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POWER PLANT EMISSIONS INVENTORY IN BATAM

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ABSTRACT

POWER PLANT EMISSIONS INVENTORY IN BATAM. This research is motivated by the rising electricity demands and a need to curb emissions from the electricity generation in Batam city, a city often called industrial city because of the large number of companies in the city. This study aims to provide an estimate of the emissions generated by all power plants which electricity produced is used for internal and external parties in the city of Batam. External parties for power plant companies can be households, as well as other companies inside and outside the industrial park. This study focuses on power plants because they are responsible for one fifth of total emissions of NOx,and a significant amount of other emissions in Batam. Primary data are obtained from field survey to all power plants in Batam. The emissions of NOx, CO, SOx, PM10, and HC are calculated using the 2013 EMEP/EEA methods and those of COx are estimated using the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines. Out of 116 companies surveyed as potential point sources, the author concluded that 24 power plants meet the criteria of companies that use the electricity generated for external user(s). After emissions inventory estimation, the author concludes the increasingly dominant coal power plant brings the highest environmental consequences. Thus the author argues that the emissions reduction actions should focus on this power plant.

Keyword: power plants, emissions, Batam

ABSTRAK

INVENTARISASI EMISI PADA PEMBANGKIT LISTRIK DI KOTA BATAM. Penelitian ini dilatarbelakangi oleh tingginya kebutuhan listrik yang dibarengi dengan kebutuhan untuk mengendalikan emisi akibat pembangkitan listrik tersebut di kota Batam, kota yang sering disebut kota industri karena banyaknya perusahaan di kota ini. Penelitian ini bertujuan memberikan estimasi emisi yang dihasilkan oleh seluruh pembangkit listrik yang listriknya digunakan untuk pihak internal dan pihak eksternal di kota Batam. Pihak eksternal perusahaan pembangkit listrik dapat berupa rumah tangga, maupun perusahan lainnya di dalam maupun di luar kawasan industri. Penelitian ini fokus pada pembangkit listrik karena pembangkit listrik bertanggung jawab terhadap seperlima dari total emisi NOx, dan sejumlah gas buang jenis lainnya. Gas buang yang dikalkulasi pada penelitian ini adalah NOx, CO, SOx, PM_{10}, dan HC menggunakan metode estimasi emisi yang digariskan oleh EMEP/EEA pada tahun 2013, sedangkan gas buang CO_x diestimasi menggunakan metode yang diinstruksikan oleh IPCC pada tahun 2006. Dari 116 perusahaan yang disurvei sebagai sumber titik potensial, penulis menemukan 24 pembangkit listrik yang memenuhi kriteria sebagai perusahaan yang menghasilkan listrik untuk pihak eksternal. Setelah memperkirakan inventorisasi emisi, penulis menyimpulkan bahwa penggunaan batu bara yang kian dominan untuk pembangkit listrik membawa konsekuensi lingkungan yang terbesar. Sehingga penulis berpendapat bahwa upaya pengurangan emisi sebaiknya bertumpu pada pembangkit listrik yang berbahan bakar batu bara ini.

Kata kunci: pembangkit listrik, emisi, Batam

INTRODUCTION

Emission releases to the environment are the starting point of every pollution problem. Thus, estimating the emissions is an important step in understanding environmental problems and in monitoring progress towards solving these. An emission inventory is used to help policy makers determine important sources of air pollutants, track

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progress and develop strategies towards emission reduction targets, and help scientists build emission trends over time and assess air quality through dispersion modeling.

Diverse methods for calculating the emissions are available, such as continuous monitoring to measure actual emissions like Rashid, M. Et all (1998) did in a field evaluation in mill boilers [1]; extrapolating the results from short-term source emissions tests like Yusoff, A. R. and Aziz, I. A. (2009) did when predicting boiler emission by using artificial neural networks model [2]; and combining published emission factors with known activity levels like Rashidi, M. and Jaswar (2014) did in predicting carbon dioxide emitted by marine transport [3]. The later method is used in this paper considering the limited data, time, staff and funding.

Given the above-average-for-decades rate of economic development in the free trade zone Batam and the degradation of air quality in the future which is likely resulted from this, it becomes necessary to use all of the scientific tools available for the management of the atmospheric environment. In the light of electricity demands rising, power plants generate energy not only for households but also for companies inside and outside of industrial zone . This paper focuses on power plants because they are responsible for more than one fifth of total NOx emissions and a significant amount of other emissions in Batam [4]. The energy sector is usually the most important sector in greenhouse gas emission inventory because it typically contributes over 90 percent of the CO_2 emissions and 75 percent of the total greenhouse gas emissions in developed countries [4]. Unless emission reduction actions are taken, the power plant emissions will not decrease anytime soon since the demand rises and the energy industry expands as the latter supplies power to not only Batam, but also to neighboring Bintan island which would be delivered in 2015 and to Singapore in 2017.

This article covers exclusively on substances that parties in Indonesia need to report under Indonesian regulation [5] such as NOx, CO, SOx, PM_{10}, and HC in addition to a substance that is responsible for global warming and climate change such as COx under Indonesian law [6]. All substances under scrutiny are emitted directly from their sources, also called as primary pollutants. When compared to other countries, the Indonesian ambient air quality standards for these substances are quite similar in some aspects as shown in Table 1.

Table 1. National Ambient Air Quality Standards For Countries

Pollutant	Assessment time	Level		
		Indonesia [5]	US [7]	Europe [8]
CO	1 hour	20 mg/m^3	40 mg/m^3	30 mg/m^3
NO_x	1 year	100 µg/m^3	100 µg/m^3	40 µg/m^3
SO_x	24 hours	365 µg/m^3	365 µg/m^3	125 µg/m^3
SO_x	1 year	60 µg/m^3	58 µg/m^3	50 µg/m^3
PM_{10}	24 hours	150 µg/m^3	150 µg/m^3	50 µg/m^3
HC	3 hour	160 ug/Nm^3	-	-

This paper discusses the estimation of power plant emission in Batam for six primary substances. Aditionally, this paper tries to give details regarding the estimated emissions for the regulated community, the government, the public, and other affected parties, as the information is substantial for air quality management process.

METHODOLOGY

Primary data are obtained from field survey to all power plants in Batam. Power plants are defined as facilities with stationary combustion appliance to generate electric power for internal use and for sale to external user(s). The emissions are calculated by multiplying emission factors with activity levels found in the survey. An emission factor is used to estimate emissions because the actual emission data is not available. Since Indonesian emission factors is not existing yet, this paper uses emission factors of EMEP/EEA methods launched in 2013 and those of COx using the Intergovernmental Panel on Climate Change (IPCC) guidelines issued in 2006. The both of methods are used instead of another method such as USEPA, because the former ones have more similarities in the combustion technologies than the latter one does given that engines in Batam were imported from European countries.

There are three Tiers presented in both methods. The Tier 1 method is fuel-based approach using the equation (1) to estimate the emissions:

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$$E_{pollutant} = AR_{fuelconsumption} \times EF_{pollutant} \quad (1)$$

Where:

$E_{pollutant}$ = annual emission of pollutant
$EF_{pollutant}$ = emission factor of pollutant
$AR_{fuel\ consumption}$ = activity rate by fuel consumption

Both of EMEP/EEA and IPCC use average value of all available data of acceptable quality (usually from national energy statistics) assuming an average or typical technology and abatement implementation.

Meanwhile, Tier 2 technique includes type of combustion plant and relative mix of fuels which is stated in equation (2):

$$E_{pollutant} = \sum AR_{i,j} \times EF_{i,j} \quad (2)$$

Where:

$E_{pollutant}$ = annual emmission of pollutant
EF = emission factor
AR = activity rate
i = type of fuel
j = type of combustion plants

Tier 2 emission factor for CO_2 is not available because Indonesia does not set national emission factors. In this paper, Tier 1 and Tier 2 emission factors used are stated in Table 2.

Table 2. Emission Factors

		Emission Factors in g/GJ by Fuel Type					
Plant Capacity		Plants > 50 MW				Plants > 50 MW	
Technology		Stationary/ Gas engine	Gas Engine	Gas Turbine Engine	Dry Bottom Boiler	Gas Turbine Engine	Wet Bottom Boiler
Pollutant	Fuel / Tier	Gas/Diesel Oil	Gaseous Fuel	Gaseous Fuel	Natural Gas	Gaseous Fuel	Sub-bitumous Coal
NOx	Tier 1	513.00	74.00	74.00	74.00	89.00	209.00
	Tier 2	1450.00	1420.00	70.00	89.00	48.00	244.00
CO	Tier 1	66.00	29.00	29.00	29.00	39.00	8.70
	Tier 2	385.00	407.00	20.00	39.00	4.80	8.70
HC**	Tier 1	25.00	23.00	23.00	23.00	2.60	1.00
	Tier 2	37.10	46.00	2.00	2.60	1.60	0.70
SOx	Tier 1	47.00	0.67	0.67	0.67	0.28	820.00
	Tier 2	46.10	0.28	0.50	0.28	0.28	820.00
PM10	Tier 1	20.00	0.78	0.78	0.78	0.89	7.70
	Tier 2	22.40	1.50	0.50	0.89	0.20	6.00
COx	Tier 1	74.10	56.10	56.10	56.10	56.10	96.10
Source Ch./Table	Tier 1 [9],[10*]	1.A.4/3-9	1.A.4/3-8	1.A.4/3-8	1.A.4/3-8	1.A.1/3-4	1.A.1/3-2
	Tier 2 [9]	1.A.4/3-38	1.A.4/3-37	1.A.4/3-35	1.A.4/3-34	1.A.1/3-17	1.A.1/3-14

* Source: All emission factors for tier 1 are from EMEP/EEA [9] except COx is from IPCC [9] chapter 2.3 Table 2.2

** Hidrocarbon (HC) is defined as equivalent with the term of non-methane volatile organic (NMVOC)

The best practice is using Tier 3 data where applicable. Unfortunately it is not applicable in this research because facility-level emission reports are not available for all relevant combustion processes in Indonesia.

RESULTS AND DISCUSSION

Energy in Indonesia, like in most countries, largely generated from combustion of fossil fuels. In Batam, although biofuel is available and can be supplied by local producers, power plants prefer fossil fuels based on technology and security of supply reasons. Local

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government is considering municipal waste for electricity generation [10] but the amount of waste in Batam alone is not enough to secure a continous supply for power plants, thus the current dominance of fossil fuels will not change in anytime soon.

The typical process scheme for power plants in Batam is shown in figure 1.

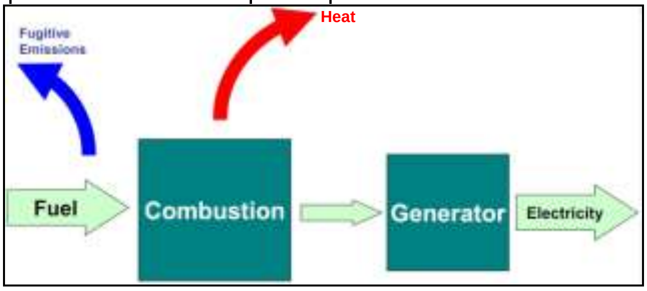

Figure 1. The Typical Process Scheme for Power Plants in Batam [9]
Source: EMEP/EEA Emission Inventory Guidebook 2013, Fig. 2-2, Chapter 1.

During combustion of the fossil fuels, heat is produced to generate electricity. Most power plants in Batam only deliver electricity excluding wasted heat because heat is not required in their own industrial process nor in their clients' manufacturing process. PT Citra Tubindo Tbk is the only company that might install cogeneration system using waste heat because it may uses waste heat for internal manufacturing process besides electricity generation.

Out of 116 companies surveyed as potential point sources, 65 companies have gensets with capacity mostly under 1 MW. Most companies use the electricity generated for back up only and do not sell electricity to external user(s), thus, this research excludes them as samples. There are 24 power plants that fulfill the above definition and their activity rate are stated in Table 3.

Table 3. Power Plants in Batam and Their Activity Profiles

No	Owner/company	Plant Name	Installed Capacity (MW)	Type of Engine Technology	Fuel	Consumption 2012	Consumption 2013	Unit
1	PT TJK Power	Tanjung Kasam	130.00	Wet Bottom Boiler	Coal	186.461	432.573.171	Ton
2	PLN Batam	Sekupang 2	18.00	Stationery Engine	Diesel	3.548.705	16.934	L
3	PLN Batam	Batu Ampar I	30.72	Stationery Engine	Diesel	1.895.658	-	L
4	PLN Batam	Batu Ampar II	10.50	Stationery Engine	Diesel	57.263	-	L
5	PLN Batam	Batu Ampar II	10.50	Stationery Engine	Fuel Oil	1.516.189	13.399	L
6	PLN Batam	Sei Baloi	12.34	Stationery Engine	Diesel	310.475	-	L
7	PLN Batam	Sei Baloi	12.34	Stationery Engine	Fuel Oil	7.394.723	-	L
8	PLN Batam	Tg Sengkuang	20.87	Stationery Engine	Diesel	1.238.110	-	L
9	PLN Batam	Latrade	3.59	Stationery Engine	Diesel	19.403	1.359	L
10	PLN Batam	Panaran	26.25	Gas engine	Natural Gas	87.999	1.105.192	mmbtu
11	PT Dalle Energy	Panaran 2	63.00	Gas turbine engine	Natural Gas	4.222.187	4.588.681	mmbtu
12	PT Dalle Energy	Panaran 3	20.60	Dry Bottom Boiler	Natural Gas	1.517.038	-	mmbtu
13	PT Dalle Energy	Panaran 4	19.00	Gas engine	Natural Gas	903.602	628.076	mmbtu
14	PT Indo Matra Power	Kabil	18.00	Gas engine	Natural Gas	1.000.701	846.475	mmbtu
15	PT Indo Matra Power	Kabil	12.00	Gas engine	Natural Gas	790.513	609.577	mmbtu
16	PT Aggreko	Panaran	33.00	Gas engine	Natural Gas	1.318.224	-	mmbtu
17	PT Jembo Energindo	Boo Baloi	9.36	Stationery Engine	Diesel	246.450	-	L
18	PT Jembo Energindo	Boo Baloi	18.72	Stationery Engine	Fuel Oil	6.110.205	-	L
19	PT Jembo Energindo	Jembo 2 Baloi	24.00	Gas engine	Natural Gas	1.403.040	1.028.271	mmbtu
20	PT Mitra Energi	Panaran 1	57.20	Gas turbine engine	Natural Gas	4.457.947	4.144.728	mmbtu

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No	Owner/company	Plant Name	Installed Capacity (MW)	Type of Engine Technology	Fuel	Consumption 2012	Consumption 2013	Unit
21	PT Panbil Utilitas	Mukakuning	42.00	Gas turbine engine	Natural Gas	815.097	800.648	mm btu
22	PT Tunas Energi	Batam Center	12.60	Gas turbine engine	Natural Gas	541.739	427.078	mm btu
23	PT Batamindo (BIP)	Mukakuning	142.00	Gas turbine engine	Natural Gas	4.525.590	4.447.844	mm btu
24	PT Citra Tubindo	Kabil	8.00	Gas turbine engine	Natural Gas	10.342.357	8.834.349	M^3
	Total		754.60					

PT Panbil, PT Tunas, and PT Batamindo manage industrial estate and generate electricity exclusively for companies within their industrial zones. However, they would supply their excess capacity to PT PLN Batam, a state-owned utility, should the latter one needs to support public demand. However, the power tariff charged by the three companies is higher than the PLN tariff but they compensate this by ensuring the high-level of security of power supply to their customers [11].

All other companies outside PT Panbil, PT Tunas, and PT Batamindo industrial zone along with residential end-users purchase power from PLN Batam. PT PLN Batam has nine plants but it continues to decrease its own production and prefers buying from independent power producer, especially PT TJK. The reason for this preference is that high speed diesel which is used by most of PLN plants, is not competitive anymore in terms of security of supply and price fluctuation. Another reason is that PT TJK offers lower tariff because it uses coals as main input supply.

To estimate the emissions of power plants in Batam, the conversion units are assumed and stated in Table 4.

Table 4. Conversion Unit Assumptions

Fuel	Calorific Value	Units
Sub-bitumous Coal in 2012*	1.97×10^{1}	GJ/Ton
Sub-bitumous Coal in 2013*	1.57×10^{1}	GJ/Ton
High Speed Diesel*	3.59×10^{-5}	GJ/L
Marine Fuel Oil	3.97×10^{-5}	GJ/L
Natural Gas	3.29×10^{1}	GJ/M^3
Natural Gas	3.94×10^{-3}	GJ/mmbtu

Because the quality of coals imported from Korea varies through out year 2012 and 2013, then the average calorific value of coals in 2012 differs with that in 2013. Meanwhile, the quality of other types of fuels tends to be persistent year to year. The calorific values used in this research are based on PLN internal data.

When compared to the gross calorific values in the United Kingdom (UK) [12], this assumptions seem plausible (look at Table 5).

Table 5. Conversion Unit Assumptions

Fuel	Calorific Value Research	Calorific Value UK	Calorific Value Variance	Units
Sub-bitumous Coal	15.7 - 19.7	26.2	(8.5)	GJ/Ton
High Speed Diesel	46.2	45.6	0.6	GJ/Ton
Marine Fuel Oil	42.3	43.3	(1.0)	GJ/Ton
Natural Gas	32.9	39.8	(6.9)	MJ/M^3

Diesel is the only type of fuel which the power plants in Batam have higher calorific value than those in the UK. Power plants in Batam use a very low quality of coal, thus the calorific value of coal in Batam is lower than that in the UK.

The increasing dominance coal power plant brings consequences on the environment. Based on emission factors (Table 2 and Table 3), activity rate of power plants (Table 4) and conversion units assumed (Table 5), the total emissions could be calculated as stated in Table 6.

Table 6. The Total Emissions of Power Plants

Pollu-	Plant Number

	tant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Emission Tier 1 2012 in Ton	NOx	768	0	0	0	0	0	0	0	0	0	1	-	0	0	0	0	0	0	0	2	0	0	2	9
	CO	32	0	0	0	0	0	0	0	0	0	1	-	0	0	0	0	0	0	0	1	0	0	1	1
	HC	4	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	9
	SOx	3.014	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0
	PM10	28	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0
	CO2	353	0	0	0	0	0	0	0	0	0	1	-	0	0	0	0	0	0	0	1	0	0	1	2
Emission Tier 2 2012 in Ton	NOx	897	0	0	0	0	0	0	0	0	0	1	-	5	6	4	7	0	0	8	1	0	0	1	7
	CO	32	0	0	0	0	0	0	0	0	0	0	-	1	2	1	2	0	0	2	0	0	0	0	8
	HC	3	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	1
	SOx	3.014	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0
	PM10	22	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0
Emission Tier 1 2013 in Ton	NOx	1.415.103	0	-	-	0	-	-	-	0	0	2	-	0	0	0	-	-	-	0	1	0	0	2	25
	CO	58.906	0	-	-	0	-	-	-	0	0	1	-	0	0	0	-	-	-	0	1	0	0	1	10
	HC	6.771	0	-	-	0	-	-	-	0	0	0	-	0	0	0	-	-	-	0	0	0	0	0	8
	SOx	5.552.081	0	-	-	0	-	-	-	0	0	0	-	0	0	0	-	-	-	0	0	0	0	0	0
	PM10	52.135	0	-	-	0	-	-	-	0	0	0	-	0	0	0	-	-	-	0	0	0	0	0	0
	CO2	650.677	0	-	-	0	-	-	-	0	0	1	-	0	0	0	-	-	-	0	1	0	0	1	19
Emission Tier 2 2012 in Ton	NOx	1.652.083	0	-	-	0	-	-	-	0	6	1	-	3	5	3	-	-	-	6	1	0	0	1	23
	CO	58.906	0	-	-	0	-	-	-	0	2	0	-	1	1	1	-	-	-	2	0	0	0	0	7
	HC	4.740	0	-	-	0	-	-	-	0	0	0	-	0	0	0	-	-	-	0	0	0	0	0	1
	SOx	5.552.081	0	-	-	0	-	-	-	0	0	0	-	0	0	0	-	-	-	0	0	0	0	0	0
	PM10	40.625	0	-	-	0	-	-	-	0	0	0	-	0	0	0	-	-	-	0	0	0	0	0	0

All numbers above are rounded numbers. Thus, zero numbers in the above table is not exactly zero. When the plant is not utilized in 2013, the plant will emit zero pollutant and dash (-) symbol is used.

As we can see from table 6, we can see that PT TJK (plant number 1) which uses sub-bituminous coals as its main input supply emits the most significant pollutant to the air, and it continues to generate more emissions from time to time. When compared to other power plants, the emissions of PT TJK stands out, thus the author argues that the emissions reduction actions should focus on this power plant either by switching the type of fuel, improving the powerplant efficiency, or capturing the COx in the flue gas and storing it [13].

CONCLUSIONS

Energy in Batam largely generated from combustion of fossil fuels, although biofuel can be supplied by local producers, power plants prefer fossil fuels for technology and supply security reasons. Local government is considering municipal waste for electricity generation but the amount of waste in Batam alone is not enough to secure a continous supply for power plants, thus the current dominance of fossil fuels will not change in anytime soon. Out of 116 companies surveyed as potential point sources, the author concluded that 24 power plants meet the criteria of companies that use the electricity generated for external user(s). All companies outside Panbil, Tunas, and Batamindo industrial zones along with residential end-users purchases power from PLN Batam. PT PLN Batam has nine plants but it continues to decrease its own production and prefers buying from independent power producer especially PT TJK. The reason for this preference is that high speed diesel that is used by most of PLN plants, is not competitive anymore in terms of supply security and price fluctuation. Another reason is that PT TJK offers lower tariff because PT TJK uses a low quality of sub-bitumous coals as main input supply. The increasingly dominant coal power plant brings environmental consequences. Hence, PT TJK that uses sub-bitumous coals as its main input supply emits the most significant pollutant to the air, and it continues to generate more emissions from time to time. When compared to other power plants, the emissions of PT TJK stands out, thus the author argues that the emissions reduction actions should focus on this power plant.

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