Technology Collaboration Programme
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International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

Snapshot of Global PV Markets 2025

WHAT IS IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCPs within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

The IEA PVPS participating members are Australia, Austria, Belgium, Canada, China, Denmark, Enercity SA, European Union, Finland, France, Germany, India, Israel, Italy, Japan, Korea, Malaysia, Morocco, the Netherlands, Norway, Portugal, Solar Energy Research Institute of Singapore (SERIS), SolarPower Europe, South Africa, Spain, Sweden, Switzerland, Thailand, Türkiye, United States, and the United Kingdom.

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WHAT IS IEA PVPS TASK 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is promoting and facilitating the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation.

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COVER PICTURE

PV panels in Lotus Parking canopies in Hangzhou China credit: LONGi

2025 Snapshot of Global PV Markets

INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

IEA PVPS
Task 1
Strategic PV Analysis and Outreach

April 2025

TABLE OF CONTENTS

Executive Summary 4
1 Snapshot of the Global PV Market in 2024 7
1.1 Evolution of Annual Installations 7
1.2 Impact of over-capacity in manufacturing 9
1.3 Focus on the Top Markets in 2024 10
1.4 Market Segmentation 10
2 Cumulative Installed Capacity in the World 11
2.1 Evolution of Regional Share of PV Installations 12
2.2 Limits of Reporting Conventions 14
2.3 Decommissioning, Repowering and Recycling 14
2.4 AC or DC Numbers? 15
3 Electricity Production from PV 16
4 Policy & Markets Trends 17
4.1 Policy Trends 17
4.2 Remuneration mechanisms 17
4.3 Prosumers Policies 18
4.4 Grid Integration and Curtailment 19
4.5 Local Manufacturing Policies 20
4.6 2025 Market Perspectives in IEA PVPS Countries 21
5 PV in the Broader Energy Transition 22
5.1 PV and Other Renewable Energy Evolutions 22
5.2 PV Fostering Development of a Cleaner Energy System 23

EXECUTIVE SUMMARY

The global **PV cumulative capacity grew to significantly over 2.2 TW at the end of 2024**, up from 1.6 TW in 2023, with **over 600 GW of new PV systems** commissioned. After several years of tension on material and transport costs, module prices continued to drop through 2024 in a still massively over-supplied market, putting tremendous financial pressure on all industrial actors on one hand but stimulating markets on the other.

Major trends include:

With active development policies, **China's annual installations increased again** to 357.3 GW or nearly 60% of new global capacity, **reaching over 1 TW** of cumulative capacity. Remarkably, China hosted almost half of global the PV capacity at the end of 2024.

The rest of the world represented just over 40% of new installations but that number grew significantly in 2024 also, adding 244.6 GW to reach 1 198.0 GW installed.

Europe demonstrated continued strong growth installing 71.4 GW (of which 62.6 GW in the EU), led by Germany (16.7 GW) and Spain (7.5 GW).

In the Americas, both major markets grew — the USA, continued strongly, adding 47.1 GW (224.1 GW cumulative) whilst Brazil continued to grow with 14.3 GW, bringing its cumulative capacity up to 52.1 GW.

India had a **positive growth** year leaping to 31.9 GW, predominantly in centralised systems. **Pakistan had a large volume of installations** reaching 17 GW, in 4th place globally for annual installations; **other Asia-Pacific markets slowed down** (Australia to 4.0 GW and Japan to 5.5 GW).

PV energy production reached more than 10% of the world electricity consumption for the first time.

The **theoretical penetration rate of PV has grown across the world** as capacity increases faster than consumption, displacing coal and gas in increasingly large volumes. More than 25 countries have installed capacities able to supply more than 10% of national consumption and half a dozen of these countries are approaching or over 20%; for those countries with the highest penetration rates, **curtailment is increasingly prevalent** and investments in grid decongestion and interconnections, as well as flexibility, storage and sector coupling will be needed in the future to take advantage of peak capacity; the provision of alternative services by generators (hybrid systems, capacity reserves, system services) is likely to become important to maintain long term profitability as curtailment is actioned both for technical reasons (supply imbalances) and markets reasons (negative prices).

Market development remains subject to regulations and **support policies, but also electricity consumption**, **wholesale prices** and **grid connection costs.** Low module prices through 2024 stimulated many markets – both in centralised and prosumer segments - however as electricity prices returned to lower levels after 2022/2023 highs, individual market segments slowed or shrank in some countries. Increased policy support has been the response in countries with strong transition targets.

PV played an important role in the reduction of CO_2 emissions from electricity once again in 2024, and PV represented more than 75% of new renewable capacity installed in 2024, contributing nearly 60% of generation from new renewable capacity.

Oversupply of PV modules in 2024 has continued to shed a light on the difficulty to align production and demand in a very versatile environment: production capacities increased significantly in China, and despite growth in most major markets, it was not sufficient to absorb all new manufacturing. Huge imports have been noticed in some specific markets such as Saudi Arabia and Pakistan, and whilst these volumes have been installed in Pakistan, some hypothesize that low prices might have led to buying without installing in other high volume import markets.

Local manufacturing remained a key subject throughout 2024 as the Chinese industries' continued over-capacity pushed module prices to record lows. The introduction of import tariffs on modules was adopted as a protection measure in a limited number of countries with active manufacturing support policies but uneven political support in other markets could also have contributed to the **difficulties in developing local PV manufacturing facilities in an already inundated market**.

International Energy Agency
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A Snapshot of Global PV Markets

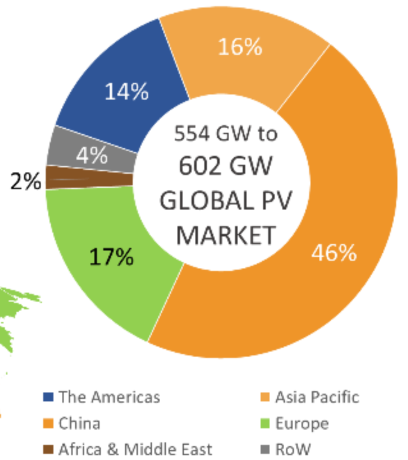
TOP PV MARKETS 2024

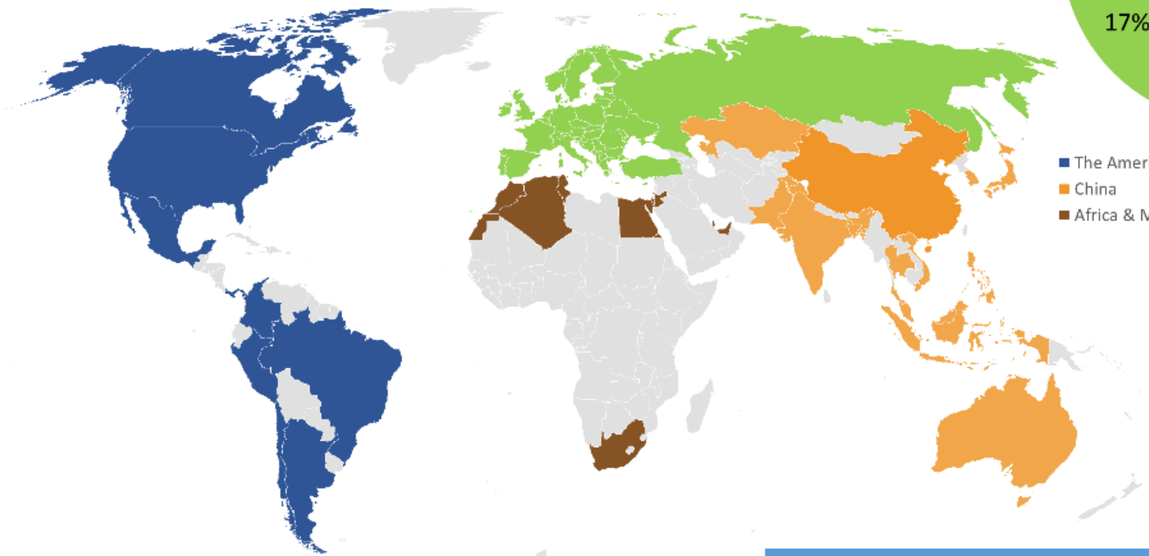
CHINA 309 GW to 357 GW

EU 63 GW

USA 47 GW

Regional share of cumulative capacity





2 246 GW were installed all over the world by the end of 2024

China is the world's #1 PV market

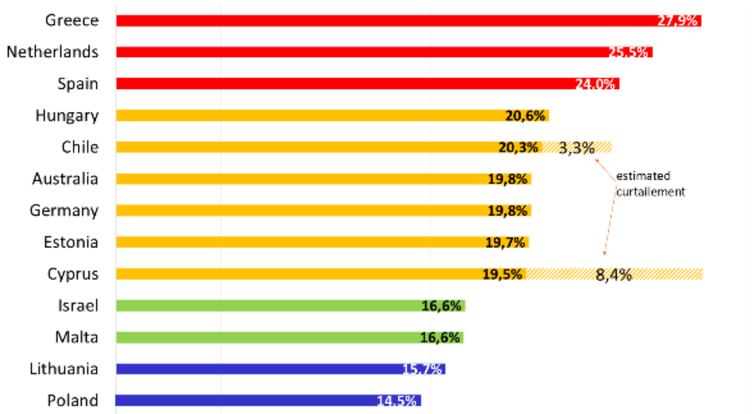
34 countries installed at least 1 GW of PV in 2024

23 countries have installed at least 10 GW of cumulative capacity at the end of 2024

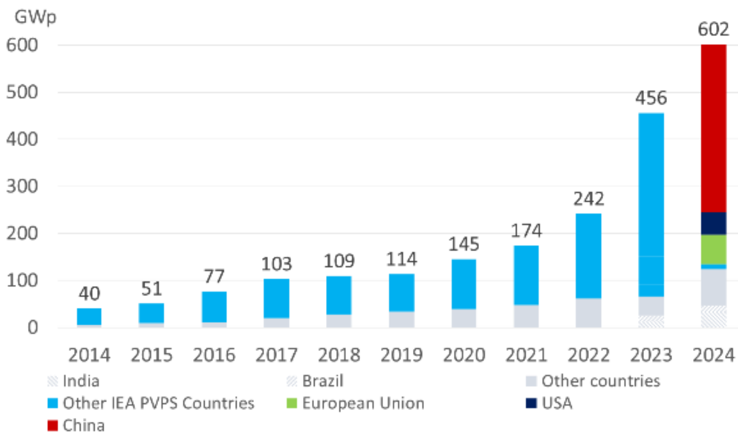
SOLAR PV PER CAPITA 2024 Watt/capita

1st	NETHERLANDS	1 547
2nd	AUSTRALIA	1 448
3rd	GERMANY	1 198

COUNTRIES WITH HIGHEST PV PENETRATION



EVOLUTION OF ANNUAL PV INSTALLATIONS



1 SNAPSHOT OF THE GLOBAL PV MARKET IN 2024

IEA PVPS continues to **produce unbiased reports** on the **development of PV all over the world**, based on information from official government bodies and reliable industry sources. This 13th edition of the "Snapshot of Global PV Markets" aims at providing **preliminary information** on how the PV market developed in 2024. The 30th edition of the PVPS complete "*Trends in Photovoltaic Applications*" report will be published in Q4 2025.

1.1 Evolution of Annual Installations

At least 2 156.5 GW of cumulative capacity was installed by the end of 2024, with a further 90 GW possible identified by IEA PVPS Experts, for an estimated **global cumulative capacity of 2 246.5 GW**. At least 554.1 GW but perhaps as much as **601.9 GW**[1] **of PV systems have been commissioned in the world last year**. Countries[2] in the IEA PVPS programme in 2024 covered 80% of annual and cumulative capacity – if India, who joined IEA PVPS from 2025 is included, this coverage increases to 85%. The growth rate fell back closer to habitual values at just over 30%, down from 89% over 2023.

In 2024, **at least 34 countries installed more than 1 GW**, up from 29 countries in 2023. **25 countries have more than 10 GW of total cumulative capacity** and seven have more than 40 GW. China alone is estimated to have passed 1 TW; the European Union (as EU27) now has 339.4 GW. The USA ranks third at 224.1 GW and India has overtaken Japan to take fourth place with 124.6 GW. Germany and Japan will both pass the 100 GW mark in 2025.

Global markets have seen sustained double-digit growth over the past five years; whilst 2024 "only" saw about 32% growth compared to 2023's nearly 90% growth, the absolute volumes are remarkable. China's market had another dynamic year as internal forces pushed to absorb manufacturing capacity bringing the national market share to 59% of new global capacity. The EU and the USA accounted for just 18% of new capacity as other markets also developed strongly - India, Brazil and Pakistan collectively installed the same volume as the EU.

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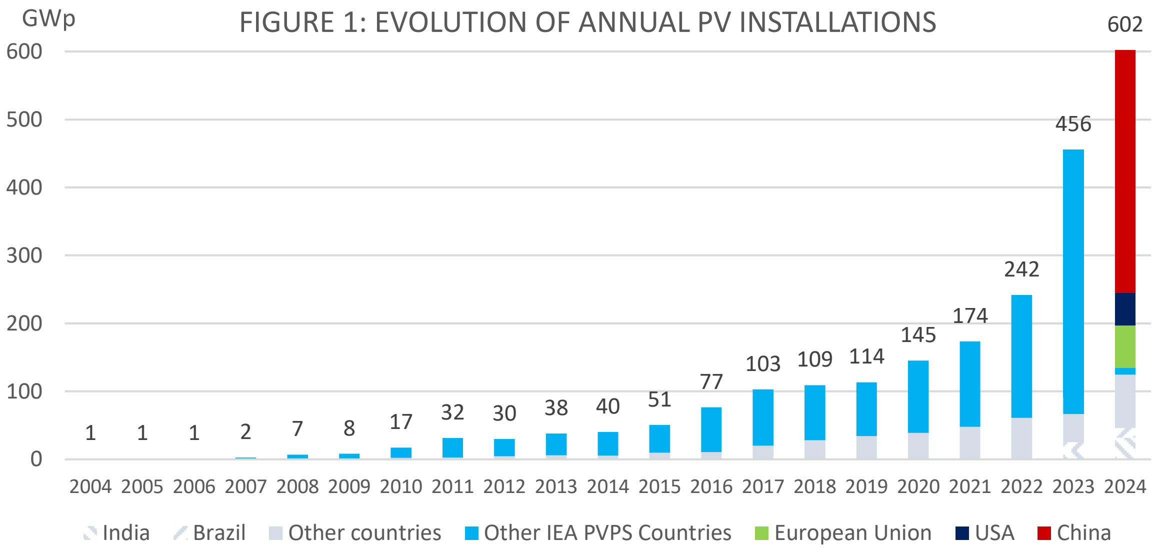
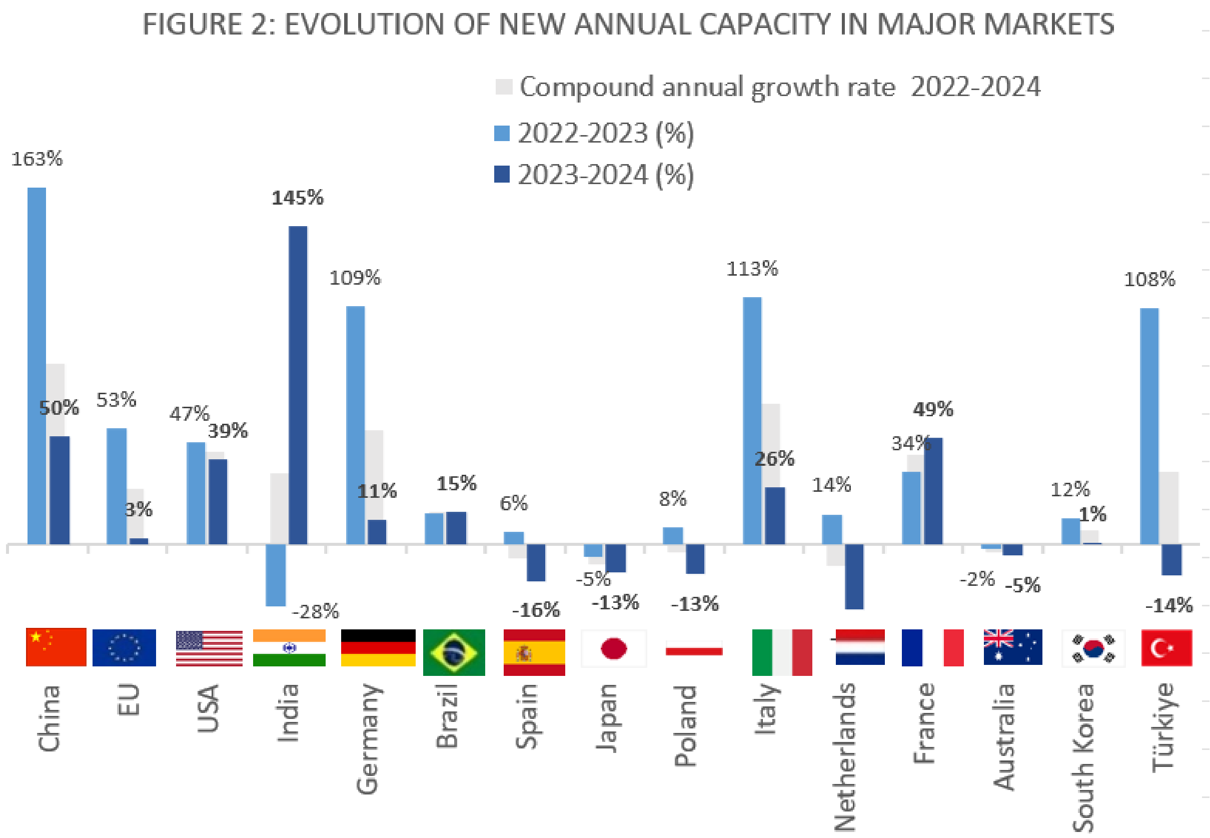
[1] The minimal annual volume of 554.1 GW considers official China reporting; the maximal annual volume of 601.9 GW considers a further 47.8 GW that may have been installed; the range in volumes is linked to the estimated choice of inverter load ratio (ILR) or AC to DC conversion ratio of Utility scale systems in China. For many figures, these two values have been represented with full (minimum) and additional shaded (maximum) bars. If not otherwise specified, compiled data refers to the higher estimated values.

[2] For the purpose of this report, IEA PVPS countries are those that are either member in their own right or through the adhesion of the EC.



Source: IEA PVPS

Growth rates in individual countries remain subject to local policies and international market prices and considerable variations can be seen between countries and year to year. Whilst growth rates have slowed (but remain positive) in many markets, others have stabilised or contracted. The EU had low growth as continued expansion in Germany and France was



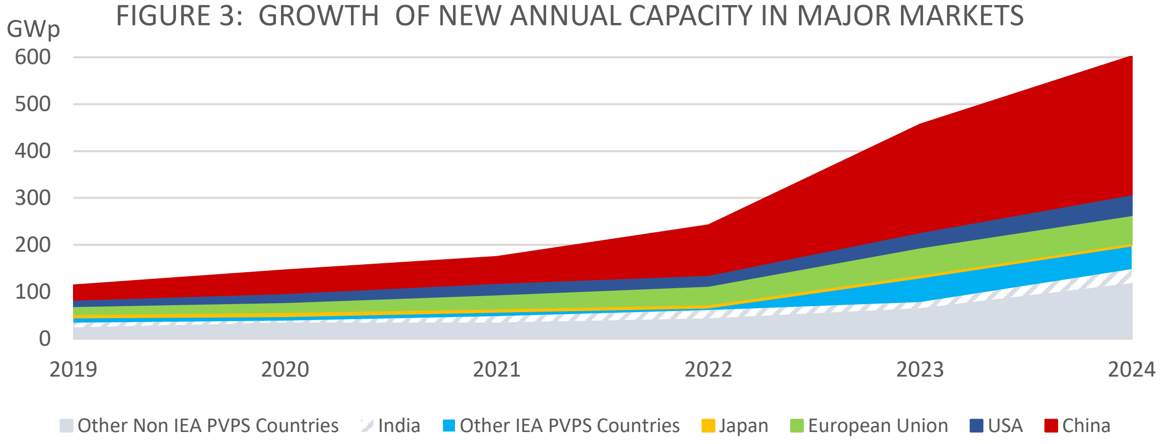
Source: IEA PVPS

balanced by slow-downs in Spain and the Netherlands. Of particular note, the Turkish market grew over the past two years and is expected to remain strong as local manufacturing develops and electricity prices remain high following the Lira's depreciation. Several GW were installed and commissioned over the end of 2023 and early 2024, impacting how data was recorded in previous reports.

The 2024 Indian market benefited from both low-cost imports and a cut-off date for using them, as well as corporate green mandates. Not shown in Figure 2, Pakistan had very strong additions to new capacity. Data quality is uncertain when it comes to installed volumes, but large volumes of modules were imported in 2023 and 2024 (24 GW over 2 years according to the China Chamber of Commerce), and larger volumes were installed in 2024 with reported new capacity more than 13 times 2023 volumes at 17 GW. Policy changes have impacted deployment budgets in South Korea, whilst stabilised consumer electricity prices have contributed to the Spanish reduced market.

These developments have not been significant enough to impact the regional distribution shares of new capacity in major markets as China continues to dominate (Figure 3).

FIGURE 3: GROWTH OF NEW ANNUAL CAPACITY IN MAJOR MARKETS



Source: IEA PVPS

1.2 Impact of over-capacity in manufacturing

In 2023, manufacturing capacity largely outstripped the market's ability to absorb new module availability. Module stocks in China and Europe grew from already high 2022 values to reach an estimated 150 GW by the end of 2023. In 2024, stocks remained high as relatively stable markets in Europe and China failed to absorb these historical stocks.

Manufacturers continued to deliver low-price modules to markets in an effort to secure cash flows, and so module prices continued to decrease across 2024. Concerted action by Chinese manufacturing led to module prices stabilising in Q1 2025 due to controlled production cuts and upwards movement in upstream costs.

These low prices, combined with different local contexts stimulated markets in China and a selection of countries including India, Pakistan, Brazil and supported modest growth in some countries in Europe.

However, the pressure on the industry remains tremendous and solutions are quite complex: with all segments of the PV value chain in significant overcapacity, the global development of

PV should accelerate rapidly to over 1 TW per year to absorb this overproduction. This is a challenge based on the current dynamics of the PV market, which could lead to massive PV developments in new business models, such as Direct Air Capture, production of green hydrogen or derivatives and more.

1.3 Focus on the Top Markets in 2024

The Chinese market grew again in 2024, although the rate slowed; it is certain that at least 309.4 GW was installed (official China reporting) but further estimations bring this to a possible 357.3 GW in 2024 (up from 277 GW in 2023 and 106 GW in 2022). With 62.6 GW of annual installations, the European Union ranked second, followed by the USA at 47.1 GW. India more than doubled last year's new volumes to reach 31.9 GW (up from 13 GW). The remarkable influx of low-price modules in the Pakistani market has positioned them in a probable fourth place, although capacity estimations are approximate. Continued growth in Germany and Brazil sees these two countries maintain their places in the Top 5. Spain, Italy and France have national markets that fluctuate year to year, coming in and out of the Top Ten periodically; with stable or moderate growth in 2023 they all appear this year.

To reach the Top Ten for new capacity in 2024, countries needed to install at least 5.5 GW of PV systems (compared to 4.2 GW in 2023 and just 1.5 GW back in 2018).

TABLE 1: TOP 10 COUNTRIES FOR ANNUAL AND CUMULATIVE INSTALLED CAPACITY IN 2024

FOR ANNUAL INSTALLED CAPACITY			FOR CUMULATIVE CAPACITY		
1	China	357.3 GW*	1	China	1048.5 GW*
(2)	*European Union*	62.6 GW	*(2)*	*European Union*	339.4 GW
2	USA	47.1 GW	2	USA	224.1 GW
3	India	31.9 GW	3	India	124.6 GW
4	Pakistan	17.0 GW	4	Germany	99.8 GW
5	Germany	16.7 GW	5	Japan	96.9 GW
6	Brazil	14.3 GW	6	Brazil	52.1 GW
7	Spain	7.5 GW	7	Spain	47.2 GW
8	Italy	6.6 GW	8	Australia	38.6 GW
9	France	5.9 GW	9	Italy	37.0 GW
10	Japan	5.5 GW	10	South Korea	31.7 GW

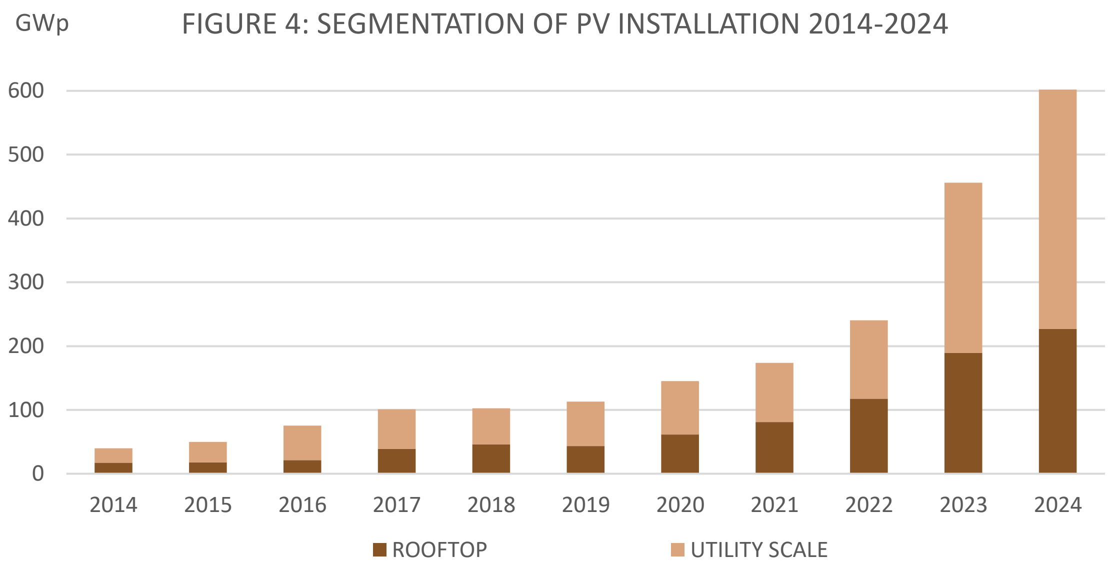
Note: The European Union grouped 27 European countries in 2024, out of which Germany, Spain, Italy, France also appear in the Top Ten, either for the annual installed capacity or the cumulative installed capacity. The European Commission is a member of IEA-PVPS through its Joint Research Centre (EC-JRC). *IEA-PVPS preliminary assessment is higher than official China reporting

Source: IEA PVPS

1.4 Market Segmentation

Both rooftop and utility scale segments grew in 2024, however the utility scale grew much more – especially in China, the USA and India. Data uncertainty in converting utility scale AC capacity to DC capacity in China (and other countries) remains important but unlike 2023, the utility scale market clearly dominated, representing over two-thirds of new capacity: the change can be explained by the fast installation rates in China aimed at absorbing the production. Whilst distributed PV remains the principal driver of growth in some markets

(Brazil, Germany, Türkiye, Italy and France for example), the sheer volume that can be installed in individual utility scale systems is leading to this segment outpacing distributed growth around the world. Newer applications such as floating PV and linear PV are more often within the centralised market, whilst agriPV and parking canopies exist across both the centralised and decentralised segments. The increase in deployment of prosumer and self-consumption remuneration models tends to be limited to smaller capacity systems, with a larger number of unit systems but much lower capacities.



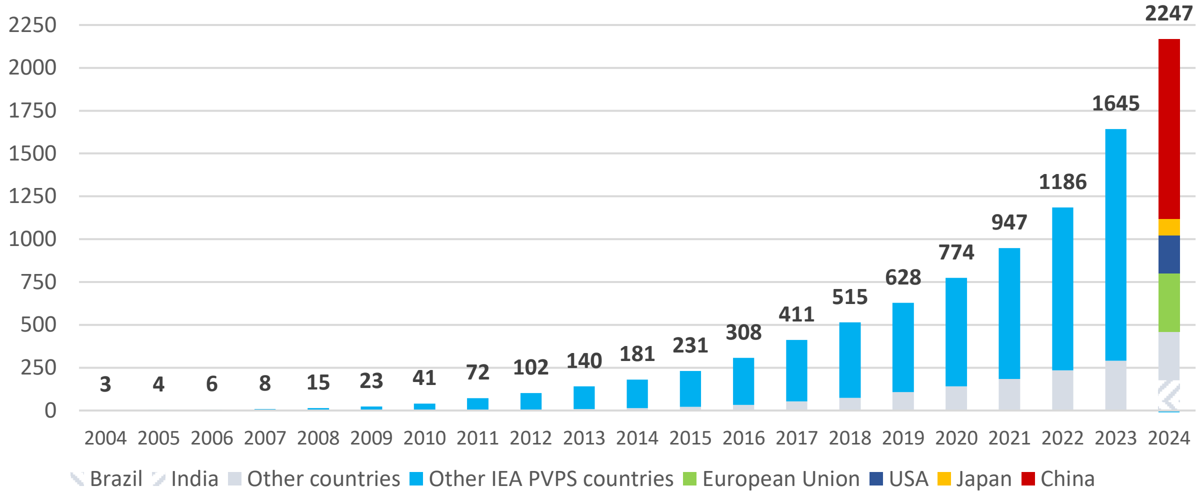
Source: IEA PVPS, Becquerel Institute

2 CUMULATIVE INSTALLED CAPACITY IN THE WORLD

In 2024, the **global cumulative installed capacity reached 2.25 TW**, as shown in Figure 5. It took more than 40 years to reach a cumulative capacity of 1.18 TW (in 2022), but just 2 years to double this. China now has nearly 50% of cumulative worldwide capacity. Growth in cumulative capacity remained over 35% — above average for the past 10 years. Within the Top Ten of total cumulative installed capacities (see Table 1 above), where last year the Chinese cumulative capacity was just over double that of Europe, this year it is triple — the faster growth rates in annual capacity leaving the EU and other countries lagging. There is still a long gap before Japan, who slipping to 5th place and has a slowing market, will be overtaken in cumulative capacity— the next markets would have to improve on this year's annual volumes over at least 5 years to catch up the more than 40 GW gap.

As India and the UK join the IEA PVPS programme in 2025, the cumulative volume of installations outside of IEA PVPS will become marginal.

FIGURE 5: EVOLUTION OF CUMULATIVE PV INSTALLATIONS



Source: IEA PVPS

2.1 Evolution of Regional Share of PV Installations

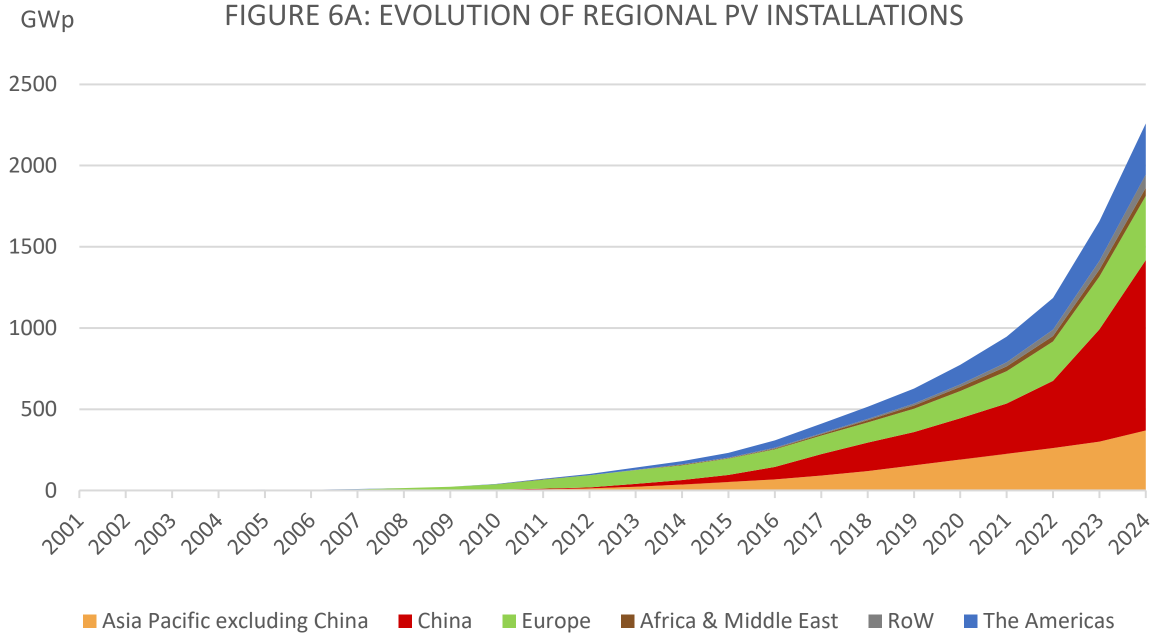
With the predominance of the Chinese market, it is no surprise that Aisa-Pacific leads in regional share. This position has been reinforced because the once-again extremely large Chinese market has grown faster than elsewhere, and other regional shares have gone down proportionally. If we exclude China from the Asia-Pacific market, what remains is roughly equivalent in size to the European and the Americas market, the first two holding 17% and the latter 14% of global cumulative PV installations.

Outside of China, **major Asia-Pacific's markets varied widely in dynamics**; India (31.9 GW) and Pakistan (17.0 GW) had strong growth whilst Japan, South Korea and Australia either slightly contracted or remained stable. These three countries have been significant contributors to markets in the past, but their combined new capacity is slowly declining towards 10 GW from a high of 18 GW five years ago and their contribution to global cumulative capacity is down to just 2% from 6% in 2020. In contrast, India has developed strongly, leaning both on ambitious manufacturing and market support as well as benefiting from low-cost imports. The ability of India to continue with the volumes seen this year will depend both on the local markets ability to function with higher cost local manufacturing and on investment in administrative procedures and labour markets. The Pakistani market this year is the result of the convergence of several factors from rising electricity costs, low-cost imports, and a rapidly expanding network of module importers and resellers - the large volume of imported modules in 2023 indicated that 2024 would be dynamic. With an estimated new capacity over 17 GW, real concerns are being raised about the local grids ability to remain stable and the viability of the whole electricity system, that has high legacy capacity costs.

The **European regional market lost several percentage points in its share of global capacity but grew as a whole, despite** reductions in Spain (due to lower competitivity on the prosumer markets as electricity consumption prices dropped, where annual capacity was down to 7.5 GW for a cumulative capacity of 47.2 GW), as well as Poland, the Netherlands and some Nordic markets. Other markets increased once again, including Germany (16.7 GW for a cumulative capacity of 99.8 GW), Italy, France and Greece. Nearly 20 countries installed more than 1 GW in Europe in 2024.

The **Americas regional market** is principally composed of the USA and Brazil, although a number of countries have smaller volumes, either based on the rise of small prosumer systems or, on the contrary, as utility scale systems are installed. With 47.1 GW new capacity, the USA market picked up compared to 2023 (33.9 GW), despite grid connection delays and some material shortages continuing in 2024. The Brazilian market continued to grow, at 14.3 GW for a cumulative capacity of 52.1 GW.

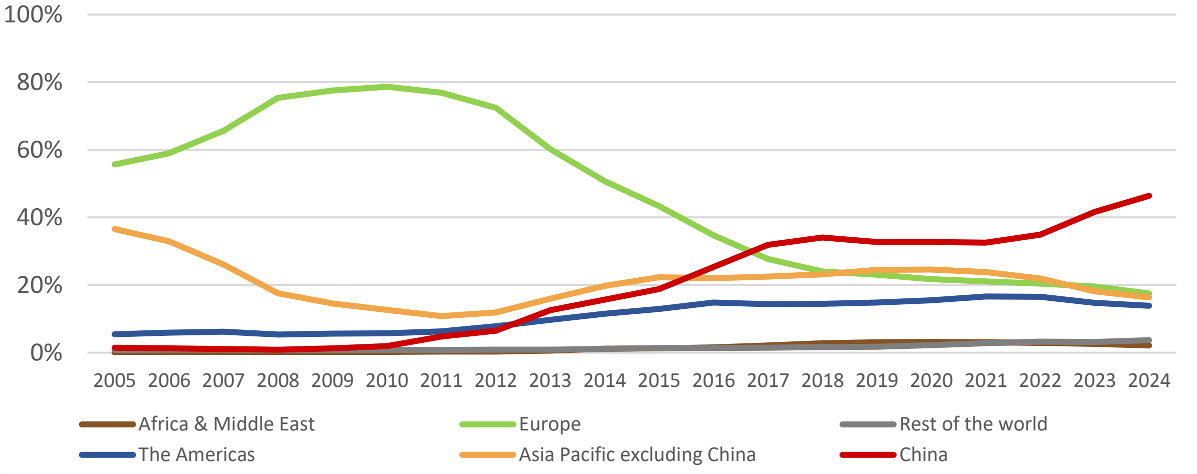
FIGURE 6A: EVOLUTION OF REGIONAL PV INSTALLATIONS



Source: IEA PVPS

In the Middle East and Africa, Türkiye was the most dynamic market, adding 4.1 GW to last year's 4.3 GW for a cumulative capacity of 19.6 GW. The South African market slowed to approximately 1.2 GW but a healthy volume of projects are in the development phases. The rest of the continent saw marginal volumes installed compared to elsewhere, despite the large pipeline of announced projects, many associated with storage or green hydrogen / ammonia.

FIGURE 6B: EVOLUTION OF REGIONAL SHARE OF GLOBAL MARKET



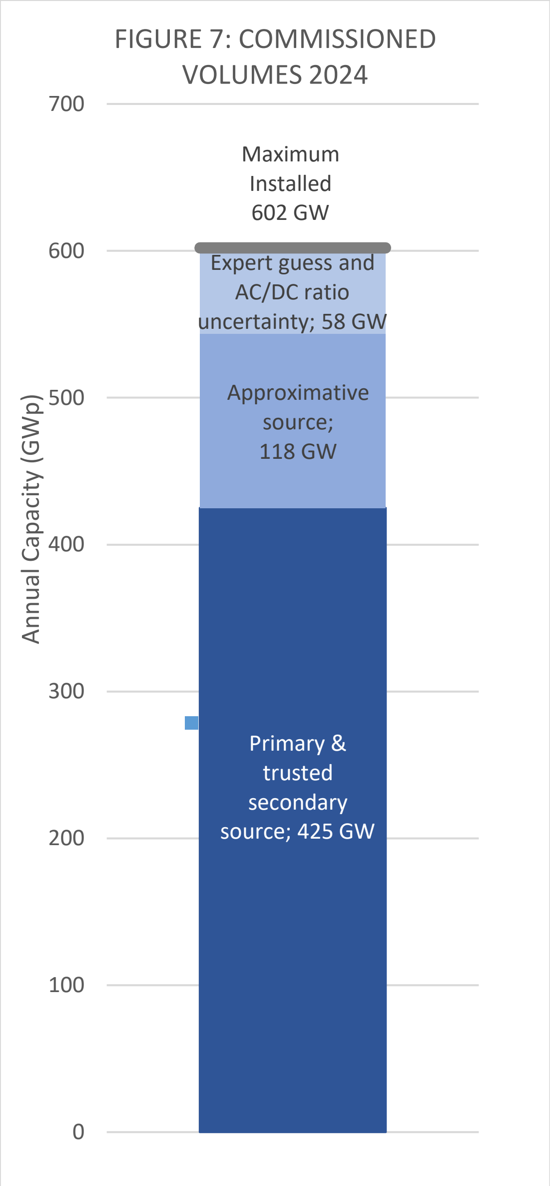
Source: IEA PVPS

2.2 Limits of Reporting Conventions

As the PV market grows constantly, **reporting of PV installations is becoming more complex**. IEA PVPS has decided to count all PV installations, both grid-connected and off-grid, when numbers are reported, and to estimate the remaining part on unreported installations. For countries with historically significant capacity and good reporting, a slow yet growing gap between shipped / imported capacity and installed capacity can be attributed to several factors including conversion factors from AC to DC, repowering and decommissioning. **Converting AC to DC power**, particularly on data sets covering a wide geographical area, is subject to a rather large uncertainty, as is demonstrated with **China data** — official reporting of utility scale is in AC power, China experts use a 1.15 or 1.2 conversion ratio whilst others use up to 1.5. France uses a 1.2 conversion ratio, Singapore 1.3 – practices vary with latitude and grid constraints. With a lack of hard data on existing systems, these ratios are built on limited surveys and standard dimensioning practices.

The extremely fast paced development of micro systems (*plug&play* systems with only a few modules), whilst not significant in overall volumes is symptomatic of the development of unreported systems reaching the market and sometimes being invisible to distribution system operators and data collection.

Other market evolutions such as off-grid applications are difficult to track even in member countries, and significant growth in installations in countries without a robust reporting system is also a likely source of underreporting. In light of this, reporting here takes into account reported and expert estimates of new commissioned capacity as well as probable unreported volumes installed in one of the above contexts.



Source: IEA PVPS

2.3 Decommissioning, Repowering and Recycling

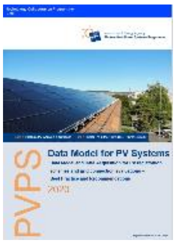
Data published by IEA PVPS reports on new annual installed capacity and total cumulative installed capacity are based on official data in reporting countries. Depending on reporting practices, historical cumulative capacity (the sum of new annual capacity) may outstrip cumulative operating capacity as systems are decommissioned. Repowered capacities replace some decommissioned capacity but also generally increase operational capacity, as the repowered capacity is higher than the initial plant capacity due to PV module efficiency improvements.

There is no standardised reporting on these subjects across IEA PVPS countries. Several countries already incorporate decommissioning of PV plants in their total capacity numbers by reducing the total cumulative number. Other countries report capacity in operation for that year, and do not include repowered volumes in new annual capacity or decommissioned volumes in operational capacity. Many countries do not track decommissioning or repowering with any consistency.

Repowering[3] is becoming more prevalent as the number of installations reaching 15 to 20 years of age increases — and some industry surveys report that for utility scale systems, repowering is more likely to be done after only 12 to 15 years. Module capacity that has been used to repower systems with defective or underperforming modules will appear in shipped volumes but not necessarily in new annual installations. **Real decommissioning is expected to be rare**, as land usage constraints and cheaper PV on buildings encourage repowering. Recycling numbers can provide a glimpse of what is happening with regards to repowering and decommissioning in countries where recycling schemes are active, however reporting is often in tonnage and the availability of data must be improved before it can be used more generally.

2.4 AC or DC Numbers?

IEA PVPS Report: Data Model and Data Acquisition for PV Registration Schemes and Grid Connection – Best Practice and Recommendations. https://iea-pvps.org/



By convention, the numbers reported refer to the nominal power of PV systems installed. These are expressed in W (or W_p). Some countries report the power output of the PV inverter (the device converting DC power from the PV system into AC electricity compatible with standard electricity networks) or the grid connection power level. The difference between the standard DC power (in W_p) and the AC power can range from as little as 5% (conversion losses, inverter set at the DC level) to as much as 60%. For instance, some grid regulations limit injections to as low as 70% of the peak power from the residential PV systems installed in the last years. Most utility-scale plants built in 2024 have an AC-DC ratio between 1.1 and 1.5. For some countries, **numbers indicated in this report have been transformed to DC numbers to maintain the coherency of the overall report.**

In general, IEA PVPS recommends registering PV systems with both the DC power and the AC value. DC power allows a reliable calculation of the energy production whilst AC power allows a better understanding of the theoretical maximum power output of the PV fleet. More information about recommendations to properly register PV plants can be found in the Data Model and Data Acquisition report (see link above).

[3] Repowering is the practice of replacing part or all of the modules of an existing system with newer, more efficient modules. In this process, the overall peak power of the system may be increased.

3 ELECTRICITY PRODUCTION FROM PV

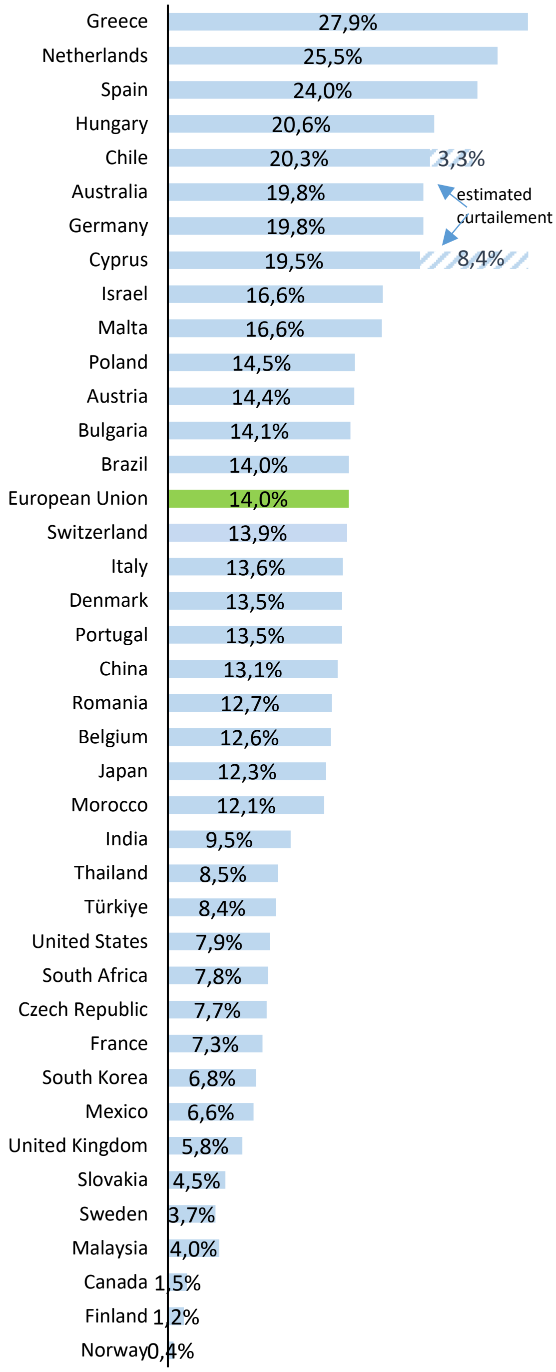
Figure 8 shows how PV theoretically could contribute to meet the electricity demand in key IEA PVPS countries and other major markets. It gives a comparative view of the **contribution the cumulative installed capacity of PV at the end of 2024 could have to 2025 electricity consumption**.

PV generation is easy to measure for an individual system but more complex for an entire country. Converting installed capacity to electricity is subject to errors - solar irradiation can vary depending on the local climate; weather can differ from year to year. Systems installed on buildings may not be at optimum orientation or have partial shading. Electricity self-consumed by prosumers is generally not metered. Where curtailment is practiced, the estimated curtailed volume may or may not be estimated (and reported) by grid managers, depending on local remuneration or regulation schemes.

Here, generation is based on the theoretical electricity production from all installed PV, calculated based on cumulative PV capacity at the end of 2024, close to optimum siting, orientation, and yearly weather conditions, and includes utility scale, self-consumption and even off grid system generation. Numbers may differ from official PV production numbers in some countries. It is evidently an optimistic evaluation, and should be considered as indicative, providing a reliable estimation for comparison between countries and does not replace official data. Electricity consumption is based on official data.

Sources of uncertainty in the PV penetration rate include consumption data (depending on availability, consumption is for the year 2023 or 2024 – as many countries reported 3% to 6% increases in consumption, using 2023 consumption data could lead to over-estimating penetration rates); how different countries report self-consumed electricity (adding, or not, as the case may be, this electricity to official consumption data); the real impact of curtailment on generation. Curtailment has only been indicated for two countries where curtailment is known to be high and official data is published - it has been included to demonstrate that part that is lost but it should be noted that curtailment is prevalent in many more countries.

FIGURE 8: THEORETICAL PV PENETRATION 2024



Source : IEA PVPS

There are now 27 countries with an estimated penetration rate over 10% (up from 18 in 2023): Greece tops the list (5th in 2023) however curtailment is a real issue and the penetration rate considering curtailment is lower than indicated; the Netherlands, Spain and Chile follow, with newcomer to the top Hungary at over 20%, followed by Australia, Germany and a few smaller countries also over 20%. The **increasingly large volumes of installed capacity are making a tangible contribution to electricity consumption around the world**. The two principal PV markets, China and the Europe Union, demonstrate this with more than 13% each. In total, **PV contribution amounts to over 10% of the electricity demand in the world.**

4 POLICY & MARKETS TRENDS

4.1 Policy Trends

Policy trends vary in response to energy transition and economic goals and PV industry and market trends. Rapid policy changes are often a reaction to evolving module prices, project profitability and trade deficits whilst more structural policy changes can be linked to energy transition goals, the cost of support mechanisms and local manufacturing stimulus.

The increasing competitiveness of PV has been a driver for many policy changes, in particular with regards to shifting towards prosumer policies and PPA facilitating measures (see below). Across Europe and in other countries, where once building regulations encouraged solar, it is becoming near mandatory or a more common requirement to increase energy autonomy – although the complexity of these mandates can mean slow deployment.

Policy support for batteries has also advanced, especially in countries with grid congestion, high penetration rates or high electricity costs. Policies and market design facilitating storage coupled with distributed and/or utility scale solar now exist in Austria, Australia, China, Germany, Italy, Japan, to name a few. In particular, mandatory coupling of storage with solar in China has led to record volumes globally.

Policies to support local manufacturing were initiated in the past years in several countries. In Europe the ability of these policies to really support the emergence of local manufacturing is in question since the price plunge of new modules through 2023 and 2024 led to a highly competitive market for manufacturers and the closure of local actors. India, Türkiye and the USA, with the ability to pass legislation in a more dynamic matter, have had more success and increased manufacturing volumes progressively since 2023.

A number of countries are currently revising PV targets within national planning or strategic documents (France, Japan, Portugal, Spain), or have set them for the first time (Austria, Norway).

4.2 Remuneration mechanisms

Tenders continued to be a popular instrument for developing commercial, industrial and utility systems, whilst PPA (power purchase agreements) and cPPA (corporate PPA, with a consumer) or even merchant PV (electricity sold on the market) are becoming more mainstream. This shift is not only due to the increasing competitivity of PV but also because of the efforts by commercial entities to keep control of future electricity costs through stable long-term contracts that meet increasingly stringent social and environmental responsibility standards.

Tenders can be exclusively cost based or integrate multiple factors such as land use, carbon footprint or geographical location. As concerns over the concentration of supply chains in China evolve, some governments (EU countries through the NZIA resilience clause, Türkiye, India) have looked to tender mechanisms to encourage local content, although trade rules can make this a complex undertaking.

Whilst through 2022 the peaking electricity costs were a strong motivator for immediate investment, the impact of fluctuations was also sufficient to push consumers to look towards more previsible supply costs and continue investing. PPA markets evolved differently across the world in 2024, with an upwards trend in prices in Japan (increased demand), and also Norh America, under the influence of strong demand for data centres and corporate responsibility programmes and reduced supply as grid connection backlogs and some equipment supply constraints continue to impact development. In Europe, PPA prices dropped as supply increased, with project developers in major markets looking to secure contracts outside of support frameworks subject to political instability. In many countries, increased demand from data centre projects is expected to be a significant driver of the market. Volumes secured for greenfield solar in Australia were significant as the mining industry works towards ESG goals.

PPA guarantee funds and security nets have been developed in some countries to increase investor and banking sector confidence in off-taker viability (France, Italy) whilst other countries are progressively opening their electricity markets to make room for PPAs (Malaysia) or looking to develop platforms to facilitate individuals and SME access to PPAs (Portugal).

The provision of alternative services by generators (hybrid parcs for larger baseloads or peak shifting with storage, capacity reserves, systems services) **is likely to become important to maintain long term profitability as curtailment is actioned** both for technical reasons (supply imbalances) and markets reasons (negative prices). Shifting from this reliance on kWh based PPAs or tenders for remuneration is inevitably complexifying management.

4.3 Prosumers Policies

Prosumers (entities that are both producers and consumers of energy) are becoming more **active market drivers around the world** as electricity consumption prices go up, PV costs go down and PV penetration rates increase, improving understanding of and access to prosumer policies.

In reaction to different factors, including increased competitivity, direct and indirect support mechanisms are being adapted in some countries to further promote prosumer policies: individual self-consumption, collective self-consumption and/or energy communities.

Prosumer excess generation can be paid for through net metering (generally in emerging markets), or net billing (in more experienced markets with smart or communicating meters). Remuneration rates vary and can be low to dissuade injections into the grid or on the contrary benefit from feed in tariffs or market premiums. These remuneration rates can be associated with a range of different constraints, from capacity limits to mandatory building integration or carbon footprints.

Collective self-consumption — where one or several PV producers (even utility-scale plants) supply one or more consumers in the same building or within a small geographical perimeter with reduced use of the public grid — continues to grow, although the wide range of mechanisms used can make it difficult to compare between countries. The use of self-consumption in collective buildings is growing rapidly around the world (many EU countries), whilst other models such as distributed (or virtual) self-consumption are becoming more prevalent. These models have in common that they allow a higher rate of self-consumption than if only one consumer is associated, and are increasingly seen as a market substitute, allowing small-scale generators to sell directly to consumers without having to become commercial operators, an often complex process.

4.4 Grid Integration and Curtailment

With increasingly high penetration rates of PV in more and more countries**, transmission and distribution system operators are having to anticipate and more actively manage PV**. Grid congestion and/or longer delays for grid connection have not allowed some local markets to develop to full potential (USA, Austria, Japan, Spain, Denmark) and in others is pushing the development of shared connections (renewable energy hubs) and hybrid parcs (USA, Australia, the Netherlands, France)

In some smaller regions (Australian, USA states, peninsular and island nations, in particular) penetration rates are so high that **PV has provided 100% of power over several hours** multiple times. These regions are actively trialling technologies and policies that will be adapted in other regions as penetration rates increase. In parallel, more and more countries are experiencing periods of time where overall supply outstrips demand – the most often coinciding with peak generation from PV. This imbalance has impacts such as affecting grid stability (increased voltage), forced cut-off (curtailment) of some generators and negative prices on electricity markets

Curtailment policies are being developed to meet the challenges these situations bring. These policies can require fundamental changes to national legislation (such as policies giving distribution grid operators the power to cut or control generation levels as passed in Greece) but also trigger policy measures to add or increase large-scale storage to provide services for grid stability (USA, Australia, China, Spain).

Policies to manage curtailment address aspects as diverse as compensation for lost generation, technical and legal mechanisms to allow network operators to remotely cut generation, obligations for generators to maintain or modulate voltage or frequency depending on the grids characteristics and managing the cost of balancing services. The impact on Contract for Difference support mechanisms is also under discussion in some countries.

Grid stability is an essential component of energy transition policies, with significant budgets being reserved across the world to adapt grids to accommodate increased penetration of renewable generation — including across interconnected networks such as the projected ASEAN Power Grid or the existing European grid. How the cost burden of managing, reinforcing and renewing grid infrastructure is shared has become one of the more sensitive topics. As these penetration rates increase, **new governance models compatible with market and climate policy driven deployment targets** will need to be established to ensure PV can be smoothly deployed.

4.5 Local Manufacturing Policies

The different disruptions of 2020 to 2022 (COVID-19, geopolitical tensions around the world, pollution episodes and human rights issues in China) have highlighted the **fragility of the PV value chain**, at a time when governments are looking to increased energy resilience. Supporting local manufacturing at various steps of the PV value chain has become important in different regions, **pushing numerous governments to support local manufacturing** through policies, subsidies and regulations.

In the EU, local manufacturing is being developed with government support, with exemptions to state aid rules facilitated by the State Aid Temporary Crisis and Transition Framework. Support schemes in Poland were approved 2024

The NetZero Industry Act (NZIA) was written to offer options for European countries to dedicate parts of the PV market to local manufacturers through specific bonuses or selection criteria in tenders and public procurement. These measures were leveraged in 2024 in Italy, for example. However, through 2023 and 2024 manufacturing in Europe (both operating and projects in development) was particularly impacted by the low module prices – the current or projected inability to manufacture modules at competitive prices became a real barrier, and policy shifts have not been rapid or decisive enough to guarantee continued developments. Several GW-scale projects remain, however some notable upstream industry actors shut down operations in 2024, leaving the EU supply chain fragilized.

In the Middle East, manufacturing projects seem to be less spurred by policies for developing supply to local markets, and more often for economic development and exports – these include 10 GW of polysilicon manufacturing (under construction) and about 15 GW of cell and module manufacturing (in project) in the Sohar Free Trade Zone in Oman, several projects in Saudia Arabia, 3 GW of module manufacturing in Egypt (under construction) and extensions to Moroccan module manufacturing lines. Türkiye launched support for local manufacturing and developing local value chains through grants and tax incentives, looking to stimulate private sector investment in the country, and added tariffs on modules imported from both China and several other countries.

South Africa initiated import tariffs on PV modules to protect local manufacturing from low priced imports.

In the USA the strong trade barriers and developmental framework, notably the Inflation Reduction Act support schemes, meant that international prices had only minor impacts on USA manufacturing and markets across 2024, with silicon cell manufacturing restarted and a module manufacturing capacity increased to over 40 GW/year. Many projects remain in development phases and much uncertainty has resulted from the change in presidency in Q1 2025.

Brazil increased import tariffs more than twice in 2024 (9.6% then 25%) in attempts to support the roughly 5 GW of local manufacturing capacity (and jobs) as low-cost Chinese modules flooded the local market. Although the volume of demand was many times that of local manufacturing capacity, quality concerns surrounding some imports have also been raised, strengthening support for policy decisions in favour of local manufacturing.

In India, local manufacturing has been supported through module import barriers, the Production Linked Incentive (PLI) Scheme and Domestic Content Requirements (DCR). The obligation for government backed projects to be supplied only from the Approved List of Models and Manufacturers (ALMM) was restarted in April 2024 after a one year pause. By the end of 2024, more than 60 GW/year of module manufacturing capacity was either commissioned or being ramped up, and about 50 GW/year of cell manufacturing projects are planned to meet the ALMM cell requirements that come into effect in June 2026.

In Australia, the 2024 Solar Sunshot program supports domestic manufacturing through production subsidies and grants.

4.6 2025 Market Perspectives in IEA PVPS Countries

Most IEA PVPS member countries expect continued steady volumes or small growth in 2025. Policy changes reducing feed in tariffs and investor support mechanisms in France, Switzerland, Sweden, Austria and the USA are likely to adversely impact these markets — although markets forces and the further development of PPAs should reduce the volatility that these policy changes could otherwise provoke. In other countries, changed policies could support more growth (Japan, Australia).

The impact of controlled production volumes in China is already being seen as module prices stabilize at the end of 2024; this will likely slow down the Chinese market, however as prices remain well below early 2022 values, it is not expected to significantly reduce the competitivity of PV in other major markets. It is expected that global inventories decline over 2025 both as a result of these controlled production volumes and the movement of Chinese stock to foreign markets — aggressively low prices through 2024 led to significant imports in countries with smaller historical markets such as Pakistan and Saudi Arabia, and whilst a portion of these volumes have been installed, much still remains either uninstalled or uncommissioned.

Significant uncertainties remain around the impacts on local grids and electricity markets of new 2025 volumes, as they become increasingly subject to congestion (grids) and negative prices (markets). Curtailment is expected to grow steadily around the world, leading to experiments in more diversified business models.

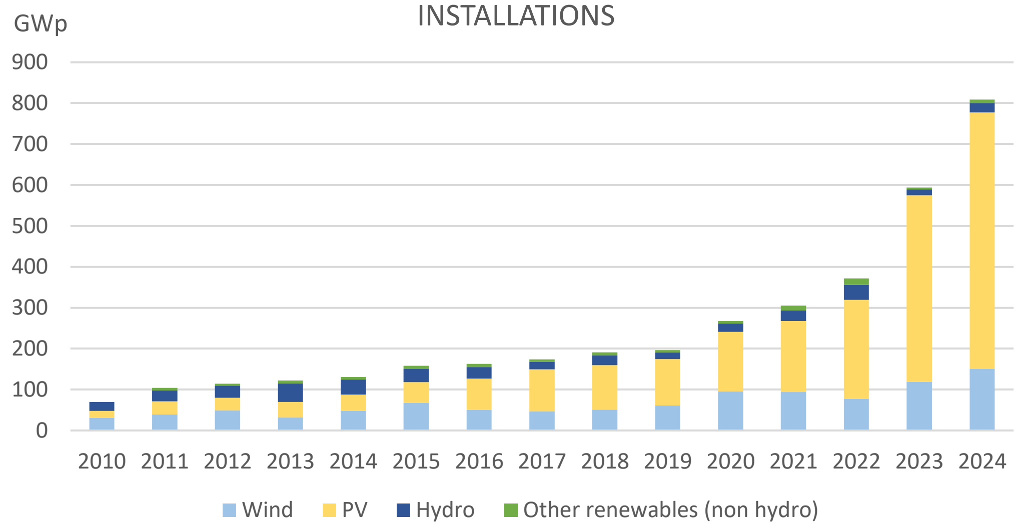
Local manufacturing in the USA is likely to be under pressure in the 2025 political climate; on the other side of the world, an increasing number of Indian facilities should come online. Consolidation in the Chinese manufacturing industry is expected as over-capacity eases only slightly.

5 PV IN THE BROADER ENERGY TRANSITION

5.1 PV and Other Renewable Energy Evolutions

In 2024, PV once again supplied more than three-quarters of new renewable generation capacity. The continued low module prices associated with current over-capacity in manufacturing, combined with continued support mechanisms and rising demand across the world for PV PPAs has meant that PV remains both profitable and attractive for private and institutional investors.

FIGURE 9: EVOLUTION OF ANNUAL RENEWABLE ENERGY INSTALLATIONS

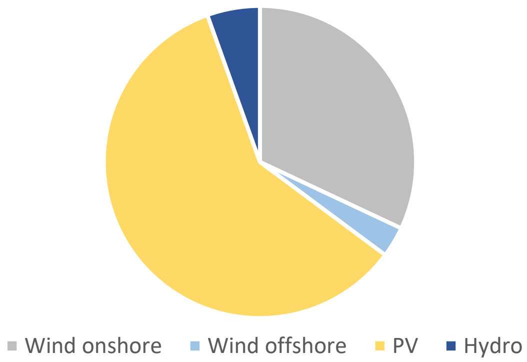


Sources: compilation of IEA PVPS, IHA, BNEF, GWEC, WWEA, IRENA and estimations for 2024

Whereas biomass and hydro installations can generally produce electricity 24 hours a day and all year-round, wind and PV installation output depend on the available resources that can vary locally – for example, with more consistent winds, offshore wind power has a higher capacity factor than onshore wind, and dependent on sunlight, PV can only produce during daylight hours.

With a lower capacity factor than wind or hydro, the share of generation coming from PV is lower than capacity shares – despite this, about 60% of new generation form renewable sources was from PV.

FIGURE 10: SHARE OF ELECTRICITY GENERATION FROM NEW CAPACITY INSTALLED IN 2024 BY SOURCE



Sources: compilation of IEA PVPS, IHA, BNEF, GWEC, IRENA and estimations for 2024

5.2 PV Fostering Development of a Cleaner Energy System

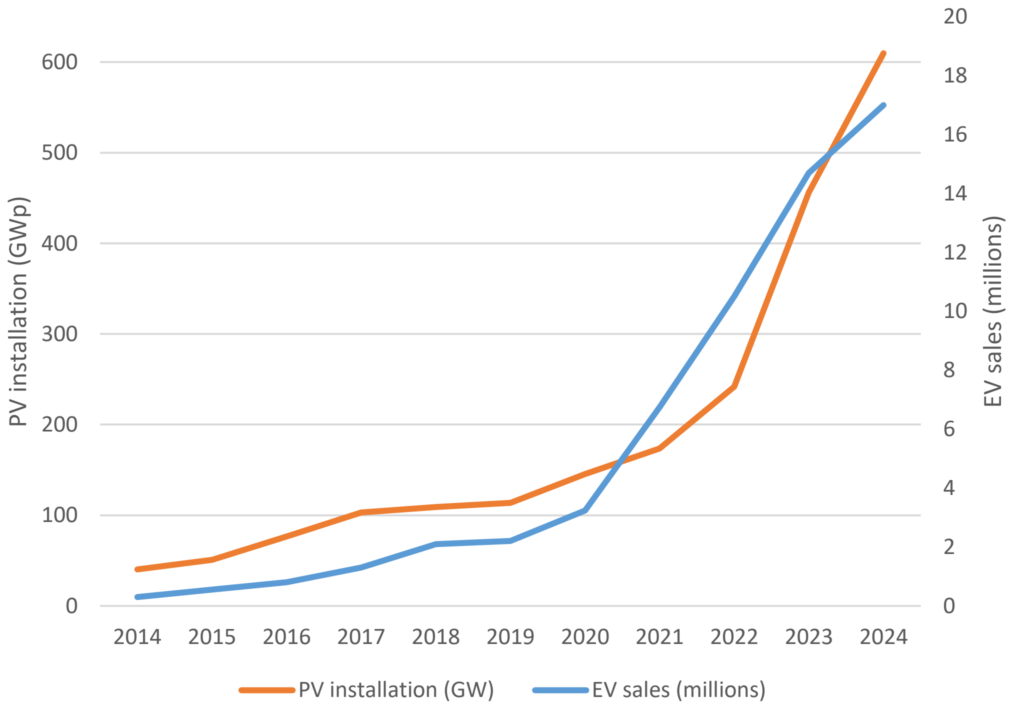
Cleaner energy systems can be built on renewable energies for electricity supply and the electrification of previously fossil fuel powered uses such as heating and transport. Combining high volumes of variable renewable energy with storage is proving to be a cost-effective, cleaner solution than maintaining often aging coal power plants or investing in new gas turbines, with supply subject to geopolitical instability, as proven over the past two years.

As PV penetration rates grow across the world, storage is becoming an important enabler; adding a little storage capacity can both smooth peak production to reduce grid capacity costs and provide a range of services that allow PV plus storage hybrid plants to replace traditional fossil fuel plants. Many support mechanisms are taking advantage of this synergy to strongly encourage hybrid systems either in residential or utility-scale markets (India, USA, Australia). Global installed battery capacity is estimated to have increased by approximately 150% in 2024.

A step further, sector coupling can provide excess solar to generate heat, cold or molecules such as hydrogen and ammonia, or power transport.

Part of the electrification of uses is the move towards electric vehicles (EVs) - the electrification of transport is well underway, with practical examples of charging EVs during peak load for grid management, a practice enabled by smart meters, whilst concepts such as virtual self-consumption, dependent on metering and secure exchange frameworks remain an attractive possibility to provide a framework for EVs as mobile storage for excess PV generation. The continued and sustained growth in EV sales across the world is an important indicator of state and consumer engagement in the transition to cleaner electricity-based economies.

FIGURE 11: EVOLUTION OF EV AND PV ANNUAL GROWTH



Source : IEA PVPS, EV Volumes, Reuters

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