Powering clean shipping: Kenya in the global power-to-x economy

Full Version

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Berlin, September 2025

Executive summary

i. Context

Global collaboration to reduce shipping emissions takes place within the International Maritime Organization (IMO). The IMO set a Greenhouse Gas Emission (GHG) Strategy in 2023 that provided the shipping sector with an important, non-binding roadmap to phase out emissions from international shipping by or around 2050, whilst promoting a just and equitable transition.[1] The strategy required translation into binding policy measures under the International Convention for the Prevention of Pollution from Ships (MARPOL). MARPOL's decision-making body, the Marine Environment Protection Committee (MEPC) and its Intersessional Working Group on GHG Emissions from Ships (ISWG-GHG) then worked to develop such measures, which were agreed at MEPC83 in April 2025[2] and are set to be formally adopted in October 2025.

Kenya has adopted a range of programmes designed to boost the development of low carbon solutions in the transport sector, including the 2023 Green Hydrogen Strategy and roadmap. With 90% of Kenya's exports traded by sea and as a regional hub for land-linked neighbouring countries, Kenya has ambitious plans for its maritime sector in particular. As part of these efforts, Kenya's first National Action Plan (NAP) for maritime decarbonisation is currently under development and is expected to be finalised in 2025. The plan will outline Kenya's policies and strategies to address GHG emissions from domestic shipping and ports, as well as to harness the opportunities associated with the shift to green fuels. This project is complementary to the NAP development with key outcomes integrated into the NAP process and vice versa.

ii. Project background

Focusing on Kenya's Power-to-X priorities as highlighted in the Green Hydrogen Strategy, this project has focused specifically on the production and use of electro-fuels (e-fuels): e-ammonia, e-methanol and e-diesel in the maritime sector. An increase in the production and use of these e-fuels will have a range of benefits for Kenya and Kenyan people. These benefits could include maximising the green renewables offer that Kenya already has to produce high value fuel products which are consistent with net zero goals, whilst generating green jobs and improving Kenya's energy resilience.

Through two in-person stakeholder workshops, interviews and a techno-economic assessment, this project considers both the supply side opportunities to produce these fuels, as well as methods of stimulating demand to offtake the fuels. Both of these elements are crucial to understanding the viability of a green shipping corridor in Kenya. A pre-feasibility

1 IMO, 2023 IMO Strategy on Reduction of GHG Emissions from Ships.

2 IMO (2025), IMO approves net-zero regulations for global shipping.

assessment was carried out to consider the routes that are best suited to a green shipping corridor initiative between Kenya and an international trade partner. As a collaborative initiative that brings together public and private stakeholders, a green shipping corridor focuses on a specific trade route, forming a coalition of actors from across the shipping supply chain – from fuel producers, over ship operators, governments and ports, through to cargo owners. Establishing green shipping corridors enables coordinated fast movement to support the development of zero-emission shipping on the specific route and therefore share risks associated with being early movers before 2030, including the cost associated with green fuels.

iii. Key findings

This analysis found that there is significant opportunity for Kenya to produce e-fuels domestically. Kenya has access to abundant renewable energy resources, including solar, wind, geothermal and hydropower as key inputs to the production of green hydrogen which is a crucial intermediary for the development of e-fuels. In particular, there is significant potential for e-ammonia to be produced at globally competitive costs, both as a prospective e-fuel for the shipping sector but also as the primary feedstock for fertiliser production. This dual role closely aligns with Kenya's priorities for green hydrogen utilisation. There is also potential for Kenya to develop its position as a regional bunkering hub to support the utilisation of e-fuels in shipping. Attracting vessels and sourcing e-fuels at scale, as well as competing regionally would be key considerations.

On the demand-side, a green corridor assessment identified trading routes which are best placed to provide the appropriate demand signal to secure offtake of greener fuels. There were several factors involved in this assessment to understand the impact that decarbonising these routes would have and the feasibility of doing so. Going forward, a feasibility assessment could be carried out on two routes identified in this study: a Netherlands cut flower route or a German coffee route, which offer the best opportunity for Kenya to pursue first mover efforts on shipping decarbonisation before 2030. This would build on the route-based assessment carried out here to further understand, in particular, the cost involved in decarbonising the routes, as well as possible solutions to other key challenges identified in this assessment.

The benefits generated from a route-based approach could also be advanced in other ways, capitalising on the nature of Kenyan trade, ambitions and strategic interests. These benefits could be pursued through a phased approach and include leveraging voluntary demand of cargo owners through book and claim[3] or in delivering a modal shift from air to sea freight for key commodities (work here has already begun by TradeMark Africa [4]

3 Book and claim is a chain-of-custody model that allows the environmental attributes of zero-emission fuels to be separated from their physical flow. This enables access to low-emission shipping services without requiring a direct physical link between cargo owners and the vessels using green fuels.

4 TradeMark Africa (2023), Kenya's green move to shift 50% of horticultural exports from air-freight to sea-freight.

and Flying Swans[5]). Kenya could also explore opportunities to access policy incentives (e.g. from the EU) through the export of e-fuels, and through developing e-fuel pilots to enhance capacity and prepare for shipping's mass market transition to reach IMO greenhouse gas emission targets.

It is especially important to consider the context within which this report was written, with the newly developed IMO Net-zero Framework affecting global shipping. Corresponding guidelines are yet to be developed, which will happen after the (assumed) adoption of the new measures in October, when an extraordinary session of the MEPC will take place. Still, key assertions can be made [6] about the possible impact of these new guidelines on green shipping if agreed in this report's context:

1. They set the sector on a path to net zero in 2050, displacing fossil fuels such that they can be expected to be the minority energy source used by the sector within the next 15 years.

2. Zero and Near-Zero (ZNZ) fuels and technologies are defined as those emitting below 19g$C02_{eq}$ / MJ through 2034 and below 14g$CO2_{eq}$/ MJ beyond 2034. Fuels meeting these requirements will be eligible for rewards.

3. The guidelines are expected to generate incremental revenues (with some analyses pointing to approximately USD11 billion per annum[7] in the first three years), with potential to use part of it to reward ZNZ fuels and to support just and equitable priorities (including national level projects related to maritime and shipping's transition, climate protection, adaptation and resilience building).

As a result of the assessment conducted here, a set of seven recommendations is proposed to support the development of e-fuel production and use in Kenya. The first four recommendations are policy recommendations that highlight key aspects identified in this project. The last three recommendations are action-oriented recommendations which offer practical next steps.

iv. Policy recommendations for the Kenya government

There is valuable ongoing work by the Government to support the development of the renewable energy and maritime sectors in Kenya. These recommendations are intended to support that work to build a robust policy and regulatory framework, send clear signals for the production and use of e-fuels, identify and access suitable financing mechanisms and further activate Kenyan industry.

5 Flying Swans, Projects: Kenya – Naivasha Consolidation Centre.

6 Global Maritime Forum (2025), IMO policy measures: What's next for shipping's fuel transition?

7 Ibid.

1. **Policy and regulation** – building on the recommendations in the Green Hydrogen Strategy [8] and the (upcoming) National Action Plan on the reduction of GHG Emissions from the shipping sector, the Government could more strongly prioritise measures which enable a streamlined process for hydrogen and e-fuel project delivery, including for permitting, land access, development of enabling infrastructure such as grid expansion, including through ongoing coordination with bodies like the Kenya Green Hydrogen Association. Connecting fuel production to the maritime sector will require policy support and incentives which target the cost gap for green fuels and the barriers to offtake that maritime sector faces, in addition to port expansion and skills development.

2. **Financing** – Kenyan-produced e-fuels are at least four times the cost of low-sulphur fuel oil (LSFO) when compared equivalently. This is not a challenge specific to Kenya but will require both public and private financial incentives to close the cost gap. While considerable subsidisation of e-fuels from the Kenyan Government may be challenging, there are other supportive actions that the Government could take to make e-fuels produced in Kenya more competitive on the global scale that are less reliant on a substantial subsidisation budget. Implementing and supporting risk-sharing mechanisms or blended finance vehicles with the private sector, including public-private partnerships, could enable further access to concessional finance. Addressing project-level factors and macro-economic risks would lower the cost of capital and enhance lending.

3. **Maximising co-benefits of the shipping transition based on International Maritime Organization measures** – there are a range of activities which would be beneficial in all scenarios, including grid expansion and strengthening, port readiness development and expansion of port regulations (including at Lamu port, as well as Mombasa). These would position Kenya well for green shipping development while retaining benefits within the local economy. Carrying out these activities with a view to possible revenue disbursement from the IMO process could also support Kenya's preparations to adhere to and support global compliance to reach full decarbonisation by 2050. Positioning the growing domestic fertiliser market as a key offtaker for e-ammonia alongside shipping may improve the likelihood of reaching final investment decision (FID) for early e-ammonia projects, whilst meeting national objectives.

4. **International partnerships** – Significant progress in greening the maritime sector has been a result of collaboration across the supply chain. Zero-emission shipping pathways can be different for every country, but many common challenges persist, particularly in addressing the cost gap for e-fuels and overcoming the chicken-and-egg problem (production awaiting a demand signal while offtakers are awaiting improvements in availability and cost of fuels which often come through scale). Knowledge exchange and technical cooperation, combined with access to international funds will strengthen Kenya's domestic and global positioning on green shipping opportunities. The key opportunities for collaboration identified here include port readiness as well as market and policy development for e-fuels.

8 Ministry of Energy and Petroleum (2023), Green Hydrogen Strategy and Roadmap, see page 7.

One example through which this type of partnership could be pursued is the EU Global Gateway Green Shipping Corridor Initiative.[9]

v. Action-oriented recommendations

5. **Activate motivated industry stakeholders** – connecting supply and demand is crucial. Ongoing dialogue through groups such as the Kenya Green Hydrogen Association around the production of hydrogen and its derivatives is tackling key challenges. There is an opportunity to connect this dialogue to the shipping industry as a potential offtake sector for e-fuels, to (a) matchmake supply and demand for e-fuels; (b) develop public/private partnerships to facilitate e-fuel production and use; and (c) ensure effective delivery of targeted policy in the ways outlined in recommendation 1.

6. **Further explore the feasibility of a green shipping corridor** – one method of stimulating demand for e-fuels in Kenya is through a route-based approach, working with other international trading partners. There are several routes with viable aspects, generally within the container sector involving cargo such as cut flowers, coffee or tea.

7. **Consider all opportunities to stimulate demand** –
   a. Accessing the potential appetite of cargo owners to support the greening of commodity transportation is currently most viable through a book and claim system (see Insight box). The Kenyan Government could support this through the initiation of international partnerships which improve the understanding of and participation in voluntary book and claim mechanisms by, for example, Kenyan fuel producers.

   b. Exploring export of e-fuels as a co-priority in addition to building a domestic market for e-fuels. The Government could support e-fuel projects under development to access policy incentive schemes through policy streamlining or other modes of public/private collaboration.

   c. Set out a timeline and initiate delivery of e-fuel pilots at Kenyan ports before 2030. Lamu Port may be taken into consideration as a promising location for these pilots and the Kenyan government could support the strategic ambitions at that port to enable green shipping activity.

9 European Commission, Global Gateway - Global Maritime Green Corridor

Insight: Book and claim

In a book and claim chain of custody system, the records that document the characteristics of a product – here, a zero-emission shipping fuel – are not connected to the physical flow of the product from the product's generation to its use. Once the fuel is produced, the attributes of the fuel (such as its greenhouse gas emission profile) are tracked separately from the physical fuel. The zero-emission fuel may be mixed with and be indistinguishable from conventional fuels during its transport to bunkering hubs and its consumption on a vessel. This decoupling allows demand for low-emission shipping to scale up without the need to overcome the many challenges of providing zero-emission fuel and cargo space with a physical link to an organisation that is willing to pay a premium for low-emission transportation services.

Source: Global Maritime Forum (2023), A Book and Claim Chain of Custody System for the early transition to Zero-emission Fuels in Shipping

Table of content

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Glossary

Blue economy: Refers to the sustainable use of ocean resources for economic growth, improved livelihoods, and job creation, while preserving the health of marine ecosystems.

Cars [unit]: Measure of a vessel's vehicle carrying capacity used to denote cargo limits for vehicle carriers.

Deadweight tonnage (DWT): Measure of a vessel's weight carrying capacity used to denote cargo weight limits for dry and wet bulk commodities.

E-ammonia: Ammonia produced combining green hydrogen - i.e. hydrogen generated through electrolysis powered by renewable electricity - with nitrogen from air. This distinguishes it from conventional ammonia production, which typically uses hydrogen from fossil fuel sources.

E-methanol: Methanol produced combining green hydrogen – i.e. hydrogen generated through electrolysis powered by renewable electricity – with carbon. The carbon is either captured from biogenic sources (e.g., a biogas plant) or point sources (e.g., a natural gas plant) or through direct air capture or direct ocean capture. 'Green' methanol is not synonymous with e-methanol, but a term that also encompasses bio-methanol.

E-diesel/E-MGO: Synthetic diesel fuel produced by combining green hydrogen – i.e. hydrogen generated through electrolysis powered by renewable electricity - with captured carbon dioxide through Fischer-Tropsch synthesis or similar processes. E-diesel acts as a drop-in replacement for conventional diesel fuel, with E-MGO referring specifically to the fuel for marine use.

Electro-fuel (e-fuel): Synthetic fuels produced using electricity as the primary energy input to drive chemical processes that convert basic feedstocks into usable fuel molecules. This process is considered a Power-to-X process.

Green shipping premium: The additional cost of using green technologies and fuels compared with using fossil technologies and fuels.

Gross tonnage (GT): Measure of a vessel's internal volume (i.e. enclosed space) used to roughly denote the size of ships that do not carry bulk cargo/commodities.

Low-sulphur fuel oil (LSFO): Ships' fuel oil with a sulphur content of maximum 0.5%. Because the IMO introduced requirements for lower sulphur oxides (Sox) emissions in 2020, LSFO and Ultra Low Sulphur Fuel Oil (ULSFO) are now used instead of traditional heavy fuel oils.

Power-to-X: Umbrella term for technological processes that transform electricity – often electricity from renewable sources – into other forms of energy or products. Example outputs ("X") include e-fuels (e.g. e-ammonia, e-methanol or e-diesel etc), chemicals, gas or heat etc.

Twenty-foot equivalent unit (TEU): Measure of a vessel's 20-foot container box carrying capacity used to denote cargo carrying limits for containerships.

Zero Emission Fuel: Fuels derived from zero carbon energy sources, including green and blue hydrogen, green and blue ammonia, batteries, sustainable biofuels, synthetic or bio methanol, synthetic or bio-LNG (liquefied natural gas) and wind propulsion. Not all zero-emission fuels can be referred to as "scalable zero-emission fuels" – some energy sources have scalability in supply clearly sufficient to meet global needs in shipping and other sectors. Other energy sources (e.g. biomass-derived) have constraints, whether biological or physical or because of sustainability/economic criteria. Full definition here.

List of figures

List of tables

1. Section: Methodology

A combination of desk research, stakeholder engagement, national expert input and analysis from the University of Maritime Advisory Services (UMAS) was used, in addition to multiple validation stages with the Kenya Maritime Authority, the International Power-to-X Hub and International Maritime Organization GreenVoyage2050 Programme to deliver this project over a 10-month period. This combination of methodologies was intended to ensure robustness and validation of the key findings. Desk research and techno-economic assessment findings were reinforced by ongoing stakeholder engagement through interviews and workshops (see Figure 1).

Desk research

- Economic, regulatory, stakeholder assessments undertaken.
- Sources: National Action Plan regulatory & stakeholder review, GIZ stakeholder mapping; International Maritime Organization regulation etc.

Interviews

- 20+ interviews with public, private and not-for-profit stakeholders taking place from December to May
- Sources: Kenya Maritime Authority, Ministry of Energy and Petroleum, African Development Bank, Kenya Flower Council, Kenya Green Hydrogen Association, Kenya Ship Agent's Association and more.

UMAS techno-economic assessment

- UMAS (a commercial consultancy which delivers applied solutions for the energy transition) used illustrative examples to explore e-fuel production scenarios, focusing on e-methanol, e-ammonia and e-MGO(e-diesel).
- UMAS utilised fuel cost models to compare cost of green fuels produced in Kenya with other global production sites.

Workshop 1, February 2025

- Alongside the National Workshop on Kenya's National Action Plan development, held a four-hour workshop in Mombasa highlighting the objectives, initial findings and sought feedback for the next phase of assessments – both on the supply and demand-side.

Workshop 2, May 2025

- Full-day workshop in Nairobi, with 20+ participants from across the shipping value chain.
- Shared key findings, supported smaller discussion groups to challenge key assumptions and identify next steps.

Support from national expert, Kenya Maritime Authority, International PtX Hub & coordination with IMO GreenVoyage2050 programme

Figure 1
Overview of methodological process

Green shipping corridor methodology

To understand the viability of a green shipping corridor, a route-based assessment was carried out. The impact and feasibility of different routes were considered through a combination of quantitative and qualitative methods. The first input was from the University of Maritime Advisory Service's Fuse model, an assessment undertaken by UMAS to understand the opportunities associated with key shipping types and commodities. Combined with qualitative inputs from research and stakeholder engagement, this project used a green corridor assessment approach developed by the Global Maritime Forum to draw conclusions about the viability of different routes.

UMAS's Fuse model drew on vessel-tracking AIS (Automatic Identification System) data. This data is collected through transceivers that are fitted on ships above 300 gross tonnes and all passenger ships, which transmit data on position, course, and speed. UMAS's Fuse model processes over 500 million AIS data points each year for the discrete voyages each ship makes. This is combined with information on the technical specification of each ship to estimate the energy consumed during the voyage, and the resulting

GHG emissions. For this project, the Fuse model was used to assess the activity of ships calling at Kenyan ports and trading along the east coast of Africa in 2023 to determine possible options for green shipping corridors. There are limits to the level of insight this data can provide and therefore is complemented by qualitative and quantitative information about Kenya's seaborne trade flows, as well as the information collated from the other methodologies used in this project.

The Global Maritime Forum's assessment approach utilised here is inspired by the 2021 report "The Next Wave".[10] This multicriteria assessment allows the comparison of key factors that make a route more or less suitable for a green corridor collaboration. It does this by considering a route's possible impact on the decarbonisation of global shipping, whilst seeking to understand its feasibility to be implemented (see Figure 2). These factors can be assessed through several qualitative and quantitative indicators outlined below.

Figure 2
Criteria for identifying and assessing green corridors

i. Identification and assessment criteria

In this section, the above described factors are explored further in the Kenyan context. These criteria provide a structural backbone for the participatory process of route prioritisation, which combined several rounds of filtering based on a combination of desk research and stakeholder input.

Impact

The potential impact of decarbonising a route can be considered with several data points.

- Kenya's biggest maritime trade partners
- Kenya's largest commodity exports
- Kenya's largest commodity imports
- Main ports serving the relevant partners/commodities
- Ports/destinations with highest potential of capturing zero-emission shipping interest
- Most important routes as identified by Kenyan stakeholders

10 Global Maritime Forum (2021), The next wave: Green corridors.

Feasibility

To understand how feasible decarbonising a route will be, one may consider how it would perform against the four green corridor building blocks: fuel pathway, customer demand, policy environment and cross-value chain collaboration.

1. **Fuel pathway**

   - Feasibility of supply and bunkering of e-fuels on the routes.
   - Cost of local fuel production and bunkering volumes.

2. **Cargo and demand**

   - The type of cargo being shipped has several consequences for the feasibility of establishing a corridor, particularly the feasibility of charging a green premium.
   - Key factors include main cargo segments, main trade partner countries for cargo segments, main trade items for biggest trade partners, types of cargo on the routes of interest.

3. **Policies**

   - Considering the gap between the price of zero-emission and conventional fuels, the policymakers at both ends of the corridor will need to consider how to support a corridor's economic viability. This could be in the form of direct subsidy support for e-fuels (in particular for the application in the maritime sector) or wider enabling environment measures.
   - Some routes may offer particularly favourable conditions due to, for example, existing bilateral cooperation with Kenya or subsidy schemes.

4. **Stakeholders**

   - Stakeholder complexity, willingness to engage and already-established collaborations all form key inputs to a green corridor pre-feasibility assessment.

2. Section: Results

Understanding the zero/near-zero emission shipping supply chain

To understand the dynamics of the zero-emission shipping value chain in Kenya, the GMF team considered multiple lenses through which to complete the analysis:

1. **Economic** – key factors considered here include the importance and relevance of maritime activity to Kenya's economy, as well as Kenya's trade profile and those of Kenya's biggest trading partners.

2. **Regulatory** – understanding the regulatory frameworks that exist to govern the maritime sector in Kenya.

3. **Stakeholder** – partly dealt with through the analysis covered in the section 'Benefits for local stakeholders' but also reflected upon here by building on the GIZ and National Action Plan stakeholder assessments.

i. Economic analysis

This paper builds on work initiated under the Kenya's National Action Plan process. To avoid duplication, below is a summary of the key aspects of our analysis which are of relevance to this project.

Despite Kenyan maritime imports and exports accounting for less than 1% of the total volume of global trade, the sector plays an important role in supporting Kenya's GDP with more than 90% of Kenyan imports and exports facilitated by seagoing ports.[11]

Kenya has nine major ports of which some are undergoing expansion and renovation to meet global standards.[12, 13] The Kenyan government is responsible for operating, managing and refurbishing the nation's ports, but this is changing with an increased push to privatise.[14] The Port of Mombasa is the premier and busiest port with a handling capacity estimated to be over 2 million TEU.[15] Another port of interest for this project is Lamu Port with plans for its significant growth over the coming years to transform it into a "vibrant commercial hub",[16] with connections to a northern corridor route under development – the Lamu Port-South Sudan-Ethiopia Transport Corridor (LAPSSET). It is slowly attracting commercial trading vessels

11 Kenyan State Department for Shipping and Maritime Affairs, National Maritime Transport Policy.
12 Kenya Ports Authority, Ports & Terminals.
13 Marine Insight (2021), 9 Major Ports in Kenya.
14 JEDCA MEDIA (2025), Kenya To Lease Key Port Assets For 30 Years In Major Privatization Push.
15 http://p3nlhclust404.shr.prod.phx3.secureserver.net/SharedContent/redirect_0.html
16 Kenya Ports Authority, Strategic Plan 2023/24-2027/28.

as its infrastructure develops.[17] See Figure 3 for a map of the biggest Kenyan ports based on their twenty-foot equivalent unit (TEU) capacity.

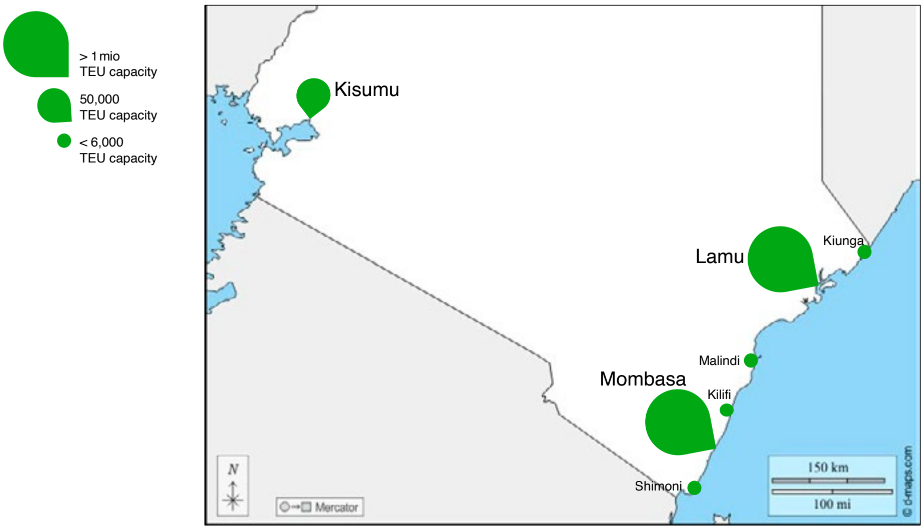

Figure 3

Map of Kenya's biggest ports, *Graphics source:* Map outline

Trade disruptions due to the Red Sea and Suez Canal concerns have had significant impacts on the 15% of Kenya's foreign trade (by volume) which is channelled through the Suez Canal.[18] This was raised as an ongoing concern by most stakeholders interviewed in this project.

The majority of ships calling at Kenyan ports are containerships, with 174 containerships making 671 calls in 2023, followed by bulk carriers with 237 ships making 259 calls.[19] Tea, coffee and horticultural crops are the main items of export, with the agricultural sector employing 75% of the population.[20] In 2022, tea accounted for almost 20% of Kenya's exports, cut flowers just over 9% and coffee just under 5%,[21] with significant variation in respective transport modes. While the majority of tea exports travel via maritime rather than air routes,[22] for instance, only 4% of 2024 Kenyan cut flower exports were sea-freighted.[23] This low share of sea-freighted transport, combined with the comparatively lower cost of shipping and Kenya's plans to transport 50% of horticultural exports via sea by 2030,[24] presents a significant opportunity for increased demand on shipping routes from Kenya.

17 Kenyan State Department for Shipping and Maritime Affairs, National Maritime Transport Policy.

18 United Nations Conference on Trade and Development (2024), Impact of shipping disruptions on trade in Africa.

19 UMAS analysis undertaken as part of this project.

20 Marine Insight (2021), 9 Major Ports in Kenya.

21 International Power-to-X Hub (2024), Stakeholder mapping and assessment for the maritime and shipping sector in Kenya.

22 Farming in Kenya Consultancy (2025), How to Export Tea from Kenya.

23 Flora Culture International (2024), The goal is to be shipping 50 per cent of Kenyan flower exports by the sea in seven years' time'.

24 Delegation of the EU to Kenya (2023), Kenya's green move to shift 50 percent of horticultural exports from air freight to sea freight

Example: Kenyan Cut Flower Industry

The cut flower industry in Kenya accounts for 1.25% of Kenya's GDP, employing over 500,000 people and affecting over 2 million people's livelihoods. Flowers are 70% of Kenya's horticultural exports, delivering to over 60 destinations worldwide, with a 40% market share in Europe. Expected to grow , the sector will remain a prominent part of Kenya's exports into the future. However, stakeholders interviewed in this project reported a growing appetite to change the way they are exported – increasingly moving from air to sea freight in an effort to reduce emissions. Where the freshness of the flowers can be maintained for the longer journey time in sea freight, which existing traffic has proven possible, sea freight offers an 80-90% reduction in emissions from the shift alone. If the flowers could be transported on ships that are also utilising e-fuels, the emissions reductions could be reduced even further. Whether there is appetite to go this step further in the sector could be explored through a Green Shipping Corridor project. More detail on this in section Green Corridors.

Tea, coffee and cut flowers are being exported to a range of geographies, including the US, EU, South Asia, Middle East and other parts of Africa. More than 70% of cut flowers and 60% of coffee is transported to Europe, but only 8% of tea.[25] Indeed, Kenya plays an important role regionally, facilitating trade for neighbouring landlocked countries in particular. Kenya mostly imports from China, by a significant margin, with the Middle East and India after.

ii. Regulatory analysis

Under Kenya's overarching Vision 2030 to be a globally competitive, prosperous country with high quality of life for all, maritime regulation connects to the blue economy as a priority sector, identified in the third Medium Term Plan (2018-2023) (MTP III). Various Ministries, Departments and Agencies are responsible for the implementation of a Sector Plan for the Blue Economy, including the Ministry of Mining, Blue Economy and Maritime Affairs, the Ministry of Road and Transport, the State Department of Shipping and Maritime, the State Department for Transport, Kenya Maritime Authority and Kenya Ports Authority. The Sector Plan proposed the development and implementation of sectoral strategies, programmes and projects for climate change mitigation, recognising its negative impact on the blue economy and in line with the Climate Change Act. Now under the fourth Medium Term Plan (MTP IV, 2023-2027), there is emphasis on the completion of the projects incorporated in MTP III, during this MTP IV implementation period, expecting to support the current administration's

25 International Power-to-X Hub (2024), Stakeholder mapping and assessment for the maritime and shipping sector in Kenya.

priority development areas under the Bottom-Up Economic Transformation Agenda (BETA).

Energy-related regulatory efforts are particularly relevant for this project. In addition to the Energy Act (2019), which emphasises Kenya's commitment to renewables development and integration of green hydrogen into the energy mix, Kenya's Green Hydrogen Strategy and Roadmap, launched in 2023, offers a vision for sustainable socio-economic development from 2023 to 2032. From low-hanging fruit to the expansion of hydrogen opportunities across various sector, the strategy initially prioritises hydrogen use in domestic fertiliser manufacturing, followed by other sectors such as aviation, shipping and steel manufacturing. A number of building blocks are envisioned to support the development of a green hydrogen economy, including the development of a collaborative governance framework, domestic market development, access to finance, policy integration, a stable legal and regulatory framework, catalytic commercial projects, skills development, and national and international partnerships.

There are some incentives available in the Export Processing Zones (EPZ) and Special Economic Zones (SEZ), such as Dongo Kundu SEZ situated in Mombasa. These include fiscal incentives like tax exemptions and administrative incentives designed to catalyse growth. For prospective fuel project developers, the offering is effectively 'plug and play', as the SEZs are conceived as consolidation hubs—meaning potential offtakers are located nearby. The SEZs are fully serviced, equipped with essential infrastructure such as reliable power supply, and situated close to water bodies like Lakes Baringo and Naivasha, requiring developers only to establish their facilities. They occupy expansive tracts of land, offering ample room for future expansion.

Similar to many countries, the Kenyan Government is yet to generate specific legislation for the production, storage, transportation and distribution of hydrogen or e-fuels. To support the coordination of efforts as the hydrogen economy develops, in line with the Green Hydrogen Strategy, the government has formed the high-level Program Coordination Committee (PCC) and the multisectoral green hydrogen secretariat while the private sector and project developers have established the Kenya Green Hydrogen Association (KGHA) These groups have supported the development of several sets of guidelines [26] to support the industry's development and manage its growth.

More broadly, regarding greening the shipping sector, the draft National Maritime Transport Policy [27] focuses on eleven objectives, including promoting investment and research. According to this draft policy, Kenya is aiming to contribute to the reduction of GHG emissions and advancing the maritime sector development agenda.

The National Climate Change Action Plan (2013-2027) sets out commitments to adopt an enabling maritime decarbonisation policy framework.

26 Energy and Petroleum Regulatory Authority (2024), Kenya's Guidelines on Green Hydrogen and its Derivatives.

27 State Department of Shipping and Maritime Affairs, Draft National Maritime Transport Policy.

This includes the installation of shore power at the port of Mombasa (with considerations for solar or wind power), the prevention of air pollution from shipping, as well as the finalisation and implementation of the Integrated National Transport Policy (INTP). The INTP includes reference to providing the regulatory framework and appropriate fiscal policies to promote energy-efficient and low-emission freight transport.

Kenya's Energy Transition & Investment Plan (2023-2050) (ETIP) was developed with a view to Kenya's commitment to fighting climate change. The ETIP addresses emissions reduction in the transport sector, including a focus on low-carbon fuels as a potential solution. The ETIP shares a commitment from the government to implement incentive mechanisms to drive the uptake of low-carbon fuels in shipping, as well as the infrastructure required to use them at ports. However, there is generally a focus on bio-fuels rather than e-fuels in this plan.

The Kenya Ports Authority's Strategic Plan 2023-24 to 2027-28 also sheds light on port-level objectives, outlining key priorities for Kenya's ports over five years, including for facilitating seaborne trade for Kenya and neighbouring countries, unlocking the region's growth potential by improving efficiency at ports and developing capacity in line with the region's growing demand.[28]

In regard to international regulation and its impact in the Kenyan context, the recent decisions taken at the International Maritime Organization's Marine Environment Protection Committee (MEPC) meetings in April 2025 should be considered. As part of the commitments made to deliver the IMO Strategy on the Reduction of Greenhouse Gas Emissions from Ships, these decided draft regulations will help to set the sector on a path to net zero in 2050. Although not yet adopted and with guidelines yet to be drawn up, it is expected that fossil fuels will be displaced such that they can be expected to be the minority energy source used by the sector within the next 15 years. However, policy measures that aim to discourage the use of fossil fuels will increase maritime logistics costs over time, unless sustained revenue disbursement can be secured which prevent significant changes to GDP. The policies agreed are expected to generate incremental revenues (with some analyses pointing to approximately USD11-12 billion per annum in the first three years),[29] with potential to use part of it to reward Zero and Near-Zero (ZNZ) fuels and to support just and equitable priorities (including national level projects related to maritime and shipping's transition, climate protection, adaptation and resilience building). These levels of revenue may not be sufficient relative to the scale required to both support early adoption of ZNZ fuels (expected through to 2035) and to fund just and equitable transition (JET). These considerations are reflected in the results of this project and its recommendations.

28 Kenya Ports Authority, Strategic Plan 2023/24-2027/28.

29 UCL Shipping and Oceans Research Group (2025), Phase-out of fossil fuels in shipping begins in earnest.

iii. Stakeholder analysis

There are a wide range of stakeholders involved in the maritime value chain in Kenya, some of them large international players (ship operators and cargo owners in particular). Both are crucial sets of stakeholders in this project and as such have been included in stakeholder engagement.

This section draws on the International PtX Hub's stakeholder mapping exercise (2024) and the National Action Plan stakeholder assessment (ongoing). Table 1 indicates the key stakeholders included in engagement for this project, through interviews, workshops or both.

E-fuels in Kenya

Category of Organisation	Key aspects of input	Comment
Government	Regulatory developments relevant to hydrogen production and key barriers requiring government support.	Their involvement at an early stage of the project is key as they set up the regulations and policies to enable green hydrogen production and adoption.
Ship operators	Opportunities, barriers and interest in uptake of e-fuels on routes involving Kenya.	While there is broad interest in shipping decarbonisation, there remains a lack of consensus among liner companies regarding the deployment of vessels powered by e-fuels. Further stakeholder engagement will be essential to demonstrate the viability of a compelling business case for such investment.
Cargo owners	Appetite to support higher cost e-fuel services for their goods (willingness to pay).	Further engagement with cargo owners will be essential in next stages of Kenya's green shipping work to encourage greater commitment to decarbonising the transport of their goods on Kenyan routes and actively signalling demand for zero-emission shipping solutions.
E-fuel producers and project developers	Key barriers to development of e-fuel production projects.	These are crucial stakeholders who will require substantial support from both government and industry stakeholders to establish green hydrogen production in Kenya.
Civil society	Ensure robust social and economic business case for greening shipping.	Highly relevant as they can influence policy favourable for green hydrogen production and adoption. Their involvement also helps ensure that the local residents also benefit from the green hydrogen development by highlighting opportunities and risks that need to be addressed.
Development Finance Institutions	Conditions to provide concessional finance, blended financing, and partial risk guarantee for green hydrogen projects in Africa.	They will be important in providing capital for green hydrogen projects and need to be involved from the onset.

Table 1
Stakeholder relevance to this project

Several key insights from the analysis on the production of e-fuels in Kenya are highlighted below. The insights were developed through the methodologies outlined previously, with most significant input from the University of Maritime Advisory Studies' techno-economic assessment.

1. Kenya can produce e-fuels with green hydrogen at a levelised cost which is competitive with other global production locations, particularly e-ammonia and e-methanol.

2. Across all fuels considered in this analysis, the most cost-effective combination of production characteristics is large-scale, Mombasa-based green hydrogen and fuel production, with small-scale projects not achieving economies of scale required to make costs levelised costs competitive.

3. There are a number of key limiting factors which, if addressed, would make Kenya's fuel more globally competitive, particularly cost of capital.

4. The bunkering and use of e-fuels in Kenya is contingent on stimulating demand and connecting this with production to secure offtake. Kenya could position itself as a regional e-fuel bunkering hub to support this but will face some key challenges in achieving this.

5. Demand stimulation opportunities are further explored in the section 'Green Corridors' and will need to be combined with strong national policy developments.

i. E-fuels landscape

The analysis undertaken here by UMAS focused on electro-fuels (e-fuels) which are green hydrogen-based fuels (using hydrogen produced from electricity from renewable resources), such as e-ammonia or e-methanol. The focus on e-fuels is due to their high scalability, whilst offering significant emissions reduction.[30]

Although green hydrogen is required for each of the fuels considered here, it is not considered as an end product for use in shipping in this analysis, because technology has not yet been deployed at scale, with higher potential for rapid scale up when utilised as a feedstock for other higher-density fuels (like e-ammonia and e-methanol).

Therefore, the analyses here considered e-ammonia, e-methanol and e-MGO (e-diesel). After renewable electricity generation, the production pathways for all three fuel types are identical up to the point of green hydrogen synthesis. Following this, the costs and processes for ammonia production (Haber Bosch), methanol synthesis (including DAC) and diesel production (Fischer-Tropsch; also including DAC) diverge.

Considering the uncertainties in the production of e-fuels, this analysis was based on some core parameters and assumptions to keep the project

30 Global Maritime Forum (2019), Definition of zero-carbon energy sources.

outcomes manageable, whilst being actionable and insightful. The main elements of the approach are listed below, with further details on other assumptions and sources outlined in detail in Annex I.

i. Wherever possible, this analysis drew data and assumptions from existing validated sources, including the Kenya Green Hydrogen Strategy and country-specific and global data from IRENA. The differences between these assumptions were considered (see Annex II).

ii. The analysis defined a list of plausible e-fuel production pathways available in the Kenya region, based on data available from existing or planned projects which was validated by project partners (see Annex III).

iii. The illustrative set of projects defined in this analysis builds on work done by H2Global [31] which identified locations with high wind and/or solar capacity.

iv. Additional analysis was conducted to consider geothermal generation – both through dedicated capacity and through curtailment (i.e. wasted electricity produced at night from existing plants).

v. Both large-scale and small-scale projects were assessed, given the opportunity both for export and interest in bunkering e-fuels at Kenyan ports, although the latter was the primary focus considering the mandate of this project.

vi. The analysis assumed that fuel pathways are limited to local production of e-fuels, i.e. excluding production in neighbouring countries.

vii. Scenarios for green hydrogen produced close to Mombasa port (i.e. with renewable electrons being transported from in-land) as well as green hydrogen production close to renewable production in-land, transported to port as a final product, were considered – with grid expansion costs factored in where necessary.

viii. This analysis focused on Mombasa. It is important to note that the viability of e-fuel bunkering may be greater at other ports outside of Mombasa, such as Lamu Port, given the space constraints at Mombasa port. It is possible to draw reasonable conclusions from this analysis for both locations.

The resulting illustrative projects were modelled to cover a range of locations and types of renewable energy resource (Table 2).

31 H2Global Stiftung (2025), Renewable Ammonia: Kenya's Business Case.

ii. State of production of e-fuels

Renewable generation location	Renewable generation type	Project scale (hydrogen production)	H2 plant location	Transport electricity to plant site	Transport e-fuels to Mombasa port
In land (Naivasha)	Geothermal	1,000 tonnes pa	In land	N/A	Truck
		50,000 tonnes pa	In land	N/A	Long distance pipeline
			Mombasa	Enhanced grid capacity	Short distance pipeline
	Geothermal curtailment	1,000 tonnes pa	In land	N/A	Truck
	Geothermal ,curtailment & solar	1,000 tonnes pa	In land	N/A	Truck
In land (Turkana South)	Wind & solar	1,000 tonnes pa	In land	N/A	Truck
		50,000 tonnes pa	In land	N/A	Long distance pipeline
		50,000 tonnes pa	Mombasa	Enhanced grid capacity	Short distance pipeline
Near Mombasa	Wind & solar	1,000 tonnes pa	Mombasa	Enhanced grid capacity	Truck
		50,000 tonnes pa		Enhanced grid capacity	Short distance pipeline

Note: "Transport electricity to plant site" refers to how the electricity as an input to the hydrogen production process has been transported to the production site. i.e. hydrogen produced close to the renewable generation site, no transport is required, otherwise transportation by grid is required.

Table 2
Illustrative projects modelled by UMAS to cover a range of locations and types of renewable energy resources

The analysis conducted by UMAS estimated the levelised cost of e-ammonia, e-methanol and e-diesel production, including delivery to Mombasa port (see Figure 4, Figure 5, and Figure 6). A range of scenarios were assessed to understand the correlation between key factors and cost. For example, scenarios were included to consider the production of green hydrogen both near the renewables sources or closer to the port, with grid[32] expansion costs factored in.

Overall, the analysis showed that costs across the locations, scales and transport options are cheapest for e-ammonia. E-diesel is the costliest option with the cheapest combination at USD 3,729/tonne and the most expensive at USD 5,902/tonne. This is compared to the cheapest options for e-ammonia and e-methanol production at USD 1,121/tonne and USD 1,667/

32 In 2023, EPRA reported that 84.65% of the energy supplied to the national grid was renewable. See Rödl & Partner (2024), Kenya's green hydrogen policy and regulatory environment.

tonne respectively, with top-end costs at no more than USD 2,660/tonne across these two fuels. Across all three fuels, the most cost-effective combination of production characteristics is large-scale – i.e. 50,000 tonnes of renewable hydrogen per year –, Mombasa-based hydrogen production. The analysis indicated that small-scale projects – i.e. 1,000 tonnes of renewable hydrogen per year – do not achieve the economies of scale required to make levelised costs competitive. It also showed that even with grid expansion costs factored in, it is cheaper to transfer electrons to a hydrogen production site close to the port, rather than producing hydrogen near the renewables source and trucking or using a pipeline to transfer to the port.

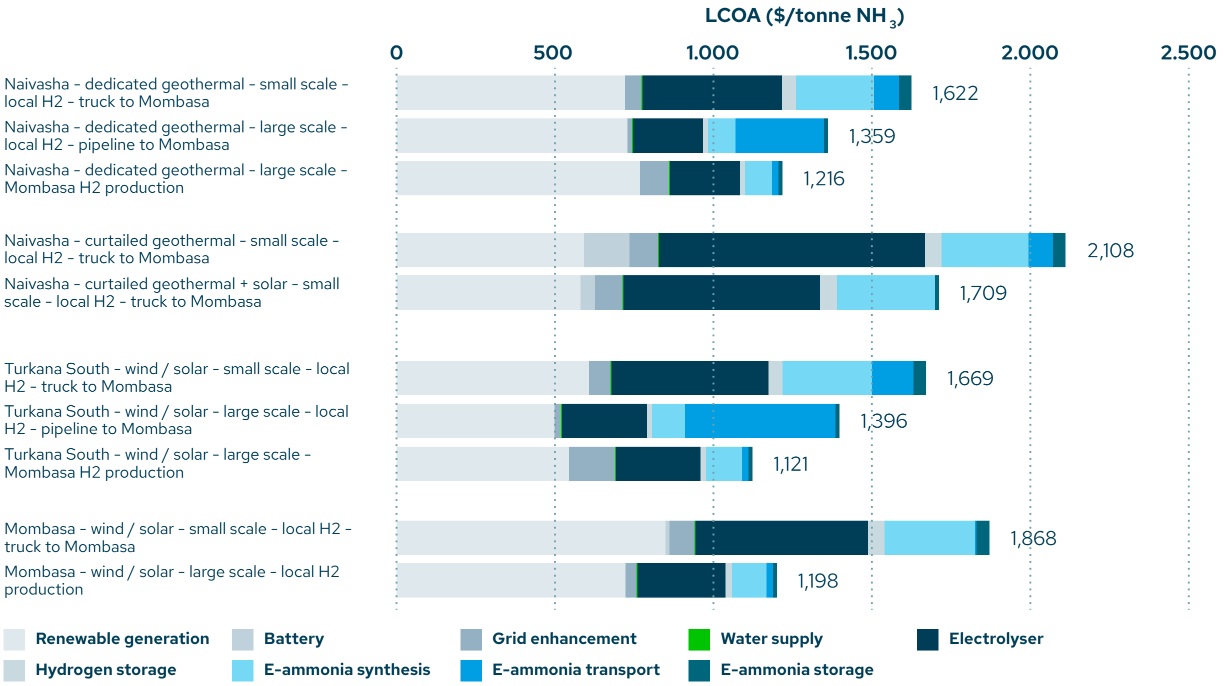

Figure 4

Levelised cost of e-ammonia (LCOA) for small and large-scale plants with different upstream renewable generation and production locations

At the lowest cost of production across the combination of production characteristics assessed here, e-ammonia currently offers the most competitive option for e-fuel production at USD 1,121/tonne. For comparison, the recent H2Global pilot auction won by Fertiglobe for renewable ammonia production in the Suez Canal Economic Zone in Egypt saw an average product price of EUR 811/tonne (approximately USD 922).[33]

Of particular relevance to Kenya is the demand for ammonia for fertiliser production. Agriculture contributes 20% to Kenya's GDP and employs 40% of its workforce[34] but relies entirely on ammonia imports since it lacks reserves of phosphate and potash. In line with the Kenya Green Hydrogen Strategy which aims to replace 20% of the country's ammonia imports with domestically produced ammonia, renewable fertiliser production offers Kenya independence from the global market (where phosphate and potash

33 H2Global Stiftung (2024), Results of the pilot auction.

34 H2Global Stiftung (2025), Renewable Ammonia: Kenya's Business Case.

can be suitably sourced).[35] Although there are ongoing discussions at the International Maritime Organization on the impact of ammonia production being redirected to shipping, these can be responded to through a more robust business case (with multiple offtakers for ammonia and larger scale plants) to seek early investment in greening the ammonia supply chain. Plus, this challenge would be limited in Kenya, given Kenya's existing reliance on imports – which could continue to supplement ammonia access until enough was produced domestically for both the shipping and agriculture sectors. This approach could also make use of the subsidies that ammonia already receives from the Kenyan government to rapidly incentivise and increase production for both sectors.

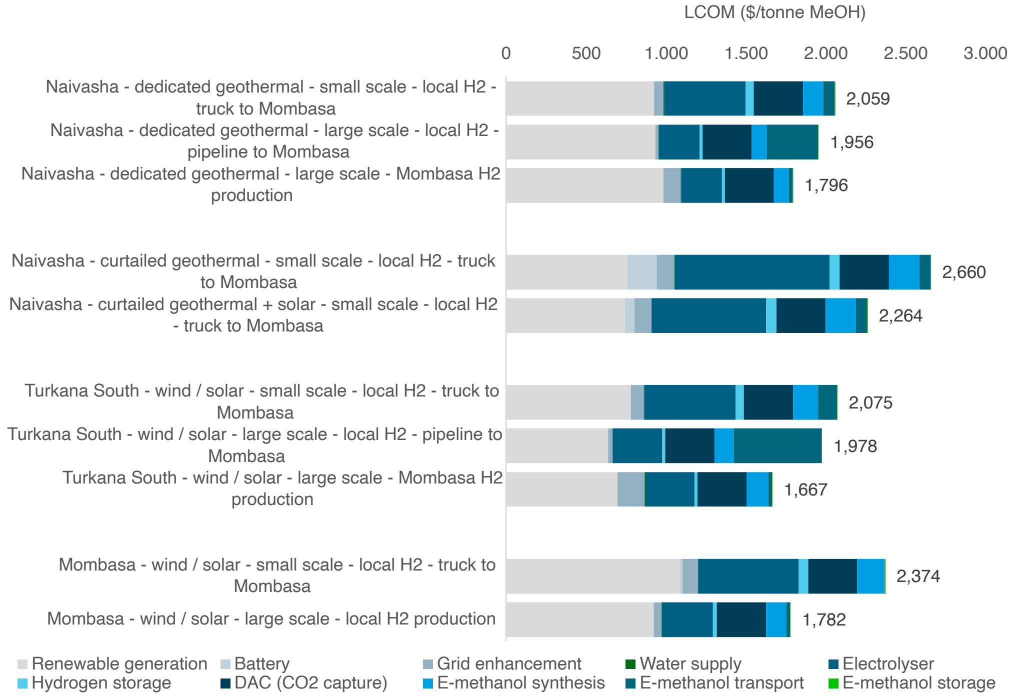

Figure 5

Levelised cost of e-methanol (LCOM) for small and large-scale plants with different upstream renewable generation and production locations

Most of the levelised cost estimations for e-methanol production are higher than those for e-ammonia. E-ammonia costs more to transport than e-methanol, but this is far out-weighed by the additional cost of sustainable CO_2 feedstock. Additional renewable electricity input is also required for e-methanol production compared to e-ammonia production.

At almost double the cost of e-ammonia and e-methanol in all scenarios, e-diesel's additional costs come from across the fuel production process. The need for more than double the amount of renewable electrons in e-diesel compared to e-ammonia production, combined with the additional cost of direct air capture for biogenic carbon results in high fuel costs. However, these are challenges faced globally, with e-diesel production incurring high energy conversion losses.[36]

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35 H2Global Stiftung (2025), Renewable Ammonia: Kenya's Business Case.

36 The Oxford Institute for Energy Studies (2024), E-diesel in the shipping sector: Prospects and challenges.

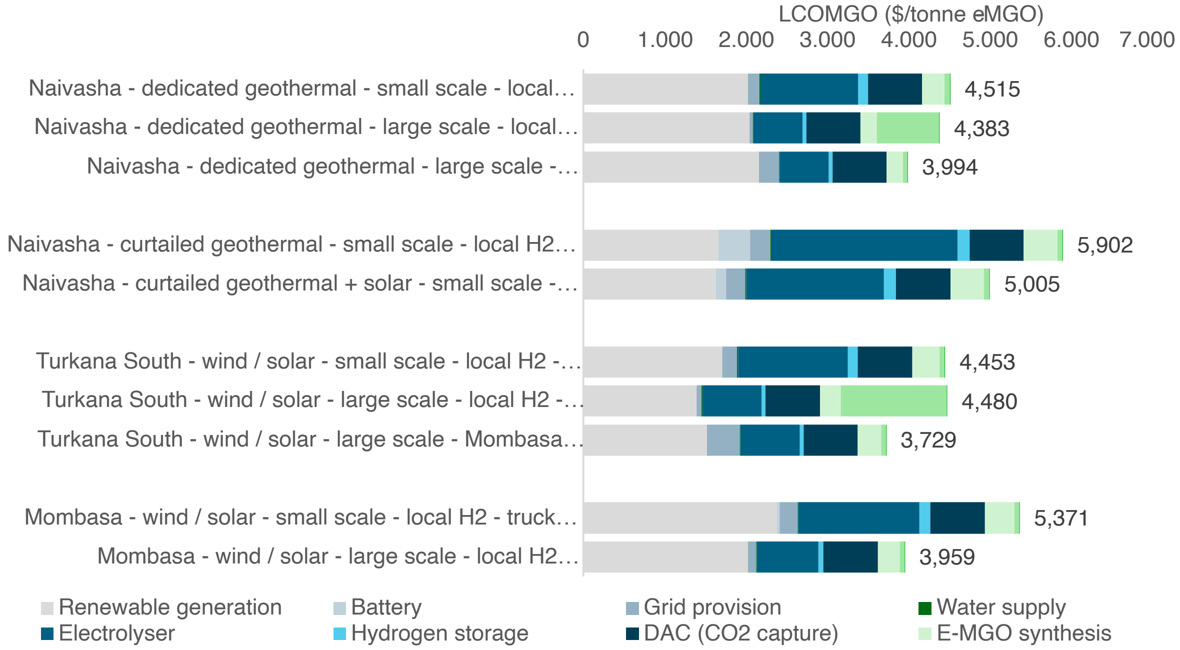


Figure 6

Levelised cost of e-MGO (LCOMGO) for small and large-scale plants with different upstream renewable generation and production locations based on UMAS analysis

Figure 7 provides a comparative summary of the cost of the three fuels delivered to Mombasa across different production scenarios. The figure includes comparisons to the average 2024 Low Sulphur Fuel Oil (LSFO) price in Rotterdam and Durban. The cost gap to LSFO is substantial, which is a challenge faced by countries globally. However, Kenya's production of these e-fuels is competitive with some other fuel production locations (see Figure 8 upcoming).

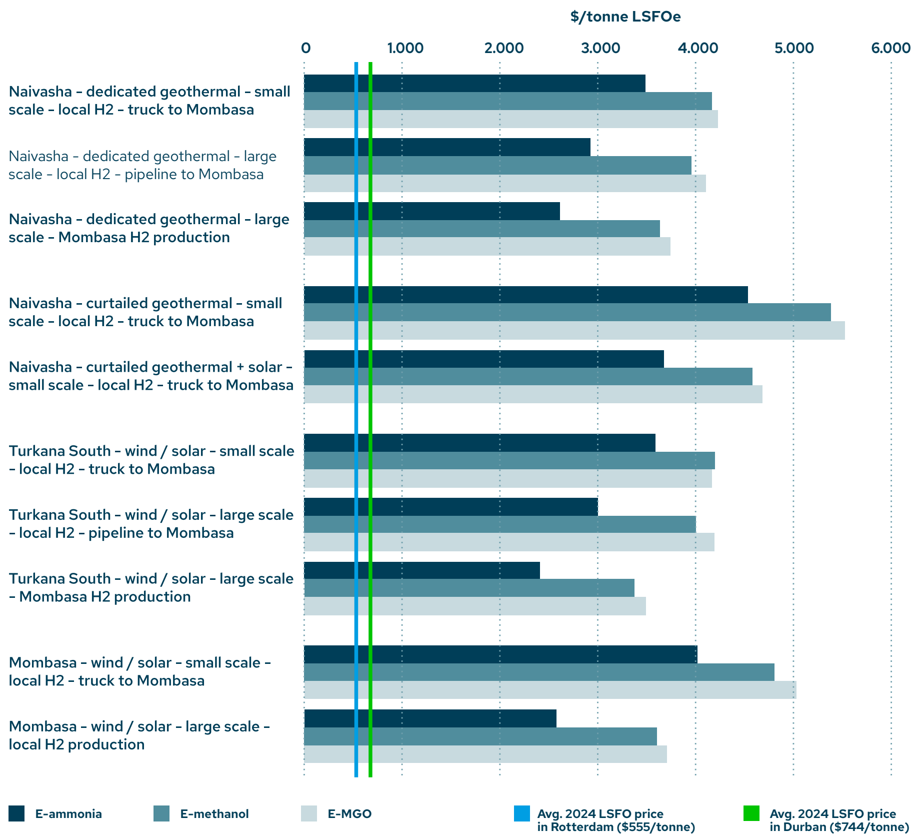


Figure 7

Cost of e-fuels delivered to Mombasa across different scenarios in relation to LSFO price

iii. Challenges to e-fuel development

Some key limiting factors to e-fuel development were highlighted through this analysis and stakeholder engagement.

The cost of capital was a recurring limiting factor cited by stakeholders. Long-term projects which need large upfront capital investment typically seek long-term funding solutions such as project finance, where funding is secured against future cash flows from the project. Financiers and investors offer proportions and costs of debt and equity which reflect their perceived exposure to risks over the period of lending/investment. The overall cost of capital is typically represented by the weighted average cost of capital (WACC) which accounts for the proportions and costs of debt and equity. However, this metric does not reflect potential differences in the timing of cash flows to debt and equity providers.

WACCs for renewable energy generation projects (for domestic consumption) vary greatly across the world, reflecting country risk and (potentially) sovereign credit rating (if the entity acting as offtaker is a state-backed utility, which can be the case in shipping e.g. state-owned ports) (see Annex IV). These WACCs can give a good indication of the funding costs that e-fuel projects may be able to access (given that e-fuel production involves renewable energy generation). However, it is not a perfect proxy as the full slate of risk exposures will differ between the projects. Nevertheless, the WACC assessment done here for renewable energy generation can provide helpful insights into the potential competitiveness of e-fuel production in Kenya compared to other locations, given that capital costs have a significant impact on levelised costs of production. For example, the levelised cost of ammonia (LCOA) for a large-scale e-ammonia project at Turkana South (Mombasa-based production) at a WACC of 13% is USD 1,121/tonne. This would fall to USD 750/tonne if the WACC were 6%, or rise to USD 1,538/tonne if the WACC were 20%. Table 3 illustrates the impact of WACC across countries in the region and beyond.

A range of factors affect the cost of capital which can be addressed through various policy measures, including construction delays (more likely with larger projects), lower than planned production volumes (large-scale projects may be better-placed here) and default risk (export-oriented projects may attract a lower risk premium). These aspects are further detailed in Annex V.

Engagement with fuel producers in Kenya highlighted a range of aspects that raise challenges in the production of hydrogen-based fuels, beyond the cost of capital. Recurring themes in conversations were the need for grid strengthening, support for the expense of feasibility studies, land rights, permitting, and securing offtakers.

Variable	Kenya	South Africa	Mozambique	Tanzania	Saudi Arabia
Assumed WACC	13%	10%	19%	12%	7%
Solar CAPEX (USD per MW)	*606*	606	606	606	455
Solar capacity factor	*16%*	*16%*	16%	16%	16%
Solar LCOE (USD per MWh)	73	63	95	70	43
Wind CAPEX (USD per MW)	1,337	1,337	1,337	1,337	1,361
Wind capacity factor	42%	42%	42%	42%	42%
Wind LCOE (USD per MWh)	66	57	84	63	49
Small-scale production (1,000 tonnes H2 per annum)					
LCOH (USD per kg H2)	8.5	7.4	10.9	8.2	6.1
LCOA (USD per tonne NH3)	*1,868*	1,614	*2,415*	1,793	1,321
Large-scale production (50,000 tonnes H2 per annum)					
LCOH (USD per kg H2)	*5.9*	*5.2*	*7.6*	*5.7*	*4.2*
LCOA (USD per tonne NH3)	*1,198*	*1,036*	*1,545*	*1,150*	*846*

Note: In this analysis, equivalent projects (based on the small and large-scale Mombasa projects) were modelled in each country; all variables are assumed to be fixed, except the cost of capital (WACC) and the renewable CAPEX (fixed across the African countries but country-specific for Saudi Arabia).

Table 3
Weighted Average Cost of Capital (WACC) impact on levelised costs of hydrogen and ammonia

It was also noted that there is a discrepancy between the scale of announced hydrogen projects and installed renewable energy capacity in Kenya.[37] Utilising geothermal curtailment could be one way of responding to this. The costs estimated in this analysis do not portray curtailed geothermal power a highly cost-competitive option – largely due to the utilisation of electrolysers. Combined with other dedicated power options however, it could present a viable route to balancing the costs of production and responding to increased needs for renewables.

37 H2Global Stiftung (2025), Renewable Ammonia: Kenya's Business Case.

Lastly, port readiness will be a key factor. With limited current bunkering activities in Kenya for fossil fuels or otherwise, the country is price-disadvantaged in regard to traditional bunker fuel because most has to be imported and because there is limited storage. There was also a ban on offshore bunkering until late 2023. Alternative fuels such as ammonia and methanol will require significant infrastructure investments on the port side.

iv. Potential for production, bunkering and use of e-fuels in Kenya

The use of e-fuels within Kenya requires the alignment of supply and demand. Kenya could position itself as a regional e-fuel bunkering hub, seek to attract traffic to bunker e-fuels, and improve the business case for further investment.

To become a regional e-fuel bunkering hub, Kenya will need to access e-fuels (whether produced domestically or imported), build infrastructure at ports to store and bunker these fuels, and attract ships that are able to use such fuels. The opportunity may also be shaped by competition from other nearby bunkering hubs – whether catering to regional, or longer-haul shipping. There are a few options for sourcing e-fuels as a bunkering hub:

1. **Small-scale domestic production dedicated solely for bunker fuel provision in Kenya** – Small-scale projects may come to fruition more quickly (and therefore be less exposed to construction risk). They may allow for easier and more flexible storage and delivery of e-fuels without dependence on large-scale infrastructure being built.

2. **Export-oriented large-scale domestic production where the local provision of bunker fuels offers an ancillary route to market for the producer** – Larger-scale, export focused projects are more likely to secure offtake agreements and thus the financing required. Larger-scale projects will also deliver e-fuels at a far lower cost and such projects may also underwrite associated port infrastructure costs.

3. **Importing of e-fuels** – Access to e-fuel imports may only be available through offtake agreements in the near-to-medium term, requiring an entity with sufficient credit quality to underwrite the agreements.

Early hubs for e-fuel bunkering are likely to arise from specific projects (whether green shipping corridors or some other first mover initiatives). Longer term, hubs are likely to emerge at the confluence of heavy shipping traffic, good quality renewables and access to cheap capital. Although there is a high number of vessels transiting the Kenyan Exclusive Economic Zone, the majority of this traffic is passing trade which would need to make a significant voyage diversion for bunkering.[38] Therefore, Kenya is likely to rely on the former option to become a regional e-fuel hub. Thus, initiatives

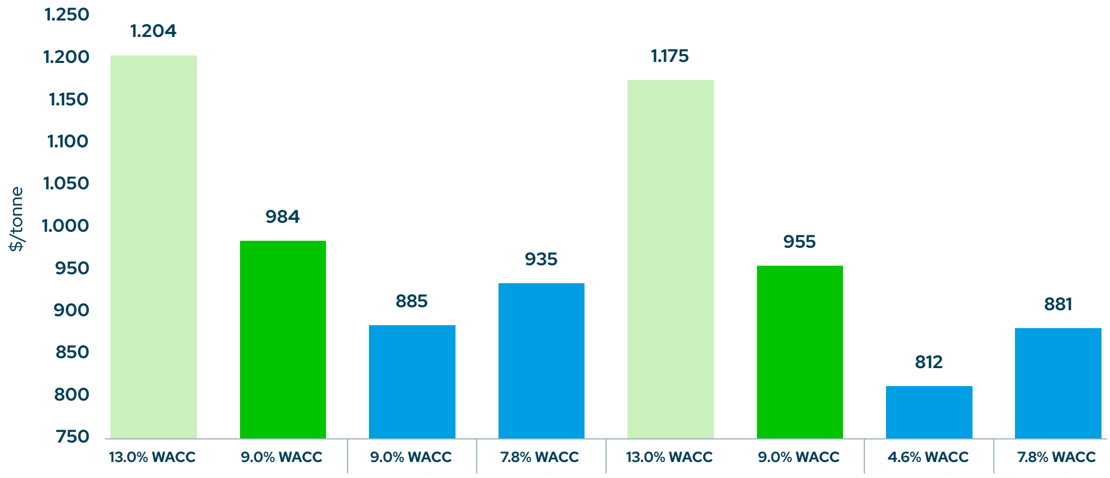
38 Draft baseline assessment initiated as part of the National Action Plan process in Kenya.

such as green shipping corridors will be important to stimulate the demand for e-fuels to secure offtake for production in Kenya.

Along the east coast of Africa, South Africa, Mozambique, and Tanzania are potential competitors for the role of a bunkering hub that serves the region (Table 3). However, South Africa (and Saudi Arabia) may form bigger hubs to meet the needs of larger-scale, longer-haul traffic.

Kenya could consider developing smaller volumes of e-fuels which could service smaller vessels and a limited number of ships that call at Kenya's ports. However, there would be two key challenges involved here. The first is economies of scale, which the analysis indicates would have significant impacts on levelised costs (see Figure 7), as well as whether smaller vessels would be ready for e-fuels. The scales of trade on the routes to and from Kenya may not offer a sufficient incentive for replacing these vessels with dual-fuel vessels to be compliant with global or regional fuel uptake targets – particularly at the outset when the cost gap is so high. E-fuel projects will require offtake agreements and will need to be large-scale to be as economical as possible. They will also require supportive policy directives[39] which create the enabling environment for these fuels to be produced and utilised within Kenya.

v. E-fuels for export



Note: The light green bars indicate the delivered cost of ammonia in $/tonne when Kenya's WACC is 13%, compared to the dark green bars when Kenya's WACC is 9%. The blue bars are the delivered cost of ammonia to the same locations from different countries. Note on assumptions: Modelled costs in Figure 8 include the cost of storage and shipping. These are not representative figures of all possible projects in these countries; some projects are likely to be lower and higher in levelised cost. The comparison is intended to be indicative of the impact of WACC on levelised costs. See Annex VI for key assumptions.

Figure 8

Cost of e-ammonia delivered to Europe and Singapore compared to other locations, with WACC comparisons, based on UMAS analysis

39 Global Maritime Forum (2023), National and regional policy for green shipping corridors.

Although the focus of the analysis was on Kenya bunkering e-fuels, some considerations about the export opportunity are included here as this was raised by several stakeholders. On the supply-side, export-oriented projects may benefit from lower cost of capital, larger production volumes (therefore greater economies of scale) and therefore attract investment. Kenya could consider exporting e-fuels to bunkering hubs in close geographic proximity, like the Middle East, or further, such as the EU or Singapore, but fierce competition is expected. However, Figure 8 indicates that Kenya can competitively produce e-fuels with the countries likely to be its biggest competitors – particularly so if Kenya can reduce the cost of capital.

It is important to recognise the desire often expressed by stakeholders to minimise Kenya's export-orientated activities to bring greater value to Kenyan people. The longer-term impact of boosting green shipping for Kenya's jobs, GDP growth and preparedness for net zero may be of greater value than the benefits that are yielded sooner, and for fewer people, in exporting e-fuels. In interviews with fuel producers, the intent to focus on export was clear. There has been minimal to no interaction so far with the proposal for shipping as a potential offtaker for e-fuel production although it could help develop a demand signal for these fuels and support the growth of a domestic market.

Benefits for local stakeholders

i. Examination of job creation potential

Greening Kenya's maritime sector presents a transformative opportunity to stimulate socio-economic development. By adopting green technologies such as energy-efficient vessel designs and alternative fuels, Kenya can unlock substantial economic and social benefits by attracting significant investment, creating jobs and invigorating local economies, particularly in key port cities such as Mombasa. These jobs would span sectors such as renewable energy production and green infrastructure maintenance.[40] There have been some concerns raised during the National Action Plan process that alternative forms of employment will need to be provided during a shift to greener shipping practices. This valid perception can be responded to through social dialogue and clarity as an approach to ensure re-skilling of maritime workers and seafarers, as well as of those employed in the wider value chain. This should also connect with wider just transition planning as energy sources within Kenya shift further.

Moreover, the transition to green shipping necessitates the development of new infrastructure, including bunkering facilities for alternative fuels. This infrastructure expansion is expected to generate employment across engineering, construction, logistics, and port operations. In addition, the growth of the green shipping industry will drive demand for skilled labour in renewable energy production, fuel storage, and vessel maintenance[41].

40 Tunley Environmental (2024), Green Shipping Corridors: All You Need To Know

41 State Department for Shipping and Maritime Affairs (2025), Kenya backs Global Green shipping transition quest.

Furthermore, the green shipping transition is poised to strengthen local value creation by fostering new skill sets and empowering existing local economic participants. The burgeoning hydrogen economy and the build-out of renewable energy capacity presents a significant opportunity for localised economic growth. This growth will be driven by direct hydrogen production and related service industries, as well as the expansion of upstream and downstream value chain segments, the development of locally required infrastructure, and the deployment of renewable energy technologies – all opening opportunities for new jobs (see Figure 9 for the estimated number of new jobs in the energy supply chain by 2050). These jobs are generally created in three markets: (1) manufacturing of component parts, (2) construction and installation, and (3) operations and maintenance.[42] Consequently, Kenya stands to secure a new, climate-neutral revenue stream, diversifying its economy and bolstering its resilience.[43]

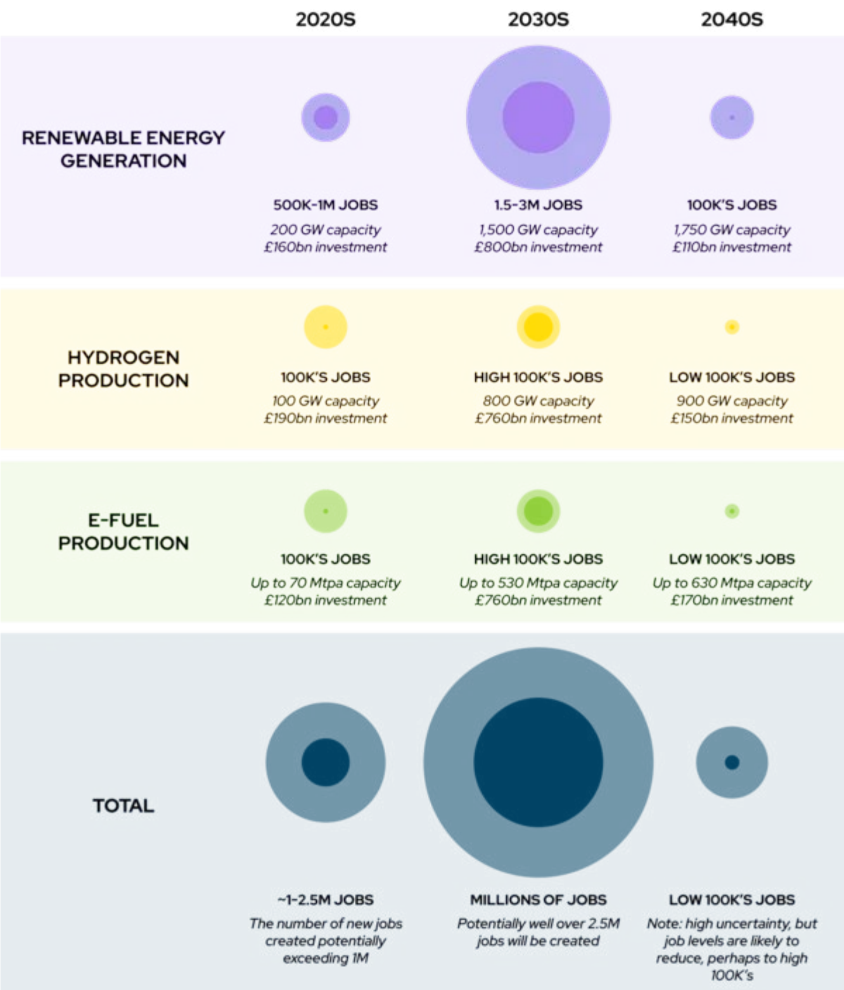


Figure 9

Job creation potential across the energy supply chain by 2050

Graphics source: Global Maritime Forum, 2024

42 Global Maritime Forum (2024), Green jobs and maritime decarbonisation.

43 Ministry of Energy and Petroleum of Kenya (2023), Green Hydrogen Strategy and Roadmap for Kenya

The expertise gained from green shipping projects will provide a solid foundation for further renewable energy and hydrogen-related initiatives. This knowledge transfer could empower Kenya to spearhead additional projects that target domestic markets, particularly those in the Global South.[44]

The accelerated renewable energy expansion driven by green shipping projects is expected to improve energy access by providing anchor demand. In addition to grid expansion connecting more local communities, surplus electricity generated through renewable energy projects could be allocated for local consumption, especially for communities around the renewable energy plants. Additionally, communities involved in the production of Kenya's key export commodities, such as the flower trade (200,000 skilled/unskilled workers and one million jobs indirectly), would be set to benefit from future-proofing these supply chains. It may also make Kenyan goods more attractive to buyers as the supply chain becomes greener.

It is important to recognise that social impacts of these initiatives must be carefully managed to determine their impact on indigenous communities. Past infrastructure projects, such as the LAPSSET corridor, have demonstrated the risks of land displacement, disruption of traditional livelihoods, and loss of cultural heritage.[45] To mitigate these challenges, inclusive planning and active engagement with indigenous peoples and local stakeholders are essential. Transparent grievance mechanisms and equitable compensation frameworks must also be established to ensure fair outcomes for affected communities.

The spill-over effects of supporting the development of green shipping extend far beyond the immediate maritime domain. These corridors serve as a catalyst for the development of renewable energy infrastructure, notably green hydrogen production, directly supporting Kenya's strategic renewable energy objectives. This development not only attracts foreign direct investment through large-scale, internationally funded hydrogen projects, but also positions Kenya as a regional leader in sustainable maritime practices, enhancing regional trade and collaborative efforts within East Africa.

ii. Consideration of relevance to SDGs

The development of green shipping in Kenya, as well as the Kenyan government's policy priorities, align well with several Sustainable Development Goals (SDGs) (see Figure 10). Specifically, it contributes to SDG 7 (Affordable and Clean Energy) by promoting the use of renewable energy in the maritime sector by offering the opportunity to improve energy access. It further aligns with SDG 9 (Industry, Innovation, and Infrastructure) by fostering the development of sustainable infrastructure, as well as with SDG 13 (Climate Action) by reducing greenhouse gas emissions from shipping. Additionally, the development of green shipping will minimise marine pollution and thereby contribute to SDG 14 (Life Below Water), while

44 IMO GreenVoyage2050 (2024), Advancing green shipping and green fuel production in Kenya.

45 International Working Group on Indigenous Affairs (2013), Kanyinke Sena, Lamu Port-South Sudan-Ethiopia Transport Corridor (LAPSSET) and Indigenous Peoples in Kenya.

contributing to SDG 8 (Decent Work and Economic Growth) through the creation of green jobs and the promotion of sustainable economic growth. The adoption of green shipping practices also supports SDG 12 (Responsible Consumption and Production) by promoting the sustainable use of resources and minimising waste.

Figure 10
Overview of aligned SDGs

Graphics source: UN Sustainable Development Goals

Green corridors

Viable green shipping corridor projects require the alignment of multiple technical, logistical, commercial, regulatory and political factors to scale zero-emission shipping activity before 2030. These include identifying potential pathways to (a) access zero-emission fuels, such as e-fuels; (b) enable investment in port storage infrastructure and bunkering assets; and (c) deploy ships capable of using zero-emission fuels to consistently carry cargoes along the corridor. They do this by focusing on trade routes that have specific characteristics that make them best placed to be first movers (e.g. favourable policy) and unlocking public-private collaboration. We've considered (a) and (b) in section 'E-fuels in Kenya', here we consider the last aspect. Using the UMAS Fuse model with 2023 data, combined with the Global Maritime Forum's Green Corridor assessment outlined in the methodology section, we collate a longlist of possible routes and draw this down into a shortlist – exploring the rationale behind these decisions. This process forms part of the initiation and early exploration phases of Green Corridor development, illustrated in Figure 11.

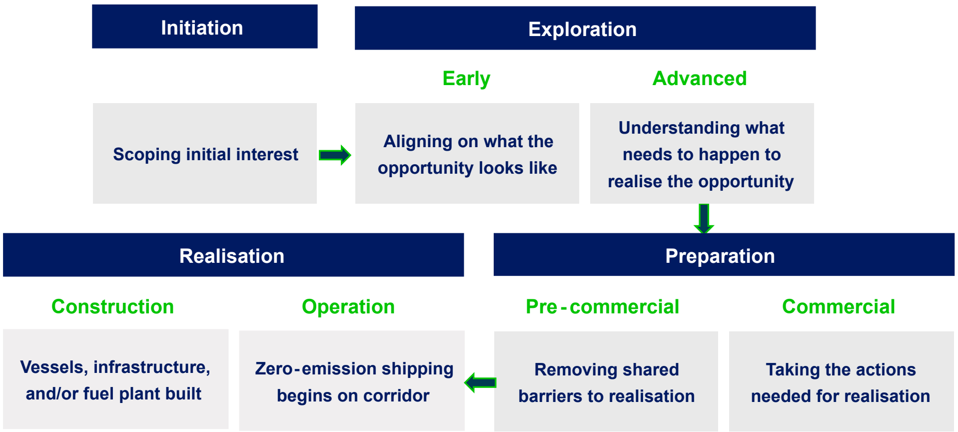


Figure 11
Green Corridor Development Pathway

Graphics Source: Global Maritime Forum (2024), Annual Progress Report on Green Shipping Corridors 2024.

i. Creating a longlist of possible routes

The project analysed which trade routes would be best suited for green shipping corridor development, with five key factors considered in the assessment:

1. **Regularity** of a shipping type or set of ships calling at Kenyan Ports to identify routes with a consistent demand signal for, and eventual use of, e-fuels.
2. **Characteristics of shipping types** in Kenya, including the size of ships, to consider the scale of demand on any route.
3. **Scale and nature of commodities traded**, in particular the opportunity to access cargo owners' willingness to pay for more expensive e-fuels.
4. **Kenyan ports** involved in trade, considering readiness for e-fuels and scale of traffic, with a focus on Mombasa as Kenya's biggest port, whilst recognising the development of Lamu Port,
5. **Trading partners** involved in key routes who may be amenable to building an international partnership with Kenya and have a suitable level of readiness to develop an e-fuel green shipping corridor.

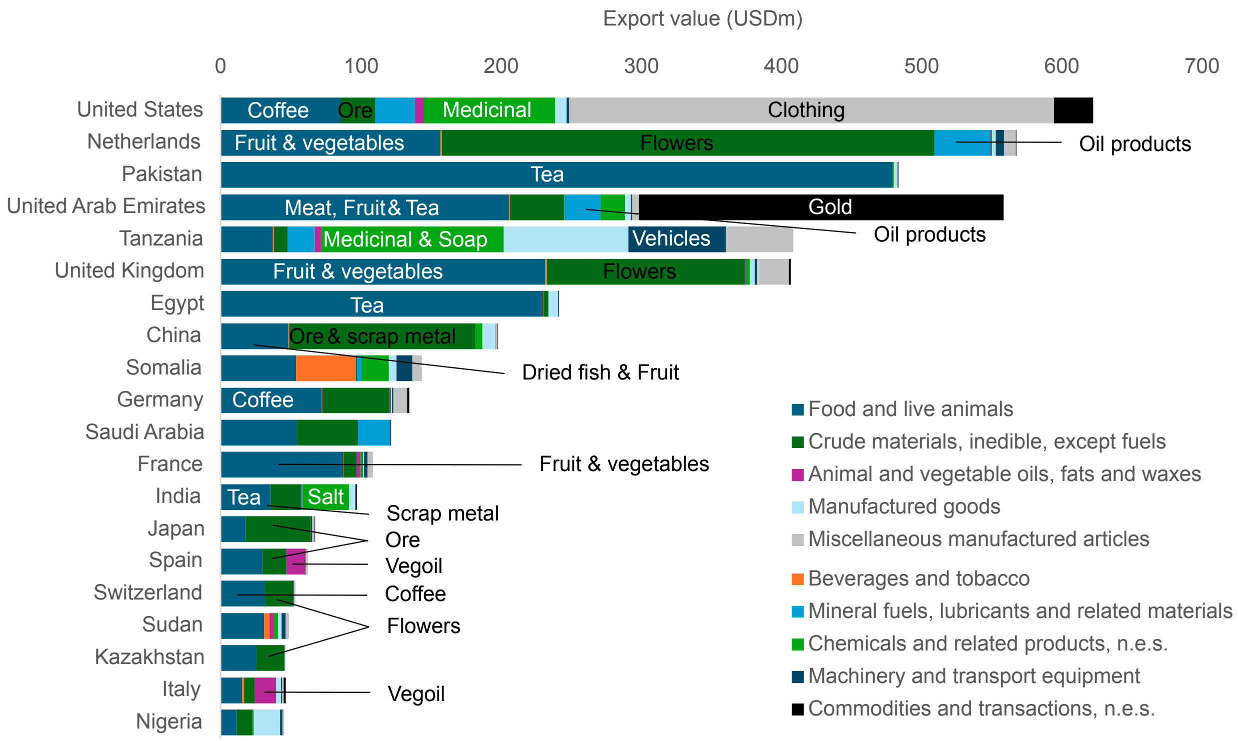
The cost gap between conventional fuels and e-fuels is also a key factor outlined in section 'E-Fuels in Kenya', highlighted previously in figure 7. Therefore, in addition to aligning supply and demand factors, the premium associated with e-fuels will require investment borne by the end consumer or subsidised by a government or regulator. This is a core consideration in any prospective green corridor[46] and is a key theme in the assessment below.

46 Global Maritime Forum (2024), Annual Progress Report on Green Shipping Corridors 2024.

Shipping types

Shipping type	No. of ships	No. of calls at Kenyan ports
Containerships	174	671
Bulk carriers	237	259
Oil/chemical tankers	135	210
General cargo ships	57	144
Other vessels	19	137
Vehicle carriers	62	98
Liquefied gas carriers	19	55
Passenger/RoRo ships	18	40
Cruise ships	4	5
Reefer ships	2	2

Table 4
Ship types calling at Kenyan ports in 2023, with focus types of this report highlighted



Note: Kenya's landlocked neighbours have been excluded from this figure as this project focuses on shipping routes.

Figure 12
Kenyan exports to top 20 nations

Source: UN Trade & Development trade matrix

There were 727 ships identified as having called at Kenyan ports in 2023. Each of these have been assigned to one of the type and categories listed in Table 4 (more detail on these ships can be found in Annex VII).

In total, these 727 ships made 28,770 calls to ports around the world. 1,621 of these port calls were in Kenya (5.6%). In many cases, a visiting ship only made a single visit to Kenya during the year, but in other cases, ships made multiple calls. In identifying possible green corridor routes, our long list focuses on the routes where ships make multiple calls; that have a degree of regularity across each of the main shipping sectors and therefore are best placed to provide the stable demand needed to justify supply chain investment. It is important to recognise that most ships which call at Kenya are in the smaller sizes, with the majority of bulk carriers up to 70,000dwt (Handymax – Ultramax) and containerships mostly up to 6,000 TEU. This will have implications for the potential demand signal that any singular route can provide and may mean that multiple routes will need to be combined to aggregate demand and provide the right stimulation for supply chain investment in e-fuels.

In this section, specific shipping types and their commodities (see Figure 12) are explored further. These have been chosen based on scale and willingness to pay (i.e. not reefer, cruise ships and passenger) and alignment with green objectives of this project (i.e. not oil or liquefied natural gas). Therefore, bulk carrier, general cargo, containership and vehicle carrier shipping is assessed further.

Bulk carrier shipping activity

Seaborne transport of dry bulk is significant in the Kenyan context, both for imports and exports, although there are a few key reasons as to why this shipping type may not be suited to a green corridor in this case.

The first reason is that the seaborne transport of dry bulk is generally described as "tramp" shipping which means visiting a wide range of ports according to demand. Although not making a shipping corridor impossible, this does raise challenges due to the lack of demand regularity for e-fuels and would require changes in the way these ships currently operate to be effective i.e. consolidating the traffic from many ships calling infrequently to a few dedicated or semi-dedicated ships. The data further indicates this with 237 bulk carriers making 259 calls at Kenyan ports in 2023, and most ships spending less than a fifth of their operational time during the year on voyages to and from Kenya. Only 18 ships called twice in 2023, but a single 35,000 dwt bulk carrier called four times. This ship sailed consistently back and forth between East Asia and East Africa carrying dry bulk cargoes in both directions (rather than on a laden-ballast basis). A route like this could be better suited to a Green Corridor but will not provide the scale of demand required to overcome the chicken-and-egg problem when it comes to zero-emission fuel adoption (i.e. production awaiting demand and vice versa).

Secondly, the bulk carriers calling at Kenyan ports were largely in the smaller range (Handysize to Ultramax), which aligns with the varied types of dry bulk cargo that we can see being imported. Since these ships have relatively low fuel consumption compared to larger vessels (Capesize or Newcastlemax bulk carriers or large containerships), this could create challenges in eliciting the right demand signal for the supply of e-fuels.

Thirdly, there are also strong signals in the shipping activity and cargo data that indicate bulk carriers often call sequentially at countries in the region, with partial discharges of cargo in each port. This could be advantageous from a cargo volume aggregation perspective, but reaching consensus between multiple countries and ports could present challenges to prospective corridor projects.

Fourthly, Kenya's exports of bulk commodities include rare mineral ores (ilmenite, zircon and rutile) and soda ash which may be suitable for Green Corridor development. However, there are some key factors that would make this challenging.

Rare mineral ores are high-value commodities (assumed to fetch approx. $400/tonne[47]) and so could indicate increased willingness to pay for decarbonised transport by cargo owners. However, the routes that this commodity travels on may pose challenges. UNCTAD data indicates that China and the US were major importers of these materials. However, no bulk carriers departing from Mombasa in 2023 immediately called after at either China or the US but some did on their second or third stop, having sailed via South Africa or Singapore. The ships which sailed via South Africa seemingly had additional cargo loaded. This could offer an opportunity for collaboration but could also complicate a green corridor route. It is also important to recognise that Kenya's largest mineral sands mine in Kwale - which extracted 65%[48] of Kenya's total mineral output value - wound down production in 2024 due to the depletion of reserves.[49] Should new mining projects be initiated, there could be an opportunity to engage with a bulk carrier owner / operator to form a green shipping corridor based upon mineral ore trade flows. However, there are other environmental considerations associated with this type of mining that may reduce appetite for global engagement on such a green corridor initiative.

Kenya also produces and exports a large volume of soda ash (approximately 300,000 tonnes per annum [50]) with plans for expansion by the biggest producers. Soda ash is used in the manufacturing of glass, chemicals and soap. UNCTAD's statistics indicate that India was the largest importer of Kenyan soda ash in 2023, – roughly 120,000 tonnes, nearly half of the total (Thailand and Uganda follow). However, due to the low value of this product and therefore a larger proportion of its cost coming from its transport, the willingness to pay increased transport costs by consumers is likely to be lower, in addition to constraints on governments in Global South countries to subsidise e-fuels and cover the cost gap in that way. To maximise the potential of this trade and include soda ash as a candidate commodity in a green shipping corridor from Kenya, the country could explore opportunities for domestic value addition prior to export. In the longer term, Kenya

47 Kenmare (2023), Half-year report.

48 Base Titanium, Kwale Mining Operation.

49 Base Resources, Kwale Mining Operation in Kenya.

50 United States Geological Survey (2023), The Mineral Industry of Kenya in 2019.

may also consider diversifying its export markets by targeting destinations where soda ash commands a significantly higher premium, in some cases exceeding 100%.[51]

From the import perspective, Kenya's largest dry bulk imports are lower-cost commodities that are typically more price sensitive than exports; namely grains, agricultural products and fertilisers. The seasonality of these products, combined with the low willingness to pay a premium due to their lower value (and considering that this premium would likely land on Kenyan consumers) would make a green corridor for these commodities challenging too.

General cargo shipping activity

General cargo ships also transport bulk cargo but are typically smaller and more versatile than bulk carriers. The ships have holds able to store non-containerised cargo and sometimes also have deck space for storing containers, vehicles etc. These ships typically have cranes, enabling cargo to be loaded and offloaded at smaller ports without such equipment. Therefore, these ships can serve as feeders, distributing a wide mix of goods and commodities to and from major to smaller ports.

While the trading profile of general cargo ships can be as global and irregular like bulk carriers, given their smaller size (and thus more expensive transportation cost on a per-tonne of cargo basis), voyages are typically shorter than bulk carriers. Ships often trade regionally with occasional switches to a different basin, but some trade exclusively on dedicated regional services. The 57 general cargo ships calling at Kenyan ports largely arrived from or departed to other ports in Kenya or to other countries within the region. In total, 21 ships called more than once in Kenya and nine called more than five times in 2023.

The regularity of these small number of ships could offer a good basis for a green corridor and this type of regional trade may align well with objectives and benefits of the African Continental Free Trade Area (AfCFTA). E-fuel pilot projects could also focus on these routes to test infrastructure, processes and handling, as well as support policy development within Kenya. However, there are two key challenges to consider in developing an international corridor on these general cargo routes. The first is the range of cargo that is carried which makes it harder to understand and then seek cargo owners to support with the premium cost of e-fuels, although book and claim could go some way in responding to this (more on this in later sections). The second challenge is scale. The ships are generally smaller on these routes and therefore the CAPEX to shift that ship or route to e-fuels is proportionately higher to the cargo carried.

51 IMARC Group, Soda Ash Prices, News, Chart, Index and Forecast.

Container shipping activity

All of the 174 container ships calling at Kenyan ports in 2023 are of a size that more typically operate on a regional scale. Two thirds of these ships called more than twice at ports in Kenya, indicating more regularity than bulk carriers (see Figure 13). The greater number of visits, the higher the likelihood that the data signals a scheduled service across a set of countries for either part of the whole of the year.

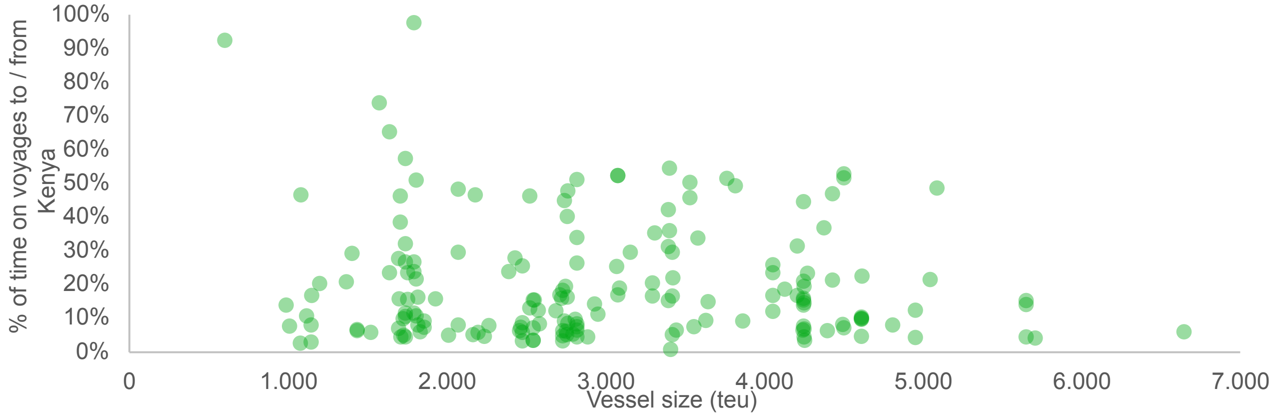


Figure 13

Container ships: size and proportion of operational time each ship spent on voyages to and from Kenya throughout the year

Source: UMAS Fuse Model

As container shipping functions through sequential port calls where cargo can be both loaded and offloaded, trading patterns need to be assessed across the end-to-end chain of countries visited. Approximately a third of the container ships calling at Kenya indicated a pattern of regular port calls. These primarily split out into services which sailed to the Middle East; South Asia (typically via the Middle East); and East Asia.

In the case of the first two, ships typically called at other countries along the coast of East Africa first; however, the container ships sailing between Kenya and East Asia almost always called only at Kenya and no other East African countries – possibly reinforcing what stakeholders have indicated as Kenya's regional transhipment hub role. Table 5 summarises these services and highlights the routes to the key transhipment hubs of Saudi Arabia and the United Arab Emirates for goods bound for Europe, and the potential volume of containerised trade with India and East Asia.

Region	No. of ships	Total TEU	Countries visited	No. of port calls
ME	13	24,945	Saudi Arabia	142
			Mayotte	44
			Jordan	40
			Tanzania	28
			Djibouti	25
			Egypt	24
			Somalia	8
			Yemen	2
			Mozambique	1
South Asia via ME	26	79,682	India	213
			United Arab Emirates	142
			Oman	89
			Tanzania	70
			Pakistan	48
			Mozambique	45
			Somalia	23
			South Africa	11
			Sri Lanka	3
			Saudi Arabia	2
			Kuwait	1
			Qatar	1
			Egypt	1
East Asia	20	69,666	China	312
			Indonesia	2
			Malaysia	93
			Singapore	145
			Sri Lanka	18
			Taiwan	1
			Tanzania	3
East Africa	3	3,514	Mozambique	6
			Tanzania	24

Table 5
Countries visited by seemingly regular services calling at Kenyan ports

Understanding transhipment dynamics will be important to considering the development of a green corridor with Europe in particular. Corridors which are not direct routes to an importer of Kenyan commodities, but which stop at another port for the cargo to be offloaded onto a larger ship (in most cases), may see a more complicated pathway to collaboration with multiple Governments and shippers. While exports to some countries in the Middle East and Asia could travel directly on existing container shipping services (for example, tea to Pakistan), containerised goods travelling to the Americas, Europe or further into Asia will rely on transhipment via countries in the Middle East or Asia.

Interviews with stakeholders did identify some direct routes, including those currently being piloted by SeaTrade.[52] Although scale may be a challenge for these smaller ships as they will be unable to singlehandedly kickstart the e-fuel supply chain, they could support a pilot phase of the project or combine with other shipping demand sources.

For green shipping corridors consisting of dedicated routes (as opposed to with a book and claim system), the liner company controlling the route will therefore be an instrumental stakeholder to coordinate the uptake of e-fuels from Kenya, through transhipment hubs, to their final destination. Understanding the dynamics of decarbonising both parts of the route (from Kenya to the transhipment hub and from the hub to the end destination e.g. Europe) would be important from two key perspectives:

a. In the case that a feeder ship operates on the first leg, it would be important to understand whether there is an incentive for a liner seeking those feeder services to decarbonise that part of the route (paying a premium to do so), rather than decarbonising their own fleet; and

b. In the case that both parts of the routes are operated by the same ship operator, considering what the comparative advantage would be to bunker in Kenya and the Middle East at the transhipment point, rather than only the latter. It is likely that Kenya would need to produce cheaper e-fuels than the Middle East, which is unlikely given the scale of renewables, the green hydrogen ambitions and Government support.

The operators of the apparently regularly scheduled services outlined in Table 5 are summarised in Table 6 below. Both scenarios are worth considering but would present challenges around scale. Indeed, all containerships currently docking in Kenya are not above 8,000 TEU, with most in the smaller ranges, so the business case for decarbonising these smaller ships (with substantially higher CAPEX) as first movers, rather than large ships in operators' fleets is weaker. However, dedicated feeder operators may have the appetite to do so, with a number of these operators doing so in Europe already.[53] As the Ports of Mombasa and Lamu expand and are ready to bunker larger ships, this could see a shift in the size of vessels berthing in Kenya, although there were varying views in interviews on whether the nature of trade in the region - i.e. relying on transhipment - is likely to change.

52 Seatrade, Seatrade, Specialised Reefer Logistics.

53 Riviera (2024), X-Press Feeders starts Europe's first green methanol network.

Region	Ship operator	No. of ships	Average teu	Total teu
ME	APL LLC	1	1,641	1,641
	CMA CGM SA	7	1,612	11,284
	MSC	4	2,654	10,615
	X-Press Feeders	1	1,405	1,405
ME / South Asia	MSC	6	3,585	21,507
	Maersk A/S	4	3,175	12,700
	CMA CGM SA	2	3,840	7,680
	Hapag-Lloyd AG	1	4,620	4,620
	Sealand Europe A/S	1	4,504	4,504
	Ignazio Messina & C SpA	1	4,380	4,380
	Doehle Shipmanagement Pte Ltd	1	3,820	3,820
	Hede Hongkong International	1	3,426	3,426
	X-Press Feeders	1	2,524	2,524
	Maersk Line Ltd-USA	1	2,478	2,478
	COSCO Shipping Lines Co Ltd	1	2,181	2,181
	SIV Mena Ship Management	1	1,756	1,756
	TS Lines Ltd	1	1,756	1,756
	Feedertech Pte Ltd	1	1,740	1,740
	Ocean Network Express Pte Ltd	1	1,708	1,708
	Sea Lead Shipping Pte Ltd	1	1,702	1,702
	Italia Marittima SpA	1	1,200	1,200

East Asia	CMA CGM SA	3	4,352	13,056
	Pacific International Lines	4	2,699	10,796
	Maersk A/S	3	3,524	10,571
	Orient Overseas Container Line	2	4,650	9,300
	COSCO Shipping Lines Co Ltd	2	3,356	6,712
	Blue Whale Maritime Pvt Ltd	1	4,211	4,211
	Sealand Maersk Asia Pte Ltd	1	3,534	3,534
	X-Press Feeders	1	3,158	3,158
	Eurobulk Ltd	1	2,824	2,824
	MSC	1	2,762	2,762
	Ocean Network Express Pte Ltd	1	2,742	2,742
East Africa	Maersk A/S	1	1,794	1,794
	COSCO Shipping Lines Co Ltd	1	1,118	1,118
	PMM Estates 2001 Ltd	1	602	602

Table 6
Operators of seemingly regular services identified in Table 5

Engagement with the biggest of these operators has been carried out as part of this project. Each are engaged in decarbonisation strategy development, with interest in e-fuels. Further engagement with these liners would be required, according to the approach agreed upon to gauge interest on specific routes.

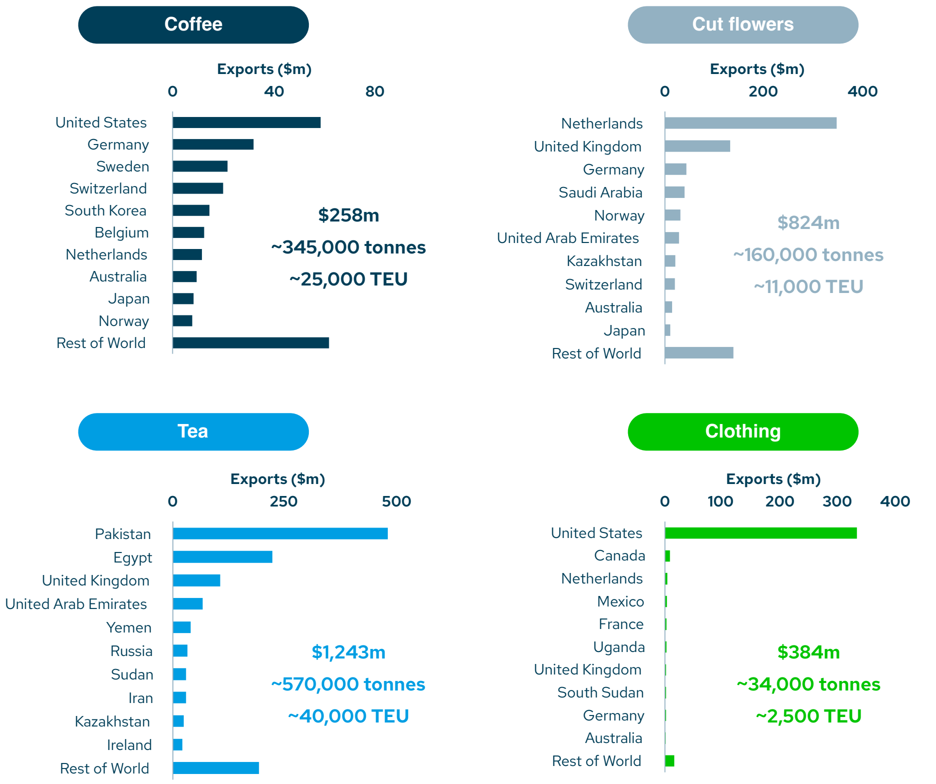
In terms of commodities to consider for a container green corridor, Kenya's high-value containerised goods exported include tea, coffee beans and clothes (see Figure 14 for main export destinations). Cut flowers are currently commonly transported by plane, but chilled shipments to Europe have been tested and have begun according to stakeholders interviewed (approx. 10-15 containers per week). Interviews with stakeholders highlighted efforts around other perishables to develop improved cool logistics and support the shift from air to sea freight, including work on greener reefers.[54] Coffee beans could also be the focus of a green corridor, with significant interest from some cargo owners to help pay the premium as members of the Zero Emission Maritime Buyers Alliance (ZEMBA).[55]

The customer base ranges from diversified (coffee) to highly concentrated (clothing). Each indicates the existence of larger importers and thus routes along which green shipping corridors could be formed, however the container ships will not be exclusively filled with these goods. Book and claim may be a mechanism which could partly respond to this, explored further later in this report. A tension may arise between the emissions reduction appetite of consumers/cargo owners and cost lowering, with the shift of perishable goods from air to sea freight with the intent of achieving both. Seeking additional emissions reductions through the decarbonisation of the ships could increase the premium beyond this appetite. However, this could be mitigated by highlighting the opportunity in this "double" emissions reduction, with the increased price of green fuels, at least partly, covered by the lower cost of sea freight – therefore limiting the premium the cargo owners face for this emissions reduction, especially if transport emissions are a high share of a cargo owners' carbon footprint. Additionally, although replacing conventional jet fuel with Sustainable Aviation Fuel (SAF) can reduce emissions by up to 80% too, it remains significantly more expensive than using green fuels in shipping – particularly when considering the far greater cargo volumes that can be transported by sea.[56]

54 Green cooling initiative, Greener Reefers in International Maritime Transport.

55 Zero Emission Maritime Buyers Alliance – ZEMBA.

56 Airbus, What is sustainable aviation fuel?.



Source: UNCTAD merchandise trade matrix; KenTrade Statistics Bulletin (quarterly trade linearly extrapolated to annual volumes; total USA export weight taken for clothing)[57]; rough conversion of tonnes to TEU based on 14 tonnes per TEU[58]

Figure 14

Value and destination of Kenyan key export goods according to 2023 UNCTAD data

57 KenTrade, Statistics Bulletin: Kenya's import & export trade data (FY 2023/2024).

58 MPC Container Ships, Industry Terms.

Vehicle carriers

Vehicle carriers transport cars, trucks and other motor vehicles from the centres of production (Europe, Asia and the United States) to global markets. Table 7 indicates the trading profile of vehicle carriers calling at Kenya, loosely split into five types.

Trading profile	No. of calls at Kenya	Total capacity calling at Kenya (no. of cars)
Asia - Africa - Americas - Asia	3	19,062
Asia - Africa - Asia	55	312,919
Asia - Africa - Europe - Americas - Asia	18	111,923
Asia - Africa - Europe - Asia	11	63,050
Europe - Africa - Asia	11	70,643

Table 7
High-level trading profile of vehicle carriers calling at Kenyan ports in 2023

Although the time spent sailing to and from Kenya is a very small proportion of the overall operating time of a vehicle-carrying ship, the end-to-end voyage profiles indicate that these ships typically operate regular trading patterns with consistent ports of call. Most ships arriving at Kenya have come from Asia (particularly Japan) and these ships then either complete a full circuit of the globe, call at Europe before returning to Asia or sail directly back to Asia (most common). Calls at countries in the Middle East are also common as part of the trading profiles that cover visits to Africa.

Kenya may function as a vehicle import hub for its landlocked neighbours, but there may also be competition from Tanzania. Almost half of the ships calling at Mombasa call immediately after at Dar Es Salam and, across the 62 vehicle carriers, calls to Tanzania are at the same frequency as those to Kenya. Visits to Kenya also often coincide with calls at multiple ports in South Africa.

Green corridors formed in this shipping sector would benefit from the consumer willingness to cover part of the cost gap for green fuels likely being higher[59] and the best opportunity in Kenya's case is likely to be an Asia-Africa-Asia corridor (see Table 8). However, given the time spent by these ships calling at other locations, a green corridor coalition may face some complexities with the required multilateralism of such a corridor, unless e-fuel is only used on certain legs of the voyages which could be likely for use of e-ammonia before 2030.

59 BCG (2024), The Real Cost of Decarbonizing in the Shipping Industry.

Ship operator	Routes					Total no. routes	No. calls in Kenya
	Asia - Africa - Americas - Asia	*Asia - Africa - Asia*	*Asia - Africa - Europe - Americas - Asia*	*Asia - Africa - Europe - Asia*	*Europe - Africa - Asia*		
Mitsui OSK Lines Ltd	1	18	2	1	1	23	35
EUKOR Car Carriers Inc		3	2	1	2	8	15
Hoegh Autoliners		2	1	2		5	13
NYK Line			6			6	11
Wallenius Wilhelmsen		3			5	8	9
Kawasaki Kisen Kaisha		5	1			6	7
Hyundai Glovis Co Ltd		1	1			2	2
SFL Management		1				1	2
Yuwa Senpaku				1		1	2
Nissan Motor Car Carrier		1				1	1
Zodiac Maritime Ltd		1				1	1

Table 8
Trading profile of vehicle carriers calling at Kenyan ports across ship operators

Ports

Ports best-suited to a green corridor are those with strong readiness for the bunkering of e-fuels and that see a significant scale of traffic deemed most relevant to green corridor development.

In Kenya's case, Mombasa is the country's biggest port handling 943,523 full TEUs and 506,430 empty TEUs in 2022. The port of Mombasa is a crucial landing point for goods, linking to the Northern Corridor which runs West across the country to neighbouring countries. Indeed, connections to ongoing inland green corridor projects could be of benefit to a green corridor, for example the Green Logistics Corridor connecting Naivasha to Mombasa Port, by capitalising on the appetite of consumers and decarbonising the full supply chain of exported goods.

The other port mentioned by project stakeholders is Lamu Port, north of Mombasa. Lamu Port had less than 30 port calls, per year, to date in 2024 consisting mainly of research and fishing patrol vessels. However, with the connection to the ongoing development of the LAPSSET (Lamu-South Sudan-Ethiopia Transport Corridor Project), Lamu port will develop rapidly to accommodate cargo handling facilities and associated infrastructures.[60] Liners interviewed in this project noted their interest in Lamu's development with great prospects as a deep seaport. They are however awaiting the increase in demand to call there, as well as further infrastructure development both at the port and the hinterland. Mombasa and Lamu ports would both need to see significant developments to have the capacity to bunker e-fuels but, with challenges around space in Mombasa port, stakeholders noted that Lamu port may have more opportunity to do so. Further analysis would be required as Lamu port develops to understand this potential.

Creating a long list

As a reminder, green corridors should create the conditions for scaling zero-emission shipping activity before 2030. They do this by (a) focusing on specific trade routes, involving the full ecosystem to coordinate activity; (b) focusing on routes which have specific characteristics that make them best placed to be first movers e.g. favourable policy, cargo owners' willingness to pay; and (c) unlocking public-private collaboration which is essential to drive progress.

From the assessment offered above, a core number of key factors involved in defining a Kenyan green corridor can be summarised to focus on routes which:

- Offer good regularity that would amount to the required level to issue a strong demand signal and secure offtake of e-fuels;
- Have higher chances of customer willingness to pay, to cover part or the whole cost gap between e-fuels and conventional fuels, therefore focusing on high-value, exported goods;
- Include ports which are focused on improving readiness for e-fuels and are connected to the shipping activity most suited to a green corridor.

Table 9 lists the routes with these characteristics, matched to their key trading nations, to form a longlist of possible green shipping corridor routes.

60 Kenya Ports Authority, Lamu.

Segment	Cargo	Key trading nations	Considerations
Dry bulk	Mineral ore exports	China	Largest mine wound down production in 2024 due to depletion
Container shipping	Tea and coffee exports	Mixed	Large volume exports with some direct transport possible to Asia and Middle East
	Cut flower exports	Europe, Middle East	Requires switch from aviation to shipping (potential wider logistical considerations); transhipment challenge for sustaining cool chain
	Apparel exports	United States	Transhipment challenge to corridor and volume likely too low to sustain dedicated service
Vehicle carriers	Cars & truck imports	Asia, Europe, United States	Likely that multi-lateral corridors will be needed; Asia – Africa – Asia trades may offer simplest opportunity

Table 9
Green Shipping Corridor Longlist

ii. Implementing in practice: creating a shortlist

There are some key considerations outside of the data explored above through UMAS' Fuse model which will support the creation of a shortlist of routes between specific ports. These include:

a. Geopolitics & strategic objectives relevant to all countries involved in the green corridor which impact the acceptability, readiness and policy framework around e-fuels;

b. Ease of working with stakeholders to build a Coalition that is aligned with the agreed low carbon trajectory;

c. Current crises and chokepoints which prevent the "normal" running of global trade.

Kenya's strategic objectives play an important role in defining which routes would be best suited for a green corridor, particularly the commodities and trading partners. These have been considered in section 'Understanding the zero/near-zero emission shipping supply chain', which included an assessment of policy from the National Action Plan process. Interviews and engagements with Kenyan stakeholders in Workshops 1 and 2 have also enabled the prioritisation of this shortlist with these strategic objectives in mind. Similarly, although not assessed in detail here, it is important to recognise the readiness of possible green corridor partner governments.

Almost all stakeholders interviewed mentioned the impact of security challenges in the red sea on trade flows in the region, particularly for perishable goods. Some ship operators offer a greener service but have seen customers make huge losses due to the red sea challenges and being forced to take longer routes. Some remain optimistic that the red sea challenges will be resolved within the year,[61] and although these challenges should be a factor in this assessment, they may not be an issue relevant once ships running on e-fuels are ready to be deployed from Kenya.

Combining these factors, with those explored to create our longlist and the assessments made in sections 'Understanding the zero/near-zero emission shipping supply chain' and 'E-Fuels in Kenya', result in the mapping of shortlisted routes in Figure 15 in terms of their impact and feasibility (based on the identification and assessment criteria from Figure 2). The Kenyan port in these routes is not explicitly indicated but would be assumed to be Mombasa until the developments at Lamu can support these goods. The shortlisted routes are illustrated on a map in Figure 16.

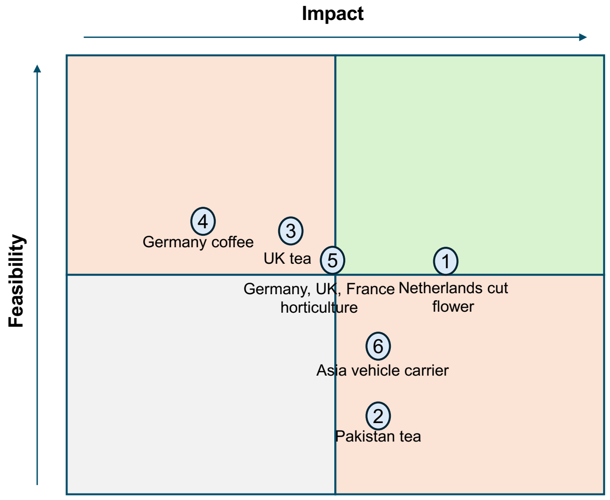


Figure 15
Matrix of shortlisted routes, plotted against impact and feasibility factors

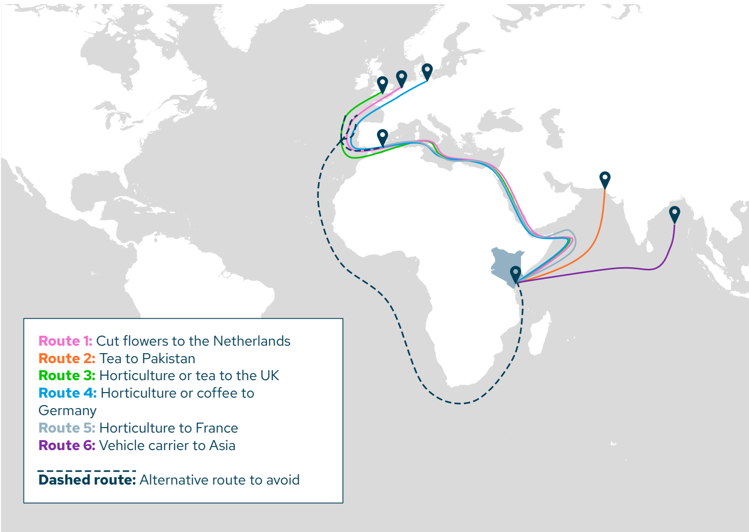


Figure 16
Map of shortlisted green shipping corridor routes
Graphics sources: Kenya outline, World map

61 ShippingWatch (2025), Sector is optimistic that container ships will be back in the Red Sea this year.

Two of these routes are explored in more detail:

Route 1 – Netherlands Horticulture

A green shipping corridor between Kenya and the Netherlands, likely the Port of Rotterdam, could access appetite from European cargo owners to decarbonise their commodity supply chain for cut flowers. The growing readiness of Dutch ports and evolving incentives to use greener shipping fuel in the EU would also support the corridor's efforts. Two key challenges would face this corridor however, with goods being transhipped via the Middle East before going to Europe and the required modal shift of cut flowers from air to sea freight at sufficient volumes to mobilise willingness to pay of cargo owners and cover the green premium. This corridor could also engage with organisations seeking to green reefers, making them more climate and environmentally-friendly to maximise impact.[62]

Route 4 – Germany Coffee

A green shipping corridor between Kenya and Germany could also access appetite from European cargo owners and benefit from the increasing readiness of German ports for greener fuels. Similarly to Route 1 however, this route is also transhipped via the Middle East and due to low volumes of cargo, would likely need to be aggregated across multiple European routes to fill enough ships to meet the offtake requirements for new e-fuel production.

Additional analysis conducted by UMAS further explores these transhipment routes, in the context of regional and international regulation in particular. The green shipping premium will need to be reframed against the rising cost of minimum compliance instigated by these regulations, in this case by the IMO and the EU.

Although significant assumptions must be made due to the uncertainty around IMO regulations, with many pathways to compliance, some key assertions can be made in this project's context (see Annex VIII):

1. On a feeder route from Kenya to the Middle East, a compliance pathway where penalty payments are made (the "pay-to-pollute" option) may be favoured due to the cost of e-ammonia in either Kenya or Saudi Arabia;

2. Kenyan e-ammonia will struggle to compete with Saudi Arabian e-ammonia (both will not be competitive in the near-term without IMO rewards, but Kenya's reward would need to be significantly higher to trigger the scale of offtake required);

3. The level of IMO reward has not yet been set, and a reward that is focused specifically on e-fuels and prioritises a just and equitable transition may make Kenya ammonia on these routes more viable.

62 Green Cooling Initiative (2025), White paper for immediate steps for a sustainable future.

Although there remains much uncertainty, the regulations from the EU and IMO will enforce increasing requirements for ships to reduce their emissions or pay penalty fees. The EU Emissions Trading System was expanded in 2024 with a ramp up to cover 50% of voyages to and from the EU and European Economic Area (EEA), and 100% of voyages within the EU and EEA by 2026. From 2025, the FuelEU Maritime regulation will require that ships sailing in, out and within Europe reduce the emissions intensity of the fuels used. The proposed IMO policy measures are also based on a fuel standard with penalties or remedial units (RUs) for non-compliance. While some questions remain, the measures already create a significant basis for long-term action looking ahead to 2040. There are many pathways to compliance but the increasing limitations on fuel intensity and likelihood of increasing RU prices, likely narrow the potential compliance options to scalable zero-emission fuels such as e-fuels like e-ammonia and e-methanol.[63]

iii. Next steps

Consider phased approach

For first mover activity prior to 2030, there are measures which Kenya could focus on to maximise their maritime potential, which are not route-based approaches (i.e. a green corridor). These could be pursued as a phased approach whilst testing further interest in green corridor routes as they offer tangible opportunities that match Kenya's priorities and ambitions in the maritime space.

1. Explore ways to leverage voluntary demand from cargo owners or the voluntary market in Europe (and other developed economies):
   → Through book and claim; or
   → Related to a modal shift from air to sea freight e.g. for cut flowers.

2. Explore opportunities to leverage policy incentives by combining demand from shipping and export;

3. Explore regional e-fuel pilots or demonstrations to enhance capacity and prepare for shipping's mass market transition.

Leveraging voluntary demand from cargo owners (Book & claim or modal shift)

Interviews with key stakeholders in the cut flower supply chain have indicated that there is significant appetite from cargo owners to reduce emissions. The modal shift from air to sea freight is already happening, with initiatives already established in Kenya to support this. Even with the potential for e-SAF being utilised into the future for air freight, the 80-90% emissions reductions would happen more quickly with a move to sea freight, with an opportunity to get to 100% reductions through the shift to green shipping fuels.

63 Global Maritime Forum (2025), IMO policy measures: What's next for shipping's fuel transition?

Collaborating across key stakeholders in the cut flower, or indeed any commodity supply chain, in Kenya to utilise a book and claim system could support Kenyan e-fuel production. Book and claim is a chain-of-custody model that allows the environmental attributes of zero-emission fuels to be separated from their physical flow. This enables access to low-emission shipping services without requiring a direct physical link between cargo owners and the vessels using green fuels. This system can help overcome logistical and geographical challenges, such as limited fuel availability or misaligned demand. By aggregating demand for zero-emission shipping and enabling it to be monetised, the book and claim model sends a vital market signal, enabling cost-sharing across the value chain to close the cost gap and encouraging investment in zero-emission vessels and fuel infrastructure. Lastly, these systems help establish needed 'virtual infrastructure'—including certification, emissions accounting, and reporting standards—providing a foundation for credible voluntary action while formal regulation continues to develop.

For instance, producers of e-fuels in Kenya can generate environmental certificates which can be bought by cargo owners or ship operators. These funds can be re-invested back into production capacity. Cargo owners willing to pay a premium for green shipping - such as those in the cut flower industry in Europe - claim these attributes for their emissions reporting, regardless of whether their goods were physically shipped on the green-fuelled vessel. Ship operators purchase the certificates for the same reason – to claim towards emissions reporting. Additionally, targeting ship owners who operate on Kenyan routes to purchase the environmental certificates from fuel producers in Kenya could provide an important demand signal for the bunkering of these e-fuels, as well as their production.

As demand for e-fuels increases, particularly in Europe where regulations such as FuelEU Maritime and the EU Emissions Trading System (EU ETS) require shipping lines to gradually switch to e-fuels, Kenya is well positioned to respond competitively due to access to renewable energy. To fully leverage this, Kenyan e-fuel producers should ensure that their fuels meet international standards, enabling them to participate in both regulatory and voluntary carbon markets through book and claim, supplying a growing base of global stakeholders.

Leverage policy incentives by combining demand from shipping and export

In addition to leveraging cargo owners' willingness to pay to cover the cost gap for green shipping fuels (the previous section), accessing policy incentives from countries seeking to import e-fuels would support the build-out of production. This could be an initial phase which sees the export of e-fuels and utilising subsidies from, for example, the EU.

Regional e-fuel pilots and demonstrations

These pilots would focus on one or a few ships running for a year on e-fuels, testing the processes which would be required to scale up the use of e-fuels. This would be complementary to a range of developments that would be beneficial in all scenarios around grid strengthening, policy development and capacity building which would well position Kenya for the mass market transition to e-fuels by the mid-2030s.

3. Section: Conclusion

Kenya could explore the development of a green shipping corridor, in particular the six routes identified. Concurrently or in a phased approach, Kenya could pursue some first steps before 2030 in the following high opportunity areas:

1. ***E-fuel production***, focused on e-ammonia. There is an opportunity to focus on export at the outset to capitalise on policy incentives offered e.g. by the EU, and build out Kenyan production and stimulate demand domestically;

2. ***Leveraging appetite of cargo owners*** to support a modal shift of cut flowers from air to sea freight and pay a premium for e-fuel production in Kenya, including through a book-and-claim system;

3. ***Future-proof local port infrastructure in preparation for global market shift*** to improve readiness for green shipping and position Kenya at the forefront of the transition, including offering incentives for cleaner ships; operating port equipment with cleaner fuels/electricity and providing shore power for calling vessels; developing safety standards for handling green fuels (with training of port workers) and building the associated storage and bunkering infrastructure where required;

4. ***Maximise the benefits to the Kenyan economy*** by setting a clear trajectory for expansion of green fuel production, delivering on the policy and finance recommendations outlined and therefore securing both direct and indirect jobs created throughout the supply chain, from renewable energy generation, to hydrogen production, to e-fuel production.

Supported by:
Federal Ministry for Economic Affairs and Climate Action
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Implemented by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Annex

Annex I

I.a. Approach used to form economic assessment of SZEF production in Kenya

Determining representative projects

- To represent a realistic dispersion of projects around the country, this analysis has built on the work by H2Global which identified locations with high wind and / or solar capacity
- Additional analysis has been conducted around geothermal generation – both through dedicated capacity and through curtailment (i.e. wasted electricity produced at night from existing plants)
- For large-scale projects, H2Global's assumption that electricity is transmitted to Mombasa to produce hydrogen / fuels for ease of export is followed; costs for grid expansion come from H2Global's analysis

Renewable energy: LCOE

- Data required to calculate LCOE: Renewable energy quality (capacity factors), costs (CAPEX / OPEX), economic life and WACCs; PPA price used to assess opportunity cost for use of curtailed geothermal
- Country-specific data from Kenya's Green Hydrogen Strategy; country and region-specific data from H2Global paper "Showcasing business cases for renewable ammonia production in Kenya" and its primary underlying data source ("PTX Business Opportunity Analyser data documentation"); country-specific and global data from IRENA

Electrolyser and hydrogen production: LCOH

- Components of LCOH: Electrolyser (efficiency, costs (CAPEX / OPEX), economic life of production facility and stacks), water (desalination)
- Global data used for electrolyser CAPEX (IEA 2024 Hydrogen Review) – this is a projection for 2030 CAPEX and includes balance of plant (BoP), i.e. is representative of the total installed cost
- The electrolyser is sized according to the load generated by the renewable resource; to produce a fixed amount of hydrogen, a larger electrolyser is needed if the capacity factor of the renewable resource is low, e.g. for solar or geothermal curtailment

E-fuel production: LCOA / LCOMeOH / LCOMGO

- Components of LCOA: Hydrogen compression / storage costs; ammonia synthesis (air separation and Haber Bosch); transport (truck and pipeline) and storage costs
- Components of LCOMeOH / LCOMGO: Hydrogen compression / storage costs; methanol /diesel synthesis costs; CO2 costs (assumed to be derived from DAC rather than point source or biomass as these would be reliant on a wider CO2 capture and storage / use or biomass harvesting value chains to be in place); transport (truck and pipeline) and storage costs

I.b. Assumptions used for modelling illustrative renewable energy generation projects

Building on regional analysis by H2Global, four locations with different renewable energy mixes have been chosen

Location	Geothermal		Wind		Solar	
	Capacity factor	% of installed capacity	Capacity factor	% of installed capacity	Capacity factor	% of installed capacity
Naivasha (dedicated geothermal)	90%	100%	-	-	-	
Naivasha (curtailed geothermal)	17%	100%	-	-	-	
Naivasha (curtailed geothermal & solar)	17%	48%	-	-	20%	52%
Turkana South (wind / solar)	-	-	58%	Small project: 54% Large project: 89%	20%	Small project: 46% Large project: 11%
Mombasa	-	-	42%	Small project: 47% Large project: 49%	16%	Small project: 53% Large project: 51%

- Capacity factors for wind and solar generation in Turkana South and Mombasa sourced from H2Global; Naivasha solar capacity factor based on Turkana South figure
- Geothermal capacity factor is from Hydrogen Strategy (90%); curtailment is based on access to surplus geothermal electricity between midnight and 4.30 am, i.e. 19% of the day (equivalent to 17% proportional to a capacity factor of 90%) and is costed at the average of the range of PPA prices quoted in the Hydrogen Strategy ($61/MWh)
- Based on the above capacity factors, LCOEs were calculated from the following sources:
    - Wind and solar CAPEX and from PTX Business Opportunity Analyser data documentation (source of data for H2Global; projection of mid-range costs in 2030 is used)
    - Geothermal CAPEX from Hydrogen Strategy (mid-point of historical CAPEX); OPEX from IRENA

I.c. Cost assumptions (and sources) for renewable energy generation

Data on renewable resource quality and generation costs and sources

Type	Variable	Value	Source / assumption
Geothermal (dedicated capacity)	CAPEX	USD 3,460 per kW	Green Hydrogen Strategy and Roadmap for Kenya (mid-point of typical CAPEX cost)
	OPEX	USD 115 per kW pa	IRENA: Renewable Power Generation Costs in 2023 (global O&M assumption)
	Economic life	25 years	IRENA: Renewable Power Generation Costs in 2023
Geothermal (curtailment)	OPEX	USD 61 per MWh	Mid-point of PPA price range quoted in Green Hydrogen Strategy and Roadmap for Kenya
Wind	CAPEX	USD 1,337 per kW	PTX Business Opportunity Analyser data documentation
	OPEX	USD 52 per kW pa	PTX Business Opportunity Analyser data documentation
	Economic life	20 years	PTX Business Opportunity Analyser data documentation
Solar	CAPEX	USD 606 per kW	PTX Business Opportunity Analyser data documentation
	OPEX	USD 16 per kW pa	PTX Business Opportunity Analyser data documentation
	Economic life	20 years	PTX Business Opportunity Analyser data documentation
All types	WACC	13%	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya

I.d. Individual LCOEs calculated for each of the illustrative renewable energy generation projects

Data on renewable resource quality and generation costs and sources

Location	LCOE		
	Geothermal	Wind	Solar
Naivasha (dedicated geothermal)	USD 76 per MWh	-	-
Naivasha (curtailed geothermal)	USD 61 per MWh	-	-
Naivasha (curtailed geothermal / solar)	USD 61 per MWh	-	USD 60 per MWh
Turkana South (wind / solar)	-	USD 48 per MWh	USD 60 per MWh
Mombasa	-	USD 67 per MWh	USD 74 per MWh

LCOE ranges from slide 13	USD 65-90 per MWh	USD 44-67 per MWh	USD 51-74 per MWh

I.e. Assumptions and sources used to calculate cost of producing renewable hydrogen

Production step	Variable	Value	Source / assumption
Grid connection	Power line CAPEX (small scale)	USD 42,800 per km	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	Power line CAPEX (large scale)	USD 288,900 per km	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	Power line OPEX	0.7% of CAPEX pa	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	Substation CAPEX	USD 52,733 per MW	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	Economic life	40 years	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
Battery storage	Battery CAPEX	USD 428,000 per MWh	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	Battery OPEX	1.5% of CAPEX pa	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	Economic life	15 years	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	Efficiency	95%	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
Electrolyser	Efficiency	67%	PTX Business Opportunity Analyser data documentation
	CAPEX (varies with scale)	USD 808 – 1,742 per kW	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya
	OPEX	5% of CAPEX pa	PTX Business Opportunity Analyser data documentation
	Economic life	90,000 hours	PTX Business Opportunity Analyser data documentation
Water desalination	Input	10 tonnes H_2O per tonne H_2	PTX Business Opportunity Analyser data documentation
	CAPEX	USD 10 per tonne H_2O pa	PTX Business Opportunity Analyser data documentation
	OPEX	4% of CAPEX pa	PTX Business Opportunity Analyser data documentation
	Economic life	30 years	PTX Business Opportunity Analyser data documentation
Hydrogen storage (tank)	CAPEX (varies with scale)	USD 538 – 1,437 per kg H2	PTX Business Opportunity Analyser data documentation
	OPEX	1.29% of CAPEX pa	PTX Business Opportunity Analyser data documentation
	Economic life	30 years	PTX Business Opportunity Analyser data documentation
All types	WACC	13%	H2Global paper: Showcasing business cases for renewable ammonia production in Kenya

I.f. Assumptions for renewable hydrogen production in each location (figures based on e-ammonia production pathway)

Illustrative plant specifications designed to output 1,000 and 50,000 tonnes of renewable hydrogen per annum

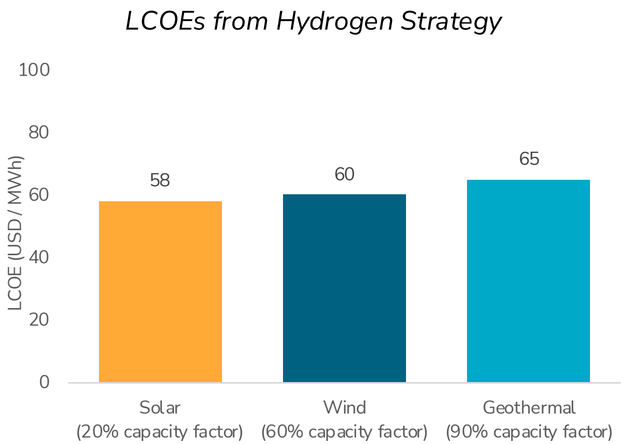
Renewable location	Renewable type & capacity (MW)	Assumed battery storage (MWh)	H_2 production (tonnes H_2 pa)	H_2 plant location	Assumed grid expansion (km)	Electrolyser capacity (MW)	Assumed H_2 storage (tonnes H_2)
Naivasha	Dedicated geothermal: 7	0	1,000	Naivasha	40	6	1
Naivasha	Dedicated geothermal: 346	0	50,000	Naivasha	40	315	55
Naivasha	Dedicated geothermal: 364	0	50,000	Mombasa	570	315	55
Naivasha	Curtailed geothermal: 37	11	1,000	Naivasha	40	18	2
Naivasha	Curtailed geothermal: 18 Solar PV: 16	4	1,000	Naivasha	40	12	2
Turkana South	Wind: 10 Solar PV: 9	0	1,000	Turkana South	40	8	1
Turkana South	Wind: 544 Solar: 65	0	50,000	Turkana South	40	454	55
Turkana South	Wind: 594 Solar: 71	0	50,000	Mombasa	900	454	55
Mombasa	Wind: 13 Solar: 15	1	1,000	Mombasa	40	9	1
Mombasa	Wind: 575 Solar: 599	0	50,000	Mombasa	40	484	77

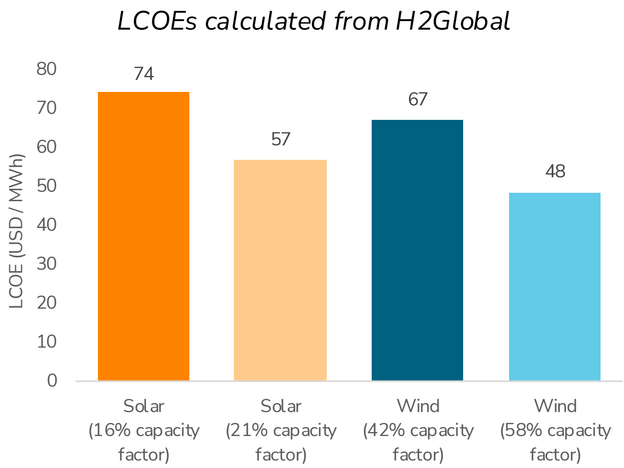
I.g. Sources of data and assumptions

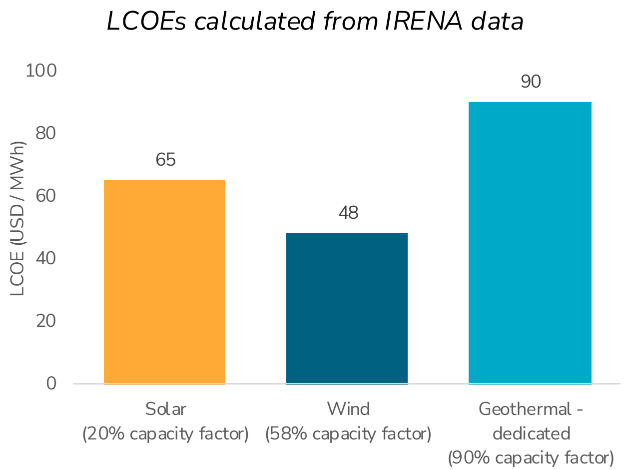
Source	Use of data
H2Global paper: Showcasing business cases for renewable ammonia production in Kenya (draft)	Solar / wind capacity factors; battery and grid expansion requirements and CAPEX / OPEX; electrolyser, hydrogen storage and ammonia synthesis CAPEX / OPEX
PTX Business Opportunity Analyser data documentation	CAPEX / OPEX data for e-fuel production not covered above
Green Hydrogen Strategy and Roadmap for Kenya	Geothermal capacity factors, CAPEX and PPA prices
IRENA: Renewable Power Generation Costs in 2023	Geothermal OPEX
IEA Capital Cost Observatory	Indicative tenors and capital structure for renewable projects
Techno-Economic Aspects of Production, Storage and Distribution of Ammonia	Costs of ammonia pipeline transportation and storage
Truck Operating Benchmarks; Panda Trailer Knowledge	Costs of ammonia, methanol and diesel transportation
Ultra-long-duration energy storage anywhere: Methanol with carbon cycling	Costs of methanol and diesel storage

Annex II

Range of LCOEs indicated in Hydrogen Strategy, H2Global paper and based on calculations from IRENA data







- Assuming a WACC of 13%; the data across the sources indicate following ranges for LCOEs:
  - Solar: USD 51-74 per MWh
  - Wind: USD 44-67 per MWh
  - Geothermal: USD 65-90 per MWh

- LCOEs vary due to capacity factor (quality of renewable resource), and CAPEX and OPEX estimates (additional cost of geothermal well exploration is captured at the project level and not in the LCOE)
- It is reasonable to assume constant CAPEX / OPEX costs for all projects within a country, but capacity factors will vary between projects

Annex III

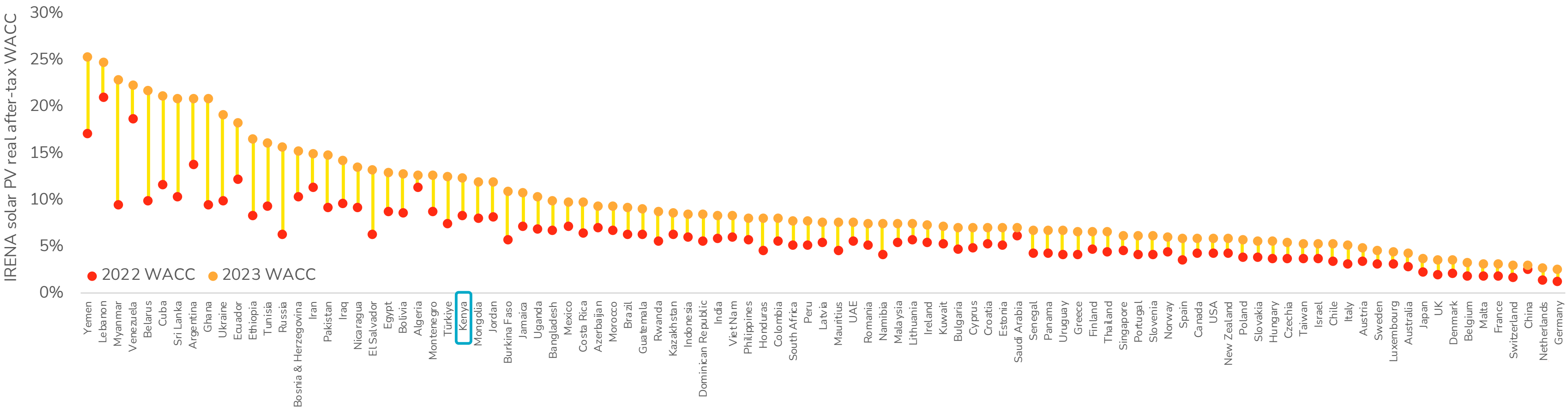
Mapping existing and prospective green hydrogen projects in Kenya: List of announced projects (not exhaustive) and current status (where known)

Below is a list of announced projects (not exhaustive) and current status (where known)

H2 Project	Product	Geography	Size	Estimated production pa	Viable pathways	Status
HDF Energy	RE and H2	Mombasa (local PV RE)	1 GW (solar capacity)	~35,000 tonnes H2[1] ~200,000 tonnes NH3[1]	All	Development studies started (Oct 23)
AMEA Power	TBD	Mombasa (in-land RE)	Geothermal; 1 GW (Electrolyser capacity)	~160,000 tonnes H2[2] ~900,000 tonnes NH3[2]	All	Announcement of a 1GW electrolyser plant in Mombasa (Sep 23)
KenGen	Fertiliser	Lake Naivasha (in-land Production)	100 MW (Electrolyser capacity)	~16,000 tonnes H2[2] ~90,000 tonnes NH3[2]	Ammonia (Fertilisers – main project goal)	KenGen Public RFP for feasibility studies in Aug 22. In Nov 2024 announced 10-year strategy that includes a focus on fertilisers.
Fortescue Future Industries (FFI)	RE and Fertiliser	Olkaria Geothermal (in-land)	300MW (Electrolyser capacity – TBC)	~50,000 tonnes H2[2] ~270,000 tonnes NH3[2]	Ammonia (Fertilisers – main project goal)	Project has not been progressed
Mombasa	RE and NH3	Mombasa (Local Wind RE)	Up to 625MW wind	~45,000 tonnes H2[3] ~250,000 tonnes NH3[3]	Power to X	Prospective
LAPPSET-LAMU-Sagittarius			Potential for wind			Prospective

1. *Assuming 20% capacity factor*
2. *Assuming 90% capacity factor*
3. *Assuming 42% capacity factor*

Annex IV
Solar PV cost of capital comparison across multiple countries



Annex V

Summary of differences in exposures to key risk factors between large and small-scale projects

Risk factor	Causes	Exposure in small domestic project vs large-scale export project
Construction	Delays in construction and cost overruns during construction	Smaller projects may have less exposure and (potentially) faster construction times which reduces the difference between required offtake price and LCOA; less associated infrastructure investment may also be required (e.g. truck vs pipeline)
Operational	Lower than planned production volumes or cost overruns during operation of plant	Large-scale projects may be better placed to access high quality renewable resources (e.g. in more remote regions) and optimise O&M and thus reduce risk
Default	Risk that offtaker defaults on agreement; could be commensurate with sovereign risk if offtaker is state-backed entity or may be linked to credit quality of corporate entity	Export-oriented projects may attract a lower risk premium if the credit quality of an international offtaker is stronger than that of a domestic offtaker
Currency	Exposure to changes in currency exchange rates: largely applies during construction period and potentially to revenues if offtake is priced at local currency	Post-construction, exposure could be mitigated for export-oriented projects if funding and offtake payments are same currency; potential mitigation for small-scale projects too if bunkers sold to regional users in USD
Jurisdiction risk	Country-based risk where changing political, legal or social landscape could impact profitability of project	Funders of both small and large-scale projects will be exposed, but the involvement of international offtakers in the latter may increase the risk premium applied
Market	Exposure to market prices for output—e.g. following initial offtake period or possibly during the period if price is linked to benchmark price (potentially another commodity)	Large-scale projects may be exposed on a small proportion of production not covered by offtake agreement; small-scale projects may
Technology	Risks associated with scaling new and untested technologies	While the renewable energy and e-fuel synthesis components of e-fuel projects is based on established technology, large-scale electrolysers are only just beginning to be developed

Annex VI
Renewable energy capacity factors used for the comparison of the WACC across countries

	Grid enhancement costs	Solar PV capacity factor (from IRENA 2023 data)	Onshore wind capacity factors (from IRENA 2023 data)
India	$30/tonne NH3	16%	32%
Brazil	$30/tonne NH3	16%	55%
Australia	$30/tonne NH3	20%	35%
Kenya (Turkana South project)	$150/tonne NH3	20%	58%

- Assumed capacity split between solar and wind: 40% - 60%.
- Assumed electrolyser load: 70%.
- Country-specific battery storage costs were not considered in the analysis.

CAPEX and OPEX assumptions for solar / wind, as well as the Weighted Average Costs of Capital (WACCs) are from the GIZ Power to X Hub dataset (see Annex I.g).

Other costs and assumptions match those used for the core analysis in the Kenyan context (see Annex I) (i.e. for electrolyser, water desalination, ammonia synth, storage etc.).

Annex VII
Summary of type, size and average age of ships calling at Kenyan ports in 2023

Ship type	Size range	No. of ships	No. of calls	Avg. size	Avg. age (yrs)
Bulk carriers		**237**	**259**	**53,910 dwt**	**13.8**
Bulk carrier: Handysize	10,000 to 43,999 dwt	62	69	33,403 dwt	14.5
Bulk carrier: Handymax - Ultramax	44,000 to 69,999 dwt	151	164	58,355 dwt	12.7
Bulk carrier: Panamax - Kamsarmax	70,000 to 99,999 dwt	23	25	77,718 dwt	19.7
Bulk carrier: Capesize - VLOC	100,000+ dwt	1	1	106,552 dwt	18.0
General cargo ships		**57**	**144**	**14,700 dwt**	**21.4**
General cargo: Heavy load carrier		2	3	34,708 dwt	13.0
General cargo: Livestock carrier		2	2	1,528 dwt	51.5
General cargo: 0-9,999 dwt	0 to 9,999 dwt	23	92	6,082 dwt	21.9
General cargo: 10,000-19,999 dwt	10,000 to 19,999 dwt	13	18	13,063 dwt	18.4
General cargo: 20,000-29,999 dwt	20,000 to 29,999 dwt	14	25	25,018 dwt	20.8
General cargo: 30,000+ dwt	30,000+ dwt	3	4	35,150 dwt	18.7
Reefer ships		**2**	**2**	**10,823 dwt**	**19.0**
Reefer		2	2	10,823 dwt	19.0
Oil / chemical tankers		**135**	**210**	**67,811 dwt**	**12.7**
Tanker: Small tanker	0 to 9,999 dwt	7	22	3,983 dwt	25.7
Tanker: Handysize / MR	10,000 to 54,999 dwt	70	106	41,041 dwt	14.0
Tanker: Panamax / LR1	55,000 to 84,999 dwt	5	5	75,763 dwt	15.8
Tanker: Aframax / LR2	85,000 to 124,999 dwt	53	77	110,847 dwt	8.9
Liquified gas carriers		**19**	**55**	**48,989 cbm**	**10.2**
LPG: Small gas carrier	0 to 31,999 cbm	7	31	7,932 cbm	9.0
LPG: Mid-sized gas carrier	32,000 to 49,999 cbm	2	2	38,295 cbm	4.5
LPG: Large gas carrier	50,000 to 69,999 cbm	1	1	59,051 cbm	17.0
LPG: Very large gas carrier	70,000+ cbm	9	21	82,181 cbm	11.6
Containerships		**174**	**671**	**2,957 teu**	**19.5**
Containership: Small feeder	0 to 999 teu	2	12	796 teu	23.5
Containership: Regional feeder	1,000 to 1,999 teu	45	209	1,607 teu	18.2
Containership: Feedermax	2,000 to 2,999 teu	54	166	2,591 teu	21.1
Containership: Intermediate (small)	3,000 to 5,999 teu	72	283	4,083 teu	18.9
Containership: Intermediate (large)	6,000 to 7,999 teu	1	1	6,648 teu	25.0

Vehicle carriers		**62**	**98**	**6,043 cars**	**16.9**
Vehicles carrier: 4,000-5,999 cars	4,000 to 5,999 cars	15	35	5,051 cars	18.3
Vehicles carrier: 6,000+ cars	6,000+ cars	47	63	6,360 cars	16.4
Cruise ships		**4**	**5**	**35,546 gt**	**23.8**
Cruise: 10,000-49,999 gt	10,000 to 49,999 gt	3	4	26,483 gt	23.3
Cruise: 50,000-99,999 gt	50,000 to 99,999 gt	1	1	62,735 gt	25.0
Passenger / RoRo ships		**18**	**40**	**21,943 gt**	**16.2**
Ferry-pax only		3	4	4,548 gt	22.0
Ferry-RoPax		2	3	1,327 gt	8.0
Ro-Ro		13	33	29,129 gt	16.1
Other vessels		**19**	**137**	**1,947 gt**	**24.6**
Service vessel: Cable layer		2	2	9,933 gt	33.0
Service vessel: Offshore		4	5	1,609 gt	23.5
Service vessel: Tug		7	69	509 gt	14.7
Fishing Vessel		6	61	1,189 gt	34.2
Total		**727**	**1,621**	**-**	**16.1**

Annex VIII
Lowest TCOs for each compliance / fuel option