
Electricity Price Outlook 2018

Perspectives for the power price in
North West Europe towards 2035

The logo for Dansk Energi, featuring a stylized 'DE' symbol followed by the text 'DANSK ENERGI' in a bold, sans-serif font.

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Contents

1. **Key Messages and Analysis Summary**
2. **Status of the Electricity Market**
 - 2.1. Historical Prices
 - 2.2. Key Tendencies for Technology, Consumption and Prices
 - 2.3. Political Drivers Related to the Electricity Market
3. **Scenarios for Electricity Prices in Northwestern Europe**
 - 3.1. Scenarios and Main Uncertainties
 - 3.2. Main Scenario Results
 - 3.3. Sensitivity Scenario Results
 - 3.4. Electricity Storage

What is the Electricity Price Outlook?

The Electricity Price Outlook is an extension of Danish Energy's earlier electricity price scenarios that, besides demonstrating different possible futures for the electricity price, also zooms in on Denmark and the terms for Danish electricity production.

While wind and solar power will make up the majority of the electricity production in the future, there is still a need for capacity for days without sunshine or wind. Thus, this outlook also investigates the situation for the Danish power plants.

Chapter 4 on the specific situation on Danish power plants has been omitted from this English translation.

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1. Key Messages and Analysis Summary

The good news: electricity can be entirely green and secure for a small additional cost

The wholesale electricity market is decisive for investment

A large part of the investment in the energy sector is dependent on expectations for developments in the wholesale electricity market. It is therefore of interest to understand the constraints and the central drivers of the market.

For this purpose, Danish Energy prepares a range of scenarios every year that outline different possible electricity price outcomes, given a number of political decisions, fuel prices and technological developments.

Furthermore, in this year's iteration, we have sought to investigate which impacts market developments might have for Danish power plants. Power plants are experiencing rapid changes currently, with fewer operational hours and an increased importance of revenues from supply of heat for district heating.

The change from an electrical system dominated by power plants with large baseload plants to one dominated by wind has consequences for our security of supply and the ability to always cover our consumption with sufficient electricity production.

Price reductions on wind and solar PV are creating a new reality

The main conclusion of our analysis is positive: it appears that electricity will become a greener, and still cheap product in the future. The recent dramatic price reductions in wind and solar power is not only good news for the green transition, it is good news for electricity consumers too.

Our analysis shows that new investments in wind and solar power are expected to limit possible electricity price increases, ensuring that the electricity price will not rise above an annual average value of 47 to 60 €/MWh. Earlier projections have indicated significantly greater increases in prices.

Electricity can become even greener for a small additional cost, ideally through a higher price on CO₂ emissions.

Additionally, it seems that the price for ensuring the desired level of security of supply is bearable, though decisions are still to be made regarding the goals for future security of supply, as well as which instruments should be used in order to ensure it.

Secure

Small extra cost
- If the market gets to pick the cheapest solutions

Green

Small extra cost
- If a fair price on CO₂ is set.

Electricity

Cheap
- Our analysis shows that the average electricity price will maintain a relatively low price level.

The not-so-good news: Electricity will not be green and secure by itself

The CO₂ price is too low to drive the green transition

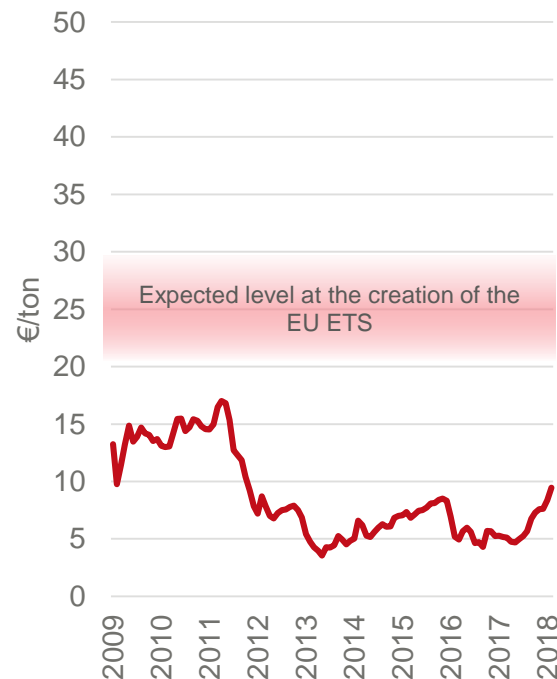
Despite numerous reforms of the EU's carbon market (ETS), the CO₂ price is still much less than the originally expected price of 20 to 30 €/ton. This is due to a large surplus of quotas that were built up after the financial crisis, primarily due to decreases in electricity consumption and industrial production.

With the new reforms this surplus is reduced but the number of quotas issued by the system is still too high. This keeps the carbon price low and means that the green transition continues to primarily be driven by national support systems, which, overall, is a less effective and more expensive way than setting a higher price on pollution.

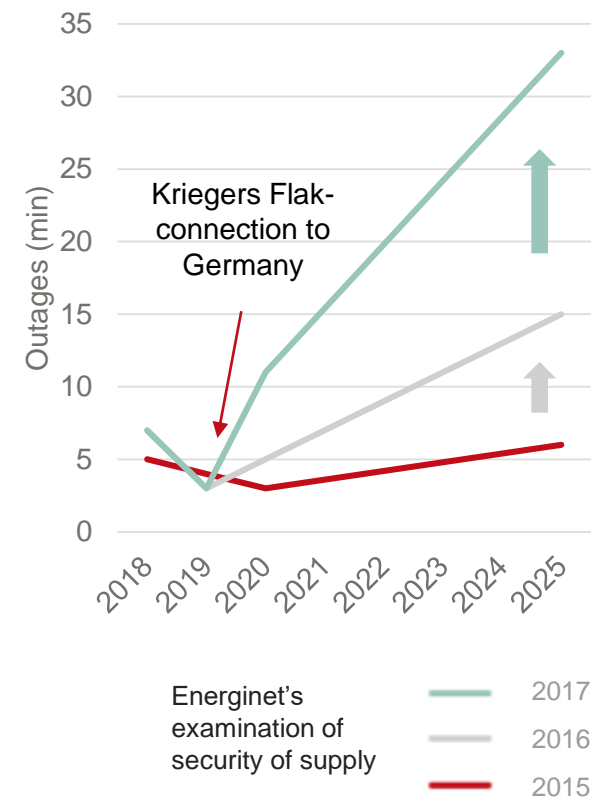
Security of supply to worsen

The Danish security of supply will move into uncharted waters in the years to come, where we cannot be sure that demand can be satisfied at all times. Luckily, it is often possible to import electricity. However, our neighbors are in the same situation as we are, as a large part of the reliable electricity production capacity in these countries will be retired during the next few years. Fewer power plants with fewer operational hours increase the risk of a lack in the technical properties that those power plants deliver today, which has already led to instances of forced operation. In the absence of a price on necessary services, the security of supply will decrease in tandem with power plant closure.

The price on CO₂ is still much less than the expected level



Forecasts for security of supply worsen year by year



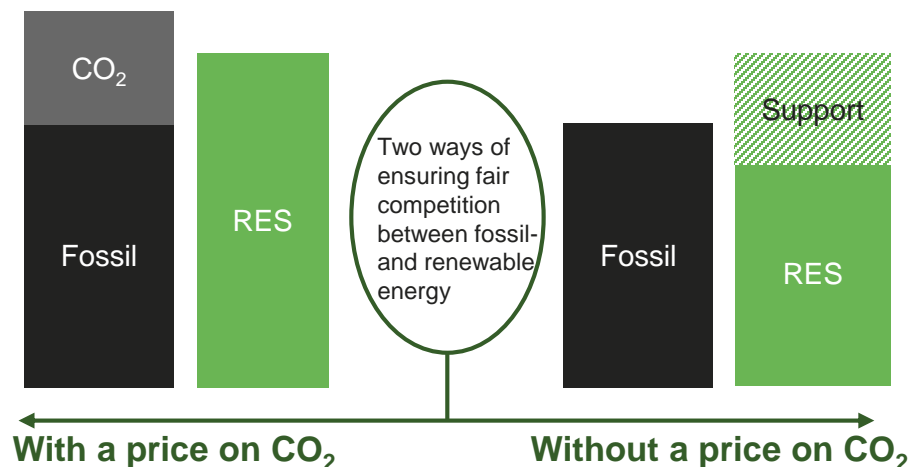
Policy instruments should use the market as much as possible

The price on CO₂ ensures green electricity and fair competition

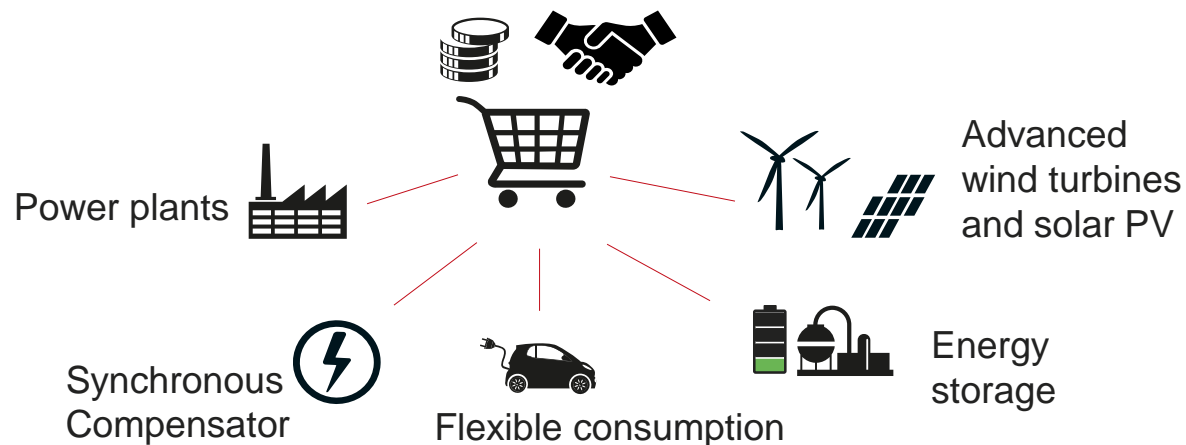
Ensuring a fair CO₂ price, will make renewables become competitive with fossil electricity production. A strong and reformed emissions trading system (ETS) is the preferred option, but hard to reach agreement on. Another solution could be to place a regional price floor among a sufficiently large group of countries. The alternative to a fair price on CO₂ is to subsidize renewable energy to ensure a certain tempo in the green transition. This is, however, a less effective and more expensive solution.

The market can deliver a high level of security of supply

Marketization of all the services the electricity system needs can ensure transparency and fair remuneration for the actors that contribute to stabilizing the electricity system. At the same time competition and innovation is cultivated. Wind turbines, solar PV, electricity storage and other technologies can also deliver some of the services that the electricity system demands and thereby supplement the power plants in ensuring the security of supply. The alternatives to marketization of services is either lower levels of security of supply, or the TSOs, investing in and operating more assets instead of the market actors.



Marketization ensures competition on delivery of services



Summary of Danish Energy's Electricity Price Outlook 2018: On developments in electricity prices and the electricity market in Northwestern Europe

1. Low costs for new wind and solar PV will limit both earnings from RES and the average electricity price. Decreasing costs for new wind and solar capacity causes electricity production from these sources to be the cheapest available. The future remuneration for wind is limited by costs for future wind.

2. Costs for electricity production from coal will continue to have great impact on the electricity price, but it is increasingly the costs for renewable energy and gas that set the price. This is further amplified by a large move away from coal in Europe.

3. Differences in the value of electricity production from different types of plants will grow. The relative remuneration for wind and solar will decrease compared to the average electricity price, while the flexible power plants relative remuneration will increase. The average electricity price will therefore become less relevant over time to producers.

4. Price reductions on RES have amplified the political appetite for the green transition. Whether the transition continues through support systems or by a higher CO₂ price is crucial to the electricity price.

5. The balance between RES and electricity consumption is crucial to the electricity price. An RES-expansion that grows much faster than the demand will bring about significantly lower prices, while higher consumption does not lead to equivalent price increases, as RES limits the price of electricity under market conditions.

6. The price of CO₂ is of great importance to power plants, wind and solar PV. High CO₂ prices will significantly lower the earnings from coal power but increase remuneration for wind and solar to a level where these can be established under market conditions, without support. Earnings for biomass-fired plants will increase with higher CO₂ prices.

7. Higher CO₂ prices today translate into rising electricity prices, but will in the future mostly translate into greater amounts of renewable energy. The expansion of wind and solar power under market conditions in scenarios with high CO₂ prices impedes electricity price increases.

8. The economics of power plants remaining in the market will improve slightly towards 2030 but fewer operational hours and increased dependence on unpredictable hours with extreme prices result in uncertain revenues.

9. Reliable electricity capacity from power plants or storage will increase in value in tandem with old plants closing. Storage is a competitor to gas power and is able to serve a large share of new reliable capacity requirements.

10. Electricity storage will be able to lower electricity production fueled by natural gas. Batteries can play a role as the future peak load plants, while long-term storage can lower the curtailment of wind and solar. Further breakthroughs for electricity storage to replace power plants requires both low costs for renewable energy and long-term storage.

11. Transmission can increase the value of wind and solar. Cables between the Nordic region and Great Britain can increase remuneration for wind power in both markets.

2. Electricity Market Status

Denmark is not an island

A small part of a large electrical system

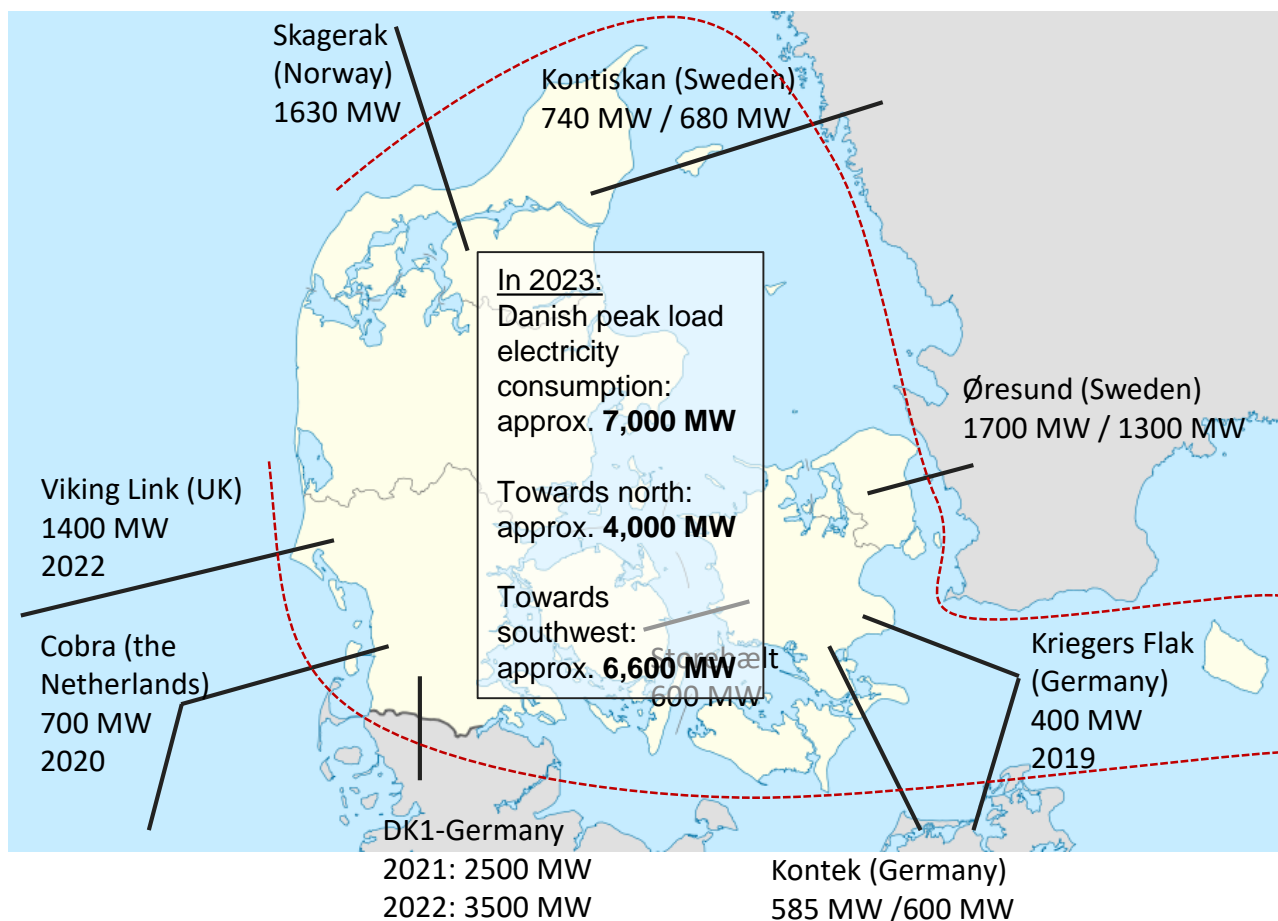
Denmark is strongly connected to our neighbors through various transmission connections, which make it possible to trade electricity across borders.

Three additional connections (to Germany, the Netherlands and the UK) have been decided upon and will be commissioned in the coming years. Likewise, the connection between Jutland and Germany is currently being upgraded.

When the new transmission connections are completed in 2023, Denmark's total transmission capacity with neighboring countries will exceed 10,000 MW. For comparison, Denmark's peak load consumption in 2023 is expected to be approx. 7,000 MW.

For this reason, Denmark is definitely not an island in electricity system terms but rather a small part of a large system, where the electricity price is set in a much larger market and where decisions in neighboring countries affect the conditions for Danish electricity production and security of supply tremendously.

Denmark with current and future transmission connections



Introduction to the electricity market

Supply and demand sets the price

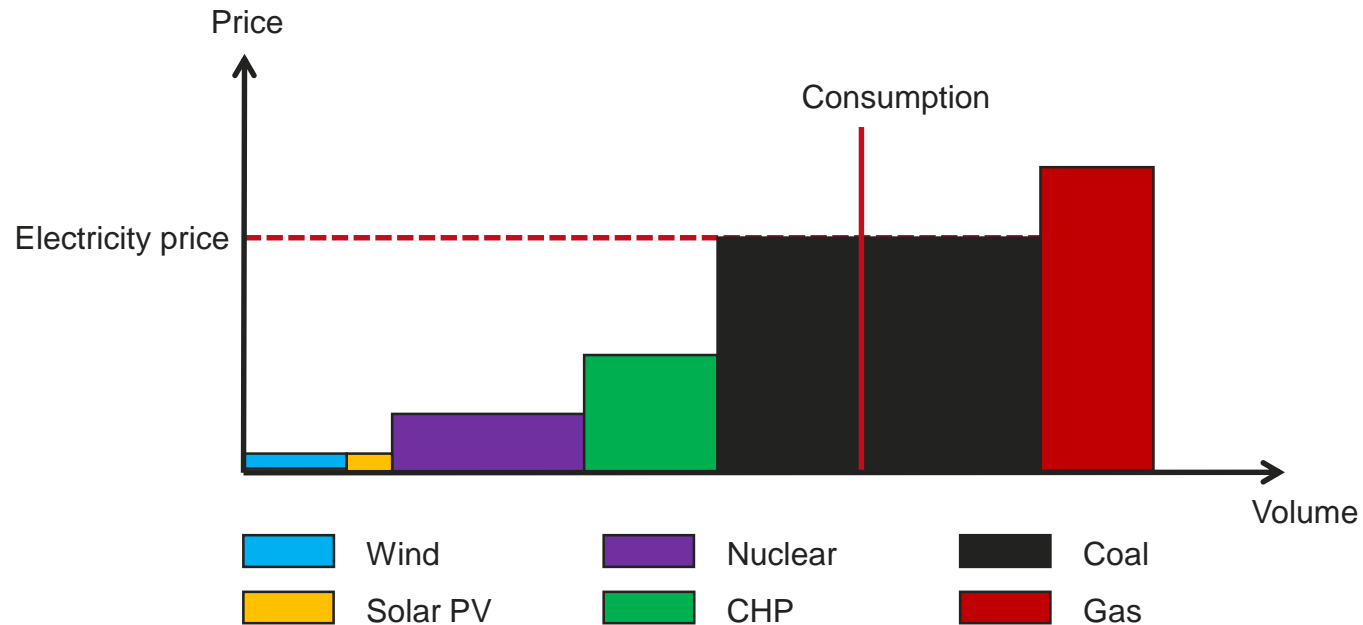
The electricity price is set every day based on bids filed by consumers and producers in the European electricity exchanges. An algorithm (Euphemia) that sets the price hour by hour in the following day in each price region then clears the market, taking into account limits in the transmission grid.

Danish electricity producers thus compete against German, Swedish, Norwegian and sometimes even Spanish producers to deliver electricity to consumers.

The various producers provide bids equal to their costs and the price is then set at the point where the supply and the demand curve cross. Wind and solar PV typically bid close to zero but earn a contribution margin equal to the electricity price. During hours with high consumption and low wind power production, gas usually dictates the price. Coal-fired power plants, with their lower marginal costs, earn a large share of their money during these hours.

During hours with strong wind the supply curve is pushed towards the right, the price becomes very low and only a low or no contribution margin is obtained.

Most expensive plant activated in every hour sets the electricity price for all



The most important parameters which set the electricity price are outside Danish influence

Denmark is generally a price taker in the electricity market.

Numerous factors affect the electricity price and Danish decision makers have little chance to influence most of them.

Today the cost of coal (coal price and CO₂ price) are of great importance to the electricity price. These are decided by the world market (primarily by decisions in China) and the EU respectively, with limited influence from Denmark.

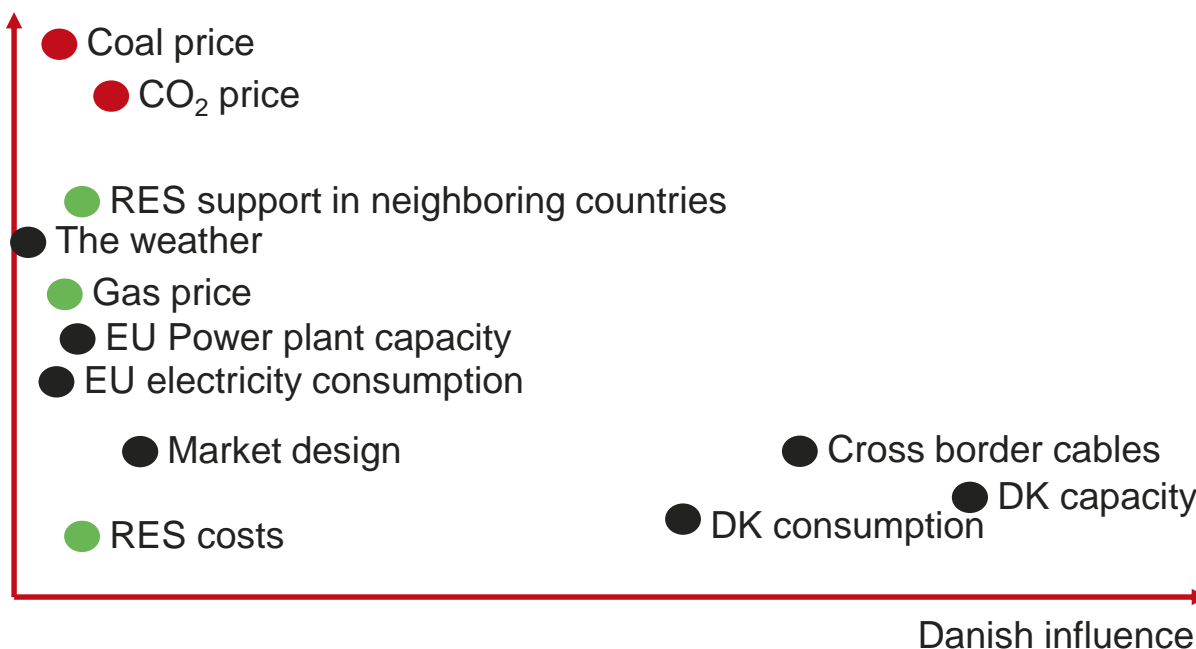
The support for RES in our neighboring countries also places a downwards pressure on the electricity price by increasing the supply of electricity and by pushing the electricity price below the costs for renewable energy.

Danish politicians can affect the consumption and capacity of power plants, wind turbines and solar PV in Denmark through frameworks such as fees, subsidies and auctions but this has a limited influence on the greater European electricity market and thereby a limited influence on the Danish electricity price.

As an example the decision to establish Viking Link will increase the Danish electricity price by approx. 1.3 to 2.7 €/MWh.

Factors that affect the Danish electricity price and Denmark's influence on these.
Red points have descending influence – green points ascending influence.

Influence



2.1 Historical Prices

Great variation in electricity prices in Europe

Neighboring countries affect the Danish electricity price

Denmark is strongly connected to our neighbors in Northwestern Europe via numerous interconnectors. The electricity price in our neighboring countries, and sometimes their neighboring countries, influences the Danish electricity price heavily. Regarding electricity, Denmark is very small compared to our neighbors which, besides having a larger population, have more electricity intensive industry.

To the North, Denmark is connected to Norway and Sweden that both have electricity systems dominated by production units with low marginal costs. This is particularly the case for hydro power but investment is flowing massively into new wind power while Sweden still have a significant amount of nuclear power. This makes these countries low price areas that are, however, very sensitive to precipitation levels.

To the South, Denmark is connected to Germany which has an electricity system with a lot of thermal capacity and nuclear power. However, the German power system is undergoing major restructuring, particularly towards solar PV and

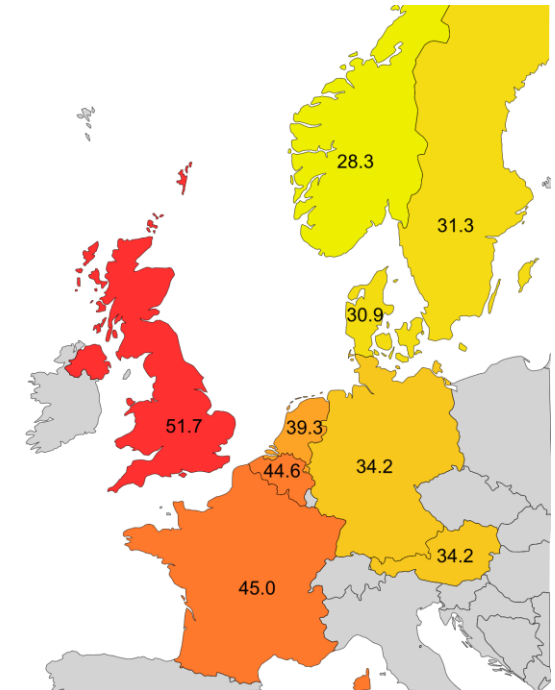
wind power. The price in Germany is historically a little higher than in Denmark.

Great Britain is traditionally the Northwestern European country with the highest electricity price. This is largely due to a high degree of natural gas electricity production and their Carbon Price Floor (CPF), which underpins the British CO₂ price.

The other Western European countries have electricity systems dominated by thermal production units and nuclear power. Generally, this provides higher electricity prices than in Denmark and the other Nordic countries.

As shown on the map, Denmark is located between low prices in the North and high prices in the South/West.

Electricity prices in Northwestern Europe in 2017 (EUR/MWh)



Source: Sypower and ENTSO-E

Electricity prices have risen again after a historically large fall

Coal and rain largely dictate the electricity price

Fuel and CO₂ prices, rain and temperatures are the main factors which determine the electricity price.

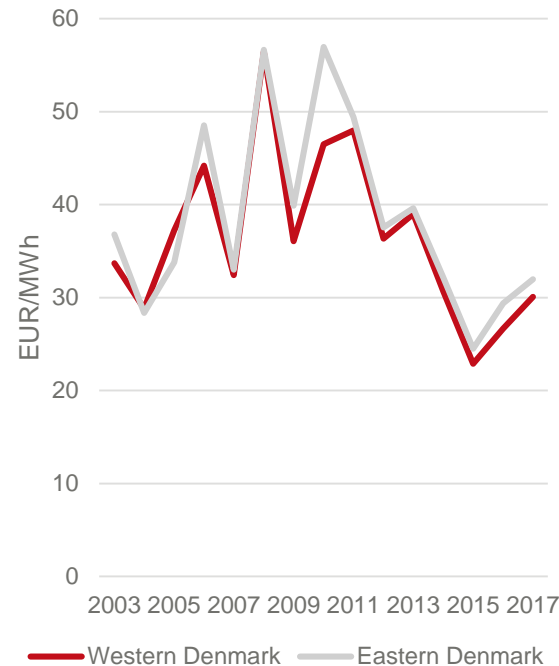
Electricity prices rose until the financial crisis in 2008, after which they fell significantly. After a short rise towards 2011, the electricity price fell almost uninterrupted until 2015 where low coal and CO₂ prices, coupled with high rainfall in the Nordic region, caused a particularly sharp fall in prices. Since then, the price has increased in tandem with the coal price.

The electricity price in the two Danish bid-areas is virtually identical, except in 2010 where Eastern Denmark and Sweden experienced several price spikes during the winter, which drove up the average.

Looking at German prices, which are influenced only to a limited degree by variations in rainfall, we can identify a significant link between the marginal costs for electricity production using coal ('MC coal') and the German electricity price.

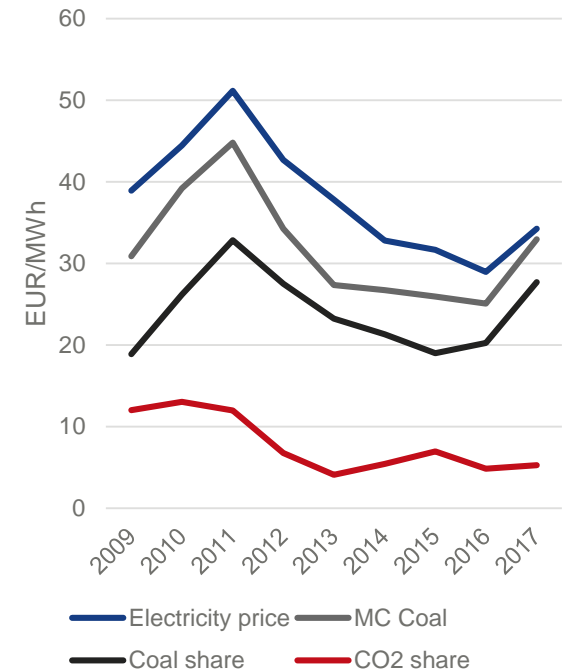
The CO₂ price has been low since 2012 and today it affects the electricity price by a modest +7 €/MWh.

Average Danish electricity prices



Source: Nordpool Spot

German electricity price determined primarily by costs for coal-fired electricity production



Source: SysPower

Greater spread in value of production

Average electricity price loses its meaning

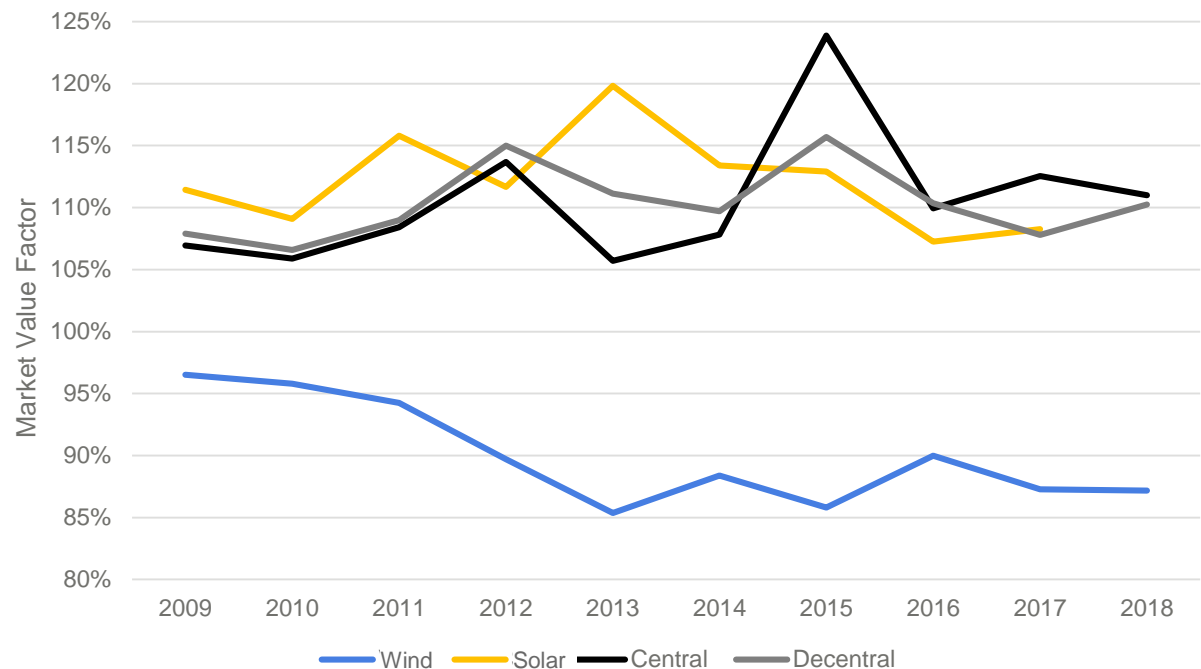
The average remuneration in the electricity market for different producers displays a gradually greater spread as the share of electricity production from wind increases. In other words, the yearly average of electricity prices is increasingly irrelevant to the market actors.

The relative market value of wind has thus been decreasing towards 2013. Today, the other producers' remuneration is about 10 % above the average electricity price, where they previously were about 7 % above average.

In 2012 and 2015, the relative remuneration for thermal plants was particularly high. These two years were so-called 'wet years', where Nordic hydro power pushed the summer prices down. As CHP plants' production are biggest in the winter season they avoided the worst price pressure from hydro.

Solar PV has historically had a significantly higher value in the market than wind and thus remunerates about 10 % above the average electricity price. This is due to solar' limited market share. In Germany, which has far more sun and wind, remuneration has declined significantly over recent years.

**Market value of electricity production relative to the average electricity price
Western Denmark**



Source: Dansk Energi pba. SysPower

Remuneration for wind and solar falls in tandem with expansion

Onshore wind in particular faces low market value today

Looking at data for Germany, which in absolute numbers has the largest RES production and consequently influences the electricity market the most, it is evident that the relative market value of wind and solar PV falls in tandem with expansion.

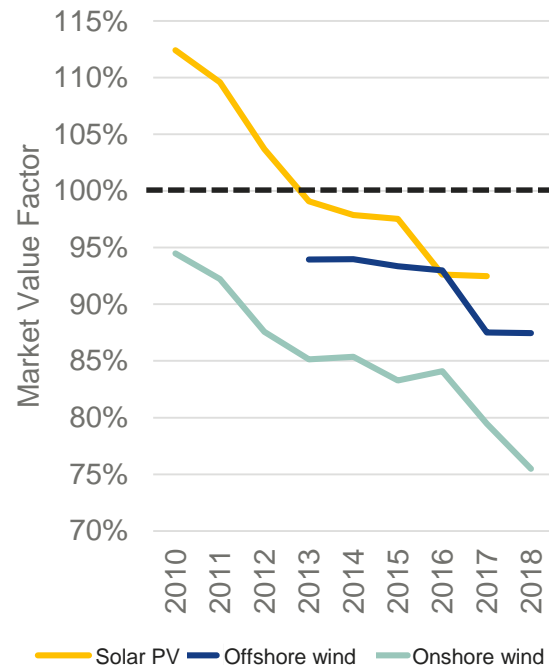
From 2013, data is available for offshore wind and the market value of the more stable offshore wind power production is seen to be higher than onshore power production. This is because production from onshore turbines to a larger extent occurs during hours with strong wind and low electricity prices.

Solar PV facing a potentially large loss of value

Solar is still worth more than wind power, but this relationship might change swiftly, which is evident from the figure on the right. If the linear projection is to be trusted, market value of the solar production is to be halved if the solar share of electricity consumption is increased to 20 %.

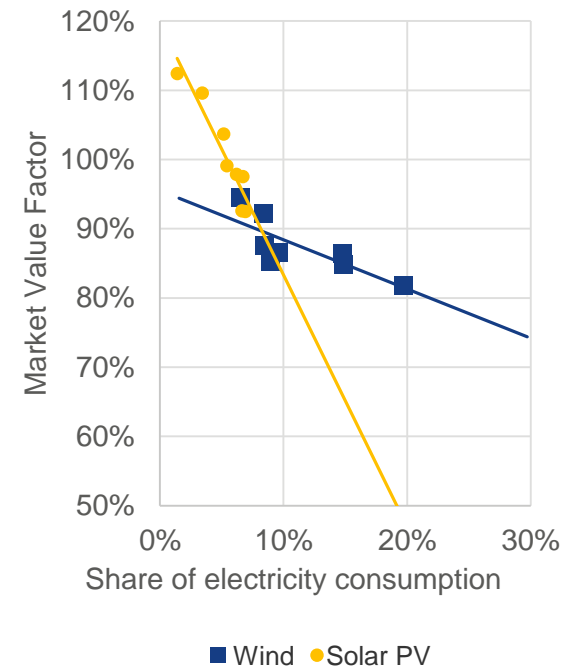
The market value of wind is experiencing a smaller fall in tandem with expansion, which is due to wind power producing more evenly and having a better seasonal match for the electricity consumption, which as with wind power, is the highest during the winter season.

Remuneration for wind and solar compared to general electricity price (Germany)



Note: 2018 alone covers January and February.

Germany



Note: Best straight lines through points provide simple projection of market value factor at higher proportions from wind and sun

2.2 Key Trends in Technology, Consumption and Prices

IEA does not predict a collapse in the coal price even with falling consumption

Large fluctuations in world market coal prices

As noted earlier, the price of coal strongly influences the electricity price.

The coal price was at a high level in 2011, at approx. 120 \$/ton. After 2011, the price declined by almost two thirds until the start of 2016, falling to a price of 43 \$/ton. At that time, various mining companies went bankrupt and the Chinese government intervened and shut down a large number of loss-making mines. The price has since more than doubled, and is at 80-90 \$/ton today.

Continued need for opening new mines

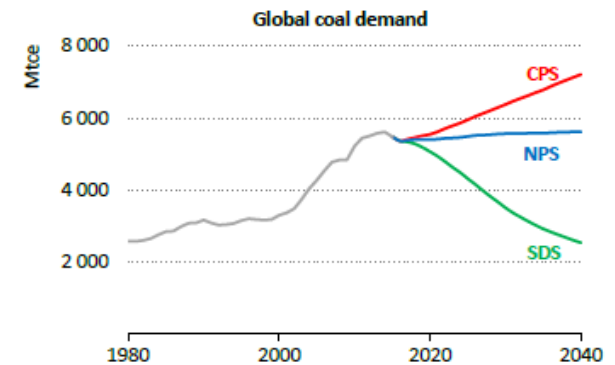
The central 'New Policies'-scenario in IEA's WEO2017 predicts a slight increase in coal consumption and coal prices from 2020 until 2040, ending at 82 \$/ton. This scenario is the starting point for the WEO-scenario in their report.

In the 'Sustainable Development Scenario' in WEO2017, the coal price is predicted to fall slightly to 64 \$/ton by 2040, despite a reduction of more than 50% in coal consumption. IEA notes that even with a reduction in production of this magnitude, there will still be a need for opening

new mines (as the closing rate of old mines is higher than the decline in consumption) and therefore the price will not collapse.

With 64 \$/ton and the current dollar rate, the coal price is contributing about 21 €/MWh to the costs for production on coal power in condensing mode. This does not include costs for operation, maintenance and carbon allowances, thus making the total price a bit higher (depending on the CO₂ price).

Global coal consumption in IEA's three WEO scenarios



Coal price historically



Price falls have brought gas back into the spotlight

The economy of gas CHP is still challenged

The economy of gas cogeneration is, roughly speaking, dictated by the price for converting gas into electricity. Gas converts into about 50 % heat and 40 % electricity, thus electricity has to be 1.25 times more expensive than gas for CHP to be better than boiler operation.

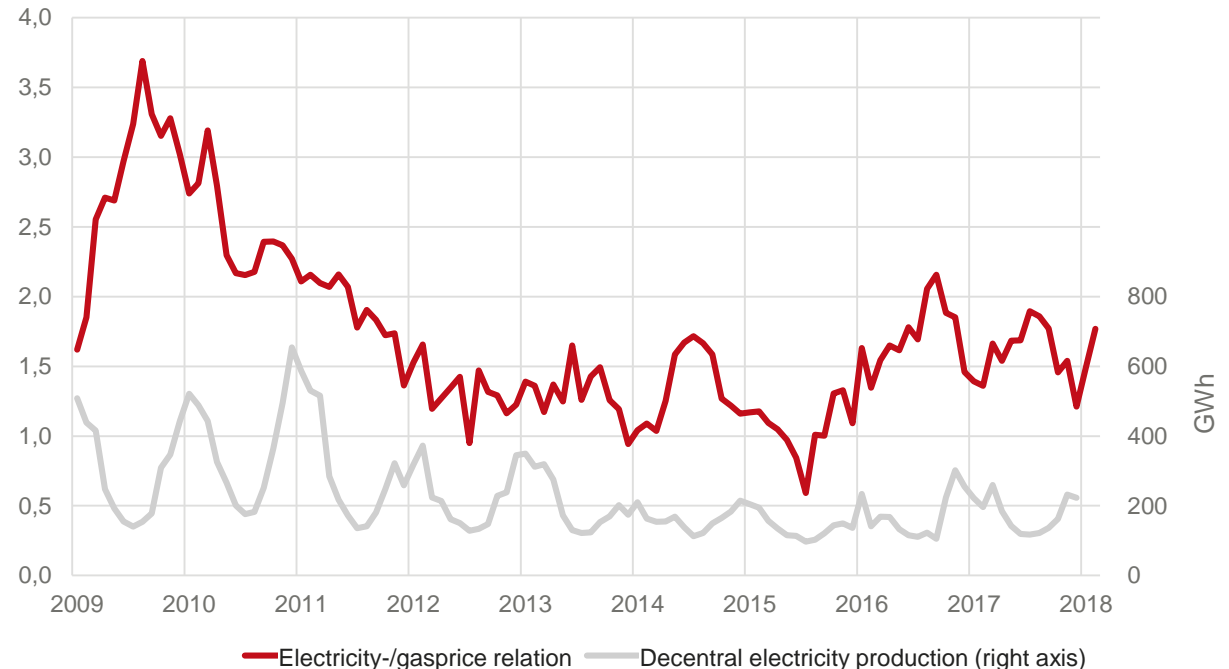
The figure shows the relationship between the electricity price in DK1 and the gas price. The relationship has been better the last year than during the four years from 2012 to 2015, thus there has been more gas CHP in 2017 than former years.

The analysis uses the monthly average of the electricity price and does not take into account that the gas CHP plants remunerates at a higher price during the hours of operation.

The gas price is calculated as the wholesale price, which does not include transport fees. In addition, the operating costs of the CHP plant are ignored.

However, the analysis reveal a strong indication of the competitiveness of gas CHP.

**Gas CHP had a little comeback in 2016-2017
Ratio between electricity and gas price in DK1**



Source: SysPower & The Danish Energy Agency's monthly statistics

Gasprice = TTF price without transport grants; Electricity price = NordPool Spot price for DK1

Decentral electricity production is comprised by more than gas (e.g. waste) and is typically CHP and thus the highest during the winter

Falling costs for RES and a boom in Swedish onshore wind

Expected remuneration has more than halved

An owner of a Swedish wind turbine has two streams of revenue: sales of electricity in the spot market and sales of RES-certificates. Investment in new projects takes into account the expectations for these two revenue streams.

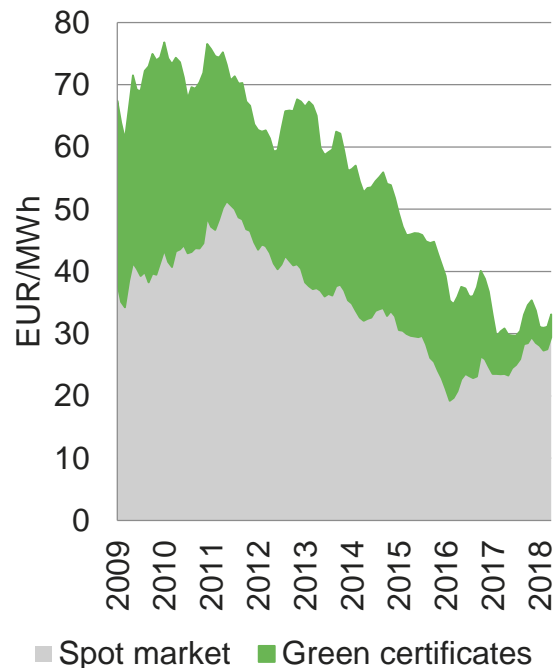
The forward markets' expectation for the sum of the two have fallen by approx. 5 €/MWh each year since 2010 and is today approx. 30 €/MWh, with a very small contribution from certificates at 3-4 €/MWh. This goes to show that we are very close to reaching subsidy-free onshore wind.

Investment boom in spite of low subsidies

Despite very low subsidies, the expansion is far from coming to a halt. The race of developers seeking to join the market before it became saturated resulted in contracts signed for 2,079 MW to be installed during the next few years.

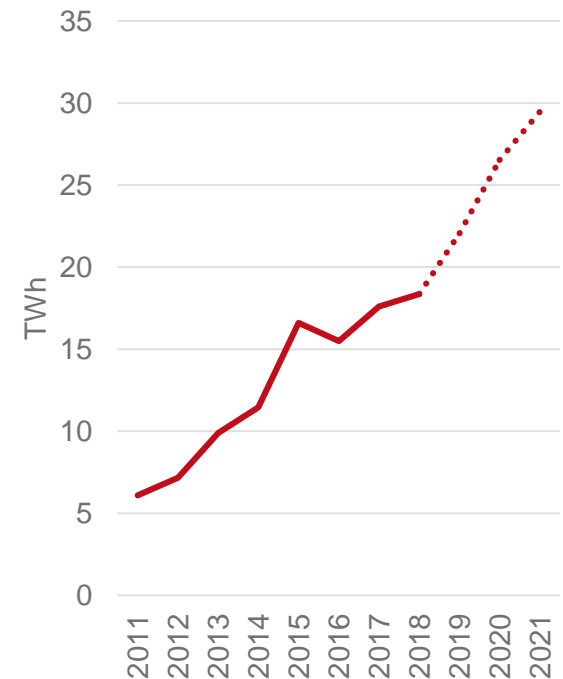
Numerous Swedish investors that own wind power projects built early in the period have had to write down their asset values following the unexpectedly large price falls on new wind power that has pushed down the remuneration for everybody.

Expected remuneration for RES based electricity production in Sweden



Source: SysPower, SKM
 Electricity price is forward+2years.
 Certificate price is forward+3years.
 Both are targets for long-term price expectations.

Swedish wind power experiencing heavy growth in spite of low remuneration



Source: Svensk Vindenergi
 Note that 2015 was a year with strong wind
 Dotted line is central scenario

Denmark is increasingly part of a net export region

Surplus for replacing nuclear power

Increasing electricity production from renewable energy and a decreasing consumption of electricity in Germany has led to massive exports of electricity to neighboring countries.

Germany installed 5.3 GW of new onshore wind and 1.2 GW offshore wind in 2017. The total wind power production exceeded 100 TWh in 2017 corresponding to about 20 % of the consumption.

The German nuclear power production will be phased out completely by 2022. Nuclear power produced 72 TWh in 2017, which is about 38 % above the net export on 52 TWh during the same year. A large share of the net export is thus expected to disappear as the majority of Germany's RES expansion will be used to replace nuclear power during the years to come. However, the electricity price will come under pressure during the next few years following the temporary surplus of capacity.

Nordic power production exceeds consumption

At the same time, the Nordic Region is becoming a bigger and bigger net exporter with its great potential for expansion of low cost wind power. The Nordic electricity consumption has grown by about 10 TWh since 2010 but RES expansion is running

even faster. The closure of four Swedish nuclear power plants will roughly be offset by the electricity production from the highly delayed Finnish nuclear power plant 'Olkiluoto 3' that is expected to go into operation next year after a ten year delay and about a 200 % budget overrun. The remaining Swedish nuclear power plants have been given a life extension until some time during the 2030s and are going to be hard to push out of the market for other actors. This year, Vattenfall have communicated a cost target of 19 €/MWh for their nuclear based electricity production.

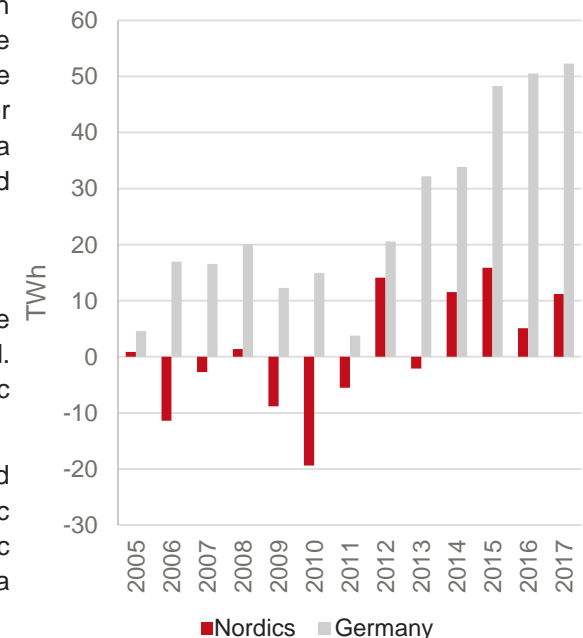
Cables can increase value of production

During the years to come more cables between the Nordic Region and Great Britain are expected. These will ensure a higher value of the Nordic production by supplanting gas in the British market.

Better connections between the Nordic region and continental Europe, Great Britain and the Baltic region are key to realizing the vision of the Nordic region as a green power plant as they enable a great RES expansion without prices collapsing.

Increased electricity consumption in the form of datacenters and electricity intensive industrial production can also contribute to exploiting the potential for Nordic wind power production.

Increasing net exports from the Nordic region and Germany



Batteries entering the electricity system as a backup

A new actor in the electricity market

During the last couple of years, batteries have been introduced in the European electricity system. Primarily functioning as a stabilizer for the electricity grid by delivering high power in short periods of time. Along with price falls, we see configurations with larger energy amounts that can discharge for hours.

Great earnings during few hours

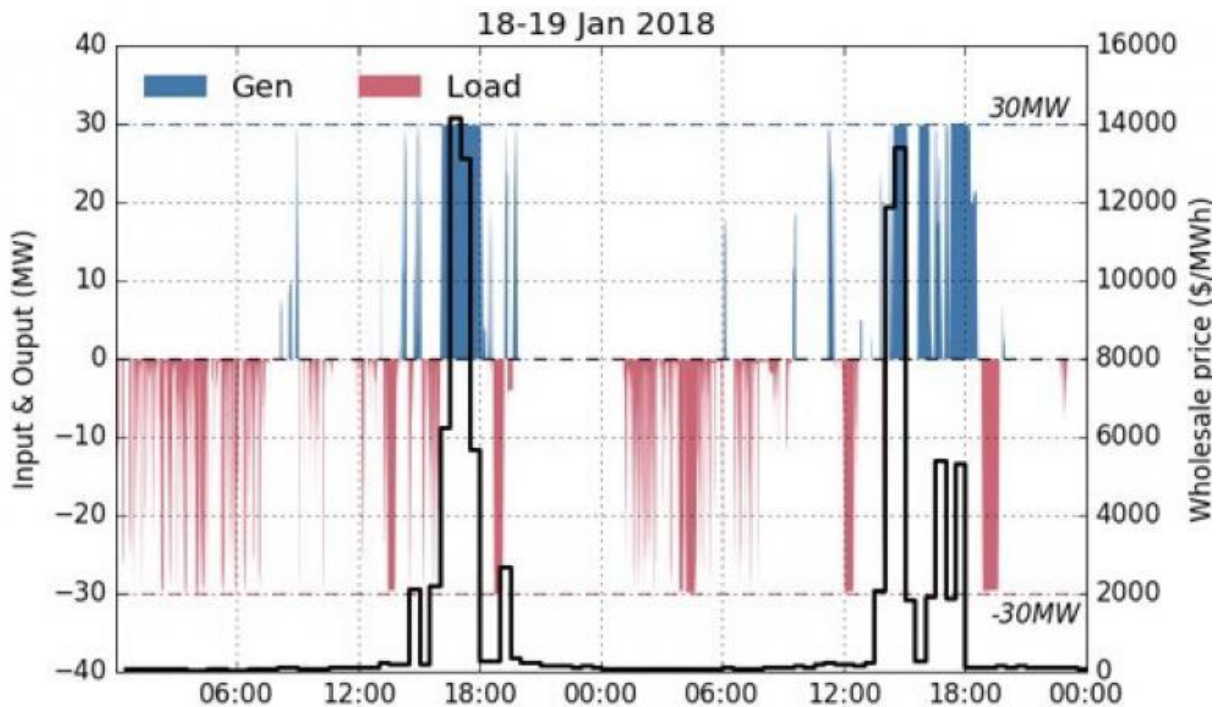
During 2017, Tesla delivered the so far biggest battery to Southern Australia in a trade that got big media coverage. The battery consists of two parts: One for delivering system- and grid services with 70 MW and 39 MWh driven by the distribution company and a privately owned share of 30 MW and 90 MWh.

The battery made money from arbitrage during the days of 18-19 January 2018 where the electricity price reached 9,300 €/MWh because of a very tight power balance. (The price cap in NordPool Spot is 3,000 €/MWh)

The battery earned about 1 million Australian dollars in total during the two days by delivering the 30 MW for a few hours with the extremely high prices.

In the figure on the right, the black line is the electricity price while red and blue shows charging and discharging.

The battery in Southern Australia makes money from selling electricity during hours with extreme prices



Source: ing.dk

2.3 Political Drivers of Importance to the Electricity Market

Political push toward green transition

Massive green transition of the electricity production.

The Paris agreement from 2015 set a target to limit the increase in the global average temperature to 2 degrees Celsius. This requires a massive green transition of the entire economy and some of the lowest hanging fruits are in the electricity sector.

The mechanisms of the agreement implies a gradually increasing level of ambition with so-called 'no backsliding' on the delivered promises.

Cheap RES brings about bigger ambitions

The EU's targets for RES is currently under negotiation. The EU Parliament wants a 35 % target in 2030, which is significantly higher than the Commission's plan with a target of 27 %.

Numerous analytics have pointed out that it is possible to raise the level of ambition significantly beyond the 27 %, especially by expansion of wind- and solar PV power in the electricity sector. The renewable energy agency, IRENA, has in their latest analysis pointed towards 34 % as the cost efficient level.

Germany has set more ambitious targets for solar PV and onshore wind expansion and announced more auctions of offshore wind in the future.

Two ways to green transition

As shown in our RES Outlook, there are two ways to realizing a green transition.

Either you let the polluters pay through a high price on CO₂ or compensate the producers of RES using government support to create fair competition.

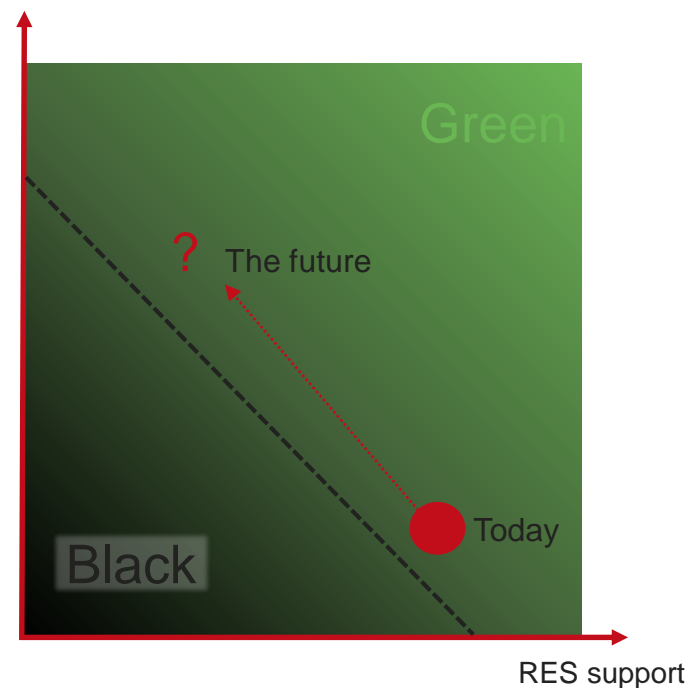
Historically the green transition with a few exceptions has primarily been driven by national support schemes as it has become evident that reaching an agreement on reforming the EU ETS system is difficult.

A higher price on CO₂ is, however, the prerequisite for RES without government support and, at the same time, can collect the lowest hanging fruits in terms of curbing emissions. (For instance reduced operation on the least efficient coal power plants).

A third option is active closures of power plants as seen in Germany where the oldest lignite power plants receive a payment to be on standby.

High ambitions demand either price on CO₂ or support for RES

CO₂ price



Massive shift away from coal in Europe

Great Britain leading the phase-out of coal

While the use of lignite in Northwestern Europe has been more or less constant since 2000, the use of (hard) coal is changing.

Electricity production based on coal was nearly halved from 341 TWh in 2013 to 177 TWh in 2017.

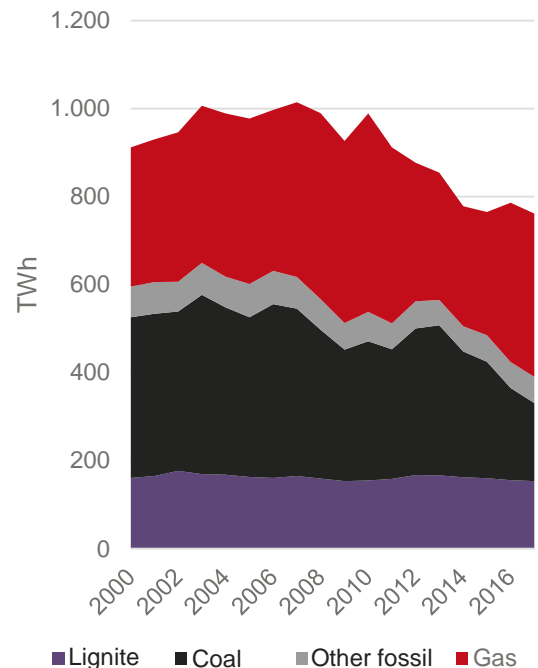
Since 2014 it has primarily been gas that has taken over while the expansion of RES has roughly compensated for the loss of nuclear power.

Numerous countries have announced an end to using coal for electricity production towards 2030 and Great Britain especially has reduced its coal consumption significantly during the last four years. This is particularly due to the establishment of the so-called 'Carbon Price Floor' that sets a floor for the CO₂ price.

More countries join the coal-free alliance

Several countries have joined the Powering Past Coal alliance and set an end date on the use of coal in electricity production in the wake of the Paris agreement. Large parts of Western Europe have announced a stop for coal and Denmark joined in 2017 with an announced coal stop in 2030. In addition, Danish company Ørsted have announced that they will stop using coal after 2023.

Electricity production on fossil fuels in Northwestern Europe



Source: Sandbag/Agora

The European countries' plans for phasing out coal



Insufficient reform of the EU ETS system has brought about low CO₂ prices

Long prospects for real scarcity

The EU's ETS carbon market was born before the financial crisis and has suffered from a massive surplus of allowances since electricity and industrial production dived after 2008.

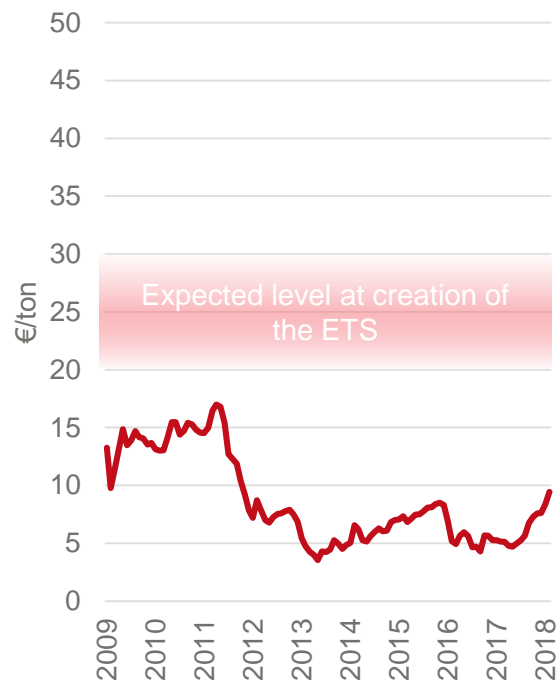
Despite numerous reforms, it has still not been successful in creating an expectation of real scarcity of quotas and thus the price has stayed under 10 €/ton since 2012. This is much below the originally expected level of 20-30 €/ton.

Since the summer of 2017, the price has increased from about five to 10 €/ton. This is probably due to a greater trust in the politicians of the EU to use the ETS to drive the green transition while at the same time new mechanisms such as the so-called 'market stabilization reserve' soon goes into operation and will soak up a large part of the historical surplus.

Continued structural surplus

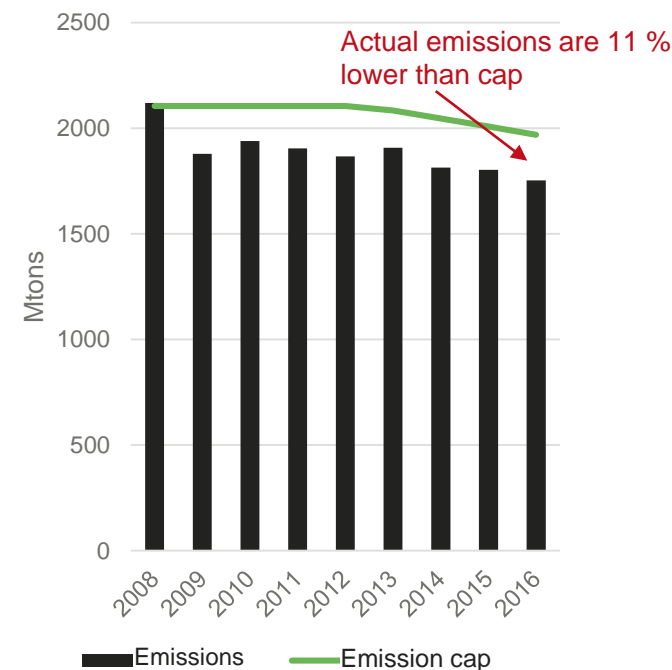
In spite of the reforms, the ETS system is still suffering from the annual number of new allowances being larger than that needed. This leads to no scarcity of allowances today even if the historical surplus would disappear. It is, in other words, not enough to handle the historical surplus. There is a need to limit the supply as well going forward.

ETS price way below 20-30 €/ton



Source: SysPower

There are still structural problems regarding over-allocation in the ETS system



Source: Sandbag

Unilateral carbon price floors distort competition

The Netherlands have adopted a national price floor for the CO₂ price starting at 18 €/ton in 2020, rising to 43 €/ton in 2030. The price floor is a top-up on the EU ETS price like in the British market.

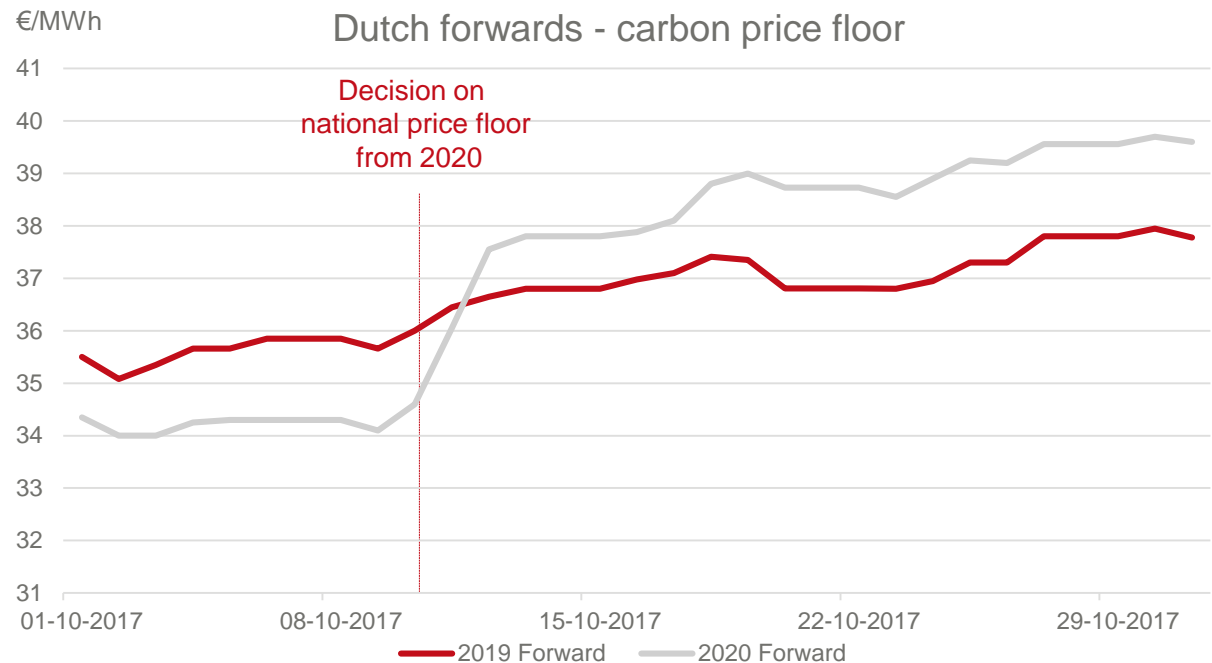
The decision came unexpectedly for the market, which reacted by increasing the electricity price on the 2020 forward contract by about 0.02 DKK/kWh more than the 2019 contract increased during the same period.

The national price floor reduces the competitiveness of Dutch electricity producers using coal and gas compared to foreign fossil-fueled plants. Therefore, the price floor will result in more imports of German coal power and thus, the climate effect is limited. The slightly higher electricity price, however, betters the economy in both domestic and foreign fossil-free electricity production.

The UK decided in 2017 to continue their price floor towards 2030. The rates are to be negotiated but the former plan aimed towards an increase from £30 to £70 per ton from 2020 to 2030.

In so far as a number of European countries agree to introduce a price floor in an area so large that fair competition can be ensured, it could be a good alternative to an EU-wide high CO₂ price.

Expectations for the electricity price increased following the agreement on a Dutch carbon price floor in October 2017



3. Scenarios for Developments in the Electricity Price in Northwestern Europe

3.1 Scenarios and Main Uncertainties

The base scenarios are defined by politically driven RES expansion

Constant consumption and pressure on green transition

The analysis assumes that Northwestern European countries will carry out a green transition regardless of the developments in CO₂ and fuel prices.

The assumption of a significant RES expansion must be understood in light of the fact that price falls on wind and solar PV have increased the political appetite for more expansion. In Denmark, an expansion delivering 100 % RES in the electrical system in 2030 is assumed, which is considered a reasonable bid for the electricity sector's contribution for the government's target of at least 50 % RES.

The electricity consumption in foreign countries is assumed to develop constantly with exception of new electricity consumption for electric vehicles. Denmark's consumption follows the Danish Energy Agency's base projection from 2017.

Forwards and WEO define constraints

The electricity price and remuneration for electricity producers in the future is largely dictated by fuel and CO₂ prices. As in our former electricity price outlooks we let the prices from the forward market and IEA's World Energy Outlook New Policy Scenario define the constraints.

In the figures to the right, marginal costs for coal and gas power are compared to the basis for last year's

electricity price scenarios.

Neither IEA nor the forward market have historically had any significant predictive power. The latter is primarily an instrument for covering risk.

The CO₂ price has increased in the forward market and is now about 10 €/ton. In the WEO scenario it is expected to increase to 13 €/ton in 2020 and 36 €/ton in 2035.

Scenarios with different competitive conditions

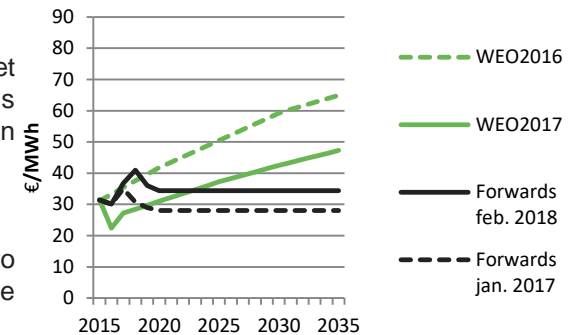
The marginal costs for production using coal rises to above 60 €/MWh in 2030 in the WEO scenario while remaining at 35 €/MWh in Forwards.

The difference in costs between electricity production using coal and gas develops almost identically in the two scenarios. The competitive relationship between RES and fossil fuels, however, develops significantly differently as RES's competitiveness is greater in WEO.

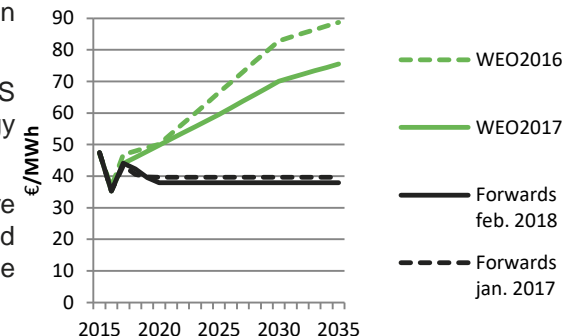
As in our RES Outlook, we base our analysis on RES costs from the Danish Energy Agency's technology catalogue.

Politically announced plans for nuclear plant closure is included in the calculations, while already passed transmission connections between countries are one of the main assumptions as well.

Coal marginal



Gas marginal



Note: All prices in chapter 3 are stated in fixed 2017-€

There are significant uncertainties about the future development

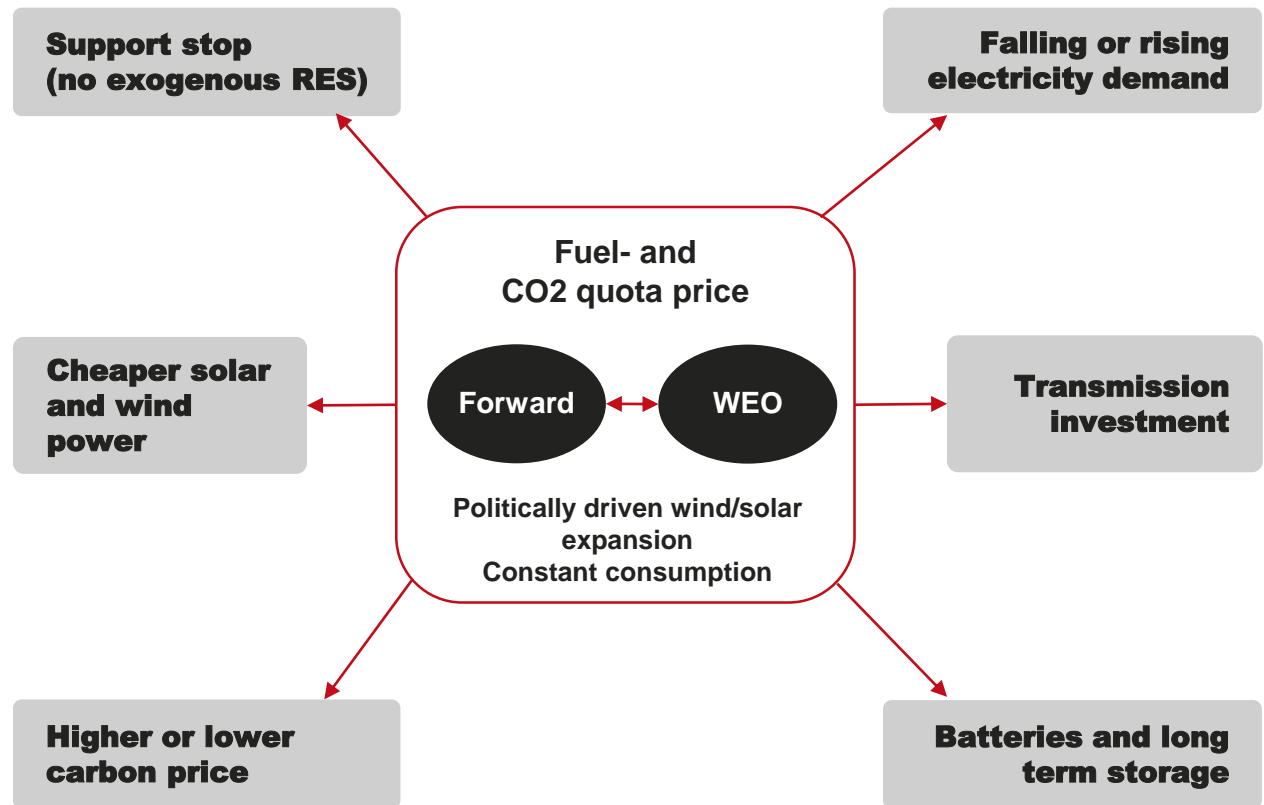
Sensitivity analysis widens the scope

Besides uncertainties in fuel- and quota prices that vary between base scenarios, there is uncertainty about numerous other developments that potentially can have great impact on the electricity price.

In addition, a number of points are best illustrated by varying different assumptions, politics and technological advances. Thus, we have chosen to model what will happen if government support for new RES projects disappears completely after 2020 and the expansion is thus only possible on market conditions.

Technology costs for wind and solar are a significant uncertainty. Indications of more sharply falling costs has prompted us to calculate a scenario with 30 % lower capital costs for solar and wind power. Furthermore, sensitivity calculations have been made on the quota price (in relation to the WEO scenario) and the electricity consumption, which is evaluated in terms of both rises and falls.

In addition, we have simulated scenarios with investment in transmission and batteries to see what effect it might have on electricity price development.



3.2 Base Scenario Results

Continued variation in electricity prices in Europe

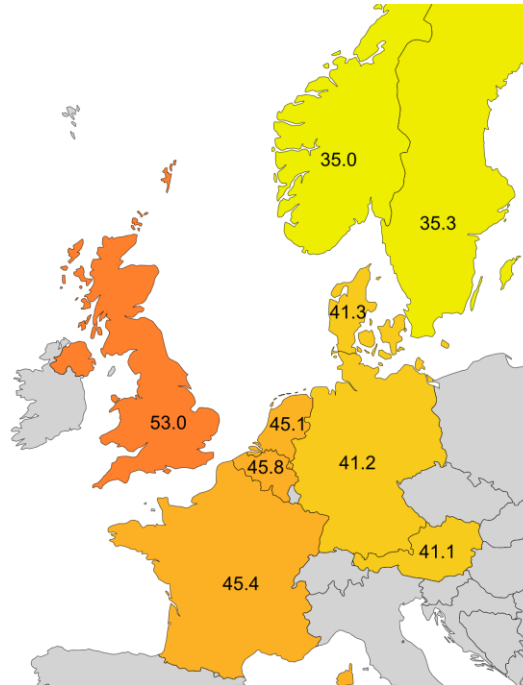
Prices highest in the South and West

The analysis shows that the relative differences in electricity prices today continues in the future. Prices are still lower in the North and higher in the South and West, where Great Britain in particular pushes the price up. The fact that the price is the highest in Great Britain is due to their CO2 price floor, among other factors. The planned price floor in the Netherlands is also modeled, but because of competitive pressure from producers in neighboring countries, the electricity price is not rising to as high levels here. The Dutch electricity price remains lower than in Belgium which remains a net importer.

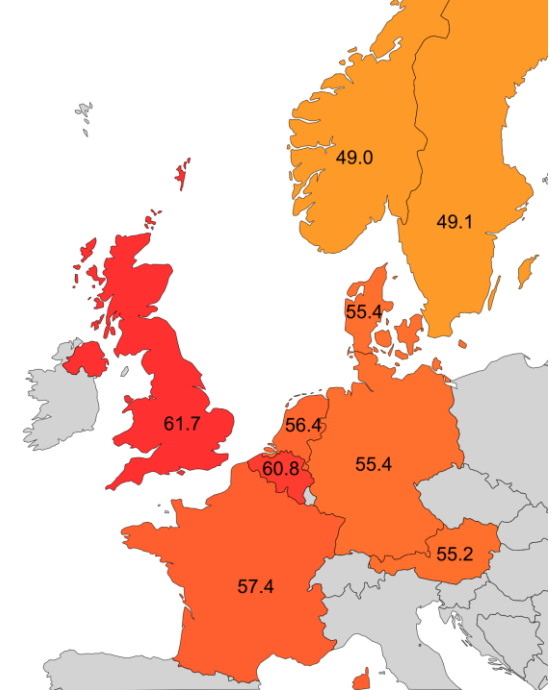
In the WEO scenario the electricity prices increase significantly more in areas with the lowest prices as the effect of a generally higher quota price breaks through here.

Denmark will receive around the same electricity prices as in Germany and about 6 EUR/MWh higher than in Norway and Sweden, which primarily is due to the absence of extreme prices in Norway and Sweden (they have more than sufficient amounts of reliable capacity from hydro power). Norway and Sweden are modelled as a combined area. In reality, Norway is split into five bidding areas and Sweden into four. Extreme prices may in practice occur in some of these areas.

Electricity prices in Northwestern Europe in the 'Forwards Scenario' (EUR/MWh) 2025



Electricity prices in Northwestern Europe in the 'WEO Scenario' (EUR/MWh) 2025



Note: All prices in chapter 3 are stated in fixed 2017-€

Green transition of the electricity system in Northwestern Europe

Politicians ensure tempo in the green transition

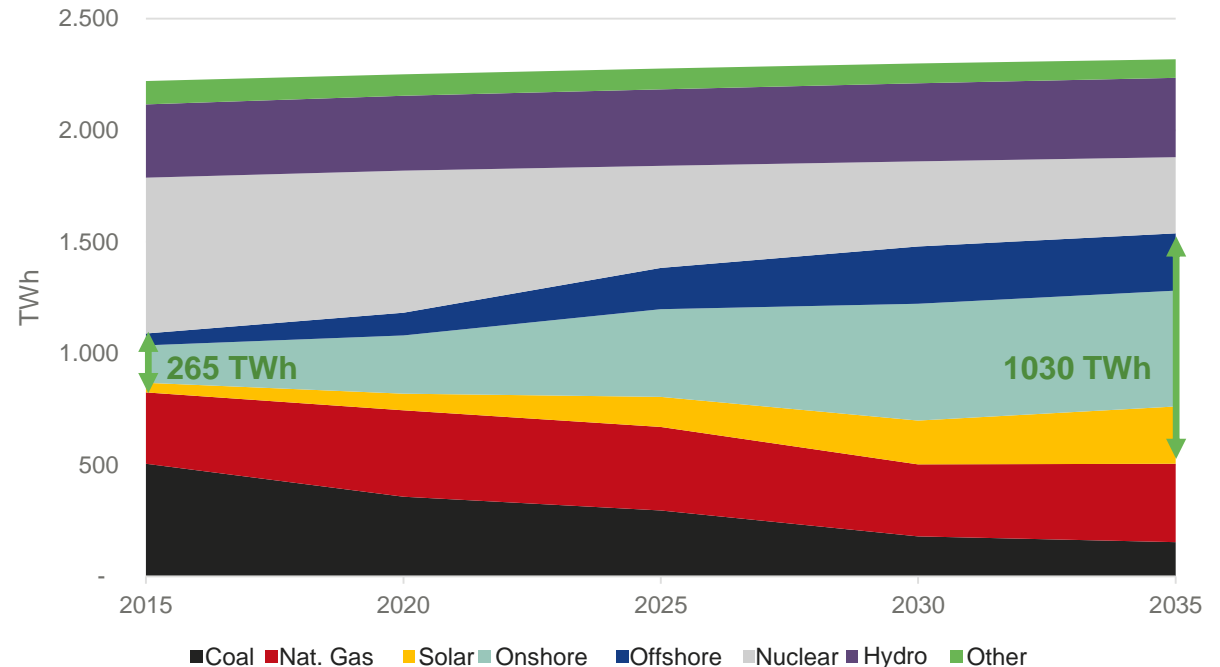
It is assumed that, through support schemes and auctions, politicians will ensure that the green transition of the electricity system continues towards 2030, making wind and solar constitute about half of the electricity production in Northwestern Europe in 2035.

It is further assumed that solar and wind is to be expanded to at least 1030 TWh, corresponding to 440 GW (66 GW offshore, 205 GW onshore and 167 GW solar) in 2035. Nuclear power will be halved and existing power plants are shut down after 45 years of operation.

In the Forward scenario, the model does not find it economically sound to invest in more RES than what has been decided politically. However, investment is still commencing with 100 GW natural gas and 21 GW (heat effect) heat pumps towards 2035.

In the WEO scenario, a corresponding amount of politically decided RES expansion is established but following the higher costs for fossil-based electricity production, some countries might be better off building further RES corresponding to 106 TWh. This RES comes into the system on behalf of natural gas.

Electricity production in Northwestern Europe – The Forwards scenario



Fuel and carbon prices significantly influence the electricity price

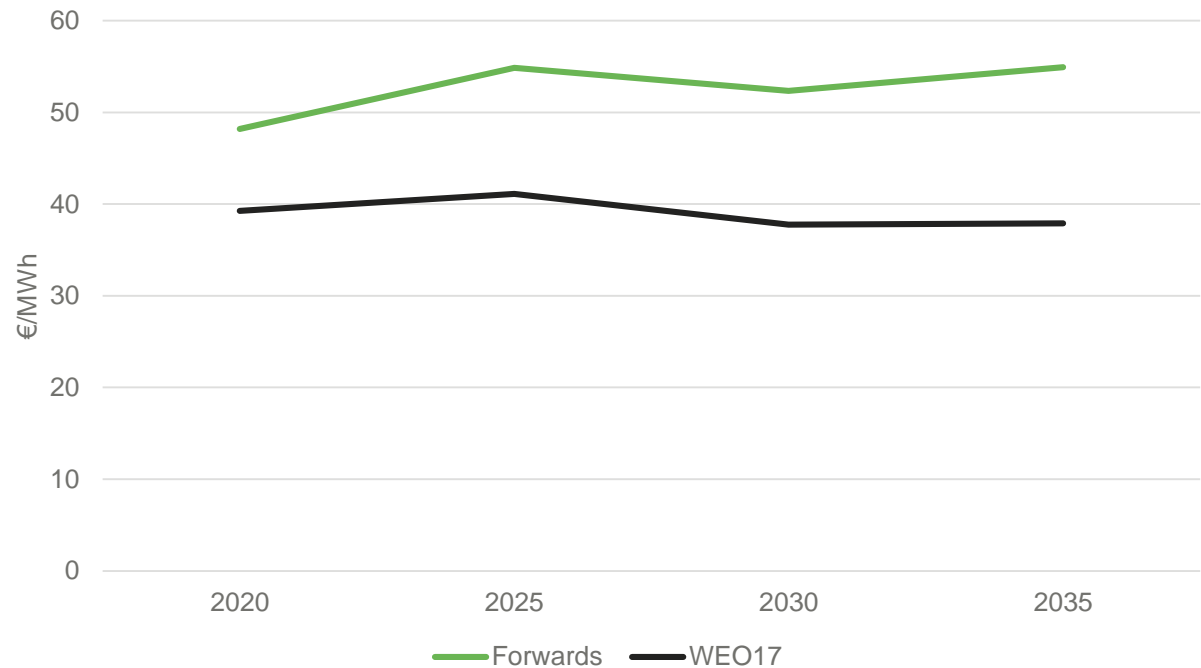
More expensive coal and gas brings higher electricity prices

The electricity price in the Forwards scenario with fixed fuel and carbon prices is close to constant through the entire period.

The price rises a little towards 2025 following a tighter capacity balance that brings about more extreme prices and because of the politically decided phase out of nuclear power in Germany during the start of the 2020s. Afterwards, the price will fall towards 2030 in tandem with the RES expansion rate being held high without other electricity production being phased out at the same rate.

The rising prices on gas and CO₂ in the WEO scenario, however, leads to a stronger increase in the average electricity price that is about 0.10 DKK/kWh higher than in the Forwards scenario.

**Electricity prices in scenarios with a constant electricity consumption
Western Denmark**



Remuneration for wind and solar PV falls further compared to the average electricity price

Expansion under market conditions might be hard

The remuneration price for solar and wind decreases over time in both scenarios in tandem with the politically driven expansion continuing at a high pace.

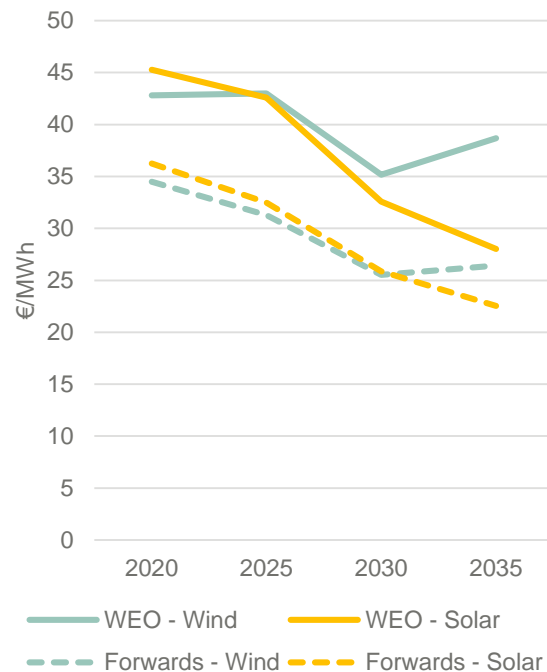
The expansion in Denmark, and the rest of the world, pressures the remuneration for solar and wind. In the Forwards scenario, where fossil-based electricity production is relatively cheap, the wind and solar remuneration falls to about 27 €/MWh in Denmark.

In 2020 wind, solar and power plants are remunerated at about the same electricity price as each other, but the spread of electricity prices in the various technologies' remuneration is broadened significantly over time. The remuneration of solar PV falls to about half of the average electricity price in 2035 in the WEO scenario.

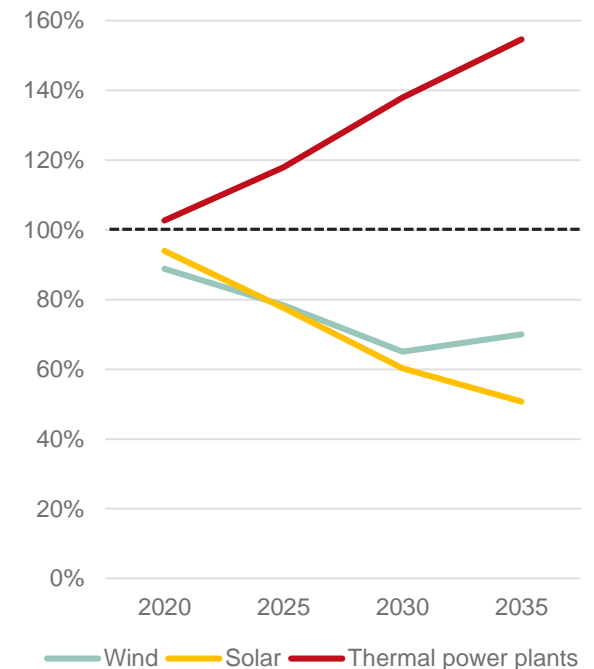
The demanded high pace in the green transition means the expansion can not be taken as given without government support. Especially in the absence of an efficient ETS quota market that delivers a high price on CO₂.

However, the continually decreasing cost of renewable energy implies that low levels of support are necessary.

Wind and solar remuneration Western Denmark



Market value factors Western Denmark WEO scenario



Investors must look towards long-term earnings

The value of production might fall over time

The prospects of decreasing earnings on wind and solar matter for the projects that are decided today. Wind and solar projects invested in today must compete against future projects.

The remuneration today is thus most likely a bad indicator for future earnings. If investments are made on this basis, the actors risk having to take large write-offs just like the Swedish example in chapter two highlights.

The analysis also shows that current conditions such as the earnings on solar PV being higher than for wind might not be true in ten years when the deployment of solar PV has reached higher levels.

The present value of electricity production in the two scenarios is found by discounting the future earnings and these should be estimated on a basis of expected future technology costs.

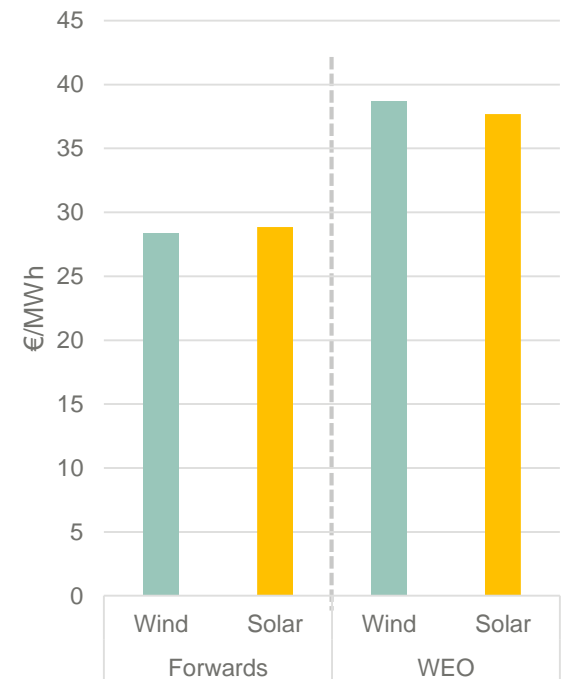
Future RES investment costs are based on the Danish Energy Agency's technology catalogue. Should these turn out to be too conservative, it will pressure future earnings for all plants further.

Differences in plant type's remuneration

As noted in our RES Outlook, different types of plants receive different remunerations in the electricity market. This is true for both solar and wind but also for different types of wind turbines that, for instance, have a smaller or larger share of their production during hours with strong wind and low prices. In chapter four of our RES Outlook, we describe these considerations in more detail. Here we have simply highlighted the average remuneration for all wind turbines.

As a rule of thumb, plant types with higher capacity factors (more even production) will receive a higher remuneration in the market. This means that new wind turbines generally realize a higher remuneration than older wind turbines and that offshore wind remunerates at a higher price than onshore wind.

Average remuneration 2020-2039



Note: Average earnings displayed as the remuneration that would deliver the same earnings over a 20 year period as the calculated electricity prices.

Power plants to become middle load rather than base load

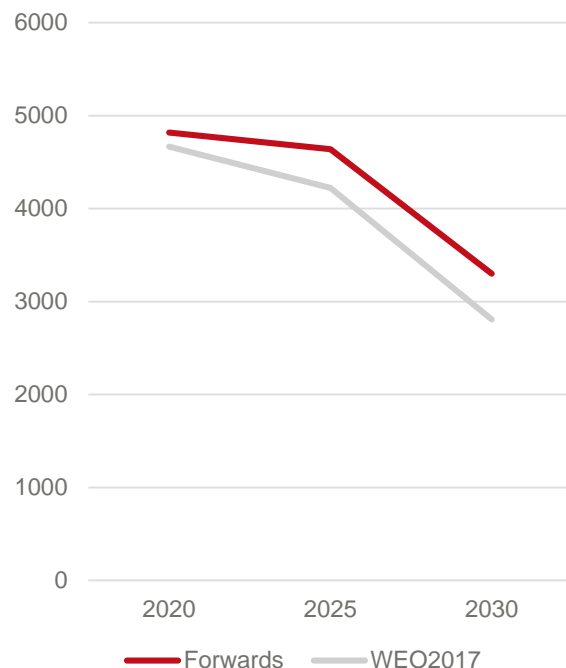
Danish power plants to receive fewer operational hours

The Danish power plants will receive fewer operational hours in the future, but with higher earnings during the hours of operation. From 2020, the western Danish power plants are going to be operational for 5000 hours, falling to 3000 hours in 2030. As can be seen from the figure on the right, there is no big difference between the two scenarios.

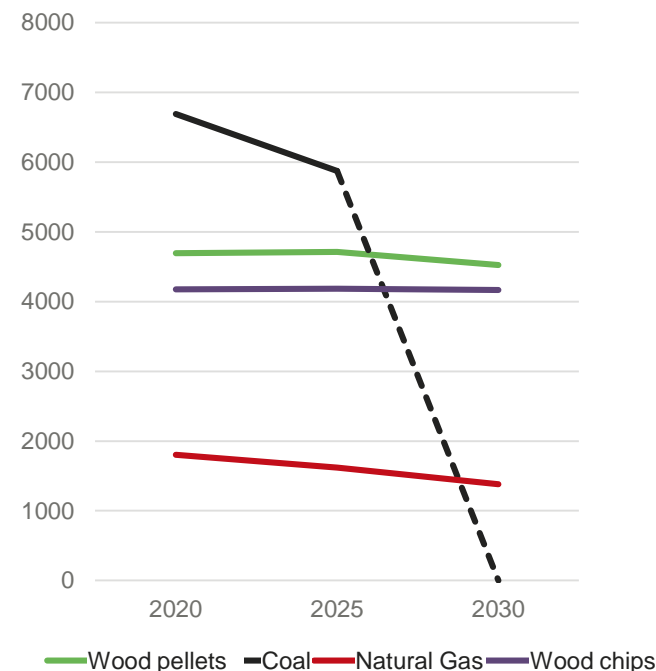
If power plants are categorized by fuel type, the decline in operational hours is shown to primarily be due to a falling number of operational hours in the coal-fueled power plants, which goes from having an operational time of about 6000 hours in the 2020s before being retired towards 2030. The gas-fueled plants can also look forward to a falling number of operational hours but are better suited for a future where the earnings in the electricity market are possible during hours with high prices.

The biomass-fueled power plants are relatively stable during the whole period as their electricity production primarily is dictated by the heat demand.

Full load hours for power plants in Western Denmark



Full load hours in Western Denmark divided by fuels – WEO Scenario



Note: Average found by dividing total power generation by total capacity available through the spot market

Coal-fueled plants economy to better slightly over time

Large share of earnings during few hours

Power plants earnings can be divided into two types: the earnings during normal operation and earnings during hours with extreme prices where the demand exceeds supply and the market is cleared at the price cap of 3000 €/MWh. As more power plants close, more of these hours will occur. The return on a new gas-fueled peak load plant demands earnings of about 48.3 €/kW annually. These earnings can be achieved when there is an average of 16 hours with extreme prices during a year.

The Balmorel Model invests to make this balance occur but in practice the frequency of extreme price hours is very hard to predict. Wind and weather play a major role for the frequency of extreme prices as well as national regulatory frameworks as capacity markets and politically determined power plant closures can quickly change the foundation for earnings from extreme prices.

The figure on the right shows the annual contribution margin from the electricity market for a generic coal-fueled power plant in the model simulations. The earnings are divided into normal operation and extreme prices. The extreme prices represent the 16 operational hours with particularly high prices, while normal operation represents

earnings from the other operational hours (typically about 4-6000 hours). The figure shows what earnings are demanded annually to pay for operation and maintenance as well as costs for return on investment of a lifetime extension, at approx. 53.7 €/kW annually.

The figure shows data for a plant that exclusively produces electricity. Including the earnings from heating sales, the power plants would be better off.

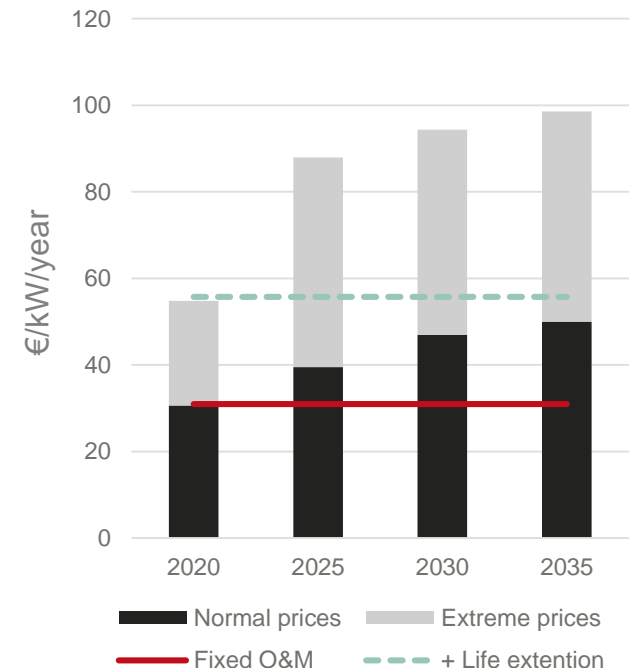
A bit more money for those that hold out

The earnings from operation during hours with normal prices is to better moderately over time and can cover the fixed operational costs in 2025. If a lifetime extension is to be repaid, the owner of the power plant has to make a bet on the relatively uncertain earnings from extreme prices.

Investment in new coal power is far from worthwhile. If it were possible it would demand 188 €/kW annually.

The earnings for coal power are decided primarily by the competitive relations with gas, which are about the same in both scenarios (the effects of higher gas prices and CO₂ prices are largely equal). Thus, the result in the WEO scenario is almost the same as shown here.

Contribution margin for a generic coal plant in DK - Forwards



Note: For the WEO scenario, the result is about 13 €/kW/year higher for normal operation.

Source: Prices for fixed operation and maintenance plus lifetime extension are based on the Danish Energy Agency's technology catalogue.

Biomass CHPs can hope for higher CO₂ prices

Fossil fuels are the main competitors

The Danish CHPs have transitioned from fossil fuels to biomass-based fuels during the last couple of years. These plants run almost exclusively in cogeneration mode and earnings from heating sales are an important part of the economy. As heating contracts are different from plant to plant, it is very hard to say anything about the general earnings of CHPs. In our calculations, we assume that the wood pellet based plants sell their heat at a price that is dependent on the wood pellet price.

In addition, we have calculated earnings from electricity sales as well as government support for electricity production. The numbers are an average of all Danish wood pellet CHPs.

The calculations reveal a very big difference in the contribution margin for the wood pellet CHPs in Denmark across scenarios. In the Forwards Scenario, the electricity prices are lower than in the WEO Scenario. This is tough to the CHPs, which often are obliged to produce electricity and heat at the same time. In 2035, the contribution margin turns negative in the Forward scenario following a lot of forced operation (CHP electricity production due to heating demands at a loss). Usually, the heat purchasers cover these losses.

Contribution margin for wood pellet CHPs in Denmark



Source: Prices for fixed operation and maintenance plus lifetime extension are based on the Danish Energy Agency's technology catalogue.

3.3 Sensitivity Scenario Results

A stop for support for wind and solar PV brings about only slightly higher electricity prices

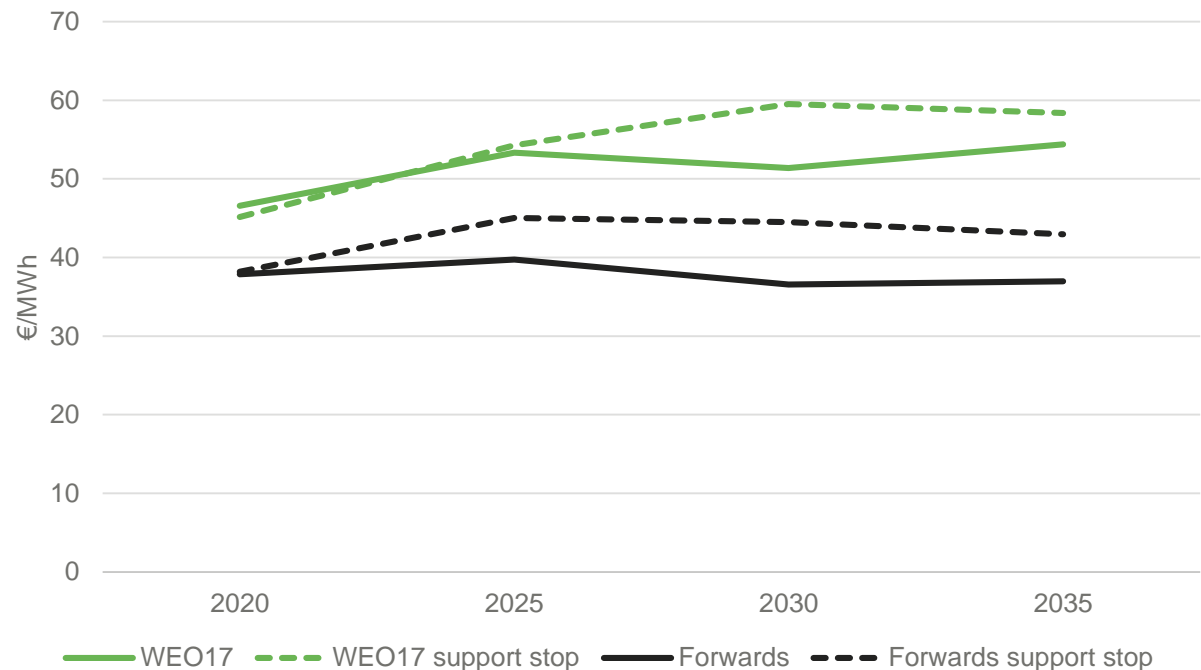
Wind, solar and gas cap the electricity price

In the support-stop scenarios, we analyze how the electricity prices will develop if the politically driven expansion were to stop in the whole of Northwestern Europe and RES had to compete under market conditions after 2020. In these scenarios, the average electricity price in Forwards and WEO rises to 47 and 60 €/MWh, respectively.

In both scenarios, investment in wind and solar at market conditions in Northwestern Europe lowers the electricity price. In the absence of support in all northern European countries, onshore wind becomes competitive under market conditions in Denmark during the 2020s, while offshore wind (incl. grid connection) is only competitive in 2030 in the WEO scenario (with the technology catalogue's expectations for the cost of investment in offshore wind).

Together with gas power, wind and solar thereby cap the electricity price significantly lower than earlier prognoses where it was usually the costs for new coal or gas power that defined the long-term electricity price in the absence of political interference.

**Electricity prices in scenarios with constant electricity consumption
Western Denmark**



Wind power caps its own earnings

Wind power competes against wind power

A stop in support makes the electricity price increase in both the Forwards and the WEO scenarios. In the WEO scenario, onshore wind becomes competitive under market conditions in the early 2020s, but as the potential for onshore wind is limited (because of availability of suitable sites) the price increases further. Therefore, owners of onshore wind turbines in this scenario can expect earnings that exceed their investment.

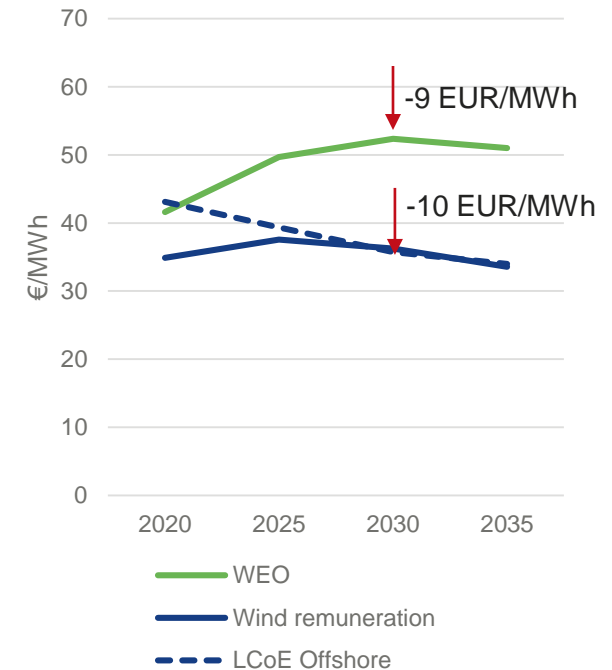
Electricity price increases continue towards 2030, where offshore wind (incl. land use) is established under market conditions. Afterwards, offshore wind halts the price increases and the electricity price stays at 60 €/MWh while wind remunerates at about 44 €/MWh.

If the capital costs for offshore wind are reduced by an additional 30 % relative to what the Danish Energy Agency's technology catalogue predicts, it will lead to a significantly lower cap on the electricity price and remuneration. Direct support for offshore wind will lower the cap even further. For the same reason, wind turbine investors should not assume higher market remuneration than the future levelized cost of wind power projects, unless the potential for new wind turbines is limited.

Electricity price and wind remuneration in WEO support-stop scenario - Western Denmark



Electricity price and wind remuneration in WEO support-stop with cheap wind - Western Denmark



-30 % capital costs for solar and on- and offshore wind.

Support-stop results in insufficient contribution from electricity sector to realize the Government's 50 % RES target

Realization of targets demands support

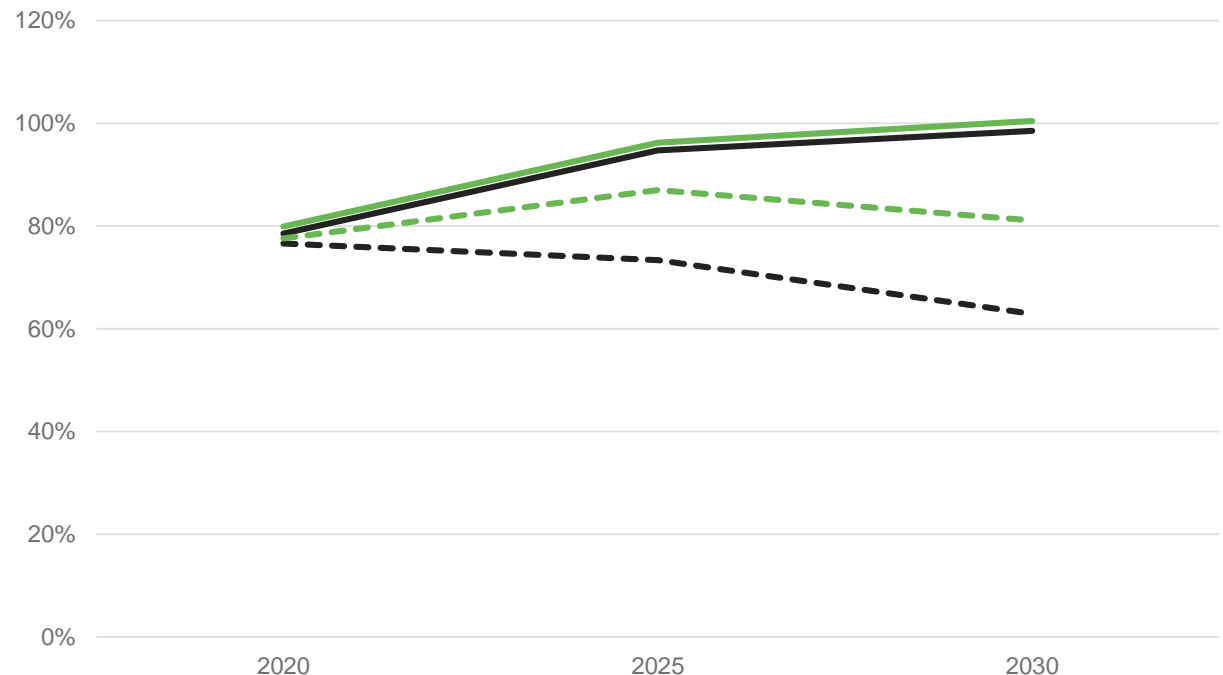
The base scenarios are designed so that RES-fueled electricity production in Denmark in 2030 exactly matches the expected Danish electricity consumption. This is considered a likely contribution from the electricity sector regarding realization of the government's 50 % target for RES in 2030.

The amounts established under market conditions in the support-stop scenarios, however, deliver far from the expected contribution for realizing the government's target. In the support-stop scenarios, the electricity production from renewable energy is 29 TWh and 37 TWh respectively (Forwards and WEO) versus 46 TWh in the political scenarios.

Need for support is limited

Our analysis shows that if Denmark is to fulfill its 50 % target in the Forwards scenario, it would demand that onshore wind and solar PV is supported with 13 to 20 €/MWh and offshore wind with about 20 €/MWh. In the WEO scenario, the need for support is a bit less following the generally high electricity prices, which are driven by high fuel and CO₂ prices. For onshore wind and solar PV, the demand for support would be about 6.7 €/MWh and for onshore wind (incl. land use) the demand will be about 13 €/MWh.

RES share of electricity in Denmark



A higher price on CO₂ ensures more RES but its effect on the electricity price is limited

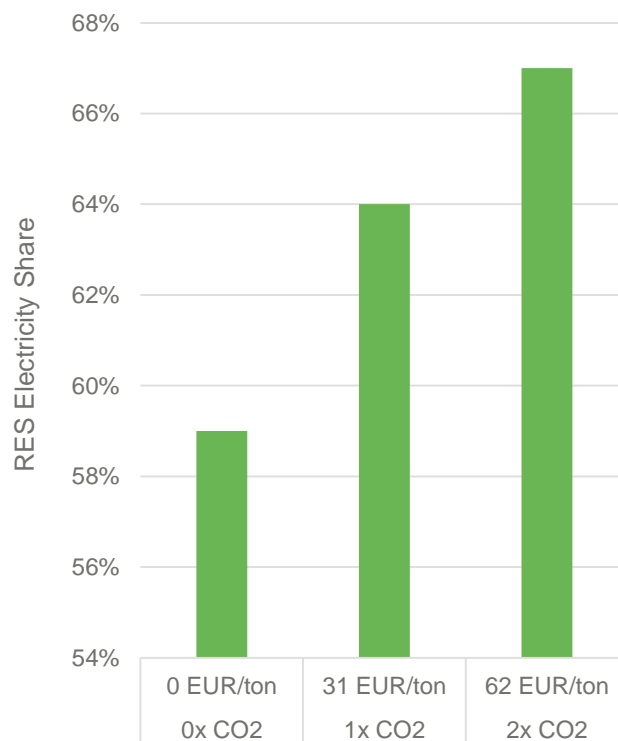
Declining impact on the electricity price

The CO₂ price strongly affects the electricity price today. A price increase of 1 €/ton translates to an increase in the electricity price of approximately 0.67 €/MWh. With wind and solar under market conditions, this relationship can change as increases in the price of CO₂ will be translated into larger amounts of renewable energy instead of higher electricity prices. A change in the CO₂ price of 30 €/ton thus translates to a change in the electricity price far from 20 €/MWh in the future. Our analysis shows that the change is just 3-5 €/MWh on average.

As the electricity price increases a bit in 2030 while the CO₂ price increases because of reduced fossil fuel reserves, the wind remuneration can be expected to become impacted less by the CO₂ price. This is due to the assumption of a flat supply curve for new offshore wind projects and this means that a bettering of the competitive situation in the market is going to be translated only into more offshore wind instead of a higher remuneration.

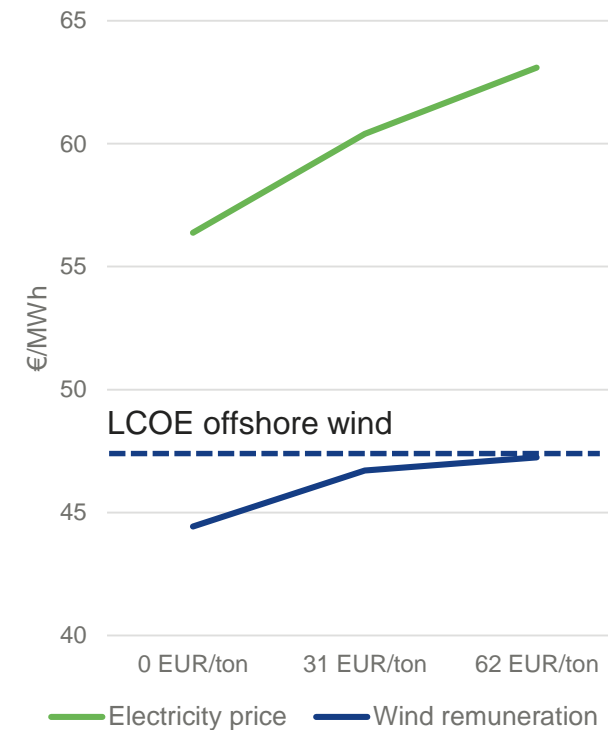
A high CO₂ price is thus important to secure the market for renewable energy. The RES share that the market by itself can reach (without direct support) in the Northwestern European electricity system is 5 % higher at a moderate CO₂ price compared to no CO₂ price and a further 3 % higher at a high CO₂ price in 2030.

A higher CO₂ price delivers more RES Northwestern Europe 2030



Note: RES comprises all renewable energy (wind, solar, hydro, biomass)

A higher CO₂ price delivers only a bit higher electricity price Western Denmark 2030



The CO₂ price is decisive for the economy in both coal power and biomass

Winners and losers at a higher CO₂ price

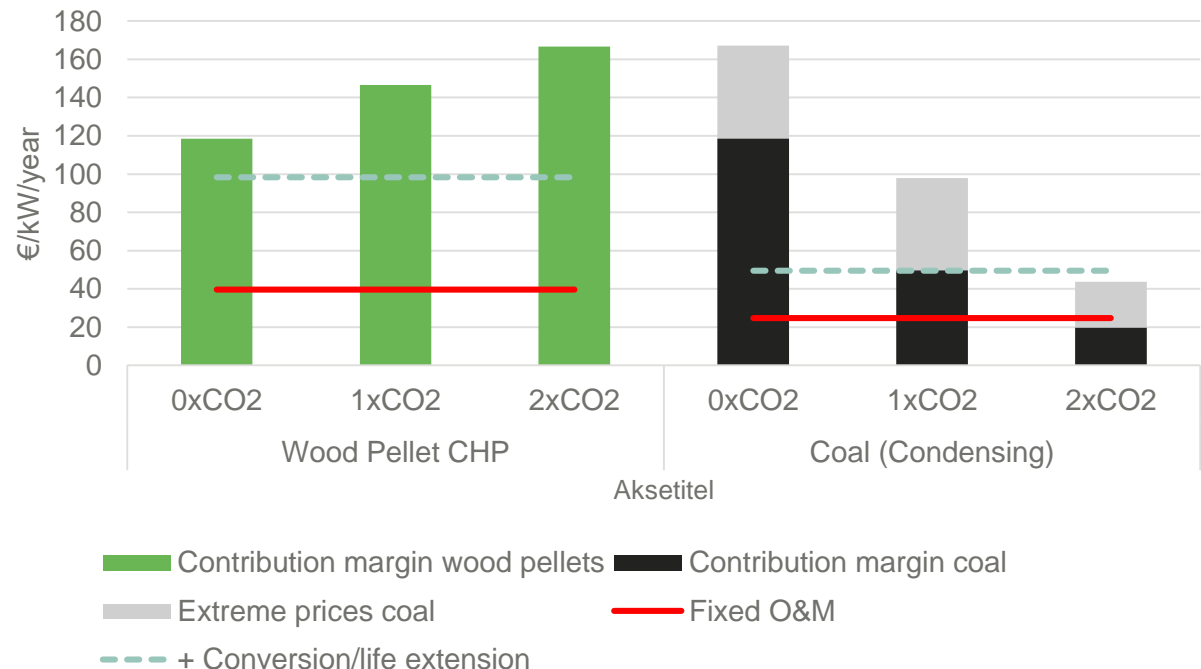
The contribution margin of coal power depends primarily on its competitive relationship with gas.

If the CO₂ price falls, coal will be strengthened in competition with the less CO₂-emitting gas. A collapse of the EU quota system will thus better the economy of coal power significantly.

On the contrary, a higher CO₂ price will make it harder to earn money on coal as it in this case coal becomes less competitive compared to both gas and renewable energy. The majority of the contribution margin of coal power in the scenario with a double CO₂ price comes from extreme prices. During these hours, the value is due to being reliable capacity, and is almost completely independent of costs for operation (as the electricity price far exceeds the variable costs).

For plants that are biomass-fueled, the competitive relationship is improved significantly at a high CO₂ price as the costs for production for both gas- and coal power increases, which in turn increases the price during hours without large amounts of electricity production from wind and solar PV.

**Contribution margin for power plants in Western Denmark – WEO2017
CO₂ price sensitivities - 2025**



The balance between RES expansion and electricity consumption is of importance for the electricity price

Higher electricity demand has little effect on price

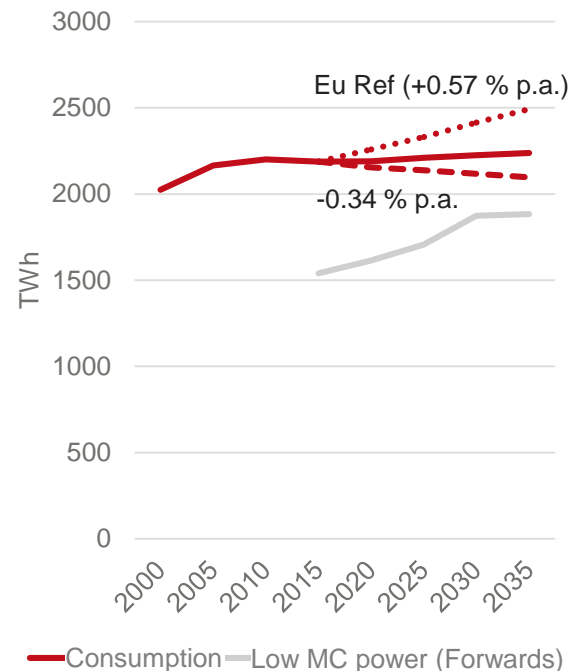
Higher electricity consumption will naturally pull the electricity prices up while a lower electricity consumption will lower the electricity prices, but the effects are not entirely symmetrical.

Our analysis shows that an increase of 0.57 % p.a., corresponding to the EU's reference scenario, only delivers a modest increase in the electricity price of about 2.7-5.4 €/MWh in 2030. On the contrary, a small fall of about 0.34 % p.a. (corresponding to the historical decline in 2010-2015) cause a decrease in the electricity price of about 4-11 €/MWh.

The asymmetric impact on the electricity price is due to the RES expansion getting out of sync with the demand in the scenario with low consumption. Further imbalances can trigger a collapse in the electricity prices when technologies with much lower variable costs can cover the entire consumption in a large share of the operational hours.

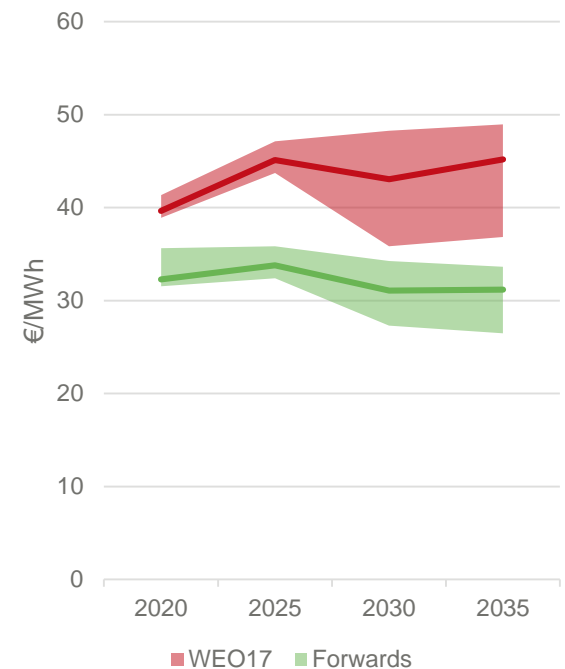
On the other hand, increasing electricity consumption would be able to deliver new RES investment and thus increase the supply of cheap production and in this way limit electricity price increases.

Annual electricity consumption and amount of cheap electricity production in Northwestern Europe



Note: Low marginal cost power production comprise PV, wind, hydro, biomass CHP, nuclear and lignite.

The span for the average electricity price in Denmark at falling and rising electricity consumption, respectively



The balance between RES and consumption is important for the economy of power plants

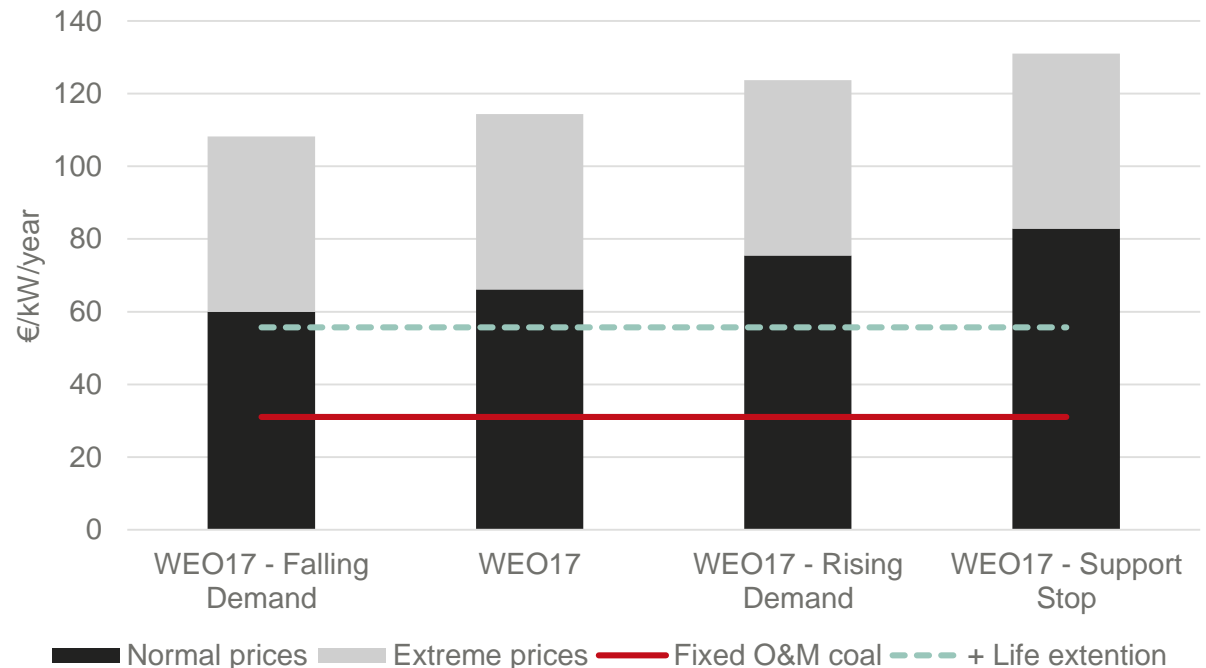
Rising electricity demand can increase earnings

The results show that the economy of coal power plants is affected by the electricity consumption, to a certain degree. Falling electricity consumption removes a part of the power plants' market as the tempo in the RES expansion is kept in place. On the contrary, rising electricity consumption will increase the market for the power plants. The power plants will, however, increasingly compete with new solar PV and wind under market conditions which will also take up a share of the increased electricity market. As wind and solar is set to win the battle of the base load even without support, the power plants' economy is increasingly decided by the battle for delivering flexible middle- and peak load and here gas power is the main competitor for both coal and biomass.

Upper limit for contribution margin

If the expansion is assumed to take place on support-free market conditions, the thermal power plants will increasingly be in direct competition with solar and wind in combination with gas power plants. Even in the support-free scenario, limited earnings for the coal power plants is evident. Thus, the upper limit on the earnings of coal power is set by the competitive relationship with RES and gas.

**The contribution margin of coal power Western Denmark 2030
WEO Scenario**



Transmission connections smoothe the prices in the region and lift remuneration for wind power

Cables increase the price in the Nordic region

It is assumed that all announced transmission connections between the countries are implemented. Additionally, the availability on the Western Denmark- Germany connection is limited when it is windy in Germany.

If the model is allowed to invest in new connections between bid areas, the expansion comes particularly from the Scandinavia towards the south and Great Britain. Between Norway and Great Britain, cables with 5.5 GW of capacity are established if investments in new interconnectors are allowed in the model. Between Denmark and Sweden, additional connections of 1.5 GW are established and between Great Britain and France, a connection of 2 GW is established.

The RES resource from the north is utilized better with the connections from Norway and Sweden to continental Europe. This causes the prices to increase by about 6.7 €/MWh on average compared to the WEO scenario. Norway and Sweden still has no extreme prices in 2030. The wind remuneration also increases by 6.7 €/MWh in both Norway and Sweden and by 4 €/MWh in Denmark.

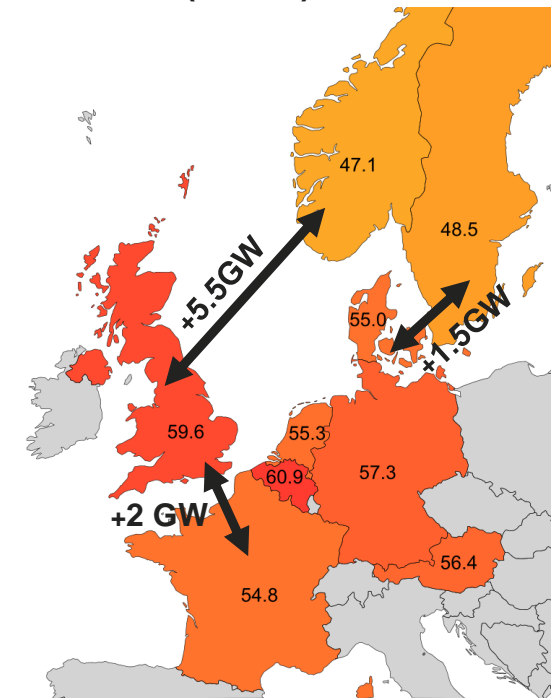
The better economy in wind power in 2030 leads to establishment of an additional 1.5 GW offshore wind under market conditions in the entire Northwestern Europe. The biggest effect is evident in 2035, where the balancing options of the cables delivers another 8.5 GW of offshore wind, which increases the RES share in the electricity system with about 2 percentage points.

Value of cables due to price variations

As shown in the figure on the right, cables are established between countries that have relatively small price differences on a annual basis (e.g. UK and France have a difference of approx. 5.4 €/MWh). The great variation in the hourly prices ensures the economy in the cable investments, as well as the lesser need for gas power which also contributes significantly to the economy of cables (due to increased transmission).

Thus, a reduction of 18 GW in gas-fired capacity is established in the scenario in 2030 and 2035 following the extra transmission capacity.

The electricity price in Northwestern Europe WEO scenario in 2030 (€/MWh)



The electricity price in Northwestern Europe WEO scenario in 2030 with additional cable investments.

Summary of the coal-fired power plants' economy

Coal power earnings largely unaffected by RES

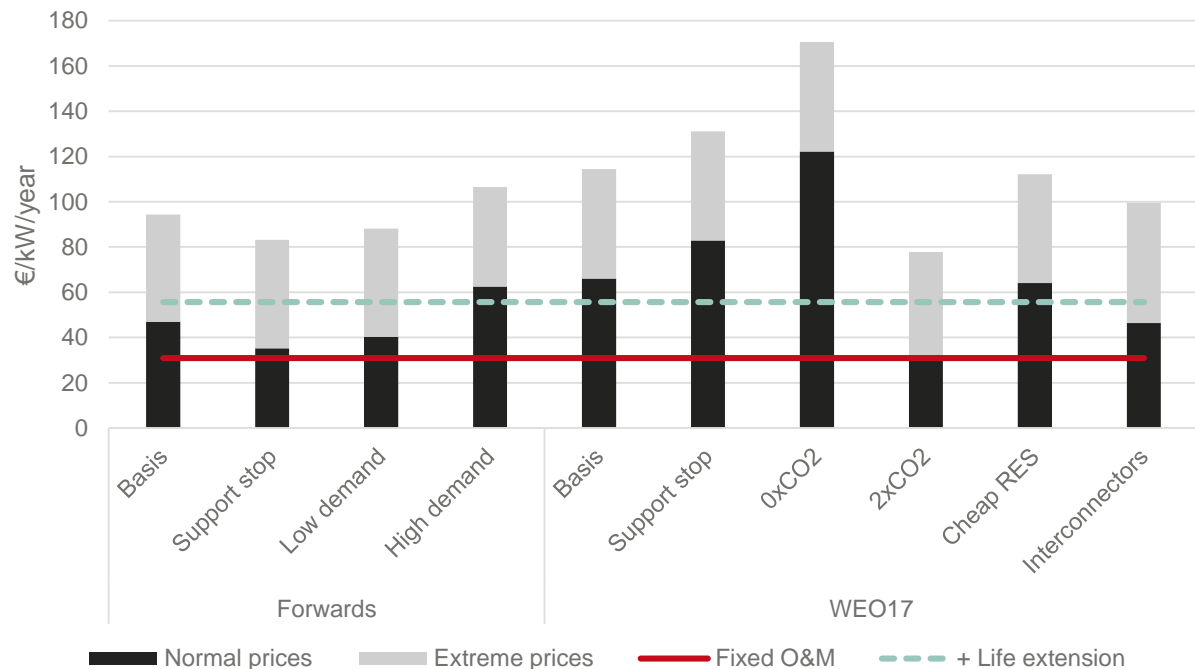
The results shows that across both forwards- and WEO scenarios, the coal-fired power plants can expect about the same (relatively low) earnings no matter if solar PV and wind are getting government support or not. Even though support for solar and wind delivers more RES and less production in the thermal plants, the electricity price will increase when it is not windy or sunny. In the same way, cheaper RES does not affect the economy of power plants.

Power plant economy is decided primarily by the competition with gas as the pricing during hours with low RES production is dictated by the price of establishing and operating new gas power plants.

The CO₂ price is decisive for plant economy

The joker for the economy of the power plants is the CO₂ price. If there are no costs related to CO₂ emission, it will likely be profitable to extend the lifetime of old coal-fired power plants. On the other hand, a doubling of the CO₂ price will make the coal plants dependent on extreme prices just to cover the fixed costs. This will probably lead to closure of plants at a higher pace than we are witnessing today.

Contribution margin for coal power plants in Western Denmark 2025



Summary of the biomass-fired power plants' economy

Competition with fossil fuels is decisive

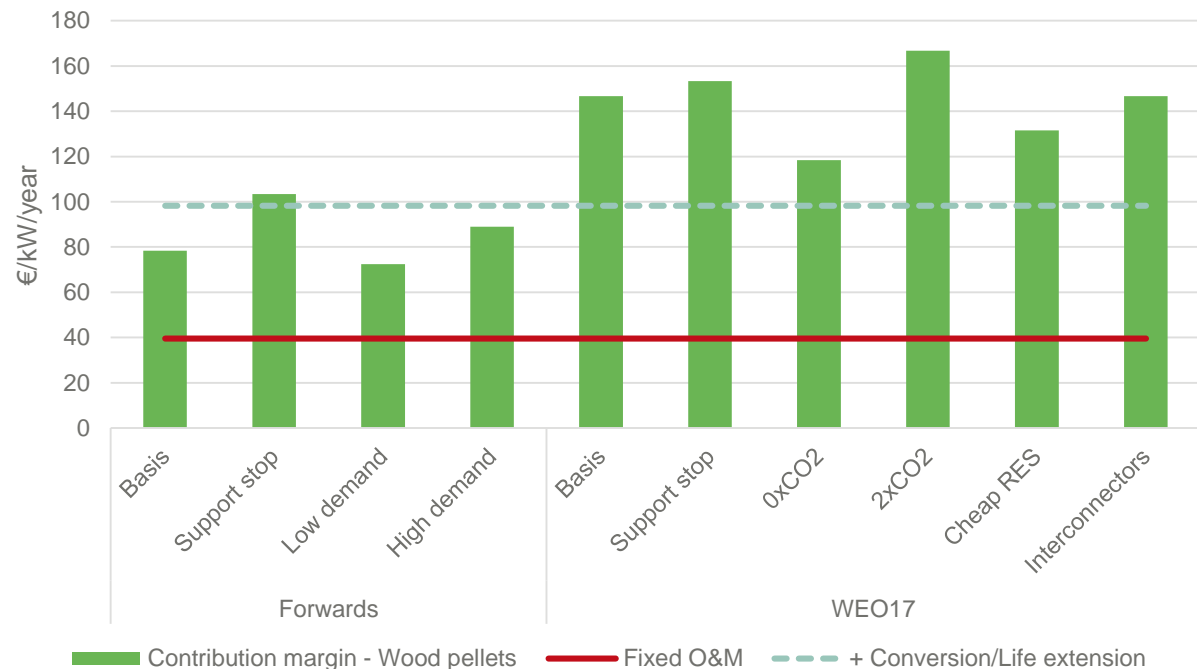
The economy in biomass CHP is primarily decided by its competitive relationship with fossil fuels. Therefore, the contribution margin in the Forwards scenarios (incl. sensitivities) is significantly lower than in the WEO scenarios.

For this reason, the CO₂ price affects the economy more than the uncertainty of the electricity consumption.

Provided that it does not play a part in the pricing of CO₂ or support conditions for biomass, the costs and support for wind and biomass matters relatively little to the economy in biomass CHP. Thus, 'Support-stop' (where the government support is removed for all new RES plants) and 'Cheap RES' have almost the same earnings for biomass CHP as the WEO base scenario.

Owners of biomass plants thus benefit the most from higher CO₂ prices and more expensive fossil fuels.

Contribution margin for wood pellet CHPs in Western Denmark 2025



Summary of the economy of wind power

Large span in remuneration

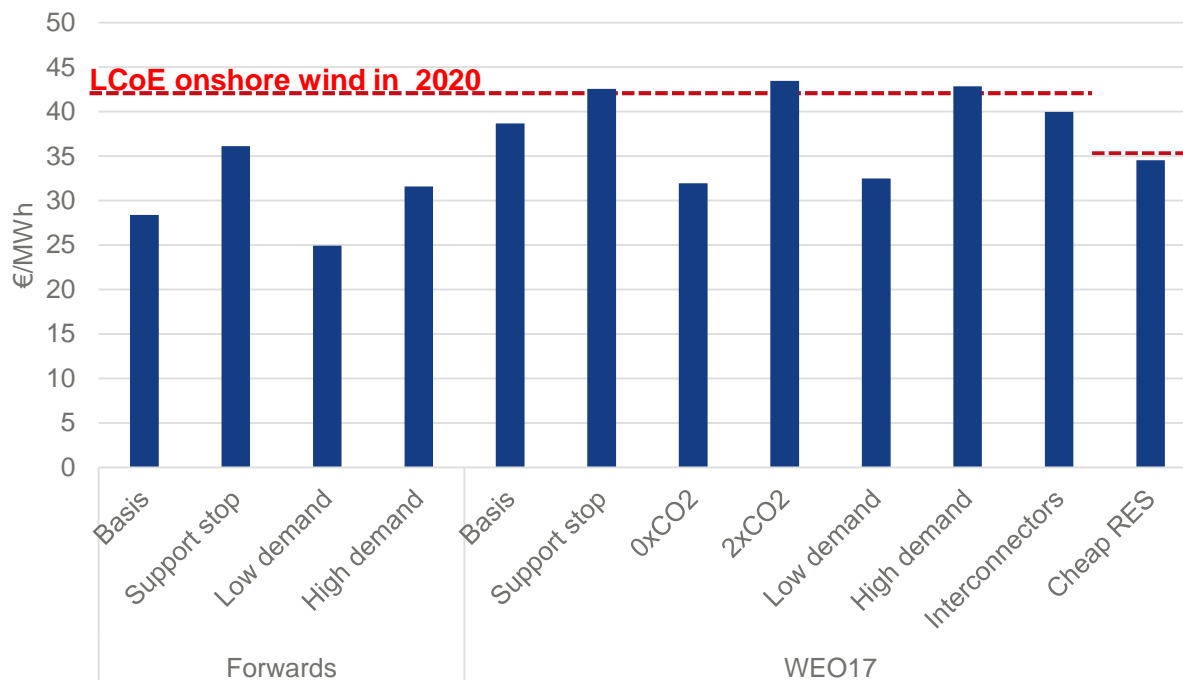
The average remuneration for a new wind turbine established in 2020 varies between 25 and 44 €/MWh across scenarios. The lowest remuneration is achieved in the Forwards scenario with decreasing consumption. The combination of relatively cheap fossil fuels and great competition from other (supported) wind turbines squeezes the remuneration in the market.

Wind competes with future wind

The average remuneration does not exceed 43 €/MWh in any of the scenarios. This is because remuneration in the scenarios with the best market conditions for new wind power (high CO₂ price and high consumption) primarily lead to a larger expansion under market conditions, which limits price increases. In the 'Support-stop' scenarios, offshore wind is also under market conditions, but much less widespread.

The scenario 'Cheap RES' underlines the point that wind power caps its own remuneration. In-so far as the cost for wind power falls significantly it too will result in lower remuneration.

Average remuneration for wind power in Denmark in 2020-2039



3.4 Electricity Storage

Electricity storage can become a game-changer in the markets

Electricity storage lives off differences in prices

Electricity storage consumes electricity during cheap hours and discharges electricity during expensive hours. The economy is thus dependent on differences in electricity prices either within a day (short-term storage) or within weeks (long term storage) – it is thus both the frequency in electricity price differences as well as the absolute difference between electricity prices that determines the economy of electricity storage.

As described above, reliability has particular value in the electricity market. Electricity storage can deliver precisely this and is therefore a competitor to peak load plants besides being able to save RES electricity production for periods with low wind and darkness.

Electricity storage can also change the competitive relationship between solar and wind depending on the type of storage. Short-term storage is a better fit for solar power that can be stored during the day for use during the night, while long-term storage is a better match for wind power as the storage can compensate for the fluctuations over longer periods of time.

Besides earnings in the spot market, electricity storage is capable of earning money from delivering system and grid services. Moreover, electrical vehicle batteries can be active in the electricity spot market if the cars are equipped with the right effect electronics,

it is plugged in and the owner has allowed the battery to be used for this purpose.

Many suggestions for the electricity storage technology of the future

The challenge for electricity storage today is that it is too expensive relative to what can be earned in the spot market; this is because the storage investment is too expensive, has too limited capacity or has too great losses during charging and discharging.

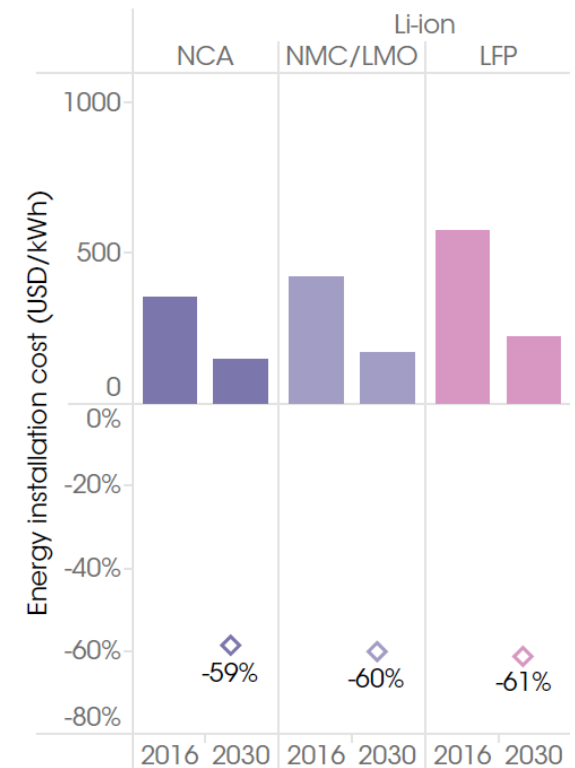
There are many technologies in play to store electricity, for example chemical (batteries), pressurised air (CAES), heat (HTES) or gas/hydrogen (via fuel cells). Today it is only pump power, in other words storage in a water reservoir, that is widespread.

The price for batteries is falling drastically, driven by demand from, among others, electrical vehicles and electronics. The figure on the right shows IRENA's expected 60 % drop in the installation price for stationary battery plants (lithium-ion) towards 2030.

We have analyzed the effect of introducing batteries with 3 hours of storage if the price drops from 250 to 150 €/kWh during 2020-2030.

In addition, a generic long-term storage facility with two days' worth of storage and 50 % electricity-to-electricity efficiency at a price of 25, dropping to 15 €/kWh.

Price for stationary battery capacity



Source: IRENA

Electricity storage will primarily compete with natural gas as a backup for wind and solar

Residual load is lowered and pressures the power plants' operational hours

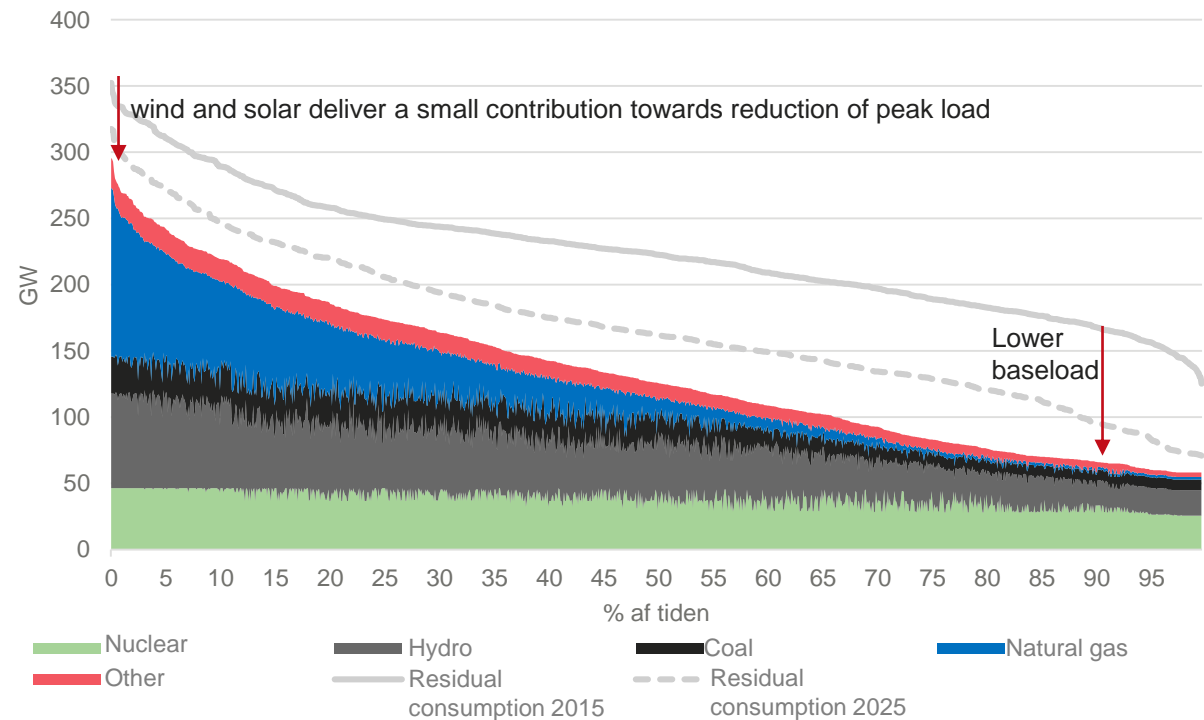
Residual load is electricity consumption, less wind and solar power production, and thus defines the need for power plants (and electricity storage).

The figure on the right shows an expected drop in the residual consumption from about 2000 to 1200 TWh in Northwestern Europe from 2015 to 2035, due to increasing solar and wind share power shares. Of the 1200 TWh, nuclear and hydropower makes up about 700 TWh. This means less operation in power plants with high marginal costs (primarily natural gas and coal) that are expected to deliver about 500 TWh in total in 2035. However, there is still a very high peak load consumption which has to be covered (about 300 GW) which arises when the electricity consumption is very high during periods with little production from wind and solar.

New power demands affect the residual load

If new electricity consumption from e.g. electrical vehicles, heat pumps or electrolysis becomes flexible, it can avoid peak load periods and will thus not increase the need for new capacity of power plants or electricity storage. Thus, the more new electricity consumption can match the wind and solar production, the less residual consumption and capacity demand results.

**Residual consumption 2035 total and distributed by fuels for 2015 and 2025
Northwestern Europe – the WEO scenario**



Electricity storage delivers peak load and halts the curtailment of wind and solar

Electricity storage delivers peak load

With the prices assumed, both types of storage outperform gas power. This is primarily due to their capital costs per MW being level with gas power. Storage thus become the obvious choice for delivery of a few hours of peak load.

The long-term storage, however, is displacing efficient CCGT plants. The combination of the two almost eliminates the need for gas-fueled peak load (OCGT).

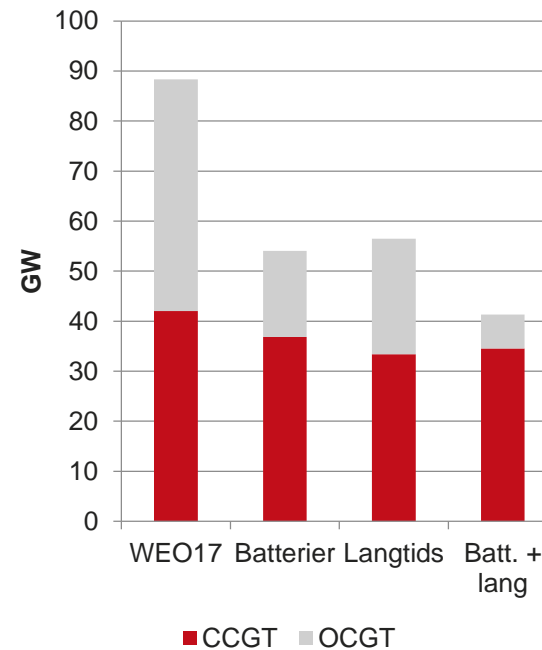
Electricity storage in 2035 can deliver about 50 TWh of the total residual consumption demand (1200 TWh), whereof about 500 TWh is delivered by fossil-fueled power plants. Electricity storage thus displaces gas at about 10 % of its production.

Storage halts the curtailment of wind and solar

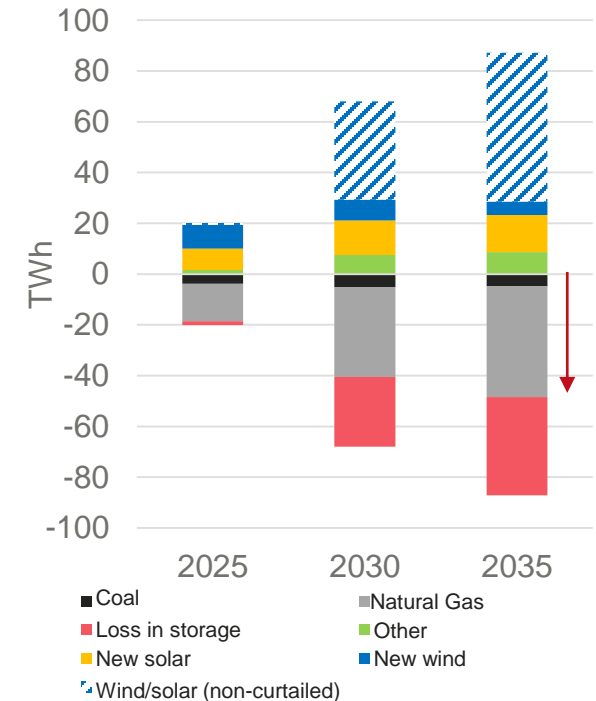
The need for electricity consumption for storage stems from when more solar and/or wind power is provided to the system than required, whereof a significant share of the wind would otherwise be curtailed.

In the WEO scenario, about 60 TWh less wind/solar is decoupled because of electricity storage, corresponding to a reduction from 6.9 to 2.0 % decoupling of wind power in 2035. The storage is thus primarily loaded with RES production that otherwise would have been lost.

Investment in gas fueled capacity in the scenarios during 2020-2035



Changes in electricity production and long-term storage in the WEO scenario



The arrow shows the net production from electricity storage

Electricity storage increases the price in the cheapest hours and reduces in the price in the most expensive hours

Electricity storage in the spot market to compete with existing and new power plants

Electricity storage can take on various parts of the residual consumption from conventional electricity production.

1) Storage as new peak load production

Electricity storage can supplant new peak load capacity. Here it would be possible to use short-term storage. The figure on the right shows that charging is happening even at high electricity prices, to discharge at extremely high prices.

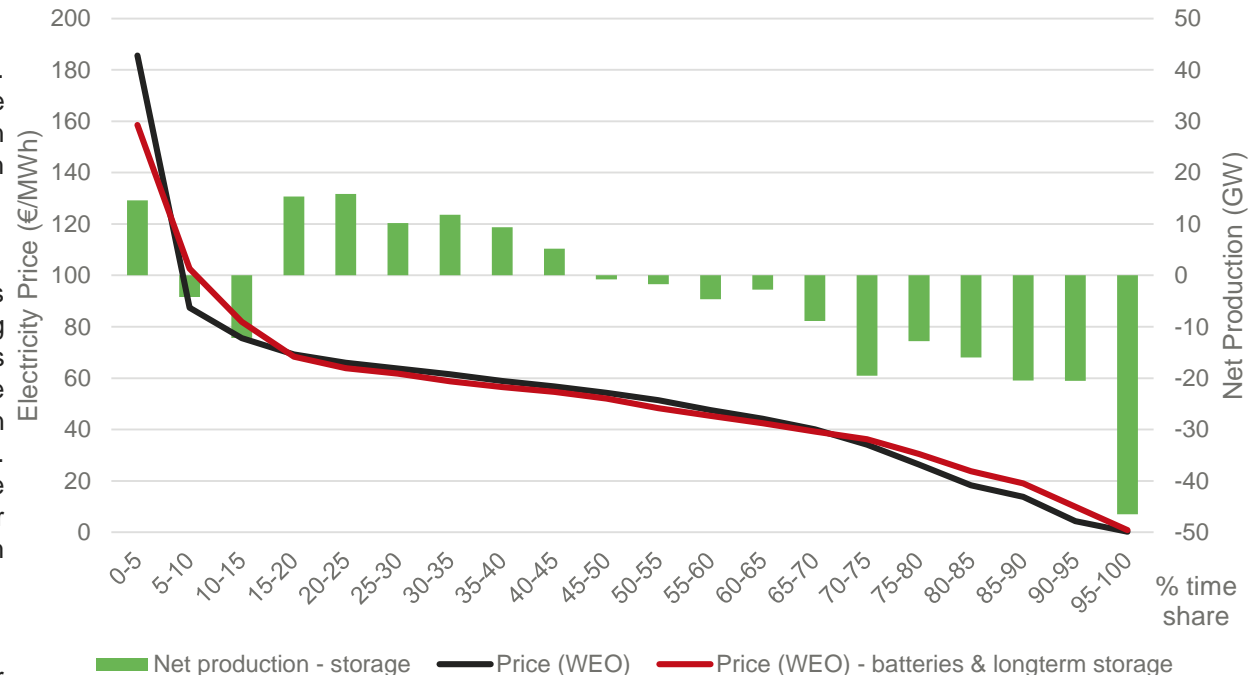
2) A move from low to moderate prices

In the figure it is evident that wind and solar power is stored during cheap hours and is discharged during relatively expensive hours. A better remuneration makes way for more wind and solar. The long-term storage stores wind power, that otherwise would have been curtailed, and saves it to periods with high prices. Collectively, the long-term storage discharge a bit more electricity than the batteries and because of the poor efficiency, the electricity consumption for long-term storage is significantly higher.

Cheap wind and solar is a prerequisite for storage

Investment in electricity storage compared to new power plants (for instance natural/biogas, biomass or nuclear power) is dependent on the LCOE for wind and solar. Thus, a breakthrough for electricity storage demands both low costs for RES and long-term storage.

Net production from storage and duration curve for prices Northwestern Europe 2035



Electricity storage will increase earnings for wind and solar

Higher remuneration for Danish wind and solar

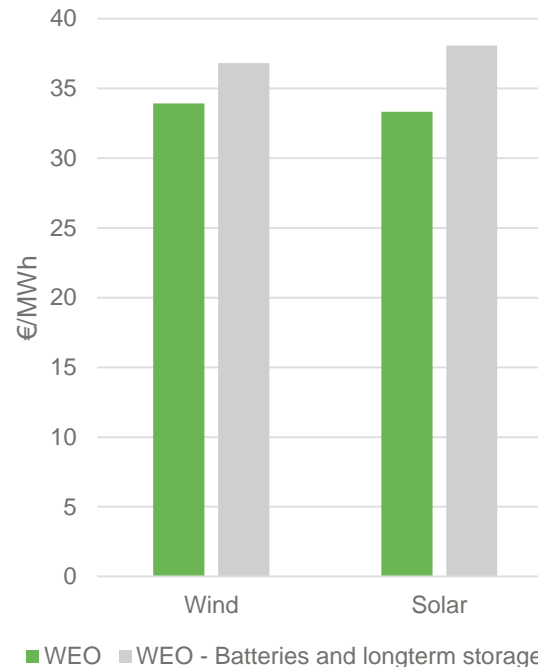
Batteries and long-term storage in Northwestern Europe increases remuneration for wind and solar in Denmark by 2.7 and 4.4 €/MWh respectively in 2030. Electricity storage can thus make a relatively large contribution to the bettering of the economy of wind and solar.

Both types of storage live off the difference between the purchase price and the remuneration price. Here, the batteries purchase electricity at about 34 €/MWh, while the long-term storage only purchases electricity when it is particularly cheap (because of the assumed low efficiency). The long-term storage purchases electricity at about 15 €/MWh on average, of which a large share is purchased during hours with zero-price. In these hours wind and solar power would otherwise have been curtailed. The remuneration price is a bit higher for batteries than for long-term storage, which is due to them being used more frequently for peak load.

In total, these purchase and remuneration prices, and the difference in efficiency, means that batteries and long-term storage have about the same gain – about 60 €/MWh in 2030.

The batteries' charge- and discharge have about 300 full cycles during a year while the long-term storage has about 30. With the assumed storage time of 3 and 50 hours respectively, this corresponds to about 900 to 1500 full load hours measured against the discharge capacity.

**Remuneration prices
Denmark 2030**



**The economy of electricity storage
Northwestern Europe 2030**



Electricity storage can lower power plants' earnings from extreme prices

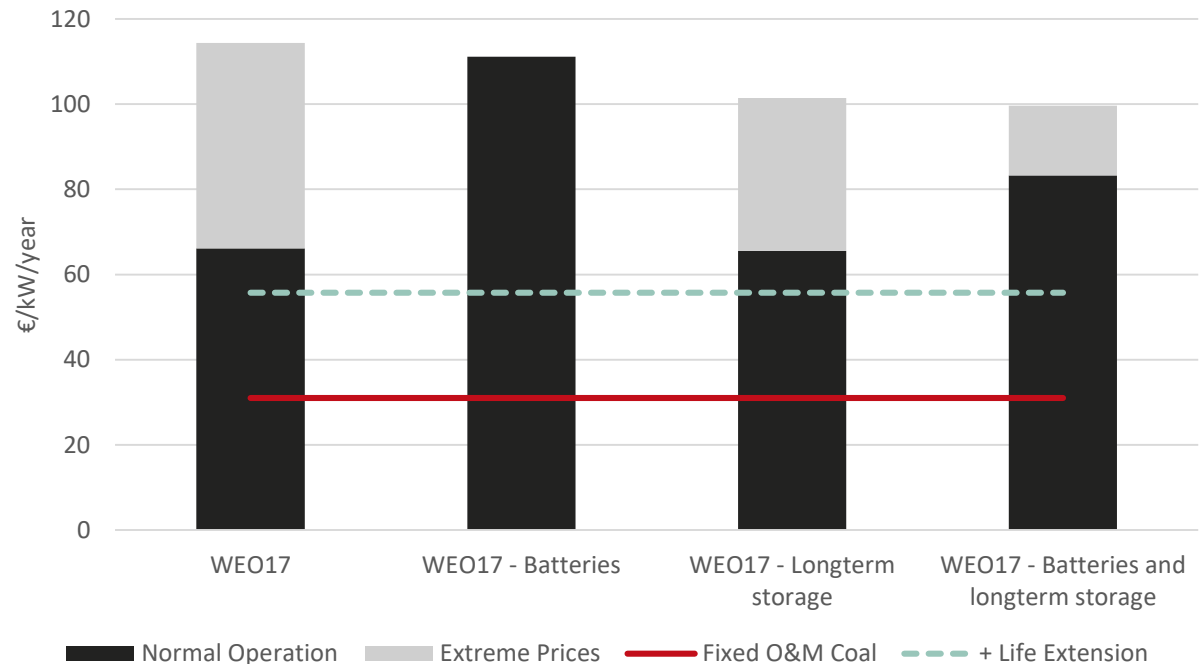
Batteries can become the peak load plants of the future

In the scenario with just batteries, our analysis shows that batteries can remove extreme prices, as they are capable of delivering peak load for a few hours cheaper than gas (OCGT). However, the batteries cannot deliver middle load of any significance because of their limited capacity. The pricing during hours with low electricity production from wind and solar will, with time, reach a level where it is possible to recoup the investment for a new CCGT plant. Thus, the number of high price hours rises together with earnings during normal operation for the power plants. Collectively, the contribution margin for coal power is thus unchanged in the figure, but the security of earnings is greater.

Long-term storage can deliver middle load

The scenario with both batteries and long-term storage, however, shows that this conclusion can be subject to change as the long-term storage competes with the CCGT plants and thus is able to reduce earnings for gas obtained in high price hours. At the same time, long-term storage is in competition with batteries and therefore it is not profitable to have as many batteries, whereby the peak load consumption is not covered completely by batteries. Collectively, the contribution margin for coal power is lowered slightly.

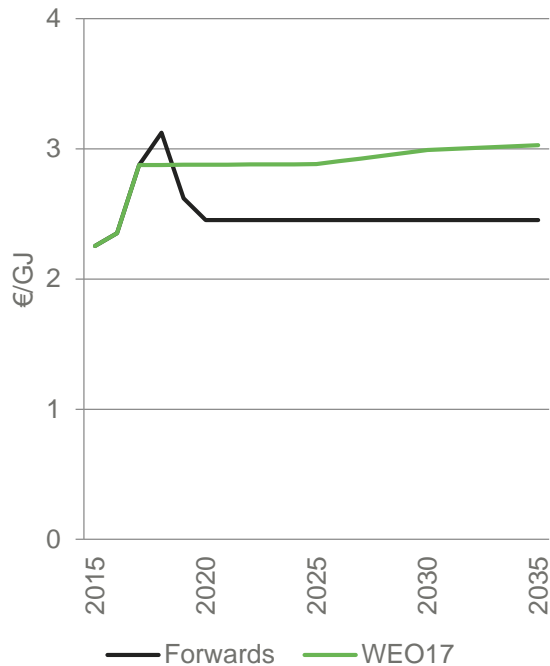
The contribution margin of coal power in Western Denmark 2030



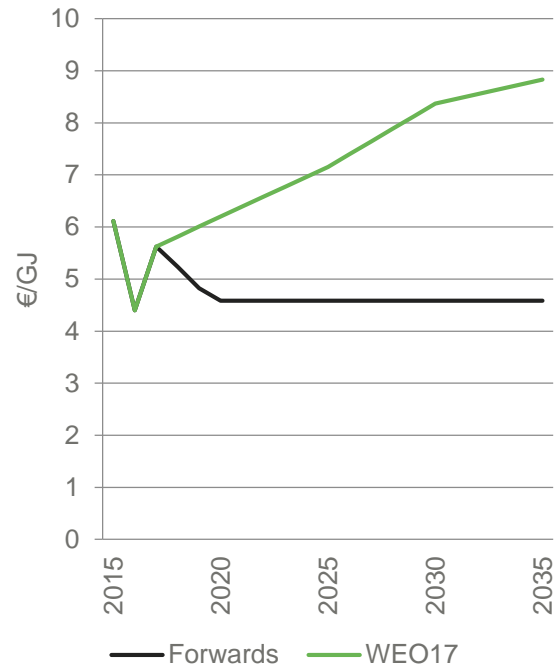
Appendix

Assumptions – Central scenarios

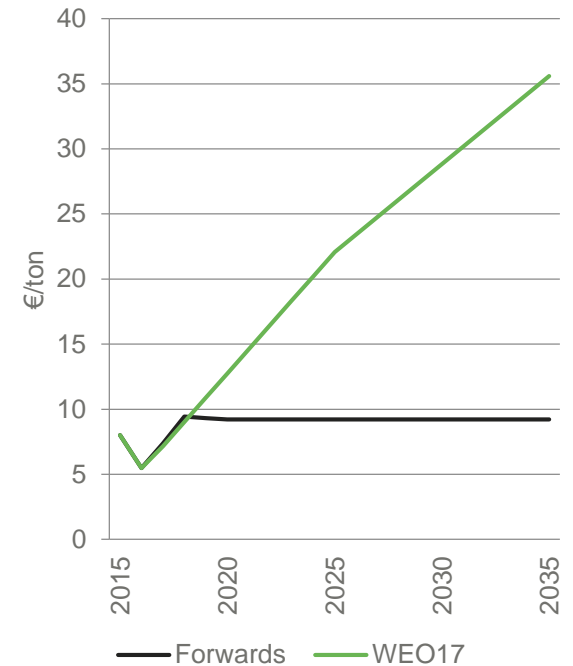
Coal price



Natural gas price



ETS price



Note: Fixed 2017 prices

Assumptions in Balmorel

Balmorel

The scenarios in this Outlook have been simulated using Danish Energy's version of the Balmorel model.

The Balmorel model is an advanced optimization model, which minimizes the total cost for district heating and electricity generation. For more information go to www.balmorel.com.

Thermal plants

The power plant capacity in the modeled area is based on Platts database for existing thermal plants in Europe. The lifetime for existing plants have been assumed to be 45, 30 and 20 years respectively for steam turbine plants, gas turbine plants and engines. Plants are removed from the model when reaching their lifetime.

The model can not decommission plants based on economic criterias.

A stable phase out of nuclear plants have been assumed based on recent political statements. Whether these statements will materialize are associated with great uncertainty.

Renewables

Onshore wind is assumed deployed to 2030 following WindEurope's high scenarios. Offshore wind is following the central scenario in "Wind Energy in Europe: Scenarios for 2030". Solar PV deployment follows EPIA's accelerated scenario.

In the support stop scenarios exogenous capacity is kept at 2020 levels.

The capacity development for renewables in Denmark follow the DEA's Basisfremskrivning from 2017.

Investments

The model can invest in new capacity if it is economically feasible. The model may invest in the following technologies:

- OCGT gas
- CCGT gas
- Coal CHP (in Germany)
- Wood pellet CHP
- Onshore wind (only in support stop)
- Offshore wind
- Large scale solar PV

Investments in onshore wind is limited, such that capacity does not exceed Wind Europe's "High Scenario".

In district heating it is further possible to invest in heat pumps and wood chip boilers.

Capital costs are annualized with a 6 % real WACC and 25 years of depreciation period in all countries and for all technologies.

Electricity demand

The electricity demand is assumed constant in the central scenarios throughout the period and set at the level of the countries demand in 2016. This is based on the assumption that increased efficiency is balanced by electrification and economic growth.

For Denmark consumption follows Basisfremskrivningen 2017.

Transmission

The interconnectors between the countries are based on the published plans from national TSO's and contains the recently approved Viking Link between Denmark and the UK.