Energy greenhouse gas emission inventory in Batu City

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Abstract. The development of the tourism sector in Batu City is in line with the development of non-agricultural activities in Batu City that dominates 66.7% of Batu City's land use pattern. This pattern is related to the energy demand in Batu City and contributes to the increasing GHG emissions from the energy sector. The energy sector contributes 24–25% of GHG emissions and it will increase along with further development of activities. The GHG emission inventory is an important step related to GHG emission reduction, and, due to the uncertainty of GHG emission distribution, the inventory was based on the sources of emission. The main purpose of this research is to make an inventory of the amount of GHG emission from the energy sector in Batu City from 3 main emission sources in Batu, namely transportation, commercial, and household. The analytical method used is the Tier 1 approach using a database of energy consumption and the number of activities as an emission source. The results show that the total amount of GHG emissions from the energy sector in Batu City is 2,562,159,822,007.89 kg/year with an average increase of 0.75% per year and is dominated by emission sources from the household sector. The average increase in GHG emissions from the transportation sector is 58.83% with a significant increase in 2015. In the commercial sector, the average annual increase in GHG emissions is 3.83%, and the household sector—as the largest energy consumer—has an average increase in GHG emissions each year of 0.75%.

1. Introduction

Energy has been demanded to support community's activities as city development progresses. However, this increase in energy demand has a negative impact on climate change [1] and of them is contribution to the production of a greenhouse gas (GHG). GHG is an emission of gases that serves to absorb infrared radiation and help determine the atmosphere's temperature. The presence of various human activities, significantly since the pre-industrial era of greenhouse gas emissions, has increased very high, increasing the concentration of greenhouse gases in the atmosphere. This leads to the onset of global warming and climate change. The results of the Global Assessment conducted by the IPCC in 2017 show that global temperatures have increased by 1°C since the industrial period. If the increase is assumed to be the same, the global temperature will increase by 1.5 °C throughout 2030–2052 [2].

The Indonesian government announced Indonesia's commitment to reduce GHG emissions by 26% by 2020 with its efforts on September 20, 2009, in the G-20 Summit in Pittsburgh, United States. The responsibility is outlined in Presidential Regulation (Perpres) No. 61/2011 regarding the National Action Plan for Greenhouse Gas Emission Reduction (RAN-GRK), which contains activities and supporting policies—then following the issuance of Presidential Regulation No. 71/2011 regarding the
Implementation of National Greenhouse Gas Inventories. The first step in GHG reduction is to conduct a city-scale GHG Inventory [3]. The GHG inventory is carried out by monitoring and collecting data on emissions source activities and calculating GHG emissions and uptake. Thus, data on the level, status, and tendency of periodical GHG emissions change from various sources of emissions and absorption, including carbon deposits, can be obtained [4]. Energy sector contributes to GHG emissions in Indonesia by 24–25% [5];[6]. The increase in population number and urban activities also increases energy demand. One of the indicators for development is the increasing number of transportation activities. Based on [7], transportation activities have a significant contribution to GHG volume. This increase in energy demand is related to the accumulation of GHG emissions [4].

Batu city is one of the cities in East Java Province with an increasing air pollution index rate every year. Based on the 2018 Performance Report of the Batu City Government Agency, the Environmental Quality Index (IKLH) of Batu City in 2017 accounted for 72.68. This index number indicates that the Environmental Quality Index is classified as moderate (ranging between 66 and 74). One of the variables used in the IKLH analysis is the air pollution index. The air quality index of Batu City in 2018 is 72.44, which is classified as moderate. (Performance Accountability System Report of Government Environmental Agency of Batu City, 2019). According to the 2017–2022 Regional Medium-term Development Plan (RPJMD) of Batu City, the ambient air quality for CO, HC, and noise parameters tends to increase every year. Transportation activities dominate the source of air pollutants in Batu city by 75%. A study stated that the forecast of CO$_2$ in Batu City from the transportation sector in 2030 will reach 2072.64 Gg [8]. One factor supporting the influence of transportation activities on air pollution is the increasing number of vehicles in Batu City. As a tourist destination, Batu city is visited by many tourists—especially on holidays—by bus and private cars, increasing emission levels in Batu City. In comparison, 25% of air pollutants come from immovable sources, such as household activities, waste burning, and natural pollutant sources.

Referring to the 2011 Presidential Regulation regarding the Implementation of National Greenhouse Gas Inventories, GHG emission levels' status needs to be reported in the annual GHG emission inventory report. Based on these regulations, the region must carry out activities in the form of the GHG Inventory. The uncertainty of the distribution of GHG emission makes the calculation must be based on the emission source with the level 1 approach of the IPCC methodology [9]. The purpose of the 2019 Batu City Energy GHG inventory activities is to identify the sources and evaluate Batu City Energy GHG's results from the transportation, commercial, and household sectors.

2. Methods
The GHG Inventory method was developed from the IPCC to the local character of each city from the perspective of production- and consumption-based emissions [3]. Sources of GHG emissions from the energy sector in Batu City are categorized as Energy Consumption Sector. Based on [10], sectors that are included in the energy consumption sector include Industrial Sector, Service Sector, Public Sector, and Household Sector. Another significant sector that also produces GHG on a large scale is the transportation sector. Research on GHG mitigation from the transportation sector stated that the use of motorized vehicles is a major source of air pollutants in major cities in Java [11].

IPCC [16] provides several approaches to make an inventory of GHG emissions that can integrate activity levels with emission coefficients per activity level [12]. In the energy sector's framework, activity data refers to the volume of fuel that has been consumed in terms of TJ [13]. Regarding the combustion of fossil fuels, emission level depends on the amount, the type of fuel, the fuel oxidation fraction, and its carbon concentration [6]. The Tier 1 method is fuel-based GHG emission inventory model. Emission factor provided in the Tier 1 method is relevant for all GHG emission [16].
The main emission source in the energy sector is the combustion of fossil fuels, such as gasoline, diesel, and LPG [4]. GHG emission consists of CO₂, CH₄, and N₂O [14]. Each GHG emission has an emission factor’s number based on energy source type, such as motor gasoline, solar premium, household LPG, commercial LPG and natural Gas.

2.1. Calculation Method of GHG Emission
The method of calculating transportation sector emissions is based on the Ministry of Forestry’s Guideline for the Implementation of National Greenhouse Gas Inventory in 2012 (Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional Kementerian Lingkungan Hidup Tahun 2012). The method used in calculating the amount of Energy GHG from the Transportation Sector is the Tier 1 method. The calculation is divided into 3, namely the estimated emissions of CO₂, CH₄, and N₂O according to Equations 1 and 2. The database in the GHG inventory of Transportation Emission is fuel consumption. Based on the frame study [15], the fuels covered in road transportation are gasoline, diesel, LNG, hydrogen, and electricity. The existing condition of the fuel typology used in road transportation in Batu City are diesel and gasoline.

2.1.1. Estimated Transportation GHG Emissions.
The equation used in make an inventory of CO₂ emissions is as follows:

\[
\text{Emissions} = \text{Consumption of Fuel} \times \text{Emission Factor} \quad \ldots \ldots \quad (1)
\]

*Emissions: CO₂ emissions
*Consumption of Fuel: fuel consumed ~ sold
*Emission Factors: CO₂ emission factors by fuel type (kg gas/TJ), IPCC default 2006

Thus, the equation for making an inventory of CH₄ and N₂O is as follows:

\[
\text{Emissions} = \text{Fuel Consumption} \times \text{Emission Factor} \quad \ldots \ldots \quad (2)
\]

*Emissions: NH₄ and N₂O emissions
*Fuel Consumption: fuel consumed ~ sold
*Emission Factors: NH₄ and N₂O emission factors by fuel type (kg gas/TJ), IPCC 2006 default

2.1.2. Methods of Calculating Commercial and Household Sector Emissions.
GHGs emitted by fuel combustion from stationary sources are CO₂, CH₄, and N₂O. The general equation used to estimate GHG emissions from fuel emissions corresponds to Equation 3 below.

\[
\text{GHG Emissions (kg/yr)} = \text{Energy Consumption (TJ/yr)} \times \text{Emission Factors (kg/TJ)} \quad \ldots \ldots \quad (3)
\]
According to the IPCC default, emission factors are expressed in units of emissions per unit of energy consumed (kg of GHG/TJ). On the other hand, the available energy consumption data is generally in physical units (tons of coal, kiloliters of diesel oil, etc.). Therefore, before being calculated in Equation 3, energy consumption data must be converted first into TJ (Terra joule) energy unit using Equation 4.

\[ \text{Energy Consumption} = \text{Energy Consumption} \times \text{Heat Value} \quad \ldots \ldots \quad (4) \]

The method used in calculating the amount of Energy GHG from the Commercial and Household Sectors is the Tier-1 Method. The equation used to determine GHG emissions from combustion is illustrated in Equation 5.

\[ \text{GHG Emission}_{\text{Fuel}} = \text{Fuel Consumption} \times \text{Emission Factor} \quad \ldots \ldots \quad (5) \]

*Fuel: stands for the type of fuel
*GHG Emission_{\text{Fuel}}: GHG emissions of a specific fuel type (kg GHG)
*Fuel consumption: the amount of fuel burned (in TJ)
*Emission Factor: Specific GHG Emission Factor by fuel type

3. Results and Discussion

Geographically, Batu City is located at 122°17’ to 122°57’ East Longitude and 7°44’ to 8°26’ South Latitude. The total area of Batu City is about 199.09 km², divided into three districts, which are Batu, Junrejo, and Bumiaji, with 5 sub-districts and 19 villages. The largest land use is non-agricultural land, with a percentage of 66.7% or an area of 13,280.17 ha.

3.1. Characteristics of the Transportation Sector

There are an increasing number in motorized vehicles in Batu City. In 2015, the number of motor vehicles in Batu city amounted to 37,766 units; meanwhile, the number of motor vehicles in Batu City added up to 98,597 units in 2016. In 2017, the number of motorized vehicles increased by 79% from the previous year, reaching 176,491 units. In 2019, there were a total of 7 public gas stations in Batu City. These seven active gas stations in Batu City indicated that the fuel demand in Kota Batu is still developing and shows high vehicle mobility in Batu City. The total sales of gasoline and diesel fuel are assumed to be the energy consumption level of Batu City that can be used for the transportation sector. The total sales of Batu City vehicle fuel in 2019 reached 149,600 liters/day, and gasoline made up the majority, with 81.82% of the total fuel sales in Batu City. This sales number increases every year and the biggest increase is the consumption of Pertalite as much as 13.6%.

3.2. Characteristics of the Commercial and Household Sectors

In 2016, the number of hotels reached 550 units. Based on the 2017 Batu Municipality in Figures, the number of hotels reached 967 units with 8,535 available rooms, and the average length of stay for guests is 1.35 days. This indicates that hotel growth in Batu city reached 75.8%. The growth of this hotel indicates the development of the Batu City's tourism sector and the increasing number of tourist trips to Batu City. The increase in the number of hotels will also increases energy demand and tourist movement, as well as, ultimately, vehicle fuel consumption. The number of small and medium industries in Batu City by 2017 reached a total of 900. It can be seen that a significant increase of small and medium industries in Batu City occurred from 2018 to 2019 of as much as 29.17% as a result of government support for the small and medium industries sector and the growing tourism sector as a local economy’s generator of Batu City.

3.3. Calculation of Transportation Sector Emissions

The total vehicle fuel consumption in 2019 reached 149,600 liters/day with the most consumed type of fuel is Pentalite, while the least consumed was Pertamax Plus. This sales amount is assumed to be the energy consumption used to analyze the energy sector's GHG emissions from transportation activities.
The following Table 2 is the results of the calculation of emissions from the transportation sector from 2009 to 2019.

### Table 1 Transportation’s GHG emission

| Year | C02 (kg/year) | CH4 (kg/year) | N2O (kg/year) | Total Emission (kg/year) |
|------|---------------|---------------|---------------|--------------------------|
| 2009 | 2,649,472.40  | 600.91        | 138.24        | 2,650,211.55             |
| 2010 | 3,266,329.37  | 814.74        | 168.64        | 3,267,312.75             |
| 2011 | 4,492,379.08  | 1,369.89      | 225.95        | 4,493,974.92             |
| 2012 | 7,401,069.52  | 2,588.27      | 364.27        | 7,404,022.06             |
| 2013 | 14,681,028.98 | 4,702.84      | 732.95        | 14,686,464.77            |
| 2014 | 21,857,483.34 | 6,768.12      | 1,096.86      | 21,865,348.32            |
| 2015 | 45,016,982.80 | 25,968.19     | 3,122.32      | 45,046,074.31            |
| 2016 | 80,497,216.80 | 31,987.66     | 3,869.66      | 80,533,074.12            |
| 2017 | 95,977,450.80 | 38,007.12     | 4,617.00      | 96,020,074.92            |
| 2018 | 111,457,684.80| 44,026.59     | 5,364.34      | 111,507,075.73           |
| 2019 | 126,937,918.80| 50,046.06     | 6,111.68      | 126,994,076.53           |

Source: Analysis, 2020

The largest accumulation of GHG emission is CO2 with the main source of most emissions being Peralite consumption at 82,900 liters/day, producing 189,584.01 kg/day of CO2 emissions. These transportation activities tend to increase on weekends and holidays due to the tourist attractions of Batu City. Overall, the total GHG emission from the transportation sector have increased, with the most significant increase occurring in 2015, reaching almost 3 times the 2014's GHG emissions. The development of tourism facilities di Batu City increased after the year 2012 and, thus, increasing the number of tourism movement to Batu City, especially on holidays and weekends. In 2015, the Museum Angkut was established as a new tourist destination with 10 tourist zones in it.

#### 3.4. Calculation of Commercial Sector (Hotel) Emissions

The calculation of GHG emissions from hotels is based on the number of hotels operating annually in Batu City and the energy source's demand of hotels as a domestic activity is LPG. This is related to the generation of GHG emissions from hotel activities.

### Table 2 GHG emission from commercial sector (hotel) in 2009-2019

| Year | Commercial Sector Total Emission (kg/year) | Small and Medium industry Total Emission (kg/year) | Total Amount |
|------|-------------------------------------------|--------------------------------------------------|-------------|
| 2009 | 15,114,024.40                             | 15,466,429.77                                   | 30,580,454.17 |
| 2010 | 15,732,498.15                             | 17,220,922.23                                   | 32,953,420.38 |
| 2011 | 15,820,503.70                             | 18,095,322.19                                   | 33,915,825.89 |
| 2012 | 16,277,729.33                             | 18,576,058.46                                   | 34,853,787.79 |
| 2013 | 16,971,653.69                             | 19,084,136.87                                   | 35,055,790.56 |
| 2014 | 18,150,468.80                             | 19,398,485.38                                   | 37,548,954.18 |
| 2015 | 18,453,603.72                             | 20,566,086.90                                   | 39,029,690.62 |
| 2016 | 18,961,682.13                             | 21,260,011.26                                   | 40,221,693.39 |
| 2017 | 19,442,418.40                             | 21,717,236.89                                   | 41,159,655.29 |
| 2018 | 20,316,818.36                             | 21,805,242.44                                   | 42,122,060.80 |
| 2019 | 22,071,310.82                             | 22,423,716.19                                   | 44,495,027.01 |

Source: Analysis, 2020

The total GHG emissions from the hotel commercial sector in 2019 reached 22,071,310.82 kg/year and has increased from 2018 to 8.63%. This increase is related to the increase in the number of hotels.
in Batu City as supporting facilities for Batu City’s tourism activities. Table 6 shows the development of GHG emissions from the commercial sector. Compared to the transportation sector, the increase in GHG emissions from the commercial sector is not too significant. The results of this analysis explain the travel characteristics of tourists who spend only 1.35 days in the city. The results also explain that the tourist attractions are evenly distributed throughout the city of Batu. Therefore, the travel distance of tourists is even higher, thus causing a more significant increase in GHG emissions from the transportation sector.

Emissions generated from the commercial sector, especially from small and medium industrial activities in Batu City in 2019 reached 22,423,716.19 kg. Compared to the previous year of 2018, the total emissions were 21,805,242.44 kg, indicating an increase in the number of emissions of 2.83% from 2018 to 2019. Based on Table 4, it can be identified that the most significant increase in GHG emissions occurred from the year 2018 to 2019 with an increase of 8.64%. The results of this analysis are in line with the percentage increase in the number of small and medium industries in Batu City, which also most significantly occurred from the year 2018 to 2019 by 29.17%.

Table 3 explains the total emissions produced by the commercial sector in Batu City from 2009 to 2019. The total GHG emissions from the commercial sector in Batu City are the sum of the volume of GHG emissions from the activities of hotels and small and medium industries. Based on the table, it can be concluded that the total emissions generated from the commercial sector in 2019 reached 44,495,027.01 kg with an average annual increase of 3.83%/year.

3.5. Calculation of Household Sector Emissions
Emissions produced from the household sector in Batu City in 2019 reached 2,561,988,332,904.35 kg. Compared to the previous year of 2018, the total emissions amounted to 2,545,959,717,673.07 kg, indicating an increase in the number of emissions of 0.62% from 2018 to 2019.

Table 3 GHG emissions from household sector in Batu City (2009–2019)

| Year | CO2 (kg/year) | CH4 (kg/year) | N2O (kg/year) | Total Emission (kg/year) |
|------|---------------|---------------|---------------|--------------------------|
| 2009 | 2,378,040,699,016.24 | 188,434,286.77 | 3,768,685.74 | 2,378,232,901,988.74 |
| 2010 | 2,399,895,149,744.49 | 190,166,018.18 | 3,803,320.36 | 2,400,089,118,813.04 |
| 2011 | 2,421,749,599,932.74 | 191,897,749.60 | 3,837,954.99 | 2,421,945,335,637.33 |
| 2012 | 2,443,604,050,390.99 | 193,629,481.01 | 3,872,589.62 | 2,443,801,552,461.62 |
| 2013 | 2,465,458,500,849.23 | 195,361,212.43 | 3,907,224.25 | 2,465,657,769,285.91 |
| 2014 | 2,489,514,546,935.92 | 197,267,389.62 | 3,945,347.79 | 2,489,715,669,691.33 |
| 2015 | 2,508,381,902,945.60 | 198,762,432.88 | 3,975,248.66 | 2,508,584,640,627.14 |
| 2016 | 2,519,029,248,130.56 | 199,606,121.09 | 3,992,122.42 | 2,519,232,846,374.07 |
| 2017 | 2,534,005,596,175.68 | 200,792,836.46 | 4,015,856.73 | 2,534,210,404,868.87 |
| 2018 | 2,545,753,959,429.12 | 201,723,768.58 | 4,059,875.24 | 2,545,959,717,673.07 |
| 2019 | 2,561,781,279,266.88 | 202,993,762.22 | 4,095,875.24 | 2,561,988,332,904.35 |

Source: Analysis, 2020

The growth that occurs every year is influenced by the rise in the population of Batu City. The higher the population, the higher the amount of fuel consumption, thus the greater the emissions produced. A significant increase occurred throughout the year 2013 and 2014 of 0.98%, but when compared to the increase of GHG emissions from transportation and commercial activities, the increase in GHG emissions from the household sector has the smallest level.

3.6. Calculation of Total Energy GHG Emissions in Batu City
The sources of GHG emissions from the energy sector in Batu City are transportation, commercial, and household activities. Total GHG emission is obtained from the accumulated volume of CO2, CH4, and N2O from each of those activities. The following table is the total GHG energy emissions generated from the transportation, commercial, and household sectors in Batu City from 2009 to 2019.
Table 4 Total energy of GHG emissions in Batu City (2009–2019)

| Years | Total GHG Energy Emissions (kg/year) |
|-------|-------------------------------------|
| 2009  | 2,378,266,132,654.46                |
| 2010  | 2,400,125,339,546.17                |
| 2011  | 2,421,983,745,438.14                |
| 2012  | 2,443,843,810,271.47                |
| 2013  | 2,465,708,511,541.24                |
| 2014  | 2,489,775,083,993.83                |
| 2015  | 2,508,688,706,391.07                |
| 2016  | 2,519,353,601,141.58                |
| 2017  | 2,534,347,584,599.08                |
| 2018  | 2,546,113,346,809.60                |
| 2019  | 2,562,159,822,007.89                |

Source: Analysis, 2020

Based on Table 4, it can be identified that the trend of GHG emissions from the energy sector increased from 2009 to 2019 with an average increase of 0.75% per year. The biggest source of emission is the household sector as this is related to the land use pattern in Batu City, which is dominated by non-agricultural land by 66.7%.

Figure 2. GHG emission from energy sector in Batu City (2009–2019)

Based on Figure 2, it can be identified that the most significant increase in GHG emissions occurred from the year 2013 to 2014 amount 0.98%. By the end of 2019, the total GHG emission reached 2,562,159,822,007.89 kg/year and an increase of 0.63% from year 2018.

4. Conclusion

The calculation of GHG emissions in Batu City involved 3 main activities, which were transportation activities, commercial activities, and household activities. All sectors showed an increase in GHG emissions from year to year, and the most significant increase came from the transportation sector in 2013. The total amount of GHG emission in 2019 is 2,562,159,822,007.89 kg/year and is dominated by the household sector, which used LPG as their daily energy source. GHG emissions from the transportation sector are caused by the high movement of tourists to Batu City on holidays and weekends. The average increase in GHG emissions from the transportation sector is 58.83% with the most significant increase occurring in 2015 and the smallest increase occurring in 2019. Since 2015, there have been many tourist attractions managed by local communities with much cheaper rates, such as tourist villages and agriculture tourism. The diversity of tourist objects and themes in Batu City...
every year increases transportation activities and has implications in GHG emissions. The average increase in GHG emissions from the commercial sector was 3.83% per year with the most significant increase occurring in 2010 at 7.76%. The average increase in GHG emissions from the household sector was 0.75% per year with the most significant increase occurring in 2014 of 0.98%. The household sector contributes the most to GHG emission at 99%. GHG particularly comes from the use of LPG on a household scale. The level of consumption and community dependence on LPG fuel are still high and always increase along with the development of the population in Batu City.

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