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The Potential of Greenhouse Gas (GHG) Emissions From Energy Consumption in Culinary MSME

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Abstract
The Earth's surface temperature increases each year due to activities carried out by individuals or companies. Calculating the carbon footprint is one way to determine the emissions generated by human activities. Micro, Small, and Medium Enterprise (MSME) business operators have the potential to contribute to the carbon footprints originating from the use of Liquefied Petroleum Gas (LPG), fuel, and electricity. This research serves as a preliminary analysis to understand MSMEs' GHG emissions from energy and fuel use and identify appropriate strategies to reduce their carbon footprint using a standardized calculation method. This research uses a carbon footprint calculation method based on the methodology established by the Intergovernmental Panel on Climate Change. The analysis results show that the most significant emission sources from culinary MSME activities are restaurants, with approximately 3,079 CO_2eq/year, followed by fried chicken at an average of 2,682 CO_2eq/year, and meatball soup at around 2,504 CO2eq/year. The MSME with the highest income is fried chicken, with an average monthly revenue of IDR 19,225,000, while the lowest income is from siomay at IDR 7,700,000 per month. Income has an impact of 93.3% on the carbon footprints. Management measures that can be taken include analyzing which stages of the production process require significant energy, so strategies can be formulated to reduce the emissions produced. Additionally, the government should promote carbon-saving movements and educate the public about energy-efficient household appliances.

Keywords: Fuel, Carbon Footprint, Electricity, LPG, MSME

INTRODUCTION

The avarage temperature of the Earth's surface has increased by about 0,85°C since 1880. Approximately 95% of the Earth's surface temperature increase is caused by human activities, and it is predicted that the surface temperature will continue to rise by 2°C to 4°C. Climate change occurs due to the accumulation of greenhouse gas (GHG) emissions generated by individuals, companies, activities, or goods measured in CO_2eq, expressed in tons of carbon dioxide emissions per year (Ribeiro et al., 2021). Through the United Nation Framework Convention on Climate

Change (UNFCCC), six types of greenhouse gases resulting from human activities are indentified, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFCs), perfluorocarbons (PFCs), and sulfur hexafluide (SF_6) (Jeffry et al., 2021).

Human activities predominantly rely on fossil fuels such as petroleum, natural gas, and coal. The demand for fossil fuels continues to increase in line with population growth, the expansion of activities, and changes in societal lifestyles (Holechek et al., 2022). The assessment of human activities that generate carbon dioxide has become increasingly important. One method to determine the emissions produced by human activities is by calculating the carbon footprint. A carbon footprint refers to the total amount of carbon dioxide emissions produced, both directly and indirectly, from the use of products (Shi & Yin, 2021). Common sources of carbon dioxide for which the carbon footprint is typically calculated include LPG, fuel, and electricity.

Numerous studies have been conducted to identify carbon footprints at various scales, including household level (Rosadi et al., 2022; Fitri et al., 2020), university level (Admaja et al., 2018), industrial level, and even transportation. Micro, Small, and Medium Enterprises (MSMEs) also utilize LPG, fuel, and electricity. Therefore, it is essential to conduct research to determine the total CO_2 emissions produced by MSMEs in the culinary sector based on the types of food they sell.

Medan Baru Subdistrict is a densely populated area, predominantly inhabited by students living temporarily in rented houses or boarding houses (Sibagariang & Saputra, 2021). The development of buildings such as housing and boarding houses has contributed to the growth of MSME businesses. This is due to the strategic location of Medan Baru Subdistrict, which is near several higher education institutions and schools (Zai et al., 2021). Various types of culinary MSMEs are commonly found in each village in Medan Baru Subdistrict, including smashed fried chicken, lontong, restaurants, fried foods, satay, siomay, meatballs, and mie balap (a type of noodle). Hence, further research is needed to determine which types of food generate the highest carbon footprint and what management efforts are appropriate to reduce the emissions produced.

To assess the energy consumption of MSMEs, a survey was conducted, collecting data on business types, revenue, LPG consumption, fuel consumption, and electricity consumption. This data allows for an analysis of the energy consumption patterns of MSMEs based on the types of culinary products they sell. A study was conducted to determine whether there is any correlation between revenue, LPG consumption, fuel consumption, and electricity consumption with the carbon footprint. Additionally, a statistical approach was employed for each type of culinary SME to examine the relationship between revenue and expenses with the emissions produced. Once the relationships between all the variables contributing to the carbon footprint of culinary MSMEs are identified, further efforts will be made to control and reduce the carbon footprint generated.

The urgency of this research lies in the limited studies that focus specifically on the carbon footprint of culinary MSMEs, especially in dense urban areas like Medan Baru Subdistrict. While previous research has explored carbon footprints in various sectors, there remains a gap in localized and food-type-specific assessments within small-scale culinary enterprises. Addressing this gap is vital for encouraging emission reduction efforts tailored to urban food vendors and supporting climate action at the community level. Therefore, this research aims to calculate the carbon footprint produced by culinary MSMEs in Medan Baru Subdistrict based on energy

and fuel consumption and to analyze the variation of emissions by food type. Additionally, it seeks to formulate appropriate emission reduction strategies that culinary MSME operators can adopt to support environmentally sustainable business practices.

RESEARCH METHODS

Time and Location of the Research

This research was conducted from July to September 2024 in Medan Baru Subdistrict, Medan City. The subdistrict consists of six villages with a total of 73 respondents who are culinary MSME actors spread across all villages.

Types and Sources of Data

This research utilizes both primary and secondary data:

a) Primary data was collected through questionnaires distributed to MSME actors to gather information on energy consumption (electricity, LPG, and fuel) and business income.
b) Secondary data was obtained from the Central Bureau of Statistics (BPS) 2023, the Ministry of Environment (KEMENLH), the Directorate General of Electricity of the Ministry of Energy and Mineral Resources (ESDM) 2018, and the IPCC 2006 guidelines.

Data Analysis Techniques

Calculate Primary and Secondary Emissions from the Use of Electricity, LPG, and Transportation Fuels. The calculations are based on the IPCC 2006 methodology using the following equations:

1) Primary Carbon Footprint from LPG Usage

LPG carbon footprint = Fuel consumption × EF × NCV

Information:

- LPG carbon footprint: Total of GHG emissions from LPG usage (Ton CO2 eq)
- Fuel Consumption: Kg/month)
- EF: Emission factor (Kg/TJ)
- NCV: Net Calorific value per unit volume of fuel (TJ/Kg)

2) Primary Carbon Footprint from Fuel Usage

Fuel carbon footprint = Fuel consumption × EF x NCV

- Fuel carbon footprint: Total of GHG emissions from LPG usage (Ton CO2 eq)
- Fuel consumption: (liters/month)
- EF: Emission factor (Kg/TJ)
- NCV: Net Calorific value per unit volume of fuel (TJ/Kg)

3) Secondary Carbon Footprint from Electricity Usage

Electricity carbon footprint = $EFCO_2$ x Electricity consumption (KWh)

- Electricity carbon footprint: Total GHG emissions from electricity usage (Ton CO2eq)
- EF: CO2 emission factor
- Electricity consumption: (kWh)

Total Carbon Footprint (Ton CO2eq) = Primary Carbon Footprint (Ton CO2eq) + Secondary Carbon Footprint (CO2eq)

Emission Factor is a value that represents the amount/quantity of pollutants emitted into the atmosphere by an activity. This research will use the emission factors set nationally/regionally and the default IPCC values.

Table 1. Emission Factor and NCV Values

No.	Emission source	Faktor Emisi	NCV	Sumber
1.	Electricity Consumption	0,00089 Ton CO_2 KWh	-	Director General of ElectricityESDM 2018
2.	Fuel Consumption	74.100 Kg CO_2/TJ	33×10^{-6}TJ/L	*Default* IPCC (KEMENLH, 2012)
3.	LPG Consumption	CO_2 17.200 Kg GRK/TJ CH_4 5 kg GRK/TJ N_2O 0.1 kg GRK/TJ	$47,3\times10^{-6}$ TJ/Kg	*Default* IPCC (KEMENLH, 2012)

The Global Warming Potential (GWP) value converts non-CO2 greenhouse gas emissions data into carbon dioxide equivalent (CO2eq).

Table 2. The GWP Values for Each Greenhouse Gas (GHG)

No.	Gas	GWP (CO_2eq)
1.	Carbon Dioxide ((CO_2)	1
2.	Methane (CH_4)	21
3.	Nitrous Oxide (N_2O)	298

The processing of questionnaires as primary data is also used to identify factors that influence the carbon footprint of MSME activities. This processing utilizes statistical tests with the SPSS program, which helps to find the correlation between income and carbon footprint and between LPG, fuel, and electricity expenditures and the carbon footprint produced in the research area. Additionally, statistical tests are conducted to determine whether sufficient evidence exists to accept or reject the hypothesis.

A linear regression analysis of income against carbon footprint is performed to assess the effect of income as an independent variable on the carbon footprint as a dependent variable. The data must undergo basic assumption tests, including normality and linearity tests. Subsequently, multiple regression analysis is conducted to examine whether there is an impact of LPG, fuel, and electricity energy consumption on the carbon footprint. A t-test is performed in multiple regression to determine whether the independent variables have a partial (individual) effect on the dependent variable.

RESULTS AND DISCUSSION

The Influence of Business Type and Strategic Location on MSME Income

The type of MSME with the highest average income of IDR 19,225,000/month is the smashed fried chicken business, while the lowest income is from siomay with an average of IDR 7,700,000/month. Langga (2021) Factors that influence the income of MSMEs include capital, sales volume, working hours, and location. In addition to capital, a key factor influencing the success of vendors in selling their goods is the location of their business. The more strategic the location, the easier it is for vendors to sell their products (Pratama, 2018). A strategic location has a high potential for buyers, meaning it is easily accessible, visible to consumers, and frequented by the target market (Husaini, 2017). Research Huda & Ismawardi (2020) has proven a correlation between location and income, indicating that the more strategic the business location, the easier it is for customers to make purchases, thereby increasing the vendor's revenue.

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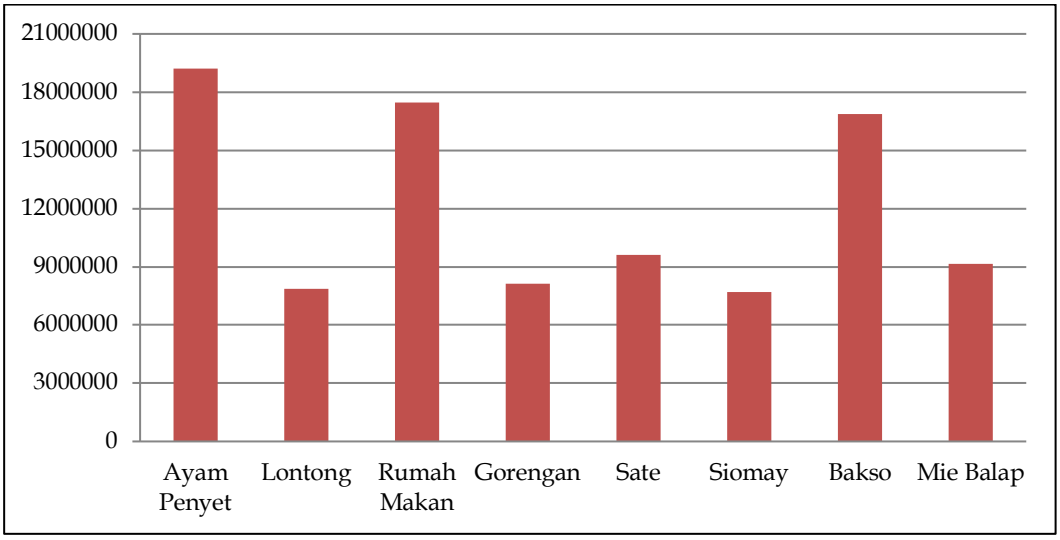

Figure 2. Respond Base on Income (Source: Data Processing, 2024)

Category of LPG, Fuel, and Electricity Consumption

The MSMEs that use the most LPG are the smashed fried chicken business, consuming 95,4375 kg/month or approximately one gas cylinder daily. This is followed by restaurants with 91kg/month, or consuming about one gas cylinder daily. The MSMEs that use the least LPG are siomay, with a consumption of 33 kg/month, or one gas cylinder every three days.

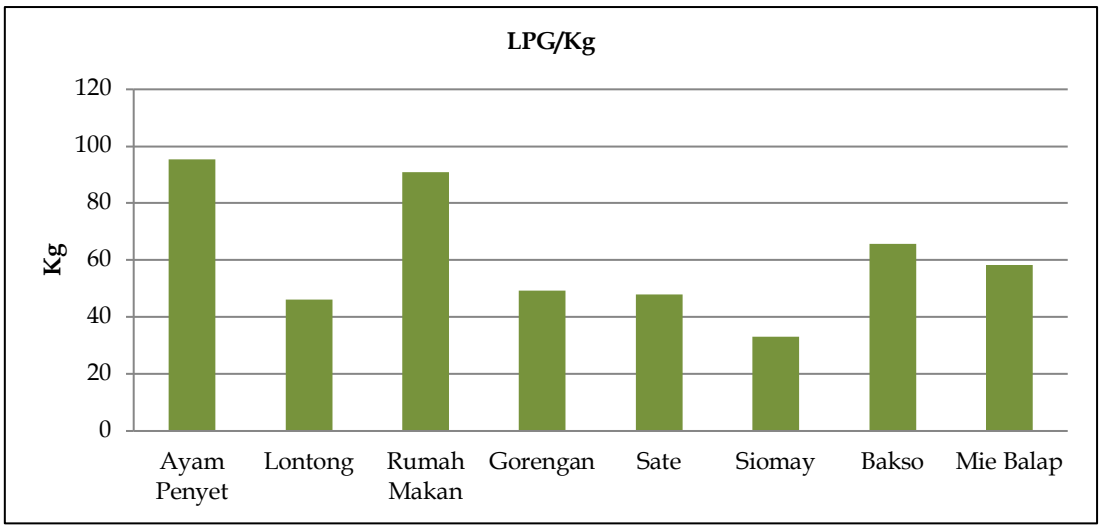

Figure 3. LPG Consumption (Source: Data Processing, 2024)

Regarding fuel oil (BBM) as an energy source, it is generally used as fuel for transportation. The MSMEs that use the most fuel oil are smashed fried chicken businesses, with an avarage consumption of 15 liters/month, followed by restaurants at 12 liters/month. The MSME that uses the least fuel oil is the fried food business, with a consumption of around 4 liters/month. The type of vehicle used for transportation is generally a motorcycle. The amount of fuel oil consumed depends on the distance to the market visited by the MSMES owner. Factors influencing differences in fuel consumption include the distance traveled, the type of vehicle used, and the extent of the road network in the area of residence.

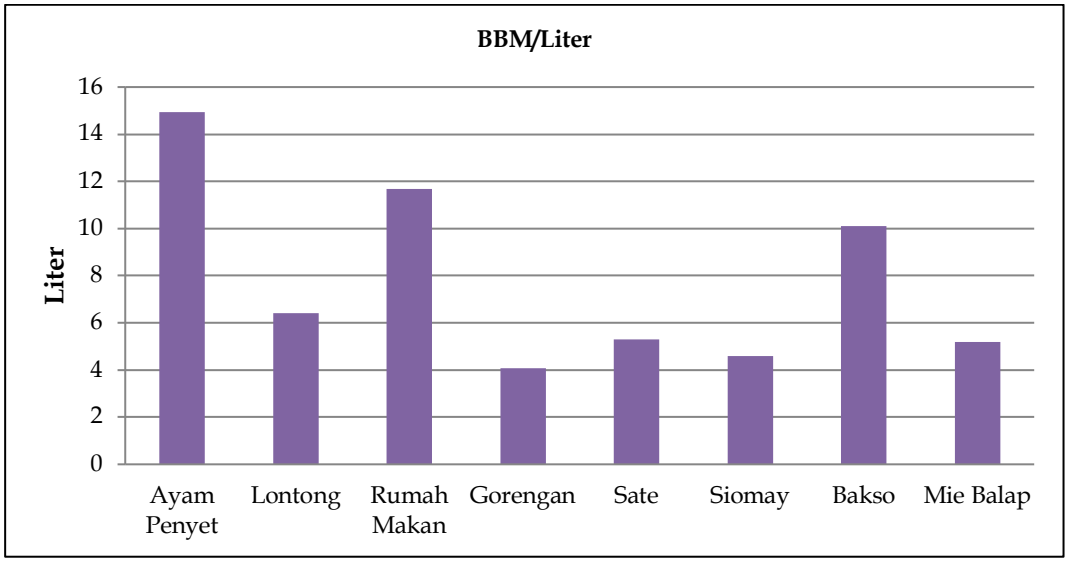

Figure 4. Fuel Consumption (Source: Data Processing, 2024)

The MSME that uses the most electricity for business operations is a restaurant, with a consumption of 173 kWh/month, followed by a meatball business, which requires approximately 146.3 kWh/month. The electricity used by MSME vendors for lighting, heating, cooling, and other purposes. The electricity consumption in restaurants and meatball businesses is due to the many electrical appliances that support customer comfort.

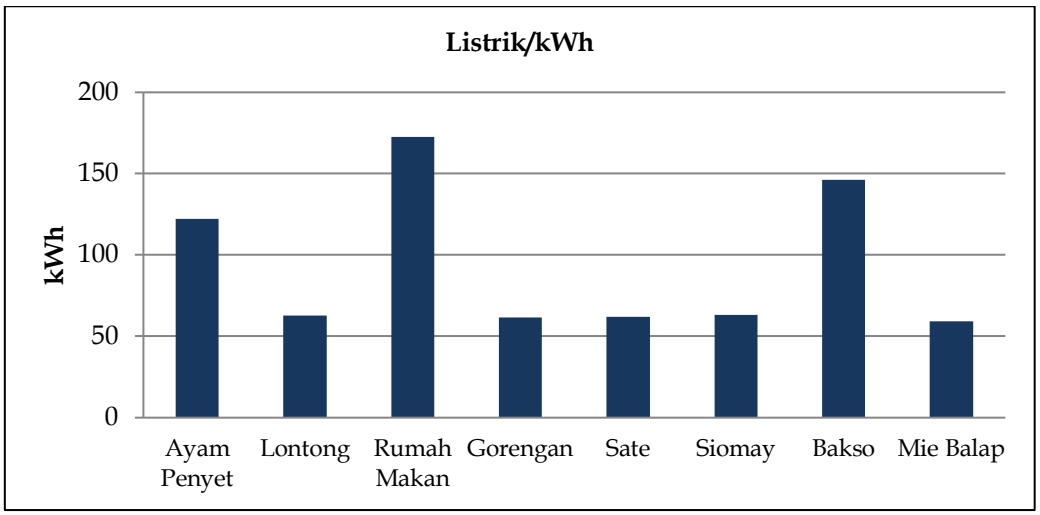

Figure 5. Electricity Consumption (Source: Data Processing, 2024)

Primary CO_2 Emissions from LPG Consumption

CO_2 emissions in this study were calculated based on the total LPG consumption of respondents in one month. The total LPG consumption was multiplied by the emission factor and NCV (Net Calorific Value). The CO_2 emission factor is 17.200 kg/TJ based on the IPCC 1996 guidelines, while the emission factor for N2O is 0.1 kg GHG/TJ, and CH_4 is 5 kg GHG/TJ.

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Table 3. CO_2 Emission from LPG Consumption

No.	MSME	Average LPG Consumption (kg/Month)	Ton Emission (CO_2eq/Year)
1.	Smash Fried Chicken	95,437	0,939
2.	Lontong	46,250	0,455
3.	Restaurant	91	0,895
4.	Fried Food	49,208	0,484
5.	Satay	48	0,472
6.	Siomay	33	0,324
7.	Meatball	65,7	0,646
8.	Mie Balap	58,2	0,572

(Source: Primary Data Processing, 2024)

The culinary MSME that generates the most primary CO_2 emissions from LPG usage is the smashed fried chicken business, with emissions of 0.939 Ton CO_2eq/year, followed by restaurants with 0.895 Ton CO_2eq/year. The MSME that generates the lowest CO_2 emissions from LPG usage is Siomay Business, with 0.324 Ton CO_2eq/year.

Table 4. Primarily CO_2 Emission from Fuel Consumption

No.	MSME	Average Fuel Consumption (liter/Month)	Ton Emission (CO_2eq/Year)
1.	Smash Fried Chicken	14,937	0,438
2.	Lontong	6,416	0,188
3.	Restaurant	11,667	0,342
4.	Fried Food	4,083	0,119
5.	Satay	5,3	0,155
6.	Siomay	4,6	0,134
7.	Meatball	10,1	0,296
8.	Mie Balap	5,2	0,152

(Source: Primary Data Processing, 2024)

The MSME that generates the highest primary CO_2 emissions from fuel usage is the smashed fried chicken business, with emissions of 0.438 ton CO_2eq/year, followed by restaurants with 0.342 ton CO_2eq/year. The MSME with the lowest fuel usage emissions is the fried food business, with 0.119 tons CO_2eq/year.

Table 5. Primarily CO_2 Emission from Electricity Consumption

No.	MSME	Average electricity consumption (kWh/Month)	Ton Emission (CO_2eq/Year)
1.	Smash Fried Chicken	122,162	1,304
2.	Lontong	62,906	0,671
3.	Restaurant	172,431	1,841
4.	Fried Food	61,783	0,659
5.	Satay	62,008	0,662
6.	Siomay	63,356	0,676
7.	Meatball	146,258	1,562
8.	Mie Balap	59,312	0,633

(Source: Primary Data Processing, 2024)

The food production process in SMEs requires electricity as an energy source to help make the production process more efficient. The type of MSME that generates the most significant secondary CO_2 emissions from electricity usage is restaurants, with 1.841 tons of CO_2eq/year, followed by meatball businesses with 1.562 tons of CO_2eq/year. The lowest CO_2 emissions are produced by noodle businesses, with 0.633 tons of CO2eq/year. This is consistent with the statement Sasmita et al. (2018), which mentions that CO_2 emissions from electricity usage are closely related to the amount of electricity consumed. This can also be influenced by the power and operating duration of the electronic devices used daily.

Table 6. Total (GHG) Emissions in the Energy Sector

No.	MSME	CO_2eq Emission/Year LPG	CO_2 Emission/yea r Fuel	CO_2 Emission/Yea r Electricity	Total (GHG) CO_2eq Emissions /Year
1.	Smashed Fried Chicken	0,939	0,438	1,304	2,682
2.	Lontong	0,455	0,188	0,671	1,315
3.	Restaurant	0,895	0,342	1,841	3,079
4.	Fried Food	0,484	0,119	0,659	1,263
5.	Satay	0,472	0,155	0,662	1,290
6.	Siomay	0,324	0,134	0,676	1,136
7.	Meatball	0,646	0,296	1,562	2,504
8.	Mie Balap	0,572	0,152	0,633	1,358

(Source: Primary Data Processing, 2024)

The calculation of total GHG emissions in micro-scale MSMEs, which are the largest emitters, shows that restaurants produce around 3.079 tons of CO_2eq/year, followed by smashed fried chicken businesses with approximately 2.682 tons of CO_2eq/year, and meatball businesses with around 2.504 tons of CO_2eq/year. In contrast, the MSME with the lowest emissions is the siomay business, with 1.136 tons of CO_2eq/year. The high total emissions produced by these types of MSMEs are due to the patterns of LPG usage, fuel consumption, and electricity consumption, which are higher than other types of MSMEs.

Table 7. Results of the Correlation Test Between Income and Carbon Footprint

		Income	Carbon Footprint
Income	Pearson Correlation	1	,829**
	Sig. (2-tailed)		,000
Carbon Footprint	Pearson Correlation	,829**	1
	Sig. (2-tailed)	,000	

(Source: Primary Data Processing, 2024)

The correlation test results between income and carbon footprint show a significance value of 0.000. The significance value <0.05 indicates that income and carbon footprint are related or correlated. The *Pearson correlation* value obtained is (+) 0.892, which signifies a direct relationship between the two variables. Thus, it can be concluded that the higher the income generated by the MSMEs, the greater the consumption of LPG, fuel, and electricity.

The correlation test results also show that the significance value for F change is 0.000. The obtained significance value <0.05 indicates that LPG expenditure, fuel expenditure, and electricity expenditure have a relationship or correlation with the dependent variable, which is the carbon footprint. The *Pearson correlation* value obtained is (+) 0.960, indicating a direct relationship between the two variables. When interpreted, a correlation value of 0.960 falls within the range of >0.75 < 1, suggesting a robust correlation. Therefore, it can be concluded that the higher the expenditure on LPG, fuel, and electricity, the greater the emissions generated.

The results of the linear regression test conducted between income and carbon footprint show a correlation/related coefficient (R) of 0.966 with a coefficient of determination (R square) of 0.933, which means that the effect of the independent variable (income) on the dependent variable (carbon footprint) is 93.3%. In the F-test, it can be seen that the significance value for the effect of LPG, fuel, and electricity energy consumption on the carbon footprint simultaneously is 0.000 < 0.05, and the F-value obtained is 44,905,754,666.441, which is greater than the F-table value of 5.41. Therefore, it can be concluded that LPG, fuel, and electricity energy consumption affect the carbon footprint simultaneously.

Carbon Footprint Mitigation Management

To mitigate carbon emissions, optimizing the transportation pattern in purchasing raw materials is essential for MSMEs. MSMEs can significantly reduce the emissions generated by minimizing the number of trips required to gather ingredients. Streamlining supply chains and consolidating deliveries can also lead to lower fuel consumption and reduced carbon footprints. Furthermore, MSME owners can intentionally adopt eco-friendly practices such as using high-octane and environmentally friendly fuels, which can further decrease the amount of pollutants emitted into the atmosphere. Research (Nabila et al., 2025) indicates that improved logistics and fuel management in small-scale enterprises can lead to reductions in carbon emissions, showcasing how minor adjustments can considerably impact sustainability.

One innovative approach noted in MSMEs, particularly in the culinary sector, involves reducing the reliance on refrigeration. Many culinary MSMEs avoid using refrigerators for storing perishable goods like vegetables, meat, and spices, instead opting for storage in open spaces. While this may initially seem inefficient, the rationale behind this decision is often cost-saving by avoiding refrigeration, owners reduce electricity consumption. This strategy has an unintended environmental benefit, reducing the carbon emissions associated with electricity use. Additionally, some MSME owners subscribe to suppliers of vegetables, meat, and chicken to eliminate the need for frequent trips to the market, further decreasing fuel consumption. This practice of optimizing operations reduces costs and lowers emissions, as demonstrated by research Sahu et al. (2021), which found that supply chain improvements can lead to financial and environmental benefits for MSMEs.

In recent years, many MSMEs have switched to using LED lights, which are more energy-efficient than traditional lighting such as HID (High Intensity Discharge). According to research Ruslan et al. (2021), LED lights consume significantly less power and have a much longer lifespan than incandescent bulbs. This transition is part of a broader effort to reduce energy consumption in MSME operations. LED lights have been shown to reduce operational costs and play a role in lowering the carbon emissions

associated with electricity use in businesses. The widespread adoption of energy-efficient lighting has been reported as a practical and impactful measure for MSMEs looking to decrease their environmental footprint.

Moreover, some MSME owners have diversified their product offerings to optimize energy use and boost income. For example, a lontong vendor may expand their menu to include fried foods and side dishes, with all the cooking processes requiring similar energy inputs. This diversification strategy maximizes energy efficiency by consolidating cooking operations and helps increase sales and profits. According to research Judijanto et al. (2023), product diversification is a common strategy employed by MSMEs to enhance both operational efficiency and revenue generation.

CONCLUSION

The MSME with the highest income is the smashed fried chicken business, with an average income of IDR 19,225,000/month, while the MSME with the lowest income is the siomay business, with an IDR 7,700,000/month. The MSME with the highest LPG consumption is the smashed fried chicken business, using 95.4375 kg/month, or approximately one gas cylinder per day. At the same time, the lowest is the siomay business, using 33 kg/month, or one gas cylinder every three days. The MSME with the highest fuel consumption is the smashed fried chicken business, using about 15 liters/month, and the lowest is the fried food business, using approximately 4 liters/month. The MSME with the highest electricity consumption is the restaurant, using 173 kWh per month, while the lowest is the noodle business, using 60 kWh per month.

The MSME with the highest GHG emissions is the restaurant, generating approximately 3.079 tons of CO2eq/year, followed by the smashed fried chicken business at 2.682 tons of CO2eq/year, and the meatball business at 2.504 tons of CO2eq/year. In the linear regression test, income has a significant influence of 93.3% on the carbon footprint, with a positive relationship between income and carbon footprint. Management strategies that can be implemented include analyzing the stages of the production process that require significant energy, allowing for the formulating of strategies to reduce the emissions generated. Typically, energy waste in production is caused by overproduction, transportation, inventory, waiting, scrap/defect, and overprocessing.

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