



An overview of Turkey's renewable energy trend

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Abstract: As an energy dependent country, Turkey is supplying almost all of its energy demand with imports, but it can significantly reduce its energy dependency exploiting its indigenous energy resources as much as possible. Turkey has started to notice and utilize its resources after 2005 with a serious contribution of the renewable energy law. In this study, renewable energy potential of Turkey is presented first. After that, renewable energy targets of Turkey in 2023 are mentioned. Following them, the development of renewable energy utilization in Turkey between 2005 and 2017 is given in detail, and discussed. According to the analysis results obtained regarding the 12 year-renewable energy development process of Turkey, it can be concluded that Turkey is in a good state regarding renewable energy shares in installed power capacity and power generation with the percentages 11% and 8%, respectively. However, it is still far away from its 2023 targets to be expected as 30% for power generation.

Keywords: Turkey, Renewable energy, Renewable energy utilization,

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1. INTRODUCTION

Turkey is like a bridge connecting Europe and Asia. Its neighboring countries are Bulgaria, Greece, Syria, Iraq, Iran, Azerbaijan, Armenia, and Georgia. It has the geographic coordinates of 39°00' North latitude and 35°00' East longitude and located in the south eastern part of Europe and the south western part of Asia. It has a population of about 80 million in an area of over 779.452 km². Its average weather is Mediterranean climate with hot summers and cool winters. With its geographical location and weather, Turkey constitutes a corridor like region for winds. On the other hand, south coast of Turkey takes enough sun for electricity production. Furthermore, because it is located on the tectonic plates, Turkey is an earthquake country meaning it has also geothermal energy potential. In addition to the all aforementioned concerns Turkey is a livestock and agriculture country and this makes it suitable for power generation from biomass energy.

Main indigenous energy resources in Turkey are lignite, hydraulic and biomass. Power is essentially generated by thermal power plants burning fossil energy resources [1,2]. In today's world however, instead of fossil energy sources, renewable energy has become a significant actor on the market due to some motivating factors. Increasing demand of energy, the depletion of fossil fuels (that also causes the rise of the prices), harmful nature of the fossil and nuclear power plants (more importantly the awareness of the public on the existing and probable environmental problems of them), and decreasing costs of the renewable energy utilization are some important ones of those factors [3-6].

Renewable energy sources enable countries both to meet the significant amount of energy requirement and also to protect the environment with the great assistance of its environment friendly nature that results in no or almost no production of air pollutants and greenhouse gases. Turkey is a very rich country with regard to renewable energy resources; especially wind, solar, geothermal, biomass, and hydraulic energies. Unfortunately, Turkey has evaluated only a small portion of its great renewable energy potential. Naturally, Turkey has been forced to become an energy dependent country due to the inadequate renewable energy utilization. For example, the imported energy dependency ratio of Turkey is 75% while it is 54% in European Union (EU), where is geographically in the neighborhood of Turkey, indicates that Turkey needs an effective energy strategy [7,8]. In this context, the reasonable way to reduce the energy dependency of Turkey is to develop the politics and strategies for improving the renewable energy activities [9,10].

When we look at the literature we come across several studies on renewable energy potential and utilization of Turkey. In one of the studies, Çapik et al. [11] stated in their study on the situation of renewable energy in Turkey that Turkey's most promising renewable energy source is wind energy with an annual mean wind speed of 2.58 m/s and a wind density of 25.82 W/m². In Toklu's study [12], it is found out that although there is a huge potential in Turkey for solar energy, the power generation by it is almost negligible. In another study of Toklu [13], biomass energy in Turkey was investigated. In his study, it is concluded that biomass energy is strategic for Turkey in power generation. Melikoglu [14] on the other hand, studied geothermal energy in Turkey. In his study, he pinpointed that the installed power capacity of geothermal energy has already reached the value of 600 MW before the end of 2015, and he criticized that geothermal energy targets in 2023 vision paper are very low and must be modified. In another study by Ozcan [15], Turkey's self-sufficiency in power generation has been analyzed. It is found out that the rate of self-sufficiency is 25.05% in 2014 while it was 54.42% in 1980, which means it is decreasing. On the other hand, self-sufficiency rate in Turkey for power generation also decreased from 77% to 37% between 1980 and 2014. He gives the high electricity demand, high dependency on imported coal and natural gas, and low renewable energy utilization as the main reasons for this change. As a suggestion it is specified that in order to achieve 2023 renewable energy targets ensuring self-sufficiency Turkey should introduce new energy policy instruments for renewable energy such as transferring subsidies to the development of renewable energy projects, putting effective carbon taxes on carbon emissions and so on. In a different study by Tükenmez and Demireli [16], renewable energy is depicted as the key for Turkey to solve its energy related problems. These problems are listed by the

authors as; depending highly on imported energy, depleting of fossil fuel reserves, rising energy prices, and increasing the environmental pollution.

In this study, renewable energy trend of Turkey, where is the one of the leading countries in terms of the renewable energy potential in Europe and the world, has been investigated to give a comprehension of links among potential, utilization, targets, and incentives regarding renewable energy. First of all, renewable energy potential of Turkey is presented. Among all the renewable energy resources in Turkey, especially wind, solar and geothermal energy resources are considered herein. Secondly, renewable energy targets of Turkey for 2023 are mentioned with the incentives that is planned to be given to the renewable based electricity generation facilities. Added to them, the development of renewable energy utilization in Turkey between 2002 and 2017 is given, and lastly, according to the analysis results obtained regarding the 15 year-renewable energy development profile of Turkey, it is determined where the current position of Turkey is in terms of achieving the available renewable energy targets, especially in 2023 that is the 100th anniversary of the Turkish Republic.

2. RENEWABLE ENERGY IN TURKEY

This section includes three subsections that briefly explain renewable energy potential, renewable energy laws and targets, and renewable energy utilization of Turkey, respectively. In renewable energy potential subsection, some key values have been given that show the amount of each one of the most important renewable energy sources of Turkey. In renewable energy laws and targets subsection, information on the laws and targets has been briefly given that trigger renewable energy sector in Turkey. In the last subsection eventually, it has been shown that if Turkey utilizes its renewable energy potential in the light of years from past to present or not.

2.1. Renewable Energy Potential of Turkey

Turkey has a great variety of renewable energies, such as wind, solar, geothermal, biomass, hydraulic, etc. Turkey is a rich country in terms of especially wind energy, which holds an important role in all the other renewable sources regarding electricity production nowadays in the world [17]. Furthermore Turkey has the first place among the EU countries regarding wind energy potential and also has a great technical wind energy potential of 88 GW. With the aid of this potential, Turkey can fight against its high energy dependency with this not polluting renewable energy, which contributes to a better air quality [18]. On the other hand, Turkey has a large amount of solar energy compared to the other countries. The average sunshine duration and the solar radiation in Turkey are 7.2 h/day and 309.6 cal/m² day, respectively. The Southeast Anatolia has the highest solar energy potential. Moreover, geothermal potential of Turkey is 31,500 MW, of which, about 80% is existing in Western Anatolia. The current utilization occupies only 3% of the geothermal energy potential [11, 19].

2.2. Renewable Energy Laws and Targets in Turkey

Preparation of the renewable energy policy in Turkey has just started but all the efforts made in this field aims to achieve the certain goals that can be described as the following: both to increase the electricity generation from renewable energy resources in Turkey and to raise its share in the total electricity generation as well as to minimize the energy dependency of Turkey. Eventually, first renewable energy law with the purpose of generating electrical energy was accomplished on May 18, 2005. After this law, certain regulations as well as amendments were realized in the following years. These regulations are dealing with either Renewable Energy Support Mechanism, declared to the public by EMRA (Energy Market Regulatory Authority of Turkey) on July 21, 2011, or domestically manufactured components used in the electricity generation facilities based on renewable energy resources, proclaimed by the Ministry of Energy on June 19, 2011. These incentives are described in Table 1 [20]. As seen from the table, the highest incentive is given to the solar energy. Solar energy potential of Turkey is promising while there is almost no power generation by it can be describe the highest incentive rates. Biomass energy follows solar energy in incentive prices according to the table as it has also a good potential but

not utilization in Turkey in terms of electricity production. Since components of power generation facilities by biomass energy are mostly made in domestically, the component incentives in biomass are lower than that of solar energy, while the feed-in tariff prices are the same. After solar and biomass, geothermal energy takes the third place in total incentive rates according to the support mechanism. Rates and reasons of the geothermal energy based power production are similar to that of biomass with just a little bit lower incentives showing importance of geothermal energy to Turkey when compared to biomass. Wind and hydraulic energies take last positions respectively in the incentive table with very near values. Turkey produces a sufficiently qualified percent of its electricity by hydraulic and wind energy, and this explains that they have less than half of the incentives for solar energy. Because Turkey also needs to increase power production by hydraulic and wind energy to decrease coal (environmental problems) and natural gas (high import problems) based power production.

Table 1. Renewable energy support mechanism

Renewable energy sources	Feed-in tariff (USD/MWh)	Max. dom. Component Incentive (USD/MWh)	Max. total price for power (USD/MWh)
Hydraulic	73	23	96
Wind	73	37	110
Solar (PV)	133	133	266
Biomass	133	56	189
Geothermal	105	27	132

To utilize its energy potential efficiently, Turkey prepared Energy Efficiency Strategy Paper in 2015 and determined some targets for renewable energy based power production with respect to the following values described in Table 2. The highest target was declared for hydraulic energy as full utilization. The second one is wind energy with the value of 20 GW. After that, solar energy was given a value of 3 GW. And lastly, geothermal energy took 0.6 GW value of power production. Total share of the renewable energy based power production was determined as 30% in 2023. When compared to the percentage of renewable sources in global electricity production, which is about 20% (15.8% Hydraulic + 4.5% from biomass, waste, geothermal, wind and direct solar) [21,22], the targets of Turkey are inspiring. On the other hand, the cost of achieving all the targets in 2023 is estimated to require investment in the renewable energy generation around 80 billion TL (6 billion TL/year), which is about 21 billion USD (1,5 billion USD/year) [7]. It is obvious from these high targets that Turkey must work very hard, that is, it must take the attention of public and foreign enterprisers to this virgin sector by removing all the obstacles preventing the development of the sector with the aid of enacting useful laws or making legal necessary amendments [23].

Table 2. Targets for energy utilization according to the energy strategy paper, vision 2023.

Energy resources	Targets (MW)
Wind energy	20,000
Geothermal energy	600
Solar energy	3,000
Hydraulic	Full utilization
The share of renewable energy in the total generation is estimated to be 30% in 2023.	

2.3. Renewable Energy Utilization

In the previous sections it was explained that Turkey has fairly abundance of renewable energy resources. But, it has not used them at the desired level also specified briefly. However, it should be noted that renewable energy utilization in Turkey was too bad almost twelve years ago, having the share of only 0.1% in the total electricity generation and its share was 10.5% as of June 2017 according to the energy reports prepared by MENR (Ministry of Energy and Natural Resources) [24].

Before investigating the renewable energy situation, shares of electricity in Turkey should be come to be known. Table 3 briefly shows electricity generation, export, import, and consumption rates of Turkey between 2002 and 2016. As seen from the table electricity generation and consumption rates of Turkey

increase every year with one or two exceptions. This makes renewable energy important for Turkey to supply its electricity from domestic energy resources.

Table 3. Electric power in Turkey

Years	Generation (GWh)	Export (GWh)	Import (GWh)	Consumption (GWh)	Generation increase (%)	Consumption increase (%)
2002	129,400	3,588	435	132,553	5.4	4.5
2003	140,581	1,158	588	141,151	8.6	6.5
2004	150,698	464	1,144	150,018	7.2	6.3
2005	161,956	636	1,798	160,794	7.5	7.2
2006	176,300	573	2,236	174,637	8.9	8.6
2007	191,558	864	2,422	190,000	8.7	8.8
2008	198,418	789	1,122	198,085	3.6	4.3
2009	194,813	812	1,546	194,079	-1.8	-2.0
2010	211,208	1,144	1,918	210,434	8.4	8.4
2011	229,395	4,556	3,645	230,306	8.6	9.4
2012	239,497	5,826	2,954	242,370	4.4	5.2
2013	240,154	7,429	1,227	246,357	0.3	1.6
2014	251,963	7,953	2,696	257,220	4.9	4.4
2015	261,783	7,135	3,194	265,724	3.9	3.3
2016	273,387	6,400	1,442	278,345	4.4	4.7

Table 4. Installed power capacity of Turkey between 2002-2017

Years	Coal (MW)	Natural gas (MW)	Other (MW)	Hydraulic (MW)	Wind (MW)	Geo. (MW)	Solar (MW)	Total (MW)
2002	6,983	8,438	4,147	12,241	19	18	0	31,845
2003	8,239	10,053	4,683	12,579	19	15	0	35,588
2004	8,296	11,349	4,500	12,645	19	15	0	36,824
2005	9,117	12,275	4,487	12,906	20	15	0	38,820
2006	10,197	12,641	4,520	13,063	59	23	0	40,503
2007	10,097	12,853	4,322	13,395	146	23	0	40,836
2008	10,095	13,428	4,072	13,829	364	30	0	41,817
2009	10,501	14,555	4,284	14,553	792	77	0	44,762
2010	11,891	16,112	4,276	15,831	1,320	94	0	49,524
2011	12,491	16,005	5,436	17,137	1,729	114	0	52,912
2012	12,530	17,164	5,335	19,620	2,261	162	0	57,072
2013	12,563	20,255	5,830	22,289	2,760	311	0	64,008
2014	14,771	21,476	5,555	23,643	3,630	405	40	69,520
2015	15,483	21,261	5,159	25,868	4,503	624	249	73,147
2016	17,316	22,217	4,878	26,681	5,751	821	833	78,496
2017 (June)	17,346	22,641	4,928	27,044	6,161	861	1,363	80,343

Table 4 shows the installed capacity values of energy resources in Turkey in the past fifteen years. First three rows come into being by the energy sources hydraulic, coal, and natural gas, respectively. The fourth energy source of Turkey in queue of installed power capacity has become wind energy for just two years. The first renewable energy source of Turkey in ready to produce power for all times is also wind energy. It is clear from Figure 1 that wind energy has been widely used and its installed capacity has increased by nearly 300 times during this period of time. It is a spectacular development, but insufficient (considering the high amount of the unused wind energy potential occupying almost 90% of the total potential). Other two renewable energy sources, which are solar and geothermal, have a small percentage for installed power capacity; they have a big rise especially for the last years though. For example, solar energy based installed power generation capacity folds up itself 2-3 times every passing year.

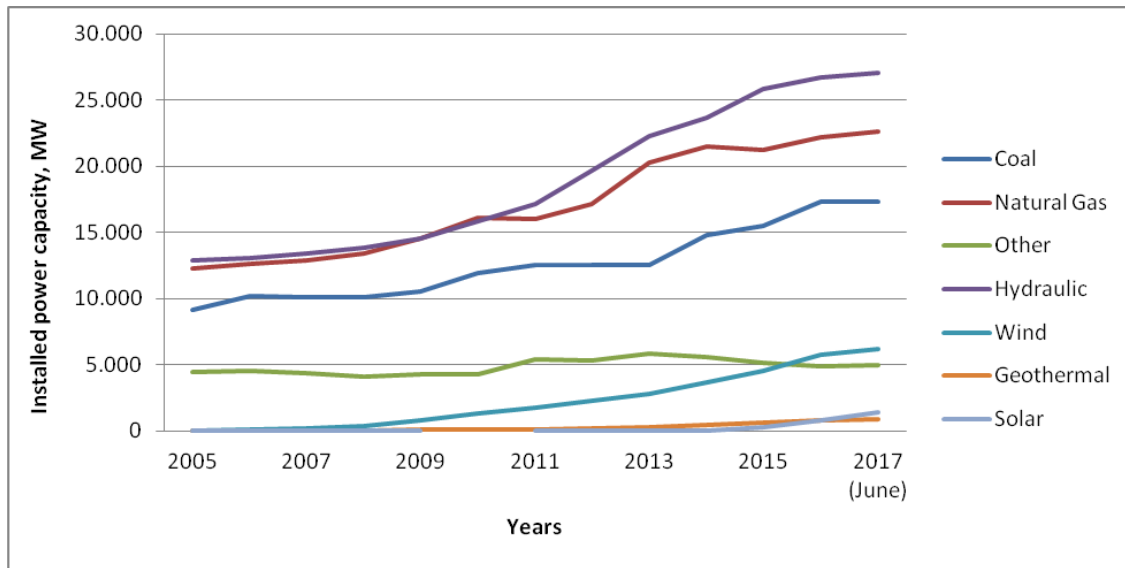


Figure 1. Development of the installed power capacities according to years

In Figure 2, contributions of all the existing energy resources to the installed power capacity between 2005 and 2017 (until July) are given. According to the figure, installed power capacity of Turkey increases continuously especially from the year 2009. Together with seeing the rise in coal, natural gas, and hydraulic energy sources, it is clear from the figure that utilization of renewable energy in Turkey is not still sufficient despite of the dramatic rising in the renewable utilization dominated by especially wind energy in the past ten years.

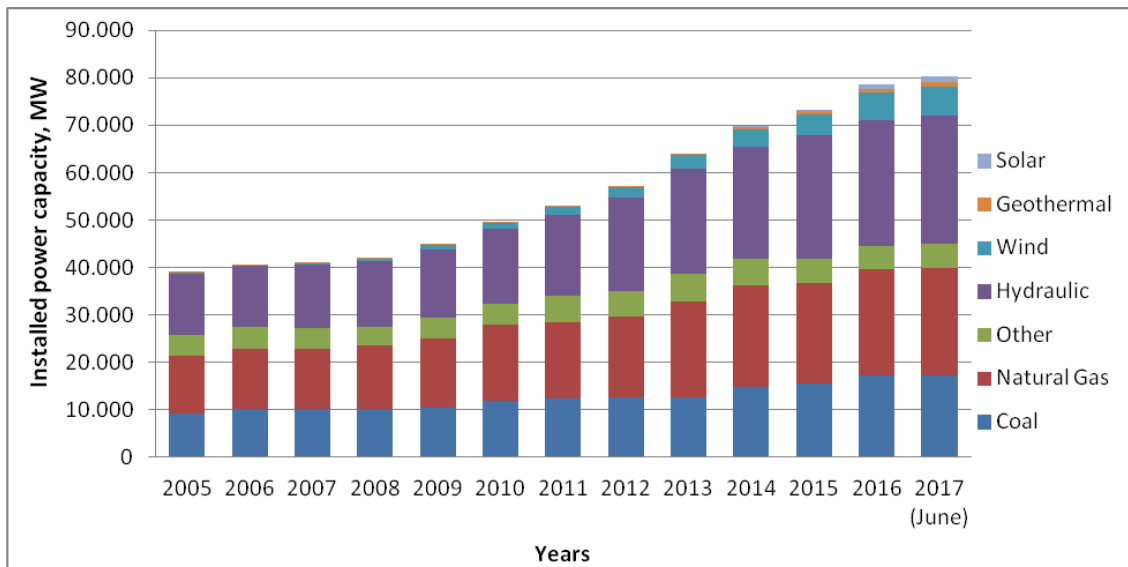


Figure 2. Share of the energy resources in the cumulative demonstration

In Table 5, percentages of all the existing energy resources to the total installed capacity of Turkey between 2002 and 2017 (until June) are given. According to the table installed power capacity of the energy sources coal, natural gas, and hydraulic do not change much over time. Installed power capacities of other thermal energy sources decrease about 5% from 2002 to 2017 in Turkey. And wind, geothermal, and solar energy resources, which are renewable energy sources, appear in the installed power capacity list of Turkey from about 0% to about 8%, 1%, and 2%, respectively through the past to the present. As seen from the table, Turkey’s electricity power facilities highly depend on thermal energy, which increases Turkey’s imports and environmental hazards. Figure 3, on the other hand, gives a comprehensive view of Turkey’s last position in installed power capacity in terms of electricity

production in 2017 (until July). Hydraulic, natural gas, and coal take the first, second, and third place, respectively as always. Other sources, which are thermal based sources also, appears in the fourth place as seen from the figure apparently. As of renewable energy sources that constitute our main subject, wind energy goes rather long ahead of solar and geothermal. Total share of the renewable sources is about 11%. The share of the solar installed power capacity shows that it has a great advance at the last years.

Table 5. Installed power capacity percentages of Turkey between 2002-2017

Years	Coal (%)	Natural gas (%)	Other (%)	Hydraulic (%)	Wind (%)	Geothermal (%)	Solar (%)
2002	21.9	26.5	13.0	38.4	0.1	0.1	0.0
2003	23.2	28.2	13.2	35.3	0.1	0.0	0.0
2004	22.5	30.8	12.2	34.3	0.1	0.0	0.0
2005	23.5	31.6	11.6	33.2	0.1	0.0	0.0
2006	25.2	31.2	11.2	32.3	0.1	0.1	0.0
2007	24.7	31.5	10.6	32.8	0.4	0.1	0.0
2008	24.1	32.1	9.7	33.1	0.9	0.1	0.0
2009	23.5	32.5	9.6	32.5	1.8	0.2	0.0
2010	24.0	32.5	8.6	32.0	2.7	0.2	0.0
2011	23.6	30.2	10.3	32.4	3.3	0.2	0.0
2012	22.0	30.1	9.3	34.4	4.0	0.3	0.0
2013	19.6	31.6	9.1	34.8	4.3	0.5	0.0
2014	21.2	30.9	8.0	34.0	5.2	0.6	0.1
2015	21.2	29.1	7.1	35.4	6.2	0.9	0.3
2016	22.1	28.3	6.2	34.0	7.3	1.0	1.1
2017 (June)	21.6	28.2	6.1	33.7	7.7	1.1	1.7

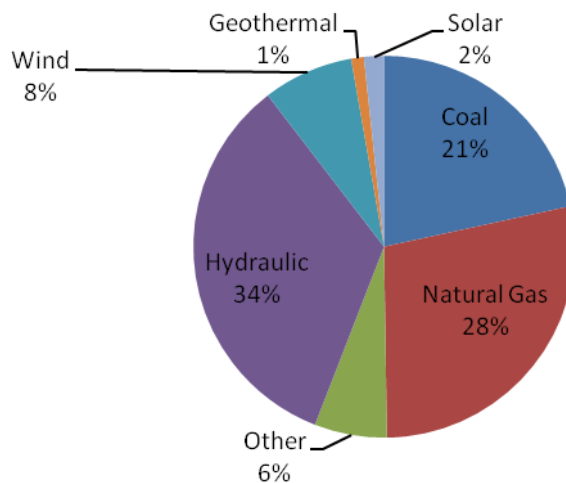


Figure 3. Percentages of the energy resources in the total installed capacity in 2017 (until July)

In Table 6, rates of wind energy to renewable energy, geothermal energy to renewable energy, solar energy to renewable energy, and renewable energy to total installed power capacity of Turkey between 2002 and 2017 (until June) are given. It is clear from the table that renewable energy in Turkey in terms of installed power capacity highly depends on wind energy. Total share of wind energy to renewable energy in Turkey is over 70% today. Solar energy follows wind energy with a share of over 16%, while geothermal energy had a share of almost half of the renewable energy in Turkey once but today it is only over 10%. Solar energy has a big development in Turkey in last several years can be understood from the table.

Table 6. Rates of energy sources in installed power capacity of Turkey between 2002-2017

Years	Wind / Renewable (%)	Geothermal / Renewable (%)	Solar / Renewable (%)	Renewable / Total (%)
2002	51.9	48.1	0.0	0.1
2003	55.8	44.2	0.0	0.1
2004	55.8	44.2	0.0	0.1
2005	57.3	42.7	0.0	0.1
2006	72.0	28.0	0.0	0.2
2007	86.4	13.6	0.0	0.4
2008	92.4	7.6	0.0	0.9
2009	91.1	8.9	0.0	1.9
2010	93.3	6.7	0.0	2.9
2011	93.8	6.2	0.0	3.5
2012	93.3	6.7	0.0	4.2
2013	89.9	10.1	0.0	4.8
2014	89.1	9.9	1.0	5.9
2015	83.8	11.6	4.6	7.3
2016	77.7	11.1	11.2	9.4
2017 (June)	73.5	10.3	16.3	10.4

In Table 7, power generation of Turkey (main energy sources) is given between the years of 2002 and 2016. Power generation in Turkey is more than doubled from 2002 to 2016. At the time of this increase, thermal energy and hydraulic based power generation grow up twice as much. As of the growth of renewable energy based power generation, it was almost nothing in 2002 according to the total amount, it was 21,230 GWh in 2016, which means an increase of 140 times bigger than the value of the beginning. In Figure 4, total electricity production increased for almost every year can be seen easily. Although installed power capacity of hydraulic and thermal energy sources (natural gas, coal and other sources) increase every year, we see they show fluctuation more or less in power generation. It is clearly seen from the figure that the only energy source that shows a continuous increase is apparently renewable.

Table 7. Power generation of main energy resources of Turkey between 2002-2016

Years	Thermal (coal+natural gas+other)(GWh)	Hydraulic (GWh)	Renewable (wind+solar+ geothermal) (GWh)	Total (GWh)
2002	95,563	33,684	153	129,400
2003	105,101	35,330	150	140,581
2004	104,464	46,084	151	150,698
2005	122,242	39,561	153	161,956
2006	131,835	44,244	221	176,300
2007	155,196	35,851	511	191,558
2008	164,139	33,270	1,009	198,418
2009	156,923	35,958	1,931	194,813
2010	155,828	51,796	3,585	211,208
2011	171,638	52,339	5,418	229,395
2012	174,872	57,865	6,760	239,497
2013	171,812	59,420	8,921	240,154
2014	200,417	40,645	10,901	251,963
2015	179,366	67,146	15,271	261,783
2016	184,889	67,268	21,230	273,387

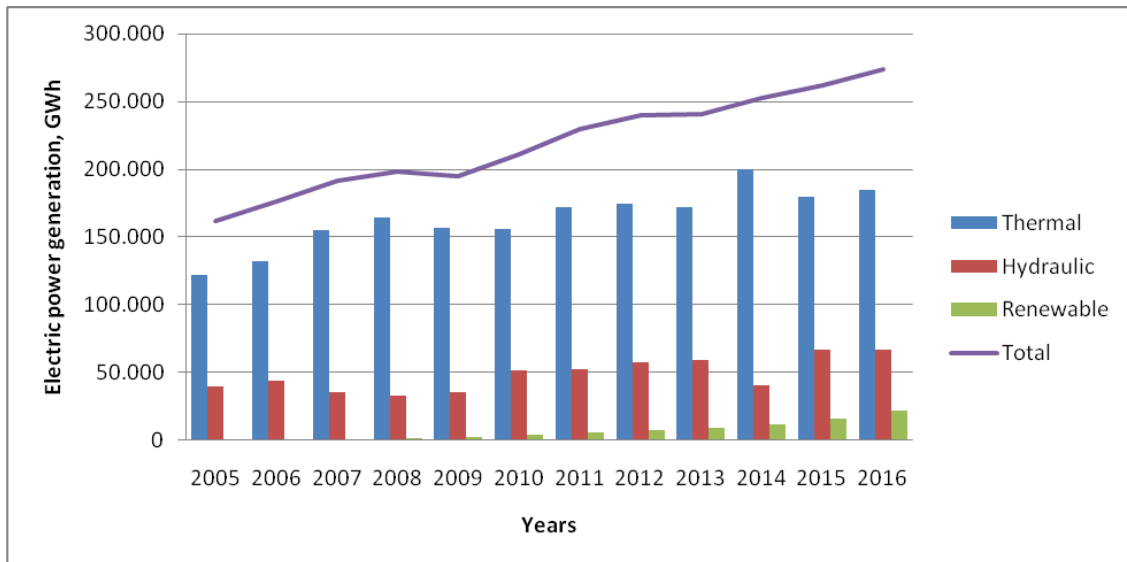


Figure 4. Power generation of main energy resources

Shares of main energy sources of Turkey in power generation are given in Table 8. According to the table it can be seen that thermal energy based power generation in Turkey increases and decreases opposing to the hydraulic energy based power generation. But, especially in the last two years, power generation from thermal energy sources decreases due to the power generation from renewable energy sources. In Figure 5, share of the main energy sources in electric generation of Turkey is seen for the whole year of 2016. Turkey produces its electricity mainly from thermal sources (coal, natural gas and other sources). Quarter part of the generated electricity of Turkey is from hydraulic based. And only the 8% of the electric power generation of Turkey is from renewable.

Table 8. Shares of main energy resources of Turkey in power generation between 2002-2016

Years	Thermal (coal+natural gas+other) (%)	Hydraulic (%)	Renewable (wind+solar+ geothermal) (%)
2002	73,9	26,0	0,1
2003	74,8	25,1	0,1
2004	69,3	30,6	0,1
2005	75,5	24,4	0,1
2006	74,8	25,1	0,1
2007	81,0	18,7	0,3
2008	82,7	16,8	0,5
2009	80,6	18,5	1,0
2010	73,8	24,5	1,7
2011	74,8	22,8	2,4
2012	73,0	24,2	2,8
2013	71,5	24,7	3,7
2014	79,5	16,1	4,3
2015	68,5	25,6	5,8
2016	67,6	24,6	7,8

3. RESULTS and DISCUSSION

Regarding all the development about renewable energy utilization in Turkey especially in the last decade, it can be concluded that the share of renewables in the electricity generation has been considerably increased during this period. Main reason for the significant but insufficient increase in the renewable energy utilization in Turkey in the last decade is strongly related to the renewable energy law in 2005, that includes some legal regulations, developments and important incentives to take private

sector's attention to this sector. As a result of this development, this sector has moved slightly and made insufficient progress due to the existence of the ambitious renewable energy targets [9].

Focusing on these percentages indicating how much of the total generated electricity is based on renewables, it can be highlighted that wind energy takes the first place among the renewables because it occupies about more than half of the total generated electricity from renewables since 2005 whereas it is near to 80% in 2016.

Eventually, firstly it can be underlined that unfortunately the unused portion of the renewable energy potential of Turkey is still too much, at non-acceptable level. In fact, the total theoretically renewable energy potential excluding hydraulic is 176,000 MW, but only about 8,000 MW is used to generate electricity now, corresponding to about less than 5% of this. That is why energy dependency of Turkey is still going on as well as keeps on wasting billions of dollars per year for the oil and gas imports. In fact, it must be urgently reduced to the minimum and acceptable level, increasing the amount of investment in this sector and providing the stability of the sector by both destructing all the barriers that do not allow native and foreign investors to launch big renewable energy projects and also making legal framework of renewable energy better and more suitable for investments [25].

7. CONCLUSION

After examining and analyzing renewable energy potential and its current utilization of Turkey, it can be briefly concluded that renewable energy has been more popular in Turkey since 2005 and also the share of renewable energy in the total electricity generation was 8% (corresponding to slightly over 21,000 GWh) while it was over 9% (corresponding to about 7,400 MW) for installed power capacity in 2016. Added to them, essentially wind energy from the available renewables in Turkey has showed significant increase. Wind energy occupies about 74% of the total renewable based installed power capacity of Turkey as of July 2017. Solar and geothermal based installed power capacities take the remaining 26% with the shares of about 16% and 10%, respectively. As a conclusion, all the developments in Turkish renewable energy sector may be considered too insufficient to be able to achieve the renewable energy targets in 2023 (30% of total energy production). Turkey must give more importance to the utilization of its renewable energy resources with the assistance of useful laws and amendments as well as major incentives which can all remove the available barriers to renewable energy investments.

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