Wind energy - powering the future

How wind energy supports a reliable, efficient and resilient energy system

INSIDE THIS WHITE PAPER

Developing a mature wind industry and value chain

The economic benefits of wind energy

Scaling offshore wind to power the future

Testing and perfecting the turbines of tomorrow

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WIND ENERGY - POWERING THE FUTURE
How wind energy supports a reliable, efficient and resilient energy system

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FRONT PAGE PHOTO
Photo credit: Vattenfall

LAYOUT
Henrik Wedel Sivertsen

EDITOR IN CHIEF
State of Green
Maja Schrøder Kristensen
msk@stateofgreen.com

TECHNICAL EDITORS
Danish Energy Agency
Simon Maul Hansen
smhn@ens.dk

DI Danish Energy Industries
Hans Peter Slente
hps@di.dk

DI Danish Energy Industries
Søren Mensal Kristensen
smek@di.dk

Green Power Denmark
Laura Berggreen
lbe@greenpowerdenmark.dk

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Executive summary

Wind energy is the backbone of the global green transition. For decades, Denmark has led the way in advancing wind power, transforming it from an emerging technology into a large-scale energy solution. Through innovation, collaboration and its strong policy frameworks, Denmark continues to shape the future of wind energy both nationally and internationally.

Wind energy is essential for building a green, flexible and resilient energy system. Denmark has developed a comprehensive wind industry covering research, development, testing, manufacturing, installation, service, maintenance, grid integration, operations – and financing. Today, wind energy supplies more than half of Denmark's electricity, proving how ambitious policies and innovation drive large-scale renewable adoption.

Denmark's legally binding climate targets include a 70 percent reduction in greenhouse gas emissions by 2030 and ambitions of climate neutrality by 2045. Close collaboration between government and industry ensures that wind energy today plays a key role in decarbonising power, transport and industry.

A flexible and well-integrated power grid is crucial for scaling up wind energy. Denmark has built an energy system that balances high shares of renewables while maintaining grid stability and a 99.99 percent security of supply. This provides valuable insights for other nations working to integrate wind power.

Beyond its environmental benefits, wind energy drives economic growth, employment and exports. The industry supports thousands of jobs across the supply chain, from technology development to operations and maintenance. A strong export focus enables Denmark to share its expertise globally and accelerate the deployment of wind energy through international cooperation. Denmark actively engages with European and global partners to expand wind power, strengthen cross-border electricity connections, and enhance energy security. Recent policy commitments across Europe reflect growing ambition to scale up offshore wind and build a more resilient energy system.

Efficient permitting processes are essential to unlocking wind energy's full potential. Denmark's streamlined regulatory framework aims to reduce project timelines and investment risks, supporting faster expansion.

Innovation remains central to Denmark's wind leadership. Advanced testing facilities, research initiatives and digital technologies continue to improve efficiency and reduce costs. Efforts to develop sustainable solutions for the full lifecycle of wind turbines are setting new industry standards.

As wind energy expands, balancing development with environmental and social considerations is crucial. Denmark is committed to ensuring wind projects coexist with nature and local communities. Strategic planning, biodiversity initiatives and engagement efforts help maximise benefits while addressing concerns.

Denmark's experience proves that ambitious renewable energy targets are both achievable and beneficial for economic growth, energy security and climate action.

FOREWORD

Building the backbone for a green and resilient energy future

BY LARS AAGAARD, MINISTER FOR CLIMATE, ENERGY AND UTILITIES OF DENMARK

Wind energy is a cornerstone of the global transition to sustainable energy. Denmark continues to play a pivotal role in this effort, driven by innovation, collaboration and a commitment to green energy. Yet, we must also approach the future with realism, recognising the challenges that lie ahead.

For decades, Denmark has transformed wind energy from a niche technology into a central component of modern energy systems. Today, wind turbines and solar PV are the backbone of the energy supply and accounted for 70 percent of Denmark's electricity production in 2024. This is a testament to what can be achieved through political ambition and private-sector innovation.

Our focus remains on leveraging Denmark's strengths to advance the European and global wind energy agenda. Through our engagement in European and international cooperation, Denmark fosters cross-border collaboration to unlock the vast potential of offshore wind - a critical component in achieving Europe's climate neutrality by 2050 and ensuring energy security.

Denmark's world-class test and demonstration facilities are central to our contributions as they serve as platforms for developing cutting-edge wind technologies now deployed worldwide. By uniting academia, industry and government, we ensure continued technological advancements.

We have demonstrated that large-scale wind integration is not only possible but essential. Denmark's ability to maintain a stable and secure energy grid with high renewable energy penetration provides a valuable blueprint for other nations navigating similar transitions. Our ambitious climate targets, including a 70 percent reduction in greenhouse gas emissions by 2030 and Danish climate neutrality by 2045, underline our determination to lead by example.

Recent geopolitical tensions have placed unprecedented strain on energy security, making it more critical than ever to address barriers to wind energy deployment. By refining regulations, ensuring long-term investment stability and fostering international collaboration, we can strengthen the foundations of a resilient and forward-looking wind industry.

This white paper underscores Denmark's commitment to wind energy, sharing lessons learned from our journey and demonstrating the transformative potential of wind. It highlights solutions and cases addressing challenges in an evolving energy landscape that are relevant in both a national, regional and global context.

Join us in shaping a green future powered by wind energy.

Lars Aagaard
Danish Minister for Climate, Energy and Utilities

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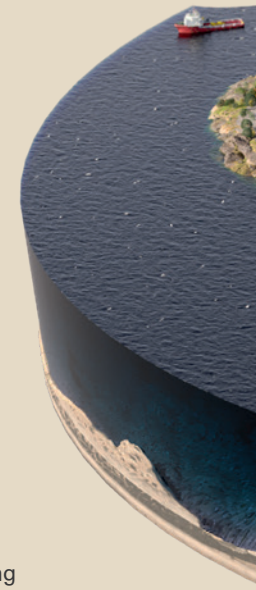
CHAPTER 1

Developing a mature wind industry and value chain

From research and manufacturing to installation, operation, and grid integration, Denmark is home to a comprehensive wind value chain that has matured over more than five decades and gained a strong global presence.



Denmark has played a pioneering role in wind energy for decades. With the development of the first onshore wind farms in the 1970s, Denmark started early in laying the foundation for a strong wind industry. By the 1980s, modern wind turbines were widely deployed in the Danish landscape, demonstrating the potential of large-scale wind energy. In 1991, Denmark made history as the first country to install a commercial offshore wind farm, marking a major milestone in the global transition to renewables.

Despite being a small country, Denmark has made significant investments in both onshore and offshore wind and has positioned itself as a leading player in the global wind energy industry, demonstrating how to utilise the power of the wind to generate clean, renewable electricity for millions of people.

Contributes to Danish economy

For more than 50 years, Denmark's wind industry has continued to mature and expand. By 2023, it employed approximately 33,500 people – representing 2 percent of total private sector full-time employment. It is an industry characterised by high productivity and a strong export focus, with the vast majority of its technology, products and services sold internationally. In 2023, wind energy accounted for over 40 percent of Denmark's total energy technology exports, highlighting the sector's significant contribution to the national economy and its ongoing growth.

Comprehensive and mature value chain

The Danish wind value chain is comprehensive, spanning the entire life cycle of a wind turbine and supported by a tightly connected network of competencies and services that work seamlessly together. Denmark is home to around 500 companies operating within the wind industry, located in close proximity to one another. This geographic concentration provides easy access to test facilities, innovation centres, production sites, and ports specifically designed to handle wind turbines.

At the core of this ecosystem are world-leading manufacturers like Vestas and Siemens Gamesa, who lead the way in wind turbine design and production. They are supported by a robust network of suppliers specialising in components, materials, advanced software and digitalisation, ensuring the industry's innovative edge.

Collaboration and innovation form the backbone of Denmark's wind industry, and a guiding principle is shared confidentiality, knowledge-exchange and a common goal to accelerate the green transition. Strong partnerships between businesses, academia and public institutions drive technological advancements, improve product quality, enhance reliability and performance, and continuously reduce costs to maintain cost-competitive and socio-economically sustainable solutions.

Explore Denmark's digital wind value chain

Dive into a digital visualisation of Denmark's wind value chain and discover companies and organisations that specialise in wind-related technology, services and products.

The platform is developed by State of Green in partnership with the Ministry of Foreign Affairs of Denmark, the Danish Energy Agency, Danish Industry, Green Power Denmark, Danish Energy Export and with funding from the European Union.

CHAPTER 2

The Climate Act defines the way

With the 2020 Climate Act, a broad majority of the Danish Parliament committed to reducing national greenhouse gas emissions by 70 percent 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 goal of becoming climate neutral by 2050, as stated in the Climate Act. However, the current government has set an even more ambitious target of climate neutrality by 2045.

Following the election, political goals were turned into broad political agreements and concrete actions. In 2019, the national Climate Act was passed with the overarching target of a 70 percent reduction of greenhouse gas emissions by 2030 compared to 1990 levels. The act became legally binding, with 94 percent of Parliament voting in favour of the agreement.

14 climate partnerships

To reach the target, the government formed 14 strategic "climate partnerships" representing all sectors of Danish industry. The partnerships each had four months to formulate recommendations on how their respective sectors could reduce emissions. The recommendations guide Danish politicians in taking the right measures while ensuring close involvement and commitment from the industry. They also help shape political agreements across sectors to reduce emissions. The manufacturing and energy sectors were among the first to reach agreements.

In recent years, Parliament has made agreements for other Danish sectors such as transport, agriculture and heating, and successfully tendered out new green technologies like Carbon Capture and Storage (CCS) and green hydrogen. These sectors are vital for the realisation of the 70 percent reduction target, and for the same reason, all political bills will be subject to a CO_2 calculation going forward, displaying their contribution to the overall CO_2 reductions.

A green beacon

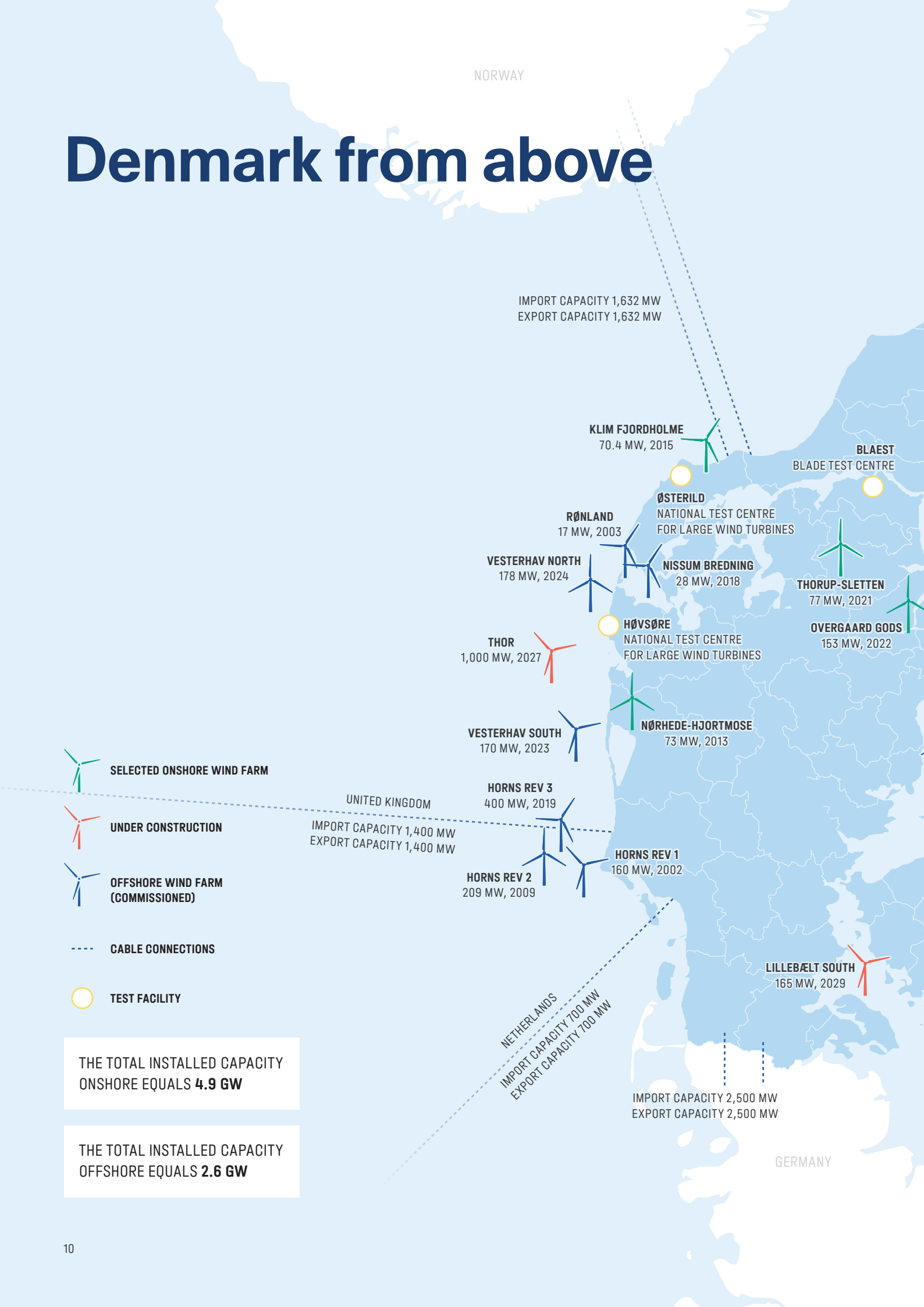
In a global perspective, Denmark has only a miniscule carbon footprint, being the source of merely 0.1 percent of the world's CO_2 emissions. So, it begs the question: Why would Denmark set such an ambitious target for greenhouse gas emission reductions? The answer is simple. Denmark has a key role in 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 still within reach if we act fast – together.

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 in all sectors. The majority of the Danish Parliament stands behind the ambitious Climate Act.

Photo credit: The Danish Parliament/ Christoffer Regild

Denmark from above



THE TOTAL INSTALLED CAPACITY ONSHORE EQUALS **4.9 GW**

THE TOTAL INSTALLED CAPACITY OFFSHORE EQUALS **2.6 GW**

Explore Denmark from above

Dive into a digital overview of Denmark's renewable energy landscape through State of Green's Greener Together Experience.

FREDERIKSHAVN
8 MW, 2003

FREDERIKSHAVN
72 MW, 2028

IMPORT CAPACITY 715 MW
EXPORT CAPACITY 715 MW

ANHOLT
400 MW, 2013

SWEDEN

TUNØ KNOB
5 MW, 1995

SAMSØ
23 MW, 2003

SPROGØ
21 MW, 2009

JAMMERLAND BUGT
240 MW, 2029

600 MW

LORC
LINDOE OFFSHORE RENEWABLES CENTRE

DTU WIND ENERGY
LARGE-SCALE TEST FACILITY

DHI

MIDDELGRUNDEN
40 MW, 2000

AVEDØRE HOLME
11 MW, 2009/2010

IMPORT CAPACITY 1,300 MW
EXPORT CAPACITY 1,700 MW

IMPORT CAPACITY 600 MW
EXPORT CAPACITY 600 MW

36 MW

KRIEGERS FLAK
604 MW, 2021

IMPORT CAPACITY 400 MW
EXPORT CAPACITY 400 MW

NYSTED
161 MW, 2003

RØDSAND 2
207 MW, 2010

IMPORT CAPACITY 600 MW
EXPORT CAPACITY 585 MW

CHAPTER 3

Seamless integration of wind into the electricity grid

Denmark's experience with integrating wind power spans decades. Today, wind energy covers 54 percent of Denmark's domestic supply of electricity, but to reach national climate targets, there is a need to go further.

The development of wind power in Denmark began in the late 1970s with the installation of the first commercial wind turbines, though modest in both size and capacity by modern standards. In 1990, wind power accounted for just two percent of Denmark's domestic supply of electricity. Today, wind turbines are much larger and more powerful, enabling a much bigger yield over the 30-year lifespan of modern turbines. Offshore wind was introduced in the early 1990s and is now the predominant solution for Denmark and several other markets moving towards 2030 and beyond.

Building a flexible, interconnected system
Forty years ago, Denmark's electricity system relied on large coal-fired power plants. Since then, policies and planning have reshaped the system, bringing diversification, market integration and distributed power generation. Small and medium-sized combined heat and power plants, a shift to biomass and widespread wind deployment have transformed the energy mix. At the same time, a highly flexible electricity system, made possible by adaptable power plants, allows for rapid regulation of supply and a stable operation at low output.

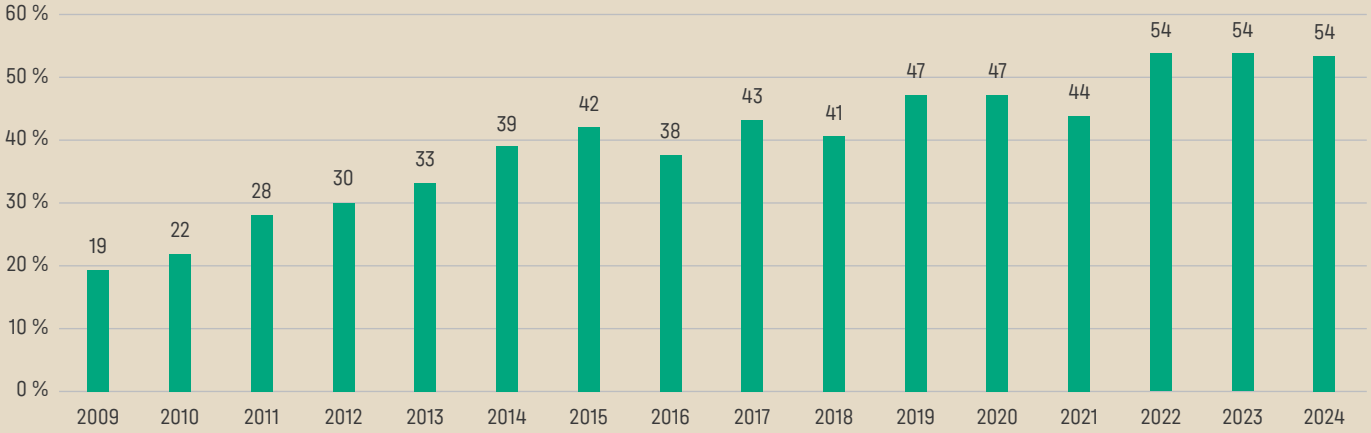
Denmark has built strong cross-border interconnectors with several neighbouring countries, including a record-breaking 765 km long offshore HVDC power cable to the United Kingdom completed in 2024. Interconnectors are essential for integrating a growing share of fluctuating renewables energy - especially wind power - as they allow surplus power production to be exported to where it's needed. In doing so, they serve as a key tool for balancing the grid and enhancing energy security for all connected countries.

Demand-side flexibility through data and AI
The next step in wind power integration relies on further electrification, sector coupling, and storage solutions, including heating, biogas, e-fuels and batteries, to create a more robust and resilient energy system. Managing larger shares of wind power will also depend on digitalisation, use of AI and data-driven solutions that enhance demand-side flexibility and support a seamless integration of fluctuating renewable energy across sectors.

Electrification is key to unlocking the potential of wind
Electricity makes up 20 percent of Denmark's total energy consumption, but electrification is gaining ground in the transport sector with a significant increase in the share of electric vehicles. District heating is also adapting, with electric boilers and large-scale heat pumps driving up the use of green electricity. Meanwhile, the industrial sector still has a large untapped potential for further electrification. To harness the full potential of renewable energy, Denmark will continue to focus on accelerated electrification across all sectors – strengthening the foundation for a greener, more resilient energy system.

Share of wind energy in the electricity grid

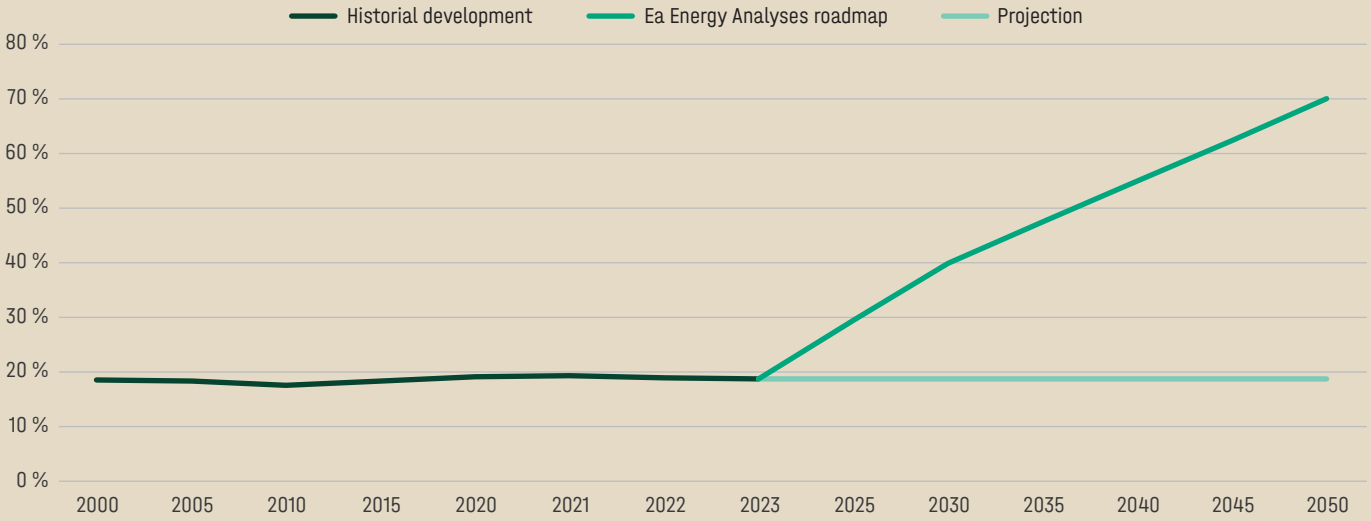
Wind energy accounted for 54 percent of Denmark's domestic supply of electricity in 2024. Despite the high share of fluctuating wind power, the security of supply remains stable at 99.99 percent.



Source: Energinet

Electrification rate in Denmark

Denmark anticipates a comprehensive electrification process leading up to 2050. Direct electrification of light transport and heating, alongside indirect electrification of hard-to-abate sectors such as heavy transport, industry and even agriculture, will play a crucial role in accelerating the transition from fossil fuel-based to renewable energy-based consumption. Below figure depicts the most ambitious scenario including rate of indirect electrification.



Source: Data on historical development: Danish Energy Agency: Energistatistik.
Source: Data for 2030 and 2050: Ea Energy Analyses: Roadmap for elektrificering i Danmark - hovedrapport (ea-energianalyse.dk).

99.99%

Denmark's security of electricity supply is 99.99 percent. In 2024, the average Danish consumer experienced only 17 seconds of power interruptions due to faults in the electricity transmission network.

Source: Energinet

Photo credit: Energinet

Viking Link: Exchanging green energy through the world's longest offshore power cable

As European countries expand their renewable energy production, balancing supply and demand across borders is crucial. Fluctuations in wind and solar generation create a need for flexible electricity exchange to ensure grid stability and efficient use of green power.

Viking Link, a 765-kilometre electricity interconnector between Denmark and the United Kingdom, enables the exchange of renewable energy between the two countries. Developed by Energinet and National Grid, the 1,400 MW high-voltage direct current (HVDC) cable allows excess wind power from Denmark to be used in the United Kingdom and vice versa, enhancing energy security and integrating more renewables into both grids.

Viking Link, which became operational in late 2023, can power 1.4 million homes and is expected to reduce CO_2 emissions by supporting fossil-free energy flows. By strengthening cross-border electricity trade, it plays a key role in Europe's transition to a greener, more resilient energy system.

CONTRIBUTORS

Energinet
National Grid
NKT

LOCATION

North Sea, Denmark
and the United Kingdom

LISTEN

Energy without borders – A story of interconnectors

Listen to State of Green's podcast episode on interconnectors featuring Danish TSO Energinet, British energy company National Grid, and Danish cable solutions provider NKT.

Photo credit: NKT

Enabling Germany's green electricity corridors

Germany aims to expand renewable energy, but most wind power is generated in the north, while demand is highest in the south. Without sufficient transmission capacity, integrating renewables efficiently into the grid remains a challenge.

As part of the German Corridors project, NKT is supplying high-voltage DC power cables to enable the underground transmission of wind energy from northern Germany to southern consumption centres. The company's advanced cable technology ensures efficient, reliable, and low-loss electricity transport, supporting Germany's transition to a greener energy system.

By delivering long-distance power transmission solutions, NKT plays a key role in balancing Germany's electricity supply and reducing dependence on fossil fuels. The German Corridors will enable the integration of large-scale renewable energy, ensuring a stable and sustainable power grid for the future.

CONTRIBUTORS

NKT
TenneT
TransnetBW

LOCATION

Germany

CHAPTER 4

The economic benefits of wind energy

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

In Denmark, the socio-economic benefits of wind primarily come from onshore wind, as it still covers most of Denmark's 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 percent of Danish wind companies' turnover. In 2020, that number had increased to 40 percent.

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 the Danish Government's ambitions to build an additional 2-3 GW offshore wind capacity, a significant number of jobs stand to be created in the process.

Given Denmark's large coastline, the offshore wind industry has a strong effect in the country. Especially, harbours such as 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 expansion plans for offshore wind, all parts of the country stand to benefit from the socio-economic effects.

With an estimated 40 percent market share, Danish companies also have a strong presence on the European offshore wind market. European offshore wind expansions significantly impact job creation in Denmark. In fact, 300 GW of wind energy in the North Sea pipeline makes for an enormous potential for the Danish wind industry. Recent projections from the Danish think tank, The Economic Council of the Labour Movement, show that a full national offshore build-out, combined with exports to projects in the North Sea, has the potential to create more than 30,000 jobs on average each year towards 2050. Furthermore, wherever wind farms are installed, they typically generate many local jobs in installation, operation and maintenance.

Wind energy as a key export industry

Energy technologies have become key elements in Danish exports, making up almost 10 percent of Denmark's total export of goods in 2023. Wind energy accounts for most of the exports, amounting to 43.7 billion DKK (5.86 billion EUR). This is almost half of the total export of energy technologies from Denmark, totalling 109.6 billion DKK (14.7 billion EUR). This is a result from both an increase in Danish manufacturing of energy technologies, 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.

DENMARK AT A GLANCE

INSTALLED CAPACITY (2024)

6,312
onshore wind turbines in operation in 2024

4.9 GW
combined capacity

668
offshore wind turbines in operation in 2024

2.6 GW
combined capacity

20.5 TWh
total annual production of wind energy in 2024

54%
of domestic electricity supply is covered by wind energy

2-3 GW
The Danish Government has an ambition of building additionally 2-3 GW offshore wind capacity

Source: Danish Energy Agency, Energinet

EMPLOYMENT (2023)

33,500
people working in the wind industry in 2023

2%
of Denmark's private sector employees work in the wind industry

Source: Green Power Denmark

ECONOMY (2023)

€ 5.9 billion
in export of wind technology and services in 2023

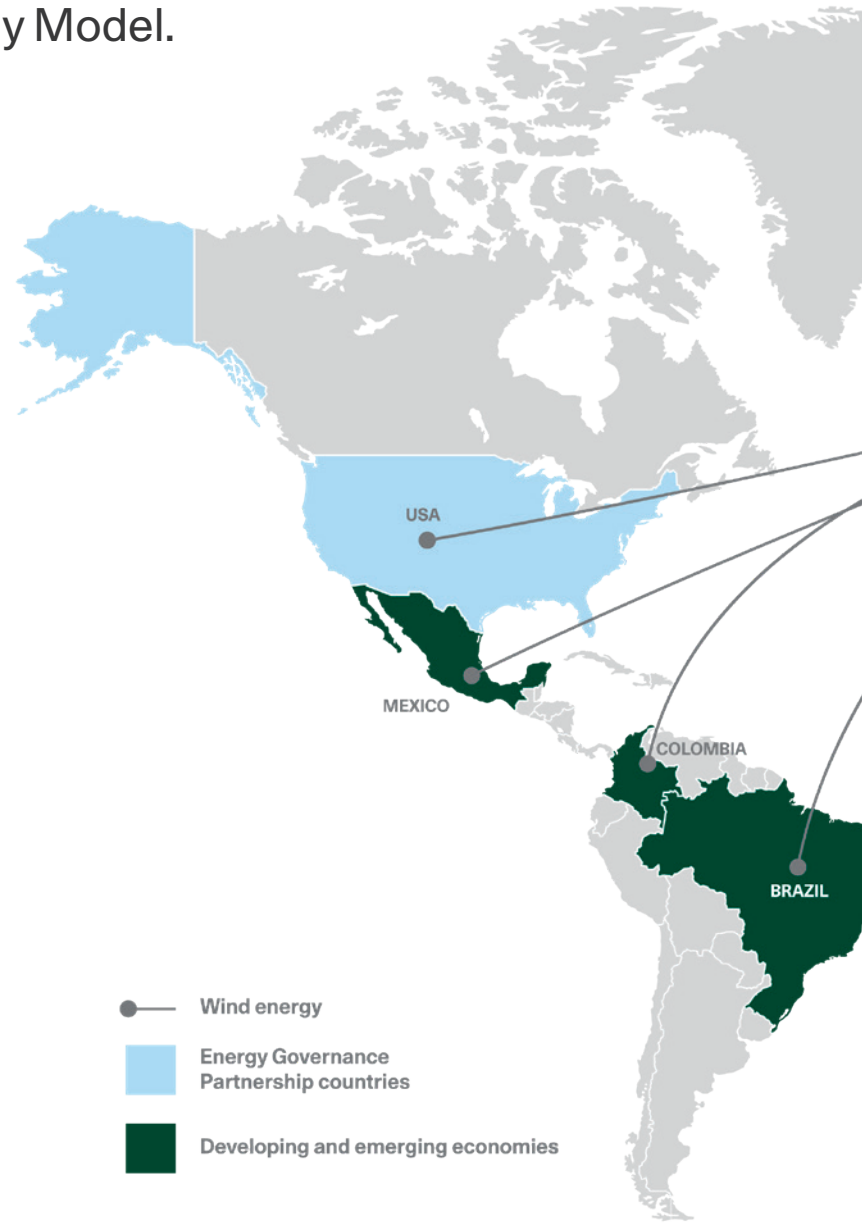
41%
of all Denmark's energy technology experts come from wind energy

Source: Green Power Denmark

CHAPTER 5

Strong international cooperation and partnerships

Through close partnerships and government-to-government cooperation with 25 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

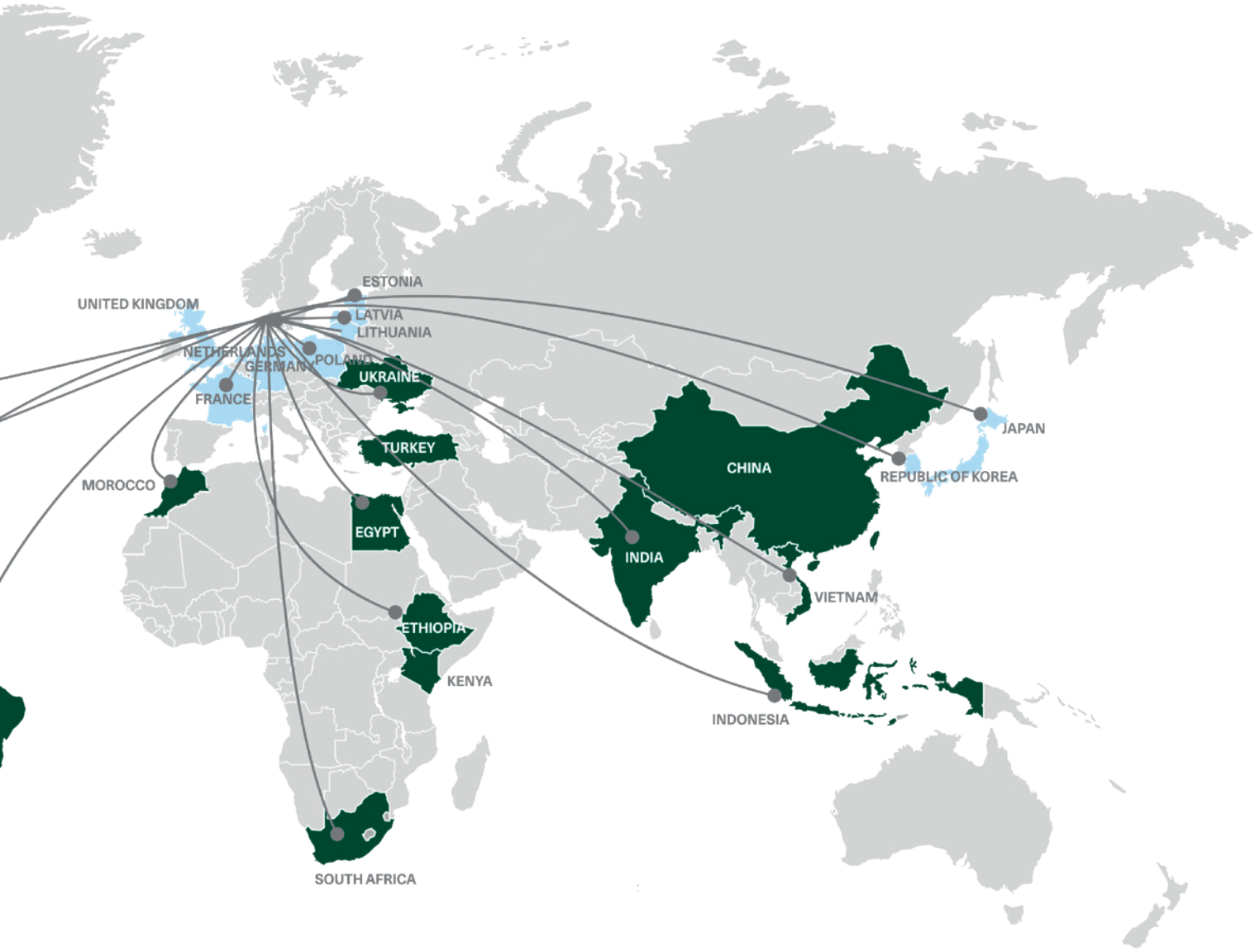
By sharing lessons learned, Denmark aims to push the global green transition and support foreign governments to leapfrog their transition towards low-carbon energy. Today, the Danish Energy Agency cooperates bilaterally with 25 emerging and developed economies. Combined, they represent around 70 percent of the global CO_2 emissions. The cooperation with select OECD countries is organised through the Energy Governance Partnership which focuses on promoting the export of Danish energy solutions to accelerate the green energy transition in partner countries. The cooperation with emerging economies aims to support the countries' climate ambitions, while ensuring an inclusive and sustainable growth.

Five 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, focusing on increasing security of supply while monitoring an increased use of variable renewable energy.
- Enhanced framework conditions for renewable energy, making the renewable energy markets more attractive for investment.
- Integration of renewable energy and flexibility of the power sector, ensuring the optimal utilisation of renewable energy.
- Promotion of energy efficiency in industry and buildings in order to reduce energy consumption.
- Strengthening the knowledge of district heating.

In addition, the Danish TSO, Energinet, holds vast experience in ensuring a record-high energy security, and 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.



Denmark has entered into partnerships with 25 countries, with 19 of these partnerships focusing on wind energy.

Photo credit: Siemens Gamesa

Collaboration with Republic of Korea accelerates offshore wind

CONTRIBUTORS

Danish Energy Agency

LOCATION

Shinan County, Republic of Korea

The Republic of Korea has an ambitious target of 14.3 GW of offshore wind capacity by 2030. With more than 2,400 kilometres of coastline, the potential for offshore wind is enormous.

As part of the Energy Governance Partnership, the Danish Energy Agency and the Korean Energy Agency have been working closely since 2018 to develop offshore wind in the Republic of Korea. The implementing agreement between the two agencies was reaffirmed during a high-level session in autumn 2024.

The collaboration between Denmark and the Republic of Korea focuses on accelerating the green transition through offshore wind development, particularly by sharing knowledge and best practices to remove regulatory barriers hindering the sector's expansion.

The Republic of Korea has historically relied on a complex regulatory framework for offshore wind, involving multiple authorities. Several bills (special acts) are pending, aimed at streamlining regulations by consolidating all permits and approvals under a single regulatory body through a one-stop-shop approach. Work on the special acts will continue in 2025.

Since 2022, the Republic of Korea has been steadily developing an auction system, and in 2024, the Ministry of Trade, Industry and Energy announced a roadmap for future offshore wind auctions, making an expected 8 GW capacity available for bidding through 2026. The auctions will be divided into fixed-bottom and floating wind turbine categories. The roadmap addresses several concerns raised by stakeholders, providing greater predictability regarding the timing and volume of upcoming tenders.

India and Denmark collaborate on offshore wind

CONTRIBUTORS

Danish Energy Agency

LOCATION

India

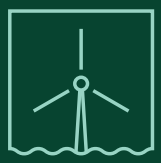
The Indian-Danish collaboration on offshore wind has contributed technical knowledge and knowhow from Denmark's long experience with offshore wind. The Danish knowledge-sharing with relevant Indian authorities has contributed to inform the development of the country's first Strategy for Establishment of Offshore Wind Projects in 2023, which again led to the preparation of the first 4 GW offshore wind tender launched in 2024.

India has set a target of reaching net-zero emissions by 2070, while the country's power demand is estimated to more than double by 2042 compared with today. Renewable energy will play a vital role in meeting future power demand while staying on track towards the net-zero target. Offshore wind has the potential to become a new source of energy, and the Government of India estimates a potential of 37 GW.

Through the joint Centre of Excellence on Offshore Wind and Renewable Energy, established in 2021, Danish experts have supported relevant partners in India in developing a transparent regulatory framework for offshore wind. This includes preparation of tender documents and assisting with mapping potential areas for offshore wind build-out, considering possible environmental and social risks by assessing port readiness in the states of Tamil Nadu and Gujarat.

The collaborative activities aim to de-risk the entire value chain, simplify processes for potential investors, and create transparency and open dialogue between public authorities and the private sector.

Historical milestones for offshore wind in Denmark



1991
Denmark was the first country in the world to take wind turbines offshore with the Vindeby offshore wind farm (5 MW). Several smaller demonstration projects followed, driven by scarcity of land and an abundance of shallow waters with excellent wind resources.

1996 -1998
A new energy action plan targeting 4 GW of offshore wind by 2030 was launched. Obligations were put on Danish utilities to construct large-scale offshore wind demonstration projects, leading to the commissioning of Horns Rev 1 in 2002 and Rødsand 1 in 2003. The projects facilitated research into environmental impacts of large-scale offshore wind and laid the groundwork for maritime spatial planning. The aim was to reduce conflicts at sea, encourage investment through predictability and protect the environment.

2016
The Danish Energy Agency received a world-record low winning bid at that time for the rights to construct the 600 MW Kriegers Flak offshore wind farm. The highly competitive auction attracted a strong international bidding field, resulting in lower subsidy payments by the Danish state. Kriegers Flak was also the first offshore wind farm with interconnectors between two countries – Denmark and Germany.

To further reduce costs for offshore wind, a 350 MW multi-site tender was introduced for six nearshore locations. This tender led to the development of two offshore wind farms, Vesterhav South and Vesterhav North. While primarily aimed at cost reduction, the nearshore tender also provided key learnings on the importance of local support, visual impacts and environmental assessments. These learnings have since been used to refine and improve offshore wind planning and tender processes.

2018
The Danish Parliament unanimously passed a new Energy Agreement in order to source 55 percent of the total energy needs from renewable energy sources by 2030. The first offshore wind farm to be tendered was the Thor offshore wind project.

2020
Denmark passed a Climate Act to cut national greenhouse gas emissions with 70 percent by 2030. A broad coalition of Danish parties in Parliament decided to establish two energy islands with associated offshore wind farms. One as an artificial island in the North Sea and one using the existing Danish island of Bornholm in the Baltic Sea.

1999
The Danish government decided in 1999 to liberalise Denmark's electricity market by 2002. The framework conditions for new offshore wind farms changed from unbundling and liberalisation towards auctioning as a market-oriented management tool.

2004
The first offshore wind tenders were launched for Horns Rev 2 and Rødsand 2, which became the largest offshore wind farms in the world at that time. This marked the beginning of a new phase using tenders as an efficient tool for offshore wind development.

2015
The Danish Energy Agency launched a support scheme for offshore wind test projects of up to 50 MW to foster further innovation and cost reductions. Subsidy was granted to the 28 MW test project Nissum Bredning in the waters of Northwestern Denmark.

2013
The tender for the Anholt Offshore Wind Farm showed the need for new framework conditions, as this auction resulted in 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 were built as demonstration projects to showcase Denmark's green transition and promote offshore wind during the United Nations Climate Conference, COP15, which was held in Copenhagen.

2021
Denmark received payment by a developer for deployment of offshore wind for the first time, as RWE was announced as the winner of the auction for the Thor offshore wind site. The German developer will pay 2.8 billion Danish kroner to the Danish state for the rights to construct the 1 GW offshore wind farm in the Danish part of the North Sea.

2024
The Danish Energy Agency granted the construction licence for the Thor offshore wind farm, which will be the biggest offshore wind farm in Denmark, when it comes into operation in 2027.

CHAPTER 6

One-Stop-Shop to accelerate offshore wind permitting

The Danish Energy Agency coordinates with all relevant authorities to collect the necessary information for offshore wind permitting, ensuring that developers have a single point of contact during the permitting phase.

By law, the Danish Energy Agency has been given the mandate to issue permits and approvals for offshore wind projects. It is the responsible authority for planning, commissioning and decommissioning of offshore wind farms in Denmark and also hosts the One-Stop-Shop for offshore wind permitting.

A streamlined permitting process
The One-Stop-Shop is an administrative procedure in which the Danish Energy Agency acts as the central authority for coordinating and collecting information from other public authorities. These authorities provide jurisdictional and technical expertise on areas such as maritime safety, radar systems, and loss of income for fishermen affected by offshore wind farm construction. The Danish Energy Agency is not the sector responsible authority in these matters, but must regulate them within the construction licence, as wind farm developers need permissions from multiple authorities to comply with various laws and regulations. To facilitate this, the Danish Energy Agency coordinates with all relevant authorities to obtain the necessary requirements set by each sector authority.

A key priority for the Danish Energy Agency is ensuring transparent processes and removing risks, making Denmark an attractive market for investors. To support this, the agency works to reduce investment risks as much as possible. A significant part of this approach is the centralised permitting system, known as the One-Stop-Shop.

Avoiding costly delays during construction
One of the most time-sensitive operations in offshore wind farm construction is when components are shipped from shore to the installation site. This process requires specialised installation vessels that are in high demand and costly to operate. If these vessels cannot be used as planned due to delays, for example in permitting, they may not be available again for a long time, which can cause further delays and additional costs.

All key authorities involved in managing Denmark's sea territory have been part of the marine spatial planning process, where offshore wind sites are identified and selected. The insights gained from this process help facilitate early planning and permitting.

Coordinating a single licensing process
When collecting all necessary information from relevant authorities, the Danish Energy Agency consolidates it into one joint licence. However, the agency does not take responsibility for other authorities or their regulatory duties. Instead, its role is to coordinate the process and keep stakeholders informed.

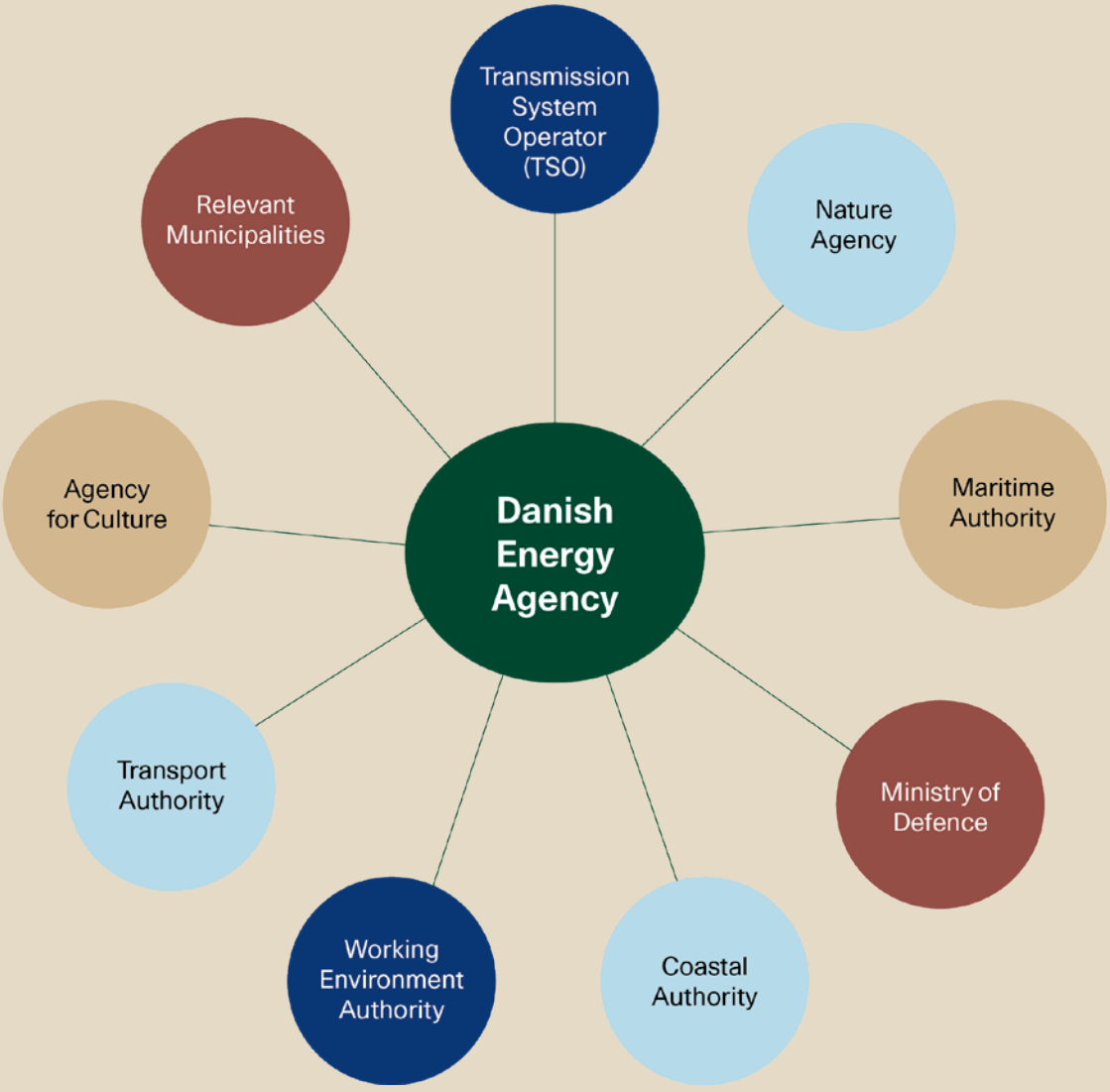
Once a specific site has been designated for offshore wind development, the Danish Energy Agency engages in extensive consultation with all relevant authorities to determine the necessary conditions and regulations to be included in the licence.

A proven tool for efficient permitting
Denmark has used the One-Stop-Shop through most of its offshore wind permitting history, starting with the Horns Rev 2 and Rødsand 2 offshore wind farms. Over time, the concept has been refined, but it has always served as a tool to mitigate delays and identify potential challenges as early as possible.

"WIND ENERGY IS CHEAP, IT IS GREEN, AND IT'S AN INEXHAUSTIBLE RESOURCE. FOR 30 YEARS, DENMARK HAS DEVELOPED FRAMEWORK CONDITIONS FOR WIND ENERGY IN OUR SURROUNDING SEAS. THEREFORE, WE ARE VERY PROUD OF THE CRUCIAL ROLE WIND ENERGY PLAYS TODAY IN THE DANISH ENERGY SYSTEM. THE SEA TERRITORY HAS MANY STAKEHOLDERS, AND THE DANISH ENERGY AGENCY'S ROLE AS THE ONE-STOP-SHOP FOR OFFSHORE WIND DEPLOYMENT IS ONE OF OUR EFFORTS TO CONTRIBUTE TO ACCELERATING THE GREEN TRANSITION.

A SMOOTH AND QUALIFIED COORDINATION WITH ALL RELEVANT AUTHORITIES IN ORDER TO GRANT THE NECESSARY PERMITS IS OF HUGE BENEFIT TO THE OFFSHORE WIND INDUSTRY. IT IS ALSO CRUCIAL TO OUR AMBITIONS OF DEVELOPING EVEN MORE ENERGY FROM OFFSHORE WIND IN THE FUTURE TO COMBAT CLIMATE CHANGE AND ENHANCE OUR SECURITY OF ENERGY SUPPLY."

KRISTOFFER BÖTTZAUW, DIRECTOR GENERAL, DANISH ENERGY AGENCY.



The figure illustrates the key stakeholders and authorities involved in the licensing process for offshore wind in Denmark. As a One-Stop-Shop, the Danish Energy Agency coordinates with all relevant authorities to obtain the necessary requirements from each sector authority, ensuring that developers have a single point of contact throughout the permitting phase.

CHAPTER 7

Scaling offshore wind to power Europe's future

With the Esbjerg, Marienborg and Ostend declarations, European heads of state have set ambitious targets, sparking optimism and accelerating the expansion of offshore wind across Europe's sea basins.

Policymakers from four North Sea countries took prompt action in the spring of 2022 when they met in Esbjerg – Denmark's leading offshore wind hub and gateway to the North Sea. Against the backdrop of the war in Ukraine, they recognised the urgent need to reduce Europe's dependence on oil, coal and gas from Russia. At the same time, energy security and climate action became equally crucial drivers of the EU's green energy transition.

The four nations committed to developing the North Sea as Europe's green energy hub and to establishing an offshore renewable energy system connecting the countries. The target for offshore wind was set to at least 65 GW by 2030 and at least 150 GW by 2050. Momentum grew quickly, and the Ostend declaration followed only a year later, with nine countries joining forces to scale up offshore wind, advance cross-border projects, and strengthen Europe's offshore wind industry. As a result, the combined target increased to 120 GW by 2030 and 300 GW by 2050.

Meanwhile, the Marienborg declaration, signed at the Danish Prime Minister's official residence, brought together Baltic Sea nations, acknowledging the region's substantial but largely untapped potential for offshore wind expansion. The agreement set a target of 20 GW by 2030 and up to 93 GW by 2050.

North Seas Energy Cooperation as a shared framework
To accelerate offshore wind development, participating countries have enhanced their cooperation in the North Sea under the North Seas Energy Cooperation (NSEC), which has been under Danish co-presidency in 2024. A formal work programme focuses on five key areas:

- **Hybrid and joint projects:** Tackling barriers to developing hybrid and joint offshore wind projects, which will be an integrated part of a meshed North Sea grid.
- **Maritime spatial planning and biodiversity:** Balancing offshore wind expansion with other maritime activities while protecting biodiversity. A coordinated approach to spatial planning and environmental assessments will support the sustainable deployment of offshore wind and grid infrastructure.
- **Support frameworks and finance:** Sharing information on national tender schedules to provide better visibility for the supply chain and exchanging best practices on tender design and support design elements to foster system and sector integration.
- **Coordinated long-term planning:** Aligning long-term onshore and offshore infrastructure planning and supporting energy sector integration.
- **Offshore green hydrogen:** Strengthening collaboration on offshore green hydrogen to enhance energy system flexibility. This includes developing common benchmarks for national green hydrogen targets and harmonising technical and market requirements across borders.

Green hydrogen will unlock offshore wind potential
It is recognised that there is a growing potential for renewable hydrogen in the energy system on the path to net zero. By providing system flexibility and enabling decarbonisation of energy-intensive industries, green hydrogen will also reinforce the business case for offshore wind in the North Sea. Sharing best practices from the North Sea collaborations will be essential for accelerating offshore wind deployment across other regions and sea basins.

European leaders gather in Esbjerg, Denmark, in May 2022 for the North Sea Summit.

Photo credit: Bo Amstrup/Ritzau Scanpix

Visualisation: Copenhagen Infrastructure Partners

Developing offshore energy hub projects globally

The transition to renewable energy requires large-scale offshore wind capacity and efficient energy transmission. Offshore energy hubs - or energy islands - that collect, store and distribute offshore wind power are a promising solution, but their development is complex, requiring expertise in infrastructure, financing and grid integration.

Copenhagen Infrastructure Partners (CIP) has launched Copenhagen Energy Islands (CEI), a new company dedicated to developing offshore energy hubs worldwide. CEI focuses on planning, financing and delivering large-scale offshore hubs that connect multiple wind farms to onshore grids and hydrogen production facilities. By drawing on CIP's experience in offshore wind and energy infrastructure, CEI aims to accelerate energy island deployment.

With offshore energy hubs set to play a key role in the global energy transition, CEI provides a specialised platform to advance their development. By enabling better integration of offshore wind, enhanced energy security, better balancing of energy systems and large-scale green hydrogen production, the initiative supports the shift to a renewable and interconnected energy system.

CONTRIBUTORS

Copenhagen Infrastructure Partners
PensionDenmark
PFA
SEB
Andel

LOCATION

Globally

CHAPTER 8

Gateways for offshore wind expansion

Port facilities are vital for expanding offshore wind. In Denmark, you will find some of the world's largest and most experienced base ports for offshore wind activities.

Port facilities are essential to offshore wind deployment, facilitating the production, installation, and servicing of wind farms. In Denmark, several of the world's most experienced ports play a key role in supporting the offshore wind sector.

Developing the right infrastructure is crucial for deploying large volumes of offshore wind energy to combat climate change. Building this capacity requires close collaboration between ports and the wind sector. In particular, the vast increase in size and volume of wind turbines continuously push port capacity and infrastructure limits. Transport routes, quay ramps, load capacity and storage areas must evolve to meet the production, installation and service needs of future generations of wind turbines.

The three roles of commercial ports in offshore wind
Danish commercial ports contribute to offshore wind development in three keyways:

- **Production ports** – Ports such as Lindø, Nakskov and Aalborg serve as manufacturing hubs for wind turbine components. Given their size and weight, components such as nacelles, blades and towers are often assembled near ports to ease transportation. Production ports require strong load-bearing surfaces, deep-water access, and large storage areas.

- **Installation ports** – Ports such as Esbjerg and Rønne function as offshore wind logistics centres, providing pre-assembly areas and quay facilities for wind turbine components before they are transported offshore. Installation ports must accommodate heavy loads, extensive storage areas, and deep-water basins. The Danish Transport Authority estimates that shipping 1 GW of offshore wind requires 250,000–350,000 m^2 of port space.

- **Service ports** – Once offshore wind farms are operational, ports near wind farm sites serve as maintenance hubs. These ports require less storage and quay space but must provide efficient access to offshore wind farms. Key Danish service ports include Hvide Sande, Thorsminde and Klintholm.

Many Danish ports have successfully transitioned from traditional industries to offshore wind, securing long-term economic benefits and employment opportunities.

Port Esbjerg is the world's largest base port for offshore wind installation. It has shipped more than 80 percent of Europe's installed offshore wind capacity and continues to expand its role in supporting offshore wind deployment.

Other Danish ports are reaping the rewards of wind energy as well. The Port of Rønne is set to support wind installations in the Baltic Sea, while the port of Thyborøn, in a town of fewer than 2,000 residents, was chosen by German developer RWE as the base port for Denmark's largest wind project to date, the 1 GW Thor Offshore Wind Farm, which will be commissioned in 2027.

Photo credit: Port Esbjerg

From fishing hub to the world's largest offshore wind port

Port Esbjerg has shifted from a fishing hub to a key offshore wind port, handling 80 percent of Europe's installed offshore wind capacity. Once Denmark's largest fishing harbour, the industry later underwent structural changes, with many individual fishermen replaced by larger players. By the early 2000s, the port sought new opportunities, aligning with Denmark's offshore wind expansion.

The offshore industry flourished in the North Sea, and in 2002, Esbjerg was chosen as the assembly and shipping site for Denmark's first large-scale offshore wind farm, Horns Rev 1. The port invested in infrastructure, upgraded quay facilities, and retrained workers from fishing, oil and gas to support offshore wind.

Today, Port Esbjerg is Europe's leading port for handling and shipping wind power. It is home to around 200 companies and 10,000 people, supporting the entire offshore wind supply chain. In 2023, Esbjerg tripled its offshore wind shipment capacity from 1.5 GW to 4.5 GW annually through improved logistics and digital tools.

This transformation has not only revitalised the local economy and created thousands of jobs but also positioned Port Esbjerg as the world's largest offshore wind port.

CONTRIBUTORS

Port Esbjerg

LOCATION

Esbjerg, Denmark

Photo credit: Odense Port

From shipbuilding stronghold to offshore wind manufacturing hub

Once home to the Lindø Shipyard, Odense Port is now Northern Europe's largest offshore wind manufacturing hub, employing over 3,200 people. For much of the 20th century, Lindø Shipyard, owned by A.P. Moller-Maersk, was synonymous with regional growth and local jobs. After closing in 2012 following the financial crisis, over 2,700 jobs were lost.

Rather than decline, the port embraced offshore wind with support from local authorities, unions, and a donation from A.P. Moller-Maersk. The site was transformed into an industrial park for wind turbine production, innovation and testing, enabling many former shipyard workers to transition into the offshore wind sector.

Today, over 120 companies operate at the port, including Vestas, which developed its 15 MW prototype nacelle on-site, and LORC, a facility testing turbine components of up to 25 MW. Over a span of 15 years, the port has become a key player in the global offshore wind supply chain, driving economic growth while advancing the renewable energy transition.

CONTRIBUTORS

Odense Port

LOCATION

Munkebo, Denmark

CHAPTER 9

Testing and perfecting the turbines of tomorrow

Test facilities are vital for maintaining a strong wind industry. In Denmark, companies have access to a wide range of world-class test facilities, enabling the industry to pursue new standards and push the technological limits of wind power.

Easy access to high-quality test and demonstration facilities is crucial for keeping the wind industry competitive and innovative while promoting knowledge-sharing. For many years, Denmark has been a hub for test and demonstration projects supporting the entire value chain of the global wind industry. Extensive collaboration between the industry, public authorities and academic community in Denmark has played a crucial role in driving this continued development progress.

A glimpse of the future

On the windy west coast of Jutland lies one of the world's largest full-scale wind turbine test facilities, Test Centre Østerild. Operated by the Technical University of Denmark (DTU), the centre hosts test stands for leading manufacturers such as Vestas, Siemens Gamesa and GE Renewable Energy. Østerild's optimal wind conditions, combined with Denmark's strong testing and production ecosystem, help manufacturers refine turbine technology and bring new models to market faster. Over the years, the centre has expanded its number of test stands and increased the maximum turbine height in the test areas to accommodate the increasing size of new turbines.

Since its establishment in 2012, the test centre has become a source of local pride in Thisted Municipality, attracting more than 30,000 visitors annually. 365 days a year, the site allows visitors to walk, cycle or drive among the nine test stands to catch a glimpse of the wind turbine technology that will shape the next five to ten years.

Testing every component

Before final testing at Østerild, each turbine component undergoes rigorous testing to identify and eliminate potential design or manufacturing flaws early in the process. This significantly reduces costs for the manufacturers compared to correcting issues after turbines have been mass-produced and installed worldwide.

Denmark is uniquely positioned as home to several state-of-the-art test facilities, offering top-tier quality and capacity while specialising in different components. As is typical of the Danish wind industry, many of these facilities have been developed through partnerships between private companies, research institutions and public authorities.

One example is the Lindø Offshore Renewables Center (LORC), which specialises in testing nacelles and drivetrain components such as gearboxes. Another leading facility is the Danish Blade Test Centre, Blaest. Collaboration agreements with both Vestas and Siemens Gamesa have contributed to the centre's growth, enabling it to house two test halls and eight test rigs capable of testing blades up to 120 meters in length.

DTU's Risø Campus has been a hub for wind turbine research since the 1970s. Today, the campus hosts one of the world's top research institutions, DTU's Department of Wind and Energy Systems, as well as several cutting-edge facilities, including one of the largest university-owned wind tunnels globally.

Extreme conditions in flexible facilities

The old Lindø shipyard, a former 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 30,000 visitors each year.

CONTRIBUTORS

DTU Wind and Energy Systems,
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 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 and Energy Systems, 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 Non-Destructive Testing (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 120 meters, scaled to fit the giant wind turbines of tomorrow.

CONTRIBUTORS

Danish Blade Test Centre (Blaest)

LOCATION

Aalborg, Denmark

CHAPTER 10

Innovative solutions for a more sustainable wind industry

In the coming years, Denmark will face a growing number of retired wind turbines. This highlights the urgent need to develop and implement sustainable technologies and processes to manage ageing turbines.

The ambition to create a more sustainable wind industry has been a priority for Danish and Denmark-based manufacturers and developers such as Vestas, Siemens Gamesa, Ørsted and Vattenfall for many years. These companies were among the first to introduce sustainability requirements for both their own operations and their suppliers, ahead of the EU's Corporate Sustainability Reporting Directive (CSRD), which mandates greater transparency throughout the entire value chain.

Vestas and Ørsted have repeatedly been recognised as two of the world's most sustainable companies. As part of their efforts to contribute to a greener industry, both companies have launched several innovative initiatives addressing present and future sustainability challenges.

Giving wind turbines a second life
Today, around 85 percent of a wind turbine is recyclable. The main challenge lies in the blades, which are made from composite materials – mainly a mix of wood, fibreglass and resin. Designed to last 20–30 years, often in harsh weather conditions, blades must be highly durable, which in turn makes them difficult to break down.

In collaboration with Danish universities and leading industry players, Vestas has initiated CETEC (Circular Economy for Thermosets Epoxy Composites), a project aimed at developing new technology to break down old wind turbine blades, enabling different components to be reused in the production of new blades.

DecomBlades is another initiative that combines knowledge from the research community and industry leaders like Siemens Gamesa, LM Wind Power, Ørsted, FLS and Vestas. The project focuses on three processes for recycling the composite materials in wind turbines blades: shredding of wind turbine blades, use of shredded blade material in cement production, and separation of composite materials using pyrolysis.

Setting higher sustainability standards
Danish authorities share the industry's commitment to promote sustainability and have introduced ambitious sustainability criteria with the latest public offshore wind tenders. These criteria include recyclability of wind turbine blades, compliance with human rights, and measures against social dumping. The non-price criteria are included as minimum requirements, helping to raise the overall sustainability standards across the industry, while ensuring a fair and objective tender process.

The Port of Thorsminde will serve as base for the operation and maintenance of Thor Offshore Wind Farm.
Photo credit: Ole Mortensen

Advancing circularity in offshore wind

Offshore wind plays a key role in the energy transition, but the industry must address the sustainability of turbine materials. Traditional rotor blades are difficult to recycle, and steel production for wind turbine towers is carbon intensive. Reducing waste and emissions is essential for scaling up offshore wind sustainably.

RWE's Thor Offshore Wind Farm, Denmark's largest offshore wind project to date, integrates recyclable rotor blades and low-carbon steel towers to reduce its environmental footprint. 40 of the wind farm's 72 turbines will feature Siemens Gamesa's recyclable blades, which allow materials to be separated and reused. Additionally, half of the project's turbines will use Siemens Gamesa's GreenerTower. The tower steel plates are made of greener steel that generates at least 63 percent less CO_2 emissions compared to conventional steel.

Once operational, Thor Offshore Wind Farm will have a capacity of more than 1 GW and will be capable of producing enough green electricity to supply the equivalent of more than one million Danish households. By incorporating circular solutions, the project sets a new standard for sustainable offshore wind, demonstrating how wind energy can reduce emissions while scaling up clean power generation.

CONTRIBUTORS

RWE Renewables Denmark
Siemens Gamesa

LOCATION

North Sea, Denmark

CHAPTER 11

A renewable transition in harmony with people and nature

Transitioning to a zero-carbon society results in visible changes to our surroundings. Denmark has a strong focus on ensuring a renewable transition in coexistence with both people and nature.

Danes are accustomed to seeing wind turbines in the landscape, as they have been deployed since the 1970s. While the public in general supports wind energy, not everyone is in favour of having turbines in their back yard. Therefore, new investments in Danish wind farms are followed by initiatives to improve acceptance among locals that are affected by wind turbines.

Incentivising local support and involvement
In Denmark, onshore wind turbine installations are discussed at local level and approved by local authorities. Experience has shown that early involvement is key to establishing local support as it creates a sense of ownership in the local community where the turbines are installed. In some cases, developers offer local citizens the opportunity to invest in the installed capacity. This fosters co-ownership and involvement. In addition, the 'green fund scheme' requires onshore wind farm owners to pay the relevant municipality a one-off sum of 40,625 EUR per MW. The funds are administered by the municipality and designated to support new local initiatives. Installing new onshore capacity thereby both contributes to local development and paves the way for a cleaner environment.

Finally, neighbours living within eight times the tip height of the wind turbines are rewarded with a 'Renewable Energy Bonus' to acknowledge their cooperation. The bonus is paid out on a yearly basis and corresponds to a share of 9.75 kW of the wind energy produced. The bonus will therefore vary over the lifetime of the wind power plant, depending on energy production and energy prices. This ensures that neighbours receive a higher reward in windy years or in times of high electricity prices.

Guarantees for property owners
Property owners who experience a perceived loss in property value due to neighbouring wind turbines are compensated if the loss of value is equal to or greater than 1 percent of the total value of the property. This framework allows any property owner living near a wind turbine (4-6 times the tip height) to apply for an 'option to buy-scheme' and sell their property to the turbine owner within a year of the first produced kilowatt hour. It protects the rights of citizens perceiving a value-loss, but also ensures that developers can complete their projects.

Biodiversity and climate – two crises solved together
Denmark faces significant challenges in halting biodiversity loss. As a result, the energy sector actively participates in several public-private partnerships, such as the Danish Biodiversity Partnership. This initiative brings together NGOs, business organisations, research institutions, and the government to develop frameworks and identify barriers, ensuring that new wind farms can be built while also restoring nature.

Photo credit: Ørsted

Restoring oyster reefs in offshore wind farms

Oyster reefs in the North Sea have nearly disappeared due to overfishing and habitat loss, reducing marine biodiversity and ecosystem health. At the same time, offshore wind farms create new opportunities to support marine life.

Ørsted, in partnership with the Ocean Health initiative of global marine contractor Van Oord, has sought a scalable solution to restore native oyster reefs within its wind farms. At Borssele 1 & 2 Offshore Wind Farm, Ørsted has deployed droppable oyster structures, which are reef structures designed to encourage oyster larvae production. These structures provide a stable habitat for oyster reefs while withstanding offshore conditions.

Deployed in October 2024, the oyster structures will help restore marine biodiversity by creating habitats for marine species and improving water quality. If successful, this model could be expanded across Ørsted's offshore wind farms globally, demonstrating how renewable energy projects can actively contribute to biodiversity restoration.

CONTRIBUTORS

Ørsted
Ocean Health
Van Oord
Technical University Delft

LOCATION

Borssele 1 & 2 Offshore Wind Farm, North Sea

Photo credit: Vestas

A community-driven approach to wind energy

The global energy transition requires widespread adoption of wind power, yet securing local support for new projects can be challenging. In many regions, permitting delays and community opposition slow down the deployment of renewable energy.

In Thyborøn, a small port town on Denmark's west coast, a local wind turbine co-operative partnered with Vestas to install the V236-15.0 MW test turbine. The project was funded by local investors and benefited from an efficient permitting process, enabled by strong public engagement and community meetings. This collaborative approach ensured widespread support and a smooth installation process.

The turbine, installed in record time without any official complaints, now contributes valuable operational data for Vestas' offshore wind technology while supplying renewable energy. The project builds on Thyborøn's long-standing tradition of community-led wind initiatives, demonstrating how local ownership and engagement can accelerate the green transition.

CONTRIBUTORS

Vestas

LOCATION

Thyborøn, Denmark

Photo credit: Andel

Windy Retreats: Breaking misconceptions about living near wind turbines

Denmark must significantly expand onshore wind energy to meet its climate targets, but local opposition often prevents new wind turbine projects. Misconceptions about noise, visual impact and living conditions near wind turbines contribute to resistance, slowing down the green transition.

To challenge these perceptions, Andel launched Windy Retreats, inviting Danes to stay for free in homes located near wind turbines. By offering first-hand experiences, the initiative allows participants to form their own opinions about what it is like to live close to wind energy production.

More than 1,200 people applied for a stay, and participating families shared their experiences, helping to dispel myths about wind turbines. Studies show that 93 percent of existing wind farm neighbours report little to no disturbance. By fostering dialogue and awareness, Windy Retreats supports Denmark's goal of integrating more wind power into the energy system.

The national ads of the campaign had a recall rate among the population of 76 percent and the campaign had a positive impact on the perception of turbines for more than 900,000 Danes.

CONTRIBUTORS

Andel

LOCATION

Several places in Denmark

Explore relevant whitepapers

From black to green – A Danish sustainable energy growth story

A case study of how an energy utility can transition from fossil fuels to renewable energy and the enabling regulatory framework that made it possible.

Green hydrogen is Danish hydrogen

Get a full overview of how hydrogen can produce green fuels for transport and industry, create value for electricity supply and the electricity grid, and deliver heat for district heating - provided the input is green energy.

Sector coupling – Unlocking renewable energy's full potential

Discover the hidden potential of sector coupling in this white paper, offering valuable insights and practical solutions that can inspire and guide global efforts towards a green and sustainable transition.

Towards zero: Denmark's push to decarbonise global shipping

Building on longstanding maritime traditions, Denmark is committed to accelerating the global transition towards climate-neutral shipping and finding ways to overcome regulatory, financial, technological and political barriers. Dive into Denmark's push to decarbonise global shipping in this white paper.

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

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