23 June 2021
Bundle

Energy transition and power prices: ING's view on long and short-term price moves

Power prices are notably volatile and hard to predict but they are an important value driver of investment in the energy system. This bundle of articles takes a thorough look at power prices and explores ways that businesses can mitigate power price risks through Power Price Agreements

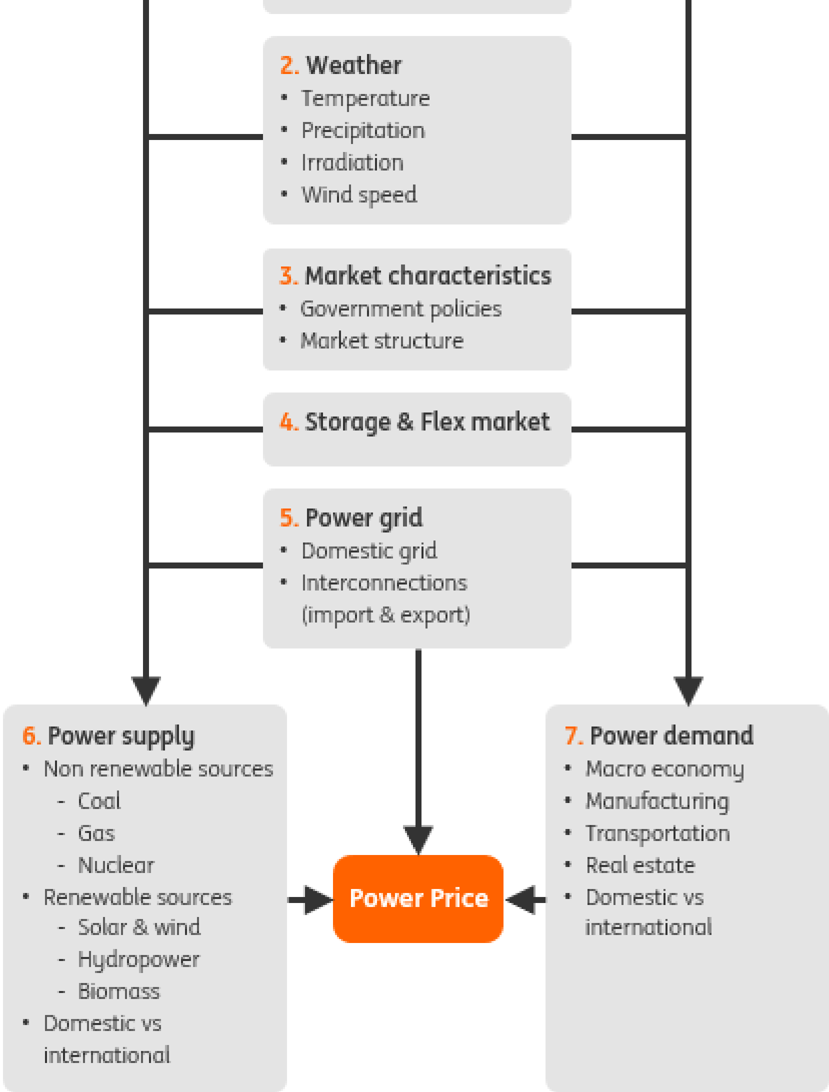
23 June 2021
Article

Unravelling the many value drivers of power prices

Power prices are notoriously volatile and hard to predict. But they are an important value driver of investment in the energy system. This article provides a conceptual framework to analyse power prices so that opportunities and risks can be properly assessed

Seven drivers of power prices

In this article, we distinguish the seven most important drivers of power prices.



Source: ING Research

1 Commodity markets: gas, coal and carbon prices

According to the International Energy Agency, around 61% of global power was generated in 2020 by power plants that run on fossil fuels, predominantly coal (36%), gas (23%) and to a much lesser extent, oil (2%). During 2020, hydro, wind and solar provided 'only' 25% of the electricity and nuclear (~11%) providing must run baseload power. So most of the time, power plants that run on fossil fuels are the price setting technologies in the merit order of power markets. The marginal costs of these power plants are determined by commodity prices, notably coal (in China and India) and gas (in most European countries and the US).

> Most of the time, gas fired power plants set the power price in Europe.

There is no shortage of long term supply of coal and gas. Proven coal reserves are by far the largest and most carbon intensive fossil fuel with around 140 years of current demand available. Proven oil and gas reserves stand at 50 to 60 years. Short-term supply heavily depends on supply chain disruptions, geopolitics, collusion in oligopolistic markets (or the lack of it) and current prices that determine the level of investment in new fossil based capacity. Many of these factors are inherently unstable, so while our 2021 Energy Outlook and Commodities Outlook provide a detailed forecast for the coal and gas markets, these markets can swing in an instant.

While there are plenty of fossil fuels available to meet future energy demand, climate policies to limit global warming provide a limitation to fossil fuel use, in particular the use of coal for power generation. The Net Zero Scenario by the International Energy Agency for example limits global warming to 1.5˚C, but requires a strong reduction in unabated coal and gas fired power plants. In this scenario, by 2050, almost 90% of electricity generation comes from renewable sources, with wind and solar PV together accounting for nearly 70%. Most of the remainder comes from nuclear energy that also does not produce emissions. In other scenarios such as the IEA Sustainable Development Scenario and ING's Fast Forward scenario, gas acts as a transition fuel and global warming is close to 2.0˚C. In all scenarios, carbon pricing, is an important policy instrument to bring about such a world, next to the continuation of subsidies on clean technologies. So in addition to coal and gas prices, carbon prices matter too.

Quantitative research shows that changes in power prices are, to a large degree, driven by changes in commodity prices.

Examples of the impact of commodity markets on power prices:

- Geopolitical conflicts can cause gas and coal prices to increase, leading to higher power prices.
- Meeting the Paris Climate Agreement Goals requires a fast and strong energy transition, including in the power sector. This requires the phase out of cheap but carbon intensive coal-fired power plants. Power prices could increase as a result.
- Rising carbon prices lead, all other things being equal, to higher power prices.

2 The weather increasingly impacts power prices, but shows a high degree of unpredictability

The weather can impact power prices in the short, medium and long run. In the short run irradiation and wind speed (for solar and wind power) and temperature and precipitation (for hydropower) are important drivers of power prices.

> Weather unpredictability means that even with perfect models and understanding of initial conditions, there is a limit to how weather forecasts are of use in predicting power prices.

But there is a limit to how far in advance accurate weather forecasts are possible. Scientists show that the weather predictability horizon is limited to 10 to 14 days only. So weather unpredictability means that even with perfect models and understanding of initial conditions, there is a limit to how weather forecasts are of use in predicting power prices.

The weather also has a **medium term** impact on power prices as the weather changes from year to year and during the year. Aurora Energy Research shows that the yearly average temperature, precipitation, irradiation and wind speed can range from circa +10% to -10% year-on-year.

Finally, climate change is expected to have a **long term** impact on weather patterns, for example in the US and Europe. In Europe the impact varies per region. It is still unclear if and how these long term trends impact power prices.

Wind and solar: lower power prices on windy and sunny days

Wind turbines and solar panels can provide the vast majority of power on sunny and windy days in countries with a lot of wind and solar power. The near zero marginal costs of wind and solar power lower the power price as a result. We find that a doubling of the share of weekly power generation from wind and solar power in European countries, on average, lowers baseload power prices by 7%.

Coal and nuclear power plants: weather and cooling water

Heatwaves can also impact power prices through their impact on cooling water for inland nuclear power plants or large coal fired power plants. The temperature of cooling water for nuclear power plants must be fairly constant for safety issues. Rivers often provide the cooling water, but they can run dry to critical levels so that water cannot be used to cool the power production. Or hot waste water discharge is prohibited as it further heats up the fresh water which could negatively impact wildlife through algae growth or fish mortality. The reduction of nuclear and coal capacity during prolonged heatwaves drives up power prices, especially in countries like France, Germany and the US.

Examples of the weather impacting power prices:

- Power prices are generally lower on windy and sunny days.
- Power prices could rise during heat waves.
- A warm winter lowers energy demand and could, ceteris paribus, lower power prices.

3 Market characteristics set the power dynamics of countries apart

The design of a power market has a huge impact on power price dynamics. In principle there are two market mechanisms: energy only markets versus capacity markets, which differ to the degree that power generators are incentivised to invest in power capacity such as fossil fuel power plants, storage capacity (e.g. batteries) or wind and solar farms.

Capacity markets provide generators fixed payments for their ability to provide power when the market needs it. As such, regular capacity payments cover (part of) the fixed costs of the power generating asset.

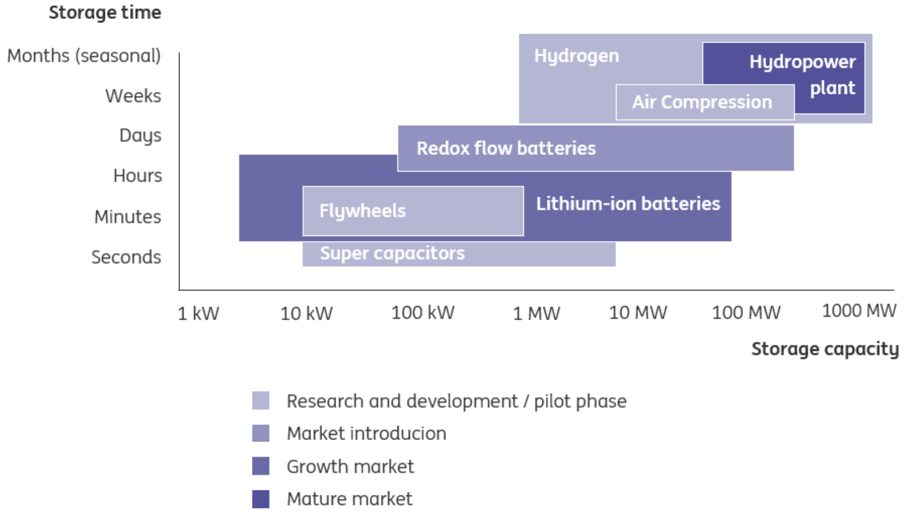
In energy only markets, generators solely rely on the power price to recover their costs. When available capacity is limited, prices can go through the roof, which allows generators to cover their fixed costs. These periods of high peak prices are rare and usually short lived, but when they happen flexible capacity generators earn a lot of money.

European countries differ in their power market set-up due to past decisions and the fact that energy policy largely falls under the domain of the member states, so there is no common strategy. The UK has a long history of capacity markets, aiming to provide security of supply to the island's power system. The Netherlands is predominantly an energy only market, but well connected to the German and Nordic capacity power market. That has resulted in power price dynamics that are very similar to the German capacity market. In the US, energy market design differs from state to state.

4 Storage and flex markets can smooth out power prices, but need to grow first

Energy has three main applications; heating, transportation and electricity. The price dynamics of electricity markets have always been amplified by the fact that electricity, until very recently, was hard to store. That stands in sharp contrast to heating and transportation as heat and gasoline can easily be stored, both technically and economically.

Technologies to store electricity differ in characteristics and market stage



Source: ING Research

The need to store electricity becomes urgent as more renewables enter the power mix and weather conditions cause an oversupply of power. The combined supply of wind and solar power often peaks at noon and can be stored in batteries to meet peak demand in late afternoon when many people return home from work and start to use electricity.

> The need to store electricity becomes urgent as more renewables enter the power mix and weather conditions cause an oversupply of power.

The mismatch in renewables supply and demand also has a seasonal component as power supply from solar and wind is high in summer months. In the Northwest European power market this can partly be matched with the vast amount of renewable hydropower from the Nordics, but most European countries lack the potential for large scale hydropower and use gas fired power plants as a back up facility.

Hydrogen, thermal storage and mechanical storage provide promising solutions to 'store' electricity. Currently, these markets are still in their infancy and it will take a couple of years before large scale storage facilities can smooth power price dynamics.

Hydrogen provides a promising solution to 'store' electricity by converting power into hydrogen and vice versa.

Storage techniques such as batteries and hydrogen offer grid operators more flexibility to match power supply with power demand in order to manage the grid frequency. This is a complex but important business as even small deviations will cause damage to electrical devices. Owners of energy storage assets can provide these frequency response services to grid operators. These services are expected to become a source of meaningful revenue in the near future.

Apart from storage capacity, demand side management offers new and additional tools to increase the flexibility of the power grid. The so-called 'flex market' is about the design of market structures, price incentives and technologies that help shift power demand from peak hours (7am till 8pm on working days) to off-peak hours (night time and at the weekends). Think of electric vehicle smart charging where cars are charged during the night when wind power can be high and prices low. As for many storage solutions the technology is proven, but it is not applied on a large scale yet. It will take a couple of years before flex-market structures are in place that change the behaviour of power-intensive activities of businesses and households to such an extent that it will dampen power price dynamics.

Examples of the impact of storage and flex markets on power prices:

- Power from solar panels can be stored in batteries during sunny hours and used during the classic demand peak in the evening. This helps to match power supply and demand which could smooth power price dynamics during the day.
- The same applies to hydrogen storage facilities which could match weekly or even seasonal variations in power supply and demand, thereby smoothing power demand.
- Smart grids could charge electric vehicles at times when renewable power is in abundance. Increased demand from electric vehicles can support power prices during these hours when they are typically low.

5 Power grids increasingly determine the speed of the energy transition in power markets

In power markets, one cannot ignore the laws of physics as every electron has to be physically transported through the power grid from the point of generation to the point where it is used by an electrical device. Power markets currently change much faster than the power grid infrastructure. That means that the power grid increasingly is a barrier, both on the demand and the supply side.

Power markets currently change much faster than the power grid infrastructure.

Interconnectors with neighbouring countries and a country's high voltage grid determine the main power flows within a country. For example, the long-time planned Nord-Sud link in Germany is intended to better connect the northern part of Germany (where there is a high supply of offshore wind) with the southern part (where there is high industrial power demand).

The grid matters too on a local scale. In the Netherlands for example, the city of Amsterdam had to temporarily call a halt to the construction of new data centres as the grid could not handle the additional power demand. And in more rural parts of the Netherlands, the planning of new solar farms was put on hold as the grid could not absorb the vast amounts of generated power on sunny days.

It is hard to pinpoint the impact of grid limitations on power prices as they prevent something from happening. As a result, one cannot look at historic prices to determine the impact.

Examples of the impact of storage and flex markets on power prices:

- Grid limitations can prevent heavy power users connecting to the grid or scaling up production. In the absence of grid limitations, power demand could have been higher, likely increasing power prices.
- Grid limitations can prevent new solar or wind farms connecting to the grid. In the absence of grid limitations, power supply from renewables could have been higher, likely lowering power prices.

6 Supply factors: renewables and interconnectors gain importance

The energy transition is very visible in the power sector due to proven technologies such as solar panels and wind turbines. It's speed of adoption is determined by the degree of policy intervention from governments and the speed of technological progress. ING distinguishes several energy transition scenarios. In its most ambitious scenario, the Fast Forward scenario which is in line with the Paris Climate Goals, the share of renewables in the global power mix rises from 28% today to 70% in 2040 and fossil fuels are phased out accordingly. We find that increasing shares of wind and solar power can, on average, lower short term power prices and could increase the cost of a low carbon energy system in the long run.

We find that power prices are generally lower as more renewables enter the power mix

With the rise of renewables, power markets need to increase scale in order to balance supply and demand. By connecting countries or states through interconnectors in the power grid, an oversupply of wind or solar energy can be transported to regions where the wind does not blow, skies are cloudy or demand is high due to industrial sites.

Examples of the impact of renewables and interconnections on power prices:

- Higher shares of solar and wind energy in the power mix tend to lower power prices.
- The Northwest European power market is highly integrated through interconnecting transmission cables both on land and sea beds. A high supply of hydro power from the Nordics or wind and solar power out of Germany could set power prices in the Netherlands and Belgium lower.

7 Demand factors: the business cycle and trend towards electrification matter

There is a strong relationship between economic activity and power demand, particularly in developing countries. In past years, energy efficiency gains in developed countries decoupled power demand from economic growth to some degree. However, Covid-19 has put this relationship in the spotlight again as industrial sites were impacted by lockdowns and supply chain disruptions. Daily power demand is one of the main indicators to accurately forecast Covid-19 induced swings in economic activity, according to ING's weekly economic activity index for the eurozone.

In the long run, electrification is an important mitigation strategy to meet the climate goals in manufacturing (hydrogen and heat pumps), transportation (electric vehicles) and real estate (heat pumps).

> Electrification is an important mitigation strategy to meet the climate goals causing higher power demand.

Power demand will also rise from adaptation strategies to climate change, such as more air conditioning in buildings. We expect current global power demand to rise by 70% to 80% by 2040 as a result. This result is stable across our energy transition scenarios. In our Fast Forward scenario, power demand growth is strong due to rapid electrification, but curbed by high energy efficiency gains in energy intensive sectors. Progress in energy efficiency is much slower in our wait and see scenario, so that moderate electrification also increases power demand.

Examples of demand factors impacting power prices:

- Lower power demand and commodity prices could lower power prices in economic downturns.
- A rise in power demand from electrification in manufacturing, transportation and real estate could, ceteris paribus, set power prices higher.

Forecasting power prices: mission impossible and mission accomplished

Given the uncertainties in the seven value drivers, forecasting power prices in many respects feels like mission impossible. As such, it does forecasters great credit to be humble in their ability to forecast power prices.

> It does forecasters great credit to be humble in their ability to forecast power prices.

In this article we have, however, depicted a clear framework to analyse the most important value drivers of power prices. It can be used to analyse long term trends that impact the expected return of a power plant, wind or solar farm over the investment period. It can also be applied to analyse actual developments that impact the monthly or quarterly financials of the asset.

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Article

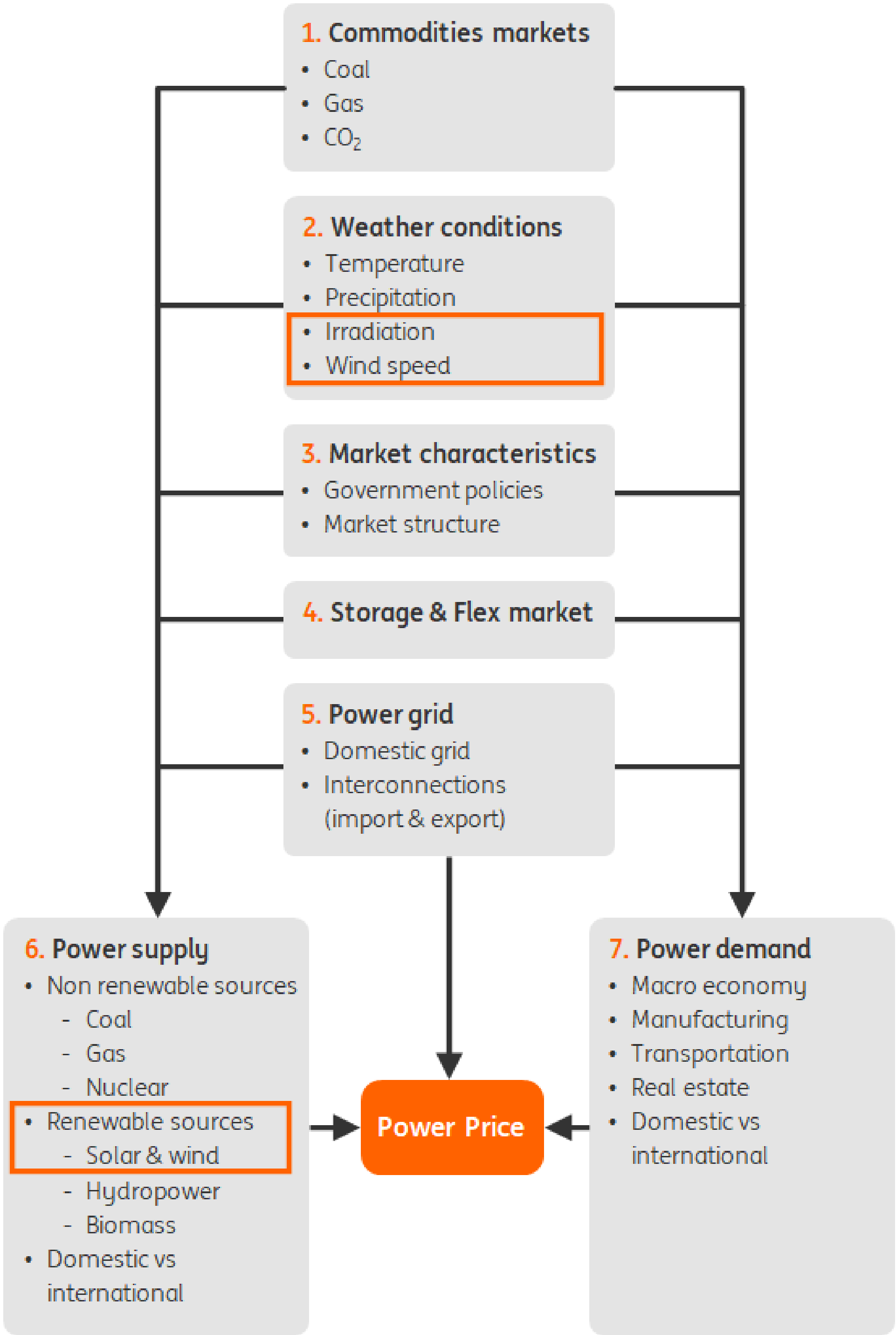
Energy transition to move power prices over the short and long-term; more volatility expected

The energy transition will increase the long term costs of the energy system and power prices could rise by 2050 as a result. But more wind and solar will push prices lower in the short term. The swing effects are highest for wind energy: a 50% increase in the share of wind power causes weekly prices to drop by -7% on average and monthly prices by -8%

Renewables are one of the many factors that determine power prices

There are many factors that determine power prices. This article analyses the impact of increasing shares of weather dependent wind and solar power on power price dynamics in some key European countries.

Scope of this study

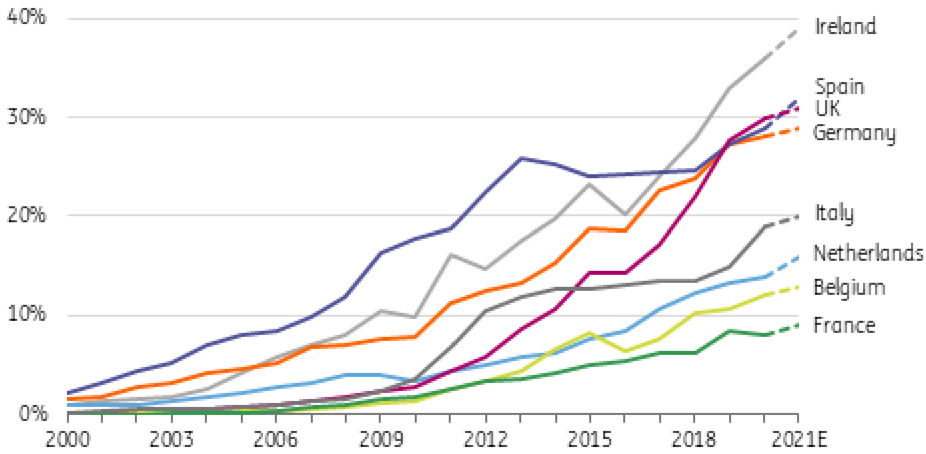


Source: ING Research

The only way is up for wind and solar power

Wind and solar power have grown massively in recent years across Europe. In Ireland, 40% of power generation is expected to come from wind turbines and solar panels in 2021, compared to around 30% in Spain, Germany and the UK. Shares are considerably lower in France, Belgium and the Netherlands, but the trend here is also upwards. So far, coronavirus has had little impact on the rise of renewables.

More power from wind turbines and solar panels



Source: BNEF, ING Research

Power prices are likely to rise long-term...

Energy systems have to change dramatically in order to reach a carbon neutral economy by 2050. How energy systems will look exactly is still unclear, but the direction is clear. By 2050, energy systems will:

- depend more on intermittent sources of renewables like solar and wind energy;
- depend more on electricity because of the electrification of energy-intensive sectors;
- be able to store energy for short (batteries) and longer periods (like hydrogen and thermal storage);
- capture and store carbon emissions from fossil fuel energy sources (CCS on fossil fuel power plants);
- have a more diversified and integrated grid infrastructure for gas, power, hydrogen and CO2.

All of these changes require vast amounts of investment in an already quite efficient, though fossil-based, energy system. The costs of the energy system will rise as a result.

Many factors call for a substantial rise in long term power prices

Value driver	Direction	Description
Electricity demand	↑	Electricity demand is expected to rise strongly due to electrification in transportation, manufacturing and the built environment
Costs of storage capacity	↑	Short term price volatility and policy measures will spur storage capacity in power markets. This will eventually dampen the short term price cannibalisation effect of renewables and smoothen power prices as a result.
Costs of new infrastructure	↑	Investments in existing power and gas grids and new grids for offshore wind, hydrogen and CCS are likely to drive up electricity costs for end users.
Carbon prices	↑	Carbon pricing is one of the most cost efficient policy instruments to reduce carbon emissions. Governments are expected to implement carbon pricing, include more sectors in existing carbon schemes and aim for higher carbon prices to meet their emission targets.
Gas and coal prices	↑ or ↓	The future of gas and coal prices is quite uncertain and depends on the pace of fossil fuel phase out. According to the IEA, gas and coal prices are likely to rise with the current climate policies of governments (IEA's stated policies scenario). This will drive up power prices in this scenario as gas fired power plants will continue to set power prices. However these policies are not ambitious enough to meet the Paris goals. In the Net Zero scenario global warming is limited to 1.5 °C as fossil fuels are phased out as soon as possible. In such a world gas and coal prices drop as a result.

Source: ING Research

...but beware the short-term power price cannibalisation

While there are good reasons to expect higher power prices in the long term, there is compelling evidence that renewables will push power prices temporarily lower in the short term dependent on season, demand and geography, which is often referred to as price cannibalisation.

Meet the cannibals: wind turbines and solar panels

Cornwall Insight defines price cannibalisation as the depressive influence on the wholesale electricity price at times of high output from intermittent, weather-driven generation such as solar panels, onshore and offshore wind turbines.

What price cannibalisation? Defining the short term

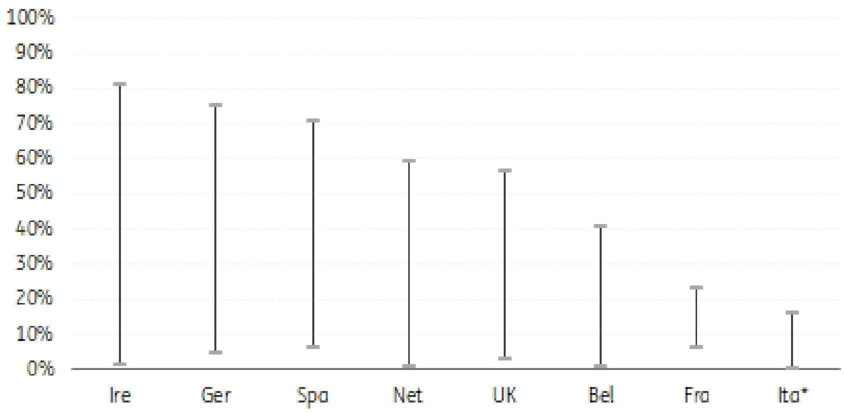
Short term price cannibalisation can happen on different timespans as weather conditions vary from hour to hour, day to day, week to week and month to month.

Intraday price cannibalisation is a major topic for owners of solar and wind farms. Solar panels for example, produce their maximum output on sunny days during midday when solar irradiation is at its best. This can cause the intraday power price to drop to low levels during these hours of high solar generation. Owners of solar farms seek to make their earnings during these hours of ample supply, but may reap a lower power price. That power price is called the captured price: the actual power price a generator is able to capture when it is generating electricity. For example, an owner of solar panels might capture only 85% of the average daily wholesale price as he produces power only in the low cost hours.

On occasions during certain hours in a day when demand is low and generation from renewables is high, wholesale and captured power prices can even be temporarily negative, causing a penalty for generators in times of high supply (unless they opt to switch off). Subsidy schemes increasingly account for this. In the Netherlands for example, owners of solar and wind farms do not receive subsidy for the power they generate if the power price is negative for more than six hours in a day, which may add to lower captured power prices. This topic of low captured prices is also strongly related to the duck curve: the way that high solar generation at midday is impacting power generation and demand for grid operators. Generators do have the option to temporarily suspend production, or install on-site storage solutions to mitigate the impact of lower power prices.

While price cannibalisation might be largest for captured power prices on an hour by hour basis, we cannot quantify it as there is no market data available on captured prices. We also want to extend our focus from the very short term to weekly and monthly power price trends. For these reasons we investigate price cannibalisation on a weekly and monthly basis on realised baseload power prices [see note 1].

The weather determines the day-to-day importance of wind and solar in the power mix



*Italy consists of six power price regions. Figures are shown for the Northern region which accounts for half of Italy's power demand in 2020.

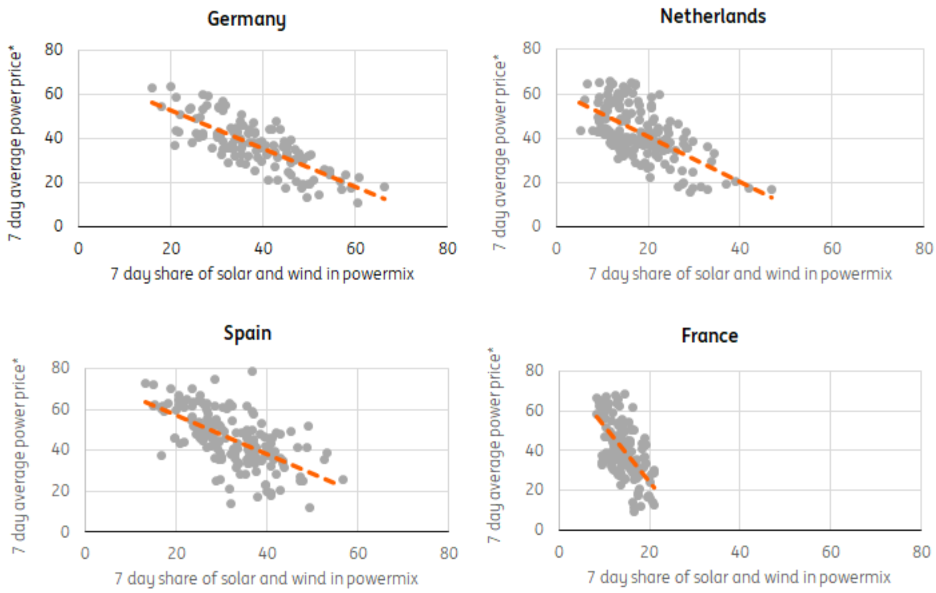
Source: ING Research based on Refinitiv

Weather conditions determine the amount of power generation from wind turbines and solar panels. On sunny and windy days they produce a lot of power, on rainy and wind-free days hardly any. The daily share of wind and solar power varies as a result; from almost zero up to over 80% in Ireland and over 60% in Germany and Spain. That's why wind and solar are called variable renewables, compared to other renewables such as hydro power and biomass that are adjustable just like coal- and gas-fired power plants. They are also called intermittent power sources as opposed to fossil fuel power plants that are available most of the time.

Renewables push power prices lower in the short-term

Our data confirms that baseload power prices [see note 1] are, on average, much lower in weeks with high power generation from wind and solar.

Negative relation between power prices and the amount of power generation from wind and solar



Source: ING Research based on Refinitiv

Wind of change for weekly and monthly power prices

While our scatter plots are telling, they do not capture the full cannibalisation effects from wind and solar power. Other factors can play a role, too. Lower commodity prices or lower electricity demand in weeks with high wind and solar generation can also contribute to a negative correlation between power prices and renewables.

We have built a model to isolate and quantify the cannibalisation effect from the many other factors that determine power prices. We apply the model to average **weekly** and **monthly** data to capture the medium term impact of renewables on power prices.

The table below presents the overall trend across the countries examined, based on a panel data regression. This technique combines the trend over time *within* countries with the differences *between* countries to assess the overall trend for the set of countries. We discuss these general outcomes first. Later on we will discuss country specific results, too.

Impact of higher shares of wind and solar on power prices

	Weekly data	Monthly data
Effect of more wind and solar power...	**...on baseload power prices**	
A 50% increase[3] in the share of wind power...	...lowers prices by **-7.1%**	...lowers prices by **-8.2%**
A 50% increase[3] in the share of solar power...	... lowers prices by -0.9% [4]	...lowers prices by **-1.7%**
Effect of other important power price drivers...	**...on baseload power prices**	
A 10% rise in gas prices...	...increases prices by **+4.9%**	...increases prices by **+3.6%**
A 10% rise in coal prices...	...increases prices by +1.7% [4]	...increases prices by **+3.7%**
A 10% rise in CO_2 prices...	...increases prices by **+2.4%**	...increases prices by **+5.5%**
A 10% rise in power demand...	...increases prices by **+3.5%**	...increases prices by **+2.6%**
A reduction of the share of nuke by 5%...	...increases prices by +0.2% [4]	...increases prices by **+0.2%**

[1] for the UK we only had monthly data on solar generation. UK is therefore included in monthly results but not the weekly results.
[2] Italy is divided in 6 power regions. We only included the largest northern region in order to prevent overrepresentation by Italy in the panel data regression.
[3] e.g. from 10% to 15%, 20% to 30% or 40% to 60%.
[4] statistically insignificant, so it cannot be ruled out that the effect is zero.
[5] e.g. from 75% to 71% (France), 50% to 48% (Belgium) or 12% to 11% (Germany), rounded numbers.

Source: ING Research

Our main findings across all the countries are:

1 Wind turbines make a difference on a weekly and monthly basis

A 50% increase of the share of wind power in the power mix lowers power prices by 7% on a weekly basis and 8% on a monthly basis. Note that the ceteris paribus clause holds and that the results represent the overall trend across the countries.

There are two reasons for the sizable impact from wind turbines.

First, wind turbines can generate power 24/7 whereas solar panels only during the day. As a result, 1 gigawatt of offshore wind capacity produces on average 4.1 terawatt hours of electricity across the globe, four times more than 1 gigawatt of solar capacity which produces 1.0 terawatt hours of electricity.

Second, wind energy has a higher share in the generation mix of many countries. For example, wind turbines generate about five times more power compared to solar panels in the UK, four times in Spain and about three times more in Germany and France. In the Netherlands wind and solar generate an equal amount of power and Italy is the only country where solar generation is higher than wind generation (about 20%).

2 Solar panels matter less on a weekly and monthly basis

A 50% increase in the share of solar power causes power prices to drop by about 2% on a monthly basis, which is four times smaller than the effect of wind turbines. On a weekly basis the result is statistically insignificant so we cannot come to a conclusive answer whether or not price cannibalisation exists.

Note that we investigate power prices on a weekly and monthly basis. As stated before, the impact from solar panels is likely to be considerably higher if one considers intraday power prices variations.

So, while solar panels might be more top of mind by consumers and businesses when it comes to renewable energy, wind turbines have a bigger impact on weekly and monthly power price averages. There is truly a wind of change.

3

On the commodity side, gas prices have the biggest impact

On a weekly basis gas prices have the biggest impact, carbon prices on a monthly basis

A 10% increase in gas prices raises power prices by 5% on a weekly basis. On a monthly basis carbon prices matter most.

4

When commodity prices move in tandem, the impact on power prices is reinforced

For example, when both gas, coal and carbon prices go up by 10%, power prices go up by 11% on a weekly basis and 15% on a monthly basis.

5

Gas prices matter more than coal prices

In general, gas prices have a bigger impact on power prices than coal prices. On a weekly basis, we don't find a significant impact of coal prices on power price dynamics. That is in line with the observation that in European countries gas fired power plants are often the price setting power plants in the merit order.

6

The law of demand holds

We find that power prices go up by about 3% if demand rises by 10%, both on a weekly and monthly basis.

7

The results are quite robust

- First, all signs are as expected. We find that, on average, higher shares of wind and solar lower power prices, rising commodity prices increase power prices, and a rise in power demand results in higher power prices.
- Secondly, the size of the measured effects is quite similar for weekly and monthly data, although a bit larger for monthly data.
- Third, most results are statistically highly significant and the explanatory power of our model is more than sufficient.

Geography matters: the impact of solar and wind differs per country

The seven findings represent the overall trend across the countries we examined. In practice, the characteristics of power markets vary substantially from one country to another or even within countries. In Italy for example, the day ahead market consists of six regions. The table below provides the country results and regional results for Italy.

When looking at specific power markets our main findings are:

1

Wind turbines have a larger impact on average weekly and monthly power prices compared to solar panels in most of the regions. In **France**, **Germany** and **Spain** price cannibalisation from wind turbines is largest.

2

For many countries we do not find a statistically significant effect from solar power on average weekly and monthly power prices at all, especially on a weekly basis. Solar does have an impact in **Germany**, **France** and the **UK** on a monthly basis but the impact is small compared to wind turbines. **Sicily** stands out as the impact from solar is large and tops wind, but it is a very small and specific power market.

3

Nuclear power is, like wind and solar, an energy source with almost zero marginal costs. It costs very little to produce an extra megawatt hour of power once the nuclear power plant is running. **France** is the country with the highest share of nuclear power (up to 75% of power generation in the yearly power mix). This has two implications.

First, maintenance or outages of nuclear power plants have a large impact on power prices. Our analyses on 2018-2020 data suggests that a 5% reduction in the share of nuclear power generation causes power prices to increase by almost 20%.

Second, with a high share of low cost nuclear power, small swings in the power supply of wind and solar have large power prices implications. For example, a 20% increase in the share of wind and solar in France has a similar impact on weekly and monthly power prices as a 50% change in **Germany**. In fact, a 50% change does not happen in France as the share of nuclear energy is so large.

These findings clearly show that power markets are not alike. Local circumstances must be taken into account when analysing investments or business cases in renewable energy.

Impact of higher shares of wind and solar on power prices

	Weekly data	Monthly data
Germany		
A 50% increase[1] in the share of wind power...	...lowers prices by **-12.5%**	...lowers prices by **-26.2%**
A 50% increase[1] in the share of solar power...	...lowers prices by -3.1% [2]	...lowers prices by **-4.1%**
A reduction in the share of nuke by 5%...	...raises prices by +0.3% [2]	...raises prices by +0.8% [2]
France		
A 20% increase[3] in the share of wind power...	...lowers prices by **-19.6%**	...lowers prices by **-21.9%**
A 20% increase[3] in the share of solar power...	...lowers prices by -0.6% [2]	...lowers prices by **-2.1%** [2]
A reduction in the share of nuke by 5%...	...raises prices by **+17.5%**	...raises prices by **+19.6%**
The Netherlands		
A 50% increase[1] in the share of wind power...	...lowers prices by **-3.7%**	...lowers prices by -2.7% [2]
A 50% increase[1] in the share of solar power...	... lowers prices by -0.7% [2]	...lowers prices by -0.5% [2]
Belgium		
A 50% increase[1] in the share of wind power...	...lowers prices by **-8.9%**	...lowers prices by **-10.2**
A 50% increase[1] in the share of solar power...	... lowers prices by -0.1% [2]	...lowers prices by -3.2% [2]
A reduction in the share of nuke by 5%...	...raises prices by **+3.1%**	...raises prices by +1.4% [2]
Spain		
A 50% increase[1] in the share of wind power...	...lowers prices by **-10.7%**	...lowers prices by **-19.0%**
A 50% increase[1] in the share of solar power...	... lowers prices by -0.9% [2]	...lowers prices by -3.6% [2]
UK[2]		
A 50% increase[1] in the share of wind power...	(only monthly data available)	...lowers prices by **-6.6%**
A 50% increase[1] in the share of solar power...	(only monthly data available)	...lowers prices by **-4.9%**
Italy – north		
A 50% increase[1] in the share of wind power...	...lowers prices by **-1.3%**	...lowers prices by -1.2% [2]
A 50% increase[1] in the share of solar power...	...lowers prices by -0.6% [2]	...lowers prices by -1.3% [2]
Italy – center north		
A 50% increase[1] in the share of wind power...	...lowers prices by **-1.8%**	...lowers prices by **-4.3%**
A 50% increase[1] in the share of solar power...	...lowers prices by **-2.2%**	...lowers prices by -2.4% [2]
Italy – center south		
A 50% increase[1] in the share of wind power...	...lowers prices by **-2.0%**	...lowers prices by **-4.5%**
A 50% increase[1] in the share of solar power...	...lowers prices by -0.4% [2]	...lowers prices by -0.1% [2]
Italy – south		
A 50% increase[1] in the share of wind power...	...lowers prices by **-5.8%**	...lowers prices by **-6.0**
A 50% increase[1] in the share of solar power...	...lowers prices by -2.8% [2]	...lowers prices by -0.8% [2]
Italy – Sicily		
A 50% increase[1] in the share of wind power...	...lowers prices by **-7.3%**	...lowers prices by **-11.3%**
A 50% increase[1] in the share of solar power...	...lowers prices by -2.3% [2]	...lowers prices by **-13.5%**
Italy - Sardinia		
A 50% increase[1] in the share of wind power...	...lowers prices by **-2.6%**	...lowers prices by -5.1% [2]
A 50% increase[1] in the share of solar power...	...lowers prices by **-2.6%**	...lowers prices by -2.5% [2]

[1] e.g. from 10% to 15%, 20% to 30% or 40% to 60% on a weekly or monthly basis.
[2] statistically insignificant, so it cannot be ruled out that the effect is zero.
[3] in France the shares of wind and solar power are more stable compared to the other regions. A 50% increase rarely happens, therefore we take a 20% deviation as reference which is quite common in France.

Source: ING Research based on data from Refinitiv

Expect more power price volatility with rising shares of wind and solar

Governments continue to push for more renewables in their power mixes. The Netherlands, for example, aims to generate about 75% of its power from renewables by 2030 compared to just under 20% now, with wind and solar providing the lion's share. The weather will have a bigger impact on short term power prices as a result, not only in terms of the level of power prices, but also the volatility of prices. Our analyses suggest that periods with the lowest power prices coincide with periods in which the share of power generation from variable renewables is highest.

Notes:

1] The baseload power price is the price for baseload power which is the electricity demand required on a continuous basis, i.e. 24 hours a day all year round, to power continuous industrial processes, and essential services such as, hospitals, traffic lights, communication services, etc. As such, the baseload power price is a benchmark for heavy power users in manufacturing, transportation, real estate and the power sector. We analyse actual day ahead baseload prices, which is the realisation of the baseload power price in the day ahead market.

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Article

Dealing with power price volatility: PPA growth continues to slow

The market for Power Purchase Agreements (PPAs) continues to grow globally. For companies, PPAs are a means to decarbonise their power supply. For developers, PPAs are a means to mitigate power price risk and stabilise cash flows. Growth is less buoyant though, with growth figures halving each year since 2018, reaching 8% in 2021

What's a PPA?

The World Business Council for Sustainable Development (WBCSD) defines a Purchasing Power Agreement (PPA) as a contract between the buyer (off-taker) and the power producer (developer, independent power producer, investor) to purchase electricity. Usually at pre-agreed prices for pre-agreed periods, but also without any pre-agreed price level or volume (route to market). The contract contains the commercial terms of the electricity sale: length, delivery point/date, volume and price. Contracts are not standardised, so many forms exists (pay as produced, baseload, or variations). The electricity can be supplied by existing renewable energy assets or new build projects.

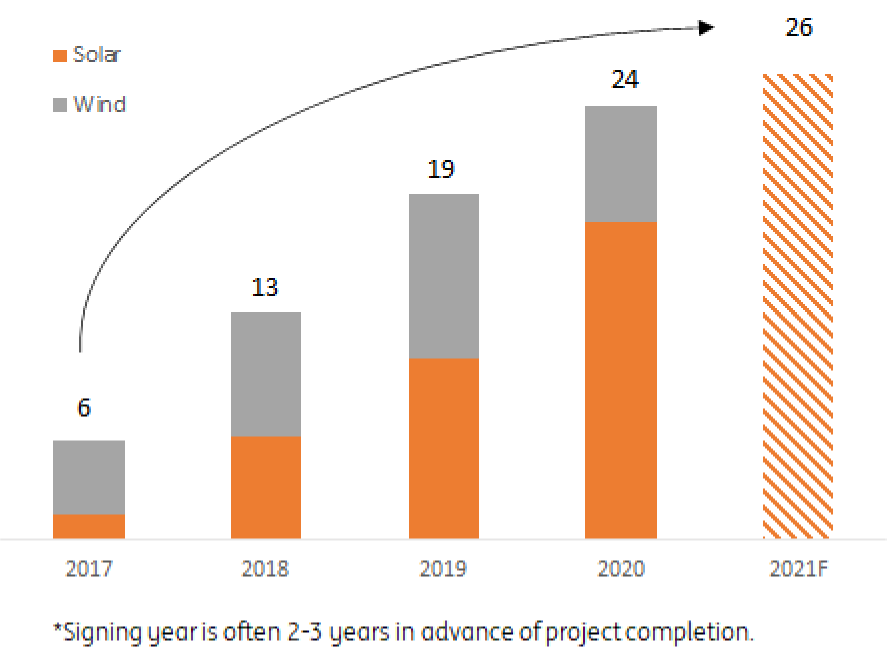
Next to corporate PPAs there are PPAs from utilities, like Vattenfall, Eneco and Stattkraft. The utility PPA market exists much longer than the corporate PPA market. In this article we use the PPA database of Bloomberg New Energy Finance which includes PPAs from corporates and utilities.

There are two types of PPAs in both markets. In the case of physical PPAs, the renewable asset and power user operate on the same grid. Think of the Dutch railroad company (NS) buying green power from Dutch solar or wind projects. That is not the case with virtual PPAs. Think of Amazon buying green power from an offshore wind farm in the Netherlands to procure the power consumption of their distribution and data centers elsewhere in Europe.

Continued but lower growth

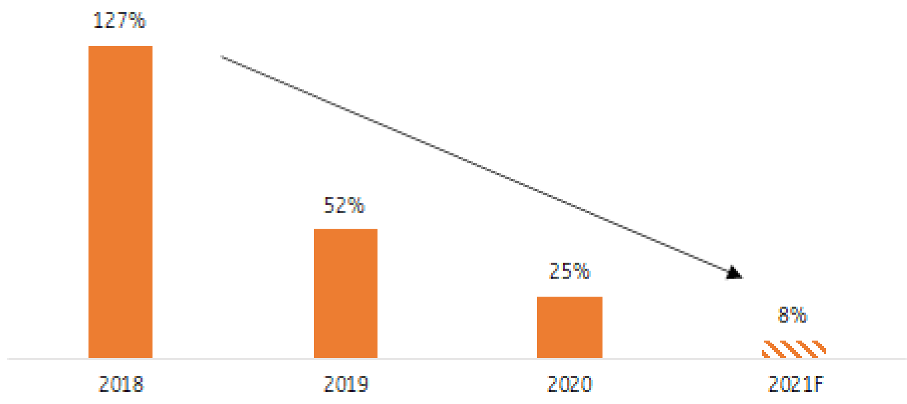
The global market for PPAs has grown rapidly, with PPA volumes rising from 6 GW in 2017 to an estimated 26 GW in 2021. The pace of growth is declining though, with growth halving each year since 2017.

The PPA market continues to grow...



Source: ING Research based on BNEF

...but growth halves every year



Source: ING Research based on BNEF

The three factors behind strong PPA growth

Three factors have contributed to the strong growth of the PPA market from 2017 onwards.

1. First, PPAs are a way to stabilise cash flows for renewable energy projects that do not derive their revenues from regulated sources. Although renewables in most power markets in Europe still benefit from regulatory support, subsidy-free bids on wind and solar projects have entered some power markets from 2017 onwards and face higher merchant risks that can be managed with PPAs. Developers are also looking for ways to stabilise cash flows to increase leverage and stabilise return on equity.

2. Second, many companies are setting clean energy targets as part of their Corporate Social Responsibility strategies. Power heavy companies in the telecom, media & technology sectors and in manufacturing are entering the PPA market as a way to decarbonise their power supply.

3. Third, electrification is an important factor to decarbonise industries that heavily rely on fossil fuels, such as manufacturing and transportation. Global power demand could rise by 80% by 2040 in our scenario that limits global warming to the goals of the Paris Climate Agreement. Sourcing power demand from renewables and managing the power price risk of renewable energy projects becomes vital in such a world.

These factors explain the strong uptake in PPA procurement from about 6 GW in 2017 to an anticipated 26 GW in 2021.

26 GW — Anticipated growth of the global PPA market in 2021

gigawatts

Push from buyers to the PPA market

Companies have different options to decarbonise their power supply. They can invest in renewable capacity themselves, for example by building on site wind turbines or solar projects. However, this requires permits and a lot of space. And if offers no solution for wind-free and cloudy days when the company also needs electricity, unless the company also invests in storage facilities like batteries. It can also extend the balance sheet if these assets are owned by the company.

PPAs are an alternative to invest in renewables

Companies can also buy green power from utilities or developers which demonstrate their 'greenness' through guarantees of origin (GOs). GOs exist in some of the North-West European power markets and are tradable certificates that guarantee that the power comes from renewable energy projects. This market has been operating for many years, but has some drawbacks for companies looking to green their power supply. First, most power is hydro power out of the Nordics but companies often want to support the energy transition towards wind and solar energy closer to their production sites. Second, there is a weak link between the generating asset and the off-taker. Nowadays, a select group of companies with high sustainability targets are demanding more control over their sustainable power procurement. Important stakeholders like NGOs demand that too. As a result, these companies more often want to have direct involvement in the development of solar and wind farms.

PPAs offer a middle way between owning wind and solar assets and the abstract market for GOs.

PPAs as a middle way between company owned renewables and GOs

	Company owned wind and solar projects	Purchasing Power Agreements (PPAs)	Guarantees of Origin (GOs)
Benefits of PPAs			
CSR fit: recognition for green electricity achievements	High	Medium	Low
Relation to production asset (wind or solar project)	High	Medium	Low
Means to stimulate growth in wind and solar projects	High	Medium	Low
Mitigating power price risk	High	Medium	Low
Drawbacks of PPAs			
Capital intensity	High	Medium	Low
Impact on balance sheet	High	Medium*	Low
Complexity of permits	High	Medium	Low
Complexity of contracts	Medium	High	Low

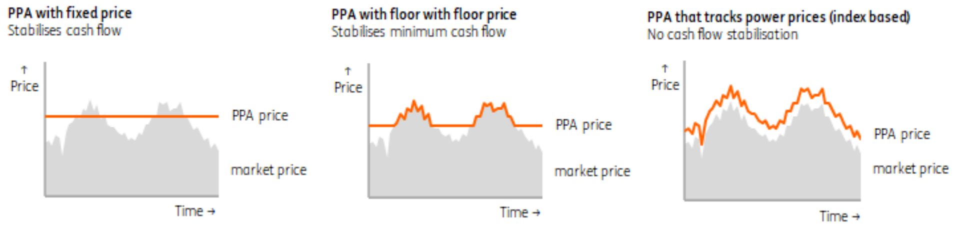
*There can be financial implications from a PPA depending on its structure and whether or not the company reports under IFRS accounting rules.

Source: ING Research

PPA price and tenor are decisive in stabilising cash flows

In principle there are two types of PPAs. Either the off-taker buys the generated power as and when a project generates renewable power. Or the off-taker requires a (hourly/monthly/yearly) baseload PPA contract whereby the generator must deliver a pre-defined quantity of MWh of electricity irrespective of whether it generates this, or not. In either case, the off-taker can buy the power at a pre-agreed indexed or unindexed price (price contract), or at the then prevailing market price in the spot market. The contracts differ in the type of price and volume volatility that is hedged. Fixed price pay as produced contracts offer the best opportunities to stabilise cash flows as the generator just gets paid for the actual MWh's produced at the pre-set or market price. Base load contracts offer considerable less value in stabilising cash flows as the generator takes dispatch and market price risk.

Different PPAs, different degrees to stabilise cash flows



Source: ING Research

Not all alike

Every PPA needs to be judged on its own merits as PPA contracts are not standardised. Nevertheless, the market continues to grow as market players seek ways to stabilise cash flows.

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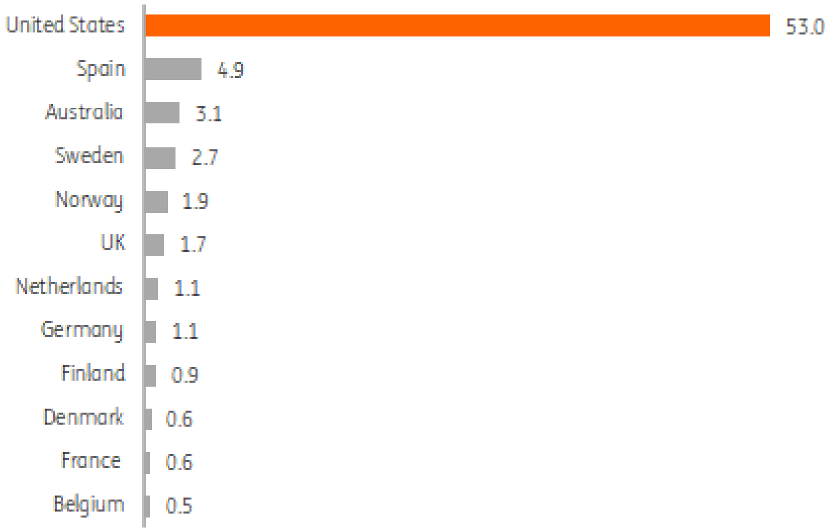
Article

American big tech goes green, driving PPA market

US based companies dominate the PPA market, with 53 GW of PPAs procured globally since 2008. American big tech companies lead the way with Amazon, Google, Facebook, Microsoft and Apple holding a top 10 position. Volumes from European companies are smaller, but they are catching up and the top players come from different sectors

This article compares the activity of US based companies, both corporates and utilities, versus European companies in the global PPA market. A Purchasing Power Agreement (PPA) is a contract between the corporate buyer (off-taker) and the power producer (developer, independent power producer, investor) to purchase electricity.

US based companies lead the way in the PPA market



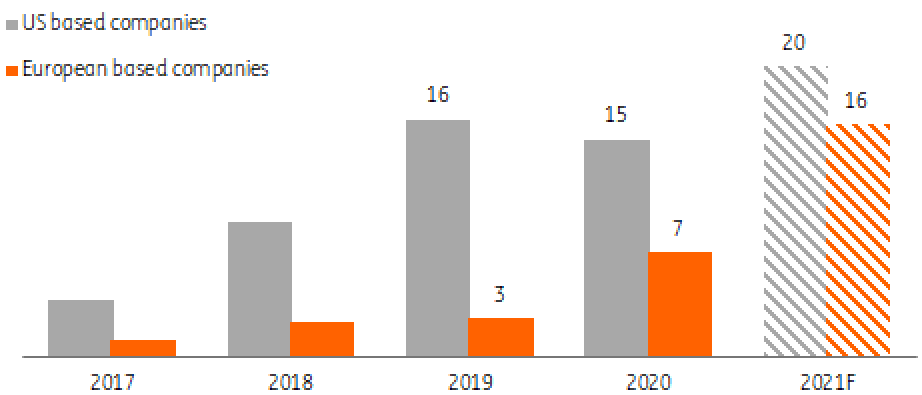
*Both corporate PPAs and PPAs from utilities.

Source: ING Research based on BNEF

...but European companies are catching up

The PPA market has a long history in the US. Hence US based companies have been most active, both in the US and abroad. PPAs in renewables are a newer phenomenon for European based companies mostly as many European countries offered regulatory support. In recent years activity from European companies is catching up towards levels from US based companies. For 2021 we expect the gap to narrow further with 20 GW of new PPAs from US based companies and 16 GW from European companies.

European companies are closing the gap with US based companies



*Signing year is often 2-3 years in advance of project completion.
Numbers include PPAs from corporates and utilities.

Source: ING Research based on BNEF

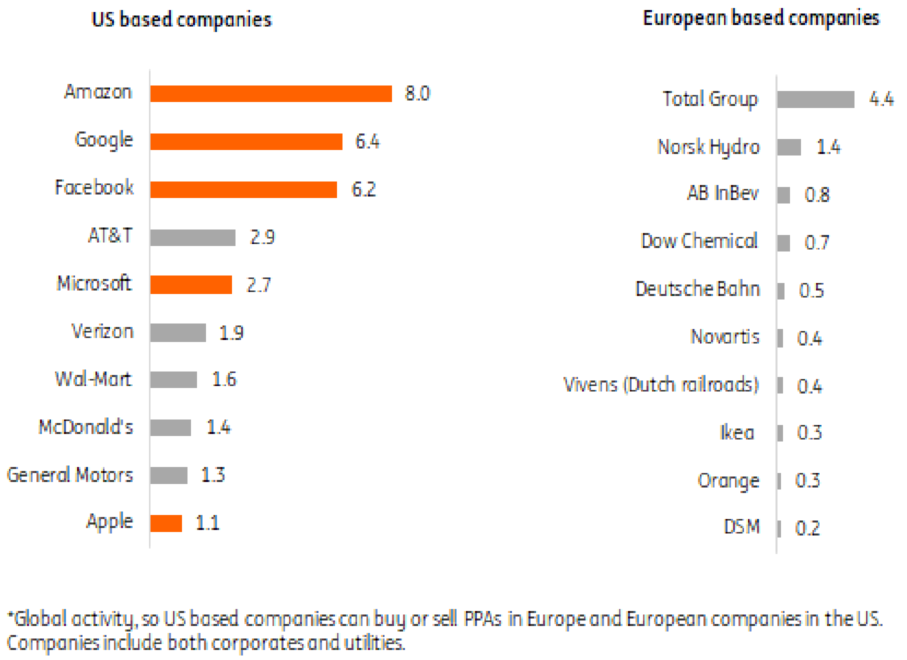
US bigtech companies dominate PPA rankings...

Bigtech dominates the PPA market among US based companies. Amazon, Google, Facebook, Microsoft and Apple together have 25 GW of PPAs outstanding. The majority is related to wind and solar projects in the US, although they now also source renewable electricity in Europe through PPAs. Amazon, for example, recently bought half of the power from Shell's offshore wind farm near the Dutch coast to green the power in their European warehouses (see table below).

...while interest from European companies comes from a wide range of sectors

Activity from European companies is catching up but activity is not dominated by bigtech companies. The five European companies most active with PPAs come from different sectors, like energy (Total), manufacturing (Norsk Hydro), food & beverages (AB InBev), chemicals (Dow) and transportation (Deutsche Bahn). Unlike Total and Norsk Hydro, the top 10 players so far have sourced less than 1 GW of green power through PPAs.

Bigtech dominates top 10 ranking of US based companies active in the global PPA market, but not so for European based companies



Source: ING Research based on BNEF

Green power generation becomes steadier when wind and solar are combined...

Some of the large players in the global PPA market source their power from both wind and solar projects. In doing so, they benefit from the different solar and wind generation profiles. The diversification effects of wind and solar and a portfolio of multiple projects at different weather locations allow off-takers to create more stable renewable power production during the day and week.

..., but mind the gap on cloudy days with little wind

However, wind and solar diversification is often far from perfect. On days or hours when the wind and solar assets of the PPA produce little power, the company still needs electricity, which it gets through the grid. PPAs are a good way to procure a companies' annual power demand in a sustainable way, but not on a daily or hourly or on a minute-to-minute basis.

PPAs in practice

Buyer	Seller	Country	Size	Description
Amazon	Shell	Netherlands 2021	380 MW	• Amazon aims to be net zero carbon emissions across its businesses by 2040. Part of that commitment is to use 100% renewable power. • Amazon buys half of the power production from offshore wind farm 'Hollandse Kust Noord' to green the power demand in their European data centers and warehouses • The contract was signed in 2021, and the project will be completed in 2023.
ASML	RWE Innogy	Netherlands 2021	250 MW	• ASML buys 250 GW of renewable power per year from a portfolio of diverse renewable energy sources including two Dutch RWE onshore wind farms, one Belgium onshor wind farm and a Dutch solar farm • The PPA starts in 2021 and has a tenure of 10 years
Kellogg's, Uber	Enel green power	US, Texas 2021	110 MW	• Enel green power has sold power from its Azure Sky wind and storage project in Texas • Kellogg's buys 100 MW, Uber 10 MW. Power from the Azure project is also sold to Akamai, Synopsys and MilliporeSigma (hybrid PPA with multiple buyers).
Orange	Engie	France 2021	51 MW	• Orange aims to reduce its direct carbon emissions by 30% in 2025 compared to 2015 and reach an electricity mix of 50% renewables. • It has signed a 15-year PPA with Engie to buy all the powe from two solar plants in the Hautes-Alpes region: 38 MWp from the L'Epine solar farm and 13 MWp from the Ribeyre solar farm. Both facilities will be operational in 2022
Nestle	Orsted	UK 2020	31 MW	• The world's largest food and beverage company, Nestlé, signed a 15-year indexed fixed price agreement with Orsted to by 31 MW of green power from Orsted's Race Bank Offshore Wind Farm • The deal is part of Nestlé UK's strategy to cover 100% of it electricity from wind power
Heineken, Nouryon, Philips, Signify	Neoen	Finland 2020	126 MW	• Heineken, Nouryon, Philips and Signify joined forces to support the development of 35 wind turbines in the Mutkalampi municipality in Finland, which is scheduled fo completion in 2023. • The consortium will buy the renewable electricity for the first 10 years. The electricity will be physically delivered t the Finnish grid while the four consortium partners benefi from the Guarantees of Origin, which demonstrate the greenness of their power.
Nike	Iberdrola	Spain 2019	200 MW	• Sports brand Nike has signed multiple PPAs with Spanish energy company Iberdrola to supply clean power to its facilities. • The latest PPA dates from 2019 and involves 40 MW of power from the Cavar wind complex in Navarra, northern Spain. In 2016 Nike signed three PPAs with Ibedrola involving project in the US. • Nike sources all its power from renewable sources in the US since 2018 and in Europe since 2020.
AkzoNobel, Google, DSM, Philips	Delta Wind en Zeeuwind	Netherlands 2016	100 MW	• Windfarm Krammer is an onshore windfarm developed b Delta Wind and Zeeuwind as a result of a citizen's initiative. The local community was actively involved in th development and members of Delta Wind and Zeeuwind participate financially. • Deltawind and Zeeuwind sell over 95% of the power to AkzoNobel, DSM, Google and Philips.

Source: ING Research based on BNEF and company websites

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Report

Assessing the impact of wind and solar energy on power prices

In this study we assess the hypothesis that higher shares of wind and solar energy in the power mix result in lower power prices and higher weather induced power price volatility

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