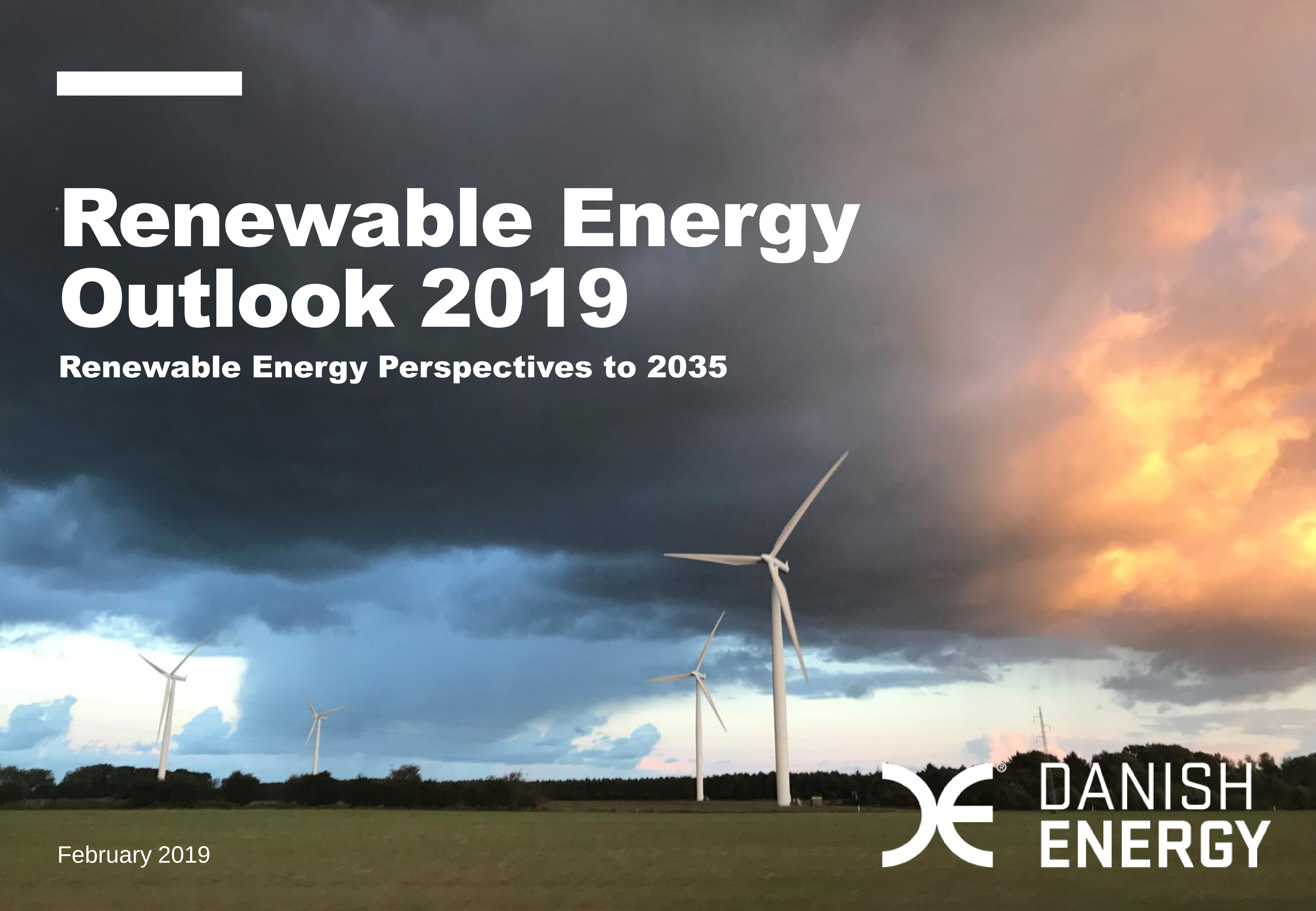

Renewable Energy Outlook 2019

Renewable Energy Perspectives to 2035

February 2019

DANISH ENERGY

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RES Outlook 2019: Electricity Will Drive The Green Transition

Electricity has a great potential for driving the green transition. The electricity sector will become an essential key player in the mitigation of the world's CO_2 emissions, helped by consumption of green electricity in the transport, heat production and industry sectors.

Never has it been more clear than today that green electricity is a solution to climate challenges, which gives rise to the question: can green electricity be established at a rate that matches our increasing demand?

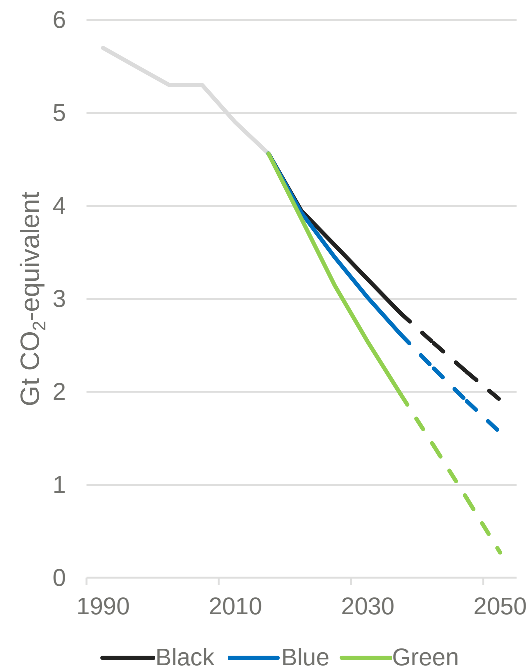
Danish Energy's RES Outlook 2019 uses the latest knowledge from the energy field and forecasts the deployment of RES during the next decade. Three scenarios are considered: black, blue, and green. We are left with the realisation that the green scenario is the only one which ensures a transition in accordance with the Paris-agreement goals, i.e. a complete reduction of emissions to zero by 2050.

The green scenario involves a significant increase in the deployment rate of green electricity generation. Across the whole of Northwest Europe, the rate has to increase by four times for offshore wind, two times for onshore wind, and six times for solar PVs compared to the current rate. Achieving this goal requires an efficient emissions trading scheme with high CO_2 prices, better integration of international electricity markets through expansion of transmission lines, efficient planning processes for green electricity deployment, and progress of storage technologies.

Europe should choose the green path and the electricity sector should leverage its large potential. This will not happen by itself; political courage and responsibility is required.

Enjoy reading!

Greenhouse Gas Emissions in Danish Energy's 3 Scenarios



Source: Danish Energy

Green Electricity Drives The Transition If Deployment and Electrification Accelerate

Green electricity is a driver in the on-going green transition. Further progress along a long hard road is required, when total energy consumption is considered.

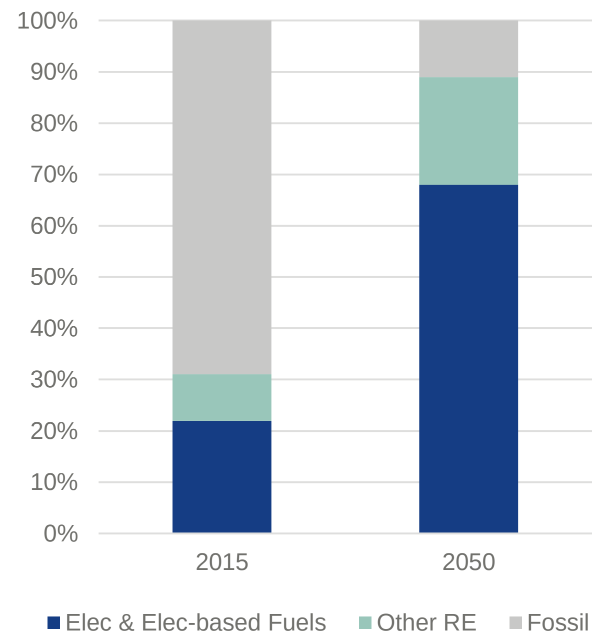
The EU Commission has recommended that we target a reduction in greenhouse gas emissions that limits the level of temperature increase to no more than 1.5°C. This is necessary to meet the bleak predictions from IPCC about a world with an ongoing increase in temperatures. This calls for a whole new green transition. If we are going to reach this goal, green electricity needs to play a much bigger role in the energy system as a whole.

In 2050, electricity in Europe should represent almost 70 % of all energy consumption, compared to 21 % in 2015. This will be achieved through significant electrification of transport, heat, and industry.

Positive trends are emerging in industry. Volkswagen has announced that their coming car fleet based on fossil fuel will be the last, and Mærsk has pronounced that they aim to be CO_2-free in their sailing activities by 2050. ThyssenKrupp made a goal to produce CO_2-free steel in 2050 with the use of hydrogen from electrolysis, with an electricity consumption corresponding to the current total use in Denmark. However, contrary to the transition which we now see occurring in the electricity system, the positions of these companies are only plans and/or visions, rather than being actual change. Trends which are extremely important to implement and disseminate, if we are going to achieve a total green transition for the benefit of the climate.

The development of ever cheaper and better PVs and wind turbines fortunately pushes us in the correct direction. Green electricity will soon be fully competitive with fossil fuels and will no longer require payments from support schemes. This is clear from looking at the latest tender on onshore wind and solar PVs in Denmark. The tender was settled with winning support prices of 3 - 4 EUR per MWh, which is extremely close to independence of support. Furthermore, several offshore wind projects outside Denmark were won without support last year.

Green Electricity and Electricity-Based Fuels Dominate the EU's 1.5°C Scenario



Source: The EU Commission

Green Electricity Can Solve The Climate Challenge Cheaply, but Land Area Is Required

Big price reductions have been seen in the green electricity generation. This is a result of technology development and industrialisation. As results of the latest tenders have shown, wind and PV are now the cheapest sources of electricity generation, and further price reductions are expected.

This development has been assisted by the EU's emissions trading scheme, which received a needed boost by a reform at the end of 2017. Since then, the price of emitting CO_2 has increased more than four times, from around 5 euro per ton CO_2 to more than 20 euro per ton. An increasing group of countries, including Denmark, has agreed to phase out coal before 2030, which will provide further impetus for green electricity deployment.

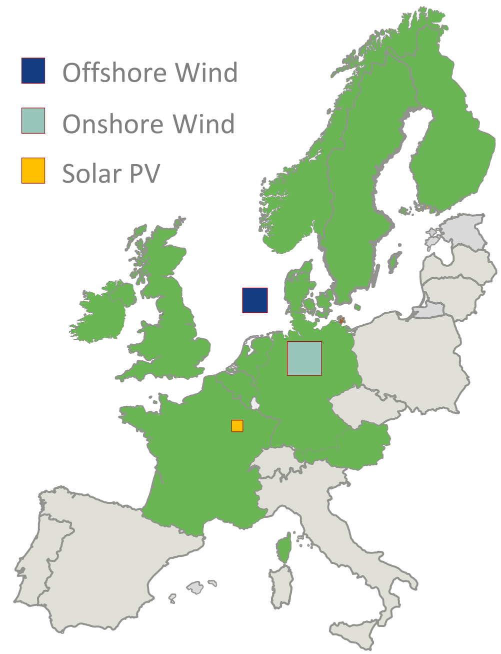
We need to continue on this path. We need to establish wind turbines and PVs to push fossil fuels out of the electricity sector and at the same time produce the extra green electricity needed to ensure green transportation, heat distribution, and industry.

However, this requires that we drive the deployment forward. The need for a bigger area for new green electricity generation is important and of course essential. For onshore wind, this is a little less than 2 % of the total land area in Northwest Europe, or a little less than the total area of Denmark. In our analysis, this is realistic to achieve within the studied region.

Storage and transmission will also contribute to balancing the production, which will result in reducing the dependency on fossil fuels furthermore. These technologies can and have to be developed.

None of the above comes without effort – therefore the ongoing transition requires completely renewed political backing.

Area Requirements for New RES by 2030 in Danish Energy's Green Scenario



Note: The green countries are analysed in the RES Outlook 2019.
Source: Danish Energy

Planning, CO_2-Price and Access to Financing Can Be Potential Barriers

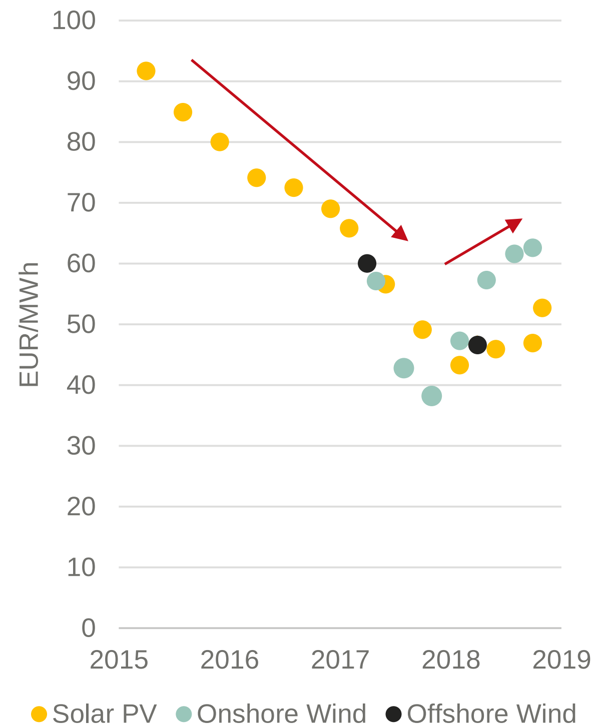
The current phase of RES deployment, could prove to be much more tricky than the previous one. Industry can deliver the required number of PVs and wind turbines, as long as politicians can ensure a suitable market framework. The real challenge lies in ensuring that is achieved.

If the planning processes for the onshore and offshore RES deployment are not efficient, the necessary green transition can potentially be stranded in many hours of handling procedures, with excessive complaint processes resulting in delays or even cancellations. The latest German tenders for onshore wind in 2018 show how the price of RES will increase if the number of approved projects allowed to compete for the tender is not sufficient. This is despite the fact that the price of technology is continuously decreasing. Bottlenecks in deployment can easily turn out to be slow processing of regulatory approvals, failing local support, and lacking grid-connections and -expansions to offset the green electricity.

Furthermore, the huge expansion will require a huge amount of capital, which potentially will be made available with returns that are much less safe than for previous projects that received a guaranteed returns from the government. If the projects have to survive on their own with uncertain revenues from the electricity market, the financial costs and thus the price of RES will increase markedly. This will postpone the green transition.

If fossil fuels are not imposed with higher costs due to their emissions, it will be difficult to get a sufficiently high amount of renewable energy competing under market conditions. The determining question is not *if* the green electricity will become free of support schemes, but rather if the market terms will support that *enough* new green electricity generation can be established.

Inadequate Area for Wind Increases German RES Prices



Source: EEG

We Are Calling for: Better Planning Processes, Higher CO_2-prices, and Good Financial Frameworks

Politicians can contribute significantly to the green transition by providing clear signals.

This can happen by having a high and stable CO_2 price, e.g. by implementing a minimum price in the quota market. Having this minimum will furthermore contribute to lowering the financing costs by reducing the risks related to the clearing of the electricity market. More clarity will ensure a cheaper green transition.

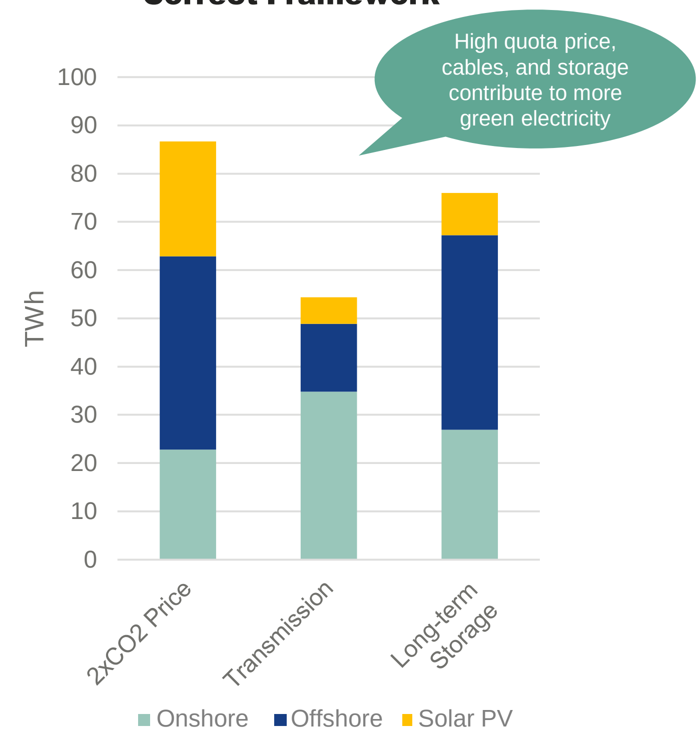
In order to achieve an efficient and cheap green transition with popular support, it is essential to have an efficient handling process that includes people at an early stage and addresses their concerns. This will assure developers that their projects can be accomplished and, as a result, guarantee that a sufficient amount of projects can be realised.

It is important that the grid expansion at both the transmission and distribution level will not be an obstacle for the implementation of green electricity generation. Storage technologies have to be developed and spread out to become an active part of the electricity system. Integrating European markets further, while developing storage technologies, will increase the value of green electricity production and cause more fossil fuels to be phased out.

Strengthening the market for Power Purchasing Agreements (so-called PPAs), settled between (large) consumers and project developers, will contribute towards cheaper green electricity by providing the project developer with security regarding the project returns. This will furthermore give the buyers more assurance of future prices of the green electricity and the possibility of contributing to the green transition.

These actions are examples of those required to support electrification. Significant developments in electrified transportation, heat pumps, smart grid-solutions, and industrial electric processes is a necessity.

Green Electricity Wins with The Correct Framework



Note: Co-development of RES electricity in Northwest Europe from the blue to green scenario

Source: Danish Energy

6 Key Messages in the RES Outlook 2019

1. Electrification will be the most important factor in the phase-out of fossil fuels in the energy system. The analysis shows that the potential of RES in the electricity sector is large enough to both substitute fossil fuel consumption in the heat and power sector and supply the new demand resulting from electrification.
2. The large price reduction on wind turbines and solar cells, as well as ongoing innovation combined with agreed goals for phasing out coal, will drive a comprehensive green transition.
3. The question is not *if* we will achieve subsidy-free green electricity, but whether we will achieve *enough* subsidy-free green electricity.
4. A high price on CO_2 is an essential instrument to securing a sufficient amount of green electricity quickly enough. The alternative is direct subsidies, which are less efficient in reducing emissions.
5. The planning framework and public opposition risk being barriers to the rate of deployment. Authorities and planning processes should, therefore, be oriented towards assessing and approving projects more rapidly than previously.
6. Financing green electricity projects can be a challenge. PPAs seem to be an attractive instrument in providing security about the future costs for electricity consumers and revenues for suppliers, further reducing the financing costs.

2. Topic: Not in My Backyard

Wind and Solar – Not in My Backyard...

The RES deployment needs to accelerate

The RES Outlook shows that an extensive deployment of renewable energy can address the climate challenge, and that this can be done without subsidies. It is no longer the economy and the lack of support which will prevent deployment. It could, therefore, be a tempting conclusion to say that we have already reached the goal; the market will make green electricity win over coal and gas.

However, the challenge which we are facing goes beyond that. The implementation of more onshore, offshore, and PV must occur at a much more rapid pace in order to achieve our climate goals, and current trends are signifying that we are moving in the wrong direction.

Sluggish authorities block deployment

The green transition will affect the landscape as areas are required to install wind turbines, PVs, and new grid infrastructure. Onshore wind, grid-expansion, and increasingly PVs are facing challenges. In the period preceding the municipal election in 2017, we saw repeating examples of wind projects being cancelled despite complying with all rules and regulations. Cancellation decisions were made by nervous municipalities, often late in a planning process, and were based on unconvincing arguments.

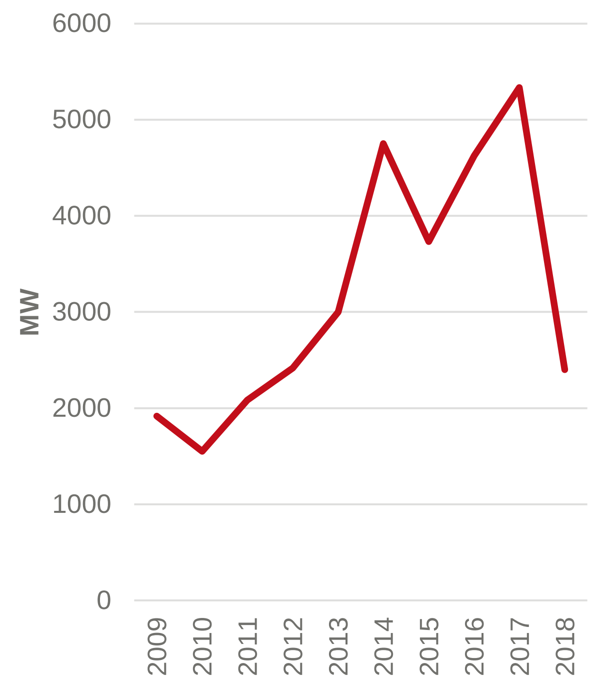
In 2017, projects with a capacity of around 35 MW were taken off the table. This is not only a challenge in Denmark. The same trend can be seen in Germany. Continuing business as usual, only nearly half of the 4 GW renewable energy which is needed to reach the national objectives of 65 % RES electricity in Germany will be realised.

Need for new solutions

New initiatives and new policies are needed. The search for flexible and faster process planning has to be initiated as well as creating a bigger understanding of and optimism towards onshore RES. Otherwise, we might risk putting the green transition to an end.

The government, municipalities, turbines owners and contractors, citizens and organisations all have a collective responsibility in finding new solutions. It will not be easy, because contrary to previous discussion, this is not just a question of economy, but instead of people, opinions, and negative experiences.

German Deployment of Onshore Wind 2009-2018



Source: Deutsche Windguard

Optimism Regarding the Green Transition is Considerable

The Danish people demand more green electricity

Danish Energy has, in connection to the RES Outlook, asked the Danish population about its opinion of the green transition. As expected from earlier studies, the results show that the support towards the green transition is huge. Of the entire population, 87 % support the transition going from a black to a green nation. Only 2 % express being against.

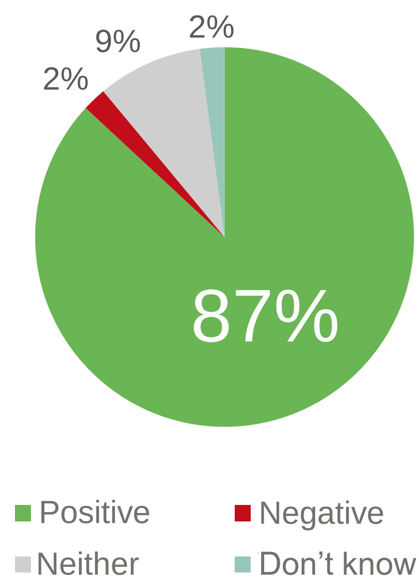
Age is not a factor

The support is large from both young and old. A small trend is showing that support is higher among people in the age group of 35-54 years. Surprisingly, the support in the 18-34 years group is not highest. In previous studies, the biggest optimisms towards green transition was normally observed in this group.

A unified Denmark

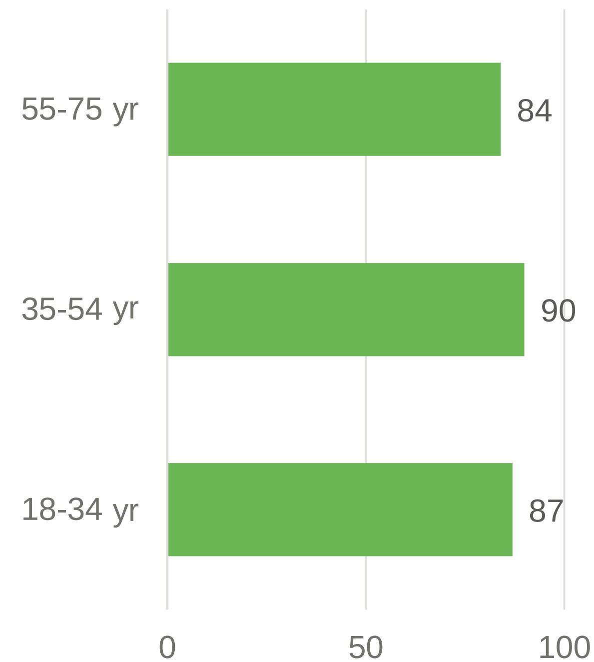
The study shows furthermore, that there are no significant regional differences. The Danish people are fundamentally agreeing that Denmark should be greener and that we should continue the deployment of wind and solar solutions.

What is your Opinion of Deployment of Green Electricity in Denmark?



Source: Userneed Survey week 4, 2019.

Share of People by Age Who Are Positive or Very Positive about Green Energy in Denmark (%)



Source: Userneed Survey week 4, 2019.

Decisions about Onshore RES Should Be Managed Locally

Planning and approval

The planning process of wind turbines and solar on land is long and comprehensive. In total, it takes 5-7 years before the wind turbine will deliver electricity to the grid. This planning horizon is often longer than the period of a local election - which can challenge the process. In the worst case, projects have been cancelled due to only a few complaints late in the process, even at times when the municipality intended to approve the wind farm.

Long process complicates public participation

Because of the long processes involved, local people who will be affected by the wind turbine installations get to know about the project and discuss their concerns at a very late stage in the process. This supports the fact that we need to focus on a new and faster way of doing wind turbine planning, where all players get involved earlier and set a positive direction.

The Danish people want to be heard

Quite simply, the Danish people want to be involved and have a voice regarding renewable energy plants, especially those built on land.

The study from Danish Energy shows that the Danish people wish to keep decentralised decision-making in the municipalities when decisions about installing wind and solar on land are to be taken. Only 24 % want parliament to decide where the turbines and PVs should be built.

Public participation – important on land

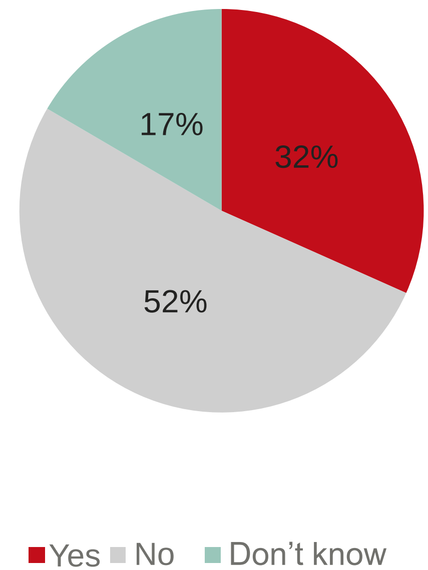
The same story applies regarding local support, where 60 % of participants agree that local people should be involved.

The picture is different when looking at wind turbines close to the shore. 52 % will not support the possibility that local opposition will be able to stop projects close to the shore, while 32 % say that the people should be asked.

The study thereby supports that the planning process should be conducted locally and that there is a large desire from locals to be involved.

It is therefore important to maintain the existing public participation by the use of public consultations, environmental assessments, and the possibility of giving complaints. However, the processes need to be made more relevant and structured.

Do you think people living close to coastal areas should be able to object to nearshore wind turbine construction?



Source: Userneed Survey week 4, 2019.

Existing Regulation Makes the Green Transition Problematic

Public engagement is important

Public engagement has been a large contributor to the development of wind energy in Denmark. Small equipment manufacturers were the ones who created the established wind turbine industry. Not until after the consolidation of the industry in the 90s did larger, partly internationally-owned and listed companies enter. The establishment of many co-owned wind turbines were correspondingly arising on the customer side. Of the 5,200 Danish wind turbines, approx. a couple of thousand remain owned by local cooperatives.

Increased opposition with industrialisation

Commercialisation and larger project scales which did not receive the same level of public support provoked rising opposition against wind turbines – the so-called NIMBY effect. It became popular to describe wind turbines as unwanted technical plants that disturb the experience of natural beauty.

The opponents won political interest locally and with political representatives. Among other things, this resulted in 2008 in a number of special rules (RES deals), which have since been developed and extended to apply to solar farms.

Regulation is an obstacle for wind and solar

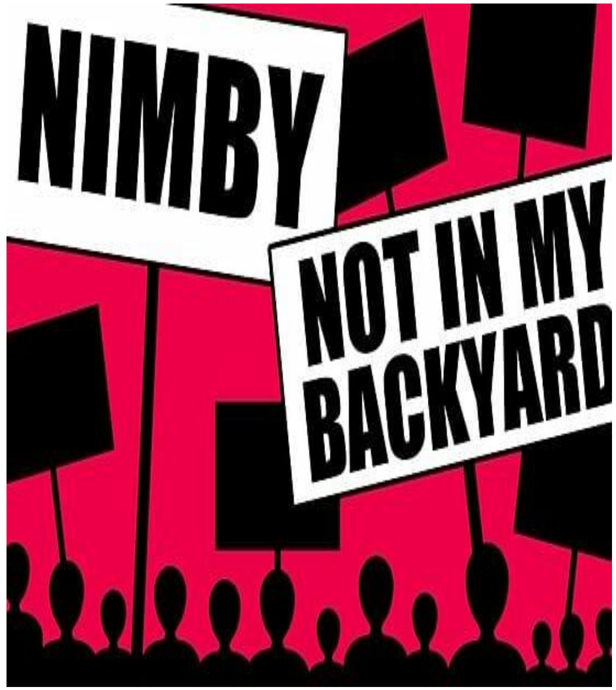
Despite their intentions, these schemes have added fuel to the fire that renewable energy – especially wind turbines – is a special kind of evil, and people living close by must receive compensation for their negative experience.

The transition to a greener energy system, beneficial to all people in Denmark, is thereby restricted by special rules, making it more complicated and resource-consuming to set up a wind turbine than to set up a mink or a pig farm.

Reward municipalities for RES support

Another challenge is that not all municipalities can contribute equally to the green transition. All else being equal, it is better to install wind and PVs in locations with a lot wind and adequate space. But the municipalities taking social responsibility and supporting the deployment are not being rewarded. RES deployment is not included in the balancing system which was made to even out differences between municipalities.

Changes in practice could help support the general balancing and contribute positively to the development of areas within the Danish rural districts.



Concerns about Wind Turbines Need to Be Respected

Wind turbines and solar cells are infrastructure

Wind turbines and PVs are infrastructure within the energy field, similar to streets and railways in the transport field. Both fields are contributing to economic growth, but can also come with certain hurdles for those living nearby.

Discomfort is experienced differently

Numerous scientific reports have concluded that the harm caused by onshore wind and solar is very small. But we are all different with different experiences, and this is a challenge that we need to take seriously.

Danish Energy's user surveys support that the Danish population, despite its optimism towards green transition, is concerned about having wind turbines in their backyard. More than 50 % of those surveyed would be concerned with noise and health issues if they became a neighbour to a wind turbine. The concerns are higher for women than for men. Furthermore, 50 % believe that their property will lose value to some or to a high degree.

Participation creates actual optimism

This illustrates the challenge that we are facing. Fortunately, solutions can be found.

Other studies show that fear is biggest when a new RES plant is in the planning phase. Once the wind turbine has been established, many of the concerns and opposition disappear.

Early inclusion of affected neighbours and an effective, inclusive process, where all concerns are addressed respectfully, will also be helpful. The possibility of making personal investments in the wind and PV projects and benefit financially can likewise contribute to public support.

A lot of these initiatives are implemented in current regulation, but the system is no longer up-to-date. Therefore, the current planning process, incentive schemes in the form of purchasing rights and compensation for loss of value, and communal involvement are all calling for radical changes. In this way, the support provided to land-based RES can be increased.

Facts about wind turbines

- No scientific evidence shows that wind turbines have direct negative health-related side effects.
- The noise from wind turbines corresponds with the sound level of quiet speaking.
- The risk of exposing neighbours to shadow-flickering is limited to two 4-6 week periods annually – often around equinox. In practice, the limit is a maximum of 10 hours per year.
- Neighbouring houses can risk a moderate loss of value. This loss is very limited, and neighbours are therefore well covered by the loss of value scheme.
- As with other industrial plants, wind turbines affect the fauna in the surrounding areas. But this is only to a small extent and mainly during construction work.

Source: Knowledge about Wind

Recommendations: Co-creation and Legislation with Solidarity

Flexibility, Freedom, and Negotiations Instead of Special Rules

Special rules and **special schemes** cannot be justified when renewable energy is established without subsidies.

The transition to a more green energy system, beneficial to the Danish people, is subject to special schemes, making it more complicated and relatively more resource-intensive to set up a wind turbine than to set up a data centre or a pigsty. Schemes involving purchasing rights and loss of value are no longer up to date and do not reflect the intention of encouraging local support.

We recommend more **freedom** in **flexibility** and **negotiations** between the parties instead of an endless amount of special rules and special schemes.

Expediting the Permitting Process

The planning process for wind turbines and solar onshore is widespread and drawn-out. In total, the process takes 5-7 years before the wind turbine provides electricity to the grid. This time frame of planning is often longer than the communal terms and can complicate the process.

RES electricity plants which add to the transition and support Danish climate objectives **should be undertaken faster**.

A new and faster planning process for wind turbines is needed, where **players get involved at an earlier stage** and thereby have the opportunity to set the direction.

Faster planning processes would also reflect the **changed EU-legislation**, where the planning process can take a maximum of 3 years. For existing wind sites, where old turbines can be replaced by new, more efficient turbines (i.e. repowered) the process can take a maximum of 2 years.

Fair Compensation Schemes Rewarding RES in Municipalities

The deployment of renewable energy in municipalities is currently not a part of the compensation schemes.

It should be considered whether the **municipalities** which actively **promote the deployment** of onshore renewable energy, and thereby bear a social responsibility benefitting all of Denmark, should be **rewarded with** improved economic incentives. This would support the general level of compensation received and contribute positively to the development of areas within the rural districts of Denmark.

3. Topic: PPAs – New Financing for RES

Why Work with Power Purchase Agreements (PPAs)?

New instrument ensuring financial security for RES electricity

Green electricity generation is cost-competitive with electricity generation from fossil fuels, but conditions around green electricity will determine the replacement rate of fossil fuels.

With the assignment of bilateral sales agreements between producer and buyer of green electricity, it is possible to boost green electricity generation. These mutual agreements are called PPAs, which stands for Power Purchase Agreements.

The buyers can be individual companies, energy companies, or other players who wish to sell green electricity to the market. Sellers include both existing and, to a large extent, also future green electricity producers.

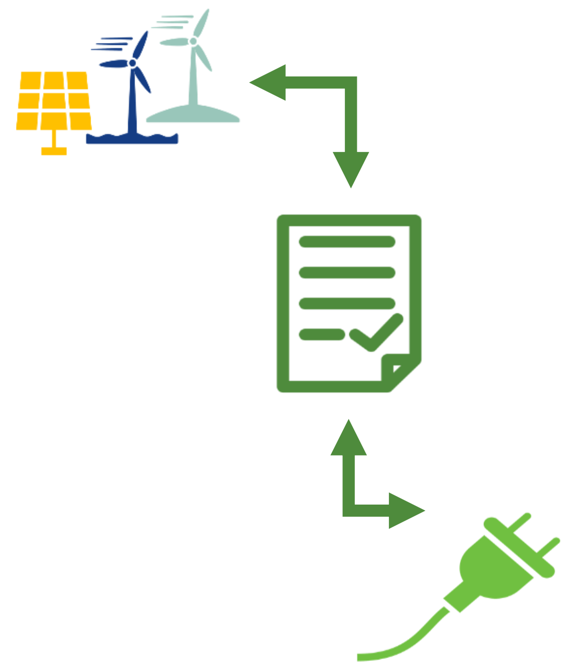
A stronger market for PPAs will help provide revenue certainty for the project developer. This is very important for green electricity. The PPAs will also provide certainty to the buyers about the future prices of the green electricity, and provide the opportunity to directly participate in the green transition.

The PPAs can help to replace some of the security which was previously provided by state support payments. However, a number of conditions need to be satisfied before the PPAs realise their full potential for strengthening green electricity generation.

More uniform conditions for competition in the development of green electricity in Europe will make it easier for the PPAs to promote a larger and more efficient market. PPAs should be signed across country borders to the same extent at which the physical market is integrated.

A PPA is an important and legitimate way of supporting green electricity and for consumers to participate in the green transition. There has been a great deal of scepticism regarding the value of purchase agreements in a market dominated by state support. However, when state support is no longer provided, the value of PPAs will increase proportionately. It is important to stress this point and to emphasise that large, but also small, consumers have the opportunity to join this market to fulfil their desire of supporting green electricity.

Bilateral Trade Agreements (PPA) Are Key for Deployment of Green Electricity



How Does a PPA Work?

Contract for purchasing green electricity

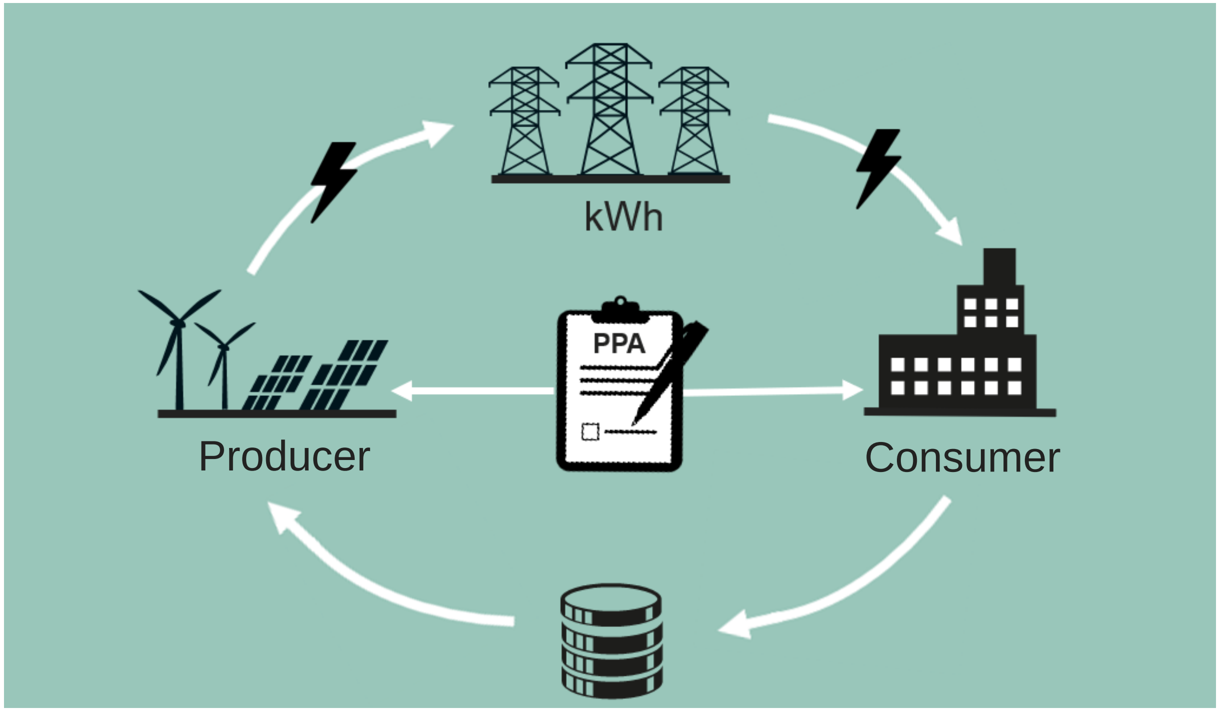
A PPA can be arranged in different ways. Two factors are often particularly important for a PPA. First of all, a price agreement between the buyer and seller is signed. Second, the PPAs are signed by producers of renewable energy, so that buyers of electricity can be ensured to get a share of the renewable energy.

The price agreement for PPAs is often valid for many years and typically fixes the price of electricity, but also sets a number of other terms, such as the way of handling fluctuation in generation.

Danish Energy expects PPAs to continue gaining more popularity in coming years. This is due to the high interest in green electricity among consumers. This is also due to the possibility of fixing or partly fixing the electricity prices in future years.

The development of the PPA market is supported by the increase in consumers, to whom this type of price agreement is beneficial. This is the case for large heat pumps and data centres, that would benefit from having a fixed price over several years.

How Does a PPA Work?



What Is The Value of a PPA for the Developer?

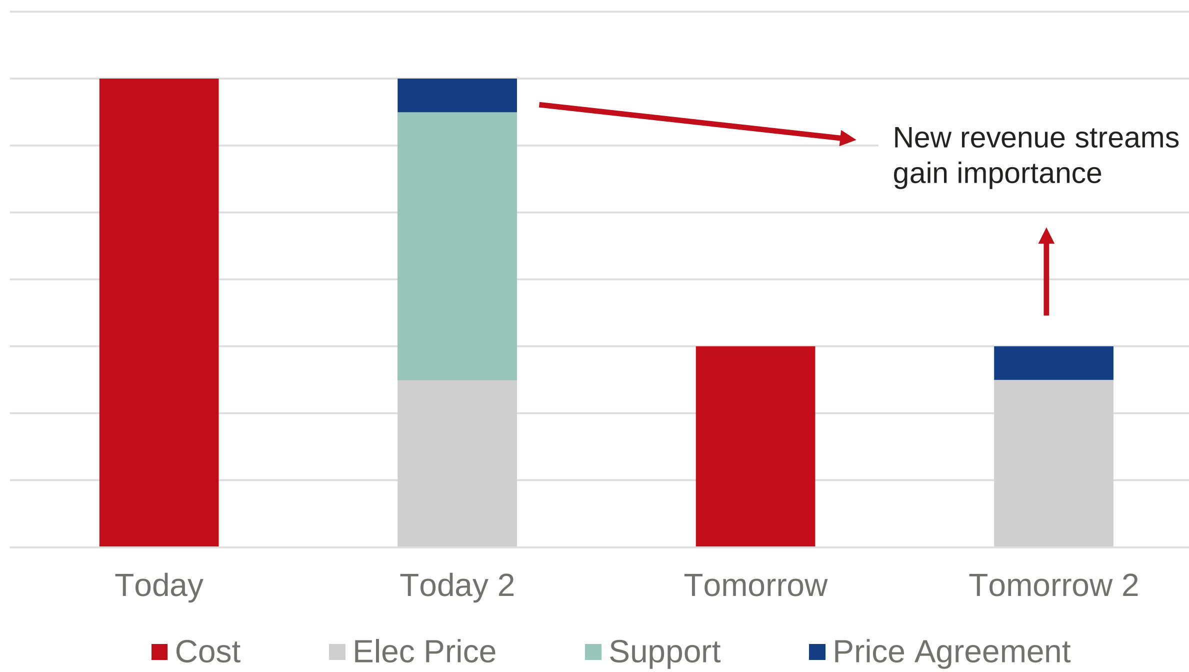
Larger relative contribution to RES finances

The importance of the PPAs in renewable energy is totally different today than compared to a couple of years ago. Clearly, it gives value to the buyer to sign a PPA. This willingness to pay has increased over the previous years. However, the most important factor in the increasing value of PPAs, from a developer's perspective, is the PPAs accounting for a larger share of the revenues than previously.

Green electricity has taken a large technological step forward in recent years. Progress which is responsible for green electricity being established at such low cost today. This leads to a corresponding decrease in the need for subsidies in the establishment of RES. Onshore wind in Denmark received until recently 34 EUR/MWh for approx. the first 9 years of the project. In the latest tender for onshore wind and PVs, the average support rate was 3.1 EUR/MWh for a period of 20 years.

The 3.1 EUR/MWh combined with the electricity price is roughly the same as the value of most PPAs, maybe even less. We are therefore reaching a scenario where purchase agreements of green energy have equal or bigger value than governmental support.

Price agreements become more prominent in the clearing price of green electricity, when costs and subsidies decline



How Does a PPA Create Value?

Selling and purchasing advantages

Both buyer and seller in a PPA base their investment decisions in the context of their financial situation, which is influenced by the revenues and expenses of their projects. Both parties gain the benefit of future cash flow security from the PPA.

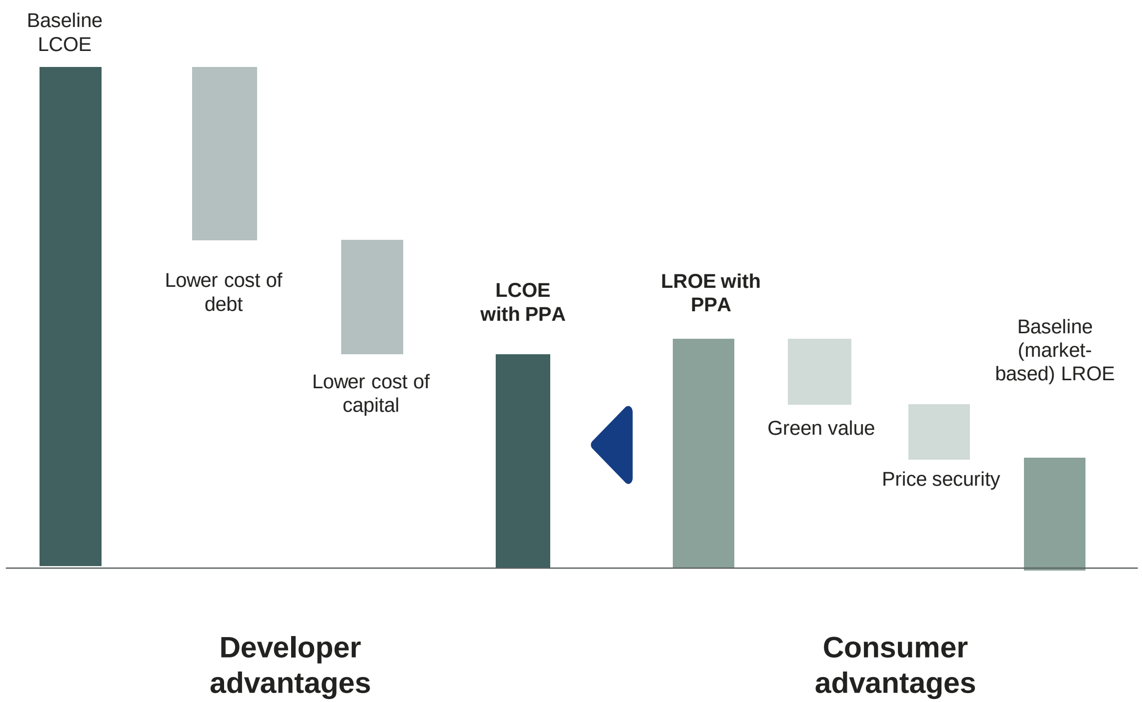
Two value-creating factors for the seller:

1. The PPA stabilises the cash flows, which reduces the risk and the risk premium associated with the return on equity.
2. Having a floor below the income streams makes the security of the project larger, which increases the possibility of receiving cheap foreign capital or leverage.

Two value creating factors for the buyer:

1. Hedging the price of electricity consumption reduces risk during fluctuations and hereby increases the willingness to pay for the electricity.
2. The ability to chose green electricity is value-adding. The buyer is ensured a direct connection to the establishment of specific green electricity generation which is increasing the value.

Advantages for buyer and seller within a PPA



Note: A PPA contributes to reducing the costs (LCOE - Levelized Cost Of Electricity) of the developer and increase the value of electricity (LROE - Levelized Revenue Of Electricity) of the buyer.

Source: Implement – Analysis of green PPAs

When Does The Buyer of a PPA Meet The Producer?

Hitting two birds with one stone

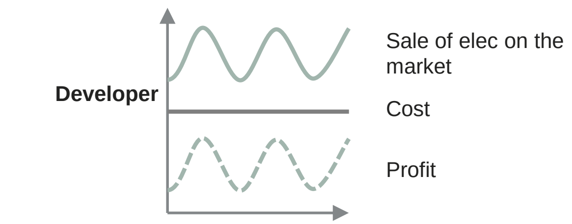
Price agreements, in the form of PPAs, can remove the electricity price risk from the developer. The risk in the developer's returns is thereby also reduced. Typically, the PPA will move these risks further down the value chain. A buyer of a PPA will in principle be secured against a price boom, but at the same time be subject to the risk of not benefitting from potential price falls.

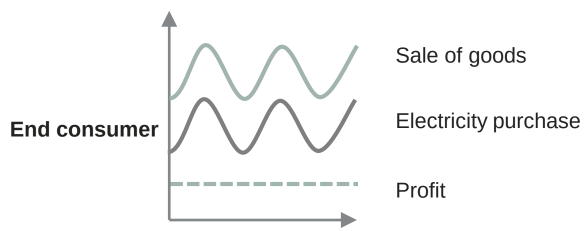
However, there is greater value in the predictability of electricity prices for both the developer and the buyer. The value of predictability to the buyer can exceed the additional cost paid to purchase electricity above the market price.

The price agreement makes sense for the consumer who, to a certain extent, can pass on the electricity prices to consumer prices, or for consumers who act on a global market, where the electricity price is not correlated with competitors. This leads to the value of price hedging exceeding the risk of price dropping.

No PPA

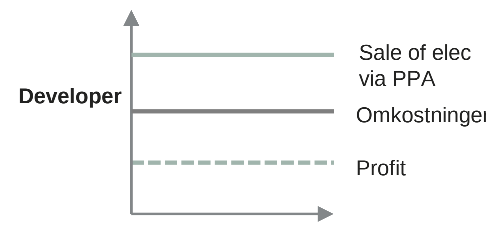
The developer sells electricity at the wholesale market. The supplier buys electricity at the wholesale market and resells with a margin. The end customer buys electricity from the supplier and sells their goods at market price.

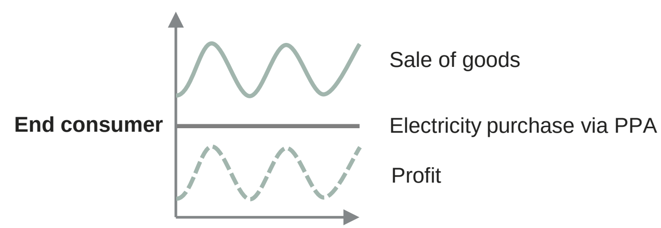




PPA between Developer and Supplier

Developer sells electricity directly to the the customer through the PPA. Illustrated below with a fixed price. The price within the PPA can also follow a price development or alternatively an underlying index.





Kilde: Implement – Analysis of green PPAs

An Example of PPAs and Their Deployment

A market experiencing high growth

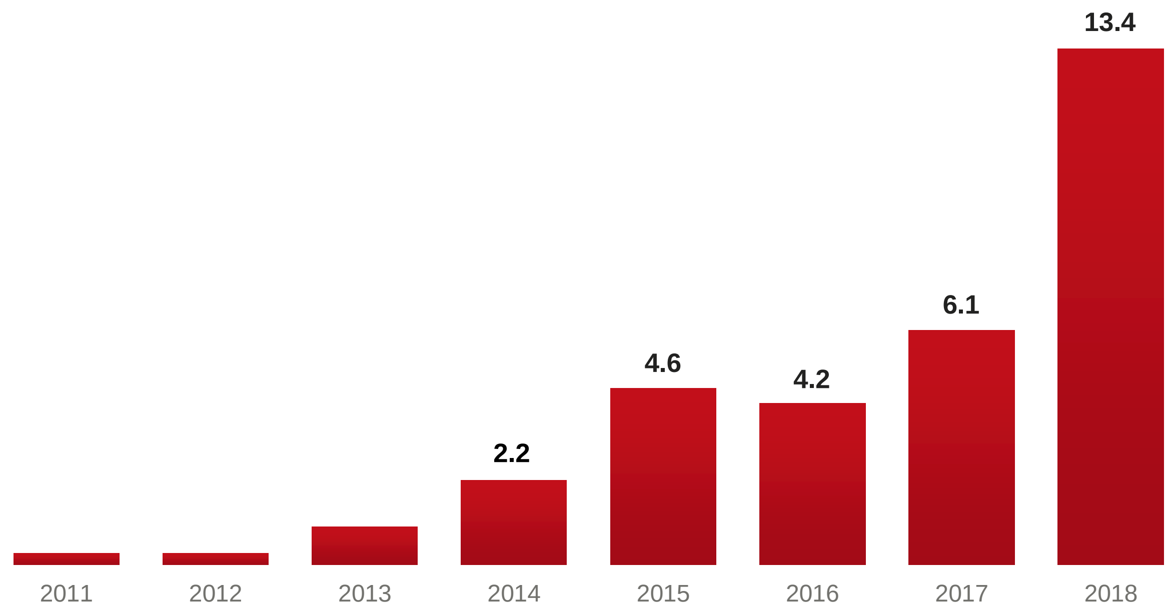
A significant increase in the use of PPAs in Europe has been seen in the previous couple of years. A great number of PPAs have been signed in Norway and Sweden in particular.

For a few companies, the PPAs are particularly attractive. Among the PPAs which have been signed in Norway and Sweden the company Hydro Energi accounts for 8.5 TWh, of which wind constitutes 50 %. This also applies for Europe's biggest PPA, the onshore project Markbygden, which has an expected annual delivery of 1.65 TWh over a 19 years period.

For a number of companies, signing PPAs have been especially relevant. Hydro Energi, who has an energy consumption of about 15 TWh in Norway, fulfils the requirement of being an ideal consumer in a PPA.

Aluminium is a globally traded product, where the price hedging over a longer period outweighs potential losses from falling electricity prices. With the low price of renewable energy, the potential loss has also decreased significantly. It is, therefore, possible to ensure long-term contracts at much lower prices than earlier. This means that PPAs will become relevant to new consumer groups.

Globally Signed PPAs (GW)



Source: Bloomberg NEF

What Is The PPA Potential in Denmark?

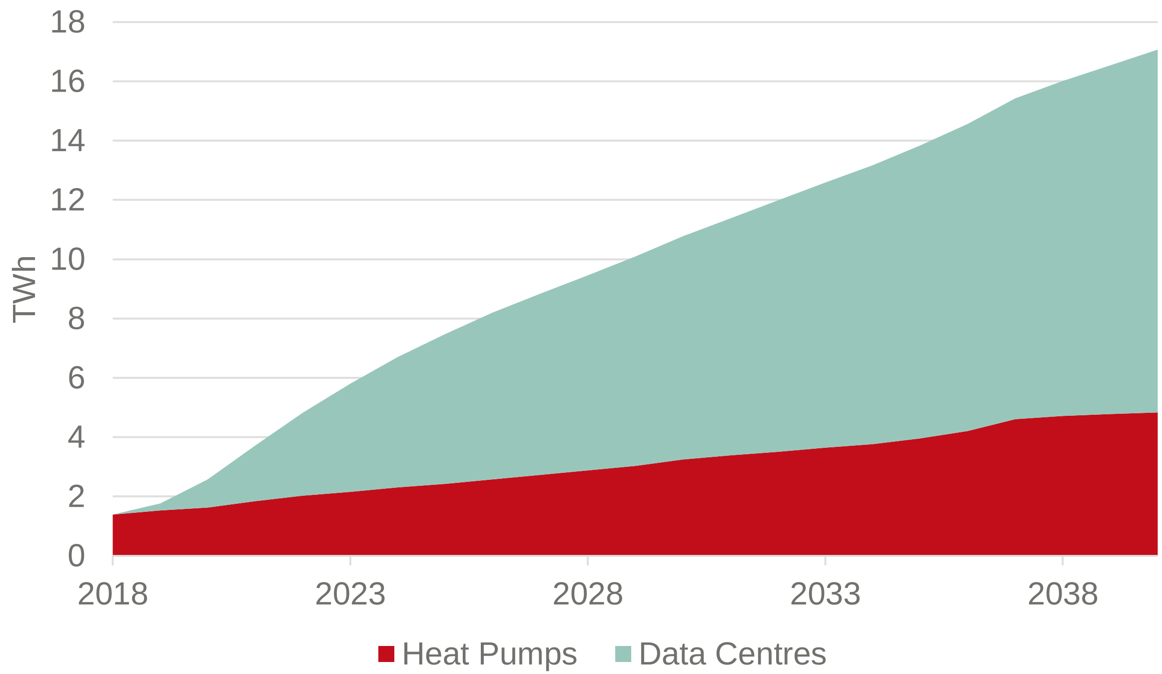
Big new consumers are evident buyers

The first PPAs in Denmark have only recently been signed. Two barriers have been inhibiting the diffusion of PPAs. Before the latest energy agreement, different support schemes existed and there was a general uncertainty in the renewable energy framework. Uncertain regimes prevent long-term price agreements. Greater certainty has come with the terms of the Energy Agreement from 2018, under which renewable energy will be developed during the following decade.

Furthermore, the establishment of new electricity consumers in Denmark for whom long-term price agreements are of special interest is showing. A Danish example is the electricity consumption in the production of district heat where there are long-term investments and long-term contracts for heating prices. Here PPAs are used to stabilise the input prices.

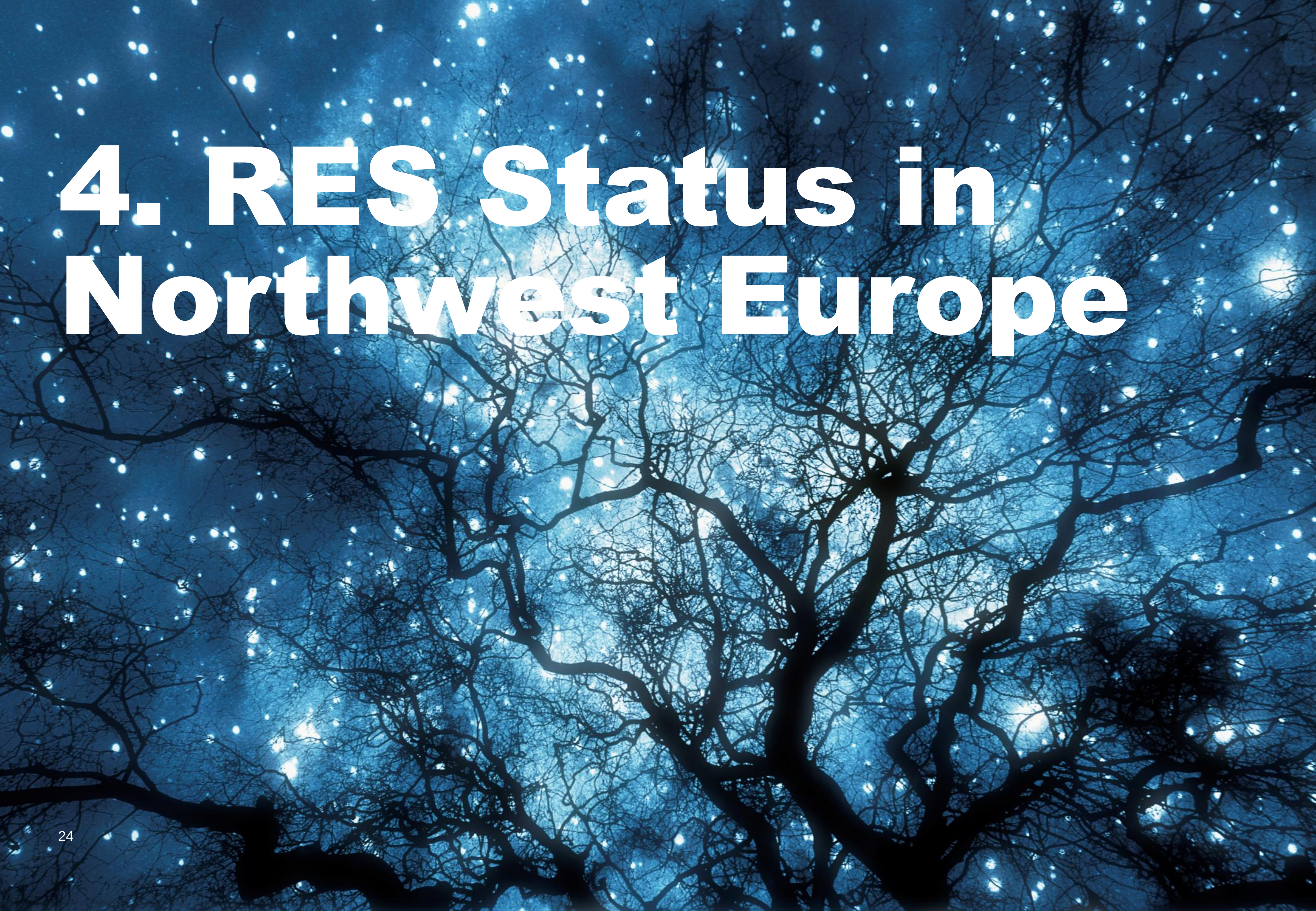
Data centres and large heat pumps are expected to expand by 8.3 TWh by 2030. This corresponds to 25 % of the current Danish electricity consumption.

Doubling of electricity consumption creates a market for PPAs



Source: The Danish Energy Agency's analysis assumptions to Energinet

4. RES Status in Northwest Europe



RES Status in Northwest Europe

Approaching a new era

We have checked the status of renewable energy in Northwest Europe, and there is good news.

Even though there are large differences between each country, all countries are showing a progression of the deployment of renewable energy within the electricity supply.

Political decisions about a coal phase-out support this trend and are the reason for the accelerating transition.

Renewable energy has become mainstream. Decades of deployment have fostered innovation and scaling advantages, which have brought down costs. The price of renewable electricity technologies has dropped sharply and diminished the need for support. We are approaching a new era where RES electricity does not require support to compete in the market.

This development is supported by the coal phase-out goals of each country in Europe, which will open up for further possibilities for new RES.

Moving towards a fossil-free energy system, the CO_2-price is crucial for the competition between renewable energy and fossil-based alternatives. It is therefore good news that reform in the EU's emission trading scheme is already reflected in the quota price, which has increased by approx. 20 €/ton since the summer of 2017. The ETS has, therefore, changed its role from previously being inconsequential to now providing a modest contribution to the green transition.

However, there are some issues requiring attention.

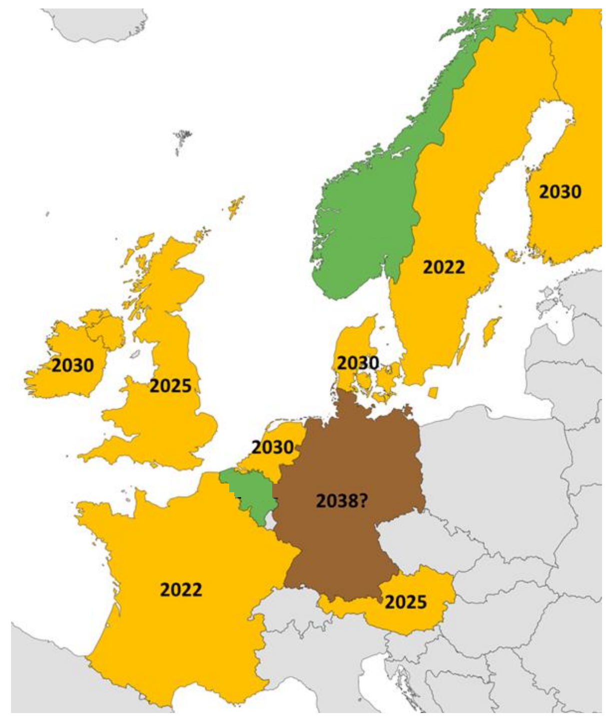
The degree of renewable energy penetration increasingly limits remuneration, such as in the hours of high wind, thereby weakening its own market value.

In addition, Germany is showing signs of a slowdown in the price reductions of RES. This is not because of a slowdown in the technology development. Instead, competition is limited due to lacking regulatory security and popular support, as well as the absence of suitable areas.

The share of RES in transport and heat is increasing significantly less than in the electricity sector. This calls for increased efforts.

Overall, positive development is showing. However, if we are to achieve a fossil-free future renewed political focus is required in coming years.

Coal Phase-Out Plans



Note: Phase-out dates for coal are indicated. Belgium and Norway are already coal-free. Germany has no legislative target.

4.1 RES in Northwest Europe Today

DANISH ENERGY

The Green Transition Has Been Unevenly Distributed in Northwest Europe

The North is the greenest region

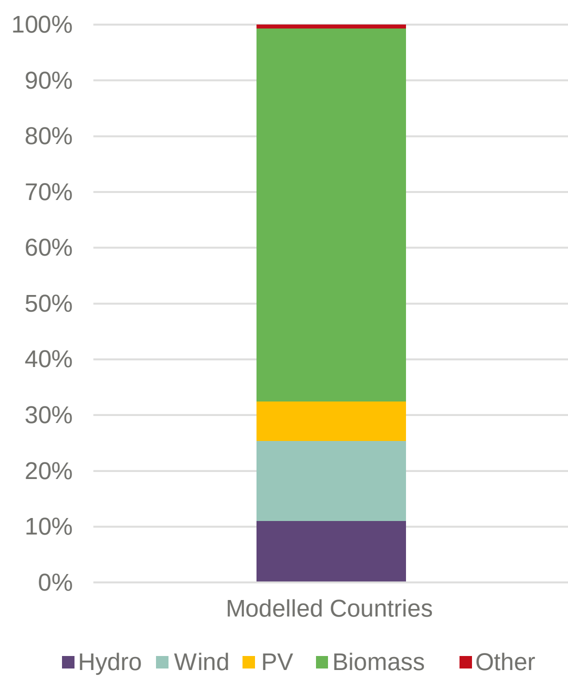
In this study, Northwest Europe is defined by the coloured countries shown on the map. This region has been modelled in the scenario analysis and has been selected due to the strong electricity connections between the countries. Denmark is strongly influenced by market developments in these countries.

Some of the world's most ambitious countries regarding the green transition are found in Northwest Europe. However, the fact is that the green transition is not equally widespread. Many countries still have an RES share as low as 10 % of the *total* energy consumption. Conversely, the North is outstanding due to its large sources of hydropower and biomass.

Biomass accounts for the largest share of RES in Northwest Europe today. Wind has taken over hydropower as the second largest source of renewable energy in recent years, and solar is following closely behind.

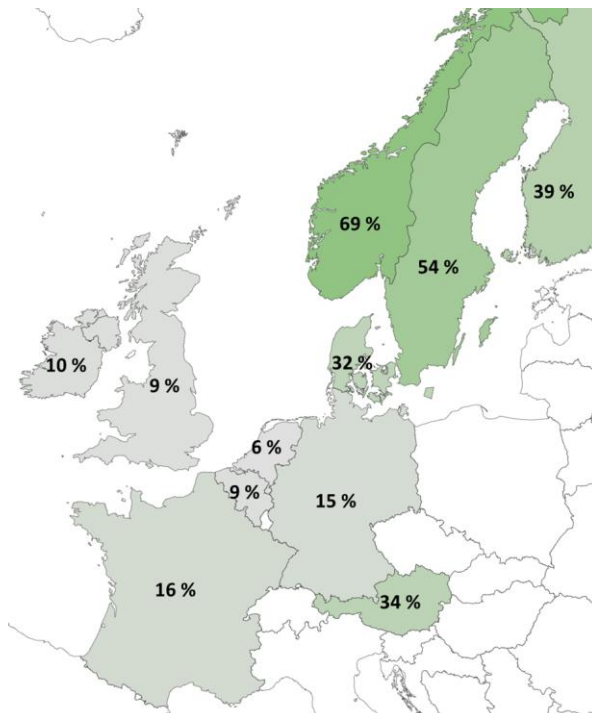
While biomass and solar deliver both electricity and heat, hydro and wind contribute solely with electricity.

RES in Northwest Europe by Source 2016



Note: Biomass includes liquid and solid biomass, biogas, and waste.
Source: Eurostat

Total RES Share 2016



Note: The modelled countries are indicated in the map
Source: Eurostat

The Electricity Sector Has The Highest Share of RES

Electricity is leading in the green transition

The share of RES in the electricity sector is higher than the share of RES in the total energy consumption of Northwest Europe.

While the RES share of the total energy consumption in Northwest Europe in 2016 was 18 %, the RES share of the electricity was 30 %. Both indicators have doubled since 2004.

In Denmark these numbers were remarkedly higher: 32 % and 54 % respectively.

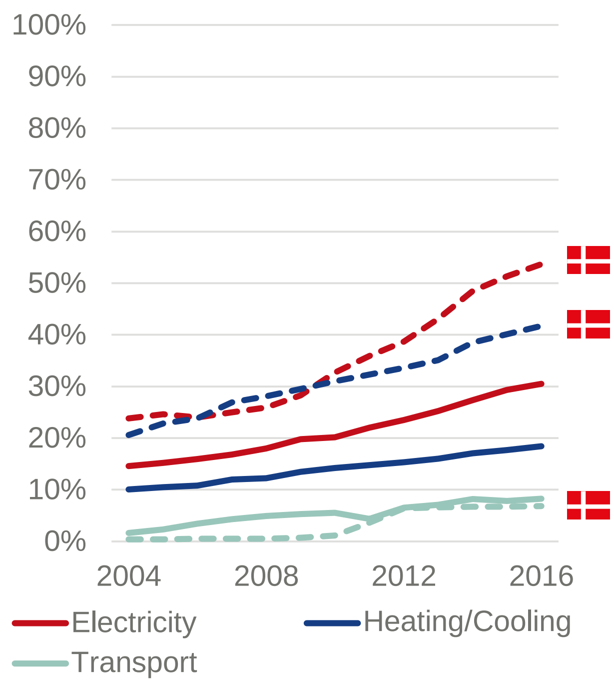
RES are a small share in the transport sector

Looking at the RES share at sector level, the largest share is in the electricity sector, followed by heating/cooling. The transport sector has the smallest RES share.

In 2016 the RES share in Northwest Europe was approx. 30 % in electricity, 18 % in heat/cooling, and 8 % in transportation.

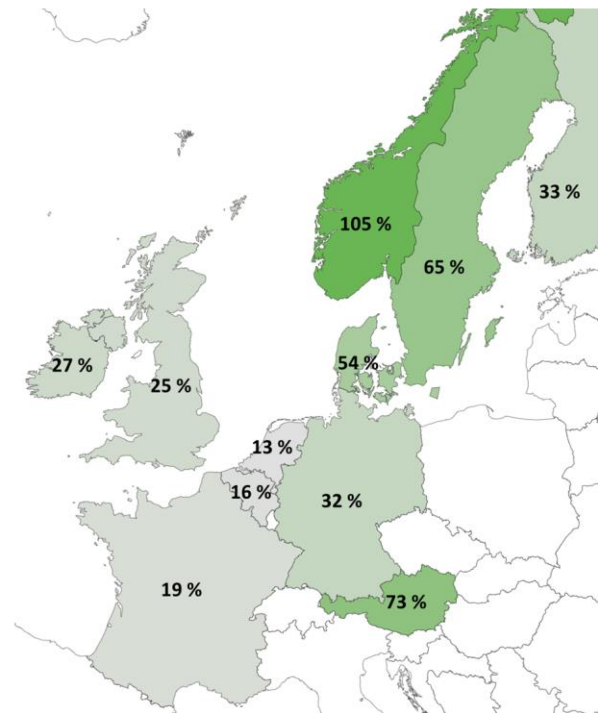
Large differences in the RES share exist between countries. Notably, Norway produces more RES electricity than it consumes. Countries such as the Netherlands, with high fossil-based production, and France, with a large share of nuclear power, have the lowest RES share in the electricity sector.

RES Shares in Northwest Europe and Denmark (Dotted) - 2004-2016



Note: The solid lines represent Northwest Europe. Total RES share is close to the share in heating/cooling
Source: Eurostat

Total RES Share in The Electricity System - 2016



Note: Electricity produced from RES as share of national electricity consumption.

Source: Eurostat

Biomass Has Played a Major Role in Replacing Coal in Denmark

An efficient temporary solution

The use of solid biomass (mainly wood) for energy has increased in Northwest Europe during recent decades. Despite the boom in PVs and wind, solid biomass is still the major source of renewable energy by a wide margin. The largest share of biomass is used for heating.

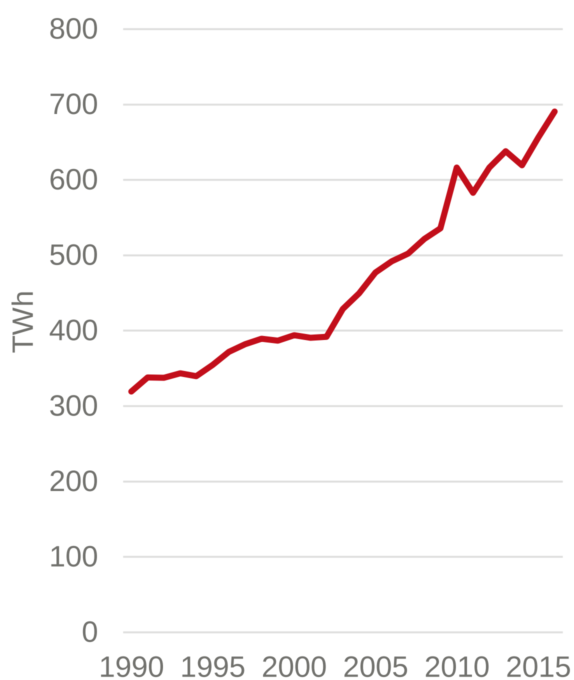
The use of biomass for energy in Northwest Europe has doubled since 1990, while electricity production from biomass has increased sevenfold.

In Denmark, conversion to biomass in power plants has reduced the coal consumption.

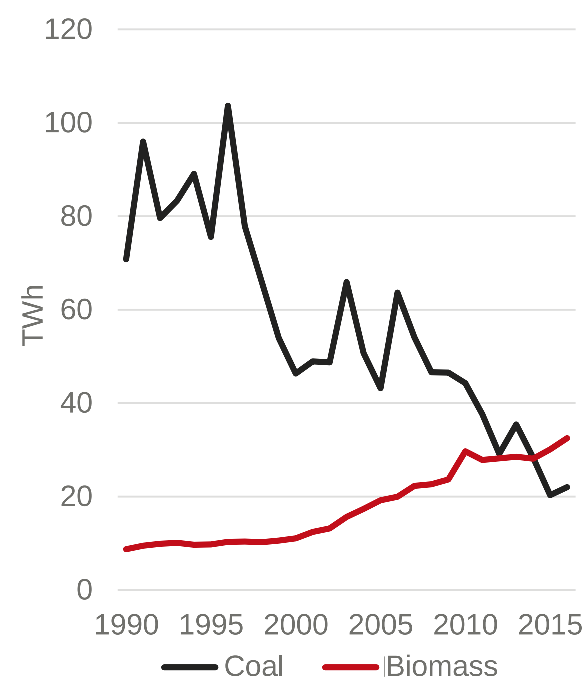
This Outlook deals mainly with wind power and solar cells, but it is noteworthy that biomass has been essential in the phase-out of coal in Danish heat and power production and has contributed to the high RES share in electricity and heat.

Hydro and wind are the dominating sources within RES electricity, but biomass accounts for 10 %. Some countries (e.g. the UK and Denmark) have decided to convert thermal plants to consume solid biomass. This will increase production in coming years.

Total Consumption of Biomass in Northwest Europe



Total Consumption of Biomass and Coal for Electricity in Denmark



Source: Eurostat

4.2 Cost of RES Technologies

DANISH ENERGY

Deployment Has Brought Price Reductions to RES

We cannot research our way to real solutions

The historical support of wind power has often been criticised for supporting the establishment of wind turbines rather than using the money for research.

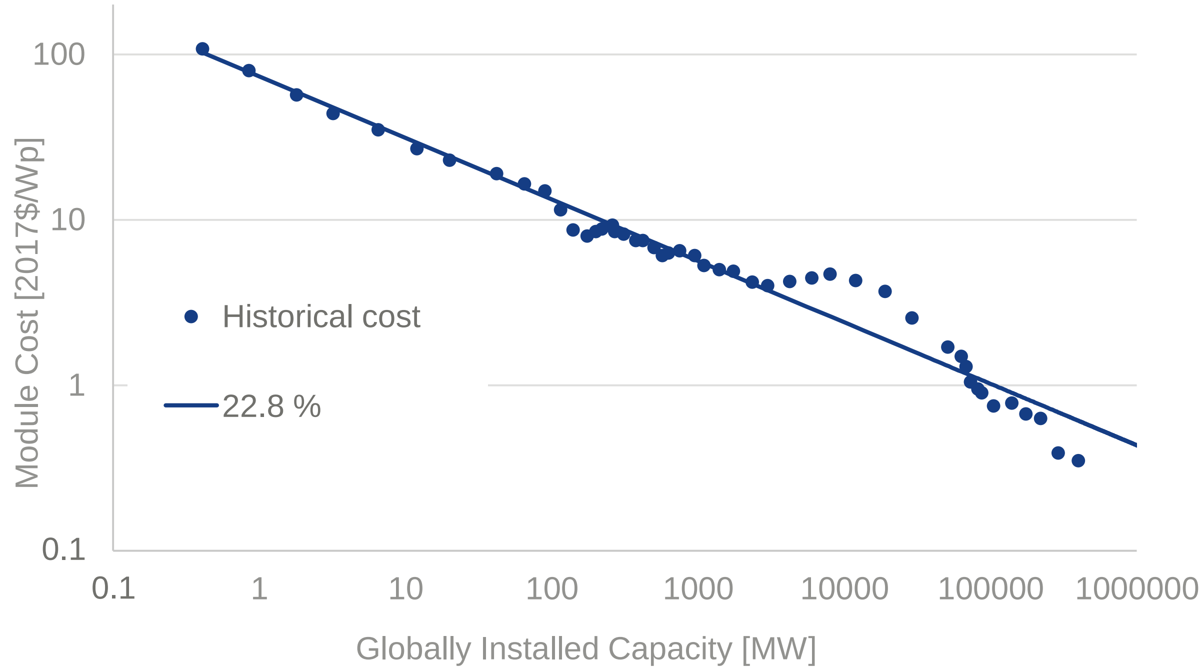
This argument is still repeated despite the fact that all evidence shows that real cost reductions are caused by increased production volumes, due to innovation and industrialisation.

This in turn provides price reductions, resulting in an even larger installed volume, leading to accelerated deployment, and further innovation and price reductions.

Thanks to decades of state support, we are now facing a time where renewable energy can exist independently and compete with fossil-based alternatives. Renewable energy is even more competitive when compensation for emissions from fossil fuels is factored in.

There is a clear correlation between the deployment volume and price. Historically, the price of PV modules has decreased 22.8 % on average, each time global capacity has doubled.

Technology Cost Decreases with Deployment
Learning Curves for PV Modules



Note: Straight lines in double logarithmic plot show that the price depends on the amount as a power function.

Source: ITRPV

Record Low Subsidies for Danish Tenders of Onshore Wind and Solar

Technology neutral tenders predict a new age

In 2018, Denmark conducted a technology neutral tender, where wind turbines and PVs were in competition regarding which technology required the lowest subsidy on top of earnings from the electricity market.

2.1 mil EUR per year, in current prices, was assigned to subsidies in the first call for tenders. The very low bids of 3.1 EUR/MWh on average resulted in projects of 165 MW onshore wind and 104 MW_{AC} PV. This corresponds to a yearly production of 680 GWh, equal to 2 % of Danish electricity generation.

The first call for tenders included 34.1 mil EUR for support. The next call will have 78.9 mil EUR. Additionally, the Energy Agreement from 2018 further sets aside 564 mil EUR to tenders between 2020 and 2024. If the result of these tenders is a subsidy of 3.1 EUR/MWh, then projects can be realised with a yearly additionally production of around 13 TWh, or approx. 40 % of the current Danish electricity consumption.

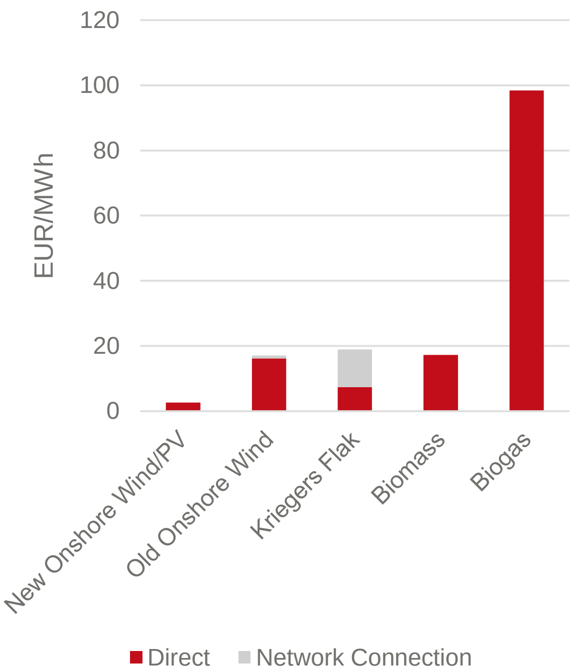
Furthermore, the new tender shows that solar and onshore wind are equal competitors, and that both technologies are beneficial to the energy system in the future.

Large differences in support between technologies

A comparison between support levels shows that new onshore wind and solar require by far the lowest level of support. The support required by offshore wind (incl. landfall) and solid biomass is five times lower than the support which is expected to be provided for electricity production from existing biogas plants towards the end of the support scheme in 2032.

Support payments for new offshore wind are expected to drop further during the coming calls for tenders, which were adopted as a part of the Energy Agreement.

Average Support for Electricity Production over 20 years



Note: Fixed 2019-prices.

Source: Danish Energy based on data from the Danish Energy Agency.

Large Scale Drives Price Reductions

Large is cheap

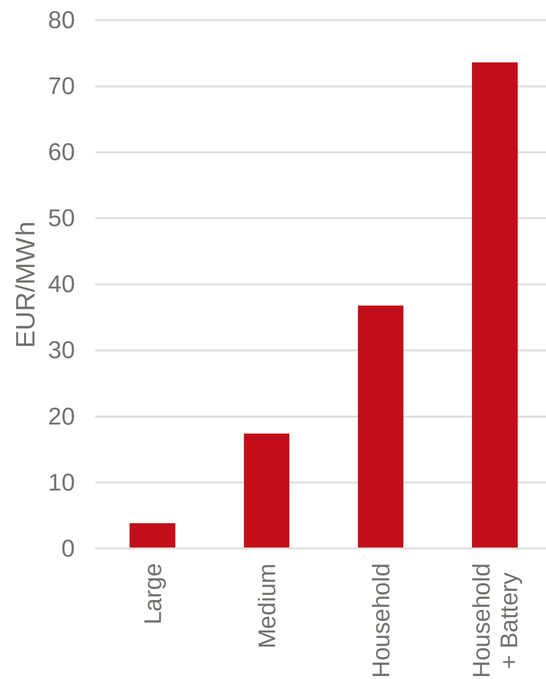
The tender for PVs in 2018 for small systems cleared at a remarkedly higher price of 17.4 EUR/MWh, which is very low historically, but very high relative to ground-mounted plants.

The indirect support to household systems is even higher. Owners of PV installations can save the electricity tax of 124 EUR/MWh for consumption that coincides with production.

For a system without a battery, this might be around 30 % of the production, which results in an indirect subsidy of 36 EUR/MWh. Systems with a battery which has higher self-consumption levels, e.g. 60 %, receive an indirect subsidy of 72 EUR/MWh. In other words, small PV installations with batteries receive about 20 times as much support as large ground-mounted installations.

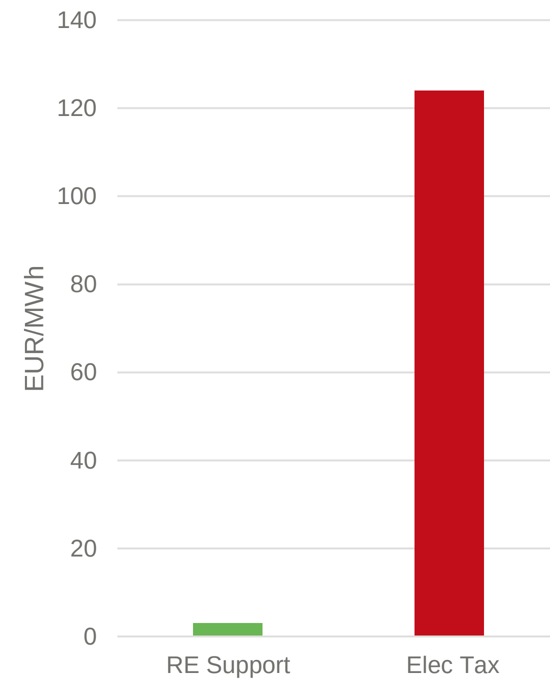
The electricity tax considerably exceeds the level of support required by large, new RES systems, which indicates that the tax is a distorting fiscal fee. The intention of the tax, which tells customers to avoid the use of electricity, cannot be environmentally justified.

Support for PV Installations



Note: The support paid to household installations is indirect, through tax exemptions for private production.

Support for Large-Scale RES Electricity and Electricity Tax



(Almost) Subsidy-Free Wind Power in The North

Price collapse threatens RES certificate market

The price of Norwegian/Swedish RES certificates has dropped sharply during the last five years. Moreover, the spot price has dropped. New wind power projects continue to be established, despite increasing expectations for reduced future revenues from these markets. This indicates significant cost reductions in wind power.

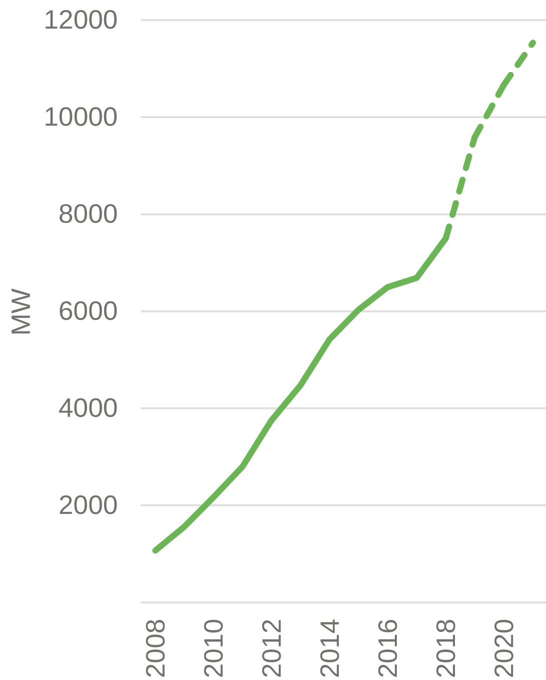
Due to the large increase in production costs of electricity from coal last year, it is now expected that Nordic onshore wind will compete with existing coal-fired plants, even without subsidies.

About 2,000 MW onshore wind is expected to be built in Sweden in 2019.

Since Sweden is almost fossil-free, the onshore wind deployment will be constrained by consumption in the Nordic countries and by available export options, such as transmission to neighbouring markets using fossil fuels (e.g. Germany).

The expected price of certificates after 2021 is around 1.3 EUR/MWh. Despite this, projects are still being implemented at a considerable pace.

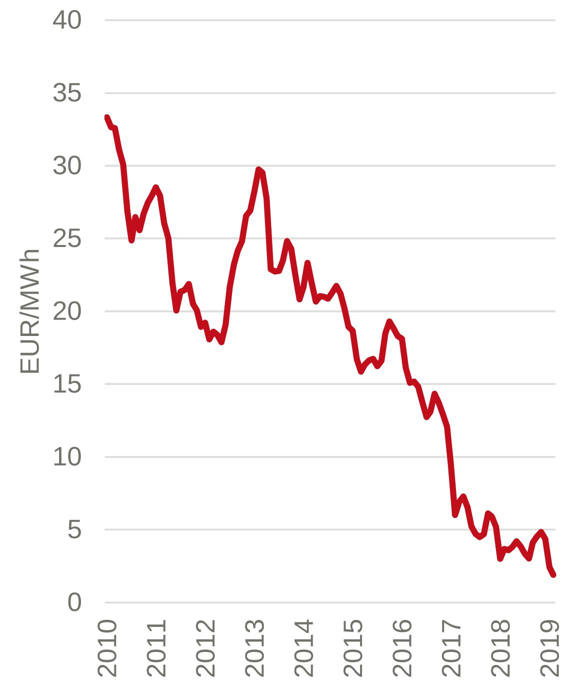
Deployment of Swedish Onshore Wind



Note: Dotted line is forecast.

Source: Svensk Vindenergi

Norwegian/Swedish RES Certificate Price (Forwards +3 Years)



Source: SysPower

Halt in German Wind and Solar Price Reductions in 2018

Approvals have become a bottleneck

Auctions in recent years have seen a steady decline in the price of solar and wind projects.

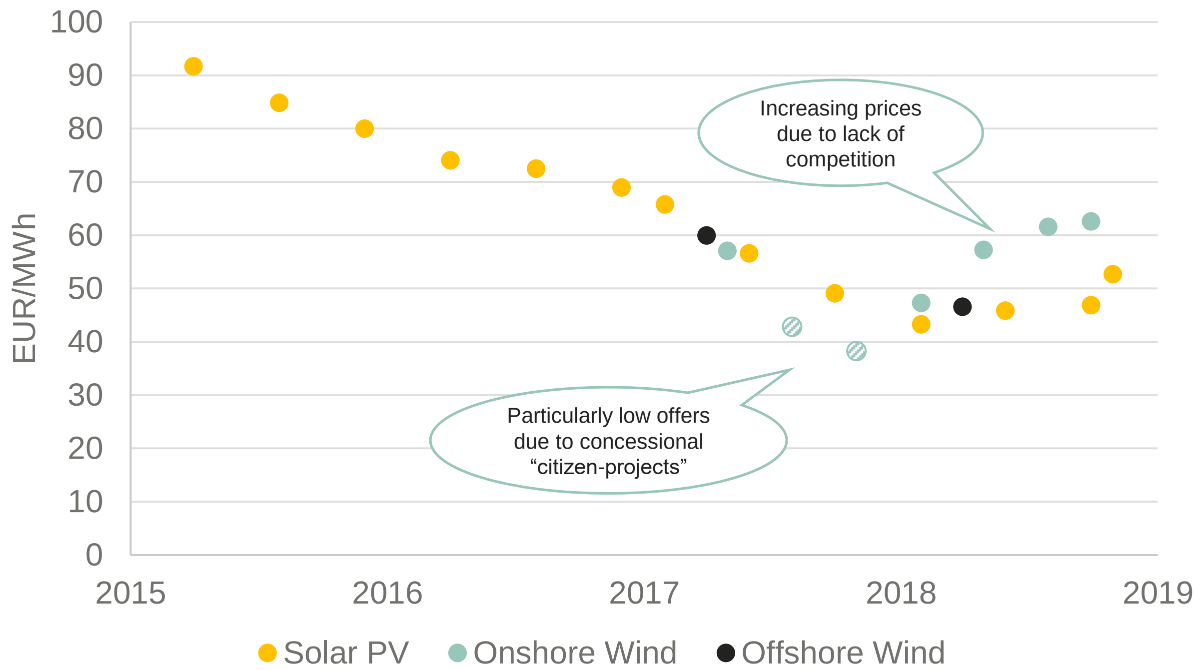
The price of new solar projects in Germany has approx. been halved since 2015. However, after uninterrupted price declines until 2017, the price increased slightly in 2018.

The price of onshore wind has also increased. The auctions held in August and October 2018 were not fully subscribed. Weakened competition resulted in higher prices.

The auctions in 2017 were open to so-called 'citizen-projects', which had particularly favourable terms, and could thereby make exceptionally low bids. The results of these auctions are not representative. The dots are therefore shaded in the figure.

Several players agree that planning conditions should be improved to ensure on-going price reductions for RES. According to the organisation, BWE, it often takes more than 500 days to receive approval for wind power project applications. Hindrances in the process are caused by more complaints and out-dated planning legislation.

German Results for Wind and PV



Note: 20 years of support, offshore wind in April 2017 includes only Ørsted's Gode Wind 3 project.

Source: EEG

The Production Costs of RES Electricity Vary Across Europe

Wind in the North and sun in the South

As well as differing electricity prices, differences in weather conditions, politics, and electricity systems also highly influence RES projects. Solar intensity generally increases further south, while areas around the North Sea have favourable wind conditions.

In addition to taxation, financing, and planning conditions, land costs and compensation paid to neighbours can vary immensely depending on the population density and the public acceptance of RES plants.

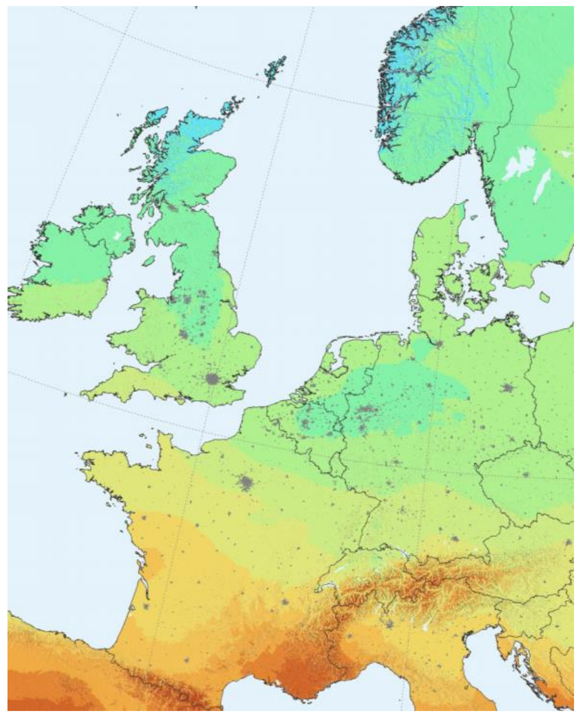
These are all factors that influence project cash flows and result in the competitiveness of RES varying across Europe, even in the case of uniform remuneration levels across all countries.

The figures show the sun and wind resources in Northwest Europe. While the sun dominates in the south, the wind resource is highest in the North and in coastal areas.

Denmark has the advantage of having a large territory in the North Sea and better onshore wind conditions compared to the southern countries.

France has the largest solar potential, with a higher, more stable production during the year.

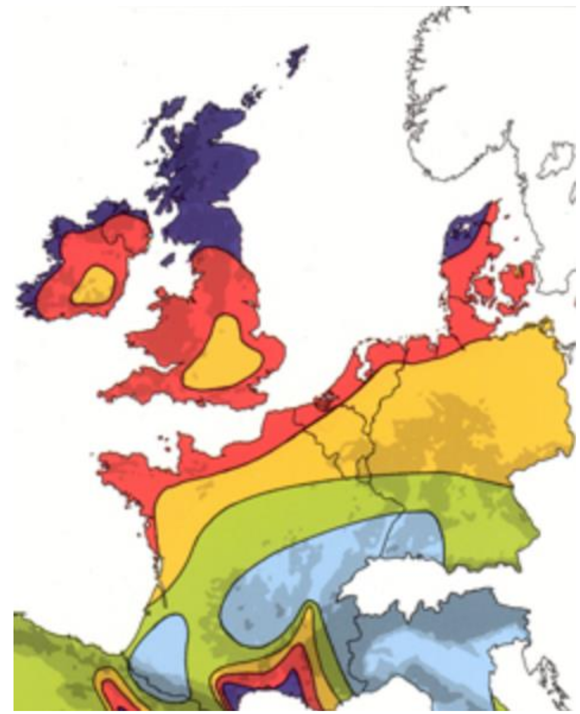
Map of Sun Resource in Northwest Europe



Note: Orange area indicates most sun.

Source: JRC

Map of Wind Resource in Northwest Europe



Note: Purple area indicates high wind.

Source: Risø DTU

4.3 Development of RES Remuneration

The Market Value of RES Electricity Production Varies Across Europe

Large price differences between east and west

The clearing of wind turbines and PVs generally follows the electricity price. The figure shows average electricity prices in 2018.

In general, remuneration in Germany and in the Nordic countries is dominated by the cost of producing electricity from coal. In the UK, remuneration is instead generally governed by consumption of gas, which is relatively expensive.

Price variations during the year depend on the nature of the systems. For instance, in France nuclear power plants fulfil a large share of demand during the summer. However, in winter increased consumption of relatively more expensive fossil fuels is required. Prices are therefore much higher during winter than in summer. This also affects wind power and PVs revenues.

In Norway and Sweden, hydropower helps mitigate fluctuations in electricity prices caused by high penetration of variable electricity technologies. This leads to higher remuneration received for power generation from wind and solar. Prices in the Nordic countries are also generally higher during winter, since the consumption is higher when it is cold and dark, and since water inflow to reservoirs is decreased significantly.

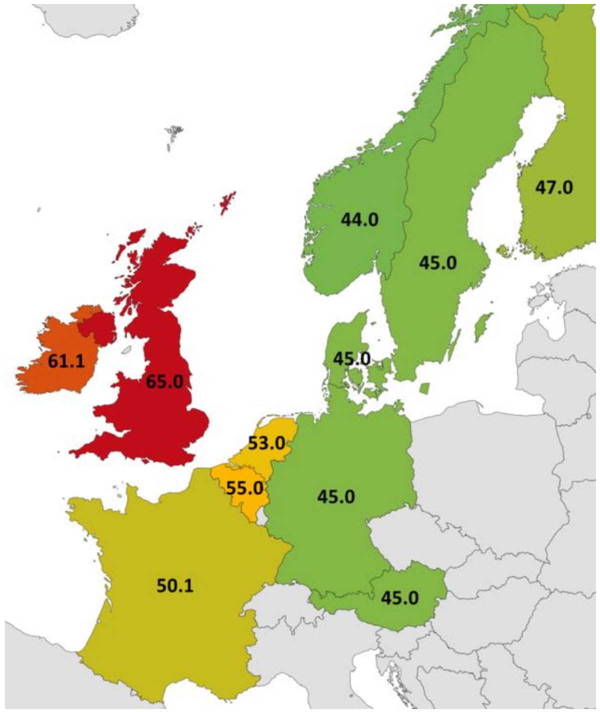
The countries of Europe are connected by transmission lines, which enable exchange of electricity across borders. In a small, well-connected country such as Denmark, the remuneration received for electricity generation from wind and PV is highly affected by RES deployment in neighbouring countries.

Typically, Northern Europe has the lowest electricity prices. Prices in Denmark closely follow the prices in other Nordic countries as a consequence of being strongly connected to Norway and Sweden via transmission lines.

Denmark is also strongly connected to Germany, where the electricity prices are also relatively low. In this way, it is mainly the German deployment of wind power which has contributed to limiting remuneration received by Danish wind turbines. Today, Germany has approx. 60 GW wind power capacity, whereas Denmark has approx. 6 GW.

The Cobra and Viking Link transmission lines, which will connect Denmark with the Netherlands and England respectively, will make it possible to export electricity to markets where its value is higher.

Electricity Prices in Northwest Europe in 2018 (EUR/MWh)



Source: Agora/Sandbag

The Quota Price is Crucial to Electricity Price and RES Remuneration

Electricity prices are the highest in 10 years

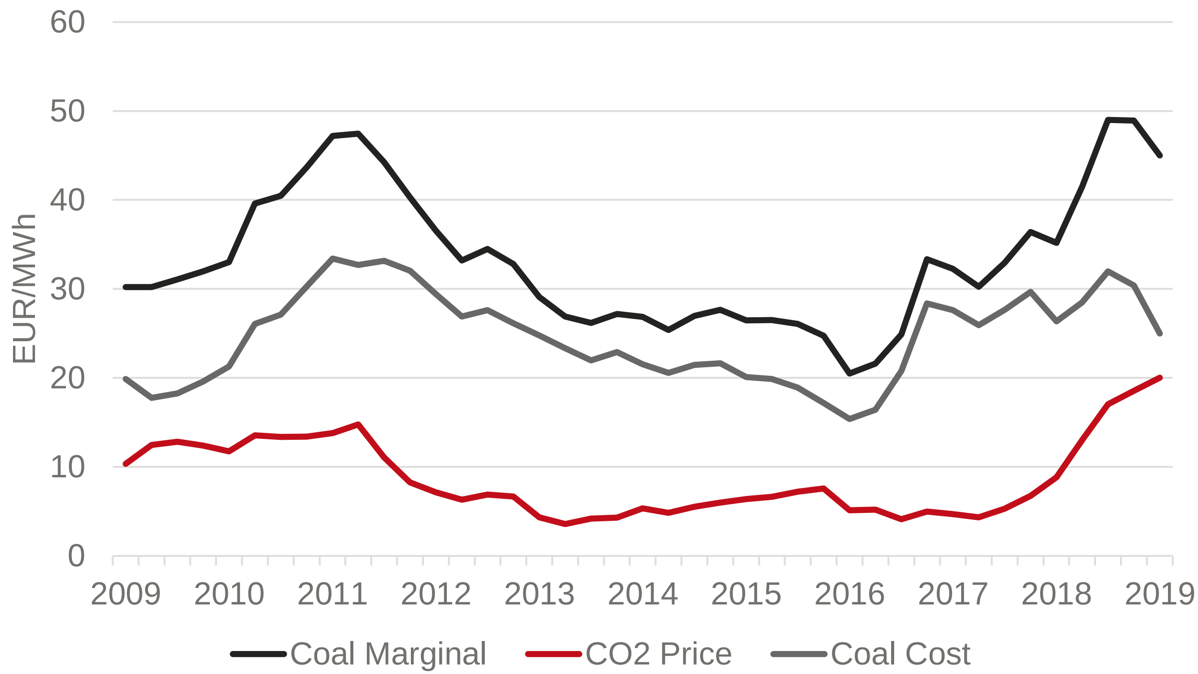
As described in Danish Energy's Electricity Price Outlook, the marginal costs of coal (the so-called coal marginal) determine the price in most of the years both in Germany and the Nordic countries. For the same reason, the costs of coal power also determine, to a growing extent, the remuneration received by wind and solar power from the electricity market.

The coal marginal was more than halved between 2011 and 2016. However, in recent years it has returned to 47 EUR/MWh, driven by increasing coal prices in 2016 and increasing quota prices in 2018.

The coal and quota prices currently account for 27 and 20 EUR/MWh of the electricity price, respectively.

The coal price is determined globally, and is mainly dictated by decisions in China. The quota price is determined by the nature of reforms ratified by the EU. Creation of the market stability reserve has restored trust in the effectiveness of the quota market, which has led to an increase in quota prices.

Coal Marginal Separated into Coal and CO_2-Contributions



Note: Quarterly values.

Source: SysPower

Wind Turbine and PV Penetration Restricts Remuneration

Pressure on wind and PV clearing

Despite low electricity prices, due to low prices on coal and CO_2, PVs and wind are challenged by restricting their own remuneration. Wind power is bid into the market when the wind is high, and the large supply causes the price to fall. A similar effect occurs for PVs, where remuneration falls during sunny days.

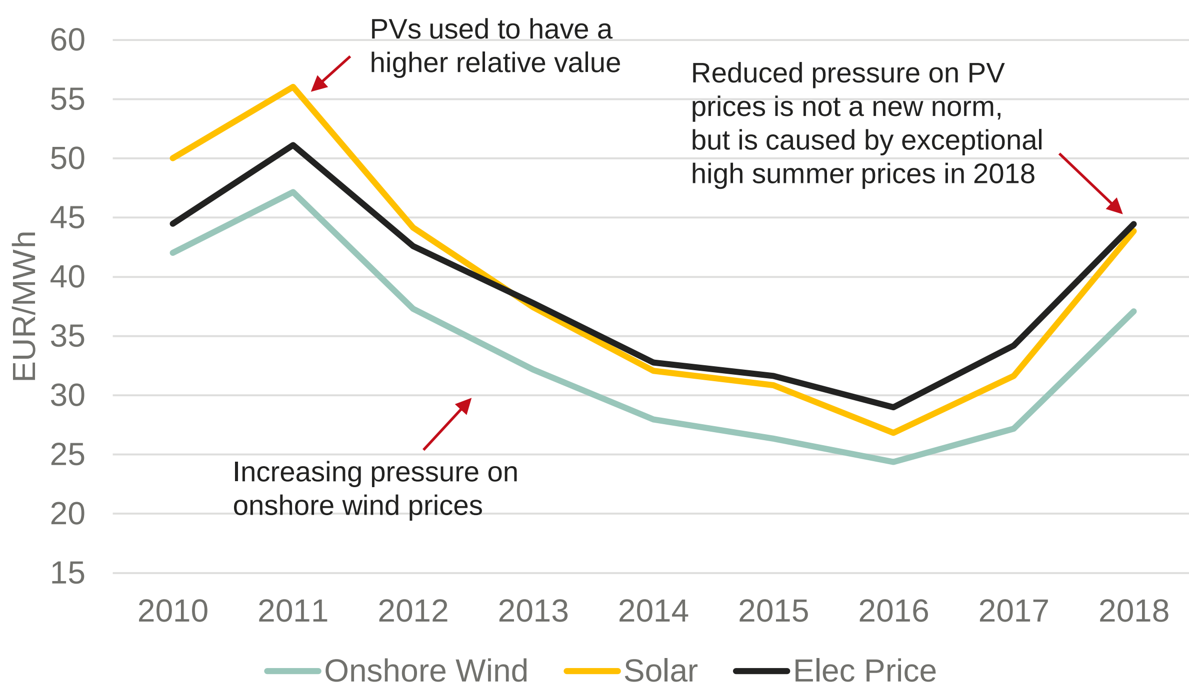
This results in wind and solar power increasingly restricting remuneration as market penetration increases.

The example from Germany (see figure) shows that the remuneration of PVs was previously higher than the average electricity price, due to higher demand during the day. This has dropped sharply since the expansion of solar in the European electricity system.

The remuneration of wind power has been more or less stable during the last five years at 85 % of the average electricity price.

Furthermore, the pressure on PV remuneration during the summer months contributes to an increase in the relative price of wind, which produces more electricity during winter.

Wind and Solar Remuneration Compared to Electricity Price (Germany)



Source: SysPower.

Wind Power Remuneration Is Low in Hours with High Wind

Strong wind is bad for remuneration

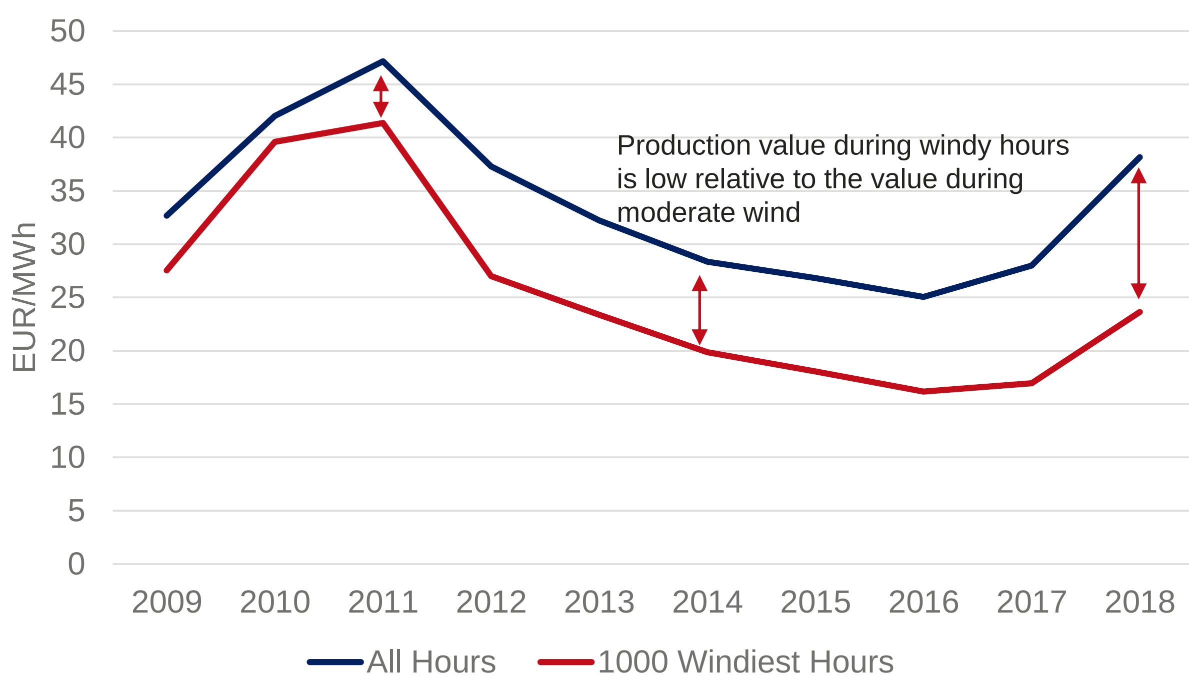
Taking a closer look at the earnings from wind turbines, it appears that the reason for the remuneration being below the average electricity price is mainly found in the hours of strong wind.

From around 2012, the difference in remuneration between all wind power and production in the windiest hours widened significantly. While the electricity price has increased since 2016, remuneration during the windiest hours has barely risen. Remuneration during the 100 windiest hours in 2018 was 24 EUR/MWh, i.e. approx. half of the average electricity price.

As the penetration of wind increases, it is expected that remuneration will be squeezed yet further during the most windy hours.

Power production from each wind turbine during these hours depends on the type of wind turbine and particularly the capacity of the generator compared to the swept rotor area. A turbine with a high generator-to-rotor-area ratio will generate a relatively large share of its power output during hours with strong wind.

Remuneration for Wind in Germany



Source: SysPower

High PV Shares Result in Low Remuneration

Remuneration for Californian PVs falling

The electricity supply of California has seen an astonishing expansion of PVs since 2012. PVs now account for approx. one sixth of consumption.

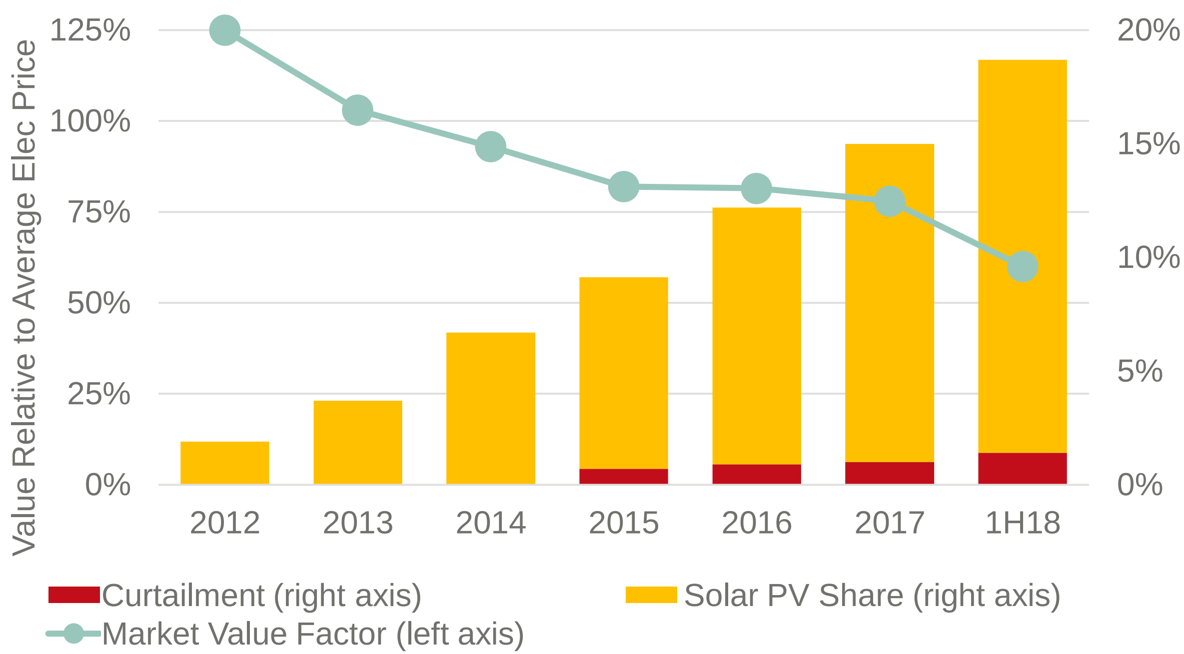
High deployment has thus resulted in a huge fall in remuneration and a moderate increase in wasted surplus production. The electricity, which previously cleared at 125 % of the average electricity price, now clears at 60 %, i.e. a reduction in relative value of over 50 %.

Different factors influence the exact values, but the conclusion is clear: the value of additional PVs decreases significantly if deployment is large.

This does not necessarily indicate that the deployment of PVs should stop. While the value of PVs has fallen, so has the cost. Therefore, new systems can operate easily with remuneration well below the average price.

It is clear to see from this case that PVs cannot cover very large shares of the energy supply without losing a lot of production value.

Relative Market Value and Share of Production from Californian PV



Source: LBL

Climate Impact of RES Increased by New Carbon Market Dynamics

RES deployment gives actual CO_2 reductions

At the beginning of 2019, the market stability reserve (MSR) of the EU's emissions trading system will come into force. The MSR works by removing a large share of the surplus quotas in the European market. The quotas can be returned to the market later, but if the number of quotas is already sufficient, then excess quotas are cancelled. It seems there will be excess quotas until at least 2030 (in accordance with the EU's 2050 strategy).

The MSR has led to a significant rise in the quota price, from approx. 5 €/ton in the summer of 2017 to almost 25 €/ton in January 2019.

The carbon market has a static upper limit (with the possibility of being changed politically), which has resulted in the 'waterbed effect', where reductions in one area have led to additional emissions in others. With the MSR, there is now a dynamic upper limit which constantly will adapt to the actual emissions.

If the demand on quotas decreases, the surplus of quotas will become bigger, and a big part of this surplus will be removed by the MSR and eventually cancelled.

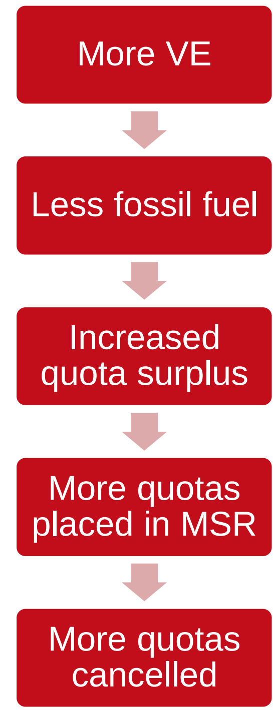
In other words, actions of nations to reduce consumption of coal and gas and increase RES electricity production will have a positive effect on the climate.

Having a higher price on quotas will thus still be preferable for driving the most efficient transition.

More reforms are expected to be seen in the EU's emissions trading system. Several countries have, for example, been demanding more ambitious goals for reduction by 2030, in order to make the EU goals comply with the Paris Agreement. The Netherlands has suggested to increase the EU's objective of reduction from 40 % to 55 % in 2030. A number of other countries, including Denmark, France, the UK, and Italy, have signed a declaration about strengthening the price setting of CO_2 emissions in the EU.

The fact that the actual emissions influence negotiations regarding new objectives is a further argument for initiatives at national level.

The New Dynamic in the ETS Market



5. Scenarios of RES Deployment in Northwest Europe

Electrification and Decarbonisation Can Meet The Paris Agreement

The green transition calls for a step-change

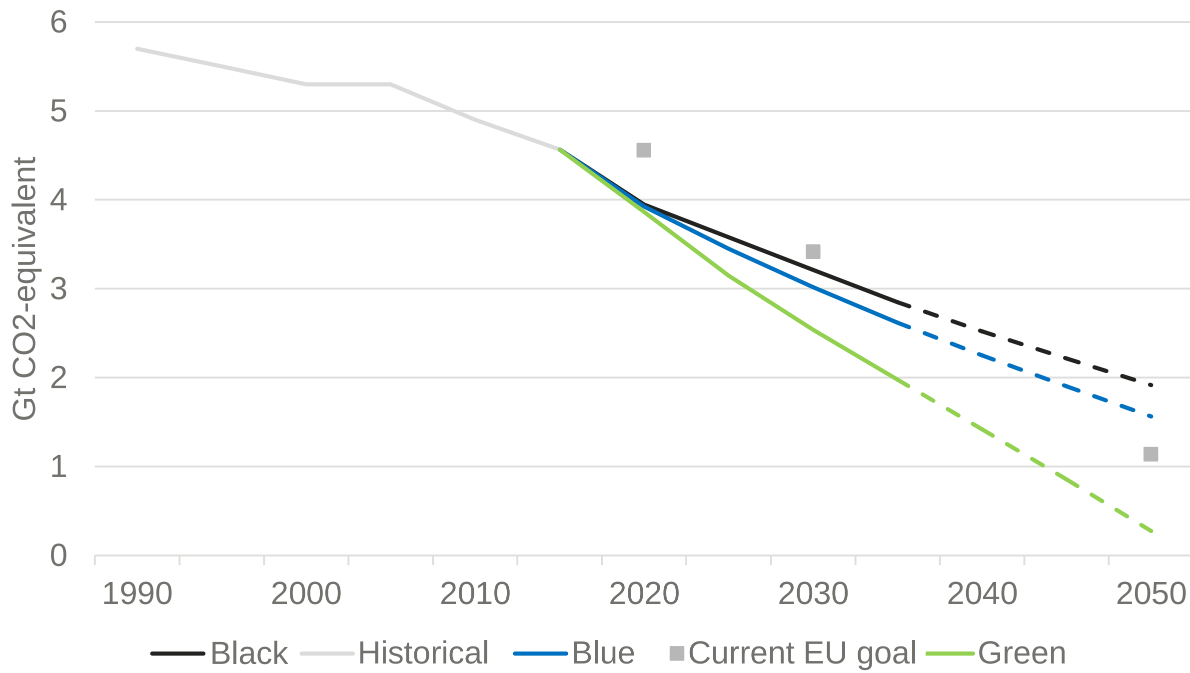
In this year's RES Outlook, we have looked into three scenarios giving rise to very different outcomes for future deployment of RES. The good news is that we can live up to the Paris Agreement, but extensive electrification and deployment of wind and PVs are necessary.

In order to make it more likely that the temperature rise will be kept below 1.5°C, it is necessary to cut greenhouse gas emissions corresponding to a straight-line reduction path towards net-zero emissions in 2050 (IPCC, 2018). This will require the current emissions to be cut by half by 2035 and that the current EU climate goals are getting strongly intensified.

Out of the three assessed scenarios, only the green scenario will meet the 1.5°C goal. This scenario involves extensive electrification and RES deployment.

Continuing business as usual (blue) will not result in sufficient reductions, but looking at a scenario where RES is not politically supported (black), the market would still lead to a substantial conversion from fossil fuels.

Greenhouse Gas Emissions in The EU



Note: Emission paths are extrapolated from 2035.
Other greenhouse gas emissions (none-CO_2) are assumed to decrease be a straight-line towards zero in 2050.
Source: Eurelectric and own calculations.

Electrification and Decarbonisation Can Meet The Paris Agreement

The easiest gains in the electricity sector

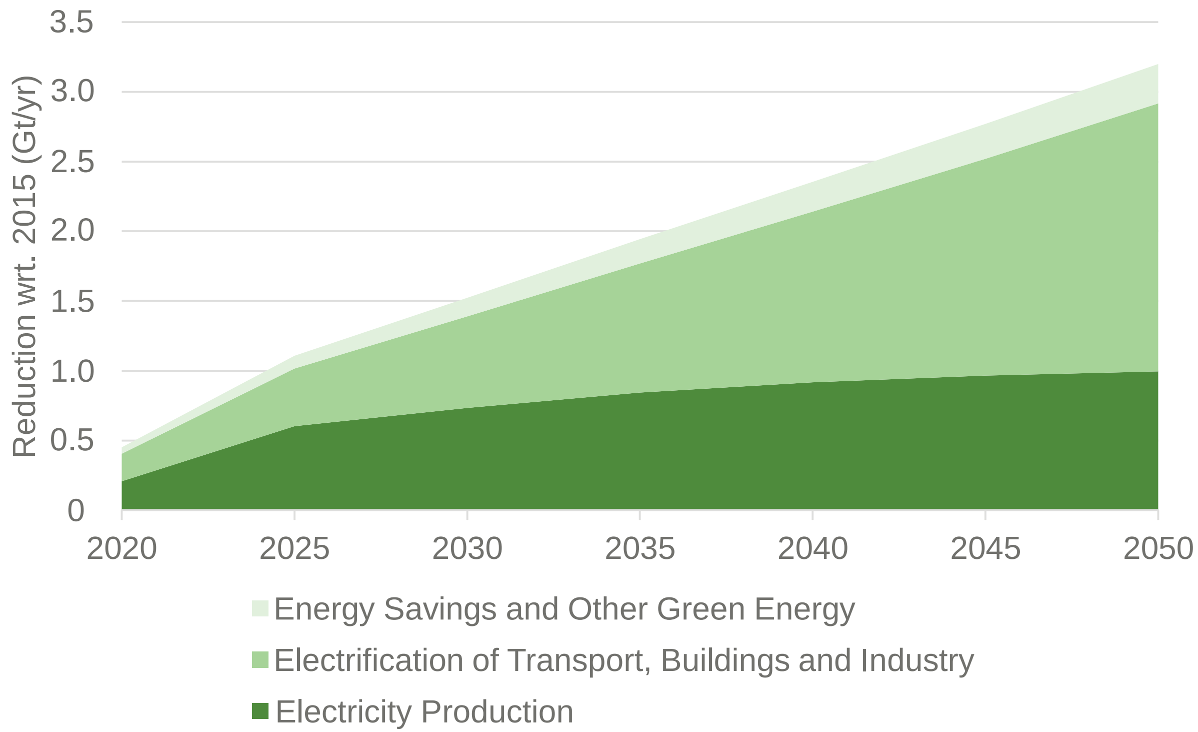
The electricity sector has a large short-term potential to reduce its own emissions by phasing out coal and replacing gas with RES. Additionally, electricity has an even larger potential for cutting emissions in other sectors (e.g. transport, industry, and heating) through electrification. This transition is only beginning to gather pace so will have a limited effect in the short run. Nevertheless, it is important that these sectors adapt in order to achieve the climate goals.

The figure shows the contribution of each sector to CO_2 emission reductions relative to 2015 levels. Contributions are divided into the following categories: the electricity sector, other sectors (by electrification), and other green initiatives (e.g. efficiency improvements).

The electricity sector has a high contribution in the early years and consequently contributes during the whole period. The total reduction until 2050 corresponds to the areas in the figure.

Electrification becomes the largest contributor of CO_2 reductions only after 2030, but its contribution in previous years is not insignificant. It is thus important to accelerate electrification.

Contribution to Reduction of CO_2-Emissions Compared to 2015
Green Scenario



Source: Eurelectric and own calculations

5.1 Scenarios and Assumptions

The Main Scenarios in The RES Outlook 2019

From the worst to the best case for RES

In order to investigate the very different outcomes of future RES deployment, three main scenarios are considered.

The black scenario provides the worst conditions for the RES deployment with a low CO_2 price, no support for RES deployment from 2025, constant electricity consumption, and no investments in additional storage or transmission capacity.

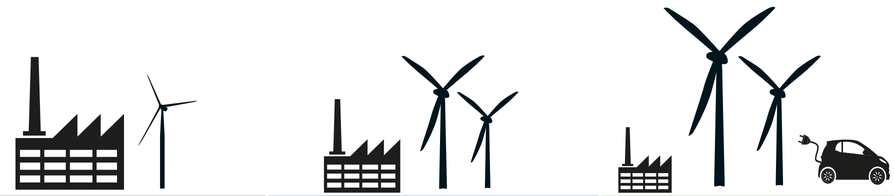
The blue scenario examines what happens if the world continues along its current path with moderate quota prices, moderate electrification, and politically secured minimum RES deployment. In this scenario, investments in batteries and additional transmission are allowed.

The green scenario considers conditions that are optimistic for the green transition, thereby representing the best case for RES.

Fuel price assumptions are the same in all three scenarios, based on the WEO2018 New Policies scenario. All scenarios have similar assumptions regarding RES potentials, maximum deployment in each country, and coal and nuclear phase-outs.

The results are presented in chapter 3.2.

Scenarios Analysed in RES Outlook 2019



	Black	Blue	Green
Quota Price	None	Moderate (approx. 30 €/ton i 2030)	High (approx. 60 €/ton i 2030)
Storage	None	Batteries	Batteries + long-term storage
Transmission	Planned projects only	Planned + investments	Planned + investments
Electricity Demand	Constant	+0.56 % p.a. (EU REF2016)	+2.1 % p.a. (Eurelectric 3)
RES Minimum	No minimum from 2025 abroad Energy agreement 2018 in DK	Politically ensured minimum investment	Politically ensured minimum investment

Key Assumptions

A number of shared scenario assumptions

Fuel prices are taken from IEA's WEO2018 New Policies scenario (see Appendix).

Minimum deployment rates for wind power have been assumed in accordance with the main scenario of WindEurope. The limit is applied until 2025 in the black case. From 2025, investments can surpass the limit if competitive under market conditions.

In Denmark, it is assumed that RES deployment is implemented in line with the Energy Agreement until 2030.

A maximum yearly RES deployment rate is assumed in certain markets (e.g. the UK where planning conditions are blocking the deployment). At the same time, an upper limit is assumed for the amount of onshore wind which can be incorporated in each country. This implies that the potential of offshore wind will be split into two groups: close-to and far-from shore. These groups have different electricity prices.

The Balmorel model simulates the day-ahead-market and investments based on market income. An energy-only market without capacity payments has been assumed. This means extreme prices will occur in the hours where exceeds production. These prices form a large part of the financial basis for reliable capacities, such as power plants and storage in the model, even though their inclusion in a real business can be questioned.

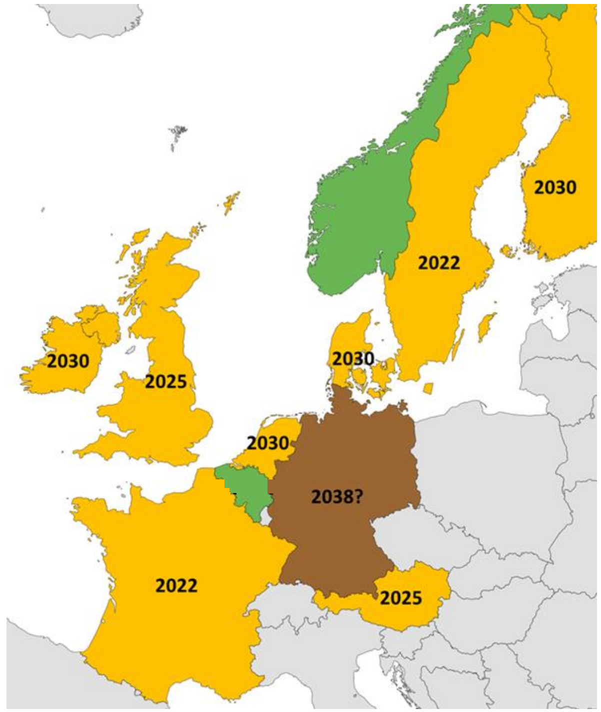
Phase-out of coal and nuclear has been assumed based on the latest political announcements.

The plans for coal phase-out in each country are illustrated in the figure. The green countries are already coal-free today. The yellow countries are planning to phase out coal in the indicated year. Germany that has not decided on a final date for coal-firing, though the German Coal Commission has recommended it to happen by 2038. In the rest of West Europe, only Spain does not have a coal phase-out goal. Germany will phase out nuclear power plants by 2022, while in France a much more conservative plan for phasing out their nuclear power was announced in 2018.

In this Outlook, we have analysed Northwest Europe (referred to as the 'model region'), which is defined by the coloured countries in the figure.

All economic results in this chapter are fixed 2019 prices, and all PV capacities are shown as Wpeak (module capacity).

Coal Phase-out Plans



Note: Phase-out dates for coal are indicated. Belgium and Norway are already coal-free. Germany has no legislative target.

RES Become Cheaper, Fossil Fuels Become More Expensive

Wind and solar get cheaper than coal and gas

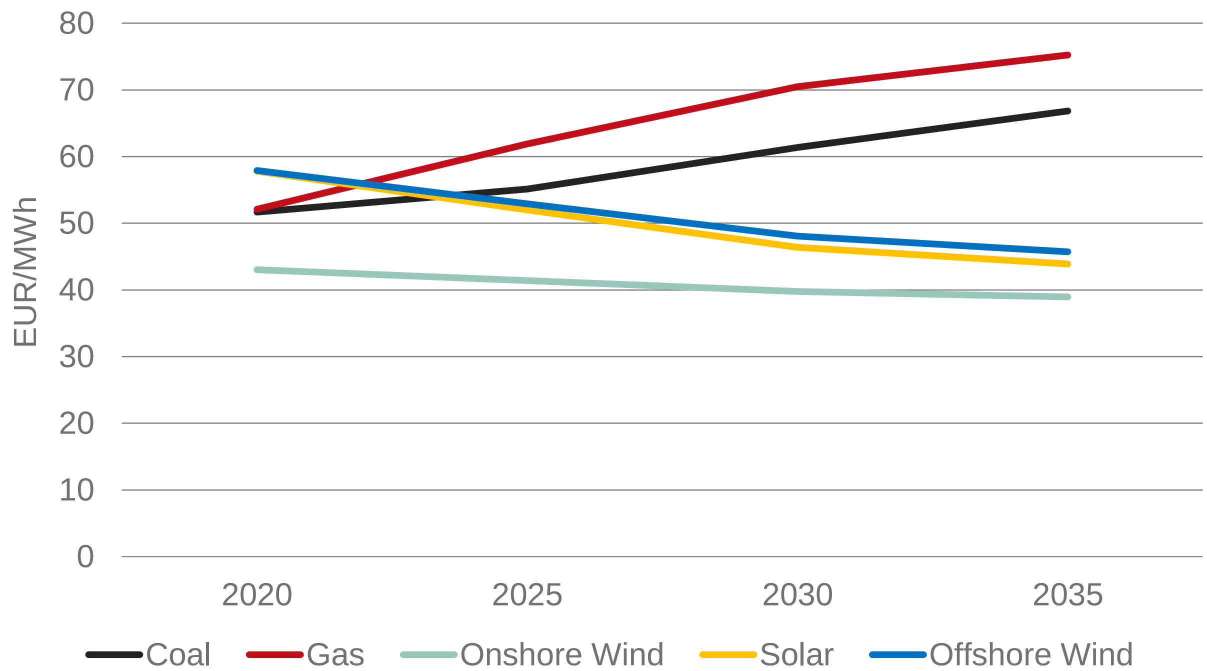
The latest edition of Danish Energy Agency's Technology Catalogue reflects market development, including enormous reductions in wind and PV power cost. Decreasing costs are expected to continue. Onshore wind is still the cheapest, but the other RES technologies are catching up. The latest technology neutral tender illustrated that PVs could compete with onshore wind.

Today, it is already much more expensive to produce electricity from coal when the construction costs of the plant are included. Remarkably, PVs and offshore wind are both expected to be cost-competitive with *existing* coal power plants in 2025.

With a moderate increase in fuel and quota price, the costs of coal and gas power will exceed the price of wind and PV the next decade.

As coal is phased out, gas becomes the new RES competitor. Gas is more expensive than coal, so significant deployment of wind and PVs is inevitable, even without support schemes.

RES and Fossil Fuels Switch Place as Expensive and Cheap Production Costs Based on The Danish Energy Agency's Technology Catalogue



Notes: A real WACC of 6 % and 25 years of depreciations have been assumed.
For the calculations a land cost of approx. 6.7 EUR/MWh has been used for onshore wind based on Energinet.
Offshore wind include landfall costs.
Source: The Energy agency's Technology Data, Energinet, IEA WEO 2018 New Policies.

Difficult to Predict Technology Costs

Technology assumptions are essential

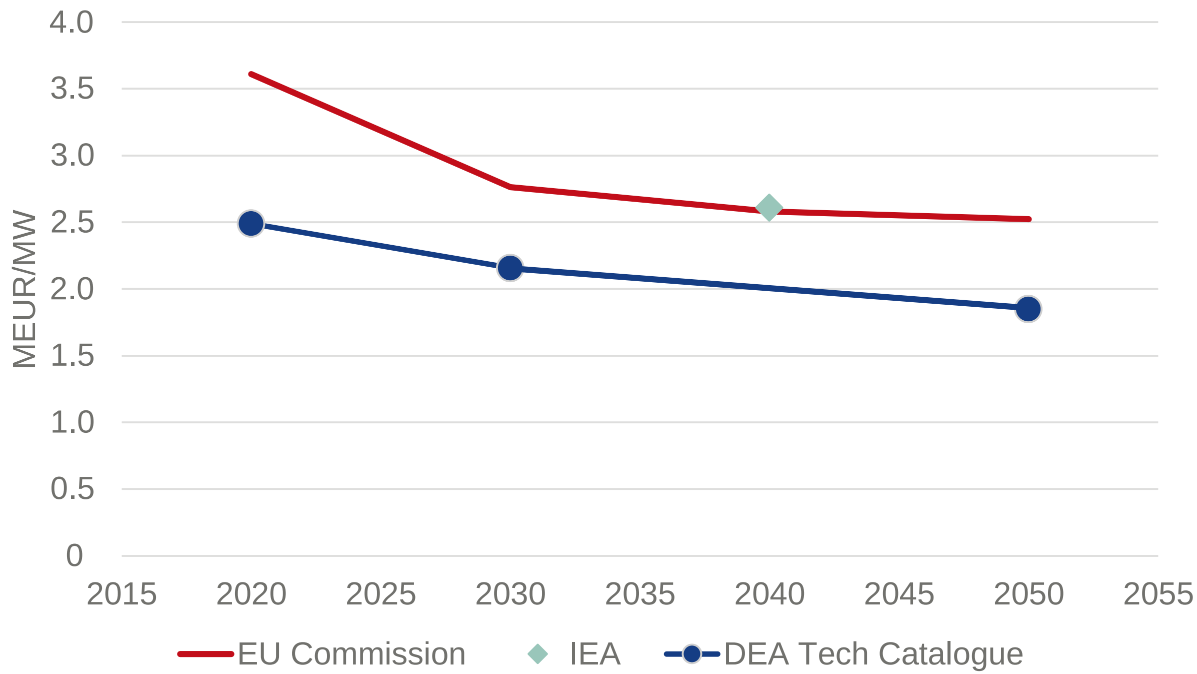
The Danish Energy's RES Outlook scenarios are based on the technology costs found in the Danish Energy Agency's Technology Catalogue.

The Energy Agency's data is better and more up-to-date source of technology costs than other international sources. The costs used for RES by the IEA and EU Commission are often too high, partly due to underestimated progress in capacity factors.

However, the Technology Catalogue has also been overtaken by reality repeatedly. The Technology Catalogue was consequently updated in May 2017 to include the latest reductions in cost for offshore wind, despite the previous estimation being only two years old.

The assumptions used are crucial for correctly assessing the costs of fulfilling ambitious climate goals. In EU Commission models, the cost used for evaluating offshore wind is currently around 35 €/MWh higher than the actual price. This results in an underestimation of when offshore wind will compete with gas. The current conditions result in an overestimation of the quota price required before offshore wind can match gas prices by 100 €/ton.

Capital Costs for Offshore Wind (incl. landfall)



Source: The Energy Agency's Technology Data, IEA, E3M

Wind Power Potentials Will Dictate Developments to a Great Extent

How much space is available?

Renewable energy is now the cheapest source of electricity, so the main question in energy system analysis has changed from “How much are politicians willing to pay for RES?” to “How much can be built, and at what price?”.

The data basis for answering these questions is surprisingly weak and assessments of potentials from different studies arrive at very different results. It is especially complicated to determine onshore wind potential since public acceptance is difficult to model.

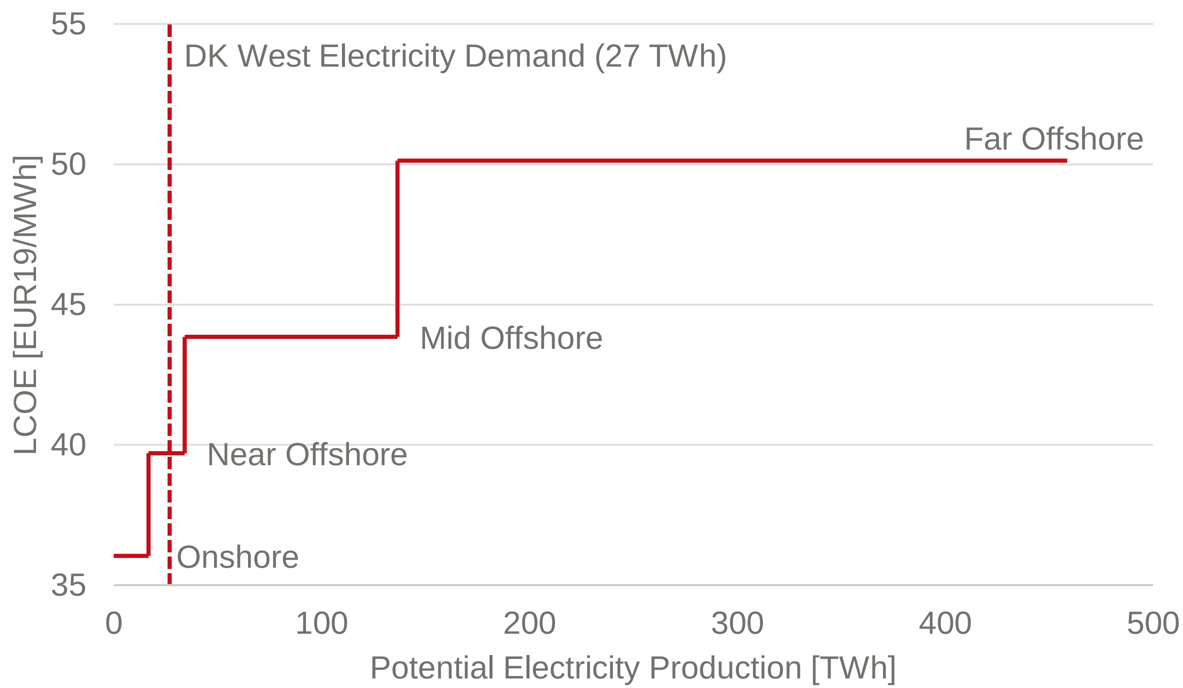
Onshore wind potentials are assumed for each country, as is maximum annual deployment rate.

The potential of offshore wind is divided into three categories based on the distance to the coast and the seabed conditions.

A rough assumption is made that all onshore wind has the same price while the cost increases with distance to the coast.

The offshore wind potential in Denmark (mainly in the North Sea) is huge and around 10 times as big as the expected electricity consumption in 2030. The potentials are given in the Appendix.

Wind Power Potentials in West Denmark



5.2 Results of Main Scenarios

Decarbonisation of Electricity Gives CO_2 Gain and Green Electrification

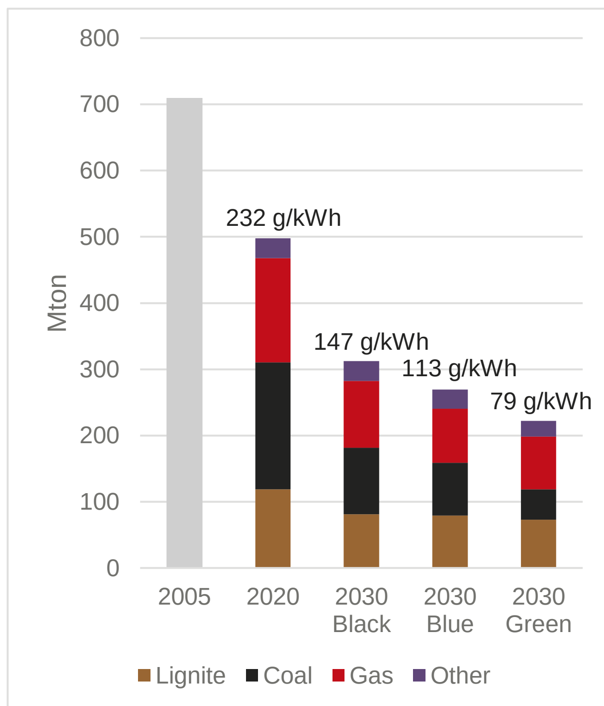
The CO_2 content continues to drop

Large cost reductions for wind and PVs give rise to the great potential for having cost-efficient reductions in CO_2 emissions from the electricity sector. The average CO_2 content in electricity production decreases in all three scenarios until 2030. Lowest emissions occur in the green scenario (79 gCO_2/kWh), and highest in the black scenario (147 gCO_2/kWh). Germany is the only country in Northwest Europe to continue coal-firing in 2030. Coal and lignite account for more than half of the total emissions by 2030, the phase-out of lignite power plants in Germany will, therefore have a crucial impact on the climate.

Electrification displaces fossil fuels

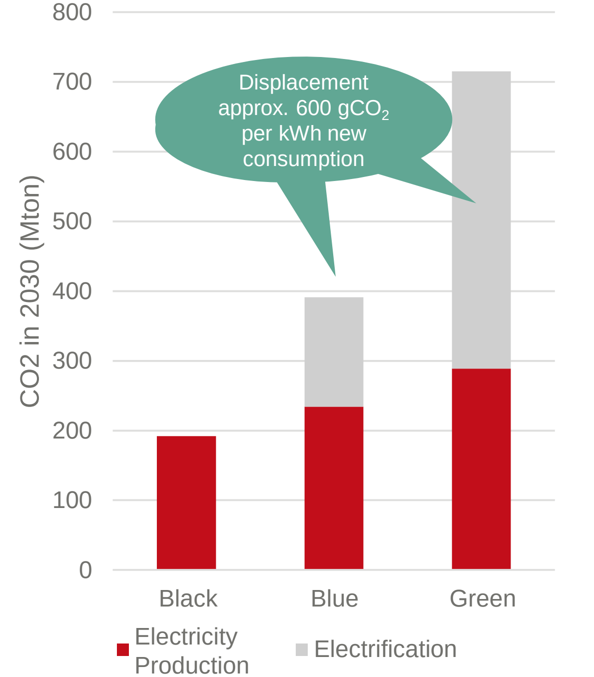
The impact of electrification on the climate depends on the technology and energy source used, but will be approx. 600 gCO_2/kWh averaged across new electricity consumption in transport, heat, and industry (Eurelectric, 2018). This number is much higher than the additional emissions from elevated production, mainly fulfilled by RES. The climate gains from the green scenario are therefore much bigger than they initially seem when looking at the isolated electricity system.

CO_2 Emissions from Electricity Production in Northwest Europe



Note: The numbers above the columns indicate the average emission per final electricity consumption.

Total CO_2-Reduction in 2030 Relative to 2020



Note: Numbers of electrification indicate the displacement of CO_2 outside the sector.

Large Difference Between RES Deployment Scenarios in Coming Years

Wind and solar deliver RES growth

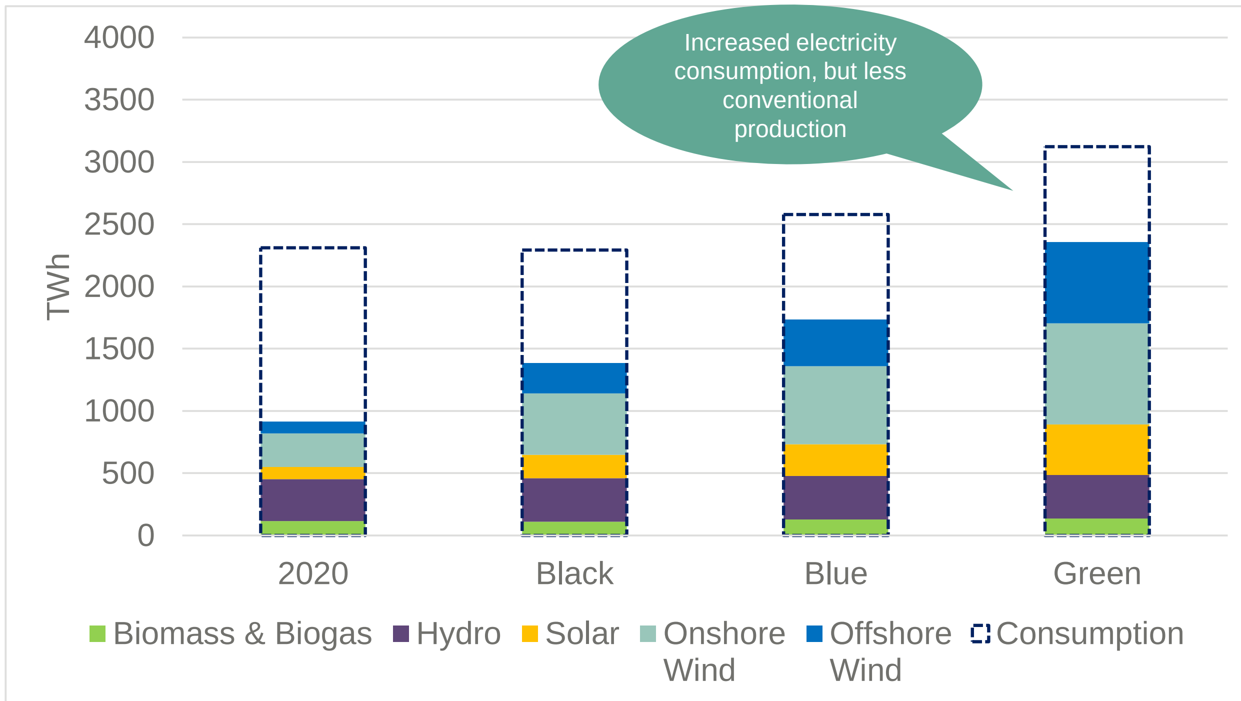
The amount of RES which will be established varies significantly between scenarios. The RES electricity production is almost 900 TWh in all three scenarios in 2020. The net deployment varies from 450 to 1,400 TWh between the black and green scenarios.

Wind power supplies the vast majority of new green energy and is supplemented by PV. Moderate growth in bio-electricity generation occurs as wind and PV are cheaper. Almost all of the hydropower potential is utilised, so more cannot be established.

In general, the production in the blue scenario is divided into shares of two onshore wind, one offshore wind, one solar, and one hydro + biomass.

The growth in electricity consumption is more offset by RES deployment in the green scenario. Conventional production is lowest in this scenario, with a RES share of 75 %. The RES share is 60 % in the black scenario, where RES are built despite poor circumstances. However, this pace is far from sufficient to achieve the climate goals. RES account for around 40 % in 2020.

RES Electricity Production and Consumption in Northwest Europe by Scenario in 2030



Note: Other electricity production is nuclear power and fossil fuels.

Efficient Planning Processes Are Key to Harvesting Potentials

Ready to rapidly speed up?

The potential of wind and PV both inside and outside Denmark is large, but an efficient approval process is required from the authorities.

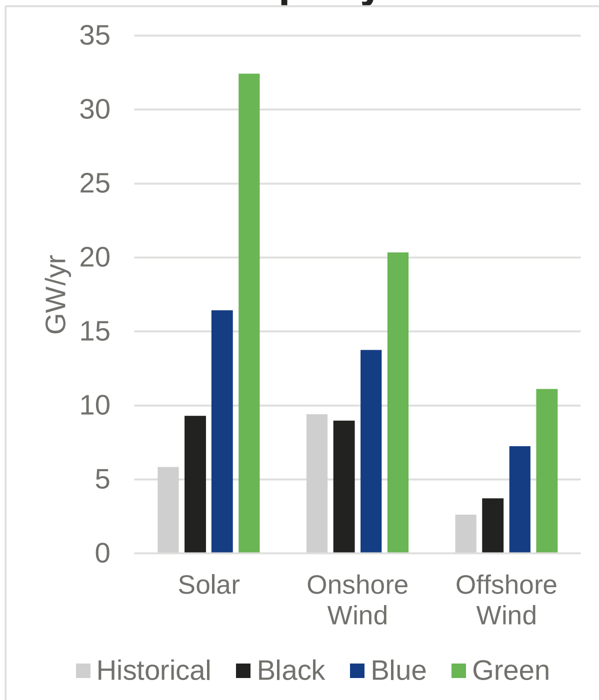
The required deployment rate in the green scenario corresponds to a deployment of PVs which is six times faster than the past three years. Onshore wind has to double its speed, while the speed of offshore needs to increase four times in order to achieve an annual average of 11 GW in Northwest Europe during the next decade.

Since the average deployment rates cannot be realised in the first years, the result will assume that the pace is much higher in the later years.

The serious increase in deployment rate places great demand on the authorities and the planning framework, which should be geared towards dealing with a much larger number of applications, complaints, and grid connections.

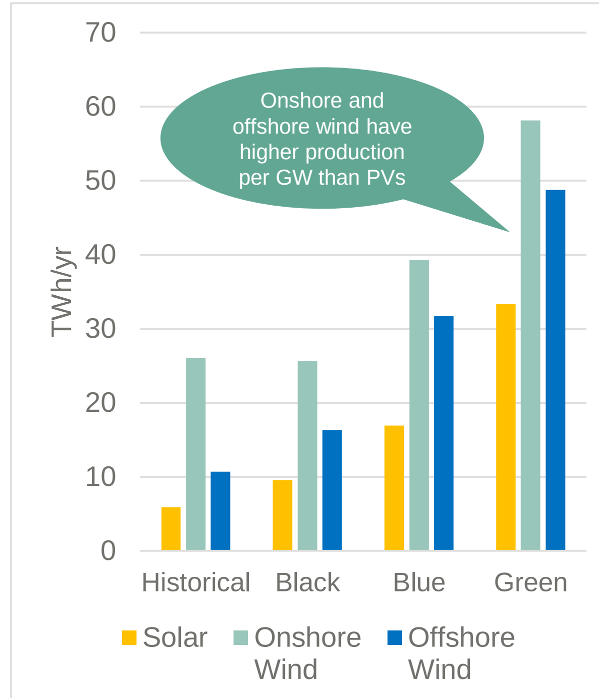
In the green scenario, almost one onshore turbine has to be built per hour, three offshore turbines per day, and 7 m^2 PV per second during the next decade.

Annual Deployment of Solar and Wind in Northwest Europe in 2020-2030 Capacity



Note: Nominal module capacities are presented for PV.
Source: IRENA (for historical values 2015-2017)

Annual Deployment of Solar and Wind in Northwest Europe in 2020-2030 Production



Note: Historical values are from 2015-2017.
Following capacity factors for new plants are assumed:
PV 12 %, onshore wind 33 %, offshore wind 50 %

Wind and Solar Will Continue to Dominate RES Deployment

Space for PVs, onshore, and offshore wind

Production from PV and wind in Northwest Europe will increase heavily from 2020 to 2035 in all three scenarios. In the blue scenario, electricity production from these sources will increase by a factor of three as a result of the stable capacity throughout the period. In the green scenario, there is a five-fold increase.

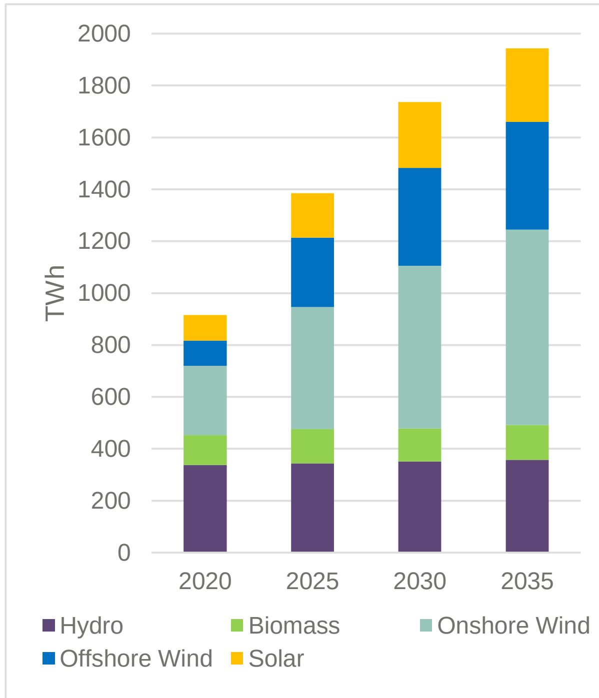
Other RES sources, such as biomass and hydro, are expected to stay constant over the period.

The onshore wind capacity doubles from 2020 to 2035, while generation rises by more than 150 % due to higher capacity factors of new turbines (higher annual production per MW capacity).

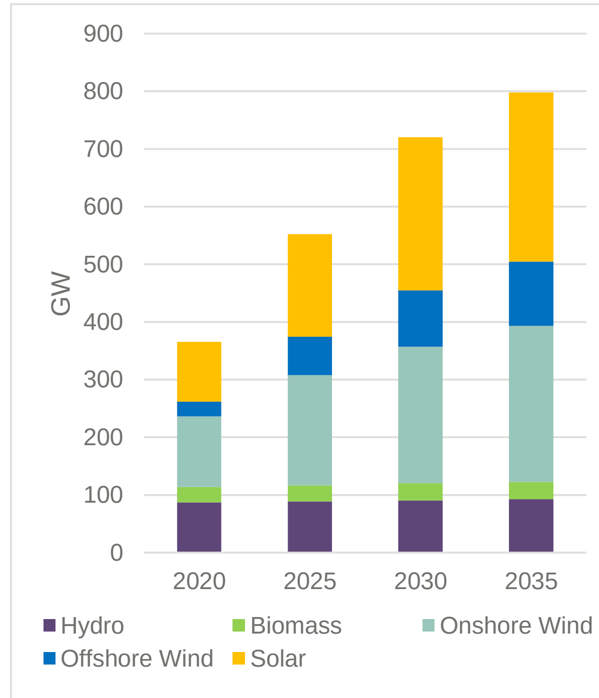
The difference in capacity factors between technologies is seen by comparing the two figures. In 2035, offshore wind accounts for 14 % of the RES electricity capacity, but 21 % of RES production, while PVs accounts for 37 % of capacity but only 15 % of electricity production.

The RES capacity will exceed 1,200 MW in the green scenario, where solar will account for 45 % of electricity capacity and 19 % of the electricity production.

Electricity Production in Northwest Europe in The Blue Scenario



Total RES Elec Capacity in Northwest Europe in The Blue Scenario



Note: PVs are measured as MWp.

Large Changes in Conventional Electricity Generation

Phase-out plans have a large impact

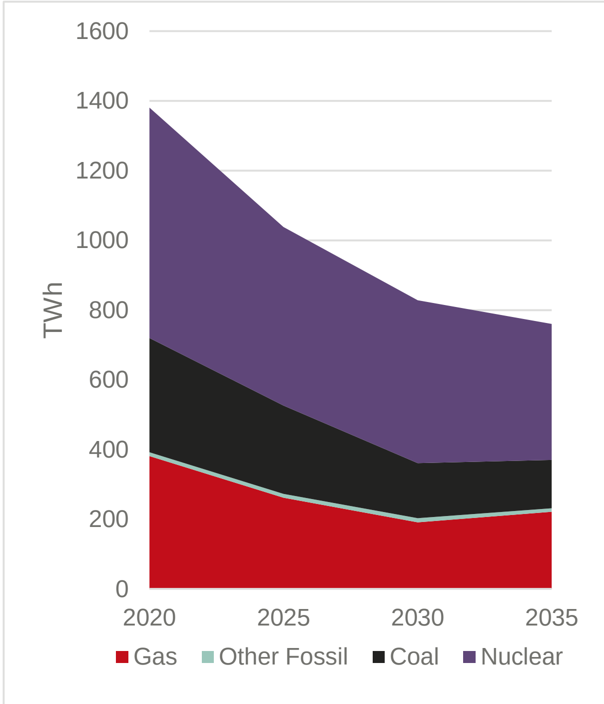
France's announcement about shutting down nuclear power and new coal phase-out announcements across Europe will cause a faster phase-out of fossil fuels than predicted. Electricity generation from coal will be halved in the next decade, while nuclear power will be reduced by 30 %.

Electricity generation from natural gas will decrease significantly compared to current levels, due to competition from wind and PVs. However, natural gas may have a small comeback after 2030, if breakthroughs in storage do not occur.

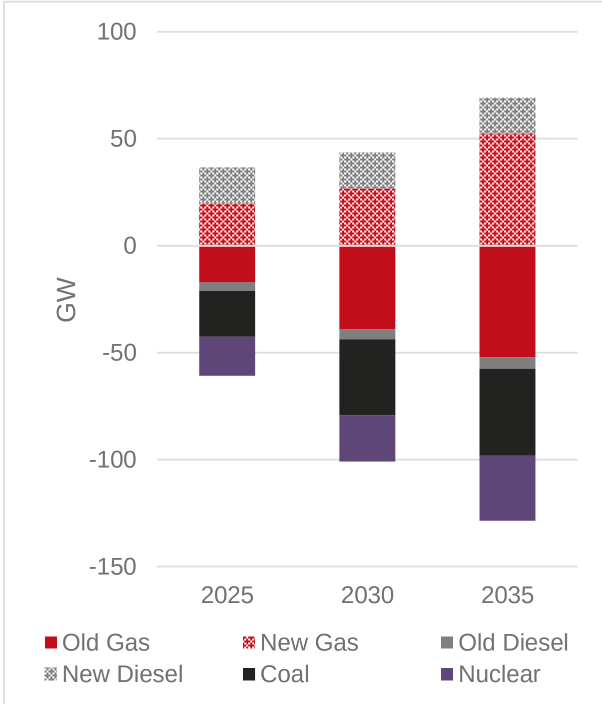
Recommendations from the German Coal Commission in January this year are more ambitious than the analysis assumes. In reality, coal will, therefore, play an even smaller role.

More than 100 GW of conventional capacity will be phased out in next decade, due to reaching the end of their technical lifetime or political targets. At the same time, almost 50 GW of new gas peak load capacity will be built. The ratio is not 1:1 due to new transmission lines, some capacity value of wind power, storage capacity, and a more narrow balance between supply and demand.

Electricity Production in Northwest Europe in the Blue Scenario



Capacity Changes from 2020 in Northwest Europe in the Blue Scenario



Current Development Ensures High RES Share, but Limited Production

The question is not *if* RES will be subsidy-free

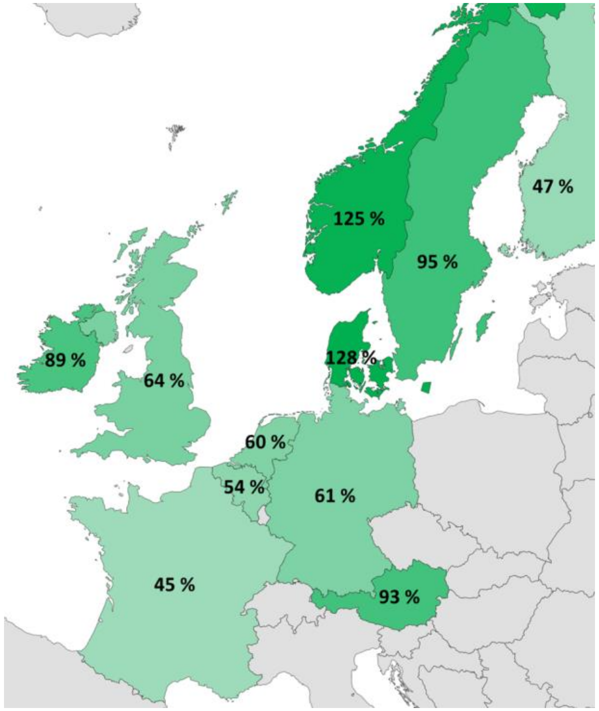
The maps show how much RES and fossil-based electricity is produced in 2030 in each country, relative to consumption. Denmark and Norway surpass 100 % RES electricity, producing more RES electricity than they use. Other countries such as Germany, Ireland and the Netherlands will continue to satisfy their demand with fossil fuels. Germany has a high share of fossil fuels as it is the only country without coal phase-out before 2030. In other countries the fossil share is due to gas (and some oil) consumption.

France and Sweden will achieve an almost fossil-free production despite having RES shares of 45 % and 95 % respectively. This is due to the high dependency on nuclear power in both countries.

Due to large wind resources, the Nordics have a great opportunity to act as a green power plant and reduce fossil fuel usage in countries such as Germany. Stable options for export are required in the form of open transmission connections.

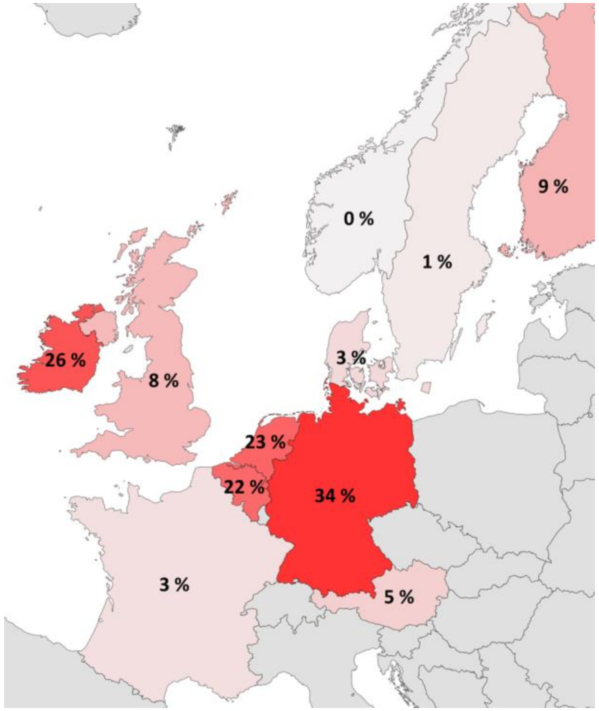
The Nordics can also act as a green power plant by importing consumption, such as from electricity intensive firms, instead of exporting green electricity.

RES Share of Elec. Consumption in 2030 in the Blue Scenario



Note: RES electricity production share of the electricity consumption.

Fossil Share of Elec. Consumption in 2030 in the Blue Scenario



Note: Fossil electricity production share of the electricity consumption.

Extensive RES Deployment in All Countries

Geographical differences between scenarios

The results show that wind turbines and PVs will be established in all countries. However, poor conditions for RES electricity in Germany hinder deployment, while markets with better wind conditions and stricter coal phase-out goals see huge deployment.

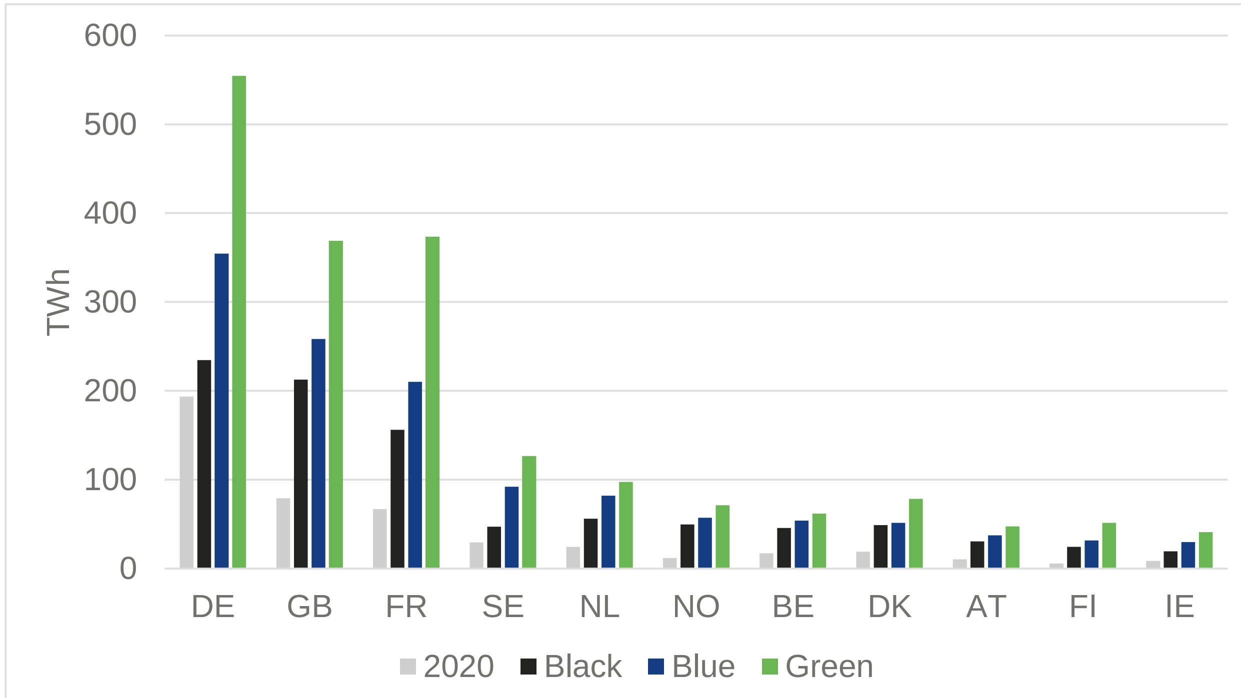
In the blue and green scenario, Germany pulls away from the others due to its large electricity consumption and improved conditions for RES to compete against coal, due to a high CO_2 price.

In the green scenario, Germany accounts for 42 % of electricity production from wind and PVs in Northwest Europe in 2020, but only 28 % in 2030.

Intensive electrification requires high wind and PV deployment growth in France. This is because nuclear power generation, which supplies half of France's electricity use in the black and blue scenarios, cannot be further increased.

In all three scenarios, Denmark sees much higher RES electricity production in 2030 than today. In the green scenario, production from RES is 78 TWh. This is driven by huge offshore wind potential and proximity to importing countries.

Geographical Distribution of Electricity Production from PVs and Wind in the Blue Scenario 2030



Wind and PVs Competitive Without Support Except in Germany

The green energy can become subsidy-free

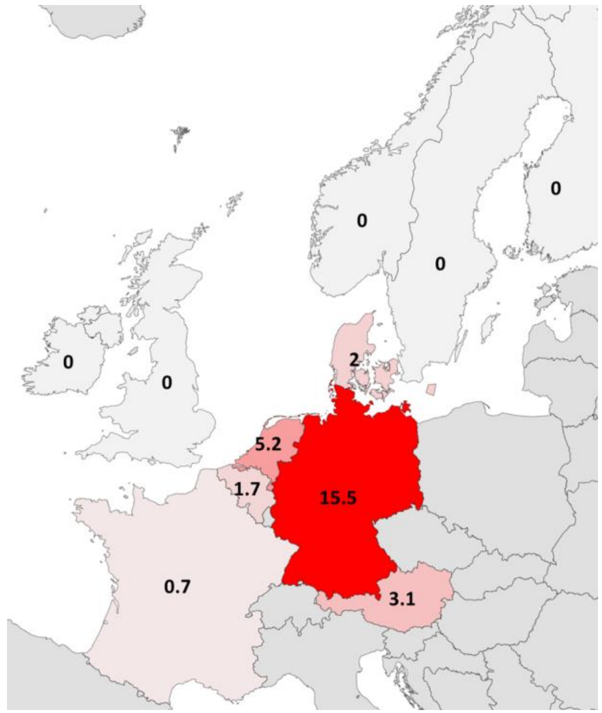
Given the assumed technology costs, PVs do not require subsidies to be established in several markets by 2025 in the blue and green scenarios. The same applies for onshore wind, except in Germany, where subsidies are required to meet political goals for onshore wind capacity, due to poor resources in central and southern Germany.

The need for support is highest in the scenario with no CO_2 cost. Support requirements are largest in Germany, but the pressure on prices also affects Germany's neighbouring countries, which also require support to achieve their deployment plans. The level of support required for onshore wind in Denmark is 2.7 EUR/MWh.

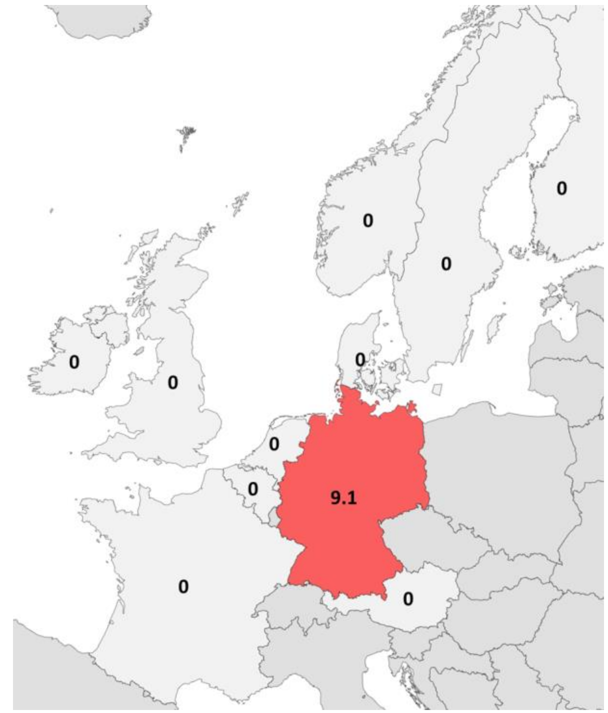
The other Nordic countries and the British Isles will be free of support even in the black scenario, which is due to better integration options (due to hydropower) and higher electricity prices.

As mentioned previously, it is no longer a question whether RES will *become* free of subsidies or not, but rather whether the amount of subsidy-free RES electricity will be *enough* to decarbonise the total energy system. This is neither the case in the black nor the blue scenario.

Need for Support to New Onshore Wind in 2025 Across Countries (Black)



Need for Support to New Onshore Wind in 2025 Across Countries (Blue)



Transmission and RES Electricity Go Hand in Hand in Deployment

Need for closer connections in Europe

The analysis shows it is advantageous to invest in new transmission lines between countries, which to a large extent strengthen existing connections.

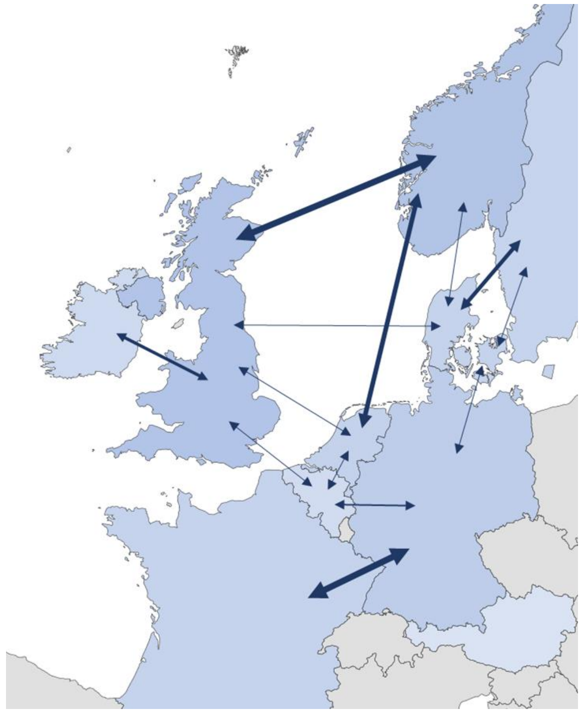
This implies that it is economically viable to strengthen connections between the Nordics and Germany via Denmark, and also for developing the connections between the UK and Norway (in addition to what is already being built).

The model invests in an upgrade of the Viking Link between Denmark and the UK in both the blue and green scenario, thereby supporting construction of the connection.

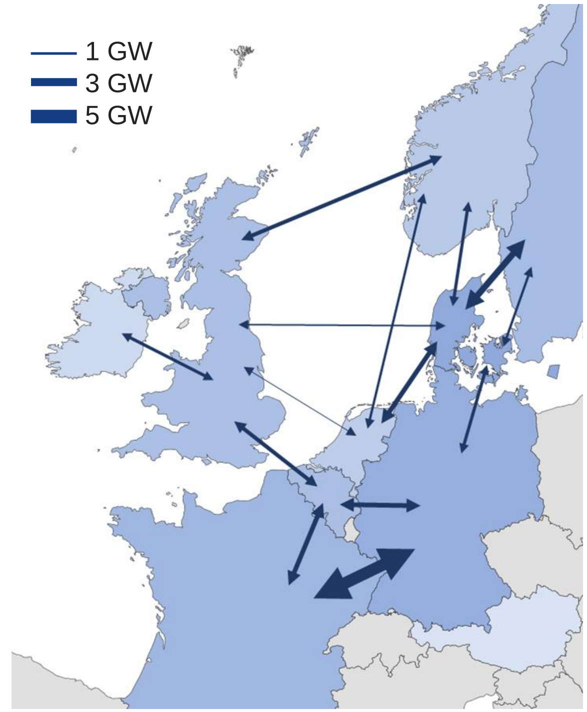
In some connections, e.g. Norway-UK, the model invests in less transmission capacity in the green scenario than the blue. The is because the model mainly uses long-term storage to balance wind power in the green scenario.

The total investment in the model is thus bigger in the green scenario than in the blue (75 GW vs. 38 GW) on top of the 106 GW existing and planned connections, which are realised in the black scenario. This is because more renewable energy is constructed as a result of higher quota prices and higher electricity consumption.

Blue in 2030



Green in 2030



Note: The thickness of the arrows is signifying the capacity of the connection.

Both figure are showing the investments relatively to the black scenario.

Storage in The Scenarios

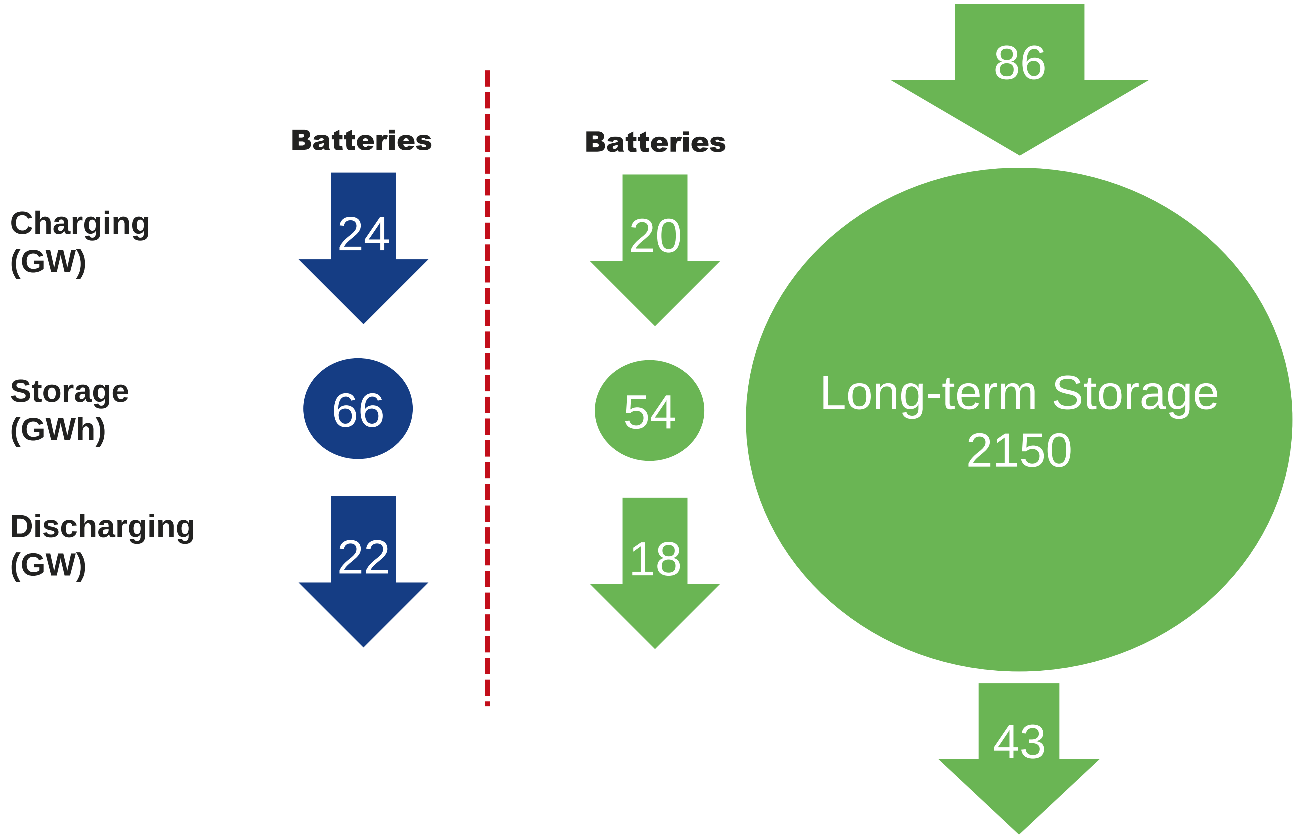
Two types of storage meet different needs

In the analysis it is assumed that battery storage can be used in the blue scenario. This is an attractive alternative to open-cycle gas turbines and diesel engine plants in the delivery of peak loads, but is subject to earnings from arbitrage trading.

In the green scenario, electricity consumption and RES deployment are large. However, this does not make the model invest in more batteries, because this scenario also assumes a breakthrough in long-term storage. Instead, the model has the opportunity to invest in generic storage that can store energy for 50 hours with an efficiency of 50 %. The amount of energy that can be stored in this way is much larger than with batteries. The long-term batteries are more suitable for the integration of wind power that experience fluctuations over longer periods. Long term storage is also a competitor to more efficient combined-cycle gas turbine power plants.

The technology used for long-term storage could be hydrogen, hot stones, pressurised air, or another alternative.

Storage Capacity in the Blue and Green Scenarios in 2030 (No Storage in The Black Scenario)



PV and Wind Will Compete with Themselves in The Future

Costs of new projects dictate remuneration

As RES deployment increases, electricity price continues to become less relevant for producers. Both PVs and wind turbines will restrict their own remuneration in the future. To what extent, depends on the deployment path, which in turn depends on new project costs. With deployment under market conditions, wind remuneration will, in theory, arrive at a level that barely ensures the economy viability of the last installed turbine.

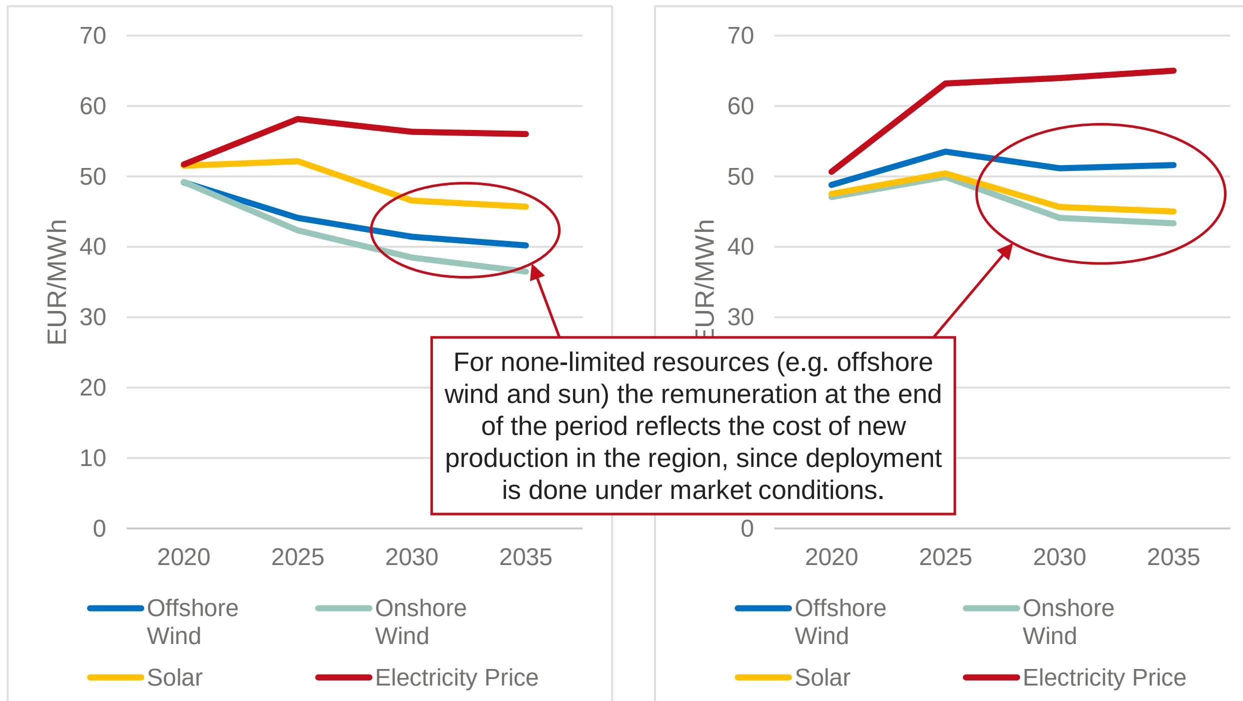
However, onshore potential is limited, so onshore wind turbines remuneration is expected to be higher than the cost since the limiting factor is the pace of project approvals.

Historically, the remuneration of PVs has exceeded the average electricity price, but will also see declining relative value as the PV technology costs fall, and new installations can be established at a cost below the electricity price.

Offshore wind remuneration is lower in Denmark than in Germany, due to the high potential of projects close to the coast which keeps the price low in Denmark. In Germany, projects must be developed much further from the coast to realise enough offshore wind capacity.

Remuneration of PV and Wind in West Denmark in The Blue Scenario

Clearing Prices of PV and Wind in Germany in The Blue Scenario



Large Deployment Gives a Low Relative Value

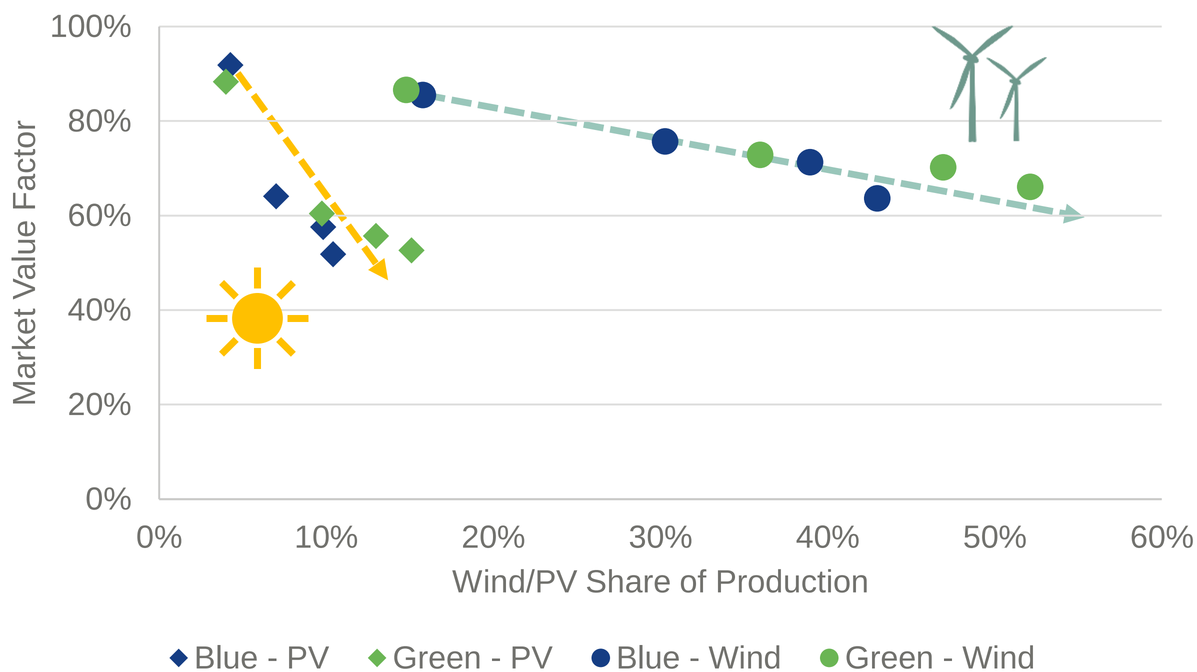
Increase pressure on PV power prices

The market value factor is the relative value of generation compared to the average electricity price. As more and more wind and PV enter the electricity system, their remuneration declines faster than the electricity price; their relative value is thereby reduced.

The market value factor decreases faster for PVs than for wind power, because the production from solar cells occurs during shorter periods and resulting pressure on prices is more intense. In general, pressure on prices is dictated by the capacity (MW), while the share of wind and PV in the system is determined by the production (MWh). Since wind produces 3-4 times as much energy as the same capacity of PV, the decline in the market value with production is 3-4 times slower for wind.

The market value factor decreases when the deployment increases in all three scenarios. This decline is slower in the green scenario, due to improved storage options.

Market Value Factors for PVs and Wind across Scenarios



Note: The market value factors are calculated as a weighted average of all countries.

5.3 Alternative Paths for RES Deployment

Future Development Is Very Uncertain

The effect of single factors

The three scenarios create a range of different outcomes, but do not specify the effect of single factors.

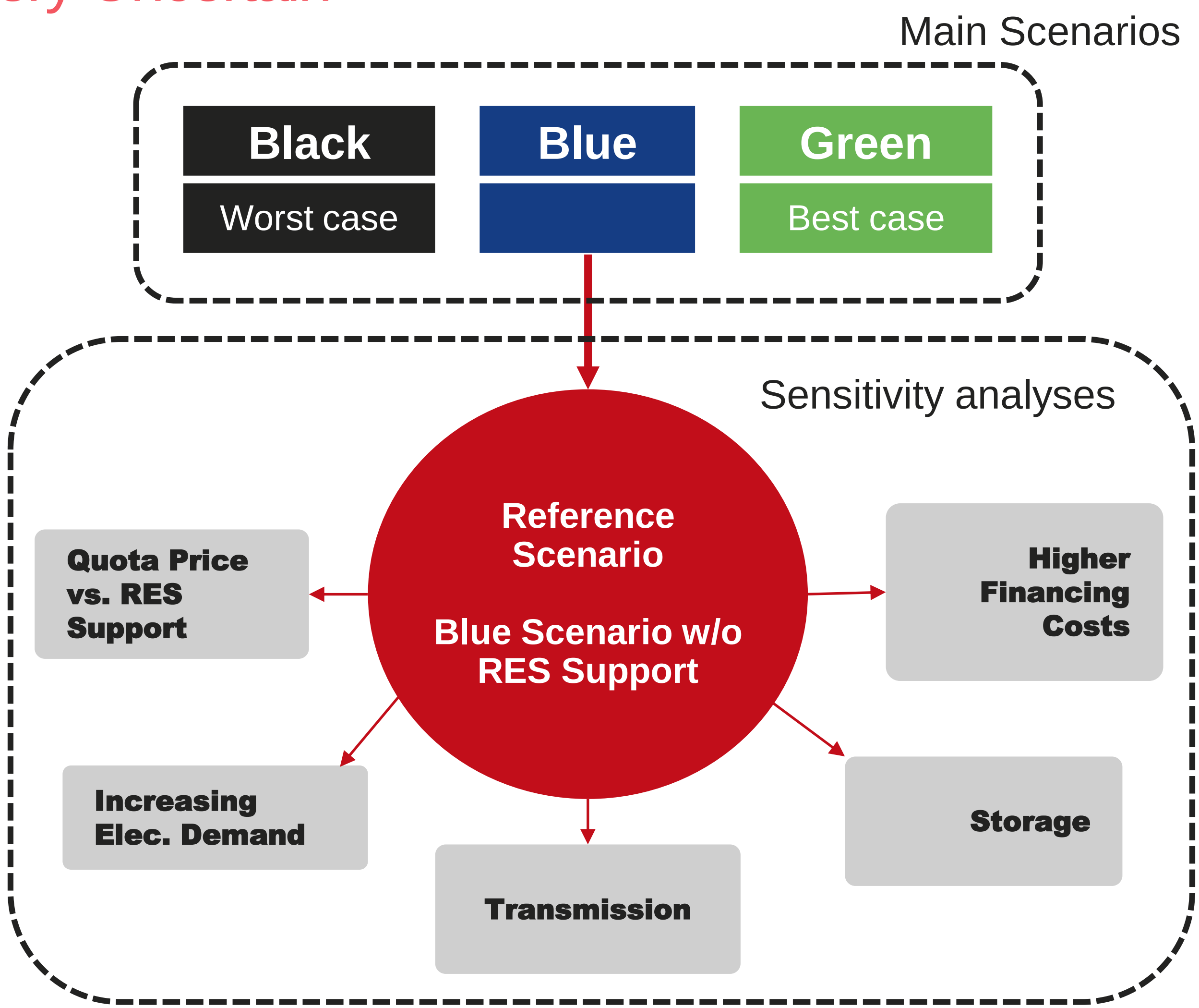
To evaluate the effect from single factors which can promote/limit RES deployment, we use a reference scenario which is based on the blue scenario but *without* subsidies. In this scenario, RES will be built under market conditions only, and the effect of changed conditions can, therefore, be seen in changing amounts of RES.

First of all, we have studied RES deployment at higher quota prices compared with direct support.

We have also studied how increased electricity consumption can be fulfilled in the absence of political support for RES deployment.

This is followed by an assessment of how storage and transmission affect RES deployment.

Finally, we have looked into the effect of having higher financing costs, as a potential result of increased market risks, as could be the case for investors lacking a counterpart for price-hedging.



Reduced CO2 Emissions with a High Quota Price

The stick is more effective than the carrot

The analysis shows that a cost-effective green transition is secured in the best way by punishing CO_2 emissions rather than supporting RES capacity. This is because a higher CO_2-price is an efficient tool for pushing coal out of power plants. RES support instead displaces both natural gas, which has a lower climate burden than coal, and CO_2-neutral nuclear power from the system.

Relative to the reference scenario, doubling the quota price (at approx. 60 EUR/ton instead of 30 in 2030) leads to a CO_2-reduction of 57 Mtons in 2030. This is more than double the reduction achieved (24 Mtons) by subsidies of 7.4 EUR/MWh in all countries.

Measured relative to the reference scenario of 270 Mtons, the initiatives lead to respective reductions of 21 % and 91 %.

Given that Denmark has only a limited influence on CO_2-prices in the EU, it can still be relevant to have subsidies as a second-best solution to ensure progress in the green transition.

A stable quota price has particular value

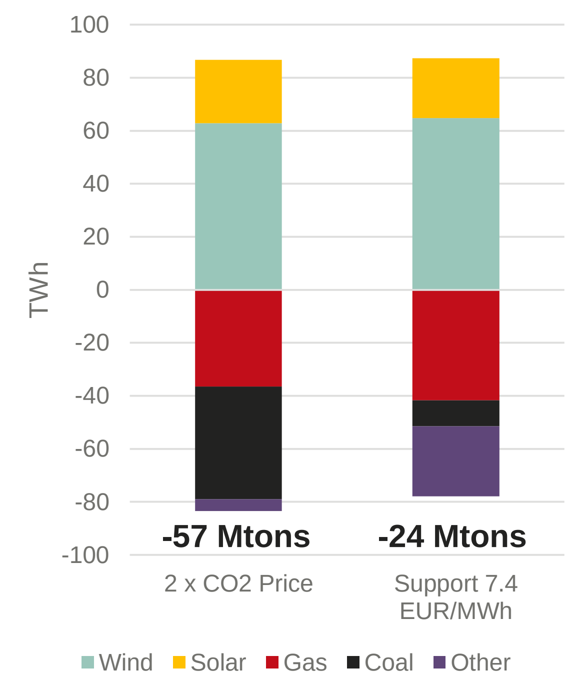
In a study by FTI Consulting in 2018, it was concluded that introduction of a minimum price on CO_2 would bring great advantage, as has been seen in the UK. Having a carbon price floor like this creates two advantages, which have not been analysed in this Outlook.

Firstly, RES producers receive higher remuneration in the short run, due to increased fossil fuel costs, which currently set the electricity market price.

Secondly, a carbon price floor in the market would create a price floor in earnings from RES projects. Projects would therefore become easier to finance and would decrease yet further in cost, due to reduced capital costs.

Since RES costs determine the electricity price in the future market to a large extent, the carbon price floor would contribute to lowering the electricity price in the long term, despite price increases in the short term.

Changes in Electricity Production in 2030 in the Reference Scenario



Increases in Electricity Consumption Are Mainly Fulfilled by Wind and PV

The market dictates RES to meet new demand

By comparing results for electricity production in a scenario with elevated consumption against the market scenario, it is possible to study how the increased consumption will be fulfilled.

A sharp increase in the electricity consumption due to electrification (2.1 % p.a. instead of 0.56 %) will result in an increase in total consumption of 480 TWh in 2030 compared to 2015, in the modelled region. New RES capacity will not be established in the short term (2020) and the extra consumption will, therefore, be supplied by increasing the operation of fossil plants. However, from 2015 onwards this will primarily be supplied by PVs and wind.

Electrification: large positive effect on climate

The electrification of heat and transport should be implemented to reduce the use of fossil fuels in those sectors. McKinsey's large study on electrification for Eurelectric last year concludes that for the electrification of each kWh, an average of 600 gCO_2 from fossil fuels is saved, which is significantly higher than the emissions from the extra electricity production.

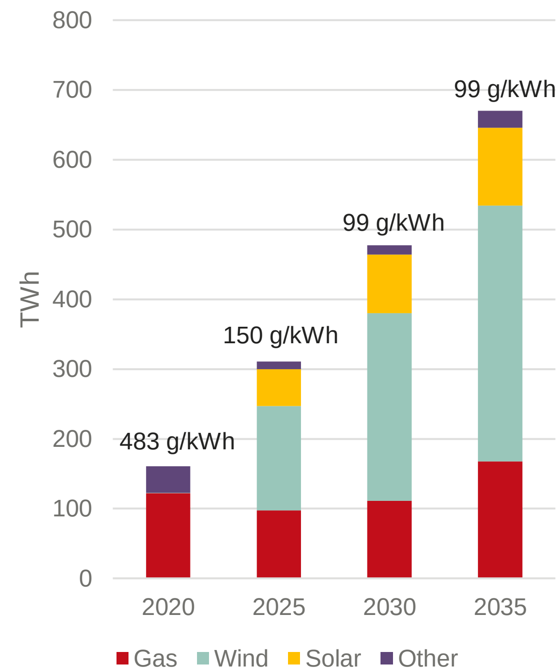
It will, furthermore, become possible to reduce the emissions from the extra electricity production, even more, for a small additional cost – either by a higher quota price or RES support.

A certain amount of gas is still needed to cover the "gaps" in the production from wind and PVs, even though storage, flexible consumption, and transmission will reduce this need over time.

The extra consumption results in investments which will affect the operation of the rest of the electricity system. The result will be that the total amount of extra emissions, compared to the extra consumption, will be 483 g/kWh in 2020 and 99 g/kWh in 2035

Even the 2020-level is smaller than the 600 g/kWh which are displaced by electrification, while the 2030-level is six times smaller.

Electrification is Fulfilled by RES Extra Production from Increased Consumption



Note: Change from EU REF2016 (+0.56 % p.a.) to Eurelectric 3 (+2.1 % p.a.)

Electrification Is Crucial to Climate Actions

CO_2-reduction is largest from electrification

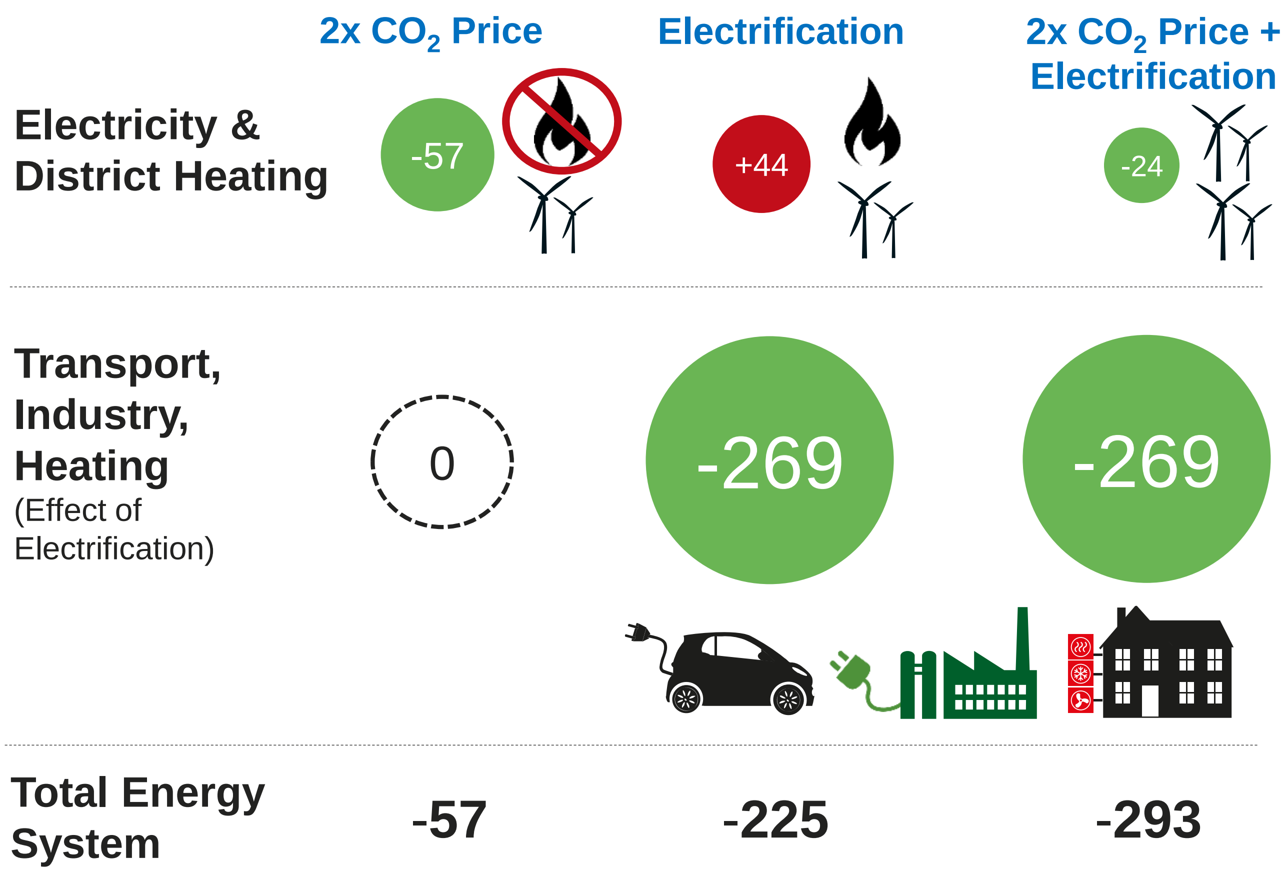
The analysis shows that a higher quota price is an important measure, but electrification is crucial for achieving the largest potential of CO_2-reductions.

A higher price on CO_2 alone will result in large emission reductions in the electricity sector, while electrification will lead to higher emissions in the sector, due to increased consumption. Combining the two effects, a small net reduction is achieved (since the increased quota price affects a larger electricity use).

However, the effects in the electricity system pale in comparison to the effects of electrification in the rest of the energy system. Here, green electricity will replace natural gas and oil through electric cars and heat pumps. Electrification with an elevated consumption of about 450 TWh can achieve 269 Mton CO_2 displacement outside the electricity sector.

It is important to stress that even with increased emissions in the electricity system (44 Mton), a huge net CO_2-gain (225 Mton) will be obtained. In 2030, new consumption due to electrification will displace much more CO_2, than emissions resulting from production of this extra electricity.

Changes in CO_2 Emissions Compared to The Reference Scenario in 2030 (Mton CO_2)



Transmission Lines Are Primarily Beneficial to Wind Power

Wind and cables knock gas out of the park

Transmission contributes to the establishment of more wind power for two reasons.

Firstly, it opens up the possibility of exporting wind power from regions with high potential for cheap wind power, such as Norway and Sweden.

Secondly, the cables facilitate balancing of electricity generation from wind across large distances. Transmission makes it possible to use these fluctuations and move production to countries where it can displace expensive alternatives and thereby gain higher value.

These two effects are not as efficient for PVs, where the production costs are much less dependent on geography (within Northwest Europe), and production trends are very similar (summer appears at the same time across Northwest Europe).

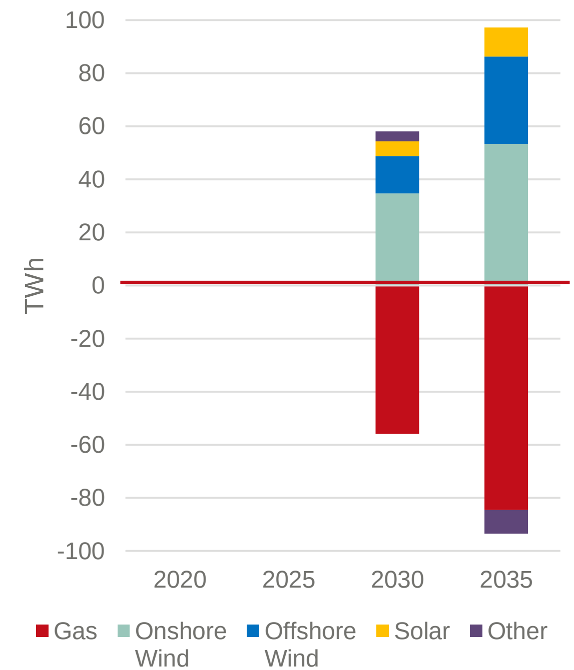
It takes a long time to realise transmission projects due to comprehensive approval processes by authorities. The model therefore only allows investments in extra capacity from 2030 onwards, if the connections are feasible.

The model chooses to invest in significant amounts of transmission capacity, which results in additional wind power production of 50 TWh in 2030 (on top of the 1000 TWh in the reference scenario). The extra production is primarily used in the displacement of power from gas.

Need for new grid planning

There is a clear synergy between the deployment of wind power and transmission, which benefit from each other. Due to this reason, they should be analysed together. This has not been the case historically, for example with the European TSOs. Every year the organisation ENTSO-E releases a grid development plan (TYNDP) with recommendations about which connections should be prioritised. The analysis is based on a fixed assumption about RES capacity, which leads to a risk of creating self-fulfilling scenarios since the grid is dimensioned to fit a specific amount of RES, which will limit further deployment.

Changes in the Electricity Production from Extra Transmission from 2030



Batteries Mainly Benefit PVs and Can Fulfil Peak Load

High value in reliability

To ensure electricity supply 100 % of the time, reliable capacity is needed. This has historically been provided by power plants and will continue being the case in the coming years.

Storage, initially batteries, will begin to challenge and take over an increasing part of this need. Even a few hours of storage can make batteries help supply peak loads in the electricity during winter evenings. As such, building gas turbines and diesel engines can be avoided.

Today, batteries play an increasing role in delivering system services, due to their good regulation skills. However, the market for delivering reliable capacity is much larger. Batteries will also contribute to the reduced need for grid strengthening and can potentially be available from parked electric cars.

Another advantage of batteries is their relatively short installation time, which is measured in months, compared to years in the case of power plants.

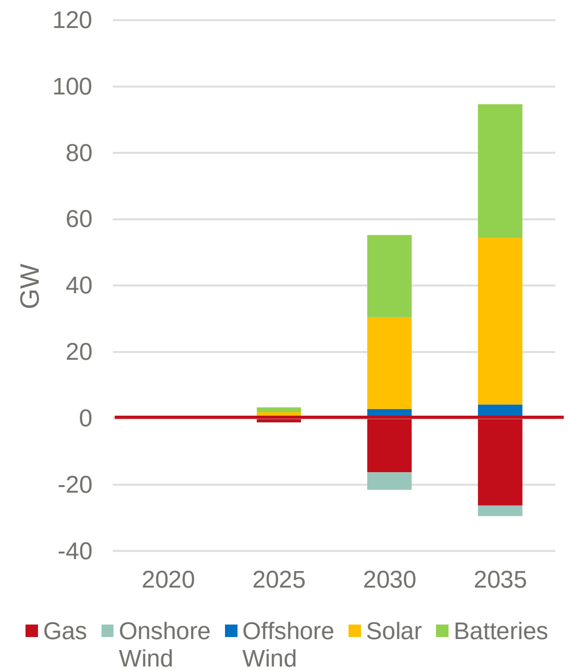
Using Li-ion battery costs from the Danish Energy Agency's Technology Catalogue, the model chooses to invest massively in battery storage from 2030 (25 GW) and even more until 2035 (40 GW).

A good match with PVs

Due to their limited discharge period, batteries are a better match to the daily fluctuations of the power generation from PVs rather than the longer duration of fluctuations in wind power.

Batteries complement PVs so well that an additional 28 GW PV is established in 2030, while only a few changes are seen in wind power investments. The biggest loser becomes gas-fired electricity production, which sees a decrease of 16 GW.

Changes in Capacity Investments in the Battery Scenario Compared to The Reference Scenario



Note: Accumulated differences in capacities.

Long-Term Storage Can Supplant New Gas Power

Moving towards a pure RES electricity system

Batteries have a low capacity cost (kW) but a high storage cost (kWh), so are only viable when their discharge period is relatively short. They can therefore only satisfy the very peak of electricity system load. Other types of storage are being developed, with a much lower price per stored kWh (e.g. high-temperature heat, compressed air, and hydrogen). We have looked into the influence of a breakthrough in one of these.

With the opportunity for long-term storage (50 hours of storage and 50 % efficiency), the model chooses to invest extensively in this technology (20 GW). Long-term storage mainly substitutes gas power plants, which the model totally leaves out, and causes a slight decline in battery (10 GW reduction).

These results assume that it is possible to build and operate long-term storage at costs comparable to an efficient gas-fired plant. Due to the high amount of wind and PV, and resulting high fluctuations in future electricity prices, long-term storage will be able to buy electricity at a cost lower than gas, including CO_2 costs.

While the price of gas (incl. CO_2) is about 38 EUR/MWh (3 kr./m^3), the average cost of electricity purchased for storage is 24 EUR/MWh. Storage can produce cheaper electricity, which can be sold in hours of high prices, compared to a gas power plant, despite the efficiency of the storage being lower. Despite constraints in the operation time, this provides improved profits.

A good match for wind power

While batteries complement PVs, long-term storage complements wind, since charging can occur during long periods with high wind and electricity can be provided during periods of low wind.

Long-term storage contributes to 70 TWh of additional wind capacity in the model region, which is more than capacity resulting from transmission. However, fewer fossil fuels are displaced due to energy losses in the storage units.

Comparison of Key Gas Power and Long-term Storage Data in 2030

Technology	CCGT Gas	Long-term Storage
Depreciation EUR/MW/yr	74,000	67,000
Fast O&M EUR/MW/yr	35,000	16,000
Variable Costs EUR/MWh	63	48
Efficiency	60 %	50 %
Max. Operating Time timer	-	50

Note: Variable costs are made up by CO_2- and energy purchases as well as variable operation costs

Financing Costs are Critical to RES Projects

Market conditions bring bigger risks

Financing costs have not been varied in the three main scenarios, but the parameter has a great influence on deployment of RES.

With the transition towards deployment under market conditions (no support), the need for venture capital which can finance projects with uncertain returns increases.

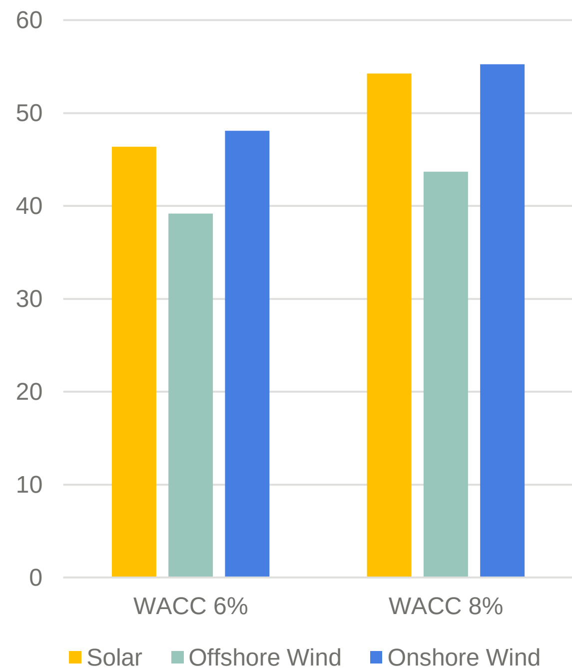
All results in this Outlook assume a 6 % real WACC and a 25 years depreciation period. However, what happens if the business requirements rise to 8 %?

Increased capital costs reduce competitiveness of capital-heavy technologies, such as wind and PVs, against gas. The change in return corresponds to an increase in investment costs of 20 %.

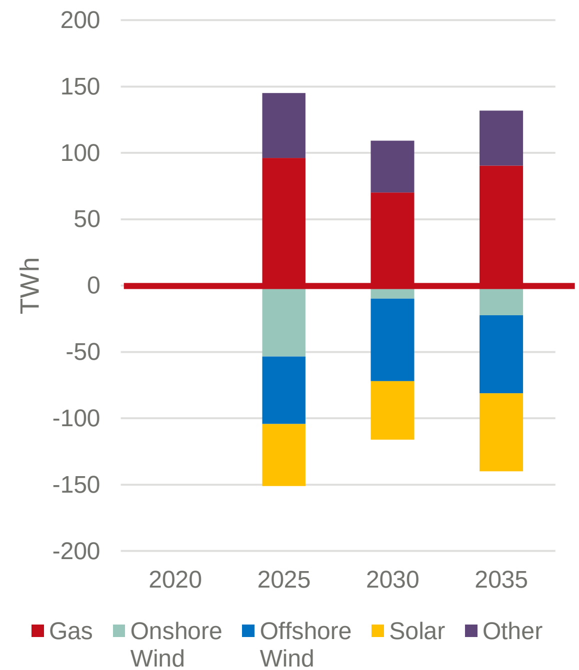
As illustrated by the figure, a higher WACC results in a reduced amount of wind and PV by 100-150 TWh, and reduced displacement of gas. The change corresponds to postponing the green transition by a few years.

PPAs can help to solve this problem, as described in the topic chapter.

LCoE of Wind and PV in 2025



Change in Total Production with 2 % Higher WACC



The Effect of Different Drivers on RES Deployment

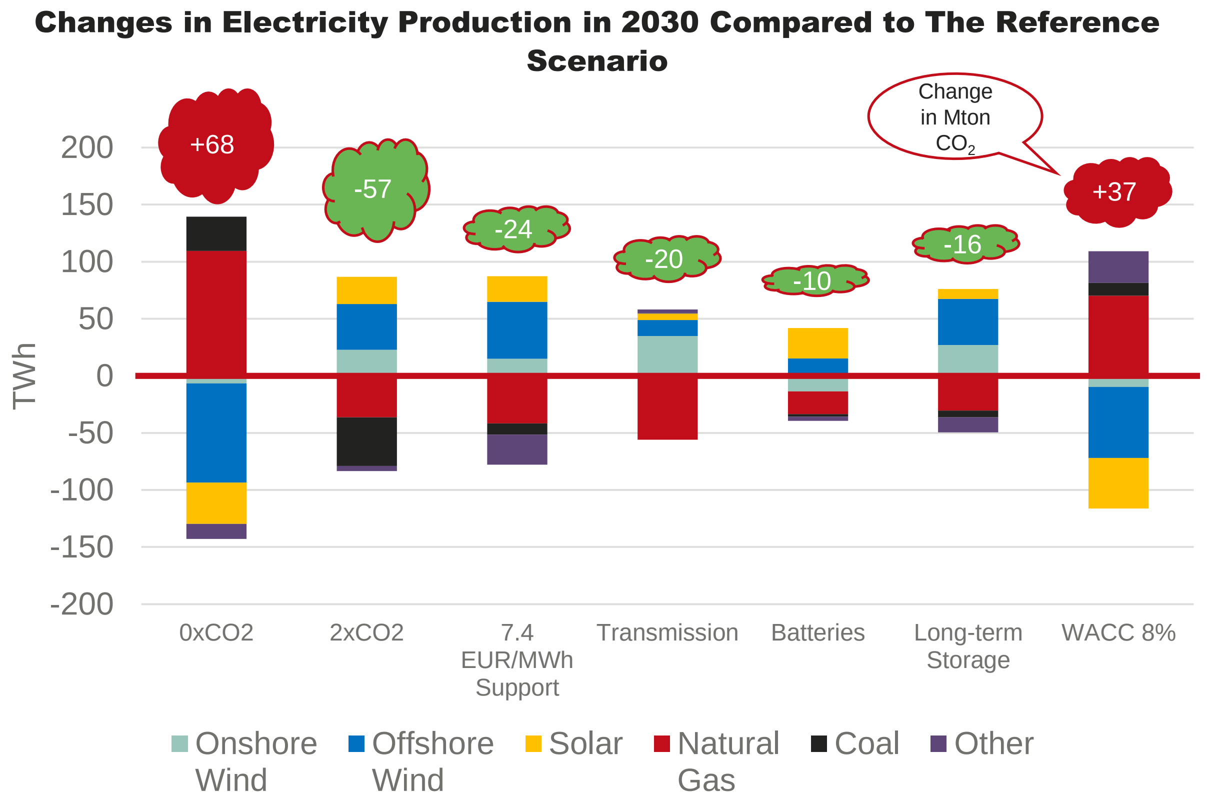
Summary of all scenarios

The figure shows the differences in electricity production in the scenarios relative to the reference scenario.

The CO_2-quota price strongly influences which technologies are implemented. The absence of CO_2-cost results in more electricity production from fossil fuels and less from RES, and vice versa. Subsidising wind and PV with 7.4 EUR/MWh has the same effect on RES production as doubling the quota price. However, the replaced electricity production is much less CO_2-intensive.

Transmission is good for wind, while batteries are good for PVs. Long-term storage has an even larger impact, mainly for wind, but also for PV. However, fossil fuel displacement is slightly reduced due to energy losses in the storage units.

Calculations with higher financing costs (8 % real WACC over 25 years, instead of 6 %) reduces the competitiveness of capital-heavy RES technologies and increases production from natural gas in particular.



Note: More/less production are not totally consistent across the scenarios, since the amount of electricity production used in heating and lost in storage are different.

The clouds show the change in Mton CO_2 emissions compared to the reference scenario.

6. Appendix

References

IPCC, 2018	https://www.ipcc.ch/sr15/
ITRPV, 2018	http://www.itrpv.net/Reports/Downloads/
Svensk Vindenergi, 2018-3	https://svenskvindenergi.org/wp-content/uploads/2018/11/Statistics-and-forecast-Svensk-Vindenergi-20181024-1.pdf
EEG	https://www.erneuerbare-energien.de/EE/Navigation/DE/Home/home.html
JRC	http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php#
Agora/Sandbag 2019	https://sandbag.org.uk/wp-content/uploads/2019/01/Sandbag_European-Power-Sector-2018.pdf
LBL, 2018	https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2018_edition_slides.pdf
EU-2050	https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en.pdf
EU REF2030	https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf
Eurelectric, 2018	https://cdn.eurelectric.org/media/3457/decarbonisation-pathways-h-5A25D8D1.pdf
IEA WEO, 2018	https://www.iea.org/weo2018/
Wind Europe	https://windeurope.org/wp-content/uploads/files/about-wind/reports/Wind-energy-in-Europe-Scenarios-for-2030.pdf
ENS Tek.kat.	https://ens.dk/service/fremskrivninger-analyser-modeller/teknologikataloger
Energinet, 2015	https://energinet.dk/Analyse-og-Forskning/Analyser/RS-Analyse-Januar-2015-Potentialet-for-landvind-i-2030
E3M	https://ec.europa.eu/energy/sites/ener/files/documents/2018_06_27_technology_pathways_-_finalreportmain2.pdf
IRENA	https://www.irena.org/ourwork/Knowledge-Data-Statistics/Data-Statistics/Capacity-and-Generation/Statistics-Time-Series
TYNDP-18	https://tyndp.entsoe.eu/tyndp2018/
EEA, 2008	https://www.eea.europa.eu/publications/europes-onshore-and-offshore-wind-energy-potential

Fuel and CO_2 Costs

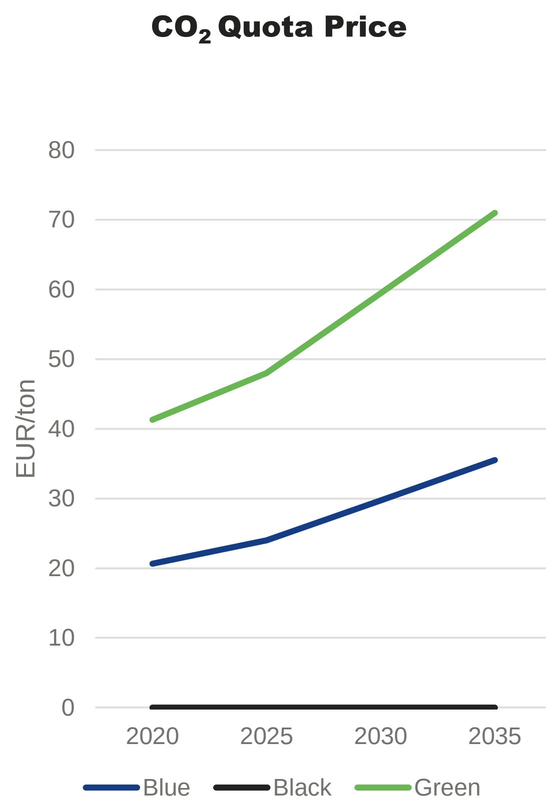
CO_2 quota price

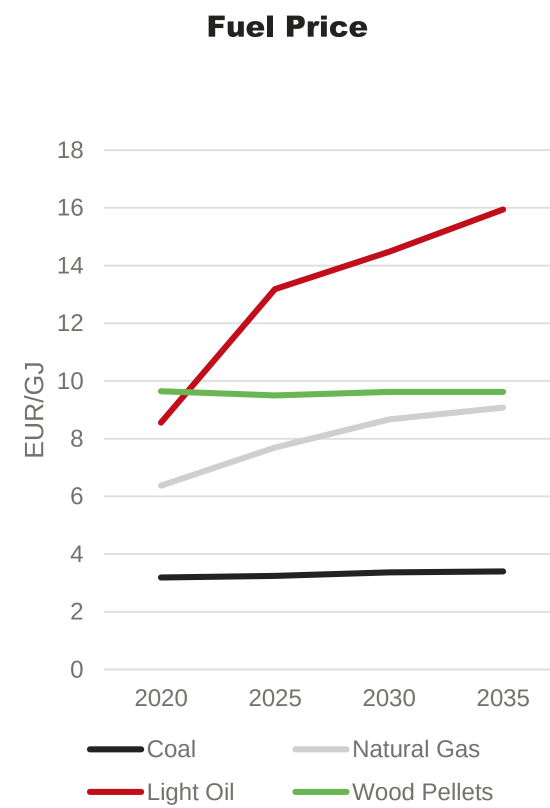
The price of CO_2 quotas in the blue scenario is taken from the WEO2018 New Policies' scenario, with an assumed price of 20 EUR/ton in 2020. This is consistent with today's prices. The price in the green scenario is twice the price of the blue scenario, while the price in the black scenario is 0 in all years.

Fuel price

Fuel prices are taken from the WEO2018 New Policies' scenario and are the same in all three scenarios analysed in this Outlook. In addition to the fuel price, the Energy Agency's fuel price surcharge for central power plants is added.

The cost of biomass is taken from the Energy Agency's latest version of the assumptions for socio-economic calculations.





Source: WEO18 New Policies, ENS

Assumptions in Balmorel

Balmorel

The RES Outlook is calculated based on Danish Energy's version of the Balmorel model.

The Balmorel model is an advanced optimisation model, which minimises the total costs of production of electricity and district heat. For more information go to www.balmorel.com.

Capacity

The power plant capacity in the model region is based on Platt's database for existing thermal plants in Northwest Europe. The lifetime of existing plants is set to 45 years, 30 years, and 20 years for steam turbine, gas turbine, and engine facilities respectively, after which they are removed from the model.

The model does not have the functionality to decommission plant for economic reasons.

The phase-out of nuclear power is based on latest political announcements.

Renewable Energy

Minimum wind power and PVs deployment is applied until 2035 based on WindEurope's central scenario (only until 2025 in the black scenario).

The development of RES capacity in Denmark follows the Energy Agreement from 2018. Further investment can be made under market conditions.

Investments

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

- OCGT gas
- CCGT gas
- Diesel peak load plant
- Wood pellet steam turbine plant
- Onshore wind
- Offshore wind
- Large-scale PV
- Li-ion batteries
- Long-term electricity storage (50 hours)
- Transmission lines

Capital costs in all countries are calculated using a WACC of 6 % real interest rate and a 25 years depreciation period.

Investment costs and O&M costs are based on DEA's Technology Catalogue.

Electricity consumption

Electricity consumption varies between scenarios. In the black scenario, it is constant throughout the whole period, based on historical data for each country in 2016. In the blue scenario, consumption increases by 0.56 % p.a., as per the EU's base scenario (EU203). In the green scenario, it increases by 2.1 % p.a., corresponding to the increase in Eurelectric's high-electrification scenario (sce. 3).

For Denmark, the same development is assumed as in the base projection in 2018.

Electric cars account for a share of the increase in consumption, but have a different consumption pattern from classical electricity consumption.

Transmission

Electricity transmission capacities between countries are based on ENTSO-Es TYNDP 2018. Since a number of the planned cable projects are uncertain, a further individual assessment of the projects has been carried out.

RES Potentials

Onshore wind

Germany has been used as the baseline with a potential of 80 GW of onshore wind. Based on the technical potentials of EEA's potential report from 2018, the other countries' potentials have been scaled to the 80 GW potential assumed in Germany.

Due to special conditions on approval and limits on grid expansions, annual deployment rates have been limited to 2 GW in the UK and 1 GW in Norway.

In Denmark, the potential has been set to 5.6 GW as a result of the limited number of onshore turbines in the Energy Agreement

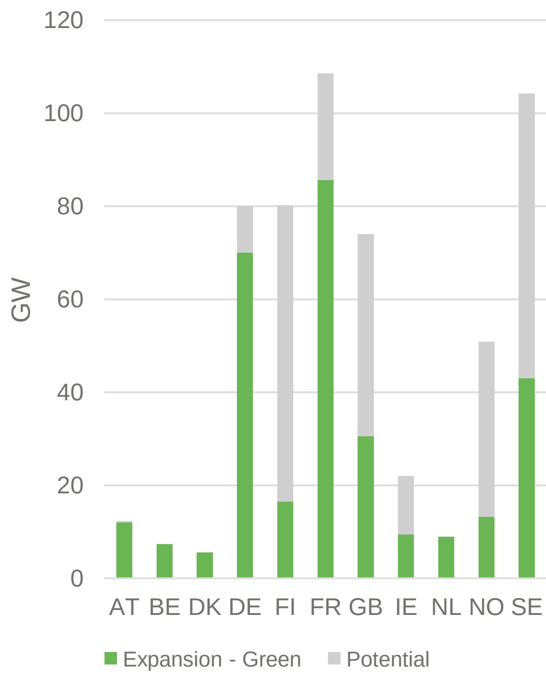
Offshore wind

Offshore wind potentials are divided into three categories according to the distance to the coast. The nearshore, offshore, and far-offshore categories have different construction costs, which increase with distance to land. For each country, the potential has been assessed in the three categories. The far-offshore potential is especially large.

PV

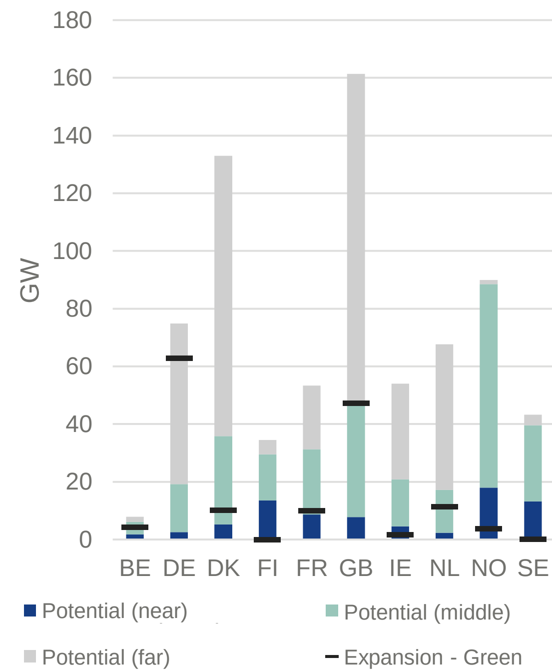
An unlimited potential of solar has been assumed.

Onshore Wind Potential



Note: The deployment rate in Norway and Great Britain is limited.

Offshore Wind Potential



Note: The deployment is shown for 2030.

Physical Causes of wind and solar remuneration

Windy winters and sunny summers

Three physical factors determine the clearing of wind and PV compared to the average electricity price: season, day, and quantity effects.

Summer is the sunniest time of year, while winter is the windiest. Since electricity consumption is highest during winter, wind power matches consumption throughout the year better than PVs.

Advocators of PVs typically point out the good match between production and consumption in the middle of the day. This correlation exists and has resulted in high market value of PVs, above the average electricity price. This effect is, however, quickly offset by the quantity effect, caused by increased PV capacity in the system.

The figures indicate how big a share of the yearly production takes place every month/hour. As shown in the hourly variation figure, an electricity system with 100 % solar cells will overproduce in the middle of the day. In addition, this shows how a possible positive match for consumption can be cancelled out by the capacity effect, since additional expansion of wind and solar will cause the remuneration to fall under the average in hours with high production.

Modern wind turbines, with more evenly distributed production, have an increased share of the production in the summer season, which better matches consumption on a monthly basis.

During the summer, wind turbines produce the most power during the afternoon when hot, ascending air from land draws extra wind from the sea, thereby increasing production from the large number of turbines located along the coast.

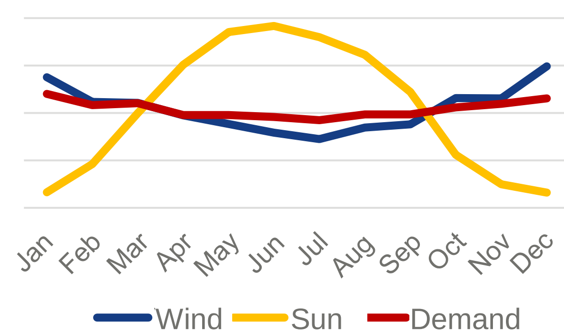
Solar production peaks when the sun is highest in the sky, around 1 pm during the summer.

An optimal split?

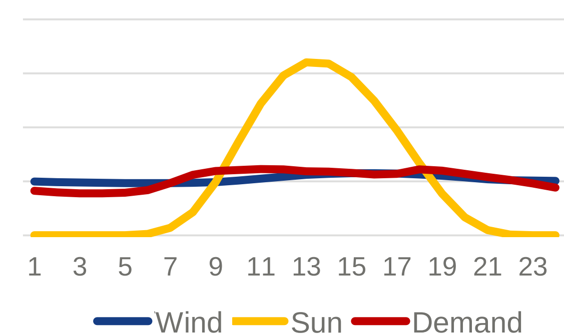
The season effect dictates that in a system based on power from wind and PVs, wind power should fulfil the largest share consumption. The share covered by PVs depends, to a large extent, on the relative costs between wind and PV, as well as how well distributed wind power production is throughout the year.

Research from the University of Aarhus has previously shown that the optimal ratio between wind and PV capacity is 80:20. However, this depends on the relative cost, and the numerous paths to this outcome from the current 40:5 ratio.

Seasonal Variation – Denmark



Hourly Variation – Denmark

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