Published: 30 November 2024

Economic Value of Greenhouse Gases Based on Household Activities in Cikarawang Village, Bogor, Indonesia

Fransisco Joan Tampubolon[1], Aceng Hidayat[2], Mohammad Iqbal Irfany[3], Daffa Aqomal Haq[4]
[1,2,3,4] *Faculty of Economics and Management, IPB University, Indonesia*

Global warming and climate change, these two global phenomena arise due to greenhouse gas pollution produced by human activities which causes thinning of the atmosphere and an increase in the earth's temperature which can threaten the continuity of human life. Indonesia is the sixth largest producer of greenhouse gases in the world. One of the human activities that contribute to greenhouse gas emissions is household activities, which contribute to greenhouse gas emissions through household activities such as consumption of vehicle fuel, fuel oil, and waste generation. This study aims to identify the greenhouse gas emissions produced by household units, analyze the relationship between the value of greenhouse gas emissions and the income of each household, and estimate the loss in the economic value of greenhouse gas emissions caused by household units. The method used in this research is the IPCC calculation method to identify greenhouse gas emissions, quantitative descriptive analysis to analyze the carbon footprint value with household income, and the economic value of greenhouse gases calculated using the 2021 Presidential Decree NEK. The results show that income, length of study, and the knowledge dummy have an influence on GHG emissions.

Keywords: Emissions; IPCC; Income; NEK

*Correspondence:
Mohammad Iqbal Irfany
iqbal.irfany@apps.ipb.ac.id

Received: 15 April 2024
Accepted: 13 November 2024
Published: 30 November 2024

Citation:
(2024) Economic Value of Greenhouse Gases Based on Household Activities in Cikarawang Village, Bogor Indonesia. Economics and Sustainability. 2.1.

INTRODUCTION

Global warming and climate change pose a threat to the human environment and endanger human survival worldwide. This event results in a reduction in the atmospheric layer and increases the Earth's temperature, which causes an increase in sea surface height because there will be additional seawater from melting glaciers and the possibility of accelerating the melting of eternal ice at the south and north poles (Ramlan 2002). Global warming is a problem in various fields, including the industrial, transportation, energy, fuel, and waste disposal sectors. One of the main causes of global warming is increasing greenhouse gas (GHG) emissions. In the international world, Indonesia is the largest GHG emitting country, which is in sixth place in producing gas emissions or GHG of around 4.47% (Aisyi et al. 2020). GHGs have a concentration of 90% coming from carbon dioxide emissions, 9% from methane, and the rest from nitrogen. The increase in the amount of carbon dioxide (CO_2) and other gases in the atmosphere is due to the increase in the use of fuel (BBM), coal, and other organic fuels (Pratama 2019). The higher the energy consumed, the higher the increase in the amount of GHG emissions in the Earth's atmosphere (IPCC 2007).

The largest contributor to GHG emissions in Indonesia is the energy sector, where, according to the results of national GHG inventory calculations, the level of GHG emissions produced continues to increase. GHG emissions produced in 2020 were 1,050,413 Gg CO_2-e, an increase of 10,796 Gg CO_2-e compared to 2010, and the emission level in 2000, the initial year the GHG inventory was carried out, increased by 235,769 Gg CO_2-e (KLHK 2021). In Indonesia, various sectors contribute to greenhouse gas emissions, as shown in Figure 1. In 2020, the energy sector contributed the largest GHG emissions of 587,635 Gg CO_2-e. As much as 15% of the national energy consumption is used by the household sector (KESDM 2021).

The carbon footprint produced by each household varies based on the electricity consumption and fuel used. Several factors influence household consumption patterns. Some of these factors, such as complex population activities, people's lifestyles, and high mobility, are predicted to produce greenhouse gas emissions (Latifa et al. 2022).

Greenhouse gases resulting from anthropogenic emissions come from several sources, one of which is human activities in the energy sector, namely the use of fossil fuels such as coal, petroleum, and gas in various human activities, which is the cause of the release of greenhouse gas emissions into the atmosphere. The use of electronic devices, such as air conditioners, televisions, computers, motorized vehicles, and industrial activities, are also examples of human activities that increase GHG emissions in the atmosphere (Wulandari. 2013). Based on this description, the objectives of this research are: 1) identify and estimate the amount of GHG emissions produced by household units, 2) analyze the relationship between the value of GHG emissions and the income of each household, 3) estimate the economic value of GHG emissions released into the environment by household units, and 4) analyze energy consumption behavior in household activities carried out in Cikarawang Village.

METHOD

Location and Time of Research

Research and data collection were carried out in Cikarawang Village, Dramaga District, Bogor Regency, West Java Province. The choice of location was done purposively because West Java Province is the province with the largest population and Cikarawang Village is one of the villages with the largest population in Dramaga District. Data collection for this research was carried out in June-July 2023.

Types and Methods of Data Collection

The type of data used in this research is primary data. Primary data were obtained by conducting interviews with household units in Cikarawang Village. Primary data include information regarding household consumption of electrical energy, fuel oil, cooking fuel, number of livestock, agricultural land, and waste generation. Secondary data in this research include several parameter values used to estimate the carbon footprint and economic value of carbon.

Sampling in this study was carried out using random cluster sampling. Cluster random sampling is a method of taking samples from population members using random sampling without paying attention to the strata within the population members (Sugiyono 2014). The respondents were residents of a household unit located in Cikarawang Village, Bogor Regency. The high population figures at the research location led to sample selection according to Slovin's theory, using the following formula:

$$n = \frac{N}{1+Ne^2} = \frac{2451}{1+2451 \times 0{,}1^2}$$

Information:
n = Number of samples
N = Total Population of Cikarawang Village Families
e = The percent allowance for inaccuracy due to sampling errors that can still be tolerated is 10%

There are seven Community Units (RW) in Cikarawang Village. To determine the distribution of the number of samples for each RW, Sugiyono's (2007) stratified sampling formula was used as follows:

$$n = \frac{x}{N1} \times N1$$

Information:
n = Number of samples $RW\ i$ (people)
X = Total population $RW\ i$ (people)
N = Total population (families)
N1= Total sample (100 families)

Table 1 Number of Samples for Each Community Unit

RW	Total Population	Number of Samples
1	417	17
2	288	12
3	337	14
4	292	12
5	371	16
6	347	15
7	326	14

Source: Primary Data processed 2023

Vehicle Fuel Consumption Carbon Emissions

The calculation of carbon emissions from vehicle fuel consumption is used to determine the carbon footprint resulting from direct carbon emissions or from household consumption in the use of private vehicles. The vehicle fuel emission factors used are the CO_2, NH4, and N2O emission factors, which are 69,300 kg/Tj, 33 kg/Tj, and 3.2 kg/Tj (IPCC 2006). Vehicle fuel consumption was obtained from the total vehicle fuel consumption of private vehicles. The CO_2 emissions were calculated using the following formula (IPCC 2006):

$$Emission = FE \times Energy\ used \times GWP$$

Information :
FE = Fuel Emission Factor
NCV = Energy content/mass unit

Fuel Carbon Emissions Using LPG

Carbon emissions from cooking fuel consumption were used to calculate carbon emissions from LPG consumption. This behavior includes direct emissions. GHG emission calculations were carried out using the following formula (IPCC 2006):

Energy used:

$$Energy\ used\ (TJ) = Consumption\ LPG \times NCV$$

Information:
Net Calorific Volume per Unit Mass = 47,3 TJ/Gg

Emissions produced:
$Emissions\ GRK = Energy\ used\ (TJ) \times FE \times GWP$

Emissions Electricity Consumption Carbon

The electrical energy used by people is very diverse, and the power of each house varies greatly. The GHG emissions produced by households from electrical energy consumption are also called indirect GHG emissions. The total greenhouse gas emissions from community electrical energy consumption were calculated using the following formula (IPCC 2006):

$$Total\ Emissions\ GRK = FE \times K$$

Information:
FE = 0,794 $KgCO_2$/kWh
K = Electrical Energy Consumption (kWh)

Calculation Formula for Carbon Emissions from Farming and Livestock Activities

The formula for calculating greenhouse gas emissions using the Tier-1 method (IPCC. 2006) To calculate CH4 gas emissions originating from the feed fermentation process in the rumen (enteric fermentation), which is issued in the guidebook (IPCC. 2006), namely:

CH4 emissions from enteric fermentation

$$Emissions\ greenhouse\ gas = Livestock\ population\ (headl) \times FE(Kg/ek) \times GWP$$

CH4 emissions from manure management

$$Emissions\ CH4\ gas\ impurities\ (CO_2\text{-}e\ tons/head) = livestock\ population\ (headl)\ \times GWP$$

Emissions N20 from manure management

$$N20\ (CO_2\text{-}e\ ton/year) = population \times (0{,}05 \times FEn)/(1000/BB) \times 365 \times 44/28 \times GWP$$

CO_2 emissions from fertilizer use

$$Emissions\ CO_2 = Fertilizer\ use \times FE\ fertilizer$$

Information:
FEe = Emissions factor from enterics (kg CH4/head/day)
FEm = Emissions factor from livestock manure (kg CH4/head/day)
28 = conversion for CH4 to CO_2 and from kg to tons
FEn = N2O Emissions Factor from livestock manure (kg N2O/kg manure / day)
265 = conversion for N2O to CO_2 and from kg to tons
44/28 = Conversion of N2O-N to N2O
0,05 = Average N excretion (kg N/head/year)
FE fertilize = 16,667 Kg/month

Carbon Emissions from Waste Generation

Waste generation in households can be calculated from the GHG emissions produced using the following formula for finding GHG emissions (Wilson 2005 in Alwin 2016):

$$Emissions\ CO_2 = Amount\ of\ waste\ produced \times Emissions\ factor$$

Information:
Emissions Factor (Emissions Factor) : 1,09

Generated waste generation

$$Waste\ generation = Number\ of\ family\ members \times Weight\ (Kg/Person/Day) \times FE$$

Analysis of the Relationship between GHG Emissions Values and Household Income

Quantitative descriptive analysis was used to determine the influence between income and carbon footprint values. Household income data were obtained using questionnaires and literature studies. The influence of carbon footprint and income was determined through regression analysis using the SPSS 26 application. Income is classified into four categories, as follows (BPS 2016 in Iqbram et al. 2020):

1. Low-income group, if the average income is ≤Rp. 2,000,000.00 per month.
2. Medium-income group, if the average income is between > IDR 2,000,000.00 to IDR 4,000,000.00 per month.
3. High-income group, if the average income is between > IDR 4,000,000.00 to IDR 6,000,000.00 per month.
4. Very high-income group, if the average income > IDR 6,000,000.00 per month.

Multiple Regression Analysis

The influence of household income, length of study, and knowledge dummy on GHG Emissions was analyzed using multiple regression analysis carried out on the results of household GHG Emissions to determine the influence between the dependent variable and the independent variable. The independent variables used were income, length of study, and knowledge dummy, and the dependent variable was home GHG emissions. The classical assumption test was carried out before conducting the multiple regression analysis. The multiple regression analysis equation is as follows:

$$lnCO_2\text{-}eq = \alpha + \beta_1 Income + \beta_2 lnLengthofstudy + \beta_3 lnD_{knowledge}$$

Information:
CO2-e = Emissions generated (kg)
Income = Income from household (Rp)
Lengthofstudy = Length of time studying formal education (year)
$D_{knowledge}$ = Knowledge of GHG Emissions (don't know (1); know (2))

Estimated Carbon Footprint Value Based on Carbon Pricing

The economic value of carbon emissions based on the carbon tax produced by household units can be calculated by multiplying the carbon price and carbon tax by the total carbon emissions released into the environment. The economic value of carbon used is the carbon price value, which is US$ 160/ton or IDR 2,437,216/ton (exchange rate IDR 15,232 as of August

31, 2023), based on data from economist Wood Mckenzie (Forest digest 2021). The formula for calculating the economic value of carbon is as follows:

$$NEK = PC \times \text{Total Emissions Karbon}$$

Information :
PC = Carbon Price
NEK = Carbon Economics Value

RESULTS AND DISCUSSION

GHG Emissions from Household Units from Fuel Consumption

Fuel consumption for each household varies greatly owing to differences in motor vehicle ownership and frequency of motor vehicle use. The fuel consumption per sub-district is shown in the following table.

Table 2 Fuel Consumption and GHG Emissions

	Total Consumption (liter)	Total Emissions (kg CO_2-e/month)
Total	2.133	5.572,618

Source: Data processed 2023

The highest GHG emissions from fuel consumption activities came from RW 1 with a fuel consumption of 528 liters and GHG emissions of 1238.36 kg CO_2-e/month with the most respondents in RW 1. This can explain that GHG emissions are influenced by the population of an area, which is in line with the statement of Santi and Sasana (2020) in their research that the population growth rate will increase the amount of carbon emissions. Meanwhile, GHG emissions produced from household units of 100 households have an average of 55.72 kg CO_2-e/month per household.

GHG Emissions from Household Units from Electrical Energy Consumption

GHG emissions from electrical energy consumption result from household electronic equipment that use electrical power. The equation used to calculate the amount of GHG Emissions is by using secondary CO_2 emissions calculations, namely by multiplying the emissions factor by the amount of power consumed by one household each month.

Table 3 Electricity consumption and GHG emissions per month

	Total Electrical Energy Consumption (kWh)	Total Emissions (kg CO_2-e/month)
Total	18.393,64	14.604,55

Source: Primary data (2023)

GHG emissions resulting from household consumption in Cikarawang Village are quite diverse, with RW 1 as the RW with the largest population producing the most GHG emissions with 3,220,114 kgCO_2-e/month.

GHG Emissions from Cooking Fuel Consumption

GHG emissions from cooking fuel consumption are produced from household cooking equipment, and the cooking fuel used can be kerosene, firewood, and LPG. The equation used to calculate the amount of GHG emissions using the IPCC Tier 1 GHG Emissions calculation was obtained by multiplying the emissions factor by the amount of cooking fuel used by one household each month. The resulting GHG emissions are 3,249.86 kg CO2-e/month.

Table 4 GHG Emissions and consumption per month

	Total Emissions (kg CO_2-e/month)	Total Cooking Fuel Consumption (kg)
Total	3249.86	1086

Source: Primary data (2023)

GHG Emissions from Household Waste Generation

Household waste generation is the amount of waste produced by a household in a month. Household waste generation in this study was obtained by looking at the type of house a household lives in and the number of family members living in that house. The generation of waste produced by the type of house can be seen in the following table.

Table 5 waste generation based on house type

House Type	Volume (Liters/Person/Day)	Weight (Kg/Person/Day)
Permanent Home	2,25	0,350
Semi-Permanent House	2	0,300
Non-Permanent House	1,75	0,250

Source: Damanhuri & Padmi 2010

The types of houses based on the construction of residential buildings refer to the 2011 Law on Housing and Settlements. There are three types of houses based on construction: permanent, semi-permanent, and non-permanent houses.

Table 6 house types based on building construction

House Type	Roofing Materials	Wall Material	Floor Material
Permanent Home	Rooftile	Wall	Ceramics
Semi-Permanent House	Zinc or Asbestos	Wood or bamboo	Cement
Non-Permanent House	Wood	Gedek	Land

Source: Regulation (Undang-Undang) year 2011

The number of respondents with permanent houses was 85, the number of respondents with semi-permanent houses was 15, and there were no respondents with non-permanent houses.

Table 7 waste generation and GHG emissions per month

	Total Waste Generation per Month (kg)	Total Emissions (kg CO_2-e/month)
Total	3745,5	4082,6

Source: Data processed 2023

The highest GHG emissions from electricity consumption activities come from RW 1 as RW with electricity consumption of 4055.56 kWh with GHG emissions of 3220.11 Kg CO_2-e/month) Meanwhile, GHG emissions generated from household units have an average of 40 .82 KgCO_2-e/month per household.

GHG Emissions from Farming and Livestock Activities.

GHG emissions from agriculture and animal husbandry result from the use of fertilizer on agricultural crops, feed, manure, and livestock activities owned by households. The equation used to calculate the amount of GHG emissions from livestock uses an emissions calculation, namely, multiplying the emissions factor by the number of livestock owned by the GWP of GHG emissions from livestock. There are two types of livestock animal emission factors: emissions from manure and emissions from enteric fermentation originating from the livestock digestion process. Meanwhile, emissions from agriculture can be determined by multiplying the emissions factor by fertilizer use.

Table 8 Total Emissions per month for agriculture and livestock

	Total Emissions (kg CO_2-e/month)
Total	2.872,5

Source: Primary data (2023)

Based on the table above, the largest producer of GHG emissions is the livestock and agriculture sector in Cikarawang Village, namely RW 5, with total emissions of 2,557.23 tonnes of CO_2-e/month. This is because in RW 5, there are seven types of livestock in the form of goats, which have the highest N2O emission factor and the second highest CH4 emission factor among other livestock, so this also influences the amount of emissions produced. Meanwhile, GHG emissions produced from household units have an average of 28.72 kgCO_2-e/month per household.

The Relationship between Carbon Footprints and Emissions Produced by Household Units and Household Income

Based on the calculation of CO_2-e emissions produced from a place and region, it is not only influenced by the population, but there are also other factors and variables that are thought to influence the value of CO_2-e emissions that will be analyzed in this research, namely income. household in one month. Income is classified into four categories as follows:

1. Low income group, if the average income is less than IDR ≤ 2,000,000.00 per month
2. Medium-income group, if the average income is between IDR > 2,000,000.00 to IDR 4,000,000.00 per month.
3. High-income group, if the average income is between IDR > 4,000,000.00 to IDR 6,000,000.00 per month.
4. Very high income group, if the average income is more than IDR > 6,000,000.00 per month

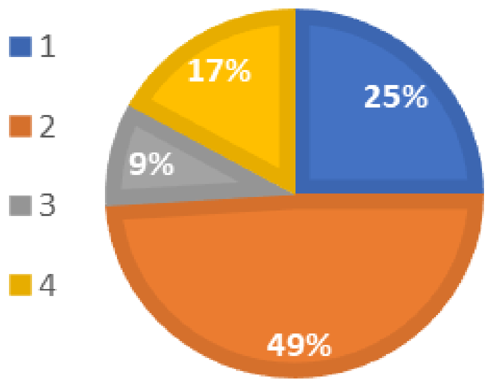

Figure 1 Population distribution based on income group

Source: Primary data (2023)

The income of the residents of Cikarawang Village is mostly in the medium income group (2) with an average income range between > IDR 2,000,000.00 to IDR 4,000,000.00 per month. The distribution of income by group is shown in the figure above. The highest income of residents in Cikarawang Village is in the medium-income group with 49% or 49 residents, followed by the low-income group with 25% and 17% of residents with very high incomes, and 9% of residents with high incomes.

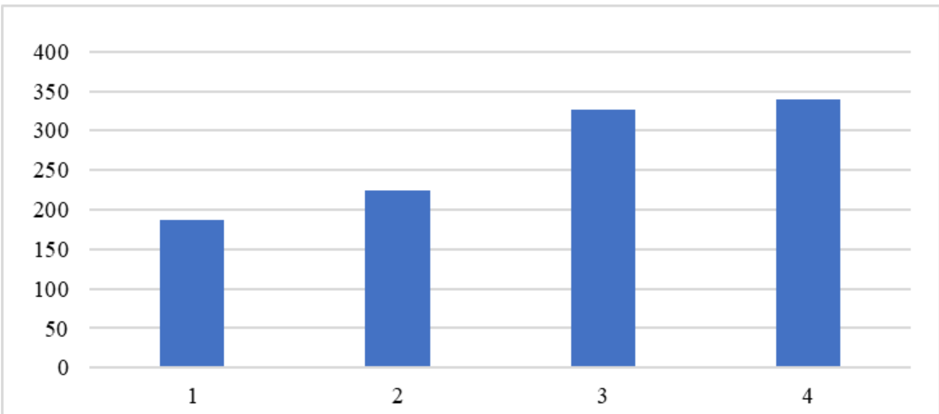

Figure 2 Distribution of GHG emissions by income group

The total GHG emissions produced in Cikarawang Village are 29,504.435 kgCO2-e/month; the medium-income group produces the most GHG emissions at 45% or 13,201.185 kgCO2-e/month of the total GHG emissions produced in Cikarawang Village. Income group 1 produces emissions of 7,468,101 kgCO2-e/month, or 25% of the total emissions. Meanwhile, the very high- and high-income groups contributed 19% and 11% or 5,621,883 kgCO2-e/month and 3,213,226 kgCO2-e/month of the total GHG Emissions in Cikarawang Village, respectively.

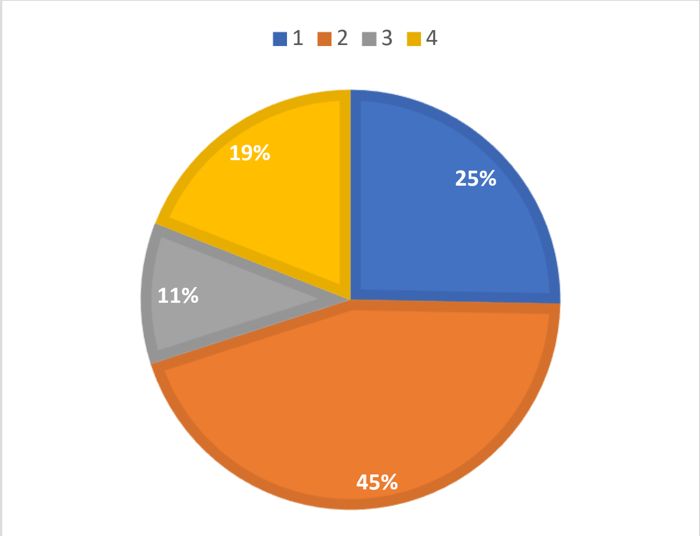

Figure 3. Average primary carbon emissions by income

Source: Primary Data (2023)

Figure 3 shows that the greater the household income, the greater the value of CO_2-e emissions produced. The CO2 Emissions value is obtained through calculations based on the amount of electrical energy, fuel, cooking fuel, agriculture, and livestock, as well as waste generation consumed by a household in one month..

Multiple Regression Analysis

a. Normality test

The normality test was carried out to determine whether the data used in the regression model were normally distributed. If the data are normally distributed, they can be subjected to regression.

Table 9. normality test results

One-Sample Kolmogorov-Smirnov Test	
	Unstandardized Residual
N	100
Test Statistic	0,051
Asymp. Sig. (2-tailed)	0,200

Source: Primary data (2023)

The normality test results table shows the results of the one-sample Kolmogorov-Smirnov test, where the significance value is greater than the real level of 0.05, so that the data can be said to be normally distributed and pass the normality test. Based on the image above, it shows the results of the One Sample Kolmogorov-Smirnov test, where the value of Asymp. Sig (2-tailed) is greater than 0.05, so the data can be said to be normally distributed and the data passes the normality test.

b. Autocorrelation Test

The autocorrelation test was used to test whether there was a correlation between confounding errors in the linear regression model (Ghozali, 2016).

Table 10. Autocorrelation test results

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0,503	0,253	0,230	0,35348	1,895

Source: Primary Data (2023)

In Table 10, we can see the results of the autocorrelation test using the Durbin-Watson method, with a value of 1.895. This value was between the dU values of 1.736 and (4-dU) of 2.264. Therefore, the model is free from autocorrelation problems.

c. Heteroscedasticity Test

The heteroscedasticity test determines whether the regression model has unequal variances in the residuals. This heteroscedasticity test will be performed using the Glejser test method.

Table 11. Heteroscedasticity test results

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.991	.690		1.435	.154
LN_Income	-.001	.047	-.002	-.021	.983
LN_Lengthofstudy	-.291	.100	-.335	-2.905	.006
Dknowledge	-.086	.068	-.142	-1.254	.213

Source: Primary data (2023)

The significance value is > 5% real level, so it can be concluded that the model is free from heteroscedasticity problems.

d. Multiple Linear Regression Analysis

Simple linear regression in this research was carried out to see the relationship between GHG Emissions as the dependent variable and income, length of study, and knowledge dummy as independent variables.

Table 12. Summary model results

R	R Square	Adjusted R Square	Std. Error of the Estimate
0,503	0,253	0,230	0,35348

Source: Primary Data (2023)

Based on the results of processing, it is known that the R square value is 0.253, which shows a relationship. The results of GHG Emissions are influenced by income by 25%, and 75% of GHG Emissions are influenced by other factors that are not included in the model.

Based on the results of data processing, it is known that the significance value of all variables is <0.05, so there is an influence between GHG Emissions and income, length of study, and knowledge dummy. Thus, the regression equation model is

$$lnCO_2\text{-}eq = \alpha + \beta_1 lnincome + \beta_2 lnlengthofstudy + \beta_3 lnD_{knowledge} + e$$

$$lnCO_2\text{-eq} = 4{,}014 + 0{,}195 lnincome + 0{,}443 lnlengthofstudy + 0{,}406 D_{knowledge}$$

Table 13. Results of multiple regression analysis

					Coefficient[a]
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	StdError	Beta		
(Constant)	4.014	0,987		4.067	0,000
Income	0,195	0,067	0,288	2.925	0,004
Lengthofstudy	-0,443	0,143	-0,322	-3.093	0,003
Knowledge	-0,406	0,098	-0,426	-4.151	0,000

Therefore, it can be concluded that GHG emissions increase by 0.195 units if income increases by one unit. This is in accordance with research by Irfany and Klasen (2017), which states that the increase in GHG emissions is mainly caused by the income effect.

GHG emissions decrease by 0.443 units if the length of the study increases by one unit. The difference in GHG emissions between people who do not know and those who do not know about emissions is 0.406 units. Table 13 also shows that the GHG Emissions knowledge dummy influences GHG Emissions by 0.406, with people not knowing about GHG Emissions.

Value of Economic Losses Resulted by Household Units

The economic value of carbon is the amount of carbon emissions produced from household activities multiplied by the world carbon price, namely US$160/ton or IDR 2,437,216/ton (exchange rate IDR 15,232 as of August 31, 2023), based on data from economist Wood Mckenzie. Economic value can be a reference or consideration in making decisions and policies related to setting targets for reducing emissions, climate change, and carbon trading. Calculation of the economic value of carbon based on Presidential Decree (2021)

$$NEK = PC \times Total\ Carbon\ Emission$$

Information:
PC = Carbon Price
NEK = Carbon Economics Value

Table 14. Economic Value of Carbon in Cikarawang Village

Number of Respondents	Economic Value ($)
100	336,71

Source: Data processed in 2023

The average value of economic losses caused by GHG emissions in Cikarawang Village is $48.10 or Rp. 732,680 per resident per month. According to economist Wood McKenzie (Forest Digest, 2021), the price of emissions must increase to US$ 160. / ton, so that the world can reduce emissions by 45% by 2030.

CONCLUSION

Greenhouse gas emissions produced by the community in Cikarawang Village are dominated by emissions from electrical energy consumption activities resulting from the use of household electronic equipment, followed by fuel oil consumption in second place, waste generation in third place, and fuel emissions. Cooking was ranked fourth, and agricultural and livestock activities were ranked last. However, this does not apply to RW 05, where greenhouse gas emissions in the agricultural and livestock sectors are the largest. The result of greenhouse gas emissions from household activities per month per household is 295,044 KgCO2-e/month. The value of greenhouse gas emissions produced by the community is directly proportional to the community's income, where the higher the community's income, the higher the emissions produced; however, revenue does not have a significant impact on the resulting increase in emissions. The value of economic losses due to greenhouse gases produced from household activities in Cikarawang Village is $3.3674/resident every month.

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