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Energy consumption, economic growth and CO2 emissions in Azerbaijan

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Abstract The primary goal of this research is to investigate the link between carbon dioxide emissions, energy consumption, and economic growth in Azerbaijan. Azerbaijan's economy is growing, and people have noticed that the country is using more energy. However, the issue of how this increase affects carbon dioxide emissions is controversial. The analyzes show that there is a linear relationship between energy consumption and carbon dioxide emissions. That is, as energy consumption increases, carbon dioxide emissions also increase. In addition, it is stated in the study that Azerbaijan focuses on fossil fuels in energy production and that this situation has an impact on carbon dioxide emissions. Policies such as increasing the use of renewable energy sources and increasing energy efficiency in Azerbaijan can help reduce carbon dioxide emissions. Finally, the Azerbaijan analysis shows that there is a linear relationship between energy consumption and carbon dioxide emissions, and policies such as the use of renewable energy sources and increasing energy efficiency can help reduce carbon dioxide emissions.

Keywords: carbon dioxide, energy consumption, economic growth, renewable energy sources

1. Introduction

From past to present, energy plays an active role in the development of societies and their socioeconomic indicators. From the existence of human beings to the industrial revolution, energy has only played a role in meeting the most basic needs of humanity, but the need for energy has come to the fore in many issues from the industrial revolution to the present day, and human beings have sought to meet this need from various sources. Various energy sources have been effective in improving socioeconomic conditions for billions of people today (Seyit 2022). Today, the relationship between carbon dioxide emissions, energy consumption, and economic growth is being studied with increasing interest around the world. This issue is important for the sustainability of economic growth, especially in developing countries. This issue is also very important in countries rich in energy resources, such as Azerbaijan. There is a close relationship between carbon dioxide (CO2) emissions and fossil fuel consumption. Fossil fuels are fuels obtained from fossils formed by the decay of organic materials hundreds of millions of years ago, such as oil, natural gas, and coal. During the combustion of these fuels, CO2 emissions are released into the atmosphere. People around the world generate high amounts of CO2 emissions due to the intensive use of fossil fuels. These emissions create a greenhouse effect and cause climate change worldwide. Especially in industrialized countries, since the use of fossil fuels is quite common, CO2 emissions are also higher in these countries. In recent years, studies on alternative energy sources have increased to replace fossil fuels. These include renewable energy sources such as solar power, wind power, and hydroelectric power. The use of these alternative energy sources will also reduce CO2 emissions by reducing the use of fossil fuels.

The relationship between carbon dioxide (CO2) emissions and economic growth has been a long-debated issue. In general, CO2 emissions increase with economic growth. This is due to increased industrial activity and increased energy demand. However, in recent years, factors such as increasing environmental awareness and sustainable development goals have increased efforts to reduce CO2 emissions. Therefore, the impact of economic growth on CO2 emissions has become an issue that has received more and more attention. Some studies suggest a negative relationship between economic growth and CO2 emissions. That is, as economic growth increases, the rate of increase in CO2 emissions decreases. This is due to the increased use of energy efficiency and clean energy technologies. However, there are also those who oppose this view. Some argue that economic growth is not enough to reduce CO2 emissions and that more comprehensive policies are needed. They also point out that developing countries need fossil fuels for economic growth and that it is more difficult to cope with rising CO2 emissions. The relationship between CO2 emissions and economic growth is complex and affects many factors. However, environmental factors such as sustainable development goals require more efforts to reduce CO2 emissions.

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In this study, the relationship between carbon dioxide emissions, energy consumption, and economic growth is analyzed through the example of Azerbaijan. Azerbaijan is a country that can export energy with its natural gas reserves. However, it is also a country that produces high levels of carbon dioxide emissions.

It's possible that the research has a few flaws that need to be ironed out before it can be fully trusted. Here are some possible limitations:

- Availability of the data and the quality of the data This research largely depends on the availability of the data used for analysis as well as the quality of the data. The validity and trustworthiness of the conclusions of the research might be called into question if the data is either insufficient, erroneous, or out of date.
- Data restrictions: There is a possibility that the research has data limitations in terms of the variables that were included in the analysis. For instance, it is possible that it does not take into account some aspects that might impact energy consumption, economic growth, and CO_2 emissions. Some examples of these types of elements are the dynamics of the population, improvements in technology, changes in legislation, and international commerce.
- The research may find that there is a connection between energy consumption, economic growth, and CO_2 emissions; nevertheless, it might be difficult to demonstrate a causal link between these three factors. It is possible that the research will not be able to identify with absolute certainty whether shifts in economic development are caused by changes in energy use or vice versa.
- Assumptions and reductions in complexity It is quite possible that the research will need the use of assumptions and reductions in complexity in order to analyse more complicated interactions. It is possible that these assumptions may not adequately depict the dynamism and complexity of energy systems, economic processes, or environmental repercussions as they exist in the actual world.
- Generalizability: It's possible that the conclusions of the research are only applicable to the situation in Azerbaijan, and that they can't be applied directly to the circumstances of other nations or areas. The results' application may be limited by a variety of factors, including but not limited to distinctive economic systems, energy sources, governmental frameworks, and cultural characteristics.
- Duration and trends: The duration of the investigation might have an impact on the results that were made. If the research just looks at a short time period, it is possible that it will not reflect any long-term patterns or structural changes in the levels of CO_2 emissions, economic growth, or energy consumption.
- Methodological issues It's possible that some aspects of the study's methodology, including the selection of statistical models or the approaches to data analysis, have certain shortcomings. There is a possibility that the research did not take into account all possible biases or uncertainties, and that the outcomes of the study might vary depending on the methodological approach used.

When evaluating the results of the study, it is essential to take into account these limitations, since they have the potential to have an effect on the overall robustness and dependability of the research conclusions.

In the study, the energy consumption and carbon dioxide emissions data of Azerbaijan are examined, and the relationship between these data and economic growth is investigated. In addition, the impact of sustainable energy policies such as energy efficiency and the use of renewable energy resources in Azerbaijan is also evaluated.

The goal of this research is to better understand the relationship between carbon dioxide emissions, energy consumption, and economic growth using Azerbaijan as an example, and to highlight the importance of sustainable energy policies. It is thought that the research to be done on this subject will make important contributions in line with the Sustainable Development Goals.

2. Literature Review

The relationship between carbon dioxide (CO_2) emissions and economic growth has been a long-debated issue. In general, CO_2 emissions increase with economic growth. This is due to increased industrial activity and increased energy demand. However, in recent years, factors such as increasing environmental awareness and sustainable development goals have increased efforts to reduce CO_2 emissions. Therefore, the impact of economic growth on CO_2 emissions has become an issue that has received more and more attention. Some studies suggest a negative relationship between economic growth and CO_2 emissions. That is, as economic growth increases, the rate of increase in CO_2 emissions decreases. This is due to the increased use of energy efficiency and clean energy technologies. However, there are also those who oppose this view. Some argue that economic growth is not enough to reduce CO_2 emissions and that more comprehensive policies are needed. They also point out that developing countries need fossil fuels for economic growth and that it is more difficult to cope with rising CO_2 emissions. The relationship between CO_2 emissions and economic growth is complex and affects many factors. However, environmental factors such as sustainable development goals require more efforts to reduce CO_2 emissions.

In this study, the relationship between carbon dioxide emissions, energy consumption, and economic growth is analyzed through the example of Azerbaijan. Azerbaijan is a country that can export energy with its natural gas reserves. However, it is also a country that produces high levels of carbon dioxide emissions.

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In a similar vein, Bayramli's (2020) paper discussed the environmental problems caused by oil in Azerbaijan. The author emphasized that these issues had their roots in the period of the USSR.

Meanwhile, Ordu's (2022) study examined the long-term cointegration relationship between primary energy consumption, renewable energy consumption, carbon dioxide emissions, and economic growth in Turkey. Using annual data for the period 1990-2019 and the ARDL bounds test approach, the findings showed that there was a long-term cointegration relationship between the variables.

Overall, these studies provide insights into the environmental challenges faced by different countries, particularly in relation to energy consumption, carbon emissions, and economic growth.

3. Dataset and Econometric Methodology Formatting the text

The data were taken from the official website of the Azerbaijan State Statistics Committee to analyze the relationship between the export revenues of the main energy resources and the development of the tourism sector. The data used in the study are quarterly data between the years 1988 and 2021. In the model, the variables are abbreviated as follows in Table 1:

Table 1 Defining variables.

Description	Abbreviation
Natural Gas Consumption	NGCA
Oil Consumption	OILCA
Carbon Dioxide Emissions from Energy	ECO2A
Gross domestic product (current US$)	GDP

Co-integration tests are used to analyze the long-term relationships between variables. The variables must be stationary of the same order in the commonly used cointegration tests. This situation creates some problems in the use of the cointegration test. These problems are eliminated by the ARDL method, which allows the analysis of the long-term relationship between variables that are not stationary in the same order. This ARDL test developed by Peseran and Smith (2001) is widely used in cointegration tests (Ethem et al. 2012). Co-integration analysis is performed with the ARDL model by using the equations below.

$$\Delta Y_t = \beta o + \beta 1 + \varepsilon i \qquad (1)$$

$$\Delta Y_t = \beta o + \sum_{i=1}^{n} \beta_i \Delta Y_{t-1} + \sum_{i=1}^{n} \beta_{\delta i} \Delta X_{t-1} + \varphi_1 Y_{t-1} + \varphi_2 X_{t-1} + \mu_t \qquad (2)$$

In the equation in (2), the symbol Δ represents the difference operator, the symbol the constant term, and the symbol the error term. First, equation (1) is estimated in order to perform the cointegration analysis. After estimating equation (1), a long-run relationship should be tested. The Wald test is used to test the existence of a long-term relationship between variables. The hypotheses of this test are as follows:

$$H_0: \delta_1 = \delta_2 = 0, \qquad H_0: \delta_1 \neq \delta_2 \neq 0 \qquad (3)$$

The statistical value F calculated for the analysis of the long-run relationship by Pesaran et al. (2001). compared the significance levels derived asymptotically in their study. If the F statistic is above the critical value, H0 is rejected and H1 is accepted. Therefore, it turns out that there is a cointegration relationship.

4. Results

4.1. Unit Root Analysis Formatting the text

Stationarity in time series means that the variance does not change depending on the time (İşleyen et al. 2017). In studies using time series data, it is important that the series be stationary. When non-stationary series are used in time series analysis, the results of the model are unrealistic, and the use of non-stationary series causes a spurious relationship between the variables subjected to the model. The most valid analysis used to determine whether a variable is stationary or its degree of stationarity is the unit root test (Damodar 2004). Although unit root tests are of great importance in econometric studies, they are used in many fields.

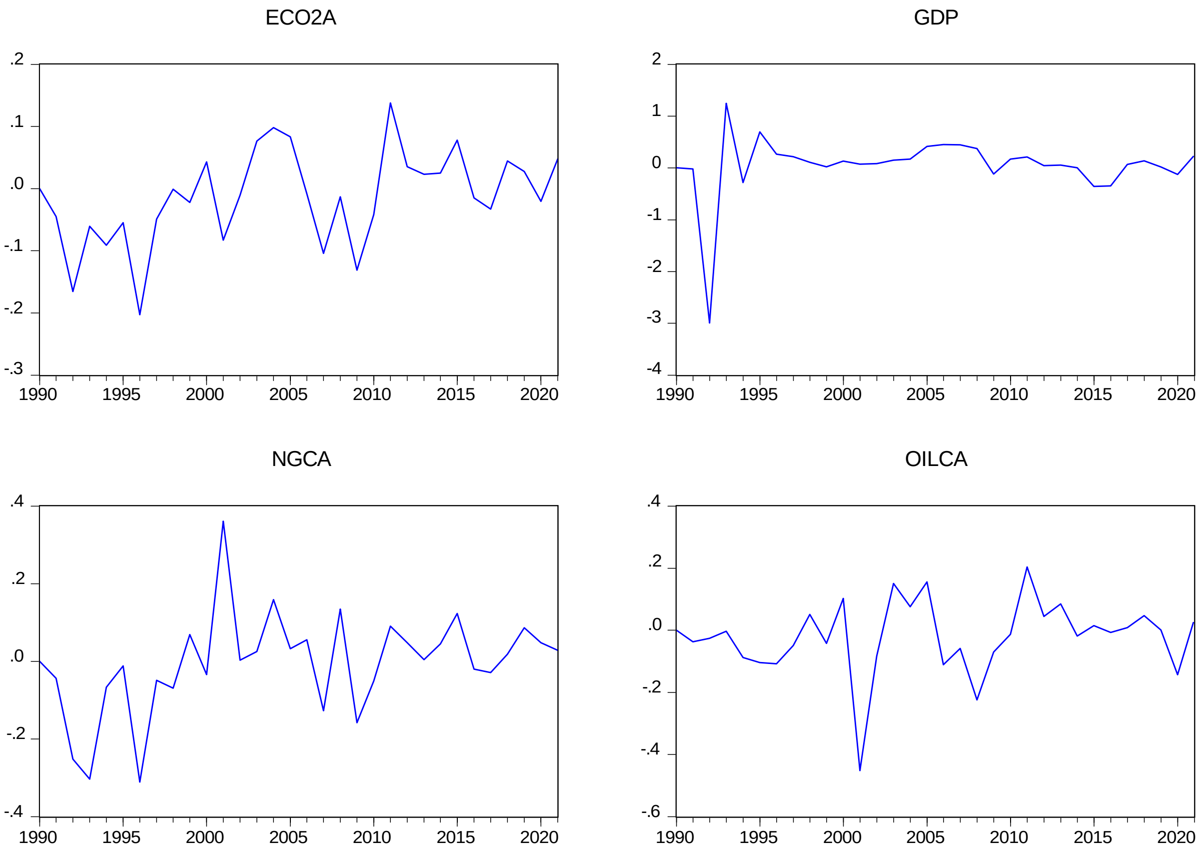
The most commonly used unit root tests in practice:

Dickey Fuller (DF).
Extended Dickey Fuller (ADF).
Phillips-Perron (PP) unit root tests.

When Table 2 is analyzed, 1%, 5%, and 10% confidence intervals are given for the variables. In the PP unit root test, NGCA, OILCA, ECO2A, and GDP appear to be stationary (Graph 1).

Table 2 Phillips-Perron (PP) unit root tests.

At Level					
		NGCA	**OILCA**	**ECO2A**	**GDP**
	t-Statistic	-4.4909	-5.0493	-3.6557	-7.0624
With Constant	Prob.	0.0012	0.0003	0.0101	0.0000
	t-Statistic	-5.1381	-5.1194	-4.4325	-7.0002
With Constant & Trend	Prob.	0.0012	0.0013	0.0070	0.0000
Without Constant &	t-Statistic	-4.5597	-4.9915	-3.6414	-7.1322
Trend	Prob.	0.0000	0.0000	0.0007	0.0000
At First Difference					
		d(NGCA)	d(OILCA)	d(ECO2A)	d(GDP)
	t-Statistic	-9.5185	-8.3610	-7.3986	-10.1706
With Constant	Prob.	0.0000	0.0000	0.0000	0.0000
	t-Statistic	-9.3468	-8.2052	-5.9374	-11.7643
With Constant & Trend	Prob.	0.0000	0.0000	0.0002	0.0000
Without Constant &	t-Statistic	-9.6838	-8.5128	-7.5267	-10.0921
Trend	Prob.	-9.5185	0.0000	0.0000	0.0000



Graph 1 Memory Root Test Results Graph.

The variables included in the analysis are not stationary at the level, as shown in table 2 and graph 1. To make the series stationary, the first difference in these series had to be taken and the unit root problem in the series had to be solved . For the series included in the analysis, when the Enhanced Dickey-Fuller test is examined, it is seen that the series are stationary at the first level because both the probability values are "0" and the critical values are absolutely smaller than the ADF test statistical. After testing the series included in the analysis to be stationary, a cointegration analysis should be performed to determine whether there is a long-term relationship at the next stage. Cointegration analysis is a test that considers whether multiple variables move with each other. If there is cointegration in the result of the test in question (if they act together in the long run), the cause-effect relationship is confirmed. Cointegration analysis is a test developed to examine the relationship between two non-stationary time series. If two or more time series are not stationary but their linear combinations are stationary, it can be said that these series are cointegrated (Bal 2012). The Johansen cointegration test was used to test the existence of a long-term relationship between the variables. The Johansen cointegration test results among the series included in the analysis are given in Table 3.

Table 3 Johansen Cointegration Test Results for NGCA, OILCA, ECO2A and GDP.

Trace Test	Eigenvalue Statistics	Trace Statistics	5% Critical Value	Possibility
None *	0.826291	101.6561	47.85613	0.0000
At most 1 *	0.635440	50.89525	29.79707	0.0001
At most 2 *	0.433699	21.63237	15.49471	0.0052
At most 3 *	0.162483	5.142102	3.841466	0.0233
Maximum Eigen Value Test	**Eigenvalue Statistics**	**Max-Eigen Statistics**	**5% Critical Value**	**Possibility**
None	0.826291	50.76082	27.58434	0.0000
At most 1 *	0.635440	29.26288	21.13162	0.0029
At most 2	0.433699	16.49026	14.26460	0.0219
At most 3 *	0.162483	5.142102	3.841466	0.0233

When Table 3 is examined, it is seen that there is a cointegration equation between the analyzed variables at 1% significance levels for Trace values. However, it is seen that there is a cointegration equation between the analyzed variables at 5% and 10% significance levels for Maximum Eagen values. The existence of cointegration equality between the analyzed variables means that there is a long-term relationship between these variables, according to the result.

4.2. Canonical Cointegrating Regression Test

Canonical Cointegrating Regression (CCR) is a method used in econometrics to analyze time series data. This method is also known as the Johansen method and is used in cointegration analysis. CCR is used to model a long-term relationship between two or more time series. To find this long-run relationship, the mean and standard deviation of errors from previous periods of the data are calculated. Then, using the mean and standard deviation of these errors, a cointegration relationship is determined, showing that two or more time series have a common trend. CCR is widely used in the analysis of various economic and financial data. For example, it can be used to analyze the relationship between the prices of financial assets such as stocks and interest rates. It can also be used in the analysis of macroeconomic data such as the consumer price index, gross national product, and other economic indicators. The CCR method is a very effective method for modeling long-term relationships in economic and financial data. However, it should be noted that the relationships between the data may change over time, and therefore the model may need to be updated.

When the DOLS test results in Table 4 are looked at, the variables with positive coefficients show that there is a positive interaction between the variables. According to the results of the analysis made with the help of the DOLS test, when the consumption of natural gas increases by one unit, the carbon dioxide emissions increase by 0.133560 units. When oil consumption increases by one unit, carbon dioxide emissions increase by 0.255460 units.

Table 4 Dynamic Least Squares (DOLS) Test Results.

ECO2A it = α + β1 NGCA it + εit ECO2A it = α + β1 OILCA it + εit ECO2A it = α + β1 GDP it + εit	DOLS NGCA to ECO2A	DOLS OILCA to ECO2A	DOLS GDP to ECO2A
R-squared	0.479785	0.451924	0.172614
R-squared	0.393083	0.360578	0.034717
Coefficient	0.531338	0.644200	-0.079177
Std. Error	0.133560	0.255460	0.108179
t-Statistic	3.978255	2.521730	-0.731913
Prob.	0.0006	0.0187	0.4713

4.3. Granger Causality Test

The Granger Causality Test is a statistical method used to determine the causal relationship between variables in a time series. This test analyzes autocorrelation structures in time series data to determine whether there is a causal relationship between two variables. The Granger Causality Test is a two-way test and tests one of the following two hypotheses: H0: X is Granger Y without reason (Y explains X). H0: Y is the cause of X without reason (X explains Y). Here, X and Y represent two variables. These hypotheses test whether the past values of one variable are useful in predicting the future values of the other variable. The Granger Causality Test is widely used in econometrics, finance, macroeconomics, and other social sciences. Especially in the field of economics, it is used to determine the causal relationships between variables such as monetary policies, inflation, interest rates, and stock prices.

In Table 5, pairwise Granger causality tests are presented. Granger causality is a statistical concept used to determine whether one time series can be used to predict another time series. The table shows the results of testing the causal relationships between various variables. The table is divided into two sections: the null hypothesis and the test results. The null hypothesis states that there is no Granger causality between the variables being tested. The test results include the number of observations, the F-statistic, and the probability associated with the test. Let's analyze the results for each pair of variables:

GDP does not Granger Cause ECO2A: The F-statistic is 0.47720, and the probability is 0.6261.Based on these results, we fail to reject the null hypothesis, suggesting that GDP does not Granger cause ECO2A.

ECO2A does not Granger Cause GDP: The F-statistic is 0.08659, and the probability is 0.9173. Similarly, we fail to reject the null hypothesis, indicating that ECO2A does not Granger cause GDP.

NGCA does not Granger Cause ECO2A: The F-statistic is 0.27794, and the probability is 0.7597. Again, we fail to reject the null hypothesis, indicating that NGCA does not Granger cause ECO2A.

ECO2A does not Granger Cause NGCA: The F-statistic is 2.59090, and the probability is 0.0949. In this case, the probability is relatively low, but we still fail to reject the null hypothesis, suggesting that ECO2A does not Granger cause NGCA.

OILCA does not Granger Cause ECO2A: The F-statistic is 0.52714, and the probability is 0.5967. Once again, we fail to reject the null hypothesis, indicating that OILCA does not Granger cause ECO2A.

ECO2A does not Granger Cause OILCA: The F-statistic is 0.27830, and the probability is 0.7594. Similarly, we fail to reject the null hypothesis, suggesting that ECO2A does not Granger cause OILCA.

NGCA does not Granger Cause GDP: The F-statistic is 0.13768, and the probability is 0.8720. We fail to reject the null hypothesis, indicating that NGCA does not Granger cause GDP.

GDP does not Granger Cause NGCA: The F-statistic is 1.34532, and the probability is 0.2787. Once again, we fail to reject the null hypothesis, suggesting that GDP does not Granger cause NGCA.

OILCA does not Granger Cause GDP: The F-statistic is 0.01753, and the probability is 0.9826. We fail to reject the null hypothesis, indicating that OILCA does not Granger cause GDP.

GDP does not Granger Cause OILCA: The F-statistic is 0.21817, and the probability is 0.8055. We fail to reject the null hypothesis, suggesting that GDP does not Granger cause OILCA.

OILCA does not Granger Cause NGCA: The F-statistic is 2.87970, and the probability is 0.0749. The probability is relatively low, but we still fail to reject the null hypothesis, indicating that OILCA does not Granger cause NGCA.

NGCA does not Granger Cause OILCA: The F-statistic is 0.57982, and the probability is 0.5674. Once again, we fail to reject the null hypothesis, suggesting that NGCA does not Granger cause OILCA.

In summary, based on the results of the pairwise Granger causality tests, there is no evidence to support the presence of Granger causality between the variables tested in the given dataset.

Table 5 Granger Causality Test Results.

Independent → Dependent	F-Statistic	Prob.
OILCT → ECO2T	0.52714	0.5967
NGCT → ECO2T	0.27794	0.7597
DGDP → ECO2T	0.47720	0.6261
NGCT → OILCT	0.57982	0.5674
DGDP → OILCT	0.21817	0.8055
OILCT → NGCT	2.87970	0.0749
DGDP → NGCT	1.34532	0.2787
OILCT → DGDP	0.01753	0.9826
NGCT → DGDP	0.13768	0.8720

5. Conclusion and suggestions

Bayramli and Kapan (2016) say that environmental problems can be solved by having an effective environmental policy, giving factories treatment facilities, getting help from non-governmental organizations, raising awareness about the environment, and looking at what developed countries have done. This study also examined the relationship between carbon dioxide emissions, energy consumption, and economic growth in Azerbaijan. The analyzes show that there is a linear relationship between energy consumption and carbon dioxide emissions, and carbon dioxide emissions increase with an increase in energy consumption. To reduce carbon dioxide emissions, policies such as increasing the use of renewable energy sources and increasing energy efficiency can help reduce carbon dioxide emissions. Analyzes made on the case of Azerbaijan show a positive relationship between energy consumption and carbon dioxide emissions, and it is concluded that policies such as the use of renewable energy sources and increasing energy efficiency can help reduce carbon dioxide emissions. In addition, when the results of the Granger causality test are examined, it is stated that the causality relationship between the variables is at the 1% and 5% level of significance. This is an important finding that supports the results of the study. Azerbaijan's example serves as a model for other countries studying the relationship between energy consumption, carbon dioxide emissions, and economic growth. The results highlight the importance of adopting a sustainable energy policy around the world.

On the basis of the data and inferences drawn from this research, a number of recommendations may be made to solve the issues posed by Azerbaijan's high energy consumption, rapid economic expansion, and high CO2 emissions:

- Encourage the use of renewable energy sources by maintaining the government's policy of providing financial incentives for their research, development, and commercialization. This is something that can be accomplished via the use of expedited regulatory procedures, feed-in tariffs, and financial incentives. Diversifying the energy mix and reducing dependency on fossil fuels may be accomplished through increasing investments in renewable energy projects such as solar, wind, and hydroelectric power.
- Enhance energy efficiency: It is vital to implement energy-efficient practises and technology if one is interested in reducing their overall energy usage. It is important to encourage families, companies, and industries to adopt energy-saving practises such as purchasing energy-efficient equipment, installing insulation, and using lighting systems. Create educational and training courses with the goal of increasing people's understanding about the advantages of energy saving.
- Increase international collaboration by working with international groups and nations in the region to share information and successful strategies for reducing emissions and implementing sustainable energy practises. Take part in endeavours such as the Paris Agreement, and do all you can to fulfil national objectives set for the reduction of emissions of greenhouse gases.
- Invest in research and development: Allocate money to research and development initiatives that are focused on carbon capture and storage, energy storage, and renewable energy technology. In order to stimulate innovation and quicken the process of transitioning to a low-carbon economy, government agencies, academic institutions, and private businesses should form partnerships.
- Raise public awareness: Initiate public awareness campaigns to educate individuals on the significance of environmentally responsible energy practises, the relevance of mitigating the effects of climate change, and the advantages of lowering CO2 emissions. Encourage different patterns of conduct as well as individual efforts to contribute to energy saving.

Azerbaijan is possible to make strides towards a more sustainable and ecologically friendly energy sector by putting these proposals into action, which will also help to promote economic development and reduce emissions of carbon dioxide. This will not only help to efforts to mitigate global climate change but will also improve energy security, produce a cleaner and healthier environment for future generations, and increase global climate change mitigation efforts..

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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