Proceeding of STIP International Conference (STIPCON), Vol. 1, No. 1, November 2024

e-ISSN 3089-1248

Evaluate the impact of Shore Side Electricity (SSE) on reducing exhaust emissions for ships, using the State Ship KN Masalembo as a case study at Tanjung Perak

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***Abstract*— Sea transportation accounts for 3% of the global greenhouse gas effect. The International Maritime Organization (IMO) is committed to reducing the impact of greenhouse gases by 50% in 2050—Indonesia is a maritime country with 10.8% of the world's ship register. High traffic has an impact on increased gas emissions. The IMO has made a policy on the Ship Energy Efficiency Management Plan. IMO recommends using Shore Side Electricity to reduce exhaust emissions, namely the use of electricity sources from land will reduce the operation of the ship's generator when berthing.**

This SSE case study uses the State Ship (KN) Masalembo at the Tanjung Perak Port. Evaluation of the impact of SSE on emission reduction is carried out by calculating electricity and fuel consumption. Based on fuel consumption, the amount of pollutants produced is known. A Descriptive quantitative method is used in this research.

Based on the calculation, the electricity demand at 220 Volt voltage is 95,028 watts, and at 380 watts is 276,210 Watts. There are 3 generators on board with different output power. There are: auxiliary engine 1-2, harbour generator, and emergency generator. Each generator has different efficiency and fuel consumption. The Comparison of SSE reduction impact is largest in aux eng 1-2 worth 206,855.13 kg pollutant/ton of fuel. Fuel cost savings of up to 92.57% every year. SSE utilization is a solution for reducing exhaust emissions in the port area. Power generation using renewable energy sources is a recommendation for supporting SSE operations.

***Keywords*— fuel, emissions, generator, electricity, Shore Side Electricity**

I. INTRODUCTION

The United Nations Conference on Trade and Development (UNCTAD) in the Review Of Maritime Transport 2022 states that more than 80% or 11 billion tons of world trade uses sea transportation [1]. Data for 2023 shows that the Asian region dominates 59% of the world's container shipping traffic. Indonesia as an archipelagic country holds a strategic role in the maritime world. Based on data for 2023, ship arrivals in Indonesia there are 196,575 ships. In terms of ranking, Indonesia occupies the seventh position in the world [2]. Based on ship register data in the world, Indonesia ranks 12th with the number of ships 11,422 or 10.8% of the total number of ships registered in the world, with an average tonnage of 2,641 deadweight tons (DWT) of registered ships [3].

High shipping traffic has consequences for increasing greenhouse gas (GHGs) emissions in Indonesia. The shipping industry accounts for 3% of global GHGs. The percentage may be small at the moment, but the rapid growth of the shipping industry is predicted to grow much higher following the rise of the shipping industry. GHGs have a negative impact on health and the environment. NOx pollutants have caused 70 thousand premature deaths per year and are predicted to increase to 178 thousand by 2040. Research from the European Environmental Agency (2017) noted that cases of premature infant deaths occurred in 41 European countries as a long-term impact of NOx pollutants. Shipping activities are the dominant factor causing emissions at ports, which reaches 55%-77% [4].

The IMO is committed to reducing GHG emissions by up to 50% by 2050. As stated in MARPOL Annex VI regarding regulations to prevent air pollution from shipping. The Ministry of Transportation also encourages port management by prioritizing sustainable and environmentally friendly principles (green and smart ports).

In 2022, in order to realize a green port, the District Navigation of Tanjung Perak uses Shore Side Electricity (SSE) for efficiency and emission reduction. Distric

Navigation of Tanjung Perak has the KN Masalembo. This study will examine the impact of the use of Shore Side Electricity in KN Masalembo, on the reduction of exhaust gas emissions that occur when ships berthing.

II. METHODS

A. Literature Review

Several researchers have studied the use of shore-side electricity in the world of shipping. B. Stolz et al (2021) conducted a study on the need for additional power at 714 major ports in the European Economic Area and the United Kingdom. This is done to calculate the electrical power needs of ships that are leaning and utilize Shore Side Electricity (SSE). Researchers made observations on ship traffic using the Automatic Identification System (AIS), to find out the electrical power needs that must be prepared by ports in Europe [5].

Dai et al., (2019) conducted an economic analysis of SSE investments. The study was carried out in the Port of Shanghai, China, using an economic feasibility scenario. Huge initial investment, high electricity selling price, and long charging are challenges in the implementation of SSE use. Environmental benefits are a consideration for the use of SSE. There is a need for subsidies for the implementation of SSE to encourage its massive use [6].

Researcher Kotrikla et al., (2017) calculated the number of emissions emitted by ships in the port of Mytilene. Researchers simulated the use of electricity from land to reduce exhaust emissions. Based on the results of the study, emissions can be reduced by providing electricity from land connected to hybrid renewable energy between wind turbines and solar power. Based on simulations, the electricity at the port can be filled with four wind turbines of 1.5 MW and solar power of 5 MW [7].

1) IMO Regulation on Reducing Exhaust Gas Emissions
The International Maritime Organization (IMO) is the world organization responsible for the safety and security of shipping and the protection of the maritime environment. The IMO focuses on shipping safety and security standards, preventing pollution from shipping activities, and facilitating international maritime cooperation. The IMO has issued several regulations to control exhaust emissions from ships.

a). MARPOL 73/78 Annex VI : Regulations on the Prevention of Air Pollution from Ships: MARPOL Annex VI is an IMO regulation on the prevention of air pollution from shipping activities. This regulation contains rules on limiting emissions of hazardous exhaust gases such as sulfur oxide (SOx), nitrogen oxides (NOx), matter particles (PM), and greenhouse gases (GHGs). In addition, there are also rules on the requirements for the use of low-sulfur fuel (LSFO) with sulfur content. The regulation has stipulated:[8]

- Emission limits for sulfur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM), and greenhouse gases (GHGs).
- The use of low-sulfur fuel (LSFO) with a maximum sulfur content of 0.5% has been in effect since January 1, 2020.

b). Initial IMO GHG Strategy: In 2018, this regulation was the IMO's initial framework to reduce GHGs emissions from international shipping activities. The targets to be achieved are:

- An average reduction in GHG emissions by 40% by 2030, compared to 2008.
- A minimum total reduction in GHG emissions of 50% by 2050, compared to 2008.

In July 2023 the IMO revised its strategy with a higher target, namely the target to achieve net-zero GHG emissions by 2050.

c) Ship Energy Efficiency:
The IMO has developed various guidelines and standards to improve energy efficiency on ships, the policy: The Energy Efficiency Design Index (EEDI) is a new standard applied to newly built ships. The goal is to guarantee a minimum level of energy efficiency for the ship so that it can reduce GHGs emissions.

The lower the EEDI value, the more energy-efficient the ship will be and the lower the GHG emissions produced. Some of the advantages of EEDI are:

- Driving innovation
- Reducing GHG emissions
- Lower operating costs

The Ship Energy Efficiency Management Plan (SEEMP) is an IMO Regulation that requires ships to be energy efficient. Shore Side Electricity is one of the strategies included in SEEMP, to reduce ship emissions at ports. IMO encourages the use of Shore Side Electricity.

d) IMO Guidelines on Shore-Side Supply of Electricity to Ships.

The IMO states that the Shore-Side Supply of Electricity to Ships is a series of recommendations published by the IMO. These guidelines provide a framework for safe, efficient, and environmentally friendly use of shoreside electricity for ships at berth.

Use of Shore Side Electricity as a means to:

- Reduce air pollution and noise in ports.
- Comply with increasingly stringent emissions regulations for ships.
- Improving energy efficiency in the maritime industry.

e) Alternative Fuels:

IMO encourages the use of alternative fuels that are more environmentally friendly, such as:

a. Liquefied natural gas (LNG).

b. Biofuels.

c. Hydrogen.

B. Type A Navigation

District Class I Tanjung Perak District Navigation of Tanjung Perak is one of the technical implementation units of navigation under the Directorate General of Sea Transportation of the Ministry of Transportation. The Navigation District has the task of carrying out navigation activities and supervising the implementation of navigation organized by government agencies and business entities.

The aid to navigation and State Ship Operational Sector has the task of managing state ships, docks, and shipyards. The base belonging to the District Navigation of Tanjung Perak is an asset where the state ships berthing. The pier is also a field for aid to navigation and navigation equipment operations.

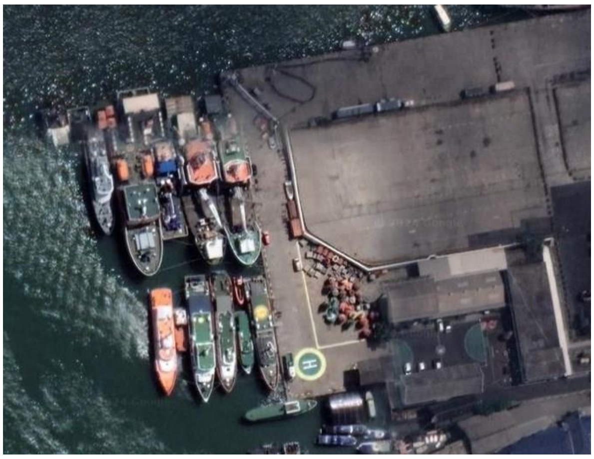

Fig. 1. Navigation District Base Pier (Google Earth)

KN Masalembo is a Class I Navigation State Ship belonging to the District Navigation of Tanjung Perak, with the main dimensions:

Length Over All (Loa)	: 60.00 meters
Length Between Perpendiculars	: 54.00 meters
Breadth	: 12.00 meters
Depth	: 04.70 meters
Design Draft	: 03.50 meters
Service Speed at 100% MCR	: 15.00 knots

Fig. 2. KN Masalembo (author, 2024)

Systems on Ships

The ship's fuel system functions to store, condition, and supply fuel to the ship's engine. The system consists of several main components, including:

a. Fuel tank: This tank is used to store the fuel of the ship.

b. Piping system: A piping system is used to transport fuel from the fuel tank to the engine.

c. Fuel oil supply pumps: Fuel pumps are used to pump fuel from the fuel tank to the engine.

d. Fuel filter (main filter): Fuel filter is used to remove impurities and contaminants from the fuel.

e. Fuel separator: A fuel separator is used to remove water from the fuel

f. Fuel heater: A fuel heater is used to heat fuel before it isupplied to the engine. Fuel heaters are necessary to increase the viscosity of the fuel and make it easier to pump and atomize.

g. Control system: The control system is used to control the flow of fuel to the engine. The control system can be either a manual or automatic system.

There are several types of fuel used on marine vessels, including:

a. Heavy Fuel Oil (HFO) is the heaviest and most viscous type of fuel oil used in the shipping industry. HFO contains high levels of sulfur, making it less environmentally friendly. This fuel is commonly used by tankers, cargo ships, and cruise ships because it is cheaper, although it is less efficient and has higher emissions. HFO needs to be heated before use to make it more liquid and can be injected into the machine. In the shipping sector, its use is regulated by the IMO to limit emissions of sulfur and other pollutants.

b. Marine Diesel Oil (MDO): is a type of fuel oil that is lighter compared to HFO. MDO is made up of a mixture of distillates, which makes it cleaner, more flammable, and produces lower emissions than HFO.

MDO has several advantages, including:

i. Lower sulfur content

ii. Easier to use

iii. More efficient because MDO burns faster and produces less residue in the engine

c. Liquefied Natural Gas (LNG): LNG is natural gas that has been liquefied. LNG is a cleaner fuel than MFOs and MDOs. LNG has lower greenhouse gas emissions and does not produce sulfur dioxide emissions.

d. Biofuels: Biofuels are fuels made from organic materials. Biofuels can be in the form of biodiesel, bioethanol, and biogas. Biofuels are more sustainable fuels than MFOs, MDOs, and LNGs.

The Ministry of Transportation has determined the calculation for direct operating costs, namely the cost of fuel needs for auxiliary motorcycles as follows [9] :

Formula for Fuel Requirements per Day (tons per day) for the Main Engine or Auxiliary Engine [10]:

B = MCR (%)×Power(max)×(SFOC (Kg/hp.h))/(BJ (Kg/Ltr)) (Ltr.h)/hp (1)

Where:

B : Fuel Consumption in Liters.Hours per HP

MCR : Nominal power of the parent/auxiliary motor calculated 0.80 to 0.95 x HP (Maximum Continuous Rating)

Daya Max: Horsepower

SFOC : Specific Fuel Oil Consumption (calculated based on the condition of the new engine with a required tolerance of 180 to 220 gr/HP/hour)

BJ : Fuel Specific Gravity (kg/ltr)

CO2 and SOx emissions are directly proportional to fuel consumption. Fuel consumption (g) can be estimated by multiplying the SFOC load (g/kWh) by the engine's energy use (kWh).

The formula to calculate the coefficient of Specific Fuel Oil Consumption (SFOC) can be formulated to estimate the fuel consumption of an engine. Here's the formula:

Coefficient = SFOC × MCR/Specific Gravity (2)

SFOC indicates fuel efficiency values. A smaller SFOC value means the engine is more efficient.

The MCR indicates the maximum power output of the engine and its effect on fuel requirements.

Specific gravity is used to convert the amount of fuel consumed in terms of volume or mass.

C. Carbon conversion factors

Once fuel consumption is known, CO2 emissions can be estimated based on the Emissions Factors (EF) value. For MDOs, this conversion factor is used in the inventory of emissions for the marine sector [11].

TABLE I. BASELINE EMISSIONS FACTORS [11]

Pollutants	**Name**	**EFs (kg pollutant/tonne of fuel)**
CO2	Carbon Dioxide	3,206
CH4	Methane	0.04–0.05
N2O	Nitrous Oxide	0.18
NOx	Nitrogen Oxides	52.14–57.62
CO	Carbon Monoxide	2.39–2.54
NMVOC	Non-Methane Volatile Organic Compounds	2.15–2.42
SOx	Sulphur Oxides	1.56–2.74
PM	Particulate Matter	0.92–0.97

D. Ship Electrical

Brake Kilowatts (BKW) is the mechanical power generated by a drive engine before it is converted into electrical power. It is defined as the power generated by the shaft of the generator drive engine, but it does not take into account the losses that occur during the conversion process from mechanical energy to electrical energy.

BKW is affected by MCR and generator efficiency. The formula used is:

$BKW = MCR \times \eta$ (3)

Where:

BKW = Brake Kilowatt (kW)

MCR = Maximum Continuous Rating (kW atau hp)

η = System efficiency (%)

The efficiency value will be high if a lot of power is converted into mechanical power on the shaft.

Kilowatts are the amount of electrical power generated or consumed by the system, taking into account the efficiency of the generator and the value of losses during the conversion process.

$KW = BKW \times \eta$ (4)

Where

η is the efficiency of the generator, the value is less than 1.0

Electrical power is the amount of electrical energy consumed or produced per unit of time, usually measured in watts (W).

$P = V \times I \times \cos(\emptyset)$ (5)

where:

P is the power (in watts, W);

V is the voltage (in volts, V);

I is the electric current (in amperes, A).

cos(∅) is the power factor, 0.8 to 0.95

In a three-phase system (380 V), the total power is calculated using the formula:

$P = \sqrt{3} \times VLL \times I \times \cos(\emptyset)$ (6)

Where:

VLL is the voltage between phases (line-to-line voltage, in volts);

I is the current in one phase (in amperes);

cos(∅) is the power factor, 0.8 to 0.95

To convert Brake Kilowatts (BKW) to Brake Horsepower (BHP), you can use the following formula:

$BHP = BKW \times 1.341$ (7)

This formula is based on the conversion that 1 kW is equivalent to 1,341 Horsepower (HP).

E. Shore Side Electricity

Energy efficiency is an important issue in the world of shipping. The IMO creates a framework in the shipping sector that deals with fuel efficiency and emission reduction. One of the procedures for reducing exhaust gas emissions is the use of Shore Side Electricit [12].

Shore Side Electricity is one of the technologies in the shipping sector in support of the Paris Climate Agreement in 2015. Shore Side Electricity is the provision of electricity from land for ship operations when docked at the port. The goal of utilizing electricity from land is to reduce the use of fossil fuels on ships. This is to support the reduction of exhaust emissions caused by shipping activities, as well as to create clean air at the port. This technology will also support the operation of battery-powered ships in the future [13].

The use of shore-side electricity is an effective step in reducing costs in maritime transportation. Several obstacles have arisen in the implementation of SSE, including those related to intensive service users. This is the cause of slow development. Socio-economically, SSE has a positive impact, and it is expected that the value of the investment carried out is in accordance with the income obtained [14].

Optimization methods in SSE planning are needed to determine the priority of locations that require SSE. Optimization is needed to determine the electrical power requirements for ships docked and to calculate the effectiveness of reducing exhaust emissions in ports. The purpose of the optimization is to get the maximum benefit for shipping and to improve air quality at the port [15].

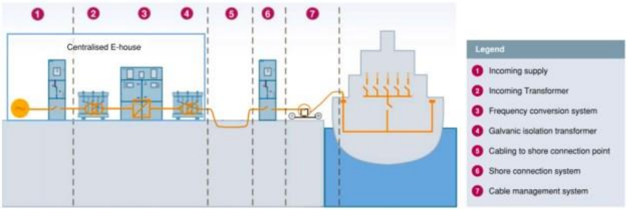

Fig. 3. Shore Side Electricity system [13]

III. RESULT

The main dimensions of KN Masalembo are as follows:

a. Length Over All (Loa) : 60.00 meters
b. Length Between Perpendiculars : 54.00 meters
c. Breadth : 12.00 meters
d. Depth : 4.70 meters
e. Draft : 3,50 meters
f. Service speed at 100 MCR : 15,00 Knots

The data of the Auxiliary Motor at KN Masalembu is as follows.

TABLE II. AUXILIARY MOTOR DATA

Generator	Brand / Type	Maximum Power (HP)	Maximum Power (KW)	Maximum Spins (RPM)
Main Genset 1 and 2	Caterpillar / C.18	514	383.29	1500
Harbour Generator	Caterpillar / C.4.4	111	82.77	1500
Emergency Genset	Caterpillar / C.4.4	76.4	56.97	1500

A. *KN Masalembo's Electricity Needs When Leaning on the Pier*

The calculation of electricity consumption is based on the General Electric Diagram document. Electrical equipment is divided into 2 (two) different voltages, namely 220 volts and 380 volts. The following is data on electrical equipment in operation along with their estimated operating time.

220 V Electrical Power Consumption at KN Masalembo

TABLE III. CALCULATION OF ELECTRICAL POWER REQUIREMENTS AT 220 VOLT VOLTAGE

NO	EQUIPMENT	SUM	POWER PER UNIT (WATTS)	TOTAL POWER (WATT)
1	TL Lamp Room Lighting	452	20	9,040
2	Main Deck Floodlights	2	500	1,000
3	Portable Electric Welding	1	900	900
4	Behind the Whistle	2	550	1,100
5	Hand Grinder	4	540	2,160
6	Pompa Air Tawar (Jet Pump)	1	1,500	1,500
7	24" LED TV	10	35	350
8	42" LED TV	2	60	120
9	Magic Com 5 Kg	2	1,450	2,900
10	Magic Com 2 Kg	2	77	154
11	Dispenser Air Minum	3	385	1,155
12	Heating Water Boiler @ 15 Liters	2	1,520	3,040
13	Large Water Jet	1	5,500	5,500
14	Small Water Jet	2	1,800	3,600
15	Washer + Dryer	3	800	2,400
16	Washing machine	1	700	700
17	Dryer	1	400	400
18	AC Wheel House/Platform	1	3,729	3,729
19	Fan	16	30	480
20	Hand Drill	4	350	1,400
21	Stove Stove	6	1,500	9,000
22	200 Liter Refrigerator	2	2,200	4,400
23	Home Theater	1	150	150
24	Active Speaker	1	250	250
25	Radio VHF	2	1,100	2,200
26	Gyro Compas	1	1,100	1,100
27	GPS Navigator	2	2,200	4,400
28	GPS Chart Plotter	1	1,100	1,100
29	Echo Sounder	1	1,100	1,100
30	Ais	1	1,100	1,100
31	ECDIS	2	1,100	2,200
32	Radar	2	1,100	2,200
33	Battery Charge MSB	1	11,000	11,000
34	Battrey Charge ESB	3	4,400	13,200
Quantity Needs				**95,028 Watts**

The Electricity Power Consumption for a voltage of 380 V at KN Masalembo is as follows.

TABLE IV. CALCULATION OF ELECTRICAL POWER REQUIREMENTS AT 380 VOLT VOLTAGE

NO	EQUIPMENT	SUM	POWER PER UNIT (KW)	TOTAL POWER (KW)
1	Battery Charge	1	6.6	6.6
2	Mooring Capstant Fwd	1	11.0	11.0
3	AHU (Air Handling Unit) Fan Motor Ac	1	16.0	16.0
4	Condenssor Motor AC	1	47.3	47.3
5	Galley & Laundry	1	16.5	16.5
6	E/R Supply Fan	2	22.0	44.0
7	G/R Supply Fan	2	4.0	8.0
8	Bilge/ Ballast/ Gs Pump	1	11.0	11.0
9	LO Transfer Pump	1	0.5	0.5
10	S.W Cooling Pump For AC	1	4.0	4.0
11	F.O Transfer Pump	1	4.0	4.0
12	Hot Water Calorifier	1	10.0	10.0
13	Air Compressor ME	1	15.0	15.0
14	F.W Transfer Pump	1	1.5	1.5
15	ME LO Circulating Pump	2	11.0	22.0

NO	EQUIPMENT	SUM	POWER PER UNIT (KW)	TOTAL POWER (KW)
16	Mooring Capstant Aft	1	5.5	5.5
17	Working Compressor & Anti Healing	1	2.2	2.2
18	Anti Healing	1	25.6	25.6
19	Refrigerator Cooler Pump	1	4.0	4.0
20	F.W Hydrofore	1	1.5	1.5
21	S.W Hydrofore	1	1.5	1.5
22	Cool & Freezer Room	1	3.0	3.0
23	E/R Lighting	71	0.04	2.84
24	Main Deck 1 Lighting	69	0.04	2.76
25	Main Deck 2 Lighting	54	0.04	2.16
26	Bridge Deck Lighting	28	0.04	1.12
27	Wheel House Lighting	17	0.04	0.68
28	Out Side Lighting	9	0.50	4.50
29	Lavatory Nav Bridge Deck, AHU, Sanitari	6	0.18	1.08
30	Workshop Exhaust Fan	1	0.37	0.37
			Quantity Needs	**276.2 KW**

B. *Fuel Requirement Calculation*

The calculation of fuel needs is calculated through several stages. First, the Brake Power (BKW) value is calculated, and then the BKW is converted to BHP. Unit conversion is also done to convert the SFOC value in gr/HP.h to Kg/HP.h. Conversion to units in Kg is necessary because the subsequent calculation uses the units of Kg and Ton.

1) Fuel Consumption Graph on Auxiliary Motors 1 and 2

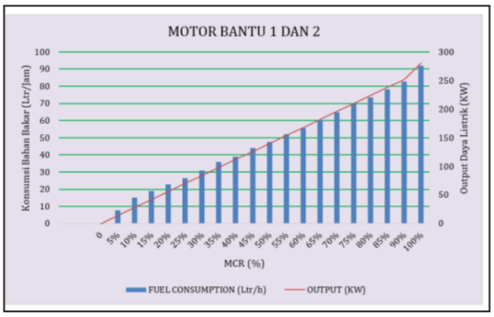

Fig. 4. Correlation of Fuel Consumption of Auxiliary Motors 1 and 2 with Electrical Power Output (analysis)

2). Fuel Consumption Graph on Harbour Generator

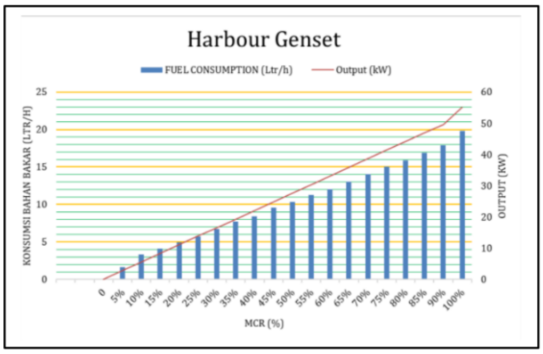

Fig 5. Correlation of Fuel Consumption of Auxiliary Motors 1 and 2 with Electrical Power Output (analysis)

3). Fuel Consumption Graph on Emergency Generator

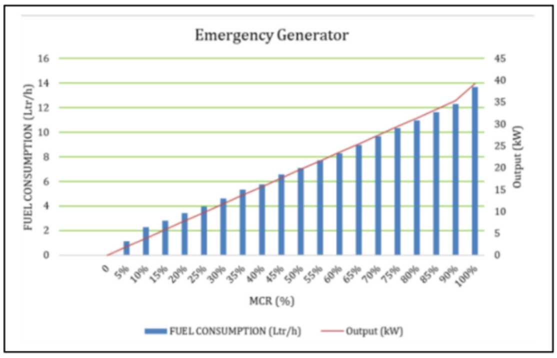

Fig 6. Correlation of Fuel Consumption of Auxiliary Motors 1 and 2 with Electrical Power Output (analysis)

Correlation of Emergency Generator Fuel Consumption with Electrical Power Output (source: analysis, 2024).

Fuel consumption calculations are based on an 80% MCR with an engine speed of 1,500 rpm. Calculation on three generators and the results are obtained as shown in table 5.

TABLE V. COMPARISON OF POWER AND FUEL CONSUMPTION

Generator	Main Genset 1 and 2	Harbour Generator	Emergency Genset
Mechanical Power (BKW)	306.60	66.22	45.58
Mechanical Power (BHP)	415.44	88.80	61.12
Fuel consumption (Ltr/H)	73.50	15.87	10.92
Fuel consumption (Kg/H)	63.21	13.65	9.40
Output Electrical power (KVA)	280.00	55.20	39.20
Output Electrical power (KW)	224.00	44.16	31.36

The percentage of fuel consumption of the generator harbour is 22% when compared to the fuel consumption of the 1 or 2 auxiliary motors. Emergency generators are only 15% of the fuel needs of auxiliary motors.

This is due to the difference in technical specifications and output power produced by each motorcycle. In terms of the percentage of power output of the generator harbor, it is only 20% of the auxiliary motor 1 or 2. For emergency generators only 14% of auxiliary motors 1 or 2. This difference in output power makes some ship equipment inoperable when leaning on the dock, due to reduced electrical power.

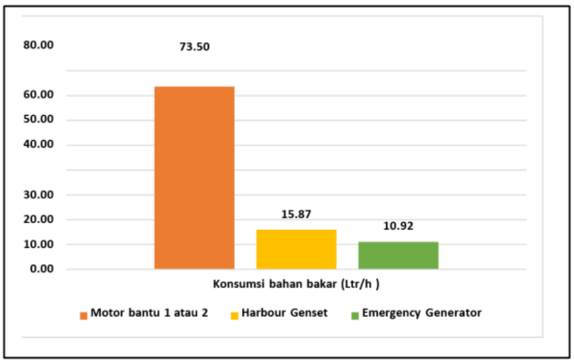

Fig. 7. Fuel Consumption Comparison (analysis, 2024)

The difference in fuel consumption is shown in Figure IV.13. For the comparison of the output power produced, it is shown in Figure IV.14

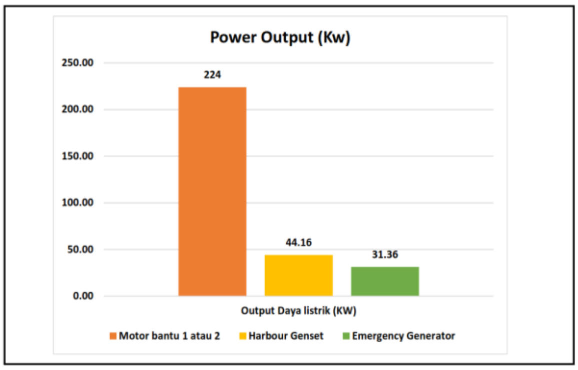

Fig. 8. Comparison of Electrical Power Output (analysis, 2024)

The use of Shore Side Electricity as a replacement for the operation of MB 1 or 2 has provided benefits both economically and to the reduction of exhaust gas emissions. Fuel consumption calculations have been obtained based on

TABLE VI. FUEL CONSUMPTION FOR 1 YEAR

Types of Generators	Fuel Consumption 1 year (Ltr)
1 or 2 auxiliary motors	643.853,39
Harbour Genset	139.042,27
Emergency Generator	95.701,17

(Source: analysis, 2024)

Based on the calculation of fuel consumption, it can be calculated that the savings that can be made can reach 92.57%, as shown in Table 6

TABLE VII. SAVINGS IN THE USE OF SHORE SIDE ELECTRICITY

Types of Generators	1 or 2 auxiliary motors	Harbour Genset	Emergency Generator
Fuel Consumption 1 year (Ltr)	643,853.39	139,042.27	95,701.17
Fuel Expenditure 1 year (Rupiah)	Rp 9,335,874,140.37	Rp 2,016,112,898.02	Rp 1,387,666,895.57
Average Shore Connection Expenditure (Rupiah)	Rp 693,600,000.00	Rp 693,600,000.00	Rp 693,600,000.00
Savings (Rupiah)	Rp 8,642,274,140.37	Rp 1,322,512,898.02	Rp 694,066,895.57
Percentage Savings (%)	92.57%	65.60%	50.02%

(Source: analysis, 2024)

C. The Impact of the Use of Shore Side Electricity on the Reduction of Exhaust Gas Emissions at KN Masalembo

The calculation of exhaust gas emissions uses the emission factor (EF) value in the IMO report document entitled Fourth IMO GHG Study 2020 Full Report, as shown in Table 1.

Based on the calculation, the value of exhaust gas emissions for one year is obtained, as shown in Table 8

TABLE VIII. TOTAL EXHAUST GAS EMISSIONS FOR 1 YEAR (KG POLLUTANT)

Pollutant	Auxiliary Motor 1-2	Harbour Generator	Emergency Generator
CO2	1,775,206,809.99	383,361,781.92	263,863,424.68
CH4	27,685.70	5,978.82	4,115.15
N2O	99,668.50	21,523.74	14,814.54
NOx	6,892,380.88	6,892,380.88	4,743,945.04
CO	1,406,433.34	303,723.93	209,049.63
NMVOC	1,339,987.67	289,374.77	199,173.27
SOx	1,517,176.13	327,639.20	225,510.23
PM	537,102.50	115,989.06	79,833.91

(Analysis, 2024)

The use of 1 or 2 auxiliary motors when the ship is docked at the dock produces a CO_2 emission value of 202,649.18 Kg of pollutants for every 1 ton of fuel. The operation of the harbour generator has an impact on reducing CO_2 emissions by up to 21.60% compared to the emissions on auxiliary motors 1 or 2. If using an emergency generator, emissions are reduced by up to 14.86%.

IV. CONCLUSION

A. Conclusion

Based on the discussion, the following conclusions were reached:

1. The total electrical power requirement is divided into 2 (two) for voltages of 220 Volts and 380 Volts, and the values are obtained: 95,028 Watts (220 V) and 276,210 Watts (380 V).

2. The comparison of fuel needs for auxiliary motor 12, harbour generator, and emergency generator is 73.50 ltr/h : 15.87 ltr/h : 10.92 ltr/h.

3. The operational priority of KN Masalembo equipment is based on the operational urgency of the equipment. Priority is given to lighting, air conditioning systems, and food, as well as some navigation equipment that must be stationed within 24 hours.

4.The impact of reducing exhaust gas emissions on KN Masalembo as a result of the use of Shore Side Electricity for one year (kg pollutant/tonne of fuel) is very significant. The reduction reached 206,855.13 kg pollutant/tonne of fuel using auxiliary engine 1-2.

B. Suggestion

1. Based on the calculation of the output power on the Harbour Generator is 44.20 KW. Calculations are not able to meet the power needs of electrical equipment on the ship. This requires a recalculation of the existing load. So its use needs to be adjusted to this load.

2. Based on the calculation of the output power on the Emergency Generator is 31.4 KW. Calculations are not able to meet the power needs of electrical equipment on the ship. So that its use needs to be adjusted to the existing load.

3. SSE is only able to serve 26% of the total electrical equipment needs operating on the ship. So it is necessary to add SSE power.

4. To support the reduction of the impact of the greenhouse effect. It is necessary to convert environmentally friendly power generation sources. And use renewable energy.

ACKNOWLEDGMENT

The author's gratitude to the District Navigation of Tanjung Perak - Directorate General of Sea Transportation.

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