MSc Program
Renewable Energy Systems

Renewable Energy Sources in Turkey: Statues Quo and Future Prospects

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“Master of Science”

supervised by
DI. Dr. Demet Suna

Denis Üzelgecici, BSc

01028620

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Affidavit

I, **DENIS ÜZELGECICI, BSC**, hereby declare

1. that I am the sole author of the present Master's Thesis, "RENEWABLE ENERGY SOURCES IN TURKEY: STATUES QUO AND FUTURE PROSPECTS", 110 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

As a country highly dependent on foreign fossil fuel sources, Turkey experiences many problems due to its increasing energy consumption in parallel with anincreasing population and rapid economic growth. Foreign fossil fuel dependency adversely affects the sustainable development of the country by hindering its economic development. Because of this, the renewable energy sources of the country should be evaluated and developed as soon as possible. The prioritization of the development of renewable energy sources to increase their contribution to electricity generation is a multi-criteria decision-making problem. Both energy and environmental goals need to be considered in selecting the most suitable renewable energy sources. In Turkey, current energy generation is not enough for the existing energy needs and in addition, electricity demand is expected to increase by 4–6 percent annually until 2023. Therefore, the government aims to increase the ratio of renewable energy resources (RES) in total installed capacity by 2023.

In this study, it has been consider which renewable energy source; solar, biomass, geothermal, wind, or hydropower, have been given priority to increase its contribution to Turkey's electricity generation.

In teh first part of this thesis, it has been examine the current situation of electricity as demand and power generation, the power market, Turkey's electricity transmission system and an outlook through the future has been discussed.

In the second part, the approval process has been looked for licensed and unlicensed project applications which has been renewed and supported in recent years due to new government guidelines.

In the next part of the study, it has been examine clean, safe environmentally friendly energy sourses, whose usage is rapidly increasing globally, and it has been looked at the past, present, positive and negative aspects of solar, wind, biomass, hydrogen, geothermal and, hydroelectric energy sources have been analyzed. Turkey has a big potential for renewable energy sources, and past and present use cases are discussed. In addition, renewable energy use and new and different application examples are included.

In the last part of this thesis a short explanation of levelized cost of energy (LCOE) has been presented. For each renewable energy system, which are based in Turkey, a LCOE calculation has been made and the results has been discussed.

All of these issues will be evaluated solely in terms of presenting an overview of the new growing

sectors of energy production, and it has been also provide an overview of the development of energy transmission infrastructure in Turkey.

In conclusion, it is thought that a variety of renewable energy sources will obtain their deserved share in total energy consumption by ensuring necessary economic growth in line with their potentials considering the negative externalities caused by fossil fuels and endorsement of economies of scale.

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1 Introduction

1.1 Motivation

The point of this thesis is to study the energy condition in Turkey. Of importance is the quantification of potential energy production to predict how much of the electricity needs can be successfully met by renewable energy sources. In addition, there is an urgent need to develop the Turkish renew- able energy sector in order to reduce Turkey's energy dependence on foreign resources. This work will also demonstrate the value of promoting renewable and green energy systems and compare five renewable energy sources that represent the solar, wind, hydro, geothermal and energy potential of biomass in Turkey.

1.2 The Objectives and Key Research Questions

The main objective of this work is to have a prediction the future of renewable energy in Turkey given the present information and resources. Energy topic of vital importance in terms of Turkey's economic growth, particularly in renewable energy technologies used in electricity production have been studied. With today's technology standards, the of advantages and disadvantages to the Republic of Turkey have been investigated.

The study will initially provide a general overview of the energy situation in Turkey, its forecasts and the planned 2023 strategies. The focus will be on renewable resources and electricity from solar wind, hydro, geothermal and biomass. Later, these topics will be discussed in three main parts, considering the processes as well as the technical and financial potential for all renewable energies. The technical potential will be analyzed in terms of which parts of the country have the highest capacity for renewable energy. A levelized cost of electricity has been made in this study, where the parameters have already been calculated from the existing power plants, in order to have a better understanding for the potential for the five renewable energy technologies. With this objective, the thesis is aimed to find answers to the questions which have been mentioned bellow,

1. What will Turkey's energy generation sector (possibly) be like in the future?
2. Where does Turkey's main potential lie (in terms of renewable energies)?
3. Why does Turkey not apply the use of renewable energy and what are the main problems?
4. How will the energy generation sector develop?

1.3 Description of Methodology

A descriptive research methodology was used for this study. To obtain the data needed to analyze the sector and policies in the field of energy production in Turkey, as well as a review of the literature was conducted to collect data on electricity generation systems and international statistics to support the arguments of the report. Most of the secondary data were reviewed through the university library using a wide range of information sources, such as the university's library system, academic and commercial journals, databases and Internet search engines.

The Regulations and the permitting process for the RES section were based on a qualitative approach based on the literature of government websites, as well as the published national newsletter. In addition, extensive research on the most common legal challenges of renewable energy projects being developed helped to have a better overview of legal aspects.

The Potential RES section in Turkey was achieved by retrieving information from existing quantitative studies, such as IEA and government resources, and integrating them with qualitative research. Different studies were found on the current situation of RES and the potential of electricity for future use.

In a systematic analysis of comparable projects and the development of renewable energy policies, the Standardized Energy Cost (LCOE) methodology was used to measure the total financial cost of generating electricity per megawatt hour between renewable energy systems over the life of the projects.

Since the comparison of complex sectors of power generation cannot be a case study and depends largely on long-term developments and policies, the research has been chosen as descriptive research approach and tried to analyze the developments as detailed as possible. The bibliographic survey is designed to list the potential of renewable energy sources in Turkey.

1.4 Hypothesis

Turkey can use more of its own renewable energy potential, resulting in the reduction of CO_2 emissions, dependence on fossil fuel imports and replacing some of its fossil fueled power stations with new forms of energy systems. energy generation.

The power generation sector in Turkey will face major changes in the near future. The current government plans to focus Turkey's power generation on fossil fuel energy. Conventional power plants, operated with fossil fuels, compensate for lost capacities. However, this practice significantly increased Turkey's CO_2 emissions. Security of supply is the most important point for the government. However, the issue of sustainable and independent energy generation is crucial for future developments.

2 State of Art Electricity in Turkey

2.1 Electricity Demand and Power Generation

Turkey has been one of the fastest growing economies in the world in the 21st century. Gross Domestic Product (GDP) is the total monetary or market value of all the finished goods and services produced within a country's borders in a specific time period. GDP growth rates between 6% (before the financial crisis in 2009) and 4.5% (since 2009) have translated into an electricity demand increase of 7% annually during the first decade, and 4-5% in recent years. Gross electricity consumption in Turkey has increased from 175 TWh in 2006 to 278 TWh in 2016. Peak load, which was 27.5 GW in 2006, almost reached 44 GW by the end of 2016. A gigawatt (GW) is equivalent to one billion watts. The development of peak demand and gross electricity consumption between 2006 and 2016 are presented in Figure 1. (Source: Teias planlama ve stratejik yonetim dairesi, 2017)

Electricity demand in Turkey peaks in the summer. The peak power demand season in Turkey switched from winter to summer in 2008, due to the increasing and widespread utilization of air conditioning for summer cooling, as well as irrigation of agricultural land. As electricity is still widely used for heating in winter, the winter peak is only about 5% lower than the summer peak. Demand is more and more centralized in urban conglomerates in the center-west and west of the country, a trend that is bound to continue. (Source: Teias planlama ve stratejik yonetim dairesi, 2017)

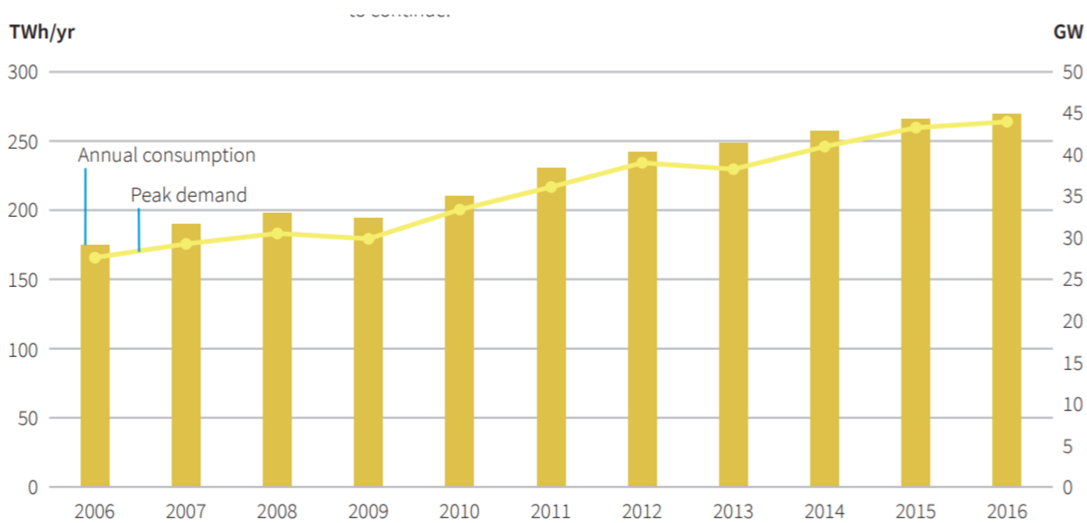

Figure 1: Peak demand and gross electricity consumption, 2006-2016 (Source: Teias planlama ve stratejik yonetim dairesi, 2017)

Generation capacity even outstripped demand growth and went up from 32 GW in 2002 to 77.8 GW at the end of 2016. The remarkable additions to the generation park, which came to a large extent from private investments enabled by the liberalization of the power market, has swept away concerns about undersupply in the market, and has led to considerable overcapacities. As most of the growth of the past decade was due to investment in large hydro and gas fired power plants, Turkey's power generation park is dominated by hydro (26.7 GW) and natural gas (25.5 GW) plants, followed by lignite (9.3 GW) and hard coal (8.5 GW); all lignite and 1 GW of hard coal fired power plants are fueled by local resources, while most hard coal power plants operate on imported fuel (7.5 GW). The development of peak demand and installed capacity in terms of primary sources is presented in Figure 2. (Source: Elektrik Istatistikleri, 2019)

One way to characterize the power output of the plant over a period (usually one year) is to specify how many hours it will take for a plant to produce that much energy when it is operating at full capacity during that time. This is the amount of full load hours(FLH). When it comes to the output of the plants, thermal generation features more prominently, due to the higher full load hours of coal and lignite plants in particular. The generation mix 2016 was dominated by natural gas power plants (33%), lignite and coal (31%); hydro contributed 25% to overall supply. The contribution of the different power generation sources is illustrated in Figure 2. (Source: Elektrik Istatistikleri, 2019)

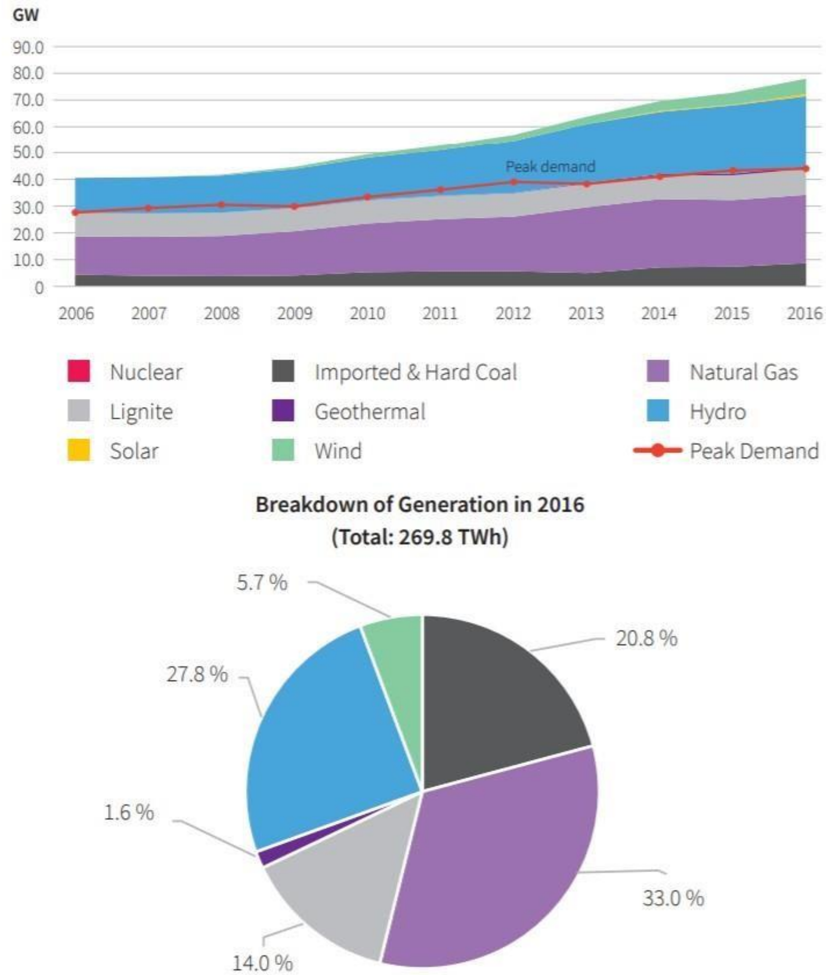

Figure 2: Breakdown of total installed capacity and electricity generation by source, 2016 (Source: Elektrik Istatistikleri, 2019)

A Power Exchange (PX) correlation is a relational dynamic when a partner decides to free or control authority. The electricity market is based on a Power Exchange (PX) market operated by Energy Exchange Istanbul (EXIST). Energy Exchange Istanbul (EXIST) is an energy exchange company legally join-stocked under the Turkish Electricity Market Law and imposed by the Energy Markets Operation License privileged by the Energy Markets Regulator Authority (EMRA) of Turkish Republic. The main function of this market is to identify the most economically efficient dispatch of available power generation. Final obligations and dispatch of power plants are determined by the national dispatch center of Turkey's TSO TEIAS in day-ahead and intra-day balancing markets, ensuring system operation and the availability of sufficient amounts of spinning reserves. (Source: ENTSO-E, 2019)

2.2 The power market with dispatch and redispatch in Turkey

The Electricity Market Law (EML) of 2001 established a wholesale electricity market in Turkey. EML, the design of bilateral agreements based on the market, Turkey would be the best way to reach citing competition in the energy industry (EMRA, 2003). Following the adoption of EML, EMRA was established and previously vertically integrated production and transmission divisions were separated.

The electricity market is based on a Power Exchange (PX) market operated by Energy Exchange Istanbul (EXIST). The main function of this market is to identify an economically optimal dispatch of available power generation: As generators bid at their marginal cost, a merit order is created, and generators receive production orders according to their offers, until demand of that specific hour is met. Network and reliability constraints are ignored in this day-ahead market clearing. (Source: Day ahead energy market, 2019)

Market Clearing Price (MCP) is the price of a product or service where the quantity given is equal to the desired amount, also called the equilibrium price. The example in Figure 3 shows the identification of the Market Clearing Price(MCP), which is stabled on an hourly basis in the day-ahead market, based on the bids of generators and requests of consumers in the market for this hour. The intersection highlights shows where demand requests and generator bids meet corresponds to the MCP for that hour.

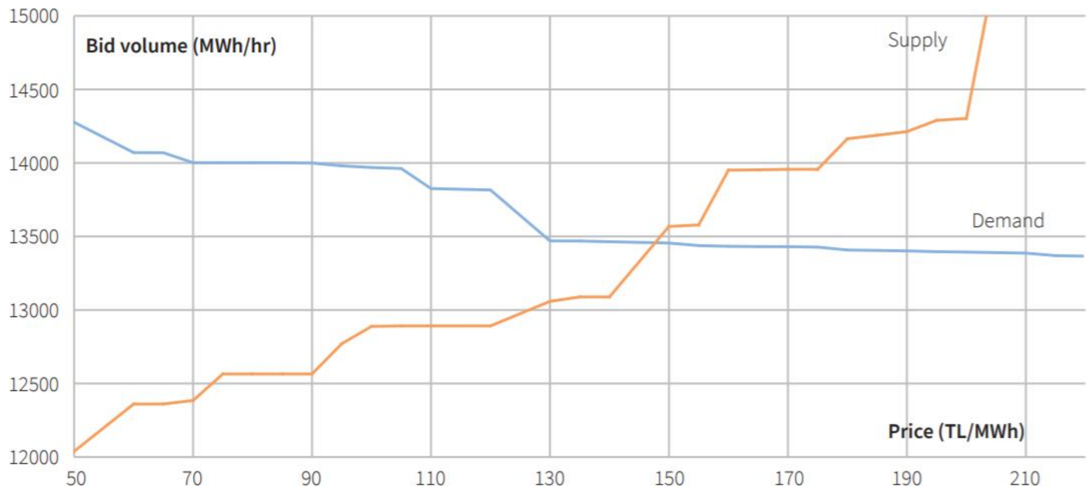

Figure 3: Day ahead market clearing for a specific hour (Source: EPIAS, 2017)

Security and reliability criteria are taken into account only in a second step, after market clearing: Final commitment and dispatch of power plants are determined by the national dispatch center of TEIAS in day-ahead and intra-day balancing markets, as illustrated in Figure 4. The security criterion, laid out in the grid code, is based on the N-1 contingency criteria: In case of failure of any single network equipment, undisturbed operation of the entire needs to be guaranteed. In addition, reliability criteria need to be fulfilled, including the availability of sufficient amounts of spinning reserves, as defined by regulations introduced by ENTSO-E. ENTSO-E, the European Network of Transmission System Operators, represents 43 electricity transmission system operators (TSOs) from 36 countries across Europe.(Source: ENTSO-E, 2016)

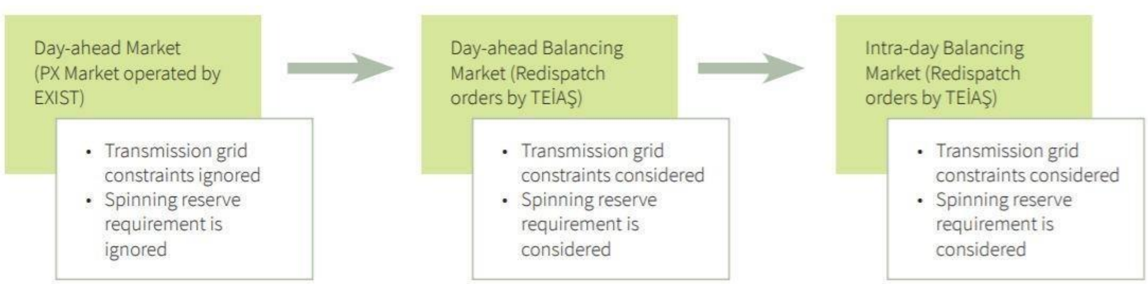

Figure 4: The responsibilities of TEIAS in PX day-ahead and intra-day balancing markets(Source: ENTSO-E, 2016)

TEIAS stands for Turkish Electricity Transmission AS and is responsible for the Turkish transmission system operator.

Three different kinds of redispatch and commitment orders are given, if necessary, for either achieving demand-balance at this hour (called “Code 0” order), for avoiding network constraints due to branch overloading (“Code 1” order) or for meeting spinning reserve requirements (“Code 2” order). The system marginal price(SMP) is calculated starting from the lowest bid price to regulate if there is energy shortage in the system, or starting from the lowest bid price in case of excess energy in the system, taking into account the net instruction volume. According to the current market rules, redispatch costs are defined as system marginal prices (SMP) and allocated to all market participants according to their consumption and peak demand level in power purchase agreements. Redispatch orders according to the different codes mentioned on a sample day, January 21, 2017 are presented in Figure 5.(Source: Exist epias transparency platform, 2019)

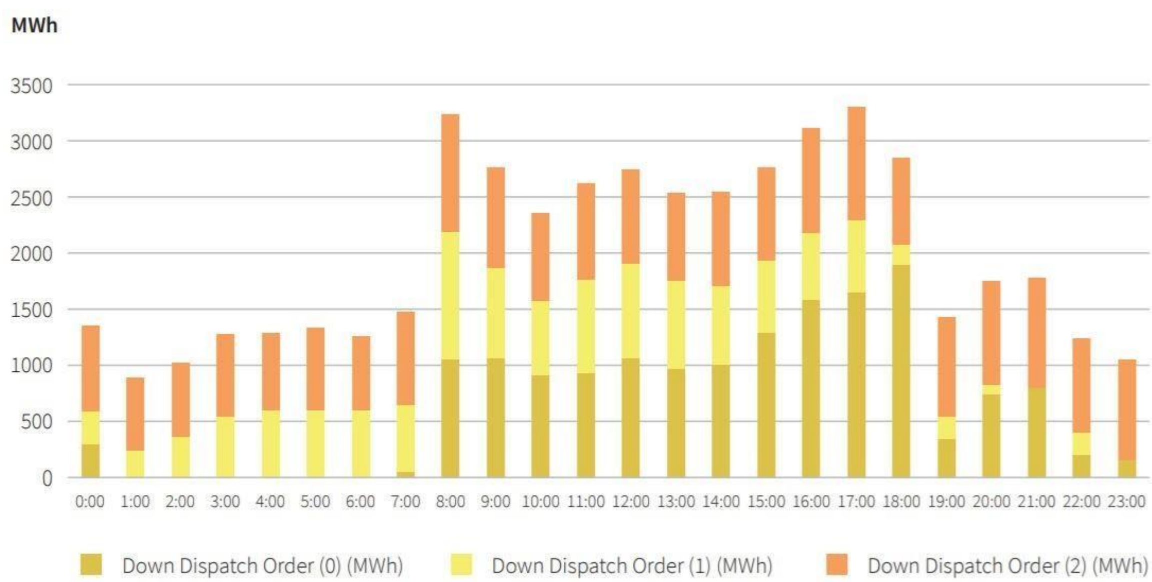

Figure 5: Redispatch orders on January 21, 2017 (Source: Exist epias transparency platform, 2019)

In Figure 5; the brown color as shows down dispatch order(0)(MWh),the yellow color shows down dispatch order(1)(MWh), the orange color shows as down dispatched order(2)(MWh). The sum of the down dispatch orders is around 1300MWh from 0:00 to 07:00. The sum of the down dispatch has risen to an average of 3000MWh from 8:00 to 18:00. From 19:00 to 23:00 the down dispatch has been down to around 1500MWh.

As a system operator, TEIAS is actively involved in managing its operating costs by reallocating resources in short-term markets (dayahead and intraday markets) based on requests from market participants to balance system load, manage congestion, and maintain system security and reliability.

2.3 The main characteristics of Turkey's electricity transmission system

The transmission grid is the backbone of power systems, connecting the different regions of the country, enabling long distance power transport, for example of hydropower generated in the East of the country, to the main demand center in the Western part. Kilovolt (kV), is a unit of electric potential. In Turkey, it is composed not only of the 400 kV system, but important transmission functions are also covered by the 154 kV system, as illustrated in Figure 6. Therefore, both systems are analyzed in this study. The state-owned company TEIAS is the sole owner of transmission assets in Turkey and responsible for both new investments in the transmission infrastructure, as well as system operation. As a monopoly, the company is regulated by EMRA with a cost-based approach to revenue limitation. (Source: Emra lisans Yonetmenligi, 2019)

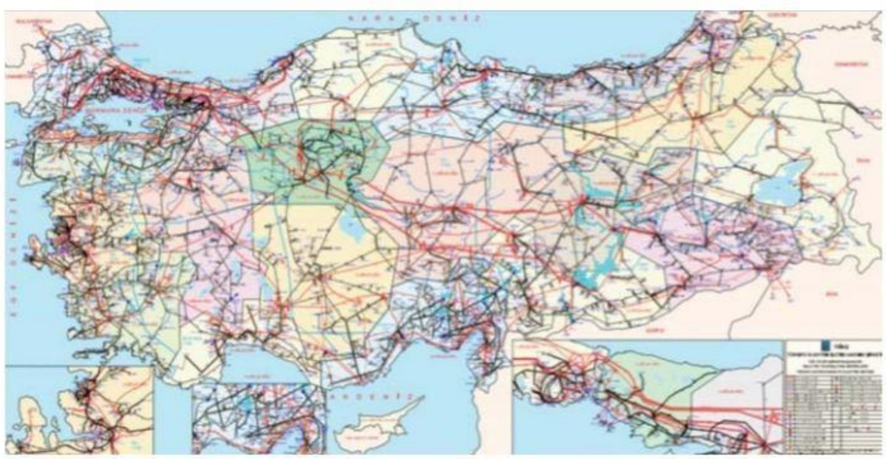

Figure 6: Map of high voltage transmission network, interconnections, thermal and hydropower plants (Source: Emra lisans Yonetmenligi, 2019)

TEIAS is required to safely operate and expand its system according to the needs of market participants. In order to carry out its duties, TEIAS prepares detailed investment plans and a capital expenditure budget. The plans and the corresponding budget are reviewed by the regulatory authority of Turkey. The proposed annual investment cost is recovered through use of transmission system charges.(Source: Use of transmission charges, 2016)

Turkey’s total electricity import and export amounts in 2016 were 6.4 TWh and 1.4 TWh, respectively. That is, net import is 5 TWh, which corresponded to 1.8% of total consumption (278.4 TWh) in 2016. Turkey is largely self-reliant in terms of electricity supply, while exchange with neighboring countries does balance supply and demand locally. The terawatt hour (TWh) is a composite unit of energy equivalent to one terawatt (1 TW) of power sustained for one hour. (Source: IEA, 2016)

The electric power system of Turkey has been synchronized with the ENTSO-E through 400 kV transmission lines with Bulgaria (two lines) and Greece (one line) since September 2010. The main advantages of the interconnection with the ENTSO-E system include grid frequency stability and sharing of spinning reserves among the ENTSO-E countries. The thermal capacity of the lines exceeds 1.500 MW, however the transfers are limited due to dynamic concerns and network constraints within Balkan region. Megawatt (MW) is used to measure the power of a power plant or the amount of electricity needed for the entire city, one megawatt equals one million watts. (Source: Tanidir et. al., 2010)

To the East, interconnections do exist with neighboring countries Syria, Iran, Iraq and Georgia. However, systems are not synchronized and interaction with these systems can therefore be controlled: The electric power export to Iraq and Syria and the import from Iran are through isolated 400 kV systems. The Power Exchange with Georgia started in 2014 through controllable, High Voltage Direct Current (HVDC) back-to-back converters located close to the border. HVDC infers for High Voltage Direct Current, a proven technology used to transmit electricity over long distances with high transmission lines or submarine cables. (Source: ENTSO-E secretariat, 2004)

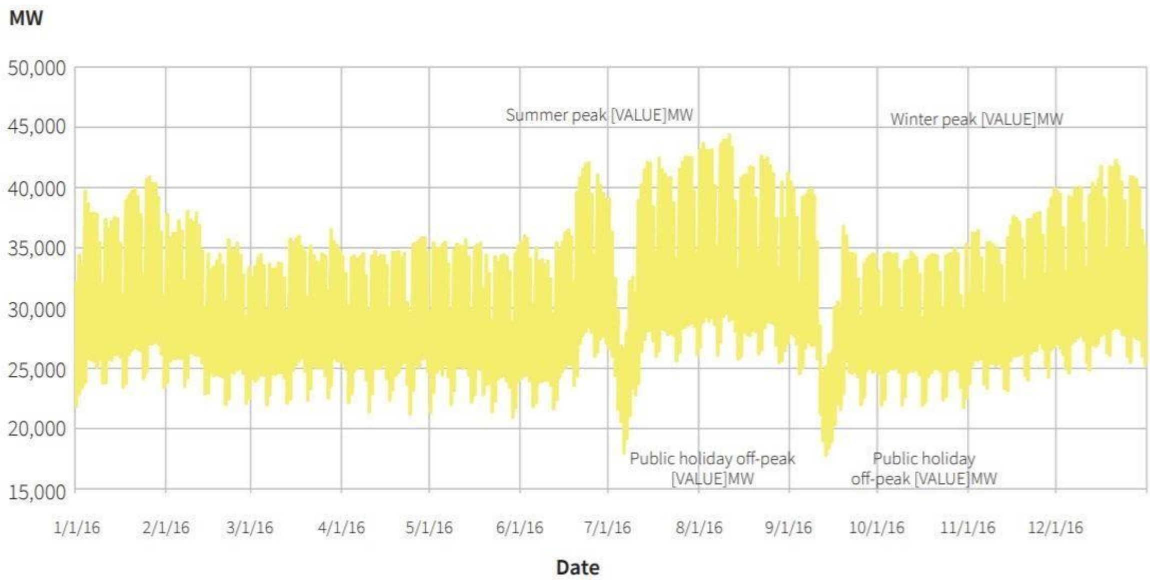

Figure 7: Summer and winter peak and religious holiday off-peak demands, 2016 (Source: ENTSO-E secretariat, 2004)

Another characteristic of Turkey's power system is that it has relatively large load deviations, mainly due to the use of steel arc furnaces. Arc furnaces, which require generation capacity of several hundred megawatts during the melting process, are widely distributed in the country. They commonly cause random and sharp changes in load which affect the power flows on interconnection lines and Area Control Error (ACE) in Turkey. The Area Control Error (ACE) is the difference between planned and actual electricity generation in a control area on the power grid, taking into account the frequency grid. Total change in power flows on the interconnectors of Turkey between Greece and Bulgaria sometimes exceeds 900 MW in less than 30 seconds, particularly when these large industrial loads are coinciding. These load changes are balanced by overall ENTSO-E rotating inertia until the frequency control via automatic generation control (AGC) acts. In an electric power system, automatic generation control (AGC) is a system for regulating the power output of multiple generators at different power plants, in response to changes in the load. These rapid changes in the demand forces TEIAS to utilize a large amount of frequency control reserve. Accordingly, the operators constantly monitor and are very sensitive to available reserve in the up/down direction as well as the changes in demand. Therefore, keeping sufficient spinning reserve and flexible generation is a major concern. (Source: ENTSO-E secretariat, 2004)

2.4 The regulatory framework for renewable energy investment

In its vision for 2023, the government of Turkey has set several targets for the renewable part of the energy sector. The primary objective is to increase the share of renewable energy sources for electricity generation to at least 30 percent by 2023. Specifically, the following renewable energy(RE) targets have been set:

- 34 GW capacity of hydro
- 20 GW capacity of wind
- 5 GW capacity of solar

The main requirement to reach these targets is to support renewable generation in the electricity market. In order to achieve this, significant reforms have been undertaken since 2005, when the first law on renewable energy was enacted, as shown in Figure 8. (Source: Turkey Electricity Market, 2019)

Figure 8: Turkish Electricity Market Reforms and Laws, 2001-2017 (Source: Turkey Electricity Market, 2019)

Investments in renewable energy technologies remained limited between 2005 and 2010, as the regulatory environment and in particular Feed-In Tariff levels were considered not attractive enough by investors. In order to encourage investment, the government of Turkey decided to amend the existing Law No. 5346 in 2010, which provided for more attractive feed in tariffs. Under the Law No. 6094, technology specific Feed-In Tariffs (FiT) were introduced. Accordingly, FiTs have been provided to renewable energy facilities that were commissioned before 31 December 2020 for a period of ten years with the tariff levels (quoted in US dollars to avoid exchange rate risk) shown in Table 1. Additionally, local content bonuses are offered to encourage local value creation. (Source: IEA, 2016)

Renewable Energy Type	Feed-in Tariff (USD ct/kWh)	Domestic production support (USD ct/kWh)	Total (USD ct/kWh)
Hydro	7.3	2.3	9.6
Wind	7.3	3.7	11
Geothermal	10.5	6.7	20
Biomass	13.3	9.2	22.5
Solar	13.3	5.6	18.9

Table 1: Feed in tariffs after Law 6094 in 2011 (Source: Renewable Enerji Sources in a Livable World, 2013)

In 2013, EMRA, announced the renewal of renewable energy support mechanism (YEKDEM). YEKDEM has been established under Turkey's domestic and national energy policy. The Government aims to make renewable energy resources more attractive for energy investors with YEKDEM. The retail companies assigned by EMRA have been required to purchase the produced electricity only from manufacturers which are subject to this mechanism. Renewable energy investors may select annually in October, whether they will operate under the day-ahead market regime in the following year (which also yields balancing requirements) or prefer direct sale according to the FiT plan (instead of trading on the market, and free of balancing requirements). With high market prices in the past, most wind and hydro investors had originally opted to operate under the market regime; however, since 2015 (Figure 9), when wholesale prices dropped below FiT levels, they have moved almost entirely under the FiT regime. (Source: Renewable Enerji Sources in a Livable World, 2013)

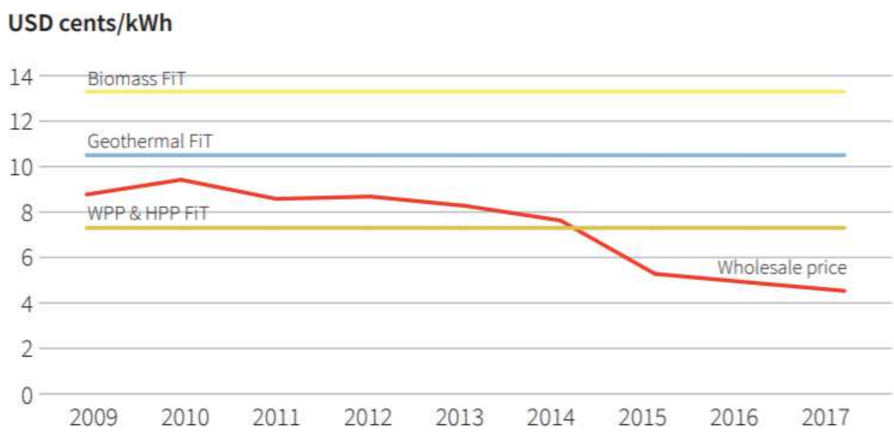

Figure 9: Average wholesale market prices and the FIT, 2009-2017 (Source: Renewable Enerji Sources in a Livable World, 2013)

A Feed-In Tariff (FIT) is a regulatory framework designed to stimulate ongoing investment in energy technology. In the figure 9; the yellow line is the biomass FIT, the blue line is the geothermal FIT, the brown line is the wind power plant and hydro power plant FIT and the red line is the wholesale price from 2009 to 2017. While the FIT for biomass, geothermal, WPP and HPP has be constant while the wholesale price has been reduced over the year.

According to Turkey's market regulation, installed power generation license from EMRA is required to get the big power plants 1 MW. Generation resources with a maximum installed capacity of 1 MW can advance from the Feed-In Tariffs without having to undergo the enduring licensing procedure. The auction regime for grid connection in particular has become a major bottleneck for larger solar investments. This is due to the fact that bidders, initially focused on securing grid connection entitlements because of the limited number of capacity, then delayed implementation as they waited for further PV system price decreases which would make their offers economically viable. A photovoltaic system, as well as a PV system, is a power system designed to provide usable solar energy through photovoltaics. As a consequence, almost all solar investment up until now fell under this “unlicensed regime”.(Source: Renewable Enerji Sources in a Livable World, 2013)

Supplementary incentives set for all renewable energy generation investment include an 85% discount in the treasury and lease fees for 10 years after commissioning; 99% discount for the licensing fee and the annual license fee for first 8 years of operation; grid connection priority and custom taxes exemptions.(Source: Renewable Enerji Sources in a Livable World, 2013)

Although the support scheme has increased investment in renewable energy generation in Turkey, there are still major barriers that cut investments short. These relate to the short period of feed in tariffs of 10 years (in many countries, FiT cover 15-20 years) and uncertainty on the period post-2020. The fact that renewable energy generators, who participate in the YEKDEM, do not have balancing responsibility, increases overall system cost and weakens the cost argument in favor of renewables in the discussion. (Source: Renewable Enerji Sources in a Livable World, 2013)

In 2017, a new hedge model for renewables, the Renewable Energy Designated Area(REDA) mechanism, was introduced in order to bring expenses down for renewables generation and incentivize local manufacturing of renewable generation assets in Turkish Republic. Public and government owned land that is categorized as highly suitable the renewable energy generation maybe defined as REDA. Within REDA, a large generation capacity of either wind or solar (1 GW in the first two tenders) is assigned to a single private consortium through tenders. Beyond the size of the investment, which shall allow for economies of scale, investors benefit from additional exemptions:(Source: Use of transmission charges, 2016)

- Renewable energy investments shall be exempt from customs tariff and value added tax for their investment costs (imported solar panels are not within the incentive scope)
- Lower license fees (only 10% of licensing fees) and annual license fee exemption for the first eight years of the operations
- Network connection priorities
- Simplified project preparation and land acquisition procedures
- For the first ten years of the investment and operation periods, an 85% discount is applied to the cost of right of easement, usage right and rent.

REDA tenders in 2017 are in line with Turkey's domestic and renewable energy strategy. The kilowatt-hour (kWh) is a unit of energy equal to one kilowatt (1 kW) of power expended for one hour (1 h) of time. The wind tender resulted in a highly competitive electricity price of USD 3.48 ct/kWh. This compares to USD 10.3 ct/kWh under the YEKDEM regime and is 40% below 2017 spot market price. (Source: Renewable Enerji Sources in a Livable World, 2013)

The 2017 tender for the 1 GW Karapınar solar PV REDA, won with USD 6.99 ct/kWh. As part of a project to build a solar power plant in Karapynar, Turkey, a plant will be built with a minimum capacity of 500 MW photovoltaic modules per year, and research and development will be carried out over the next 10 years. (Source: Use of transmission charges, 2016)

2.5 Outlook for the future

Several trends that have shaped the power sector in the past decade are expected to continue, and additional drivers are becoming apparent. Demand on Turkey's electricity market will continue to grow as industrialization and urbanization expand. Official figures expect growth between 4% and 5.5%. (Source: IEA, 2016)

According to the Ministry of Energy and Natural Resources, the total amount of investment required to meet the energy demand in Turkey by 2023 is estimated to be around USD 110 billion, more than double the total amount invested in the last decade. The private sector will continue to play an important role in creating new power generation and, developing the distribution system. Public attitudes will play a role as well, especially when it comes to adding large hydroelectric dams and attracting new investment in nuclear, lignite and renewable energy power stations. (Source: Republic of turkey prime ministry, 2019)

The past focus on gas and hydro technologies stands to experience a major shift. The potential for additional large hydro plants is decreasing, and increasing gas imports may disrupt the trade balance, raise import dependence and create competition with non-power sectors fuels. The goal of diversifying the power mix while prioritizing domestic production puts a special emphasis on local resources. These include both fossils (predominantly lignite) and renewables (solar, wind, geothermal and any remaining potential from hydro). The increase of renewable energy capacity is a key element of the government strategy for the long-term adequacy of electricity supply. Further drivers are the benefits of renewables for air quality, climate change mitigation and socio-economics. (Source: Turkey Electricity Market, 2019)

In its "2023 vision", Turkey's government has set several targets for renewables: These include 34 GW of hydro, 20 GW of wind and 5 GW of solar. Falling technology costs will increasingly drive the construction of more wind and solar PV installations. Globally, more generation capacity has been added since 2015 in renewable energy technology than in fossil fuel capacity. With further efficiency gains and cost decreases expected for wind and solar (10% and 25%, according to the IEA), this global trend will likely continue, as will strong interest from investors in bringing renewables capacity to the Turkey's market. The IEA, implies for International Energy Agency and it concentrate on providing energy sources and economic development while protecting the environment.

REDA (Renewable Energy Designated Area) tenders have demonstrated that there is great potential to reduce the cost of solar and wind generation in Turkey. This will make these technologies more economically viable/attractive for corporate consumers in Turkey. (Source: Turkey Electricity Market, 2019)

	2016[48]	Government Targets 2023*	ENTSO-E MAF (2025)**	Base Case 2026
Peak Demand	44 GW	N/A	N/A	69.2 GW
Consumption	278 TWh	440 TWh	458 TWh	439 TWh
Annual Demand Growth	-	7.3%	5.7%	5.1%
Imported Coal	7.5 GW	30.0 GW	8.2 GW	10.2 GW
Hard Coal	0.6 GW			0.6 GW
Lignite	9.3 GW		10.8 GW	13.3 GW
Natural Gas	25.5 GW	N/A	27.8 GW	28.1 GW
Nuclear	0.0 GW	9.3 GW	3.6 GW	6.8 GW
Wind	5.8 GW	20.0 GW	14.2 GW	14.0 GW
Hydro	26.7 GW	34.0 GW	36.8 GW	37.5 GW
Solar PV	0.6 GW	5.0 GW	6.0 GW	6.0 GW
Geothermal	0.8 GW	N/A	N/A	1.45 GW
Others	1.7 GW	5.0 GW	6.0 GW	1.7 GW
Total Installed Capacity	**78.4 GW**	**N/A**	**107 GW**	**119.6 GW**

Table 2: Official power sector projections / Base Case assumptions (Source: IEA, 2016)

3 Regulations and Permitting Process for RES

3.1 The permitting process of the unlicensed application

In this section, the permitting process of power plants will be explained from the start to the end. The process is made up of 8 steps for the application.

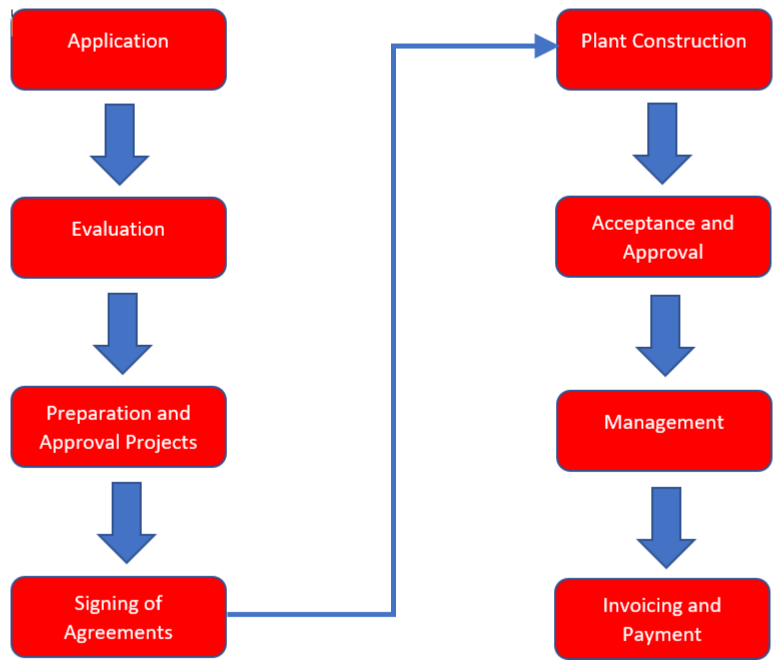

Figure 10: Process approval process for unlicensed applications (Source: Enerji Enstitusu, 2019)

3.1.1 Application

After the adjustment of Unlicensed Electricity Production in the Electricity, all documents provided in support of an application must be complete and can not be modified or revised after submission. The following documents are required for a successful application: (Source: Official Gazette No.28229, 2012)

1. The application form for the production connection depending on the RES. (Source: Official Gazette No.28782, 2013)
2. The original version or a notarized copy of the original property deed. If necessary, the initial lease of the property in question and maybe a copy of the title deed. If the land belongs

to a public authority or a forest, you must provide a certificate indicating that the land has the right to be used in this way, including the words ”This land has been approved for the construction of a power plant”.

3. The technical characteristics of the power plant presented in a single diagram.

4. The lease agreement with list of authorized signatures.

5. If the desired location is in an industrial zone with a distribution license, the complete application and all relevant supporting documents must be submitted simultaneously to the above mentioned Industrial Zone Authorities and distribution companies.

6. A consumption invoice and the withdrawal of bank application fees.

Applications are submitted to the distributor once a month and will be evaluated by a commission of at least three members. The majority is required for the vote on a specific application to be valid. In this forecasting process, applications containing incorrect or missing documents will be rejected.

The decisions taken by the commission in the pre-assessment phase are subject to explicit express authorization with a full explanatory report for approval. The competent authority shall then announce, by no later than the 5th day of the following month, all decisions before the assessment on its official scoreboard and/or online.

3.1.2 Evaluation

On the 5th day of each month, the distributor will receive all officially announced applications, as well as applications submitted to the Special Provincial Authorities.

- Applications are classified as high and low power plants. For high voltage, the distribution feeder in the transmission substation standards and for low voltage, the distribution substation standards criteria are followed.

- Each application is rated independently of its connection and system usage. Technical assessment is carried out in accordance with standard rules, regulatory requirements, relevant technical guidelines and compliance with relevant guidelines.

- The results of the technical evaluation are known to all and published in official scoreboards and/or on the websites of distributors.

- After the technical evaluation, the potential connection applications are placed in a priority evaluation step, where the conditions are verified according to the connection point and the connection center.

- The evaluations are completed according to the list of priorities. The technical results of applications that are not linked to the connection center criteria are accepted without being evaluated by the priority list.

- Approved and rejected applications will be announced on the 20th day of each month on the official scoreboards and/or on the websites of the Distributors.

- Alternative liaison proposals proposed by distributors are considered a positive response if the claimant makes changes in his statement. In 30 days of repot of the distributor, the holder of the application may declare his acceptance of the offer in writing and agree to comply with the terms and conditions proposed by the relevant distributor. Otherwise, the alternative proposal for the first application remains invalid.

- Within 30 days of the formal announcement of acceptance, the applicant will receive a "Acceptance Letter for the Connection Agreement". If the candidate does not receive confirmation of acceptance of the affiliation contract, consent to his application remains invalid.

- In some cases, it is necessary to get TEIAS entries according to the specified connection center. The application will then be held at the technical valuation level until further information is available from TEIAS.

- The acknowledgment letter of the connection agreement is issued by the distributors as a template.

3.1.3 The preparation and approval of projects

Candidates who receive a letter of confirmation will have 180 days to complete and submit the following documents, as well as system and usage agreements:

- All approvals, approvals, certifications, etc. required.

- Production Plants Projects that comply with the Power Plant Project Regulation published by the authorities or agencies approved by the Department of Energy. (Source: Official Gazette No.29221, 2014)

- Delays due to required certificates, permits and authorizations are not considered a reason to extend the 180-days submission deadline. (Source: Official Gazette No.28809,2013)

- The liaison project that connects the installation to the distribution system requires the approval of the relevant ministry or judicial authorities with the authorization to operate the ministry.

- In the case of unexpected delays caused by external third parties or factors beyond the applicant's control, he must obtain a document confirming this fact. The certification documentation must be submitted together with any other required project documents. In this case, the Distributor may extend the offer period to up to 3 months. However, there can be no guarantee that such extensions will be granted for the entire period of 3 months. The resulation of the distributor to grant renewals depends on the number of applications received at the time of application. During the last five days of the 180-days period, the status of the applicant will be officially announced on the official billboards and / or on the websites of the distributors.

3.1.4 The signing of agreements

Applicants submitting project proposals within 180 days will be asked to sign an agreement to enter the system and use the system within 30 days of submission. If candidates do not submit their documents on time, they will lose the right to sign an official contract with the distributor concerned.

3.1.5 Plant construction

Systems with an installed capacity of more than 11 kW must be properly designed for remote monitoring and control. The system owner must provide the necessary equipment for this. The distributor must have an appropriate communication infrastructure to enable remote monitoring and control. Remote monitoring and control systems must detect stop and start signals from the distribution company. Each remote monitoring and control system must be able to meet the minimum communication requirements of a remote monitoring system, the start of generator power, and the status of the network connection. These parameters should also include the means for monitoring the active and reactive power, the power factor, the current, the voltage, the frequency, the harmonics and the total error of the harmonics. The cost of this data communication will be charged according to the applicable laws.

The grounding of the plant must be in accordance with the distribution system grounding and the usual grounding requirements for other electrical installations of this size and its specifications. The protection system settings at the connection point of the plant must fit with the limits set out in Article 17.3 of the communication on the introduction of unlicensed electricity generation in the electricity market. (Source: Official Gazette No.28229, 2012)

When setting up a production facility with a low-voltage connection, located at the same location as the consumption point, two measuring devices are assigned. One of them measures the purchase and sale of energy by two-way transmission with the distribution system on an hourly basis, the other measures the energy produced in the plant itself. The high voltage connections are made according to the corresponding directive. Energy meters must be placed in easily accessible locations by the distribution company. The positions of the positioned pieces must be included in the project proposal. If the implementation of a suitable measuring system is to be completed, the distributor can determine the final locations of the meters to be installed. The construction period for non-hydro plants to be connected to high voltage is two years. For all other types of low voltage connected plants, the construction time is one year. (Source: Official Gazette No.30431, 2018)

3.1.6 Acceptance and approval

During commissioning and approval, the metering system is inspected prior to sealing and registration by sales managers and the commissioning and approval of metering systems is completed. If a production plant is operated parallel to the grid, the voltage fluctuation must not exceed 3.3%. For synchronous generators with a power of up to 500 kW, parallel commissioning with synchronization devices take place. For higher amounts, the requirements are specified in the liaison agreement.

3.1.7 Management

The protection, connection and other elements of the plant are checked and recorded periodically. The sales company can inspect the plant at any time. The recorded data must be made available to the company at regular intervals. A copy of this recorded data remains with the owner.

The plant should not provide power to the power grid that could disconnect it from the distribution network, even when trying to protect life and property against short-circuit currents or in the event of a power shortage. The isolated power plant of the network can supply the consumables independently of the sector.

The operator of the plant is obliged to disconnect the system from the power grid in mandatory operating situations until a solution can be found. However, at no time can a solution include operation that exceeds the allowed level. If the owner wishes to change the plant's power level or protection plan, the owner must make a formal request to the distributor and obtain the necessary approvals in accordance with the regulatory requirements and the news release.

3.1.8 Invoicing and payment

The energy production and consumption data is received every hour by the switches located at the interface between the production plant and the distribution system. Excessive amounts of energy are calculated by comparing the data on total energy input and total energy consumption. If the energy input is greater than the energy consumed, this data is recorded daily and monthly.

The payment will be made in Turkish Lira and will be determined by the exchange rate of the Turkish Central Bank on the date on which the energy is supplied. The following conditions must be met:

- The distributor determines the amount of excess energy depending on the resources paid daily under the Renewable Energy Sources Act.
- The total amount to be paid to unlicensed manufacturers for each billing period will be calculated and sent to the Market Financial Settlement Centre for the first six days of each month.
- The Market Financial Settlement Centre pays the distribution company, which pays manufacturers the amount calculated in accordance.

3.2 The permitting process of licensed application

According to the Electricity Market Licensing Order, there are seven different license categories. (Source: Official Gazette No.30431, 2018)

- Production license: A license privileged by EMRA for the production and sale of electricity in any existing or planned generation plant. The total share of a private company and its subsidiaries can not reach 20% of Turkey's total installed capacity.
- Car manufacturer license: a license granted to a legal entity that generates energy primarily for its own use.
- Car producer group license: a license granted to a legal entity that generates energy primarily for the consumption of its partners.
- Transport license: a license granted to a legal entity having a resistance of more than 36 kV for the transmission of electricity.
- Distribution license: a license granted to a legal entity with a resistance of more than 36 kV for the distribution of electricity.

- Wholesale license: a license granted to a legal entity responsible for the resale of electricity.
- Retail license: a license granted to a legal entity responsible for the sale of electricity to consumers.

The following Figure 11 describes a general licensing process that includes a contest to bid for tenders. In general, applications are sent directly to EMRA once the available capacity in one area has been allocated. They are tested according to their technical specifications and sent to TEIAS. In cases where there is more than one successful bid, a contest is held. Once the winner has completed all the necessary documents in time, he/she requests the EIA and receives a license. The applicant acquires the necessary forestry, land and building permits. In the final phase, the applicant receives approval from the Department of Energy and Natural Resources.

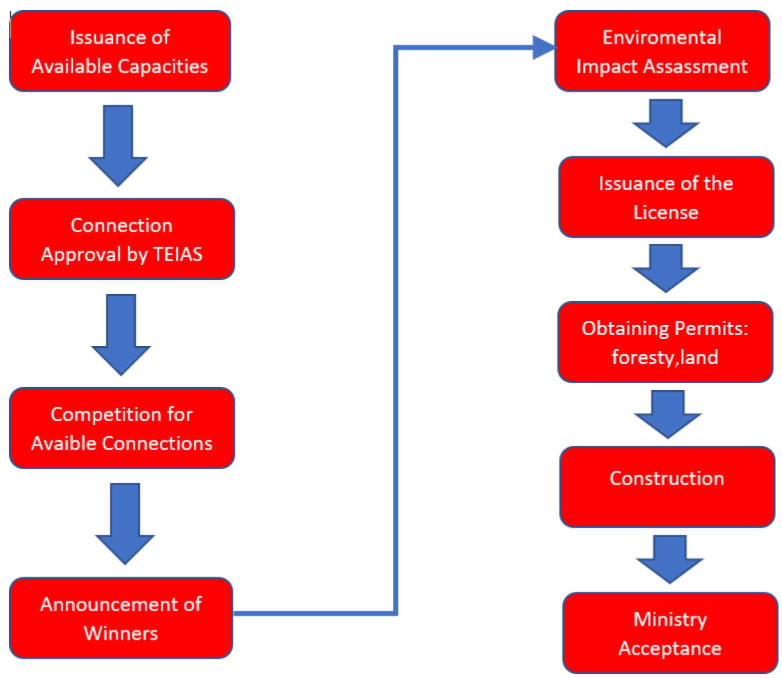

Figure 11: Licensing process diagram for authorized applications (Source: Official Gazette No.30431, 2018)

3.2.1 Application for a License for the RES

The following documents are required for EMRA license applications, which must be included for a complete and successful application what to do in order to get a license for each of the renewable energy types. (Source: Official Gazette No.30431, 2018)

- An application form

- a commitment declaration
- a certificate of approval of all responsible persons on behalf of the legal entity
- a statute with the most recent changes approved by the Commercial Registry Office
- A certificate certifying that the accounts of the auditors have checked the absence of criminal records for the last 6 months for, the Chief Executive Officer, the Deputy Chief Executive Officer, the members of the Board of Directors and the individuals holding legal persons with more than 10% of shares.
- The documents related to the production facility are as follows; Information form downloadable from EMRA, an investment Delivery Schedule, a 1/25.000 scaled map showing the location of the plant, a settlement project for the plant, a declaration stating whether the site is located in a sensitive zone as described in the Environmental Impact Assessment Regulation, a declaration regarding the current zoning status of the settlement, articles of association with Trade Registry approval of the legal entity with its latest revisions, a list of the shareholders and how they are directly or indirectly related to their share proportions and prices.
- Documents indicating the true capital of the legal entity, the initial balance sheet of the independent audits carried out last year or approved by an accountant or a tax office; If the legal person is newly formed, the registration statement must be submitted.
- A guarantee letter; Applications submitted for the production activity will also require a confirmation letter.
- A statement from an authorized administrative authority authorizing the installation of a production unit in an industrial or free trade zone.

For production licenses, automatic producer licenses and automatic producer group applications, the timetable for the delivery of the investment, which describes the technical details of the power plant project, must be approved by EMRA. The final decision will be made by a licens- ing committee and officially announced on the EMRA website. The EMRA Approval Committee determines the amount of the guarantee certificate for each MW installed capacity for generation license applications.

All required documents must be submitted according to the official EMRA list of documents. Submissions will be evaluated by EMRA within 10 days. Another 10 days are planned into the schedule for the recording of the missing documents. If the missing documents are not submitted on time or the legal entity is withdrawn, the application is deemed as “not filed” and all documents are returned to the applicant.

3.2.2 Monitoring and Evaluation

Candidates who have submitted the right applications will be informed and will have to pay 1% of the license fees to EMRA within 10 working days. Otherwise, the application is considered invalid. After receipt of the payment, the notation of the corresponding application begins. This does not mean that the license has been approved. Rejected applications may appeal within 10 days, but only in the case of violation of their personal rights. In license applications for wind and solar power plants, the necessary measures must be performed in accordance with the prescribed legal forms.

The evaluation of the connection between the plant and the transport and/or distribution system, as well as the system usage data, will be sent to TEIAS or the distributor for verification. This review process is complete and will be sent to EMRA within 45 days. TEIAS sends EMRA the available capacity of the substation to connect a wind turbine with each wind turbine application and publishes it on its website. If the capacity of the plant exceeds that of the substation, only a modification of the power of the turbine is necessary so that the planned location of the plant does not change. If the applicant does not modify the wind turbine or accept the change within 10 business days, the applications will be rejected. If, after the technical evaluations, several applications for a wind turbine are presented for the same station, the application that best meets the requirements of TEIAS and approved by EMRA can be connected to the system. In this case, additional documents may be requested from the legal entities.

In accordance with Regulation No 27049 of 11.09.2008, the Electricity Monitoring and Management Authority carries out a technical analysis of wind turbines for authorization applications. If the application is rejected, the application will also be rejected by the EMRA Admission Authority.

3.2.3 Approval

Once EMRA has received approval from other countries, the request will be completed within 45 days. All applications must be approved by the EMRA Board of Directors. If the application is rejected, the letter will be sent within 10 business days indicating the reasons for the refusal with a guarantee letter. If the license has been approved, the following documents must be submitted.

- All shares of a company must bear the name of the stock exchange. The minimum capital available for the license is 20% of the total investments planned for the production license, at least 15% of the transfer or purchase of the distribution area for the distribution license, 2.000.000 TL for the wholesale license, 1.000.000 TL for retail licenses 200.000 TL for each sales service area.

- The payment receipt of the balance of the used license.
- The guarantee certificate includes a reduced amount, depending on the type of resources, the installed capacity and the type of texts requested by EMRA.
- The signing of a TEIAS agreement for a contribution to renewable energy, which was reached at the end of a competition for the production of wind energy.
- If the location of the installation requires an environmental impact assessment, the results of the installation assessment should also be presented.

Upon presentation of these documents, the licenses will be issued within 90 days of the notification. If the documents referred to in this article are submitted within 90 days, projects with a "Positive Environmental Impact Assessment" will have 300 days to submit documentation confirming a positive assessment under the Regulations. to assess the environmental impact. Relevant legal entities must request an Environmental Impact Assessment within 30 days of notification.

3.3 The Drawbacks in a Permission Process

3.3.1 Connection to Transmission Lines

Transmission lines are one of the concealed issues of power plant establishments. If planning is not done sufficiently, the project can need to be modified, which can lead to additional delays and unforeseen budget problems.

Environmental Impact Assessment (EIA) is the process of assessing the likely impact of a proposed project or development on the environment, taking into account the interrelated socio-economic, cultural and human health consequences, both beneficial and adverse. An EIA isn't required if the transmission lines are under 15 km. However, for distances greater than 15 km, a general EIA is required. However, if no transmission line is available prior to implementation, a secondary application is required.

3.3.2 Environmental Factor

An environmental impact assessment is one of the limiting factors in the approval process due to land-based issues. For the application of EIA, the results of the environmental impact assessment must be either positive or announce that 'an environmental impact assessment is not required'.

Evaluation applications are submitted by companies recognized by the Ministry of the Environment and Urban Development.

This procedure usually lasts at least 6 months. If authorities or a public hearing request additional documents, the process may take longer. To the detriment of the reasons for the delay, the applicant is fully responsible for the timely submission of the application during the EIA procedure.

3.3.3 Land Dispute

Land ownership is the basis of all applications and has a significant impact on the licensing process. Depending on the ownership status, the procedure and the relevant local authorities change. The territory of the country is mainly divided up into:

- State land
- Forest land
- Agricultural land
- Private land

Most of the procedural issues concern forests or agricultural land subdivided into National Park Areas, Protected Areas, Agricultural Lands, Meadows and Forest Areas of Type 2B. The latter area, Type 2B Forest, is a type of state-owned land that has lost the characteristics of a forest but cannot be expropriated for other uses. This has led to a major debate over its future use. All types of land require obtaining a field permit from the appropriate local authorities. In most approval procedures, there are on average 10 authorities involved in the approval process. As expected, these new steps can help delay the entire process.

3.4 The Benefits in a Permission Process

If the project falls into the public-private partnership category, it will be easier to comply with the requirement for public interest, and the expropriation of land will usually take less time. The property can be rented for a short time until the purchase or expropriation is completed. There are two main sources of support for RES projects.

At industrial enterprises; projects prepared to implement the measures identified in the study of the energy survey and restoration of energy conservation potential are called efficiency improvement projects (VAPs). VAP is prepared in order to implement the necessary measures to eliminate energy wastage, losses and inefficiencies in industrial enterprises. VAP supports provide support for the projects that will be implemented by enterprises for their energy efficiency. Industrial enterprises requesting VAP support shall submit to the Directorate General the projects they have prepared for the companies in accordance with the principles and procedures published by the General Directorate. The General Directorate may not apply, postpone or extend the application period, and may not apply for more than one term. (Source: Enerji Isleri Genel Mudurlugu, 2019)

A voluntary Agreement refers to an agreement made by the General Directorate with the commitment to reduce the energy density by an average of at least ten percent in the three years after an industrial enterprise has been contracted according to the reference energy density of the past five years. Volunteer Agreement supports are given to enterprises that fulfill their commitments at the end of the agreement period. The legal entities willing to make voluntary agreements with the General Directorate apply to the General Directorate in October every year using the application form published on the website of the Directorate General. The General Directorate may not apply, postpone or extend the application period, and may not apply for more than one term. (Source: Enerji Isleri Genel Mudurlugu, 2019)

4 The RES Potential in Turkey

4.1 Solar RES

4.1.1 Low and High Temperature Solar Heating

The most commonly used technology for obtaining solar energy at low temperatures is called "Solar Collectors" technology. In these systems, solar rays are absorbed in the collectors, the absorbed rays heat the water in the pipes in the system. This is heated water; is used for heating houses, hot domestic water supplies, heating greenhouses, and hot water supplies for industrial plants.

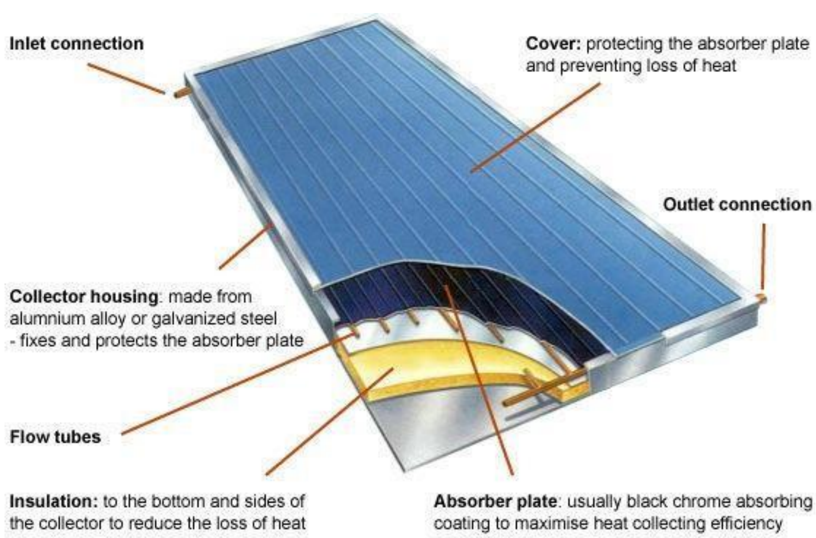

Figure 12: Low Temperature Plate Collectors (Source: Patience & Pamphilon, 2019)

Solar collectors are used in many countries, especially in countries close to the equator. These systems are well used in countries such as the USA, Japan, France, Italy, Greece and Israel. Even in a country like Sweden, where sunny days are scarce, hot water can be obtained at -4 ° C and 70 ° C at solar collectors. This is followed by 9-10 million M2 WITh Japan and Turkey. (Source: Mauthner at. al.,2019)

Apart from solar collectors, thermal solar energy systems are also utilized. These contain; solar ponds, water treatment systems, product drying systems and solar cookers. (Source: Thermal Sun Technologies, 2012) Solar cookers are tools that are planed to take advantage of the heat obtained by collecting the sun's rays in bowl-shaped structures. In these stoves, food can be cooked, and water can be heated. This technology is widely used in countries like China, India, Pakistan and Kenya which have some of the highest solar energy potential in the world. (Source: Schulze, 2015)

By utilizing solar energy, high temperatures are obtained and nowadays electric energy production, which is one of the most needed energy types, is realized. Several methods are used in this type of energy production.(Source: Schulze, 2015) These include; parabolic trough collectors, parabolic dish collectors and central receiving type (densifier).

By concentrating the sun's rays in the collectors in a parabolic trough collector, high temperatures of up to 400°C are obtained. Liquid materials that reach high temperatures are sent to power plants to generate electricity.

In parabolic bowl systems, high temperatures up to 1400°C can be achieved with focused solar collectors, from which can be obtained high temperature water and steam. The obtained water or steam energy can be used directly in industrial plants as well as in power generating plants.

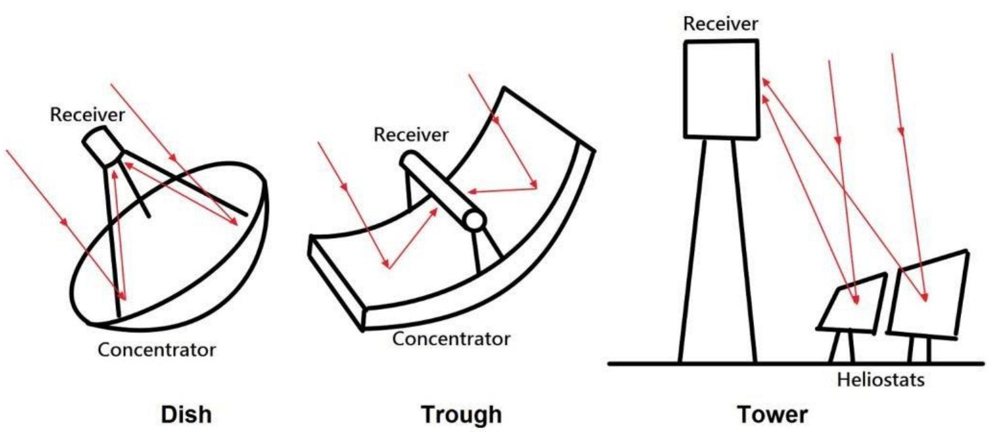

Figure 13: High Temperature Concentrating Collectors (Source: Tew, 2016)

The systems with central receiver consist of two units. They consist of a tower carrying the receiver and mirrors to reflect the sun's rays to the receiver. In this system, by obtaining high temperatures, hot water and steam is obtained for the operation of electrical generators. (Source: Schulze, 2015)

These systems simply work in the same way, but they vary in terms of the collectors used. In power plants where parabolic trough collectors are used as the collecting element, the working fluid is circulated in the absorber tube located at the focus of the collectors. Then, superheated steam is obtained from this heated liquid. The same method is used in systems using parabolic bowl collectors, or with a motor placed in the center, electricity is generated directly. On the other hand, in central receiver systems, the sun's rays are reflected to the receivers with the help of planar mirrors. The working fluids heated in the receiver then generate electricity by conventional means. (Source: General Directorate of Energy Affairs, 2019)

4.1.2 Photovoltaic Solar

It was the French chemist Becquerel who discovered that sunlight could be transformed directly into electricity. In the 1950s, the photovoltaic effect of silicon was discovered at Bell Laboratories in the USA and a solar cell production with 5% efficiency was achieved. Solar cells are semiconductor materials that convert sunlight falling directly onto their surface into electrical energy. Solar cells work on the basis of photoelectric principles, that is, when light falls on them, an electric voltage is created at the ends of the cell. The source of the electrical energy produced by the cell is the solar energy reaching its surface. (Source: Turkey Environment Foundation Publications, 2006)

Based on the structure of the solar cell, solar energy can be converted to electrical energy with an efficiency of 5% to 20%. Today, this rate has been increased to up to 33%. In order to increase the power output, a plurality of solar cells are mounted in parallel or in series on a surface, and this is called a solar cell module or a photovoltaic module. Depending on the power consumption, the modules can be linked in series or parallel to each other to form systems from several watts to megawatts. (Source: Turkey Environment Foundation Publications, 2006)

Solar cells can be used wherever electrical energy is needed. Depending on the application, the solar cell modules are combined with accumulators, battery charge controllers and various electronic support circuits to create a solar cell system. This, can be used nowadays especially in areas that are far away from settlements and in areas that do not have electricity networks, where it is difficult and expensive to transport fuel to a generator.

Typical applications of solar energy are where solar cell systems are used independently of the national electricity grid. These include communication stations, rural radio, radio and telephone systems, measurements in electricity and water distribution systems, weather observation stations and, indoor or outdoor lighting systems. In addition, electrical appliances such as TVs, radios, refrigerators in remote homes, domestic water pumps, forest watch towers, lighthouses, first aid, alarm and security systems, earthquakes and weather observation devices, medical devices and similar things can be powered by solar energy.

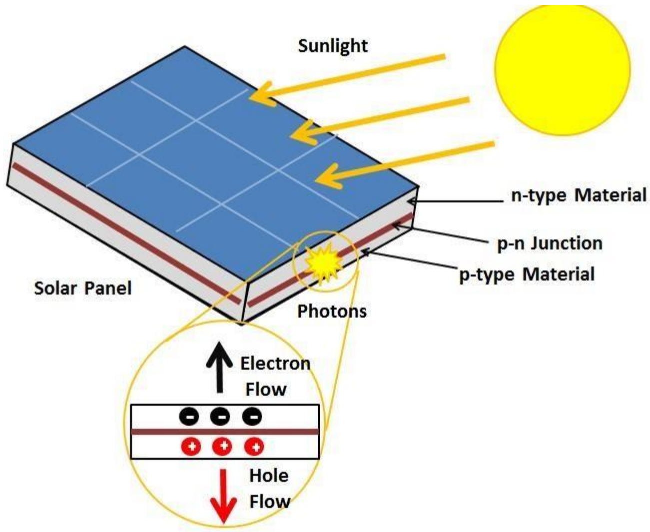

Figure 14: Photovoltaic Solar Cell (Source: Photovoltaic effect, 2015)

The production of electricity by solar cell plants is carried out in most of the developed countries. However, its usage has been limited due to the high installation costs and the lack of continuous solar radiation because of the many developed countries are in places where sunlight is restricted. When the capacities of solar cell installed in the world are examined; the share of Germany is 36%, Japan is 36%, the USA is 12.5%, and the share of developed countries such as China, India, Spain, the Netherlands, France and Italy is around 1%. As can be seen from the data, it is shown that Germany, Japan and the United States have achieved important successes in the production of solar power plants, and they account for a large share of 85% of the total installed capacity in the world. (Source: IEA PVPS, 2019) It is noteworthy that Germany and Japan, which are not included in the zone with the highest solar capacity, will be the leaders in this matter.

4.1.3 Solar Energy in Turkey

Turkey, due to its geographical position in terms of solar energy potential, is in a good position in relation to many other countries. According to data from the State Meteorology Affairs

duration of sunshine and warm up my intensity measured in the years 1966-1982 are available from the General Directorate of utilizing data Renewable Energy General Directorate (YEGM). According to a study conducted there is an average annual sunshine duration in Turkey of 2640 hours (daily total of 7.2 hours). The average total heating intensity was 1,311 kwh/m2-year (3.6 kwh/m2 per day). Turkey has a high solar energy potential of, approximately 110 days. (Source: Turkyilmaz, 2012) The solar energy potential of Turkey is given in the table below.

Months	Turkey Global Radiation Values (kWh / m2-day)	Turkey Sunbathing Times (Hours)
January	1.79	4.11
February	2.5	5.22
March	3.87	6.27
April	4.93	7.46
May	6.14	9.1
June	6.57	10.81
July	6.5	11.31
August	5.81	10.7
September	4.81	9.23
October	3.46	6.87
November	2.14	5.15
December	1.59	3.75
Average	4.2	7.5

Table 3: Solar energy potential in Turkey (Source: Turkey's Energy Outlook, 2018)

The regional distribution of Turkey's average annual solar radiation and sunshine duration values are shown in the following Table. Turkey's biggest potential for solar energy is the South East Anatolia Region, followed by the Mediterranean Coast.

Turkey's Total Annual Regional Distribution of Solar Energy Potential		
Region	Total Solar Energy (kWh/m2-year)	Solar Time (Hour/year)
Southeastern Anatolia	1460	2993
Mediterranean	1390	2956
Eastern Anatolia	1365	2664
Central Anatolia	1314	2628
Aegean	1304	2738
Marmara	1168	2409
Black Sea	1120	1971

Table 4: Turkey's Regional Distribution of Solar Energy Potential (Source: Turkey's Energy Outlook, 2018)

According to the official website of YEGM; the values given in the table are actually less than the actual potential of Turkey. In addition, since 1992, the General Directorate of State Meteorological Affairs have been taking solar energy measurements for the purpose of measuring solar energy values more accurately. As a result of the measurement of this work in progress, the solar energy potential of Turkey is expected to rise by an additional 20-25%.

As can be seen from the figure below, especially in the Mediterranean and Southeast Anatolia there is a high solar capacity. Here, water heaters are used at full capacity for the whole year. In other regions, water heaters can operate at full capacity for 70% of the year. (Source: Turkey Environment Foundation Publications, 2006) Efforts have also been made to increase the success of solar water heating with new legal regulations.

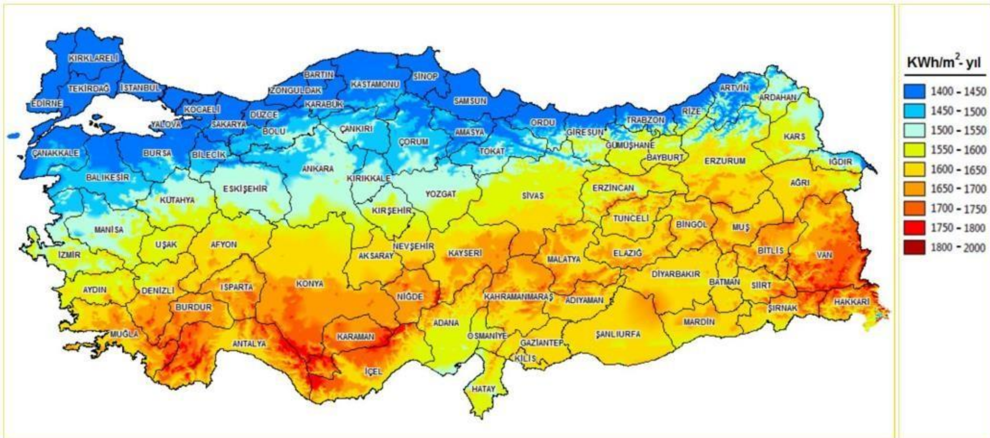

Figure 15: Solar Radiation Map of Turkey (Source: YGM, 2019)

In Figure 15, the solar radiation map of turkey has been given. The blue color is from 1400MWh to 1550 MWh, the orange color is from 1550MWh to 1700Mwh and the red color is from 1700MWh to 2000MWh. The further you move to the south on the map the more the color turns from blue to red.

In the field of solar energy in Turkey is more advanced flat plate solar collectors. There are mostly used for obtaining hot water. It is possible to find many companies operating in this field in Turkey. According to official sources, the number of these firms is known to be more than 100. (Source: Turkey Environment Foundation Publications, 2006) The majority of solar collectors are used in the Aegean and Mediterranean regions, but they are also used in other parts of Turkey in recent years. The contribution of thermal energy produced by solar collectors to primary energy consumption is shown in the Table by years.

Photovoltaic (PV) growth is expected to be slow in 2019 due to funding problems, but it will start growing again in the 2020s. Since May 2018, "unlicensed" photovoltaic projects can have a generation capacity of up to 5 MW. Solar power plants are manufactured in Turkey. In 2016 PV produced 3755 Terajoules, or about 1TWh of Turkey's 300TWh annual power generation.

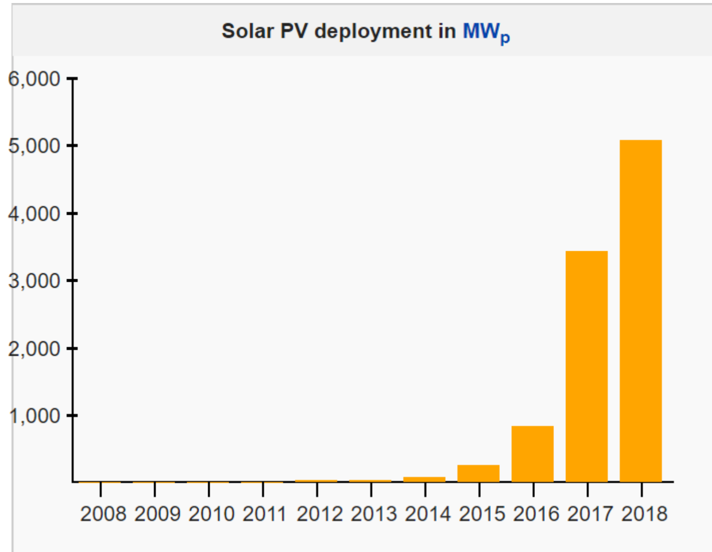

Table 5: Solar Power Generation in Turkey (Source: Solar power in Turkey, 2019

Table 5, shows that installed solar PV was minimal until 2014. The rise started in 2014 and after 2014 there has been a significant rise at the deployment of installed PV. This deployment has been risen to around 5GW in 2018.

Turkey has a significant solar energy potential. However, applications in this area have not been developed sufficiently. The lack of a specific plan and program among the public institutions, research institutes and universities working on solar energy, and the unreliable and uncoordinated conduct of these activities make the point reached in solar energy systems insufficient.

The establishment of an independent top coordination committee on solar energy for the implementation of the studies and the experiences gained up to date, and this board bringing together the working and operating parties on this issue and providing information and making the necessary legal arrangements will increase the utilization rate of solar energy.

4.1.4 Drawbacks and Complications

However there are many advantageous aspects of the use of solar energy, there are some disadvantages. It is not easy to use compared to liquid and gas fuels. For example; The power generated by solar cells used in automobiles is very low compared to vehicles using fossil fuel. Another problem is the lack of operation of solar powered vehicles in the absence of sunlight.

One of the obstacles to the utilization of solar energy is the diffusivity of solar energy. Large surfaces are needed to collect this energy. It is also an intermittent energy source, since it is not possible to generate energy from this source at night and on cloudy days. This situation necessitates the storage of the obtained solar energy. One solution that has been attempted is using accumulators. However, since the high costs of accumulators increase the cost of solar energy, there has been little progress on this issue. (Source: Schulze, 2015)

In general, the problems encountered in the use of solar energy are as follows.; (Source: Uyar, 2016)

- The initial investment is high.
- There are fluctuations in performance according to weather conditions and the amount of daylight.
- Solar power plants can be quite ugly in the landscape and they take up a large area due to low cycle efficiency.
- Energy storage is required in the absence of daylight if it is not connected to the main system.
- Some materials used in the production of solar cells are likely to be toxic.
- Solar energy is highest in tropical and sub-tropical regions. However, consumption is most common in the northern countries with mild and cold climates.

4.1.5 Factors Affecting the Growth of Solar PV RES

Solar energy is one of the most environmentally intimate renewable energy sources. One of the most important environmental problems, global warming, one of the causes of CO2 emissions does not occur as a result of solar power plants. Using solar energy helps protect the environment by avoiding the use of fossil fuels, greenhouse gas emissions, and other chemical waste. Solar energy technologies have environmental advantages compared to traditional energy sources. These advantages include the absence of waste products during operation, low greenhouse gas emissions, the absence of toxic gas emissions, the reduction of power grid transmission lines, and the prevention of pollution of water resources. In addition, solar energy contributes significantly to employment and provides social and economic benefits.

Solar cells are reliable and durable. The use of solar cells may be more economical in places where there is no electricity grid. Because there is no other expense after the investment of solar cell systems, each house can provide for its own energy needs with the solar cells installed on its roof. Thus, transmission costs and energy transport losses will be eliminated. (Source: Arslan, 2017)

There are many reasons that make use of solar energy necessary. There are some of those; (Source: Uyar, 2016)

- An Abundance of solar energy potential in many parts of the world,
- No external dependence,
- Solar power systems are reliable and virtually maintenance free,
- They are an inexhaustible and clean energy source,
- Having an inexpensive source if the initial investment cost is not considered,
- They are not subject to energy crises,
- A simple technology can be used,
- Since there is no transportation problem, solar energy can be easily obtained if necessary.

4.2 Wind RES

4.2.1 The Technical Potential of Wind Energy

Electricity Generation from Wind Energy is realized through wind turbines. Wind power generation is realized by converting the motion energy generated by the wind blowing on the installed wind turbines into electrical energy by means of a generator. Wind energy turbines consist of a propeller, a shaft and a generator. Nowadays, in many parts of the world, wind turbines are installed on or in modern buildings. Wind turbines can generate energy for a long time. Although this is uncertain, they probably have a life span of 20-40 years. Many studies and experiments have been carried out on wind turbines and it is stated that the most suitable turbines for today's conditions are models consisting of a tubular tower, three blades and generators. (Source: Schulze, 2015)

Wind turbines applications are examined in three groups. The first of these is the grid-connected alternating current (AC) applications, where all or more of the energy produced in wind turbines is transferred to the national electricity grid. Alternating current (AC) is a type of electric current in which the direction of electron flow passes back and forth at regular intervals or in cycles. The second application is direct current (DC) applications, independent of the national electricity grid, provided that the site's energy is supplied directly from wind turbines. Direct current (DC) is the unidirectional flow or movement the of electric charge carrier. The current density may change over time, but the overall direction of movement remains unchanged. A third application is weather stations, railway alarms, lanterns, fire watchtowers and remote DC system applications that are soon used to meet the electricity requirement. (Source: Turkey Environment Foundation Publications, 2006)

Electricity production from wind energy is increasing day by day. While the wind power installed capacity of the world was 2160 MW in 1990, it had increased to 18000 MW in 2000 and 93000 MW in 2007. Wind energy is known to have a very high average annual growth rate of 25-30%. (Source: Schulze, 2015) Although its share in general energy consumption is not sufficient today, it is gradually increasing.

4.2.2 Wind Energy in Turkey

The wind atlas in Figure 16 below, Atlas of Wind Energy Technical Potentials(REPA), was published in 2016by the Ministry of Energy and Natural Resources. While there is a considerable variation of wind resources across the country, wind speeds above 7 m/s can be found in almost all regions of Turkey. Particularly attractive conditions are present in the Aegean, Marmara, and

Eastern Mediterranean regions; these are also the areas where most wind power projects have been realized and are planned by developers. The Ministry of Natural Resources and Energy estimates the potential for attractive wind power generation with wind speeds above 7.5 m/s, measured at 50 m above ground, to be at 48 GW. Taking into account the rapid technology and cost development, which allows wind power to be generated economically also at less ideal wind speeds below 7.5 m/s, the actual economic potential may actually be substantially higher than this figure. (Source: Turkey's Energy Outlook, 2018)

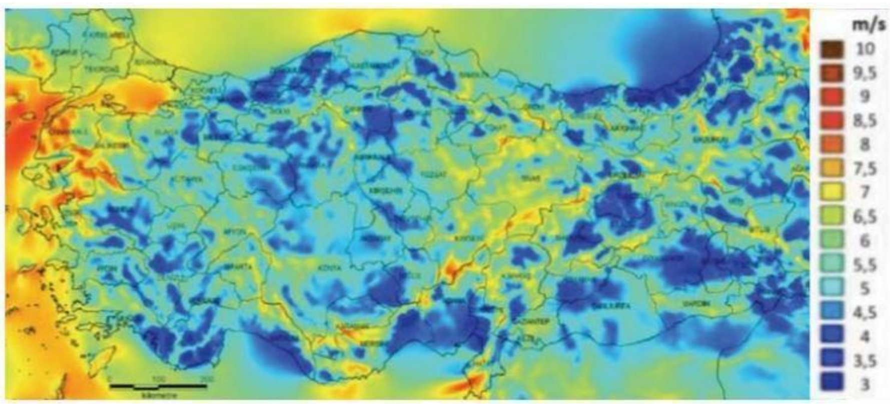

Figure 16: Wind speed atlas of Turkey (50 meters height and 200 meters resolution) (Source: Turkey's Energy Outlook, 2018)

In Figure 16, the wind speed map of turkey shown. The blue color is where the wind speed is 4.5m/s or lower, the yellow and green color is where the speed of the wind is from 4.5m/s till 7m/s, and the red color is where the wind speed is more than 7m/s. The west cost of Turkey has much higher wind speed that the red rest of country while the north and the south of the country has a high wind speed but still less than the west coast of turkey.

The Electricity Market Law (EML) applies to the production, transmission, distribution, wholesale and retail sales, import and export of electricity, market operations, and the rights and obligations of all individuals and legal entities involved in such activities. The first law to deal with renewable energy sources such as wind energy in Turkey was the Electricity Market Law in 2001. With this law, the government's abandonment of the purchase guarantee at a certain price caused wind energy investments to decrease. The most important legal work related to wind energy was put forward with the law No. 5346. The law on the use of renewable energy for electricity generation was adopted on May 10, 2005. The purchase guarantee period provided for electricity by the Law was increased from 7 years to 10 years and the price base of USD 7.3 cents / kWh was brought to speed up the investments to be made in this sector. (Source: General Directorate of Meteorology, 2019)

Available Wind Energy Installed Capacity and Power Generation licensed wind power installed capacity connected to the grid in Turkey with a total of 160 wind power plants by the end of 2017 in October 6353.8 MW (7.7% of Turkey's total installed power) has reached. The energy produced in these plants by the end of October 2017, 14 412 GWh (5.88% of total energy production Turkey) was produced. A Gigawatt hours, abbreviated as GWh, is a unit of energy equals to one billion watt hours and is equivalent to one million kilowatt hours. The development by years of wind farms installed capacity and wind energy production in Turkey is shown in Figure 17. (Source: Turkey's Energy Outlook, 2018)

Figure 17: Turkey Wind Power Plant of the Year by the Council of Development (Source: Turkey's Energy Outlook, 2018)

In Figure 17, the blue column shows as power in MW and the brown line shows production in GWh for Turkey Wind Energy Development. The Power in 2010 was 1829.15MW and the power has been increased in 2017 to 6553.8MW. The production was in 2010 2916.4GWh and has risen till 2016 to 15517.1GWh. In 2017 the production has been reduced slightly to 14412GWh.

The distribution of wind farms by region is consistent with the potential shown in REPA. Izmir, Balıkesir, Manisa, Hatay, Çanakkale, Osmaniye, Kayseri, Afyon, Istanbul, Aydın and Kırklareli are the provinces where wind power plants are concentrated (Figure 17). (Source: Turkey's Energy Outlook, 2018)

Assessed Wind Power Plants in April 2015, approximately 42,000 MW of applications were received from associate degree applications received by EMRA for capacity allocation of 3,000 MW. The Energy Market Regulatory Authority (EMRA) is a system integrator of renewable energy solutions serving the local market and surrounding countries using portable desalination and water treatment systems based on clean technologies. As a result of the inspection conducted by EMRA, the competitions are expected to be held in 2016 for capacity, which is directed to YEGM for technical evaluation and TEIAS for connection opinion, and the process's prolongation to 2017 caused concerns about the sustainability of investments and growth in the sector. For the 710 MW of the 3000 MW RES capacity allocation for which an associate degree application was received, the competitions were held by TEIAS on 21-23 June 2017 by open auction method on the basis of offering the lowest price per kilowatt hour to the electricity to be produced. Around 300 projects competed in 11 regions with a total power of 10,300 MW. As a result, the 710 MW capacity to be connected to the system was allocated to projects (Figure 18). (Source: Turkey's Energy Outlook, 2018)

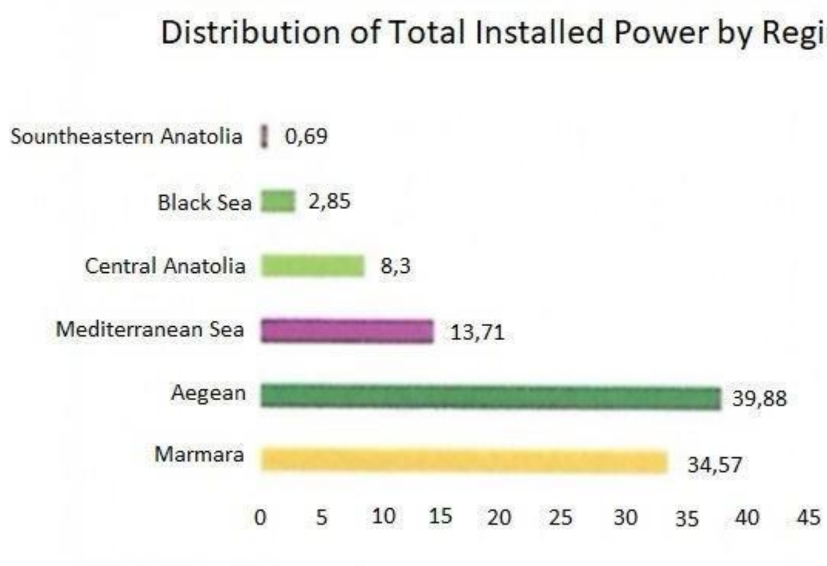

Figure 18: Wind Power Installed Capacity (as of July 2017) Region (Source: Turkey's Energy Outlook, 2018)

In Figure 18, a graph of the distribution of total installed power by region is given in percentage. The brown color represents 0.69% for the southeastern Anatolia, the green color shows 2.85% for the Black Sea, the light green shows 8.3% for the central Anatolia, the purple is 13.71% for the Mediterranean Sea, the dark green shows 39.88% for the Aegean and the yellow color represents 34.57% for the Marmara region.

4.2.3 Drawbacks and Complications

There is uncertainty in the future of the support system. This constitutes an unpredictable investment environment in terms of projects under license and construction processes and applications to be received in 2018. Uncertainty may pose problems for banks in project finance and the feasibility of projects may be affected. In order to support investments based on renewable energy sources, the path to be followed should be clarified as soon as possible. (Source: Turkey's Energy Outlook, 2018)

The work of the Siemens-Türkerler-Kalyon joint venture group, which won the renewable energy resources area tender, is to localize the production of the Siemens company, which also sells to the world market, that is, to create equipment localization and sub-industry branches. Therefore, the project development process should be monitored carefully, the rules regarding permits and licenses should be simplified, transactions should be increased and risks should be assessed by simulating investment. (Source: Turkey's Energy Outlook, 2018)

In the area of renewable energy resources area;

- There is no target for domestic (design and) manufacturing of components which are not produced in Turkey yet.
- There is no understanding of the transfer of technology or of the transfer of the right of use of this technology to a local institution or company.
- In terms of technical specifications there is no article regarding the intellectual property rights of the final product (new design, software, methods, materials, parts, components, etc.) that can be obtained as a result of Research and Development studies. In this case, the technology shall be wholly owned by the Technology Providing Firm.

Efforts should be made to overcome these issues.

Wind power towers, wings, wing main and intermediate materials include (glass fiber, fiber and lamination resin, multiaxial braids, vacuum bagging consumables) with some fasteners (wing connection studs and nuts, tower bolts, flanges and special fasteners) etc. And given that some components in the supply chain cannot be made by a single company, any break in the supply chain creates high costs. Therefore, stronger cooperation opportunities should be created in the supply chain. It should be noted that if the market is not large enough and stable, or if the requirements of domestic production are subject to too many rules, domestic production can lead to the production of wind equipment with higher costs.(Source: Turkey's Energy Outlook, 2018).

It is thought that negative price quotations given in wind power plant(WPP) capacity allocation competitions will lead investors to supply the turbine components from abroad with ''Exim'' credits, which will have a negative impact on the development of a domestic industry.

Efforts should be made to complete the necessary permits and approvals related to wind power plants and to take necessary measures to assess the problems experienced.

The existing producers in the country should be provided with the support they need in the case of small-strong WPPs. Test and certification programs that correspond to international standards document the confidence of the new product and the turbine quality. Therefore, local turbine manufacturers should be provided with support for the registration of the quality of their products. (Source: Turkey's Energy Outlook, 2018)

Necessary arrangements should be made in fiscal legislation in order to solve the problem of the fact that the natural persons who establish unlicensed power plants cannot collect the surplus electricity energy they sell to distribution companies.

Studies on wind energy and the social acceptance of wind power plants should be carried out to measure the public response during the EIA processes of wind power plants, as applied in EU countries. This scope of work includes; (Source: Turkey's Energy Outlook, 2018)

- physical and environmental factors (power plant and turbine sizes, power plant design, visual impact, noise, distance of turbines, ecological site characters.)
- psycho-social factors (knowledge about wind energy, proximity, general trend, benefits and costs.
- social and institutional factors (participatory planning, local ownership, public participation, campaigns). In this area, as it has been applied in Denmark for a period, the provision of comprehensive information and local ownership (a certain proportion of local people to share in the project or share of income) may change the public's view of the project.

Many people work in all areas related to wind energy (turbine design, engineering calculations, procurement processes, manufacturing, tests, quality and certification, wind measurements and evaluation, power plant design, license application and obtaining necessary permissions, construction, acceptance, energy estimation, etc.) Therefore an inventory of those who plan to do such work should be prepared and a database should be created for the study areas. (Source: Turkey's Energy Outlook, 2018)

Particular attention should be given to detailed monitoring, evaluation and reporting on the development of wind energy. Monitoring, evaluation and reporting should be carried out to cover different periods, short term and long term. The policies implemented in the reports; employment, resource security, technological development and innovation, domestic production, rural development and capacity development and the benefits of reducing emissions should be clearly defined, and direct or indirect benefits of the policies implemented. Financial and non-financial effects should also be measured. (Source: Turkey's Energy Outlook, 2018)

4.2.4 Factors Affecting the Growth of Wind RES

From an economic point of view, electricity generation from wind power increases significantly as the wind energy market grows. Production costs have been reduced by up to 50% in 15 years. This will not only be a pleasing development, but also will contribute to the preservation of economic balances. (Source: Turkey's Energy Outlook, 2018)

Wind energy systems; production, maintenance, operation, and so on provide significant employment in areas reducing unemployment rates. The most comprehensive study of employment impacts was conducted in 1998 by the Danish Wind Turbine Manufacturers Association. According to the statistics of the Union; 17 work-years are gained for every 1 MW of wind power produced and 5 work-years are gained for each MW of power installed. The number of people employed by wind energy worldwide is calculated as 90-100 thousand. According to the European Wind Energy Agency, the number of employees in the sector is expected to reach 960 000 by 2020. (Source: Turkey's Energy Outlook, 2018)

One of the most significant causes for the rapid development of wind energy is the low environmental impact of this resource. The very low amount of carbon released to the environment during the production of electricity will ensure that air and water resources remain cleaner and healthier and have a positive impact on climate change.

Since wind energy is included in the green energy group under the Kyoto Protocol, it can play an important role in increasing foreign capital inflows by creating an environment for energy exports.

Wind turbines are much easier to be disposed of after use than other energy systems. As the wind is a domestic resource, it is largely independent of world energy markets. The technology is relatively simple to set up and operate. Wind turbines are modular, can be manufactured in any size and can be used individually or in groups. The commissioning of wind turbines can take as little as three months from the start of construction to the transition to commercial production. (Source: Turkey's Energy Outlook, 2018)

Since the land where wind power plants are established can also be used for other purposes. It can be used in different fields such as agriculture and livestock. In addition, the land can continue to be used as before after the power plants have completed their life and been dismantled. (Source: Turkey's Energy Outlook, 2018)

4.3 Hydro RES

4.3.1 Small and Big Hydroelectric Power Plants

Hydroelectric power plants are classified according to installed power potential. There is no consensus on this issue internationally. Different institutions can set different upper limits for mini and micro hydroelectric power plants. However, the generally accepted definition for Small Hydroelectric Power Plants (SHEPP) is "hydroelectric power plants capable of generating up to 10 MW". In Turkey, the UN Industrial Development Organization (UNIDO) made by the classification system is used. According to this classification, HEPPs are divided into 4 main groups in terms of the power they produce. Hydropower or hydroelectricity(HEPP) refers to the conversion of energy from flowing water into electricity. (Source: Turkey Environment Foundation Publications, 2006)

Power Plant Type	Installed Power (KW)
Micro Hydroelectric Power Plants	0.1-100
Mini Hydroelectric Power Plants	101-1000
Small Hydroelectric Power Plants	1001-10 000
Large Hydroelectric Power Plants	Greater than 10 000 KW

Table 6: Classification of Hydroelectric Power Plants by Installed Power (Source: Turkey's Energy Outlook, 2018)

Huge HEPPs, both during the construction phase and after the begin of water retention have a much larger environmental impact than SHEPPs, SHEPPs later came into the agenda and investments in this area have started to increase. Although SHEPPs are not a new energy source, their usage area is increasing day by day. (Source: Kaya & Koc, 2014) SHEPPs are an increasingly used as an alternative energy source, especially in rural areas where no other power plants are built.(Source: Uzlu, 2008)

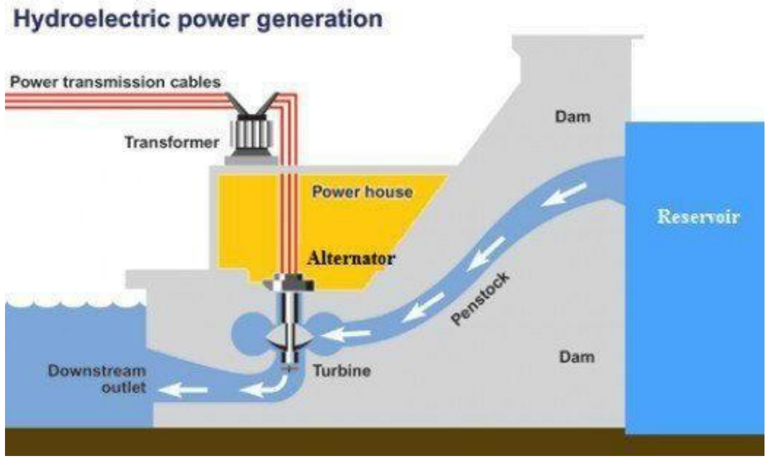

Figure 19: Hydroelectric Power Generation (Source: Turkey's Energy Outlook, 2018)

Compared to large-scale LHEPPs, SHEPPs have many advantages such as less financing, less maintenance and repair costs, a short-term for construction, flood protection, drinking and potable water supply, fishing, tourism and employment. There are a reliable and clean renewable energy source. Since SHEPPs do not require much time and generally large investments during the projecting and construction phase, they can be made with small regional financial resources and private institutions. (Source: Turkey Environment Foundation Publications, 2006)

In the evaluations related to energy, large hydroelectric power plants are evaluated in the classical renewable resource group, while SHEPPs are included in the new and renewable resources group. (Source: Turkey Environment Foundation Publications, 2006) The share of small hydroelectric power plants in total hydroelectric power production in the world varies between 5-10%. Currently installed SHEPPs in the world meet 40 GW of the world's energy needs. Total SHEPP potential is estimated at 100 GW . (Source: Kaya & Koc, 2014)

4.3.2 Small Hydroelectric Power Plants in Turkey

The energy produced by SHEPPs utilizing water power varies depending on the rainfall pattern. Turkey's precipitation varies, greatly according to season and region. In Turkey, the average annual rainfall is 643 mm3, when it comes to the average amount of money per year to 501 billion m3 of water. Approximately 50% of this water is mixed into the atmosphere by evaporation, while 35% reaches lakes or seas through streams and rivers. The rest feeds groundwater. (Source: Gokdemir et. al., 2012)

In Turkey, gross per capita water a potential at the beginning of 2000 is estimated to be 3000 m3. According to international assessments, countries with more than 10 000 m3 of water per capita per year are water rich, and countries with potential between 10 000 m3 and 3000 m3 are self-sufficient; Countries with a potential between 3000 m3 and 1000 m3 are considered to be water scarce countries. Countries with a potential of less than 1000 m3 per capita each year are thought water poor countries. Considering the growing population and climate change effects, Turkey is among the countries to have water shortages in the future. (Source: Gokdemir et. al., 2012)

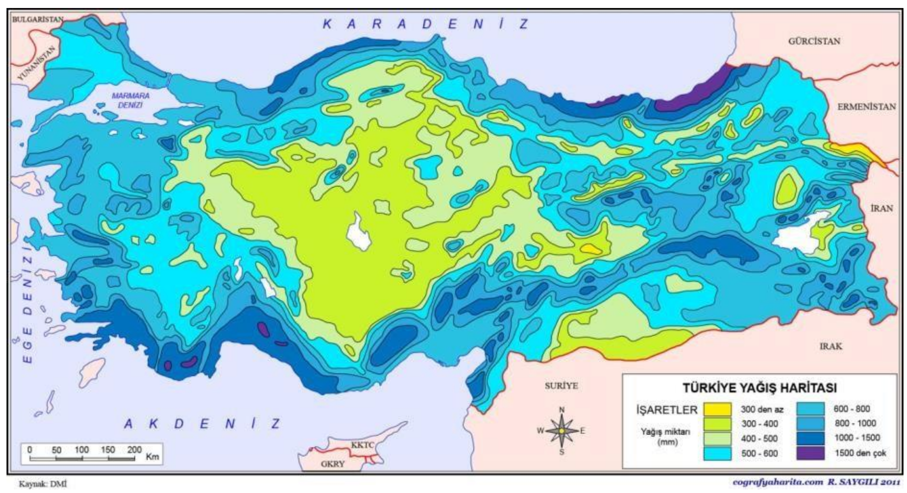

Figure 20: Turkey Rainfall Map (Source: Turkey's Energy Outlook, 2018)

In Figure 20, the map for Turkey's rainfall has been given. The color green shows a rainfall from 300mm from 500mm, the color blue shows a rainfall from 500mm to 800mm, the color dark blue is rainfall from 800mm to 1500mm, the color purple shows rainfall of more than 1500mm. As can be seen on the map the center of Turkey has a less rainfall than the rest of the country. The most rainfall is on the cost and to the east of Turkey as can be seen with the color blue. The north eastern Black Sea cost purple and has the highest rainfall in Turkey overall.

The development of small hydropower plants in Turkey began in 1902 in Tarsus. Since then, many SHEPP plans have been built by government agencies, the private sector and local municipalities in many regions. However, to date, priority has been given to large HEPPs. Investments in SHEPP have increased in recent years due to environmental factors, international treaties, and the assessment of streams and rivers that could have been used while experiencing energy shortages. (Source: Turkey Environment Foundation Publications, 2006) In recent years, due to the expansion of the use of natural gas in electricity production from thermal power plants the country has become increasingly become dependent on energy coming in from outside Turkey. In order to avoid or reduce this dependence, Turkey should use more economically operable hydraulic capacity.

Turkey has all kinds of possibilities for technology infrastructure that can use installed hydroelectric power plants. The best example of this is the construction of the Atatürk Dam and Hydroelectric Power Plant, which is one of the few dams and power plants in the world, built largely by local companies. In Turkey, there is also the technology and investment necessary for the establishment of small and medium-sized power plants. It is much easier to build SHEPPs, which can be built in a shorter time compared to large HEPPs and have relatively low legal and financial obligations. Therefore, the private sector is more interested in such power plants. Many projects have been completed in this field in the last few years. (Source: Turkey Environment Foundation Publications, 2006)

As of today, the number of projects to be realized by the private sector within the framework of the Electricity Market Law No. 4628 is around 1595. The "Water Use Right Agreement" ve and the process of obtaining the ''HEPP License" obtained by the agreement turned the HEPP License into a commercial commodity. In this case, the right to use the many rivers in Turkey in an uncontrollable manner was transferred to the private sector. As a result, "the HPP License Exchange" has been created. (Source: Turkey Environment Foundation Publications, 2006)

Unlicensed with Regulation Regarding Electricity Production Electricity Market, there has been a significant increase in micro and small HEPP construction in Turkey. As of March 2011, around 2000 applications were received throughout the country. It is clear that micro and small HEPPs will be established in many rivers and streams in the coming years. When establishing such plants, it is necessary to allow very good research, conduct environmental assessments, ensure the protection of ecological values of the region, consideration of the needs of the people of the region before the construction of these plants is allowed. Otherwise, irreparable losses may occur.

4.3.3 Big Hydroelectric Power Plants

It should be noted that capacity factors for hydro generation vary considerably year by year as seen in Figure 21, due to varying precipitation levels (snow and rainfall); in this regard, 2016 can be considered as an average year.

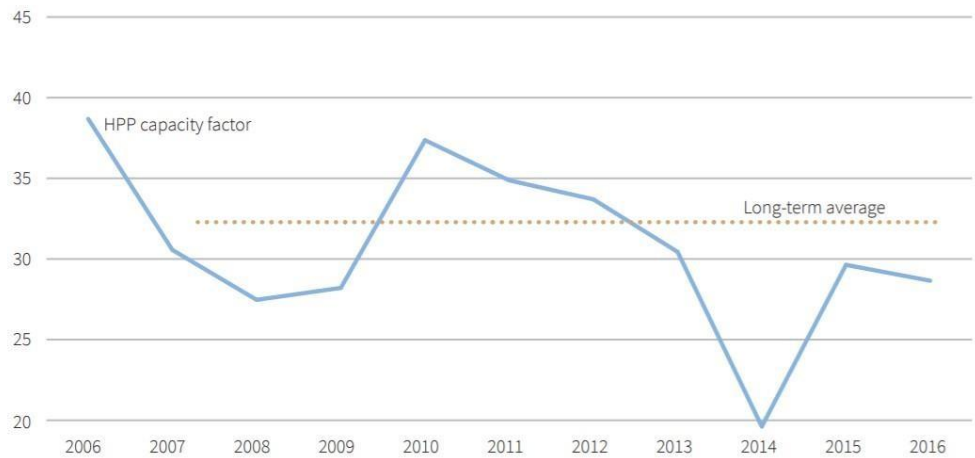

Figure 21: Average capacity factor of hydropower plants and the long-term average, 2006-2016 (Source: Turkey Electricity Production and Transmission Statistics, 2016)

In Figure 21, as shown the average capacity factor of hydropower plants and the long-term average from 2006 to 2016. The long term average is 32,5 from 2006 to 2016. The HPP capacity factor has been fallow in 2008 below the long term average for 32,5. There was a rise in 2010 which passed the long term average with 37 in 2010. There was another drop of HPP capacity factor from 2010 to 2014. The HPP capacity factor was the lowest in 2014 with under 20.

Turkey's share of electricity generation in hydropower production was around 60% in 1980. But from the 1990s natural gas and since the year 2000 imported coal has increasingly been used for electricity generation and as a result of wrong policies and this reduced capacity to 16% in 2014. After 2014 the was a slight increase but the HPP capacity was still under the long term average.

Capacity (MW)					
Year	Thermal	Hydraulic	Others	Sum	H/E %
1985	5.229,3	3.874,8	17,5	9.121,6	42,5
1990	9.535,8	6.764,3	17,5	16.317,6	41,5
1995	11074,0	9.862,8	17,5	20.954,3	47,1
2000	16.052,5	11.175,2	36,4	27.264,0	41,0
2005	25902,3	12.906,1	35,1	38.843,5	33,2
2010	32.278,5	15.831,2	1.414,4	49.524,1	32,0
2011	33931,1	17.137,1	1.842,9	52.911,1	32,4
2012	35.027,2	19.609,4	2.422,8	57.059,4	34,4
2013	38.648,0	22.289,0	3.070,5	64.007,5	34,8
2014	41.801,8	23.643,2	4.074,8	69.519,8	34,0
2015	41.847,4	25.867,8	5.432,4	73.147,6	35,4
2016	43.862,2	26.681,1	7.954,1	78.497,4	34,0
November 2017	45.619,7	27.211,7	10.307,5	83.138,9	32,7

Generation (GWh)					
Year	Thermal	Hydraulic	Others	Sum	H/E %
1985	22.168,0	12.044,9	6,0	34.218,9	35,2
1990	34.315,3	23.147,6	80,1	57.543,0	40,2
1995	50.620,5	35.540,9	86,0	86.247,4	41,2
2000	93.934,2	30.878,5	108,9	124.921,6	24,7
2005	122.242,3	39.560,5	153,4	161.956,2	24,4
2010	155.827,6	51.795,5	3.584,6	211.207,7	24,5
2011	171.638,3	52.338,6	5.418,2	229.395,1	22,8
2012	174.871,7	57.865,0	6.760,1	239.496,8	24,2
2013	171.256,0	59.245,8	8.791,5	239.293,3	24,8
2014	200.416,6	40.644,7	10.901,5	251.962,8	16,1
2015	177.852,2	66.897,9	14.861,5	259.611,5	25,8
2016	182.688,4	67.274,0	23.425,2	273.387,6	24,6
November 2017	189.652,3	53.192,9	22.031,8	264.876,9	20,0

Figure 22: Turkey's electricity installed capacity of development and production between 1985-2017(Source:Turkey's Energy Outlook, 2018)

The biggest Hydropower power plant in Turkey is the Atatürk hydropower plant with a capacity of 2405 MW. The following biggest hydropower plants are Karakaya hydropower plant. Keban hydropower plant and Altinkaya hydropower plant with an installed power capacity of 1800 MW, 1330 MW and 703 MW as shown in Table 23. There are 12 more hydro power plants currently in construction which have more than 250 MW capacity.

Nr.	Plant Name	Provinces	Operating Company	Installed Power (MW)
1	Atatürk Barajı ve HES	Şanlıurfa	EÜAŞ	2.405
2	Karakaya Barajı ve HES	Diyarbakır	EÜAŞ	1.800
3	Keban Barajı ve HES	Elazığ	EÜAŞ	1.330
4	Altınkaya Barajı ve HES	Samsun	EÜAŞ	703
5	Birecik Barajı ve HES	Şanlıurfa	EÜAŞ	672
6	Deriner Barajı ve HES	Artvin	EÜAŞ	670
7	Beyhan Barajı ve HES	Elazığ	Cengiz Enerji	582
8	Oymapınar Barajı ve HES	Antalya	Cengiz Enerji	540
9	Boyabat Barajı ve HES	Sinop	Boyabat Elektrik	513
10	Berke Barajı ve HES	Osmaniye	EÜAŞ	510
11	Hasan Uğurlu Barajı ve HES	Samsun	EÜAŞ	500
12	Artvin Barajı ve HES	Artvin	Doğuş Enerji	332
13	YedigözeSanibey Barajı	Adana	Sanko Enerji	311
14	Ermenek Barajı ve HES	Karaman	EÜAŞ	302
15	Borçka Barajı ve HES	Artvin	EÜAŞ	301
16	Sır Barajı ve HES	Kahramanmaraş	EÜAŞ	284
17	Gökçekaya Barajı ve HES	Eskişehir	EÜAŞ	278
18	Göktaş Barajı ve HES	Adana	Bereket Enerji	276
19	Alkumru Barajı ve HES	Siirt	Limak Enerji	276

Table 7: Hydro power plants with more than 250 MW in operation(Source:Turkey's Energy Outlook, 2018)

4.3.4 The Drawback and Complication

Streams; feeds groundwater and surface waters. Each stream provides life by transporting the minerals that it dissolves from where it passes through to the organisms living in and around it. However, interventions that interrupt the flow of water or change the direction of the water, such as the removal of water from the source, the withdrawal from the ground, or the construction of a hydroelectric power plant on a river, adversely affect all living things from microorganisms living in the water to the people living near the river. Turkey rapidly increasing investments in hydropower, the current state of the river basin, climatic features and so on have not been studied. 'Watershed planning', which is an indispensable condition of HEPP investments, has been neglected. Many projects have been implemented with inadequate engineering and are hydrology, inefficient and devoid of integrated planning. In particular, failure to optimize production between successive HEPPs leads to inefficient use of water and economic losses. (Source: Turkey's Energy Outlook, 2018)

In many HEPP projects, it is stated that the water values are not correct, the flood calculations, the installed power and production figures are exaggerated and inaccurate. For this reason, the hydroelectric potential should be redefined from a realistic point of view, and small capacity and low efficiency projects should be cancelled along with projects whose social costs are higher than their benefits and which the people of the region do not want. (Source: Schulze, 2015)

In order to ensure social, economic and ecological sustainability (continuity of natural life) along the river, the regulation on the release of water from HEPPs was added to the related regulation after the implementation of many HEPPs. This sometimes means falling under capacity in a project designed without consideration for life water. In some cases, the amount of underwater life preserved is insufficient for the continuation of the ecological system. Moreover, considering the transfer of water usage rights to the private sector, climate changes and droughts, will be a big problem for the local people in the coming years. (Source: Turkey's Energy Outlook, 2018)

In the construction of hydroelectric power plants, many trees are cut down to open roads for the opening of the road for the construction machinery for, water intake and for structures such as, reinforced concrete retaining walls, and for sand and gravel required for road construction which is obtained from quarries opened in forest areas. Excavation of riverbeds and valleys is also a problem. In addition, the use of explosives in stone quarries causes the destruction of the surface layer and underground rocks that delay the flow of water, and the explosions displace the living things in the region.(Source: Turkey's Energy Outlook, 2018)

There are many deficiencies and errors in the preparation of the EIA reports. In particular, environmental consultancy firms, who are assigned to prepare EIA reports and complete the related procedures, can prepare reports by, copy and paste methods in a very short period of time without examining the area and the project as necessary, and often without even seeing the project area. The Ministry of Environment and Urbanization, which has the authority to audit and decide on the relevant processes and reports, encourages the immediate implementation of the project rather than preventing it from its environmental impact. Therefore, the Public Participation Meetings held in the project area and the Inspection-Evaluation Commission (IDK) meetings held in the relevant units of the Ministry remain for show only. One of the most significant problems is the evaluation of the structures in the river basins as if they were independent from each other. Structures should be handled together, not separately, and EIA assessments should be conducted basin-based and integrated, as a result decisions should be made by determining the cumulative environmental impacts. (Source: Turkey's Energy Outlook, 2018)

Water structures are highly risky. In addition, the dam structures are not the structures under the responsibility of the investors, but also public facilities that may create problems concerning many segments of the society in case of a disaster, public supervision on the water and water structures has been disabled by the Regulation on the Supervision of Water Structures issued on 12.05.2015, where the investment was placed in the hands of private sector organizations. However, the audit should observe the criteria for the protection of public and social resources, the fulfillment of scientific, technical and engineering requirements and the protection of community interests. It should be ensured that HEPP investments are made in compliance with the rules to be followed from the beginning of the project up to the construction and operation phases, as well as the scientific, technical and ethical requirements, and of course the public interest. (Source: Turkey's Energy Outlook, 2018)

4.3.5 Factors Affecting the Growth of Hydro RES

The most important advantage to be gained by the use of SHEPPs is that they have almost no impact on the environment. In order to realize this low impact, the location of the SHEPP should be determined well and the project should be designed in harmony with the environment.

Some of the water held in SHEPPs is kept in such a way that it will flow between the water holding area and the turbine discharge point and the living spaces of the living things in the water are protected. (Source: Dalkir & Sesen, 2011)

SHEPPs do not cause the gases that cause the greenhouse gas effect during the generation of electricity to be released into the atmosphere. It is a clean and environmentally friendly energy that helps prevent the increased pollution in the atmosphere caused by fossil fuels. (Source: Dalkir & Sesen, 2011)

Small hydroelectric power plants play an important role in meeting the energy demands of rural areas, which are hard to access and cannot be supplied from the national system. (Source: Dalkir & Sesen, 2011) They also provide economic benefit to rural areas by preventing losses of the electricity to be transferred from the national power line.

Most of the investment cost of hydroelectric power plants consists of domestic expenditures. This is a positive contribution to the increase in domestic production. The external dependence on power plant investment is at the lowest level and very little foreign resources are needed in SHEPPs. Industrial building work required for the manufacture of water turbines for power plants in Turkey now reached the last stage. It is planned that all of the machines of mini, micro and even small hydroelectric plants will be built with domestic facilities in the near future. (Source: Dalkir & Sesen, 2011)

The economic life of these plants is very high compared to other plants. Initial investment costs are lower than large hydroelectric power plants. Expenditures for the establishment of SHEPPs are recovered in a maximum of ten years. The construction period of the SHEPPs is quite short and takes between 2-5 years. In addition, SHEPP can be established to generate electricity at the exit of irrigation dams, drinking water networks and irrigation canals. (Source: Ozdemir et. al.,2011)

These plants are also useful for the supply of drinking and potable water in the region where they are established. They are domestic resources and are not affected by the energy crises that can be experienced because they are not dependent on the outside. They have positive effects such as energy and flood protection, improving environmental agriculture, supporting fishing, afforestation and improving the aesthetic quality of the environment(Source:Ozdemir et. al.,2011)

4.4 Geothermal RES

4.4.1 The Technical Potential of Geothermal

The areas of utilization of geothermal energy are given in Table 2.6. By using technological innovations from geothermal energy, significant heat and electrical energy can be obtained. Geothermal energy is suitable to be established and developed as small power plants with 5-10 MW power, it is not affected by weather changes and users in the long term, and has independence from the price fluctuations of fossil fuels. Its price is low enough to compete with coal thermal power plants and natural gas, it is also an important energy source in terms of the environment as the emission value it emits in closed systems is zero. Direct use of geothermal in the world is the equivalent of 4.9 million in residential heating. (Source: Enis, 2003)

Places of Use	Temperature °C
Evaporation of High Concentration Solution, Cooling by Ammonium Absorption	180
Production of heavy water by hydrogen sulfide, drying of diatoms	170
Drying timber, like fish. food drying	160
Production of aluminum by Bayer's	150
Quick drying of farm products (Canning)	140
Sugar industry, salt production	130
Obtaining clean water, increasing salinity	120
Drying of cement	110
Organic matter drying (Seaweed, meat, vegetable etc.)	100
Fish drying	90
Home and greenhouse heating	80
Cooling	70
Poultry and barn heating	60
Mushroom growing, Balneological baths (Spa Treatment)	50
Soil heating, urban heating (lower limit) health facilities	40
Swimming pools, fermentation, distillation, health facilities	30
Fish farms	20

Table 8: Uses of Geothermal Energy According to Temperature Value (Source: Enis, 2003)

Electricity is produced from geothermal fluid with a temperature of 200 ° C or more. However, with new technologies developing day by day, electricity can be produced from the fluid with low hopper output up to 150 °C. With a system developed in recent years called binary cycle, electricity can be generated from waters with temperatures up to 80 ° C using low gases with low evaporation points. (Source: Enis, 2019)

4.4.2 Geothermal Energy in Turkey

Turkey has great importance in terms of geothermal energy due to its geological location and its tectonic structure. It ranks fifth in the world in terms of resource richness. Turkey, because it is a country located in the Alpine-Himalayan belt has a high potential for geothermal energy. Of this known potential 6 TWh is suitable for electrical energy and 19 TWh is suitable for direct use. (Source:Enis, 2003)

Turkey, with this geothermal potential is able to meet 5% of its total electrical energy requirement and 30% of the thermal energy requirement in heating. When their weight average is calculated it is enough to cover 14% of Turkey electrical and thermal energy needs. (Source: Atesogullari et. al., 2015) Geothermal resources are mostly found in western, northwestern and central Anatolia. (Source: Enis, 2003)

Thermal power input for power plants is measured in megawatts(MWt). Turkey's theoretical geothermal energy potential is estimated at between 31,500 to 60,000 MWt, 4809 MWt capacity is calculated as the actual available techniques. 2,880 MWt of the technical capacity has been proven, 805 MWt in residential heating, 612 MWt in greenhouse heating, 380 MWt in thermal facility heating, 1.005 MWt in thermal spring use, 1.5 MWt in fruit drying and 42, 8 MWt is used in heat pump application. Megawatts electric(MWe) refers to the electricity output capability of the plant, and megawatts thermal refers to the input energy required. The technical potential of electricity generation was considered to be 600 MWe until recently. The revised potential is expected to increase to 1500-2000 MWe with new discoveries considering the current technology and developments. ITU Energy Institute foresees that this figure can be increased to 2000 MWe with new field research and drilling works. The total installed capacity of the power plants online has already reached 1037.3 MWe. Meanwhile, the total installed capacity of the power plants is 230 MWe and exploration and field studies are continuing for the project with a capacity of approximately 650 MWe. (Source: Turkey's Energy Outlook, 2018)

The total installed capacity of geothermal power plants in Turkey has exceeded the value of 1000 MWe. As a conclusion of the investments made in recent years Turkish Republic has become the fastest growing country in the world in geothermal energy. The geothermal installed power in the world is approximately 14.000 MWe and Turkey ranks 4th in the world according to 2017 data. (Source: Turkey's Energy Outlook, 2018) Information and estimates of current and expected geothermal installed power capacities according to the ongoing projects are given in Figure 23.

More than 30 companies continue their exploration and drilling works for geothermal projects. (Source: Turkey's Energy Outlook, 2018)

According to the Figure 23 below from 2007 till today there was a increase in the in installed capacity as well as the number of wells drilled. The number of the wells drilled has been constant since the year 2015. The installed capacity is expected to grow in the coming years for 2019 and 2020.

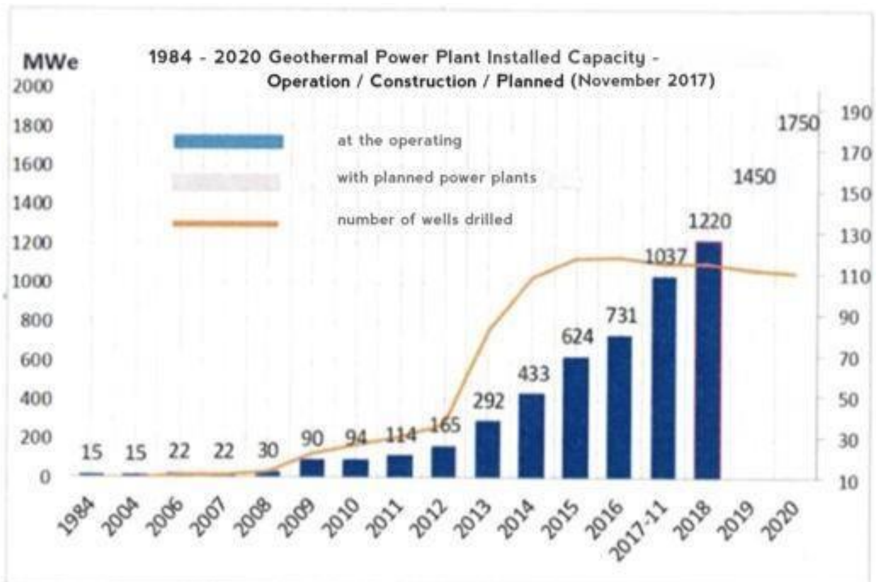

Figure 23: Geothermal Power Plant Installed Power (Source: Turkey's Energy Outlook, 2018)

In Figure 23, the geothermal power plant installed power has been given. The blue column shows geothermal power plant installed capacity while the orange line presents the number of drillings for geothermal power plant. There was a small increase in installed power until 2011. After 2011 installed power has increased significantly so that the installed power has reached to 1220MWe in 2018. The drilling number has been increased little from 1984 till 2011. After 2011 the drilling number advanced notably until 2015. After 2015 the drilling number has been stable

In the Table below shows the construction of geothermal power plants from 2013 until 2017. Most geothermal plants are Binary Power Plant. From 2007 until today there has been an increase in installed capacity as well as the number of wells drilled. The number of the wells drilled has been constant since the year 2015.

Power Plant Name	Year	Plant Type	Turbine Company	Installed Power	Investor Company
Caferbey Salihli	2017	Binary	Ormat	16	Sanko Eenrji
Kizildere III U2b	2017	Binary	Ormat	15,8	Zorlu Eenrji
Kizildere III U2a	2017	Flash	Toshiba	52	Zorlu Eenrji
TBK Kuyucak	2017	Binary	Exergy	22	Sanko Eenrji
Efe 6	2017	Binary	Ormat	27	Gürmat Elektrik
Kizildere III U1b	2017	Binary	Ormat	23	Zorlu Eenrji
Kizildere III U1a	2017	Flash	Toshiba	60	Zorlu Eenrji
Sultanhisar	2017	Binary	Atlas Copco	22	Celikler Holding
Afyon	2017	Binary	Turboden-MHI	3	AFJET
Morali	2017	Binary	Exergy	24	Karizma Enerji
Meger(Dora 3a)	2016	Binary	Ormat	21	Mege Enerji
Karkey	2016	Binary	Exergy	12	Karadeniz Holding
Türkerler	2016	Binary	Ormat	24	Turkerler
Greeneco 2x12.5	2016	Binary	Exergy	25	Greeneco
Enerji Holding	2016	Binary	Exergy	24	Enerji A
Pamukören-5	2016	Binary	Atlas Copco	22,5	Celikler Holding
Pamukören-4	2015	Binary	Atlas Copco	22,5	Celikler Holding
Zorlu	2015	Flash/Binary	Toshiba+TAS	45	Zorlu Eenrji
MTN	2015	Binary	Atlas Copco	8	MTN Enerji
Karkey	2015	Binary	Exergy	12	Karadeniz Holding
Efe-1	2015	Flash	Mitshibushi	47,5	Gurmat Elektrik
Efe-4	2015	Binary	Exergy	25	Gurmat Elektrik
Pamukören 3	2015	Binary	Ormat	22,5	Celikler Holding
Akca Enerji	2015	Binary	Ormat	3,5	Akca Enerji
Efe 3	2015	Binary	Ormat	25	Gurmat Elektrik
Ken	2015	Binary	Ormat	22,5	Maren Enerji
Kerem	2014	Binary	Ormat	24	Maren Enerji
Türkerler	2014	Binary	Ormat	24	Turkerler Enerji
Mega(Dora 3b)	2014	Binary	Ormat	20	Mege Enerji
Efe 2	2014	Binary	Ormat	25	Binary Gurmat
Kizildere 2	2013	Flash/Binary	Fuji+TAS	80	Zorlu Eenrji
Pamükören 2	2013	Binary	Atlas Copco	22,5	Celikler Holding
Pamükören 1	2013	Binary	Atlas Copco	22,5	Celikler Holding
BM	2013	Binary	Ormat	9,8	BM Enerji
Mega(Dora 3a)	2013	Binary	Ormat	21	Mege Enerji

Table 9: Geothermal District Heating System in Turkey (Source: Turkey's Energy Outlook, 2018)

In Turkey it is known, around 1000 geothermal wells with hot water and mineral water resources are available. The number of geothermal fields with temperatures above 40 °C is 170. 11 of these are high temperature fields and suitable for electricity production. These are; Aydın-Germencik 232 °C, Manisa-Salihli-Göbekli 182 °C, ÇanakkaleTuzla 174 °C, Aydın-Salavatlı 171 °C, Kütahya-Simav 162 °C, İ zmir-Seferihisar 153 °C, Manisa-Salihli-Caferbey 150 °C Aydın-Yılmazköy is 142 °C, İzmir-Balçova is 136 °C, İzmir-Dikili is 130 °C. The Denizli-Kızıldere fields in Turkey, geothermal suitable for electricity production is established at 20 MW power plant is scheduled to produce 12 MW of electricity. (Source: Turkey Environment Foundation Publications, 2006)

Established in Denizli Sarayköy, Turkey's first geothermal power plant, built in 1984, has an installed capacity of 20.4 MW. In 2000, the power plant generated 75.5 million kWh of energy and Turkey's share of geothermal energy available for consumption in general are known to be 0.1%. (Source: Enis, 2003)

In Turkey in 2006, 21.85 MW geothermal power production capacity was in operation, with the opening of 6 plants, which are shown in Table 2.9 they reached around 97.25 MW. 161 There are 13 field containing potentially suitable for electricity generation in Turkey and these sites are located in western Anatolia. The apparent capacity of these sites is 100 MWe. This capacity will be increased to 550 MWe when the development of all sites is done. (Source: Atesogullari et. al., 2015)

Turkey has among the highest geothermal potential for medium temperature pitches. The resources in this group are suitable for direct use as heat in industrial process as well as generating electricity with binary systems. (Source: Atesogullari et. al., 2015)

In 1964 Turkey began for the first time to use heating from geothermal energy utilization in a hotel in Balikesir Gonen. Again in 1987, it was first used in residential heating in Gönen and has a capacity of 16.2 MW. (Source:Enis, 2003) Currently in Turkey; There are geothermal central heating systems in Gönen, Simav, Kirsehir, Kızılcahamam, Afyonkarahisar, İzmir(Balçova Narlıdere Dokuz Eylül University Medical Faculty Hospital and Campus) , Sandıklı, Kozaklı, Diyadin, Salihli, Edremit, Sarayköy, Bigadiç and Yozgat (Sarıkaya). In these locations, houses and buildings are heated by geothermal energy. (Source: Atesogullari et. al., 2015)

Spa tourism in Turkey is a fast-growing sector. It is said that four million people visit the hot springs annually. Increasing the number of foreign visitors (assuming better accommodation facilities will contribute to our country's earning significant income in health tourism. Afyon, Balcova, Cesme, Gonen, Kizilcahamam and Kozakli all have large spa areas. In addition, Adapazarı-Akyazı and Yalova-Armutlu in places such as spa and circuit services. Besides, these thermal water is transported to 18 large hotels by laying a 42 km hot water pipeline in Çeşme, Izmir.(Source: Atesogullari et. al., 2015)

When we look at the production of chemical materials from geothermal sources in the commercial sense; for example, while the total carbon dioxide (CO2) production worldwide is 21 000 tons, In Turkey (Denizli-Kızıldere), there is a CO_2 factory with an installed capacity of 120,000 tons per year. (Source: Enis, 2019)

Turkey's rise in the use of geothermal energy in recent years, though not sufficient, and with an emphasis on heating and thermal tourism-spa applications, has the potential to be used more effectively. With the development of electricity production from geothermal energy, increasing investments in spa tourism and diversifying its usage areas, it will be possible to make more use of geothermal energy potential.

Adequate disclosure causes benefit from geothermal energy in Turkey, are technical, financial and management issues. Technical problems include low temperature sources, calcite deposition in reservoirs, wells and surface equipment during production and environmental problems. One of the most significant reasons for not developing geothermal energy rapidly in Tury is insufficent investment in geothermal energy projects. Projects and applications involving the use of low temperature sites in the heating of residential areas, greenhouses and in some industrial areas can be realized through the efforts of local administrations as well as a clear geothermal policy from the state. For example; In İ zmir, Manisa, Denizli, Aydın, Ağrı, Şanlıurfa, Balıkesir and Kütahya provinces, 2104 acres of greenhouse area with a capacity of 207.4 MWt is heated with geothermal energy. (Source: Atesogullari et. al., 2015)

The state sector in Turkey has withdrawn from geothermal energy, which it has invested in for many years. After the Geothermal Resources and Natural Mineral Waters Law was enacted in 2007, the private sector has started to show great interest in investment in geothermal energy. Recently, investors who had never heard of geothermal energy have begun to want to invest their savings in this energy sector which will gain importance in the future. Geothermal energy is particularly attractive to investors due to its advantage in electricity generation. (Source: Atesogullari et. al., 2015)

The aim of the Law on Geothermal Resources and Natural Mineral Waters, which was enacted in 2007, is; to regulate the procedures and principles regarding the efficient search, exploration, development, production, protection of natural resources, geothermal and natural mineral water resources, ownership of these resources and transfer of rights, economic evaluation and abandonment in harmony with the environment. In addition, with the entry into force of this law, license rights will be granted by legislation and local politicians working together with the Central Government and Local Administration (Special Provincial Administrations). (Source: Atesogullari et. al., 2015)

In today's world where the need for energy is increasing energy is and becoming more expensive to obtain, the necessary precautions and controls should be in place in order to use geothermal energy as a renewable, environmentally-friendly and economic energy source. It should be kept in mind that geothermal energy is not fully renewable and may cause uncompensated environmental problems if it is not used properly.

4.4.3 Drawback and Complications

Although geothermal energy is recognized as an environmentally friendly resource, geothermal fluid causes corrosion, decay, calcification, and pollutes the surface water when discarded because of the bor mine it contains, causing water and soil pollution. (Source: Badruk, 2019)

The continuous cycle of the water in the underground layers of the geothermal energy is obtained by dissolving the minerals in the layers, causing the water to become polluted and the soil being polluted and salted by the use of this water. In addition, withdrawal of the water supplied from the groundwater layer adversely affects the water retention capacity of the surface and leads to the deepening of the water layer. Precautions should be taken for environmentally friendly geothermal application. (Source: Badruk, 2019)

In cases where the necessary precautions are not taken during the use of geothermal energy resources, some environmental problems may occur. For example, environmental problems such as temperature and noise, and in addition, chemical waste materials such as mercury, arsenic, lead, lithium, ammonia in the geothermal fluid can cause serious environmental problems. (Source: Badruk, 2019)

Another disadvantage related to the use of geothermal energy is that it is necessary to use this energy source on site because its transportation over long distances is limited. Today, geothermal energy can only be transported up to 100 km. (Source: Badruk, 2019)

As for the economy of district heating systems, Kaygan (2008) conducted a stochastic study for district heating systems (some already established). They don't look profitable with real low fixed rate heat tariffs. Many were studied and not one of them resulted in a profitable business. Other studies, such as conceptual planning of the expansion of the Balçova district heating system, have resulted in negative NPV with actual tariffs. (Source:Turkey's Energy Outlook, 2018)

4.4.4 Factors Affecting the Growth of Geothermal RES

Geothermal energy use is of big importance in terms of decreasing the consumption of fossil fuels and preventing environmental problems such as the greenhouse effect and acid rain. Geothermal energy should be used properly in order not to be harmful to the environment. That is to say, the return of the used geothermal fluid to the reservoir by back pressure must be facilitated. Returning the fluid to the underground also extends the service life of geothermal energy. (Source: Schulze, 2015)

In todays geothermal power plants based on geothermal energy, CO2, NOx, SOx emissions are not high and especially zero in central heating systems. Carbon dioxide emissions in coal-fired power plants are 1600 times higher than in geothermal power plants. Natural gas plants have at least 2000 times more carbon dioxide emissions than geothermal plants. (Source: Turkey Environment Foundation Publications, 2006)

The unit cost of electricity obtained from geothermal energy is cheaper than other energy sources. Although the initial installation cost of power plants using geothermal energy is high, the low operating cost and the lack of any cost of the resource used ensure that the economic return is higher than other power plants. (Source: Turkey Environment Foundation Publications, 2006)

Geothermal energy is a domestic energy source that does not require high technology. Therefore, countries benefiting from geothermal energy are protected from international crises while being freed from technological and political devotion. (Source: Schulze, 2015)

Geothermal energy is a continuous source of energy that is not affected by short-term meteorological events. It is an energy that is not affected by daily changeable weather events as in solar and wind energy. It is a very efficient energy source. It can be used as direct heat energy, it is used also to obtain electrical energy at high temperatures. In addition, the remaining hot water after the energy is obtained can be used and, the yield from the source is increasing by evaluating different applications. (Source: Schulze, 2015)

4.5 Biomass, Biofuel and Biogas RES

4.5.1 The Technical Potential of Bioenergy

Biomass is generally used to provide heat, produce fuel and generate electricity. Industrial, urban and other waste materials that cause environmental pollution are used within the scope of biomass energy technologies and many solid, liquid and gaseous fuels alternative to fossil fuels are obtained. Biomass fuels include such as biodiesel and bioethanol. These fuels are environmentally inmate therefore they do not cause greenhouse gas emissions. Biomass produced in Turkey the years of 2013 and 2014 are as shown in Table 10. (Source: Turkey's Energy Outlook, 2018)

Year 2013	Gross Electricity Production with Biomass	3.010	TEP
	Gross Electricity Production with Biogas	72.571	TEP
	Heat Production with Biogas	35.803	TEP
Year2014	Biomass Production	3.152.193	TEP
	Biogas Production	232.738	TEP
	Liquid Biofuel Production	58.000	TEP

Table 10: Turkey Biomass Production Status (Source: Turkey's Energy Outlook, 2018)

According to TEIAS 2017 year-end data the total installed capacity of power plants in Turkey is 200 MW and annual production is 295,510.6 GWh; In contrast the total installed capacity of Biogas, Biomass, Waste Heat and Pyrolytic Oil Power Plants is 634.2 MW and annual electricity generation is 2,796.6 GWh. (Source: Turkey's Energy Outlook, 2018)

4.5.2 Bioethanol Use in Turkey

Bioethanol is produced from raw materials containing sugars (such as sucrose, starch, cellulose) that contain enough glucose or can be converted into glucose. Raw materials used in bioethanol production are generally divided into three main groups;

- Raw materials containing sucrose (for example sugar beet, sorghum and sugar cane)
- Raw materials containing starch (for example wheat, corn and barley)
- Lignocellulosic raw materials (for example straw, wood and grass)

The technology of bioethanol production from the first and second group of raw materials in the list is well established today. However, the production of bioethanol from the third group has not been fully achieved because the technology and the production process has not been fully optimized. Therefore, bioethanol, which is mostly commonly produced today, is called ‘’the first generation bioethanol”. In fact, when the production process is perfected, the production of bioethanol from lignocellulosic sources will be much more economical because lignocellulosic raw materials are both considerably more expensive and much cheaper than cereals. Bioethanol produced from these raw materials is called “second generation bioethanol” and this technology is expected to be introduced after 2025. (Source: Turkey’s Energy Outlook, 2018)

In Turkey, the production of bioethanol is made from sugar beets, and especially for bioethanol production, the mainly primary sources are listed below,

- sugar beet and residues
- potato
- wheat and residues
- corn and cobs
- other lignocellulosic materials (grass, vegetable waste / residues, energy crops, etc.)

Figure 24 the production quantities of different agricultural products is given below for 2016 in Turkey. These products can also be used to produce different biofuels, particularly bioethanol. However, bioethanol production from these agricultural products is not preferred be- cause these resources (except residues) are also used in the food industry. (Source: Turkey’s Energy Outlook, 2018)

Bioethanol can be used as an alternative to gasoline in vehicles or mixed with gasoline in different ratios. Legally in Turkey, up to 5% can be mixed with gasoline. However, since the Special Consumption Tax (SCT) is applied only to 2% contributions, a maximum 2% contribution is made. Bioethanol, which can be added up to at 10% without any modifications to the vehicles, requires some changes to the engine at higher mixing ratios.

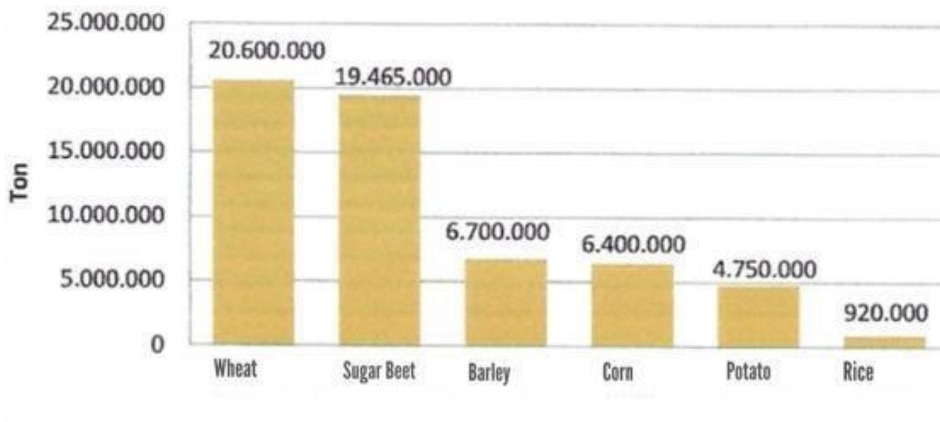

Figure 24: Year 2016 Production Quantities of Agricultural Products in Turkey (Source: Turkey's Energy Outlook, 2018)

In Figure 24, the production quantities of agricultural products in Turkey has been given for 2016. Wheat has the highest agricultural productivity with 20.6 million tonnes. while sugar beet has the second highest productivity with 19.47 million tonnes. Barley, corn and potatoes have a similar production with 6.7 million ton, 6.4 million ton and 4.75million tonnes each. The lowest agricultural production is rice with 920 thousand tonnes.

The most suitable raw materials for bioethanol production in Turkey are sugar beet and pulp, corn, potatoes and other cellulosic biomass resources. The potentials of some bioethanol production raw materials are given in Table 11. (Source: Turkey's Energy Outlook, 2018)

Raw Materials	Biotanol production potential (l/ton)
Sugar cane	**70**
Sugar beet	**110**
Sweet potato	**125**
Potato	**110**
Manioc	**180**
Corn	**360**
Rice	**430**
Barley	**250**
Wheat	**340**
Pulp and other cellulosic materials	**280**

Table 11: Bioethanol Raw Materials and Potential Production Quantities (Source: Turkey's Energy Outlook, 2018)

According to a study conducted in 2010 in Turkey, it is stated that 5.8 billion liters of bioethanol can be produced annually by potato, sugar beet and wheat cultivation [20]. If not used for food, the bioethanol production potential produced in 2017 from wheat, sugar beet, barley, corn, potato and rice can be calculated as 14 billion liters. Considering the annual fuel consumption Turkey with 5.8 billion liters of ethanol production available, it is understood to correspond to %2.8 of the total gas consumption.(Source:Turkey's Energy Outlook, 2018)

Agricultural Products	Production (Ton)	Bioethanol Production Potential (l/ton)	Amount of Bioethanol to be Obtained (m3)
Wheat	20.600.000	340	7.004
Sugar beet	19.465.000	110	2.141
Barley	6.700.000	250	1.675
Corn	6.400.000	360	2.304
Potato	4.750.000	110	523
Rice	920.000	430	396
		Total	**14.042**

Table 12: The amount of bioethanol which can be obtained from some agricultural products produced in 2017 in Turkey (Source: Turkey's Energy Outlook, 2018)

Bioethanol has an significant place in all biofuels due to its similarity with gasoline and it is a potential alternative to fossil fuels. Bioethanol can be produced in existing ethanol production facilities in Turkey, with a current potential of approximately 800,000 liter/day. Currently, there are 3 active bioethanol production facilities for fuel purposes and sugar beet, wheat and corn are used in these facilities. (Source: Turkey's Energy Outlook, 2018)

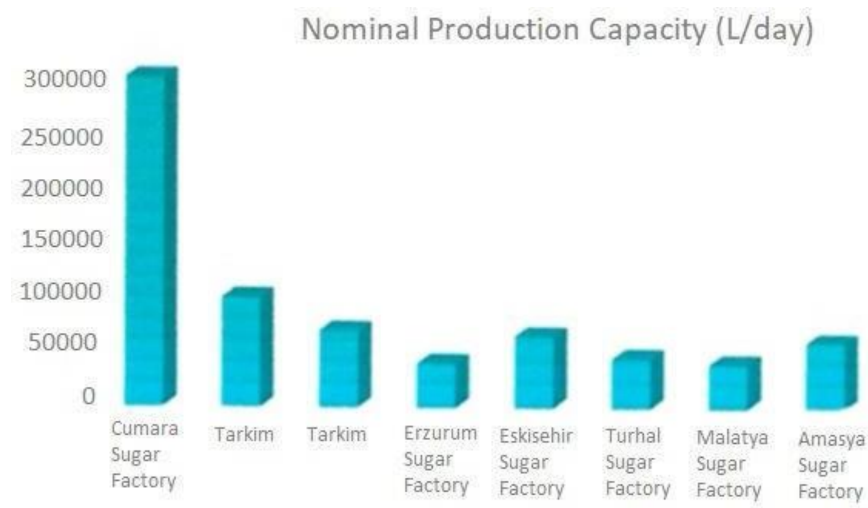

Figure 25: Current bioethanol production and total potential in Turkey (Source: Turkey's Energy Outlook, 2018)

In Figure 25, the current bioethanol nominal production capacity in liters per day in turkey has been represented. The Cumara Sugar Factory has the highest production with a value around 300000L/day. The other factories have a value between 50000L/day and 10000L/day.

There are 12 plants for producing bioethanol in Turkey, and 8 of them have the capacity to produce biofuel. However, only 3 of them produce bioethanol as fuel, while others use ethanol for beverages.

In 2010, bioethanol production in Turkey was 60 million liters by the end of 2015, bioethanol production in Turkey is the annual 150 million liters at the level of the distribution between the manufacturing companies that manufacture Tarkim Inc. / Bursa 44 million liters, Tezkim Inc. / Adana 22 million liters, Konya Sugar Inc / Cumra 84 million liters. Current production increased by %10 and as of 2017, Turkey is estimated to have reached a total of about 165 million liters. (Source: Turkey's Energy Outlook, 2018)

Bioethanol produced in Çumra Sugar Factory Bioethanol Plant, which is a subsidiary of Konya Sugar Factory, is designed to be produced directly from sugar beet molasses, directly from beet or sugar. It is used as a fuel blending product in vehicles and is also used in the printing industry. This investment made by Konya Şeker in order to evaluate the by-product molasses produced after sugar production and to turn it into a product with high economic value is one of the most important investments in renewable energy in Turkey. The facility, which has %56 of the installed capacity of Turkey's bioethanol, supplies products to large fuel distribution companies. (Source: Turkey's Energy Outlook, 2018)

Petroleum Office is the only company in Turkey using bioethanol. According to the information obtained, the average annual sales of 95 octane unleaded gasoline is 600.000 m3. Approximately 62,000 m3 of bioethanol is required annually depending on the 2% addition requirement. For the production of this amount of bioethanol; 64,500 tons of wheat, 72,500 tons of corn or 210,000 tons of sugar beet should be used. If the usage rate is increased to 5% with the legal regulations, the annual bioethanol requirement is estimated to be 157,000 m3. (Source: Turkey's Energy Outlook, 2018)

When Turkey needs to import 90% of its oil needs, the importance of energy security is emerging. In order to reduce this dependence on oil, realistic, efficient and sustainable policies should be established. In Turkey, in the case of gasoline, bioethanol blending ratio of 5% would lead to the removal of approximately 135 million liters of bioethanol from animal feedstock supplies. In Turkey in 2013 the amounts of feedstock required for bioethanol amount to 356 thousand tons of corn (6%), 1 million 244 thousand tons of sugar beet (7.5%), 448 thousand tons of beet molasses (72%) and 240 thousand tons of wheat (1.8%). Approximately 16-18 million hectares of cultivated land is located in Turkey, so it is considered that these figures will not create any problem for the specified production. (Source: Turkey's Energy Outlook, 2018)

On the other hand, molasses production depends on sugar quotas. In the production of bioethanol, molasses must be shifted from the sectors that use molasses (yeast, feed, cosmetics etc.) to be raw materials. This means imports for the country. Moreover, Turkey's molasses production does not fully meet the demand of the country. Similarly, corn production is lower than domestic demand. However, it is thought that the increase in production can be achieved by price and support policies. (Source: Turkey's Energy Outlook, 2018)

4.5.3 Biodiesel Usage in Turkey

Biodiesel is an alternative biofuel to diesel fuels which can be obtained from oilseed plants and waste oils. These oilseed plants are plants such as canola, safflower, soybean and sunflower. In addition, animal fats, such as frying oils, fish oil and residual oils can be used in biodiesel production. Biodiesel, like bioethanol, can be mixed with diesel fuels in certain proportions, or alternatively it can be used alone. In many parts of the world, B-letter systems are used for biodiesel blended fuels. This system is based on the amount of biodiesel added to the diesel fuel. For example, B20 is signification a mixture of 20% biodiesel and 80% diesel fuel. (Source: Turkey's Energy Outlook, 2018)

In Turkey, canola is produced on approximately 54.000 acres of land, and the total area given over the production of oilseed plants, 6.6 million acres. The proportion of canola in the production of 2.8 million tons of oilseed plants equates to approximately 12,600 tons per year. (Source: Turkey's Energy Outlook, 2018)

The biggest advantage of using biodiesel is that it is environmentally friendly and produced from domestic sources. Further advantages of biodiesel can be listed as being easy to access and renewable, having high combustion efficiency, low sulfur and aromatic contents, high cetane number and a high biodegradability. With the production and use of biodiesel, the entry of imported petroleum-derived fuels into the country will be reduced and thus, the use of fuel that is both environmentally friendly and economical will increase. (Source: Turkey's Energy Outlook, 2018)

Turkey produces only 15% of the amount of oil it uses, buying the rest from abroad. Diesel fuels have the highest share in oil consumption as a result of, marine and land transportation and industrial applications with a rate of 34%. (Source: Turkey's Energy Outlook, 2018)

Despite the increase in popularity of biodiesel, the production of oilseed plants is decreasing due to wrong political strategies. Illegally produced biodiesel has also caused problems in vehicle engines. In addition, the price of oilseed plants has risen due to popularity. In fact, for the production of biodiesel, plant imports from abroad have increased. However, sub-standard biodiesel production, has been interrupted and almost stopped due to the increase in prices and the dissatisfaction of users. In recent years, as in the world of work on the production of biodiesel from algae Turkey also sees great interest is made. If algae and biodiesel production processes are optimized and continuous production and legal arrangements organised in a positive way this will support diesel fuel demand in the sector. (Source: Turkey's Energy Outlook, 2018)

The major part of the cost of biodiesel production is raw materials. It was stated by producers that biodiesel production did not save costs with the introduction of SCT application. Currently, this sector has been put on hold in Turkey.

A special consumption tax was introduced for Turkish Biodiesel Production in official government paper 27857, dated February 25, 2011. As a result, most manufacturers have revoked their licenses and those with licenses have been unable to produce biodiesel. Only one company in Turkey has a production of 20 thousand tons. Since 2005, 80 enterprises have received biodiesel processing licenses in Turkey but 25 of these licenses have been terminated and 43 have been revoked by 2018. As of 2018, the licenses of only 14 enterprises are still in force. Only 5 of the companies whose licenses are in force were licensed between 2005 and 2007 and 9 of them were licensed after 2014. The total processing capacity is around 1.5 million tons with the enterprises whose license has not been revoked or terminated, but this is largely idle. Companies with a biodiesel Processing License in force at the beginning of 2018 are shown in Table 13. (Source: Turkey's Energy Outlook, 2018)

According to the Communique on the Amendment to the Technical Regulation Communique No: 28067 dated 27 September 2011 published in the Official papers, the content of the Fatty Acid Methyl Ester produced from domestic agricultural products of diesel fuel types must be at least 1% as of 1.1.2014, at least 2% as of 1.1.2015 and at least 3% as of 01.01.2016. (Source: Turkey's Energy Outlook, 2018)

Business Name	Starting date	End Date	Facility District	Facility Province
Çevrem Alternatif Enerji Biyodizel ve Petrol Ürünleri Gıda Sanayi Ticaret Limited Şirketi	15.02.2007	15.02.2019	Nurdagi	Gaziantep
Ömer Bucak İnşaat Taahhüt Sanayi ve Ticaret Limited Şirketi	22.02.2007	22.02.2019		Şanliurfa
Piteks Petrol İnşaat Tekstil Gıda Kimya Sanayi ve Ticaret Limited Şirketi	01.03.2007	01.03.2019	Tuzla	İstanbul
Db Tarımsal Enerji Sanayi ve Ticaret Anonim Şirketi	20.09.2007	20.09.2019	Torbali	İzmir
Deha Bitkisel Atık Yağ Toplama Geri Kazanım Biyodizel Üretimi Sanayi ve Ticaret Anonim Şirketi	30.09.2014	30.09.2026	Dilovasi	Kocaeli
Aves Enerji Yağ Ve Gıda Sanayi Anonim Şirketi	25.12.2014	25.12.2026	Akdeniz	Mersin
Tbe Biyodizel Tarımsal Enerji Üretimi Sanayi ve Ticaret Anonim Şirketi	16.04.2015	16.04.2027	Kartepe	Kocaeli
Maysa Yağ Sanayi Anonim Şirketi	05.10.2016	05.10.2028	Basaksehir	İstanbul
Kolza Biyodizel Yakıt ve Petrol Ürünleri Sanayi ve Ticaret Anonim Şirketi	01.12.2016	01.12.2028	Tuzla	İstanbul
Özgür Geri Kazanım ve Yağ Sanayi Ticaret Limited Şirketi.	16.05.2017	16.05.2029		Ankara
Biodizel Enerji Sanayi ve Ticaret Anonim Şirketi	03.08.2017	03.08.2029	Ergene	Tekirdag
Öz-Ova Tar.Ür.Çır.Pre.Teks.Köm.Oto.Nak. Biyodizel Akaryakıt Tur. Gıda İnş. İt.İhr Sanayi ve Ticaret Limited Şirketi	13.12.2017	13.12.2029	Kirikhane	Hatay

Table 13: Biodiesel Licensed Companies(Source:Turkey's Energy Outlook, 2018)

4.5.4 Biogas Usage in Turkey

Apart from liquid biofuels, biogas is one of the most popular organic material origin fuels in Turkey. Biogas is an alternative to natural gas obtained by fermentation of organic materials (animal waste, plant waste / waste, sludge, etc.) in an oxygen-free environment. Biogas can be used in all areas where natural gas and LPG are used. Liquefied petroleum gas or liquid petroleum gas (LPG), also called propane or butane, are mixtures of flammable hydrocarbon gases used as fuel in heating appliances, cooking appliances and vehicles.

Biogas production is significant not only because it provides energy, but also for the disposal of wastes of organic origin that may harm the environment. In addition, fermented fertilizer produced by the biogas production process plays a major role in agricultural activities. Unlike other renewable energy sources, biogas production and systems do not require geographical constraints and high technology requirements. (Source: Turkey's Energy Outlook, 2018)

Biogas can be used in combi boilers, ovens, gas lamps, transportation vehicles and internal combustion engines with minor modifications. This energy can be converted into thermal energy and electrical energy. The fermented fertilizer produced at the end of the process is more efficient than the fertilizers commonly used in Turkey. The carbon-nitrogen ratio of this fertilizer is very suitable for plant production and growth. At the same time, the disposal of pathogens in the manure, especially in systems where animal wastes are used and deodorization can be counted among the advantages of fermented fertilizer. The total biomass energy potential is considered to be around 16–32 million tonnes of oil equivalent and the amount of animal waste is 2.3 million tonnes of oil equivalent. Especially in rural areas in Turkey, it is possible to support the production and use of biogas and economic and social development. Indeed, it is known that around 2.2 m3. 9 billion m3 of biogas can achieved from biogas systems using animal disposal. (Source: Turkey's Energy Outlook, 2018)

In addition to gasification for electricity generation, there are also facilities that use the direct combustion of waste biomass. Table 14 lists the newest biogas, biomass, waste heat and pyrolytic oil power plants.

Facility Name	Location	Company name	Power (MW)
Odayeri Çöp Gazı Santrali	İstanbul	Ortadoğu Enerji	34
Toros Tarım Samsun Atık Isı Santrali	Samsun	Toros Tarım	31
Mutlular Biyokütle (Orman Atığı) Enerji Santrali	Balıkesir	Mutlular Enerji	30
Mamak Çöplüğü Biyogaz Tesisi	Ankara	ITC Katı Atık Enerji	25
ÇadırtepeBiyokütle Santrali	Ankara	ITC Katı Atık Enerji	23
Sofulu Çöplüğü Biyogaz Santrali	Adana	ITC Katı Atık Enerji	16
Akçansa Çimento Atık Isı Santrali	Çanakkale	Enerjisa Elektrik	15
ITC Antalya Biyokütle Santrali	Antalya		14
Kömürcüoda Çöplüğü Biyogaz Santrali	İstanbul	Ortadoğu Enerji	14
Eti Alüminyum Atık Isı Elektrik Santrali	Konya	Cengiz Enerji	13
Zeus Biyokütle Enerji Santrali	Kırklareli	Zeus Enerji	12
Eti Maden Bandırma Atık Isı Santrali	Balıkesir	Eti Maden	12
ITC-KA Sincan BiyokütleGazlaştırma Tesisi	Ankara	ITC Katı Atık Enerji	11
Bağfaş Gübre Fabrikası Biyogaz Santrali	Balıkesir	Bağfaş Gübre Fabrikası	9.92

Table 14: List of Biomass Plants in Use (Source: Turkey's Energy Outlook, 2018)

4.5.5 Drawback and Complications

Although biomass energy is an environmentally friendly energy source in general, it can create some environmental problems depending on the type of biomass used. For example, pollution from incineration of waste and similar wastes can cause environmental problems. There is a possibility of combustion and explosion of gases released during storage and separation of garbage. (Source: Arslan,

2017) If sufficient precautions are not taken, garbage storage facilities also cause visual pollution and bad smells.

Perhaps the most dangerous and negative aspect of biomass energy is producing it from crops like wheat, barley, corn, potato, sugar beet, etc. The reason is that the basic nutrients that people meet their nutritional needs with are consumed by machines. Farmers plant biodiesel raw-materials in their fields instead of wheat, so food prices are gradually increasing. In today's world, where the world's population exceeds eight billion and there are people who starve to death due to lack of food in some regions, it will be regarded as a negative development regardless of how much it is beneficial in other ways. In the face of the growing world population existing resources do not increase but remain constant. Despite of yield increases in agriculture are provided by different technical methods, it is assumed that these resources will not be sufficient for feeding people after a while.

In the use of biomass resources, the substances that human and other living things can consume as nutrients should not be used as energy sources, whereas the energy to be produced from wastes harmful to the environment and plants that are not used as nutrients will be sustainable and more environmentally friendly.

4.5.6 Factors Affecting the Growth of Biogas RES

Since waste materials are generally used in biomass production, environmental problems caused by these wastes are prevented. If biomass is used as fuel it provides a reduction in greenhouse gas emissions of 50-85% when used in gasoline and diesel vehicles and instead of fossil fuels for heating purposes of 75-90%. (Source: Yilmaz, 2009)

The energy obtained from biomass is a continuous, not intermittent energy source that can be used in every kind of rural and urban settlement, and in all kinds of energy needs, as in solar and wind energy. As with fossil fuels, it can be moved and stored.

Wastes generated during biogas production can be used as more efficient biogas than chemical fertilizers. In addition, animal wastes used in biogas production are put into the biogas plant instead of leaving them exposed, which may prevent some diseases. (Source: Schulze, 2015)

Energy can be obtained from garbage, which is a big problem for cities. Waste thermal power plants installed near the cities significantly eliminate the pollution caused by garbage in the environment. (Source:Ozer, 1996)

Energy forestry, defined as the growing of trees as biomass sources and using these trees as energy, is important because it will significantly reduce dependence on oil and coal, prevent environmental pollution and increase the use of renewable resources. Canada aims to make energy forestry the country's primary energy source in the medium and long term. (Source: Saracoglu, 1996) Energy forestry is also effective in reducing soil losses (erosion), increasing green areas, preventing desertification and keeping forest fires under control.

The production technology of biodiesel is relatively simple and economical relatively to the production technologies of other alternative fuels. Biodiesel is an environmentally friendly fuel that can improve engine characteristics, can be used in land and sea transportation, is suitable for use in heating systems and generators, and can be used without any design changes to existing diesel engines. Since the total of CO_2 taken from the atmosphere during the formation of oilseed plants, which are the raw material of biodiesel, is almost equilibrium to the amount of CO_2 released into the atmosphere when the biodiesel is burned, the use of biodiesel does not increase the amount of CO_2 in the atmosphere and thus does not cause global heating. (Source: Arslan, 2017)

The use of biomass energy in general; Besides providing advantages such as reducing oil imports, protecting the environment, use of biomass energy leads to creating local business opportunities, the development of energy agriculture, the storage of garbage and the elimination of visual environmental pollution. Especially, biofuels are said to be the best sources of renewable energy to replace fossil fuels in the future.

5 Comparison of RES in Turkey

The decarbonization and transformation of the energy system involves both technical and economic efforts. The cost of current and future power generation largely depends on the cost of expanding and operating power plants. In particular, the costs of renewable energy technologies have changed significantly in recent years. This development is based on technological innovations such as the use of cheaper and more efficient materials, lower material consumption, more efficient production processes, higher productivity and automatic mass production of components. The aim of this study is therefore to analyze the current and future cost situation as transparently as possible in the form of LCOE. LCOE, or levelized cost of energy is a term which portrays the cost of the power produced by solar over time, usually the warranted life of the system.

In this chapter of this Thesis, the following contents of this will be examined,

- Analysis of the current situation and the future market development of photovoltaic, wind turbines, small hydro power plants, geothermal powers and biogas plants in Turkey
- Economic modeling of technology-specific LCOE conditions for different installations and locations that underpin joint market financing costs
- Evaluation of various technology and financial parameters based on a sensitivity analysis of individual technologies

5.1 Calculation of Levelized Cost of Electricity

The method of level electricity cost (LCOE) let's you to compare power plants with different generation structures and costs. LCOE is the result of comparing all the costs that arise during the life of the power plant for the construction and operation of the plant, with the sum of the amount of energy produced during the life cycle. Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period. The calculation can be carried out either on the basis of the method of net present value (NPV), or on the basis of the so-called annuity method. When applying the "Net Present Value" method, the investment costs, as well as the payment flows of income and expenses over the life of the station, are calculated by discounting associated with the general reporting date. For this, the present value of all costs is divided by the current cost of generating electricity. Discounting electricity generation initially seems incomprehensible from a physical point of view, but is a consequence of financial mathematical transformations. The main idea is that the generated electricity implicitly corresponds to the income from the sale of this energy. Thus, the further this income is in the future, the lower the present value will be. Total annual expenses over the entire operational period consist of investment expenses and operating expenses incurred during the service life. For the calculation of LCOE for new plants, the following applies, (Source: Kost et. al., 2018)

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}}$$

Besides, the following applies for the formula of the total annual costs in the calculation of the LCOE:(Source:Kost et. al., 2018)

- LCOE = Levelized Cost of Electricity in EUR/kWh
- I0 = Investment expenditure in EUR
- At = Annual total cost in EUR per year t
- Mt,el = Produced amount of electricity in kWh per year
- i = Real interest rate in %
- n = Economic lifetime in years
- t = Year of lifetime (1, 2, ... n)

By discounting all costs and the amount of electricity generated over the life of the same reporting date, LCOE comparability is ensured. (Source: Kost et. al., 2018)

LCOE is a cost-based benchmarking calculation, not an input rate calculation. They can only be calculated by adding additional influencing parameters. Self-consumption rules, tax laws and the realized income of operators complicate the calculation of the reduced rate based on LCOE results. A further limitation arises from the fact that the LCOE calculation does not consider the cost of electricity generated within the power system at a given hour of the year. At this stage, it should be emphasized that this method is an abstraction of reality, aimed at the comparability of various power plants. This method is not suitable for determining the profitability of a enterprise. For this purpose, a financial calculation, which considers all income and expenditures with a cash flow model must be carried out. (Source: Kost et. al., 2018)

The calculation of LCOE using the annual revenue method can be understood as a simplification of the NPV method and is available in two different versions. On the one hand, LCOE can be defined as the annualized investment and operating costs and the average electricity yield ratio. The calculation is based on the following formula. (Source: Kost et. al., 2018)

$$LCOE = \frac{\left(I_0 + \sum_{t=0}^{n} \frac{A_t}{(1+r)^t}\right) * ANF}{\frac{\sum_{t=1}^{n} M_t}{n}}$$

An annuity ratio is the total of discount factors for maturities from 1 to t inclusive, when the cost of capital is the same for all relevant maturities. The Annuity Factor (ANF) is calculated as follows: (Source: Kost et. al., 2018)

$$ANF_{t,i} = \frac{i * (1+i)^t}{(1+i)^t - 1}$$

In an even simpler version, LCOE is calculated on the assumption that the amount of electricity produced yearly, and the annual operating costs are constant throughout the observation period. (Source: Kost et. al., 2018)

$$LCOE = \frac{(I_0 * ANF) + A}{M}$$

LCOE has become a very useful and valuable comparative method to analyze various energy technologies in terms of cost. The LCOE calculation method is considered as a criterion for evaluating the economic viability of individual projects as well as various generation technologies worldwide and allows you to compare different energy technologies in terms of costs. (Source: Kost et. al., 2018)

LCOE can be apply to assistance decision making. However, accurate explanations of the economic applicability of the technology cannot be made based on a single LCOE analysis. However, it should be noted that LCOE is a cost-based indicator that does not include revenue. (Source: Kost et. al., 2018)

5.2 Input Data for Levelized Cost of Electricity Calculation

In order to make the calculation which has been mentioned in the chapter calculation of levelized cost of electricity input data is needed for each RES. These inputs will be discount rate, rated capacity, full load hours, investment costs, Operation and Maintenance (incl. all variable costs), real escalation of Operation and Maintenance costs. The project lifespan will be taken as 15 years for each RES technologies. Additionally, fuel costs and fuel price escalation will be added for a Biomass RES since this technology is dependent on fuel such as wood chips, agricultural residues, food residues etc. The fuel costs and price increase will be considered to be zero for the rest of RES.

These inputs will be taken only from power plants which exist currently in Turkey. For all kind of Power Plants, the discounted rate will be the same which is 15% and the operation and maintenance rate will be 2,5% per year. In an excel sheet the LCOE will be calculated according the formula mentioned at the chapter calculation of levelized cost of electricity. Some of the values have been converted from dollars into euros with an exchange rate of 1$ = 0,9014€ based on 07.08.2019 values.

In this calculation, the produced amount of electricity is equal to the product of Full Load Hours and Rated Capacity. The annual total cost is equal to the Operation and Maintenance (incl. all variable costs). The input data for each RES technology are shown in Tables 15-19;

Solar RES		
Investment Horizon	15	[year]
Investment Cost	2122120	[€/MW]
O&M(inc. all variable costs)	140060	[€/MW]
O&M Rate	2,5	[%/year]
Rated Capacity	1.95	[MW]
Full Load Hours	1841	[hours/year]
Discounted Rate	15.00%	[%/year]
Fuel Cost	-	[€/MW]

Table 15: Input Data for Solar Power Plant (Source:Taktak & Ili, 2018)(Source: Ertugrul & Kurt, 2014)(Source: Batur et. al., 2015)(Source: Erdem at. al., 2015)

Wind RES		
Investment Horizont	15	[year]
Investment Cost	18900000	[€/MW]
O&M(inc. all variable costs)	259938	[€/MW]
O&M Rate	2,5	[%/year]
Rated Capacity	14	[MW]
Full Load Hours	3156	[hours/year]
Discounted Rate	15.00%	[%/year]
Fuel Cost	-	[€/MW]

Table 16: Input Data for Wind Power Plant(Source: Taktak & Ili, 2018)(Source: Ertugrul & Kurt, 2014)(Source: Batur et. al., 2015)(Source: Erdem at. al., 2015)

Hydro RES		
Investment Horizont	50	[year]
Investment Cost	1900000	[€/MW]
O&M(inc. all variable costs)	8200	[€/MW]
O&M Rate	2,5	[%/year]
Rated Capacity	1	[MW]
Full Load Hours	3408	[hours/year]
Discounted Rate	15.00%	[%/year]
Fuel Cost	-	[€/MW]

Table 17: Input Data for Hydro Power Plant(Source: Taktak & Ili, 2018)(Source: Ertugrul & Kurt, 2014)(Source: Batur et. al., 2015)(Source: Erdem at. al., 2015)

Geothermal RES		
Investment Horizont	15	[year]
Investment Cost	1900000	[€/MW]
O&M(inc. all variable costs)	190000	[€/MW]
O&M Rate	2,5	[%/year]
Rated Capacity	1	[MW]
Full Load Hours	7446	[hours/year]
Discounted Rate	15.00%	[%/year]
Fuel Cost	-	[€/MW]

Table 18: Input Data for Geothermal Power Plant(Source: Taktak & Ili, 2018)(Source: Ertugrul & Kurt, 2014)(Source: Batur et. al., 2015)(Source: Erdem at. al., 2015)

Biomass RES		
Investment Horizont	15	[year]
Investment Cost	15370600	[€/MW]
O&M(inc. all variable costs)	802702	[€/MW]
O&M Rate	2,5	[%/year]
Rated Capacity	10	[MW]
Full Load Hours	7446	[hours/year]
Discounted Rate	15.00%	[%/year]
Fuel Cost	153706	[€/MW]

Table 19: Input Data for Biomass Power Plant(Source: Taktak & Ili, 2018)(Source: Ertugrul & Kurt, 2014)(Source: Batur et. al., 2015)(Source: Erdem at. al., 2015)

5.3 Levelized Cost of Electricity of Energy Technologies

The sensibility of the LCOE has been calculated and presented in a graph with the inconstant variables. These inconstant variables Operation and Maintenance, discount rate and full load hours(FLH).

The LCOE values with the sensitivity for each RES technology are shown in graphs, each of these input have been calculated separately from a range of -10% to 10% with a increasing step of 1% on the X-axis. The X-axis represent the change of each input, namely Operation and Maintenance, FLH and Discounted Rate. The Y-Axis represents the LCOE value in euro/MWh. These calculations and graphs have shown, how much an influence the input data has on the LCOE for each RES. The range of the Y-axis will be 40e/MWh.

The blue is line in the graphs is represents the sensitivity of operations and maintenance while the red line represents as the Full Load Hours sensitivity and the green line represents discounted rate sensitivity.

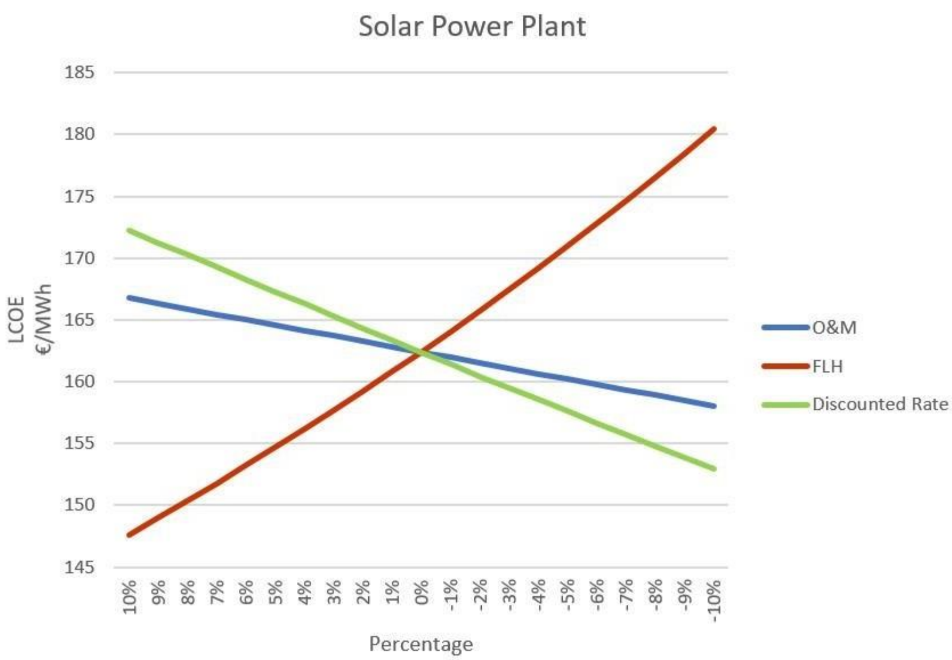

Figure 26: LCOE calculations of Solar Power Plant(own calculation)

The LCOE calculation for Solar Power Plant have been made as shown in Figure 26. The LCOE range on the Y-axis is from 145e/MWh to 186e/MWh. With the values given, the LCOE has been calculated as 162.39e/MWh. With the range of 10% to -10% on the X-axis the Operation and Maintenance is from 166.75e/MWh to 158.02e/MWh, the Full Load Hours is from 147.63e/MWh to 180.43e/MWh, the Discounted Rate is from 172.26e/MWh to 152.94e/MWh. The LCOE is most sensitive to Full Load Hours while it is least sensitive to Discounted Rate.

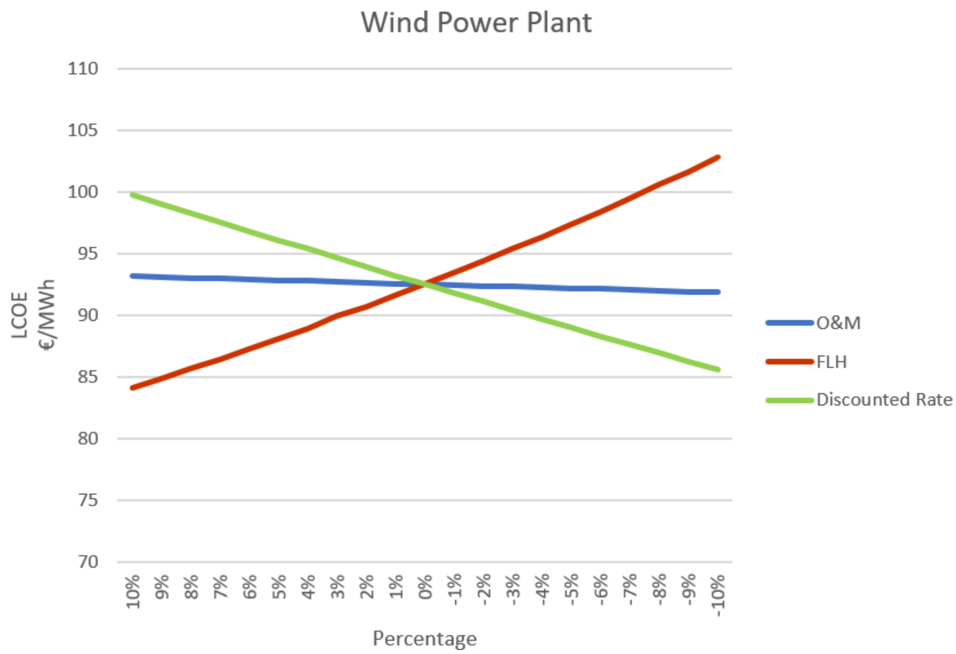

Figure 27: LCOE calculations of Wind Power Plant(own calculation)

The LCOE calculation for Wind Power Plant has been made as shown in Figure 27. The LCOE range on the Y-axis is from 70e/MWh to 110e/MWh. With the values given, the LCOE has been calculated as 92.51e/MWh. With the range of 10% to -10% on the X-axis the Operation and Maintenance is from 93.17e/MWh to 91.85e/MWh, the Full Load Hours is from 84.1e/MWh to 102.79e/MWh, the Discounted Rate is from 99.76e/MWh to 85.56e/MWh. The LCOE is most sensitive to Full Load Hours while it is least sensitive to Discounted Rate.

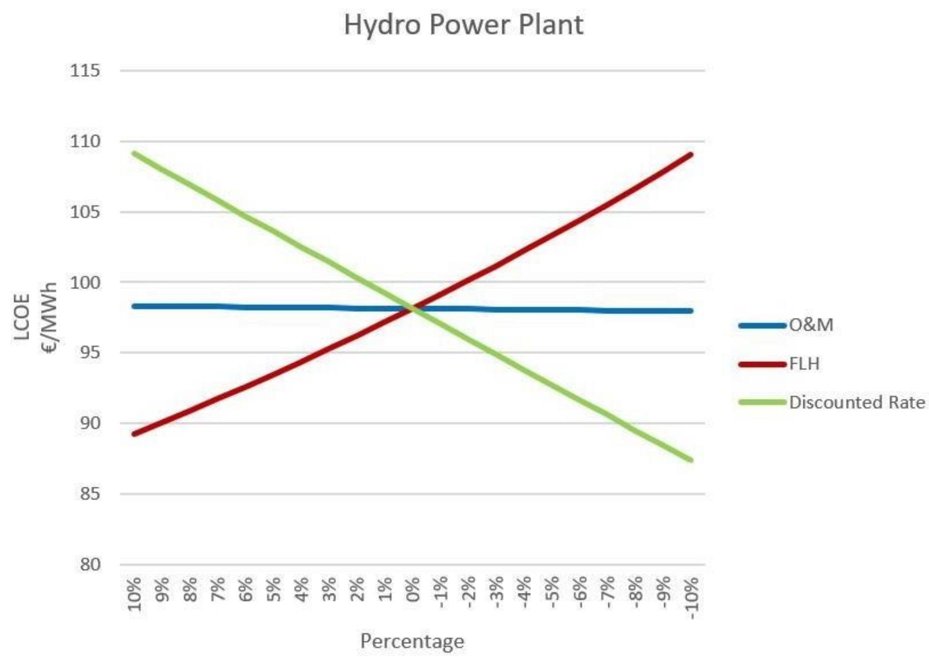

Figure 28: LCOE calculations of Hydro Power Plant(own calculation)

The LCOE calculation for Hydro Power Plant is shown in Figure 28. The LCOE range on the Y-axis is from 180e/MWh to 120e/MWh. With the values given, the LCOE has been calculated as 98.17e/MWh. With the range of 10% to -10% on the X-axis the Operation and Maintenance is from 98.32e/MWh to 97.95e/MWh, the Full Load Hours is from 89.22e/MWh to 109.04e/MWh, the Discounted Rate is from 109.17e/MWh to 87.37e/MWh. The LCOE is most sensitive to Full Load Hours while it is least sensitive to Discounted Rate.

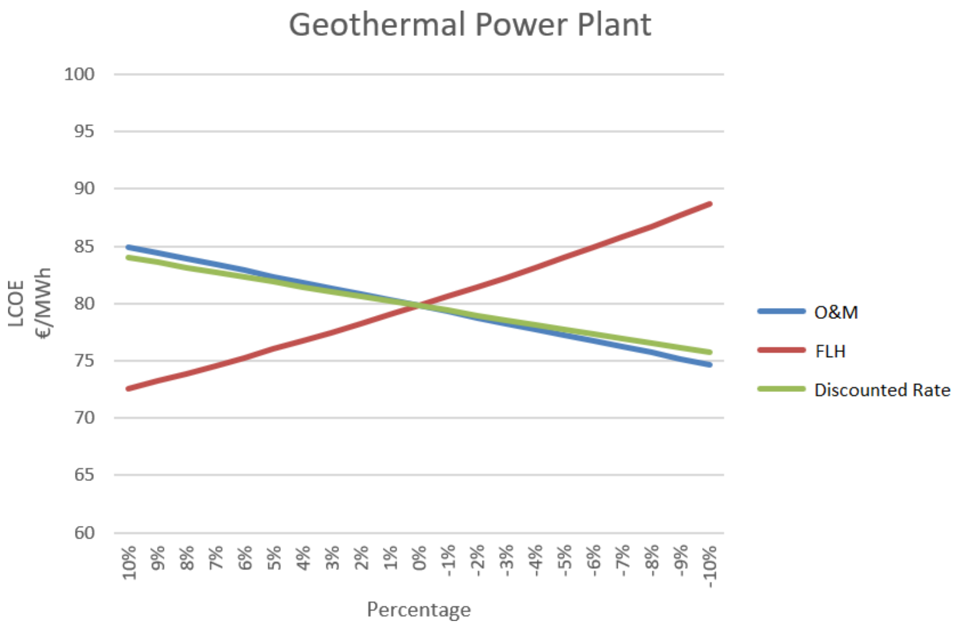

Figure 29: LCOE calculations of Geothermal Power Plant(own calculation)

The LCOE calculation for Geothermal Power Plant is shown in Figure 29. The LCOE range on the Y-axis is from 60e/MWh to 100e/MWh. With the values given, the LCOE has been calculated as 79,8e/MWh. With the range of 10% to -10% on the X-axis the Operation and Maintenance is from 84.9e/MWh to 74.8e/MWh, the Full Load Hours is from 72.6e/MWh to 88.5e/MWh, the Discounted Rate is from 84.7e/MWh to 75.2e/MWh. The LCOE is most sensitive to Full Load Hours while it is least sensitive to Operation and Maintenance costs. This sensitivity ranking is different than the other calculations.

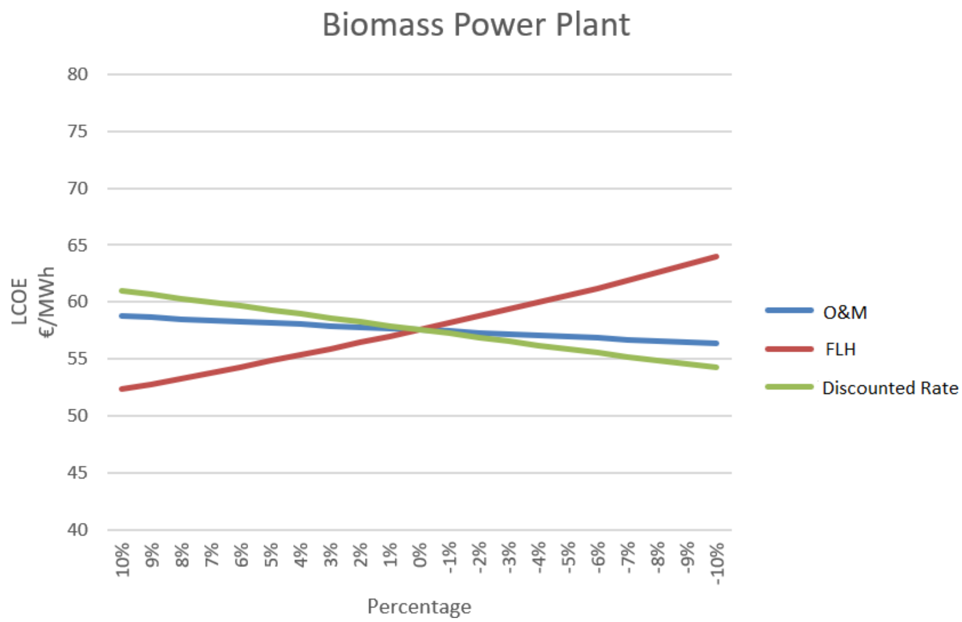

Figure 30: LCOE calculations of Biomass Power Plant(own calculation)

The LCOE calculation for Biomass Power Plant is shown in Figure 30. The LCOE range on the Y-axis is from 40e/MWh to 80e/MWh. With the values given, the LCOE has been calculated as 57.56e/MWh. With the range of 10% to -10% on the X-axis the Operation and Maintenance is from 58.3e/MWh to 56.3e/MWh, the Full Load Hours is from 52.5e/MWh to 64.7e/MWh, the Discounted Rate is from 60.8e/MWh to 54.7e/MWh. The LCOE is most sensitive to Full Load Hours while it is least sensitive to Discounted Rate.

As can be seen the Full Load Hours and discounted rate have a inverse ratio to the LCOE while the operation and maintenance has a direct ratio to LCOE. The Full Load hour has more sensitivity compare to operation and maintenance and also a direct ratio. Apart from in Figure 27, the discounted rate has more sensitivity to operation and maintenance. The sensitivity of direct ratio and operation and maintenance are more or less the same in Figure 28, 29 and 30 while in Figure 26 and 27 the sensitivity difference is much more noticeable. Meanwhile the sensitivity of Full Load Hours is also much higher in Figure 26, 27 compare to Figure 28,29 and 30.

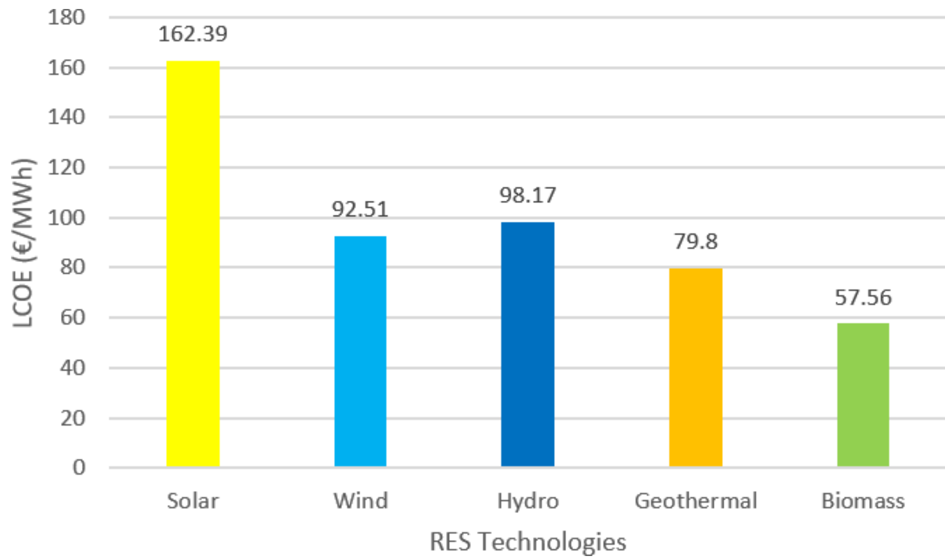

Figure 31: A LCOE comparison of RES technologies(own calculation)

To have a better overview, the LCOE values of each five calculated RES technologies have been presented in the figure 31. The X-axis is the LCOE from 0e/MWh to 180e/MWh. On the Y-Axis are the RES technologies which are solar, wind, hydro, geothermal and biomass. Solar LCOE has been represented in yellow, wind LCOE has been represented in light blue, hydro LCOE has been represented in dark blue, geothermal LCOE has been represented in orange, biomass LCOE has been represented in green color. As mentioned before the LCOE for solar is 162.39e/MWh, for wind 92.51e/MWh, for hydro 98.17e/MWh, for geothermal 79.8e/MWh, for biomass 57.56e/MWh. The highest value of LCOE is the wind RES followed by solar, geothermal and biomass RES. The lowest value of LCOE is the Hydro RES.

6 Conclusion

Turkey is due to the young population and growing economy is one of the fastest growing consumer markets in the world. According to the 3rd chapter, regulations and permitting process for RES, and the current state of energy dependency in the country influenced Turkish political and legal authorities to take some significant steps towards the development of the RE sector not only to promote sustainable development but also to meet the needs of the growing population in an environmentally sound way. New legislations, incentives, and promotions of RE are supporting investment in this sector. Natural and renewable resources, such as wind and solar, play a more important role in the development of this sector.

As stated by, the 4th and 5th Chapter which indicate the RES potential in Turkey and comparison of RES in Turkey, solar energy has the biggest potential among the renewable energy resources. Furthermore, regions like South Anatolia and the Mediterranean Regions have high solar radia- tion and are predicted to produce more electricity from solar energy. The estimated potential is many times greater than the electricity demand in 2016 and only limited by the area provided. In fact, just the area of Istanbul (about 0.3% of Turkey's total area) would be enough to meet the current electricity demand in 2023. Even with a high LCOE value, which is 162.39e/MWh with the high sensibility, the LCOE can be lowered if the decisions for the PV installation would be made wisely. The FLH can be dramatically increased if PV power plants are constructed in the South Anatolia and the Mediterranean regions. The operations and maintenance costs can be reduced if the financial management is be done correctly so extra expenses will are avoided. The discount rate has also a noticeable impact on the value of LCOE. Depending all these fac- tors within Turkey the LCOE has a high chance to compete with the other RES energy technologies.

The second highest potential, wind potential, located in the Marmara and Aegean Regions, can cover at least a fifth of the today's electricity demand. The actual electricity production varies depending on the use of the turbines on the right place. Therefore, the economically feasible electricity potential varies on a larger scale between 35 and 75 TWh per year. Furthermore, as in the case similar to a photovoltaic power plant, even if it has a high LCOE value, which is 92.51e/MWh with the high sensitivity, the LCOE can be reduced in a suitable position if decisions are made reasonably for installing a wind turbine. If a wind farm is built in the Marmara and Aegean regions, the FLH hours can be significantly increased. Operation and maintenance costs can be decreased if the financial supervision is performed correctly, so extra costs can be eluded. The discount rate reduction has a major influence on the cost of LCOE. Depending on all of these factors in Turkey, the LCOE of wind power has a chance to compete with other energy technologies.

150 to 160 KW, around three quarters of the current electricity demand, the first electricity generating technologies in Turkey provided with hydro power. Only about 30% of this potential, of which up to 50% is provided through the Euphrates and the Tigris River, is used. Among all the other RES technologies, hydro power plant have the lowest LCOE compared to the other technologies. This is a reason why hydro power plants are the most attractive for a financial investment. The sensibility is also lower than PV and wind power plant so the LCOE level of, 98.17e/MWh, for a hydro power plant should be see big variations depending on the location. However it has been noted that the installation sites are limited since the most profitable rivers for hydro power plants have already been built on. Other rivers do not have the same potential or are under environmental protection. In hydropower plants, a large number of fish die because there are no fish gates which can be installed. Some species have already become extinct. Another issue is that there is a high potential that the villages nearby can be underwater as a result of HEP construction. Therefore hydro power plant take 3rd place as a potential renewable energy source after PV and wind power plant.

The Country’s geothermal electricity potential is mostly located at the Alpine-Himalaya Orogen belt in Turkey’s west regions and is estimated to about 15 to 25TWh per year. This potential may seem low; however, the potential of geothermal electricity from other renewable energy sources is less variable than electricity and can be used to meet the basic load. Geothermal energy has the advantage of producing electricity and providing heat as well. The LCOE value, which is 79.8e/MWh, is in the middle when to compare to the other technologies of LCOE. Thus, with a high potential and a medium LCOE level geothermal energy contains a high level of risks with the drilling phase of geothermal as a main factor. This can lead to high investment cost and as a result the LCOE would increase dramatically which makes this technology less appealing.

Turkey's biomass power potential is approximately 200 TWh per year. However, this potential has not been significantly exploited due to the high cost of converting biomass into gases needed for actual electricity generation and a technologically difficult process. The LCOE level, which is 57.56e/MWh, is the second lowest compared to the other 5 RES technologies. A big disadvantage is the logistics of the fuel and the fuel price, which do not occur with the other tech- nologies. The logistics should be close the fuel resources. If the fuel for the biomass is imported from another country this can have a negative influence on the logistics. The fuel price is not stain- able and therefore the costs can vary significantly in a country such as Turkey. Therefor biomass would be the least preferable of these 5 RES technologies.

7 List of Abbreviations and Symbols

AC = Alternating Current

ACE = Area Control Error

AGC= Automatic Generation Control

ANF = Annuity Factor

DC = Direct Current

EIA = Environmental Impact Assessment

EML = Electricity Market Law

EMRA = Energy Market Regulatory Authority

ENTSO-E = European Network Transmission System Operators for Electricity

EXIST = Energy Exchange Istanbul

FIT = Feed in Tarif

FLH = Full Load Hours

GDP = Gross Domestic Product

GW = Giga Watt

GWh = Giga Watt hours

HEPP = Hydroelectric Power Plant

HVDC = High Voltage Direct Current IDK = Inspection Evaluation Commission

IEA = International Energy Agency

KV = Kilo Volts

KWh = Kilo Watt hours

LCOE = Levelized Cost of Energy

LPG = Liquefied Petroleum Gas

MCP = Market Clearing Price

MW = Mega Watts

MWe = Mega Watts Electric

MWt = Mega Watts Tons

NPV = Net Present Value

PV = Photovoltaic

PX = Power Exchange

RE=Renewable Energy

REDA = Renewable Energy Designated Area

REPA = Atlas of Wind Energy Technical Potentials

RES = Renewable Energy Systems

SHEPP = Small Hydroelectric Power Plant

SMP = System Marginal Prices

TEIAS = Turkey Electricity Transmission AS

TL = Turkish Lira

TWh = Tera Watt hour

US = United States

USD = United States Dollar

VAP = Efficiency Enhancing Project

WPP = Wind Power Plant

YEGM = General Directorate of Renewable Energy

YEKDEM = Renewable Energy Resources Support Mechanism

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