NORTHERN CORRIDOR TRANSIT AND
TRANSPORT COORDINATION AUTHORITY

THE PORT OF MOMBASA

EMISSIONS INVENTORY BASELINE REPORT

STRATEGIES FOR REDUCTION
OF PARTICULATE MATTER AND
BLACK CARBON EMISSIONS

JUNE 2017

UNEP

KENYA PORTS AUTHORITY

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LIST OF ABBREVIATIONS AND ACRONYMS

AQ	Air Quality
BC	Black Carbon
BEI	Baseline Emission Inventory
CCAC	Climate and Clean Air Coalition
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
ECA	Emission Control Area
EF	Emission Factors
EF_g	Particulate matter produced per unit mass of fuel consumed (grams per ton)
EF_p	Particulate matter produced per unit mass of fuel consumed (pounds per ton)
GHG	Greenhouse Gas
GT	Gas Turbine
HDDVEI	Heavy Duty Diesel Vehicles & Engines Initiative
HSD	High Speed Diesel
IMO	International Maritime Organization
KMA	Kenya Maritime Authority
KPA	Kenya Ports Authority
LNG	Liquefied Natural Gas
MARPOL	International Convention for the Prevention of Marine Pollution from Ships
MD	Marine Diesel
MOT	Ministry of Transport
MSD	Medium Speed Diesel
NCTTCA	Northern Corridor Transit and Transport Coordination Authority
NH_3	Ammonia
nm	Nautical Miles
N_2O	Nitrous Oxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxide
O_3	Ozone
OGV	Oceangoing Vessel
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter 2.5 micrometers or less in diameter
PM_{10}	Particulate Matter 10 micrometers or less in diameter
ppm	Parts per Million
RO	Residual Oil
SDGs	Sustainable Development Goals
SO2	Sulfur Dioxide
SOx	Sulfur Oxide
SSD	Slow Speed Diesel
ST	Steam Turbine
TEUs	Twenty-foot Equivalent Units
TSP	Total Suspended Particulates
VECC	Vehicle Emission Control Center
VOC	Volatile Organic Compound
VSR	Vessel Speed Reduction
WHO	World Health Organization

ACKNOWLEDGEMENT

The Northern Corridor Transit and Transport Coordination Authority acknowledge the support of Kenya Ports Authority, Kenya Maritime Authority, NEMA and Rift Valley Railways for their contribution and support during the data collection exercise and analysis of the data.

The Secretariat wishes to extend its special gratitude to UNEP for their support which enabled the Secretariat to carry out the Baseline Emissions Inventory for the Port of Mombasa.

Lastly, the Secretariat appreciates the valuable contributions and comments made by all the stakeholders during the validation workshop for this report on Mombasa Port Emissions Inventory.

FOREWORD

International freight transport accounts for over 40% of carbon dioxide (CO_2) emissions of the entire global transport sector which represents about 7% of the global Greenhouse Gas emissions (GHG). These emissions are projected to increase if no intervention is done to avert the trend. UNEP and NCTTCA began collaborations towards implementing the Green Freight initiatives to reduce GHG and particulate matter emissions along the Northern Corridor. This includes sensitization of stakeholders to create awareness of the effects of GHG emissions, development of a Green Freight Program for the Northern Corridor and establishing baseline data on emissions at Mombasa Port.

The Northern Corridor; the transport system linking the port of Mombasa to the great lakes region countries of Burundi, Eastern DRC, Kenya, Rwanda, South Sudan, Tanzania and Uganda is a key freight route for goods to and fro the Port of Mombasa. The port recorded a total cargo traffic growth of 2.4 % from 26.73 million tons in 2015 to 27.36 million tons in 2016 reflecting strong growth in imports and exports to and from the region.

This increase in global trade of goods and materials is a key driver of economic development and links suppliers and consumers through an increasingly interconnected complex transport system mainly driven by diesel-powered cargo vessels, trucks, and trains.

While diesel fuels are preferred in the transport sector due to being relatively energy efficient as compared to gasoline or jet fuel, its contribution to transportation-related climate warming greenhouse gases and other short-lived climate pollutants, particularly black carbon, is significant. This made it critical to implement a green freight program right from the port of Mombasa an area with activities requiring large consumption of diesel (heavy fuels) by ships, port operations, cargo trucks and trains. This report apportions the emissions at the port under different categories to enables each stakeholder to take appropriate measures to reduce the emissions under their respective controls.

Although the report shows that emissions by trucks at the port are much lower than those by the vessels, it must be noted that the figures reflect emissions by trucks while in the port area alone. Given the long distances covered by trucks when delivering merchandise, the time spent while idling in traffic snarl-ups and when waiting to be loaded or offloaded, total fuel consumed and emissions made is expected to be much more. This calls for urgent need for the Northern Corridor to start spearheading activities towards reduction of GHG emissions along the entire Northern Corridor transport system.

In accordance with the Global Green Freight Action Statement issued at the 2014 UN Climate Summit in New York, the Global Green Freight Action Plan calls on governments, private sector, civil society, and other actors to work in concert to align and enhance existing green freight efforts, develop and support new green freight programs, and to incorporate black carbon reductions into green freight programs.

This report clearly reflects the need for collaborative efforts by all stakeholders towards reduction of emissions and the recommendations provided are also in line with the goal of the Global Green Freight Action Plan to enhance the environmental and energy efficiency of goods movement in ways that significantly reduce the climate, health, energy, and cost impacts of freight transport around the world. Full implementation of the recommendations in this report will contribute substantially to the implementation of a sustainable green freight program for the Northern Corridor. All public and private sector players are encouraged to join efforts to reduce emissions towards the protection of our environment.

United Nations Environment,
Economy Division

PREFACE

It is my pleasure to present to you the Mombasa Port emission baseline report 2017. This report is a product of one of the activities towards the implementation of the Green Freight Transport Policy for the Northern Corridor recently adopted by the NCTTCA Executive Committee.

The NCTTCA developed a Green Freight Programme with the support of UNEP, UNCTAD and Climate and Clean Air Coalition (CCAC). The ultimate goal of the Northern Corridor Green Freight Programme is to improve fuel efficiency of freight transportation, reduce Particulate Matter (PM), black carbon, oxides of nitrogen and carbon dioxide (CO_2) emissions.

The Northern Corridor Green Freight Programme adopted several strategies to achieve its goal which includes; raising awareness on pollutant impacts and mitigation strategies such as use of improved quality of fuel, vehicles and infrastructure; advocating for a shift to more sustainable transport systems and modes; streamlining transport activities by actions such as optimizing routes, consolidating loads and reducing empty runs; identifying areas of action and overcoming barriers by enhancing capacity and mobilizing support; improving scientific understanding of climate pollutant impacts and mitigation strategies and promoting best practices and showcasing successful efforts; awareness on road safety and accidents mitigation.

Observing that to be able to tell whether the initiatives are bearing fruit there is need to have a baseline data for the Key Performance Indicators for monitoring and measuring performance over time. The NCTTCA still with the support of UNEP embarked on establishing baseline emissions for the Northern Corridor starting with the Port of Mombasa which is the key transit node and one of the major contributors to international freight transport emissions due to the volume and size of transport and cargo handling equipment calling and operating at the Port.

The Mombasa Port baseline emission report outlines the key activities and areas contributing to GHG and particulate matter emissions. The baseline emissions have been established using a stepwise approach methodology for estimating emissions from fossil fuel combustion at the Port of Mombasa using emission factors applied to the data collected. The emissions at the port were examined under four key categories; ship emissions, emissions from port operations, emissions from vehicles and emissions from railway operations.

The baseline report shows that Ocean-going vessels account for about 94.7% (522,698,400) of CO_2 Emissions while at the port of Mombasa and anchoring. On the other hand, trucks calling at port contribute 4,179 tons of CO_2 and 15 tons of NO_X per year, while at the port area. This is an indicator that emissions from trucks along the Northern Corridor are significant given that the estimated emissions above are for trucks when in the Mombasa Port area alone. Considering the emissions the trucks make to and fro their

transit journeys from the port there is need to reduce emissions from trucks in particular and vehicles in general plying the Northern Corridor.

Protection of the environment should be of concern to everybody. In the transport industry even as we look towards facilitation of trade and reduction of the cost of doing business we need to be mindful of protecting our environment by adopting sustainable green freight transport practices. Several emission mitigation measures have been proposed which include:

- Mandatory use of low sulphur fuel at berth
- Use of cold ironing for vessels while at berth
- Vessel speed reduction
- Use of Liquefied Natural Gas (LNG) bunkering facilities
- Reduction in congestion of trucks at the port
- Reduction of truck idling and adoption of retrofit technologies especially for vehicles more than 8 years old.
- Periodic mandatory vehicle inspection
- Infrastructure development to minimize congestion and traffic snarl ups along the Northern Corridor.
- Intermodal transportation of goods.

This report has an action plan for reduction of emissions at the Mombasa Port to support the implementation of the recommendations made.

We hope that this report together with the Northern Corridor Green Freight Programme document and the Mombasa Port Green Policy Charter will support the initiatives towards reduction of the GHG and Particulate Matter emissions at Mombasa Port. All stakeholders are called upon to embrace the recommendations of this report towards sustainable green freight transport along the Northern Corridor.

Fred Tumwebaze
Ag. Executive Secretary

1 BACKGROUND

The Northern Corridor Transit and Transport Coordination Authority

The Northern Corridor is a multimodal trade route linking the landlocked countries of the Great Lakes Region with the Kenyan maritime sea port of Mombasa. The Northern Corridor Transit and Transport Agreement (NCTTA) is a treaty signed in 1985 and revised in 2007 for regional cooperation with a view to facilitating interstate and transit trade, between the member States of Burundi, Kenya, Rwanda, Uganda and Democratic Republic of Congo. South Sudan acceded to the Agreement in 2012.

The NCTTA is a comprehensive agreement with defined 11 Protocols on strategic areas for regional cooperation relating to: Maritime Port Facilities, Routes and Facilities, Customs Controls and Operations, Documentation and Procedures, Transport of Goods by Rail, Transport of Goods by Road, Inland Waterways Transport of Goods, Transport by Pipeline, Multimodal Transport of Goods, Handling of Dangerous Goods and Measures of Facilitation for Transit Agencies, Traders and Employees.

The objectives of the agreement are currently based on 3 pillars of sustainable transport namely economic pillar aiming at promoting efficient and competitive transport; social pillar with the view to fostering an inclusive transport and the environmental pillar for a green freight transport.

The Northern Corridor Transit and Transport Coordination Authority (NCTTCA) was established and mandated by the Member States to oversee the implementation of the agreement, to transform the Northern trade route into an economic development corridor and making the corridor a seamless, efficient, smart and green Corridor.

More recently, the Northern Corridor Integration Projects Head of States Summit reiterated the mandate of the NCTTCA to strengthen the strategic planning of sustainable regional infrastructure and enhance monitoring of the corridor freight logistic chain.

The Port of Mombasa

The Port of Mombasa is the key entry and exit point for cargo to and fro a vast hinterland that include Burundi, Democratic Republic of Congo, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Tanzania, and Uganda. There has been an upward trend in the volume of cargo handled through the Port of Mombasa over the years from 26.73 million tons in 2015 to 27.36 million tons of cargo in 2016. To improve the cargo throughput of the port, a new container terminal with an annual capacity of 550,000 twenty foot equivalent units (TEUs) per year was commissioned.

The Port of Mombasa is managed by the Kenya Ports Authority (KPA), a parastatal fully owned by the Government of Kenya.

Figure 1: Areal Map for the Port of Mombasa

Arial view of the new Mombasa Container Terminal and the Dongo-Kundu Road

The Port has realized tremendous infrastructure development such as the construction of the SGR and the Dongo-Kundu road which will ease evacuation of imports from the Port as well as receipt of goods for export through the Port. These developments have future implications on emissions at the Port of Mombasa.

The Northern Corridor Green Freight Program

The Northern Corridor Green Freight Programme is a launching pad of a phased implementation of a holistic Sustainable Freight Transport Strategy which is underpinned by sustainable transport policies, planning strategies and investment decisions that effectively balance the economic, environmental and social objectives.

The Northern Corridor Green Freight Programme comes in line with the recently adopted global and continental frameworks-such as the Addis Ababa Action Agenda, 2015 Paris Climate Agreement, Agenda 2063 of the African Union, and the 2030 Agenda for Sustainable Development (Agenda 2030) focused on the Sustainable Development Goals (SDGs) - which provide a supportive backdrop for adopting and following through on green economy initiatives. The Corridor's Green Freight Programme draws upon other Green Freight Programs whose ultimate goals is to promote collaborative effort in the freight industry to help address its impact on environmental, social, and economic conditions, both globally and in the regions in which they operate.

In the short term, the Northern Corridor Green Freight Programme is aimed at aligning its strategic plan to green freight initiatives by improving the fuel efficiency of road transportation; reducing of Particulate matter (PM) and, black carbon, Oxides of nitrogen (NO_X) and CO_2 emissions that contribute to climate

change. The program also aims at reducing road accidents and advocates for inter-modal shift along the Northern Corridor. This is of particular relevance with the transport sector being a major contributor to ambient particulate matters in major cities and accounts for about 19% of global black carbon. Its health impact is estimated to be over 3.2 million annual deaths globally.

To build the NCTTCA capability for information management and use for strategic policy formulation, the Authority has customized the corridor emission model for consistently gathering data and monitoring the implementation of the program for future-focused basis. Through the Northern Corridor Emission Model, the NCTTCA has established that baseline emissions (g/ton-km) for CO, VOC, NO_x, PM, black carbon and CO_2 along the northern corridor are set at 0.190; 0.091; 0.628; 0.038; 0.022 and 75 respectively. Using various approaches specified in Green Freight Programmes, the NCTTCA has the objective to cut emissions of Particulate Matter (PM), black carbon emissions and Oxides of nitrogen (NO_x) grams per ton-km by at least 10% and reduction of CO_2 emission intensity grams per ton-km by 10% by 2021.

2 THE BASELINE EMISSION INVENTORY FOR THE PORT OF MOMBASA

Diesel engines are commonly used to power ocean going vessels (OGV) as well as trucks, locomotives, harbour crafts (tugs, tow boats, pilot vessels etc.), and cargo handling equipment (cranes and lifts) in ports, producing emissions with significant amounts of particulate matter (PM), considerably contributing to regional air pollution. Black carbon (BC), a short-lived climate pollutant, is a solid carbonaceous particle and component of fine PM produced as a by-product of incomplete combustion of carbon-based fuels such as residual fuel oil used in marine diesel engines. In addition to its human health impacts, BC emissions are the second most important human emission after carbon dioxide in terms of its climate forcing.

The Heavy Duty Diesel Vehicles and Engines Initiative (HDDVEI) of the Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants (CCAC) aims to catalyse major reductions in PM/BC from heavy duty diesel vehicles and engines in targeted countries and regions through adoption of clean fuel and vehicle regulations and policies. The baseline on emissions from operations at the Port of Mombasa is a critical first step towards developing strategies to reduce PM/BC emissions from the Port.

Black Carbon Emissions at the Port of Mombasa

Black carbon (BC) is a primary aerosol emitted directly from incomplete combustion processes such as fossil fuel and biomass burning. Atmospheric particulate black carbon has been linked to adverse health outcomes. Studies also suggest that black carbon accelerates sea ice melting and the loss of this ice would lead to more rapid warming with a possibility of irreversible climate change. However, black carbon particles do not last very long in the atmosphere hence reducing the amount being produced can have immediate effects on the rate of climate change.

At the port of Mombasa, Black carbon is generated from the burning of fossil fuels by Trucks, Diesel generators, ships calling at the port and fishing vessels.

For this study however, the tight time frame and the nature of data sets available did not provide authoritative grounds for the estimation of black carbon emissions from the port of Mombasa. The best methodology would require equipment and sufficient time to arrive at nearly accurate estimates and facilitate a better understanding of BC emissions relevant for the development of bottom-up accounting from fossil fuel sources at the port of Mombasa. Long term measurements of the aerosols are therefore recommended to better understand the total picture of aerosol particles including seasonal variation at the port.

In the short-run, policy measures to mitigate the adverse effects may include road vehicle emissions control regulations, comprehensive government policy including the development air quality monitoring system, as well as fleet and equipment upgrade at the port of Mombasa.

3 METHODOLOGY

Fuel use and greenhouse gas emissions (CO_2-e) associated with the Ocean Going Vessels, operation of equipment, as well as the air pollutants attributed to fuel combustion such as sulphur dioxide (SO_2), particulate matter, and oxides of nitrogen (NO_X), were investigated.

The Baseline Emissions Inventory (BEI) focuses on the estimation of the magnitude of emissions from the various sources, linking emissions with port operations, projecting the trend of port emissions over time, preparing an action plan and prioritizing future emission reduction measures for the port of Mombasa.

The baseline inventory process applied a step-wise approach for estimating emissions from fossil fuel combustion at the Port of Mombasa. Total emissions at the Port were a summation of the following:-

a) Emissions from the ship on maneuvering

b) Emission by the ship at the port and on anchorage

c) Emissions by equipment at the port of Mombasa

d) Vehicles and trucks accessing the port of Mombasa

e) Rail locomotives acceding the port of Mombasa

f) Electricity usage at the port of Mombasa

Emissions were estimated from either the fuel consumed or the distance moved in the course of operations. A simplified formula for estimating emissions from fossil fuel combustion is as follows:-

$$E_{FC,t} = \sum_a (Fuel_{a,t} \times EF_a$$

Where:

$E_{FC,t}E_{FC,t}$ = Net emissions of Fuel Consumption in year t

$Fuel_{a,t}Fuel_{a,t}$= Amount of Fuel of type a consumed in year t

EF_aEF_a=Emissions factors of fuel type a

aa= Fuel type (diesel or gasoline etc.)

For commuters accessing the port of Mombasa, the average data method was applied to estimate the emissions generated by cars and commuter buses. Calculations were arrived at using the formula below:

$$E_c = \sum T_e \times \%E_t \times 2C_d \times W_y \times E_f$$

$$E_b = \sum T_e \times \%E_t \times 2C_d \times W_y \times E_f$$

Where:

E_c = Emissions from employee commuting cars

E_b = Emissions from employee commuting buses

T_e = Total number of employees

$\%E_t$= Percentage of employees using mode of transport

$2C_d$= One way commuting distance (vehicle-km or passenger-km)

W_y= Working days per year

E_f=Emission factor of transport mode (kg CO2 e/vehicle-km or kg CO2 e/passenger-km)

Therefore:

$$Total\ CO_2\ Emissions = E_c + E_b$$

Emissions resulting from the combustion of fuels from port operations were arrived at through estimates from the fuel utilization. Emission factors[1] were used to record resultant statistics.

Overall, the focus year was 2017. The goal was to get either get monthly or quarterly data and extrapolate for the year. In case of the ship data, the Month of May had the highest number of ships calling compared to the other months in 2017 and previous years. The estimated emission figures therefore give the upper limits. Compilation for all the months would require closing all data gaps and sufficient time given that most processes are manual.

[1] *The emission factors are weighted averages for fuel type taking into account the engine type and variations of the operations.*

4 EMISSIONS SOURCES AT THE PORT OF MOMBASA

Emissions from the Port of Mombasa can be separated into five main source categories:

Ship Emissions

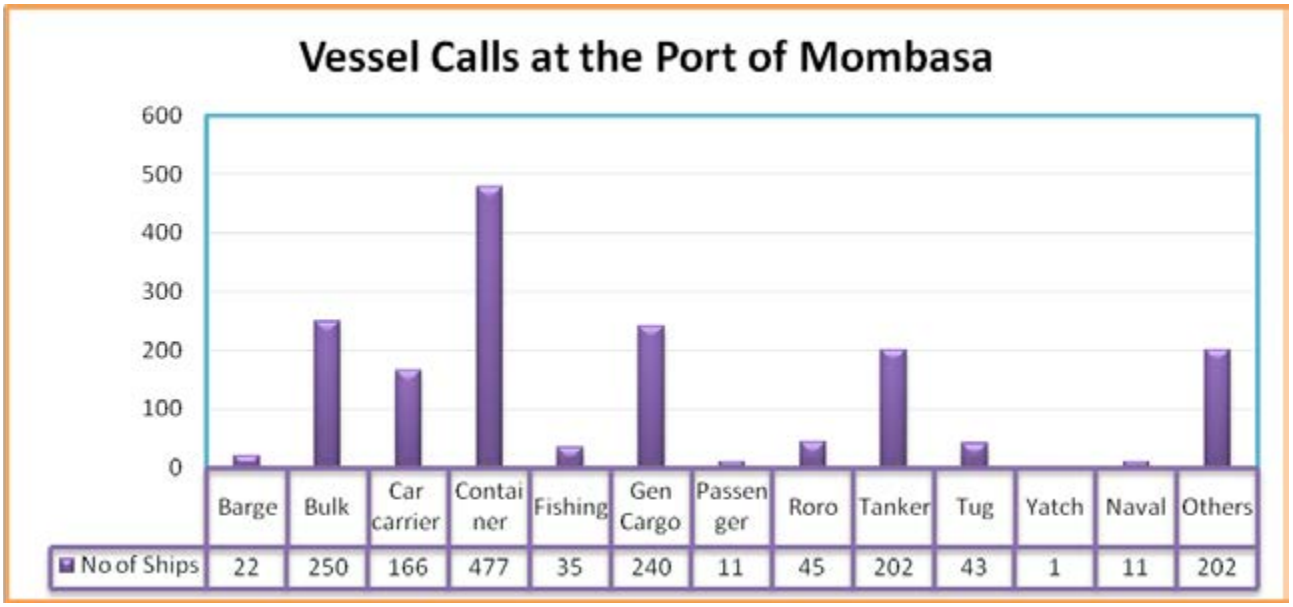
Ships are generally powered by large diesel engines operating on low quality fuel oil of relatively high sulfur content. These large slow revving diesel engines produce more NOx and particle emissions per unit of power output than smaller automotive diesel engines. The sulfur content of marine fuels is emitted as SO_2, leading to secondary formation of very fine aqueous sulfate particles.

Ships use diesel powered electrical generators on board for lighting, air conditioning, control systems, fuel and water systems, bow thrusters and cargo handling. Ships also use oil fired boilers for fuel heating, cargo heating and to produce steam to supply turbines for cargo and ballast pumping. Cruise ships have relatively high electrical loads to supply the needs of passengers. Container vessels also use electricity to run refrigerated containers. Oil tankers tend to use fairly inefficient steam driven pumps to deliver cargo, driven by oil fired boilers.

Port entrances are the greatest source of emissions, followed by auxiliary engines at berth and auxiliary boilers at berth. While the berth emissions were less than the cruise emissions, the proximity of berth emissions to population centres causes greater adverse health effects.

The port of Mombasa receives various Ships per year. In 2016, the following numbers of port calls were registered:

Figure 2: Vessel Calls at the Port of Mombasa

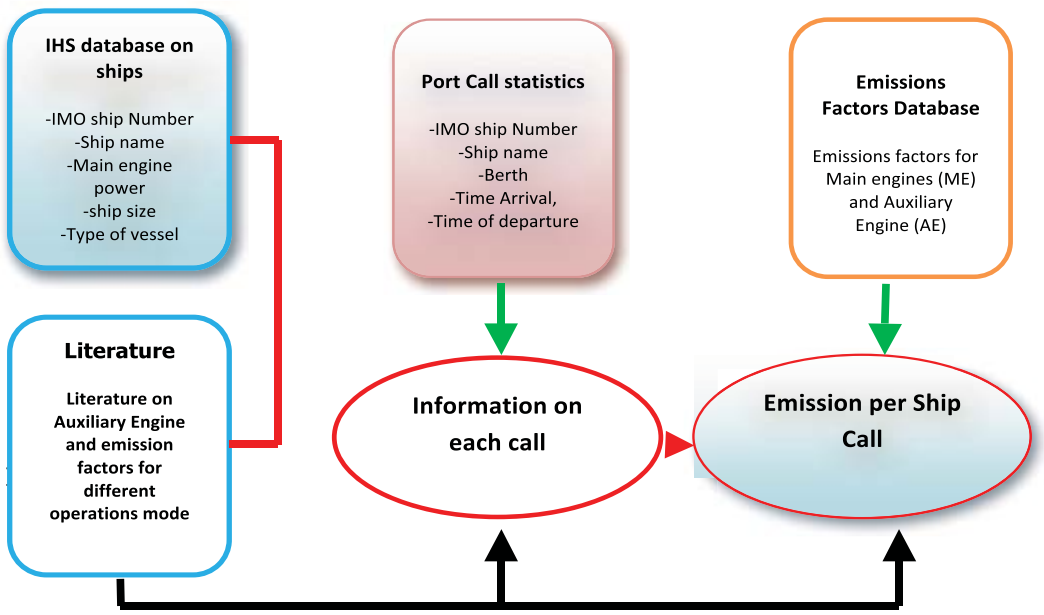


Mombasa port Annual review and bulletin of statistics, 2016

From the above figure, 28% of the Ships that called at the port of Mombasa in 2016 were container ships, 16% were ships carrying bulk cargo and 14% were carrying general cargo. The three categories of Ships calls by cargo types constituted 58% of the total calls at the port of Mombasa. Therefore, 42% of the calls registered were from Ships carrying other types of cargo; significant among them were the tankers which formed about 12% of the calls for the year.

For the estimation of Ships related emissions at the port of Mombasa, samples were taken from the time the ship arrives at the fairway buoy, in the fairway channel, manoeuvring at berth until exit from the port are. Port calls were received from KMA; this included the name of the ship and time for ship operations. The information was used to march with the ISH database or Lloyds register.

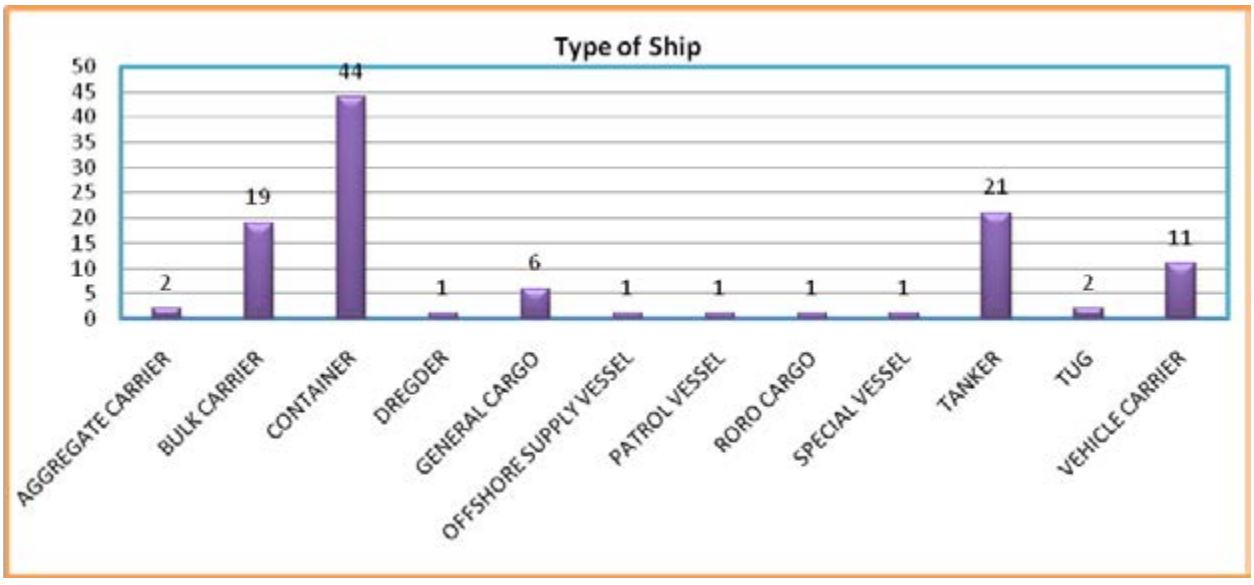
Figure 3: Ship Emissions Estimation Flow Chart



Source: Mombasa Port Emissions Inventory May, 2017.

For the baseline survey, data for the month of May, 2017 was used to determine the yearly estimates for vessels calling at the Port. During May 2017, a total of 110 Ships called at the port of Mombasa. The figure below provides the detailed breakdown by type:

Figure 4: Number of Ships that called at the Port of Mombasa in May 2017



Source: KPA

Results:

Using the emissions factors (see appendix1), the following emissions were estimated for the Ships that calls at the port of Mombasa.

Table 1: Emissions at the Port and anchoring

Main Pollutants(tons)				Particulate Matter		Greenhouse Gas Pollutants		
NOx (tons)	CO (tons)	SOx (tons)	NH_3 (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	CO_2 (tons)	CH_4 (tons)	N_2O (tons)
9,544.92	595.08	6,579.96	1.996	328.865	328.865	479,302.32	2.898	20.634

Source: Emissions baseline survey 2017

Table 2: Emission for Maneuvering

Main Pollutants(tons)				Particulate Matter		Greenhouse Gas Pollutants		
NOx (tons)	CO (tons)	SOx (tons)	NH_3 (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	CO_2 (tons)	CH4 (tons)	N2O (tons)
774.36	97.56	617.76	0.181	107.221	107.221	43,396.08	0.603	1.084

Source: Emissions baseline survey 2017

Key Note:

Fishing Vessels and Ferry Movements are not part of the analysis as the available database does not detail all movements for Fishing Vessels and Ferries.

Emissions from Port Operations

In estimating the emissions from Port operations, the primary source of information was fuel consumption from various filling stations at the port of Mombasa (i.e. Bowser, Tug and Mooring Boats, Terminal Engineering Station and Kapenguria Fuel Station). Operations vehicles, cranes, and other equipment source fuel from these stations. For the baseline purposes, data was obtained for the three consecutive months of February, March and April, 2017. Based on the information gathered, a monthly average obtained as summarized below:

Table 3: Average Monthly Fuel Utilization Data

Month	Diesel (l)	Petrol (L)	Lubricants	
			Liquid	Molten(Kg)
February	467,648	5,527	13,430	540
March	470,317	7,120	15,117	610
April	485,723	5,130	14,880	572
Average	**474,563**	**5,926**	**14,476**	**574**

Source: KPA Monthly average fuel utilization data

However, the port of Mombasa also uses electricity from the grid for cranes, lighting and office air-conditioning and other functions. The baseline obtained the below five months data of electricity usage from KPA.

Table 4: Estimated Electricity Usage at the Port of Mombasa

Year	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17
Total (kWh)	**2,020,728**	**1,809,479**	**1,893,639**	**2,015,774**	**2,136,179**

Source: KPA Monthly electricity utilization data

To estimate emissions from Port operations, the following emission factors were applied to arrive at results:

Table 5: Emission factors used for diesel engines

Emissions	**Boat**		**Heavy Duty Machinery**	
	EF	**Units**	**EF**	**Units**
NOx	67.5	g/kg	11.32	g/kg
CO_2	3,188	g/kg	3172.31	g/kg

Source: EFDB Emission Factors Database

Results:

Based on the fuel utilization data, the estimated emissions values were multiplied by 12, to give annual emissions estimates. The emissions factors were sourced from the online EFDB emission factors database provided by intergovernmental panel on climate change (IPCC).

From the data obtained, it was estimated that the tug and mooring boats stations discharged on average 148,756 litre of diesel monthly. Therefore the calculated figures for emissions stand at 8,473,606g and 400,205,283g of NO_x and CO_2 annually respectively.

For heavy duty machinery using diesel such as mobile cranes and stand-by generatorsemissions were estimated at 44,257,623g and 12,402,729,650g NO_x and CO_2 respectively. The general assumption here was that petrol was only used for commuter services which are covered under the previous section. Petrol used in operation vehicles or light truck was not used since it wasn't possible to disaggregate the data.

For electricity usage, the data from the monthly electricity bills and the emission factor applied was 0.332297783 ($kgCO_2/kWh$). The emission factor was extracted from the technical paper on electric specific emissions factors for grid electricity (Brander M. et al, 2011).

Based on the average electricity consumption per month at the port of Mombasa, (i.e. 1,975,160kW/h). The estimated Carbon Emission Equivalents per year stands at, 7,876,095kg CO_2 e.

Emissions from Commuters

Questionnaires were administered to Port employees to determine estimates related to fuel consumption attributable to commuters at the port of Mombasa. The questionnaires were intended to obtain the following information:

a) Average distance travelled by employee per day, mode of transport whether by their personal car or port bus service.
b) Average number of working days per year.

The total number of the employees at the port of Mombasa was estimated at 10,000, while total employees working days were estimated at 255 days per year; taking into account the provisions for public holidays and personnel leave days. The baseline information gathered indicated that 30% of the staff at the Port uses personal vehicles, while 5% of the employees use the commuter buses. The majority (65%) of the Port employees therefore walk to their work places within the port area.

Results:

Based on the information gathered, emissions by commuters at the port of Mombasa were estimated using the formula explained in the methodology section. The table below shows estimated emissions generated by personnel cars and commuter buses accessing the port of Mombasa.

Table 6: Estimated Emission by Personnel Cars and Commuter Buses

Descriptive Details				Emissions (CO Equivalents)	
Number of Port Employees	Average Distance per year Travelled (Cars)	Average Distance per year(Commuter Bus)	Average Distance Travelled per Day	Bus Commuter Services	Personal Cars Accessing the Port
10,000	**2,700 KM**	**4,300 KM**	**30 km**	**117,500 kg CO2 e**	**4,230,000 kg CO2 e**

Source: Emissions baseline survey 2017

From the above table, it can clearly be seen that about 97% (4,230,500kg CO_2 e) of emissions from the Port commuters is resulting from personal cars, therefore less than 3% of the commuters emissions (117,500kg CO_2 e) results from the buses accessing the port.

Emissions from the Trucks Accessing the Port

Raw data was collected on Heavy Diesel Trucks that accesses the port of Mombasa. The information gathered was analyzed and summarized in the table x. For each berth, the operator was asked to complete the time in hours that a truck spends in the port loading or disc arching and movement/ maneuvering. Based on the information received, the data was reviewed and the average number of trucks accessing the Port estimated. Emission factors were then applied to the activity and duration for the Port stay. The average distance covered by a truck while at the Port was estimated at 10km.Based on records, the Port registers between 410 and 750 trucks per day.

Generally, Trucks take time manoeuvring within the Port, ferrying containers within the Port and to the local Depots. Emissions also occur for trucks while idling on queuing. To estimate emissions resulting from Heavy Duty Diesel Trucks (HDDTs), the following emissions factors were applied:

Table 7: Emission Factors for Heavy Duty Diesel Trucks and Light Duty Trucks

Emission Type	Heavy Duty Diesel trucks	Light Duty
NO_x	3.52g/km	0.68g/km
Co_2	987g/km	415g/km

Source: Emissions baseline survey 2017

Results:

The table below shows annual estimated emission for CO_2 and NO_x based on the average 580 Heavy Duty Diesel Trucks accessing the port of Mombasa on daily basis. As it was not possibly to disaggregate the Heavy Duty Diesel Trucks from the Light Duty Trucks accessing the Port due to information gaps (at least for the baseline), the assumption made was that the vehicles are HDDTs and HDDTs emission factors was applied.

Table 8: Estimated C02 and NOX Emissions by Heavy Duty Diesel Trucks at the Port

Emission level (CO_2) kg	NO_x
4,178,958.00	**14,903.68**

Source: Emissions baseline survey 2017

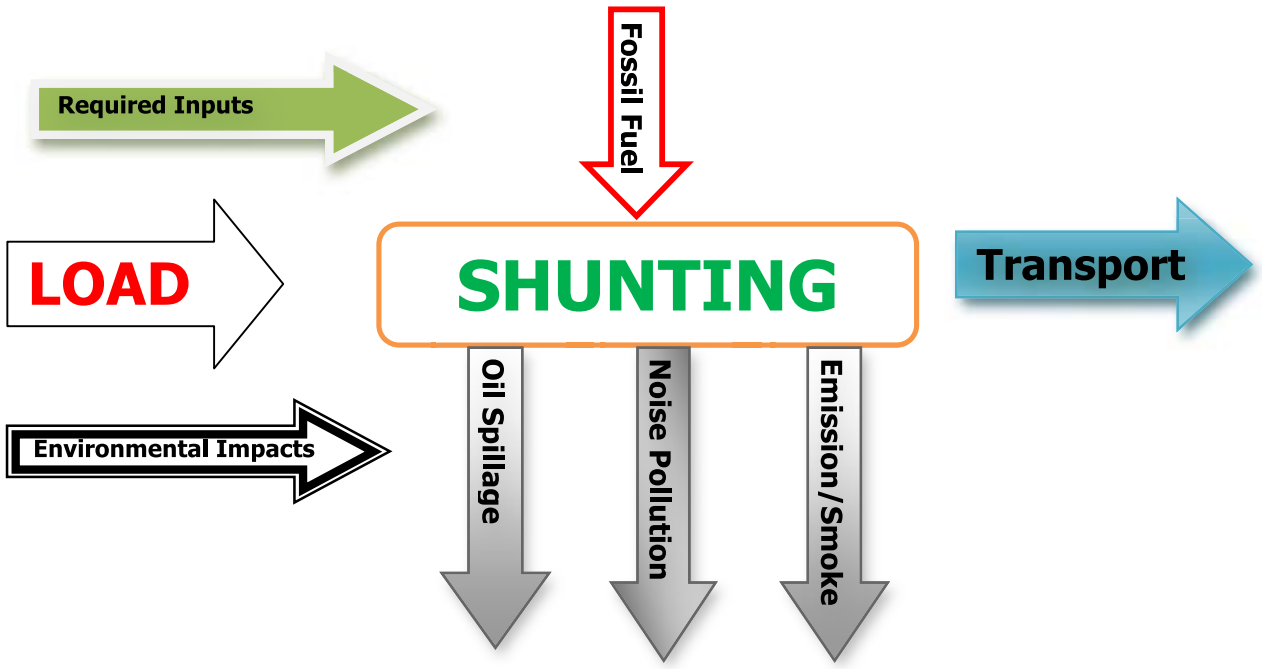
Emissions from Rail Operations

Rift valley Railways carries out its operations on the railway network within the Port facility. Rail emissions were based on the data from the RVR while the emission factors for rail were adopted from Eco Transit data 2010).

Among RVR operations is shunting of trains through motive power. These operations have outputs that have a bearing on the environment namely, emission of exhaust fumes and noise pollution. Emissions from engines are usually calculated by means of quantifying the fuel consumption from the power production first and then multiplying the consumption by emission factors for different compounds. Emission factors (EF) used are then related either to the generated power EFp (g(species)/kWh) or to the fuel consumed EFf(g(species)/kg(fuel)), where the first one divided by the specific fuel consumption (SFC, unit g(fuel)/kWh) is equal to the second one.

Emissions from a locomotive engine will depend on the type of fuel used as well as on characteristics of the engine. Locomotives considered were those for shunting.

Figure 5: Processes in the Shunting Operations



Source: Mombasa Port Emissions Inventory May, 2017.

The specific fuel consumption (SFC), expressed as mass of fuel per unit of work by the engine (g/kWh), depend on the engine size and type.

The following emissions factors were used:

Table 9: Emission Factors for Rail Operations

Emission	*Unit*	*Value*	*Reference*
CO_2	g/kg	3179	From typical carbon content and heating value
NOX	g/kg	48.3	Ecotransit 2010
$PM_{2.5}$	g/kg	1.3	Ecotransit 2010

Source: NCTTCA Emissions Baseline Survey 2017

The table below gives consumption per day for shunting operations for locomotives approved to operate within the port.

Table 10: Locomotives Consumption per day for Shunting Operations

Engine Class	Horse Power	Category	Fuel Capacity	Consumption	Utility
62/73	950/1,600	Shunting	1950 Litres	280 litres per day	24 hrs/day, every day
93	2,550	*Trip Train	5,000 Litres	9 ltr/km (total 27 ltr/day)	3trips/day

Source: RVR, NCTTCA Emissions Baseline Survey 2017

**the trips are considered from gate 18 to KPV yard (approx. 500 meters)*

The extent of the emissions from the locomotive engines depends essentially on the engine power, Combustion processes, Standard of maintenance and Quality of fuel.

Results:

The table below is a summary of the emissions as a result of railway operations

Table 11: Emissions from Railway Operations

Emission	Unit	Emissions(kg)
CO_2	Grams	**288,262. 36**
NO_X	Grams	**4,379.70**
$PM_{2.5}$	Grams	**117.88**

Source: NCTTCA Emissions Baseline Survey 2017

Summary Emissions (Kg) for the Port of Mombasa

Emissions at the port of Mombasa originate from various sources. Although not all sources are intensively investigated, the key sources are covered in the current emissions baseline inventory for the Port. However, emissions originating from port expansion related works have not been included in the current analysis. The table below shows summary of estimated emissions by sources for the port of Mombasa.

Table 12: Summary of Port Emissions by Sources

Source	CO_2	NO_X	$PM_{2.5}$
Rail	288,262.36	4,379.70	117.88
Electricity use	7,876,095.00		--
Tug and mooring boats	400,205.28	8,473.61	--
Heavy Machinery	12,402,729.65	44,257.62	--
Trucks	4,178,958.00	14,903.68	--
Employees Personal cars	4,230,000.00	--	--
Commuter Buses	117,500.00	--	--
Emissions at the Port and anchoring	479,302,320.00	9,544,920.00	328,865
Emission for Maneuvering	43,396,080.00	774,360.00	107,221

Source: NCTTCA Emissions Baseline Survey 2017

Highlights of Key Findings

The following highlights are extracted from the results of the Baseline Emissions Inventory for the port of Mombasa:

1. Ocean-going vessels account for about 94.7% (522,698,400) of CO_2 Emissions while at the port of Mombasa and anchoring. While Heavy Machinery and Electricity use accounts for 2.2% (12,402,730) and 0.1% (7,876 tons) respectively. On the other hand, about 0.8% of the CO_2 Emissions at the port is from Trucks and Commuter vehicles.
2. Container vessels, are the most prevalent vessel type (28%) that calls at the port of Mombasa, and therefore represent the greatest share of fuel use and emissions.
3. Three-quarters of the time that ocean-going vessels spend in the port area is at berth, which is where the greatest amount of fuel consumption and emission of greenhouse gases occurs.
4. Trucks accessing the port (medium and heavy commercial vehicles) travel an estimated over 2.5 million kilometres in the port area per year. Truck types include: –semi-trailers– B-doubles (carrying up to one 20-foot containers and one 40-foot container).
5. Mercedes actros are the dominant vehicle type accounting for over 90% of the fleet accessing the port. Most of these trucks accessing the port are newer trucks with good emission control specifications, however, just outside the port, older trucks are common for movement of cargo from yard to yard mostly grains and fertilizers
6. Rail accounts for an estimated 0.05% (288,262kg) of the CO_2-e at the port of Mombasa. The low percentage figure may be attributed to ration of cargo transported by rail from the port of Mombasa.
7. Over 95% of the equipment (mostly forklifts) in the port area has a 5 year and below age of which some may contribute significantly to the emissions at the Port.

5 EMISSIONS PROJECTIONS AT THE PORT OF MOMBASA

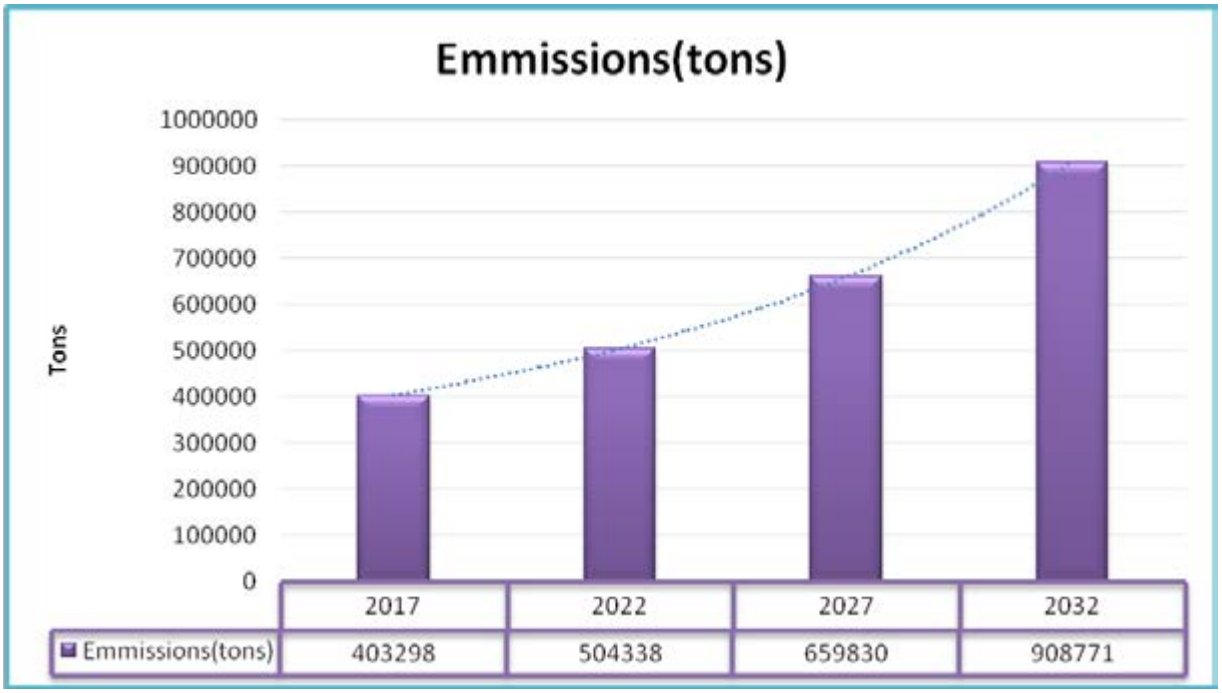
The Port of Mombasa is the busiest East African port and it is the largest general purpose port. The port recorded a total cargo traffic growth of 2.4 % from 26.73 million tons in 2015 to 27.36 million tons in 2016 reflecting strong growth in imports and exports to and from the region.

As trade increases, so do the emissions attributed to the movement of cargo by sea and by land. As part of the commitment to minimizing impacts on the local environment, the Port of Mombasa recently developed the Green Port Policy to reduce emissions from port-related transport.

The current expansion of the port of Mombasa through the Mombasa Port Development Project which includes Construction of a Second Container Terminal and other areas of development such as expansion of Gates, Yard Capacities, Berths 11 – 14 development , Cruise Ship Terminal and the proposed Dongo Kundu Free Port will have an impact in the level of emission.

Using the methodology used in the KPA Green Port Policy, GHG emissions are projected to increase by 125%by 2032 in a business as usual (BAU) scenario.

Figure 6: Emissions Projections for the Port of Mombasa



Source: KPA/NCTTCA 2017

Most of the greenhouse gas emissions are from the ships calling at the port of Mombasa and mitigation measures would mostly focus on ships emissions to reverse the trend. One of the critical interventions would be for the country to ratify MARPOL Annex VI regulations for the Prevention of Air Pollution from Ships. This would be followed by development of regulations and working with IMO in designation of emission free areas.

The MARPOL Annex VI regulates the emission to the atmosphere of specified pollutants from ships, including nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs) and heavy metals, and chlorofluorocarbons (CFCs). These substances contribute to environmental problems including acidification/acid rain (NOx, SOx), eutrophication or oxygen depletion of inland and some coastal waters (NOx), the creation of ground level ozone (VOCs and NOx), the depletion of atmospheric ozone (CFCs) and the accumulation of PCBs and heavy metals in the food chain – i.e., a wide range of both regional and global environmental concerns.

6 GLOBAL BEST PACTICES AND RECOMMENDATIONS FOR EMISSION REDUCTION

Some of the globally recommended emissions mitigation options include:

a) Mandatory use of low sulfur fuel at berth

The use of low sulfur fuel, (0.1% by mass or less) in ship auxiliary engines and auxiliary boilers if berthed for more than 2 hours, or the use of exhaust gas scrubbers to achieve equivalent results. The use of fuel with sulfur content 0.1% or less by mass is mandatory for ships at berth in EU ports, or equivalent reductions in SO_2 emissions by use of exhaust gas scrubbers.

b) Mandatory use of low sulfur fuel within a given distance from the coast

Vessels are required to use low sulfur fuel in ship main engines, auxiliary engines and auxiliary boilers within a given distance of the coast.

Recommendations:

- ***Vessels berthing at the port should be required to use fuel with low sulfur content of 0.1% by mass or less and alternatively use exhaust gas scrubbers.***
- ***Furthermore, requirements be made for the use of low sulfur fuel in ship engines, auxiliary engines and auxiliary boilers within a given distance from the coast.***

c) Sulfur Reduction Incentives

Port fees have been differentiated according to the sulfur content of fuel used by the ship while at berth. The World Ports Climate Initiative (WPCI) model involves a graduated fee according to environmental performance relative to international norms, measured by the Environmental Ship Index (ESI).

Recommendation:

- ***The Mombasa Port should consider applying differentiated port fees according to sulfur content of fuel used by the vessels while at berth.***

d) Shore power (Cold Ironing)

Some ports are mandating the use of shore power where facilities are provided by the ports. In a number of cases capital grants have been offered to frequent users of ports to assist in the installation of suitable infrastructure on visiting ships.

Recommendation:

- ***The Mombasa Port should expedite installing facilities for cold ironing and furthermore make it mandatory where the facilities are available for vessels at berth to use cold ironing.***

e) Voluntary use of low sulfur fuel

Some shipping companies are voluntarily choosing to use low sulfur fuel. The Fair Winds Charter involves a number of shipping lines who are voluntarily using fuel of sulfur content 0.5% or less. Maersk, for example recently announced that it will voluntarily use low sulfur fuel in some ports.

f) Vessel Speed Reduction (VSR)

Reducing vessel speed within a specified geographical limit reduces fuel consumption and emissions. The Ports of Los Angeles and Long Beach in California, for example, offer reduced port fees for voluntary speed reduction to 12 knots within 20 or 40 nautical miles of the coast.

g) Liquefied Natural Gas (LNG) bunkering facilities

Planning for LNG bunkering facilities at ports to supply fuel to LNG powered vessels would encourage uptake of LNG fuelling. This is a growing international trend offering large reductions in emissions of SO_2, NO_x and PM_{10} emissions at relatively low cost compared with other control measures, although LNG fuelling is really only an option for new ships.

Recommendation:

- ***The Mombasa Port should work towards installation of LNG bunkering facilities to support LNG fuelling at the Port especially foe new vessels.***

h) Extending or improving measures

To reduce congestion and improve truck turnaround times at the Port, which in turn reduce idling emissions. Additional measures could include; engaging with port corporations and industry on the feasibility of differentiated fees for trucks of different emissions performance standard with the aim of encouraging cleaner vehicles at the port. Sensitivity to pricing would need to be investigated with industry.

Recommendations:

- ***Vehicles operating at the port should be subjected to mandatory periodic inspection compliance checks. This should apply to all vehicles in the region.***
- ***Furthermore, support driver education to help reduce truck idling and the adoption of retrofit technologies through the Diesel Retrofit Program, targeting older vehicles.***

i) Strengthen the framework for monitoring emissions at the Port

In order to evaluate the initiatives towards reduction of emissions at the port and to measure emission levels at the port the following recommendations are crucial:

Recommendations:

- ***Adopt marine vessel emission factors and load factors for all types and ages of the vessels. Furthermore adopt emission factors specific for $PM_{2.5}$***
- ***Support stepwise determination of emissions at the Port it is recommended that the vessels calling at the Port should declare the number, capacity and type of fuel used by their auxiliary engines while at berth.***
- ***Movement of vessels from one point to another within the port area should be properly documented and considered when determining port emissions.***
- ***For general conformity purposes, the emission inventory process should be improved by the development of emission factors for on-dock equipment that better represent their in-use duty cycle.***
- ***It is recommended that KPA spearhead the development of test cycles for dock equipment that realistically represent the operating patterns of this equipment.***
- ***Currently, the Government of the Republic of Kenya through KPA and KMA is taking measures to improve the intensity of emissions at the port of Mombasa. While a substantial amount of work would have to be done to reduce the emissions such as of NOx, $PM_{2.5}$, VOC, SOx, CO, and CO2, there appears to be many challenges. It is therefore recommended that KPA/KMA and other stakeholders collaborate towards awareness creation and dedicated emissions reduction efforts.***

7 ACTION PLAN FOR EMISSIONS REDUCTIONS AT MOMBASA PORT

An Action Plan is a policy-level document that guides the implementation of the emissions reduction measures. The goal of the Action Plan for the port of Mombasa is to develop and recommend feasible, cost-effective strategies and programs to reduce air emissions and health risks from operations at the Port of Mombasa, while allowing port development to continue bringing revenue and jobs to the City of Mombasa.

Emissions reduction initiatives include mandated regulatory measures such as clean fuel content initiatives, and voluntary measures such as vessel speed reductions and cold ironing. The following section provides an Action Plan aimed at emission reductions tenable through the implementation of the proposed measures. The emission benefits on full compliance with both the regulatory and voluntary measures are likely to reduce emissions at the port of Mombasa to desirable levels.

The majority of the ocean-going vessels emission reductions of PM are associated with sulfur fuel requirements, while the sulfur fuel requirements; VSR program and truck program would each contribute to similar reductions in NOx emissions. Notably, the sulfur fuel requirements would occur across ocean-going vessel at all operating modes including hotelling at the berths. In contrast, the VSR program would only reduce emissions from the main engines during cruise and slow cruise modes which tend to be further from areas of public access. A truck replacement program would also provide emission reductions.

Implementation of the Action Plan involves incorporating the GHG reduction measures into the Port's ongoing policy development, planning activities, and business operations. All measures in the Action Plan should be further developed and approved by the relevant Port Authorities prior to implementation. All new policies and measures should be evaluated based on existing Green Port Policy developed for the port of Mombasa.

The below Action Plan contain a number of potential emission reduction policies and measures selected to help meet the key emissions reduction targets set by the port of Mombasa. It is anticipated that full adoption of the Action Plan would place the Port at the forefront of the region's environmental planning efforts.

Table 13: Action plan for emissions reductions at the port of Mombasa

EXPECTED OUTCOMES	STRATEGY/ACTION POINTS	OUTPUT INDICATORS	STAKEHOLDERS		TIMEFRAME		
			LEAD	PARTNER	SHORT TERM[2]	MEDIUM TERM[3]	LONG TERM[4]
Emissions from Vessels/Ships Reduced and Mastered.	a) Installation of shore power sources to enables vessels to turn off engines while docked and connect to shore Electricity sources.	Shore power sources installed at the Port of Mombasa.	**KPA KMA**	Shipping companies			
	b) Advocacy for cleaner alternative fuels that meet or exceed Emissions Control Area requirements set by the Port.	Advocacy programs for cleaner alternative fuel reviewed and implemented.	**KPA KMA**	IMO (International Maritime Organization), UNEP, NCTTCA, Shipping companies			
	c) Regulating for Vessels Speed Reduction (VSR) close to port of Mombasa to reduce the intensity of emissions.	Vessels Speed Reduction regulations fully enforced.	**KMA**	Shipping companies			
	d) Initiatives establishing incentives targeting the vessels/ships that meet the required standards.	Initiatives targeting vessels/ships with required standards introduced and implemented.	**KMA KPA**	Shipping companies			
	e) Establishing an efficient emissions data management system and database for the port of Mombasa.	Efficient emissions data management system and database established for the Port of Mombasa.	**KPA**	Port community, KMA			

[2] *Short Term: Between one and five years*
[3] *Medium Term: Between five and fifteen years*
[4] *Long Term: Between fifteen and thirty years*

EXPECTED OUTCOMES	STRATEGY/ACTION POINTS	OUTPUT INDICATORS	STAKEHOLDERS		TIMEFRAME		
			LEAD	PARTNER	SHORT TERM[2]	MEDIUM TERM[3]	LONG TERM[4]
Emissions from Port Operations Reduced and Mastered	a) Advocacy for the use of alternative cleaner fuels for heavy machines used in operations at the port of Mombasa.	Advocacy programs for the use of alternative cleaner fuels for heavy machines launched.	**KPA**				
	b) Shifting from the excessive use of diesel operated machines to electric machines to cut down on emissions.	Over 50% of the diesel operated machines replaced by electric machines.	**KPA**				
	c) Developing an inventory for all Heavy Duty Diesel Operated machines and devise measures to minimize use of aged machineries in operations.	An inventory developed for all Heavy Duty Diesel Operated machines and use of aged machineries in operations minimized.	**KPA**				
	d) Coordination with key stakeholders and relevant departments to identify and explore potential emission reduction projects and seek funding supports.	Key stakeholders are consulted; potential emission reduction projects explored and funding and supports sought.	**KPA**	KMA, NCTTCA, IMO, Port community, etc.			
	e) Reviewing the baseline emission inventory, identify specific activities and sources; and investigate further the emissions reduction targets for the port of Mombasa.	The current baseline emission inventory reviewed, specific activities identified and new emissions reduction targets set.	**KPA KMA NCTTCA**	UNEP and Other Partners			

EXPECTED OUTCOMES	STRATEGY/ACTION POINTS	OUTPUT INDICATORS	STAKEHOLDERS		TIMEFRAME		
			LEAD	PARTNER	SHORT TERM[2]	MEDIUM TERM[3]	LONG TERM[4]
Emissions from Heavy Duty Diesel Trucks and Commuters Vehicles Reduced and Mastered	a) Enforcing Green Driving at the port of Mombasa through efficiency campaign focused on truck driving habits and operations.	Green Driving enforced at the port of Mombasa through efficiency campaign.	**KPA**	NCTTCA, KMA, Transport Associations (KTA), Port Community			
	b) Cutting down trucks congestions at the Port reducing turn/wait times within and at the entry points at the port of Mombasa.	Trucks congestions at the Port cut down and turn/ wait times within and at the entry points reduced.	**KPA**	Port Community			
	c) Taking administrative measures to reduce idling by Trucks accessing the Port to pick cargo.	Administrative measures taken to reduce idling by Trucks accessing the Port to pick cargo.	**KPA KMA**	Transport Associations (KTA) and port community			
	d) Requesting from KTA and other logistics sectors list of truck operators in their drayage Truck Registry that access the Port of Mombasa for emissions related data updates.	List of truck operators in their drayage Truck Registry that access the Port of Mombasa updated.	**KPA**	Port community, Transport Associations			
	e) Regulating the number of commuter vehicles accessing the port of Mombasa to reduce emissions from commuters sources.	Number of commuter vehicles accessing the port of Mombasa regulated to reduce emissions.	**KPA**	KPA Staff, Port Community			

EXPECTED OUTCOMES	STRATEGY/ACTION POINTS	OUTPUT INDICATORS	STAKEHOLDERS		TIMEFRAME		
			LEAD	PARTNER	SHORT TERM[2]	MEDIUM TERM[3]	LONG TERM[4]
Emissions from Rail Locomotives Reduced and Mastered	a) Improving on the current rail Infrastructure to ensure latest clean technologies and operations are utilized at the Port of Mombasa.	The current rail Infrastructure improved to ensure latest clean technologies and operations are utilized.	**KPA**	RVR, NCTTCA, SGR, KERC (Kenya Railway Corporation)			
	b) Enforcing regulations to reduce locomotive idling at the Port to cut down on unnecessary emissions while picking cargo.	Regulations enforced to reduce locomotive idling at the Port.	**KPA**	KERC			
	c) Transitioning locomotive engines to latest technology, such as hybrids with electric options and capabilities.	Locomotive engines transitioned to the latest technology, such as hybrids with electric options and capabilities.	**KPA**	KERC			
Emissions at the Port of Mombasa Reduced through Collective Efforts	a) Establishing program for reducing emissions through shipper, logistics, and carrier participation.	Program for reducing emissions through shipper, logistics, and carrier participation established.	**KPA**	Donors, NCTCA, KMA, Port community…			
	b) Developing a comprehensive Clean Air Strategy with public support and data-driven to reduce multi-sector emissions at the port of Mombasa with clearly set performance targets.	Comprehensive Clean Air Strategy with public support and data-driven developed to reduce multi-sector emissions at the Port.	**KPA KMA**	NCTTCA, Development Partners			
	c) Engaging the Port Community to constitute a formalized path for community dialogue and engagement for tackling emissions issues at the port of Mombasa.	The Port Community engaged to constitute a formalized path for community dialogue and engagement for tackling emissions issues.	**KPA**	Port Community			

Annexes:

Annex 1: Emission Factors

The following emissions base factors were used:

Table 14: Port and Anchor Emissions (base factors in g/KWh)

Engine type	Fuel type	Fuel Consumption (sfc)	Main Pollutants					Particulate Matter			Greenhouse Gas Pollutants		
			NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2.5	CO2	CH4	N2O
MSD	MD	217	13.8	0.9	0.2	1.7	0.003	0.2	0.2	0.2	690	0.004	0.031
	RO	227	14.5	0.9	0.2	10.4	0.003	0.5	0.5	0.5	722	0.004	0.031
HSD	MD	217	11.8	0.8	0.5	1.7	0.003	0.4	0.4	0.4	690	0.01	0.031
	RO	227	12	1.3	0.5	10.4	0.003	0.5	0.5	0.5	722	0.01	0.031

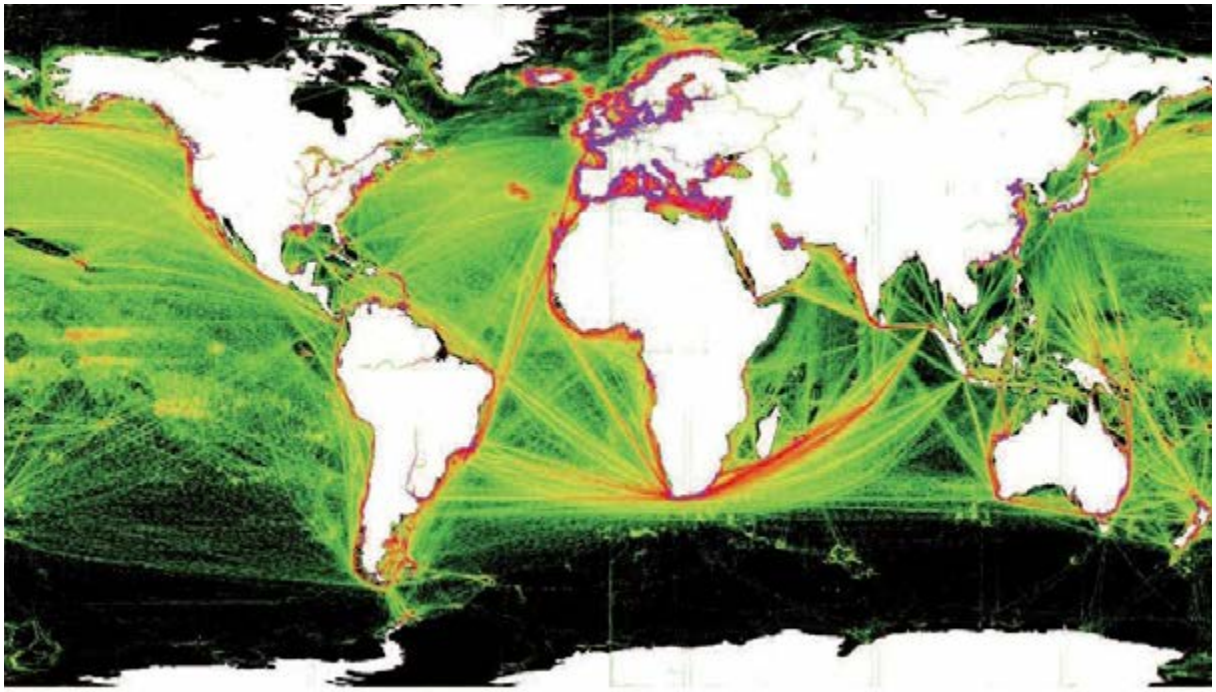
Source: Lloyds Ships Register

Table 15: Maneuvering (base factors in g/KWh)

Engine type	Fuel type	Fuel Consumption (sfc)	Main Pollutants					Particulate Matter			Greenhouse Gas Pollutants		
			NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2.5	CO2	CH4	N2O
SSD	MD	204	13.6	1	0.6	1.6	0.003	0.4	0.4	0.4	647	0.012	0.031
	RO	215	14.5	1	0.6	9.9	0.003	2.6	2.6	2.6	682	0.012	0.031
MSD	MD	226	10.6	2.2	0.4	1.8	0.003	0.4	0.4	0.4	717	0.008	0.031
	RO	237	11.2	2.2	0.4	10.9	0.003	1	1	1	752	0.008	0.031
HSD	MD	226	9.6	2.2	0.4	1.8	0.003	0.4	0.4	0.4	717	0.008	0.031
	RO	237	10.2	2.2	0.4	10.9	0.003	1	1	1	752	0.008	0.031
GT	MD	330	3	0.5	0.5	2.6	0.0004	0.05	0.05	0.05	1049	0.01	0.08
	RO	336	3.1	0.5	0.5	15.4	0.0004	0.25	0.25	0.25	1067	0.01	0.08
ST	MD	330	1.6	0.4	0.2	2.6	0.0004	0.6	0.6	0.6	1049	0.004	0.08
	RO	336	1.7	0.4	0.2	15.4	0.0004	1.6	1.6	1.6	1067	0.004	0.08

Source: Lloyds Ships Register

Annex 2: Potential energy efficiency improvements in Ships



Operational
Weather routing **1-4%**
Autopilot upgrade **1-3%**
Speed reduction **10-30%**

Auxiliary power
Efficient pumps, fans **0-1%**
High efficiency lighting **0-1%**
Solar panel **0-3%**

Aerodynamics
Air lubrication **5-15%**
Wind engine **3-12%**
Kite **2-10%**

Thrust efficiency
Propeller polishing **3-8%**
Propeller upgrade **1-3%**
Prop/rudder retrofit **2-6%**

Engine efficiency
Waste heat recovery **6-8%**
Engine controls **0-1%**
Engine common rail **0-1%**
Engine speed de-rating **10-30%**

Hydrodynamics
Hull cleaning **1-10%**
Hull coating **1-5%**
Water flow optimization **1-4%**

Source: International Council on Clean Transportation (ICCT), Long-term potential for increasing shipping efficiency through the adoption of industry-leading practices, Wang & Lutsey, 2013.

Annex 3: Key Regulations under MARPOL Annex VI

Regulation 12 – Prohibits the use or release of ozone-depleting substances (CFCs). New installations containing ozone-depleting substances are prohibited on all ships; however, existing installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1st January 2020.

Regulation 13 – Restricts NO_x emissions from diesel engines according to a corresponding technical code and applies to engines with a power output of more than 130 kW, installed or subject to a "major conversion" after 1st January 2000 (except emergency generators). NOx emission from an engine is closely related to the design of the engine. The quality of the fuel itself also has a significant impact on the NOx emission level, and is addressed in regulation 18.

Regulation 14 – Restricts SO_x emissions from ships by introducing maximum sulphur content in marine fuels of 4.5 per cent. In addition, MARPOL Annex VI identifies SOx emission control areas (SECA). From the above, it is apparent that vessels may have to carry several grades of fuel oil, and thus overcome related potential practical problems.

Regulation 15 – States that in ports where there is a need to control the emission of VOCs, there are also a requirement for the ports to ensure appropriate recovery facilities are available.

Regulation 16 – Prohibits the incineration of certain substances, including; PCBs, garbage containing traces of heavy metals, refined petroleum products containing halogen compounds and residues from MARPOL Annex I, II and III cargoes.

Regulation 18 – Contains standards regarding the quality documentation requirements for fuel oil. The fuel oil must be free from inorganic oil, is not to include added substances or chemical waste and is not to exceed the sulphur limits of 4.5 per cent or 1.5 per cent. With respect to documentation, a bunker delivery note must be issued and retained specifying, among others, the oil-product name, density at 15 degrees Celsius and the sulphur content.

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