http://ejournal.seaninstitute.or.id/index.php/Ekonomi
Jurnal Ekonomi, Volume 12, No 02, 2023
ISSN: 2301-6280 (print) ISSN: 2721-9879 (online)

FACTORS AFFECTING CARBON DIOXIDE EMISSIONS IN INDONESIA

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ARTICLE INFO

Keywords:
Gross Domestic Product,
Foreign Investment,
Energy Consumption,
Carbon Dioxide Emissions

ABSTRACT

Carbon dioxide emission is one result of human activities in everyday life. Carbon dioxide emissions if left unchecked will damage the environment which will have an impact in the future. This study aims to determine how much influence economic growth, foreign investment, energy consumption and population have on carbon dioxide emissions in Indonesia. This study uses secondary data for the period 1980-2021 sourced from the Indonesian Central Statistics Agency (BPS), the Investment Coordinating Board, the World Bank, Our World In data and Energy Outlook. The analysis model uses the Vector Error Correction Model (VECM). The results of the study show that economic growth, foreign investment, and energy consumption do not have a significant effect in the short term, but in the long term they have a significant effect on carbon dioxide emissions. Population does not have a significant influence on carbon dioxide emissions in Indonesia, both in the short and long term.

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1. INTRODUCTION

In the era of the industrial revolution 4.0, global warming increased along with increased economic development, this problem became a serious environmental problem in the eyes of the world. Emissions of greenhouse gases, especially carbon dioxide, are increasing due to economic activity, which has an impact on the extreme global climate. In particular, the increase in greenhouse gas emissions has led to policy changes to minimize the occurrence of rapid climate change without neglecting long-term growth (Pratama & Panjawa, 2022). To achieve long-term sustainable economic goals, several countries have used the Sustainable Development Goals (SDGs) strategy. Economic growth in a country is indeed important, but environmental conditions must also be improved to maintain human survival in the future. In the Qur'an, God's Word is in accordance with the SDGs: "And let us not cause damage to the earth after (Allah) has repaired it and pray to Him with fear (will not be accepted) and hope (will be granted). Indeed, Allah's mercy is very close to those who do good." (QS al-A'raf [7]: 56)

According to Dietz and Rosa (1997), the rapid growth of CO2 emissions is caused by anthropogenic factors including population, economic activity, technology, politics and economic institutions, attitudes, and beliefs. Indonesia ranks sixth as a world CO2 producing country based on the World Resources Institute (WRI, 2016). The process of industrialization as a form of increasing economic development causes a high level of environmental degradation. The relationship between the environment and economic growth rests on the Environmental Kuznets Curve (EKC), the initial development process of a country will experience environmental degradation, but up to a certain point of income the process will be reversed, and awareness of environmental quality will be formed.

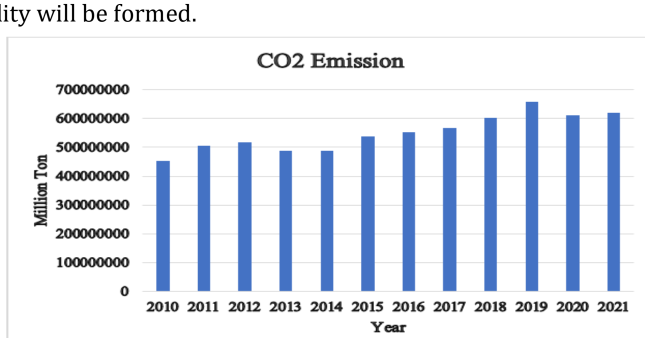

Figure 1. Indonesia's Carbon Dioxide Emission Growth for the 2010-2021 period

Figure 1 shows the growth of CO2 emissions which has grown quite significantly. In 2020 CO2 emissions in Indonesia, which amounted to 609,786.1 million tons, were lower than in 2019, which amounted to 659,435.7 million tons, this was due to large-scale restrictions in Indonesia due to the Covid-19 pandemic. Reducing CO2 emissions will continue to go hand in hand with a sustainable economic movement. Based on the type of fuel in 2013, the largest contributor to carbon dioxide emissions was coal at 40%, followed by fuel with a share of 35%, the rest by natural gas, LPG, and biofuels.

Indonesia has the fourth largest population in the world with a population growth rate of around 1.30% per year. With a dense population reaching 237 million people in 2021, the demand for energy consumption will also increase. Energy is an important element that cannot be separated from economic growth. energy consumption is a means to drive the industrialization of the economy as well as a means of accumulating development capital both complementary and substantial in producing outputs in the economy (Stern, 2011).

Based on the energy outlook data (2021) it shows that the level of consumption for each sector is very high. In 2016-2019 the demand for energy is very high and is dominated by the transportation sector. However, in 2020, there was a decrease in total energy consumption, reaching 118.3 MOTE, a decrease compared to 2019 of 132.6 MTOE. This was due to restrictions on community activities caused by the pandemic.

2. LITERATURE REVIEW

Economic development with industrialization will certainly affect the level of CO2 emissions resulting from development support activities that will create a country's economic growth rate. This is in accordance with Muhammad, S. S's research (2020), that economic growth has a significant positive effect on increasing CO2 emissions in developed or developing countries. Meanwhile, research conducted by Lulu Kurniarahma et al (2020) shows that economic growth has a significant negative effect on CO2 emissions in the long term and has no effect in the short term. Another study conducted by Widyawati, et al (2021) found that economic growth has no significant effect on CO2 emissions.

Economic growth will always be accompanied by an increasing population growth. The population that increases every period will affect the demand for needs and the availability of scarce resources. This is also one of the causes of increased CO2 emissions which is in line with research conducted by Mahendra, et al (2022) population has a significant positive effect on increasing CO2 emissions. Research conducted by Birdsall and Griffin (1991) states that there is no long-term equilibrium relationship but implies a short-term dynamic relationship between CO2 emissions and population growth.

Activities supporting economic growth and the endless needs of the population also require high energy consumption. Fulfilment of energy consumption as fuel from sectors supporting the economy will of course also increase CO2 emissions, especially in the industrial or commercial sectors. This is in line with research conducted by Musri Annisa and Karimi et al (2022) which states that energy consumption has a significant positive effect on CO2 emissions. This is contrary to the results of research conducted by ulfa et al that energy consumption has no significant negative effect on CO2 emissions and is supported by research by Kartikasih and Setiawan that energy consumption has no statistical effect on CO2 emissions.

Investment is needed in a country to support the government's economic policies, and investment plays an important role in determining the direction of economic development (Sahu & Kumar, 2020; Santi & Sasana, 2021). From the point of view of sustainable development, there are two approaches to economic growth, namely the Pollution Hacen Hypothesis and the Pollution Halo Hypothesis which state that FDI and environmental degradation have a mutually influencing relationship. Where Pollution Halo Hypothesis can reduce the level of environmental pollution. This is consistent with previous research which shows that even though the estimated coefficient of FDI is small, it states that pollutants will decrease when FDI flows increase, this implies that FDI has a positive effect on environmental improvement in Indonesia (Hong Linh et al., 2015). However, economic growth and increased movement of capital in the world have led to different views on environmental pollution (Abumunshar et al., 2020; Ma et al., 2019; Pratama, 2022). Especially developing countries forget about environmental problems to attract foreign direct investment to improve the economy of developing countries (Kurniarahma et al., 2020; Gunarto, 2020). In developing countries, many companies have few taxes and few regulations, which means FDI has brought environmental problems in the host country. Based on the literature, this situation is referred to as the "Pollution Haven Hypothesis" (Kizilkaya, 2017).

Growing economic activity will cause even more severe environmental damage because the government only focuses on economic growth. Therefore, this study was conducted to analyze the factors that may affect CO2 emissions for the 1990-2021 period using VECM econometric analysis to explore the relationship between CO2 emissions, economic growth, foreign investment, energy consumption and population in Indonesia.

From previous theory and research, it is interesting to examine the effect of gross domestic income, foreign investment, energy consumption and population on carbon dioxide emissions in Indonesia with a dynamic approach (VECM).

3. METHODS

In analyzing the relationship between the dependent variable and the independent variable in this study using the VECM (Vector Error Correction Model) regression model. VECM is a derivative of VAR with the same assumptions, but all must be stationary in the first differentiation or have cointegration relationships between variables that can be used in stationary time series (Basuki & Prawoto, 2017).

The Vector Error Correction Model (VECM) is designed to estimate short-term or long-term relationships between variables in time series data. In economics, VECM model analysis is used to determine whether there is a long-term equilibrium relationship between economic variables, to test whether there is a causal relationship between economic variables and to construct an impulse response function to describe short-term dynamic relationships over time between economic variables. The autoaggressive vector model (VAR) and vector error correction model (VEC) are the methods used in designing a non-structural relational model between economic variables.

There are several steps that need to be carried out in regression with this approach. It should be remembered that time series data in general has a stochastic nature, namely a situation where the data has a non-stationary trend. Stationary data have values that tend to fluctuate around their average. Non-stationary data will affect spurious regression results. Dickey and Fuller developed a unit root test which is used to test the stationarity of time series data using the Augmented Dickey Fuller Test (ADF) with a significance level of 5%. According to Gujarati (2022) the form of the stationarity test with ADF analysis is in the following equation:

$$\Delta Ft = \alpha 0 + \gamma t - 1 + \beta \Sigma \sum_{i=1}^{\rho} \Delta Ft - i + 1 + \in t \ldots \ldots \ldots \ldots \ldots \ldots$$

The above equation shows that the null hypothesis (H0) indicates there is a unit root and the first hypothesis (H1) indicates there is no unit root. The unit root test can be described through the following model:

$$Y_t = \delta Y_{t-1} + u_t$$

If the above equation is reduced by Y_(t-1) on the right and left sides, then we get:

$$Y_t - Y_{t-1} = \partial Y_{t-1} - Y_{t-1} + u_t$$
$$\Delta Y_t = (\partial - 1) Y_{t-1} + u_t$$

Or it can be stated as follows:

$$\Delta Y_t = \beta Y_{t-1} + u_t$$

In estimation, the VAR approach is very sensitive to the length of the data lag. Lag testing is carried out to minimize autocorrelation problems and to find out the period of an endogenous variable in influencing past variables or changes in other variables. Based on the Akaike Information Criterion (AIC), Schwarz Information Criterion (SC) and Hannan Quinnion (HQ) criteria, the number of lags (orders) in a data can be determined.

The next test after the data indicates cointegration is the error correction method. The difference in the degree of integration between the variables requires that the long-term concurrent and error correction equations be tested simultaneously. However, if there is no difference in level between the variables, it is declared feasible to continue the next test, namely by using the first difference variable. Lee and Granger are designations for variables that are cointegrated but have different levels of integration.

The general form of the VECM model with a long lag (p-1) is as follows:

$$\Delta \gamma t = \alpha + \beta_1 \Delta \gamma_{t-1} + \beta_2 \Delta \gamma_{t-2} + \cdots + \beta_p \Delta \gamma_{t-p+1} + \varepsilon_t$$

Where $e_{t-1} = Y_{t-1} - (\varphi + \omega X_{t-1})$

From the test above, the best VECM model is obtained, after which it is necessary to do forecasting. Furthermore, forecasting evaluation is carried out because even though the best model has been used, there are still indications of errors. There are four evaluation methods that are often used by researchers, namely the Mean Square Error (MSE), Mean Absolute Deviation (MAD), The Mean Absolute Percentage Error (MAPE) and The Mean Percentage Error (MPE).

4. RESULTS AND DISCUSSION

The stationary test or unit root test is one of the tests in the Vector Error Correction Method (VECM) which determines the next stage of test results, this is because it determines whether the data in this study is stationary or not. When the data in a study are not stationary, it will be difficult to estimate the model, or it is said to be an oblique regression because the values tend to fluctuate not around the average. In the unit root test usually use the test method.

Augmented Dickey Fuller (ADF), where the data is said to be stationary if the t-ADF value is less than the five percent level or if the results at each time are the mean, variance and covariance in each lag are the same.

Through the unit root test, in this study using the Augmented Dickey-Fuller test to test the behavior of the data, namely knowing whether the data is stationary at the level.

Table 1.Unit Root Test Results at Level

Variable	T-Statistic ADF	T-Critical Value 5%	Probability	Information
GDP	1,583864	-2,935001	0,9993	No Stationer
FDI	-2,615915	-2,935001	0,0980	No Stationer
Energy Cons	4,115053	-2,935001	1,0000	No Stationer
Population	-0,799563	-2,935001	0,8086	No Stationer
CO_2	0,331286	-2,935001	0,9772	No Stationer

Based on the unit root test for each variable, it shows that at the level, all variables are declared non-stationary and not significant at the 0.05 significance level. All variables are said to be non-stationary because the data is not constant from time to time and tends to fluctuate over a set period. The non-stationary data at the level occurs because of a short-term or long-term relationship between the independent variable and the dependent variable. Therefore, the test can be continued with the unit root test at the first difference level if the level is not stationary (Kuncoro, 2011).

Table 2.Unit Root Test Results at First Difference

Variable	T-Statistic ADF	T-Critical Value 5%	Probability	Information
GDP	-4,607884	-2,936942	0,0006	Stationer
FDI	-6,006373	-2,943427	0,0000	Stationer
Energy Cons	-3,625424	-2,936942	0,0095	Stationer
Population	-10,54845	-2,936942	0,0000	Stationer
CO2	-5,979510	-2,938987	0,0000	Stationer

Through the VAR stability test in the form of a roots of characteristic polynomial for all the variables used multiplied by the number of lags of each VAR. This test is very necessary because it relates to the final stage, where if the VECM model is unstable then the IRF and DV analysis will also be invalid. The VAR estimation is said to be stable if the modulus value is less than one. In this study, the Roots of Characteristic Polynomial table shows a modulus value > 1, which means that the VAR estimate is stable. Here are the results:

Table 3. Stability VAR

Root	Modulus
0.631991	0.631991
-0.067764 – 0.175781i	0.188390
-0.067764 + 0.175781i	0.188390
- 0.066483 – 0.016096i	0.068404
- 0.066483 + 0.016096i	0.068404

Based on Table 3 above, the modulus value is less than one (> 1) meaning that the estimated VAR stability to be used in the IRF and FEDV analysis is stable. Therefore, the next step can be carried out, namely the cointegration test with the optimal lag length of 1.

In general, the cointegration test aims to determine whether the non-stationary group of variables at the level has met the integration process requirements or not. The results of the Johansen cointegration test are shown in the following table:

Table 4. Cointegration Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None*	0.670586	115.4981	69.81889	0.0000
At most 1*	0.527056	72.19092	47.85613	0.0001
At most 2*	0.461384	42.98854	29.79707	0.0009
At most 3*	0.287782	18.85716	15.49471	0.0150
At most 4*	0.134238	5.621660	3.841466	0.0177

Trace test indicates 5 cointegration eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinno-Haug-Michelis (1999) p-values

Based on Table 4, cointegration of the four rank variables occurs, where the value of the trace statistic is greater than 0.05 critical value. This is evidenced by the trace statistical values of 72.19092, 42.98854, 18.85716, and 5.621660 which are greater than the critical values of 47.85613, 29.79707, 23.00395, and 3.841466, which means that H0 is rejected while H1 is accepted, or it can be said that each variable in the study have a relationship of balance and movement in the long run (cointegration) with each other.

After carrying out several stages, namely data stationarity test, determining the length of the lag, testing the stability of the VAR model, Granger causality analysis and cointegration test. At the cointegration test stage, it was found that there were four cointegration ranks at a test level of 0.05, which means that the VECM (Vector Error Correction Model) model in this study can be continued. VECM is a form of restricted VAR, namely limiting the long-term relationship of endogenous variables so that they converge into cointegration relationships, but still allow the existence of short-term dynamics. The following are the results of VECM estimation in this study:

Table 5. Estimation Results of theVECM Model in Short Time

Variable	Coefficient	t-statistic
cointEq1	-1.176094	-4.55994***
D(LOG(CO2(-1)))	0.456158	1.85956*
D(LOG(GDP(-1)))	-0.010512	-0.12678
D(LOG(FDI(-1)))	-0.007707	-0.38998
D(LOG(ENERGI_Cons(-1)))	-0.777525	-2.31962***
D(Log(POP(-1)))	2.076903	1.20610
C	0.055690	1.98529*

The error correction parameter to indicate the existence of an adjustment mechanism from the short term to the long term is 2.07%. Based on Table 5 there is one significant variable at the five 5% level plus one error correction variable in the short-term relationship. The ENERGY variable has a significant effect on CO2 in the short term, which is located at lag 1, while the variables GDP, FDI and POPULATION have no significant effect in the short term at lag 1 on CO2.

Based on the results above, it can be concluded that in the short term only the ENERGY variable has an effect, while the GDP, FDI, and POPULATION variables have no effect on CO2 in Indonesia in the short term. In full, the long-term VECM estimation results in this study are as follows:

Table 6.Estimation Results of the VECM model in Long Time

Variable	Coefficient	t-statistic
GDP	-0.194640	-7.44721***
FDI	-0.038631	-3.38233***
ENERGY_Cons	-0.254203	-2.49234***
POPULASI	-0.659826	-1.18432

Table 6 above shows that through the long-term VECM (Vector Error Correction Model) estimation at lag 1, the PDB variable has a t-statistic value greater than the long-term adjustment value, namely -7.44721 > 2.07, which means H0 is rejected and H1 is accepted, or it can be stated that the GDP variable has a significant effect on the CO2 variable. With a coefficient value of the GDP variable of -0.194640, this means that if there is an increase in GDP by one percent in the previous year, it will reduce CO2 in the current year by -0.194640. The results of the study are in accordance with the hypothesis which states that the GDP variable has a significant effect on carbon dioxide, as supported by research conducted by Widyawati et al (2021), Kurniarahma et al (2020) and Akram (2013) which shows that economic growth significant negative effect in the long term on carbon dioxide emissions and no effect in the short term. This happens because a country that has high economic growth can reduce carbon dioxide emissions by paying attention to the environment supported by various sustainable development policies that will affect the quality of the environment and can reduce carbon dioxide emissions.

Estimating the long-term VECM (Vector Error Correction Model) at lag 1, the PMA variable has a t-statistic value greater than the long-term adjustment value, namely -3.38233 > 2.07, which means H0 is rejected and H1 is accepted, or it can be stated that the PMA variable has an effect significant to the CO2 variable. With a FDI variable coefficient of -0.038631, this means that if there is an increase in GDP by one percent in the previous year, it will reduce CO2 in the current year by 0.038631. The results of this study are in line with the findings of Linh and Lin (2015), Tang and Tan (2015), and Zhang, C and Zhou, X (2016). Where the results of research found that FDI improves environmental quality by reducing CO2 emissions. FDI encourages technological progress and improves environmental welfare by introducing environmentally friendly technologies and products. And they found that foreign companies from polluting-intensive industries pay more attention to the environment than domestic companies.

Estimating the long-term VECM (Vector Error Correction Model) at lag 1, the ENERGY variable has a t-statistic value greater than the long-term adjustment value, namely -2.49234 > 2.07 which means H0 is rejected and H1 is accepted, or it can be stated that the Energy variable influences CO2 variables in the long term. The results of this study are in line with the findings of Sasana & Putri (2018) that energy consumption has a negative and significant effect on CO2. This is because various countries in Asia have implemented programs to reduce CO2 emissions, one of which is with technology. Where the energy consumption index in this study is the kWh electricity consumption per capita.

Estimating the long-term VECM (Vector Error Correction Model) at lag 1, the POPULATION variable has a t-statistic value greater than the long-term adjustment value, namely -1.18432 <2.07, which means H0 is accepted and H1 is rejected, or it can be stated that the POPULATION variable is not effect on CO2 variables in the long term. The results of this study are different from the hypothesis which states that the POPULATION variable has no significant effect on carbon dioxide either in the long term or in the short term. The results of this study are in accordance with the findings of Knapp & Mookerjee (1996) which show that there is no long-term equilibrium relationship but implies a short-term dynamic relationship between carbon dioxide emissions. Additionally supporting evidence by (Satterthwaite (2009) and Zhu & Peng (2012) concluded that the increase in the number of urban consumers and their consumption levels, not population growth, is driving the increase in greenhouse gas emissions. Changes in population structure play a more important role than size that population.

The short-term and long-term VECM estimation results above are valid, this is because it is known that the value of the coefficient of determination R-squared shows a value of 0.412 or 41.2 percent of 1.00 or 100 percent where, changes in the dependent variable (CO2) can be explained by the independent variables (GDP, FDI, ENERGY and POPULATION) are 41.2%, the remaining 58.8% is explained by other variables. VECM analysis is not only used to find out how the independent variable relates to the dependent variable but can also be used to determine the response and time needed to return to its balance point and see how much influence the composition of each independent variable has on the dependent variable.

VDC (Variance Decomposition) analysis aims to provide information related to the proportion of movement or contribution to the influence of the independent variable shock on the dependent variable. In this study, Variance Decomposition analysis was used to see how much influence the GDP, FDI, ENERGY and POPULATION variables had on the CO2 variable with the type of annual timeseries data for the period 1980 to 2021. This period, it was felt, sufficiently illustrated how much influence the independent variables had on the dependent variable. The results of the analysis of variance decomposition in this study are as follows:

Table 7.Vriance Decomposition

Variance Decomposition of CO2						
Period	S.E	LOG (CO2)	LOG (PDB)	LOG (PMA)	LOG (ENERGI)	LOG (POPULASI)
1	0.064798	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.086766	84.87106	7.837783	1.772986	2.086462	3.431710
3	0.096179	73.44540	16.07961	5.309609	1.701794	3.463592
4	0.104296	66.68817	19.90858	7.205653	3.142428	3.055171
5	0.113726	63.69606	21.09930	7.555719	4.829371	2.819558
6	0.123484	61.94687	21.88559	7.579160	5.745547	2.842841
7	0.132466	60.11700	22.83886	7.715777	6.422089	2.906268
8	0.140769	58.40960	23.66525	7.979378	7.126119	2.920650
9	0.148705	57.07104	24.23771	7.975839	7.797428	2.917984
10	0.156359	56.05050	24.64692	8.022774	8.356441	2.923368

Based on Table 7 above, in the first period, CO2 is greatly influenced by CO2 itself by 100 percent. While in the first period, GDP, FDI, ENERGY and POPULATION have not influenced CO2. Furthermore, in the second period, the GDP variable contributed a shock of 7.837783 percent. Then in the following period it always experienced an increase until the 10th period, namely to 24.64692 percent, and in that period the biggest shock was given by the GDP variable.

In the second period, the FDI variable contributed a shock of 1.772986 percent and it always increased until the 10th period of 8.022774 percent. In that period, the FDI variable gave the biggest shock for 10 periods. Meanwhile, the ENERGY variable in the second period contributed a shock of 2.086462 percent and experienced a significant decrease in the second period of 1.701794 percent. Furthermore, in the 3rd to 10th period there was a significant increase. In the last period, it showed the number of 8.356441 percent as the largest percentage in 10 periods.

Finally, the POPULATION variable contributed 3.431710 percent in the 2nd period, then in the 4th period it decreased with a contribution of 3.055171 percent lower than the previous period. In the 10th period the POPULATION variable contributed 2.923368 percent. The largest percentage with the number 3.463592 is in the 3rd period.

5. CONCLUSION

Economic growth has no negative and significant effect on carbon dioxide emissions in the short term, but economic growth has a negative and significant long-term effect on carbon dioxide emissions in Indonesia. The estimated coefficient value in the long term means that there is a negative influence from economic growth, namely the higher the economic growth, the lower carbon dioxide emissions in Indonesia. This shows that the EKC curve applies to Indonesia, where the higher the economic growth, the higher the awareness of the environment.

Foreign investment does not have a negative and significant effect on carbon dioxide emissions in the short term, but foreign investment has a negative and significant effect on carbon dioxide emissions in the long term. The estimated coefficient value in the long term means that there is a negative influence from FDI, namely the higher the foreign investment, the lower carbon dioxide emissions in Indonesia. It can be concluded that it is possible for countries to be able to specialize in their industries which have a comparative advantage so that income increases, structural transformation and technological progress occur. Therefore, there is a need for policies that are aligned with sustainable development.

Energy consumption has no negative and significant effect on carbon dioxide emissions in the short term, but energy consumption has a negative and significant long-term effect on carbon dioxide emissions in Indonesia. The estimated coefficient value in the long term means that there is a negative influence from consumption, namely the higher the energy consumption, the lower carbon dioxide emissions in Indonesia. This shows that policies related to the transformation of fossil energy into Renewable Energy for a sustainable economy are quite effectively implemented, besides that there are innovations related to environmentally friendly fuels which are also supporting the reduction of carbon dioxide emissions.

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