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# Study on the Carbon Emission Evaluation in a Container Port Based on Energy Consumption Data

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**Abstract:** Increase as much as 87°C every year. Nowadays, 90% of the transportation for industry is done by sea. There are two components sharing the most vital role in sea transportation, i.e. ships and ports. This research focused on the calculation of the emissions in the whole process in the ports, which covered berthing, the unloading processes, transfer from piers to stacking spots, stacking and vice-versa. The method of this research involved collecting the data of the ports' performances for one year, which covered berthing, equipment and utility, fuel consumption, and electricity. The researched port was Belawan International Container Terminal (BICT), Medan, Indonesia. The emission factor used for fuel was based on the policy issued by the Ministry of Environment that has ratified IPCC 2006, and, as for the electricity, the emission factor of the Java Madura Bali power plant was used, i.e. 0.844 kg of CO<sub>2</sub>/KWH. It was found out that the fewest emissions in terms of the emissions from the whole equipment were those in BICT, as many as 15.93 kg of CO<sub>2</sub>/TEU. As for the emissions produced by fuel or direct emissions in a port, those in BICT as many as 15.38 kg of CO<sub>2</sub>/TEU. In respect of the emissions from the whole process in a port, from berthing to taking containers out of the port, the emissions in BICT as many as 29.08 kg of CO<sub>2</sub>/TEU. A huge number of emissions were produced from berthing. With the use of power on shore, this number will shrink, and it will eventually considerably lessen the number of the whole emissions in the port.

Keywords: Fuel Consumption, Container Terminal, Carbon Emission Port

## 1. Introduction

Today's global trade makes the sailing sector one of those with vital roles in it. The need for sailing services keeps Global warming is an existing phenomenon, which will keep existing. In reference to the report of IPCC (Intergovernmental Panel on Climate Change), the global warming caused by the industrial world raises the earth's temperature as much as 0.87 % and will rise to 1.5°C each year between 2032-2052 <sup>1)</sup>. The increase in the number of industrial activities will cause an increase in the number of goods distributions, either the products or the production. In terms of goods distribution, the distribution by sea (ship) is the cheapest, cheaper than that by air or by land and more than 90% of global trade is done by sea, and there is no reason to believe that it will be on the decrease in the future <sup>2)</sup>. Speaking of goods distribution by sea, there are two elements playing the most vital roles in it, ships and ports. In Indonesia, there are 3.089 ports, which are managed by PT Pelabuhan Indonesia, the Ministry of Transportation and Special Terminals for Private Interests. Of the umpteen ports, there is one claiming that it adopts the green port concept. It is the port of Terminal Teluk Lamong, which is managed by PT Pelabuhan Indonesia 3. Considering the

huge number of ports in Indonesia, either international or domestic, there must be plenty of emissions produced. The evaluation of the emissions a port produces and the application of the concept of an environmentally friendly port (with small numbers of emissions) really need carrying out in Indonesia. Comprehensive and profound work in those forms will answer the challenge to environment protection.

The calculation of emissions in a port started with the Port of Long Beach in America in the year 2009 <sup>3)</sup>. Such calculation is done in four models in Taipei in order to know the emissions from containers and then the effective route for the containers is determined <sup>4)</sup>. In Busan, Korea, the calculation is also done, with the approach of speed, distance, and consumption models for every implement per distance <sup>5)</sup>. In Los Angeles, the calculation includes the whole types of active ships and the entire equipment used in the corresponding port, which will then be analyzed to figure out the potential emission reduction <sup>6,7)</sup>. Another study applying the bottom-up method was conducted in Nanjing Longtan Container. It dealt with the conditions and specifications of the equipment, the burden factor for the equipment and the modification of the emission factor <sup>8)</sup>. Besides direct calculation, the study involved predictive calculation based on the movement of

and the distance covered by each implement<sup>9,10)</sup>. In order to have a few emissions, so that a port can be considered environmentally friendly, each implement is analyzed<sup>11)</sup>. They should be environmentally friendly too<sup>12)</sup>. This research analyzed the energy consumption of the Rubber Tired Gantry, Automatic Stacking Crane, and Yard Truck<sup>9,13,14)</sup>. So as to reduce the emissions of these implements, the power sources of some implements were modified into electricity because of the fewer emissions produced, and, in the future, it is possible to use a renewable source like wind or the heat of the sun<sup>15)</sup>. Because renewable energy is higher cost than conventional primary energy, it is thought that the increase in the ratio of renewable energy causes a bad influence on electricity charges. In addition, some Japanese industries say that raising the electricity price can be considered as a cause of overseas relocation. Therefore, these are phenomena are matching to the green paradox<sup>16)</sup>. As to reduce the emissions of CO<sub>2</sub>, Developing 1D models for CO<sub>2</sub> adsorption using different capture materials using CFD commercial software that has a built-in feature that can describe the multiscale mass transfer in the macro- and micro-pores<sup>17)</sup>.

The initiative of energy saving in container terminal has been conducted by reduce power consumption in refrigerated containers, the results show this methods effective to reduce power consumption in this area<sup>18,19)</sup>. Other study in the reduction of emission in container terminal was conducted by simulation using building energy simulation, the result indicated some factors affected in the increasing of energy consumption i.e. solar radiation, container position and weather condition<sup>20-22)</sup>. Smart ventilation is investigated for energy conservation in buildings using consideration of CO<sub>2</sub> concentration<sup>23)</sup>.

To calculate the emissions from diesel, the researcher used the emission factor issued by the Ministry of Environment that has ratified IPCC 2006<sup>24)</sup>. For each KWH, the emission factor depends on the energy source of the power plant. In Indonesia, the majority of the energy sources come from coal, whose emission factor is very high, i.e. 1.140 kg/kwh<sup>25)</sup>. As for the emission factor of the power plants in Indonesia, especially that providing electricity for Java, Madura and Bali, it is a bit lower, i.e. 0.84 kg/kwh<sup>26)</sup>.

The calculation of the emissions from berthing is also important because the auxiliary engine of the ship keeps working during the loading and unloading. About 55%-77% of the total emissions in a port comes from ships<sup>27)</sup>. The calculation of the capacity of a ship's additional engine refers to the capacity of the ship<sup>3)</sup>. When berthing, the energy factor needed by an additional engine is 40%<sup>28)</sup>. The research on the emission factors for getting the data of the emissions from ship engines is categorized on the basis of the used fuel, whether it is gas, diesel or dual fuel<sup>29)</sup>.

The previous research only relates to the emissions produced by every implement separately. None deals with

the calculation of emissions from berthing. Neither has this type of research been done in Indonesia before, so this research is unprecedented in Indonesia. This research focused on the calculation of the emissions in the whole process in the ports, which covered berthing, the unloading processes, transfer from piers to stacking spots, stacking and vice-versa. This calculation was based on the used energy. In this case, the emissions of fuel were different from those of electricity. The calculation of the electric emissions was based on the emissions produced by the power plant in the area, and the calculation of the fuel emissions was based on the policy issued by the Ministry of Environment that has ratified IPCC 2006. This research is important because it informs how many emissions are produced by a container terminal in Indonesia, and it also evaluated the emissions from every implement.

## 2. Methodology

### 1. Data Collection

The data collection was done by visiting the ports and looking at the reports on the operational performances of the companies within a year's time. Such a report consists of:

#### a. Data of the Equipment, Specifications and Utility

These data contain the numbers of implements the ports had, the implements like container cranes, rubber tired gantries, straddle carriers, reach stackers, and truck terminals. The specifications of each of these implements were also checked for the data, including the years they were made in, the transport capacities, the capacities of the engines, and the dimensions. The amount of time for which each implement worked, in hours, and the availability in one year. This availability was calculated based on the number of hours the implement was used in one year minus the required time for maintenance and the time for which it stopped working.

#### b. Energy Consumption

This data consists of the amounts of fuel (liter) and electricity (KWH). Each implement's usage of fuel was calculated every month for one year. For a port which had no such data, the calculation was based on the data of the implements' utilization, with the consumption factor for each implement.

#### c. Berthing

This data consists of the names of the resting ships in one year and the duration of the berthing. The calculation of berthing starts from a ship's being tied up to its being untied. The data of each ship covers the number of the containers unloaded and loaded, and the length and capacity of the ship.

### 2. Calculation of Emissions

The calculation of emissions was divided into two parts, i.e. the emissions from port activities and the emissions from ships. The calculation of the emissions from port activities was done to calculate the emissions from each implement, either the implements using fuel or electricity. The calculation of the emissions from ships was based on the capacities of the ships' auxiliary engines and the emissions from the engines. Figure 1 shows the process of unloading containers in a port; vessel at berth, container loading and unloading, head truck transportation, and container receiving and delivery.

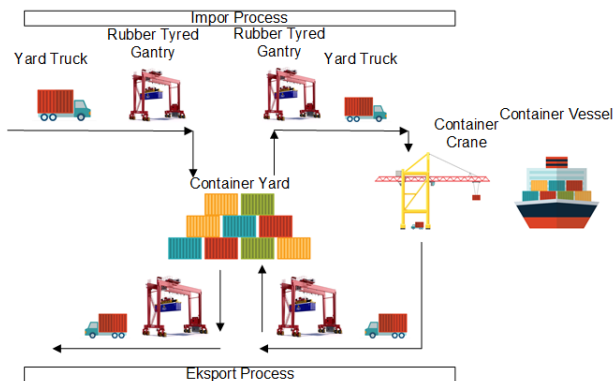


Fig. 1: The overview of processes in the Port in Indonesia.

#### a. Emissions in a Port

Emissions in a port are the number of emissions from container cranes, container handling and head trucks.

$$E_{port} = E_{cc} + E_{ch} + E_{tt}$$

$$E_{port} = E_{asc} + E_{rtg} + E_{sc} + E_{rs} + E_{sl}$$

$$E_{port} = E_{cc} + E_{asc} + E_{rtg} + E_{sc} + E_{rs} + E_{sl} + E_{tt}$$

$E_{cc}$  = Emission container crane

$E_{ch}$  = Emission container handling

$E_{tt}$  = Emission terminal truck

$E_{asc}$  = Emission automated stacking crane

$E_{sc}$  = Emission straddle carrier

$E_{rs}$  = Emission reach stacker

$E_{ch}$  = Emission container handling

$E_{sl}$  = Emission side loader

$$E = EC \times EF$$

$$EC = Utility \times EFF$$

$EC$

= Energy Consumption ( Liter, KWh)

$EF$  = Emission factor (g/kWh)

Utility = Use of equipment in one year (hour)

$EFF$  = Fuel Consumption factor (l/hour)

The emission factor used in this research was based on

the guidelines of inventorying gas of the national greenhouse issued by the Indonesian Ministry of Environment, who has ratified IPCC 2006, in the year 2012<sup>24)</sup>.

Table 1. Fuel Emission Factor<sup>24)</sup>

Fuel	FE Default IPCC 2006 immovable source, Ton/GJ			FE Default IPCC 2006 movable source, Ton/GJ		
	CO2	CH4	N2O	CO2	CH4	N2O
Diesel (IDO/ADO)	74100	3	0.6	74100	3.9	3.9

Table 2. Heat Value<sup>24)</sup>

Fuel	Heat Value
Solar (HSD, ADO)	3.60E-05

Table 3. Emission Factor

Fuel	Emission Factor (kg/liter)		
	CO2	CH4	N2O
FE Solar (ADO)	2.67	1.404E-04	1.404E-04

The emission factor in Table 1 was multiplied by the value of heat in Table 2 to get the emission factor in kg/liter like that in Table 3. The emission factor of the electricity network in Java-Madura-Bali is 0.844 kg of CO2/KWH<sup>26)</sup>.

#### b. Emissions from Ships

The emissions from ships are the number of emissions from the auxiliary engines of ships while they are in the port.

$$E_{ship} = PS \times PF \times EF$$

$PS$  = Power Ship ( KW)

$PF$  = Power Factor (%)

$EF$  = Emission Factor (g/kWh)

Power ship is obtained from the capacity of a ship, like in Table 4, and  $PF$  is the power factor used by a ship when it is resting, like in Table 5.  $EF$  is the emission factor for a ship consuming diesel, like in Table 6.

Table 4. Auxiliary Engine Power

No	Capacity (TEUS)	Power
1	200	265
2	400	494
3	600	896
4	800	1371
5	1000	1600

6	1200	1999
7	1400	2396
8	1600	2796
9	1800	3176
10	2000	3516
11	2200	3823
12	2400	4458
13	2600	4730
14	2800	5094
15	3000	5310
16	3200	5759
17	3400	6209
18	3600	6661
19	3800	7009
20	4000	7356
21	4200	7704

Table 5. Estimated Power Utilization at Different Operational Modes in the Port Area <sup>28)</sup>

Engine	In Port Basin	Maneuvering	At Anchor/At Berth
Main engine	20%	20%	0%
Auxiliary engine	40%	50%	40%

Table 6. Emission Factor Auxiliary Engine <sup>29)</sup>

Emission	EP (g/kW/hour)
CO <sub>2</sub> Emission	609.00
NO <sub>x</sub> Emission	12.00
CO Emission	0.50
HC Emission	0.50
Particulates	0.44
S content	1.00
SO <sub>2</sub> Emission	3.99



Fig. 2 : Layout BICT

Table 7. Characteristic BICT

1	Operation	
	Throughput	526039 TEUS/year
2	Berth	
	Length	500 meters
	Width	31 meters
	Depth	10 meters
3	Container Yard	
	Area	158464 m <sup>2</sup>
	Capacity	14988 TEUS
	Ground Slot	3342
	Reefer	144

This terminal is located on the 3°47'46" N and 98°43'09" E of Medan, North Sumatera. It is the only international terminal on Sumatera Island, and it serves as the bridge connecting the industrial regions in North Sumatera. It is also side by side to the domestic container terminal, PT Pelindo 1. The layout of BICT is in Figure 2 and the characteristics are in Table 7. As for the data of the used equipment, it is in Table 8.

### 3. Data and analysis

#### 1. Data of the equipment and its utility

Table 8. Distribution Equipment and Its Utility

No	Equipment	BICT	
		Quantity	Utility (%)
1	Container Crane Electric	1	22.89
2	Container Crane Diesel	5	58.41
3	Rubber Tired Gantry Crane	12	47.41
4	Automated Stacking crane	-	-
5	Straddle Carrier	-	-
6	Reach stacker	2	19.66
7	Side Loader	1	21.08
8	Head Truck	24	30.74

In Table 8, which contains the data of the implements in BICT. It is in line with the productivity of terminal, in

### 3. Characteristics of the Ports

#### 1. Belawan International Container Terminal (BICT)

BICT capacity is 526.039 TEUS. For the main implements, i.e. CC and RTG/ASC, BICT only one of the six CC's is electrically operated.

### 3. Consumption of Fuel and Electricity

Table 9. Fuel and Electricity Consumption

Month	BICT	
	Liter	KWH
January	234,145	19,152
February	183,842	26,847
March	231,210	33,345
April	244,427	19,152
May	283,322	26,676
June	272,818	24,282
July	233,426	11,286
August	259,649	34,200
September	257,956	41,895
October	288,589	36,081
November	262,418	33,003
December	281,612	36,936
Total	3,033,414	342,855

In Table 9 the biggest consumption belongs to BICT, divided into usage every month which. BICT uses diesel for all the equipment. The electricity consumption in BICT is low because only one of the implements is electrically operated.

### 4. Numbers of Visiting Ships

Table 10. Ships Call

No	BICT			
	Capacity (TEUS)	Number of Ship	Power (KW)	Berthing Time (Hour)
1	200	0	265	0.00
2	400	115	494	25.16
3	600	0	896	0.00
4	800	16	1371	22.83
5	1000	66	1600	20.81
6	1200	137	1999	23.66
7	1400	55	2396	19.59
8	1600	77	2796	32.11
9	1800	55	3176	31.44
10	2000	27	3516	29.98

Based on Table 10, in BICT, the containers result from the production of the close-by regions. The visits of big ships, with the capacities above 2500 TEUS. BICT has a depth of 10 meters only.

### 5. Emissions

Table 11. Emission Terminal Equipment

No	Equipment	BICT	
		ton	%
1	Container Crane Electric	289.37	3%
2	Container Crane Diesel	4421.65	53%
3	Rubber Tired Gantry Crane	2393.00	29%
4	Automated Stacking crane	-	0%
5	Straddle Carrier	-	0%
6	Reach stacker	183.79	2%
7	Side Loader	59.12	1%
8	Head Truck	1034.37	12%
	Total	8381.31	100%
9	Port Equipment	8381.31	39%
10	Ship	13184.25	61%
	Total	21565.55	100%

The emissions of every implement based on the fuel or electricity consumption were then calculated. The result is in Table 11. The most emissions are produced by head trucks. It is because the large number of head trucks, which have high utility. The largest number of emissions from berthing belongs to JICT because the number of resting ships in this port is larger than those in the other ports.

### 6. Emissions per TEU

Table 12 shows the result after every emission was added and then the emissions were categorized into three, i.e. the emissions from all the implements, the emissions from the fuel-powered implements, and the emissions from the electrically powered implements, and then they were added to the emissions from berthing. Each of these emissions was then divided by the productivity of the corresponding port to figure out the emissions per TEU produced by the port.

Table 12. Emission in Port

Terminal	Equipment Emission (ton)	Equipment Emission Using Fuel (ton)	Ship Emission (ton)	Total Emission (ton)	Through put	Equipment Emission (kg/TEU)	Equipment Emission Using Fuel (kg/TEU)	Total Emission (kg/TEU)
BICT	8,381.31	8,091.94	6,913.50	15,294.49	526,039	15.93	15.38	29.08

#### 4. Conclusion

With the emissions from fuel and berthing being considered, the result of the emissions produced by each port was categorized into three. The categories are based on emissions from fuel only since those from electricity were not in the corresponding port, but in the power plant.

Based on the emissions from all the equipment, BICT produces emissions as many as 15.93 kg of CO<sub>2</sub>/TEU. The head trucks in BICT produce 12% of the emissions respectively.

Based on the emissions from all the equipment excluding the electrically operated implements, BICT produces emissions as many as 15.38 kg of CO<sub>2</sub>/TEU. Based on the emissions from the equipment using fuel, the emissions produced by BICT are not much different. It is because of the electricity consumption is smaller than the fuel consumption. The emissions from electricity are not produced in the terminals, but in the power plants.

Based on the emissions from all the equipment and berthing, BICT produces emissions as many as 29.08 kg of CO<sub>2</sub>/TEU.

Ships produce the most emissions in a port so that power on shore should be used to reduce emissions in a port. So, the number of emissions ships usually produce can be lowered even to zero. The effectiveness of unloading should also be increased so that the time one ship spends on berthing is shorter. As for the emissions from the equipment in a port, the use of electrically operated equipment can minimize the use of fuel so that the produced emissions are fewer.

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