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Estimation of Carbon Footprint Emission Consumption in Electricity from Individual Student: Case Study in Department of Economics, Universitas Diponegoro

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ABSTRAK

Penelitian ini bertujuan untuk menganalisis estimasi emisi jejak karbon berdasarkan konsumsi listrik harian, serta memberikan strategi yang ditujukan untuk mengurangi emisi gas rumah kaca. Metode yang digunakan metode kuantitatif yaitu menggunakan statistik deskriptif. Pengumpulan data diperoleh secara purposive sampling terhadap mahasiswa ekonomi Universitas Diponegoro, dengan jumlah sampel sebanyak 61 mahasiswa. Penelitian ini menggunakan rumus perhitungan emisi CO_2 yang diperoleh dari perkalian penggunaan energi listrik peralatan elektronik dengan faktor emisi sesuai dengan Kementerian Energi dan Sumber Daya Mineral (ESDM) berdasarkan IPCC Guidelines, 2006. Hasil menunjukkan bahwa estimasi jejak karbon per kategori, yang menyajikan perbandingan konsumsi barang elektronik pada mahasiswa kelas menengah atas dan kelas menengah bawah, terdapat 3 kategori yaitu rendah, sedang dan tinggi dimana dari tabulasi silang diperoleh hasil pada kategori rendah sebesar 93 persen dari total 100 persen. Oleh karena itu, mahasiswa yang mengonsumsi listrik sehingga menghasilkan emisi karbon di Universitas Diponegoro tergolong rendah yaitu mencapai 93 persen dan konsumsi tertinggi mencapai 4,92 persen yang mana masih berada di bawah 5 persen baku mutu konsumsi karbon yang merupakan suatu capaian yang baik dalam membantu menjaga keberlanjutan lingkungan universitas.

Kata kunci: *Jejak Karbon, Emisi Karbon, Listrik, Gas Rumah Kaca, Pemanasan Global*

ABSTRACT

This research aims to analyze estimated carbon footprint emissions based on daily electricity consumption, as well as provide strategies aimed at reducing greenhouse gas emissions. The method applies a quantitative approach using descriptive statistics. Data collection was obtained through purposive sampling of economics students at Diponegoro University, with a total sample of 61 students. The CO_2 emissions calculates by multiplying electricity use with the ESDM emission factor based on the 2006 IPCC Guidelines. The result shows that the estimated carbon footprint per category, which presents a comparison of the consumption of electronic goods among upper middle class and lower middle-class students, there are 3 categories: low, medium and high where cross tabulation obtained results in the low category of 93 percent out of a total of 100 percent. Therefore, the students who consume electricity resulting in carbon emissions at Diponegoro University are relatively low, reaching 93 percent and the highest consumption reaches 4.92 percent, which is still below 5 percent of the carbon consumption standard, which is a good achievement in helping to maintain the sustainability of the university's environment.

Keywords: *Carbon Footprint, Carbon Emission, Electricity, Greenhouse Gas, Global Warming*

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1. INTRODUCTION

The issue of carbon in Indonesia has recently become one of the important issues because global warming is a major threat to the environment and world economic development and gives rise to Greenhouse Gases (GHGs) (Ministry of Energy and Mineral Resources of Indonesia, 2019; Rachmatika & Rosalina, 2023). Greenhouse gases (GHGs) are gases that have a direct or indirect impact on global warming on climate change (Fitri et al., 2020). The greenhouse effect is a phenomenon where gases collect and trap heat in the earth's atmosphere and cause an increase in global temperatures (IPCC, 2006). According to Rocha et al. (2023), one of the greenhouse gases that plays the most role in triggering global warming is carbon dioxide (CO_2). The increasing levels of greenhouse gases (GHG) in the atmosphere, especially due to human activities, have increased the greenhouse effect and consequently caused an increase in the earth's temperature (IPCC, 2006).

Each greenhouse gas has a Global Warming Potential (GWP), which was designed to facilitate comparisons of the global warming consequences of different gases (Sipayung, 2023). Greenhouse gases from anthropogenic emissions arise from multiple sources, including the energy sector. The excessive use of fossil fuels in general worldwide such as petroleum, coal, and gas in diverse activities is the major cause of the release of greenhouse gas emissions into the atmosphere (Wulandari & Hermawan, 2013). One of the popular measurements that can provide evidence that there is carbon income from electronic devices in individual boarding house residents is by calculating the carbon footprint (Qian et al., 2023). Salim & Shridhar (2019) stated that carbon footprint is a greenhouse gas (greenhouse gas) produced by an activity. It is connected to the quantity of greenhouse gases created in our everyday life through the use of fossil fuels for power, heating, transportation, and others.

Previous research conducted by Bera (2022) where a significant gap between the living conditions and lifestyles of people living in rural and urban areas in India, there were considerable disparities in the yearly per capita carbon footprint (households, travel, lifestyle, and overall carbon footprint) between various income levels in rural and urban locations. Another notable distinction is the variation in monthly expenditure categories between urban and rural households. In line with research from Zhang et al. (2015), where the significant increase in living standards in the study due to accelerated economic development has resulted in an undue increase in household energy use. Followed by the implementation of policies to reduce the negative impact of household behavior on the environment and technologies with low carbon intensity advantages are also being promoted to improve energy efficiency and reduce carbon emission pollution.

The following research aims to estimate the use of carbon in the consumption of electronic goods. Unlike previous results that examined at the household level, this research focused on carbon estimation in the use of electronic devices in the younger generation. As is known, today's young generation can be said to be unable to live without technology (Zhitomirsky-Geffet & Blau, 2016). The massive use of technology will certainly lead to an increase in electricity use which will ultimately contribute to carbon production (Goldstein et al., 2020). This is certainly not realized in detail by humans in general, this research will contribute as a material for evaluating the use of electronic goods in the younger generation, precisely students.

2. METHODS

2.1. Literature Review

2.1.1. Carbon Footprint

Carbon Footprint is defined as a measure of the total amount of carbon dioxide emissions that are direct (primary) or indirect (secondary) caused by excessive activities and accumulation from the use of products in daily life (Doulabi & Hejazi, 2018). The carbon footprint is the total amount of greenhouse gas emissions that are directly and indirectly the result of an activity or accumulated during the production process stages (Galli et al., 2012). Meanwhile, according to Salim & Shridhar (2019), carbon footprint is the greenhouse gas produced by an activity. This study explores more broadly the amount of greenhouse gas produced in our daily lives through the burning of fossil fuels for electricity, heating, transportation and others towards today's generation z.

The carbon footprint itself is divided into two main sources, primary carbon footprint and secondary carbon footprint. The primary carbon footprint is a source of CO_2 emissions that come from direct combustion. The secondary carbon footprint is a source of the amount of CO_2 emissions produced indirectly, such as electricity consumption. Facts and research results of experts show that there is a tendency for the amount of greenhouse gases such as CO_2 in the atmosphere to have exceeded the limit that should be (Goldstein et al., 2020). Carbon footprint can be used to calculate the activities of individuals, populations, governments, companies, organizations, processes, and industrial sectors (Wardhana, 2016). The consumption-based approach to carbon footprinting could expand the production-based approach inventoried by National Greenhouse Gas Agencies, following as agreed in the Kyoto Protocol (Galli et al., 2012).

Human activities that have the potential to cause CO_2 emissions can be calculated by looking at the use of fossil fuels in everyday human life in the form of petroleum or natural gas which directly through the transportation used can produce CO_2 and looking at excess consumption of electricity for daily needs (Rahmadania, 2022). CO_2 emissions from electricity use activities produce from power plants as a supplier of electrical energy used and the CO_2 value produced is calculated from the amount of electricity used daily. The carbon footprint, also known as the Carbon Footprint (CFP), is expressed in tonne CO_2 equivalent(tCO_2e) or kg-equivalent-CO_2($kgCO_2e$) (Salim & Shridhar, 2019;Wiedmann & Minx, 2008). Action based on carbon footprint can not only leverage and strengthen the growing international cooperation between developing countries and developed countries, but also make consumers aware of how much greenhouse gas emissions are caused by their lifestyles and indirectly also increase awareness among governments and businesses about the magnitude of emissions (Lenzen et al., 2018).

2.1.2. Life Cycle Assesment (LCA)

A life cycle assessment evaluates the environmental impact of products and services, taking into account emissions and resource usage during manufacturing, distribution, use, and disposal (Zhang et al., 2015). LCA is broken down into three distinct analytical steps: (1) identifying the processes involved in a product's life cycle, (2) measuring the environmental pressures resulting from emissions, resource use generated by each of these processes, and (3) assessing environmental externalities and combining externality indicators (Goldstein et al., 2020).

Process-based LCA, input-output LCA, and hybrid LCA are some of the most commonly utilized life cycle methodologies. Process-based LCA is a bottom-up approach that describes each individual step in the supply chain in terms of material inputs and environmental outcomes. Input-output LCA is a top-down approach that looks at and indicates the resource and waste emissions implications of producing a particular good or service, while hybrid LCA brings together the benefits of all of these methodologies while incorporating their uniquely valuable qualities (Salim & Shridhar, 2019). The LCA in this study considers the emissions and resource use associated with the use and disposal of an everyday electricity product by individual students during their activities over a one-month period.

2.1.3. Global Warming

Global warming is caused by significant emissions of greenhouse gases, including CO_2, which are externalities from fossil fuels and deforestation (Zhu et al., 2021). The accumulation of dangerous gas concentrations in the atmosphere causes the greenhouse effect, where the sun's heat collects and cannot escape into the atmosphere and drastically increases the temperature on the earth's surface (Pratiwi & Fitri, 2021;Abdul Maulud et al., 2021). The environmental externalities that occur can be shown by facts such as increasingly extreme climate change, increasingly hot air waves, and disproportionate sea levels. Extreme climate change is a climate change that is directly or indirectly related to various human activities and can change the composition of the global atmosphere with the emergence of natural climate variables that are directly proportional to the time period (Rahmadania, 2022).

Climate change continues to be a direct and dangerous obstacle to the survival of all creatures on this earth, and it is our business and responsibility as humans to restore any environmental damage to restore the balance of nature (Yao et al., 2021). The increase in the amount of carbon in the atmosphere continues to increase year by year. Since the industrial revolution in the 18th century, fossil fuels in the form of coal and petroleum have continued to be used. The combustion process of this fuel used continuously releases CO_2 and results in an increase in the amount of carbon concentration in the atmosphere. This excessive concentration affects the rise in the earth's surface temperature which continues to rise because the heat from solar radiation is completely trapped by the earth's mantle (Fitri et al., 2019; Suwarni et al., 2021).

One of the reasons for global warming is that some of the sunlight that goes to the earth is deflected by the atmoster and reflected back to the outside of the earth and some of it reaches the earth's surface and is reflected into the atmosphere as a type of energy that moves slowly and is called infrared radiation (Myori et al., 2019; Fachri et al., 2015). This infrared radiation causes heat and is absorbed by greenhouse gases such as air vapor, carbon dioxide, ozone and methane which are then trapped in the atmosphere so that it continues to affect the rise in temperature on the earth's surface (Putra et al., 2019; Julisman et al., 2017). Greenhouse gases (GHGs) are gases in the atmosphere that function as the earth's mantle to absorb solar radiation in the atmosphere so as to keep the earth's surface temperature warm, but the excess of these gases will cause unusual warming or global warming. This is caused by natural processes and various human activities (Qian et al., 2023).

According to the UNFCCC (United Nations Framework Convention on Climate Change) (2022), the UN convention on climate change states that six gases are classified as GHGs, namely carbon dioxide (CO_2), dinitrous oxide (N_2O), methane (CH_4), sulfurhexafluoride (SF6) and perfluorocarbons (PFCs). All of these GHGs have varying global warming potentials and are generated by various human based activities, especially fossil fuel burning and deforestation. However, based on the report of the Intergovernmental Panel on Climate Change (IPCC) in 2013, there has been an acceleration of global warming due to the increase in greenhouse gas (GHG) production in the atmosphere derived from the utilize of fossil fuels and other human based activities such as land use change and conversion. The IPCC update on Global Warming of 1.5°C in 2017 stated that the current temperature of the earth has mount up by about 1°C set side by side to pre-industrial times (Rachmatika & Rosalina, 2023).

2.2. Research Method

This study uses a quantitative method (Creswell & Creswell, 2018). Primary data obtained by quantitative method by filling out questionnaires to respondents. The research was conducted at Diponegoro University, precisely the Department of Economics and Business. The data in this study is the daily electricity consumption of respondents for 1 month with a forward count starting on September 10

– October 10, 2023. The sample of respondents in this study amounted to 61 students who were taken by purposive sampling technique with the criteria of undergraduate students of the economics program who took courses in natural resources and environmental economics. The number of people with these criteria is 105 people, so the number of respondents is said to be sufficient because it is twice the standard of data adequacy for statistics. This study explained a quantitative analysis using descriptive statistics with bar chart with line, cross tabulation and bar charts.

Carbon Dioxide (CO_2) emissions in this study are included in the carbon footprint of secondary emissions where are emissions produced from all electronic appliances in households that utilize electrical power. The calculation used to calculate the amount of secondary CO_2 emissions is by multiplying the secondary emission factor followed by the amount of power consumed by one student in one month. The formula for calculating secondary CO_2 emissions uses calculations from the Ministry of Energy and Mineral Resources of Indonesia with a Ministerial Regulation issued referring to the internationally agreed guidelines for national GHG inventories for the energy sector, namely the 2006 Guidelines for National Greenhouse Gas Inventories Volume 2 for Energy issued by the Intergovernmental Panel on Climate Change (IPCC) (Qian et al., 2023; Fitri et al., 2020).

Secondary CO_2 emissions with the following calculation formula (Ministry of Energy and Mineral Resources of Indonesia, 2019):

$$CO_2 Emissions = EF \times Electricity\ Consumption$$

Information:

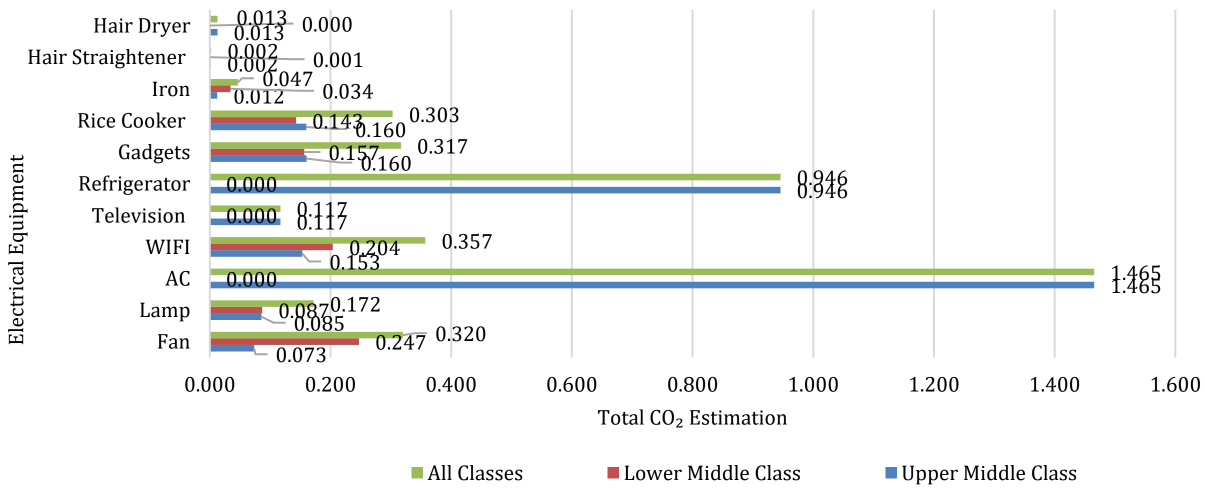
Electricity Consumption: Electricity consumed (KWh).

EF: CO_2 Factor Emissions from electricity consumption.

3. RESULT AND DISCUSSION

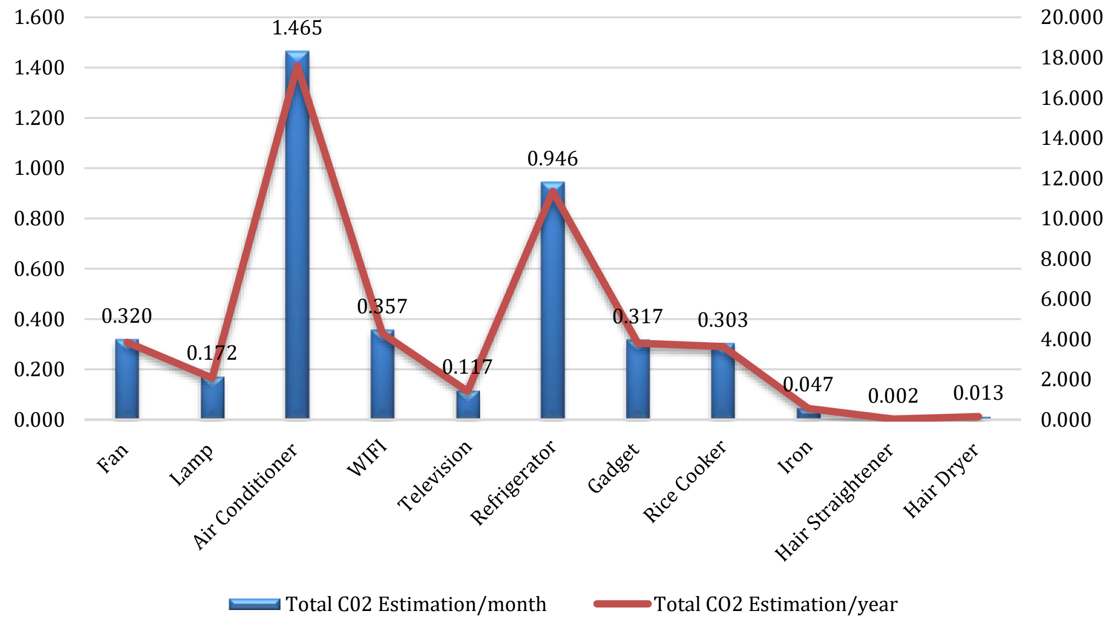
The results are described using descriptive statistical analysis which serves to describe the research data, especially highlighting key metrics such as minimum (min), maximum (max), average (average), and standard deviation (std dev) for details of the research variables.

Figure 1 shows the results of the comparison of estimated carbon footprint in electricity consumption in upper middle and lower middle school students. Components consisting of 11 electronic items that are widely consumed on a daily basis. The three components of electronic goods that produce the highest carbon footprint are air conditioners of 1.465 tons of CO_2/house/month, then there are refrigerators or refrigerators of 0.946 tons of CO_2/house/month, followed by WIFI of 0.357 tons of CO_2/house/month. Where the highest upper middle-class students use air conditioners, refrigerators, rice cookers and gadgets, in contrast to lower middle school students who use fans, WIFI and gadgets the most as items that produce the most carbon. Meanwhile, the three components with the lowest carbon footprint estimates for all students are hair straighteners of 0.002 tons of CO_2/house/month, the second is a hair dryer of 0.013 tons of CO_2/house/month, and the third is an iron of 0.047 tons of CO_2/house/month.



Source: Primary data, processed (2024)

Figure 1. Comparison of Estimated Carbon Footprint on Electricity Consumption (N=61)



Source: Primary data, processed (2024)

Figure 2. Estimated of Carbon Footprint Emissions in Electricity Use per Month and Year (N=61) (ton CO_2/house)

Table 1. Carbon Footprint Analysis on Electricity Consumption (N=61)

Electrical Equipment	Carbon Footprint of Electricity Consumption (ton CO_2/house/month)			
	Mean	Minimum	Maximum	Std. dev.
Fan	0,04568	0,01057	0,01196	0,00056
Lamp	0,02493	0,00542	0,00719	0,00073
Air Conditioning (AC)	0,20935	0,04750	0,05826	0,00368
WIFI	0,05102	0,01232	0,01360	0,00045
Television	0,01670	0,00012	0,02788	0,01045
Refrigerator	0,13510	0,03291	0,03392	0,00038
Gadgets	0,04525	0,01071	0,01181	0,00043
Rice Cooker	0,04328	0,00925	0,01182	0,00098
Iron	0,00665	0,00063	0,00273	0,00071
Hair Straightener	0,00032	0	0,00043	0,00016
Hair Dryer	0,00182	0,00028	0,00060	0,00014

Source: Primary data, processed (2024)

Table 2. Cross-Tabulation Analysis between Electricity Consumption and Carbon Emissions (N=61)

Electricity Consumption per Month	Carbon Dioxide Emissions (CO_2)							
	Low (0,000 - 0,499)		*Medium (0,500 - 0,999)*		*High (1,000 - 1,500)*		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Low	46	75,41	11	18,03	0	0	57	93,44
Medium	0	0,00	1	1,64	0	0	1	1,64
High	0	0,00	2	3,28	1	1,64	3	4,92
Total	46	75,41	14	22,95	1	1,64	61	100

Source: Primary data, processed (2024)

Figure 2 provides an overview of the estimated of carbon footprint emission of electricity use from individual student who get 3 items as the largest contributors, with the total of Air Conditioner (AC) with 1.465 ton/month equal to 36 percent, followed by refrigerators at 0.946 ton/month equal to 23 percent, and WIFI at 0.357 ton/month equal to 9 percent. The middle yield was occupied by 3 items, namely gadgets, rice cookers, and fans with an estimated result of 8 percent. As for the lowest use, it is found in hair straighteners, hair dryers and irons because judging from the rarity of people who have these items.

Table 1 explains the carbon footprint of electricity consumption with the average yield or average of the three highest items, namely air conditioning with 0.20935 tons of CO_2/house/month. As for the minimum carbon footprint in student electricity consumption, the first is hair straightener of 0 because it is the least expensive item for students to have. The maximum result for carbon footprint in student electricity consumption is three items with the highest carbon footprint, namely air conditioning with 0.05826 tons of CO_2/house/month. The standard deviation results show that the gadget has a large range of variation results while hair straighteners with a small range of variation in the data.

Table 2 is the result of the cross-tabulation between students' electricity consumption and the results of carbon dioxide (CO_2) estimation which is measured based on 3 categories, namely low, medium, and high. In the low category cross-tabulation obtained 93 percent of the total 100 percent. The medium category is 2 percent of the total and the high category gets 5 percent of the total 100 percent. Where it can be seen from the results of this cross-tabulation estimation that electricity consumption in economics students is relatively low. This study obtained quite different results from the previous study conducted by Bera (2022) there are significant implications in carbon footprint (household, travel, lifestyle, and total carbon footprint) between the lives of different income groups in rural and urban areas, while in this study it was assumed that each student's income was the same as their lifestyle. However, in the research of Zhang et al. (2015), the improvement of living standards greatly affects the increase in household energy consumption, so it needs to be balanced with the implementation of policies to encourage energy efficiency and reduce carbon emissions, just like the results of this study that students also use electrical equipment efficiently and begin to realize the impact of carbon emissions on the surrounding environment.

4. CONCLUSION

The estimated carbon dioxide (CO_2) emissions based on the results of a survey from economics students at Diponegoro University who took economics and natural resources and environment courses through questionnaires and calculations of the Intergovernmental Panel on Climate Change (IPCC) obtained a total emission value of 4.0584 tons of CO_2/month so that per year it contributes a carbon emission value of 48.7013 CO_2/year. Where these results were obtained from 11 types of electronic goods that are routinely consumed by all students, including fans, lights, air conditioners, WIFI, televisions, refrigerators, gadgets, rice cookers, clothes irons, hair straighteners, and hair dryers. Based on the maximum and minimum estimated values, it is known that there are three electrical appliances that contribute the highest and lowest carbon dioxide (CO_2), namely the three highest are air conditioners, refrigerators, and televisions, while the three lowest are hair straighteners, televisions, and hair dryers.

Based on this study, it is also known how the results of carbon footprint estimation per category, where there are 3 categories, namely low, medium, and high where cross tabulation obtained results in the low category of 93 percent. The medium yield was 2 percent of the total and the high category obtained 5 percent of the total 100%. Therefore, it can be concluded that the use of electricity consumption by economics students at Universitas Diponegoro is classified as low or low reaching 93 percent, which is a good achievement in helping to preserve the university environment.

Based on the results and discussion, it can be understood that individual student income greatly affects lifestyle patterns and daily electricy usage. Income here can come from funding from individual families, side jobs, to scholarships or other funding that can help support daily life activities.

Knowing that some of the electronic goods above contribute a fairly high carbon dioxide (CO_2) emission value, a strategy that can be taken as a first step to reduce or prevent an increase in the value of carbon dioxide (CO_2) emissions is to start switching to eco-friendly standard electrical equipment followed by low-watt electricity consumption. As well as starting to recognize and utilize equipment, both electric and non-electric, which is included in renewable energy is also environmentally friendly. Researchers hope that this research can help both current and future generations to be more aware of the importance of reducing the use of household appliances that produce carbon dioxide (CO_2), although it is difficult to avoid but we can start reducing or switching to more eco-friendly appliances. The author hopes that for future research, it can further develop research areas and strategies and solutions for diversion of carbon dioxide (CO_2) consumption.

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