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The European Solar Communication—Will It Pave the Road to Achieve 1 TW of Photovoltaic System Capacity in the European Union by 2030?

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Abstract: The urgency of a clean energy transition in the European Union is now not only driven by concerns about climate change, but also by using local renewable energy resources to reduce the dependency on foreign energy imports. Solar photovoltaic electricity generation is acknowledged as one of the pillars of this transition and various policy measures were implemented over the last two years to not only accelerate the deployment of solar photovoltaic electricity generation systems, but also to rebuild a competitive solar value chain in Europe to hedge against solar photovoltaic component supply chain disruptions. However, the current political ambitions still do not pay sufficient attention to the importance of solar photovoltaics as a major contributor to the necessary future renewable energy supply. According to the market trend between 2017 and 2022, the currently average EU installed capacity of 474.55 W_p/capita will not reach the necessary 2246 W_p/capita or 1 TW_p target by 2030. At the moment, only seven member states have an installed capacity per capita higher than the average EU value.

Keywords: solar photovoltaics; European solar communication; EU solar energy strategy; EU PV market; 1 TW_p PV capacity; European Green Deal

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1. Introduction

The urgency of the clean energy transition was highlighted with the publication of the 6th Intergovernmental Panel on Climate Change (IPCC) assessment report in April 2022 [1] and the geopolitical developments in the first half of 2022. As a reaction, the European Commission published the REPowerEU communication and the European Union (EU) solar energy strategy communication in March and May 2022, respectively [2,3]. As an intermediate step towards climate neutrality (European Green Deal, EGD) by 2050, in December 2020, the European leaders endorsed the Commission's proposed target to reduce net emissions by at least 55% by 2030. To achieve this, the European Commission proposed the "Fit for 55" package of EU legislative measures, which, amongst other actions, sets a target of 40% participation of renewable energies in the EU's energy mix.

Solar energy and photovoltaics (PV) in particular were identified as one of the cornerstones of a rapid and more ambitious deployment of renewable energy technologies in order to meet the climate-neutrality objective in 2050 and a significant reduction in the EU's dependence on imported fossil fuels [4,5]. Although, the currently proposed measures include a strong component to diversify the source of fossil fuel imports away from Russia, a path on how to phase out their use entirely is not yet so clear. The full implementation of the "Fit for 55" proposals would lower the Union's gas consumption by 30%, still requiring over 200 bcm, by 2030.

In December 2022, the European Council reached a provisional deal with the European Parliament on the revision of the European Union Emissions Trading System (EU ETS) [6]. This deal includes an increase in the overall ambition of emissions reductions by 2030 in the sectors covered by the EU ETS to 62%, compared to the 61% target proposed by the European Commission.

In the "Green" scenario of the New Energy Outlook (NEO) 2021, Bloomberg New Energy Finance (BNEF) forecasted a worldwide doubling by 2030 and a 460% increase in the electricity generation by 2050 compared to 2019 [7]. A total of 98% of the roughly 120,000 TWh should then be supplied by renewable energy sources. The dominant drivers of the increase in this scenario are the electrification of transport, industrial processes, and buildings, as well as a major use of green hydrogen.

At the end of 2021, the world-wide installed capacity of PV electricity generation systems was 965 GW_p and the EU accounted for roughly 18% or 171 GW_p [8]. The preliminary range of installation numbers for 2022 shows that worldwide installation of PV systems has increased from about 180 GW_p in 2021 to something between 230 and 260 GW_p in 2022. The EU installed at least 41 GW_p in 2022, less than half of China with 87.4 GW_p [9].

For the EGD, an impact assessment was performed, which forecasts only a slight increase in the electricity generation in the EU (EU27) to reach between 3100 and 3200 TWh in 2030 [10]. According to the used model, solar PV electricity should contribute 14% compared to 5% in 2020. It is important to note that the impact assessment reports the solar capacity in alternating current (ac) to be comparable to conventional power generation plants based on rotating machines. In the impact assessment, a PV capacity 360 to 370 GW_{ac} capacity was calculated to reach the 2030 target.

The IEA has determined that the REPowerEU and EU solar energy strategy target of 720 GW_p by 2030 can be accomplished with minimum average additions of approximately 60 GW_p per year. In its main scenario, with 50 GW_p average annual additions per year, the installed capacity in 2030 will be 70 GW_p less than the target set. Their accelerated scenario is not optimistic, reporting only 780 GW_p by 2030 (with 65 GW_p average annual additions per year) [11]. According to SolarPower Europe's EU Market Outlook for Solar Power 2022–2026, a medium scenario for 2030 would include an installed EU PV capacity of 920 GW_p and an ambitious scenario over 1 TW_p [12].

A requirement of the Renewable Energy Directive II (RED II) was that the European member states submitted national energy and climate plans (NECPs) in 2019, outlining the plans of each member state and how they planned to reach the old 2030 target [13].

In its first part, the current paper presents the current PV status in the EU, analyses of the perspectives of EU member states' PV markets and lists the PV relevant initiatives for further PV expansion and deployment. The installed capacities per capita are calculated at EU member state level and comparisons to the NECP targets, as well as to the EU installed capacity of 1 TW by 2030, are made. In its second part, it evaluates the effectiveness of ambitions for PV for the EU's clean energy transition with respect to the EU solar energy strategy (part of the REPowerEU package) and pays particular attention to the necessity of the supply chain security expansion of EU manufacturing in the view of the newly adopted policies in the United States and India, a significant parameter identified also in other work [14]. Published work addressed and analysed previous policies [15–19], but we identified a gap in analysis as far as the latest developments are concerned.

The novelty of the present work lies in the consideration of the current policy environment that characterises the PV sector in such a crucial time as this, when there is need to significantly increase PV installation capacity in the EU while strengthening the resilience and competitiveness of net-zero technology manufacturing and, in particular, that of PV, the cornerstone of technologies helping towards EU climate neutrality.

2. Current Situation

As shown in Figure 1, the capacity of grid-connected solar PV systems in the EU has increased from 34.2 GW_p to about 211 GW_p between 2010 and the end of 2022 [9]. The three leading countries in terms of PV capacity, Germany, Italy, and Spain, account for 56% of the total EU capacity. In 2022, 12 EU countries installed more than 1 GW_p of new

PV capacity (Austria, Belgium, Denmark, France, Germany, Greece, Netherlands, Poland, Portugal, Spain, and Sweden).

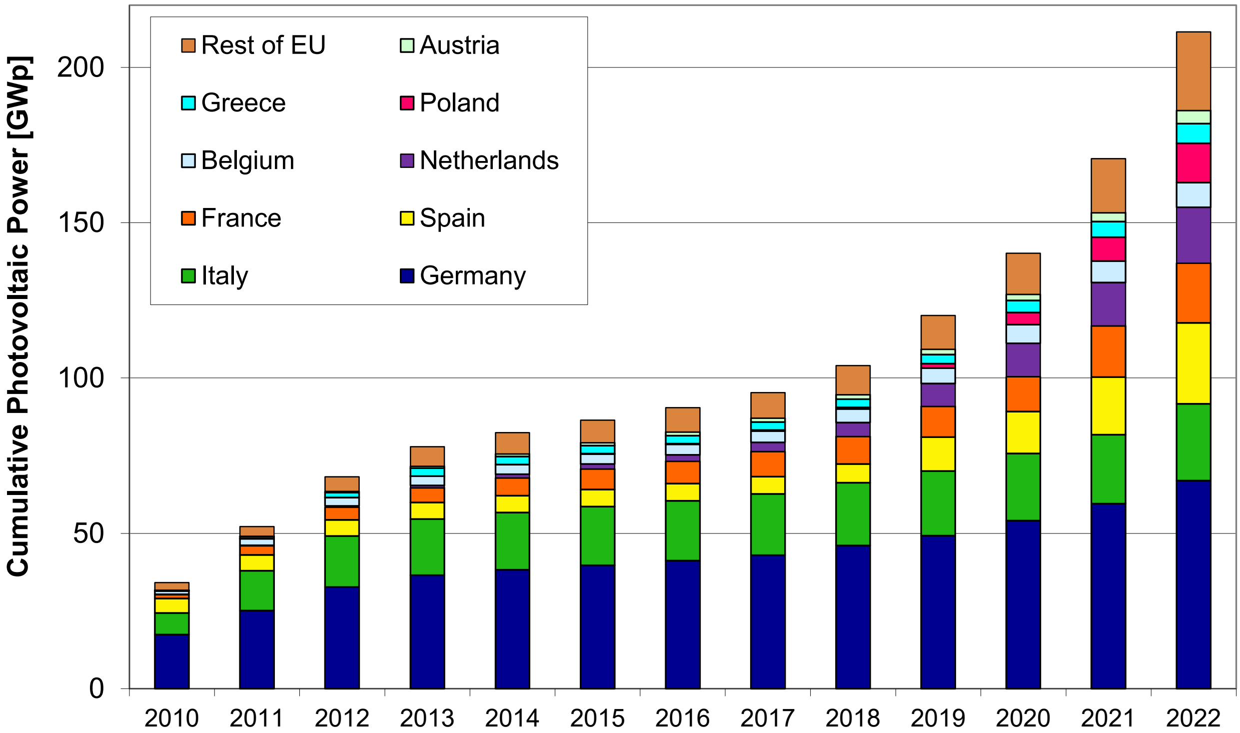

Figure 1. Grid-connected PV capacity in the EU [9].

The EU solar energy strategy calls for an additional PV capacity of 450 GW_p between 2021 and 2030, which would mean a roughly four-fold increase in the nominal capacity to over 720 GW_p by 2030. Compared to 2022, this would require an annual market volume increase to over 100 GW_p annually by 2030, which is achievable if the current market trend can be maintained.

As shown in Table 1, the pledged PV capacity of 260 GW_p in the low case and 340 GW_p in the high case of the NECPs are by far insufficient to reach the new targets of the EGD. If the current market trend (2017–2022) is maintained, the 2030 PV capacity in 18 member states will be higher than the 2030 targets, thus, demonstrating the low ambition level.

Table 1. Installed solar photovoltaic capacities at the end of 2022, high case NEPC targets for 2030, new policy trends and market trend (2017–2022) (in the case of a compound annual growth rate (CAGR) of 30% and more between 2017 and 2022 (countries indicated with *), the growth rate is capped from 2023 to 25%).

Country	Capacity 2022 [GW_p]	Capacity 2030 (NECP High) [GW_p]	Capacity 2030 (New Policy Trends) [GW_p]	Capacity 2030 Current Market Trend (2017–22) [GW_p]	Capacity 2030 Needed to Have 2246 W_p per Capita or 1 TW_p Total [GW_p]
Austria	4.20	12.00	13.00	28.39	20.21
Belgium	8.00	11.00	22.00	26.54	26.03
Bulgaria	2.01	2.90	3.20	5.33	15.61
Croatia	0.20	0.77	0.77	1.61	9.23
Cyprus	0.50	0.80	0.80	2.91	2.72
Czechia	2.36	3.98	3.98	2.68	24.05
Denmark *	4.40	7.84	7.84	26.35	13.00
Estonia	0.25	0.42	0.42	16.84	2.99
Finland	0.61	1.20	1.20	12.33	12.44
France	19.15	25.00	47.30	55.83	146.60

Table 1. *Cont.*

Country	Capacity 2022 [GW_p]	Capacity 2030 (NECP High) [GW_p]	Capacity 2030 (New Policy Trends) [GW_p]	Capacity 2030 Current Market Trend (2017–22) [GW_p]	Capacity 2030 Needed to Have 2246 W_p per Capita or 1 TW_p Total [GW_p]
Germany	67.00	70.51	215.00	139.79	188.17
Greece	6.40	8.00	13.00	25.18	23.40
Hungary *	3.80	6.00	6.50	21.86	21.70
Ireland*	0.45	1.50	1.50	2.65	11.10
Italy	24.80	51.12	72.00	42.69	135.79
Latvia	0.01	0.50	0.50	0.44	4.24
Lithuania	0.22	1.53	1.53	1.19	6.11
Luxembourg	0.22	1.11	1.11	0.62	1.41
Malta	0.33	0.26	0.26	1.84	0.99
Netherlands *	18.00	36.00	36.00	107.40	38.47
Poland *	12.59	7.30	30.00	74.02	85.01
Portugal *	4.15	9.00	10.00	24.76	22.91
Romania	1.80	5.89	5.89	2.93	43.21
Slovakia	0.63	1.20	1.20	0.82	12.26
Slovenia	0.40	1.65	1.65	0.73	4.67
Spain *	26.10	44.00	92.00	156.27	105.00
Sweden	2.71	2.50	3.50	16.69	22.68
Total	211.29	313.98	592.15	798.69	1000

Figure 2 shows the installed PV capacity per capita in the EU. The EU average at the end of 2022 was 474.55 W_p. In order to achieve a cumulative PV capacity of 1 TW_p, this number has to be increased to 2246 W_p per capita.

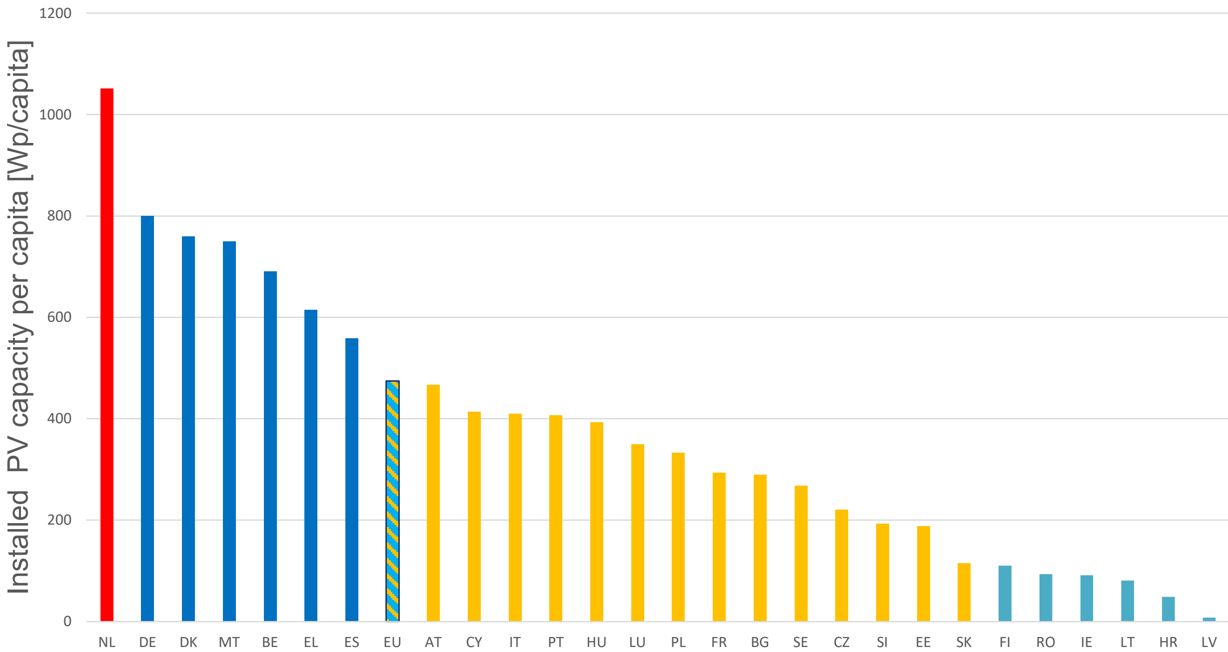

Figure 2. Grid-connected PV capacity/capita in the EU [9]. (colour code: red—No 1; dark blue—above EU average; hatched—EU average; yellow and light blue—below EU average; light blue—below 100 W_p/capita).

In terms of installed capacity per capita, the Netherlands are leading in the EU with 1051 W_p, second only to Australia with 1168 W_p. Six EU countries have more than the European Union average, namely, Germany (800 W_p), Denmark (760 W_p), Malta (750 W_p), Belgium (690 W_p), Greece (614 W_p), and Spain (558 W_p). So far, only five countries have not yet installed at least 100 W_p per capita. Based on previous analysis for 2019, Germany was surpassed by the Netherlands, and Denmark entered the top five EU countries, while Italy lost its fourth place position and has now less than the EU average [20]. Furthermore, according to the above-mentioned analysis and our calculations, the EU average installed PV capacity per capita has increased by only 220 W_p between 2019 and 2022.

With such a market increase, the issue of the security of supply becomes more important. In order to hedge against supply chain disruptions, which occurred in the last two years during the COVID pandemic, the EU has to rebuild its local manufacturing capabilities along the full value chain [21].

Therefore, the EU solar energy strategy communication includes a number of building blocks to achieve this in a timely manner. The following initiatives aim to deliver the expected outcome:

- European solar rooftops initiative;
- Utility scale deployment including multi use of land, such as agri-photovoltaics (agri-PV), floating-photovoltaics (FPV), PV on noise barriers, etc.;
- Solar value for buildings, districts, and cities;
- Preparing the energy network for the efficient distribution of solar energy;
- Establishment of a resilient supply chain;
- Supporting investments regarding EU PV manufacturing (de-risking, funding).

One of the pillars of the EU solar energy strategy to accelerate the installations of solar photovoltaic systems is the European rooftops initiative. Rooftop systems have the advantage of using existing structures and avoid conflicts with other public goods such as the environment. Rooftops in the EU have the technical potential to generate at least 680 TWh of electricity and install 560 GW_p of PV systems [22]. In addition, an additional 50 GW_p could be added until 2030, if on all of the 1.5 million new buildings constructed in the EU each year, a 4 kW_p PV system would be added. In addition, existing building facades could be utilised. The potential to install PV on building facades is estimated between 400 and 800 GW_p [23].

This initiative is expected to generate 19 TWh of electricity after the first year of its implementation (this is 36% higher than the Fit for 55 projections).

For the utility scale solar photovoltaics deployment, a number of options exist, utilising widely untapped areas [24]. This includes using already built-up areas without occupying additional land. In addition, solar PV electricity production could be concentrated in areas where a significant demand increase is already happening with the significant increase in electric vehicles (EVs), e.g., next to or on the existing road infrastructure. The electricity produced can be used locally to fuel electricity-based road transport.

The 31 regions in the EU with coal mining activities, which have to be phased out over the next decade, offer another no-regret option for the installation of PV systems. Together these regions have a technical potential of about 520 GW_p for PV power on the mining areas and surrounding suitable land [25].

Agri-PV is another application, which has the potential to be a win–win for renewables, agriculture, and other sustainability dimensions. According to SolarPower Europe, the potential of agri-PV in Europe amounts to about 900 GW_p if installed on just 1% of the arable land [26,27].

A recent study on estimating the potential electricity output of installing FPV on existing hydropower reservoirs in EU suggests that by using less than 15% of the total area of the selected EU reservoirs area, FPV can produce an amount of electricity equivalent to 50% of the current hydropower generation [28]. Installing FPV on only 2.3% of total EU (27) hydropower reservoir areas studied could produce 42.3 TWh annually, doubling the installed capacity of the hydropower reservoirs. Most of the analysed countries can add over 50% of the existing hydropower generation capacity in the same reservoirs by installing FPVs in less than 15% of the total available reservoir area.

3. Outlook

The cumulative PV power capacity additions under the EU solar energy strategy requires a compound annual growth rate (CAGR) of 17.5%, which is slightly lower than current market trend of 18%. To reach 1 TW by 2030, CAGR would have to increase to 22%, which is feasible according to industry analysts.

The actual PV capacity of one European Union member state (Malta) already exceeded the political targets, whereas in seven member states (Czech Republic, Germany, Italy, Latvia, Romania, Slovakia, and Slovenia), the market trend between 2017 and 2022 (Table 1) was behind the political ambitions. Only one country, Germany, has higher targets in W_p/capita than the needed EU average of 2246 W_p/capita to reach 1 TW_p in 2030. However, even if the current market trend can be maintained until 2030, it is likely that the EU as a whole will not reach the 2246 W_p/capita target, but it is possible that eleven countries (Austria, Belgium, Cyprus, Denmark, Estonia, Greece, Hungary, Malta, the Netherlands, Portugal, and Spain) could exceed it.

Despite the fact that all this development is looking impressive, it has to be noted that the European Union is still on a laggard route to becoming carbon neutral and realise a renewable energy supply by 2050 [29]. To lead the energy transition, the EU would need to have a cumulative installed PV capacity about 10 times the current 211 GW_p by 2030. Figure 3 illustrates the projection until 2030.

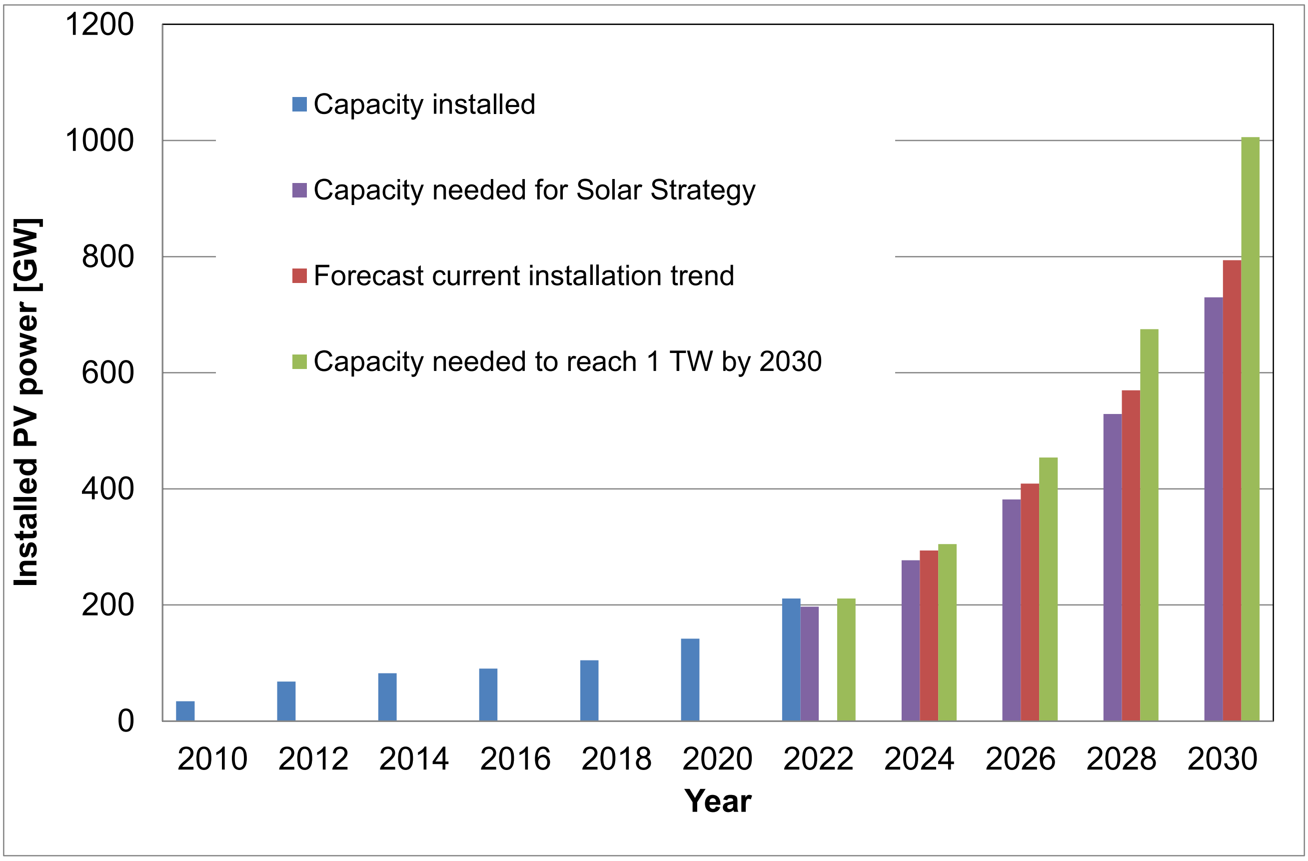

Figure 3. Actual and projected photovoltaic installations from 2010 to 2030 in the EU.

As already mentioned earlier, even the current market growth highlights the importance of the security of PV component supply. To tackle this issue, the European Union needs to invest to rebuild its local manufacturing capabilities along the full value chain.

One measure is that the EU formally launched the Solar Photovoltaic Industry Alliance in December 2022. The alliance has set the objective of reaching 30 GW_p of European PV manufacturing capacity by 2025, across the entire value chain. Achieving this target translates into an annual EUR 60 billion gross domestic product (GDP) in Europe, and the creation of over 400,000 new jobs [30]. Similarly, in an effort to interrupt the geographical concentration of PV manufacturing in China and boost their domestic PV manufacturing capacities, the USA and India have implemented the Inflation Reduction Act (IRA) legislation (USD 114 billion by 2031) and Production-linked incentive (PLI) scheme (USD 2.4 billion), respectively [31,32]. However, the EU alliance needs to proceed cautiously and firmly in order to avoid having EU manufacturing companies fleeing to countries with better investment conditions, such as the USA.

The main goals of the European Solar PV Industry Alliance are to diversify the international supply of PV components along the value chain as well as securing diversified sources of raw materials. Equally important is the rebuilding and scaling of EU manufacturing capacities for competitive, innovative, and sustainable PV products and system components.

The next tasks of the alliance will be to elaborate and implement a strategic action plan based on:

- Identification of manufacturing scale-up bottlenecks and providing recommendations;
- Identify and facilitate access to finance, including the establishment of commercialisation pathways for solar PV manufacturing;
- Establish and provide a framework for cooperation on PV development and deployment;
- Ensure the continuation of international partnerships and build resilient global supply chains;
- Make sure that solar PV research and innovation is supported and funded;
- Building awareness about the necessity of a circular and sustainable manufacturing industry and product use, as well as a better communication about the needs and opportunities;
- Ensure that a skilled workforce for the PV manufacturing and deployment industry along the whole value chain is properly educated and available for the future expansion of the sector.

4. Conclusions

The present work analyses the current PV installed capacity status in the EU, calculates the needed installed PV capacity per capita in the 27 EU member states to reach the 1 TW_p target by 2030, and comments on how the EU actions and initiatives will achieve this accomplishment.

The average EU installed capacity per capita is currently 474.55 W_p. In order to achieve the 1 TW_p target, this value needs to increase to 2246 W_p/capita. Seven EU member states are above the EU average installed capacity per capita and five below the 100 W_p/capita. Germany has the highest targets in W_p/capita, higher than the EU average required for the 1 TW_p target. It is most likely that the EU as an average will not reach the needed 2246 W_p/capita, but eleven member states may exceed their targets.

An invigorated EU PV market needs a development strategy for the full PV value chain, supported by research and innovation. This should include new cell and module manufacturing in the EU, with significant job creation potential. This is acknowledged by the launch of the new European Solar Industry Alliance, which should accelerate this process.

The European Green Deal's circular economy action plan is of high importance, with its aim of promoting sustainability across the whole value chain and encouraging businesses to offer reusable, durable, and repairable products. In addition, the proposed 'renovation wave' of public and private buildings can also be an important stimulus for using PV products to achieve near-zero energy buildings. The EU solar energy strategy communication is an important signal that Europe is strongly committed to rapid PV deployment scale-up and wants to avoid the "Stop-and-Go" policy obstacles of the past (such as in case of setting the feed-in tariff or premiums in the past policies) and by this, it can secure a more business-friendly environment for the European industry to grow.

The acceleration of fossil fuel phase-out, a precondition for the 1.5 °C goal, will require an even faster deployment of renewable energy sources and photovoltaics. Together with the uptake of electromobility and green hydrogen for industrial processes, the demand for photovoltaics in the European Union could exceed 1 TW_p by 2030.

Last, but not least, the development of the PV markets needs a dimension for a just transition, by ensuring a significant share of decentralised PV to provide local jobs and ensure citizen participation.

Despite the undoubted effort in the past two years to accelerate the deployment of photovoltaics and develop a competitive EU solar value chain, this paper wants to point out that there is still a very high potential for photovoltaics to contribute as the cornerstone of the EU's energy transition and climate neutrality. This paper highlights the need for further ambitions regarding photovoltaics, a major contributor to the necessary future renewable energy supply.

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Nomenclature

General	
Agri-PV	Agri-photovoltaics
BNEF	Bloomberg New Energy Finance
CAGR	Compound Annual Growth Rate
EGD	European Green Deal
EU	European Union
EU ETS	European Union Emissions Trading System
EV	Electric vehicle
FPV	Floating-photovoltaics
GDP	Gross domestic product
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
NECP	National energy and climate plans
NEO	New Energy Outlook
PV	Photovoltaics
PLI	Production-linked incentive
RED II	Renewable Energy Directive II
Technical	
bcm	Billion cubic metres of natural gas
GW_{ac}	Gigawatt alternating current
GW_p	Gigawatt peak
kW_p	Kilowatt peak
TW	Terawatt
TWh	Terawatt hour
TW_p	Terawatt peak
W_p	Watt peak
W_p/capita	Watt peak per capita

References

1. Intergovernmental Panel on Climate Change. IPCC Sixth Assessment Report, WG III. 2022. Available online: https://www.ipcc.ch/report/ar6/wg3/ (accessed on 20 December 2022).
2. European Commission. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, REPowerEU: Joint European Action for More Affordable, Secure and Sustainable Ener. 2022. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN (accessed on 8 March 2022).
3. European Commission. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Solar Energy Strategy. 2022. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A221%3AFIN&qid=1653034500503 (accessed on 8 March 2022).
4. Kougias, I.; Taylor, N.; Kakoulaki, G.; Jäger-Waldau, A. The role of photovoltaics for the European Green Deal and the recovery plan. *Renew. Sustain. Energy Rev.* **2021**, *144*, 111017. [CrossRef]
5. Arantegui, R.L.; Jäger-Waldau, A. Photovoltaics and wind status in the European Union after the Paris Agreement. *Renew. Sustain. Energy Rev.* **2018**, *81*, 2460–2471. [CrossRef]
6. Council of the European Union. 'Fit for 55': Council and Parliament Reach Provisional Deal on EU Emissions Trading System and the Social Climate Fund. 2022. Available online: https://www.consilium.europa.eu/en/press/press-releases/2022/12/18/fit-for-55-council-and-parliament-reach-provisional-deal-on-eu-emissions-trading-system-and-the-social-climate-fund/ (accessed on 20 November 2022).
7. Bloomberg New Energy Finance. *New Energy Outlook 2021*; Bloomberg New Energy Finance: New York, NY, USA, 2021.
8. Jäger-Waldau, A. Snapshot of photovoltaics 2022. *EPJ Photovolt.* **2022**, *13*, 9. [CrossRef]
9. Jäger-Waldau, A. Snapshot of Photovoltaics 2023. *EPJ Photovolt.* 2023; *to be submitted*.
10. European Commission. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Impact Assessment on Stepping up Europe's 2030 Climate Ambition Investing in a cl. 2020. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020SC0176 (accessed on 30 November 2022).
11. IEA. Is the European Union on Track to Meet Its REPowerEU Goals? 2022. Available online: https://www.iea.org/reports/is-the-european-union-on-track-to-meet-its-repowereu-goals (accessed on 10 January 2023).
12. SolarPower Europe. Europe EU Market Outlook for Solar Power 2022–2026. 2022. Available online: https://api.solarpowereurope.org/uploads/5222_SPE_EMO_2022_full_report_ver_03_1_319d70ca42.pdf?updated_at=2022-12-19T08:21:34.541Z (accessed on 10 January 2023).
13. European Commission. Renewable Energy Progress Report. 2020. Available online: https://data.consilium.europa.eu/doc/document/ST-11866-2020-INIT/en/pdf (accessed on 30 November 2022).
14. Bórawski, P.; Holden, L.; Bełdycka-Bórawska, A. Perspectives of photovoltaic energy market development in the european union. *Energy* **2023**, *270*, 126804. [CrossRef]
15. Eyl-Mazzega, M.-A.; Mathieu, C. *The Geopolitics of the Global Energy Transition, Chapter: The European Union and the Energy Transition*; Springer: Cham, Switzerland, 2020; Available online: https://link.springer.com/chapter/10.1007/978-3-030-39066-2_2 (accessed on 30 November 2022).
16. Madsen, D.N.; Hansen, J.P. Outlook of solar energy in Europe based on economic growth characteristics. *Renew. Sustain. Energy Rev.* **2019**, *114*, 109306. [CrossRef]
17. da Silva, P.P.; Dantas, G.; Pereira, G.I.; Câmara, L.; De Castro, N.J. Photovoltaic distributed generation—An international review on diffusion, support policies, and electricity sector regulatory adaptation. *Renew. Sustain. Energy Rev.* **2019**, *103*, 30–39. [CrossRef]
18. Breyer, C.; Bogdanov, D.; Gulagi, A.; Aghahosseini, A.; Barbosa, L.S.N.S.; Koskinen, O.; Barasa, M.; Caldera, U.; Afanasyeva, S.; Child, M.; et al. On the role of solar photovoltaics in global energy transition scenarios. *Prog. Photovolt. Res. Appl.* **2017**, *25*, 727–745. [CrossRef]
19. Tagliapietra, S.; Zachmann, G.; Edenhofer, O.; Glachant, J.M.; Linares, P.; Loeschel, A. The European union energy transition: Key priorities for the next five years. *Energy Policy* **2019**, *132*, 950–954. [CrossRef]
20. Wolniak, R.; Skotnicka-Zasadzień, B. Development of Photovoltaic Energy in EU Countries as an Alternative to Fossil Fuels. *Energies* **2022**, *15*, 662. [CrossRef]
21. Chatzipanagi, A.; Jäger-Waldau, A.; de Langavant, C.C.; Letout, S.; Latunussa, C.; Mountraki, A.; Georgakaki, A.; Ince, E.; Kuokannen, A.; Shtjefni, D. *Clean Energy Technology Observatory: Photovoltaics in the European Union—2022 Status Report on Technology Development, Trends, Value Chains and Markets*; Publications Office of the European Union: Luxembourg, 2022. [CrossRef]
22. Bódis, K.; Kougias, I.; Jäger-Waldau, A.; Taylor, N.; Szabó, S. A high-resolution geospatial assessment of the rooftop solar photovoltaic potential in the European Union. *Renew. Sustain. Energy Rev.* **2019**, *114*, 109309. [CrossRef]
23. European Commission. ENSPRESO—SOLAR—PV and CSP. 2019. Available online: https://data.jrc.ec.europa.eu/dataset/18eb348b-1420-46b6-978a-fe0b79e30ad3 (accessed on 30 November 2022).
24. Jäger-Waldau, A. The Untapped Area Potential for Photovoltaic Power in the European Union. *Clean Technol.* **2020**, *2*, 440–446. [CrossRef]

25. Bódis, K.; Kougias, I.; Taylor, N.; Jäger-Waldau, A. Solar photovoltaic electricity generation: A lifeline for the european coal regions in transition. *Sustainability* **2019**, *11*, 3703. [CrossRef]
26. Chatzipanagi, A.; Taylor, N.; Thiel, C.; Jaeger-Waldau, A.; Dunlop, E.; Kenny, R. Agri-Photovoltaics (Agri-PV): How Multi-Land Use Can Help Deliver Sustainable Energy and Food. 2022. Available online: https://publications.jrc.ec.europa.eu/repository/handle/JRC129225 (accessed on 10 January 2023).
27. SolarPower Europe. *Agrisolar Best Practices Guidelines*; SolarPower Europe: Brussels, Belgium, 2021; pp. 1–52.
28. Kakoulaki, G.; Sanchez, R.G.; Amillo, A.G.; Szabo, S.; De Felice, M.; Farinosi, F.; Bisselink, B.; Seliger, R.; Kougias, I.; Jaeger-Waldau, A. Benefits of pairing floating solar photovoltaics with hydropower reservoirs in Europe. *Renew. Sustain. Energy Rev.* **2023**, *171*, 112989. [CrossRef]
29. Breyer, C.; Bogdanov, D.; Ram, M.; Khalili, S.; Vartiainen, E.; Moser, D.; Medina, E.R.; Masson, G.; Aghahosseini, A.; Mensah, T.N.O.; et al. Reflecting the energy transition from a European perspective and in the global context—Relevance of solar photovoltaics benchmarking two ambitious scenarios. *Prog. Photovolt. Res. Appl.* 2022; *early view*. [CrossRef]
30. European Commission. REPowerEU: New Industrial Alliance to Boost the EU's Solar Power and Energy Security. 2022. Available online: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7617 (accessed on 10 January 2023).
31. Ministry of Commerce & Industry of India. Status of Production-Linked Incentive Schemes. 2021. Available online: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1710134 (accessed on 10 January 2023).
32. Wood Mackenzie. US Climate Bill to Boost Domestic Annual Renewables Investment to Nearly US$114 Billion by 2031. 2023. Available online: https://www.woodmac.com/press-releases/us-climate-bill-to-boost-domestic-annual-renewables-investment-to-nearly-us$114-billion-by-2031/ (accessed on 1 March 2023).