European Solar

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Capitalist Solutions to Climate Change

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Written November 2020.

Introduction

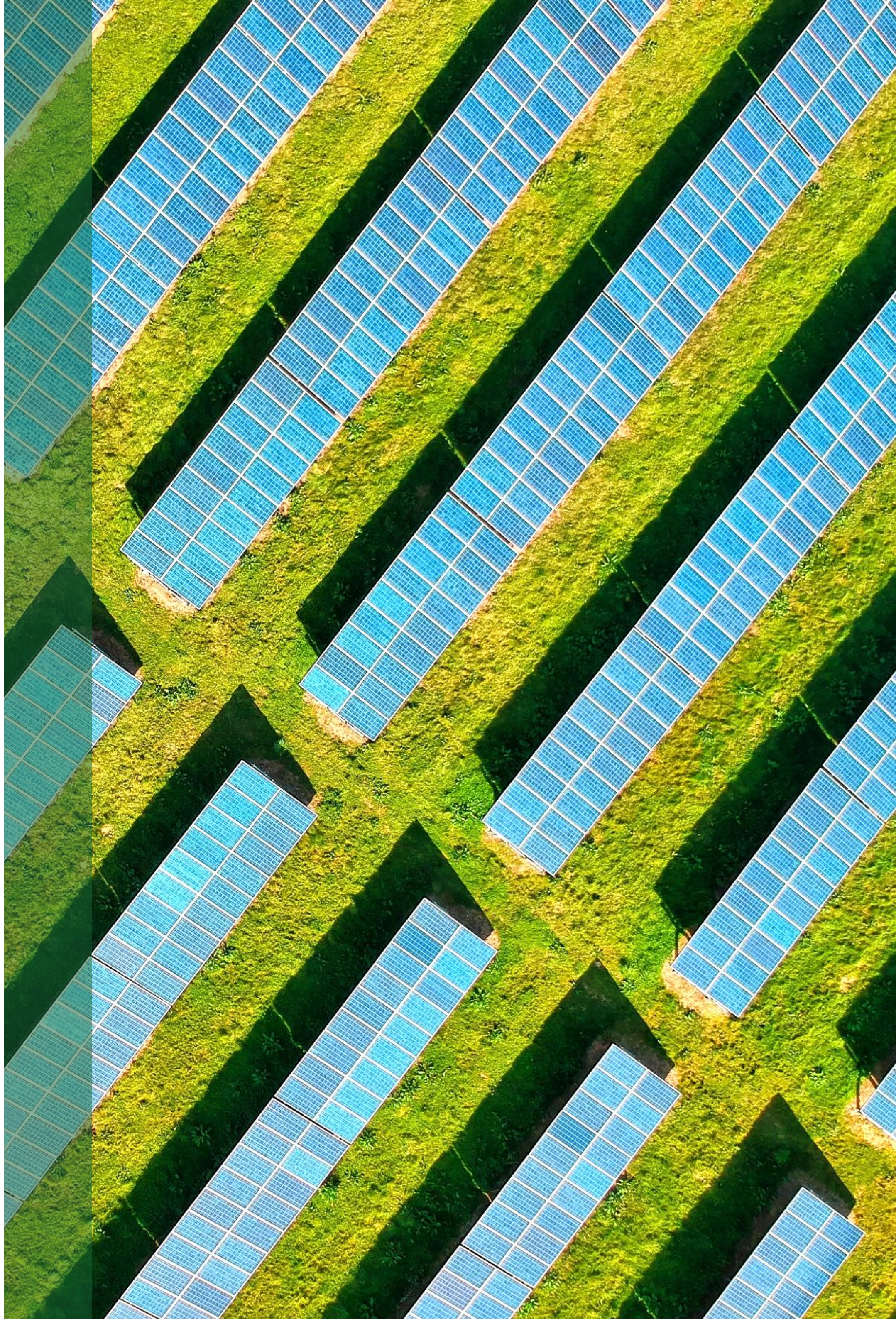
The world's best solar PV (photovoltaic) projects now offer the cheapest electricity in history, according to the IEA (International Energy Agency). Given this cost competitiveness, together with its renewable nature, it is not surprising that PV made up about half of global electricity generation capacity additions last year.

In this report we provide a high level introduction to the use of PV within Europe, one of the largest global PV markets. Our focus is on the member states of the EU. Now is a particularly interesting time for the EU PV sector, which, although growing at a furious pace, currently only provides about 4% of the EU's total electricity.

As you might expect, the pandemic has not been without its impact on the ongoing EU PV rollout. However, the resilience shown has been impressive, and there is the hope of a 'post pandemic' bounce, in part due to the green-tilted €750 billion pandemic recovery instrument the EU has now approved.

Pandemic aside, the picture for PV is as compelling as it ever has been, supercharged by the recent political commitment to make the EU a climate neutral area by 2050. Such an ambitious target should obviously provide a strong government-led following wind for PV, though governments are by no means the only ones driving the market; PV is becoming ever more attractive to a range of other stakeholders, from individual households, through to the tech giants, and all those in between. This is true even in the post-subsidy world that is beginning to emerge.

In the case of 100% renewables by 2050 - a slightly stronger assertion than just being climate neutral, one eye-opening estimate has PV providing 62% of the EU's electricity by this date. For investors looking to supply a slice of the estimated €3 trillion in capital needed to make this a reality, this is potentially a golden opportunity, a complete transformation of the energy system in which to take part.



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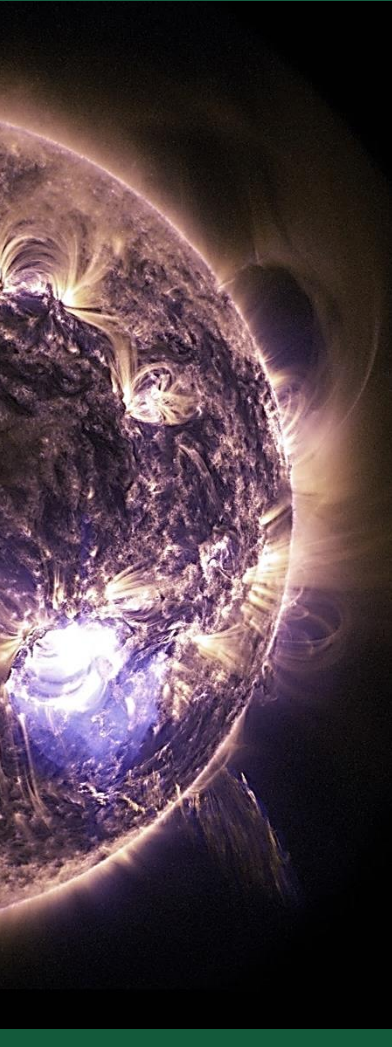


Overview

In this section we take a very broad look at the use of PV in Europe and compare it with the other continents. For those unfamiliar, we also cover the classification of PV systems. To kick things off we look at the available resource, which directly plays into the viability of PV projects, especially unsubsidised ones.

Solar Resource

As you might expect, latitudes below 45º have the strongest solar resource, as measured by the average annual energy output of a unit size of PV, see **Figure 1**, below left. This means that Southern European countries (e.g. Spain, Portugal) have conditions for PV that are excellent - if not the absolute best - from a worldwide perspective. As we move up through Europe, the resource declines notably, see **Figure 2**, below right. Despite this, some of the more northerly countries in Europe (e.g. Germany, UK) are those that have deployed PV the most. This suggests that the resource is only one of several factors influencing deployment.

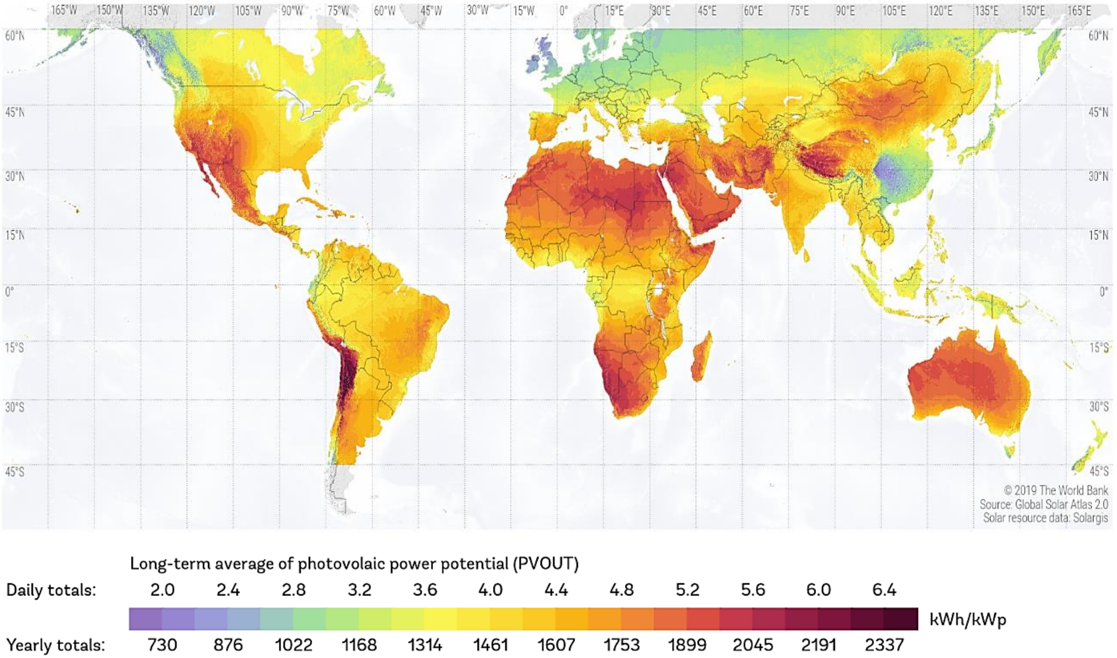


Figure 1 - map of worldwide PV potential. Source: Solargis.

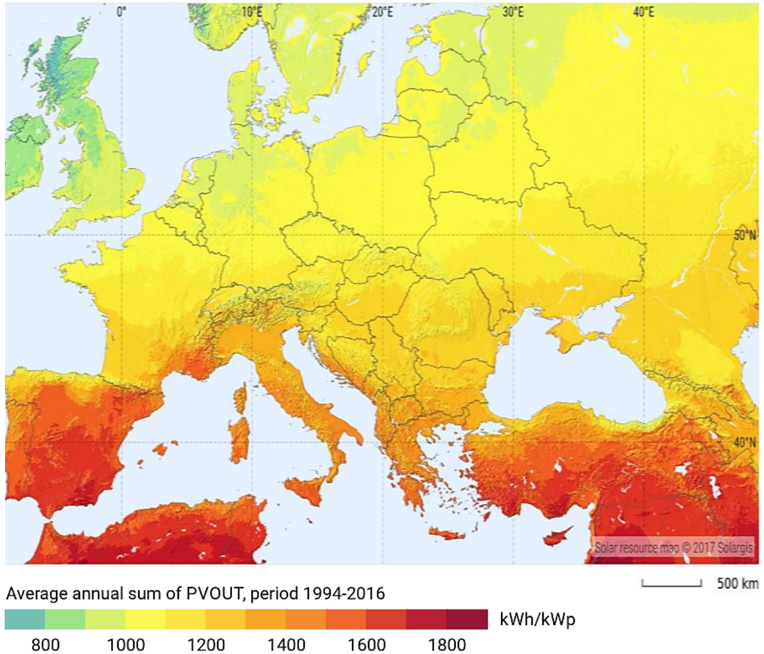


Figure 2 - map of European PV potential. Source: Solargis.

Installed Capacity

Europe has played an important role in the history of PV, with the launch of Germany's feed-in tariff scheme at the start of the century arguably the starting point of the grid-connected PV era (we explain feed-in tariffs later; in short, they are a subsidy). In the space of two decades, PV has grown to a cumulative installed capacity worldwide of over 630 GW, see the top part of **Figure 3**, right.

During this exponential growth period, Europe remained the dominant force in terms of yearly capacity additions - bottom part of **Figure 3** - until about 2013, when the Asia-Pacific and China regions began their own meteoric ascents. It also remained the largest market by cumulative capacity until about 2017, when phenomenal growth in China pushed Europe down to the second largest market.

After flat-lining during the middle of the 2010s, a new growth phase has developed in Europe over the last few years, both for the continent and the subset of this that is the EU. After increasing 21% to 11.2 GW in 2018, annual PV additions in Europe more than doubled to 22.9 GW in 2019 (with the EU adding 16.7 GW of this). This was ~20% of global PV additions in 2019. Note that in this document 2020 is included in the 'Market Forecast' section.

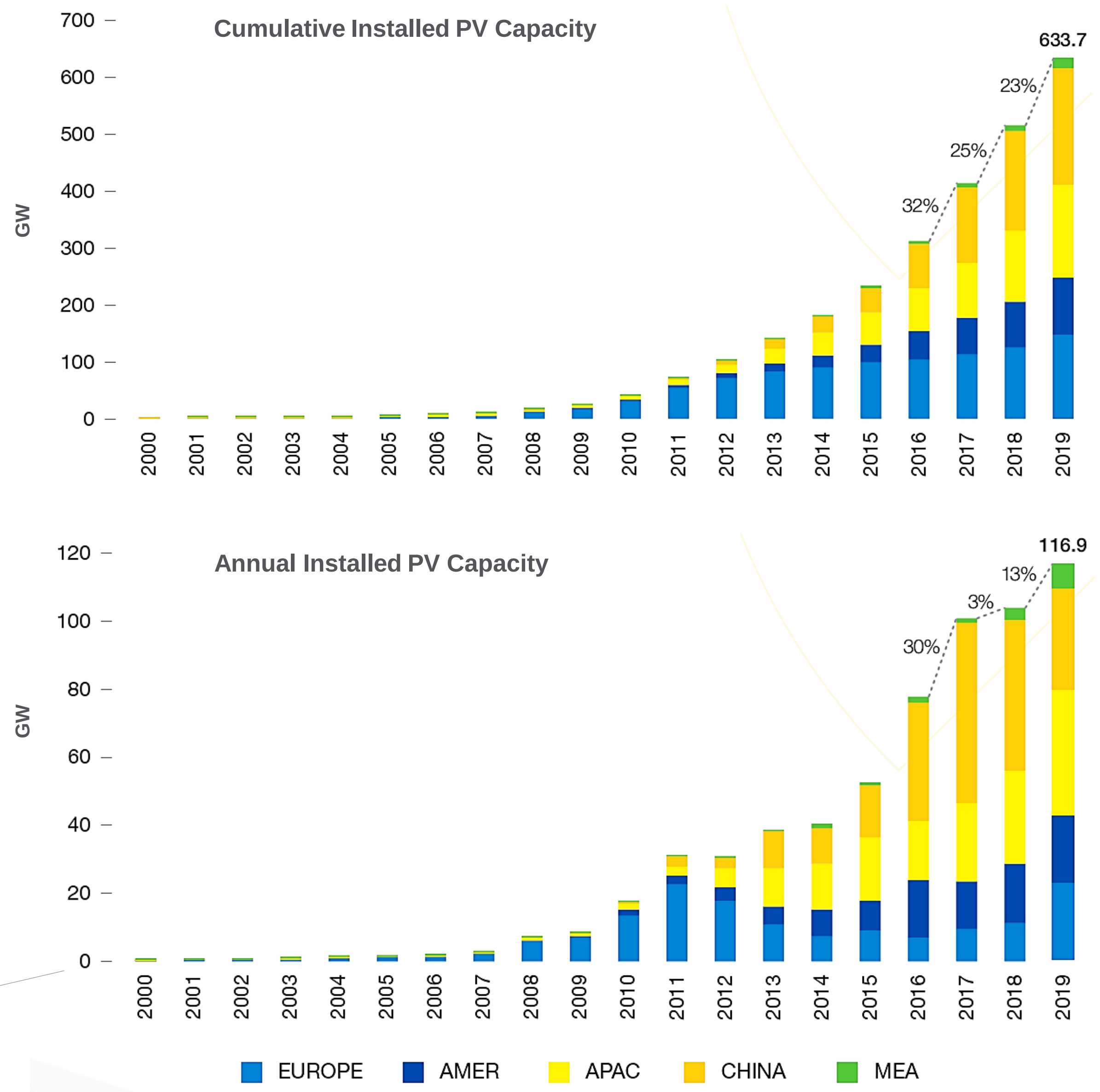


Figure 3 - installed PV capacity by region (GW). Top, cumulative installed capacity. Bottom, annual installed capacity. AMER - the Americas. APAC - Asia-Pacific excluding China. MEA - Middle East and Africa. Source: SolarPower Europe (2020): Global Market Outlook for Solar Power 2020-2024.

PV In The Mix

To get a better handle on the rise of PV we now compare the deployment of PV with other energy generation technologies.

In 2019, PV made up 48% of all electricity generation capacity additions worldwide, see **Figure 4**, below, and **Figure 5**, right. As in the year before, not only was more PV added than all fossil fuel and nuclear power generation capacities combined, 2019 also saw nearly twice as much power installed as wind, and more than all other renewables combined. As we have already hinted at and explore in detail later, the main drivers of this dominance have been and remain low cost and supportive policy.

Looking at **Figure 5** it is clear that - despite recent progress - the infiltration of PV into the electricity system is still relatively limited. At the end of 2019, PV only accounted for 8.5% of global energy generation capacity, 2.6% of global power output, and about 10% of renewable power output. And if we look at all renewables combined, these only supplied about 25% of global power output. This implies a significant market opportunity for renewables as countries decarbonise their economies to fight climate change, a process that seems inevitable at this point, given widespread support.

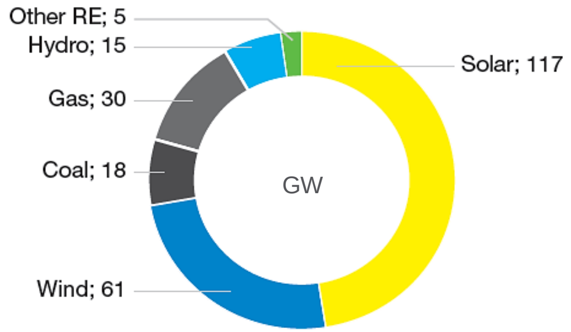


Figure 4 - global net power generation capacity added in 2019, by technology (GW). Source: SolarPower Europe (2020): Global Market Outlook for Solar Power 2020-2024.

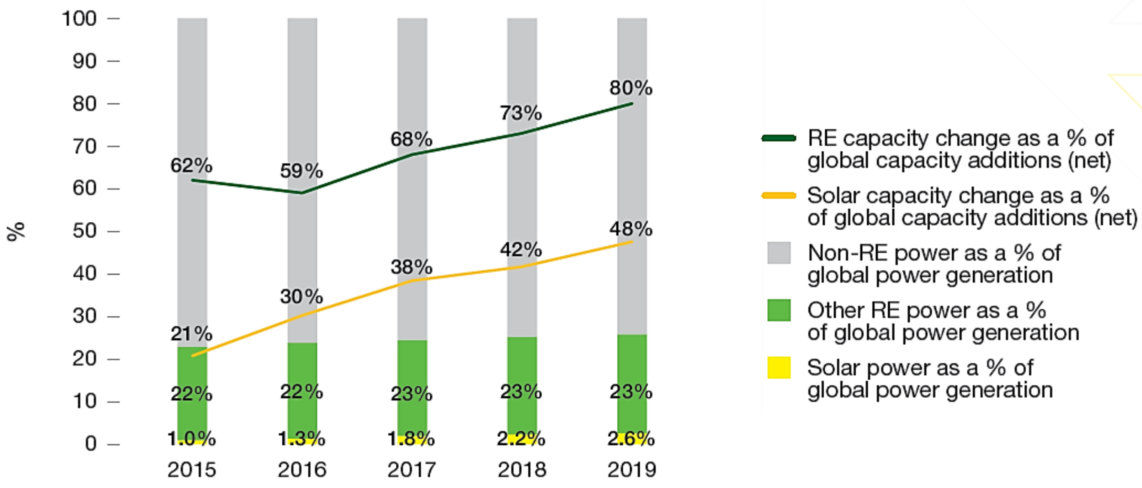


Figure 5 - global solar and renewable (RE) capacity/power as a share of total capacity/power. Source: SolarPower Europe (2020): Global Market Outlook for Solar Power 2020-2024.

As we cover in detail later, the EU has committed to becoming 'climate neutral' by 2050. This includes the complete decarbonisation of its electricity system. For most EU countries, PV and wind are the main options for achieving this, with nuclear, hydro, biomass, carbon capture and others likely to have a selective supporting role. As we quantify later, PV is increasingly competitive against all alternatives. In the EU, PV is already slightly more advanced than in the world as a whole - PV's share of total electricity generation is about 4% in 2019, up from about 1% in 2010. This is shown in **Figures 6** and **7**, overpage. **Figure 6** shows the generation mix in 2019, while **Figure 7** shows how the renewable share of generation has progressed over the last decade. **Figures 6** and **7** illustrate some key points:

- About a quarter of EU electricity comes from nuclear power. This is down about 10% on a decade ago, likely reflecting older plants going offline, and the lack of new plants coming online due to high relative cost, slow build times and mixed political support.

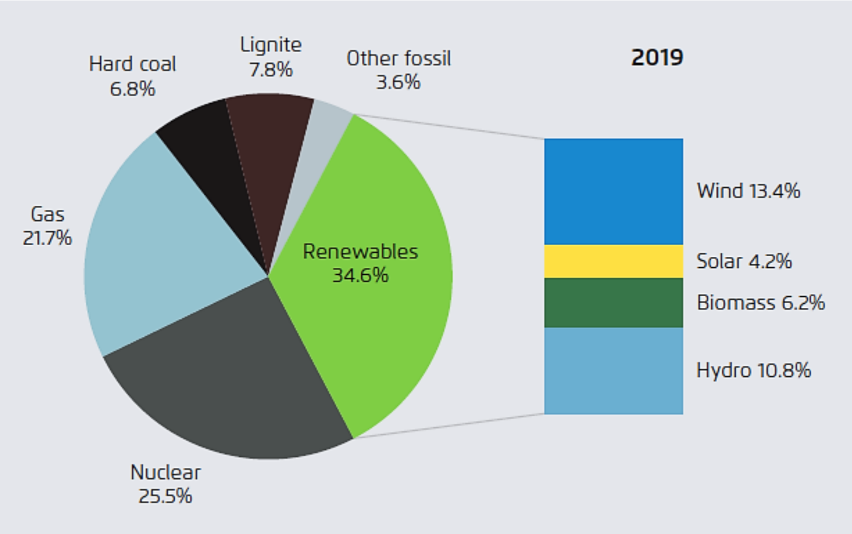
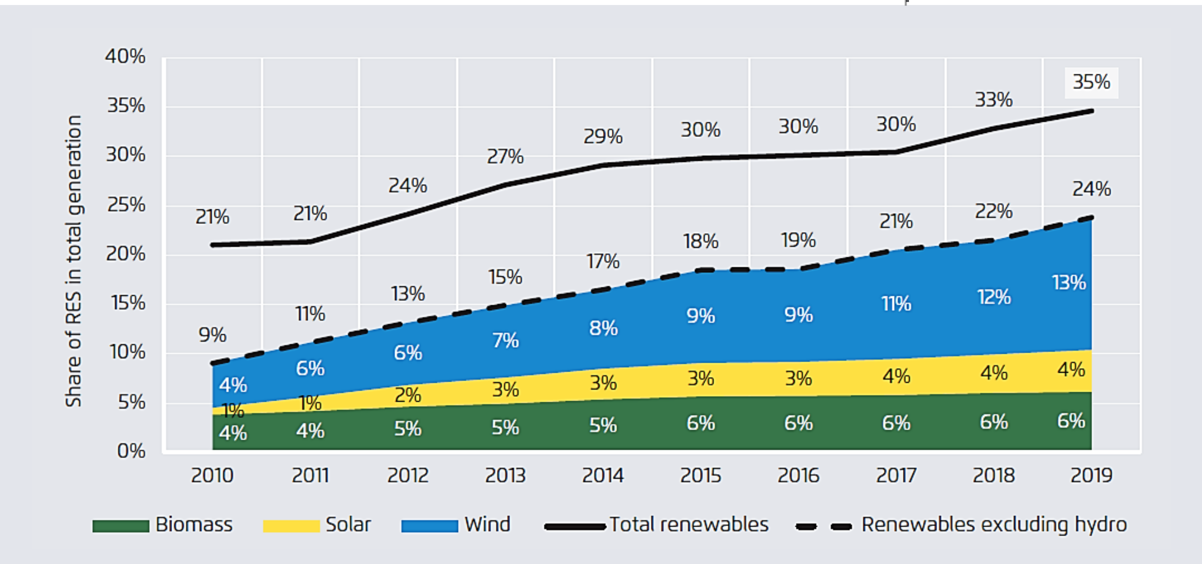


Figure 6 - EU electricity generation mix in 2019. Source: [The European Power Sector in 2019: Up-to-Date Analysis on the Electricity Transition](), by Agora Energiewende and Sandbag.

Figure 7 - EU renewables share as a percentage of gross electricity production. Source same as **Figure 6**.



- Coal and lignite combined remain a minor but not insignificant source of EU electricity. Their electricity output has fallen about 43% over the past decade, and as we cover later, many countries already have plans in place to phase them out completely. Capacity will have to come from elsewhere.
- Until recently, hydro was the dominate source of renewable electricity in the EU, but has not significantly changed its share of generation in the past decade.
- Wind overtook hydro as the leading renewable electricity source in 2018.
- Of all the renewable sources, PV has been the fastest growing on a relative basis over the past decade, with wind not far behind.

See [Appendix 1]() for a country-by-country breakdown of generation capacity in the EU.

As a brief aside, it is worth stating that the EU has a liberalised electricity market, meaning one in which electricity generation, supply and the electricity networks are separate regulated entities, with generation and supply open to competition. This market design has been introduced over the past three decades via EU legislation.

Included in EU legislation is the internal energy market, a set of rules to enable the harmonised, tariff-free trading of electricity between member states. Much more about the design of the EU electricity market [can be found in this (slightly dated) document]().

PV Classification

Before preceding further, it is useful to spell out the diversity that is implied under the term PV. Skip this section. Ignoring the specific type and make of technology involved, PV projects can be classified along several dimensions, including:

Nameplate capacity - the power output of the project under standard conditions. In this report, nameplate capacity is given in DC (meaning the power pre-invertor - the device that converts DC solar panel output into useful AC electricity). PV is an easily scalable technology, with nameplate capacities ranging from a few kW into the 100s of MW. This allows PV to operate in larger, centralised, or smaller, distributed forms.

Mounting - e.g. rooftop, ground, building-integrated or floating. Rooftop and ground-mount projects are by far the most common, with larger ground-mount systems increasingly incorporating tracking systems that move with the sun. The commercialisation of floating PV is in its early stages, the main benefits being more efficient land use and the cooling provided by the water improving panel efficiency. Building-integrated PV (BIPV) remains a niche market due to high costs, but has cosmetic advantages and may be able to increase the energy output from a given building compared to a rooftop-only install. Examples of BIPV include solar roof tiles, facades and windows.

Grid-connection - off-grid or grid-connected. PV projects are mostly grid-connected so some or all of the electricity generated can be sold, though can also be used to provide clean power in situations where a grid connection is not available, most usefully in combination with energy storage, covered overpage.

Projects that use electricity on-site are called '**self-consumption**' systems. Self-consumption of PV creates no ongoing carbon emissions and has minimal ongoing cost. These benefits can potentially be extended by using on-site PV to power the carbon-free electrification of things currently powered by fossil fuels. Two examples of this are PV plus EV (Electric Vehicle) charging, and PV plus heat pumps to provide heat for buildings, though the latter is not an ideal setup given the mismatched seasonality involved. As electricity is consumed at the grid edge, self-consumption also allows for increased consumption of renewable electricity without stressing the electricity grid.


Rooftop


Building integrated


Ground


Floating


Residential

C&I


Utility-scale

Grid-exporting PV projects potentially present a challenge in their integration, both in having the capacity to connect them to the grid in the first place, and in dealing with the high variability of and high correlation between these systems.

Use of energy storage - e.g. lithium ion batteries. Although still relatively expensive, adding storage is potentially advantageous for both the PV project and the wider electricity system. For self-consumption projects, storage has the potential to increase self-consumption and to open up new applications, such as use as short-term grid backup and for the overnight residential charging of EVs. For grid-exporting projects, storage's time-shifting capability may increase the value of electricity sold and make PV a more useful and lucrative network resource by enabling it to provide (a wider range of) flexibility services to grid operators.

In addition to these (and other) properties, PV projects can be classified more broadly into 'segments', reflecting their application - residential, commercial, industrial or utility-scale:

Residential systems typically operate in the single-digit kW range, consist of rooftop panels, and are grid-connected (although primarily intended for self-consumption), with the homeowner being the main off-taker - the entity using the electricity (buying it first, if relevant).

At the opposite end of the scale, **utility-scale** systems are large - 1 MW and up -, typically consist of ground-mount panels, and exist to supply electricity to the grid, just like a gas-fired power plant would. The off-taker is typically a utility company or large corporation.

Commercial and **industrial** systems sit in between these two extremes, and are often lumped together using the term '**C&I**'. These are typically rooftop or ground-mount, with self-consumption the main purpose. The size of these projects tends to be smaller than utility-scale projects - commercial <250 kW and industrial <1 MW. The main off-taker in these cases is the company for whom the system was installed.

Key Driver: Cost

The PV market in Europe (and elsewhere) is being driven mainly but not exclusively by two factors: (a) cost, covered in this section; (b) the policy environment, see the next section.

LCOE

One way of looking at the cost of PV is to use the 'Levelised Cost of Energy' (LCOE). The LCOE is a way of comparing costs between technologies using a standardised methodology that outputs the average price of electricity that a project must obtain to provide an acceptable return to equity investors *.

The top part of **Figure 8**, right, shows how the mean, unsubsidised LCOE values for utility-scale PV and other power technologies have developed over the past decade. As is illustrated very clearly here, PV has experienced an almost order of magnitude reduction in cost over the past decade, and now is similar in cost to wind, though its cost is still falling faster than wind. Both wind and PV are now cheaper than gas, and significantly cheaper than coal and especially nuclear (whose cost is noticeably rising).

The bottom part of **Figure 8** shows the 2019 LCOE ranges for the PV segments - introduced on the previous page - and other power technologies. These ranges come from allowing some underlying cost or performance assumptions to vary, reflecting differences found in real life. As you might expect, PV is most

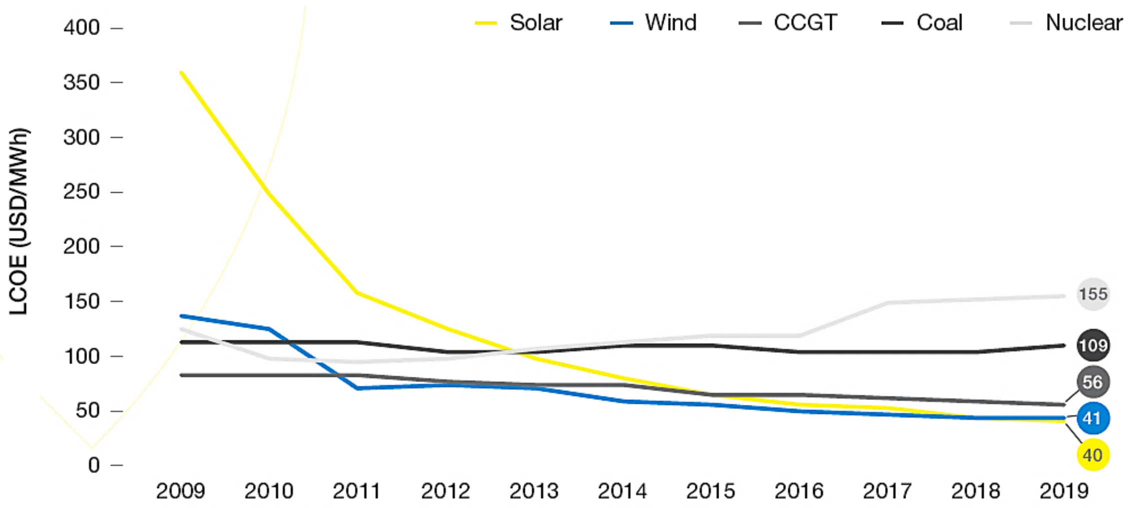
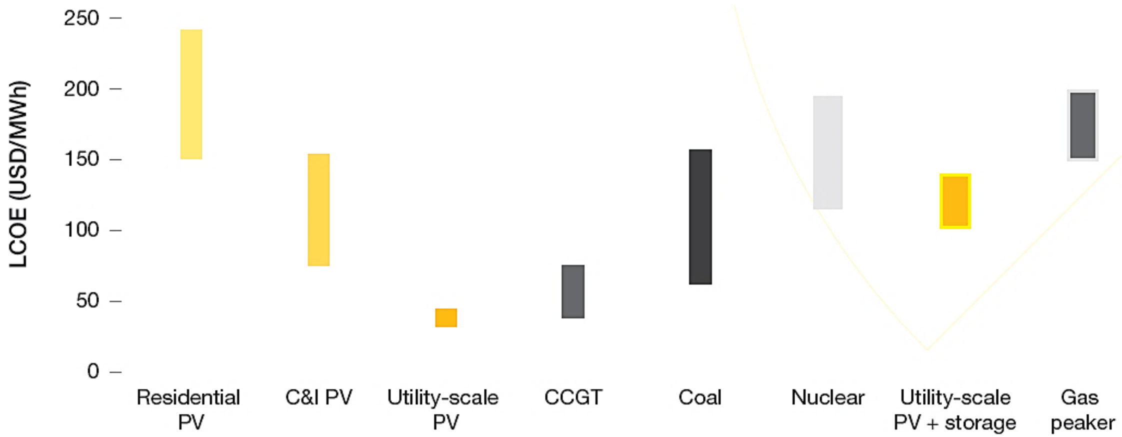


Figure 8 - levelised cost of utility-scale PV and other power sources ($/MWh). Top, 2009-2019, mean, unsubsidised LCOE values. Bottom, 2019 LCOE range. Both are nominal terms, post-tax. Source: SolarPower Europe (2020), Global Market Outlook for Solar Power 2020-2024. CCGT - Combined Cycle Gas Turbine. C&I - Commercial and Industrial.



* LCOE calculations on this page come from Lazard, who use a 12% IRR as the acceptable equity return, assuming 60% debt (at 8% interest rate) and 40% equity.

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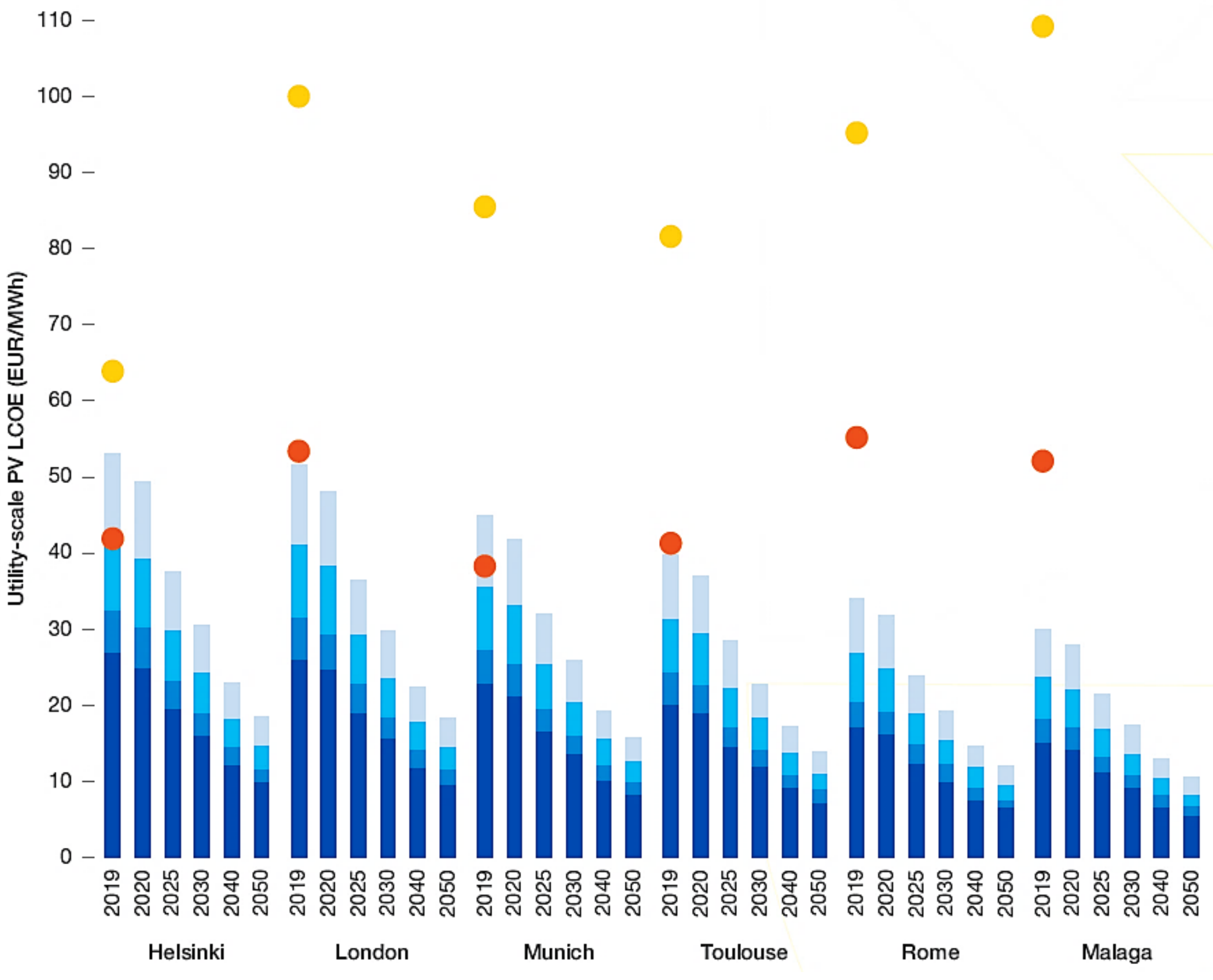
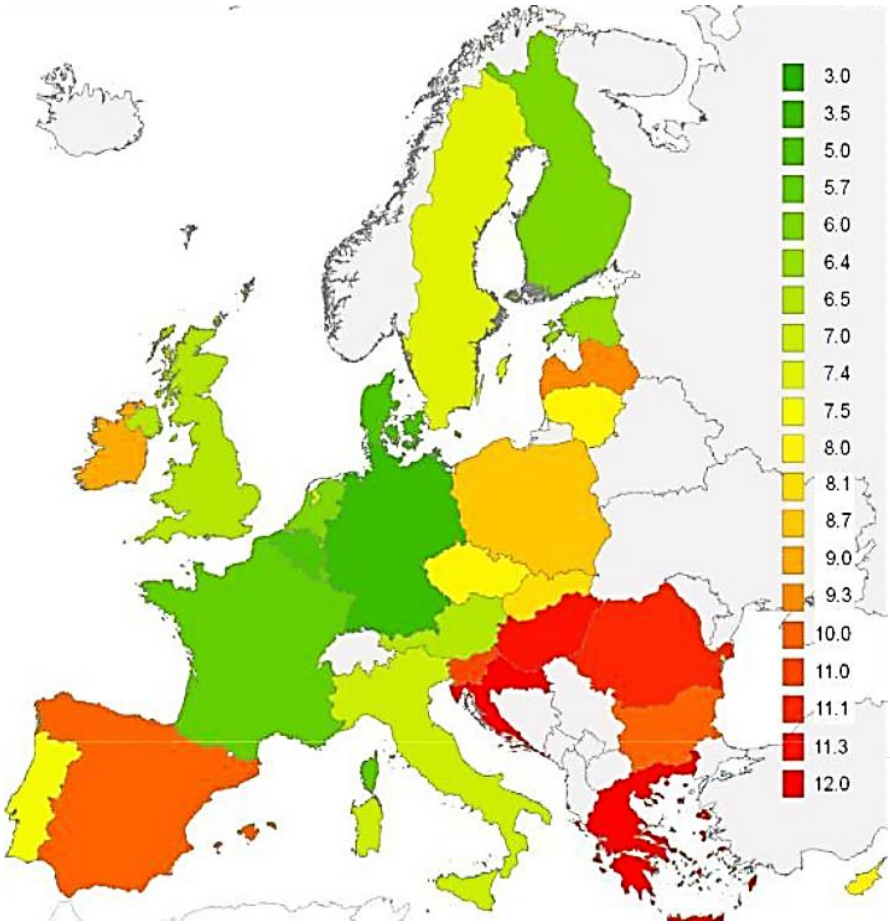


competitive at utility-scale, though both C&I and even residential PV segments are, to a lesser extent, competitive against some forms of conventional generation. Interestingly, the utility-scale PV plus storage combination is now cheaper than gas turbines used to meet peak demand (known as gas peakers). Both are able to perform a similar function, but PV plus storage is now cheaper - as well as obviously cleaner - largely due to the falling price of batteries.

Note that **Figure 8** underplays the advantage that PV has over conventional generation in Europe, in part because it ignores subsides and carbon pricing, both very much part of the picture, as we explore later. In addition, the LCOE calculations assume a Weighted Average Cost of Capital (WACC) of 7.7%. This is a very important assumption as the cost of capital typically contributes up to half of the cost of new PV projects. The IEA has found that the cost of capital for PV projects is, in reality, much lower than this on average in Europe, at 2.6-5%. See their World Energy Outlook 2020. In that report the IEA states that 'for projects with low-cost financing that tap high-quality resources, PV is now the cheapest source of electricity in history'. This quote highlights that the quality of the solar resource (shown back in **Figure 1**) is another key

Figure 9a - forecast utility-scale PV levelised cost in six European locations, 2019-2050 (€/MWh). Source: SolarPower Europe, EU Market Outlook for Solar Power 2019-2023. WACC - Weighted Average Cost of Capital.

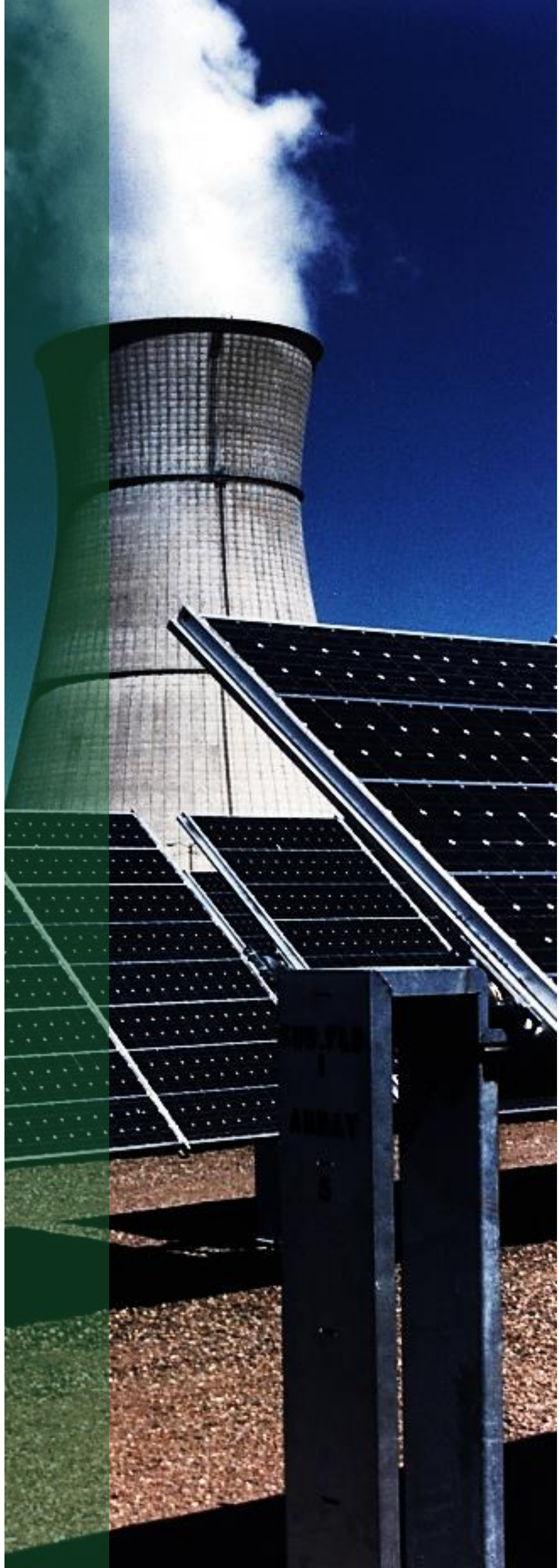
determinant of cost. **Figure 9a**, on the previous page, shows how letting the cost of capital and the location of the PV system within Europe vary impacts the LCOE. It quantifies explicitly how important the cost of capital is to the overall LCOE - e.g. in 2019, 2% WACC is very roughly 40% cheaper than 10% WACC. **Figure 9b**, below, gives some indication of how the WACC varies across member states (though please note this is slightly dated and for rooftop not utility-scale solar - the intended takeaway from this is the approximate ordering of WACC between countries). **Figure 9a** also quantifies how much more competitive PV is in the south of Europe - e.g. in 2019, Malaga (Spain) is roughly 40% cheaper than Helsinki (Finland).



Although LCOE forecasts should generally be taken with a pinch of salt, **Figure 9a** implies that PV's precipitous LCOE decline could still have some way to go. For the technical reasons why this a reasonable assumption, see the 'Trends' section of SolarPower Europe's report 'Global Market Outlook for Solar Power 2020-2024'.

Finally, **Figure 9a** suggests a simplistic way to assess project viability in a country - look at the gap between the relevant electricity price - e.g. wholesale (red dots), industrial (yellow dots) or residential (not shown here) - and the LCOE. Bigger gap means potentially more viable.

Figure 9b - Weighted Average Cost of Capital (WACC) of rooftop solar PV systems in the EU, 2016 (%). Source: PV Status Report 2019, European Commission.



Government Renewables Auctions

Although the LCOE is useful, it's theoretical. The reality of PV's competitiveness can be observed more concretely in the results of government renewables auctions and tenders. These are procurement mechanisms in which renewable energy supply or capacity is competitively solicited from sellers. Governments get an increased supply of renewable electricity in a controlled manner and (in theory) at least cost, while the winners typically get a guaranteed price per kWh for electricity generated over a multi-year period, usually covering the debt repayment period of the project. The mechanism may be focussed on certain technologies - e.g. PV, wind, etc. - or be technology-neutral. Appendix 6 lists the EU auctions/tenders held in 2019. The distinction between an auction and a tender is that with tenders factors other than pure price are typically taken into account in determining the winners. We look at other ways governments influence PV development shortly; this is one of the more important and direct ways, especially for larger-scale projects.

Figure 10 shows the global average prices for recent wind and PV tenders/auctions. Since auctions for commissioning in 2019, PV has been cheaper than wind, on average. In several EU countries, including Denmark, Germany, the Netherlands and Spain, PV has shown that it can win technology-neutral tenders against any other renewable technology.

Although Europe has not historically had the cheapest auctions in the world, the world's lowest solar power contract at the time was awarded in Portugal's first solar energy auction in 2019 at 1.47 € cents/kWh (1.65 $ cents) for a 150 MW system. In 2020, Portugal set another world record in their second auction with a roughly 10% lower price.

We will not go into any detail but another useful way of assessing PV's cost is to use the transaction values when PV projects are bought and sold. More in this report from Deloitte.

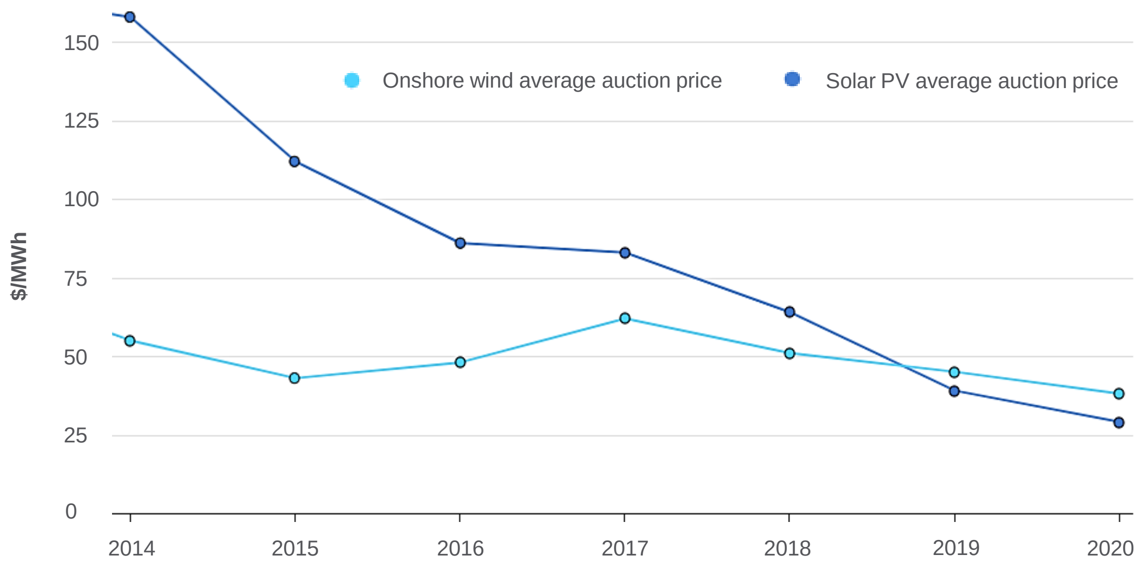


Figure 10 - global wind and PV average auction prices by commissioning date, 2014-2020 ($/MWh). Source: International Energy Agency (IEA).

Key Driver: Policy

In this section we look at the second of the two main drivers of the European PV market - the policy environment. This is a complicated area as policy in member states is determined at EU, national and potentially also sub-national levels. Government policy is one of the key factors that has helped drive down the cost of PV, and, now that is so competitive, governments are increasingly taking solar into account in their climate strategies, even as the need for explicit subsidies is - or would otherwise be - starting to fade. We start with broad, EU-level policy, before moving on to broad and then fine-grained member state policy.

Current EU-Wide Targets

The EU completed a major update of its energy policy framework in 2019 in the clean energy for all Europeans package, currently being turned into national law by member states. This package includes a number of targets that member states must meet by 2030. These are updated versions of a similar set of targets for 2020 which have been important in stimulating recent PV activity. Relevant targets include those that focus on:

Greenhouse gas emissions - the EU is committed to a binding target of an at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990, to be fulfilled jointly by member states. This is the target stated in the EU's Intended Nationally Determined Contribution (NDC) under the Paris Agreement, the international agreement to limit global warming. This target is being implemented by a range of legislation, including the EU Emissions Trading System (ETS), the Effort Sharing Regulation, the Land Use, Land Use Change and Forestry Regulation, and the CO_2 Standards for Cars and Vans Regulation. We outline a couple of these to the right; search on the EU website for more detail.

The EU's Emissions Trading System (ETS) covers greenhouse emissions from large-scale facilities in the power and industry sectors, as well as the aviation sector. See **Figure 11**. The ETS covers around 45% of the EU's greenhouse emissions, making it the largest carbon market in the world. It operates on the 'cap and trade' principle, which puts a cap on the total greenhouse gas emissions that can be emitted under the system. Within the cap, which reduces over time, companies receive or buy emission allowances (EUAs), which they can trade with one another as needed to meet penalisable obligations under the system. See the current price of EUAs. Sectors not covered by the ETS - such as housing, agriculture, waste and transport - are instead covered by the Effort Sharing Regulation, which gives each member state a bespoke annual target for cutting emissions in those sectors.

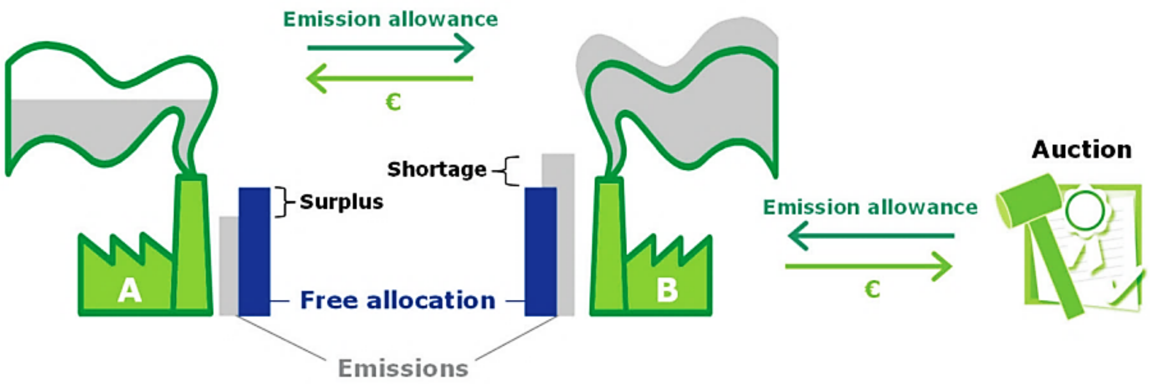


Figure 11 - the basic principles of the EU's Emission Trading System (ETS). Source: EU ETS Handbook. See this source for a fuller explanation.

Overall energy use - by 2030 the EU is looking to reduce overall energy usage by 32.5% compared to a 2007 baseline. This is stipulated in the Energy Efficiency Directive. In practice this means most EU countries will have to achieve new final energy consumption savings of 0.8% each year for the 2021-2030 period.

Renewables as a share of final energy consumption - the EU has an overall target of renewables contributing 32% to final energy consumption by 2030. This target is included in the Renewable Energy Directive, which includes bespoke 2030 targets for each member state. The 32% figure translates into around 57% renewable electricity in the EU power system by 2030. This target is clearly very important for PV.

Energy use in buildings - the EU is aiming to decarbonise its entire building stock by 2050. This is part of the Energy Performance of Buildings Directive. A key component of this directive is the requirement that all new buildings starting in 2021 must be 'nearly zero-energy buildings' (NZEB). These are defined as having very high energy performance, with the low amount of energy that these buildings do require coming mostly from renewable sources, see **Figure 9**.

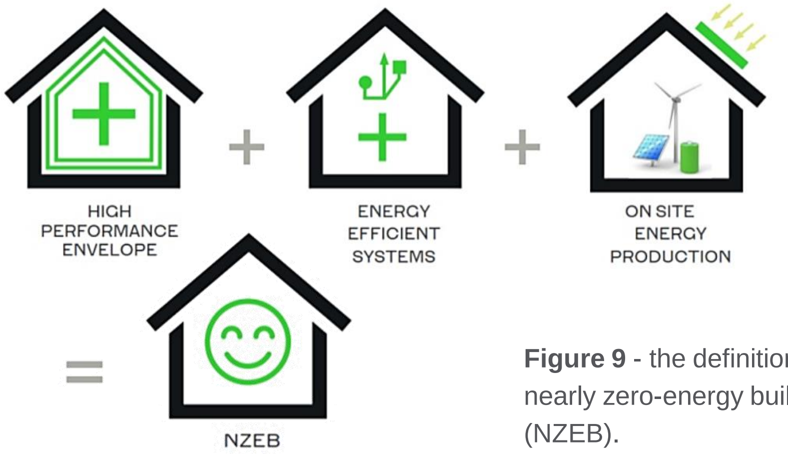


Figure 9 - the definition of a nearly zero-energy building (NZEB).

European Green Deal

Since adopting these 2030 targets, the EU has already increased its climate ambitions in the European Green Deal, a plan to make its economy sustainable, including becoming 'climate neutral' - meaning net-zero greenhouse gas emissions - by 2050, see **Figure 10**, overpage. This is currently a political commitment, though the intention is to make it legal through the European Climate Law.

To provide a balanced pathway to this 2050 goal, it has been proposed that the EU-wide 2030 greenhouse gas reduction target be increased from 40% to at least 55%. Implementing this will require all relevant legislation to be reviewed and updated as necessary, including the renewables target. It is estimated that with this 55% target, annual investment in the energy system will need to be around €350 billion higher in the coming decade (2021-2030) than in the previous decade (2011-2020).

One of the many prongs of the Green Deal is the Renovation Wave strategy, which aims to double annual building energy efficiency renovation rates in the next ten years, renovating 35 million inefficient buildings by 2030. It has been proposed that this strategy include a 'massive rollout of rooftop solar'.

Other relevant strategies proposed as part of the Green Deal include the EU strategies for Energy System Integration and Hydrogen. The hydrogen strategy is particularly eye-catching as it sets a goal of 6 GW of electrolysers for the generation of green hydrogen by 2024, and 40 GW within the EU (and 40 GW in nearby countries) by 2030. Only 250 MW exist globally today, according to Wood Mackenzie. These new electrolysers will need to be powered by clean energy from PV or otherwise. Learn more about hydrogen in our sector report on the subject.

To achieve the goals set by the Green Deal, the related Investment Plan will aim to mobilise at least €1 trillion in sustainable investments over the next decade, roughly 50% of this coming directly from the EU budget (30% of the total EU budget), the rest from other public and private sources, with the InvestEU investment programme key. One part of the plan, the Just Transition Mechanism, aims to mobilise at least €100 billion in investments over the period 2021-2027 to support workers and citizens of the regions most impacted by the transition.

The European Investment Bank's (EIB) contribution to the Green Deal Investment Plan is expected to amount to around €250 billion. The EIB is the lending arm of the EU. However, over the next decade the EIB will 'aim to support' a larger €1 trillion of investments in 'climate action and environmental sustainability', gradually increasing the share of its financing dedicated to this sector to reach 50% of its operations in 2025 and from then on. In addition, the EIB will no longer consider new financing for unabated, fossil fuel energy projects, including gas, from the end of 2021 onwards.

The Role of Private Finance

As 350 PPM is a private equity firm, it would be remiss of us not to point out that the Green Deal Investment Plan relies on and includes specific measures aimed at leveraging private finance. Even prior to the Green Deal, the EU was already taking important steps to unlock sustainable private finance, as seen in the Action Plan on Sustainable Finance, adopted in 2018.

More concrete recent steps taken to unlock private finance include:

- The launch of the International Platform on Sustainable Finance in 2019, whose members include the EU and 14 other countries. The objective of this platform is to 'scale up the mobilisation of private capital towards environmentally sustainable investments'.
- The expected launch in 2021 of the Renewable Energy Financing Mechanism. This mechanism is designed to allow member states to cooperate on renewable energy projects. It would allow, for example, Sweden to invest in a PV project in Greece but count the emissions reductions achieved toward its own targets.

These and other moves by the EU should help stimulate the private financing of PV. According to SolarPower Europe, the main obstacle to such financing today is the lack of regulatory certainty in several EU countries, increasing the cost of capital and therefore harming the profitability of PV investments.

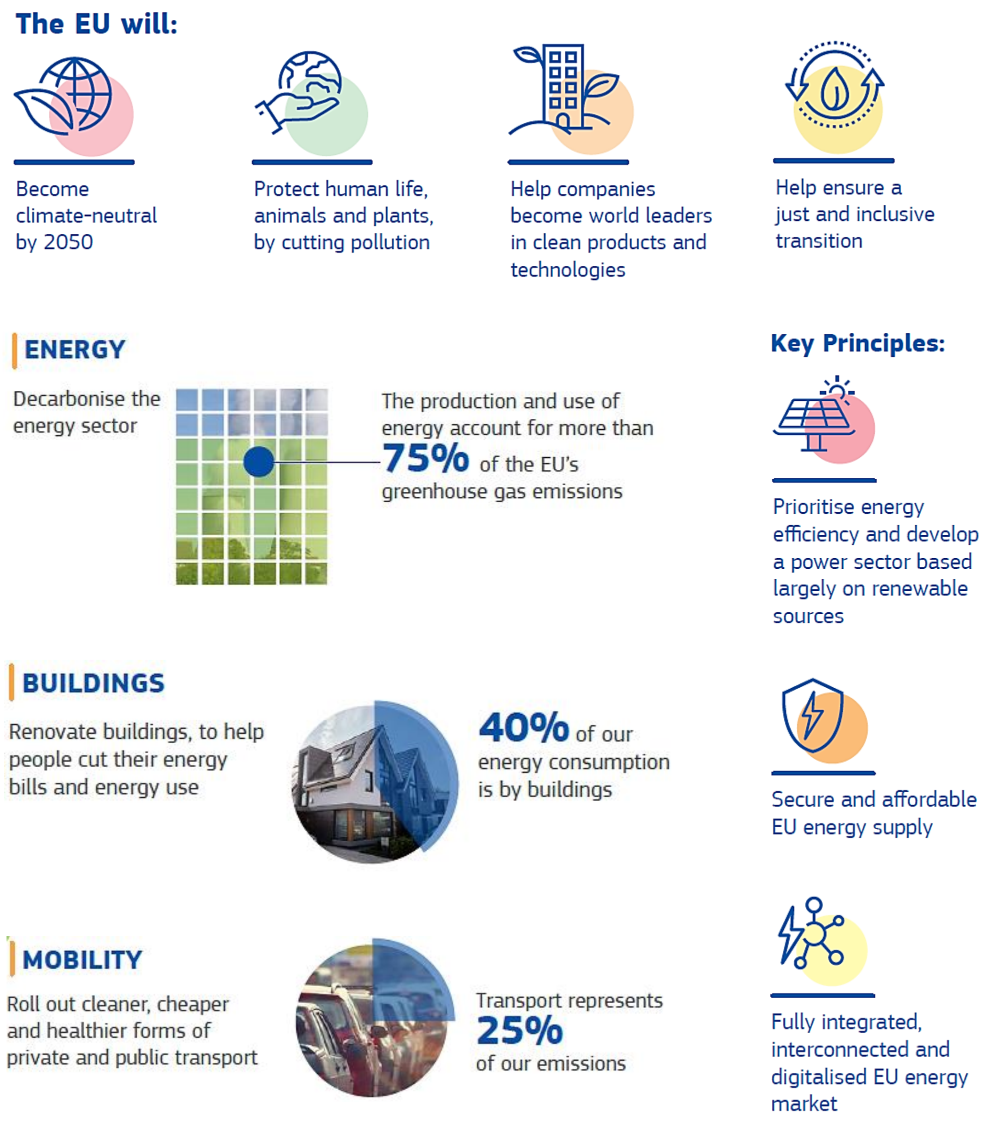


Figure 10 - key aspects of the European Green Deal. Source: various EU leaflets.

Broad Member State Policy

EU member states have to comply with EU legislation at a minimum but may choose to go further than required. They also have to convert EU directives - that state what must be done but not how it must be done - into concrete national policy. For these (and other) reasons, this means that national policy differs quite significantly between member states. In this section we outline a few of the broadest elements of national policy.

Guided by EU targets but sometimes extending beyond them and adding others, many member states have bespoke energy and climate targets. Targets relevant to PV include: renewable share of (primary or) final energy consumption, see **Figure 11**, below left; renewable share of electricity generation, see Appendix 3; less common, technology-specific share of electricity generation, see Appendix 4; and installed capacity or generation from a specific technology, see Appendix 5. In addition to these, some member states have bespoke greenhouse gas targets, with the most common choice being net-zero by a given year. The target year varies by country: Finland - 2035, Austria - 2040, Sweden - 2045, and Denmark, Germany, France and Spain all targeting 2050, as is the UK.

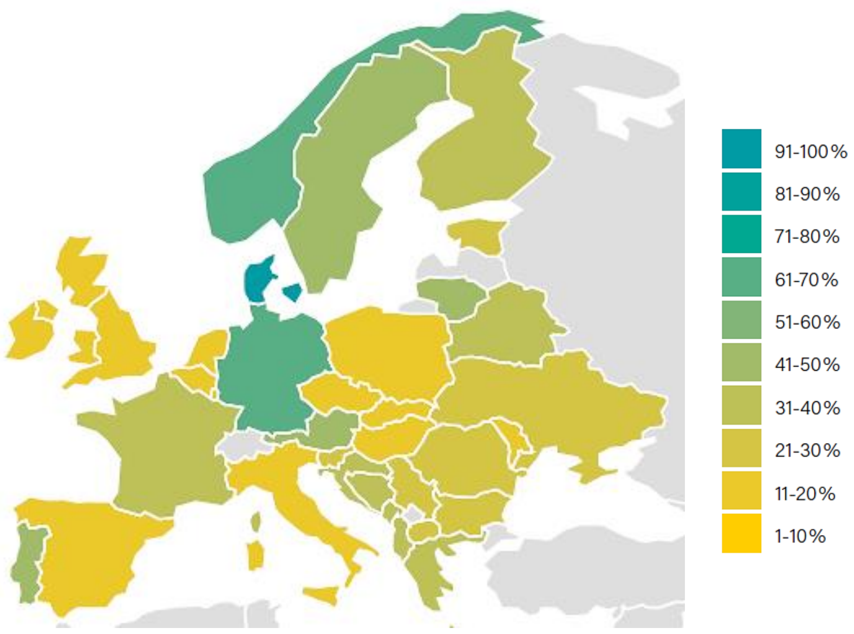


Figure 11 - national targets for renewables as a share of final energy consumption, by a specific year, in place at end-2019. Source: Renewables 2020 Global Status Report by REN21.

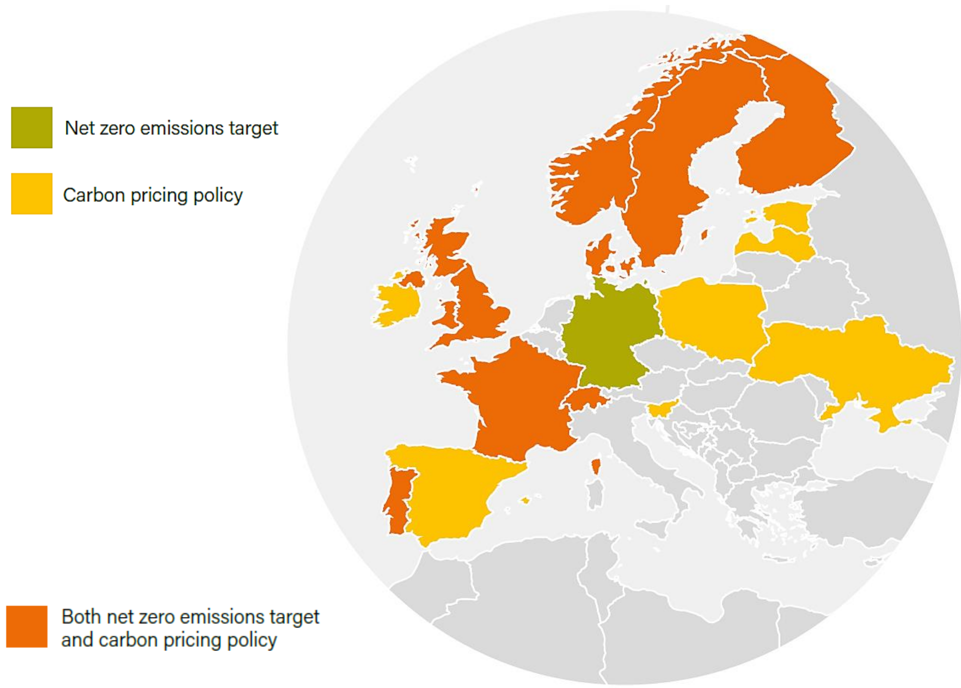
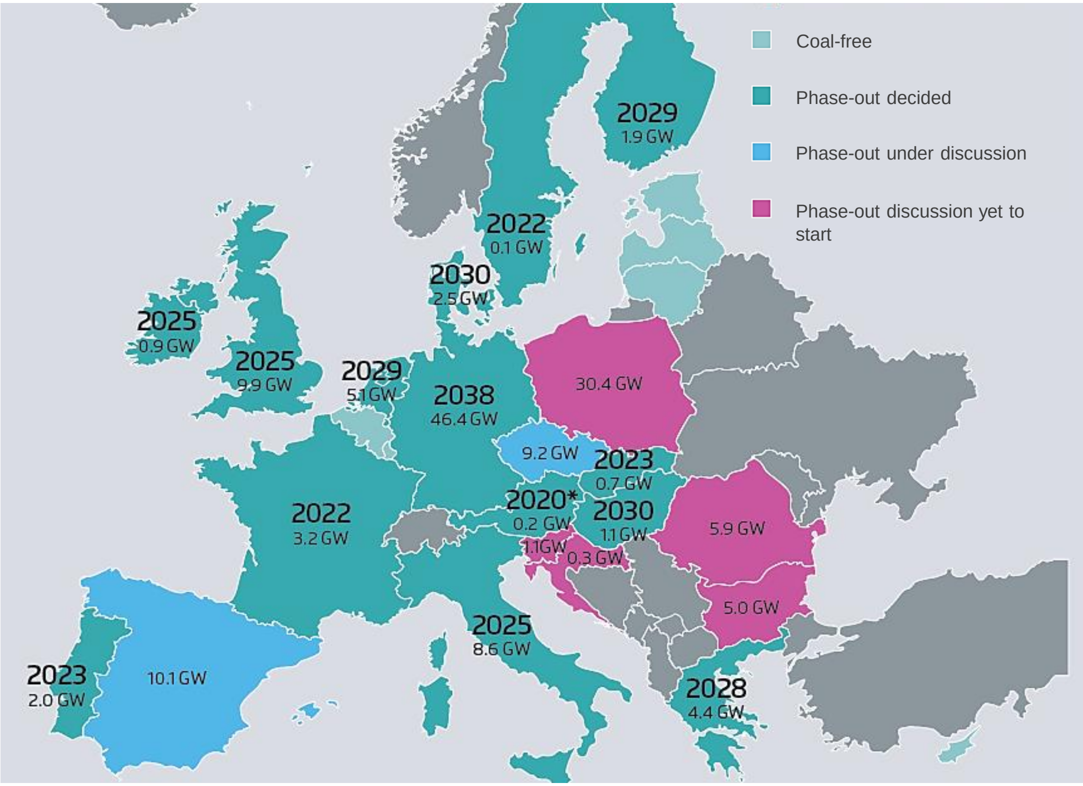


Figure 12 - member states with net-zero emissions targets or carbon pricing policies, early 2020. Source: Renewables 2020 Global Status Report by REN21.

To discourage the use of fossil fuels and to encourage the switch to renewables, several member states have introduced a national carbon pricing policy that is separate from and additional to the EU's Emissions Trading System, introduced earlier. **Figure 12**, on the bottom right of the previous page, shows the countries with a net-zero emissions target, a carbon pricing policy, or both.

The use of coal is obviously not compatible with the Green Deal but several member states still have considerable coal-powered generation, with Germany being the worst offender. Germany, along with all but a few of the Eastern European countries, have already decided on phase-out dates for coal and put phase-out plans in place (Germany is also phasing out all nuclear generation by 2022). The status of the phase-out discussions and the target phase-out dates are given in **Figure 13**, below left. Coal phase-out clearly represents an additional opportunity for PV.

There are other things that will have to be phased out to comply with the Green Deal, e.g. combustion engine vehicles - see **Figure 14**, below right, for announced phase-out dates for passenger cars (there is no EU date yet), fossil fuel heating, and fossil fuel subsidies, which amounted to €50 billion across the EU in 2018.



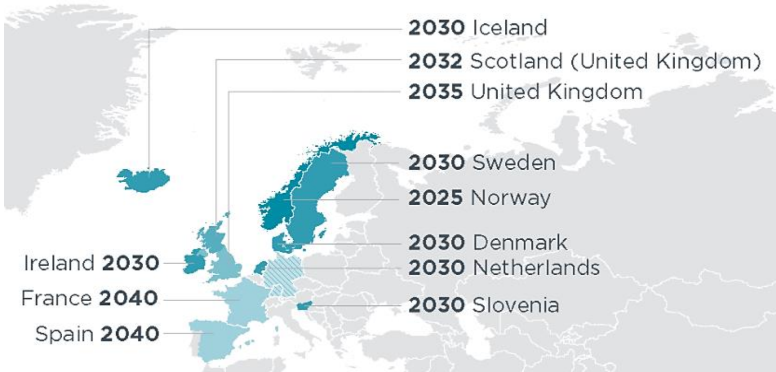


Figure 14 - European countries with announced phase-out dates for new sales of passenger combustion engine passenger cars, as of end-2020. Source: The International Council on Clean Transportation (ICCT) staff blog.

Figure 13 - status of coal phase-out discussions and target phase-out dates, as of end-2019. Source: The European Power Sector in 2019: Up-to-Date Analysis on the Electricity Transition, by Agora Energiewende and Sandbag.

Renewable Electricity Policy

We now move on to the specific policies by which governments and their energy regulators influence the uptake of renewable electricity and PV in particular, thereby implementing the broader policy ambitions covered earlier. Skip section. Although there is some overlap, we divide these policies into those mainly aimed at centralised or distributed renewable electricity production, and those focussed on the energy system integration of both types. See Appendix 2 for an overview of which of the policies apply to each member state. For more detail see the National Energy and Climate Plans (NECP) for 2021-2030 (these will change for the Green Deal).

One area of policy that potentially applies across all our categories are **fiscal incentives** and **public financing**. Both play a role in spurring investment in the installation of renewables and are widely used. Examples of fiscal incentives include: reductions in sales, energy, CO_2, VAT or other taxes; investment or production tax credits. Public financing includes direct public investment, as well as government loans, grants, capital subsidies or rebates.

Centralised Policy

Policies that promote large-scale, centralised, renewable power include:

- **Feed-in policies (tariffs and premiums)** (23 EU countries, end-2019)

Feed-in policies typically work as a subsidy paid by the government for each unit of electricity produced (known as a feed-in tariff), or an amount above the market price of electricity (known as a feed-in premium), over a fixed period. Feed-in policies have been used to help both centralised and decentralised renewables, though the trend is to use tenders and auctions to support centralised renewables, rather than feed-in policies.

- **Tenders and auctions** (19 EU countries)

Many countries continue to turn to competitive auctions or tenders in place of feed-in policies for large-scale renewables. We described these in an earlier section.

- **Tradable Guarantee of Origin (GO) certificates** (all EU countries)

All EU countries are obliged to operate a Guarantee of Origin (GO) scheme, a way of proving and tracking that electricity is from a renewable source, see **Figure 15**. A single GO certificate is awarded to certify the generation of one unit of renewable electricity. GOs have monetary value and are tradeable, either separate from or bundled with the sale of the electricity itself. GOs allow companies to prove that they have met externally imposed renewable electricity obligations (see next page) and provide one way that companies can voluntarily source renewable electricity; we look at others later. GOs also provide a small amount of additional income to renewable generators from their sale. In 2019, the EU required its member states to recognise GOs issued by other states.

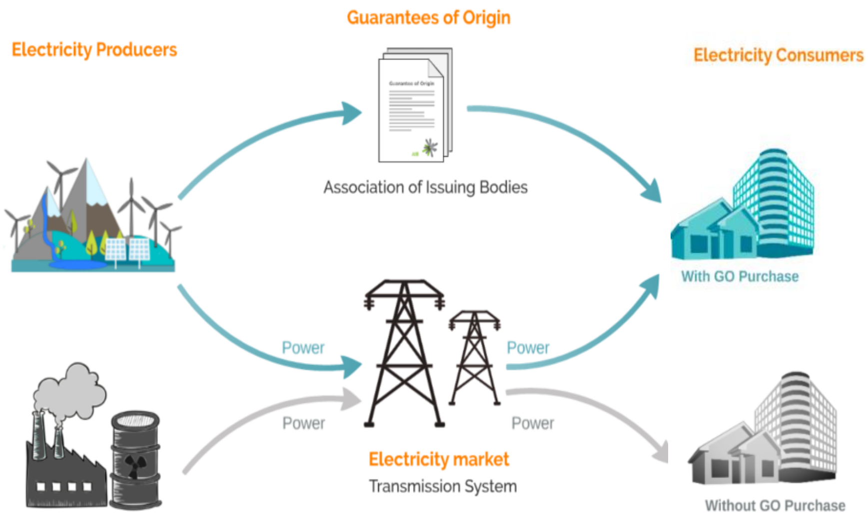


Figure 15 - the EU's GO scheme. Source: trackmyelectricity.com.

- **Renewable Portfolio Standard (RPS) and other quota obligations** (8 EU countries)

To give a rather wordy official definition, a Renewable Portfolio Standard (RPS) (also known as a 'renewable electricity standard', 'renewable obligation', or 'mandated market share') is an obligation placed by a government on a utility company, group of companies or consumers to provide or use a predetermined minimum targeted share of installed renewable capacity, or of renewable electricity generated or sold. A penalty may exist for non-compliance. This method is relatively rare in the EU.

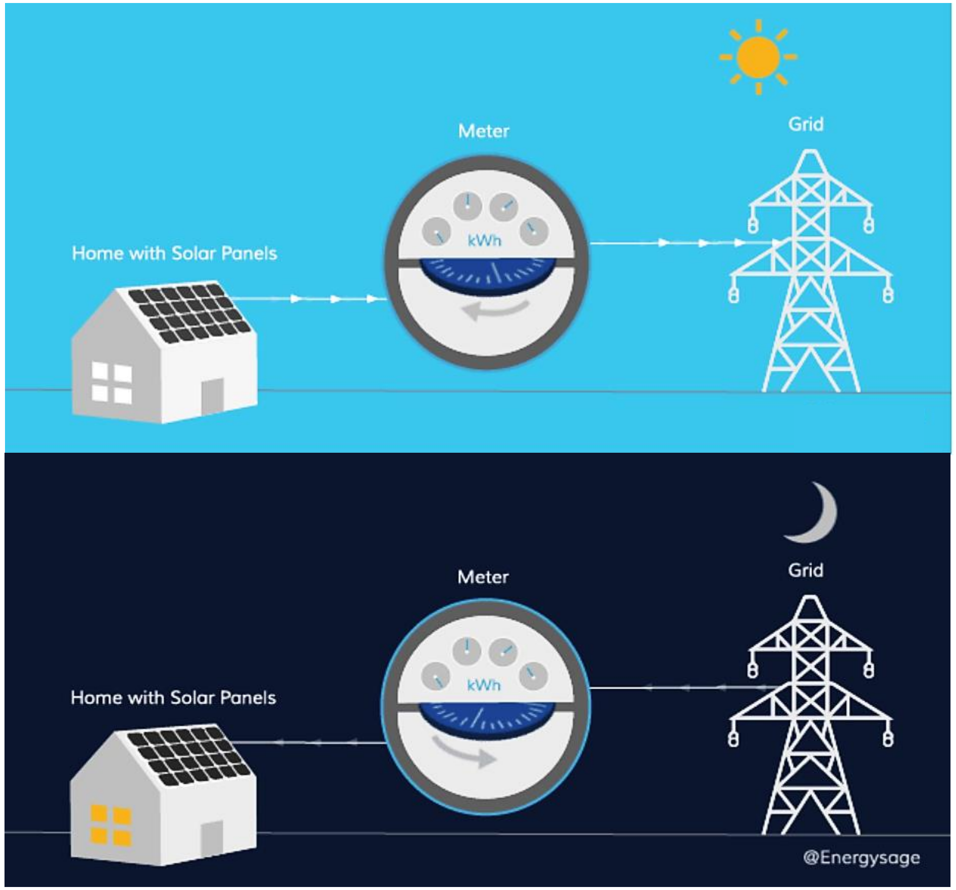


Figure 16 - how net metering works. Source: energysage. Learn more about net metering at this source.

Distributed Policy

Policies that promote the deployment of smaller-scale, distributed, renewable technologies - mainly aimed at self-consumption rather than grid export, though grid export is often important for the economics - include:

- **Tenders and auctions** (19 EU countries)

Although tenders and auctions are more commonly used for centralised renewables, some countries use them for smaller systems too - typically down to commercial but not residential size.

- **Feed-in policies (tariffs and premiums)** (23 EU countries)

Feed-in policies - explained on the previous page in relation to centralised renewables, though more common and often more generous for distributed systems - and net metering policies - see below - provide alternative mechanisms for the renumeration of electricity exported from distributed renewables. These are the main support mechanisms for residential PV in particular (other residential policy influences are covered on the next page).

- **Net metering policies** (14 EU countries)

Under a net metering framework, excess electricity injected into the grid can be used at a later time to offset consumption from the grid, see **Figure 16**. Loosely speaking, the grid is used as a 'backup system' for excess power production. Although a simple system, without added limits net metering is very generous - the remuneration of excess production is made at the retail price. A variation of net metering called **net billing** calculates the value of the excess electricity fed into the grid at the (much lower) wholesale price.

- **Solar mandates** (a few sub-national EU regions, e.g. German state of Bremen)

Solar mandates stipulate that solar *must* be used in certain circumstances. Typically this applies to rooftop solar for new build properties, and sometimes also for major renovations. Such mandates are rare.

- **Community energy policies**

Community energy policies permit or foster the development of community energy projects - local residents or businesses jointly participating in a renewable energy project. An example policy is **virtual net metering (VNM)**, an extension of the net metering system described above, in which multiple customers can receive net metering credits tied to their portion of a shared system.

System Integration Policy

Policies that can advance the integration of centralised and/or distributed renewables include:

- **Policies to improve the electricity infrastructure and grid connection process**

As noted earlier, renewables can present a challenge in their integration; the existing electricity infrastructure was not designed for large amounts of variable and distributed generation. Policies to expand or modernise national grid infrastructure are therefore key, as are policies to improve interconnections between countries. Assuming there is capacity for renewables to connect to the grid, the administration of the connection process is also important, allowing credible projects to get connected as quickly and cheaply as possible.

- **Changes to electricity market design**

Like the physical grid infrastructure, the rules that determine how the electricity markets operate were not designed with renewables or enabling technologies such as energy storage and digital infrastructure (smart meters, smart appliances, digital monitoring and automation etc.) in mind. Updated rules allow for and make more economic the integration of renewables and enabling technologies on all scales. For more about the concept of digitalisation as applied to solar and its relation to policy, see this SolarPower Europe report.

Taking residential solar as an example, relevant rules include those related to:

- Grid access - whether residential PV has 'priority access' to the grid, meaning it is never told that it cannot export electricity to the grid.
- Market access - whether residential PV systems and community PV energy projects are able to access markets, both for the direct sale of electricity and for grid flexibility services.
- Smart meter - whether a household has the right to have a smart meter installed. Smart meters are required for schemes such as net metering and dynamic pricing, see below.
- Dynamic pricing for electricity consumption - whether a household is financially rewarded for shifting electricity consumption to times when energy is widely available and cheap.
- Grid access charging - whether a household is charged fairly for access to the grid, given that it is using the grid less by self-consuming a certain proportion of their electricity.

In 2019, as part of the previously mentioned clean energy for all Europeans package, legislation was adopted that benefits residential PV by addressing, to a certain degree, most (not all) of the issues mentioned above. This package included a redesign of the EU's electricity market rules to make the 'electricity market fit for the challenges of the clean energy transition'. The details can be found at the above links.

Market History

Following on from the broad strokes of the '[Overview](#)' section, in this section we drill down into the history of the the EU PV market on a country-by-country basis.

Cumulative Installed Capacity

Figure 17, right, shows the last two decades of PV growth in the EU. The top part of **Figure 17** shows cumulative installed PV capacity up to the end of 2019 (we talk about the bottom part separately later). From this it is clear that Germany is the region's largest PV operator by far, with 49.9 GW of capacity, followed by Italy at 20.5 GW. Combined, Germany and Italy are home to over half of the EU's solar capacity. The UK (13.3 GW), Spain (10.6 GW) and France (~10 GW) also have significant, two-digit GW markets.

Looking beyond these high-fliers, twelve other EU countries have capacities in the one-digit GW category. Two of these are quite sizeable - the Netherlands (6.7 GW) and Belgium (4.7 GW) - while the bulk of EU countries fall in the 1-2 GW category (Austria, Bulgaria, Czech Republic, Denmark, Hungary, Greece, Poland, Portugal, Romania). The majority of EU member states had more than 1 GW installed at the end of 2019, a fact that was not true at the end of 2018.

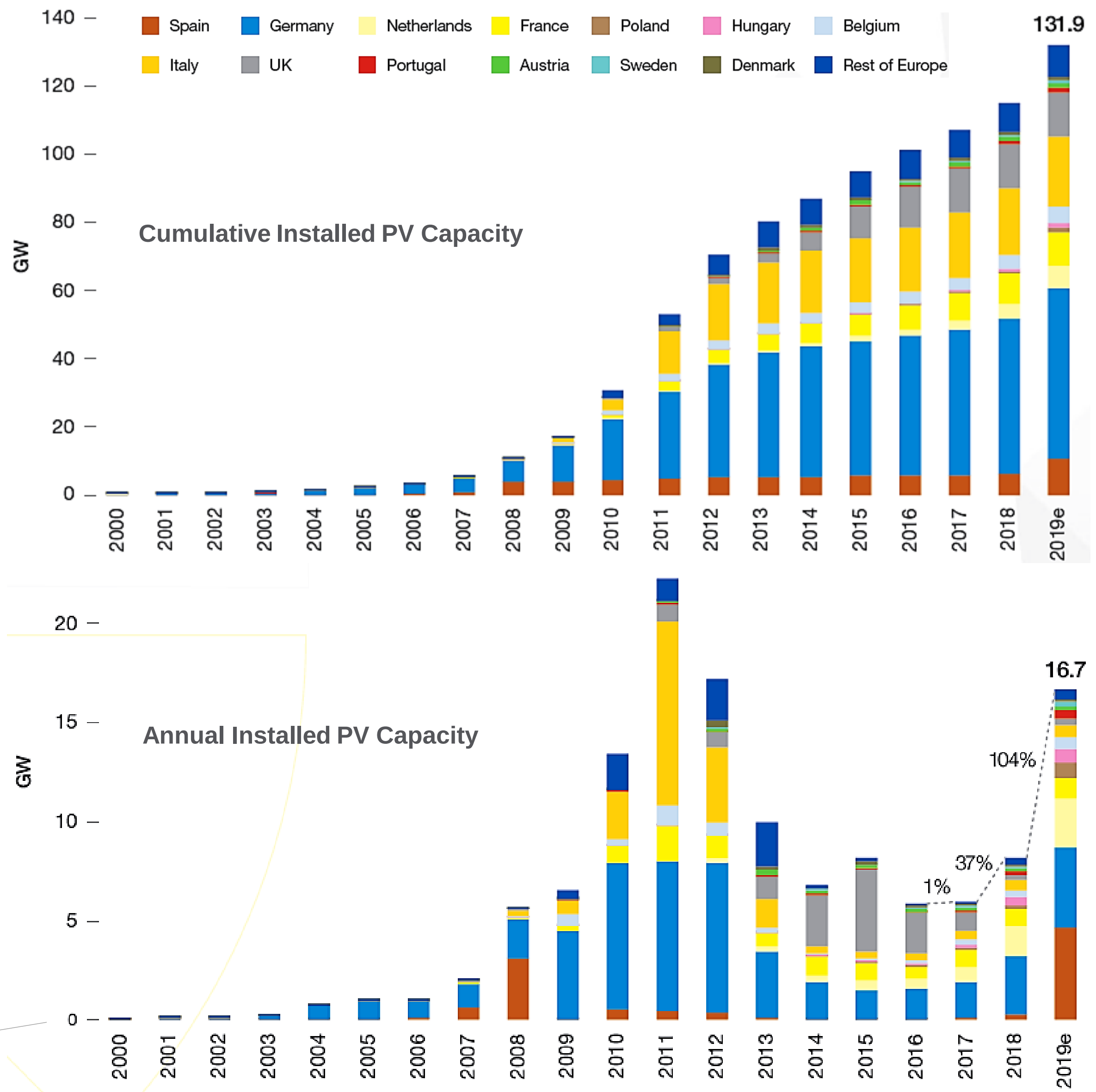
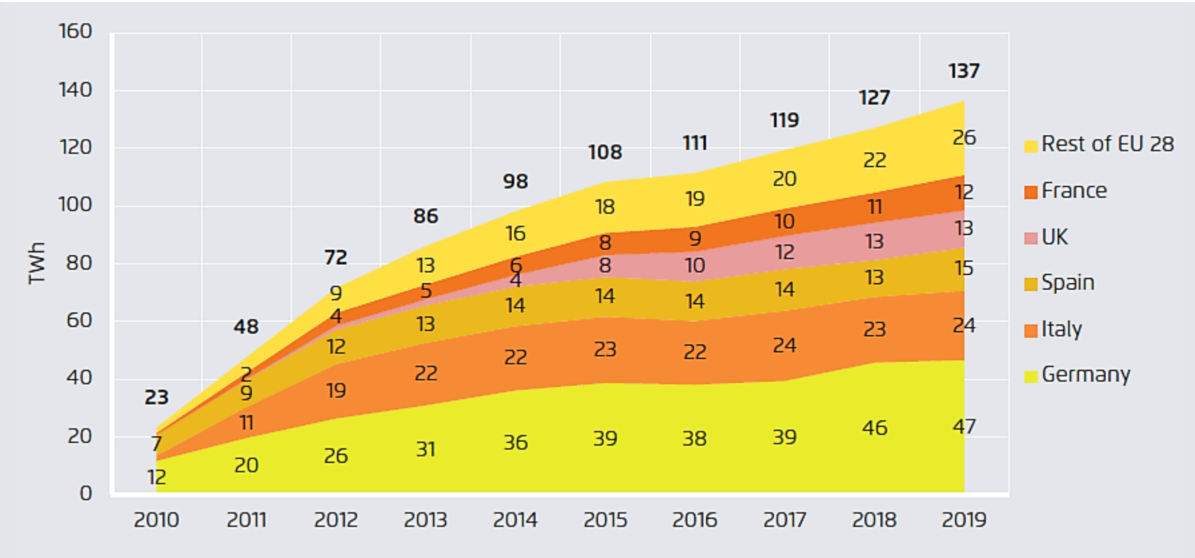


Figure 17 - EU installed PV capacity (GW). Top, cumulative installed capacity. Bottom, annual installed capacity. Source: SolarPower Europe, [EU Market Outlook for Solar Power 2019-2023](#).



Power Generation

Figure 18, left, shows what the installed PV capacities of **Figure 17** mean in terms of electricity generated by PV over the past decade. It shows - perhaps more clearly than **Figure 17** - the dominance of Germany, Italy, Spain, the UK and France.

To add a little perspective to the numbers of **Figures 17** and **18**, **Figure 19**, below, shows PV's share of total generation in each member state. We gave the average EU value of ~4% earlier, but here you can see that member states vary from having 0% to 8% of total generation from PV, with Italy, Germany, Greece and Spain leading the pack, and Sweden, Poland and Finland generating very little of their electricity from PV. See [Appendix 1](#) for a detailed breakdown of how each member states generates electricity. **Figure 19** suggests a loose relationship between the available solar resource ([Figure 1](#)) and historical PV deployment within a country, but other factors are clearly also important, e.g. policy environment and competition.

Figure 18 - EU PV electricity generation. Source: [The European Power Sector in 2019: Up-to-Date Analysis on the Electricity Transition](#), by Agora Energiewende and Sandbag.

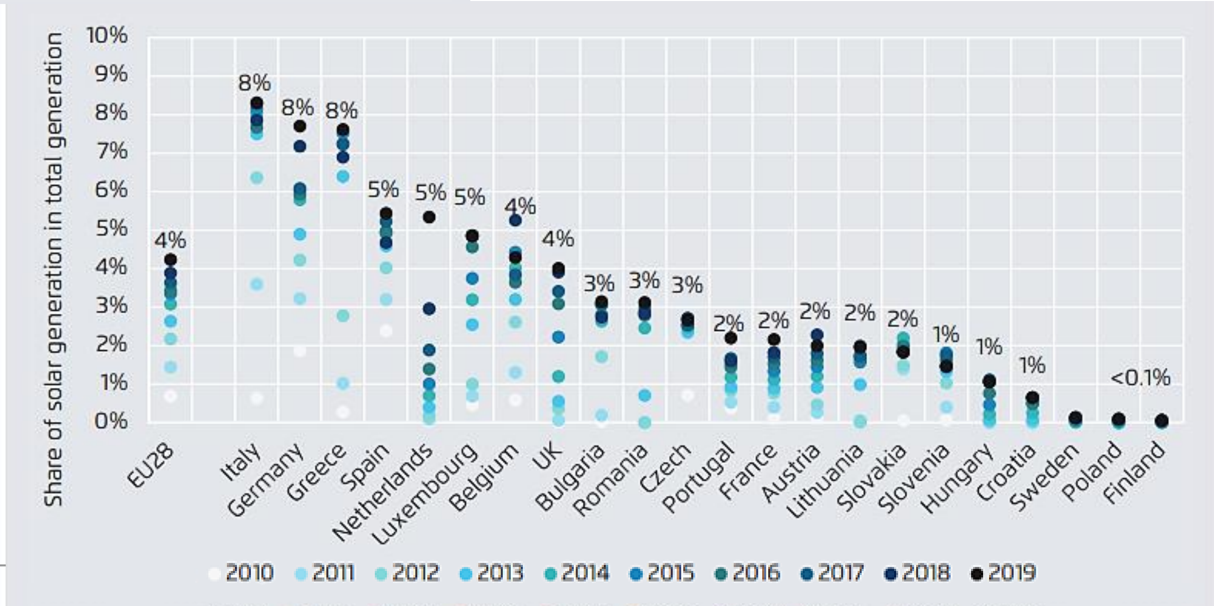


Figure 19 - PV as a percentage of national electricity production, by EU country. Source: see **Figure 18**.

Reasons For Current Boom

The bottom part of **Figure 17**, two pages back, shows the annual installed EU PV capacity. From this it is clear that there was a strong period of growth centred around 2011. This boom was driven by high, mostly short-lived feed-in tariffs in a few member states, aiming to kick-start a still immature market with very high costs (see **Figure 8**). It is not surprising that this boom was not sustained.

Figure 17 also shows that the market is now experiencing a similar-scale growth spurt to the one around 2011, expanding 16.7 GW in 2019, about double the 2018 figure. **Figure 20**, right, shows the recent growth more clearly than in **Figure 17**. Spain, Germany and the Netherlands have been the epicentres of recent growth, though, as hinted at by **Figure 20**, almost all member states exhibited higher installation numbers in 2019 than the year before.

The question we now attempt to address is: what is causing the current boom (and it is sustainable)? To answer this we will first outline some broad reasons for the boom, then zoom into a few of the fastest growing EU markets to give a flavour of some country-specific drivers.

Broad Reasons For Boom

At the highest level, the current boom has been fuelled both by broadening use *across* member states - including those who have not been very active in PV in the past (e.g. Poland), or are finding it once again after a period of relative dormancy (e.g. Spain) - and increased use *within* member states.

On a national level, demand has been supported mainly by

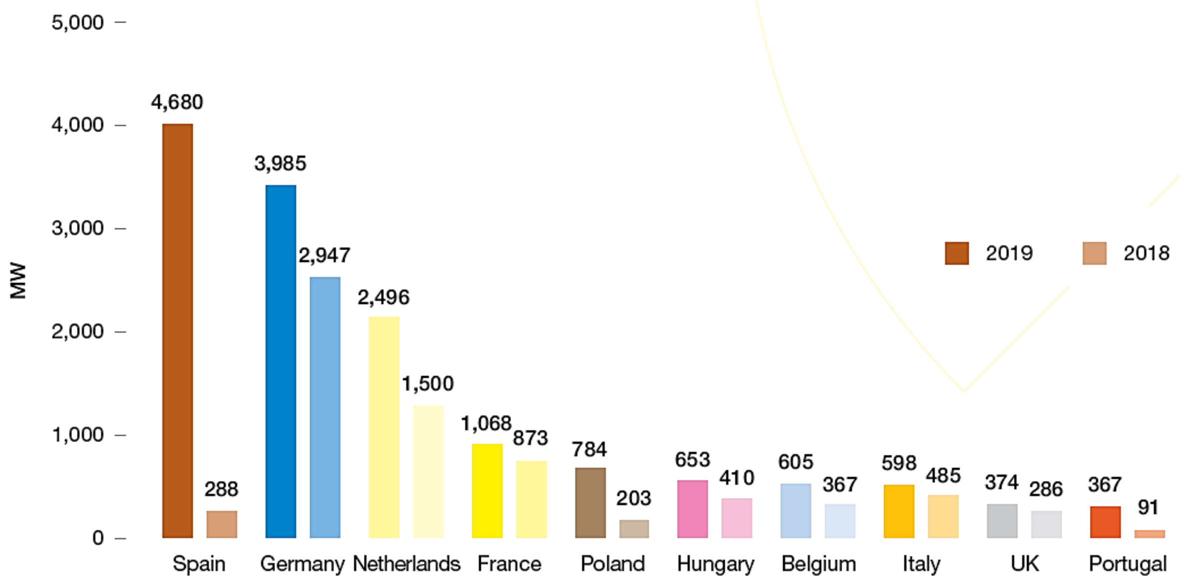


Figure 20 - top 10 EU PV markets, 2018 - 2019. Source: SolarPower Europe (2020): Global Market Outlook for Solar Power 2020-2024.

the two key drivers we have already discussed in some detail - cost reduction and policy support. These are not the only reasons, though. For example, PV has greater technological maturity now - it is simply a better product. Combined, these factors suggest there is every reason to believe that this current boom *is* fundamentally more sustainable than the one around 2011, as is quantified by the forecasts we present in the final section of this report. Though we do not claim this is anything like the full picture, we now flesh out some of the broad reasons driving recent demand…

Government Tenders/Auctions

As previously discussed, member states have been working towards their mandated EU 2020 targets relating to energy and climate change. This is part of the reason for a string of renewable energy tenders/auctions for large-scale renewables, some specifically for delivery before the end of 2020 (e.g. Germany, Spain), with PV having been successful at record low prices in some recent auctions, including technology-neutral ones. Now that the end of 2020 approaches, this short term effect will obviously vanish. The focus now shifts to the more ambitious 2030 targets. Auctions are likely to remain key in meeting these targets too.

Increased Self-Consumption

For self-consumption systems, the falling cost of PV, combined with the high retail electricity price in most EU markets, has made the financial case more compelling, both for households and companies.

To illustrate, EU household electricity prices averaged 200 €/MWh in 2019, very roughly double industrial electricity prices (see Figure 9), and both within the range of the relevant LCOE from Figure 8. However, household electricity prices differ greatly between countries - from 100-300 €/MWh, see Appendix 7 - making the case for unsubsidised self-consumption fundamentally stronger in some countries. These differences come from variability in both the wholesale price - see **Figure 21**, right - and the various network charges and other taxes that get stuck on top, see Appendix 7.

On top of the unsubsidied case getting stronger, feed-in and net metering policies have been providing direct financial support in some countries. The increased use and rapidly falling price of battery storage, together with the benefits of digital and smart energy products, has also supported the case for self-consumption.

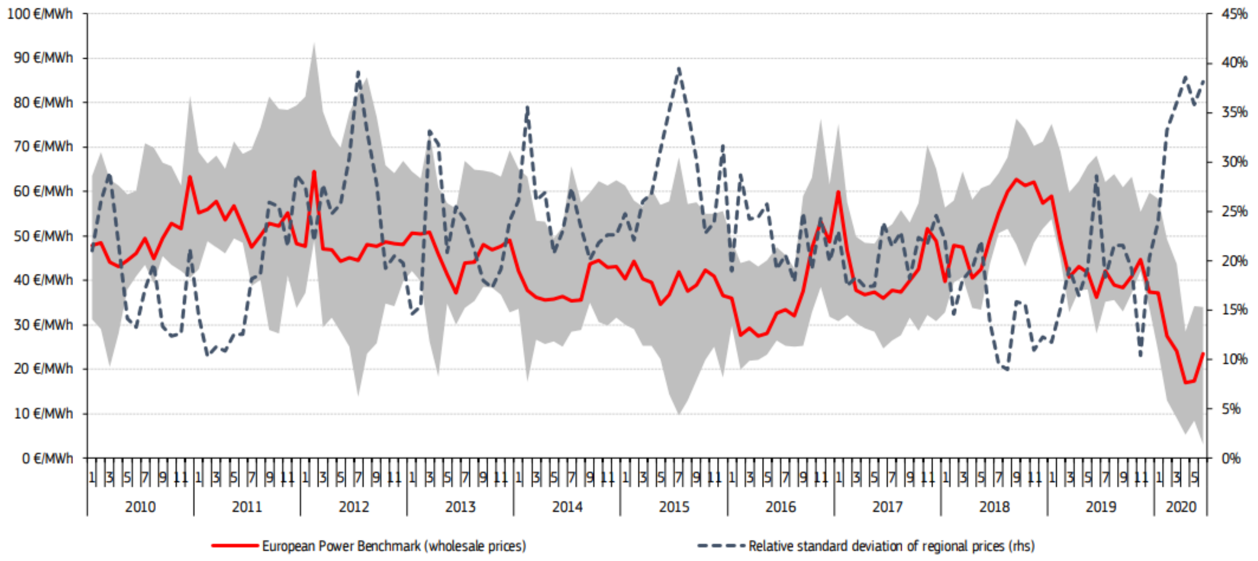


Figure 21 - European wholesale electricity price benchmark; lowest and highest regional prices and dispersion. Source: European Commission, 'Energy prices and costs in Europe'. The grey background represents the difference between the minimum and maximum price. The 2020 dip in prices is due to the pandemic.

The Shift Towards Subsidy-Free Projects

For utility-scale, grid-exporting systems, the EU is seeing the start of a shift along a line with subsidised projects at one end and unsubsidised, all-merchant projects at the other. Although climate change is giving governments a reason to perhaps ramp up PV subsidies, in general, as PV's cost falls it is only natural that subsidies are reduced and then removed.

An **all-merchant** project is one that relies solely on revenues generated by selling its electricity on the wholesale markets. It has no long-term, fixed-price contracts in place with a government or any other entity. This is clearly risky as wholesale prices are freely floating (see **Figure 21**, above), so revenues are not known in advance, and therefore such a project may struggle to find financing to get built in the first place. Even so, the falling cost of PV means an all-merchant business model has come into the realm of feasibility under optimal circumstances in Europe. By optimal circumstances we mean the best resource (see **Figure**

1), the highest wholesale electricity price - which we have already stated vary significantly between countries - and preferably the existence of extra revenue available from providing flexibility services to the grid operator.

In general though, in the absence of subsidies - either because these do not exist, or do exist but are too low in value, or are simply not needed to make the economics work - project developers are looking to reduce market exposure compared to an all-merchant project. Hedging contracts are one way of doing this (e.g. a fixed volume hedge), but the preferred method is to enter into a long-term agreement for some entity to buy a project's future power output at some agreed price via a **Power Purchase Agreement (PPA)**. PPAs have traditionally been signed with utility companies, and these remain the preferred option due to their low risk and long contract term (~20 years). However, over the last couple of years, PPAs have begun to be signed with large corporations as well, who typically still provide low counterparty risk, though contract lengths are commonly much shorter (~10 years). These are known as **corporate PPAs**, see below for more detail. Solar PPAs are increasingly competitive with wholesale power markets in a number of European countries, making them an attractive way of procuring renewable electricity. The first pure solar PPA-based project in the EU emerged in Spain in 2018, which also saw the world's largest PPA signed for a 708 MW plant in 2019. Such subsidy-free projects have since spread elsewhere in Europe.

Corporate Renewable Power Sourcing

Sourcing renewable power has become a crucial part of the energy and sustainability strategy of many leading corporations, most notably the RE100 group of companies, who have a combined electricity usage greater than Australia and are aiming to power themselves with 100% renewable power.

Broadly speaking, there are four methods via which a company can source renewable power. These are shown in **Figure 22**, right. As well as those methods we have already mentioned in this section - investing in renewables for self-consumption and the use of corporate PPAs to secure electricity from

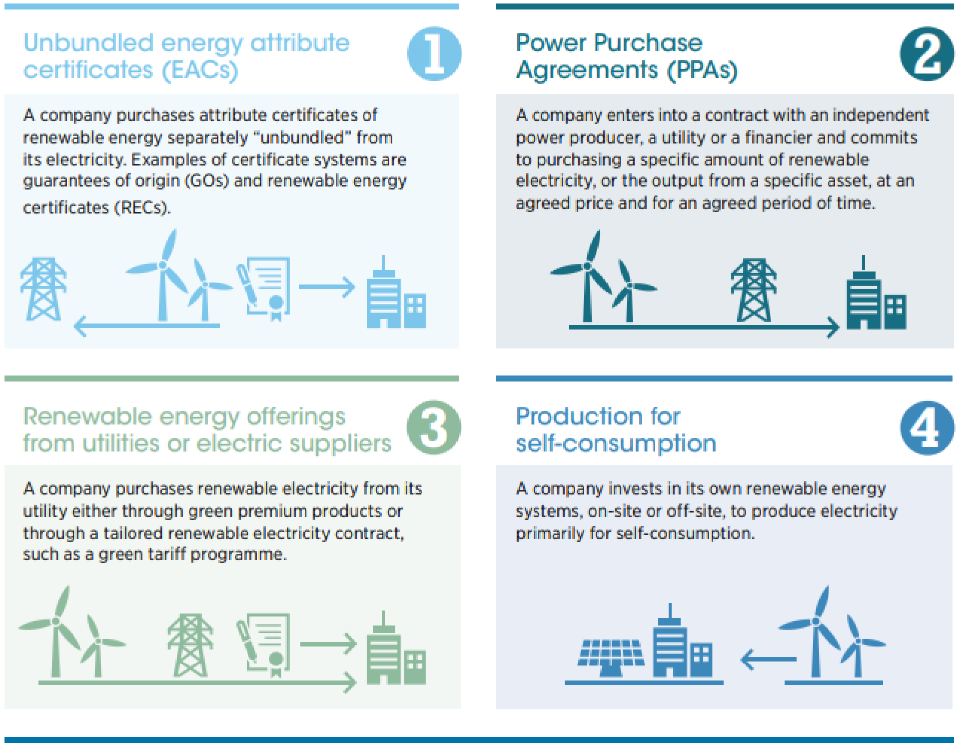
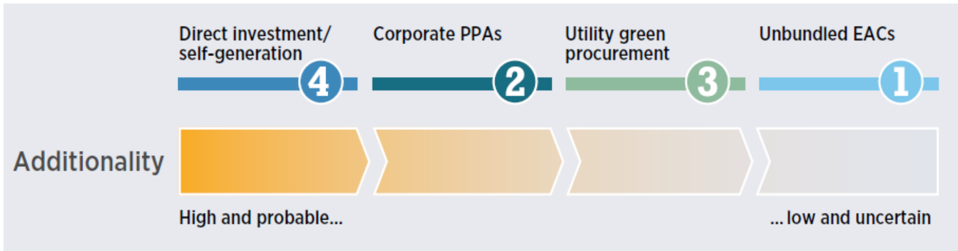


Figure 22 - above, models for the corporate sourcing of renewable electricity; below, the additionality (defined in the main text) of these models. Source: Corporate Sourcing of Renewables: Market and Industry Trends, IRENA (2018).



an external supplier - companies can also procure renewable power through their electricity supplier, or can buy Guarantees of Origin (GO) certificates and electricity separately. We introduced the GO system earlier. Note that these methods are not equal in what is termed their 'additionality', see the bottom of **Figure 22**, defined as the 'net incremental renewable capacity deployed as a direct result of corporate sourcing of renewable energy beyond what would occur in its absence'. This implies that how renewables are sourced by companies has a direct impact on the growth of renewables, with self-consumption and corporate PPAs likely to be most beneficial. It is lucky for the growth of PV, then, that these two methods are becoming increasingly popular, both because of their additionality and other factors, such as greater control and potentially lower cost.

The trend towards corporate PPAs began in the US, though is now rapidly being embraced in Europe as well, where the market for corporate PPAs, mostly driven by the heavy industry and computing sectors, has grown to a cumulative capacity of more than 7 GW in 2019, distributed across 12 EU countries, according to SolarPower Europe. So far, corporates have primarily chosen wind over PV for renewable PPAs as it has been easier to access large renewable power volumes from big wind farms; smaller, commercial PV systems have rather been directly installed on-site. With the advent of large-scale PV power plants in Europe, low-cost PV is likely to play a much bigger role in corporate sourcing. See a map of EU corporate PPA usage and more at the RE-source platform.

Country-Specific Reasons For Boom

It is beyond our scope to look at the specific market drivers in all the European countries, but we will briefly cover the three fastest growing 2019 markets. These illustrate quite how important policy has been and remains in determining overall PV rollout speed and the type of PV that is deployed.

Spain

Spain has largely been a dormant market over the past decade, though it spiked into life in 2019, echoing an earlier spike in 2008. This was due to technology-neutral renewable auctions held in 2017, aiming to comply with 2020 EU targets. The 4 GW of utility-scale PV projects successful at auction had to be grid-connected by the end of 2019. Other recent market drivers include - as mentioned above - the first unsubsidised PV plants coming online starting in 2018, and a reform of regulations around self-consumption in the same year (the end of the 'Sun Tax'), to comply with EU legislation. There was reportedly a pipeline of over 100 GW of (mostly unsubsidised) PV projects as of end-2019.

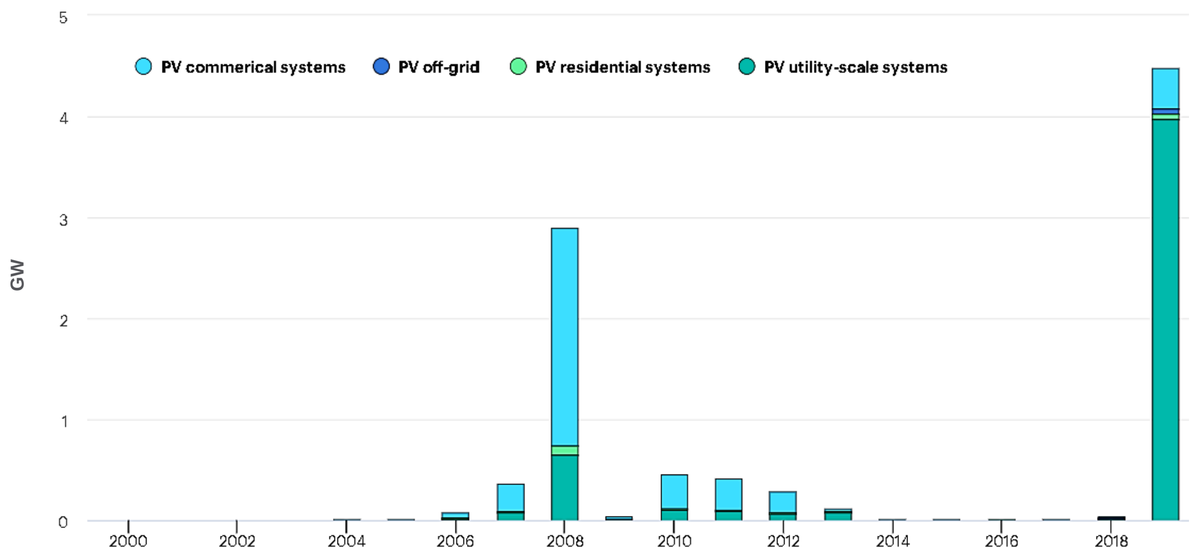


Figure 23a - historical annual PV additions for Spain (GW). Source: IEA, Renewables 2020 Data Explorer.

Germany

Germany has consistently been the leading EU PV market. It was especially strong during the 2011 boom, and its market has been ramping up again since the middle 2010s. In contrast to Spain, whose growth in 2019 was almost entirely utility-scale, the majority of Germany's 2019 growth took place in medium- to large-scale commercial systems (ranging from 40 kW to 740 kW), driven by a feed-in premium policy. Tender-based, ground-mount systems (above 750 kW), and feed-in tariff (available below 100 kW) based residential systems each contributed about 15% to this well-rounded market. Germany has regular tenders anyway - solar only, and mixed solar and wind - but put on extra tenders in an attempt to meet 2020 EU targets. Subsidy-free projects have begun to be developed in Germany, though not with the frenzy seen in Spain.

The Netherlands

A late bloomer compared to Spain and Germany, the Netherlands has been ramping up (from a near zero base) since the middle 2010s. The Netherlands has traditionally been a rooftop market - with limited space sometimes cited as a reason - and this remained the case in 2019. The residential segment made up about 40% of growth, driven by a long-running net metering programme, with a similar share for the C&I segment. The utility-scale PV segment was responsible for around 20% of the market. The major driver of the C&I and utility-scale segments was a technology-neutral tender scheme. Subsidy-free projects are not yet a thing in the Netherlands, though are projected to be by the mid-2020s.

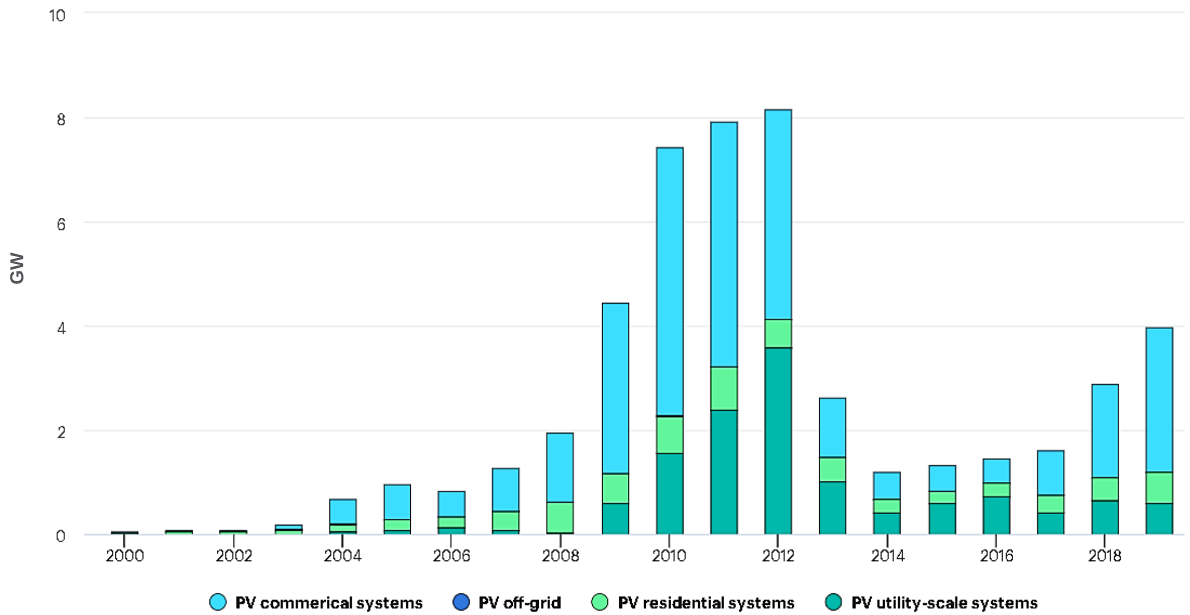
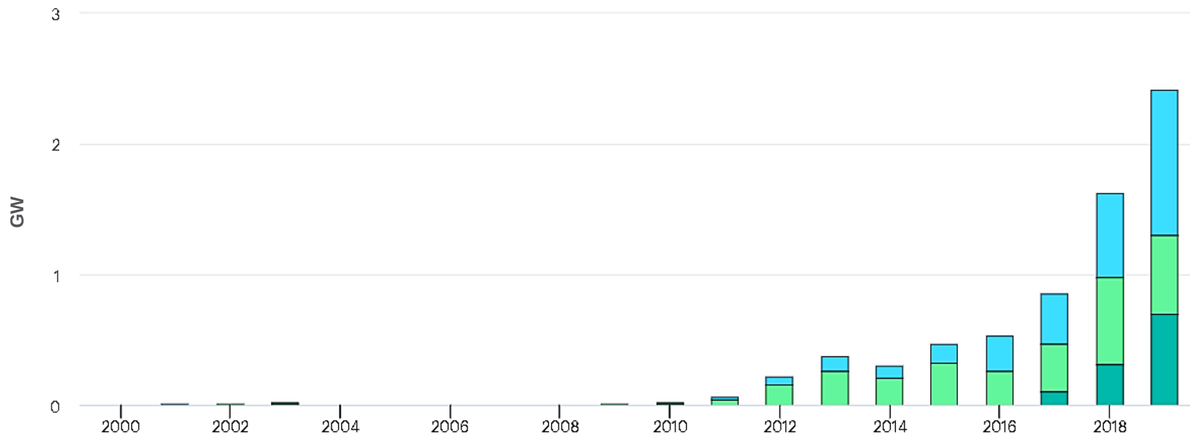


Figure 23b - historical annual PV additions for Germany, top, and the Netherlands, bottom (GW). Source: IEA, Renewables 2020 Data Explorer.



Segments

In Europe, there is no such thing as a ‘typical’ PV market, with member states varying considerably in their PV penetration and distribution between segments. **Figure 24**, right, nicely illustrates quite how inhomogeneous the EU market is in terms of segmental distribution. For example, Romania is almost entirely utility-scale, whilst, at the other extreme, Slovakia has no utility-scale and is almost entirely commercial. If you average across member states about 20% of the EU’s cumulative PV capacity was residential, 30% utility-scale and 50% C&I, at the end of 2019.

As hinted at previously, these differences between countries are largely an issue of historical policy. The member states that at some point offered very attractive feed-in tariff programmes applicable at utility-scale are still dominated by the utility-scale segment. However, hardly anything has been installed since these feed-in schemes were terminated. This is the case for the Eastern European countries Romania, Bulgaria and Czech Republic, and, until recently, for Spain.

In several Western European markets, like Austria, Belgium and the Netherlands, utility-scale PV traditionally did not play a role; policy has always been focussed on rooftop PV. That changed in the Netherlands after PV’s low cost enabled it to win large shares in its technology-neutral tendering scheme.

Germany is one of a few countries that has been able to grow its PV sector in a much more balanced fashion - balanced both over time (more or less continuous PV additions) and between segments. This is due to support across segments and over time.

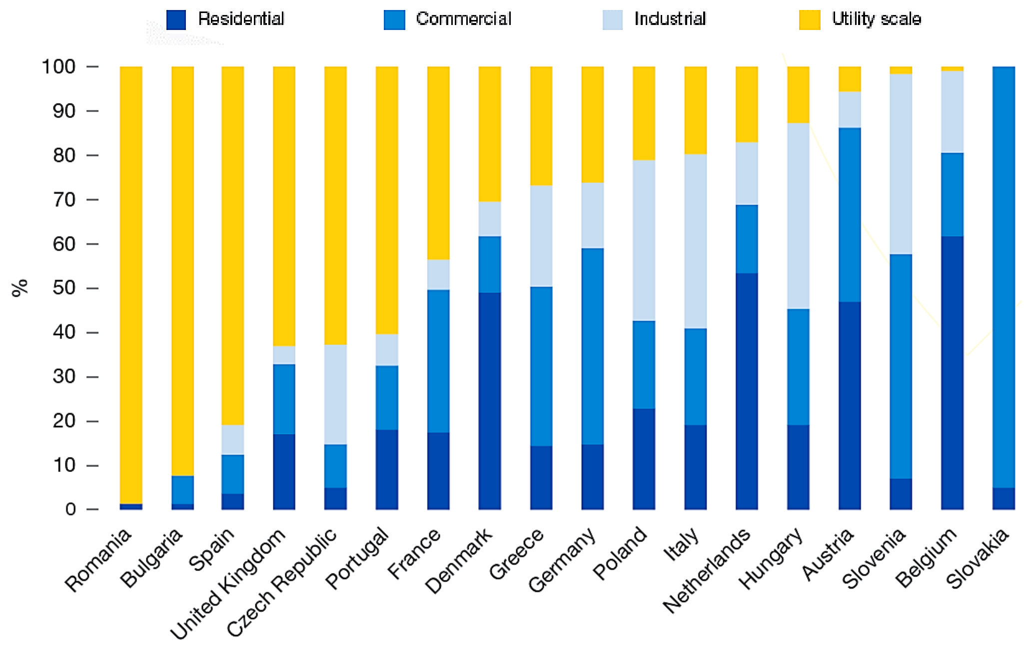


Figure 24 - EU total PV capacity by segments, end-2018. Source: SolarPower Europe, EU Market Outlook for Solar Power 2019-2023.

PV Portfolio Owners

We round out this section with a look at who owns European PV assets. Overall, the market is highly fragmented due to the large proportion of small-scale distributed assets installed and owned by individual residential, commercial or industrial consumers. At larger scale, ownership is dominated by infrastructure asset funds. The largest of these is Octopus Investments, which chiefly holds assets in the UK acquired during its partnership with Lightsource (now Lightsource BP). Octopus is number 3 in one top 50 list of European PV asset owners. See Appendix 8 for the top 20 of this list.

Together, infrastructure asset funds and other institutional investors own about 55% of European PV assets, see **Figure 25**. Institutional investors therefore play a key role in Europe's solar market, though the evolution of the market toward riskier merchant deals could change that. Such assets may be less attractive to risk-averse investors, meaning we could see a greater role for large utilities, likely to be more comfortable with exposure to wholesale power price risks. Utilities currently own about 12% of European solar assets.

According to our reference top 20 list, the top PV asset owner in Europe is Enerparc - a vertically-integrated independent power producer (IPP) focused on the German market. IPPs are non-utility generators, typically not owned by the national electricity company or public utility. IPPs own about a third of European PV assets.

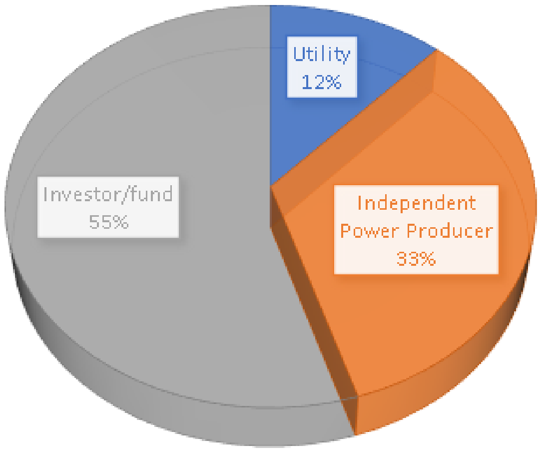


Figure 25 - top 50 European solar asset owners by type, 2019.
Source: 'Top 50 European Solar Portfolios' by Solar Plaza.

Market Forecast

In this final section we present some forecasts for the EU PV market. We divide the section into a short-term forecast, covering the next five years, 2020 included, and a more speculative long-term forecast, going out to 2050.

Short-Term Forecast

Forecasts are difficult to do at the best of times, let alone during a pandemic. To give some idea of a possible short-term path for EU PV, we present some results from the International Energy Agency's (IEA) '[Renewables 2020]' report. This came out in early November 2020, so mentions and factors in - to some extent at least - recent developments related to the pandemic, if not the most recent.

On the pandemic, the IEA is relatively upbeat. It states that electricity-generating technologies have 'shown their resilience to the crisis', especially at utility-scale. And that, despite the short-term challenges emerging from the pandemic, the 'fundamentals of renewable energy expansion have not changed', with renewables forecast to account for 95% of the net increase in global power capacity through 2025, with PV alone accounting for a healthy 60%.

Therefore, despite the pandemic, the forecast is that the EU PV market will maintain or even increase its growth rate in 2020, see **Figure 26**, right. **Figure 26** shows two forecasts in one - a main case and an accelerated case, the later of which assumes more favourable policy and economic conditions.

As an explanation for this continued growth in 2020, it is suggested that faster expansion of utility-scale projects - especially in Germany, France and Poland - will compensate for the decline in rooftop additions resulting from individuals and

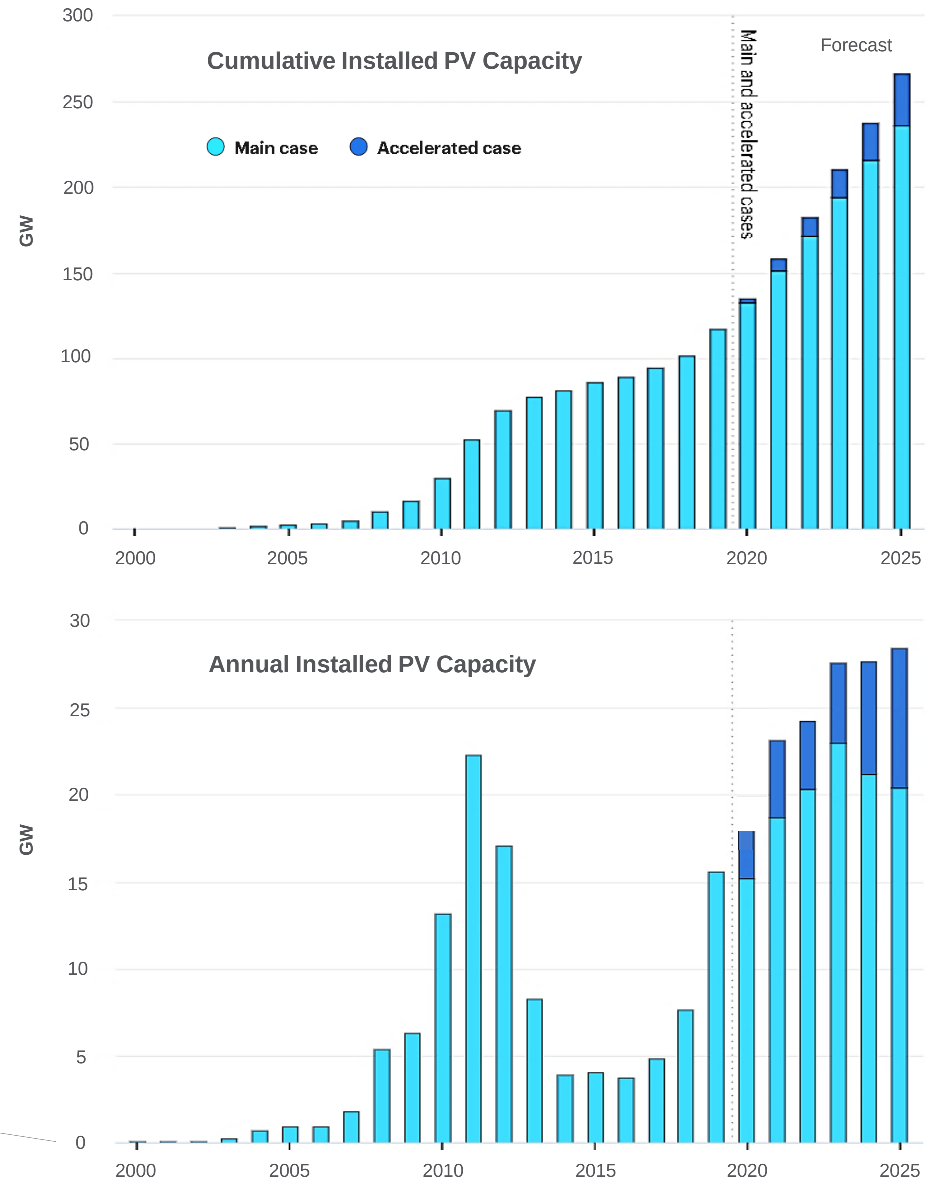


Figure 26 - EU installed PV capacity forecast, 2020-25 (GW). Top, cumulative installed capacity; bottom, annual installed capacity. Source: IEA, Renewables 2020 Data Explorer.

companies reprioritising investments; *this* is where the pandemic has had more of an impact. Higher growth is also expected because of the increasing attractiveness of net metering in Turkey (in the process of joining the EU), Poland and the Netherlands.

Beyond 2020, net additions are forecast in the main case to increase steadily to 2023, before tailing off a little into 2025, adding on average ~20 GW per year between 2021 and 2025. This IEA forecast is more or less consistent with Wood Mackenzie's 'Europe solar PV market outlook 2020'. This growth is expected to be underpinned by similar drivers to those outlined earlier for the current market - most obviously, ongoing cost declines and member state governments attempting to reach currently legislated and then Green Deal strengthened 2030 targets. Against this backdrop and still within the 2021-2025 period, we additionally forecast the following market dynamics (the more specific quantitative forecasts come directly from the IEA):

- Utility-scale PV plays an increasingly important role in the overall market, with its share rising from 41% in 2021 to an average of 55% annually by 2023-25, owing to an increase in competitive auctions. Over the past year, legislation to introduce or extend auction support has either been proposed or passed in a number of major markets (incl. Italy, Poland, Spain and Germany).
- Utility-scale projects continue to get larger.
- Whilst the majority of utility-scale projects continue to utilise business models supported by auctions, the shift towards subsidy-free projects extends. Globally, subsidy-free renewable projects (all, not just PV) triple from less than 5% to more than 15% of all projects.
- Corporate sourcing expands as a key enabler of subsidy-free projects.

  This forecast seems reasonable given that corporate demand for renewable electricity is currently significantly higher than the availability of renewable energy projects able to supply it, according to SolarPower Europe.
- Distributed PV continues to increase gradually, driven by steady growth in the commercial segment from self-consumption, net metering and, in some cases, auctions. However, the impact of support scheme changes on large commercial systems in key markets is a forecast uncertainty (incl. Germany, France and the Netherlands). Residential PV maintains steady growth, led by self-consumption in Germany and net metering in the Netherlands and Poland.
- Energy storage becomes increasingly common across all segments.
- Over the slightly longer timeframe 2020-25, major oil and gas companies' investments in new renewable electricity capacity increase tenfold.

To add to this list, it is known that governments will dole out pandemic-related stimulus packages in the near-term. The largest of these is the EU's own €750 billion NextGenerationEU initiative, a temporary instrument with a focus on member states hit hardest by the pandemic (Italy and Spain likely the biggest beneficiaries). The largest amount of money goes to the Recovery and Resilience Facility, a ~€670 billion mix of grants and loans to be used for 'investments and reforms, including in green and digital transitions'. In addition to this short term measure, a ~€1 trillion seven-year EU budget has been agreed, running from 2021-27. In total, 30% of EU funds will be spent 'to fight climate change' over this period. In addition to the EU-wide stimulus package, some member states' national pandemic recovery plans have put climate front and centre, most notably France and Germany, who have earmarked €30 billion and €50 billion, respectively, for investment in green projects.

A final market dynamic worth highlighting is the expected increase in demand for electricity due to ongoing electrification. Although more relevant to the long-term forecast outlined later, the electrification of a range of sectors - heavy industry, heat, transport and, related to all these, hydrogen production - will visibly pick up pace over the next five years through both natural market momentum and government intervention. This is likely to be most visible with road transport - EVs are set to become much more common and renewable electricity will be needed to recharge them; the key point is that this is *new,* not existing electricity demand.

Short-Term Country Forecasts

Following on from our brief historical look at three example markets earlier, in this section we look - equally briefly - at the IEA forecasts for these same countries from 2020-2025.

Spain

Spain's PV market is expected to take a bit of a breather in 2020, after outsized EU target driven growth in 2020, before growth returns in subsequent years. Expansion is expected to remain almost entirely in utility-scale projects, with the majority unsubsidised and supported instead by PPA and/or direct exposure to wholesale markets. There is a pipeline of over 7 GW of these currently under construction, with the considerably larger pipeline of projects currently under development aided by new regulations in 2020 to speed up permit approvals. Auctions are expected to return in 2023 after a three-year break, with the central assumption that 2 GW is awarded every year. However, annual growth is forecast to decelerate during 2023-25 due to uncertainty over future power demand. Distributed PV is more sensitive to potentially weaker economic conditions caused by the pandemic, and is expected to remain a minor part of the overall market, despite supportive regulatory reforms in 2018.

Germany

Germany is expected to slightly extend growth in 2020 compared to 2019, due to a robust development slate of projects from auctions (including special ones aimed at EU 2020 targets), and the continued attractiveness of self-consumption. Additions are forecast to expand in 2021 owning to utility-scale projects from previous auctions coming online, as well as growth in unsubsidised projects, still relatively new to Germany. Beyond 2021, PV additions will be highly influenced by a recent update to renewable policy that comes into effect in 2021. The IEA forecast is based on slightly wrong assumptions about this update. The key points are that: (a) PV auctions are confirmed out to 2028 and increased in size to an average of 2 GW/year (from 600 MW); (b) there are new 'innovation' tenders for combinations of renewables (or renewables and storage), starting at 500 MW/year; (c) systems between 300-750 kW newly can either participate in tenders or receive a feed-in premium for 50% of the electricity they generate. More on these changes here.

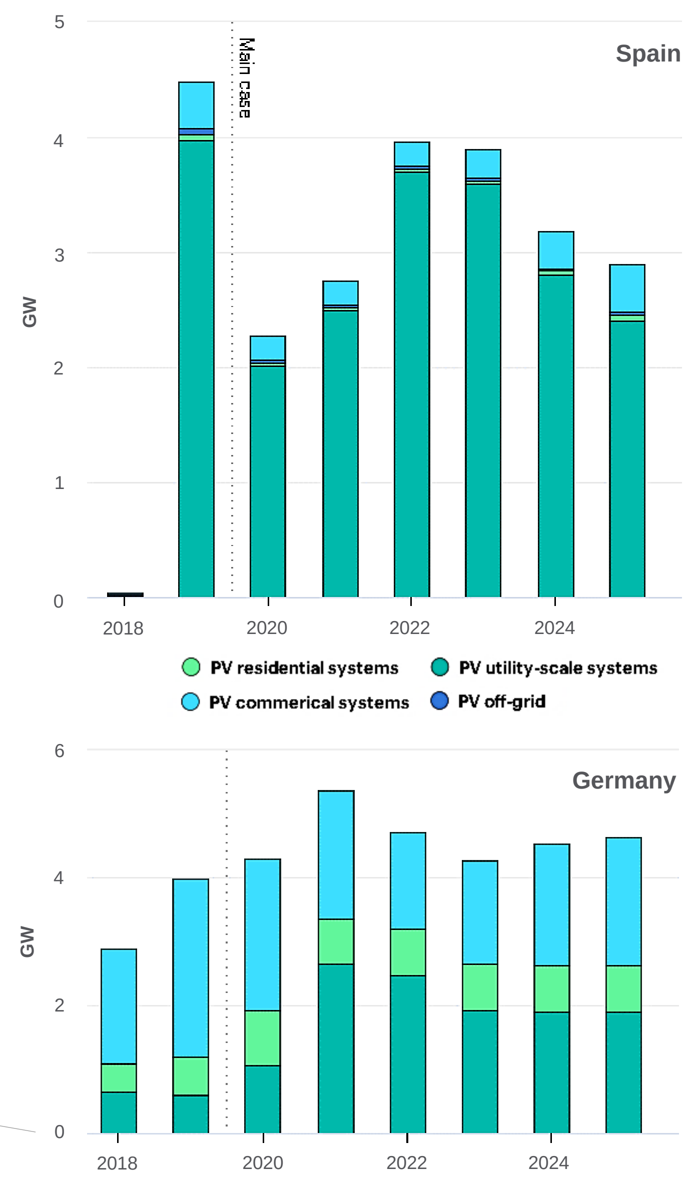


Figure 27a - forecast annual PV additions for Spain, top, and Germany, bottom (GW). Source: IEA, Renewables 2020 Data Explorer.

The Netherlands

The Netherlands' PV market is forecast to carry on expanding at a healthy clip in 2020, driven by the same factors as in previous years - the tender scheme for commercial and utility-scale PV, and net metering for residential PV. 2021 and 2022 are expected to be in line with 2020. Beyond 2022, policy deadlines drive capacity additions, with the strongest growth forecast for 2023 as remaining projects commission before the tendering scheme is phased out by 2025. New tender design rules raise concerns about PV's competitiveness - PV must now compete with non-electricity technologies. This uncertainty appears in the forecast as declining additions in 2024 and 2025. As for residential PV, after a 2021 dip, this is expected to maintain more or less steady growth throughout the forecast period. However, a slow phase out of net metering starts in 2024, reducing the profitability of this segment.

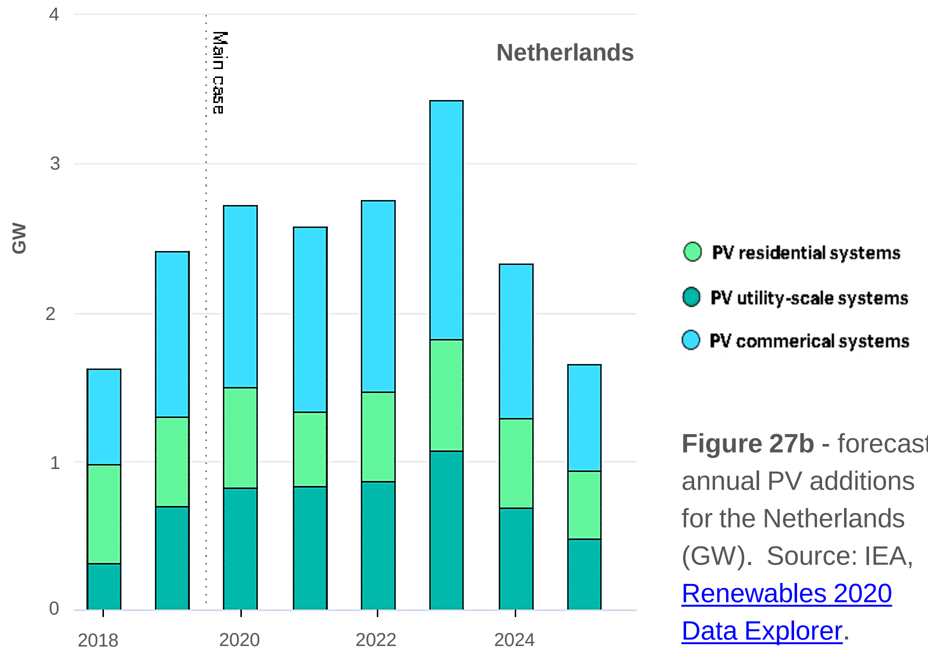


Figure 27b - forecast annual PV additions for the Netherlands (GW). Source: IEA, [Renewables 2020 Data Explorer](#).

Challenges

There are various challenges standing in the way of European PV growth, both over the next five years and beyond. Very broadly speaking, these challenges, some mentioned earlier and some of which only apply in certain countries, include:

- Regulatory uncertainty. You would hope and expect this to reduce as countries look to provide optimal conditions for meeting Green Deal targets.
- High cost of capital (on average, though, Europe has a relatively low cost of capital). This is linked to regulatory uncertainty.
- Physical and procedural restraints on getting viable projects grid-connected.
- Lack of incentives for grid operators to fully exploit and reward the flexibility PV (especially PV + storage) can provide.
- Lack of PV-enabling digital infrastructure (smart meters etc.) and related data standards.
- Complexity, non-standardisation and limitations of corporate renewable sourcing methods. We mentioned four categories of methods earlier, but there are at least 14 variants, some only possible in some countries. For PPA-based methods, there are various legal and other restrictions that constrain their use.
- Covariance risk - the risk that as utility-scale PV proliferates, merchant projects will all be selling into wholesale markets at the same time, collapsing prices.
- As well as the relevant points covered above, rooftop self-consumption is also limited by:
    - Lack of awareness, especially of the possible business models (such as the option of third-party financing, where available).
    - Lack of access to finance.
    - Inadequacy of billing mechanisms for promoting self-consumption (e.g. excessive grid access charges).

This list is not comprehensive. For a more detailed list of challenges, see SolarPower Europe's report 'EU Market Outlook for Solar Power 2019-2023'.

Off The Beaten Path

350 PPM and sister company and solar developer Solar 350 are always on the lookout for investment opportunities slightly off the beaten path. A country like Spain may be the obvious place to seek to develop utility-scale PV in Europe, but the competition is fierce, with a huge pipeline of projects already underway. An alternative strategy is to focus on those countries that have a decent solar resource, a strong need to clean up their electricity sector, but with minimal PV capacity already installed. There will be fundamental reasons for this lack of capacity, but assuming a country has the grid capacity, and regulatory conditions are or become conducive to PV, new countries are likely to come into the realm of possibility for foreign developers, especially as costs continue to decline.

One obvious way in which you can imagine conditions for PV improving dramatically in a given country is if that country joins the EU. In joining the EU, a process that historically has taken 2-8 years, the country must adopt EU legislation, which is becoming more pro-renewables by the day, as covered earlier. In addition, becoming an EU member should open up EU-related financing opportunities (e.g. access to EIB loans), improving the financing conditions for PV projects.

Countries currently in the process of joining the EU include North Macedonia, Montenegro and Serbia, all formerly parts of Yugoslavia, as well as Albania and Turkey (which has a stellar solar resource and a moderately-sized solar market already). Bosnia and Herzegovina, and Kosovo, also former parts of Yugoslavia, are looking to join the EU but do not yet meet the requirements. The last two former Yugoslavia members not so far mentioned - Croatia and Slovenia - have already joined the EU. We highlight the former Yugoslavian countries as they meet our earlier conditions - high coal and minimal solar use, despite middling to strong resource availability. Combined, these countries have a technical potential for PV of about 16 GW, [according to IRENA] (International Renewable Energy Agency).

Figure 28 - map showing the countries mentioned in this section. Countries in yellow are part of the EU.

To highlight one of these countries, Croatia has a technical potential of 3.2 GW, according to IRENA, but had just 69 MW of PV installed at the end of 2019, most of this residential and commercial, built under an expired feed-in tariff or current net metering scheme. However, in 2020 the government introduced a tender scheme, with plans to allocate around 1 GW of PV capacity, the majority at utility-scale. If all allocated and built this would represent a 15-fold increase in capacity.

Croatia is one example of why it is worth keeping an eye off the beaten path. Another example - like Croatia but on steroids - is Ukraine (not part of the EU and not looking to join), which burst into life as a globally significant PV market in 2019, adding ~4 GW to become a ~5.5 GW market, driven by a lucrative feed-in policy. Read more about Ukraine in Solar Power Europe's Global Market Outlook.

Long-Term Forecast

Having considered the picture out to 2025, we conclude this report by extending our forecast out to 2050. Fundamentally, it is hard to imagine PV not playing a significant role in 2050, assuming the EU heads towards and then meets its climate neutral target by this date. This would mean a decarbonised electricity (and wider energy) sector, but that still leaves the magnitude of the role for PV somewhat unclear - there are multiple ways this decarbonisation could take place. As suggested earlier, wind and PV will almost inevitably form the backbone of any decarbonisation process, but the split between the two and the extent of contributions from other sources - especially nuclear and carbon capture - are not at all certain. The extent of the role for hydrogen is also unclear.

To give an idea of what Europe's 2050 electricity system could possibly look like, we present some headline results from an extensive study done by the Finnish Lappeenranta-Lahti University of Technology (LUT). This study simulated the transition to a 100% renewable energy system by 2050. Based on the locally available renewable energy sources, the simulation computed the cost-optimal mix of technologies for different regions of the world. The headline results for Europe (not just the EU) include:

- The total installed electricity generation capacity grows massively, from 1200 GW in 2015 to around 11,400 GW by 2050. This is not due to significant changes in population or energy demand per capita, rather due to wide-scale electrification, with electricity providing most of the energy that previously came from fossil fuels.
- Overall, PV and wind, along with some hydropower, constitute the majority of installed capacity in 2050. Fossil fuels (other than synthetic) and nuclear power disappear altogether. See **Figure 29**, right.
- A larger share of wind capacities are installed up to 2030, but in the later part of the transition, PV dominates the shares of installed capacities, reaching 8940 GW by 2050 (78% of total capacity). This is an almost unbelievably large number, given

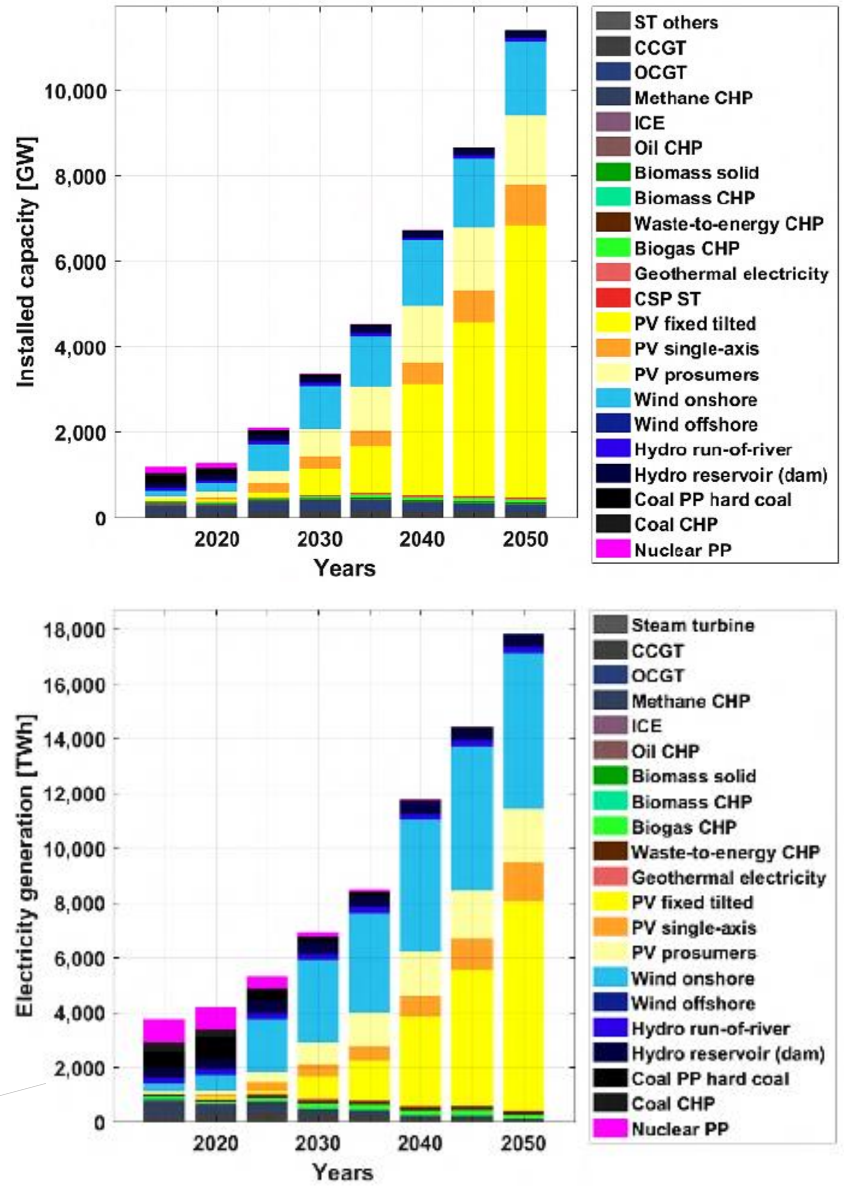
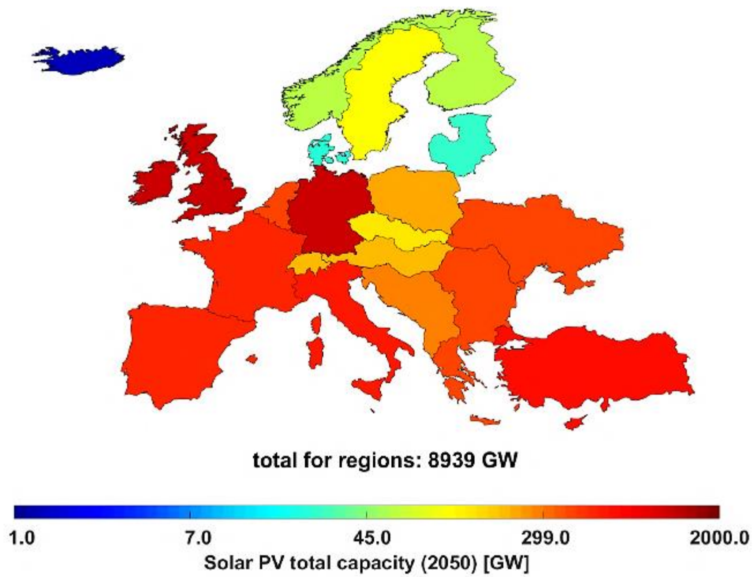
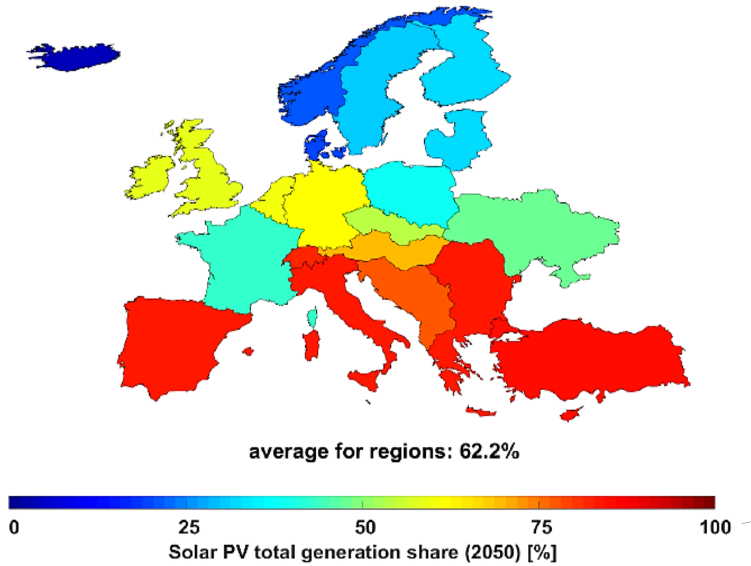


Figure 29 - simulated installed capacities (top) and electricity generation (bottom), by technology, assuming 100% renewables in 2050. Source link above in main text.





that the total installed PV capacity globally is currently about 650 GW. The estimated expenditure to install this amount of PV is €3 trillion. By contrast, wind reaches a paltry 1767 GW of capacity by 2050 (15% of total capacity).

- In terms of electricity generation, PV supply increases through the transition from 29% in 2030 to about 62% by 2050, 'becoming the lowest cost energy source' (arguably already is). Wind energy increases to 32% by 2030 and contributes a stable share of the mix up to 2050.
- As you might expect, PV capacities are predominantly in the southern regions of Europe, due to better solar resources there, while wind energy capacities are mainly in the northern regions of Europe, due to better wind conditions. The top part of **Figure 30**, left, shows the PV capacity picture, while the bottom part of **Figure 30** shows the PV generation share, both in 2050.

These results clearly paint a very rosy picture for PV, but the artificial setup of the simulation and contrasting forecasts from elsewhere - arguably far more realistic - suggest reason for caution. For example, BloombergNEF, in its New Energy Outlook 2020, do see the clean power transition going furthest and fastest in Europe compared to other parts of the world. However, it sees wind and PV together accounting for only 74% of electricity generated in 2050 (not 94%), with wind supplying more than 50% of overall generation (not 32%). And it implies that the ten-fold growth of overall generation capacity suggested in the LUT simulation could be one hell of an overestimate. There is some agreement, though - both sources make an estimate of 30% of electricity generation coming from PV in 2030, though Bloomberg add the condition this would be limited to Southern Europe.

To conclude this report, it is worth contrasting this 30% figure with the current situation - as we have seen, PV currently provides just ~4% of electricity in Europe. For investors, therefore, this is potentially a golden opportunity, a complete transformation of the energy system in which to take part. We recommend taking a closer look.

Figure 30 - 2050 simulated regional variation in PV capacity (top) and PV's share of total electricity generation (bottom), assuming 100% renewables in 2050. Source given on previous page in main text.

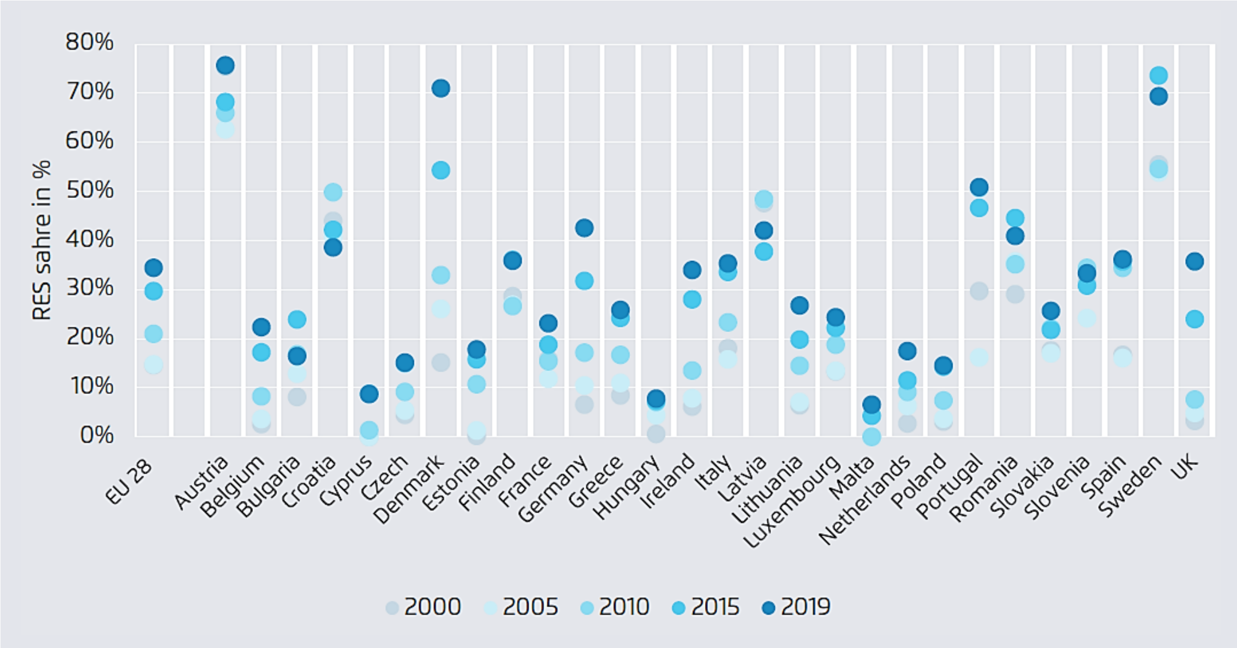
Appendices

Appendix 1a: EU 28 Power Production in 2019, by Fuel and Country

Source: The European Power Sector in 2019: Up-to-Date Analysis on the Electricity Transition, by Agora Energiewende and Sandbag.

TWh	Lignite	Hard Coal	Other fossil	Gas	Nuclear	Hydro	Solar	Wind	Biomass	Consumption	Imports	Production
EU 28	252	218	117	699	821	348	137	432	199	3239	16	3222
Austria	0	2	3	11	0	44	1	8	4	76	2	73
Belgium	0	0	4	24	43	1	4	9	5	89	-2	92
Bulgaria	18	0	0	3	17	3	1	1	0	38	-6	45
Croatia	0	1	0	3	0	6	0	1	1	19	7	12
Cyprus	0	0	5	0	0	0	0	0	0	5	0	5
Czech	35	1	2	6	30	3	2	1	5	74	-13	86
Denmark	0	5	0	0	0	0	1	16	9	37	6	31
Estonia	0	1	6	0	0	0	0	1	1	10	2	8
Finland	3	5	1	4	24	12	0	6	13	87	20	68
France	0	4	11	38	399	63	12	35	7	509	-61	570
Germany	114	57	26	91	75	19	47	126	51	569	-37	605
Greece	13	0	5	18	0	5	4	7	0	62	10	52
Hungary	4	0	0	9	16	0	0	1	2	46	13	33
Ireland	2	2	0	16	0	1	0	8	1	30	0	30
Italy	0	18	15	138	0	45	24	20	27	330	41	289
Latvia	0	0	0	3	0	2	0	0	1	7	1	7
Lithuania	0	0	0	1	0	1	0	2	1	13	8	4
Luxembourg	0	0	0	0	0	1	0	0	0	8	6	2
Malta	0	0	0	1	0	0	0	0	0	3	1	2
Netherlands	0	17	6	74	3	0	6	11	4	121	0	121
Poland	43	77	3	14	0	3	0	15	7	172	10	161
Portugal	0	6	1	17	0	11	1	14	3	57	3	54
Romania	13	0	1	9	11	16	2	7	1	61	1	60
Slovakia	1	1	1	2	15	5	1	0	2	29	2	28
Slovenia	4	0	0	1	6	5	0	0	0	16	0	16
Spain	0	13	17	85	58	26	15	55	6	282	7	275
Sweden	0	0	3	0	67	66	0	22	12	143	-26	171
United Kingdom	0	7	6	130	56	9	13	65	36	344	22	322

Appendix 1b: EU 28 Share of Renewables in Total Generation



Source: [The European Power Sector in 2019: Up-to-Date Analysis on the Electricity Transition](), by Agora Energiewende and Sandbag. RES - Renewable Electricity Supply.

Appendix 2: EU 28 Renewable Energy Targets and Policies, 2019

Country	Renewable energy targets	Renewable energy in INDC or NDC	Regulatory Policies							Fiscal Incentives and Public Financing			
			Feed-in tariff/ premium payment	Electric utility quota obligation/RPS	Net metering/billing	Biofuel blend, renewable transport obligation/mandate	Renewable heat obligation/mandate, heatfeed-in tariff, fossil fuel ban for heating	Tradable REC	Tendering	Reductions in sales, energy, CO_2, VAT or other taxes	Investment or production tax credits	Energy production payment	Public investment, loans, grants, capital subsidies or rebates
Austria	E, P, HC, T		●		●	●		●		★[6]	●		●[6], ◖[6]
Belgium	E(N), P, HC, T			◖	◖	●		●	●, ○	●[6]	●		◖
Bulgaria	E(N), P, HC, T		●			●							●[6]
Croatia	E(R), P, HC, T		●			●							●[6]
Cyprus	E, P, HC, T		●		●	●			●				●
Czech Republic	E, P, HC, T		●			●		●		●[6]	●		●[6]
Denmark	E(R), P, HC, T		●[6]		●	●	●[8, 9]	●	●, ○	●[6]	●		●[6]
Estonia	E(R), P, HC, T		●			●						●	●, ☆[6]
Finland	E, P, HC(R), T(R)		●			☆	★	●	●	☆[6], ●[7]		●	●[6]
France	E(R), P(N), HC, T	●	●			☆	●[8], ★	●	●, ○	●[6]	●[6]		★[6]
Germany	E(R), P(R), HC, T		●, ☆*			●	●	●	●, ○	●	●		●[6], ★
Greece	E(R), P(R), HC(R), T		●	●	●	●	●[8]	●	●, ○	●[6]	●		●, ☆[6]
Hungary	E, P, HC, T		●		●	●			●	●			●[6]
Ireland	E(R), P(R), HC, T	●	●			☆	●[8]	●	●, ○	★[6]			☆[6,7]
Italy	E, P, HC, T		●		●	●			●, ○	●	●[6]		●[6,7], ★*
Latvia	E, P, HC, T		●		●	●			●	●			
Lithuania	E(R), P, HC(R), T(R)		●[6]	●	●	●	●[8]		○	●[6]			●, ★[6]
Luxembourg	E, P, HC, T		☆			●							●, ☆[6]
Malta	E, P, HC, T		●		●	●			●	●			●[6]

Source: Renewables 2020 Global Status Report by REN21. Extracts from Table 3.

Country	Renewable energy targets	Renewable energy in INDC or NDC	Regulatory Policies: Feed-in tariff/ premium payment	Electric utility quota obligation/RPS	Net metering/billing	Biofuel blend, renewable transport obligation/mandate	Renewable heat obligation/mandate, heatfeed-in tariff, fossil fuel ban for heating	Tradable REC	Tendering	Fiscal Incentives and Public Financing: Reductions in sales, energy, CO_2, VAT or other taxes	Investment or production tax credits	Energy production payment	Public investment, loans, grants, capital subsidies or rebates
Netherlands	E, P, HC, T		●		●	●	●[8]	●	●, ○	★[6]	●[6]	●	☆[6]
Poland	E, P, HC(R), T		●	●		●		●	●, ○	●			●[6], ★
Portugal[2]	E(R), P(R), HC(R), T(R)		●	●		●	●	●	○	●			●, ☆[6]
Romania	E, P, HC, T			●	★	●		●					●[6]
Slovak Republic	E, P, HC, T		●			●		●		●[7]			●[6]
Slovenia	E, P, HC, T		●		●	●		●	●	●	●		●[6]
Spain[3]	E, P(R), HC, T				☆	●	●[8]		●	★	●	●	●[6]
Sweden	E, P, HC, T		● (removed)	●		●		●		●	●		●
United Kingdom	E, E*(N), P, HC, T		● (removed)	●		☆	●[8]	●	●, ◖	●		●	●[6], ☆[7]

Targets

- **E** Energy (final or primary)
- **P** Power
- **HC** Heating or cooling
- **T** Transport
- ***** Indicates sub-national target
- **(R)** Revised
- **(N)** New

Policies

- ★ New (one or more policies of this type)
- ★* New subnational
- ☆ Revised (from previously existing)
- ☆* Revised sub-national
- ● (grey) Removed
- ● Existing national policy or tender framework (could include sub-national)
- ◖ Existing sub-national policy or tender framework (but no national)
- ○ National tender held in 2019
- ◖ (open) Sub-national tender held in 2019

[2] FIT support removed for large-scale power plants.

[3] Spain removed FIT support for new projects in 2012. Support remains for certain installations linked to this previous scheme.

[6] Includes renewable heating and/or cooling technologies.

[7] Includes aviation, maritime or rail transport.

[8] Heat FIT

Appendix 3: EU 28 Renewable Share of Electricity Generation Targets

Country	Target	Status in 2018[a]
EU-28	→ 57% by 2030	32.1%
Austria	→ 70.6% by 2020	77%
Belgium	→ 21% by 2020	20% (2018)
Bulgaria	→ 16.7% by 2020	17%
Croatia	→ 39% by 2020	71%
Cyprus	→ 16% by 2020	8%
Czech Republic	→ 14.3% by 2020	13.7% (2018)
Denmark[f]	→ 50% by 2020 → 100% by 2050	76%
Estonia	→ 17.6% by 2020	14%
Finland	→ 33% by 2020	44%
France	→ 40% by 2030	20%
Germany	→ 40-45% by 2025 → 55-60% by 2030 → 80% by 2050	38%
Greece	→ **34.3% by 2020** → **63.54% by 2030**	32%
Hungary	→ 10.9% by 2020	
Ireland	→ 42.5% by 2020 → **70% by 2030**	29%
Italy	→ 26% by 2020	39%
Latvia	→ 60% by 2020	50%
Lithuania	→ 45% by 2030 → 100% by 2050	83%
Luxembourg	→ 11.8% by 2020	58%
Malta	→ 3.8% by 2020	16%
Netherlands	→ 37% by 2020	15%
Poland	→ 19.3% by 2020	14%
Portugal	→ 59.6% by 2020 → 80% by 2030 → 100% by 2050	52.2%
Romania	→ 43% by 2020	41%
Slovak Republic	→ 24% by 2020	23%
Slovenia	→ 39.3% by 2020	32%
Spain	→ 39% by 2020 → 74% by 2030 → 100% by 2050	38%
Sweden	→ 100% by 2040	55%
United Kingdom	→ no national target	34%
Scotland	→ *100% by 2020*	
Wales	→ *70% by 2030*	

Source: Renewables 2020 Global Status Report by REN21. Extracts from Table R6. **Bold** means a new/revised target in 2019.

[a] Status data are for 2018 unless otherwise noted.

[f] In March 2012, Denmark set a target of 50% electricity consumption supplied by wind power by 2020.

Appendix 4: EU 28 Targets for Technology-Specific Share of Electricity Generation as of End-2019

Country	Technology	Target
Belgium		
Flanders	*Solar PV*	*30% by 2020*
Denmark	Wind power	50% by 2020
Germany	Solar power	**17% by 2030**
United Kingdom	Wind power (offshore)	33% by 2030

Source: Renewables 2020 Global Status Report by REN21. Extracts from Table R7. **Bold** means a new/revised target in 2019.

Appendix 5: EU 28 Targets for Installed Capacity or Generation as of End-2019

Country	Technology	Target
Austria	Bio-power from solid biomass and biogas	200 MW added 2010-2020
	Hydropower	1 GW added 2010-2020
	Solar PV	1.2 GW added 2010-2020
	Wind power	2 GW added 2010-2020
Belgium		no national target
Wallonia	*Electricity*	*8 TWh per year by 2020*
Croatia	Hydropower	1,655 MW by 2020
Finland	Bio-power	13.2 GW by 2020
	Hydropower	14.6 GW by 2020
	Wind power	884 MW by 2020
France	Hydropower	0.1 to 2 GW by 2023
	Ocean power	380 MW by 2020
	Solar power	18.2-20.2 GW by 2023; [8 GW by 2020]; 45 GW by 2030
	Wind power (offshore)	1 GW per year; 2.4 GW by 2023; 4.7 to 5.2 GW by 2028
	Wind power (onshore)	21.8 to 26 GW by 2023
Germany	Bio-power	100 MW added per year
	Solar PV	**2.5 GW added per year; 98 GW by 2030**
	Wind power (onshore)	2.8 GW tendered per year through 2019; 2.9 GW per year after 2019
	Wind power (offshore)	**20 GW added by 2030**
	Wind power (total)	**67 to 71 GW by 2030**
Greece	Solar PV	2.2 GW by 2030

Source:
Renewables 2020 Global Status Report by REN21. Extracts from Table R8. **Bold** means a new/revised target in 2019.

Country	Technology	Target
Italy	Bio-power	19,780 GWh per year generation from 2.8 GW capacity by 2020
	Geothermal power	6,759 GWh per year generation from 920 MW capacity by 2020
	Hydropower	42,000 GWh per year generation from 17.8 GW capacity by 2020
	Solar PV	50 GW by 2030
	Wind power (onshore)	18,000 GWh per year generation and 12 GW capacity by 2020
	Wind power (offshore)	2,000 GWh per year generation and 680 MW capacity by 2020
Poland	Wind power (offshore)	10 GW by 2040
Portugal	Electricity	14.7 GW by 2020; 27.9 GW by 2030
	Hydropower	7 GW by 2020; 8.7 GW by 2030
	Wind power	5.4 GW by 2020; 9.3 GW by 2030
	Solar	1.9 GW by 2020; 9 GW by 2030
	Other (biopower, geothermal and wave)	0.5 GW by 2020; 0.6 GW by 2030
Spain	Solar PV	39 GW by 2030
	Solar thermal	7 GW by 2030
	Wind power	50 GW by 2030
	Hydroelectricity	16 GW by 2030
Sweden	Electricity	25 TWh more renewable electricity annually by 2020 (base year 2002)
	Electricity	26.4 TWh common electricity certificate market with Norway by 2020
United Kingdom	Wind power (offshore)	39 GW by 2030, one-third of electricity by 2030

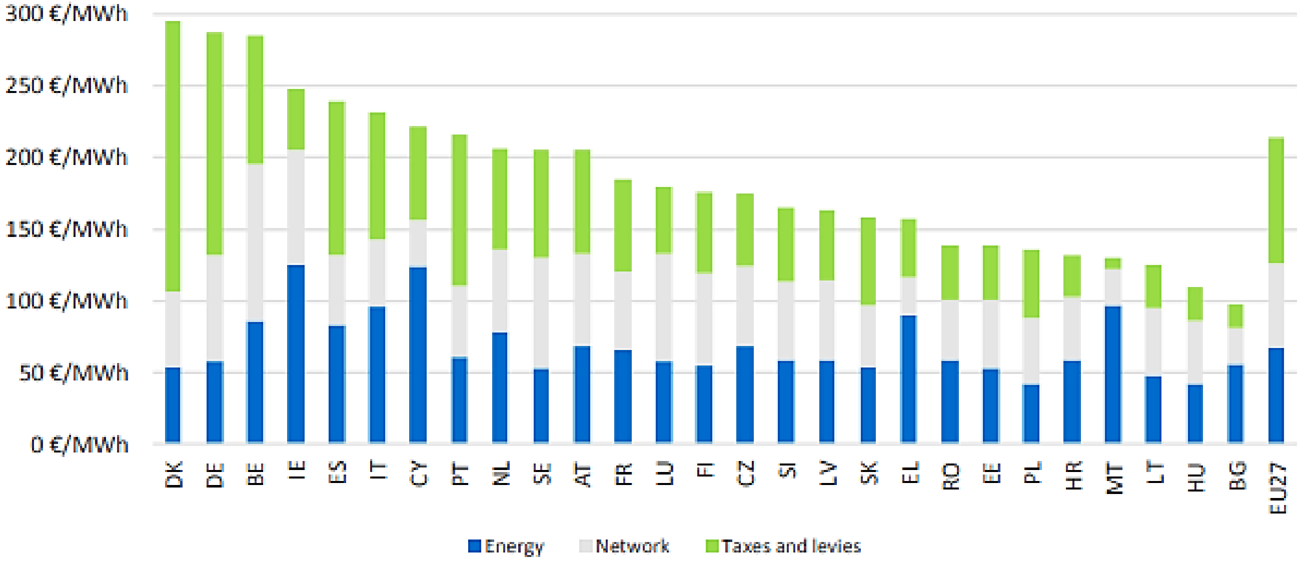
Appendix 6: EU 28 Renewable Power Tenders held in 2019

Country	Technology	Description
Denmark	Solar PV	83 MW awarded
	Solar power and wind power (hybrid)	93 MW solar-wind hybrid facilities awarded (including 34.1 MW solar PV capacity)
France	Wind power (offshore)	600 MW awarded
	Solar PV (ground-mounted)	855 MW awarded
	Solar PV (ground-mounted)	858 MW awarded
Germany	Solar PV	153 MW awarded
	Solar PV	501 MW awarded
	Wind power (onshore)	500 MW awarded
Greece	Solar power and wind power (joint auction)	437.78 MW awarded
	Solar PV	143 MW awarded
	Solar power	105.09 MW awarded
	Wind power	179.5 MW awarded
	Wind power	224 MW awarded
Ireland	Technology-neutral among renewable technologies	13,500 GWh announced
	Energy storage	110 MW awarded
Italy	Solar power, wind power	4.8 GW announced (650 MW combined solar and wind, 600 MW rooftop PV)
Lithuania	Technology-neutral among renewable technologies	300 GWh allocated
Netherlands	Wind power (offshore)	760 MW awarded

Source:
Renewables 2020 Global Status Report by REN21. Extracts from Table R12.

Country	Technology	Description
Poland	Wind power (onshore)	2.2 GW awarded
Portugal	Solar power	1.3 GW awarded
	Energy storage	50-100 MW announced
	Solar PV (floating)	50 MW offered
United Kingdom	Wind power (offshore)	5.47 GW awarded
	Wind power (onshore)	330 MW awarded

Appendix 7: Household EU Electricity Prices, 2019



Source: European Commission, '[Energy prices and costs in Europe](#)'.

Appendix 8: Top 20 European PV Asset Owners, 2019

Rank	Name	Size (MW)	Type	HQ	Founded
1	Enerparc AG	1,500.00	IPP	Germany	2008
2	Encavis	1,150.86	IPP	Germany	2001
3	Octopus Investments	1,070.60	Investor	UK	2000
4	Foresight Group	968.00	Investor	UK	1984
5	EF Solare Italia	800.00	Investor	Italy	2016
6	NextEnergy Capital Group	789.60	Investor	UK	2013
7	Aquila Capital	775.00	Investor	Germany	2001
8	Engie	746.00	Utility	France	2008
9	Sonnedix	646.00	IPP	UK	2009
10	EDF Energies Nouvelles	605.12	Utility	France	1946
11	Obton A/S	600.00	Investor	Denmark	2008
12	Greencoat Capital	489.00	Investor	UK	2009
13	Bluefield Solar Income Fund Ltd	465.30	Investor	UK	2009
14	Blue Elephant	424.45	Investor	Germany	2015?
15	KGAL	384.00	Investor	Germany	1968
16	EFG - Hermes	365.00	Investor	Egypt	1984
17	British Solar Renewables	356.00	IPP	UK	2010
18	Re:cap	350.00	Investor	Switzerland	2014
19	Neoen	348.00	IPP	France	2008
20	Tenergie	347.00	IPP	France	2008

IPP – Independent Power Producer

Source: 'Top 50 European Solar Portfolios' by Solar Plaza.

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