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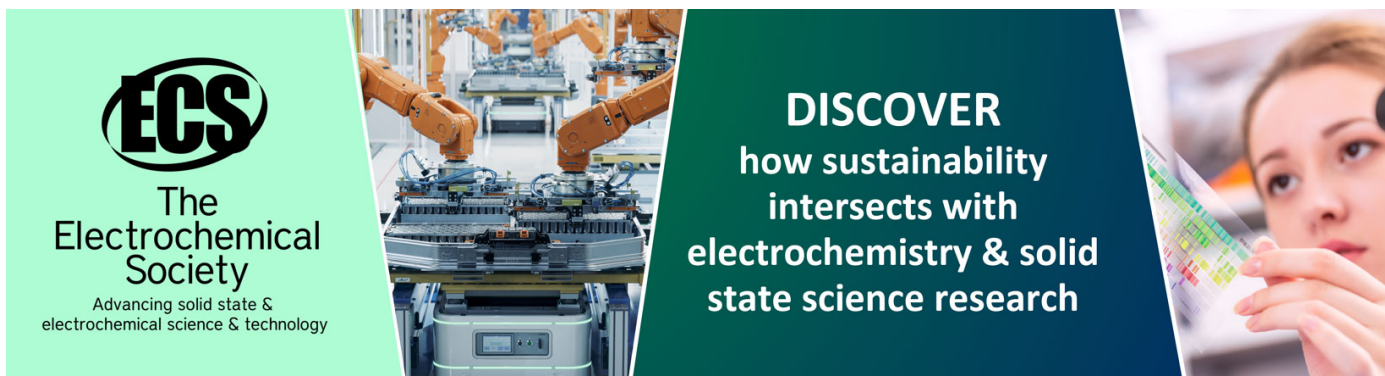
Emission Inventory of Pollutants (CO, SO₂, PM_{2.5}, and NO_x) In Jakarta Indonesia

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Emission Inventory of Pollutants (CO, SO₂, PM_{2.5}, and NO_x) In Jakarta Indonesia

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Abstract. Emission inventory of pollutants (CO, SO₂, PM_{2.5}, and NO_x) from various sectors included power plants, road transportation, industry, and residential and commercial was conducted in Jakarta for the year 2005-2015. Emissions load of these pollutants was calculated using GAINS (Greenhouse gas model - Air pollution Interactions and Synergies) model, based on energy used. Control technology was also applied for pollutants emitted from power plant, industry as well as residential and commercial, while control of EURO II and EURO III were considered for transportation sector. Emission inventory result shows that in 2015, the total emission load for NO_x and CO were estimated around 52.9 kton and 143.9 kton respectively. The biggest contributor to these pollutants were from road transportation sector which contributed of 57%, and 93% for NO_x and CO respectively. From transportation sector, heavy-duty vehicles is the biggest contributor of NO_x and BC emission, while for CO is mostly emitted from motorcycles. While total emission load for PM_{2.5} in Jakarta is about 4.6 kton, and it is mostly emitted from road transportation and industrial combustion sectors which are 2.1 kton (46%) and 0.4 kton (43%), respectively. The heavy duty vehicles was still the highest contributor of PM_{2.5} emission in the transport sector. The total SO₂ emission load is 19.7 kton, and it is mostly released from industrial combustion that contribute almost 67% of total emission.

Keyword: Emission inventory, pollutants, power plant, industry, residential and commercial, transportation, GAINS, Jakarta

1. Introduction

Population growth and economic activities that are resulted by rapid urbanization and industrialization [1] lead to higher energy consumption in various sector. On the other side, energy consumption also could lead to increase the air pollution level as well as GHGs emission and it could cause harmful effect to human health and environment. It occurred in Asian countries, specifically in developing countries such as Indonesia especially in a big city like Jakarta, thus it is clearly essential to obtain an accurate emission estimates [2] of air pollutant to not only understand and add the knowledge but also assist to disperse the consciousness between public and policy makers [3]. In order to prioritize the control on targeted pollutants and sources, and to identify the important sources of specific pollutants, emission inventory is conducted in Jakarta which has a very high population density and high economic activities. Emission inventory is a comprehensive listing by sources of air pollutant emissions in a



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geographic area during a specific time period and it is a significant tool to estimate the air quality [4]. On the other side, it is also important to consider control strategy and policy development to solve the air pollution in Jakarta. This study aims to conduct an emission inventory of NO_x, CO, SO₂ and PM_{2.5} from various sectors including power plant, industries, residential and commercial as well as road transportation from 2005-2030 using GAINS model with the 2015 data as base line data. Several control technologies and policy intervention applied currently in Jakarta will be included in the data analysis.

2. Material and methods

2.1. Study Area

This study was conducted in Jakarta, with high population of nearly 10.1 million (Indonesia Statistic Berau, 2015) which has total land area of 662.33 km² and 6997.5 km² of sea area. It is astronomically lies between 6°12' south latitude and 106° 48' east longitude with the average altitude on 7m above sea level (Indonesian Statistic Berau). As consequences of high population density, there many various activities that could generate emission. However, this study focuses mainly on emission from power plant, industries, residential and commercial, and road transportation.

2.2. Sources of Activity Data

Top-down (based on fuel consumption) approach was carried out to estimate the energy used from each sectors which then used as input to the model. Type of fuels included in this study consist of natural gas, coal, LPG, diesel and gasoline. The number of vehicles and vehicle kilometer travelled (vkt) were also used as input to the GAINS model especially for road transport sector. All data were mostly obtained from the related government agency and Indonesia state-owned companies such as Ministry of Energy and Mineral Resources, National Natural Gas Company, Department of Transportation, and National Oil Company, while the emission factors used were mostly from the GAINS.

2.3. Data Preparation

Gain required certain data format and template for their data input. In principle data processing is classified into two groups.

2.3.1. Non- Transport Sectors

The actual fuel consumption data for non-transport sector (power plant, industries, residential and commercial) were available from 2010-2017, while for the data other than that year were estimated using the actual data trend until year 2030. Several type of fuels used as an input to the model from various sectors included coal, natural gas, diesel oil and LPG consumption. All the data were then converted to energy used unit (peta joule) according to the template from GAINS model.

2.3.2. Transportation sector

For the transport sector, beside the energy used data (peta joule), the number of each type vehicles and VKT were also needed as input data. In this study, the type of vehicles were classified into several vehicle categories, which are diesel light duty vehicle, gasoline light duty vehicle, heavy duty vehicle as well as motorcycle.

2.3.3. GAINS MODEL

GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) is the model developed by International Institute for Applied Systems Analysis developed to estimate global emissions of pollutant as well as GHG. Technically, this model calculate the emission in 5-year intervals until 2050 [4] which has a certain template to input the data. In this study, the emission inventory was only calculated from

2005 until 2030, which 2010 and 2015 data were the actual data. Numerous of sectors are included in this model, comprises energy, domestic, industrial combustion and processes, road and non-road transport as well as agriculture[4]. However, this study only calculate several sector which are power plant (energy), residential and commercial (domestic), and industrial combustion. To estimate the current and future emission, this model used a technology-based methodology as follows [5]:

$$E_p = \sum_k \sum_m A_k ef_{k,m,p} X_{k,m,p}$$

Where k,m,p is the type of activity, abatement measure, and pollutant, respectively. While E_p is emission of pollutant p, A_k is activity data of type k, and $ef_{k,m,p}$ is emission factor of pollutant p for the activity of k after applied the control measure m (m includes the no control situation), and $X_{k,m,p}$ is the penetration of control measure m for pollutant p from activity k[5].

2.4 Control Technologies

Control technologies such as FGD (Flue Gas Desulfurization), ESP and cyclone applied for power plant and industries were consider in estimating future emission load. In addition, policies implementation of EURO IV, CNG, Electronic Road Pricing (ERP) in 2020 and Electric Vehicle (EV), Scrapping in 2020 for transportation sector were also evaluated.

3. Results and discussions

3.1. Energy Used

The emission inventory was carried out using GAINS model based on consumption of fuel or energy used. **Table 1** shows the total energy used (in peta joule) in Jakarta from 2005 to 2030. The energy used was estimated based on the actual energy consumption up to 2015. In general, energy consumption in Jakarta continue to increase due to economic activities and population growth. It start from just below 350 PJ in 2005, then decreased to around 320 PJ in 2010, whereas, the energy used slightly rose in 2015. However, it is predicted significantly increase until the end of given period (2030) which reach approximately 600 PJ.

3.2. Emission Estimation

3.2.1 Business as Usual

The emission load estimated from 2005 – 2030 can be seen in **Figure 1**, It shows the contribution of each source to the different pollutant. Generally, from year 2005 to 2010 there are significantly decrease of the total emission load for all pollutant. This was caused by the used of kerosene and biomass as fuel in their activities particularly from the residential sector in 2005.

Table 1. Energy Used by sector (in peta joule)

[PJ/yr]	2005	2010	2015	2020	2025	2030
Power & heating plants	101.18	101.79	100.3	96.37	115.88	143.79
Residential combustion	84.66	39.99	50.71	60.18	70.11	83.99
Industrial combustion	73.93	87.44	85.64	110.58	157.19	238.95
Road Transport	83.3	92.06	95.92	105.16	117.6	132.68
Total	343.07	321.28	332.57	372.29	460.78	599.41

However, the usage of this kind of fuels were no longer used in Jakarta and was change to natural gas (LPG) fuel, so that the emission load decrease significantly in the year of 2010 and after, based on Indonesian President Regulation No.104 2007.

The total of emission load for NO_x in 2015 estimated around 52.9 kton. The main source is road transportation that contribute more than a half of total (57%). Whereas, the heavy-duty vehicles is the biggest contributor of NO_x in Jakarta. The power plant emitted around 24% of total, while the remaining sources only contribute below 20%.

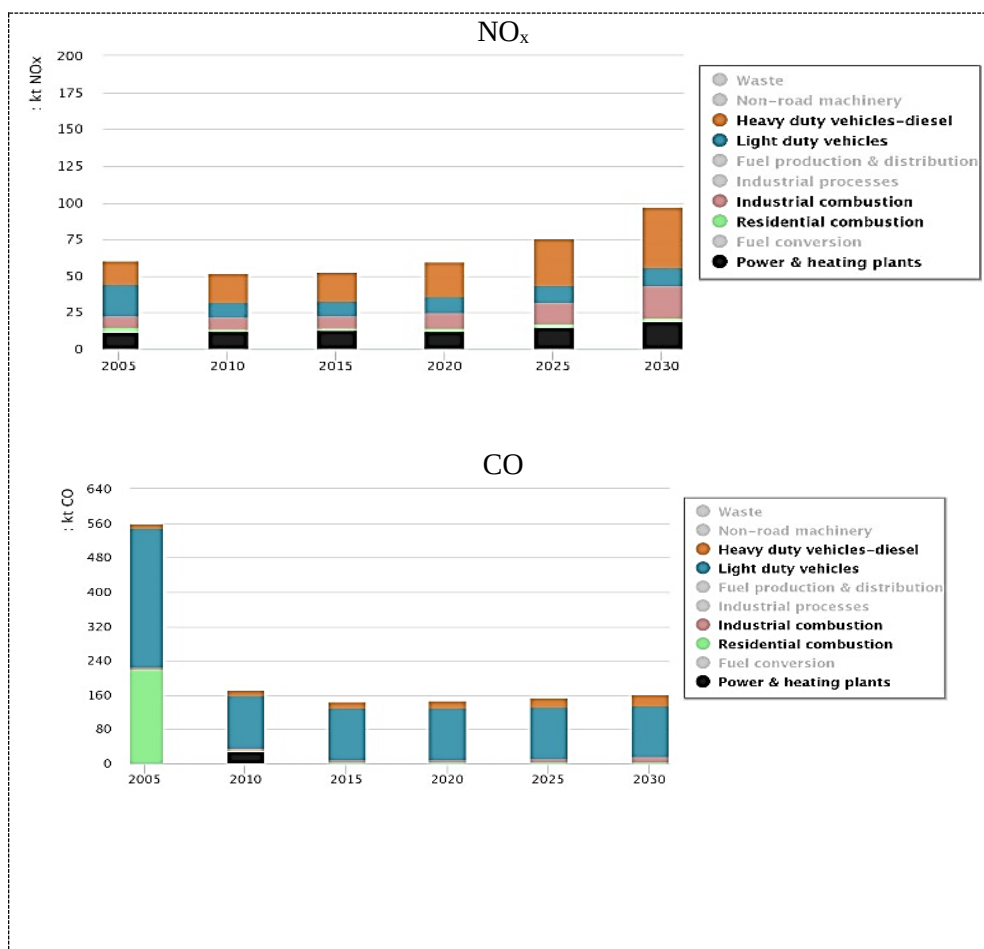
The road vehicles is also gave a significant emission of CO to the ambient air in Jakarta that released almost 93% of total in 2015 where the light duty vehicles, especially from motorcycle was the highest contributor. The total emission load in this year reached 143.9 kton. The second highest contributor was from industrial sector that emitted around 4% of total.

Total SO_2 emitted in Jakarta was 19.7 kton in 2015, it was mostly released from industrial combustion that contribute almost 67% of total. While the power plant was the second main contributor which contribute almost a quarter of total. Similar to other pollutant, the emission SO_2 continue to increase after the year of 2015

The total emission load for $\text{PM}_{2.5}$ in 2015 is about 4.6 kton, it is mostly emitted from road transportation and industrial combustion sectors that are 2.1 kton (46%) and 1.4 kton (43%), respectively, where the heavy-duty vehicles still the highest contributor of $\text{PM}_{2.5}$ emission.

3.2.2 Emission Load with Control Technology

Implementation of control technology in industrial and power sectors as well as scenarios on policy intervention for transport sectors were evaluated in this study. Applied air pollution control such as Cyclone, ESP and FGD) could significantly reduce emission of SO_2 and $\text{PM}_{2.5}$. Further reduction can be achieved with additional policy intervention from transport sector. The potential impact of applied control technologies and policy intervention to emission reduction can be seen in **Figure 2**.



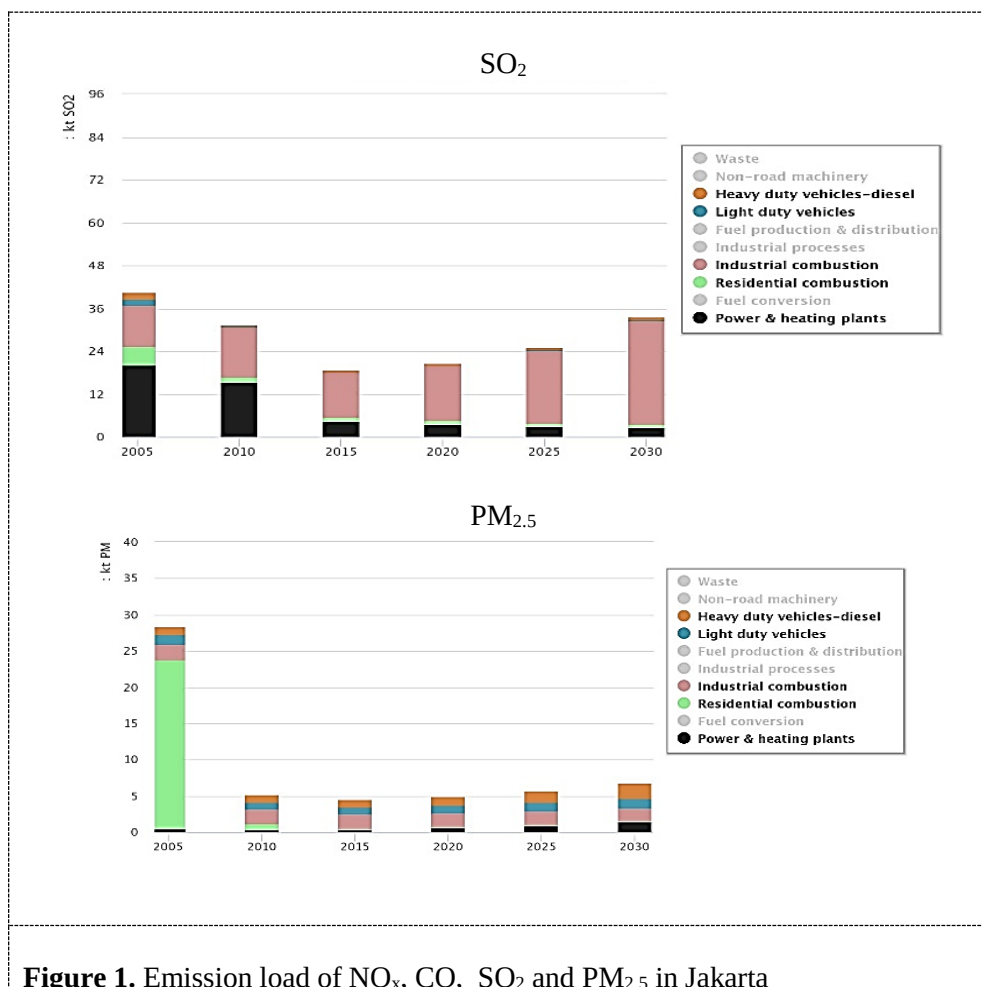


Figure 1. Emission load of NO_x, CO, SO₂ and PM_{2.5} in Jakarta

Emission load of SO_x and PM_{2.5} in 2015 was significantly decrease after were applied air pollution control in industry and power plant (52% and 42%). While in 2020, scenario in transportation sector were effectively reduce emission of SO₂, up to about 67-78%, however, it was estimated about 19% reduction of PM_{2.5}.

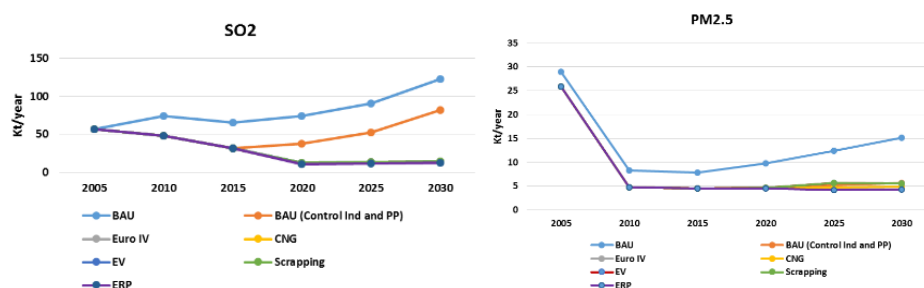


Figure 2. Emission Reduction with Control technologies & Policy intervention

4. Conclusions

The total emission load for the base line year in 2015 for CO, SO₂, PM_{2.5}, and NO_x is estimated around 143.9 kton, 65.4 kton, 7.8 kton, and 48.3 kton, respectively. Road transportation is the biggest contributor of NO_x (57%), and CO (93%), where heavy duty vehicles is the biggest contributor of NO_x, while for CO is mostly from motorcycles. PM_{2.5} in Jakarta mostly emitted from road transportation and industrial combustion sectors that are 46% and 43%, respectively, where the heavy duty vehicles is still the highest contributor of PM_{2.5} emission. While, SO₂ mostly released from industrial combustion that contribute almost 67% of total. Emission load of SO_x and PM_{2.5} were significantly decreased after Air pollution control were applied in industry and power plant sectors as well as policy intervention in transportation sector.

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