Offshore Wind Energy: Full Speed Ahead

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Summary

Commercial-sized offshore wind farms have become a reality in Denmark. A 160 MW offshore wind farm, the worlds largest so far, has just been erected at Horns Rev in the North Sea and will start operating before the end of 2002, and in 2003 another wind farm of 158 MW will be constructed at Rodsand in the Baltic Sea. The construction of these two huge wind farms is a consequence of the targets set by the Danish energy plan "Energy 21", thus achieving a 50 per cent wind penetration in the electricity grid by 2030. At the moment, the Danish government is considering introducing a tender system for future offshore wind farms in Denmark. The energy policy interest in wind energy in Denmark is primarily based on its ability to deliver large volume CO2 reductions from power generation cheaply.

Shortage of land sites in north-western Europe is one reason for this move offshore. Other reasons include significantly higher wind speeds than on land, and thus higher energy production at sea. In addition, new research results indicate that wind speeds at sea are higher than what was previously estimated. The marine environment gives more stable winds with less turbulence and less wind shear, facilitating the design of cheaper turbines with a longer lifetime.

To be economic, offshore wind farms have to be large (100 MW and above), and use large turbines (2 MW and above). New foundation technologies, using steel rather than concrete has improved the economics of offshore wind power dramatically. Wind turbines at sea would have a longer design lifetime due to lower mechanical fatigue loads. If this is taken into account, energy costs per kWh may be as low as 4 eurocents per kWh, although more conservative estimates point to 5 eurocents/kWh using present day technologies.

Other than decreasing installation costs even further, technical challenges are abundant in this frontier line of wind technology. Logistics and grid integration will pose interesting problems, and phasing up to 50 per cent wind into the Danish electricity grid, will mean a longer term redesign of grid technology in the direction of a more flexible, decentralised system with large amounts of CHP and heat storage, plus a more co-ordinated use of wind and the neighbouring countries' hydro resources.

From an environmental point of view offshore wind farms have few drawbacks. A new scientific study has shown that wind farms at sea have no significant influence on bird life. A life-cycle calculation of energy use in manufacturing, deployment and maintenance of an offshore wind farm by the author shows that the energy thus consumed is less than 2.5 per cent of the energy produced by the farm, thus making wind energy one of the cleanest generating technologies available.

1. Introduction

More than 4,000 megawatts (MW) of wind power may be installed offshore in Denmark in the course of the coming 30 years. Larger wind turbines, cheaper foundations, and new research on offshore wind conditions are boosting the confidence of both power companies, government, and turbine manufacturers.

While wind energy is already economic in good onshore locations, wind energy is about to cross another frontier: The economic frontier set by shorelines. Danish researchers and developers are about to challenge conventional wisdom on electricity generating technologies: With future costs around 4 to 5 eurocents per kWh, offshore wind energy is rapidly becoming competitive with other power generation methods.

Already in the beginning of the 1990s, two offshore pilot wind farms of 5 MW each were built in Denmark by the electric utilities using conventional wind turbines: Vindeby in 1991 and Tunoe Knob in 1995. These projects were smaller scale pilot projects, with costs substantially above the figures indicated above.

In 2000, a 40 MW wind farm consisting of 2 MW machines was built at Middelgrunden off the Copenhagen harbour. The offshore technology is presently about to take a huge step forward with the construction of two important demonstration projects built by the utilitility companies: a 160 MW wind farm at Horns Rev in the North Sea which will start running by the end of this year; and another 158 MW wind farm at Rodsand in the Baltic Sea which is expected to be in operation from the autumn of 2003.

Both projects have the expected size of future offshore projects, due to economies of scale. Wind farms of this size will be veritable power plant units. The 80 wind turbines at Horns Rev alone are expected to produce 160 million kWh every year - enough to cover the electricity consumption of 133,000 Danish households, or to power all the refrigerators in Denmark.

2. Reasons for Going Offshore

2.1 Land Sites in Short Supply in Some Countries

One of the primary reasons for moving wind farm development offshore is the lack of suitable wind turbine sites on land. This is particularly the case in densely populated countries like Denmark or the Netherlands with a relatively flat landscape.

2.1 Higher Wind Speeds

Equally important, however, is the fact that wind speeds are often significantly higher offshore than onshore. An increase of some 20 per cent at some distance from the shore is not uncommon. Given the fact that the energy content of the wind increases with the cube (the third power) of the wind speed, the energy yield may be some 73 per cent higher than on land. Economically optimised turbines, however, will probably yield some 50 per cent more energy at sea than at nearby land locations.

(Bear in mind, that since the fuel is free, economically optimal wind turbines will generally have capacity rates as low as 25 to 30 per cent).

In countries like the UK, however, the difference between good land sites and offshore sites may be smaller or nil, since turbines on land are often situated on hilltops where the wind speeds up significantly compared to the speed in flat terrain.

2.2 More Stable Winds

It is a frequent misunderstanding that wind power generation requires very stable winds. In most wind turbine sites around the globe, in fact, the wind varies substantially, with high winds occurring rather infrequently, and low winds occurring most of the time.

If we look at the typical statistical wind distribution, most of the energy output is in fact produced at wind speeds close to twice the average wind speed at the site. In addition, in e.g. Europe and a number of other locations around the globe wind speeds happen to be positively correlated with peak electricity use (more wind during the day than at night, more wind in winter than in summer) raising the value of the wind to the grid by 40 to 60 per cent, compared to a completely random wind pattern.

Having said this, it should be added, that of course it is generally an advantage to have a stable power output form a wind farm. At sea, periods of complete calm are generally extremely rare, and quite short-lived. Thus the effective use of wind turbine generating capacity will be higher at sea than on land.

2.3. Huge Offshore Wind Resources

Offshore wind resources are enormous: Wind energy resources in the seas of the European Union with water depths up to 50 metres are easily several times larger than total European electricity consumption.

The offshore wind resource is obviously somewhat unevenly distributed among countries. In the case of Denmark, offshore wind energy may theoretically supply more than ten times national electricity consumption, due to large areas with shallow waters (5 to 15 m depth).

2.4. Low Surface Roughness: Cheaper Turbines

Another argument in favour of offshore wind power is the generally smooth surface of water. This means that wind speeds do not increase as much with the height above sea level as they do on land. This implies that it may be economic to use lower (and thus cheaper) towers for wind turbines located offshore.

2.5 Lower Turbulence: Longer Lifetime

The temperature difference between the sea surface and the air above it is far smaller than the corresponding difference on land, particularly during the daytime. This means that the wind is less turbulent at sea than over land. This, in turn, will mean lower mechanical fatigue load and thus longer lifetime for turbines located at sea rather than land. No precise calculations are as yet available, but we may guess at something like 25 to 30 year lifetime for a turbine with a design lifetime of 20 years on land.

3. The Challenges Offshore: Costs

The primary reason delaying offshore development of wind farms has been cost. Although the price of wind turbines has been falling some 20 per cent per kW installed power over the past three years, and installation costs per kW installed on land have declined due to up scaling of turbines, installation costs offshore have remained more or less stable.

Foundations and grid connection of large wind farms on land may be purchased at a relatively modest cost of less than 60,000 EUR per wind turbine (e.g. in the case of the Rejsby Hede wind farm in Denmark, consisting of 39 wind turbines of 600 kW each). Foundations costs were 6 per cent of project costs, while grid connection accounted for 3 per cent.

Offshore, however, foundations and cables add significantly to project costs. In the Danish offshore wind farm at Tunoe Knob (1995), for instance, wind turbines are placed at 5 to 10 metre water depth. Here, foundation costs per turbine were at the level of 23 per cent of project costs while grid connection costs were around 14 per cent of project costs.

3.1 Economies of Scale

Economies of scale in the offshore wind energy area are two dimensional: In terms of machine size, and in terms of number of units per farm.

3.1.1 Megawatt Turbine Size

Waves, and in some areas pack ice, are the most important factors determining the required strength and weight of offshore foundations for wind turbines. Consequently it is far more economic to use larger wind turbines, since the size and costs of foundations do not increase in proportion to the size of the wind turbine.

Another important cost factor is grid connection. Here, it is obviously far cheaper to attach fewer turbines to the grid for a given wind farm size.

Larger machines save money on maintenance, since the number of units that have to be visited by boat will be smaller.

A 2 to 2.5 megawatt wind turbine has typically a rotor diameter of 75 to 85 metres. This is approx. 25% more than the wingspan of a Boeing 747. Most of the Danish megawatt machines have in fact been designed for offshore siting.

Further up scaling of wind turbines is to be foreseen in the years to come, although the logistics of handling such large units on land have already become quite difficult.

Tower diameters should preferably not exceed 4.2 or 4.4 metres, if they are to be transported in normal sections by road or rail.

3.1.2 Larger Wind Farms, from 100 MW

The economically optimum size for an offshore wind farm will be significantly higher than on land. The cost of installing an undersea 150 MW cable is not very different from the cost of at 10 MW cable. Larger volume production of turbines and steel foundations will also tend to decrease costs.

The optimum size for an offshore farm today appears to be 100 MW or above. The upper limit is largely governed by the number of sites which can be prepared for installation during a season (summer half year) using a single sea crane and a limited number of barges, diving crews etc. [1]

3.2 New Foundation Technologies

While economies of scale are important, the most interesting breakthrough in offshore technology has been new engineering studies done under the auspices of the Offshore Wind Turbine Commission chaired by the Danish Energy Agency. Preliminary indications point to a 35 per cent decrease in foundation costs, due to the use of steel rather than concrete foundations. [2]

While concrete platforms tend to become prohibitively heavy and expensive to install at water depths above 10 metres, it appears that all of the new technologies will be highly economic until at least 15 metres water depth, and possibly beyond such depths. In any case, the marginal cost of moving into deeper waters is far smaller than what was previously estimated.

Corrosion protection of steel foundations can be done electrically, using so called cathode protection requiring little or no human intervention after the system is installed.

3.2.1 Gravity Foundations

The majority of the present offshore wind farms in Denmark are placed on reinforced concrete foundations built onshore and floated out to sea where they are filled with gravel and sand, much like traditional bridge building technology. Such a foundation is known as a "gravity foundation" since it relies on gravity to keep the turbine in place.

One of the newer technologies offers a similar method, but using a cylindrical steel tube placed on a flat steel base on the bottom of the sea. Such a foundation is considerably lighter, allowing barges to transport and install many foundations rapidly, using the same fairly lightweight crane used for the erection of the turbines. These foundations are filled with olivine, a very heavy mineral, which gives the foundation sufficient weight to withstand waves and ice pressure.

3.2.2 Mono Pile Foundations

Other foundation technologies include "mono pile" foundations, effectively extending the turbine tower under water, and drilling or ramming it into the sea bed. The new Danish offshore wind farm at Horns Rev uses this foundation technology.

3.2.3 Tripod Foundations

Finally, for larger water depths, three legged steel platforms similar to offshore oil rigs are being studied. These foundations have the advantage that they require less protection against erosion than the other types of foundations, which generally have to be protected by boulders (in sandy areas).

3.3 Reusing Foundations

While foundations are built to last 50 years, wind turbines are presently built to last 20 years. With a somewhat larger expected lifetime of, say 25 years, the same set of foundations can be used for two successive generations of wind turbines. If the foundations can thus be recycled, it may lower electricity generating costs offshore by another 25-33 per cent, with costs roughly achieving parity with typical onshore sites in Denmark.

3.4 Conclusions on Costs

Current studies of the kWh cost of energy from offshore wind turbines in Denmark by the Danish utilities indicate a cost of 0.36 DKK/kWh = 0.05 EUR/kWh using standard IEA calculation methods. [1], [9] The calculations cautiously assume that present technologies are used, and assume a 20 year lifetime.

If we consider a 25 year lifetime, costs will be 9 per cent lower.

Danish power companies (in their initial applications for planning permission) have indicated that their projects require a 50 year design lifetime for foundations, towers, main shafts, and the wind turbine nacelle housing. If we assume a 50 year lifetime, with a very conservative refurbishment cost equivalent to replacing the turbine itself completely at present costs, then the energy price become 0.283 DKK/kWh = 0.04 EUR/kWh.

These costs include all installation and maintenance costs, including grid reinforcement. The grid reinforcement component is quite important in so far as it involves e.g. building 150 km of 400-600 kV power lines in the case of one of the larger farm groups of 600-900 MW. [3]

4. More Wind at Sea

The first two Danish pilot offshore schemes at Vindeby and Tunoe Knob have given very important advances in the knowledge of the offshore environment.

Even if higher wind speeds were expected at sea, the results from Tunoe Knob indicate that offshore wind energy output is 20 to 30 per cent larger than forecasts made by traditional wind modelling methods.

The Risoe National Laboratory in Roskilde, Denmark, which is known world-wide for its WAsP wind modelling software, and the European Wind Atlas [4], is in the process of revising its basic models after the experience gained from Vindeby, Tunoe Knob, and four new offshore meteorological masts erected in 1996.

It appears that the wind shade effect from land obstacles such as tall cliffs is more significant at sea than what the traditional models say. On the other hand, wind speeds farther offshore are higher than model predictions.

A research programme is currently in progress to improve offshore wind modelling. The programme relies on improved data collection from a number of offshore meteorology masts erected by the Danish utilities SEAS and Elsam.

5. Offshore Turbine Design Modifications

The wind turbines used in the current offshore projects are largely standard machines, usually with some additional corrosion protection. Gradually, interesting modifications are beginning to appear, however.

Since the beginning of offshore deployment, high voltage transformers have of necessity been installed inside the wind turbine towers. Other than better corrosion protection, this gives the additional advantage of heating the equipment, thus avoiding cold starts of the turbines.

Another interesting modification is a design change allowing a ten per cent increase in rotor speed, increasing the effectiveness of the turbines by some five to six per cent. Higher rotational speed always carries a noise penalty, but as the theoretical sound level on shore several kilometres away is minus 3 dB(A), this is not a concern at all.

Since the availability of a wind turbine is very important, all of the wind turbines at Horns Rev have been mounted with a special hoist platform on top of the nacelle to allow the service personnel to access the turbines from helicopters when the weather conditions make access by boat impossible. This solution is particularly interesting in a location like Horns Rev where the sea tends to be rather rough: the turbines may be accessible by sea only half of the time, thus the availability issue is essential. Using helicopters also saves travel time: it takes 2 hours to reach the wind farm by boat, but only 15 minutes by helicopter.

Furthermore, the wind turbines both at Horns Rev and Rodsand will be equipped with food, toilets, sleeping bags, etc., so that the personnel can spend the night in case the weather conditions leave them stranded at the site.

Finally, the turbine manufacturers have taken a leaf out of the Navymen's book: The offshore turbines are painted in the standard NATO light grey camouflage colour, and the rotor blades were manufactured in exactly the same colour. The result is that even a slight amount of haze makes the turbines disappear completely when viewed from the shore.

6. Wind Farm Operation, Logistics

Remote surveillance of offshore farms will obviously be even more important than on land. Radio links for this purpose have already been in operation at the Tunoe Knob and Vindeby offshore wind farms for some years. Fine optic cables are used at Horns Rev. With the large multimegawatt machines foreseen for future farms, it may be economic to install e.g. extra vibration sensors, a technology which is well known in industry to ensure optimum maintenance of machinery. Since weather conditions may prevent service personnel from approaching the wind turbines at times of bad weather, it is extremely important to ensure a high availability rate of offshore wind turbines, (similar to the 98 to 99 per cent average achieved by onshore turbines). Preventive maintenance check programmes may need to be optimised for remote offshore locations.

7. Environmental Impact of Offshore Wind Farms

7.1 Wildlife Considerations: Ducks don't Care

The existing Danish offshore projects have been very thoroughly researched by biologists. At Vindeby test fishing was done in the area of the wind turbines before they were built and after commissioning.

The result was a surprising increase in fishing yields, attributable to the fact that the turbines foundations appear as an artificial stone reef. Mussels grow on the foundations of the turbines, and the flora and fauna in the area have generally improved in variety since the construction of the wind farm. There are few birds at Vindeby, so no ornithology studies were feasible.

At Tunoe Knob, however, a very extensive three year study was used to determine the effects on the very large local population of eiders (Somateria molissima). [5] The wind farm was in fact located in that very area at the request of researchers from the Danish Environmental Agency, who wanted a testing ground with a large bird population.

A small observation platform with a cottage was placed on the sea approximately one kilometre form the wind farm. Very extensive observations from the tower have been performed, counting the bird population, and studying flight behaviour. In addition, aerial surveys have been used. Finally, divers have repeatedly investigated the seabed for mussels, and using exclosures (wire netting preventing bird access to certain areas of the seabed) to be able to determine the feeding habits of the eiders. A nearby control site with no wind turbines was used to determine the effect of the wind farm.

The result has been that the birds' presence is well correlated with the presence of suitable food, but no statistically significant impact on bird behaviour from the farm itself has been detected. Bird studies will continue with the erection of future farms, however, since different species of sea birds will be involved.

Likewise, other environmental studies will be conducted in connection with the two Danish offshore demonstration farms currently under construction. At Rodsand, for example, some of the seals are monitored from satellites to study whether the wind farm has an impact on their patterns of behaviour.

7.2 Human Considerations: People don't Care

A storm of complaints rose over the eastern part of Jutland in 1992 when the plans for an offshore wind farm at Tunoe Knob were published. It turned out to be much ado about nothing.

Light reflections, noise, reduced property value and a negative impact on the local fauna were among the fears of the critics of the offshore wind farm. No one has complained about the wind turbines, however, since they started rotating in 1995.

Also at Middelgrunden, located in the waters just outside the Copenhagen Harbour, complaints have ceased after the construction of the wind farm. Once the turbines are there, people seem to accept their presence. This corresponds to the experience gained onshore.

The two commercial-sized offshore wind farms under construction at Horns Rev and Rodsand are located so far from the coast (at distances ranging from10 to18 km) that the visual impact of the farms is expected to be minimal or non existent when viewed from the shore, depending on weather conditions.

7.3 CO2 and Global Energy Balance (Life Cycle) Considerations

Wind turbines generate no CO2, NOx or SOx during their operation, and very little energy is required for the manufacture, maintenance and scrapping of a wind power plant. In fact, with moderate wind onshore sites, a wind turbine will recover all the energy spent in its manufacture, installation and maintenance in less than three months. With a 20 year lifetime that gives a thermal efficiency (comparable to conventional power plant's 45 per cent) of no less than 8,000 per cent!

For offshore turbines the results may be even better due to longer expected lifetime of the turbines, cf. section 2.4 above. [6]

8. Impact on the Future Electricity Supply System

8.1 Grid Integration

Grid connection of offshore wind farms is not a major technical problem per se, in the sense that the technologies which are involved are well known. Optimising these technologies for remote offshore sites will be important, however, to ensure reasonable economics.

The first commercial-sized offshore wind farms in Denmark will be located some 10-20 km from shore, at water depths from 5 to 10, possibly 15 metres. The farm sizes will range from 150 to 160 MW. The first two farms of this size at Horns Rev and Rodsand are built using the present 2- 2.2 MW generation of wind turbines.

Undersea cabling connecting offshore farms to the main electrical grid is a well known technology. Undersea cables will have to be buried in order to reduce the risk of damage due to fishing equipment, anchors, etc. If bottom conditions permit, it will be most economic to wash cables into the seabed (using high pressure water jets) rather than digging or ploughing cables into the bottom of the sea.

Inside the future large offshore wind farms in Denmark, 20-40 kV connections will be used. In the middle of each farm there will be a platform with a 30 to 150 kV transformer station, plus a number of service facilities. Connection to the mainland will be done using 120 to 150 kV connections.

Undersea cables have a high electrical capacitance, which may be useful to supply reactive power to the farms. It may be optimal to have some form of variable reactive power compensation built into the system, depending on the precise grid configuration. If the distance to the main grid is considerable, an interesting alternative could be to connect the farms to the mainland using high voltage direct current connections (HVDC).

Total generating capacity in Denmark was approx. 13,000 MW in 2001, including 2,500 MW of wind power. The construction of substantial new offshore wind energy capacity will change the very nature of the present electricity supply system.

8.2 A Very Different Electricity Supply System 8.2.1 Plans for the Year 2030: 4000 MW Offshore

With more than 2,500 megawatts installed onshore, Denmark already covers some 18 per cent of its electricity consumption from wind energy (fall 2002).

In view of the rather optimistic conclusions above, the Danish power companies have expressed their interest in constructing more large offshore wind farms of some 300 to 600 megawatts each, built in modules of 120 to 150 megawatts, using multimegawatt wind turbines.

The Danish energy plan for the period until 2030, "Energy 21", envisages a total of some 4,000 megawatts placed offshore, with wind covering some 50 per cent of electricity consumption by 2030. [7]

The Danish government has recently decided to investigate the possibility of basing a future offshore wind programme on a new tender system. A report on this issue is expected by November 2002.

8.2.2 Cheap CO2 Removal

The basic reason for installing such large amounts of wind power is simple: Wind is a very inexpensive way of reducing CO2 emissions cheaply. In fact, the Danish Energy Agency has calculated that the social cost of saving one tonne of CO2 by switching from modern coal fired power generation to wind has dropped from about 10 USD per tonne of CO_2 in 1996 to zero today (not accounting for environmental benefits). [8] While these estimates were calculated on land-based wind turbines, the cost per tonne of CO_2 saved through the use of offshore turbines is still slightly positive. Given current cost trends in the industry, and the fact that cost estimates for future farms have been largely based on current technology, it seems likely that the excess cost of using wind power rather than coal will be close to zero or negative in a few years time. Wind Energy will account for more than a third of the CO_2 emission reduction planned in Denmark for the year 2005 (7 out of 20 per cent decline compared to 1988).

8.2.3 The Scandinavian Power Balance

Denmark currently has about 13,000 MW of installed electrical generating capacity, and an annual electricity consumption of around 33 TWh. The country is linked to both Germany, Sweden and Norway. The links to Sweden and Norway, in particular, already play an important role in balancing the electricity supply in Scandinavia. Norway has a large, 99 per cent hydro-based system with an annual production of some 120 TWh. In periods of drought, Denmark's supplies large amounts of electricity to the other countries, in other periods Denmark imports large amounts of electricity. With a future total wind generating capacity of about 6,000 MW in Denmark, there will be lots of electricity available at periods of high winds. During those periods, the Norwegian hydro system could effectively be used for inexpensive energy storage, returning the current later, during periods of relative calm weather. Thus, the combination of wind and hydro are ideal, and would possibly enable larger amounts of wind power to be installed in Danish waters.

8.2.4 Systems Design for Large Scale Introduction of Renewables

Large amounts of non-dispatchable renewables, such as wind, will require an electricity system with far more decentralised power generation, and with considerably more flexibility than the present Danish electricity system.

Interestingly, the general trend in Denmark is moving in that direction already, due to a large scale conversion from large, centrally located power plant to small, local gas fired CHP (combined heat and power generating) plant. Heat storage plays an important role in this system to allow a certain decoupling of heat and electricity use, to ensure an economically and environmentally sound way of running the system.

The excess systems costs of introducing large amounts of renewables in the grid in the years to come will be fairly reasonable, due to the fact that the introduction is taking place in a planned manner during a 40-year period during which most equipment would be replaced anyway. The fascinating problems involved would merit a separate paper; cf. the analysis by Risoe National Laboratory, ELSAM and ELKRAFT in [9].

9. Conclusions

9.1 Economic Benefits

Offshore wind energy is clearly an economically viable technology for the 21st century. The present technology indicates generating costs in the range of 4 to 5 eurocents per kWh, according to IEA standard methodology (on the basis of 120 to 150 MW projects at water depths from 5 to 15 metres). Even without the environmental benefits included, offshore wind energy is thus very close to being competitive, both in comparison with onshore wind, and in comparison with other generating technologies.

9.2 Environmental Benefits

Offshore wind energy can make a significant impact on the emission problems related to conventional power generation technologies, partly because the offshore wind resource base is huge, partly because the technology is cost competitive.

The Danish example shows that costs of mitigating CO2 problems can be brought down to a tolerable level. In fact, even though Denmark has a 18 per cent wind energy penetration in the electrical grid (2002), electricity prices in Denmark (excluding indirect taxes) are still among the lowest third in the European Union, according to IEA statistics.

9.3 System Requirements

Large amounts of wind power will of course require a more flexible electrical grid than what we know today, both in terms of handling a fluctuating power input, and in terms of the flexibility of other types of power plant (and possibly user load) in the system. In cases where there is a possibility of combining hydro power and wind, large scale introduction of wind would appear to be a particularly attractive option, since hydro is the cheapest form of electricity storage available.

9.4 Challenges

Offshore wind energy opens a new frontier of technological challenges. Further up scaling of wind turbines, which are already the largest rotating machinery on earth, will be a challenge to manufacturers. Other challenges can be found in mass production of cheap foundations, and improving the logistics of installation, surveillance, and efficient maintenance.

Watch the seas around Denmark to catch a glimpse of the first commercial-sized offshore wind farms in Europe!

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