

## A Review of the Development of Solar Energy Capacity in Turkey

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**Abstract** – The recent energy crisis has compelled countries worldwide to focus on energy production using renewable energy sources. Consequently, renewable energy capacity has experienced significant growth, with solar energy playing a substantial role. Interest in solar energy systems is increasing day by day, leading to widespread installations of solar energy systems. Electricity generation based on solar energy, a crucial renewable energy source, has particularly witnessed substantial growth in developed countries. Turkey has emerged as one of the countries demonstrating progress in this field. As of June 2022, the solar-based installed electricity capacity in Turkey reached 8.479 MW, accounting for 8.35% of the total installed capacity. With this percentage, Turkey ranks among the top eight countries in Europe in terms of solar energy production capacity, surpassing many advanced European nations. This study examines the current status and development of solar energy capacity in Turkey, while also comparing it with other countries that have made significant strides in this area. Specifically, since 2019, there has been a rapid upward trend in solar-based electricity production, with an increase of approximately 3.5 MW. While this growth is significant in a short period, as solar energy applications for electricity generation continue to expand, countries will intensify their efforts to achieve targeted capacity increases at a faster pace.

**Keywords** – Photovoltaic Systems, Solar Energy, Renewable Energy, Turkey

### I. INTRODUCTION

From the past to the present, numerous researchers have embarked on the quest for new energy sources due to global energy crises. In this context, intensive research has been conducted on alternative fuels and alternative solution methods that can replace fossil resources. For countries to achieve sustainable development, a continuous supply of clean, safe energy with minimal environmental impact is necessary [1]. In this regard, research on renewable energy sources emerges as a significant aspect. This situation increases interest in renewable energy sources.

Turkey places great importance on the development of renewable energy sources. Increasing the use of domestic and renewable energy sources is among the main priorities according to the National Energy Policy adopted in 2017. In terms of installed capacity in renewable

energy, Turkey has risen to 5th place in Europe and 12th place globally. As of the end of 2022, renewable sources account for 54% of the total installed capacity in Turkey [2].

Effective utilization of solar energy is among the key aspects in the operation of the renewable energy sector [3]. One of the first systems that come to mind when talking about renewable energy is photovoltaic (PV) energy systems. These systems are energy production systems that directly convert solar light into electrical energy [4]. As a result, electricity generation can be achieved with these systems almost anywhere in the world, and it is anticipated that the number of such facilities will continue to increase. Undoubtedly, China holds a leading position in this field [5]. However, this study focuses on Turkey. Among European countries, Germany, which has the highest production capacity, falls significantly behind

Turkey, which has an average annual sunshine duration of approximately 1600 hours, compared to Turkey's average annual sunshine duration of 2741 hours [6,7]. This difference can be attributed to the financial support instruments, loans, and tax regulations applied to renewable energy sources in Germany [8]. In France, laws have been established for solar energy systems, and all of the generated energy is sold to the grid [9]. This stimulates investors and encourages them to invest more in this sector. In Spain, despite continuously decreasing installation costs since 2007, there has been a significant increase in photovoltaic facilities due to high incentives. This has positioned Spain as the fourth country among European countries, following the Netherlands. Since joining the EU, Poland, which is obliged to follow and implement suitable policies, including climate-focused ones, has increased its solar energy capacity from 2 MW in 2013 to 11,167 MW by the end of 2022 [10]. Similarly, in Italy, legal regulations and incentives related to renewable energy sources have directed the power derived from solar energy systems towards an upward trend, as seen in other EU countries [11]. As a result, Italy ranks second among EU countries.

The conditions for photovoltaic energy production vary significantly from country to country. This is due to the variability of energy policies and public support programs for renewable energies, particularly photovoltaics. Between 2013 and 2022, the solar energy capacities of countries in the European continent increased by approximately threefold, reaching a total installed capacity of 227,779 MW by the end of 2022. This accounts for approximately 22% of the world's solar energy capacity. Within this ratio, Germany ranked first with an installed capacity of 66,554 MW by the end of 2022, while Poland and the Netherlands demonstrated growth in this field [12].

Despite its dependence on fossil fuels, Turkey, as a developing country, is experiencing significant growth in the renewable energy sector [13]. It is inevitable that solar energy will play a crucial role in reducing Turkey's dependency on fossil fuels in the future.

This study evaluates the development of solar energy capacity in Turkey, which is one of the most important renewable energy sources. Statistical data for Turkey and other countries were obtained from reports provided by the International Renewable Energy Agency (IRENA). Additionally, examinations and evaluations were conducted through official websites of the respective energy ministries. The following sections examine the results of solar energy capacity development in Turkey and compare them with other leading countries in this field.

## II. FINDINGS AND DISCUSSION

### A. Solar Energy Structure in Turkiye

Due to its geographical location and climate, Turkey offers favorable conditions for the utilization of renewable energy sources, particularly for electricity generation. However, the choice of energy sources in each region should progress towards the most suitable energy production capacity based on renewable energy sources wherever possible. In this context, Turkey, which boasts a significant solar energy potential, has been assessed using the Solar Energy Potential Atlas (SEPA) prepared by the Ministry of Energy and Natural Resources. According to SEPA, the average annual total sunshine duration is 2,741 hours, and the average annual total radiation value is calculated to be 1,527.46 kWh/m<sup>2</sup> [7]. The general potential outlook and monthly average global radiation distribution presented in SEPA are shown in Fig. 1.

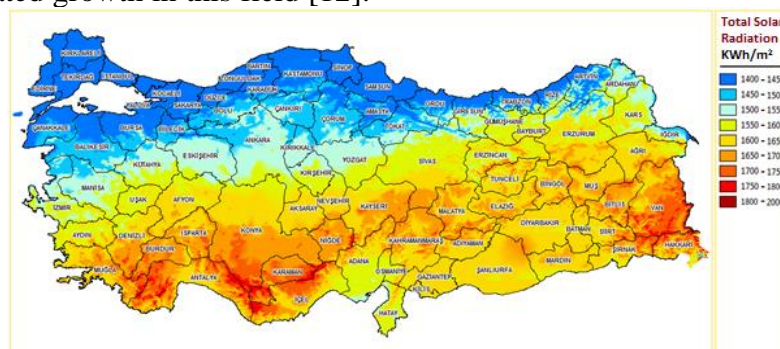


Fig. 1 Average global radiation distribution in Turkiye

In the SEPA, regions that benefit from high levels of solar radiation are indicated by shades of red, ranging from light to dark. The South-eastern Anatolia region stands out as one of the regions with the highest solar energy potential in Turkey, while the Mediterranean and Eastern Anatolia Regions also possess significant potential.

When looking at the global scale, Turkey also possesses a high solar energy potential capacity. In this context, along with other countries, the solar

energy capacity worldwide continues to increase steadily. The variation in global solar energy capacity over the years is depicted in Fig. 2. In 2013, the global solar energy capacity stood at 140,514 MW, and due to incentives and investments made, it has reached levels of 1,053,115 MW by the end of 2022. This represents an approximately 750% increase over the past decade.

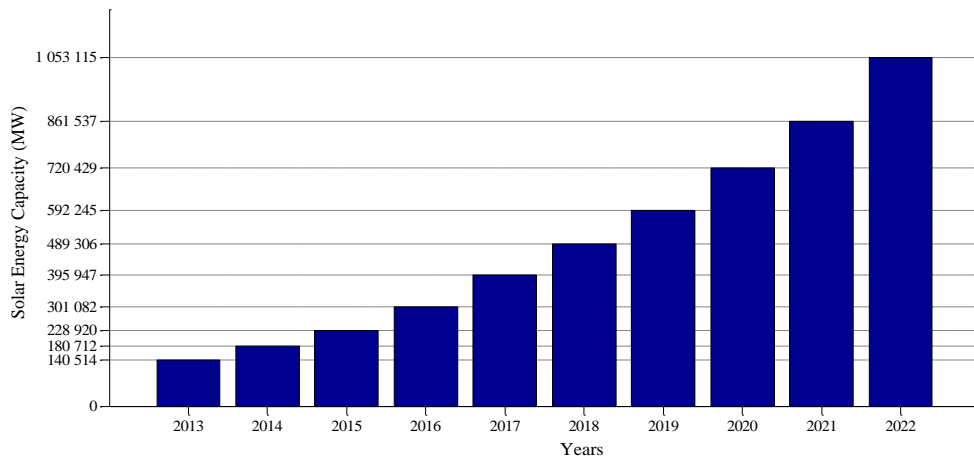


Fig. 2 Variation in global solar energy capacity over the years

International Energy Agency (IEA) predicts that solar energy will become one of the mainstream energy sources by 2050 and contribute to approximately 11% of global electricity production at that time [14]. In this context, Turkey is continuously increasing its solar energy capacity and striving to rank high in solar energy investments. The variation in Turkey's solar energy capacity over the years is depicted in the graph

presented in Fig. 3. In the mid-2010s, with the regulations regarding renewable energy sources introduced by the Energy Market Regulatory Authority (EMRA), the solar energy capacity, which was at 19 MW in 2013, experienced significant growth, especially in 2017, and reached 9,426 MW by the end of 2022 with another rapid increase.

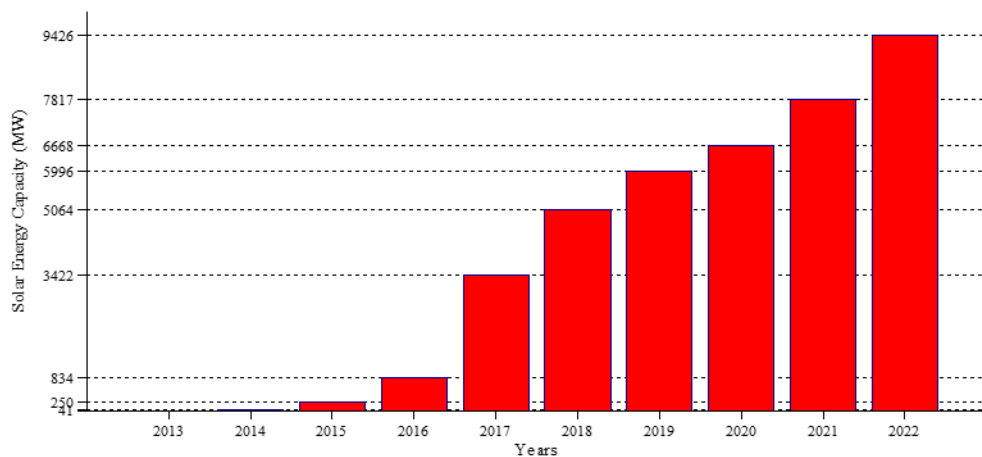


Fig. 3 Variation in solar energy capacity in Turkey over the years

Asia countries account for 56.75% of the total solar energy capacity on Earth, with 597,573 MW. Among these countries, China holds 65% of this share, with 393,032 MW. European countries, on the other hand, contribute approximately 22% of the global solar energy potential, amounting to 227,799 MW. The 27 independent states that are members of the European Union collectively represent approximately 88% of this capacity, with 200,647 MW. Germany, which has the highest solar energy capacity among these countries,

accounts for nearly one-third of the entire EU capacity, with 66,554 MW. Following Germany, Italy, the Netherlands, Spain, France, the United Kingdom, Poland, Ukraine, Belgium, and Greece have significant solar energy capacities. Even these countries together cover approximately 98% of the solar energy capacity of EU countries. The solar energy capacities of these countries in the past decade, as well as the position of Turkey among these countries, are shown in Fig. 4.

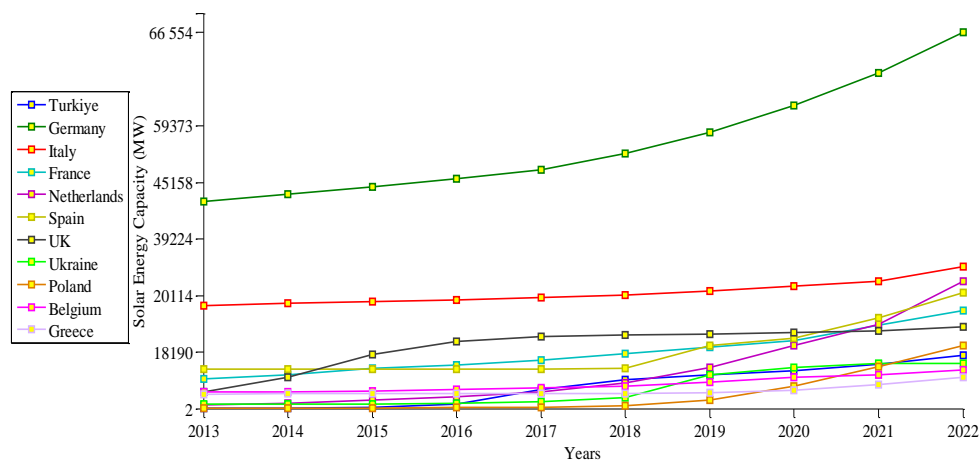


Fig. 4 Turkey's position among the selected European Union countries

As seen in Fig. 4, the fastest progress in the past decade has been made by Poland, which increased its solar energy capacity from 2 MW in 2013 to 11,167 MW in 2022, and the Netherlands, which elevated its solar energy potential from 650 MW in 2013 to 22,590 MW. The primary objective of this development is to enhance energy efficiency and reduce the environmental footprint of the energy sector in these countries, in addition to aligning with the legal targets outlined in the state's energy policy [15,16]. Germany, on the other hand, holds the position of being the leading European country that has consistently advanced its solar energy capacity over the years. Although Turkey is not among the European Union countries, it has

demonstrated rapid growth in this field by increasing its solar energy capacity from 19 MW in 2013 to 9,426 MW in 2022. Thus, Turkey ranks as the second country after Poland among the EU member states that have increased their solar energy capacity in the past decade. The reason behind this is the introduction of legal regulations and capacity allocations that enabled the implementation of previously underutilized incentive mechanisms and the promotion of renewable energy facilities [4]. Table 1 presents the recent status of the selected European Union countries and Turkey, indicating the countries with the highest solar energy capacities.

Table 1. Solar energy capacities (MW) of European Union Countries and Turkey

Years	Turkey	Germany	Italy	France	Netherlands	Spain	UK	Ukraine	Poland	Belgium	Greece
2013	<b>19</b>	36710	18190	5277	650	6994	2937	748	2	2902	2579
2014	<b>41</b>	37900	18600	6034	1007	7001	5528	819	27	3015	2596
2015	<b>250</b>	39224	18907	7138	1526	7008	9601	841	108	3132	2604
2016	<b>834</b>	40679	19289	7702	2135	7017	11914	955	187	3329	2604
2017	<b>3422</b>	42293	19688	8610	2911	7027	12760	1200	287	3621	2606
2018	<b>5064</b>	45158	20114	9672	4608	7068	13059	2003	562	4000	2652
2019	<b>5996</b>	48914	20871	10817	7226	11111	13224	5936	1539	4637	2834
2020	<b>6668</b>	53671	21656	12065	11108	12440	13462	7331	3955	5573	3288
2021	<b>7817</b>	59373	22600	14819	14911	16019	13799	8062	7416	6012	4277
2022	<b>9426</b>	66554	25083	17419	22590	20518	14412	8062	11167	6898	5557

Table 2 illustrates the solar energy capacities of Turkey and its neighboring countries between 2013 and 2022. Turkey, located as a bridge between Asia and Europe, is a peninsula country surrounded by seas on three sides. It shares borders with Greece and Bulgaria in Europe, and with Georgia, Armenia, Azerbaijan, Iran, Iraq, and Syria in Asia. Many of these neighboring countries are situated in

a warm climate zone, making them highly suitable for electricity generation through solar power plants. However, due to economic and energy policies in these regions, the increase in solar energy capacity has been progressing at a relatively slow pace.

Table 2. Solar energy capacities (MW) of Turkey's neighboring countries

Years	Turkey	Greece	Bulgaria	Armenia	Azerbaijan	Georgia	Syrian	Iran	Iraq
2013	<b>19</b>	2579	1039	---	1	---	---	1	30
2014	<b>41</b>	2596	1029	---	2	---	---	9	37
2015	<b>250</b>	2604	1028	---	5	---	---	9	37
2016	<b>834</b>	2604	1030	1	25	0	---	43	37
2017	<b>3422</b>	2606	1031	2	28	1	1	184	37
2018	<b>5064</b>	2652	1033	17	35	1	1	286	37
2019	<b>5996</b>	2834	1044	50	33	3	2	346	37
2020	<b>6668</b>	3288	1100	106	35	5	12	430	37
2021	<b>7817</b>	4277	1275	217	48	18	33	456	37
2022	<b>9426</b>	5557	1948	306	51	18	60	539	42

Although there is a general increase in solar energy capacities among the countries listed in Table 2, Turkey stands out as the country with the highest solar energy capacity. Despite being members of the European Union, Greece and Bulgaria have not made significant progress in terms of solar energy capacities. During the ten-year period from 2013 to 2022, Greece increased its solar energy capacity by approximately 2.15

times, while Turkey increased its capacity by approximately 500 times. Among the Asian countries, Iran also increased its solar energy capacity by approximately 500 times. However, this ratio is relatively low compared to the overall average of Asian countries. The comparison of Turkey's solar energy capacity with its neighboring countries is shown in Fig. 5.

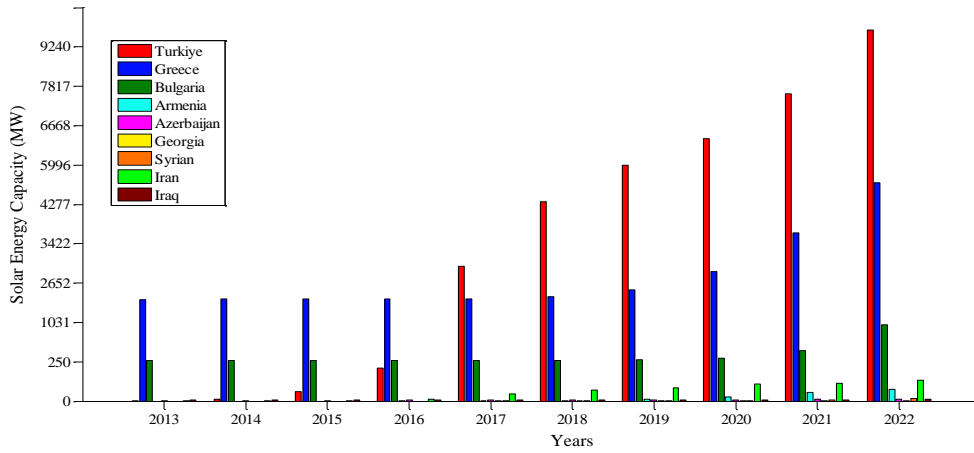


Fig. 5 Comparison of Turkey with border countries in terms of solar energy capacities (MW)

### III. CONCLUSION

The increasing energy demand and the risks posed by climate change have prompted countries worldwide to revise their policies and increase investments in renewable energy sources. This approach aims to address the financial burden created by energy dependence while aligning with countries' future goals. However, when examining investments and regulatory frameworks, it becomes evident that these efforts are not yet sufficient. Consequently, some countries have achieved their targets ahead of schedule, while others have yet to reach desired levels. Therefore, accurate analysis of investment and incentive systems and the establishment of appropriate policies are crucial.

In terms of climate conditions, Turkey has a higher renewable energy capacity, especially in solar energy, compared to many European Union (EU) countries. However, several EU member states such as Germany, Poland, and the United Kingdom currently meet a significant portion of their electricity needs through renewable energy sources and aim to further increase this proportion in the future. Despite its advantageous geographical location, Turkey lags behind many European countries in terms of solar energy capacity. Therefore, the future plans for renewable energy should set higher targets. To achieve this, it is crucial to enhance and increase incentives for investors in the installation of clean energy sources and prioritize clean energy as a key component of energy security.

In this study, the current solar energy capacity of Turkey has been examined over the past 10 years, and it has been compared with the solar energy capacities of certain European Union (EU)

countries and other neighboring countries that share borders with Turkey. It has been observed that Turkey has increased its solar energy capacity, particularly since 2017. The reason behind this increase is the growing significance of renewable energy as a global resource and the effective utilization of financial support in this field. The main factor contributing to Turkey lagging behind some European countries is the relatively shorter duration of incentives for solar energy capacity compared to countries with higher capacity, such as France. To improve the incentive system in Turkey, it is necessary to address existing shortcomings and implement additional incentive schemes.

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