2025, 9 (1), 1-19

Uluslararası Ekonomi, İşletme ve Politika Dergisi

International Journal of Economics, Business and Politics

https://dergipark.org.tr/tr/pub/ueip

CO_2 Emissions Forecast Based on Renewable and Non-Renewable Energy Consumption in Türkiye

Türkiye'de Yenilenebilir ve Yenilenemez Enerji Tüketimlerine Dayalı CO_2 Emisyonları Öngörüsü

Hüseyin Coşkun [a*] **Hakan Eygü** [b]

[a] Lecturer, Bayburt University, Department of Finance, Banking and Insurance, Vocational School of Social Sciences, Bayburt/Türkiye; PhD Student, Ataturk University, Graduate School of Social Sciences, Department of Econometrics, Erzurum/Türkiye, hcoskun@bayburt.edu.tr, ORCID: 0000-0003-4557-9813

[b] Assoc. Prof. Dr., Atatürk university, Faculty of Economics and Administrative Sciences, Department of Econometrics, Erzurum/Türkiye, hakaneygu@atauni.edu.tr, ORCID: 0000-0002-4104-2368

ARTICLE INFO

Article Type
Research Article

Keywords
CO_2 Emissions
Renewable Energy
Non-Renewable Energy
AARDL Model
Econometric Simulation

Received: Dec, 02, 2024
Accepted: Mar, 21, 2025

ABSTRACT

This study aims to reveal the impact of renewable and non-renewable energy consumption on CO_2 emissions in Türkiye and the potential to reach the CO_2 emission level targeted in the 2030 Paris Agreement. In the first stage, the cointegration relationship was analyzed with the AARDL model approach using annual data for 1965-2022. According to the results of the analysis, in the long run, non-renewable energy consumption increases CO_2 emissions, while renewable energy consumption decreases CO^2 emissions. In the second phase of the research, three scenarios were prepared for each of renewable and non-renewable energy consumption. For nine scenarios, including combinations of these scenarios, CO_2 emissions that may occur until 2030 were estimated using the econometric simulation method. According to the estimation results, the low non-renewable energy consumption and high renewable energy consumption scenario was determined as the scenario that can reduce CO_2 emissions the most until 2030. However, even in this case, it is understood that more investment in renewable energy will be required since the 2030 CO_2 emission reduction target will not be achieved. Therefore, policymakers need to enact policies to increase incentives for renewable energy generation in both the public and private sectors and take steps to improve the necessary infrastructure.

MAKALE BİLGİSİ

Makale Türü
Araştırma Makalesi

Anahtar Kelimeler
CO_2 Emisyonu
Yenilenebilir Enerji
Yenilenemez Enerji
AARDL Modeli
Ekonometrik Simülasyon

Geliş Tarihi : 02 Aralık 2024
Kabul Tarihi: 21 Mart 2025

ÖZ

Bu çalışmada, Türkiye'de yenilenebilir ve yenilenemeyen enerji tüketiminin CO_2 emisyonları üzerindeki etkisi ve 2030 Paris Anlaşması'nda hedeflenen CO^2 emisyon düzeyine ulaşma potansiyeli ortaya konulmaya çalışılmıştır. İlk aşamada, 1965-2022 yıllık verileri kullanılarak AARDL model yaklaşımıyla eşbütünleşme ilişkisi analiz edilmiştir. Analiz sonuçlarına göre, uzun vadede yenilenemeyen enerji tüketimi CO_2 emisyonlarını artırmakta, yenilenebilir enerji tüketimi ise CO_2 emisyonlarını azaltmaktadır. Araştırmanın ikinci aşamasında yenilenebilir ve yenilenemez enerji tüketiminin her biri için üç senaryo hazırlanmıştır. Bu senaryoların kombinasyonlarını içeren dokuz senaryo için 2030 yılına kadar oluşabilecek CO_2 emisyonları, ekonometrik simülasyon yöntemi kullanılarak tahmin edilmiştir. Tahmin sonuçlarına göre, düşük yenilenemeyen enerji tüketimi ve yüksek yenilenebilir enerji tüketimi senaryosu, 2030 yılına kadar CO_2 emisyonunu en fazla azaltabilecek senaryo olarak belirlenmiştir. Ancak bu durumda bile 2030 CO_2 emisyon azaltım hedefine ulaşılamayacağından yenilenebilir enerjiye daha fazla yatırım yapılması gerekeceği anlaşılmaktadır. Bu nedenle, politika yapıcıların hem kamu hem de özel sektörde yenilenebilir enerji üretimine yönelik teşvikleri artıracak politikalar yürürlüğe koymaları ve gerekli altyapıyı iyileştirmeye yönelik adımlar atmaları gerekmektedir

1. Introduction

Pursuing economic growth represents a primary macroeconomic objective across all economies (İmamoğlu and Özdemir, 2023: 101). From the past to the present, countries have prioritized phenomena such as production, industrialization, and energy to facilitate growth.

---

* *Corresponding Author / Sorumlu Yazar*

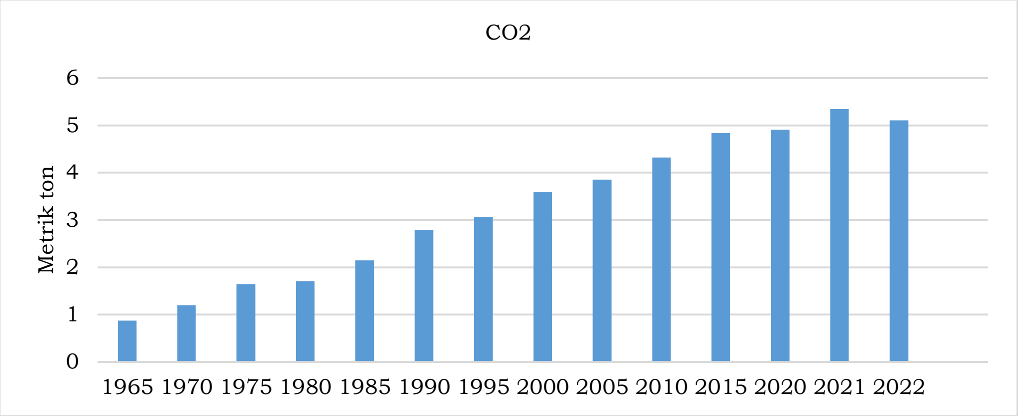
Cite as/Atıf: Coşkun, H. and Eygü, H. (2025). CO_2 Emissions Forecast Based on Renewable and Non-Renewable Energy Consumption in Türkiye. *International Journal of Economics, Business and Politics,* 9(1), 1-19. https://doi.org/10.29216/ueip.1594788

Although energy was not previously regarded as a direct input in production, it is now acknowledged as a crucial factor in modern economic growth (Rafiq and Salim, 2009: 336). Energy, regarded as a principal driver of economic growth, can be derived from non-renewable and renewable sources. The former encompasses oil, natural gas, and coal, while the latter includes hydroelectricity, solar, wind, and geothermal energy (Ellabban et al., 2014: 749). Energy is a crucial element in the production process. However, using energy derived from fossil resources has been identified as a significant contributor to environmental degradation (Caglar et al., 2022: 2). The utilization of energy derived from fossil resources has resulted in the worsening of environmental concerns, including climate change and global warming. This is attributable to the emission of greenhouse gases, such as carbon dioxide (CO2) and methane, which contribute to the accumulation of greenhouse gases in the atmosphere. This situation is further exacerbated by human activities (Kronsell, Rosqvist & Hiselius, 2016: 703; Koçak & Şarkgüneşi, 2017: 51). In recent years, as energy consumption has increased, issues related to production, industry, and climate change have emerged (IEA, 2016a). In light of these challenges, it is widely acknowledged that one of the most effective strategies for achieving global climate targets is to enhance the utilization of renewable energy sources in energy production. It is argued that using energy derived from renewable sources is more cost-effective and environmentally benign than that derived from non-renewable sources (IEA, 2016b; Pata ve Yılancı, 2020: 804).

Turkey exhibits a markedly elevated rate of carbon emissions compared to the global average (BP, 2021). The accelerated growth in carbon emissions has resulted in a series of adverse effects, including global temperature increases, alterations in sea levels, and the proliferation of airborne pollutants, all of which pose a significant risk to human survival (Inglesi-Lotz and Doğan, 2018). In the present era, renewable energy sources, including solar, wind, geothermal, and biomass energy, are regarded as alternative energy sources due to the inherent risks associated with non-renewable energy sources and the finite nature of these resources (Kaya vd., 2018: 220; Canbay, 2019: 141).

In order to prevent climate change, global warming, and pollution, countries have come together from time to time to reduce pollutant emissions and have tried to implement some decisions. In 1972, the United Nations Declaration on the Human Environment was accepted in Stockholm. 1992, the United Nations Conference on Environment and Development was held in Rio de Janeiro. In 1997, the Kyoto Protocol was adopted. In 2015, the Paris Agreement was adopted. Finally, in 2021, the Glasgow Climate Pact was signed, and decisions were taken to reduce emissions that cause pollution. The Paris Agreement has been acknowledged as a legally binding agreement involving the participation of 187 countries as of 2020, with the objective of reducing emissions to combat climate change. The principal aim of the agreement is to reduce the global temperature increase to below 2°C (Türkeş, 2022: 36). For this purpose, it was decided that the countries party to the agreement would reduce their CO2 emissions as soon as possible and submit them as 'Nationally Determined Contributions' every five years (T.C. Dışişleri Bakanlığı, 2023). In 2015, Turkey presented a target to reduce its emissions by 21% in 2030 in accordance with the reference scenario. However, it officially became a party to the agreement on 10 November 2021 (Çevre ve Şehircilik Bakanlığı, 2023). At the summit held in Glasgow, it was agreed that the emission targets set until 2030 should be reviewed and strengthened by 2022 (Çetinkaya and Akar, 2022: 37). At the Ministerial Session held on 15-16 November 2022, Turkey updated its 21% reduction target until 2030, increasing it to 41% (T.C. Dışişleri Bakanlığı, 2023). Figure 1 illustrates the fluctuations in Turkey's CO2 emissions over the 57 years between 1965 and 2022.

Figure 1: Per Capita CO² Emissions in Turkey (1965-2022)



Source: World Bank and Our World in Data, 2024.

Figure 1 shows that emissions have increased significantly in Turkey since 1965 with the desire for economic growth. As can be seen from Figure 1, the agreements made and decisions taken did not have the desired effect in reducing emissions. CO2 emissions in Turkey, which reached 5.34 mt per capita in 2021, decreased in 2022 to approximately 5.10 mt.

In light of the above information, the main objective of this study is to determine the impact of renewable and non-renewable energy consumption on CO2 emissions in Turkey and to reveal Turkey's potential to reach the 2030 CO2 emission targets committed in the Paris Agreement. The effects of renewable energy consumption, non-renewable energy consumption, economic growth, and trade openness on CO2 emissions have been considered while revealing Turkey's potential to reach its committed targets. The contributions of the study planned for this purpose to the literature can be summarised as follows: (i) This research forecasts the CO2 emissions of Turkey, a party to the Paris Agreement, until 2030 according to different energy consumption scenarios using econometric simulation method. This brings a more comprehensive perspective to energy and emission reduction policies. (ii) It also reveals the long-run and short-run relationships between energy consumption, economic growth, trade openness, and CO2 emissions. (iii) The long-run and short-run relationships are investigated using the Extended Autoregressive with Distributed Lag (AARDL) model approach, which is an up-to-date approach with robust results. The following section of the paper presents the theoretical framework and literature review. The next section introduces the dataset, model, and methodology, and the following section section presents the findings of the analysis. The last section presents the results of the study and makes policy recommendations.

2. Literature Review

The concepts of pollution, growth, and energy, which occupy the agenda of both developed and developing countries, have been the most emphasized concepts of recent times. Countries aiming for economic growth must consume energy resources in many areas such as industry and industry (Bilgili et al., 2016: 19044). Therefore, researchers focusing on pollution reduction policies should consider the relationship between CO2, energy consumption (renewable energy consumption, non-renewable energy consumption and total energy consumption) and economic growth. After the studies of Grossman and Krueger (1991) and Selden and Song (1995), which examined the relationship between economic growth and environmental pollution, called the environmental Kuznets curve hypothesis, this relationship has been addressed by many researchers. In the test of this hypothesis, which suggests that economic growth increases pollution up to a certain point but decreases it after a certain point, some studies have only examined the relationship between economic growth and environmental pollution (Grossman and Krueger, 1995; Martınez-Zarzoso and Bengochea-Morancho, 2004; Georgiev and Mihaylov, 2015). However, Stern et al. (1996) and Coondoo and Dinda (2002) emphasized that the variables included in the models may affect the relationship between economic growth and pollution in studies conducted on different countries or groups of countries. De Bruyn (1997: 499) suggested that structural changes between countries may affect the causality relationship between economic growth and pollution. In their studies conducted by Solarin et al. (2017) for India and China, Sari Hassoun et al. (2018) for Algeria, Apergis et al. (2018) for Sub-Saharan African countries, Anwar et al. (2022) for 15 Asian countries and Akhtar et al. (2023) for Malaysia, it was determined that the economic growth variable would increase the CO2 level. Chica-Olmo et al. (2020) suggested that a country's economic growth can be affected by the renewable energy consumption of neighboring countries. In this case, it can be said that other variables than economic growth can directly or indirectly affect the environment. In addition to economic growth, many studies have been conducted in which variables that are thought to have an effect on pollution as independent variables are included in research models (De Bruyn, 1998; Başar and Temurlenk, 2007; Halıcıoğlu, 2009; Pao and Tsai, 2010; Ahmed and Long, 2012; Öztürk and Acaravcı, 2013; Haseeb et al., 2018; Okumuş, 2020; Bulut, 2021; Çağlar, 2022; Karahasan and Pınar, 2022; Bekun et al., 2023).

The most important variable in explaining CO2 emissions in Turkey is income, followed by energy consumption and international trade (Halıcıoğlu, 2009: 1157). Expanding international trade may increase energy consumption and, thus, environmental pollution. However, environmental pollution can be reduced as new technologies exported through international trade are more environmentally friendly, and environmental policies can be implemented with increasing income levels (Grossman and Krueger, 1991: 35). In addition, international trade, on the one hand, leads to depletion of natural resources, resulting in higher CO2 emissions and lower environmental quality (Chaudhuri and Pfaff, 2002: 36; Dinda, 2004: 450), and on the other hand, it leads to competition among countries and thus can reduce CO2 emissions by increasing the efficiency of use of scarce resources (Helpman, 1998: 583; Shahbaz et al., 2012: 2952). Grossman and Krueger (1995: 372) argued that international trade may positively affect environmental pollution in developed countries but may have a negative effect in developing countries. In their studies on the Turkish economy, Çetin and Şeker (2014: 226) and Yılmaz and Dilber (2020: 471) found that foreign trade openness increases environmental pollution. Nasir and Rehman (2011), working on the economy of Pakistan, a developing country like Turkey, found that international trade has an increasing effect on CO2 emissions. Tiwari et al. (2013), in their study of the Indian economy, showed that trade openness increases CO2 emissions.

In today's world, most of the energy is obtained from fossil resources. However, with the increasing demand for energy, these resources are becoming scarce (Sari Hassoun and Ayad, 2020). The risk of extinction of non-renewable energy sources, CO2 emissions from this energy consumption, and environmental pollution problems have convinced countries that non-renewable energy sources should be replaced with renewable energy sources. In this context, determining the factors affecting pollution has also been the subject of scientific studies and has taken a vast place in the literature. When the literature on the relationship between total energy consumption, non-renewable and renewable energy consumption and CO2 emissions is examined (Hanif et al., 2019; Shafiei and Salim, 2014; Erdoğan et al, 2020; Çetin and Sezen, 2018; Qashou, 2022; Acaravcı and Erdoğan, 2018; Pata and Çağlar, 2021; Farhani and Shahbaz, 2014; Apergis et al. 2010; Mahalik et al., 2021; Wang and Zhang 2020; Karaaslan and Çamkaya, 2022), it is seen that studies differ in modeling CO2 emissions and produce different results. This situation has caused the issue to maintain its importance today.

The relationship between CO2 emissions and energy consumption has been the subject of extensive investigation by researchers from various countries and country groups. Sari Hassoun et al. (2018) concluded in their study in Algeria that fossil energy consumption positively affects CO2 emissions, while renewable energy consumption negatively affects CO2 emissions. In their studies on Asian countries, Anwar et al. (2021) and Hanif et al. (2019) concluded that the consumption of non-renewable energy leads to an increase in emissions, whereas the consumption of renewable energy has the opposite effect, resulting in a decrease in emissions. The findings of Shafiei and Salim (2014), Erdoğan et al. (2020), and Destek and Shina (2020) indicate that non-renewable energy consumption is associated with an increase in emissions, whereas renewable energy consumption is linked to a reduction in emissions. These results were observed in studies conducted on OECD countries. Apergis and Payne (2009) examined the relationship between energy consumption and CO_2 emissions for Central American countries and identified a bidirectional causality relationship between the two variables. Mahalik et al. (2021) conducted research on the BRICS countries and concluded that non-renewable energy consumption increases CO2 emissions, while renewable energy consumption has the opposite effect, resulting in a decrease in CO2 emissions. Similarly, Cheng et al. (2019) argue that renewable energy supply is an effective means of reducing CO2 emissions per capita. Pata (2021) and Doğan and Öztürk (2017) found that non-renewable energy consumption increases CO2 emissions and renewable energy consumption decreases CO2 emissions in their studies in the USA. Examining the impact of renewable and non-renewable energy consumption on CO2 emissions in China, Chen et al. (2019) show that non-renewable energy has a positive impact on CO2 across the country, while renewable energy has a negative effect on CO2 emissions in the Eastern and Western regions. Rahman and Alam (2022) studied 17 Asia-Pacific countries and showed that total energy consumption positively affects CO2 emissions in panel countries. Boontome et al. (2017) conducted research for Thailand and Bento et al. (2016) for Italy and suggested that renewable energy consumption can be used as a solution to reduce pollution. Acaravcı and Erdoğan (2018) examined the impact of renewable energy production on environmental pollution in Brazil, Canada, China, Russia, and the United States and found that energy production has a negative effect on environmental pollution.Apart from these common results in the literature, there are also different results. Apergis et al. (2010), who conducted a study on 19 developed and developing countries, and Pata and Çağlar (2021), who conducted a study on China, concluded that renewable energy consumption has no significant effect on reducing CO2 emissions. Farhani and Shahbaz (2014), in their study on Mena countries, found that renewable energy consumption increases CO2 emissions as well as non-renewable energy consumption. Dam (2018) showed that total energy consumption in EU countries is associated with an increase in CO2 emissions.

In addition to these studies in the international literature, there are also many studies on Turkey in the national literature. Some of the studies on Turkey are presented in Table 1.

Table 1: Variables and Explanations

Author/Year	Period	Methodology	Results
Çetin and Sezen (2018)	1970-2014	SVAR	Shocks in renewable energy consumption reduce CO2 emissions, whereas shocks in non-renewable energy consumption increase CO2 emissions.
Karasoy and Akçay (2018)	1965-2016	ARDL	While increases in non-renewable energy consumption increase CO2 in the long term, renewable energy consumption reduces CO2 in both the short and long term.
Qashou (2022)	1988-2018	BARDL	In both the short and long term, renewable energy consumption reduces CO2, while non-renewable energy consumption increases CO2
Karaaslan and Çamkaya (2022)	1980-2016	ARDL	Non-renewable is associated with an increase in CO2, while renewable is associated with a decrease in CO2.
Bulut (2017)	1970-2013	FMOLS, DOLS, Kalman filter	Both renewable and non-renewable energy consumption contribute to increasing CO2 emissions.
Bulut (2021)	1970-2016	ARDL	Ecological footprint is negatively related to renewable energy consumption.
Pabuçcu and Bayramoğlu (2016)	1990-2015	Artificial Neural Network Model	It is anticipated that Turkey will cause more CO2 emissions than the amount it committed to by 2030.
Yenisu (2018)	1960-2013	Grander Causality	There is a one-way causality running from energy consumption to CO2 emissions.

Göv and Kapkara Kaya (2023)	1998-2019	LASSO metod	It is positively related to CO2 emissions from energy consumption.
Ağbulut (2022)	1970-2016	Machine learning algorithms	Transport-related CO2 emissions are forecasted to increase approximately 3.4 times by 2050.
Aydin (2014)	1971-2010	MLRA, Trend analysis	In 2025, energy-related CO2 emissions will increase by 47.75% compared to 2010 and reach 334 metric tons.
Hamzacebi and Karakurt (2015)	1965-2012	Analytical and artificial intelligent models	In 2025, CO2 emissions will increase by 64% compared to 2010, reaching 496 metric tons.
Pata (2018)	1974-2014	ARDL, FMOLS	Energy consumption has no significant impact on CO2 emissions.
Yavuz (2014)	1960-2007	OLS, FMOLS	The increase in energy consumption per capita causes an increase in CO2 emissions per capita.
Öztürk and ÖZ (2016)	1974-2011	Maki Cointegration Test, DOLS	Increasing energy consumption increases CO2 emissions.
Eylasov (2023)	1990-2020	ARDL	Renewable energy consumption reduces CO2 emissions
Öcal et al. (2020)	1968-2016	ARDL	Energy consumption does not significantly affect CO2 emissions but increases the ecological footprint.
Daştan and Eygü (2024)	1980-2018	AARDL	Energy consumption does not significantly affect CO2 emissions.

Although there are many studies in the literature on the determinants of CO2 emissions, very few studies have been conducted on the values that CO2 emissions may reach in the future. Aydın (2014), Hamzacebi and Karakurt (2015), Pabuçcu and Bayramoğlu (2016), Ayvaz et al. (2017), and Ağbulut (2022) have made future estimates for CO2 emissions. In these studies, different estimation methods and CO2 modeling have caused differences in the results. This situation necessitates supporting the results with current studies. In addition to the contribution of all these studies to the literature, this study includes renewable and non-renewable energy consumption in modeling CO2 emissions. In addition, unlike other studies, the study will provide literature richness and give ideas to policymakers by using the econometric simulation method for the estimation of 2030 CO2 emissions.

3. Data Set and Methodology

The study employs annual time series data for 1965-2022 to examine the influence of renewable and non-renewable energy consumption on pollution levels. The data on renewable and non-renewable energy consumption and CO2 emissions were obtained from the Our World In Data web page. The gross domestic product (GDP) data were obtained from the World Bank database. As the deadline for the disclosure of pollution data is 2022, data for 2023 could not be included in the dataset. The variables employed in the study, together with their respective explanations, are presented in Table 2.

Table 2: Variables and Explanations

Variables	**Abbreviations**	**Explanations**
Pollution	LCO2	Carbon dioxide (CO2) emissions per capita (mt)
Renewable Energy Consumption	LREC	Primary energy consumption from RE sources per capita (kilowatt-hours)
Non-Renewable Energy Consumption	LNREC	Fossil fuel consumption per capita (kilowatt-hours)
Economic Growth	LGDP	Gross Domestic Product per capita (Constant 2015 US$)
Trade Openness	LTRADE	Total imports and exports as a share of GDP

In the study where natural logarithms of all variables were used, $LGDP$, $LGDP^2$, $LNRE$, LRE and $LTRADE$ variables were included in the model where $LCO2$ was taken as the dependent variable. The mathematical model established to represent the investigated relationship between the variables is given below.

$$LCO_2 = \beta_0 + \beta_1 LGDP + \beta_2 LGDP^2 + \beta_3 LNREC + \beta_4 LREC + +\beta_5 LTRADE + \varepsilon$$

Since the model will be estimated with time series data, it should be ensured that the variables are stationary for the estimation results to be consistent. Since the statistical values obtained from the analyses made with non-stationary data sets will not be valid, it will not be possible to accept the study results. Unit root tests that take structural breaks into account are also used with ordinary unit root tests. If the series is found to be stationary with the ordinary unit root test, there is no need to apply the structural break unit root test (Mert and Çağlar, 2019: 97; Coşkun and Eygü, 2020: 237). As the first step of the analyses, the stationarity tests of the variables were tested with Augmented Dickey-Fuller (ADF) and Lee Strazicich (LS) unit root analyses.

To determine the cointegration relationship between the variables, the AARDL model developed by Sam et al. (2019) was used. In addition to the cointegration conditions in the ARDL model developed by Pesaran et al. (2001), Sam et al. (2019) developed an F test that tests the joint significance of lagged independent variables. This approach, called the Augmented ARDL, allows the analysis of variables with different degrees of stationarity and eliminates the requirement that the dependent variable be first-degree stationary. In the presence of a cointegration relationship, long-term and short-term coefficients can be estimated. The ARDL model established for the study is as follows:

$$\begin{aligned}\Delta LCO2_t = \beta_0 + \beta_1 DU2000_t + \beta_2 DU2008_t + \sum_{i=1}^{m} \gamma_{1i} \Delta LCO_{2_{t-i}} + \sum_{i=1}^{n} \gamma_{2i} \Delta LGDP_{t-i} + \sum_{i=1}^{p} \gamma_{3i} \Delta LGDP^2{}_{t-i} \\ + \sum_{i=1}^{q} \gamma_{4i} \Delta LNREC_{t-i} + \sum_{i=1}^{r} \gamma_{5i} \Delta LREC_{t-i} + \sum_{i=1}^{s} \gamma_{6i} \Delta LTRADE_{t-i} + \theta_1 LCO_{2_{t-1}} + \theta_2 LGDP_{t-1} \\ + \theta_3 LGDP^2{}_{t-1} + \theta_4 LNREC_{t-1} + \theta_5 LREC_{t-1} + \theta_6 LTRADE_{t-1} + \varepsilon_t\end{aligned}$$

In the model, β_0 represents the model constant, Δ the difference operator, ε_t the model error term, and DU_t the dummy variable for structural break. Testing whether the ARDL model satisfies assumptions such as normality, autocorrelation, and heteroscedasticity is necessary. In this study, the normality test is performed with the Jarque-Bera test, the autocorrelation test is performed with the Breusch-Pagan LM test and the changing variance test is performed with the White test. If these assumptions are met, the validity of the F test to determine the cointegration relationship will be accepted.

Following the identification of the cointegration relationship, three scenarios (low, base, and high) were constructed for renewable and non-renewable energy consumption to facilitate future forecasts. Pollution forecasts for 2023-2030 were also produced in alignment with these scenarios. Different scenarios have not been created for economic growth and foreign trade openness. It is assumed that these series will increase annually in parallel with the average annual growth rate observed between 1965-2022 (economic growth 2.8% and foreign trade openness 4.49%). In creating scenarios, if there is an officially determined target or a declared rate increase, the scenarios can be determined according to these rates (Soğukpınar et al., 2023: 35899). However, if there is no officially declared forecast, scenarios can be produced within the framework of economic theory by calculating periodic increase rates (İmamoğlu and Coşkun, 2023: 50). As the targets set by the Ministry of Energy and Natural Resources within the context of the 2019-2023 strategy plan are not available for 2023-2030, the characteristics of the independent variables were employed in creating the scenarios. In creating the base scenarios, the data sets for the 2023-2030 period were constructed by applying the average annual increase rates for renewable and non-renewable energy consumption observed during the 1965-2022 period (7.53% for renewable energy consumption and 3.56% for non-renewable energy consumption) to the years 2023 and beyond. To create low and high scenarios, it was first necessary to identify the median of the annual increase rates. The average of the below-median increase rates (-9.16% for renewable energy consumption, -0.42% for non-renewable energy consumption) was accepted as the annual increase rate for the low scenario. The average above-median increase rate (23.03% for renewable energy consumption, 7.52% for non-renewable energy consumption) was accepted as the annual increase rate for the high scenario. CO2 emissions were predicted for 2023-2030 in line with the nine scenarios created.

4. Findings

Before estimating an econometric model, the stationarity levels of the variables used must be determined. The findings obtained from the Augmented Dickey-Fuller (ADF) and Lee Strazicich (LS) unit root tests applied to the variables used in the study are shown in Table 3.

Table 3: Stationarity Test Results

	With Constant and Trend	
	ADF test results	**LS test results**
LCO2	-2.8350*	-4.6448 [1985, 2000]
ΔLCO2	-6.7983***	-7.0896 [1999, 2009]***
LGDP	0.4989	-6.1437 [1978, 1998]**
ΔGDP	-7.3682***	-7.6225 [1992, 1998]***
LNREC	-2.9297**	-5.4326 [1979, 1993]
ΔLNREC	-7.5068***	-7.0793 [1999, 2013]***
LREC	-1.2369	-4.6879 [1993, 2014]
ΔLREC	-8.5233***	-6.6923 [1975, 1996]**
LTRADE	-1.1001	-5.7742 [1980, 2007]
ΔLTRADE	-6.2076***	-7.5728 [1977, 1981]***

Note: *, **, *** indicate significance at 10%, 5%, and 1% levels, respectively, and [ ] indicates breakout years.

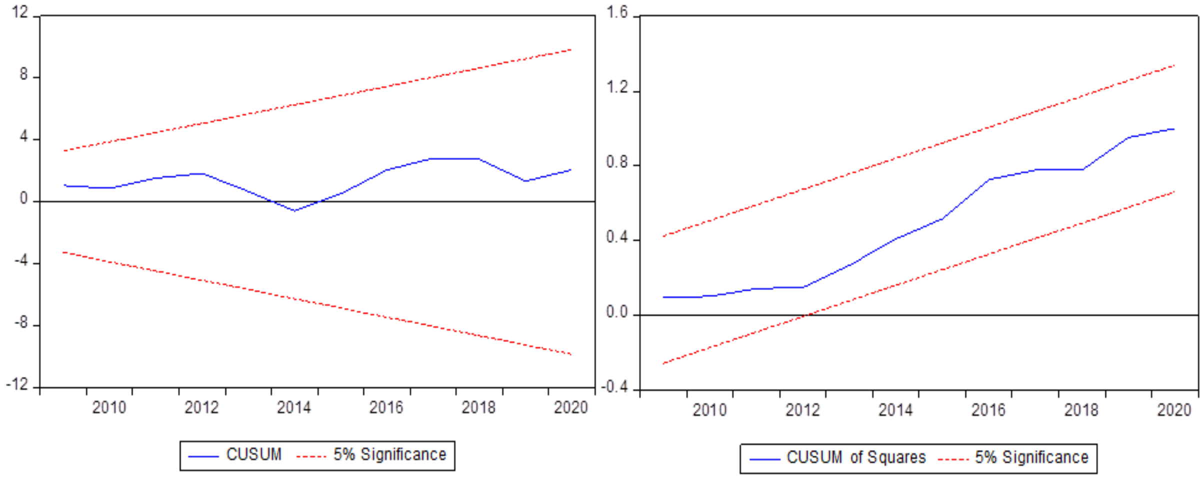
Table 3 shows that the unit root results differ when structural breaks are taken into account. In this case, it would not be correct to ignore the effect of an exogenous shock. Therefore, including the years 1999 and 2009, which are significant for the dependent variable LCO2, in the model will help the results to be more realistic. Since these break dates may be related to the 2000 and 2008 crises in Turkey, the dates 2000 and 2008 are included in the model as two separate dummy variables. The unit root test results show that the maximum degree of stationarity for all variables is 1. Since the maximum stationarity degree is one and all variables are not stationary at the same level, it would be appropriate to apply the ARDL approach. Since the data set is annual, the maximum lag length was selected as two, and the most appropriate model according to the Schwarz information criterion was determined as ARDL(1,0,0,1,0,0). It is essential to verify the results of the selected model and to provide assumptions such as normality, autocorrelation, and variance. Therefore, the results of the tests are presented in Table 4.

Table 4: Diagnostic Test Results of ARDL (1,0,0,1,0,0) Model

R-squared	0.998151
Adjusted R-squared	0.997781
F-statistic	2698.779 (0.0000)
Jarque-Bera	7.328745 (0.0257)
Breusch-Godfrey Serial Correlation LM Test	1.122397 (0.3348)
Heteroskedasticity Test: White	0.909620 (0.5254)
Ramsey RESET	0.874524 (0.3866)

When Table 4 is examined, it is seen that the F statistic is sufficiently large, and the probability value is less than 5%. In this case, it can be said that the model is statistically significant at the 5% significance level. The normality test was performed with the Jarque-Bera test, and the calculated probability value was found to be greater than 1%. The autocorrelation test was performed with the LM test, and the changing variance test was performed with the Breusch-Pagan-Godfrey test, and the probability values were found to be greater than 5%. In other words, the errors in the model were normally distributed, and there was no autocorrelation or heteroskedasticity problem. In addition, when the Ramsey Reset test results were examined, it was seen that the model pattern was determined correctly. To assess the stability of the coefficients obtained from the model, Cusum and CusumSQ graphs were examined, and the results are shown in Figure 2.

Figure 2: Cusum and CusumSQ Test Results



According to Cusum and CusumSQ graphs, it can be said that there is no structural break problem in the model and the prediction coefficients are stationary. The results of these tests show that the long and short-term prediction results to be obtained from the ARDL (1,0,0,1,0,0) model are stationary. After the diagnostic tests, it was first investigated whether the variables were in a cointegration relationship, and the results of the AARDL test conducted to determine this relationship are given in Table 5.

Table 5: AARDL Test Results

Model	DU	Test	Critical Value		
$f(GDP, GDP^2, NREC, REC, TRADE)$	2000 2008	F_{all} = 6.1986 *	Narayan (2005)		
			%10	%5	%1
			3.583	4.160	5.408
		$t_{dependent}$ =-5.3197*	Pesaran et al. (2001)		
			%10	%5	%1
			-3.86	-4.19	-4.79
		$F_{independent}$ =7.1861*	Sam et al. (2019)		
			%10	%5	%1
			3.54	4.17	5.68

Note: * represents significance at 1% significance level.

When the test results given in Table 5 are analyzed, it is seen that the F statistic value obtained is greater than the upper bound critical values. In this case, it can be said that there is a cointegration relationship between the variables. The existence of a cointegration relationship means that long-run coefficients will be valid, and the ARDL(1,0,0,1,0,0) model can be used for future forecasting, which is the purpose of the study. The long-run coefficients obtained from the estimation are presented in Table 6.

Table 6: Long-Term Forecast Results (Dependent Variable: LCO2)

Variable	Coefficient	Standard Error	t-statistic	Probability Value
LGDP	7.612903	2.072453	3.673378	0.0006
LGDP2	-0.405109	0.109353	-3.704580	0.0006
LNREC	0.487038	0.137970	3.530022	0.0010
LREC	-0.037236	0.021127	-1.762477	0.0848
LTRADE	0.053822	0.023764	2.264911	0.0284

Upon examining the long-run coefficients presented in Table 6, it becomes evident that non-renewable energy consumption exerts a positive influence on CO2 emissions. In contrast, renewable energy consumption demonstrates a negative effect on CO2 emissions over an extended period. A 1% increase in non-renewable energy consumption will result in an approximate 0.49% increase in CO2 emissions, whereas a 1% increase in renewable energy consumption will lead to a 0.04% reduction in CO2 emissions. Furthermore, the coefficients relating to economic growth demonstrate that the Environmental Kuznets Curve hypothesis applies to Turkey. In other words, economic growth initially increases CO2 emissions, reaching a threshold after which it has a negative effect. In conclusion, economic growth contributes to environmental protection by reducing CO2 emissions. Furthermore, it is established that trade openness exerts a positive influence on CO2 emissions over the long term.

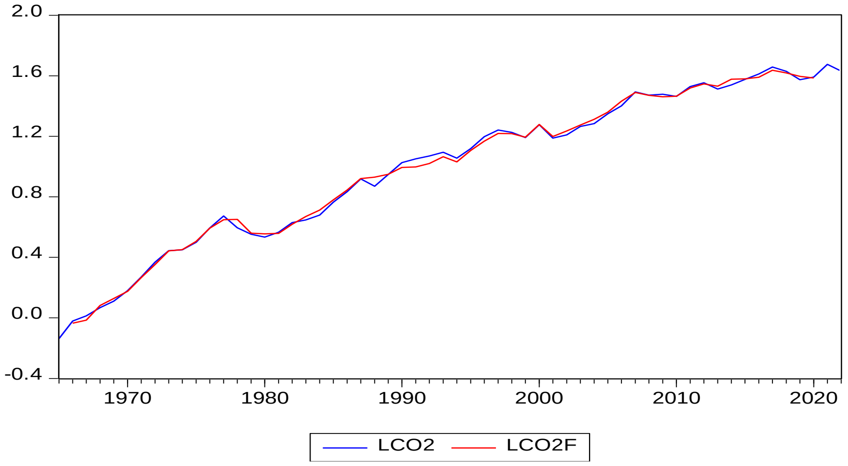
In the event of a long-run relationship being present, it is essential to guarantee the efficacy of the error correction mechanism through the construction of an error correction model. The results of the estimated error correction model are presented in Table 6.

Table 7: Error Correction Model Estimation Results (Dependent Variable: (ΔLCO2)

Variable	Coefficient	Standard Error	t-statistic	Probability Value
C	-26.86556	4.179796	-6.427482	0.0000
Δ(LNREC)	0.588649	0.072365	8.134471	0.0000
DU2000	0.017573	0.022041	0.797287	0.4295
DU2008	-0.019200	0.022016	-0.872080	0.3878
CointEq(-1)*	-0.691482	0.107567	-6.428377	0.0000

The error correction coefficient presented in Table 7 is negative and statistically significant. In this case, it can be said that the error correction model works, and deviations from the long-term balance will be balanced in the short term. The coefficient of -0.691482 indicates that approximately 69.15% of the deviations from the balance are fixed in the next period (after 1 year). Furthermore, an examination of the short-term coefficients reveals that non-renewable energy consumption exerts an increasing influence on pollution levels. It is found that a 1% increase in non-renewable energy consumption in the short term increases CO2 emissions by approximately 0.59%. Up to this part of the study, the effect of renewable and non-renewable energy consumption on CO2 emissions in Turkey for the period 1965-2022 has been investigated, and short-term and long-term effects have been revealed. In the next section, CO2 emissions will be forecasted under different energy consumption scenarios. Before future forecasting, whether the ARDL model is suitable for prediction is first tested. For the ARDL (1,0,0,1,0,0) model, the period 1965-2022 is forecasted, and the results of the actual CO2 emission values and the CO2 emission values obtained from the dynamic forecast are shown in Figure 3.

Figure 3: Reconciliation of Forecast Results with Actual Values



As illustrated in Figure 5, the results of the dynamic forecasting process conducted using the ARDL model are in close alignment with the actual values, exhibiting minimal discrepancies. This demonstrates that the specified ARDL model is an effective tool for forecasting. Furthermore, the Theil inequality coefficient and the mean absolute percentage error (MAPE) are frequently employed to assess the forecasting performance of the model. A Theil inequality coefficient approaching zero indicates that the model exhibits robust forecasting capability. Lewis (1982) posits that a MAPE coefficient below 10 signifies an 'extremely accurate forecast,' one between 10 and 20 represents a 'good forecast,' one between 20 and 50 denotes a 'reasonable forecast.' A coefficient exceeding 50 indicates a 'wrong forecast' (Soğukpınar et al., 2023). Table 8 presents the Theil and MAPE values for 1965-2022.

Table 8: Theil and MAPE Values

Theil Inequality Coefficient	0.010239
MAPE	7.398617

In the forecasting result, the Theil coefficient, which indicates the predictive power of the model, is close to zero, and the MAPE value is less than 10, which means that the forecasting power of the model is high. In this direction, a total of nine different pollution forecasts were made for three different scenarios created for renewable and non-renewable energy, and the forecast results for the period 2023-2030 are shown in Table 9.

Table 9: Forecast Results for the Period 2023-2030

	NREC(L)/REC(D)	**NREC(L)/REC(B)**	**NREC(D)/REC(H)**
2023	5.1034	5.0862	5.0725
2024	5.0973	5.0589	5.0284
2025	5.0882	5.0277	4.9800
2026	5.0763	4.9938	4.9288
2027	5.0618	4.9574	4.8755
2028	5.0446	4.9186	4.8202
2029	5.0248	4.8775	4.7630
2030	5.0025	4.8343	4.7040
	NREC(B)/REC(L)	**NREC(B)/REC(B)**	**NREC(B)/REC(H)**
2023	5.2308	5.2132	5.1992
2024	5.3411	5.3008	5.2689
2025	5.4469	5.3822	5.3311
2026	5.5510	5.4607	5.3897
2027	5.6538	5.5372	5.4458
2028	5.7555	5.6117	5.4995
2029	5.8558	5.6842	5.5507
2030	5.9548	5.7545	5.5994
	NREC(H)/REC(L)	**NREC(H)/REC(B)**	**NREC(H)/REC(H)**
2023	5.3559	5.3379	5.3235
2024	5.5857	5.5436	5.5102
2025	5.8145	5.7454	5.6908
2026	6.0476	5.9493	5.8719
2027	6.2862	6.1566	6.0549
2028	6.5307	6.3676	6.2402
2029	6.7810	6.5823	6.4277
2030	7.0373	6.8006	6.6173

Note: L, B and H represent low, base and high scenarios respectively.

As illustrated in Table 9, in the low scenario of non-renewable energy consumption, CO2 emissions in 2030 for the low, base and high scenarios of renewable energy consumption are estimated to be approximately 5 mt, 4.83 mt and 4.7 mt, respectively. In 2030, the projected CO2 emissions per capita for the low, base and high scenarios of renewable energy consumption are estimated to be approximately 5.95 mt, 5.75 mt and 5.6 mt, respectively. In the event of a high scenario of non-renewable energy consumption (with the demand for non-renewable energy continuing to increase), CO2 emissions in 2030 for the low, base and high scenarios of renewable energy consumption will reach approximately 7.04 mt, 6.8 mt and 6.62 mt, respectively.

5. Results and Recommendations

Pollution, which every country has adopted as a problem, directly or indirectly threatens ecological life. Pollution reduction studies, which started in Stockholm in 1972 with the participation of many countries in the world and continue today, have also come to the agenda of the scientific world and have been the subject of scientific studies for decades. In recent years, many academic studies have been conducted to determine the factors that cause pollution, and pollution reduction policy recommendations have been made in line with the results of the studies.

This study aimed to determine the relationship between CO2 emissions and energy consumption and to forecast the levels of CO2 emissions that may occur according to different renewable and non-renewable energy consumption preferences in Turkey. For this purpose, the existence of a cointegration relationship between the variables was first tested using the AARDL model. The test results showed that the variables were fully cointegrated. In the long-term relationship examined, it was determined that non-renewable energy consumption increased CO2 emissions, while renewable energy consumption decreased CO2 emissions. Turkey, a developing country, needs more energy as it strives to grow. Although efforts have been made to increase renewable energy consumption to provide this energy, when the data of the study period is taken into account, it is noteworthy that non-renewable energy consumption continues to increase. However, since the increase in CO2 emissions will lead to environmental and health problems, it becomes necessary to turn to renewable energies instead of non-renewable energies, which are a strong driver of CO2 emissions. In addition, in the long-term forecast results, it was seen that the Environmental Kuznets Curve Hypothesis was valid in the Turkish economy as of the period 1965-2022. This shows that although economic growth has an increasing effect on CO2 emissions in the early periods, this effect will reverse after a certain level of growth. As a result, economic growth will have a decreasing effect on CO2 emissions. This result is also consistent with the findings of Öztürk and Acaravcı (2013), Bölük and Mert (2015), Pata and Yurtkuran (2018), Çetin and Saygın (2019), and Rahman et al. (2021). When the long-term effect of trade openness is examined, it is revealed that this variable has a positive effect on CO2 emissions. This result is consistent with Halıcıoğlu (2009), Nasir and Rehman (2011), Tiwari et al. (2013), Çetin and Şeker (2014) and Yılmaz and Dilber (2020). The error correction model established after estimating the long-term relationship revealed that approximately 69.15% of the deviations from the long-term balance that occurred in the short term reached the balance after one year. The short-term coefficients obtained from the error correction model show that non-renewable energy consumption has an increasing effect on pollution.

According to the 2023-2030 CO2 emission forecast findings, if Turkey consumes renewable and non-renewable energy in the high scenario to meet its energy needs, the CO2 emission per capita, which was 5.11 mt in 2022, will increase by approximately 30% and reach approximately 6.62 mt in 2030. However, since the increase in CO2 emission is undesirable, increasing non-renewable energy sources in the high scenario will be an unacceptable policy combination. Even if non-renewable energy consumption is not given weight in the following years, it is likely to be used increasingly as much as the average increase in its use since 1965. This is the realization of the base scenario for non-renewable energy. When the non-renewable energy consumption base scenario and the renewable energy consumption high scenario are combined, there will be no decrease in CO2 emission in 2030 compared to 2022. CO2 emission will increase by approximately 9.6% compared to 2022 and reach 5.60 mt per capita in 2030. The situation that can reduce CO2 emissions while meeting energy needs is where non-renewable energy consumption is low and renewable energy consumption is high. In this case, where a shift towards renewable energy sources rather than non-renewable energy sources will be adopted, it is forecasted that CO2 emissions per capita will decrease by 8% compared to 2022 and will be approximately 4.70 mt in 2030. In Turkey, where the increase in pollution has not been prevented in general over the years, it is thought that it will be challenging to reach the CO2 emission figures targeted for 2030 with the policies implemented in previous years under the assumption that other factors are constant. This means more investments will be needed than those made in renewable energy. For this reason, it is thought that policy makers should put guiding policies into effect to increase guidance and incentives for renewable energy production in both the public and private sectors and take steps to improve the necessary infrastructure. It is thought that the recent increase in renewable energy investments in the Turkish economy may contribute to the solution to this pessimistic situation. It is expected that renewable energy investment supports (solar energy, wind energy, and hydroelectric power plant investment supports) will be provided to entrepreneurs through studies carried out by development agencies, and the ministry will raise the margin of renewable energy in total energy consumption in the coming years.

Support and Acknowledgement Statement: No external support was used in the preparation of this research.
Researcher's Contribution Rate Statement: The authors' contribution share in the study is equal.
Conflict of Interest Statement: As the study's authors, we do not declare any conflict of interest.
Research and Publication Ethics Statement: All rules specified in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed at every stage of this research. None of the actions specified under the heading "Actions Contrary to Scientific Research and Publication Ethics" of the directive were carried out. During the writing process of this study, citations were made in accordance with ethical rules, and a bibliography was created. The study was subject to plagiarism control**.**

References

Acaravcı, A., & Erdoğan, S. (2018). Yenilenebilir enerji, çevre ve ekonomik büyüme ilişkisi: Seçilmiş ülkeler için ampirik bir analiz. *Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi,* 13(1), 53-64.

Ağbulut, Ü. (2022). Forecasting of transportation-related energy demand and CO2 emissions in Turkey with different machine learning algorithms. *Sustainable Production and Consumption*, 29, 141-157.

Ahmed, K., & Long, W. (2012). Environmental Kuznets curve and Pakistan: An empirical analysis. *Procedia Economics and Finance,* 1, 4-13.

Akhtar, R., Masud, M. M., Al-Mamun, A., & Saif, A. N. M. (2023). Energy consumption, CO2 emissions, foreign direct investment, and economic growth in Malaysia: An NARDL technique. *Environmental Science and Pollution Research,* 30 (22), 63096-63108.

Anwar, A., Siddique, M., Dogan, E., & Sharif, A. (2021). The moderating role of renewable and non-renewable energy in environment-income nexus for ASEAN countries: Evidence from method of moments quantile regression. *Renewable Energy,* 164, 956-967.

Anwar, A., Sinha, A., Sharif, A., Siddique, M., Irshad, S., Anwar, W., & Malik, S. (2022). The nexus between urbanization, renewable energy consumption, financial development, and CO2 emissions: Evidence from selected Asian countries. *Environment, Development and Sustainability,* 24, 6556-6576.

Apergis, N., & Payne, J. E. (2009). CO2 emissions, energy usage, and output in central America. *Energy Policy*, 37(8), 3282-3286.

Apergis, N., Jebli, M.B., & Youssef, S.B. (2018). Does renewable energy consumption and health expenditures decrease carbon dioxide emissions? Evidence for Sub-Saharan Africa Countries. *Renewable Energy,* 127, 1011-1016.

Apergis, N., Payne, J. E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, RE energy, and economic growth. *Ecological Economics*, 69(11), 2255-2260.

Aydin, G. (2014). The Development and Validation of Regression Models to Predict Energy-related CO2 Emissions in Turkey. *Energy Sources, Part B: Economics, Planning, and Policy*, 10(2), 176–182.

Ayvaz, B., Kusakci, A. O., & Temur, G. T. (2017). Energy-related CO2 emission forecast for Turkey and Europe and Eurasia: A discrete grey model approach. *Grey Systems: Theory and Application,* 7(3), 436-452.

Başar, S., & Temurlenk, M. S. (2007). Environmental Kuznets curve: An empirical analysis for Turkey. *Journal of Economics and Administrative Sciences*, 21(1), 1-12.

Bekun, F. V., Gyamfi, B. A., Etokakpan, M. U., & Çakir, B. (2023). Revisiting the pollution haven hypothesis within the context of the environmental Kuznets curve. *International Journal of Energy Sector Management*, 17(6), 1210-1231.

Bento, J. P. C., & Moutinho, V. (2016). CO2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. *Renewable and Sustainable Energy Reviews*, 55, 142-155.

Bilgili, F., Öztürk, I., Koçak, E., Bulut, U., Pamuk, Y., Mugaloğlu, E., & Bağlıtaş, H. H. (2016). The influence of biomass energy consumption on CO2 emissions: A wavelet coherence approach. *Environmental Science and Pollution Research,* 23, 19043-19061

Bölük, G., & Mert, M. (2015). The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach. *Renewable and Sustainable Energy Reviews*, 52, 587-595.

Boontome, P., Therdyothin, A., & Chontanawat, J. (2017). Investigating the causal relationship between non-renewable and renewable energy consumption, co2 emissions and economic growth in Thailand. *Energy Procedia,* 138, 925-930.

BP (2021). Statistical review of world energy. Access address: Https://Www.Bp.Com/En/Global/Corporate/Energy-Economics/Statistical-Review-Of-World-Energy.Html

Bulut, U. (2017). The impacts of non-renewable and renewable energy on CO2 emissions in Turkey. *Environmental Science and Pollution Research*, 24(18), 15416-15426.

Bulut, U. (2021). Environmental sustainability in Turkey: An environmental Kuznets curve estimation for ecological footprint. *International Journal of Sustainable Development & World Ecology,* 28(3), 227-237.

Çağlar, A. E. (2022). Türkiye'de çevresel Kuznets Eğrisi hipotezinin araştırılmasında çevresel patentlerin rolü: Genişletilmiş ARDL ile kanıtlar. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 15(4), 913-929.

Caglar, A. E., Zafar, M. W., Bekun, F. V., & Mert, M. (2022). Determinants of CO2 emissions in the BRICS economies: The role of partnerships investment in energy and economic complexity. *Sustainable Energy Technologies and Assessments, 51*, 101907.

Canbay, Ş. (2019). Türkiye'de iktisadi büyüme ile yenilenebilir enerji tüketiminin çevre kirliliği üzerindeki etkileri. *Maliye Dergisi,* 176, 140-151.

Çetin, M., & Saygın, S. (2019). Çevresel Kuznets Eğrisi Hipotezi'nin ampirik analizi: Türkiye ekonomisi örneği. *Yönetim ve Ekonomi Dergisi*, 26(2), 529-546.

Çetin, M., & Şeker, F. (2014). Ekonomik büyüme ve dış ticaretin çevre kirliliği üzerindeki etkisi: Türkiye için bir ARDL sınır testi yaklaşımı. *Yönetim ve Ekonomi: Celal Bayar Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 21(2), 213-230.

Çetin, M., & Sezen, S. (2018). Türkiye'de yenilenebilir ve yenilenemeyen enerji tüketimi, ekonomik büyüme ve karbondioksit salınımı arasındaki ilişki: Bir Svar (yapısal var) analizi. *Journal Of Management and Economics Research*, 16(1), 136-157.

Çetinkaya, G., & Akar, S. (2022). Türkiye'nin küresel karbon bütçesindeki payı: Öngörü senaryoları ile bir değerlendirme. *Maliye Çalışmaları Dergisi*, 68, 33-50.

Çevre ve Şehircilik Bakanlığı (2023, 23 December). Türkiye Cumhuriyeti niyet edilen ulusal olarak belirlenmiş katkı. Erişim adresi: https://yesilekonomi.com/files/The_INDC_of_TURKEY_v_15_19_30-TR.pdf.

Chaudhuri, S., & Pfaff, A. (2002). *Economic growth and the environment: What can we learn from household data*? Working Paper. USA: Columbia University.

Chen, Y., Wang, Z., & Zhong, Z. (2019). CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. *Renewable Energy*, 131, 208-216.

Cheng, C., Ren, X., Wang, Z., & Yan, C. (2019). Heterogeneous impacts of renewable energy and environmental patents on CO2 emission-evidence from the BRIICS. *Science of The Total Environment,* 668, 1328-1338.

Chica-Olmo, J., Sari-Hassoun, S., & Moya-Fernández, P. (2020). Spatial relationship between economic growth and renewable energy consumption in 26 European countries. *Energy Economics*, *92*, 104962.

Coondoo, D., & Dinda, S. (2002). Causality between income and emissions: A country group-specific econometric analysis. *Ecological Economics,* 40(3), 351-367.

Coşkun, H., & Eygü, H. (2020). Ar-GE Harcamaları ve İhracat İlişkisinin İncelenmesi: Türkiye Örneği. *Anemon Muş Alparslan Üniversitesi Sosyal Bilimler Dergisi,* 8(İktisadi ve İdari Bilimler), 233-242.

Dam, M. M. (2018). Enerji ve büyümenin çevre kirliliğine etkisi: AB ülkeleri için panel veri analizi. *Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 5(2), 163-174.

Daştan, M., & Eygü, H. (2024). An empirical investigation of the link between economic growth, unemployment, and ecological footprint in Turkey: Bridging the EKC and EPC hypotheses. *Environment, Development and Sustainability*, 26(7), 18957-18988.

De Bruyn, S. M. (1997). Explaining the environmental Kuznets curve: Structural change and international agreements in reducing sulphur emissions. *Environment and Development Economics*, 2, 485-503.

De Bruyn, S.M., Berg, J.C.M., & Opschoor, J.B. (1998). Economic growth and emissions: Reconsidering the empirical basis of environmental Kuznets curves. *Ecological Economics,* 25, 161-175.

Destek, M. A., & Sinha, A. (2020). Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic co-operation and development countries. *Journal of Cleaner Production,* 242, 118537.

Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics*, 49(4), 431-455.

Doğan, E., & Öztürk, I. (2017). The influence of renewable and non-renewable energy consumption and real income on CO2 emissions in the USA: Evidence from structural break tests. *Environmental Science and Pollution Research*, 24(11), 10846-10854.

Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). RE energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews,* 39, 748-764.

Erdoğan, S., Okumuş, I., & Güzel, A. E. (2020). Revisiting the environmental Kuznets curve hypothesis in OECD countries: The role of renewable, non-renewable energy, and oil prices. *Environmental Science and Pollution Research*, 27(19), 23655-23663.

Eylasov, N., Gasim, N., Aliyev, F., & Şahinler, A. N. (2023). Impact of renewable energy consumption on CO2 emissions in Türkiye: Evidence from ARDL and Bayer-Hanck Cointegration Techniques. *Green Economics*, 1(2), 111-125.

Farhani, S., & Shahbaz, M. (2014). What role of renewable and non-renewable electricity consumption and output is needed to ınitially mitigate CO2 emissions in MENA region. *Renewable and Sustainable Energy Reviews*, 40, 80-90.

Georgiev, E., & Mihaylov, E. (2015). Economic growth and the environment: Reassessing the environmental Kuznets curve for air pollution emissions in OECD countries*. Letters in Spatial and Resource Sciences*, 8(1), 29-47.

Göv, A. ve Kapkara Kaya, S. (2023). Türkiye Örneğinde Çevresel Kalitenin Belirleyicileri: LASSO Yaklaşımı. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 54, 25-37.

Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American Free Trade Agreement.* National Bureau of Economic Research Working Paper 3914, NBER, Cambridge.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2), 353-377.

Halıcıoğlu, F. (2009). An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy,* 37(3), 1156-1164.

Hamzacebi, C., & Karakurt, I. (2015). Forecasting the Energy-related CO2 Emissions of Turkey Using a Grey Prediction Model. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 37(9), 1023–1031.

Hanif, I., Aziz, B., & Chaudhry, I. S. (2019). Carbon emissions across the spectrum of renewable and non-renewable energy use in developing economies of Asia. *Renewable Energy*, 143, 586-595.

Haseeb, A., Xia, E., Baloch, M. A., & Abbas, K. (2018). Financial development, globalization, and CO2 emission in the presence of EKC: Evidence from BRICS countries. *Environmental Science and Pollution Research*, 25, 31283-31296.

Helpman, E. (1998). Explaining the structure of foreign trade: Where do we stand?, *Weltwirtschaftliches Archiv*, 134(4), 573-589.

IEA (2016a). Energy and Air Pollution. World Energy Outlook Special Report, Paris.

IEA (2016b). World Energy Outlook 2016. IEA, Paris. Access address: https://Doi.Org/10.1787/Weo2016-En

İmamoğlu, İ. K., & Coşkun, H. (2023). The Future of Export-Based Growth Policies in the Turkish Economy: An Econometric Simulation Approach. *Erzurum Teknik Üniversitesi Sosyal Bilimler Enstitüsü Dergisi,* 17, 39-56.

İmamoğlu, İ. K., & Özdemir, D. (2023). Yönetişim, inovasyon ve ekonomik büyüme arasındaki ilişkiler: Gelişmiş ve gelişmekte olan ülke örnekleri. *Külliye,* 4(1), 99-133.

Inglesi-Lotz, R., & Dogan, E. (2018). The role of renewable versus non-renewable energy to the level of CO2 emissions a panel analysis of Sub-Saharan Africa's βig 10 electricity generators. *Renewable Energy,* 123, 36-43.

Karaaslan, A., & Çamkaya, S. (2022). The relationship between CO2 emissions, economic growth, health expenditure, and renewable and non-renewable energy consumption: Empirical evidence from Turkey. *Renewable Energy,* 190, 457-466.

Karahasan, B. C., & Pinar, M. (2022). The environmental Kuznets curve for Turkish provinces: A spatial panel data approach. *Environmental Science and Pollution Research,* 29(17), 25519-25531.

Karasoy, A., & Akçay, S. (2018). Effects of renewable energy consumption and trade on environmental pollution: The Turkish case. *Management of Environmental Quality: An International Journal,* 30(31), 437-455.

Kaya, K., Şenel, M. C., & Koç, E. (2018). Dünyada ve Türkiye'de yenilenebilir enerji kaynaklarinin değerlendirilmesi. *Technological Applied Sciences*, 13(3), 219-234.

Koçak E., & Şarkgüneşi, A. (2017). The renewable energy and economic growth nexus in Black Sea and Balkan Countries. *Energy Policy*, 100, 51–57

Kronsell, A., Rosqvist, L. S., & Hiselius, L. W. (2016). Achieving climate objectives in transport policy by including women and challenging gender norms: The Swedish case. *International Journal of Sustainable Transportation*, 10(8), 703-711.

Mahalik, M. K., Mallick, H., & Padhan, H. (2021). Do educational levels influence the environmental quality? The role of RE and non-RE energy demand in selected BRICS countries with a new policy perspective. *Renewable Energy,* 164, 419-432.

Martınez-Zarzoso, I., & Bengochea-Morancho, A. (2004). Pooled mean group estimation of an environmental Kuznets curve for CO2. *Economics Letters,* 82(1), 121-126.

Mert, M. and Çağlar, A. E. (2019). *Eviews ve gauss uygulamalı zaman serileri analizi.* Ankara: Detay Yayıncılık.

Narayan, P. K. (2005). The Saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics,* 37(17), 1979–1990.

Nasir, M., & Rehman, F. U. (2011). Environmental Kuznets curve for carbon emissions in Pakistan: An empirical investigation. *Energy policy,* 39(3), 1857-1864.

Öcal, O., Altınöz, B., & Aslan, A. (2020). The effects of economic growth and energy consumption on ecological footprint and carbon emissions: evidence from Turkey. *Ekonomi Politika ve Finans Araştırmaları Dergisi,* 5(3), 667-681.

Okumuş, İ. (2020). Türkiye'de yenilenebilir enerji tüketimi, tarım ve CO2 emisyonu ilişkisi. *Uluslararası Ekonomi ve Yenilik Dergisi*, 6(1), 21-34.

Our World In Data (2024, 10 April). Access address: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

Our World İn Data. (2024, 10 April). Access address: https://Github.Com/Owid/Energy-Data.

Öztürk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics*, 36, 262-267.

Öztürk, Z., & Öz, D. (2016). The relationship between energy consumption, income, foreign direct investment, and CO2 emissions: the case of Turkey. *Çankırı Karatekin Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 6(2), 269-288.

Pabuçcu, H., & Bayramoğlu, T. (2016). Yapay sinir ağlari ile CO2 emisyonu tahmini: Türkiye örneği. *Gazi Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 18(3), 762-778.

Pao, H. T., & Tsai, C. M. (2010). CO2 emissions, energy consumption and economic growth in BRIC countries. *Energy Policy,* 38(12), 7850-7860.

Pata, U. K. (2018). Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: testing EKC hypothesis with structural breaks. *Journal of cleaner production*, 187, 770-779.

Pata, U. K. (2021). Renewable and non-renewable energy consumption, economic complexity, CO2 emissions, and ecological footprint in the USA: Testing the EKC hypothesis with a structural break*. Environmental Science and Pollution Research,* 28(1), 846-861.

Pata, U. K., & Caglar, A. E. (2021). Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: Evidence from Augmented ARDL approach with a structural break. *Energy,* 216, 119220.

Pata, U. K., & Yilanci, V. (2020). Financial development, globalization and ecological footprint in G7: Further evidence from threshold cointegration and fractional frequency causality tests. *Environmental and Ecological Statistics,* 27(4), 803-825.

Pata, U. K., & Yurtkuran, S. (2018). Yenilenebilir enerji tüketimi, nüfus yoğunluğu ve finansal gelişmenin CO2 salımına etkisi: Türkiye örneği. *Uluslararası İktisadi ve İdari İncelemeler Dergisi,* (Prof. Dr. Harun Terzi Özel Sayısı), 303-318

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal Of Applied Econometrics,* 16(3), 289–326.

Qashou, Y., Samour, A., & Abumunshar, M. (2022). Does the real estate market and renewable energy induce carbon dioxide emissions? Novel evidence from Turkey. *Energies,* 15(3), 763.

Rafiq, S., & Salim, R. A. (2009). Temporal causality between energy consumption and income in six Asian emerging countries. *Applied Economics Quarterly*, 55(4), 335.

Rahman, M. M., & Alam, K. (2022). CO2 emissions in Asia–Pacific region: Do energy use, economic growth, financial development, and international trade have detrimental effects?. *Sustainability*, 14(9), 5420.

Rahman, M. M., Karim, A. A. M. E., Ahmed, Z., & Acet, H. (2021). Environmental Kuznets curve (EKC) for Bangladesh: Evidence from fully modified OLS approach. *JOEEP: Journal of Emerging Economies and Policy*, 6(2), 5-14.

Sam, C. Y., McNown, R., & Goh, S. K. (2019). An augmented autoregressive distributed lag bounds test for cointegration. *Economic Modelling*, 80, 130–141.

Sari Hassoun, E. S., & Ayad, H. (2020). Renewable energy and eustainable development: Evidence from 17 OECD countries. *Uluslararası Ekonomi İşletme ve Politika Dergisi*, 4(1), 41-60.

Sari Hassoun, E. S., Mékidiche, M., & Guellil, M. S. (2018). Examining the connection amongst renewable energy, economic growth and carbon dioxide emissions in Algeria. *EKOIST Journal of Econometrics and Statistics,* 14(29), 199-223.

Selden, T. M., & Song, D. (1995). Neoclassical growth, the J curve for abatement, and the inverted U curve for pollution. *Journal of Environmental Economics and Management,* 29 (2), 162-168.

Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: A comparative analysis. *Energy Policy,* 66, 547-556.

Shahbaz, M., Lean, H. H., & Shabbir, M. S. (2012). Environmental Kuznets curve hypothesis in Pakistan: Cointegration and Granger causality. *Renewable and Sustainable Energy Reviews,* 16(5), 2947-2953.

Soğukpınar, F., Erkal, G., & Özer, H. (2023). Evaluation of renewable energy policies in Turkey with sectoral electricity demand forecasting. E*nvironmental Science and Pollution Research, 30*(13), 35891-35912.

Solarin, S. A., Al-Mulali, U., & Ozturk, I. (2017). Validating the environmental Kuznets curve hypothesis in India and China: The role of hydroelectricity consumption. *Renewable and Sustainable Energy Reviews,* 80, 1578-1587.

Stern, D. I., Common, M. S., & Barbier, E. B. (1996). Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development. *World Development,* 24(7), 1151-1160.

T.C. Dışişleri Bakanlığı. (2023, 12 December). Paris Anlaşması. Erişim adresi: https://www.mfa.gov.tr/paris-anlasmasi.tr.mfa.

Tiwari, A. K., Shahbaz, M., & Hye, Q. M. A. (2013). The environmental Kuznets curve and the role of coal consumption in India: Cointegration and causality analysis in an open economy. *Renewable and Sustainable Energy Reviews*, 18, 519-527.

Türkeş, M. (2022). İklim diplomasisi ve iklim değişikliğinin ekonomi politiği. *Bilim ve Ütopya,* 332, 31-45.

World Bank Data. (2024, 10 April). Access address: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?locations=TR.

Yavuz, N. Ç. (2014). CO2 emission, energy consumption, and economic growth for Turkey: evidence from a cointegration test with a structural break. *Energy Sources, Part B: Economics, Planning, and Policy,* 9(3), 229-235.

Yenisu, E. (2018). Enerji tüketimi, CO2 emisyonu ve ekonomik büyüme ilişkisi: Türkiye örneği. *Van Yüzüncü Yıl Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 3(5), 9-29.

Yılmaz, M., & Dilber, İ. (2020). Elektrik tüketimi, ekonomik büyüme ve dış ticaret açıklığının CO2 emisyonu üzerine etkisi: ARDL sınır testi. *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergis*i, 22(2), 459-475.