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The Effect of Population, GDP, Non-Renewable Energy Consumption and Renewable Energy Consumption on Carbon Dioxide Emissions in G-20 Member Countries

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ABSTRACT

The purpose of this study is to analyze the effect of population, gross domestic product (GDP), consumption of non-renewable energy (RE), and RE on carbon dioxide (CO_2) emissions in The G-20 Member Countries for the period of 2010-2019. The data used in this study is panel data. The data used in this study is secondary data obtained from the World Bank and BP Statistical Review of World Energy. This study uses panel data regression analysis through the E-views 11 program. The results of the analysis in this study show that (1) the population has a positive and significant effect on CO_2 emissions (COEs) in Thhe G-20 Member Countries, (2) GDP has a positive and insignificant effect on COEs in The G-20 Member States, (3) consumption of non-RE has a positive and significant effect on COEs in The G-20 Member States, (4) consumption RE has a negative and significant effect on COEs in The G-20 Member States, (5) Population variables, GDP, non-RE consumption, and RE consumption together have a significant effect on COEs in The G-20 Member Countries.

Keywords: Carbon Dioxide Emissions, Population, Gross Domestic Product, Non-Renewable Energy Consumption, Renewable Energy Consumption
JEL Classifications: O44; Q56

1. INTRODUCTION

Climate change is one of the big problems that arise at this time and requires immediate action. Climate change occurs because of the phenomenon of rising earth's temperature or often referred to as global warming. At first the earth's temperature rose slowly, which was only about 0.2°C from the year 1000 to the 19th century. However, the increase increased rapidly in 1850, namely 0.35°C in 1910-1940 and 0.55°C in 1990-2000. In addition, according to Intergovernmental Panel on Climate Change records, in the last 100 years there has been an increase in global average temperature of 0.78°C (1906-2005) (Team SOS, 2011). 2019 was the second warmest year on record for 140 years, with temperatures averaging 0.95°C (1.71°F) at different global sea and land surfaces (NOAA National Centers for Environmental, 2020).

Global warming is one of the impacts of increasing greenhouse gases (GHG) from the atmosphere caused by human activities which results in an increase in the greenhouse effect. The main GHG are water vapor, carbon dioxide (CO_2), methane, nitrous oxide, ozone and halocarbon gases. Global GHG emissions consist mostly of CO_2 around 74% and the other part comes from methane, nitrous oxide and fluorinated gases (consisting of hydrofluorocarbons [HFCs], PFCs, SF6 and NF3) with 17%, 5% and 3% respectively (Olivier and Peters, 2020).

Most of the world's greenhouse gas emissions come from CO_2 emissions (COEs). From Figure 1 it can be seen that COEs in the world in 2010-2019 are fluctuating but tend to increase, the increase comes from various factors. One of the factors that contribute the most to COEs is the consumption of non-renewable energy (RE) (fossil energy).
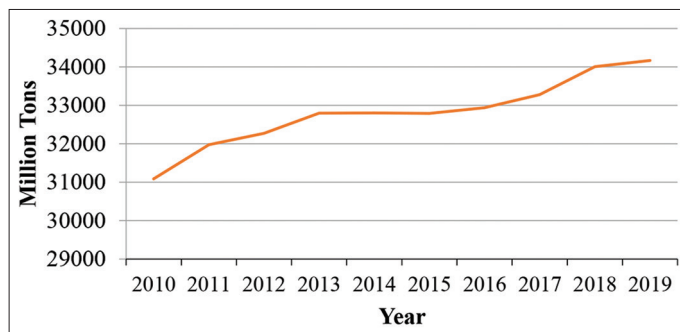
Source: BP Statistical Review of World Energy (2020) processed

The six largest emitting countries of CO_2 are China, the United States, the European Union, India, Russia and Japan which accounted for 67% of the total COEs in the world in 2019. The six countries are member countries of G -20 (Group of 20). The G-20 is an association of 19 countries and 1 European Union, namely the United States, Saudi Arabia, Argentina, Australia, South Africa, Brazil, Britain, China, Italy, Japan, Germany, Canada, South Korea, Mexico, Turkey, France, Russia, India, Indonesia and the European Union. The G-20 is an international forum that aims to discuss policies and cooperation related to sustainable world economic growth, international trade, and financial regulation. G-20 member countries represent about 65% of the world's population, 75% of global trade, at least 85% of the world economy, and G-20 member countries consume more than 80% of the world's energy and consequently 75% of total COEs (Badan Pusat Statistik, 2021).

There are several factors that can lead to an increase in COEs. One of the most important factors that have an indirect impact on COEs is the population. The increasing population will make the goods and services needed more and more to meet the needs of the population. The increasing demand for goods and services makes more resources to be processed together with other aspects of the processing industry, agriculture and service industry, where environmental pollution is a by-product (Suparmoko, 2017).

The total population of the G-20 member countries in 2010-2019 has increased and the G-20 member countries also represent about 65% of the world's population. So that indirectly the increase in population in the G-20 Member States will cause an increase in energy consumption in the world.

The economic performance of a country can be measured properly using the value (Gross domestic product [GDP]) of the GDP of that country. GDP is the total national income and total expenditure on the output of goods and services. The G-20 aims to achieve strong, sustainable and balanced global economic growth. From 2010 to 2019 the GDP value of the G-20 member countries was relatively increasing. It can be said that the G-20 member countries are trying to achieve economic development.

The G-20 has an important role in the problem of world energy utilization because the G-20 Member States consume more than 80% of the world's energy. In 2019 the G-20 accounted for 81.5% of fossil fuels from primary energy supply. Progress in the transportation, building and industrial sectors is lagging behind and many members of the G-20 are still losing tree cover, thereby reducing important carbon sinks (Climate Transparency, 2020).

In addition to the use of non-RE in the process of fulfilling human needs, RE is also used. The limited amount of non-RE makes it necessary to develop the use of RE. G-20 members account for 80% of the world's total installed renewable power generation capacity, and hold 75% of the total global deployment potential of all RE in the energy sector for the period from 2010 to 2030 (Commision, 2016). The number of G-20 member countries experiencing drastic development of the use of RE is only 6 regions out of 20 existing regions, so it can be said that other countries are less than optimal in optimizing RE as a source of energy consumed. This is also evident from the comparison value of the amount of RE consumption is very much less than the amount of non-RE consumption (NRNC).

2. LITERATUR REVIEW

CO_2 is a greenhouse gas consisting of one carbon atom and one oxygen atom bonded to both sides. GHGs are gas molecules that have more than two atoms and are part of the Earth's atmosphere. GHGs can occur naturally and are formed as a result of human activities (anthropogenic). According to the Kyoto Protocol, anthropogenic GHGs consist of six types, namely, CO2, CH4 (methane), N2O (nitrous oxide), HFC3 (Nugroho, 2016).

According to Fakrulloh and Wismuyani (2019), population is the total number of people or residents in an area, the number of occupants both humans and other living things in a certain room. Population is all people or residents in an area. Population is a group of people who occupy an area and are bound by several applicable rules and interact with each other continuously (Said, 2019).

GDP is the total national income and total expenditure on the output of goods and services. GDP is often considered the best measure of a country's economic performance. GDP aims to summarize economic activity in a certain value of money over a certain period of time. GDP can be viewed in two ways: GDP as the total income of everyone in the economy and GDP as total expenditure on the economy's output of goods and services. There are two types of GDP, namely nominal GDP and real GDP. Real GDP is a calculation of GDP where the value of goods and services is measured using current prices. Nominal GDP does not accurately reflect the extent to which the economy can satisfy the demands of households, firms, and governments. A better measure of economic prosperity would account for the economy's output of goods and services and would not be affected by changes in prices. For this purpose, economists use Real GDP. Real GDP is a calculation of GDP where the value of goods and services is measured using constant prices. Real GDP shows what will happen to spending on output if quantity changes (Mankiw, 2006).

RE or RE resources are resources that can be continuously available as a source of production input with an infinite time limit or in other words it will always be there. Non-RE or non-

RE resources are resources whose supply as production inputs is very limited or in other words, if used continuously, they will run out (Syeirazi, 2018).

3. METHODS

This research is a descriptive study with a quantitative approach. There are 5 variables used in this study, namely 4 independent variables and one dependent variable. The dependent variable is COEs. While the independent variables are population, GDP, NRNC, and RE consumption.

This research uses secondary data and literature study. Secondary data were obtained from the World Bank and BP Statistical Review of World Energy. This study uses panel data with a sample size of 190 samples. Annual time series data starts from 2010 to 2019 (10 years), while the cross section data used are G-20 member countries consisting of 18 countries 1 European Union namely the United States, Argentina, Australia, South Africa, Brazil, United Kingdom, China, Italy, Japan, Germany, Canada, South Korea, Mexico, Turkey, France, Russia, India, Indonesia and the European Union. Saudi Arabia is also a member of the G-20 but in this study it was not included because Saudi Arabia's RE resources are still limited to nuclear, wind and solar energy.

This study uses panel data regression analysis with the help of the E-views 11 program. There are several ways that can be used to estimate the regression model in panel data regression, namely the Common Effect Model, Fixed Effect Model, and Random Effect Model. To determine the best estimation model, previously, the model suitability test was carried out with the Chow Test, Haustmant Test, and Lagrange Multiplier (LM) Test. When the best estimation model has been found, then panel data regression is carried out. After that, the significance test was carried out by conducting a statistical test consisting of t test, R^2 test, and F test.

4. RESULTS AND DISCUSSION

4.1. Model Fit Test
Based on the Chow test shows that the Chi-square probability value is 0.0000. So in this case it states that Ho is rejected and Ha is accepted, which means that the best model according to the Chow test is Fixed Effect. Based on the Haustman test results show that the probability value is 0.7955. So in this case it states that Ho is accepted and Ha is rejected, which means that the best model according to the Haustman Test is Random Effect. Based on the LM test show the Breusch-Pagan probability value of 0.0000 (In the Both column). So in this case it states that Ho is rejected and Ha is accepted which means the best model according to the LM Random Effect Test.

4.2. Panel Data Regression Analysis
Based on the results of the regression above, the following equation is obtained:

$$LnY = 3,684958 + 0,096790LnX_1 + 0,013989LnX_2 +$$
$$0,936413LnX_3 - 0,010282LnX_4 + \varepsilon$$

Information:
LnY   : COEs
LnX1   : Population
LnX2   : GDP
LnX3   : NRNC
LnX4   : RE Consumption
ε   : Error Term/Residual

4.3. Statistic Test
4.3.1. Coefficient of determination (R^2)
Based on the results of the Random effect panel data regression test, the Adjusted R-squared value is 0.924642, which means that the variable COEs are influenced by population, GDP, NRNC, and RE by 92.46% while 7.54% is influenced by other variables that are not in the regression model.

4.4. Partial Test (t-test)
Based on Table 1, the value of t table in this study is 1.65313 with a degree of freedom (df) = 190-5 = 185 and a significant level of 95% (α= 5%). So based on the t-statistical test it can be explained that 1) The population has a t count greater than t-table, namely 2.888803 > 1.65313 with a probability value of 0.0043 less than the significant level value nilai α = 5%, then the population has a positive and significant effect on COEs CO_2 in G-20 Member Countries 2010-2019. (2) GDP has a t-count value smaller than t-table which is 0.471408 < 1.65313 with a probability value of 0.6379 greater than the significant level value α = 5%, then GDP has a positive and insignificant effect on COE in G-20 Member Countries 2010-2019. (3) Consumption of non-RE has a t-count value greater than t-table which is 30.61718 > 1.65313 with a probability value of 0.0000 which is smaller than the value of the significant level α = 5%, then the consumption of non-RE has a positive and significant effect on COEs in G-20 Member Countries 2010-2019. (4) RE consumption has a t-count value smaller than t-table, namely -2.012601< -1.65313 with a probability value of 0.0456 smaller than the significant level value α = 5%, so that the consumption of RE has a negative and significant effect on COEs in G-20 Member Countries 2010-2019.

4.5. F Test Results
Based on Table 2, the results of the regression analysis, the calculated F value is greater than F table, namely 580.7603 > 2.42 which means that together the population variables, GDP, NRNC, and RE have a significant influence on COEs in G-20 Member Countries 2010-2019.

5. DISCUSSION

5.1. The Effect of Population on COEs in G-20 Member Countries
Based on the results of the analysis above, it shows that the population during the period 2010 - 2019 has a positive and significant influence on COEs in G-20 member countries with a probability value of 0.0043 less than the significant level value α = 5%. This is in accordance with the hypothesis that the population in G-20 member countries has a positive and significant effect on COEs in G-20 member countries.

The size of the population will affect the emission of CO_2. This can happen because with the increasing population, the needs that must be met are increasing and with the increasing population, more activities will be carried out that result in environmental pollution. The daily routines carried out by residents are emitters of CO_2 such as driving a car or motorbike that runs on gasoline or gas and the use of electricity that comes from burning oil or coal. So the increasing population will increase COEs if people continue to use or consume non-RE.

From Figure 2 it can be seen that the total population in the G-20 Member States from 2010 to 2019 has always increased. This increase will indirectly affect the needs of the population that must be met and if seen from Figure 3 it can be seen that the population's consumer of non-RE is much more than the consumption of RE. This is what makes COEs increase in the G-20 Member States.

The results of this study are in line with research conducted by Nikensari et al. (2019) which states that in high-income and lower-middle-income Asian countries before and after the MDGs are set, it is stated that the higher the population, the higher the COEs. This research is also supported by research conducted by Firdaus (2017) which states that the population in the Regional Comprehensive Economic Partnership countries has a positive relationship with significant COEs at the 99% confidence level. An increase in the total population by 1 unit will increase COEs by 1.14E-08 on average, cateris paribus.

5.2. Effect of GDP on COEs in G-20 Member Countries

Based on the results of the analysis above, it shows that GDP during the period 2010 - 2019 has a positive and insignificant effect on COEs in G-20 member countries with a probability value of 0.6379 greater than the standard value. Significant $\alpha = 5\%$. This is not in accorandce with the hypothesis that GDP in G-20 member countries has a positive and significant effect on COEs in G-20 member countries.

GDP is the total value added from all business elements in a particular country, or the total value of final goods and services originating from all elements of the economy. In the process of achieving GDP, there are various components used, this is what makes GDP in G-20 Member Countries not significantly affect COEs. If seen from Figure 4 it can be seen that the total GDP in G-20 Member Countries from 2010 to 2019 has increased every year but this is different from COEs in G-20 Member Countries, it can be seen from Figure 5 it can be seen that the emission of CO_2 in the G-20 Member States is fluctuating. With this it can

Figure 2: Total population of G-20 member countries
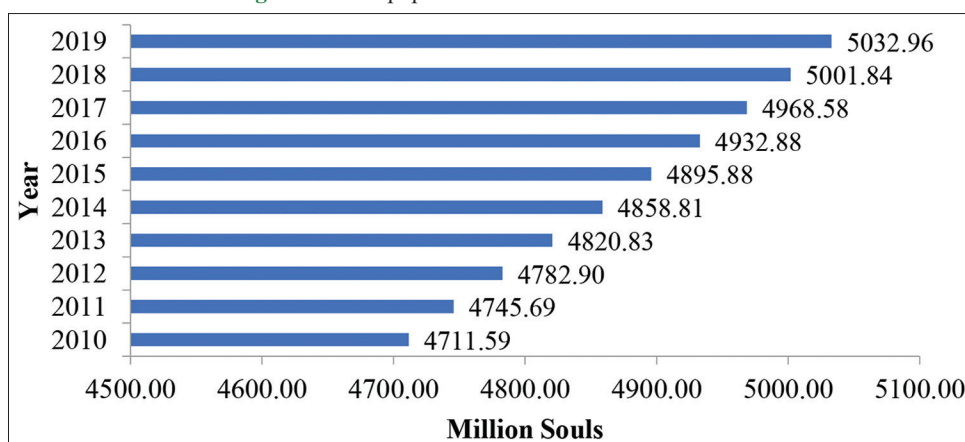
Source: World Bank (2019) processed

Figure 3: Total non-renewable energy consumption and renewable energy consumption of G-20 member countries
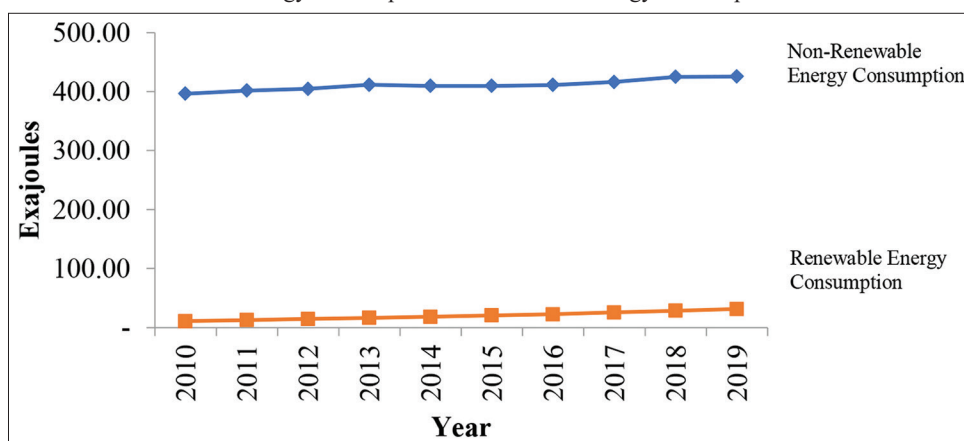
Source: World Bank (2019) processed

be said that an increase in GDP will not always increase COEs, depending on the components used by each country in the process of achieving it. This insignificance is also due to the fact that the G-20 Member States have committed to take various actions to reduce the use of non-RE for RE. This also makes the increase in GDP in the G-20 Member Countries does not significantly affect the increase in COEs.

The results of this study are in line with research conducted by Candra (2018) which states that the GDP in the Eight ASEAN Countries does not have a significant relationship to the CO2 variable with a probability value of 0.0697 and a coefficient of 0.000203. This research is also supported by research conducted by Tang (2017) which states that GDP has no significant effect on CO_2 in 17 countries in ASIA, which means that GDP has a relatively small relationship to CO_2.

5.3. The Effect of NRNC on COEs in G-20 Member Countries

Based on the results of the analysis above, it shows that the consumption of non-RE during the period 2010 - 2019 has a positive and significant effect on COEs in G-20 member countries

with a probability value of 0.0000 less than the significant level value $\alpha = 5\%$. This is consistent with the hypothesis that NRNC in G-20 member countries has a positive and significant effect on COEs in G-20 member countries.

Non-RE is the largest source of increased COEs in the world. According to Olivier and Peters (2020), 89% of COEs in the world come from the use of non-RE with the contribution of coal 32%, petroleum 39% and natural gas 29%. In 2019 G-20 in 2019 G-20 accounted for 81.5% of fossil fuels from primary energy supply, due to increased consumption of oil (1%) and gas (3%). Many G-20 countries lack effective targets and policies in key sectors. Progress in the transportation, building and industrial sectors is lagging behind and many members of the G-20 are still losing tree cover, thereby reducing important carbon sinks (Climate Transparency, 2020).

From Figures 6 and 7 it can be seen that the consumption of non-RE as a whole from 2010 to 2019 in the G-20 countries is fluctuating but tends to increase, this is also in line with the movement of total COEs in the G-20 Member States which are fluctuates and tends to increase as well. This means that the

Figure 4: Total gross domestic product of G-20 member countries
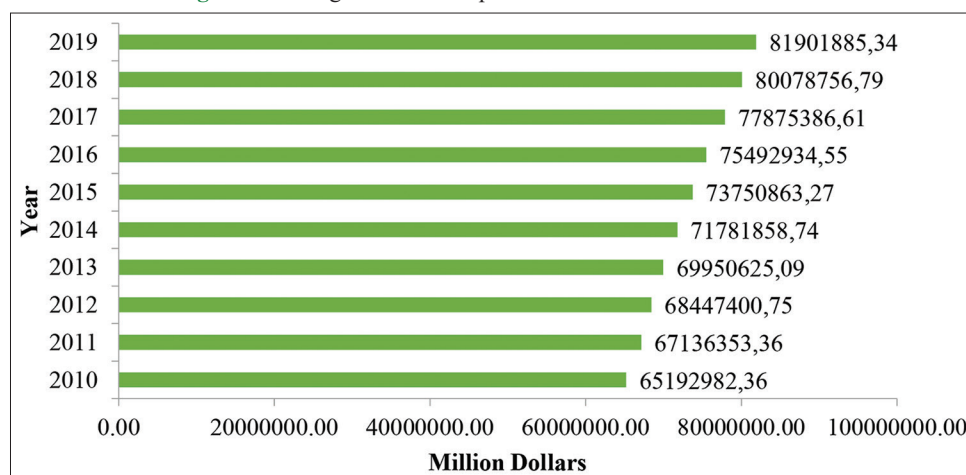
Source: World Bank (2019) processed

Figure 5: Total carbon dioxide emissions of G-20 member countries
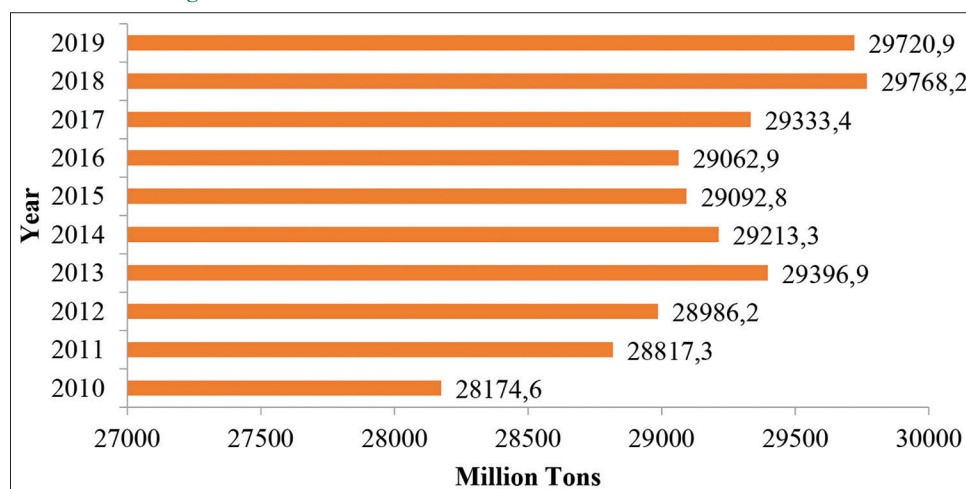
Source: BP Statistical Review of World Energy (2020) processed

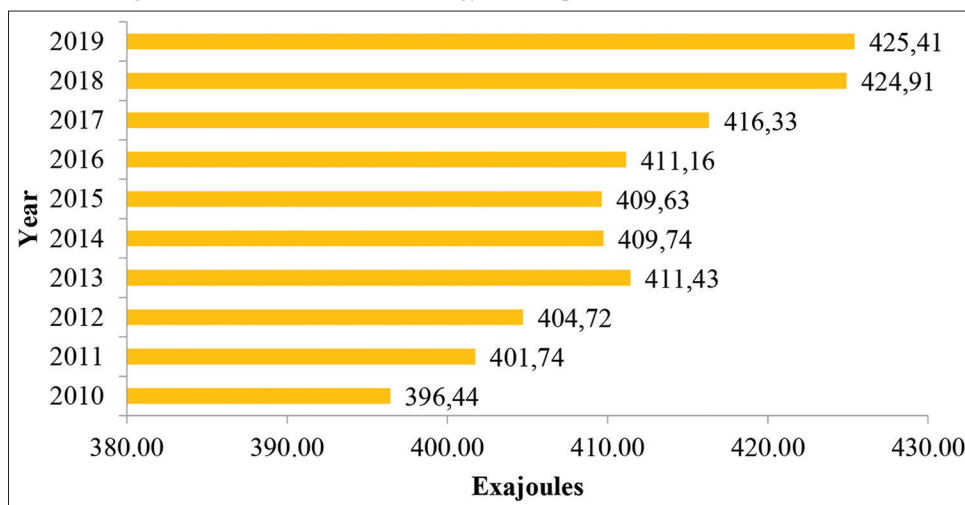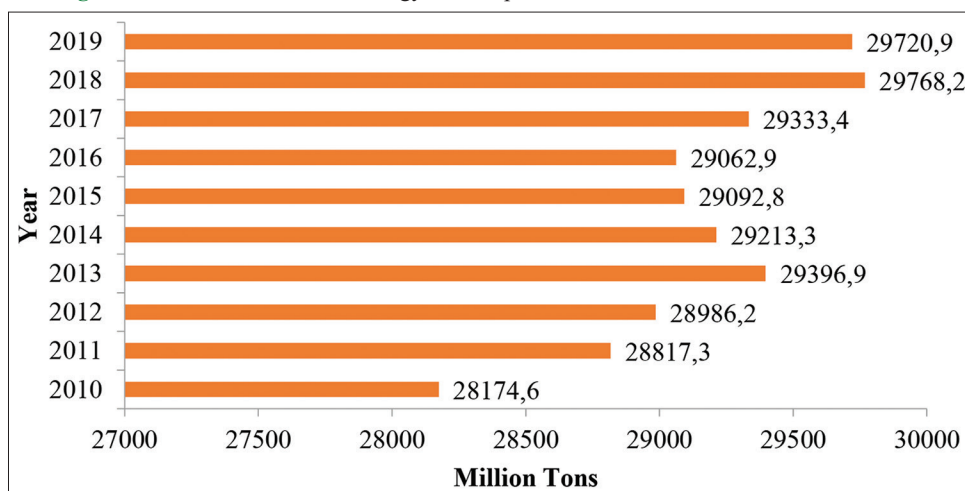Figure 6: **Total** non-renewable energy consumption **of G-20** member countries

Source: BP Statistical Review of World Energy (2020) processed

Figure 7: Total non-renewable energy consumption of G-20 member countries 2010–2019

Source: BP Statistical Review of World Energy (2020) processed

increasing consumption of non-RE, the emission of CO_2 will also increase in the G-20 Member States in 2010-2019.

The results of this study are in line with research conducted by Tirtayasa et al. (2021) which states that NRNC in the four largest ASEAN economies (Indonesia, Thailand, Singapore and Malaysia) has a positive effect ($\alpha = 0.0831$, $P < 0.01$) to COE. The coefficient implies that an increase of one unit in NRNC causes an increase of 0.08 units in COE. This research is also supported by research conducted by Wijaya (2017) which states that statistically energy consumption in ASEAN countries has a significant effect on CO2, with a t-test of 0.0000 with an alpha value of <1%. The regression coefficient value for the energy consumption variable shows a positive result, which is 0.046389.

5.4. The Effect of RE Consumption on COEs in G-20 Member Countries 2010-2019

Based on the results of the analysis above, it shows that the consumption of RE during the period 2010–2019 has a negative and significant effect on COEs in G-20 member countries with a probability value of 0.00456 smaller than the significant level value

$\alpha = 5\%$. This is in accorandce with the hypothesis that NRNC in G-20 member countries has a negative and significant effect on COEs in G-20 member countries.

The older the year, the more the needs of the population that must be met. Sources of non-RE are limited in number and have a negative impact on the environment so that RE is needed to meet the needs of the population, where RE is considered more environmentally friendly because it is low in emissions and on the other hand the amount is not limited. Many researches and policies are carried out by countries in the development of RE.

According to the Commision (2016), the G-20 holds 75% of the total global deployment potential of all RE in the energy sector for the period from 2010 to 2030. Therefore, G-20 members are in a position to lead the development of global RE and many engaged in innovative activities to enhance research, development and use of RE. There are several G-20 member countries that have developed RE, this can be seen from Figure 8 which shows that there is a tendency to increase the consumption of RE from 2010 to 2019 in every G-20 member

country and when viewed as a whole, consumption RE in the G-20 Member States also experienced an increase from 2010 to 2019 (Figure 9).

Consumption of RE in G-20 Member States from 2010 to 2019 tends to increase, this is only with COEs in G-20 Member States which are volatile but have decreased in several years. The increase in COEs that occur is due to the strong influence of the use of non-RE. This means that the consumption of RE in G-20 Member States in 2010 - 2019 has a negative effect on COEs, although the effect is still small. This small influence is caused by the strong use of non-RE in the G-20 Member States.

The results of this study are in line with research conducted by Sasana and Aminata (2019) which states that RE in Indonesia is negatively and significantly related to the amount of COEs, as RE has a coefficient of 5.2192 with a significance t-statistic value at = 10%. This means that increased use of RE will reduce

COEs significantly. This research is also supported by research conducted by Heryadi and Hartono (2016) which states that RE in G20 countries has a negative and significant relationship with COEs with a coefficient of −0.0171.

5.5. The Effect of Population, GDP, Consumption of Non-RE, and Consumption of RE on COEs in G-20 Member Countries

Based on the results of the F test that has been carried out related to the influence of Population, GDP, Consumption of Non-RE, and Consumption of RE on COEs in G-20 Member Countries in 2010-2019 shows that the F value count more than F table, which is 580.7603 > 2.42 which means that Ha is accepted and Ho is rejected, so it can be said that together the population variables, GDP, NRNC, and RE have an influence significant effect on COEs.
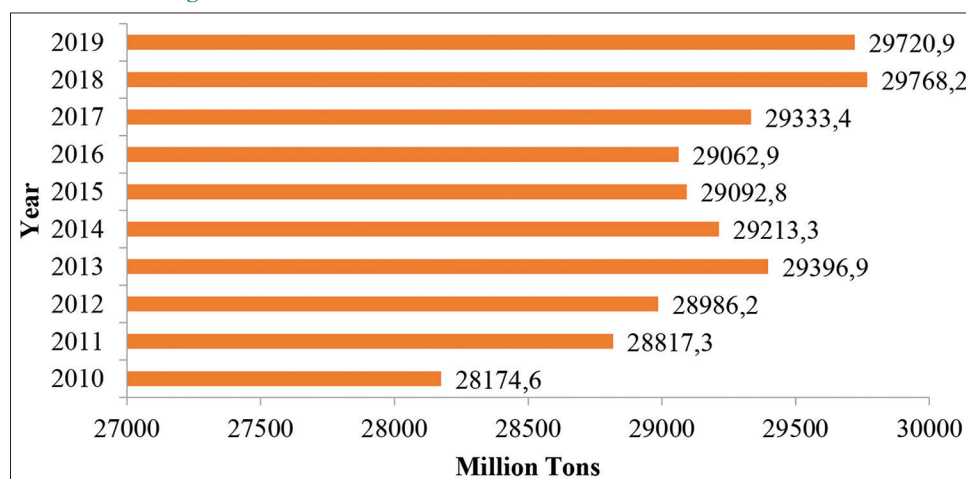
The increasing population makes the economy need to provide more goods and services to maintain or improve a country's

Figure 8: Renewable energy consumption in G20 member countries 2010–2019
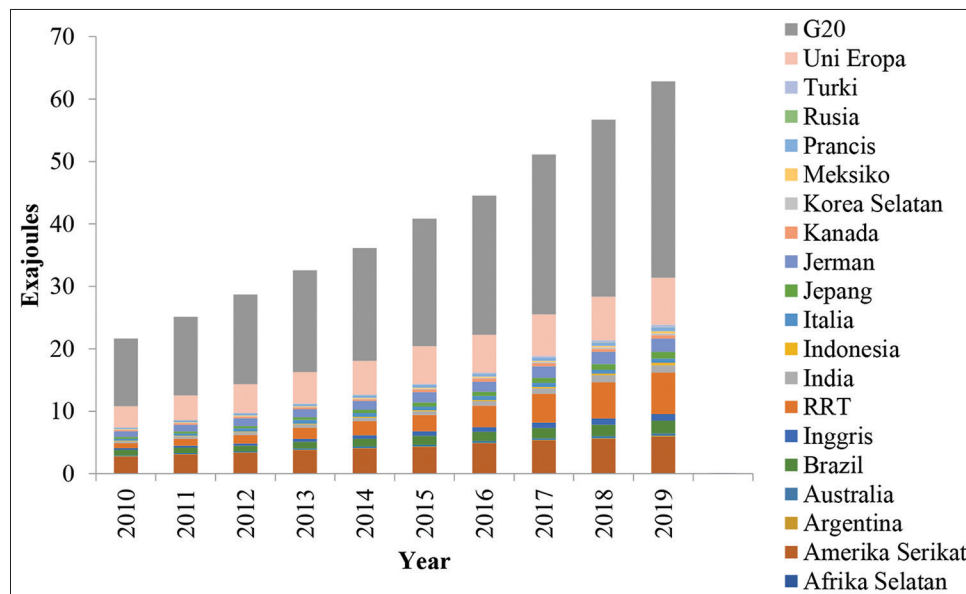
Source: BP Statistical Review of World Energy (2020)

Figure 9: Total carbon dioxide emissions of G-20 member countries

Source: BP Statistical Review of World Energy (2020) processed

Table 1: T-statistics test results

Variable	t-statisic	Prob.
LN_X1	2.888803	0.0043
LN_X2	0.471408	0.6379
LN_X3	30.61718	0.0000
LN_X4	-2.012601	0.0456
C	8.925283	0.0000

Source: Eviews 11, 2021 (data processed)

Table 2: F test results

F-statistic	580,7603
Prob (F-statistic)	0.000000

Source: Eviews 11, 2021 data processed

standard of living. This activity is referred to as a means of achieving economic development. The economic performance of a country can be measured properly using the value (GDP) of the GDP of that country. GDP is the total national income and expenditure on the output of goods and services. The goal of the G-20 is to achieve strong, sustainable and balanced global economic growth. In the process of achieving this, the G-20 Member States still use non-RE sources which in the process of utilization will emit various exhaust gases and the most of which is COEs. To meet the need for energy, G-20 Member States are also developing RE sharing which is considered more environmentally friendly and low in emissions. Although the development is still not optimal, it is carried out by each G-20 Member State.

The results of this study are in line with research conducted by Sasana and Aminata (2019) which states that economic growth, total use of primary energy, energy subsidies, use of RE, and population growth simultaneously affect COEs in the country. Indonesia with F-statistics is 161.0099 and P = 0.0000. This research is also supported by research conducted by Nikensari et al. (2019) which states that all independent variables in each of these models (economic growth, population, and energy consumption) together have a significant effect on COEs, because has a prob value. F statistic <0.05.

6. CONCLUSION

Based on the results of research and discussion of this research, the population variable (X1) has a positive and significant effect on COEs in the G-20 Member States. This means that every increase in population will result in an increase in CO_2 in the G-20 member countries. The GDP (X2) variable has a positive and insignificant effect on COEs in G-20 Member States. This means that every increase in GDP does not necessarily result in an increase in COEs in G-20 Member States, in the process of increasing GDP there are various components in it, not only components that result in an increase COE. The NRNC variable (X3) has a positive and significant effect on COEs in the G-20 Member States. This means that any increase in consumption of non-RE will result in an increase in COEs in the G-20 Member States. The variable of RE consumption (X4) has a negative and significant effect on COEs in G-20 Member States. This means that any increase in the consumption of RE will result in a decrease in COEs in the G-20 Member States. Population variables, GDP, NRNC, and RE together have a significant influence on COEs in G-20 Member States.

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