Akdeniz İİBF Dergisi 2025, 25 (1) 20-32

AKDENİZ İİBF DERGİSİ
Akdeniz İİBF Journal
https://dergipark.org.tr/tr/pub/auiibfd

e-ISSN 2667-7229 http://dx.doi.org/10.25294/auiibfd.1612024

Comparative Analysis of Sustainable Solar Energy Use in the Context of Energy Policies: The Cases of Türkiye and Germany

Sürdürülebilir Güneş Enerji Kullanımının Enerji Politikaları Bağlamında Karşılaştırılması: Türkiye ve Almanya Örneği

Ferat KAYA[a]

ARTICLE INFO

Article History
Received 3 January 2025
Accepted 11 March 2025
Available Online 17 April 2025

Article Type Research Article

Keywords

Energy,
Renewable Energy,
Solar Power Plant,
Photovoltaic,
Türkiye-Germany.

ABSTRACT

The amount of energy consumption is one of the main criteria for technological and economic advancement in countries. In order to meet the increasing energy need, there is an increasing tendency towards renewable energy, which is an alternative to fossil fuels and sustainable. Countries are turning to solar power plants, which are safe, environmentally friendly, and sustainable energy sources, to protect themselves from the effects of a possible energy crisis.

Türkiye, which is dependent on energy imports, is increasingly recognizing the importance of its renewable energy resource potential. Based on the generation obtained from investments in solar power plant construction and the number of sunshine days, it is observed that Türkiye has a twofold higher investment viability level compared to Germany. This study comparatively analyzes the support provided by Türkiye and Germany for photovoltaic (PV) plants, focusing on energy policies. Germany aims to reduce its dependence on imports by diversifying its energy sources in accordance with its articulated vision. The study concludes that distinctions have emerged between Türkiye and Germany in terms of solar energy generation, influenced by factors such as energy purchase prices, purchase guarantees, energy policies, access to financing, incentives, economic development, legal regulations, and costs. Utilizing these data, the study seeks to identify the shortcomings of Türkiye's energy policies related to the generation of PV plants, thereby contributing to the existing literature in this field.

MAKALE BİLGİSİ

Makale Geçmişi
Başvuru 3 Ocak 2025
Kabul 11 Mart 2025
Yayın 17 Nisan 2025

Makale Türü Araştırma Makalesi

Anahtar Kelimeler

Enerji,
Yenilenebilir Enerji,
Güneş Enerji Santrali,
Fotovoltaik,
Türkiye-Almanya.

ÖZ

Enerji tüketim miktarı, ülkelerin teknolojik ve ekonomik yönden gelişmişlik seviyesini gösteren önemli ölçütlerden biridir. Artan enerji gereksinimini karşılamak amacıyla fosil yakıtlara alternatif ve sürdürülebilir nitelikteki yenilenebilir enerjiye yönelim artmaktadır. Ülkeler olası bir enerji krizinin etkilerinden korunmak için güvenli, çevre dostu ve sürdürülebilir enerji kaynağı olan güneş enerji santrallerine yönelmektedir.

Enerji ithaline bağlı olan Türkiye'nin, yenilenebilir enerji kaynak potansiyeli her geçen gün daha önem kazanmaktadır. Güneş enerji santral yapımına yönelik yatırımdan elde edilecek üretim ve güneşlenme gün sayısı baz alındığında Türkiye'nin, Almanya'dan iki kat daha fazla yatırım yapılabilirlik seviyesine sahip olduğu görülmektedir. Bu çalışma; Türkiye ve Almanya'nın fotovoltaik (PV) santrallerine verdikleri desteği, enerji politikaları alanında karşılaştırmalı bir şekilde analiz etmektedir. Almanya ortaya koyduğu vizyon doğrultusunda enerji çeşitlemesine giderek dışa bağımlılığını azaltma hedefi ortaya koymaktadır. Türkiye ile Almanya arasında güneş enerji üretimine yönelik; enerji alım fiyatı, alım garantisi, enerji politikaları, finansman bulma, teşvikler, ekonomik gelişmişlik, yasal düzenlemeler ve maliyet gibi farklılıklarla güneş enerjisinden yararlanma miktarları arasındaki ayrımın oluştuğu sonucuna varılmıştır. Bu verilerle Türkiye'nin PV santralleri üretimine yönelik enerji politikaları alanında eksikliklerinin neler olduğunun tespitiyle literatüre bu alanda destek olunmaya çalışılmıştır.

[a] Asst. Prof. Dr., Dicle University, Faculty of Economics and Administrative Sciences, Department of Political Science and Public Administration, Diyarbakır, E-Posta: f.kaya@dicle.edu.tr, ORCID: https://orcid.org/0000-0003-3704-7251

⚠ Yazarlar bu çalışmanın tüm süreçlerinin araştırma ve yayın etiğine uygun olduğunu, etik kurallara ve bilimsel atıf gösterme ilkelerine uyduğunu beyan etmiştir. Aksi bir durumda Akdeniz İİBF Dergisi sorumlu değildir.

1. Introduction

"The sun will be the fuel of the future."

Anonymous, April 1876, Popular Science

The amount of energy reaching the surface of the earth from sunlight in ninety minutes is more than the amount of energy used in a year worldwide (IEA, 2011: 31-32). Studies on the utilization of such a huge renewable energy source have gained momentum with the increasing technology. Electricity generation from solar energy is carried out in two methods. The first method is the direct conversion of sunlight into electrical energy through PV and the second method is the generation of electricity from steam energy solar focusing systems. This study focuses on the PV systems in Türkiye and Germany.

Solar energy investments are determined by the political and economic development of countries rather than their solar energy potential. It is seen that countries with high solar energy potential do not lead in solar energy investments. China, the USA and Japan lead the world in solar energy investments (Zielinski, 2022: 10). Germany, which has a low energy potential in terms of insolation, follows these countries and ranks first in solar energy investment in Europe. In addition, Germany holds the leading position globally in terms of installed solar power generation capacity per capita (Federal Statistical Office, 2022).

Türkiye has experienced a rapid increase in energy demand in recent years owing to economic growth, population boom, and rising standards of living. Türkiye, which meets its energy demand mostly from fossil energy resources and is largely dependent on external sources of primary energy, has been experiencing an energy security problem by importing energy and having a current account deficit every year. The problem of external dependency on energy and the use of fossil fuels with high import costs also bring environmental problems. Although Türkiye is a resource-rich country in regards to its renewable energy resource capacity, it does not benefit sufficiently from renewable resources other than hydroelectricity and traditional biomass resources. The importance of Türkiye using its renewable energy potential more effectively in terms of reducing energy-related emissions increases every year. Solar energy, which has a high potential as a renewable resource, is of great importance as a domestic resource in fulfilling Türkiye's increasing electricity needs.

This paper compares solar energy utilization in Türkiye and Germany in the context of their respective energy policies, examining the highlights of state support, incentives, and legal regulations. Germany, a pioneer in the adaption of renewable energy, has established a robust framework to promote solar energy, while Türkiye, which has significant potential for solar energy that has yet to be utilized, has faced challenges in using this resource effectively. Germany stands out especially with its "Energiewende" (Energy Transition) policy. This policy has enabled Germany to use solar energy as an important tool in the transition of separate energy sources. Germany is a frontrunner in the adoption of solar energy through significant investments in renewable energy infrastructure through technological innovations. In Germany one of the biggest challenges is related to the geographical limitation of solar energy use and adequacy of solar radiation. In contrast, Türkiye has a large untapped solar energy potential. Solar energy policies in Türkiye have been shaped by various legal regulation aimed at promoting renewable energy sources. However solar energy policies in Türkiye are newer compared to Germany and legal regulations in this area in the development process. The main obstacles to using solar energy in Türkiye are high initial costs, lack of sufficient infrastructure, and difficulties in developing domestic production capacity. Another important problem is the lack of policies, support and investments put forward by the state. This study examines the energy policies, economic impacts, and the barriers and opportunities that shape solar energy development in both countries. This paper also explores the differences and similarities in solar energy policies between the two countries, highlighting the effectiveness of such policies in promoting solar energy development.

2. Methodology

Although studies on climate change, one of the biggest problems encountered on a global scale, began in the post-1970 period, the most effective studies were carried out under the initiative of the United Nations and international institutions after 1980. Serious efforts have been made to reduce human-induced greenhouse gas emissions with the "United Nations Framework Convention on Climate Change" in 1992, the "Kyoto Protocol" in 1997, and the "Paris Agreement" in 2015. With the Kyoto and Paris Agreements, there has been a worldwide trend towards renewable energy sources with high energy efficiency that will reduce greenhouse gases. Since renewable energy sources are seen as the ultimate goal in the coming period, Türkiye needs to focus on technological and economic investments in renewable energy as soon as possible and receive support from the academic community. For this reason, Germany, which is the leader in solar energy production within the EU, is chosen and it is aimed for Türkiye to take serious steps towards this field.

Türkiye, which has a strong potential in solar energy resources, is being analyzed comparatively with Germany in terms of energy policy, solar energy investment, and development rate. Although Germany is not as strong as Türkiye in its potential for solar energy, it is the number one country in Europe with the amount of solar energy production. Türkiye is an energy importing country and therefore cannot conduct its own policy independently. It can get out of this vicious circle with the generation of renewable energy, which is domestic energy. The following criteria were effective in selecting Germany as the relevant country in this context;

- Germany, which is among the founding member states of the EU, is preferred because Türkiye is an EU candidate country,
- Germany, together with France, is one of the locomotive countries of the EU,
- Although Germany is in a disadvantaged position concerning its solar energy, it ranks 1st in the EU with its solar energy generation amount,
- Germany is in a favorable position in terms of industry and technology and can serve as a model for Türkiye,
- Comparing the policies, incentives and support mechanisms implemented by Germany until today with the

example of Türkiye and determining what are the missing or wrong policies implemented.

This study focuses on the policy decisions, directives, implemented incentives, technological investments, employment policies, production capacities, and cost calculations regarding PV solar energy production adopted by Türkiye and Germany after 2000. Additionally, the exclusion of other leading solar energy countries such as China, the USA, and Japan from the comparison restricts a comprehensive understanding of global solar energy utilization, while solely comparing Türkiye and Germany may yield more focused insights. This choice is one of the other limitations of the research and the purpose is to understand the topic by focusing only on the energy policies of the two countries in a comparative way. Other solar energy technologies, such as concentrated solar power, are excluded, and the scope is limited solely to PV systems.

This study adopts a qualitative case study approach based on literature review, policy analysis, and legislative examination. The use of secondary data sources instead of primary data collection (e.g., field studies or expert interviews) may limit the study's originality. While analyzing energy policies, this study does not provide an in-depth examination of grid integration challenges or socio-political factors in both countries. The significant differences in economic conditions, subsidy structures, and market dynamics between Türkiye and Germany further complicate direct comparisons. Additionally, solar energy efficiency can vary considerably between regions (e.g., Bavaria versus Berlin in Germany, or Mersin versus Artvin in Türkiye). Although the study acknowledges the high initial costs and financing challenges in Türkiye, it does not include a detailed cost-benefit analysis.

This study compares the sustainable use and policies of PV solar energy in the context of the energy policies of Türkiye and Germany. Statistical data from various globally and nationally significant organizations have been utilized. The energy transitions, energy investments, and the role of solar energy in sustainable energy policies of two countries have been evaluated based on the reports of the International Energy Agency, Renewable Global Status, and Eurostat. Data from Germany's Fraunhofer Institute for Solar Energy Systems and the Federal Statistical Office are analyzed to evaluate Germany's solar energy investments, support programs, policy incentives, and financing mechanisms. Data from the Republic of Turkey Ministry of Energy and Natural Resources are used to evaluate Türkiye's solar energy potential, current and future energy policies, and investments. Ultimately, within this literature framework, the PV solar energy potentials, investments, current and future policies, incentives, and financing processes of Türkiye and Germany are compared to identify the deficiencies in Türkiye's energy policies and to examine how the German model could be adapted.

In the literature, there are various studies on renewable energy policies, economic-technological dimensions of solar energy and PV systems. However, the number of studies addressing the solar energy potential and policies of Türkiye and Germany is relatively limited. This study aims to contribute to the literature by providing a comparative analysis of the solar energy policies of Türkiye and Germany, with a particular focus on PV solar energy systems.

3. Development of Solar Energy Potential and Systems in Germany and Türkiye

In 2024, Türkiye's energy outlook has shown significant changes with increasing energy demand and production. Notably, the rise in fossil fuel-based energy production has positioned Türkiye as the country with the highest emissions from this sector in Europe. Türkiye has increased the share of coal in electricity generation, obtaining 36.3% of its total energy production from coal (Fig. 1). For the past three years, there has been a continuous increase in coal-fired energy production, reaching a record level in 2024 (IEA, Türkiye: 2024). Natural gas followed coal with a share of 21.2%. As of June 2024, Türkiye's total installed power capacity reached 110,539 MW, with 57.3% of this capacity derived from renewable energy sources. By July 2024, hydropower plants accounted for 28.9% of the total installed power, while wind and solar energy plants collectively accounted for 25.2% of the total installed power (TSKB, 2024: 2). These data highlight Türkiye's significant progress in the renewable energy sector and its aim to further enhance its potential in this field in the future.

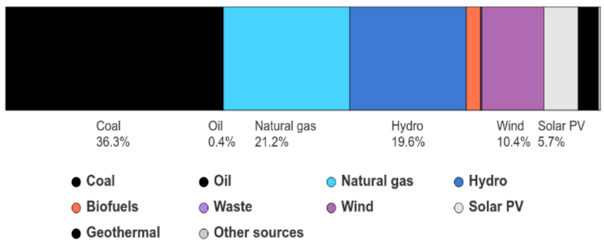

Fig. 1. Türkiye's Electricity Generation 2023

Source: International Energy Agency (2024).

Türkiye possesses considerable potential for harnessing solar energy, as it is located within sunbelt region (Frentzou, 2024: 64). Although Türkiye, located in the sunbelt at 36^0-42^0 northern parallels, is geographically well positioned in terms of solar energy potential, it does not utilize from solar energy as much as it should. A very low portion of the current solar energy potential in Türkiye is used to generate electricity. The primary application of solar energy potential in Türkiye is thermal systems. In 2019, Türkiye emerged as Europe's largest market for thermal energy systems and the second largest in the world, following China, in terms of newly installed collector area (Çelik et al, 2023: 1589). Although there are no regulations or incentives in Türkiye, thermal installations used in hot water generation on roofs are in a pioneering position. Thermal systems used in hot water generation and greenhouse heating are widely used in the southern parts of Türkiye. The utilization capacity of low-temperature thermal solar energy systems in Türkiye is quite high, and the majority of the collectors produced by the manufacturing companies are exported and benefit the Turkish economy (Akdemir, 2021: 36). Although the investments made in this field in Türkiye are sufficient, there are deficiencies in the necessary technological investments.

Türkiye's electricity generation amount as of the end of 2023 was 326,3 TWh (R.T. (Republic of Türkiye) Ministry of Energy and Natural Resources Electricity, 2024).

Türkiye generates 42,3% of its total electricity from renewable energy sources. Among renewable energy sources, 19,6% of the total installed capacity is generated from hydroelectric power plants, 10,4% from wind and 6,7% from solar (R.T. Ministry of Energy and Natural Resources Electricity, 2024). Among Türkiye's renewable energy sources, the majority of its energy supply is based on hydroelectric energy.

The Solar Energy Potential Atlas was developed by the Ministry of Energy to determine the solar energy production potential in Türkiye. Relevant data on solar radiation, temperature and other meteorological factors are essential for analyzing solar energy potential and determining appropriate locations for solar energy investments. Solar radiation reaches the earth in the form of direct or diffuse radiation and the concepts of Direct Normal Irradiation (DNI), Diffuse Horizontal Irradiance (DHI) and Global Horizontal Irradiation (GHI) are used to measure the solar energy potential in the region. DNI, which is perpendicular to the atmosphere and is not affected by factors such as clouds, atmosphere and dust and DHI, which is scattered by molecules and particles in the atmosphere and does not follow a direct path, indicates the amount of radiation received per unit. The sum of the direct diffuse and reflected solar radiation reaching the horizontal surface, in other words, the sum of DNI and DHI constitutes the GHI. GHI data is used to determine the power from solar energy in PV power estimations.

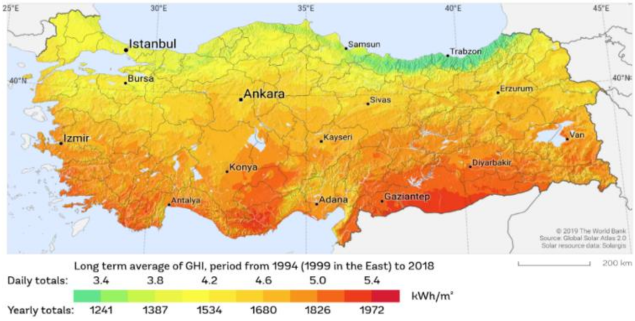

Fig. 2. Türkiye Global Horizontal Irradiation

Source: The World Bank Group & Solargis, (2019).

The amount of energy from the sun goes from dark red to light. While the southern regions of Türkiye have more energy potential, the energy potential decreases as you move north (Fig. 2). Nevertheless, the values seen in the north of Türkiye are higher than the highest potential regions of Germany. Türkiye's daily total sunshine time is 7.58 hours/day and Türkiye's annual total sunbathing time is 2766.5 hours/year. Türkiye's average annual total radiation intensity is 1521.7 kWh/m2 per year (R.T. Ministry of Energy and Natural Resources Solar, 2024). It is seen that Türkiye has a high sunlight potential.

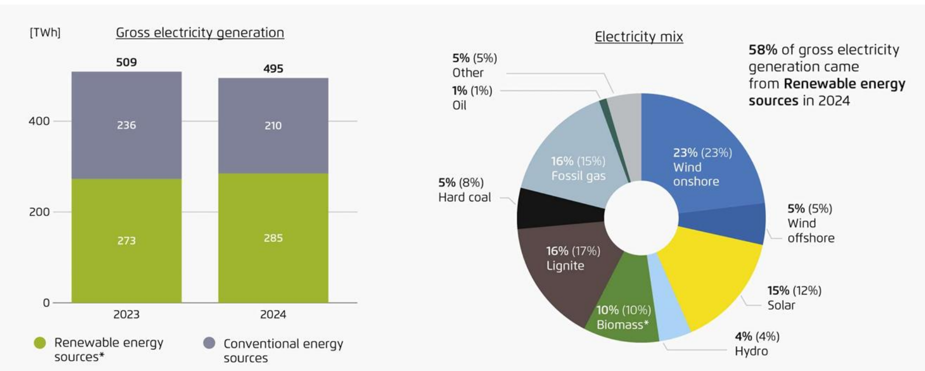

Fig. 3. Germany Electricity Mix 2024

Source: Zackariat et al., (2025: 14).

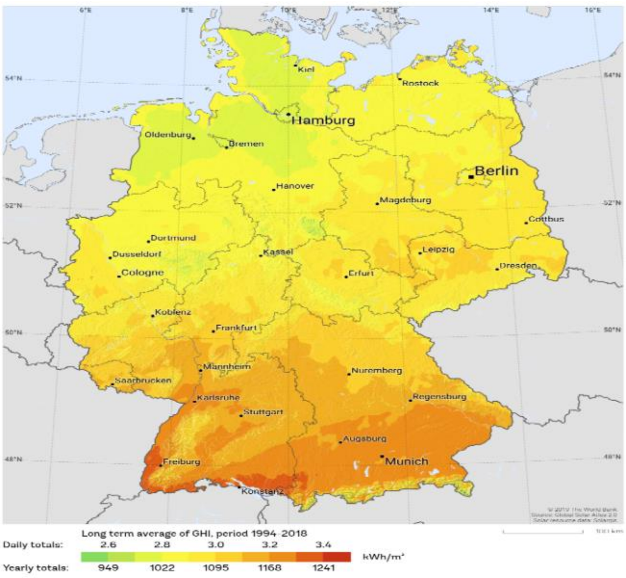

Fig. 4. Germany Global Horizontal Irradiation

Source: The World Bank Group & Solargis, (2019).

In 2024, Germany's energy sector stands out with the increasing share of renewable energy sources and the decline in fossil fuel consumption. Germany generated 58% of its total electricity from renewable energy sources (Fig. 3). The production from coal-fired thermal power plants decreased by 31%**,** while lignite consumption recorded a 9% decline (Enerdata, 2025). Wind energy continues to play a dominant role in electricity generation. As a result of these changes, Germany's carbon emissions from energy production have significantly decreased. With the increasing dominance of renewable energy sources and the decrease in fossil fuel consumption, Germany's energy outlook is becoming more sustainable than ever before.

As seen in Fig. 4, Germany, located between the 47º-55º parallels, is further north of Türkiye. Despite its low solar energy potential, Germany has become a leader in Europe by shifting towards PV systems. While Germany generates 54.6 GW/h of electricity from solar, Türkiye generates 11.7 GWh. Germany's daily total sunshine time is 4.4 hours/day and Germany's annual total sunbathing time is 1600 hours/year. The average annual total radiation intensity is 1088 kWh/m2 per year in Germany (Wirth, 2021: 25).

When the GHI and DNI values of Germany and Türkiye are compared, Türkiye has a clear superiority. While Türkiye's Solar Irradiance Potential daily insolation value is 4.60, Germany has a value of 2.98 and Türkiye has a better value in terms of solar irradiance potential (Fig. 5). Although Germany has less energy potential than the northern regions of Türkiye, it generates more electricity in terms of the systems it uses shows that the efficiency of the systems used by the countries is also a major factor in addition to the potential.

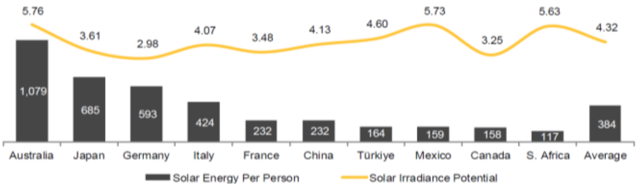

Fig. 5. G20 Countries with the Highest Per Capita Solar Energy Generation (Top 10) and Solar Irradiance Potential (kWh/person, kWh/m²/day, 2021)

Source: Pwc, (2024).

Considering the growth in integrated capacity for electricity generation, solar energy is a leading renewable energy source. The main factor for this growth in solar energy is the drastic decline in levelized costs of energy (LCOE). LCOE is analogous to the payback concept for energy systems. It indicates how much investment cost will be spent to produce a unit of electricity, including the initial capital investment, maintenance costs, fuel costs for the system (if any), operating costs, and discount rates (Sayigh, 2012: 37). Subsidies, tax breaks, and other government programs can help to reduce the LCOE of sustainable low-emission renewable energy systems. In determining the LCOE, the energy producer company or the state facilitates the analysis by combining variable costs such as the investment cost of the system, return on investment, financing conditions such as interest, operating and dismantling costs into a single measurement. The levelized energy costs of solar energy decreased by 90% from $323 in 2009 to $30 in 2021 (Fig. 6).

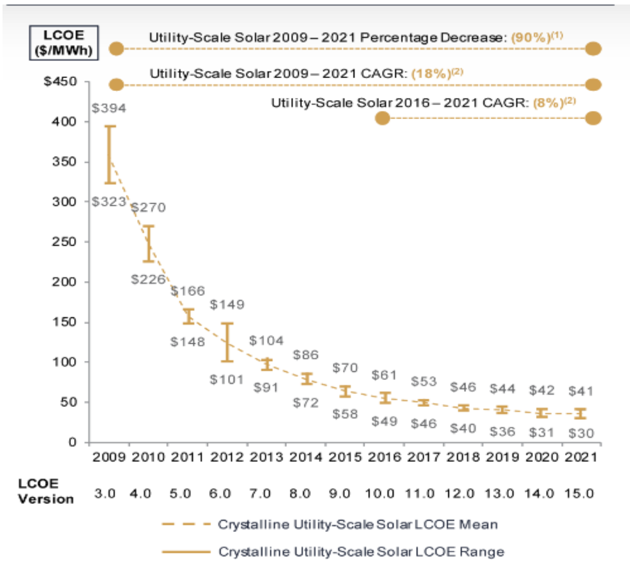

Fig. 6. Unsubsidized Solar PV LCOE

Source: Lazard, (2021).

Germany, which has a strong economy, has become an important actor in solar energy generation with its political stability and correct energy policy. Germany is making the necessary technological investments as it moves towards becoming Europe's leading PV market. Germany has been developing its solar energy installed capacity over the years. It is aimed to expand the installed PV capacity to 200 GW by 2030 (Fig. 7.).

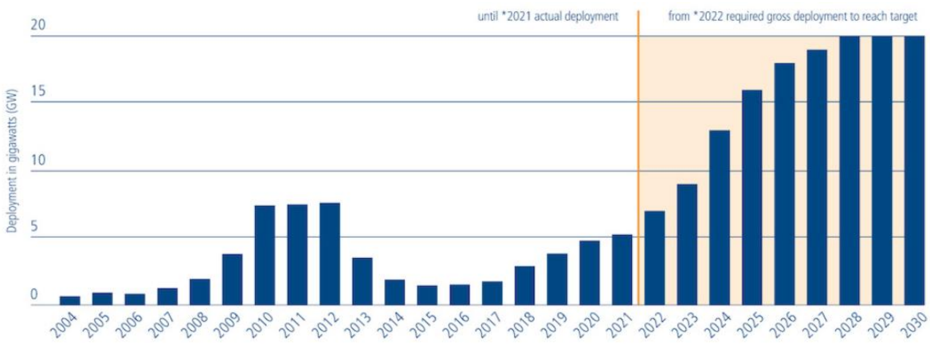

Fig. 7. Annual Photovoltaics Development in Germany (2004-2030)

Source: Intersolar Europe, (2022).

The EU strives to ensure that the energy sector is competitive, sustainable, high-quality, consumer-friendly and reliable services at affordable prices. The EU, which combats climate change and takes important initiatives to create a sustainable clean environment, attaches particular importance to renewable energy policies. EU countries submit progress reports on renewable energy targets every two years. In the last report presented in 2023, it was stated that EU member states reached a level of 22%, exceeding the binding 2020 renewable energy target by 2% (Eurostat, 2023). Germany exceeded the 2020 and 2030 targets (Table 1), which constitute an important component of the EU's climate and climate change framework, reaching 49% levels in renewable energy production (Edo, 2023: 21). Germany aims to reach 60% share of renewable energy in in its total energy consumption by 2050, with the aim of increasing the share of renewable energy sources in electricity consumption to 80% by the same year. The energy targets envisaged by Germany are ahead of the targets set by the EU and carry out a pioneering policy within the EU. Germany's pivotal role as a vehicle manufacturer, it plays a crucial part in fulfilling European Union's objectives of enhancing energy security, decarbonizing its economy and improving energy efficiency (Hafner and Raimondi, 2022).

Table 1. EU's climate and energy targets

Energy targets	Targets for 2020	2030 climate and energy framework
Greenhouse gas emission reduction (compared to 1990 levels)	%20	%40
Renewable energy sources' share in energy consumption	%20	%27
Enhancing energy efficiency	%20	%27

Source: Edo, 2023: 26

The EU has created a roadmap for the green transformation process required by the Paris Climate Agreement with the European Green Deal in 2019. The European Green Deal is the new growth strategy that aims to make Europe the world's first climate-neutral continent with the net zero greenhouse gas emissions by 2050. One third of the €1.8 trillion investments from the Next Generation EU Recovery Plan, and the EU's seven-year budget will finance the European Green Deal (European Commission, 2024). According to the Green Deal, the EU accelerates the shift to sustainable and smart mobility, preserves and restores ecosystems, supplies clean-affordable, secure energy, and protects the health (European Commission, 2019). Renewable sources will have an important role for energy efficiency and other sustainable solutions.

Türkiye, which is late in solar energy production, launched its first largest solar energy project in Karapınar in 2017 with state incentives. The electrical energy generation facility with a capacity of 1000 MW has a domestic contribution rate of 74.62%. This project, implemented with the Renewable Energy Resource Area model, aims to increase the contribution of domestic production from renewable energy technologies and carry out research and development (R&D) activities. With this regulation, the determination, evaluation, protection and utilization of renewable resource areas located on public and treasury lands and thus the use of state-owned lands have been opened for energy production purposes. While the second and third steps of this project implementation were for wind energy, the fourth application was again for solar energy and it was decided to conduct 74 separate tender processes, each in the range of 10-20 MW (R.T. Ministry of Energy and Natural Resources, YEKA Model 2021). Instead of importing the necessary parts for the project, it is aimed to support the domestic market, expand the solar energy sector and increase employment. Due to financial instability, the modules that were supposed to be produced by 2018 could not be processed and many factories halted the assembly (Tsagas, 2019). Karapınar PV power plant, started generating electricity in 2021, supports production with 1.0 GW of energy production in 2023.

One of the incentives implemented in Türkiye is the exemption from license fees or the opportunity for unlicensed production. With unlicensed production, the investor is exempted from the obligation to obtain a license for the first 8 years up to the kW/h projected by the state and pays 10% of the fee in the following years (Şencan, 2022: 700). The fact that 10 GW of the 11.7 GW production in 2023 was produced from unlicensed production can be explained by the fact that this process is more convenient and applicable (Fig. 8).

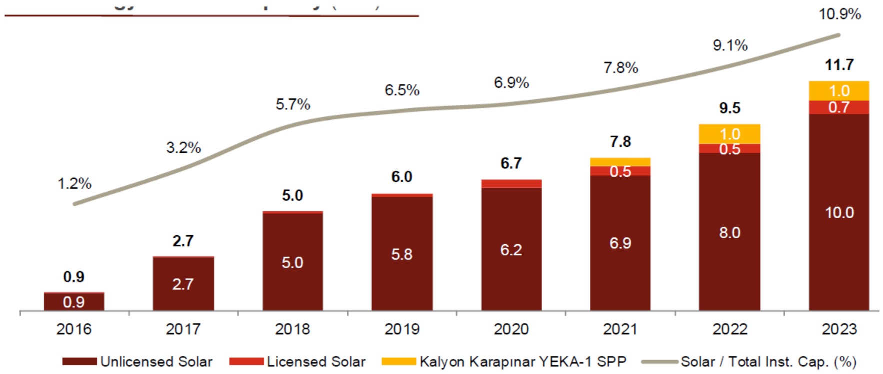

Fig. 8. Solar Energy Installed Capacity (GW)

Source: Pwc, (2024).

Germany and Türkiye have leveraged diverse renewable energy sources while establishing targets to augment the contribution of renewable energy to their electricity generation. While Türkiye produces energy from wind energy after hydroelectric power plants among renewable energy sources, Germany benefits from solar energy after wind energy among renewable energy sources.

Germany, which started investing in solar energy in 2004, has been developing its power plants in terms of both technology and capacity. Solar electricity generation is getting more cost effective every year with technological advances. Germany's significant cost advantage in renewable energy is a factor in its being a role model for Türkiye (Telli et al., 2021:420). Due to technological advancement, the learning curve and scale economies, the costs of PV power plants, that constitute the largest expense, are decreasing by an average of 12% per year (Fig. 9). There has been a 75% decrease since 2008. In 2006, the average unit price of a solar power plant was 4600 €/kWp, and this rate decreased to 1000 €/kWp in 2021.

Germany has implemented various reductions in electricity tariffs with the growth figures seen in the economy and new pricing policies. The constant revision of the purchase price in Germany according to the current situation has both protected the state economy and enabled the sector to be kept in a continuously investable position. The decreases in hardware and software costs have been effective in the significant decline in PV system prices over the last decade. In Germany, PV system prices decreased from 2941.30 E/kW in 2011 to 1392.13 E/kW in 2022 (Fig. 10).

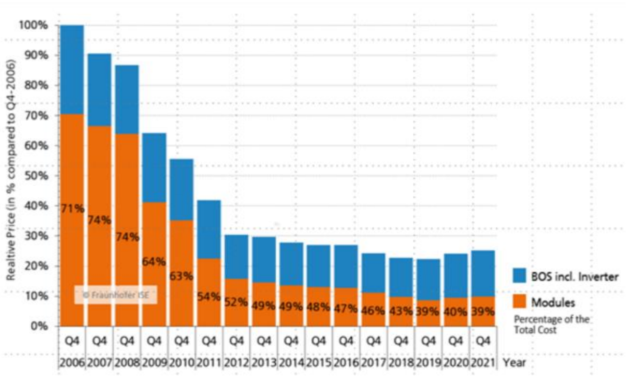

Fig. 9. Price Change with Technological Development in Germany (2006-2021)

Source: Wirth, (2024: 9).

The positive price development in PV systems stagnated after 2020. One of the increasing reasons for this stagnation is the rising cost of polysilicon and the increasing cost of PV modules due to supply chain disruptions caused by the Covid-19 pandemic (Kraschewski et al., 2023: 3). The decrease in electricity demand due to Covid-19 has almost no impact on the electricity generation of solar energy in the first half of 2020. This is because solar generation is delayed compared to when it is actually built (Jones, Graham and Tunbridge, 2020: 8). In the aftermath of the COVID-19 pandemic, the pronounced deceleration of the economy, coupled with a relative stabilization in electricity demand, created an opportunity for a transition towards clean energy technologies and the utilization of domestic resources (Kat, 2023: 9).

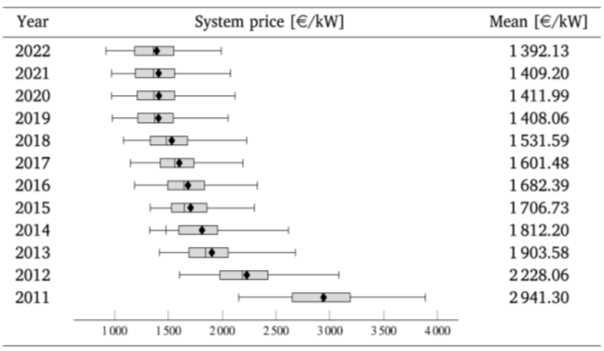

Fig. 10. Germany PV System prices (€/kW) from 2011 to 2022

Source: Kraschewski et al., (2023: 4).

4. The Role of the Solar Energy Sector in the Energy Policies of Germany and Türkiye

Since 2000, The EU has published new directives every two or three years aimed at increasing the utilization of renewable energy, along with the release of White and Green Papers post-1980. The EU has issued these directives in line with the Kyoto Protocol provisions. The economic and energy bottleneck experienced after 2000 has made it compulsory for the EU to adopt measures for a sustainable energy strategy. The 2001 directive promoted the generation of electricity from renewable energy sources within the internal electricity market (European Council, 2001). The fulfillment of climate change commitments, ensuring environmentally sustainable energy security and encouraging the transition from fossil fuels to renewable energy sources have been actively pursued (European Council, 2003). This directive requires the reduction of greenhouse gases in all fuels, as well as the continuity of environmental, economic and social conditions. These goals of the EU were also included in the context of "Action Plan for Energy Efficiency: Realizing the Potential" in 2006. In order to build a more sustainable future, it emphasized the need to increase energy generated from renewable sources and to invest in new energy technologies through mandatory targets. A mandatory national framework directive was issued for the share of energy from renewable sources in total energy consumption (European Council, 2009). In the "Clean Energy for All Europeans" directive published by the EU in 2016; the EU outlined its goals to become a pioneer in energy efficiency and renewable energy, as well as to provide fair agreements for consumers (European Commission, 2016). In the 2020 Strategy, the EU proposed an investment of %3 in R&D and the private sector (European Commission, 2020). In 2023, it adopted the Renewable Energy Directive, which aims to increase the share of renewable energy to 42.5% by 2030 (European Council, 2023).

After the 2011 Fukushima Daiichi nuclear accident, Germany shifted to alternative sources of energy instead of nuclear energy. For this purpose, the Energiewende policy was formulated in 2011, reflecting the desire to transform Germany into a zero-carbon society and improve energy efficiency. The German Energiewende refers to a transition from the current energy system, which is predominantly based on fossil fuels, to one that relies on renewable energy sources, particularly wind and solar PV technology, for energy generation (Schischke et al, 2023: 2). This transition involves reducing the share of fossil-fuel and nuclear electricity generation while increasing the utilization of renewable energy sources to between 80% and 95% by 2050 (Renn & Marshall, 2016). For this purpose, the fact that 18% of the energy generated from nuclear energy will be directed to alternative sources is obvious (Gielen et al, 2019: 39). In the Energiewende, it was decided to shut down all nuclear plants by 2022 and all coal-powered power plants by 2038. Due to the current energy crisis triggered by the Russia-Ukraine war, Germany had to extend the life of the last nuclear reactor until April 2023 (Nakamura et al., 2024: 2). Germany, which has been generating electricity from nuclear energy since 1962, terminated this production as of 2024 (Fraunhofer, 2025).

In response to the challenges caused by Russia's invasion of Ukraine and the disruption in global energy markets, the European Commission is implementing the REPowerEU Plan, which aims to gradually phase out fossil fuel imports from Russia. REPowerEU, which enforced in 2022, has helped the EU to save energy, diversify its energy sources and promote clean energy. It has provided significant support in preventing Russia from using its energy resources as a weapon. While 45% of EU's gas imports came from Russia in 2021, this rate dropped to 15% in 2023 (European Commission, 2022). The EU sanctions have prohibited the maritime import of Russian crude oil, refined petroleum products and coal. As a result of the EU's efforts in the energy sector, energy prices, which peaked in 2002, began to decrease gradually.

Türkiye has enacted laws in line with EU energy directives. The Kyoto Protocol was ratified by Türkiye in 2004. In 2005, Law No. 5346 titled "Utilization of Renewable Energy Resources for the Purpose of Generating Electricity" was enacted to promote the expansion of renewable energy sources for electricity generation and to develop the domestic manufacturing sector associated with these technologies. This law also encompasses the certification of the production and use of renewable sources. These positive trends can also explain why the accession negotiations between Türkiye and the EU were facilitated in 2005. In 2007, Law No. 5627 titled "Energy Efficiency" covered the procedures and principles to be applied in reducing the burden of energy costs on the economy, protecting the environment and utilizing renewable energy sources (Official Gazette, 2007). In order to increase renewable energy usage, the "Electricity Energy Market and Supply Security Strategy Document" in 2009, the "Turkey Climate Change Strategy" in 2010, the "Renewable Energy Support Mechanism (referred to as YEKDEM)" and the "Regulation on Unlicensed Electricity Production" in 2011, the "Energy Efficiency Strategy Document and Regulation on Wind and Solar Measurements in the Electricity Market" in 2012, the "Electricity Market Law No. 6446" in 2013 and the "Turkey National Renewable Energy Action Plan" in 2014 were published.

Türkiye issued a regulation on the "Energy Sector Research and Development Projects Support Program" in order to provide support R&D support for sustainable energy policies and energy supply security. The regulation revised in 2013 aimed to improve renewable energy technologies and domestic energy resources, electro-mechanical equipment manufacturing technologies, energy efficiency technologies, energy transmission, and harmful emission reduction technologies. In 2016, the "Regulation on Supporting Domestic Components Used in Facilities Generating Electricity from Renewable Energy Sources" was published and the 2011 regulation was abolished. With this amendment, the domestic contribution support for unlicensed electricity generation facilities was abolished and this support was limited to licensed power plants (Official Gazette, 2016). In order to support energy supply security, incentives for funding domestic coal mining and coal-fired power plants were determined with Law No. 3305. In 2016, in contrast to the EU's renewable energy policies, energy policies were developed by offering additional incentives such as purchasing guarantees to power plants using domestic lignite.

The energy transition refers to the global shift within the energy sector from fossil-based energy production and consumption systems towards renewable energy sources. The objective of the energy transition is to mitigate greenhouse gas emissions associated with energy production through various decarbonization strategies (S&P Global, 2020). Germany ranks fifth worldwide in terms of transition readiness, which enables the assessment of the appropriate environment for the energy transition as it is one of the top three countries in terms of regulation and political stability (World Economic Forum, 2023: 36). Germany also gives importance to the finance, investment, education and human capital (Fig. 11). The "German Renewable Energy Sources Act" has played a crucial role in the energy transition for expanding the renewables. This constitutes the basis for the Energy Industry Act, the legal basis of the German Industry, enhances innovation, supply security and ensures a sustainable generation of energy. In addition, this law regulates grid access and storage of electricity from renewable sources. Enhancing energy efficiency and disseminating renewable energy sources are the basic elements of the energy transition.

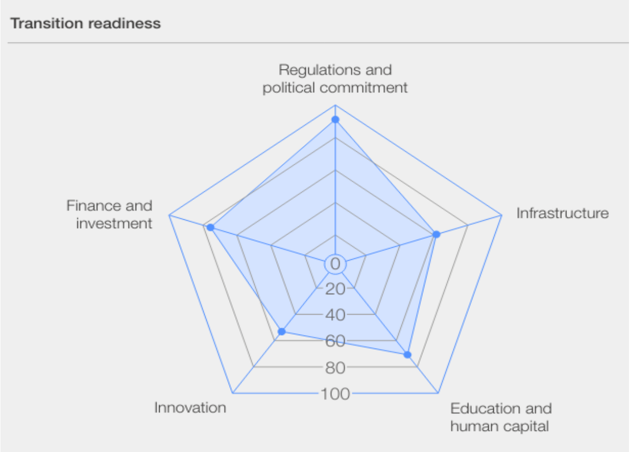

Fig. 11. Energy Transition Readiness of Germany, 2023

Source: World Economic Forum, (2023: 35).

Several incentives can stimulate renewable energy deployment. There are four types of incentives that can be categorized: R&D, fiscal and tax, market development, grid connection, and tariff incentives (Qadir et al., 2021: 3597). In 2022, the German authorities invested 70 million euros in energy research. 13 million euros of this was used to support photovoltaics research (Fig. 10.). 18% of energy research support was allocated only to PV investment. While production technologies received the largest support in PV investments, basic research PV systems, and technologies also received a share of this budget (Fig. 12).

Financial incentives are one of the economic supports granted by the state to implementers during renewable energy production and consumption. Incentives are offered through instruments such as long-short term loans, environmental tax exemption, accelerated depreciation, carbon tax, withholding tax support and value added tax exemption (environmental tax – real estate tax - customs tax - corporate tax exemption) (Qadir et al., 2021:3598). Feed-in tariffs and tax exemptions are among the most important incentives provided to investors for renewable energy resources to participate in production.

The number of years that the produced energy will be guaranteed by the state is important in terms of eliminating uncertainties for investors. Updateable purchase cost calculations that prioritize the investors and users have enabled investments in Germany to continue on a stable line. Türkiye provides feed-in tariffs for renewable energy systems for a duration of 10 years from the date of commissioning (Şencan, 2022: 700). Due to the fact that the feed-in tariffs applied in Türkiye are not updated on an annual basis, the unit cost of the energy produced remains far below and the desired results are not achieved in energy investments. Germany has set the feed-in tariffs as 20 years from the first day and has not made any changes. Germany has encouraged PV expansion by eliminating possible doubts (Wirth, 2024: 9). While it may take 7-10 years for power plants with high solar energy potential in Türkiye to recover their investment costs, providing a 10-year feed-in tariffs fraught with uncertainty and risk for investors. In Germany, even if the amount of profit from solar energy is low, the risk factor is eliminated with the purchase guarantee, allowing the investor to make plans by seeing the future.

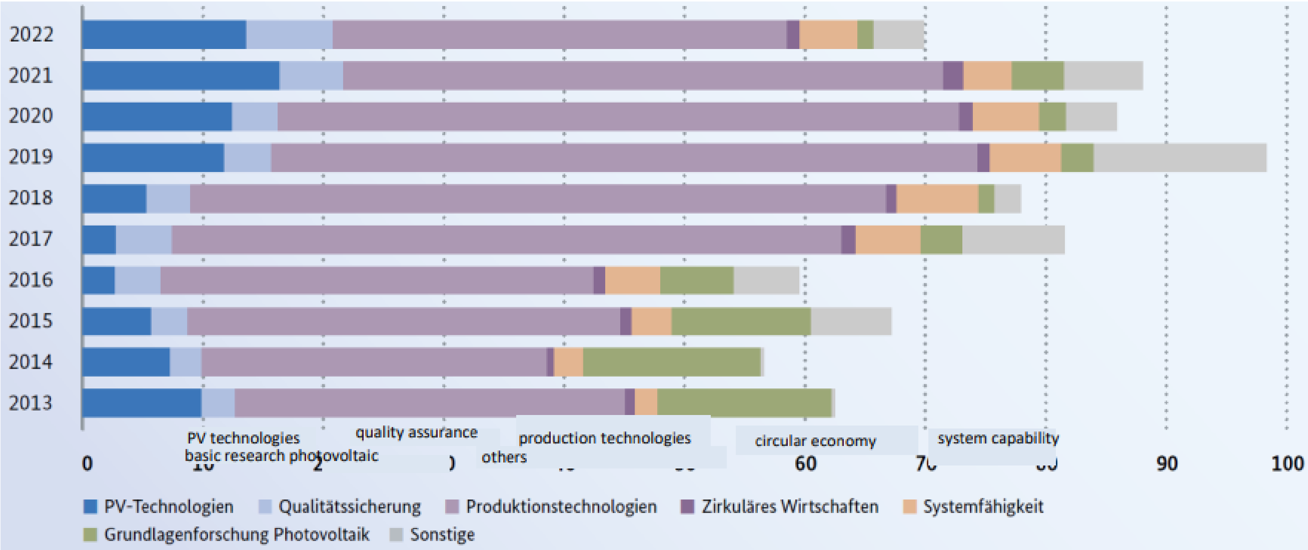

Fig.12. Funding for PV research categorized by technology in €/million

Source: Wirth, (2024:24).

Employment in the solar PV sector increased by 30% from 2019 to 2022, reaching 3.9 million jobs worldwide (Fig. 13). Employment in the electric vehicle and batteries sector has increased incomparably with other sectors. The solar energy sector leads the way in terms of employment compared to other renewable energy sectors. The energy sector necessitates more qualified labor than many other sectors, with 36% of the energy workforce requiring some form of tertiary education and 51% some vocational training (IEA, 2023: 34). Construction, which involves the installation of solar panels, represents almost half of PV jobs, making the largest contribution to employment. Polysilicon, wafers, cells, modules and inverters, racking, mounting and other components represent around %20 of total employment which %77 of these jobs are concentrated in China where the vast majority of the world's solar panels are manufactured (IEA, 2023: 65).

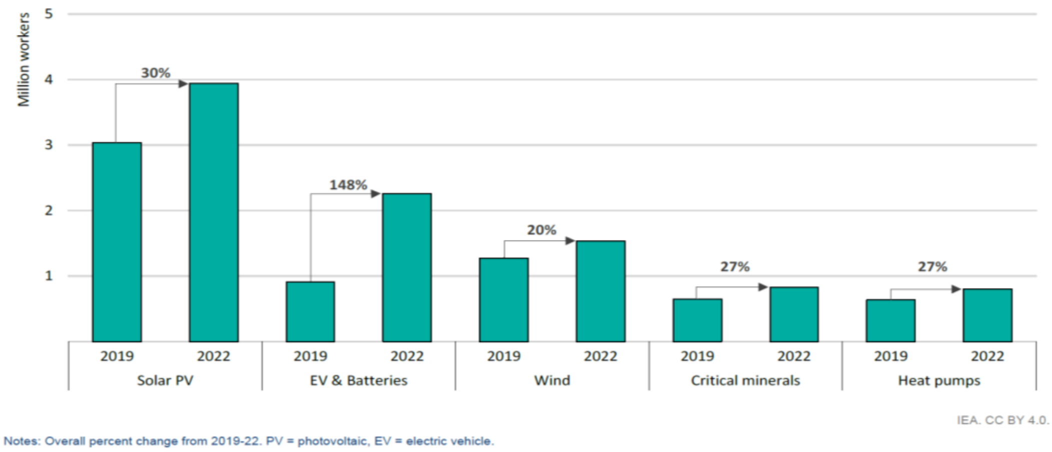

Fig. 13. Global employment growth and percent change in selected sectors. 2019-2022

Source: IEA, (2023: 21).

In Germany, approximately 340,000 individuals are employed in the renewable energy sector, and more than 189 universities, along with 120 research institutes are actively involved in the country's energy transition efforts (Edo, 2023: 22). In Germany, the solar industry employed 84,100 people in total in 2022, while 24,000 people were employed in the PV industry (Wirth, 2024: 23). The employed people work in the inverters, manufacture of materials, manufacture of intermediate and final products modules, mechanical engineering for cell and module production, installation, power plant operation and maintenance.

The majority of renewable energy sector employees in Türkiye work in hydroelectric power plants. Approximately 26.000 people work in the solar industry, which corresponds to almost ¼ of all renewable energy sector employees (Fig.

14). Employment in the solar energy sector is analyzed by sub-sectors such as project development and consultancy, contracting company, operation, maintenance, repair, panel-construction, parts manufacturers, etc. In recent years, despite the increasing number of producers, the capacity on the production side is not fully utilized due to the decreasing demand as investors have difficulties in financing. In order to utilize the capacity efficiently, it is crucial to maintain stable demand within this sector while simultaneously offering various incentives to support its growth (Solar3GW, 2024: 11).

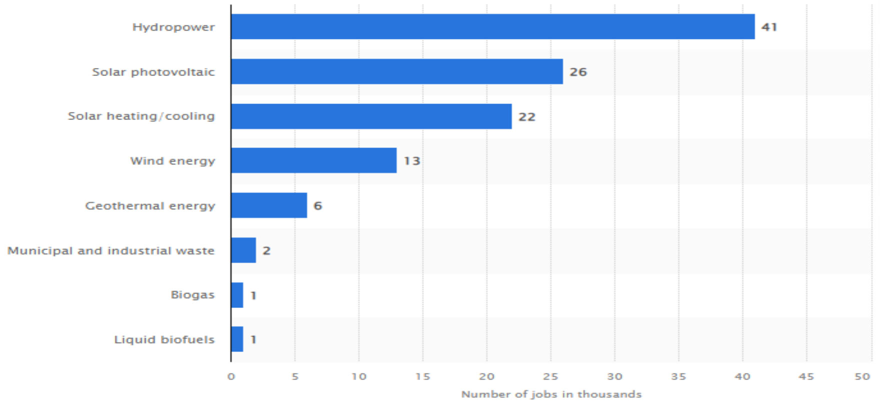

Fig. 14. Number of renewable energy sector employees in Türkiye in 2002

Source: Statista, (2024).

The solar energy sector in Türkiye and Germany varies in line with the economic structure of the countries' economic structure, investments and incentives, level of technological development, and environmental concerns. Germany aims to increase renewable energy through fixed price guarantees, feed-in tariffs, grants, subsidies and financial incentives. In order to generate electricity through renewable energy sources and support investors, Türkiye established the YEKDEM program in 2011. Different incentives and support systems are applied for each type of renewable energy. The purchase price for solar energy is determined as 13.3 $/cent. Türkiye contributes a total of 6.7 $ cent/kWh if all components are domestically produced (Table 2). Türkiye continues to support solar energy with fixed feed-in tariffs, domestic manufacturing production and customs duty exemptions.

Table 2. Chart II, Domestic Contribution Rate for Materials Produced in Türkiye (%)

Facility Type	Domestic Manufacturing	Domestic Contribution Prices (US Dollar cent/kWh)
Photovoltaic Solar Energy Based Production Facility	1- PV panel integration and solar structural mechanics manufacturing	0,8
	2- PV Modules	1,3
	3- Cells forming the PV Module	3,5
	4- Invertor	0,6
	5- Material that focuses the sun's rays on the PV Module	0,5

Source: Law on the Utilization of Renewable Energy Resources for Electricity Generation, https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5346.pdf

Although PV panel factories are established in Türkiye with domestic capital, there is currently no factory with the capacity to produce 100% domestic PV panels. Cells imported from abroad are converted into modules through the lamination process, using domestic glass and aluminum frames. For the necessary substructure materials used to mount the module to the ground, as well as auxiliary industry components such as junction box that facilitate the transmission of electricity generated in the PV system, domestic production is utilized (Cebeci, 2017: 91). One of the main costs of PV system investments is the import expenses resulting from the need to source machinery and equipment from abroad. Most of the machinery and equipment in Türkiye is currently imported. The high manufacturing capacity and competitive advantage of low-cost manufacturing countries like China reduce the likelihood of domestic production of power plant machinery and equipment in countries such as Türkiye in the short term.

Compared to other European countries, Germany has made the most widespread efforts to use PV systems in buildings. In 2017, a new model called "Mieterstrommodell" was developed, which aims to enable multi-apartment buildings to share PV systems (Fina et al. 2018: 3). This model allows the common use of PV systems in multi-apartment buildings through the relationship between the tenant and the landlord.

The total cost of PV investments consists of the initial cost of the investment, maintenance, and operating costs. While the largest expense in PV power plants is the initial investment cost, the annual operating cost corresponds to approximately 1% of the investment costs (Wirth, 2021:7). When calculating the initial investment cost of a facility to be built in any region, the cost is calculated by calculating whether it will be covered by credit or equity. Investors prefer credit since the construction of an average power plant costs $700,000. In 2024, the current interest rate at the German Central Bank is 2.23% (Deutsche Bundesbank Eurosystem, 2024), while the current interest rate at the

Turkish Central Bank is 50% (Central Bank of the Republic of Türkiye, 2024). Therefore, when the interest rates of the power plant built in Germany and Türkiye are calculated, the cost of the power plant built in Türkiye will have an interest rate of 47.77% higher than the power plant built in Germany. Therefore, a PV plant built in Türkiye with the same budget will cost more, which will increase the initial investment cost and reduce profitability. Operating costs are increasing day by day due to the fiscal policies implemented in Türkiye. Markets have become unpredictable due to tight monetary policy, increased inflation, and uncertainties in payments.

5. Conclusion

Germany and Türkiye have followed different approaches to solar energy, with Germany leading in technological innovation, policy support, and market integration. Türkiye's current solar energy potential is higher than countries that are poor in terms of solar energy potential, such as Germany. However, Türkiye's renewable energy generation level is considerably low in relation to its potential. The utilization of the existing potential should aim to ensure energy supply security while mitigating the adverse effects of fossil fuel consumption on the national economy. Meeting the increasing energy demand with limited resources can be achieved by following a correct and effective energy policy. The relatively short purchase guarantee period in renewable energy in Türkiye, deficiencies in legal regulations, inadequacy of the grant and incentive system, high unit cost price due to inadequate technological capacity, high-interest loans and financing problems are the obstacles preventing Türkiye from using its solar energy potential effectively and efficiently. In order to overcome these obstacles, Türkiye should make radical structural changes in order to increase solar energy investments. Energy purchase prices need to be updated on an annual basis and possible losses must be prevented before they occur. Türkiye currently limits the purchase guarantee period for solar energy to 10 years. This process, which is not sufficient to cover the cost of the investment, causes the investor to avoid the investment as it poses a risk. It would be beneficial to revise the purchase guarantee period to encourage investors.

Countries that have achieved technological development invest more in renewable technologies. The technologies and policies implemented by Germany, which continues to depend on foreign sources for fossil resources but continues to provide incentives for solar energy and begins to close down thermal power plants, are an important source of experience for Türkiye. Türkiye's incentives for thermal power plants cause a decline in interest in renewable energy. Incentives for the mining sector need to be gradually reduced. The incentives and targets set for solar energy should be continued in a planned manner to instill confidence in investors. Fiscal policies that can activate the supply and demand side of the sector should be implemented with the awareness of a clean and sustainable environment, without seeking economic income.

Germany, which has established the legal frameworks for renewable energy since the 1980s, has supported investments with systematically updated incentives and support mechanisms. Germany provides confidence to investors through its high level of economic development and long-term incentive systems. In contrast, Türkiye faces several barriers to effectively and efficiently utilizing its solar energy potential. These barriers include the relatively short purchase guarantee period for renewable energy, deficiencies in a legal framework, an inadequate grant and incentive system, high unit cost prices due to inadequate technological capacity, high-interest loans, and financing. In order to increase solar energy investments, Türkiye must undergo radical structural changes. Energy purchase prices should be updated on an annual basis and measures should be taken to prevent potential losses before they occur. Türkiye currently limits the feed-in tariffs for solar energy to 10 years. This process is insufficient for covering investment costs, causes risks for investors, and leads to reluctance to invest. It would be beneficial to revise the purchase guarantee period to encourage investors.

It is important for Türkiye to demonstrate economic and political stability in its solar energy investments by accelerating bureaucratic regulations, updating and revising the incentive mechanisms for the sector, and supporting related industries in promoting domestic production. This is crucial for ensuring the continuity of the investment process. Türkiye should set achievable and realistic goals instead of long-term and difficult targets. By adhering to the established strategies, Türkiye can increase its credibility in the international system and potentially rank among the countries considered investable by other nations.

Türkiye needs to increase and diversify its incentives. Türkiye needs to set current targets in line with the decisions taken at the Paris Conference and implement them without deviating from its objectives. The revenues generated from carbon taxes should be allocated to R&D studies in the field of renewable energy or offered as incentives to investors. Since the R&D process is not static, it must always be strengthened with investments and support. Reducing the loss-leakage rate by improving the infrastructure and network system and supporting technological innovation studies by both civil and government institutions will enable Türkiye to grow its renewable energy sector and reduce dependence on fossil fuels. A "Solar Energy Strategy" should be determined, which will shape the future of solar energy in Türkiye, involving all stakeholders (universities, manufacturers, public institutions, technology companies, etc.).

It is crucial for Türkiye to adopt policies that encourage domestic production and support the development of the domestic manufacturing sector. With domestic production, production costs will decrease and it will have the potential to reduce Türkiye's dependence on foreign sources through its employment-creation effect. Investments in solar energy technologies will not only strengthen Türkiye's economy but also contribute to the labor market by creating new employment opportunities.

References

Akdemir, S. D. (2021). *Opportunities and barriers for the application of solar heat for industrial processes technologies to Turkish industrial parks* (Master's thesis). Middle East Technical University.

Cebeci, S. (2017). *Türkiye'de güneş enerjisinden elektrik üretim potansiyelinin değerlendirilmesi* (Uzmanlık Tezi, T.C. Kalkınma Bakanlığı, İktisadi Sektörler ve Koordinasyon Genel Müdürlüğü, Yayın No: 2977).

Central Bank of the Republic of Türkiye. (2024). Governor Fatih Karahan PhD's speech at the briefing on inflation report. Retrieved from https://www.tcmb.gov.tr/wps/wcm/connect/en/tcmb+en/main+menu/announcements/remarks +by+governor/2024/speechg08_11_2024 (Accessed on November 19, 2024).

Çelik, O., Yılmaz, S. E., Yıldızhan, H., & Ameen, A. (2023). Consumer purchasing behavior and its organizational evaluation toward solar water heating system. *Energy Reports, 10*, 1589-1601.

Deutsche Bundesbank Eurosystem. (2024). Central bank interest rate. Retrieved from https://www.bundesbank.de/en/statistics/money-and-capital-markets/interest-rates-and-yields/central-bank-interest-rates/central-bank-interest-rates-793456 (Accessed on November 19, 2024).

Edo, G. I. (2023). The German energy system: Analysis of past, present, and future developments. *Advanced Energy Conversion Materials, 4*(1), 18-28.

Enerdata. (2025). Germany's power generation fell by 4% I 2024, 59% came from renewables, Available online: https://www.enerdata.net/publications/daily-energy-news/germanys-power-generation-fell-4-2024-59-came-renewables.html#:~:text=Transport-,Germany's%20power%20generation%20fell%20by%204,2024%2C%2059%25%20came%20from%20 renewables&text=According%20to%20preliminary%20data%20from,4%25%20decrease%20compared%20to%202023. (accessed on 20 February 2025).

European Commission. (2016). *Clean energy for all Europeans*. Retrieved from https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en (Accessed on August 27, 2023).

European Commission (2019). Communication from the Commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and The Committee of the Regions- The European Green Deal 2019 Report, Brussels.

European Commission (2020). Report from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions 2020 Report, Brussels.

European Commission (2022). REPowerEU affordable, secure and sustainable energy for Europe, Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en (accessed on 2 March 2025).

European Commission (2024). "The European Green Deal", Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 2 March 2025).

European Council. (2001). *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0077&from=EN (Accessed on August 27, 2023).

European Council. (2003). *Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0030&rid=10 (Accessed on August 27, 2023).

European Council. (2009). *Directive 2009/28/EC of the European Parliament and the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&rid=8 (Accessed on August 27, 2023).

European Council. (2023). *Directive 2023/2413 of the European Parliament and the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023L2413 (Accessed on September 5, 2024).

Eurostat. (2023). EU overachieves 2020 renewable energy target. Retrieved from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220119-1 (Accessed on August 26, 2024).

Federal Statistical Office Germany. (2022). Data from the municipal directory cities and districts by area, population, and population density. Retrieved from https://www.destatis.de/DE/Themen/Laender-Regionen/Regionales/Gemeindeverzeichnis/Administrativ/04-kreise.html (Accessed on May 23, 2023).

Fina, B., Fleischacker, A., Auer, H., & Lettner, G. (2018). Economic assessment and business models of rooftop photovoltaic systems in multiapartment buildings: Case studies for Austria and Germany. *Journal of Renewable Energy*, 1-16.

Fraunhofer. (2025). Public Electricity Generation 2024, Available online: https://www.ise.fraunhofer.de/en/press-media/press-releases/2025/public-electricity-generation-2024-renewable-energies-cover-more-than-60-percent-of-german-electricity-consumption-for-the-first-time.html#:~:text=As%20in%202023%2C%20photovoltaic%20expansion,by%20the%20 end%20of%202024. (Accessed on 26 February 2024).

Frentzou, M. G. (2024). *Turkey's path towards energy transition* (Master's thesis). University of Piraeus, Department of International & European Studies, MSc in Energy: Strategy, Law, and Economics.

Gielen, D., Boshell, F., Saygin, D., Bzialian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews, 24*, 38-50.

Hafner, M., & Raimondi, P. P. (2022). Energy and the economy in Europe. In *The Palgrave Handbook of International Energy Economics* (pp. 731-761). Springer: International Publishing.

International Energy Agency (IEA). (2011). *Renewable energy technologies: Solar energy perspectives*. Paris: Cedex.

International Energy Agency (IEA). (2023). *World energy employment 2023*. Paris: Cedex.

International Energy Agency (IEA). (2024). Available online: https://www.iea.org/countries/turkiye/energy-mix (Accessed on 26 February 2024).

Intersolar Europe. (2022). *Solar energy in Germany takes center stage*. Retrieved from https://www.intersolar.de/news/solar-energy-in-germany-takes-center-stage (Accessed on May 23, 2023).

Jones, D., Graham, E., & Turnbridge, P. (2020). *Wind and solar now generate one-tenth of global electricity: Global half-year electricity analysis*. Ember. London.

Kat, B. (2023). Clean energy transition in the Turkish power sector: A techno-economic analysis with a high-resolution power expansion model. *Utilities Policy, 82*, 1-14.

Kraschewski, T., Brauner, T., Heumann, M., & Breitner, M. H. (2023). Disentangle the price dispersion of residential solar photovoltaic systems: Evidence from Germany. *Energy Economics, 121*, 1-8.

Lazard. (2021). *Levelized cost of energy*. Retrieved from https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/ (Accessed on November 5, 2022)

Nakamura, T., Maruyama, A., Masuda, S., & Lloyd, S. (2024). The impact of Russia's invasion of Ukraine on Germany's energy choice attitudes among residents in German states with nuclear power plants in commission or decommissioned. *Sustainability 2024, 16*(1999). 1-31.

Official Gazette. (2007). *Enerji Verimliliği Kanunu, Kanun No. 5627*. Retrieved from https://www.resmigazete.gov.tr/eskiler/2007/05/20070502-2.htm (Accessed on August 28, 2023)

Official Gazette. (2016). *Yenilenebilir enerji kaynaklarından elektrik enerjisi üreten tesislerde kullanılan yerli aksamın desteklenmesi hakkında yönetmelik, Sayı: 29752*. Retrieved from https://www.resmigazete.gov.tr/eskiler/2016/06/20160624-1.htm (Accessed on May 14, 2024)

PwC. (2024). *Solar energy industry in the world and in Türkiye*. Retrieved from https://www.pwc.com.tr/solar-energy-industry-in-the-world-and-in-turkiye (Accessed on November 15, 2024)

Qadir, S. A., Al-Motairi, H., Tahir, F., & Al-Fagih, L. (2021). Incentives and strategies for financing the renewable energy transition: A review. *Energy Reports, 7*, 3590–3606.

Renn, O., & Marshall, J. P. (2016). Coal, nuclear and renewable energy policies in Germany: From the 1950s to the “Energiewende”. *Energy Policy, 99*, 224-232.

Republic of Turkey Ministry of Energy and Natural Resources. (2021). *YEKA Model*. Retrieved from https://enerji.gov.eng/eigm-renewable-energy-production-yekamodel (Accessed on August 23, 2023)

Republic of Türkiye Ministry of Energy and Natural Resources. (2024). *Electricity*. Retrieved from https://enerji.gov.tr/infobank-energy-electricity (Accessed on March 21, 2024)

Republic of Türkiye Ministry of Energy and Natural Resources. (2024). *Solar*. Retrieved from https://enerji.gov.tr/bilgi-merkezi-enerji-gunes-en (Accessed on October 28, 2024)

Sayigh, A. (2012). *Comprehensive renewable energy*. Elsevier Ltd. Amsterdam.

Schischke, A., Papenfuß, P., Brem, M., Kurz, P., & Rathgeber, A. (2023). Sustainable energy transition and its demand for scarce resources: Insights into the German Energiewende through a new risk assessment framework. *Renewable and Sustainable Energy Reviews, 176*, 1-15.

Solar3GW. (2024). *Türkiye güneş enerjisi sektöründe istihdam*. Retrieved from https://www.solar3gw.org/wp-content/uploads/2024/06/Solar3GW-Istihdam-Raporu_Final_120624-sikistirilmis-3.pdf (Accessed on October 17, 2024)

Statista. (2024). Number of renewable energy sector employees in Türkiye in 2002. Retrieved from https://www.statista.com/statistics/893602/renewable-energy-employment-numbers-turkey/#statisticContainer (Accessed on October 17, 2024)

S&P Global. (2020). What is energy transition? *S&P Global*. Retrieved from https://www.spglobal.com/en/research-insights/market-insights/what-is-energy-transition (Accessed on August 20, 2024)

Şencan, D. (2022). Yenilenebilir enerjide Türkiye’nin dünyadaki rolü ve uygulanan teşviklerin değerlendirilmesi. *Ömer Halis Özdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *15*(3), 693-709.

Telli, A., Erat, S. & Demir, B. (2021). Comparison of energy transition of Turkey and Germany: energy policy, strengths/weaknesses and targets. Clean Technologies and Environmental Policy 23, 413–427. https://doi.org/10.1007/s10098-020-01950-8.

Tsagas, I. (2019). Mega projects, mega problems. *PV Magazine*. Retrieved from https://www.pv-magazine.com/2019/03/29/mega-projects-mega-problems/ (Accessed on August 24, 2023)

The World Bank Group & Solargis. (2019). *Global Solar Atlas*. Retrieved from http://global.solaratlas.info (Accessed on August 21, 2023)

TSKB. (2024). Aylık Enerji Bülteni, Available online: https://www.tskb.com.tr/uploads/file/enerji-bulteni-agustos-20240905.pdf (accessed on 22 February 2024)

Wirth, H. (2021). *Recent facts about photovoltaics in Germany*. Fraunhofer ISE. Freiburg.

Wirth, H. (2024). *Recent facts about photovoltaics in Germany*. Fraunhofer ISE. Freiburg.

World Economic Forum. (2023). *Fostering effective energy transition 2023 edition insight report*. Geneva.

Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanun (5346 Kanun No.) (2005). Retrieved from https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5346.pdf (Accessed on August 30, 2024)

Zackariat, M., Hartz K., Huneke, F. (2025). The energy transition in Germany: state of play 2024, review of key developments and outlook for 2025. Berlin: Agora Energiewende.

Zielinski, M., Fletcher, J., Ewen, M., Fulghum, N., & Turnbridge, P. (2022). Global electricity review. Ember. London.