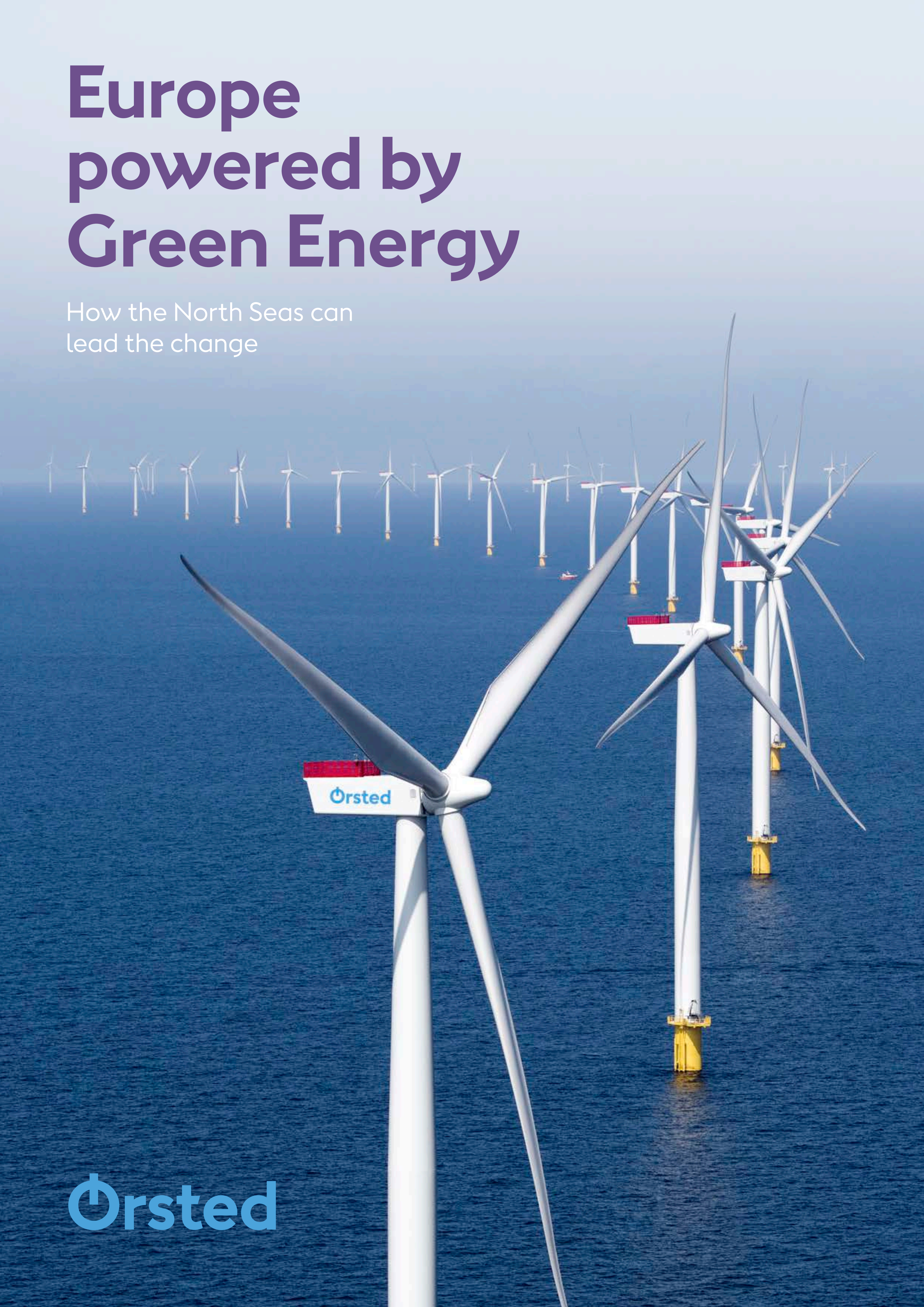
Europe powered by Green Energy

How the North Seas can lead the change



Ørsted

Executive summary: A Europe powered by green energy

In 2017, renewable energy reached a breakthrough in Europe, when it became cheaper to install offshore wind power than to build new fossil-fuel based power plants.

This is a remarkable achievement on its own. It confirms that it's economically viable to build a European economy that runs on green energy. And this is vital if Europe is to meet its commitment in the Paris Agreement to limit global temperature increases to 2 degrees above pre-industrial levels by 2100, while striving towards 1.5 degrees.

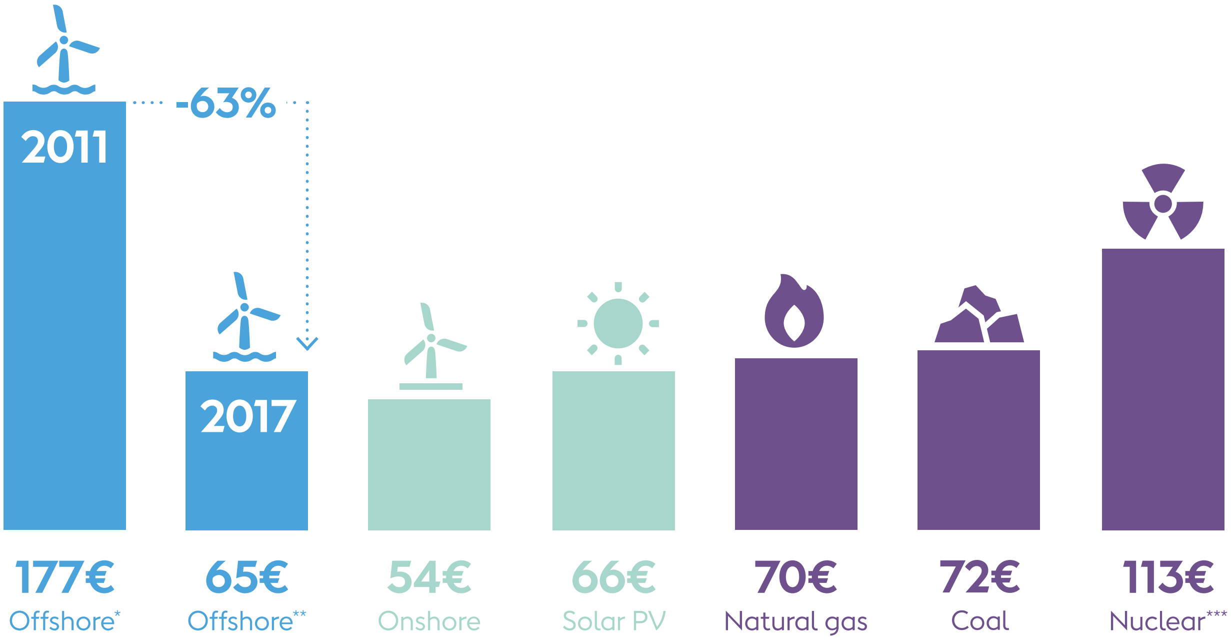
It also means that the focus of debate in this important arena is now shifting from "how much green energy can we afford?" to "what type of green transformation do we want to see and what framework can enable it?"

Together with onshore wind and solar power, offshore wind power can become the backbone of Europe's green transformation. In the North Seas – in which we include The North Sea, The Baltic Sea and the Atlantic Ocean around France, Ireland and the UK – Europe sits on some of the best offshore wind resources in the world. It's an immense and untapped potential that can supply energy equal to the maximum production of Europe's existing coal and lignite-fired power plants two times over, and lay the foundation for transforming energy demand through electrification of transport, heating and industry.
To realise this potential, governments should aim to construct a framework where green energy investments are driven by the market, allowing competition between private investors and developers competing in both planning and realising new renewable plants, including offshore wind farms.

Four principles could help guide our thinking about how such a framework should look for offshore wind power: strong **carbon pricing, collaboration** between countries, **competition** for the full scope of projects, i.e. by including transmission assets, and finally **confidence** in Europe's ability to set ambitious goals and reach them. We call them the four C's.

The cost of offshore wind energy has fallen 63% in six years

Cost of offshore wind energy compared with other sources[1]
EUR per MWh (2016 prices), year of FID



1. Bloomberg New Energy Finance (BNEF) for sun, CCGT and Coal plants for Northwest Europe, Danish Energy Agency and BNEF for onshore wind. For offshore wind: Including cost of transmission – Calculated as Levelised revenue (subsidy and market price) of electricity over 25yrs lifetime as a proxy for the levelised cost to society. 3.5% real discount rate used. *West of Duddon Sands, UK ** Hornsea 2, UK *** Hinkley Point, UK – Same approach as for Offshore Wind. Strike price of GBP 92.5 per MWh in 2012 real prices. Lifetime of 60yrs, 91% capacity factor.

The dream has become reality

Since 2007, Europe has pursued its stated ambition to transform itself into a low carbon economy. The EU's greenhouse gas emissions were to be reduced by 80-95% by 2050, compared to 1990. The Paris Agreement will require even more ambitious targets.

Change is happening. The share of green energy in Europe has increased from 11% in 2007 to 17% in 2016[2].

This development is driven primarily by changes in the European power sector. In 2016, for instance, 86% of new generation capacity installed in Europe was renewable[3]. Even so, carbon reductions are not happening fast enough in the power sector. In 2016, for instance, almost half of European power production came from fossil assets.

In other sectors such as transport, industry and buildings, respectively making up 34, 18 and 16% of energy related emissions in Europe[4], change is even slower. With the current pace, it will prove difficult to reach the EU's carbon reduction target for 2050.

However, in recent years, something remarkable has happened in Europe, which has implications for the whole world: new-built green energy became cheaper than new-built black energy. For the first time in history, utility scale wind and solar power can outcompete coal and natural gas in power generation across many European countries.

Wind and solar energy have become less expensive as a result of large scale deployment and as a result of a period of great political push for renewables. Renewable energy targets and economic support from governments have provided the necessary scale and clarity on buildout ambitions. This allowed the green energy industry to take up the challenge, to invest, invent and bring down costs.

This also goes for offshore wind, a technology which until a few years ago was largely unknown or regarded as rather exotic and costly by policy makers and the public.

But the unprecedented recent cost reductions have changed all that. In 2012, the industry promised to drive costs for contracted wind farms below EUR 100 per MWh before 2020. This goal was reached and surpassed well ahead of time – costs of energy actually dropped to EUR 65 per MWh in just six years.

For example, in 2011, Ørsted committed to building West of Duddon Sands wind farm in the UK, with a projected cost of electricity of EUR 177 per MWh. Six years later, in 2017, we committed to building the Hornsea 2 project with an expected cost of energy of only EUR 65 per MWh – equal to a 63% cost reduction.

In Germany (April 2017 and April 2018) and in the Netherlands (March 2018), where transmission costs are excluded from the projects, contracts were granted without subsidies at all.

2. Eurostat, Share of energy from renewable sources in gross final consumption of energy 2004-2016
3. EEA, Renewable energy in Europe — 2017 update. 4. EURELECTRIC, Decarbonisation pathways European economy.

Offshore wind power is now among technologies that offer cost effective and scalable renewable energy, alongside onshore wind and solar power. This development has enormous potential to change Europe's energy system, by turning the seas into green power plants. Rapidly falling cost means renewable energy offers a foundation on which Europe's green economy can be built.

Abundant, domestic and cost efficient renewable energy offers the key to many of the societal ambitions of European countries. A key to maintaining a modern and competitive economy; a key to Europe continuing to take on its global responsibility and combat climate change; a key to a Europe less dependent on imported fossil energy and a key to reducing the negative health and environmental impacts of burning fossil fuels.

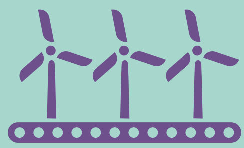
Several renewable technologies are already contributing to Europe's energy system and will play a role going forward. Of these, none today offer both the scalability and cost-efficiency of solar, onshore and offshore wind power to sustain an accelerated transformation and become the backbone of the European energy system. In 2017, these three alone made up 77% of new European power generation capacity[5].

By 2040, European power production from solar, onshore and offshore wind is expected to grow by 190% compared to today, whereas other renewable sources are projected 35% growth[6].

Development on the scale required, however, depends on a strong and open transmission grid to integrate and transmit the energy to European consumers.

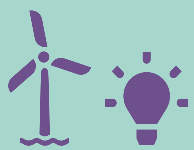
What made offshore wind energy cheaper than black energy

Several factors have contributed to the reducing costs of offshore wind energy, including:



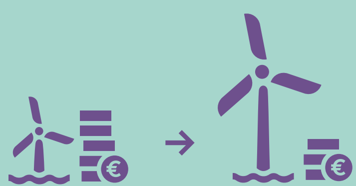
Industrialisation

Clear and ambitious national plans for buildout allowed for industrialisation in every part of the supply chain. This enables economies of scale, with standardisation and procurement for multiple projects simultaneously, and execution excellence, thus bringing down the cost per unit.



Innovation

Research, development and the drive for improvement has resulted in cheaper, more efficient and durable components, and in new methods of production, maintenance and means of transportation and installation. And digitalisation, with enhanced sensoring, better modelling and real-time monitoring, has made offshore wind power more easily integrated into the energy system, thus creating more value for the supplied energy.



Scale

Both turbines and farm sizes have grown significantly, yielding more production per turbine and hence producing at a lower cost of energy. For instance, the largest turbine commercially available has grown from 3,6MW (2010) to 8,8MW (2018), and within a few years it will reach 12MW and more. Likewise, the world's largest offshore wind farm has grown from 300MW (2010) to 630MW (2013) and by 2022 Hornsea 2 will reach 1386MW.

5. Wind Europe, Wind in Power 2017
6. IEA, World Energy Outlook 2017 (NPS)

There are, however, important differences between these three types of renewable energy: solar, onshore and offshore wind power.

Solar is abundant, especially in Southern Europe. But the production from Europe's more than 100GW of photovoltaic panels is focused around peak sunlight hours at noon and in the summer months, whereas energy in Northern Europe is needed most in the evenings and during the dark and cold winter months.

Of all the energy sources, onshore wind power is the cheapest when installed on good and windy sites[7]. And with more powerful winds blowing in the winter months, both onshore and offshore wind power fits the demand profile of Northern Europe. But with more than 150GW of onshore wind power installed, further buildout is often hindered by space limitations and local opposition to visual impacts and noise emission in typically densely populated Europe.

Offshore wind power, with 16GW installed in Europe today, is not limited by space restrictions. And since the wind blows stronger at sea, a higher amount of energy can be produced per turbine. The so-called capacity factor (measuring the actual output as a share of total output capacity over a period of time) is in some cases twice that of onshore wind power. It also means offshore wind generation feeds electricity into the grid more often, as offshore winds blow more consistently. For example, the total fleet of offshore wind farms in Denmark generates electricity 98% of the time[8].

This makes a compelling case for an ambitious buildout of offshore wind power. It can provide a domestic, renewable and affordable energy source for an increasing share of European energy consumption.

Furthermore, it would consolidate Europe as the centre for a global industrial complex, with offshore wind energy encompassing a significant proportion of the more than 260,000 Europeans who, according to Wind Europe, are either directly or indirectly employed in the wind energy sector[9].

Already today, offshore wind is revitalising coastal areas around the North Seas, that have suffered from years of economic decline. Offshore wind creates local jobs, e.g. in constructing and operating port facilities, building turbine components and foundations and in the construction of wind farms and transmission lines. And as offshore wind farms are built to last 25 years or more, each wind farm is a long-term engagement, creating local and regional jobs in operation and maintenance for many years.

7. Danish Energy Agency and BNEF
8. Energinet
9. Deloitte for Wind Europe, Local impact, Global Leadership

Renewable energy technologies

Many technologies will be part of the future energy system. A strong and complementary energy system requires a mix of the available solutions, which, aside from solar, onshore and offshore wind power, includes:

Hydro power is a major component of European green energy supply and will continue to be so, particularly in balancing variable wind and solar power. But the natural potential has largely been exploited and public concerns and regulation to protect biodiversity makes it hard to see hydro contributing with much higher volumes. The existing hydro will instead play an increasingly important role as a balancing resource.

Biomass, sourced on strict sustainability criteria, is now an immediate way to phase out coal on combined heat and power plants especially in colder Northern Europe, and provider of flexibility. In the long run, the power and heating sectors will also be linked by electrification, replacing combustion with electricity in heating, as well as in transport and industry.

Biogas and advanced biofuels from organic waste can be used for power and heat generation or as green fuel in the transport sector. This reduces the need for landfills or waste combustion while making the most of society's resources. Bioenergy is, and will remain, an important source of energy.

Heat pumps hold great potential for heat generation from renewables, both by extracting renewable heat from natural heat sources, and from using renewable electricity in the operation. They'll also act as an integrator of the power and heat sector.

Battery power storage is a promising technology, especially for balancing the electricity grid and for shaping the electricity demand, e.g. from minute to minute and between day and night.

Other storage technologies and energy carriers are available as well, such as power-to-hydrogen, enabling long term and grid sized storage and an alternative route to decarbonisation for some sectors, such as in industry. Where economically feasible, these hold great potential for storage, as well as for sector coupling between renewable power sources, such as wind and solar power, and the existing gas infrastructure.

Other technologies are being developed but are still not cost competitive on a European scale. Geothermal energy and grid sized hydrogen fuel cell applications are examples.

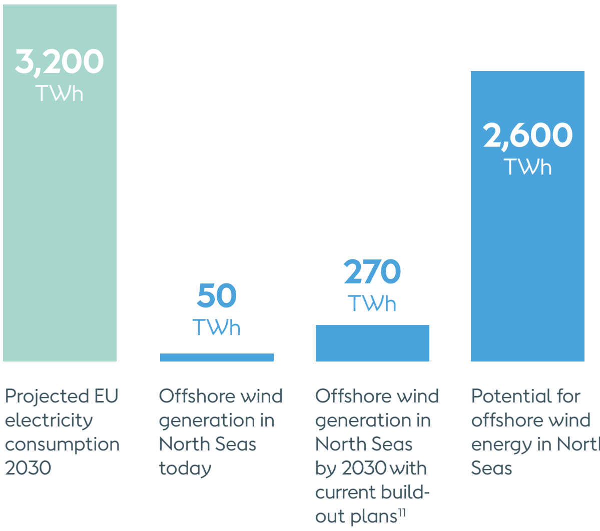
The North European potential

Europe sits on one of the world's best offshore wind resources – the North Seas. Here, wind speeds are high, relatively constant and the waters are shallow, providing good conditions for bottom fixed foundations.

For decades, the North Sea has provided Europe with oil and gas. This lowered our dependence on imported oil and created jobs and economic growth. This era is coming to an end. However, the North Seas can continue to be a major power hub for Europe, now by providing green energy.

A 2017[10] study of the space utilisation, technology costs and seabed and wind conditions in the North Seas concludes that by 2030, offshore wind in the North Seas could supply approximately 80% of Europe's existing electricity demand at a maximum cost of EUR 65 per MWh. In total, this would entail 607GW of offshore wind power in the North Seas, of which around one seventh is in the Baltic Sea, two sevenths in the Atlantic Ocean and the rest in the North Sea. This is the economically viable potential. Today, less than 4% of this potential is utilised.

The North Seas can supply 80% of European electricity demand



Though it's gradually changing its power mix, Europe still relies on coal for a large share of its electricity. Today, coal, gas and nuclear power makes up 23%, 23% and 22% of European electricity generation, respectively. By 2030 this will fall to 14%, 18% and 22% under current policies[12]. A lot of coal or lignite fired power plants will have to be replaced by renewables, if Europe is to have any chance of meeting its existing CO_2 targets.

Offshore wind can replace a large part of coal-based generation. In fact, the total potential for economically viable wind in North Seas can supply energy equalling the maximum production of all existing coal-fired power plants in Europe – two times over.

How much of the potential we can realise will ultimately depend on the transmission grid, the regulatory framework and market conditions. As for solar and onshore wind, a grid is required to transmit the offshore wind power to consumers across the continent. Nonetheless, the potential of offshore wind is enormous.

In sum: The North Seas has a large untapped potential. If harnessed, offshore wind can provide abundant and green energy, at prices lower than fossil energy. This can help Europe overcoming its dependence on imported energy and to honour the goals of the Paris Agreement – all while providing coastal regions across Northern Europe with well-paid jobs.

10. BVG Associates for Wind Europe. 11. Current political goals and announcements in key markets equals about 50GW additional capacity, capable of generating 220TWh per year at 50% capacity factor.
12. IEA, World Energy Outlook 2017 (NPS).

European offshore wind energy potential equals twice the capacity of all European coal fired power plant[13]

The North European seas holds the potential to generate 2,600 TWh of electricity per year. This corresponds to the total power production capacity of all coal fired power plants of Europe – two times over.

2,600TWh

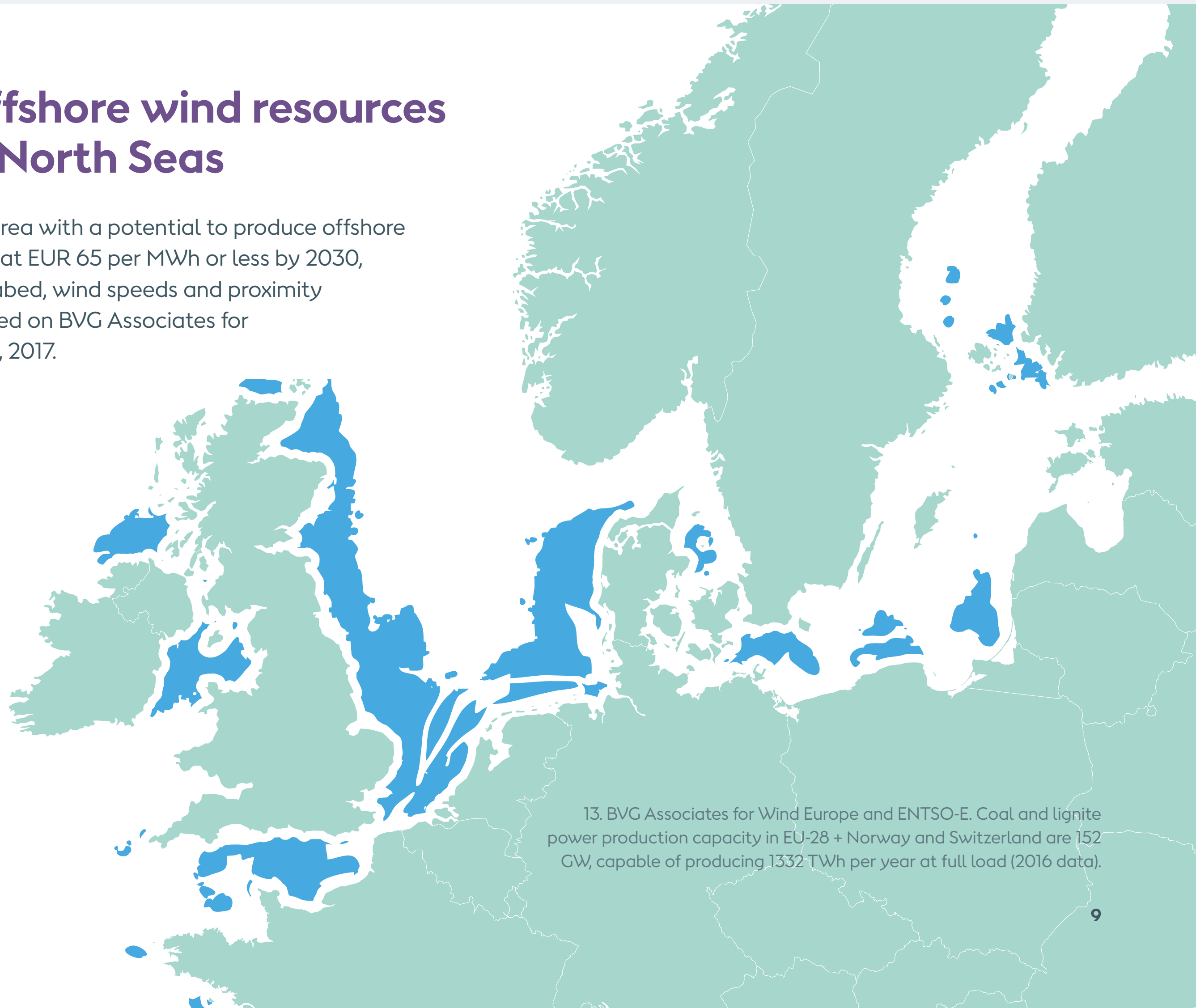
Economically viable offshore wind energy potential by 2030 (EUR 65 per MWh or less)

1,332TWh

Maximum annual production from all European coal fired power plants (2016)

The offshore wind resources in the North Seas

Map of sea area with a potential to produce offshore wind energy at EUR 65 per MWh or less by 2030, based on seabed, wind speeds and proximity to ports. Based on BVG Associates for Wind Europe, 2017.



13. BVG Associates for Wind Europe and ENTSO-E. Coal and lignite power production capacity in EU-28 + Norway and Switzerland are 152 GW, capable of producing 1332 TWh per year at full load (2016 data).

What will it take to tap the green energy of the North Seas?

How do we realise the full potential of the offshore winds of the North Seas at the lowest cost as quickly as possible while ensuring reliability?

To begin with, it will require an updated approach. Until now, the buildout of offshore wind has been the result of a discussion about how much renewable energy we can afford and dependent upon national planning and the allocation of sites and subsidies.

Now that green energy has proven to be cheaper than black – and with the need to drastically accelerate the green transformation to limit climate change – this approach and our focus must change. We need to change the conversation in order to identify and agree upon the principles on which future policy can be built.

We suggest these four as a starting point for this new conversation:

1. **Carbon pricing as a driver for investments**
2. **Collaboration between countries and regulators**
3. **Competition for full scope of projects**
4. **Confidence that the green transformation is possible**

1

Better carbon pricing

Offshore wind energy is moving closer to the market prices of electricity. While this is great news for the green transformation, incentives are still needed to promote investment in renewables and to decommission fossil generation assets.

Renewable developers and financiers need long term visibility of electricity prices. This means the buildout speed and cost of offshore wind energy is affected by political factors, e.g. by the way market for energy is designed, as well as the price on CO_2 emission allowances, as determined by the European Emissions Trading Scheme (ETS). Factors that can increase stability and long-term visibility for investors include:

Increased EU carbon reduction target

To have a fair chance of limiting the global temperature increase to less than 1.5 degrees by 2100, European carbon emissions needs to be reduced by more than 95% by 2050.

Given the cost reductions in renewable energy, increasing the European carbon reduction target to at least a 45% reduction by 2030 compared to 1990 is a realistic option. This could be translated politically into a higher price on carbon emissions, which in turn would increase confidence in building subsidy-free renewable energy and make it more likely to achieve net-carbon neutrality by 2050.

Comprehensible carbon pricing

Cutting carbon emissions is difficult without a meaningful price on carbon to give market players the right incentives. But the current carbon price is still well below the cost of CO_2 emissions needed for the ETS to align Europe with the Paris Agreement[14]. There's a need for stronger market signals. Currently, the ETS is oversupplied with emission allowances. To keep the balance in the ETS, and ensure it has a role in the decarbonisation of the economy, surplus allowances should gradually be retracted from the market and cancelled. An alternative, and supplementary, approach is for countries to form a "coalition of the willing" and voluntarily enforce a mutual CO_2 price floor to reduce regulatory uncertainty. This can be done by imposing an additional carbon tax on power producers (like in the UK), which tops up the ETS allowance price to an agreed-upon level.

Stable strike prices

There are many political uncertainties to investors in the European energy sector: Uncertainty about how European policy makers will ensure the Paris commitments are met. Uncertainty about the commitment to the ETS, which has led to a fragile CO_2 pricing. And a substantial uncertainty about how coal plants will be phased out to reduce overcapacity and carbon emissions. These uncertainties have great influence on electricity prices. This forces investors to add a risk premium, and it may lead to delays or even cancelations of planned investments.

But the uncertainty can be overcome and managed to ensure the lowest cost and most effective delivery on build out targets, to the benefit of both customers and society. This can be done through a system like the contracts for difference (CfD's) in the UK, where project developers compete do deliver the lowest bid on a stable strike price – which could become lower than the market price – and therefore gets certainty for the level of income with less risk of construction delays. If electricity prices turn out to be higher than the agreed strike price, rate payers will take all the benefit of the lower strike price. CfD's are a good tool for overcoming the political uncertainty and risk in current energy and climate politics.

14. E.g. though recently climbing to ca. EUR 13-16 per tCO_2e, the current ETS price as of June 2018 is still only a fraction EUR 45-55 that is the expected price range for 2021-2030 within a Paris-compliant ETS. Carbon Tracker, 2018.

2

More collaboration between countries

As offshore wind farms grow larger and move further from shore, and as an increasing share of Europe's energy supply is generated by sun and wind, the need for collaboration between countries increases. This, on the other hand requires coordination of grid planning, integration of energy systems and harmonised regulation.

Grid

Offshore wind farms are typically established with a single grid connection to the nearest shore. But many alternative configurations have been suggested, e.g. clustering of more farms with a shared connection to shore, or hybrid projects with offshore wind farms situated on interconnectors between two or more price zones. Recently, the prospect of creating an artificial island on Dogger Bank in the middle of the North Sea has been proposed, to function as a transmission and service hub for offshore wind power.

No solution should be ruled out. But it's important to take a stepwise approach, continually exploring the feasibility of different solutions, as technology and regulatory regimes advance. As wind farms move further from shore and projects grow in size and complexity, regulators should acknowledge the competences of project developers and other industry players, e.g. by letting them design and build the optimal offshore grid solution.

To allow this to happen, a framework should enable developers to include interconnectors as part of new projects where feasible, subject to the approval of national transmission system operators (TSOs).

Better interconnectedness

Finding a way to bring the energy from offshore wind power plants to the consumption centres of Europe is a significant challenge. Securing European interconnectedness is not just a matter for offshore wind power but for any of solar, onshore and offshore wind power. Interconnectedness is a necessity for making the European green transformation a success.

Therefore, states and TSOs could be incentivised to optimise planning and operation of transmission grids and interconnectors from a regional perspective, and to overcome potential bottlenecks in the European transmission grid.

Regulatory differences

Many technical standards and requirements regulating offshore wind farms are formulated nationally. This hampers synergies across borders, as wind farms, crews and vessels must follow different letters of the law, though often with the exact same intent – e.g. regarding paint for foundations, markings for aviation and navigation or vessel equipment.

Currently, work is undergoing to harmonise the standards and rules regulating the offshore wind energy sector. Accelerating this work will further reduce the cost and enable realisation of the potential of the North Seas.

Existing cooperation

Work has started to alleviate barriers and facilitate a more efficient buildout of offshore wind. For instance, The North Seas Countries' Offshore Grid Initiative has worked to facilitate coordination and development of offshore grid in the North Sea since 2009. In 2016, the EU Commission initiated the North Seas Energy Cooperation together with ten countries in the North Sea region, working to facilitate the build out.

3

Competition for full scope of projects

Regulation should leverage the competences of the industry by enabling competition between developers for the full scope of projects. This would lower the cost of offshore wind energy even further.

Full scope

While the cost of energy from offshore wind farms has more than halved over the past decade, grid connection and transmission hasn't followed the same downwards cost curve. In part, because these elements are not subject to the same competition as the production assets, meaning TSO's aren't sufficiently incentivised to ensure lowest possible cost to consumers.

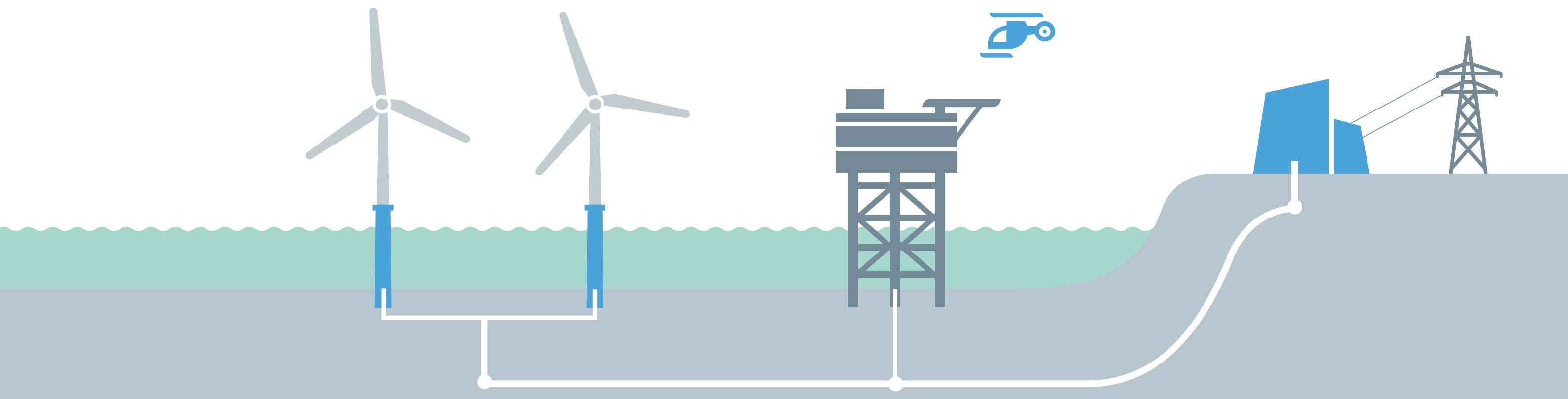
Currently, several countries let the market actors bid for the contract of the wind farm, and then ask the TSOs to build the transmission. Estimates based on cost development in markets with competition for full scope show that including transmission assets in the project scope can help reduce cost of transmission by 10-30%, totalling a significant proportion of the final project cost[15].

Flexibility in choosing sites for projects

Developers are in a unique position to identify the most optimal sites based on wind conditions, water depths and sea bed conditions as well as synergies with existing or future project. This is why governments should aim for an open-door approach, where larger gross areas are designated, and market actors are able to scope for the best sites. States and/or TSOs should of course continue to determine grid capacity based on how much power production a region can absorb.

Giving developers full scope could drive cost further down

The full scope of an offshore wind project.



	Wind farm	Transmission
Limited scope (eg DK*, DE, NL) →	Developer responsibility	TSO responsibility
Full scope (eg UK, USA, Taiwan, France) →	Developer responsibility	Developer responsibility

15. Public available data, internal Ørsted cost assumptions and own calculations. Total levelised cost of energy delivered (LCOE) of transmission assets including CAPEX and OPEX, onshore and offshore project elements included. Detailed cost assessments based on 12 German, Danish and Dutch transmission. Projects commissioning from 2015–25. Project size from 400–900MW. Total project cable length 60–260km. Both HVAC and HVDC projects. Projects include: DolWin1–3 and 6, BorWin3 and 5, SylWin2, Borssele 1 and 2, Ostwind1, Horns Reef 3, Kriegers Flak. * Denmark is currently considering including the full scope for upcomming offshore wind farms.

4

More confidence

It may sound strange, especially coming from an energy company, but the fourth principle is to demonstrate more confidence. One of the main requirements for creating a Europe running entirely on green energy is the belief that it's possible.

The last decade of debate about green energy has demonstrated a tendency to look at the existing energy system, technologies and capabilities and then assume that the prevailing trends will continue or that similar methods will apply in the future.

This has inevitably led to the conclusion that the green transformation cannot happen or will be too expensive.

But the green transformation will and should be disruptive. It will radically reshape the energy infrastructure that has fuelled the economic growth of the past century. We cannot assess our chances of building the energy system of tomorrow based on the technologies of yesterday.

In this situation it matters how we dare to think. If we think of the green transformation as too challenging and risky, we'll design a policy that is short-sighted and aimed at protecting what already exists.

On the contrary, when we allow ourselves to be optimistic, we take calculated risks and adopt policies that allow for new technology to be developed. We'll see challenges as opportunities to learn and innovate.

The fact that green energy has become cheaper than black is a testimony to the value and effect of this confident approach.

The next phase of the green transformation

Over the past 15 years or so, Europe has been through the first phase of the green transformation. We have built renewable energy on top of the old fossil and nuclear based energy systems. In this same period, we have managed to bring down the cost of renewables and given birth to a green industry.

We have now entered the next phase of the green transformation. Renewables are moving to the centre of the energy system. This is a fundamental and disruptive change. It's already producing numerous questions that we don't have the answers to today. But that's the point. If we had all the answers we wouldn't have a climate change problem any longer.

As a contribution to the conversation, we have suggested four principles – four C's – Carbon pricing, Collaboration between states, Competition for the full scope of projects, and Confidence in Europe's green transformation. Europeans can realise the full potential of the North Seas and meet our long-term energy and climate goals. We can build a Europe that runs entirely on green energy.

At Ørsted, we're ready to take on a larger responsibility together with the rest of the industry to invest and to innovate, to take on a broader role in planning and connecting wind farms at sea, to drive down cost even further, and to continue the dialogue on how to shape our common energy future.

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Our vision

Ørsted has a vision of creating a world that runs entirely on green energy. Ørsted develops, constructs and operates offshore wind farms, bioenergy plants and innovative waste-to-energy solutions and provides smart energy products to its customers.

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