Greenhouse Gas Inventory Standard for Cities: a Case of Jakarta

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Abstract. This paper presents the results of a study on developing the GHG Emissions Inventory for Cities in Indonesia, in which Jakarta has become a case study. The inventory has measured and disclosed a comprehensive GHG emissions inventory and to total these emissions using an approach that categorizes all emissions into scopes, depending on where they physically occur, i.e., Scope 1 for direct emissions and Scope 2 for indirect emissions. The GHG emission level of Scope 1 is estimated based on the IPCC 2006 (Tier-1/2), while Scope 2 employs national/local emissions factor that refers to the grid-connected emission factor of JAMALI. Based on the latest inventory in 2018, the GHG emissions profile of Jakarta is summarized as follows, i.e., the GHG emissions of Scope 1 is from direct fuels combustion in transport, industry, commercial and residential sectors (33.5%), fuels combustion in two power generations located in Jakarta (13.8%), and the remaining 3.8% is from waste treatment activity. The GHG emission of Scope 2 (48.8%) comes from the use of electricity (supplied by JAMALI-grid) generated outside the boundary of Jakarta. In addition, this study also shows estimates result of local pollutants that are affecting air quality.

1. Introduction

Jakarta, the capital city of Indonesia, is one of the megacities with a high population density (more than 10.57 million population, 1.19% pa, 662 km² of land area) and high economic activities (GDP growth 6.17% pa [1]). Cities are usually the center of business and service, resulting in high demand for energy, especially electricity and fuels for transportation. However, Jakarta also has industrial activities and electricity generations that still rely on fossil fuels. The activities of supplying and consuming energy in those sectors become the main source of GHG (Green House Gas) emissions of Jakarta. A city’s capability to take effective actions on mitigating climate change and monitoring the progress depends on having access to good quality data on GHG emissions. Planning for climate actions in Jakarta begins with developing a city or subnational GHG inventory. The GHG emissions inventory enables cities to understand the GHG emissions contribution and reduction potential of different activities. Emissions inventory methods that cities have used to date vary significantly. This inconsistency makes comparisons between cities difficult, raises questions around data quality, and limits the ability to aggregate local, subnational, and national government GHG emissions data. Greater consistency in GHG accounting is required to allow for more credible and meaningful reporting. The use of widely accepted methodology is recommended, thus this study adopts 2006 IPCC Guidelines for inventorying GHG emission.

Jakarta's unique and interesting characteristics are identified among others: i) Jakarta, though a big city, has fossil-fuelled power plants located inside the city which is connected to the regional grid
ii) Jakarta, as a place of livelihood, is daily crowded by people from inside and outside Jakarta (mainly from surrounding satellite cities). Based on the result of the Jabodetabek (Jakarta-Bogor-Depok-Tangerang-Bekasi) commuter survey in 2014, Bodetabek commuters who carried out activities in Jakarta were 1,382,296 [2]. These people's activities certainly determine the GHG emission level of Jakarta; (iii) Jakarta's domestic solid waste are transported to and processed at the Bantar Gebang disposal site (TPST Bantar Gebang), which is located in one of the neighboring city (Bekasi) within a different administrative territory (West Java Province); (iv) In Jakarta, several manufacturing industries consume a significant amount of energy such as food and beverages, oleo-chemicals products (soap, detergents, and other products), glass, ceramic, precious metal (purifying and refining unit), and steel industries. These industrial activities only emit GHG emissions from energy use, hence, the industrial process and product use (IPPU) emission category is not covered in the Jakarta GHG inventory. The described characteristics above are the background to determine the scope of GHG emission sources and the approach to estimating the emissions to be reported under city level inventory. This paper will present an analysis of methodology and data used for estimating GHG emissions from the energy and waste sectors in Jakarta. In addition, the estimation also includes local pollutants.

Scope of GHG Emission Sources in Jakarta

Jakarta population activities result in emissions within and outside territorial boundaries. Therefore, it is necessary to set an inventory boundary to avoid double counting and incomplete inventory.

Figure 1 illustrates the details of GHG emission sources and the city inventory boundary for Jakarta. The category of emission coverage is based on the location where the emission is generated, namely: Scope 1, Scope 2, and Scope 3 [3]. In Jakarta, the emission source category comprises only two scopes, Scope 1 and Scope 2. Scope 1 emission category is defined as all emissions that are generated within the territory of the city, such as emissions from fuel combustion activities in local power generation, transportation, industrial, commercial, residential, and others. Emissions from the waste sector, which originate from domestic waste (solid and wastewater) and industrial wastewater treatments taking place in Jakarta, are also within Scope 1 (direct emission). Scope 2 emission category is defined as emissions resulting from the use of electricity. Despite electricity production in Jakarta power plants (PT PJB UP Muara Karang and PT Indonesia Power UPJP Tanjung Priok), the electricity consumed in Jakarta is from JAMALI (Java-Madura-Bali) grid where the associated GHG emission is included in Scope 2 (indirect emission). As mentioned previously, emission from fuel combustion in the Jakarta power plant is regarded as Scope 1. Scope 3 emission category is defined as emissions that are generated outside the territorial boundary caused by materials or activities associated or owned by the city territory. In the case of Jakarta, some activities emit GHG outside the Jakarta region due to the treatment of Jakarta's own MSW (municipal solid waste), i.e., landfilling and composting of MSW at the TPST Bantar Gebang in Bekasi (outside Jakarta). Even though MSW is treated outside Jakarta, the emission cannot be considered Scope 3 due to the landfill area has become the authority of Jakarta, so it is accounted for in Scope 1.

All international and domestic aviation is also accounted for as Scope 3 since both have out-boundary flight destinations. Regardless, in-boundary aviation (Scope 1) also commonly occurs in a megacity like Jakarta (air patrols). Domestic water-borne transportation can be accounted as Scope 1 if it has an in-boundary destination (note that Jakarta has several islands in the north of Jakarta). Water-borne transport for domestic out-boundary and international are included in Scope 3. Nevertheless, cross-boundary transportation related to commuting activities as well as all aviation and water-borne transportation where the fuel purchases are inclusively registered in Jakarta is accounted for in Scope 1, given the difficulty in distinguishing fuel consumption recorded. Due to data in-availability, the Jakarta inventory has not yet covered emissions related to life-cycle perspectives such as embodied emissions from food, materials, and fuels used in the city [4].
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2. Methodology

The methodology used for estimating GHG emissions in the energy and waste sectors is according to the IPCC 2006 Guidelines [5]. GHG emission inventory in the energy sector of Jakarta uses a sectoral approach, in which GHG emissions are estimated according to energy use in each subsector. Meanwhile, the GHG emission estimate for the domestic solid waste disposal site of Jakarta uses the FOD (First Order Decay) method. Tier-1 (using default factors) and Tier-2 (using local parameters) are incorporated in the estimations based on the availability of data.

2.1. GHG Emission Estimates Methodology for Energy Sector

a) Direct GHG Emission (Scope 1)

The calculation of direct GHG emissions uses the Tier-2 approach with emission factor (CO₂ gas) of each type of fuel is based on local emission factors published by LEMIGAS Research and Development Center and TEKMIRA Research and Development Center. Meanwhile, emission factors of the other two gases (CH₄ and N₂O) refer to the default value of IPCC 2006 (Tier-1). The Tier-1 and Tier-2 emission factors for mobile and stationary combustions are presented in Table 1. The activity data used in the inventory are collected through a practical survey and interview conducted by the data surveyor team. The data obtained are then verified and validated by the data provider through Focus Group Discussion (FGD). The data of fuel consumption are collected from various related institutions, such as the Jakarta Industry and Energy Agency, PT. Pertamina, BPH Migas, and PT. PGN. While the primary energy consumption data in power generation is specifically collected from PT PJB UP Muara Karang and PT Indonesia Power UPJP Tanjung Priok.

Table 1. Emission factors (Tier-1 and Tier-2) in the transportation and power subsectors[6], [7], [8]

| Fuels                  | Mobile combustion Subsector: Transportation | Stationary combustion Subsector: Power generation |
|------------------------|---------------------------------------------|--------------------------------------------------|
|                        | Mobile combustion Subsector: Transportation | Stationary combustion Subsector: Power generation |
|                        | CO₂, kg CO₂/TJ | CH₄, kg CH₄/TJ | N₂O, kg N₂O/TJ | CO₂e, kg CO₂e/TJ | CO₂, kg CO₂/TJ | CH₄, kg CH₄/TJ | N₂O, kg N₂O/TJ | CO₂e, kg CO₂e/TJ |
| Motor gasoline a        | 72,600 | 33 | 3.2 | 74,285 | 72,600 | 33 | 3.2 | 74,285 | 72,600 | 33 | 3.2 | 74,285 |
| Motor gasoline b        | 72,967 | 33 | 3.2 | 74,652 | 72,600 | 33 | 3.2 | 74,285 | 72,600 | 33 | 3.2 | 74,285 |
| Jet kerosene, avtur     | 73,333 | 0.5 | 2.0 | 73,964 | 73,333 | 0.5 | 2.0 | 73,964 | 73,333 | 0.5 | 2.0 | 73,964 |
| Other kerosene, kerosene| 73,700 | 0.5 | 2.0 | 74,331 | 73,333 | 0.5 | 2.0 | 73,964 | 73,333 | 0.5 | 2.0 | 73,964 |
| Gas/Diesel Oil, ADO/HSD | 74,453 | 3.9 | 3.9 | 75,724 | 69,467 | 3.9 | 3.9 | 75,934 | 74,149 | 3.9 | 3.9 | 75,934 |
| Gas/Diesel Oil, IDO     | 74,067 | 3.9 | 3.9 | 75,358 | 74,067 | 3.9 | 3.9 | 75,358 | 74,067 | 3.9 | 3.9 | 75,358 |
| Residual Fuel Oil (RFO), MFO, HFO | 75,167 | 7.0 | 2.0 | 75,934 | 75,167 | 7.0 | 2.0 | 75,934 | 75,167 | 7.0 | 2.0 | 75,934 |
| LPG                    | 63,100 | 0.1 | 0.2 | 64,464 | 63,100 | 0.1 | 0.2 | 64,464 | 63,100 | 0.1 | 0.2 | 64,464 |
| CNG                    | 57,600 | 0.01 | 0.1 | 57,600 | 57,600 | 0.01 | 0.1 | 57,600 | 57,600 | 0.01 | 0.1 | 57,600 |
| Bio-gasoline            | 3,705  | 3.705 | 3.705 | 1,226  | 3,705  | 3.705 | 3.705 | 1,226  | 3,705  | 3.705 | 3.705 | 1,226  |

Figure 1. The GHG emission sources and inventory boundary considered in DKI Jakarta
b) Indirect GHG Emission (Scope 2)

Jakarta electricity demand is supplied by the JAMALI-grid where local power plants (PT PJB UP Muara Karang and PT Indonesia Power UPJP Priok) are also connected. Therefore, the calculation of GHG emissions from electricity use in the industrial, commercial, residential, transportation, and other subsectors use the emission factor of the JAMALI-grid available from the Directorate General of Electricity-MEMR (see Table 2). The data on electricity consumed in each end-user subsector are obtained from PT. PLN Disjaya.

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|------|------|------|------|------|------|------|------|------|------|
| On-Grid, Ton CO₂/MWh | 0.738 | 0.778 | 0.823 | 0.855 | 0.840 | 0.923 | 0.770 | 0.706 | 0.706 |
| Off-Grid, Ton CO₂/MWh | 0.744 | 0.686 | 0.701 | 0.703 | 0.706 | 0.706 | 0.706 | 0.706 | 0.706 |

2.2. GHG Emission Estimates Methodology for Waste Sector (Scope 1)

Calculation of GHG emission in landfill uses the Tier-2 approach or improved Tier-1 since it involves local parameters. Local parameters used in the estimates, i.e., waste composition and dry matter content, are obtained from survey results at the TPST Bantar Gebang conducted by ITB-JICA study (2015) [14]. The use of the local parameters is in conjunction with the default DOC (Degradable Organic Carbon) parameter of IPCC 2006. Estimation of GHG emissions from MSW composting and incineration, as well as domestic and industrial wastewater treatments, uses the Tier-1 approach. The activity data in the waste sector are from the government offices as well as private sectors related to waste treatment facilities, such as DKI Jakarta Environmental Agency, PT. NOEI, PD PAL Jaya, DKI Jakarta Health Agency, and Agency of Water Resources of DKI Jakarta.

3. Result and Discussion
3.1. GHG Emission Result in Energy Sector

Figure 2 shows the direct GHG emission profile generated from fuel combustion in Jakarta 2010-2018 based on subsectors. High mobilization in Jakarta causes near half (48.8%) of the total GHG emissions were generated from the transportation subsector, followed by power generation (29.1%), manufacturing industry (16.0%), and residential (5.1%), and the remaining 0.8% from the commercial and other subsectors. The level of GHG emissions shows an increasing trend in 2010-2018. However,
GHG emissions exceptionally descended in 2014, presumably due to the vast shifting to low emitting fuels (natural gas). For the record, fuel combustion emissions are all considered as Scope 1 (direct emissions) due to incapability to distinguish fuel consumption recorded in Jakarta, whether it fuels for domestic, in-boundary, out-boundary, or international destinations.

GHG emissions of the waste sector in 2018 consisted of MSW disposal site, composting, incineration of MSW, and domestic as well as industrial wastewater treatment. The level of GHG emissions in the waste sector amounted to 2.2 million tons CO$_2$e in 2018. The most substantial GHG emissions were from landfilling of MSW in TPST Bantar Gebang and domestic wastewater treatment, which respectively reached 1,095 million tons CO$_2$e (49.9%) and 1,093 million tons CO$_2$e (49.8%). An insignificant level of GHG emissions came from MSW incineration, composting, and industrial wastewater treatment, which overall amounted to 0.006 million tons CO$_2$e (0.3%). For the record, the GHG emission inventory of industrial wastewater has only started since 2017.

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Besides GHG emissions, the level of air quality is also assessed based on parameters of NOx, CO, and NMVOC gases released from the energy sector. Source: calculated from activity data and IPCC 1996 default emission factors

Figure 5 shows the increasing trend of air pollutants that in line with the increase in energy consumption. Pollutant levels increase by 41% from 791 kilotons (2010) to 1,116 kilotons (2018). The air pollution comes from stationary and mobile sources, including transportation, industrial, commercial, residential, and other subsectors. The transportation subsector is consistently become the largest emitters in DKI Jakarta (see Source: calculated from activity data and IPCC 1996 default emission factors).

Figure 6. It is due to the increasing use of private vehicles, which also triggers the dominance of CO pollutants (70.8% in 2018) released from vehicle exhausts. Increased utilization of public transportation is necessary to create better air quality, overcome traffic congestion, improves efficiency, and reducing emissions.

4. Conclusion

Jakarta GHG emission inventory is implemented by adopting the IPCC 2006 methodology (methodology transparency). Tier-1 is the primary approach used to estimate the GHG emissions level, yet Tier-2 is also implemented whenever local parameter data are available. Jakarta territorial boundary and activity characteristics are the basis for developing an inventory boundary (Scope 1 and Scope 2), which in line with the city-level GHG inventory system implemented internationally. Hence, it becomes comparable to other cities in terms of climate city recognition. Scope 3 is un-announced in Jakarta inventory considering the out-boundary location (related to MSW disposal site) has become the authority of Jakarta, so it is accounted for in Scope 1 instead. Nevertheless, GHG emissions related data of Jakarta still needs improvement in terms of completeness, consistency, and accuracy.

In conclusion, Jakarta inventory can be considered as an appropriate and useful example for other regions in Indonesia in systematically implementing GHG emissions inventory methodology. Jakarta inventory can provide fundamental information needed to develop a climate change mitigation plan. Based on the latest year (2018) inventory, some useful insights can be summarized as follows: (i) Although it is an indirect emission source, grid electricity is a major GHG emission contributor reaching 28.16 million tons CO₂e (48.8%); (ii) Direct GHG emissions (except energy industry) are the
second largest contributor (33.5%) amounted to 19.26 million tons CO₂e. The majority of direct GHG emissions come from transportation, followed by manufacturing industries, residential and commercial buildings; (iii) The third-largest emission source comes from the energy industry, i.e., power plants located in the DKI Jakarta area, with a contribution of 7.92 million tons of CO₂e (13.8%); (iv) Waste sector has a less significant share (3.8%) of GHG emissions in Jakarta.

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