PHOTOVOLTAIC SOLAR ENERGY: BIG AND BEYOND

SUSTAINABLE ENERGY TO LIMIT GLOBAL WARMING TO 1.5 DEGREES

Vision and claims of the European Technology and Innovation Platform for Photovoltaics (ETIP PV)

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Disclaimer

The opinions expressed in this document are the sole responsibility of the European Photovoltaic Technology and Innovation Platform and do not necessarily represent the official position of the European Commission.

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1. INTRODUCTION

The paper provides the evidence base to support our paper "Photovoltaic Solar Energy: Big and Beyond – vision and claims of the European Technology and Innovation Platform for Photovoltaics (ETIP PV)" released for the COP24 intergovernmental climate conference in Katowice, and now available in several languages. It also expands on the points mentioned.

The report uses the notion of defossilisation. This term builds on the more familiar "decarbonisation", but recognises that it is not carbon atoms per se that must be prevented from reaching the atmosphere, but those carbon atoms that come from a fossil source.

2. SUMMARY

Photovoltaics is a proven technology capable of making a substantial contribution to a sustainable global energy system. The case for photovoltaic solar electricity (Solar PV) is summarised here:

- **Solar PV has recently become the lowest cost source of electricity in most parts of the world**
- **Solar PV can be used in all geographic regions and its generating capacity can be installed rapidly and scaled up modularly**
- **Solar PV can drastically reduce GHG emissions from the power sector and in other sectors through electrification**
- **Solar PV supports a socially acceptable energy transition by offering employment, distributed generation and integrated applications as well as new business opportunities**
- **Solar PV, in combination with wind energy, storage and conversion ("Power-to-X") is the cornerstone of the future sustainable energy system**
- **Solar PV needs to be deployed rapidly, massively, and globally including within Europe to limit global temperature rises to 1.5 °C**
- **More PV component manufacturing and PV generating capacity are needed in Europe to seize economic opportunities and to reduce dependence on energy imports and on PV technology imports**

The European Technology and Innovation Platform for Photovoltaics (ETIP PV) envisions a world with 100% renewable electricity supply where electricity is accessible to all and where electricity makes major inroads into satisfying final energy demand for living including communications, zero-emission transport and mobility, efficient heating and cooling, and even sustainable fuels, chemicals and materials. By applying Solar PV, buildings will increasingly become places of energy production and not only of energy consumption. Thanks to the abundant availability of sunlight, the technology's modularity, and continuous cost reductions, Solar PV can become the largest source of energy worldwide [Ram, 2017 and Bogdanov, 2019].

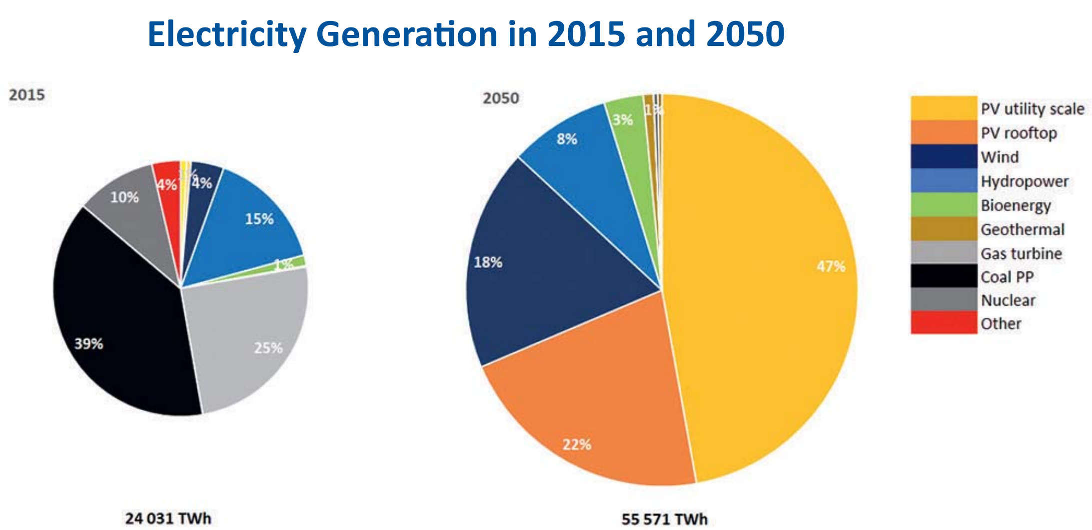


Figure 1 Researchers at LUT have shown that on the assumption that i) no nuclear-, coal-, or oil-based power plants are installed after 2015, and ii) the renewable energy capacity share increase does not exceed 4% per year (3% between 2015 and 2020), then the cost of consumed electricity is minimized worldwide in 2050 with the generation mix shown. Solar PV has a share of 69%. Slide is based on [Ram, 2017].

Tackling climate change and seizing economic opportunities

ETIP PV aims to actively support achieving the European Union's green energy policy goals as well as the additional actions needed to limit global temperature rise to 1.5°C [IPCC, 2018]. The latter implies realising zero GHG emissions around 2050 and negative emissions thereafter. In the words of the European Parliament [EP, 2017]: *"In line with the aim of the Paris Agreement to achieve a balance between anthropogenic emissions by sources and removals of GHG by sinks in the second half of the 21st century, the EU should aim on an equitable basis, to reach net-zero emissions domestically by 2050, followed by a period of negative emissions."*

Solar PV is able to meet the challenge of drastic defossilisation and there is big potential for further improvements in all related technology with accelerated research, development and innovation (RD&I). Already today it provides a power generation solution which is more efficient and cheaper than conventional energy sources in most parts of the world. Thus Solar PV, which is competitive today, is the ideal foundation for an emission-free, sustainable power mix, especially in combination with wind energy, energy storage and secondary conversion of electricity into other forms of energy (power to heat, fuels, chemicals and materials – "P2X"). Moreover, the **growing Solar PV sector offers great business and economic opportunities over the entire span of the industry from materials and components to systems and services**. Europe should put itself at the forefront of large-scale deployment, ambitious technological development and advanced manufacturing, sustainability of production, quality and efficiency of solar products, reliability of operation and the development of business models that capture PV's value.

The importance of market growth, manufacturing and innovation

The EU led in PV installations until 2012 but had fallen to only 6% of the global PV market by 2017, with installations in Asia, the Americas and recently Africa now dominating. EU governments must stimulate the European PV market in order to reap the economic benefits that PV brings and give a boost to Europe's PV industry. PV is a strategically important part of the coming sustainable energy system. Mastery of PV technology should not belong to one country or region. At the same time as barriers to the rapid uptake of centralized and decentralized PV installations are removed, policies to promote local manufacturing should be put in place, which is key to gaining local political backing. **ETIP PV wants the EU-based manufacturing industry to regroup** and succeed in the extremely competitive global Solar PV sector, providing high-quality, technologically advanced products at scale. For this to happen, the EU must **ensure a large and growing market for Solar PV installations** that **values high-quality, highly sustainable products**.

Solar PV is transforming Europe's and the world's energy system and energy industry and ETIP PV is committed to actively support this to the benefit of climate and economy, as a contribution to the future of mankind and responding to the Sustainable Development Goals shown below.

Selected United Nation's Sustainable Development Goals

3. NEW VISTAS: THE WIDE-OPEN HORIZONS OFFERED BY A LOW-COST, SCALABLE CLEAN ENERGY SOURCE: PV

Roughly as much time separates today and 2050 as separates today and the dawning of the internet, when worldwide PV installations were measured in tens of kilowatts (a hundred thousand times smaller than today). Technology can move very fast, making accurate prediction of the future of an industry at the start of its exponential growth futile. The statements that follow are speculative.

Taking as a premise that PV will become the not only relatively the lowest cost source of electricity but also extremely cheap in absolute terms, it is safe to say we will use much more of it. We will head towards the 'Electrification of Everything': electricity will take the place of primary energy in the production of heat, fuels and materials [IRENA, 2019a]. The takeover has been underway in some sectors for a decade: heat pumps increasingly provide low-temperature heat to energy-efficient buildings and substitute fossil fuels as they do so. Electric vehicles, bikes and scooters are becoming familiar sights. The use of electricity in industry in preference to fossil fuels will emerge in the next decade. While electricity can provide high-temperature heat directly, it will need to be further transformed into another energy carrier, hydrogen, to tackle process emissions. The substitution of traditional fossil-fuel based reductants by renewable-energy derived hydrogen will be demonstrated and if political leaders commit the world to a tough enough defossilisation schedule, adopted widely by 2050.

Hydrogen is also a necessary precursor for PV's use in organic compounds, i.e. in the chemicals that are the basis of the world's polymers, dyes, fragrances, medicines and other goods. Photosynthesis is the origin of the vast majority of planet's organic compounds, but it might be possible to improve on the efficiency of photosynthesis (energetic or economic) through a combination of PV, electrolysis, capture of CO_2 from the air [Fasihi, 2019] or a point source [Farfan, 2019], and chemical reaction of the produced hydrogen and CO_2 to produce an organic compound. It will be energy-intensive, but viable if energy is cheap enough. If the compound is long-lasting, preventing the return of the carbon to the atmosphere for decades, then PV will be driving Carbon Dioxide Removal (CDR), and reducing atmospheric CO_2 concentrations. Designing CDR systems that match intermittent renewable energies will be key for stringent climate change mitigation [Creutzig, 2019].

"By 2050, water desalination will be nearly 40 times the amount of 2015. This will require substantial desalination capacities and some water storage. Desalination will account for approximately 4% of total primary energy demand in 2050, which can be fully met with renewables."

[Ram, 2019]

A vision for 2050 would not be complete without an assessment of how PV's fortunes may be intertwined with those of other technologies with an impact on the electricity system. Candidates are technologies whose growth is comparably fast. High-performance batteries are one such new technology. They enable the use of electricity in mobile devices and they buffer the variability of supply from wind and PV generators. Another is information and communications technology (ICT). Worldwide the electricity consumption of networks (wireless and wired) and data centres is expected to increase from 1 000 TWh in 2018 to 6 500 TWh in 2030 [Nature, 2018]. By that date, once the consumption due to the production of ICT equipment and the consumption in consumer devices (TVs, computers, mobile phones) is added in, an estimated 21% of the world's electricity demand will be for making or driving ICT.

The opportunity for synergies between the PV and the ICT boom depends on the ability to manage PV's variability (for example in combination with other forms of electricity generation and demand) and on the ability of data centres or data networks to ramp their power consumption up or down. Data centres tend to be sited in cold climates, where there is less PV potential. On the other hand, the ICT industry has come to dominate the segment of the power market consisting of corporate agreements to purchase renewable electricity, including PV. Renewable energy companies in 2016 had more power contracted to ICT companies than all other categories of company combined. We think the compatibility of PV and ICT will be confirmed and that PV, as a low-cost power source, will facilitate the data-driven and AI-assisted world, allowing computers to run our lives and entertain us in ever more sophisticated ways.

The integration of PV into landscapes and infrastructure will expand the capacity of PV installed. From a societal perspective any deep defossilisation strategy must efficiently use the whole available zero-impact rooftop area for PV generation [ETIP PV, 2017a], i.e. those of Europe's roofs that are not generally visible to people will be fully covered with PV by 2050. Parts of buildings that are visible will incorporate PV in aesthetically pleasing ways, for example, with building elements containing PV (known as 'Building-Integrated Photovoltaics'), possibly custom-made. PV not mounted on buildings will take up space efficiently (for example in a way that affords dual use of the space), in a way that looks nice, or both. PV on farmland or floating PV will become commonplace.

More objects will contain PV cells, giving them 'power autonomy'. Cars with cells integrated into their exposed surfaces will be an early example. Coupled with the integration of advanced, networked ICT, objects with PV could gain a kind of 'intelligence autonomy' allowing them to operate as robots with varying degrees of independence. A vast network of objects relaying information about their state to each other has been called the Internet of Things. These robots will come into their own in remote locations, performing tasks where delaying a day is not critical, thereby minimising the need for batteries. Think ocean-going robots cleaning up the Great Pacific Garbage Patch.

More generally, PV lets mechanical solutions to managing the world's life-support systems (including food production) take over from chemical treatments, which sometimes do severe damage. It (or electricity more generally) might provide the controlled environment needed to produce protein without livestock (e.g. lab-grown meat or directly grown proteins), thereby freeing up the land used for rearing them and for producing their feed, and avoiding their methane emissions. Electrification can reach deep into all aspects of society.

3.1. Synthetic transport fuels from PV electricity

Deep defossilisation of the transport sector implies substantial increases in electricity demand, first for direct electrification such as for passenger and freight transport on roads by cars, buses, trucks, but also for indirect electrification for hydrocarbon-based fuels, such as synthetic jet fuel, which can be produced by Fischer-Tropsch synthesis via electricity and hydrogen (as bio-kerosene may require too much land). Forecast direct and indirect electricity demand for Europe's transport sector according to scenarios developed by LUT accounts for about 750 TWh and 130 TWh (2030) and about 1670 TWh and 6280 TWh (2050), respectively [Ram, 2018].

3.2. Opportunities for solar integration into buildings and landscapes

3.2.1. Integration into buildings

Buildings are responsible for 40% of final energy consumption and 36 % of CO_2 emissions in the EU. About 75% of existing buildings are energy-insufficient while only 0,4-1,2% of the building stock is renovated each year, depending on the Member State. This represents a vast untapped potential for energy efficiency improvement as well as for the integration of renewable energy technologies, in particular using solar building skins (building-integrated photovoltaics- BIPV). Building management systems will become more widespread and more sophisticated (better able to anticipate users' needs, better able to react to data coming from beyond the building (e.g. meteorological data, energy prices), wired to more sensors and actuators, more energy efficient). Closer collaboration between the building industry (including architects, engineers and investors), the BIPV industry and the R&D sector is needed to ensure that products that exist are used, and to bring new products to the market.

Cities cover less than 5 percent of the Earth's land, but concentrate over half of the world's population, with 80 percent projected for 2050. They account for over 70% of global energy use. Under business-as-usual projections, global energy use in buildings could double or triple by 2050. Instead, renovation rates must be increased, and standards set at levels that demand high performance. Buildings with low energy demand compared to the amount of sunlight that falls on them should produce more energy from renewable energy sources than they need, the surplus sold to citizens, companies and providers of city services. By 2050, the first cities should have appeared that fully cover their energy needs from renewable sources and also export more renewable energy on an annual basis than they import. Any solution for climate change by energy system transformation must explicitly address sustainable urban heating and cooling, as well as electricity.

> ***"We have reached a critical point in understanding that cities can be the source of solutions to, rather than the cause of, the challenges that our world is facing today. If well-planned and well-managed, urbanization can be a powerful tool for sustainable development for both developing and developed countries."***
>
> **New Urban Agenda [UN, 2017]**

3.2.2. Integration into other landscapes

The integration of renewable energies in cities, in particular building integration of photovoltaics (BIPV), represent huge opportunities in combination with increased energy efficiency [REN21, 2019]. But so does integration of PV into the landscape, particularly where this can be done unobtrusively or in such a way that it improves the original function of the landscape. Floating PV is one example [Farfan, 2018]. We can expect it first to be deployed over reservoirs where it can reduce evaporative loss. Later, floating PV arrays could appear among offshore wind turbines (i.e. in parts of the sea out of bounds to shipping and fishing) feeding electricity to offshore energy hubs that might transmit the electricity to land or transform it into another energy carrier.

Ground-mounted PV can be good for agriculture, providing shade and humidity in arid regions. Compatibility with sheep farming has been demonstrated. Research projects mounting well-spaced modules several metres above farmland so that the land beneath can continue to be cultivated by usual means are testing the productivity of this form of agriculture.

3.3. A vision for the grid

The defossilisation of the European economy will be accomplished mainly with electricity, this electricity coming exclusively from climate-neutral sources, which will be renewable energy sources to a very large extent. Generation technologies with complementary generation profiles will be combined in a way to optimise system stability. At world level, the IEA's Sustainable Development Scenario of 2018 finds renewable electricity would have to contribute roughly 66% of the final energy demand by 2040, a finding consistent with LUT/EWG's [Ram, 2017- Figure KF-1 – see also Box below]. To provide stability locally, renewable energy power plants will increasingly "hybridise", i.e. contain more than one generation technology. To maintain system security, high-quality grid-integration technologies are essential to manage the flows within and between the plants.

Shares of wind and PV in total electricity supply under LUT/EWG's Global Energy System based on 100% Renewable energy- Power Sector [Ram, 2017 – See also Figure 1]

	2030	2040	2050
PV	37%	56%	69%
Wind	32%	26%	18%

As ETIP SNET VISION 2050 acknowledged, by 2050, electricity networks will operate with a very high penetration of power electronics and associated monitoring and control equipment. They will respond dynamically, be secure (resistant to faults or attacks) and relay information between all voltage levels. All generation and consumption, including where this happens simultaneously at one site, will be visible to the system, allowing the system to react optimally to any perturbation.

These emerging technologies will facilitate an integrated grid with reduced inertia that is enabled by adapted monitoring, control equipment, and new protection solutions with associated cyber-secure, fast data communication devices. Methods for planning and operations are adapted to these new circumstances by relying on more power electronics-based control, electronic switches, grid-inherent controls, distributed and decentralized control techniques. It is expected that the adapted technologies can handle all network states in a reliable way so that the overall system remains resilient against unforeseen, sudden events.

The effects of PV will be felt beyond the electricity grid. So profound will its impact on the energy system be, that other grids carrying heat or gas will be repurposed to fit around it, carrying heat generated or gas generated from PV electricity.

3.4. Electricity stored and transformed

To achieve the high levels of PV and other RES in electricity and energy mix it is of prime importance to address the issue of intermittency in resource availability. For this reason, large-scale roll-out of storage and conversion technologies is expected in the years ahead [CSIRO, 2018].

Solar PV, in combination with wind energy, storage and conversion (“Power-to-X”) is the cornerstone of the future sustainable energy system

3.4.1. Traditional Storage

The traditional means to store electricity in large quantities has been to use hydropower reservoirs, sometimes refilled by pumps.

Other techniques to bulk-store electricity for a period of months are well known, but not widely used. They include batteries or storage in the form of hydrogen, maybe compressed (even compressed air has been used as a store). In an era where PV is very widely deployed and, it might even make sense in many parts of Europe to convert PV electricity to heat in summer and to store that heat compactly until winter, when it can be released for space heating or domestic hot water.

3.4.2. Conversion

As envisioned in ETIP SNET VISION 2050, by that date, Power-to-Gas and Power-to-Heat conversion allow for the efficient coupling of electricity, gas and heat networks, together with Gas-to-Power-and-Heat and Gas-to-Heat conversion technologies. The prevalence of these technologies will depend on their relative competitiveness. In 2050, coupling heat and electricity production will impact the gas grid, where electricity storage can be performed in different ways (thermal, chemical, or electrical energy). Coupling electricity and gas networks with electrolyser and methanation units enable long-term (seasonal) storage, flexibility options for the electricity grids and supply for the transport and industry sectors. This can also provide an adequate energy supply at moderate overall cost even at times when renewable generation is low or in very high demand conditions. Coupling electricity and liquid fuels is key to supply the transport sector (ships and airplanes) with low-carbon fuels (including different biofuels) and for industry using carbon-neutral inputs.

Achieving net zero emissions by the end of the century requires the use of “carbon dioxide removal technologies”, which would be driven by electricity. They would complement natural carbon sinks.

3.5. Information and communication technologies create marketplace for new services and exchanges

In this transition from conventional to sustainable solutions with RES as the main source of energy and a myriad of technologies complementing, enabling or supporting it, digitalisation is needed, and it is strongly present. Digitalisation brings the intelligence that turns the system into a functional integrated solution that is highly efficient and resilient.

Our vision is that in the RES-dependent integrated grid, empowered consumers of any size can access directly or indirectly energy markets to sell energy (as prosumers), buy it, and adjust their needs of consumption via low-cost, cyber-secure communication and Internet services. These information and communications technologies can provide dynamic information (price, quality, state of the system, incentives for energy systems-friendly actions).

Digitalisation thus provides better, user-friendly services to all kinds of customers for planning, maintenance and operational issues, fostering information, analytics, and connectivity today :

- Several million households actively participate in real-time, automated demand response (electricity, heating and cooling) with connected appliances and equipment, in addition to the existing and emerging solutions for industry and commerce.
- Aggregation of smart charging technologies for electric vehicles, stationary batteries, heat pumps and power-to-gas provides controllable electricity loads.
- Decentralised control techniques and peer-to-peer electricity trade permeates local energy communities and their interconnection to the electricity system.
- Shared platforms facilitate data exchange and decision-making in all parts of the integrated energy systems, thus enabling advanced planning, operation, protection, control and automation of the energy systems.

Optimized and interconnected services provide real-time information to operators and aggregators as well as to users connected to an energy network, thereby enhancing system balancing and resilience in case of faults.

PV systems, via their inverters, can provide voltage or frequency control, active or reactive power regulation; and via integrated ICT, will be a valuable partner in creating a marketplace for new service and exchanges.

Communication within and between PV plants deliver data that is analysed insightfully, allowing faults to be detected and diagnosed, maintenance to be planned efficiently and reliable high performance of PV plants to be maintained. Interoperable components and software will be needed for this.

4. GETTING THERE: COST REDUCTION, GROWTH, MARKETS AND OTHER ENABLERS

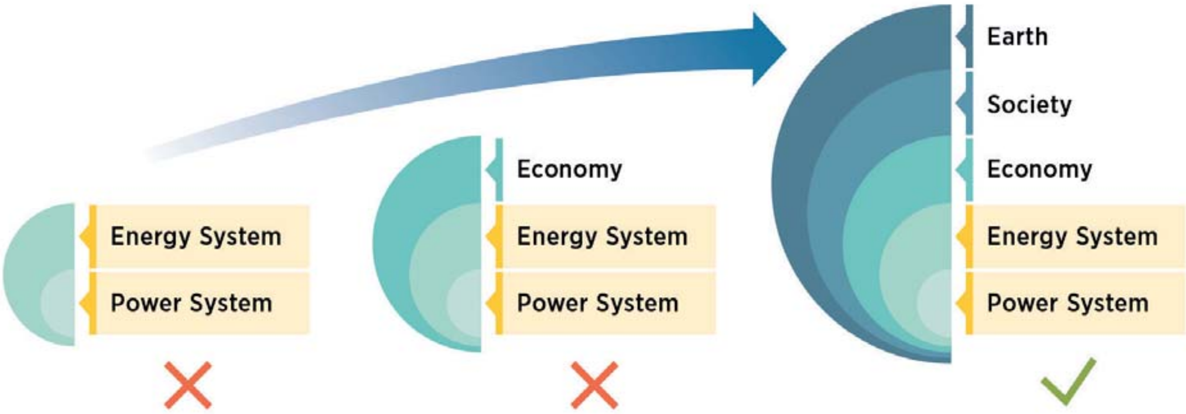


Figure 2 The embedded nature of the energy system [IFigure 13 of RENA, 2019a]

4.1. PV's dramatic cost reduction

Solar PV is already today a form of power generation that is not only cheaper than conventional energy sources but also, in most parts of the world, other renewable energy sources. It has vast potential for further cost reduction, which will allow services it had been unimaginable to provide with electricity to be provided in just this way, as explained above.

Since 1980, prices of complete PV systems (€/kW – see Figure N) as well as generation costs (Levelised Costs of Electricity; LCoE – €/kWh) have come down by a factor 50 to 100 and efficiencies have been increased by a factor 2. Roadmaps to reach higher increases (up to 24%) with high probability exist (see Annex).

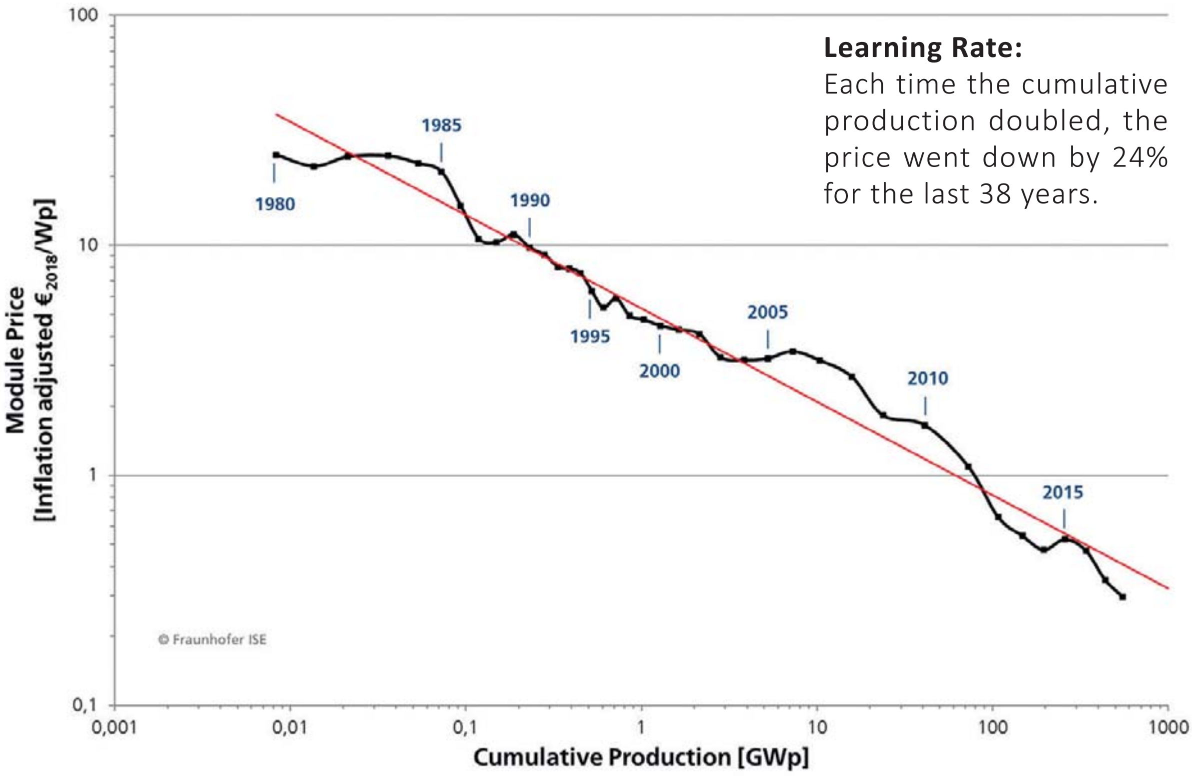


Figure 3 Price Learning Curve made up of all commercially available PV technologies [Fraunhofer ISE: Photovoltaics Report, updated: 9 April 2019]

Through scaling up, PV generation costs will be brought down by another factor of (typically) 3 to 4 in the medium term.

This price reduction has helped PV achieve grid parity in many European countries. The true competitiveness of Solar PV – a European case study [ETIP PV, 2017a] looked at three segments of the PV installation market in Europe (small-scale systems installed on homes, where the homeowner otherwise buys electricity on the retail market; mid-sized systems on commercial premises and large systems). Of the ten countries examined, under reasonable assumptions, about five are competitive today in every market segment. By 2050, buyers of PV systems in all 31 towns from across Europe considered in the study can expect to save money compared to buying electricity from the grid even for high costs of capital.

4.2. Growth (historical and forecast)

For almost two decades, PV has been one of the fastest developing technologies in the world [Jäger-Waldau, 2017]. 13 years after the publication of the Vision Paper by the European Photovoltaic Technology Research Advisory Council [PV-TRAC, 2005], the worldwide installed Solar PV power capacity has increased 100 times to over 500 GW at the end of 2018.

Solar PV can be used in all geographic regions and its generating capacity can be installed rapidly and scaled up modularly

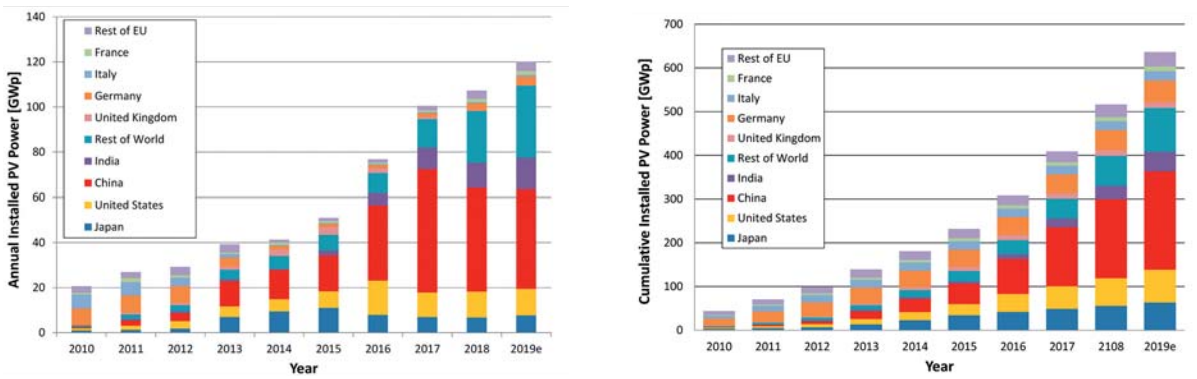


Figure 4: left: Annual worldwide installed PV power capacity 2005-2019; right: cumulative global installations 2010-2019 [Jäger-Waldau, 2019]

Despite this explosive growth, PV still only supplied about 2% (500 TWh) of worldwide annual electricity demand [Jäger-Waldau, 2019]. An increase to 22% (6 300 TWh) is projected for 2025 and to 69% (38 000 TWh) in 2050 [Ram, 2017]. The corresponding capacities to deploy are 4 TW and 22 TW. Annual installation rates would typically need to be a factor 10 greater than they are today to reach these totals. This is only for the power sector in its present structure. Taking into account the broad electrification in the sectors heat, transport and industry, then the PV electricity demand will be much higher. Latest estimates range up to about 104 000 TWh in 2050 which would require about 63 TW of installed PV capacity [Ram, 2019].

Europe must play its part: The European Union needs to increase its capacity from 115 GW at the end of 2018 (chart below) to more than 600 GW by 2025 and 4-9 TW by 2050 depending on PV's use in overall energy supply. But in recent years, installation rates have fallen. From being the leading region until 2012, the EU fell to less than 6% of the global PV market in 2017. PV installations are now down to 2009 levels, while installations in the Americas and Asia are currently ten times those in Europe.

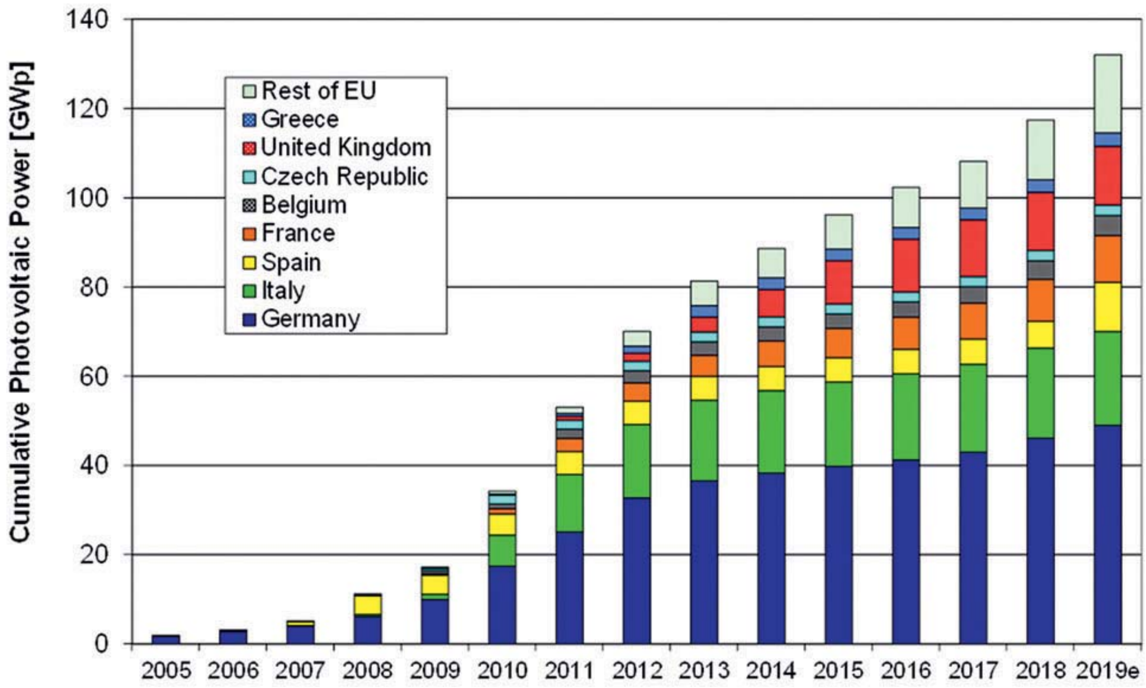


Figure 5: Cumulative Photovoltaic Power [GWp] 2005 - 2019 [Jäger-Waldau, 2019]

4.3. Markets and other enablers

For the energy transition to be driven by people and their choices, and to reward innovation, efficient markets are needed that provide a level playing field for all stakeholders.

The feed-in tariff era is coming to an end as PV generation is already competitive in many markets and subsidies are not needed anymore. The European Union is pushing for the gradual replacement of feed-in tariffs by market-based schemes, at least for larger systems. A typical scheme is an own-consumption regulation that allows the owner of a PV system to use the electricity from it and avoid (nearly fully) the cost of buying that quantity of electricity from the grid. Additionally, the owner can sell the electricity he does not consume to the grid at the wholesale market price.

But in 2050, the remuneration model will look very different. In recent years, [wholesale market] prices have been going down and are already at a level that discourages investment in almost any new generation capacity. Selling to that market therefore looks unlikely to be a reliable source of income in future. Meanwhile, the structure of distribution grid tariffs is changing from a variable or per-kWh price to a fixed or power-related fee, reducing the saving that can be made from own-consumption (or indeed the savings that can be made from any reduction in electricity purchase from the grid).

We've said earlier that from a societal perspective it is not efficient not to use all zero visual-impact rooftop area for PV generation. Exploiting this potential is essential to meet the target of limiting global average temperature rises to 1.5°C by mid-century, but a new market model will be needed that makes investing in this kind of PV attractive. The current "own-consumption" model, which requires high shares of PV electricity to be consumed on site, tends to put an economic limit on the size of the system. The new model might be one that recognises PV's benefits for the system. For example, Sinha et al. [Sinha, 2013] have concluded that the cost of non-use of renewable electricity, mainly Solar PV, would be in the range of 49-390 €/MWh, comprising grid stabilising, financial fuel hedging, value of avoided capacity etc; while in Sweden today, prosumers that feed in electricity receive 5 €/MWh more than the wholesale market price in recognition of the grid benefit they provide [ETIP PV, 2017a].

As RES-dependent markets grow, flexible energy storage, power conversion, and demand flexibility play a key role as products and services in energy markets.

4.4. Managing a TW-scale industry

Upscaling from the current annual 100 GW to TW production calls for further standardization of e.g. designs, processes, tools, materials & chemicals which is linked to new applications. The automotive industry / transport sector and the smartphone industry successfully underwent such growth and the Solar PV industry can learn from their experiences.

To supply an annual TW market including the supply chain in a sustainable way, many PV technology developments (manufacturing and R&D) are needed. We should not undervalue the importance of human resources, where even more PV experts will be needed to make the success, projections and expectations happen. Only continuous support and coordinated action across Europe and worldwide can make the vision of TW-scale production a reality.

4.5. A share of manufacturing for Europe, capitalising on Europe's R&D&I capacity

PV is a sector of strategic importance for the EU economy, providing energy independence, industrial jobs and economic growth. In Europe, the strategic importance of an independent energy supply is often ignored. Renewables are changing the balance of power, taking it away from fossil-fuel exporting countries [IRENA, 2019b]. For over two decades, Europe led in technological development, state-of-the-art manufacturing, sustainability of production and quality and efficiency of solar products. It would be an error for Europe to become heavily or completely dependent on imports of key components of its major source of electricity in the future.

More PV component manufacturing and PV generating capacity are needed in Europe to seize economic opportunities and to reduce dependence on energy imports and on PV technology imports.

Europe therefore has much catching up to do if wishes to carve out an appreciable role for itself in advanced manufacturing of PV, sustainability of production, and quality and efficiency of solar products to deliver reliable high performance over the expected lifetime of a PV plant. It should be in the forefront in large scale deployment, ambitious technological development.

Even if the emergence of huge overcapacities outside Europe did severe damage to the EU industry, the EU value chain from raw materials and equipment to complete PV solar systems has survived. Together with the support of a unique R&D ecosystem, this is the basis for the EU manufacturing industry to keep its significant technological advantage over industrial followers outside Europe.

Research, Development and Innovation (R&D&I) in PV must range over a wide area spanning technology, engineering, business model innovation, societal acceptance and more.

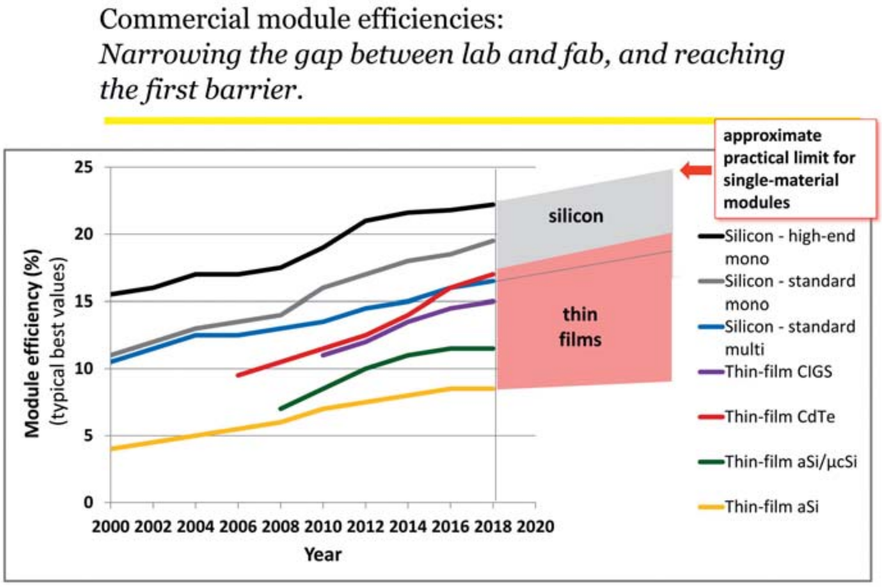
Europe must continue to invest in R&D&I as well as industrial production over the full value chain to be able to play an active role with a strong industrial position. Organising research work efficiently and securing the commitment of industrial stakeholders requires a coordinated approach at the European level [EC, 2017].

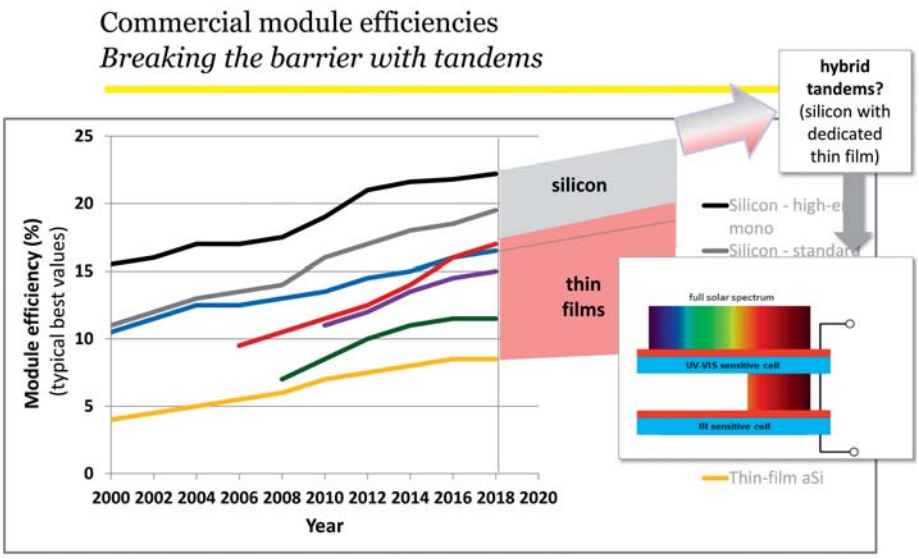
5. ETIP PV'S ROLE

ETIP PV connects R&D actors with EU based industry to raise the profile of the sector and to formulate recommendations on industry policy (including R&D) for the EU. We aim for Europe to offer high-quality PV technology to the world at scales much larger than today.

The requests we made to policymakers in our Open Letter of 2017 [ETIP PV, 2017b], which many companies, organisations and R&D centres signed, are still valid: R&D money and cheap finance is needed to support the construction of large-scale manufacturing sites in the EU across the whole value chain. So too is smart regulation that looks at the eco-credentials of products and might allow them recognition and a privileged place in public tenders.

6. ANNEX: SOLAR PV TECHNOLOGY TRENDS AND NEEDS





Source: Wim Sinke (ECN part of TNO)

Higher efficiencies will be developed and lead to further cost reductions for use in large-scale in some applications and regions where space is limited or costly.

7. References

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