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Snapshot of photovoltaics – March 2025

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Abstract. Clean energy investments increased by 10.7% per annum to USD 2,083 billion or 1.9% of global gross domestic product in 2024. Investments in solar photovoltaics even grew by 20.5% to reach USD 514 billion and resulted in the installation of new photovoltaic systems with almost 600 GWp. The global installed solar photovoltaic capacity exceeded 2.2 TWp at the end of 2024, doubling in less than three years. The number of countries installing 1 GWp per year or more has increased to 36. After the 2022 price spike for solar photovoltaic hardware and battery storage, prices in both markets continued to decrease in 2024. Levelised costs of electricity for non-tracking solar photovoltaic systems as well as levelised cost of battery storage reached new lows. The global benchmark of levelised cost for electricity for tracking PV systems decreased as well, but is still considerably higher mainly due to higher costs for labour, balance of systems and debt in the USA. The general trend towards electrification of heating, transport and industry creates additional demand for renewable electricity, including solar. The annual growth rate of the photovoltaic market is expected to be around 20% for 2025. However, a more rapid deployment of renewable energy is needed to stay on track for no more than 1.5 °C global temperature increase.

Keywords: Renewable energies / photovoltaics / energy challenge / policy options / market development

1 Introduction

2024 was a year with record-breaking temperatures which led to a series of heatwaves, droughts, storms, floods and wildfires with severe consequences for millions of people [1]. The World Meteorological Organisation confirmed that 2024 was the warmest year recorded with about 1.55 °C above the pre-industrial average [2]. This year of extreme weather conditions and temperature increase highlighted the threats to human life due to anthropogenic warming and should make clear the urgency and need to speed up the energy transition from the current fossil-based energy system to a renewable based one.

During COP 28, 123 countries signed the renewable energy pledge to triple the capacity of renewable energies by 2030 compared to 2022 [3]. However, compared with 2022 the renewable capacity has to increase 3.2 to 3.4 times globally to be in alignment with the Paris Agreement and compatible with the 1.5 °C limit. Scenarios from the International Energy Agency (IEA), net zero by 2050 scenario (NZE_{2024}), the International Renewable Energy Agency (IRENA) and Climate Analytics give a range between 11.2 TW_{AC} and 11.5 TWAC for the renewable energy capacity by 2030 [4–6].

The required electricity generation for IEA NZE_{2024} has increased again compared to the 2023 predictions by 4.1% for 2023 and 4.4% for 2050. According to the World Energy Outlook (WEO) 2024 renewable electricity generation should account for 23,337 TWh in 2030 and 70,936 TWh in 2050. Compared to the actual electricity generation by renewables of 9,029 TWh in 2023 this requires an increase by 169% until 2030 and 686% until 2050. The share of renewable electricity generation in this scenario is almost 59% in 2030 and over 88% in 2050. The main sources of renewable electricity generation in 2030 will be solar photovoltaic with 9,212 TWh (6,699 GW_p) and wind 7,114 TWh (2,731 GW_{AC}). To reach the solar photovoltaic capacity, a tripling of the existing capacity at the end of 2024 (2,243 GW_p) is required (Fig. 1). Together solar PV and wind are expected to provide 41% of the total electricity production in 2030. This development can be observed globally, even if the pace of renewable energy deployment is varying from country to country as well as the technology mix.

Looking at the WEO predictions over the last years, two key observations emerge. First, the WEO predictions were always significantly lower than the actual market development and as a consequence a continuous increase of the predicted solar photovoltaic capacities, with a growth rate well above that of all other electricity generating capacities. As a consequence, the WEO scenarios should be seen as a conservative benchmark and not a prediction of future capacity developments for PV.

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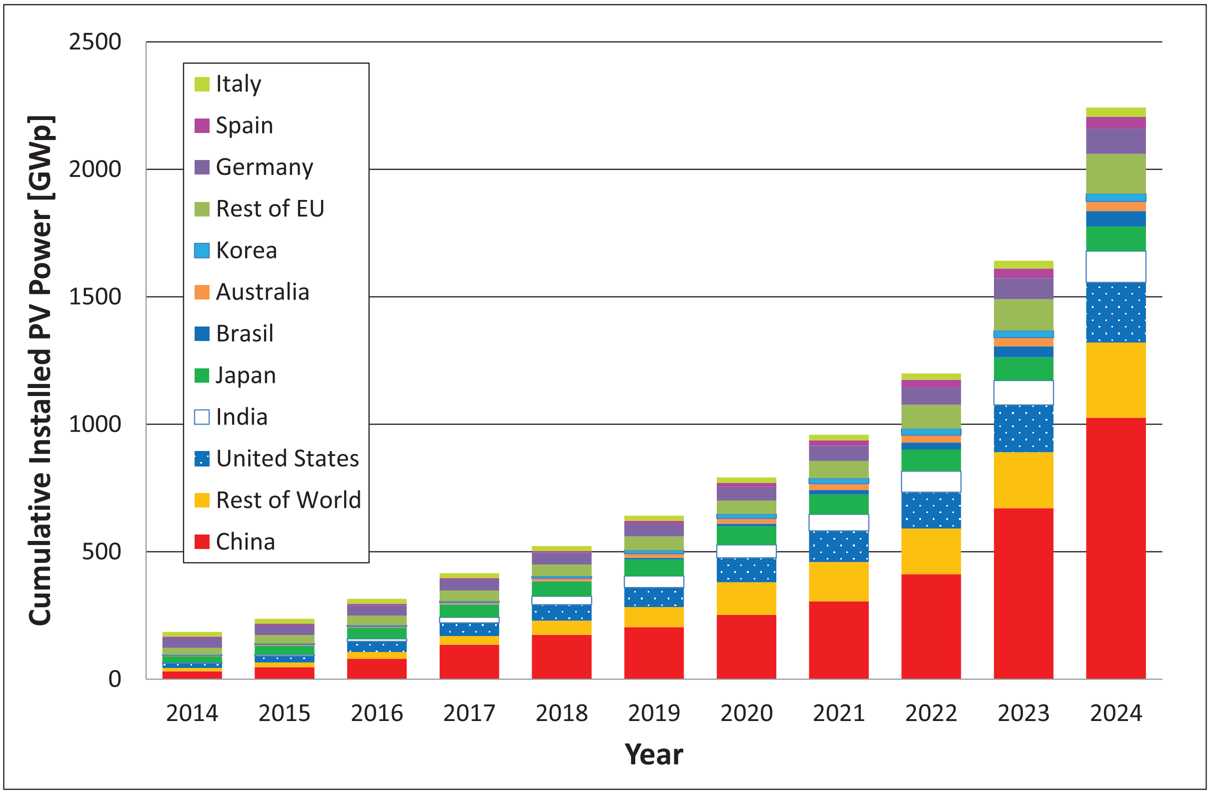

Fig. 1. Cumulative photovoltaic installations from 2014 to 2024 (data source: [7,8] and own analysis).

This development is due to the continuation of cost reduction for PV systems and the advantage of PV technology that it can be deployed in every country as well as in a modular way almost everywhere on this planet from installations with a few W_p capacity to multi-GWp solar plants.

In 2024, global investments in clean energy increased by 10.7% per annum to USD 2,083 billion or 1.9% of global gross domestic product (GDP) (GDP) [9,10]. Investments in solar power generation amounted to USD 521 billion (concentrated solar power: USD 7 billion, PV: USD 514 billion), second to electrified transport with USD 757 billion, followed by USD 452 billion for clean shipping, USD 390 billion for grids, USD 195 billion for wind, USD 54 billion for energy storage and USD 11 billion for all other renewable generation technologies.

Various studies exist which predict that between USD 100 trillion and USD 275 trillion would be needed to transition to a net-zero economy for the time span of 2021 to 2050 [11–14]. This would translate into average annual spending between USD 3.5 and 9.2 trillion.

While this may seem substantial it should be seen in comparison to the current annual direct and indirect government subsidies for fossil fuels, which amounted to USD 7 trillion or 7.1% of worldwide GDP in 2022 [15]. Environmental and health costs, which account for roughly 60% of the USD 7 trillion, as well as foregone consumption taxes are included in this calculation according the International Monetary Fund (IMF). A faster deployment of renewables could significantly reduce these health costs as the largest share is attributable to air pollution [16,17].

Despite the fact that annual renewable power investments increased from USD 372 billion in 2020 to USD 728 billion in 2024 (+96% or + USD 356 billion) annual investments in the global fossil fuel supply increased in absolute money from USD 742 billion to USD 1,116 billion (+USD 374 billion) [18]. However, the gap is closing.

But how realistic is the NZE_{2024}? Models of different research groups show much higher needs for renewables and PV to stay on a 1.5 °C trajectory [16,19–21]. Taking into account a balance between climate costs and the United Nations (UN) development goals, these scenarios have a range between 60 and 80 TW_p by 2050. The electricity demand for the electrification of heat generation, transport, with preference of direct electrification where possible, and industry is considered, the needed capacity increases even further [22,23].

Uncertainty in reported capacity numbers

Not all countries report standard nominal power capacity for solar PV systems (DC capacity expressed as Wp under standard test conditions), but instead cite the inverter or electrical grid connection capacity, which is in AC. Over the last decade "overpowering", i.e. when the DC capacity is larger than the AC capacity [24] has gradually increased and DC/AC ratios of up to 2 can be observed. This means that the nominal capacity of the PV system can be significantly higher than the reported AC capacity. Overpowering of PV systems leads to a better utilization of the grid connection capacity and can be more cost-effective than installing voltage stabilisers to maintain steady supply at the required power.

Looking at energy system scenarios, modellers are only interested in AC capacity, since the electricity grid operates with alternating current. Therefore, significant differences can exist between the actual needed nominal power of PV systems, which in turn determines the number of modules needed, and the modeled network PV capacity.

The capacity numbers of PV installations in this study are given in nominal DC power or Wp. Production volumes of PV cells and modules are reported here in W_p as well. Where national statistics report capacities in AC, a conversion factor based on industry information and project descriptions is used to give a DC value.

2 PV solar cell production

Global solar cell production[1] estimates range from 740 to 780 GW_p for 2024 and with all the new capacities added will increase further in 2025. The fact that shipment figures, sales numbers and solar products are reported inconsistently as well as the decreasing number of public companies and different accounting and reporting rules all add to uncertainty in this data.

For this study, data were collected from stock market reports of listed companies, press releases and market reports, which were then cross checked. For 2024 this led to an estimate of 758 GW_p, an increase of about 20% compared to 2023 (Fig. 2). The share of thin film solar modules is estimated to be between 2 and 3%. Numbers from previous years were updated where necessary. China exported over 50 GW_p of solar cells and 235 GW_p of solar modules.

Production capacities along the value chain of solar PV continued to expand in 2024 [8]. The biggest increase was for polysilicon, where capacity rose by over a million tonnes, mainly in China. The total polysilicon production capacity of 3,353,700 tonnes now available would be enough to manufacture 1,597 GW_p of silicon solar cells. Wafer, cell and module production capacity growth rates were more moderate with 3.5, 10.3 and 11.5% respectively. The corresponding commissioned capacities would be sufficient to manufacture 1,420 GW_p of wafers, 1,250 GW_p of solar cells and 1,390 GW_p of modules. However, a considerable fraction of these capacities consists of older production lines with non-standard wafer formats and lower efficiencies, which are likely no longer competitive. Therefore, the effective state-of-the-art production capacity is significantly lower, yet still substantially exceeds the actual market size.

Between 2014 and 2024, the volume of solar cell manufacturing increased at a compound annual growth rate (CAGR) of 31%. If this trend were to continue, the annual production would rise to 3.8 TW_p by 2030. But even with a reduction to 20%, the annual solar cell production in 2030 would be 2.25 TW_p. This would be in line with the needed production volume to support a 100% renewable energy scenario by 2050 [21,22,25].

With respect to the rapid expansion of solar photovoltaic (PV) and the capacities needed for a renewable energy supply, the question arises whether or not the availability of key materials to sustain this growth of PV.

Until now, numerous studies have been conducted which show that various alternative routes in solar cell and module design are possible and the overall availability of materials does not present a roadblock for the global multi TW growth of PV [26]. However, the economic provision of some materials can be affected by different industrial developments if other products compete for the same resource.

Silicon, the base material for more than 95% of all solar cells, is one of the most abundant materials on Earth. The absolute availability of silicon is not the problem, but the economic availability of high purity quartz (SiO_2 with 99.99% + purity) used to manufacture crucibles for Czochralski single crystal silicon ingot growth and silica sand for polysilicon production has to be secured [27]. In addition, silica sand is needed for solar glass as well as all other glass products.

Consumption of some contact materials needed, e.g. silver, indium and bismuth, is of concern for the industry. Therefore, research to reduce the amount of material per W_p as well as the identifying alternatives and improvement in manufacturing efficiency are high on the research agenda of industry and its research partners [28,29].

Research and technological progress continues to increase solar cell efficiencies as well as developing a better understanding of alternative contact materials and solar cell concepts. For some thin film technologies, production volumes could be limited [30,31]. Overall, modern module designs using circular manufacturing concepts and reduce material use—particularly for balance-of-system components is of equal importance to achieve the required growth of the PV industry [32].

3 Solar PV electricity generation and markets

After an increase in the global benchmark levelised cost of electricity (LCOE) (levelised cost of electricity) for electricity produced by large PV systems between the

[1] Solar cell production capacities mean:
– In the case of wafer silicon based solar cells, only the cells.
– In the case of thin-films, the complete integrated module.
– Only those companies which actually produce the active circuit (solar cell) are counted.
– Companies which purchase these circuits and make modules are not counted.

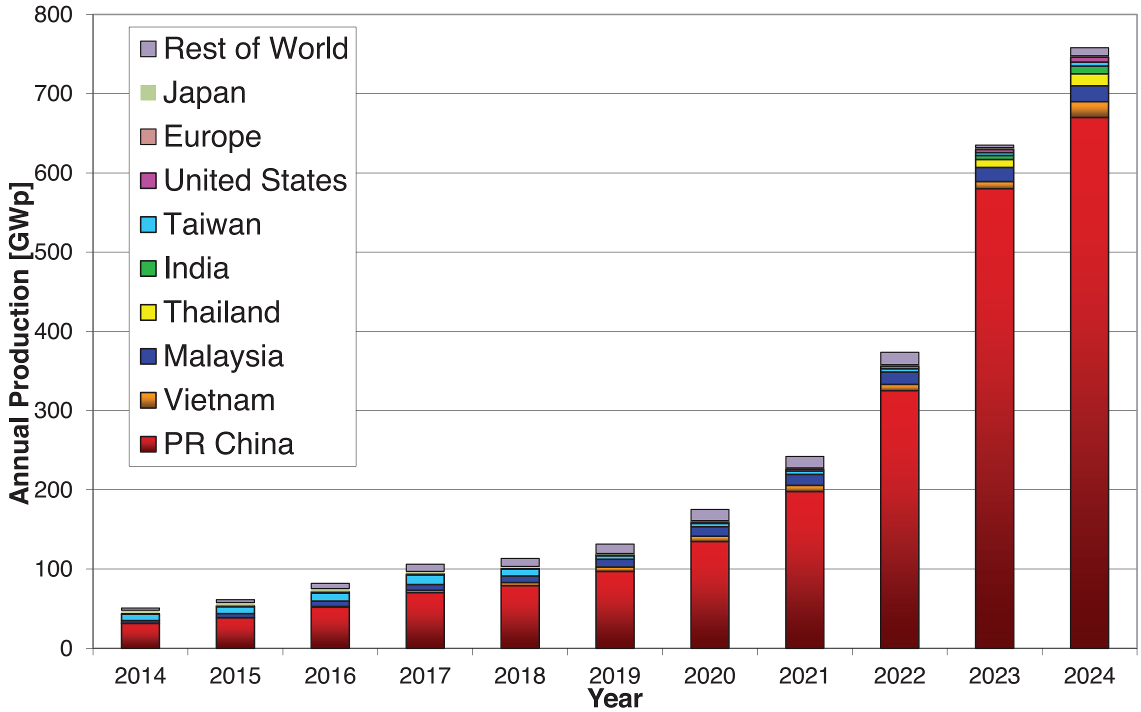

Fig. 2. World PV Cell/Thin Film Module Production from 2014 to 2024.

end of 2021 and 2022, the decrease for non-tracking systems from 2023 on led to a record low of USD_{2024} 36 per MWh at the end of 2024 [33]. The main reason for this was the lower module prices due to the oversupply along the value chain. LCOE for PV tracking systems remained at USD_{2024} 51 per MWh, influenced by the higher costs for labour, balance of systems and financing in the USA. The full range of LCOE for PV systems varied between USD 30 (China) and 98 (South Korea) per MWh.

After freight costs peaked in January 2022 (fivefold increase compared to H1 2020), they were in the same range as 2020 for most of 2023 with a tendency to fall towards the end. In the beginning of 2024, the shipping disruptions in the Red Sea increased freight costs, which peaked in July 2024 (about 3.5 times higher than at the beginning of the year) before falling towards the end of 2024 to levels about double at the beginning of 2024 [34].

An increasing challenge are the escalating tensions in light of new tariffs and trade wars globally. China has signalled potential restrictions for certain battery components, PV manufacturing equipment and certain critical raw materials.

LCOE benchmark costs only show the general trend. Due to local factors like financing and labour costs, regulatory requirements, import duties and taxes, the actual local generation costs can vary significantly. Site-specific solar irradiation and the choice of technology tracking or no-tracking PV system design, string or central inverter configuration, fixed operation and maintenance (O&M) as well as connection costs add to this. Total financing cost or Weighted average cost of capital (WACC) plays an important role on the final generation costs, regardless of the size of the PV system [35]. Another determining factor, which influences the willingness to invest and the financing costs for new renewable power generation systems is the competition in the respective electricity market and the ability to freely participate in it [36]. To summarise: stable and reliable political and regulatory conditions are important factors to attract investors.

Battery systems are increasingly recognised as a key enabler for a more rapid integration of high PV shares into existing electricity grids. Despite a growing uncertainty about the level of manufacturing capacity expansion in Europe and the USA, battery manufacturing expansion is still outpacing the demand growth [34]. These developments can lead to a wider spread in capital expenditure for battery systems. After a 20% decrease for lithium battery packs in 2024 compared to 2023, only a moderate decrease of 1 to 3% is expected in 2025. The global benchmark LCOE for a four hour battery storage project has decreased by 23% to USD_{2024} 104/kWh [37]. The lowest prices can be found in China. The latest battery energy storage system auctions in December 2024 and January and March 2025 saw bids between USD 60.5 and 82 per kWh [38].

The annual installations of storage capacity increased by 56% and reached 69.5 GW capable to store 168.8 GWh. 2023 investments in electricity storage reached USD 2024 53.9 billion (+ 36.5%). Five countries installed more than 1 GW namely China (36.1 GW), USA (13 GW), Germany (4.4 GW), Italy (1.8 GW) and Australia (1.6 GW).

For the first time since 2012, investment in small-scale PV systems (USD_{2024} 288.9 billion) was higher than investments for large scale PV plants (USD_{2024} 225.2 billion). Total PV investment rose by 23%, whereas the new installed capacity increased by 41% to 597 GW_p

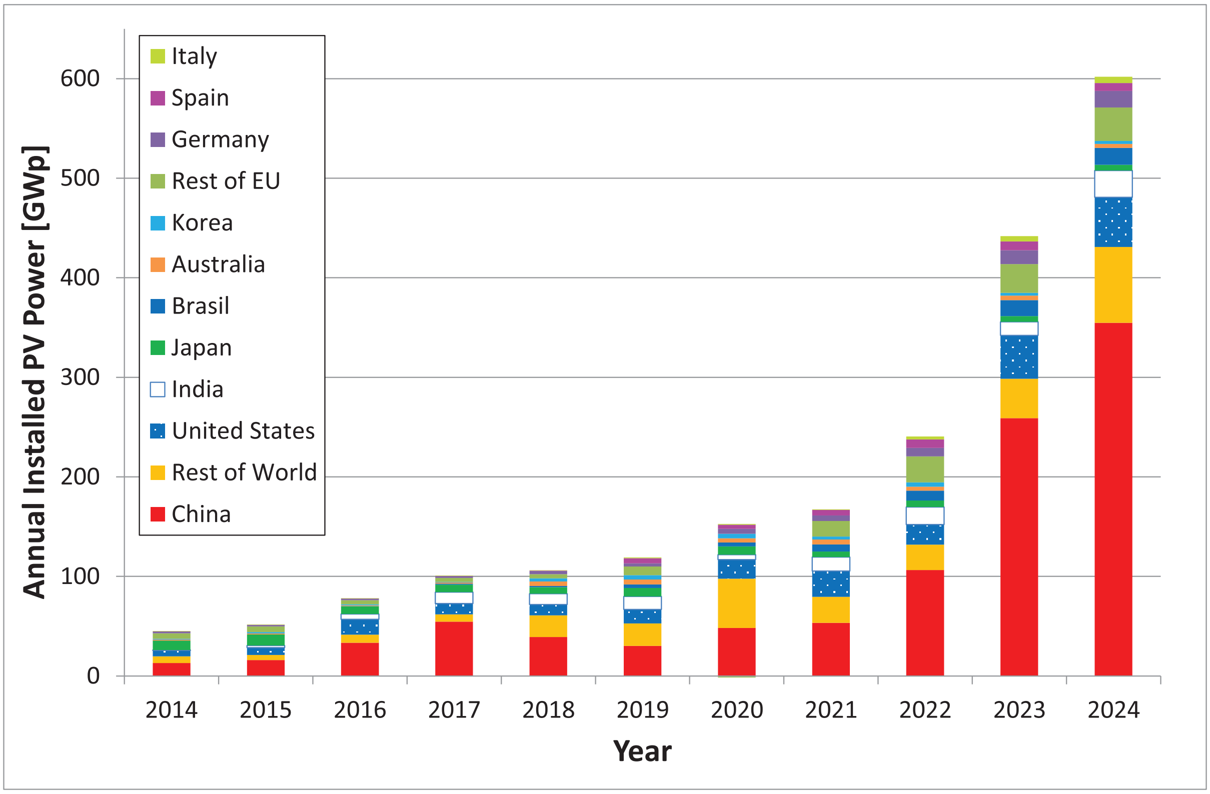

Fig. 3. Annual photovoltaic installations from 2014 to 2024 (data source: [7,8] and own analysis).

(Fig. 3) and the cumulative global installed capacity now exceeds 2.2 TWp according to preliminary data (Fig. 1). This is towards the upper side between conservative (495 GW_p) and optimistic forecasts (628 GW_p) [8,39]. Market forecasts for 2025 vary from a shrinking market to a significant increase to around 700 GW_p, which would bring the total cumulative installed PV capacity close to 3 TW_p.

At the end of 2024, China had a cumulative installed capacity of about 1.03 TW_p, representing almost 47% of the total global installed PV capacity of 2.24 TW_p. The European Union follows with about 15% or 338.5 GW_p and the USA with 235.7 GW_p (10.5%) (Fig. 1).

These absolute capacity numbers have to be put into relation to the population density and available area to install PV systems. In 2024, the number of countries with more than 500 Wp per capita has increased from 21 in 2023 to 31. Between 2022 and 2024 the global average has increased from 148 W_p per capita to 272 W_p per capita in 2024 (Fig. 4). To reach the IEA NZE2024 targets, this figure must rise to 652 Wp per capita by 2030 and 1,755 Wp by 2050. For more ambitious scenarios aiming for a fully renewable energy supply, more than four times this per capita capacity would be required by 2050.

Africa – Despite the vast solar potential in Africa shown in the Solar Atlas of the World Bank..., the utilisation of solar PV is still in its infancy [39]. The African Development Bank estimates a PV potential of 11 TW_{AC}, which looks like a lower benchmark, given the fact that the area required would just be 0.5% of the total African land area [40]. The area required for PV systems is slightly less than the 0.6% of total land area of the current urban centres and only one third of the 1.5% needed for urban areas in 2050 [41]. The expected increase in land area for urban areas also is a huge opportunity for rooftop PV in Africa and decentralised electrification.

In 2024, the PV market in Africa grew by over 30% to reach 31.5 GWp. The African Solar Industry Association reports lower numbers in its Africa Solar Outlook 2025 with a disclaimer that these are an underestimate due to various reasons [42]. On a per capita base Africa is well below the world average (272 W_p) with 24 W_p and no country has yet exceeded the 100 W_p per capita threshold. The number of African nations which have more than 1 GW_p solar PV installed has increased from five to six, namely Egypt, Kenya, Morocco, Nigeria, Tunisia and South Africa.

Eight countries have more than 500 MW_p and another 15 are now home to more than 100 MW_p of PV capacity. Hydropower is still the largest source of renewable electricity generation (approx. 160 TWh) and supplies about 17% of the demand. However, changing patterns in rainfall and temperatures caused by climate change could not only hamper future hydropower expansion, but reduce the power generation of existing plants as well [43]. The currently installed PV capacity in Africa can generate roughly 50 TWh, but the continent's vast solar resources are still underutilised. Combining existing hydropower plants with floating PV on their reservoirs could help to better utilise the existing hydro resources and enhance the

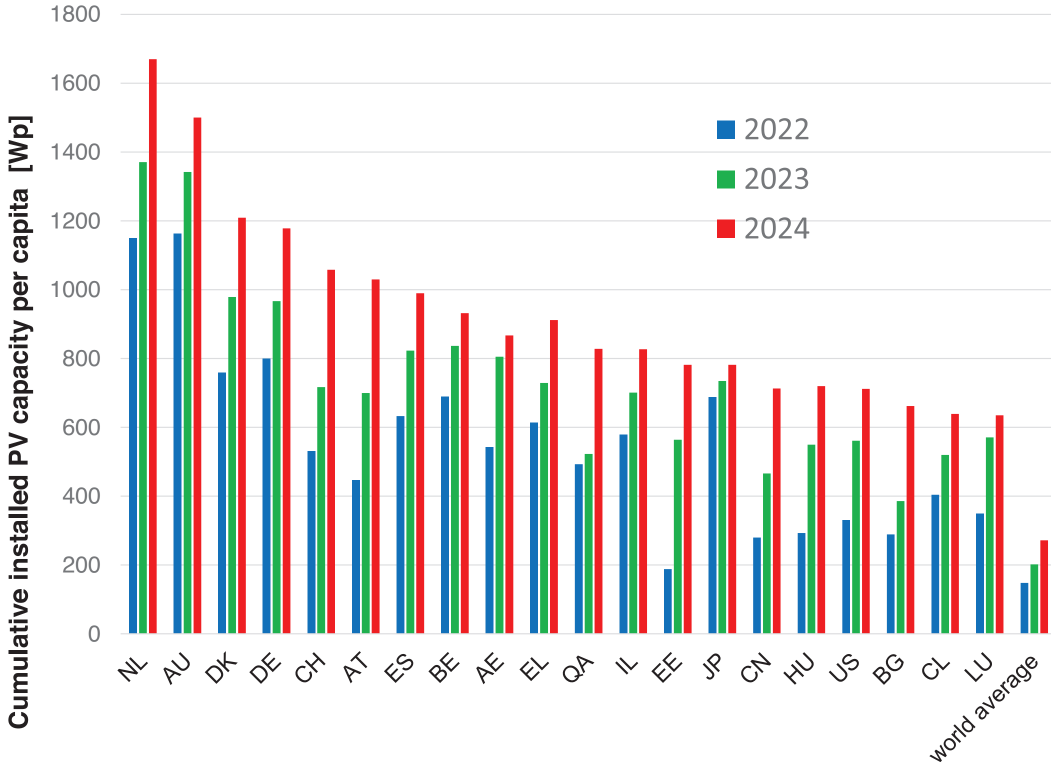

Fig. 4. 20 Countries with the highest cumulative photovoltaic capacity per capita in 2024 and the world average value. For comparison, earlier values are given as well (data source: [7,8] and own analysis).

economic performance of the plants. If just 1% of the reservoirs' area would be covered with floating PV, it would increase the electricity power output of these plants by 50% [44].

One of the successful tools to finance large scale solar PV projects in Africa and emerging economies is the World Bank's Scaling Solar programme [45]. Seven African nations, Côte d'Ivoire, Ethiopia, Madagascar, Niger, Senegal, Togo and Zambia have signed financing agreements and plants in Madagascar, Senegal and Zambia have already been realised.

The AfDB launched the "Desert to Power" initiative in 2018. The aim of the programme is to deploy 10 GW solar power for the 250 million people in 11 countries (Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Nigeria, Senegal and Sudan) across the Sahel zone by 2030. Five investment projects with an investment close to USD 415 million in Burkina Faso, Chad and Sudan with a combined capacity of 102 MW_{AC} were included in the Desert to Power portfolio in February 2022 [46]. In December 2022, the African Development Bank approved two more Desert to Power investment projects, and the Sahel G5 Desert to Power Financing Facility with an investment volume of approximately USD 715 million and an additional PV capacity of 548.5 MW_{AC}. Since then six PV plants with a total capacity of 184.6 GWAC became operational (Burkina Faso 80.6 GW_{AC}, Mali 40 GW_{AC}, Mauretania 34 GW_{AC}, Nigeria 30 GW_{AC}) [47]. In December 2023 the AfDB approved the financing of the Mauretania – Mali interconnection project to build a 1373 km long 224 kV power line including a 600 MW_{AC} transfer capacity between the two countries and a 50 MW_{AC} solar PV plant in Mauretania [48]. The project should be operational by 2031.

Americas: In 2024 the North and South American market grew by 25% to over 74 GWp, mainly driven by the strong performance in the USA (+22%). The strong performance in the USA was driven by the Inflation Reduction Act (IRA), which was signed in the fall of 2022 [49]. As in the last years the largest markets were the USA (49.99 GW_p), Brasil (16.9 GW_p) and Chile (2.1 GW_p).

The total installed PV capacity in the Americas increased to 341 GWp or 335 Wp per capita, which is 23% more than the world average. The USA still accounts for more than 69% of the total PV capacity in the Americas, which is only a slight reduction from the 70% level reached in 2022. Due to the government change in the USA and the uncertainties regarding the IRA, market expectations for 2025 are for a declining market in the USA by up to 30% and a moderate growth in the other countries. It is expected that more than 50 GW_p can be added in 2025.

Asia and Pacific Region: In 2022, China changed its national reporting system from nominal capacity to AC capacity. Now the new installed nominal capacity has to take into account the DC to AC overcapacity and the ratio of residential to commercial/utility scale installations. For 2024 the National Energy Administration of China reported 277.2 GW_{AC} of new installed PV capacity [50]. With the assumption that about 20% of this capacity was decentralised (DC/AC ~ 1) and the rest large scale (DC/AC ~ 1.35) this translates to approximately 354 GWp.

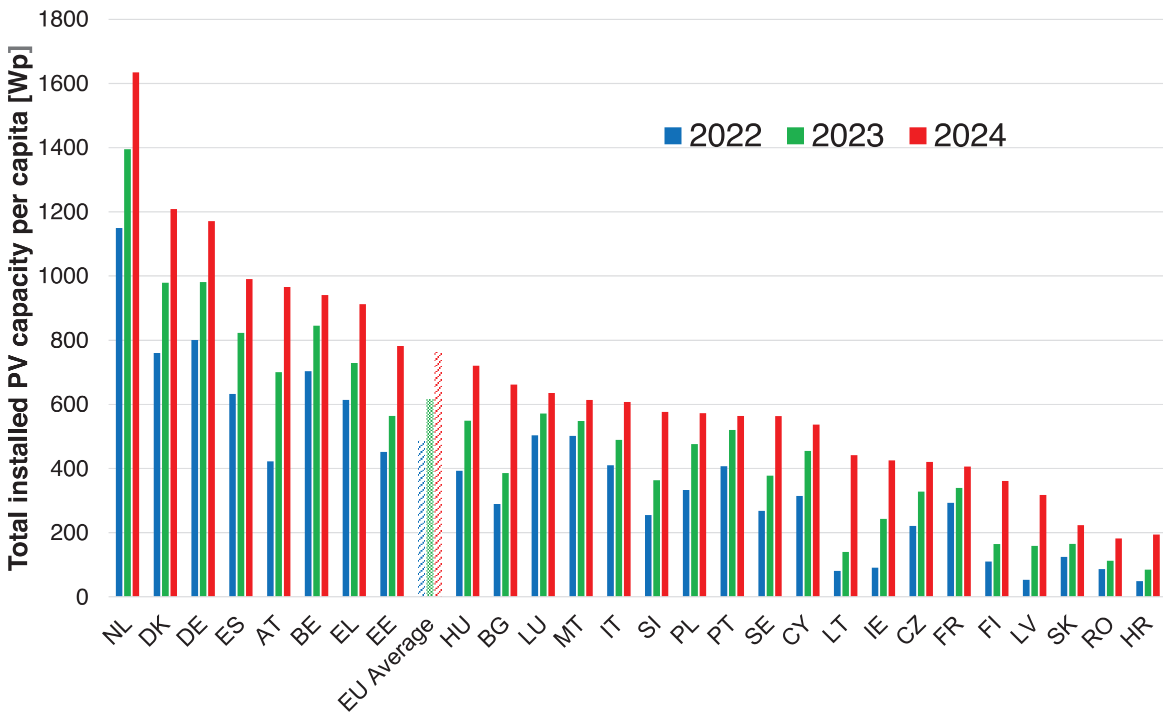

Fig. 5. PV capacity per capita in the EU for 2022 to 2024 (data source: [7,8] and own analysis).

Mercom reported that India added 25.2 GW_{AC} of solar PV capacity of which 87% were large scale installations in 2024 [51]. The share of the residential sector was 3.2 GW_p. With the above DC/AC ratios India had installed 32.9 GW_p in 2024, the third largest capacity after China and the USA.

A big surprise is Pakistan. According to a report by the World Economic Forum in November 2024, Pakistan will have imported more than 22 GW_p of solar modules from China in 2024 [52]. This comes after solar modules for about USD 1 billion were already imported in 2023. Over the course of the year 2023 module prices dropped from about USD 0.24/W_p to USD 0.14/W_p. The imported module capacity in 2023 could therefore have been between 5 and 5.5 GWp. However, the new grid connected capacity was much lower. Then where did all the capacity go?

To understand this, it is interesting to look at the electricity consumption on the national grid in 2023. The drop of about 16 TWh or 10.5% indicates that a growing number of people and small enterprises are either going off-grid or are generating behind the meter with a combination of already existing diesel gen-sets, batteries and solar PV systems [53]. Preliminary data show that this trend continued in 2024.

Bangladesh, Indonesia, Malaysia, Oman, Qatar, Saudi Arabia and Uzbekistan also saw significant market growth. Overall the Asian-Pacific PV market grew by 46% to 436 GWp. Total installed PV capacity at the end of 2024 was a little over 1.42 TW_p or 312 Wp per capita. Growth of 25 to 30% in 2025 is considered possible, which would increase the annual market to the range of 560 GW_p.

European Union: The revised Renewable Energy Directive, with an overall renewable energy binding target of at least 42.5% at EU level by 2030–but aiming for 45%, went into force in November 2023 [54]. As a result, the 2019 National Energy and Climate Plans (NECPs) required an update, which the member states had to submit by the end of June 2024. By the end of November 2024 all 27 Member States had submitted drafts, but only 14 handed in their final NECPs.

An analysis of the current NECPs reveals that the political ambition of the Member States falls short of the targets set by the 2022 Solar Energy Strategy [55]. Specifically, the total of the individual NECP targets is still below 700 GW_p, despite current market trends suggesting that reaching 1 TW_p is feasible.

After two years of growth rates above 40%, the growth in 2024 was 13%, corresponding to added PV systems with a capacity of 64.6 GW_p and a total installed capacity of 338.5 GWp. PV was 83.5% of the total capacity installed in Europe. For 2025 a similar growth in the range of 10 to 15% is expected. Even with this lower growth rate an annual market of more than 100 GW_p in 2030 is possible [56], and EU Solar Energy Strategy's target of achieving a nominal capacity of over 720 GWp (600GWAC) by 2030 will be exceeded [57].

15 countries of the European Union have installed more than 1 GW_p of new PV capacity[2] in 2024, namely Germany (16.75 GW_p), (Spain (7.85 GW_p), Italy (6.25 GW_p), Netherlands (4.65 GW_p), France (4.35 GW_p), Poland (3.65 GW_p), Austria (2.85 GW_p), Romania (2.65 GW_p), Greece (1.9 GW_p), Portugal, Sweden (1.65 GWp) each, Bulgaria (1.4 GW_p), Denmark, Hungary (1.35 GW_p) each and Czech Republic (1.05 GW_p).

[2] The capacity numbers are +/− 0.1 GWp.

For a transition to a sustainable 100% renewable energy supply, progressive net zero energy transition scenarios predict that solar photovoltaic power generation capacity could increase up to 8.3 TW_p in Europe (EU + Albania, Kosovo, Icland, North Macedonia, Norway, Moldova, Serbia, Turkey, Ukraine, and United Kingdom) [21,25]. According to the United Nations (UN), the population in Europe will reach about 675 million by 2050 [58]. This would require a PV capacity per capita of 12.3 kWp by 2050. For the European Union, which at the end of 2024 had an average of 760 Wp per capita, this would necessitate a 16-fold increase in capacity between 2024 and 2050 (Fig. 5). So far eight countries are above the EU average and four have already more than 1 kW_p per capita installed.

4 Conclusions

It took 68 years (1954–2022) to install the first TW_p of PV. The second TW_p was installed in less than 3 years (2Q 2022–4Q 2024) and the third TW_p of PV will be reached either at the end of 2025 or the 1Q 2026. The question now is: when will the annual PV market exceed 1 TW_p?

The analysis of 100% renewable energy scenarios show that PV and wind power are the two most significant building blocks for a transformation to a sustainable and cost-effective renewable energy based energy system [59].

Independent of existing differences about the technology pathways, political ambitions and real market developments, all scenarios foresee a significant growth of PV power in the coming decades. The bandwidth of scenario expectations ranges from a 12-fold increase in the NZE WEO 2024 scenario (21.6 $TW_{AC} \approx 26$ TW_p) to a 36 fold increase (80 TW_p) in more ambitious scenarios compared to the existing capacity at the end of 2024 [5,21].

Approximately 0.3% to 1% of the world's land area would be needed, and only a fraction of the 3%, which is now home to about 70% of the world population [60]. However, huge unused potentials exist in these urban areas for PV on rooftops, facades and traffic infrastructure like parking facilities, roads or railways. Additional potential exists on already-used land areas such as brownfield or novel applications such as agri-PV, dams and dikes as well as floating PV systems [44,61–67].

The uptake of solar photovoltaic electricity generation is accelerating for economic reasons, as it becomes the lowest cost power source in a steadily increasing number of countries. Together with decreasing battery costs, battery and solar PV systems have become the preferred choice for many people in countries with unstable electricity supply as an easy way to a reliable supply.

Despite these developments, photovoltaic and battery technology still have a considerable cost reduction potential along the whole value chain. The electrification trend of our energy use, which includes heating and transport as well as the production of hydrogen and related products from renewable energy sources, together with the overall need to provide CO_2 free energy, are the drivers behind the continuous growth of PV installations. The technical characteristics of solar PV, its modularity, a very low CO_2 footprint (based on a full life cycle analysis), make it a perfect solution for dense urban environments and a crucial pillar for realizing a net-zero carbon energy supply by 2050 [64].

A key challenge still is the existence of a truly enabling and stable policy framework. One of the main problems is that there is a lot of positive encouragement, but the decisive policy actions are lacking or being implemented too slowly. In order to make the energy transition work, fundamental system changes are needed.

A key enabler for the acceleration of renewable energy use is that the costs for storage can be lowered faster and more of it is added where needed. This will not happen by itself. There are still challenges ranging from perception, legal and regulatory conditions as well as technical limitations of the existing transmission and distribution systems to be overcome. So far however, the necessary adaptation and transformation of the energy networks, changes of electricity market business models nor the political will to accelerate the use of renewable energy sources such as PV is not in line with the urgency to decarbonise our energy supply by 2050.

We as members of civil societies have to embrace the fact that more individual and societal effort is needed to realise the energy transition and to stay on a pathway for a maximum of 1.5 °C global temperature increase. We cannot wait and depend on politicians and energy interest groups, but need to act as responsible citizens to preserve this planet for our children. Already in 1882, during a visit to Canada, Oscar Wilde said in a speech given in Ottawa "The things of nature do not really belong to us, we should leave them to our children as we have received them" [68].

Disclaimer

The views expressed are based on the information currently available to the author and may not, under any circumstances, be regarded as stating an official or policy position of the European Commission.

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Conflicts of interest

The author declares to have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

Data are available on request.

Author contribution statement

A. J.-W. is the sole author.

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