REPORT FROM MEGAVIND
MAY 2015

Danish Knowledge Institutions and their Contribution to a Competitive Wind Industry

MEGAVIND

Contents

Photo front page:

Siemens Wind Power

1. Preface

Megavind is Denmark's national partnership for wind energy, and acts as catalyst and initiator of a strengthened strategic agenda for research, development, and demonstration (RD&D). Megavind is the Danish equivalent of the European Technology Platform for Wind Energy; TP Wind.

Established in 2006, the role of Megavind is to strengthen public-private cooperation between the state, businesses, knowledge institutions and venture capital to accelerate innovation processes within a number of areas of technology.

Megavind's vision is for Denmark to continue to develop its position as the hub of globally leading companies and research institutions within the field of wind energy and that these companies will be the first to deliver competitive wind energy on market terms in the dominating wind energy markets.

In May 2013, Megavind published a revised main strategy that gave an overall status of the RD&D environment in Denmark. The strategy also delivered recommendations to areas where separate strategy processes were required, the present strategy being one.

This strategy will focus on increasing the ability of Danish knowledge institutions (universities and GTS institutes[1]) to contribute in maintaining the Danish sector as world leader in the development of competitive wind power solutions. The strategy will in particular address collaboration between business and knowledge institutions as well as industry involvement in research and development projects funded by public programs. Focus will be on bringing companies with little or no experience in collaboration with knowledge institutions. The main target groups are researchers with wind energy related activities and R&D departments at small and medium sized companies (SMEs) and large component suppliers.

Furthermore, the strategy will address the main barriers in making knowledge created in knowledge institutions available for industry – including the commercialization of public funded research.

The content of this strategy report has been developed by a group of experts, listed as follows:

- Peter Hjuler Jensen and Jens Nørkær Sørensen, DTU Wind Energy
- John Dalsgaard Sørensen, Aalborg University
- Christina Aabo, DONG Energy
- Per Hessellund Lauritsen, Siemens Wind Power
- Philip Carne Kjær, Vestas Wind Systems
- Erik Østergaard Madsen, Fritz Schur Energy
- Signe Arnklit, Offshoreenergy.dk
- Jakob Lau Holst and Anja Pedersen, Danish Wind Industry Association (Megavind secretariat)

The strategy has been peer reviewed by members of the Danish Research Consortium for Wind Energy (DRCWE) and the Consortium's advisory board[2].

1 GTS – Advanced Technology Group is a network consisting of nine independent Danish research and technology institutes whose primary obligation is to accelerate the pace of bringing knowledge from labs to business. The GTS organizations operate on a more commercial basis than the universities in providing consultancy services to companies and also have access to state-of-the-art laboratories and test facilities

2 Read more about the Consortium Partners: www.dffv.dk

2. Executive Summary and Key Recommendations

Megavind's vision is for Denmark to continue to develop its position as the hub of globally leading companies and knowledge institutions within the field of wind energy and that these companies will be the first to deliver competitive wind energy on market terms in the dominating wind energy markets.

Denmark houses a wind industry that includes complete supply chains both when it comes to the components within in a wind turbine and when it comes to the offshore wind industry that builds offshore wind power plants (elements outside the wind turbine). Moreover, Denmark has a very strong wind energy research and test environment.

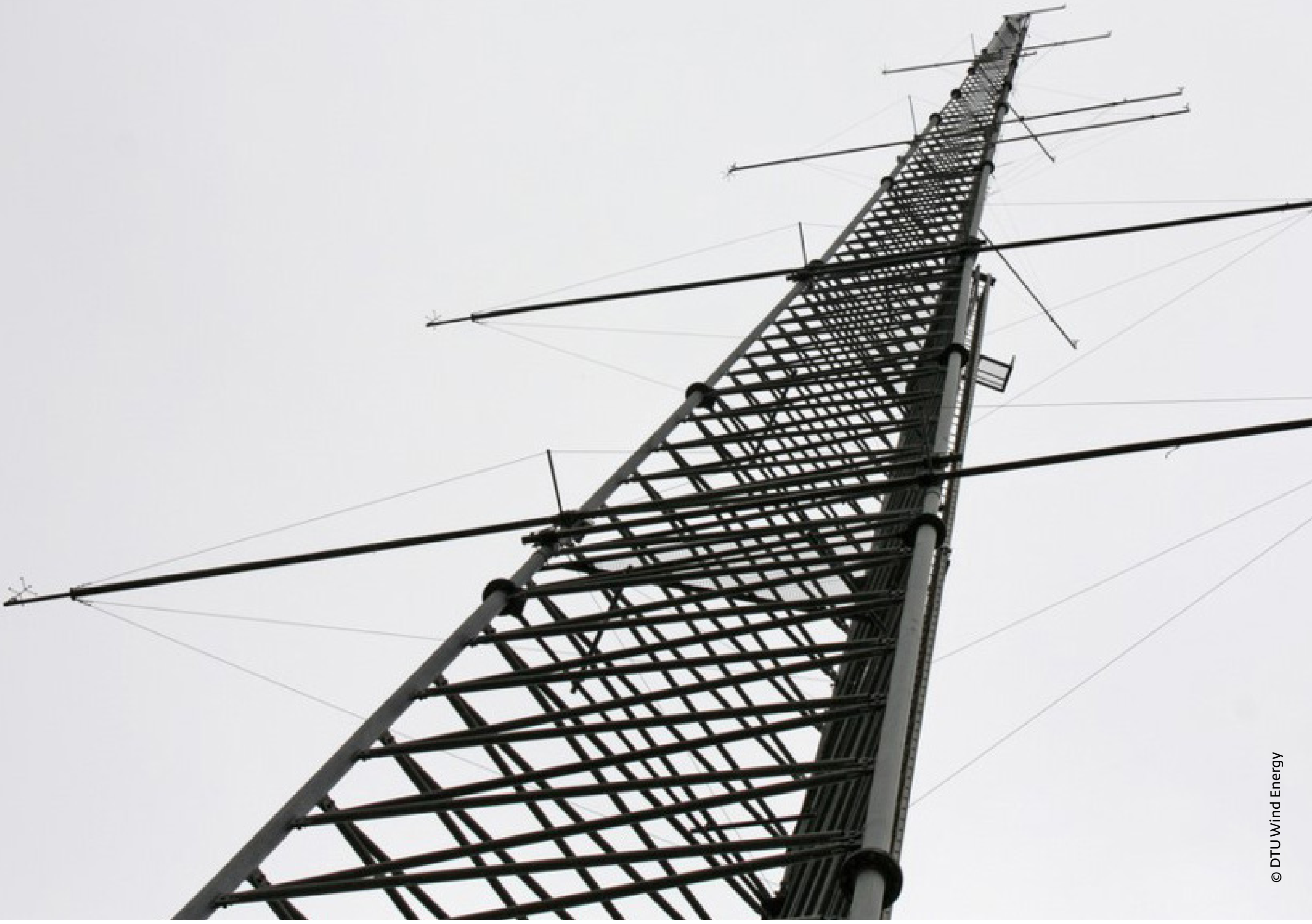
The main strategy report from Megavind (May 2013) concludes that one of the weaker areas in the Danish Hub is the cooperation between knowledge institutions and the industry although some improvement has taken place over the last 6-7 years (section 3).

Studies show that a company's innovation ability is closely linked to company performance and that companies that are innovative have higher growth rates than non-innovative companies. In Denmark, universities have over the past decade collaborated in publicly co-funded research, development and demonstration (RD&D) projects with one in every six wind industrial companies. Participating companies are overall satisfied with the result, and want to pursue more interaction. However, most RD&D projects are conducted with a relatively limited number of companies, and only 6% of all wind industrial companies collaborated more than once with universities. There is thus a large potential for increasing university contribution towards increased innovation in the Danish wind industry. This effort will also result in cost of energy (CoE) reductions and more reliable products – both are goals that Megavind works towards.

2.1 Background

Historically, there has been close cooperation between the OEMs[3] and knowledge institutions in Denmark. In the 1980s and 1990s, the universities played a crucial role in developing larger and more efficient wind turbines. The universities initiated large research programmes especially in the field of aerodynamics/aeroelasticity that helped to accurately dimension the turbines to withstand the loads they were exposed to. Research in wind resources both with regard to mapping good wind sites and to get a better understanding of how the wind affected the turbine, wake effect, wind farm lay out etc. were also vital elements to make wind energy an effective alternative.

3 Original equipment manufacturer: A term used by the sector for wind turbine manufacturer.



© DTU Wind Energy

In the 00s, the OEMs reached a size and maturity where dependency on knowledge institution expertise became less critical on the short term to help calculate and verify new prototypes. Presently, OEM R&D departments include in-house experts on all areas. The knowledge institutions continue to work closely together with OEMs and utilities and contribute with important research activities. But the common research activities now of a more generic and long term nature and not so much “in the present engine room”.

Over the same time span, especially the component suppliers have experienced an increasing need for innovation activities and R&D cooperation e.g. to develop, test and verify their components. There is a continuing ongoing competition among component suppliers to deliver the best components from a CoE perspective. CoE is the driving force for virtually all activities in the sector and is the key parameter for new technologies, selection of suppliers etc. The less mature offshore wind industry is also striving to bring down CoE and needs help to standardise and verify components and processes. This strategy focuses on how the industry and knowledge institutions should handle this transition in the sector.

The benefits of closer cooperation for both universities/GTS institutes and the industry are as follows:

Benefits for the industry:

- Opportunity for applying the latest research in R&D activities
- Opportunity to recruit R&D candidates with an updated knowledge
- For large and small suppliers in particular access to knowledge areas that is not embedded in the company through:
  - Cooperation in R&D projects (shared knowledge (medium/long term)
  - Consultancy services (exclusive knowledge (short/medium term)
- Student projects
- Development of common industry standards and practices for test and verification based on research results
- Access to test, validation and demonstration infrastructures

Benefits for the universities and GTS institutes:

- Funding for research projects through company participation that strengthens research areas
- Ensures relevant research both in ongoing and new research areas
- Opportunity for knowledge sharing with industry experts in joint projects
- Application of research results in commercialised products provides an opportunity for feedback and proves value of research in the industry
- Opportunity for publications together with the industry
- Increased interaction with the industry will result in stronger industry involvement in educational activities and increased quality and relevance for students
- For GTS: Established business model for test and validation of components and processes based on standards and norms

2.2 Status

In connection with this strategy process, Megavind decided to examine the extent of project participation and cooperation in the publicly funded programmes in Denmark in order to get a clearer picture of how both the industry and knowledge institutions perform.

Energiforskning.dk is the common web portal for the publicly funded RD&D programmes for energy technology. Going back to the late 1990s, the portal holds 268 projects with wind energy focus (April 2015), Megavind has looked at the 175 projects that have been financed from 2003 to 2014. In analysing the dataset, Megavind has primarily looked at what type of companies have participated and interacted with knowledge institutions.

The data from Energiforskning.dk confirms Megavind's pre-assumption that both OEMs and utilities have had and still have many project participations with the knowledge institutions. Projects with a specific product focus have had a more narrow participation from the industry e.g. an OEM, perhaps a supplier and one or two knowledge institutions. But projects with a more general focus and with a long term research perspective generally includes participation both from competing OEMs and utilities.

The challenge lies with the small and medium sized companies (SMEs) and larger component suppliers[4]. Only a handful of these can show more than two project co-operations with universities. The vast majority of these companies have only participated

4 SMEs are companies with less than 250 employees and either a turnover of less than €50 m and/or a balance sheet of less than €43 m. Large component suppliers are in this connection, suppliers of wind turbine components that have more employees and a larger turnover and/or balance sheet.

in publicly funded RD&D projects once although many have expressed intentions of future project involvement.

Over the years, the situation has improved. Statistics show that the number of unique company participations (entire value chain) in publicly funded projects have increased from 9 in 2003 to 21 in 2014. By far the most companies have been active in the Energy Development and Demonstration Programme (EUDP) that support projects with a large innovation and development content. Evaluating comments from the companies reveal that most have been satisfied with the project and application process.

2.3 Gaps and barriers

There is an efficient interaction between the very large industry players (OEMs and utilities) in the sector and the knowledge institutions. But the increasing competition between countries and research institutions requires increasing and more efficient collaboration between industry and the knowledge institutions.

The primary challenge is to bring knowledge institutions and the remaining value chain closer together. Many of the companies in the Danish wind sector that do have innovation activities have traditionally engaged in these together with customers or sub-suppliers and only few have had regular project interactions with knowledge institutions. Barriers lie both in the organisational structure from both sides and in the time frame that they operate within.

The R&D departments at the SMEs and larger component suppliers are for the most part not geared to engage in projects with the knowledge institutions. The resources that they must allocate for this task is therefore proportionally much higher than those in the larger companies and this taken from companies that in general have a lot fewer resources for R&D purposes available.

The smaller companies also normally operate with a much shorter time frame and do not have the outlook nor resources for long term strategic R&D activities. The R&D challenges that these companies meet must be solved quickly and this is corresponds poorly with knowledge institution reality.

For the large industry players, there are many common projects and the R&D departments are more an equal match for the knowledge institutions both with regard to R&D resources and to a certain extent also time frame. The relatively large R&D departments at OEMs and utilities have the human resources as well as organisational structure available to enter into both R&D projects and mutual test activities with the knowledge institutions. The large companies are equipped to handle both intellectual property right (IP) issues and other resource consuming elements in a project set-up.

Also, the large players all have the resources for long term strategic planning. A new wind turbine concept can take a decade to develop – and this corresponds well with the longer time frame in the university environment. When focus is on long term generic research, competing companies participate with mutual benefits for all. The situation changes when projects contain elements that companies view as a competition parameter. One success criteria for the public RD&D programmes is as many company participations as possible also within a single project. This deflates the outcome of projects as the will to share knowledge tends to fall as the number of players increase.

On the knowledge institution side, the main barrier is the lack of focus on SMEs in general as these may be perceived as much more challenging to work with both with regard to the time frame horizons and organisational differences described above.

2.4 Conclusions and Recommendations

SMEs hold large unexploited potentials for growth, a fact that both EU and national authorities recognise and try to support through programmes that will improve competences and sharpen the competitive edge for SMEs. SMEs in the wind industry hold the same potential and are therefore subjected to the same focus. At the same time, the wind industry is a well-defined industry with many networking activities so increased corporation between the knowledge community and SMEs and larger component suppliers should be a doable exercise.

In order to improve cooperation between universities/GTS and industry and thus improving university contribution to making the industry more competitive, Megavind recommends the following:

Megavind recommendations

Actions	Target group	Initiators
Ongoing mapping of R&D cooperation needs– both for the wind turbine component and the offshore solution supply chains	SMEs and large component suppliers	Danish Research Consortium for Wind Energy, Megavind
Address the gaps and barriers between desired industry collaboration and university competences. Establish an instrument for knowledge institutions to understand and absorb the needs of the SMEs that are revealed in the mapping exercise described above	GTS and universities	Danish Research Consortium for Wind Energy, Megavind
Create awareness in industry and universities of the current R&D interaction opportunities available e.g. EUDP, Innobooster, vouchers for preliminary projects, the Innovation Agents, student projects.	Industry and universities	Sector and public programmes
Find and market the "exemplary cases" of companies that have benefitted from interacting with knowledge institutions.	Industry	Sector
An analysis that describes the existing gap in the educational value chain e.g. for electrical engineers, marine and technical engineers, industrial technicians etc.	Industry and university	Sector

3. Introduction

Denmark is regarded as a leading wind energy hub. There is a strong presence of manufacturers and suppliers and the entire supply chain is available within short distance from each other. This is the case for both onshore and offshore supply chain.

A combination of a skilled labour force, leading knowledge institutions, a varied range of state of the art test facilities and a long, common wind energy history makes Denmark an attractive and leading competence centre for wind energy. However, a competence centre can lose ground if the bearing pillars of on-going development change or erode, or if competing competence centres grow stronger and take over on some of the strengths normally presumed Danish.

The mapping of the Danish hub below is taken from Megavind's main strategy from May 2013 showing development on 6 key pillars in the Danish Hub. An identical exercise was performed in a Megavind strategy from 2007 and development over the 6 years is shown in figure 1 below.

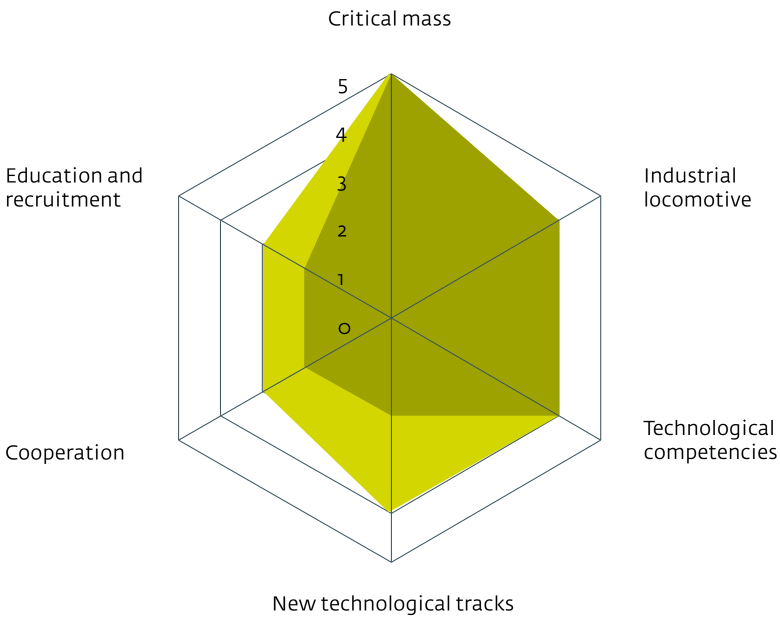
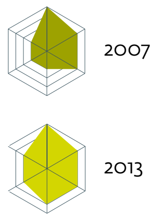


Figure 1.
Overall rating of the Danish competence centre for wind energy based on information from figure 5.1.



The strengths of the Danish wind energy competence centre (hub) can be summarized as follows:

The Danish wind industry has a strong critical mass, large market shares, and major innovation driven companies. Strengths that have been built through decades of focused efforts in RD&D – and not the least an innovative environment with widespread cooperation.

It is the industrial cooperation and knowledge sharing environment which attracts foreign companies to the Danish wind energy cluster. The Danish companies and their employees have a knowledge pool in the field of wind energy that is incomparable internationally and the creative, self-driven working environment is very productive when it comes to innovation. A strong research community and industrial cluster for wind energy demands high scores in all the above areas. However, education/recruitment and cooperation stand out as challenges. There is a need to increase the efforts in these areas.

The traditional cooperation between industry and political decision makers is also still important to create stable and supporting framework conditions, which is a very important prerequisite for the development of the wind power hub. Public investments in RD&D and innovation are of immense importance. This was present in the early decades of the Danish wind industry development and gave the perfect take-off.

3.1 Strategy focus

Based on the result of the matrix above and the identification of cooperation, education and recruitment as weaknesses in the hub, the recommendation in the 2013 report was a new strategy that further addressed these issues.

The present strategy will therefore focus on increasing the ability of Danish research and educational institutions to contribute in maintaining the Danish sector as world leader in the development of competitive wind power solutions. The strategy will in particular address collaboration between business and knowledge institutions as well as industry involvement in research and development projects funded by public programmes. Furthermore, the strategy will address the main barriers in making knowledge created in knowledge institutions available for industry.

The conclusions from 2013 are based on inputs from the Megavind steering committee and other key players in the sector. In order to perform a more in-depth analysis of the situation, Megavind has chosen to partly base the recommendations in this strategy on available data.

3.1.1 Method description

The analysis included in chapter 5 is based on several data sources. Primarily, data has been extracted from Energiforskning.dk which is a common web portal for all the publicly funded RD&D programmes for energy technology. Going back to the late 1990s, the portal holds 268 projects with a wind energy focus (April 2015), Megavind has looked closer at the 175 projects that have been financed by four programmes from 2003 to 2014. Megavind has also had access to a list of 98 wind related projects that have been rejected by the EUDP. 39 of these received funding for their projects after altering the application.

Furthermore, Megavind has performed interviews with 17 companies that have headed projects funded by the RD&D programmes. The companies were asked to evaluate the project with regards to application and project process as well as outcome. The companies were also asked about their interaction with knowledge institutions both with regard to the project in question but also in general.

Megavind has also briefly looked at other publicly funded initiatives directed toward SME interaction with knowledge institutions more specifically the Knowledge Pilot Programme and the Knowledge Coupon Programme to see if the companies in the wind sector have been active here.

4. The Danish RD&D structure within wind energy

A pre-requirement for strong and competitive RD&D environment are 3 well-functioning entities:

1. A leading research environment
2. An industry where all elements in the value chain are represented
3. A committed and flexible public infrastructure (RD&D programmes and test facilities)

Like a milking stool, it will fall if one of the 3 is weakened or disappears.

4.1 The Research Community

Historically Danish Universities, like the industry, have played a leading role in the global wind energy sector. Also today, especially the former Risø National Laboratory (now DTU Wind Energy), DTU itself and Aalborg University (AAU) house some of the world's leading wind energy researchers.

Danish research is primarily carried out by experienced researchers and senior researchers which signals a certain level of quality. In other countries, PhDs conduct many research activities without the same level of experience.

DTU Wind Energy, an institute working exclusively with wind energy related activities, employs 240 people and other DTU Institutes e.g. Electrical Engineering and Civil Engineering also have substantial wind activities. In Aalborg, the activities are spread out on several different departments but especially Energy Technology, Mechanical and Manufacturing Engineering and Civil Engineering have leading researchers.

Within the last few years, University of Southern Denmark (SDU) and Aarhus University (AU) have initiated research projects with relation to the wind sector. Many of these activities are focused on business and industry infrastructure e.g. supply chain issues.

Apart from the universities, GTS institutes represent an important role in the Danish R&D infrastructure. Especially four of the nine GTS institutes have wind energy related activities: FORCE Technology, DELTA, Danish Technological Institute and DHI.

Danish Research Institutions within Wind Energy

THE TECHNICAL UNIVERSITY OF DENMARK (DTU)

- 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 and construction safety onshore and offshore
- Water-structure-seabed interaction
- Design of electrical components
- Sensors, test and measurement technique
- Control, monitoring and forecasts
- Power quality and grid connection
- System modulation of wind turbines and wind farms
- Economy and system analysis
- Aerodynamics, aeroelasticity and aeroacoustics
- Hydrodynamic loads, response and offshore construction safety
- Water-structure-seabed interaction
- Soil – foundation interaction
- Material and production technology
- Control, monitoring and forecasts
- Construction safety
- 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 lighting

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
- 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 power drive train
- Electro-technical components, power electronics and generators
- Wind farm power dispatch and control systems
- Wind farm electrical system design and optimization
- Power forecasting
- Reliability of structures and components
- Structural dynamics and vibration control
- Design load basis and reliability
- Operation and maintenance
- Construction and materials
- Soil – foundation interaction
- Wave loads and water-structure-seabed interaction
- Production planning and logistics
- Single turbine control

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

UNIVERSITY OF SOUTHERN DENMARK

Faculty of Business and Social Sciences

Department of Entrepreneurship and Relationship Management in Kolding Research Group; ReCoE

- 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
- Competences

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

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 highstress wind turbine applications

AARHUS UNIVERSITY

- Mechanical modelling of composite materials
- Multi-body dynamics with non-linear flexibility
- Experimental dynamics and damage detection
- Turbulence modelling
- Wind-farm modelling, optimisation and control
- Modelling of renewable energy systems
- Data mining and failure detection

4.1.1 Danish Research Consortium for Wind Energy

Being a small country, coordination of activities within the Danish border is not an insurmountable task. But coordination of activities does not happen by itself and recognition of necessity as well as a willingness to contribute to the task is required.

In May 2002, the Danish Research Consortium for Wind Energy (DRCWE) was established[5]. DRCWEs primary role was to ensure a coordination of research and educational activities, so that the identical competencies in the main universities did not pursue parallel projects with similar content. The Consortium partners held regular coordination meetings each bringing a draft list of projects for the publicly funded R&D programmes.

In this way, much competition for funding of similar projects was avoided and a more detailed knowledge of each other's activities was established. In 2007, a university reform with a major restructuring of the research community merged 25 institutions into 11. The reform also meant a merger of DTU and Risø National Laboratory and in the restructuring process consortium activities dwindled.

The Consortium was revived in 2012 with an expanded list of partners but with the same purpose. Partners are now DTU, AAU, AU, DHI, FORCE Technology and DELTA. Apart from research and education coordination, the Consortium now also hosts an annual two day conference where all the latest Danish research results are presented.

The result is an active network among the participating knowledge institution where researchers are updated on research activities and relevant cooperation partners.

5 Originally, the Consortium partners were Risø National Laboratory, Technical University of Denmark, Aalborg University and DHI. DRCWE web site http://www.dffv.dk (in Danish only)

4.1.2 University trends

Danish universities have two primary tasks: research and education. But there is an increasing expectancy from society for universities to canalise knowledge into the industry and hereby contribute to innovation and growth.

The definition technology transfer covers the direct transfer of research based knowledge, technology and/or instruments from knowledge institutions to private of public companies. This can be done through licensing, sale of patents or IP rights. Another way is through establishment of spin-out companies that continues to develop and commercialise inventions.

Technology transfer

Technology transfer only constitutes a small percentage of university and company interaction. Most knowledge transfer takes place through education of students and researchers, joint RD&D projects and other types of cooperation.

One challenge for universities is the trend that researchers are more motivated to research and educate than to interact with the industry as the former is perceived by many as career promoting the latter not to the same extent. Technology transfer is therefore mainly performed by enthusiasts that regard industry interaction and commercialisation of research as an integrated part of their research activities[6].

The universities recognise this challenge and work to solve it. A report from 2013 published by the Danish think tank DEA[7] lists a number of actions that some universities have taken to improve the situation:

6 Fra Forskning til Faktura, DEA 2013

7 Fra Forskning til Faktura, DEA 2013

1. Develop incitements to engage in technology transfer and industry interaction e.g. through increasing the prestige connected with these activities.
2. Improve the attitude toward the Technology Transfer Offices TTO. Many researchers have negative first and second hand experiences with the original TTOs[8].
3. Facilitate access for researchers to relevant companies.
4. Increase researchers knowledge of what R&D challenges the companies face as well as heightening the mobility between the public and private sector.

University reach out activities for industry cooperation
Most universities have matchmaking services and a single point of entry that can help find relevant experts across the university. This helps outsiders penetrate a large organisation in the quest for relevant experts but it does not help the individual departments in their aim for more interaction with the industry.

The matchmaking offices at the universities are not equipped or established to act as "business developers" for the individual departments.

4.2 Industrial value chains

Approximately 500[9] companies in Denmark deliver products and services to the wind energy sector. All value chain segments are represented and the companies can be divided into two parallel supply chains:

1. Suppliers of components and services to the wind turbine itself
2. Suppliers to the offshore industry of components and services that are outside the turbine.

Companies in the two individual value chains do not have the same history of wind R&D development and industry cooperation and they face somewhat different future challenges. But the suppliers all meet a continuing demand of new innovative solutions, improved quality, documented reliability and lower CoE.

4.2.1 Wind turbine component suppliers

Many suppliers of wind turbine components have been part of the sector for decades, others have joined in recent years with significant growth rates. The group of component suppliers can be divided into several groups along the R&D scale. On the one end, companies that deliver of-the-shelf standard products that are also used in other industries and on the other end companies with products that have been especially designed for wind turbines.

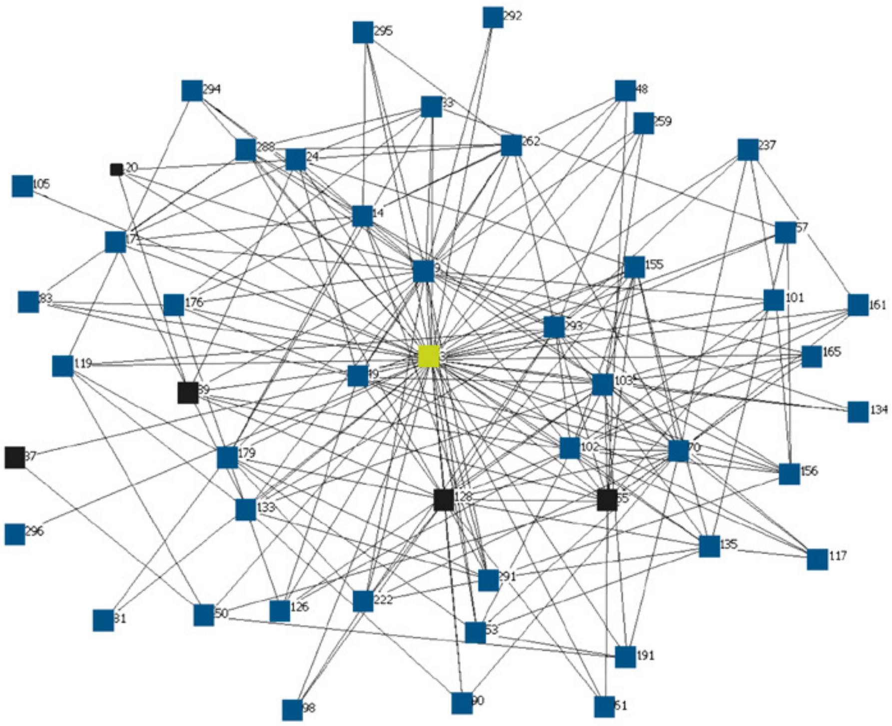
The turbine component suppliers with special wind energy R&D activities have a history of customer/supplier interaction to adapt their product to turbine specifications. Historically the interaction for most suppliers of key components have been directly with the OEM as well as own sub suppliers. The company interaction is a complex mesh as illustrated in Figure 2.

8 The original TTOs were not equipped properly to fulfil the tasks they were assigned to. Much of the original staff has been replaced with business developers and legal experts (Fra Forskning til Faktura, DEA 2013)

9 Danish Wind Industry Association database

Figure 2.
Overlapping knowledge relations with turbine manufacturers. Blue markings are suppliers stating that they have shared knowledge with both Siemens Wind Power and Vestas Wind Systems in Denmark. Black markings are suppliers stating that they have only shared knowledge with the turbine manufacturer in the centre of the network map.

(Source: Denmark–The Wind Power Hub: Transforming the supply chain)



The financial crisis has escalated the already ongoing globalization process both customer and production wise. The wind turbine market has changed from a few turbines in a single sale many to private customers to large wind farms where customers typically are large utilities. This has been a game changer with regard to improved technical performance and especially over the last 5-6 years, OEMs have increased focus on systematisation and standardisation of production and much higher quality demands both from themselves but also their suppliers.

Some OEMs strive to reduce the very complex exercise of handling a large group of suppliers and hundreds of product specifications. The strategy is therefore to outsource much of the product responsibility to fewer preferred suppliers of component systems and buy large component systems instead of individual components to assemble the systems in-house. The requirement for test, documentation and verification is thus also placed with the component suppliers – a task many are struggling to handle.

On top of this, the component suppliers are measured against one key parameter: Cost of energy. All other elements e.g. quality, being prerequisites, the component suppliers are met with a continuing demand from their customers to deliver a cheaper product[10].

Component suppliers are also met with demands of local sourcing close to global production facilities. This poses challenges with regard to a uniform quality standard at all production units.

10 A cheaper product from a cost of energy perspective is not necessarily the cheapest tag price from an overall perspective. If the cheapest product breaks down and causes a production stop it will prove very expensive.

4.2.2 The offshore value chain

The offshore wind industry is still relatively young and the value chain includes companies and competences from many other industries e.g. oil and gas and the maritime industry. Accumulation of knowhow and best practice is still fairly limited but the companies are facing increasing pressure from owners, developers and society to bring down CoE significantly in a project to project market. Across the value chain increased cooperation is essential and calls for increased company and network interaction.

The challenges are for the most part not identical with those of the turbine component suppliers as most of the offshore companies are involved in installation and service activities and to a lesser extent component innovation and production processes – one exception being support structures.

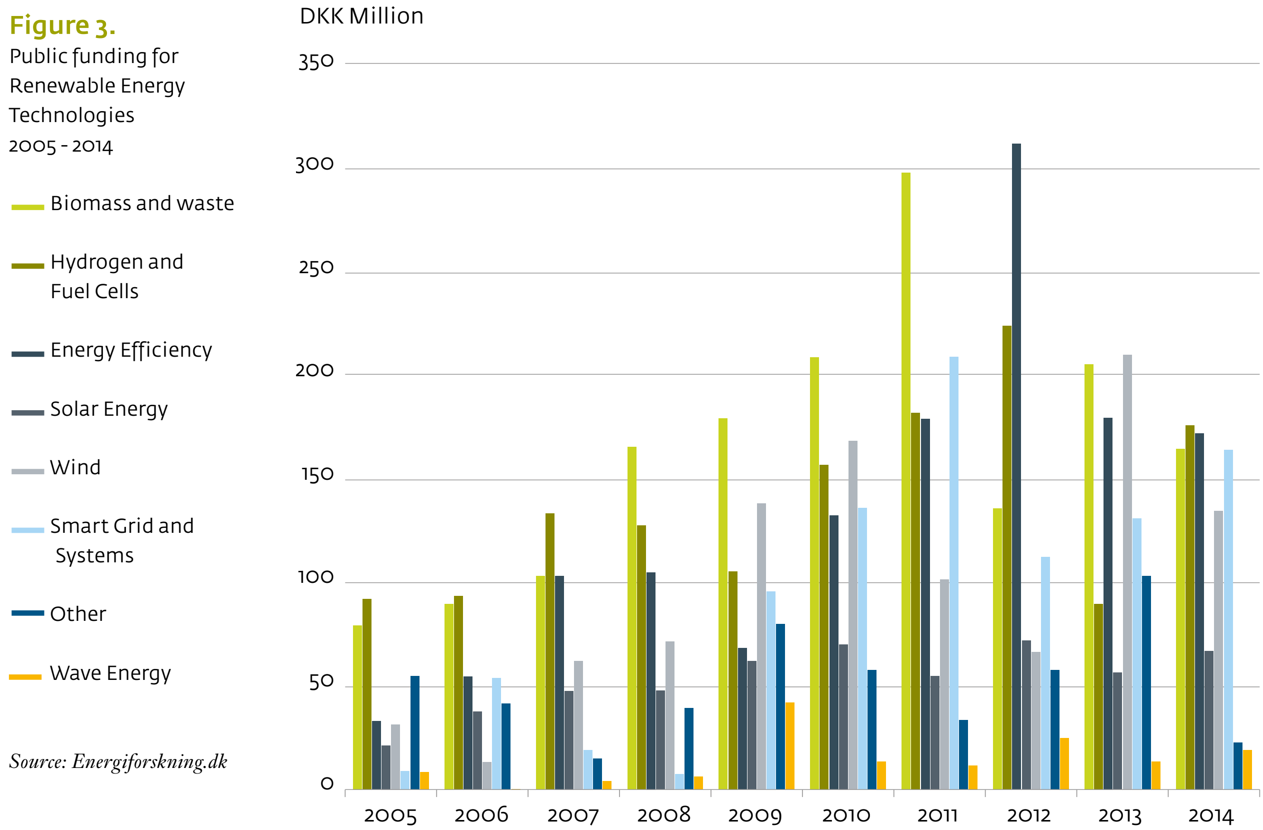
In December 2010, Megavind published an offshore strategy to accelerate CoE reduction with a list of technology areas that could be trimmed. The strategy was followed by an offshore road map that pinpointed some of the key technology areas that can lead to significant CoE reductions[11].

4.3 Funding infrastructure

In Denmark, primarily 4 publicly funded RD&D programmes have supported wind energy related projects over the years. The programmes are spread along the R&D scale, so that one programme, Danish Council for Strategic Research (DSF) supported projects with mainly research content and at the other end EUDP supported projects with a large development and demonstration focus. The Danish National Advanced Technology Foundation and the ForskEL programme supported projects that can contain all elements. But the ForskEL programme focuses on grid interaction only. On 1 April 2014, the Danish National Advanced Technology Foundation and DSF merged into InnovationsFonden.

11 Megavind web site: http://www.windpower.org/da/fakta_og_analyser/megavind.html

Figure 3.
Public funding for Renewable Energy Technologies 2005 - 2014



Source: Energiforskning.dk

Figure 3 shows the distribution of funding to renewable energy technologies from the 4 programmes for 2005-2014.

4.3.1 GreenLabs

In 2010, the Danish Energy Agency introduced the GreenLab programme to support large renewable energy test facilities. The GreenLabs programme allocated DKK 210 m for renewable energy test facilities to be distributed in 2010-2012.

In 2011, 2 "GreenLabs" with wind energy related activities received support: The nacelle test facility at LORC with DKK 76 m and PowerLab.dk at DTU with DKK 15 m adding a total of DKK 91 m to the total sum awarded to Danish wind energy projects.

In 2012, a consortium led by DTU Wind Energy received DKK 30 m from GreenLabs to build an advanced grid test facility. Legal issues regarding ownership etc. has slowed down establishment of the test facility.

4.3.2 Other funding

In 2012, it was decided to place a national wind tunnel at DTU. The state and Region Zealand supported the facility with DKK 40 m and DKK 14 m (see box).

Test facilities

Over the last 5 years, Denmark has made substantial investments in test facilities to meet the requirements from both universities and the industry.

- Østerild – National Test Center for Large Wind Turbines: A test site with 7 test beds that can accommodate wind turbines up to 250 m and 16 MW.
- Østerild – Advanced Grid Test Facility: To test very large wind turbines interaction with the grid.
- LORC (Lindoe Offshore Renewables Center) – 2 nacelle test rigs of up to 10 MW
- LWT (Lindoe Welding Technology) – Commercial fabrication-lab with a 32 kW high-power laser system
- DTU Wind Tunnel – 100 m long boxformed tube with maximum wind speed of 378 km/h
- PowerLab.dk – a world-class experimental platform of a smart electric power system

4.3.3 Industry in-house investments

Danish statistics show that every time public research funds and programmes invest DKK 1 in wind energy research, development, demonstration and test, private companies invest DKK 5[12]. The industry has invested billions of DKK in in-house test and demonstration located in Denmark.

The two large Danish based OEMs have chosen to locate the majority of their R&D activities and adjoining test facilities in Denmark. Vestas Wind Systems has invested in a nacelle test rig that can test up to 20 MW in Aarhus and a blade test facility in Lem. Siemens Wind Power has nacelle test facilities in Brande and blade test facilities in both Brande and Aalborg. Both OEMs test wind turbines at Høvsøre and Østerild and have test sites both for proto type and pre series in other parts of Denmark.

Foreign OEMs and utilities also invest in tests in Denmark. Nordex GmbH has a test turbine at Høvsøre and Envision Energy and EDF Enérgies Nouvelles have test sites at Østerild.

Moreover, DONG Energy has a near-shore demonstration facility for 6 turbines and consequently 6 foundations at Frederikshavn. LM Wind Power has invested in a wind tunnel and of course full scale testing of blades at their Global Technology Center in central Jutland. LM Wind Power, Svendborg Brakes and kk-electronics have a test turbine at Høvsøre.

Other suppliers have also invested in in-house facilities.

12 DAMVAD, Forsknings- og erhvervsmæssige styrkepositioner i den danske vindenergisektor, May 2014

5. Gaps and Barriers

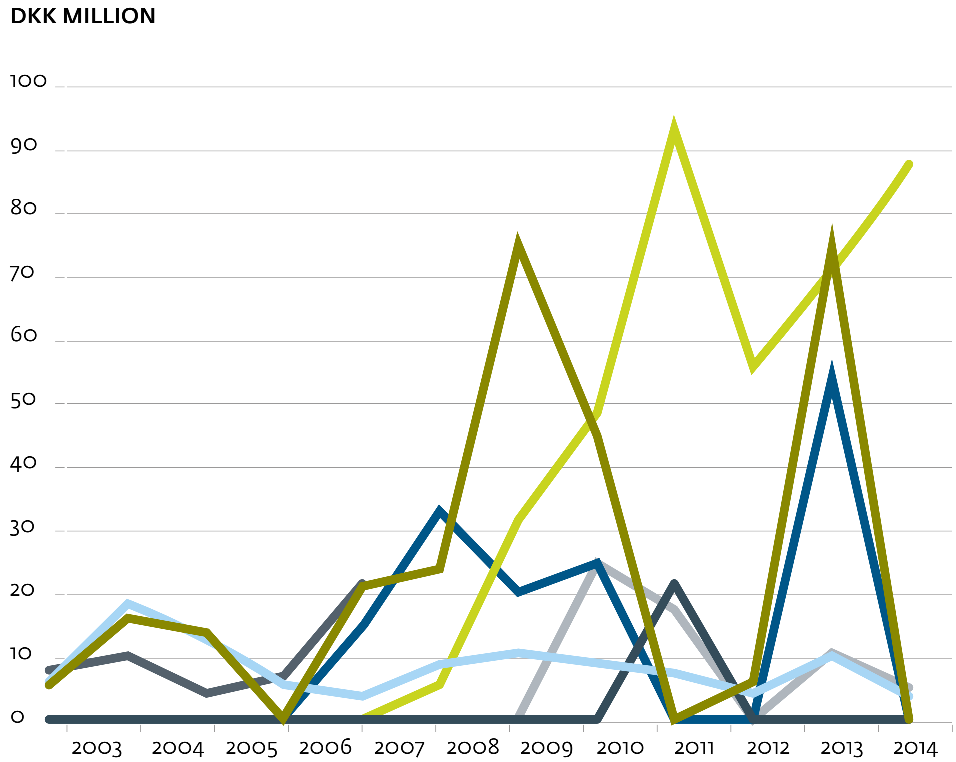
In spite a long and valuable track record for cooperation between the industry and universities/GTS, there is still room for improvement on many levels. The wind industry is still young compared to other sectors with the same societal footprint and needs help both to deliver a product that is a competitive solution on the energy market and to ensure the competitive edge for Danish companies in a fierce global competition. The knowledge produced by the knowledge institutions can contribute to solving both challenges.

5.1 Industry and university presence in the Danish RD&D programmes

Energiforskning.dk is the common portal for the public RD&D programmes. Going back to the late 1990s, the portal holds 268 projects (April 2015), Megavind has looked at the 175 projects that have been financed from 2003 to 2014. In analysing the dataset, Megavind has primarily looked at type of company participation and interaction with universities etc.

Over the 12 year period, there have been several mergers in the industry. In order to present the data as simple as possible, only existing organisations remain.[13]

Figure 4.
Annual increase/decrease in public funding



(The Energy Research Programme was in 2008 replaced by the Energy Development and Demonstration Programme (EUDP).

5.1.1 Industry participation

A total of 79 companies have been active in publicly financed, wind energy related RD&D projects from 2003-2014. There are approximately 500 companies with wind energy related activities in Denmark which means that only 16% have engaged in public RD&D projects.

13 E.g. Risø National Laboratory is included under DTU Wind Energy, NEG Micon is now Vestas, Energi E2 and Elsam Engineering is now DONG Energy.

NUMBER OF PROJECTS

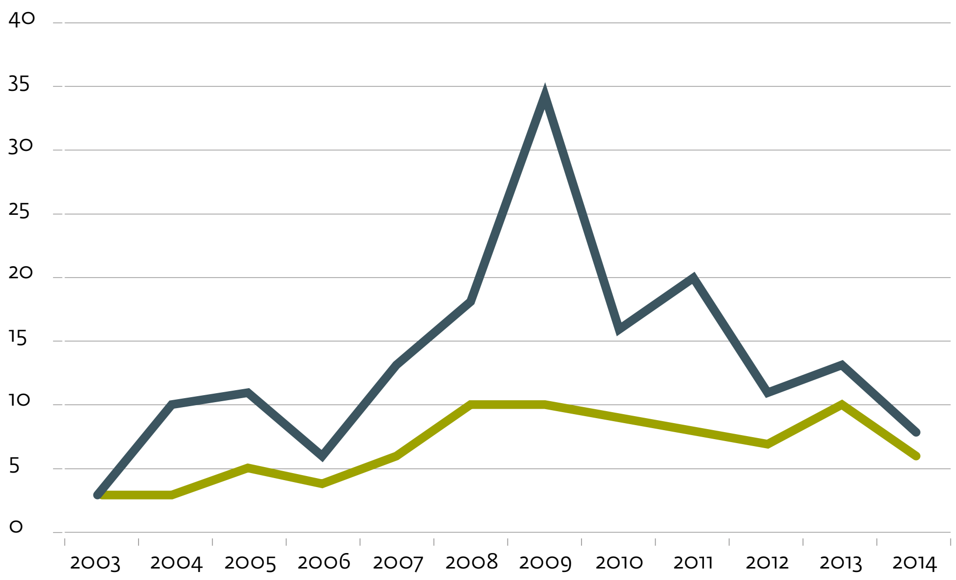


Figure 5.
OEMs, utilities and large component supplier's participation in RD&D projects

Large companies' participation

Participation without duplicates per year

(Energiforskning.dk)

Industry involvement for the large companies indicates a gradual increase in the number of company participations per year until 2008 when duplicates (the same company participates more than once per year) are disregarded. From 2009-2012, there is a dramatic drop by more than two thirds of company participations when duplicates are included. The drop can be explained by the financial crisis that with some delay hit the industry hard in 2009/2010.

NUMBER OF PROJECTS

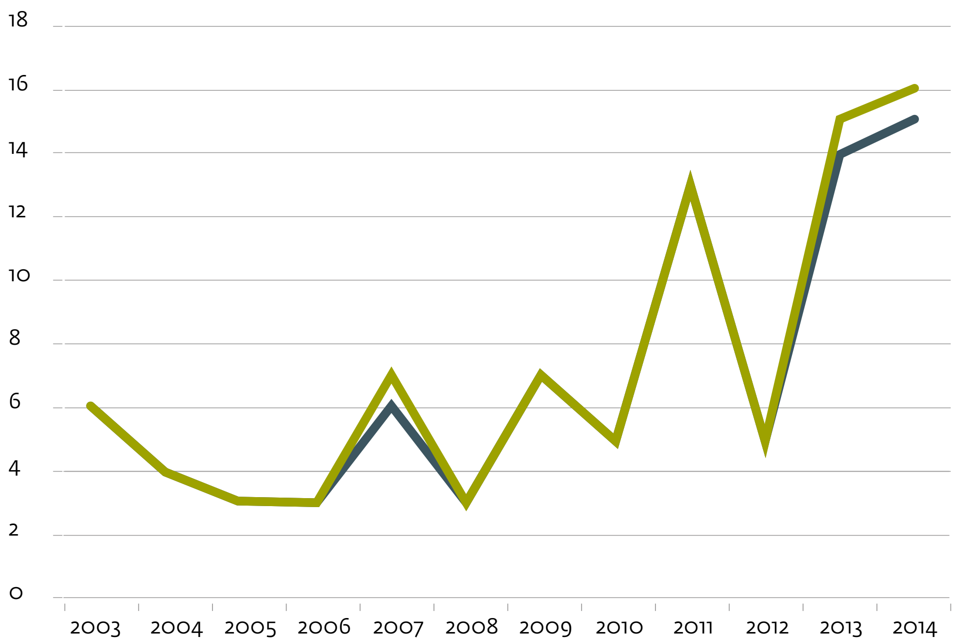


Figure 6.
SME participation

SME participation without duplicates per year

SME participation

(Energiforskning.dk)

Between 2003 and 2104, SMEs have participated 84 times in a project financed by one of the RD&D programmes equal to 55 unique companies. The annual sum of SME activity over the years has been modest and only a few projects have sent the curve steeply up or down. But despite the limited number of total projects there is a clear tendency of increased participation also when duplicates are removed. The drop from 2011 to 2012 (13 to 5 companies) may be explained by a lack of resources as a result of the long financial crisis.

5.1.2 University and GTS participation

DTU is by far the largest player from the knowledge institutions. But the balance is somewhat shifted by the fact that all participations from Risø National Laboratory has been included under DTU (Wind Energy) and these were two independent entities prior to January 2007.

DTU has 157 participations in projects over the 12 year period. This is almost four times as many as Aalborg University with 44 participations – Aarhus University has 3 participations. The GTS organisations have 27 project participations lead by DHI and DELTA with 10 and 8 and both have been project leader in four projects each.

Universities as project leaders
When heading projects DTU can show 145 company participations over the 12 year period (39 unique companies)[14] but 72% of company involvement in DTU headed projects is divided among 6 companies.

The other university in Denmark with significant wind activities, Aalborg University (AAU) shows a much shorter company list as project leader: 9 company participations (5 unique companies). But when projects are included where neither AAU nor DTU head projects, the number of company interaction is more aligned with AAU: 75 (30 unique) and DTU: 86 (51 unique).

The tendency is clear both in projects headed by the universities and in projects where the universities are mere project participants. The majority of the R&D activities that the university share with the companies are with a small excusive group of the large companies in the industry. Another notable conclusion is that the list of companies is considerably longer and much more varied in the projects where universities are invited "on board", than in the cases where they orchestrate the projects.

5.2 Barriers and gaps for industry involvement in public RD&D

Companies participate in publicly funded R&D projects to strengthen their innovation activities. Depending on company size, the time span differs slightly. Large companies have resources for a longer period to transform access to knowledge and technology into product innovation and increased competitiveness than SMEs. For the OEMs in the wind sector, it can take a decade from the decision is made to develop a new wind turbine concept and until the result is commercialised.

Companies do not participate in projects with the anticipation of having products ready for market when the project is completed. They choose to participate to gear their own R&D investments, lower the financial risk and to be part of more ambitious projects than they can lift on their own. This applies for companies across most sectors and is not exclusive for the wind industry[15][16].

5.2.1 Company ability to engage in public RD&D initiatives

A total of 75 companies have been active in publicly financed, wind energy related RD&D projects from 2003-2014. But 46 equal to 61% of these have only been active once and a very exclusive group of 5 – utilities and OEMs with LM Wind Power as the exception – have participated in more than 10 projects.

14 If foreign companies without a Danish company registration are included the figure is 49

15 Fra forskning til innovation, DEA and DI (Confederation of Danish Industry), April 2014.

16 Conclusion from 17 company interviews conducted by Megavind.

The group of utilities and OEMs very clearly dominate the industry presence in the public RD&D programmes. But when it comes to the next tiers in the supply chain the pattern is more or less the same for the larger component suppliers and the SMEs. A large group of companies including both SMEs and larger suppliers have only participated once in a publicly funded project. 8 of the component suppliers, with more than 250 employees, have participated more than once in a publicly funded project and 5 have participated more than twice. 15 SMEs have participated in more than one project and only 3 have been active in more than 2 projects.

Of the 500 companies with wind energy related activities in Denmark, only 16% of these have engaged in public RD&D projects as mentioned above and only 6% of the companies have participated more than once.

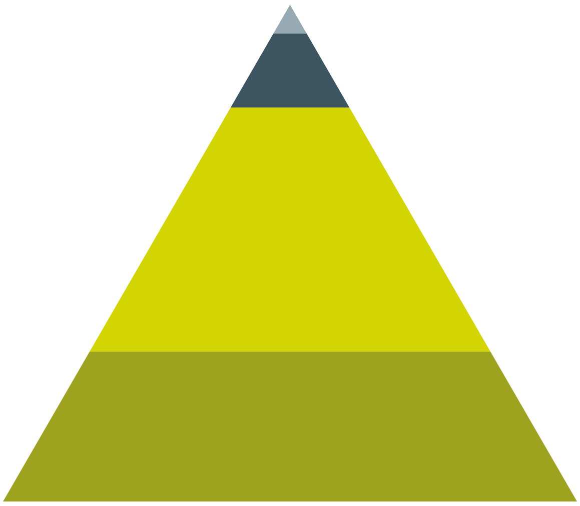


Figure 7.
Innovation triangle for wind energy

- Innovative –participates frequently in public funded R&D programs
- Innovative – seek cooperation with researcher etc.
- Innovative - but not currently involved in public funded R&D programs
- No dedicated R&D activities, deliver standard off-the-shelf products also used in other sectors or other services

The companies in the wind sector can thus roughly be divided into four groups. A bottom group that do not have any separate wind energy R&D activities e.g. companies with off-the-shelf standard products (see also section 4.2.1).

Another group have development activities e.g. upon demand from their customers, when their suppliers present new opportunities or by picking up inspiring ideas from other companies. In general, R&D activities are integrated in company operations and need not be a separate activity. They often do not involve external experts that brings new knowledge to the company. Expert assistance is in general sought for quick problem resolutions.

A third, group have taken a step further to engage in external R&D activities e.g. through the publicly funded programmes. This is group includes the companies that have participated once in projects as well as the companies that have sought assistance through other innovation programmes.

The fourth group includes a small group of 12 companies with 3 or more project participations that have a strategic R&D focus and have regular cooperation with external experts. The challenge for the sector is to create mobility in layers 2 and 3 of the triangle and to help more companies move into the two top layers.

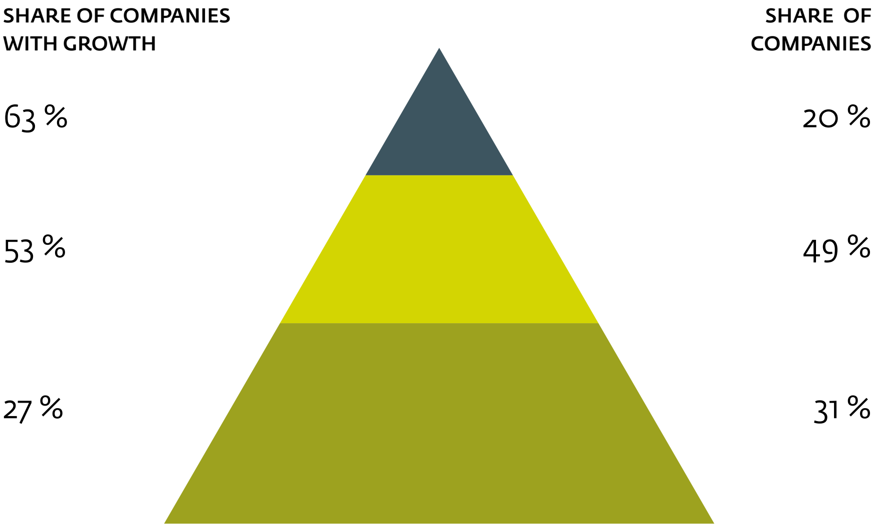
Studies from other sectors show that there is a clear connection between the companies' ability to be innovative and how well they perform in general. Figure 8 depicts the result of an analyses of the food industry in the Region Zealand. Only 27% of the non-innovative companies had experienced growth over the last 3 years. For the innovative companies that interacted with external experts 63% had experienced growth[17].

17 LB Analyse 2014 "Future perspective for the food industry in Region Zealand"

Figure 8.

- Innovative, frequent R&D cooperation
- Innovative, but no interaction with researchers
- No innovation activities

Source: LB Analyse



5.2.2 Danish RD&D public infrastructure from a company perspective

The most popular programme from a company point of view is the Energy Development and Demonstration Programme (EUDP). The larger companies are also very active in the ForskEL programme but this primarily applies for utilities and OEMs. Of the 65 company participations in the ForskEl programme, utilities cover 33 and OEMs 12 participations.

Megavind has interviewed 17 companies that have taken the role as project leaders in an application process or an approved project. Three of the companies have headed two or more projects and 3 companies have only headed one project but have been project participants in one or more. 14 received funding and 3 had submitted applications that were rejected[18]. 3 of the companies were in the category large component suppliers and 14 were SMEs[19].

All but one had sent applications to EUDP, the other programme was ForskEl. The vast majority of the interviewed companies were satisfied with the application process and the following project administration. Several of the interviewed companies had their application rejected in the first try but altered the application after dialogue with the EUDP secretariat and received funding when reapplying.

From 2008-2013, 98 wind related projects have been rejected by the EUDP. 39 of these received funding for their projects after altering the application. Only one of the 3 interviewed companies that did not receive funding was dissatisfied with the application process although a second company would have liked a meeting to elaborate on the grounds for rejection. Two of these companies are not planning to reapply.

12 of the 14 approved companies wrote the project application themselves, a couple had the applications proof read by externals. The 3 companies that did not receive funding either wrote the application together with a university or used external consultants. Only one of the 14 funded companies states that they will not apply for funding again in Denmark but will continue activities with international partners.

Conclusively, the companies seem satisfied with the infrastructural set-up in the EUDP programme. The lack of participation from the majority of companies in the sector cannot be explained by a bureaucratic and heavy administrational load. This could very well be a preconception by many companies and one way to eliminate this could be by marketing the good cases more intensively in the sector.

18 Megavind has only had access to rejected applications from the EUDP programme.

19 There have been two other "large component suppliers" on the interview list. But the secretariat has not been able to access the person in charge of the project process.

5.2.3 Other general programmes

For several years, the Ministry of Higher Education and Science has offered knowledge support for especially SMEs with the Knowledge Pilot programme[20] and the Knowledge Coupon programme[21]. These two programmes have been directed towards SMEs in all sectors and have supplemented the RD&D programmes by offering an introduction to the "knowledge society" for companies who have not had interactions with knowledge institutions before.

From August 2014, the two programmes have been replaced by the Innobooster programme[22]. The purpose of the programme is similar to the abovementioned programmes and also aimed at boosting innovation in SMEs.

From 2010-2013, the Knowledge Coupon programme granted funds to 1,448 companies. 17 companies with wind energy activities received funding. 5 of these companies have also participated in the RD&D programmes. In the Knowledge Pilot Programme 931 companies received funding but only 4 of these had wind related activities and two of these have also participated in the RD&D programmes. Megavind only has data for 2010-2013 from the knowledge programmes and this data is too recent to conclude if the companies have been active here before the RD&D programmes and if there has been a bridging function.

Another programme administered and carried out by the GTS institutes is the Innovation Agents[23], also financed by the Ministry of Higher Education and Science. Innovation agents from GTS institutions visits a company, analyses its innovation potential and delivers a set of recommendations that can be followed by possible project initiatives.

20 The Knowledge Pilot Programme is a Danish subsidy scheme aimed at increasing knowledge dispersion throughout the economy by subsidising the employment of university graduates in SMEs which do not typically make use of resources of these individuals. http://planipolis.iiep.unesco.org/upload/Denmark/Denmark_Science_innovation_Higher_Education.pdf

21 In the knowledge coupon programme a company could apply for DKK 100,000, for which they can buy knowledge or a service from a university or GTS.

22 http://innovationsfonden.dk/innobooster/

23 http://www.innovationstjek.dk/

RD&D activities are also funded through other channels. The Danish Business Authority manages initiatives like the Regional Business Development Centres[24]. The core task for the 5 centres is to map opportunities and challenges for new and small enterprises with growth ambitions and potentials.

5.2.4 Student activities

Many of the large companies have an infrastructure that successfully handle student internships and graduate programmes. The large companies also have the sufficient resources available to offer guest lecturers at the educational institutions e.g. summer school programmes. This both contributes to bringing an industrial content into the class room and helps companies in promoting themselves to the future candidates.

All of the above puts them ahead in the race for the most talented candidates and establishes a valuable network within the educational institutions. Moreover, the project collaboration both on master and PhD level is a valuable contribution to company RD&D activities. SMEs also cooperate with universities and have in-house projects with students but data showing the extent of this has not been accessible.

5.2.5 Industry interaction with universities in RD&D projects

One very important selection criteria in the Danish public RD&D programmes is company participation. The public funds must be matched to some extent by co-financing from the project participants. In most programmes, researcher resources can be fully financed by the project whereas companies can only receive up to 50% funding of their allocated resources. Universities are therefore dependent to some extent on securing company participation in their projects.

Companies in general, experience being contacted late in the application process with a participation request, leaving them without any real influence on project content or outcome. Some find it hard to decline to avoid jeopardizing relations to the researcher. But

24 http://danishbusinessauthority.dk/entrepreneurship

there is also an overall interest to secure as much support as possible for R&D activities through public funding even though the individual company only benefits marginally[25].

Depending on the company type, knowledge based or production companies, the experience with knowledge sharing differs. For companies with almost the same level of knowledge as the universities there is a competition element with regard to knowledge sharing and universities are only invited to join because it is prerequisite to receive funding. Production companies mention access to new knowledge delivered by universities or GTS institutes as one very important reason for participating in these projects[26][27].

Inputs from company interviews conducted by Megavind also conclude that there is a cultural difference in the way that companies and universities participate in projects. Focus and time conception is not the same. Several companies state that it is important to set realistic but sharp deadlines in the project planning and to hold researchers to the deadlines and focus on the end result. Participating researchers have a tendency to dig more thoroughly into the subject than required and to pursue other leads than what the project content and end result dictates.

5.3 Gaps in value chain competences

As mentioned above the Danish sector includes all value chain elements both when it comes to on- and offshore wind turbines as well as installation of these. This complete representation also means that embedded in the sector is an overall system understanding of the turbine and its interaction with the grid which is unsurpassed elsewhere.

In order to preserve this stronghold and an overall system understanding it is important to keep focus on potential bottlenecks and gaps in the cluster of knowledge and aim to avoid or close these if possible by ensuring a stable flow with relevant competences from the educational system.

The companies in the sector reports of difficulties in recruiting personnel with the following qualifications:

- Electrical engineers
- Marine and technical engineers
- Industrial technicians

The list is not complete and should be supplemented through a more extensive analysis of what competences is most needed in the industry and how bottlenecks and competence gaps can be eliminated.

25 Fra forskning til innovation, DEA and DI, April 2014.

26 Fra forskning til innovation, DEA and DI, April 2014.

27 Conclusion from 17 company interviews conducted by Megavind.

6. Conclusions and recommendations

All infrastructural elements are present in the Danish sector to back the cooperation between industry and knowledge institutions. The industry can deliver to complete value chains and extensive investments in test facilities. The universities can deliver world class researchers and an educational system that deliver specialized personnel to the industry. The publicly funded RD&D initiatives deliver both test facilities and programmes that are embraced positively by at least the industry participants. The only major missing piece of the puzzle is to strengthen the cooperation between the knowledge institutions and the large component suppliers and SMEs of the Danish wind sector.

The overall conclusion to industry and university interaction in the public RD&D programmes is that in general there is a good interaction between universities, OEMs and utilities. The large R&D departments and universities match each other well when it comes to organisational structure and for the existing project constellations also time frame. For the rest of the value chain there is a more sporadic interaction which is more frequent when companies initiate it.

In order for universities and GTS institutes to contribute to a competitive wind industry, increasing focus must be placed on the interaction with two middle groups of companies in the innovation triangle that have innovation activities but either only few or no interactions with universities and GTS institutes. Infrastructural barriers like IP rights, technology transfer and legal issues in establishing common test facilities are inferior focus areas in the present situation and will only be important for very few companies if the overall industry interaction with universities is not improved.

On the industry side, the sector must work on more focused joint R&D initiatives in order to start a migration for the two middle groups of companies up through the innovation triangle. This can be done both by working with innovation on a sector level and by marketing the public programmes further, the innovation programmes and EUDP in particular, to the industry. Interviews with companies that have applied for funding through the EUDP show that applying for and administrating a publicly supported project is manageable and that the gain is worth the effort. More resources should also be put into mapping the RD&D needs for the two value chains and how these can be met by the knowledge institutions.

The universities and GTS institutes must increase focus on how they can encompass the competences sought by the two value chains, so that they can contribute to the RD&D requirements that the companies are facing e.g. with regard to verification, test and validation.

To eliminate competence gaps and bottlenecks in the industry, the sector must increase focus on ensuring that the right qualifications are present in the Danish work force. The present gaps must be clarified further through and a sector analysis.

In order to improve cooperation between knowledge institutions and industry and thus improving university contribution to making the industry more competitive, Megavind recommends the following:

Megavind recommendations

Actions	Target group	Initiators
Ongoing mapping of R&D cooperation needs– both for the wind turbine component and the offshore solution supply chains	SMEs and large component suppliers	Danish Research Consortium for Wind Energy, Megavind
Address the gaps and barriers between desired industry collaboration and university competences. Establish an instrument for universities to understand and absorb the needs of the SMEs that are revealed in the mapping exercise described above	Universities	Danish Research Consortium for Wind Energy, Megavind
Create awareness in industry and universities of the current R&D interaction opportunities available e.g. EUDP, Innobooster, vouchers for preliminary projects, the Innovation Agents, student projects.	Industry and universities	Sector and public programmes
Find and market the "exemplary cases" of companies that have benefitted from interacting with knowledge institutions.	Industry	Sector
An analysis that describes the existing gap in the educational value chain e.g. for electrical engineers, marine and technical engineers, industrial technicians etc.	Industry and university	Sector

EHRHORN HUMMERSTON

SECRETARIAT: DANISH WIND INDUSTRY ASSOCIATION
Rosenørns Allé 9, 5
DK-1970 Frederiksberg C
Tel: +45 3373 0330
www.megavind.windpower.org/