CITAC

Fuelling Africa's Potential: Bridging the Gap in Energy Infrastructure

2024

PUMA ENERGY

Research commissioned by Puma Energy

Foreword by Puma Energy

Over the past few years, the world has experienced a pandemic, economic uncertainty, increased geopolitical tensions, and unprecedented supply chain disruption. These events have exposed just how fragile the energy system is, especially for countries in Sub-Saharan Africa.

While grappling with pressing issues such as healthcare, education, food, water, and employment – all of which require reliable and affordable energy access to thrive – these countries are also balancing socio-economic priorities with global decarbonisation and energy transition expectations.

In partnership with CITAC, Puma Energy has commissioned this white paper to highlight the challenges in fuel supply in Sub-Saharan Africa and identify opportunities to improve and drive energy affordability, efficiency, and security in these supply chains. The paper outlines the reality of the infrastructure investment needed to enable energy access and socio-economic progress today, while also helping to meet future energy needs in a lower carbon world.

Puma Energy's purpose is energising communities. As a company that operates primarily in high potential growth markets, this means taking a responsible approach to providing reliable energy access to people and businesses, often in underserved communities. Across our markets, it's clear that traditional fuels - especially for transportation and power - will remain prevalent for the immediate future, while the share of lower carbon and clean energy steadily grows.

As we look ahead to what a sustainable energy mix of the future needs to look like alongside an equitable energy transition, we must not lose sight of the importance of energy access and security, especially across economies in the Global South.

About Puma Energy

Puma Energy is a leading global downstream energy business, safely providing energy in more than 35 countries, primarily across central America and Sub-Saharan Africa. Our downstream business segments include fuels, aviation, lubricants and bitumen. Our purpose is energising communities to help drive growth and prosperity by sustainably serving our customers' needs in high potential countries around the world.

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2024

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SECTION

1 Executive summary

1. Executive summary

This paper aims to highlight the challenges in fuel supply in Sub-Saharan Africa (SSA) and identify opportunities to improve and drive efficiency in those supply chains.

The need for energy

Sub-Saharan Africa remains the most economically underdeveloped region in the world. Energy sits at the core of economic growth. Whether directly consumed in industry or supporting the movement and livelihoods of citizens, energy is the lifeblood of the economy. Energy shortages directly impact people's lives and economic development.

Economic and Clean Petroleum Product Demand Growth Correlation

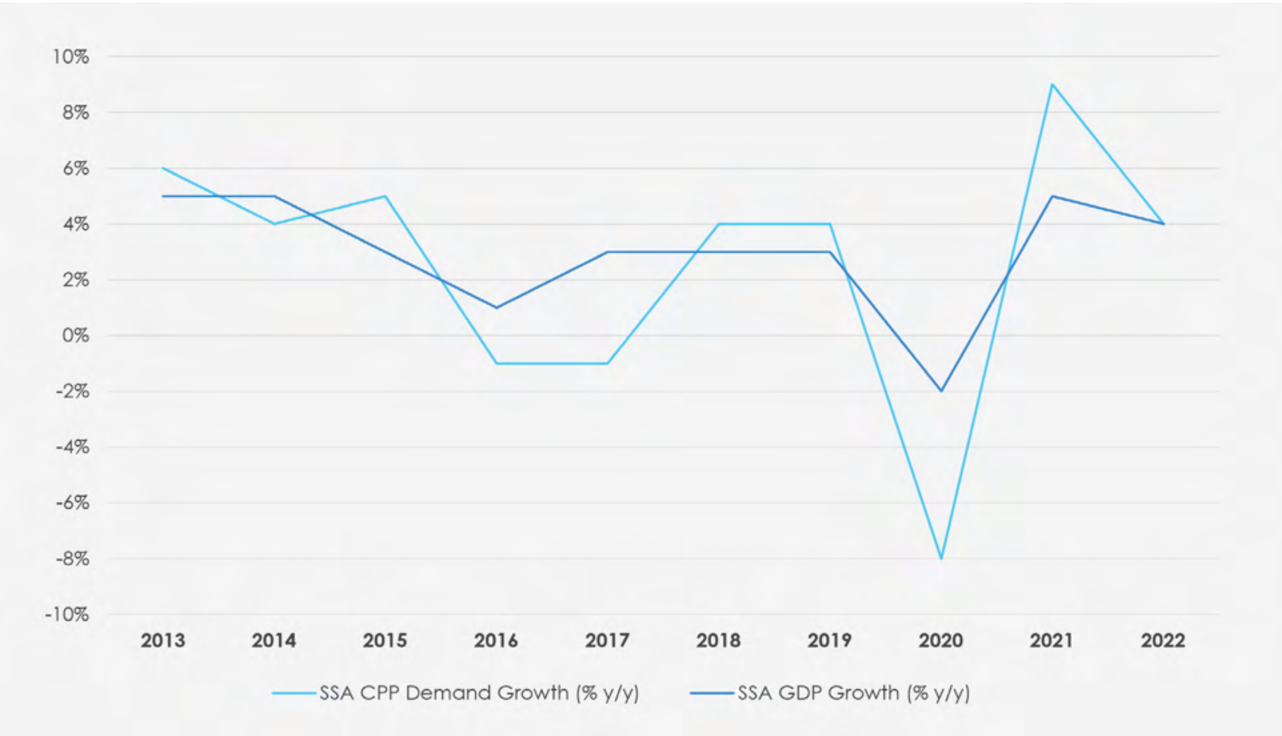


Figure 1: Economic & Clean Petroleum Product demand growth correlation. Source: CITAC Africa, IMF WEO April 2023.

African Primary Energy Mix Forecast (Mtoe)

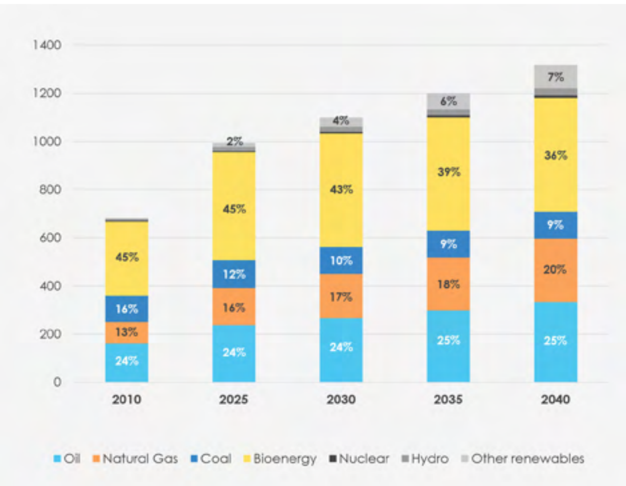


Figure 2: Primary Energy Mix, Sub-Saharan Africa.
Source: IEA AEO 2019, Stated Policies.

As shown in the graph, Africa has long relied on oil products to support economic development. They provide a readily available, decentralised source of energy that can be transported from producer to consumer through robust and adaptable supply chains. With time, renewable energy options will play a greater role in the energy mix in Africa but thus far, despite efforts to develop such diversification in Sub-Saharan Africa, they have not yet scaled to meet demand. Unreliable power generation and/or distribution has been disruptive to economic activity even in major African economies such as South Africa and Nigeria. Securing reliable electricity provision at competitive prices will support the roll out of renewable electricity generation as well as increase the prevalence of electric vehicles, electric stoves, lighting, heating, and similar applications. This is a goal that will take time to achieve as it requires the development of effective policy, improvement of security, and attraction of investors, along with many other challenges. In the meantime, the energy needs of today must be met with practical means.

Africa's population is growing rapidly, and the rate of urbanisation is accelerating as rural populations migrate to cities – which are the economic centres – or as cities expand to swallow rural settlements. These demographic trends are leading to a rising demand for energy, placing ever greater strain on energy supply systems and infrastructure. This means there is a need to scale up the efficient supply of fuels such as gasoline, diesel, and jet fuel to meet energy demand with the technology available in country. Improving supply chain efficiency through the removal of bottlenecks and cost saving practices will directly contribute to lowering the price of energy for African consumers.

Africa's challenge

In 2022, Sub-Saharan African demand for clean products (oil products that are used by everyday consumers, namely gasoline, diesel, Jet A1, and kerosene) totalled 91.3mn mt, up 3.7% y/y. This follows a 9.2% y/y increase in 2021 as the market recovered from the effects of the COVID-19 pandemic and demand fundamentals continued to drive rising oil product consumption.

CITAC forecasts, incorporating data from UN population projections, projected demand growth for clean products will remain strong, rising by 49.7mn mt or 56% between 2023-2040, to reach a total of 142 mn mt. Continued economic development, population growth, and urbanisation trends underpin the growing need for clean products over the forecast period. Robust supply chains and sourcing systems are needed to support this growing energy need.

Increasingly, meeting demand has proven challenging. Domestic refining capacity has not managed to keep pace with demand requirements. Refinery output of clean products has fallen from 32mn mt in 2013 to just 17mn mt in 2022, resulting in a net clean product shortfall that has risen from 49mn mt to 80mn mt over this period.

Demand for oil products is set to continue to grow. Clean product demand is set to rise 56% from 2022 levels by 2040 to reach 142mn mt. New refining capacity in the form of the Dangote project along with other developments will help to narrow the clean product shortfall. This shortfall is forecast to stand at 67mn mt in 2030, down from 80mn mt in 2022. It will continue to expand from this point in the absence of further capacity additions. From a logistical standpoint, it is worth noting that with refineries of the scale of Dangote, seaborne product exports from Nigeria will be necessary. Assuming that these exports are then to be supplied into West and Central Markets, these markets will still require significant investment in import infrastructure to handle the volumes delivered by vessel.

Sub-Saharan Africa Demand (000mt)

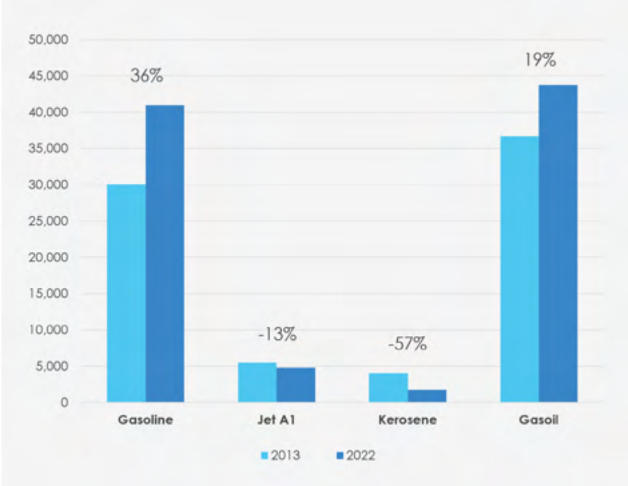


Figure 3: Sub-Saharan Africa Demand.

Sub-Saharan Africa Balances

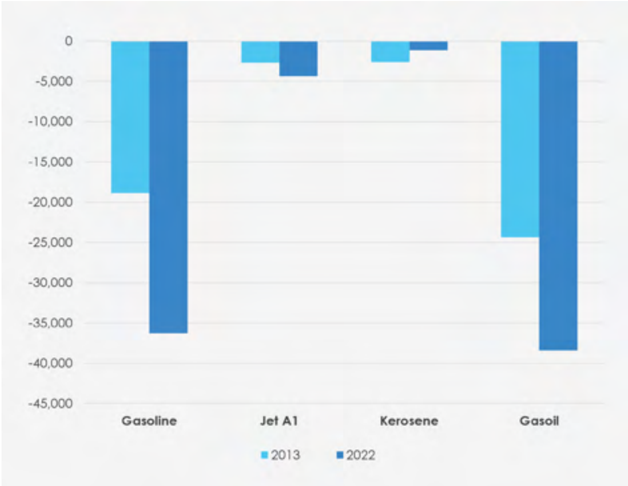


Figure 4: Sub-Saharan Africa Balances.

Addressing supply chain constraints

Driving efficiency and improving supply security

From a mid and downstream supply perspective, much of the associated infrastructure in Africa is ageing and suffers from a lack of investment, outdated policy frameworks, and insufficiencies in regional, national, and urban energy planning — especially compared to other regions across the world. Furthermore, efforts have not been able to keep pace with rapidly growing populations, and urbanisation trends. This has resulted in fragmented supply routes, bottlenecks and insufficient infrastructure capacities that contribute to an overreliance on trucks, congestion in cities and ports, and disrupted access to energy – collectively resulting in increased costs for governments and citizens. This is impairing the region's socio-economic development potential. While, historically, international funding and aid has helped to support and develop supply chains, national budgets are under pressure from higher interest rates, inflationary pressures, the fallout from conflicts, and the global pandemic. Therefore, it is important that infrastructure projects are economically defensible or, where they are not, policies are developed to support projects that will bring a direct benefit to society. Further, the cost of borrowing and the depreciation of African currencies in many countries makes investment a challenge.

CITAC has identified elements of the supply chain that can be improved through the application of best practice and sound investment. This includes streamlining border controls and customs procedures, accelerating truck loading and evacuation policies, and similar debottlenecking efforts. These measures have the additional advantage of reducing the number of trucks required to serve demand, bringing with them an environmental dividend as emissions related to energy distribution are cut and road congestion eased. The number of road traffic accidents could also be lowered. Such efforts have the potential to bring cost savings of between 0.3% of 2023 GDP in RSA to as high as 5.4% of 2023 GDP in Mozambique.

Also worth noting is that parts of the supply chain infrastructure used in traditional fuels, if planned correctly, can be adapted to transitional fuels and lower carbon energy alternatives, including sustainable aviation fuels, LPG, and green hydrogen while also benefitting wider trade infrastructure (ports, railways etc.). This complements, rather than displaces, decarbonisation of the power sector through resources such as wind, solar, and hydro.

Across the supply chains studied later in this paper, a total of 750kt of GHG emissions could be saved in 2030 through the adoption of pipelines – removing as much as 95% of trucks required.

Supply chain challenges and recommendations

The key objective of supply chains is to ensure adequate provision of energy to the consumer and at the most economic price point possible. The key features needed to achieve these goals are:

- Conducive regulations
- Market-based pricing of fuel products
- Adequate infrastructure

Regulations

The regulatory environment is essential to fostering efficient and competitive supply chains that deliver the best possible value to the consumer while safeguarding the interests of that consumer. Common regulatory barriers seen in SSA include:

- Different product specifications between neighbouring or regional countries prevent the use of shared infrastructure due to the risk of contamination of one product to another which limits economies of scale.
- Non-harmonised pricing policies between neighbouring and regional countries can drive smuggling, undermining investment and government revenue generation.
- Inefficient and lengthy border crossing and customs processes drive up prices for the end consumer.

CITAC recommends governments pursue a regional approach to market regulation and policy. A regional approach facilitates better economies of scale, creating the potential for land-linked countries to coordinate volumes to be imported in harmony with neighbouring transit countries. Similarly, harmonisation of specifications facilitates improved security of supply for countries that can potentially source products from neighbouring markets in the event of supply disruptions.

Harmonising product specifications has been a key facilitator of improved economics of supply and ensuring supply routes can be diversified without relying on segregated supply chains. Harmonisation has already been achieved in many sub-regions and efforts are underway, led by the African Union (AU) through the African Refiners and Distributors Association (ARDA), to harmonise product specifications across the continent. As growing attention on specifications leads to changes at different speeds in different countries, maintaining harmony across regions where it exists today will be an important factor to coordinate.

A strong example of a regional approach is the East Africa Community (of which DRC, Burundi, Kenya, Rwanda, Somalia, South Sudan, Uganda, and Tanzania are members), which introduced common product specifications in 2015 mandating 50ppm sulphur specifications and which fostered improved security of supply by ensuring harmonised specifications among the member states – excluding Somalia and DRC which are yet to implement these.

Another element of harmonisation is pricing, as discussed below.

Pricing

- Product pricing is regulated in many countries in SSA through price structures. Methodologies differ, but such price structures seek to allocate calculated values to some or all of the components that contribute to the pump price: base quote, premium, jetty throughput charges, storage, trucking fees, and similar. The challenge is that these calculated figures rarely reflect reality and stifle competitivity among operators in the downstream, with fixed margins encouraging inefficiencies. In some markets margins are not revised for extended periods. This is the case in Cameroon, for example, where storage fees are insufficient to incentivise new investments in the sector, leading to storage capacities that are ill-suited to meet growing demand – especially in the event of outages. Market pricing, by contrast, encourages competition, creating the potential for lower costs to consumers.

CITAC recommends governments seek to reflect real market costs and prices in pump prices. In CITAC's experience, price structures see only infrequent revisions to their methodologies and would benefit from monthly reviews, at a minimum, to align more closely with international market prices. A recommendation for regulators is to ensure that price structures reflect as truly as possible the costs associated with supplying the market, including aspects such as costs of finance, freight, construction materials, fuels, and similar. This is typically done by scheduling regular price structure reviews and ensuring the regulator is up to speed with changes in the international market and shifting costs in their own market, as well as identifying areas where the price structure allocates excessive or insufficient margins to operators. Other markets have embraced full market liberalisation – allowing marketers to reflect costs in their pump prices which, in a non-monopolistic and well-regulated market, sees customers benefitting from a choice of services and prices.

Infrastructure

- Single points of failure: These are seen across many African supply chains, leading to a risk of major disruption if a key terminal, pipeline, jetty, or refinery is taken offline, often with very limited optionality to continue imports via another route. A key recent example of this is the SGP terminal in Conakry which suffered a catastrophic fire in 2023 and, with no viable alternative for importing gasoline and Jet A1 at scale, imports had to be conducted through a makeshift ship-to-truck rack, with imports supplemented by overland trucking from neighbouring Sierra Leone. Even with these measures, shortages have plagued the market in early 2024.
- Security stock policies are often inadequate, or not enforced due to financial or ullage constraints. This leaves markets exposed to supply disruptions.
- Ageing infrastructure often suffers from a lack of maintenance, modernisation and investment, resulting in deteriorating supply economics. State-owned infrastructure in particular faces these challenges. This can be storage, railways, ports, pipelines and similar, as they are often not subject to the same economic realities that private operators are. This can result in costly delays and demurrage - the charge payable by the charterer to the shipowner when a vessel fails to discharge (or load) within the time agreed.

CITAC recommends a multi-faceted approach to ensure infrastructure bottlenecks can be relieved and supply chain risks can be minimised.

Debottlenecking and scaling up

Governments need to identify where bottlenecks will appear based on projected trends. This entails evaluating existing and planned infrastructure and mapping its adequacy against demand projections and supply dynamics so that further investment in infrastructure can be secured in a timely manner. Further, certain trends, such as the reliance on trucking for bulk transportation, must also be identified as a challenge to scale: eventually, alternative bulk transportation methods will be needed to support the growing volumes of product required.

A key factor behind rising bottlenecks is the fact that Sub-Saharan Africa is urbanising rapidly. African urban planners are struggling to keep pace with the rate of growth of their cities. This leads to inefficient road systems and large, sprawling neighbourhoods. The rapidly growing urban population causes increasing congestion on road networks – typically the primary method for transporting people and goods – among other challenges. The issue of congestion is made worse by the fact that most major cities in coastal African countries are also major working ports which support the import and export of goods, placing greater strain on logistics networks.

Given these demographic trends, it is essential to start thinking of solutions to the problems associated with increasing congestion: higher rates of traffic accidents, productivity losses, higher pollution, and disruption to the supply of goods. Where possible, rail, pipelines and larger ports can present efficient solutions to the continent's growing logistical problems.

Diversification of supply

Diversification of supply chains is key to avoiding product outages. Over-reliance on a single piece of infrastructure or a single supply route exposes markets to the risk of supply disruption. Market operators must identify single points of failure in their markets and seek to develop contingencies or mandate the use of alternative supply sources. Even if this entails additional costs, such measures minimise the impact of supply chain failures on the population and economy.

Land-linked Ethiopia, for example, is supplied via a lengthy supply chain: Jet A1 is delivered into Djibouti, where it is loaded onto trucks and transported over 800km by road to Bole Addis Ababa International Airport – the main demand centre. The country remains at risk of supply disruptions due to its reliance on this single supply chain; there are no pipelines or rail alternatives that could support the market. The impact of any supply chain disruptions threatens to ripple well beyond Ethiopia's economy, as the country's main airport is a key international hub and the base of Ethiopian Airlines – a major international airline linking a host of African countries with destinations around the globe.

To highlight an alternative, more secure supply chain, the OR Tambo airport in Johannesburg is supplied by pipeline from two refineries but there are also options to supply by truck and rail; the result is a well-diversified supply chain that is resilient to disruptions.

Security stocks

The invasion of Ukraine led to major disruption of the flow of oil products, particularly gasoil. The tight supply and corresponding spike in prices as market players scrambled to secure barrels resulted in delays in supply to African countries and a sharp climb in product premia – a cost to be borne by the consumer or government.

The IEA recommends member states hold security stocks of no less than 90 days of net imports. African states without such measures in place, or with inadequate stocks, would benefit from a similar security buffer.

Improve security environment

Security challenges vary in their nature across Africa from outright conflict to vandalism to theft. The risk of theft and losses are a recurring concern among marketers who are reluctant to use pipelines or rail facilities, often preferring to use trucks for transportation to minimise the scale of losses when they do occur. A recommendation would be for operators of pipelines and rail to guarantee a cap on the level of losses to users and to implement security measures to ensure losses are kept to a minimum and ensure confidence among clients is maintained.

Drive efficiency in natural monopolies

Often natural monopolies (e.g. pipelines, railways, ports, refineries, power generation, grid-based distribution) are run by state enterprises. Operators across Africa complain about inefficiencies stemming from the unoptimised operation of infrastructure by such enterprises. Inefficiencies typically lead to substantial losses at these state enterprises, requiring the state to intervene and provide financial liquidity.

90 days

IEA recommends that member states hold security stocks of no less than 90 days of net imports

Efficiency at state-run infrastructure enterprises can be improved by introducing greater accountability across management for the financial performance of the facility. Applying more rigorous project management techniques to ensure timely execution of maintenance, expansion, and investment could help to make ageing state-run infrastructure more economical, helping to reduce the cost to the end consumer.

Another approach is the introduction of a private partner. Private-public partnerships can deliver improved efficiencies by applying best management practices and cost efficiencies while not relinquishing control over assets with national strategic importance.

Environmental imperatives

The Greenhouse Gas (GHG) footprint of most African countries is miniscule in global terms. This reality underpins arguments for Africa's energy transition to be a just transition. Africa must play a role in meeting global warming targets and indeed it possesses significant resources to contribute to the global fight against climate change from abundant green hydrogen generation capacity to vast rainforest coverage, a key carbon sink. Africa, however, cannot pursue the aggressive path of decarbonisation championed in the developed world due to its current lack of scalable zero or low carbon alternatives. Rapid decarbonisation of Africa's energy mix would have significant economic and social consequences due to the lack of readily available alternatives to fossil fuels. It is expected, therefore, that Africa will need to focus on reducing the environmental impact of the fossil fuels on which it relies as its demand for these energy sources continues to rise.

In pursuit of reducing the environmental impact of the energy industry in Africa, steps can be made to reduce the GHG emissions associated with everyday economic activity. In the case studies included in this paper, for example, efficiencies in truck loading and evacuation can lead to a 25% reduction in the number of trucks needed to support oil product distribution. Equally, investment in rail and pipelines brings opportunities to cut GHG emissions by displacing trucks. These are considerations worth taking into account when evaluating investment in supply chains and infrastructure planning.

25% fewer trucks needed

to support oil product distribution if efficiencies are gained

Country case studies: Botswana, Mozambique, Namibia, Tanzania, Zambia

Individual country-level analyses recommendations can be found in the country case studies section of this report. These case studies review in depth today's supply chains and how they are expected to evolve over the forecast period to 2040, highlighting key bottlenecks and challenges associated with the current infrastructure and where they can be anticipated and avoided.

One challenge is the bulk trucking of oil products. Today, trucking accounts for 83% of oil product primary transportation in Africa. Trucking in these markets is characterised by significant, costly inefficiencies related to ports, storage, truck loading and evacuation processes. In Malawi, for example, there is an incentive of around $200mn over the next 15 years to improve truck turnaround times in Matola and Dar es Salaam, key import corridors for the inland market. Meanwhile, addressing the identified inefficiencies across the outbound supply chains of all the countries analysed through improved truck loading and turnaround times, together with quicker product clearing, is estimated to save a cumulative $4.7bn between 2024 and 2040. Investment in port dredging, deeper port draught, 24-hour berthing, high-capacity discharge pumps and dedicated marine loading arms, with automated equipment will give rise to faster discharge rates and quicker vessel turnaround times providing potential annual demurrage savings of around $300mn across key Eastern and Southern African corridors with an estimated cumulative saving of $5.3bn between 2024 and 2040.

$10bn potential savings

by addressing the identified inefficiencies across countries analysed

Trucking is necessary today but brings inherent risk in the form of road traffic accidents, losses, congestion, environmental damage, and similar. For this reason, CITAC has analysed the potential for using pipelines as an alternative to trucking for bulk oil product transportation. The case studies include a review of the potential viability for pipeline infrastructure to be established or, where pre-existing pipelines are already in place, expanded.

Significantly, the rising demand strengthens the economic justification for pipeline construction as initial construction costs do not scale linearly with the increased capacity of the pipeline: the cost of building a 10" pipeline is less than 25% higher than an 8" pipeline as the costs to lay the pipeline are similar, while the cost of the materials required is also positively impacted by the economies of scale. The larger the volumes to be transported, the better the economic foundation for such a project. The findings of the case studies are summarised in the following tables.

This first table summarises the key constraints in each market and when they will become a pinch point in the supply chain, as well as the countries that are affected (the native market as well as any transit markets):

Supply Corridor	Constraint	When	Solutions	Countries affected
Durban	• Berth Capacity • Jet/Kero Tankage • Diesel Tankage	• Now • Now • Now	• Build products SBM (or convert crude SBM to products) • Debottleneck berth equipment • Build/acquire tankage	Botswana, eSwatini, Lesotho, South Africa, Zimbabwe
Richards Bay	• Berth capacity • LPG Tankage • Gasoil Tankage • Gasoline Tankage • Jet/Kero Tankage	• 2040 • Now • 2025 • 2030 • 2030	• Debottleneck berth equipment • Build extra tankage	Botswana, eSwatini, Lesotho, South Africa, Zimbabwe
Maputo	• Berth capacity • Jet/Kero Tankage • LPG Tankage • Evacuationt rates	• 2025 • Now • 2035 • Now	• Debottleneck berth equipment • Build tankage • Improve truck loading and clearing efficiency (extra bays, faster loading rates, streamline clearing, truck staging)	Botswana, eSwatini, Lesotho, Mozambique, Zimbabwe
Beira	• Berth capacity • Gasoline Tankage • Evacuation rates • NOICZIM pipeline	• Now • 2035 • Now • 2025	• New oil berth(s), Build product SBM, debottleneck berth equipment • Build tankage • Improve truck loading and clearing efficiency (extra bays, faster loading rates, streamline clearing, truck stagging) • Relace pipeline	DRC, Lesotho, Malawi, Mozambique, Zimbabwe, Zambia
Dar-es-Salaam	• Berth Capacity • Gasoline Tankage • Tazama pipeline	• 2030 • 2040 • 2025	• Debottleneck SBM, debottleneck berth equipment • Build/acquire tankage • Pipeline debottleneck (gets to 2030 demand) • Replace pipeline by 2030 • Spur line to Mbeya to supply Malawi	Zambia, Malawi

This second table summarises the potential for underground pipeline construction projects along the key supply corridors and their viability:

Corridor	Length/ diameter	Annual t'put* MML/yr (Avg 2030-2040)	Investment Estimate***	Investment as % of 2023 GDP of participating countries	Breakeven** $/m³	Current road cost, $/m³	Viable?
DBN-Gauteng******	555km / 24"	4500 (7900 max)	$1.6 bn	0.4% (RSA)	35	45-55	Included as a real-world case for comparison purposes. Currently operational with no expansion required. Current (avg) MPP fee is 37 $/m³
Beira-Harare	208km / 18"	4800	$260 mn	0.5% (Moz, Zim)	11-13	60-70	Yes. Current pipeline fee is 45 $/m³
Harare-Lusaka	760km / 14"	2000	$665 mn	1.1% (Zim, Zam)	70-80	65-80	Yes
Beira-Lusaka	1625km / 18"	2700	$1.9 bn	2.3% (Moz, Zam)	150-165	155-180	Yes
DES-Ndola	1750km / 20"	3800	$2.2 bn	1.9% (Tanz, Zam)	125-140	145-170	Yes. Current pipeline fee: 46$/m³
Tarlton-Gaborone	320km / 10"	1350	$200 mn	0.05% (RSA, Bots)	25-30	25-35	Yes
Matola-Gaborone	850km / 10"	1350	$530 mn	0.1% (Moz, RSA, Bots)	85-95	65-80	Possibly - may require a subsidy
Nacala-Lusaka-Lubumbashi	2475km / 18"	2800****	$2.2 bn	1.3% (Moz, Mal, Zim, Zam, DRC	165-185	155-215	Yes
WB-Gaborone	1480km / 14"	2500*****	$1.3 bn	3.8% (Nam, Bots)	110-125	105-125	Yes

** Corridor gasoline & gasoil volumes only, ** 15-year payback, 20% cost of capital, *** 62,500 $/km/inch*
***** Assumes all Beira in transit vols switch to Nacala, ***** Assumes all Bots & Beira to Zambia vols switch to WB*
******* DBN-Gauteng multiproduct pipeline, actual cost (123,000 $/km/inch)*
If the DES-Ndola pipeline is replaced, offtake spurs could enable Malawi vols to shift to this corridor

SECTION

2 Introduction

2. Introduction

2.1 Aims and objectives

This paper aims to highlight the challenges in fuel supply in Sub-Saharan Africa and identify opportunities to improve and drive efficiency in these supply chains.

The challenge of meeting the need for energy

Africa is experiencing significant energy demand growth, driven by population expansion and economic development. Globally, the energy transition is underway with low, or zero carbon objectives adopted by many companies, governments and supra-national organisations. In certain pockets across Africa, the transition away from traditional carbon-intensive energy sources can be seen in the domestic and commercial sectors in the form of rising electrification, the use of solar, wind, hydro, and geothermal power generation, with hydropower the main source of energy among these alternatives. In addition, efforts to adopt cleaner-burning fuels, such as the uptake of LPG to displace biomass in cooking, biofuels, and natural gas, have also made good progress. However, the pace of the rollout of renewable electricity generation and electrification in Africa is insufficient to meet the growing energy demand today. Electricity grid coverage, capacity, and reliability mean the rollout of renewable electricity is slow. Tight capital availability is another key barrier to accelerating electrification growth rates.

In the transportation sector, the outlook for low-carbon energy solutions remains challenging. Limited personal finances mean that many of the cars purchased are sourced second-hand from the international market and imported, with the vast majority of these being internal combustion engine (ICE) vehicles. Some very small-scale electric vehicle take up has been seen in certain locations but the aforementioned electricity generation challenges along with limited charging infrastructure make ICE vehicles the practical and affordable option for the vast majority of citizens today. With time and innovation, low-carbon solutions will be rolled out across the transportation sector, but they cannot be scaled up to replace ICE vehicles in the near term. Indeed, with the exception of hydro and solar power, many clean energy alternatives have different levels of technology and commercial readiness, and deployment levels. Further challenges include price hurdles as well as insufficient regulatory support in many Sub-Saharan African countries.

Over a longer horizon, the expansion of renewable electricity coverage, the introduction of electric vehicles, and similar developments seen in the energy transition across developed countries will be implemented across Africa. But there is a growing need for energy that has to be met today. As a result, many African countries are looking to simultaneously build out their renewable and conventional energy supply to achieve their socio-economic growth ambitions.

This means there is a need to scale up the efficient supply of fuels such as gasoline, diesel, and jet fuel to meet energy demand with the technology available in country. Improving supply chain efficiency through the removal of bottlenecks and cost-saving practices will directly contribute to lowering the price of energy for African consumers. Such efforts are much needed given the inflationary pressures seen recently stemming from global supply chain disruptions, the Russian-Ukrainian war, subsidy repeal in some markets, and rising global tensions, especially in the Middle East. For this reason, it is imperative that the supply and distribution of fuels is carried out in the most efficient manner possible and that costly bottlenecks are eliminated.

Driving efficiency and improving supply security

Efforts have not been able to keep pace with rapidly growing populations, and urbanisation trends. This has resulted in fragmented supply routes, bottlenecks, and insufficient infrastructure capacities that contribute to an overreliance on trucks, congestion in cities and ports, and disrupted access to energy – collectively resulting in increased costs for governments and citizens.

From a mid and downstream supply perspective, much of the associated infrastructure is ageing and suffers from a lack of investment, outdated policy frameworks, and insufficiencies in regional, national, and urban energy planning – especially when compared to other regions across the world. Furthermore, efforts have not been able to keep pace with rapidly growing populations and urbanisation trends. This has resulted in fragmented supply routes, bottlenecks, and insufficient infrastructure capacities that contribute to an overreliance on trucks, congestion in cities and ports, and disrupted access to energy – collectively resulting in increased costs for governments, businesses and citizens. This is impairing the region's socio-economic development potential. While, historically, international funding and aid has helped to support and develop supply chains, national budgets are under pressure from higher interest rates, inflationary pressures, the fallout from conflicts, and the global pandemic. Therefore, it is important that infrastructure projects are economically defensible or, where they are not, policies are developed to support projects that will bring direct benefit to society.

Further, the cost of borrowing and the depreciation of African currencies in many countries makes investment a challenge. For this reason, CITAC has identified elements of the supply chain that can be improved through the application of best practice and sound investment. This includes streamlining border controls and customs procedures, accelerating truck loading and evacuation policies, and similar debottlenecking efforts. These measures have the additional advantage of reducing the number of trucks required to serve demand, bringing with them an environmental dividend as emissions related to energy distribution are cut, road congestion is eased, and the number of road traffic accidents could also be lowered.

Importantly parts of the supply chain infrastructure used in traditional fuels, if planned correctly, can be adapted to transitional fuels and lower carbon energy including sustainable aviation fuels, LPG, and green hydrogen – and also benefit wider trade infrastructure (ports, railways etc.). This complements, not displaces, the decarbonisation of the power sector through resources such as wind, solar, and hydro.

Within this context, this paper seeks to:

- Demonstrate the immediate and growing need for energy to support economic activity and improve citizens' quality of life.
- Indicate the challenges surrounding fuel supply across the continent, an area that remains underexamined and underdeveloped.
- Highlight the challenges in the current fuel supply and identify specific opportunities to drive efficiency and improvements, through the use of country case studies.
- Identify opportunities for increased collaboration across the African energy sector to enhance country and regional planning, optimisation, investment, and coordination between traditional fuels and lower carbon pathway efforts.

2.2 Africa's energy challenge

Sub-Saharan Africa remains the most economically underdeveloped region in the world. According to the IMF's latest data*, SSA's per-capita GDP (on a purchasing power parity basis) was an estimated $4,828 in 2023, compared with an estimated $67,971 in the G7 group of countries. Economic development can lead to greater revenue generation for governments to provide key services for citizens; it can lead to the creation of employment; it can lead to an improvement in quality of life.

Energy sits at the core of economic growth. Whether directly consumed in industry or supporting the movement and livelihoods of citizens, energy is the lifeblood of the economy. Energy shortages directly impact people's lives and economic development.

$4,828 vs $67,971

per capita income of SSA | **per capita income of G7 countries**

Latest IMF data release in April 2024.

Africa has long relied on liquid fuels to support economic development. They provide a readily available, decentralised source of energy that can be transported from producer to consumer through robust and adaptable supply chains. Traditionally, the decentralised nature of liquid fuel supply chains in Africa has lent itself well to private investment. The decentralised nature of these supply chains encourages competition, diversification, and scalability. By contrast, grid-based energy solutions such as railways and pipelines can be a bottleneck if run inefficiently as is often the case with state-owned infrastructure: it is essential that such infrastructure is run efficiently and competitively in order to take advantage of the inherent economic benefits.

Despite efforts to develop grid-based and/or clean energy distribution systems in Sub-Saharan Africa, they have not yet scaled to meet demand. Unreliable power generation and/or distribution has been disruptive to economic activity even in major African economies such as South Africa and Nigeria.

Economic and CPP Demand Growth Correlation

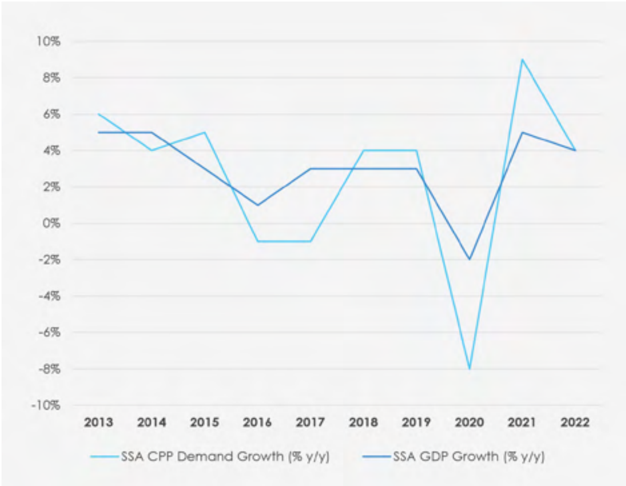


Figure 5: Economic & Clean Petroleum Product demand growth correlation.
Source: CITAC Africa, IMF WEO April 2023.

The African continent has a rapidly growing population. According to UN estimates, a new African was born every second in 2023 while in Europe the rate is one birth every 4.6 seconds.

This growth rate has made Africa's population greater than that of China in 2023 and, with no fall in birth rates forecast, the UN estimates the continent will be home to over 2bn inhabitants by 2040. This is a fundamental driver of energy demand as each member of society will have energy requirements to support their livelihoods.

Further, economic dynamics have led to a growing trend of urbanisation in Africa. According to the UNPD, the number of cities with over 10mn inhabitants is set to rise to six by 2035, from just three two decades previously. Meanwhile, a large number of other cities are expected to grow rapidly. The trend of urbanisation is driven primarily by strong fertility rates in Africa but limited economic opportunities outside of major cities, which means that rural populations are increasingly converging on cities in search of employment, driving up urban populations.

Population Growth

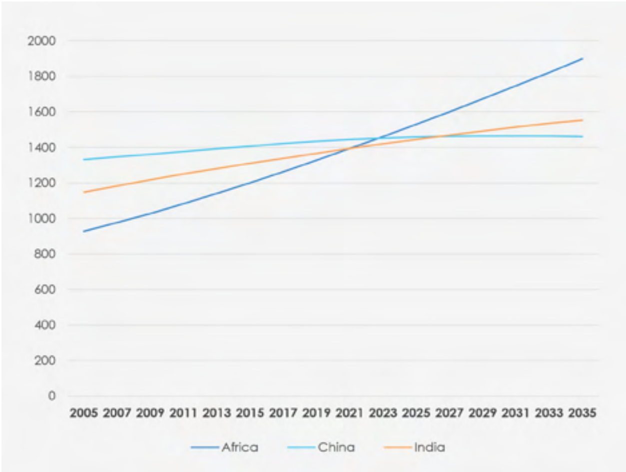


Figure 6: Population Growth Africa, China, & India. Source: UN Population database.

The urbanisation trend is depicted below. One of the things of note in this graphic is that the majority of rapidly growing cities and megacities are on the coast, typically in locations where the country's major port sits, such as Lagos, Luanda, or Dar es Salaam. The rapid growth of the population will add to the congestion already seen on the streets of these cities, posing a mounting challenge for companies seeking to import and evacuate oil products efficiently. Traffic jams, pollution, and accidents are commonplace while the cost of poor productivity to all members of society is punitive. Businesspeople can take hours to cross the city from meeting to meeting, while a greater number of trucks is needed in the fleet due to the amount of time they spend making each journey.

African Cities by Population

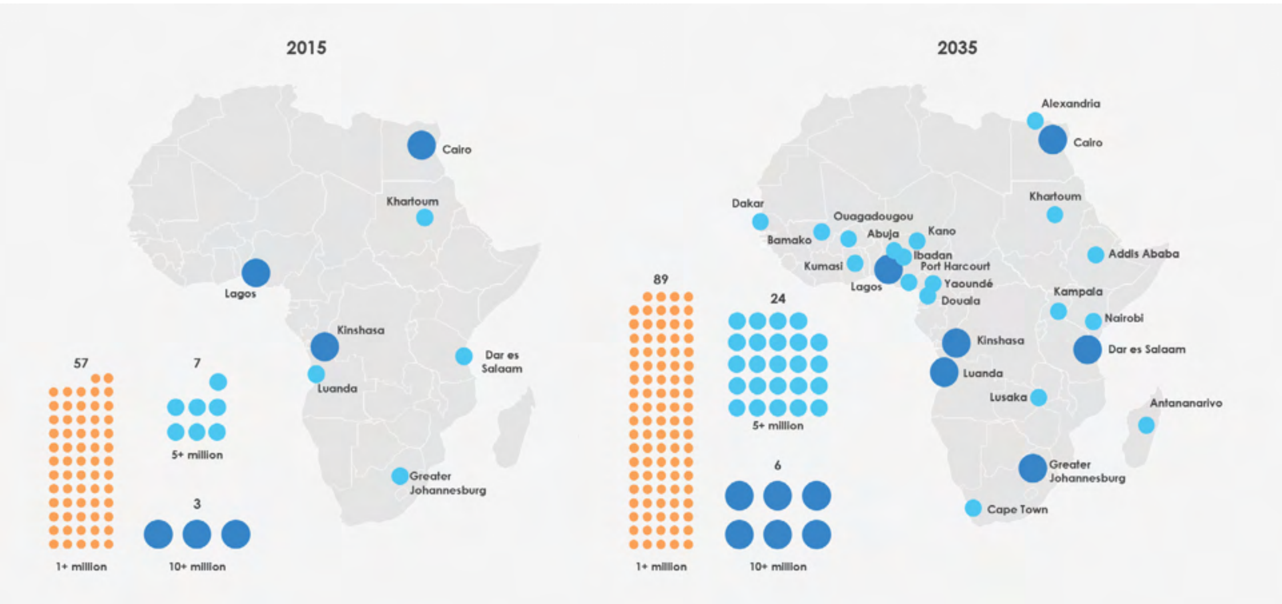


Figure 7: African urbanisation. Source: World Population Prospects 2019, UN Department of Economic and Social Affairs.

The challenge going forwards will be to ensure that future members of Africa's society are not subject to energy poverty but, rather, prosper. With liquid fuels continuing to play a central role in Sub-Saharan Africa's energy mix, it will be essential to ensure that SSA's energy demand is met reliably and economically.

2.3 Scaling up complex supply chains

African liquid fuels supply chains today are complex and fragmented, leading to inefficiencies and driving costs higher for governments and the end consumer. Further to this, these supply chains lead to negative externalities such as urban congestion, road traffic injuries and air pollution.

Sub-Saharan Africa is urbanising rapidly. African urban planners are struggling to keep pace with the rate of growth of their cities. This leads to inefficient road systems and large, sprawling neighbourhoods. The rapidly growing urban population leads to increasing congestion on road networks – typically the primary method for transporting people and goods – among other challenges. The issue of congestion is made worse by the fact that most major cities in coastal African countries are also major working ports which support the import and export of goods, placing greater strain on logistics networks.

Given these trends, it is essential to start thinking of solutions to the problems associated with increasing congestion: higher rates of traffic accidents, productivity losses, higher pollution and disruption to the supply of goods. Where possible, rail, pipelines, and larger ports can present efficient solutions to the continent's growing logistical problems.

SECTION

3 Sub-Saharan Africa supply and demand

3. Sub-Saharan Africa (SSA) supply and demand

3.1 Historical SSA supply and demand (2013-2022)

In 2022, Sub-Saharan African demand for clean products (oil products that are used by everyday consumers, namely gasoline, diesel, Jet A1 and kerosene), totalled 91.3mn mt, up 3.7% y/y. This follows a 9.2% y/y increase in 2021 as the market recovered from the effects of the COVID-19 pandemic and demand fundamentals continued to drive rising oil product consumption.

Gasoline demand rose to a fresh peak in 2022 at 41.0mn mt, an increase of 11mn mt since 2013. Gasoline demand growth has been underpinned by rising consumption in the passenger transportation sector, as a greater number of citizens travel greater distances for work – and as congestion in urban centres intensifies. SSA has added close to 1,000 service stations per year for the past five years, reflecting the rate of demand growth and infrastructure required to support it.

Sub-Saharan Africa Demand (000mt)

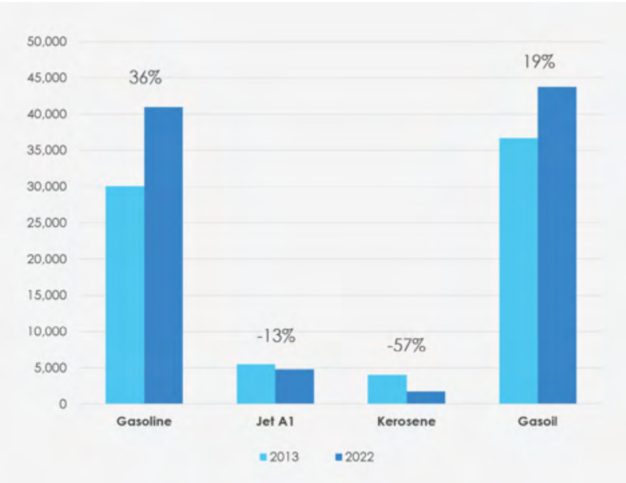


Figure 8: Sub-Saharan Africa Demand.

Gasoil demand rose 1% y/y to 43.7mn mt in 2022, up 7mn mt since 2013. Demand for gasoil is largely driven by demand from primary industry and bulk transportation, with power generation representing another demand sector. Demand for gasoil typically swings with the value of raw commodities, with higher prices driving higher levels of activity in the extractives sector.

The pandemic led to a sharp collapse in Jet A1 demand, which fell 46% y/y in 2020, but as international air travel recovers Jet A1 consumption is rising, up 22% y/y in 2021 and 16% in 2022. At 4.8mn mt in 2022, demand for the product remains well below pre-pandemic levels of 6.3mn mt.

Kerosene is typically consumed in residential applications, for cooking and lighting. Demand for the product stood at 1.8mn mt in 2022, sharply down from levels of 4mn mt in 2013 as government subsidies have been repealed and the supply of LPG, a cheaper and cleaner-burning fuel, scaled up.

SSA demand is met by combination of refinery output and product imports. The challenge historically has been relatively limited refinery capacity, under-maintenance, a lack of modernisation, and underutilisation of these assets. Recently, a series of refinery closures or outages in South Africa, Sudan, Ghana, Nigeria, and Cameroon have impacted supply chains. Further, the output of the refineries is poorly matched to local demand: limited upgrading capacity has resulted in high yields of fuel and naphtha, relative to world-class counterparts, while tightening sulphur specifications have proven a difficult challenge to overcome. Given that demand is overwhelmingly skewed towards clean products, much of the fuel oil is exported from the region for processing elsewhere or used in industries such as shipping. The SSA refining industry has seen a fall of 47% in its CPP output between 2013 and 2022, falling from 32mn mt to 17mn mt.

Sub-Saharan Africa Clean Product Demand

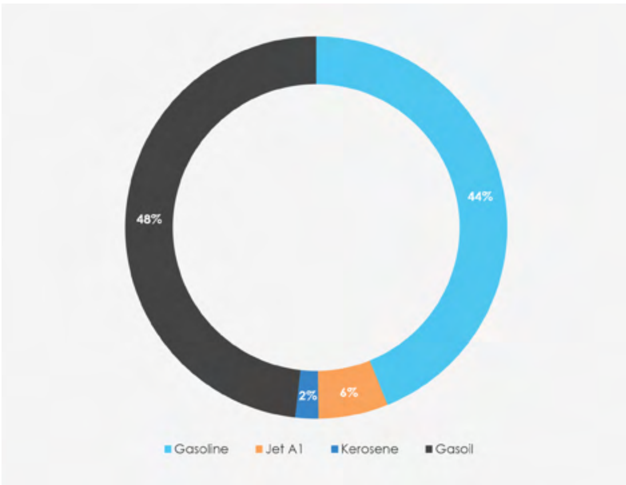


Figure 9: Sub-Saharan Africa Clean Product Demand.
Source: CITAC ADD+.

Sub-Saharan Africa CPP Ref Output

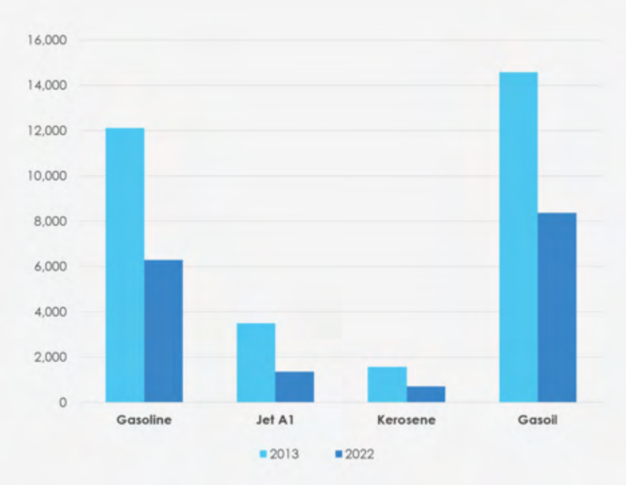


Figure 10: Sub-Saharan Africa Forecast Ref. Output.

Sub-Saharan Africa Balance (000mt)

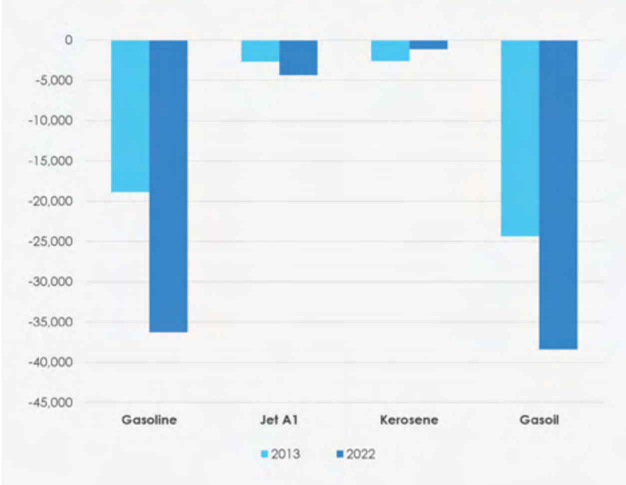


Figure 11: Sub-Saharan Africa Forecast Balance.

A growing burden has been placed on import infrastructure to facilitate the rising import volumes required to meet oil product demand in SSA. The CPP shortfall between local production and demand has surged 65% between 2013 and 2022 to reach 80mn mt.

3.2 Supply and demand outlook

CITAC forecasts, incorporating data from UN population projections, IMF economic forecasts, and IEA sectoral demand profiles, project demand growth for clean products is to remain strong, rising by 49.7mn mt, or 56%, between 2023-2040.

Continued economic development, population growth, and urbanisation trends underpin the growing need for clean products over the forecast period. These factors will drive a 50% increase in gasoline demand between 2023 and 2040 as passenger kilometres increase, driven by strong population growth, urbanisation, and urban sprawl.

Gasoil demand is forecast to see the strongest outright growth in demand, rising 59%, or 27mn mt, by 2040 to 72mn mt. The continued development of primary industry, power generation applications, and transport-sector demand will drive gasoil consumption rates across SSA.

Jet A1 demand is only forecast to return to pre-pandemic levels in 2024, at 6.7mn mt before rising to 8.1mn mt in 2030 and 10.3mn mt in 2040. Passenger transportation demand is the main driver for Jet A1 consumption growth over the forecast period as economies become increasingly interlinked, and a growing number of passengers supports expansion of capacity in the aviation sector.

56% growth in fuel demand in Sub-Saharan Africa expected by 2040

Sub-Saharan Africa Demand (000mt)

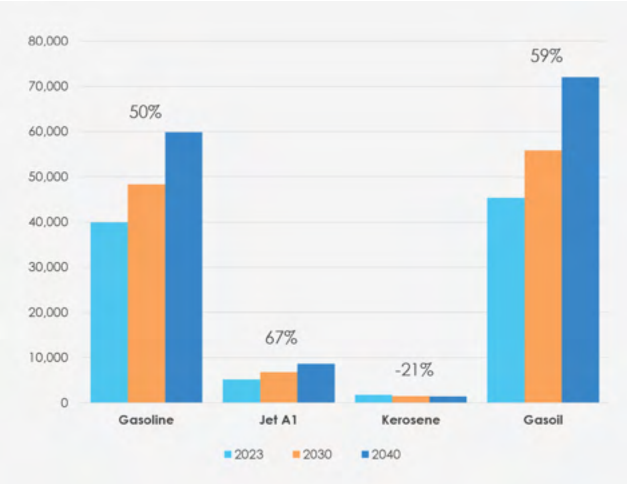


Figure 12: Sub-Saharan Africa Forecast Demand.

Sub-Saharan Africa Ref. Output (000mt)

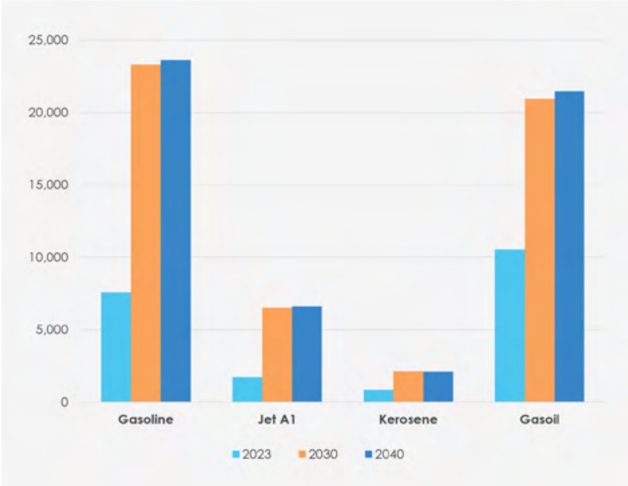


Figure 13: Sub-Saharan Africa Forecast Ref. Output.

Demand for kerosene continues to trend downwards over the forecast period, from 19mn mt in 2023 to 1.5mn mt in 2040, as alternative forms of domestic energy, such as electricity and LPG, meet demand going forwards.
SSA's domestic production capacity is undergoing a major change thanks to new projects such as the Dangote refinery coming onstream. This promises to curb the growing shortfall. Refinery output of clean products is forecast to recover to 53mn mt in 2030, from the 17mn mt produced in 2022. Further increases in domestic refining capacity are possible, but due to them being in early stages of development they are not included in CITAC's forecasts.

The SSA CPP shortfall is set to narrow over the medium term, falling to 67mn mt in 2030 from 80mn mt in 2022, but widen from that point to 98mn mt by 2040. From a logistical standpoint, it is worth noting that with refineries of the scale of Dangote, seaborne product exports from Nigeria will be necessary. Assuming that these exports are then to be supplied into West and Central Markets, these markets will still require significant investment in import infrastructure to handle the volumes delivered by vessel.

Sub-Saharan Africa Balance (000mt)

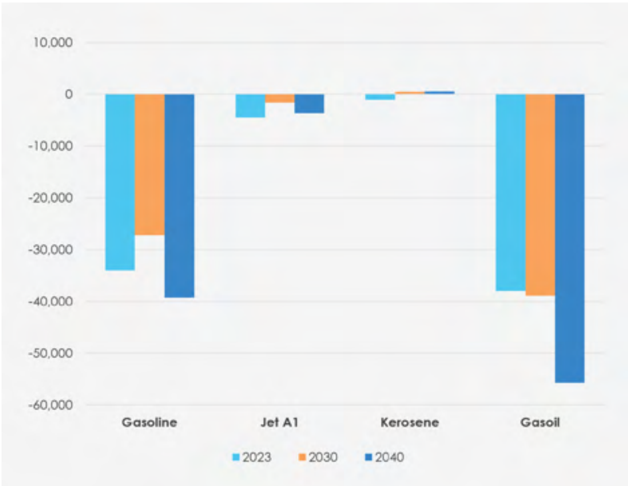


Figure 14: Sub-Saharan Africa Forecast Balance.

3.3 Outlook for Africa's energy mix

Hydrocarbons form a key part of Africa's energy mix with other forms of energy, namely biomass and natural gas, also playing key roles as set out in this section.

The chart to the right shows the primary energy mix for the countries in Africa, as presented in the IEA's 2019 Africa Energy Outlook. The IEA's projections show oil is set to continue to remain a key source of energy on the continent through to 2040, with the quantity of oil consumed projected to rise 41%. Rapid uptake in renewables and continued expansion of natural gas use on the continent will help meet incremental demand, resulting in the current growing share of oil in the energy mix levelling off at 25% by the middle of next decade.

Hydrocarbons play an essential role in meeting Sub-Saharan Africa's energy needs today and are expected to continue to do so over the coming decades. While private companies have begun offering smaller-scale renewable power generation solutions to homes, coupled with finance packages, these have mainly displaced biomass for domestic and small-scale commercial applications. The much-needed large-scale power generation capacity and distribution grids required to support electrification of industrial and transportation sectors have proven difficult to maintain, operate, and expand. To accelerate the energy transition, governments and private investors need to work hand-in-hand on a regional approach to ensure that the security environment is supportive of the sustainable operation of distribution grids and that electricity generation is managed in an accountable, competitive, and reliable fashion. Securing reliable electricity provision at competitive prices will support the rollout of renewable electricity generation as well as increase the prevalence of electric vehicles, electric stoves, lighting, heating, and similar applications. This is a goal that will take time to achieve as it requires the development of effective policy, improvement of security and attraction of investors along with many other challenges. This is the objective for the longer term – but action needs to be taken today to put in place a plan that will realise this goal.

African Primary Energy Mix Forecast (Mtoe)

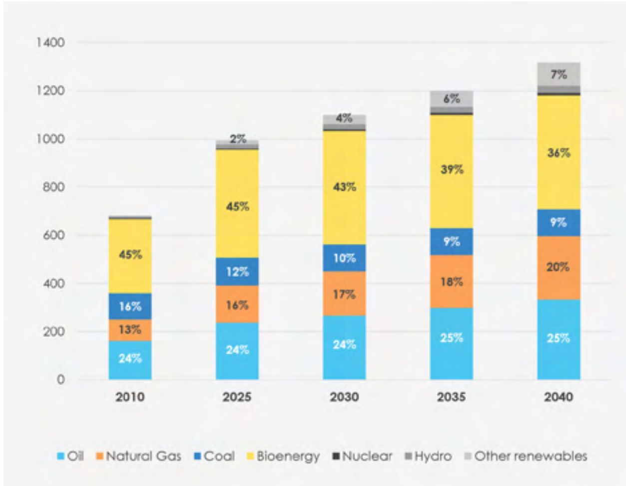


Figure 15: African Primary Energy Mix forecast.
Source: IEA AEO 2019, Stated Policies.

Illustrating the scale of the challenge, the IEA indicates SSA's road transportation sector's energy mix is today 99% oil products, and this is forecast to fall by just four percentage points by 2030 as biofuel blending is ramped up. The agency meanwhile cites the lack of large-scale energy production and distribution infrastructure as key barriers to the penetration of electric vehicles, limiting uptake to two/three wheelers and some buses. Africa's adoption of electric vehicles and technologies capable of consuming clean energy will run on a longer timeline than that seen in the developed world.

While the IEA anticipates a sharp increase in renewable energy uptake in SSA, this will largely displace biomass in residential applications. SSA oil product consumption is forecast to continue to rise as a key energy source for transportation and industrial applications.

3.4 GHG emissions in Sub-Saharan Africa

Africa's GHG emissions are a fraction of those produced in developed regions. Sub-Saharan Africa accounted for just 676mn mt CO_2e in 2020, just 2.13% of worldwide emissions, despite being home to 15% of the world's population. Africa continues to pursue a path of economic development – essential to ensuring the needs of its society and population can be met. Economic development on the continent has typically moved in tandem with energy demand, with this correlation illustrated in the graph below.

2.13%

The amount of worldwide emissions Sub-Saharan Africa accounts for

CPP Demand Growth vs GDP Growth

Figure 16: Clean petroleum product demand growth vs GDP growth. Source: CITAC, IMF.

The breakdown of GHG emissions by source and by African country is shown in the chart on the following page. South Africa produced 388mn mt (34%) in 2022 followed by Egypt at 188mn mt (17%), Algeria at 134mn mt (12%) and Nigeria at 88mn mt (8%). In Sub-Saharan Africa, 57% of 2020 GHG emissions came from South Africa and 13% from Nigeria, with Ghana, Kenya, Angola and Ethiopia generating a combined 9.5%. Together these six countries generate 80% of the SSA GHG emissions. Of the 20% GHG emissions emitted from the remaining 41 countries in SSA, 45% comes from road transport and 28% from electricity and heat generation.

Africa GHG Emissions by Source (2020) - mn mt CO_2e

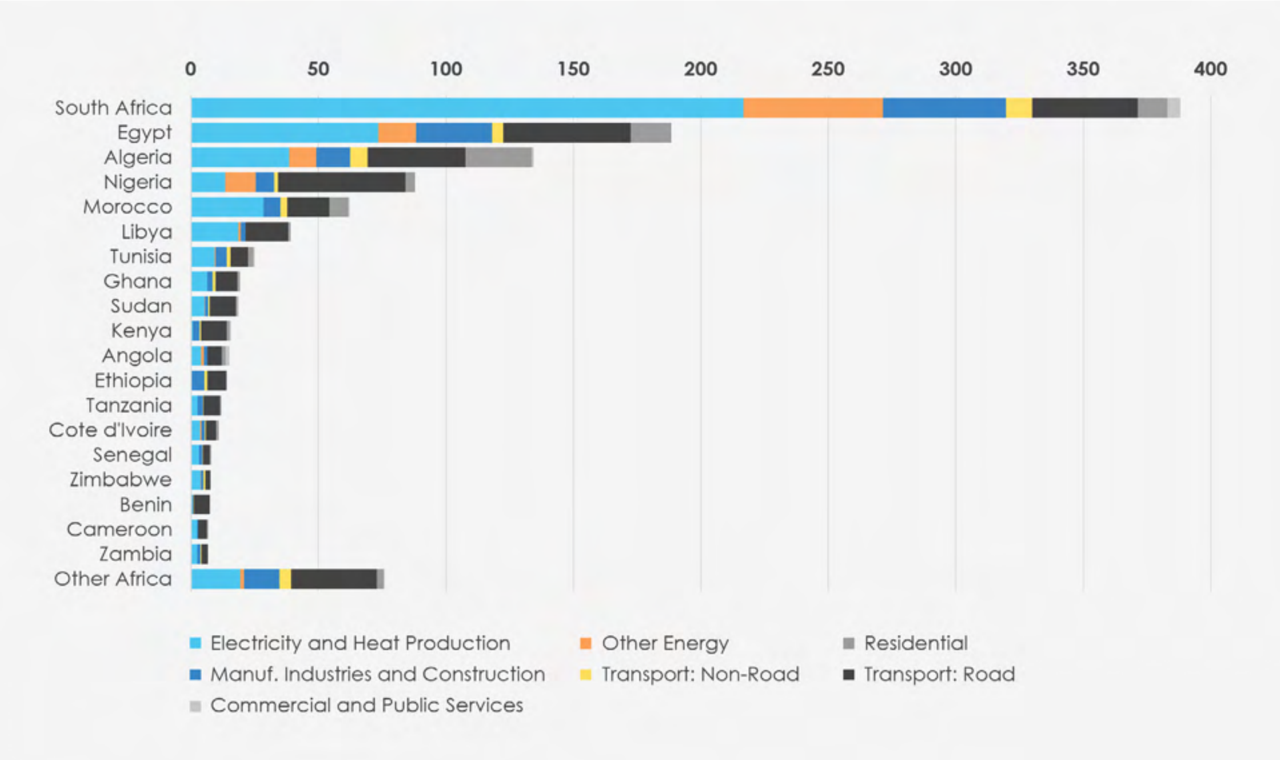
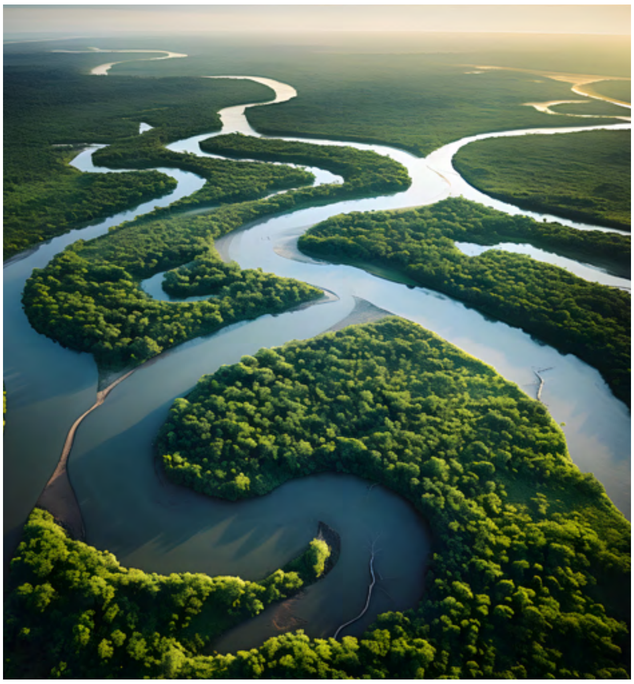


Figure 17: Sub-Saharan Africa GHG Emissions by source. Source: IEA.

The GHG footprint of most African countries is miniscule in global terms. This reality underpins arguments for Africa's energy transition to be a just transition. Africa must play a role in preventing global warming targets. It possesses significant resources to contribute to the global fight against climate change, from abundant green hydrogen generation capacity to vast rainforest coverage, a key carbon sink. Africa, however, cannot pursue the aggressive path of decarbonisation championed in the developed world due to its current lack of scalable zero or low-carbon alternatives. Rapid decarbonisation of Africa's energy mix would have significant economic and social consequences due to the lack of readily available alternatives to fossil fuels. It is expected, therefore, that Africa will need to focus on reducing the environmental impact of the fossil fuels on which it relies as its demand for these energy sources continues to rise.

In pursuit of reducing the environmental impact of the energy industry in Africa, steps can be made to reduce the GHG emissions associated with everyday economic activity. In the case studies included in this paper, for example, efficiencies in truck loading and evacuation can lead to a 25% reduction in the number of trucks needed to support oil product distribution. Equally, investment in rail and pipelines brings opportunities to cut GHG emissions by displacing trucks. These are considerations worth taking into account when evaluating investment in supply chains and infrastructure planning.

Africa, however, cannot pursue the aggressive path of decarbonisation championed in the developed world due to its current lack of scalable zero or low-carbon alternatives.



SECTION

4 Sub-Saharan Africa (SSA) supply chain analyses

4. Sub-Saharan Africa (SSA) supply chain analyses

4.1 Supply chains in Sub-Saharan Africa

Supply chains in Sub-Saharan Africa are characterised by limited diversification and scale across ports and infrastructure. Oil refining capacity in the region is present but it falls far short of meeting domestic needs. In 2023, the net clean product shortfall was 77.5mn mt, placing pressure on import infrastructure to support demand through supply from the international market.

77.5mn mt

net clean product shortfall in 2023

Supply chains play a crucial role in underpinning economic activity: transportation, aviation, industry, power generation, cooking and more are all areas that suffer major disruption in the event of supply chain failure. The impact of such outages on the economy and livelihoods is tangible. It is therefore crucial to understand the current infrastructure serving the population and the challenges faced by facilities today and over the coming years as demand continues to grow.

Refineries

Sub-Saharan Africa has 25 refineries with a total capacity of 1.34mn b/d (67mn mt/y). Many of these facilities are old, lack modern technology, and suffer frequent disruptions to operations.

This contributes to a mismatch between refinery output and local demand, producing excess naphtha and fuel oil which must be exported. Meanwhile financial and technical challenges mean utilisation is typically low - just 30% in 2022. Going forward, new refining capacity, namely the Dangote refinery (Nigeria) and the Sentuo refinery (Ghana) which both conducted tests in Q1 2024, along with the Cabinda refinery project (Angola) which is due onstream later in 2024, are all expected to play a growing role in meeting domestic energy requirements. It is worth noting, however, that these are concentrated in West and Central Africa, with no new capacity expected across the rest of the sub-continent.

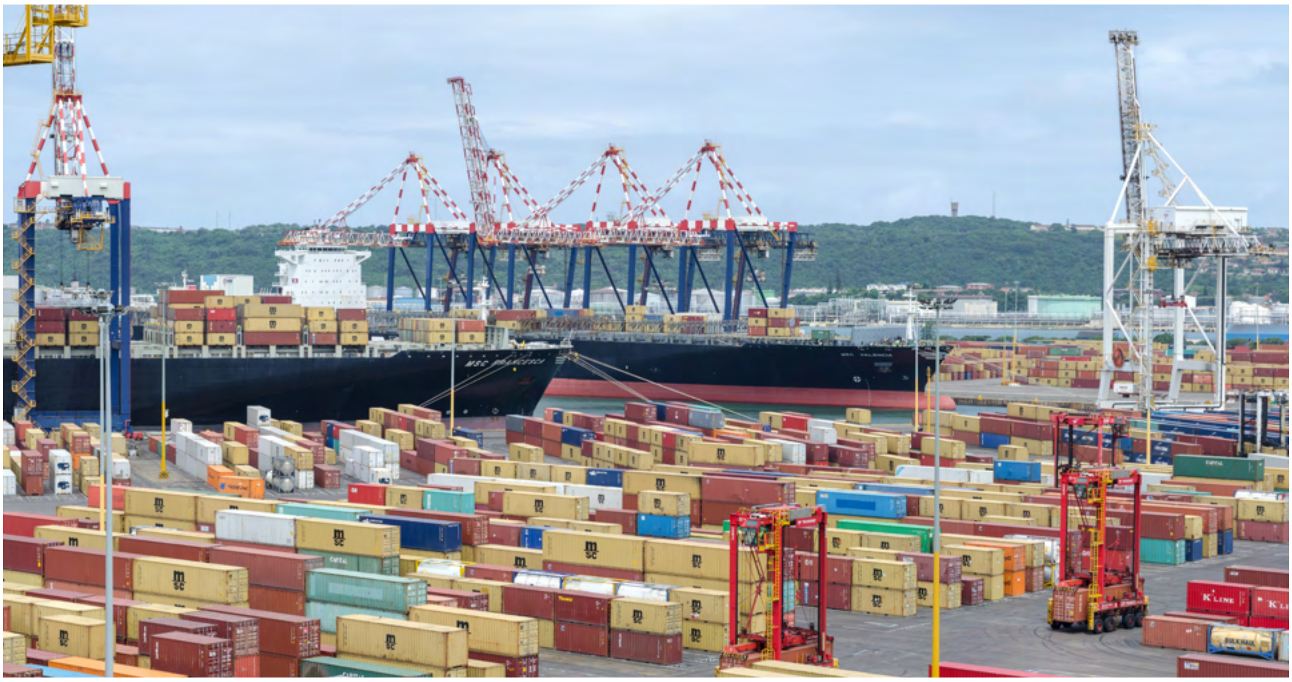
Even with this additional capacity, SSA will continue to rely on imports of products to support demand growth. While today the net clean product shortfall is 77.5mn mt, this will widen to 98mn mt by 2040, placing a greater strain on ports, storage, and transportation infrastructure.

Ports

Ports in Africa vary in capacity and efficiency, but many are inefficient and constrained. Of 170 berths in Africa, 59% have draft restrictions of <10m - required to receive 35,000dwt vessels, typically the minimum size for international trade. Shallow drafts restrict importers to supply by barge and small tankers. This limits economies of scale, constrains import rates, and often requires ship-to-ship (STS) transfers to receive products from the international market – adding $20-30/mt to the landed price of the cargo.

$20-30/mt

added to the landed price of cargo



Historically, port cities were hubs of economic activity. This led to the rapid growth of these cities and rising congestion. As a result, many ports face challenges in evacuating delivered goods. Developing new ports would help to debottleneck the supply processes into markets across the subregion. Congestion is set to rise. In 2022, clean product imports equated to 2,398 35,000dwt vessels; this will rise 14% to 2,724 by 2040. Meanwhile, ports face increasing traffic for the import and export of other goods and raw materials, leading to further congestion. Further port capacity is essential to support the continued expansion of economies and improve the efficiency of import/export operations.

Storage facilities

Product imports are discharged into coastal tanks and typically loaded into road tankers for onward transport to service stations, B2B customers, secondary depots, or primary receiving terminals in hinterland countries. Coastal tanks also handle much of the output from local refineries without truck loading racks.

$1.4bn

investment required in the expansion of primary storage capacity by 2040

One of the key challenges faced by the sub region is that storage facilities are limited in size, curbing efficiencies of scale, hampering the discharge of large cargoes, and limiting the scope for maintaining security stocks. SSA has 317 coastal storage facilities with clean product capacity, of which just 18 could be classed as 'World Scale' (i.e. capacity >150,000m3). At the time of writing, a further seven coastal terminals are actively under construction, of which two will have a capacity greater than 150,000m³. World Scale storage facilities offer improved economies of scale over atomised, small storage facilities, and lead to more efficient product handling operations. By contrast, many terminals have limited capacities, restricting the size of cargoes able to be received, while the small tank sizes at these smaller terminals (the average tank size in SSA is a tiny 6,990m3) lead to higher construction costs per m3 and lead to inefficient use of capital and land.

Max. Port Draft

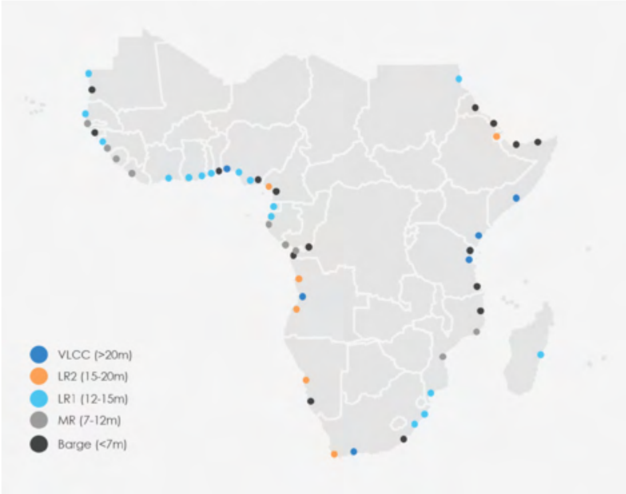


Figure 18: Max. Port Draft.

Transportation

Due to the limited coverage of railways and pipelines, along with restricted economics for large scale infrastructure solutions, trucking forms the backbone of oil product distribution in Sub-Saharan Africa. 83% of Sub-Saharan Africa's oil product's primary transportation, that is volumes evacuated from import terminals and refineries, is by road truck. In the developed world, pipelines and rail are much more prevalent in primary transportation, linking import terminals with inland storage facilities and distribution hubs, thereby debottlenecking ports while achieving economies of scale. Worldwide, trucks are mostly used for last-mile deliveries from secondary storage terminals, or directly from the source - whether that be domestic refineries or imports.

83%

of Sub-Saharan Africa's oil products is transported by road trucks

Rail is used in just seven Sub-Saharan African countries for primary evacuation, but it is typically slower than road transportation, with schedules limited by locomotive and rail car availability, and maintenance issues of both equipment and rail. Rail transportation offers benefits in terms of economy, decongestion of roads, and lower emissions, and is therefore typically a valuable and desirable form of infrastructure to have operating. In many countries, private companies report rail is operated by inefficient monopolies, with marketers finding it more reliable to transport products by truck. Further, losses reported from rail transportation are typically higher than from road transportation.

Rail has significant potential to debottleneck supply chains, lower emissions, and achieve economies of scale while presenting a diversified transportation platform. Rail can carry a broad variety of loads, helping to decongest the typical alternative, road. If the aforementioned challenges can be overcome, rail presents an attractive option for African countries. Governments could seek to drive uptake of rail by improving the underlying economics: ensuring efficient management of networks, privatisation, and investment in locomotives and rolling stock. In countries where governments have mandated a proportion of oil products be moved by rail, marketers report high rates of losses, theft, and delays – which led to costs that must be borne by the consumer or subsidies from the government which can be challenging to justify.

There are nine oil product pipeline networks in SSA spanning a collective 13,000km, although not all are in service. The challenge associated with pipelines in Africa has typically been under-maintenance, leading to leaks while poor security along the length of pipelines results in theft, contributing to costs borne by the consumer or government. Pipelines are challenging to monitor and present a very attractive target for thieves who can syphon products from a pipeline in remote regions with little risk of being apprehended. Pipelines do present an attractive option for debottlenecking ports, cities, and roads – but their high initial cost, coupled with the aforementioned risks, has resulted in limited uptake. Solving environmental and security concerns, and strong regulation is necessary to avoid excessive exploitation of infrastructure monopolies.

Clean Product Pipeline Lengths (km)

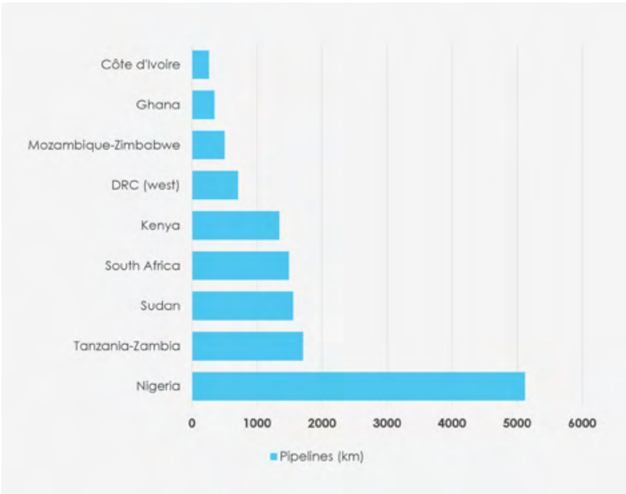


Figure 19: SSA Pipelines. Source: CITAC.

4.2 Aviation: Jet A1 supply chains

For Jet A1 supply, product quality assurance is essential. Jet A1 is recertified at every stage in the supply chain: loading into vessel, discharging into storage, loading into road trucks, discharging into secondary storage, and on down the supply chain. The complexity of supply chains in Africa and, in some cases, the lack of dedicated infrastructure for the Jet A1 supply chain, increases the risk of quality degradation, supply disruptions and the cost of supply. Fundamentally, the fewer recertifications required, the more competitive the price and the lower the chance of contamination. This can be achieved variously by facilitating mother vessels to proceed directly to berth, without the need for lightering; having tank farms large enough to segregate Jet A1 deliveries, reducing the risk of contamination; avoiding the use of secondary storage and instead transporting directly from the source (import terminal/refinery) to the airport.

Jet A1 shortages cause significant costs and delays for airlines, passengers, and businesses, and take a direct toll on the economy.

As an example, land-linked Ethiopia is supplied via a lengthy supply chain. Jet A1 is delivered into Djibouti, where it is loaded into trucks and transported over 800km by road to Bole Addis Ababa International Airport – the main demand centre. The country remains at risk of disruptions to supply due to its reliance on this single supply chain; there are no pipelines or rail alternatives that could support the market. The impact of any supply chain disruptions threatens to ripple well beyond Ethiopia's economy, as the country's main airport is a key international hub and the base of Ethiopian Airlines – a major international airline linking a host of African countries with destinations around the globe. To highlight an alternative, more secure supply chain, the OR Tambo airport in Johannesburg is supplied by pipeline from two refineries but there are also options to supply by truck and rail; a well-diversified supply chain that is resilient to disruptions as a result.

The lack of dedicated infrastructure for the Jet A1 supply chain, increases both the risk of supply disruptions and the cost of supply.

4.3 Supply chain challenges

The key objective of supply chains is to ensure adequate, safe and secure provision of energy to the consumer at the most economic price. The key features needed to achieve these goals are:

- Conducive regulations
- Market-based pricing of fuel products
- Adequate infrastructure
- Robust HSEQ processes and culture

Examples of how these features are important are explained in detail below.

Regulatory barriers

- Product specifications are not harmonised across the sub-continent, with such coordination limited to key regions such as the East Africa Community. This leads to inefficiencies and increased costs for consumers as different product specifications prevent the use of shared infrastructure due to the risk of contamination of one product to another which limits economies of scale.
- There are 11 different levels of permissible sulphur content in gasoil, ranging from 10ppm (0.001%) to 10,000ppm (1.0%) across the 50 AU member states with official specifications.
- For gasoline, there are 12 different permissible levels of sulphur content from 10ppm (0.001%) to 2,500ppm (0.25%).
- Differences in pricing regulation can result in disparities in prices in neighbouring countries. This can drive smuggling and result in stockouts in markets where the product is cheaper. Harmonising pricing policies, particularly pricing dates and quotes will help to minimise such imbalances.
- Inefficient border crossings and regulation further increase prices for the end consumer. These vary from lengthy customs clearances and import duties.
- In certain markets, the allocation of volumes to marketers is carried out by a central importing body, based on historical volumes sold by marketers. This can make it a challenge for marketers to scale up their operations and fails to encourage efficiencies on behalf of marketers with long-standing commercial positions/supply contracts in the market.

Product pricing

- Product pricing is regulated in many countries in SSA through price structures. Methodologies differ, but such price structures seek to allocate calculated values to some or all of the components that contribute to the pump price: base quote, premium, jetty throughput charges, storage, trucking fees, and similar. The challenge is that these calculated figures rarely reflect reality and stifle competitivity among operators in the downstream, with fixed margins encouraging inefficiencies. In some markets margins are not revised for extended periods. This is the case in Cameroon, where storage fees are insufficient to incentivise new investments in the sector, leading to storage capacities that are ill suited to meet growing demand – especially in the event of outages. Market pricing, by contrast, encourages competition, creating the potential for lower costs to consumers.

Infrastructure

- Single points of failure: Many countries rely on a single piece of infrastructure to receive or distribute the majority of oil products, with alternative options either insufficient or challenging to scale up at short notice and with little in the way of security stocks to meet demand in the case of such disruption. A key recent example of this is the SGP terminal in Conakry which suffered a catastrophic fire in 2023 and, with no viable alternative for importing products at scale, imports had to be conducted through a makeshift ship-to-truck rack, with imports supplemented by overland trucking from neighbouring Sierra Leone. Even with these measures, shortages have plagued the market.

$30,000/day

Prevailing demurrage fees for an MR-sized vessel in August 2023

- Security stocks: A lack of robust security stock maintenance protocols on the continent leaves many markets vulnerable to shortages (see p.36 for more details).
- Ageing infrastructure: A lack of maintenance, updating, and investment has left key pieces of infrastructure falling behind world standards. State-owned infrastructure in particular faces these challenges – this can be storage, railways, ports, pipelines and similar – as they often are not subject to the same economic realities that private operators are. This can result in costly delays and demurrage - the charge payable by the charterer to the shipowner when a vessel fails to discharge (or load) within the time agreed. Wait times are extending from current typical minimums of 3-5 days. Berth capacity constraints are set to become a major issue in 2024 as we reach 100% capacity according to CITAC's modelling. This is often due to berth congestion as a consequence of under-investment in ports, but other factors can play a part. In August 2023 prevailing demurrage fees for an MR-sized vessel were around $30,000/day, so a 35,000mt cargo waiting for five days would incur a demurrage fee of over $4/mt. This cost is passed down the supply chain and is ultimately borne by the end-consumer.
- Equally, natural monopolies such as railways, pipelines, or ports are often run in inefficient ways due to the lack of competition or due to guaranteed state-provided financial support (occasionally bailouts) for continued operations. In other instances, monopolies can arise at certain links in the supply chain: trucking lobbies are often very strong, equipped with the power to shutdown bulk transportation in countries where there are few alternatives. This outsize strength can lead to inefficiencies and higher costs for the consumer as a result. This is the case in countries such as Malawi, Mali and Zambia, where trucking lobbies have strong powers due to the lack of alternative transportation options.

Côte d'Ivoire: Diversified supply chain cuts truck outs in Abidjan

Côte d'Ivoire is one of the few SSA countries to have successfully diversified its onshore liquid fuel supply chains. Product is evacuated from Abidjan, where production and imports are concentrated, by road tankers but also by rail and pipeline.

The SITARAIL line, which links Abidjan to Ouagadougou, moved nearly 300,000m3 of product in 2022, while the PETROCI pipeline, which links Abidjan to Yamoussoukro, moved 1.8mn m3. Together, these rail and pipe movements spared Abidjan close to 55,500 truck outs in 2022, or 152 truck outs per day. Use of both facilities is underpinned by government directives mandating minimum usage quotas – despite any economic arguments for simply loading products onto trucks.

The Ivorian example illustrates how pipeline and rail, with the support of a strong political will, can effectively debottleneck an otherwise congested region.

SITARAIL. Source: CITAC.

PETROCI pipeline. Source: PETROCI.

Figure 20: Côte d'Ivoire: Diversified supply chain cuts truck outs in Abidjan.

4.4 Supply chain recommendations

In order to improve the supply chain and strengthen security of supply, there needs to be a focus on streamlining regulations to reflect market pricing and support for investment in infrastructure. This will contribute to improved supply economics.

Regulation

Regional approach

Governments with interlinked supply chains would benefit from coordinating on policy. Harmonising product specifications has been a key facilitator of improved economics of supply and ensuring supply routes can be diversified without relying on segregated supply chains. Harmonisation has already been achieved in many sub-regions and efforts are underway, led by the African Union (AU) through the African Refiners and Distributors Association (ARDA), to harmonise product specifications across the continent. As growing attention on specifications leads to changes at different speeds in different countries, maintaining harmony across regions where it exists today will be an important factor to coordinate.

A regional approach facilitates better economies of scale, creating the potential for land linked countries to coordinate volumes to be imported in harmony with neighbouring transit countries. Similarly, harmonisation of specifications facilitates improved security of supply for countries that can potentially source products from neighbouring markets in the event of supply disruptions.

A strong example of a regional approach is the East Africa Community (of which DRC, Burundi, Kenya, Rwanda, Somalia, South Sudan, Uganda, and Tanzania are members), which introduced common product specifications in 2015 which mandated 50ppm sulphur specifications and fostered improved security of supply by ensuring harmonised specifications among the member states - excluding Somalia and DRC which are yet to implement these.

Pricing

Market pricing

Pricing regulation is prevalent across Africa, where the use of price structures – which dictate margins for transport, storage, retail, jetty operations, and similar – is common. In CITAC's experience, price structures see only infrequent revisions to their methodologies and would benefit from a monthly review, at a minimum, to align more closely with international market prices. A recommendation for regulators is to ensure that price structures reflect as truly as possible the costs associated with supplying the market, including aspects such as costs of finance, freight, construction materials, fuels, and similar. This is typically done by scheduling regular price structure reviews and ensuring the regulator is up to speed with changes in the international market and shifting costs in their own market, as well as identifying areas where the price structure allocates excessive or insufficient margins to operators.

Harmonising product specifications has been a key facilitator of improved economics of supply and ensuring supply routes can be diversified without relying on segregated supply chains. Harmonisation has already been achieved in many sub-regions and efforts are underway, led by the African Union (AU) through the African Refiners and Distributors Association (ARDA), to harmonise product specifications across the continent.

Infrastructure

Debottlenecking and scaling up

Growing demand is placing oil product infrastructure under increasing strain. The case studies in this report show berth constraints appearing in Mozambique, leading to delays, and pipeline capacity limits being reached in Zimbabwe and Tanzania. Governments need to identify where bottlenecks will appear, based on projected trends. In the case of the listed bottlenecks, additional berth capacity should be installed at the port of Beira in Mozambique, while capacity expansions (or flow-rate improvers) should be considered in Zimbabwe and Tanzania.

The risk of not acting is that it causes delays or disruptions to the supply of energy to the domestic market as well as productivity losses from the additional congestion. It must be remembered that all products that cannot be transported by pipeline are then transported by road, leading to increased road congestion. Similarly, ports are key points for handling imports and exports and so congestion in ports constrains economic activity. The delays from congestion lead to higher costs, such as demurrage, which are ultimately borne by the consumer or government.

Diversification of supply

Diversification of supply chains is key to avoiding product outages.

Over-reliance on a single piece of infrastructure or a single supply route exposes markets to the risk of supply disruption.

A recommendation of this paper, therefore, is for market operators to identify single points of failure in their markets and to seek to develop contingencies or mandate the use of alternative supply sources. In Burkina Faso, for example, the national oil company Sonabhy stipulates in its tender that supply of hydrocarbons is split across its transit corridors of Cote d'Ivoire, Ghana, Togo, Benin, and Niger to minimise the risk of disruption to any single supply corridor. This strategic approach does entail higher costs than simply seeking the most competitive supply premia available but helps to minimise disruptions.

Security stocks

The invasion of Ukraine led to major disruption to the flow of oil products, particularly gasoil. The tight supply and corresponding spike in prices as market players scrambled to secure barrels resulted in both delays to supply into African countries and a sharp climb in premia – a cost to be borne by the consumer or government.

The IEA recommends member states hold security stocks of no less than 90 days of net imports. African states without such measures in place, or inadequate stocks, would benefit from a similar security buffer (see box p. 36 for more details on security stocks).

Improved security environment

Security challenges vary in their nature across Africa from outright conflict to vandalism to theft. The risk of theft and losses are a recurring concern among marketers who are reluctant to use pipelines or rail facilities often preferring to use trucks for transportation to minimise the scale of losses when they do occur. A recommendation would be for operators of pipelines and rail to guarantee a cap on the level of losses to users and to implement security measures to ensure losses are kept to a minimum.

Drive efficiency in natural monopolies

Often natural monopolies (e.g. pipelines, railways, ports, refineries, power generation, grid-based distribution) are run by state enterprises. Operators across Africa complain about inefficiencies stemming from the unoptimised operation of infrastructure by such enterprises. Inefficiencies typically lead to substantial losses at these state enterprises, requiring the state to intervene and provide financial liquidity. In the course of CITAC's research for this paper, inefficiencies in the operation of state-run infrastructure in Mozambique, Namibia, and Botswana among others were identified as a constraint on the economic supply of products to the market.

Efficiency at state-run infrastructure enterprises can be improved by introducing greater accountability across management for the financial performance of the facility. Applying more rigorous project management techniques to ensure timely execution of maintenance, expansion, and investment could help to make ageing state-run infrastructure more economical, helping to reduce the cost to the end consumer.

Another approach is the introduction of a private partner. Private-public partnerships can deliver improved efficiencies by applying best management practices and cost efficiencies while not relinquishing control over assets with national strategic importance.

Environmental and social

Reduce impact of trucking on society

Trucking, which accounts for 83% of oil product primary transportation in Africa, brings inherent risk. The risk of road accidents is significant, causing injury and death. Displacing trucks with pipelines or rail uptake helps to reduce the risk of such incidents as does improving the quality of roads, regulating drivers' working hours, enforcing truck quality standards, and similar practical solutions.

Reduce emissions footprint of supply chain

Displacing trucks through the increased use of pipelines and rail will also help to reduce the environmental impact of oil product transportation in Africa. Across the supply chains studied later in this paper, a total of 750kt of GHG emissions could be saved in 2030 through the adoption of pipelines – removing as much as 95% of trucks required, assuming Jet A1 continues to be transported by road for quality assurance purposes.

Case study: Liquid fuel transport modes and negative externalities

Context

This box highlights the risks and impacts from an over-reliance on trucks as a mode of transport to distribute fuels.

Rapid population and urbanisation growth, along with soaring imports of used vehicles, have overwhelmed road networks in Sub-Saharan Africa, contributing to gridlock, road safety risks, and air pollution across the sub-continent. The productivity lost through traffic jams, road traffic injuries (RTI), and pollution-related illnesses is a growing strain on economic growth.

Road tankers have contributed to these phenomena, particularly around ports, depots, and service stations. A lack of alternative modes of primary transport (pipeline, rail, barge), and a lack of investment in wider infrastructure has seen the number of tankers on SSA's roads rise commensurately with energy demand growth. 83% of SSA's fuel demand is moved exclusively by road tanker, according to CITAC. Key issues that result from this over-reliance on road trucks include: (i) economic; (ii) health and safety; and (iii) environmental impacts.

SSA has 13,264km of operational product pipelines, concentrated in a handful of countries (see map). This is in stark contrast to the US and Europe which have favoured the development of extensive pipeline systems for reasons of cost, efficiency, safety, and environmental friendliness.

The US, for instance, is criss-crossed by a product pipeline network of over 100,000km. Because they are typically buried, these vast pipeline networks go unnoticed by most consumers, even though they operate 24/7 – unlike most terminals and truck fleets. Pipelines move 64% of US energy commodities, according to the US Department of Transportation. Rail accounts for roughly 4%. The balance is split between barge and road.

Product pipeline density in the US is 19x times higher than in SSA. Each day the 2.5mn b/d Colonial pipeline alone moves more clean products than the whole of SSA consumes. The pipeline crosses the coastal states linking Texas to New Jersey, with spurs serving multiple depots and airports.

19x higher density

USA pipeline network compared to SSA

Figure 23: Pothole repairs, Abidjan. Source: CITAC.

Existing product pipelines in SSA are all operating at capacity, and rail freight is not available in the vast majority of countries, forcing incremental volumes into road tankers.

Clean Product Pipeline Lengths (km)

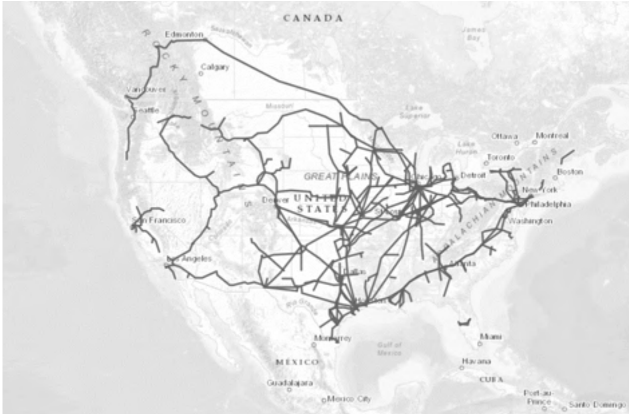


Figure 21: US product pipeline network. Source: EIA.

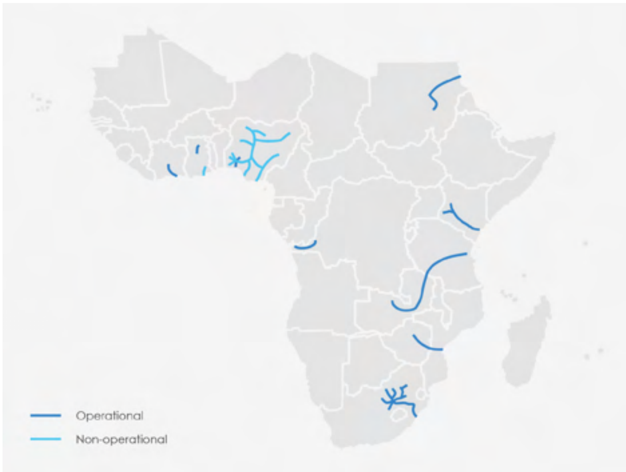


Figure 22: SSA product pipeline network. Source: CITAC.

Economic impact

From Lagos to Nairobi, hours-long traffic jams are the daily reality for millions of Sub-Saharan Africans. The road damage wrought by road tankers and other heavy vehicles further exacerbates congestion by disrupting the free flow of traffic.

The economic and psychological impact of this traffic congestion Fuelling Africa's Potential: Bridging the Gap in Energy Infrastructure is largely unexplored, and highly dependent on base lines, but some research has already been conducted. A 2019 study by the Nairobi Metropolitan Authority (NaMATA) ranked a as the fourth most congested city in the world, putting the economic cost of the capital's traffic jams at 100bn Kenyan Shillings (USD694mn), or 1% of GDP.

Health and safety impact:

- Worldwide, road traffic injuries (RTI) kill over 1.3 million people every year and injure an estimated 50 million more, according to the World Health Organization and AMEND. RTI are now the leading cause of death for children and young people between the ages of 5 and 29.
- Sub-Saharan Africa (SSA) has the highest RTI rates in the world and though the region has only 2% of the world's vehicles, it accounts for 16% of road deaths.

2% number of worlds' vehicles in SSA **vs** **16%** of road deaths worldwide

Figure 24: Traffic in Accra, Ghana. Source: CITAC.

- RTI statistics specifically relating to road tankers are not available, but accidents are common. In November 2021, 154 people were killed and 304 more were injured when a road fuel tanker collided with another truck at a busy junction in Freetown, Sierra Leone, and subsequently exploded. The death toll from this single accident was equal to the total fatalities recorded across the Unites States' entire oil and gas pipeline network between 2009 and 2022.
- Pipeline transport is the safest mode of transport in terms of human injuries and fatalities. Over the past 20 years, the US Pipeline and Hazardous Materials Safety Administration has recorded 13 fatalities/year on average across its entire 3.3mn km pipeline network, the vast majority of which is gas pipelines. Product pipelines make up only 100,000km of this total.

Climate change, air pollution and other environmental impacts

Road tankers in SSA emit around 1.04kg of CO_2 per km. This is based on emission levels of around 2.6kg of CO_2 per litre of diesel burned and a typical fuel economy of around 40 litres per 100km. In SSA, trucks are older and spend lots of time in slow traffic and idling before they hit the open road and even then, there are few highways.

Conversely, rail and pipeline transport produce considerably lower emissions, even where their operations either 1) consume diesel directly, or 2) use oil products for the generation of the electricity they consume.

Road tankers also release other harmful air pollutants – Nitrogen oxides (NOx), Volatile Organic Compounds (VOC), Sulphur oxides (SOx), Hydrocarbons (HC), Carbon Monoxide (CO), Particulate Matter (PM) and Metals — which contribute to premature deaths from various illnesses.

383,419 deaths

caused by ambient air pollution in Africa in 2019

Ambient air pollution (AAP) was responsible for 383,419 deaths across Africa (including North Africa) in 2019, according to the latest available data from the UN Environment Programme. UNEP cautions that the AAP-related disease burden will continue to rise as the continent's economies urbanise and industrialise. While road transport produces the greatest negative externalities in terms of injuries/fatalities, congestion, and emissions, it is the least likely to cause a one-off environmental catastrophe. Pipeline, barge or rail spillages, on the other hand, can cause far-reaching and long-lasting damage to species, habitats and water supplies.

Negative externalities of various transport modest

Mode	Injuries/fatalities	Congestion impact	Emissions	Spillage impact
Road	High	High	High	Low
Pipeline	Low	Low	Low	High
Rail	Medium	Low	Medium	Medium
Barge	Low	Low	Medium	High

Figure 25: Negative externalities of various transport modes. Source: CITAC.

In August 2020, the Colonial Pipeline leaked 7,600m^3 (the equivalent of 200 truckloads) of gasoline in the Oehler nature reserve in North Carolina, USA. The consequent soil/groundwater clean-up operation is ongoing and will last for several years. In the same month, a freight train with 25 tank wagons derailed and caught fire in Carmarthenshire, southern Wales, spilling 446m3 of diesel – some of it into the river Loughor.

Inventory cover and energy access

Inventory management is a key component of any supply chain resilience strategy. Most Western nations are members of the International Energy Agency (IEA) which imposes substantial stockholding obligations as a condition of membership:

In contrast, many Sub-Saharan African countries carry less than 10 days of demand cover, exposing businesses, airports, and consumers to stockouts when normal supply patterns are disrupted. This can either be due to natural events such as flooding or similar, or due to conflict – the outbreak of war in Ukraine in 2022 disrupted the flow and availability of oil products across the world and drove a sharp spike in prices. When shortages occur, consumers can be forced to spend hours, or even days, queueing or searching for fuel. No SSA countries are IEA Members.

IEA member countries are required to ensure oil stock levels equivalent to no less than 90 days of net imports and to be ready to collectively respond to severe supply disruptions affecting the global oil market. Member countries have substantial flexibility in how they meet the stockholding obligation which can include stocks held exclusively for emergencies and stocks held for commercial purposes (both in the form of crude oil and as refined products), as well as holding stocks in other countries under bilateral agreements. Each member country is thus able to determine how to fully meet their IEA stockholding commitment in the manner most appropriate to their domestic circumstances. Generally, regulators in these markets work with the private sector for the management of these stocks by mandating minimum stock levels as a condition of granting an operating license. Governments need to ensure that pump prices allow for the initial purchase and maintenance of security stocks which entail significant CAPEX and OPEX. In some countries the government maintains and manages stocks directly.

Source: IEA

Even where stockholding policies exist, they are rarely enforced, particularly if there is no stockholding line item in the national price structure. In practice, therefore, local marketers carry the minimal stock necessary to avoid:

- The large OPEX requirements and financing costs associated with carrying large inventories.
- The penalties payable to industrial/commercial customers when contractual volumes are not delivered on time. Where marketers do fail to fulfil their supply contracts with B2B customers, those customers risk having to slow down, or even temporarily halt, their own operations.

The map below shows countries that have suffered Jet or road fuel stockouts since March 2022. Short-notice alerts, known as Notice to Airmen (NOTAMs), issued in relation to the non-availability of Jet or Avgas at small regional airports have been ignored for the purposes of this analysis; only shortages at major international airports have been included.

Clean Product Shortages in SSA Since March 2022

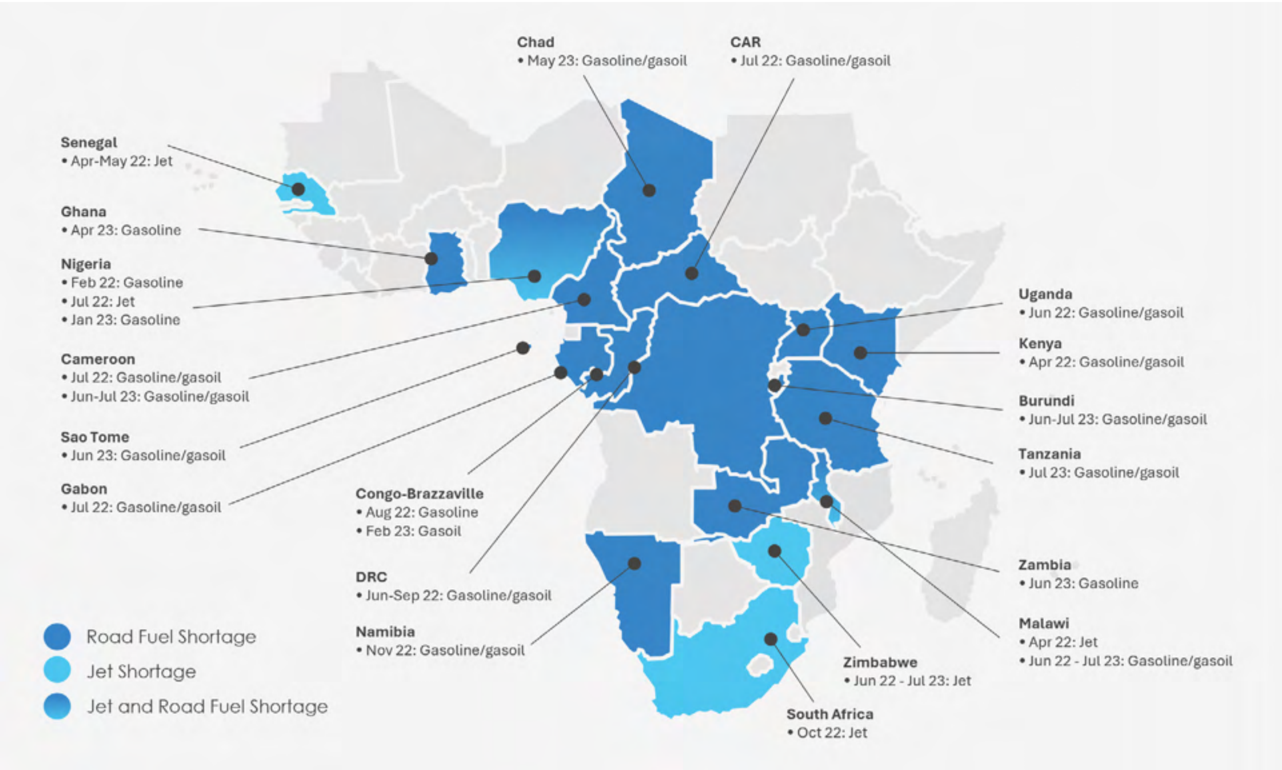


Figure 26: Clean product shortages in SSA since March 2022.

SECTION

5 Country case studies

5. Country case studies

5.1 Regional supply overview

To illustrate the supply challenges Africa is facing, CITAC has conducted a series of country-level case studies, analysing supply chains in Southern and Eastern Africa (see countries in blue, opposite). This is a region where coastal countries' supply infrastructure is crucial both for domestic supply and for supply to inland markets. The inland markets are therefore entirely reliant on the robustness of supply chains and risk severe disruption to supply and economic activity in instances where supply chains fail.

Due to geography and the historical development of certain supply corridors, Mozambique and Tanzania play a central role in supplying the interior: Zimbabwe, Zambia, Malawi, Rwanda, Burundi. Following the closure of refineries in South Africa and a tightening of product availability in that country, meanwhile, Botswana has sourced increasing volumes of product from Mozambique and Namibia.

The key findings and recommendations from the case studies are evaluated below:

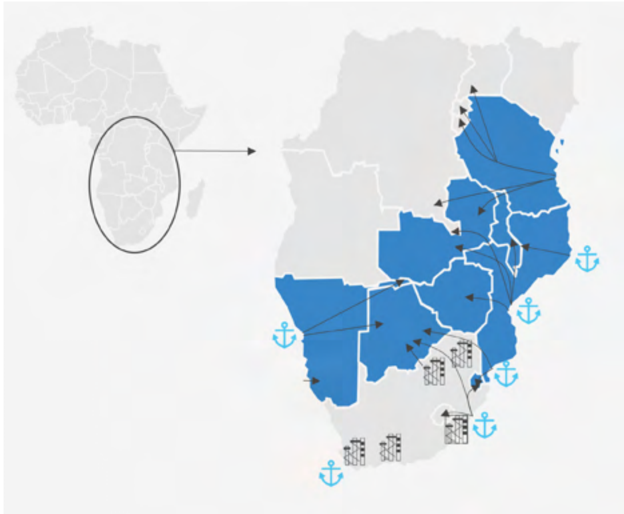


Figure 27: Case study map.

Supply Corridor	Constraint	When	Solutions	Countries affected
Durban	• Berth Capacity • Jet/Kero Tankage • Diesel Tankage	• Now • Now • Now	• Build products SBM (or convert crude SBM to products) • Debottleneck berth equipment • Build/acquire tankage	Botswana, eSwatini, Lesotho, South Africa, Zimbabwe
Richards Bay	• Berth capacity • LPG Tankage • Gasoil Tankage • Gasoline Tankage • Jet/Kero Tankage	• 2040 • Now • 2025 • 2030 • 2030	• Debottleneck berth equipment • Build extra tankage	Botswana, eSwatini, Lesotho, South Africa, Zimbabwe
Maputo	• Berth capacity • Jet/Kero Tankage • LPG Tankage • Evacuationt rates	• 2025 • Now • 2035 • Now	• Debottleneck berth equipment • Build tankage • Improve truck loading and clearing efficiency (extra bays, faster loading rates, streamline clearing, truck staging)	Botswana, eSwatini, Lesotho, Mozambique, Zimbabwe
Beira	• Berth capacity • Gasoline Tankage • Evacuation rates • NOICZIM pipeline	• Now • 2035 • Now • 2025	• New oil berth(s), Build product SBM, debottleneck berth equipment • Build tankage • Improve truck loading and clearing efficiency (extra bays, faster loading rates, streamline clearing, truck stagging) • Relace pipeline	DRC, Lesotho, Malawi, Mozambique, Zimbabwe, Zambia
Dar-es-Salaam	• Berth Capacity • Gasoline Tankage • Tazama pipeline	• 2030 • 2040 • 2025	• Debottleneck SBM, debottleneck berth equipment • Build/acquire tankage • Pipeline debottleneck (gets to 2030 demand) • Replace pipeline by 2030 • Spur line to Mbeya to supply Malawi	Zambia, Malawi

Table 1: Case study summary table.

As part of its case study analysis, CITAC also assessed the feasibility of building pipeline capacity to serve the key arteries. Many of these are economically viable however, this is highly dependent on the set of assumptions used.

The Dar es Salaam pipeline replacement project was used to benchmark and forecast the capital cost for the various routings listed in the table below. This project consists of a 12-inch, underground pipeline, quoted at $600,000/km to which we added 25% escalation to account for inflation and hidden costs. The analysis also assumes a relatively short payback in 15 years and a high cost of capital at 20%, in line with what we expect investors in African infrastructure would require.

The table below summarises the viability for various corridors in Southern and East Africa where the pipeline is considered viable if the breakeven $/m³ cost of the pipeline (compounded annual payback divided by annual volume) is below or very close to the current road transport rate on the same routing.

Many factors will influence the capital cost such as the elevation the pipeline will make, the pumping rates hence size of pump, and the number of pumps, as well as any staging tanks and infrastructure to deal with product interfaces. The multi-product pipeline in South Africa cost $2.9mn/km, though this is a 24-inch line, climbs 1,750m above sea level and included staging tanks in Durban and a 180,000m³ inland terminal.

Since many of these pipeline routings cross country borders, they will be dependent on inter-governmental cooperation and joint financing with supporting policy frameworks for tariff structures and operating procedures together with commitments to subsidies, should this be required. It is worth noting however that there are tangible benefits to society in the form of decongestion, improved productivity, and lower GHG emissions that come with the development of such infrastructure. This analysis is summarised as follows:

Corridor	Length/ diameter	Annual t'put* MML/yr (Avg 2030-2040)	Investment Estimate***	Investment as % of 2023 GDP of participating countries	Breakeven** $/m³	Current road cost, $/m³	Viable?
DBN-Gauteng******	555km / 24"	4500 (7900 max)	$1.6 bn	0.4% (RSA)	35	45-55	Included as a real-world case for comparison purposes. Currently operational with no expansion required. Current (avg) MPP fee is 37 $/m³
Beira-Harare	208km / 18"	4800	$260 mn	0.5% (Moz, Zim)	11-13	60-70	Yes. Current pipeline fee is 45 $/m³
Harare-Lusaka	760km / 14"	2000	$665 mn	1.1% (Zim, Zam)	70-80	65-80	Yes
Beira-Lusaka	1625km / 18"	2700	$1.9 bn	2.3% (Moz, Zam)	150-165	155-180	Yes
DES-Ndola	1750km / 20"	3800	$2.2 bn	1.9% (Tanz, Zam)	125-140	145-170	Yes. Current pipeline fee: 46$/m³
Tarlton-Gaborone	320km / 10"	1350	$200 mn	0.05% (RSA, Bots)	25-30	25-35	Yes
Matola-Gaborone	850km / 10"	1350	$530 mn	0.1% (Moz, RSA, Bots)	85-95	65-80	Possibly - may require a subsidy
Nacala-Lusaka-Lubumbashi	2475km / 18"	2800****	$2.2 bn	1.3% (Moz, Mal, Zim, Zam, DRC	165-185	155-215	Yes
WB-Gaborone	1480km / 14"	2500*****	$1.3 bn	3.8% (Nam, Bots)	110-125	105-125	Yes

** Corridor gasoline & gasoil volumes only, ** 15-year payback, 20% cost of capital, *** 62,500 $/km/inch*
***** Assumes all Beira in transit vols switch to Nacala, ***** Assumes all Bots & Beira to Zambia vols switch to WB*
******* DBN-Gauteng multiproduct pipeline, actual cost (123,000 $/km/inch)*
If the DES-Ndola pipeline is replaced, offtake spurs could enable Malawi vols to shift to this corridor

Table 2: Pipeline analysis summary table.

6. Country focus:

Botswana

680,000
Population growth
2023 - 2040
(World Bank)

4%/y
Average annual
GDP growth
2023 - 2028 (IMF)

397kt
CPP imports
increase
2022 - 2040

2.1%
CPP imports
CAGR
2022 - 2040

6.1 Oil product supply and demand

Botswana's clean oil product demand stood at 879,000mt in 2022. Industrial demand for products stems mainly from extractives, as well as tourism. Private use in vehicles and generators also drives demand. Demand fell 2% from a 2013 high, largely due to the impact of Covid on tourism.

The market is expected to post continued growth in oil product demand going forward. Domestic clean product demand is forecast to rise 42% to 1.3mn mt by 2040.

6.2 Overview of supply chain

Botswana is supplied by three main transit corridors:

- Via South Africa, through Durban, then by pipeline to Tarlton and then by truck or rail, or into Richards Bay and then by truck, or lifted directly from the Natref refinery;
- Via Mozambique through Matola by truck;
- Via Namibia through Walvis Bay by truck.

Currently 80% of Botswanan oil product imports go through South Africa, though this is forecast to decrease to around 40% by 2040 as volume shifts to the Maputo and Walvis Bay corridors over the forecast period. Currently 95% of the South Africa supply flows through the Durban corridor but this is forecast to drop to 86% by 2040 as volumes shift to Richards Bay.

Botswana has a total of 76,000 m³ of CPP storage, concentrated around the key demand centres of Francistown and Gaborone. Both of these depots are served by rail and road.

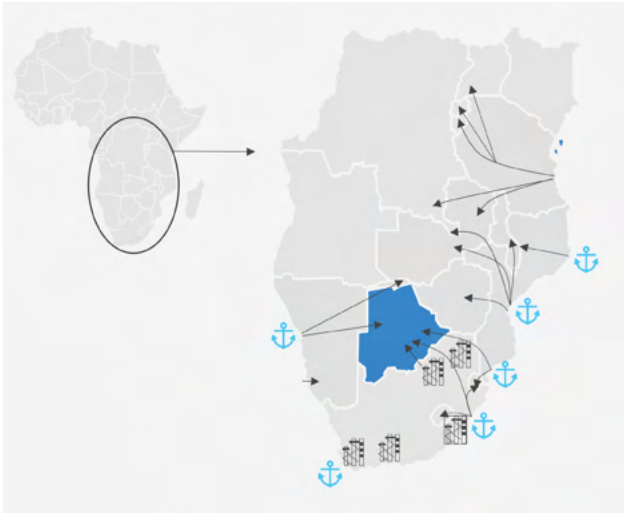


Figure 28: Botswana supply chain map.

Botswana Supply by Transit Corridor

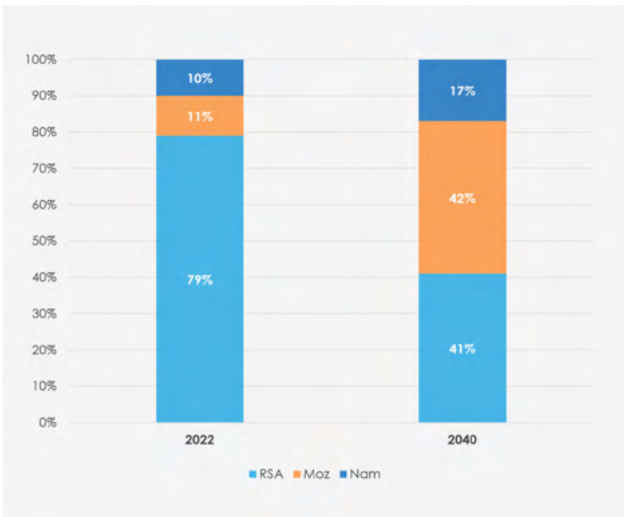


Figure 29: Botswana supply by transit corridor.

6.3 Bottleneck identification

The overall supply chain risk for Botswana is moderate to high as supply is dependent on flow via neighbouring countries.

- This is mitigated to some extent by supply via three corridors, but the high dependence on South Africa is a risk.
- To reduce this risk, greater volumes need to move via the Richards Bay, Maputo or Walvis Bay corridors.

In the table below, the berth capacity, #35kt cargoes, demurrage costs, and tank utilisation relate to the total volumes coming into each port where Botswana's demand will contribute to the constraints or receive their share of the costs based on their share of the volume in each corridor. As can be seen, berth constraints in Durban are already high and are expected to remain so, similarly for Matola – these are indicated by the orange highlighting for these highly congested facilities. By contrast, the supply chains through Richards Bay and Walvis Bay indicate lower levels of congestion. The metrics in the lower section of the table relate only to volumes in the Botswana supply chains in each supply corridor. As can be seen, South Africa remains a key supplier but, as that country faces increased supply challenges in the wake of refinery closures, Botswana is expected to ramp up imports via the alternative corridors of Matola and Walvis Bay.

Botswana Supply Corridors		South Africa, Durban			South Africa, Richards Bay			Mozambique, Matola			Namibia, Walvis Bay		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
Berth Capacity		high	high	high	low	low	medium	high	high	high	low	low	low
35 kt Cargoes	#	299	328	341	19	30	54	39	61	78	34	42	54
Demurrage (est.)	$mn	15.3	16.7	17.4	1.0	1.5	2.8	2.8	4.4	5.7	1.6	2.0	2.5
Tank Capacity	turns/yr	low	Kero	Kero & DSL	low	low	low	Kero	Kero	Kero	low	low	low

Botswana Supply Chains		South Africa, Durban			South Africa, Richards Bay			Mozambique, Matola			Namibia, Walvis Bay			TOTAL Botswana		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
CPP Demand	kt/yr	658	540	444	19	30	52	95	320	533	88	130	222	**860**	**1,021**	**1,250**
% of Corridor Volume		8%	6%	4%	8%	6%	4%	8%	16%	21%	9%	10%	13%			
Truck Outs	#/yr	9,219	7,156	5,304	532	881	1,533	2,660	8,932	14,847	2,451	3,635	6,182	**14,862**	**20,603**	**27,865**
Distance Driven	000 km/yr	8,724	6,772	5,020	504	833	1,450	4,800	16,116	26,790	7,353	10,905	18,545	**21,381**	**34,628**	**51,805**
GHG Emissions (est.)	$mtCO_2e$	9,640	7,483	5,547	557	921	1,603	4,683	15,724	26,138	8,125	12,051	20,492	**23,005**	**36,179**	**53,779**
Trucks in the Fleet	#	87	69	50	8	14	18	46	159	262	75	110	181	**216**	**352**	**511**

Table 3: Botswana Supply Corridors.

Bottlenecks for specific nodes in the supply chain and recommendations are detailed below:

Trucking

Botswanan supply in 2022 equated to 9,200 truckloads from South Africa, 2,700 in Matola, and 2,500 loads in Walvis Bay making a total of 14,900 truck deliveries into Botswana, either direct to customers or via the Gaborone and Francistown terminals. Total loads are forecast to grow by 90% to 27,900 total truck deliveries by 2040, however the source of these loads will shift from Durban to Richards Bay, Matola, and Walvis Bay in line with expectations around demand shifting out of Durban. A 90% increase in truck numbers brings with it challenges in terms of congestion, traffic, and higher emissions rates, making solutions such as improved efficiency and diversification to other modes of transport, such as rail, key.

- Durban truckloads will likely decrease by 40% whilst Botswana destined volumes through Richards Bay, Matola and Walvis Bay will increase by 188%, 458% and 152% respectively (all off a low base).
- GHG emissions from trucks bridging fuel to Botswana were 23kt CO_2e in 2022, which will rise to a forecast 54kt CO_2e by 2040 if all volumes continue to move via road. Part of this growth in emissions also occurs as product shifts out of the Durban-Inland pipeline and onto road via the other corridors.

Efficiency gains will be crucial both to reduce costs to end consumers and the outright number of trucks required in the fleet – thereby cutting congestion and traffic. Truck loading delays in both Durban and Matola are common, with South African transporters being reluctant to load in Matola due to long delays.

- If truck loading and clearing procedures can be improved and streamlined and average driving speeds increased in line with typical operational metrics in South Africa, savings in the Botswana supply chain alone are estimated at $5-8mn/yr in the Matola corridor ($104mn in cumulative savings between 2024 and 2040) and $4mn/yr in the combined Durban and Richards Bay supply corridors ($56mn in cumulative savings between 2024 and 2040), giving an incentive of $160mn over the next 15 years to improve truck turnaround times in Durban, Richards Bay and Matola. The added benefit of improved efficiency is that the number of trucks in the fleet will also decrease by around 25%.
- Truck loading in Walvis Bay is quite efficient (gate to gate time of 60-90mins) however due to the long travel distance to Botswana, potential savings of $3-5mn/yr can be realised if turnaround times can be improved (loading and discharge times improved and average driving speeds increased).

Rail solutions

Each of Botswana's supply corridors has rail linkage where transport rates/m^3 are generally lower than by road. Market participants cite similar challenges in Namibia, South Africa & Mozambique: that there are insufficient rail cars, rail cars are poorly maintained, there are insufficient locomotives for hauling and for shunting, and most loading and offloading terminals have insufficient loading arms, resulting in long delays with loading and thus poor supply reliability.

The benefits of rail are the reduced GHG emissions from rail. A typical road tanker carries around 32mt and generally emits 30-40 g/mt-km (depending on fuel consumption). A long-haul diesel train can carry up to 1800mt and will emit around 7-12 g/mt-km (again depending on fuel consumption). Benefits also include reduced road usage and reduced traffic accidents.

- Using 2030 for comparison, the current volume of product trucked will generate GHG emissions of 36kt CO_2 that year compared to around 10.5kt CO_2 if the same volume is moved by rail.

Construction of sufficient siding space, additional loading bays, loading arms and pumps for efficient loading of rail tank cars will cost $4-6mn per terminal, with an additional investment of $20,000 per rail tank car to obtain and refurbish a dedicated fleet of rail cars.

- The cost saving on rail in the Durban-Gaborone corridor (assuming pipeline to Tarlton, then rail vs. road to Gaborone) is around $20/mt.
- In the Matola corridor, the longer distance provides savings to Gaborone of closer to $25/mt due to the longer distance. In the Walvis Bay corridor, deliveries by rail to Gaborone are expected to be $35/mt cheaper than by road.

Pipeline solutions

A 24" multi-product pipeline transporting only gasoil and gasoline runs between Durban and various terminals in the inland market of South Africa where a mix of these inland terminals are used to road- bridge products to Botswana. Supply to Botswana is also purchased from the two inland refineries but since the inland production is short relative to the local South African demand and the Durban-Inland corridor is also short, the incremental product moving to Botswana is essentially all imported.

- The South African New Multi Product Pipeline of 24" cost R29 bn ($1.6 bn) to construct, which works out to approximately $122,000/km/inch of pipeline. Based on current throughput volumes, 15% cost of capital and 15-year payback, a fee of $35/m^3 is required which compares well to the current actual average tariff of $37/m^3. A bulk truck will cost $55/m^3 to transport fuel over the same distance with a potential to reduce this to $45/m^3 through load, discharge, and driving efficiencies. This provides a $10-20/m^3 incentive to use the pipeline and provide a payback for the investment.
- A 10" pipeline will suffice to move the full Botswana gasoil and gasoline required volumes out to 2040 and could be constructed between Tarlton and Gaborone covering a distance of approximately 320km. The capex for this is estimated at $200mn with a resulting tariff of 25-30$/m^3 required to pay off this investment (assuming a 20% cost of capital and 15-year payback). Currently the road bridging cost from Tarlton to Gaborone is $31/m^3, implying a pipeline investment should pay back without significant subsidies. The diameter of the line could be reduced but then it will be constrained by 2040.
- If the pipeline runs from Matola, it will cover a distance of 853km and have an estimated investment cost of $530mn. Based on the full Botswana demand flowing through this pipeline, a tariff of 85-95$/m^3 will be required as compared to the current road bridging cost of $77/m^3 (which has the potential to reduce to $64/m^3 through efficiency gains). The pipeline cost on this routing is above, yet close to, the road bridging cost, making a pipeline project viable through minimal subsidies.
- If Botswana swung its full product supply through Walvis Bay and added capacity to move the southern Zambia demand currently moving through the Beira corridor, a 14-inch pipeline covering a distance of 1,480km would be required to move the combined forecast annual demand to Gaborone out to 2040. The southern Zambian demand would then need to be road bridged from Gaborone to Lusaka. The capital investment for this pipeline is forecast to be $1.3bn and, based on the forecast Botswana and Zambian volume flowing through it, a tariff of 110-125$/m^3 will be required as compared to the current road bridging cost of 105-125$/m^3. The pipeline cost on this routing is basically equal to the road bridging cost, making a pipeline project in this corridor viable as compared to road bridging cost in this corridor. This routing is worth further consideration in light of the delays in all of the southeastern ports of Africa, however it results in a higher delivered price to Gaborone as compared to $68/m^3 from South Africa ($38/m^3 pipeline fee to Tarlton + $31/m^3 on a new pipeline). Without the southern Zambian demand, a Walvis Bay-Gaborone 10-inch pipeline is required, though due to the long distance will have a capital cost of $925mn and breaks even at 150$/m^3 making this routing unviable without a subsidy.
- Extending the South African pipeline network to Botswana is more viable than a new pipeline from Matola, however the Matola routing decouples Botswana from dependence on South African infrastructure and provides an alternate supply chain routing, thus providing greater supply chain strength and resilience. With the addition of the southern Zambia volume through Walvis Bay, supply can shift away from the congested Mozambican corridors for both countries, but this results in a higher delivered price that needs to be weighed against the additional 'end-to-end' efficiency savings that this routing will bring.

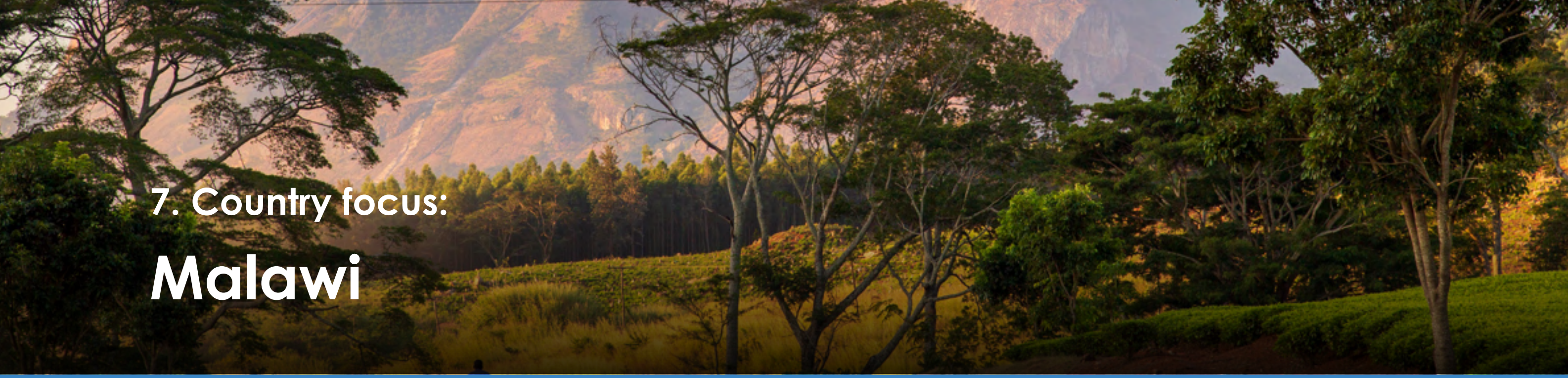
Conclusions

Reinforcement of diversified supply chains will be key for Botswana going forward. The tighter availability of products in South Africa following the closure of refining capacity, coupled with the higher need for imports will strain import logistics into the country, limiting South Africa's ability to supply Botswana's growing oil product demand needs. Therefore, there is a need to improve efficiency along the supply corridors from Mozambique and Namibia through coordination with their governments and the operators of key infrastructure, such as ports and railways to solve the bottlenecks highlighted above. Indeed, savings of $3-5mn/y could be realised through efficiency gains in truck-based evacuation via Namibia, while via Matola these would be in the region of $5-8mn/yr. Meanwhile, measures can be taken to improve capacity limitations along the South African supply chain, along with efficiency gains of $4mn/yr.

The major constraints in the Botswana supply chains are the berth capacity in Durban and Matola.

- Durban has four dedicated liquid fuel berths and 50% of a 5th berth with marine loading arms (MLAs) for each grade on each berth and pipelines for different product grades. Debottleneck solutions include faster pumping rates (pump replacement or booster pumps), larger pipeline diameters (will also enhance pumping rates), and greater port operating efficiency (more tugs & pilots, quicker berthing, faster line-up). These enhancements can generate demurrage savings of $12-13mn/yr in Durban where the Botswana volumes flowing through Durban should (in theory) pick up their share of the savings.
- The main challenges with supply via Mozambique are berth capacity constraints at Matola which already represent a significant bottleneck in supply and will become increasingly acute with growing volumes imported unless investment in import infrastructure is carried out. By contrast, supply into Walvis Bay is unconstrained, although the overland supply logistics require efficiency improvements, while the Walvis Bay – Gaborone supply chain at 1,500km is almost twice as long as the Maputo-Gaborone chain. The Maputo and Walvis Bay port fuel terminal capacities, constraints, and de-bottlenecking opportunities are discussed in greater depth in Mozambique and Namibia sections respectively.
- At a political level, finding a more efficient arrangement for the export of products from Mozambique into Botswana, a SACU member, would help to reduce the reported lengthy delays on the border between the two countries.

Further efficiency gains could be achieved through increased usage of rail capacity but for this to be achieved, investment needs to be made into the rail network to improve reliability, reduce losses, and achieve competitivity with trucking. This would involve the addition of more locomotives, increased loading/unloading capacity, maintenance of rail cars and similar measures as outlined above to displace trucking volumes. This would help to decongest road infrastructure as well as reduce the environmental impact of transporting oil products.



7. Country focus:

Malawi

10.1mn	**3.8%/y**	**415kt**	**4.4%**
Population growth 2023 - 2040 (World Bank)	Average annual GDP growth 2023 - 2028 (IMF)	CPP imports increase 2022 - 2040	CPP imports CAGR 2022 - 2040

7.1 Oil product supply and demand

Malawian oil product demand has been constrained by supply in recent years due to currency challenges which have made it difficult for businesses to operate and for importers to source goods and oil products from the international market.

Clean oil product demand was 355kt in 2022, up 29% in a decade, as the market recovered from a financial crisis and severe droughts in the early 2010s. Demand only recovered above 2010 levels in 2017.

The outlook is for continued growth in oil product demand, although this is dependent on the government's ability to stabilise the currency. CITAC forecasts clean product demand to grow to 771kt by 2040, an increase of 117%. This strong anticipated demand growth is largely because demand today is constrained by supply, but also due to the economic potential and sustained population growth in the country.

7.2 Overview of supply chain

Malawi is supplied by three main supply chains, all currently on the road: 44% via Beira, 10% via Nacala and 46% via Dar es Salaam. No change in the sourcing splits is forecast, though supply could be shifted from the congested Beira and Dar es Salaam corridors to Nacala. Road infrastructure from Nacala to Malawi is poor, however, impacting driving time as well as wear and tear on the trucks. This, coupled with instability in the northern regions of Mozambique, has prevented the growth of the Nacala supply chain.

Malawi has rolled out a security stock construction programme in recent years, and new terminals are being built across the country. Clean product storage currently amounts to 83,000m³.

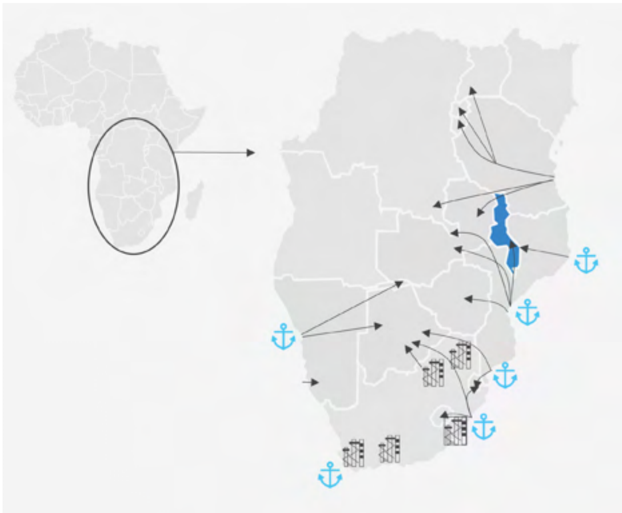


Figure 30: Malawi supply chain map.

Malawi Supply by Transit Corridor

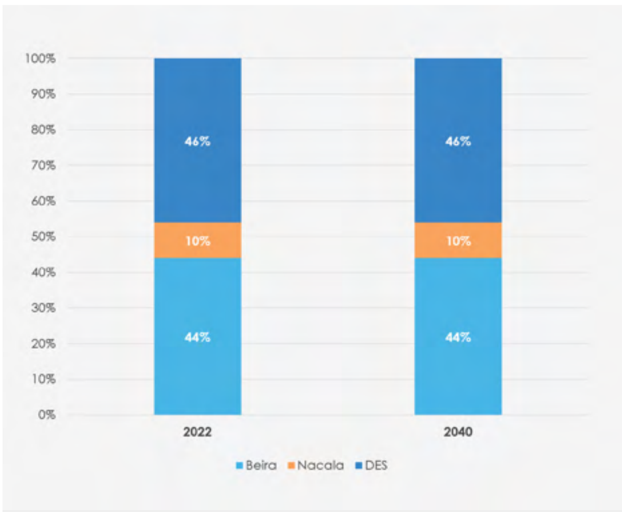


Figure 31: Malawi supply by transit corridor.
Source: CITAC.

7.3 Bottleneck identification

In the Malawi supply corridor, shown below, the berth capacity, #35kt cargoes, demurrage costs, and tank utilisation relate to the total volumes flowing through each of the three established supply routes. Malawi will contribute its proportional volume share to each of these items and costs. Note the rising constraints, highlighted in orange, in the supply corridors of Beira and Dar es Salaam, while tank capacity for gasoline in Beira and Dar es Salaam becomes a pressing issue over the forecast period. The metrics in the lower section of the table relate only to volumes in the Malawi supply chains in each supply corridor.

Malawi Supply Corridors		Mozambique, Beira			Mozambique, Nacala			Tanzania, Dar es Salaam		
		2022	2030	2040	2022	2030	2040	2022	2030	2040
Berth Capacity		high	high	high	low	low	low	low	medium	high
35 kt Cargoes	#	84	111	151	15	19	24	171	226	297
Demurrage (est.)	$mn	188	248	337	1.2	1.6	2.0	14.0	18.5	24.3
Tank Capacity	turns/yr	low	gasoline	gasoline	low	low	low	low	low	gasoline
Pipeline Capacity		high	max	max				high	max	max

Malawi Supply Chains		Mozambique, Beira			Mozambique, Nacala			Tanzania, Dar es Salaam			TOTAL Malawi		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
CPP Demand	kt/yr	157	216	342	36	49	77	163	223	351	**355**	**488**	**770**
% of Corridor Volume		44%	44%	44%	10%	10%	10%	46%	46%	46%			
Truck Outs	#/yr	4,196	5,823	9,234	991	1,361	2,147	4,727	6,658	10,677	**9,913**	**13,842**	**22,057**
Distance Driven	000 km/yr	8,568	11,891	18,855	1,968	2,703	4,264	14,567	20,520	32,907	**25,103**	**35,114**	**56,025**
GHG Emissions (est.)	$mtCO_2e$	9,467	13,139	20,835	2,174	2,987	4,711	16,097	22,675	36,362	**27,738**	**38,801**	**61,908**
Trucks in the Fleet	#	96	131	206	22	30	45	92	124	193	**210**	**285**	**444**

Table 4: Malawi Supply Corridors.

Bottlenecks for specific nodes in the supply chain and recommendations are detailed below:

Ports

Malawi is reliant on the ports of Beira and Nacala in Mozambique, and Dar es Salaam in Tanzania. Both Beira and Dar es Salaam are already congested, with demurrage estimated to more than double at Beira by 2040 and rise by almost two thirds in Dar es Salaam over the period.

It is important that investments are made in these ports to debottleneck them in anticipation of the growing demand. The government should seek to coordinate with private and public actors in these countries to drive investment into these import routes for the construction of new berths and the debottlenecking of offtake logistics. This would likely involve the construction of additional berths at the port of Beira and, potentially, the installation of SBMs at these locations.

The port of Nacala in Northern Mozambique also presents an attractive location for expansion of oil product import infrastructure but requires investment both in terminals as well as infrastructure linking the port to demand centres; this could be rail or road infrastructure. Doing so would alleviate the congestion at Beira and Dar es Salaam, helping to cut costs to the end consumer.

Trucking

If truck loading and clearing procedures can be improved and streamlined and average driving speeds increased, savings in the Malawi supply chains alone are estimated as follows:

- $4-6mn/yr in the Beira corridor ($79mn in cumulative savings between 2024 and 2040).
- Around $1mn/yr in the Nacala corridor ($18mn cumulative savings between 2024 and 2040.
- $5-8mn/yr on Malawi-destined volumes in the Dar es Salaam corridor ($107mn in cumulative savings between 2024 and 2040).

Collectively, therefore, there is an incentive of around $200mn over the next 15 years to improve truck turnaround times in Matola and Dar es Salaam. The efficiency gain from improved truck utilisation and quicker turnaround times where the fixed cost is covered by a greater volume hauled in each month per truck would help to cut costs to the consumer. The added benefit of improved efficiency is that the number of trucks in the fleet can also be decreased by around 23%.

Malawi supply in 2022 comprised 4,200 truckloads from Beira, 990 loads from Nacala and 4,700 loads from Dar es Salaam, making a total of 9,900 truck deliveries into Malawi, either direct to customers or via the Lilongwe and Blantyre terminals. Total loads are forecast to grow by 125% to 22,000 total truck deliveries into Malawi by 2040.

GHG emissions from trucks bridging fuel to Malawi were 28kt CO_2e in 2022, forecast to rise to 62kt CO_2e by 2040 if all volumes continue to move via road.

Rail solutions

Malawi has historically imported products from Mozambique by rail. Cyclone damage to the line has resulted in oil product transportation solely by road tankers. Repair to the rail line, along with coordination with the line operator, could cut logistics costs and help to diversify supply routes which would mitigate the risk of disruptions to supply into Beira, or Dar es Salaam, Malawi's other key sources of supply for imported product. In 2023, rail handled +/-18m litres of product from the third and fourth quarter of 2023 for Malawi versus +/-94m litres delivered to Moatize (in Mozambique) via the same corridor (source Nacala logistics). The regulator together with the Government continue to advocate for increasing activities through Nacala.

Pipeline solutions

A pipeline runs between Dar es Salaam and the mothballed Indeni Refinery in Ndola, passing the northern border of Malawi at Mbeya. The line is designed to carry 1100 kt/yr and the current tariff is $45/mt ($36/m³) plus $6/mt ($5/m³) storage fee in Ndola.

The first section is 8" in diameter and covers 954km and a second 12" covers 758km. The line was built to carry crude oil to the Indeni refinery but has been converted to diesel service following the closure of the refinery in 2021.

With expansions to capacity, the pipeline could have a spur developed to supply into Malawi. An expansion of the line to 20" would facilitate the supply of products to cover the full Malawi and Zambian demand and part of DRC demand for gasoline and gasoil. Initial estimates indicate this expansion would cost $2.2bn and require a throughput fee of $125/m³ to pay back the investment based on forecast volumes, a 20% cost of capital and a 15-year payback. Smaller offtake lines from Mbeya to Lilongwe in Malawi and Ndola to Lubumbashi in DRC could reduce the overall investment but then have smaller volumes from which to payback the construction costs. Compared to trucking rates to Lilongwe of 145-170$/m³, a pipeline investment looks attractive in this corridor and a project worth pursuing.

The benefit of placing more product into a pipeline is the 'unlock' this provides with loading trucks in the Dar es Salaam port, as well as GHG reductions and decreased impact on the road infrastructure. It would also help to decongest the road infrastructure around Malawi, offering economic gains.

Conclusions

The key recommendation for Malawi is to ensure continued coordination with the public and private sector in Tanzania and Mozambique to ensure optimal supply of oil products. Specific areas of focus should be the berth capacities in Dar es Salaam and Beira, which are going to become increasingly congested as oil product demand in the region continues to grow.

There are also benefits to be reaped from diversification of supply logistics. Currently, Malawi is reliant on trucks for the supply of oil product but, as mentioned above, rail and pipeline offer benefits as alternative means of product supply, as well as reducing the environmental impact of transporting increasing volumes of oil products over the coming decades.

8. Country focus:
Mozambique

17.9mn
Population growth
2023 - 2040
(World Bank)

8.9%/y
Average annual
GDP growth
2023 - 2028 (IMF)

3.9mn mt
CPP imports
increase
2022 - 2040

3.4%
CPP imports
CAGR
2022 - 2040

8.1 Oil product supply and demand

Mozambican demand has grown rapidly over the past decade, driven by strong industrialisation as the country moves to develop natural gas resources. Mozambican CPP demand grew to 1.8mn mt in 2022, up 78% over a decade.

Mozambique is a key supply corridor to inland markets Zimbabwe, Malawi, Zambia, Botswana, and Eastern DRC – many of which are seeing strong demand growth, resulting in increasing pressure building up on import and distribution infrastructure. Pressure has mounted further following the closure of the Zambian refinery, Indeni, in 2021 leading that country to move to rely solely on imports.

Continued economic growth in Mozambique and the broader region is expected to drive oil product demand ever higher. Domestic CPP demand is forecast to rise 57% to 2.9mn mt by 2040. The increase in hinterland demand will see CPP imports for domestic consumption together with transit volumes rise 85% from 4.6mn mt to 8.5mn mt in 2040. This challenge will require significant investment into Mozambique, which has increasingly become the gateway to the regional market encompassing Zimbabwe, Zambia, Malawi, Botswana, DRC, and South Africa.

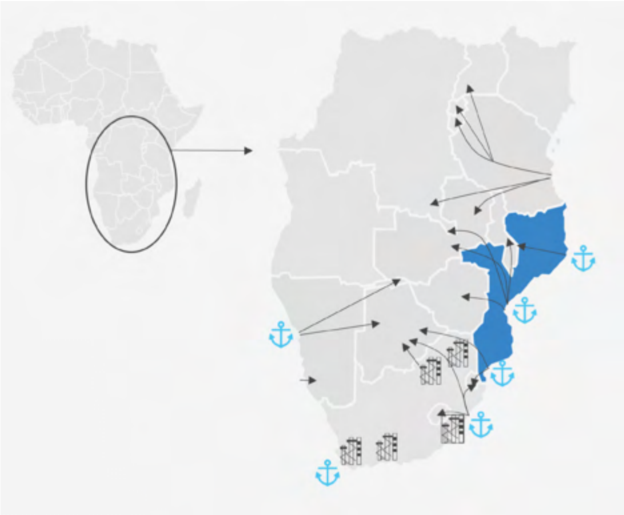


Figure 32: Mozambique supply chain map.

8.2 Overview of supply chain

Mozambique has three key ports of entry for oil products: Beira, Matola, and Nacala. The port of Pemba also receives some small volumes. Of these, Beira receives the largest share thanks to robust offtake infrastructure – despite facing draft challenges.

Mozambique's extensive coastline has led to it playing a natural role as a transit hub for hinterland countries. This sees Mozambique handling volumes of product for Zimbabwe, Zambia, Malawi, Botswana, DRC, and South Africa. Following the closure of refineries in South Africa, Mozambique's strategic importance for regional oil product supply is forecast to increase. The following graphs indicate the size of transit volumes and the share of product to be delivered via each port for each transit destination.

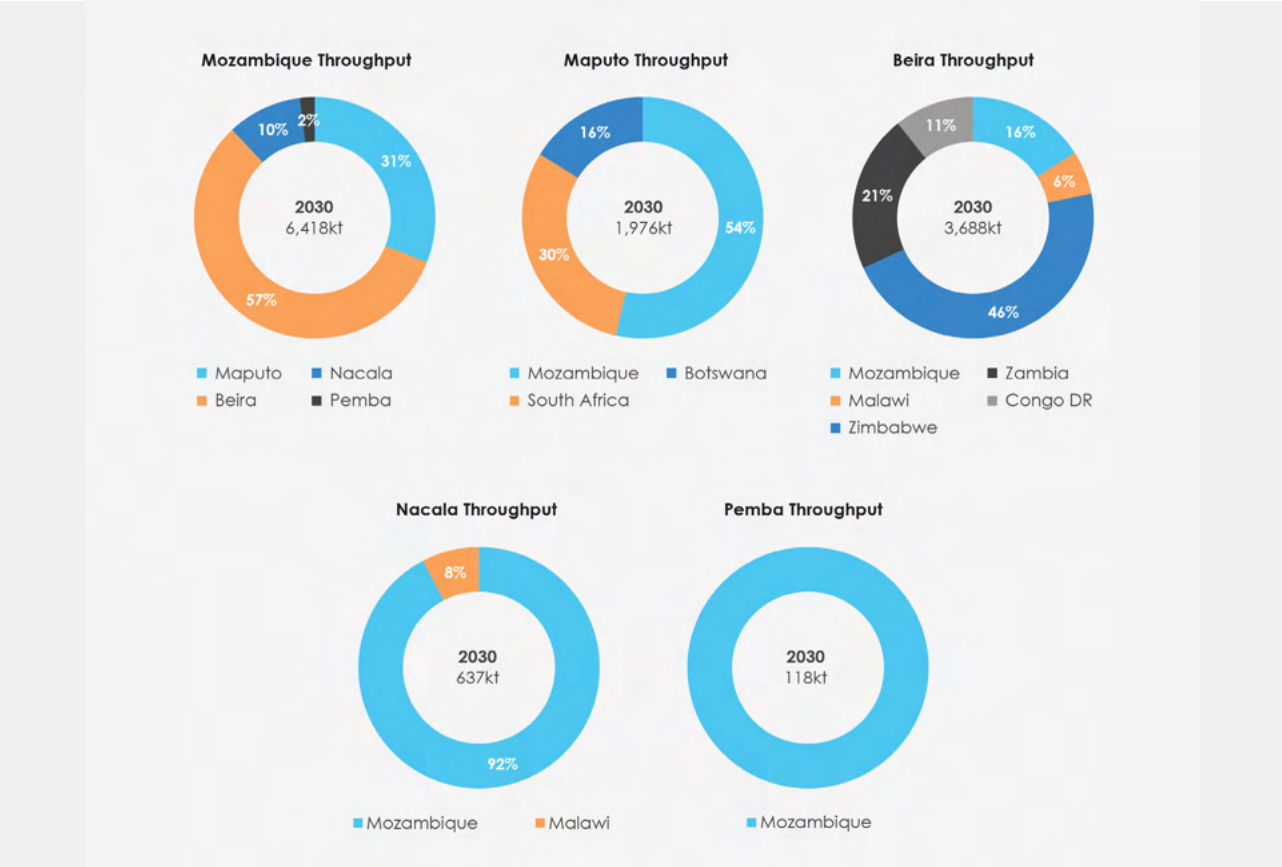


Figure 33: Mozambique Corridor Throughputs.
Source: CITAC.

Mozambique has significant clean product storage capacity, totalling 1.4mn m^3. However, tankage for certain products (notably gasoline) is constrained at some locations. These constraints are covered in more detail, below. Much of the storage capacity is clustered around Maputo and Beira, serving local and transit demand.

Mozambique is linked to Zimbabwe by the NOICZ pipeline. This is a key facility for evacuating products from the port of Beira to the hinterland, relieving the pressure on road and rail infrastructure. The pipeline is at capacity, with limited scope for further capacity increases in its current operational state.

Mozambique has rail networks in the North and the South, which have been used for transporting oil products – but cyclone damage has limited utilisation. Local marketers have reported delays, and losses can impede the economic potential of rail for the distribution of oil products. Tanker trucks are therefore the primary mode of transportation aside from the pipeline, mentioned above.

8.3 Bottleneck identification

The overall risk of supply chain disruption through the Maputo and Beira corridors is high, placing significant supply reliability risk on the six countries supplied via Mozambique as well as for Mozambique itself.

Key supply chain metrics are shown below, with orange highlighted elements indicating that there is high congestion in these supply chain nodes. The berth capacity, #35kt cargoes, demurrage costs, tank utilisation and pipeline capacity relate to the total volumes coming into each port. The metrics in the lower section of the table also relate to the total corridor volume to show the impact of the transit volumes in Mozambique. The fuel terminals in all ports of the country are managed directly by the state-owned company Empresa Nacional de Portos e Caminhos de Ferro de Moçambique (CFM). Public-private partnerships (PPP) under a concession regime, have become the principal port model for other commodities presenting an opportunity for PPPs in the fuel segment.

Mozambique Supply Corridors		Mozambique, Matola			Mozambique, Beira			Mozambique, Nacala			Mozambique, Pemba		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
Berth Capacity		high	high	high	high	high	high	low	low	low	low	low	low
35 kt Cargoes	#	39	61	78	84	111	151	15	19	24	3	4	5
Demurrage (est.)	$mn	2.8	4.4	5.7	188	248	337	1.2	1.6	2.0	0.2	0.3	0.4
Tank Capacity	turns/yr	Kero	Kero	Kero	low	gasoline	gasoline	low	low	low	low	low	low
Pipeline Capacity					high	max	max						

Mozambique Supply Chains		Mozambique, Matola			Mozambique, Beira			Mozambique, Nacala			Mozambique, Pemba			TOTAL Mozambique		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
CPP Throughput*	kt/yr	1,218	1,976	2,482	2,782	3,688	5,068	496	637	798	92	118	144	**4,588**	**6,418**	**8,492**
Local Demand	kt/yr	828	1,058	1,058	460	588	721	460	588	721	92	118	144	**1,840**	**2,352**	**2,646**
Local % of Corridor		68%	54%	43%	17%	16%	14%	93%	92%	90%	100%	100%	100%	**40%**	**37%**	**31%**
Truck Outs*	#/yr	33,967	55,085	69,183	40,059	60,934	98,895	13,816	17,753	22,260	2,565	3,278	4,023	**90,407**	**137,050**	**194,360**
Distance Driven*	000 km/yr	15,906	36,879	49,812	65,532	100,831	160,272	3,250	4,343	6,275	256	328	402	**84,945**	**142,381**	**216,761**
GHG Emissions (est.)*	mtCO_2e	16,955	38,667	51,578	72,413	111,418	177,101	3,592	4,799	6,934	283	362	444	**93,243**	**155,247**	**236,056**
Trucks in the Fleet*	#	223	460	602	706	1,065	1,675	69	89	118	12	14	17	**1,010**	**1,628**	**2,412**

** Includes transit volumes*

Table 5: Mozambique Supply Corridors.

Bottlenecks for specific nodes in the supply chain and recommendations are detailed below:

Maputo corridor: Ports

The Matola fuel terminal in the port of Maputo has three marine loading arms (MLAs) of 16" each for gasoline, Jet A1/kerosene and gasoil. Avgas comes through the Jet system. There is also a smaller 12" MLA for LPG. The terminal has just one jetty where discharge rates are limited due a line pressure cap. The port has a draft of 11.5m with maximum vessel sizes limited to 40-50kt. Generally, vessels carry more than one grade providing additional delays to discharges.

The jetty currently has excess capacity but it is anticipated that, as Durban becomes constrained, volumes supplying South Africa and Botswana will shift to the Maputo corridor. This will cause the berth to reach capacity around 2025 and be 56% over capacity by 2040.

The forecast throughput growth will result in the number of 35kt vessels growing by 90% by 2040 with a CAGR of 4.0%.

By 2040, demurrage in the port is forecast to grow to between $5-6 mn/yr. However, with improvements to discharge procedures and product evacuation rates, demurrage savings of $2.5-3.9 mn/yr are possible.

Matola Port Liquid Fuel Capacity Forecast

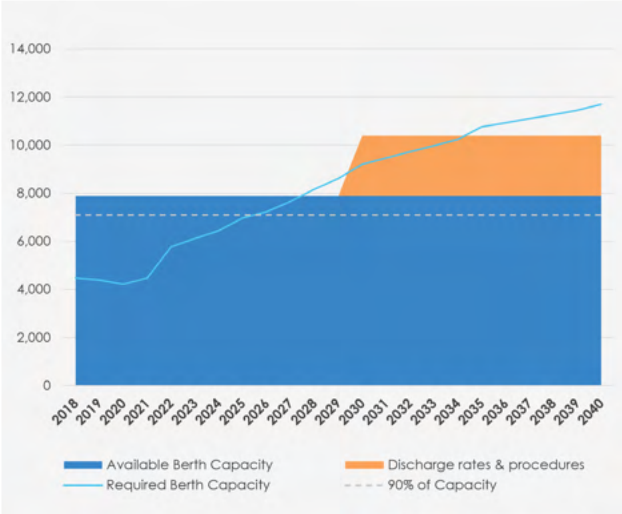


Figure 34: Matola Port Liquid fuel capacity.
Source: CITAC.

Gasoline, Jet A1, and gasoil tank turns in the port are forecast to rise to 7, 8 and 10 turns per year by 2040 with no additional capacity required.

Maputo corridor: Trucking

In 2022 approximately 34,000 truckloads of clean products left Matola and travelled a combined 16mn km, where part of this distance is inside Mozambique and part in neighbouring and destination countries. This is forecast to nearly double, reaching 70,000 loads by 2040. Gantry capacity, including loading bays, number of loading arms, and loading rates will need to be expanded to cater for this growth. A step change in the port inspection, customs and clearing efficiency is also required to debottleneck the evacuation.

Based on the total km driven by each truck, total GHG emissions from trucking oil products are estimated at 16.9kt CO_2e in 2022, rising to 52.0kt CO_2e by 2040.

Improving truck loading rates, discharge rates and streamlining clearing procedures have the potential to generate $20-25mn per year in reduced transport rates across the entire CPP volume moving through this corridor (cumulative $380mn between 2024 and 2040).

Maputo corridor: Conclusions

Expansion of berthing facilities in the port of Maputo will be needed as local and transit demand continue to grow, to reduce the risk of congestion and resulting demurrage. It is recommended that these requirements are modelled, and investment timelines established to avoid deteriorating supply economics.

Truck loading efficiency gains can be achieved by streamlining loading and evacuation rates as outlined above. Partly, the onus for this is on the government to investigate options for easing the burden of customs processes, and partly this onus will lie with private terminal and truck operators in the country to streamline these processes.

Beira corridor: Ports

The Beira liquid fuel terminal has two berths. The port has a draft of 11.5m with maximum vessel sizes limited to 40-50kt. Vessels generally carry more than one grade providing additional delays to discharges. Berthing is also limited by tidal conditions which can be countered by dredging or installing an SBM.

The berth is already constrained and will essentially grind to a halt as volumes grow. Volumes could be shifted to Nacala but the evacuation infrastructure from Nacala needs substantial investment for this to be feasible.

With improved pumping rates and efficiency gains in discharge procedures and additional equipment, tugs, pilots, and staff could result in a capacity increase of as much as 30%. This however does not alleviate the bottleneck sufficiently.

An additional berth (with the same capacity as the current berths) will provide an additional 50% capacity and debottleneck the port out to about 2035. Ideally, 2 additional berths or an SBM are required to properly debottleneck this corridor.

Beira Port Liquid Fuel Capacity Forecast

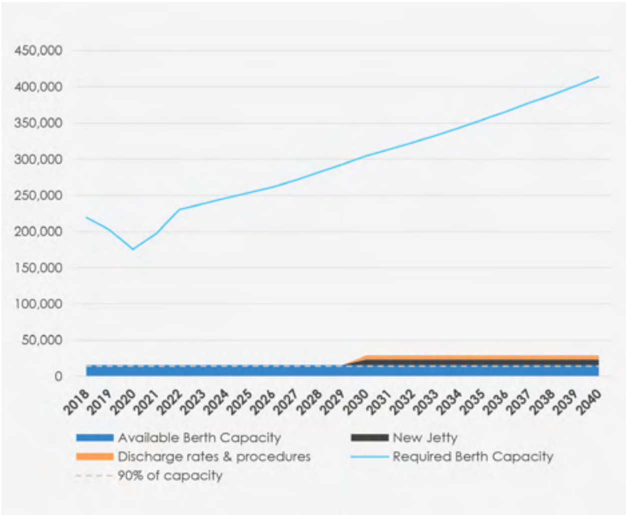


Figure 35: Beira Port Liquid fuel capacity forecast. Source: CITAC.

Approximately 84, 35kt equivalent cargoes discharged in 2022 but this is forecast to increase 4 times to 151 vessels by 2040.

Demurrage is currently in the region of $190mn per year and will grow to $337mn by 2040. The existing berth is already over its 'maximum' capacity, hence an additional berth together with additional tugs and pilots are also required to improve berthing and line-up times. With these improvements, demurrage savings of $200-300mn a year can be realised.

Gasoline tankage is expected to become constrained by 2034 and will see tank turns rise to around 15 by 2040 requiring additional investment in tankage. Jet, kerosene and gasoil tank turns in the port are forecast to rise to 5, 2 and 7 turns per year by 2040 with no additional capacity required.

Beira corridor: Trucking

In 2022, approximately 40,000 truckloads of clean product were evacuated, which travelled a combined 66mn km, where part of this distance is inside Mozambique and part in neighbouring and destination countries. This is forecast to grow by 147% to 99,000 loads by 2040. Gantry capacity including loading bays, number of loading arms and loading rates will need to be expanded to cater for this growth. A step change in the port inspection, customs and clearing efficiency is also required to debottleneck the evacuation.

Based on the total km driven by each truck that uses the Beira corridor, GHG emissions are estimated at 72kt CO_2e in 2022, rising to 177kt CO_2e by 2040.

Improving truck loading rates, discharge rates and streamlining clearing procedures has the potential to generate $30-50mn per year in reduced transport rates across the entire CPP volume moving through this corridor (cumulative $700mn between 2024 and 2040). The saving comes through increased truck utilisation which significantly impacts the volume over which the fixed cost element in the transport fee is covered.

Beira corridor: Rail

Rail on the Beira-Harare route will cost in the region of \$15/m³ compared to road bridging at \$32/m³. Beira-Tete will cost \$35/m³ vs. \$54 /m³ on road. Liquid fuel volumes in this corridor are unlikely to justify the extension of, say, the Beira-Tete line into Blantyre or Lusaka but if the line also connected the Zambian copper belt and southern DRC mines to Beira, this could justify the investment enabling the freight savings to be realised with a consequential reduction in GHG emissions of 300% through shifting volumes onto rail.

Availability of rail cars, more rail car maintenance, availability of locomotives and sub-standard loading and offloading facilities make rail unattractive without substantial upgrades in capacity and operating efficiencies.

Beira corridor: Pipelines

A 10" multi-products pipeline runs between Beira and the Mutare terminal in Harare covering a distance of 208km with a maximum capacity of 150kt per month. The Zimbabwe demand for gasoline and gasoil alone exceeds the available capacity in the pipeline

Two expansion options have been proposed: the first will increase the capacity to 200 kt/month (2,400kt per yr) and the second to 300 kt/month (3,600 kt per yr).

The capacity needed in the chart to the right shows gasoline and gasoil volumes only for the Mozambican market supplied via Beira and the Beira corridor demand destined for Zimbabwe, southern Zambia and the DRC. Supplying Malawi via Harare would be sub-optimal.

Beira Pipeline Capacity

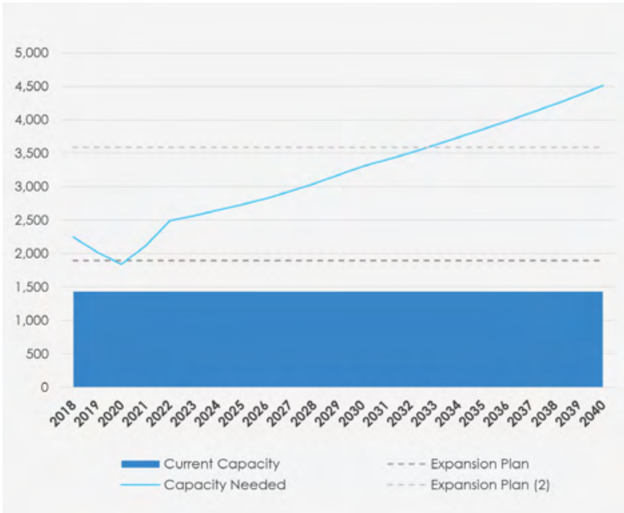


Figure 36: Beira Pipeline Capacity.
Source: CITAC.

The current road bridging cost from Beira to Mutare is around \$69/m³ and the current NOICZIM pipeline fee is \$45/m³. Replacing the existing line with a 20" line is required to carry the corridor gasoline and gasoil transit volumes out to 2040 and beyond, estimated to cost \$260 mn. This includes the Zambia & DRC volumes in this corridor shifting to this new pipeline and then being road bridged to Zambia and DRC respectively. Based on a 20% cost of capital, 15-year payback period and forecast volumes, the capital recovery cost is just 11-13 \$/m³ as the distance covered is quite short, providing approximately \$35/m³ before operating costs to pay back the investment. The added benefit of placing more product into a pipeline is the 'unlock' this provides with loading trucks in the Beira port as well as GHG reductions and decreased impact on the road infrastructure. The congestion may however just move to Mutare unless a new 'state of the art' terminal in Mutare with efficient clearing processes is included in this supply chain. A 14-inch pipeline will suffice to move just the Zimbabwe gasoil and gasoline demand out to 2040. Again, due to the short distance of just 208km between Beira and Harare, the capex for the smaller diameter line is forecast to be \$39mn providing a breakeven of 16\$/m³ (based on the same cost of capital and payback period).

A pipeline extension from Mutare to Lusaka (or Ndola) could carry the Zambia, Malawi and DRC volumes currently moving in the Beira corridor. This demand (out to 2040 and beyond) will require a 14" pipeline covering 760km and will have an estimated capital cost of \$665mn. Amortising this over 15 years with a 20% payback will result in a capital recovery of 70-80\$/m³, compared to the existing road bridging cost over that distance of 80\$/m³ which could be driven down to \$65/m³ if loading and discharge rates, together with clearing procedures in Beira and across the border are streamlined. Such a pipeline is therefore feasible and worth developing a more detailed business case.

Beira corridor: Conclusions

Beira port is already heavily congested and requires debottlenecking, either through the construction of onshore berth capacity or the installation of an SBM in order to reduce the significant demurrage currently being accrued by vessels in the port.

The 150% increase in trucking volumes by 2040 will generate significant congestion on road routes out of Beira. The challenges for the government and private sector will be to find a solution to this. Pipelines or rail solutions could be developed and enhanced to shift volumes of product off the roads, thereby debottlenecking major road arteries. The above-suggested expansion to the NOICZ pipeline through the installation of a larger line, along with extensions beyond Mutare present an attractive option, given the proven success of the pipeline currently serving this trajectory. This would require government to governments agreements to realise. More efficient operations of the rail network, and investment in new locomotives and capacity would further provide an alternative to ever-growing truck volumes.

Nacala corridor: Ports

The Port of Nacala is the largest deep-water natural harbour on the East African coast. It has one fuel jetty with three loading arms and a draft of 60m+ enabling vessels carrying 200kt to berth. Demand through the corridor is just 10% of the volumes moving through Beira with some 90% of the volume consumed in the local Nacala area (very little transit volumes).

The berth is not constrained, and the port has sufficient tankage in all grades out to 2040 based on current corridor splits with gasoline, Jet A1/Kero and gasoil reaching 12, 4 and 10 turns by 2040.

Currently the equivalent of 15 35kt vessels call each year, rising to 24 by 2040. Demurrage is estimated at $1mn a year, rising to $2mn by 2040. Demurrage is not due to berth congestion but rather due to slow pumping rates and inefficient operating procedures.

Nacala corridor: Trucking

In 2022, approximately 13,800 truckloads moved the clean product demand which travelled a combined 3.25mn km, mostly inside of Mozambique, to supply the local demand. This is forecast to grow by 60% to 22,300 loads by 2040. Gantry capacity including loading bays, number of loading arms and loading rates will need to be expanded to cater for this growth.

Based on the total km driven by each truck, GHG emissions are estimated at 3.6kt CO_2e in 2022, rising to 6.9kt CO_2e by 2040.

Improving truck loading rates, discharge rates, and streamlining clearing procedures has the potential to generate $5-6mn per year in reduced transport rates across the entire CPP volume moving through this corridor, for a cumulative saving of $98mn. The saving comes through increased truck utilisation which significantly impacts the volume over which the fixed cost element in the transport fee is covered.

Nacala corridor: Rail

Rail lines currently run from Nacala to Blantyre. However, reliability of rail in the Malawi supply corridors has caused oil marketing companies to favour road deliveries. Up to 20% of Malawi demand used to come through this corridor. In March 2023, rail lines were washed away by the cyclone that hit the area, causing supplies to the hinterland to drop down to just 10% currently.

Poor road infrastructure and connectivity to major East African hubs has resulted in under development of the port infrastructure. Furthermore, poor efficiency, lack of rail cars and locomotive availability, as well as poor rail loading equipment in the port has left this corridor under-utilised despite the deep and uncongested port.

Opportunities exist to repair the rail lines and invest in efficient reliable rail sidings and equipment.

Fuel volumes alone are unlikely to incentivise the government to make these investments. The Nacala rail line goes to Tete, across the southern part of Malawi. A Brazilian company owns and utilises the line 99% for transporting coal from their Phala mine to Nacala whilst little to no fuel runs down this line. Extending the line, from Tete to where the Zambia and DRC mines are located, could provide the additional tonnage needed to justify the upgrades needed.

Construction of sufficient siding space, additional loading bays, loading arms and pumps for efficient loading of rail tank cars will cost $4-6mn per terminal with an additional investment of $20,000 per rail tank car to obtain and refurbish a dedicated fleet of rail cars.

Rail from Nacala to Blantyre will cost in the region of $60/m^3 compared with $77/m^3 for road, providing a cost saving with an associated 300% reduction in GHG emissions on a g/mt-km basis.

Nacala corridor: Pipelines

Potential exists to build a pipeline between Nacala and Blantyre (or Lilongwe) with smaller lines fanning out from Blantyre to Harare as well as Lusaka, Ndola, and Lubumbashi.

The trunk line would need to be 14", however the linking lines could be smaller. A line of 14" average diameter running 2,500km will cost in the region of $2.2bn. If all Mozambique transit volumes in the Beira corridor moving to Zambia, Malawi and DRC were to move in this new pipeline, a capital recovery cost of 165-185$/m^3 is required, assuming a 20% cost of capital and 15-year payback.

Road bridging costs over 2,500km are currently $215/m^3 with potential to reduce this to $155/m^3 if port congestion bottlenecks are reduced, making it worth developing an investment like this further.

Nacala corridor: Conclusions

Nacala presents a major opportunity for debottlenecking regional supply chains. The uncongested, deep draft port allows for large vessels to berth, providing strong economies of scale.

The challenge for the government is to develop the infrastructure at the port and, perhaps more importantly, between the port and key demand centres. This could involve the expansion of the rail network or the development of a more robust road system to facilitate efficient evacuation of products. Equally, a pipeline solution would allow for efficient evacuation at scale, as detailed above.

9. Country focus: Namibia

743,000	2.6%/y	647kt	2.8%
Population growth 2023 - 2040 (World Bank)	Average annual GDP growth 2023 - 2028 (IMF)	CPP imports increase 2022 - 2040	CPP imports CAGR 2022 - 2040

9.1 Oil product supply and demand

Namibia clean product demand grew to 1mn mt in 2022, up 21% in a decade. Demand faltered during the pandemic as the tourism industry contracted significantly, but the market has since recovered.

Namibia acts as a conduit for products to Botswana, Zambia, South Africa, and Southern DRC, although due to the significant distances involved, these volumes are relatively small.

Domestic clean product demand is forecast to rise by 56% to 1.4mn mt by 2040. The increase in hinterland demand will see total imports for domestic, together with transit volumes, rise by 64% to 1.7mn mt in 2040.

9.2 Overview of supply chain

Namibia has a relatively simple supply chain: products are imported predominantly into Walvis Bay, from where they are transported by truck mainly to onward destinations (either domestic or transit). There is some rail used for oil product transportation, although marketers have reported inefficiencies in the operation of the rail network, which has resulted in minimal volumes being transported by rail in the country.

There is another port, at Lüderitz, which receives some small volumes to support mining operations in the south of the country. Products are evacuated from the port by truck.

Namibia has 268,000m³ of clean product storage. 90% of this is concentrated in Walvis Bay.

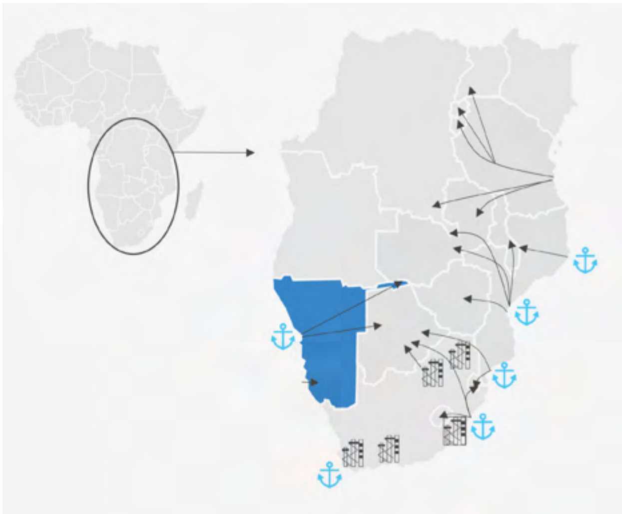


Figure 37: Namibia supply chain map.

9.3 Bottleneck identification

The overall supply chain risk in Namibia is low with subsequent low risk to countries receiving transit volumes via Namibia.

In the table below the berth capacity, #35kt cargoes, demurrage costs, tank utilisation, and pipeline capacity relate to the total volumes coming into each port. The metrics in the lower section of the table also relate to the total corridor volume to show the impact of the transit volumes in Namibia, though only 10% of volumes transit through to Botswana currently.

Namibia Supply Corridors		Namibia, Walvis Bay		
		2022	2030	2040
Berth Capacity		low	low	low
35 kt Cargoes	#	34	42	54
Demurrage (est.)	$mn	1.6	2.0	2.5
Tank Capacity	turns/yr	low	low	low

Namibia Supply Chains		Namibia, Walvis Bay			Botswana, Walvis Bay			TOTAL Namibia		
		2022	2030	2040	2022	2030	2040	2022	2030	2040
CPP Throughput*	kt/yr	918	1,142	1,432	88	130	222	**1,006**	**1,272**	**1,653**
% of Corridor Volume		91%	90%	87%	9%	10%	13%			
Truck Outs*	#/yr	25,593	31,839	39,909	2,451	3,635	6,182	**28,043**	**35,474**	**46,090**
Distance Driven*	000 km/yr	20,218	25,152	31,528	7,353	10,905	18,545	**27,571**	**36,058**	**50,072**
GHG Emissions (est.)*	$mtCO_2e$	22,341	27,793	34,838	8,125	12,051	20,492	**30,466**	**39,844**	**55,330**
Trucks in the Fleet*	#	239	296	370	75	110	181	**314**	**406**	**551**

** Includes transit volumes*

Table 6: Namibia Supply Corridors.

Bottlenecks for specific nodes in the supply chain and recommendations are detailed below:

Ports

The Walvis Bay fuel terminal consists of the Namcor jetty with 15m draft, which can accommodate two vessels simultaneously, but they must discharge different grades. There is also a smaller, older berth with 8m draft used primarily for aviation fuels.

Generally, all transit volumes and offshore volumes move through this port. Vessels generally carry more than one grade providing some delays to discharges.

The jetties currently have excess capacity out to 2040 and beyond.

Currently the equivalent of 34 35kt vessels discharge each year in Walvis Bay, which is forecast to rise to 54 vessels per year by 2040 (60% growth).

Demurrage in the port is currently estimated to be $1.6mn per year, growing to $2.5mn by 2040. Increasing discharge rates and speeding up berthing times and line displacements can save this cost entirely.

Walvis Bay Port Liquid Fuel Capacity Forecast

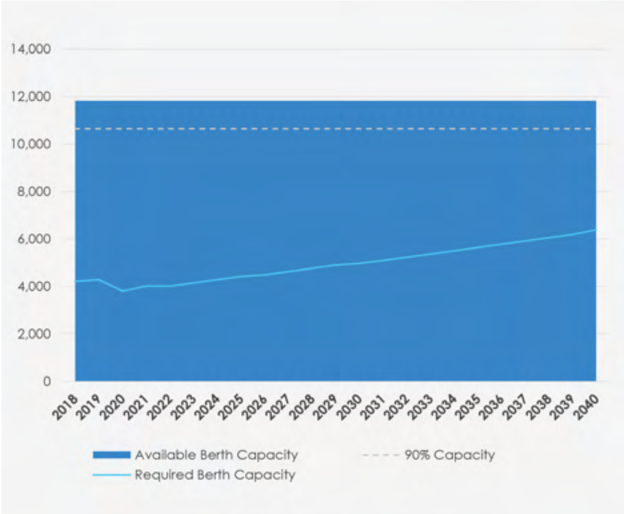


Figure 38: Walvis Bay Port Liquid fuel capacity forecast. Source: CITAC.

There are no tankage constraints in the port over the forecast period with gasoline, Jet A1/IK and gasoil tank turns rising to 10, 3 and 11 turns per year respectively by 2040 with no additional capacity required. Additional capacity would offer greater optionality for multiple players to import simultaneously, which today leads to ullage constraints – particularly for gasoline, according to local players.

If 100% of the Zambia and Botswana demand currently moving through other supply chains shifts to the Walvis Bay corridor today, then the berths would already be constrained. If such a switch were to happen, berth capacity would need to double by 2040 with subsequent investment in gasoline and gasoil tankage as well as gantry capacity.

The port of Lüderitz has 7,000m^3 of storage, draft of 7.5m and a maximum LOA of 160m due to a small turning circle. The jetty is also dedicated to fuels hence berthing is along the quay side. These constraints result in the cost to ship smaller quantities exceeding the $30/m^3 location differential allowed in the price structure. Generally, just gasoil is supplied through Lüderitz.

Trucking

In 2022, approximately 28,000 truckloads of clean products left the port and travelled a combined 28mn km, where most of this distance is inside Namibia. This is forecast to grow by 65% to 46,100 loads by 2040, driving a combined 50mn km in the year. Gantry capacity, including loading bays, number of loading arms, and loading rates are sufficient for the forecast period and forecast transit volumes.

Based on the total km driven by each truck, GHG emissions are estimated at 30.5kt CO_2e in 2022, rising to 55.3kt CO_2e by 2040.

Truck loading in Walvis Bay is quite efficient but long-hauling on poor roads to outlying areas of the country impacts on truck utilisation rates. Efficiency gains could be realised if road conditions were improved, generating fleet savings of $5-6mn per year based on the current volumes flowing through this corridor. The saving comes through increased truck utilisation which significantly impacts the volume over which the fixed cost element in the transport fee is covered.

Rail

Railage rates between Walvis Bay and Windhoek are $22/m^3 compared to $24/m^3 by truck, where transporters typically benchmark their rates against the rail rates since the railage rate sets the recovery in the price structure.

The Trans-Kalahari Railway project envisages a 1,500km rail link between Walvis Bay, Gaborone and the mining district northeast of Gaborone near the South African border. The project is on hold, however, and liquid fuel volumes would not justify this investment without the accompanying mining tonnage.

Railage rates could be in the region of $115/m^3, compared to $146/m^3 to road bridge fuel across the same distance. The challenge faced in Namibia is inefficiency in rail operations, according to local companies, which results in significant haulage continuing to be moved by road tanker. The challenge for Namibia therefore is to improve the efficiency of the rail network to attract volumes that are currently being trucked inland.

Pipelines

If the full Botswana and Zambia volumes all shifted to the Walvis Bay corridor a 1,500km 14" pipeline would be required to carry this volume to Gaborone out to 2040 and beyond. The capital cost of the line would be $1.3bn, requiring a transport fee of 110-125$/m^3 based on a 20% cost of capital and a 15-year payback. Road bridging rates over the same distance are currently 105-125$/m^3, making such a pipeline viable. However, since most of the demand is concentrated between Walvis Bay, Windhoek and Luderitz, a network of smaller lines is likely more optimal.

Conclusions

Namibia's supply chains are uncongested. The main port of Walvis Bay has additional capacity open to it and evacuation from the port to the hinterland is unobstructed. Efficiency gains are possible through increased uptake of rail – this would be key in displacing trucks from the road as volumes for the Namibian and transit markets continue to grow over the forecast period.

10. Country focus:

Tanzania

37.5mn
Population growth
2023 - 2040
(World Bank)

2.9%/y
Average annual
GDP growth
2023 - 2028 (IMF)

3.8mn mt
CPP imports
increase
2022 - 2040

2.6%
CPP imports
CAGR
2022 - 2040

10.1 Oil product supply and demand

Tanzania is one of the larger markets in the region, with clean product demand of 3.4mn mt in 2022. This is 53% higher than a decade ago, with growth having been supported by economic expansion over this period.

The market is supplied by imports only, with infrastructure having to support the import of products for the domestic market as well as transit markets such as Zambia, Malawi, Burundi, Rwanda, Uganda, and Eastern DRC subject to pricing and availability. In 2022, 2.7mn mt of product transited Tanzania. In 2022, therefore, 6.3mn mt of oil products was imported into Tanzania.

A steady economic outlook and continued expansion of the vehicle fleet underpins a forecast rise of 49% in Tanzanian clean product demand to 5.1mn mt in 2040. The increase in hinterland demand meanwhile will see total CPP imports for domestic together with transit volumes rise 64% to 9.8mn mt in 2040 from 2022 levels of 6mn mt.

10.2 Overview of supply chain

Tanzania has three primary ports for oil product imports: Dar es Salaam, Tanga, and Mtwara. Of these, Dar es Salaam is the largest, handling 90% of total clean product imports in 2022.

Evacuation has traditionally been predominantly by trucks. However, the conversion of the crude oil pipeline linking Tanzania to Zambia in 2022 has allowed clean products to be transported along its length. The pipeline is currently used exclusively for gasoil. There is also a rail network in Tanzania linking Dar es Salaam and Tanga to Mwanza and Kigoma in Tanzania as well as to Zambia. Currently, rail is used mainly to serve the trajectory of Dar es Salaam-Zambia/Malawi.

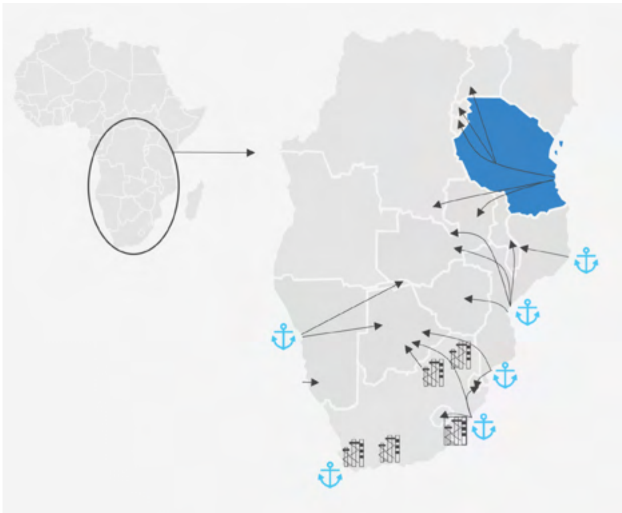


Figure 39: Tanzania supply chain map.

Dar es Salaam Corridor, Throughput by Country

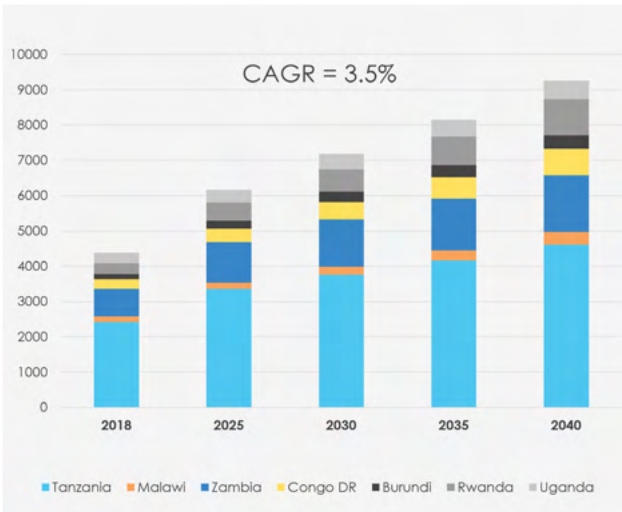


Figure 40: Dar es Salaam Throughput.
Source: CITAC.

10.3 Bottleneck identification

The overall supply chain risk in the Dar es Salaam corridor is currently medium, growing to high by 2030 as congestion threatens smooth import operations. This will place significant supply reliability risk on the seven countries supplied through this corridor in the medium term. Key supply chain metrics are shown below.

In the table below, the berth capacity, #35kt cargoes, demurrage costs, tank utilisation, and pipeline capacity relate to the total volumes coming into each port. The metrics in the lower section of the table also relate to the total corridor volume to show the impact of the transit volumes in Tanzania.

Tanzania Supply Corridors		Tanzania, Dar es Salaam			Tanzania, Tanga			Tanzania, Mtwara		
		2022	2030	2040	2022	2030	2040	2022	2030	2040
Berth Capacity		medium	high	high	low	low	low	low	low	low
35 kt Cargoes	#	84	111	151	15	19	24	171	226	297
Demurrage (est.)	$mn	188	248	337	1.2	1.6	2.0	14.0	18.5	24.3
Tank Capacity	turns/yr	low	low	gasoline	low	low	low	low	low	low
Pipeline Capacity		high	max	max						

Tanzania Supply Chains		Tanzania, Dar es Salaam			Tanzania, Tanga			Tanzania, Mtwara			TOTAL Tanzania		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
CPP Throughput*	kt/yr	5,600	7,182	9,256	293	355	436	52	63	77	**5,945**	**7,600**	**9,768**
Local Demand	kt/yr	3,100	3,762	4,613	293	355	436	52	63	77	**3,444**	**4,180**	**5,125**
Local % of Corridor		55%	52%	50%	100%	100%	100%	100%	100%	100%	**58%**	**55%**	**52%**
Truck Outs*	#/yr	162,567	214,252	281,678	8,162	9,906	12,145	1,440	1,748	2,143	**172,170**	**225,906**	**295,966**
Distance Driven*	000 km/yr	249,404	347,568	476,062	4,081	4,953	6,073	432	524	643	**253,917**	**353,046**	**482,778**
GHG Emissions (est.)*	$mtCO_2e$	275,591	384,063	526,049	4,510	5,473	6,710	477	579	711	**280,578**	**390,115**	**533,470**
Trucks in the Fleet*	#	2,212	2,975	3,977	61	74	90	11	12	14	**2,284**	**3,061**	**4,081**

** Includes transit volumes*

Table 7: Tanzania Supply Corridors.

Bottlenecks for specific nodes in the supply chain and recommendations are detailed below:

Ports

The Dar es Salaam (DES) liquid fuel terminal has two berths and a Single Point Mooring (SPM) facility for product discharges. The berths have drafts of 14.7m and 7m respectively. The draft at the SPM is 25m, enabling 150kt vessels to moor and discharge. Vessels generally carry more than one grade providing additional delays to discharges as line-ups are changed and common pipelines flushed.

Improved pumping rates and efficiency gains in discharge and line-flushing procedures as well as additional equipment (such as tugs, pilots) and staff could enable a 30% increase in capacity. This will push the forecast berth constraint out beyond 2040.

Approximately 170 35kt equivalent cargoes discharged in 2022. This will increase by 74% to 297 by 2040.

Demurrage is currently in the region of $14-16mn per year and will grow to $23-25mn by 2040. With additional tugs, pilots, and line-up times, demurrage savings of $10-12mn a year can be realised.

There are no tankage constraints in the port currently and only gasoline tankage is expected to become constrained by 2040.

DES Port Liquid Fuel Capacity Forecast

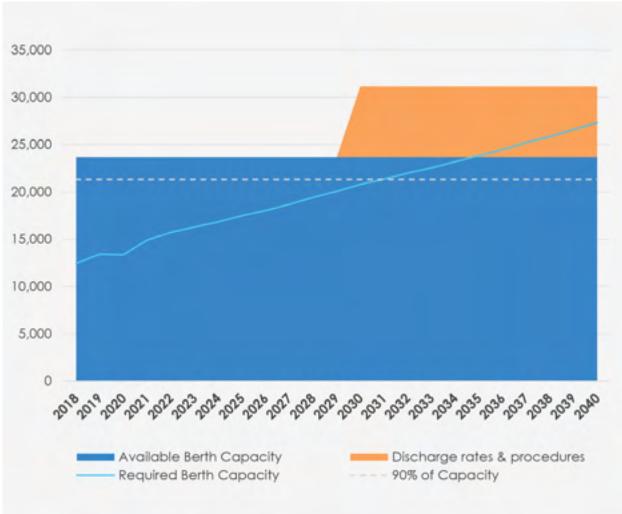


Figure 41: Dar es Salaam port liquid fuel capacity forecast. Source: CITAC.

Trucking

In 2022, approximately 163,000 truckloads moved clean products demand out of the Dar es Salaam port which travelled a combined 250mn km, where part of this distance is inside Tanzania and part in neighbouring and destination countries. This is forecast to grow by 72% to 282,000 loads by 2040. Gantry capacity including loading bays, number of loading arms, and loading rates will need to be expanded to cater for this growth. Improvements in the port inspection, customs and clearing efficiency is also required to improve evacuation efficiency.

Based on the total km driven by each truck that uses the Dar es Salaam corridor, GHG emissions are estimated at 276kt CO_2e in 2022, rising to 526kt CO_2e by 2040.

Improving truck loading rates, discharge rates and streamlining clearing procedures - together with upgrades to road networks to enable higher average driving speeds - has the potential to generate $130-150mn per year in reduced transport rates across the entire CPP volume moving through this corridor (cumulative $2bn between 2024 and 2040). The saving comes through increased truck utilisation which significantly impacts the volume over which the fixed cost element in the transport fee is covered.

Rail

The Tanzanian Rail Company (TRC) has a modern, efficient rail loading facility in Dar es Salaam, capable of loading 22 rail cars across two parallel racks operated by two separate entities: one side for TAZARA gauge and the other for the older, TRC gauge. The tariff on the line to Mbeya is $60/m³ compared to $77/m³ on road, providing an incentive to use this mode of transport. Product can then either be road bridged into Malawi ($77/m³) or continue by rail to Ndola ($66/m³). The full DES-Ndola rail cost of $126/m³ is a significant increase compared to the current $36/m³ Tazama tariff, but sufficiently less than the current $170/m³ road bridging cost from DES to Ndola which would justify investments to improve the efficiency and reliability of the rail supply chain.

Switching volumes to rail has the added benefit of reducing GHG emissions from 30-40 g/mt-km to 7-12 g/mt-km.

There is potential to construct a rail link from Mbeya to Lilongwe which will need to cover approximately 700km. At a cost of $1.5 mn/km, the investment to build this line will be $660mn, requiring a tariff of $229/m³ to pay back this investment in 15 years assuming a 20% cost of capital. The road cost on this route is currently approximately $54/m³, making this investment difficult to justify.

Pipelines

A pipeline runs between Dar es Salaam and the mothballed Indeni Refinery in Ndola, passing the northern border of Malawi at Mbeya. The line is designed to carry 1100 kt/yr and the current tariff is $45/mt ($36/m³), plus $6/mt ($5/m³) storage fee in Ndola.

The first section is 8" in diameter and covers 954km and a second 12" covers 758km. The line was built to carry crude oil to the Indeni refinery but has been converted to diesel service since the refinery closed in 2022.

The line currently only carries 80% of Zambia's gasoil demand. On this basis the line is underutilised currently but will hit maximum capacity around 2028.

The capacity needed shown on the chart includes the full gasoline and gasoil demands for Zambia and Malawi and 25% of the DRC gasoline and gasoil demand.

Plans to inject flow improvers provide a small expansion of the maximum capacity, pushing out the timing of the Zambia diesel constraint, but has limited impact on trucking volumes in the corridor.

Dar es Salaam Pipeline Capacity

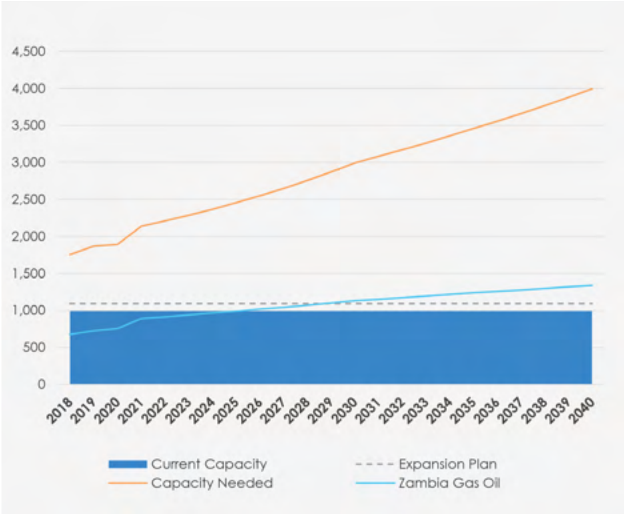


Figure 42: Tazama pipeline capacity forecast.
Source: CITAC.

A 20" line is required to pump the full capacity needed shown in the chart above out to 2040. This is estimated to cost $2.2bn and will require a throughput fee of 125-140$/m³ to pay back this investment based on forecast volumes, a 20% cost of capital, and a 15-year payback. Smaller offtake lines from Mbeya to Lilongwe and Ndola to Lubumbashi could reduce the overall investment but then have smaller volumes from which to pay back the construction costs.

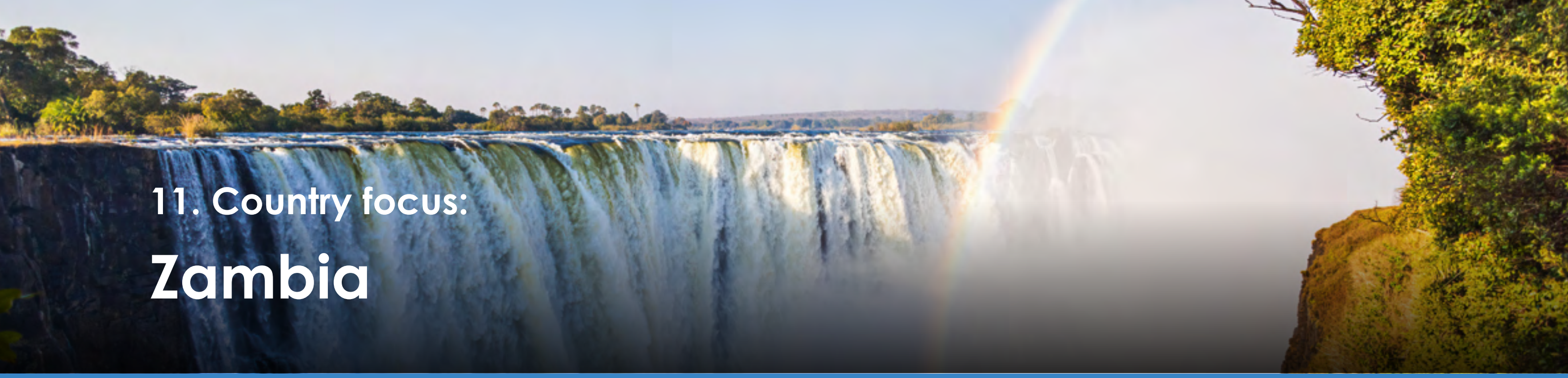
The current road tariffs to Ndola, Lilongwe, and Lubumbashi are $170, $145 and $157/m³ respectively, making this pipeline investment viable. This will however result in a substantial increase over the existing pipeline tariff of 46$/m³ and will flow through into the inland market pricing structures to recover the higher pipeline tariff required.

The benefit of placing more product into a pipeline is the 'unlock' this provides with loading trucks in the Dar es Salaam port, as well as GHG reductions and decreased impact on the road infrastructure.

Conclusions

The growing demands on the port from rising oil product consumption in Tanzania and transit markets is set to drive growing congestion around key ports, namely Dar es Salaam. Additional berth infrastructure projects or an additional SBM are therefore worth considering.

Expansion of rail capacity and improvements in efficiency are also key to debottlenecking the congested roads around the city of Dar es Salaam. The pipeline already plays a key role here, and additional capacity in the form of flow accelerators or a larger diameter pipe would further help to facilitate more efficient evacuation from the port of Dar es Salaam to the hinterland.



11. Country focus: Zambia

10.5mn
Population growth 2023 - 2040 (World Bank)

4.6%/y
Average annual GDP growth 2023 - 2028 (IMF)

989kt
CPP imports increase 2022 - 2040

2.7%
CPP imports CAGR 2022 - 2040

11.1 Oil product supply and demand

Zambia's oil product demand has risen 56% in a decade to reach 1.6mn mt per annum. This growth has been driven by an expanding vehicle fleet and growing activity in energy-intensive industries such as mining.

Historically the market was supplied by a combination of imports and output from the Indeni refinery, but the Indeni refinery ceased operations in 2021 leaving the country reliant solely on imports of oil products.

Domestic clean product demand is forecast to rise by 61% to 2.6mn mt by 2040.

11.2 Overview of supply chain

Zambia is today supplied exclusively by product imports. These are conducted either by road tanker or product pipeline. The country is linked to the port of Dar es Salaam by the TAZAMA pipeline, a facility which was previously used for the transportation of crude oil for the now shuttered refinery, which now carries low sulphur gasoil for the domestic market at a rate of 840,000mt per year. Road tankers are used to transport products from the port of Beira, with some additional road tankers used to bolster supply from Tanzania.

Zambia has a total of 220,382m^3 of clean product storage. The split between Zambia's two main supply corridors is as follows: 35% via Beira and 65% via Dar es Salaam (DES). Supply via Nacala is possible though not used currently. There are also occasional imports from Walvis Bay in Namibia.

The swing in corridor weighting by 2040 is because 70% of the gasoline supply comes through Beira, whereas 80% of the gasoil comes through Dar es Salaam. Zambian gasoline demand is forecast to grow at 4.6% CAGR over the period and gasoil at 3.1% CAGR. Barring any additional pipeline construction, no change in the sourcing splits is forecast however, supply could be shifted from the congested Beira and Dar es Salaam corridors to Nacala. Road infrastructure from Nacala to Zambia is poor, impacting driving time as well as wear and tear on the trucks.

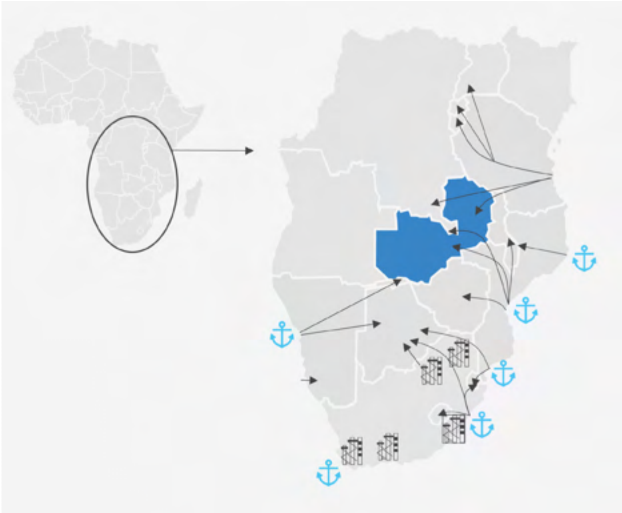


Figure 43: Zambia supply chain map.

Zambia Supply by Transit Corridor

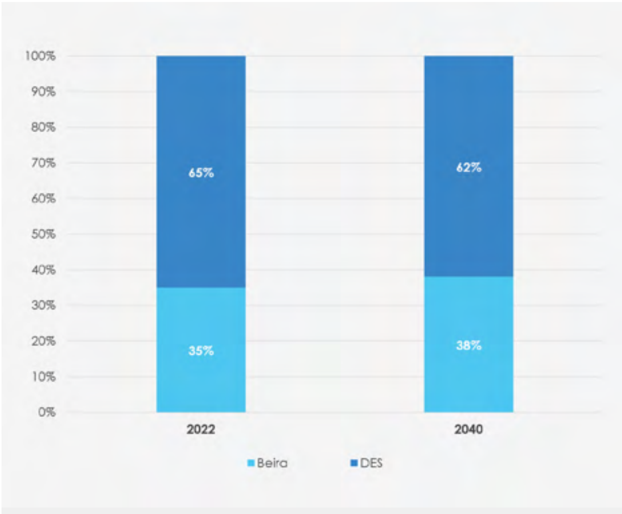


Figure 44: Zambia supply by transit corridor. Source: CITAC.

11.3 Bottleneck identification

In the Zambia supply corridors shown below, the berth capacity, #35kt cargoes, demurrage costs, and tank utilisation relate to the total volumes flowing through each of the two supply ports. Zambia will contribute its proportional volume share to each of these items and costs. The orange highlighted cells represent heavily congested nodes in the supply chain, or infrastructure that is at capacity. The metrics in the lower section of the table relate only to volumes in the Zambia supply chains in each supply corridor.

Zambia Supply Corridors		Mozambique, Beira			Mozambique, Nacala			Tanzania, Dar es Salaam			Namibia, Walvis Bay		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
Berth Capacity		high	high	high	low	low	low	low	medium	high	low	low	low
35 kt Cargoes	#	84	111	151	0	0	0	171	226	297	34	42	54
Demurrage (est.)	$mn	188	248	337	0.0	0.0	0.0	14.0	18.5	24.3	1.6	2.0	2.5
Tank Capacity	turns/yr	low	gasoline	gasoline	low	low	low	low	low	gasoline	low	low	low
Pipeline Capacity		high	max	max				high	max	max			

Zambia Supply Chains		Mozambique, Beira			Mozambique, Nacala			Tanzania, Dar es Salaam			Namibia, Walvis Bay			TOTAL Zambia		
		2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040	2022	2030	2040
CPP Demand	kt/yr	564	779	991	0	0	0	1,050	1,337	1,612	0	0	0	**1,614**	**2,115**	**2,603**
% of Corridor Volume		35%	37%	38%	0%	0%	0%	65%	63%	62%	0%	0%	0%			
Truck Outs	#/yr	15,070	20,971	26,740	0	0	0	30,483	39,872	49,065	0	0	0	**45,552**	**60,843**	**75,804**
Distance Driven	000 km/yr	31,797	44,250	56,421	0	0	0	112,481	147,126	181,048	0	0	0	**144,278**	**191,376**	**237,469**
GHG Emissions (est.)	$mtCO_2e$	35,136	48,896	62,345	0	0	0	124,291	162,574	200,059	0	0	0	**159,427**	**211,470**	**262,404**
Trucks in the Fleet	#	331	459	584	0	0	0	839	1,069	1,292	0	0	0	**1,170**	**1,528**	**1,876**

Table 8: Zambia Supply Corridors.

Bottlenecks for specific nodes in the supply chain and recommendations are detailed below:

Ports

The major constraints in the Zambian supply chains are the berth capacity in Beira and, in the longer term, the berth capacity in Dar es Salaam. Gasoline tankage becomes constrained in Beira in 2034 and in Dar es Salaam in 2040.

Trucking

Zambian supply in 2022 comprised 15,000 truckloads from Beira, and 30,500 loads from Dar es Salaam, making a total of 45,500 truck deliveries into Zambia, either direct to customers or via the Lusaka & Ndola terminals. Total loads are forecast to grow by 66% to 76,000 total truck deliveries into Zambia by 2040.

If truck loading and clearing procedures can be improved and streamlined and, average driving speeds increased, savings in the Zambian supply chains alone are estimated at $12-18 mn/yr in the Beira corridor ($260mn in cumulative savings between 2024 and 2040) and between $35-45 mn/yr in the Dar es Salaam corridor Bay ($658mn in cumulative savings between 2024 and 2040), giving an incentive of around $920mn over the next 15 years to improve truck turnaround times in Beira and Dar es Salaam. The efficiency gain is through improved truck utilisation due to quicker turnaround times where the fixed cost is covered by a greater volume hauled in each month per truck.

The added benefit of improved efficiency is that the number of trucks in the fleet can also be decreased by around 20%.

GHG emissions from trucks bridging fuel to Zambia were 159kt CO_2e in 2022, forecast to rise to 262kt CO_2e by 2040 if all volumes (that exceed the pipeline capacity) continue to move via road.

Pipelines

The Tazama pipeline from Dar es Salaam to the Indeni refinery in Ndola has a maximum capacity of 1,100 kt/yr and the current tariff is $45/mt ($36/m³) plus $6/mt ($5/m³) storage fee in Ndola. Only gasoil moves in this line, which is currently running at its maximum capacity, though it has 10% creep expansion possible if flow improver is injected. Detailed discussion of the Beira, Nacala and Dar es Salaam corridors including pipeline and rail expansion options and indicative transport rates are in the Mozambique and Tanzania sections respectively, where the Zambia volumes will pick up their share of costs, benefits and GHG emission reductions.

A side case looking at the potential of a pipeline from Walvis Bay to Gaborone that could also carry Zambia destined products is discussed in the Walvis Bay corridor analysis of the Namibia country focus section with a resulting breakeven pipeline tariff of 110-125$/m³ to recover the capital investment. Road bridged product from Beira to Lusaka costs 180$/m³ with the potential to reduce to 155$/m³ if loading and transit efficiencies are improved. Demurrage in the Beira corridor is currently approximately 70$/mt (85$/m³) which gives a delivered price in Lusaka of 265 $/m³. Which could theoretically reduce all the way down to around 155-160$/m³ if berthing and offloading efficiency are also improved.

From Walvis Bay, road bridged product to Lusaka costs 230-270$/m³ and from Gaborone to Lusaka costs 125-145$/m³. The delivered price in Lusaka via a new Walvis Bay to Gaborone pipeline plus road bridge to Lusaka will be of 235-270 $/m³.

If a potential Walvis Bay to Gaborone pipeline was extended to Lusaka, moving just Zambian volumes in the Beira corridor, the economics are not viable without a subsidy. However, if the Zambian volumes moving through the Dar es Salaam corridor are added, the breakeven pipeline tariff needed is 95-110$/m³ which is less than the road hauling cost on that route. This still results in higher landed costs than the delivered prices via road ex Dar es Salaam and ex Beira only if efficiency gains in the Beira port are realised. This analysis is summarised in the table below.

Zambia Supply Analysis

Route	Mode	Rate ($/m³)	Demurrage ($/m³)	Delivered Price ($/m³)	Potential efficiency gain ($/m³)	Comment
Beira-Lusaka	Road	180	84	264	25+80=105	
Beira-Lusaka	Pipeline (18")	150-165	5	155-170		Zambia & Malawi vols in Beira corridor
Dar-Ndola	Road	170	3	173	25	Ndola vols only
Dar-Ndola	Pipeline (20")	125-140	3	158-173		Zambia, Malawi & DRC vols in Dar corridor
WB-Gaborone	Road	125	2	127	20	
WB-Gaborone	Pipeline (14")	110-125	3	113-128		Namibia, Botswana & Zambia via Beira only
WB-Gaborone	Pipeline (18")	85-100	3	88-103		Namibia, Botswana & ALL Zambia (Beira & Dar corridor)
Gaborone-Lusaka	Road	145		145	20	
Gaborone-Lusaka	Pipeline (8")	150-165		150-165		Zambia via Beira only
Gaborone-Lusaka	Pipeline (14")	95-110		95-110		ALL Zambia (Beira & Dar corridor)
WB-Lusaka via Gabs	Road	270	2	272	20	
WB-Lusaka via Gabs	Pipeline	260-290	2	262-292		Zambia via Beira only
WB-Lusaka via Gabs	Pipeline	180-210	2	182-212		ALL Zambia (Beira & Dar corridor)

Table 9: Zambia Supply Analysis.

Conclusions

Zambia is already well supported by a supply chain spanning two ports and incorporating a pipeline. There are further benefits to be reaped from cultivation of the rail network in Tanzania and Mozambique to handle greater volumes, as well as potential for the expansion of the pipeline to support greater volumes of product imports. The main challenge facing the country going forwards is the increasing congestion at the major ports of Beira in Mozambique as well as Dar es Salaam in Tanzania. Greater diversification of supply into Namibia or, indeed, via the Lobito corridor in Angola, as well as harnessing the potential of the uncongested port of Walvis Bay would help to unlock greater supply security and offer stronger optionality and competitivity of pricing.

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Annex 1: Definition of metrics

Definition of metrics	
Tank Turns	Annual demand ÷ by the total coastal storage for a specific grade in the port. • <18 turns per year: good • 18-24 turns per year: tight • 24+ turns per year: constrained
Liquid Bulk Capacity	Actual tonnage vs. theoretical maximum tonnage
Berth Capacity	Hours to work cargo vs. theoretical maximum hours to work cargo (includes time to berth, time to discharge, time to leave, efficiency of equipment, etc.)
# Truck Outs/yr	Annual volume through the corridor ÷ by the typical size of one truck (45m^3).
# km Driven	# Truck outs x average driving distance for each load
GHG Emissions	GHG Emissions (mtCO_2/yr) = 1105 gCO_2/km x total km driven per year ÷ 1,000,000 2.6 kg CO_2 emitted / litre of diesel fuel consumed Fuel consumption will likely range between 30 and 50 l/100km - gives 1105 gCO_2/km.
# Trucks in the Fleet	The total volume per month ÷ the volume one truck can move in a month. Uses an assumed load time, average driving speed and discharge time and the average driving distance for each load to calculate how many times a truck can be used in one month and hence the volume that one truck can move each month.
# Trucks in the Fleet (shift case)	The total volume per month ÷ the volume one truck can move in a month. Uses a more efficient load time and discharge time, faster average driving speed and the average driving distance for each load to calculate how many times a truck can be used in one month and hence the volume that one truck can move each month.

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