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COST AND ENVIRONMENTAL BENEFIT IN THE USE OF SHORE CONNECTION IN BJTI PORT

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Abstract. Shipping activities as one of the energy users generate air pollution and GHG (GHG) emissions. The main source of these emissions is fossil fuels which are used in various activities in human life and one of them is fortransportation, including shipping activities. One of the potential mitigation actions that can reduce these emissions is by utilizing the shore connection at the port. The purpose of this study is to obtain the potential for reducing emissions from vessels anchored at the BJTI Port and the efficiency of vessel fuel costs. This study used a mixed method by calculating the vessel emissions and in-depth interviews with the port operator and government officials. By using the shore connection, it can reduce up to 24,55% of CO_2, air pollution 99,3% of SO_2, and the efficiency of fuel cost by 79,82%.

Keywords: shore connection, GHG emissions in port, vessel emissions, cost, and environmental benefit

Introduction

At the 21st Conference of Parties (COP) UN Climate Change meeting in Paris France in 2015, The Government of Indonesia committed to reducing GHG emissions by 29% on its efforts and up to 41% if it gets international support by 2030 compared to Business as Usual (BAU) conditions (KLHK, 2016). This commitment was delivered by the President and then stated in the National Determined Contribution (NDC) document. Before the COP21, The Government of Indonesia has run mitigation actions to combat the climate change, and these actions are stated in the Presidential Decree Number 61 Year 2011 concerning National Action Plans for Reducing the GHG Emissions, and the Ministry of Transportation has also created a Ministerial Decree Number KP 201 Year 2013 concerning The Establishment of National Action Plans for Reducing GHG Emissions in the Transportation Sector and the GHG Inventory of the Transportation Sector from 2010 to 2020. Based on these regulations, Indonesia is still implementing the climate mitigation actions, including the transport sector as the sub-sector of energy.

Although transportation has an important role in our daily life, it produces emissions and induces both air pollution and GHG. The World Health Organization (WHO) states that air pollution originating from ambient air (outdoor) is a major environmental health problem affecting human health, whether it occurs in low, middle, or high-income countries. Ambient air pollution in urban and rural areas is estimated to cause 4.2 million premature deaths worldwide per year in 2016, leading to cardiovascular and respiratory diseases and cancer (WHO, 2019). Shipping activities also contribute to air pollution and GHG. These shipping activities contribute to 15% of NO_x and 5-8% of SO_x worldwide, both of which pose serious threats to human health and the environment (Zis, Bell, & Psaraftis, 2016). In the UK, it is estimated that the total costs caused by air pollution can reach £ 54 billion per year. Health problems due to exposure to air pollution also cause high costs for people and businesses. In the UK, these health costs increase to £ 20 billion every year (Innes & Monios, 2018).

The main source of GHG emission is fossil fuels, which are used in various activities in human life and one of them is transportation activities. Since the issuance of the Minister of Transportation Decree Number KP 201 Year 2013, climate mitigation actions have not been carried out optimally, especially in the sea transportation. It can be seen that out of 7 actions, up

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to 2016 only 2 actions have been reported and verified by the Ministry of Environment and Forestry (KLHK, 2017) namely: The Efficiency of Port Operational Management, especially for the use of solar cell technology on Sailing Navigation Aid and Vessel Modernization action for pioneer vessels. For this reason, the researchers are interested in further study about the potential of mitigation action that can contribute to reducing the GHG emissions in sea transportation, especially the mitigation action for the Efficiency of Port Operational Management, that one of the target indicators is the prevention of air pollution through the program to shut down the vessels' auxiliary engine and switching it with the port electricity when the vessels are berthing. In this case, the port electricity means the utilization of shore connection at the port. By turning off the vessel's engine when berthing at the port, it will save fuel so that it can save the expenses. In Indonesia, one of the public ports that already implemented the shore connection is Berlian Jasa Terminal Indonesia Port (BJTI Port) in Surabaya, East Java Province.

To fulfill Indonesia's commitment to reduce GHG emissions, especially in the transportation sector, the research will observe and find that sea transportation is not optimal in carrying out the climate mitigation actions.

The research problems can be identified as follows:
a. There are no GHG emission reduction calculation methods for several mitigation actions in sea transportation.
b. There is no further identification about new mitigation actions that could potentially reduce emissions in sea transportation.
c. Activity data has not been collected properly.
d. There is lack of human resource capacity in sea transportation on the issue of climate change, especially the calculation of GHG inventories and GHG emission reductions.
e. There is lack of attention of stakeholders so that the issue of climate change has not become the mainstream in transportation policy.

The research questions of this study as follows:
a. How much potential are the GHG emission reduction and air pollution reduction from the use of shore connections at BJTI Port?
b. How much potential is the cost efficiency of vessel fuel from the shore connection facilities at BJTI Port?

Method

This study used mixed method with sequential explanatory design, which combines quantitative and qualitative methods sequentiallyand in the first stage of this study it is conducted using the quantitative method and in the second stage is carried out with the qualitative method (Sugiyono, 2016). The quantitative method used for counting the emissions generated from vessels while berthing at the port and the shore connection emissions generated in the electricity grid, so that the potential for emission reduction and emission inventory is obtained. The qualitative method used for fitting up the quantitative data, which is based on several in-depth interviews with the port operator and the officials at the Ministry of Transportation and The Ministry of Environment and Forestry.

Discussion and Results

To be able to start the vessel engine, a vessel needs fuelboth for the main engine and auxiliary engines. The fuel used in vessel engines is still depend on fuel oil. The biggest cost for the operation of a vessel is the cost of vessel fuel which can reach 47%, then the cost for the port 46% and D.O (Delivery Order) of 7% (Valentito, 2012). Because of the high cost of these fuels,

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shipping companies are looking for alternatives to reduce these costs, including technical strategies such as using efficient vessel engines, using propellers that have high efficiency, etc. Another strategy to reduce fuel costs is to use the shore connection facility at the port. Thus, the vessel no longer needs to start the engine during loading and unloading activities or while berthing at the port.

The terminology of shore connection is known by various terms, such as "Alternative Maritime Power", "Cold Ironing", "On-shore Power Supply", "Shore to Vessel System" and "Shore Side Electricity." According to Ibrahim S. Seddiek, Mosaad A. Mosleh, and Adel A. Banawan, shore connection is the electrical connection between vessels and port while vessels are berthing at the port, which was designed to reduce the fuel consumption and emissions (Seddiek, Mosleh, & Banawan, 2013). Devi Hotnauli Samosir, M. Markert, and Wolfgang Busse define that the shore connection is a process that allows a vessel to turn off its engine when it is anchored and connect it to an energy source that comes from land. This process allows the vessel's emergency equipment, cooling system, heating system, lighting, and other equipment to keep getting the electricity continuously when the vessel carries out the loading and unloading process (Samosir, Markert, & Busse, 2017). The picture below shows the illustration of the shore connection.

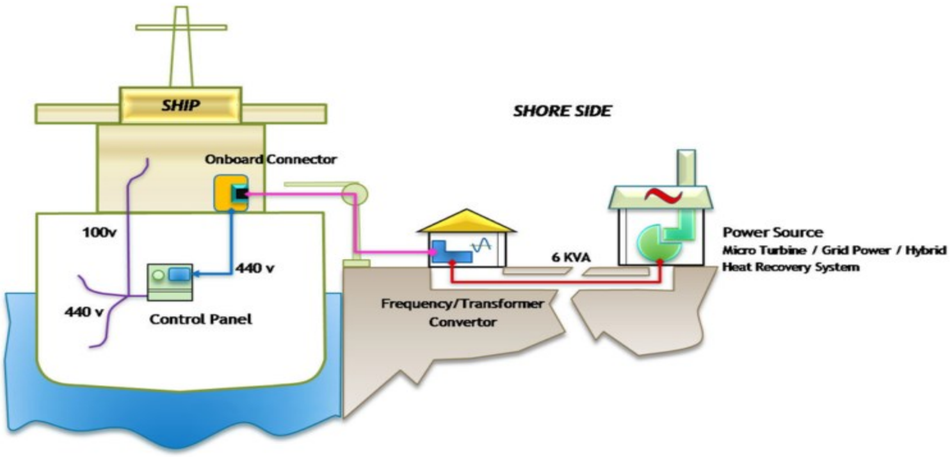

Figure 1. Shore Connection Illustration

Source: https://glomeep.imo.org/technology/shore-power/ (IMO, 2019a)

Vessel operations produce exhaust emissions because of the fuel combustion in the engines, which can cause GHGs and air pollution. This study only considers CO_2 as the GHG emissions and SO_x as the air pollutant. GHG emissions from the fuels combustion at moving sources are GHG emissions from transportation activities, including from the vessels. The main GHG emitted by fuel combustion in the transportation sector is CO_2. Fossil fuels also contain traces of sulfur compounds, and SO_x is produced when they are burned. Exposure to SO_x can damage health by its action on the respiratory system. The majority of the SO_x emitted to the air is from power generation, and the contribution from transport sources is small (shipping being an exception) (Song, 2016). Under MARPOL Annex VI, the global sulfur cap for fuel oil used on-board ships is reduced initially to 3.50%m/m (from the previous 4.50%), effective from 1 January 2012, then progressively to 0.50% effective from 1 January 2020 (IMO, 2019b).

The vessel emission calculation method used in this study is the method used by the California Air Resources Board (CARB) based on the book of the United States Environmental Protection Agency (USEPA, 2017).

$$E = EF \times KW \times LF \times Hr$$

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E = *Amount of emissions of a pollutant emitted during one period*
EF = *Auxiliary engine emissions factor (gr/KWh)*
KW = *Power of the auxiliary engine (kW)*
LF = *Vessel type and engine-use-specific auxiliary engine hoteling load factor (%)*
Hr = *Hoteling/berthing time (hours)*

The following formula is a basic formula used for calculating the shore power emission when using the shore connection (USEPA, 2017), that actual data about the electricity demand of the shore connection per year and per vessel is needed which can be obtained from the port operator:

$$SPE_{ijk} = \textit{Electricity Shore Power Demand} \times SEF_{ik}$$

$SPE_{i,k}$ = *Shore power emissions for pollutant i, in year k*
$SEF_{i,k}$ = *Shore power emissions factor for pollutant i, in year k*

The shore power emissions factor is the electricity emission factor from the power plant/grid that distributes electricity to the port.

Data on electricity generation based on facilities can be obtained from companies serving the local electricity network, or data sourced from the Ministry of Energy and Mineral Resources. In this case, the BJTI Port is located in East Java Province where the electricity system is included in the interconnection category of the Jamali region (Java, Madura, Bali), so there is no need to separate the power plants that distribute electricity to BJTI Port. Then, it is also necessary to include the transmission and distribution losses data that occur in the electrical connection system of the Jamali network. The transmission and distribution losses data were obtained from the Electricity Statistics in 2017, which is for the Jamali region is 10.8% (KESDM, 2018a). This transmission and distribution losses data are used for calculating the shore connection emissions.

$$SPE_{i,k} = \frac{\textit{Electricity Shore Power Demand} \times SEF_{i,k}}{(1 - \textit{T/D losses})}$$

$SPE_{i,k}$ = *Shore power emissions for pollutant i, in year k*
$SEF_{i,k}$ = *Shore power emissions factor for pollutant i, in year k*
T/D losses = *Electricity transmission and distribution losses*

Referring to the Ministry of Environment and Forestry provisions, the GHG emission reduction is calculated as the difference between the amount of GHG emissions before mitigation actions (baseline emissions) and the amount of emissions after mitigation actions (mitigation emissions) (KLHK, 2018).

$$\text{Emission Reduction} = \text{Baseline Emission} - \text{Mitigation Emission}$$

In the context of shore connection as the climate mitigation action, so the baseline emission is the vessel emissions when using the auxiliary engine while berthing at the port, and the mitigation emission is the shore connection emission.
The vessel's auxiliary engine load factor and emissions factor can use the data provided by the USEPA as shown in Table 1 and Table 2 below. The emission factor used in this study is the emission factor of vessel fuel with a sulfur content of 0.5% as has become the IMO mandatory which implemented since 1 January 2020.

Table 1. ***Auxiliary Engine Berthing Load Factor***

Auto Carrier	Bulk Carrier	Container Vessel	Passenger Vessel	General Cargo	Miscellaneous	RORO	Reefer	Tanker

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24 %	22 %	17 %	64 %	22 %	22 %	30 %	34 %	67 %

Source: (USEPA, 2017)

Table 2 ***Auxiliary Engine Emissions Factor for Medium Speed Engine*** **(g/kWh)**

Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	SO_x
MDO (0.1% S)	0,09	1,1	690	13,9	0,25	0,23	0,4
MDO (0.5% S)	0,09	1,1	690	13,9	0,38	0,35	2,1
HFO	0,09	1,1	722	14,7	1,5	1,46	11,1

Source: (USEPA, 2017)

From the Table 2 above, the auxiliary engine emission factor used for counting the baseline emission (vessel emission when berthing using the auxiliary engine) is only the SO_x emission factor. The approach was calculated to national (country specific) emission factor for SO_x produced from emission sources of power plants in the Jamali region, because there is no references regarding this national emission factor. The calculation result of national electricity emission factor for SOx is 0,066 gr/KWh. For the CO_2 emission factor of vessel fuel, the national emission factor is used for diesel oil which is published by The Ministry of Energy and Mineral Resources (KESDM, 2018b). While the CO_2 emission factor for the Jamali electricity system is 0.9 tons CO_2/MWh (KESDM, 2019). This national electricity emission factor for SO_x and CO_2 are used to calculate the mitigation emissions.

PT. Berlian Jasa Terminal Indonesia, also known as BJTI Port, is one of a subsidiary of PT. Pelabuhan Indonesia III (PT. Pelindo III) which is a spin off from the Terminal Business Division of PT. Pelindo III Tanjung Perak Port Branch and was established on January 9, 2002. The port focus is handling domestic container loading and unloading activities at the Berlian Terminal in Tanjung Perak Port in Surabaya, as well as managing other supporting activities related to port services. Since June 2015, with a new enthusiasm based on the tagline "Pulse of the Life of the Country", the BJTI Port expands the scope of its business outside of Surabaya by managing operational activities and maintenance of equipment and loading and unloading tools at 8 Branches in the area of PT. Pelindo III, in Gresik, Benoa, Bima, Maumere, Sampit, Batulicin, Kumai and Lembar Branches.

BJTI Port has 3 spots of the shore connection facilities operated since February 2018 and in 2019, and there will be an addition of 6 spots. During 2018, there were 70 vessels berthed at BJTI Port using the shore connection facilities. The specifications of the shore connection at BJTI Port are: 380 Volts of Voltage, 500 kVA of installed power capacity, cable lugs, cable connection without plug, and the KWh Meter for monitoring electricity usage.

Figure 2. Electric Panel at the dock of BJTI Port

Figure 3. Powerhouse of the shore connection electrical installation

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1. Potential Reduction in GHG Emissions and Air Pollution

From 70 vessels that have used shore connection during 2018 at BJTI Port, there is a potential reduction of GHG emission and air pollution based on the efficiency level of the engine generator set where the calculation results are presented in the following table.

Table 3. Potential Reduction of GHG Emission (CO_2) and Air Pollution (SO_x) Based on The Efficiency Level of The Generator Set at BJTI Port in the Year 2018

Genset Efficiency	GHG Emission Reduction CO_2 (tonnes)	Percentage of CO_2 Reduction	Air Pollution Reduction SO_x (tonnes)	Percentage of SO_x Reduction
20%	16,68	24,55%	0,53	99,30%
21%	13,44	20,78%	0,50	99,26%
22%	10,50	17,01%	0,48	99,22%
23%	7,82	13,23%	0,46	99,19%
24%	5,36	9,46%	0,44	99,15%
25%	3,09	5,69%	0,42	99,12%
26%	1,00	1,92%	0,41	99,08%
27%	-0,93	-1,86%	0,39	99,05%
28%	-2,73	-5,63%	0,38	99,01%
29%	-4,40	-9,40%	0,36	98,98%
30%	-5,96	-13,17%	0,35	98,94%

Source: Data Processing Result (Author, 2019)

The table above shows that the higher efficiency level the potential for emissions reduction is less. It shows that at the efficiency level of the engine generator set 27% to 30% and there is no reduction in GHG emissions because if the efficiency of the generator set at the auxiliary engine is already high, it can save the vessel fuel. On the other hand, the emission factor of the Jamali region is high because there are still many fossil fuels in the power plant's energy mix. For the potential reduction in air pollution, specifically SO_x, it shows similar results to a reduction in CO2 emissions. The SO_x potential reduction is much bigger than the CO_2 reduction. Thus, the shore connections will be more effective in reducing air pollution than GHG emissions.

2. Potential Savings in Fuel Cost

From the obtained data, fuel consumption data from 70 vessels have used the shore connection at BJTI Port during 2018. The data is in the form of the amount of vessel fuel consumption per hour (liters/hour). By using the reference price of diesel oil for the shipping industry of Rp. 16,187 / liter, selling price of electricity by the port is Rp. 2,350 / KWh and the shore connection installation fee of Rp. 400,000 / vessel, then the cost efficiency recapitulation results are obtained as follows.

Table 5 Recapitulation of Vessel Fuel Cost Efficiency by Utilizing Shore Connection at BJTI Port in 2018

Number of Vessels Using Shore Connection & Energy Usage	70 vessels with the total shore connection demand of 50.790,31 KWh or equal with fuel consumption of 45.120,5 liters
Fuel Costs If the Vessels Still Use Auxiliary Engine	Rp. 730.365.534

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Shore Connection Costs	Rp. 147.357.229
Costs Differences	Rp 583.008.305
Fuel Costs Efficiency	(Rp 583.008.305 / Rp. 730.365.534) x 100 %
	= **79,82 %**

Source: Data Processing Result (Author, 2019)

Conclusion

Utilization of shore connection at the port shows positive results especially in the environmental aspect with a reduction in the GHG emissions (CO_2) and air pollution (SO_x). Shore connection will be more effective if it is used for vessels with old technology or vessels with low-efficiency generator engines. Shore connection will reduce air pollution more than GHG emission. Shore connection is a facility that is also proven to be able to save on vessel fuel usage so that shipping companies can save on fuel costs.

Shore connection can be used as a climate mitigation action for sea transportation. To encourage shore connections to be implemented continuously, commitment and regulation from the government is required. This shore connections mitigation action can be included in the regulation of the Ministry of Transportation to achieve the GHG emission reduction targets up to 2030 in line with the Government of Indonesia's NDC (Nationally Determined Contribution) targets. Furthermore, regulations concerning ports that are environmentally friendly, one of which is by implementing shore connections also need to be drafted so that the port can develop action plans for more comprehensive environmental management. Policies are also needed to provide incentives for vessels and ports that have applied the green port principles, so that they will be more excited to support the GHG emission reduction and the air pollution reduction. Related to the calculation of GHG emission and air pollution reduction from the use of shore connections, the calculation guidelines are required. Data collection on vessel fuel consumption is also needed so that the vessel can calculate the exact comparison between vessel fuel costs and shore connection costs. Thus, the shipping companies can truly feel the benefits of the facility in terms of fuel cost efficiency.
The GHG emission reduction from the use of shore connections will be much greater if the port electricity source comes from renewable energy power plants. Therefore, the port can analyze the renewable energy potentials that can be utilized at the port. This will have a positive impact, because the port will be independent in the supply of energy and no longer rely on the local electricity network which so far still relies on fossil fuels.

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