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POTENTIAL SOLUTIONS AND CHALLENGES OF RENEWABLE ENERGY FOR THE ECONOMIC AND TECHNICAL ASPECTS OF ENERGY SYSTEM INDEPENDENCE: THE CASE OF TURKEY

Alp Ertunga Çetinkaya

Examiner(s): Professor Esa Vakkilainen

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ABSTRACT

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The Republic of Turkey is a member of both OECD and G20. Republic of Turkey is standing at a perfect place for world economic and strategic balance. The OECD stands for Organization for Economic Co-operation and Development and the G20 is an international forum which gathers the world's major 20 economies. Moreover, with a growing and young population Republic of Turkeys goal to be a member of G10. Turkey's economy showed great success and determination for that road, growing even during the global pandemic in 2020. One of the challenges on this road is Turkey's energy import dependency and to make this growth even more sustainable Turkey needs energy independence. For this aim renewable energy have so much importance. This master thesis aims to show and discuss the renewable energy in Turkey from different point of view such as economic, potential and technical mainly focusing on the bioenergy.

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Last but definitely not least, I am so sincerely grateful for my dear father and mother. They have fully supported me every moment in my life in every way so that I can reach my goals and dreams to be a better person for my family, country and the world.

SYMBOLS AND ABBREVIATIONS

Roman characters

atm	Atmospheric pressure	[bar, Pa]
T	temperature	[ºC, K]
W	Watt	[W]
V	volume	[m3]

Greek characters

α	incidence angle	[°]

Subscripts

1	inflow
2	outflow
kr	critical
mit	measured

Superscripts

$'$	stator
$''$	rotor

Abbreviations

RES	Renewable Energy Sources

PPP Purchasing Power Parity

GDP Gross Domestic Product

OECD member countries The Organisation for Economic Co-operation and Development (OECD; French: Organisation de Coopération et de Développement Économiques, OCDE) is an intergovernmental economic organisation with 38 member countries, founded in 1961 to stimulate economic progress and world trade.

WPP World Population Prospects

USD United States dollar

UN United Nations

MW Mega Watt

WCEP Water consumption: total energy production

BCM Billion Cubic Meters

Mtoe Million Tons Equivalent

OSCE Organization for Security and Co-operation in Europe

EU European Union

PPP Purchasing Power Parity

UCTEA CHAMBER OF MECHANICAL ENGINEERS

BEPA Biomass Energy Potential Atlas

TL Turkish Lira

TEMA Turkish Foundation for Combating Soil Erosion

TABLE OF CONTENTS

ABSTRACT

ACKNOWLEDGEMENTS

SYMBOLS AND ABBREVIATIONS

1. INTRODUCTION 10
   1.1 Background 10
   1.2 Biofuel Potential and Future 12
   1.3 Challenges 13
   1.4 Solutions 13
2. INCREASING POPULATION AND ENERGY DEMAND OF THE EARTH 14
   2.1 Population and Energy Consumption 14
   2.2 Fossil Fuel and Clean Water Crisis 16
   2.3 Beginning of renewable energy utilization 18
3. ECONOMIC AND ENERGY STATUS IN REPUBLIC OF TURKEY 21
   3.1 Air Pollution in Republic of Turkey 25
   3.2 Drought in Turkey 26
   3.3 Energy Dependency 28
   3.4 Current Deficit 28
4. BIOENERGY STATUS IN TURKEY 31
5. RENEWABLE ENERGY POTENTIAL OF TURKEY 42
   5.1 Solar Energy 42
   5.2 Wind Energy 43
   5.3 Hydropower 45
6. RENEWABLE ENERGY POTENTIAL OF TURKEY 46

7. NEW DETECTED GAS FIELDS 51

8. RESULTS AND DISCUSSION 53

8.1 Current Study 53

8.2 Future Work 53

9. CONCLUSIONS 55

REFERENCES 56

1. INTRODUCTION

1.1 Background

Energy has a significant role in economies worldwide, both in terms of supply and demand, and it is essential for human survival. This significance is derived from the energy sector's structural interdependence with other sectors of the economy. Energy is a mandatory input in the production process, and it is also a necessary input in the process of raising the level of welfare in societies. Energy, which is one of the most fundamental building blocks of economic development, plays a significant role in defining the development levels of countries as well as the international policies of those nations. Moreover, this increases the dependency of the countries in this interconnected world. There is a strong connection between energy producers and consumers countries (Figure 1).

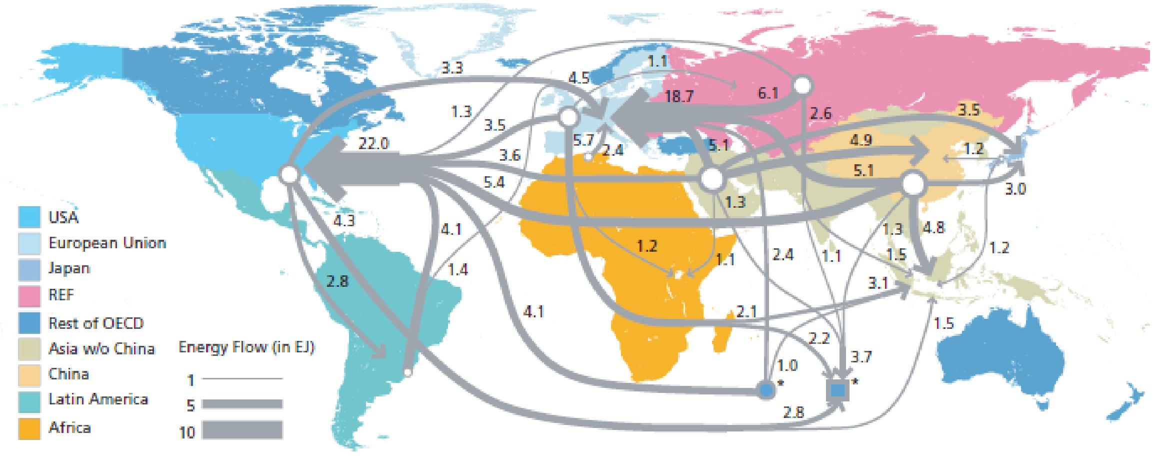

Figure 1. World Crude Oil Trade Map 2015 (Global Energy Assessment: Toward a Sustainable Future, page 129)

Economic growth is a contentious topic among economists for many years. Electrical energy has become a vital component of both economic and social life in our modern era of technology. Its ease of use, its status as a clean energy source, its ability to be converted to other forms of energy at any time, its widespread use in all aspects of daily life, and its status as an indispensable resource in tandem with technological progress have led to the evaluation of electricity consumption as one of the most important indicators of a country's level of development. In other words, the widespread use of electricity in all areas of life and the increase in consumption are indicators of the improvement in the general well-being of society. There is no doubt that electricity has played an important role in helping countries complete their industrialization processes. Furthermore, the increased energy demand is shifting for 100 % electricity grids (Bridgea, Adhikarib, Fontenlab, 2014).

As the electricity increasing it’s importance energy independence is also gains value in this interconnected world. Renewable energy is the most reliable and powerful source of energy independence and strength. Solar, wind, geothermal, hydraulic, biomass, wave, and hydrogen energy are some of the renewable energy sources available. The fossil fuels used to generate energy on the planet account for more than 70 % of total energy consumption. (Figure 2).

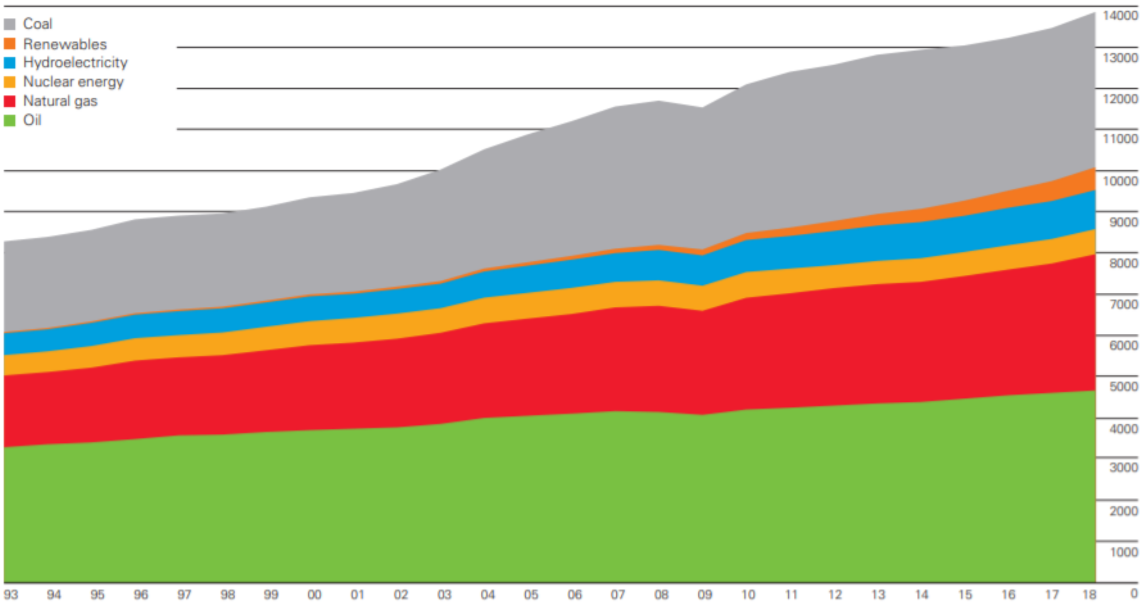

Figure 2. World Energy Consumption Graph Million Tones Oil Equivalent (BP Statistical Review of World Energy 2019 | 68th edition, page 10)

1.2 Biofuel Potential and Future

Bioenergy had been the major source of energy for thousands of years for lightning, heating, protecting and cooking from the beginning of civilization. Biofuels technologies in both gaseous, solid and liquid are keep advancing due to the research in the last decades. Moreover, the advantage of biopower compare to wind turbines can be used to generate heat which increase the total efficiency. In addition, there is far enough biomass from plants for compositing the absences of fossil fuels. Some of the solid biofuels types are wood chips, firewood, wood charcoal and wood pellets. Also some of the liquid biofuels are pyrolysis bio-oil, biodiesel, bioethanol. Commercial synthesis of bioethanol from plant dry matters increased the current yearly supply of 22 billion gallons, which is mostly made up of food crops. Biogas produced from organic wastes has huge potential to replace natural gas usage by up to 25% due to the acceleration of biogas in China and Europe. (Guo, et al., 2014)

Figure 3 shows a prediction for the syngas market – world total 2040

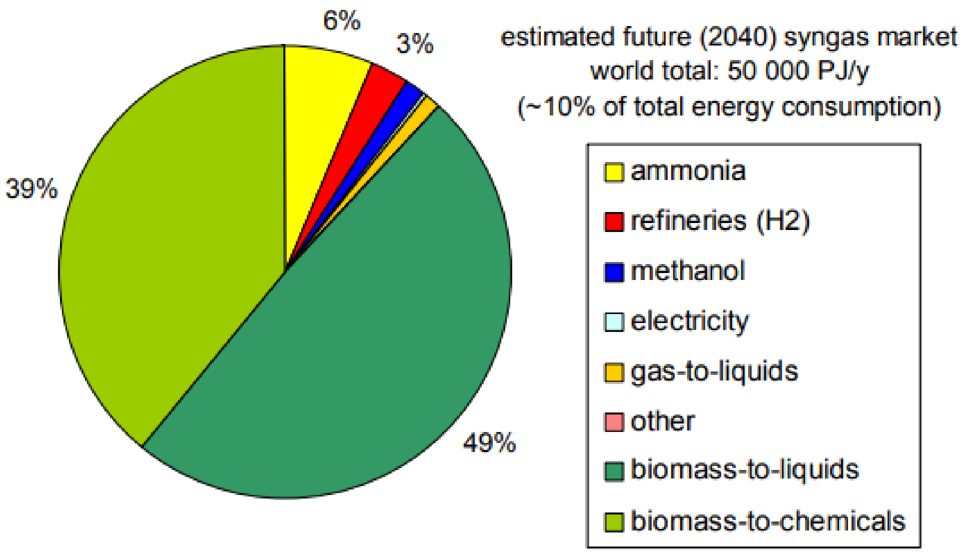

Figure 3. World Syngas Market 2040 (Rauch and Boerrigter, 2005)

This figure refers to syngas market will reach 10% of the world's total energy consumption.

1.3 Challenges

According to the assumptions world will consume energy 50% more in 2050 compared to today from many reasons such as increased population and welfare of the societies. Moreover, this will also lead to 40% more clean water consumption in 2050 from many reasons like agricultural increase due to biofuels and for the increased populations water demand. This will lead to food shortages because it’s also predicted that in 2050 35% less food will be produced. In addition, when everything combined increased population, less food production, shortage of clean water, increased biofuel production, decreased fossil fuel usage if it won’t be perfectly managed it could lead to catastrophe for the world. This means more immigration from underdeveloped countries to the developed countries. (PWC., 2021)

1.4 Solutions

This thesis has 11 sections. The first section introduces the importance of the energy sector and economic development relation also shifting in the energy sector for renewables and biofuels potential and future with challenges. The second section tells the correlation between increasing population and energy consumption in the world. Also, clean water crisis due to the increased water consumption and how to decrease water consumption in the energy sector with using more renewable energy. The third section states the general economical challenges, energy dependency, currency deficit, air pollution problems which are both challenges and reasons for improving renewables energy sector. The fourth section stars with general bioenergy situation in Turkey and how to improve the water usage efficiency. The fifth section is about other renewable energy alternatives’ potential in Turkey. The seventh section analyses Turkey's new term investment plans in the renewable energy sector and decrease in the usage of clean water in the energy sector with this plan. In addition, challenges of offshore wind farms for Turkey. The eighth state sates the natural resources found in Turkey. The final state is the conclusion of this thesis.

2. INCREASING POPULATION AND ENERGY DEMAND OF THE EARTH

2.1 Population and Energy Consumption

The world population increased from around 4 million 12 thousand years ago to 190 million in 0 BCE which is approximately 0.04% population growth annually. During the last 300 years, the population has increased from 600 million to 7,7 billion. (Roser, et. al., 2013). World Population Prospects (WPP) suggest that the world population will continue to increase and in 2030 will become 8,5 billion, in 2050 9,7 billion and 10,9 billion in 2100 (Figure 4("How certain are the United Nations global population projections?"(they say 95%), 2019, p. 1).

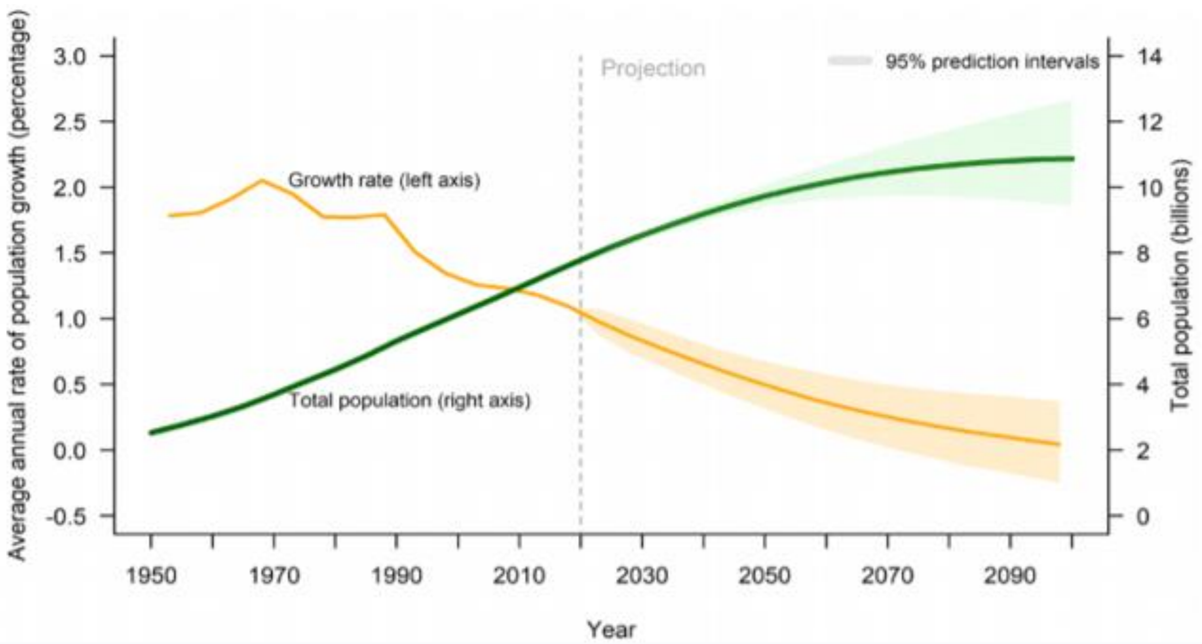

Figure 4. Reprojections of world population UN, 2019 (World Population Prospects 2019, page, 5).

There are many important factors influencing the increase in electrical energy consumption. The most important are the increase of population and income levels, Improvements in living standards, as well as expansion of the number of machines, devices, and tools that operate on electrical energy including its easy utilization and the price of the sale.

With population growth comes an increase in electricity consumption, which is exacerbated by changes in consumption structure and technological advancement. The two most important factors driving increased electricity consumption, particularly in developing countries, are population growth and economic growth, which are defined as an increase in the level of income earned. The figure 5, presents the population is directly proportional with the emission levels.

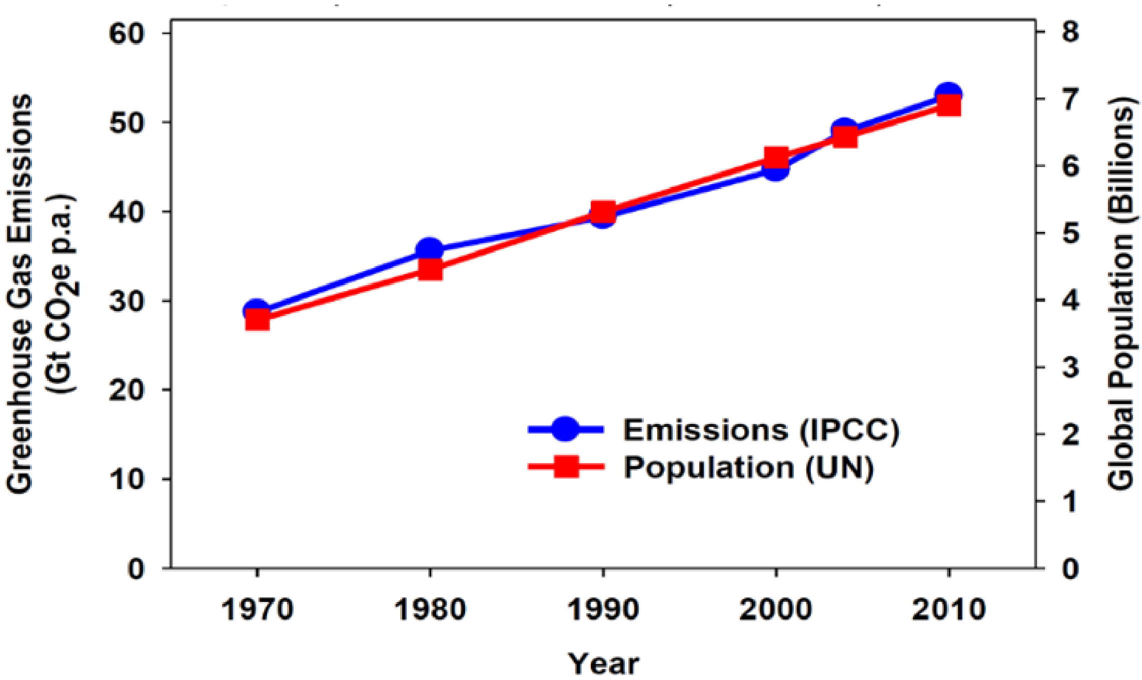

Figure 5. Relationship of Emissions and Energy Consumption with Population Growth (The Renewable Energy Revolution Real Climate Action in the Sunshine State, 2016)

Because of the widespread use of high-tech electrical appliances in everyday life, the demand for energy has increased. People's demand for higher living standards in developing countries and rapid population growth in those countries are two of the most important drivers of increased electricity consumption.

The energy consumption of OECD member countries and non-OECD member countries was roughly comparable in 2007. Nonetheless, energy consumption in OECD countries is expected to increase by 14% between 2007 and 2035.

While, energy consumption in non-OECD countries as predicted will increase by 84% during the same period. (Figure 6) (Gertler, et al., 2012).

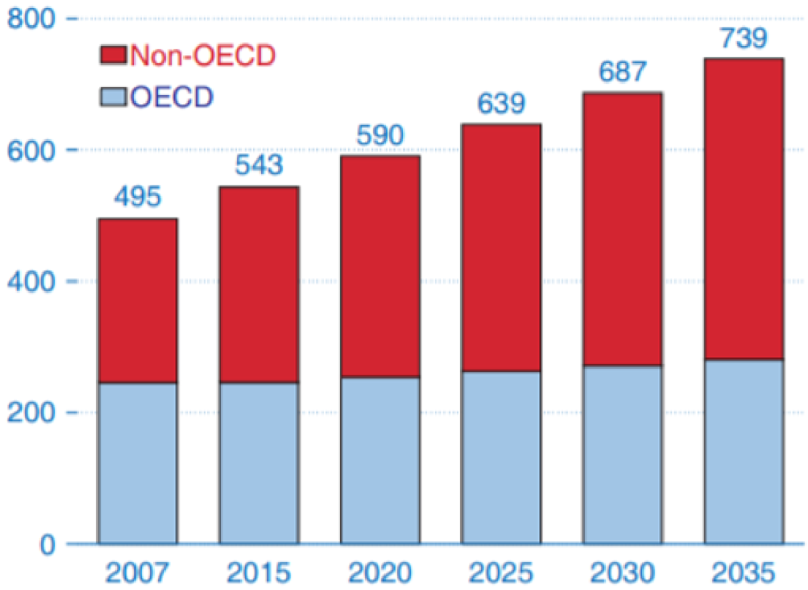

Figure 6. 2007-2035 Consumption Energy Consumption Graph of World Market (International Energy Outlook, 2010)

2.2 Fossil Fuel and Clean Water Crisis

The Industrial Revolution was the beginning of ground-breaking changes. The world is on the edge of a clean water catastrophe and the ramifications that will follow. It is predicted that by 2050, at least half of the world's population will be affected by a water scarcity situation. Also, it is predicted that by 2025 water consumption for agriculture would rise 60% globally. (Boretti, Rosa, 2019). Furthermore, this will result in increased fame and immigration. Two hundred eighty-one million people live as immigrants in the world now, which is a significant amount of people. (UN, 2020).

The use of renewable energy sources may significantly reduce clean water waste. If renewable energy sources are used instead of coal, water consumption will be reduced by eight times.

If renewable energy sources are used instead of oil and gas, water consumption will be reduced by a factor of 26,4 times (Figure 7).

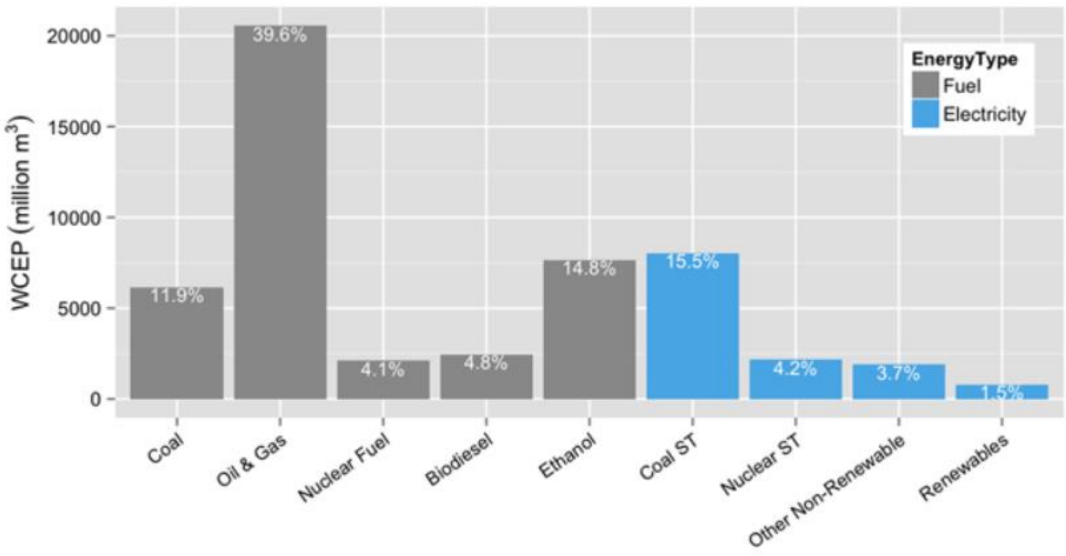

Figure 7. Total global Water consumption: total energy production (WCEP) by major energy category (Spang, et al., 2014).

International Energy Agency predict that in 2030 world’s water consumption for energy sector will increase due to the Biofuel usage and this will be a bigger problem for increased population of Earth by 2030. (Figure 8).

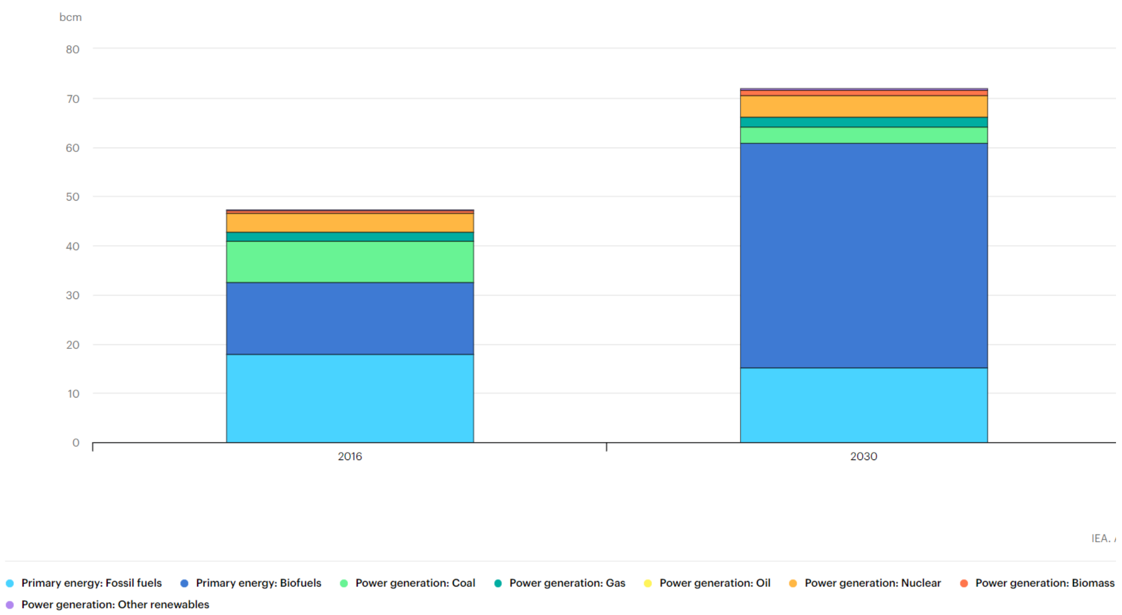

Figure 8. Sustainable development scenario (2016-2030) for the energy sector, water consumption globally according to fuel types (International Energy Agency, 2020)

This increase in the clean water usage could be balanced with renewable energy.

Table 1. Possible Clean Water Saving with Renewable Energy Utilization instead of Nuclear, Coal and Gas.

	Water Consumption by 2016 (billion cubic meters)	Water Consumption by 2030 (billion cubic meters)	Water Consumption by 2030 (billion cubic meters) if renewables used instead of Nuclear Gas, Coal
Primary Energy: Fossil fuels	18 BCM	15,1 BCM	15,1 BCM
Power Generation: Gas	1,9 BCM	1,9 BCM	–
Power generation: Biomass	0,5 BCM	1,1 BCM	1,1 BCM
Power generation: Nuclear	3,8 BCM	4,4 BCM	–
Power generation: Coal	8,4 BCM	3,3 BCM	–
Primary energy: Biofuels	14,5 BCM	45,8 BCM	45,8 BCM
Power generation: Other renewables	0,2 BCM	0,5 BCM	2,598 BCM
Total Water Consumption	47,3 BCM	72,1 BCM	64,598

There could important amount of clean water could be saved with small changes like these. In in assumption 7,502 billion cubic meters of clean water was saved.

2.3 Beginning of renewable energy utilization

Due to highly developed and inexpensive production technologies, fossil fuels have been widely used over the last two centuries. Nonetheless, the 1973 Oil Crisis created a climate of insecurity in the energy resources sector for the first time in history. This climate of insecurity has sparked widespread interest in renewable resources around the world, and the use of petroleum-based energy has been deemed risky, despite the fact that oil prices have fallen significantly since the mid-1980s. Because of increasing natural gas and oil prices, as well as the "necessity of ensuring energy security," "diversification of energy" has emerged as one of the most important elements of energy policies today. This issue becomes particularly important for many energy-dependent developing countries, such as Turkey, which lacks access to energy resources. For these countries, this issue becomes a matter of economic independence. These considerations have resulted in the inclusion of renewable energy sources in the energy distribution grid (Venn, 2002).

Another development that has aided the development of renewable energy sources is the rise in environmental consciousness that began in the 1990s and continues today. This awareness has resulted in the recognition that traditional energy production and consumption have direct negative effects on the natural resources and environment at the local, regional, and global levels, as well as the support for renewable energy sources that do not emit polluting emissions into the atmosphere, which are referred to as "clean energies” (Koomey, et al., 1990).

Renewable energy sources are portrayed as the most easily accessible alternative to the countries' reliance on fossil fuels to meet their energy needs. Energy supply become approximately 2,5 times greater between 1971 and 2018, rising from 5.518,625 Mtoe (million tons equivalent oil) to 14.281,888 Mtoe (million tons equivalent oil). In 2018, when looking at the types of resources that meet the energy supply, it is estimated that oil accounts for 31 % of total energy supply, coal accounts for 27 % of total energy supply, natural gas accounts for 23 % of total energy supply, fossil fuels account for 81 % of total energy supply, biofuels and waste account for nine percent of total energy supply, hydro accounts for three percent of total energy supply, nuclear accounts for five percent of total energy supply and other renewable energy sources account for two percent of total energy supply. (International Energy Agency, 2020).

As a result, geothermal, wind, solar, nuclear, and bioenergy, energy storage technologies are excellent and equitable solutions from nature to meet today's energy needs. They are also environmentally friendly.

Nature's energy is the best solution we have, and there is enough potential for all of the world's energy demand if we use it properly. (Figure 9).

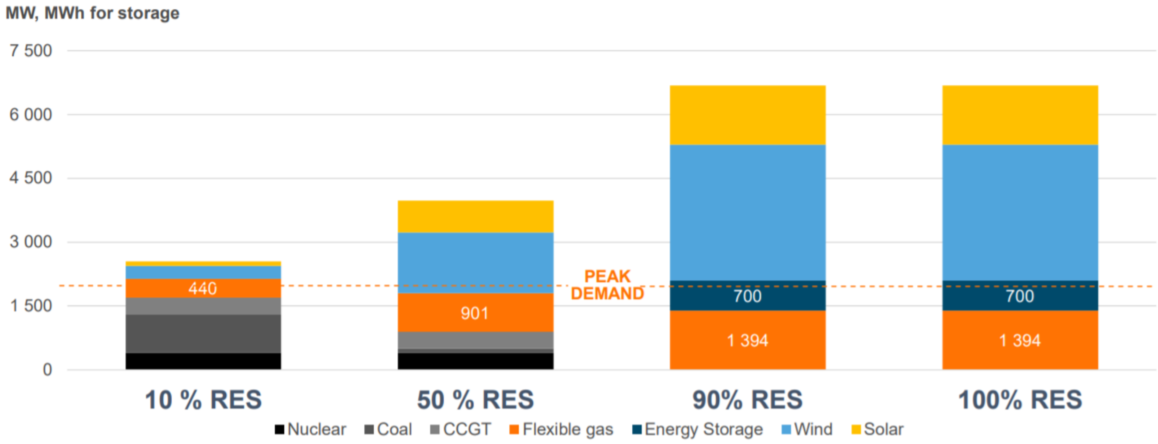

Figure 9. 100% Renewable energy pathway (Towards a 100% renewable energy future," n.d.).

3. ECONOMIC AND ENERGY STATUS IN REPUBLIC OF TURKEY

Republic of Turkey is located mostly in Anatolia and a small part in Thrace, the southeast extension of the Balkan Peninsula. It borders Bulgaria in the northwest, Greece in the west, Georgia in the northeast, Armenia, Iran, and Azerbaijan in the east, and Iraq and Syria in the southeast. The island of Cyprus and the Mediterranean to the south. The Aegean Sea surrounds it to the west and the Black Sea to the north. Along with the Bosphorus and the Dardanelles, the Sea of Marmara separates Anatolia from Thrace, Asia, from Europe. Turkey has significant geostrategic power as it is located at the crossroads of Europe and Asia.

Turkey has a unitary structure in administration, which is one of the most important factors shaping Turkish public administration. Considering the three powers in the basic functioning of the state, the legislature, the executive, and the judiciary, local governments have almost no power. The administration of provinces and other units comes after the central government. Local governments are established to serve only where they are located. Governors at the beginning of the provinces, district governors, are in charge as administrators. Besides the governor and district governor, other high-level officials are appointed by the central government and mayors.

Moreover, Turkey is divided to 6 regional investment regions. (Regional Investment Incentive Scheme) (Figure 10).

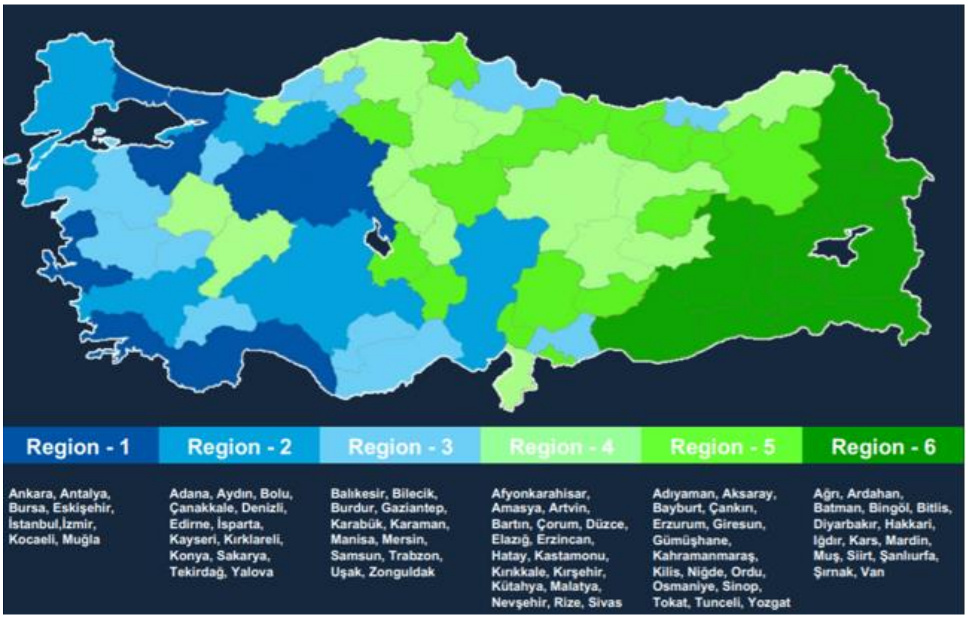

Figure 10. Regional Investment Incentive Scheme (invest in Turkey, why invest in Turkish energy sector, 2018).

The capital city of Turkey is Ankara. The provinces are the country's major administrative units, with 81 provinces. These provinces are divided into 973 districts. Furthermore, the country is divided into seven regions and twenty-one sub-regions based on demographic, economic, and geographic factors, although these regions are without any governmental framework.

The Republic of Turkey is a member of Organisation for Economic Co-operation and Development (OECD), the Council of Europe, Organization for Security and Co-operation in Europe (OSCE), and the Group of Twenty (G20) communities, and as such, it is fully integrated into the international community. It first joined the European Economic Community as an associate member in 1963, then joined the EU Customs Union in 1995, and finally began negotiations for full membership in the European Union in 2005.

In 2020 the cumulative total of direct investments made by Turkish investors abroad reached 43,9 billion dollars. (“Turkish entrepreneurs’ investments abroad reach $44 billion”, 2021). Turkey’s Gross Domestic Product (GDP) increased from 240,253 billion dollars in 2002 to 778,4 billion dollars in 2018, a more than threefold increase when compared to 2002. (World Bank, “GDP (current US$) – Turkey”). Turkey’s GDP per capita increased to $27,942 in

2018 when measured in Purchasing Power Parity (PPP), according to the World Bank. (World Bank, GDP per capita, PPP (current international $) – Turkey). The Turkish economy grew by 2,8 % in 2018, according to official figures. Turkey's sustainable economic growth over the years (Figure 12) and this sustainable growth keep continuing (Figure 11) even in the global pandemic times when most of counters economies were shrunk.

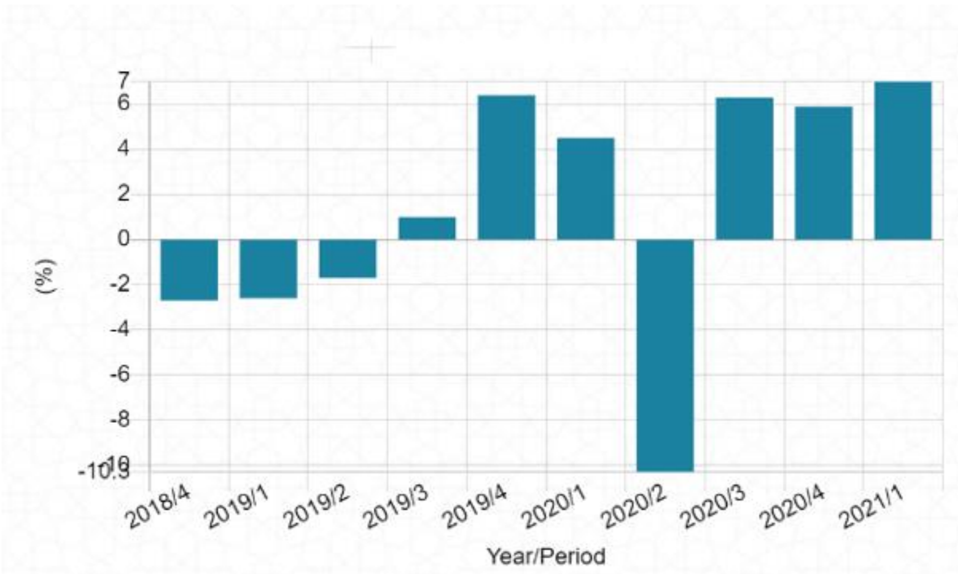

Figure 11. GDP growth rate % of Turkey (Turkish Statistical Institution)

Figure 12. Growth rate % of Turkey at World Pandemic (Reuters News Emerging Markets March 1, 2021).

Moreover, Turkey’s economy kept growing even in the world’s pandemic times. Turkey's 5th rank in the European electricity market and energy consumption in addition 4th in natural gas consumption in Europe. (Investment Office of the Presidency of Turkey, 2020). Figure 14 shows that Turkey is increasing its energy consumption but also stabilizing natural gas use and increasing renewable energy sources more. However, from Figure 15 it can be seen that still natural gas and coal are major energy production methods. Also, Non-Licensed power plants are account for a small portion of the energy consumption (Figure 13).

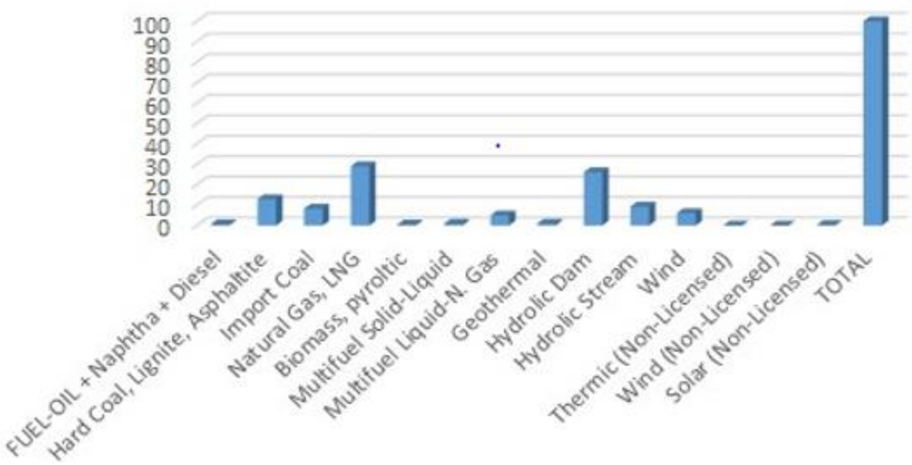

Figure 13. Turkey's electricity production from different sources for year 2015 (UCTEA, 2016).

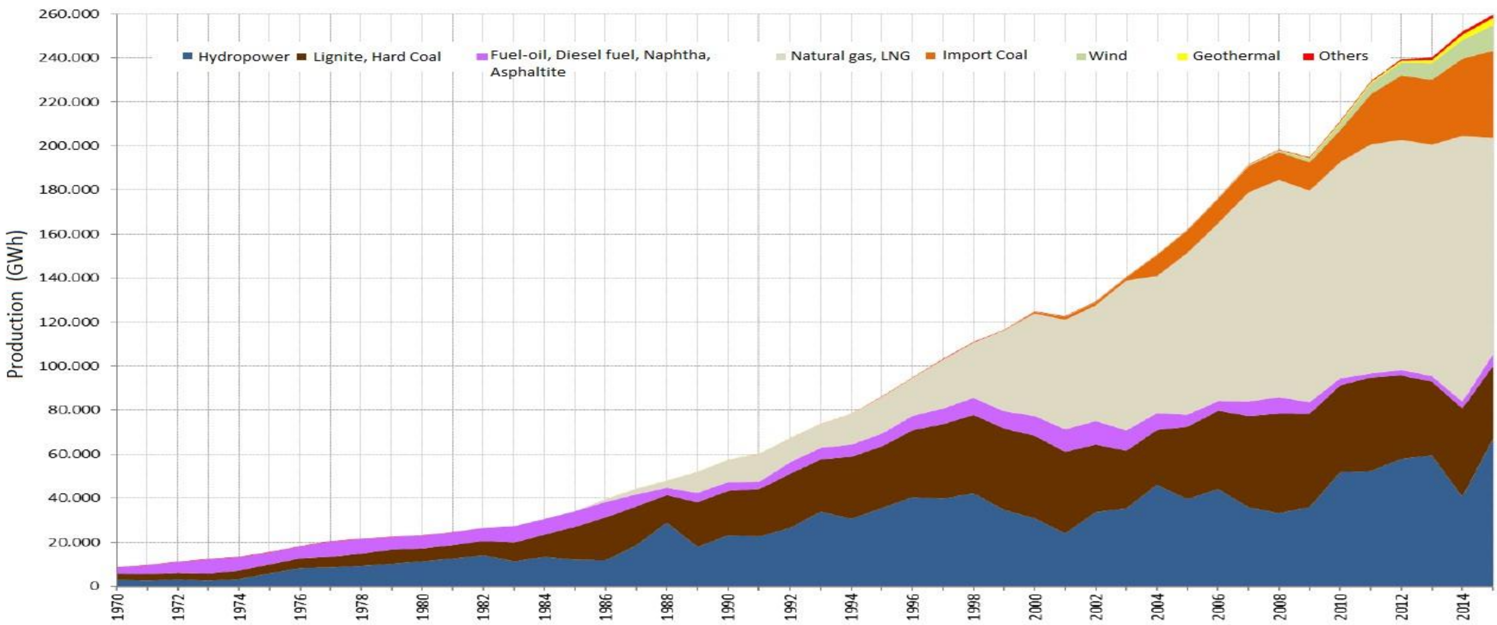

Figure 14. Distribution of electricity production from different energy production in Turkey from 1970 to 2015 (UCTEA, 2016).

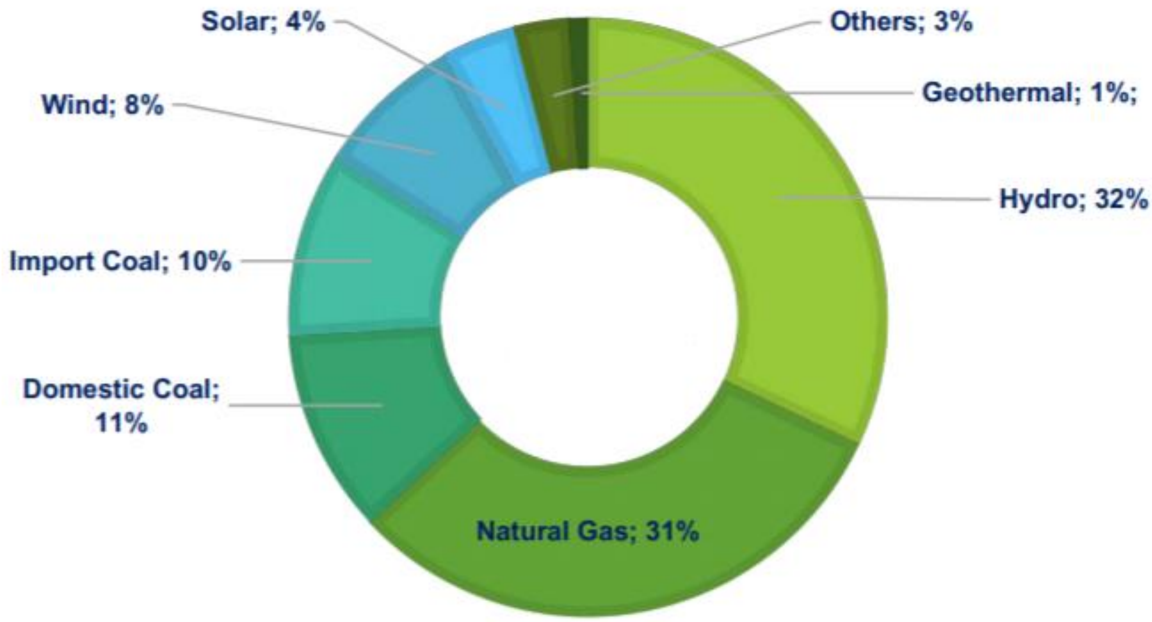

Figure 15. Installed capacity end of 2017 (invest in Turkey, why invest in Turkish energy sector, 2018).

3.1 Air Pollution in Republic of Turkey

Regulations and the causes of the air pollution differs from western neighbours of Turkey. In long term goals there are improvements planned and one of the important step in that way is to increasing the renewable energy share of the grid. However, the emission per capita levels and emission per km^2 values of Turkey is lower than Turkey. This is because of the large geography and population of Turkey. The air pollution values differ from region to region because of the population and industrialization. Western parts locate biggest cities of Turkey such as Ankara, Istanbul and Izmir have above average pollution levels have also above World Health Organization air pollution limits. Moreover, in some parts of the Turkey emission per capita levels and emission per km^2 values are exceed the European indicates especially in winter times. In addition, there other factors such as levels of industrialization and living standards makes comparison harder with other countries and cities. Like in the table seemed the major cause of the air pollutions are domestic heating and industry urbanization and industrialization, to name a couple of trends. (Table 2) (Bayram, et. al., 2000).

Turkey is currently obligated to combat air pollution as a result of a number of regulations, international protocols, and conventions. Apart from these, a number of organizations within the public administration organization as well as members of civil society are engaged in the fight against air pollution. (Bayram, et. al., 2000).

Table 2. Air pollution in Turkey (Bayram et. al., 2000).

Air quality parameter	Turkish limits (present)		Turkish limits (probable revisions)		WHO guidelines (Europe)[c]	EC regulation
	Short term[a]	Long term[b]	Short term[a]	Long term[b]		
SO_2, µg/m^3	400	150	250	100	125 (daily) 50 (annual)	125 (daily) 50 (long term)
PM_{10}, µg/m^3	300	150	200	100	–	80 (annual)
NO_2, µg/m^3	300	100	200	80	200 (1 hr)	50 (long term)
NMVOC, µg/m^3	–	140	–	140	–	–
CO, µg/m^3	30 000	10 000	10 000	5 000	10 000 (8 hrs)	–

a

Short-term limit value is the figure which should not be exceeded by 95% of all air quality data generated over a period of interest.

b

Long-term limit value is the arithmetic mean of all air quality data over a long period of time.

c

Revised WHO air quality guidelines.

3.2 Drought in Turkey

Turkey has precipitation anomalies. These anomalies in precipitation do not follow a significant course. Also with the climate change effect, this leads to extreme weather events either harsh drought or heavy flow. Droughts are classified into four broad categories; agricultural, socioeconomic, meteorological and hydrological. Agricultural drought is first level which causes loss of plant root with soil. The second level is the hydrological drought which occurs when reservoirs and hydrological systems are lack of compensating the demand. The last level is happening after the length and the magnitude of the is increased socio-economical drought. At this level nature and residents at indirect or direct treat. Power plants may run out of cooling water to operate and hydro power plants may need to shut down due to lack of water which are both important treat for the energy systems. Approximately two-thirds of soil in Turkey is Cambisols/Cambisols-Leptosols and 24 % of the soil is combination of Fluvisols, Vertisols, Calcisols, Cambisols which are most suitable soil for cereals and field crops. However, cost of Mediterranean Sea and birder zone between Syria have probability to face extreme drought. There are some measures can be taken for this vulnerability against nature and risk management is one of the way for decreasing social and economic losses caused by extreme weather events. One of the risk management solution is to increasing modern agricultural methods for decreasing social and economic losses from extreme drought. Also, modern irrigation methods will also increase the water usage efficiency of the farms which is significantly important solution against precipitation anomalies. In addition, Turkey is suffering intense drought in 2021 (Turkes, 2019) (Figure 16).

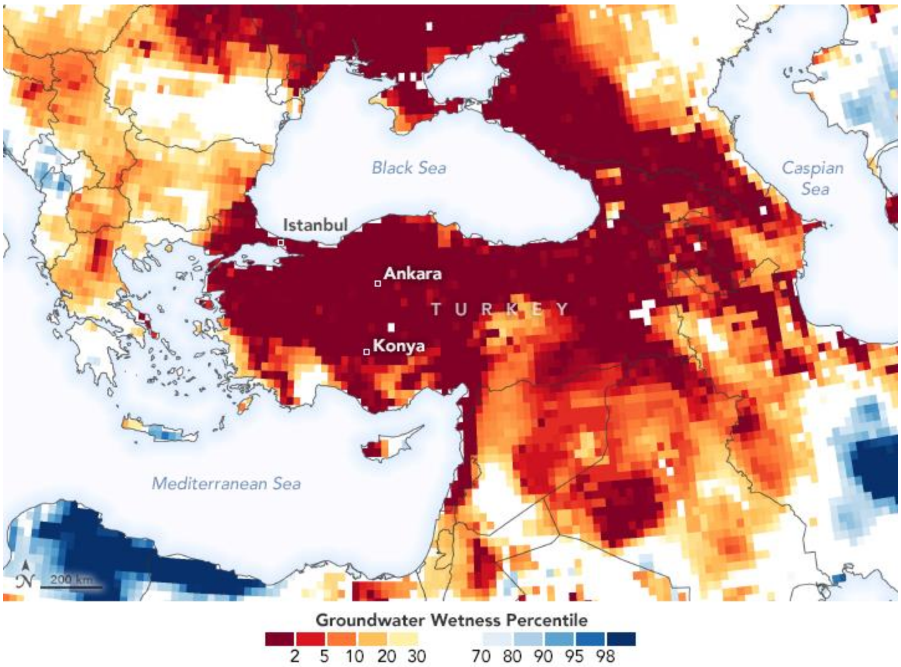

Figure 16. Turkey Experiences Intense Drought. (NASA, 2021).

3.3 Energy Dependency

With the growth of globalization, international trade has grown to enormous proportions, and no society, including Turkey, cannot afford to remain outside of this transformational process. These energy sources such as coal, oil, and natural gas, all fossil energy sources for production and nearly 60 percent of the world's proven oil and gas reserves is situated in Turkey's vicinity. Also, Turkey's energy demand has grown at the quickest rate of any OECD country during the last two decades but Turkey is forced to import approximately 74% of its energy sources from abroad since fossil energy sources are insufficient. The high reliance on imported energy sources harms a country's economy by raise of energy prices, the costs of production and distribution which effects inflation, the exchange rate, economic growth, and a country's current account deficit.

The Turkish government is also pursuing the goal of becoming a regional trade center for energy, which will help to ensure the diversity of energy routes and sources. For instance, TurkStream, Trans Anatolian Natural Gas Pipeline (TANAP), South Caucasus Natural Gas Pipeline (SCP), Baku-Tbilisi-Ceyhan Crude Oil Pipeline (BTC), Turkey-Greece Natural Gas Interconnector (ITG) and Baku-Tbilisi-Erzurum Natural Gas Pipeline (BTE), are important projects for making Turkey an energy trade center.

Additionally, enhance the proportion of domestic and renewable energy in electricity generation. Turkey is rated fifth in Europe and 12th in the world in terms of renewable energy installed capacity, with renewables accounting for 52 percent of Turkey's installed power at the start of 2021 (Turkey’s International Energy Strategy, Republic of Turkey Ministry of Foreign Affairs, 2021).

3.4 Current Deficit

Since a current account deficit means that a country owes this amount to other countries, the source of this debt must be determined. The balance of payments current account items that create the current account deficit should be monitored. There are four sub-items that make up the current account. The most important of these is the goods balance, which includes exports and imports, and is generally known as the foreign trade balance. The second sub-item is the balance of services, which includes trade in services. The third sub-item was the income balance, which included revenues, and the last item was current transfers, which included unrequited transfers.

While the goods balance and income balance fed the current account deficit by constantly taking negative values in the 1989-2015 period in Turkey, the services balance and current transfers acted to reduce the current account deficit by constantly adding positive values in the same period. In Turkey, the contributions of four items to the current account deficit are observed in the 1975-2015 period (Figure 17). According to the graph, the goods balance contributes the most negatively to the current account deficit, and the services balance makes the greatest positive contribution.

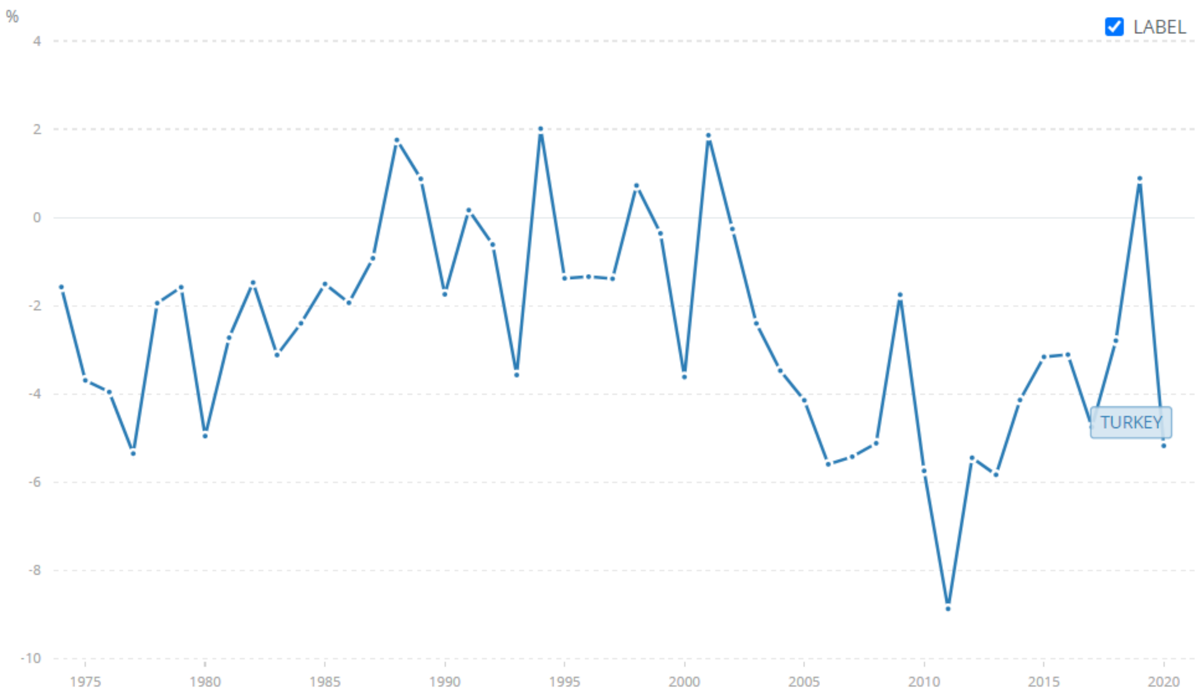

Figure 17. Current Account Balance (% of GDP) Turkey between 1974-2020 (The World Bank, 2021).

Since the four sources of current account deficit are goods, current transfer, services and the income balance. It can be said that 1989 was a turning point for the Turkish Economy with the liberalization of its' international financial transactions to become an open economy in a larger extent. Since than Turkey's goods balance or foreign trade balance, as it is commonly known, gave a deficit in the 1989-2015 period. Considering the sub-items of the import part of the goods balance between 2014 and 2006, which is the largest item feeding the current account deficit, for the specified period, it is seen that imports of intermediate goods constitute between 73% and 70% of total imports. While the share of investment goods in total imports is between 17,4% and 14,3%, it is observed that the rate of consumption goods is remains between 13,6% and 11%. In this case, it is possible to say that imports of intermediate goods make the biggest contribution to the current account deficit in the goods balance. Approximately 70% of energy dependency on imported resources is a significant problem that triggers the foreign trade deficit and, therefore the current account deficit. (Alçın, 2019).

4. BIOENERGY STATUS IN TURKEY

Bioenergy is the second smallesest source in Turkey renewable energy installed power capacity distribution (Figure 18) with more than 50% of bioenergy belongs to biogas (Figure 19).

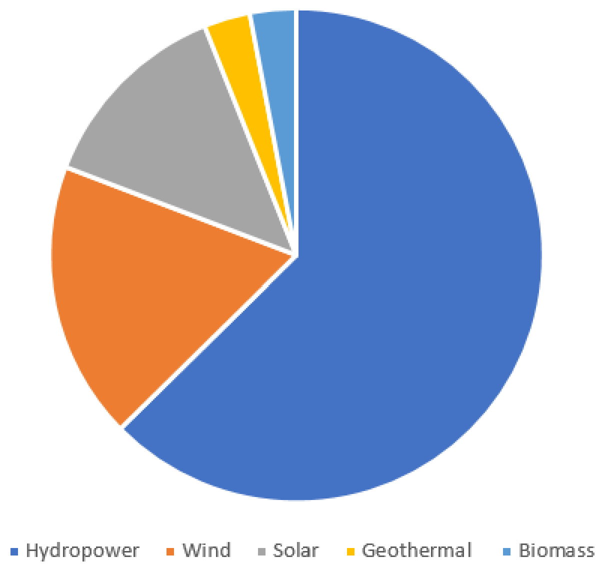

Figure 18. Turkey renewable energy installed power capacity distribution, in % (PWC., 2021)

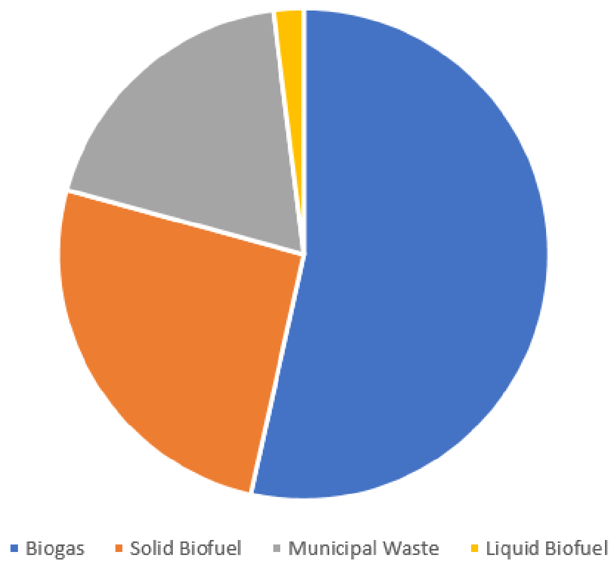

Figure 19. Biomass installed power distribution in Turkey, in %, 2019.

4.1 Bioenergy Resources

Some factors have contributed to the inclusion of bioenergy resources on the national agenda. Firstly, it is to reduce the environmental damage caused by fossil fuels by one of the following methods: Reducing the risks to human health posed by exhaust emissions, Reducing reliance on foreign energy sources, especially coal and Achievement of agricultural development objectives. In order to address the extreme fluctuations in oil prices that have occurred in recent years (WTI oil prices were average 56 USD per barrel in 2005; they reached up to 145 USD at the beginning of 2008), as well as to address the emergence of economic crises, it is necessary to mitigate global warming and its consequences, to prevent the expansion of damage to the ozone layer (ozone hole area approximately covers 20-25 million km^2), and to serve as a strategic fuel in global or local crisis.

Increasing the multiplier effect of agricultural development in developing countries by ensuring the integration of agricultural products with industry. Because it has a higher certain number than petroleum diesel, it has a number of advantages when it comes to engines, including improved combustion and fuel efficiency. In terms of transportation and storage, it does not fall under the category of "Dangerous Goods" as defined by international standards. It is considered a safe fuel, which is why it is used.

Turkey, which is among the top 10th country in the world in terms of global agricultural economy in 2019, Turkey is biggest agricultural economy in Europe (Investment Office of the Presidency of Turkey, 2019). Turkey has considerable amount of bioenergy potential that can be utilised for energy. Agriculture, forest, organic municipal waste, and animal waste are some of the biomass resources available in Turkey. Turkey's usable bioenergy potential is estimated to be approximately 33 Mtoe, and the energy production potential from crops is estimated to be approximately 20 Mtoe. It is projected that forest residues have the potential to supply approximately 5,4 Mtoe of Turkey's energy needs (Toklu, 2017).

According to the distribution of forest areas in Turkey by geographical region, the Black Sea Region accounts for 24%, the Mediterranean Region accounts for 19%, the Aegean Region accounts for 18%, the Marmara Region accounts for 14%, Central Anatolia accounts for 11%, Eastern Anatolia accounts for 8%, and South Eastern Anatolia accounts for 6% of total (Gulsen, Yenigun, 2021).

Figure 20 shows the mapping of the distribution of the forest in Turkey.

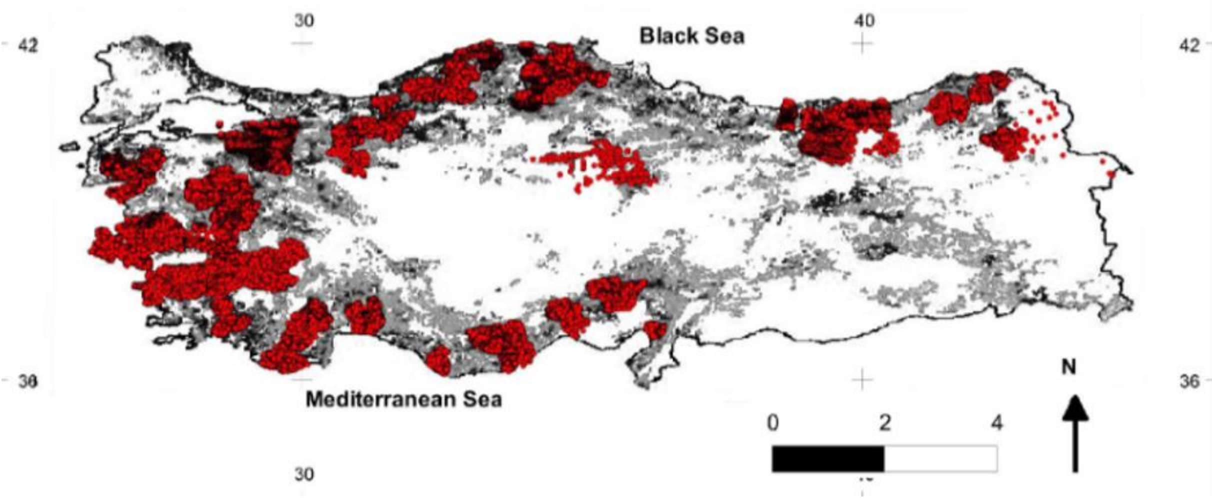

Figure 20. Distribution of forest areas in Turkey (Yılmaz, Tolunay, 2012).

It is viable to use the high thermal values of wood and non-wood forest residues for modern energy production in efficient and eco - friendly facilities in the Marmara, Black Sea, Mediterranean, and Aegean regions, where energy consumption is high. The region, which ranks second in terms of forest assets behind the Black Sea region, should capitalize on this advantage through smart policy and production processes that do not harm the forest assets. The Mediterranean region is the most important tourist destination in our country, which results in an increase in energy demand and consumption during the summer months. The greatest woody biomass potential for bioenergy is found along the western and southern coasts, particularly in the Mediterranean region, which has a high level of forestry activity.

Moreover, wastes have gradually become a major issue, the total amount of generated plant waste, animal wastes, municipal waste in 2020 is 288,255 million tons. Each year, these wastes are disposed of in stream beds or burned. Both processes, however, have a significant negative impact on the environment. Methane gas is released during the natural decay process of wastes stored in open containers, and decay waters contaminate the soil. These waters, when combined with soil, pollute the soil due to their high nitrogen, nitrate, and phosphate content. Carbon dioxide gas is released into the air when they are incinerated for disposal. These regions are critical in terms of assessing greenhouse gas emissions.

As an agricultural country, Turkey has abundant resources of agricultural wastes and product wastes. Turkey have a full potential of 34 million tons equivalent of oil in total energy potential calculated from plant waste, animal wastes, municipal waste, forest waste. In

Turkey, plant production is 171,399 million tons, which can be considered as a biomass energy source. In contrast to 171,399 million tons of production, plant waste is approximately 62,207 million tons were generated in the field and after processing. The approximate economic energy equivalent of these plant wastes is 1,462 million tons of equivalent (BEPA, 2020). Figure 21 is the map of animal waste annually generated by 81 provinces.

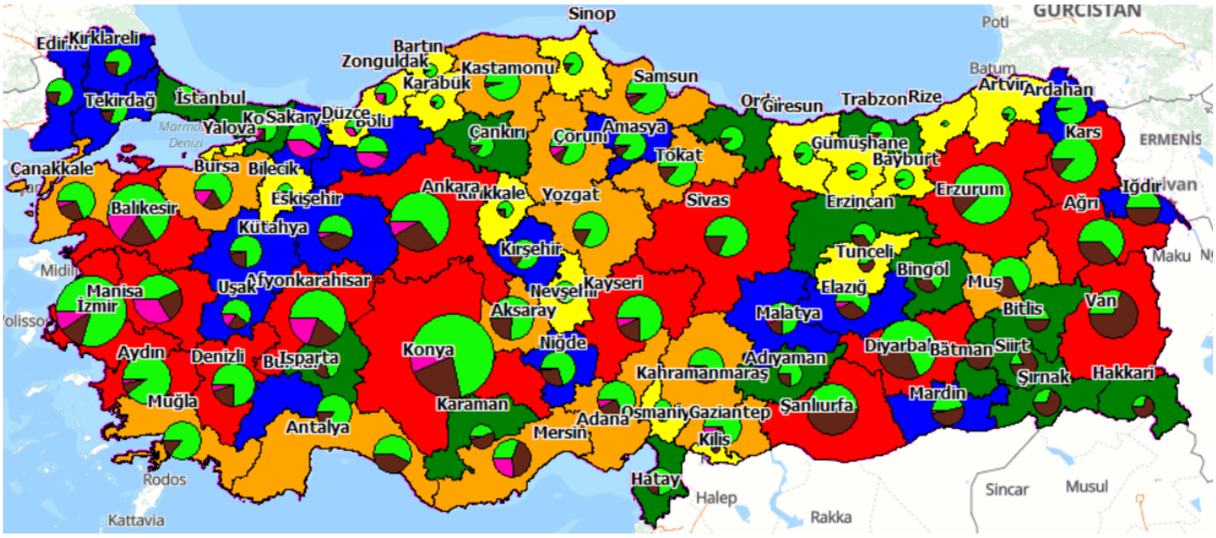

Figure 21. Animal wastes annually produced by 81 provinces at 2020 (GDRE, 2021).

Yellow: 0,14 – 0,98 million ton/year

Green: 0,98 – 1.69 million ton/year

Blues: 1.69 – 2.37 million ton/year

Orange: 2.37 – 3.39 million ton/year

Red: 3.39 – 10.87 million ton/year

Figure 22 is the map of agricultural waste annually generated by 81 provinces.

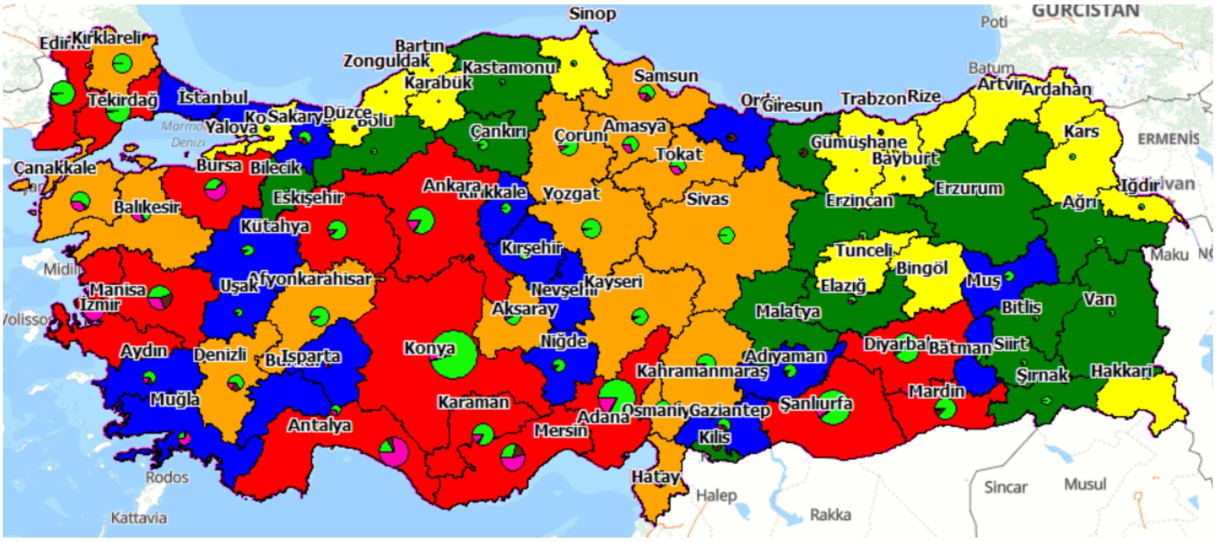

Figure 22. Agricultural waste annually produced by 81 provinces at 2020 (GDRE, 2021).

Yellow: 0,005 – 0,16 million ton/year

Green: 0,16 – 0,34 million ton/year

Blues: 0,34 – 0,72 million ton/year

Orange: 0,72 – 1.16 million ton/year

Red: 1.16 – 5.76 million ton/year

Figure 23 is the map of municipal waste annually generated by 81 provinces.

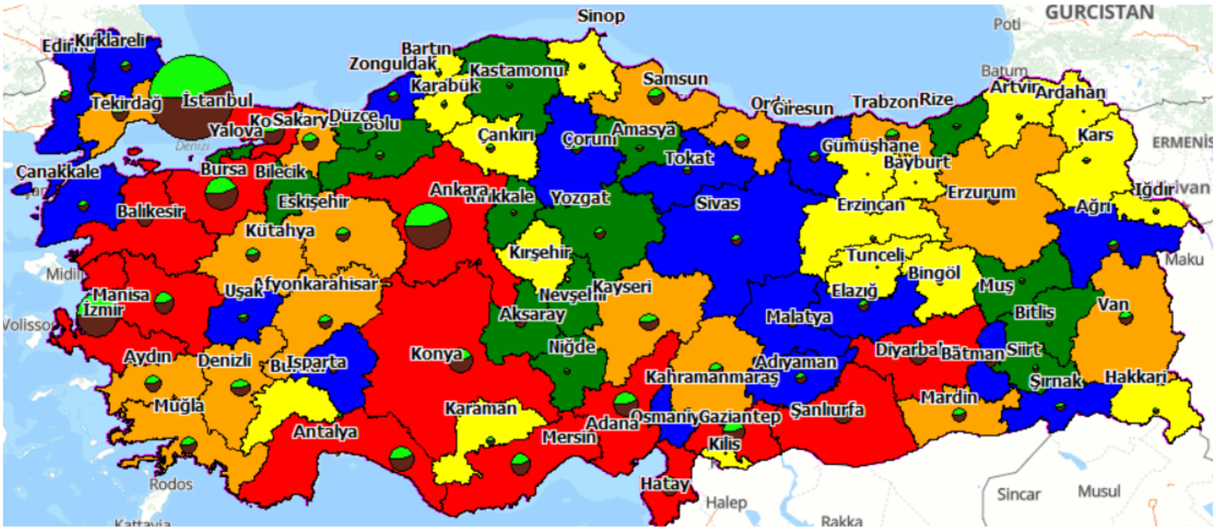

Figure 23. Municipal waste annually generated by 81 provinces at 2020. (GDRE, 2021).

Yellow: 0,025 – 0,09 million ton/year

Green: 0,09 – 0,145 million ton/year

Blues: 0,145 – 0,23 million ton/year

Orange: 0,23 – 0,48 million ton/year

Red: 0,48 – 7,1 million ton/year

4.2 Biodiesel and Bioethanol

The energy used in Turkey is met primarily from fossil fuels; it is not self-sufficient in terms of petroleum resources, 92% of the need is met through imports, billions of dollars are paid out for oil purchases, country economy has been negatively affected due to abnormal increases in oil prices (The Importance of the Fuel Distribution Industry in Turkey's Economy, 2021). As of 2008, 28,4 million liters of biodiesel and 50,6 million liters of bioethanol were consumed in Turkey (Boluk, Koc, 2013). Making the use of biodiesel and bioethanol mandatory in the EU will increase the demand for biodiesel, bioethanol, and biofuels in the country in the coming years, considering the EU harmonization process.

It is projected that 220 million litres of bioethanol would be required to make a 5% ethanol mix in gasoline (5 percent bioethanol, 95% gasoline). Turkey is expected to produce about 0.3 million m^3 of bioethanol as a gasoline additive (10 percent bioethanol, 90% gasoline). Turkey's gasoline usage will require 4.65 billion litres of bioethanol, according to estimates (100 percent bioethanol, 0 percent gasoline) (Melikoglu, Turkmen, 2019). In global scale, share of biofuels utilization is relatively small in Turkey.

Figure 24 is a estimation for how Turkey's Biomass Energy consumption will evolve in the future.

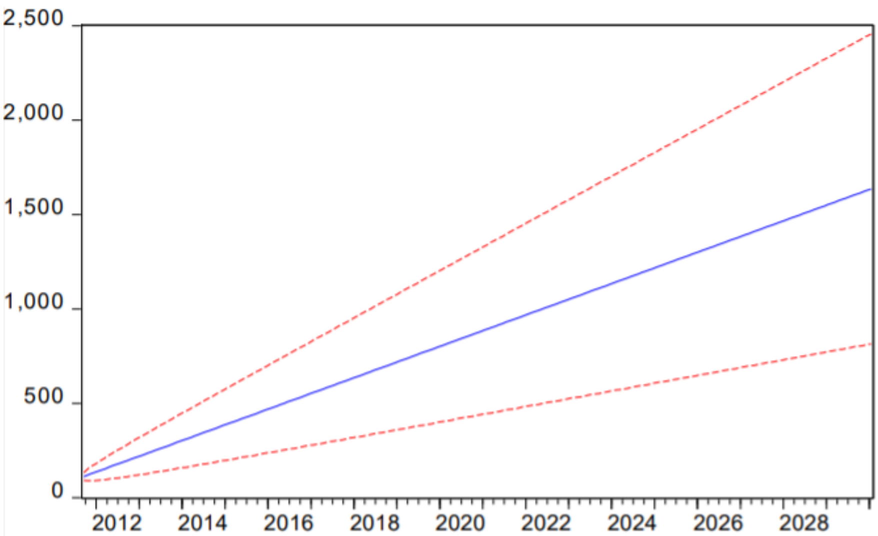

Figure 24. Estimated Installed Power of Biomass Energy by 2030 - Turkey (MW) (Güllü, 2021)

In this prediction, it's estimated that the installed power capacity of the licensed bioenergy power plants is as follows (Table 3).

Table 3. Turkey Renewable Energy Installed Power Capacity Distribution (PWC, 2021)

Year	Total (MW)
2015	345
2016	467
2017	575
2018	739
2019	1163
2020	1485

4.3 Bioenergy Water Problem and Solution

Turkey's population is projected to reach 100 million by 2030, resulting in a drop in water use per capita to 1,120 m3. Turkey is on the danger of becoming a "water-scarce" country, as these forecasts indicate. Meanwhile, as a result of the growing detrimental consequences of climate change, drought has emerged as a significant threat to Turkey's agriculture. Agriculture accounts for 73% of all water consumption in Turkey, and agricultural biomass production holds an important percentage in biomass production; for this reason, increasing water efficiency is a key point. It is critical to increase agricultural output's water efficiency. Seventy-three percent of the water used in agriculture in Turkey is used to irrigate crops, and 82 percent of this water is used in the form of 'flood irrigation,' which is the sort of irrigation in which the majority of the water is wasted. The percentage of drip irrigation systems, which is one of the economic irrigation systems, is 1%. 38% of the water used in irrigation is met from groundwater, and as a result of unconscious irrigation, groundwater is depleted. Figure 25 is the general water consumption map of Turkey.

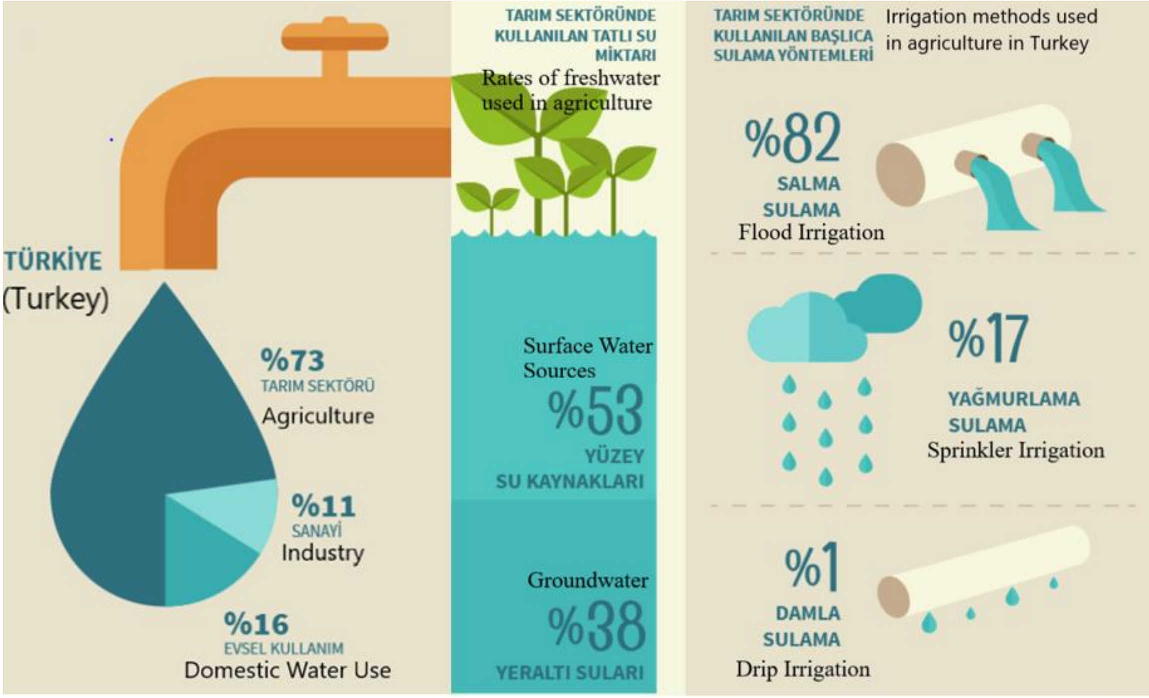

Figure 25. Water Used in Turkey (Su TEMA., 2021).

The fallowing experiment made at NetLogo free and open-source software. NetLogo is a multi-agent programmable modeling environment. This experiment is aim to analyse the total water usage in 3 different irrigation methods and plants loss. (FarmIrrigation Model Netlogo, 2016).

Table 4. Water Consumption in Different Irrigation Methods and Crops.

	Drip Irrigation	Chanel Irrigation	Surface Irrigation
Peppers	371533 Litre	394588 Litre	864653 Litre
Maize	371374 Litre	394057 Litre	863972 Litre

Figure 26 is the experiment made with Drip Irrigation.

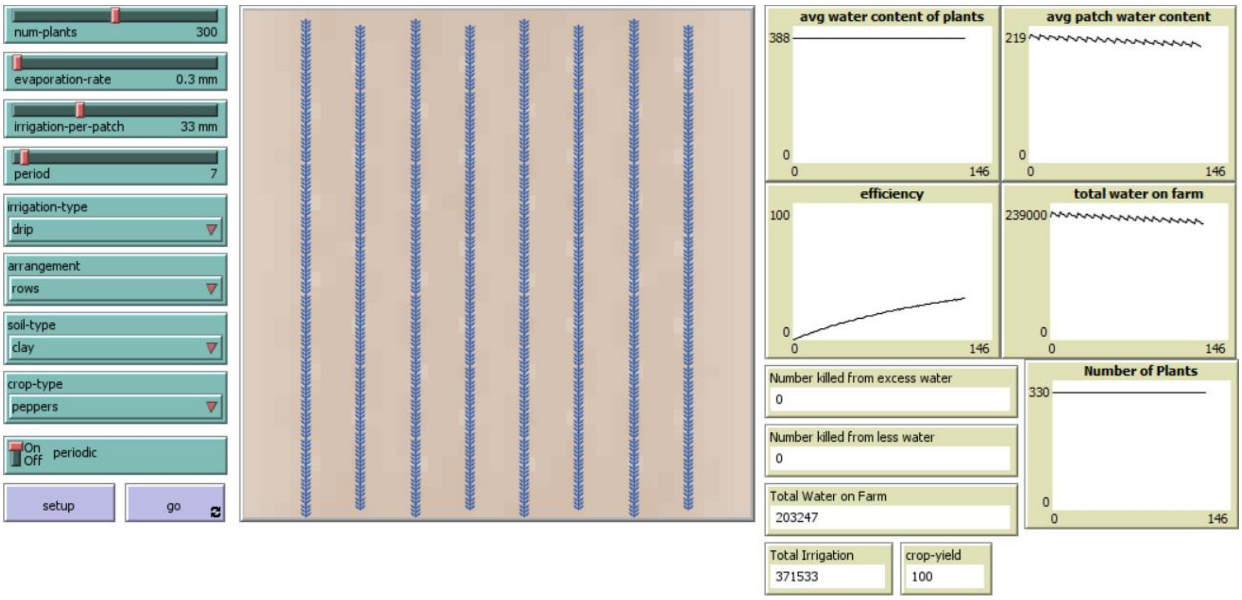

Figure 26. Drip Irrigation This method is proved to be most efficient in both water saving and economical way found from the results.

Figure 27 is the experiment made with Chanel Irrigation.

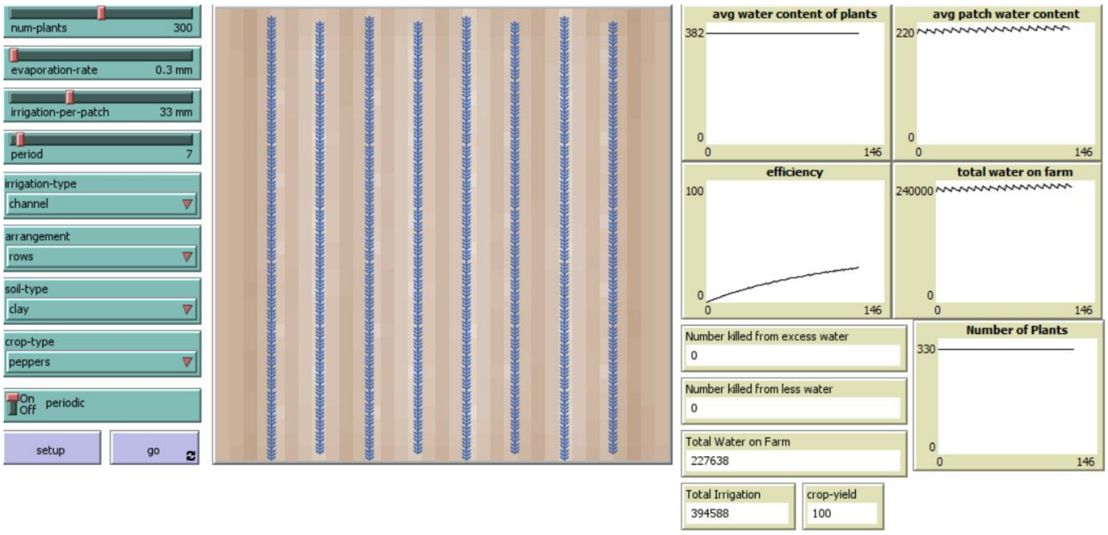

Figure 27. Chanel Irrigation

This method is common in developing countries and however it's not efficient as drip irrigation still efficient method.

Figure 28 is the experiment made with Surface Irrigation.

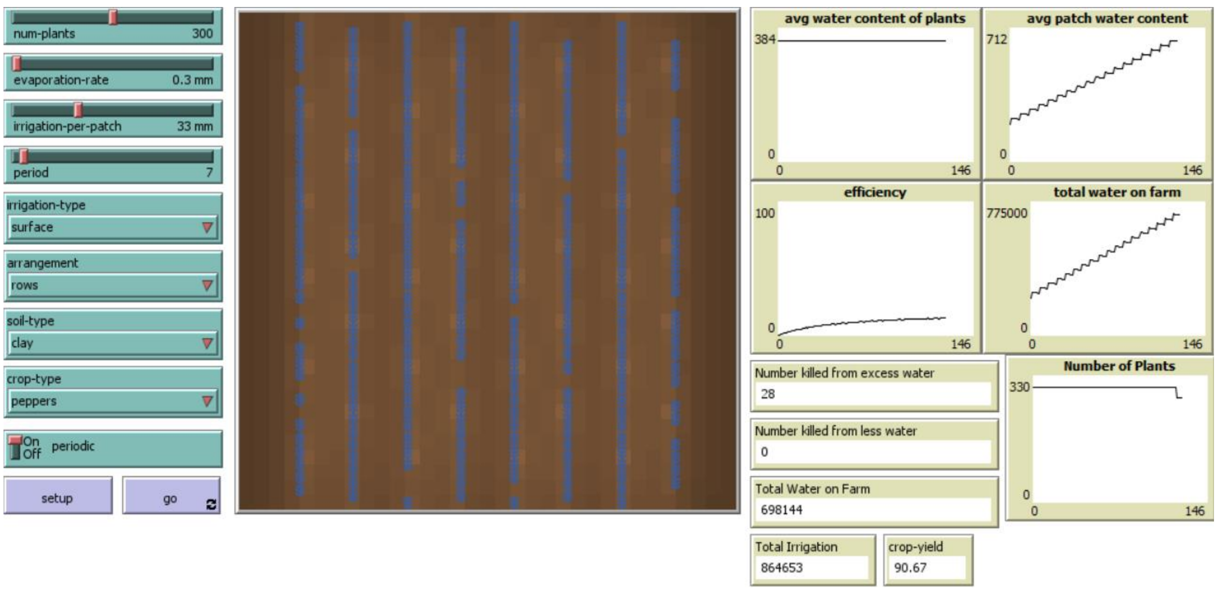

Figure 28. Surface Irrigation

In this it seen that in the efficiency of clean water usage this was the least efficient method among the others. Moreover, another important aspect is after ground fulfilled enough water plants started to die due to the over water. This scientifically known that over water usage in irrigation enable the root of the plants from reaching the oxygen and this means the drawing of the planet. Furthermore, over water in irrigation is lead to erosion as a result of the disturbed soil structure. Heavily eroded soil produces a reduction in soil quality by reducing the amount of fertile area in the uppermost layer of soil. When the soil quality deteriorates, the plant is deprived of the micro- and macronutrients that it requires to thrive.

5. RENEWABLE ENERGY POTENTIAL OF TURKEY

5.1 Solar Energy

Turkey is among the countries with high solar energy potential. It has been determined that approximately the daily sunshine duration is 7,5 hours, and the total daily solar radiation value is 4,18 kWh/m². The total sunshine duration is determined as 2741,07 hours in the annual calculations, and the average total solar radiation intensity is 1527,46 kWh/m²-year. It is observed that these values are considerably higher than most countries when compared to European countries (Solar, 2021)

The "Solar Radiation Model," which was developed by the Turkish State Meteorological Service, was used to create maps of the distribution of solar radiation in Turkey's different regions. With the model outputs produced for Turkey's 3610 grid points, a 20 km resolution data archive for the years 2004-2017 was created using the model outputs. Tests were conducted on the accuracy of the calculated Solar Radiation data using measurements collected from 54 ground-based observing stations. After conducting a statistical evaluation, it was discovered that the model outputs were on average 98 percent reliable. Figure 30 shows the solar radiation map of Turkey.

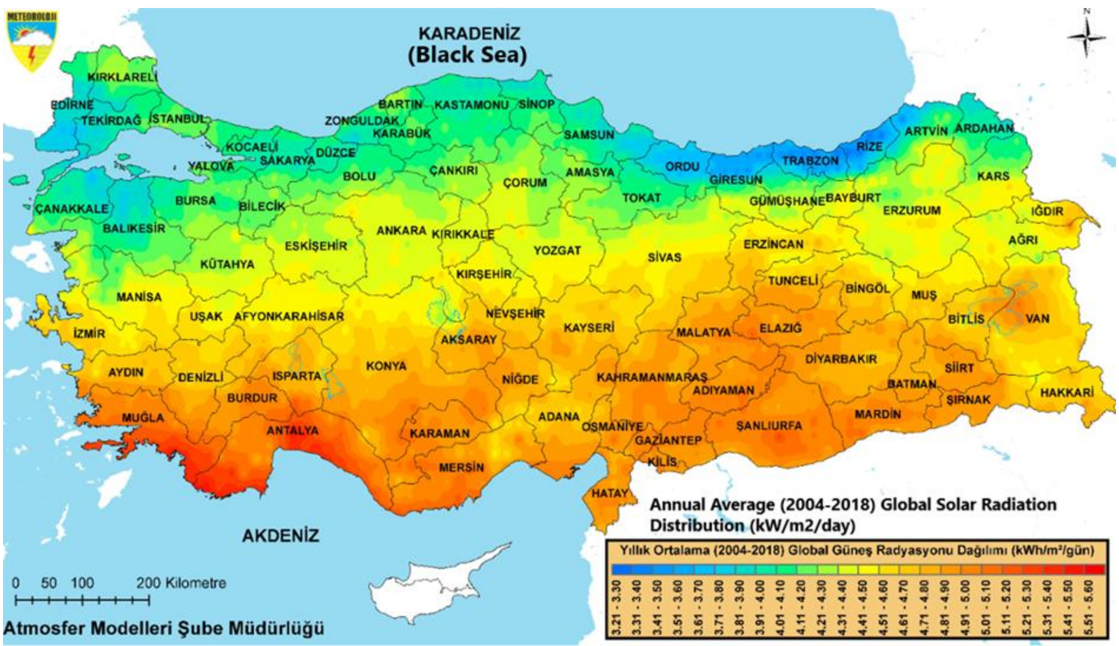

Figure 30. Annually Irradiation of Turkey (General Directorate of Meteorology 2016).

Moreover, like it has showed in the map Southern regions of Turkey have higher Solar Irradiation Energy than Norther regions. Calculations showed that Antalya's average monthly solar radiation value is 4,51 kWh/m² and Karaman's average monthly solar radiation value is 4,55 kWh/m² (Turkey Solar Radiation Distribution, 2017). Furthermore, these values are above the average and these two cities are located in Region 1 category (Regional Investment Incentive Scheme), which is better for investments (invest in Turkey, why invest in Turkish energy sector, 2018). In addition, these two cities both have either arid or semi-arid regions (2020 Drought Assessment, 2020). For this reason, solar farms have solving an important problem with being water efficient solutions.

5.2 Wind Energy

In addition to 7,591 MW of installed power, there are approximately 7,869 MW of projects and capacity allocations in the construction or pre-license process as of the end of 2019. In Turkey at 50m height average wind speed is 6,33 m/s and which makes approximately power of 282 W/m^2 at maximum efficiency level 59%. Moreover, at 100 m height average wind speed is 7,31 m/s and which makes approximately power of 434 W/m^2 at maximum efficiency level 59%.

Formula for calculating power used:

$$P = \frac{\pi}{2} r^2 v^3 \rho\eta$$

$$\rho = 1{,}2\ kg/m^3\ (Air\ Density)$$

$$\eta = \text{Efficiency (\%)}$$

$$\text{v} = \text{wind speed } (\frac{\text{m}}{\text{s}})$$

$$\text{r} = \text{radius of the wind Turbine (m)}$$

Wind resource information was produced using a medium-scale numerical weather forecast model and a micro-scale wind flow model. Turkey's potential wind energy has been found as 48,000 MW. The total area corresponding to this potential corresponds to 1,30% of Turkey's surface area. Figure 31 shows that the wind map of Turkey (Teneler., Wind Energy in Turkey, 2017). Moreover, Balıkesir, Çanakkale, and Izmir are exampled three cities with average wind speed over 7 m/s are either arid or semi-arid regions, which increase the importance of renewable sources in the case of being water efficient compared to traditional fossil fuel power plants (2020 Drought Assessment, 2020). In addition, Izmir takes place in Region 1 (Regional Investment Incentive Scheme), Çanakkale in Region 2, Balıkesir in Region 3, which prior regions for the investments (invest in Turkey, why invest in Turkish energy sector, 2018). Which are located in Marmara Region took 34,7% of the wind farms are located and Aegean Region of the wind farms are located (Teneler., Wind Energy in Turkey, 2017).

Izmir at 50m average wind speed 7,54 m/s, Balıkesir at 50m average wind speed 7,27 m/s, Çanakkale at 50m average wind speed 7,47 m/s (Global Wind Atlas) .Which makes power values in

Izmir = 477 W/m^2, Balıkesir = 427 W/m^2, Çanakkale = 464 W/m^2

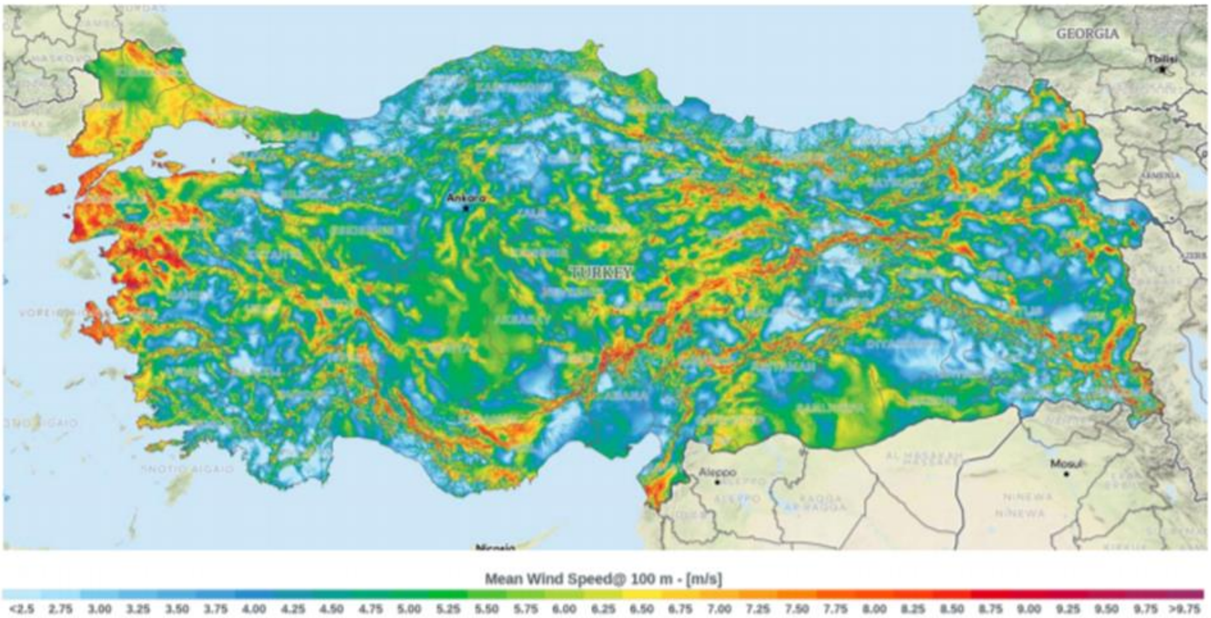

Figure 31. Average Wind Speed at 100m above of sea level - Turkey (Teneler, 2017)

5.3 Hydropower

Hydraulic energy is one of the oldest types of clean energy and it uses the potential energy of water to produce electricity. In Turkey annual precipitation can differ a lot from year to year either wet season or dry season. The average precipitation between 1981 to 2010 has been calculated as 574 mm. Moreover, annual precipitation differs from significantly according location (Sensoy et al., 2016). Annual precipitation in Turkey varies between 200-2500 mm, and the average annual rainfall of 501 billion m3. Numerous dams and hydroelectric power plants have been built so far to control the regimes of the Turkish rivers, thus preventing flood damages and providing drinking water, irrigation benefits, and energy from the stored water. Turkey has plan about the completion of the dams, irrigation of 7,254,454 hectares of land, protection of 704,868 hectares of land from floods and drying of 130.326 hectares of land. Turkey planned to reach the transmission of 9856,3 hm3 of water to cities and towns as drinking water. (Kumbur et al., 2005). Turkey's officially planned to reach 116.0 TWh of electricity demand will be compensated by the Hydropower power plants by 2023. In addition, this result with hydropower even gaining more important role in renewable energy share (Melikoglu,2013).

6. RENEWABLE ENERGY POTENTIAL OF TURKEY

To safeguard Turkey from the water scarcity problem, increasing the use of renewable energy sources is another vital approach. The figure below shows that Turkey intends to raise its installed renewable energy capacity from 46,400 MW to 66,500 MW by 2023, representing a 43 percent increase in installed capacity in only four years.

Figure 32 shows Turkey's near term plans for the renewable energy.

Source	2019	2023
Hydraulic	32,000	34,000
Wind	10,000	20,000
Solar	3,000	10,000
Geothermal	700	1,500
Biomass	700	1,000

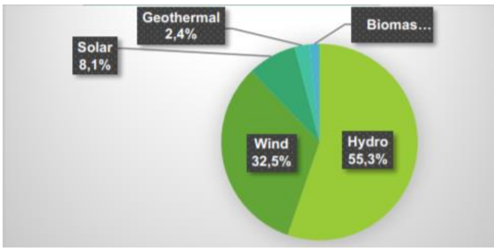

Figure 32. Planned Energy Projection of Turkey at 2023 (invest in Turkey, why invest in Turkish energy sector, 2018).

Furthermore, transitioning to renewable energy is just as crucial as making the appropriate investment in a renewable energy technology that is appropriate for the region's needs. The picture below illustrates how the water usage of different renewable energy sources varies significantly from one another. However, it also impacts the water sources that are used in the process, such as the sea and rivers, lakes; however, this aspect of the problem is not addressed in this research. The table shows that wind and solar technologies enable significantly more water-efficient solutions than their counter-parts in the lower-tier technologies.

Table 5. Renewable Energy Water Consumption Comparison. (Macknick, Newmark, Heath, Hallett, 2012).

Water Withdrawal to Produce 1 Megawatt-Hour of Electricity (Thousands of Gallons)	Wind	Solar	Geothermal	Biomass	Hydropower
Median	0	1	221	480	4,491
Min	0	0	461	553	1,425
Max	0	5	700	965	18,000

Table 6. Planned Renewable Energy Projection of Turkey at 2023 Comparison at the Perspective of Water Consumption.

	Wind	Solar	Geothermal	Biomass	Hydropower
Renewable Installed Capacity 2019 (MW)	10,000	3,000	700	700	32,000
Targeted Renewable Installed Capacity 2023 (MW)	20,000	10,000	1,500	1,000	34,000
Water Withdrawal to Produce 1 Megawatt-Hour of Electricity (Thousands of Gallons)	0	1	221	553	4,491
Water Withdrawal to Produce Electricity 2019 (Thousands of Gallons)	0	3,000	154,700	387,100	143,712,000
Water Withdrawal to Produce Electricity 2023 (Thousands of Gallons)	0	10,000	331,500	553,000	152,694,000

This table shows that the planned installed capacity increases the future water consumption of renewable energy plants. From the table, even the installed capacity power was far less in the geothermal, biomass, and hydropower power plants significantly consume far more water than wind and solar farms. In addition, this is a significant risk for a semi-arid country to use less water in every aspect. For this reason, 2023 plans are sensible in this manner with investing more in solar and wind farms.

Table 7. Renewable Investment Amount Per Unit for Fuel Sources. (Guide to Invest in Turkish Renewable Energy)

	TOTAL INVESTMENT AMOUNT PER UNIT (TL/MW_M)
Wind	2,500,000
Solar	3,000,000
Geothermal	2,100,000
Biomass	1,900,000
Hydropower	2,000,000
Coal	1,500,000
Natural Gas	1,000,000

Although emissions, water consumption are essential factors, the other major factor is the cost. The values taken from the Presidency of the Republic of Turkey Investment Office show that coal and natural gas power plants are still cost-efficient compared to renewable energy solutions. In addition, renewable energy solutions with traditional methods such as hydro, biomass, and geothermal power plants are proved to cost less compared to wind and solar farms. To decrease the cost of the renewable energy projects, there are essential support founding and project are constantly given by the Turkish state, such as YEKA projects and many others.

Turkey is a half-island country surrounded by the sea in both south, west and north. Moreover, with the longest coastal area in Meditation, the second largest coastal area at the black sea, and the Islands sea in the West, there are many options for constructing an offshore wind farm. However, it has been seen from the figure below all those seas have significantly deep for construction and this comes with an economic cost that makes the projects unfeasible.

Figure 33 shows that depth of the three seas which are surrounding Turkey makes construction of offshore wind turbines economically and technically too difficult.

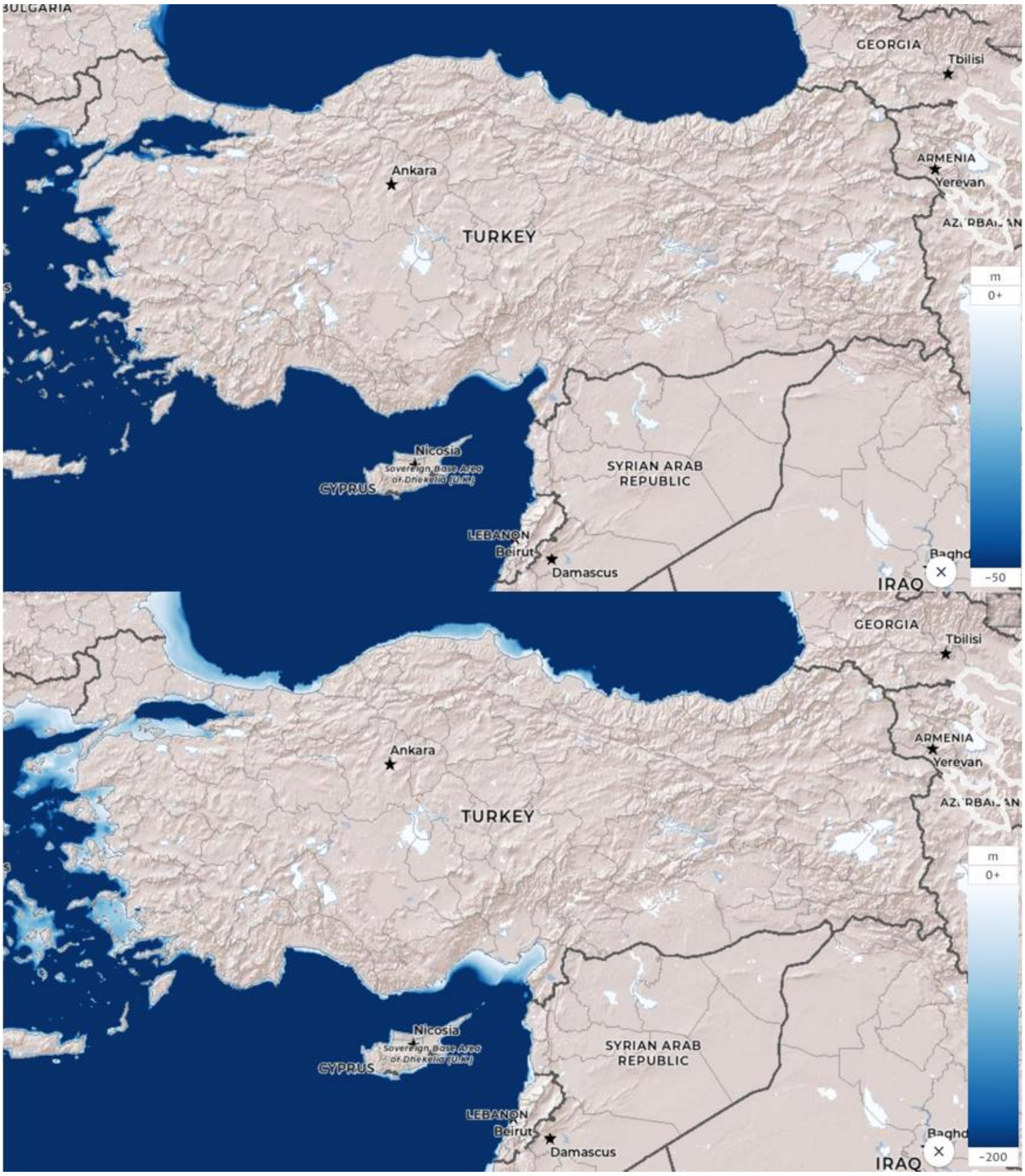

Figure 33. Depth of the coastal areas (Global Wind Atlas).

Figure 34 shows the deep water wind turbine variants.

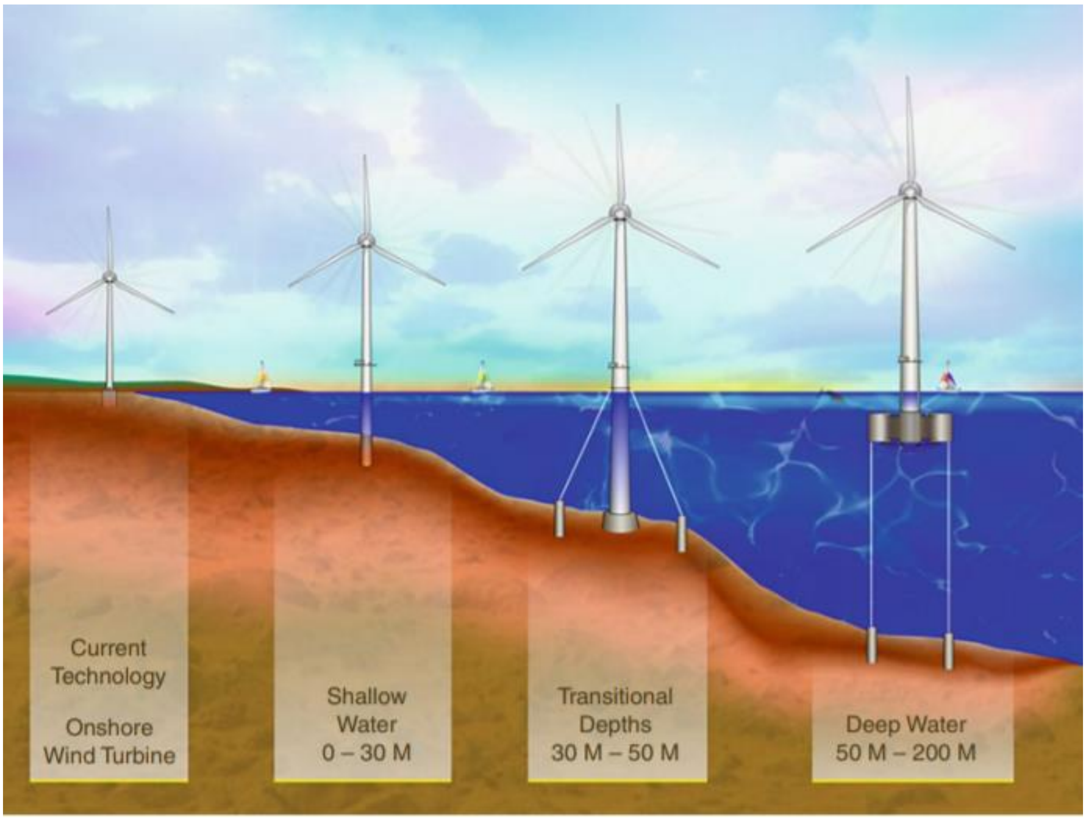

Figure 34. Deep Water Wind Turbine Development (Dalén, 2016).

As illustrated in the image above, between 50 m and 200 m are in the deep-water group. This means most of Turkey's coastal area needs a deep-water offshore wind turbine, or it can't be possible or feasible to construct. Figure 35 explains that there is a direct proportion between the depth of the sea and cost of the wind turbine.

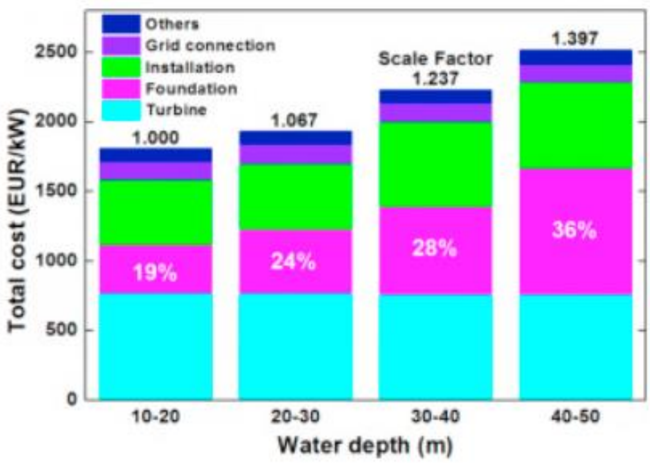

Figure 35. Cost of offshore Wind Turbine Projects (A review of foundations of offshore wind energy convertors: Current status and future perspectives, 2018).

7. NEW DETECTED GAS FIELDS

According to the first data from the According to the "Amasra-1 point" in the Black Sea, there is a substantial amount of gas in the region. In addition, Turkey found 405 billion cubic meters of gas in the Tuna-1 well in the Black Sea last year. This was the largest gas discovery in the Black Sea, and it was announced that its production could begin by 2023. The Turkish Ministry of Energy declined to comment on the Amasra discovery. However, Turkish President Recep Tayyip Erdogan hinted at the gas reserve in a television interview, announcing that he would deliver "good news" from the Black Sea coast on Friday. Previous announcements on the Black Sea gas fields had led to an increase in Turkish assets, from bonds to stocks. (“The natural gas reserves in the Tuna-1 zone of the Sakarya field have reached 405 billion cubic meters in total”, 2020)

When the Sakarya field reaches the production level it is expected to provide 30% of the gas needed by Turkey. The discoveries will also decrease Turkey’s energy import and could save an average of $6 billion annually (Erkul, 2021). Turkey's contracts with Russian Gazprom PJSC, Azerbaijani Socar, and Nigerian liquefied natural gas producers to supply approximately 16 billion cubic meters per year will expire soon (Evans, 2020).

The Sakarya Amasra-1 well, which was discovered by the Fatih Drilling Ship, contained 135 billion cubic meters of natural gas. As a result, the total reserve increased to 540 billion cubic meters in volume. When natural gas is ready for use, it will make a significant contribution to the growth of the Turkish economy. (Aydogan M, 2021).

Turkey intend to bring natural gas from the sea to the land in three stages, starting with the first. It is the first stage that will see the installation of natural gas production systems beneath the seabed. The second stage will consist of a facility that will process natural gas on land and prepare it for consumption. The pipeline, which will connect the system at sea to the facility on land, will be the third stage of the project's development. (Jakovljev, 2020)

This is also an opportunity to use natural gas power plant with using hybrid fuel both natural gas+ biogas (Figure 36).

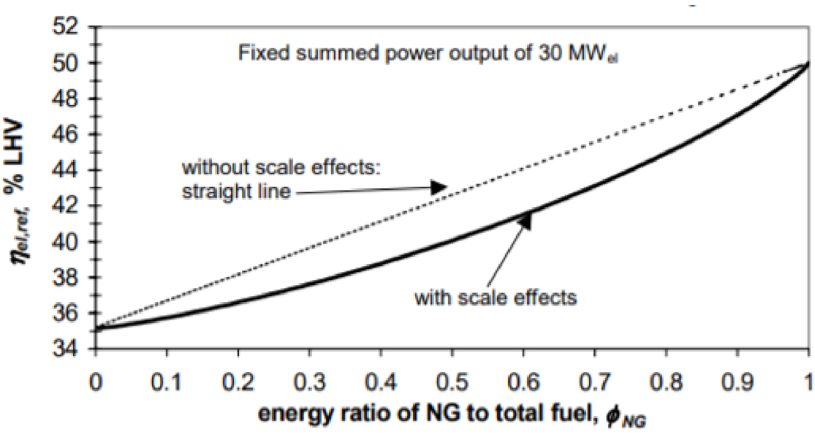

Figure 36. Natural Gas Hybrid Combined Cycles. Single-Fuel Efficiency Values (Petrov., 2003).

8. RESULTS AND DISCUSSION

8.1 Current Study

This research analyzed that the world is about the edge of an increased energy, clean water, economic, environmental etc. series of problems also Turkey. For this both global and local problem there are certain thing can be made by Turkey have been found. The necessity of changing for renewables with also considering Turkey's capabilities without damaging the Turkish economy and causing clean water problem have been discussed. The outputs were showed that Turkey is using it's bioenergy capacity at a low level and if the capacity will be increased using surface irrigation method this will cause more negative effect than the positive effect. The solution for this problem is that increasing bioenergy capacity using drip irrigation method will have a positive effect on clean water resources, air quality level, energy independency, and economy as it is not an imported source of energy. Moreover, it has been found that hydro power and geothermal power plants have the same over water consumption problem for this reason it will cause problem to increase their capacity without considering Turkey's drought problem. However, it has been found that solar and wind farms are ideal for countries with drought problems as a water efficient solution. But in the other side it has discovered that cost of the renewable energy power plants still more than the fossil fuel power plants and this is another big challenge for Turkey. Especially offshore wind farms are found economically and technically a big challenge for Turkey. Furthermore, for economic reasons new detected natural gas sources in Turkey is certainly needed for boosting Turkish economy. For that reason, planning should be balanced with considering all of these aspects for the good of Turkey and the world.

8.2 Future Work

The World's and Turkey's population, energy demand are increasing and water, food and energy scarcity will be a bigger problem both in local and global level. For this reason, further researches should be made in the area of more efficient bioenergy generation in Turkey and for the world. Finding the ways to decrease the cost of building new renewable energy power plants is also essential in this road. It’s also an important note that in future hybrid power plants will also gain an important status because of their flexibilities for the demand. This is also one of the aspect have found in this research flexibility is needed using different solutions in a combined and compact way to create more efficient and environmental solutions both for Turkey and World. Last but not least energy storage technologies are missing key for the boosting the renewable energy industry.

9. CONCLUSIONS

In this study, potential solutions and challenges for the economic and technical aspects of a Turkish energy system independency and sustainably have been identified, analyzed, and discussed. Turkey's vast green energy potential was one of the main aims, which included bioenergy technologies, solar PV, hydropower, wind energy, and bioenergy, among other renewable energy technologies. Turkey's total sunshine duration is determined as 2640 hours in the annual calculations, and the average total solar radiation intensity is 1311 kWh/m²-year which is considerably higher than most countries when compared to European countries. This shows that solar energy is an asset critical for Turkey's energy independence and this potential should be used. This thesis showed that inefficient irrigation methods used in agriculture is the main challenge for the drought and lack of capacity usage in bioenergy. Also drip irrigation have been found most efficient method for increasing water efficiency in agriculture which should be used to boost up capacity usage in bioenergy field. It’s also seen that the necessity of decrease in the energy import for this reason renewables and bioenergy ought to be used. In addition to this, new detected natural gas fields can decrease the consumption of coal and this results in economical gain with more eco-friendly fossil fuel. As a result, a better future exists for the good of people and the environment economically with renewables.

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