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# Solar Energy Policies in Türkiye and Comparative Lessons from Europe

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## Abstract

The rising global energy demand, the urgency of climate change mitigation, and increasing concerns over energy security have significantly elevated the strategic importance of renewable energy sources. Among them, solar energy has emerged as a leading option due to its high technical potential, low environmental hazardous impact, and broad applicability. Türkiye, with over 2,700 hours of annual sunshine and substantial land availability, stands out as one of the most advantaged countries in Europe in terms of solar potential. However, the share of solar power in its total electricity generation remains limited. This study analyzes Türkiye's solar energy landscape by examining technical capacity, installed power, incentive mechanisms, permitting procedures, local participation, and industrial infrastructure. For comparative purposes, five OECD countries (Greece, Spain, Portugal, Mexico, and Italy) were selected based on their similar solar potential and economic structures. Through a multi-dimensional policy comparison, the study identifies both strengths and structural shortcomings in Türkiye's current framework. It offers concrete policy recommendations, including the simplification of regulatory processes, support for high-value domestic manufacturing, and the promotion of distributed energy models such as energy cooperatives. Overall, the study concludes that Türkiye's solar energy transformation requires a more coherent, long-term, and institutionally integrated policy approach in order to reach its full potential.

**Keywords:** Solar Energy, Renewable Energy Policies, Comparative Energy Policies, Energy Policy in Türkiye, Solar PV Incentives.

**JEL Codes:** Q42, Q48, Q58, F50

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## 1. Introduction

Rising global energy demand, intensified efforts to mitigate climate change, and ongoing concerns over security of supply necessitate a fundamental reorientation of energy policy. Renewable energy sources lie at the center of this shift. Solar power, in particular, has become an indispensable component of energy transitions because it combines high technical potential, low environmental impact, and strong practical applicability (Erenel & Aigul, 2023; Koyuncu, 2024).

Türkiye is among the most advantaged countries in Europe for solar energy, with average annual sunshine exceeding 2,700 hours and ample land availability. Nevertheless, electricity generated from solar remains limited both as a share of total energy supply and in per-capita installed capacity (Yolcan & Köse, 2020). This gap prompts a policy inquiry into whether Türkiye is effectively converting its technical potential into outcomes through its economic and institutional arrangements.

This study evaluates Türkiye's solar policies not only at the national level but also from a comparative perspective. Greece, Spain, Portugal, Mexico, and Italy were selected because they combine high solar irradiation with OECD membership and socio-economic profiles similar to Türkiye's. The primary criterion was the presence of technical potential and transition opportunities comparable to Türkiye. The comparison provides a basis for assessing how alternative policy approaches might be interpreted and applied in the Turkish context.

Within this framework, the study first examines Türkiye's solar potential and current status, followed by an assessment of existing policies and regulations. The following section presents a comparative analysis of the selected countries to highlight policy diversity, implementation performance, and differences in institutional infrastructure. The final section develops actionable policy recommendations for Türkiye and discusses the findings in an integrated manner.

## 2. Methodology

This study adopts a qualitative, interpretive approach. Data used throughout the study were compiled from the energy ministries and national energy agencies of the relevant countries, as well as from institutional sources such as the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), and Eurostat. Priority was given to recency, and the most up-to-date statistics available as of 2023 were used wherever possible.

The comparison relies on indicators such as installed solar capacity in gigawatts, annual sunshine duration in hours per year, the share of solar in electricity generation, incentive mechanisms including net metering, feed-in tariffs, and contracts for difference, tax arrangements, permitting procedures, and installation timelines.

The selection of Greece, Spain, Portugal, Mexico, and Italy was based on their combination of relatively high solar potential, OECD membership, and socio-economic or institutional proximity to Türkiye. These countries also represent different policy models in solar energy, making them suitable for drawing comparative lessons relevant to the Turkish context.

Table 1. Criteria for Selecting the Comparative Countries

| Country | Solar Irradiation / Technical Potential | OECD Membership | Socio-Economic or Structural Similarity to Türkiye | Policy Relevance (Incentives, Permitting, Distributed Generation) |
|---|---|---|---|---|
| **Greece** | Very high solar potential (≈2,750 hours) | Yes | Comparable economic and geographic context | Advanced net metering & virtual net metering; rapid permitting reforms |
| **Spain** | Among the highest in Europe (≈2,750 hours) | Yes | Similar transition challenges | Strong self-consumption model, simplified permitting, tax incentives |
| **Portugal** | Very high irradiation (≈2,850 hours) | Yes | Medium-sized economy with comparable constraints | Collective self-consumption and community energy best practices |
| **Italy** | Moderate–high solar potential | Yes | Similar energy transition dynamics | Strong tax incentives (Superbonus), REC and community energy reforms |
| **Mexico** | High solar irradiation (≈2,730 hours) | Yes | Emerging economy with structural parallels | Distributed generation leadership, simplified interconnection rules |

## 3. Solar Energy Potential and Current Status in Türkiye

Türkiye's geographical location gives it a significant advantage in terms of solar energy potential. According to the Solar Energy Potential Atlas (GEPA) prepared by the Ministry of Energy and Natural Resources, the country's annual average sunshine duration is 2,741 hours, corresponding to about 7.5 hours per day. The annual average solar irradiation is calculated as 1,527 kWh per square meter, or approximately 4.18 kWh per square meter per day (GEPA, n.d.). Although this potential is distributed across the entire country, regional variations are pronounced. The highest levels of sunshine duration and irradiation are observed in Southeastern Anatolia and the Mediterranean regions, followed by Eastern Anatolia, the Aegean, and Central Anatolia. The Black Sea region, by contrast, has the lowest potential due to persistent cloud cover and high precipitation (Kapluhan, 2014; Eser & Polat, 2015).

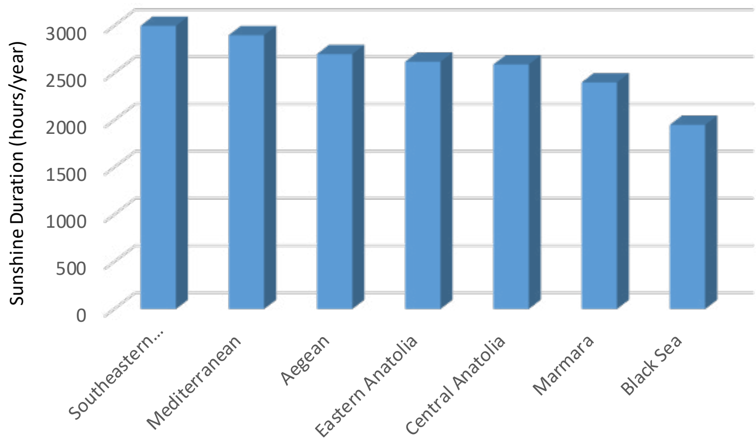


Figure 1. Average Annual Sunshine Duration by Region in Türkiye
Source: General Directorate of Meteorology (2025). https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx

In addition to land-based opportunities, there is also considerable potential on water surfaces. The Ministry of Energy and Natural Resources has identified reservoirs and lakes as suitable sites for floating solar power plants and has estimated an additional capacity of about 80,000 MW in this category (Damyan, 2024).

According to Figure 1, Türkiye's installed solar capacity has grown markedly over the past decade. While it stood at only 40 MW in 2014, it reached 12,427 MW by the end of 2023. Nearly all of this increase came from photovoltaic (PV) systems, whereas concentrated solar power (CSP) technology remained limited to just 1 MW (GENSED, 2025).

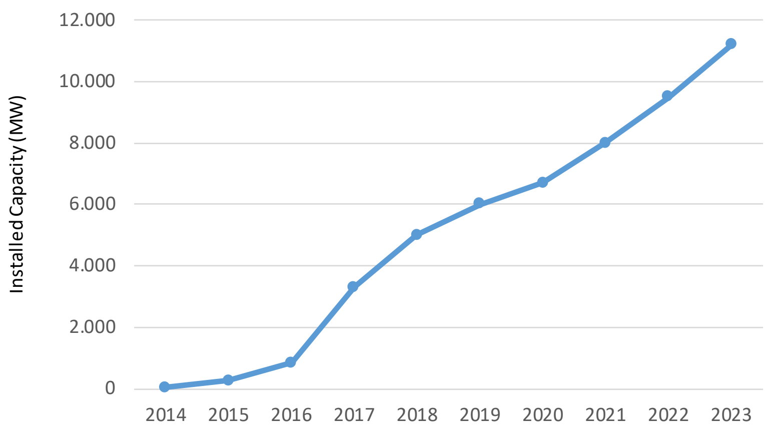


Figure 2. Installed Solar PV Capacity in Türkiye, 2014–2023 (MW
Source: Gümüş, B. S. (2024). Türkiye electricity review 2024. Ember. https://ember-climate.org/insights/research/turkiye-electricity-review-2024/

As of 2023, installed solar capacity surpassed wind for the first time, exceeding 12 GW in total. Of this capacity, about 2 GW came from newly commissioned plants, while the remainder resulted from PV systems integrated into hybrid power stations. By 2024, the share of solar energy in total electricity generation had risen to 7.5 percent (Ministry of Energy and Natural Resources, 2025a; TEİAŞ, 2024).

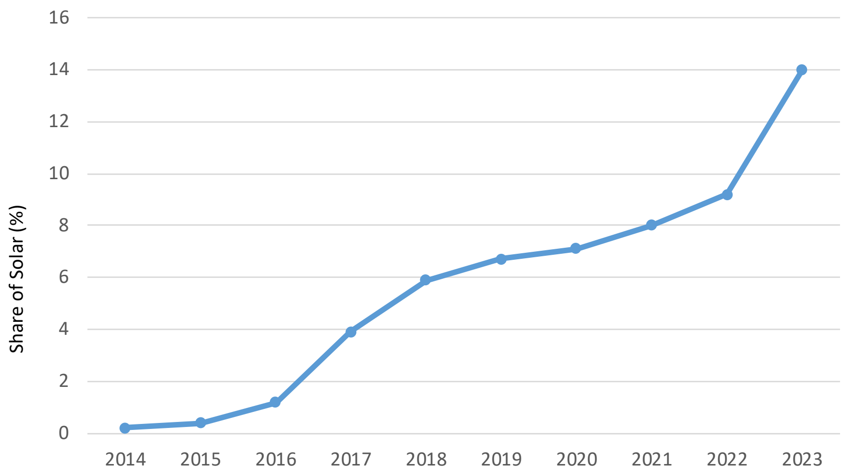


Figure 3. Share of Solar Energy in Türkiye's Total Installed Capacity (%)
Source: TEİAŞ. (2024). Electricity Generation Statistics of Türkiye 2024. https://webim.teias.gov.tr/file/7cd3bee1-4b5d-4710-95e4-609e1880ce4c?download

Figure 3 illustrates the development of solar energy's share in Türkiye's total installed capacity between 2014 and 2023. Starting at 0.2 percent in 2014, the share rose rapidly to 4.5 percent by 2017, followed by a relatively stable trend between 2018 and 2021. In 2022 and 2023, however, growth accelerated markedly. By 2023, solar's share of total electricity generation reached 5.7 percent, its highest level to date. This surge was driven by regulations facilitating unlicensed generation, the expansion of rooftop PV systems in organized industrial zones, new hybrid power plant investments, and increasing private sector interest stimulated by carbon regulations.

One of the most striking features of capacity growth is that plants have been built largely under the unlicensed generation scheme. By the end of 2023, 85 percent of total installed capacity consisted of unlicensed plants, and 90 percent of the 2,390 MW commissioned in 2023 also fell under this category (GENSED, 2025; Gümüş, 2024, p. 17). The main reasons for preferring unlicensed generation are shorter procedural requirements, the absence of a mandatory company registration, and no capacity obligation (EPDK, 2025).

Table 2. Distribution of Licensed and Unlicensed Solar PV Installed Capacity in Türkiye (%), December 2023

| Type of Solar Power Plant | Installed Capacity (MW) | Share (%) |
|---|---|---|
| **Unlicensed** | 9,628 | 85.2 |
| **Licensed** | 1,665 | 14.8 |
| **Total** | 11,293 | 100 |

Note: Data are based on TEİAŞ statistics for December 2023. Variations in figures reported by other sources stem from mid-year or post-year updates and from whether hybrid systems are included.

Table 2 shows that, as of December 2023, roughly 85 percent of Türkiye's installed solar capacity consisted of unlicensed plants. This distribution indicates that investors have largely pursued the unlicensed model, underlining the guiding influence of the regulatory framework in this area. At the same time, the capacity factor of PV plants varies significantly depending on installation type and technological configuration. While the average capacity factor is around 20 percent for licensed plants, it is approximately 17 percent for unlicensed ones. In large-scale projects equipped with bifacial panels, such as the Karapınar YEKA, the factor can reach as high as 30 percent (PwC Türkiye, 2024). This variation demonstrates that efficiency is shaped not only by installation models but also by the technology deployed.

Despite these developments, Türkiye's progress in solar energy remains limited compared to its technical potential. Countries with significantly lower annual sunshine hours, such as Germany, Poland, and the United Kingdom, have overtaken Türkiye in both installed capacity and generation levels. By 2023, Türkiye's installed solar capacity was 12.42 GW, whereas Germany had reached 81.5 GW, Poland 14.9 GW, and the United Kingdom 14.4 GW (IRENA, 2024). Moreover, in terms of the share of solar in total electricity generation, Türkiye dropped four places in the European ranking. With a share of 7.5 percent, it lagged far behind Greece (24 percent), Spain (21 percent), Portugal (17 percent), and Italy (8.9 percent) (Gümüş, 2024; Kaya, 2025).

Taken together, these findings reveal that Türkiye's ability to realize its solar potential is determined not only by natural conditions but also by institutional capacity, the stability of the investment environment, and the coherence of energy policy. Geographic advantages alone—such as irradiation levels and land suitability—are insufficient. Long-term incentive schemes, transparent and accessible regulatory frameworks, and streamlined administrative processes are equally critical. Achieving sustainable and inclusive growth in solar energy requires the consistent interaction of these elements (Turhan, 2025). Türkiye's recent momentum demonstrates that steps taken in this direction are reflected tangibly in the generation portfolio. However, sustaining this momentum will require continued commitment to regulatory stability, grid infrastructure investments, and the integration of domestic industry.

## 3.1. Existing Policies and Regulations in Türkiye

The development of the solar energy sector depends not only on technical potential and market dynamics but also on the guiding influence of public policy and the clarity of the regulatory framework. In recent years, Türkiye has introduced a range of support mechanisms, legal arrangements designed to ease investment procedures, and structural reforms that incentivize unlicensed generation, all of which have played a decisive role in the expansion of solar investments.

This section examines the main policy instruments, in particular the Renewable Energy Support Mechanism (YEKDEM)and Renewable Energy Resource Area tenders (YEKA), as well as bureaucratic hurdles in installation processes, tax policies, unlicensed generation models, and regulations targeting local stakeholders. The analysis evaluates these measures within an analytical framework, highlighting their strengths and weaknesses.

### 3.1.1. Support mechanisms: YEKDEM and YEKA

YEKDEM is one of the key policy tools shaping solar investments in Türkiye. The Turkish government implemented a new Renewable Energy Support Mechanism (YEKDEM) in 2021, different from previous programs, to reduce fossil fuel consumption for electricity generation and encourage using renewable energy resources (Erdem & Gürtürk, 2025). However, due to exchange rate volatility after 2018 and the burden on public finances, the system was converted to a Turkish lira-based model in 2021. This created risks for projects with costs denominated in foreign currency (IEA, 2021; PwC Türkiye, 2024). Updates in 2023 and 2025 raised tariffs and local content incentives, yet the erosion of fixed lira prices by inflation has limited investor confidence (İnanç, 2023; 2025).

Within YEKDEM, local equipment incentives were intended to encourage the domestic production of components such as panels and inverters. In practice, however, most of the production has remained assembly-based, while in technology-intensive areas such as inverters, external dependence persists (PwC Türkiye, 2024). Incentives have at times been used merely for cost advantages, with limited evidence of genuine technology transfer (Flora et al., 2019; IEA, 2021). For this reason, it is critical not only to provide additional income through the mechanism but also to monitor the domestic quality of production (Law No. 5346, Article 6).

Before implementing YEKA, different Renewable energy incentive mechanisms adopted in Türkiye. Renewable energy law was enacted in 2005 and the feed-in tariff mechanism started to be utilized. Another incentive policy Türkiye carried outbefore the YEKA auctions is the pre-licensing tenders prepared between 2013 and 2017 for wind and PV power plants (Ozcan, 2021).

YEKA model represents a broader strategy, targeting not only energy generation but also technology transfer and the development of domestic industry. Through large-scale land allocations, purchase guarantees, and R&D requirements, it differs from YEKDEM (Ministry of Energy and Natural Resources, 2024). Nevertheless, the long-term and high-cost nature of projects has increased financial obligations, leading to delays and cancellations in some tenders (Gümüş, 2025). Moreover, the model's restriction to large investors has limited market diversity.

Even so, YEKA is important for advancing domestic technologies and integrating industrial policies in a comprehensive manner. Its measure of success is not only installed capacity but also the extent of technology transfer and R&D outcomes.

In sum, solar investments in Türkiye are structured around YEKDEM and YEKA. YEKDEM supports small and medium scale investors with relatively low entry barriers, while YEKA offers a more strategic but higher-risk framework geared toward large capital groups. Operating both mechanisms together can create a balanced policy architecture that promotes both diffusion and technological depth.

In European countries, feed-in tariffs and various net metering models have long accelerated small-scale investments. Although similar mechanisms exist in Türkiye, uncertainties in implementation details and bureaucratic obstacles limit their effectiveness (Flora et al., 2019). The fact that local equipment support has remained largely assembly-oriented further highlights the need to strengthen Türkiye's R&D and technology development capacity (PwC Türkiye, 2024).

### 3.1.2. Solar power plant installation processes and bureaucratic barriers

The installation of solar power plants is directly linked not only to technical feasibility but also to the efficiency of administrative procedures. One of the main challenges for solar investments in Türkiye is the lengthy and unpredictable processes associated with licensing, grid connection permits, and project approvals. These factors negatively affect investor decision-making and frequently lead to project delays (İnanç, 2025).

Although procedures for unlicensed generation projects have been relatively simplified, in practice investors face inconsistent interpretations across different regions, which undermines confidence. In some cases, distribution companies delay grid connection permits, while overlapping responsibilities between institutions such as TEDAŞ and TEİAŞ, along with municipalities taking longer than expected to issue zoning permits, reduce the predictability of the process (PwC Türkiye, 2024).

Connection capacities set by TEİAŞ constitute one of the most critical constraints for planning solar investments. In Southeastern and Central Anatolia, where solar irradiation is high and investor interest is strong, limited transmission infrastructure restricts the number of connection permits that can be issued. This prevents technically feasible areas from being economically utilized and complicates site selection planning (IEA, 2021).

Investors also face uncertainty regarding zoning plan compliance, environmental impact assessment exemptions or exceptions, and differing interpretations between central and local authorities. While the process is faster in organized industrial zones, in rural areas the same regulations are applied inconsistently, prolonging the process (Flora et al., 2019).

Another structural problem in installation procedures is the limited administrative capacity to handle large volumes of applications. Especially during peak application periods, investors report that their files are left pending for months and responses are delayed. This not only causes time loss but also increases project costs (PwC Türkiye, 2024; Flora et al., 2019).

In this context, it is evident that installation processes are shaped not only by legal procedures but also by administrative capacity, transparency, and consistency in implementation. To accelerate solar investments, it is essential to establish a one-stop application system, increase digitalization, introduce standardized implementation guidelines, and create stronger coordination mechanisms between local administrations and central authorities.

### 3.1.3. Taxation and financial regulations

The scalability of solar energy investments is linked not only to technical and bureaucratic procedures but also to taxation and financial incentive mechanisms that directly shape investors' cost structures. In Türkiye, value-added tax (VAT) exemptions, customs duty waivers, fiscal advantages provided under investment incentive certificates, and the increasingly important carbon tax policy play key roles in this regard.

Since a large share of solar equipment is imported, customs duty exemptions provide direct cost advantages to investors. Exemptions on panels, inverters, and mounting systems have accelerated project development, particularly at times when domestic production was not sufficiently widespread. Similarly, VAT exemptions serve as a significant incentive for small- and medium-scale unlicensed projects. Rooftop PV systems in Türkiye are exempt from VAT, which substantially reduces upfront investment costs (PwC Türkiye, 2024).

Advantages granted under investment incentive certificates, such as tax reductions, social security premium support, interest support, and land allocation, are primarily available to large-scale licensed projects. However, the system is constrained by lengthy application and approval procedures, which limit its effectiveness (Ministry of Industry and Technology, 2012, Article 5).

Although Türkiye has not yet fully implemented a carbon tax regime at the international level, Law No. 7552 on Climate, published in the Official Gazette on 9 July 2025, has established the legal foundation for carbon pricing. The law introduces measures for the establishment of an emissions trading system and related carbon pricing instruments. Within this framework, greater reliance on low-emission sources such as solar power is anticipated. At the current stage, however, carbon pricing has not yet become a decisive factor in investment decisions (Official Gazette, 2025; World Bank, 2023; Gyam et. al., 2023).

For these financial instruments to be effective, predictability of regulations and consistency in implementation are essential. Sudden changes in incentive conditions undermine investor confidence and negatively affect access to financing.

In conclusion, taxation and financial incentive mechanisms in Türkiye offer structural tools that can accelerate solar energy investments. Yet their effectiveness depends on being implemented in a coherent, streamlined, and long-term framework, which is critical for ensuring stability in investment decisions.

### 3.1.4. Unlicensed generation and self-consumption practices

One of the most significant regulations that has enabled the democratization of solar energy investments in Türkiye is the practice of unlicensed electricity generation. This model has facilitated market entry for small-scale producers such as households, businesses, and public institutions, contributing to the wider adoption of solar energy. Under Article 14/b of Electricity Market Law No. 6446 and the provisions of the Regulation on Unlicensed Electricity Generation, the initial capacity cap of 500 kW was later increased to 1 MW and then to 5 MW. However, shortcomings in institutional capacity, delays in zoning and connection permits, and procedural ambiguities continue to undermine investor confidence (EPDK, 2022; Clapartners, 2024).

The expansion of rooftop solar systems, in particular, has both strengthened energy supply security and generated significant cost savings for users. As of 2022, the majority of unlicensed solar producers in Türkiye were industrial facilities, organized industrial zones, and large retail chains (Flora et al., 2019). In contrast, the share of individual consumers in rooftop installations remains limited. By 2025, the total installation cost of 5-10 kW rooftop PV systems in Türkiye ranged between 126,000 and 370,000 TL, depending on roof conditions, inverter choice, mounting system, and financing arrangements (Powerenerji, 2025). This cost band is comparable to residential installations in Spain and Greece.

Excess energy generated under the unlicensed model can be fed into the grid through net metering. Monthly net metering was introduced in 2019, allowing consumers to better balance production and consumption over the course of a year and to plan their finances more effectively. Beyond energy savings, this model also has the potential to accelerate returns on investment at the micro level (Gümüş, 2024).

The integration of local administrations and cooperatives into the unlicensed model is also of critical importance. Municipalities, for example, can deploy solar systems for street lighting or wastewater treatment plants, serving both as role models and as pioneers of self-sufficient public institutions. The use of solar systems in agricultural irrigation not only reduces farmers' costs but also aligns with broader rural development strategies.

In conclusion, unlicensed generation and self-consumption practices play a transformative role in Türkiye's solar energy strategy. Simplifying implementation procedures, making grid connections more transparent, and providing guidance for small investors would further unlock this potential. Supporting distributed generation will also contribute to the transformation of Türkiye's centralized energy structure while enhancing the country's energy supply security.

### 3.1.5. Regulations for municipalities, organized industrial zones, and individual installations

In expanding solar energy in Türkiye, not only central incentives but also the regulatory support of intermediary actors such as municipalities and organized industrial zones is of critical importance. This section examines regulations for municipalities, organized industrial zones, and individual consumers, highlighting both opportunities and limitations in practice.

From the perspective of municipalities, Law No. 5393 on Municipalities and Law No. 5018 on Public Financial Management and Control grant the right to produce their own energy (Official Gazette, 2005; 2003). Rooftops of public buildings, wastewater treatment facilities, and park lighting systems can be equipped with solar power systems. However, this potential has not been fully realized. Limited access to financing, insufficient technical expertise, and complex tendering procedures have kept investments at a modest level. To enable greater participation by local governments in solar energy projects, central policies providing project financing, training, and technical support are increasingly important.

Organized industrial zones are the largest unlicensed producers of solar energy. By 2023, many organized industrial zones had expanded rooftop PV applications, and some regions developed joint generation and distribution models. Current regulations allow organized industrial zones to generate electricity to meet their own consumption, but restrictions remain on selling surplus electricity to the grid (PwC Türkiye, 2024). This discourages large industrial investors from utilizing their full renewable generation potential and creates uncertainty in grid integration.

For individual consumers, solar investments are usually limited to small-scale rooftop systems. Regulations allow these users to meet their own electricity needs and to feed surplus power into the grid through net metering. However, high upfront costs, limited access to technical consultancy, and a lack of financing alternatives in the banking system pose significant barriers. For households in particular, low-interest loan mechanisms, standardized installation guidelines, and awareness campaigns carried out through municipal and public partnerships could help overcome these obstacles (IEA, 2021; Ministry of Energy and Natural Resources, 2024).

Innovative models such as shared rooftop systems, energy cooperatives, and apartment-based sharing schemes remain limited because they are not explicitly defined in the regulatory framework. This slows down the spread of energy democracy and citizen-driven energy transition. Regulations similar to community-based generation models widely used in Europe should be integrated into Türkiye's framework.

In conclusion, for solar energy to achieve broad social adoption, not only large investors but also municipalities, organized industrial zones, and individual consumers must actively participate in the process. This requires simplifying and clarifying regulations while implementing specific incentives tailored to small- and medium-scale actors. Such an approach would not only expand installed capacity but also enhance social ownership and contribute to local development.

## 4. Current Status of Selected OECD Countries

The development of the solar energy sector in OECD countries is shaped not only by their technical potential and market dynamics but also by the institutional clarity, regulatory stability, and long-term policy signals provided by governments. Although the selected countries differ in their economic scale and administrative structures, they share common features such as high solar irradiation, established policy frameworks, and supportive mechanisms for distributed generation. In this context, examining their current status offers valuable insights into how different policy architectures influence solar deployment. The subsections below present a detailed overview of each country's solar energy landscape, focusing on incentive schemes, permitting processes, grid infrastructure, and market performance.

### 4.1. Spain

With an annual average of 2,750 sunshine hours, Spain has one of the highest solar potentials in Europe. In terms of solar power generation, the country benefits from an average of 5.3 peak sun hours per day, though this varies across regions and seasons. Spain's annual average global horizontal irradiation is about 1,700 kWh/m², equivalent to 4.6 kWh/m² per day (PVKnowHow, 2024a).

Spain is undergoing a significant transformation in solar energy. The government's roadmap, published at the end of 2021 to encourage self-consumption, includes more than 30 regulatory and support measures and targets 19 GW of self-consumption capacity by 2030 (CAN Europe, 2024a). The current National Energy and Climate Plan (NECP) envisions 76.4 GW of solar capacity, a 95 percent increase compared to earlier targets (ElDiario, 2023). By 2022, installed self-consumption capacity had reached 5.4 GW, with 61 percent in industry and 39 percent in the residential sector (APPA, 2023). As of 2025, Spain's total installed solar capacity had reached 65.8 GW (PVKnowHow, 2025a), and solar accounted for 21 percent of total electricity generation in 2024 (Ember-energy, 2025). However, rising interest rates, declining electricity prices, and delays in public support measures caused residential investments to fall by 25 to 50 percent in 2023 (ElPais, 2023).

Since 2019, self-consumption investments have operated under a simplified balancing system through Royal Decree 244, which exempts investors from certain taxes (CAN Europe, 2024a). However, Spain does not apply a traditional feed-in tariff or production premium. In regions such as Valencia and Catalonia, direct subsidies of up to 40 percent are provided through European recovery funds. Municipal incentives allow for property tax reductions of up to 50 percent, while income tax declarations offer deductions of 20 to 60 percent (Fundación Renovables, 2022). In addition, a new €500 million self-consumption fund was approved in 2023 (ElPais, 2023).

Permitting has been largely simplified for individual systems, with no requirement for permits on installations below 15 kW in urban areas and a maximum processing time of two months. Collective systems, however, still face delays from distribution companies, bureaucratic burdens, and communication issues (CNMC, 2023). Energy communities are also on the rise, with 291 communities active by the end of 2023. Yet, the legal framework for community-based generation is still incomplete, and progress in this area largely depends on civil initiatives and local government leadership (REScoop, 2023).

In terms of costs, the average installation price of a typical 3 kW residential system in 2025 ranges between €4,000 and €8,000 without storage. In major cities such as Madrid, prices start at €4,500, while more competitive rates are available in regions like Andalusia and Galicia. For larger systems of 5–7 kW that include advanced components such as batteries and microinverters, total costs can reach €12,000. Installation times vary between one and three months, but since digital application systems are not yet fully functional across all regions, mismatches remain between individual initiatives and public administration (Wollyhome, 2025).

In conclusion, while Spain continues to show strong growth in solar energy, self-consumption investments still face structural challenges such as financial instability, regulatory gaps in collective projects, and bureaucratic hurdles. Even so, nationwide smart meter coverage, regional incentives supported by EU funds, and growing REC participation provide promising signals for the future.

### 4.2. Italy

Italy has gained significant momentum in solar energy in recent years, with its installed solar power capacity surpassing 40 GW as of 2025 (Strategic Energy, 2025a; PVKnowHow, 2025b). Much of this growth has come from small-scale residential systems under 20 kW, particularly those below 12 kW, which recorded an annual increase of 239% (Italia Solare, 2023). The country benefits from approximately 2,225 hours of sunshine annually, with high potential in southern regions such as Sicily, Puglia, and Sardinia. Average global horizontal irradiation ranges between 1,200–1,700 kWh/m²/year (PVKnowHow, 2024b). As of 2024, solar accounted for 11.5% of total electricity generation (Berlen, 2025).

Incentive mechanisms in Italy include various tax deductions and subsidies. The "Bonus Casa" provides up to 50% income tax reduction, while the "Superbonus," reduced from 110% to 90% in 2023, has been especially effective for low-income households (CAN Europe, 2024b). In addition, a €200 million fund administered by GSE supports PV installations for low-income families in 2024–2025. The agricultural sector benefits from subsidies of up to 80% for rooftop PV systems, while the Transizione 5.0 tax scheme grants up to 150% deductions for EU-manufactured high-efficiency modules (PV Magazine, 2025).

For collective and community self-consumption, two support pillars exist: (i) a premium tariff scheme paid over 20 years (total budget €3.5 billion), and (ii) an investment grant covering up to 40% of eligible costs (€2.2 billion budget, funded by the RRF). Rooftop PV in agriculture and agro-industry has been subsidized up to 80% since April 2023 (CAN Europe, 2024b).

In terms of permitting, small rooftop systems benefit from simplified procedures. Systems up to 50 kW require only a single application form. Under the PNRR framework, authorization timelines are capped at 60 days in regular zones and 90 days in protected areas. Furthermore, the "ex-lege suitable areas" rule exempts many regions from permit requirements (CMS Law, 2023). However, delays remain common in large-scale projects, and grid investments outlined in the NECP have yet to materialize.

By 2023, turnkey PV installation costs were reported at €1.25–1.70/W for small residential rooftops, €1.10–1.50/W for commercial rooftops, €0.85–1.15/W for industrial rooftops, and €0.50–0.90/W for large-scale ground-mounted plants (IEA-PVPS, 2024). Financing is supported by RRF funds, public banks, and green bonds.

Italy has also advanced self-consumption and energy community models. The "Scambio sul posto" net metering system was phased out, replaced by collective and community-based energy sharing. Renewable Energy Communities (RECs), capped at 1 MW, are supported through interactive GSE platforms that facilitate user matching. A new scheme approved by the European Commission in late 2023 grants premium payments above market price for 20 years and up to 40% investment grants for REC projects (CAN Europe, 2024b; ARERA, 2023; Aras & Kandemir, 2023). Nevertheless, the country still lacks a comprehensive national strategy to address energy poverty.

## 4.3. Mexico

Mexico stands out as one of the countries with the highest solar potential globally, with an average of 2,730 hours of sunshine annually (Mexico Energy, 2024). By 2024, the country's installed solar capacity had reached 12.6 GW, accounting for approximately 5.3% of total electricity generation (SolarPowerEurope, 2025). Nationwide, solar generation averages 1,600–1,900 kWh per year per installed kWp (PVKnowHow, 2024c).

The Mexican government has pursued a distributed generation (DG)-oriented policy framework to expand solar energy. The 2014 Electricity Industry Law and the 2015 Energy Transition Law enabled small producers to connect to the grid and sell surplus electricity. Within this framework, the Clean Energy Certificates mechanism grants one certificate for each 1 MWh of renewable generation, which can then be traded on the market, improving the financial attractiveness of DG projects. To improve access for low-income households, the "Bono Solar" (Solar Bond) program was introduced, leasing rooftops for solar panel installations to reduce electricity bills.

Although its first phase was cancelled due to bureaucratic obstacles, the program is expected to relaunch after 2025 under the name "Hogares Solares" (Solar Homes). Most DG users in Mexico prefer net metering contracts with the Federal Electricity Commission, while net billing and gross sales schemes are also available. By mid-2024, more than 450,000 DG connections were registered, reaching around 4 GW of capacity and generating $5.2 billion in investments. The average payback period of five years makes these systems an attractive option (De la Torre, 2024). Financing programs such as FOTEASE, FIDE, and CSOLAR also support small and medium-scale consumers with credit, grants, and guarantees (IEA & IITD, 2024, pp. 175–187).

Under the Plan México strategy, tax incentives apply across all sectors, including residential PV systems. These incentives include import duty exemptions, accelerated depreciation, and tax deductions for equipment investments, reducing initial costs and accelerating returns (EY, 2025). Distributed PV producers under 500 kW are classified as "Exempt Generators," relieving them of some permitting obligations. For these systems, only limited formalities such as interconnection requests are required. Plan México also aims to further simplify approval procedures for rooftop systems (Arreola et al., 2024).

The average installation cost of a residential solar system in Mexico is about 50,000 pesos (≈USD 2,830). Operating expenses represent roughly 20–25% of total production costs, with labor costs ranging between USD 15–30 per hour and electricity expenses between USD 0.10–0.50 per kWh depending on tariffs (PVKnowHow, 2024c). Administrative, maintenance, and quality control costs also remain significant in the overall cost structure.

From a legal standpoint, the Energy Transition Law (valid until 2024) mandated that 35% of electricity generation must come from renewable sources. This target is reinforced by PRODESEN, the national electricity system development plan. In addition, the General Law on Climate Change and DG-specific regulations have played a central role in incentivizing small-scale projects (PVKnowHow, 2024c).

## 4.4. Portugal

Portugal, with an annual average of 2,850 hours of sunshine, is among the European countries with the highest solar potential. In terms of solar electricity generation, annual production reaches between 1,200–1,800 kWh per kWp installed capacity (PVKnowHow, 2024d). As of May 2025, the country's installed solar capacity surpassed 6.17 GW. In the first five months of the year, solar accounted for around 10% of total generation, while in May alone it reached a record share of 17%. The share of renewables in total electricity consumption during the same period stood at 82% (Strategic Energy, 2025b).

In Portugal, self-consumption investments gained a comprehensive legal framework through Decree-Law No. 15/2022, which reformed the previously limited net metering model. The regulation introduced VAT exemptions, tax-free treatment of surplus electricity sales below €1,000, and partial grid fee reductions for seven years. In addition, the environmental fund program launched in 2023 offers direct grants targeting collective consumption and energy communities (SolarPower Europe, 2024a). Notably, legislation explicitly ensures the participation of all consumers, including low-income households, in Renewable Energy Communities (REScoop, 2024).

From a taxation perspective, no fees are charged for self-consumption PV systems up to 30 kWp, while projects below 100 kWp are exempt from environmental impact assessment. Moreover, EU-backed incentive funds totaling €350 million support local equipment manufacturers, boosting domestic panel production and job creation (PVKnowHow, 2024d). However, coordination problems between central and local administrations, combined with staff shortages, have slowed approval processes. In collective self-consumption projects, licensing can take more than a year (SolarPower Europe, 2024b).

Installation times vary by project, but residential rooftop systems are typically completed within 2–4 months. A 5 kWp system, including inverter and mounting, costs between €6,000–€8,000. Higher-quality equipment, battery integration, and smart monitoring systems increase costs, but subsidies and financing instruments substantially shorten payback periods (The Portugal News, 2025).

For permitting, projects below 30 kWp benefit from a simplified procedure and the "positive silence" principle for small-scale installations. Nevertheless, delays remain in REC and collective self-consumption projects. To address this, a digital application platform was introduced in 2023 (CAN Europe, 2024c). The legal framework for energy sharing allows collective use within 2 km in low-voltage grids and 20 km in high-voltage grids. Furthermore, the deployment of 5.5 million smart meters signals the existence of a robust digital infrastructure for monitoring and consumption management (Smart Energy, 2024).

## 4.5. Greece

Greece encounters a high amount of sun insolation, making it an excellent site for solar energy production. The national average sunshine duration is around 2,750 hours per year, with southern regions reaching maximum levels (PVKnowHow, 2024e). Maps published by the Joint Research Centre (JRC) of the European Commission indicate that annual global horizontal irradiation for PV modules ranges between 1,600–1,800 kWh/m² in areas such as Crete, Rhodes, the Peloponnese, and around Athens (JRC, 2008). Combined with a high frequency of clear skies and low aerosol loads, these conditions place Greece in a highly favorable position for PV efficiency. In cities such as Athens, Heraklion, and Kalamata, annual output for a 1 kWp system can reach 1,300–1,350 kWh (Vigkos & Kosmopoulos, 2024).

By 2025, Greece's installed PV capacity reached about 13 GW, tripling over the past eight years (PVKnowHow, 2025c). In 2024, PV investments totaled approximately €1.6 billion, largely driven by utility-scale projects in non-agricultural land areas. In terms of solar's share in electricity consumption, monthly peaks have reached as high as 20–25%, while the overall annual share stands at 24%. This is well above the European average (8.6%) and places Greece alongside leaders such as Germany and the Netherlands (HELAPCO, 2025; Psomas, 2024). Renewables overall account for 57% of electricity generation (Our World in Data, 2024). Growth has been supported by both centralized power plants and distributed applications such as rooftop PV and agricultural installations.

The investment environment has improved significantly following Laws 4685/2020 and 4951/2022. The abolition of the production license requirement and its replacement with a "Producer Certificate," alongside digitalization of approval procedures, reduced permitting to as little as 14 months (CMS, 2024). In addition, Greece introduced the legal framework for offshore photovoltaic plants, under the provisions of

Law 4951/2022, providing for 10 pilot floating solar projects (ICLG, 2024). The support framework shifted from feed-in tariffs to competitive two-way Contracts for Difference (CfDs), though fixed-price support remains available for small producers. Net metering, which remains limited in Türkiye, is widely applied in Greece, supplemented by virtual net metering (VNM) that allows municipalities and individuals broader self-consumption opportunities (CAN Europe, 2024d). While there is no local-content requirement, low import tariffs of 0–2% on PV equipment facilitate investment (ZhengBackpack, 2024).

Tax incentives and financial support mechanisms are substantial. Rooftop PV systems qualify for personal income tax deductions, and eligible projects may receive grants covering 30–65% of investment costs (CMS, 2024). Greece is fully integrated into the EU Emissions Trading System (EU ETS) and provides public support for carbon capture and storage technologies in carbon-intensive sectors (European Parliament, 2025). Financing options for solar projects are diverse, with the European Investment Bank and the Recovery and Resilience Facility offering green bonds and credit mechanisms (CAN Europe, 2024d).

At the individual level, installation costs remain competitive. Average costs are about €3/W, with a 4.2 kW system priced at roughly €8,600, falling to around €6,450 after tax reductions (Creative Construction, 2024). For large-scale projects, financing is supported by EU programs, with particular focus on storage-integrated systems in island regions. In terms of permitting, Producer Certificates, Environmental Impact Assessments, grid connection approvals, construction permits, and operating licenses are processed through a digital platform (ICLG, 2024). Coordination between central and local authorities is ensured via institutions such as HEREMA S.A., which serves as a model for renewable energy projects, including solar.

## 5. Comparative Policy Analysis and Recommendations for Türkiye

With an annual average of around 2,741 hours of sunshine, Türkiye has a higher technical solar potential than many European countries. However, this advantage is not fully reflected in installed capacity or in solar power's share of total electricity generation. For instance, as of 2023 Türkiye's installed solar capacity was approximately 22.6 GW (Ministry of Energy and Natural Resources, 2025b), whereas countries with lower irradiation levels in Europe have already achieved significantly higher figures.

The main reasons for this gap include Türkiye's relatively late start in solar investments, regulatory instability, the limited predictability of incentive schemes, and insufficient engagement of local-level actors. In contrast, the countries analyzed introduced their support mechanisms earlier, built structures that facilitated distributed generation, and were more effective in integrating local stakeholders into the transition process.

Table 3. Comparison of Solar Energy Policies and Implementation Indicators in Selected Countries

| Country | Sunshine Duration (hours/ year) | Installed Solar Capacity (GW) | Share in Electricity Generation (%) | Support Mechanisms | Tax Incentives | Average Installation Time | Net Metering |
|---|---|---|---|---|---|---|---|
| **Türkiye** | 2.741 | 22.6 (2025) | 7.5 (2024) | YEKDEM (TL based), YEKA | VAT exemption, limited social security relief | 3–9 months | Yes (limited) |
| **Spain** | ~2.750 | 65.8 (2025) | 21 (2024) | Net metering, subsidies | Property and income tax deductions | 1–3 months | Yes (active) |
| **Italy** | ~2.225 | 40 (2025) | 11.5 (2024) | Superbonus, GSE funds | 90–150% tax deductions | 2–3 months | Abolished / REC sharing |
| **Greece** | ~2.750 | 13 (2025) | 24 (2024) | CfD, net metering | 30–65% grants, low import tariffs | 2–4 months (max. 14 large) | Yes (+ Virtual) |
| **Portugal** | ~2.850 | 6.17 (2025) | 17 (2024 peak) | Self-consumption, collective support | VAT exemption, community subsidies | 2–4 months | Yes (advanced) |
| **Mexico** | ~2.730 | 12.6 (2024) | 5.3 (2024) | CEL, Solar Bond | 30% subsidies + accelerated depreciation | 5–7 months | Yes (simplified) |

Note: The table has been prepared based on the information provided in the sections above.

When Table 3 is examined, it becomes evident that although Türkiye shares some structural similarities with other countries, it offers limited economic predictability for investors. In particular, the shift of the YEKDEM system to a TL-based structure after 2021 has exposed investors to currency risks given their foreign exchange–denominated costs, thereby undermining income stability. By contrast, countries such as Spain and Portugal have supported returns on investment more directly through mechanisms like net metering, simplified net metering, and investment grants.

Italy has accelerated rooftop PV installations by offering up to 90% tax deductions through the "Superbonus" and "GSE funds," targeting both households and low-income groups. In Türkiye, however, tax incentives remain largely limited to VAT exemptions, with no direct incentives such as income tax deductions or investment premiums. Although the YEKA model provides strategic support for large investors, it does not extend to smaller-scale stakeholders. Expanding Türkiye's economic incentive system to cover a wider investor base and designing direct financial support schemes for individual and local actors appears critical.

Beyond technical capacity, the speed and predictability of permitting processes play a decisive role in scaling solar investments. In Türkiye, overlaps of authority among TEİAŞ, TEDAŞ, and distribution companies, coupled with application backlogs and regional inconsistencies, make the process risky and slow for investors. By comparison, Portugal has introduced the "positive silence" principle for projects under 30 kWp, while Spain has eliminated permitting requirements altogether for residential systems under 15 kWp. Greece has digitized its producer certificate system and capped permitting at a maximum of 14 months. In these countries, installation approvals are typically finalized within one to four months, whereas in Türkiye, the process ranges from three to nine months.

Adopting the "digital one-stop-shop" model used in many European countries could alleviate this bottleneck. In this model, all permits and approvals are processed through a single online platform, applications are tracked transparently, and automatic approval mechanisms are applied to small-scale systems. Implementing such a system in Türkiye would shorten processing times and enhance investor confidence.

Streamlining bureaucratic procedures, clarifying the division of responsibilities between local and central authorities, and expanding digital application systems represent key reform areas that could accelerate installation timelines in Türkiye (Kaya & Kaya, 2025).

Although the majority of Türkiye's installed solar capacity has been realized under the unlicensed production framework, it cannot be said that the distributed generation model has matured. Subcategories such as residential rooftop systems, apartment-based applications, and cooperative models remain underdeveloped. The most common user profiles are industrial facilities and organized industrial zones. By contrast, countries such as Italy, Portugal, and Greece have promoted energy cooperatives, RECs, and next-generation energy-sharing mechanisms, which expand not only production but also the reach of energy democracy.

For example, in Portugal, EU-supported funds are allocated to energy communities, while in Greece advanced models such as VNM are applied for non-industrial users. The absence of explicit legal definitions for such models in Türkiye prevents the establishment of energy communities and restricts small investors' access to the market. To broaden the base of distributed generation, a dedicated legal framework for cooperatives, pilot municipal projects, and regulations on shared rooftop use should be prioritized.

Türkiye's YEKA model stands out as a policy instrument designed not only to expand generation capacity but also to promote domestic industry integration and technology transfer. Large-scale investments have been implemented through projects such as Karapınar YEKA, creating a significant assembly infrastructure in panel production. However, much of this production remains limited to assembly, and dependence persists in high-tech components such as inverters. In countries like Italy and Spain, EU funds support not only manufacturing but also R&D, efficiency improvements, and innovation-driven processes.

Moreover, tax advantages are differentiated not just by capacity but also by module efficiency (for instance, Italy provides additional deductions for modules with efficiency above 21.5%). In Türkiye, domestic production support remains confined to limited tools such as per-kWh bonus payments. Unless the YEKA model evolves into a technology-oriented industrial policy, its ability to generate long-term added value will remain constrained. Strengthening the framework through mandatory technology transfer requirements, the establishment of R&D centers, incentives for high-efficiency products, and domestic product grants for small investors is therefore essential.

## 6. Strengths and Weaknesses of Türkiye

Türkiye's current status in solar energy should be assessed not only in terms of technical data but also with reference to policymaking processes, investment climate, local participation, and industrial capacity. The analysis indicates that while Türkiye holds considerable advantages, these have not yet been systematically or sustainably translated into outcomes. Table 3 summarizes Türkiye's strengths and weaknesses in solar energy policy along four main dimensions.

Table 4. Strengths and Weaknesses of Türkiye in the Field of Solar Energy

| Dimension | Strengths | Weaknesses |
|---|---|---|
| **Potential** | High annual solar irradiation (2,700+ hours), large land availability | Insufficient grid infrastructure, limited transmission capacity |
| **Policy** | Diverse support mechanisms (YEKDEM, YEKA, and unlicensed generation) | Frequent changes in incentive schemes, investor risk under TL-based model |
| **Local Participation** | Strong adoption in Organized Industrial Zones (OIZs), industry-driven investments | Low share of residential rooftop systems, absence of legal framework for energy cooperatives |
| **Industry** | Expanding panel production capacity, new investments | Predominantly assembly-based production, dependence on imports for inverters and cells, limited R&D |

This assessment shows that Türkiye possesses not only natural advantages but also a strong regulatory background, investment infrastructure, and industrial entrepreneurship. However, for this structure to develop sustainably, there is a need for comprehensive strategies aimed at clearly identifying and addressing structural weaknesses.

In particular, many of the weaknesses are directly related not only to technical capacity but also to institutional stability, regulatory continuity, and participatory governance models. In this context, the "lessons learned from practices" presented in the following section will serve as a guide for Türkiye to make more effective use of its existing strengths.

## 7. Lessons Learned from Practices and Policy Recommendations

When examining solar energy practices in selected countries, it becomes evident that many of the structural challenges currently facing Türkiye have already been successfully addressed in different contexts and at various scales elsewhere. The experiences of these countries offer not only best practices to emulate but also policy insights that can be adapted to Türkiye's specific context.

One of the most notable models for strengthening investor confidence is Greece's CfD mechanism, which provides producers with protection against market fluctuations while ensuring fiscal predictability for the state. In contrast, Türkiye's TL-based YEKDEM scheme has exposed investors to risks from exchange rate volatility and inflation, undermining income stability. Introducing currency-indexed or inflation-adjusted tariffs could encourage medium- and long-term investment decisions.

For small-scale investors, Italy's Superbonus and Spain's property tax deductions have had a strong impact on rooftop solar adoption. In Türkiye, however, tax incentives are largely limited to VAT exemptions, without deeper income- or investment-oriented measures. To encourage households, apartment owners, and small businesses to adopt rooftop PV systems, instruments such as income tax deductions, accelerated depreciation, and low-interest loans should be implemented.

The duration of permitting processes is another key factor shaping investment decisions. Spain exempts systems under 15 kWp and Portugal under 30 kWp from lengthy permitting, applying automatic approval if applications receive no timely response. This has significantly shortened installation timelines. In Türkiye, however, permitting remains fragmented across distribution companies, TEDAŞ, and TEİAŞ, with regional inconsistencies. Digital single window platforms, legal deadlines for processing, and exemptions for small-scale systems should be prioritized to reduce delays.

The expansion of distributed generation also depends on supportive frameworks for energy communities and cooperatives, as seen in Portugal and Greece. While Türkiye's OSBs have established strong industrial-based distributed generation, participation by households and local actors remains limited. A clear legal framework is needed for apartment-scale shared systems, rural cooperatives, and municipal-led production models. Regulations must address issues such as sharing distances, billing methods, tax exemptions, and governance structures. Public incentives for such initiatives would not only increase social ownership but also advance energy justice.

In terms of industrial policy, Türkiye has achieved considerable panel production capacity, but much of this remains low value-added assembly (Koyuncu, 2024). In Italy and Spain, support schemes are tied not only to production volumes but also to efficiency, patented technology, and R&D. Türkiye's YEKA model should be restructured to include differentiated incentives for high-efficiency products, tax breaks for R&D activities, and mandatory technology transfer. Smaller-scale "mini-YEKA" tenders aimed at SMEs could further broaden the industrial base.

In sum, Türkiye's solar energy policy is largely aligned with the right priorities, but achieving sustainable results requires both short-term simplification and long-term strategic reforms. Ensuring regulatory stability, facilitating investment, strengthening grid infrastructure, and expanding community-based energy models must remain top policy priorities.

To avoid leaving these goals at the level of general strategy, concrete steps should be mapped out across short, medium, and long-term horizons. Table 5 outlines a proposed roadmap for Türkiye's solar energy policies, specifying which institutions should take responsibility at each stage.

Table 5. Proposed Roadmap for Türkiye's Solar Energy Policies

| Period | Policy Step | Responsible Institution(s) | Expected Impact | Risk / Prerequisite | Implementation Difficulty | Critical Stakeholders |
|---|---|---|---|---|---|---|
| Short term (0–2 | Digital single-window permitting; automatic approval for systems <30 kW | MENR, TEDAŞ, TEİAŞ, EMRA | Installation period ≤6 months, increased investor appetite | Digital infrastructure delays; resistance from distribution companies; lack of staff capacity | Medium | Distribution companies, municipalities, investors, IT providers |
| | Micro-incentives (tax deductions, low-interest loans, accelerated depreciation) | Treasury, MENR | Boost for rooftop/SME investments | Fiscal pressure on treasury; risk of misuse; over-subscription | Medium | Banks, SMEs, households, commercial installers |
| Medium term (3–5 years) | Revision of YEKDEM with FX/inflation indexation or pilot CfD (≤1 GW) | MENR, EMRA | Investor confidence, mid-to-long-term capital inflows | Budget uncertainty; CfD design flaws; inflation volatility | High | Large investors, financial institutions, grid operators |
| | Mini-YEKA (50–100 MW, SME-focused) | MENR | Expansion of domestic manufacturing base | Financing constraints; inadequate R&D capabilities | Medium | SME manufacturers, industry clusters, chambers of commerce |
| | Legal framework for energy cooperatives | Parliament, MENR, Municipalities | Local participation, energy justice | Legal complexity; low local capacity; resistance from incumbents | Medium–High | Cooperatives, rural communities, households, NGOs |
| Long term (5+ years) | R&D incentives, localization of inverters/cells | MENR, TÜBİTAK, Ministry of Industry | High value-added production | Technology gap persists; insufficient private R&D investment | High | PV manufacturers, universities, tech startups |
| | Grid investments + storage (2026–2030) | TEİAŞ, TEDAŞ | Greater solar integration, supply security | High capital cost; long permitting times | High | Transmission companies, storage developers, regulators |
| | Municipality/ community-based programs | Municipalities, MENR | Energy democracy, local ownership | Financing limitations; administrative capacity differences | Medium | Local govts, cooperatives, citizens, regional dev. agencies |

## 8. Conclusion

This study has examined Türkiye's solar energy sector through a multidimensional lens, spanning technical potential, policy structure, implementation practices, and international comparisons. Solar energy is one of Türkiye's most strategic resources for both enhancing energy security and achieving carbon neutrality targets. Despite an annual sunshine duration exceeding 2,700 hours and significant land potential, current installed capacity and the share of solar in electricity generation remain below expectations.

Comparative analysis demonstrates that although Türkiye is technically more advantaged than many European countries, it has failed to achieve sufficient momentum due to slow permitting procedures, fragile incentive schemes, and limited local-level participation. In particular, the streamlined authorization processes, net metering frameworks, and community-energy incentives of Spain, Portugal, and Greece—as well as investor-oriented tax instruments such as Italy's Superbonus and Mexico's income tax deductions—provide important lessons for Türkiye.

Türkiye's strengths include the presence of support mechanisms such as YEKDEM and YEKA, growing domestic panel production capacity, and widespread installations in organized industrial zones. However, to translate these advantages into lasting success, greater institutional consistency, regulatory stability, and administrative capacity are required. Gaps in coordination among TEİAŞ, TEDAŞ, and distribution companies, the limited involvement of municipalities, and restricted access to incentive schemes for individual investors remain critical barriers to further development.

Against this backdrop, Türkiye's solar policy should not focus solely on capacity targets but be reshaped around a broader transformation perspective: simplifying permitting procedures, expanding micro-level incentives, establishing a legal framework for energy cooperatives, and steering domestic industry toward high-tech production. At the same time, the governance dimension must not be overlooked: municipalities, civil society, and the private sector should be integrated as active participants in the transition process.

Türkiye should also aim to increase R&D activities in the field of renewable energy through introducing new support schemes. Increased R&D activity would also help the renewable energy sector to close the technology gap and ease the trade deficit by shifting domestic production towards more technologically advanced solar and wind energy equipment that is located higher up the respective value chains (Gomez et al., 2019).

At the international level, solar energy is not only a component of national energy policies but also a key element of global energy governance. The European Union's Green Deal, 2030 targets, and carbon border adjustment mechanisms directly influence Türkiye's energy transition. Expanding renewable energy capacity simultaneously strengthens Türkiye's economic integration with the EU and enables fulfillment of its Paris Agreement commitments. Moreover, from an energy security perspective, solar investments are vital: in a context of high fossil fuel dependency, renewable diversification broadens Türkiye's foreign policy maneuvering space. Thus, solar policies directly shape not only domestic markets but also Türkiye's international position, regional energy diplomacy, and reputation within the global climate regime.

Future research could further enrich the findings of this study by incorporating quantitative modeling, scenario-based simulations, or hybrid methodological approaches to evaluate the long-term economic and technical impacts of policy choices on solar deployment. Comparative analyses across a broader group of emerging economies, as well as micro-level studies on household adoption, community energy models, and distributed generation economics, would provide deeper insight into the social and behavioral drivers of solar uptake. Additionally, policy-oriented research focusing on grid integration, storage technologies, and the interaction between carbon pricing and renewable energy incentives could offer valuable guidance for both national and local decision-makers.

In conclusion, solar energy represents not only an economic asset for Türkiye but also a strategic investment at the intersection of environmental sustainability, energy independence, and social participation. With the right policies, predictable incentives, and inclusive governance models, solar energy can become a cornerstone of Türkiye's low-carbon future.

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