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Solar Energy Industry in the World and in Türkiye

March 2024

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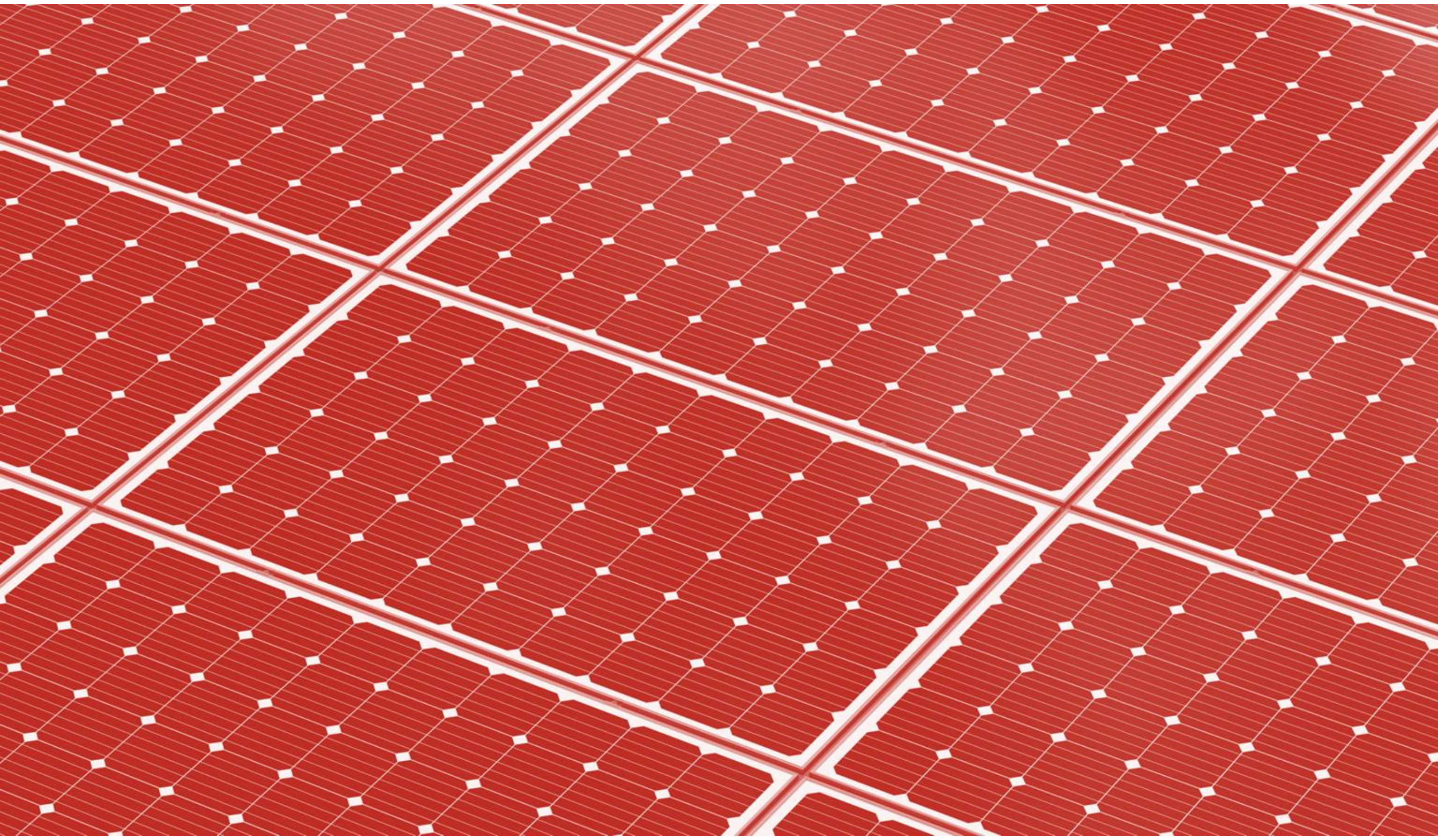

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Foreword

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The volatility of conventional fossil-based energy sources during the 2022 Global Energy Crisis has threatened the sustainable electricity supply in the short-term and resulted in the reconsideration of countries' given Net Zero Emissions commitments for the long-term. However, the Crisis has also had a significant impact on better understanding the global debate on the implications of the sustainable energy supply, as well as on accelerating required action steps. Despite its negative impacts, the 2022 Energy Crisis marked its place in the history as a milestone which confirmed the problems stemming from the dependence on fossil resources and the critical role of renewable energy sources in energy security.

Studies published by different authorities predict solar energy's emergence as the fastest-growing generation technology within the process of green transformation of electricity generation through reducing electricity-generation based carbon emissions. The same trend is also observed on the National Energy Plan of Türkiye which was published in 2022. Regulations introduced in 2023 allowing renewable electricity generation through power plants with storage facilities and hybrid electricity generation also support this plan. Alignment between the global and national targets emphasize Türkiye's commitment towards harnessing its potential in solar energy and the country's endeavour in not only contributing to energy security on a national level, but also towards a sustainable future. In this context, the targets set in Türkiye's National Energy Plan are being embraced and recognized by local investors. Within a relatively short time of a decade, Türkiye has rapidly adopted solar energy – a generation technology which historically was not represented in the country's total installed capacity – and included into the national energy generation portfolio; as well as completed and planned further investments in manufacturing facilities capable of producing solar modules with significantly high local content ratios.

As PwC Türkiye, we are proud to share this research study with you which conveys the historical development, current overview, and future expectations of solar energy generation and the companies manufacturing solar cells and modules from both a global and a local perspective. Our research has been compiled from publicly-available sources to be presented to public attention.

1

Transition to Green Economy and Role of Solar Energy

The Paris Climate Agreement, the European Green Deal, and The Glasgow Climate Pact are the three most important initiatives that focus on climate change and support sustainable development.

1 The Paris Climate Agreement

The Paris Climate Agreement aims to fight global climate change and was adopted by 197 countries at **COP21** in Paris on 12 December **2015**. The agreement entered into force on 4 November **2016** and was approved by 191 countries. The aim is to limit the global average temperature increase to **2°C**,and preferably keep it under **1.5°C**.

The countries that adopted the agreement determine their contributions to decreasing greenhouse gas (GHG) emissions as soon as possible to achieve the long term temperature goal and present **Nationally Determined Contributions (NDCs)** regarding their plans. The NDCs are reviewed and updated every five years.

Türkiye became a party to the Paris Climate Agreement ***in October 2021*** *and* ***announced*** *its* ***2053 Net Zero Emissions Target.***

In April 2021, *Türkiye published its updated* ***NDCs.***

Determined Commitments

GHG Emissions	⬇ 55% (1990-2030)
Net Zero Carbon Emissions Target	2050
Global Temp. Incr. Upper Limit	2ºC

2 The European Green Deal

The European Union aimed to be a climate-neutral continent under the European Green Deal published on 11 December **2019**, and accordingly set road maps in several areas such as industry, finance, energy, and transportation. The European Green Deal aims to decrease GHG emissions by **at least 55%** by **2030** and reach **zero GHG** emissions by **2050**.

One of the most important practices of the European Green Deal is the EU Carbon Border Adjustment Mechanism (CBAM). The CBAM has been implemented so that the Emission Trading System (ETS), which has limited carbon emissions in the EU on a carbon allowance basis since 2005 under the European Green Deal, covers exports to the EU.

Following the European Green Deal, Türkiye implemented its ***Green Deal Action Plan****. Türkiye also approved and implemented the* ***Renewable Energy Resource Guarantee System (YEK-G)****.*

Determined Commitments

GHG Emissions	⬇ 55% (1990-2030)
Net Zero Carbon Emissions Target	2050
RE Resources' Share in Electricity Generation	40%

3 The Glasgow Climate Pact

The Glasgow Climate Pact was adopted and published by **200 countries** on 13 November **2021** after **COP26** in **Glasgow**.
At COP26, progress made after the Paris Climate Agreement was evaluated for the first time and the Glasgow Climate Pact highlighted that countries should develop actions and update their commitment to limiting the global average temperature increase to 1.5°C.

Although several countries have made new long-term commitments to achieving net zero, short-term targets and commitments determined for 2030 do not seem clear.

Under the Glasgow Climate Pact, countries were called to ***gradually decrease*** *coal-derived energy* ***for the first time****.*

Determined Commitments

GHG Emissions	⬇ 55% (1990-2030)
Net Zero Carbon Emissions Target	2050
Suspension of new coal-fired thermal power plants' construction	

Source: MENR

The level of implementation of the targets agreed in the Conferences of the Parties organized in the last 3 years on policies against climate change and the role of renewable energy in climate change were examined and updated renewable energy targets have been set.

History of the UN Conference of the Parties (COP) on Climate Change and Highlights of the Conferences in the Last 3 Years

1995: COP1 – Berlin, Germany

The Conference of the Parties started to be organized annually between the signatory countries of the UN Framework Convention on Climate Change (UNFCCC) after the convention entered into force.

1997: COP3 – Kyoto, Japan

The Kyoto Protocol, which is seen as the first step against climate change, was adopted during the conference. The implementation of the Protocol started in February 2005.

The process of finalizing the detailed implementation of the Kyoto Protocol, which started with COP3, continued to be the main theme of the Conferences of the Parties until the Paris Climate Agreement was organized at COP21.

2015: COP21 – Paris, France

The Paris Climate Agreement, the largest global climate change agreement following the Kyoto Protocol, has been adopted and aims to limit the increase in global average temperature to **2°C**.

2021: COP26 – Glasgow, United Kingdom

With the Glasgow Climate Pact adopted during COP26, the global average temperature increase targets set in the Paris Climate Agreement were assessed for the first time.

- Limiting global warming to 1.5°C
- Gradual phase-off of coal use

2022: COP27 – Sharm el Sheikh, Egypt

COP27'de bir önceki Konferans sırasında kararlaştırılan hedeflerin gerçekleştirilmesi üzerinde durulmuştur. 12 şirketin üyeliği ile kurulmuş olan Endüstri Karbonsuzlaştırma Birliği (AFID) ilk toplantısını COP27'de gerçekleştirmiştir.

- 'Loss and Damage Fund' for countries most affected by global warming

2023: COP28 – Dubai, United Arab Emirates

At COP28, more than 130 countries **endorsed targets to triple global renewable energy capacity to 11 TW by 2030 and increase global energy efficiency from 2% to 4% by 2030.**

As a first in the history of the Conference of the Parties, the 'Global Stocktake' report was presented to analyze the realisation and progress of the targets set. In the relevant report, the slow progress on climate change and lagging behind in the realisation of the targets were emphasised. As a result of the report, the countries parties decided to accelerate their processes in all areas until 2030.

- Global RE capacity to reach 11 TW in 2030
- Analyzing the realization levels of the targets through a global report
- Reaching ~200 GW of RE capacity of AFID, which is formed by +30 companies, mainly Siemens and TATA
- 'Hydrogen Declaration of Intent' signed by 37 countries

Source: IRENA, IEA, UNFCCC

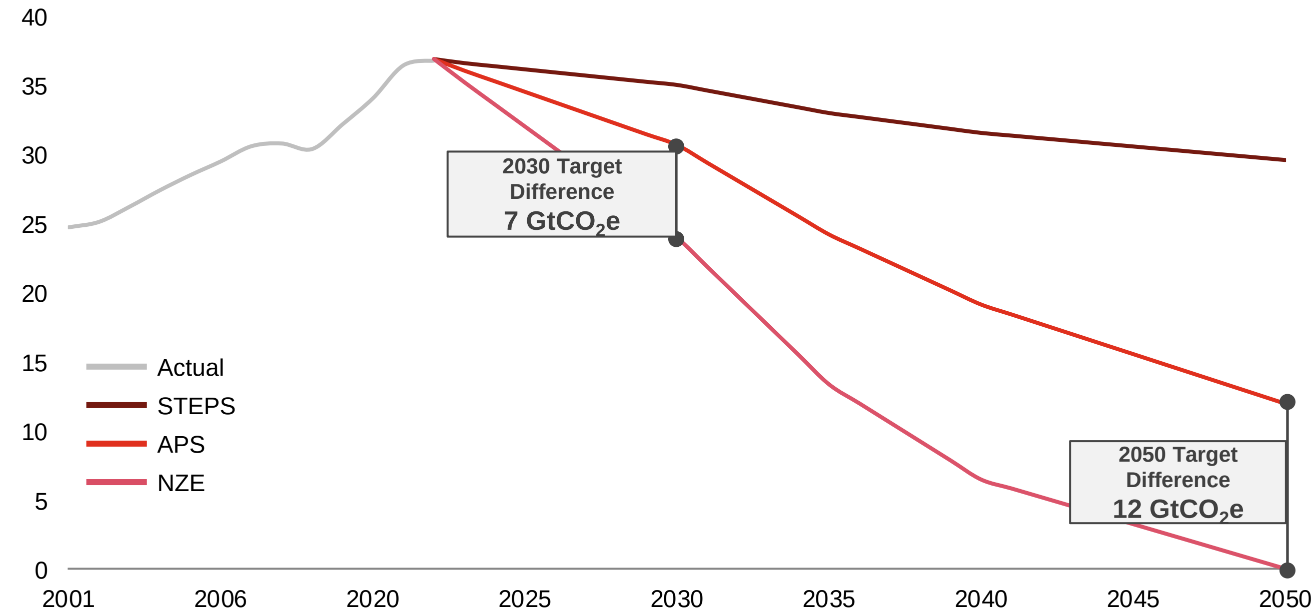
Given the updated net zero emission targets and NDCs, it is necessary to first implement the 2030 policy targets to reach the net zero emission target.

In the World Energy Outlook (WEO) report published in October 2023, IEA shared its new road map for carbon emissions, taking the updated net zero targets into account. The road map **was created using the Stated Policies Scenario** (STEPS: the scenario created based on the latest status and stated policies of each country), **the Announced Pledges Scenario** (APS: the scenario where countries are assumed to have implemented the policies announced completely and on time) and **the Net Zero Emissions Scenario** (NZE: the scenario where all policies which would limit global warming to 1.5°C will have been implemented).

Although carbon emissions continued to increase in 2021 and 2022 due to the global energy crisis, IEA assumes that APS would result in carbon emissions being only **7 $GtCO_2e$** away from the NZE in 2030 and **12 $GtCO_2e$** away in 2050.

Graph 1

Global Carbon Emissions (2001-2050, $GtCO_2e$)



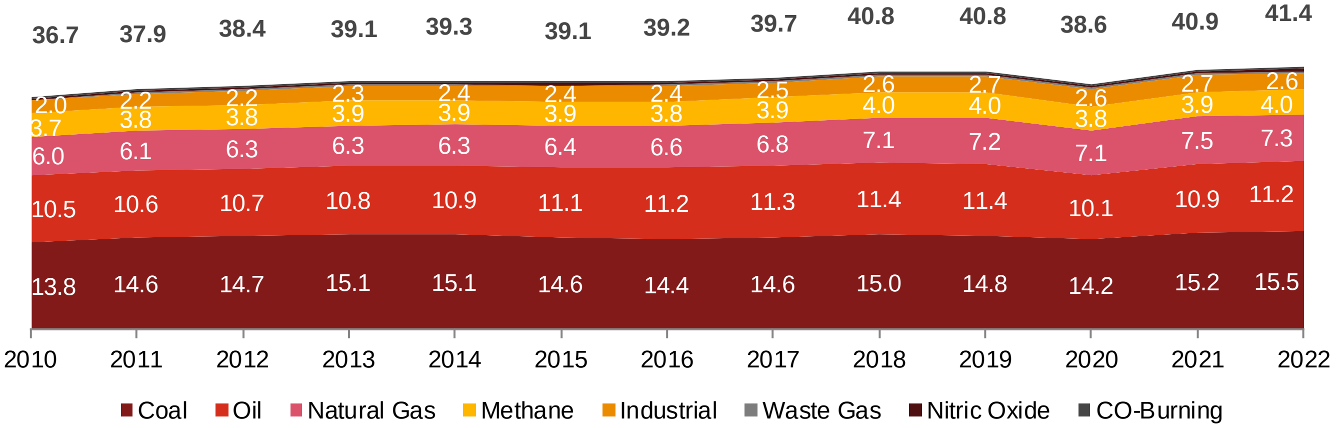
	Actual Emissions Global carbon emissions as of 2022.
	STEPS The scenario that considers the latest policies applied and actions taken by each country. STEPS assumes that the global warming will be limited to 2.4°C in 2050.
	APS The scenario predicting each country will comply with the NDCs and all other announced policies completely and on time. APS assumes that the global warming will be limited to 1.7°C in 2050.
	NZE This scenario assumes that if all net zero carbon targets are reached by 2050, global warming will be limited to 1.4°C in 2050.

Source: IEA

Country NDCs as of February 2024 in relation to their 2050 Net Zero targets are as follows.

Graph 2

Global Energy Related GHG Emissions ($GtCO_2$) **and the Latest NDCs to Reduce GHG Emissions**




Germany aims to be GHG neutral by 2045 and decrease its GHG emissions by 65% and 88% in 2030 and 2040, respectively, compared to 1990 levels.


The United Kingdom updated its NDCs to reflect increased targets. The UK aims to decrease its GHG emissions by 68% compared to 1990 levels.


Spain aims to decrease carbon emissions by at least 55% by 2030 compared to 1990 levels and to be carbon neutral by 2050.


Italy aims to decrease net GHG emissions by at least 55% by 2030 compared to 1990 levels, and take coal out of its energy mix by 2025.


Hungary aims to decrease carbon emissions by at least 40% by 2030 compared to 1990 levels and to be carbon neutral by 2050.


Poland aims to decrease carbon emissions by 65% in 2030 compared to 1990 levels and to be carbon neutral by 2050.


Argentina raised its GHG neutrality target and aims to keep its carbon emissions under 349 million tonnes in 2030 and to be carbon neutral in 2050.


Brazil updated its commitment to decrease GHG emissions by 37% in 2025 compared to 2005 and by 50% by 2030 and to zero out in 2050.


South Africa aims to decrease its coal share by diversifying its energy portfolio by 2030 and to reach net zero emission with updated NDCs by 2050.


Romania aims to increase its renewable energy resources to 30% of the total by 2030 and to gradually close coal-fired thermal power plants.


The Netherlands aims to decrease its GHG emissions by 49% by 2030 compared to 1990 levels and by 95% by 2050.


Mexico updated its previous NDC target to decrease GHG by 36% by 2030 and now aims for a 40% decrease.

Source: IEA, CAT

Rapid normalisation of the global economy after the pandemic and the 2022 Global Energy Crisis triggered by 2022 developments caused carbon emission levels to increase surpass the targets, and short- and medium-term net zero targets to be revised.

Factors and Results of the 2022 Global Energy Crisis (1/2)

Fast Economic Normalisation

With the impact of the COVID-19 pandemic decreasing at the end of 2021, the global economy normalised more than expected. The global GDP growth of 6.3% for 2021 announced by the IMF was higher than the estimations released in July 2020, January 2021, and July 2021.

Table 1

IMF 2021 GDP Estimations and Results

GDP	2021E (07/2020)	2021E (01/2021)	2021E (07/2021)	2021 GDP
World	5.4%	5.5%	6.0%	6.3%
Advanced Economies	4.8%	4.3%	5.6%	5.6%
Emerging Markets	5.9%	6.3%	6.3%	6.9%

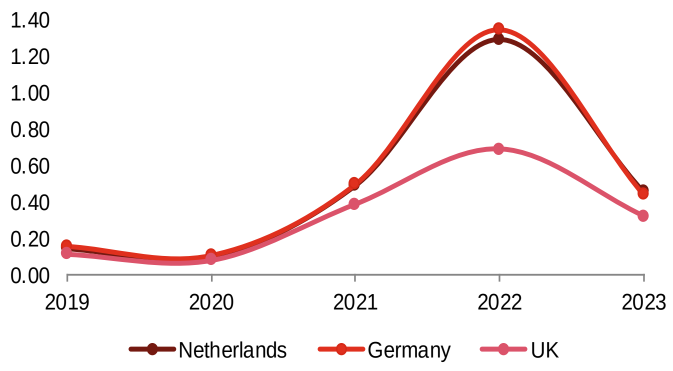
Increasing Electricity Demand and Energy Price Increases

With the rapid normalisation of the global economy, global electricity demand also increased in 2021. The global soar of commodity prices by 80%on average in 2021 compared to 2020 levels reflected in a substantial increase in the global energy prices.

As natural gas became the preferred source to supply electricity in response to the increase in electricity demand – due to having less carbon emissions compared to coal-fired power plants – the natural gas prices have experienced an upward shift since 2021. The Russia-Ukraine Armed Conflict at the start of 2022 has further fuelled the significant increase in the natural gas prices.

Graph 3

Natural Gas Prices in the Netherlands, Germany, & the UK (EUR/m³)



Global Energy Crisis and Its Impact

The rapid economic normalisation and increases in the energy prices resulted in an energy crisis which is felt globally. The crisis slowed the economic growth in 2022, led to global problems in the food industry by increasing agricultural costs, and caused energy transition plans to be reviewed.

Table 2

2021 and 2022 GDP Growth

GDP	2021	2022
World	6.3%	3.5%

Source: IEA, IMF, World Bank, Bloomberg, PwC Analysis

Rapid normalisation of the global economy after the pandemic and the 2022 Global Energy Crisis triggered by 2022 developments caused carbon emission levels to increase surpass the targets, and short- and medium-term net zero targets to be revised.

Factors and Results of the 2022 Global Energy Crisis (2/2)

Results of the Crisis

With the impact of the crisis, the global natural gas supply changed and was diversified. Similarly, Türkiye changed its natural gas supply strategy and shifted its attention on LNG imports.

As a result of the crisis, the EU took steps to decrease dependence on Russian natural gas, with LNG imports from the USA, Australia, and Qatar and natural gas imports from Azerbaijan, Algeria, and Norway were increased. This move by the EU also caused a change in natural gas supply chains in Asia.

In addition, the EU set goals for gas storage and started purchasing natural gas using a common mechanism among its members.

The crisis also resulted in the increase of the share of fossil fuels used in the global electricity generation.
In 2022, coal use increased by 1.2% globally and by 6.5% in the EU compared to 2021. Particularly in the EU and the UK, thermal plants, which were planned to be closed due to the crisis have restarted operations.

Graph 4

EU Natural Gas Storage Fill Rates

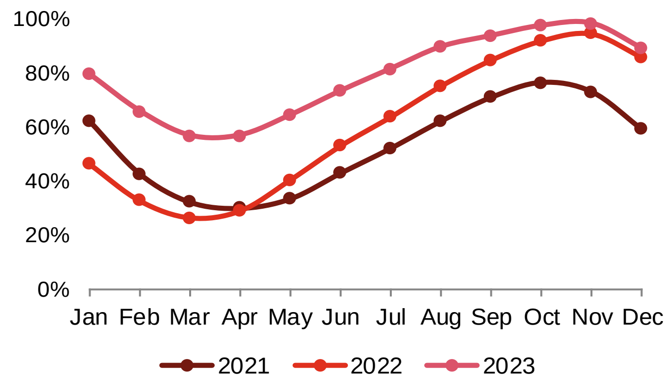


Table 3

Thermal Power Plants in the EU/UK Which Restarted Operations due to the Crisis

- 6 thermal power plants which were set to be decommissioned by 2025 received extensions.
- Thermal power plants planned to be decommissioned restarted operations.
- The capacity usage limit for thermal power plants (35%) has been removed.
- The decommissioning processes of 3 thermal power plants were cancelled and their lifetimes have been extended.

Updated Net Zero Targets

The crisis also caused a change in NDCs, which were determined on a country basis in the scope of the Paris Climate Agreement. 90% of the countries presented that had presented NDCs updated their NDCs after the 2022 Global Energy Crisis.

IEA, in its updated Road Map for Net Zero report, used a two-phase perspective and created its 2050 Net Zero road map based on short-term (2030) targets to identify steps more clearly.

Table 4

2050 Net Zero Scenario Targets

Criteria	Realisations (as of 2022)	2030 Targets (2050 NZ Scenario)
Renewable Installed Capacity	3,6 TW	11 TW
Coal Demand	5.800 Mtce	3.250 Mtce
Oil Demand	100 mb/d	77 mb/d
Nat. Gas Demand	4.150 bcm	3.400 bcm
Carbon Emissions	37 GtCO2	~ 25 GtCO2

Source: IEA, European Commission, Gas Infrastructure Europe, PwC Analysis

Carbon tariff, which is based on the ETS for industries with high carbon emissions in the European Union, will also be applied equally for exports from these industries to the EU based on the Carbon Border Adjustment Mechanism.

The Carbon Border Adjustment Mechanism (CBAM)

CBAM is a carbon tariff developed by the EU for imports into the Union from industries with high carbon emissions. It aims to implement a tariff equivalent to the carbon tariff applicable in the ETS effective as of 2005 to limit emissions of high carbon industries in the EU for exports leaving the EU. In the CBAM, carbon emission rights will be exercised via CBAM certificates, and importers will be able to trade these certificates.

The transitional period of CBAM started on 1 October 2023, and the implementation period, which will include financial obligations, will start on 1 January 2026.

CBAM's Basis: The EU Emissions Trading System (ETS)

EU ETS is an emissions cap and trade system that has been in effect since 2005. It aims to decrease emissions arising from high carbon industries in the EU. In the ETS, on which the CBAM is based, an upper emissions limit has been determined for each industry and such limits are divided into emission allowances called EU Allowance – EUA (1 EUA = 1 tonnes CO_2 equivalent emissions). **Allowances granted in the scope of the ETS are reduced every year to reduce emissions in the EU, and are mostly allocated by auction. Allowances granted for free will be eliminated at the beginning of the CBAM implementation period.**

The CBAM aims to prevent carbon leakage arising from producers in the EU who fail to decrease emissions sufficiently due to the ETS practice and who therefore shift their production to countries with more flexible emissions rules than the EU or aim to make high carbon emissions exports from outside the EU.

Industries Within CBAM Scope

- Iron and Steel
- Fertilizer
- Aluminium
- Electricity
- Cement
- Hydrogen

Of the products to be imported into the EU from the specified industries,

*(1) carbon emissions occurring during production **(direct emissions)** and*

*(2) carbon emissions occurring in the production of electricity used during production **(embedded emissions)***

are included in the scope of the CBAM.

Brief History of the CBAM

2020 The EU presented the European Green Deal and announced it will reach net zero GHG emissions in 2050 and will be the first continent to reach this target.

2021 The Fit for 55 policy package, which envisions decreasing GHG emissions by 55% in 2030 compared to 1990 and includes the CBAM, was accepted.

May 2023 - Oct 2023 The European Parliament approved the CBAM with a majority vote, and the CBAM was promulgated in the EU Official Gazette and entered into force as a law.

As of 1 October 2023, the transitional period, which is the first phase of the CBAM covering 1 October 2023 – 31 December 2025, officially began.

Source: Turkish Ministry of Trade, European Union

In the CBAM transition period, reporting obligations are imposed only on a quarterly basis, and as of 1 January 2026, the financial obligation phase will begin with the use of CBAM certificates.

Steps to be Taken in the Transitional Period

During the transition period between 1 October 2023 and 31 December 2025, exporters **will only be subject to quarterly reporting obligations.** The aim of the transition period is to establish the principles of CBAM practices, gather data based on reporting obligations, and perform system improvements using this data in the implementation period when the financial obligations of the CBAM will start.

CBAM Reporting Elements

Of the products to be exported to the EU:

- **HS codes by product**
- **Total export volumes**
- **Direct and embedded emission amounts**
- **Processes used in production and details**
- **Information on where they will be used**
- **Detailed country of origin information**
- **Carbon taxes that have already been paid to other countries**
- **Carbon taxes to be paid to other countries**

Until 1 January 2025, exporters will conduct the CBAM reporting using three different emissions calculation methods. As of 1 January 2025 solely the EU's calculation method will be used.

Starting from 2026: CBAM Implementation Period

At the end of the transition period, products included in the scope of the CBAM will be exported **only by the Authorized CBAM Declarant.** Additionally, in the implementation period, exporters must record CBAM notices on the CBAM Central Electronic Registry System, which covers the whole EU, for direct and embedded emissions of exported products **annually** (by 31 May of each year) and must submit CBAM certificates equal to the total emission costs.

Exporters of industries included in the scope of the CBAM may obtain CBAM certificates corresponding to their emissions from the competent authority of the EU country for the exports. The CBAM certificates are priced based on the existing weekly EUA numbers for each industry. (1 CBAM certificate = 1 tonnes CO_2 equivalent emission = 1 EUA)

The Authorized CBAM Declarant of the importer declares the direct and embedded emissions of the imports and submits certificates corresponding to the declared emissions.

If the importer could prove that carbon tariff has been paid in another country for the relevant import, the CBAM obligation is discounted based on the already paid carbon tariffs.

Impacts of the CBAM in Türkiye

With the start of CBAM transition period reporting, several companies in Türkiye which have high embedded carbon emissions based on electricity consumption and which operate in the industries included in CBAM's scope aim to generate the electricity utilised in the production process from renewable resources and accordingly decrease their carbon emissions before the Implementation Period.

Such companies which generate electricity from renewable resources for their own consumption tend towards establishing unlicensed solar power plants. Accordingly, it is predicted that unlicensed SPP capacity in Türkiye will continue to increase with CBAM's implementation.

Source: Turkish Ministry of Trade, European Union

Türkiye updated its NDC in 2023 and raised its 21% mitigation from increase target to 41%.

Graph 5

Türkiye's NDC

2015
The first NDC was presented.

2021
Türkiye became a party to the Paris Climate Agreement.

2021
Türkiye announced its Net Zero Emission and Green Development targets.

2023
Türkiye updated its NDC.

Türkiye accepted the Paris Climate Agreement at COP21 but did not start the process of becoming a signatory party during the initial acceptance. The first NDC was presented in 2015. In the first NDC, which used 2012 as the reference year, Türkiye committed to reducing its GHG emission increases by 21% by 2030.

After becoming a party to the Paris Climate Agreement in **October 2021**, Türkiye announced **the 2053 Net Zero Emission and Green Development** targets.

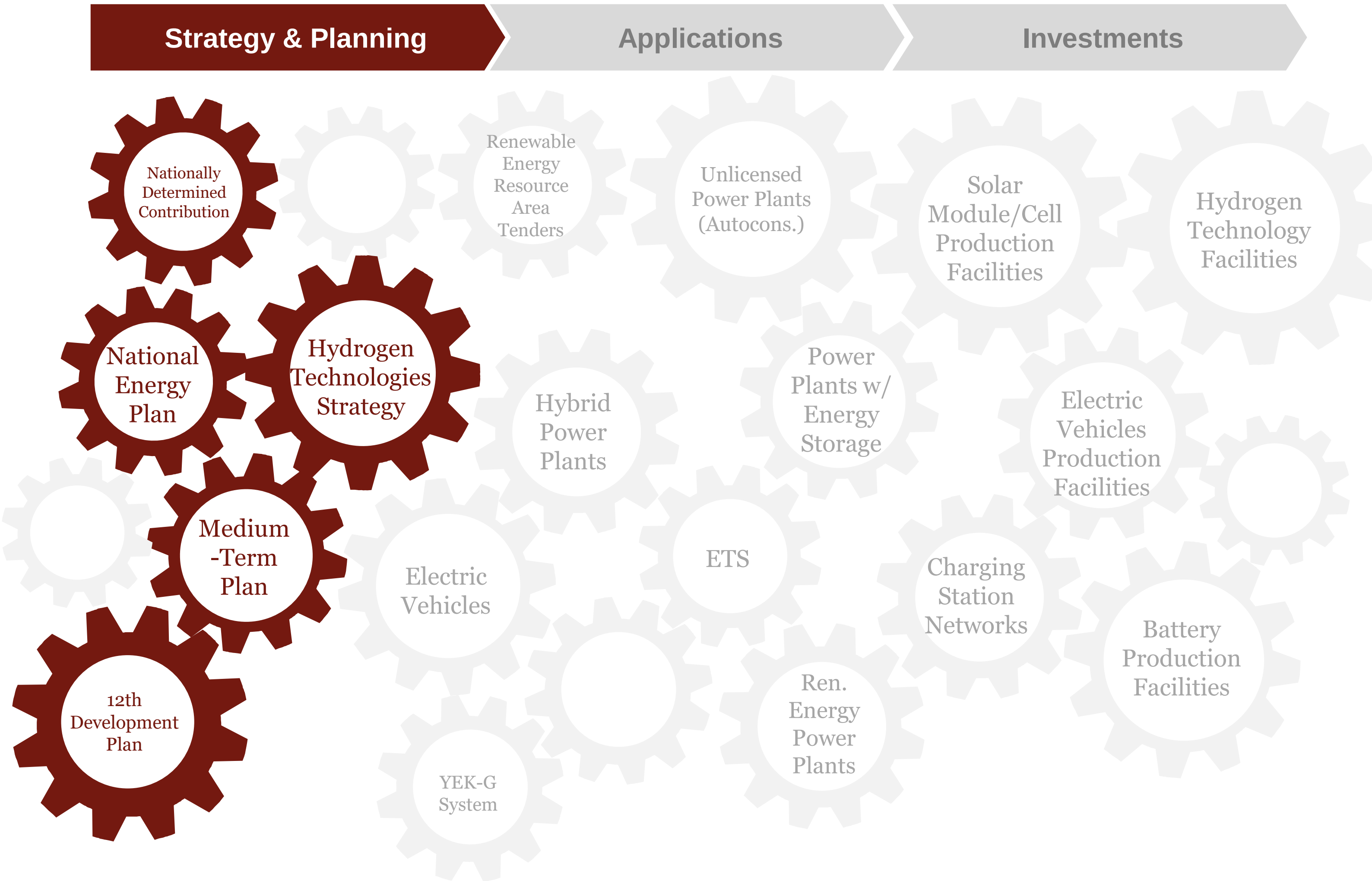
In **April 2023**, Türkiye **updated its NDCs** within the scope of COP27 and raised its 21% emission mitigation from increase commitment for 2030, which was announced in 2015, to 41%. 2038 was identified as the year in which emission levels would be highest. The updated NDC includes sector strategies, and covers mitigation and compliance plans in energy, industry, transportation, agriculture, building, waste and land use, land use change, and forestry (LULUCF).

As it is necessary for countries party to the Paris Climate Agreement to change their NDCs every five years by increasing their targets, Türkiye is expected to present its second NDC before COP30 which is planned for the end of 2025.

	Initial NDC - 2021	Updated NDC - 2023
GHG Emission Targets	21% Mitigation from Increase	41% Mitigation from Increase by 2030
Emissions Level (2030, Excl. LULUCF)	999 MtCO2e	763 MtCO2e
Emissions Compared to 1990 & 2010 (Excl. LULUCF)	355% Above 1990 Emissions by 2030 151% Above 2010 Emissions by 2030	247% Above 1990 Emissions by 2030 91% Above 2010 Emissions by 2030
Determined After	Paris Climate Agreement	Glasgow Climate Pact
Industry Coverage	Economy-Wide	Unchanged
Gas Coverage	All Greenhouse Gases	Unchanged

Source: The Ministry of Energy and Natural Resources, CAT

To support Türkiye's 2053 Net Zero Emission and Green Development Targets, several strategies and plans were developed, various applications were identified, and investments in selected areas are being carried out.



After its announcement of becoming a party to the Paris Climate Agreement in 2021, Türkiye declared its **2053 Net Zero Emission** targets. In December 2022, the Turkish state published its **National Energy Plan,** supporting the net zero targets. The National Energy Plan identifies actions to increase the share of renewable energy in the scope of Türkiye's Net Zero targets and highlights priorities. The plan aims to increase renewable energy installed capacity in the first stage and emphasizes investments in other technologies that will help reduce emissions, particularly hydrogen and efforts & plans on energy efficiency, using domestic resources. Additionally, as of April 2023, Türkiye's **NDC** was updated and the target for mitigation from increase for 2030 was increased to 41%.

The Medium Term Programme published in September 2023 includes economic, social, and environmental targets for the 2023-2026 period and policies regarding these targets, and also covers the Green Transformation programme, which is in line with Türkiye's net zero emission targets. Applications regarding climate change were handled holistically and the importance of decreasing Türkiye's dependence on foreign sources for energy using renewable energy was emphasized. The 12th Development Plan published in October 2023 stated the policies introduced in the National Energy Plan and the Medium Term Programme would continue as planned.

Source: Publicly Available Resources

The National Energy Plan published in May 2022 is a road map drawn for the period through 2035 from the perspective of the Ministry of Energy and Natural Resources to support Türkiye's 2053 Net Zero Emission targets.

Türkiye announced its 2053 net zero emission and green development targets upon being a party to the Paris Climate Agreement in October 2021. The National Energy Plan published in December 2022 summarises the targets to be met by 2035 from the perspective of the Ministry of Energy and Natural Resources to support the 2053 vision. The National Energy Plan will be renewed every five years.

The National Energy Plan projects that as of 2035, electric consumption will be 510.4 TWh (2023: 322 TWh)[1], and installed capacity will be 189.7 GW (2023: 107 GW)[1].

It is estimated that the installed **renewable energy** capacity will be **65%** of total installed capacity in 2035. ***It is predicted that solar energy occupy the largest share among all renewable energy installed capacity, with a share of 43%.***

Energy density between 2000 and 2020 decreased by 25%, and in the scope of the National Energy Plan it is projected to have **decreased by 51%** in 2035 compared to 2000. This rate projected for Türkiye for the 2020-2035 period is similar to the rates projected for Germany and France.

It is projected that a domestic coal plant with 1.7 GW installed capacity will be included in the system by 2030. There is no plan for eliminating coal.

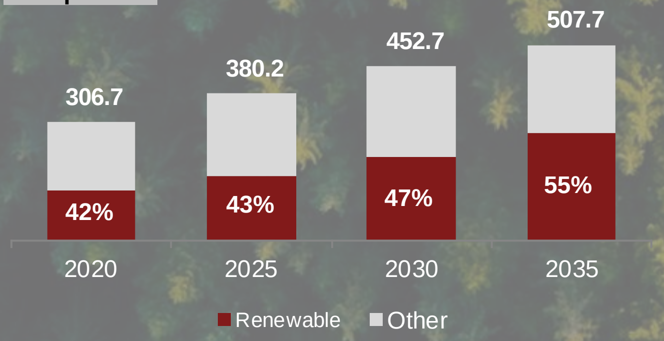
According to the National Energy Plan, the most significant **fundamental targets** in 2035 are as follows:

	Inst. Capacity	Share of Ren. Energy (%)
	52.9 GW	43%
	35.1 GW	29%
	29.6 GW	24%

As renewable energy installed capacity increases, intermittent electricity generation also increases, raising the need for battery-storage capacity which provides system flexibility. It is expected that battery capacity will reach 7.5 GW and electrolyzer capacity will reach 5.0 GW in 2035 in order to meet the flexibility requirements.

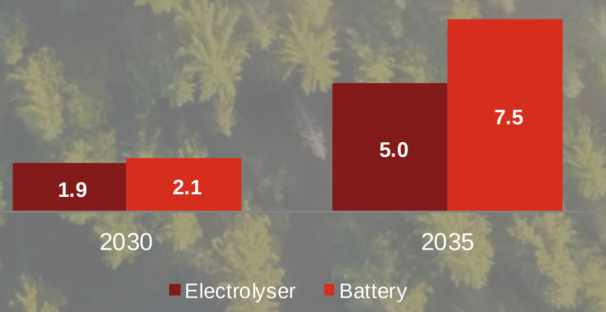
Electricity Generation Targets (TWh), Share of Renewable Energy (%)

Graph 6



electrolyzer and Battery Capacity (GW)

Graph 7



Source: Türkiye National Energy Plan, EMRA, TEİAŞ

[1] *Year end data for 2023.*

Türkiye's Hydrogen Technologies Strategy and Road Map published by MENR in January 2023 emphasises the importance of hydrogen technologies to the 2053 Net Zero Emission targets and outlines Türkiye's goals and plans in this area.

Hydrogen energy is a chemical energy released in molecules as a result of the decomposition of pure hydrogen. This energy can be converted into thermal and electric energy using different methods.

Hydrogen possesses different names based on how it is obtained. The output of produced hydrogen through renewable energy is called Green Hydrogen, whereas the hydrogen resulting from the decomposition of the fossil fuels is referred to as Blue Hydrogen. Hydrogen is crucial for sustainability and clean energy production in the energy industry and is considered an important alternative for decreasing dependence on fossil fuels and for reducing carbon emissions.

The Hydrogen Technologies Strategy and Road Map aims to perform studies to develop and spread hydrogen technologies and strengthen Türkiye's hydrogen infrastructure.

Installed Capacity Targets
electrolyzer installed capacity is expected to reach **2 GW** by **2030**, **5 GW** by **2035** and **70 GW** by 2053.

Production Costs
Hydrogen production costs are expected to be approx. **2.4 USD/kgH** by 2035, and decrease to **1.2 USD/kgH** by 2053.

First Priority Industries
Implementation of **incentive mechanisms** to spread **hydrogen use** in carbon-heavy industries

R&D Support Mechanism
R&D support mechanisms regarding **domestic resource use in hydrogen production and storage**

Public-Private Partnership
Prioritising **public-private partnership** to increase productivity and commercial demand

Green Hydrogen and Ammonia
Focusing on green hydrogen and ammonia exports to Türkiye's commercial partners

As a first step in the transition to hydrogen energy, the HYSouth Marmara Hydrogen Valley Project and South Marmara Hydrogen Shore Platform Guided projects in Balıkesir will be implemented.

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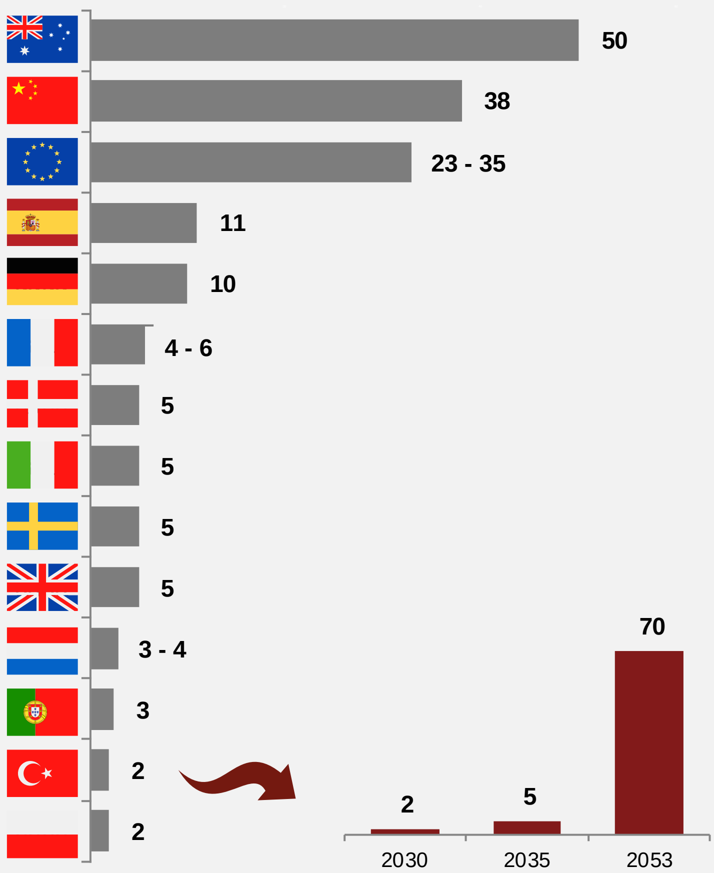
Graph 8

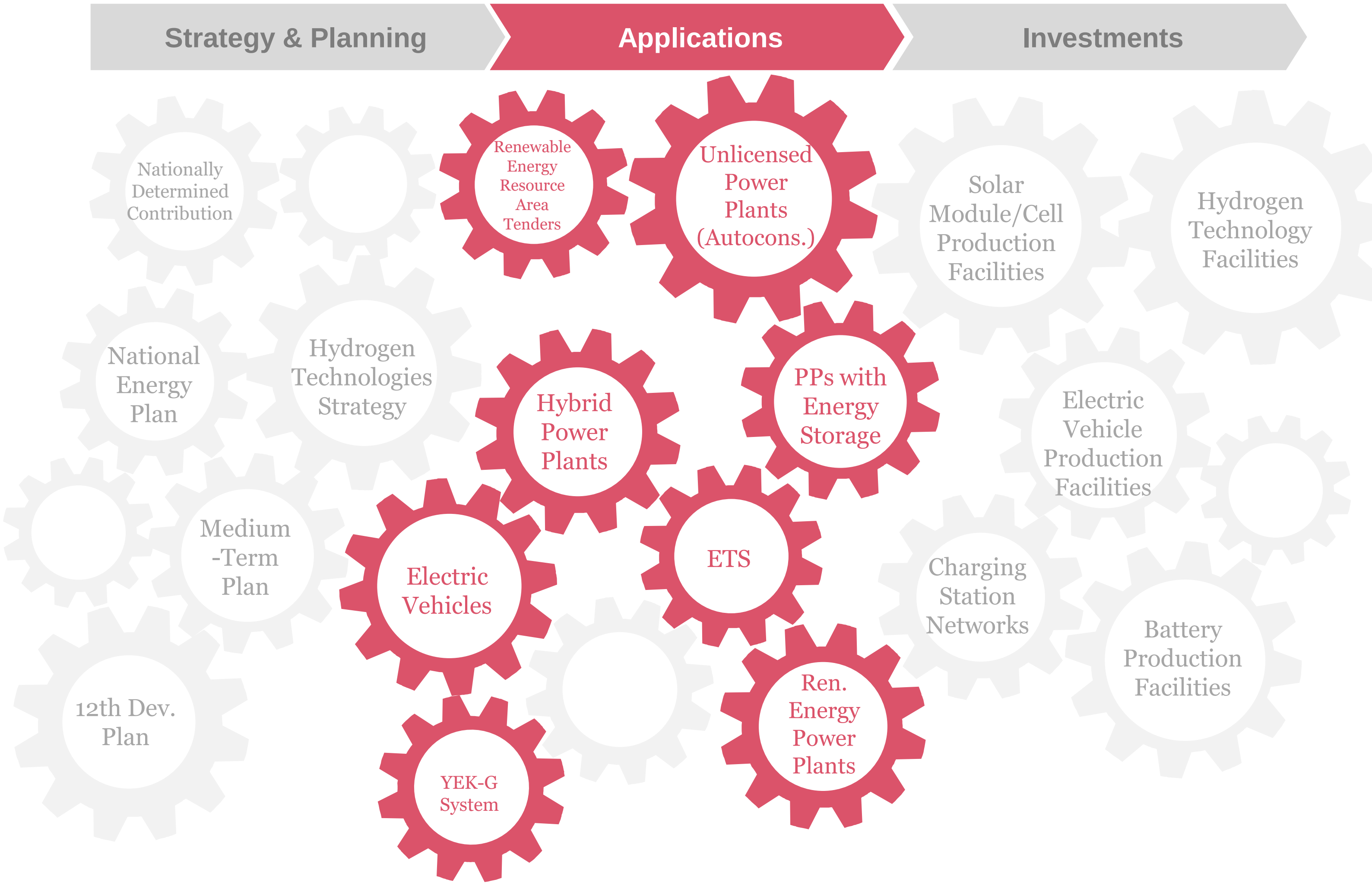
Although countries are still in the start-up stages for hydrogen plants, many have started to invest in this area. Countries' **electrolyzer capacity targets (GW)** for 2030 are as follows:



*Within the scope of the 2053 Net Zero Targets, the aim for Türkiye's electrolyzer installed capacity is to reach **70 GW**.*

Source: MENR

In addition to increasing renewable energy capacity within the scope of 2053 Net Zero emission targets, practices and investments were implemented to increase electrification in order to reduce carbon emissions.



Applications Supporting the Increase of Renewable Energy Installed Capacity

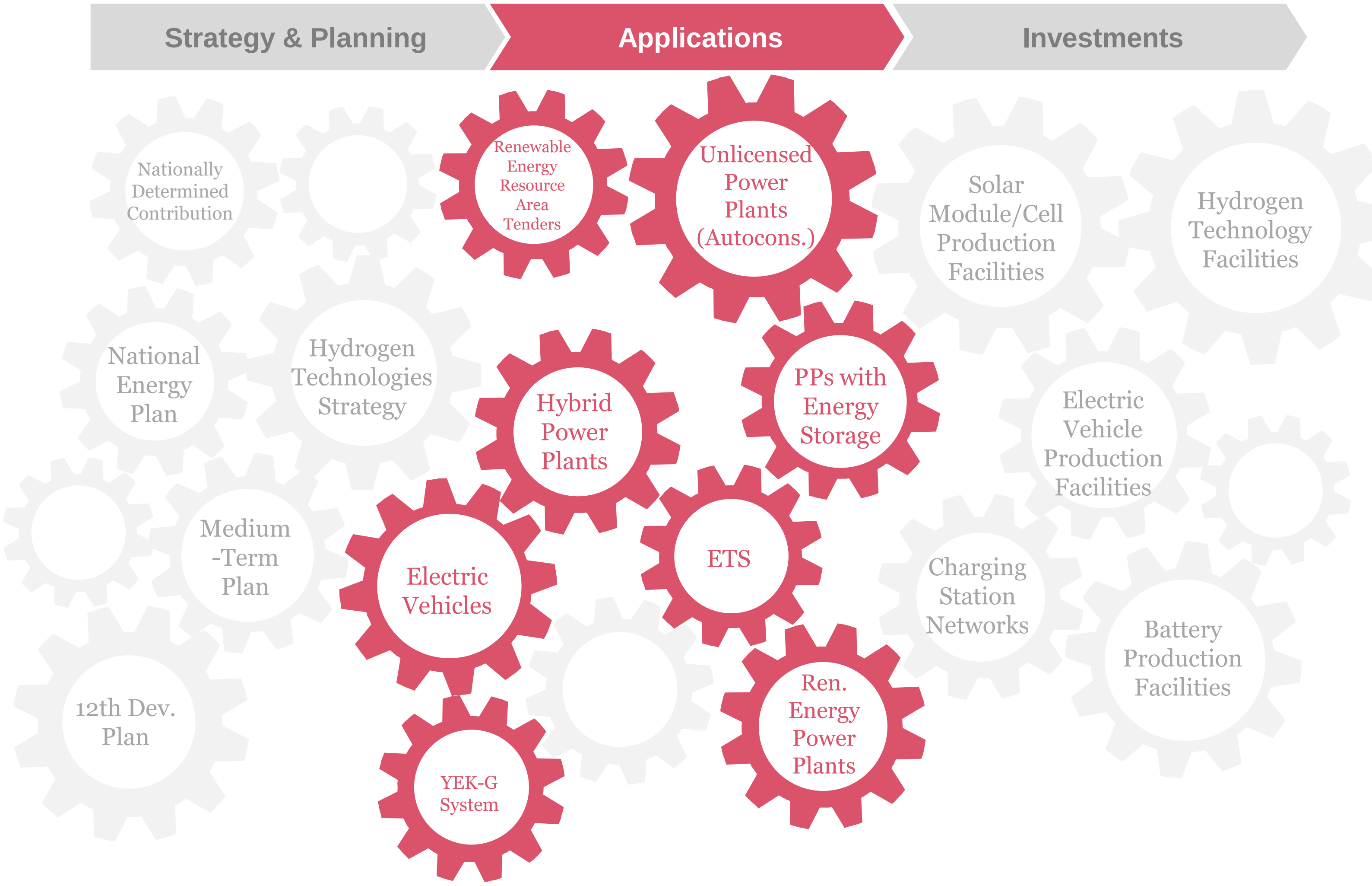
1. Renewable Energy Resource Area Tenders
2. Hybrid Power Plants
3. Power Plants with Energy Storage
4. Renewable Energy Resource Guarantee and ETS

Applications Supporting More Widespread and Distributed Use of Electricity

1. Unlicensed Power Plants
2. Electric Vehicles

Source: Publicly Available Resources

In addition to increasing renewable energy capacity within the scope of 2053 Net Zero emission targets, practices and investments were implemented to increase electrification in order to reduce carbon emissions.



Renewable Energy Resource Area (YEKA) Tenders

The YEKA tenders, which have recently arisen as the most significant source for increasing Türkiye's licensed electricity generation based on renewable energy sources, were first held in 2017. Further iterations between 2021-2023 were designed to include more investors. On aggregate, **3 YEKA tenders and 2.85 GW of installed capacity for WPPs** alongside **3 YEKA tenders and 3 GW of installed capacity for SPPs** were held. The Medium Term Programme and the 12th Development Plan highlight that YEKA tenders are planned to be a main factor in Türkiye's green transformation by taking the localization rate of the tenders into account.

Hybrid Power Plants

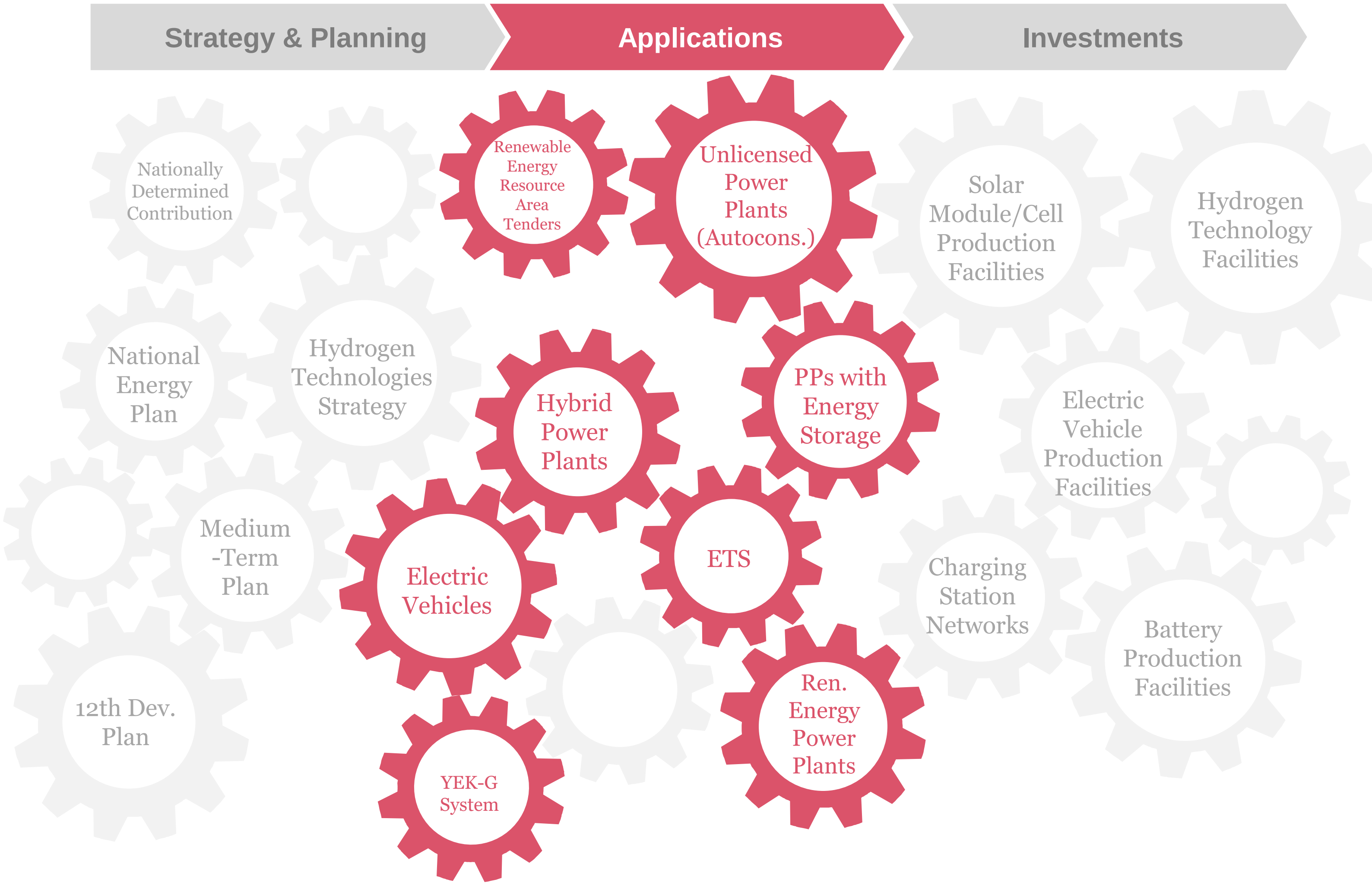
Regulations regarding hybrid power plants were arranged in the decision promulgated in the Official Gazette in November 2022.

As of February 2024, there are **247 licensed hybrid power plants** with the secondary resource of **246** of hybrid plans being **solar energy**.

Total secondary resource installed capacity of the licensed hybrid power plants reached **2.5 GW**. **0.5 GW** of these plants are currently in operation and **c. 1.9 GW** are expected to commence operations in the near future.

Source: The Ministry of Energy and Natural Resources

In addition to increasing renewable energy capacity within the scope of 2053 Net Zero emission targets, practices and investments were implemented to increase electrification in order to reduce carbon emissions.



Power Plants with Energy Storage

EMRA started accepting pre-license applications for power plants with energy storage in November 2022 and granted the first pre-license in April 2023.

> 575
Total Pre-license[1]

	c. 355 Pre-licensed SPP with Storage	**c. 13.6 GW** Pre-licensed Capacity
	c. 220 Pre-licensed WPP with Storage	**c. 15.7 GW** Pre-licensed Capacity

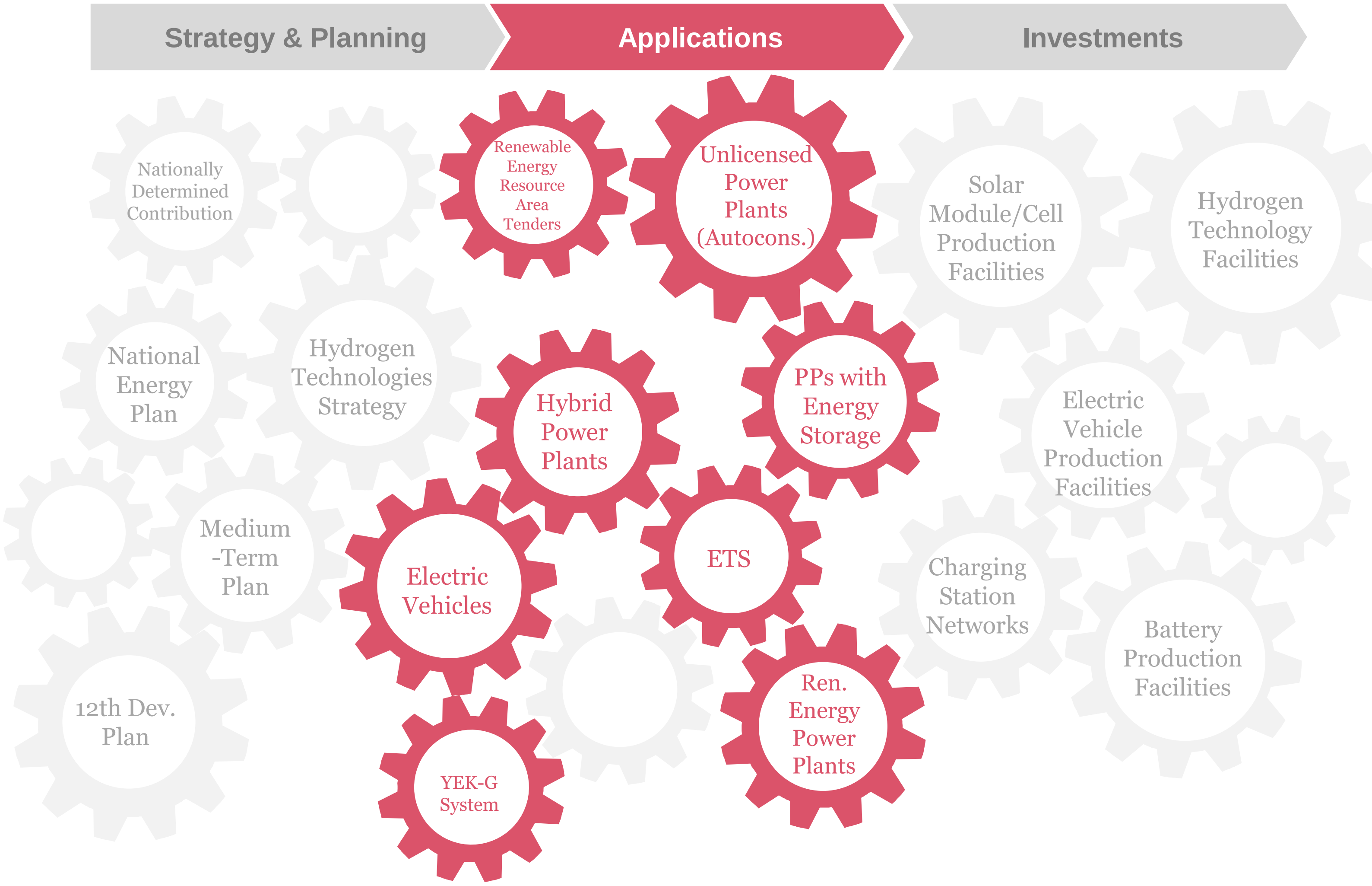
Unlicensed Power Plants

Unlicensed power plants account for **c. 10% of Türkiye's total installed capacity** with **10.7 GW** of installed capacity. Approximately **93% of the unlicenced capacity belongs to solar**.
The aim of the regulation changes in the 2019-2022 period was to reduce electricity generation from unlicensed power plants towards autoconsumption for all end users. Accordingly, companies wishing to save on electricity costs, protect themselves from price fluctuations in commodities that have fossil fuel sources, reduce carbon emissions, and be competitive in markets in developed countries prioritise unlicensed power plant investments (of which unlicensed SPPs form an overwhelming majority).

[1] *Data on power plants with energy storage are shown as of February 2024.*

Source: MENR

In addition to increasing renewable energy capacity within the scope of 2053 Net Zero emission targets, practices and investments were implemented to increase electrification in order to reduce carbon emissions.



Electric Vehicles (EV) and Electric Vehicle Charging Stations

The transportation industry is responsible for approximately 23% of carbon emissions in Türkiye and more than 90% of the emissions arise from road transportation. Therefore, to achieve net zero emission targets it is important for electric vehicle usage to be widespread. In addition to developments in electric vehicles and battery technologies, incentives like Special Consumption Tax (SCT) discounts that support transformation were granted and regulatory publications like the Draft Regulation on Charging Station Services were prepared.

While **electric vehicles sales** in Türkiye constituted **c. 0.5%** of overall automobile sales in **2021**, in 2023 they accounted for an average of **7%** and reached **13% for all time high in September 2023.** In November 2023, the basis of 10% SCT for electric vehicles with an engine power below 160 kW was increased from TRY 1.25 million to TRY 1.45 million. With another regulation made in the same month, the obligation to have a service in Türkiye and a resident representative was introduced for electric vehicles to be exported to Türkiye from all other countries except the EU and the countries that have a Free Trade Agreement with Türkiye.

As of January 2024, the total number of electric vehicles sold in Türkiye is close to 87,000. As of February 2024, the number of charging stations has reached approximately 6,700 and the total number of sockets in these stations has reached approximately 15,000, with 1 charging socket per 6 electric vehicles.

__The National Energy Plan__ foresees that the market share of electric vehicles will reach __25%__ by __2030__. In this context, the number of electric vehicles is expected to reach 1.6 million, while the number of electric vehicle charging stations is projected to reach 100,000.

Source: MENR, Istanbul Policy Center, Automotive Distributors and Mobility Association

Building on the Renewable Energy Resource Guarantee System, started in 2021 within Türkiye's Net Zero targets to certify electricity is produced from renewable resources, there is a plan to establish a domestic ETS based on the EU model to limit carbon emissions.

The YEK-G System

The Renewable Energy Resource Guarantee (YEK-G) System, which has been active since **June 2021**, was designed to track all stages of electricity produced from renewable resources. Companies holding a renewable energy production and supply license may participate in the system on a voluntary basis. Renewable Energy Resource Guarantee System certificates may be issued for each 1 MWh of electricity, are internationally recognised, and may be used for carbon footprint calculations.

YEK-G System Certificate Exchange Methods

Bilateral Agreements

The certificates are transferred via agreements signed by system users and are reported to Energy Exchange Istanbul (EXIST).

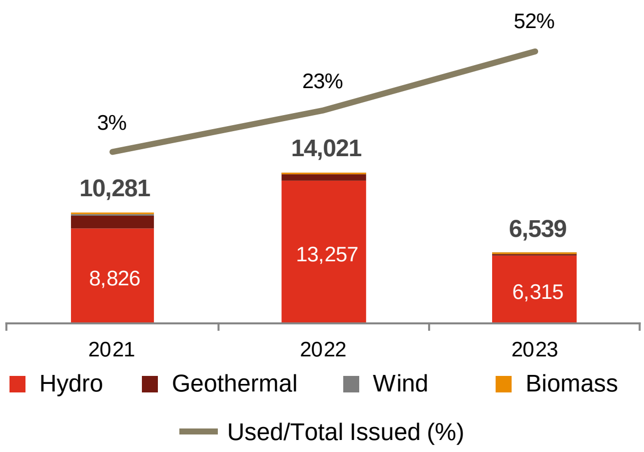
Organized Renewable Energy Resource Guarantee System Market

System users may exchange the YEK-G System certificates in the organized market.

If a YEK-G System certificate is not processed for use within 12 months of the production period, the certificate is cancelled. Expired certificates are destroyed and are not processed for any other use.

Graph 9

Total Capacity of YEK-G System Certificates Issued in the Organized Market (GWh)



Domestic ETS Efforts

EMRA has recommended establishing a domestic carbon market to promote reduction of GHG emissions in a cost effective and productive manner. There is a plan to allocate carbon emission allowances in a domestic ETS similar to the EU's own ETS mechanism.
EMRA prepared the Draft Regulation on Operating Carbon Markets for a domestic carbon market system and intended to collect public opinions and ideas. It is predicted that the draft regulation will be finalised in the following months to establish a domestic carbon market.

YEK-G System Certificate

Documents that the electricity used has been produced from renewable energy resources and certifies the source of the electricity.

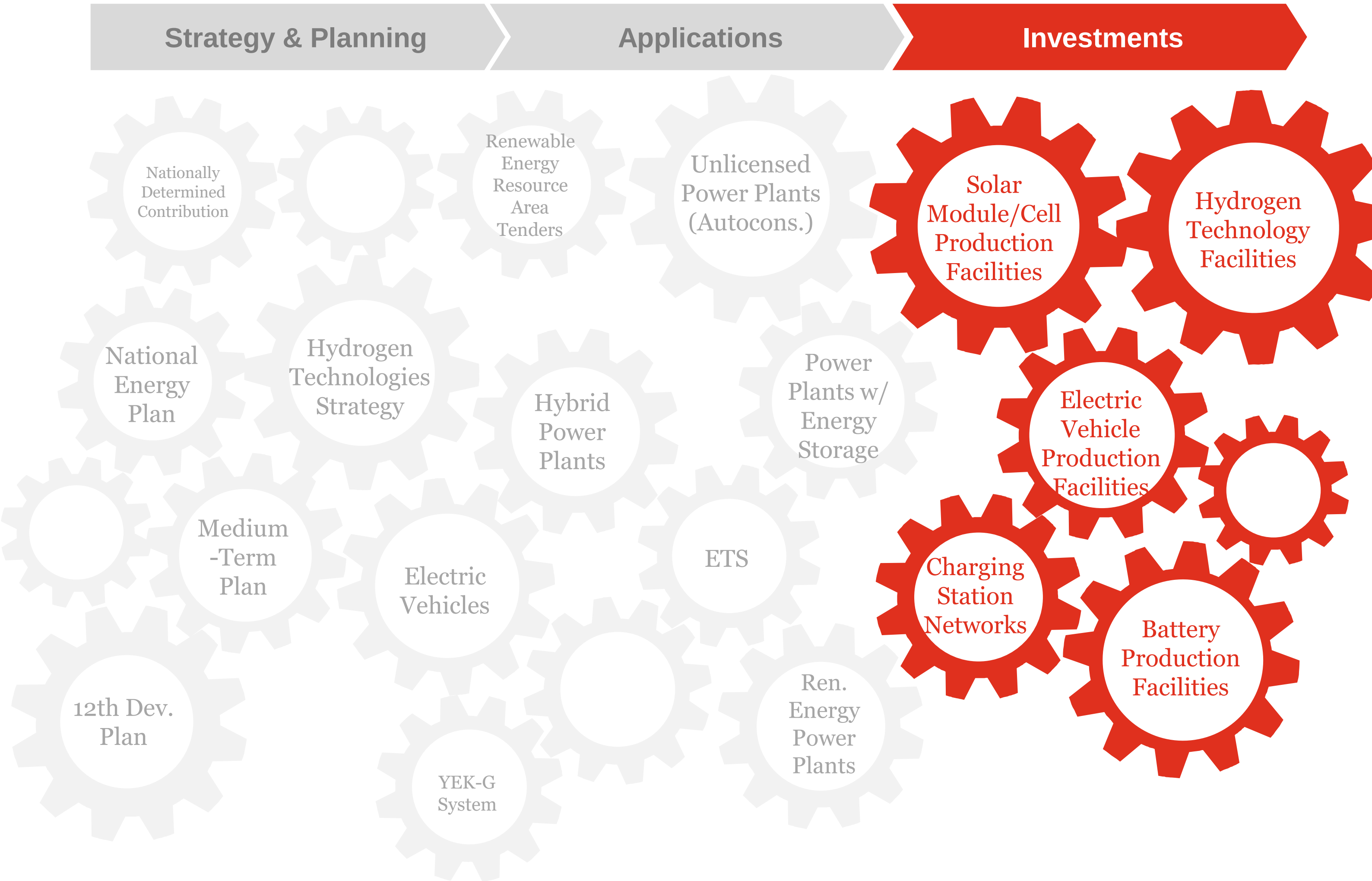
Domestic ETS

Designed as a carbon market and proposed to be built based on the EU's ETS. It was created specifically for carbon emissions.

Both the Renewable Energy Resource Guarantee System and domestic ETS applications are planned as part of renewable energy transformation within the scope of Türkiye's net zero targets. Therefore, it is predicted that these two processes will support each other and will continue in both medium and long term policies.

Source: EXIST, EMRA, PwC Analysis

In addition to increasing renewable energy capacity within the scope of 2053 Net Zero emission targets, practices and investments were implemented to increase electrification and develop hydrogen technologies in order to reduce carbon emissions.



Solar Module/Cell Production Facilities	Increase in the renewable energy installed capacity and supporting policies have resulted in Türkiye obtaining facilities capable of producing solar cells. Solar industry participants continue their investments in additional cells and modules.
Hydrogen Technology Facilities	For the transition to a hydrogen-based economy, R&D activities take place in different regions and partnerships are formed to develop the production and utilization areas of different hydrogen technologies.
Electric Vehicle Production Facilities	Increasing the share of EVs in Türkiye's vehicle parc became the main goal, in line with transport electrification targets. Accordingly, local venture TOGG commenced operations with Ford Otosan, Toyota, and TEMSA also manufacturing EVs locally.
Charging Station Networks	As the number of EVs in Türkiye's vehicle parc increase, EV charging stations (EVCS) gained widespread importance. EVCS participants in Türkiye have created a charging network ecosystem with a total of 6,700 charging stations.
Battery Production Facilities	Currently, Pomega and Aspilsan's battery investments commenced operations. In addition to these initiatives, other players such as YEO/Reap Battery and TOGG/Siro are also progressing in their battery production facility investments.

Source: Publicly Available Resources

Given the increase of renewable energy installed capacity, investments in solar modules and battery production are critical to lower Türkiye's dependence on foreign sources.

Prominent Solar Cell and Module Investments of Türkiye

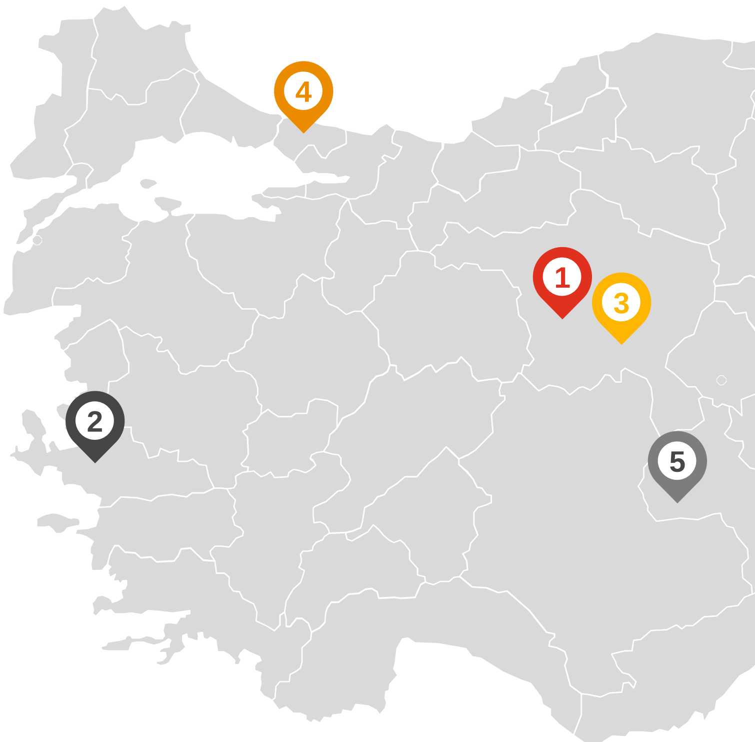
Numerous companies in Türkiye produce solar modules and continuously increase production capacities. Kalyon PV, with its fully-integrated solar module & cell production facility stand out from the rest of the participants.

1 Kalyon PV

Kalyon PV was established by Kalyon Holding in Ankara to build **a fully-integrated solar module production facility** to satisfy the requirements of YEKA SPP-1 tender. Kalyon PV's solar module and cell production facility is one of the very few fully-integrated module production facilities in the world & sole in Europe. R&D activities are also performed in the facility.

2 Smart Solar

Founded in 2014, Smart Solar produces solar modules through its production facilities based in Gebze and Dilovası. Within its recently-completed newest facility in İzmir/Aliağa, Smart Solar aims to manufacture **solar cells** alongside module manufacturing.



Prominent Battery Investments

Several energy and technology companies have started focusing on battery production facilities in Türkiye, thus accelerating the processes for facility investments.

3 Pomega Energy Technologies

Pomega, a subsidiary of Kontrolmatik Technologies, invests in LFP battery cells and energy storage systems with a 3 GWh-capacity facility in Ankara/Polatlı. Pomega plans to produce LFP battery cells and packages, hybrid energy solutions, and EV charging support systems. Phase 1 of the factory (0.7 GWh) was competed as of **2023.**

4 Reap Battery

Reap Battery was founded as a subsidiary of YEO Teknoloji in İstanbul/Tuzla to develop energy storage technologies by investing in a new production facility. Reap Battery, which plans to offer large-scale energy storage solution systems, aims to start mass production in the second half of 2024 and reach 1 GWh capacity within the first year.

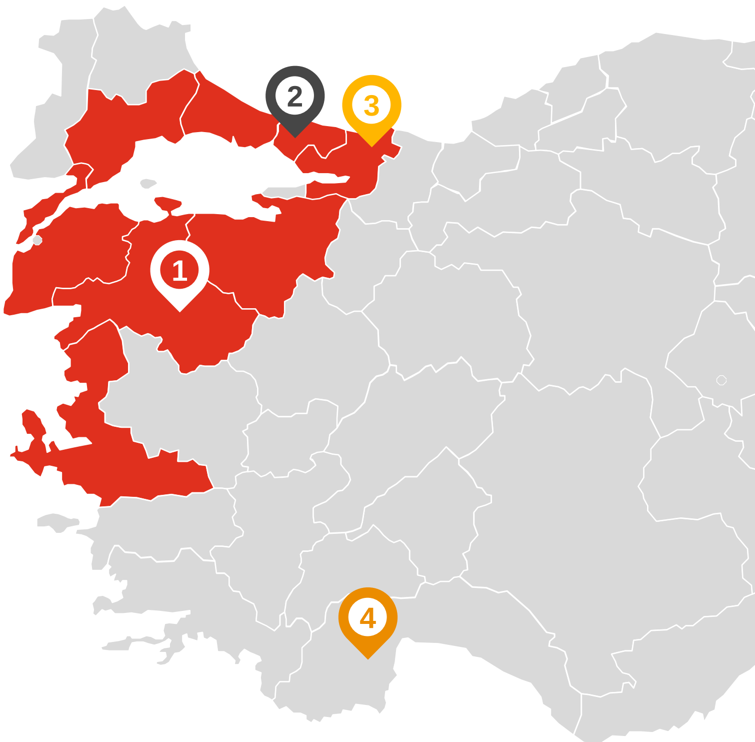
5 Aspilsan

Aspilsan Enerji established **Türkiye's first lithium ion battery production facility** in Kayseri. With a 220 MWh production capacity, the installation of the facility started in October 2020, and the facility started mass production as of June **2022** and is the first company in Europe to mass produce lithium ion batteries.

Source: Publicly Available Resources

With the National Hydrogen Technologies Strategy and Roadmap, investments and focus on green hydrogen are expected to accelerate in Türkiye.

The South Marmara Hydrogen Shore (HYSouth Marmara Valley Project) and South Marmara Hydrogen Shore Platform Guided Projects are significant projects in the hydrogen production and technology areas of Türkiye.



1 S.Marmara Hydrogen Shore and S.Marmara Hydrogen Shore Platform

Also known as the HYSouth Marmara Valley Project, this project is considered to be the first step of the transition to hydrogen energy, and is expected to take 5 years. Enerjisa Üretim aims to produce 500 tonnes of green hydrogen annually in the Bandırma Energy Base, and plans to use this hydrogen in facilities in South Marmara. It also aims to produce methanol and ammonia, for which Türkiye is dependent on foreign sources, using green methods. In the scope of the project, solid-phase hydrogen storage work will continue as a result of investing in sodium borohydride production.

Under the **Guided Project** the plan is to build the first domestic green hydrogen production facility in the Bandırma Energy Base. A feasibility study of the first green industry and hydrogen training centre in Türkiye will be conducted.

2 Hydrogen Technology R&D Project

The SOCAR Türkiye R&D and Innovation Centre and Sabancı University are cooperating on Hydrogen-based technology work.

The project aims to reduce electrolyzer cost and increase productivity and lifetime.

3 TÜPRAŞ Green Hydrogen Project

TÜPRAŞ plans to **produce green hydrogen** in its solar power plants in **Kırıkkale** and **Batman** in 2025 and to sell the green hydrogen to **logistics** and **transportation** industries.

4 GAZBİR Hydrogen Project

The **Hyvillage** project, a hydrogen **R&D laboratory**, was built in 2021. According to research, **up to 20%** of a natural gas mixture may be composed of hydrogen. The purpose of the Hyvillage project is to mix a certain amount of **hydrogen into natural gas** and supply the gas mixture to houses, test laboratories, and central heating system test laboratories.

Source: Publicly Available Resources

The increase in the electric vehicle market share renders investments in electric vehicle charging stations critical.

Zorlu Energy Solutions – ZES

Launched in 2018, ZES is the provider with the highest number of charging stations in Türkiye. In September 2022, 51% stake in ZES was acquired by Kuwait Wealth Fund.

Establishment: 2018

Total Charging Stations[1]: 1,689

AC Charging Plugs[1]: 3,004

DC Charging Plugs[1]: 429

Charging Station Market Share: c. 29%

Eşarj

Eşarj was founded in 2008 and the majority of its shares were purchased by Enerjisa Enerji in 2018.

Establishment: 2008

Total Charging Stations[1]: 506

AC Charging Plugs[1]: 255

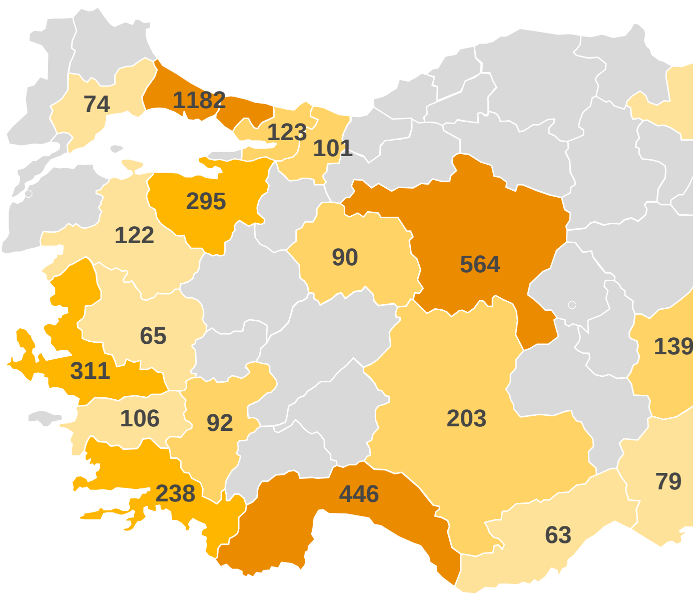
DC Charging Plugs[1]: 955

Charging Station Market Share: c. 9%

Other Players;

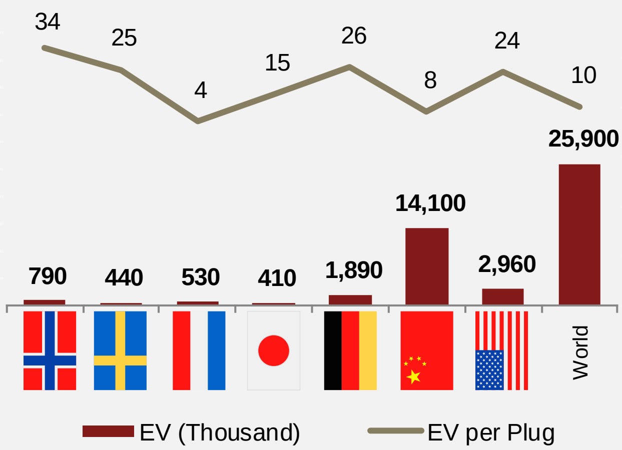
ARMATEC, CW Enerji, en yakıt, Güzel Enerji Akaryakıt, kalyon-EV, ŞarJET, Enertürk Enerji, VOLTRUN, SHARZ, WAT

As of February 2024, the **total number of charging stations is 6,700**, **the number of plugs** in these stations is **15,000 including 8,563 AC plugs and 4,413 DC plugs**. There are **six electric vehicles per charging plug**, and the plug density is generally concentrated in the west of Türkiye.



The number of vehicles per plug has fluctuated over the years, depending on the vehicle park. Türkiye was ranked above the world average for number of vehicles per plug as of 2022.

Graph 10



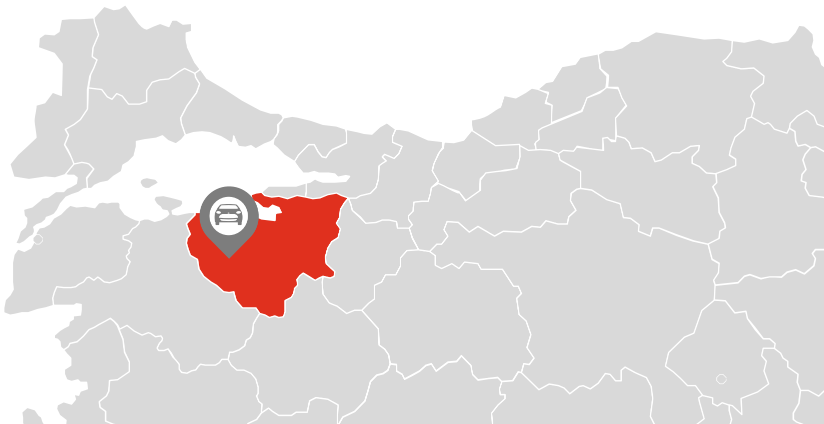
1 *Shown as of February 2024.*

Source: Publicly Available Resources

TOGG, the first electric vehicle venture in Türkiye, started sales in 2023, and investments in electric vehicle battery production have also gained momentum.

Türkiye's Automobile Joint Venture Group (TOGG) is an electric vehicle manufacturer based in Türkiye.

It was established in 2018 in partnership with Anadolu Group, BMC, Turkcell, Zorlu Holding, and the Union of Chambers and Commodity Exchanges of Türkiye. In April 2023 TOGG started selling its first model, with a goal of producing **five models** and reach 1 million production units by **2030**. TOGG completed 808 sales within the first 6 months of 2023.



Trugo is a charging station service provider established as a 100% subsidiary of TOGG. Since August 2023, Trugo operates 272 stations across **all provinces** of Türkiye.

In September 2021, TOGG launched **Siro Silk Road Temiz Enerji Depolama Çözümleri Teknolojileri** in partnership with Farasis Energy Inc. Siro was established to provide energy storage solutions for automotive and non-automotive use, and started producing battery modules and packages it developed in 2023. Siro aims to start producing batteries and reach 20 GWh of production capacity in 2026. TOGG Siro has signed a long-term financing agreement totalling 400 million Chinese Yuan to be utilized for machinery and equipment investments in January 2024.

In Türkiye, there are several companies that **operate and which are in the investment stage** of **electric vehicle battery production**.

TEMSA performs R&D activities and produces electric vehicle batteries in its production facility built in Adana in 2021. The company expects that more than one half of its bus volume shifts to electricity-based as of 2025.

As of 2024, an additional 30% customs duty was imposed on imports of prismatic LFP batteries weighing 1kg or more originating from the Far East countries. With this change, battery manufacturers in Türkiye have obtained an edge against imported batteries.

Source: Publicly Available Resources

Global renewable energy installed capacity has been rapidly increasing in line with the 2050 Net Zero emission targets. It is projected that the share of solar energy in the installed capacity of renewable energy will reach 66% in 2050.

The breakdown of CO_2 *emissions for 2022 by industry is demonstrated below.* ***Fundamental actions*** *that may reduce carbon emissions in line with net zero targets are being identified, especially in industrial production and the energy industry.*

24%	23%	15%	10%	6%	22%
Industrial	Energy	Transport	Other Energy	Buildings	Agriculture, Forestry etc.

Industrial Manufacturing

- Maintaining processes with high carbon emissions through electricity, hydrogen, or other technologies
- Adopting circular production approaches
- Deploying and scaling layered production to reduce waste

Energy

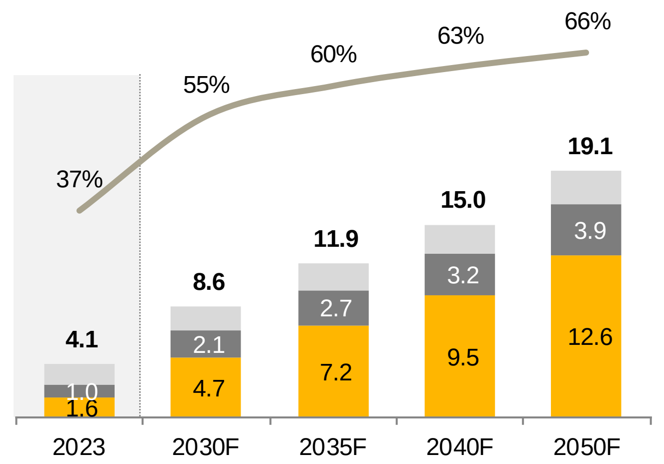
- Decreasing dependence on fossil fuels
- **Increasing renewable energy capacity**
- Developing energy efficiency
- Developing distribution infrastructure
- Developing storage system
  Deploying smart grid technologies

Transportation

- Increasing electric vehicle and battery production
- Developing battery infrastructure
- Improving charging stations network

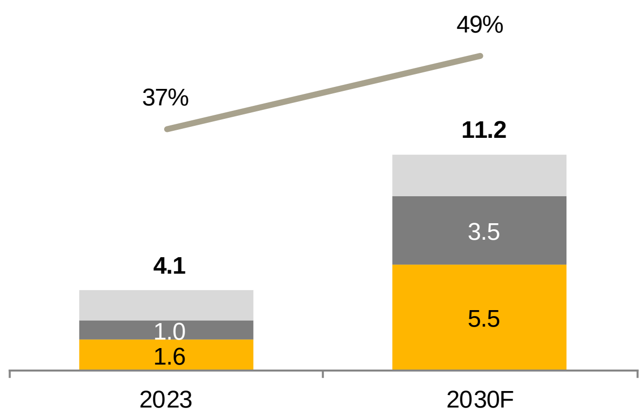
Graph 11

Global Renewable Energy Installed Capacity Forecasts (IEA, TW)



Graph 12

Global Renewable Energy Installed Capacity Forecasts (IRENA, TW)



Solar | Wind | Other Renewables | Solar/Renewables (%)

Advantages of Solar Energy Compared to Other Renewable Resources

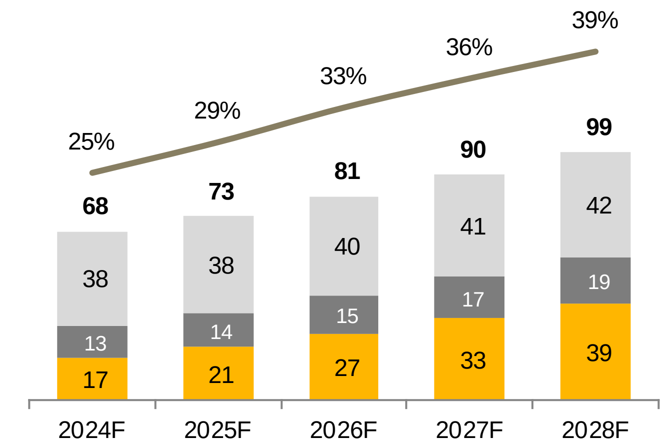
- Low set-up/operating cost and ease of set-up
- Optimal technology for hybrid energy systems
- Suitable for distributed energy systems
- Integration into city and land ecosystems through various applications *(Roof- Agriculture-Floating SPP systems)*

Source: IPCC, IEA, IRENA

It is projected that the share of solar energy in renewable energy will increase parallel to the total renewable installed capacity increase of Türkiye. Solar energy emerges as the most preferred source for increasing renewable energy capacity.

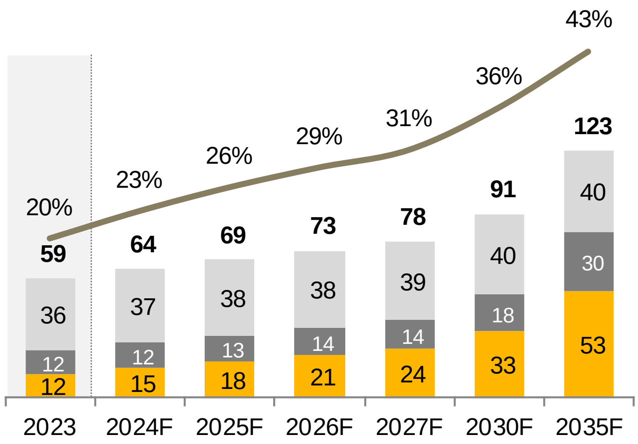
Graph 13

Renewable Energy Installed Capacity Forecasts in Türkiye (IEA, GW)



Graph 14

Renewable Energy Installed Capacity Forecasts in Türkiye (National Energy Plan, GW)



Solar | Wind | Other Renewables | Solar/Renewables (%)

Share of Solar Energy in Renewable Energy

Parallel to the global renewable energy increase trends, it is predicted that solar energy will have the highest share of total installed capacity of renewable energy in Türkiye. ***Practices in Türkiye that aim to increase the renewable energy installed capacity mostly use solar energy.***

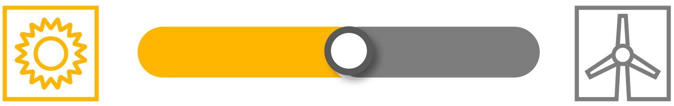
Unlicensed Power Plants

As of February 2024, 10 GW of the total 10.7 GW of unlicensed power plant installed capacity in Türkiye consists of unlicensed SPPs. It is projected that the share of solar energy will increase further as a result of unlicensed SPP investments for autoconsumption.

Hybrid Power Plants

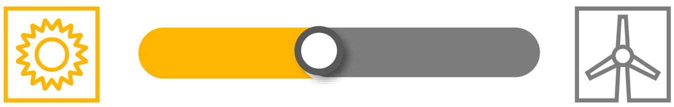
246 of 247 hybrid power plants, which have been licensed by EMRA as of February 2024, are hybrid SPPs. The total secondary installed capacity of hybrid PPs with solar as secondary resource is 2.5 GW, with c. 540 MW currently being active.

YEKA Tenders



3 GW capacity in three YEKA tenders for SPPs and 2.85 GW capacity in three YEKA tenders for WPPs were allocated. The YEKA SPP-5 is planned and will oversee an installed capacity allocation of 1.2 GW, while the YEKA Offshore WPP is currently still being planned.

Power Plants with Energy Storage



As a result of pre-license applications for PPs with energy storage, 355 pre-licenses and c. 13.6 GW of capacity for SPPs with storage and 220 pre-licences and c. 15.7 GW of capacity for WPPs with storage were allocated. Pre-license applications were suspended as of October 2023.

Source: IEA, National Energy Plan

New technologies in electricity generation from solar energy such as agrisolar and floating SPP, have started to be used widely around the world.

With the rapid increase of the global population, the need for food and energy has also increased. Agrisolar, which has the potential to provide substantial solutions in this area, integrates agriculture applications into solar energy systems, and offers a mutually beneficial model bringing the agriculture and energy industries together. Agrisolar refers to practices such as providing agricultural machines with solar energy, installing solar power modules on roofs in agricultural areas, and integrating module installation with agricultural activities through Agrivoltaic solutions considering different perspectives such as the sunlight method.

Efficiency in food production can be increased by managing sunlight by providing shade for modules based on climate, and installation in areas with high insolation potential increases electricity generation.

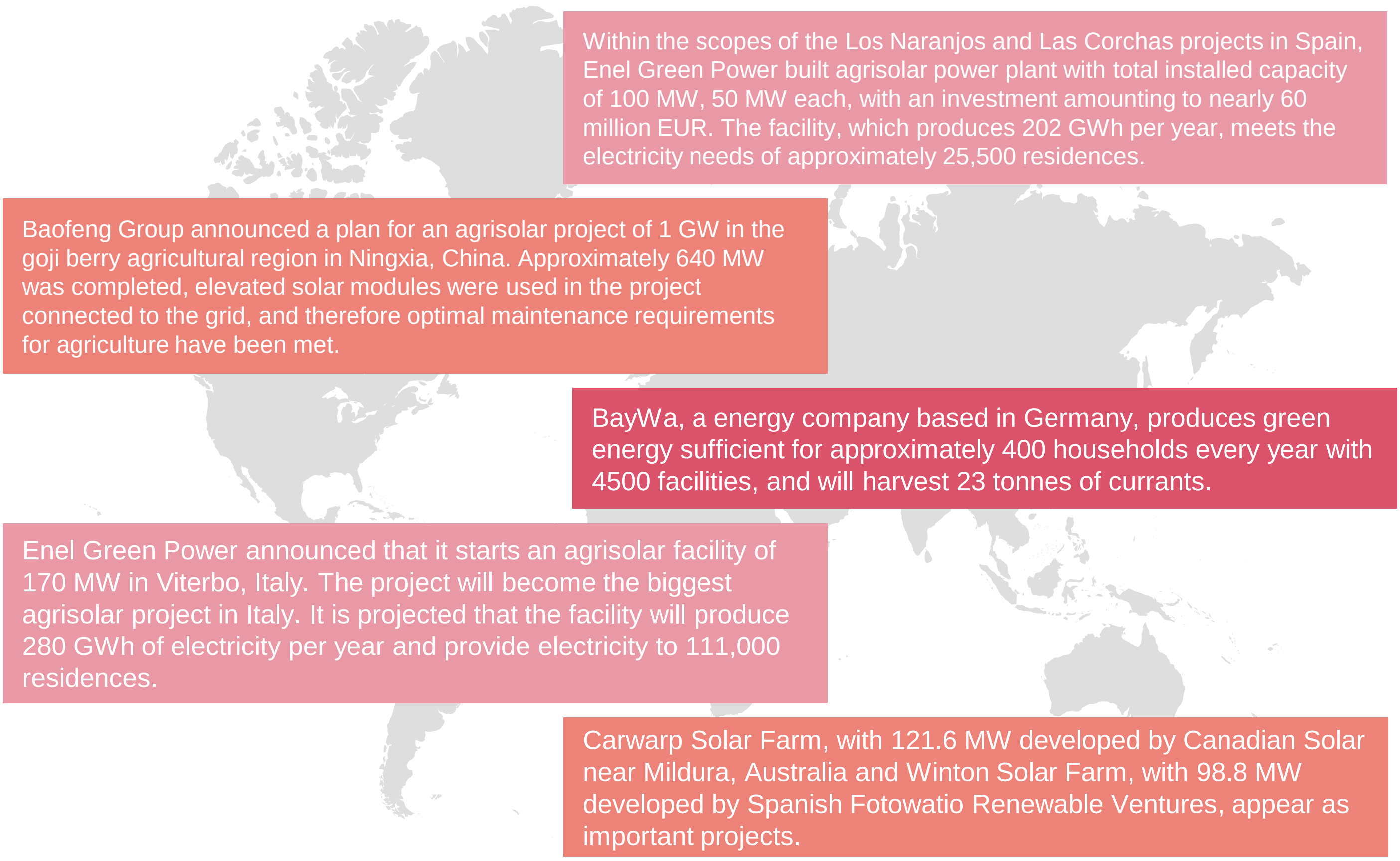
- Offers areas with high insolation potential for solar module installation and increases land use efficiency.
- Creates high electricity generation potential in areas of high irradiance. Increases agricultural sustainability.
- Creates high efficiency potential by protecting agricultural activities from unexpected weather events.
- Protects against extreme irradiation, lessens water loss in soil and high humidity & decreases water consumption.
- Supports rural areas in being more competitive and sustainable.

Agrisolar, which is becoming increasingly widespread in many countries, has high installation potential. As long as they are integrated into the existing agricultural activities, agrisolar practices can be used for crops and greenhouses using elevated solar modules and in livestock areas via installation on the ground.

Module producers perform R&D activities for agrisolar practices and countries support the development of agrisolar practices and determine incentives and regulatory frameworks.

Source: Publicly Available Resources

It is predicted that Agrisolar applications, which integrate the agriculture and energy industries, will also become popular in Türkiye.



Within the scopes of the Los Naranjos and Las Corchas projects in Spain, Enel Green Power built agrisolar power plant with total installed capacity of 100 MW, 50 MW each, with an investment amounting to nearly 60 million EUR. The facility, which produces 202 GWh per year, meets the electricity needs of approximately 25,500 residences.

Baofeng Group announced a plan for an agrisolar project of 1 GW in the goji berry agricultural region in Ningxia, China. Approximately 640 MW was completed, elevated solar modules were used in the project connected to the grid, and therefore optimal maintenance requirements for agriculture have been met.

BayWa, a energy company based in Germany, produces green energy sufficient for approximately 400 households every year with 4500 facilities, and will harvest 23 tonnes of currants.

Enel Green Power announced that it starts an agrisolar facility of 170 MW in Viterbo, Italy. The project will become the biggest agrisolar project in Italy. It is projected that the facility will produce 280 GWh of electricity per year and provide electricity to 111,000 residences.

Carwarp Solar Farm, with 121.6 MW developed by Canadian Solar near Mildura, Australia and Winton Solar Farm, with 98.8 MW developed by Spanish Fotowatio Renewable Ventures, appear as important projects.

Agrisolar Examples in Türkiye

1 Ayaş Agrisolar Project

Ayaş Agrisolar, established in Ankara, is the first solar power plant with a sun tracking system in Türkiye. In this system, which has 122 kW of capacity, elevated modules were used and electricity generation and agricultural activities were performed at the same time. In the project carried out by ODTÜ-GÜNAM, Kalyon PV provided module support and CW Enerji provided inverter support. Also in the scope of the ODTÜ – GÜNAM projects is a plan to conduct agrisolar projects, one in Kayseri and two in Bursa, in 2024.

2 Komşuköy Project

In İstanbul, Enerjisa Üretim began the agrisolar system project Komşuköy, which will produce 20 kW of power and 24 of KWs storage capacity. Under the Komşuköy project, electricity will be produced for autoconsumption in the system, and product efficiency studies of plants with high shadow tolerances will be performed.

3 PV4Plants

PV4Plants, which will be carried out in Türkiye, Spain, and Denmark in the scope of the Horizon project, aims to increase land use efficiency, crop yield, and renewable energy production under the coordination of Kalyon PV and with ODTÜ – GÜNAM, YTÜ, and 14 other establishments.

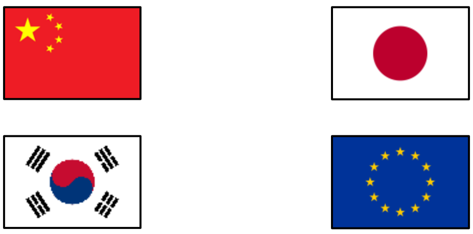
Source: Publicly Available Resources

As of 2022, global floating SPP capacity reached approximately 5.6 GW, and floating SPP applications continue to spread widely.

Floating SPP systems are created by installing solar modules on floating platforms. They increase potential area in countries with limited land and can provide different advantages compared to solar power plants built on land by being installed in water areas close to existing grids like hydroelectric dams. Given their advantages, floating solar power plants have high potential for contributing to sustainability targets and for providing more benefits from solar energy in electricity generation.

The first floating SPP was built in Japan in 2007, and there are now floating SPPs operating in several European countries, mainly in Asia. Total floating SPP capacity is estimated to increase by 68%, reaching approximately **5.7 GW** by 2022. **China** accounts for **70%** of the total capacity, with the remainder largely located in **Japan**, **Korea** and **Europe**.

It is predicted that the global floating SPP capacity will reach 60 GW as of 2030.



- Increases available space potential and decreases land use for SPP.
- Decreases evaporation rate on the surface where it is built and provides water savings.
- Increases plant efficiency when integrated to hydroelectric power plants.
- Reduces production costs when integrated to hydroelectric power plants
- Modules are less affected by heat compared to installation on land, and module performance and efficiency also increase.

Source: IEA PVPS, SolarPower Europe

As floating SPP capacities increase around world, Aydem Yenilenebilir Enerji stands out in the floating SPP area in Türkiye.

Cirata floating SPP, built with a 100 million USD investment and commissioned in November 2023, is the largest floating solar power plant in Southeastern Asia, is built on a 200-hectare reservoir, and has 1 GW of hydroelectric capacity. The power plant has installed capacity of 192 MW and consists of 340,000 modules, and the plan is for the electricity produced to meet the needs of 50,000 households.

In India, there is a plan to build a floating solar power plant with 600 MW of capacity on the Omkareshwar Dam on the Narmada river and another with 1 GW of capacity on the Indira Sagar Dam. The plan was to complete installation of the first phase of 278 MW in November 2023.

Huaneng Power International completed one of the largest floating solar power plant projects and announced a facility with 320 MW of capacity in Shandong (Dezhou), China. The facility is expected to produce 550 million kWh of electricity annually.

In Anhui, China, a floating solar power plant project of 150 MW was completed in 2018 and connected to the grid. Built on 320-hectares, this project provides power to nearly 94,000 households.

200 MW of the world's largest floating solar power plant project of 2.1 GW, planned by South Korea near the Saemangeum tidal flats by the Yellow Sea, was commissioned. Once the project is complete, the plan is for 77 million solar modules to be installed. Also, the project is predicted to provide electricity to 1 million households.

Floating SPP Examples in Türkiye

Aydem yenilenebilir enerji

Aydem Yenilenebilir Enerji announced plans to invest in

1. **24.1 MW** floating SPP for Adıgüzel HPP
2. **5.6 MW** floating SPP for Göktaş HPP
3. **1.4 MW** floating SPP for Dalaman HPP

It is projected that the hybrid floating SPPs will become operational in 2024.

Draft Legislation on Floating SPPs in Türkiye

The draft legislation presented in February 2024 named *Amendments to the Mining Law and Certain Other Laws* includes regulation changes within the energy, utilities & resources industry. The draft legislation states that renewable energy generation plants could be established without the need of a construction plan in areas declared as YEKA Fields by MENR within seas, reservoirs, artificial & natural lakes; with the exception of reservoirs and wetlands from which drinking and utility water is supplied and the coasts and coastlines covered under the Coastal Law.

Source: Publicly Available Resources

2

Solar Energy and Solar Module Market in the World

The cells used in module production are mostly created using silicon based cell technologies. The crystalline silicon cell production process takes place in the stages summarized below.

Road to Solar Cell

Sand

The raw material for solar module cell production is polysilicon, which is produced from sand. Sand is processed with carbon in furnaces at 2,000°C to obtain raw silicon. Then, the raw silicon is subjected to a process called the **Siemens** method. In this method, raw silicon is gasified and then purified in distillation columns.

Polysilicon

Polysilicon, also known as polycrystalline silicon, is a silicon-based material composed of crystallites. It is the raw material of the most widely used technology in solar cell production. Since polysilicon purity is one of the most important factors directly affecting cell yield in cell production, use of high-purity polysilicon is preferred.

Ingots

For the production of ingots, polysilicon is first melted in special furnaces at a temperature of 1,450°C. Ingots are formed by dipping a rod in melted polysilicon and rotating it. It is possible to produce ingots with both single (mono) and plural (multi) crystal structures. Today, monocrystalline ingot production is preferred because it is more efficient.

Wafer

After cutting the heads and tails of the cylindrical ingots, the edges are trimmed to form a brick-like shape. This ingot structure is sliced with diamond-coated wire saws to obtain wafers for usage in cell production.

Cell

The solar cell is obtained by subjecting wafer slices to nearly 30 chemical and physical processes. Currently there are five technologies in the solar cell production process yet solely three are in use. The most dominant cell production technology on the market is crystalline silicon technology using polysilicon as raw material.

Source: PwC Analysis

Similar to solar cells and modules, Chinese companies also stand out in polysilicon production.

Polysilicon → Ingot → Wafer → Cell

Polysilicon, is a high-purity silicon form that is an important raw material in the solar photovoltaic supply chain. It is highly resistant to temperature fluctuations and has strong insulation properties.

There are **three major technologies** in polysilicon production. The **Siemens** method is the method most used in China, which is the polysilicon producer with the most capacity in the world. The other two technologies are the FBR and UMG processes.

Using the Siemens method, polysilicon of various purity levels can be produced. Today, polysilicon with purity levels between 9N and 11N is produced for cell production.

Polysilicon Usage Areas

- Solar Photovoltaic
- Semi-conductors
- Silicon (cosmetics, construction, medicine)
- Aluminium (PFA, casting, extrusions for automotive)

A standard solar module is approximately 1.7-2 meters wide and 1 meter long, usually containing 60 or 72 cells (full-cut). **The amount of polysilicon** used in a standard module is about 2 grams per watt[1] on average. Module power usually varies between 250 and 400 watts, but modules with higher power can also be produced. For the relevant module power range, this corresponds to approximately **0.5 to 0.8 kilograms** of polysilicon per module, although figures may vary depending on module design and efficiency.

With new technologies, thinner cells in the 150-180 micron range have become widespread. Thinner cells lead to less polysilicon use for the same area.

As in module and cell production, the majority of leading companies in polysilicon production are of Chinese origin.

Table 6

(MT)	2023
TW SOLAR	350,000
GCL	250,000
DAQO NEW ENERGY CORP.	205,000
WACKER	80,000
HSC HEMLOCK SEMICONDUCTOR	18,000[2]

[1] *Can vary depending on the type of cell used.*

[2] *Since HSC Hemlock Semiconductor 2023 capacity information is not available, 2022 capacity information is shown.*

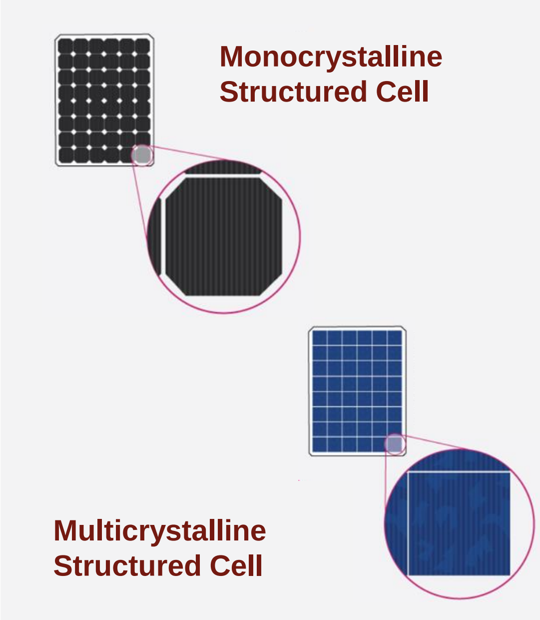
Source: PwC Analysis, Publicly Available Resources

After polysilicon is formed into ingots, it is sliced in different thicknesses to create wafers to form the base of the solar cell. Wafer thickness is one of the factors that affects efficiency at the cell stage.

Polysilicon → **Ingot** → **Wafer** → Cell

Ingots can be produced in both monocrystalline and multicrystalline forms. Monocrystalline ingots are produced using single crystal polysilicon, and multicrystalline ingots are produced using polysilicon containing irregular and different crystal structures.
Monocrystalline ingots are produced with a method called the **Czochralski Process.** In this method, the ingot is obtained by melting polysilicon in a furnace at a temperature of 1,450°C and then growing the tungsten steel rod immersed in the melted polysilicon by spinning it around. For the multicrystalline ingot production process, the melted polysilicon is poured into cubic containers to form ingots and is allowed to cool. Although the manufacturing process of multicrystalline ingots is simpler than that of monocrystalline ingots, surface defects are more likely due to contact with other materials such as containers which negatively affect cell efficiency.

Currently, monocrystalline ingot production is more preferred than multicrystalline ingot production based on its higher efficiency.

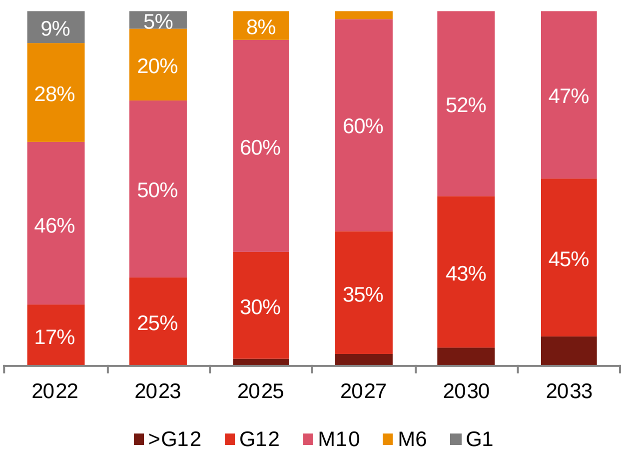


*The next stage of the production process consists of cooling the cylindrical ingot and cuting off the head and tail parts. The resulting structure is called a **brick.***

Wafers refer to the slices obtained by cutting ingot-shaped structures with diamond-coated, high-speed wire saws.

Graph 15

Market Share by Monocrystalline Wafer Type (%)



The ingot loses nearly 50% of its material during the forming and the slicing processes. Lost material can be reprocessed and re-added to the ingot production process afterwards.

Wafers with different sizes can be used in solar module production. While the most commonly used size is M10, the amount of G12 type wafers is expected to increase in the next 10 years.

G12	210 x 210 mm	M10	182 x 182 mm
M6	166 x 166 mm	G1	159 x 159 mm

Source: ASES, ITRPV, PwC Analysis, Publicly Available Resources.

Currently there are five technologies used for solar cell production. However, the global cell market is mainly composed of cells produced with the crystalline silicon manufacturing technology.

Polysilicon → Ingot → Wafer → **Cell**

Solar Cell is the most important electronic component of the module. It collects and absorbs photons emitted from the sun on a semiconductor material and converts them into electric current, enabling a solar module to function. Cells are obtained by putting the wafers formed after the slicing stage through more than 30 chemical and physical semiconductor manufacturing processes.

Solar cells in the current day can be produced using different raw materials. Different cell types are compared based on **cell efficiency,** which is the rate the cell converts solar irradiance into electrical energy.
Cell efficiency can vary depending on the raw materials used for the cell, the number of p-n junctions that can generate electricity, and the amount of irradiance and heat received from the sun. For crystalline silicon cells with a single p-n junction (currently the most common cell type) the theoretical maximum efficiency limit, called the Shockley-Queisser Limit, is 33%.

By combining different types of semiconductor materials or using a hybrid form ('multi-junction'), the theoretical efficiency limit of c-Si cells can be increased. New cell technologies continue to be tested in the laboratories to to present more efficient cells into widespread use.

Crystalline-Silicon Cells

Thin-Film Cells

Emerging Photovoltaics

Cell technologies are **categorised** under **5** headings.

1. Crystalline Silicon (c-Si) Cells

Crystalline Silicon cells use polysilicon, a purified form of the semiconductor element silicon, as the raw material. c-Si technology is the first photovoltaic (PV) technology developed. Currently, c-Si cells are the most widely used technology and are estimated to occupy **c. 95%** of the global cell market. c-Si cells have a single p-n junction which generates electricity from sunlight.

Efficiency Range[1]
Min: 21.2%
Max: 27.6%

Sub-categories of c-Si cells:

- **Monocrystalline:** Obtained by ensuring the silicon used in the ingot stage has a single uninterrupted crystal structure. *It is the most preferred cell type.*
- **Multicrystalline:** Obtained from ingots formed with polycrystalline-structured silicon. *Multicrystalline cell efficiency is lower compared to monocrystalline cells.*
- **Silicon Heterojunction (HJT):** Formed by adding thin layers of amorphous silicon (a-Si) to monocrystalline silicon. *Its share in the market is expected to increase in the coming years.*
- **Thin-Film Crystal:** Formed by adding thin-film technology on a c-Si base. *It has low efficiency and is not commonly used.*

Source: VDMA - ITRPV 2023, NREL, Publicly Available Resources

[1] *Based on the data provided by NREL in a laboratory setting.*

Currently there are five technologies used for solar cell production. However, the global cell market is mainly composed of cells produced with the crystalline silicon manufacturing technology.

Polysilicon → Ingot → Wafer → **Cell**

2. Thin-Film Cells

Thin film cells are technologically different from the polysilicon-to-cell process, but are obtained by adding/spraying thin film coatings with photovoltaic properties onto a glass base. They are the second generation cell technology that emerged after crystal silicon cells. It was preferred more often before the decrease of polysilicon prices, however, today its market share is thought to be limited to **c. 5%** .

Efficiency Range[1]
Min: 14.0%
Max: 23.6%

Sub-categories of Thin-Film Cells:

- **CIGS (Copper Indium Gallium Selenide)** Obtained by adding CIGS in solid solution on a glass base. ***Use in the market is slightly limited compared to c-Si cells due to lack of raw materials and the efficiency decrease at the module stage.***
- **CdTe (Cadmium Telluride):** Formed by adding CdTe as a semiconductor material to a glass-based cell. ***Can cause toxic material pollution, yet is available in the global market, notably used by First Solar.***
- **Amorphous Silicon (a-Si):** Obtained by using amorphous (non-uniform) silicon alone as a semiconductor material. ***Versions of amorphous silicon that don't include c-Si are less efficient.***

3. Emerging PV Technologies

As a result of the continuous development of photovoltaic solar cell and module applications, the group of cell technologies developed as an alternative to the first two technologies used is called "Emerging PV". Emerging PV technologies, which are first used in the 1990s, are currently mostly utilised in the research stage or in the laboratory environment, and have not been subject to widespread use in the global market.

Efficiency Range[1]
Min: 13.0%
Max: 33.9%

Cell Technologies Under Development:

Although no exact classification exists, the types of PV cells that are currently being developed include:

- **Organic and inorganic-based,**
- **Perovskite,**
- **Dyesensitized cells,**
- **Quantum dotted cells,**
- **Tandem (hybrid using multiple technologies).**

As this is a developing area, it is likely that new technologies will be included in the coming years.

Perovskite and Perovskite/Si Tandem

Perovskite, an organic structure consisting of the mineral calcium titanium oxide, can be used alone or together with silicon as a hybrid cell (in tandem).
It is expected that, with further development, perovskite/Si tandem cells (33.9% efficiency), which combine the high efficiency of perovskite with the long useful lifespan of silicon, will become one of the most dominant technologies in the cell market by 2027.

Source: VDMA - ITRPV 2023, NREL, Publicly Available Resources

1 *Based on the data provided by NREL in a laboratory setting.*

Currently there are five technologies used for solar cell production. However, the global cell market is mainly composed of cells produced with the crystalline silicon manufacturing technology.

Polysilicon → Ingot → Wafer → **Cell**

4. Multijunction Cells

Efficiency Range[1]	Min: 32.9%	Max: 47.6%

5. Single-Junction GaAs Cells

Efficiency Range[1]	Min: 27.8%	Max: 30.8%

Multi-junction and single-junction GaAs cells are formed by combining multiple p-n junctions or combining gallium arsenic (GaAs) with a single-junction cell. Although both technologies can achieve much higher efficiency levels than standard c-Si cells due to having multiple p-n junctions, their uses are limited to laboratory or very limited space applications.

Cells with the Highest Market Share and Efficiency

PERC (passivated emitter rear contact) cells, which currently use c-Si technology and are of monocrystalline structures, are the most widely used cells in the global cell market. TOPcon (tunnelling oxide passivation) cells, also from mono c-Si technology, are predicted to become the most common cell type in the next 10 years.

PERC Cells

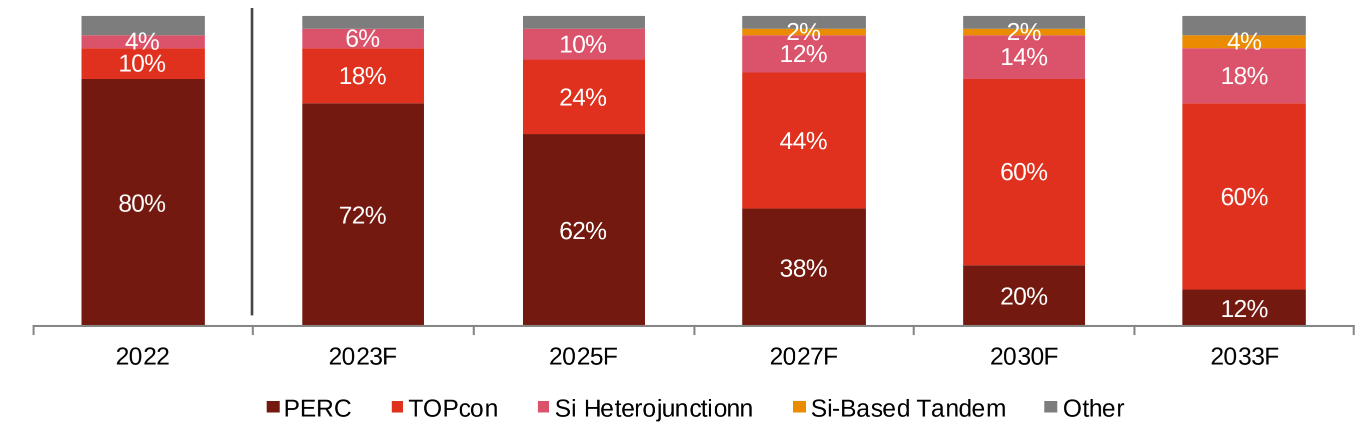
PERC cells allow the reuse of sunlight leaked from other layers which could not be converted into electricity through an additional layer added by laser to the lowest layer of the crystalline silicon-based cell.

TOPcon Cells

TOPcon solar cells have been first experimented by the Fraunhofer ISE in early 2010s. TOPcon cells have a tunnel oxide layer placed between the c-Si layer and the transparent conductive oxide layer to rearrange sunlight absorption, increasing efficiency.

Graph 16

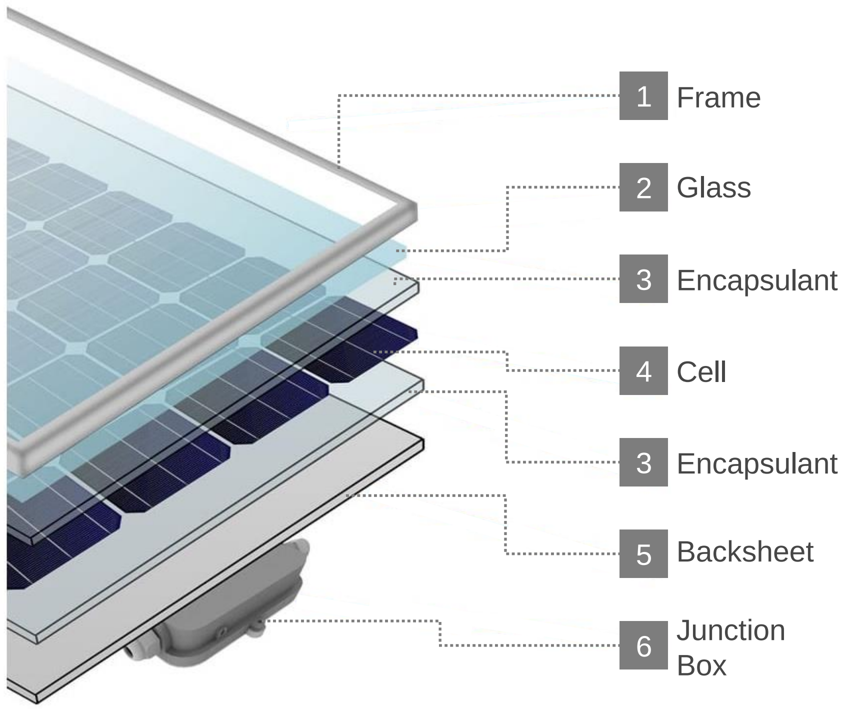
Global Market Share by Cell Type (%)



Source: VDMA - ITRPV 2023, NREL, Publicly Available Resources

1 *Based on the data provided by NREL in a laboratory setting.*

Cells become part of a structure that containin multiple layers during the assembly of the solar module.



1. The frame provides modules with structural durability. It protects modules from impact and harsh weather conditions. It also allows for easy module installation.
2. The solar glass is the outer layer of the module and must be robust and shiny for the module to perform better. It protects solar cells from harsh weather conditions, dirt, and dust.
3. The encapsulant provides mechanical integrity by bringing certain parts of the module together. It also provides electrical isolation of the solar cells and reduces the impact of external blows.
4. Main center of the electricity generation within a module. Cells are connected with both serial and parallel connection with the help of metallic conductors, and produce the total power of the module.
5. The backsheet is the rear layer and provides both mechanical protection and electrical insulation to the internal circuit against the external environment.
6. The junction box connects the modules to each other and protects them from the outer environment by collecting all the electrical leads from the solar module on one panel. It also transmits the direct current (DC) generated in the solar module.

Source: PwC Analysis

1. Because it is the most stable substance, glass is loaded into the production line first.
2. Encapsulant is laid on the glass surface.
3. On top of the encapsulant, serially connected cells are lined up.
4. The in-module circuit is completed by making serial or parallel connections of the lined cells.
5. Encapsulant and backsheet are placed on top of the circuit installation.
6. Afterwards, the module enters the EL station and the cells or solders are checked.
7. Post inspection, the layers are integrated by applying heat and pressure.
8. Furthermore, excess encapsulant and backsheet materials are cut off.
9. Aluminium frames are assembled and the module is created.
10. The module is tested for leakage, resistance, IV, EL, and electrical connection.

Similar to cell technologies, solar modules can be classified into multiple types. The most widely used modules are assembled of crystalline silicon cells and modules using thin-film technology.

Module Type Overview:

Parallel with cell technologies, solar modules created with cells produced using different technologies are also separated into different types. The most common types of modules currently in use contain **silicon**-based cells, which represent **c. 95%** of cell technology. In this regard, module types are parallel to the technologies used by cells within the module.

Silicon-Based Modules

Most Widely Used

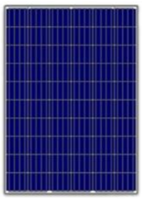
Efficiency Range[1]

- **Min: 8.2%**
- **Max: 24.7%**

Contains different cell types produced through the crystalline silicon technology. Includes different sized modules suitable for both household, commercial, and industrial use.

Monocrystalline Modules:

Consist of cells formed from a single crystal silicon. Provide **25 years** of life and the highest efficiency range **(22.7-24.7%)**. The cost remains higher than other silicon-based modules.



Polycrystalline Modules:

Consist of cells formed from multicrystalline silicon. Although the polycrystalline modules have the same lifespan as monocrystalline, they have a lower efficiency range **(20.4%)**. The recyclability of used materials is higher compared to monocrystalline modules.

Chalcogenide Modules

Most Cost Effective

Efficiency Range[1]

- **Min: 19.2%**
- **Max: 20.3%**

Chalcogenide modules are formed by cells manufactured with thin film technology. Therefore, modules with this technology are also known as thin film modules.

Thin Film Modules

They contain cells created using thin film technology. They have a lower efficiency range **(19.2-20.3%)** compared to crystalline silicon based modules. Because this is a very flexible module type, it can be used on many different areas.

Other Module Types

In addition to monocrystalline, multicrystalline, and thin film modules, which are the three most commonly used module types; **amorphous silicon, gallium arsenic, hybrid and emerging module technologies** also exist. However, modules using technologies other than silicon or thin film have a limited use.

Source: VDMA - ITRPV 2023, NREL, Publicly Available Resources

1 *Based on the data provided by NREL in a laboratory setting.*

Different technologies are employed to further increase solar module efficiency.

1 Half Cut Technology:

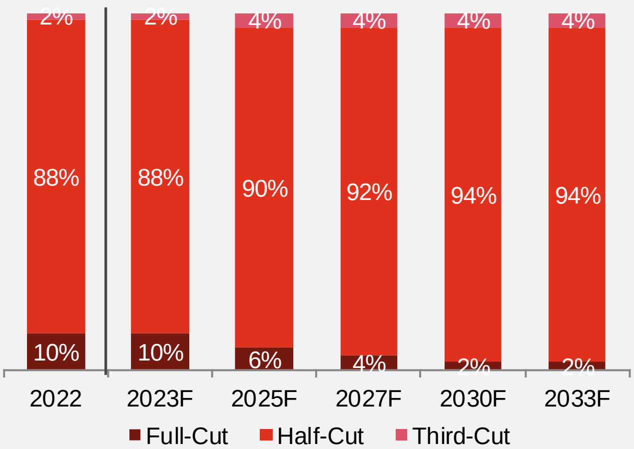
The cells used in the module are cut in half and positioned on the module as half-cells. With this technology, the module is less affected by the absence of daylight and cell deterioration, and module efficiency increases due to the greater number of circuits.

Although the same technology was tried with cells divided into three, the desired efficiency was not achieved. Today, half cut technology is dominant for cells manufactured from wafers smaller than M10 (182 mm^2).

For cells manufactured from M10 and larger wafers, full-cut technology is not used.

Graph 17

Breakdown by Cell Size for Cells Formed From <M10 Wafers (%)



2 Bifacial Technology:

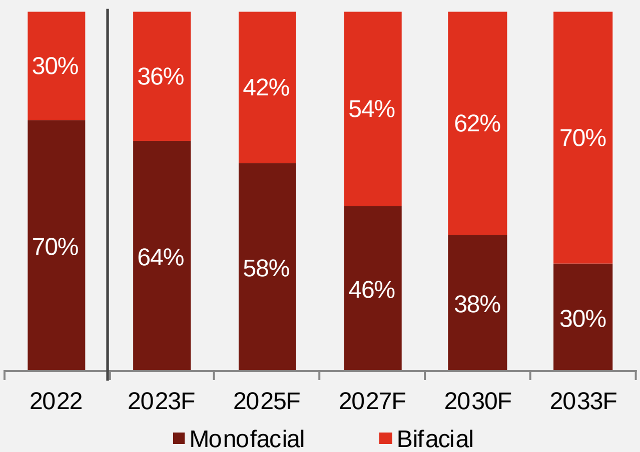
Bifacial modules, one of the most frequently used technologies on solar modules currently, can generate electricity from both the back and the front surfaces.

The reflected sunlight is recycled using a glass or transparent surface on the back of the module.

Although most of the modules currently produced still use monofacial technology, the proportion of bifacial modules in the market is projected to increase to over 50% by 2027.

Graph 18

Bifacial/Monofacial Surfaced Modules (%)



3 Multi-Busbar Technology:

The number of soldered ribbons is increased to connect cells in series and draw electrons from the cells more efficiently.

Module efficiency is thereby increased by reducing cracks that may occur in the module.

4 Tracker Technology:

Increasing module efficiency by allowing solar modules to follow the movement of the sun allows more solar energy to be generated. These modules make a significant contribution to cell efficiency in months that are more cloudy.

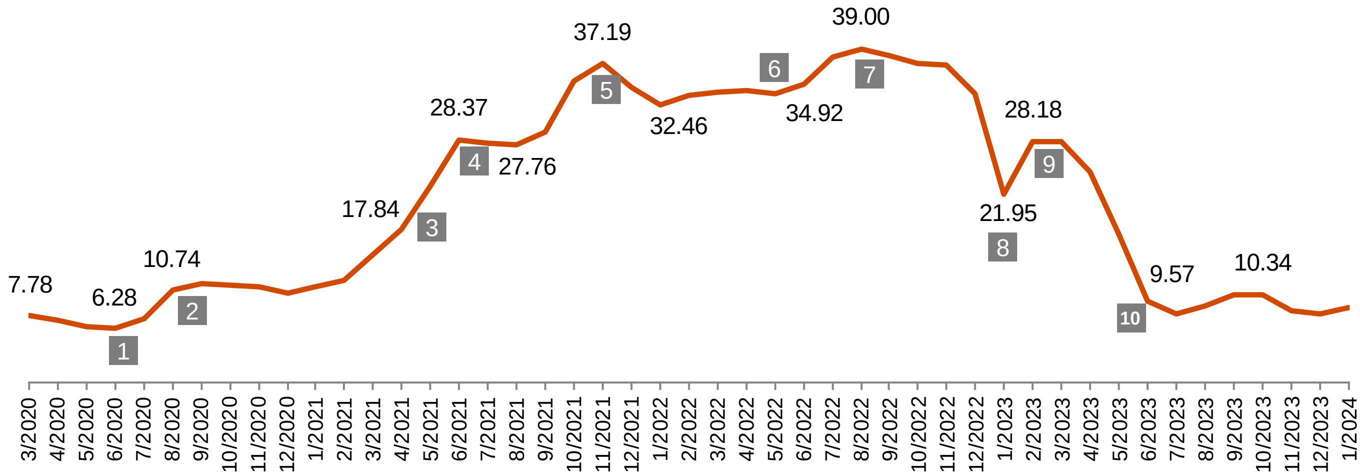
NREL has observed energy gains of 4-11% when tracker technology is used in bifacial modules.

Source: VDMA - ITRPV 2023, NREL, Publicly Available Resources

As polysilicon is the primary raw material of solar cells and modules, any polysilicon price fluctuations are directly reflected in cell and module pricing.

Graph 19

Polysilicon Prices (China, USD/kg)



1. Demand driven by Covid-19 Pandemic, record low levels are achieved.
2. Explosions at Xinjiang and flood at Sichuan Yongxiang temporarily remove capacity of 68,000 MT from the market.
3. Panic buying of manufacturers of wafers, cells & modules, hoarding impulse of manufacturers.
4. Large utility-scale projects being pushed out into 2022.
5. Global installation rush, large module manufacturers increase capacities and demand.
6. Heatwave in China causing polysilicon plants to halt production.
7. Chinese government agency invite all regional authorities to coordinate reducing prices as all-time high is reached.
8. Demand reduction due to oversupply of wafers and increased capacity of Chinese polysilicon manufacturers.
9. Polysilicon and wafer manufacturers decrease utilization rates.
10. Prices plunge due to oversupply, Chinese polysilicon manufacturers undergo large-scale capacity expansions.

A **high correlation** exists between **polysilicon prices**, the raw material of solar modules, and **cell and module prices**. Upward and downward trend changes in polysilicon prices directly affect cell and module prices.

R^2

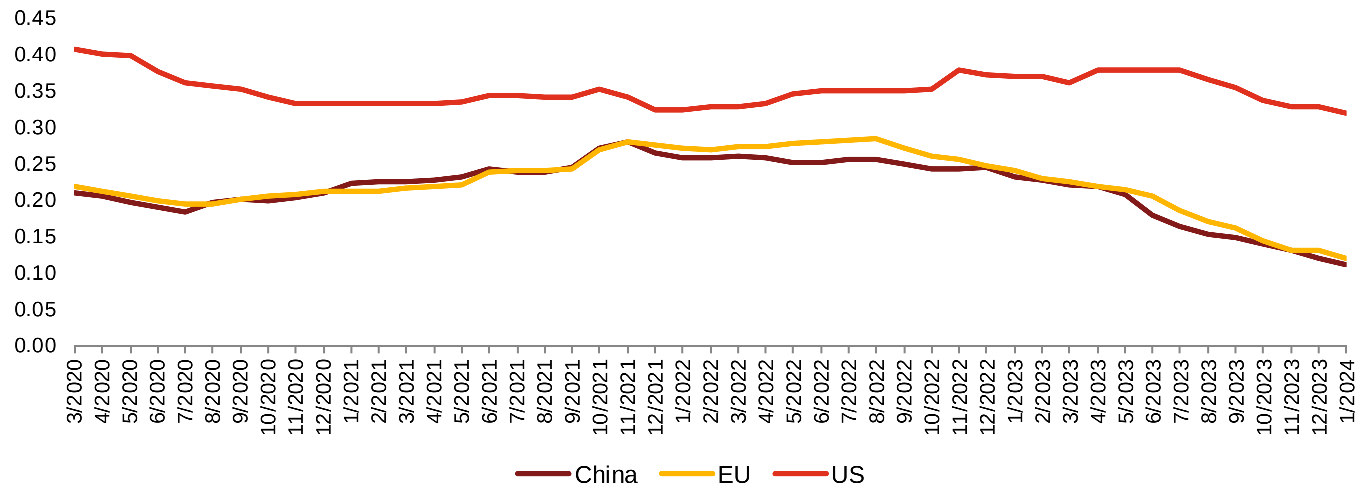
Polysilicon ⟷ Cell	Polysilicon ⟷ Module	Cell ⟷ Module
0.78	**0.71**	**0.88**

Source: Bloomberg, PwC Analysis

Module prices are considerably lower in China and the EU, where Chinese modules are widely used, compared to prices in the US.

Graph 20

Module Prices in China, EU & US (USD/W)

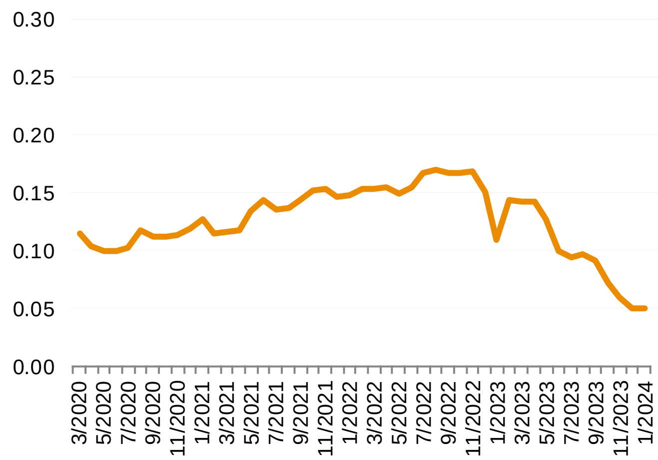


As both the Chinese and the EU market are supplied by Chinese module manufacturers which own the largest share in the global solar module market, the prices in both markets remain similar to the global average.

The anti-dumping measures imposed by the US towards the solar module and cell imports from China forms the basis of the price premium in the US, where prices are **c. 2.5x of the Chinese/EU prices**. In addition, the significant increase in module demand in the US as a result of the Inflation Reduction Act (IRA) incentives and the current domestic module production shortage results in unmet demand. The demand surge, coupled with continued module imports, have led to higher module prices in the US.

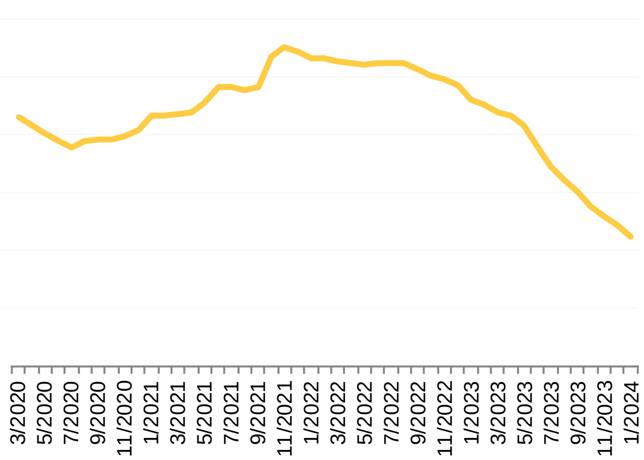
Graph 21

Global Average Cell Price (USD/W)



Graph 22

Global Average Module Price (USD/W)



Source: Bloomberg, PwC Analysis

Following the increase in fossil fuel costs in recent years, the decline in the cost of electricity generated from renewable energy sources has improved the competitiveness of renewable energy sources.

Levelized Cost of Electricity (LCOE)

Levelized cost of electricity is the average net present cost of expected electricity generation of a generation facility over its operational life. LCOE is obtained by dividing the total cost of the generation facility by the amount of electricity that the facility is expected to generate over its lifetime. This calculation, which also takes into account the cost of capital, represents the average price of electricity that a project must realize in order to create value, and is often used for investment planning purposes and for comparing different electricity generation methods.

Table 7

Average Unit Cost of Electricity Generation[1] (USD/kWh)

	2010	2022	%
Bioenergy	0.082	0.061	↓ 25%
Geothermal	0.053	0.056	↑ 6%
Hydro	0.042	0.061	↑ 47%
Solar	0.445	0.049	↓ 89%
Wind (Onshore)	0.107	0.033	↓ 69%
Wind (Offshore)	0.197	0.081	↓ 59%

Electricity generation from renewable sources is becoming increasingly more cost-effective. A rapid decline in generation costs was observed between 2010-2022 which is tied to technological advancements, productivity gains, generatşın optimization, competitive supply chains, and improved producer experience. In particular, generation costs for wind and solar experienced significant decreases.

Among all renewable generation sources, solar energy has observed the largest decrease in average unit cost of electricity generation between **2010** and **2022** by **89%**. The primary reason of the major drop in costs emerges as the fall in module prices.

Although supply chain disruptions and rising commodity prices have placed pressures on the costs in many regions, the global average cost of solar power generation demonstrated another decreased by **2%** in **2022** with **China** dominating the global solar capacity increases.

Following the increase in fossil fuel prices in recent years, the decline in the average cost of electricity generated from renewable energy sources became significantly important, with **cost reductions** and the **environmental benefits** of electricity generated from renewable sources increasing the competitiveness of renewable energy compared to non-renewables.

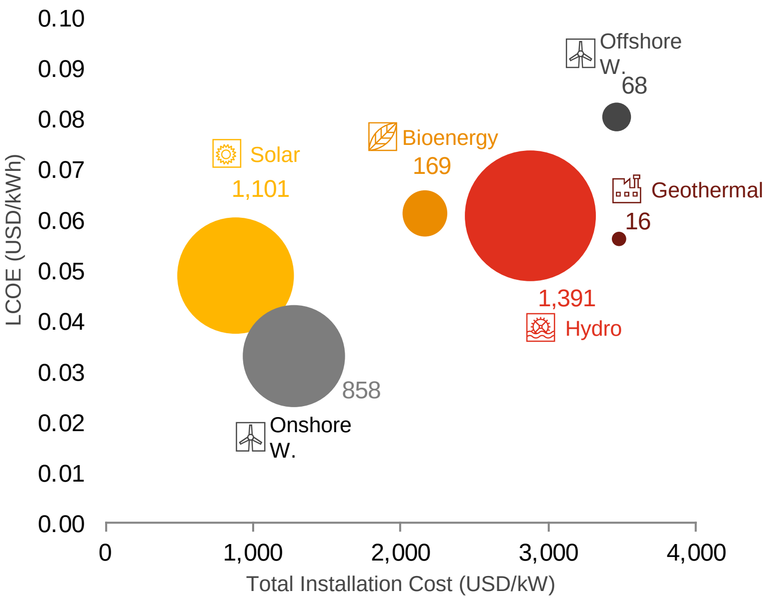
*(1) IRENA's cost database, which is the source of the information provided in the graph, includes data on approximately **22,000** renewable energy generation projects with total installed capacity of **2,317 GW** operating in various countries, particularly China, the US, Brazil, and Germany.*

Source: IRENA, PwC Analysis

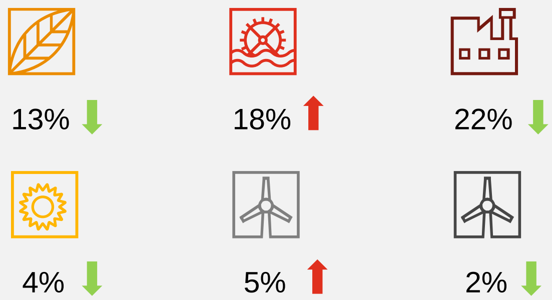
The technology with the greatest decrease in average electricity generation cost between 2010 and 2022 among renewable sources appeared as solar energy, with a decrease of 89%.

Graph 23

Renewable Energy Resources Cost Comparison[1] (USD, 2022)

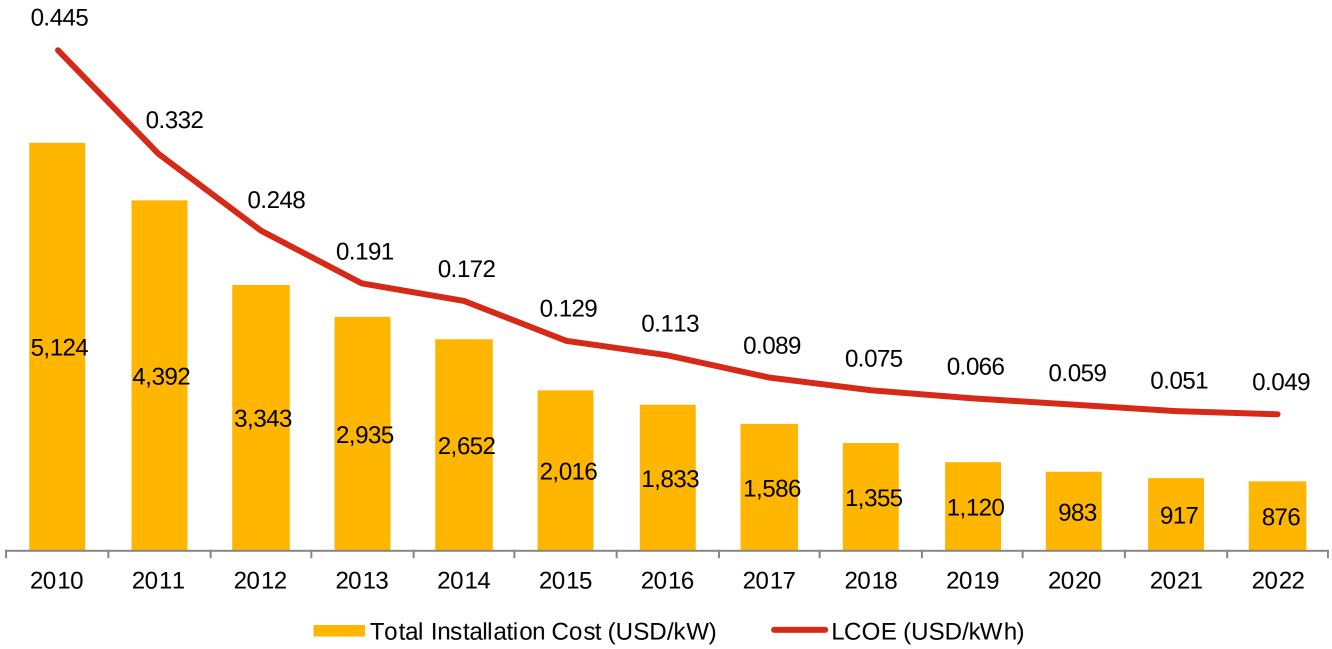


Between 2021 and 2022, average electricity generation costs based on renewable energy sources have changed as follows:



Graph 24

Global Solar Energy Total Installation Cost (USD/kW) **and LCOE** (USD/kWh)



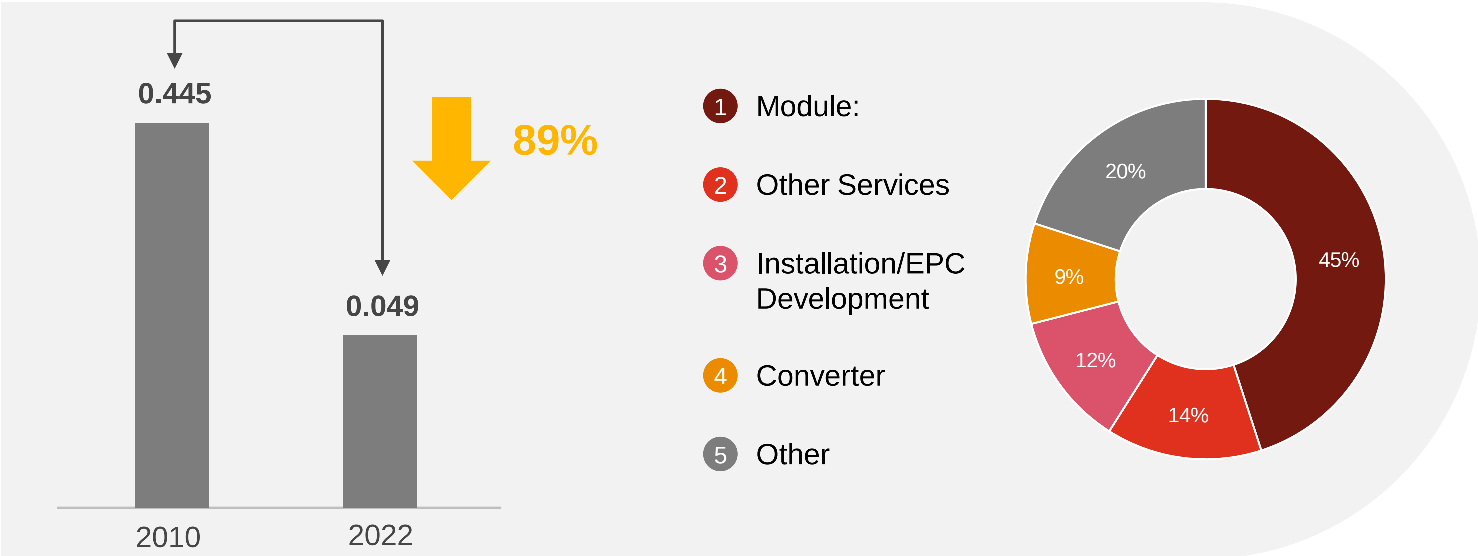
[1] *Balloon size represents installed capacity size.*

Source: IRENA

Factors affecting the average cost of solar electricity generation the most are the development of module and cell technologies, as well as the decline in module prices.

Graph 25

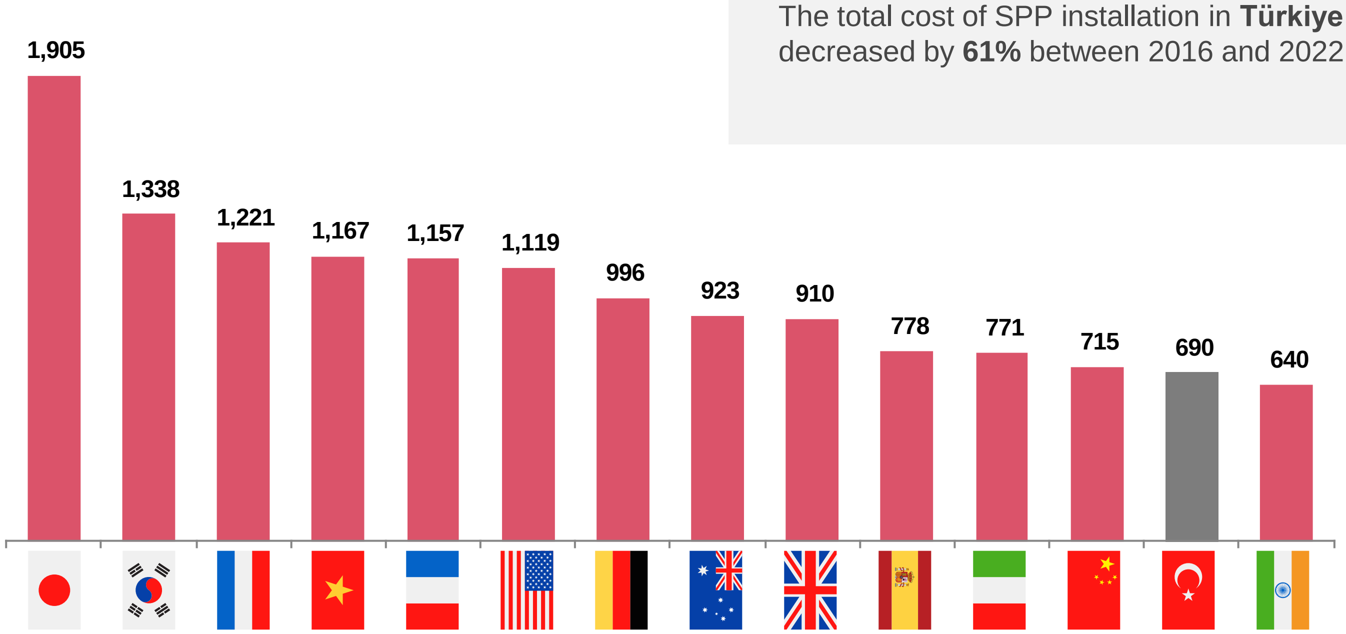
Factors Affecting the Average Unit Cost of Solar Energy Generation (2010-2022)



Graph 26

On-Grid Solar Power Plant (SPP) Total Installation Cost by Country (USD/kW, 2022)

The total cost of SPP installation in **Türkiye** decreased by **61%** between 2016 and 2022.

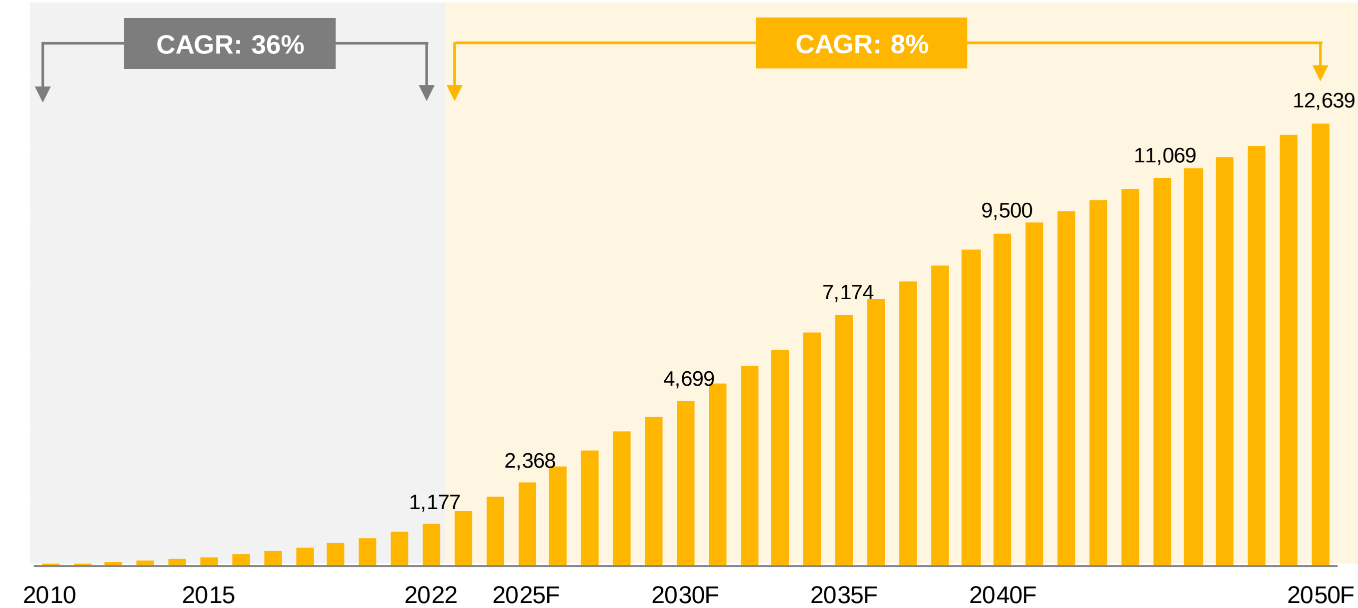


Source: IRENA

Based on the reports of the International Energy Agency, global solar installed capacity is expected to reach 7,639 GW in 2030 and 12,639 GW in 2050.

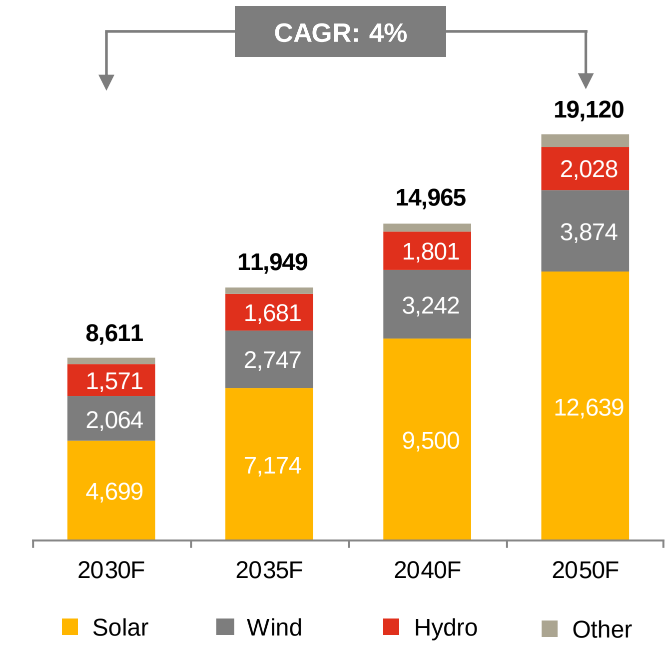
Graph 27

Global Solar Energy Installed Capacity (GW)



Graph 28

Renewable Energy Installed Capacity Forecasts (GW)



In 2050, **66%** of the total reneable energy installed capacity is projected to belong to **solar energy.**
In addition, solar energy installed capacity, which is projected to grow **8%** on average annually between 2023 and 2050, is estimated to possess the **highest projected growth rate** among all renewable energy sources.

	Solar	Wind	Hydro
CAGR [1]	8%	5%	1%
Share of Ren. Energy (2050 estimates)	66%	20%	11%

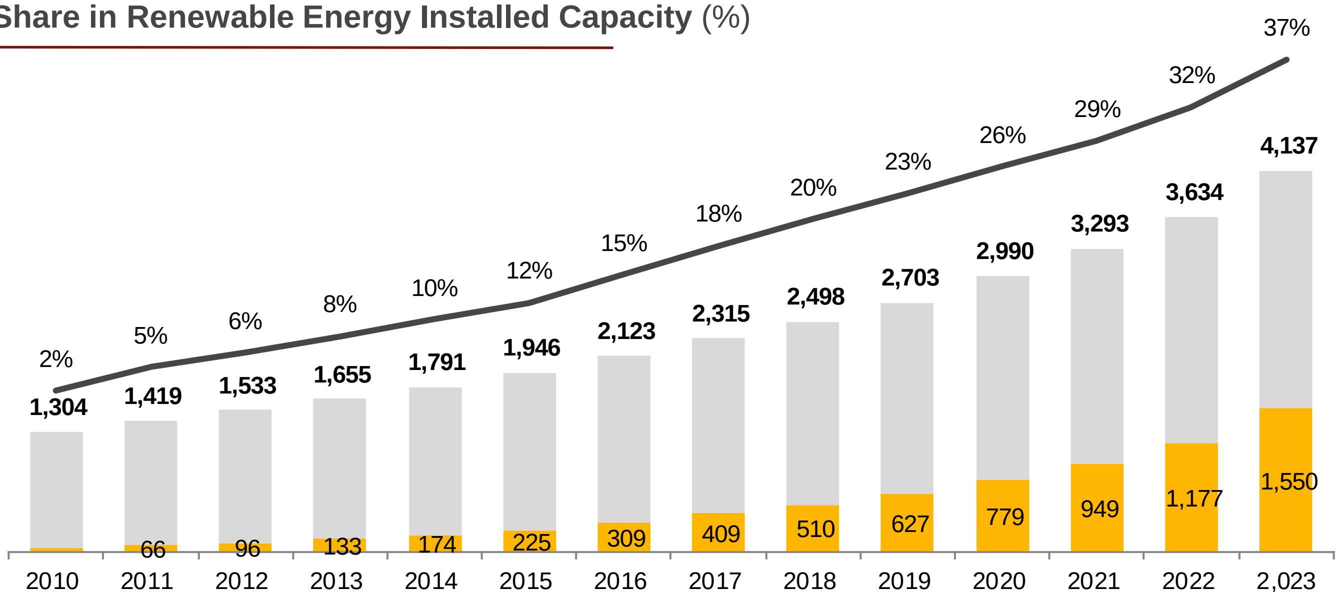
Source: IEA, Publicly Available Resources

[1] *CAGR between 2023 and 2050 is shown.*

The share of solar energy in global renewable energy installed capacity has been continuously increasing since 2015.

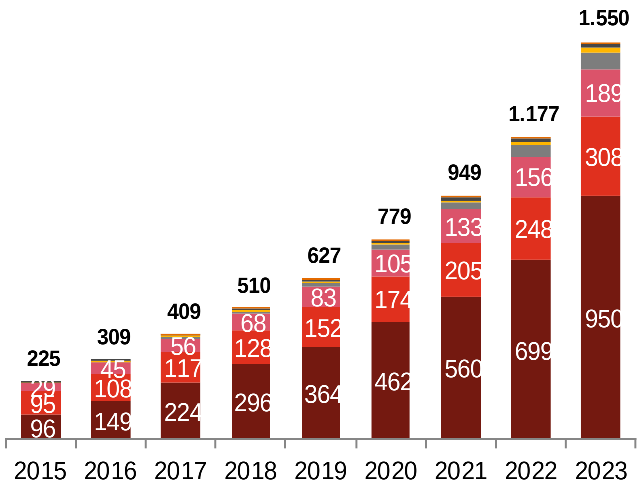
Graph 29

Solar Energy Installed Capacity (GW) **and Share in Renewable Energy Installed Capacity** (%)



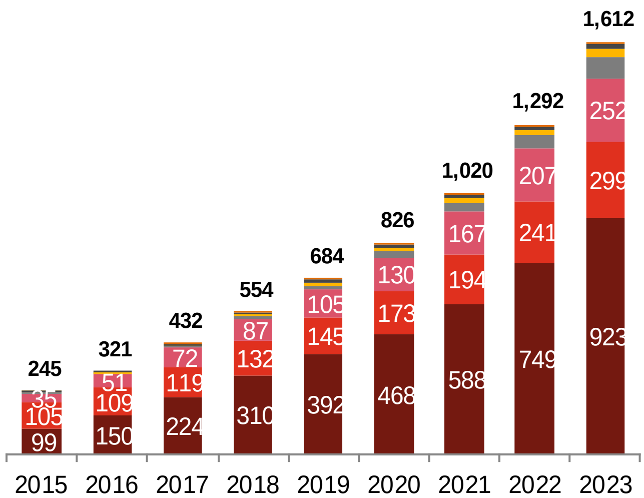
Graph 30

Global Breakdown of Solar Energy Installed Capacity (GW)



Graph 31

Global Breakdown of Electricity Generation from Solar Energy (TWh)



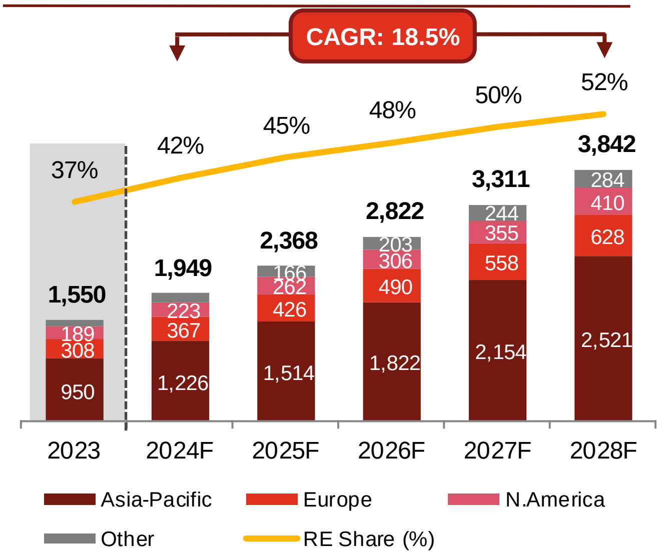
Asia-Pacific
Europe
North America
Latin America
Middle East
Africa
Eurasia

Source: IEA

Global installed solar energy capacity is expected to continue its recent growth, mainly in China, the EU, and the US.

Graph 32

Global Solar Energy Installed Capacity Growth Forecast (GW)



The global solar installed capacity grew by an average of 27% annually between 2015 and 2023, and is projected to further grow by an average of **18.5%** annually for the 5-year period between 2024-2028. The share of solar within total renewable energy capacity is also projected to increase gradually and exceed **50%.**

Approximately **90%** of the installed capacity growth between 2024-28 is projected to stem from the Asia-Pacific, Europe and North America regions.

Regions and Countries with the Highest Projected Installed Capacity Growth

According to IEA forecasts, Asia-Pacific, Europe and North America stand out as the regions with the highest solar energy installed capacity in the world, both realized and in future forecasts. However, the solar capacity presence of all three regions are dominated by either a single country or a bloc.

1	**Asia-Pacific**	**2024-28 Incr.: 1,571 GW**		
	China	+1,306 GW	83%	*China has the largest installed solar energy capacity in the world, thanks to its leadership in cell/module production and the >USD 60b incentives provided.*
2	**Europe**	**2024-28 Incr.: 321 GW**		
	EU	+265 GW	83%	*Solar energy breakthroughs in the EU are steadily increasing, reducing its dependence on fossil fuels and reaching zero GHG emissions.*
3	**North America**	**2024-28 Incr.: 221 GW**		
	USA	+211 GW	95%	*As renewable energy incentives under the IRA came into effect in 2022, it is assumed the US solar sector will grow significantly over the next 10 years.*

Other Regions

With the exception of China, the US, and the EU, most of the world's solar power installed capacity growth is projected to take place in Latin America and the Middle East regions. Between 2024 and 2028, increases in installed capacity is projected to reach c.100 GW in Latin America and c. 40 GW in the Middle East region.

Source: IEA, PwC Analysis

The three largest markets for solar energy have differing market dynamics and suitability for module exports.

Comparative Analysis of Market Conditions and Suitability for Module Exports of the Three Markets with the Most Solar Energy Installed Capacity

	China	EU	US
Installed Capacity Growth (2024-28)	**1,306 GW**	**265 GW**	**211 GW**
Supportive Policies	The solar sector has been eligible for special incentives as a strategic sector in China since 2010.	Solar is one of the sectors prioritised and supported under the EU Green Deal.	Investment into solar energy is planned to exponentially increase after IRA incentives.
Module Import Restrictions	There are no special restrictions on imports of solar modules/cells.	Anti-dumping duties on Chinese modules were lifted in 2018.	Anti-dumping duties are applied to modules and cells originating from China, Vietnam, Malaysia, Thailand, and Cambodia.
Module Manufacturing Operations	The domestic market is dominated by local producers due to its leading position in global module/cell production.	Predominantly dominated by Chinese manufacturers. Intra-EU module production is under implementation.	The investments announced under the IRA target > 100GW of domestic module production capacity.
Average Module Prices	2023 Average: **0.18 USD/W**	2023 Average: **0.19 USD/W**	2023 Average: **0.36 USD/W**
Module Export Opportunities	Chinese manufacturers do not import a material amount of modules except from their Southeastern Asia branches.	Non-EU module imports are allowed. Revamp of the domestic market aims to lower foreign dependance in the long term.	UL certification[1] required **and modules and cells must not originate from China or the four SE Asian countries**.
Module Export Eligibility Level	Not Suitable	Limited Eligibility	**Suitable for Exports**

The Most Suitable Market for Module Exports USA

With the incentives included in the IRA, which came into effect in 2022, the US has become the country with the second-highest solar energy capacity growth target after China. Domestic module production activities are expected to increase under the IRA, yet the US will continue to require imported solar modules during and after implementation of the IRA. **The sharply-increasing demand and high module prices make the US the most favourable and accessible market for solar module exports.**

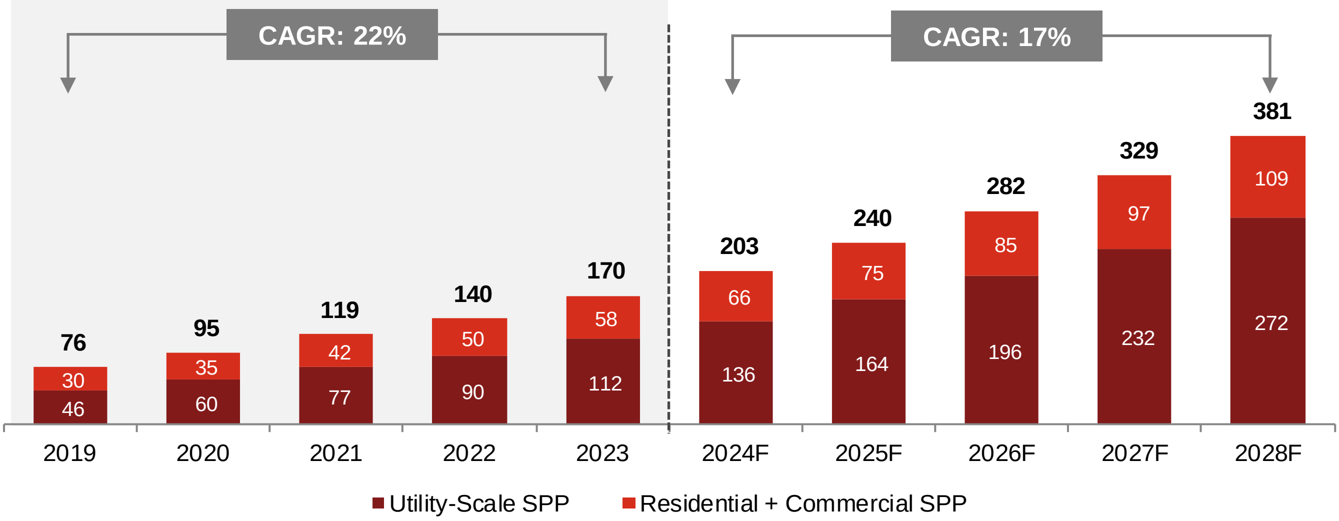
Source: IEA, Bloomberg, Publicly Available Resources, PwC Analysis

1 *UL certification certifies that a solar module has passed the quality and qualification tests required for use in the US.*

The decline in the cost of solar energy and the IRA incentives aimed at renewable energy sources form the basis of the strong forecasted increase in the solar energy installed capacity of the US.

Graph 33

Solar Energy Installed Capacity in the US (GW)



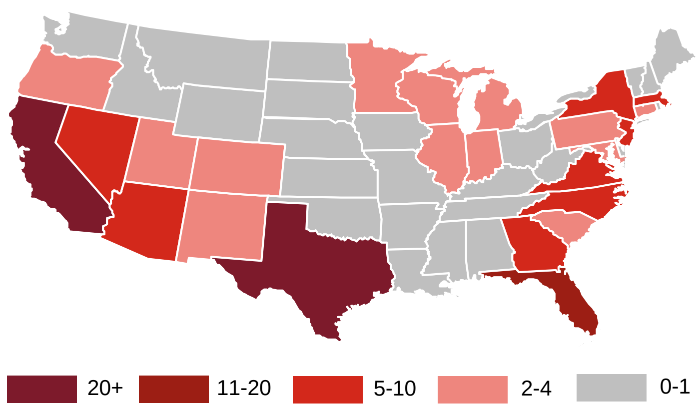
Development of Solar Energy in the US

Demand for solar energy in the US increased over the years as financial and operational costs started a decreasing trend in 2015 and the following years. The number of residential and utility-scale SPPs built in the southern and western parts of the US, particularly in California, have significantly increased.

Decline in solar energy costs, combined with the tax incentives provided by the IRA which entered into force in August 2022, have led to significant capacity increase announcements, especially in utility-scale and residential SPP projects.

Graph 34

US Solar Installed Capacity Breakdown by States (January 2024, GW)



Solar installations in the US are concentrated in southern states due to their solar irradiance potential. The aim of the tax incentives offered under the IRA is to increase solar energy installation in other states which possess considerably less installed capacity, especially through encouraging the use of residential SPPs.

All utility-scale SPPs over 200 MW in the US are located in southern/western states. The largest SPP in the US as of February 2024 is the Copper Mountain Solar Facility in Nevada (c. 800 MW).

Source: IEA, SEIA, PwC Analysis

Significant solar power capacity growth targets supported by policy stability render the US as the most profitable export market for solar module manufacturers in Türkiye.

Growth Catalyst of the US Solar Energy Industry: IRA

Inflation Reduction Act (IRA)

IRA, which was signed into law on 16 August 2022, aims to lower the inflation in the US through multiple headlines, one of which is the promotion of clean energy. To achieve clean energy transition, the IRA offers various incentives to renewable energy investors and producers in the form of tax credits and rebates – with the goal of elevating the use of renewable energy in the US.

Major Solar Energy Incentives in the IRA

Investment Tax Credit (ITC)

For residential, commercial and utility-scale SPP installations, 30% of the investment amount (in the base case) can be deducted from federal income or federal corporate income taxes in the year of installation. In addition, a 30% tax deduction (in the base case) for selected projects for the production of solar modules or other components in the value chain is also provided.

Production Tax Credit (PTC)

PTC is a tax credit provided for each component within the solar energy value chain manufactured domestically. PTC is calculated on the basis of units manufactued and deductible from federal corporate income tax in the fiscal year of production.

- Polysilicon: **USD 3/kg**
- Wafer: **USD 12/m2**
- Cell: **USD 0.04/W**
- Module: **USD 0.07/W**

Tax Credit Monetization

Tax incentives under the PTC can be received as direct payments instead of tax deductions for the first five years of investment. In addition, the tax credits accumulated under the PTC and the ITC can also be transferred to third parties.

Benefits of the IRA to the US Solar Industry

- Policy Consistency
- Clean Energy
- Production Increase

The incentives provided under the IRA over a 10-year period provided stabilisation for the sector, strengthened the infrastructure necessary for clean energy transformation in the US, and led to significantly increases in domestic production activities.

Impact of IRA in US Solar Energy Development

Between 2024 and 2028, solar energy installed capacity is expected to increase **c. 200 GW**.

With the announed facility investments the US aims to reach **c. 120GW module and c. 50GW in domestic cell production** capacity by 2030.

Although the incentives provided by the IRA aim to shift module and other solar component manufacturing into the US, the need for imported modules and cells into the USA will continue to meet the IRA-influenced demand surge. ***SEIA predicts that the import module needs of the US will remain stable in the long-term.***

Source: IEA, SEIA, PwC Analysis

The US has introduced steep anti-dumping tariffs and countervailing duties against solar imports from China and other Southeast Asian countries. The measures in place yield an opportunity for other countries wishing to export to the US to gain export market share.

Anti-Dumping Tariff and Countervailing Duty Practices in the US

With the help of special incentives and the Renewable Energy Law enacted in 2005, China has quickly become the world's largest solar component manufacturer.
Module prices in the US domestic market fell by 60% as Chinese manufacturers broke through to the US market. American producers filed an application for the imposition of anti-dumping (AD) tariffs and countervailing duties (CVD) in 2011, claiming that competition was cut off.

Oct 2011 — Six US companies filed applications with the Department of Commerce (DoC) to impose anti-dumping (AD) tariffs and countervailing duties (CVD) on imported modules and cells.

Dec 2012 — The US DoC announced the imposition of AD/CVD on Chinese modules and cells. Upon this announcement, Chinese manufacturers started to shift their production lines to countries such as Taiwan, etc.

Feb 2015 — Existing AD measures started to cover modules and cells originating from Taiwan. In addition to manufacturing location, the location of module assembly is also included in the AD measures.

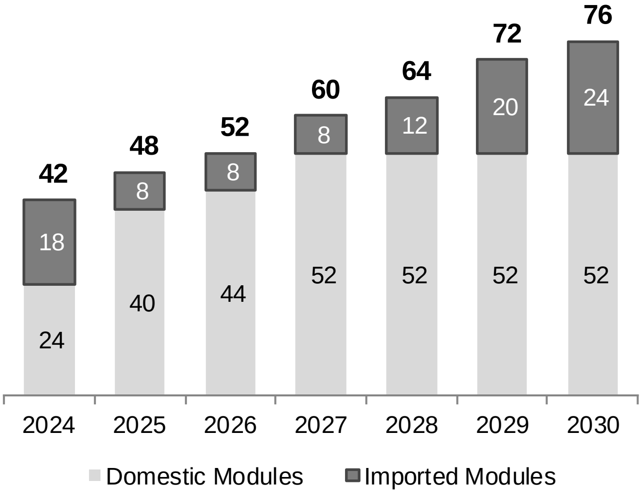
Jan 2018 — The Trump administration imposed VAT on all imported modules and cells. The practice was continued by the Biden administration yet with less strict conditions.

Jun 2022 - Aug 2023 — **The US Department of Commerce has determined that Chinese module and cell imports from four Southeast Asian countries (Vietnam, Malaysia, Cambodia, Thailand) are violating AD/CVD practices and included these four countries in the scope of the AD/CVD measures.**

The Biden administration stated that imports from four countries will not be affected by AD/CVD until June 2024.

Graph 35

Origin of Modules Used in the US (GW)



SEIA assumes that module imports to the US will decline especially between 2025 and 2028 as the full effects of the IRA incentives will be reflected; **but will increase again from 2028 onwards as production capacity in the domestic market stabilizes.**

The AD/CVD to be applied to four Southeast Asian countries, covering c. 75% of US module imports in the last five years, stands out as an opportunity for companies from other countries which are ready to export modules to the US.

Regulations for Exporting Modules from Türkiye to the US

UL certification serves as the proof that all legal obligations necessary to sell modules in the US market have been met.
Raw materials in module production must also have UL certification.

In addition to module production, cell production must also take place outside China and the four Southeast Asian countries affected by AD/CVD measures.

kalyon·PV

As of Report Date, solely Kalyon PV meets all the requirements for exporting modules from Türkiye to the US, based on its vertically integrated production facility.

Source: US Department of Commerce, Publicly Available Resources

The solar installed capacity growth forecast of the EU is expected to be similar with the growth forecasts of the US. However, unlike the US market, Chinese module manufacturers possess the majority of the EU market.

Solar Energy Industry in the EU

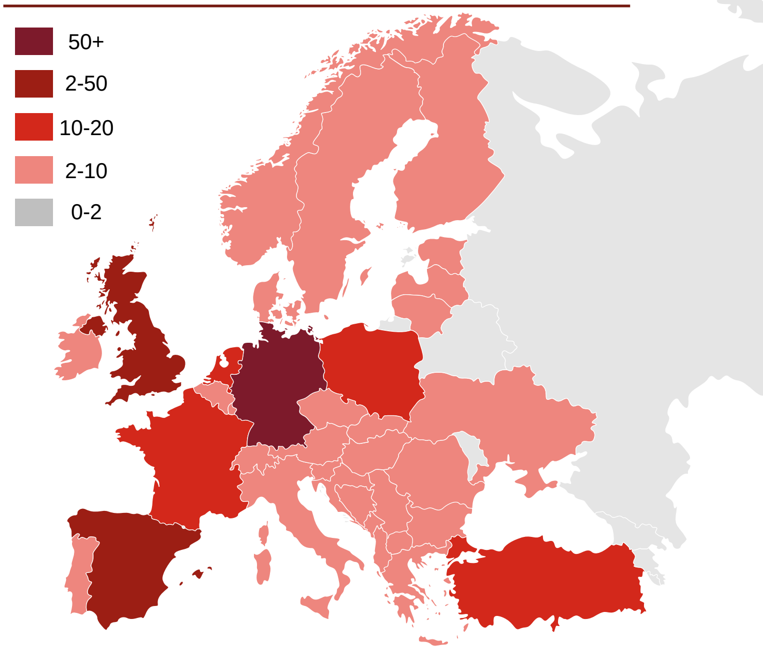
Installation of solar energy in the EU is accelerating in response to the upcoming energy crisis.

The new policies and targets proposed in the European Green Deal are expected to stimulate solar investments significantly in the coming years.

The EU's growth potential in this area is similar to that of the US, with an expected increase of more than **200 GW** of total installed solar capacity in EU countries over the next five years.

Graph 36

Installed Capacity Growth in Europe (2024-28,GW)



Anti-Dumping Measures in the EU

December 2013
The EU imposed anti-dumping tariffs and countervailing duty measures on cells and modules purchased from China.

2013

2014

May 2014
Numerous major Chinese manufacturers agreed with the EU that they would not sell below fair value under free market conditions, resulting in the EU suspending measures against them.

February 2016
Previously abolished tariffs were reintroduced and executed until March 2017.

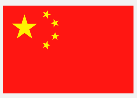
2016

2017

March 2017
AD/CVD measures were extended for only 18 months instead of the expected five years.

2018

September 2018
All AD/CVD measures were lifted.



Dominance of Chinese Module Manufacturers in the EU Market

With the removal of the European Commission's AD/CVD proceedings on Chinese solar modules, Chinese module manufacturers have restarted to dominate the EU market, with c. 75% of all module exports to the EU in 2022 originating from China. However, the EU aims to lessen its dependence on a single country (China) for solar energy, similar to the bloc’s goal of lessening its ties with Russia with regards to fossil fuels. In addition, the bloc also plans to implement incentives similar to those in the US to stimulate its internal market.

Source: IEA, SolarPower Europe, Trade Map, Publicly Available Resources

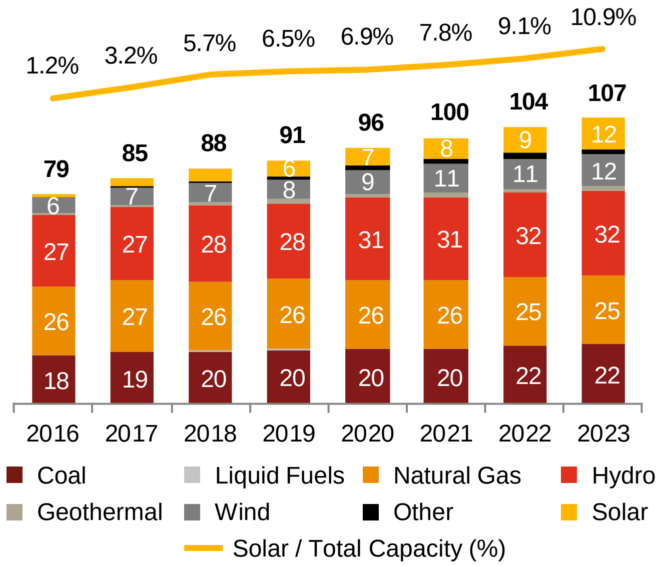
3

Solar Energy and Solar Module Market in Türkiye

Solar energy installed capacity in Türkiye exceeded 10 GW in 2023 and formed more than 10% of the country's total installed capacity for the first time.

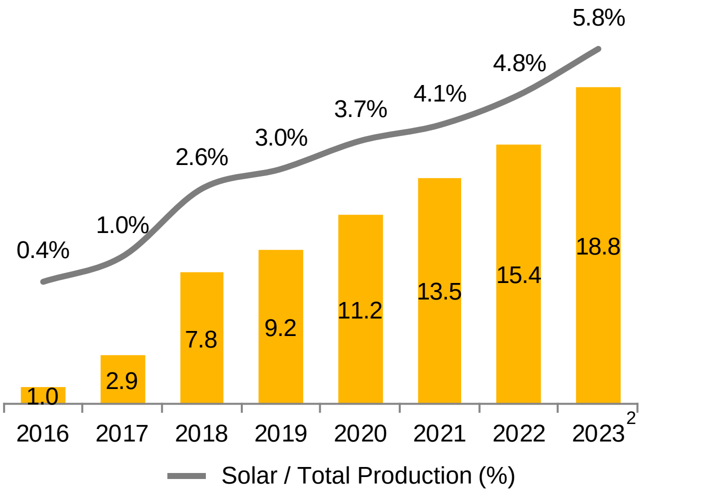
Graph 37

Total Installed Capacity in Türkiye (GW)



Graph 38

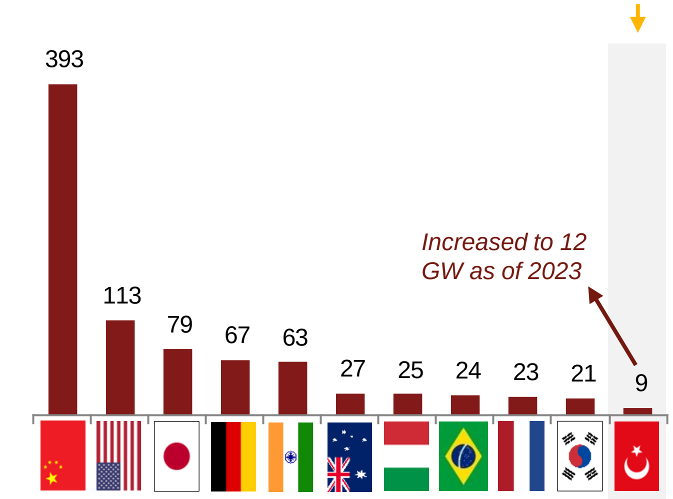
Electricity Generation from Solar Energy (TWh)



Graph 39

Installed Capacity of Türkiye[1] (GW) and Türkiye's Global Ranking

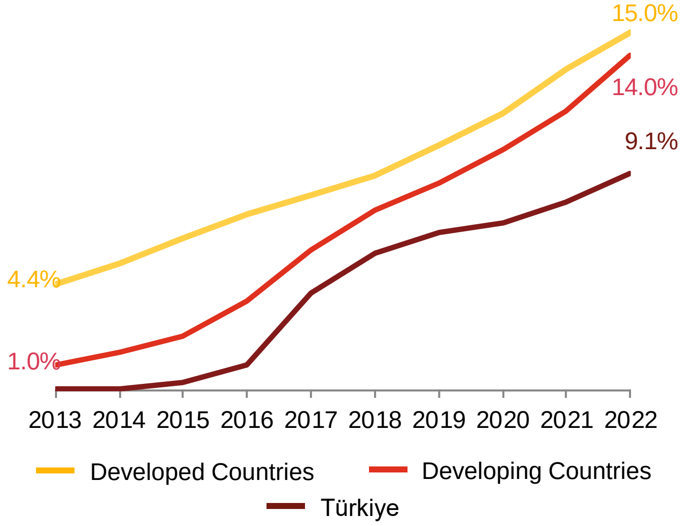
	2010	2022
Total Renewables	14th	12th
Solar	51st	16th



Graph 40

Solar Energy Installed Capacity Analysis

Türkiye's solar energy installed capacity lagged behind the averages of both developed and developing countries over the past decade. However, progress made since 2015 results in Türkiye narrowing the gap with both averages.

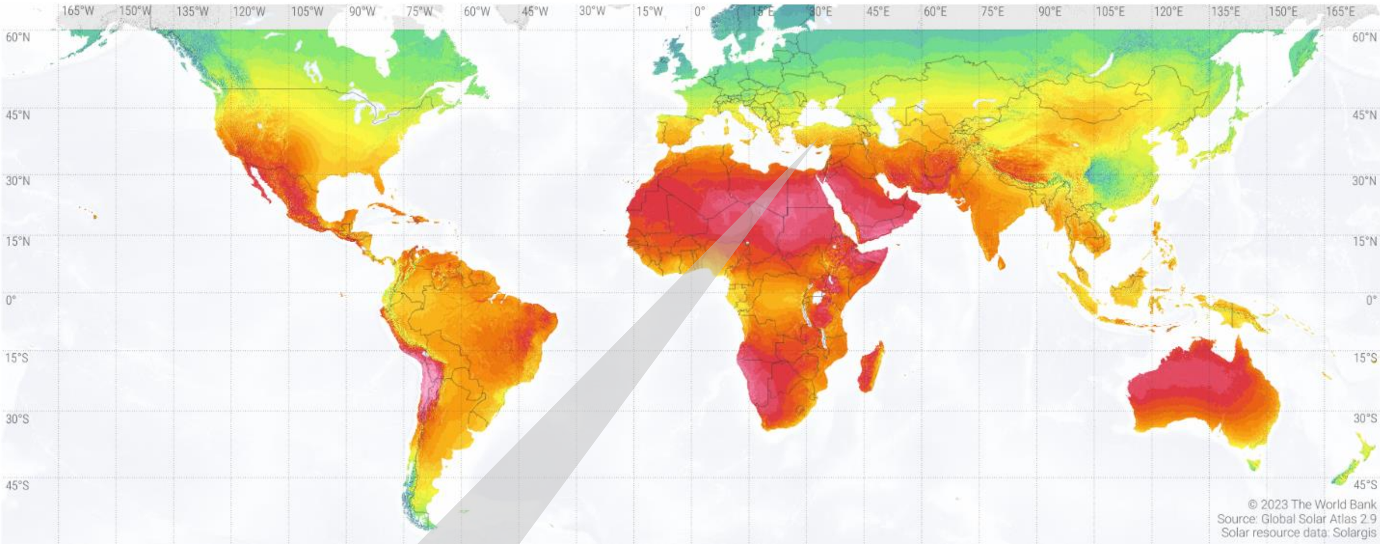


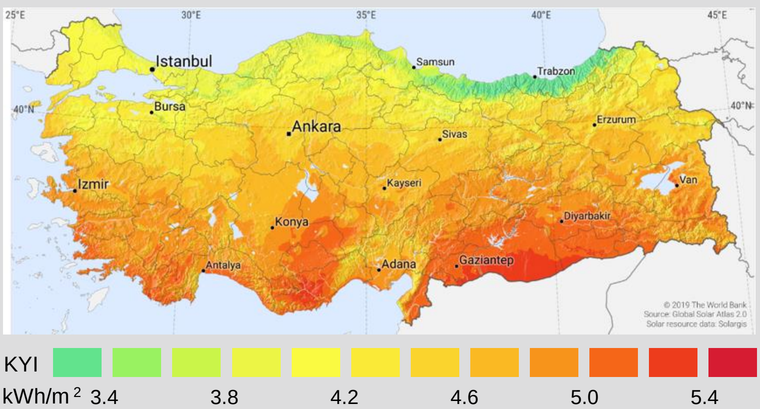
[1] *Denotes Installed Capacitiy of 2022.*

Source: TEİAŞ, EMRA, Publicly Available Sources

Türkiye’s solar irradiance level and potential to generate electricity from solar energy is high compared to many countries. Owing to this potential, solar energy emerges as the main focus area for the targeted green transformation in Türkiye.

Global Solar Atlas, World Bank



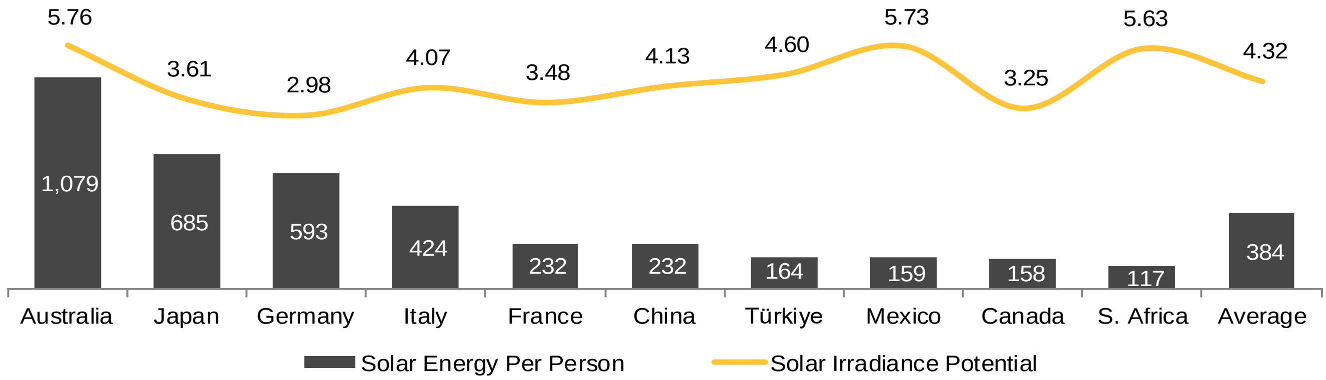


According to the Global Solar Atlas published by the World Bank, the regions where solar energy potential is high are positioned between latitude 30° north and latitude 30° south.

Although Türkiye does not have as much of a solar irradiance advantage compared to regions between the coordinates specified above as its coordinates of latitude 36° north and latitude 42° north being outside of the maximum solar energy potential zone, the country receives more irradiance compared to theUSA, China and many European countries, therefore having more solar energy generation potential per square meter.

Graph 41

G20 Countries Producing the Highest Solar Energy Per Person (Top 10) and Solar Irradiance Potential (kWh/person, kWh/m²/day, 2021)

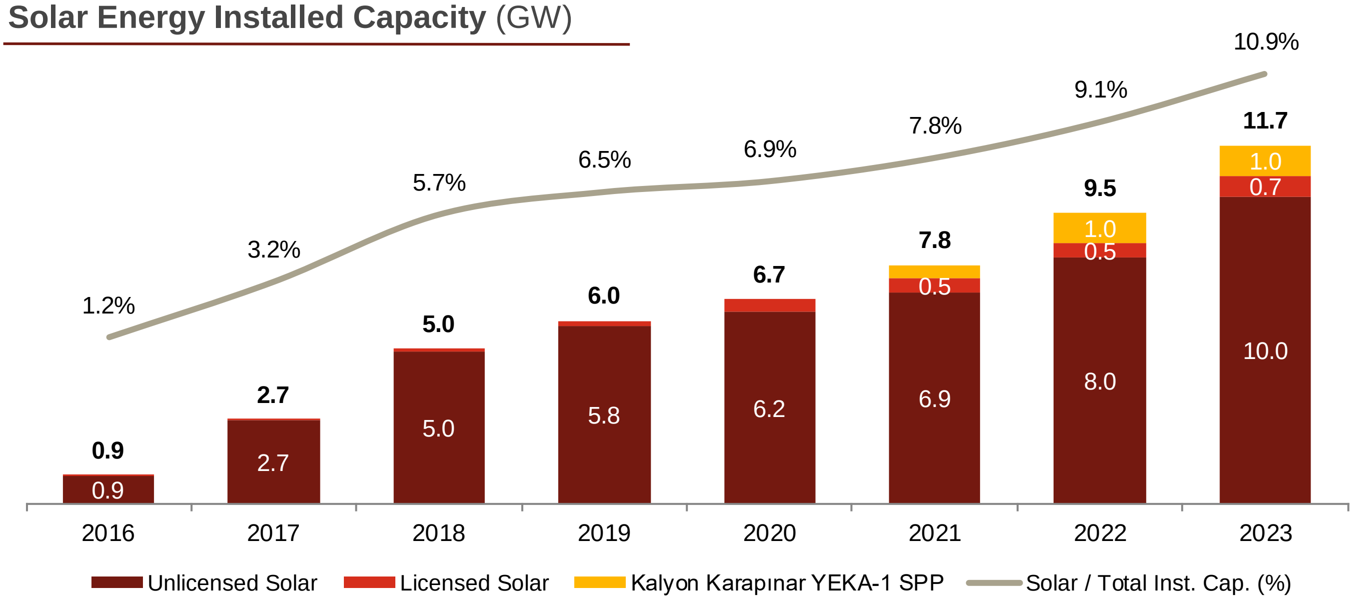


Source: World Bank, Solargis, SHURA

From 2017 onwards, advancements made to increase the licensed SPP capacity through YEKA tenders, and surge in the installation of unlicensed SPPs aiming to benefit from the first iteration of YEKDEM FiT have contributed to the significant solar capacity increase in Türkiye.

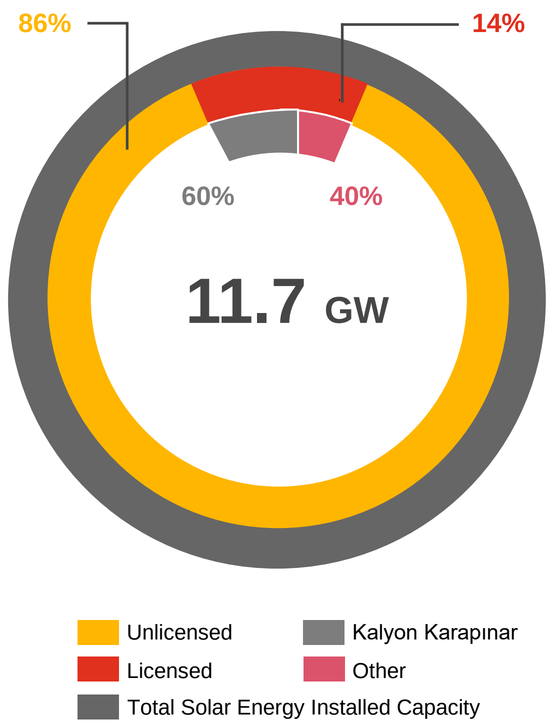
Graph 42

Solar Energy Installed Capacity (GW)



Graph 43

Solar Installed Capacity Distribution (%)



Unlicensed Power Plants

Currently, unlicensed SPPs account for more than 85% of the installed solar energy capacity in Türkiye. Unlicensed SPP development has been led by financial investors until 2019, and afterwards by investors seeking to develop SPPs for autoconsumption.

Licensed Power Plants

Currently, licensed power plants cover pre-YEKA and YEKA SPP-1. Following the introduction of regulations for hybrid power plants and power plants with energy storage, it is predicted that the share of licensed SPPs will increase.

Kalyon Karapınar YEK-1 SPP

The Kalyon Karapınar SPP, which has a capacity of 1 GW and was completed in March 2023, was established in Konya/Karapınar by Kalyon Holding as a result of the first YEKA SPP tender held in 2017.

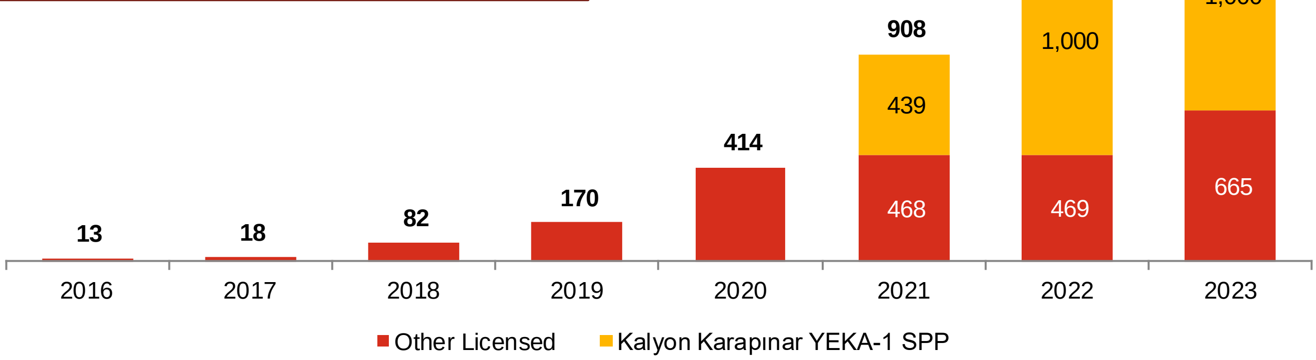
Source: TEİAŞ

The total installed capacity of the licensed SPPs in operation as of February 2024 is 1.7 GW, accounting for 14% of the total installed solar energy capacity in Türkiye.

Graph 44

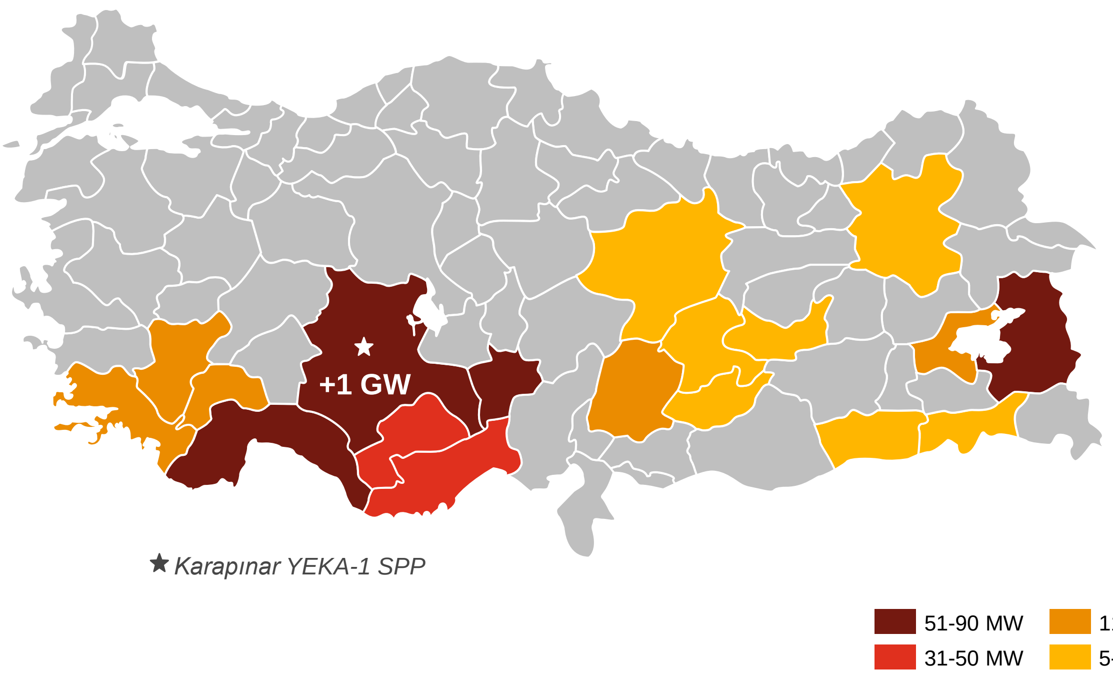
Licensed SPP Installed Capacity (MW)

Unless noted otherwise, the MW term used throughout the report refers to Megawatts-electric (MWe), which is the total operating capacity of a power plant.



Graph 45

Breakdown of Licensed SPP Installed Capacity by Province[1]



[1] *The breakdown of installed capacity on the map excludes Kalyon Karapınar YEKA-1 SPP.*

Source: TEİAŞ

The commissioning of Kalyon Karapınar YEKA-1 SPP resulted in the largest increase of the licensed SPP capacity within Türkiye.

Licensed Top 10 SPPs (MW)

#	Company	SPP	Location	Capacity
1	kalyon	Karapınar YEKA-1 SPP	Konya	1,000 MW
2	ecogreen	G4 Bor-2 SPP	Konya	96 MW
3	kalyon	G4 Bor-3 SPP	Niğde	92 MW
4	RHG ENERTÜRK ENERJİ	Gün Güneş Van Arısu SPP	Van	45 MW
5	KIVANÇ	Kıvanç 2 SPP	Mersin	35 MW
6	TEKSİN	Teksin SPP	Karaman	33 MW
7	POLATENERJİ	Cıngıllı SPP	Niğde	26 MW
8	RHG ENERTÜRK ENERJİ	Gün Güneş Ant. Akseki	Antalya	23 MW
9	FERNAS	Fernas-4 SPP	Burdur	20 MW
10	artıbirenerji	Küçükköy SPP	Antalya	19 MW

kalyon

1 GW
Installed Capacity

3.5 million
Solar Modules

2 million people
Electricity need met

1.5 million tonnes
Emission Reduction

20 million m^2
Land Size

The Kalyon Karapınar YEKA-1 SPP is **the largest** solar power plant in Europe. **It has 1 GW of installed capacity**.

The Karapınar SPP was built by Kalyon Enerji, the winning bidder of the YEKA SPP-1 tender. The installation of the power plant started in 2020 and was completed in March 2023.

The YEKA SPP-1 competition was held according to the **local production-based allocation** method. Therefore, **Kalyon PV, which is the first vertically-integrated solar module production facility** in Türkiye, was built to meet the **local content ratio** requirement for the solar modules used in the power plant. 80% local content ratio was achieved in the solar modules manufactured by Kalyon PV.

50% of Kalyon Enerji, the operator of the power plant, was sold to International Energy Holdings, based in the UAE, on 11 August 2022.

Source: EMRA, Publicly Available Sources

The National Energy Plan published by the Ministry of Energy and Natural Resources in 2022 is a road map outlining the stages of Türkiye's transition to clean energy.

Upon signing the Paris Agreement in October 2021, Türkiye committed that its national economy will reach net zero emissions by 2053. The National Energy Plan outlines the levels that should be reached by 2035 in order to stay on track with delivering Türkiye's net zero emission commitments for 2053.

2035 Projections of the National Energy Plan

The share of solar and wind energy in renewable energy installed capacity is expected to reach approximately 67%, and the share of both solar and wind in total installed capacity is expected to reach approximately 44%.

It is predicted that the share of renewable energy sources in electricity generation will gradually increase from 40% (in 2023) to 55% at the end of 2035.

It is assumed that the total installed capacity of battery storage systems, which may bring additional flexibility to the energy system, will reach 7.5 GW as of 2035.

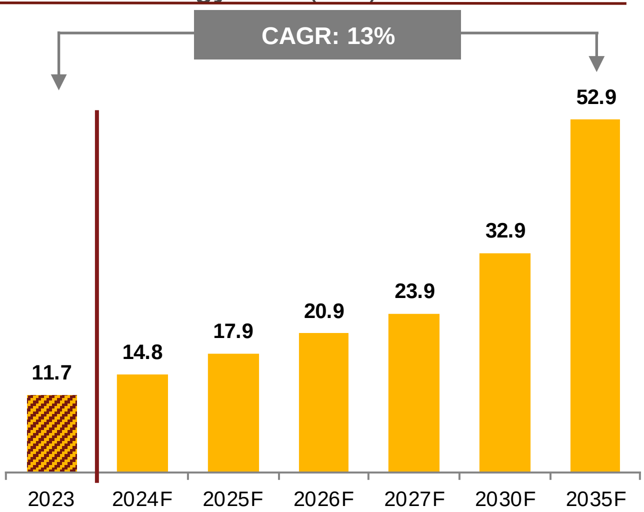
Solar Energy in the National Energy Plan

Considering Türkiye's current electricity system capabilities and its renewable energy potential, the Ministry of Energy and Natural Resources estimates that solar energy installed capacity will correspond to 28% of total installed capacity in 2035 and approximately 43% of renewable energy installed capacity.

National Energy Plan projections assume that solar energy installed capacity will increase by **3 GW/year** between 2025 and 2030 and **4 GW/year** between 2030 and 2035.

Graph 46

Solar Energy Installed Capacity in the National Energy Plan (GW)



Source: Türkiye National Energy Plan, TEİAŞ

The Medium Term Programme published by the Presidency of Türkiye in September 2023 provides a detailed roadmap for green transformation by considering Türkiye's 2053 net zero emission targets.

Green Energy Transformation Approach in the MTP

The green energy transformation of Türkiye will be realized by holistically considering the country's net zero emissions targets of 2053, the Green Deal Action Plan prepared in accordance with the EU harmonisation process, and Türkiye's national development priorities:

1. Support reduction of emissions arising from greenhouse gases
2. Increase the ability to adapt to global climate change
3. Prioritise competition and efficiency simultaneously
4. Conduct the green energy change on a playing field level to all stakeholders
5. Develop national incentive mechanisms using global financing resources

Policies for Renewable Energy Resources in the Medium Term Programme

- Widen the renewable energy use in existing and new organized industrial zones and free zones
- Deploy innovative, sustainable financing resources for green transformation in the framework of environmental, social and governance criteria
- Ensure YEKA practices include local content requirements
- Assess Türkiye's heat potential and enact heat supply regulations for the use of waste heat
- Support R&D and innovation activities for technologies that contribute to energy transformation e.g. energy storage, hydrogen & carbon capture
- Adopt buildings with 'almost zero energy' approach that aims to use renewable energy at a certain rate in public, commercial, and residential buildings

Policy practices for the specified renewable energy sources are mostly in line with solar energy use in Türkiye. The continuation of the YEKA model, storage solutions, and increase in financing resources have the potential to result in an increase in licensed SPP installed capacity, whereas increasing renewable energy sources in buildings, OIZ incentives, and evaluation of Türkiye's heat potential also have the potential to result in an increase in unlicensed SPP installed capacity.

Source: Presidency of the Republic of Türkiye Department of Strategy and Budget

The 12th Development Plan published in October 2023 addressing the targets of 2024-2028 sustains green transformation-based policies outlined on the National Energy Plan and the Medium Term Programme for the energy, utilities & resources industry.

12th Development Plan (Target Period for 2024-2028)

The development plan is based on the long-term national planning and considers global and regional elements currently affecting Türkiye.

The investments for green transformation and renewable energy sources reflected in the National Energy Plan (2022) and the Medium Term Programme (2023) previously published by the Ministry of Energy and Natural Resources and the Presidency of Türkiye that lay out the energy national roadmap are also included in this plan to reinforce Türkiye's long-term targets.

Table 8

Energy Targets Published in the 12th Development Plan

Category	2023 Year End	2028 Year End	Total Increase	Yearly Increase
Total Inst. Capacity (GW)	107.1	136.0	28.9	5.8
Wind Inst. Capacity (GW)	11.8	18.0	6.2	1.2
Solar Inst. Capacity (GW)	11.7	30.0	18.3	3.7
Share of Renewables in Generation (%)	42%	50%	8%	2%
Battery Storage Capacity (GW)	-	5.0	5.0	1.0

The 2023 year-end data are based on the predictions of the Presidency's Department of Strategy and Budget.

The annual increase was calculated by dividing the increase between the end of 2023 and the end of 2028 by five, based on the five-year period considered in the development plan.

The Role of Solar Energy in the Energy Transformation

Based on the assumptions that installed solar energy capacity will account for **c. 65%** of the installed capacity increase planned for the period covering 2024-2028 and that the share of renewable energy capacity within the total installed capacity will rapidly rise from **10%** to above **20%;** the 12th Development Plan reflects that solar energy will be the main driver of Türkiye's green transformation and national energy policies for the near future.

Source: Presidency of the Republic of Türkiye Department of Strategy and Budget

Türkiye's solar energy capacity development has been realized through a staged approach. Currently, the capacity allocation could be evaluated by three main phases.

First Phase

Pre-YEKDEM FiT and First YEKDEM FiT Phase

- No tender models existed before YEKDEM FiT, and the process consisted of applications for projects developed by investors.
- Purchase guarantees considered the specific dynamics of the investor and project.
- The first YEKDEM FiT entered into force in 2005 but demand was limited.
- Purchase guarantees were granted to the first applicants and there was no tender process.

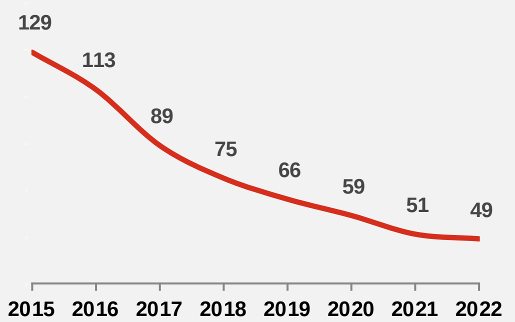
2015 Tenders

2015 Solar Tenders

- In 2015, a new tender system was implemented for solar power plants.
- 600 MW of solar energy capacity in total was allocated.
- Winners in the tender were determined by a one-time TL-based contribution fee to be paid per MW. The payment was to be paid within three years after the COD.

Graph 47

Global Average Solar Energy LCOE Analysis (USD/MWh)



Although a total of 600 MW in licenses was distributed through solar tenders in 2015, most of the plants receiving their licenses commenced oeprations in 2022 and afterwards.

Among the main factors that triggered an approximately seven-year delay in the operation start of the licensed power plants were the decline in the levelized cost of electricity in solar for the relevant years and the fact that the companies with power plant licenses decided to wait for the most appropriate time in terms of overall cost.

Current Allocation

Current Capacity Allocation Scheme

1 YEKA Tenders

The main tender model currently being used to develop renewable energy and is predicted to continue in the future.

Currently, only one tender (YEKA SPP-5) with 1.2 GW capacity is planned.

Both Medium Term Programme and the 12th Development Plan underlined that YEKA tenders will remain in place.

2 Other

Unlicensed Power Plants: Power plants aimed for autoconsumption.

Hybrid Power Plants: Plants combining electricity generation by combining different technologies. As of February 2024, c. 45 power plants were in operation.

Power Plants with Energy Storage: EMRA offered the opportunity to establish power plants that store energy in a way that does not exceed the installed capacity stated in the license. However, applications were suspended as of October 2023.

Capacity Increase: TEİAŞ declares monthly installed capacity increases for active, unlicensed, and hybrid power plants.

Source: EMRA, Bloomberg

In the scope of the Regulation published by the Ministry of Energy and Natural Resources, the YEKA investment model was implemented in October 2016 for large-scale renewable energy sources.

The YEKA model regulation was promulgated in the Official Gazette on 9 October 2016.

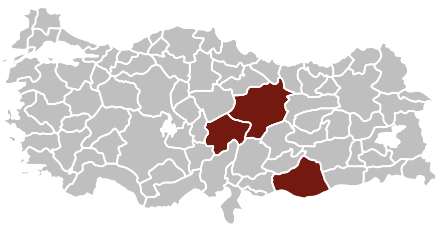
In this investment model, installed capacities for pre-determined renewable energy resource areas (YEKA) are allocated to potential investors by considering their offers. Also, the pre-determined technical specifications may be taken into account and an obligation to use local components while producing the power plants could be implemented.

The investment model created in the scope of the YEKA regulation increases the share of electricity generation from renewable sources, and enables cost reductions for electricity purchases, development of new technologies in renewable energy, and the increase of qualified human capital. Moreover, with the local production-based allocation model (YÜKT), the technological transfer through the establishment of R&D centres and production facilities will be enabled, as well as support for the creation of employment in various industries will be supported.

Renewable Energy Resource Areas (YEKA) Published on 30 September 2023

According to the notice published by the Ministry of Energy and Natural Resources in the Official Gazette, five new YEKA areas were established. The new YEKA areas are listed as:

- Kayseri-4
- Kayseri-5
- Kayseri-6
- Sivas
- Şanlıurfa



2 new YEKA areas have been determined based on the publication on the Official Gazette dated 16 January 2024

- G3 Aksaray 2-53
- G3 Aksaray 2-54

Determination of YEKA Fields

1 YEKA Determined by the Ministry of Energy and Natural Resources

YEKA Determination → Competition → Agreement

A competition is organized after the areas determined by MENR through technical work are published in the Official Gazette.

2 YEKA Determined by Investor

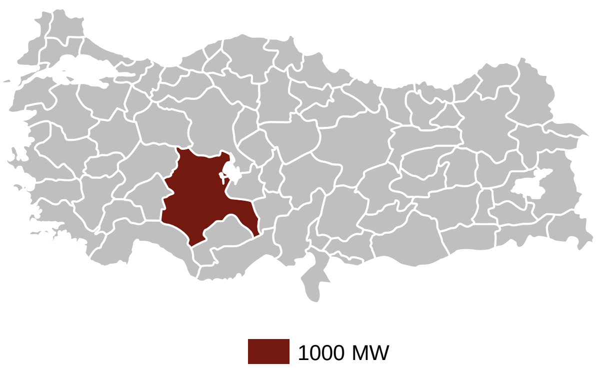
Competition → Agreement → YEKA Determination

YEKA field is determined by the investor winning the 'YEKA-Purpose Connection Capacity Allocation Competition' under the condition that the field is within the area allocated for connection. The determination is then approved by MENR.

Source: MENR

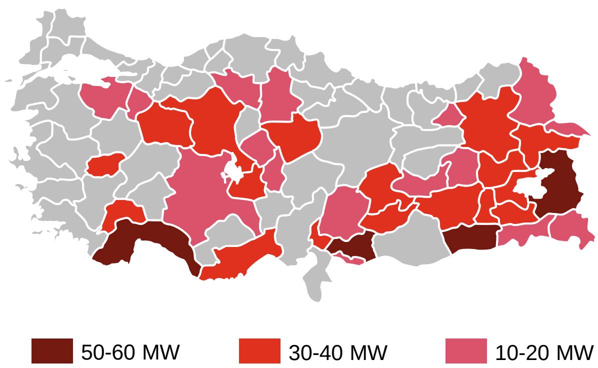
YEKA tenders previously held for relatively larger capacities between 2017-2019 were changed to accomodate smaller scale capacities after 2020, in order to enable an increased number of smaller-scale investors to participate.

YEKA SPP-1



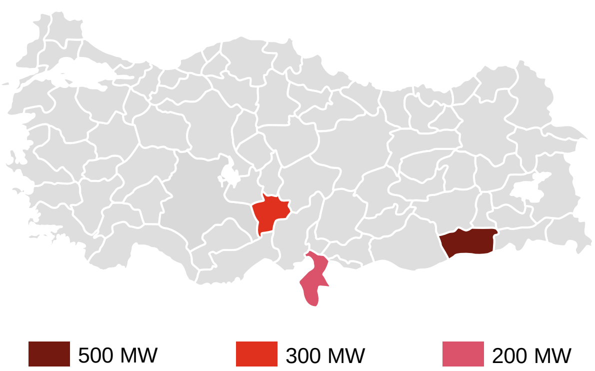
The YEKA SPP-1 was established based on the local production-based allocation model. In this scope, Kalyon Group established Kalyon Güneş Teknolojileri (Kalyon PV), an integrated solar module production facility. Kalyon PV, which also performs R&D activities, manufactures the solar modules used in the YEKA SPP-1, with a local content ratio greater than 80%. The YEKA SPP-1 in Konya Karapınar was completed in March 2023 with its total installed capacity reaching 1,000 MW.

YEKA SPP-3 (Mini-YEKA SPP)



The YEKA SPP-3 tender for 74 SPPs in 36 provinces, having a total capacity of 1,000 MW are distributed to SPPs with 10, 15 or 20 MW capacities using the allocation for exchange of domestic goods usage (YMKT) model. 15-year purchase guarantee agreements were signed with the investors quoting the lowest prices on a TL/kWh basis in an auction. The YEKA fields were determined by the winning investors and announced upon the approval of the MENR. Prices were determined in TL, and were protected against inflation and foreign exchange risk by an escalation mechanism. The purchase price ceiling was determined as USD 53/MWh.

YEKA SPP-4



The YEKA SPP-4 tender for 15 SPPs in 3 provinces with a total capacity of 1,000 MW are distributed to SPPs with 200, 300, or 500 MW capacities. As a result of price quotes received at auction, winners were granted purchase price guarantees for the first 23 GWh of electricity generated per MWe in each facility. **MENR offered the option to sell electricity in the spot market instead of at a tender price and the right to establish a facility with storage after the pre-license signature date if the facility construction is completed before the projected construction end date.**

Source: MENR

YEKA SPP-1 was completed in 2017, whereas the YEKA SPP-3 and YEKA SPP-4 saw their competition processes finalised, yet field work and the licensing stages are currently ongoing. At present, the YEKA SPP-5 is solely on the planning phase.

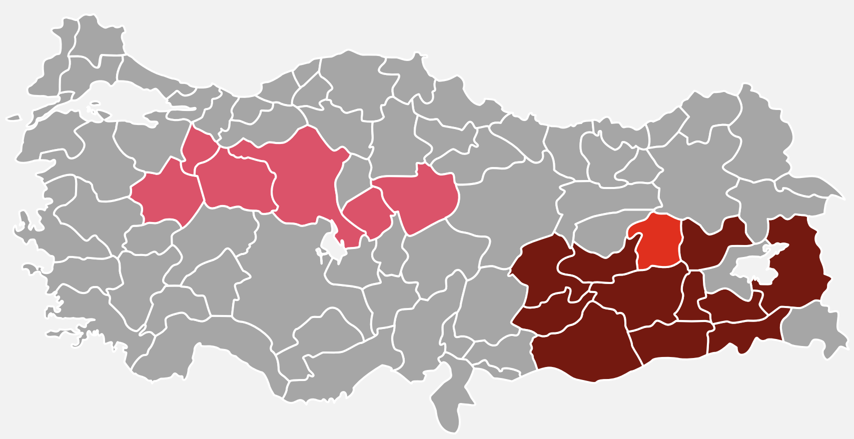
Table 9

YEKA SPP Tenders

	YEKA SPP-1	YEKA SPP-3	YEKA SPP-4		
Location	Konya/Karapınar	36 Connection Regions	Niğde/Bor 3 Conn. Regions	Hatay/Erzin 2 Conn. Regions	Şanlıurfa/Viranşehir 10 Conn. Regions
Date	20 March 2017	April-May 2021	Apr-22	Jun-22	Jun-22
Capacity	1,000 MW	1,000 MW	300 MW	200 MW	500 MW
Ceiling Price	80 USD / MWh	350 TL / MWh	950 TL / MWh	950 TL / MWh	
Winning Bid	69.9 USD / MWh	218 TL / MWh	397 TL / MWh	590 TL / MWh	539 TL / MWh
Winning Company	Kalyon	Margün, Gün Güneş, Bakırlar Tekstil, Eksim	Smart, Ecogreen, Kalyon	Limak, IC İçtaş Enerji	Egesa, Eksim, Kalyon, Ral Enerji, Reşitoğlu
Purchase Price Guarantee Period	15 years	15 years	First 23 GWh/MW to be produced		
Local Content Ratio	60% for first 500 MW 70% for second 500 MW	%60	%75		

The YEKA SPP-3 and YEKA SPP-4 competitions were completed, but field work and license/pre-license processes of the projects continue. Once the installation processes of the relevant tenders are complete, **the installed solar energy capacity in Türkiye will increase by 2,000 MW. The local content ratio requirement** for the SPPs within the context of both tenders range between **65%-75%.**

Planned YEKA SPP Tenders - YEKA SPP-5



80-110 MW

40-70 MW

10-30 MW

On 30 September 2021 a YEKA competition between 74 regions was announced. It included 10, 20, and 30 MW SPPs for a total capacity of 1,500 MW for the YEKA SPP-5 to be awarded to 23 regions.

On 12 February 2022, a correction notice was published and the total capacity was decreased to 1,200 MW. Also, it was announced that a YEKA competition using the allocation for exchange of domestic goods usage method (YMKT) would be held for 66 SPPs in 18 regions.

1,200 MW Total Capacity

18 Regions

66 Competitions

Source: MENR

Hybrid generation plants are created by combining electricity generation plants that use different technologies. In addition to cost advantages, the main purpose of hybrid power plants is to generate electricity with higher efficiency.

Building electricity generation facilities depending on more than one source became possible upon the promulgation of the Regulation on the Adjustment of the Electricity Market License Regulation in the Official Gazette on 8 March 2020.

On 2 November 2022, EMRA's decision amending the Principles and Procedures on the Determination of Power Plant Fields of Generation Facilities Subject to Pre-license or License in Electricity Market (the Principles and Procedures) has been published in the Official Gazette of Türkiye.

With this change, **limitations were lifted** regarding the **total installed capacity** of units using secondary sources for hybrid power plants that use **wind energy** as a main source.

Excluding wind power plants, the hybrid power plant capacities for **all power plants for which wind is not a main source** were determined based on the following:

Total Capacity ≤ 50 MW

That the capacity of secondary source does not exceed the total installed capacity of the main source.

Total Capacity > 50 MW

The maximum capacity of the secondary source is calculated by adding:
(1) 50 MW and
(2) half of the remaining capacity of the main source above 50 MW.

For all main sources, the total installed capacity of secondary sources cannot exceed the capacity stated in the license.

The installed power of secondary sources cannot exceed 100 MW in total.

Advantages Provided by Hybrid Power Plants

- Potential for greatly benefiting from resources thanks to the integration of different energy sources
- Generating more sustainable energy when combined with non-sustainable systems
- Minimising the impact of seasonal conditions
- Generation potential with lower costs
- Provides convenience for grid use and integration compared to one source

Source: Official Gazette

With the slowdown in large scale investments slowing and changes in new regulations, many renewable energy companies announced plans to increase capacity and transform power plants which have a single source into hybrid power plants.

Solar is preferred more than other power plants as a secondary source in hybrid power plants due to advantages such as low installation costs, ease of installation, and ease of integration.

As of February 2024, there are **247 licensed hybrid power plants** and the supplementary source of **246** among them is **solar energy**. **Total supplementary source installed capacity** of licensed hybrid power plants where the supplementary source is solar reached **2.5 GW**. Approximately **540 MW** o these plants are in operation, while plants with **c. 1.9 GW** are expected **to start operating**.

Hybrid Power Plants Completed in Türkiye[1]

Company	Power Plant	Main Source	Secondary Source
Aydem yenilenebilir enerji	Uşak WPP	Wind 105 MW	Solar 82 MW
Kalehan Genç Enerji	Aşağı Kaleköy HPP	Hydroelectric 500 MW	Solar 80 MW
Ece Tur Şirketler Grubu	Kangal WPP	Wind 128 MW	Solar 40 MW
Sanko Enerji	Akyel WPP	Wind 40 MW	Solar 40 MW
Akın Holding	Sertavul WPP	Wind 30 MW	Solar 30 MW
Cengiz Enerji	Hamsi WPP	Wind 35 MW	Solar 35 MW
Mutluer energy	Mutlu 5 WPP	Wind 44 MW	Solar 25 MW
İsken	Iskenderun Import Coal	Import Coal 1,308 MW	Solar 21 MW

[1] *The above hybrid power plants were listed according to secondary source capacity, and information about the first eight power plants is detailed in the table above. The detailed facilities began their operations and their installed capacity is given in Megawatts-mechanic (MWm).*

Source: EMRA

With the slowdown in large scale investments slowing and changes in new regulations, many renewable energy companies announced plans to increase capacity and transform power plants from single source to hybrid power plants.

The licensed hybrid power plants are listed based on their installed capacity of the secondary source. The table contains details on the top 30 plants, with those highlighted in gray indicating plants that started to operate as of February 2024. The remaining plants have obtained secondary source licenses but have not yet started to operate.

Company	Power Plant	Main Source	Secondary Source
BORUSAN	Saros WPP	138 MW	94 MW
BİLGİN ENERJİ	Aliağa WPP	120 MW	85 MW
Aydem	Uşak WPP	105 MW	82 MW
KALEHAN GENÇ ENERJİ	Aşağı Kaleköy Barajı ve HPP	500 MW	80 MW
TATLIPINAR	Tatlıpınar WPP	113 MW	79 MW
HİDRO GEN	Soma Kolin TES	510 MW	77 MW
BAK ENERJİ	Yahyalı WPP	96 MW	71 MW
SELENKA ENERJİ	Cerit WPP	90 MW	70 MW
ECE	Kangal WPP	128 MW	40 MW
dh demirer holding	Kuyucak WPP	50 MW	50 MW
ARES ELEKTRİK	Bağlama WPP	50 MW	50 MW
CENGİZ ENERJİ	Çerkeş WPP	50 MW	50 MW
emba	Hunutlu TPP	1320 MW	48 MW
AL-YEL ELEKTRİK	Geycek WPP	168 MW	47 MW
GALATAWIND	Taşpınar WPP	61 MW	43 MW
ENERGO-PRO	Alpaslan II Barajı ve HPP	280 MW	42 MW
akfen YENİLENEBİLİR ENERJİ	Üçpınar WPP	99 MW	40 MW
SANKO ENERJİ	Akyel - 1 WPP	40 MW	40 MW
Ağaoğlu	Kartal WPP	39 MW	39 MW
aksa ENERJİ	Bolu-Göynük Electricity Plant	270 MW	38 MW
CENGİZ ENERJİ	Hamsi WPP	35 MW	35 MW
SELENKA ENERJİ	Bafa WPP	35 MW	35 MW
MOGAN	Kocatepe WPP	88 MW	33 MW
AKIN HOLDING	Sertavul WPP	30 MW	30 MW
EKSİM enerji	Killik WPP	90 MW	29 MW
Mikail Enerji	Çamınbaşı WPP	27 MW	27 MW
SANCAK	Bağlar WPP	100 MW	26 MW
MUTLUER energy	Mutlu WPP - 5	44 MW	25 MW
ZORLU ENERJİ	Kızıldere-3 GPP	165 MW	25 MW
YATAĞAN TERMİK ENERJİ	Yatağan Termik Santrali	666 MW	24 MW

The Ministry of Agriculture and Forestry changed a regulation to allow licenses to be granted for solar power plants in forest land that is no longer productive. This regulation aims to facilitate the construction and use of hybrid power plants and promote their construction.

Following the announcement of this regulation change, **10 coal-fired thermal power plants** have obtained licenses for secondary sources. The total installed solar energy capacity of hybrid power plants, with coal-fired thermal power as their primary source, has reached **243 MW**.

As of February 2024, the top 3 hybrid coal-fired thermal power plants with the highest secondary source capacity, as listed below:

Power Plant	Main Source Installed Cap.	Secondary Source Installed Cap.
Soma Kolin TPP	510 MW	76 MW
Hunutlu TPP	1,320 MW	48 MW
Bolu Göynük TPP	270 MW	38 MW

Source: EMRA

Electricity storage is regulated by the relevant legislation in Türkiye, published on the Official Gazette dated 9 May 2021. EMRA started accepting pre-licence applications for electricity storage facilities in November 2022 and awarded the first licence in April 2023.

According to the legislation on the regulation of electricity storage activities, 4 different types of electricity storage facilities could be installed: independent facility, facility integrated to a production plant, facility integrated to a consumption facility, and facility installed by a grid operator. The following requirements apply for each facility type:

1 – Independent Facility

Requires obtaining a supplier licence and possessing an installed capacity of at least 2 MW.

2 – Facility Integrated to a Production Plant

Requires possessing a production licence from EMRA and possessing an installed capacity not greater than the capacity of the licenced production plant.

3 – Facility Integrated to a Consumption Facility

Requires the approval of the grid operator and possessing an installed capacity not greater than the contracted capacity of the consumption facility.

4 – Facility Installed by a Grid Operator

Requires possessing a production licence from EMRA and possessing an installed capacity not greater than the capacity of the licenced production plant.

In addition to these power plant types, universities can establish electricity storage facilities not exceeding 1 MW for use in their R&D activities.

Most Utilized Facility Types

The majority of the electricity storage facilities fall within the first two categories and are integrated to a solar or a wind power plant.

According to EMRA, the investment for SPP/WPP's with an integrated storage facility has faced a sharp increase since the start of the acceptance of pre-licence applications, with approximately 6,000 applications being submitted. **EMRA ceased accepting further pre-license applications for storage facilities as of October 2023.**

Total Pre-Licenses & Future Goals

More than **500** storage facilities integrated to a production plant received pre-license approvals as of February 2024.

The pre-licensed facilities amount to a total storage capacity of **c. 30 GW**.

Pre-licensed SPPs with storage have doubled the total number of pre-licensed WPPs with storage.

Source: Official Gazette, EMRA, TÜREB, PwC Analysis

As of February 2024, EMRA granted approximately 600 pre-licenses for facilities with storage.

Pre-License	SPP with Storage	WPP with Storage
c. 575 Total Number of Pre-licences	c. 355 Pre-licensed SPP with Storage	c. 220 Pre-licensed WPP with Storage
c. 29.3 GW Pre-licensed Capacity	c. 13.6 GW Pre-licensed Capacity	c. 15.7 GW Pre-licensed Capacity

The eight companies with the highest pre-license solar power plant storage in Türkiye are shown below.

1	ERSİS ENERJİ	Portakal SPP	Ins. Capacity: 250 MW	Storage: 250 MW
2	EH	Niğde Merkez SPP with Storage	Installed Capacity: 250 MW	Storage: 250 MW
3	KIVANÇ	Kıvanç SPP	Installed Capacity: 250 MW	Storage: 250 MW
4	Harput	Harput SPP with Storage	Installed Capacity: 250 MW	Storage: 250 MW
5	kalyon	Süel SPP with Storage	Installed Capacity: 200 MW	Storage: 200 MW
6	EH	Kocacılı SPP with Storage	Installed Capacity: 200 MW	Storage: 200 MW
7	Aydem enerji	Keberli SPP	Installed Capacity: 200 MW	Storage: 200 MW
8	Aydem enerji	Güzelkuyu SPP	Installed Capacity: 250 MW	Storage: 250 MW

Source: EMRA, PwC Analysis

The introduction of YEKDEM FiT to the Turkish electricity market increased investments in renewable energy power plants, as it provided the required framework and incentives for market players looking to engage in renewable investments.

The initial YEKDEM FiT provided renewable generators with the option to sell their output at fixed prices for ten years. **Renewable energy power plants commissioned up to 30 June 2021 were covered by the initial FiT of the YEKDEM scheme.**

Table 10

Initial YEKDEM Feed-in Tariff

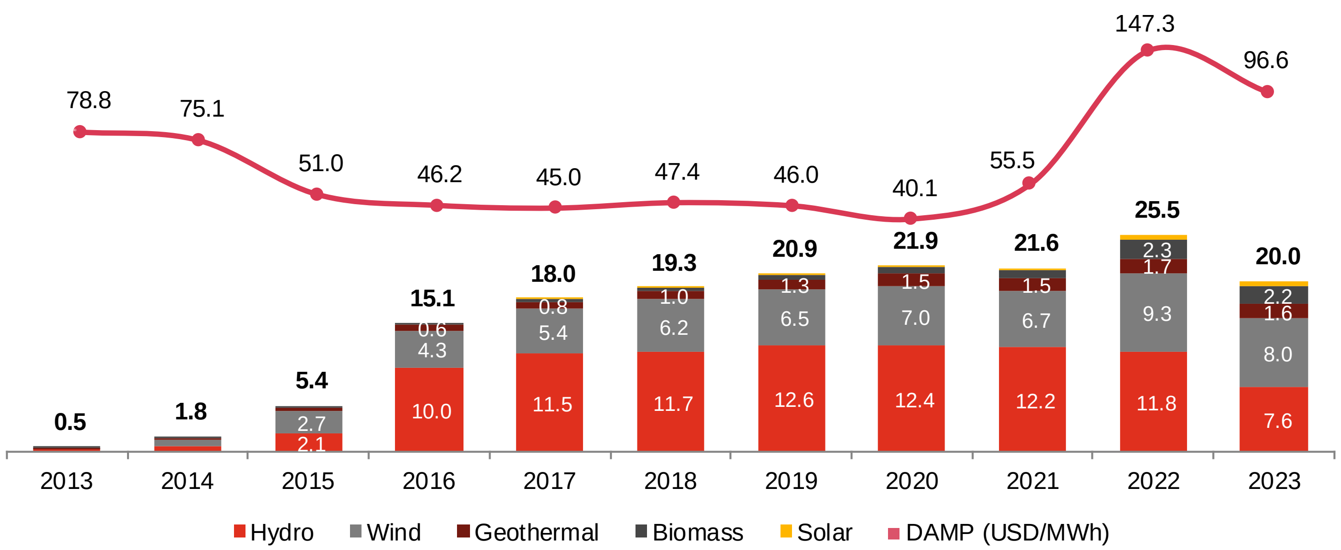
Renewable Energy Source	YEKDEM (USD/MWh)	Local Component Incentive (USD/MWh)
Hydro	73	10 – 23
Wind	73	6 – 37
Geothermal	105	7 – 27
Solar	133	4 – 56
Biomass	133	5 – 67

The first version of the support mechanism offered USD denominated purchase guarantees for the power plants enlisted in the scheme. In addition to 10-year FiT, enlisting plants were granted USD denominated local component incentives, if the criterias were met. As the frequency of the large-scale currency depreciations increased, MENR has decided to introduce a new support mechanism encompassing new conditions for the power plants to be commissioned after 30 June 2021.

Graph 48

Total Installed Capacity of Power Plants That Benefited from YEKDEM FiT (GW)

Both hydro and wind power plants have benefitted from YEKDEM FiT the most between 2015-2021 as during the same period the price guarantee given to both sources, which was at USD 73/MWh, remained above the annual average day-ahead market price (DAMP) – which is the market clearing price. From 2022 onwards, DAMP became more advantageous compared to the guaranteed YEKDEM FiT, with the shift in prices resulting in a decrease in the number of plants benefitting from YEKDEM FiT, which mostly include hydro and wind power plants that do not have a clause requiring guaranteed YEKDEM FiT payments in their loan terms.



Source: EMRA, Energy Exchange Istanbul (EXIST)

First introduced in 2005, YEKDEM Feed-in Tariff attracted the attention of investors after 2015 due to the sharp drop observed in DAMP. YEKDEM FiT scheme has been updated in 2021 and 2023.

As the frequency of the large-scale currency depreciations increased, USD denominated YEKDEM FiT started to cause fiscal pressure on the Treasury. As a result, MENR introduced a new TL denominated support mechanism encompassing new conditions for the power plants to be commissioned after 30 July 2021. The power plants commissioned between 1 July 2021 and 31 December 2025 will be eligible to benefit from the new TL denominated 10-year FiT. The new schedule includes a domestic component incentive for 5 years if it is approved that 51% of the components used in the power plant are domestically manufactured.

On 1 May 2023 , the new FiT mechanism was revised and extended to better reflect the expectations of the market participants and respond to the recent developments in the energy markets. Compared to second iteration of the FiT, the latest iteration included an overall hike in FiT and weights of the hard currencies used in the escalation formula have been increased.

Table 11

Latest YEKDEM Feed-in Tariff from May 2023

Renewable Energy Source		YEKDEM FiT (TL/MWh)	YEKDEM FiT Duration (Years)	YEKDEM FiT Floor (USD/MWh)	YEKDEM FiT Ceiling (USD/MWh)	Local Component Incentive (TL/MWh)	Local Component Incentive Duration (Years)
Hydro	Reservoir	1,440.0	10	67.5	82.5	288.0	5
	Run of River	1,350.0	10	63.0	77.0	288.0	5
Wind	Onshore	1,060.0	10	49.5	60.5	288.0	5
	Offshore	1,440.0	10	67.5	82.5	384.5	5
Geothermal		2,020.0	15	94.5	115.5	288.0	5
Biomass	Landfill Gas	1,060.0	10	49.5	60.5	288.0	5
	Biomethanization	1,730.0	10	81.0	99.0	288.0	5
	Thermal Disposal	1,349.0	10	57.5	80.0	215.8	5
Solar		1,060.0	10	49.5	60.5	288.0	5
Solar / Wind with Storage		1,250.0	10	58.5	71.5	384.5	10
Pumped-Storage Hydro		2,020.0	15	94.5	115.5	384.5	10
Wave & Marine Current Power		1,350.0	10	63.0	77.0	384.5	10

Most Significant Changes Implemented with the Latest YEKDEM FiT

1. Inclusion of offshore wind, storage facilities, pumped-storage hydroelectric and wave & marine current power to the FiT
2. Extension of FiT duration provided to geothermal plants to stimulate stagnant GPP installed capacity
3. Introduction of a FiT floor in addition to ceiling to better absorb the FX rate risk faced by IPPs
4. Application of escalation formula for the local content incentive (previously only FiT was subjected to escalation)
5. Increased focus on changes in FX rates regarding the escalation formula (previously inflation indexes had the larger weight)
6. Escalation frequency reduced to monthly updates (previously FiT was updated quarterly)
7. The power plants commissioned between 1 July 2021 and 31 December 2030 will be eligible to benefit from their respective FiT displayed above (previously the eligibility interval ended on and 31 December 2025).

Source: EMRA

Third iteration of YEKDEM Feed-in Tariff supports a more reflexive and hard-currency based scheme for the eligible renewable energy power plants.

YEKDEM Escalation Mechanism Implemented in 2021

YEKDEM FiT in Month A = **YEKDEM FiT_A** =

$$\text{YEKDEM } FiT_{A-3} \times \left[\left(26\% \times \frac{PPI_{A-2}}{PPI_{A-5}}\right) + \left(26\% \times \frac{CPI_{A-2}}{CPI_{A-5}}\right) + \left(24\% \times \frac{\text{USD Exchange Rate}_{A-2}}{\text{USD Exchange Rate}_{A-5}}\right) + \left(24\% \times \frac{\text{EUR Exchange Rate}_{A-2}}{\text{EUR Exchange Rate}_{A-5}}\right)\right]$$

Weight of Inflation Indexes: **52%**

Weight of Change in Exchange Rates: **48%**

Update Frequency: **3 Months**

YEKDEM Escalation Mechanism Updated in May 2023

YEKDEM FiT in Month A = **YEKDEM FiT_A** =

Local Component Incentive (LCI) on Month M = **LCI_M** =

$$\text{YEKDEM } FiT_{A-1} \times \left[\left(25\% \times \frac{PPI_{A-2}}{PPI_{A-3}}\right) + \left(15\% \times \frac{CPI_{A-2}}{CPI_{A-3}}\right)\right.$$

$$LCP_{A-1} \times \left.\left(30\% \times \frac{\text{USD Exchange Rate}_{A-1}}{\text{USD Exchange Rate}_{A-2}}\right) + \left(30\% \times \frac{\text{EUR Exchange Rate}_{A-1}}{\text{EUR Exchange Rate}_{A-2}}\right)\right]$$

Weight of Inflation Indexes: **40%**

Weight of Change in Exchange Rates: **60%**

Update Frequency: **1 Month**

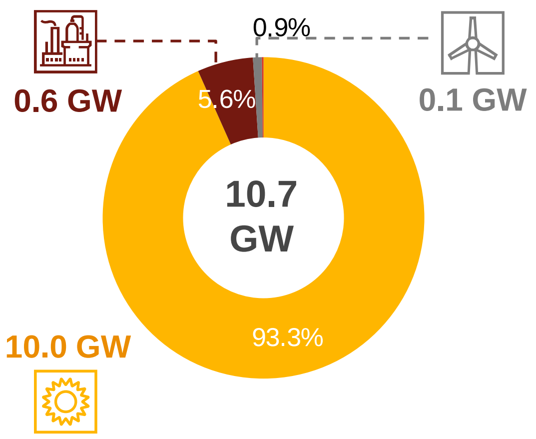
With the revision implemented on 1 May 2023, the escalation formula used to update the YEKDEM Feed-in Tariff became more reflexive due to more frequent updates. As a result of the change in weights of the escalation formula components, YEKDEM FiT became more responsive to the changes in USD and EUR FX rates, which have substantial impact on Turkish energy markets. Both with the introduction of USD denominated YEKDEM FiT floor and changes in the formula weights reduce the FX rate risk of renewable energy producers, similar to the USD denominated initial YEKDEM FiT.

Source: EMRA

More than 90% of the unlicensed power plants in Türkiye use solar energy due to operational and cost-related advantages. With the impact of the regulation amendments, the share of unlicensed SPPs in total SPP installed capacity has decreased in recent years.

Graph 49

Unlicensed Installed Capacity Distribution (December 2023)

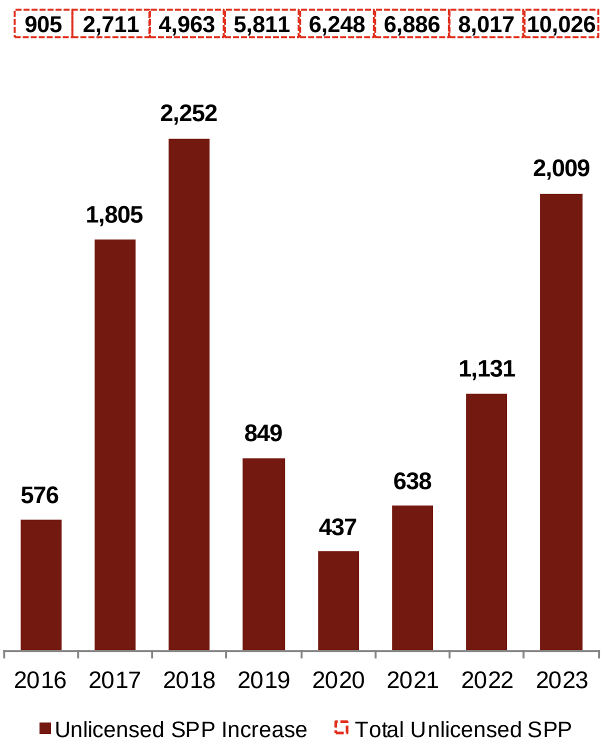


Unlicensed electricity generation in Türkiye has increased mainly due to solar energy investments since 2011. The share of unlicensed power plants in Türkiye's total installed capacity had exceeded **10%** as of the end of 2023, and the total unlicensed power plant installed capacity had grown to **10.7 GW** from **0.4 GW** in 2015. Solar power plants account for **93%** of the installed unlicensed power plant capacity in Türkiye.

The main reasons unlicensed electricity generation focuses on solar energy are the constant downward trend of solar module costs, the solar irradiance potential of Türkiye, the fact that efficiency in solar energy depends on the power plant size, and the operational ease of solar module installation compared to other technologies.

Graph 50

Unlicensed SPP Installed Capacity Increases and Total Unlicensed SPP Capacity (MW)



Source: TEİAŞ

Prior to the regulation amendment in May 2019, unlicensed power plants were allowed to benefit from the USD-based YEKDEM tariff, which led to a significant increase in the installed capacity of unlicensed power plants between 2016-2019, mainly through unlicensed SPPs. An annual average of 2 GW of unlicensed SPPs were installed especially in 2017 and 2018, which directly reflects the effects of the first YEKDEM tariff.

Regulation amendments made in May 2019, December 2020 and August 2022 aims to gradually shift the generation in unlicensed power plants towards solely meeting the autoconsumption needs of institutions and individuals.

The regulation change of August 2022 states that unlicensed power plants which received their call letters after 12 May 2019 can only sell the amount of electricity equalling two times of their own consumption.

Amendments made since 2019 have significantly changed conditions regarding unlicensed power plants. Currently, amendments aim to shift unlicensed electricity generation to solely meet autoconsumption needs.

Before 2019

There is no limit on electricity that may be sold to the grid

Can benefit from the first YEKDEM FiT tariff

Can benefit from local component and regional investment incentives in the scope of YEKDEM FiT

After 2019

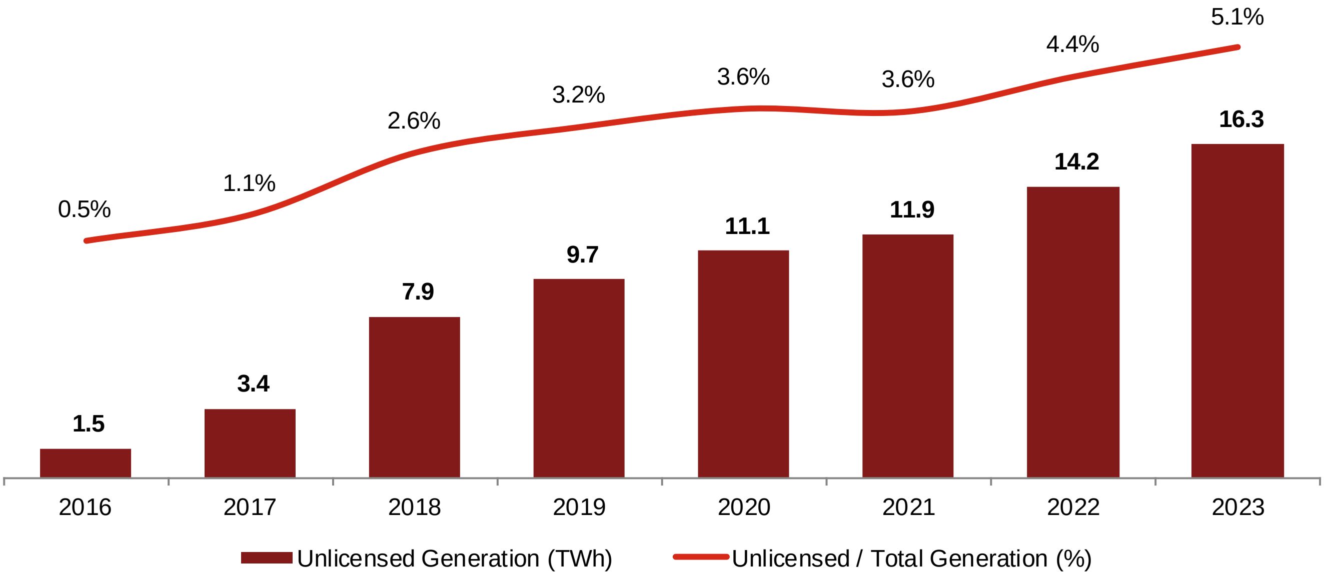
Electricity equalling autoconsumption amount can be sold to the grid

Cannot benefit from any YEKDEM FiT tariff

Can benefit from 4th region incentives including VAT and customs duty exemption

Graph 51

The Share of Unlicensed Electricity Generation in Total Generation (2016-2023, TWh, %)



The Share of Unlicensed Generation in Total Generation

The share of unlicensed generation remained relatively stable due to generation for auto-consumption after 2022. However, since regulations are changed frequently, it is expected that the share of unlicensed generation may fluctuate in the upcoming periods.

Allocation of New Unlicensed Capacity by TEİAŞ

Between 2022-2023, EMRA announced that it will allocate the unrealized capacities of the canceled YEKA auctions and WPP projects allocated in the pre-YEKA period to unlicensed, hybrid and existing licensed power plants through capacity increases. In February 2024, EMRA announced a total capacity allocation of 7.5 GW, including 3.75 GW transmission and 3.75 GW distribution capacity for unlicensed power plants.

2023: **2.37 GW**

2024: **3.75 GW**

Source: TEİAŞ, Official Gazette, Publicly Available Resources

Numerous companies from different industries are installing unlicensed SPPs for autoconsumption. In February 2024, a draft legislation amendment was submitted regarding the regulation for obtaining licences for unlicensed power plants.

Regulation on Unlicensed Power Plants Established for Autoconsumption

Based on the Regulation on Unlicensed Electricity Generation, unlicensed electricity for persons and private companies can be generated **on autoconsumption basis**.

Unlicensed Generation for Autoconsumption:

As per sub-paragraphs (c) and (ç) of the first paragraph of Article 5 of the Regulation, facilities based on renewable energy sources which have the same measurement point for generation and consumption.

Unlicensed power plants in the scope of 5.1.ç serve for autoconsumption purposes.

Additional Unlicensed Generation:

Based on the sub-paragraph (h) of the first paragraph of Article 5 added to the regulation in May 2021, generation facilities based on renewable energy and established **at the same or in a different point** as the consumption facility. The amendment included in August 2022 lifted the obligation for such facilities to be in the same distribution region as the consumpiton facility. ***Unlicensed power plants in the scope of 5.1.h serve as additional unlicensed power plants for producers who want to meet their autoconsumption from solar energy but are not able to obtain sufficient installation area and/or when generation in this scope of autoconsumption falls short.***

The Latest Amendment on the Unlicensed Regulation and Its Impact

Based on the latest amendment of the Regulation on Unlicensed Electricity Generation entered into force on 1 October 2023:

On condition that **private persons or private companies that built generation facilities in the scope of both 5.1.ç and 5.1.h** *run their facilities located at the autoconsumption point in the scope of Article 5.1.ç*, the electricity to be sent to the grid *(2 times the contract capacity in the connection agreement for municipalities, industrial establishments, and organizations engaged in agricultural irrigation, equal to contract capacity in the connection agreement for other persons)* from the additional facility established in the scope of Article 5.1.h will not be evaluated as being free of charge in the scope of YEKDEM FiT and may be sold based on the unlicensed producer's tariff group in the scope of YEKDEM FiT upon the completion of a monthly settlement calculation.

Additionally, as of 1 October 2023, it was decided that applications for unlicensed power plants would be transferred to an electronic platform.

On 29 January 2024, the draft legislation on *Amendments to the Mining Law and Certain Other Laws* submitted to the Turkish Grand National Assembly, proposed to change the licensing process for unlicensed electricity generation facilities which will complete their 10-year term under YEKDEM FiT.

The draft legislation aims to change the licensing process for unlicensed facilities as specified under Article 6 of the Law No. 5346 on *the Utilization of Renewable Energy Resources for Electricity Generation*. The draft amendment requires the payment of a one-time license fee for the acquisition of a license and a contribution fee to YEKDEM FiT system which is calculated as the difference between the YEKDEM FiT price specified for the plant's source and the hourly day-ahead market price (DAMP) whenever DAMP is greater than YEKDEM FiT for the plant's source.

Currently Proposed Licensing Process	One-time payment of a licensing fee + Payment of a contribution fee to YEKDEM FiT system in cases where the hourly DAMP is greater than the YEKDEM FiT price specified for the source of the power plant.

Source: TEİAŞ, Official Gazette, Publicly Available Resources

Numerous companies from different industries are installing unlicensed SPPs for autoconsumption. EMRA stated that unlicensed SPP applications reached 35 GW by the end of 2023.

The transition period of the Carbon Border Adjustment Mechanism, which aims to reduce carbon emissions from imports to the EU began on 1 October 2023 with electricity being classified as a sector with high carbon emissions under CBAM. Therefore, numerous large companies which possess a high level of electricity consumption have started to cover autoconsumption needs with unlicensed SPPs in order to avoid being subject to a carbon tariff under CBAM.

Companies Announcing Unlicensed SPP Investments for Autoconsumption and Announcement Year of the Investment

Company	Inst. Capacity	Year
TOSYALI HOLDING	2,500 MW	2024
ERDEMİR / İSDEMİR	1,000 MW	2024
OYAK	1,000 MW	2022
Türk Telekom	406 MW	2023
TURKCELL	300 MW	2023
kalyon PV	140 MW	2023
arçelik	82 MW	2023
GÜRSOY GRUP	80 MW	2023
ÇİMKO	54 MW	2023
SEZA ÇİMENTO	50 MW	m.d.
UĞURLULAR	40 MW	2023
SASA	40 MW	2022
ETİ KROM	38 MW	2023
ÇEMTAŞ	32 MW	2023
ÇİMENTO KONYA	30 MW	2022
BOĞAZİÇİ BETON	15 MW	2023

Source: Publicly Available Resources

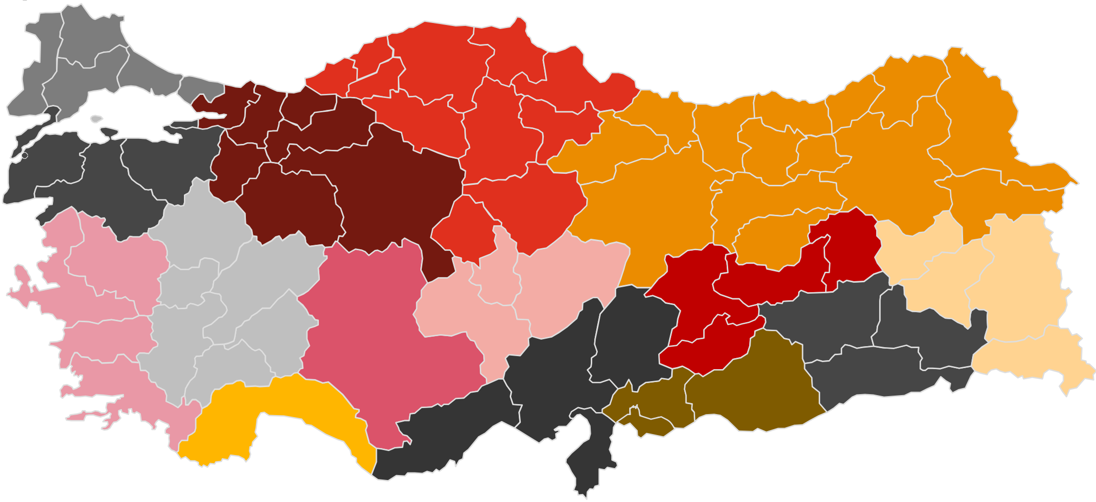
Following the reallocation of the installed capacity of the cancelled YEKA auctions and pre-YEKA WPP projects in 2022 and 2023, EMRA announced the allocation of 7.5 GW of transmission and distribution capacity for unlicensed power plants as of February 2024.

The allocation of the entire connection capacity announced by TEİAŞ for the 5-year period between 2023-2027 to WPP and SPP projects with storage by EMRA, in parallel with the significant number of applications and pre-licenses granted in this category, caused a bottleneck in the allocation of connection capacity, especially for unlicensed SPP investments for autoconsumption.

A total of 2.37 GW connection capacity was announced for unlicensed facility investments in March 2023, which was rapidly allocated. In February 2024, EMRA re-allocated a total capacity of 7.5 GW, of which 3.75 GW for transmission and 3.75 GW for distribution, for unlicensed electricity generation facilities in order to increase investments in unlicensed projects and to reduce the number of projects requiring connection capacity.

Table 12

Regional Transmission Capacities Announced in February 2024 for Unlicensed Power Plants (MW)



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

TEİAŞ determined February 2024 unlicensed capacity allocations based on 15 regions.

Region	Capacity	Region	Capacity	Region	Capacity
1	100	6	100	11	450
2	100	7	250	12	100
3	600	8	200	13	550
4	100	9	100	14	300
5	450	10	100	15	250
Total					**3,750**

Source: TEİAŞ, EMRA, Official Gazette

As of February 2024, there are multiple companies in Türkiye which manufacture solar modules. Kalyon PV is the only company producing cells and operating in all stages of the solar module value chain based on its vertically integrated manufacturing facility.

Solar Module Market in Türkiye

A high number of market participants are manufacturing solar modules in Türkiye with the advancements in the solar module technologies, rapid increase observed in Türkiye's solar energy installed capacity, and constant decreases in the manufacturing costs.
Even though a large number of players are active in the module manufacturing market, it is observed that the majority possess a production capacity of less than 1 GW, with only 8 companies posting a manufacturing capacity over 1 GW.

*As of February 2024, solely **Kalyon PV** produces solar cells with its **vertically integrated facility**.*
***Smart Solar** will start production from the cell stage in its new facility in İzmir/Aliağa during 2024.*

Table 13

Major Players with 1 GW or More Solar Panel Production Capacity

Company Name	Manufacturing Capacity	Level of Integration (Excluding Polysilicon)			
		Ingot	Wafer	Cell	Module
Kalyon PV	2.0 GW – Module 1.2 GW – Cell	Available	Available	Available	Available
Smart Güneş Teknolojileri	2.9 GW – Module 2.0 GW – Cell[1]	Not Available	Not Available	Available	Available
Sirius powered by Elin	3.5 GW – Module	Not Available	Not Available	Not Available	Available
Schmid Pekintaş Energy	2.5 GW – Module	Not Available	Not Available	Not Available	Available
CW Enerji	1.8 GW – Module	Not Available	Not Available	Not Available	Available
Alfa Solar Enerji	1.8 GW – Module	Not Available	Not Available	Not Available	Available
HSA Enerji	1.0 GW – Module	Not Available	Not Available	Not Available	Available
Daxler Energy	1.0 GW – Module	Not Available	Not Available	Not Available	Available

Manufacturing Available | Manufacturing Not Available | Public Company (Smart, CW Enerji, Alfa) | Vertically Integrated Company (Kalyon PV)

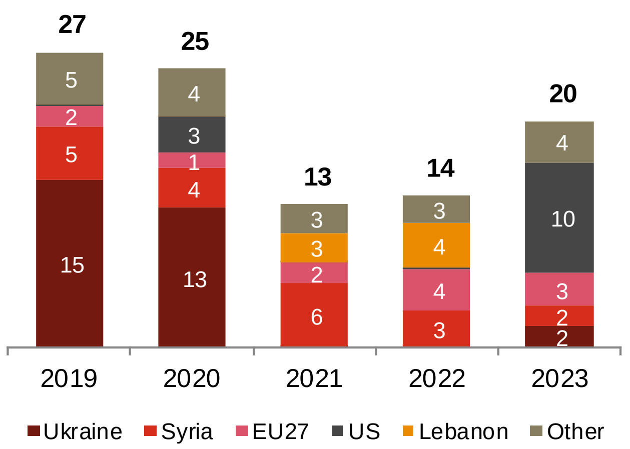
[1] *Smart Solar's cell production is planned to start during 2024.*

Source: Publicly Available Resources, Company Websites

Over the recent years, module manufacturing in Türkiye aimed to cater for the local demand. The US stands out as the most meaningful among potential export markets for module manufacturers in Türkiye.

Graph 52

Annual Module Exports of Türkiye[1] (USD m)



Solar Module Exports in Türkiye

Compared to the market size within Türkiye, the solar module exports remained non-material until 2023.

The EU countries have secured their spots within the top 5 module export destinations over the past 5 years. The US, on the other hand, has emerged with USD 10 million of exports in 2023 and became the primary export destination for the past year.

For the last few years, module manufacturing in Türkiye was performed with the aim of catering to the local market and stood only at the module level of the production value chain.

Based on the demand increase in the US caused by the Inflation Reduction Act as detailed in section 2 of this report, both the module/cell manufacturing in the US and module exports outside the US increased significantly. Such growth has directly affected Türkiye, which began exporting modules to the US.

As of 2024, only Kalyon PV could export modules from Türkiye to the US. Due to the US anti-dumping tariff applying to module/cell manufacturers based in China, Vietnam, Cambodia, Malaysia, and Thailand, in order to export modules from Türkiye to the US, solar cells must be produced in Türkiye instead of supplying cells from the producers based in the aforementioned countries.

The US market appears as a meaningful export market for module manufacturers in Türkiye due to the sheer demand potential and relatively high module prices. More solar manufacturers should engage in cell manufacturing within Türkiye in order to increase module exports to the US market.

[1] *Free Zones within Türkiye are excluded.*

Source: TÜİK, IEA, SolarPower Europe, Publicly Available Resources

Kalyon PV operates in every stage of the module value chain with a vertically integrated facility, gathering solar module, cell, wafer, and ingot manufacturing under a single roof.

Company Information

Kalyon PV was established in Ankara in 2017 for the purpose of building a fully integrated solar module production facility to cater for the tender requirements upon Kalyon Holding winning the YEKA SPP-1 tender.

Phase 1 of the Kalyon PV factory was commissioned on 19 August 2020, and phase 2 was commissioned on 1 May 2021. The factory has five facilities, including four production facilities and an R&D hub.

- Factory Area: **250,000 m²**
- Local Cont. Ratio: **> 80%**
- Certificates: **30 +**
- Employees: **c. 2,000**
- Module Manuf.: **2.0 GW**
- Cell Manufacturing: **1.2 GW**
- R&D Team: **100 +**
- US Export Certificate: **UL Certificate**

Vertically Integrated Manufacturing Stages

Polysilicon
Polysilicon, the only raw material necessary for production, is imported from countries other than China.

It is mandatory to import polysilicon from countries other than China in order to export modules to the US.

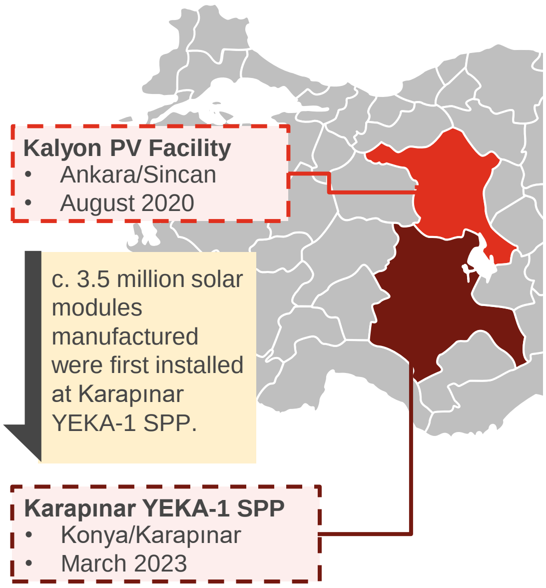
Ingot
Polysilicon is melted at 1,450°C and converted into cylinders weighing 450 kg.

Wafer
Ingots are formed into 3-meter rectangular structures and turned into slices with as thin as 170 microns.

Cell
Wafer slices are complete 30+ chemical and physical processes and are converted to a structure which produces electricity from sunlight.

Module
Modules are created by soldering 108 or 144 half cells, depending on size.

Location



Place in Module Manufacturing Value Chain

Many manufacturers operate in one or more points in the global module manufacturing value chain. However, the number of vertically integrated companies covering all stages of the value chain is limited to **Jinko Solar**, **Trina Solar**, **LONGi, and JA Solar, located in China, Canadian Solar in Canada, Hanwha Q Cells in South Korea, and REC Group in Singapore.** *Kalyon PV is the only vertically integrated facility in Europe.*

Module Types

M10 Series
- Power generation between 375 and 555 W
- Module efficiency between 20.7% and 21.4%

G1 Series
- Power generation between 380 and 410 W
- Module efficiency of 23.3%

Cell Types

PERC Cell
- Up-to-date technology dominant in the market
- Cell efficiency rate between 20% and 22%

TOPCon Cell
- New technology for the future
- Cell efficiency rate of more than 24%.

Source: Publicly Available Resources, Company Website

An investigation was initiated in November 2023 to extend the scope of anti-dumping tariffs, which have been applied against Chinese solar modules in Türkiye since 2017, to 5 more countries. Practices against solar module and cell imports have been increased in 2023.

Module and Cell Import Regulations

2017 — **(1 April):** An anti-dumping (AD) tariff of USD 20-25/m² is introduced for modules imported from Chinese manufacturers.

2020 — **(14 April):** Surveillance Duty was introduced for module imports and a surveillance certificate was made compulsory. Base customs value was set at USD 25/kg.

2023 — **(27 January):** Surveillance Duty was also introduced for cell imports and a surveillance certificate was made compulsory. Base customs value was set at USD 60/kg.

2023 — **(15 September):** The AD tariff applied to Chinese manufacturers hasbeen extended for another 5-year term.

2023 — **(24 October):** Documentation requirements for the surveillance certificate for module imports were tightened.

2023 — **(24 November): The deduction of VAT paid on all taxes, duties and fees accrued under the surveillance duty and AD tariff which is included in the VAT base was abolished.**

2023 — **(25 November): An investigation was initiated regarding the imposition of AD tariffs on modules originating from Malaysia, Vietnam, Thailand, Croatia and Jordan.**

The restrictions on module imports, which have been in place since 2017, have increased significantly with the decisions that entered into force in 2023.
In particular, the investigation on expanding the scope of AD tariffs could result in a non-material module import to Türkiye, considering the share of the imports originating from the countries subject to the AD investigation.

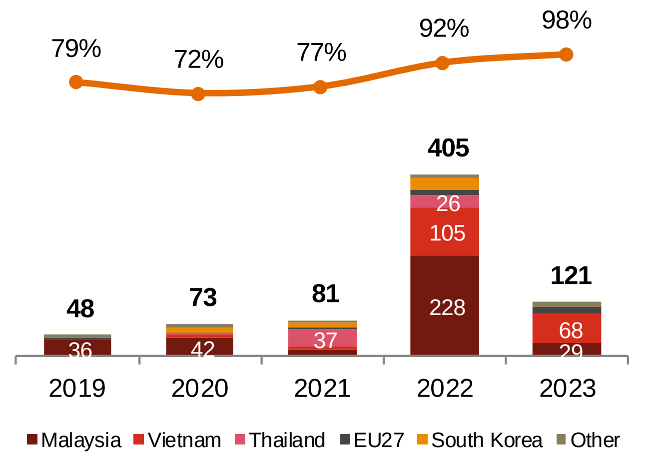
Anti-Dumping Tariffs in Force

The anti-dumping tariffs currently in force varies on the basis of the Chinese manufacturers from which the imports are made and/or the facility where manufacturing is carried out. In this context, the AD tariff was set at USD 20/m² for the manufacturers and facilities below, and USD 25/m² for all other Chinese manufacturers.

- Hanwha Q Cells – Qidong Plant
- Zhejiang Jinko Solar ve Jinko Solar
- Chint Solar – Zhejiang Plant
- BYD Industrial – Shangluo Plant
- Canadian Solar – Changsu ve Luoyang Plants
- CEEG Solar ve CEEG Nanjing
- Changzhou Trina Solar
- Hainan Yingli New Energy Resources
- Yingli Energy China
- Hefei Chinaland Solar
- Jiangsu Seraphim Solar
- Perlight Solar
- Renesola Jiangsu

Graph 53

Annual Module Imports of Türkiye¹ (USD m)



Share of module imports from Malaysia, Vietnam, Thailand, Croatia and Jordan, which were included in the AD investigation as announced in the Official Gazette dated 25 November 2023.

¹ *Free Zones within Türkiye are excluded.*

Sources: Publicy Available Sources

In addition to the AD tariff already in force, the ban on VAT deduction stemming from the anti-dumping tariff and surveillance duty from 24 November 2023 onwards has led to a significant increase in module and cell import costs to Türkiye.

In Türkiye, the AD tariffs have been applied against solar modules imported from Chinese manufacturers since 2017. As of 2020, **surveillance duty**, which is an indirect tax practice and aims to increase the VAT basis of the importer, has started to be applied on solar module imports at a unit customs value of USD 25/kg, regardless of the origin of the imports.

In 2023, the duration of the AD tariff was extended by another 5-year term and an investigation was initiated to cover imports from Malaysia, Vietnam, Thailand, Croatia and Jordan. **In addition, as of 24 November 2023, the deduction of VAT paid on all taxes accrued under the AD and surveillance duty which is included in the VAT base was abolished.**

Sample Anti-Dumping Tariff and Surveillance Duty Calculation

Import Forming the Basis of the Tax Calculation		
Module Power	a	530 W
Module Area	b	2.6 m^2
Module Weight	c	32 kg
Module Unit Price	d	0.11 USD/W
Pre-Tax Import Costs	e	**a * d = 58.3 USD**

In the sample calculation, the unit price of the imported solar module is taken as **USD 0.11/W** and the import amount before all accrued taxes corresponds to **USD 58.3.**

As of the date of the report, there is no customs duty applied in Türkiye for photovoltaic modules or cells.

Accrued AD Tariff, Surveillance Duty and VAT		
Anti-Dumping Tariff	f	20 USD/m^2
Surveillance Duty	g	25 USD/kg
Accrued ADT	h	**b * f = 52.0 USD**
Accrued SD	i	**c * g =** 800.0 USD
Accrued VAT	j	**(h + i) * 20% =** 170.4 USD
Non-deductible VAT	k	**j – (e * 20%) = 158.7 USD**

The AD tariff was calculated as USD 20/m^2 as applied to the largest Chinese manufacturers and the surveillance duty was calculated as USD 25/kg, which is the base customs value.

The surveillance duty, which is an indirect tax, is not subject to a direct payment, but causes an increase in the VAT basis calculated at step (j).

As of 24.11.2023, the difference between the VAT accrued on ADT and SD and the VAT accrued on the pre-tax import cost is not deductible.

Total Import Cost After Tax		
Pre-Tax Cost	e	58.3 USD
ADT Payable	h	52.0 USD
VAT Payable (Non-Deductible)	k	158.7 USD
Total Cost	l	**e + h + k = 269.0 USD**

After 24.11.2023, the total cost calculated by the sample calculation is USD 269 which implies a total import cost of **USD 0.51/W**. Before the ban on the VAT deduction, the total cost (e + h) was observed as USD 110.3 (USD 0.21/W).

Following the regulation change in November 2023, the total cost of module/cell imports to Türkiye were increased significantly.

Source: Publicly Available Sources, PwC Analysis

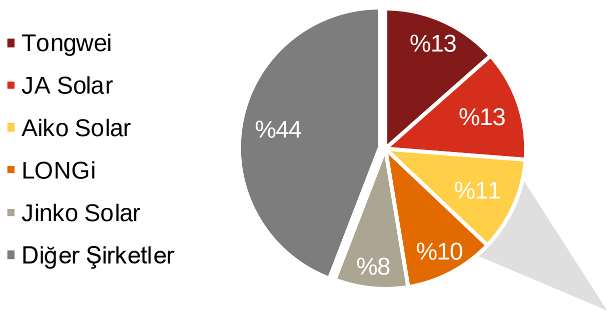
4 Analysis of Public Market Players

In 2022, 78% of the total global sales of solar cells and modules were conducted by just top 10 companies. When comparing the top 10 companies in 2010 and in 2022, it is evident that companies based in China dominate the market.

Graph 54

Annual Solar Cell and Module Sales (GW)

Solar module sales are experiencing rapid growth, and a limited number of companies are responsible for all sales. An analysis of the distribution of sales by company reveals that in 2010, the top five companies were responsible for 36% of all sales, while the top 10 companies made 64% of sales. However, in 2022, the top five companies account for 56% of total sales, and the top 10 companies responsible for 78%. Notably, a significant portion of the companies that lead in global solar module sales are based in China.



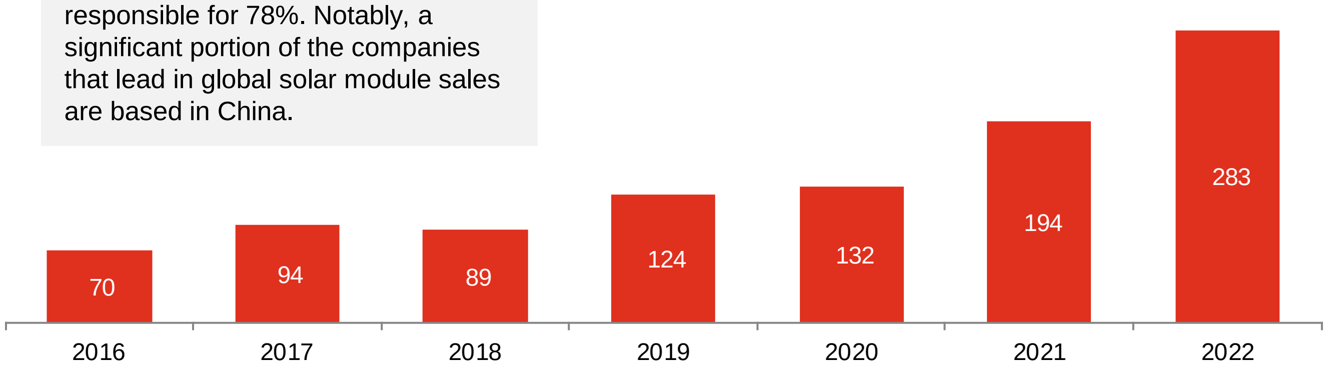


Table 14

Annual Solar Cell and Module Sales (2010, 2022)

Company	Country	2010	
		GW	%
Suntech	China	1.5	5%
JA Solar	China	1.5	5%
First Solar	USA	1.4	5%
Yingli	China	1.1	4%
Q-Cells	Germany	1.0	3%
Sharp	Japan	0.9	3%
Trina Solar	China	0.9	3%
Motech	Taiwan	0.9	3%
Jintech	Taiwan	0.8	3%
Kyocera	Japan	0.6	2%
Top 10		**10.5**	**36%**
Others		18.5	64%
Total		**29.0**	**100%**

Company	Country	2022	
		GW	%
Tongwei	China	38	13%
JA Solar	China	36	13%
Aiko Solar	China	31	11%
LONGi	China	29	10%
Jinko Solar	China	24	8%
Canadian Sc	Canada	17	6%
Trina Solar	China	15	5%
SolarSpace	China	12	4%
Talesun	China	10	3%
First Solar	USA	9	3%
Top 10		**220**	**78%**
Others		63	22%
Total		**283**	**100%**

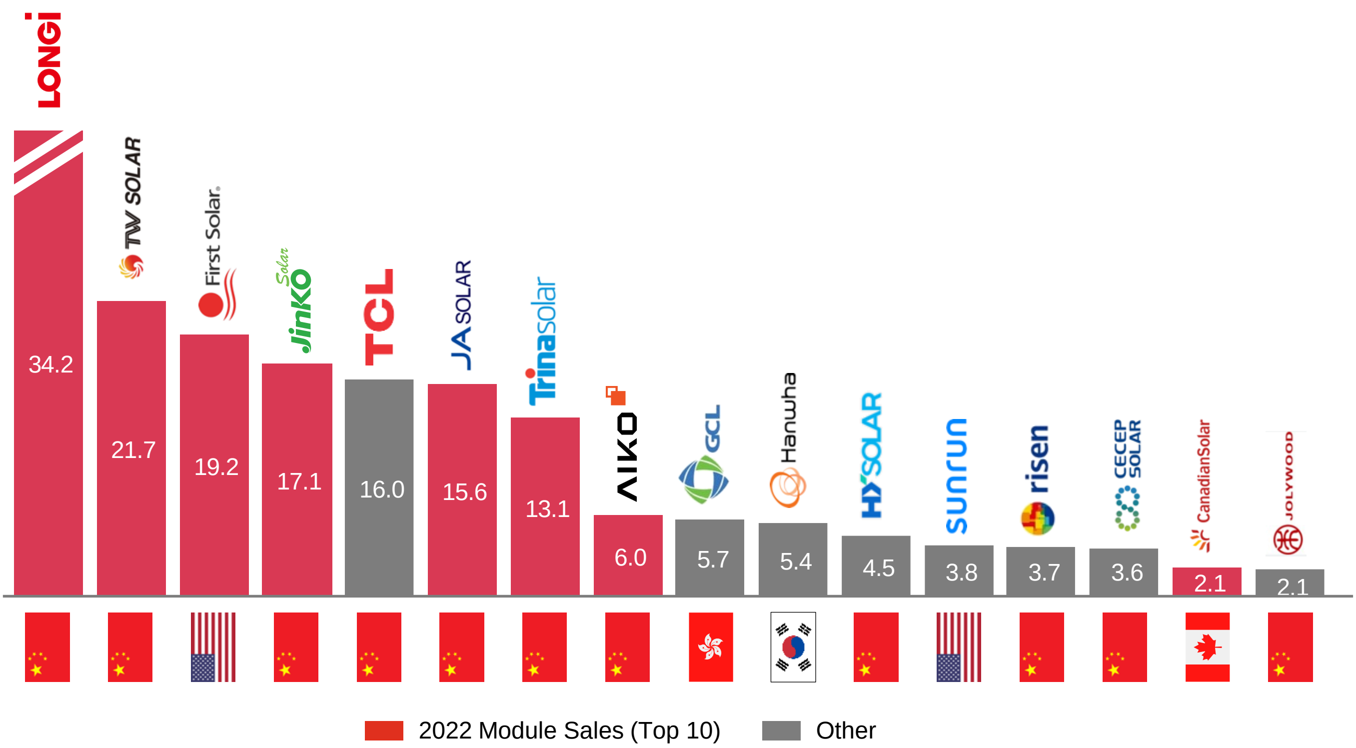
Companies based in China dominate global module market. From 2010 to 2020, only four companies managed to stay in the top 10 module sellers.
Also, there were only two companies that are not based in China among the top 10 module sellers in 2022.

Source: NREL

The majority of companies engaged in module production worldwide and with the highest market capitalization are based in China.

Graph 55

Market Capitalization - Global Market Players (USD billion)



Publicly traded companies with a market capitalization exceeding USD 2 billion, involved in manufacturing activities within the solar module value chain, were analyzed

Within this scope, it was found that 8 out of the top 10 companies with the highest module sales in 2022, according to the NREL report, are publicly traded, and the market capitalization of these eight companies exceeds USD 2 billion.

The following pages provide a detailed analysis of the companies with the highest module sales in 2022 and a market capitalization exceeding USD 2 billion.

Source: NREL

Companies engaged in global panel production activities also operate in various parts of the panel production value chain.

LONGi

LONGI was established in China in 2000. As of the end of 2022, LONGI had a sales volume of **USD 18.7b** and sold **52 GW** wafers, **31 GW** cells and **27 GW** modules in the first half of 2023.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022)
85 GW Wafer
47 GW Module

Prod. Cap. (2022)
133 GW Wafer
50 GW Cell
85 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	8,361	12,689	18,703	18,654
Gross Profit	2,002	2,520	2,717	3,176
GP Margin (%)	*24%*	*20%*	*15%*	*17%*
EBITDA	1,792	2,204	1,968	2,240
EBITDA Margin (%)	*21%*	*17%*	*11%*	*12%*
Enterprise Value	25,010	62,518	53,834	33,782
EV/EBITDA (x)	14.0x	28.4x	27.4x	15.1x

TW SOLAR

Tongwei was established in China in 2006. With **14 GW** panel and **70 GW** cell capacity, Tongwei has reached **90 GW** cell and **55 GW** panel capacity as of June 2023. By the end of 2026, it aims for **150 GW** cell capacity.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022)
78 GW Cell
8 GW Module

Prod. Cap. (2022)
70 GW Cell
14 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	6,770	10,205	20,649	20,799
Gross Profit	1,106	2,582	7,814	6,465
GP Margin (%)	*16%*	*25%*	*38%*	*31%*
EBITDA	945	2,177	6,835	5,957
EBITDA Margin (%)	*14%*	*21%*	*33%*	*29%*
Enterprise Value	14,588	32,711	32,918	26,270
EV/EBITDA (x)	15.4x	15.0x	4.8x	4.4x

First Solar

First Solar was established in China in 1999. First Solar has module capacity of **13 GW** as of June 2023 and targets a capacity of **21 GW** by the end of 2026.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022)
21 GW Module

Prod. Cap. (2022)
10 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	2,711	2,923	2,619	3,162
Gross Profit	698	740	128	859
GP Margin (%)	*26%*	*25%*	*5%*	*27%*
EBITDA	574	710	47	737
EBITDA Margin (%)	*21%*	*24%*	*2%*	*23%*
Enterprise Value	5,459	8,352	9,082	17,547
EV/EBITDA (x)	9.5x	11.8x	n.m.	23.8x

Jinko Solar

Jinko Solar was established in China in 2006. By the end of 2022, Jinko Solar, which is the largest panel supplier with **130 GW**, targets **75 GW** wafer, **75 GW** cell and **90 GW** panel capacity.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022)
47 GW Module

Prod. Cap. (2022)
65 GW Wafer
55 GW Cell
70 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	5,156	6,386	11,987	15,761
Gross Profit	728	781	1,161	2,196
GP Margin (%)	*14%*	*12%*	*10%*	*14%*
EBITDA	527	607	746	1,573
EBITDA Margin (%)	*10%*	*10%*	*6%*	*10%*
Enterprise Value	n.a.	n.a.	19,791	19,203
EV/EBITDA (x)	n.a.	n.a.	26.5x	12.2x

Source: Capital IQ, Publicly Available Resources

Companies engaged in global panel production activities also operate in various parts of the panel production value chain.

TCL

TCL Zhonghuan Renewable Energy Technology was established in 1981 in China. The company has increased its monocrystalline production capacity to **165 GW** in June 2023.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 7 GW Wafer

Prod. Cap. (2022): m.d.

(USD m)	2020	2021	2022	9M23
Net Sales	2,919	6,471	9,716	9,021
Gross Profit	543	1,311	1,518	1,737
GP Margin (%)	*19%*	*20%*	*16%*	*19%*
EBITDA	634	1,251	1,509	1,911
EBITDA Margin (%)	*22%*	*19%*	*16%*	*21%*
Enterprise Value	11,125	20,573	24,662	23,659
EV/EBITDA (x)	17.5x	16.4x	16.3x	12.4x

JA SOLAR

JA Solar was established in China in 2005. In May 2023, the company has announced its new n-type module, enabling module capacity to reach 630 W.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 78 GW Module&Cell

Prod. Cap. (2022): 50 GW Cell

(USD m)	2020	2021	2022	9M23
Net Sales	3,959	6,502	10,582	11,464
Gross Profit	641	951	1,526	2,169
GP Margin (%)	*16%*	*15%*	*14%*	*19%*
EBITDA	616	840	1,269	1,787
EBITDA Margin (%)	*16%*	*13%*	*12%*	*16%*
Enterprise Value	4,970	13,227	22,028	17,368
EV/EBITDA (x)	8.1x	15.7x	17.4x	9.7x

Trinasolar

Trina Solar was established in 1997 in China. Trina Solar targets **50 GW** n-type wafer, **75 GW** cell and **95 GW** panel production capacity.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 43 GW Module

Prod. Cap. (2022): 65 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	4,506	7,002	12,331	14,798
Gross Profit	695	971	1,583	2,295
GP Margin (%)	*15%*	*14%*	*13%*	*16%*
EBITDA	460	527	976	1,502
EBITDA Margin (%)	*10%*	*8%*	*8%*	*10%*
Enterprise Value	5,628	13,288	20,761	16,695
EV/EBITDA (x)	12.2x	25.2x	21.3x	11.1x

AIKO

Aiko was founded in China in 2009. Aiko Solar, which has made a total of **110 GW** panel sales, aims to achieve **86 GW** of n-type capacity.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 110 GW Cell (Cumulative)

Prod. Cap. (2022): 36 GW Cell

(USD m)	2020	2021	2022	9M23
Net Sales	1,480	2,435	5,085	4,367
Gross Profit	217	131	657	836
GP Margin (%)	*15%*	*5%*	*13%*	*19%*
EBITDA	202	99	512	609
EBITDA Margin (%)	*14%*	*4%*	*10%*	*14%*
Enterprise Value	3,508	5,177	7,149	6,356
EV/EBITDA (x)	17.4x	52.1x	14.0x	10.4x

Source: Capital IQ, Publicly Available Resources

Companies engaged in global panel production activities also operate in various parts of the panel production value chain.

GCL

GCL Technology Holdings was established in Hong Kong in 2006. GCL focuses on granular silicon and wafer production and currently has a production capacity of **280,000 MT** of granular silicon.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 46 GW Wafer

Prod. Cap. (2022): 55 GW Wafer

(USD m)	2020	2021	2022	9M23
Net Sales	2,247	2,655	5,209	5,805
Gross Profit	575	877	2,537	2,646
GP Margin (%)	*26%*	*33%*	*49%*	*46%*
EBITDA	715	668	2,327	2,501
EBITDA Margin (%)	*32%*	*25%*	*45%*	*43%*
Enterprise Value	6,954	8,603	8,706	6,354
EV/EBITDA (x)	9.7x	12.9x	3.7x	2.5x

Hanwha Solutions

Hanwha Solutions was founded in 1952 in South Korea. The compnay also operates in different fields such as chemistry, aviation and construction. Hanwha targets to increase the module capacity of their production facilities in the USA to **5.1 GW** in 2024.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): m.d.

Prod. Cap. (2022): 10 GW Cell, 12 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	8,449	9,004	10,857	10,196
Gross Profit	1,760	1,835	2,218	1,998
GP Margin (%)	*21%*	*20%*	*20%*	*20%*
EBITDA	1,073	1,164	1,304	1,074
EBITDA Margin (%)	*13%*	*13%*	*12%*	*11%*
Enterprise Value	5,974	7,605	7,377	8,253
EV/EBITDA (x)	5.6x	6.5x	5.7x	7.7x

HY SOLAR

Hoyuan Green Energy was established in China in 2002. Besides manufacturing machinery, the company has announced investments for increasing monocrystalline silicon production capacity by **40 GW** and cell production capacity by **24 GW**.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 32 GW Wafer

Prod. Cap. (2022): m.d.

(USD m)	2020	2021	2022	9M23
Net Sales	461	1,718	3,177	1,919
Gross Profit	126	338	630	329
GP Margin (%)	*27%*	*20%*	*20%*	*17%*
EBITDA	107	303	485	257
EBITDA Margin (%)	*23%*	*18%*	*15%*	*13%*
Enterprise Value	1,865	7,779	6,030	4,507
EV/EBITDA (x)	17.4x	25.6x	12.4x	17.6x

sunrun

Sunrun was established in 2007 in the USA. The company manufactures **solar cell storage products** in addition to solar modules. Sunrun has reached a production capacity of **6.4 GW** as of June 2023

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): m.d.

Prod. Cap. (2022): 6 GW Cell&Module

(USD m)	2020	2021	2022	9M23
Net Sales	922	1,610	2,321	2,352
Gross Profit	179	244	299	183
GP Margin (%)	*19%*	*15%*	*13%*	*8%*
EBITDA	(222)	(278)	(172)	(266)
EBITDA Margin (%)	*-24%*	*-17%*	*-7%*	*-11%*
Enterprise Value	9,510	17,775	14,584	15,223
EV/EBITDA (x)	n.m.	n.m.	n.m.	n.m.

Source: Capital IQ, Publicly Available Resources

Companies engaged in global panel production activities also operate in various parts of the panel production value chain.

risen

Risen Energy was established in China in 1986. In 2022, the company has increased cell and module capacities by **3 GW** each in Malaysia and China. As of 2023, Risen Energy reached Hyper-ion solar cell and module production capacity of **15 GW**.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 14 GW Module

Prod. Cap. (2022): 25 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	2,460	2,964	4,260	4,986
Gross Profit	326	189	422	639
GP Margin (%)	*13%*	*6%*	*10%*	*13%*
EBITDA	167	(20)	248	404
EBITDA Margin (%)	*7%*	*-1%*	*6%*	*8%*
Enterprise Value	2,631	3,279	3,501	3,383
EV/EBITDA (x)	15.8x	n.m.	14.1x	8.4x

CECEP SOLAR

Cecep Solar was established in China in 2010. In addition to production of solar cells and components, Cecep Solar also develops and sells software and hardware for artificial intelligence applications.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 30 GW Cell&Module (Cumulative)

Prod. Cap. (2022): 4 GW Cell, 8 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	813	1,106	1,339	1,342
Gross Profit	392	460	438	448
GP Margin (%)	*48%*	*42%*	*33%*	*33%*
EBITDA	532	580	560	556
EBITDA Margin (%)	*65%*	*52%*	*42%*	*41%*
Enterprise Value	4,779	7,046	6,676	5,903
EV/EBITDA (x)	9.0x	12.1x	11.9x	10.6x

CanadianSolar

Canadian Solar was established in Canada in 2001. As of June 2023, it has reached **20 GW** ingot, **21 GW** wafer, **26 GW** cell, **37 GW** module capacity.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 21 GW Module

Prod. Cap. (2022): 20 GW Wafer, 20 GW Cell, 32 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	3,476	5,277	7,469	7,883
Gross Profit	690	926	1,265	1,417
GP Margin (%)	*20%*	*18%*	*17%*	*18%*
EBITDA	440	503	660	985
EBITDA Margin (%)	*13%*	*10%*	*9%*	*12%*
Enterprise Value	2,780	4,102	3,956	4,539
EV/EBITDA (x)	6.3x	8.2x	6.0x	4.6x

中来股份 JOLYWOOD

Established in China in 2008, Jolywood not only manufactures cells and modules but also deals in significant quantities of cell **backsheets**. Jolywood has sold a total of **125 GW** of cell backsheets.

Polysilicon › Ingot › Wafer › Cell › Module

Sales Vol. (2022): 4 GW Cell&Module (Cumulative)

Prod. Cap. (2022): 4 GW Cell, 3 GW Module

(USD m)	2020	2021	2022	9M23
Net Sales	779	916	1,389	1,603
Gross Profit	137	102	209	253
GP Margin (%)	*18%*	*11%*	*15%*	*16%*
EBITDA	91	57	116	152
EBITDA Margin (%)	*12%*	*6%*	*8%*	*9%*
Enterprise Value	1,058	1,898	2,976	2,775
EV/EBITDA (x)	11.6x	33.5x	25.6x	18.3x

Source: Capital IQ, Publicly Available Resources

Following its IPO in 2022 and opening a new facility in 2023, Smart Solar will become the second company to manufacture solar cells in Türkiye.

Smart GÜNEŞ TEKNOLOJİLERİ

Smart Solar was founded in 2014. In addition to its module production facilities in Gebze and Dilovası, it commissioned a new facility in İzmir/Aliağa in 2023. In addition to module production, Smart Solar offers engineering, procurement, and installation (EPC) services.

Polysilicon › Ingot › Wafer › **Cell** › **Module**

*In its new production facility in İzmir/Aliağa, completed in 2023, it aims to produce cells beginning in **2024**.*

Module Capacity
2.9 GW

***Cell Capacity** (2024)*
2.0 GW

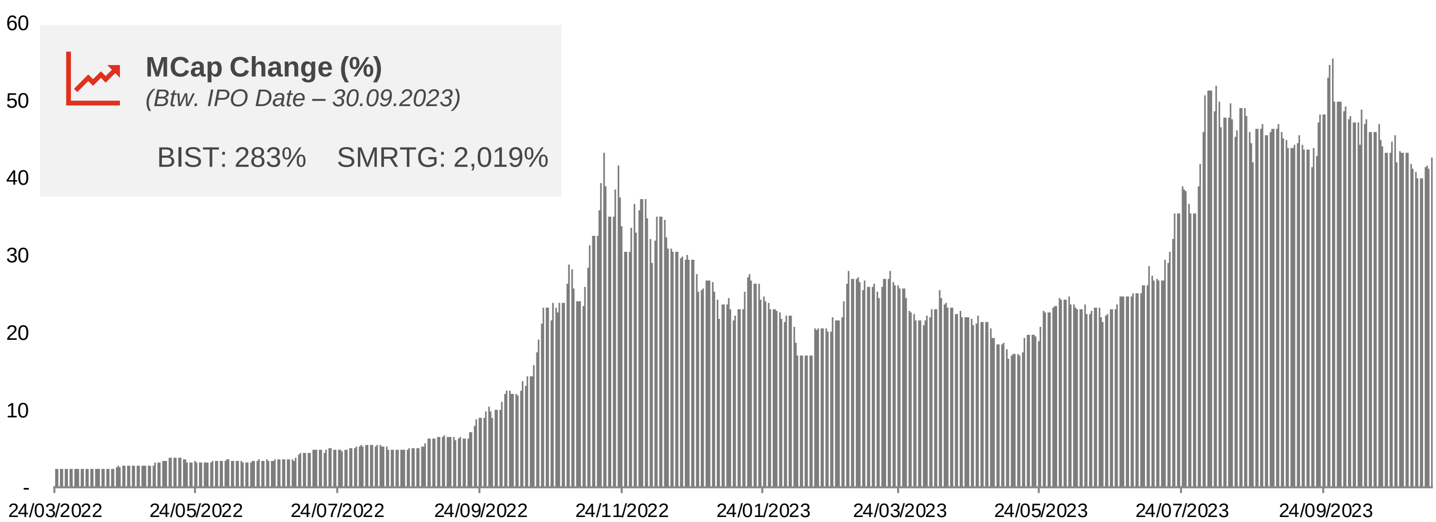
Initial Public Offering Information

	(TL m)
IPO Date	24.03.2022
IPO Equity Price (TL)	14.0
IPO Shares (%)	25.0% [1]
Total IPO Value	535
Total Mcap After IPO - TL	2,356
Total EV After IPO - TL	2,510
Total Mcap After IPO -USD	159
Total EV After IPO - USD	170

Financial Information

(TL m)	2021	2022	9M23
Net Sales	846	2,200	5,322
Gross Profit	135	366	1,318
GP Margin (%)	*16%*	*17%*	*25%*
EBITDA	112	281	1,032
EBITDA Margin (%)	*13%*	*13%*	*19%*
Enterprise Value - TL	n.a.	12,100	30,199
Enterprise Value - USD	n.a.	663	1,202
EV/EBITDA	n.a.	43.1x	29.3x

Market Capitalization (TL billion)



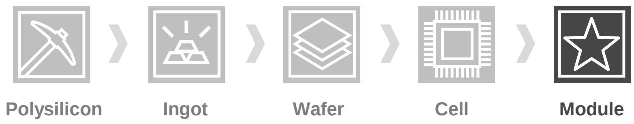
[1] *In October 2023, another 2% of Smart Solar was offered to the public.*

Source: Capital IQ, Publicly Available Resources, Company Websites

Completed its IPO in 2023, CW Energy operates in multiple areas in the solar energy value chain in addition to solar module production.

CW Enerji

CW Energy was established in Antalya in 2010 and operates in the fields of solar module production, licensed and unlicensed SPP installation/project design, and on-grid/off-grid systems. With the new production line commissioned in 2023, CW Energy has solar module production capacity in four facilities and has increased its total production capacity to 1.8 GW.



Module Capacity
1.8 GW

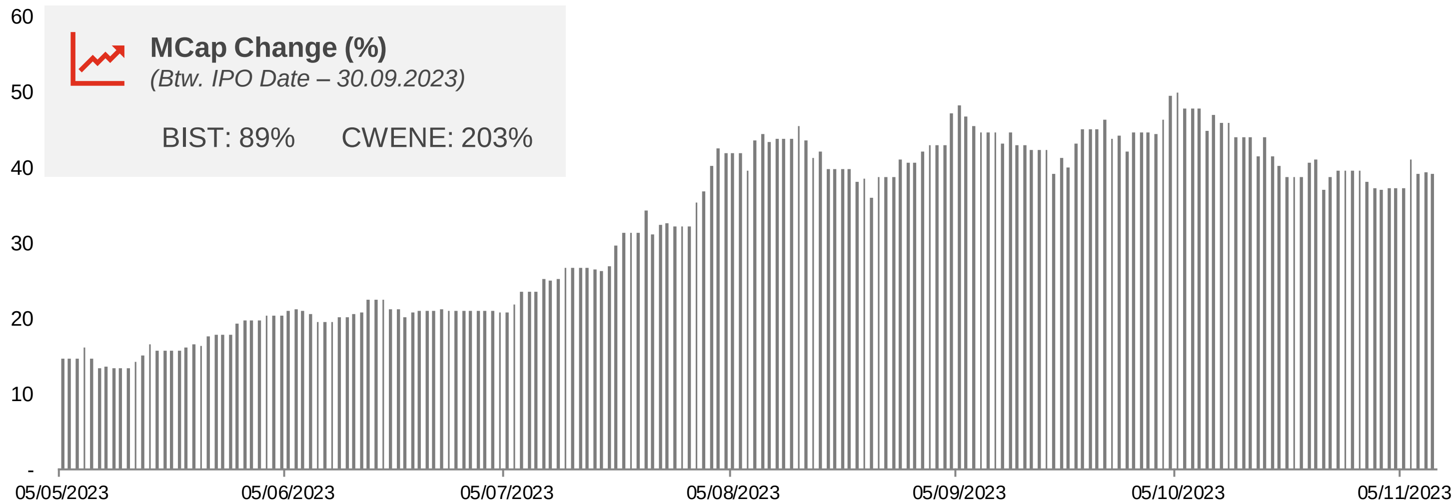
Initial Public Offering Information

	(TL m)
IPO Date	05.05.2023
IPO Equity Price (TL)	108.6
IPO Shares (%)	24.2%
Total IPO Value	3,258
Total Mcap After IPO - TL	14,776
Total EV After IPO - TL	14,955
Total Mcap After IPO -USD	759
Total EV After IPO - USD	768

Financial Information

(TL m)	2021	2022	9M23
Net Sales	1,003	4,758	8,555
Gross Profit	160	1,083	2,176
GP Margin (%)	*16%*	*23%*	*25%*
EBITDA	143	992	1,897
EBITDA Margin (%)	*14%*	*21%*	*22%*
Enterprise Value - TL	n.a.	n.a.	30,702
Enterprise Value - USD	n.a.	n.a.	854
EV/EBITDA	n.a.	n.a.	16.2x

Market Capitalization (TL billion)



Source: Capital IQ, Publicly Available Resources, Company Websites

Alfa Solar was founded in 2011 and held an IPO at the end of 2022. With the completion of its new facility investment, Alfa Solar has module production capacity of 1.8 GW.

Alfa Solar produces solar modules with production capacity of 1.8 GW at its production facility on 40,000 m² in Kırıkkale. Initially having 1.3 GW of capacity, the plant was expanded in 2023, adding additional capacity of 500 MW. Alfa Solar is the second solar module manufacturing company that held an IPO in Türkiye.

Polysilicon › Ingot › Wafer › Cell › **Module**

Module Capacity
1.8 GW

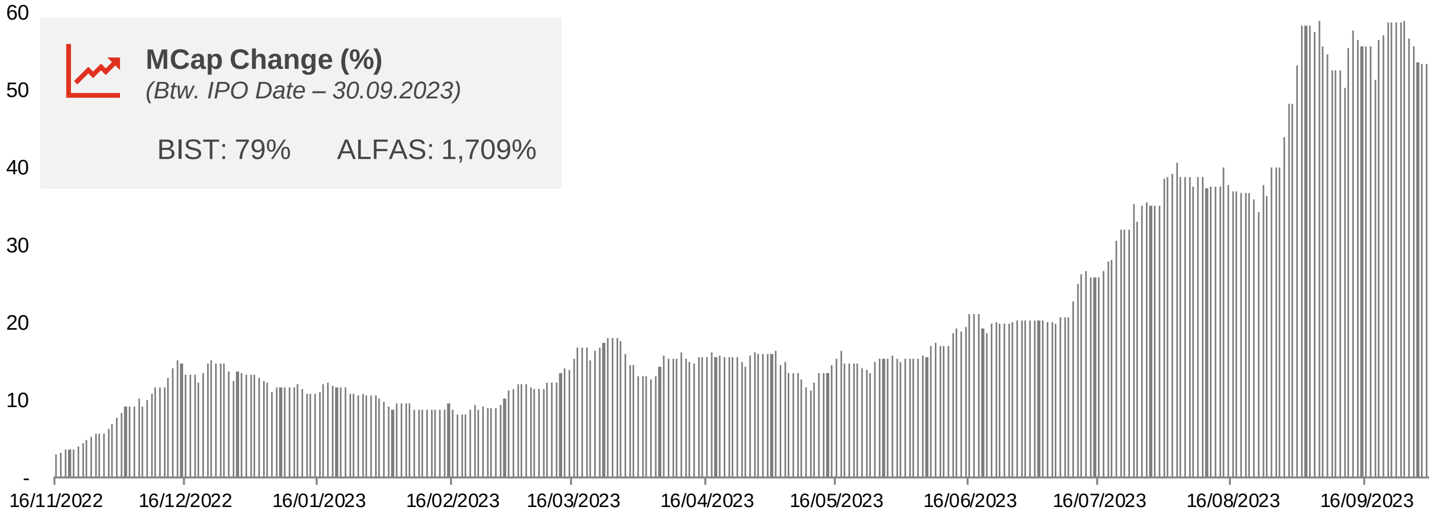
Initial Public Offering Information

	(TL m)
IPO Date	16.11.2022
Equity Price (TL)	58.5
IPO Shares (%)	20.0%
Total IPO Value	538
Total Mcap After IPO - TL	2,960
Total EV After IPO - TL	2,856
Total Mcap After IPO -USD	159
Total EV After IPO - USD	154

Financial Information

(TL m)	2021	2022	9M23
Net Sales	439	2,297	5,522
Gross Profit	77	483	1,356
GP Margin (%)	*18%*	*21%*	*25%*
EBITDA	79	488	1,304
EBITDA Margin (%)	*18%*	*21%*	*24%*
Enterprise Value - TL	n.a.	9,759	20,423
Enterprise Value - USD	n.a.	521	647
EV/EBITDA	n.a.	20.0x	15.7x

Market Capitalization (TL billion)



Source: Capital IQ, Publicly Available Resources, Company Websites

5

Appendices

Glossary (1/4)

Definition	Explanation
%	Percentage
°C	Degrees Celsius
AD	Anti-Dumping
Agri-PV	Agrivoltaic
APS	Announced Pledges Scenario
ASES	American Solar Energy Society
a-Si	Amorphous Silicon
BCM	Billion Cubic Meter
BOTAŞ	BOTAŞ Petroleum Pipeline Corporation
c.	Circa
CAGR	Compound Annual Growth Rate
CAT	Climate Action Tracker
CBAM	Carbon Border Adjustment Mechanism
CdTe	Cadmium Telluride
CIGS	Copper, Indium, Gallium, Selenide
CO2	Carbon Dioxide
COP	Conference of the Parties
Covid-19	COVID-19 Pandemic
CPI	Consumer Price Index
c-Si	Crystalline Silicon
CVD	Countervailing Duties
DAMP	Day-Ahead Market Price
DC	Direct Current
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
EMRA	Energy Market Regulatory Authority
ESG	Environmental, Social, and Governance

Glossary (2/4)

Definition	Explanation
ETS	Emission Trading System
EU	European Union
EUA	European Union Allowance
EUR	Euro
EV	Electric Vehicle
EXIST	Energy Exchange Istanbul
GaAs	Gallium Arsenic
GAZBİR	Natural Gas Distribution Companies Association of Türkiye
GDP	Gross National Product
GHG	Greenhouse Gas
GW	Gigawatt
HIT	Silicon Heterojunction
HS Code	Harmonized System Code
HTSR	Hydrogen Technologies, Strategy, and Roadmap
IEA	International Energy Agency
IMF	International Monetary Fund
IPC	İstanbul Policy Center
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
IRENA	International Renewable Energy Agency
ITC	US Investment Tax Credit
kW	Kilowatts
kWh	Kilowatt-hour
LCOE	Levelized Cost of Energy
LFP	Lithium Iron Phosphate Battery
LNG	Liquefied Natural Gas

Glossary (3/4)

Definition	Explanation
LULUCF	Land Use, Land Use Change, and Forestry
Mb/d	Million Barrels per Day
MENR	Republic of Türkiye Ministry of Energy and Natural Resources
METU-GÜNAM	Middle East Technical University Center for Solar Energy Research and Applications
Mtce	Million Tonnes Coal Equivalent
MtCO2e	Metric Tonnes of Carbon Dioxide Equivalent
MTP	Medium Term Programme
MW	Megawatt
MWe	Megawatt Electric
NDC	Nationally Determined Contribution
NEP	National Energy Plan
NREL	National Renewable Energy Laboratory
NZE	Net Zero Emissions Scenario
ODMD	Automotive Distributors and Mobility Association
PERC	Passivated Emitter and Rear Contact
PPI	Producer Price Index
PTC	US Production Tax Credit
PV	Photovoltaic
PwC	PricewaterhouseCoopers
R&D	Research and Development
RE	Renewable Energy
SEIA	Solar Energy Industries Association
SPP	Solar Power Plant
STEPS	Stated Policies Scenario
TANAP	The Trans-Anatolian Natural Gas Pipeline Project
TEİAŞ	Turkish Electricity Transmission Corporation

Glossary (4/4)

Definition	Explanation
TOPcon	Tunnel Oxide Passivated Contact
TW	Terawatt
TWEA	Turkish Wind Energy Association
TWh	Terawatt-hour
UK	United Kingdom
UL	Underwriters Laboratories
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
USD	US Dollar
VAT	Value Added Tax
W	Watt
WEO	World Energy Outlook
WPP	Wind Power Plant
YEKA	Renewable Energy Resource Area
YEKDEM FiT	Renewable Energy Resources Support Mechanism Feed-in-Tariff
YEK-G	Renewable Energy Resource Guarantee System
YTU	Yıldız Technical University
YÜKT	Local Production Based Allocation

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In addition to the references listed, the websites of the companies below and/or the annual reports, financial reports, investor presentations, and sustainability reports for periods covering 2021 and 2022 for publicly-available companies among those listed below have been used as source within the relevant pages of this report.

- *Alfa Solar Enerji A.Ş.*
- *Canadian Solar Inc.*
- *Cecep Solar Energy Co., Ltd.*
- *CW Enerji Mühendislik Tic. ve San. A.Ş.*
- *Daxler Enerji A.Ş.*
- *Elin A.Ş*
- *First Solar, Inc.*
- *GCL Technology Holdings Ltd.*
- *Hanwha Solutions Corporation*
- *Hoyuan Green Energy Co., Ltd.*
- *HSA Enerji A.Ş.*
- *JA Solar Technology Co., Ltd.*
- *JinkoSolar Holding Co., Ltd.*
- *Jolywood Solar Technology Co., Ltd.*
- *Kalyon Güneş Teknolojileri Üretim A.Ş.*
- *LONGi Green Energy Technology Co., Ltd.*
- *Risen Energy Co., Ltd.*
- *Schmid Pekintaş Güneş Enerji Sistemleri San. ve Tic. A.Ş.*
- *Shanghai Aiko Solar Energy Co., Ltd.*
- *Smart Güneş Enerjisi Teknolojileri Ar-Ge Üretim San. ve Tic. A.Ş.*
- *Sunrun, Inc.*
- *TCL Zhongguan Renewable Energy Technology Co. Ltd.*
- *Tongwei Solar (Hefei) Co., Ltd.*
- *Trina Solar Co., Ltd.*

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Thank you...