create blended-finance products that de-risk PtX capex for domestic banks and private investors.

The partnerships will provide Partial Risk Guarantees (PRGs) where development banks can underwrite up to 50% of commercial loan portfolios, covering political and payment default risk, provide concessional credit lines with low-interest, ten- to fifteen-year tenors earmarked for renewable power plus PtX equipment. Lastly, the partnerships can provide technical assistance grants to train local underwriters on PtX project appraisal and environmental-social risk management.

This partnership will expand lending capacity, provide more competitive loan terms, and increase local-currency financing for PtX ventures.

7.2.4 Private Equity Funds × Sector Incubators

These can support early-stage PtX startups with growth capital and sector-specific business development. The partnerships can involve:

Seed and Series A investments: Where equity cheques are tied to milestone-based disbursements such as prototype commissioning, first offtake LOI).

Mentorship and network access: Here incubator-led workshops on regulatory navigation, go-to-Market strategies, and partnership brokering within floriculture clusters can be done.

Follow-on funding readiness: Structured support can be provided to prepare startups for larger DFI or corporate venture rounds.

These partnerships will produce a pipeline of locally rooted PtX innovators, accelerated go-to-market timelines, and diversified technology options.

7.2.5 Local Research Institutions × International Research Centres

To advance the defossilisation of Kenya's cut flower sector, it is essential to localise R&D for PtX technologies through collaboration between local research institutions and international research centres. Key priority areas include:

Feedstock Characterisation and Process Optimisation: Conduct trials using locally available bio-residues, green hydrogen, and captured CO_2 to adapt conversion technologies—such as Fischer-Tropsch and Haber-Bosch processes—to Kenya's specific feedstocks and grid conditions.

Pilot-Scale Demonstration Projects: Establish field laboratories in agro-industrial hubs such as Naivasha to

evaluate system integration, performance, and durability under local constraints, including grid variability and water availability.

Open-Access Data Platforms: Develop shared, transparent datasets on environmental impacts, cost trajectories, and PtX performance metrics to inform evidence-based policy and investment decisions.

Capacity Building and Skills Transfer: Initiate joint post graduate programs, researcher exchange schemes, and technical workshops to build a robust pipeline of local PtX scientists and engineers.

These initiatives will drive innovation, reduce reliance on imported expertise, and embed PtX capabilities within Kenyan institutions—laying the foundation for sustainable, locally adapted, and economically viable defossilisation pathways.

7.3 Funding Opportunities

7.3.1 German BMZ / KfW Bank Group Green Financing

German BMZ and the KfW Bank Group offer green financing opportunities that can support development of PtX projects in Kenya[63]. BMZ provides support through initiatives like climate-smart agriculture programs, often implemented via partners like GIZ. KfW, through its green finance portfolio, offers concessional loans and climate-focused funding such as for renewable energy, energy-efficient systems, and sustainable agriculture. These are mainly channelled through local financial institutions.

BMZ has previously allocated €270 million PtX Development Fund to was open companies in Kenya. The fund also had a grant contributing to the total investment costs with a target size of €30 million[64].

7.3.2 EU Global Gateway & Innovation Fund

The EU's Global Gateway initiative is already mobilizing dedicated support for Kenya's emerging PtX sector. According to the Green Hydrogen Organisation, the European Union is offering approximately US $13 million in grants under its Global Gateway framework to spur both public and private investments in Kenya's green hydrogen (and downstream PtX) value chains[65].

[63] "German Federal Ministry for Economic Cooperation and Development BMZ)," https://safinetwork.org/members/german-federal-ministry-for-economic-cooperation-and-development-bmz/

[64] Unlocking Green Hydrogen Projects with EU's Innovation Fund and Germany's PtX Development Fund | BLOMSTEIN

[65] Kenya | Green Hydrogen Organisation

7.3.3 Kenya Green Bond Programme

The Kenyan Green Bonds Programme offers a ready-made platform for PtX developers to raise long-term, low-cost capital by issuing labelled green bonds targeted at institutional and retail investors. By aligning PtX project eligibility with the Programme's approved use-of-proceeds categories—such as renewable energy generation, industrial fuel synthesis, and low-carbon transport fuels—electrolyser plants, methanol/SAF synthesis units, and associated renewable power installations can qualify for bond financing.

7.3.4 Bilateral and multilateral Export Credit Agencies (ECAs)

ECAs can play a pivotal role in de-risking and financing PtX projects in Kenya by offering long-tenor loans, political-risk guarantees, and export-credit insurance that together cover a substantial portion of project costs.

Loan Guarantees & Insurance: Agencies such as UK Export Finance (UKEF) and the U.S. Export-Import Bank (EXIM) typically guarantee up to 85 percent of a project's commercial debt[66], covering both supplier and buyer risk. This allows PtX developers to secure lower-cost, longer-term financing for high-capex components like electrolysers and synthesis reactors. EXIM's Sub-Saharan Africa mandate, for example, offers guarantees that cover 100 percent of the financed export value and up to 50 percent of local costs, with repayment terms up to 18 years for renewable-energy projects[67].

Concessional Export Credits: The African Export–Import Bank (Afreximbank) has established a US $3 billion Country Programme with the Government of Kenya, deploying loans, guarantees, and advisory services for trade and infrastructure[68]. PtX ventures can tap this programme for competitively priced capital and political-risk cover, especially when sourcing electrolysers or modular fuel-synthesis units from overseas OEMs.

7.3.5 GET.invest & GET.prospect

GET.invest is the European Union-backed programme dedicated to catalysing private investment in decentralised renewable energy across emerging markets, including Kenya. Under its East-Africa country window, GET.invest offers a suite of instruments directly relevant to PtX developers. One of these instruments is the PtX Development Fund that provides non-reimbursable grants (≥ €10 million) for industrial-scale projects[69] spanning renewable power, electrolysis, hydrogen storage, and downstream fuel synthesis—ideal for demonstrators converting cut-flower residues into methanol or SAF near Naivasha and Eldoret clusters.

7.3.6 Acumen Resilient Agriculture Fund (ARAF)

ARAF is a US $58 million equity fund aimed at enhancing climate resilience for smallholder farmers in Africa. It invests in agribusinesses providing solutions like solar-powered irrigation, energy-efficient processing, and clean transport, particularly in East and West Africa[70]. Developers of PtX projects satisfying the fund requirements can leverage the fund in the develop of the plants.

7.3.7 The Green Climate Fund (GCF)

GCF can play a pivotal role in catalysing PtX initiatives in Kenya by offering a suite of tailored financing instruments across the project lifecycle. At the outset, Kenyan PtX developers can tap the GCF's *Project Preparation Facility (PPF)* for grants of up to USD 1.5 million[71]. These funds underwrite critical

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[66] Impact manager Acre raises $100 mln for African climate infrastructure | Reuters
[67] Sub-Saharan Africa | EXIM.GOV

[68] Afreximbank launches US$3 billion Country Programme with the Government of Kenya. - African Export-Import Bank
[69] PtX Development Fund - GET.invest

[70] "FP078: Acumen Resilient Agriculture Fund (ARAF)," https://www.greenclimate.fund/project/fp078
[71] https://countries.ndcpartnership.org/funding-and-initiatives-navigator/green-climate-fund-gcf-project-preparation-facility

early-stage activities—pre-feasibility and full feasibility studies, environmental and social impact assessments, risk analyses, and tender-document preparation—ensuring that electrolyser installations, methanol or SAF synthesis units, and ammonia-retrofit refrigeration pilots are designed to international best practice before attracting larger capital commitments.

Once a robust proposal is in hand, the GCF's *Private Sector Facility (PSF)* can deploy blended instruments—partial credit guarantees, concessional loans, equity investments, and contingent grants—to de-risk commercial financing.

To mitigate foreign-exchange and liquidity risks inherent in importing electrolysers and synthesis equipment, the GCF can provide *currency-hedging instruments* and *local-currency lending facilities*[72]. This ensures that debt service obligations match shilling-denominated revenue streams, insulating projects from exchange-rate volatility.

7.3.8 The European Green Deal Fund

The European Green Deal Fund (EGDF) can be mobilized to finance PtX projects in Kenya through multiple, complementary instruments under the Team Europe/Global Gateway umbrella:

Grants via the Africa-Europe Green Energy Initiative: Through the Africa-Europe Green Energy Initiative (part of the Global Gateway Investment package), the EU has allocated €3.4 billion in grants for African renewables, with a dedicated "clean hydrogen" window offering up to €100 million in de-risking support for Power-to-X pilot plants and first-of-a-kind facilities in North and East Africa[73]. Kenyan PtX developers can apply to these calls to cover up to 30–40 percent of project CAPEX—particularly for modular electrolysis units, methanol synthesis skids, and small SAF upgrading lines.

InvestEU External Action Guarantees: Under the InvestEU External Action – Infrastructure & Innovation window, EGDF provides first-loss guarantees (up to 50 percent) and interest subsidy schemes for EU-backed loans. Kenyan PtX projects can partner with the European Investment Bank (EIB)[74] or the European Bank for Reconstruction and Development (EBRD) to secure long-tenor debt, with EGDF guarantees lowering perceived risks and reducing the Weighted Average Cost of Capital by 100–300 bps.

Targeted Calls for Global Gateway Hydrogen Corridors: In 2024 the EU launched the "Global Gateway Clean Hydrogen Corridors" call (budget €150 million) specifically to connect African PtX producers with European off takers. Kenyan proposals—e.g., a methanol/SAF pilot co-located with flower-residue aggregation centres—can compete for these grants, conditional on signing LOIs with anchor consumers such as airlines and green fertiliser importers.

[72] Green Climate Fund : Credit Enhancement for Infrastructure | IISD
[73] Africa-EU Energy Partnership: Africa
[74] Kenya: EIB and Kenya strengthen green hydrogen cooperation

8. Action Plan and Implementation Roadmap

This Action Plan and Implementation Roadmap lays out a clear, phased pathway to advance PtX deployment within Kenya's cut-flower sector. Organized into Near-Term (1–3 years) and Medium-Term (3–5 years) horizons, it pairs ambitious policy and regulatory milestones with hands-on technology pilots and financing mechanisms. At each stage, defined lead agencies and supporting partners—from government ministries and regulators to flower farms, technology providers and financiers—will collaborate to build capacity, de-risk investments and refine technical, economic and environmental parameters for PtX fuels and refrigeration retrofits.

Action Plan and Implementation Roadmap

Phase/Term	Timeline	Key Activities
	0 -1 year	**Stakeholder Coalition Building** • Convene growers/exporters (via KFC), PtX Hub, regulators and financiers. • Establish Steering Committee with a dedicated Policy Working Group to fast-track regulatory scans. **Policy & Regulatory Scan & White Paper** • Review existing energy, aviation and agricultural laws; identify PtX gaps. • Publish "PtX Roadmap White Paper" recommending national PtX targets, Feed in Tariffs/auction extensions to green hydrogen, cheap off-peak electricity tariffs intended for PtX, VAT/duty waivers on PtX equipment. ***Lead: Ministry of Energy & Petroleum, EPRA support.***
Near Term	1 -2 years	**Technology & Vendor Assessment** • Request for Information (RFI) to electrolyser, fuel-synthesis and refrigeration-retrofit vendors. • Compare modular versus centralized PtX plant options. ***Lead: Ministry of Energy & Petroleum, EPRA support.*** **Business Case & Policy Alignment**

		• Develop high-level techno-economic models that incorporate proposed policy incentives. Validate assumptions with regulators to secure draft policy commitments. **Feasibility Studies** • Technical and economic feasibility for PtX pathways using cut-flower residue (methanol, SAF, green ammonia). • Site selection analysis near major flower clusters (Naivasha, Eldoret). • Lead: Research institutions (e.g., University of Nairobi), PtX Hub. Support: Kenya Flower Council (KFC), EPRA. **Refrigeration System Ammonia Retrofit Pilot** • Assess retrofitting existing cold-storage and transport refrigeration units to run on ammonia-based refrigerants. • Engage cold-chain equipment vendors and pilot retrofits at key pack-houses near flower clusters. • Lead: Cold-chain equipment vendors & pack-house operators. **Support: Kenya Flower Council, National Environment Management Authority**.
	2-3 years	**Formalize Policy Instruments** • Issue EPRA guidance to enable PtX FiTs or dedicated auction windows for green hydrogen and derivatives. • Ministry of Roads and Transport issues draft SAF blending mandate with specific targets such as 2–5 percent by volume by a given timeline. **Financing & Procurement** • Close blended-finance deals: PRGs from AfDB/EIB, concessional credit lines with guarantees. • Issue first green bond under Kenya Green Bond Programme for PtX capex. **Solar PV + Electrolysers** • Deploy co-located solar arrays (5–10 MW) with modular electrolysis (1–2 MW). • Establish power purchase agreements or feed-in arrangements. • Lead: Renewables developers, IPPs. **Support: EPRA, Ministry of Energy.**
Medium Term	2-5 years	**Pilot SAF from bio residues** • Secure sandbox-style licensing waivers from EPRA and National Environment Management Authority (NEMA). • Design and commission small-scale syngas → SAF demonstration unit (50–100 t/year). • Monitor yields, quality, lifecycle emissions. • Lead: Technology provider consortium.

Support: Exporters cooperative, aviation partner (e.g., Kenya Airways).

4-5 Years

Capacity-Building & Trials

- Train regulators, bankers, and farms on new policies and technologies.
- Conduct first batch of pilot flights using demo SAF.

Impact Monitoring & Policy Feedback

- Launch carbon-tracking platform compliant with PROSPECT data standards.
- Submit biannual policy-update reports to Cabinet, recommending adjustments based on pilot performance.

Policy Maturity

- Parliament enacts Carbon Levy on aviation fuel, with revenues reinvested via the Green Aviation Fund.

Regulatory Mainstreaming

- EPRA publishes full PtX FiT schedule and off-peak tariff rules.
- KCAA finalizes permanent SAF blending regulations
- Kenya Bureau of Standards (KEBS) issues Kenyan Standards for PtX fuels.

Logistics & Market Integration

- Incentivize sea-freight modal shift through reduced port fees for certified green-logistics shipments.

Stakeholder Roles & Responsibilities

1. Stakeholder	2. Role	3. Responsibilities
4. Flower farms	5. Feedstock suppliers 6. Green ammonia offtake & trial partners	7. Supply and aggregate bio-residues 8. Participate in e-fertiliser off-take consortia 9. Provide refrigeration system ammonia refrigerant retrofit pilot sites
10. KFC	11. Demand champions	12. Coordinate farmer outreach 13. Collect agronomic performance data 14. Advocate for policy adoption, consolidate stakeholder feedback, and provide data-driven evidence to policymakers.
15. PtX Technology Providers	16. Design, build, operate PtX units	17. Deliver modular electrolysis and upgrade reactors 18. Train local operators 19. Share performance data
20. Kenya Airways & Cargo Carriers	21. SAF anchor off-takers	22. Commit to SAF purchase agreements 23. Provide technical guidance on fuel specifications
24. Renewable IPPs & Developers	25. Renewable power suppliers	26. Develop dedicated solar/wind arrays 27. Structure power contracts suitable for PtX loads
28. Financial Institutions & Donors	29. Provide blended finance & guarantees	30. Structure blended-finance products that leverage new policy instruments 31. Underwrite green bonds 32. Report on policy impact to guide refinements.
33. Ministry of Energy & Petroleum and EPRA	34. Policy & oversight	35. Lead drafting and enactment of PtX FiTs, off-peak tariffs, licensing sandboxes, and hydrogen auctions.
36. Ministry of Transport and KCAA	37. Policy & oversight	38. Issue and enforce SAF blending mandates 39. Oversee aviation-fuel standards.
40. NEMA	41. Policy & oversight	42. Fast-track environmental approvals through regulatory sandboxes and pilot exemptions.
43. KEBS	44. National standards developer	45. Develop Kenya standard specifications for green hydrogen, SAF, methanol, and ammonia fuels.
46. Research Institutions	47. Feasibility, R&D & capacity building	48. Conduct techno-economic studies 49. Develop training curricula 50. Host stakeholder workshops
51. Port & Logistics Operators	52. Cold-chain & modal-shift enablers	53. Upgrade cold-chain assets 54. Adapt insurance and contracts 55. Optimize maritime routes 56. Negotiate green freight terms 57. Track shipment emissions

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105. Pudaruth, Sameerchand. (2020). ELECOM 2020: 2020 3rd International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ELECOM): conference proceedings: University of Mauritius, 25-27 November. IEEE.
106. State Department for Energy, “Draft National Energy Policy 2025-2034,” Ministry of Energy & Petroleum . Accessed: Mar. 07, 2025. [Online]. Available: https://www.bing.com/ck/a?!&&p=226149c22df6937103872ba5235053b3ccf8b579070c1f4a8d20147043ab1ed0JmltdHM9MTc0MTIxOTIwMA&ptn=3&ver=2&hsh=4&fclid=293092a2-48ce-6a99-1624-861549336b5a&psq=Kenya+national+energy+policy&u=a1aHR0cHM6Ly9lbmVyZ3kuZ28ua2Uvc2l0ZXMvZGVmYXVsdC9maWxlcy9GaW5hbCUyMERyYWZ0JTIwJTIwTmF0aW9uYWwlMjBFbmVyZ3klMjBQb2xpY3klMjAxODAyMjAyNS5wZGY&ntb=1.
107. The Crops (Horticultural Crops) Regulations, 2020Accessed: Feb. 21, 2025. [Online]. Available: https://ks1758.afa.go.ke/media/resources/Published_hort_Regulations_1-1_1.pdf.
108. Strategy MIDORI and Climate Smart Agriculture. Accessed: Feb. 25, 2025. [Online]. Available: https://www.maff.go.jp/e/policies/env/env_policy/04_Strategy_MIDORI_and_Climate-Smart_Agriculture.pdf.
109. The European Green Deal - European Commission. Accessed: Mar. 03, 2025. [Online]. Available: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/story-von-der-leyen-commission/european-green-deal_en.
110. Understanding REACH. Accessed: Mar. 06, 2025. [Online]. Available: https://echa.europa.eu/regulations/reach/understanding-reach
111. U. N. Environment, “Methyl bromide.” Accessed: Mar. 07, 2025. [Online]. Available: https://www.unep.org/ozonaction/what-we-do/methyl-bromide

10 .Annexes

10.1 Annex A: Analysis of PtX Pathways Cost-effectiveness, Feasibility and Environmental Benefits

10.1.1 E-Fertilisers Adoption Comparative Analysis

Cost-effectiveness	Currently decentralised solar power plants provide cheap electricity for decentralised green ammonia production as stated by TalusAg at its green ammonia plant in Naivasha. These energy sources can significantly reduce operational costs, making green ammonia pricing comparable to that of conventional grey nitrogenous fertilisers. The production of green ammonia will be ramped up when abundant low-cost electricity from the KenGen Industrial Park in Naivasha become available[75]. Currently, dedicated green ammonia plants are small in capacity and additional decentralised green ammonia plants are likely to have low production capacities due to the high investment requirements.
Feasibility	The adoption of e-fertilisers is a viable and proven defossilisation strategy in Kenya. To ensure economic feasibility: • KenGen's Industrial Park in Naivasha should be leveraged for centralised production due to the promised low-cost electricity supply. • In regions lacking such infrastructure—such as Mount Kenya, Kajiado County, Athi River, Eldoret and Kiambu County—the establishment of decentralized solar power plants is recommended to support localised green ammonia production.
Environmental benefits	Switching to green ammonia e-fertilisers could lead to a reduction of approximately 97.9 to 1,476.99 tCO_2e in GHG emissions annually per flower sector. This transition represents a significant step toward climate-smart agriculture and aligns with Kenya's broader sustainability goals.

75 Government Declares Olkaria a Special Economic Zone to Boost Industrialisation and Clean Energy Investment

10.1.2 Low Carbon Ammonia Adoption Comparative Analysis

Cost-effectiveness	Ammonia-based industrial refrigeration systems are 10–20% less expensive to install than systems using HCFCs and HFCs, due to the ability to use smaller-diameter piping[76]. Ammonia is also a cost-effective refrigerant, with reported prices of US$0.52/kg globally and US$0.59/kg in Africa[77] grey ammonia and a projected 120% premium for green ammonia[78], making it more affordable than conventional synthetic refrigerants such as HFCs[79,]. Due to its superior thermodynamic properties, ammonia systems can consume up to 20% less energy than HCFC systems[80], resulting in a typical return on investment within two years[81]. Additionally, these systems require less maintenance and offer longer operational lifespans (often exceeding 20 years)[82], further reducing total cost of ownership.
Feasibility	Ammonia is well-suited for industrial-scale refrigeration[83]. For smaller systems (1.5 kW to 50 kW), CO_2 (R-744) systems may be more appropriate[84,85].
Environmental benefits	Ammonia has a Global Warming Potential (GWP) of zero[86], meaning it does not contribute to direct greenhouse gas emissions[87]. Its high COP also leads to lower electricity consumption, which in turn reduces indirect emissions from power generation. This makes ammonia a highly sustainable choice for refrigeration in the cut flower industry.

76 Ammonia Vs HFC/HCFC- The guide to finding a better refrigerant | Danfoss
77 Ammonia price index - businessanalytiq
78 Ammonia industry net-zero tracker - Net-Zero Industry Tracker 2023 | World Economic Forum
79 Ammonia vs Synthetic Refrigerants: Which is Better for Cooling Systems | GA Enns
80 Ammonia | HC
81 Halton Hills' Net Zero Journey: Ammonia Heat Pumps
82 Think Natural Refrigerants are an Expensive Investment, Think Again
83 https://hillphoenixindustrial.com/ammonia-r-717-refrigerant/
84 https://www.danfoss.com/en/markets/refrigeration-and-air-conditioning/dcs/commercial-co2-refrigeration/
85 The Danfoss Multi Ejector range for CO_2 refrigeration: design, applications and benefits | Danfoss
86 Ammonia – Providing the right temperature for change
87 Glossary:Carbon dioxide equivalent - Statistics Explained - Eurostat

10.1.3 Use of SAF Fuelled Cargo Planes for Cut Flower Export Comparative Analysis

Cost-effectiveness	SAF remains significantly more expensive than conventional fossil jet fuel, with production costs ranging from 2 to 7 times higher. Estimated markups range between 120% and 700% over standard kerosene[88]. For example: • FT-SPK SAF: Minimum projected cost is US $1.44 per litre[89]. • HEFA-SPK SAF: Minimum selling prices exceed US $1.00 per litre. • Fossil Jet A: Typically priced between US $0.30 and US $0.60 per litre under normal crude oil conditions[90]. Given these disparities, SAF is currently not cost-competitive without substantial subsidies or policy incentives, which may limit its near-term adoption by airlines.
Feasibility	SAF blends of up to 50% are fully compatible with existing aircraft engines and airport infrastructure, requiring no modifications to fuel systems or supply chains[91]. Regulatory momentum is also growing: • EU Refuel Aviation Regulation mandates SAF blending starting at 2% in 2025, rising to 70% by 2050[92]. • UK SAF Mandate requires 2% SAF blending from 2025, increasing to 22% by 2040[93]. While SAF is expected to become mainstream in the medium to long term, Kenya currently lacks domestic production capacity[94], meaning any SAF used locally must be imported.
Environmental benefits	SAF can reduce greenhouse gas emissions by 27% to 87%, depending on the biomass feedstock and production pathway. Advanced waste-based and energy crop pathways offer the highest reductions. For context, transporting one tonne of cut flowers by air from Jomo Kenyatta International Airport (JKIA) to Amsterdam emits approximately 7,030 kg CO_2e. Using SAF could reduce this by: • Low-end estimate (27%): 1,898 kg CO_2e saved • High-end estimate (87%): 6,116 kg CO_2e saved

[88] M. J. Watson *et al.*, "Sustainable aviation fuel technologies, costs, emissions, policies, and markets: A critical review," *J Clean Prod*, vol. 449, p. 141472, Apr. 2024, doi: 10.1016/j.jclepro.2024.141472.

[89] J. P. Ahire *et al.*, "Techno-economic and environmental impacts assessments of sustainable aviation fuel production from forest residues," *Sustain Energy Fuels*, vol. 8, no. 19, pp. 4602–4616, 2024, doi: 10.1039/D4SE00749B.

[90] K. Moriarty, A. Milbrandt, and L. Tao, "Port Authority of New York and New Jersey Sustainable Aviation Fuel Logistics and Production Study," 2025. [Online]. Available: www.nrel.gov/publications.

[91] Alternative Fuels Data Center: Sustainable Aviation Fuel

[92] ReFuelEU Aviation - European Commission

[93] The SAF Mandate: an essential guide - GOV.UK

[94] How Kenya Airways plans to unleash the country's untapped SAF potential

10.1.4 Use of Green Methanol in Marine Shipping of Cut Flowers Comparative Analysis

Cost-effectiveness	Production cost is a critical factor in the adoption of alternative marine fuels. Green methanol (bio methanol) is moderately priced . In market terms: • Bio methanol: US $700– US $900 per tonne[95] • E-methanol: US $800– US $1 600 per tonne[96] • Green Ammonia: US $700 – US $1400 per tonne[97] • LNG: US $350– US $400 per tonne[98] Despite its higher cost relative to fossil-based fuels, bio methanol's renewable origin and low emissions make it a compelling transitional fuel—especially in contexts with carbon pricing or emissions regulations.
Feasibility	Methanol offers a practical balance among alternative marine fuels: • Energy Density: 19.9 MJ/kg (about half that of diesel, but higher than hydrogen and ammonia) • Storage: Liquid at ambient conditions, allowing use of modified diesel infrastructure • Safety: Low flash point (11°C) and wide flammability range require enhanced safety protocols, similar to LNG • Material Compatibility: Corrosive properties may necessitate engine material upgrades or additives Compared to gaseous fuels like hydrogen and ammonia, methanol's liquid form and simpler storage requirements make it more feasible for near-term adoption.
Environmental benefits	Green methanol can reduce CO_2-equivalent emissions by up to 96% compared to conventional marine fuels[99] over the entire life cycle of ships. While hydrogen and ammonia offer zero CO_2 emissions at the point of use, they face challenges related to production emissions, toxicity (ammonia), and complex storage. Methanol, particularly when derived from bio-residues, provides a more immediate and scalable path to defossilisation with fewer infrastructure and safety hurdles.

[95] Irena and Methanol Institute. (2021). *Innovation Outlook: Renewable Methanol*.
[96] Irena and Methanol Institute. (2021). *Innovation Outlook: Renewable Methanol*.
[97] Green Ammonia – An Alternative Fuel - FutureBridge
[98] Lng As A Bunker Fuel Market Size & YoY Growth Rate, 2032
[99] https://www.cleanenergywire.org/news/green-methanol-best-candidate-make-shipping-climate-neutral-report

10.1.5 Utilisation of Maersk-KRC Green Logistics Initiative & Sea Freight Comparative Analysis

Cost-effectiveness	Transitioning from air freight—currently averaging USD 5.80 per kg out of Jomo Kenyatta International Airport (JKIA)—to the Maersk-facilitated rail and sea route can nearly halve logistics costs. Following successful trial shipments from NICD to PoM, exporters estimate sea freight charges at approximately USD 2.80 per kg, yielding a cost saving of USD 3.00 per kg[100]. For a standard 20-foot container carrying 20 tonnes (20,000 kg) of cut flowers, this translates to USD 60,000 in freight savings per shipment. These savings can significantly improve exporter margins or enable more competitive pricing in European markets.
Feasibility	The March 2025 pilot shipment confirmed the technical feasibility of using the Maersk-facilitated rail-sea logistics corridor for cut flower exports. Refrigerated containers carrying Kenyan blooms were successfully transported via the SGR from NICD to PoM, then shipped onward to Rotterdam. Throughout the journey, temperature profiles met export-grade cold-chain standards, ensuring product quality. Stakeholder feedback from the trial highlighted only minor operational bottlenecks, which are being addressed ahead of commercial scaling[101]. The initiative is further supported by the "Combi-Track" public-private partnership, backed by the Dutch government and TradeMark Africa, which provides a structured framework for scaling up the model using existing SGR capacity and port infrastructure[102].
Environmental benefits	Utilizing sea freight via the green logistics corridor reduces CO_2 emissions per kg-km by over 98% compared to air freight—0.019 g CO_2/kg-km versus 1.054 g CO_2/kg-km[103]. Over a typical 7,000 km route, this translates to an emissions saving of approximately 7.25 kg CO_2 per kg of flowers.

[100] Flower exporters eye sea freight as air costs shoot up - Business Daily
[101] Cool transportation solutions for boosting Kenya's flower exports | Maersk
[102] Kenya's green move to shift 50% of horticultural exports from air-freight to sea-freight - TradeMark Africa
[103] Shift from Air to Sea freight: a key lever to reduce transport emissions

10.2 Annex B: PESTEL Criteria

10.2.1 Scoring Criteria

Evaluation of each candidate PtX pathway was done with a scale of -2 to +2, similar to scale used in **Baseline Study on the Potential for Power-To-X/Green Hydrogen in Kenya** undertaken by Tractebel Engineering GmbH on behalf of GIZ GmbH and Ministry of Energy of Kenya

Average Score	-2	-1	0	+1	+2
Description	insufficient	Sufficient	Satisfactory (Neutral)	Good	Very Good

10.2.2 PESTEL Multicriteria Assessment

Criteria	Description
POLITICAL	
National Strategy Alignment	Ensuring the initiative supports and advances the country's overarching development and economic plans.
Inter-agency Coordination	Strength of coordination between the Ministries, agencies & other stakeholders
International Partnerships & Funding	Presence of bilateral support for PtX projects in Kenya
Reduce Importation	Develops local production capacities to decrease reliance on importation
Provide additional reliability to commodities supply	Strengthens domestic supply chains to ensure consistent availability of key inputs.
Reduce Importation Dependencies	Diversifies sourcing and boosting local industries/production to minimize external supply vulnerabilities.
Reduce impact of foreign exchange	Cuts import to lower pressure on the national currency and stabilize exchange rates.
Contribution to NDC Obligations	Aligns with Kenya's Nationally Determined Contributions under the Paris Agreement to meet emissions targets.
Honour International Policies	Adheres to global environmental treaties and commitments
ECONOMICS	
Capital & Operating Costs	Evaluates upfront investment and ongoing expenses required to establish and run the project.
Return on Investment & Payback	Measures profitability and the time needed to recoup the initial outlay.
Access to Finance & Incentives	Assesses availability of loans, grants, tax breaks, and other financial support mechanisms.

Market Competitiveness	Determines how the offering stacks up against existing alternatives in price and performance.
Site close to supply (of RE and other input) and demand for output	Locates facilities near energy resources and end-use markets to minimize logistics costs.
Preferential financing (IFI, DFI) possible	Explores concessional funding opportunities from international and development finance institutions.
Funding of GHG reduction technologies supported internationally	Leverages global climate finance programs for emissions-cutting solutions.
Cost-benefit relation: CO2 reduction cost efficiency	Compares cost per ton of CO_2 avoided against benchmark values.
Existence of Infrastructure	Verifies presence of necessary transport, grid, and storage networks to support operations.
Scaling up / down costs potential / restrictions	Analyses how unit costs change with project expansion or contraction.
Is there a national / regional market / demand for the product incl. possibility to expand to other production.	Gauges current consumption levels and opportunities for entering new markets.
SOCIAL	
Labor & Skills	Assesses availability of a trained workforce and the need for upskilling or recruitment.
Community Acceptance	Gauges local residents' support and potential social license to operate.
Worker Health & Safety	Ensures operations meet standards to protect employee well-being.
Gender & Social Inclusion	Promotes equitable participation and benefits across genders and marginalized groups.
Conflicts in planning zones	Identifies land-use disputes or competing interests that could delay project siting.
Willingness by Stakeholders to embrace the technology	Evaluates readiness of investors, regulators, and end-users to adopt the proposed solution.
TECHNOLOGICAL	
Technology Maturity	Assesses the development stage of the technology from lab-scale to commercial deployment.
Infrastructure Requirements	Identifies the physical systems (e.g., grid connections, pipelines) needed for implementation.
Integration with On-Farm Renewables	Evaluates how seamlessly the solution can tie into existing solar, biogas, or wind setups on-site.
Operational Flexibility	Determines the ability to adjust output in response to fluctuating supply or demand
Has the technology/measure been proven globally through pilot projects or even full installations?	Confirms whether the technology has been validated through international pilot projects or full-scale installations.

Is the technology/measure available off the shelf	Checks if the solution can be procured directly from vendors without bespoke development.
Regional/national level: as above, in country, region	Assesses local or regional availability, support, and market presence of the technology.
Innovation potential / learning curve	Gauges opportunities for further improvements and the time needed for operators to gain proficiency.
Flexibility of technology (in terms of operation, adaptation to supply/demand)	Measures how easily the technology can be modified to cope with changes in inputs or outputs.
Construction/implementation schedule (short/long, easy/complicated)	Estimates the duration and complexity of deployment from groundbreaking to commissioning.
Safety standards easy to fulfil	Ensures the technology meets national and industry safety regulations with minimal adaptation.
Project already pre-developed (in Kenya) / documents, preliminary. design etc. (in part) available	Reviews any existing feasibility studies, designs, or pilot setups already initiated domestically.
Supply / evacuation of input/output (e.g. infrastructure exists, easy to be build)	Reviews any existing feasibility studies, designs, or pilot setups already initiated domestically.
Know-how (O&M, R&D) available (research organisations, service companies, experts)	Checks for the presence of O&M expertise, R&D capacity, and service providers within the country.
ENVIRONMENTAL	
Carbon Abatement Potential	Evaluates the amount of greenhouse gas emissions the project can avoid or remove over its lifetime.
Water Footprint	Measures the total water consumption and withdrawal associated with the technology's lifecycle
Biodiversity & Land Use	Assesses impacts on ecosystems, habitat integrity, and land availability for competing uses.
Circularity & Waste	Determines opportunities for material reuse, recycling, and minimization of residual waste streams.
Mitigation measures available / possible	Identifies strategies to prevent, reduce, or compensate for adverse environmental effects.
LEGAL	
Legal / regulatory frame exists (incl. safety standards etc.)	Confirms that pertinent laws, regulations, and safety codes are in place to govern the project.
Safety & Standards	Ensures mandatory technical and operational standards are defined and enforceable under law.
Trade & Export Regulations	Reviews rules, tariffs, and certifications affecting the import, export, and sale of goods.
Intellectual Property & Technology Transfer	Assesses protection of innovations and legal frameworks for licensing or cross-border tech sharing.

Land availability (also for international investors)	Verifies clear land tenure, leasing arrangements, and foreign-investment provisions for site acquisition
Similar processes / projects in the past / present	Examines existing legal precedents and case studies to inform regulatory compliance.
Doing business / bureaucracy / corruption	Evaluates administrative complexity, approval timelines, and governance risks impacting project execution.
Project already pre-developed (in Kenya) / documents etc. (in part) available	Identifies any existing permits, feasibility studies, or design documents to streamline approvals.

10.3 Annex C: PESTEL Analysis

Criteria	E-fertilisers Adoption	Green Ammonia Refrigerant Adoption	SAF Fuelled Cargo Planes Use	Green Methanol Fuelled Sea Vessels Use	Utilisation of Maersk-KRC Green Logistics Initiative & Sea Freight
Political (P)	1	1	1	1	1
Economic (E)	0	0	1	0	1
Social (S)	0	0	0	0	0
Technology (T)	-1	0	0	0	1
Environmental (E)	0	1	0	1	0
Legal (L)	0	0	0	1	0

10.4 Annex D: Project Costs &

10.4.1 Electrolyser & Haber-Bosch Plant Costs

Here's a summary of typical capital-expenditure (CAPEX) ranges for water-electrolyser systems and Haber–Bosch ammonia synthesis units, expressed on a per-unit basis:

Unit Type	Metric	CAPEX range (USD)
Alkaline electrolyser	Installed power (kW)	850 – 1 400 $/kW[104]
PEM electrolyser	Installed power (kW)	1 500 – 1 800 $/kW[104]
Brownfield Haber–Bosch plant	Annual capacity (t NH_3/year)	900 – 1 100 $/t[105]

[104] International Energy Agency, 2019

[105] The capital intensity of small-scale ammonia plants – Ammonia Industry

Greenfield Haber–Bosch plant	Annual capacity (t NH_3/year)	1 300 – 2 000 $/t[105]

10.4.2 An Order-of-Magnitude CAPEX Estimate for a 1.2 t NH_3/day (438 tNH_3 per year) Green Ammonia Plant ("Greenfield" Build).

Assumptions

- 1 kg NH_3 requires 0.176 kg H_2[106] and 10 kWh of electrical energy (electrolysis + compression)[107]
- PV capacity factor 20% (solar only; no storage)[108]
- Greenfield "plant" CAPEX (Electrolyser stack + Balance of Plant (BoP) + Haber–Bosch (H-B) Synthesis Loop+ Air Separation Unit (ASU) = USD 1 300–2 000 per t NH_3 Per year[105]
- Utility-scale PV installed cost = USD 691 /kW (2024 global average)[109]
- Ammonia Production OPEX assumed values (ammonia synthesis, Cryogenic air separation and electrolyser operation) = 6.5% of CAPEX[110]
- Assumed Green Ammonia costs: 900 to 2,700 USD/tonne[111].

1. Total CAPEX & Annual OPEX

Item	Calculation	USD
Electrolyser + H-B Plant CAPEX	438 t/yr × [1 300 to 2 000 USD/t-yr]	569 400 – 876 000
PV array size	4 380 MWh/yr ÷ (8 760 h/yr × 0.20 CF) = 2 500 kW	–
PV CAPEX	2 500 kW × 691 USD/kW	1,727,500
Total CAPEX	Plant + PV	2,276,900 – 2,603,500
Annual OPEX (6.5 % of CAPEX)	0.065 × (2,276,900 – 2,603,500)	148,000 – 169,228

10.4.3 Refrigeration Systems Ammonia Retrofitting

1) Equipment and Fittings Change

Equipment Change	Notes

[106] USAID. (2023). *Capacity Building Workshop for Financial Institutions on Green Hydrogen*.
[107] International Energy Agency. (n.d.). Towards hydrogen definitions based on their emissions intensity.
[108] International Energy Agency & Nuclear Energy Agency. (2020). Projected Costs of Generating Electricity.
[109] International Renewable Energy Agency (IRENA). (2025). *Renewable Power Generation Costs in 2024*. Abu Dhabi: International Renewable Energy Agency
[110] Saygin, D., Blanco, H., Boshell, F., Cordonnier, J., Rouwenhorst, K., Lathwal, P., & Gielen, D. (2023). Ammonia Production from Clean Hydrogen and the Implications for Global Natural Gas Demand. Sustainability (Switzerland), 15(2). https://doi.org/10.3390/su15021623
[111] OECD (2025), The Role of Shipbuilding in Maritime Decarbonisation: Impacts of Technology Developments and Policy Measures, OECD Publishing, Paris, https://doi.org/10.1787/0c8362c0-en.

Compressors	HFC/HFO compressors are often not suitable (oils, design); ammonia-rated semi-hermetic / screw / reciprocating compressors are installed
Evaporator	Exchangers must be ammonia-compatible (tube material, brazing). Many copper-tube evaporators need replacement[112].
Condensers	Condensers sized and materials checked/replaced for NH_3 operating pressures[113]
Refrigerant piping and fittings	Replace copper tubing & brass fittings with carbon-steel, stainless steel or ammonia-compatible materials; add isolation valves, sight glasses and strainers rated for ammonia[112]
Oil separators & oil system components	Ammonia systems use different oils and separators; may need full oil system rework[113].
Receivers and pressure vessels	Liquid receivers, surge drums and any pressure vessels must be ammonia-rated and coded.
Heat exchangers	Replace or reconfigure if materials incompatible or sizing changes[113]
Expansion devices & metering (TXV/orifices)	Selection for ammonia service; some HFC TXVs may be reused but typically replaced[113].
Controls and safety interlocks	New safety logic, pressure/temperature interlocks, alarms required for NH_3
Gas detection & ventilation	Fixed ammonia sensors, alarm panels, mechanical ventilation / extraction fans, emergency systems.
Relief devices & rupture discs	Sized and installed to ammonia codes, plus discharge piping to safe location.
Machinery room & structural modifications	Secondary containment, segregation, doors, drains, dedicated rooms for NH_3 equipment per code.

2) Retrofing/Installation Costs

- Retrofitting cost = $7,000/TR[114].

[112] Materials Compatibility Guide(1006)
[113] United Nations Industrial Development Organisation, 2019: Preparing for HCFC phase-out: *Fundamentals of uses, alternatives, implications and funding for Article 5 countries*

[114] International Association of Refrigeration Warehouses (2014): Low Ammonia Charge Refrigeration Systems for Cold Storage White Paper

- Auxiliary equipment power consumption = 10%[115].
- HFC Refrigeration system Coefficient of Performance (COP) = 3[116]
- Ammonia Refrigeration system Coefficient of Performance (COP) = 3.6, a conservative value[117]
- Electricity tariff= Kes 25 (USD 0.19) per kWh

10.4.4 Sustainable Aviation Fuel Plant CAPEX & OPEX[118]

Facility	Annual SAF Output (Litres)	Total Capitcal Investment (Million)
n^{th} facility	120 million	USD 1,509
Pioneer facility	40 million	USD 1,267
Proposed Facility	21.25 to 28.75 million	Under n^{th} (mature) case: USD 267–362 Pioneer (FOAK) case: USD 673–911[119]

Feedstock (agricultural residues) Price $110/ton

1. **Assumptions**

- Annual OPEX (6.5 % of CAPEX)
- Feedstock: Agricultural Residues
- Annual Feedstock Volume = 113000 Metric Tonnes
- In 2024, Kenya Airways consumed about 436,894 tonnes of non-renewable jet fuel[120]. According to Kenya Airways Sustainability Report (2024), KQ is committed to developing SAF in Kenya
- SAF cost per litre: UD $2.56 (€2.21)[121]

Annual production Capacity (Litres)	nth (Mature) Facility	120,000,000	
	Pioneer (FOAK) Facility	40,000,000	
	Feedstock Cost (USD/Tonne)	110	
	Production Technology	FT	
Total Investment Cost (USD)	nth (Mature) Facility	1,509,000,000	
	Pioneer (FOAK) Facility	1,267,000,000	
CAPEX (USD/Litre)	nth (Mature) Facility	12.575	
	Pioneer (FOAK) Facility	31.675	
THIS STUDY VALUES			
	nth (Mature) Facility	21.25	29

115 Refrigeration Equipment: Engineering Reference — EnergyPlus 8.9

116 Ghanbarpour, M., Mota-Babiloni, A., Makhnatch, P., Badran, B. E., Rogstam, J., & Khodabandeh, R. (2021). ANN Modeling to Analyze the R404A Replacement with the Low GWP Alternative R449A in an Indirect Supermarket Refrigeration System. Applied Sciences, 11(23), 11333. https://doi.org/10.3390/app112311333

117 Pudaruth, Sameerchand. (2020). ELECOM 2020: 2020 3rd International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ELECOM) : conference proceedings : University of Mauritius, 25-27 November. IEEE.

118 ICAO'S SAF Rules of Thumb

119 These figures are order-of-magnitude estimates and assume linear scaling of both gasification/FT and downstream upgrading equipment

120 **Kenya Airways.** (2024). *Sustainability report 2024*

121 SAF Market | EASA

Annual production Capacity (Litres)	Pioneer (FOAK) Facility	21.25	29
Total Investment Cost (USD)	nth (Mature) Facility	267,218,750	361,531,250
	Pioneer (FOAK) Facility	673,093,750	910,656,250
Minimum Selling Price (USD/L)	nth (Mature) Facility	2	
	Pioneer (FOAK) Facility	3.8	
Production Scenario		**Low**	**High**
Annual Selling Revenue (USD)	nth (Mature) Facility	42,500,000	57,500,000
	Pioneer (FOAK) Facility	80,750,000	109,250,000
OPEX	nth (Mature) Facility	17,369,219	23,499,531
	Pioneer (FOAK) Facility	43,751,094	59,192,656
OPEX Escalation Rate	2.50%		
Annual Discount Rate	10%		
Green Ammonia Price Deescallation Rate	5%		
Feedstock Cost Escalation	0.50%		

10.4.5 Bio Methanol (MeOH) Costs

Scenario	CAPEX
low-CAPEX case	1,560 USD/t MeOH / year[122]
high-CAPEX case	2,220 USD/t MeOH / year)[122]
14 840 t/year: low-CAPEX case (nth of a kind plant)	23.2 M USD[123]
14 840 t/year: high-CAPEX case (nth of a kind plant)	32.95 M USD[123]
14 840 t/year FOAK Plant	30.1 – 49.4 M USD[123]
Biomethanol Cost (USD/tonne)	€1,193[124] (USD 1,395)
Low OPEX	78 USD/t MeOH/Year[122]
High OPEX	222 USD/t MeOH/Year[122]

[122] IRENA AND METHANOL INSTITUTE (2021), Innovation Outlook : Renewable Methanol, International Renewable Energy Agency, Abu Dhabi
[123] Projections
[124] Methanol Institute (n.a), Economic Value of Methanol for Shipping Under FuelEU Maritime and EU ETS (https://www.methanol.org/wp-content/uploads/2024/09/ECONOMIC-VALUE-OF-METHANOL-FOR-SHIPPING-PAPER_final.pdf)

International PtX Hub

On behalf of:

Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

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