



Hacettepe University Graduate School of Social Sciences

Department of Economics

**THE EFFECT OF RENEWABLE ENERGY RESOURCES ON  
ECONOMIC GROWTH: A CASE STUDY FOR TURKEY**

Tuğçe AYDOĞAN GÖKCÜ

Master's Thesis

Ankara, 2021



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## ABSTRACT

AYDOĞAN GÖKCÜ, Tuğçe. *The Effect of Renewable Energy Resources on Economic Growth: A Case Study for Turkey*, Master's Thesis, Ankara, 2021.

The need for energy increases with the use of energy in almost every field, the development of technology and the increase in population, and this situation may lead to an increase in the dependence of countries on foreign energy with insufficient energy resources and negatively affect the country's economy. If countries are dependent heavily on imports in terms of energy resources, they may be exposed to negative economic consequences. Renewable energy has positive features such as being produced domestically, being inexhaustible and environmentally friendly. At this point, the provision of energy consumption from renewable or non-renewable energy sources may be related to the country's economy and studies are carried out on this relationship. In this study, due to the importance of renewable energy sources, the relationship between total renewable energy sources, economic growth and CO<sub>2</sub> emissions were investigated for short and long term for Turkey. When examining this relationship, by using data between 1972 and 2018, Granger causality test, SVAR and ARDL method were applied. According to the findings, the Granger causality test revealed that there was no relationship between renewable energy consumption, economic growth and carbon dioxide emissions, and the neutrality hypothesis was supported. SVAR and ARDL methods show that renewable energy consumption, CO<sub>2</sub> emissions and economic growth affect each other in both short and long term. While it is seen that all variables are in a positive relationship with each other with the SVAR method, according to the ARDL method, which has a reliability advantage in short samples, it has been revealed that there is a positive relationship between renewable energy consumption and economic growth and a negative relationship with carbon dioxide emissions. According to the results obtained from the ARDL method, as the consumption of renewable energy increases, economic growth will increase and CO<sub>2</sub> emissions will decrease.

### **Key words:**

Energy, Renewable Energy, Economic Growth, CO<sub>2</sub>, Real GDP per capita, SVAR Analysis, ARDL Test

## ÖZET

AYDOĞAN GÖKCÜ, Tuğçe. *Yenilenebilir Enerji Kaynaklarının Ekonomik Büyümeye Etkisi: Türkiye Uygulaması*, Yüksek Lisans Tezi, Ankara, 2021.

Enerjinin neredeyse her alanda kullanılıyor olması, teknolojinin gelişmesi ve nüfus artışıyla enerjiye olan ihtiyacın artmakta ve bu durum, enerji kaynakları açısından yetersiz olan ülkelerin enerjide dışa bağımlılığının artmasına, ülke ekonomisinin olumsuz olarak etkilenmesine yol açabilmektedir. Ülkeler, enerji kaynakları bakımından büyük oranda ithalata bağlı kalması durumunda ekonomik açıdan olumsuz sonuçlara maruz kalabilmektedir. Yenilenebilir enerjinin, yurt içinde üretilebilir olması, tükenmiyor olması ile çevre dostu olması gibi olumlu özellikleri vardır. Bu noktada, enerji tüketiminin yenilenebilir ya da yenilenemez enerji kaynaklarından sağlanması ülke ekonomisiyle ilişkili olabilmekte ve bu ilişki üzerine çalışmalar yapılmaktadır. Yenilenebilir enerji kaynaklarının önemi nedeniyle, bu çalışmada Türkiye için toplam yenilenebilir enerji kaynakları tüketimi, ekonomik büyüme ve karbondioksit emisyonu arasındaki ilişki kısa ve uzun dönem için incelenmiştir. Bu ilişki incelenirken, 1972 ile 2018 yılları arasındaki veriler kullanılarak Granger nedensellik testi, SVAR metodu ve ARDL metodu uygulanmıştır. Elde edilen bulgulara göre, Granger nedensellik testinde yenilenebilir enerji tüketimi, ekonomik büyüme ve karbondioksit emisyonu arasında bir ilişki olmadığı ortaya çıkmış ve tarafsızlık hipotezi desteklenmiştir. SVAR ve ARDL metotları kullanılarak yapılan incelemelerde, yenilenebilir enerji tüketimi, karbondioksit emisyonu ve ekonomik büyümenin hem kısa hem de uzun dönemde birbirini etkilediği ortaya konulmuştur. SVAR yöntemi ile tüm değişkenlerin birbiriyle pozitif bir ilişki içinde olduğu görülürken, kısa örneklerde güvenilirlik avantajı olan ARDL yöntemine göre, yenilenebilir enerji tüketimi ile ekonomik büyüme arasında pozitif ve karbondioksit emisyonu ile negatif bir ilişkisi olduğu ortaya çıkmıştır. ARDL yönteminden elde edilen sonuçlara göre yenilenebilir enerji tüketimi arttıkça ekonomik büyüme artacak ve karbondioksit salınımı azalacaktır. Türkiye’de hem çevre kirliliğini azaltmak hem de ekonomik büyümeyi destekleyebilmek için yenilenebilir enerji kaynakları önemli olarak

görülmekte ve bu nedenle yenilenebilir enerjiye yönelik destekleyici politikalar artırılmalıdır.

**Anahtar Sözcükler:**

Enerji, Yenilenebilir Enerji, Ekonomik Büyüme, CO<sub>2</sub>, Kişi Başına Reel GSYİH, SVAR Analizi, ARDL Test

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## ABBREVIATIONS

**ADF:** Augmented Dickey-Fuller

**AIC:** Akaike Information Criteria

**AR:** Auto-Regressive

**ARDL:** Auto-Regressive Distributed Lags

**BP:** British Petroleum

**CO<sub>2</sub>:** Carbondioxide

**CUSUM:** Cumulative Sum

**DOLS:** Dynamic Ordinary Least Squares

**ECM:** Error Correction Model

**EMRA:** Energy Market Regulatory Authority

**EU:** European Union

**FGLS:** Feasible Generalized Least Squares

**FIT:** Feed-in-tariff

**FMOLS:** Fully Modified Ordinary Least Squares

**GDP:** Gross Domestic Product

**GNP:** Gross National Product

**HEPP:** Hydroelectric Power Plants

**IEA:** International Energy Agency

**IRENA:** International Renewable Energy Agency

**kWh:** Kilowatt hour

**MFA:** Minister Foreign Affairs

**MTOE:** Millions of Tonnes of Oil Equivalent

**MWh:** Megawatt hour

**OECD:** Organisation for Economic Co-operation and Development

**OLS:** Ordinary Least Square

**POLS:** Pooled Ordinary Least Square

**PP:** Philips-Perron

**RES:** Renewable Energy Sources

**RESET:** Ramsey Regression Equation Specification Error Test

**REN:** Renewable Energy

**REM:** Random Effects Model

**SUR:** Seemingly Unrelated Regression

**SVAR:** Structural Vector Auto-Regression

**VAT:** Value Added Tax

**VECM:** Vector Error Correction Model

**YoY:** Year over Year

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## INTRODUCTION

Energy in general is defined as the ability to work and it is an abstract concept, but it provides movement and displacement when viewed physically. It is known that energy is not lost but can be converted into each other. We need energy for everything we do to keep our lives and to have a comfortable life. For example, we need energy for warming, lighting, transportation and the need to use electronic appliances with the help of modern technology.

With the development of mankind and the advancement of technology, energy is one of the most needed sources. The fact that energy is so important to humans has created economic dependence on energy among countries. This dependency can affect the countries negatively since energy is important input for economic growth. Countries may face economic problems when they depend on other countries in terms of energy and when they do not have alternative energy sources, just as in the 1973 and 1979 oil crisis. In 1973, with the onset of the fourth Arab-Israeli war, Arab oil industry nations imposed petroleum embargo on pro-Israeli western countries to attack Israel. For this reason, international oil prices more than doubled and caused energy and economic crises in western countries (Zhao, 2018). The oil shock in 1979 occurred when the Iran-Iraq war started. It was the second big shock occurred in the oil market. Oil supply has shortened and oil prices have risen rapidly, causing major adverse effects on producers, consumers and the oil industry. (Middle East Institute, 2009). The 1973 and 1979 oil crisis effect Turkey also negatively because Turkey is a country that has to import oil. The growth rate of Turkey, which was 7.42% in 1972, decreased to 3.2% in 1973 (Senel et al. 2018). These crises enabled countries to be cautious about energy security because such crises are likely to reappear. Therefore, since the economies of countries depend on energy and energy security should be provided, they should be on search of alternative energy sources.

Along with population growth and enhancing welfare, energy demand is increasing day by day. At the same time, the progress of technology maintains to raise the energy

demands of all countries. According to British Petroleum (BP) report (2019) “global primary energy consumption grew at a rate 2.9% in 2018, almost double its 10-year average of 1.5% per year, and the fastest since 2010.” In the circumstances, increasing energy demand leads to the problems of security of energy supply and environmental pollution. BP’s report (2019) shows that “carbon emission grew by 2 %, the fastest growth for 7 years”. Together with increased energy demand, even if people move to fossil-based non-renewable sources of energy, they are faced with the problems that will eventually become exhausted. Republic of Turkey Ministry of Energy and Natural Resources (MENR) report (2017) remarks that coal will be consumed after 114 years, natural gas 53 and oil 51 years. In addition, non-renewable energy sources created carbondioxide (CO<sub>2</sub>) emissions and this leads to environmental pollution. In order to meet this increased energy need without polluting the environment, countries have started to attempt their existing energy policies and increasingly started to move from fossil-based resources to renewable sources. As per BP report (2019) “growth in renewable energy is 14.5% in 2018 and renewable energy become the world’s fastest growing energy source.”

The reduction of external dependency by the sustainable production of energy and the production of its stable, reliable, environmentally sensitive and large majority within its own borders become significant since the problem created by foreign dependency on energy is clearly seen in the oil crisis of 1973-1979. For these reason, to decrease environmental pollution and for the purpose of raising the consumption of renewable energy sources Kyoto Protokol was signed in 1997 and Turkey became a signatory in 2009. Since Negotiation of the Kyoto Protocol<sup>1</sup> (1997), countries underline that renewable energy should be used instead of non-renewables, and this protocol says that one of the biggest factors giving rise to global warming is usage of non-renewable energy sources, must be reduced and clean energy resources should be used instead. Halıcıoğlu (2009) says that carbondioxide is the most polluted gas and carbondioxide is responsible for 58.8% greenhouse gas emission. The European Union continue to implement policies to raise the usage of renewables. For example, the new recast Directive (EU) 2018/2001 identifying commitment of Member States to supply the energy needs with at least 32%

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<sup>1</sup> For further details on Kyoto Protocol, see [https://unfccc.int/kyoto\\_protocol](https://unfccc.int/kyoto_protocol).



renewable sources (14% for transportation) until 2030 particularly points decreasing greenhouse emissions. As a European Union (EU) candidate country and member of International Energy Agency (IEA), Turkey has started to implement necessary legislations to increase the energy supply security, to increase diversity of energy sources, lessen environmental pollution and align with the renewable energy strategies of the European Union. For example, the communiques on ethanol blending with gasoline since 2012 and on biodiesel blending with diesel fuels since 2018 entered into force to reduce the dependence on imported energy, increase resource diversity, ensure effective recovery of vegetable waste oils, reduce environmental pollution and align with renewable energy policies of the EU. These legislations had been prepared based on Turkish Petroleum Market Law No. 5015 and are executed by Energy Market Regulatory Authority (EMRA).

Sustainable development is a concept that includes economic growth. Economic growth is able to be measured in the short and long term, but sustainable development must be for long-term and so, ecological balance and economic growth must be considered together for sustainable development. Economic development that is ecologically sustainable can be defined as a sustainable economic development, protecting the needs of generations without natural capital consumption and giving importance to environmental quality that is, providing the balance between the economy and the ecosystem (Gürlük, 2001). Therefore, the concept of renewable energy is an energy source that has a place in sustainable development. For Turkey, which is in the development process poses the importance of a balanced and sustainable economic growth. Therefore, as renewable energy sources are energy that do not harm the environment and can be produced within the borders of countries, as in all countries has been a significant energy sources for Turkey. Also, energy independency is significant for Turkey's economic growth.

With renewable energy becoming so popular, studies have been conducted in the literature on the relation between economic growth and renewable energy. The relation

between renewable energy and economic growth in these studies is based on various countries and also different methodologies for different years. In the literature, in general, renewable energy is considered as a whole and its impact on growth is examined. In addition, more than one country was handled and panel tests were used in other studies in general. In this work, the effects of total renewable energy on economic growth will be examined. It is distinguished from other studies by studying with a single country, Turkey rather than more than one country. Moreover, the literature has a certain number of work on Turkey in terms of renewable energy resources and economic growth relationships. This thesis will differentiate from other work because a certain number of work made for Turkey, CO<sub>2</sub> emissions will be also used in the model and comparison will be made using different methods. The methods used in the study are the most widely used methods in the literature, but it is seen that the analysis is generally made using one by one. In this study, it is provided to make comparisons by using all of these methods together. In addition, while researching the relation between economic growth and renewable energy consumption, current data will be used and this relationship will be analyzed through a demand-side approach. Real gross domestic product per capita (GDP per capita) will be utilized as a measurement of economic growth. In this thesis, the impact on economic growth of renewable energy is examined for Turkey which is in the development process and by analyzing the significance of renewable energy on economic growth, to contribute to policy makers to get an idea on this issue is aimed.

In order to give direction to the work before analysis conducted with the data, Turkey's economy and energy perspective, worldwide especially on the development of economically developed countries and in Turkey's renewable energy with emphasis been aimed at a comparison. Renewable energy sources types are described in general terms, explanations on the energy sources in Turkey and areas of usage. Studies that have similar analyzes or results that can contribute to this study are included in the literature review section. The relationship between renewable energy sources, economic growth and CO<sub>2</sub> emissions was tested by Structural Vector Auto-Regression (SVAR) analysis and Auto-Regressive Distributed Lags (ARDL) test between 1972-2018 and the result of this study is given in the conclusion.

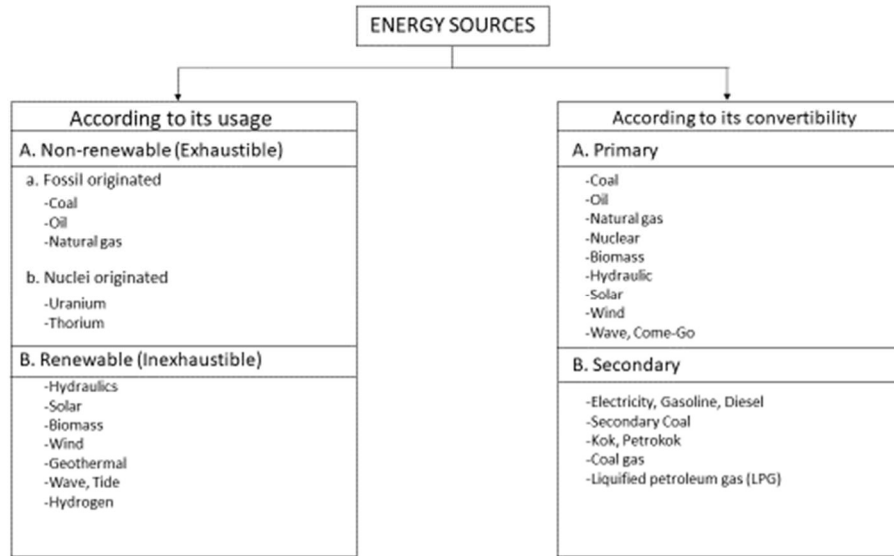
# **CHAPTER 1**

## **INFORMATION ON THE ENERGY AND ECONOMIC GROWTH**

### **1.1. ENERGY SOURCES**

Energy resources are divided into two according to their usage and convertibility. According to their usage energy sources are classified into two as non-renewable (exhaustible) and renewable energy (inexhaustible) sources. When renewable energy resources are used are the energy sources that can remain the same, do not decrease, that is, they are inexhaustible. Conversely, non-renewable energy sources can be defined as energy resources that cannot be recycled when used or take a long time to recycle and these resources are divided into two. The first of these are fossil sourced and these are natural gas, oil and coal. The second is from nuclei and these are uranium and thorium. In addition, renewable energy sources can be considered as solar energy, wind, biomass, hydraulics, geothermal, wave tide and hydrogen (Koc and Senel, 2013).

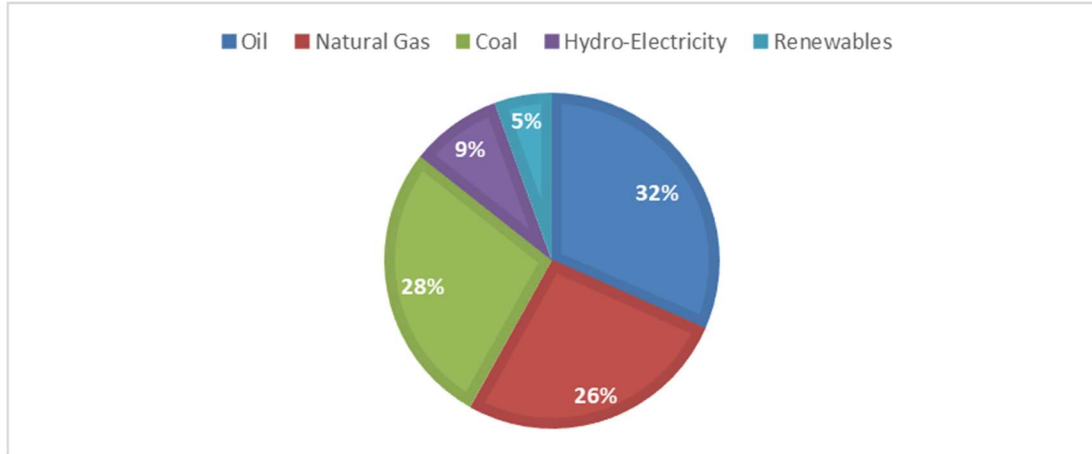
According to their convertibility, energy sources can be categorized into two as primary energy sources and also secondary energy sources. The former is considered as energy sources that have not subjected to any change or conversion and these are natural gas, oil, coal, nuclear, large-scale, hydraulic, solar, wind, wave and tidal. The latter is considered as energy sources procured in consequence of the transformation of primary energy sources and these are electricity, diesel, gasoline, secondary coal, air gas, coke, petrococoe, and liquefied petroleum gas (Koc and Senel, 2013).

**Table 1: Energy Sources**

Source: Koc and Senel, 2013

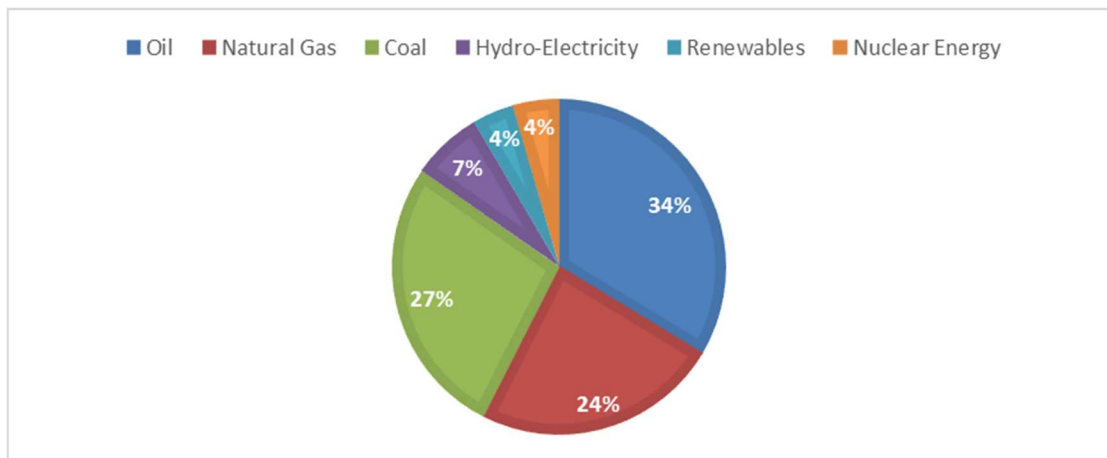
When we look at the graphics (Figure 1 & Figure 2) prepared according to the data from BP, the share out of energy sources in energy usage in 2018 in Turkey and in the world for hydro-electricity and for the other renewables the rate of Turkey is almost close the world's. On the other hand, for Turkey the share of hydro-electricity and the renewables are 14% of total energy sources and it is a low rate since other energy sources create CO<sub>2</sub> emissions and the dependency on other nations.

**Figure 1: The Ration of Energy Sources in Energy Consumption in Turkey in 2018**



Source: BP Statistical Review-2019, authors own calculation

**Figure 2: The Ration of Energy Sources in Energy Consumption in the World in 2018**



Source: BP Statistical Review-2019, authors own calculation

### 1.1.1. Non-Renewable Energy Sources

Finite natural energy sources, in which the speed they are consumed is higher than their emergence, are called non-renewable energy sources (Chen, 2020). Non-renewable energy is not sustainable. We continue to use it since the need for energy increases day by day with factors such as the development of technology and the increase of the

population. Using these energy sources, which cannot renew themselves in a short time, will cause problems in energy supply security. Natural gas, coal and oil are most popular examples of nonrenewable resources and these are fossil originated. Uranium and thorium are also non-renewable energy sources and these are nuclei originated (Koc and Senel, 2013).

Energy sources that are formed by the decay of plant and animal residues under the soil for millions of years, fossilization under heat and pressure are called fossil fuels. Fossil fuels are the most common non-renewable energy sources and carbon is the main element in fossil fuels. In this reason, while producing energy from fossil fuels carbon dioxide gas exits, which causes environmental pollution. The trend towards consumption of renewable energy rather than non-renewables is gaining momentum because of the fact that it cannot provide energy supply security and it will be exhausted. Also, it causes greenhouse gas emission and global warming. In addition, it damages to the environment and they are not the sustainable energy sources.

### **1.1.2. Renewable Energy Sources**

Infinite natural and clean energy sources, in which their emergence is higher than the speed they are consumed, are called renewable energy sources. With the flow of nature, they are energy sources that can renew themselves in a short time. Renewable energy sources have the specialities of accessibility, availability and acceptability. Since, the most significant characteristic of renewables is that they contribute to the reduction of foreign dependency in energy, help protect the environment by reducing carbon dioxide emissions and increase employment as they are domestic resources, and receive widespread and strong support from the public. (Ozkaya, 2004). The IEA defines renewable energy sources as the center of alteration to a more sustainable system of energy that reduces carbon dioxide emissions.

Solar, wind, hydraulic, geothermal, biomass, wave tide and hydrogen are the renewable energy resources. The sources of these types are itemized in the table below.

**Table 2: Renewable Energy Types and Sources**

RENEWABLE ENERGY TYPES	SOURCE OF ENERGY
Solar Energy	Sun
Wind Power	Wind
Geothermal Energy	Ground Water
Hydraulic Energy	Rivers and Streams
Biomass Energy	Biological Wastes
Wave Energy	Oceans and Seas

Source: (Karagol and Kavaz, 2017)

#### **1.1.2.1. Solar Energy**

As a result of the hydrogen inside the sun combining into helium solar energy is formed. Solar energy reaching the world is significantly more than the solar energy consumed in the world. Solar energy coming to the world is 20 thousand times the energy used by humanity in a year. Solar energy technology is divided into two fundamental classes which are photovoltaic solar technology and thermal solar technologies (MENR, 2020). Solar energy is an important energy source due to its abundant, clean, environmentally friendly, accessible, financially viable, employment creative feature, increasing supply security and eliminating energy dependency.

#### **1.1.2.2. Wind Power**

Due to the difference in temperature and pressure that occurs when the sun heats the surface and the atmosphere, air flow occurs. Wind is formed by the displacement of air masses between the atmosphere and the surface of the earth. A small amount as 1-2% of

the energy that the sun sends to the earth turns into wind energy (MENR, 2020). Wind power is an important energy source as solar energy due to its abundant, clean, environmentally friendly, accessible, financially viable, employment creative feature, increasing supply security and eliminating energy dependency.

#### **1.1.2.3. Geothermal Energy**

It is the inner heat of the earth. This heat spreads from the hot zone in the center towards the earth (MENR, 2020). Geothermal energy involves the utilization of geothermal source, which is defined as underground heat in the depths of the earth's crust and defined as hot water and steam, whose temperatures are above the regional atmospheric temperature (Adiyaman, 2012). In addition to the advantages of solar and wind energy, it is important that it is not affected by weather conditions.

#### **1.1.2.4. Hydraulic Energy**

Hydroelectric power plants (HEPP) generate a mechanical energy depending on the amount of water, the height of the water and the flow rate of the water, and it transmits this energy to the tribunes by channels. The electrical energy generated by the water turning the tribunes is called hydroelectric energy. Therefore, the use of hydraulic energy is more common for rough terrains and wetlands. Hydraulic energy is an important energy source as solar energy due to its clean, environmentally friendly, long technical life, domestic resource, employment creative feature, increasing supply security and eliminating energy dependency.

#### **1.1.2.5. Biomass Energy**

In general, biomass is known as vegetative organisms that store solar energy as a result of photosynthesis. It has emerged as the origin of plants and living organisms (MENR, 2020). Biomass energy is mainly derived from all kinds of organic waste, plant and animal waste, forest and forest products, urban and industrial waste. Three important fuels,



biodiesel, bioethanol and biogas, can be obtained from biomass energy. Biomass energy is obtained by burning or processing biomass resources. In addition to the advantages of wind and solar energy, biomass energy can be shown as suitable for storage and can be used almost anywhere. In addition, since it uses carbon dioxide when biomass is formed, that is, CO<sub>2</sub> has been taken from the atmosphere to form these substances before, the amount of CO<sub>2</sub> in the atmosphere is balanced when biomass energy occurs.

#### **1.1.2.6. Wave Energy**

It consists of the fluctuations that occur in the seas and the pressure that occurs as a result of the fluctuations. It is abundant because it is water-borne, but it is a type of energy that is used less because it is affected weather conditions and also, to obtain partially is difficult because it is not technologically convenient.

#### **1.1.2.7. Hydrogen Energy**

Hydrogen exists in nature in combination with elements. For example, it coexists with oxygen in water. Hydrogen, which is not found alone in nature, needs to be processed and converted to use it as energy. In addition to the common features of renewable energy, MENR (2020) says that one of the most important advantages of using hydrogen as energy is that it is a fuel that is on average 1.33 times more efficient than petroleum fuels and can be stored. It is also an energy that can be found abundantly because it is in the water.

### **1.2. RENEWABLE ENERGY SOURCES IN THE WORLD**

In order for renewable energy to take place in the economies of the nations and increase the rate of contribution, most countries support renewable energy and are in an effort to increase these supports. For example, one of the most common policies for electricity produced from renewable energy is feed tariffs (FITs). These tariffs are those that guarantee a fixed payment for a certain time period for electricity sold to the electricity

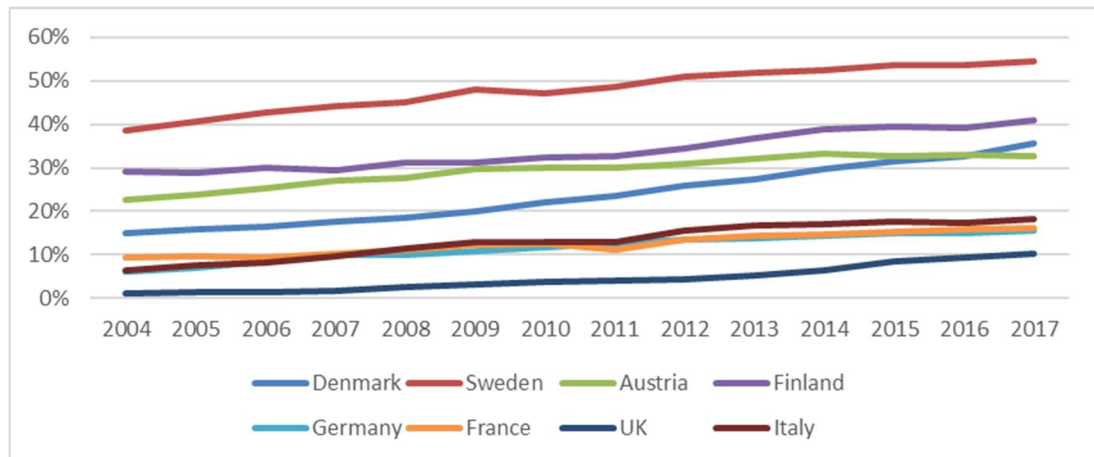
grid. Extra costs are reflected to the consumer, not the manufacturer, or covered by governments. Some governments guarantee a higher price for those who are expensive or underdeveloped and need to be supported (Bahar et al. 2013). Another regulatory policy is net metering / billing. Net metering provides consumers, who produce their own electricity from renewable energy, not when the electricity is generated, but whenever they want to use it. In other words, customers pay the net amount of electricity generated from renewable energy. When customers connect renewable energy systems to a distribution network, they can sell the over-produced electricity to this network (U.S. Energy Information Administration, 2018). One of the policies used to support renewable energy fuel consumption is biofuel blend obligation and renewable heat obligation. There are countries that determine the obligatory mixing ratio for biofuel mixing in fuel and there are countries that determine obligation to supply some of the heating energy from renewable energy. Another regulatory policy is tradable Renewable Energy Certificate. It is given for each kWh or MWh produced by the renewable energy producer. This mentioned certificate is a tool to meet the renewable energy obligations by buying and selling in the market and also to trade between consumers and / or manufacturers. Tendering is also a policy and it is a supply mechanism where renewable energy producers can sell in a competitive environment (REN21, 2019).

Public financing and fiscal incentives policies for renewable energy can take various forms in countries. There are countries that use all or a few of them Public financing and fiscal incentives for renewable energy examples in countries can be tax incentives, investing or producing tax credits, reducing in sales, carbondioxide, energy, Value Added Taxes (VAT) or can be other taxes, energy output payment, public investment, grants, loans, capital subsidies and rebates.

According to the data obtained from the European Commission, when we look at 8 countries with large economies from European countries and look at the ration of renewable energy into total, it is understood that all of them showed a great development in terms of the ration of renewables in energy usage. These 8 countries are: Denmark,

Sweden, Austria, Finland, France, United Kingdom (UK), and Italy. Sweden is the furthest renewable energy use rate in energy use from these 8 countries and the countries in the European Union with 54.5 percent and Finland is followed by 41 percent.

**Figure 3: Change of Renewable Energy by Years**



Source: European Commission, authors own calculation

Therefore, what kind of policies these two countries, which are Sweden and Finland, have is important since these have the biggest share in the usage of renewable energy. In addition, according to Bp Statistical Review of World Energy Report (2019), Germany, Spain, the United Kingdom (UK), Italy, Portugal, Denmark, Finland, Ireland and New Zealand are the countries that contribute to more than 20% of the power produced in renewable energy.

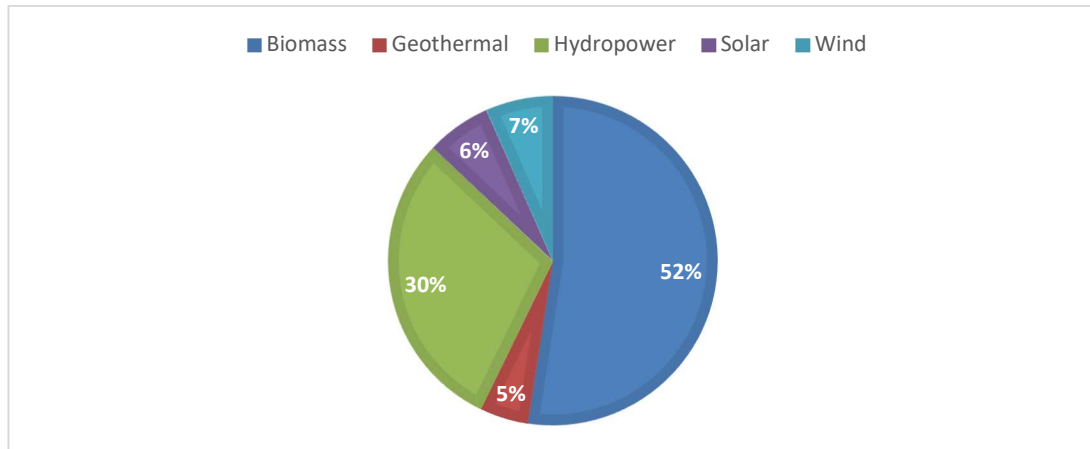
The State of Finland implements its energy policies through various means to increase renewable energy use. It provides subsidies to production and investments for sustainable energy production. One of these subsidies is the "energy aid" subsidy. With this subsidy, government support is provided for research for renewable energy. Subsidy II is called "Investment Aid for Renewable Energy and New Energy Technologies" and this provides investment support for new energy technologies and renewable energy. Another vehicle

is "premium in tariff". Here, electricity producers that produce and sell electricity that generates electricity from wind, biomass and biogas receive a variable premium tariff equal to the difference between the target price and the market value for a period of 12 years. Tenders are another tool for the Finnish state. The purpose of this is to support a lower cost renewable energy development. There are also tax regulations for fuels that cause CO<sub>2</sub> emissions. Less tax is available for less carbon dioxide emissions. For transportation, there is a biofuel quota also. For heating and cooling there are subsidies and price-based mechanism (Europe, 2013).

In Sweden, for transportation biofuel quota and tax regulation mechanism exist. Tax reductions in renewable energy use for heating and cooling are among the main incentives in Sweden. Tax cuts are available for households who want to consume renewable energy to heat and to cool. In addition, extra taxes are levied for those who use, produce or import fossil fuels. Also, nitrous oxide tax is collected from heat generators according to nitrogen oxide emissions. The Kingdom of Sweden is implementing a system that obliges electricity suppliers to prove that electricity is produced from a certain percentage of renewable energy for electricity generation. Also, for production of electricity from renewable energy there are tax regulation mechanisms and subsidies (Europe, 2013).

According to International Energy Agency (2019) data, it is seen that Research and Development payments for renewable energy in the world have increased from 2012 to 2018. In addition, the venture capital investment in clean energy has increased again from 2012 to 2018 and made a huge leap in 2018.

**Figure 4: The Share of Consumption of Renewable Energy Sources as an Average between 2013 and 2017 in the World**



Source: International Renewable Energy Agency, authors own calculation

The share of consumption of renewable energy sources chart as an average between 2013 and 2017 in the world has been prepared according to data from IRENA. According to this graph, biomass consumption has the highest share with 52 percent compared to other renewable energy resources. Biogas, liquid biofuels, solid biofuels and renewable energy wastes are included in the biomass. It is seen that the most used renewable energy resource in the world after biomass as a renewable energy source is hydropower with 30 percent. Worldwide consumption of solar energy (solar thermal and solar PV) and wind energy have the rates respectively 6 percent and 7 percent. Geothermal energy use is 5 percent and other renewable energy consumption is negligible worldwide.

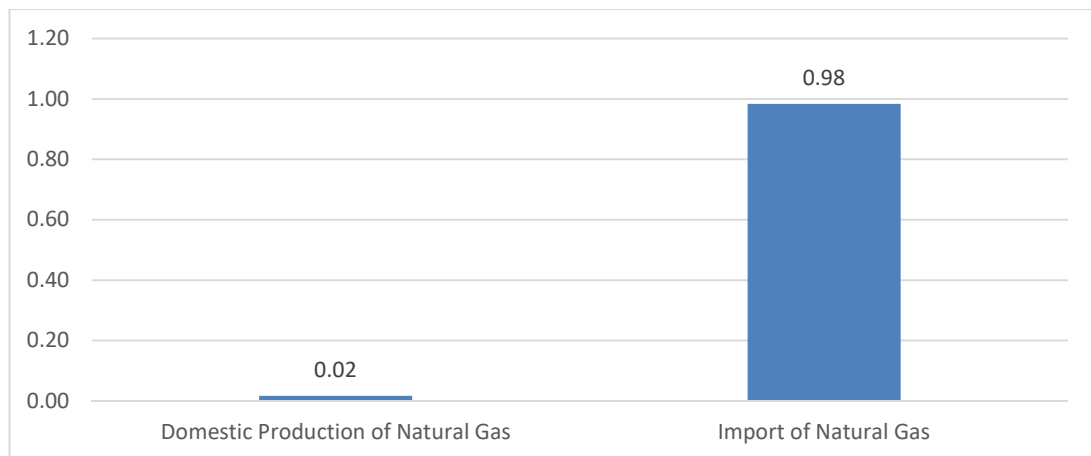
### 1.3. ENERGY STRATEGY OF TURKEY

Due to the importance of energy for our life, it is seen as a strong source internationally. “Geography of Energy (production, consumption and transfer zone region) in particular Turkey gain attention as a center that combines a scenic route and geography of energy supply and demand. Oral and Ozdemir (2017) says that Energy Geography (especially the region of production, consumption and transfer zone) is considered as a natural route that unites countries that need to meet their energy supply and demand. Turkey has attracted the attention as a scenic route between energy supply and demand in global

energy geopolitics. Turkey considers its position with regard to energy is significant in determining the energy strategy. In addition, it also turns to energy sources where it can meet the energy demand without harming the environment. Therefore, renewable energy sources take its place in Turkey's energy strategy. In addition to an orientation to the use of not environmentally damaging energy, sources to provide the raising energy need in Turkey and strategies to decrease the dependence on foreign sources of energy are determined. According to MENR report (2017), Turkey is ranked in primary energy consumption 19th and the share of 1.0% in the world's total primary energy usage as of 2017.

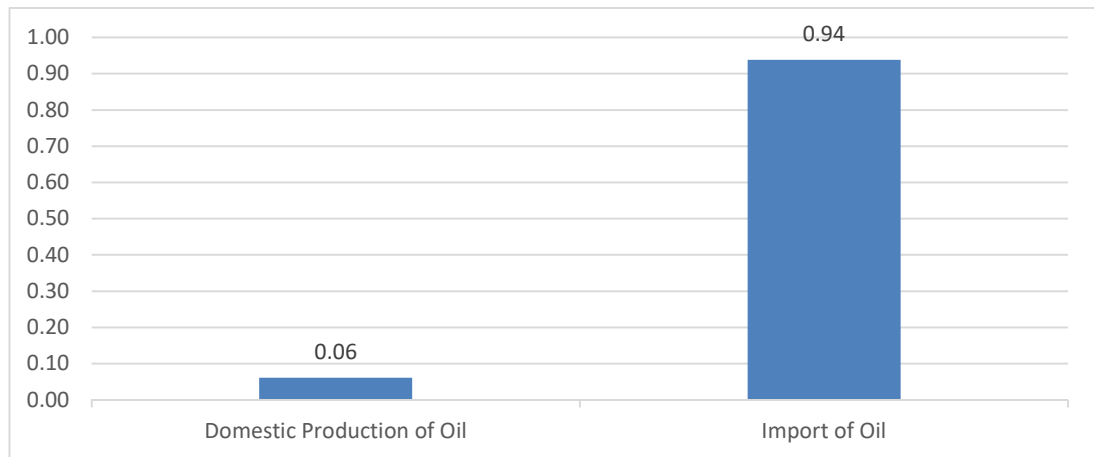
Due to Turkey's limited energy resources and increasing of energy demand Turkey's dependence on foreign energy sources increases. The approximate calculation with data from MENR shows that imported natural gas is 94% and imported oil is 98% in Turkey.

**Figure 5: In the Last Decade the Share of Domestic Production and Imports of Natural Gas in Turkey**



Source: MENR, authors own calculation

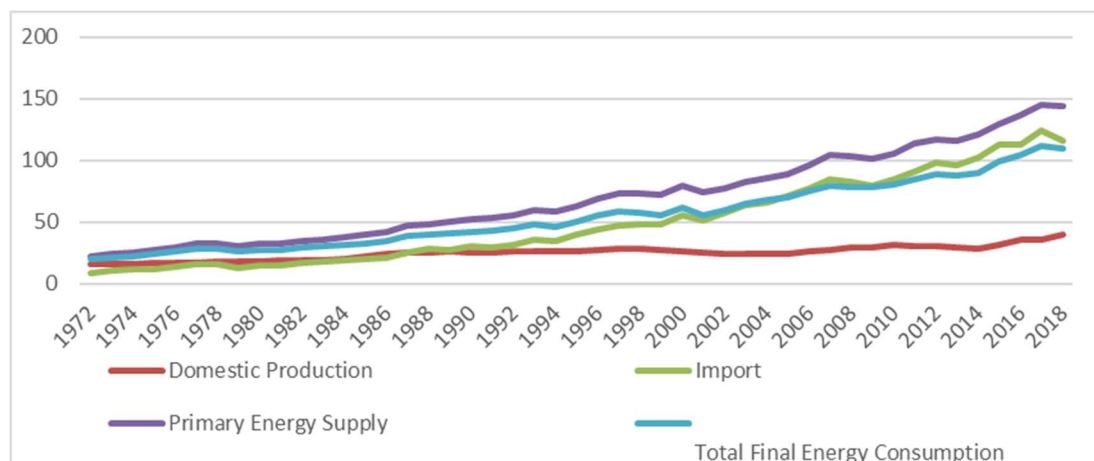
**Figure 6: In the Last Decade the Share of Domestic Production and Imports of Oil in Turkey**



Source: MENR, authors own calculation

In addition, for 1998-2018 years MENR data shows that while domestic production remains almost stable, imports increase with energy consumption increases.

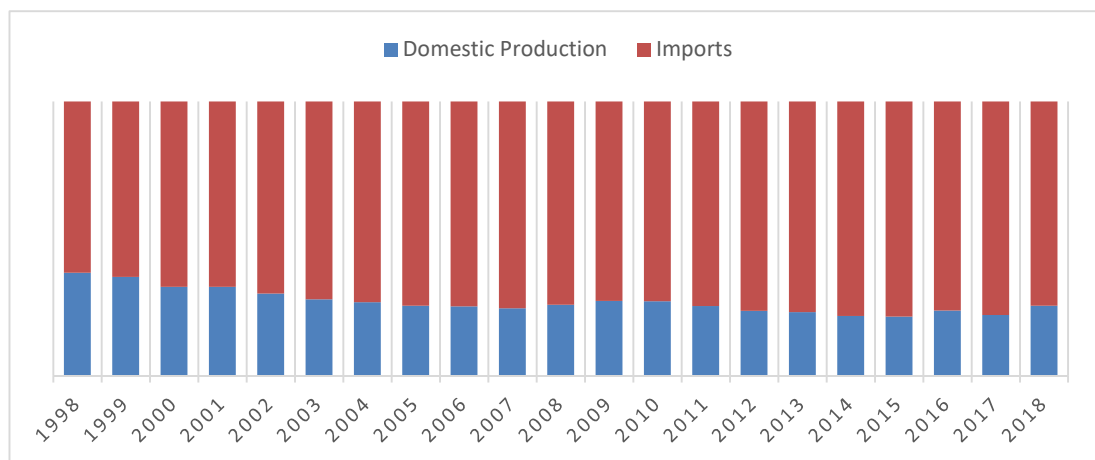
**Figure 7: Turkey's Domestic Energy Production, Final Energy Consumption, Primary Energy Supply and Energy Imports (mtoe)**



Source: MENR, authors own calculation

Turkey imports energy to be adequate energy demand and Turkey's energy imports in the average level of 73% between the years 1998 and 2018. Turkey may become more dependent on imports to meet this demand as energy demand increases. That's why, while Turkey determine energy strategy energy demand and dependence on foreign sources of energy is particularly considered.

**Figure 8: In the Last Decade the Share of Domestic Production and Imports in Energy Supply in Turkey**



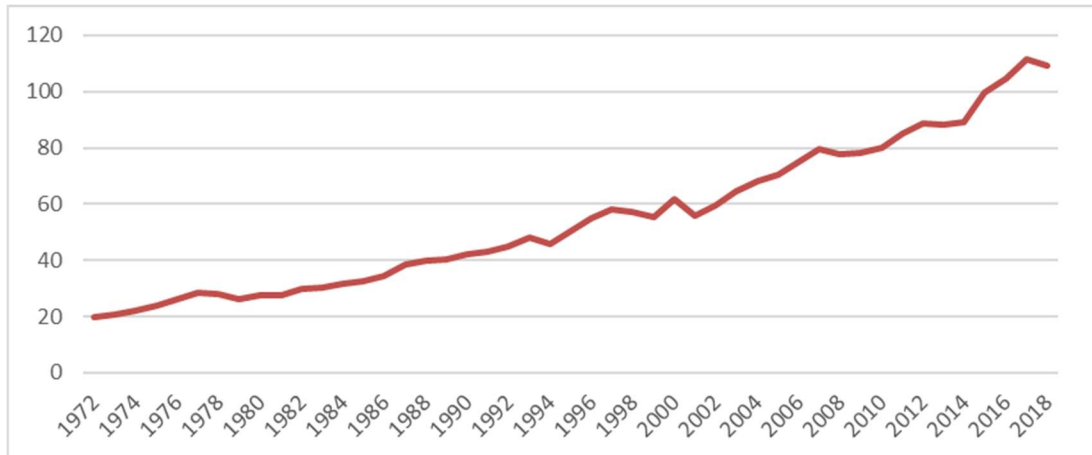
Source: MENR, authors own calculation

Both the rapidly increasing energy demand and the fact that a significant portion of the countries in question are dependent on foreign energy and experience significant balance of payments keep their economical and financial balances constantly fragile. (Demir, 2013). It has been evaluated that a new energy crisis that may occur in the world for foreign countries dependent on energy will negatively affect the economic activities of the country and will have negative effects on the level of economic growth and welfare. (Tekbas and Yildirim, 2019) In particular, Turkey should decrease the energy imports because dependence on energy sources cause foreign trade and current account balances deficit (Uzumcu and Topal, 2019). Turkey's increasing energy demand, the structure dependent on external energy supply sources, Turkey's importance given to the environment and geopolitical location takes into consideration when Turkey determine the energy strategy. For this reason, raising the ration of domestic and renewable energy



sources is among the basic elements of energy strategies of Turkey (MFA, 2019). MENR data shows that Turkey's demand for energy has increased by almost six times from 1972 until 2018.

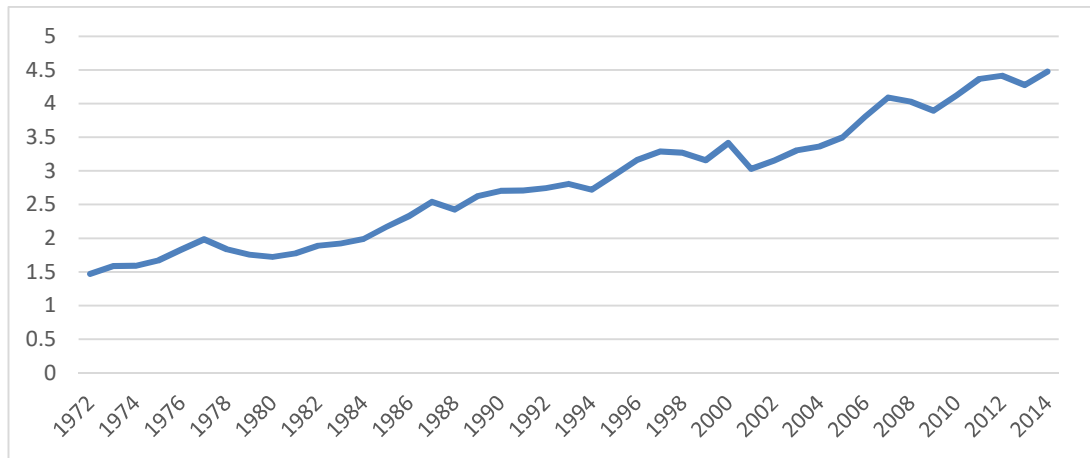
**Figure 9: Total Final Energy Consumption (mtoe)**



Source: MENR, authors own calculation

Also, World Bank data shows that the carbon dioxide emissions that cause greenhouse gases from 1972 until 2014 has increased by almost three times in Turkey. Increased carbon dioxide emission is a major environmental problem for Turkey. Therefore, while Turkey specify energy strategy had to take the environmental factors into consideration as in other countries have also.

**Figure 10: Carbondioxide Emissions (metric tons per capita)**



Source: World Development Indicators, authors own calculation

#### **1.4. RENEWABLE ENERGY SOURCES IN TURKEY**

Turkey has shown remarkable development in the renewable energy and has started to implement its energy policies in various ways to enhance the usage of renewable energy. Feed-in-tariff (FIT) is one of the implemented policies of Turkey to support the renewable energy usage. Thanks to FIT, it has been guaranteed that its power plants, which were operational by 2015, will pay the fixed tariff price for 10 years. This tariff is suitable for all renewable energy sources and there are different tariffs according to the renewable energy source type. In addition, the state guarantees that electricity, which cannot be produced or sold, will be purchased for 10 years. Also, REN21 Global Status Report (2019) show that loans, grants, public investment, capital subsidies and rebates are available in Turkey. The transmission system used for renewable energy has applied a 50 percent discount on usage fees for 5 years. The government has provided some incentives for investments in electricity produced from renewable energy sources. These incentives include being completely exempt from VAT for investment equipment, exempt from customs duty in case of importing investment equipment, and exempted from additional fees. In addition, an additional incentive for 5 years under certain conditions was provided to the facilities operating in 2015 and before, producing some equipment used in renewable energy facilities. For 10 years, the power plants operating in 2020 and before

are given 85 percent discount on the lease, easement and usage rights of the transmission lines. Again, under certain conditions, license exemptions were brought to power plants producing renewable energy (Behrendt, 2017). In addition, two percent of biofuels, which are biodiesel and ethanol, mixed with fuels are exempted from special consumption tax (MENR, 2014).

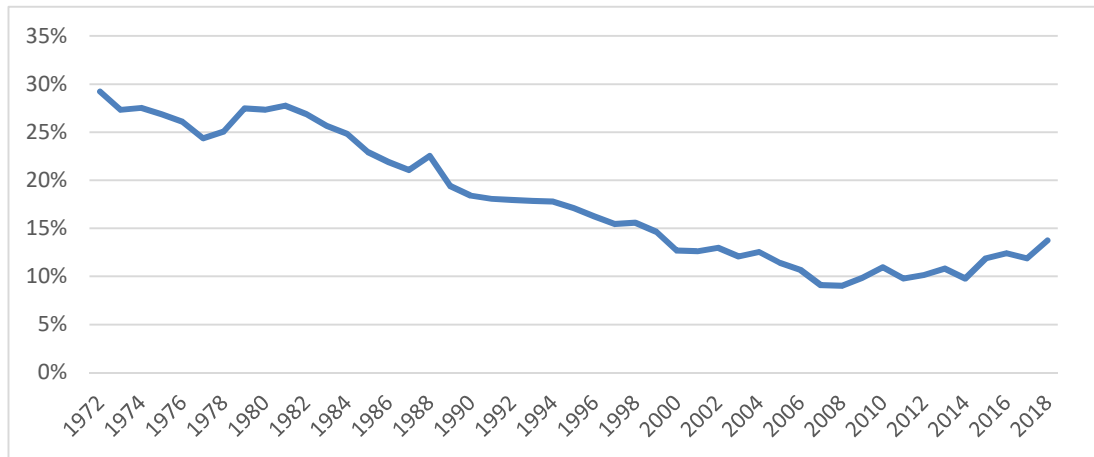
The tendering is another policy tool to promote renewable energy. Renewable Energy Regions where the renewable energy capacities will be tendered have been created (YEKA tender) and the tenderers submit a 15-year bid for the tariff. The tender system is suitable for all renewable energy sources. With this tender system, the investment in renewable energy is supported (Europe, 2013).

The obligation of blending biodiesel to diesel types and the obligation of blending ethanol to gasoline types were also created to incentive the renewable energy usage. While the obligation of blending ethanol to gasoline types was 2 percent since 2013, this rate was increased to 3 percent since 2014 and only domestic ethanol can be used (Energy Market Regulatory Authority, 2012). As of 2018, at least 0.5% biodiesel blend has been made compulsory for diesel varieties. Biodiesel must be produced from domestic agricultural products and / or vegetable waste oils (EMRA, 2017).

According to data from MENR, the ration of renewable energy resources in total energy resources usage decreased between 1972 and 2008. This share had the lowest rate in 2008, but this rate increased in the period from 2008 to 2018. The reason for the usage of renewable energy resources from 1972 to 2008 decreased from about 30 percent to 9 percent, because the need for energy resources increased, and non-renewable energy resources were preferred more than renewable energy resources. In addition, the decline in biomass use rates between 1972 and 2008 also led to a decline in renewable energy usage. In the period from 2008 to 2018, the need for energy resources has increased, however, since the importance of renewable energy is known, it is seen that there has been a partial transition from non-renewable energy sources to renewables. Renewable

energy resources which is used in Turkey will be examined in other sections of this thesis and it will be seen that particularly the consumption of solar and wind energy has been increased from 2008 until 2018.

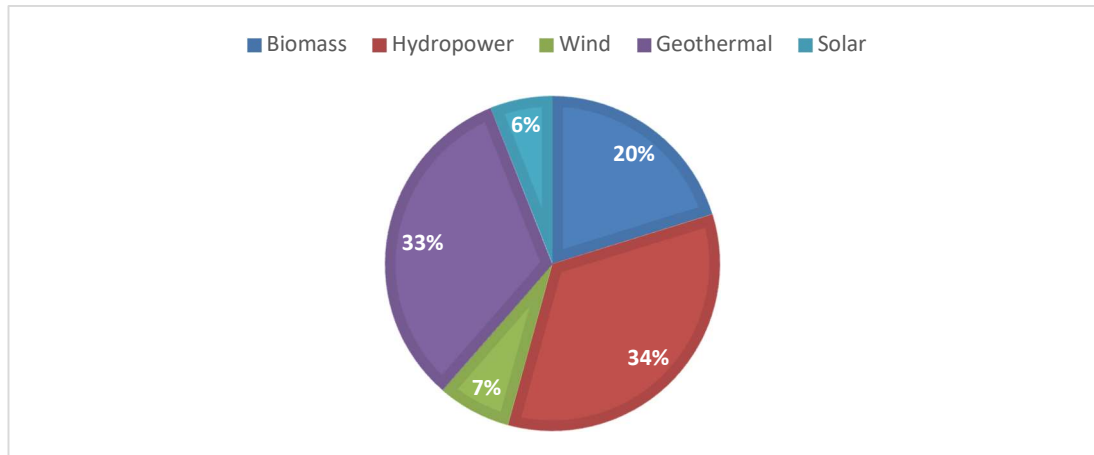
**Figure 11: The Ration of Renewable Energy Consumption in Total Consumption in Turkey**



Source: MENR, authors own calculation

In addition, as seen in the graph, although our renewable energy use has improved compared to other developed economies, it has an average rate.

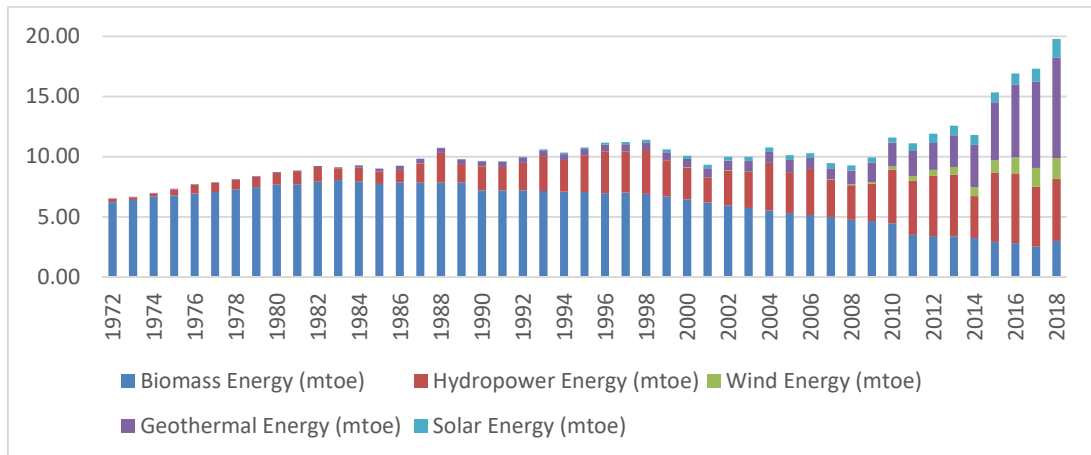
**Figure 12: The Ration of Consumption of Renewable Energy Sources as an Average between 2013 and 2017 in Turkey**



Source: MENR, authors own calculation

The chart of the share of consumption of renewable energy sources as an average between 2013 and 2017 in Turkey has been prepared according to data from MENR. According to this graph, hydropower energy consumption has the highest share with 34 percent compared to other renewables and geothermal energy consumption almost equal to the share with hydropower energy consumption with 33 percent. It is seen that the most used renewable energy source in Turkey after hydropower and geothermal energy as a renewable energy source is biomass energy with 20 percent. Biogas, liquid biofuels, solid biofuels, pellets and renewable energy wastes are included in the biomass. Wind energy use and the consumption of solar energy (Solar Thermal and Solar PV) have the rates respectively 7 percent and 6 percent. Other renewable energy consumption is not available in Turkey.

**Figure 13: The Share of Types of Renewable Energy Sources by Years**



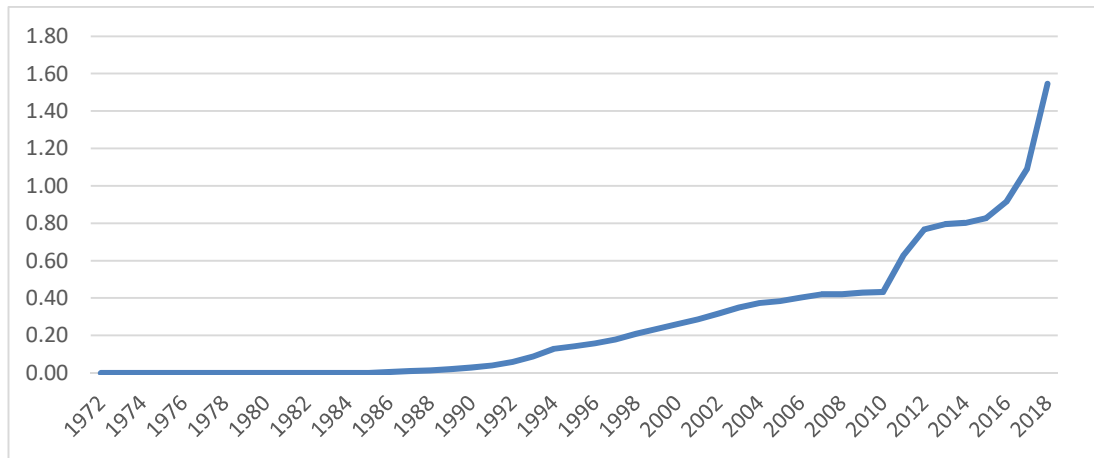
Source: MENR, authors own calculation

According to the graph, when the beginning year is 1972 is accepted, it is seen that biomass energy was the most consumed renewable energy source at the beginning. It is observed that hydropower energy has also been used as renewable energy resource as the year progress and the share of other renewable energy resources has started to increase as the share of biomass energy decreases as we progress towards 2018.

#### 1.4.1. Solar Energy in Turkey

Solar energy is the type of the renewable energy, which is non-harmful environmentally and which is ease of installation and ease of use, can be used in Turkey in some areas such as heating, electricity and lighting.

**Figure 14: Solar Energy by years in Turkey (mtoe)**



Source: MENR, authors own calculation

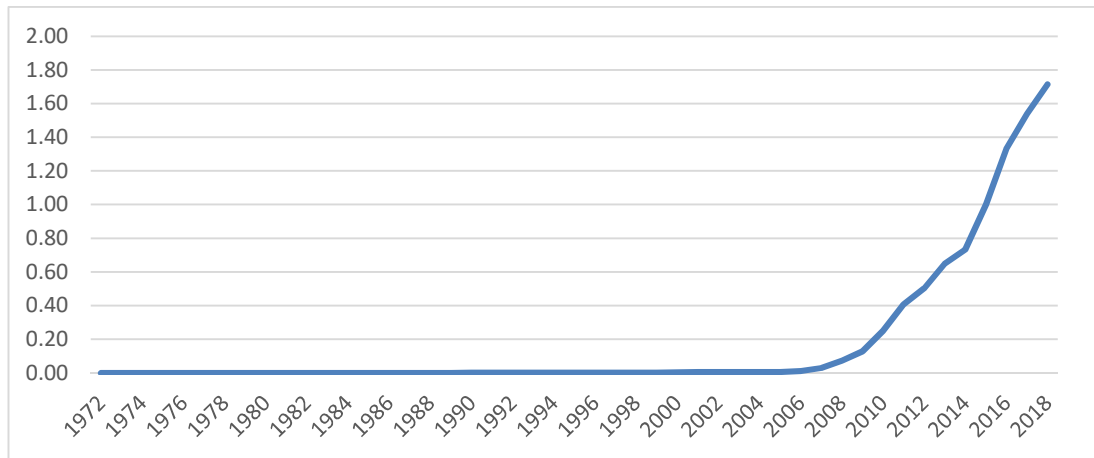
According to the graph, which shows the change of solar energy consumption by years prepared with data from MENR, no solar energy was used until 1986. It has increased steadily since 1986. The rate of increase between 2010 and 2012 is high and the rate increase between 2016 and 2018 is also high. Also, when it comes to the last years it is increased speedily and the fact that solar energy consumption is at its highest level in 2018 is seen.

In addition, according to the data from IRENA, between 2013 and 2017, average solar energy consumed in Turkey compared with solar energy consumed in the world, it is seen that Turkey ranks 7th in the world.

#### **1.4.2. Wind Energy in Turkey**

Wind energy, a type of the renewable energy resources, is clean, environmentally friendly and inexhaustible. The use of wind energy, which has low maintenance costs and operating costs and is easier to operate with its facility, is increasing today. It can be used in areas such as water pumping, grain grinding, cooling and lighting.

**Figure 15: Wind Energy by years in Turkey (mtoe)**



Source: MENR, authors own calculation

According to the graph, which shows the change of wind energy consumption by years prepared with data from MENR, no wind energy was used until 2001. The rate of increase between 2006 and 2018 is high. Also, the fact that wind energy consumption is at its highest level in 2018 is seen.

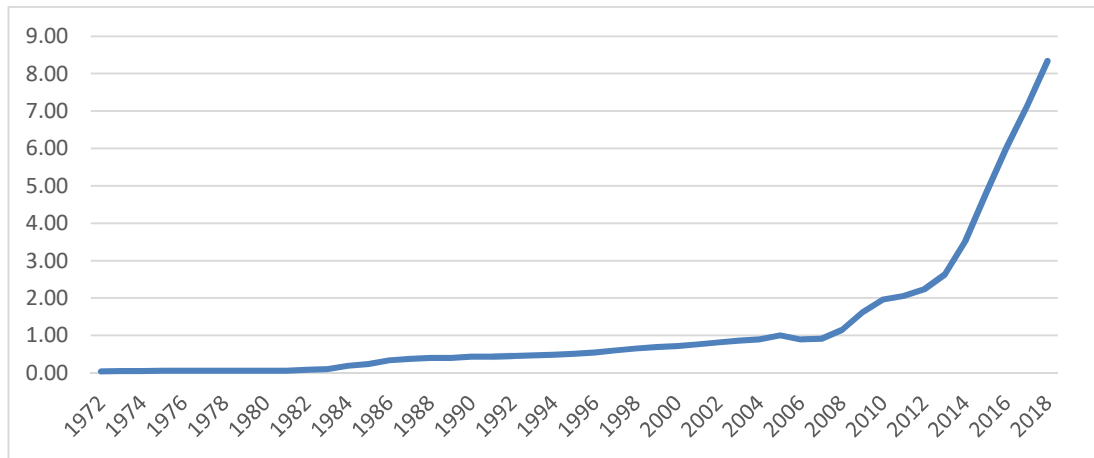
In addition, according to the data from IRENA, between 2013 and 2017, average wind energy consumed in Turkey compared with wind energy consumed in the world, it is seen that Turkey ranks 12th in the world.

### 1.4.3. Geothermal Energy in Turkey

Geothermal energy, which has features such as low investment costs, being environmentally friendly and efficient, has various uses in areas such as electricity generation, heating and industry.



**Figure 16: Geothermal Energy by years in Turkey (mtoe)**



Source: MENR, authors own calculation

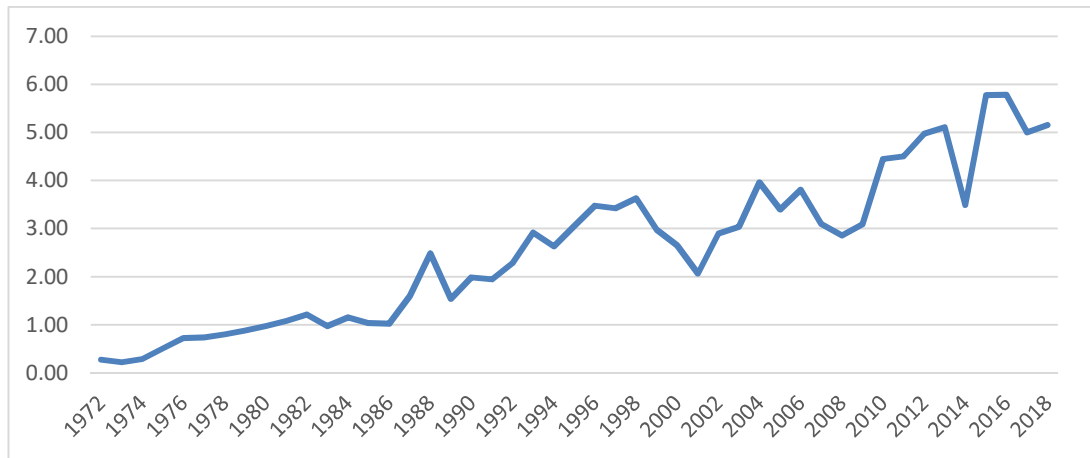
According to the graph, which shows the change of geothermal energy consumption by years prepared with data from MENR, geothermal energy was used since 1972. The rate of increase between 2012 and 2018 is high. Also, the fact that geothermal energy consumption is at its highest level in 2018 is seen. In the time period from 2016 up to 2018, the most widely used energy source, geothermal energy has been in Turkey.

In addition, according to the data from IRENA, between 2013 and 2017, average geothermal energy consumed in Turkey compared with geothermal energy consumed in the world, it is seen that Turkey ranks 4th in the world.

#### **1.4.4. Hydropower Energy in Turkey**

Renewable energy source hydropower energy, which has a long technical life, low maintenance costs and high efficiency and is environmentally friendly, generates electricity, but it has various uses such as agriculture and industry.

**Figure 17: Hydropower Energy by years in Turkey (mtoe)**



Source: MENR, authors own calculation

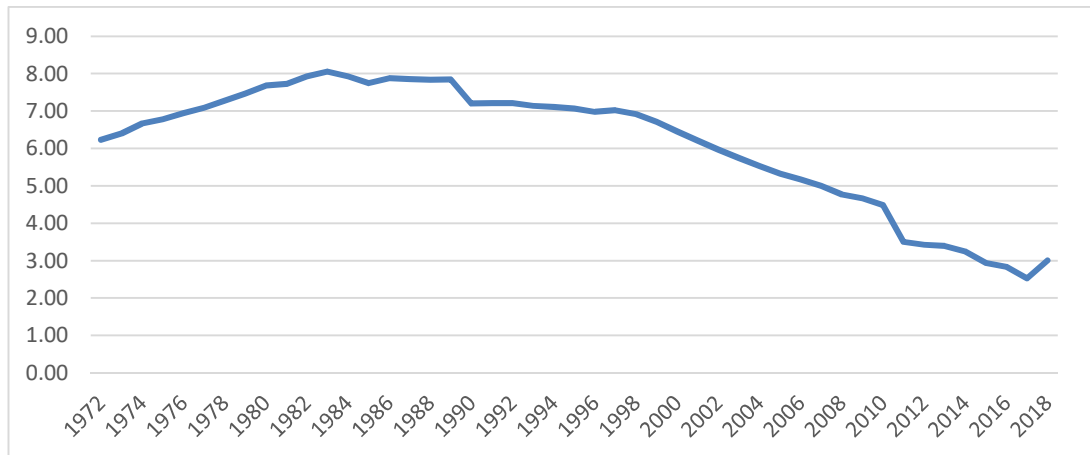
According to the graph, which shows the change of hydropower energy consumption by years prepared with data from MENR, hydropower is a renewable energy source consumed since 1972. Hydropower is the most used energy source after the use of biomass energy from 1972 to 2010. In the years 2011 to 2015 has been the most widely used renewable energy sources in Turkey. From 2015 to 2018, it became the second most used renewable energy resource after geothermal energy, which is the most used renewable energy resource. Also, the fact that hydropower energy consumption is at its highest level in 2015 and 2016 is seen.

In addition, according to the data from IRENA, between 2013 and 2017, average hydropower energy consumed in Turkey compared with hydropower energy consumed in the world, it is seen that Turkey ranks 12th in the world.

#### **1.4.5. Biomass Energy in Turkey**

Biomass energy, which is easy to obtain and used for energy efficiency in every scale, has the ability to be stored and environmentally friendly, can be used for heating, as an energy in motors and to create by-products.

**Figure 18: Biomass Energy by years in Turkey (mtoe)**



Source: MENR, authors own calculation

According to the graph, which shows the change of wind energy consumption by years prepared with data from MENR, biomass is a renewable energy source consumed since 1972. Biomass is the most consumed energy source from 1972 to 2010 in Turkey. From 2011 to 2013, it became the second most used renewable energy source after hydropower, which is the most used renewable energy source. Between 2014 and 2018, the use of biomass energy started to decrease significantly.

In addition, according to the data from IRENA, between 2013 and 2017, average biomass energy consumed in Turkey compared with biomass energy consumed in the world, it is seen that Turkey ranks 30th in the world.

## 1.5. TURKEY'S ECONOMIC GROWTH

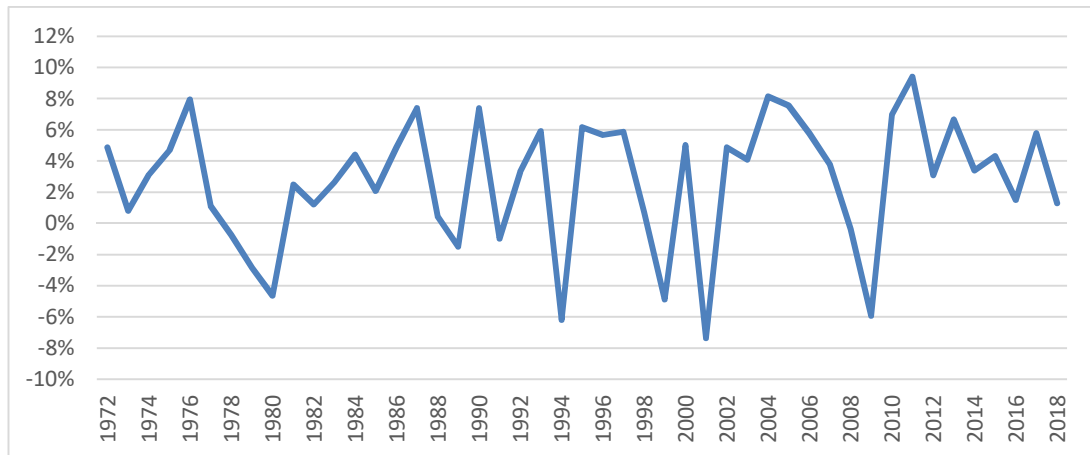
Economic growth is the real increase in production potential or real gross domestic product of a country in a year which can be quantified. Growth refers to the increase in economic activities and an increase in per capita income. These increases must be continuous in order to be accepted as growth.

GDP is expressed as the currency value of the production of all final services and goods within a country in an obvious time. The gross domestic product is used when calculating economic growth as it is directly or indirectly affected by many macro indicators. GDP is used instead of GNP as the main measure of economic evaluation, because international economic integration is intensified, economic boundaries do not know political boundaries, GDP is easier to measure and GDP represents the power of creating economic employment better. Real GDP measures the change of production between periods by evaluating goods and services produced at different periods with the same prices.

When calculating the real growth rate in an economy, it will be the best way to remove the changes in the population from the increase rate in production. The concept used for this is when the real GDP per capita is divided by the population of the country the real GDP per capita is obtained. Real GDP and real GDP per capita are used as a quantity of economic growth. In this thesis, per capita GDP data will be used and data will be obtained from World Development Indicators.

The years between 1972 and 2018 in Turkey, when we consider the growth rate, which the growth of GDP per capita, it is declined in some years and occurred minus direction is seen in the some years. Growth and growth rate can be affected by various macro variables. Looking at the growth of Turkey's GDP per capita seems to be fluctuations between 1972 and 2018. In 1980, 1994, 2001, 2008 years in which the economic crisis occurred growth of gross domestic per capita showed a negative growth in Turkey. Another noteworthy point here is that GDP per capita growth in Turkey has declined in some years, and the GDP per capita growth has decreased in the years of 1973 and 1979 oil crises. As it is said, the negativeness of GDP per capita growth or decrease in some years may be due to many reasons. However, as in the crises of 1973 and 1979, the negative effects of energy dependency are seen and suggest renewable energy is possibly significant for economic growth. At this point, in this study, whether renewable energy sources affect the economic growth will be investigated.

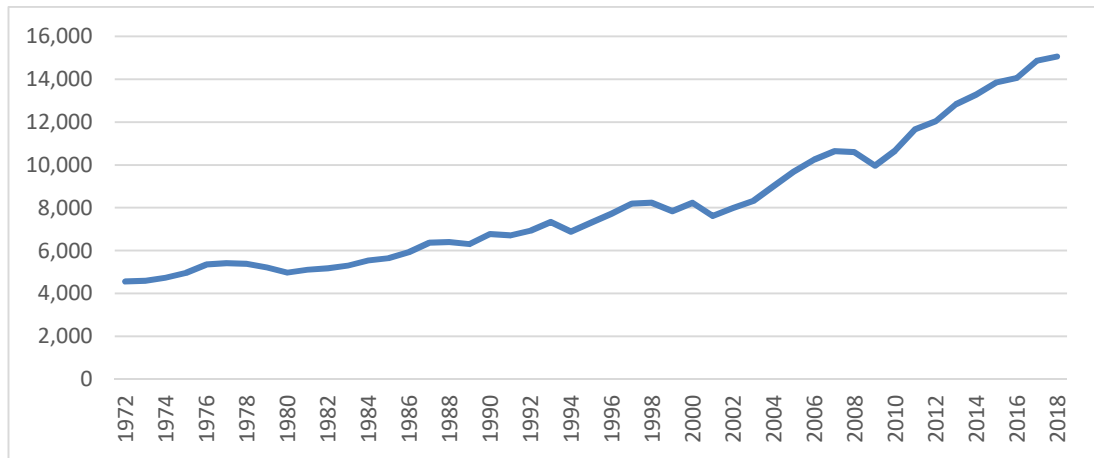
**Figure 19: GDP per capita Growth by Years in Turkey**



Source: World Development Indicators, authors own calculation

The reason for calculating the GDP in dollars is that the comparison between the countries can be provided and there are no big differences in price changes. As seen in the graph, the data are shown in GDP per capita based on 2010 US dollars. From 1972 to 2018, the GDP per capita increased by about 3.5 times. While GDP per capita was 4,221 US dollars in 1972, it increased in general until 2018 even though it decreased in some years compared to the previous year. Compared with 1972, the GDP per capita in 2005 was about 2 times the GDP per capita in 1972, the GDP per capita in 2011 2.5 times the GDP per capita in 1972, the GDP per capita in 2015 3 times the GDP per capita in 1972 and the GDP per capita in 2018 3.5 times the GDP per capita in 1972. We can mention GDP per capita showed a high increase in terms of quantity in these years compared to 1972. On the other hand, as seen in the graph, in 1973, 1978, 1988, 1998 and 2008, GDP per capita remained stable compared to the previous year. In addition, in 1979, 1980, 1989, 1991, 1994, 2001 and 2009, GDP per capita decreased compared to the previous year.

**Figure 20: GDP per capita (constant 2010 US\$) by Years in Turkey**



Source: World Development Indicators, authors own calculation

Also, according to TURKSTAT data and World Development Indicators data, it is accounted that for 1972-2018 years the mean of amount of energy imports is 14,550.6 million dollars. This corresponds to approximately 2.9 percent of GDP. This is a high rate for a single import item.

## CHAPTER 2

### **THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND RENEWABLE ENERGY: A LITERATURE REVIEW**

Whether the energy consumption is in association with economic growth has been studied comprehensively in the literature since energy use is seen as vital for sustainable development. (Farhani and Rejeb, 2012). In studies conducted in the literature, four different hypotheses put forward when examining the relationship between economic growth and energy consumption or renewable energy consumption. In the studies, one of these four hypotheses is supported by applying different countries, different years and different methodologies.

The first of the four hypothesis that explain relationship of these two variables is growth hypothesis. It is the hypothesis that energy consumption affects economic growth directly and also indirectly. In the growth hypothesis, energy consumption is considered as the complement of labor and capital. When there is a one-way causality to economic growth from energy consumption, in that case the growth hypothesis is asserted. In this hypothesis, economic growth is positively (negatively) impacted as energy consumption increases (decreases). The second of these four hypotheses is conservation hypothesis. This hypothesis is the inverse of the growth hypothesis. Economic growth affects energy consumption both directly and indirectly in this hypothesis. The conservation hypothesis is alleged where there is a one-way causality toward energy consumption from economic growth. In this hypothesis, energy consumption is positively (negatively) affected as economic growth increases (falls). Another hypothesis is the feedback hypothesis. In this hypothesis, economic growth and energy consumption are affected each other. The feedback hypothesis is supported when there occurs a bidirectional relation between these variables. Finally, another hypothesis is the neutrality hypothesis. In this hypothesis, energy consumption has slight effect on economic growth or it doesn't affect economic

growth. That is, energy consumption can be an insignificant component of economic growth.

There are several works with different outcomes in the literature. In these studies, economic growth is mostly evaluated by real GDP or GDP in per capita. There are studies looking at renewable energy consumption, non-renewables consumption or amount of total energy consumed, economic growth and CO<sub>2</sub> emissions relations.

Fang (2011), utilizing the multivariate OLS method with the help of the cobb-douglas function, for China, presented the relation between renewable energy and economic growth by putting to use information from 1978 to 2008, and revealed a one-way direction relation from renewables to economic growth. Thus, growth hypothesis is supported.

Tiwari (2011) applies a structural variance analysis for India between 1960 and 2009 by studying on the relation between renewable energy, carbondioxide emissions and GDP. It uses hydroelectricity consumption for renewable energy, million tons as a measurement of carbondioxide emissions and GDP per capita constant 2000US \$ for GDP as a measure of economic growth. Doing this study reason is that India took place after China in hydroelectricity production and a study made for this method for India was not found until then. The study reveals that GDP increases and carbondioxide emissions decrease when there occurs a positive shock in renewable energy consumption and also states that when a positive shock hits the GDP, CO<sub>2</sub> emissions is affected very highly from this circumstance. By using the variance decomposition method, it is revealed that renewable energy consumption explains a very important part of share of renewable energy source forecast error variance of GDP, and that the negligible part of share of renewable energy source forecast error variance of carbondioxide emissions. Consequently, it shows in this study that a same-way relation occurs between economic growth and renewable energy usage.



Leitão (2014) examines the causality between globalization, economic growth, CO<sub>2</sub> emissions and renewable energy using data from the 1970s and 2010 years for the Portuguese economy. While doing this study, he uses time series analysis which are OLS, GMM, Granger Causality. As a result, growth hypothesis is supported by revealing the fact that causality occurs to economic growth from renewable energy.

In the study of Cinar and Yilmazer (2015) the supply-side approach and the demand-side approach are used with two different models simultaneously. In the study, developing countries are analyzed by panel data analysis which is panel ARDL with the data between 1990 and 2013. The reason for this study to be done for developing countries is that developing countries are becoming dependent on energy imports due to increasing costs, intensive industrialization activities and raising energy demand. The traditional production function of Cobb-Douglas puts in the practice in the supply-side approach and the impacts of renewable and non-renewable energy sources on economic growth are examined. In the demand side approach, the factors of renewable energy consumption are investigated. Here, it has been detected that production of electricity from renewable energy sources contributes to growth more than production of electricity from non-renewables.

Bhattacharya et al. (2016) analysed whether renewable energy usage is associated with economic growth in 38 countries by utilizing the observations between 1991 and 2012. The selected nations are those with much renewable energy consumption. While examining the relationship, panel estimation technique which is panel OLS method is used. As a result of this work, renewable energy is found to be effective on economic growth. Therefore, growth hypothesis is alleged.

Using data between 1990 and 2012, Fotourehchi (2017) analyzes the causality between economic growth and renewable energy for 42 developing nations by applying Canning and Pedroni (2008) panel causality test and Granger causality test. The conclusion found

in mentioned study is that the real GDP at the significance level of 5% renewable energy usage is the Granger cause. When renewable energy is substituted with non-renewable energy, it is beneficial for growth. Here, a one-way and positive relationship has been found from renewable energy to growth. The reason of being done this study for developing countries is that the economic development of these countries is unsustainable and it is desired to investigate what effect it will have on economic growth if renewable energy is replaced by non-renewable energy.

Using the FMOLS and DOLS panel model estimators and ECM and SUR analysis techniques, Sadorsky (2009) searches the relation between consumption of renewable energy and economic growth for eighteen developing countries between 1994 and 2003. In the long term, since increasing per capita revenue causes to a raise in use of renewable energy, conservation hypothesis is supported.

The study of Ocal and Aslan (2013) about the economic growth and renewable energy usage relationship in terms of Turkey between 1990 and 2010. ARDL and Toda-Yamamoto causality test indicates that one-way direction causality in renewable energy usage from growth. Thus, conservation hypothesis is alleged.

Salim et al. (2014) tried to search the linkage between renewable energy and non-renewable and economic growth taking data between 1980 and 2011 for 29 OECD countries. While doing this study, Panel Granger applied the causality test and as a result, a unidirectional causality was found and conservation hypothesis is supported.

Bakırtas and Cetin (2016) studies the link between renewable energy use and economic growth with panel data analysis approaches, which are POLS, REM and FGLS analysis techniques. This study is conducted for G-20 countries between 1992 and 2010. Renewable energy usage per capita is applied as a criterion of renewable energy

consumption and real GDP per capita is figured as a criterion of economic growth. In this work, how the change in renewable energy for each person affected real GDP per capita is investigated. As a result, it is exposed that there is a long-term linkage between consumption of renewables and economic growth. Moreover, the conservation hypothesis is accepted in this study.

Apergis and Payne (2010a) examines 13 Eurasian regions and 1992 and 2007 years the relation renewable and non-renewable energy sources on economic growth with panel data analysis, which is the heterogeneous panel cointegration test for a short and long term. As a consequence of the study, a bidirectional causality is determined and feedback hypothesis emerges.

Apergis and Payne (2010b) analyses the relation between renewable energy sources and the economic growth for OECD countries using data between 1985 and 2005. While examining this relationship, he uses panel data analysis which are panel cointegration and ECM and also granger causality. Consequently, mutual causality is determined and feedback hypothesis is alleged.

Apergis and Payne (2011) analyzes the relation between economic growth and renewable energy for 6 Central American nations between 1980 and 2006. For this study, he uses panel data analysis, panel cointegration and also ECM, so determines the mutual causality linkage between these two variables. Hence, feedback hypothesis is asserted.

Apergis and Payne (2012) searches the causality among the non-renewables, renewable energy sources and growth between 1980 and 2007 for 80 countries since countries orientate towards renewable energy sources because of environmental problems, volatile and high energy prices. Panel causality test outcomes reveal that these source of energy

create a positive effect on economic growth. It also supports feedback hypothesis by revealing bidirectional causality between these variables.

Fuinhas and Marques (2012) for 5 countries which are Portugal, Turkey, Italy, Greece and Spain, uses the ARDL test and examined the linkage between renewables and growth by using data from 1965 to 2009. The outcomes of this work shows a bidirectional causality and feedback hypothesis is asserted.

Silva et al. (2012) works the linkage between renewables, growth and carbon dioxide emissions using the SVAR method using data from 1960 to 2004 for four countries. As a result, bi-directional causality was determined and feedback hypothesis is supported.

Tugcu et al. (2012) analyzes the relation between both non-renewable and renewable energy sources and also economic growth of G-7 countries between 1980 and 2009 with Hatemi-j causality test. The result shows that bidirectional causality and feedback hypothesis exist.

Pao and Fu (2013) uses ECM in his study on the amount of renewable energy consumed and economic growth for Brazil between 1980 and 2010. As a result of the study, a bidirectional causality is obtained between them and so feedback hypothesis is revealed.

Lin and Moubarak (2014) used Granger causality tests, ARDL and also Johansen cointegration between 1977 and 2011, and alleged feedback hypothesis by finding a two-way causality for China between renewable energy and economic growth.

The work put forward from Sebri and Ben-Salha (2014) tested the relation between renewable energy, carbondioxide emissions and economic growth in BRICS countries between 1971-2010, using ARDL and Granger causality method, and obtained a two-way causality among these variables. Thus, feedback hypothesis was asserted.

Akay et al. (2015) examines whether causality relationship occurs among the renewable energy (billion kilowatt hours), carbon dioxide emission (metric ton per capita) and economic growth (constant 2005 US \$) for the Middle East and North Africa (MENA) regions applying the observations between 1988 and 2010. It consists of panel causality, panel VAR model, variance decomposition analysis and also impulse-response functions by applying generalized moment method. The reason for using the MENA region here is that it is a vast country in terms of renewable energy potential. As a consequence of the work, a two-way relation is obtained between economic growth and renewable energy and so the feedback hypothesis is asserted. It is also revealed a one-way relation from CO<sub>2</sub> emissions to renewable energy. Increasing the amount of renewable energy consumed will affect economic growth positively and conversely CO<sub>2</sub> emissions negatively.

Jebli and Youssef (2015) researched the renewable and non-renewable energy sources and economic growth relationship in 69 regions by applying panel cointegration techniques in their research between 1980-2010 and found while growth is affected by renewable energy sources this interaction in short run is found one-way causality and growth hypothesis was alleged, bidirectional causality was found and feedback hypothesis is asserted in the long run.

Shahbaz et al. (2015) researches for Pakistan the usage of renewable energy and economic growth relationship by applying ARDL and VECM Granger Causality methods in the time period between the first quarter of 1972 and the last quarter of 2011. The finding is bidirectional causality.

Dogan (2016) analyses the relation between usage of non-renewable and renewable energy and economic activity for Turkey through ARDL, Gregory-Hansen Cointegration, Johansen Cointegration, VECM-Granger Causality methods in the time period between 1988 and 2012 and bidirectional causality is founded and feedback hypothesis is supported.

Mucuk and Gerceker (2016) conducts a study on whether renewable energy is associated with economic growth between 2000 and 2013 for BRICS-T countries using Panel ARDL technique. In this study, real GDP is measured with fixed 2005US \$. The relationship between renewables and economic growth is examined by reason of the fact that non-renewables are exhaustible and increase imports. In this study, a positive correlation is found in the long term but it is observed that there exists no relationship in the short term.

Rafindadi and Ozturk (2017) studies the relation between renewables and growth for Germany in the time period between the 1st quarter of 1971 and the last quarter of 2013. In this work, bidirectional causality is asserted by using a VECM Granger causality test.

Odugbesan and Rjoub (2020) study for yearly data from 1993 to 2017 and about relation between growth, CO<sub>2</sub> emissions, urbanization, and also consumption of energy in Mexico, Indonesia, Nigeria, and Turkey by using ARDL method and they conclude that feedback hypothesis is supported for Mexico and Turkey.

Chien and Hu (2008) analyzed 116 countries' economies using the Structural Equation Model for 2003 and could not find a noteworthy and direct relation between renewable energy and GDP. Payne (2009) analyzes whether a link can be mentioned between renewable energy or non-renewable use and also real GDP between 1949 and 2006 for US using the Toda-Yamamoto test. There is a trend towards renewable energy sources

due to countries' dependence on foreign sources and increased greenhouse gas emission are considered. It includes hydroelectricity, geothermal, solar, wind and biomass as renewable energy sources, and uses coal, natural gas and petroleum as non-renewables. As a result of the study, neutrality hypothesis is alleged by revealing no relation between renewable or non-renewable energy sources and real GDP.

Ozturk and Acaravci (2010) study for 1968-2005 and for Turkey to introduce the relation between growth, CO<sub>2</sub> emissions, energy use and employment ratio by applying ARDL method and also Granger causality test and they found that the long run relationship exists between the variables when ARDL method is applied but Granger causality show that CO<sub>2</sub> emission and energy usage do not cause economic growth. In other words, neutrality hypothesis is stated when Granger causality test is applied.

Menegaki (2011) examines the causality between renewables and growth for the 27 European regions between 1997 and 2007. While doing this study, the REM is used and also final energy usage, emissions of greenhouse gas emissions and employment are involved in the model as independent variables. As a result of the analysis, no relation is found between these variables. Thus neutrality hypothesis is alleged.

Yildirim et al. (2012) analyses whether renewable energy is related with economic growth using the Khatami Causality method using the data between 1949 and 2010 for the US. The neutrality hypothesis is supported by revealing that there is no relationship between them.

Atasoy (2019) examines about causality between usage of renewable energy and growth economically in Turkey for 1990-2018 and no significant relationship is found and neutrality hypothesis is supported when Granger causality and also Toda-Yamamoto causality test are applied.

## CHAPTER 3

### DATA, METHODOLOGY AND EMPIRICAL RESULTS

This chapter consists of three parts. Following a brief description of the data used in the study, we introduce details on the methodology of the unit root tests, Granger-Causality test, Structural Vector Auto Regression (SVAR) model and Auto-Regressive Distributed Lag (ARDL) model and empirical results are exhibited lastly.

#### 3.1. DATA

We use annually renewable energy composing of sum of the biomass, solar, wind, hydropower, geothermal energies in millions of tonnes of oil equivalent (MTOE), CO<sub>2</sub> emissions in million tonnes and GDP per capita (constant 2010 \$) for 1972-2018 to determine the direction and size of the relation between these three variables. Renewable energy composing of sum of the biomass, solar, wind, hydropower, geothermal energies in millions of tonnes of oil equivalent (MTOE) data are taken from Ministry of Energy and Natural Resources (MENR), CO<sub>2</sub> emissions in million tonnes from British Petroleum (BP) and GDP per capita (constant 2010 \$) from World Bank Development Indicator. The summary statistics for these variables are showed in Table 3.



**Table 3: Descriptive Statistics for the Dataset (1972-2018)**

Series	Description	YoY Growth Rates		Source
		Average	Standard Deviation	
Gross Domestic Product	per capita, constant 2010 \$	8123.3	2979.1	WB
Total Renewable Energy	millions of tonnes of oil equivalent	10.4	2.6	MENR
Biomass Energy	millions of tonnes of oil equivalent	6.1	1.6	MENR
Hydropower Energy	millions of tonnes of oil equivalent	2.6	1.6	MENR
Wind Energy	millions of tonnes of oil equivalent	0.2	0.4	MENR
Geothermal Energy	millions of tonnes of oil equivalent	1.2	1.8	MENR
Solar Energy	millions of tonnes of oil equivalent	0.3	0.3	MENR
CO <sub>2</sub> emissions	million tonnes	179.3	98.3	BP

### 3.2. METHODOLOGY

In this section, the method of econometric analysis such as unit root tests, Granger causality test, Structural Vector Auto Regression (SVAR) model and Auto-Regressive Distributed Lag (ARDL) model used in this work will be introduced respectively. The reason for the inclusion of carbon dioxide emissions in the model while investigating the impulse of renewable energy sources on economic growth stems from the environmental friendliness, which is one of the most essential characteristics of renewable energy resources. In addition, carbondioxide emission is seen as a representative of non-renewable energy and is one of the most used variables in studies in the literature. The methods applied in this study have also shown through tests that the carbondioxide

emission is suitable for the model. While analyzing the effect of renewable energy on economic growth, it is thought that environmental pollution should also be taken into account. Furthermore, it is desired to contribute to the literature from a different perspective. The reason for using Granger causality, ARDL and SVAR models when conducting this analysis is to identify the short-term and long-term relationships between renewable energy sources, economic growth and also carbondioxide emissions. The methods used in the study are the most widely used methods in the literature, but it is seen that the analysis is generally made using one by one. In this study, it is provided to make comparisons by using all of these methods together.

### **3.2.1. Unit Root Tests**

Any time series is stated to be stationary on condition that its expectation, variance and covariance remain constant over time. There exist several reasons why stationary series will be used in econometric analysis. The first one is that autocorrelations which means that correlation between the series and its lagged values of the series gradually die out for stationary series. Moreover, we can not use t and F distributions for testing the standard hypothesis. Therefore, it is crucial to identify whether the series stationary or not. In general, unit root tests will be utilised to determine stationary for the series. Therefore, we use two well-known unit root tests which are augmented Dickey-Fuller test and Philips-Perron test.

#### **3.2.1.1. Augmented Dickey-Fuller (ADF) Test**

Augmented Dickey-Fuller (ADF) test is widely-used method to identify stationarity for the series. Its null hypothesis states that unit root problem exist in the series that is series has non-stationary behavior. The intuition behind the test is that if the series has stationary behavior, lagged values of the series have relevant information in predicting the series and this occurs when the null hypothesis will be rejected.

The testing procedure for the ADF test is as follows:

$$Y_t = \rho Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \rightarrow \Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \quad (1)$$

$$\begin{aligned} Y_t &= a_0 + \rho Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \rightarrow \Delta Y_t \\ &= a_0 + \delta Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \end{aligned} \quad (2)$$

$$\begin{aligned} Y_t &= a_0 + a_2 t + \rho Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \rightarrow \Delta Y_t \\ &= a_0 + a_2 t + \delta Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \end{aligned} \quad (3)$$

where  $Y_t$  is a original series,  $a_0$  is constant,  $a_2$  the coefficient on a time trend.

We should use equation (1) for the series including no constant, equation (2) for the series including constant and equation (3) for the series containing constant and trend.

$H_0 : \delta = 0$ , Series is not stationary.

$H_1 : \delta \neq 0$ , Series is stationary.

We should use  $\tau$  test statistics obtained by Dickey-Fuller's Monte-Carlo simulations instead of  $t$  statistics to test the null hypothesis. If the value of  $\tau$  calculated is less negative than Dickey-Fuller or McKinnon Dickey-Fuller critical value, we can reject the null hypothesis and we can clear that we have clear evidence to say the series is stationary.

ADF test is more useful when the autocorrelation problem exists. However, a problem with the ADF test is that what order of auto-regressive (AR) process are not known. We can choose as a fundamental guide for selecting appropriate lag length ( $p$ ) is to utilize the general to specific procedure. Also, we support the results by using another method to select the proper lag order using the one with lowest information criteria, which is the Akaike Information Criteria (AIC).

#### **3.2.1.2. Philips-Perron (PP) Test**

Philips-Perron (PP) test is another widely-used method to determine the unit root. Similar to previous test, its null hypothesis is that time series is integrated by order one which means that time series is not stationary. On other hand, PP test differ from ADF test in different way. The main way is that while ADF test is a parametric test, PP test is based on non-parametric approach. There is no need to determine the lag length in PP tests and the test is robust to common forms of heteroscedasticity in the error term. This is the stronger side of the PP test than the ADF test.

#### **3.2.2. Granger Causality Test**

If a variable has delayed values of another variable that provides information in addition to its own lagged values, that variable is the granger cause of the other variable. That is, if the knowledge of the past values of the X variable allows Y to be predicted more precisely, then the X variable is the Granger cause of the Y variable. Granger causality test indicates both whether the variables are the cause of each other and the direction of the causality of the relationship. It tests whether a time series is beneficial in predicting another time series. In this study, the variables were selected as total renewable energy

resources consumption, CO<sub>2</sub> emissions and economic growth, and it was investigated whether there is a causality relationship with each other.

$$y_t = \alpha_1 + \sum_{i=1}^p \beta_i x_{t-i} + \sum_{j=1}^q \gamma_j y_{t-j} + e_{1t} \quad (1)$$

$$x_t = \alpha_2 + \sum_{i=1}^p \theta_i x_{t-i} + \sum_{j=1}^q \delta_j y_{t-j} + e_{2t} \quad (2)$$

In this model, there are 4 different situations:

- If  $\beta = 0$  and  $\delta \neq 0$   $y_t$  granger causes  $x_t$ .
- If  $\beta \neq 0$  and  $\delta = 0$   $x_t$  granger causes  $y_t$ .
- If  $\beta \neq 0$  and  $\delta \neq 0$   $y_t$  and  $x_t$  granger cause each other.
- If  $\beta = 0$  and  $\delta = 0$   $y_t$  and  $x_t$  do not granger cause each other.

### 3.2.3. Structural Vector Autoregression Model

To capture the relationship between total renewable energy in millions of tonnes of oil equivalent (REN), CO<sub>2</sub> emissions in million tonnes (CO<sub>2</sub>) and GDP per capita (constant 2010 \$), we use structural vector autoregression (SVAR) model including three variables for 1972-2018 period. We choose the SVAR model rather single equation since there might be concerns about the robustness of the coefficient estimates obtained from single equations due to the correlation and feedback relations between the three variables. In order to completely remove the question marks, a SVAR model will be estimated and the equation coefficients will be re-evaluated within the framework of the impulse-response functions.

The model is constructed as follows:

$$y_t = \sum_{i=1}^q A_{i-1} y_{t-i} + e_t \quad (4)$$

While  $y_t = (\Delta \ln(\text{GDP}), \Delta \ln(\text{REN}), \Delta \ln(\text{CO}_2))$  is identified,  $e_t$  represents orthogonalized independent shocks.  $y_t$  is 1x3 matrix. It is assumed that matrix A is the lower triangle. That is, in order to determine the effect of growth shock on energy, it has been assumed that growth affects renewable and carbon dioxide emissions in the same period but energies affect growth with a delay. Considering various criteria<sup>2</sup>, the ideal lag length (q) is determined as 1.

#### 3.2.4. Auto Regressive Distributed Lags (ARDL) Model

In order to empirically analyse short and long-run relationships between the variables, we apply ARDL model as an alternative method. The model is advanced by Pesaran and Shin (1999) and Pesaran et al. (2001). In comparison with the other cointegration methods, ARDL model has various different advantages. The first advantage is that the variables must not be integrated of same order in ARDL procedure. It means that the variable level to be included in the model can be stationary at level, I (0) or can be stationary at the first difference, I (1) and this does not interfere with the implementation of the boundary test. The second usefulness is that ARDL model is comparatively more effective for sample sizes which are small and also finite. The last one is that ARDL model gives the unbiased estimates in the long-run (Harris and Sollis, 2003).

The long-run equation of the ARDL model is as follows:

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<sup>2</sup> Akaike Information Criterion, Final prediction error and LR (sequential modified LR test statistics are among these criteria.)

$$REN_t = a_0 + \sum_{i=1}^m a_{1i} REN_{t-i} + \sum_{i=0}^m a_{2i} CO_{2(t-i)} + \sum_{i=0}^m a_{3i} GDP_{(t-i)} + u_t \quad (5)$$

The short-run equation of the ARDL model is as follows:

$$\begin{aligned} \Delta REN_t = a_0 + \sum_{i=1}^m a_{1i} \Delta REN_{t-i} + \sum_{i=0}^m a_{2i} \Delta CO_{2(t-i)} + \sum_{i=0}^m a_{3i} \Delta GDP_{(t-i)} \\ + a_4 EC_{t-1} + u_t \end{aligned} \quad (6)$$

EC represents the error correction model which shows how soon shocks that occur will stabilize in the long term due to independent changes in the short run.

### 3.3. EMPIRICAL RESULTS

#### 3.3.1. Unit Root Tests Results

In this work, Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests are applied to identify stationarity for total renewable energy, CO<sub>2</sub> emissions and GDP per capita by using data in 1972-2018. While table 4 and table 5 show the ADF unit root test outcomes of the variables in terms of level and first difference respectively, table 6 and table 7 indicates that PP unit root test results of the variables in terms of level and first difference respectively. It is clearly seen that both tests address that all variables at level are not stationary for all significance levels. However, both tests point out that all variables at the first difference do not have unit root for all significance levels. We say that each of variables are integrated order one, I(1).

**Table 4: ADF Unit Root Test Results (Level)**

Variables	t statistic	Critical Values			p-value
		1%	5%	10%	
$\ln(\text{REN})$	0.44	-3.58	-2.92	-2.6	0.98
$\ln(\text{CO}_2)$	-1.34	-3.58	-2.92	-2.6	0.63
$\ln(\text{GDP})$	0.68	-3.58	-2.92	-2.6	0.99

**Table 5: ADF Unit Root Test Results (First Difference)**

Variables	t statistic	Critical Values			p-value
		1%	5%	10%	
$\Delta \ln(\text{REN})$	-6.47	-3.58	-2.92	-2.6	0.00
$\Delta \ln(\text{CO}_2)$	-7.65	-3.58	-2.92	-2.6	0.00
$\Delta \ln(\text{GDP})$	-6.48	-3.58	-2.92	-2.6	0.00

**Table 6: Phillips-Perron Unit Root Test Results (Level)**

Variables	Adjusted t statistic	Critical Values			p-value
		1%	5%	10%	
$\ln(\text{REN})$	0.46	-3.58	-2.92	-2.6	0.98
$\ln(\text{CO}_2)$	-1.56	-3.58	-2.92	-2.6	0.49
$\ln(\text{GDP})$	0.74	-3.58	-2.92	-2.6	0.99



**Table 7: Phillips-Perron Unit Root Test Results (First Difference)**

Variables	t statistic	Critical Values			p-value
		1%	5%	10%	
$\Delta \ln(REN)$	-6.51	-3.58	-2.92	-2.6	0.00
$\Delta \ln(CO_2)$	-7.73	-3.58	-2.92	-2.6	0.00
$\Delta \ln(GDP)$	-6.48	-3.58	-2.92	-2.6	0.00

### 3.3.2. Granger Causality Results

Table 8 shows the Granger causality outcomes and we use the variables in the first difference form since unit root tests point out that the variables are I (1). The table indicates that the whole variables are not granger cause each other. To capture the relationship between the variables, we apply SVAR analysis in the next subsection. Granger causality results confirm neutrality hypothesis in which consumption of energy has small or no effect on economic growth. This result confirms the studies of Atasoy (2019) and Ozturk and Acaravci (2010) which is used Granger causality tests in Turkey for different years and is supported the neutrality hypothesis. Granger causality test supports neutrality hypothesis in the long term and the reason may the fact that the rate of the consumption of renewable energy sources is less than the rate of the consumption of other energy sources in Turkey. In addition, since Granger causality examines the relationship between two variables, it may be necessary to look at different dynamics when looking at the relation between economic growth and renewable energy, so there may be the problem of using missing variables. Therefore, a comparative review using SVAR and ARDL methods is requested.

**Table 8: Granger Causality Test Results**

<b>Null Hypothesis</b>	<b>F-statistic</b>	<b>p-value</b>
DLOG(CO2) does not Granger Cause DLOG(REN)	0.47860	0.4929
DLOG(REN) does not Granger Cause DLOG(CO2)	0.23363	0.6314
DLOG(GDP) does not Granger Cause DLOG(REN)	0.69718	0.4085
DLOG(REN) does not Granger Cause DLOG(GDP)	0.18822	0.6666
DLOG(GDP) does not Granger Cause DLOG(CO2)	0.86336	0.3581
DLOG(CO2) does not Granger Cause DLOG(GDP)	0.47953	0.4924

### 3.3.3 Structural Vector Autoregression (SVAR) Results

SVAR model confirms diagnostic tests. By using the VAR Residual Serial Correlation LM Test, it was seen that there was no serial correlation in residuals. VAR residual heteroskedasticity test showed that the variance of residuals is homoskedastic. Also, according to Jarque-Bera Normality test variance of variables are jointly distributed normal. Figure 21, 22 and 23 shows the impulse-response results of the SVAR model. We see that when one percent shock occurs in the total renewable energy, GDP per capita increases almost 1.4 percent at most in period 2 and then it stabilizes at the 1.2 percent level. Moreover, all responses of the GDP per capita to shock in the renewable energy are statistically significant for the whole periods (Figure 21, panel (a)). However, accumulated responses of the total renewable energy are not statistically significant until

third periods. One percent shock in GDP per capita increases renewable energy by almost one percent. Also, we see that stabilization level of the accumulated responses of the renewable energy to one percent shock in GDP per capita is lower (0.8 percent) (Figure 21, panel (b)).

**Figure 21: Accumulated Responses of GDP (REN) to One Percent Shock in REN (GDP)**

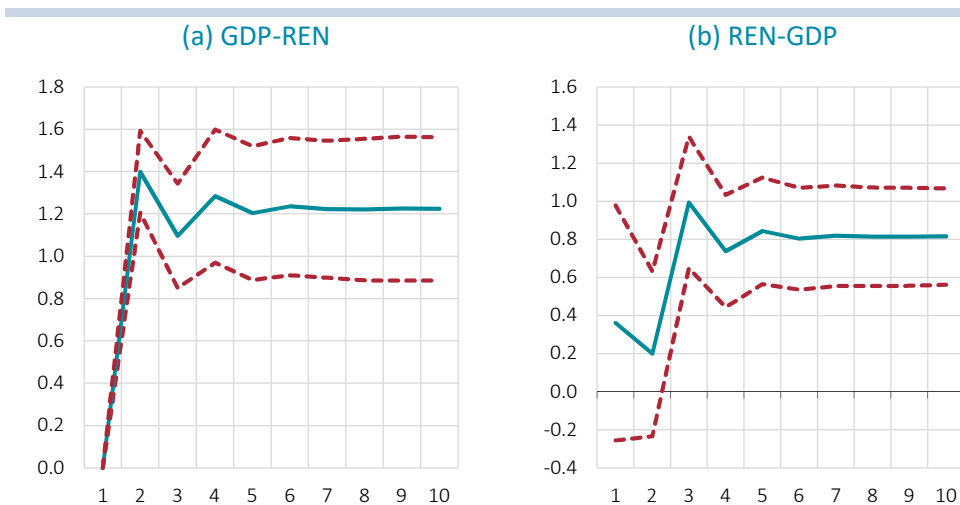


Figure 22 shows the accumulated responses of GDP ( $\text{CO}_2$ ) to one percent shock in  $\text{CO}_2$  (GDP). We can easily see that one percent shock in  $\text{CO}_2$  increases GDP per capita by 1.3 percent a period after the shock and then stabilizes at the 0.7 percent level over time (Figure 22, panel (a)). Figure 22, panel (b) indicates that accumulated responses of the  $\text{CO}_2$  emissions to one percent shock in GDP are greater.

**Figure 22: Accumulated Responses of GDP (CO<sub>2</sub>) to One Percent Shock in CO<sub>2</sub> (GDP)**

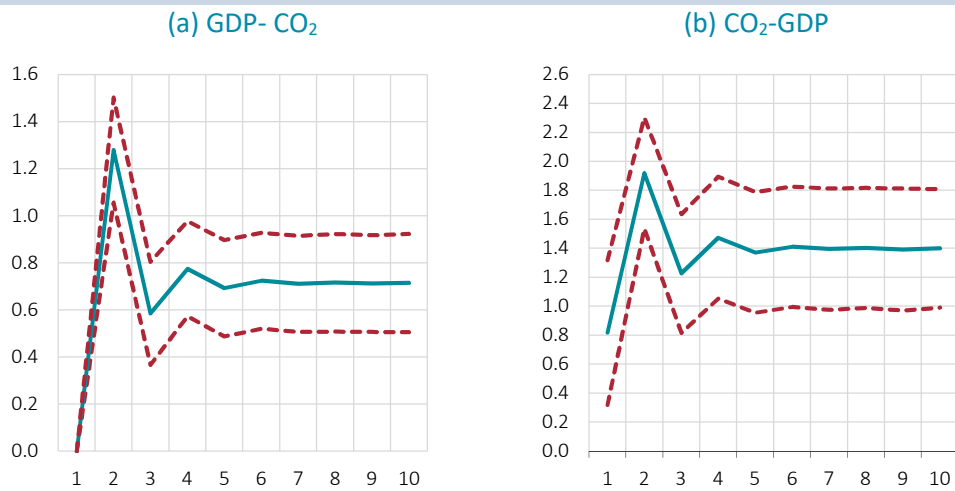
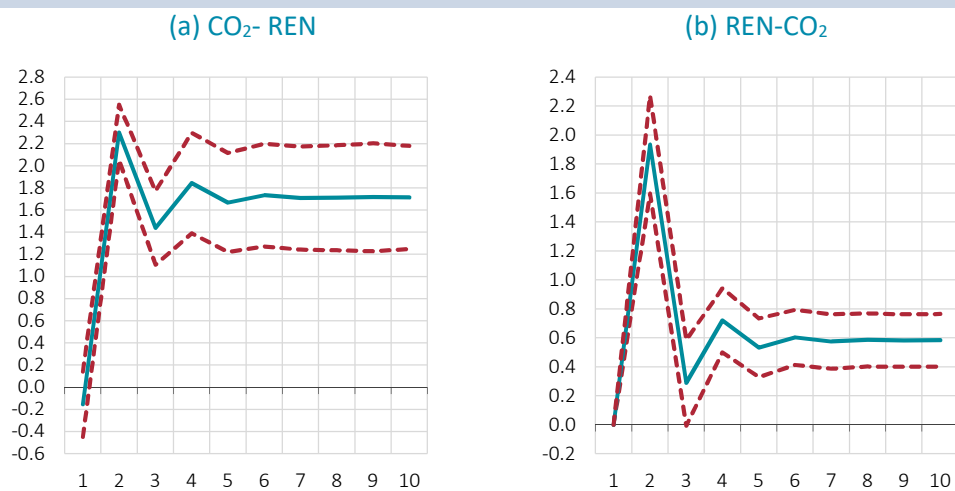


Figure 23 shows the accumulated responses of CO<sub>2</sub> (REN) to one percent shock in REN (CO<sub>2</sub>). It is surprisingly seen that both variables affect each other positively. While one percent shock in CO<sub>2</sub> emissions increases REN by 2.3 percent a period after the shock, one percent shock in REN increases CO<sub>2</sub> by 2.6 percent a period after the shock. In the long run, shock in the renewable energy affects CO<sub>2</sub> to a greater extent.

**Figure 23: Accumulated Responses of CO<sub>2</sub> (REN) to One Percent Shock in REN (CO<sub>2</sub>)**



### 3.3.4. ARDL Results

In this section, we present the ARDL results which enable us to predict the short and long-term relationships at the same time within a model applying the Ordinary Least Squares (OLS) method. We apply it separately by choosing renewable energy as dependent variable, by choosing GDP per capita and by choosing CO<sub>2</sub> emissions as dependent variable. First, we affirm that none of the variables is I (2) by using information in the section 5.1. The suitable lag structure of the ARDL model is selected following a general-to-specific technique that considers Schwarz information criteria and the outcomes of diagnostic tests. By using the Breusch-Godfrey test, we see residuals from ARDL model have not serial correlation. When renewable energy is dependent variable and when GDP is dependent variable, normality and validity function form are checked via Jarque-Bera and RESET test respectively. Also, CUSUM and CUSUM-squared tests confirm parameter stability. Since F-statistics is greater than critical values, we can say that renewable energy, GDP per capita and CO<sub>2</sub> emissions have short and long run relationships (Table 9, Table 10 and Table 11).

**Table 9: ARDL Bounds Tests for Short Run & Long Run When the Dependent Variable is Renewable Energy (Null Hypothesis: No Level Relationship)**

<b>Short Run</b>				
<b>Test Statistics</b>	<b>Value</b>	<b>Significance</b>	<b>I (0)</b>	<b>I (1)</b>
F-statistic	4.241623	10%	2.63	3.35
K	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5
<b>Long Run</b>				
<b>Test Statistics</b>	<b>Value</b>	<b>Significance</b>	<b>I (0)</b>	<b>I (1)</b>
F-statistic	4.241623	10%	2.788	3.54
K	2	5%	3.368	4.203
		1%	4.8	5.725

**Table 10: ARDL Bounds Tests for Short Run & Long Run When the Dependent Variable is GDP per capita (Null Hypothesis: No Level Relationship)**

<b>Short Run</b>				
<b>Test Statistics</b>	<b>Value</b>	<b>Significance</b>	<b>I (0)</b>	<b>I (1)</b>
F-statistic	4.599788	10%	2.63	3.35
K	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5
<b>Long Run</b>				
<b>Test Statistics</b>	<b>Value</b>	<b>Significance</b>	<b>I (0)</b>	<b>I (1)</b>
F-statistic	4.599788	10%	2.63	3.35
K	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

**Table 11: ARDL Bounds Tests for Short Run & Long Run When the Dependent Variable is CO<sub>2</sub> Emissions (Null Hypothesis: No Level Relationship)**

<b>Short Run</b>				
<b>Test Statistics</b>	<b>Value</b>	<b>Significance</b>	<b>I (0)</b>	<b>I (1)</b>
F-statistic	8.312778	10%	2.63	3.35
K	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5
<b>Long Run</b>				
<b>Test Statistics</b>	<b>Value</b>	<b>Significance</b>	<b>I (0)</b>	<b>I (1)</b>
F-statistic	8.312778	10%	2.63	3.35
K	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

The findings from the ARDL model including renewable energy as dependent variable are figured in Table 12. The results confirm long-run relation between the total renewable energy, carbondioxide emissions and GDP per capita exist. Unlike SVAR results, CO<sub>2</sub> emissions decreases renewable energy in the long run since coefficients of the CO<sub>2</sub> emissions are negative. On the other hand, GDP per capita increases renewable energy. The intuition behind might be that as growth increases, investments in renewable energy resources increase in the long run. As the long run, the coefficients of the GDP per capita



and carbon dioxide emissions are positive and negative respectively as expected in the short run. We see that the error correction term's coefficient is quite small.

**Table 12: ARDL Results When the Dependent Variable is Renewable Energy**

	<b>Short Run (ECM Regression)</b>
DLOG(CO2)	-0.634235***
DLOG(GDP)	0.775345***
DLOG(GDP(-1))	-0.383258**
CointEq(-1)	-0.037823***
	<b>Long Run (Levels Equation)</b>
C	-2.321966***( 0.767991)
LOG(REN(-1))	-0.037823( 0.084179)
LOG(CO2(-1))	-0.208438***( 0.074941)
LOG(GDP(-1))	0.391548***( 0.128067)
DLOG(CO2)	-0.634235***( 0.225482)
DLOG(GDP)	0.775345***( 0.257813)
DLOG(GDP(-1))	-0.383258***( 0.224607)
<b>Diagnostic Checks</b>	
Number of Obs.	45
Jarque-Bera Test p-value	0.743898
Breusch–Godfrey LM Test p-value	0.2787
Ramsey RESET Test p-value	0.4262

Note: In parenthesis, standard errors are involved which is robust with respect to heteroscedasticity.

\*  $p < 0.10$ , \*\*  $p < 0.05$  and \*\*\*  $p < 0.01$ .

The outcome of the ARDL model including GDP per capita as dependent variable are figured in Table 13. The results confirm that long-run relation between the total renewable energy, emissions of CO<sub>2</sub> and GDP per capita exist. Similar to SVAR results, in the long run, CO<sub>2</sub> emissions increases GDP per capita since coefficients of the CO<sub>2</sub> emissions are positive. Renewable energy also increases GDP per capita. As the long run, the coefficients of the renewable energy and CO<sub>2</sub> emissions are positive as expected in the short run. We see that the error correction term's coefficient is slightly big.

**Table 13: ARDL Results When the Dependent Variable is GDP per capita**

	<b>Short Run (ECM Regression)</b>
DLOG(CO2)	0.550894*** (0.084202)
DLOG(CO2(-1))	0.161098* (0.082047)
DLOG(REN)	0.233891*** (0.065995)
DLOG(REN(-1))	0.271448*** (0.086761)
DLOG(REN(-2))	0.252110*** (0.087769)
DLOG(REN(-3))	0.134400 (0.088998)
CointEq(-1)	-0.354267*** (0.079075)
	<b>Long Run (Levels Equation)</b>
C	2.173132*** (0.595997)
LOG(GDP(-1))	-0.354267*** (0.094675)
LOG(CO2(-1))	0.252761*** (0.062865)
LOG(REN(-1))	-0.132029* (0.066861)
DLOG(CO2)	0.550894*** (0.104603)
DLOG(CO2(-1))	0.161098 (0.104300)
DLOG(REN)	0.233891*** (0.073074)
DLOG(REN(-1))	0.271448** (0.102371)

DLOG(REN(-2))	0.252110** (0.105483)
DLOG(REN(-3))	0.134400 (0.101136)
<b>Diagnostic Checks</b>	
Number of Obs.	43
Jarque-Bera Test p-value	0.649210
Breusch–Godfrey LM Test p-value	0.2315
Ramsey RESET Test p-value	0.1486

Note: In parenthesis, standard errors are involved which is robust with respect to heteroscedasticity.  
 \*  $p < 0.10$ , \*\*  $p < 0.05$  and \*\*\*  $p < 0.01$ .

The outcome of the ARDL model including CO<sub>2</sub> emissions as dependent variable are figured in Table 14. The results confirm that long-run relation between the total renewable energy, CO<sub>2</sub> emissions and GDP per capita exist. Unlike SVAR results, renewable energy decreases CO<sub>2</sub> emissions in the long run as coefficient of the renewable energy is negative. On the other hand, GDP per capita increases CO<sub>2</sub> emissions. The intuition behind might be that as growth increases, the total use of energy and accordingly carbondioxide emissions increase in the long run. As in the case of the long run, the coefficients of the GDP per capita and renewable energy are positive and negative respectively as expected in the short run. The coefficient of the error correction term is slightly big is seen.

**Table 14: ARDL Results When the Dependent Variable is CO<sub>2</sub> Emissions**

	<b>Short Run (ECM Regression)</b>
DLOG(CO2(-1))	-0.228069** (0.108568)
DLOG(GDP)	0.762890*** (0.125391)
DLOG(REN)	-0.248964*** (0.081843)
CointEq(-1)	-0.129536*** (0.021627)
	<b>Long Run (Levels Equation)</b>
C	-0.980278** (0.480288)
LOG( CO2(-1))	-0.129536*** (0.045682)
LOG(GDP(-1))	0.176871** (0.080510)
LOG(REN(-1))	0.039709(0.052375)
DLOG(CO2(-1))	-0.228069* (0.115590)
DLOG(GDP)	0.762890*** (0.138130)
DLOG(REN)	-0.248964*** (0.089279)
<b>Diagnostic Checks</b>	
Number of Obs.	43
Jarque-Bera Test p-value	0.011109
Breusch–Godfrey LM Test p-value	0.3293
Ramsey RESET Test p-value	0.0194

Note:

In parenthesis, standard errors are involved which is robust with respect to heteroscedasticity.

p&lt; 0.10, \*\* p&lt; 0.05 and \*\*\* p&lt; 0.01.

\*

## CONCLUSION

Since we use energy in almost all areas to sustain our lives, it is known how important energy is. For this reason, even if there are not enough resources to produce energy in countries, it has to obtain energy from different countries in order to survive. In addition, with the development of technology and the increase in population, the need for energy and therefore the demand is increasing. This creates dependence on foreign energy for countries with insufficient energy resources in their country. Outsourcing of energy, which has an important share in the economy, can cause difficulties, especially in a crisis or conflict between countries. This can lead to an economic crisis and has results that are difficult to recover. Therefore, renewable energy sources draw attention at this point. Because renewable energy resources are produced domestically and the resource is not exhausted because it can renew itself. Another important point is the environmental pollution problem. Since it is known that the environmental pollution caused by energy is to a great extent and we cannot stop energy use as long as we continue our lives and the importance given to environmental cleanliness has increased, the importance of renewable energy resources has started to emerge awhile. Many countries provide incentives to enhance the amount of renewable energy resources consumed and try to reach the goal of raising the use of renewable energy. If Turkey remains fully dependent on imports of getting energy resources, this can affect Turkey poorly. Therefore, it is significant to raise the renewables usage in Turkey. Renewable energy sources classify hydraulics, solar, wind, geothermal, biomass, wave tide and hydrogen. As the characteristics of renewable energy resources, we can say that it is sustainable, environmentally friendly and can be provided with domestic production.

In this thesis, by the reason of the importance of renewable energy resources, by analysing the relationship between economic growth some results have been presented by applying several methods. In the literature, the relationships between energy resources and economic growth have been analyzed in short and long term by using different countries, different time intervals and different methods and 4 different hypotheses have been put forward. These are the neutrality hypothesis, conservation hypothesis, growth hypothesis,

and feedback hypothesis. While the growth hypothesis states a unidirectional relationship from energy usage to economic growth, conservation hypothesis asserts a unidirectional relation to energy consumption from economic growth, in contrast to the growth hypothesis. While the feedback hypothesis supports the fact of a two-way relationship, from energy usage to economic growth and to consumption of energy from economic growth, the neutrality hypothesis argues that there is not relation between energy use and economic growth.

In this study, 3 different methods are used: Granger causality test, SVAR and ARDL methods. In addition, variables are got between 1972 and 2018, total renewable energy consumption, economic growth (GDP per capita) and CO<sub>2</sub> emissions in Turkey were used. In the Granger causality test was revealed there was not relation between consumption of renewable energy, economic growth and carbondioxide emissions, and so the neutrality hypothesis was supported. When using the SVAR and ARDL methods, both in the short term and in the long term it has been found that each has an effect on the others. Thus, the feedback hypothesis was supported. While a positive relationship with each other occurs among all of these variables with the SVAR method, according to the ARDL method, which has a reliability advantage in short samples, it was observed that the renewable energy usage occurs a positive relation with economic growth and negative relation with carbon dioxide emissions. According to the results obtained from the ARDL method, as the consumption of renewable energy increases, economic growth will increase and CO<sub>2</sub> emissions will decrease.

Both to decrease the environmental pollution and to increase economic growth the significance of the renewable energy should be emphasize in Turkey. The increase of the amount of the renewable energy resources used is required to be seen by policy makers as critical and to increase the supportive policies for renewable energy are important for Turkey since renewable energy usage increases the economic growth which is the critical for a country. With current data used in this thesis, the relationship between the renewable energy resources, economic growth and CO<sub>2</sub> emissions is investigated and contributed to

studies in Turkey by comparative analysis. In future studies, each renewable energy resources on economic growth effects can be examined due to its scarcity in the literature, and studies can be expanded by using different countries, different periods and different methods.

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