MARITIME TECHNOLOGY COOPERATION CENTRE AFRICA
(MTCC-Africa)

CAPACITY BUILDING FOR CLIMATE MITIGATION IN THE MARITIME SHIPPING INDUSTRY
THE GLOBAL MTCC NETWORK (GMN) PROJECT

Pilot Project on Voluntary Fuel Consumption Data Collection and Reporting (DCR)

Prepared
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1.0 Introduction

1.1 Project Background
MTCC Africa with the support of International Maritime Organization (IMO) with funding support from European Union (EU) established a pilot project to study Fuel Consumption Data Collection and Reporting in the shipping and maritime sector. MTCC Africa, is an African centre established with the theme of, "Capacity Building for Climate Mitigation in the Maritime Shipping Industry". Through MTCC Africa a number of focal point partners have been established to support all the regions of Africa.

The aim of the pilot project was to help monitor the level of emission of greenhouse gases (GHG) and with an aim of recommending mechanisms for reducing them from the shipping sectors. This was to be achieved through technical assistance and capacity building to promote energy efficiency and related technology transfer and uptake.

Therefore, MTCC Africa pilot project on Fuel consumption data collection and reporting was a key deliverable for the commitment through a contractual agreement with International Maritime Organization. This project was implemented through support from Collecte Localisation Satellites (CLS) who provided the requisite technology for the achievement of the results. This report presents the results of implementation of this pilot project as well as the recommendations.

It is worth noting that MTCC Africa has carried out awareness workshops on the pilot project. These visits to the following places;

- Workshop in Walvis Bay, Namibia
- Workshop in Madagascar
- Workshop in Ghana
- National and regional workshops held in Kenya

1.2 Objectives
The main aim of the project was to access the level of carbon emission from ships operating regularly in African ports and other parts of the world through a voluntary data collection and reporting mechanism. This main objective was to be achieved via the following specific objectives

- To establish and implement an efficient voluntary data collection and reporting (DCR) mechanism for fuel consumption monitoring based on IMO strategy on reduction of greenhouse gas emissions in the shipping sector.
- To test the performance of the DCR system in estimating greenhouse gas emissions from shipping lines based on Energy Efficiency Operational Index (EEOI)
- To create awareness on the requisite technology for fuel consumption data collection reporting to stakeholders as a monitoring tool of greenhouse gases in shipping sector
- To recommend mechanisms of controlling greenhouse gas emissions

1.3 Project Justification
The project targets maritime sector as an area of regulation of greenhouse gases that are the driving force behind climate change. Therefore, a monitoring of fuel consumption by use of a
Data Collection and Reporting e-system will provide quantitative data leading to identification of mechanism of controlling these emissions. The data available currently are estimates and approximations which may not provide the accurate extent of the level of emissions in this sector. The project sought to build capacity in Kenya and the African region. The trained personnel were meant to play an active role in championing for climate change mitigation and adoption of policies/regulations that control release of pollutant gases. Through the implementation of voluntary reporting it is possible to quantify the evolution of fuel consumption.

The proposed mechanism of data collection, reporting and analysis throughout the three-year project period ensured an implementation of an effective monitoring mechanism. Hence allowing project evaluation.

1.4 Report Organization
This report is organized into the 5 chapters with the current being an introduction that contains the background that put the project into context followed by an enumeration of objectives of the pilot project and a justification. The second section is a brief analysis of past work and guidelines of International Maritime Organization as pertains to the use of EEOI for estimating shipping lines performance. The third section delves on the activities that were undertaken to set up the DCR system.

The fourth chapter contains the approach used in estimation of EEOI part of analysis and some key findings based on the collected data. Some discussions of the results have also been included. The final chapter presents some conclusions based on the findings from the project and a highlight of recommendations that MTCC Africa deduced from the completed work.

2.0 A Brief Review
Shipping sector is responsible for over 90% of world trade. It is comprised of cargo ships, tankers, dry bulk, among others and play a key role in globalization of economies. Transporting large quantity of goods over long distances in the shortest time depends on the speed at which the ship moves. This, along with other technical and operational parameters driving the energy efficiency of the ships, in turn affects the rate at which emissions such as carbon dioxide and other gases are released to the environment. It is for this reason that International Maritime Organization was mandated to develop standards that reduce carbon footprint in the shipping sector [1].

The International Maritime Organization (IMO) through the Marine Environment Protection Committee (MEPC) agreed in April 2016 to the Amendment of MARPOL Annex VI to have a mechanism of fuel oil consumption data collection and reporting in a new Regulation 22A [2]. According to this amendment, ships of 5,000 gross tonnage and above are required to collect and submit fuel consumption data to maritime administrations under whose jurisdiction they lie, from 1st January 2019 in accordance to the methodology described in the Ship Energy Efficiency Management Plan (SEEMP). The administrations were further expected to submit this data anonymously to IMO Ship Fuel Oil Consumption Database, which would form a basis for policy making and formulation of regulations.

Maritime transport is currently the spine of world trade and globalization. Twenty-four hours a day and all the year round, ships transport cargo to all corners of the world. This is poised to continue growing with the anticipated rise in world trade activities in the years to come, in response to growing populations and the need to alleviate poverty through enhanced access to basic materials, goods and products. In this regard, maritime transport will be useful in
sustaining economic growth and spreading prosperity throughout the world, thereby fulfilling critical social and economic functions. In 2018, the volume of maritime transported reached 11 billion tonnes consisting of dry bulk commodities, containerized cargo, other dry bulk, oil, gas and chemicals [3]. These environmental, social and economic dimensions of maritime transport are essential and should be fully considered in any strategy, policy, regulatory framework or action.

The International Maritime Organization (IMO), a specialized agency of the United Nations (UN), is at the forefront in setting standards for safety, security and environmental performance of international shipping. It is also committed to addressing all technical matters pertaining to safety of life at sea, efficiency of navigation, and the prevention and control of marine and air pollution from ships. This is achieved through the associated legal and administrative mechanisms which promote co-operation among member states and the availability of shipping services to world trade on a non-discriminatory basis.

With the acute awareness of the constant rise in the concentrations of greenhouse gases in the atmosphere, there is an urgent need to mitigate the resulting consequences of climate change. IMO started working on the reduction of Greenhouse gases (GHGs) in 1997 through the adoption of Conference resolution 8 on CO2 emissions from ships [4]. The IMO Assembly further adopted resolution A.963(23) on IMO policies and practices related to the reduction of greenhouse gas emissions from ships, this requested the MEPC to develop mechanism needed for greenhouse gas emission reduction in the international shipping line. This guideline further required that a baseline be developed for GHG and a mechanism be established for describing a ship’s GHG efficiency in terms of GHG emission.

It was against this background that a voluntary ship CO2 emission index was approved for use on interim basis by Assembly MEPC 53. This is the Energy Efficiency Operational Index (EEOI) that would assist parties in the shipping sector to evaluate CO2 emissions. The guidelines also observed that CO2 emission from a ship was directly related to the consumption of bunker fuel oil, and hence the EEOI could also provide useful information on a ship’s performance with regard to fuel efficiency.

Further guidelines were developed for Ship Energy Efficiency Management Plan in resolution MEPC.282(70) of 2016 [5]. The guidelines provide that a mechanism be established for monitoring ship and fleet efficiency performance and areas to be considered when seeking to optimize ship performance. The guidelines also recommended the use of established methods of monitoring and particularly identifies EEOI as an international standard for determining the energy efficiency of a ship or a fleet. It is therefore captured in the guidelines as a primary tool, though other tools exist.

The initial global CO2 reduction strategy for CO2 in the international shipping sector was adopted by parties to MARPOL Annex VI at the MEPC 62. Further amendments included regulations on Energy Efficiency for ships that made Energy Efficiency Design Index (EEDI) mandatory for new ships and SEEMP for all ships. These regulations apply to ships of gross tonnage of 400 and above and were to enter into force from 2013. A study to project and analyze effectiveness of the EEDI and SEEMP was commissioned by IMO. This study involved assessing the potential reduction of CO2 emissions for years 2020, 2030, 2040 and 2050 as a consequence of the introduction of the EEDI and the SEEMP. It also took into account the effect of a management plan as a tool that increases efficiency as well as addressing
the fuel costs and cost savings. The details of this study are captured in the MEPC 63/INF.2 [6].

From the foregoing it is notable also that SEEMP constitutes a tool for ships to improve their energy efficiency. This can only occur with a comprehensive monitoring tool and SEEMP recommends that a standard tool such as EEOI be adopted. It is against this background that MTCC Africa sought to utilize EEOI in order to complement the monitoring efforts envisaged under the SEEMP guidelines. To realize this goal, it was essential to acquire data on fuel consumption and hence the CO2 emissions in shipping lines. To achieve this MTTC Africa established the pilot project on fuel consumption data collection and reporting so as to monitor and subsequently help control greenhouse gas emissions.

The project involved acquisition of fuel consumption data collection mechanism utilizing a procedure that has been presented in following sections. The results of this and the analysis are intended to offer useful insights in the development of mechanism for emissions reduction that will not only contribute to CO2 emissions reduction in the shipping and maritime sector but also lead to efforts to improve energy efficiency through proper management and planning.

3.0 Methodology
3.1 Overview
This project involved establishment of pilot voluntary Data Collection and Reporting (DCR), E-Systems to monitor emissions arising from the shipping sector. MTCC Africa identified a method in which ship fuel data collection and reporting was to be carried out in accordance with regulation 22A of Annex VI of the MARPOL Convention. MTCC Africa engaged Collecte Localise Satellites (CLS) to set up a system for the fuel consumption data collection. CLS is a France based international company specialized in the supply of Earth observation and monitoring solutions. The system consisted of;

- Manual System involving use of Thorium X tablets fitted with a standardized e-form (sample obtained from IMO guidelines)
- Automatic System involving use of Sat boxes to provide real time fuel oil consumption data. Further details of this are presented in Section 3.7.
- Web-based platform for display of reported data.

The Thorium X tablets e-form contained information; vessel identification (IMO) number, gross tonnage, net tonnage, deadweight tonnage), voyage information start and end date, latitude and longitude, distance travelled, hours underway and fuel consumption data (type of fuel, amount of fuel used, and method used to measure fuel consumption). Figure 3.1 shows the Thorium X tablet and a view of its display.

3.2 Identification of Vessels
Implementation of the project depended on voluntary participation of stakeholders in the shipping and maritime sector. Thus, it not only required cooperation from the owners of shipping vessels but also the crew members running the vessels. In this regard, MTCC Africa embarked on a sensitization campaign to have support from these stakeholders. Some of the approaches used in the sensitization include;

- Stakeholders workshops: Shipping lines were invited to national and regional stakeholders workshops.
Meetings were held with shipping companies in which MTCC Africa sensitized shipping lines about fuel consumption data reporting project and its relevance to the sector. Figure 2.2 shows MTCC staff meeting a member of shipping line. There were 5 shipping lines visited for this sensitization.

Figure 3.1: Manual fuel consumption data collection system on Thorium X tablet

- Formal requests: This was through formal communication in which shipping lines were requested to volunteer their ships to participate in the pilot project on fuel data collection and reporting.
- Onboard visits: MTCC-AFRICA staff together with shipping line representatives went on board different ships to sensitize shipping crew on the project goals.

The above efforts resulted to two shipping lines committing to participate in MTCC-AFRICA project in which:

- One shipping line identified nine (9) of its vessels that would participate in the project. The ships were identified based on their operation route being within African region.
- A second shipping line plying northern and western coasts ports of Africa identified four (4) of its vessels that would participate in the pilot project. This shipping line was identified based on our collaboration with CLS. One of these vessels also accepted to have MTCC Africa install a SAT Box for automatic data collection.
- Through our focal point partners NIMASA and SAMSA, MTCC Africa was able to identify 2 more vessels plying their regions and that agreed to participate in the pilot project.

3.4 Anonymous Reporting of Data

From the onset MTCC Africa had to recruit companies who would be comfortable in revealing data concerning their vessels performance voluntarily. Therefore, MTCC Africa had to sign non-disclosure agreement with participating vessels as a sign of good will that data obtained would be presented anonymously. For ease of presentation the following coding has been adopted to designate participating vessels (and which is also captured in Table 3.1).
a) Alphabet Letter - signifying a particular vessel (name withheld)
b) Numeral – signifying the version of electronic form used in data collection. For example;
   - 1 denotes the electronic form captured all other data except cargo data (was used initially),
   - 2 denotes a revised version of the e-form that captured all data including cargo data
   - 3 denotes the data collection on the vessel involved use of SAT Box

MTCC Africa developed an electronic form for data collection. However, a review of the electronic form revealed that the form did not provide for capture of data that enable computation of EEOI. This was noted when data collection from the first group of shipping lines was at an advanced stage. The problem was collected and a second version of form was developed which was then used for data collection from the other shipping lines.

3.5 Training on Thorium X tablet and Themis Platform
CLS trained MTCC Africa staff on operation of the Thorium X tablet and how to interact with online Themis Platform for data collection and processing.

3.5.1 Training of MTCC Africa Staff
This was held from 11th to 12th April 2018 at the MTCC-AFRICA center in Mombasa to sensitize MTCC Africa staff on use of tablet for data collection and how to access data online. The training shown in Figure 2.3 and Figure 2.4 was conducted by 2 CLS technical officers. The training involved sensitization of among others;

- Specifications details of Thorium X tablet, its care and handling and physical features.
- Data entry procedure through use of e-form
- Data verification and transmission to the Themis platform via satellite communication.

Members were also informed that the tablets have mechanism of capturing data as draft in the event of network challenges and this data is transmitted at a later moment network is accessible.

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Figure 3.3: MTCC Africa staff undergoing training conducted by CLS (1st day)
MTCC-Africa staff were also trained on how to monitor and download collected data for further analysis. Practical demonstration on board a vessel was also carried out aboard a vessel as shown in Figure 3.5.

Figure 3.5: MTCC Staff and trainers boarding a vessel A1
3.5.2 Tablets Delivery and Training of Ship Crew

The MTCC-AFRICA team trained ship crew members on pilot project and its importance and subsequently delivered the tablets. The training consisted of; Overview of GMN Network and MTCC-AFRICA, MARPOL Annex VI requirements on fuel consumption Data Collection and Reporting, Data Collection and Reporting using Thorium X tablet and the Themis Platform. The training targeted crew members consisting of; the captain, chief engineer, second mate, second engineer and third engineer. Table 3.1 shows the dates training was carried out for the different various vessels (reported anonymously)

As part of implementation of the MTCC-AFRICA regional outreach Nigerian Maritime and Safety Agency (NIMASA) participated in delivery of tablets and training of ship crew. NIMASA is an MTCC-AFRICA west African focal point partner. They delivered a tablet and trained the crew of an oil/chemical tanker plying western African region.

Table 3.1: Tablet Delivery Dates to Various Vessels

<table>
<thead>
<tr>
<th>S/No</th>
<th>Vessel Name</th>
<th>Delivery Date</th>
<th>Delivered By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MV A1</td>
<td>15th April 2018</td>
<td>MTCC Africa, Mombasa</td>
</tr>
<tr>
<td>2</td>
<td>MV B1</td>
<td>30th April 2018</td>
<td>MTCC Africa, Mombasa</td>
</tr>
<tr>
<td>3</td>
<td>MV C1</td>
<td>21st June 2018</td>
<td>MTCC Africa, Mombasa</td>
</tr>
<tr>
<td>4</td>
<td>MV D1</td>
<td>16th June 2018</td>
<td>MTCC Africa, Mombasa</td>
</tr>
<tr>
<td>5</td>
<td>MV E1</td>
<td>1st July 2018</td>
<td>CLS</td>
</tr>
<tr>
<td>6</td>
<td>MV F2</td>
<td>1st March 2019</td>
<td>CLS</td>
</tr>
<tr>
<td>7</td>
<td>MV G2</td>
<td>1st March 2019</td>
<td>MTCC Africa, Mombasa</td>
</tr>
<tr>
<td>8</td>
<td>MV H2</td>
<td>30th March 2019</td>
<td>MTCC Africa, Mombasa</td>
</tr>
<tr>
<td>9</td>
<td>MV P3</td>
<td>13th July 2019</td>
<td>CLS</td>
</tr>
<tr>
<td>10</td>
<td>MV I2</td>
<td>29th April 2019</td>
<td>CLS</td>
</tr>
<tr>
<td>11</td>
<td>MV J2</td>
<td>9th May 2019</td>
<td>NIMASA- MTCC Africa west Africa focal point</td>
</tr>
<tr>
<td>12</td>
<td>MV M2</td>
<td>24th June 2019</td>
<td>MTCC Africa</td>
</tr>
<tr>
<td>13</td>
<td>MV L2</td>
<td>18th June 2019</td>
<td>SAMSA – MTCC Africa southern Africa focal point</td>
</tr>
<tr>
<td>14</td>
<td>MV K2</td>
<td>18th July 2019</td>
<td>MTCC Africa, Mombasa</td>
</tr>
<tr>
<td>15</td>
<td>MV N2</td>
<td>20th July 2019</td>
<td>MTCC Africa, Mombasa</td>
</tr>
</tbody>
</table>
Additionally, South Africa Maritime Safety Agency (SAMSA) another MTCC-AFRICA focal point coordinator in the southern African region participated in the training and delivery of tablets to ship crew to a bulk carrier vessel plying southern African region. Further training and delivery of tablets were also delivered to vessels which ply the route between the West African and Europe among other continents in which case MTCC-AFRICA engaged CLS to deliver the tablets to the ships. The delivery of the tablet was preceded by a similar training of crew members by the focal point coordinator.

Some of the challenges encountered in the process of data collection include;

- a) Inconsistent data entry by crew members
- b) Uncooperative ship crew
- c) Change of management and operation route of the ships

3.5.3 Data Collection and Reporting
Data collected from the tablets by ship crew was transmitted at the following intervals;

- Standby for departure to full away
- From full away to noon
- Noon to noon while the ship is still underway
- Noon to end of passage
- End of passage to alongside/anchorage
- For shorter voyages, data was sent on arrival at the port of destination (from full away to the end of passage)

Once the data was obtained, it was accessible through the Themis Platform and available to MTCC Africa staff.

3.5 Review Visits
MTCC-AFRICA went on board several vessels participating in the data collection at the Port of Mombasa to review the progress of data collection and establish the challenges if any that the crew may be experiencing.

3.6 Use of SAT box for Automated Data Collection
3.7.1 Background
The automatic fuel data collection and reporting system involved the use of SAT boxes to provide real time data transmission. SAT box is a system connected to the engine room of a ship and remotely to a web-based platform through satellite link. In this system fuel flow sensors in the engine room were linked to satellite via the SAT box device mounted at the upper deck of the ship in an installation shown in Figure 3.18.
3.7.2 Identification of ship for SAT Box Installation

While several shipping lines agreed to participate in manual fuel data collection using tablets identifying ships that could participate in the automatic fuel data collection presented some key challenges. This is because many ships are not compatible to requirements of SAT Box. Below is a highlight of some of the challenges

a) Vessel Compatibility: A SAT box is normally installed in a ship having an on board digital fuel flow meter at either the engine room or the bridge where sensors could be fitted to measure the amount of fuel consumed. However, most of the participating vessels did not have digital flow meters
b) Signal Accessibility: For signal to be transmitted from the SAT box to the satellite it was necessary to have a beacon at the upper deck. However, fuel flowmeters are found in the engine room in the lower decks. Therefore, wall drilling work and installation of cabling from the engine room to upper deck had to be on a number of floors in order to install the cables connecting sensors in the engine room and the SAT Box hardware.

c) Financial Constraints: The initial amount of funds that were to be spent of SAT Box had not factored the cost of installation.

The above challenges were overcome due to the partnership between MTCC-Africa and CLS, in which a vessel was identified and a company called Wartsila engaged to install the sat-Box. Note that the initial target was to fit four (4) vessels with the automatic data collection systems. Based on the above challenges and due to additional installation costs MTCC Africa and CLS agreed to focus on installation of one Sat-Box. Therefore, budget of procuring the second SAT-Box was taken up by installation of the first Sat-Box.

3.7.3 Installation of SAT-BOX

The vessel that was fitted with SAT-Box and the process of installation is shown in Figures 3.20 to Figure 3.22. The installation work was carried out from 10th to 13th July 2019.

Figure 3.20: Illustration of the part where the SAT box sensing system was to be installed

Figure 3.21: SAT Box data collection system including cabling and harness
3.7.4 Training of MTCC-Africa Staff on Sat-Box Data monitoring

CLS carried out training of staff of MTCC Africa use of SAT box technology as part of the agreement between them. The training was carried out on 1st and 2nd of August 2019 at MTCC-Africa boardroom and consisted of:

- Highlight of SAT box installation process onboard P3,
- A review of features of the data collection forms on the tablets
- Review of features of data collection platform THEMIS.

One shortcoming noted with use of SAT-BOX was that it was only connected to fuel flow meters feeding the main engine. For purposes of analysis, MTCC-Africa required data on all the fuel consumed onboard the ship, including the auxiliary engine fuel consumption. In addition, data on cargo (number of TEUs) would also be needed to compute EEOI. This type of data could not be collected automatically and hence required that MTCC Africa team obtain the cargo information from the participating shipping line.

Initially, MTCC Africa proposed to compare and verify further, data from ships official logs upon calling to ports where MTCC Africa has partners. However, the shipping line chose to work with MTCC Africa through our contracted partners CLS. This approach had challenges since CLS has also not been able to obtain information from the shipping line. Therefore, it was not possible to verify the data obtained from the ship official logs for further analysis of SAT Box data.
4.0 Data Analysis and Reporting

4.1 Background
In this chapter preliminary data analysis is presented as obtained from online data reporting platform. It is worth noting that the findings from the data obtained from the shipping vessels participating in the project is reported anonymously. From the data obtained the following was noted:

- Heavy fuel oil is the most common fuel used in the shipping lines plying African routes. These ships also utilize diesel/gas oil occasionally.
- Ships operating in African routes have no installed emission reduction methods.
- There is no use of LNG as fuel which has lower carbon emission compared to all other fuels by ships operating in African routes.

4.2 Quantity of Collected Data
Table 4.1 shows the extent to which data has been collected from 15 participating vessels. This translates to 2452 data set in which over 80% of the vessels have been able to transmit data. It is also notable that more than half of the ships have been utilizing electronic form version 2 which contains data worth of calculation of EEOI. Though MTCC Africa has been able to obtain data set from 13 of the vessels it has only been possible to obtain data sufficient for calculation of EEOI from 8 ships due to the challenges cited in section 3.5.2. Of the vessels in
which MTCC Africa has analysed data, it has been possible to compute EEOI of 9 vessels namely B1, D1, F2, G2, H2, J2, K2, M2 and N2 by the time of completion of this report.

Table 4.1: Status of Fuel Data Collected from Volunteer Ships

<table>
<thead>
<tr>
<th>S/No</th>
<th>Code name</th>
<th>Period of Data Collection (days)</th>
<th>Quantity of Data Transmitted</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1</td>
<td>469</td>
<td>335</td>
<td>Cargo data not submitted</td>
</tr>
<tr>
<td>2</td>
<td>B1</td>
<td>469</td>
<td>485</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>3</td>
<td>C1</td>
<td>257</td>
<td>354</td>
<td>Cargo data not submitted</td>
</tr>
<tr>
<td>4</td>
<td>D1</td>
<td>30</td>
<td>44</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>5</td>
<td>E1</td>
<td>180</td>
<td>288</td>
<td>Cargo data not submitted</td>
</tr>
<tr>
<td>6</td>
<td>F2</td>
<td>180</td>
<td>48</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>7</td>
<td>G2</td>
<td>198</td>
<td>111</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>8</td>
<td>H2</td>
<td>180</td>
<td>150</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>9</td>
<td>I2</td>
<td>154</td>
<td>0</td>
<td>No data transmitted</td>
</tr>
<tr>
<td>10</td>
<td>J2</td>
<td>150</td>
<td>39</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>11</td>
<td>K2</td>
<td>127</td>
<td>87</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>12</td>
<td>L2</td>
<td>74</td>
<td>0</td>
<td>No data transmitted</td>
</tr>
<tr>
<td>13</td>
<td>M2</td>
<td>98</td>
<td>139</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>14</td>
<td>N2</td>
<td>80</td>
<td>26</td>
<td>EEOI Computed</td>
</tr>
<tr>
<td>15</td>
<td>P3</td>
<td>79</td>
<td>346</td>
<td>Cargo data not submitted</td>
</tr>
</tbody>
</table>

The status of the other ships is as follows

- A1, C1, E1 and P3 were yet to submit the cargo data despite our effort to contact them on the same.
- Vessel L2 has informed us that the crew has been submitting data yet we cannot access it in the Themis platform. Our personnel have: (1) guided the crew on ways of updating the tablet software (2) updated the tablet which was submitted by the South African focal point partners. Despite these attempts the data transmission has not been reflected on the Themis platform.
- The crew of I2 has not transmitted any data at all and it has not been possible to reach them.

Despite the above challenges MTCC Africa has analysed the available data and continues to communicate with stakeholders to obtain data from participating ships. This effort is through official means and also through emails.
4.3 EEOI Computation
The analysis of the data from 9 of the participating vessels is presented in this section. This involved computation of EEOI based on guidelines from IMO guidelines [1]. In the guidelines the EEOI is defined as ratio of mass of carbon dioxide (CO2 emitted per unit of transport work in an expression appearing in the form;

\[ EEOI = \frac{\sum_j FC_j CF_j}{m_{cargo} D} \]  

where
- \( j \) is the fuel type
- \( i \) is the voyage number
- \( FC_j \) is the mass of consumed fuel \( j \) at voyage \( i \)
- \( CF_j \) is the fuel mass to CO2 mass conversion factor for fuel \( j \)
- \( m_{cargo} \) is cargo carried (tonnes) or work done (number of TEU)
- \( D \) is the distance in nautical miles corresponding to the cargo carried or work done

Average EEOI was also computed from the following expression

\[ Average \ EEOI = \frac{\sum_i \sum_j FC_j CF_j}{\sum_i m_{cargo} D} \]  

The data set has been obtained based on the definition indicated in section 3.5.3. For the pilot project 2 MTCC Africa computed EEOI based on the following steps as per the guidelines of IMO

- A defined period of EEOI computation
- Based on the available data EEOI was computed for a period of more than 3 months on average.
- The data source: Shipping lines that volunteered to submit data and operating within the region of Africa

4.4 Findings and Discussions
Shown in Figure 4.1 (a) is the variations in EEOI and the variations in Cargo for vessel H2 (a container ship built in 2013) across 21 voyages. The fuel consumption and the speed were also noted to fluctuate as shown in Figure 4.1(b). Though sea and weather conditions could have
contributed to the trend it was noted that the least emissions were noted to be in the 12th voyage which had the highest amount of transport work. As noted in Figure 4.1 (b) the vessels had a speed nearly equal to the average for all voyages. Voyage 1 had the highest emissions corresponding to the least transport work. Indeed, at this voyage the vessel had a speed well below average (26.6 knots) which could have been further been influenced by unfavorable sea and weather conditions. The average EEOI was found to be $1.44 \times 10^{-5} \text{tCO}_2/(\text{t.nm})$.

Figure 4.1: Status of MV H2 ((a) EEO and Cargo and (b) Fuel and Speed
Shown in Figure 4.2(a) is the EEOI and Cargo for the vessel G2 which is found to fluctuate across the 11th voyages while Figure 4.2 (b) shows fuel fluctuations across the voyages. This is a container ship built in 2002. These fluctuations are not only related to the transport work but also to the fuel consumption. It is noted that the least emissions per unit of transport work were in voyage 1 while the highest emissions were in voyage 5 (associated with the lowest transport work). It would have been important to see the influence of speed on voyage 5 but it was not clear why the crew never recorded the speed data for the 11th voyages. The average EEOI is however $1.31 \times 10^{-5}$ tCO2/(t.nm), which is of the same order of magnitude as that of vessel H2.

Figure 4.2: Status of Vessel G2((a) EEOI and Cargo (b) for Vessel G2
Shown in Figure 4.3 (a) is the EEOI and cargo data for ship D1 which is a container ship that was built in 2008. Though the EEOI is obtained for 4 voyages, is also noted to fluctuate based on transport work. The average EEOI $4.6 \times 10^{-5}$ tCO2/(t.nm) which though 4 times lower than EEOI for the other vessels (H2 and G2) could be contributed by the fact that the ships carried higher average amount of transport work (more than 10 times compared to other ships). Though the number of voyages were smaller, they were not expected to contribute significantly to the reduced EEOI.

![Graph showing EEOI and Cargo data for Ship D1]

Figure 4.3: Status of Ship D1

Shown in Figure 4.4 is the status of vessel M2 in which EEOI was found to fluctuate in an inverse trend relative to transport work. It is notable that the highest emissions were in the 6th voyage that had the lowest transport work. For this ship also the fuel consumed during the 6th Voyage was uncharacteristically low (18.1 tonnes) for a distance travelled of 206 nautical miles. This could be an erroneous entry of data by the ship’s crew. The average EEOI was found to be $1.87 \times 10^{-5}$
Figure 4.4: Status of EEOI, Cargo and Fuel for ship M2

Shown in Figure 4.5 is the EEOI for ship J2 which is a tanker built in 2001. Though this ship has a fluctuating EEOI its average EEOI was found to be much larger than for vessel G2, H2, D1 and M2 as shown in Table 4.2. This was attributed to the lower quantity of cargo carried (more than a third on average compared to the other ships) and the fact that the vessel operates on short voyages. It is worth noting that J2 is an oil tanker built in 2001, hence age contribute to its lower energy efficiency (hence higher emissions).
Shown in Figure 4.6 is the EEOI for the vessel K2 (Vessel built 2013), which was found to fluctuate based on an inverse proportion to the transport work. The highest emissions were notable in the 3rd voyage while the lowest were in the 7th voyage and each was associated with an inverse variation in the transport work. The average EEOI was 1.93x10^{-5}, a value of the same order of magnitude as the other ships (H2, G2 and M2) and this could be attributed to the fact that the ship performs nearly the same average transport work under the same conditions.
Figure 4.6: Status of EEOI and Cargo for vessel K2

Shown in Figure 4.7 (a) is the variation of EEOI and cargo for vessel B1 across 4 voyages. This is a container ship built in 2013 and has EEOI that fluctuated across the 4 voyages in an inverse relationship to the transport work (Figure 4.7(b)). Although the data collected was for 4 voyages, it enabled computation of a realistic average EEOI \(6.57 \times 10^{-5} \text{tCO2/(t.nm)}\) that was of the same order of magnitude as the average EEOI for Ship D1 (as seen in Table 4.2).

Figure 4.7: Status of EEOI (a) and Cargo (b) for Ship B1

Shown in Figure 4.8 is the EEOI variations for ship F2 for 3 voyages. This is a container vessel built in 2010. Its EEOI was found to have a fluctuating trend across the 3 voyages in an inverse
relationship to transport work, it may not be fair to compare the obtained average EEOI of 3.9 \( \times 10^{-5} \) tCO2/(t.nm) to other vessels due to the low number of voyages. However, this value was of the same order of magnitude as vessel D1.

![Graph](image)

**Figure 4.8: EEOI for Ship F2**

Figure 4.9 presents results for Vessel N2 (a container vessel built in 2013) in which data available was for 2 voyages. There is an inverse relation between EEOI and cargo though other factors such as sea and weather conditions could have contributed to the fluctuations. The average EEOI was found to be 7.75 \( \times 10^{-5} \) tCO2/(t.nm). This ship had the lowest number of voyages based on data obtained from ship crew.
5.0 Standard EEOI
On the basis of the computed values of EEOI MTCC Africa proposes the following values that can be utilized as standard EEOI for container ships based on the dead weight and power output.

Table 5.1 Standard EEOI

<table>
<thead>
<tr>
<th>S/No</th>
<th>DWT (Tonnes)</th>
<th>Engine Power (Kw)</th>
<th>Standard EEOI (tCO2/(t.nm))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>38477</td>
<td>21735</td>
<td>1.6E-05</td>
</tr>
<tr>
<td>2.</td>
<td>45349</td>
<td>22890</td>
<td>1.7E-05</td>
</tr>
</tbody>
</table>

This proposed standard EEOI is based on the average EEOI values obtained from the ships data that had been collected for more than 7 voyages.

6.0 Annual Efficiency Ratio
MTCC Africa has calculated annual efficiency ratio (AER) based on the following formula below [7].

\[
AER = \frac{\sum_j F_{C_j} C_{F_j}}{DWT \times D} \tag{5.1}
\]

Where
• $j$ is the fuel type
• $i$ is the voyage number
• $FC_j$ is the mass of consumed fuel $j$ at voyage $i$
• $CF_j$ is the fuel mass to CO2 mass conversion factor for fuel $j$
• $DWT$ is the Dead Weight
• $D$ is the distance in nautical miles corresponding to the cargo carried or work done

Shown in Table 6.1 is the computed values of AER for 2 ships. These are the only ships that MTCC Africa had managed to obtain annual data. The annual efficiency ratios for the two ships differ by 10 times with B1 having less emissions. This could be attributed to differences in age (Mv A1 was built in 2004 while Mv B1 was built in 2013)

Table 6.1: AER for 2 ships

<table>
<thead>
<tr>
<th>Ship Type</th>
<th>HFO (Tonnes)</th>
<th>LFO (Tonnes)</th>
<th>DIESEL/Gas (Tonnes)</th>
<th>Distance (nm)</th>
<th>DWT</th>
<th>Annual Efficiency Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mv A1</td>
<td>1721.6</td>
<td>0</td>
<td>21</td>
<td>21661</td>
<td>10683</td>
<td>2.35E-05</td>
</tr>
<tr>
<td>Mv B1</td>
<td>10643.7</td>
<td>637</td>
<td>30.7</td>
<td>95262.3</td>
<td>45361</td>
<td>8.17E-06</td>
</tr>
</tbody>
</table>

7.0 Emissions within Port Limits

Presented in this section are the emissions of carbon dioxide, methane and nitrous oxide computed based on emission factors and fuel consumption for each ship. The variations are based on the amount of data collected and not on ships engine efficiency. Shown in Figure 7.1 is the CO2 emission computed for 9 of the ships. The highest contributions of emissions are notable from the vessel B1 and G2.
Shown in Figure 6.2 is the methane and nitrous oxide emissions computed for 9 of the ships. Similar distributions were observed for nitrous oxide and methane except the values were lower. The concentration of methane demonstrates incomplete combustion of the fuel. Methane has 20 times the global warming potential compared to carbon dioxide and efforts should be made by engine designers to minimize it. High emission of nitrogen oxide demonstrate that combustion is associated with high temperatures that cause oxidation of nitrogen. The highest values were notable for ship B1 while the lowest values were noted for ship D1.
Figure 7.2: CH4 and N2O Emissions from various Ships

8.0 Air Quality Monitoring Report

8.1 Background
The Maritime Technology Centre- Africa (MTCC-Africa) undertook an assessment of the general air quality at the port of Mombasa as a complementary study to Pilot Project 2 on fuel consumption data collection and reporting. The aim of the project was to obtain information useful as a reference for subsequent surveys especially after the implementation of the initial pilot projects 1 so as to compare the results before and after shore power project.

The Kenya Meteorological Department (KMD) was sub-contracted by MTCC Africa to carry out this study. KMD utilized a mobile Air Pollution Monitoring Laboratory to carry out the survey. The study that was carried out in 2018 was in two phases and covered six sites within the port. The first phase was carried out from 27th February to 9th March 2018 while the second phase was done from 26th July to 5th August 2018.

8.1.2 Objectives
The main objective of air quality survey was to generate baseline information regarding air pollutants within the port. This was to be achieved via the following specific objectives.

a) Establish a technique of surveying the air pollution within the port
b) Survey the extent of emissions within the port and compare with existing international and national regulations

8.1.3 Project Rationale
The port of Mombasa has over the years had challenges with the management of the high levels of air pollution during handling of bulk dusty cargo especially clinker (mainly dust) due to lack
of suitable handling equipment. MTCC-Africa air quality survey was the first comprehensive air quality survey undertaken at the port which covered more areas in which more pollutants were measured. It was envisaged that the results of the study would help KPA monitor the levels of air pollutants especially particulates matter arising from bulk cargo handling. This would then contribute to measures that further control the emissions.

8.2 Methodology
8.2.1 Equipment
The equipment used was the mobile laboratory shown in Figure 8.1 and 8.2. This is equipment provided by the Kenya Meteorological Department who were subcontracted by MTCC Africa to carry out this monitoring.

Figure 8.1: Mobile air pollution laboratory
8.2.2 Survey Sites and Pollutants Monitored
Table 8.1 illustrates the six sites selected for the survey spread over both Conventional/General cargo area as well as the Container terminal. It is notable that there are more general cargo berths in the port than container berths hence more monitoring sites (sites1-4) for general cargo areas.

Table 8.1: Site Details

<table>
<thead>
<tr>
<th>S/No</th>
<th>Site No</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Site 1</td>
<td>Yard No.1/2</td>
</tr>
<tr>
<td>2.</td>
<td>Site 2</td>
<td>Yard No. 5</td>
</tr>
<tr>
<td>3.</td>
<td>Site 3</td>
<td>Shimanzi Oil Terminal (SOT)</td>
</tr>
<tr>
<td>4.</td>
<td>Site 4</td>
<td>K-section near HQs</td>
</tr>
<tr>
<td>5.</td>
<td>Site 5</td>
<td>Berth 16 area</td>
</tr>
<tr>
<td>6.</td>
<td>Site 6</td>
<td>Yard No. 19</td>
</tr>
</tbody>
</table>

The measurement of the pollutants focused mainly on carbon dioxide, carbon monoxide, Nitrogen Oxides (NOx), Nitrogen Dioxide, Sulfur dioxide and Particulate matter. The mobile Laboratory was stationed at each site for 48 hours.

8.2.3 Challenges During Measurement
Only 2 surveys were carried out. A scheduled 3rd Survey for the first quarter of 2019 was not carried out due to delays in the certification of the laboratory. According to Kenya Meteorological Department (KMD), the periodic calibration and certification/licensing by external partners from South Africa had not been carried out by the time of completion of the report.
8.3 Results and Discussion of Air Quality

Figure 8.3 illustrates the concentration of coarse particulate matter (PM\(_{10}\)) for phase 1 and 2. Higher levels of PM\(_{10}\) at all the sites were noted for phase 1 compared to phase 2. This was attributed to existence of construction activities during phase 1 as well as presence of high wind speed during phase 2 which caused faster dispersal of pollutants. The highest 24-hour average was 127.78 µg/m\(^3\). From the sites World Health Organization Air Quality Guideline for PM\(_{10}\) and PM\(_{2.5}\) for 24-hour duration (which are respectively 50 µg/m\(^3\) [8]) were exceeded in all the sites except site 2. However, the results of the second survey showed that none of the sites exceeded the 24-hour World Health Organization limits. Also noted was the fact that the 24-hour average for PM\(_{10}\) levels at all sites were within the limit of Kenya’s Air Quality regulations 2014 (Green bar).

Figure 8.3: Measured Concentration of Course Particles

Figure 8.4 shows the concentration of fine particulate matter measured at the port of Mombasa from phase 1 and 2. It was found that there were levels of PM\(_{2.5}\) at all the sites for phase 1 as compared to phase 2. These levels exceed the WHO limit of and 25 µg/m\(^3\) Higher.

Figure 8.4: Measured Concentration of Fine Particles
This variations could be attributed to construction activities during phase 1 and high wind speeds during phase 2. The highest average 24-hour concentration was 59.92 g/m³. Also this value is within the limit of Kenya’s Air Quality regulations 2014 (Green bar)

Figure 8.5 shows the Sulphur dioxide concentration measured at the 6 sites. The Sulphur dioxide were observed to be low for both surveys. It was found that only sites 4 and 6 had 24-hour mean of Sulphur dioxide that exceeded the WHO limit of 20 µg/m³ (approx. 7.63 ppb) for phase 1 survey.

However, none of the sites exceeded Kenya’s Environment Management and Coordination Act (EMCA) Air quality Regulation 24-hour mean of 125 µg/m³ (green bar - 48 ppb) [2]. The highest emissions were observed to be average at 16.29 ppb from survey one.

Figure 8.6 shows the concentration of CO2 within the port of Mombasa. Highest average mean 24-hour concentrations were found to be on site 2 and 4 for phase 1 survey while the highest for phase 2 were on site 1 and 2. Though not harmful it is the driving force behind global warming and hence climate change. It also demonstrate the level of activity utilizing combustion of fossil fuel. The highest measured value for 24-hour average was 385.76 ppm which lower than the world average levels of approximately 400ppm as at 2018.
The concentration of carbon monoxide are shown in Figure 8.7 in which the highest concentrations are on site 1 and 6 for both the first and second surveys. Although carbon monoxide is only harmful under indoor conditions it nevertheless indicates the quality of combustion of fossil fuels. Vehicle emissions are major sources of this toxic pollutant and the presence of more heavy machinery for construction during phase 1 could be the reason for the higher levels in phase 1. High wind speeds could be responsible for the dispersion rate in phase 2 could be the reason for the lower levels of carbon monoxide in this phase. Highest 24-hour average at 0.99 ppm
The level of NO2 emissions are as shown in Figure 8.8. Nitrogen dioxide levels generally low for both assessments. Equipment malfunction affected phase 2 figures for 3 sites. The pattern is the same as noted in the other measurements in which there are more emissions in phase 1 than 2 attributed to construction activities and high wind speeds recorded. Highest 24-hour average for at 16.29 ppb which is below national regulations of 100ppb and below the WHO guidelines of 150ppm.

Figure 8.8: Measured Concentration of Carbon Monoxide

9.0 Conclusions and Recommendations

9.1 Conclusions

The voluntary participation of all the stakeholders has contributed positively to the success of this project. From the findings of this pilot project it can be concluded:

- HFO is the predominant fuel used by ships operating in African routes.
- The low EEOI contribute low emissions to environment and is affected by a number of factors including transport work (fuel and distance) as well as other factors such as speed, sea and weather conditions. This was also found in a study commissioned by Royal Belgian Ship Owners Association and presented to MEPC 69 [8]

On port air quality there were a numbers of major construction projects that were ongoing during phase 1 survey especially the Standard gauge railway and other yards rehabilitations projects at the container terminal. The implementation of the MTCC-Africa project was expected to adoption of such regular monitoring practices by not only KPA but also other ports in Africa. It is on this basis that KPA to high its own air quality monitoring expert charged with monitoring air quality on quarterly basis. The frequency of assessments is expected to increase to monthly.
9.2 Recommendations
There are a number of recommendations that MTCC Africa would wish to make regarding this and other future pilot projects

- It would be important to extend the study to other types of ships such as roro, bulk carriers, research vessels and other smaller vessels such as ferries found within Africa.
- More sensitization campaigns need to be carried out to emphasize the regulations governing ship energy efficiency and emissions from fuels inorder to reduce greenhouse gases.
- It would be important to install shore power for African ports to minimize emissions when ships are docked in the ports.
- It is necessary that shipping lines explore mechanisms of emissions reduction and install systems that reduce emissions on board ships.
- It is necessary that further work be carried out to establish influence of use of non-conventional fuels such as biofuels and electricity in emissions reduction.
- It is recommended that shipping manufacturers explore renewable technologies such as wind and solar to minimise fossil fuels used in running auxiliary systems.
- It would be important to use other tools such as Energy Efficiency Design Index EEDI and Ship Energy Efficiency Management Plan (SEEMP) to study the level of fuel efficiency from ships operating in African ports.
- It would be essential to understand the degree of pollutants within ports in Africa so that intervention measures are carried out.

Acknowledgement
MTCC Africa has been working closely with several stakeholders in implementation of Pilot Project 2 on fuel consumption data collection and reporting. MTCC Africa appreciate their invaluable support which the project would not have been successful. These include;

- International Maritime Organization (IMO) and the funding partner European Union for providing MTCC Africa with funding for establishment of the centre and also availing funds for this pilot project including other operational activities.
- State Department for Maritime and Shipping Affairs, Ministry of Transport, Infrastructure, Housing and Urban Development, Kenya: The state department has provided strategic direction and leadership for MTCC-Africa as the Chair of the Project Steering Committee and has supported the management and running of MTCC-Africa. In addition to this, the ministry has been engaged in promoting the publicity of MTCC Africa in their forums.
- Kenya Maritime Authority: Is a co-host and strong partner of the MTCC-Africa. KMA has continually supported the implementation of the project and has seconded its staff on part time basis to provide technical support for the project.
- Kenya Ports Authority (KPA): As a co-host and strategic partner for MTCC-Africa KPA has seconded employees on part time basis to MTCC Africa.
- Collecte Localisation Satellites (CLS): Provided training and technical support in form of tablets, web based platform, satbox and linked MTCC Africa to shipping lines operating between west African ports and Europe.
• MTCC Africa focal point partners (SAMSA and MIMASA for their continued support in terms of delivery of tablets to vessels operating in their ports
• Shipping lines who volunteered some of their vessels plying within the African route and who participated in the fuel consumption data collection and reporting project. They also allowed the installation of Sat-Box automatic data collection system.

References
3. Review of Maritime Transport UNCTAD, United Nations 2019
6. MEPC 63/INF 2 Air pollution and Energy Efficiency, 2011
8. MEPC 69, Further technical and operational measures enhancing the energy efficiency of international shipping.
9. WHO/SDE/PHE/OEH/06.02, WHO Air Quality Guideline for Particulate Matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide, 2005
10. Environmental Management and Coordination (Air Quality) Regulations 2014