

Estimation of Carbon Dioxide Greenhouse Gas Emissions from Household Activities in Bojonegoro Regency

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Abstract— The energy sector from household activities is one of the contributors to carbon dioxide greenhouse gas emissions. The increase in population is a factor that can increase greenhouse gas emissions. This study aims to determine the value of greenhouse gas emissions and to map greenhouse gas emission zones. This research is a quantitative descriptive. The sampling method is simple random sampling and emission zone mapping using ArcMap 10.6. The data in this study were obtained by using questionnaires and direct interviews with respondents. The emission sources analyzed in this study come from the consumption and type of motor vehicle fuel, the consumption and type of cooking fuel, and the consumption of electrical energy. The highest value of greenhouse gas emissions resulting from household activities in Bojonegoro Regency is Balen District with an emission value of 139,048 tons/year. Meanwhile, the lowest greenhouse gas emission is Sekar District with an emission value of 22.725 tons/year. The total emission from household activities in Bojonegoro Regency is 2048,355 tons/year. Emission zone mapping is mapped into 10 zones. Balen sub-district is a sub-district that has the highest CO₂ emission value with an emission value of 139,048 tons/year. Sekar, Kasiman, and Kedewan sub-districts are classified as sub-districts that have low CO₂ emission values with emission values of 22,725 tons/year, 32,041 tons/year, and 28,498 tons/year.

Keywords: *greenhouse gases, household activities, IPCC.*

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1. Introduction

Global warming is the process of increasing the average temperature of the atmosphere, oceans and earth. Global warming can affect climate conditions on earth. Climate change is a change in morphology and intensity of climatic factors over a very long period of time. The atmosphere works to hold and store the heat from the sun that is received by the earth [1]. The ozone layer in the atmosphere can protect life on earth from ultraviolet B radiation [2]. However, carbon dioxide gas (CO₂) in the atmosphere can trap infrared radiation so that heat will be stored on the earth's surface as a greenhouse gas effect. Global greenhouse gas emissions have been increasing since pre-industrial times, with a 70% increase between 1970 and 2004 attributable to human activities [3]. CO₂ gas accounts for 95% of energy sector emissions and as much as 70% of it is from stationary combustion activities [4]. Emissions of methane gas (CH₄) increased by about 40% from 1970, while emissions of nitrous oxide (N₂O) increased by about 50% [3].

Carbon dioxide is a greenhouse gas that causes global warming that is trapped in the atmosphere due to human activities. Fossil fuels used in human activities such as oil, gas, coal, diesel will emit CO₂ [5]. The abundant amount of carbon dioxide gas in the atmosphere causes cooling in the stratosphere, thereby triggering the acceleration of the hole in the ozone layer [6]. 80% of CO₂ gas

pollutants come from burning fossil fuels and the remaining 20% comes from deforestation and forest fires. CO₂ gas is also produced from motor vehicle fuels and power plants. Human activities (anthropogenic) can cause an increase in the amount of CO₂ gas by 30% and the gas is trapped in the atmosphere for 500 years [7].

The energy sector is the most important sector in the greenhouse gas inventory. Sectors that have contributed to air pollution include 60% of the transportation sector; 25% of the industrial sector; 10% of the household sector; and 5% from the waste sector [8]. Household activities are one of the sources of increasing greenhouse gas emissions [9]. An increase in population can result in increased greenhouse gas emissions, especially CO₂ [10].

Based on the Central Bureau of Statistics of Bojonegoro Regency, until 2020 the population in Bojonegoro Regency is 1.301.635 people with a growth rate of 1,01%. The area of this district is 2307.06 km² with a population density of 205.90 km² with a high density category based on SNI 03-1733-2004. The growth rate in Bojonegoro Regency is included in the medium category, so that the number of residents each year will increase. This will increase the number of household activities as well.

Based on the Presidential Regulation of the Republic of Indonesia Number 71 of 2011 concerning the Implementation of the National Greenhouse Gas Inventory, the method of conducting a greenhouse gas inventory is to calculate the emission and absorption of greenhouse gases including carbon storage. Emission sources that have carbon storage can come from the energy sector which includes transportation and households. To find out the activities that result in changes in greenhouse gas emissions in an area, it is necessary to report the greenhouse gas inventory in each sector every year. Bojonegoro Regency is one of the regencies that does not yet have a greenhouse gas inventory reporting document.

2. Method

This research is a type of quantitative descriptive research. The calculation uses the method issued by the IPCC (Intergovernmental Panel on Climate Change). The variables used in this study were the consumption and type of motor vehicle fuel, the consumption and type of cooking fuel, and the consumption of electrical energy. Primary data were obtained from the results of questionnaires and field observations. Secondary data needed are the number of households and a map of Bojonegoro Regency. The sampling method in this study uses probability sampling, which is a sampling technique that provides equal opportunities for each member of the population to be selected as a member of the sample. Determination of the number of samples using the Yamane formula as follows:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

where:

n = Number of research samples

N = Total population

e = Sampling error (usually 5%, meaning 95% confidence level)

Based on the above formula, the number of respondents in this study can be calculated as follows:

$$n = \frac{440233}{1+(440233 \times 0,05^2)}$$

$$n = 399,636 = 400 \text{ respondents}$$

The formula used to calculate carbon emissions based on the IPCC (2006) is as follows:

$$\text{Fuel consumption} = \text{Amount of fuel} \times \text{net calorific value} \quad (2)$$

$$\text{Emissions} = \text{fuel consumption} \times \text{emission factor} \quad (3)$$

The value of the emission factor and calorific value depends on the fuel used. The calculation of emissions generated from these fuels uses an approach to the value of emission factors and Net Calorific Value which can be seen in the following table:

Table 1. Value of Emission Factor and NCV of Each Fuel

Fuel Type	Emission Factor (kg/TJ)	Net Calorific Value (TJ/Gg)	Fuel Type	Emission Factor (kg/TJ)	Net Calorific Value (TJ/L)
LPG	63100	47,3	Gasoline	69300	33×10^{-6}
Firewood	112000	15,6	Solar	74100	36×10^{-6}

The CO₂ emission factor for the use of electrical energy is 0.000725 ton/KWh [11].

3. Result and Discussion

3.1. CO₂ emissions from consumption and types of motorized vehicle fuels

CO₂ emissions from consumption and types of motorized vehicle fuels calculation example:

a. Gasoline

Amount of fuel = 240 L/year

NCV of gasoline = 33×10^{-6} TJ/L

Gasoline emission factor = 69,300 kg/TJ

Energy consumption = amount of fuel $\times$ NCV

= 240 L/year $\times$ (33×10^{-6} TJ/L)

= 0.00792 TJ/year

CO₂ emissions = energy consumption $\times$ emission factor

= 0.00792 TJ/year $\times$ 69.300 kg/TJ

= 548,856 kg/year

= 0.548856 tons/year

b. Solar

Total fuel = 720 L/year

NCV solar = 36×10^{-6} TJ/L

Solar emission factor = 74,100 kg/TJ

Energy consumption = amount of fuel $\times$ NCV

= 720 L/year $\times$ (36×10^{-6} TJ/L)

= 0.02592 TJ/year

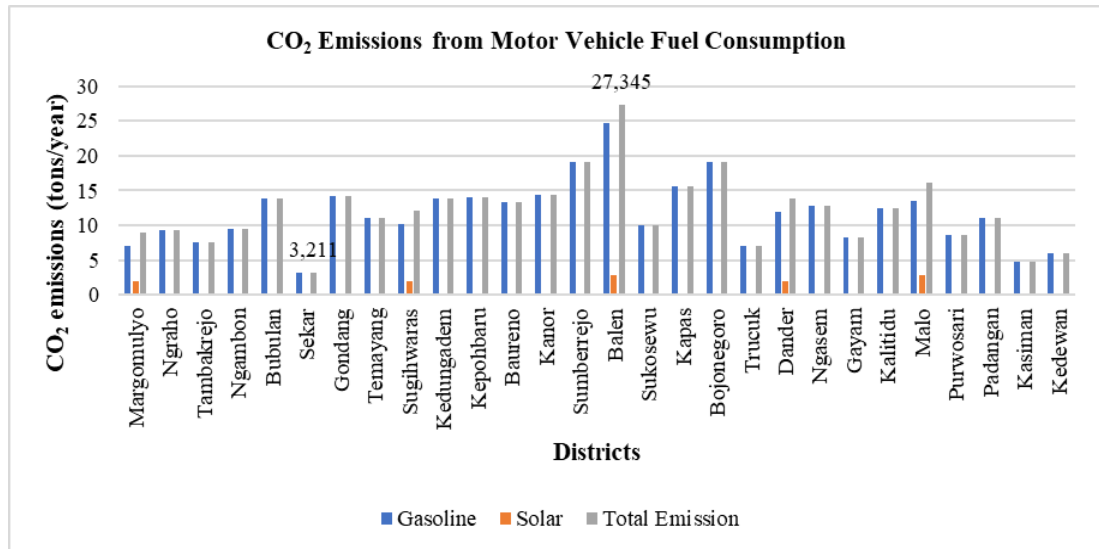
CO₂ emissions = energy consumption $\times$ emission factor

= 0.02592 TJ/year $\times$ 74,100 kg/TJ

= 1920,672 kg/year

= 1.920672 tons/year

The above calculation is used to calculate all greenhouse gas emissions from the use of motorized vehicles from all respondents. Based on the above calculation, the CO₂ emissions from the use of motorized vehicles in Bojonegoro Regency are as follows:



Based on the above, the highest CO₂ emission is in Balen District with a total emission of 27,345 tons/year. The lowest CO₂ emissions are in Sekar District with a total emission of 3,211 tons/year. The level of consumption of gasoline and/or diesel fuel is influenced by the average distance traveled per month and the average ownership of motorized vehicles in each household [12].

3.2. CO₂ emissions from consumption and type of cooking fuel

CO₂ emissions from consumption and type of cooking fuel calculation example:

a. LPG

Amount of fuel = 72 kg/year = 0.000072 Gg/year

NCV LPG = 47.3 TJ/Gg

CO₂ emission factor = 63100 kg/TJ

Energy consumption = amount of fuel × NCV

$$= 0.000072 \text{ Gg/year} \times 47.3 \text{ TJ/Gg}$$

$$= 0.0051 \text{ TJ/year}$$

CO₂ emissions = energy consumption × emission factor

$$= 0.0051 \text{ TJ/year} \times 63100 \text{ kg/TJ}$$

$$= 322.34 \text{ kg/year}$$

$$= 0.32234 \text{ ton/year}$$

b. Firewood

Amount of fuel = 2520 kg/year = 0.00252 Gg/year

NCV firewood = 15.6 TJ/Gg

CO₂ emission factor = 112000 kg/TJ

Energy consumption = amount of fuel × NCV

$$= 0.00252 \text{ Gg/year} \times 15.6 \text{ TJ/Gg}$$

$$= 0.0393 \text{ TJ/year}$$

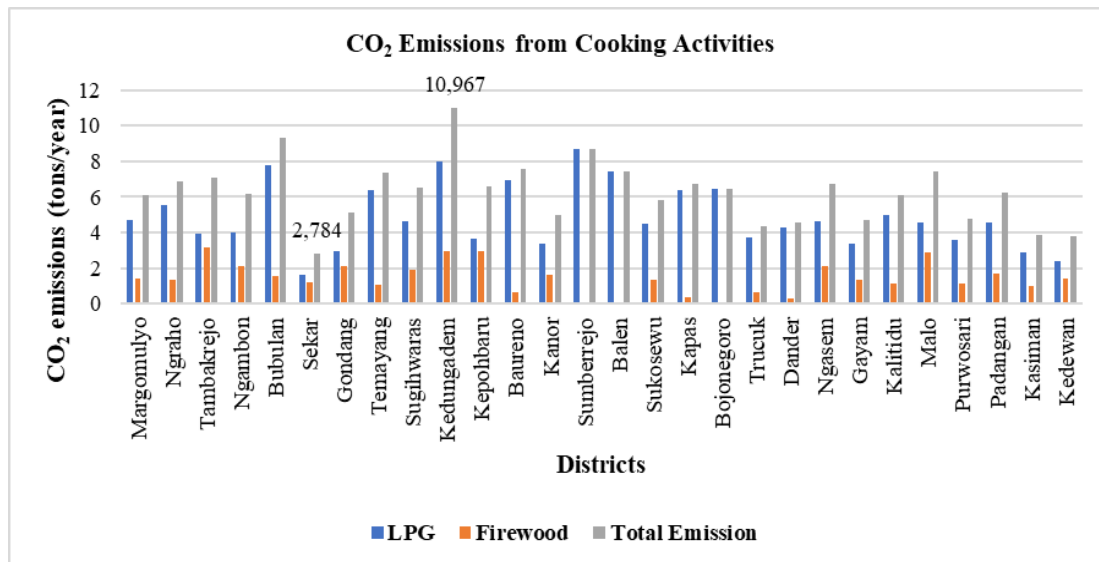
CO₂ emissions = energy consumption × emission factor

$$= 0.0393 \text{ TJ/year} \times 112000 \text{ kg/TJ}$$

$$= 2480.6 \text{ kg/year}$$

$$= 2.4806 \text{ tons/year}$$

The above calculation is used to calculate all greenhouse gas emissions from cooking fuel consumption of all respondents. Based on the above calculations, the CO₂ emissions from the use of cooking activities in Bojonegoro Regency are as follows:



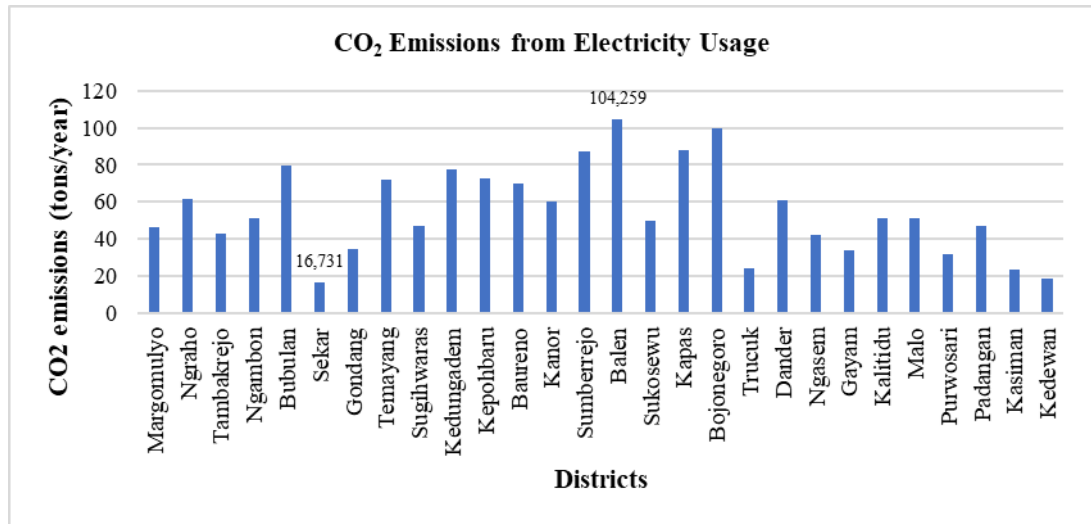
Based on the picture above, the highest CO₂ emission from cooking activities is in Kedungadem District with a total emission value of 10,967 tons/year. In this sub-district, emissions from LPG consumption are 7,989 tons/year and emissions from fuel wood consumption are 2,977 tons/year. The high total emission in Kedungadem District is because residents use more than one type of fuel, namely LPG and firewood. The lowest CO₂ emissions from cooking activities are in Sekar District with a total emission of 2,784 tons/year. Emissions from consumption of LPG in this sub-district are 1,589 tons/year and emissions from consumption of firewood are 1,195 tons/year. In this sub-district, the pattern of LPG consumption is low even though it uses more than one type of fuel. The high contribution of household energy use that produces CO₂ emissions and the number of households is a very influential factor in producing CO₂ greenhouse gas emissions [12].

3.3. CO₂ emissions from electricity consumption

Calculation example:

$$\begin{aligned}
 \text{Energy consumption} &= 2485,2071 \text{ kWh/year} \\
 \text{Electric emission factor} &= 0,000725 \text{ ton CO}_2/\text{kWh} \\
 \text{CO}_2 \text{ emissions} &= \text{energy consumption} \times \text{emission factor} \\
 &= 2485.2071 \text{ kWh/year} \times 0.000725 \text{ tons CO}_2/\text{kWh} \\
 &= 1.97 \text{ tons/year}
 \end{aligned}$$

The above calculation is used to calculate all greenhouse gas emissions from electricity consumption of all respondents. Based on the above calculation, the CO₂ emissions from electricity consumption in Bojonegoro Regency are as follows:



Based on figure above, the highest CO₂ emission resulting from the consumption of electrical energy is Balen District with a total emission of 104,2591 tons/year. The average household in this sub-district uses 900 kWh of electricity so that the emissions produced by these households are high. Another factor that affects CO₂ emissions is the number and type of electronic equipment used in each household [12]. The lowest CO₂ emission is Sekar District with a total emission of 16.7308 tons/year. The amount of CO₂ emissions from electricity consumption depends on the number of kWh used in each household. The number of kWh used is greatly influenced by the electrical power required for electronic equipment and the duration of its use. The average household in this sub-district uses 450 kWh of electricity so that the emissions produced are low.

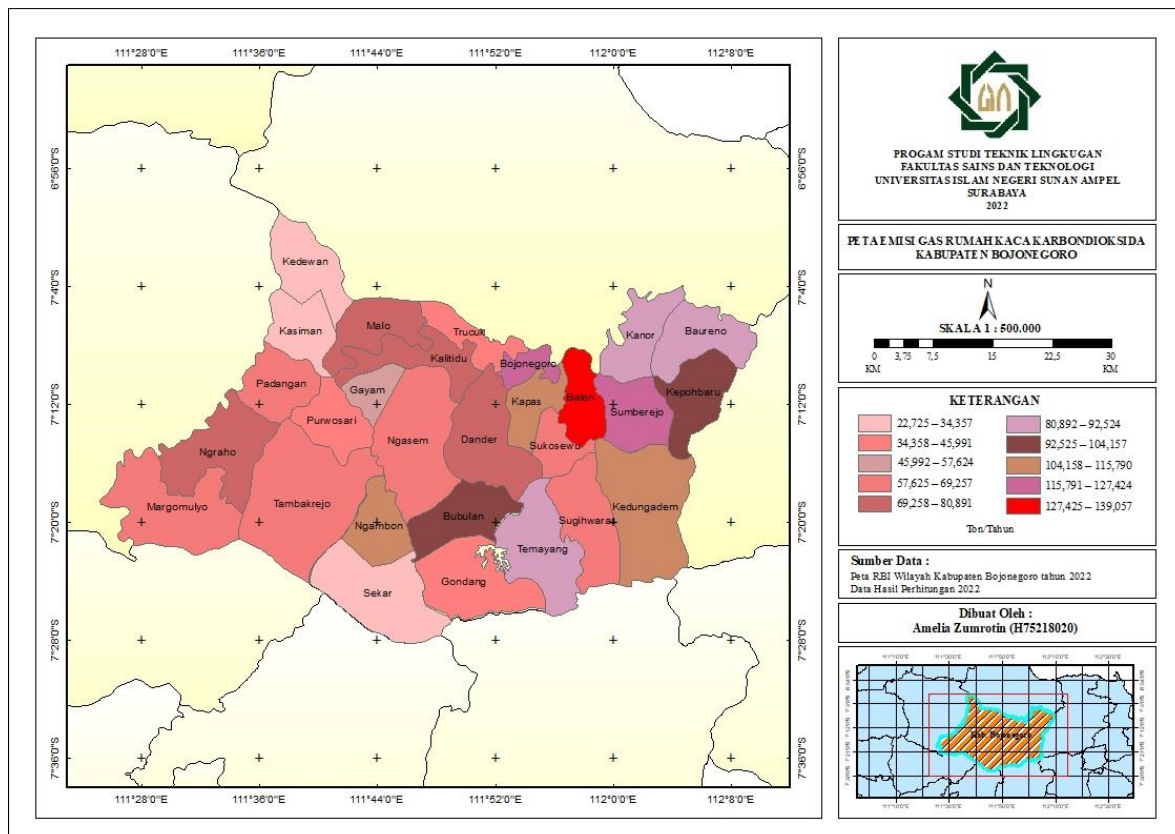
Mapping of greenhouse gas emissions is seen from the total CO₂ emissions from consumption and types of motorized vehicle fuels; consumption and type of cooking fuel; and consumption of electrical energy. After obtaining the results of CO₂ emissions from these three aspects, the total CO₂ emissions of all sub-districts in Bojonegoro Regency are obtained as presented in the table below.

Table 2. Total CO₂ Greenhouse Gas Emissions in Bojonegoro Regency

Districts	Total CO ₂ Emission (tons/year)	Districts	Total CO ₂ Emission (tons/year)
Margomulyo	61,131	Bojonegoro	124,940
Ngraho	77,919	Trucuk	35,388
Tambakrejo	57,370	Dander	79,328
Ngambon	66,668	Ngasem	61,565
Bubulan	102,798	Gayam	47,071
Sekar	22,725	Kalitidu	69,403
Gondang	43,907	Malo	75,019
Temayang	90,507	Purwosari	45,235
Sugihwaras	66,006	Padangan	64,635
Kedungadem	102,413	Kasiman	32,041
Kepohbaru	93,056	Kedewan	28,498
Baureno	90,928	Bojonegoro	124,940
Kanor	79,928	Trucuk	35,388
Sumberrejo	114,842	Dander	79,328
Balen	139,048	Ngasem	61,565
Sukosewu	65,478	Gayam	47,071
Kapas	110,508	Kalitidu	69,403

After knowing the total CO₂ emission in Bojonegoro Regency, then the emission level of each

sub-district is described in the form of a map. The map shows the level of CO₂ emissions based on the scale of each sub-district which is classified into 10 zones according to the emission level in each region. The results of the mapping can be seen in the following figure.



Based on the mapping above, the sub-districts included in zone 1 are Sekar, Kasiman, and Kedewan sub-districts with CO₂ emission values of 22,725 tons/year; 32,041 tons/year; and 28,498 tons/year. The sub-districts included in zone 2 are Gondang, Trucuk, and Purwosari sub-districts with CO₂ emission values of 43,907 tons/year; 35,388 tons/year; and 45,235 tons/year. Districts included in zone 3 are Gayam District with a CO₂ emission value of 47,071 tons/year. The sub-districts included in zone 4 are Margomulyo, Tambakrejo, Ngambon, Sugihwaras, Sukosewu, Ngasem, and Padangan sub-districts with CO₂ emission values of 61,131 tons/year; 57,370 tons/year; 66,668 tons/year; 66,006 tons/year; 65,478 tons/year; 61,565 tons/year; and 64,635 tons/year. The sub-districts included in zone 5 are Ngraho, Dander, Kalitidu, and Malo sub-districts with a CO₂ emission value of 77,919 tons/year; 79,328 tons/year; 69,403 tons/year; and 75,019 tons/year. The sub-districts included in zone 6 are Temayang, Baureno, and Kanor sub-districts with a CO₂ emission value of 90,507 tons/year; 90,928 tons/year; and 79,928 tons/year. The sub-districts included in zone 7 are Kepohbaru District with a CO₂ emission value of 93,056 tons/year. Districts included in zone 8 are Ngambon, Kedungadem, and Kapas with a CO₂ emission value of 66,668 tons/year; 102,413 tons/year; and 110,508. Districts included in zone 9 are Sumberrejo and Bojonegoro districts with CO₂ emission values of 114,487 tons/year and 129.94 tons/year. The sub-districts included in zone 10 are Balen District with a CO₂ emission value of 139,048 tons/year.

4. Conclusion

The type of fuel and the pattern of fuel consumption affect the value of carbon dioxide greenhouse gas emissions. Emissions produced by LPG are smaller than firewood because of the value of the emission factor. Emissions produced by diesel fuel are greater than gasoline because of the value of the emission factor. The electrical power used in the household affects the emissions

produced, besides that the type of household furniture can also affect the value of carbon dioxide greenhouse gas emissions from household activities.

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