Estimating Greenhouse Gas Emissions from Household Activities: A Case in Bogor Indonesia

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Climate change is a result of global warming. Global warming is caused by an increase in the concentration of greenhouse gases (GHGs) in the atmosphere. One of the largest GHG-contributing sectors is the energy sector, which includes households with various activities. Household activities include using LPG, electricity, gasoline, waste generation, and farming and livestock activities to meet the household's needs. The level of GHG emissions produced in households is influenced by income, years of study, and knowledge of emissions. The objectives of this study are to estimate the amount of GHG emissions generated from household activities, analyze the factors that influence GHG emissions, and estimate the value of the carbon economy. The analytical methods used are quantitative descriptive analysis, IPCC (2006) method, multiple linear regression, and economic value analysis. The results showed that: (1) CO2-eq emissions generated in Sinarsari Village for 100 respondents amounted to 32,011.68 kg CO2-eq/month, and the amount of GHG emissions in one village scope amounted to 853,431.36 kg CO2-eq/month. (2) Income, length of study, and emission knowledge dummy influence GHG emissions. 3) Carbon economic value based on carbon pricing is Rp287,415,199.70/month.

Keywords: IPCC; Economic Value of Carbon; Income; Influence; MRA

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INTRODUCTION

World climate change is an international issue currently in the spotlight of many people. Climate change is one of the impacts of global warming. Global warming is a global phenomenon due to an increase in the average temperature of the Earth's atmosphere, oceans, and land (Rosadi *et al.* 2022). Global warming occurs due to excessive emissions of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NOx), and other gases in the atmosphere. This results in sunlight reflected by the Earth as infrared and ultraviolet radiation that will be forwarded to outer space, most of which is reflected to the Earth by greenhouse gases formed in the atmosphere, causing an increase in surface temperature on Earth (Latuconsina, 2010). GHGs are gases that can trap the heat needed to keep the Earth's temperature stable. However, the large amount of carbon emissions released into space and the increasing concentration of other GHGs cause a thickening of the atmospheric layer. The thickening of the layer causes the greenhouse effect.

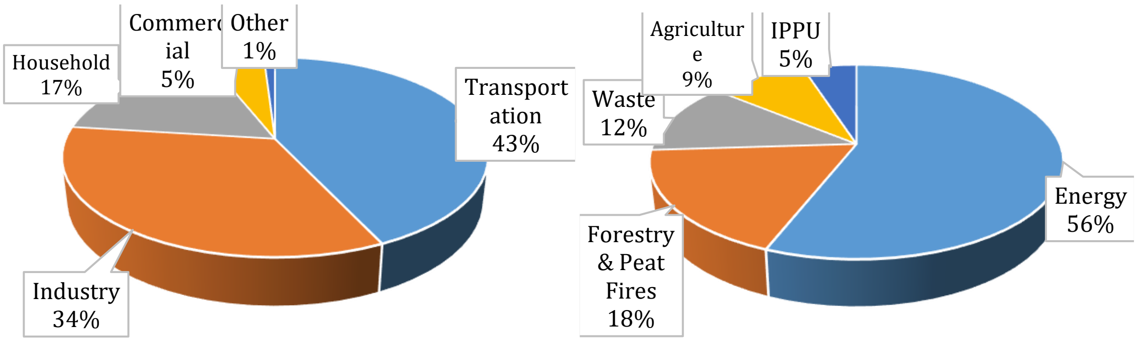

Figure 1 Sector contribution and energy consumption per sector in 2020
Source: processed from KLHK 2021

The National GHG Inventory 2020 results show that the energy sector is the highest national GHG contributor in 2020 at 56%. This is due to significant energy consumption from transportation, industry, households, commercial, and others (National Energy Council 2021). Based on the national energy balance in Figure 1, 2020, the household sector contributed 17% to national energy consumption. Although it is not the most significant contributor to GHG emissions like the industrial sector, the household sector is one of the consumers in the industrial sector's production. Thus, the household sector is a contributor to GHG emissions.

BPS data (2022) states that Indonesia's population has increased yearly. The increase in population will be followed by an increase in GHG emissions produced by the community due to the increase in the amount of energy consumed in fulfilling daily activities, which will impact global warming (DLH Semarang 2018). One of the largest populations in West Java is Bogor Regency.

Bogor Regency is the most populous region in West Java, with a population of 5.56 million people or 11.27% of the population of West Java (BPS 2022). Based on Widyawati *et al.* (2021), the higher the population, the more GHG emissions will increase. Sinarsari Village is one of the villages in the Dramaga Sub-district with the second highest density level after Dramaga Village. Wiratama (2016) stated that the denser the population in an area, the higher the fuel and electricity consumption in household use. Increased consumption of fuel energy and electricity will increase the GHG emissions produced. Thus, increased consumption in an area directly contributes to increased global average temperature due to the resulting GHG emissions.

Hakim and Laksmiwati (2019) mentioned that human activities cause an increase in GHG. Human activities include activities in households. Activities within each household produce different GHG emissions due to the diversity of activities. These household activities include the energy sector, transportation sector, farming and livestock activities, and waste generation. The energy sector comes from electricity use and LPG use. The transportation sector comes from the use of fuel oil (BBM). The farming and livestock sector is derived from using urea fertilizer and the number of livestock owned that can cause CH_4 and N_2O emissions. The waste generation sector is derived from the estimated waste generated from each household.

Activities in Sinarsari Village contribute to GHG emissions at the household level from the consumption of cooking fuel, electricity, vehicle fuel (gasoline), waste, and agriculture and livestock. GHG emissions that continue to increase will cause negative impacts on the environment. Until now, few studies have discussed GHG emissions at the household level, especially in Bogor Regency. So, this research is essential to see data on energy consumption patterns at the household scale that produce GHG emissions. It is also necessary to calculate the amount of GHG emissions in Sinarsari Village resulting from household activities to minimize emission sources at the household level. Therefore, this study aims to estimate the amount of GHG emissions generated from household activities, analyze the factors influencing GHG emissions in Sinarsari Village, and estimate the economic value of GHG emissions generated from household activities in Sinarsari Village.

RESEARCH METHODOLOGY

Location and Time of Research

The research was conducted in Sinarsari Village, Bogor Regency. The selection of the research location was purposely made considering that Sinarsari Village is one of the villages with the highest density and most significant population in the Dramaga Sub-district. Data collection in the field was carried out in June - July 2023.

Data Type and Source

The types of data used in this research are primary and secondary. Primary data was obtained by conducting direct observations and interviews with the village community using structured questions (questionnaires). Secondary data was obtained through literature studies of previous research, the internet, journals, reference books, related agencies, and other sources that assisted the author in obtaining data.

Respondents in this study are the community in Sinarsari Village, which is a household unit in which there are GHG-emitting activities. The method of determining sources is determined by cluster random sampling. The cluster random sampling method is used to determine the sample if the population to be studied is substantial (Sugiyono, 2015). The number of samples in this study was determined using the Slovin formula with an error rate of 10% with the calculation:

$$n = \frac{N}{1+Ne^2} = \frac{2666}{1 + 2666\,(0{,}1)^2} = 96{,}38 \approx 100$$

Description

n = Sample size (HH)

N = Population size (2666 HH)

e = error tolerance (10%)

As for the size or number of sample distributions for each neighborhood (RW) spread across Sinarsari Village, Sugiyono's formula (2015) was used, namely:

$$n = \frac{X}{N} \times n_1$$

So that the results are obtained:

Table 1 Sample size data for each neighborhood (RW)

Neighborhood (RW)	Total HH	Total sample (HH)
01	777	29
02	661	25
03	823	31
04	405	15
Total	**2666**	**100**

Source: Author (2023)

Data Processing and Analysis Methods

Estimation of GHG Emissions

The amount of GHG emissions based on household activities is calculated using the method established by IPCC 2006 (Intergovernmental Panel Climate Change), calculated using tier 1. In addition, this emission calculation will convert CH_4 and N_2O emissions into CO_2-eq. Therefore, a conversion factor called GWP (Global Warming Potential) is required. The GWP value is sourced from the Fifth Assessment Report-IPCC 2014 with a CH_4 conversion value of 28 and an N_2O conversion value of 265.

a. Electricity Consumption

CO_2 *Emission = C x EF*

Keterangan:

C = Consumption (kWh/month)

EF = Emission factor (0,000794 ton CO_2/kWh based on Director General of Electricity (2016)

b. Cooking fuel consumption

GHG Emission = C x EF x NCV x GWP

Information

C = Consumption (kg/month)

EF = Emission Factor (kg/Tj)

NCV = Net Calorific Value (Tj/kg)

GWP = Global Warming Potential (Conversion CH_4, N_2O ke CO_2-eq)

Table 2 GHG emission factor values and net calorific value of cooking fuels

Cooking fuel	Emission Factor GHG (kg/Tj)			NCV (Tj/kg)
	CO_2	CH_4	N_2O	
LPG	63100	5	0,1	47,3 x 10^{-6}
Kerosene	71900	10	0,6	43,8 x 10^{-6}
Firewood	112000	300	4	15,6 x 10^{-6}

Source: IPCC (2006)

c. Vehicle fuel consumption

GHG Emission = C x EF x NCV x GWP

Keterangan

C = Consumption (liter/month)

EF = Emission Factor (kg/Liter)

NCV = Net Calorific Value (Tj/kg)

GWP = Global Warming Potential (Conversion CH_4, N_2O ke CO_2-eq)

Based on the Ministry of Environment (2012), the NCV value can be expressed in units (TJ/L) using the NCV of fuel in Indonesia.

Table 3 Emission factor values and net calorific value of vehicle fuels

Fuel	Emission Factor GHG (kg/Tj)			NCV (TJ/liter)
	CO_2	CH_4	N_2O	
Gasoline (Premium, Pertalite, Pertamax, Pertamax plis, Pertamina dex)	69300	33	3,2	33 x 10^{-6}
Solar	74100	3,9	3,9	36 x 10^{-6}

Source: IPCC 2006 and KLH 2012

d. Waste

The calculation of GHG emissions from waste generation is obtained from the number of family members multiplied by the amount of waste generation based on the type of house.

Table 4 Waste generation by house type

House type	Volume (liter/person/day)	Weight (kg/person/day)
Permanent House	2,25 – 2,5	0,35 – 0,40
Semi Permanent House	2 – 2,25	0,30 – 0,35
Non-Permanent House	1,75 - 2	0,25 – 0,30

Source: Damanhuri *et al.* 2009

The calculation of GHG emissions from waste generation, namely:

CO_2 Emission = C x EF

Keterangan:

C = amount of waste generated (kg/month)

EF = Emission factor 1.09 (Wilson 2005)

e. Agriculture and Livestock

In agriculture, GHG emissions are estimated based on CO_2 emissions from the use of urea fertilizer:

CO_2 Emission = C x EF

Information:

C = Quantity of fertilizer (kg)

EF = 0.20 ton/year (IPCC 2006)

In livestock farming, GHG emissions are estimated based on the fermentation process of livestock digestion and livestock manure that produces CH_4. Meanwhile, N_2O is obtained from the calculation of emissions based on manure.

The formula for calculating emissions from livestock:

$CH_{4digestion}\ Emission = C \times EF \times GWP$

$CH_{4feses}\ Emission = C \times EF \times GWP$

$N_2O_{feses}\ Emission = C \times R \times FE \times BW \times 44/28 \times GWP$

Information:

C = Number of livestock (head)

EF = Emission factor (kg/head/month)

BW = Body weight (kg/ head/month)

R = Average N excretion of 0.05 kg/head/year or 0.004167 kg/head/month

44/28 = KN_2O-N to N_2O conversion

GWP = *Global Warming Potential* (Conversion of CH_4, N_2O ke CO_2-eq)

Table 5 Farm CH_4 emission factor values

Livestock type	EF $CH_{4pencernaan}$ (kg/head/year)	EF $CH_{4kotoran}$ (kg/head/year)
Beef cattle	47	1
Dairy cows	61	31
Sheep	5	0,20
Goat	5	0,22
Chicken	0	0,02

Source: IPCC (2006)

Table 6 Farm N_2O emission factor values

Livestock type	EF N_2O (kg/head/day)	Body Weight (kg)
Beef cattle	0,34	250
Dairy cows	0,47	300
Sheep	1,17	45
Goat	1,37	45
Chicken	0,05	1,5

Source: IPCC (2006)

Therefore, the total GHG emission value of the farm is:

$GHG\ Emission = Emisi\ CH_{4digestion} + Emisi\ CH_{4feses} + Emisi\ N_2O_{feses}$

Quantitative Descriptive Analysis

The relationship between GHG emissions and household income was analyzed using quantitative descriptive analysis. GHG emission data was obtained from the first objective calculation. Income data for each household was obtained from a questionnaire. According to Nata *et al.* (2020) income is classified into 4 as follows:

1. Low-income group (group 1), if the average income is ≤ IDR 2,000,000/month.
2. Medium income group (group 2), if the average income is > IDR 2,000,000 - IDR 4,000,000/month.
3. High-income group (group 3), if the average income is > IDR 4,000,000 - IDR 6,000,000/month
4. Very high-income group (group 4), if the average income is > Rp6,000,000/month

Multiple Linear Regression

According to Ghozali (2018), multiple linear regression is an analysis used to determine the direction and magnitude of the influence of the independent variable on the dependent variable.

Classical Assumption Test:

1. Normality Test

The normality test is used to see whether the residual value is usually distributed. The Kolmogorov-Smirnov test will be carried out to show that the data is usually distributed. If the significance> 0.05, then the data is normally distributed, while if the significance <0.05, then the data is not normally distributed.

2. Heteroscedasticity Test

The heteroscedasticity test aims to test whether the regression model causes inequality of variance from the residuals of one observation to another (Ghozali 2018). One way to determine whether there are symptoms of heteroscedasticity is to do the Glejser test. If the significance value is> 0.05, then there are no symptoms of heteroscedasticity in the regression model, while if the significance value is <0.05, there are symptoms of heteroscedasticity.

3. Multicollinearity

According to Ghozali (2018), the multicollinearity test tests whether there is a high correlation between the independent variables in the regression model. It can be seen from the VIF (Variance Inflation Factor) value to determine multicollinearity in the regression model. If the VIF value is < 10.00, then there is no multicollinearity, while if the VIF value is > 10.00, then there is multicollinearity in the regression model.

4. Autocorrelation

The autocorrelation test is a test conducted to determine whether, in a linear regression model, there is a correlation between confounding errors (residuals) in period t and confounding errors in period t-1 (previous) (Ghozali 2018). The test used is the Durbin-Watson (DW) test. A model has an autocorrelation problem if the DW value is smaller than dL or more significant than (4-dL). A model has no autocorrelation problem if the DW value lies between dU and (4-dU).

Statistical Criteria Test

1. F-test

The F test determines the effect of independent variables together (simultaneously) on the dependent variable (Ghozali 2018). The independent variable affects the dependent variable if the calculated F value> F table and the significance value <0.05. If the value of F count < F table and the significance value> 0.05, the independent variable simultaneously does not affect the dependent variable.

2. T-test

The T-test determines the effect of each independent variable individually on the dependent variable. If the t value> t table and the Sig value <0.05, then there is an influence of the independent variable (X) on the dependent variable (Y). If the t value < t table and the Sig value> 0.05, then there is no influence between the independent variable (X) and the dependent variable (Y).

3. Coefficient of Determination (R^2)

The coefficient of determination is the amount of diversity (information) in the dependent variable (Y) that can be explained in the regression model. The coefficient of determination is used to see how much the contribution of the influence of the independent variable (X) is simultaneously on the dependent variable (Y). The R2 value shows the percentage of diversity in the dependent variable (Y) (Napitupulu *et al.* 2021). The greater the R2 value, the greater the influence of variable X on Y, and the better the regression model obtained.

Multiple Linear Regression Model

The independent variables in the study are income, study time, and dummy knowledge related to GHG emissions. While the dependent variable is CO_2-eq emissions. The regression equation model, namely:

$$\mathit{ln}CO_2\text{-eq} = \alpha + \beta_1 \mathit{lnIncome} + \beta_1 \mathit{lnST} + \beta_1 D_K + \varepsilon$$

Description

CO_2-eq : Emissions generated (kg)

Income: Income from Household (IDR)

Study time : Study time seen from the last education level (years)

D_K : Emission Knowledge Dummy

1. Don't know => 1
2. Know => 0

α : Constant (intercept)

βn : Estimated Parameter (n=1, 2, 3)

ε : error

Research Hypothesis:

1. Income has a positive influence on CO_2-eq emissions. An increase in income will increase the CO2-eq emissions produced.
2. The length of the study has a positive influence on CO_2-eq emissions generated. Increased learning will increase CO_2-eq emissions.
3. The emission knowledge dummy explains the difference between people who know emissions and those who do not know about the CO_2-eq emissions produced. The more people do not know about emissions, the higher the CO_2-eq emissions produced.

Estimating the Economic Value of Carbon

The economic value of carbon is defined as the valuation of GHG emissions. NEK is one of the instruments for GHG emission reduction. The estimated economic value of GHG-emitting household activities is calculated using the carbon price. NEK can be calculated with the following formula:

$$EVC = \textit{Total emissions} \times \textit{carbon price}$$

Keterangan:

EVC : Economic value of carbon (IDR)

Total emissions : Total emissions generated from households (ton CO_2-eq)

Carbon price : Carbon pricing value (IDR/ton CO_2-eq)

RESULTS AND DISCUSSION

GHG Emissions Estimation

The estimation of GHG emissions carried out in this study consists of the use of LPG every month, gasoline every month, waste generated every month, fertilizer use every month, as well as the number of livestock and manure produced every month from 100 respondents (RT) in Sinarsari Village. The estimated amount of consumption and emissions generated can be seen in Table 7.

Table 7 Activities and emissions generated

Activities	CO_2 Emission	CH_4 Emission	N_2O Emission	Total GHG Emissions (kg CO_2-eq/month)
Estimated LPG Emissions				
993 kg/month	2.963,74	6,58	1,24	2.971,56
Estimated Electricity Emissions				
18607,8 kWh/month	14.774,59	-	-	14.774,59
Estimated Gasoline Emissions				
3575 liter/month	8.175,668	109,0089	100,0428	8.384,719
Estimated Emissions from Farming and Livestock Activities				
67.33 kg/month fertilizer and 164 chickens	1.122,447	7,65	53,35	1.183,455
Estimation of Waste Emissions				
4310 kg/month	4.697,355	-	-	4.697,355
Total GHG Emissions (kg CO_2-eq/month)				**32.011,68**

Source: Primary data, processed (2023)

Estimated Emissions from LPG

Based on Table 7, it was found that the total GHG emissions from LPG consumption amounted to 2,971.56 kg CO_2-eq/month, which is equivalent to 99 kg CO_2-eq/day. This was obtained from the use of LPG by households of 3 kg/month by 11 RTs, 6 kg/month by 24 RTs, 12 kg/month by 24 RTs, and households that use LPG more than 12 kg/month by 41 RTs. GHG emissions are directly proportional to the amount of LPG consumption. Households that use less LPG will produce less emissions than households that use more LPG. This is consistent with the research of Latifa *et al.* (2022), which states that the greater the use of LPG fuel, the greater the emissions.

Estimated Emissions from Electricity

Based on Table 7, it was found that the total GHG emissions from electricity use amounted to 14,774.59 kg CO_2-eq/month, which is equivalent to 492 kg CO_2-eq/day. This was obtained from 49 households using 450 VA electricity, 41 households using 900 VA electricity, 8 households using 1300 VA electricity, and 2 households using 2200 VA electricity.

Estimated Emissions from Gasoline

Based on Table 7, it was found that the total GHG emissions from gasoline consumption amounted to 8,384.719 kg CO_2-eq/month or equivalent to 279 kg CO_2-eq/day. Households with high mobility levels (using private vehicles) tend to produce more significant GHG emissions. Based on interviews in the field, it was also found that the number of vehicle units will increase in line with the increase in income.

Estimated Emissions from Farming and Livestock Activities

Based on Table 7, it was found that the total GHG emissions generated from farming and livestock activities amounted to 1,183.455 kg CO_2-eq/month, equivalent to 39 kg CO_2-eq/day. The results of interviews in the field with 100 respondents found that some people in Sinarsari Village have side jobs as farmers or breeders. In addition, some people have yards behind their houses to plant cassava, sweet potatoes, and livestock in the form of chickens for personal household consumption.

Estimated Emissions from Was

Based on the calculation of emissions generated from waste generation, the resulting emissions can be seen in Table 11. Based on Table 11, the results show that the total GHG emissions generated from waste generation for 100 respondents is 4,697.355 kg CO_2-eq/month, equivalent to 156 kg CO_2-eq/day. The number of household members influences the waste generated from each household. This is because the waste emissions calculation comes from the house type.

1. Total emissions generated

The total emissions generated are derived from the sum of GHG emission calculations carried out on 100 respondents from the consumption of LPG, electricity, gasoline, agriculture, and livestock, as well as waste generated. From the research results on 100 respondents, the GHG emissions from household activities amounted to 32,011.68 kg CO_2-eq/month, equivalent to 1,067 kg CO_2-eq/day. To see the distribution of GHG emission results for each source, it can be seen in Figure 2.

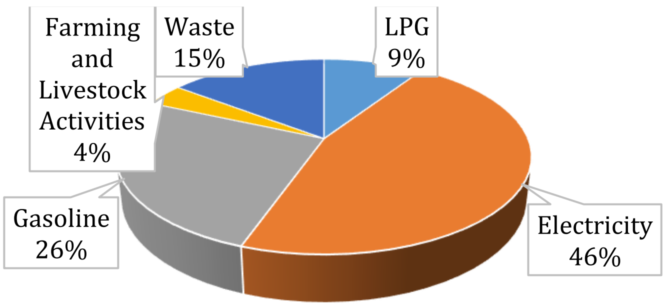

Figure 2 Distribution of GHG emissions from 100 respondents
Source: Primary data, processed (2023)

The most significant GHG emission comes from electricity, which accounts for 46% of household emissions. The second largest GHG emission comes from gasoline (transportation). This is by the Ministry of Energy and Mineral Resources (2020) that the most significant GHG emissions are electricity generation and transportation, respectively.

After calculating GHG emissions for 100 respondents, the total number of households in Sinarsari Village will be estimated. Based on Sasmita *et al.* (2018), total GHG emissions can be obtained by multiplying the average sample emissions by the total number of households in Sinarsari Village. Thus, the following calculation is carried out.

Table 8 Estimation of total GHG emissions within the village scope

Total GHG Emissions (kg CO_2-eq/month)	Sample Size	Emissions Average (kg CO_2-eq/month)	Total Head of Household	Total GHG Emissions (kg CO_2-eq/month)
32.011,68	100	320,1168	2.666	853.431,36

Source: Primary data, processed (2023)

The results of calculating total GHG emissions in one scope in Sinarsari Village amounted to 853,431.36 kg CO_2-eq/month, which is equivalent to 28,514.38 kg CO_2-eq/day. To see the total emission sources from the estimation of total GHG emissions in Sinarsari Village, it can be seen in Table 9.

Table 9 Estimation of each GHG emission source within the village scope

Total LPG Emissions (kg CO_2-eq/month)	Total Electricity Emissions (kg CO_2-eq/ month)	Total Gasoline Emissions (kg CO_2-eq/ month)	Total Waste Emissions (kg CO_2-eq/ month)	Total Agriculture and Livestock Emissions (kg CO_2-eq/ month)
79.221,73	393.890,62	223.536,61	125.231,48	31.550,91

Source: Primary data, processed (2023)

The largest source of emissions is electricity, followed by gasoline, waste, LPG, and livestock farming. The distribution in percent is the same as the distribution with 100 respondents. The distribution of emission sources can be seen in Figure 2.

2. Total Emissions by Income

Household income is classified into 4 levels, low (≤Rp2,000,000), medium (>Rp2,000,000 - Rp4,000,000), high (>Rp4,000,000 - Rp6,000,000) and very high (>Rp6,000,000). To compare income to GHG emissions, see Figures 3 and 4.

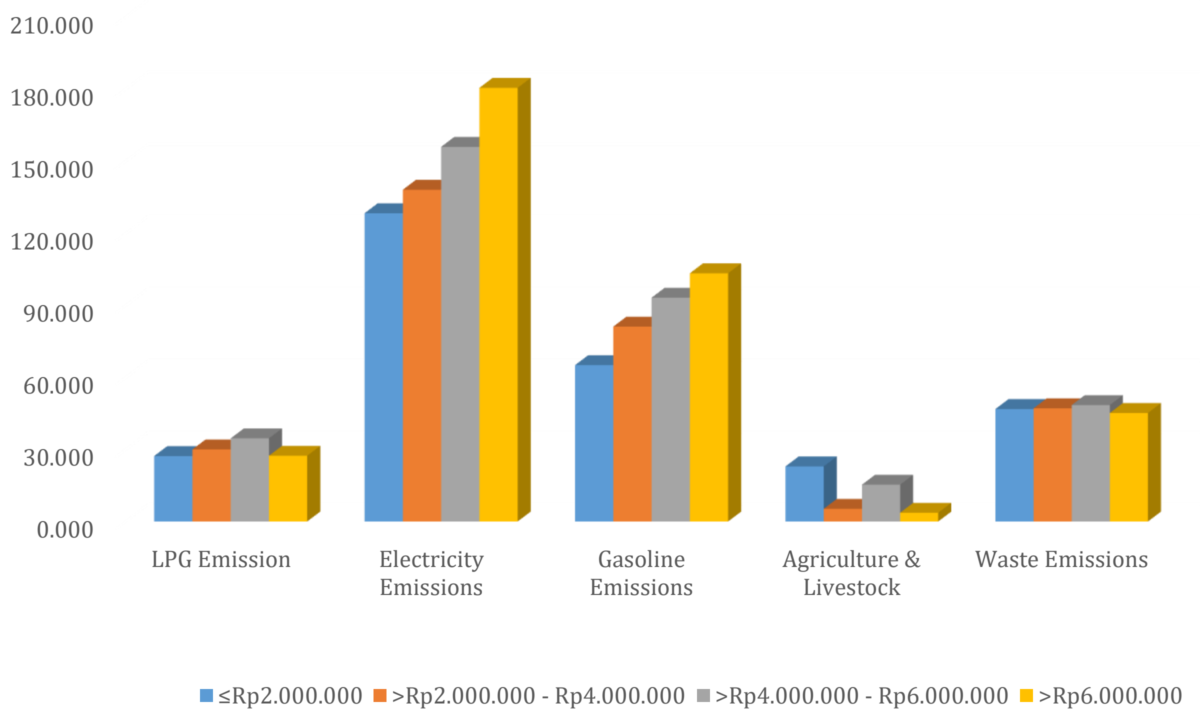

Figure 3 Relationship between average GHG emissions from emission sources
Source: Primary data, processed (2023)

Based on the data obtained from 100 respondents, it is known that the relationship between income and GHG emissions in LPG sources has increased. However, the emissions have decreased at very high incomes (>Rp6,000,000). This is because most people with very high incomes have a high level of mobility (outside activities), so the intensity of LPG use tends to decrease. The relationship between income and GHG emissions from electricity sources increased. The relationship between income and GHG emissions in gasoline consumption is positive. In addition, income in the very high category (>Rp6,000,000) is the highest GHG emitter due to high mobility. The relationship between income and GHG emissions in waste generation is fluctuating. This is because the calculated waste generation uses waste generation per household member based on the house classification. Therefore, the higher the number of household members, the higher the GHG emissions. The relationship between income and GHG emissions in farming and livestock activities fluctuates. This is due to the characteristics of the respondents, who have an income of less than IDR 2,000,000. Many people raise livestock and grow cassava/tube to be used for daily fulfillment.

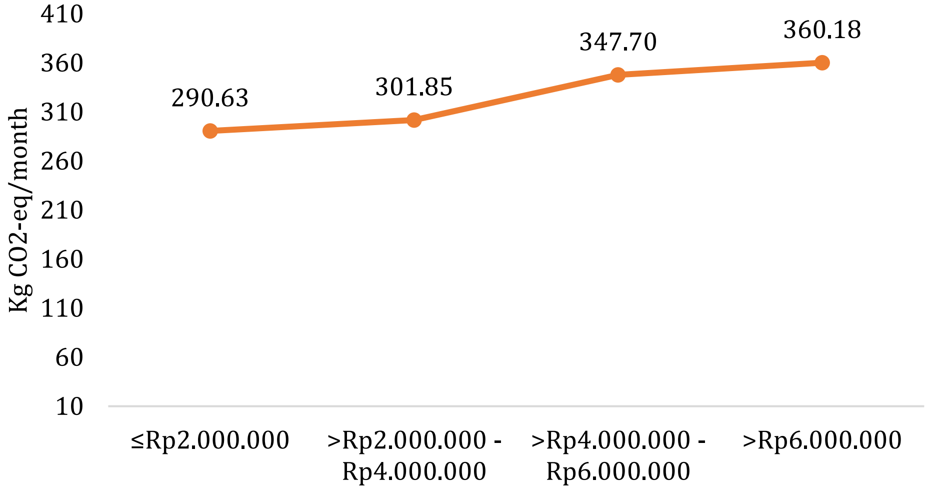

Figure 4 Relationship of average GHG emissions by income group
Source: Primary data, processed (2023)

Based on the calculation of GHG emissions carried out on 100 respondents, the relationship between income and GHG emissions produces an increasing graph. The higher the household income, the greater the GHG emissions. This is based on the research of Irfany and Klasen (2017), who found that when the income group increases, the emissions produced will also increase.

Higher incomes tend to use higher consumption, such as gasoline and electricity (Figure 3). Higher consumption is partly due to people's needs and lifestyles. The increase in higher consumption will result in higher GHG emissions compared to lower-income groups.

3. Total Emissions by Education Level

The level of education of the community will have an impact on the standard of living and the progress of thinking about things objectively. Recent education will affect the level of knowledge about GHG emissions.

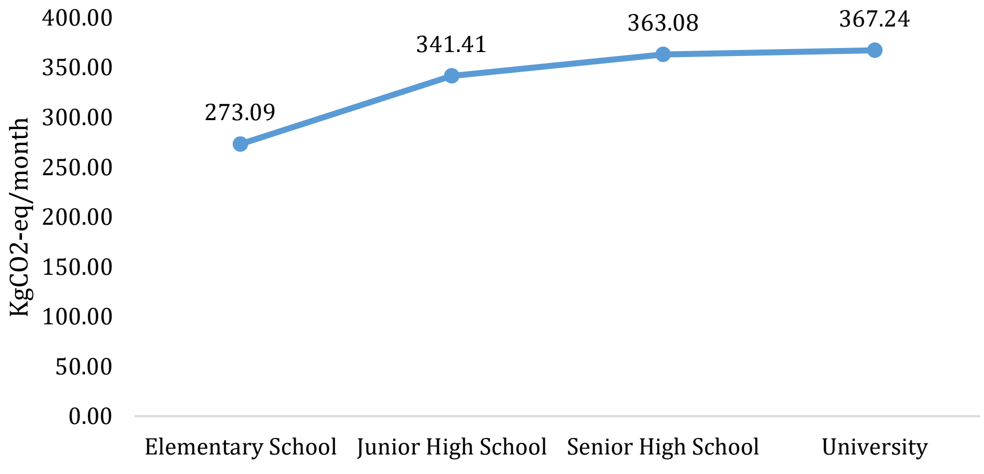

Figure 5 Relation of average GHG emissions to the latest education
Source: Primary data, processed (2023)

Based on Figure 5, the education group has an increasing pattern from elementary school to university level. This is to the research of Irfany and Klasen (2017), which explains that an increase in income will increase the carbon footprint (GHG emissions). In addition, according to Julianto D (2019), the higher the education, the greater the income. Thus, this is consistent with Figure 4 regarding the relationship between income and emissions.

4. Total Emissions by Knowledge GHG Emissions

The calculation of total emissions based on knowledge of GHG emissions was carried out to see the difference in GHG emissions between communities that know about emissions and communities that do not know about emissions. People who do not know GHG emissions tend to come from communities at the elementary, junior high, and high school education levels. People who know GHG emissions tend to come from people at the high school and university levels.

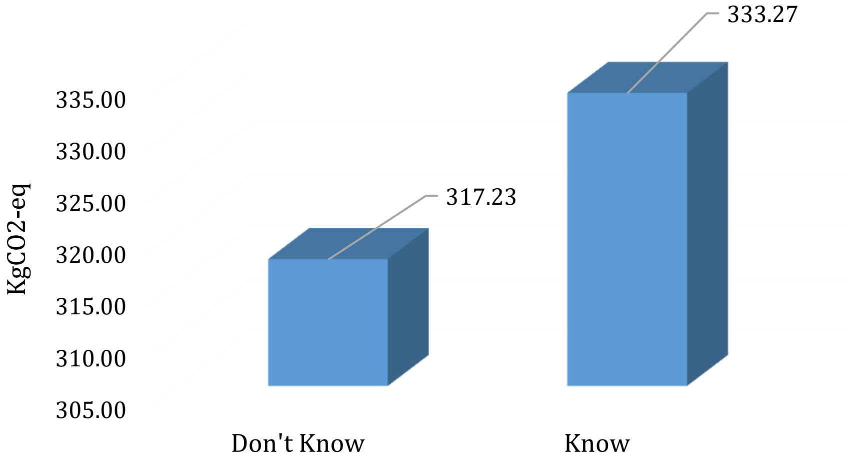

Figure 6 Average GHG emission relationship of GHG emission knowledge
Source: Primary data, processed (2023)

Figure 6 shows that households that know about GHG emissions produce higher GHG emissions than households that do not know about GHG emissions. The results of the descriptive analysis are not in line with the research hypothesis (the less knowledgeable about GHG emissions, the greater the emissions). This is because the calculation of people who know GHG emissions is limited to 18 households with high school and university education, with higher emission graphs than households with the last education below (Elementary school/junior high school).

Factors Affecting Greenhouse Gas Emissions

The dependent variable in this study is CO_2-eq emissions. The independent variables used are education, length of study, and GHG emission knowledge level dummy. Before multiple linear regression estimation calculations are carried out, classical assumption and statistical criteria tests will be conducted.

Table 10 Multiple linear regression model estimation results

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	2.025	.649		3.120	.002
	LnIncome	.181	.046	.383	3.962	.000*
	LnLength of Study	.350	.116	.383	3.013	.003*
	D_Knowledge	.256	.099	.300	2.577	.011*

Dependent Variable: LnCO_2eq
R-square : 0.302 | F-statistic : 13.878
Adjusted R-square : 0.281 | Sig. F : 0.000001*

Notes: *Significant at 5% absolute level
Source: SPSS 26, processed (2023)

The table shows that income, years of study, and emission knowledge dummy significantly affect the 5% real level. The equation of factors affecting GHG emissions resulting from household activities is:

$$Ln\text{CO}_2\text{-eq} = 2{,}025 + 0{,}181\,Ln\text{Income} + 0{,}350\,Ln\text{LoS} + 0{,}256\text{D}_\text{K} + \varepsilon.$$

1. Classical Assumption Test

The normality test is carried out to determine whether the error term is close to the normal distribution. The normality test with the Kolmogorov-Smirnov Test (Attachment 1) shows a significance value of 0.200> 5% absolute level. So, the data spreads normally. In addition, in the multicollinearity test (Attachment 2), each independent variable has a VIF value <10, so it can be concluded that the model does not occur in multicollinearity. The autocorrelation test was conducted using the Durbin-Watson method (Attachment 3). It resulted in a DW value of 1,984 (between dU and (4-dU)), so it can be concluded that the model is free from autocorrelation problems. The heteroscedasticity test is carried out using the Glejser test (Attachment 4) with a significance value> 5% absolute level, so it can be concluded that the model is free from heteroscedasticity problems.

2. Statistical Criteria Test

Statistical criteria tests were conducted with the F test and t-test. The F test was conducted to see the feasibility of the model regarding the influence of all independent variables on the dependent variable. Based on the F test (A 5), the significance value is < 5% absolute level, so it can be concluded that all independent variables simultaneously affect the dependent variable (CO_2-eq emissions). Meanwhile, the t-test is conducted to see the feasibility of the model regarding the influence of each independent variable on the dependent variable. Based on the T-test (Attachment 6), all independent variables have significance values < 5% absolute level. So, the independent variable affects the dependent variable.

The model's coefficient of determination (R2) (Attachment 7) is 0.302. It can be interpreted that 30.2% of the independent variables in the model can explain changes in the dependent variable (CO_2-eq emissions), while other factors explain the rest.

3. Economic Criteria Test

The income coefficient (LnIncome) is 0.181 with a significance value of 0.0001 < 5% absolute level. This shows that the income variable has a significant influence and has a positive relationship. When income increases by 1%, CO_2-eq emissions will increase by 0.181% with the assumption of ceteris paribus. This is to the research of Irfany and Klasen (2017), which explains that an increase in income will increase the carbon footprint (GHG emissions).

Length of Study

The coefficient value is 0.350 with a significance value of 0.003 < 5% absolute level. This shows that the length of the study variable significantly influences CO_2-eq emissions. The higher the education, the higher the CO_2-eq emission. If the length of the study increases by 1%, then CO_2-eq emissions will increase by 0.350% with the assumption of ceteris paribus. This is to the research of Irfany and Klasen (2017), which states that CO_2-eq emissions will increase along with the education level of the household head.

Emission Knowledge Dummy

The coefficient value of the GHG emission knowledge dummy is 0.256, with a significance value of 0.011. The emission knowledge variable significantly affects the 5% absolute level. The difference in CO_2-eq emissions generated between people who do not know emissions and people who know emissions is 0.256 with the assumption of ceteris paribus.

Estimated Economic Value of Carbon

The calculated carbon economic value is used to estimate the economic loss received by society if a carbon price is applied. In addition, the economic value of carbon is helpful as a consideration in policy-making to address climate change in GHG emission reduction efforts. Carbon economic value can also be used to mobilize green financing and investment. The carbon price used is based on Joseph Stiglitz, which is USD22/ton or equivalent to IDR336,776/ton (exchange rate of IDR15,308 as of August 18, 2023). So the economic value of carbon in one scope of Sinarsari Village is equal to the:

EVC = 853,43 ton CO_2-eq x Rp336.776/ton CO_2-eq
EVC = Rp287.415.199,70/month
Average EVC of each household = Rp107.808/month

Based on the results of the carbon economic value, it was found that the carbon economic value in Sinarsari Village amounted to Rp287,415,199.70/month. If the calculation is carried out for each household (RT), the carbon economic value generated by each RT is IDR 107,808/month. This means that the value of economic losses in the community within one village scope is Rp287,415,199.70/month or Rp107,808/month per household).

CONCLUSION

Based on the research that has been conducted, the conclusion obtained from the amount of GHG emissions produced by 100 respondents is 32,011.68 kg CO2-eq / month, which is equivalent to 32 tons of CO2-eq / month. GHG emissions in one village are 853,431.36 kg CO2-eq/month, which is equivalent to 853 tons of CO2-eq/month. The most significant emission is from electricity consumption, which accounts for 46% of the total GHG produced by household activities. The most minor emissions are from agriculture and livestock, accounting for about 4% of the emissions. The relationship between income and GHG emissions is positive. From the simple regression calculation, it is found that income has a positive influence on GHG emissions. In addition, learning duration and emission knowledge dummy also have a positive influence on GHG emissions. The economic value of carbon in one village scope obtained from calculating the world carbon price in one village scope amounted to Rp287,415,199.70/month.

REFERENCES

[BPS] Badan Pusat Statistik. 2023. Jumlah Penduduk Pertengahan Tahun (Ribu Jiwa), 2021-2023. [diakses pada 2023 Maret 22]. https://www.bps.go.id/indicator/12/1975/1/jumlah-penduduk-pertengahan-tahun.html.

[BPS] Badan Pusat Statistik. 2022. Kecamatan Dramaga dalam Angka 2022. Bogor: Badan Pusat Statistik.

Dewan Energi Nasional. 2021. Laporan Hasil Analisis Neraca Energi Nasional 2021. [diunduh 2023 Maret 22]. https://den.go.id/index.php/publikasi/documentread?doc=buku neraca-energi-2021.pdf.

DLH Semarang. 2018. Laporan akhir inventarisasi GRK Kabupaten Semarang tahun 2013-2017. [diakses pada 2023 Maret 22]. https://webdlh.kamisatu.co.id/public/deploy/pdf/1658894168_f846c22704 c1a10fc696.pdf.

Hakim A, Laksmiwati D. 2019. Sosialisasi Perangkat Pembelajaran Berbasis Lingkungan Untuk Guru Ipa Smp/Mts Di Lombok Barat Dalam Upaya Mengurangi Laju Pemanasan Global. Jurnal Pendidikan dan Pengabdian Masyarakat. 2(1): 68-74.

Intergovernmental Panel on Climate Change. 2014. Climate Change 2014: Synthesis Report.

Intergovernmental Panel on Climate Change. 2006. IPCC Guidelines for National Greenhouse Gas Inventories Introduction.

Irfany MI, Klasen S dan Yusuf RS. 2015. The Consumption Based Carbon Footprint of Households in Sulawesi, Jambi, and Indonesia in 2013. Courant Research Centre: Poverty, Equity and Growth-Discussion Papers no 186. University of Göttingen.

Irfany MI, Klasen S. 2017. Affluence and Emission Tradeoffs: Evidence from Indonesian Households' Carbon Footprint. Environment and Development Economics. 22: 546–570. doi: 10.1017/S1355770X17000262.

Julianto D, Utara PA. 2019. Analisa Pengaruh Tingkat Pendidikan terhadap Pendapatan Individu di Sumatera Barat. Ikraith Ekonomika. 2(2): 122-131.

Latifa RA, Sari KE, Meidiana C. 2022. Faktor Rumah Tangga yang Memengaruhi Emisi CO2 di Kelurahan Jodipan, Kota Malang. Planning for Urban Region and Environment Journal. 11(3): 89 – 100.

Latuconsina H. 2010. Dampak Pemanasan Global terhadap Ekosistem Pesisir dan Lautan. Jurnal Ilmiah Agribisnis dan Perikanan. 3 (1): 30-37. http://tria.wordpress.com-aktivitaspembelajaran.

Nata MIA, Endaryanto T. Suryani A. 2020. Analisis Pendapatan dan Tingkat Kesejahteraan Rumah Tangga Petani Pisang di Kecamatan Sumberejo Kabupaten Tanggamus. Jurnal Agribisnis. 8(4): 600-607.

Rifai MA, Nuryartono N, Irfany IM. 2018. Carbon Foodprint Based on Household Consumption: Case Study on Cocoa Farmer's Household in Polewali Mandar. Journal of Sustainable Development. 11(6): 15-26. doi: 10.5539/Jsd.V11n6p15.

Rosadi D, Saily R, Zaiyar, Jusi U. 2022. Identifikasi Jejak Karbon Skala Rumah Tangga Sebagai Upaya Mengatasi Perubahan Iklim. Indonesian Journal of Construction Engineering and Sustainable Development. 5 (2): 15- 23. doi: 10.25105/Cesd.V5i2.15629.

Sasmita A, Asmura J, Andesgur I. 2018. Analisis Carbon Footprint yang dihasilkan dari Aktivitas Rumah Tangga di Kelurahan Limbungan Baru Kota Pekanbaru. Jurnal Teknik Waktu. 16(1): 96-105.

Wilson AM. 2005. Campus Carbon CalculatorTM, Clean Air-Cool Planet Special Publication. [diakses pada 2023 Maret 22]. http://www.sightlines.com/clean-air-cool-

planet-transitions-operations-to-university-of-new-hampshires-sustainability-institute/.
Wiratama IGNM, Sudarma IM, Adhika IM. 2016. Jejak Karbon Konsumsi LPG dan Listrik pada Aktivitas Rumah Tangga di Kota Denpansar, Bali. Jurnal Ecotrophic. 10 (1): 68-74.

APPENDIX

Attachment 1 Normality test

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		100
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	.27490988
Most Extreme Differences	Absolute	.064
	Positive	.058
	Negative	-.064
Test Statistic		.064
Asymp. Sig. (2-tailed)		.200[c,d]

Attachment 2 Multicollinearity test

Coefficients								
		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	2.025	.649		3.120	.002		
	LnIncome	.181	.046	.383	3.962	.000	.779	1.285
	LnLength of Study	.350	.116	.383	3.013	.003	.451	2.219
	D_K	.256	.099	.300	2.577	.011	.535	1.869

a. Dependent Variable: Ln CO_2eq

Attachment 3 Autocorrelation test

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.550[a]	.302	.281	.27917	1.988

a. Predictors: (Constant), D_K, LnIncome, LnLength of Study

b. Dependent Variable: Ln CO_2eq

Attachment 4 Heteroscedasticity test

Coefficients						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.155	.419		.369	.713
	LnIncome	-.014	.030	-.054	-.467	.641
	LnLength of Study	.093	.075	.186	1.236	.219
	D_K	.073	.064	.157	1.137	.259

a. Dependent Variable: ABS_RES

Attachment 5 F-test

ANOVA[a]

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.245	3	1.082	13.878	.000[b]
	Residual	7.482	96	.078		
	Total	10.727	99			

a. Dependent Variable: Ln CO_2eq

b. Predictors: (Constant), D_K, LnIncome, LnLength of Study

Attachment 6 T-test

Coefficients

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.025	.649		3.120	.002
	LnIncome	.181	.049	.383	3.962	.000
	LnLength of Study	.350	.116	.383	3.013	.003
	D_K	.256	.099	.300	2.577	.011

a. Dependent Variable: Ln CO_2eq

Attachment 7 Coefficient of Determination (R^2)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.550[a]	.302	.281	.27917

a. Predictors: (Constant), D_K, LnIncome, LnLength of Study

b. Dependent Variable: Ln CO_2eq