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Estimation of CO_2 Emissions from Transportation, Waste, and Energy Activities in Office Environments

Fidela Almadea[1], Raden Kokoh Haryo Putro[2].*

[1] *Environmental Engineering, Faculty of Technology and Science, UPN Veteran Jawa Timur, Surabaya, Indonesia*
[2] *Environmental Engineering, Faculty of Technology and Science, UPN Veteran Jawa Timur, Surabaya, Indonesia*

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CORRESPONDING AUTHOR

*E-mail: 21034010110@student.upnjatim.ac.id

A B S T R A C T

Office activities contribute to carbon dioxide (CO_2) emissions through transportation, electricity consumption, waste generation, and LPG use. This study estimates CO_2 emissions from a municipal government office in Kediri City using the IPCC Tier 2 methodology. Data were collected through vehicle counts, electricity consumption records, waste measurements, and interviews regarding LPG usage. The results show that electricity consumption is the dominant source of emissions, accounting for 51,120 kg CO_2/year. Transportation activities contributed 882 kg CO_2/year, while waste generation and LPG consumption generated 133.28 kg CO_2/year and 161.17 kg CO_2/year, respectively. Overall, energy use is the primary driver of emissions in office environments. These findings provide baseline data to support energy efficiency improvements and sustainable office management strategies to reduce carbon emissions

.Contribution to Sustainable Development Goals (SDGs)
SDG 13 – Climate Action
SDG 7 – Affordable and Clean Energy
SDG 11 – Sustainable Cities and Communities
SDG 12 – Responsible Consumption and Production

1. INTRODUCTION

1.1. Research Background

Climate change is one of the most serious environmental challenges facing the world today. It is a result of global warming and the effects of greenhouse gases (GHGs)[1]. The greenhouse gases referred to include carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (NO_x). These Greenhouse Gases (GHG) emissions are caused by increasing industrial activities, transportation, electricity production, fires, and mining activities.

CO_2 is the largest contributor to emissions in terms of volume and is mainly produced through electricity consumption and transportation, which are the primary sources of CO_2 emissions [2]. According to the Intergovernmental Panel on Climate Change (IPCC), over 15 years from 1990 to 2005, global temperatures increased by approximately 0.15°C to 0.3°C. Furthermore, if GHG emissions are not significantly reduced, global temperatures are projected to reach or exceed 1.5°C by 2030–2035[3]. Kediri City is the third-largest city in East Java Province after Surabaya and Malang. Therefore, along with the development of infrastructure and increasing population density in Kediri City, it is necessary for the municipal government and environmental experts to conduct analyses and mitigation efforts related to CO_2 emissions, as stipulated in Presidential Regulation No. 14 of 2024 concerning the implementation of carbon capture and storage activities in every institution[4].

Transportation activities and electricity consumption associated with office operations can generate emissions that contribute to global warming. Therefore, research is needed to describe current conditions and the potential future increase in emissions.

1.2. Literature Review

1.2.1. Greenhouse Gases

Greenhouse gases are gases present in the atmosphere that can absorb and emit radiation from sunlight[5]. Greenhouse gases can be formed naturally or as a result of human activities. An increase in the concentration of greenhouse gases in the atmosphere can lead to global warming. Global warming occurs when greenhouse gases continue to accumulate in the air, causing an increase in the average temperature of the atmosphere, land, and oceans on Earth, which ultimately results in extreme climate change and difficulty in predicting seasonal patterns[6] .

Greenhouse gas emissions can be caused by several factors, particularly the use of coal, petroleum, and natural gas, as well as deforestation and forest fires. Nitric acid emissions are generated by vehicles and industrial activities, while methane emissions are primarily caused by industrial and agricultural activities. Several factors contribute to the increase in greenhouse gas concentrations, including the use of fossil fuels, forest degradation, agricultural and livestock sectors, and waste [7].

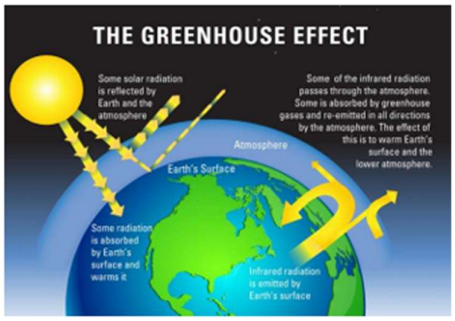

Fig 2.1 *The greenhouse effect*
Source : https://moondoggiesmusic.com/efek-rumah-kaca/#gsc.tab=0

1.2.2. Greenhouse Gas Inventory

The greenhouse gas emission inventory is the process of data collection to calculate GHG emissions using a sectoral approach, which is based on activity sectors or emission-producing sectors within a specific area, such as transportation, residential, industrial, agricultural, and livestock sectors. By conducting a greenhouse gas emission inventory, researchers can determine the amount of emissions generated by each activity sector, compare emission levels over recent years, and perform spatial analysis of emission source burdens. The results can be used to support regional spatial planning, such as the development of green open spaces in areas with high emission levels [8].

1.2.3. Carbon Dioxide (CO_2) Emissions

Carbon dioxide (CO_2) is an odorless and colorless gas produced by all plants, animals, and microorganisms. In addition, CO_2 is also generated through the combustion of fossil fuels. CO_2 accounts for the largest share among the six main greenhouse gases and acts as the primary driver of the greenhouse effect in the atmosphere. CO_2 emissions continue to increase rapidly due to fossil fuel combustion and human activities such as industrialization, agriculture, urbanization, lifestyle patterns, and international trade, which are major contributors to fossil fuel consumption[9]. One of the sectors that significantly contributes to CO_2 emissions is the transportation sector, as energy use in this sector largely depends on petroleum-based fuels such as gasoline, diesel, and jet fuel. The resulting emissions are influenced by the number of trips made by each type of vehicle annually, as well as changes in vehicle fuel efficiency, including travel distance and the type of fuel used[2].

1.3. Research Objective

This study aims to analyze the estimated CO_2 emissions from transportation and energy activities in office environments.

2. MATERIALS AND METHODS

The sampling location was at a municipal government institution in Kediri City. Data collection included emissions from vehicles, waste generation, electricity consumption, and LPG usage. Emission calculations were based on the collected data.

Data collection for vehicle emissions—specifically from vehicles passing through the office entrance to the parking area (average)—was conducted daily for two weeks in the morning and afternoon. Electricity consumption was obtained from secondary data, waste generation was determined from waste weighing data before being transported to the landfill, and LPG consumption data were obtained through interviews with informants.

3. RESULT AND DISCUSSION

3.1. CO_2 Emissions from Transportation

Office activities are closely associated with employees' vehicle use. Generally, the vehicles used include motorcycles and cars. However, to support office operations, several other vehicles, such as dump trucks are also utilized. All of these motor vehicles emit pollutants that can harm the environment. Therefore, it is necessary to calculate the emissions produced by motor vehicles. The data required to calculate these emissions include the number of motorcycles, private cars, operational vehicles (such as tosa vehicles), and dump trucks. Data collection was conducted in August 2025. The initial step in vehicle emission calculation involved direct measurement of the distance from the entrance gate to the parking area using a measuring tape, resulting in a travel distance of 73 meters. Subsequently, the number of vehicles entering and exiting the office area was calculated using a traffic-counting application. Daily vehicle data are presented in Table 1.

Table 1: Recapitulation of Vehicles Entering and Leaving the Office.

Week	Types of Vehicles			
	Car (S)	Motorcycle (B)	Tossa (S)	Dump Truck (S)
1	93	1695	87	171
2	105	1639	90	168
Total	198	3334	177	339
Unit/day	14	238	13	24
Unit/month	424	7144	379	726
Unit/year	5162	86870	4745	8838

Based on data from vehicles passing through the office area, the CO_2 emission load can be calculated based on the IPCC Tier 2. The formula for calculating CO_2 emissions is as follows:

$$\mathbf{Q = Ni \times Fei \times Ki \times L}$$

Information :

- Q : Total CO_2 emissions (g/hour)

• Ni : Number of motorized vehicles (vehicles/hour)
• Fei : CO_2 emission factor for motorized vehicles (g/liter)
• Ki : Vehicle fuel consumption (liters/km)
• L : Road length (km)

The results of the calculations can be seen in Table 2.

Table 2 Vehicle Emission Calculation

Types of Vehicles	Quantity	Road Length (km)	Emission Factor (gr/l)	Fuel Consumption (liter)	CO2 Concentration g/day	Total Concentration (kg/day)	Total Concentration (kg/month)	Total Total (kg/year)
Motorcycle (B)	238	0,073	2597,9	0,0266	1201,3	2,4	73	882
Car (S)	14	0,073	2924,9	0,1064	321,3			
Tosa (S)	13	0,073	2924,9	0,1064	287,2			
Dump Truck (S)	24	0,073	2924,9	0,1168	603,9			

Source: Research findings, 2025

Based on the results of the emission calculations for each vehicle type and the number of vehicles, the total emissions produced were 882 kg CO_2 per year. Emissions from motorcycles amounted to 438.8 kg CO_2, emissions from cars were 117.4 kg CO_2, emissions from dump trucks were 220.6 kg CO_2, and emissions from tossa vehicles were 104.9 kg CO_2.

3.2 CO_2 Emissions from Electricity Consumption

Office activities represent one example of electricity use that can trigger CO_2 emissions. To calculate CO_2 emissions from electricity consumption, data on total electricity consumption in kilowatt-hours (kWh) are required. Based on the secondary data, the total electricity consumption for office activities was 5,877 kWh. The applied electricity emission factor was 0.725 kg CO_2, and the Global Warming Potential (GWP) of CO_2 was set to 1. The formula used to calculate CO_2 emissions from electricity consumption in office activities refers to the IPCC guidelines, as follows:

Emissions CO_2 = EF × Electricity Consumption (kWh)

Using this formula, the calculated CO_2 emissions from electricity consumption amounted to 4,260 kg CO_2 per month or 51,120 kg CO_2 per year. This is mainly due to the use of electronic equipment with high electricity consumption, such as air conditioners (ACs), computers, and other electrical appliances.

3.3 CO_2 emissions from waste generation activities

Office operational activities generate solid waste that contributes to carbon dioxide (CO_2) emissions. Organic and inorganic waste can release CO_2 through natural decomposition processes at the final disposal site (landfill) or through open burning[10]. The composition of the generated waste consists of organic waste (leaves and twigs) and inorganic waste (plastic and paper).

Data collection for the waste sector was conducted by weighing the waste at temporary waste storage bins within the office before it was transported to the landfill. Waste transportation was carried out depending on when the bins reached full capacity. Data on waste generation and composition served as the primary data used to estimate CO_2 emissions from waste management activities. The waste generation and composition at the research location are presented in Table 3 and Figure 1.

Table 2 Office waste generation

Minggu Ke-	Hari	Jumlah Sampah (kg)
1	Rabu	67
	Sabtu	48
2	Rabu	78
	Sabtu	65
Jumlah		258
Rata-Rata per minggu		129
Sampah per bulan		516
Sampah per tahun		6192

Source: Research findings, 2025

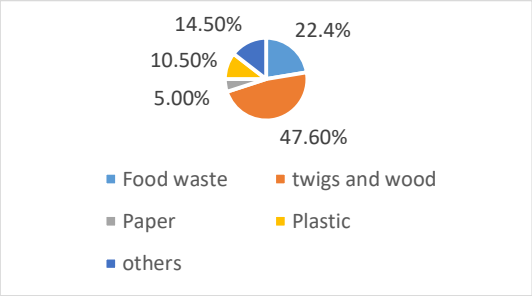

Fig 1 *Waste Composition*
Source: Research findings, 2025

Based on the waste generation data in the office area, CO_2 emission loads can be calculated using the IPCC method, which classifies waste into two categories: organic and inorganic. The equation used to calculate CO_2 emissions is as follows:

A. Organic Waste

$$CH_4\,E = (MSW \times DOC \times DOC_f \times MCF \times F \times \tfrac{16}{12}) - R \times (1 - OX)$$

Information :

- CH_4 E : Quantity of waste generated (ton/year).
- DOC : (Degradable Organic Carbon)
- DOC_f : Degradable DOC fraction (typically 0.5 for non-landfill waste).
- MCF : (Methane Correction Factor)
- F : Methane fraction in landfill gas (typically 0.5).
- $\frac{16}{12}$: Conversion factor from carbon (C) to methane (CH_4).
- R : Conversion factor from carbon (C) to methane (CH_4).
- OX : Methane oxidation factor (typically 0.1 for landfills).

B. Inorganic Waste

$$CH_4\,E = (MSW \times EF)$$

$$CO_2eq\ E = E\ CH_4 \times 28$$

Information:

- CH_4 E : Quantity of waste generated (ton/year).
- MSW : Total waste generated (tons/year)
- EF : Factor emissions

Based on the emission calculation results from the waste sector, it was found that emissions from office waste amounted to 14.28 kg CO_2/year for organic waste and 119 kg CO_2/year for inorganic waste. Therefore, the total CO_2 emissions generated from office waste amount to 133.28 kg CO_2/year.

3.4 CO_2 Emissions from LPG Consumption

LPG consumption at the office originates from canteen activities. The canteen uses LPG gas for daily cooking activities. Data on

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LPG consumption were obtained through direct interviews with two informants. The total amount of LPG used per month by both informants is 15 3-kg LPG cylinders (commonly known as "melon" gas cylinders). Table 3 presents the total LPG cylinder usage:

Table 3: LPG Consumption for Canteen Activities

Narasumber	Jenis Tabung	Penggunaan LPG (tabung/bulan)	Total Penggunaan LPG (kg/bulan)
1. Bu wawan	3 kg	9	27
2. Bu Pri	3 kg	6	18
Total			**45 kg/bulan**
			540 kg/ tahun

From the total amount of LPG used, the resulting CO_2 emissions can be calculated. The formula used to calculate CO_2 emissions according to the IPCC guidelines is as follows:

$$\mathbf{CO_2\ E = LPG\ consumption\ x\ FE\ x\ NCV}$$

The calculation results show emissions of 13.4308 $kgCO_2eq$/month or 161.170 $kgCO_2eq$ /year.

4. CONCLUSION

This study estimated CO_2 emissions from transportation, electricity consumption, waste generation, and LPG use in an office environment of Kediri City using the IPCC approach. The results show that electricity consumption is the dominant source of emissions, accounting for 51,120 kg CO_2/year. Transportation activities contributed 882 kg CO_2/year, while waste generation and LPG consumption produced 133.28 kg CO_2/year and 161.17 kg CO_2/year, respectively. Overall, office operational activities contribute significantly to carbon emissions, with energy use as the primary driver. These findings highlight the importance of improving energy efficiency and implementing emission reduction strategies to support sustainable office management and climate action initiatives.

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