Wind energy, driving the global market

How wind is pushing the ambitions for a renewable energy transition

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WIND ENERGY — DRIVING THE GLOBAL MARKET

How wind is pushing the ambitions for a renewable energy transition

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FRONT PAGE PHOTO

Photo credit: Vattenfall

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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 intermittency of renewable energy.

Denmark was the first country to install a commercial offshore wind farm 30 years ago and has been a first mover in the wind industry for decades. In 2019, Danish wind turbines covered the equivalent of 47.2 per cent of the Danish electricity consumption, which is a new record and more than a 7 per cent increase from 2018.

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 33,000 people. The availability of a highly skilled workforce, state-of-the-art 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 4,800 turbines with a combined effect of 6.9 GW are installed in Denmark today with a majority of them onshore. The 6.2 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 electricity 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 energy sources is declining and the latest tenders for offshore wind farms in Denmark have the lowest Levelized Cost of Electricity (LCOE). This means 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, 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 financing 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.

Sharing wind energy

BY DAN JØRGENSEN, DANISH MINISTER FOR CLIMATE, ENERGY AND UTILITIES

Wind is an abundant renewable energy resource to be developed much further in the future to reduce our dependency on fossil fuels and ensure our energy security. By 2020, wind energy accounted for over 15 per cent of electricity consumed in the EU. In Denmark, the leading country in wind energy, it reached almost 50 per cent. Wind energy plays a key role in reaching Denmark's target of 70 per cent greenhouse gas emission reductions by 2030.

Today, wind energy is already a reliable and competitive pillar in the European energy supply – and throughout the world, major countries such as the United States, China, India and Brazil are among the largest investors in wind energy. Wind energy grows in virtually all countries.

In Europe, targets and plans are in place to accelerate wind energy much further in the future. In the field of offshore wind energy, plans are to 5-double capacity by 2030 – and to 25-double to 300 GW by 2050.

Denmark is taking bold steps in this direction with plans to establish an artificial island as an energy hub 80 km off the west coast of Denmark. The energy hub will serve as an offshore power plant gathering and distributing green electricity from hundreds of wind turbines surrounding the island directly to consumers in countries surrounding the North Sea. The energy hub will produce yet unseen amounts of green electricity and is a flagship project for the green transition in Europe. Fully implemented, it will be able to cover the consumption of 10 million European households.

As a pioneer and leader in wind energy, Denmark has much to share with its partners: Experience in planning, building and connecting wind energy to the grid ensuring maximum efficiency at lowest cost. We also know how to ensure efficient integration of still larger amounts of wind energy in energy systems – and thereby increase electricity use in the whole economy through sector coupling. Further, Denmark is home to some of the world's most prominent technological and commercial players in wind energy – eager to share their experience and engagement with partners worldwide.

We invite you to join us. We are ready to engage, and we look forward to continuing the wind journey with our many international partners.

Dan Jørgensen
Danish Minister for Climate, Energy and Utilities

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CHAPTER 1

Denmark — a frontrunner in wind energy

From agricultural windmills to specialised wind turbines, the Danish wind industry is at the forefront of technological developments. With onshore wind being the cheapest electricity source, electrification of our society is the next big step.

Wind turbines were initially used in agriculture to grind grains and pump water. But in 1891, the Danish physicist Poul la Cour experimented with wind energy as a source of electricity. Supported by government funds, he created a turbine supplying the school he worked at with direct current. In 1894, La Cour even experimented with wind energy storage transforming electricity from his wind turbine into hydrogen.

Danish engineers continued to improve the wind turbine technology during World War I and II to maintain the electricity supply during shortages. By the end of World War I, three per cent of the 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 - fossil fuel prices were simply lower.

A regained interest in wind
The first oil crisis in 1973-74 changed this perception. Highly dependent on imported energy, the early 1970s crisis led to increased electricity costs in Denmark. As a result, wind energy and renewable 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 wind energy. By the early 1980s, around 20 manufacturers of turbines were active in Denmark, and after a phase of consolidation in the 1990s, the industry became dominated by large, partly internationally owned and listed companies.

Outperforming fossil fuels
Today, the Danish wind industry employs more than 33,000 people with a turnover of EUR 19 billion in 2019. In constant search for more efficiency and lower energy costs, the size of wind turbines has grown steadily over the years. While most turbines in the early 1990s had sizes of up to 225 kW, the newest models reach no less than 15 MW. As a result, the cost of wind energy technology has dropped drastically over the years. Wind turbines are now a highly cost-efficient way to produce electricity. In fact, onshore wind energy is the cheapest source of energy in Denmark and many other parts of the world – outperforming any fossil fuel.

Harnessing energy of wind offshore is more expensive than onshore. However, the benefits are a richer and more stable wind resource with fewer neighbour concerns when turbines are installed in open seas. As a first mover in offshore wind, Denmark pioneered the market by installing the world's first offshore wind farm in 1991. Today, the Danish value chain for both offshore and onshore wind covers a wide range of technologies and services aimed at all phases of wind projects.

Powering the future
As the cost of wind energy continues to drop, its role in the transition of our energy system grows. With that, Denmark invests heavily in electrification. A classic example of direct electrification is replacing traditional fuels with electricity – like electric cars and electric heat pumps. However, there are also indirect paths, such as Power-to-X. Instead of replacing fuel with electricity, electricity is transformed into liquid fuels like hydrogen for heavy vehicles or ammonia for ships.

To support the electrification of the Danish society, the Danish parliament has continuously updated its Energy Agreement. In 2019, it enacted a national Climate Act with a legally binding target of reducing national greenhouse gas emissions by 70 per cent by 2030 (compared to 1990 levels) and reaching climate neutrality by 2050.

To reach this target, more wind energy will have to be installed on natural and constructed offshore hubs. The wind industry itself has already started to lay out a strategy to reduce the carbon footprint of its own value chain.

Furthermore, to maintain the stability of electricity supply at 99.99 per cent, Denmark must keep improving the way it integrates the intermittent energy from wind and other renewables through storage and increased collaboration with neighbouring countries.

Photo credit: State of Green

CHAPTER 2

The Climate Act defines the way

With the 2020 Climate Act, a broad majority of the Danish Parliament committed to reduce national greenhouse gas emissions by 70 per cent by 2030. The act is legally binding, making it a green international beacon.

The Danish Parliamentary election in 2019 showed that global warming is at the very top of voters' minds. The election became a "green game changer" with numerous political initiatives aimed at bringing Denmark closer to its ultimate goal of becoming climate neutral in 2050.

Following the election, these initiatives were turned into broad political agreements and concrete actions. In December 2019, the national Climate Act was passed with the overarching target of a 70 per cent reduction of greenhouse gas emissions by 2030 compared to a 1990-level. The act became legally binding with 94 per cent of parliament voting in favour of the agreement.

13 climate partnerships

To reach the target, the government formed 13 strategic "climate partnerships" representing all branches of Danish industry. The partnerships each had four months to formulate their recommendations on how their industry could reduce emissions. The recommendations today serve as a guide for the Danish politicians on taking the right measures, while maintaining a close involvement and commitment from the industry.

The recommendations are used in formulating political agreements across sectors to reduce emissions. Amongst the first to have a binding set of rules were the production and energy sectors. Here, a broad agreement was reached in the summer of 2020. The agreement introduced the establishment of energy islands, a substantial increase in the national offshore wind capacity, and other initiatives promoting a green transition. Overall, the agreement paves the way for a 3.4 million tonnes reduction in CO_2 emissions by 2030 out of the roughly 20 million tonnes needed to reach the 70 per cent target.

In the coming years, the Danish Parliament will add agreements for other Danish sectors e.g., the transportation and the heating sectors. These sectors are vital for the realisation of the 70 per cent target as electrification of the Danish society will be a catalyst. For the same reason, all political bills will be subject to a CO_2 calculation going forward, displaying their contribute to the overall reduction.

A green beacon

Seen in a global perspective, Denmark only has a miniscule carbon footprint, being the source of merely 0.1 per cent of the world's CO_2 emissions. So, it begs the question: Why would Denmark set such an ambitious target for greenhouse gas emission reductions? The answer is simple. Denmark has a key role in showing the world how to decouple CO_2 emissions from economic growth.

In the coming years, Denmark is likely to push forward on the green transition to illustrate to the world that green business is good business. In doing so, Denmark will continue to demonstrate that achieving the climate targets set forth in the Paris Agreement of 2015 is indeed within reach.

Over the coming years, Denmark will embark upon a widescale electrification to reach its 2030 greenhouse gas emissions reduction target. Oil, coal, and gas must give way for green electricity from wind energy in all sectors. The majority of the Danish Parliament stands behind the Climate Act that sets the bar high for the green transition.

Photo credit: The Danish Parliament/Christoffer Regild

CHAPTER 3

Electrification with wind energy

Direct electrification with renewable energy is central to decarbonise a range of sectors. Yet, some industry processes and heavy-duty transport require other green fuels and feed-stocks. The solution is hydrogen and e-fuels produced from renewables.

Denmark expects comprehensive direct electrification of both transport and heating in the coming years. Direct electrification is achieved when the energy source of a process is converted from fuel to electricity. Using renewable energy in direct electrification bring several societal benefits.

Emissions are for instance eliminated when fossil fuels are replaced with electricity generated from renewable energy. In many cases energy efficiency is also improved. Electric vehicles have an energy efficiency of around 80 per cent, while combustion engines in cars only have an energy efficiency of about 30 per cent. Also, electric heat pumps are 3-4 times as efficient as conventional boilers.

Indirect electrification
While direct electrification can be utilised in light transport and heating, other industries require energy dense fuels where electricity falls short. The electricity stored in chemical batteries has an insufficient energy density for powering long distance heavy transport and some industrial processes requiring high temperatures. In Denmark, the production of building materials alone would require about 10 TWh of electricity annually. The entire Danish industry and heavy transport sectors would require 50-60 TWh. This corresponds to the output from 15 GW offshore wind farms.

Indirect electrification is a sustainable solution to this. Indirect electrification is achieved when electricity is applied in chemical process to forge new, energy dense products. An example is electrolysis, where electricity from renewables is used to split hydrogen and oxygen molecules. Renewable hydrogen can be used in transport, industry and even agriculture. Alternatively, it can be combined with captured renewable carbon to create synthetic e-fuels where the only bi-product is essentially oxygen.

Electrification of transport
E-fuels can easily be implemented into existing liquid fuel infrastructure like tanks, pipelines, and engines. Like oil and gas, e-fuels can be transported by sea or pipelines over long distances. In this way, e-fuels also function as energy storage.

In Denmark, a consortium of companies within the road, maritime, aviation and energy sectors is already embracing the change. The consortium plans to produce renewable hydrogen at large scale, using energy from offshore wind. Initially, the hydrogen will be used for fuel-cell electric vehicles. As the project scales towards 2030, the hydrogen will be combined with a source of carbon – e.g., from sustainable biomass – to form green e-fuels for shipping and aviation.

Globally, the transport sector stands to gain large reductions in CO_2 emissions through electrification. In Denmark alone, CO_2 emissions from the transport sector could be reduced by 6.2 million tonnes.

Storage

The main challenge for wind and solar power is the inability to regulate their output. One solution to this is to introduce cost-efficient storage capacity to the electricity system. In Denmark, several alternative storage technologies are being developed.

High-temperature thermal storage

The Danish energy company, Andel (former SEAS-NVE) has developed a high-temperature thermal storage solution in collaboration with the Technical University of Denmark, Aarhus University Geoscience, the Danish Energy Association, Energinet and Rockwool. In this, the energy is stored in rocks heated up to 600 degrees with air from an electric fan heater. The heat will later be extracted to drive a conventional electric turbine. The ambition is to implement the solution on a large scale throughout Denmark at competitive prices, while addressing the challenge of storing large amounts of energy in a cheap, environmentally friendly manner.

CONTRIBUTORS

Technical University of Denmark (DTU), Aarhus University, the Danish Energy Association, Energinet and Rockwool

LOCATION

DTU Risø Campus, Roskilde

Photo credit: Mike Wichmann

Lithium-ion battery storage

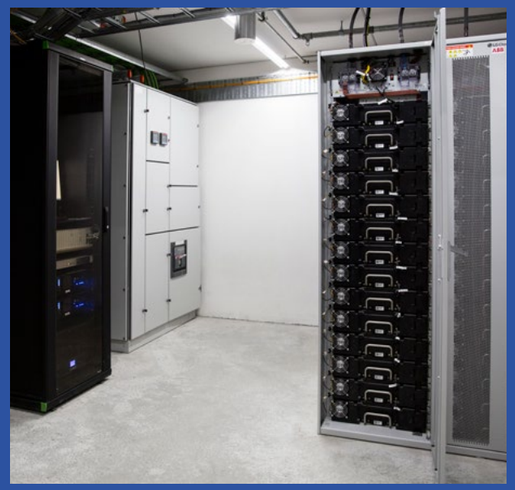
ABB has commissioned Denmark's first urban energy storage system. The lithium-ion based battery energy storage system (BESS) is integrated with the local electricity grid. The battery storage solution will account for a significant part of the energy system, in which solar and wind energy will provide the majority of electricity production. Since renewable energy production is intermittent, the storage system will be a key element for ensuring the security of energy supply.

CONTRIBUTORS

ABB, EnergyLab Nordhavn

LOCATION

Nordhavn, Copenhagen



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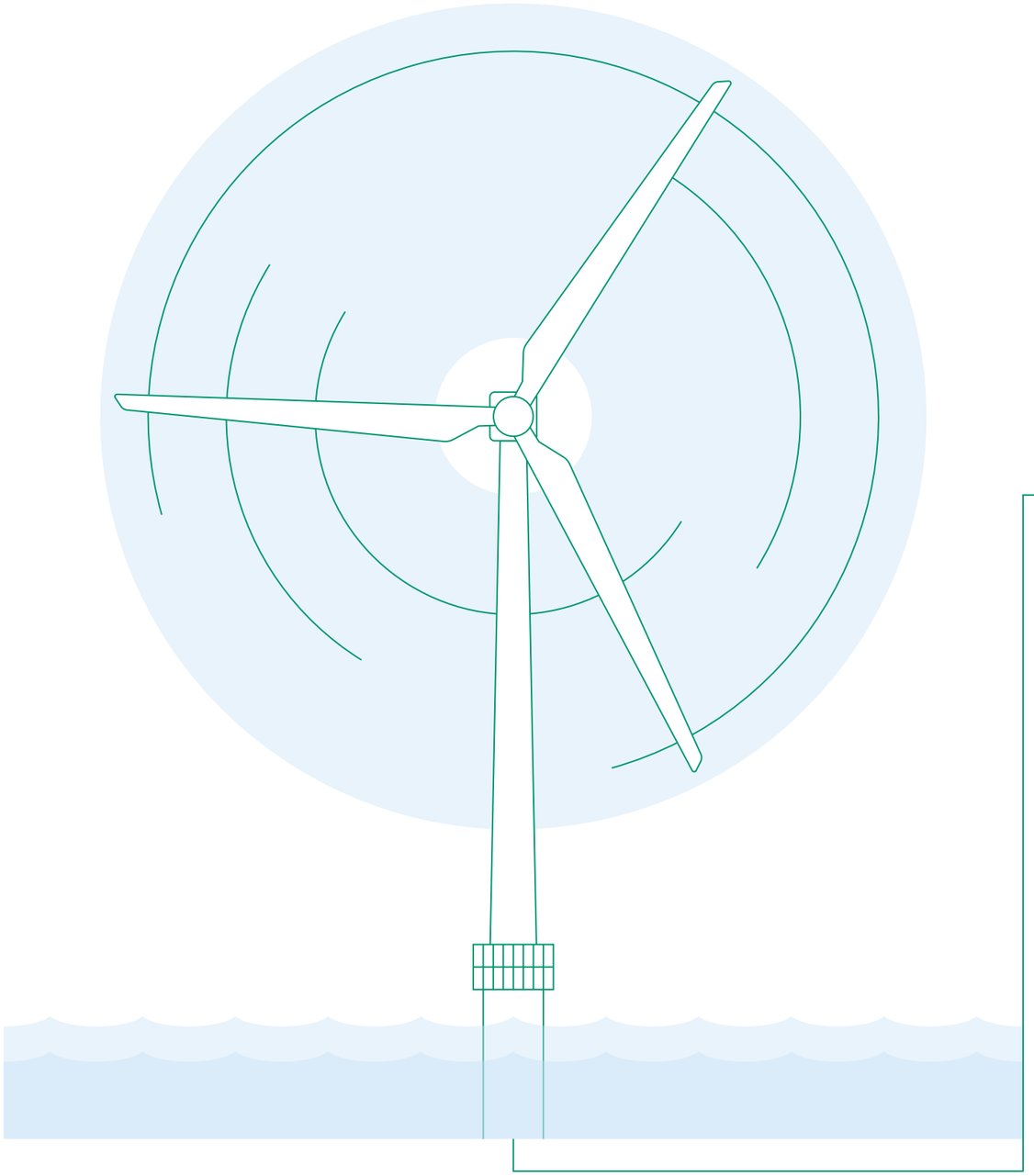


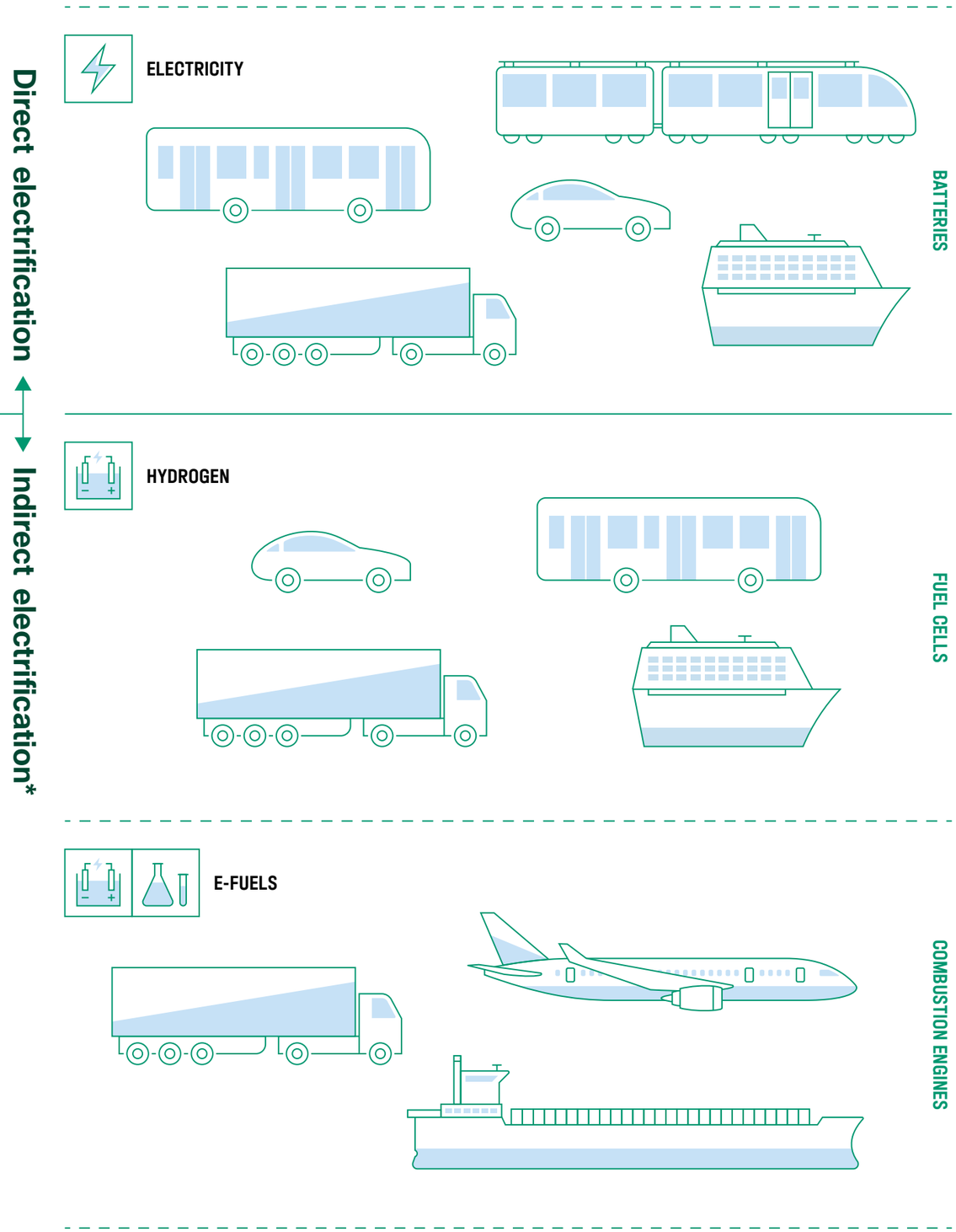
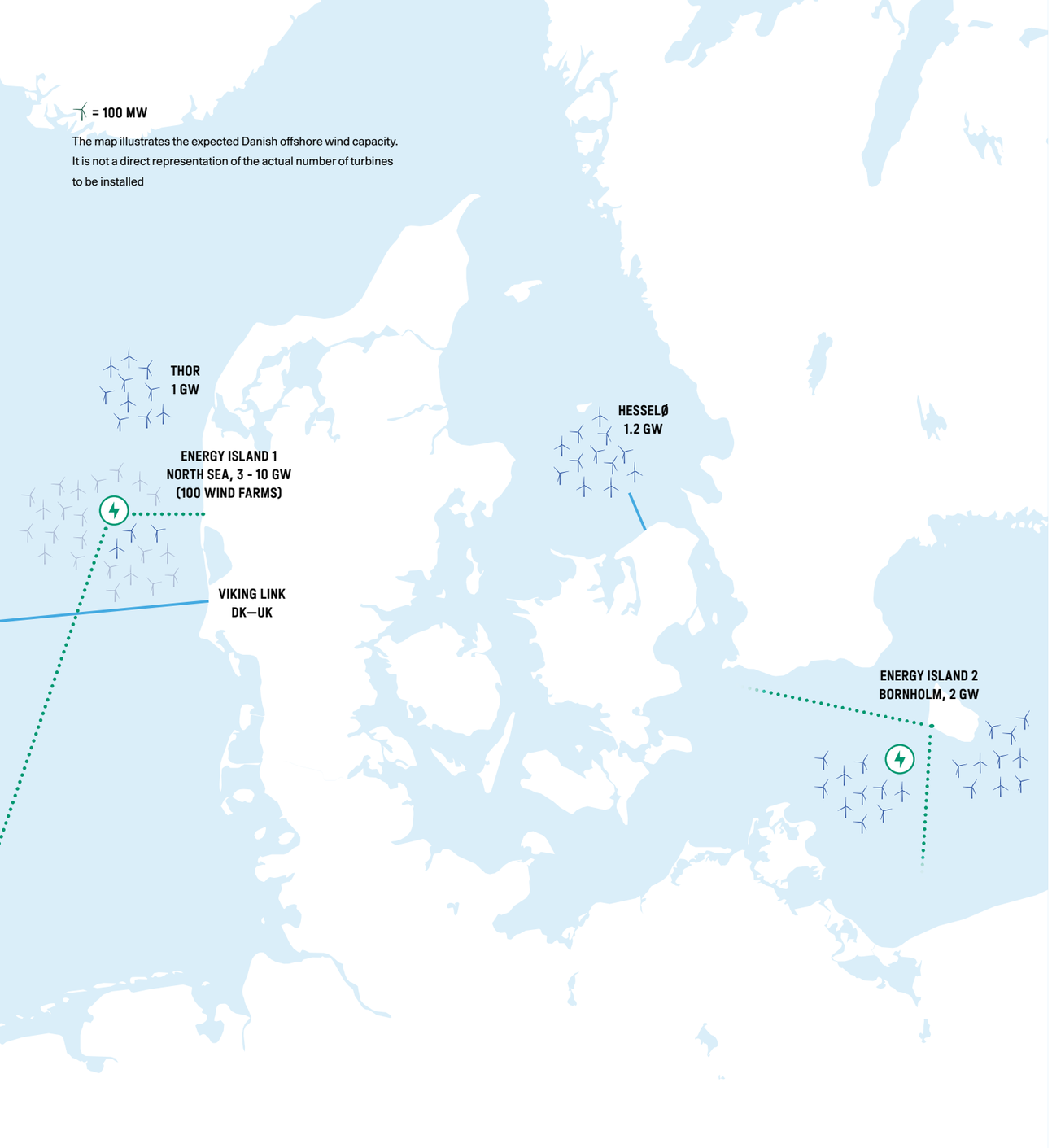


FIGURE 1

Direct and indirect electrification of transport

Wind energy can be used in both the direct and indirect electrification of the transport sector. Either as a source for the electricity stored in batteries or as the energy used to produce renewable hydrogen and other hydrogen based products known as e-fuels.

* The figure is for illustrative purposes and not exhaustive



North Seas Energy Corporation
Today, Denmark collaborates with the Netherlands, Germany, Belgium, Luxembourg, France, Ireland, Sweden, and Norway on the planning and construction of offshore wind farms through the North Seas Energy Cooperation (NSEC). The collaboration shares best practices, enhances coordination and harmonises regulation to ultimately reduce costs. Going forward, a greater need for joint and hybrid projects, coordinated maritime spatial planning and the alignment of technical standards is expected.

PLANNED WIND FARMS
POTENTIAL WIND FARMS
ENERGY ISLAND
PLANNED INTERCONNECTOR
POTENTIAL INTERCONNECTOR

CHAPTER 4

The Danish waters

With its large sea area, shallow waters and stable wind resources, Denmark has a vast potential for offshore wind. In the North Sea, Denmark will establish the first energy hub in the world with up to 10 GW of offshore wind capacity.

The Danish Sea area (12 nautical mile zone, exclusive economic zone and internal waters) covers 105,000 km² of largely shallow waters. This makes it both significantly larger than those of the Netherlands, Germany, and Poland, and ideal for bottom-fixed wind turbine foundations. The latter being a prerequisite for producing cost efficient wind power offshore.

Denmark's proximity to load centres like the United Kingdom, Benelux, Germany, and Poland provides opportunities for connecting offshore wind farms directly to neighbouring markets. Over half of the 300 GW offshore wind capacity that the EU aims to install by 2050 is expectedly located in the North Sea. A large share of this could be installed cost-competitively in Danish waters.

An energy exporter
Today, the Danish electricity consumption is around 35 TWh. Through direct and indirect electrification, the electricity demand is expected to increase to 50-70 TWh by 2030 in step with Denmark's emission reduction targets.

By 2033, the Danish offshore wind capacity will alone comprise 7 GW, generate up to 40 TWh by 2035, and surpass the current Danish electricity consumption. This means that Denmark stands to become a net exporter of electricity in the next decades.

Hybrid assets
Traditionally, offshore wind farms have been planned and built as single projects with single radial connection directly to shore. This changed in 2012 with the Danish decision to build the Kriegers Flak Offshore Wind Farm in the Baltic Sea in conjunction with an interconnector between Denmark and Germany: A so-called 'hybrid asset'.

Hybrid assets benefit from the ability to fully utilise the transmission system by both transporting power produced from an offshore wind farm to shore and serving as an interconnector. When there is excess capacity in the cable because the wind farm is not operating at full load, the cables of Kriegers Flak acts as an interconnector, importing and exporting electricity, to the benefit of Danish and German power producers and consumers. A need for fewer cables combined with higher cable utilisation rates have lowered overall project costs and investment needs.

Energy hubs
As offshore wind farms grow and move further from shore, great synergies can be achieved by combining more projects into offshore 'hubs' or 'islands' with shared transformation and connections to more markets. Denmark aims to build two such energy hubs. One by the island Bornholm in the Baltic Sea with an initial capacity of 2 GW offshore wind connected to both Denmark and Germany. The intention is to use Bornholm as a fixed platform for a transmission substation and potentially an operation and maintenance base. The hub can later be expanded with more capacity and connections to e.g., Germany and Sweden.

The second energy hub, constructed as an artificial island about 80 km off the west coast of Jutland, will initially cover around 120,000 m², supporting the infrastructure required for 3 GW offshore wind farms by 2033. Phase 2 includes the expansion of the physical island up to 460,000 m² and up to 10 GW.

CHAPTER 5

Strong international cooperation and partnerships

Through close partnerships and government-to-government cooperation with 19 countries, Denmark seeks to accelerate global emission reductions by sharing lessons learned from the Danish Energy Model.

Denmark has almost 50 years of experience in transitioning its energy system from black to green. Over these five decades, Denmark has shown how to sustain economic growth and high living standards, while reducing fossil fuel dependency and mitigating climate change. This is called the Danish Energy Model.

The backbone is a political framework characterised by an ambitious, long-term outlook and broad political support. The experience now serves as a catalyst for other countries with whom Denmark seeks to optimise the value of their energy system based on the Danish Energy Model.

Bilateral collaboration
By sharing lessons learned, Denmark aims to push the global green transition and support foreign governments to leapfrog their transition towards low-carbon energy sectors. Today, the Danish Energy Agency cooperates bilaterally with 19 emerging and developed economies. In addition, Denmark has a number of short-term country collaborations including *The Danish Energy Transition Initiative*.

These count Germany, Mexico, the Netherlands, Ukraine, Kenya, Poland and United Kingdom, where wind power is not part of the program. Specific offshore wind collaboration is set up with relevant authorities in China, India, Japan, South Korea, France, Turkey, the United States and Vietnam. On onshore wind power, the Danish Energy Agency collaborates with Egypt, Ethiopia, Indonesia and South Africa. Combined, the countries represent more than 60 per cent of global CO_2 emissions.

Four areas of expertise
The focus of the government-to-government cooperation is to assist local authorities and institutions in the green transition of their energy systems, while maintaining stable economic growth. Based on Danish knowhow, the partnerships revolve around:

- Long-term energy modelling and planning
- Enhanced framework conditions for renewable energy
- Integration of renewable energy and flexibility of the power sector
- Promotion of energy efficiency and district heating

In addition, the Danish TSO, Energinet, holds vast experience in ensuring a record-high energy security. It works as a close partner in many of the country partnerships. Danish embassies in partner countries also play a crucial coordinating role.

Promoting green developments
By supporting a shift towards more sustainable energy systems, renewable energy installations grow and new markets for green solutions mature. This supports the market development for wind power and energy efficient solutions and reduces the barriers for green investors.

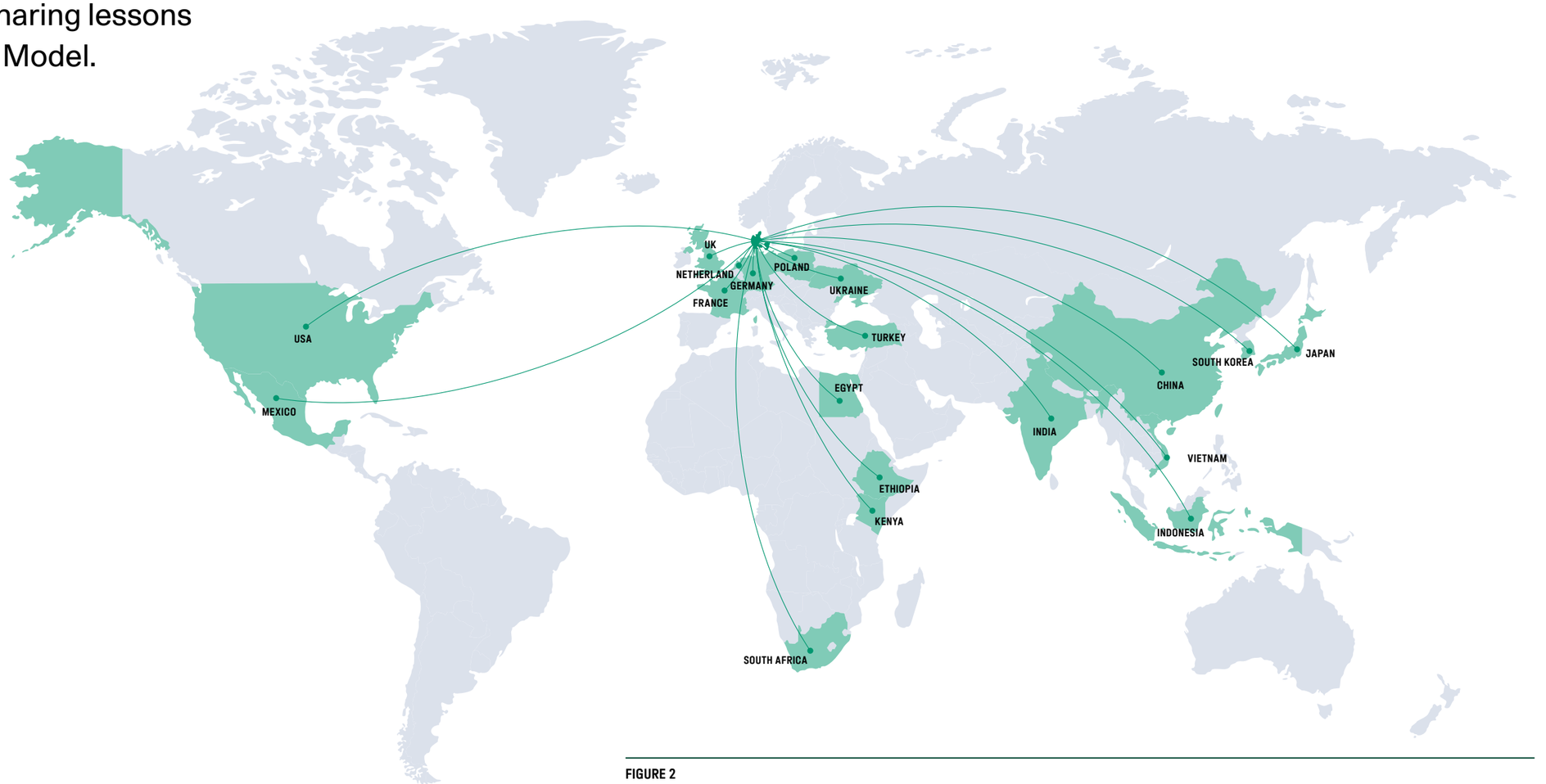


FIGURE 2

Denmark has entered into partnerships with 19 countries around the world, representing more than 60 per cent of global CO_2 emissions.

US collaboration on offshore wind tenders

Since 2017, the Danish Energy Agency has formally cooperated with the American Bureau of Ocean Energy Management (BOEM) via the Energy Governance Partnership (EGP). The partnership focuses on sharing experiences with the planning and regulatory environment for offshore wind farms in Denmark. In 2018, the EGP-program started a collaboration on offshore wind with New York State Energy Research and Development Authority (NYSERDA) and with California Energy Commission (CEC). The collaboration covers diverse offshore wind tendering topics like risk management, regulatory streamlining, environmental mitigation measures, long-term planning and consenting. In 2020, the EGP-program expanded its cooperation to New Jersey Bureau of Public Utilities (NJ BPU), also on offshore wind and the regulatory environment.

CONTRIBUTORS

Danish Energy Agency

LOCATION

New York, United States of America

Indian tie-up on offshore wind

In 2021, the Indian Ministry of New and Renewable Energy and the Danish Energy Agency established a Centre of Excellence for offshore wind. Based in India, the ambition is to become a leading hub for renewable energy in South and East Asia. Visioned to promote inclusive approaches to offshore wind, the centre seeks to reduce investor's risk and secure coherent planning towards a cost-effective sector. As India's Prime Minister Narendra Modi highlights: "Denmark has the skills, India has the scale".

CONTRIBUTORS

Danish Energy Agency

LOCATION

India

CHAPTER 6

A new era of offshore wind tenders

As a pioneer within offshore wind, Denmark has extensive experience in developing best-practice framework conditions with minimal risk and regulatory constraints. With solid political backing, Denmark leans in on a future where electricity from offshore wind will be generated with minimum subsidies.

Offshore wind is inherently a complex business, hence planning procedures and allocation of risks are both important issues when designing a regulatory framework. The Danish approach for tendering new offshore wind farms is the result of many years of experience in setting up conditions for large-scale wind farms. The initial groundwork was laid in 2002 prior to the announcement of the very first offshore wind tender – Horns Rev 2. Since then, regulation, planning, and tender models have evolved and adapted.

Flexibility and de-risking are key

It has been a priority to secure transparency and flexibility for investors to make the Danish market attractive. Relevant stakeholders are invited to market dialogues to discuss the tender material. Full flexibility is given to design the wind farm. The awarding criteria are very clear, and only financial and technically competent companies can participate in the process.

Another principle of the Danish model is efficiency, which is achieved via the one-stop-shop concept. This is embedded in Danish legislation and allows the Danish Energy Agency to be the single point of contact throughout all phases of establishing offshore wind projects – from early planning to commissioning and operation. This approach reduces the risk of unforeseen regulatory barriers and enhances thorough planning and coordination amongst authorities.

New measures for future offshore tenders

Over the years, the Danish framework conditions have led to healthy competition in the market serving to push down cost. To stay ahead of the newest developments, Denmark consistently seeks to improve the planning, regulation, and tender procedures. These could be technological improvements challenging the regulations or regulatory barriers to new sources of finance. It could also be other issues that pose a disproportionately large risk to the project and thus raise the cost.

Today, the Danish Energy Agency is implementing new ways of driving down the costs and still maintain a high degree of security for investments. As part of the Energy Agreement from 2020, political parties in the Danish Parliament have agreed to establish two offshore wind farms with an individual capacity of around 1 GW before 2030. The principles in the agreement are to pave the way for a green transition on market conditions. Therefore, new measures are included in the ongoing tender of the Thor Offshore Wind Farm (800-1,000 MW). This counts a new subsidy scheme (CfD model) and a different interface solution for the grid connection. The interface gives the developer the responsibility to construct, own, and operate these installations.

The second tender, Hesselø Offshore Wind Farm (800-1,200 MW), can potentially become the largest offshore wind farm in Denmark with the 200 MW "overplanting" option given to developers. Also, the option of adding batteries, storage, and PtX facilities is a concept, which has not been applied in previous tenders. Both projects are expected to be commissioned latest by 2027 with the aim to foster innovation, optimise grid solutions, and ultimately lower the total cost of the offshore wind farm.

"INNOVATION OF FRAMEWORK CONDITIONS IS EXTREMELY IMPORTANT TO REDUCE RISK AND LOWER THE COST OF THE OFFSHORE WIND TECHNOLOGY. FRAMEWORK CONDITIONS ARE KEY TO THE ATTRACTIVENESS AND BANKABILITY OF OFFSHORE WIND PROJECTS. OFFSHORE WIND TECHNOLOGY WAS BORN IN DENMARK, AND WITH MORE THAN 30 YEARS OF UNIQUE EXPERIENCE IN BUILDING WIND FARMS WE HAVE REACHED A POINT WHERE WE NEED TO THINK IN NEW WAYS,"

KRISTOFFER BÖTTZAUW, DIRECTOR GENERAL, DANISH ENERGY AGENCY.

Denmark has pioneered the expansion of wind energy for decades. In 1991, the world's first offshore wind farm was installed in Vindeby with a nameplate capacity of 4.95 MW. 30 years later, Denmark installs its largest offshore wind farm to date, Kriegers Flak. With a capacity of 600 MW, it can power 600,000 Danish households. By 2030, Denmark will expand its offshore wind capacity with a further 7 GW as part of implementing the Danish government's 2020 Climate Act.

Photo credit: Vattenfall A/S

FIGURE 3

Historical milestones of offshore wind in Denmark

1991

Denmark becomes the first country in the world to take wind turbines out to sea with the Vindeby offshore wind farm (5 MW). Several smaller demonstration projects follow, driven by scarcity of land and an abundance of shallow waters with great wind resources.

1996 -1998

A new energy action plan “Energy 21” targeting 4 GW offshore wind by 2030 is launched. Obligations are put on Danish utilities to construct large-scale offshore wind demonstration projects. It leads to the commissioning of Horns Rev 1 in 2002 and Rødsand 1 in 2003. The projects enable research in environmental impacts of large-scale offshore wind and lay the groundwork for maritime spatial planning and maritime planning committees. The ultimate aim is to reduce conflicts at sea, encourage investment through predictability and protect and improve the environment.

1999

The Danish government decides to liberalise Denmark’s electricity market by 2002. The framework conditions for new offshore wind farms change from unbundling and liberalisation towards auctioning as a market-oriented management tool.

2004

The first offshore wind tenders are launched for Horns Rev 2 and Rødsand 2, becoming the largest offshore wind farms globally at the time. A new phase has started using tenders as an efficient tool for offshore wind development.

2015

The Danish Energy Agency launches a support scheme for offshore test projects of up to 50 MW to foster further innovation and cost reductions. Subsidy is granted to the 28 MW test project Nissum Bredning in the waters of North-western Denmark.

2013

The tender for the Anholt Offshore Wind Farm shows the need for new framework conditions, displaying low competition levels due to strict time constraints, high penalties, no pre-qualification, and supply chain bottlenecks due to a growing British offshore wind market.

2009

The Avedøre Holme and Sprogø offshore wind farms are built as demonstration projects to showcase the Danish green transition under the UN Climate conference COP15.

2016

A world record winning bid is received for the 600 MW Kriegers Flak at 49.9 EUR/MWh, based on great competition and a strong international line-up. It is the first offshore wind farm with interconnector between two countries – Denmark and Germany.

A 350 MW multi-site tender is issued for six nearshore areas as a cost reducing option for offshore wind. While the tender price is lowered, key learnings are gained on the importance of local support, visual impacts and environmental assessments. This is later used to fine-tune and rethink offshore wind planning.

2018

The Danish Parliament unanimously passes an Energy Agreement to source 55 per cent of total energy needs from renewable energy by 2030. The agreement includes three large-scale offshore wind farms to be constructed before 2030, among which are the Thor and Hesselø Offshore Wind Farms.

2020

Denmark passes a Climate Act to cut emissions 70 per cent by 2030. A broad coalition of Danish parties decides to establish two energy islands and associated offshore windfarms. One as an artificial island in the North Sea and one on the Danish island Bornholm in the Baltic Sea.

CHAPTER 7

The economic benefits of wind energy

Wind energy has a well-documented positive socio-economic effect. From job creation to export, wind energy plays a central role in the Danish economy.

In 2019, the Danish wind industry directly employed 33,159 people, over 2 per cent of all private employment in Denmark. Indirectly, the wind industry supports a further 63,000 jobs in adjacent industries. The wind industry also contributes significantly to taxes with 13.8 billion DKK (1.9 billion EUR) paid in 2018 through the primary value-chain.

Several municipalities across the country benefit economically from the wind industry. Denmark's second largest municipality, Aarhus, received 138 million DKK (18.6 billion EUR) in municipal income tax from the industry in 2018. Ringkøbing-Skjern, the third largest municipality in terms of income tax, received more than five percent of the municipality's tax income from wind industry employees.

In Denmark, the socio-economic benefits of wind primarily come from onshore wind, as it still covers most of the wind capacity. This underlines onshore wind's continued importance. Meanwhile, the effect of offshore wind is growing. In 2010, offshore wind activities made up 20 per cent of Danish wind companies' turnover. In 2020, that number had increased to 40 per cent.

New gigawatts and job creation

In 2020, the socio-economic effect of offshore wind installations was documented for the first time. The analysis showed that 1 GW of offshore wind energy generates employment equal to 14,600 man-years for Danish suppliers from direct, indirect, and derived job effects. With almost 10 GW of new wind energy installation in the Danish pipeline, a significant number of jobs stand to be created in the process.

Given the country's large coastline, the offshore wind industry has a strong effect. Especially, harbours like Grenå by the Kattegat Sea, Hvide Sande by the North Sea, and Rønne in the Baltic Sea exemplify how wind energy contributes significantly to the local economy with opportunities for growth and development. With Denmark's ambitious expansion plans for offshore wind all parts of the country stand to benefit from the socio-economic effects.

With an estimated 40 per cent market share, Danish companies also have a strong presence on the European offshore wind market. European offshore wind expansions have a significant effect on job creation in Denmark. In fact, an estimate shows that 9,100 man-years of labour are generated in Denmark for every single GW offshore wind investment made in the EU. With 450 GW of wind energy in the EU pipeline towards 2050, this makes for an enormous potential for the Danish wind industry.
Furthermore, wherever wind farms are installed they typically bring many local jobs in relation to installation, operation, and maintenance.

Wind energy as a key export industry

Energy technologies and services have become key in Danish exports, making up almost 14 per cent of Denmark's total export goods in 2019. This year also saw a new record of exports in wind energy technologies and services of 68.5 billion DKK (9.2 billion EUR). This is more than half of the total export of energy technologies from Denmark, totalling 122.7 billion DKK (16.5 billion EUR).

The increased wind energy exports result from both an increase in Danish exports of energy technologies[1], as well as a general global increase in demand for wind energy. A strong focus on export of energy technologies and services has opened for unique opportunities for both Danish and international partners.

[1] Includes district heating, bioenergy, and other efficient forms of energy

An example of Denmark's global reach is the monolithic cooperation between the Danish and South Korean energy agencies. Through a collaboration agreement with Esbjerg Municipality, Ulsan Metropolitan City aspires to become an international offshore wind hub like Port of Esbjerg. The collaboration underlines the key role Denmark's unique offshore wind experiences and strong industry play in the ambitious plans of other countries. Mayor of Ulsan, Song Cheol-Ho (left), with mayor of Esbjerg, Jesper Frost Rasmussen (right) in 2020.

Photo credit: Esbjerg Municipality

CHAPTER 8

Do you speak wind turbine?

Denmark has more than 4,100 wind turbines onshore (>25 kW) and 630 wind turbines installed offshore. In August 2021, the wind capacity reached almost 6.9 GW.

In recent years, the share of wind in the Danish electricity consumption has increased steadily from 18 per cent in 2004 to 46.1 per cent in 2020. By 2030, wind energy is expected to cover almost 70 per cent of the electricity consumption.

Denmark is closely connected to its neighbouring countries and export/import electricity on an hourly basis.

In 2020, an average kWh in Denmark consisted of 66 per cent wind, hydro, and solar power, 8 per cent coal, 16 per cent waste, biomass, and biogas, 6 per cent natural gas, 3 per cent nuclear power, and 1 per cent oil.

A wind turbine installed in 2020 has a lifespan of at least 25 years. During its lifetime it can produce up to 40 times the amount of energy that went into manufacturing, transporting and installing it.

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

In Denmark, the current month with the highest wind penetration in the electricity grid was January 2020. This month 66 per cent of the electricity consumption was on average covered by wind energy.

The day with the record highest wind penetration was February 6th, 2020, where wind energy covered 115 per cent of the domestic electricity consumption.

The highest wind penetration for one single hour was on April 13th, 2020, where wind energy covered 165 per cent of the domestic electricity consumption.

FIGURE 4

Danish wind capacity and wind energy share 1990-2030

Source: Danish Energy Agency. KF21 (frozen policy)

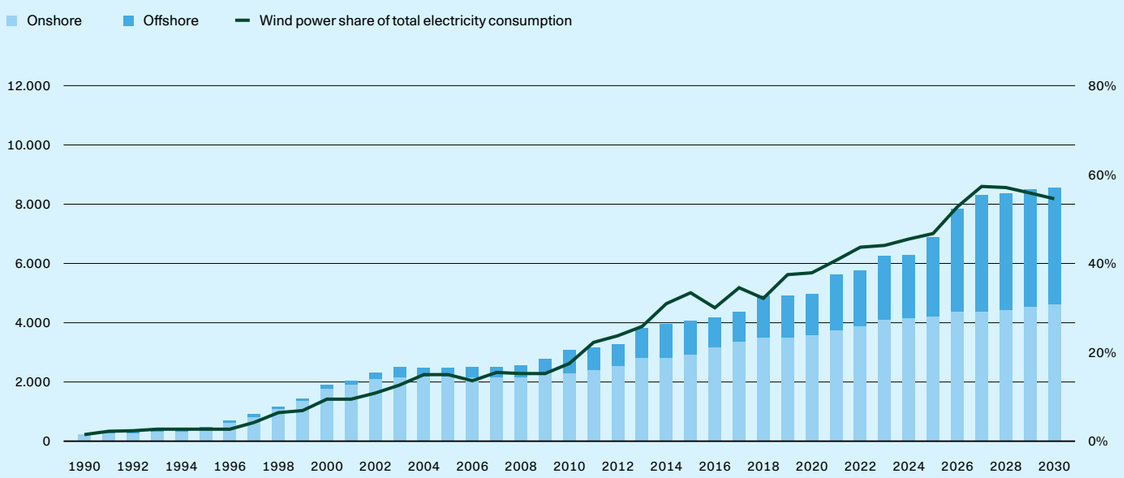


FIGURE 5

Do you speak wind turbine?

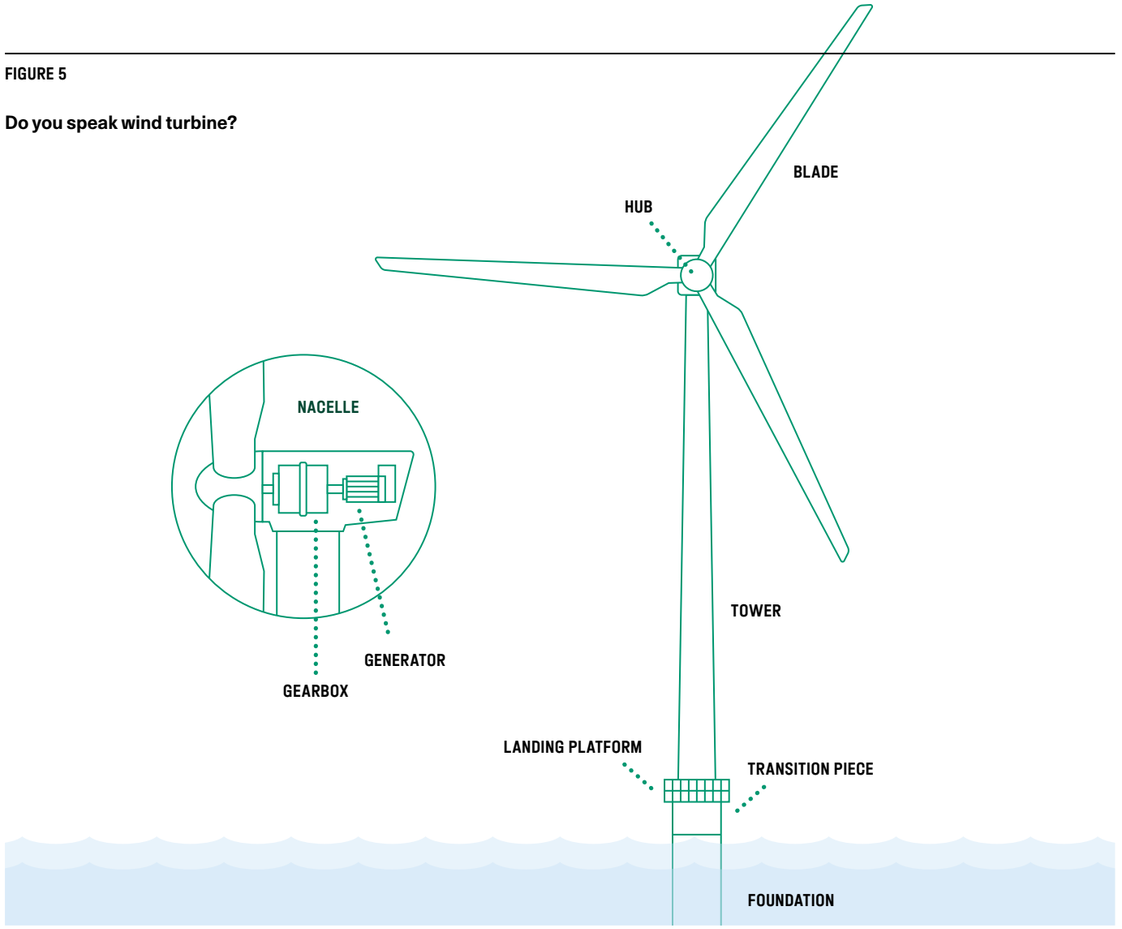


FIGURE 6

Different types of foundations

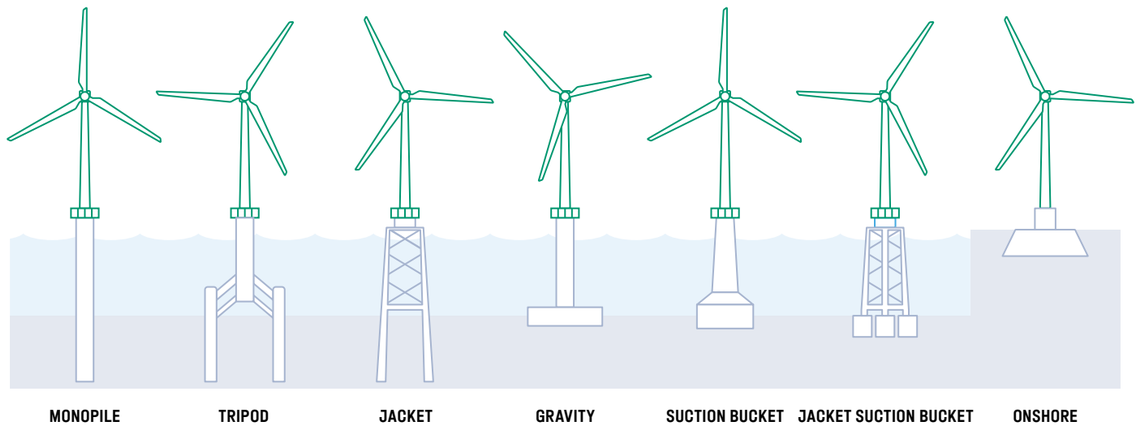
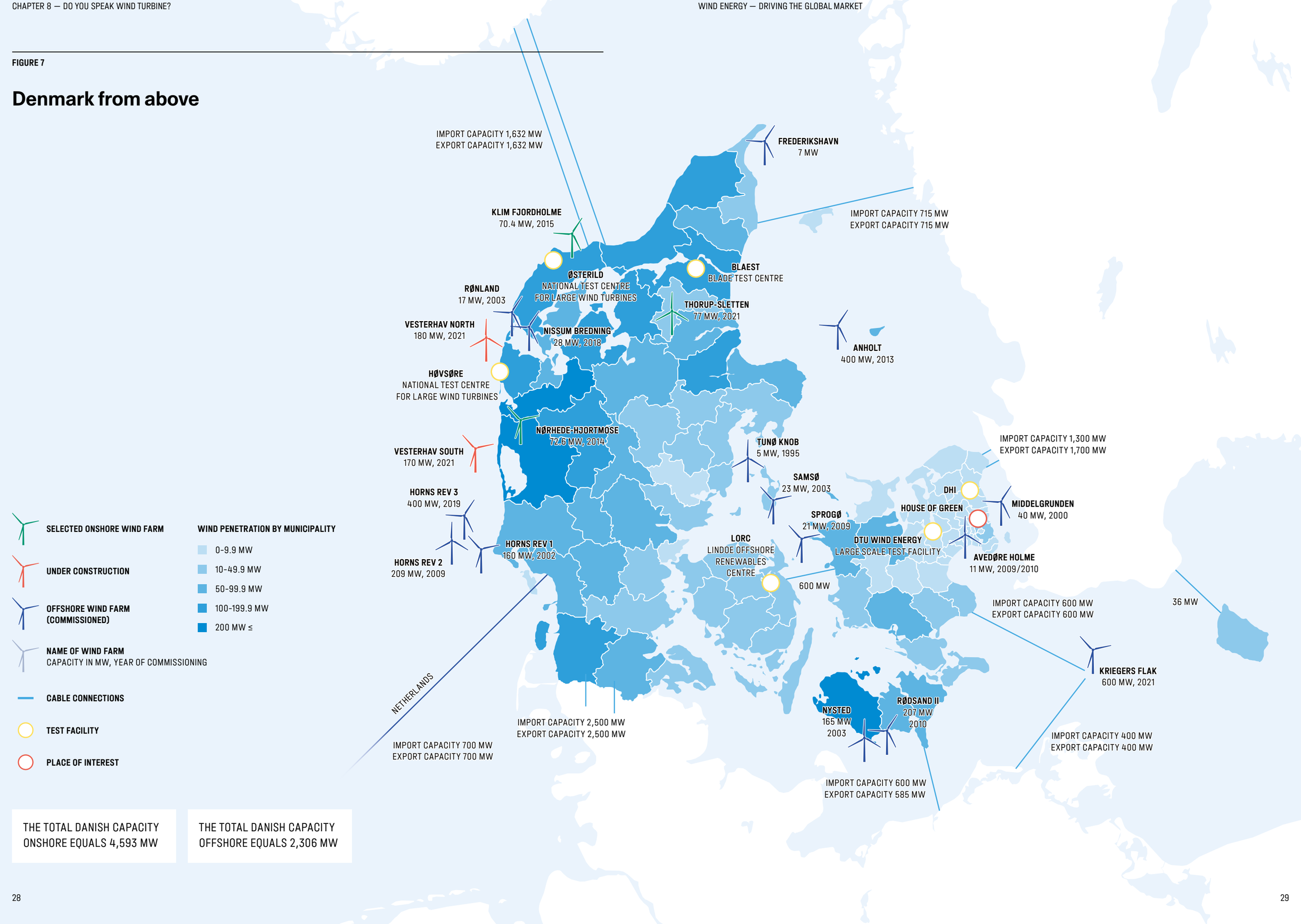


FIGURE 7

Denmark from above



CHAPTER 9

From NIMBY to PIMBY

Transitioning to a zero-carbon society results in visible changes to our surroundings. Everyone will have a role to play in the future and agree to the changes that come with a society running on renewables.

Most of the Danish population favours the green transition regardless of the renewable technology. Danes are used to see wind turbines in the landscape, especially onshore wind turbines as they have been deployed since the 1970s.

Whether it is new powerlines, large-scale solar PV farms, biogas plants, or wind farms the plans for placement are often debated locally: "Why are the wind turbines placed here and not somewhere else?" This view is often referred to as the NIMBY-effect: "Not In My Back Yard". As green infrastructure cannot always be installed out of sight, new infrastructure investments in Denmark are followed by initiatives to help locals go from NIMBY to "PIMBY": "Please In My Back Yard".

Incentivising local support and involvement
In Denmark, the green transition is a democratic process where everyone can part take and make their voice heard. All onshore wind turbine installations are discussed at local level and approved by local authorities. Experience has shown that early involvement is key to establish local support for new onshore wind projects. It creates a sense of ownership in the local community where the turbines are installed.

When new wind turbines are installed, an 'option for purchase scheme' ensures that shares equivalent to minimum 20 per cent of the installed capacity is offered for local citizens to invest in. This fosters co-ownership and involvement.

In addition, the 'green fund scheme' requires wind farm owners to pay the relevant municipality a one-off sum of 1,700-22,000 EUR per MW. The funds are for the municipality to invest in new local initiatives and developments. Installing new onshore capacity thereby both contributes to the local economy and paves the way for a cleaner environment.

Co-ownership and bonus
To support local green initiatives, Danish authorities offer 'green loan guarantees' to citizens that wish to buy their own wind turbines through a model of cooperative ownership. The loan guarantee fund is established to smoothen the investment decision for citizens seeking to play an active part in the green transition.

Finally, neighbours living within eight times the tip height of wind turbines are awarded a 'Renewable Energy Bonus' based on a part of the wind turbine production. The bonus acknowledges their cooperation and goodwill.

Guarantees for property owners
Danish authorities have also installed mechanisms to secure property owners who have a perceived loss of property value due to neighbouring wind turbines. They are compensated if the loss of value is equal or higher than 1 per cent of the total value of the property.

The value-loss framework enables any property owner living near a wind turbine (4-6 time the tip height) to apply for an 'option to buy-scheme' and sell their property to the turbine owner within a year from the first produced kilowatt hour. This framework of guarantees ensures the rights of any citizens perceiving a value-loss, but also for developers that their projects can be completed.

General requirements for onshore wind turbines:

- Wind turbines must have a minimum distance to neighbouring properties of 4 x tip height.
- Shadow casting from wind turbines on neighbouring properties must not exceed 10 hours per year.
- Noise limits in residential areas/dwellings are 39 dB (wind speed of 8 m/s) and 37 dB (wind speed of 6 m/s).
- Noise limits in open landscape are 44 dB (wind speed of 8 m/s) and 42 dB (wind speed of 6 m/s).
- Low frequency noise must not exceed 20 dB. The limit for low frequency noise applies in all areas and to the calculated noise level at both 6 and 8 m/s wind speed.

Read more at https://eng.mst.dk/air-noise-waste/noise/wind-turbines/.

In 2019, the city of Hirtshals made history becoming home to the first ever subsidy free onshore wind project in Denmark. The wind farm's four V136-4.2 MW turbines located at the Port of Hirtshals are financed exclusively through local investments from citizens and industry. The ownership model and the massive local support for the project are a testament to how wind energy and local growth goes hand in hand.

Photo credit: Port of Hirtshals

CHAPTER 10

The effects of wind turbine noise

Danish scientists have conducted a multiyear study on the effects of noise from wind turbines on selected conditions concerning human health. Finished in 2019, the study which is the most comprehensive of its kind did not find any conclusive evidence of a direct link between wind turbine noise and human health.

Denmark has been installing wind turbines onshore since the 1970s and parallel to this, the Danish authorities have stored vast amounts of data on citizens' health as well as accurate data on the location and make of all wind turbines erected over the years.

Even though no prior connection between human health and exposure to noise from wind turbines had been identified, the Danish Health Authority ordered a large national health survey to be conducted from 2014 to 2019 to gain more knowledge on the area and thereby clear any doubts or concerns of potential health effects of wind turbine noise.

Over this five-year period, the Danish Cancer Society studied the potential association between exposure to noise from wind turbines and the risk of diabetes, cardiovascular events, adverse birth outcome, redemption of antihypertensive medication, myocardial infarction, stroke, and redemption of sleep medication and antidepressants. The Danish Health Authority, which is the highest medical authority in Denmark, concluded that the six medical research articles produced in the study found no conclusive evidence of an association between exposure to wind turbine noise and negative health effects. Therefore, the Danish authorities found no reason to change the legislation.

The study design was cohort, following all Danish citizens in the age group between 25 and 84 years living within a radius of 6 km from a wind turbine for a minimum of one year between 1980-2013. In total, 553,000 households were included in the study which also contained weather and noise data from 7,500 turbines.

Less noise from new wind turbines

Since the study was conducted, the technology development of wind turbines has advanced further, marking improvements to noise levels, too. Today's modern wind turbines have noise insulated nacelles, and the turbines' components are designed to limit noise dispersion throughout the entire construction. Both gears and generators are now mounted in a way that reduces the noise level as much as possible, rendering mainly the swishing sound from the rotating blades.

While a typical 100 kW wind turbine from the 1980s and a typical 500 kW turbine from the 1990s both emit around 100 dB, a modern onshore wind turbine can only emit a maximum of 44 dB when installed in an open landscape. In comparison, normal speech typically has a sound pressure of 60 dB, while a car passing by at a 10 meters distance emits around 75 dB.

Noise limits

- Noise limits in residential areas/dwellings are 39 dB (wind speed of 8 m/s) and 37 dB (wind speed of 6 m/s).
- Noise limits in open landscape are 44 dB (wind speed of 8 m/s) and 42 dB (wind speed of 6 m/s).
- Low frequency noise must not exceed 20 dB. The limit for low frequency noise applies in all areas and to the calculated noise level at both 6 and 8 m/s wind speed.

Debate over the health effects of wind turbines sparked a five-year scientific study in Denmark that included 553,000 households. Based on the findings, the Danish Health Authority concluded, that there is no direct association between exposure to noise from wind turbines and the health effects studied.

CHAPTER 11

Raising the bar for wind energy technology

Denmark is world famous as a pioneer in the wind energy sector. This goes hand-in-hand with a massive technological leap taken by the industry, building on 130 years of knowledge and capacities developed in the Danish wind energy value chain.

Experience and innovation, combined with a high level of integration of future technologies, has made Denmark a true wind energy hub.

Future flagships are 'Made in Denmark'
As wind turbines grow in size, so does their efficiency and power. Over the past decade, modern wind turbines have grown substantially is scale, and the longer blades, higher towers and other finetuned elements allow for a higher production output.

As a country with short geographical distances, a well-developed infrastructure, and highly skilled work force, Denmark has a unique environment for research, development, test and demonstration of new wind energy technology. To support this, the Danish government has allowed for the establishment of two world leading test sites for full-scale testing of both onshore and offshore wind turbines: Test Centre Østerild and Test Centre Høvsøre.

Having access to full-scale test facilities allows manufacturers to determine how their new wind turbine technology will perform under real operating conditions. The turbines are tested on their design, performance, safety and noise emission, and as the prototype turbines in the test centers are connected to the Danish grid, manufacturers are also able to meticulously measure and assess their turbine platforms interplay with the grid system.

Innovative projects founded in Denmark
To maintain competitiveness of the fast-moving wind industry it is key to foster and nourish and innovative R&D environment.

At DTU Wind Energy innovative efforts are taking place within the area of floating wind energy – and in 2020 they initiated the testing of new platform types. The Danish Innovation Fund has invested 15.8 million DKK (2.1 million EUR) in the project, that will develop and optimise the designs of floating turbine foundations. Other projects like ZEBRA, with Denmark-based LM Wind Power as a main collaborator, are taking steps to lower the carbon footprint from wind turbine production to reduce environmental impact. The Danish research environment has even begun looking into how offshore foundation platforms can act as artificial reefs and spawning area for fish. In other words, innovation is a key driver in improving the sustainability of the industry as a whole.

This diversity of research topics showcases the need for a holistic approach to wind energy innovation.

Standardisation starts with Danish companies
Another equally important factor in the quest to secure the competitiveness of wind energy is the costs of manufacturing. Standardisation efforts have been crucial in lowering the levelized costs of energy (LCoE) and making wind energy the most viable and cost-effective form of renewable energy today.

APQP4Wind, a Danish organisation focusing on standardisation in 'Applied Product Quality Planning' for the wind industry, has ensured that a standardised approach to quality assessment has progressed rapidly in the last few years. Through cross-industrial collaboration headed by Siemens Gamesa and Vestas, APQP4Wind has developed a common quality assurance methodology for the global wind industry that helps reduce risk and lower the costs associated with poor quality. What started as a Danish initiative has now been deployed globally with companies all over the world being trained and certified to apply the framework in their own production processes. This ensures a collective and worldwide push to reduce the cost of wind energy.

FIGURE 8

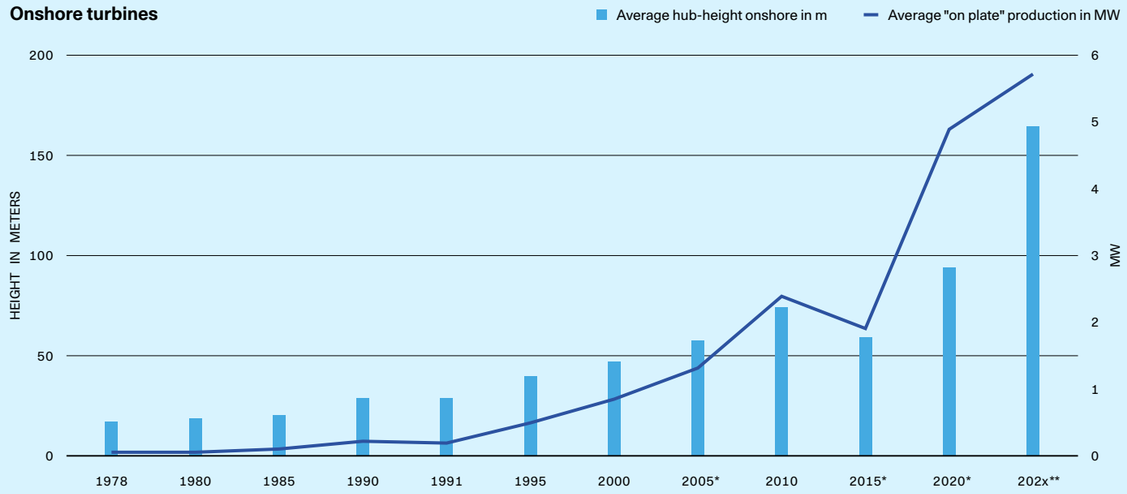
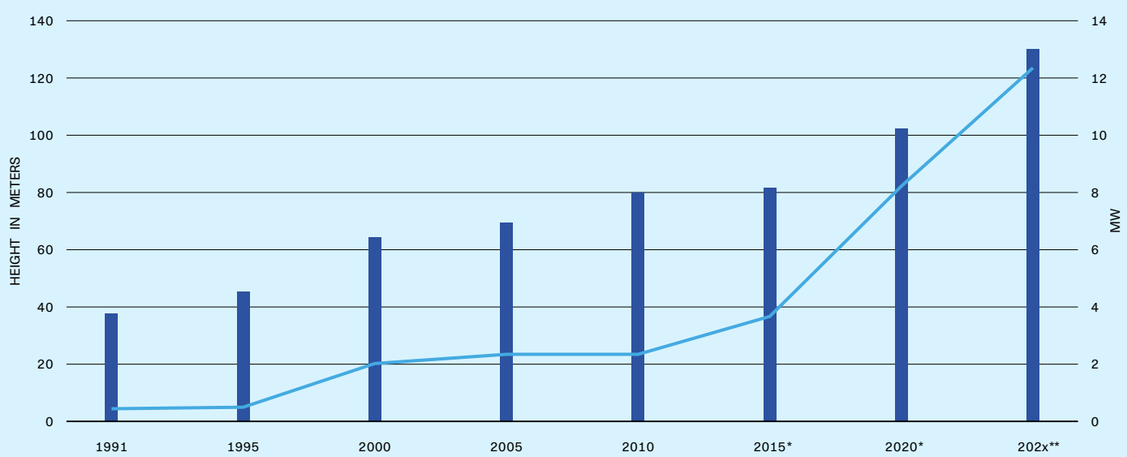


FIGURE 9



As a result of the rapid development and increased usage of wind energy, wind turbines have grown significantly in size and capacity. In 2020 and 2021, we have seen several manufacturers launch wind turbines with record-breaking tip-heights and platform capacity hitting the fabled 15 MW-point.

NB: All data used are on the basis of the turbines' installation year, and include turbines which are both in use and decomissioned.

* = As no offshore installation happened in the year, the number indicates the latest installed turbines. For 2005 this was 2003, for 2015 it was 2013 and for 2020 it was 2018.

** = These numbers are based on publically available information about the largest future and announced turbines from GE, Vestas, MHI Vestas and Siemens Gamesa on both the offshore and onshore market.

CHAPTER 12

Testing the turbines of tomorrow

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

Access to high quality test and demonstration facilities is key in maintaining a competitive wind industry and fostering innovation and knowledge-sharing. For many years, Denmark has been a hub for test and demonstration projects in the global wind industry with several facilities catering to different needs. A high level of collaboration between industry, public authorities and the academic community in Denmark has played a crucial role in this development.

Access to the right test facilities ensures component quality, which helps to reduce the levelized cost of energy (LCoE) for wind. By testing each component in the wind turbine vigorously and by testing prototype wind turbines in both part and full scale, potential design or production errors can be identified and eliminated in the development phase. This is much cheaper than having to correct them after the turbines have been mass-produced and installed in markets across the world.

Test and demonstration facilities are thus essential in the development of new technologies and solutions.

Visual statement of world leadership in the field

On the west coast of Jutland, one can find two of the largest full-scale test facilities in the world: Test Centre Høvsøre and Test Centre Østerild. Both centres are run by DTU Wind Energy (part of the Technical University of Denmark) and are home to test stands for wind turbine manufacturers like Vestas, Siemens Gamesa, GE Renewable Energy, Nordex, GE-Alstöm, and Envision Energy. The two sites stand as visual testaments to the Danish wind industry's test and demonstration capabilities. Since their establishment in 2002 and 2012 respectively, the rapid technology development has led to both an expansion in the number of testing stands and an increase in maximum turbine height in the test areas to accommodate the ever-increasing size of new turbines.

Close collaboration facilitates unique dynamics

Having testing facilities is one thing, but the unique dynamics between private companies and high-profile research institutions ensure that market needs, R&D and testing runs in a symbiotic relationship. An example of the close cooperation between test centres and industry is the Danish Blade Test Centre, commonly known as Blaest, in Aalborg. In 2019, a long-term agreement with Vestas on full scale testing of the manufacturer's blades paved the way for investments in a new test hall with three test rigs capable of testing blades of up to 100 meters.

Another example is the DTU Risø Campus (main location of DTU Wind Energy) that originally started out as a government-funded scientific research organisation. Today, the research centre has grown into a successful institute under the Technical University of Denmark with cutting-edge facilities for renewable energy.

As these cases demonstrate, close collaboration between public, private, and academic actors can ensure competitive test facilities, benefitting the industry as a whole. For Denmark, it has resulted in a position as a hub for the global wind industry and a strong anchor for tomorrow's wind energy value chain.

"THE DANISH ENVIRONMENT FOR TESTING IS ONE THAT IS UNIQUE AND THAT HAS PAVED THE WAY FOR DENMARK'S POSITION AS A GLOBAL HUB FOR INNOVATION AND DEVELOPMENT IN THE FIELD OF WIND ENERGY."

JAN HYLLEBERG, CEO, WIND DENMARK

Extreme conditions in flexible facilities

The old Lindø wharf, an old dockyard in the city of Odense, hosts a range of incredibly versatile testing facilities. Combining unique infrastructure with invaluable experience in the field of offshore wind energy and the facilities needed, Lindø Offshore Renewables Center (LORC) has become a place to test and push nacelles and offshore equipment to its extremes. Through LORC's three different testing facilities, nacelles can undergo high-capacity testing, lifetime operational testing, and grid compliance testing allowing for testing of components of up to 25 MW. LORC also offers extreme weather testing and mechanics testing. LORC's unique infrastructure, manifested in its gantry crane, allows very heavy loads of equipment to be moved around, and the detachable roofs of the testing areas ensures flexibility in the movement of equipment.

CONTRIBUTORS

Lindø Offshore Renewables Center (LORC)

LOCATION

Munkebo, Denmark

Ideal testing grounds for offshore and onshore

DTU's test centre at Østerild is at the cutting edge of both onshore and offshore testing. With its unique location close to the coast in flat terrain. The site offers a mean wind speed of 8 m/s in 100m height, which is the needed minimum for testing large wind turbines. This has allowed Østerild to become home to the largest test centre in the world. Test Centre Østerild accommodates up to a total of nine testing stands, with wind turbines of a total height of 330 meters at five of the testing stands, and 250m at the remaining four. The test centre also invites the public to follow their work: A unique on-site visitor's centre facilitates learning and knowledge-sharing in the areas of renewable energy and wind energy welcoming up to 40,000 visitors each year.

CONTRIBUTORS

DTU Wind Energy, Test Centre Østerild

LOCATION

Østerild, Denmark

Pushing the bar for what is possible

The wind energy facilities at DTU Risø Campus are on track to becoming a central hub for testing the capacity and capability of several aspects of the wind turbine. With the national wind tunnel, named Poul la Cour Wind Tunnel and a Large-Scale Facility, DTU Risø Campus ranges in the very top amongst the world's largest university-owned and operated facilities in the field. The Large-Scale Facility allows for testing of blades made for medium-sized wind turbines. It has three testing stands capable of testing blades of up to 15m, 25m and 45m, or other slender structures, and it offers a variety of static load as well as fatigue tests. The Poul la Cour Wind Tunnel enables for consistent and precise tests of a wind turbine blades' performance in different wind conditions.

CONTRIBUTORS

DTU Wind Energy, Risø Campus

LOCATION

Roskilde, Denmark

Expanded testing facilities for ever-expanding turbine blades

The Danish Blade Test Centre (Blaest) stands out as a leading blade test facility owned by DNV, FORCE Technology and DTU. Drawing on decades of experience in the field of wind turbine blade testing, Blaest offers all the structural tests necessary for type certification of blades. Special services, such as NDT inspections and repair of test blades, are offered through local collaboration partners. In 2020, a new 5,000 m^2 test hall with three test rigs was put into operation at Blaest, which allows the facility to test blades with a staggering length of about 110 meters, scaled to fit the giant wind turbines of tomorrow.

CONTRIBUTORS

Danish Blade Test Centre (Blaest)

LOCATION

Aalborg, Denmark

CHAPTER 13

Bringing down costs

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 has 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, creating 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, but also the industry's unique ability to do this through cooperation and partnerships across the entire value chain. Throughout the years, companies in the wind industry have developed a strong tradition of working together and pooling the knowledge and know-how needed to find new and improved solutions that deliver further reductions to the cost of wind energy.

Close and connected
Just within the peninsula of Jutland, hundreds of wind energy companies work in close proximity to each other. Collaboration across a flexible and cost-efficient value chain rely on shared confidentiality, knowledge sharing and working to push the industry forward together.

It is also the close collaboration between the academic community, public authorities and the industry that has prepared the ground for great advancements within research, innovation, test, and demonstration.

Partnerships and packages
In recent years, the wind industry has experienced a high level of consolidation and bundling of products.

The latter meaning that Danish suppliers are teaming up to pool services and products into actual systems. Companies can strengthen their strategic position by delivering complete system or packaged solutions to top supply chain players such as turbine manufacturers or wind farm owners. This entails an even closer cooperation across the Danish value chain.

Introducing common 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. In adhering to common standards, suppliers need fewer manufacturing and quality controlling processes, leading to fewer product failures. Standardisation can be applied to numerous areas within the wind industry and the development and deployment of standards is expected to increase in the coming years, underlining the importance of a close collaboration across the value chain.

The Danish wind industry has a longstanding tradition of partnerships and collaborations across the entire value chain. Manufacturers join forces with suppliers to optimise products and work processes, suppliers form partnerships to deliver packaged solutions, and industry and research community build bridges to form the basis for the next ground-breaking technological advancements.

"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."

JAN HYLLEBERG, CEO, WIND DENMARK.

Photo credit: State of Green

Learn more about Danish energy solutions, find more cases from around the world and connect with Danish experts:

www.stateofgreen.com

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Ministry of Environment of Denmark

Ministry of Foreign Affairs of Denmark