

DENMARK – WIND ENERGY HUB





PHOTO: SIEMENS WIND POWER


DANISH WIND
INDUSTRY ASSOCIATION

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Use the QR codes and stay updated on the ever-evolving Danish wind industry. Also read this publication online and find more links and information.



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This profile of the Danish wind industry describes the many competences offered by the hundreds of companies working with wind energy in Denmark – competences that combined create a unique wind energy hub.

TEAM UP WITH THE BEST!



Denmark is the first country in the world to actively pursue a strategy to build an energy system that is independent of fossil fuels. Wind energy already accounts for more than one third of the total electricity consumption in Denmark. No other country has integrated this much wind into the grid. In the future, this renewable and cost-efficient resource will form the backbone of Denmark's electricity supply.

The vision of the Danish Wind Industry Association (DWIA) is to make Denmark the home of the most competitive wind industry in the world. This will ensure the position of Denmark's highly competitive, innovative and globally-oriented wind industry.

DWIA's vision will help drive developments in the wind industry further, ensuring that Denmark develops the world's best wind technology and smart energy system.

Bringing down costs

We have almost 40 years' experience with developing and installing innovative and energy-efficient wind turbines onshore and nearly 25 years of experience offshore. Over the years, the industry has grown strong and has made a positive contribution to the Danish economy. Onshore wind has become the cheapest source of energy in Denmark, while offshore wind remains slightly more expensive than onshore wind and fossil fuel. However, the future looks bright as experience and skills have placed Danish companies in the forefront of bringing down the costs.

We can expect to see a vast expansion in wind energy capacity in markets all over the world. The advantages are many as more wind energy will benefit the climate, create jobs, and boost national energy production in markets focusing on renewables.

More wind energy will also benefit the companies located in the strong and close-knit Danish wind industry where our global focus has led to today's leading position.

Skills making the difference

The success of the Danish wind industry is the result of special skills throughout the supply chain. Danish companies have developed unique technology solutions, for which there is global demand.

At DWIA, we believe that companies can only grow by benchmarking against the best of their peers. Your business will be teamed up with the best players in the industry at DWIA. Representing more than 30 years of experience in handling political interests, building networks and generating know-how, we are the natural partner for all the wind energy stakeholders.

A handwritten signature in black ink, reading 'Jan Hylleberg'.

JAN HYLLEBERG
CEO, DANISH WIND INDUSTRY ASSOCIATION

JOIN THE FUTURE. THINK DENMARK



When Denmark decided to become entirely independent of fossil fuels by 2050, the obvious first question was: how?

The answers are many, but essential is the development of an intelligent energy system, capable of managing the fluctuations of renewable energy – and implementation of some of the finest solutions from a number of technologies. Wind energy is an essential piece in the Danish jigsaw.

The national policy has been a catalyst for renewable R&D for decades. And nowhere more than in wind energy where Danish companies and research institutions have been at the technological forefront since the 1970s.

Remarkable technological leaps have been seen since then – and the work in test centers around the country shows that much more is in the pipeline. It is exciting times to look forward to.

A handwritten signature in black ink, appearing to read 'Finn M.'.

FINN MORTENSEN
EXECUTIVE DIRECTOR, STATE OF GREEN

GLOBAL HOT SPOT FOR WIND ENERGY



Leading wind energy companies, such as Vestas, Siemens Wind Power, MHI Vestas Offshore Wind, Envision, LM Wind Power, Bladt Industries, A2SEA and Titan Wind Energy, have located central parts of their global operations in Denmark. This reflects Denmark's position as a global leader in wind energy. This country is one of the best in which to develop and produce wind energy technology.

Skills, network and a flexible and innovative labor force make Denmark the perfect location for companies working with wind energy. Denmark is a great place to develop markets, supply chain, technologies and products.

A combination of political focus on renewable energy, a highly educated and specialized labor force and state-of-the-art test facilities make it attractive to develop, manufacture, test and promote wind energy technology in Denmark.

Invest in Denmark welcomes international businesses to Denmark. We can advise on business matters, clusters and competencies, arrange fact-finding missions and facilitate networks both before, during and after setting up operations. In short, we measure our success in terms of how well we contribute to the success of foreign businesses.

A handwritten signature in black ink, appearing to read 'Dorte B.'.

DORTE BECH VIZARD
DIRECTOR, INVEST IN DENMARK

DENMARK IN THE LEAD

A quick look at the numbers says it all: In Denmark, wind turbines are a vital part of the energy system, providing around 39% of Danish electricity in 2014. In January 2014, wind turbines delivered on average 63% of total consumption. Today, Denmark uses most wind energy per citizen in the world. The record share highlights Denmark's position as a leading light in the pursuit of tomorrow's more renewable and cost-competitive energy system.

The Danish lead is built on years of research, development and innovation in wind energy technology. It was Denmark that connected the world's first onshore wind turbine to the grid in 1976. It was joined by the world's first offshore wind

farm in 1991. Once the brainchild of a handful of idealistic pioneers, the wind industry has become a global industry in just a few decades – and more is still to come.

Total wind energy capacity in Denmark is almost 5,000 MW, with nearly 1,300 MW (2014) located offshore. This ensures Denmark a second place for installed offshore capacity surpassed only by the UK.

Plans for the future utilization of wind energy are ambitious, benefitting the climate and strengthening Denmark's capacity to compete.

60%

WIND ENERGY BY THE END OF 2021



PHOTO: SIEMENS WIND POWER



PHOTO: VESTAS WIND SYSTEMS



WIND ENERGY IN THE DANISH ENERGY SYSTEM

In the early days of wind energy, it seemed unlikely that wind could cover more than 5-10% of Denmark's electricity consumption. However, the energy system operators and producers of wind energy have repeatedly exceeded their own expectations and thresholds. The result is a unique and expanding utilization of wind energy, which benefits the consumers, the climate and national energy security.

Denmark has focused on developing a robust, flexible and internationally integrated energy system, which is capable of handling large volumes of fluctuating energy production. The integration of variable volumes of wind energy, combined with an embedded flexibility in the rest of the energy system, is a core competence that makes the Danish energy system a model for other countries.

The efforts have resulted in the Danish energy system providing one of the world's most secure and stable supplies of electricity, while increasingly integrating more wind energy into the grid.

More wind needs smarter thinking

In the future, Denmark will focus on carefully developing smarter solutions, which will ensure cost-competitiveness and further reduce the dependence on foreign fossil energy. Denmark aims to be free of fossil fuels by 2050.

Leading the implementation of wind energy calls for an increased scalability in energy production, consumption and trading. Danish energy companies and grid operators have therefore specialized in forecasting the production of and demand for renewable energy in Denmark and neighboring countries.

As part of the Northern European power market, Denmark is already interconnected with Sweden, Norway and Germany. Meanwhile, interconnections with the Netherlands and the UK are in the pipeline.

From wind to heat

Even now, there are days when Danish wind turbines produce more electricity than Denmark needs. This is expected to happen more frequently in the future. At the national level, Denmark focuses strongly on using surplus electricity in other parts of the energy system – especially in transportation and heating.

The Danish district heating system is one of a kind. The system covers 62% of all buildings and provides excellent opportunities for using electricity at times when wind energy production is high and prices low.

In Denmark, electricity is believed to be the best mean society has to cover its energy demands – for domestic purposes, transportation, heating and industrial production.



PHOTO: ABB



IMPORTANT FACTORS FOR A HIGH WIND ENERGY PENETRATION

- Predictability of wind and bioenergy resources
- Scalability of fossil energy production
- Interconnection with neighboring energy markets
- Using electricity in district cooling and heating and transportation
- Smart domestic electricity usage

POLITICAL COMMITMENT DRIVES THE WIND INDUSTRY

In 2012, the Danish Parliament set a clear course for the energy sector in Denmark. Having made an overall commitment to a fossil-free future (2050), the current Energy Agreement includes a target of 3,100 MW of new capacity from onshore and offshore wind. As a result, wind energy is expected to cover 60% of the Danish electricity consumption by the end of 2021.

The agreement secures a substantial expansion of the Danish wind energy capacity offshore, near-shore and onshore. The offshore expansion alone corresponds to the annual consumption of 1.4 million average Danish households.



1,400 MW OFFSHORE WIND ENERGY IN THE PIPELINE:

- 600 MW will be built at the Kriegers Flak offshore wind farm. Earliest grid connection in 2019 and completion no later than 2022.
- 400 MW will be built at the Horns Rev 3 offshore wind farm. Earliest grid connection in 2017.
- 400 MW near-shore wind turbines will be installed by 2020.

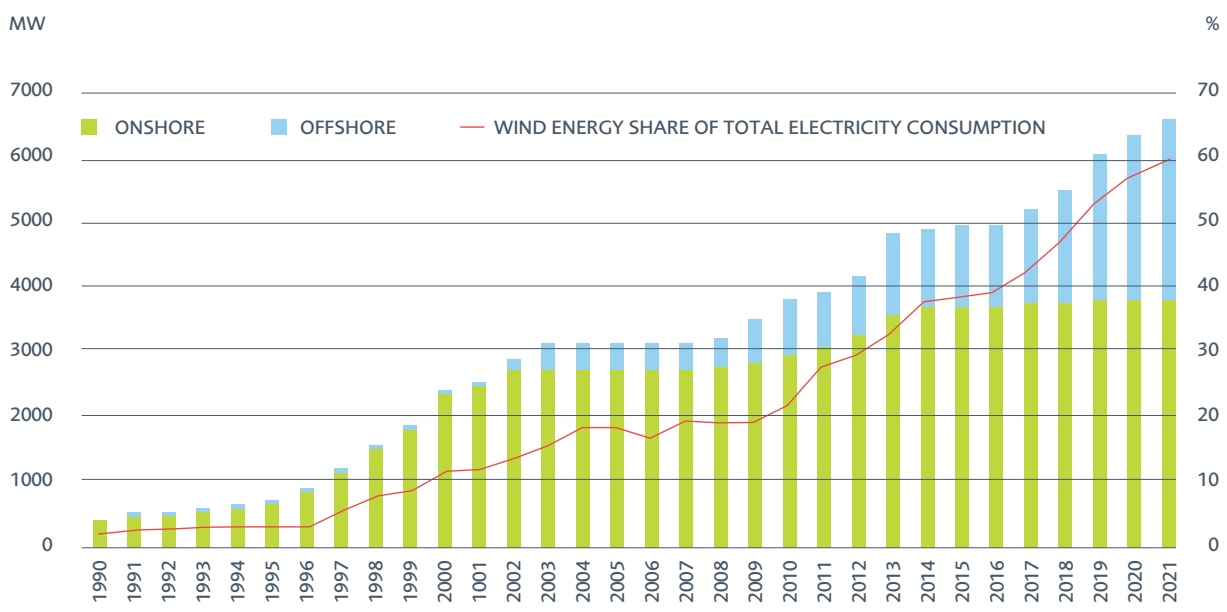
To replace aging onshore wind turbines, 1,800 MW of new capacity will be added onshore between 2012 and 2020. New turbines are larger and more effective than the old ones they replace, so the landscape will feature fewer but bigger and more effective wind turbines. These political goals are an important step in Denmark's steady movement towards fossil fuel independence – with a helping hand from a globally recognized Danish wind energy sector.

All in all, Denmark will reduce its green house gas emissions by 40% by 2020 compared to 1990. It is even possible that the CO2 reduction target and the percentage of wind will be surpassed as wind turbines are becoming increasingly efficient.

Stay updated on the Danish progress



The importance of wind energy is growing



Electricity from wind turbines will become more prominent in the coming years. At the beginning of 2020, wind energy generation is expected to cover 53% of Danish electricity consumption, reaching 60% at the end of 2021.

STABILITY IS KEY FOR THE WIND INDUSTRY



PHOTO: VESTAS WIND SYSTEMS

Stability plays an important role in the successful green development of any energy system. In Denmark, stable political frameworks, innovative project financing and support for ongoing wind capacity additions have created a model wind market.

For many Danes, wind energy is synonymous with Denmark and the special Danish dedication to greening the economy. The key word for the strong focus, continuous expansion and persistent commitment to mitigating climate change and creating jobs is **stability**.

During the last 30 years, a series of political administrations have provided the wind industry with long-term transparent plans for the implementation of renewable energy sources. Political foresight makes Denmark highly innovative in its approach to reducing its dependence on fossil fuels.

Different investments are important

Denmark is at the forefront when it comes to financing new

wind farms and has been so throughout the maturing of the market. In the early days, wind farms were mainly financed by private investors. As the scale of investment grew, institutional investors took over. In particular, large-scale pension funds have played a central role in infrastructure investment in recent years. By investing heavily in other markets, Danish private and public investors are playing an important role in financing new onshore and offshore wind farms around the world.

In Denmark, new onshore wind turbines must be co-financed by private local investors. This is a legal requirement and it is unique to Denmark. The return on investment over the lifetime of a wind turbine is regarded as a stable infrastructure investment. At the same time, local investors have part-ownership of the wind turbines in their neighborhood.

A combination of political goals and a strong will to invest creates a stable framework for the development of wind energy in Denmark.

DANISH WIND
INDUSTRY ASSOCIATION

Developers | Wind turbine manufactures | Component suppliers | Materials and surfaces | Energy companies | Logistics | Service and maintenance providers
 Consultants | Wind turbine suppliers | Training and education providers | Research and development

Test Centre Østerild
 TP Wind
 University of Southern Denmark
 The Technical University of Denmark
 Copenhagen University College of Engineering
 Aarhus University
 Aalborg University
 Concito
 Lindoe Offshore Renewable Center
 Test Centre Høvsøre
 European Wind Energy Association
 Danish Research Consortium for Wind Energy
 Danish Wind Turbine Owner's Association
 Hub North
 Offshoreenergy.dk
 Supplier network
 Global Wind Organization
 QA-network
 Value of wind
 Offshore Wind Denmark
 Developer Forum
 Megavind

V/derOurWind
 Planning network
 Offshore planning network
 Danish Energy Agency
 Energinet.dk
 Media
 Political and industry associations
 Ministry for Climate and Energy
 Danish municipalities and regions
 The Danish political parties
 Ministries

Danish Wind Export Association
 Match-making
 Fact-finding
 Internationalization
 Danish Export Association
 Invest in Denmark
 State of Green
 The Danish Trade Council
 The Danish embassies globally
 Ministry of Foreign Affairs
 The Export Credit Fund
 European Wind Energy Association
 Danish consul generals and chambers of commerce
 Global Wind Energy Council
 Foreign Embassies in Denmark

- Primary network and members of DWIA
- Networks and offers provided by DWIA alone or with partners
- Selected collaboration partners

AT THE CENTER OF THE **HUB**

The Danish Wind Industry Association is the voice of the wind industry in terms of communications with authorities, research institutions, universities, and international stakeholders.

In managing member interests, DWIA facilitates numerous networks and initiative where stakeholders meet. Providing networks exclusive to members as well as collaborative offers, DWIA recognizes the industry needs for sharing and generating knowledge. In networks, members have the opportunity to share experiences, develop business, and discuss market opportunities and challenges.

The Danish wind industry is full of opportunities and DWIA offers an excellent way into the very hub of the industry already representing and servicing more than 260 member companies.



PHOTO: DWIA / KEENPRESS

DENMARK – THE SUPPLIER HUB

Danish supply chain and production capabilities form a unique wind energy supplier hub. Strong and extensive collaboration, commitment to innovation and years of experience form the basis of a strong and progressive hub that is able to compete internationally.

For nearly 40 years, companies in the Danish wind industry have developed and built wind turbines, installed them and integrated wind into the energy system. The wind industry is continuously pushing the boundaries for what is technologically feasible in the field.

Today, Denmark is home to some of the world's leading companies. A total of more than 500 companies, working in all areas of the wind industry, are located in Denmark.

The industry is an unparalleled network of experience, expertise and competencies covering every link in the supply chain. Wind turbine manufacturers, energy companies, components suppliers, services and installation providers as well as consultants and investors form a unique and close-knit wind supplier hub.

A strong supplier hub - now and in the future

Competitive parameters and supplier requirements have developed by leaps and bounds in the last decade. While focus remains on the innovative capabilities of the suppliers, there has also been increasing focus on other aspects, such as quality management, time to market, and servicing.

The Danish supply chain has adapted to the changing landscape, and has remained competitive in the global marketplace. When it comes to lowering the cost of wind energy, Danish suppliers have a strong hand.

The current evolution of the supply chain structure is evidence of the maturity of the Danish supplier hub. Drawing inspiration from both the automotive and aerospace industries, industrialization of the wind industry is moving forward, and it is becoming evident that the Danish supply chain can set the standards for structural changes and new business models, such as system solutions.



PHOTO: NIEBUHR GEARS





PHOTO: NORDEX

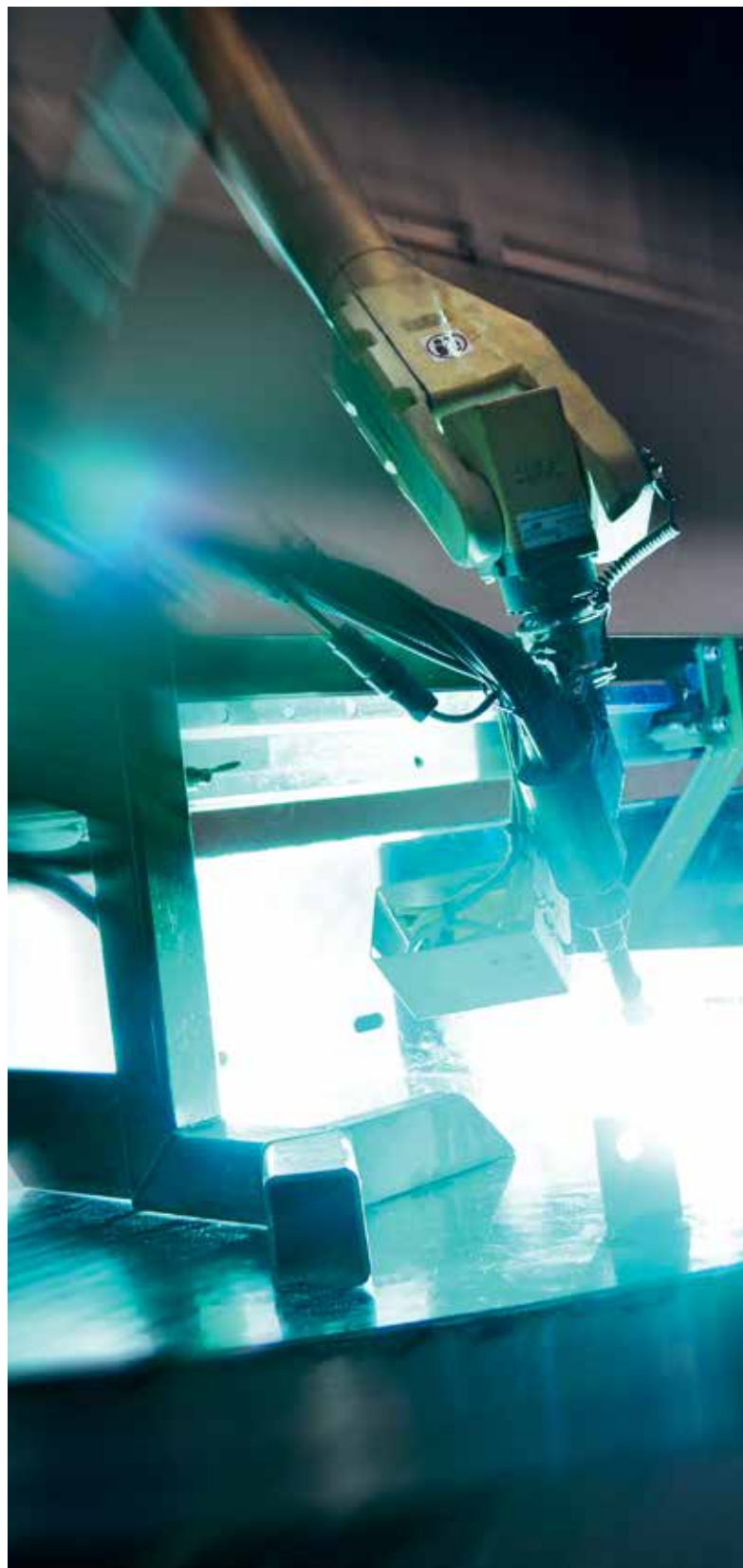


PHOTO: KK-ELECTRONIC



PHOTO: ALUWIND

More business collaboration

Manufacturers continue to demand more integrated solutions and system solutions, rather than single components.

Danish suppliers are leading the field and are meeting these demands. Meanwhile, there is a growing need for better collaboration in the wind industry, which explains why suppliers are increasingly joining forces in collaborative networks.

Moving towards more integrated system solutions reinforces the need for the wind industry to consolidate and cooperate. Strong ties between the wind turbine manufacturers and the so-called "system suppliers" are in the best interest of all parties. These suppliers achieve the status of development partners for next generation wind turbines – another advancement which serves to underline the strength of the Danish supplier hub.

**AS A COUNTRY
SURROUNDED BY WATER, DENMARK
HAS STRONG TIES WITH THE SEA.
SUPPLIERS AND WIND TURBINE
MANUFACTURERS ARE DEPENDENT
ON HARBORS TO DISPATCH PRODUCTS
TO THE GLOBAL MARKET. IN 2013,
THE DANISH WIND INDUSTRY
EXPORTED PRODUCTS AND
SERVICES WORTH EUR
6.5 BILLION.**

OVERFLOW OF DANISH OFFSHORE **DNA**

The offshore wind industry has evolved tremendously in the past 25 years. Over the years, Danish companies have massively impacted the professionalization of the industry. Thanks to our early start, there is Danish DNA in almost every offshore project installed today.

Every link in the offshore supply chain is represented in Denmark. Hundreds of companies are involved in wind turbine production, substructures, logistics, investment, development, installation and servicing. They form a close-knit network with unique competences.

Two Danish manufacturers, Siemens Wind Power and MHI Vestas Offshore Wind, dominate the global market for offshore wind turbines. Together, they have produced almost ninety percent of the offshore wind turbines installed. A growing offshore market is encouraging more companies to enter the industry. In Asia and North America, wind turbines are now being moved offshore, where the winds are stronger and steadier.

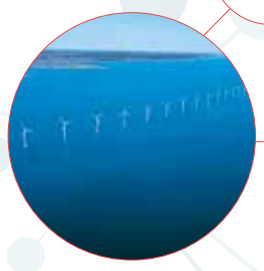
**110
MW**



Lillgrund SWEDEN 2007

- DANISH DELIVERIES**
- Seabed preparation
 - Wind turbines
 - Substation installation
 - Wind turbine installation
 - Substation topside design
 - Gravity foundation manufacturing
 - Substation topside manufacturing
 - Logistics
 - Substructure design
 - Monitoring of waves and currents
 - Substructure main constructor
 - Aviation obstruction light systems

**40
MW**



Middelgrunden DENMARK 2001

- DANISH DELIVERIES**
- Developer and operator
 - Turbines
 - Turbine installation
 - Substructure design
 - Design of substation foundation
 - Substructure main constructor
 - Substructure installation
 - Foundations and transition pieces
 - Logistic
 - Project finance



**90
MW**

Kentish Flats UNITED KINGDOM 2005

- DANISH DELIVERIES**
- Developer
 - Wind turbines
 - Wind turbine installation
 - Substructure main constructor
 - Substructure design
 - J-tube installation
 - Grouting
 - Logistics



Did you know that nearly 9 out of 10 offshore wind turbines in Europe are produced by Danish based wind turbine manufactures?



**630
MW**

London Array
UNITED KINGDOM 2013

- DANISH DELIVERIES**
 Developer and operator
 Wind turbine installation
 Wind turbines
 Substructure installation
 Design of substation foundation
 Substructure main constructor
 Substructure design
 Monopiles and transition pieces
 Grouting
 Logistics
 Monitoring of wind, waves and currents
 Project finance



**468
MW**

Cape Wind
UNITED STATES 2016

- EXPECTED DANISH DELIVERIES**
 Project management
 Project finance
 Wind turbines
 Foundations
 Foundation design



**400
MW**

Anholt
DENMARK 2013

- DANISH DELIVERIES**
 Developer and operator
 Wind turbines
 Wind turbine installation
 Substation installation
 Substation design
 Substation manufacturer
 Export cables
 Export cable installation
 Substructure main constructor
 Substructure design
 Monopiles and transition pieces
 Monopile and transition piece installation
 Export cable manufacturing
 Export cable installation
 Grouting
 Logistics
 Geophysical investigations
 Environmental Impact Assessment
 Project finance



**209
MW**

Horns Rev 2
DENMARK 2009

- DANISH DELIVERIES**
 Accommodation platform
 Wind turbines
 Developer
 Foundations
 Foundation installation
 Foundation design
 Operator
 Wind turbine installation
 Substation
 Project finance
 Substation installation

STILL MOVING FIRST IN OFFSHORE WIND

In 1991, pioneering Danish companies and entrepreneurs installed the first offshore wind farm. It was revolutionary at the time, though the wind farm had just 5 MW capacity.

Since then, a number of record-breaking offshore wind farms have been built in Denmark sustaining Danish leadership in offshore wind. Today, Danish companies remain at the leading edge, implementing new ways of building offshore and applying new technologies.

Around one third of the Danish wind industry's EUR 11 billion turnover (2013) comes from the offshore wind sector. The offshore industry is home to a number of global leaders. These are companies which dominate not only in the number

of installed MW, but also in innovation. Danish companies lead the field when it comes to unlocking the potential of offshore wind, by continually bringing down the cost of energy.

Find Danish offshore wind companies



PHOTO: A2SEA

BRINGING DOWN THE COSTS

There is still some way to go before offshore wind reaches grid parity, at which point it will be possible to build and operate an offshore wind farm without subsidies. The main challenge for the wind industry and other stakeholders – governments, universities and financial institutions – is to reduce the entire cost base for offshore wind farms in order to reduce the cost of energy.

Reducing the Cost of Energy does not necessarily mean that suppliers should create cheaper components. This can especially be done by creating integrated solutions and more innovative components. The advances will lead to offshore wind becoming more competitive and an even more attractive alternative to fossil fuels.

Cost-cutting national R&D strategy

Since the mid-1990s, research has focused on offshore foundations, wave load and seabed conditions. As a result, Danish research communities now have a vast pool of knowledge about modern offshore support structures. With practical experience of designing, manufacturing and installing support structures for offshore wind farms, Denmark has a unique store of knowledge and an invaluable technical data set.

In 2010, the Danish Megavind technology platform presented a new vision and strategy for offshore wind. The aim is to drive down the cost of energy from offshore wind farms and for offshore wind to become competitive with new power plants such as coal by 2020.

Learn more about Megavind



PHOTO: DONGENERGY



PHOTO: VESTAS WIND SYSTEMS



PHOTO: VESTAS WIND SYSTEMS

OFFSHORE WIND HAS COME TO STAY

More and more wind turbines are being installed offshore as the advantages are legion. Firstly, there is an abundance of wind resources with wind speeds that are more powerful and constant than onshore. Offshore wind farms can produce large volumes of energy at increasingly competitive prices and thus help reduce our dependence on fossil fuels. For 25 years Denmark has followed this path and several other countries in existing and new markets are planning to build more offshore wind farms.

There is massive potential. Enough offshore wind energy could be produced in the North Sea alone to cover European Union electricity needs several times over.

Groundbreaking 600 MW Kriegers Flak

The Kriegers Flak offshore wind farm is part of the Danish Energy Agreement. When it is finished (before 2022), the 600 MW wind farm will be Denmark's largest, producing electricity equivalent to approx. 600,000 households.

Kriegers Flak is a unique project located at relatively low depths in the waters between Denmark and Germany. Upon completion, these two countries will have created the world's largest offshore electricity grid, which will show other countries to integrate wind energy in more than one market.

Near-shore wind farms

In a unique initiative, 400 MW capacity divided between several smaller wind farms will be built close to the Danish shores. The so-called near-shore wind farms will be built 4-20 kilometers from the coast.

Local communities are encouraged to become engaged in the projects through local joint ownership. Local citizens and companies close to the wind farms will be offered a chance to invest in the projects and become co-investors with a minority stake. This is common practice onshore in Denmark. Neighbors share the cost and profits of the wind farms.



Did you know that Denmark has almost 1,300 MW of offshore wind energy? By 2020, this capacity will have doubled.

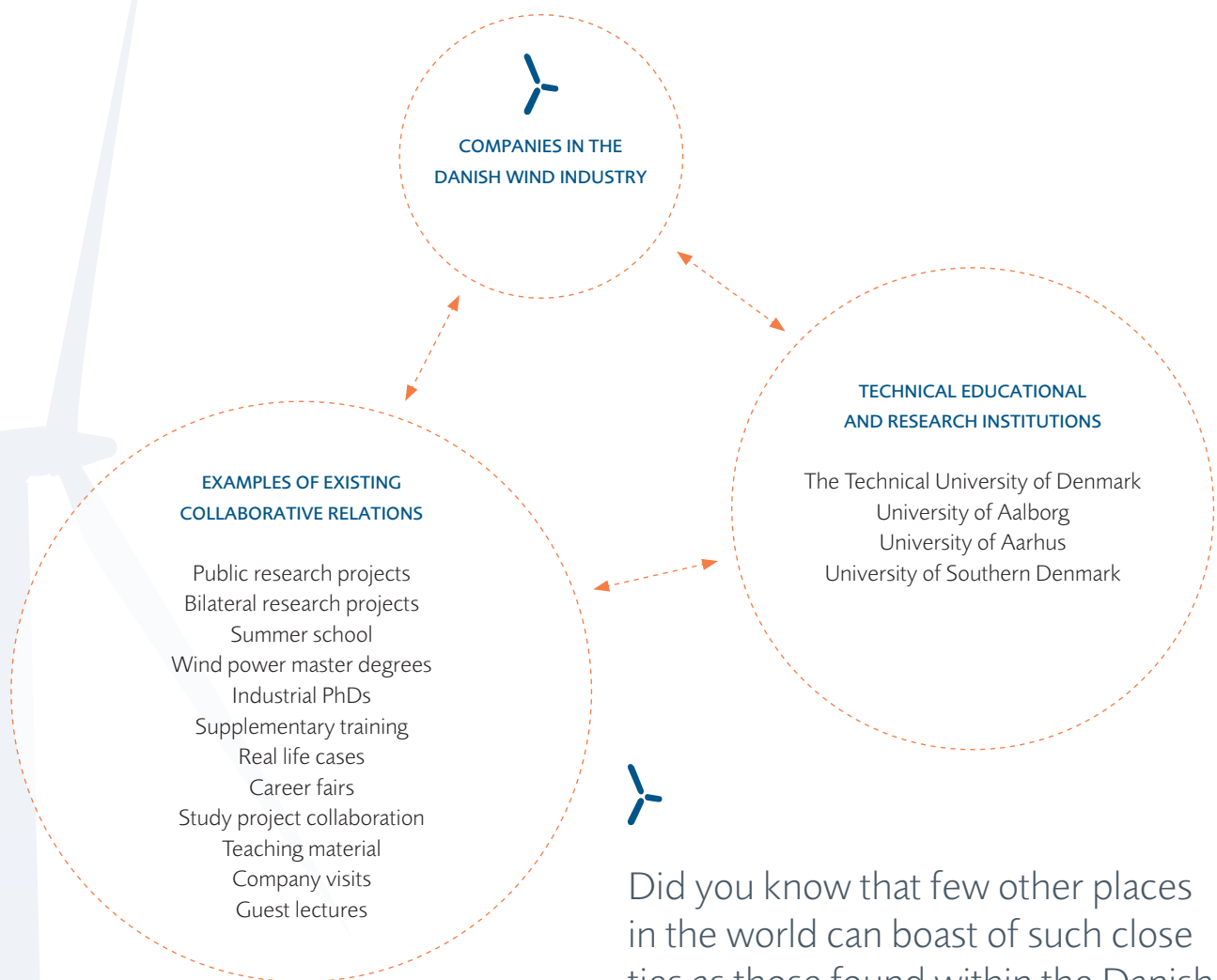




PHOTO: DONG ENERGY

COLLABORATIVE INNOVATION NETWORKS

The Danish wind industry is built on a strong foundation of close collaboration between research institutions, universities and companies. In Denmark, expertise, education, innovation and industry combine to form a strong network for global development of wind energy.



Did you know that few other places in the world can boast of such close ties as those found within the Danish wind industry? A strong network between companies and research institutions is father to interdisciplinary collaboration at a wide range of test facilities as well as numerous other initiatives in Denmark.

COMPETENCES IN CLOSE PROXIMITY

Proximity is key to effective R&D. Denmark is a textbook example as manufacturers have production and R&D facilities within easy distance, not only of each other, but also of test facilities for testing wind turbines. This is unique and important, as production, R&D, testing and verification of the turbines are interconnected.

Hundreds of companies in the Danish wind industry form a substantial hub. All different kinds of competences and

services are also close at hand, which makes collaboration easier. Moreover, suppliers find it easier to take part in the research, development and test environment, contributing invaluable know-how, innovation and employment opportunities to the wind industry.

Over the years, geographical proximity and close collaboration in the wind industry have convinced many international companies of the advantages of settling in Denmark.



DENMARK'S PIONEERING RESEARCH



PHOTO: DWIA

Danish universities have a longer track record of working in wind energy research than most. In the late 1970s, when a budding industry started to produce wind turbines, a test facility for wind turbines was established at Risø National Laboratory (now DTU Wind Energy).

The Danish government assigned Risø to approve turbine prototypes before they could be sold on the Danish market. This was an early example of close cooperation between the universities and industry on testing and improving designs and research programs. The universities and industry continue to cooperate today, each benefitting from the other's competences and resources.



KEY R&D ACTIVITIES IN THE DANISH WIND ENERGY HUB

- World-leading wind energy research institutions
- Access to highly educated wind energy personnel
- A large group of experienced R&D professionals in the industry
- State-of-the-art test facilities, both private and publicly financed

The Danish research environment has expanded parallel with the wind industry. Although strong research environments are developing in other countries, Danish research institutions are still among the best in the world.

Dedicated wind energy research

Danish researchers rank in the top five when it comes to the number of research publications on wind energy. Danish publications are among those cited most by other researchers.

The Danish Research Consortium for Wind Energy constitutes the backbone of network activities within the Danish research community. The consortium strives to coordinate research and educational activities to create synergies.

SELECTED INSTITUTIONS AND RESEARCH COMPETENCES PART OF DWIA

DTU - WIND ENERGY AND

OTHER DEPARTMENTS

- Wind resources, wind loads and climate technology
- Wind simulation and turbulence
- Aerodynamics, aeroelasticity and aeroacoustics
- Hydrodynamic loads and response
- Structural and system dynamics
- Structural design and materials
- Materials and production technology
- Design load basis
- Sensors, test and measurement technique
- Control, monitoring and forecasts
- Power quality and grid connection
- Construction safety onshore and offshore
- Soil – foundation interaction
- High voltage and electrical plants

DELTA

- Indoor noise levels at neighbor dwellings
- Isolation factors in houses
- Human perception of noise
- Perceived annoyance
- Expert knowledge of psychoacoustics
- Infrasound & Low frequency noise
- NoiseLAB, data acquisition and monitoring
- Environmental reliability testing
- Lightning
- Static electricity
- Tower and blade lightning

FORCE TECHNOLOGY

- Hydro- and aero dynamics on offshore structures and platforms
- Construction safety (i.e. corrosion, fatigue etc.) of offshore constructions
- Service operations (training/simulation) concerning wind turbines
- Design and maintenance of offshore constructions
- Water-structure-seabed interaction

AALBORG UNIVERSITY

- Strategic Energy Planning, Smart energy systems and Ownership
- Wind power grid and energy system integration
- AC/DC connections of offshore wind farms – multi-terminal systems
- High voltage and protection of electrical plants
- Fault diagnosis of large-scale wind turbines
- Wind farm electrical system design and optimization
- Structural dynamics and vibration control
- Reliability and design load basis
- Operation and maintenance
- Materials, mechanical design and wind turbine blades
- Soil – foundation
- Wave loads and water-structure-seabed interaction
- Production planning and logistics
- Control systems

DHI

- Metocean parameters (waves, currents, ice) in coastal and offshore areas
- Hydroelasticity, hydrodynamic loads, response and construction safety
- Water-structure-seabed interaction
- Environmental impact assessments and noise

DANISH TECHNOLOGICAL INSTITUTE

- Conformance test specification for Smart Grid components
- Specification of energy storage systems for wind market
- Wind energy storage capacity, safety, stability and degradation testing
- Wind turbine component and system inspection and failure analysis
- Novel engineered surfaces for high-stress wind turbine applications

UNIVERSITY OF SOUTHERN DENMARK

Faculty of Business and Social Sciences

- Supply Chain Management
- Offshore Wind supply chains
- Supply Chain innovation in Offshore Wind Energy
- Industrialization the Offshore Wind Energy supply chain
- Reduction of cost of energy
- Ambidexterity, the exploration-exploitation balance

Faculty of Engineering

- Fault detection and prediction
- Performance monitoring
- State abstraction
- Design of test scenario for nacelle + turbine
- Vortex induced vibrations of off-shore turbine towers during transportation
- Energy system analyses
- Coupling of wind power with electrolysis and hydrogenation of bio-carbon into hydrocarbons
- Operation and maintenance



PHOTO: VESTAS WIND SYSTEMS

THE RIGHT HUMAN RESOURCES

The companies in the Danish wind industry have always had close ties to research and educational institutions. Companies are often able to exert an influence on how future employees are trained. Institutions and companies alike thereby make use of the latest research results and upgrade the knowledge of new and existing employees.

Not only is Denmark a hub for production, testing and research, it is also a hub for wind energy education. Danish educational institutions work closely with companies and help to fill a growing need for specialists. In Denmark we can foresee and meet the demand for various skills, and education is therefore an essential cornerstone in the wind industry. The Danish wind industry employs more than 28,000 people (2013).

Through targeted, effective and practical training, the Danish wind industry is striving to increase its global competitiveness. The industry is committed to a belief that strong technical competences are needed to further reduce costs and optimize production. Blue-collar workers in the industry are highly trained and willing to adapt to new conditions. Recognizing that innovation is imperative, most employees continue to update their skills throughout their working lives.

All levels of education needed

The Danish wind industry encompasses all types of human resources and all levels of education, from engineers and technicians to skilled and unskilled laborers as well sales personnel and executives.

Common to everyone in the industry is a high degree of specialization. Employees' skills are constantly upgraded in response to developments in the wind industry.

The Danish Technical University was the first university in the world to have an engineering Masters program which focused on wind technology. The MSc program was introduced in 2002. DTU has since entered international coalitions with other post-graduate wind energy programs with universities within the EU and beyond.

Several other Danish universities and educational institutions also turn out wind energy specialists. Students benefit from the availability of a large number of companies that are willing to collaborate with them and become real-life cases for their projects. PhD. students often contribute to corporate innovation.



Did you know that foreign companies are establishing themselves in Denmark to gain access to the skills and competencies available in the Danish wind industry?

TEST AND DEMONSTRATION IS CRUCIAL

Test and demonstration facilities are crucial to technological and system innovation in the Danish wind industry. Denmark offers companies several options by which to test and try out their latest technologies, often in close partnership with other institutions.



Did you know that any part of a wind turbine can be tested in Denmark?

FOUNDATIONS AND LARGE COMPONENTS

LORC Component and Substructure Testing is a cooperative venture between LORC and FORCE Technology. It focuses on partial testing of specific areas, such as foundation joints, and experiments with new design rules. The center is equipped with a 20 meter long strong floor with 4 meter high reaction walls for testing components at loads beyond 200 tons, an outdoor test site for full-scale foundations, and a climatic chamber measuring 8 x 8 x 18 meters.

LIGHTNING TESTS

Testing Lab Denmark ApS is located in central Jutland. The test equipment is mobile, facilitating testing at outdoor test fields and on customers' premises. The test equipment delivers impulse currents up to 250,000 Amperes and impulse voltages up to 2,000,000 V.

WELDING

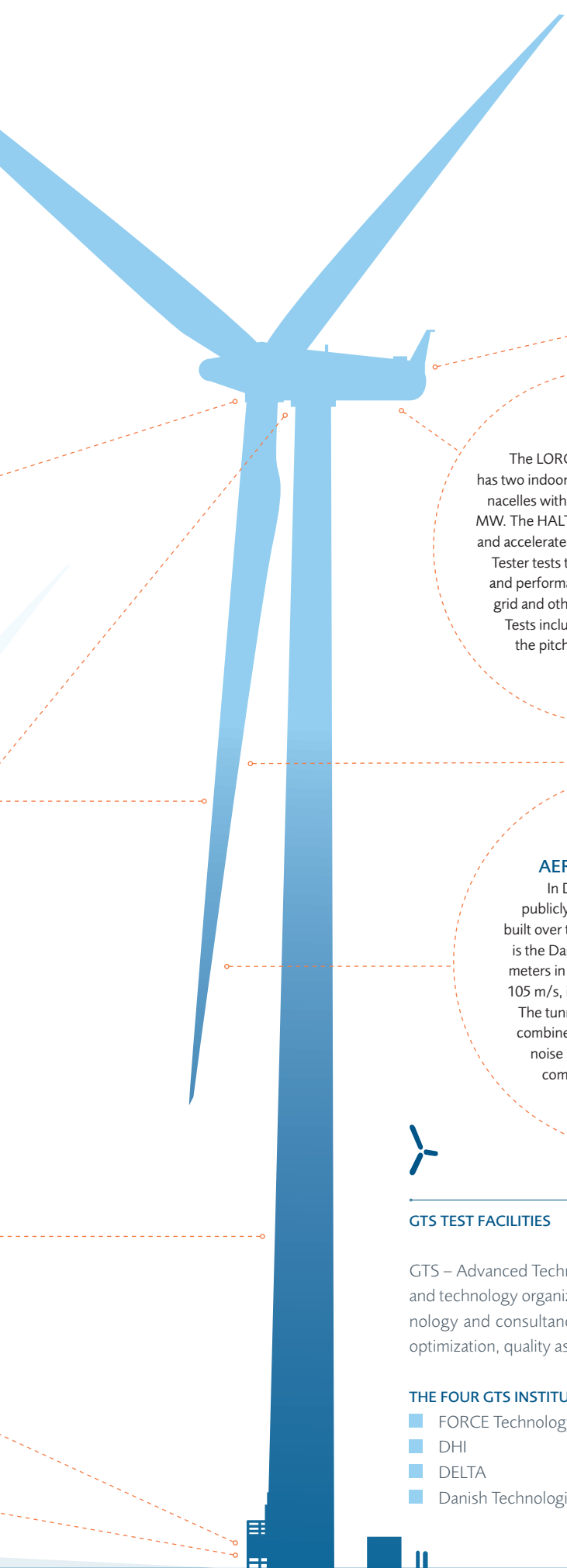
The Lindoe Welding Technology facility is managed by LORC and FORCE Technology. The welding center is equipped with a 32 kW high-power laser system and offers state-of-the-art welding services built on decades of welding technology know-how.

MATERIAL TESTING

DTU Wind Energy houses facilities for testing materials in three ways. Microscopes for investigating the micro structure of materials, a mechanical testing laboratory, which tests the strength, toughness and lifetime of materials, and Fiberlab that tests composite materials and components.

DRIVETRAIN

DTU has facilities for testing the loads on the shaft, bearings, and gearbox. The facility has a 1 MW nacelle and can perform tests under different conditions, e.g. speed fluctuations, torque and emergency shutdowns.



LARGE WIND TURBINES

DTU Wind Energy has two test facilities for large wind turbines. The Høvsøre Test Site for large wind turbines provides facilities for testing turbines of up to 165 meters at high wind speeds similar to the strong, constant winds offshore. In 2012, Test Center Østerild was inaugurated. This facility has sites for seven prototypes of up to 250 meters. The Danish government has launched an initiative to identify additional test sites for both prototypes and pre-series turbines.

NACELLES

The LORC Nacelle Testing center has two indoor facilities for testing full-scale nacelles with a power output of up to 10 MW. The HALT Tester conducts mechanical and accelerated lifetime tests. The Function Tester tests the nacelle's functionalities and performance in interaction with the grid and other nacelles in a wind farm. Tests include hub testing, in which the pitch system is operational.

BLADE TESTING

The Blade Test Centre (BLAEST) houses facilities for testing three blades at a time. In Aalborg, blades up to 60 meters are tested, while the Viborg facility allows for testing blades up to 85 meters. The only current limitation is the building itself, which can be extended as the need arises. BLAEST performs pliability, fatigue and static tests as well as model analysis and thermographic investigations.

AERODYNAMICS & NOISE

In Denmark, several private and publicly funded wind tunnels have been built over the years. The newest development is the Danish National Wind Tunnel. At 100 meters in length and with wind speeds up to 105 m/s, it is Denmark's largest wind tunnel. The tunnel offers unique opportunities to combine measurements of aerodynamics, noise and high flow rates. There is no comparable test facility anywhere in the world

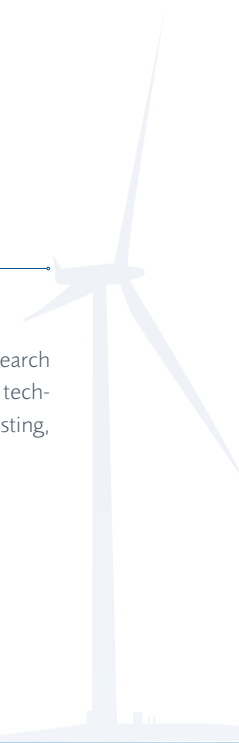


GTS TEST FACILITIES

GTS – Advanced Technology Group is a network consisting of nine independent Danish research and technology organizations called the GTS institutes. The GTS institutes offer knowledge, technology and consultancy, cooperation on technological and market-related innovation, testing, optimization, quality assurance, certificates and benchmarking.

THE FOUR GTS INSTITUTES WITH WIND ENERGY ACTIVITIES ARE:

- FORCE Technology
- DHI
- DELTA
- Danish Technological Institute



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DANISH WIND EXPORT ASSOCIATION

The Danish Wind Export Association offers networking, market intelligence and joint export drives for Danish companies who wish to strengthen their international sales to the global wind industry. The association is jointly owned by the Danish Wind Industry Association and the Danish Export Association and serves more than 300 companies in the Danish wind industry.

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International Business Development Manager
Dorte Burin

Export Coordinator
Susanne Toft



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As part of the Ministry of Foreign Affairs of Denmark, Invest in Denmark is a customized one-stop service for foreign companies looking to set up business or research activities in Denmark. We provide your company with a tailor-made solution for locating your business in Denmark, and we measure our success by how well we contribute to yours. So if your company is considering a business or R&D set-up, or looking to access one of Europe's most skilled talent pools, make us your first stop.

You'll find us in central hot spots around the world. Our specialized staff has the corporate background, industry insight and well-connected networks to advise you on every aspect of locating in Denmark. Not just when you set up, but also as your business grows. Our tailor-made solutions include connecting companies with key local contacts, arranging fact-finding tours and providing comprehensive benchmark analyses. We make sense of local legislation and advantages of locating in Denmark – all free of charge and in guaranteed full confidentiality.

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STATE OF GREEN

Denmark has decided to lead the transition to a green growth economy and become entirely independent of fossil fuels by 2050. This process is followed with keen interest around the world – as are the world leading competences in Danish companies. As the official green brand for Denmark, State of Green helps set up relations between international stakeholders and leading professionals in Denmark within energy, climate, water and environment.

State of Green is a public-private partnership founded by the Danish Government, the Confederation of Danish Industry, the Danish Energy Association, The Danish Agriculture & Food Council and the Danish Wind Industry Association.

Denmark wants to inspire the world. And through the visitors' and exhibition center, House of Green, and the State of Green Tours project, State of Green brings thousands of decision makers from both the political and the business sphere to Denmark.

Get in touch with more than 460 Danish companies, organizations and institutions on www.stateofgreen.com

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