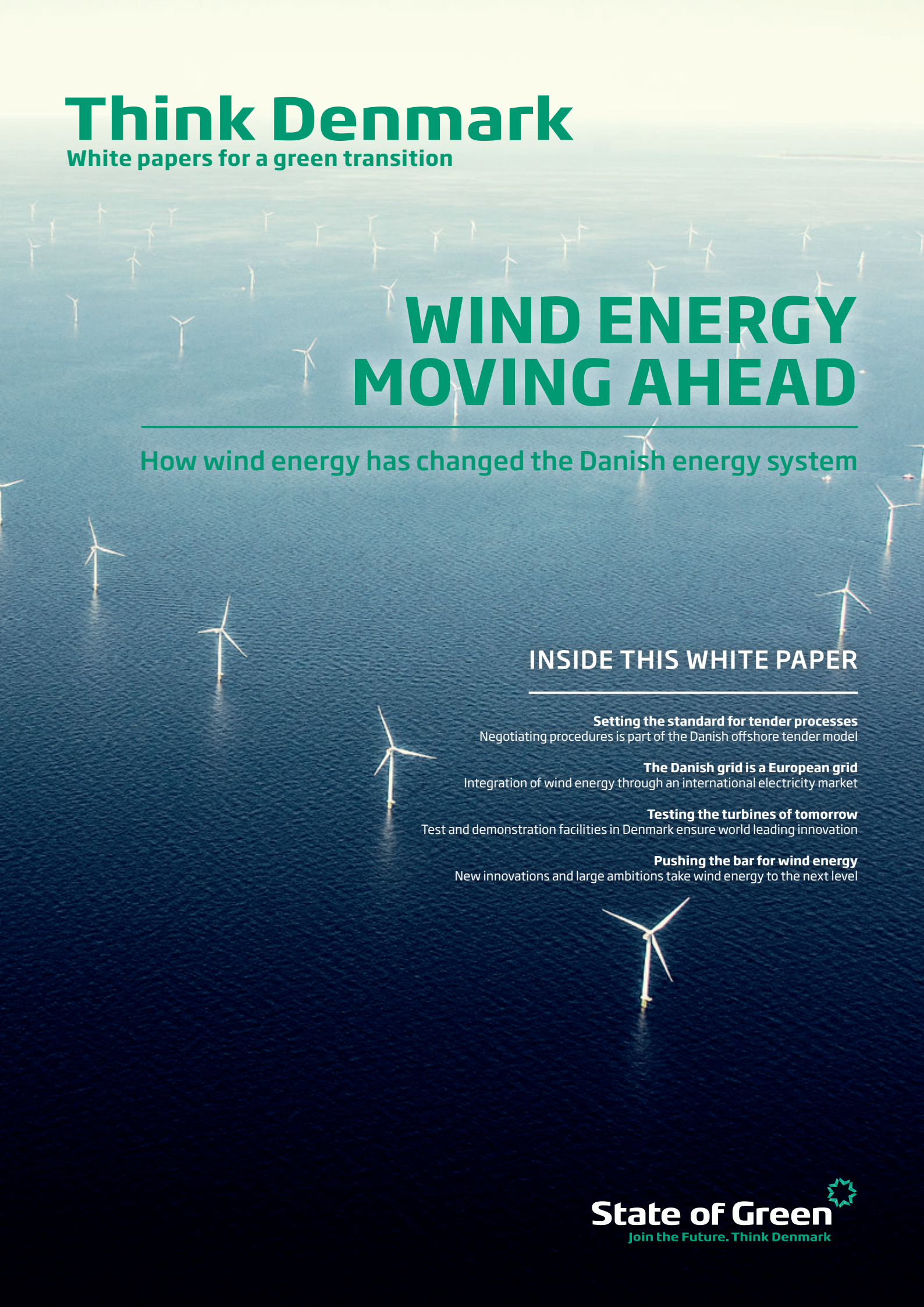
Think Denmark

White papers for a green transition

WIND ENERGY MOVING AHEAD

How wind energy has changed the Danish energy system



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State of Green
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WIND ENERGY MOVING AHEAD
How wind energy has changed the Danish energy system
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Cover photo showing Anholt Offshore Wind Farm. Photo: DONG Energy

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EXECUTIVE SUMMARY

As the first country in the world, Denmark has decided to lead the transition and become entirely independent of fossil fuels by 2050. One element in reaching this target is to expand the share of renewable energy harnessed from wind, and this encompasses driving the development of an intelligent energy system capable of managing the fluctuations of renewable energy.

Denmark was the first country to install a commercial offshore wind farm 30 years ago and has been first mover in the wind industry for decades. In 2016, onshore and offshore wind turbines provided around 40% of Denmark's electricity consumption and we plan to go further with over 50% of electricity consumption to be generated by wind energy by 2021.

Global hub for wind energy innovation
Denmark is a global hub for wind energy innovation and development and the Danish wind industry employs more than 31,000 people. The availability of a highly skilled workforce, superb facilities for testing prototypes and a comprehensive network of companies, research institutions and government research programs make up an innovative R&D environment like nowhere else in the world. In Denmark, you can test all parts of a wind turbine from nacelles and blades to full-scale, almost market-ready, turbines, which is why companies from all over the world have located central parts of their R&D operations in Denmark.

Securing a stable and cost-effective supply
Approximately 4,750 turbines supply more than 5 GW of electricity to Denmark. The 5 GW constitute more than a third of the overall Danish production capacity. The large-scale wind energy integration is made possible by a well-developed transmission infrastructure, capable of handling the fluctuating wind energy resource. The Danish grid is connected to the neighbouring countries, enabling the import and export of energy during peak periods.

Setting the framework for a green transition
The cost of transitioning to renewable sources is declining and the latest tenders for offshore wind farms in Denmark have the lowest Levelised Cost of Electricity (LCOE). This means that that no other offshore wind farms in the world can provide power at a lower price, all expenses over the lifetime of the farm taken into consideration. An element in the success of low costs is the Danish tendering model, which includes both prequalification and a preliminary technical dialogue with potential tenderers and investors. Despite the declining costs, the projects still have to be financed and Denmark is leading the way with both wind turbine cooperatives for private citizens and large-scale public-private financial models, for instance through blended finance.

About this white paper
This white paper takes you through all the elements of the success story of wind energy in Denmark. From the starting point and what we now consider small-scale wind turbines to the projects and technologies that push the bar and the ambitions for wind energy as a source of renewable energy. We hope you will be inspired.

WIND ENERGY – FUELLING THE EUROPEAN ENERGY UNION

Wind energy plays a key role in Europe's transition to clean energy. Having led global climate action in recent years, Europe is now showing example by creating the conditions for sustainable jobs, growth and investments. The European Energy Union will modernise the EU economy and boost clean energy, equipping all European citizens and businesses with the means to make the most of it.

By Maroš Šefčovič, Vice President of the European Commission, in charge of Energy Union

Wind turbines are iconic symbols of the green transition, gaining momentum around the world. Yet, here in Europe, their role is far beyond symbolic; wind energy accounts for over 15% of the European electricity supply, exceeding even 40% in some member states, such as Denmark.

But a lot more still needs to be done. The Energy Union is one of the top priorities of the European Commission with a simple overarching objective: ensuring that every European citizen has access to secure, sustainable, and competitive energy. We have set the EU on a path towards at least 40% reductions in CO_2-emissions, at least 27% renewable energy and 30% increase in energy efficiency by 2030. These are ambitious but realistic targets for Europe – as long as we all work together.

Wind energy has a tremendous potential and value in realising the Energy Union. It delivers environmental benefits and reduces both air pollution and CO_2-emissions. It therefore has a direct positive impact on citizens' wellbeing. Meanwhile, investments are becoming increasingly competitive and the cost of wind energy has reduced significantly across Europe. This is a trend we expect will continue.

Wind energy also creates jobs, both in advanced research and in development, skilled and unskilled manufacturing labour as well as local installation and service jobs. Employment in wind energy has increased fivefold in the EU from 2005 to 2013, with total associated employment numbers of about 320,000 in 2014. Apart from jobs, these investments work simultaneously to diminish European dependency on imported fossil fuels.

The Energy Union is putting Europe on track to benefit from yet higher shares of wind energy and other renewable energy sources. Important instruments in this regard are improved physical infrastructure for power transmission within countries and across borders; smarter grids and improved market mechanisms enable the integration of fluctuating renewable energy sources across larger markets; and smarter energy systems enable more flexibility in demand-response, storage and consumption. We are harmonising rules on renewables and their promotion across countries.

To conclude, wind energy is a strong driver in the European Energy Union. It will definitely benefit from our cross border infrastructure and the growing markets to accommodate it, creating a more unified and green energy system. We must harness wind as an important energy source, which creates a triple benefit for people, businesses and the environment – in Europe and beyond!

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1. DENMARK – A FRONTRUNNER IN WIND ENERGY

How historical developments made Denmark a leader in wind energy

The history of wind energy traces back to Denmark in 1891, where the first electricity generating wind turbine powered a single school. Today, onshore wind is one of the cheapest sources of energy for electricity production in Denmark, and the next generation of wind turbines will be able to power up to 10,000 households.

By Finn Mortensen, Executive Director, State of Green

Windmills were initially used in the agricultural sector for grinding grains and pumping water but in 1891, the Danish physicist Poul la Cour started experimenting with wind energy as a source of electricity. Supported by funds from the Danish state, he created a turbine, which supplied the school he was working at with direct current and he even experimented with wind energy storage.

Danish engineers continued to improve the wind turbine technology during World War I and World War II in order to maintain the electricity supply during energy shortages. By the end of World War I, 3% of Danish electricity consumption was covered by wind energy. However, while ingenious, the technological development almost came to a standstill with the justification that wind turbines would not be able to compete with traditional power plants due to the low fossil fuel prices.

A regained interest in wind

The first oil crisis in 1973-74 changed this perception. Highly dependent on imported energy, the crises of the early 1970s lead to increasing electricity costs in Denmark and as a result, wind energy as well as other alternative energy sources re-emerged. The wind industry that arose in the late 1970s was a result of a large public engagement and political goodwill towards the development and expansion of wind energy.

By the early 1980s, around 20 manufacturers of wind turbines were active in the Danish wind industry, and after a phase of consolidation of the industry in the 1990s, the wind industry became dominated by large, partly internationally owned and listed companies.

Harnessing the future of wind energy

Today, the Danish wind industry employs more than 31,000 people and the industry's turnover was EUR 11.8 billion (DKK 87.7 billion) in 2015. According to a study by the Danish Energy Agency, onshore wind energy has become one of the cheapest energy sources for new electricity generation in Denmark, undercutting coal and natural gas.

In a search for even more efficiency and lower costs of energy, the size of the turbines has grown steadily over the years and while most turbines in the early 1990s had sizes of up to 225 kW, the newest generations of wind turbines now reach 9 MW. The larger turbines make it economically feasible to harness wind offshore, where the higher wind speeds make up for the larger costs. The upcoming Danish offshore wind farms, Horns Rev 3 and Kriegers Flak, will reach sizes of 400-600 MW.

The development of the Danish wind energy technology is remarkable. The first commercial turbines had an output of 22 kW and the blades in the photo, dated 1980, are 7.5 metres long and made for 55 kW turbines. The blades of the newest offshore turbines are almost 90 metres long.

Photo: Vattenfall Vindkraft

Repowering wind turbines

In 2015, Vattenfall decommissioned 35 old wind turbines to install 22 new 3.2 MW Siemens Wind Power turbines in the Klim project in Northern Jutland. To date, Klim wind farm is one of the largest onshore wind farms in terms of production. With an accumulated capacity of +70 MW and a yearly production of 256,000 MWh, Klim wind farm provides electricity for 64,000 households corresponding to a production triple that of the former 35 wind turbines.

At Nørrekær Enge wind farm nearby Løgstør, Vattenfall decommissioned 77 wind turbines and replaced them with 13 Siemens Wind Power 2.3 MW wind turbines. Here, the new project has more than doubled the electricity production. With an annual production of approx. 120 million kWh, the farm at Nørrekær Enge supplies electricity for approx. 30,000 households and several decommissioned wind turbines at Nørrekær Enge have been sold off for new projects in Cuba.

These two large-scale repowering projects have had a positive impact on the surrounding area of the wind farm sites, and the replacing of older wind turbines has improved the project efficiency.

Vattenfall Vindkraft

The world's first offshore wind farm has retired

In 1991, the world's first offshore wind farm was built close to shore in the shallow waters off Vindeby in Denmark. After more than 25 years of service, the 11 turbines in DONG Energy's Vindeby offshore wind farm were recently decommissioned. Although Vindeby's turbines of 0.45 MW are small compared to current standards, they have been of vital importance for the industry. Vindeby was the cradle of the offshore wind industry.

Creating the world's first offshore wind farm has helped DONG Energy and the industry gain experience with scaling up the technology and reducing costs, which has reached a level that makes offshore wind attractive to countries facing replacement of end-of-life coal-fired power plants. Today, offshore wind farms have reached utility-scale, and a single one of the largest turbines currently commissioned produces more power than the entire Vindeby offshore wind farm.

DONG Energy

Photo: DONG Energy

2. THE DANISH ELECTRICITY GRID IS A EUROPEAN GRID

Large wind energy share and high security of supply

Experience from Energinet shows that a strong electricity grid, an international electricity market and a flexible electricity system are essential to ensure efficient integration of large renewable energy volumes.

By Peter Jørgensen, Vice President Associated Activities, Energinet.dk

We were once afraid of what would happen when wind energy generation reached 5% of the total consumption. We then worried about approaching 10% – would the system be able to cope? Some years later, we said that 20% had to be the absolute limit! However, in 2016, Danish wind turbines produced more than the total electricity consumption for 317 hours of the year, and we barely give this any thought.

We are reminded of the extraordinary success of Danish wind energy generation when, year after year, we ascertain that it has increased to 33, 39 or 42% of total Danish electricity consumption. This makes the world sit up and take notice.

Wind as a source of energy

The success is based on the share of wind energy and its efficient integration with other energy sources. Energinet is the Transmission System Operator responsible for the system, but we cannot take all the credit for Denmark having come so far. We are a part of the success, but Danish wind energy history is a result of a well-functioning interaction between industry, regulators, the energy sector, citizens and others.

It is not an easy task to balance an electricity supply system with large volumes of varying energy while maintaining one of the highest levels of security of supply in Europe. For one hour in 2016, the wind energy share in the Danish electricity system reached 139% and for a full day, the wind energy share reached 103%. Conversely, 2016 also had days with low wind energy production and on one day, the wind turbines only contributed 1% to the electricity consumption.

Balancing the grid

Both days are success stories. Danes did not wonder about whether there was any supply in their sockets on either of those days. This success is based on three prerequisites:

1. Denmark has an efficient electricity system in which flexible power stations, local CHP plants, wind turbines and solar energy interact to form a holistic power supply.

2. Denmark has a well-developed electricity grid, which can handle large fluctuations. We can import or export electricity corresponding to approx. 80% of our maximum electricity consumption.

3. Denmark is part of a well-functioning Nordic and European electricity market. Danish producers sell electricity to consumers in neighbouring countries when they can generate electricity at favourable prices – often in windy conditions. And we import Norwegian hydroelectric power, German wind and solar energy, Swedish nuclear power etc. during hours in which producers in our neighbouring countries have the best prices.

The day-to-day electricity markets and state-of-the-art system operation ensure the balance in the electricity system and efficient integration of renewable energy. Energinet's task is to ensure the secure and cost-efficient supply of electricity, so consumers continue to have a high level of security of supply at affordable prices. This requires a continued development of the cross-border network cooperation and trading as well as regional and pan-European solutions.

Photo: Energinet.dk

Cumulated installed wind energy capacity per 1000 inhabitants (by December 2016)

Denmark	915,9
Sweden	661,8
Germany	608,7
Portugal	514,1
Spain	496,8
Austria	302,9
EU28	301,3
Finland	280,5
Netherlands	254,9
Estonia	235,6
UK	222,4
Greece	220,1
Belgium	210,9
Cyprus	186,3
France	180,7
Lithuania	170,7
Romania	153,2
Italy	152,6
Poland	152,3
Croatia	100,7
Luxembourg	100,7
Bulgaria	96,6
Ireland	59,9
Hungary	33,5
Latvia	32,0
Czech Republic	26,6
Slovenia	1,5
Slovakia	0,6
Malta	0

Source: WindEurope, Eurostat

The North Sea offshore grid

The European Union has set the laudable goal to complete the internal energy market in order to integrate renewables better, reduce CO_2 and provide affordable electricity to consumers. Although building interconnections can take decades, ten governments have now agreed to jointly explore the rollout of an offshore grid as part of the North Seas declaration on energy cooperation.

This top-down political commitment should lead to bottom-up action that propels offshore wind to the next level. The ministers of Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and United Kingdom signed the declaration, which aims to reduce the costs, accelerate the deployment of wind energy at sea and develop interconnection.

The agreement came right after 11 energy companies had signed a declaration saying offshore wind can reduce costs to EUR 80/MWh by 2025 if governments commit to a strong pipeline of projects. Clear and long-term plans for deployment of offshore wind will unlock new investments, reduce the cost of capital and allow the industry to meet the cost-reduction target.

WindEurope

New Danish-Dutch connection

In 2019, electricity will be transmitted directly between Denmark and the Netherlands. The 320 kilometre COBRA cable will run from the Danish west coast to the Port of Eemshaven in the Netherlands. The interconnection will have a capacity of 700 MW, supplying up to 700,000 consumers with electricity. This will not only improve security of supply, but also support the green transition, as the international electricity market will be strengthened.

COBRA is an acronym for 'Copenhagen, Brussels, Amsterdam', and the name underlines both a wish for a strong interconnection through the North Sea and a more integrated European electricity grid, but also the EU's wish to promote the single market for energy. The COBRA cable is a joint project between Dutch TenneT and Danish Energinet and it is supported with EUR 86.5 million by EU's European Energy Programme for Recovery.

The picture shows how the pipe, in which the cable will run, is drilled several hundred metres below dunes on the Danish Wadden Sea island of Fanø.

Energinet.dk

Photo: Robert Attermann, Red Star Foto Danmark

3. LOCAL GRIDS – KEY TO AN EFFICIENT ENERGY SYSTEM

Regulation of local grids must encourage the integration of renewables

Thanks to the decentralisation of electricity production from wind turbines and solar cells, the electricity grid in Europe is about to be turned upside down. Over half of the Danish electricity production is now fed directly into the distribution grid.

By Anders Stouge, Deputy Director General, Danish Energy Association

Distribution grids are rarely the centre of heated public debate. However, they have a crucial role in facilitating a transition towards cleaner and more distributed energy sources.

Over half of the Danish electricity production is now delivered at lower grid levels directly into the distribution grid from wind turbines, CHP plants and solar cells. And the volumes are increasing year on year. Danish distribution system operators (DSOs) have enabled the smooth integration of this rising level of decentralised production.

"If we don't do something and just treat innovation like any other cost for operators of distribution grids, regulation will undermine an efficient green transition."

Anders Stouge,
Deputy Director General
Danish Energy Association

It has required an important balancing act and a change of role for Danish DSOs. The system has moved from a one-way flow from large, central electricity producers down the grid to consumers over to a system with ever changing flows of power between many small units, of which some dependent on market and weather conditions operate as both producers and consumers.

Danish DSOs have acted as the flexible backbone of the electricity system. This has been achieved through necessary investments in innovation, maintenance and expansion of the distribution grids, allowing DSOs to handle a different production profile from renewable energy. This conversion needs to adapt to an even higher extent than today with a continuously rising share of fluctuating electricity sources.

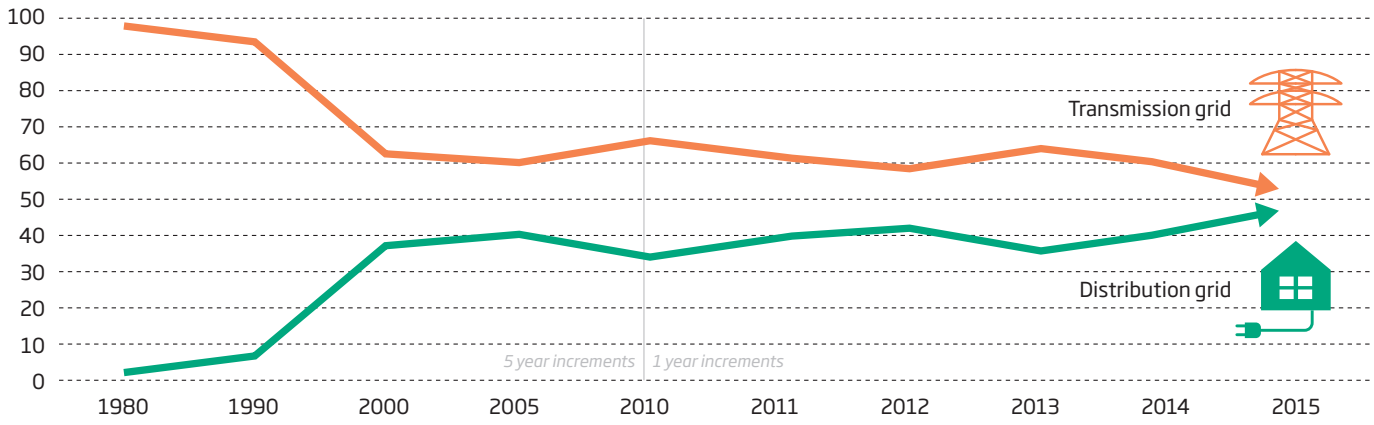
All electricity systems transitioning away from fossil fuels will experience tremendous upheaval and to handle it, the DSOs must participate in innovation projects with their expertise in grid operation and with new technical installations. Grid companies are the only ones who can test new ideas such as flexible electricity consumption close to the customers, which is essential in bringing research results out of the laboratory and into real application. In this context, Danish DSOs are at the cutting edge of this transition.

DSOs play a key role in the introduction of new innovative ideas that can improve the grid and develop a smart energy system for the benefit of customers. As the DSOs are natural monopolies, they develop innovative concepts within a regulatory framework.

Regulated companies must be run efficiently, but regulation must allow scope for development. If the DSOs are only encouraged to make short-term cost reductions they will come to a standstill, and society will pass a large bill onto the next generation. Short-term efficiency now must not be sought at the expense of optimal solutions for an electricity grid supporting an extensive production of renewable energy.

From 100% coal to 56% green production
Denmark is currently home to 4,750 wind turbines, covering around 40% of the electricity consumption. Add to this the several hundred smaller CHP plants and almost 100,000 solar cells. In all, 56% of the Danish electricity consumption was covered by green electricity in 2016.

Electricity production is increasingly linked directly to the distribution grid
The share of electricity production which is connected directly to the distribution grid



Over half of Danish electricity production is now delivered into the distribution grids from wind turbines, CHP plants and solar cells. The volumes are increasing year on year.

Source: Danish Energy Agency, Energinet.dk

Photo: Jysk Energi

1,000% wind energy

A strong wind blows across the north-western part of the Jutland peninsula, and many wind turbines, solar cells and local CHP plants cover the equivalent of several hundred per cent of the annual electricity consumption.

Jysk Energi operates the distribution company NOE Net and is co-owner of the supply network company Vestjyske Net 60 kV. Together, they supply approx. 430 GWh of electricity to their customers. Local electricity production is around 935 GWh. During windy weekends, the distributor sends off more than ten times the local consumption to other parts of the country. At NOE Net, wind turbines, CHP plants and solar cells cover more than 1,000% of the local electricity consumption over shorter periods. Wind turbine capacity alone is close to 400 MW, and with 7-8 large wind turbine and solar cell projects in 2017 and 2018 – including Vesterhav Nord at 170 MW in the North Sea – capacity will increase to 700 MW.

Jysk Energi

Energy park harvests energy from wind and sun

In Nørhede-Hjortmose, close to the North Sea, 22 3.3 MW Vestas turbines and 69,000 solar cell panels produce plenty of electricity for the grid. Private investors have installed the 72 MW of wind energy and 15.2 MW of solar cells, contributing to the local municipality's goal to become 100% self-sufficient in green heating and electricity by 2020. Thanks in part to the wind turbines and solar cells, the residents and businesses of the municipality have already reached an estimated coverage of 60%."Yes, it is a truly spectacular park. The solar cells are installed between the wind turbines and do not bother anyone", says technical manager Per Nielsen of RAH, who is responsible for the combined network and connection of the solar cells to the 10 kV grid.

The consumption of electricity in RAH's supply area is almost 60,000 MWh per year. Local production of electricity from wind turbines, solar cells and CHP plants amounts to approx. 90,000 MWh per year and thus since 2014, the RAH area has been an exporter of green energy.

RAH

Photo: RAH Service

4. BRINGING DOWN COSTS TOGETHER

Close cooperation is essential to reduce the cost of wind energy

In less than 40 years, wind energy has developed into a mature, reliable and cost-effective technology. Despite already being one of the cheapest and cleanest technologies, wind energy will continue to decrease in price when new innovative ideas are applied.

By Jan Hylleberg, CEO, Danish Wind Industry Association

Through the years, cost reductions have been a guiding principle for the players in the wind industry. Creating smarter, stronger and more innovative products and solutions have increased the effectiveness of the wind turbine, thus lowering the price of electricity produced from wind energy. Denmark is home to some of the world's leading wind turbine manufacturers and suppliers. In total, some 500 companies working in all areas of the wind industry are based in Denmark, making up a globally unique supply chain and close-knit network of competences and services. However, what makes the wind industry in Denmark stand out is not only the ability to innovate and bring down costs, it is also the industry's unique ability to do this by cooperating with each other across the supply chain. Throughout the years, companies in the wind industry have developed a strong tradition of collaborating on various aspects, which will help lower the price of wind energy even further.

Collaborators galore

Across Denmark and especially on the peninsula of Jutland, the concentration of companies focusing on wind energy is impressive, with hundreds of companies within a short distance. In the Central Denmark Region, 1 in 25 private sector employees are employed in the wind industry, emphasising the scope of the industry.

From single items to systems

Less is more when it comes to suppliers and in reaction to this relatively new tendency, Danish suppliers are teaming up to pool services and products into actual systems. By delivering a complete technical system or packaged solutions to end consumers such as wind turbine manufacturers or wind farm owners, collaborating companies can strengthen their own strategic position. This entails an even closer cooperation between Danish wind turbine manufacturers and the clustered sub-suppliers, enhancing manoeuvrability in technological innovations and the ability to bring down costs.

Introducing standards

The wind sector has adopted many standards and best practices from other sectors. In recent years, the matter of standardisation in the wind industry has taken a big leap forward in Denmark and companies and business organisations are coming together to form standards that are designed specifically for application within the wind industry alone. By adhering to common standards, suppliers need fewer manufacturing and quality controlling processes, leading to fewer product failures. Standardisation can be expanded to numerous areas within the wind industry and the development and deployment of standards is expected to increase in the coming years. In this process, the strong tradition for cooperation in Denmark will be very relevant. Having a well-functioning supply chain is of paramount importance when it comes to making wind energy even more competitive in the race to be first with the newest, best and most competitive products.

Photo: Danish Wind Industry Association

Photo: Bladt Industries

Collaboration secures cost reductions on offshore jacket foundations

A considerable part of the cost associated with installing wind turbines offshore is the price of the foundations that are put on the seabed. Danish steel processing company Bladt Industries is involved in a number of projects to lower the price of the offshore jacket foundations. Established by Bladt, 60 international companies have formed a task force on jacket foundations in a new, first of its kind, push to lower costs. The task force meets to address obvious ways in which manufacturing processes and working procedures can be improved across the supply chain.

In another project, Cejacket, a number of leading companies in the wind industry have set a goal of cost reductions of 6-8% by making the large jacket foundations in smaller modules that are assembled closer to the site of use. The project will also focus on the atomisation of welding as a means to increasing the quality and decreasing the amount of work hours used on each jacket foundation.

Bladt Industries

System suppliers creating an efficient and competitive supply chain

Handling the thousands of parts that go into each wind turbine is a massive undertaking. In response to the challenge, the Danish company Aluwind acts as a system supplier, functioning as a link between the wind turbine manufacturers and smaller suppliers. The system supplier handles all aspects of sourcing and contracting, thereby reducing the number of suppliers that send their individual parts directly to the wind turbine manufacturer.

Aluwind typically receives parts from 50-100 suppliers and combines them with parts from their own production, ultimately assembling all parts into large kits (systems) that are loaded into standard shipping containers. The preassembled kits are then transported to and installed in the wind turbines. Each kit can easily be adjusted to fit individual projects around the world, thereby in turn make sourcing more strategic and easier, which helps lower the price of a wind turbine.

Aluwind

Photo: Aluwind

Photo: Danish Wind Industry Association

A standard for the wind industry by the wind industry

Two of the world's leading wind turbine manufacturers, Siemens Wind Power and Vestas Wind Systems, have united with leading suppliers KK Wind Solutions and LM Wind Power in a first of its kind project. The project, called APQP4Wind, will ensure that manufacturers and suppliers communicate in the same technical language when working with quality assurance. Having such a common framework helps minimise the risk of expensive production errors and thereby reduces the cost of energy, which is of benefit to the entire value chain.

The project launched in early 2017 with a set of training courses and a manual, allowing participants to incorporate the APQP4Wind standard into their own production process. Both the manual and the training concept will be developed further before being fully deployed across the Danish value chain. Over time, the ambition is to make it a global standard for the wind industry, starting in Denmark. APQP4Wind is facilitated by the Danish Wind Industry Association and supported by the Danish Industry Foundation. APQP4Wind is a registered trademark of the Danish Wind Industry Association in Denmark.

APQP4Wind.org

Joint, strategic recommendations from Megavind

To ensure the competitiveness of the Danish wind industry, the strategic partnership Megavind formulates recommendations that serve as key indicators for both the industry and the government in regards to creating the right conditions for a competitive Danish wind industry. The strategies and recommendations are formulated in close collaboration between industry players and universities and have resulted in several important advances for the wind industry, for instance new test centres. The partnership functions as a catalyst for new incentives that foster better testing, demonstration and research strategies.

In 2015, the Megavind partnership developed a model to calculate the costs of offshore wind. The calculator is free for all to use and ensures a common way of calculating the Levelised Cost of Energy (LCOE) that everyone agrees upon. Today, the calculator is widely used to track the cost reductions made in offshore wind.

Megavind

Photo: State of Green

A STRONG SUPPLIER HUB

Selected examples of Danish footprints in offshore wind

Anholt 400 MW
Denmark 2013
Danish deliveries:
Developer and operator
Wind turbines
Wind turbine installation
Substation installation
Substation design
Substation manufacturer
Export cables
Export cable installation
Substructure main constructor
Substructure design
Monopiles and transition piece
Monopiles and transition piece installation
Export cable manufacturing
Export cable installation
Grouting
Logistics
Geophysical investigations
Environmental Impact Assessment
Project finance

Horns Rev 2 209 MW
Denmark 2009
Danish deliveries:
Developer
Accommodation platform
Wind turbines
Wind turbine installation
Foundations
Foundation installation
Foundation design
Operator
Substation
Substation installation
Project finance

Gode Wind 1-2 582 MW
Germany 2016
Danish deliveries:
Developer and operator
Wind turbines
Wind turbine installation
Array cables installation
Substation design
Substation MV/HV equipment
Monopiles and transition piece
Logistics
Geophysical investigations
Project certification
Project finance

London Array 630 MW
United Kingdom 2013
Danish deliveries:
Developer and operator
Wind turbines
Wind turbine installation
Substructure installation
Substructure main constructor
Substructure design
Design of substation foundation
Monopiles and transition piece
Grouting
Logistics
Monitoring of wind, waves and currents
Project finance

Photo: Danish Wind Industry Association, Bent Nielsen

DO YOU SPEAK WIND TURBINE?

As a rule of thumb, every MW installed offshore can generate the annual electricity consumption of roughly 1000 Danish households.

The share of wind in the Danish electricity consumption has increased steadily during the last years: 18% in 2004, 33% in 2013, 42% in 2015 and 37.6% in 2016. By 2021, it is expected that wind energy will cover over 50%.

In 2016, the average capacity of a new onshore wind turbine installed in Denmark was 3 MW.

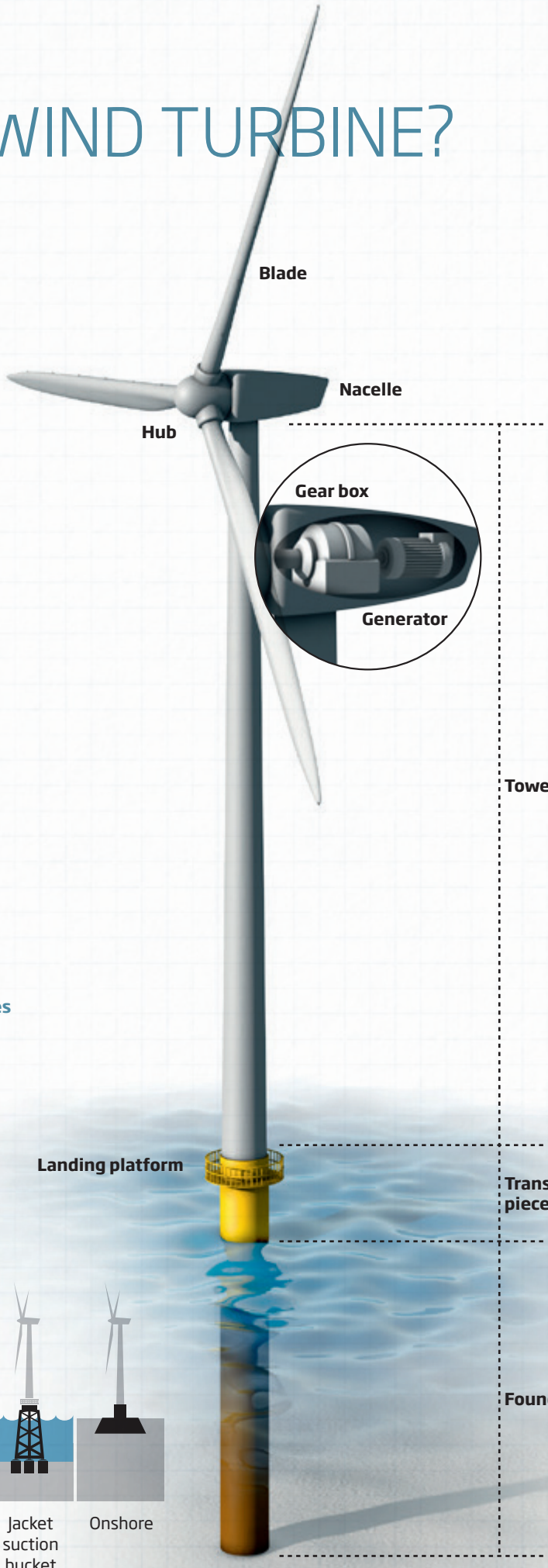
By the end of 2016, 910 kW of wind energy was installed per 1,000 Danish citizens.

In 2015, an average kWh in Denmark consisted of 58% wind, hydro and solar power, 19% coal, 13% waste, biomass and biogas, 6% natural gas, 4% nuclear power and 0% oil.

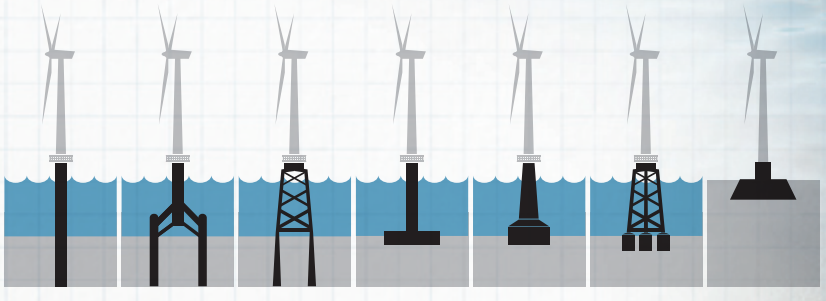
Every now and then, the Danish wind turbines produce more than what the Danish market can consume. On 17 April 2016, the wind share in the Danish electricity grid was 103.6% and the surplus was exported to Sweden, Norway and Germany though the interconnected grid between the countries.

In its lifespan of 25 years, a wind turbine can produce up to 40 times the amount of energy that went into constructing it.

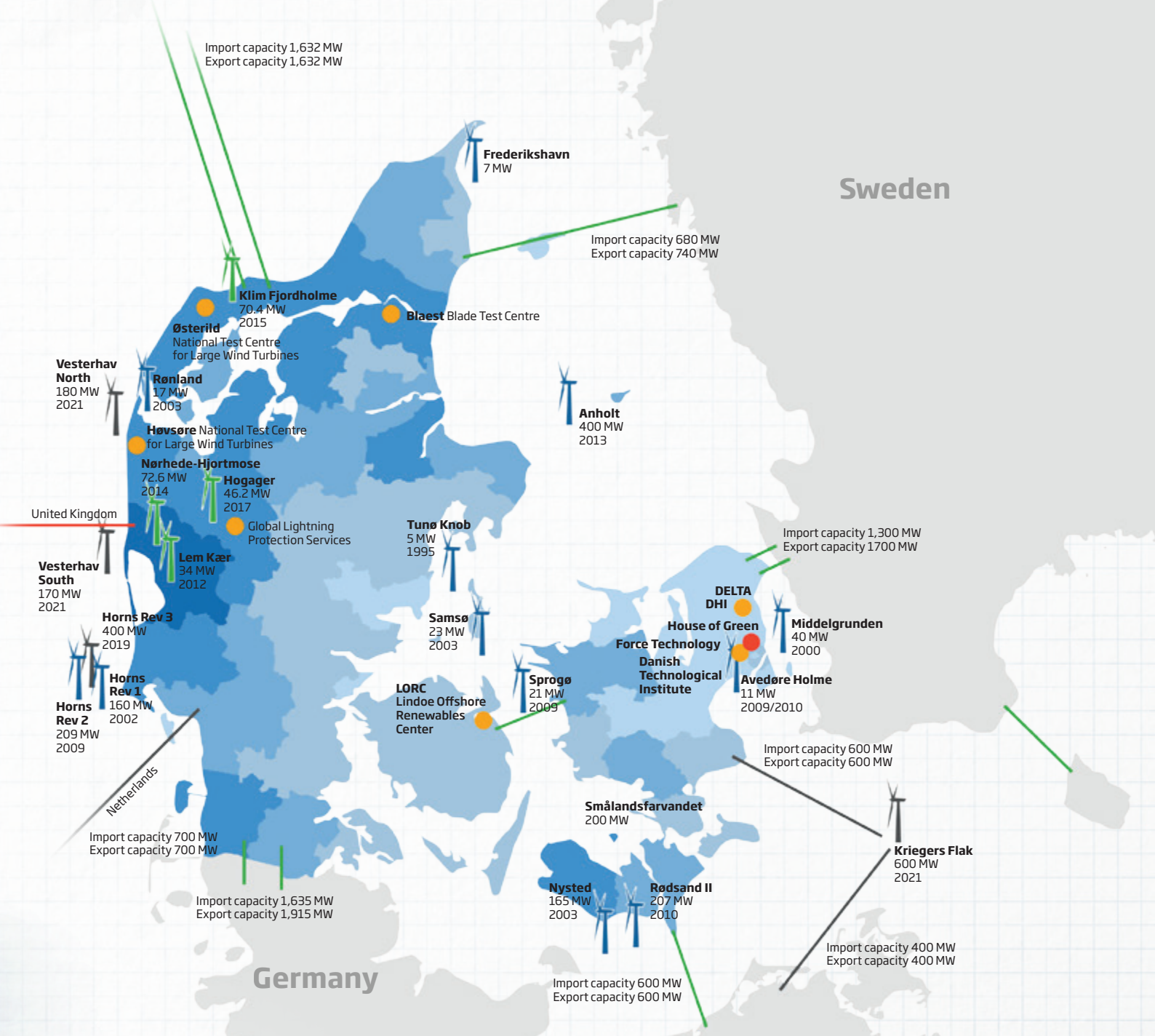
Security of supply is very high in Denmark and the Danes have electricity in the socket 99.997% of the time.



Different types of foundations:



DENMARK FROM ABOVE



Selected onshore wind farm

Offshore wind farm (Commissioned)

Under construction

Cable connections (Current)

Cable connections (Proposed)

Under construction

Test facility

Place of Interest

Wind penetration by municipality

- 0 - 9,9 MW
- 10 - 49,9 MW
- 50 - 99,9 MW
- 100 - 199,9 MW
- 200 - 600 MW

Name of wind farm
Capacity in MW
Year of commissioning

The total Danish capacity onshore equals 3.978 MW

The total Danish capacity offshore equals 1.266 MW

5. TESTING THE TURBINES OF TOMORROW

Test and demonstration facilities in Denmark ensure world-leading innovation

Test facilities are key to maintaining a strong wind industry. In Denmark, companies have access to a range of world-class test facilities, securing a unique setup which allows the industry to set new international standards and push the limits for the modern wind turbine.

By Jan Hylleberg, CEO, Danish Wind Industry Association

The pursuit for new innovations is a never-ending quest across the Danish wind industry. To test the feasibility of ideas and the durability of new solutions, companies go through exhaustive testing. The aim is to come up with a solution, which is better than the previous, while at the same time lowering the production costs and ensuring consumers a competitive price on electricity produced from wind turbines whether they are installed onshore or offshore. By testing each component in the wind turbine vigorously and by testing prototype wind turbines in part and in full scale, potential design or production errors can be identified and corrected before the final product is delivered to the customer.

Identifying and eliminating design and production errors in the early testing phases is much cheaper than having to correct them after the turbines have been mass-produced and installed in markets across the world. Thus, having access to the right test facilities help reduce the levelised cost of energy (LCOE) for wind.

A visual testament to the Danish wind industry's abilities can be found in the rural area of Østerild where seven large test turbines are installed. Østerild is currently the only place in the world where measurements on turbines of up to 250 metres in height can be made. Further south, on the island of Funen, wind turbine manufacturers can test nacelles simulating a full lifetime of operating in shifting and rough conditions at LORC (Lindoe Offshore Renewables Center).

LCOE is defined as the production cost of each unit of electricity generated over the lifetime of a wind farm, taking into account a wind farm's development costs, capital investments, financial costs, and lifetime running costs.

Test facilities and knowledge attracts international players

The extensive knowledge about wind energy has attracted a number of influential players from the international wind industry to Denmark. Among them are Chinese manufacturers such as Envision Energy and Goldwind who have both opened R&D divisions in Denmark. Envision Energy is also present at Østerild along with GE-Alstom and alongside the Danish manufacturers Siemens Wind Power, Vestas Wind Systems and MHI Vestas Offshore Wind.

Research institutions contribute

Danish technical universities have a longer track record of working in wind energy research than those of most other countries. In the late 1970s, when an emerging industry started producing, a test facility for wind turbines was established at Risoe National Laboratory (now DTU Wind Energy).

The Danish government assigned Risoe to approve turbine prototypes designs before they could be sold to the Danish market. This was an early example of close cooperation between the universities and the industry on testing and improving designs and research programs. The universities and the industry continue to cooperate today, each benefitting from the other's competences and resources. The Danish research environment has expanded in parallel with the wind industry. Although strong research environments are developing in other countries, Danish research institutions remain among the best in the world.

Five important elements in a strong testing environment

- State-of-the-art test facilities, both privately and publicly funded
- World-leading wind energy research institutions
- Access to highly educated wind energy personnel
- A large group of experienced R&D professionals in the industry
- Short distance between test sites and companies' R&D divisions

Photo: MHI Vestas Offshore Wind

Photo: Siemens Wind Power

Test scheme in Nissum Bredning

The global wind market players continuously seek opportunities to develop offshore test projects which potentially reduce production costs of electricity from offshore wind farms and keep offshore wind energy cost competitive. In July 2015, the Danish Energy Agency published a call for applications for tests of new technologies to establish and operate wind energy production offshore. Turbines in the test scheme receive a Contract For Differences of approx. EUR 0.09/kWh (DKK 0.7/kWh) for approx. 11 years and then market price until decommissioning. Based on minimum criteria, such as technical and financial capacity to ensure a potential for development and the commercial perspective of the test elements, the aid was granted to I/S Nissum Bredning Vind for their 28 MW test project in February 2016. The project's main test elements are a Siemens Wind Power 7 MW wind turbine, a new Siemens Wind Power designed concept of gravity jacket foundation and concrete transition piece, a slender tower concept, 66 kV cables and a switchgear solution.

Nissum Bredning Vind I/S, Jysk Energi A.m.b.a.,
Siemens Wind Power A/S

Østerild - where the sky is the limit

The largest turbines are designed for a life offshore. However, testing of offshore turbines often has to take place onshore, and there is no better place to do this than somewhere with relentless and rough winds. The world's largest test centre for large wind turbines is located in Østerild, Denmark. The test centre has room for seven turbines with a maximum height of 250 metres and a capacity of 16 MW. Today, the rural area is home to prototype wind turbines from wind turbine manufacturers from around the world. In close collaboration with the wind turbine manufacturers, the Technical University of Denmark (DTU) is leading the research at Østerild. At the same time, DTU shares the story of wind energy with the 50,000 visitors that make their way to the impressive test centre each year. In the coming years, the test centre will be expanded in order to be able to test even taller wind turbines before they are installed offshore.

Technical University of Denmark - DTU

Photo: Technical University of Denmark - DTU

Photo: LORC

Exposed to the extremes of nature

The employees at LORC are experts in matching broad knowledge of offshore wind with deep knowledge of how to get the most out of LORC's full-scale test facilities at Lindø. At LORC, the customers are the experts on their own assets. Partners and outside experts are brought in with different focus areas to supplement the test scenario.

The Function Test Facility is used to verify the performance and robustness of the nacelles' electrical systems as well as grid compliance when exposed to the extremes of nature in a controlled test environment. Equipped with a 13 MW direct drive motor providing in excess of 12 MNm of torque allows testing of nacelles in the 10 MW regime on the Function Test Facility at LORC. Additionally, other full-scale test facilities can perform Highly Accelerated Life-Time Test (HALT) or Climatic Testing, where the harsh environment offshore can be simulated by means of temperature, humidity and salt spray.

LORC

Giant wind turbine blade captures more energy from the wind

Offshore wind energy is envisioned to play a significant role in the delivery of clean, renewable energy in the future and the cost is constantly reduced. Offshore wind projects coming online today are already delivering power at almost half the price of those finished in 2012 due to increased competition and larger turbines and components. A good example of that is the 88.4 metre blade for offshore application, introduced by LM Wind Power in June 2016. The giant blade is based on a newly developed carbon-glass hybrid technology and has been designed, manufactured and tested to last for 25 years of life offshore, in the harshest weather conditions and roughest seas. One wind turbine with 88.4 metres blades can generate enough electricity to power 10,000 European homes.

Facts

- Length: 88.4 metres
- Weight: 34 tons
- Tip speed: 300 km/h
- Manufactured by LM Wind Power in Lunderskov, Denmark in June 2016

LM Wind Power

Photo: LM Wind Power

6. BUILDING A GREEN FUTURE

Wind energy means jobs, growth and exports

The green agenda is a growth agenda. It provides jobs, growth and exports in the wind industry, local jobs in installation, service and maintenance, and it provides a clean and modern energy supply for a competitive economy.

By Troels Ranis, Director, Danish Energy Industries Federation

Wind power is clean energy from an abundant natural resource. The benefits of wind energy from an environmental and climate point of view are well documented.

Furthermore, as the technology matures and is scaled up, and the energy systems and markets integrate still more wind energy, the price of wind energy is coming down and it delivers a valuable contribution to a secure and stable energy system.

Thereby, wind energy is an integrated part of a competitive business environment, attracting investment and engagement from global companies in search of reliable, green energy at competitive prices.

Wind as a source of employment

As wind energy has grown big in Denmark, Europe and beyond, so has the wind industry. Today, the wind industry is a strong contributor to jobs, growth, exports and wealth. According to WindEurope, the European industry employs over 300,000 people and accounts for a EUR 72 billion (DKK 535 billion) annual turnover.

According to the Danish Wind Industry Association, the wind industry employs more than 31,000 in Denmark today, corresponding to 2% of the private sector employment of the country. The wind industry provides jobs at all levels of qualification and most jobs are located outside the capital area. In fact, 80% of the wind industry's jobs are placed in the western, predominantly rural, part of Denmark.

Installation of wind energy creates jobs in the installation phase as well as long-term jobs within operation and maintenance. The installation of 100 MW offshore wind capacity creates 1,800 jobs in the installation phase.

It's green and it's good business

In 2015, exports of wind technology accounted for more than EUR 4.4 billion (DKK 33 billion), equivalent to 5% of total Danish exports of goods.

According to the Danish Energy Industries Federation, total energy technology exports in 2016 accounted for 11.8% of total Danish exports of goods. This is the highest share among EU countries and it proves that Denmark is highly competent and specialised in exports of energy solutions including wind technology.

Danish export of energy technologies has grown at a strong pace in recent years with wind technology as an important driver. The vision shared by government and the energy industry is to double Danish export of energy technologies to EUR 19 billion (DKK 140 billion) by 2030.

"Wind energy creates jobs and growth in the wind industry and local jobs in building, operation and maintenance of wind parks. Further, wind energy is part of a modern, diversified and resilient energy system utilising local, renewable energy resources and contributing to growth and competitiveness in society at large."

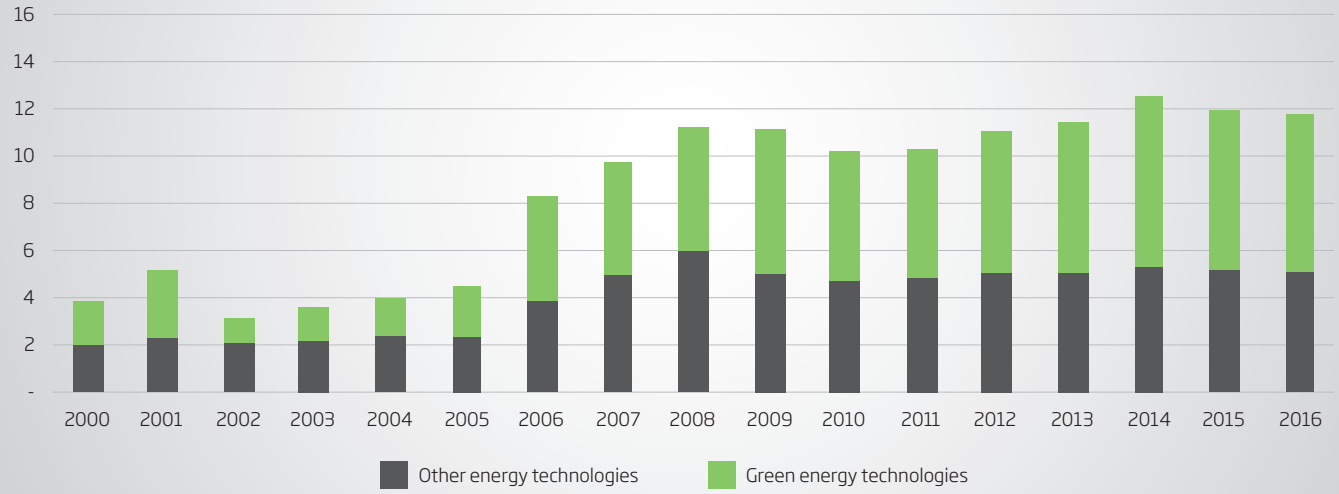
Troels Ranis, Director,
Danish Energy Industries Federation

Overall, the expansion of wind energy leads to job creation in the industry and related sectors. The installation of wind projects leads to significant local employment in the installation phase as well as jobs in operation and maintenance in the whole life span of the project. Many such jobs exist in Denmark due to the large wind industry and vast installation of wind generation capacity throughout the country. International experience shows that wind projects lead to local job creation and growth – both in the installation phase and permanently.

Construction of the Burbo Bank Extension offshore wind farm

Photo: MHI Vestas Offshore Wind

Share of energy technology in total Danish export of goods 2000-2016



Note: Export figures excluding oil rigs
Source: Danish Energy Technology Exports 2016 by Danish Energy Industries Federation, Danish Energy Association and the Danish Energy Agency

Green technology as driver for exports

In 2016, Denmark's exports of energy technology amounted to over EUR 10 billion (DKK 74.3 billion), corresponding to 11.8% of the country's total exports of goods. This is the highest share of energy technology exports among EU15 countries where the average share of energy technology in total exports of goods is 7.1%.

Analysing Danish export figures further shows that green technologies accounted for 57% of energy exports in 2016 and that the export value of green technology has grown by 44% since 2010. Wind technology constitutes an important part of this figure and this testifies that Denmark is indeed highly specialised in exports of modern and green energy technology and that the green transition is indeed a growth agenda for Denmark.

Confederation of Danish Industries

Wind farms create many local jobs

Experience from the numerous wind farms built over the years shows that they create many local jobs, even if the turbines themselves are produced elsewhere.

The 400 MW Anholt Offshore Wind Farm created 8,000 temporary jobs, of which 1,400 were for skilled/unskilled workers. Many of these jobs were linked with the town of Grenaa, from which materials for foundations, for example, were shipped. Many of the workers involved in erecting the turbines lived in or near Grenaa. Following completion, the wind farm created 70-100 permanent jobs for operational and maintenance workers.

Djurs Wind Power (DWP) was established to underpin this local anchorage in Grenaa and it is currently affiliated with 32 companies employing a total of 1,200 people. These companies are system suppliers that offer an all-encompassing array of services ranging from know-how, in the areas of planning, production, assembly and installation, to operations and maintenance. DWP has set up a point of contact for the 32 companies, which offer a variety of solutions and services, thus strengthening the local network and creating more jobs.

3F - United Federation of Danish Workers

Photo: DONG Energy

7. SETTING THE STANDARD FOR TENDER PROCESSES

Negotiating procedures is part of the Danish offshore tender model

As part of the Danish Energy Agreement from 2012, two large-scale offshore wind farms will be commissioned before the end of 2021. The 400 MW Horns Rev 3 and the 600 MW Kriegers Flak projects will therefore become part of the Danish transition to a green energy supply.

By Martin Hansen, Deputy General Director, Danish Energy Agency

The Danish tender process for offshore wind farms

In Denmark, the tendering model for offshore wind farms is a negotiated procedure, which includes both prequalification and a preliminary technical dialogue with potential tenderers and investors. The tendering procedures for the offshore wind farm projects Horns Rev 3 and Kriegers Flak were initiated simultaneously, but the procedures were finalised in Spring 2015 and Fall 2016, respectively. In both cases, the Danish Energy Agency (DEA) was the contracting authority.

Screening of potential wind farm sites

In the selection of suitable areas for wind farms as well in the preparation of tender documents, the DEA is in continuous dialogue with other relevant authorities regarding subjects of common interest surrounding any project. These include the grid connection, the national defence aspect, the navy and commercial shipping traffic, the protection of the natural environment, the extraction of raw materials and the fishery and marine archaeology. The dialogue reduces the risk of any conflicts of interest for the selected areas.

The upfront dialogue with the potential tenderers and investors

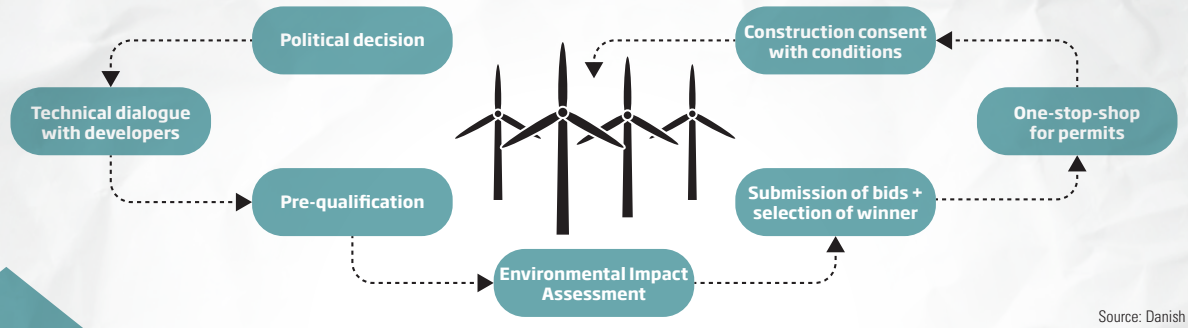
The establishment of an offshore wind farm is a complex investment project. Ongoing technical developments and changes in the economy puts great demands on the design of the framework conditions in the tender documents. In order to ensure that potential tenderers can offer their views on these framework conditions and contribute to make these attractive and flexible for the market, the DEA conducts a technical dialogue. This means that the DEA asks the market specific questions based on selected themes, and simultaneously, that the DEA invites potential tenderers to volunteer their supplementary ideas and suggestions.

In order to further reduce the risk for all parties involved, the DEA seeks information about the market challenges faced by investors. This means that potential mistakes can be corrected in the initial phase of a tendering process and before the publication of a contract notice and contract documents. All comments and suggestions for changes to the process are published anonymously in order to help establish and determine the framework conditions, which are included in the final contract documents.

The awarding criteria

The Danish Energy Agency coordinates and grants all the necessary permits and licenses needed in the commissioning of the offshore wind farms. This coordination from one single authority is the so-called one-stop-shop concept. The only awarding criteria in the tendering of a Danish offshore wind farm project is the price (DKK/kWh) for the first 50,000 full-load hours, which roughly corresponds to a subsidy period of 11-12 years. For the rest of the estimated 25-year lifetime of an offshore wind farm, electricity is sold at market price.

ONE-STOP-SHOP CONSENT PROCEDURE

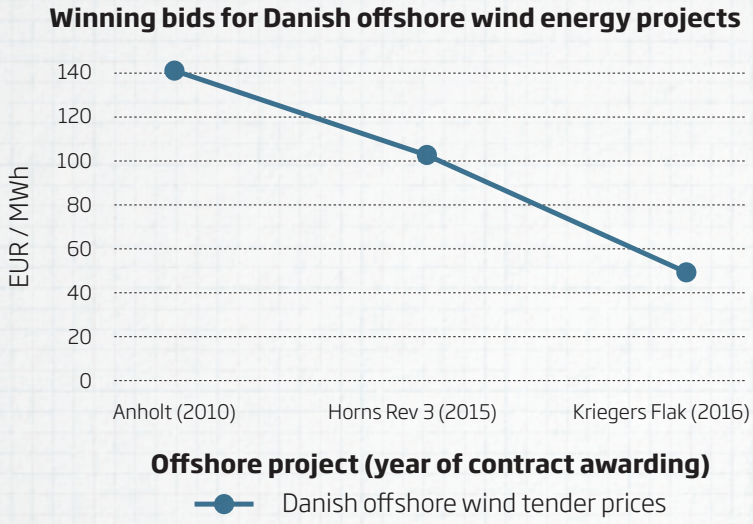


Source: Danish Energy Agency

The Danish Energy Agency as a one-stop-shop

Offshore wind farms require thorough and well-considered planning, which takes into account a multitude of interests related to e.g. the natural environment, safety at sea, offshore resource extraction, visual interests and grid transmission conditions. In Denmark, a number of different permits are required to establish an offshore wind farm, and these permits are granted by several different authorities. To make it easier and faster for project developers who have been awarded contracts to establish offshore wind farms, the Danish Energy Agency (DEA) has developed a one-stop-shop concept. The concept works as a single point of access on issues related to main permits, where the DEA will grant the required permits and coordinate with relevant authorities. This way, the one-stop-shop concept handles the largest administrative issues and interests related to the construction of offshore wind farms. The concept thus ensures a smooth process for project developers, and the DEA can contribute to a better understanding of these projects at the offices of other authorities.

Danish Energy Agency



Anholt, 400 MW (2010)
EUR 141/MWh

Horns Rev 3, 400 MW (2015)
EUR 103.1/MWh

Kriegers Flak, 600 MW (2016)
EUR 49.9/MWh

Source: Danish Energy Agency

Historically low bid for offshore wind farm

In November 2016, Vattenfall won the tender to build Kriegers Flak, which at 600 MW will become Denmark's largest offshore wind farm. The tender price of EUR 49.9/MWh (DKK 372/MWh) also makes Kriegers Flak the cheapest offshore wind project to date. The low price reflects a more mature market for offshore wind energy, with an increasing number of players entering the market, enhancing competition. Furthermore, flexibility and a simple, proven process in the tender procedure handled by the Danish Energy Agency contributed to the success of the low-priced winning bid. The last years have seen a seen a significant cost decrease in the offshore wind energy technologies and this has drastically lowered the tender prices from EUR 141/MWh (DKK 1,048/MWh) in the Anholt tender in 2010 to Kriegers Flak 49.9/MWh (DKK 372/MWh) in 2016. By 2021, Kriegers Flak will generate electricity corresponding to the annual consumption of more than 600,000 households – equivalent to 23% of all households in Denmark.

Vattenfall Vindkraft

Government-to-government agreements

The Danish Energy Agency (DEA) cooperates with the governments of several emerging countries in order to contribute to their reduction of carbon emissions and to assist in their energy transition towards low-carbon economies. These partnership programmes include, among others, China, Mexico, South Africa and India. The potential impact of a green energy transition is as large as 3 billion energy consumers, encompassing more than 50% of the global greenhouse gas emissions.

The cooperation is primarily focused on policy improvements in long-term energy planning and modelling, renewable energy integration and deployment, energy efficiency interventions and climate change mitigation. DEA actively promotes public-private cooperation based upon experiences in the development of the Danish energy model in close corporation with the private sector. A tangible example of DEA bilateral cooperation is the close cooperation with key Chinese stakeholders to improve the integration of large amounts of wind-generated electricity to the grid.

National Energy Administration (NEA),
China National Renewable Energy Centre (CNREC),
Energinet.dk, Ea Energy Analyses

Source: Danish Energy Agency

8. BLENDED FINANCE CAN MOBILISE PRIVATE CAPITAL FLOWS TO EMERGING AND FRONTIER MARKETS

Investing in renewable energy in high-risk markets is possible through public-private financial models - e.g. blended finance

Investing in 365 wind turbines in Kenya to contribute to reduce the country's dependence on import of fossil fuels could seem too ambitious and too high-risk for a Danish institutional investor like PensionDanmark. The investment is only possible through blended finance models.

By Torben Möger Pedersen, CEO, PensionDanmark

Pure private investments would be completely unfeasible due to high risk and lack of country-specific knowledge. However, blended finance models have made these investments possible through the Danish Climate Investment Fund (KIF). KIF offers risk capital and advice for climate investments in developing countries and emerging markets in Asia, Africa, Latin America and parts of Europe. KIF has made its first big investment of EUR 11.6 million (DKK 87 million) in a wind farm at Lake Turkana, Kenya. The wind power project will be the largest wind park in Sub-Saharan Africa, and the 310 MW wind farm will produce around 20% of Kenya's current installed electricity generating capacity at a very cost-efficient price and will replace fuel imports of approx. EUR 120 million (DKK 900 million) annually.

Fund managed by IFU

The commitments to KIF are split between the Danish government, IFU - Denmark's Investment Fund for Developing Countries – and the institutional investors PKA, PBU and PensionDanmark. PensionDanmark has committed EUR 27 million (DKK 200 million) to investments through KIF. EKF, Denmark's Export Credit Agency, has simultaneously provided approx. EUR 135 million (DKK 1 billion) in loan guarantees. EKF's guarantee relieves the funding providers of risk, thus enabling the institutional investors' participation.

The fund is managed by IFU, which, since its inception 50 years ago, has participated in 1,200 investments in more than 100 countries in cooperation with Danish trade and industry. Therefore, KIF and IFU can offer strong financial experience, substantial knowledge about local business conditions and a broad international network.

Investments through the Danish Climate Investment Fund, where public and capital works together, promises to deliver attractive returns to the institutional investors and benefits Danish companies by placing orders in Denmark. The Danish company Vestas is supplying the 365 wind turbines at Lake Turkana.

Blended finance

In short, blended finance can make this type of investments in emerging and frontier economies bankable. The concept has three key characteristics:

- Leverage: Use of development finance and philanthropic funds to attract private capital into deals
- Impact: Investments that drive social, environmental and economic progress
- Returns: Financial returns for private investors in line with the market rate, based on real and perceived risks

Blended finance can foster private financing for environmentally friendly projects enabling the diffusion of climate-friendly technology throughout the economy, and at the same time initiate projects, that under normal circumstances would involve too high a degree of risk for private investors, bankable and financially sustainable. Especially the ability to reduce political and regulatory risks through the use of blended finance models are central to what makes the model relevant. KIF is expected to ensure induced investments of approx. EUR 1-1.2 billion (DKK 7-9 billion) due to the fund investing with local investors in the projects.

Blended Finance:

OECD defines blended finance as the strategic use of development finance and philanthropic funds to mobilise private capital flows to emerging and frontier markets. Blended finance deliberately channels private investment to sectors of high-development impact while at the same time delivering attractive risk-adjusted returns. The Danish Climate Investment Fund is one example. Others include The IFC-Canada Climate Change Program, Global Environment Facility and The Danish Agribusiness Fund.

Photo: Prøvestenen Vindmøllelaug

Wind turbine cooperatives - citizens as co-owners

With the commissioning of a new onshore wind project in Copenhagen in 2014, the wind turbine cooperative Prøvestenens Vindmøllelaug was formed. The project consists of three 2 MW turbines of which one is owned by private citizens through the cooperative and two are owned by the Danish utility company HOFOR.

HOFOR developed and initially financed the project and then offered 33% the shares to locals in a preferential option to purchase. Wind turbine cooperatives have existed in Denmark for decades. According to the Danish Act on Renewable Energy it is mandatory to offer at least 20% of the ownership in new onshore and near shore wind farms to local citizens. The ownership is usually offered as shares of approx. 1,000 kWh in annual production. The purpose of this provision is to promote local acceptance from neighbours to wind farms through co-ownership and in the case of Prøvestenens Vindmøllelaug, the cooperative consists of 4055 shares owned by 516 shareholders. Each year, the board of the cooperative is elected at the annual general meeting and the cooperative idea is that one share equals one vote.

HOFOR, Prøvestenens Vindmøllelaug

Making offshore wind attractive to investors

For institutional investors, investment in offshore wind is attractive because of long investment periods, stable returns and a strong cash flow. Offshore wind can serve as a substitute to certain bond types. However, the institutional investors' lack of experience with these projects has given ground to the formation of specialised infrastructure funds such as Copenhagen Infrastructure Partners (CIP), who, unlike most other infrastructure funds, have a long investment period (20 years). The CIP investment in the 588 MW UK offshore wind project Beatrice is a good example of how and why the industrial approach works. The two stakeholders of Beatrice, the UK energy company SSE and the Chinese investor SDIC, developed the project from 2009 and CIP entered the project with a 35% share at the last stage of the development. This was late enough for the development risks to be significantly reduced yet early enough to allow CIP to participate in the optimisation of risk allocation.

Copenhagen Infrastructure Partners

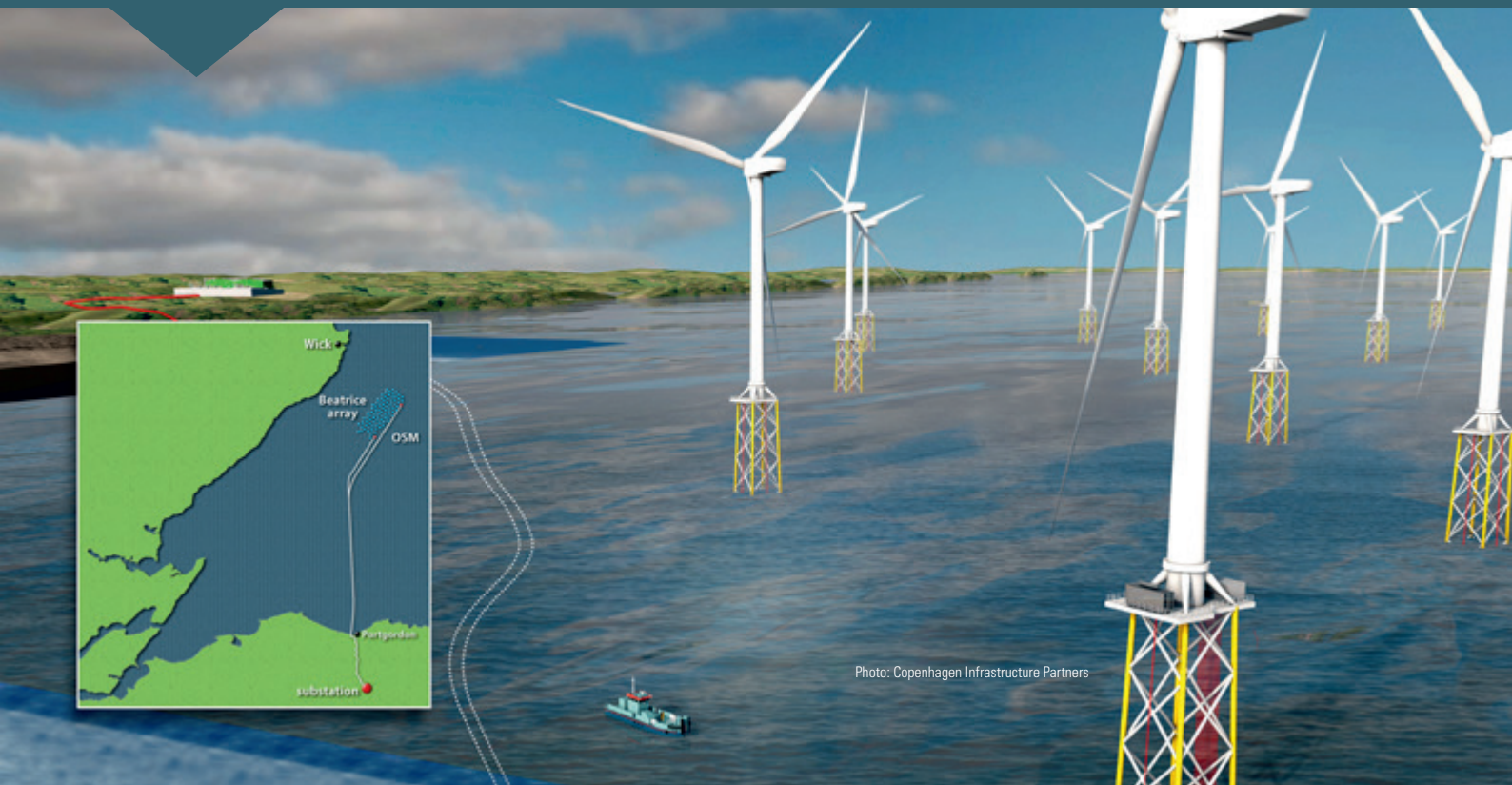


Photo: Copenhagen Infrastructure Partners

9. PUSHING THE BAR FOR WIND ENERGY

New innovations and large ambitions take wind energy to the next level

Since the 1970s, the wind energy sector has transformed itself from an infant industry to a commercial success with a proven product. Yet research, test and demonstration ensure a constant push for higher ambitions and innovation. As a result, the Danish companies maintain a strong focus on product development and continue to explore, green solutions to meet the global demand for renewable energy sources.

Illustration: DONG Energy

Hornsea Project One

With a capacity of 1.2 GW, Hornsea Project One will be the world's first offshore wind farm to exceed 1 GW in capacity and become - by a considerable margin - the world's largest ever offshore wind farm. It will be capable of powering well over 1 million UK homes when operational in 2020. Hornsea Project One is located 120 kilometres off the Yorkshire coast and the project will span a total area of approx. 407 km2. The project will use 7 MW wind turbines each with a height of 190 metres - larger than the Gherkin building in London. As part of the project, DONG Energy will construct the longest ever offshore high voltage AC electrical system. The system will take the clean electricity produced by the wind turbines, transmit it to shore and then feed it into the national grid. This system includes more than 900 kilometres of cables.

Hornsea Project One will mark yet another milestone for offshore wind as a utility-scale, domestic source of renewable energy. And importantly, offshore wind can bring economic revitalisation to coastal areas and create thousands of jobs in construction, manufacturing and operations.

DONG Energy

Photo: MHI Vestas Offshore Wind

The world's most powerful turbine

With an aim to drive down the cost of offshore wind while increasing the energy output per turbine, MHI Vestas Offshore Wind has brought its V164-8.0 MW to market. The nacelle is 20 metres long, 8 metres wide and 8 metres high. Each blade is 80 metres long and weighs more than 35 tonnes. The prototype, located at the Østerild National Test Centre for Large Wind Turbines, broke the energy generation record for a commercially available offshore wind turbine in December 2016 by producing 216,000 kWh over a 24-hour period. MHI Vestas has now uprated the 8 MW wind turbine, enabling it to reach 9 MW at specific site conditions. The increased production will add value to projects and save on Capital Expenditure (CAPEX) costs, as fewer turbines are needed to meet park capacity.

In April 2016, the first two commercial 8 MW turbines were commissioned in an onshore project at Maade in Denmark. The 258 MW Burbo Bank Extension offshore project in Northwest England, developed by the Danish utility company DONG Energy, is the world's first offshore wind park (32 turbines) to fully comprise the record breaking 8 MW platform.

MHI Vestas Offshore Wind

Challenging the known wind concepts

In cooperation with the Technical University of Denmark, Vestas has installed a concept demonstrator turbine to test the technical feasibility to operate and control a multi-rotor turbine. The test turbine has four refurbished 225 kW nacelles instead of one with a total of 12 blades. In July 2016, the turbine produced its first kWh and this was an important step in the monitoring and testing phase. With the test turbine, Vestas is challenging the scaling rules, which imply that turbines have to grow in size to increase their energy output. The aim is to lower the levelised cost of energy (LCOE) of wind as well as address transport and installation challenges in some markets. Many new load and control features will need to be developed, tested, and proven to assess the technical and eventually the commercial feasibility of the concept, and first after successful demonstration will Vestas know more about the possible use of the technologies.

Vestas Wind Systems

Photo: Vestas Wind Systems

Learn more about Danish wind solutions, find more cases from around the world and connect with Danish expertise at:

stateofgreen.com/wind-energy

State of Green is a non-profit, public-private partnership founded by:

Confederation of Danish Industry

DANISH ENERGY ASSOCIATION

Danish Agriculture & Food Council

DANISH WIND INDUSTRY ASSOCIATION

Ministry of Industry, Business and Financial Affairs

Danish Ministry of Energy, Utilities and Climate

Ministry of Environment and Food of Denmark

Ministry of Foreign Affairs of Denmark