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ALTENER PROJECT 4.1030/Z/01-103/2001

**GUIDELINES TOOL FOR PLANNING AND IMPLEMENTATION OF COASTAL
OFFSHORE WIND PARKS**

SUMMARY

**THE EUROPEAN NEAR COASTAL OFFSHORE WIND ENERGY POTENTIAL IS
READY TO BE UTILISED – GUIDE LINES HOW TO DO IT**

In a number of EU countries there are plans for utilising the offshore wind energy potential, and in some EU countries the implementation has started. The utilisation of this offshore wind energy potential shall be based on a double strategy of both utilising the potential far out at sea and the near coastal potential. In some EU countries there are tendencies that only the offshore far out at sea potential will be utilised.

A newly finished EU Altener project gives guidelines, how the near coastal offshore wind energy potential can be utilised giving guide lines on physical, planning, organizational and financial elements of carrying out offshore wind energy projects.

1. Good reasons for utilising the near coastal offshore wind energy potential

1.1 Good reasons for utilising the offshore wind energy potential

At the present stage offshore wind energy utilisation can't economically compete with good on land sites. Therefore, in regions with abundant sources of good on land sites for wind turbines, there is basically no need for establishing offshore wind energy parks.

Anyway there are reasons for developing the offshore wind energy potential in some regions of Europe. To mention the most important:

- The on land wind energy potentials are in many regions limited for physical, planning and public acceptance reasons, and for some regions, the available potential has been utilised.
- The utilisation of the on land wind energy potential can be constrained by extra costs related to weak grids, difficult terrain (mountains etc.), especially when the best sites have been utilised.
- Offshore utilisation offers potential large scale projects well suited for large energy companies. This might not be the case for on land sites.

A combination of the reasons mentioned above can motivate establishing offshore wind parks.

Offshore wind utilisation has had shorter time to develop, meaning that there is a potential of improving the economy of offshore wind compared to on land sites.

An important disadvantage of offshore wind energy is the greater risk due to the offshore conditions related to the insecurity of the type of sea bottom and of bad weather in the construction period and extra costs for operation and maintenance. With the increased experience these risks can be reduced but not disappear.

1.2 The near coastal offshore wind energy potential is ready to be utilised:

There are several reasons, why the near coastal offshore wind energy potential is ready to be utilised:

- For economic reasons sea depths of up to around 10 meters are the most attractive for offshore wind utilization. These depths are most common near to the coast.
- The grid connection cost is an important cost element in establishing offshore wind parks. Shorter distance from the coastline means less costs for grid connection.
- For cooperatively-locally owned wind parks it can be a positive socio-economic factor that an offshore wind park is close to the area, where the cooperative owners are living, creating a physical connection. This are as examples the case for the Middelgrunden and Samsøe offshore wind parks.

In a number of European countries there is a great reluctance of establishing offshore wind parks near to the coast, due to insecurity concerning planning and the reactions from the different local stakeholders.

As will be demonstrated below, there can be ways of overcoming these barriers for establishing near coastal offshore wind parks. It is important on a European level to work with the barriers for establishing near coastal offshore wind parks in order to make it possible to exploit this important resource for CO₂-free energy production.

2. Technical-economic guidelines for establishing near coastal offshore wind parks

2.1 Wind resource assessment – micro level:

Establishing an offshore wind measurement mast, including 1 year of measurements, must be calculated to cost at least 100,000 € according to DK experiences. It is therefore a relatively costly operation.

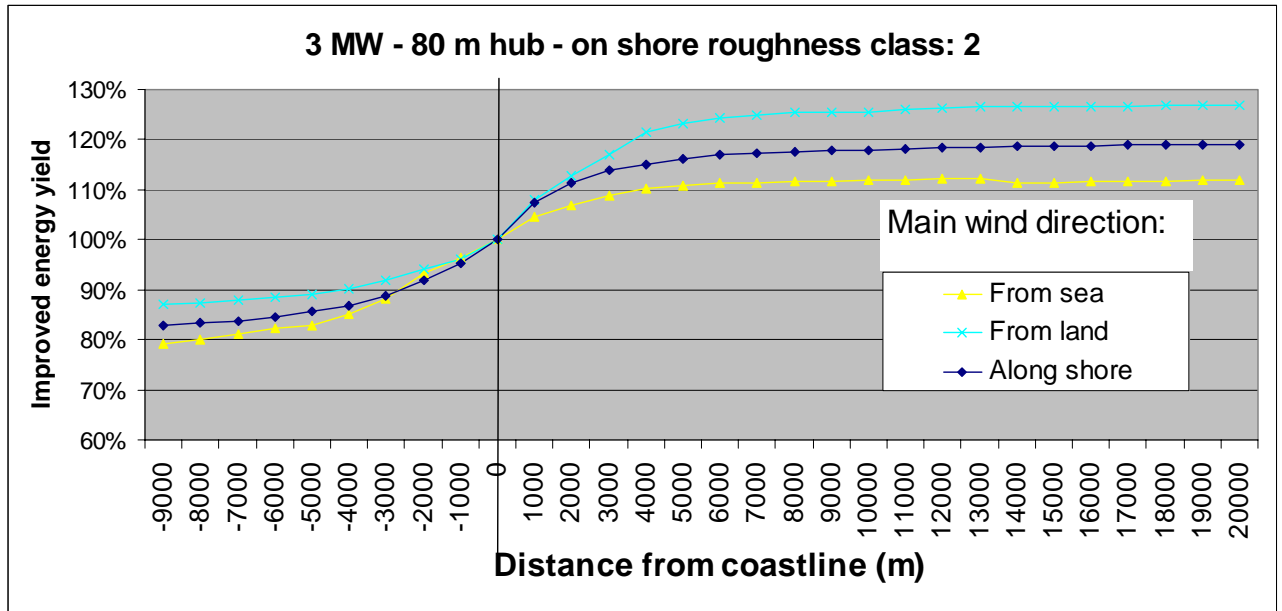


Figure 1 Change in energy production with distance from coastline

Based on a wind direction distribution, where around 60% of the energy production comes from main wind direction (like in Denmark where 60% comes from west-southwest directions, the decrease typically will be 12%-28% at shore near sites depending on the orientation of the coastline relative to main wind direction. At distance more than 5 km there will be almost no reduction. If the wind direction is more uniform (e.g. at Crete, Greece, where almost 100% of the energy comes from north west), the sensitivity of the coastline orientation will be higher. Also if there are mountains or higher roughness on land the decrease versus distance will change.

2.2 Water depths and foundation costs:

So far, water depths outside 2m - 30m have not been considered relevant for offshore wind farms. Below 2 m there will be problems with accessibility by boat (but special designed vehicles might be an alternative for transportation of the equipment to site). More than 30 m has so far been considered to expensive – but there is not an exact upper limit. Even floating WTGs are considered for very large water depths.

3 types of foundations are normally considered as alternatives:

- Gravity (2- 20 m)
- Mono pillar (5 – 30 m)
- Jacket (15 – 30 m)

Basis price for 8 m water depth based on experiences from Denmark so far:

- 250-300 €/kW complete with installation. Traditionally foundation cost on land are 40 – 50 €/kW, so the increase is around a factor 7.
- Increase per m additional water depth roughly: 2%

- The foundation costs represent 20-25% of the total project costs
- The foundation costs can vary very much with seabed conditions and weather conditions (high waves, tidal or icing)

2.3 Grid connection:

Grid connection cost can vary much. One of the main uncertainties is where the nearest connection point on land is which is “strong enough” to take the feed in power from the wind farm. Often there will be needs of upgrading the grid on land and maybe install a new land based sub station. These costs for grid connection can be everything between zero and millions of EURO.

For the connection from the shore to the off shore wind farm, following guidelines can be given.

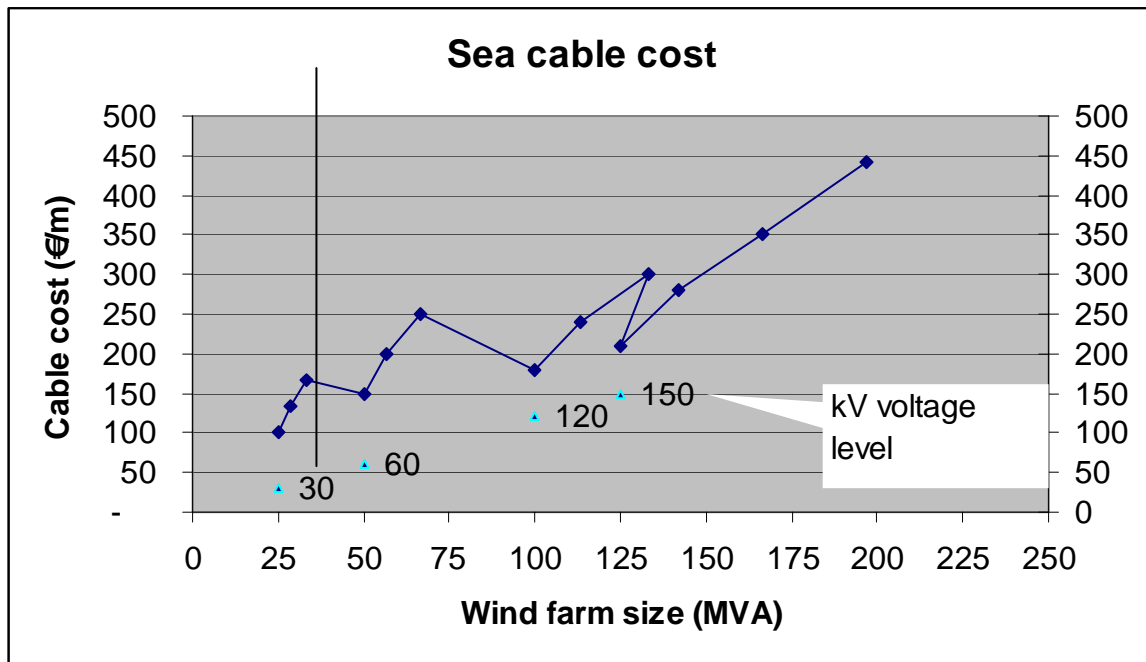


Figure 2 Cost of different cable sizes - for each voltage group 300, 400, 500 mm² CU cables are shown - for 150 kV level also 630 mm² CU cables are shown as rightmost point.

2.3.1 Cable roll out and wash down:

Costs from 15 – 70 €/meter - depending on the bottom conditions and the need of washing down the cable – on rocky water bottom, wash down are of cause not possible, and other cover arrangements might be needed. But it might also not be needed if there is no sea traffic in the region.

2.3.2 Internal cables between wind turbines:

In-between the wind turbines normally 30 - 33 kV are used, while this is the typically transformer size in the offshore wind turbines (on land normally 10 – 20 kV are used). The reason for not using higher voltage in the wind turbines is mainly that the space demand for higher voltage is much higher and the arrangement will not fit into the standard tower sizes. The manufactures are working on solutions for this.

The cost of 150 mm² CU interconnection cables is approximately 85 €/m. These are normally large enough for the internal connection (depending on the connection layout, there might be used larger cables for a part of the connection) – also here cable wash down may be added.

2.3.3 Transformer station off shore:

For larger wind farms, where more than 33 kV connection to land will be needed (more than approx. 40 MW), an off shore transformer arrangement will be needed. Cost of this is pretty high. For the Danish large off shore projects, 150/32 kV - 180 MW transformer cost is approximately 8 million €(60 mill. DKK), including foundation and installation costs.

2.3.4 Grid losses and voltage increase:

Not only the cost are important, but also the losses and voltage increase can be deciding factors for choosing the right voltage level and cable dimensions.

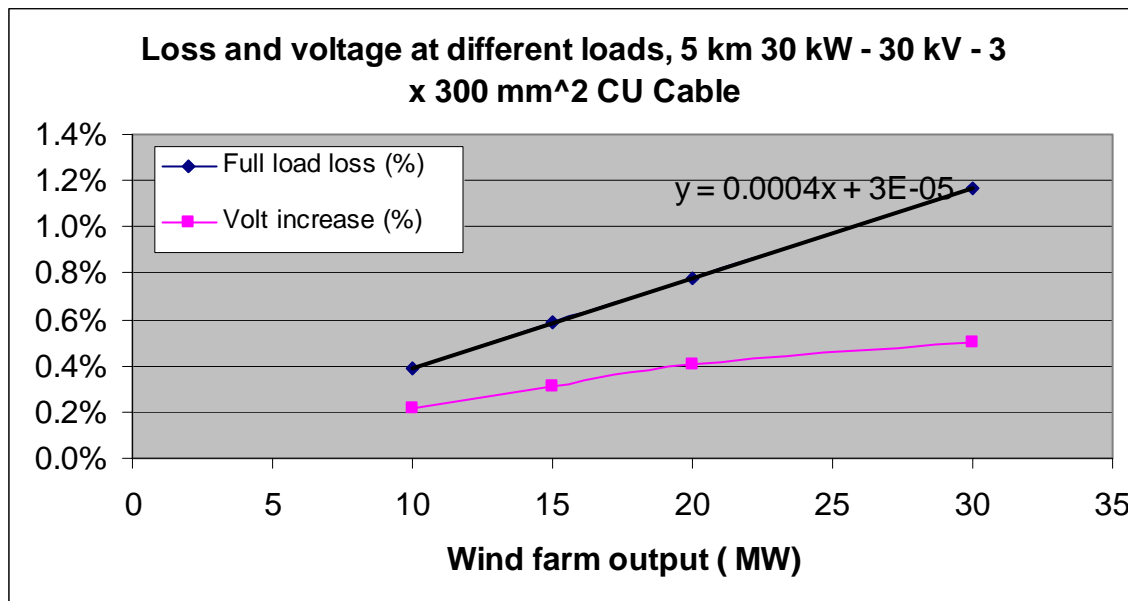


Figure 3 Loss and voltage increase versus load

The figure above show a calculation example for a 30 MW windfarm, which goes “to the limit” of the cable capacity.

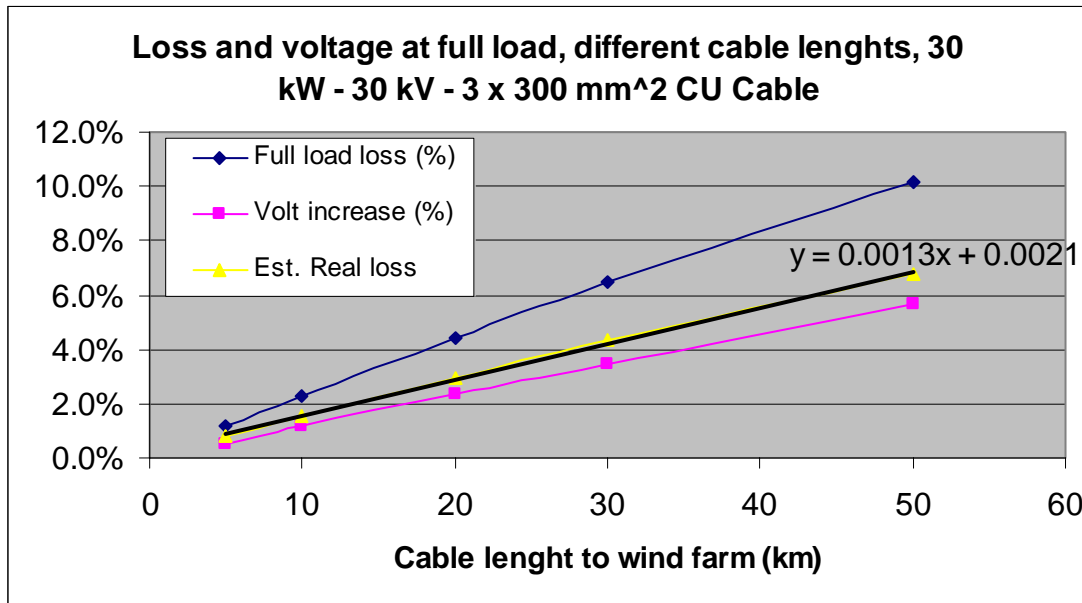


Figure 4 Losses above around 2% will normally make it feasible to increase the voltage.

Above an example showing the losses versus cable length. It is seen that the loss is 0.13% + 0.2% per km cable length for the connecting cable between land an off shore wind farm. So e.g. at 10 km connection it will be 1.3% + 0.2% = 1.5%.

Additionally there will be losses in the internal cable connection in the wind farm. The voltage increase at 50 km cable length is below 6% so this should cause no problems.

2.4 Costs of offshore wind turbines:

From Vestas following add on for Horns Rev off shore project are identified:

Extras at Vestas 2 MW Horns Rev offshore wind turbine
Helio-platform (Helicopter landing)
Stationary tool box in each WTG
Improved tower surface
Nacelle with heaters and temperature regulators
Extra platforms in tower (for grid connection and handy room)
Containers for garbage
Survival kit for 3 days for service personnel
150 tons tower where normal are 110 tons to adapt to monopile foundation
2 flight marking lamps on nacelle
Red paint on blade tips

Extra costs of around 10%. In other offshore projects the helicopter platform is not needed.

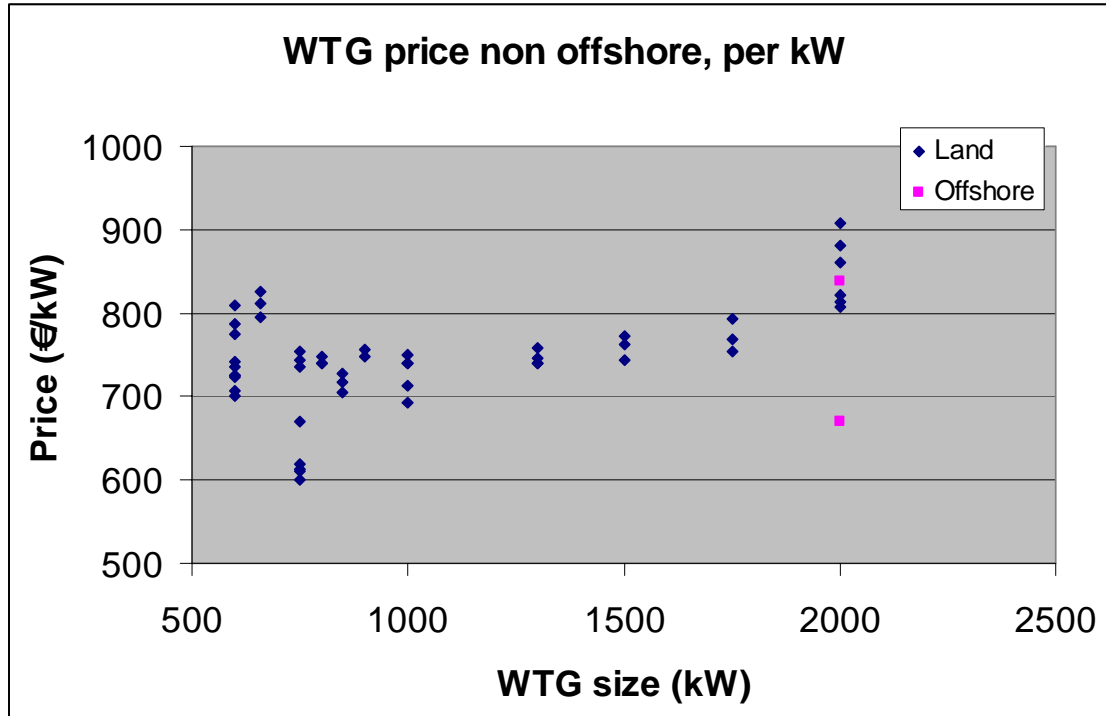


Figure 5 Examples on WTG prices mainly on shore from Danish WTG catalogue 2001 (EMD). The two very different offshore prices for 2 MW WTGs is Middelgrunden (Bonus) and Horns Rev (Vestas), where the Bonus turbines are with a smaller rotor diameter and a smaller hub height, but at the Horns rev solution there are also much extra equipment (e.g. Helicopter platform) that can explain the difference.

WTG prices vary quite much. In the figure, the latest overview of Danish WTGs (WTG-survey November 2001) and two offshore examples are shown. Note that the rotor diameter of course is important. The low WTG price offshore is from Middelgrunden, 2 MW Bonus with 76 m rotor, which can be considered as a DEMO project and thereby low price – the other offshore are Horns Rev, Vestas with 80 m rotor diameter (10% more swept area). This price must be considered realistic so far. So concluding a price level around 850 €/kW should be realistic for a feasibility study.

2.5 Feasibility of near coastal offshore wind parks:

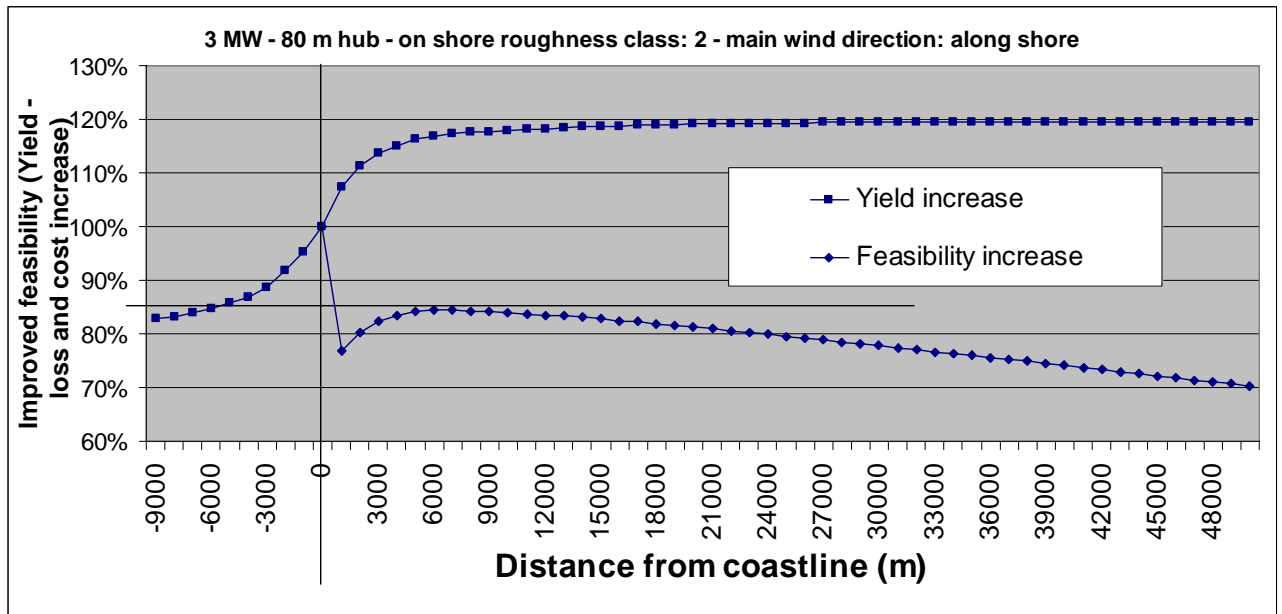


Figure 6 Feasibility 6 km offshore is approximately the same as 6 km on shore - and the "ideal" distance off shore in this example.

Interesting in the DK-example in the figure is that at the given assumptions, a site 6 km offshore is the most feasible and at a distance of 6 km from shore on land (flat land), the feasibility is exactly the same (if the operational cost do not differ). Most feasible is a site direct at the coastline.

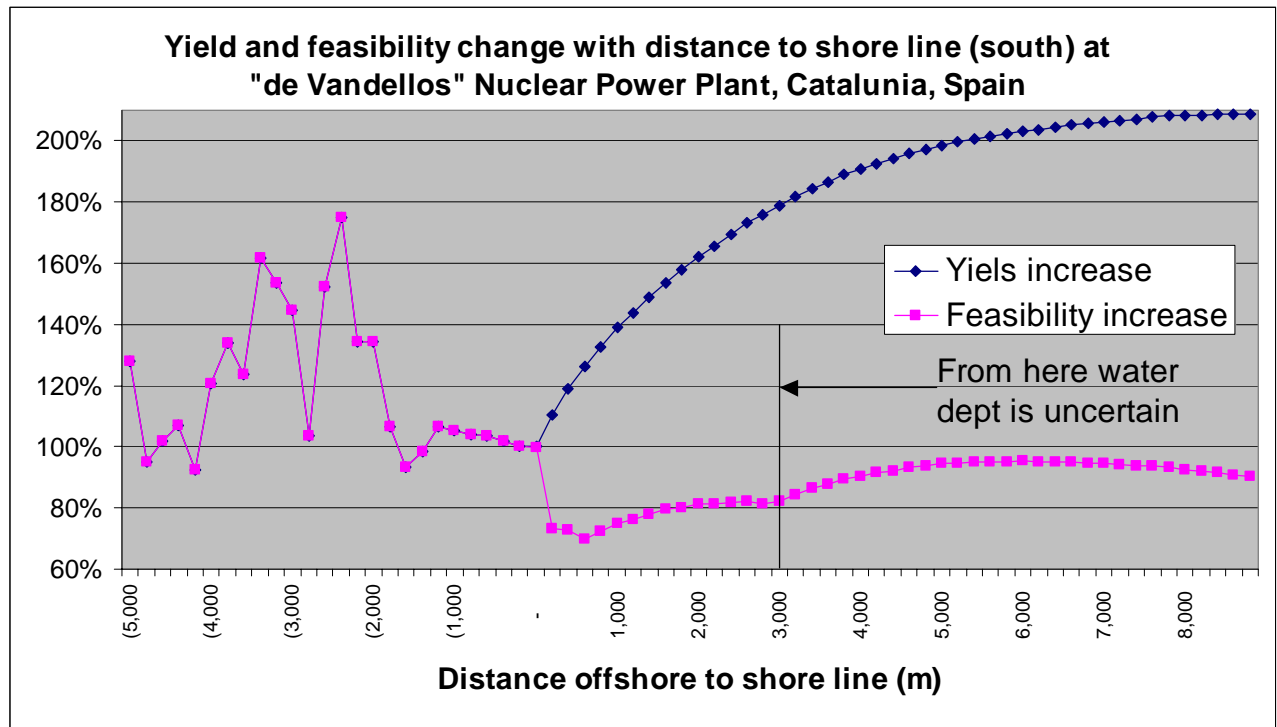


Figure 7 Another example is the Ebro Delta south of Barcelona, Spain. Here the mountains on shore and the fact that the main wind direction is from shore makes the picture look much more complex. Wind turbines on mountain ridges, has the best feasibility.

3. Guidelines how to overcome socio-economic barriers for exploiting the near coastal offshore wind energy potential

At the political, planning, financing and development levels there are scepticism for utilization of the near coastal offshore wind energy potential, because the potential barriers are seen as being too strong and creating too great a risk.

In Denmark there are 6 near coastal offshore wind parks and only 2 far from the coast wind parks. 3 of the coastal wind parks have been established in 2002-and 2003. The near coastal Middelgrunden Offshore Wind Park out of the harbour of Copenhagen has as the first MW-turbine offshore wind park been the reference for the new generation of offshore wind parks. Also in Sweden, Netherlands and UK have been established near coastal offshore wind parks. In several cases it has therefore been possible to overcome the barriers.

Among the most important guidelines for overcoming barriers for establishing near coastal offshore wind parks can be mentioned:

3.1 The scope

The scope of project has to be more than just making profit for the investors. Typical additional scopes can be:

- Local ownership with local income generation.
- Sustainable energy generation for environmental reasons (environmental symbol).
- Demonstration of new technology of importance for national/regional income generation and employment.

When critics come up (it always will) against a proposed offshore wind park, it is important to have in the public debate etc. qualified and substantial motives and arguments for the wind park. Otherwise there can be a tendency that the proposed coastal offshore wind park is rejected at the planning level.

3.2 The ownership

Local ownership or co-ownership can be important for acceptance of a proposed near coastal offshore wind park. This is the case for the Middelgrunden, Samsøe and Roenland near coastal offshore wind parks in DK. The local ownership can as examples take place through:

- Public cooperative ownership – with a greater number of typically small cooperative owners (Middelgrunden, Samsøe and Roenland).
- Local municipality (Samsøe).
- Local private investors (Samsøe and Roenland).
- Local publicly owned utility (Middelgrunden).

3.3 Siting

Several near coastal offshore wind parks are sited as a part or near of technical landscapes of a harbour, industrial plant or similar. This type of site can improve the public acceptance (Middelgrunden, Roenland and Frederikshavn). The potential disadvantage can be that in harbours the wind parks are very visible for many people reducing the public acceptance (Frederikshavn).

Another possibility is to place the offshore wind park in an area with few/no inhabitants, who have their view influenced by the wind park (Samsøe, DK).

3.4 Screening checklist for barriers and checklist for overcoming barriers for establishing near coastal offshore wind parks

As a tool for evaluating the potential barriers for establishing near coastal offshore wind parks a screening checklist has been developed.

As a tool for making an action plan for overcoming barriers, a checklist has been made.

4.The SEAWIND EU Altener-project as background for guidelines for establishing near coastal offshore wind parks

The guidelines for establishing near coastal offshore wind parks are developed by partners from Denmark, Germany, Spain and France as a result of a EU SEAWIND Altener-project carried out in 2002-2003 (No.1003/2001).

As background was used the experiences from established near coastal offshore wind parks in EU, especially the Middelgrunden project in DK, and the experiences from establishing the Samsøe Offshore Wind Park in parallel with developing the guidelines. The main responsible partners for developing the technical/economic guide lines are EMD, DK, a consultancy company specialised in software for planning and economic evaluation of wind energy – and the organisational, planning and financing guide lines, Green Globe Energy, DK, a consultancy company responsible for management, planning, financial and organisational matters of the Samsøe Offshore Wind Park.

Regional case studies were carried out in 3 EU regions with regional partners testing the guidelines at the regional level. These cases were:

- Rousillon-Lanquedoc, FR, with the test of a near coastal 72 MW offshore wind park at Aigues Mortes, 4 km from the coastline. The regional partner is ARCHIMEDES, a sustainable energy consultancy company based in the region.
- Catalonia, ES, with a test of a near coastal 52.5 MW offshore wind park at the Ebro Delta. The regional partner is ICAEN, the Catalan authority responsible for wind energy planning of Catalonia.
- The Butendiek 240 MW Offshore Wind Park in the North Sea 35 km west of Sylt. The partner is Butendiek GmbH. This case is not near coast, but included anyway to use the experience from a large cooperative offshore wind energy project.

The guidelines were also tested in cases in the regions of Yorkshire and North West Regions of UK and at the southeast coast of Ireland in cooperation with regional partners.

4.1 Software Development for Offshore Optimization

The WindPRO software tool (www.windpro.com) is improved in several ways to better support offshore development. While WindPRO is a general tool for project development, it can already handle the most important issues for offshore development like park layout design, energy calculation, economy calculation and environmental documentation (noise, flicker, ZVI, photomontage and animation). But for offshore some needs for improvements has been identified, the most important of which are:

1. More advanced park layout design (arc layout and parallel rows in radials)
2. Optimization of “regular pattern layouts” including water depth considerations

An example on an optimization taking all cost changes into consideration for finding the optimal WTG spacing is shown below.

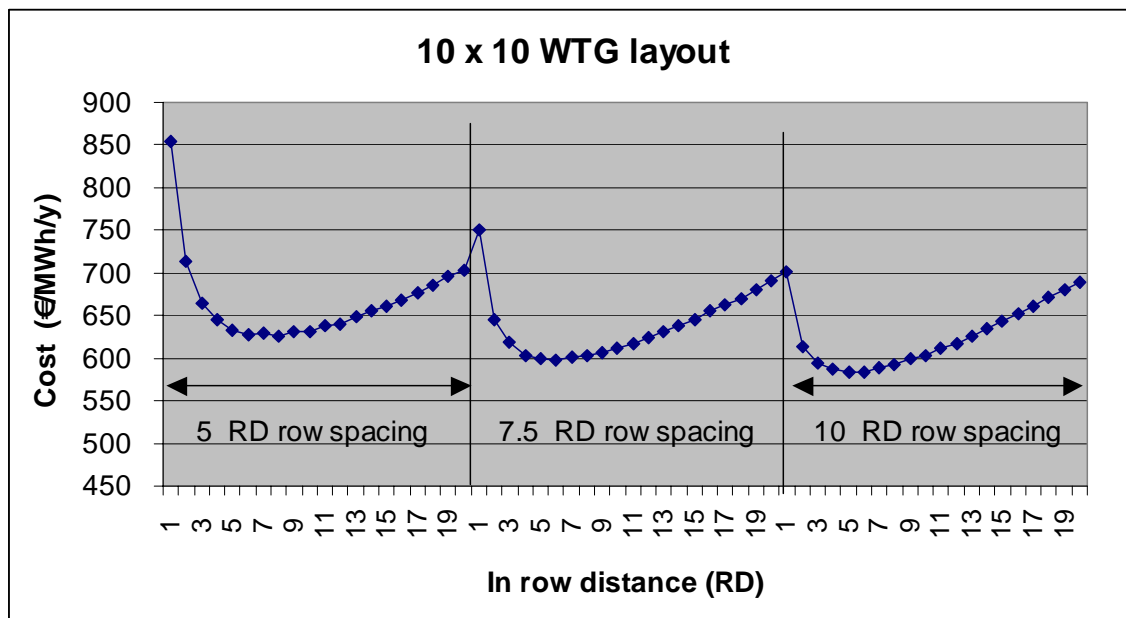


Figure 8 There has been performed 30 runs varying the in row distance for three different row distances. The 10 RD (Rotor Diameter) spacing performs best, and has its optimum at 5 RD in row distance.

5. Recommendations

To promote the exploitation of the near coastal offshore wind potential of EU it is proposed that the EU Commission carries out in cooperation with national and regional authorities an overall registration of the EU potential of near coastal wind energy potential using the result from the SEAWIND study here presented.

A co-operation should be established with interested regional authorities about developing a “European Atlas of the Potential for Near Coastal Offshore Wind Energy”. The Atlas should be based on:

- Registration of physical elements such as sea depth, wind resources, grid connection possibilities etc. in representative European regions.
- Testing the socio-economic model in several regions developed in the SEAWIND project to evaluate the real potential taking into account socio-economic factors.