Danish offshore wind rises to new heights with cost cutting collaboration

A United Industry Thinking Big

2015

Offshore wind at heart of all-renewables power system for Denmark
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Innovations drive cost reduction in balance of plant infrastructure
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Best practice for a lean and mean operational strategy
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A united industry thinking big

Denmark has a unique position in offshore wind. We are among the world leaders in development and implementation of new technology and we are adept at creating innovative and lasting solutions across the sector.

Each day we demonstrate how to integrate large volumes of wind energy into the Danish power system, and that offshore wind is an important and effective player in the transformation to a green energy supply. At the same time we maintain a cutting edge focus on driving down the cost of offshore wind energy through a range of public-private partnerships working in close collaboration with industry.

Setting foot in Danish waters means riding the wave of innovation and becoming part of the adventure. This magazine takes you on a voyage through Denmark’s unique offshore wind seascape.

We start with how to structure a national power system based largely on wind energy before taking a look at how well coordinated research plays a major role for innovation. Next we explore how the Danish industry’s shared focus on scaling up projects and adopting better construction practices is set to achieve significant cost reductions and make life safer for workers. Our voyage nears its end with the story of how Denmark reaches out to share its knowledge with other countries and in turn learns from their expertise. Last but not least we look at how experience gained from a quarter century of offshore wind plant operation in Denmark provides unique insight into how best to develop highly efficient and safe operations and maintenance routines.

Welcome aboard. Enjoy the ride!

Jan Hylleberg
CEO, Danish Wind Industry Association

Morten Basse
CEO, Offshoreenergy.dk

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This magazine is distributed through multiple channels to decision makers in the Danish offshore wind industry, opinion forming stakeholders and a large proportion of industry membership in Denmark. Additional distribution is to Danish political, science and education sectors, industries closely aligned with the offshore wind business and to participants at the EWEA Offshore 2015 event in Copenhagen, Denmark. It will be displayed at airports in Denmark and hotels in Esbjerg throughout 2015.
Green transition with offshore wind

Three decades successfully integrating wind energy into the power system have given Denmark the know-how and confidence to not only wave goodbye to all fossil fuel use but set a deadline for doing so. Today the country is building a power system for tomorrow. It will be based on offshore wind.

By 2035 offshore wind is to be the single largest contributor to electricity and heating in Denmark. Wind will be meeting 75% of demand for heat and power, with just over half of that coming from offshore capacity. Solar and other renewables will provide the remainder.

The country’s electricity system operator, Energinet.dk, is already investing in the power system structure needed. The national energy political goal, agreed to by a large parliamentary majority, is independence from fossil fuel by 2050, including for transport. Nuclear is not in the frame.

Energinet.dk describes itself as independent public undertaking reporting to the Ministry of Climate, Energy and Building. Its stated role is to integrate an increasing volume of wind, solar and biogas while maintaining the current level of security and affordability of electricity supply.

Wind scenario comes top

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Of four scenarios studied, wind comes out ahead of the other three: biomass; purchase of green credits overseas; and carbon capture and storage. The wind scenario includes biomass that is sustainable per head of population in a global perspective, says Energinet.dk’s Anders Bavnhøj Hansen, chief consultant for system development.

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Wind on the wires in Denmark: As each offshore wind farm comes on line its output displaces fossil fuel generation until offshore and onshore wind combined are meeting more than 70% of demand. The national energy strategy is supported by a large parliamentary majority. Source: Energinet.dk

Text: Karin Jensen

Onshore wind capacity
Offshore wind capacity
Wind power production as percentage of classic consumption

Wind on the wires in Denmark: As each offshore wind farm comes on line its output displaces fossil fuel generation until offshore and onshore wind combined are meeting more than 70% of demand. The national energy strategy is supported by a large parliamentary majority. Source: Energinet.dk

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Energinet.dk is charged with realising the strategy and is building the required support into the system under a long-term investment plan. An interim target of an all-renewables electricity and heating supply by 2035 has been set by government, provided that reaching it in just 20 years is economically defensible.

“It’s a big challenge and a major transformation of the energy system so in order to prepare for the long term planning and to provide input to research and development, we’re working quite a lot on various scenarios for the long term energy system with emphasis on 2020, 2035 and 2050,” says Energinet.dk’s Anders Bavnhøj Hansen, chief consultant for system development.

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compared with other technologies, including combined cycle gas and so-called clean coal.

Security of supply

Energinet.dk’s default position on security of supply in an all-renewables system is for no interruption to electricity delivery. Maintaining supply in periods from half a day to seven days of low wind and solar output at times of high demand is a challenge, admits the operator. But that is the benchmark it has set after analysis of ten years of wind data to ensure a robust power system in Denmark with 75% wind.

Although it is technically feasible for Denmark to balance an all-renewables supply with demand within its own borders by running a system with considerable excess capacity, it would be a challenging and expensive option. “It would require a lot of idle production capacity just standing by and waiting for days with no wind. And on really windy days you would have to shut down some of the wind farms,” says Johannes Guldbæk, group leader at Energinet.dk’s control centre.

A more rational approach for nation states in Europe is to integrate their energy supply in a single system. No longer should every country operate as an energy island if Europe is to rid itself of the excess power capacity that lies at the heart of the EU electricity market’s current economic failings.

Denmark is taking the lead in not insisting on the expense of balancing its supply and demand nationally. Instead it will make use of its geographical position, sandwiched between a hydro system to the north and a thermal system to the south. Interconnections to Sweden, Norway and Germany have long been established and another to the Netherlands is planned, with talk of a link to the UK, too.

Access to hydro systems up north and to the east provides a way of storing excess wind energy. “You can shut down hydro power monumentally and store it in reservoirs,” says Bavnhej Hansen. Guldbæk adds: “Geographical differences can be offset by having a larger area to exchange power in. It’s an advantage to have a large coherent system.”

Creating flexibility

Crucially, a more closely interlinked international power grid and gas infrastructure will enable the flexibility needed Europe-wide to maintain security of supply as the penetration of renewables rises. More flexibility must come from both customer demand and generation supply. Demand response programmes are being rolled out that reward both industrial and domestic customers who agree to reduce their electricity usage for shorter or longer periods.

For supply side flexibility in the electricity system, Energinet.dk’s plan is for much of it to come from international integration with hydro-power, supported by heat pumps in Denmark’s widespread district heating system and what amounts to battery storage available in parked electric vehicles plugged into the grid. Storage of gas from renewable sources will contribute to providing overall energy flexibility.

Large energy stores

“If you’re looking at the storage capacity of the energy system today, district heating, gas, storage and the grid itself are doing a pretty good job. But if demand response programmes come to the fore it’s going to have a major impact on making the grid more flexible.”

Full speed ahead licensing

Just three licences are required to build a government sponsored offshore wind farm in Danish waters – a licence for preliminary site investigations, a licence to install turbines and a licence to exploit wind power for a given period. All three are granted by one authority, the Danish Energy Agency (DEA), making it an effective one-stop-shop for offshore wind permits.

“We want cheaper offshore wind in Denmark but in order to do that we need to reduce the risk for the developer and make it easier to get through the administrative system,” says Lisbeth Nielsen, chief advisor for energy resources at the agency.

The DEA coordinates most steps of the permitting process with other government bodies such as the Danish Maritime Authority and the Environmental Protection Agency. A hearing among these bodies seeks to clarify whether there are major obstacles which could put a stop to a project. Any specific requirements are incorporated into the licence with a clearly mapped path for how to fulfil them and where to seek guidance.

“It means that when you bid for a tender to establish an offshore wind farm in Denmark you have a high level of security, meaning little risk of a showstopper later in the project,” says Nielsen.

A different licensing process applies for wind developers applying to get their foot in the “open door” procedure for generally smaller near-shore projects. They must first seek a licence for preliminary site investigations and conduct an Environmental Impact Assessment before applying for a building licence. Again, most of the permitting is done by the DEA under the one-stop-shop concept.

For the large government sponsored projects the procedure is more streamlined. “Once you’ve awarded a tender you will receive a licence to carry out preliminary investigations and a licence to establish as well as a contract. This means that we have eliminated the processing time for the first two licences,” says Nielsen. “The licence to exploit the wind power is not needed until later in the process,” she adds. “We can see from the tenders that we have lower prices compared to other countries.”

Karin Jensen

Text

Smooth waters: Managing the ups and downs of generation from Denmark’s largest wind farm, the Anholt 400 MW facility, is plane sailing. Photo DONG
There are really quite large stores in the energy system today

Anders Bavnhøj Hansen
Energinet.dk

Denmark: A United Industry Thinking Big
FACILITIES FOR OFFSHORE
– LONG TERM & PROJECT LEASE, HEAVY

- 6.4 million m² industrial park & harbour area
- 500,000 m² planned port expansion with 1000 m quay
- 4400 m quay with crane coverage
- International port with up to 11 m depth
- Large production halls up to 12,444 m²
- Large storage areas with room for expansion
- Dry deck 90 m x 315 m
- Lifting capacity of up to 1000 tons
- Internal transport of up to 1000 tons
- Special transports of up to 2000 tons
- Mobile harbour cranes 60 & 150 tons
- Workforce facilities for up to 5000 people
- Car park for 2000 vehicles
- Canteens, meeting rooms & conference facilities
- Offices & workshops
AND HEAVY INDUSTRIES
LIFT & TRANSPORT UP TO 1000 TONS

www.lindo-industripark.dk
In close formation on cost cutting flight path

Denmark’s technology lead in offshore wind is steeped in the country’s legendary spirit of cooperative enterprise. Shoulder to shoulder the sector works on cost cutting innovation, though without compromising fierce competition between companies.

When representatives from Siemens Wind Power and MHI Vestas Offshore Wind sat down together for the inaugural meeting of the new Cost Reduction Forum it was to look past the intense competition that normally drives the two offshore wind technology leaders to the much broader goal of making their entire industry more competitive. The forum was launched by the Danish offshore industry’s innovation and knowledge centre, Offshoreenergy.dk, back in September 2014.

The scene at that first meeting, says Offshoreenergy.dk CEO Morten Basse, was typical of a unique balancing act that has made Denmark a leader in advancing offshore wind energy. “We have managed to focus on collaboration when it is relevant and on competition when it is relevant,” he says.

Although Denmark installed the world’s first offshore wind energy project in Vinddeby in 1991, it was far from a foregone conclusion the country’s wind industry would proceed to dominate the sector as it has done. The challenge of raising the scale of investment required in a country with a population of just five million should have put it at a disadvantage compared with industrial giants Germany, Britain and even the Netherlands.

Small is beautiful

But Denmark’s size has actually been a benefit, argues Jakob Lau Holst, chief operating officer at the Danish Wind Industry Association. Companies representing at least 80% of the wind energy value chain are clustered within 300 kilometres of the port of Esbjerg on Denmark’s North Sea coast, the national centre of activity for assembly, export, installation, and service of offshore wind turbines. Esbjerg is where two of the largest and most globally significant players in the industry, MHI Vestas Offshore Wind and Siemens Wind Power assemble many of their offshore turbines and the town hosts a number of specialists in offshore wind, including shipping companies, operations and maintenance service firms and marine construction experts.

The concentration of so much of the global offshore wind supply chain in such a relatively small geographic area creates a naturally close business community and is typical of Denmark’s legacy of economic development through grassroots cooperatives, says Holst. The intimacy encourages the kind of free flow of ideas and knowledge between researchers and manufacturers that helped drive Danish onshore technology forward in its early days. “There is a closeness and an interlinked history that help us,” he adds.

It is this cooperative mindset that lies at the heart of both Offshoreenergy.dk’s Cost Reduction Forum and the Danish Wind Industry Association’s Megavind partnership, a separate though related initiative. Both groups share common goals: to dramatically reduce the cost of offshore wind energy while also ensuring Danish companies have the tools they need to maintain their competitive edge in the global marketplace.

Mega alliance

Megavind brings together industry, academia and government in a coordinated effort to
We have 30 years’ experience offshore and our teams participate in most offshore wind projects.
accelerate the technological innovation that will make offshore wind competitive with other electricity generating sources. It set an ambitious target in 2010 of cutting the levelised cost of energy from offshore wind 50% by 2020. To get there, it said, newly built offshore wind farms would have to produce roughly 25% more electricity per installed MW; the capital cost per installed MW would have to drop by approximately 40%, and operation and maintenance expenditure reduce by about half.

Since then, says Holst, the partnership has been working to map out the strategy that will help the industry meet those goals. “Megavind is designed to inform decision makers about how to prioritise research and development activities,” Holst says. “In the process of getting there we have actually had quite a bit of alignment among actors within the industry on what are the most important next steps.”

The partnership has already seen some high-profile success with the establishment of dedicated full-scale test facilities designed to help wind turbine manufacturers move new machines to market more quickly and with less risk of expensive failures.

Twice as fast at half the cost
The National Test Center for Large Wind Turbines at Østerild opened in October 2012 and was followed by development of a state-of-the-art nacelle test bed, one of the facilities available at the Lindø Industrial Park’s offshore renewables test centre, known as LORC, on the large island of Funen between Jutland and the main island of Zealand. It started operations in September 2014. “You can draw a straight line from a Megavind recommendation to those facilities,” says Holst.

The LORC nacelle and test centre (page 19), notes Holst, was financed with a combination of public and private investment, designed with significant input from co-sponsors Siemens Wind Power and Vestas Wind Systems and built at roughly half the cost of comparable facilities in other markets. “I think an interesting story that maybe is not often told is this has been done very quickly and in a spirit of collaboration that I don’t know if you see elsewhere,” he says.

Megavind is looking to bring that same type of thinking to the broader value chain. It has been involved in creating a strategy, to be released in early 2015, examining how to better connect the knowledge developed at Denmark’s research institutions to component suppliers and other companies active in the wind energy space.

“Research in universities is quite close to the market in this industry compared to research in many other fields. But we can see there is a gap and we can make a lot of progress in bringing down the cost of energy, and also advancing the competitiveness of our members, if we help them apply more of the technologies that have been brought forward by universities. If we can bring more of that collaboration about, then there are gains to be made,” says Holst.

“This is interesting for us because of the composition of the Danish industry. Everyone knows the large companies, they are global players. But there is a very large undergrowth of small and medium-sized enterprises. In the Danish context many of them might be big, but they’re still, in global terms, fairly small companies with processes still to be fully developed. It is a young industry and even if they have a very large turnover, things have been moving so fast that their organisations are really not reflecting the complexity of this business.”

Industrialisation and standardisation
A key area of focus is the industrialisation of processes that will make installation of offshore wind farms faster and cheaper, says Holst, as well as cross-industry standardisation to drive efficiencies and build scale. “We are planning some work on standardising specifications for subsystems,” says Holst. “This may sound trivial, but it is how the auto industry has brought down the cost of a car. We don’t have that in the same sense. We use standards applied in other industries and we have them at a very high level of a turbine, but not when you get down to parts and bits and pieces.”

Megavind is also looking to drive some common understanding of one of the most fundamental questions facing the offshore sector in its drive to lower costs. How can it calculate and demonstrate in a uniform way the Levelised Cost of Energy (LCOE) produced by an offshore wind plant? The range for offshore wind LCOE is huge from project to project, depending on the characteristics of a specific site, such as wind strengths, water depths, the distance from shore and the seabed conditions. “It is not even like comparing apples and pears, but more like bicycles and pears. They are completely different,” says Holst.

Measuring cost
“Come 2020 we have promised targets, but how do we actually measure we are there and how can we communicate to each other how we get there? What is the low-hanging fruit? What is the contribution to bringing down costs, for example, of a new type of foundation versus another type of foundation. We have to calculate that in the same way and agree on how we estimate costs before we can actually have a more coordinated approach to bringing them down,” says Holst.

Megavind is presenting its findings for a common methodology for establishing the LCOE of offshore wind at EWEA OFFSHORE

Steering the way: The role of the Cost Reduction Forum is to drive cost cutting by the many companies involved in installation and O&M, says Morten Basse, CEO of Offshoreenergy.dk

Photo Jonas Ahlstrøm
Plenty of wind – isn’t it great! Today, wind covers about 40% of the electricity production in Denmark. During the 1970’s, the Danes started to harness the wind onshore to produce energy locally. In 2002, they looked to the sea when DONG Energy installed the world’s first large-scale commercial offshore wind farm. Making use of our Danish roots, DONG Energy has become world leader in the construction of offshore wind farms. Today, our target is to reduce the costs of offshore wind and make offshore wind fully competitive with conventional energy technologies.

Green, independent and cost-effective energy.
That’s what we believe in.
2015, the European Wind Energy Association’s offshore conference in Copenhagen. The largest players in the sector have already said good for its key principles (page 14).

**Executing the strategy**
Standardisation is also an important area of focus for Offshoreenergy.dk’s Cost Reduction Forum. The forum includes 30 companies, from consulting and advisory firms, construction companies and installation vessel operators to the big offshore wind operators, component suppliers and Danish turbine suppliers. They have agreed to pool their knowledge and experience to zero in on areas where changing how the industry does things could bring large savings.

Megavind and the Cost Reduction Forum have carefully crafted their efforts to dovetail at the juncture of strategy and execution.

While Megavind concentrates on strategy, says Basse, the Cost Reduction Forum focuses on execution.

The forum has carved out its own niche, limiting its deliberations to offshore project installation and operations and maintenance (O&M). “We expect the big operators and the big component suppliers and the universities to work on cost reduction for big components. The installation process and O&M are more complex because a large number of companies are involved, so who is going to drive cost reduction? We have decided that we are,” says Basse.

He admits it is a huge task. “The strategy of the Cost Reduction Forum is not to try to eat the elephant all at once, but break it down into smaller pieces,” he explains. “If we can show success, then we might create a positive ball rolling.”

**Fast track to critical mass**
Forum members have identified five areas of focus, with a goal of reducing costs by 40% in each to realise Megavind’s strategic objectives. The forum’s task is to stimulate collaborative effort until solutions to key challenges are fully developed and successfully implemented. Some specific individual projects are funded through public-private partnerships.

The first of the five focus areas is development of a white paper to outline ways to drive efficiency in competitive bidding by identifying, for example, some standard work packages. Offshore substations are currently manufactured as one-offs for each wind farm, but if the industry could agree to some level of standardisation in their configuration, it would realise gains. The industry, Basse notes, needs to be more methodical about taking lessons learned from one wind farm project to the next. “To drive costs down it is all about volume,” he says. “We have a tendency to start all over again when we start a new project, which means we never get critical mass.”

Second, the industry needs to look at developing a set of standardised contracts. “There are so many different ways of putting contracts together that we are wasting too much administration and preparation time,” says Basse.

Third, within offshore O&M, a key focus is to improve access to wind turbines by technicians in a wider range of weather conditions. “If we can increase our operations and maintenance window from forty percent of the time to say sixty or seventy percent of the time, then we have increased efficiency and reduced costs,” Basse says. “That’s got to be done through innovation. Just as an example, today there is a rule saying that when you...”
have 1.5 metre wave heights then you stop accessing the turbines. Say we can develop crew boats that can safely access the turbine in 2.5 metre wave heights. Then we can increase the time available at the turbine.”

**Robots and logistics**

Fourth, innovation in how the industry performs subsea maintenance is another critical area. Using robots instead of divers is one example that holds the promise of cost savings. “There is a fairly heavy product development task to be performed here,” says Basse.

Last but not least, the forum intends to map the entire transportation and logistics process to identify where the greatest potential for improvement lies and steer members to devise better practices.

Working groups will be created in 2015 to take a deep dive into the five focus areas. By the end of the third quarter of the year, each group will present its findings to the full steering group, which will decide which solutions to pursue and implement in the entire industry.

**Pain and gain**

“We will have to see what happens when we see the concepts, because it is obvious you cannot reduce cost by 40% without hurting someone. Somebody must do things differently to what they do today,” reasons Basse. “The money must come out of a pocket somewhere.” A significant proportion of the savings, however, will be taken care of by innovations that result in better products less likely to fail and improved productivity. “But there need to be efficiency gains as well.”

The key is that all 30 companies are participating voluntarily and working out the solutions for themselves, says Basse. By discussing what services and products are likely to become obsolete and where mergers and acquisitions would pay off, members collectively plan for a profitable future by taking difficult decisions today.

“The strategy is to work so much together and involve everybody so much that once we come to the point where they need to bite the bullet we will, in a way, have come past the point of no return,” concludes Basse.

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### Leading the world

**Denmark’s main wind turbine test facilities**

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<tr>
<th>Facility</th>
<th>Activities</th>
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<tbody>
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<td>DTU Wind Energy (Risø)</td>
<td>Wind tunnel for aerodynamic and acoustic testing</td>
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<tr>
<td></td>
<td>Test bed for drive train loads</td>
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<tr>
<td>Havnsøe Test Site, Lemvig</td>
<td>High wind speed test site for turbines up to 156m tip height</td>
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<tr>
<td>LCRC Test Center, Linda</td>
<td>Nacelle grid interaction test rig Drive train loads test bed</td>
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<td></td>
<td>Welding services (foundations)</td>
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<tr>
<td>Østerild Test Centre, Thisted</td>
<td>Test site for 7 prototypes with up to 250m blade tip height</td>
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### Action points

**Harbours in Denmark serving the wind industry**

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<th>Activities</th>
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<tr>
<td>Aabenraa</td>
<td>Exports/shipments</td>
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<td>Aalborg</td>
<td>Blade production Blade shipments</td>
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<td>Aarhus</td>
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<td>Bornholm</td>
<td>Potential O&amp;M base</td>
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<td>Esbjerg</td>
<td>Turbine exports Turbine assembly/installation Wind farm operations Service &amp; maintenance base</td>
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<td>Grenå</td>
<td>Turbine installation base Service &amp; maintenance base</td>
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<td>Hvide Sande</td>
<td>Ready for use as O&amp;M base</td>
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<td>Rømø</td>
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<td>Thyborøn</td>
<td>Aspiring O&amp;M base</td>
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### Library of knowledge

**Offshore Wind Farms in Denmark 1991-2015**

<table>
<thead>
<tr>
<th>Project</th>
<th>MW</th>
<th>Operator</th>
<th>Turbine supplier</th>
<th>No. of units</th>
<th>Water (m)</th>
<th>Kms to coast</th>
<th>Online</th>
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<tr>
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**By discussing what is likely to become obsolete members collectively plan for a profitable future by taking difficult decisions today**

*Morten Basse*

CEO Offshoreenergy.dk
A collaborative effort to cut 40% from the cost of offshore wind generation by 2020 is the promise made to governments by a broad wind industry platform, including utilities DONG Energy and Vattenfall. To fulfil that promise without endless argument about which members of the supply chain are saving how much and where, development of an agreed methodology for how to calculate each element of the cost of producing one unit of offshore wind electricity and the cuts being made was seen as an essential first step.

No sooner said than done, Denmark’s Megavind, a strategic industry partnership, has guided the birth of an offshore wind cost calculator like no other. The calculator, a mathematical formula, allows users to input a variety of data in a standardised way to arrive at a levelised cost of energy (LCOE) that all can agree on. LCOE, by definition, is the production cost of each unit of electricity generated over the working life of the plant taking into account a wind farm’s development cost, capital investment, financial costs, and lifetime running costs, net of inflation.

**Lower risk premium**

"Depending on the methodology used, two persons can reach very different estimates of LCOE for a planned wind farm simply due to differences in calculation method," says Jakob Lau Holst, Megavind’s caretaker. "There are many ways to model it in a spreadsheet. When a turbine manufacturer negotiates terms with a utility customer and each using different modelling, agreement on finer details is made that much harder. As a result, both will add a risk premium which pushes up the LCOE," he adds.

A common industry standard for LCOE modelling solves the problem. It enables like-for-like comparison of wind farm costs; it helps pave the way for common efforts to cut costs by identifying main cost drivers and their relative potential for LCOE reduction; and it provides a basis for benchmarking progress towards the minus 40% goal.

**Tested by leaders**

The cost calculator’s design mirrors that already used by the offshore wind industry to evaluate the cost elements when deciding to invest in a project. It has been tested in a collaborative effort by the companies who initiated it: DONG Energy, Vattenfall, E.ON, Siemens Wind Power, Vestas Wind Systems, MHI Vestas Offshore Wind and DTU Wind Energy, a Danish research institute. The group is fiercely committed to lowering the LCOE for offshore wind and sees the

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**Standardised calculation of LCOE avoids the addition of a risk premium**

Wind turbine pilots flight simulator

Using flight simulator technology to test a drive train’s ability to withstand loads promises better, faster and cheaper testing of new turbines

Researchers at Denmark’s Aalborg University in Northern Jutland have teamed with R&D A/S, an Aarhus-based consulting engineering firm, to develop a simulator designed to test wind load on turbines more effectively and inexpensively.

At the centre of their efforts is the same kind of hexapod technology used in flight simulators. A hexapod robot has six independent hydraulic cylinders, or actuators, and is able to move in any direction or orientation. That way, researchers say, the system will be capable of simulating any kind of wind-induced load to the turbine drive train that a manufacturer wants to test.

**Mechanical wind tunnel**

“Bearings, transmission, generators and various connections can all be exposed to various degrees of highly precise stress and the effect of each individual part can be evaluated very accurately,” says Jes G Andersen, a civil engineer at R&D A/S and the project leader. Hexapod technology is also simple and replicable, he adds, making it less costly than typical one-off test bench designs.

The aim of the three-year project, which has a DKK 12 million budget (€1.6 million), is to create what is essentially a mechanical wind tunnel, capable of replicating the exact loads a wind turbine would be subjected to in real-life situations. It provides a much more realistic test than is typical today. Right now, most of the lifetime tests of wind energy systems are based on subjecting components and subsystems to simplified cyclical loads on test beds.

“Today there is a tendency to create wind loads in such a simple manner that they create errors and points of failure that might not happen in a real-life situation. You simply will not find the correct issues,” says Andersen. “The more realistically applied the pattern of wind load is, the better chance you have of finding the errors and points of failure that will go on to be problematic and expensive.”

**Energy efficient**

The goal is to compress the entire 25-year lifetime of the wind turbine into just half a year of testing, allowing turbine manufacturers to bring technology advances to market more quickly. And because recreating a quarter-century of wind load requires massive amounts of electricity, accounting for as much as 30-50% of the costs incurred on test systems available today, the Aalborg and R&D team is also aiming to come up with a design that maximizes energy efficiency and reuse.

The team includes four people from Aalborg University, which has emerged as one of the world’s leading centres for wind turbine technology research, and eight from R&D A/S, which has extensive experience in developing test systems for wind turbines.

The project is receiving DKK 8 million (€1 million) in funding from the Danish Energy Agency’s Energy Technology Development and Demonstration Programme.

**Complex loads:** In a flight simulator (right) the six legs of a hexapod robot allow the cockpit to move with six independent degrees of freedom, simulating pitch, yaw and roll. Replace the cockpit with the hub of a wind turbine and the technology can be used to simulate wind induced load on the components.
calculator as a first step towards accurately measuring and monitoring industry progress. Moreover, depending on the granularity of data available, the model allows the user to look at lifetime cost of the main components and contracts in a wind farm starting from the point it is coupled to the onshore grid. Differences in national market structures are also accommodated for in the formula.

Publicly available
The cost calculator is publicly available as an open source calculation sheet for downloading from Megavind’s web page on the website of the Danish Wind Industry Association (megavind.windpower.org). Competitive interests do not allow the model presented to be populated with data, but Megavind encourages third party consultants to enter their own data for public use.

The calculator was created for Megavind by ESP Consulting, an energy consultancy operating out of London, Copenhagen and Amsterdam.

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Big scale test facilities indoors and outdoors

Shortening the time it takes to get a new wind turbine off the drawing board, through testing and onto the market is a sure path to cutting costs. The option to put complete nacelles through their paces on a purpose built indoor test rig with full grid interaction before further testing at an open air site is unique to Denmark. Cost savings promise to be substantial.

In one of several huge buildings occupied by a variety of companies at Denmark’s Lindø Industrial Park a massive new wind technology test rig is providing offshore turbine manufacturers with a unique window into the complex interactions between next-generation wind turbines and the grid infrastructure they feed. Advanced grid simulation and accelerated testing of how a huge modern wind turbine not only performs, but integrates with the grid, answers a pressing need of the entire wind industry in its efforts to cut costs and de-risk new turbine designs.

The rig opened for business in September last year and is part of the technology testing facilities offered by LORC, an offshore renewables test centre inaugurated at the former Lindø shipyard in 2010. At Munkebo, on the north coast of the main island of Fønøen that makes up the centre of Denmark, LORC’s location benefits not only from the sheer scale of facilities available at the one-time shipyard, but also from the site’s direct link to the Kattegat Sea. That provides access to both the North Sea and the Baltic Sea, hotbeds of offshore wind development.

Grid code tests made easy

A nacelle installed on LORC’s function test rig, which was built by American General Electric, can be run with a real-life 33 kV connection to see how it performs on a normal grid, or tie into an artificial grid that can test how the turbine will behave in a range of extreme and rapidly changing conditions. “We have variable voltage all the way up to 40 kV and down to, in theory, zero,” says Lars Stylsvig Rasmussen, LORC’s program manager. “We can supply any voltage amplitude we want to the nacelle.”

That capability allows manufacturers to easily assess how the turbine rides through voltage dips and temporary over-voltage conditions. The rig also enables them to
perform necessary grid code tests that can be difficult and slow to complete in the field, or at a conventional wind turbine test site, where technicians must work with the available wind, or wait for a suitable wind strength.

“The standards today describing how to do these grid tests say you have to perform all the voltage tests at very low load, perhaps twenty per cent of the nominal turbine. Then you have to do it again at fifty per cent power and also at ninety per cent and above,” Rasmussen says. “On site you have to wait for these conditions. You have to set up your equipment and then you have to wait for the wind to be at the right level in order to conduct these tests. At our facility, we just have to program it in.”

**A virtual wind farm**
LORC’s function tester can also manipulate grid frequency in a range of 45-65 hertz, something not possible in the field, which can help uncover potential electrical malfunctions and faults in turbine protection systems that would otherwise be difficult to detect. Eventually, it will also be able to simulate operation in a full wind farm, allowing manufacturers to test how the turbine behaves in relation to the rest of the plant and how the output of the wind farm varies during a variety of grid events.

The centre’s grid testing capabilities are part of a highly integrated system that assesses not only how the turbine interacts with the grid, but how its hardware systems interact with each other and with the turbine software. One of LORC’s unique features, says Rasmussen, is that the nacelle is tested with the rotor hub attached, something no other facility can do.

**Mirroring real life**
“We have the hub included, and we also have the pitch system active. So the same controllers that are reacting in the field are reacting in our test set up. When you do a test in our facility, where you can for example, change the wind speed from ten metres a second up to twelve metres a second and then down to seven metres a second, the turbine will react the same way here as it will on site,” he explains. “We are able to perform the most realistic trials in the world.”

The ability to efficiently and effectively test turbines in all sorts of normal and abnormal operating conditions should drive down the development time for new offshore products, says Rasmussen. “When you develop new turbines you can cover a lot of the testing in facilities like this instead of waiting for the turbines to be erected offshore or onshore test sites. And when you have new versions of existing products, like the tendency now for a lot of manufacturers to power up their turbines a bit, that implies a lot of retesting. That will be quite easy to do in a facility like ours, where you can very quickly learn how the systems will react.”

**The great outdoors**
The LORC facility is an important complement to Denmark’s state-of-the-art National Test Center for Large Turbines at Østerild, says Jakob Lau Holst at the Danish Wind Industry Association. The Østerild centre, opened in 2012, has seven test stands designed to accommodate turbines with tip heights of up to 250 metres, a capability unmatched at any test site in the world.

“The site at Østerild is also unique in the sense that during one year, you can make a full power curve test between ten and twelve times because the wind regime at that specific location is so harsh and extreme. It resembles North Sea conditions because it is fairly close to the North Sea coast in one of the most windy regions of Denmark,” says Holst. “Most of the wind conditions that a wind turbine will meet anywhere in the world will happen at that site.”

While prototype testing of fully assembled wind turbines is essential, it is also expensive. It can cost up to €50 million to test a turbine for two years at Østerild, says Holst, making an indoor test bed like LORC an attractive option for early-stage testing of new technologies. “We can start testing the wind turbine or nacelle before we take it to prototype testing, so we can weed out a lot of problems before we get to that more expensive stage.”

**Test and test again**
If issues do show up on prototype machines, LORC is a place where wind turbine engineers can test and refine possible fixes, Holst adds. “It’s a way of looking at many angles of the same type of fault, again and again and again.”

Vestas Wind Systems, the onshore Vestas business, is leasing the facility on behalf of Denmark: A United Industry Thinking Big
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of MHI Vestas Offshore Wind. It is the first wind company to use the LORC function tester, leasing the facility for 30 months with plans to put the new MHI Vestas Offshore Wind V164 8 MW machine through its paces. But first it is conducting testing on a V112-3.3 MW nacelle, a wind turbine model used both onshore and offshore. “The 3 MW from Vestas is a pretty proven platform, so we haven’t had the big findings yet. But of course we learned a lot about different test programmes and different ways to solve issues that we find along the way. There are months of preparation for testing of the next-generation turbine, where I expect to have much more findings because it is a much newer product,” says Rasmussen.

Vestas is not ready to say when it will bring the V164 nacelle to LORC, says Albert Winnenmuller from MHI Vestas Offshore Wind where he is chief project manager for the model. Like Rasmussen and Holst, however, he sees the new facility as key to the industry’s efforts to frontload as much functional testing as possible to mechanical test rigs before prototypes are erected outdoors. “Testing the power train and nacelle in a controlled environment in test centres allows a deeper understanding of turbine operation prior to a prototype installation,” he explains. “This will result in prototypes performing to a higher capacity in a much shorter time and reduce time required for field testing and therefore reduce time to market.”

With the function tester operational, LORC is in the process of sorting out financing for a second, adjacent test bench that will house a highly accelerated lifetime test (HALT) rig. Focussed more on mechanical issues and the lifetime durability of the turbines and their components, it is expected to start operating in 2016.

Public-private collaboration

LORC expects to follow a similar model to fund the HALT facility as it did the function tester, which was built with a DKK 76 million (€10.2 million) grant from Green Labs DK, a government source of funding for test facilities, and nearly DKK 100 million in private investment, including contributions from a group of industry heavyweights that includes turbine makers Vestas Wind Systems and Siemens Wind Power, Danish power company DONG Energy, a heavyweight offshore wind player, and the University of Southern Denmark.

LORC decided to go with a twin-dock approach to provision of test rigs after extensive consultations with its founding companies and other industry players. Different companies had different needs that could more easily be met with two test benches, explains LORC CEO Torben Lorentzen. “It means we can have two customers in at the same time and we do not have to charge a price for a facility that has other capabilities than what the customer wants to pay for.”

LORC is also working with Denmark’s FORCE Technology, a specialist engineering knowledge company with annual turnover of DKK 1 billion (€134 million), to build a facility that will test the design and robustness of substructures like foundation joints. The collaboration will also include a climatic chamber that will expose components to the extreme temperature variations and corrosive environments found offshore. Furthermore, a welding centre will explore new production methods using high-power lasers.

Putting the power train through its paces in a controlled environment reduces the time spent on field testing
The widespread adoption of basic safety training standards in the offshore wind sector is a critical step towards protecting workers at sea and in the port, especially as the industry continues its expansion into new markets and locations far from land.

“Training people in the same way to the same set of criteria saves lives. It is as simple as that,” says Jakob Lau Holst, chief operating officer of the Danish Wind Industry Association. A beneficial spin-off is that standardisation of training also lowers cost.

The Danish association was contracted last year to host the permanent secretariat of the Global Wind Organisation (GWO), a group of 13 leading wind turbine manufacturers and project owners that came together in 2009 with the aim of creating an injury-free work environment across the industry. At the time, says Holst, each company was responsible for its own safety training. That meant that a Siemens technician working on a DONG Energy project, for example, would have to go through at least two different safety courses.

Simpler is safer
“The complexity was too great. There were double training budgets and a waste of valuable time,” says Holst, who acts as the GWO’s chief secretary. “More importantly, because a worker could be trained in slightly different ways, there was also a greater risk for that person. If your trained response to a given situation varies from one company to another, the differences add to the risk in potentially harmful situations.”

The GWO has created a basic safety training standard, with five modules covering both the onshore and offshore sectors. It also laid out a process where training providers could be certified. So far, about 100 companies have met its criteria and offer one or more of the GWO-approved training modules.

“That is not a lot. We need several hundred,” says Holst. “Right now, we cover northern Europe pretty well and some areas of the US. We hope to increase the number of certified training providers everywhere, including emerging markets and in Asia.”

Industry standard
Working with an established industry group like the Danish Wind Industry Association is a practical way for GWO to speed implementation of its standard. It is also working with British wind association RenewableUK to launch an online database this year for companies to check if a person has been trained to the GWO standard. The fact that GWO’s founding members represent about 80% of the offshore wind market should also prompt training providers to get certified, adds Holst. “We expect this will spread as an industry standard pretty fast.”

GWO is maintaining the standard, incorporating the wind industry experience of Danish based companies like DONG Energy, MHI Vestas Offshore Wind, Siemens Wind Power and Vestas Wind Systems, but also Maersk, the Danish shipping and offshore oil giant, Denmark-based global training provider Falck Safety Services, and others active in the sector. It also plans to roll out new safety training standards for technicians.

Global mindset
Holst believes the selection of Denmark as headquarters for GWO reflects not only the Danish industry’s commitment to collaboration, but also its broad global experience in wind, particularly offshore. “We know as global players that we need to find a way of working that fits into the setting of every major market in the world,” he says. “That is the mindset that Denmark brings to this.”

Practice makes perfect: Application of one set of safety rules by every company at every stage of every offshore wind project will not only save lives, but money too

Photo: Viking
Wind turbine manufacturers today require systems and solutions from the supply chain more than individual components from a range of companies. Sub-suppliers that form alliances and present packaged solutions will be tomorrow’s winners, says Morten Basse, CEO of Offshoreenergy.dk, an industry knowledge and innovation network. His organisation helps facilitate alliances among Danish wind industry suppliers aimed at delivering total solutions to specific industry challenges.

For the big wind turbine producers, contracting a series of expert companies individually to each provide one part of a total system is time consuming and costly to manage compared with managing a single interface with an allied group. Denmark, with its myriad of small companies with specialist wind industry knowledge, often run by people with years of shared industry experience, is ideally positioned to respond to the new trend, says Jan Hylleberg, CEO of the Danish Wind Industry Association.

“Danish companies have been good at organising themselves in groups and cooperative constellations to supply a complete solution. Suppliers who before delivered directly to the big producers now deliver to other sub-suppliers who take care of the direct relation with the wind turbine producer,” he adds.

An example is KK Wind Solutions which last year changed its name from kk-electronics to reflect its changed business strategy from simply delivering electronics for wind turbine control systems to being a systems and solutions provider. “We partner with customers at every stage of the value chain, from development of systems to manufacturing, supply chain solutions and service in the field,” says CEO Tommy G. Jespersen.

Among others, KK has formed an alliance with Danish Total Wind to extend its offering beyond the turbine and into high voltage services such as grid connection of wind turbines. It is also working with Danish blade supplier LM Wind Power on embedding sensor technology in blades to feed wind speed and direction information to the turbine control centre.

KK has served the wind industry for 35 years. With a staff of 800 it operates out of six countries, including the US, China and Korea.

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Innovation in infrastructure

In industries still maturing the scope for cost reduction is huge. Offshore wind is no exception to that rule, particularly with regard to the “balance of plant”, or non-turbine parts of a project. These have a shorter industrial history than the wind turbine itself and represent a larger chunk of the total expenditure, so promise most potential for savings through innovation.

For the offshore wind industry, cost reduction is not just about perfecting specialised wind turbines for use at sea but also about optimising all parts of a project. On land a wind turbine represents 75% of a project’s cost, but offshore the cost of the turbine is less than 40% of the total capital expenditure. The balance of the remaining outlay goes to project development and financial costs, the electrical infrastructure, the turbine foundations, and to pay for construction.

Cost cutting innovations in this “balance of plant” are essential for further improving the business case for offshore wind and making it affordable for society, says Michael Hannibal who heads up the offshore unit at Siemens Wind Power. “Even if we gave the turbine away for free we still wouldn’t be able to cut overall costs by 40%,” he notes, referring to the offshore wind sector’s agreed 40% goal for cost reduction.

“We need to look at whoever can contribute, make it affordable and non-subsidised long term, a viable business to be in, for utilities and for the entire value chain. Then we need to make sure that all parts of the value chain are being analysed, look at where we have waste contributors, where do we lose time, momentum, where do we spend money on something which may not contribute to value,” he says.

“But we cannot reach the needed levelled cost of energy alone. We need the foundations suppliers, the designers, the electrical systems and the designers of the electrical systems and we need the authorities to work with the industry. Rules, regulations, standards need to support lean ways of doing it, and support cost efficient ways of doing it,” says Hannibal.

Application of improved technology and implementation of better procedures and processes will by definition reduce capital expenditure (CAPEX). Savings in CAPEX, however, are a false economy if they lead to a reduction in quality that raises spending on unplanned maintenance and repairs during the operating life of both the wind farm and its infrastructure, including the electrical hardware. Getting the balance right between reducing CAPEX while at the same time boosting quality and reliability to also reduced operating expenditure (OPEX) is a critical challenge.

Simplified grid

Siemens is aiming at both CAPEX and OPEX reductions in a radically new approach to electrical infrastructure for offshore wind. “When it comes to the grid, then of course Siemens is one of the leading grid provider companies, grid solution companies, so we have been looking at how we can play an even larger role in that part. We have had a cross-regional, or global set-up of people working on the issue of doing this radically smarter,” says Hannibal.

He declines to reveal further details ahead of the EWEA OFFSHORE 2015 event, where Siemens Wind Power is presenting its new transformer solution. “We are extremely proud of this, it will contribute to the equation of bringing costs down and make it affordable to have a cleaner society,” says Hannibal. “This will be a significant contributor to an extremely simplified grid solution. It will ben-
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A decent jacket
For long-term owners of offshore wind plant like Siemens Wind Power technology, reducing OPEX as well as CAPEX is paramount. In most areas, revolutionary innovation in balance of plant is unlikely, believes Samuel Leupold, wind business CEO at DONG. “I see more evolutionary steps,” he says. DONG’s work on developing robust foundations that cost less to build and install exemplifies this approach.

“We have pretty much already optimised the monopile solution,” he says. But small incremental improvements can still be achieved through data collection and analysis that allow critical reviews, such as for the design load assumptions that decide the dimensions of a monopile and how much steel has to be paid for. “We have indications that design loads in the past were rather on the conservative side,” he says.

DONG has raised its sights beyond monopiles, however. Larger projects require larger sites and this often means moving further from the coast where deeper water is more likely. “That requires jacket foundations,” says Leupold. He is convinced an optimised jacket foundation design “is the next thing the industry needs” to take it into deeper water.

“If you look at the market today, nobody really has a jacket that looks like an industrialised jacket fit for mass manufacturing,” he says. “We are working hard on that.” DONG’s focus is on a jacket with suction buckets that can be mass manufactured and adapted to a variety of seabed conditions (box). That will dispense with the practice of using specific types of foundation for specific seabed terrain, even within the same project. The key is to use standardised components and sub-modules, says Leupold.

Siemens new concept
Siemens Wind Power shares that view. “We can use the same tools as we’re using today to industrialise foundations. Serial production, breaking it down to components that can be transported around and bought in bulk,” says Jesper Møller, head of offshore concepts and solutions. The new Siemens foundation will most likely be a hybrid jacket, partially gravity-based,” he says. The concept has been developed with the support of Danish engineering company Ramboll.

“It’s not decided yet whether Siemens will produce the new foundation itself. It’s not important for us. We’re not doing this to get a share of the foundation market but to make foundations affordable for our customers so they can buy more turbines,” says Møller. With a target to cut foundation costs by 40% the company has reached about 33%. An innovation project launched 18 months ago to reduce the cost of a jacket foundation from €6 million to €3.6 million has hit the €4 million marker.

All aspects of the process have been analysed to identify savings, not just in manufacturing and installation, but also in the equipment needed in the vessel business to support the new concept, the interface with the turbine and the access for maintenance work, adds Henrik Lynderup, head of sub-structure technology.

Future foundations
In separate initiatives a range of Danish companies are developing and testing radically different types of foundation. What they have in common is that all are designed for use in relatively deep water, using simplified installation processes that reduce the costly reliance on specialised vessels. Savings from advances in foundation technology are expected to cut 10% off the cost of offshore wind generation, according to The Carbon Trust, a British institution backing several R&D initiatives through its Offshore Wind Accelerator programme.

Jacket with suction buckets
Borrowing a well-known technology from offshore oil and gas platforms, DONG Energy has installed the first jacket foundation with suction buckets for use with a wind turbine. The full scale prototype, with suction buckets on each of the jacket’s three feet, is being tested and monitored in a proof-of-concept project at the Borkum Riffgrund 1 offshore wind farm in Germany. Each nine metre diameter steel bucket is sucked into the seabed by the application of negative pressure. With no piling it is a noise-free and single-lift installation process that can be done without the use of expensive jack-up vessels, says DONG’s head of wind Samuel Leupold. The suction bucket jacket can be used in water depths of 30-60 metres.

“It has experienced its first winter storms sweeping across it, so we are already measuring how the structure behaves on the seabed under real conditions,” Leupold says. “Next we will install the turbine on it and then we will monitor.” That monitoring will be over a 12-month period. “We are very confident that the data will confirm that this is a concept we can apply going forward.”

The suction bucket jacket is designed by DONG Energy and Dutch SPT Offshore with technical support from large Danish engineering firm Ramboll and backing from The Carbon Trust.

Single giant suction bucket
Denmark’s Universal Foundation, owned 82% by Norway’s Fred Olsen group, has completed advanced trials of its single suction bucket concept, installing and retrieving a scaled down eight metre diameter version in a variety of soil conditions under the North Sea. The functionality of the internal top soil levelling system is proven and marks a major step in the de-risking of suction technology, says the company’s Lars Kjuel Kristensen. Combining the benefits of a gravity-based foundation, a monopile and a suction bucket, it can be installed in a wide variety of seabed conditions and has the potential to be significantly cheaper than the monopile or jacket solutions. Combined with universal substructure technology, it can be used in a variety of water depths to depths of 100 metres and beyond.

The skills and equipment needed to install the suction bucket jacket will be commonplace. According to Leupold, “So it’s not far-fetched that we could see the jacket foundation making a significant impact on the offshore wind market in the next 15 years.”
Scale up and be selective

Bigger projects, bigger turbines and strict discipline in selection of sites will drive down costs with immediate effect. But the opportunities bring challenges too

By far the biggest potential for bringing down the cost of an offshore wind megawatt hour over the lifetime of the plant is to scale up the size of projects and build them in the right place using larger turbines, says Samuel Leupold, who heads the wind business at Danish power company DONG Energy. “Small sites without optimal seabed and wind conditions are just driving cost in the wrong direction,” he says.

Projects of 200-240 MW have been too small. DONG will avoid these in future. “Let me be very clear. These sites do not have the right size,” says Leupold “We need to go to larger projects, larger site sizes, construct offshore wind in tranches of six-hundred or more megawatt at a time, and we need to apply even larger turbines in the future.”

Bigger projects allow for a portfolio approach to construction. They reduce unproductive time between one project and the next, particularly when vessels are laid off only to be called up again a couple of months later. “This is driving costs up because there is a lot of changeover in mobilising and demobilising and pushing up overall installation time,” says Leupold.

In a young industry he speaks with the voice of experience. Not only has DONG built more offshore wind than any other company, it also owns 26% of the world’s around 8.5 GW of operational capacity, a larger slice than any other single investor.

The new normal

“We’re going to significantly increase the size of the projects in order to support our cost-out target,” says Leupold. DONG is already making good on that promise, he notes, pointing to its recently consented 1200 MW Hornsea project in the UK and the two-part German Gode Wind project now under construction. Combined and built by DONG as one project, Gode Wind amounts to 582 MW using a single turbine model, the new generation Siemens 6 MW machine. All 97 Gode Wind turbines are scheduled to be fully commissioned in 2016.

Crane free gravity foundation

A gravity based foundation developed by Seatower, a Norwegian firm with a strong complement of Danish staff, is expected to be a game changer in the industry, says company CEO Petter Karal. “It will bring down costs significantly because it doesn’t require large installation vessels, only simple tug boats,” he says. Gravity foundations are towed to their destinations and can be efficiently mass produced. Danish engineering group MT Højgaard has installed a prototype of the Seatower foundation off the French coast. It is a “big leap forward” from the older types of concrete foundations used in Denmark’s first offshore wind farms, says the firm’s Kim R. Andersen. A hollow structure made from concrete and steel, it is well-suited to deep water, he says. After seabed preparation the foundation is pumped with seawater and sunk into place. Gravity is cheaper than steel, notes Karal. Several foundations can be installed in parallel within a short weather window, also in high waves, says MT Højgaard. The prototype is being tested at the French Fécamp 498 MW offshore project being developed by Eoliennes Maritimes France, a consortium comprising EDF Energies Nouvelles, DONG Energy and Germany’s wpd Offshore.

Scale up and be selective

Bigger projects, bigger turbines and strict discipline in selection of sites will drive down costs with immediate effect. But the opportunities bring challenges too
Rethinking offshore wind construction

More efficient working practices on land and offshore, standardisation of routines and systems, technology advances to eliminate costly processes. These are the immediately available options for reducing the cost of building offshore wind facilities. Danish experience puts them well within reach.

Cheaper, quicker and safer construction is a key focus for the offshore wind industry in its efforts to drive down cost. As the industry matures so does its understanding of what to pay attention to and where to save. Four distinct paths for advancing best practice construction have emerged: improved onshore logistics, standardisation of parts and processes, less use of highly specialised construction vessels and expanding the window of suitable weather for working at sea.

“A significant part of where you get the efficiencies from is the people that are designing around the operation. The know-how and engineering skills within your teams. These make the difference. That is really key to getting full efficiency out of a vessel in this industry. It is not the steel box or vessel itself,” says Jens Frederik Hansen, CEO of Danish vessel supply and offshore wind contractor A2SEA. “This is what we prove daily at A2SEA.” As contractor it has been involved in around half of the installed offshore wind capacity in Europe.

Harbour logistics

“It is about planning the work by making the maximum utilisation of what you can load and how you can operate with the vessel when you get offshore,” he adds. Those skills are anchored in the onshore engineering organisation. Logistics onshore need to be optimised in terms of port facilities and transport distances. Hansen continues, citing Denmark’s Port of Esbjerg as a good example. “If harbour logistics could be optimised in several more places that would lower some of the transport distances that we spend hours sailing,” he says.
Standardisation

A key problem across the industry is a failure to align construction and installation standards and best practice processes. “The wind industry has still not been able to come together to try to harmonise some of the issues that are going on or that the industry could benefit from,” says Hansen. Customer requirements and specifications can vary dramatically from case to case, country to country. “It would be easier for the industry if you adapted from a set of standards. The process can be streamlined and I expect the lead developers will drive such standardisation.” From MHI Vestas Offshore Wind, Bo Bjerregaard agrees. The different requirements of customers can increase complexity he says. “Every time you have to do things differently, you have to mount things differently. Some customers want an extra USB at the bottom of the tower; another wants an extra sign on top of the nacelle, some on the doors, and so on,” he says. “You cannot standardise everything, but if we could start to standardise things even on a small scale that will really be good for the whole industry.”

Hannibal’s vision is clear-cut: “Hopefully we can have all elements of an offshore wind farm streamlined across different countries working within offshore so we end up with a common European standard, a standard which may eventually end up being the benchmark standard and trendsetter for a global offshore industry.”

Expensive vessels

The offshore wind industry’s reliance on specialist vessels and cranes adds significantly to the cost of plant construction. Jack-up vessels with legs that extend to the seabed have been the essential workhorse for the industry, but they are expensive says DONG Energy’s head of wind, Samuel Leupold. One way of reducing their use would be to develop foundations that do not require piling, for which a jack-up is essential. That would help reduce costs significantly, he says.

“If you need to pile a jacket you need a jack-up vessel,” Leupold continues. “In the future, if you use suction bucket technology you can do that without using jack-ups. We can use a normal floating vessel using a dynamic positioning system and that is good enough for lifting the jackets into the sea.”

Bjerregaard also believes that rethinking the use of construction vessels can result in considerable savings. An installation vessel typically costs around €220,000 a day and cranes have limitations, he says. “It may be more up to us to think a little bit different about the way we design the feeds and design the frames — a tool that can do the same for the tower as for the nacelle that you can use for more purposes. We are looking into a lot of different options to ensure that we are not that dependent on big cranes.” From A2SEA, Hansen says the vessel supply industry is, “Pretty well prepared for the upgrade to a larger size of turbine.” At the same time, vessels coming onto the market since 2012 can operate in higher waves than previously, expanding the weather window for construction. “A real gain in the efficiency of turbine installation is coming from minimising the time you spend waiting for better weather,” he says. Hansen expects further improvements in vessel design.

Time savers

Expanding the weather window is as much about the right procedures as the right vessels, says Leupold. Partial pre-assembly of rotors onshore to enable full rotor lift would logically suggest shorter installation time, but DONG has discovered otherwise. “You cannot do that if the wind is more than seven to eight metres a second and therefore we have changed to single blade lift,” he says. Lifting one blade a time can be done in winds of up to 12 m/s, he adds. “You can finalise the whole campaign for the project in shorter time and you can send home the very expensive installation vessel earlier on.”
Hansen is sceptical about suggestions that money could be saved by towing complete wind turbines to their destination as a floating structure for sinking to the seabed. “The weather windows and the sailing conditions you require to bring completed turbines offshore would completely change the efficiency of offshore wind dramatically,” he says. “Weather-wise, you would only have limited windows where you could take the fully assembled turbines offshore. I think it would be a step back. You could save some hours for offshore assembly but on the other hand the weather windows needed for shipping or taking the full complete turbines offshore would definitely be affected negatively.”

He applies the same reasoning to the use of large floating cranes to install offshore wind turbines as has been seen in China. “Should similar things be constructed in Europe it would be extremely expensive,” he believes.

Floating foundations
Some research by Danish companies into eliminating the cost of construction at sea through the use of floating offshore wind turbines is ongoing. Engineering group Ramboll is conducting research into wave forces together with Aalborg University in a project with government backing and in 2011 Vestas Wind Systems provided a 2 MW turbine for the WindFloat experiment in the Atlantic Ocean off Portugal, a project it participates in with Energías de Portugal and American company Principle Power. Vestas provides it with service and maintenance. From MHI Vestas Offshore Wind, Matt Whitby says the project is going well but the company has nothing further to add.

Pre-assembly for plug and play

Years of experience installing offshore wind turbines has taught MHI Vestas Offshore Wind that the more assembly and commissioning done on land the less money spent at sea. “What we are aiming for is to build our offshore projects onshore,” says the company’s Bo Bjerregaard, head of pre-assembly. “We do what we call pre-commissioning, meaning that we have tested the tower, nacelle and everything, including all the high voltage parts.”

Such pre-commissioning pays off. “Today we are testing all our switchgears. We are testing all our ancillary systems, testing basically everything.” The result is enhanced technician safety and less spent on troubleshooting. “Every time we have a technician in transit it’s also a lost technician hour,” he says. “Our aim is plug and play solutions.”

On the dockside
Key components produced in the factory are trucked to portside facilities at Esbjerg, Denmark’s major offshore wind construction harbour, where the pre-assembly work is done. “The hub and drive train are already pre-assembled on the nacelle. We put in the cooler, get all the tools in the right spot and pre-commissioned,” Bjerregaard says. “The tower is where we have the majority of the work, dealing with all the cables,” he adds.

“That means when you go into a tower it will be exactly as if you’re going into a new installed onshore tower or turbine. You go in, you open the door, you turn on the switch for the lights, you will be able to use all electrical outlets, can take the lift up. Everything is in place, in good order, completely clean and ready to use. That’s exactly how we will receive the tower offshore.” Once pre-commissioned it is loaded as a single component onto the vessel in an upright position.

Rotor blades come complete from the factory. “We don’t have to do anything to them except load them onto the vessel,” he says. Using a proprietary “blade stacker”, MHI Vestas Offshore Wind has transformed its blade handling procedures. “Before we had nine different handling stages and now we only have one.” Blades are moved from the truck straight into the blade stacker, which is raised onto the vessel in a single lift.

The components for eight turbines at a time are hoisted aboard and on their way in no more than 48 hours, says Bjerregaard. “Then we install in five steps.” Pre-assembly has shortened the whole process considerably and placement of the tower, nacelle and blades is done faster than for an onshore turbine, he adds.

Provided harbour facilities are sufficient to support the “plug and play” approach and size of vessel required, Bjerregaard sees it being adopted as standard for deployment of the V164 8 MW turbine anywhere in Europe. He believes the costs benefits will be substantial. “If we can save time then we can also save cost and at the end of the day it will also save our customers. They will be more competitive that way.”

Additional reporting by Karin Jensen
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Expertise flows two ways across the Atlantic

From turbine technology to engineering know-how and financial project management, Danish offshore wind expertise is in demand overseas, also in the United States. But know-how can also flow two ways. The sheer scale of American big industry means there is also much it can bring to help industrialisation of offshore wind in Europe.

Denmark’s offshore wind industry has had significant success developing local partnerships in key offshore markets around the fringes of the North Sea, like the UK, Germany, and the Netherlands. But the business case for doing the same in the far-off United States is less clear cut. The Atlantic Ocean, however, is revealing itself to be not so much a barrier as a breeding ground for know-how exchange that is set to bring the benefits of foreign investment to both European and American shores.

One way to forge a connection between the Danish and US offshore wind industries is to create partnerships that allow American companies to get their feet wet in European waters, says Morten Basse, CEO of Denmark’s Offshoreenergy.dk, an industry innovation and networking group. “We are not just focusing on how we can bring Danish companies out into foreign markets, but also how we can bring US companies to Europe and involve them in projects. They have enormous reserves of knowledge and experience in large scale industrial manufacturing to share with us,” says Basse.

Back in November 2014 he joined 19 Danish offshore wind companies on a trade mission to the US, travelling the east coast from Massachusetts to Virginia visiting man-

Text: Diane Bailey
ufacturing facilities and meeting with local officials.

**Nuclear submarines**

“In America they have capabilities and manufacturing capacity on a different scale than many European, particularly Danish, companies. While we were on the east coast, we talked to a shipyard that is building nuclear submarines. So don’t tell them about safety, about systems, about engineering and about building on a large scale. We can’t teach them anything about that,” says Basse. Indeed, Americans can likely help Europe industrialise offshore wind on a scale unknown so far by bringing cost-efficient processes across the ocean. “In return we can teach them about specific applications within the offshore wind industry,” says Basse. “It should be possible to bring these things together. At least we have planted the seed.”

The current uncertainty surrounding the American offshore wind business is a challenge, Basse admits. Danish companies are still waiting for a project to near construction more than 14 years after the 468 MW Cape Wind development off the coast of Massachusetts was announced.

“The problem in the US is that right now there is just Cape Wind and a few demonstration projects,” says Basse. But the worse thing Danish companies can do is sit on their hands, he adds: “It becomes a Catch-22 situation. We cannot just wait and say we’ll come back in five years and see whether there is any volume or not. By then the US offshore projects may well have materialised, but we won’t have nurtured the right connections to be a relevant partner if we lie low now.”

From November’s trade mission, the message from the US states is that they are not just interested in building offshore wind projects, says Basse, but in creating an industry. That is key to taking advantage of the US opportunity, agrees Mark Rodgers at Energy Management Inc (EMI), the Massachusetts-based company developing Cape Wind in Nantucket Sound.

“It is important that Danish companies looking to the US offshore wind market understand that we need to build a domestic offshore wind supply chain while continually increasing the percentage of jobs associated with these projects being supplied domestically,” Rodgers says.

The Cape Wind team, he says, has looked to Denmark for lessons on how to make the fledgling US offshore industry’s flagship wind farm a success even before announcing the project. “We visited some of the early Danish offshore wind farms such as Middelgrunden and met with Danish companies involved in the offshore wind sector,” says Rodgers.

**Historical collaboration**

“Denmark is a leader in offshore wind and we want our project to benefit from the knowledge that has gained over decades of time and dozens of projects. We might be building America’s first offshore wind farm but it will be the seventieth-something offshore wind farm in the world when it is built and the wind turbine doesn’t know whether it is in the North Sea or the Baltic Sea or Nantucket Sound,” he adds.

Whether Cape Wind turbines will be the first to start spinning in US waters remains to be seen. The project’s two utility customers dealt the embattled project a serious blow in January by cancelling power purchase agreements covering the first 364 MW phase of construction. But if and when the project finally goes ahead, Danish companies will have played a pivotal role.

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Hardware backed by finance

The Cape Wind team’s repeated trips across the Atlantic Ocean, which have continued throughout the wind farm’s development, helped draw Danish companies into the project. From Denmark, Siemens Wind Power is to supply 101 of its 3.6 MW turbines for the first 364 MW phase, with an option to add another 29 turbines later. It will also provide service and maintenance to the multibillion dollar project for the first 15 years of commercial operation. Denmark’s Bladt Industries, based in the north Jutland city of Aalborg, will manufacture the transition pieces for the turbine foundations, which have been designed by a consortium led by large Danish consultancy Ramboll. K2 Management, a Danish offshore wind project engineering and management consulting firm based in Aarhus on the east Jutland coast, is providing EMI with services ranging from the evaluation of foundation and electrical contractors to project planning and construction management.

While finalising financing has been a struggle, Cape Wind is also tapping into Danish financial services. Eksport Kredit Fonden, Denmark’s state-owned export credit agency, is providing Cape Wind with a $600 million loan guarantee tied to the use of technology from Denmark. Meantime, PensionDanmark has made a conditional commitment to providing a $200 million mezzanine loan to the project, making the investment through a fund managed by Copenhagen Infrastructure Partners K/S (CIP).

CIP’s five senior partners are all former top executives at DONG Energy and were directly involved not just in building the offshore wind business at the Danish state-owned company, but also in the construction and operation of some of Europe’s largest projects. That experience is what CIP can contribute to a US offshore wind industry still in its infancy and a North American financial community that has had little exposure to the technology, says CIP senior partner Christina Grumstrup Sørensen.

Lessons in risk

“From a financier perspective, there are many very professional and deeply experienced companies in the US. We, at CIP at least, are a small company with a niche focus. I don’t think we can teach them a lot about the financing world. I think it has more to do with how we view risk and get comfortable with the risk in this type of asset class. We can bring something to the table there,” she says.

Although CIP is confident offshore wind energy will eventually take off in the US, given the shallow waters, high winds and large load centres along the northeast coast in particular, exactly when that will happen remains unclear. The company is watching other potential projects as they progress. “We’re keeping our eyes open and having dialogues, but just on an informal basis so far,” Sørensen says.

The Maryland model

An agreement leveraging Danish expertise in offshore wind energy has helped the US state of Maryland carve out what it sees as a competitive advantage in the race to attract investment in the emerging American offshore wind sector.

The state passed legislation in 2013 creating a system of offshore renewable energy credits to stimulate development of up to 500 MW of offshore wind. It quickly turned to Denmark to help it navigate the regulatory and risk management issues associated with the plan’s implementation. The Maryland Energy Administration signed an agreement with the Danish Energy Agency (DEA) in November 2013 designed to give the state access to Danish experts and external advisors.

The Danish agency has acted as a resource for the Maryland initiative, says the administration’s offshore programme representative Ross Tyler, sharing knowledge and practical experience on questions ranging from project permitting to transmission planning and grid integration. The partnership has also helped forge business connections between the two countries.

Avoiding pitfalls

“The DEA has taken the role of a quiet non-judgemental parent, which without prescriptive advice, has allowed us to forge ahead and proactively create the Maryland model for developing offshore wind,” says Tyler. As a result, Maryland has been able to avoid potential pitfalls as it looks to become a US offshore wind leader.

“The European offshore wind industry has an image that the US is one large market. This means when public news highlights the setback in one state, Europe sees this as a setback for the nation. It is important for each state to differentiate itself,” Tyler adds.

The agreement with the DEA, which had expired at the end of 2014, has been extended through June 2015 while the Danish government considers whether to continue the partnership for another two years. The agency’s participation has been funded through a Danish government programme, established in 2013, that is providing DKK 5 million (€672,000) over two years to foster climate-related bilateral cooperation with governments in one or two industrialised countries.

Massachusetts too

“Maryland is not the only US state to look to Denmark for help in laying an offshore wind market. Former Massachusetts Governor Deval Patrick, who left office in January, led a delegation to Copenhagen in September to discuss cross-Atlantic collaboration.

“It is essential we establish strong relationships with industry leaders abroad so we can learn from their experience to grow the industry at home,” Patrick told Danish offshore wind industry leaders and government officials during the visit.
When Envision Energy CEO Zhang Lei wanted an offshore turbine able to withstand the typhoons that sweep across the waters off China’s southern coast he turned to Denmark for the engineering expertise needed to come up with a workable solution. Now with a 30-strong team of senior engineers located in Denmark at the Shanghai company’s Global Innovation Centre in Silkeborg, the next step is for Envision to transfer Danish know-how directly into its home market.

Envision is working with Offshoreenergy.dk, a Danish wind industry networking body, on an initiative that will connect offshore sub-suppliers in Denmark with their Chinese counterparts. The aim is to bringing much-needed experience to Chinese offshore wind, a market that despite government targets of 5 GW by 2015 and 30 GW by 2020, has yet to really take off. No more than about 450 MW is installed to date.

But things are moving extremely quickly, says Anders Jakobsen, business development engineer at Envision Energy Denmark. Envision won a deal from developer Longyuan Power last year to supply its 4 MW offshore model to the 130 MW Rudong Chaojiandai project in eastern China and is hoping that its plan to foster partnerships between Danish and Chinese companies will position it to capture a significant share of the market as it grows.

“It gives us a better business position in China because we are taking experience with us to the market,” Jakobsen says. By exposing Danish suppliers to the highly competitive Chinese market it can help them create efficiencies in their processes that they can bring back to Europe, he adds. “We want to restart the learning curve and hopefully make our Danish sub-suppliers stronger.”

Envision and Offshoreenergy.dk have brought together companies from across Denmark’s offshore wind supply chain, including component suppliers AH Industries and Ringkøbing Maskinværksted, installation and maintenance specialist Vento Energy Support, and transportation and logistics company Deugro. The group is planning its first trip to China.

The decision by a Chinese turbine producer to focus its research efforts in Denmark raised eyebrows at the time, says Jakobsen, with some critics worried it was out to steal ideas from a tight-knit Danish industry. But in reality, he says, setting up shop in Denmark made sense for a company bent on offering a high-quality product.

In Denmark Envision continues to test its innovative 3.6 MW prototype turbine with two blades, which was installed at Thyborøn on the windy northwest coast in 2012. Next up is testing of a three blade, 3 MW onshore turbine at the Danish national test centre at Østerild, starting in the spring.

Traffic grows on Chinese bridge to Denmark

Text Diane Bailey
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Best practice operational strategy

By taking full control of wind farm operation the owners can maximise financial output, which is not always the same as maximising electricity output. Flexible schedules and rapid response teams are a must. The emerging strategy is for owners to maintain a skilled in-house workforce but to outsource specific tasks to external professionals.

The challenge of maximizing production at offshore wind farms while at the same ensuring the long-term integrity of the turbines requires strong coordination between operational priorities on the one hand and the challenges associated with service, maintenance and repair of the hardware on the other hand, say two of the largest operators of European offshore wind facilities, both with bases in Denmark.

“It’s a big investment and of course you have to be very clear in your balance,” says Michael Simmelsgaard, head of global operations for DONG Energy. Few companies face a bigger challenge in maintaining that balance than DONG. The state-owned company is the world’s largest operator of offshore wind, with just over 2.5 GW spinning and a target of increasing that to 6.5 GW by 2020.

About 1 GW of DONG Energy’s operating portfolio lies off the coast of Denmark and some of those projects are among the longest-lived offshore wind farms in the world. It gives DONG unique insight into the most effective offshore operational strategy. And with just a three per cent loss in production because of turbine downtime in 2014, it appears the company is using those insights to good effect. “This is a level that is very close to what we see at onshore projects,” says Simmelsgaard.

On the surface, DONG’s approach seems simple. Make sure the turbines are generating for maximum production when the wind is blowing strongly and be ready to perform whatever maintenance is required when it is not. “We optimise our strategy to be able to be flexible in order to do the service and the preventive maintenance in periods of low wind,” Simmelsgaard says. “Even in the most harsh environment, we have 40 to 60 days a year where we can go out and do the work.”

Flexibility in outsourcing

One of the ways DONG Energy has created that flexibility is by having its own in-house operations and maintenance (O&M) team, currently about 500 strong. The company made that decision early on, creating a system where its staff work alongside teams from the turbine manufacturer during the warranty period to build up their knowledge and expertise.

“We didn’t want to be in a situation where our only choice at the end of a warranty period was to extend again with only one supplier. The market situation five years ago was that there was no one else,” Simmelsgaard says.
Denmark: A United Industry Thinking Big

Having in-house capabilities creates a pride of ownership that motivates the team

Michael Simmelsgaard
DONG Energy

Today, the field is much different. DONG regularly brings in hardware manufacturers and specialised service providers in key areas like blades and drive trains. It logged just under two million work hours at its project sites last year, Simmelsgaard says, the equivalent of about 1300 workers. That means that even with a base team of 500, the company had to contract out for up to 800 more. “It is more or less a mixture, making sure we have the right guys to do the right things,” he says. “We don’t want to do things where people are better at it in the market.”

Having in-house capabilities, though, carries a number of advantages. It creates a pride of ownership that motivates the team and gives the company a deeper understanding of the causes and costs of lost production, says Simmelsgaard. As important, it allows DONG Energy to take charge of maintenance planning and scheduling.

Owners in control

“It gives me the possibility to take the very clear decision on whether to leave the technicians on quayside today because production is too high, or to send them out.” Simmelsgaard says. “It is more difficult to write that into a contract with a subcontractor, to make sure the right balance is struck between production and hours in the turbine and the cost associated with that.”

European utility Vattenfall, the world’s second largest offshore wind operator largely thanks to its historical acquisitions in the Danish power system, also takes over O&M on its wind farms once the turbine warranty has expired. “We don’t necessarily do all the maintenance ourselves but we will be in control so that we plan what is going to be done and when to do it,” says Bent Johansen, Vattenfall Wind Power’s Danish head of generation. “We think that’s where we are going to create more value.”

Although weather is key to every decision on offshore O&M, other factors come into play. It is not just about maximising electricity output, says Johansen, but financial output as well. “When a turbine stops we always evaluate if we should send someone out there right away. That depends very much on the wind forecast, what the electricity prices are right now, and how they will be in the near future,” he says. Vattenfall may also choose to stop turbines in windy periods of oversupply and low prices, Johansen adds, noting that Denmark has seen periods of negative pricing on its electricity market. Reasons for shutting down turbines can be technical, but they can also be driven by market economics, he says.

Data, data and data

Making these kinds of strategic decisions requires information and both DONG and Vattenfall have invested heavily in data collection and analysis. Vattenfall has a surveillance centre at Esbjerg on Denmark’s west coast that is monitoring an operating portfolio that will jump to 1.3 GW when the 288 MW Danish wind plant off Germany completes commissioning this spring. “That is what helps us with our planning,” says Johansen.

Robust data analysis can help operators catch problems before they become faults, plan service so it is not done too early or too late, and make the most effective use of time at the turbine by bundling maintenance tasks.

Do as little as possible

“Ideally from a cost, but even more from a safety perspective, for us the most important thing is to do as little as possible. If you don’t do anything it doesn’t cost anything and no one gets hurt. That would be the ideal scenario,” says Simmelsgaard. “But when it comes to the point where you actually have to do it, the better prepared you are and the better plan you have, the safer and more efficient it will be.”

At a wind farm level only, data analysis can alert operators to single units that may be underperforming compared to the rest of the turbines. Data collected across an entire operating fleet can uncover important patterns or trends, especially when the age of the projects covers a wide range. “I think we definitely believe in fleet-wide analysis, because then you can utilise the learnings from the earlier turbines,” says Simmelsgaard.

“I have some oil and gas colleagues who are very envious that I have close to 900 units that I can learn from, all the way from the monopiles to cables to everything in the turbine. And I can bring that knowledge to the next wind park,” Johansen has seen a shift from even just five years ago, when a lot of the industry’s attention was on new project development. “The focus is moving more to operating the existing wind farms,” he says. “It is where the money comes from in the end.”

Blades built to last

With blade tip speeds on offshore wind turbines reaching more than 300 kilometres an hour, even something as seemingly harmless as a collision with a raindrop can be a problem. “If you jump into a pool from a height of just four or five metres, that is already pretty scary. Now try the same at 300 kilometres per hour and do it for 20 years in a row without any maintenance. Imagine what you would look like at the end of it,” says Roel Schuring, vice-president of engineering at the Denmark-based blade manufacturer LM Wind Power.

The company that has logged over 3000 equivalent blade-years of operating experience at offshore wind parks since 1991, when it supplied blades to the world’s first wind turbines offshore, at Vindeløby, Denmark.

Schuring’s analogy points to one of the major challenges for the offshore wind industry when building blades to last. High speed winds and repeated contact with the rain, hail, and salt crystals can cause pitting, gouging and delamination along the leading edge of the blade. That can result in costly repairs, changes in aerodynamic performance that risk a drop in annual energy...
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"Leading edge erosion and protection of the leading edges is one of the biggest problems right now," says Povl Brandsted, a professor in composites and materials mechanics at the wind energy department of the Technical University of Denmark (DTU Wind Energy).

**Leading edge solutions**

The challenge has sent the industry in search of lasting solutions, ranging from applying leading edge tape to polyurethane topcoats that act as a collision barrier. DTU Wind Energy is in the process of patenting a system and LM Wind Power is working on the commercial rollout of its own coating after testing showed a significant boost in longevity with minimal aerodynamic impacts.

The wind industry has also been working with the research community to investigate exactly how leading edge erosion happens. "The problem is that the mechanism of the erosion has not been studied in full. It needs more attention," Brandsted says. "We have to know the mechanism that creates it in order to protect against it." Brandsted works with 30 people in the composites and materials unit at DTU Wind Energy, which has about 250 researchers and technical personnel working on all aspects of the industry. His team is hoping to access public funding for blade erosion studies which he says are needed now.

**Collaboration pays off**

Brandsted started working on wind turbine blades in 1978. He wants to see even more collaboration across all players in the composites and wind businesses to enable everybody to benefit from hoped for major improvements in blade technology and materials. "We need to have the suppliers of fibres and resins and manufacturers of blades speaking together in order to improve the materials," he says.

He points to a partnership involving DTU Wind Energy, fibreglass company 3B, resin supplier DSM, and Siemens Wind Power, which won a JEC Europe Innovation award last year for developing a new, more environmentally friendly resin. "That is an example of how it really pays to collaborate," Brandsted says.

**New hybrid carbon**

LM Wind Power and DTU Wind Energy have benefitted from their own collaboration on the materials side. The move to larger turbines that generate more power at less cost requires ever longer, but also lighter blades. "The biggest challenge in reducing weight as much as possible is how to keep stiffness in the blade," Brandsted explains. Carbon fibres are significantly lighter and stiffer than the fibreglass composites predominantly used today, but lose strength when compressed.

Their joint research project to find the right mix of the two types of fibres, partly funded by Innovation Fund Denmark, led to the development of a new hybrid carbon material that LM Wind Power is prototype testing this spring.

The wind O&M industry’s increasing interest in using remote monitoring and data analysis to improve turbine reliability is also making its mark in the blade business. DTU Wind Energy is working on adapting sensors and surveillance methods used in the aircraft and aerospace industries to monitor the performance and structural health of turbine blades. "We have to have all these sensors speak together. They should be intelligent and not just say we have a problem but tell us what action to take," says Brandsted.

A combination of blade monitoring and turbine individual pitch control enabled a 10% reduction in load and blade deflection on the LM 73.5 metre blade developed for Alstom’s 6 MW Haliade direct-drive offshore turbine, says Schuring.

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**Repair challenge:** Reducing expenditure on blade maintenance requires better understanding of the mechanics of erosion. Close collaboration between researchers and industry is coming up with some answers.

*Photo: LM Wind Power*
Owners and equipment suppliers are not the only wind industry players thinking big to drive down costs. Managers in the service and maintenance sector are also focused on the advantages brought by economies of scale. With the global wind market expanding at a compound annual growth rate of 25% over three decades, the wind industry has had to run fast, and nowhere more so than in service and maintenance. “The speed of change in wind is faster than in any other industrial segment,” says Ulf Rye Bertelsen, CEO of Denmark’s All NRG, a new service and maintenance provider with a long pedigree that belies its short history. “We have moved from five hundred kilowatt turbines onshore to multi megawatt turbines offshore within a decade,” he says.

Keeping up with demand for industrial scale maintenance and repair services on ever bigger wind farms, particularly offshore, has been a stretch for Europe’s scattered market of relatively small service firms. The response has been a rash of mergers and acquisitions and the emergence of a new breed of beefed-up service company with a high concentration of expertise. All NRG, launched late last year, is typical of the trend though with an offshore wind specialisation. It merges three companies and many thousands of hours of Danish wind offshore experience under one name. “We need to be bigger and bigger,” says Bertelsen. That includes taking on greater responsibility. “Not only for the logistics, but also for the solutions we provide,” he says.

**Flexibility in numbers**
The new firm, with 900 staff, brings together the combined installation, service and maintenance experience of VB Enterprise, a grid connection specialist, APPRO Wind, a provider of manpower, engineering and installation services for the wind industry, and Q-Star, a source of specialised services to the offshore oil and gas and wind sectors, including welders, electricians and rope access experts.

“Now we have a situation where we can form flexible teams that can perform different jobs,” he says. Whereas previously wind farm operators would have to contract for different jobs from different companies, All NRG can pair an electrician with a hydraulic fitter to form a specifically qualified work team. It drives down overall cost, says Bertelsen. “One of the things we do not do is take over all the service contract,” says Bertelsen. The business model is to work together with wind farm owners and their equipment suppliers. The firm acts as a central conduit of information. An All NRG technician can channel a problem directly to the right sub-supplier with the right solution whereas a more distant wind farm owner risks a tedious journey across multiple desktops to find a resolution. “We know our industry,” says Bertelsen. “We know the company that supplied the part initially and can go direct to them.”

**Not yet good enough**
Challenges remain, however. “We as an industry are still not good enough. We are not qualified enough to read the signs or messages we get from our systems,” he continues. The way forward is co-operation across the entire offshore business and absorbing into wind power the learning that All NRG’s professionals bring from their parallel work in the oil and gas industry. “It has to be done in a joint effort together with the owners, turbine manufacturers and the service companies,” Bertelsen says. “We run a much better chance of coming up with cost reduction if we work together.”

As many as 65% of all visits to offshore wind turbines are for unscheduled service and maintenance, he says, which are far more costly than scheduled trips. “In the oil and gas sector, 65% of visits are planned. That’s a big difference.” Closing that gap by improving the use of predictive maintenance systems and gaining more experience will drive costs down.

“All NRG is financially backed by Denmark’s government-owned ATP pension fund. “We have been involved with 96% of all the wind turbines installed in the North Sea,” says Bertelsen. “That is a very strong position to be in.” Clients include several major wind turbine suppliers including Siemens Wind Power and MHI Vestas Offshore Wind as well as wind farm owners like DONG Energy.

“The offshore wind O&M sector needs to get much better at predicting when we need to do a job,” he says. “You can increase service intervals without big challenges but this will still require that your turbine tells you when it needs maintenance in between. That is still probably the biggest challenge we have. We have not yet equipped turbines so that they tell us when they need service.”

Text Gail Rajgor

**Not good enough yet: The frequency of costly unscheduled service visits is 35% greater in offshore wind than in oil and gas.**

We can learn to do better, says Ulf Rye Bertelsen of service giant All NRG.
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Big data and sophisticated diagnostic capabilities are a key part of improving reliability of offshore turbines and reducing the need for service and maintenance visits on the high seas, says Torben Bang, chief operating officer of Siemens Wind Service. “Our offshore strategy is to do more onshore,” says Bang.

“What we’ve strengthened in the design of the turbines is our capabilities, being able to model how the turbine would behave under normal operation – and if the turbine starts to reach certain boundaries, being able to do early corrective action.”

Right now about 85% of alarms registered by the company’s monitoring centre are resolved remotely with no technician dispatched to the site, he says. “Very often we predict abnormal operations so early that it will never result in an alarm,” he says. “It gives a very stable way of operating the wind farms and keeping high reliability on the turbines, thereby increasing energy production.”

Turbine manufacturers are increasingly focused on mining the reams of data collected at each turbine for ways to keep them operating smoothly and clues for improving the technology. Siemens Wind Power monitors more than 8000 onshore and offshore turbines worldwide that together stream more than 200 gigabytes of new data to its diagnostic centre in Brande, Denmark each day. More than 300 million diagnostic calculations are performed on that data every week.

Reliability gains
The work has resulted in some significant reliability gains, says Bang. The company predicts more than 98.5% of all gear tooth cracks and bearing damage before they can lead to failure. And Bang believes it is early days yet in learning how to exploit the information for best effect.

The industry is also working in other areas to ensure its technology is built to last, says Bang. Manufacturers are conducting much more extensive testing “with the clear aim to improve the reliability of the product prior to sending it into serial production,” he notes.

Testing is key, agrees Anders Bach Andersen, senior project manager for the V164-8.0 MW offshore turbine at MHI Vestas Offshore Wind. “The key to reliability of offshore wind turbines is to ensure a thorough testing and verification process,” he says.

Test and test again
The company has moved much of its testing away from the prototype and back to the test centres, like the in-house facility Vestas Wind Systems opened in its home base of Aarhus in 2013, where variables like wind speed, temperature, vibration and electrical grid can be controlled. “The results from the testing process is fed back into the design phase to ensure the highest quality and reliability of the turbine,” Andersen says. The work has helped drive a continuing decline in the lost production factor, which measures the amount of potential energy from the wind not captured by the turbine, to less than two per cent across the installed offshore fleet, he says.

Quality control is another continuing and important area of focus, agree Andersen and Bang. “After design and after testing, then the biggest risk we have is actually the quality of the individual components going into the individual turbine. Therefore a lot of emphasis is also put into continuing to strengthen the quality process even further,” Bang says. “Years back, I think we were seeing more design challenges, where now we see more the risk of quality issues in the components we are buying.”
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New vessels for bigger demands

The offshore wind industry’s search for economies of scale is sending it further offshore to bigger sites using bigger turbines. These distant and giant electricity production units, spread over many nautical square miles, make demands on vessel capabilities never encountered before to service, maintain and repair hundreds of turbines over time periods of 25 years and more.

Until now, access to offshore wind farms for service technicians has largely been provided by fleets of relatively small crew transfer vessels (CTVs) daily dispatched from operations and maintenance centres located at nearby ports. They are built to nose up to the tower to enable technicians to step from the bow onto a ladder or platform, an access method known as bump and jump. If the weather turns for the worse they can dash back to shore.

**New solutions**

But for wind farms located hours from the nearest harbour a new approach is required. Two Danish companies experienced in providing vessel services to the offshore wind industry are offering separate but related solutions. For daily operations and maintenance (O&M), ESVAGT is offering purpose built vessels with accommodation for around 60 people and capable of working in a wind farm for up to two weeks at a time. Two of these advanced Service Operation Vessels (SOVs) are entering the market in early 2015 and a third is on the way.

For exchange of major components, however, a jack-up vessel that transforms into a stable platform jacked up on legs extended to the seabed, is the favoured option. DBB Jack-Up Services, based in Aarhus, is responding to that need. A long term charter for a DBB Jack-Up vessel configured for O&M work has been agreed with Siemens Wind Power.

ESVAGT’s Ole Ditlev Nielsen, chief commercial and safety officer, says SOVs will “enhance logistics, efficiency and operational capabilities” for far offshore wind projects. The savings in fuel and crew transfer time will pay for the cost of operating a large vessel compared with many CTVs. An SOV provides full spare parts storage, workshops, internal cranes, and social facilities including a cinema as well as meeting rooms and offices. They are also equipped with ESVAGT’s newly developed three and 12-man Safe Transfer Boats, updated versions of standard CTVs for taking technicians from the SOV to the turbines when conditions permit. They feature powerful thrusters to ensure good performance in heavy seas.

**Already tested**

ESVAGT has tested the SOV concept on a smaller scale for the past four years at Bligh Bank offshore wind farm in Belgium. “Bligh Bank is one of the turbine parks where they have most uptime, more than 98%,” says Nielsen, indicating proof of concept.

Long term charters ranging from five to ten years have been contracted with Norway’s Statoil and Siemens Wind Power. The first two SOVs will be used in the Baltic 2 and Butendiek offshore wind farms, respectively in the Baltic Sea and North Sea, both using Siemens Wind Power turbines. A third on order is destined to serve Statoil’s 400 MW
Dudgeon Offshore Wind Farm off the east coast of England from autumn 2016.

Each SOV is equipped with a self-balancing platform and gangway system to allow wind turbine technicians to simply walk to work from the ship and onto the turbine. “As the waves move the vessel up and down, the access system just spans like a bridge, not moving at all, compensated by hydraulic systems. Then we can actually access the turbines in higher waves than traditional equipment,” says Torben Bang, chief operating officer at Siemens Wind Service. The system increases the periods when weather conditions allow safe transfer of workers, saving costs wasted in having equipment and crews on hold waiting for a “weather window” to open up.

**Positive psychology**
Nielsen adds that working from an SOV has also demonstrated a positive “psychological effect” that effectively expands the weather window without further investment. In periods of marginal weather for safe technician transfer, shore-based CTVs may decide the window of opportunity is too narrow to be sensibly utilised. “When you’re out there already, if you suddenly get a small window, you take the opportunity. You don’t if you have to sail one or two hours from shore,” he says.

Bang agrees. Using a traditional shore to turbine set up, weather downtime can be as much as 46%, he says. “So 46% of the 365 days per year you can’t access the turbines. With this new system we expect to reduce it to 10%.” The net result is more turbine uptime and a positive impact on the cost of energy, he says.

**Jack-ups for big jobs**
Replacement of major components, as opposed to daily O&M, is a task for which Siemens Wind Power has signed a three year agreement with DBB Jack-Up for a purpose built vessel for delivery in 2016 on permanent standby. The vessel will be used to exchange blades, gearboxes, generators, and transformers, saving time and money by not having to contract, equip, load parts and rapidly mobilise a vessel for an unscheduled exchange and then demobilise again on completion, says Siemens Wind Power.

The new vessels do not obviate the need for CTVs for projects within two hours or so of land, or the use of permanent accommodation platforms fixed to the seabed at wind farms further out. The decision about which option is best depends on the exact distances from the service harbour involved.

For DONG Energy’s Horns Rev 2 wind farm, 30 kilometres off the Danish west coast and a three to five hour round trip for a CTV, an accommodation platform was deemed the best solution. More recently Vattenfall has commissioned one to house its 50-strong O&M team for the DanTysk project, located 90 kilometres from the mainland off the German and Danish coast. The wind farm will be operated from a control centre at Esbjerg, but with service staff working on site in two week shifts. Crew still need to be transferred to and from platforms and this is done mostly by CTVs or in some instances helicopters when the cost can be justified.

Additional reporting by Diane Bailey

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**J.A.K.**

**Positive psychology**

Nielsen adds that working from an SOV has also demonstrated a positive “psychological effect” that effectively expands the weather window without further investment. In periods of marginal weather for safe technician transfer, shore-based CTVs may decide the window of opportunity is too narrow to be sensibly utilised. “When you’re out there already, if you suddenly get a small window, you take the opportunity. You don’t if you have to sail one or two hours from shore,” he says.

Bang agrees. Using a traditional shore to turbine set up, weather downtime can be as much as 46%, he says. “So 46% of the 365 days per year you can’t access the turbines. With this new system we expect to reduce it to 10%.” The net result is more turbine uptime and a positive impact on the cost of energy, he says.

**Jack-ups for big jobs**

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Additional reporting by Diane Bailey

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**J.A.K.**

**Antiflame meets offshore industry requirements for protective clothing:**

- DS/EN 340
- DS/EN 1149-5
- DS/EN ISO 11611
- DS/EN ISO 11612
- DS/EN 61482 KL.1

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**Froude’s daughter:** From the large mother vessel, crew can step directly onto a turbine, but faster access is provided by a Safe Transfer Boat. It can ferry three technicians to turbines close by at speeds of up to 26 knots when conditions permit, bumping against the tower to allow them to jump across. **Photo Esvagt**
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