Technology Collaboration Programme
by iea

International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

Snapshot of Global PV Markets 2023

Report IEA-PVPS T1-44:2023

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 countries are Australia, Austria, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance, the Solar Energy Industries Association, the Solar Energy Research Institute of Singapore and Enercity SA are also members.

Visit us at: www.iea-pvps.org

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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- **Design:** IEA PVPS

COVER PICTURE

4.6MW PV system on an old industrial site at Retzwiller (France) image credits : TRYBA ENERGY.

ISBN 978-3-907281-43-7: 2023 Snapshot of Global PV Markets

INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

IEA PVPS
Task 1
Strategic PV Analysis and Outreach

Report IEA-PVPS T1-44:2023
April 2023

ISBN 978-3-907281-43-7

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The global PV base once again grew significantly in 2022, reaching **1 185 GW (≈ 1,2 TW)** of cumulative capacity according to preliminary market data, both despite and because of post-covid prices hikes and European geo-political strife. With **240 GW of new systems installed** and commissioned, and nearly a dozen countries with penetration rates over 10%, (over 19% for Spain!), PV has demonstrated that it is a serious, major, long-term contributor to cost competitive electricity generation and emissions reductions of the energy sector.

Major trends include:

- The **Chinese market continues to dominate** both new and cumulative capacity and added **106 GW[1]$_{DC}$** or 44% of new capacity to reach 414,5 GW of cumulative capacity, more than double that in Europe. This strong growth follows that of previous years - 54,9 GW in 2021 and 48,2 GW in 2020, and evenly balanced between centralised and distributed systems.
- **Europe demonstrated continued strong growth** with **39 GW installed**, led by Spain (8,1 GW), Germany (7,5 GW), Poland (4,9 GW) and the Netherlands (3,9 GW). High electricity market prices have reinforced the competitivity of PV and several countries have acted policies to further accelerate PV in line with EU and national energy sovereignty engagements – whilst others are enacting policies to reduce injections because of grid congestion.
- The **American market contracted to 18,6 GW** under the combined influence of trade issues and grid connection backlogs, whilst Brazil installed a high 9,9 GW, nearly doubling the previous year's new capacity.
- **India once again showed strong growth with 18,1 GW**, predominantly in centralised systems, and a PV penetration of nearly 10%. Strong volumes from Australia (3,9 GW despite supply chain issues), and Korea round out the regional market.
- **Japan remained steady at 6,5 GW**, the same as in 2021.

Nine countries now have penetration rates over 10% with Spain, Greece and Chile above 17%, and whilst grid congestion has become an issue, policy measures, technical solutions and storage are already providing workable solutions to enhance PV penetration.

Individual markets remain sensitive to policy support despite competitivity across most market segments in many countries, however **policy support is moving to indirect measures** such as accelerated permitting or facilitating prosumer models or managing grid congestion. **Increasing concerns about the concentration of the upstream supply chain in China** has led to initiatives and policy support for local manufacturing.

PV played an important role in the reduction of the CO_2 emissions from electricity in 2022, with two-thirds of new renewable capacity installed in 2022, generating over 50% of generation from new renewable capacity and avoiding approximately **1 399 Mt** of annual CO_2 emissions, up 30% from 2021. This represents around 10% of the total electricity and heat sector emissions and 4% of all energy emissions. This continued positioning PV as one of the key existing and developing solutions to fight climate change here and now.

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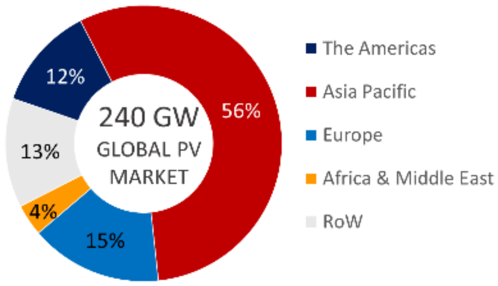
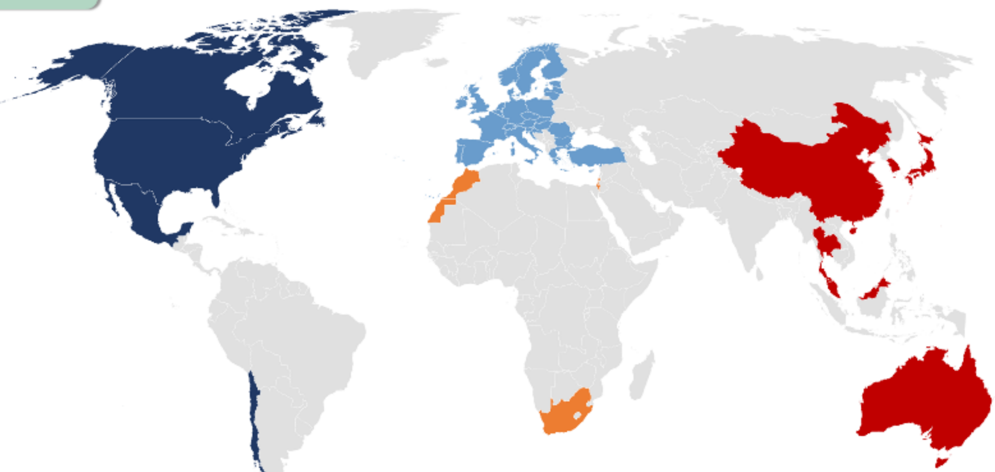
[1] All capacity data in this report is DC, unless specified otherwise. For some countries, this means publishing different values to official data – for example, China's National Energy Administration (NEA) publishes in AC and PVPS applies a conversion ratio from AC to DC. See section 5 for more information.

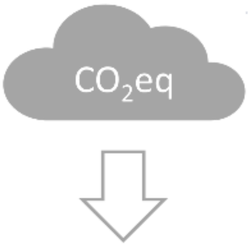
A Snapshot of Global PV Markets

TOP PV MARKETS 2022

- CHINA 106 GW
- EU 38,7 GW
- USA 18,6 GW







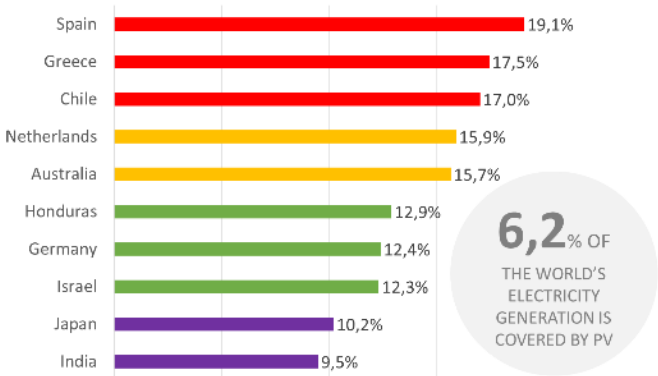
1 399 Mt
CO_2 emissions
avoided in 2022

- **1185 GW** were installed all over the world by the end of 2022
- **China** is the world's **#1** PV market
- **23** countries installed at least **1 GW** of PV in 2022
- **16** countries have installed at least **10 GW** of cumulative capacity at the end of 2022

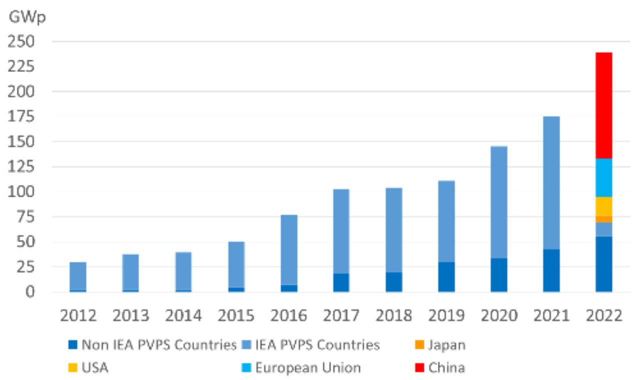
SOLAR PV PER CAPITA 2022 Watt/capita

		Watt/capita
1st	AUSTRALIA	1 166
2nd	NETHERLANDS	1 040
3rd	GERMANY	807

COUNTRIES WITH HIGHEST PV PENETRATION



EVOLUTION OF ANNUAL PV INSTALLATIONS



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1 SNAPSHOT OF THE GLOBAL PV MARKET IN 2022

IEA PVPS has distinguished itself throughout the years by **producing unbiased reports** on the **development of PV all over the world**, based on information from official government bodies and reliable industry sources. This 11th edition of the "Snapshot of Global PV Markets" aims at providing **preliminary information** on how the PV market developed in 2022. The 28th edition of the PVPS complete "*Trends in Photovoltaic Applications*" report will be published in Q4 2023.

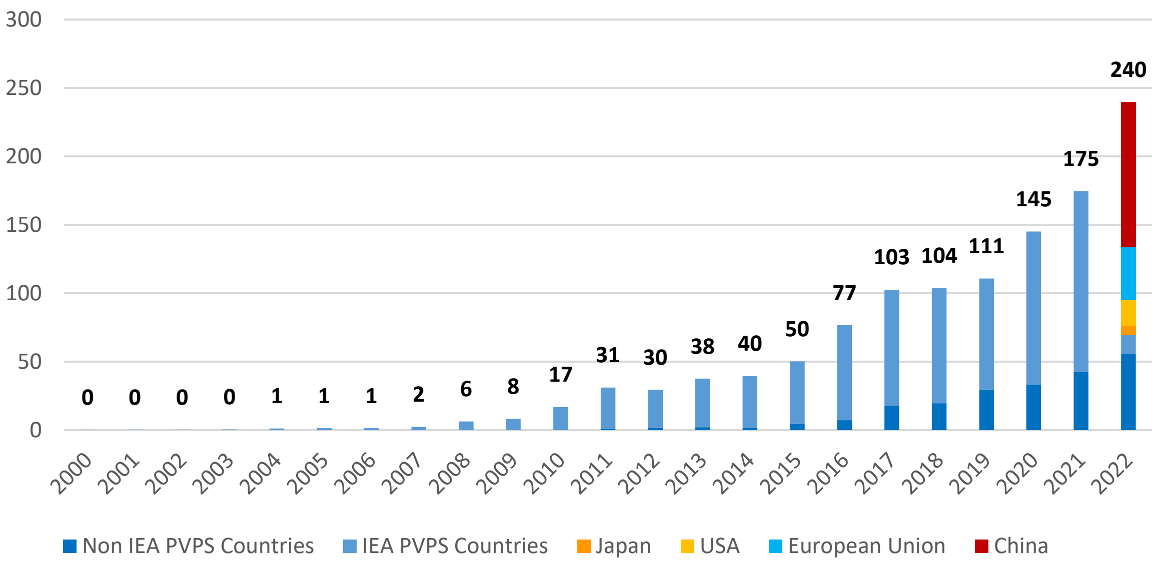
1.1 Evolution of Annual Installations

It appears that 1 185 GW represents the minimum installed cumulative capacity by the end of 2022, and at least 240 GW of PV systems have been commissioned in the world last year. IEA PVPS countries[2], for whom there is a firm level of certainty in the data, represented 953 GW (or 80%) of cumulative capacity and 184 GW (77%) of annual installations.

In 2022, **at least 23 countries installed more than 1 GW**.

Sixteen countries (not including the EU) now have more than 10 GW of total cumulative capacity, five have more than 40 GW. China alone represented 414,5 GW followed by the European Union (as EU27), which led rankings until 2015, but now ranks second (209,3 GW), the USA ranks third (142 GW) and Japan fourth (85 GW).

FIGURE 1: EVOLUTION OF ANNUAL PV INSTALLATIONS



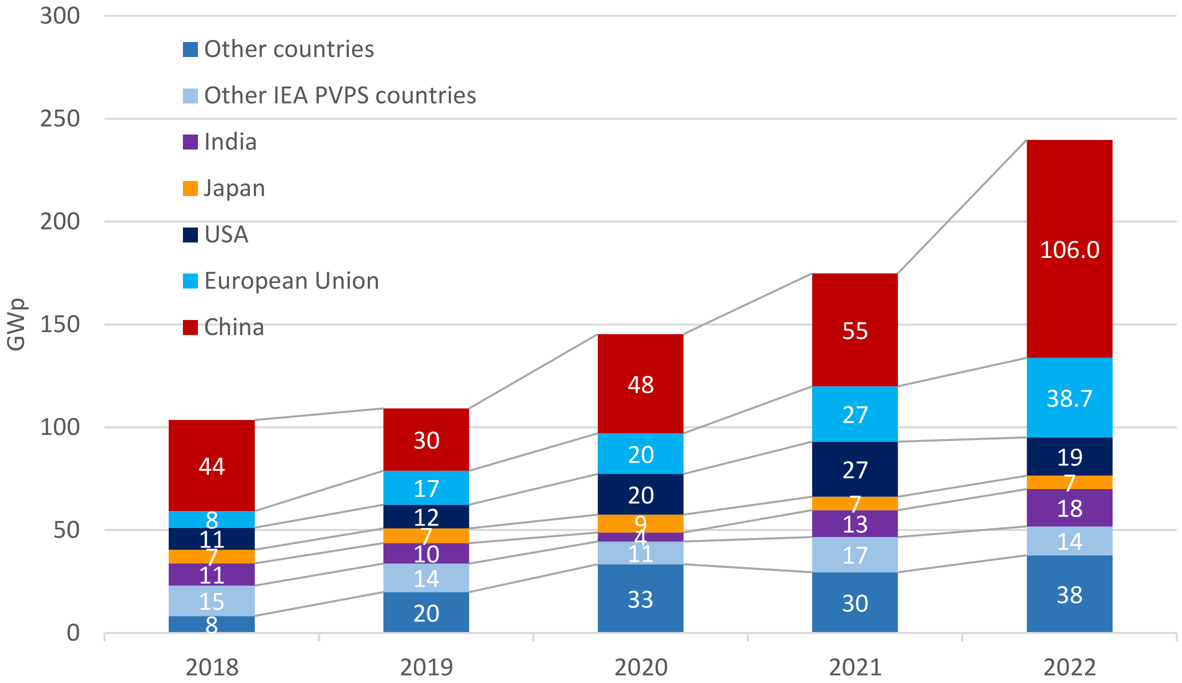
Source: IEA PVPS

With continued dynamic growth, China remains the major regional market in 2022 with over 45% of new capacity, a market share not seen since 2018; strong growth in Europe and to a lesser extent the USA and India account for another 30%. Figure 2 below illustrates **the changing dynamics of the global PV market**, and the influence of the Chinese PV market,

[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.

but also **the fast pace of growth in India and emerging countries**. Japan, once a principal market maintains a steady rhythm of new projects but with no market acceleration as elsewhere.

FIGURE 2: 2018-2022 GROWTH PER REGION



Source: IEA PVPS

1.2 Impact of International Trade Disruptions and the Ukraine War

After three years **it is still difficult to precisely quantify the impacts of the pandemic**. Of the principal markets, only India showed a contraction in 2020, and all other principal markets showed growth through 2020 to 2022 **despite significant disruption to the supply chain and trade with increases in polysilicon, glass, aluminium, steel, and freight costs, and hence module and system costs**. In parallel, since early 2022 the political tensions in Europe and resulting reduced gas acquisitions have resulted in much higher wholesale and domestic electricity prices, not just in Europe but across a range of other countries as far as Australia.

The increase in costs, especially in 2022, do not seem to have slowed growth in PV markets apart from in India (where red tape constraints can explain much of the delays), although in some countries especially in Europe very competitive medium and large-scale systems were cancelled or put on hold as their business models couldn't hold up to increased costs. It is highly possible that **stable costs could have led to faster growth rates**, although, considering manufacturing capacity, there may have still been prices rises on polysilicon, even if new manufacturing plans had been launched earlier.

By mid-2022 **transport and material costs were mostly stabilising**, and PV markets continued to grow. Overall, it is difficult to distinguish if this acceleration effect is stronger or weaker than the braking effect of higher PV hardware prices.

The **enhanced PV competitiveness in many countries has brought grid parity to a much larger range of segments** than even 18 months ago, from domestic systems to utility scale systems, with impacts on policy and financing mechanisms that are discussed in Section 7.

The **resiliency of the PV market despite the major economic and logistic disruptions is remarkable** and shows the potential of the technology to limit economic downturns and social damage brought on by regional or worldwide upheaval. Green recovery plans and better regulations could propel the PV industry far beyond the current installation trends to meet the Paris Climate Agreement.

1.3 The Top Markets in 2022

The Chinese market grew again at a remarkable rate and installed 106 GW in 2022 (up from 55 GW in 2021), or 44% of the global market. With 38,9 GW of annual installations the European Union ranked second followed by the USA where an estimated 18,6 GW were installed, a market hit by trade disputes and grid connection backlogs, followed by India with an increased market of 18,1 GW. Brazil comes in fourth with an estimated 9,9 GW, the most dynamic market in Latin America.

TABLE 1: TOP 10 COUNTRIES FOR INSTALLATIONS AND TOTAL INSTALLED CAPACITY IN 2022

FOR ANNUAL INSTALLED CAPACITY			FOR CUMULATIVE CAPACITY		
1	China	106 GW	1	China	414,5 GW
(2)	*European Union*	*38,7 GW*	*(2)*	*European Union*	*209,3 GW*
2	USA	18,6 GW	2	USA	141,6 GW
3	India	18,1 GW	3	Japan	84,9 GW
4	Brazil	9,9 GW	4	India	79,1 GW
5	Spain	8,1 GW	5	Germany	67,2 GW
6	Germany	7,5 GW	6	Australia	30 GW
7	Japan	6,5 GW	7	Spain	26,6 GW
8	Poland	4,9 GW	8	Italy	25 GW
9	Australia	3,9 GW	9	Korea	24,8 GW
10	Netherlands	3,9 GW	10	Brazil	23,6 GW

Note: The European Union grouped 27 European countries in 2022, out of which Germany, Spain, France, the Netherlands and Italy also appear in the Top Ten, either for the installed capacity or the annual installations. The European Commission is a member of IEA-PVPS through its Joint Research Centre (EU-JRC).

Source: IEA PVPS

To reach the Top Ten for new capacity in 2022, countries needed to install at least 3 GW of PV systems (compared to 1,5 GW in 2018). Korea and France gave way to Poland and the Netherlands despite reasonable performance. The Top Ten of total cumulative installed capacities shows more inertia due to past levels of installations: France exited the Top Ten for cumulative installed capacity in 2022 and was replaced by Italy that is now back in the Top Ten. There remains a significant gap between the first five and the next five; Australia, Spain, Italy, Korea and Brazil have very similar cumulative capacities of between 20 GW and 30 GW, under half as much as number five, Germany.

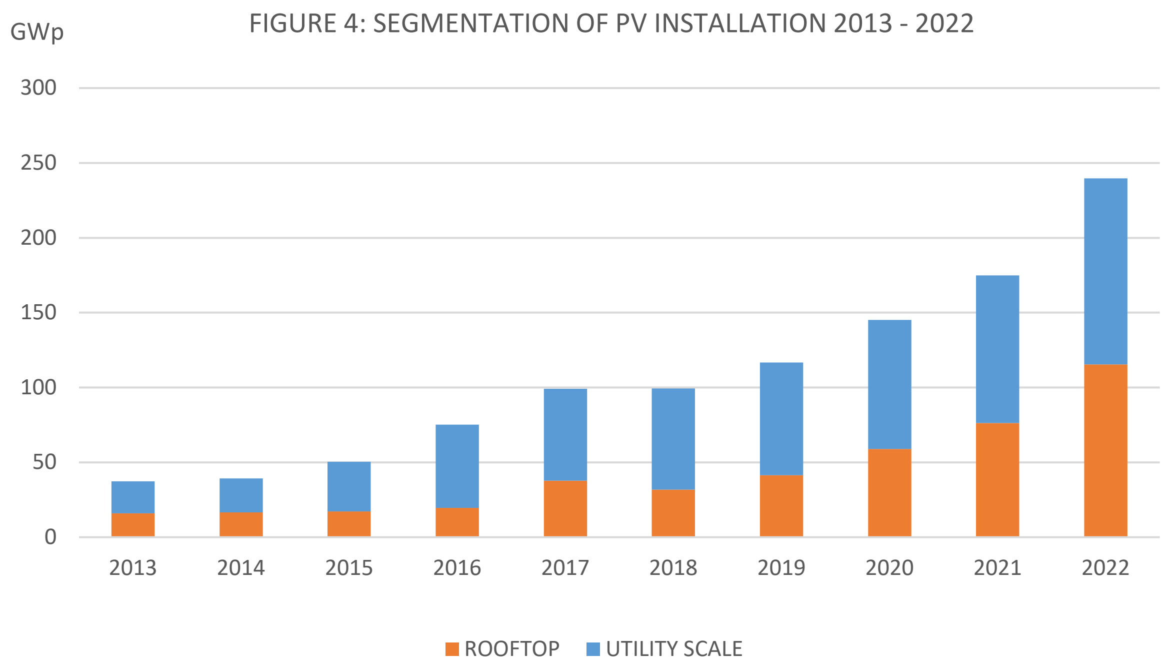
2 MARKET SEGMENTATION

Preliminary data indicates that in absolute terms, **both rooftop and utility scale segments grew in 2022**. Market segments were balanced, with 48% of new capacity on rooftops. The share of the rooftop segment has been growing continuously since 2018 as markets open in new countries and decreasing costs makes it more accessible for residential and commercial investors, with notable volumes (>2,5 GW) and market shares in China, Brazil, and Germany as well as Poland and Australia.

On both segments **new applications are in growth**; from BIPV in the rooftop segment to utility scale floating PV.

Still marginal but growing, agrivoltaic projects and BIPV are as yet hard to quantify, as are VIPV/VAPV[3] volumes (PV integrated in vehicles) although they are expected to develop well in the coming years.

Technological evolutions, such as bifacial PV will also impact the development of these new market segments.



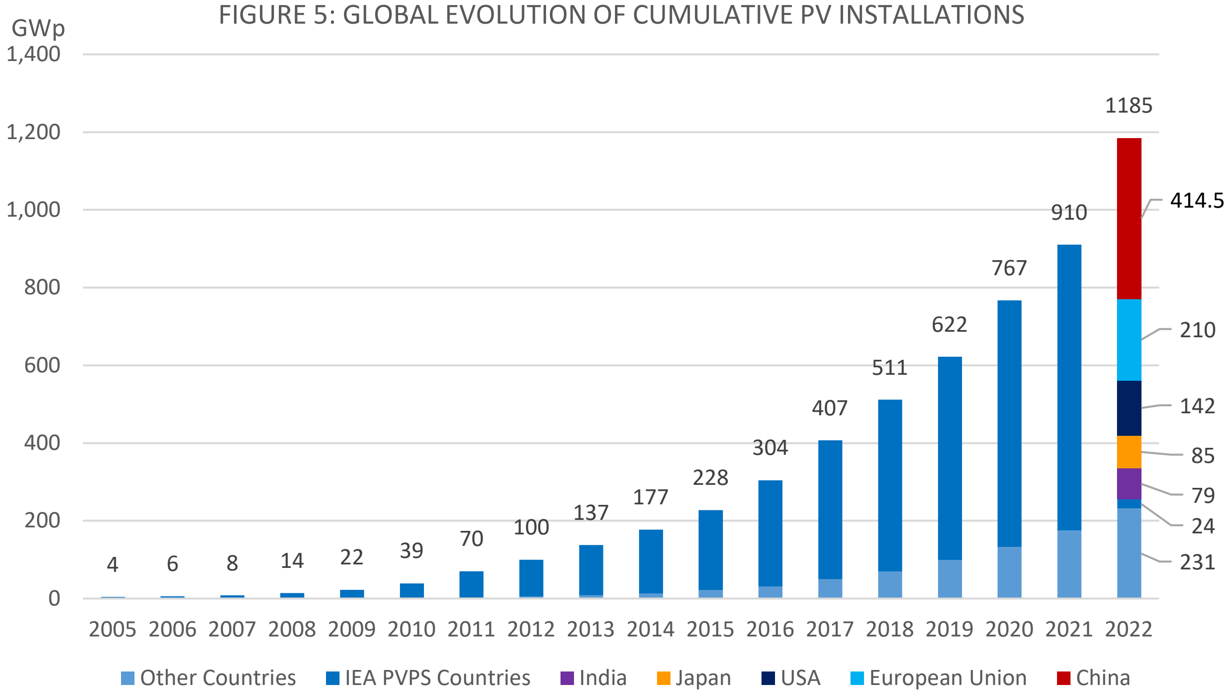
Source: IEA PVPS, Becquerel Institute

[3] BIPV – Building Integrated PV; VIPV – Vehicle Integrated PV; VAPV - Vehicle Integrated PV

3 CUMULATIVE INSTALLED CAPACITY IN THE WORLD

In 2022 the **global cumulative installed capacity passed the symbolic 1 TW mark**, reaching an estimated 1 185 GW, as shown in Figure 5. Frontrunners - from China down to India and then Germany (67,2 GW) have at least 30 GW more than the next countries. Their positions are unlikely to be challenged in 2023 or 2024, not even a doubling or tripling of Brazil's dynamic 2022 market (9,9 GW) would be sufficient. Brazil joined the next group of countries with smaller, similar cumulative capacities of between 20 GW and 30 GW: Australia, Spain, Italy, Korea and now Brazil.

FIGURE 5: GLOBAL EVOLUTION OF CUMULATIVE PV INSTALLATIONS



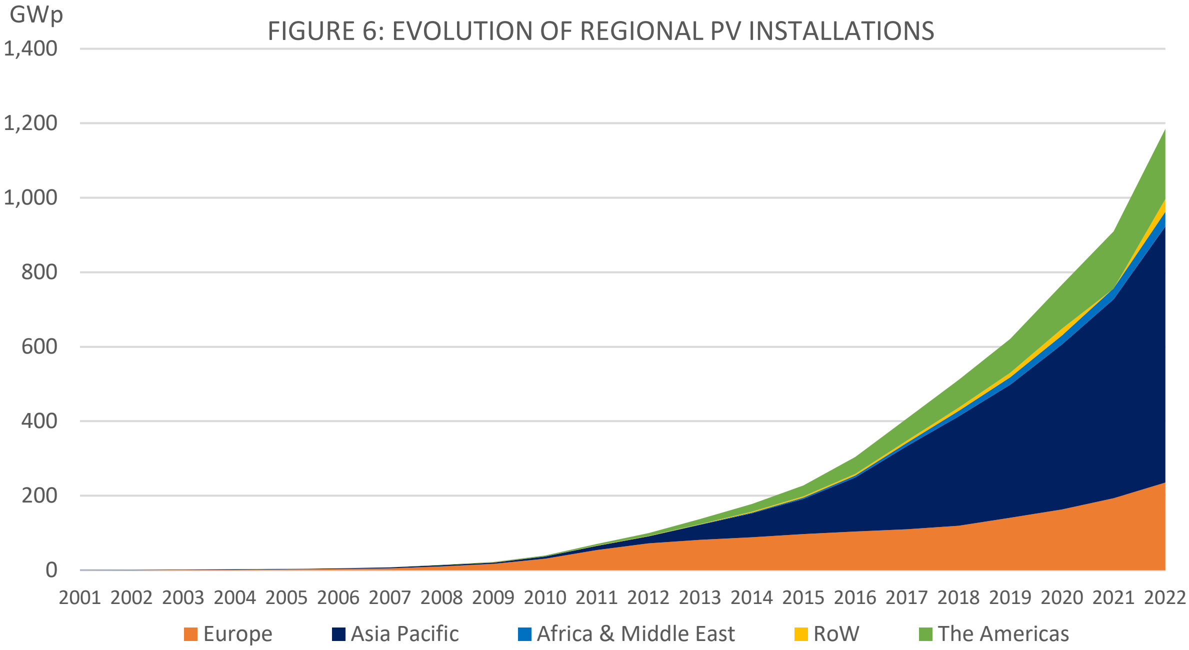
Source: IEA PVPS

4 EVOLUTION OF REGIONAL PV INSTALLATIONS

The distribution of regional market shares has remained steady since 2018. **Asia Pacific has captured the major share with 64% of the total cumulative installed capacity in 2022** (see Figure 6), driven by China with strong contributions from India. Japan installed a stable 6,5 GW whilst markets in both Korea (down to 3,6 GW) and Australia (3,9 GW) contracted slightly - supply chain challenges and investment lags in Australia should be resolved in 2023. Some smaller established Asian markets - Taiwan and Malaysia, also experienced growth in 2022, where other markets, such as Thailand, Singapore, Indonesia and the Philippines have seen only slow or intermittent growth over the years.

In the European Union, Spain took the lead with 8,1 GW after four years steady between 4 GW and 5 GW annually. Germany followed closely with 7,5 GW after a fourth year of over 120% increase then Poland (4,9 GW installed) with a similar growth rate. The Netherlands ranked fourth with 3,9 GW installed. They are followed by France with 2,9 GW and Italy (2,5 GW). A further five countries installed over 1 GW: Denmark (1,6 GW), Greece (1,4 GW), and Austria and Hungary both at 1 GW. European countries not in the EU installed a combined 3,4 GW in 2022, led by Turkey (1,6 GW), Switzerland (850 MW) and the UK (555 MW). Notable growth was observed in Norway (+300% relative increase), Italy (+163% relative increase), Sweden (+96%) and Slovenia (+98% relative increase).

FIGURE 6: EVOLUTION OF REGIONAL PV INSTALLATIONS



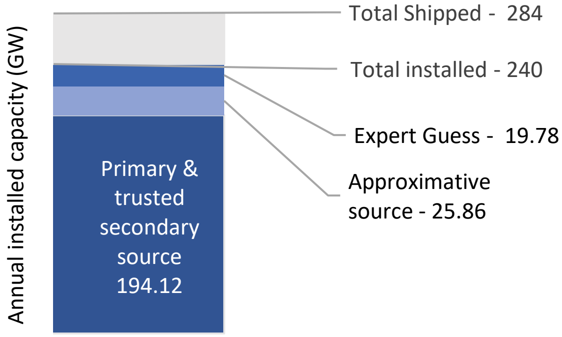
Source: IEA PVPS

Despite the **US market's underperformance** (18,6 GW, down from 27 GW in 2021), **the overall Americas market increased**, pulled by **strong growth in Brazil** (9,9 GW installed in 2022), followed by Chile which installed around 1,8 GW and Mexico with 680 MW. The market in Canada grew at around 449 MW installed capacity in 2022.

In the Middle East and Africa, **Israel installed an additional 1,2 GW**, a significant increase compared to the previous year, followed by Qatar (0,8 GW). Africa and the Middle East represented around 3% of global PV installations in 2022 with off-grid installations growing rapidly and rooftop PV outside of any regulatory scheme are progressing in many countries rapidly.

5 LIMITS OF REPORTING CONVENTIONS

FIGURE 3: INSTALLED VS SHIPPED VOLUMES 2022



SOURCE: *IEA PVPS*

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. 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 third 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. Data on estimated shipped capacity, in inventories, has been incorporated in Figure 3 to improve market visibility.

5.1 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, cumulative capacity (the sum of new annual capacity) may outstrip 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 is still relatively unusual given the age of the oldest installations, but it is expected to increase in the near future - serial defects with backsheets manufactured in the period 2009 – 2011 is a good example, as the past 2 years have seen a few hundred MW replaced. 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 encourages 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.

In the coming years, **IEA PVPS will follow the dynamic evolution of decommissioning, repowering and recycling closely**, with the expected impact on the installed capacity, market projections for repowering and the decline in PV performances due to ageing PV systems.

5.2 AC or DC Numbers?

IEA PVPS Task 1 Report:

Data Model and Data Acquisition for PV Registration Schemes and Grid Connection – Best Practice and Recommendations

Available for download here.

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 2022 have an AC-DC ratio between 1,1 and 1,6. 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 and QR code above).

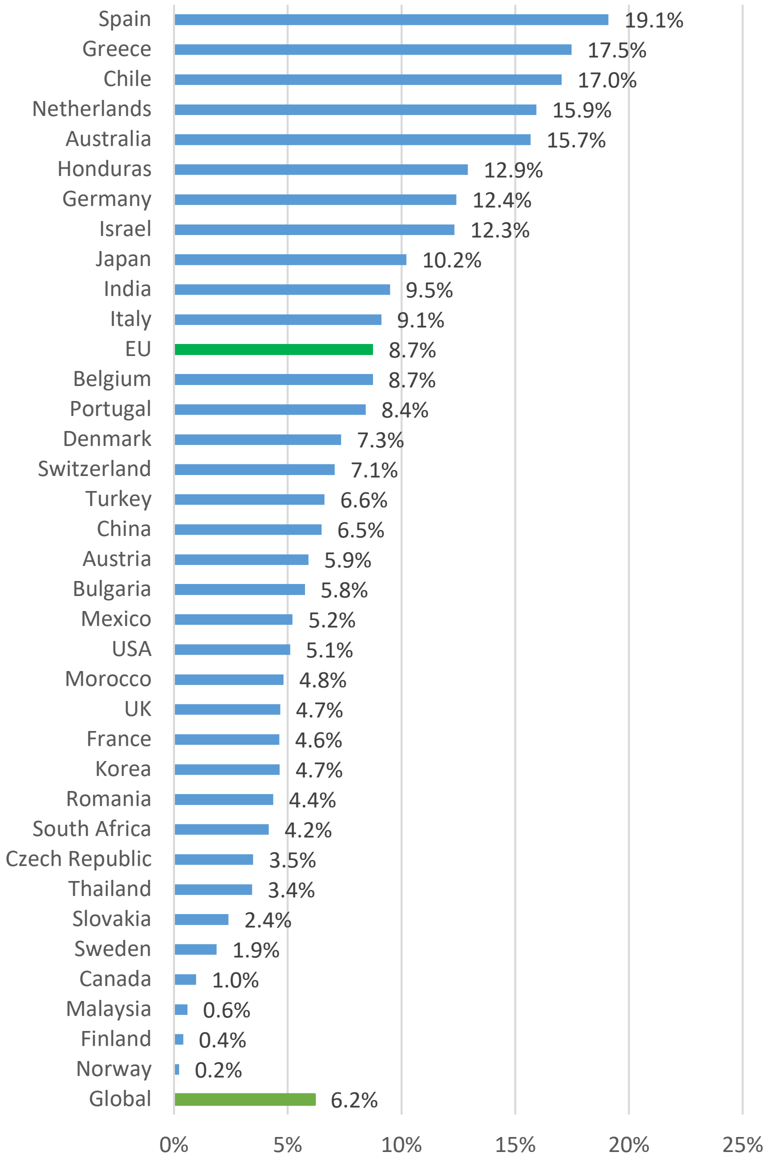
6 ELECTRICITY PRODUCTION FROM PV

PV generation is easy to measure for an individual system but more complex for an entire country. Electricity self-consumed by prosumers is generally not metered. 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 in December will have produced only a fraction of their annual electricity output; systems installed on buildings may not be at optimum orientation or may have partial shading during the day.

PV penetration is based on the theoretical electricity production from PV per country, calculated based on cumulative PV capacity at the end of 2022, close to optimum siting, orientation, and yearly weather conditions.

Figure 7 shows how PV theoretically contributes to meet the electricity demand in key IEA PVPS countries and others, based on the installed capacity by the end of 2022. Numbers are estimates based on total cumulative capacity at year's-end and they may differ from official PV production numbers in some countries. They should be considered as indicative, providing a reliable estimation for comparison between countries and do not replace official data.

FIGURE 7: THEORETICAL PV PENETRATION 2022



Nine countries now have penetration rates over 10% (up from 7 in 2021): Spain at over 19%, Greece and Chile above 17% and the Netherlands and Australia over 15%. High penetration rates are not reserved for small are sunny climates, nor for countries with very low consumption as demonstrated by both Germany and India in the top group – the **increasingly large volumes of installed capacity are making a tangible contribution to electricity consumption around the world**. The two principal markets China (6,5%) and Europe (8,8%) demonstrate this. In total, **PV contribution amounts to 6,2% of the electricity demand in the world.**

7 POLICY & MARKETS TRENDS

7.1 Policy Trends

The **combination of market competitivity, climate action goals and the search for energy sovereignty has led to changes in policy** support for photovoltaics in a number of countries in 2022 – often in quite contradictory directions.

Some countries (China, Australia…) are phasing out support mechanisms for end users (tenders, feed in tariffs, direct and fiscal subsidies) as PV has become competitive, whilst others (Germany, Austria) have stepped up support (new remuneration bonus for prosumers, increased tender capacities) to drive further capacity growth to meet climate imperatives. In parallel, many countries have used indirect support mechanisms addressing permitting complexity and costs, facilitated access to electricity markets or grid access policies for prosumers to accelerate PV deployment.

The past year has demonstrated that despite PV competitivity, **national markets remain sensitive to policy**, with different segments responding to policy changes as they become effective. This is particularly visible in emerging applications, such as agrivoltaics, floating PV or collective self-consumption and energy communities. In particular, two major subjects have mobilised policy makers in 2022 – grid access policies and support of local manufacturing. **Grid access policies have emerged as a limiting factor** in an increasing number of countries and markets, as congestion and shifting of cost-burdens slows projects and worries Distribution System Operator's - DSO's. **Support for local manufacturing** in the context of PV targets, disrupted supply chains and the high concentration of manufacturing capacity in China has led to some reformative support policies around the world.

7.2 Competitive Tenders & Merchant PV

Tenders continued to be the **main driver of utility scale PV development in 2022**, although the increase in electricity prices led to a surge in projects exploring PPA (Power Purchase Agreements or merchant PV) as a financing mechanism in many countries (Europe, Americas).

Despite this, many countries continued to run tenders in 2022, although factors such as the attractiveness of market electricity costs or poorly anticipated reserve prices led to lower subscription rates than expected in some countries (Germany, France, Spain). The increase in material and transport costs in 2021 and 2022 may have impacted the viability of some successful candidates, with projects being delayed (Spain) or state organisations considering adjusting remuneration methods (France).

The increased market competitivity has led to the termination or gradual phasing out of tenders, for example in Australia, China – elsewhere, climate engagements or market imperatives have led to new or increased volumes to be tendered (Germany, Saudi Arabia).

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

Merchant PV (direct sales on electricity markets or through PPA) is growing steadily as PV developers and owners **take advantage of higher electricity prices to avoid the constraints of tenders** (timing, restrictive conditions, or insufficient volumes) or as the sole alternative when support mechanisms are phased out. Some countries are experimenting with non-monetary support to encourage the development of market PPAs, such as guarantee funds, virtual PPA frameworks (Malaysia) or tenders for grid access (Spain).

7.3 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 and PV penetration rates increase, improving understanding of and access to prosumer policies.

Prosumer excess generation is generally paid for through net metering (traditionally 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 (many EU countries), whilst other models such as distributed (or virtual) self-consumption are becoming more common. 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.

In the Clean energy for all Europeans package, the European Union introduced the concept of Renewable Energy Communities (REC) and of Citizen Energy Communities (CEC). REC should allow citizens to sell renewable energy production to their neighbours, while some crucial components are the definition of the perimeter and the tariffication for grid use. Those key components are defined in the national implementation in the member states. This concept of energy communities is likely to expand existing PV market segments and to allow cost reductions for consumers not able to invest in a solar installation themselves.

7.4 Grid Access Policies

With increasingly high penetration rates of PV in more and more countries, and **some small regions reaching 100% RES over several hours or days**, transmission and distribution system operators are having to **anticipate and more actively manage PV**. New policies have been proposed or implemented to manage grid access and cost sharing, from tenders for capacity (Spain) to cut offs of solar exports in case of saturation (Australia) or taxes on grid exports (California, Belgium).

How the cost burden of managing, reinforcing and renewing grid infrastructure is shared has become one of the more sensitive topics. Increased behind-the-meter generation can reduce revenue collected on consumption, whilst midday exports can congest grids and impact grid balancing. As 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.

7.5 Local Manufacturing Policies

The different disruptions of 2021 and 2022 (covid, geopolitical tensions around the world and pollution episodes in China) have highlighted the **fragility of the PV value chain**, at a time when governments are looking to increase generation from PV. 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 regulation – notable examples include the USA's Inflation Reduction Act (IRA), While trade conflicts have diminished in intensity in the last years, the willingness to support local production has increased with initiatives in Europe, the USA, India, Morocco or Saudi Arabia. This reflects the growing perception of the importance that PV could take in the coming years and the willingness to secure strategic production in some countries.

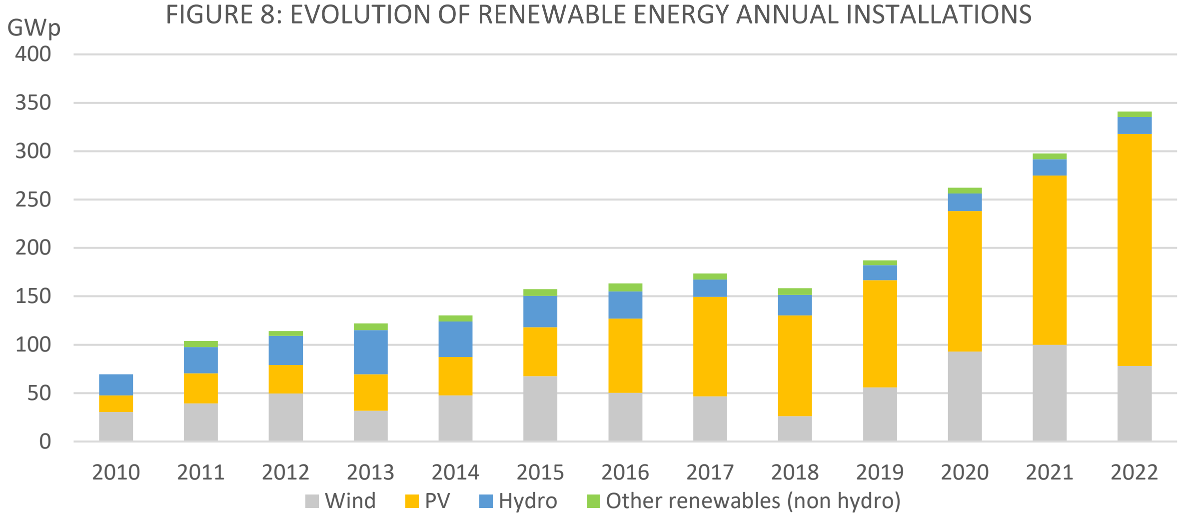
This trend is increasing globally, often without a clear understanding of the industry dynamics and the complexities of PV manufacturing, which will lead to less real projects than what some governments would like to see. Materials supply for the PV manufacturing industry is growing as a percentage of total material consumption, and precautions must be taken when analysing the impact growth in PV manufacturing could have on global supply chains and other industries.

8 PV IN THE BROADER ENERGY TRANSITION

8.1 PV and Other Renewable Energy Evolutions

PV is playing a major role the energy transition – and in 2022 represented **two thirds of all new renewable electricity technologies**, thanks to its consistent costs, technical performance and accessibility, and generally faster permitting procedures than wind or hydro. As installed volumes increases, so does workforce competency and investor confidence, allowing solar to be adopted as a safe, mature technology investment. With the hindsight of the past three years, clearly **solar is now a mainstream energy source**.

FIGURE 8: EVOLUTION OF RENEWABLE ENERGY ANNUAL INSTALLATIONS

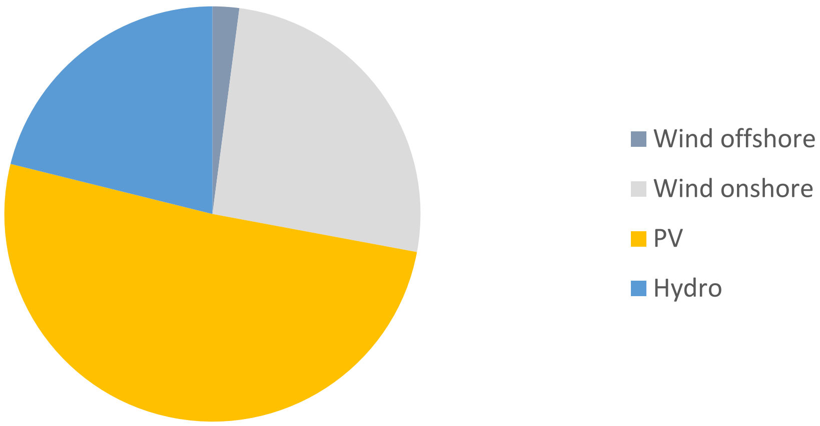


Sources: compilation of IEA PVPS, BNEF, GWEC, IRENA and estimations for 2022

In 2022, solar PV generated approximately 50% of the total renewable electricity production from new production assets despite being two thirds of new capacity. The difference between capacity and generation is due to the different capacity factors of renewable technologies.

Whereas biomass installations can virtually produce all day and all year-round, wind and PV installations' outputs strongly depend on the available resources that can vary locally.

FIGURE 9: ELECTRICITY PRODUCTION OF THE RENEWABLE ENERGY CAPACITY INSTALLED IN 2022



Sources: IEA PVPS, BNEF, GWEC and estimations for 2022

8.2 Impact of PV Development on CO_2 Emissions

Global energy related CO_2eq emissions increased to 36 800 Mt in 2022[4], just 0,9% more than 2021, much lower than expected considering the shift from gas to coal in some countries. The total emissions of the electricity and heat sector reached 14 600 Mt of CO_2eq in 2022, an all-time high.[5] PV played an important role in the reduction of the CO_2 emissions from electricity in 2022, **avoiding approximately 1 399 Mt of annual CO_2 emissions**, up 30% from 2021. This is calculated as the emissions that would have been generated from the same amount of electricity produced by the different grid mixes in all countries and taking into consideration life cycle emissions of PV systems.

This amount of avoided CO_2 emissions represents around 10% of the total electricity and heat sector emissions (+3% from 2021) and 4% of all energy emissions.

[4] IEA, Global Energy Review: CO2 Emissions in 2022, March 2023 (https://www.iea.org/reports/co2-emissions-in-2022)

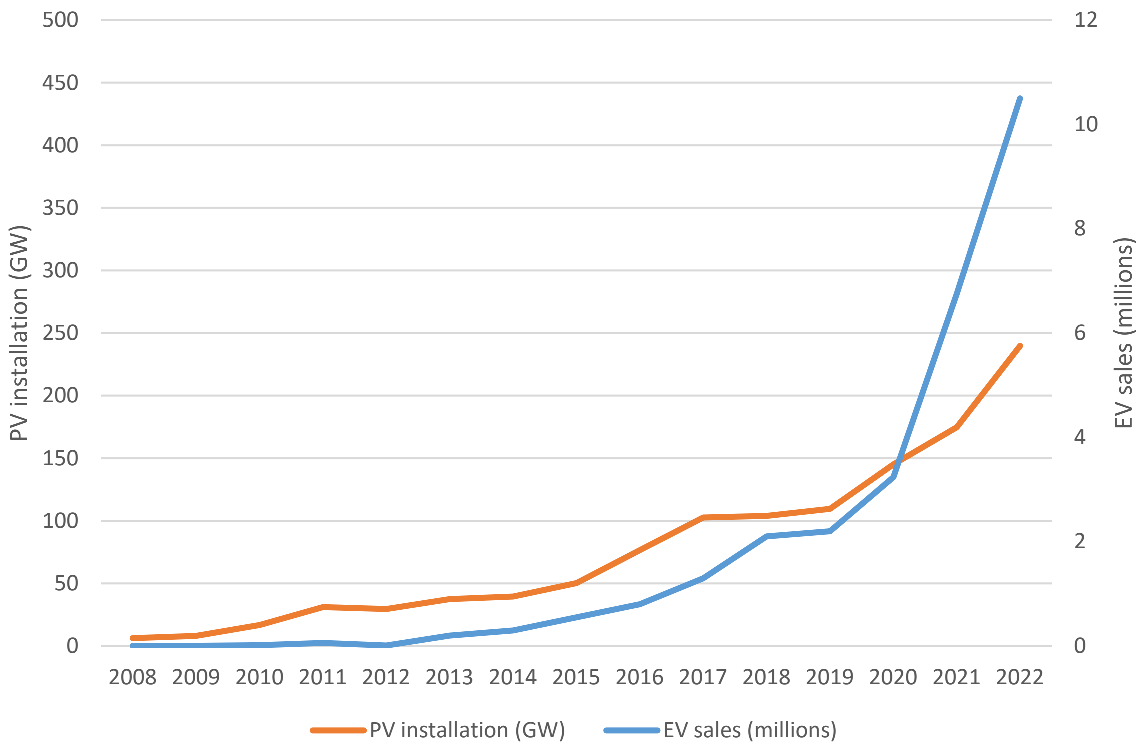
[5] IEA, Global Energy Review: CO2 Emissions in 2022, March 2023 (https://www.iea.org/reports/co2-emissions-in-2022)

8.3 PV Fostering Development of a Cleaner Energy System

PV provides direct and immediate carbon emission economies as it replaces or displaces fossil fuel generation. Anticipating large amounts of cost competitive green electricity from PV soon, an increasing number of research, pre-industrial and commercial investments are being made to leverage the future electricity production for hydrogen or other molecules such as ammonia, methanol, toluene or similar, seen by many as technologies with a potential to tackle climate change.

The electrification of transport is accelerating in many countries and whilst the link between PV development and EVs is not yet fully understood, the growth of self-consumption policies and grid congestion limiting injections are factors to be considered. Charging EVs during peak load implies rethinking power generation, grid management and smart metering, and concepts such as virtual self-consumption could rapidly provide a framework for EV's as mobile storage for excess PV generation. With **10,5 million EVs sold in 2022 (+60% on 2021)**, the growth curve of EV sales crossed that of PV this year, demonstrating an accelerated development beyond that of PV.

FIGURE 10: EVOLUTION OF EV AND PV ANNUAL GROWTH



Source : IEA PVPS & EV Volumes

Technology Collaboration Programme
by iea

ISBN 978-3-907281-43-7