Combinations with Offshore Wind Parks

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THE EARLIEST REFERENCES ON THE POTENTIAL OF COMBINING fixed offshore installations with marine aquaculture emerged some 10–15 years ago in the US with suggestions for using old oil platforms for other purposes, possibly due to high costs of deconstruction. More recently, the concept has been proposed to combine wind power parks and mariculture facilities in order to improve the use of limited space at sea.

New sites through smart combinations?

Introduction

One of the limiting factors to new forms of using marine resources is the availability of suitable sites where cultivation or farming facilities may be installed. The so-called "spatial efficiency" principle postulates that sea space is a valuable public good and that the sea is no repository for problematic land uses. Thus space should be used sparingly: uses should be concentrated as much as possible to keep other areas free and co-uses, synergies and multiple spatial use should be promoted. Spatial scarcity is not only a technical issue but also depends on social perception, which suggest that it is easier to add a new use to an already "used" area rather than breaking into or disturbing a so far unused space.

The "spatial efficiency" concept is already an integral part of the German Maritime Spatial Planning Law. With maritime spatial planning becoming more and more of a reality it is expected that the principle of "spatial efficiency" will also become common rule in other countries.[1]

Even though this principle holds true for all sea areas throughout the world, the case for spatial limitations is especially dramatic in the Baltic Sea Region, where coastal and near shore areas host a highly competitive group of uses, including shipping (trade or private), sand extraction or disposal, military practice as well as areas which are sectioned off for specific purposes such as pipelines, cables, wind farms, nature reserves and other marine and coastal protected areas. Recreational activities as well as commercial fisheries and mariculture are additional interests.[2] In view of this highly competitive group of uses, it is difficult to find suitable places for aquaculture in the Baltic Sea Region. Combinations with offshore windmill parks may thus be an option to be considered.

A large number of offshore wind farms are already in operation, particularly in the Danish EEZ of the Baltic Sea. More are planned or under construction in most of the Baltic EU member states. Their increasing number, volume and spatial placement call for multiple use concepts that shall reap additional benefits from these areas.

As is now well known, aquaculture offers the potential to provide an additional source of food, feed and bioenergy. In addition, some aquaculture systems (e.g. algae, mussels) may simultaneously provide services like removing from the water nutrients coming from agricultural runoffs, wastewater and sewage treatment. From an economic point of view, synergistic effects may arise from the multiple use of existing installations and land-sea connections and maintenance requirements may be reduced. Furthermore, marine wind parks are often placed in low depth areas, which have served as traditional fishing areas. Mariculture in these areas could be a way to compensate for losses in the traditional fishery.

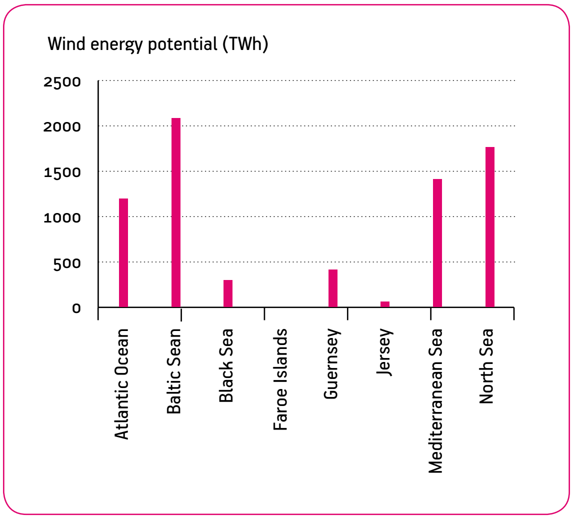
Offshore Wind Parks in the Baltic Sea Region

Technical Potential

Wind energy potential in the offshore Baltic is substantial: the unrestricted technical potential is estimated by the European Environment Agency (EEA) to exceed 2000 TWh per year, making this the region with the highest technical potential[2] in the EU (assuming the potential area for offshore wind energy generation is limited to depths less than 50 m).

The Baltic Sea offers better conditions in comparison with other areas such as the North Sea, where conditions are much harsher (high salinity, extreme wind and waves, deep waters, long distance to shore, tricky accessibility), which makes offshore wind energy more expensive in this area. In the Baltic Sea, less advanced technology is needed due to the milder conditions and the easier access to the sites, resulting in cheaper maintenance costs due to better all-year-round accessibility. These conditions translate into clear economic advantages: investment costs in the Baltic Sea Region are approximately € 1.2 million per MW compared to approximately € 2.7 million per MW elsewhere.

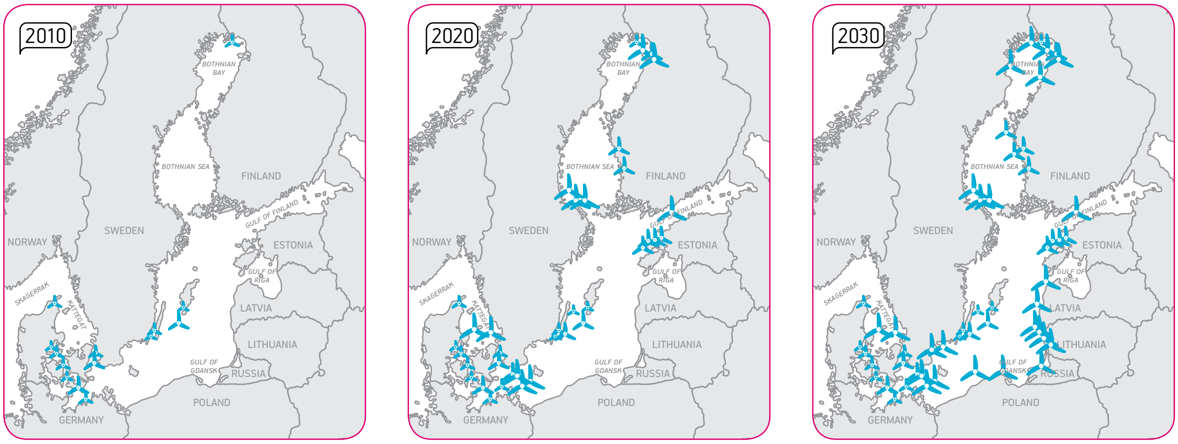
Figure 1: Unrestricted technical offshore wind potential 10–30 kilometres from the coast.[3]



Limiting Factors

However, theoretical technical potential for offshore wind does not take into account the fact that other given or projected uses of the sea areas (such as shipping routes, boat traffic, fisheries, military use, cables, oil extraction and other human activities) may limit the potential for offshore wind developments.

Figure 2: Outline of the present, planned and projected wind mill farms in the Baltic Sea area. (Data from WWF).



Spatial planning policies are then required to guide the proper use of the available sea areas. Relatively new utilisations of the sea, such as wind farms, are an integral part of any maritime spatial planning policy. In the Netherlands, United Kingdom and Poland for example, spatial planning measures require that wind farms be build at least 12 nautical miles away from the coast (about 22 km), mainly due to their visual impact.[3]

In light of these considerations, it is assumed that in practice only 4 % of the offshore area within 0–10 km from land might be available for development of wind farms and 10 % of the areas 10–30 km and 30–50 km from the coast.[2] For areas with a distance from the coast above 50 km, a larger share could be utilised because this area is relatively large and other functions such as shipping are less concentrated. Therefore it is assumed that 25 % of the areas above 50 km may be used for wind farms.

If these restrictions are applied, the unrestricted technical potential for offshore wind drops by a factor of ten in Europe (and probably even more in the Baltic Sea due to lack of suitable sites). However, the resulting amount of electricity from offshore wind would still be sufficient to fulfil about 78 % of the projected electricity demand in Europe in 2030 (5,100 TWh).[2]

Current Projections

In the Baltic Sea Region, the predicted increase in energy production from offshore windmill parks in coming years is substantial The predicted amount of electric energy in MW produced by offshore wind parks in the Baltic Sea Region in 2030 is estimated to 25,000 MW, with the number of wind farms estimated at 65 to 70. Though most Baltic States are working on planning and legal implementation of wind parks in the region, no comprehensive mapping of existing or planned wind power parks in the Baltic Sea Region has been done to date.

Table 1: Number of Baltic Sea offshore wind farms and electricity production capacities (in MW) in 2010 and predicted numbers for 2020 and 2030. Data from HELCOM and WWF.[2, 4]

	2010	2020	2030
Number of offshore wind farms in the Baltic Sea	13	42	67
Electricity production capacities (in MW) of Baltic Sea offshore wind farms	436	10 843	25 000

Space Availability

The expected increase in the number of offshore wind parks in the Baltic Sea is going to be to be accompanied by an increase in the individual park size. This is due to the fact that the size of individual windmills is expected to increase and thus also the distances required between them. Individual wind turbines in Rødsand II in Lolland, Denmark currently have a capacity of 2.3 MW, though for 2014 Siemens is already planning serial production of offshore windmills with a capacity of 6 MW. These mills have a rotor diameter exceeding 130 m. Performance studies have shown that the optimal distance between the individual mills in a park is 7 times the rotor diameter or about 1 km for the aforementioned 6 MW windmills.

It should be noted that the overall space taken up by wind parks would be substantially greater if rotors were to remain smaller. The comparable numbers of space theoretically available for combined uses for 1 and 2 MW windmills are listed below. These estimates are made for comparison purposes only and do not suggest expected areas which could be realistically occupied by wind parks and combined uses, as it is difficult to imagine that such large expanses of the Baltic Sea would be acceptably turned into windmill parks.

60–70 parks each consisting of 400 1 MW windmills would occupy an area of at least 14,800 km^2. Here 3,700 km^2 would theoretically be available for mariculture within the offshore wind parks

70 parks each consisting of 200 2 MW windmills would occupy an area of at least 9,100 km² (2 % of the sea area of 370,000 km²). At least 2,300 km² would theoretically be available for mariculture.

PUTTING IT INTO PERSPECTIVE

It is estimated that by 2030, the Baltic Sea Region could see approximately 4,100 offshore windmills with a 6 MW capacity, located in 65–70 parks. This would correspond to an area of no less than 3,500 km². Some investigations suggest that at least 25 % of the space between the individual windmills in these parks may be used for other purposes and activities such as mariculture systems.

Applications

Harvesting of Natural Fouling Agents

In its simplest form, the combination of offshore wind farms with other uses could focus on the harvest of fouling agents in the submerged parts of the windmill constructions. The algae, seaweed and mussels harvested could be used as alternative protein resources for example for fish feed or as a biomass contribution to local energy systems (gasifiers).

The yield from this type of harvesting is reported to be up to 40 kg of biomass per square meter per year in the North Sea.[5] A study from the Baltic reported a yield of 10 kg/m², with the biomass containing a substantial removal of heavy metals, nitrogen, and phosphorus.[6,7]

Figure 3: Possible Combinations with Offshore Wind Parks.

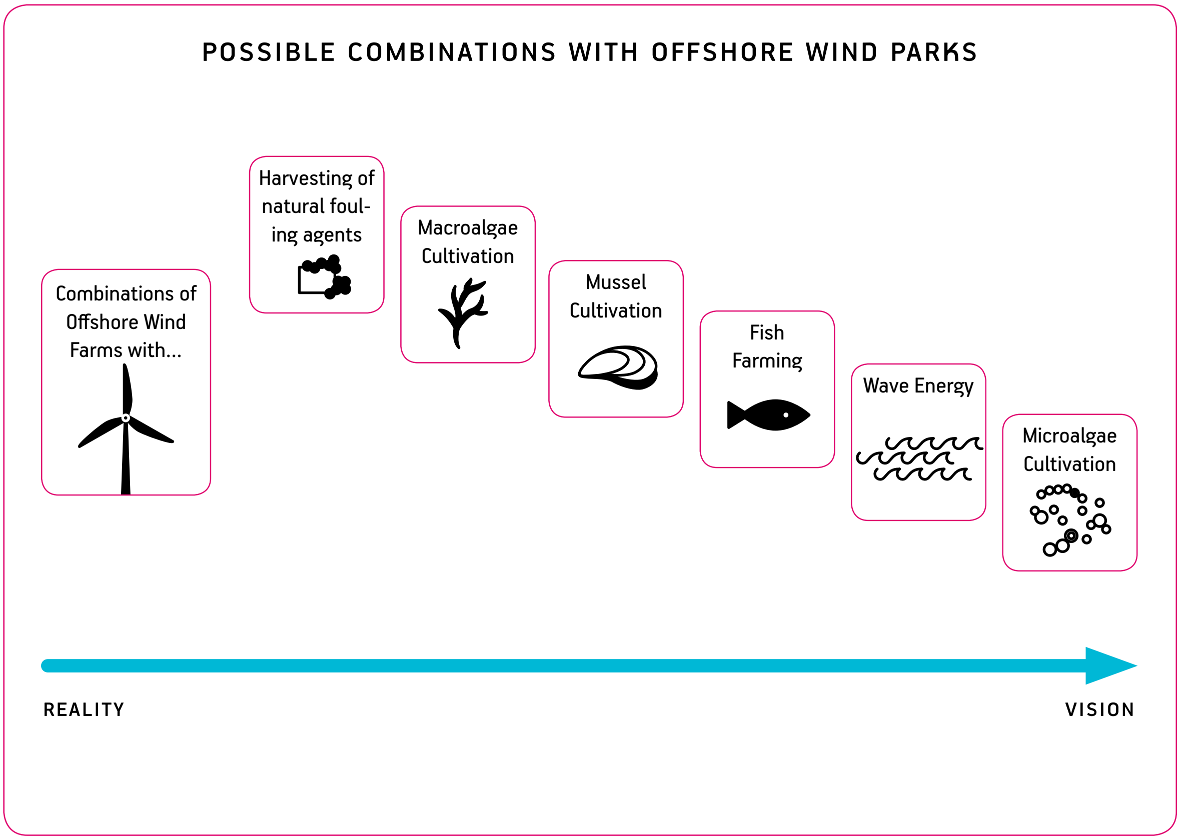


Figure 4: Fouling on wind mill foundations (photo: Mathias Andersson / Azote).

Macroalgae Cultivation

Generally macroalgae are more suitable for cultivation at sea than microalgae since they do not need to be enclosed. Usually, so-called "settling-lines" are inoculated in hatcheries onshore and thereafter placed in the cultivation systems offshore. The techniques currently used could probably also be applied in windmill parks, but there are currently no commercial examples of macroalgae cultivation within offshore wind farms. Some research and testing have taken place in the Netherlands and Denmark and more tests are planned for 2012–2013. Generally it appears that some types of seaweed may anchor well to solid structures like windmill constructions, nets and lines.

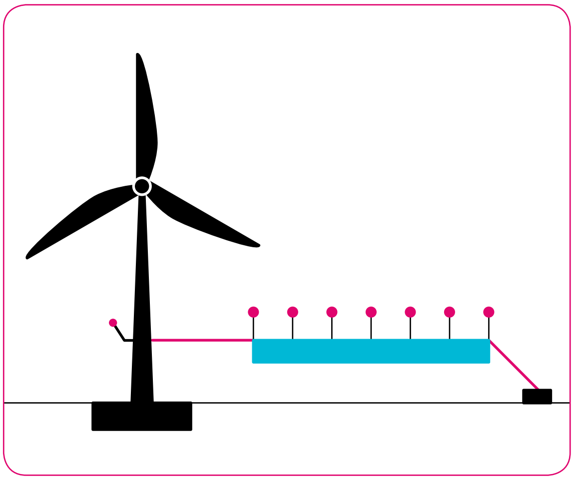
Mussel Cultivation

A Danish feasibility study has shown that mussel farming is possible in combination with windmill farms, with the mussels settling on strings, nets and solid structures and attached to the mill foundations.[8] However, the present design, operation and management of the farms as well as the rough wind and wave conditions provide challenges. Furthermore, the presence of mussels could attract birds, with increased risk of collision with turbines as a likely consequence. However, bottom culture within the parks may be a feasible alternative for increasing the mussel production areas. Large-scale production would probably reduce operating costs.

With salinity levels decreasing towards the eastern Baltic Sea, opportunities for production of high quality mussels (for human consumption) decrease in these areas. However the biomass from these areas may still be useful for other purposes, such as nutrient removal, feed and biogas production.

Calculations have been undertaken for Rødsand II, Denmark, using Swedish mussel production data[7] and assuming that nutrient removal properties of mussels would not change if the mussel farm installations were located within a windmill park. Results show a potential annual production of 2000 tonnes of mussels containing 20 tonnes nitrogen and 2 tonnes phosphorus if production facilities were to be set up on all park windmills. Thus, simple, low intensive mussel cultivation in future wind parks could account for a substantial removal of nutrients from the sea.[6] Within the SUBMARINER project, a test line for cultivating mussels and macroalgae has been installed at the Danish Rødsand II wind park in autumn 2012 (see figures 5 and 8).

Figure 5: Diagram showing system for cultivation of mussels at the offshore wind park Rødsand II. Redrawn from 6



Fish Farming

Fish farming in offshore windmill parks would consist, in its simplest form, in the installation of currently known and used fish production facilities within the area of the wind parks. These would probably be operated in cooperation with the wind park's own set up for operation and management. The proper sustainable approach would consist of the installation of Integrated Multi Trophic Aquaculture (IMTA) (see "Sustainable Fish Aquaculture" Chapter) production facilities within the wind park area.

This type of combination is more feasible to take place in the future, as the individual windmill constructions increase in size and the parks will occupy larger areas, meaning that the individual towers occupy comparatively less space (less than 1 % of the park area), leaving space for other structures and production facilities between the mill towers.

Wave Energy

Recently a new combination of wind and wave energy production systems has been proposed, using the towers of the individual windmills for fixation of wave energy devices. The concept was developed at the University of Klaipeda[9] and is intended for Baltic Sea low wave conditions. It consists of closed tubes containing the wave energy generator and a buoy activating the generator. The tubes are attached to the windmill tower. The wave energy generating tubes may be anchored in a way that prevents possible vibrations, that is, symmetrically around the tower.

In the short term, due to the relative immaturity of offshore renewable energy technologies, it is generally seen as too early to deploy combined wind-wave platforms. However, co-location of devices could eventually realise large benefits with respect to infrastructure and represents an important opportunity, with benefits from joint utilisation of electrical infrastructure and potentially of operations and maintenance teams, vessels and infrastructure. Six principal areas have been identified where immediate technical synergy opportunities exist between the offshore wind and wave energy sectors:

- Common foundation types
- Sharing of lessons learnt for effective array layout design
- Common mooring/fixed connection points
- Grid connection and integration
- Common power take off technologies
- Sharing of lessons learnt for effective design and technology development to reduce the need (and associated cost) for operations and maintenance (remote monitoring is a good example of this).

Both sectors can also take advantage of lessons learnt in order to accelerate their development

Figure 6: Concept of a combined wind and wave energy production system.[9]

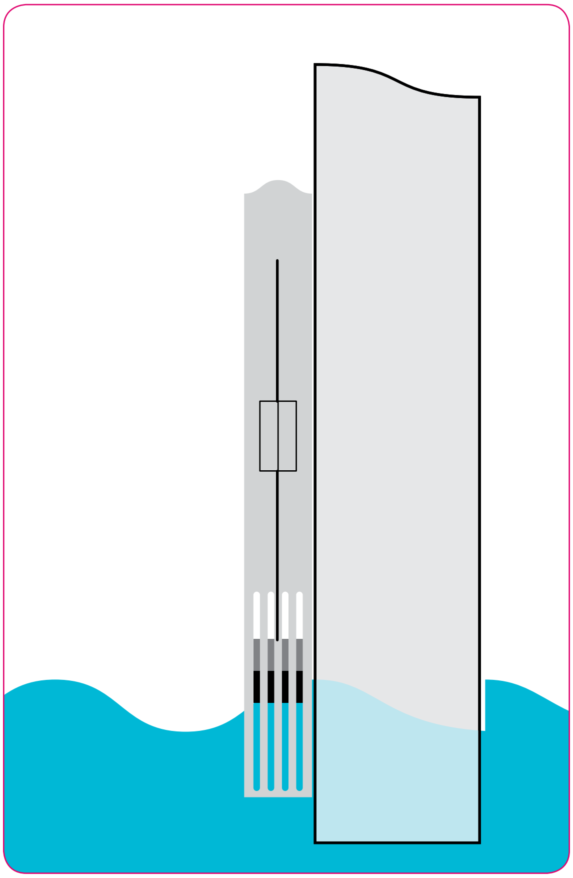


Figure 7: Visualisation of a windmill park with photobioreactors.[10]

and penetration into the European energy market. Both also share a similar context in terms of governmental marine policies, marine stakeholders and spatial constraints.

Microalgae Cultivation

The combination of offshore wind farms with microalgae cultivation is mostly limited by the fact that microalgae cultivation at sea is in and of itself still a challenge. Technologies currently under development, such as the OMEGA (Offshore Membrane Enclosure for Growing Algae) system, which consists of algae culture bags with osmotic membranes, could presumably also eventually be anchored to the windmill foundations.[10, 11]

Technology

Despite growing interest in the concept of combining offshore wind farms with other uses such as mariculture there are still very few concrete examples worldwide. Most references to the topic are purely theoretical and often speculative.

Substantial research on the combination of mariculture and offshore wind farms is being led by the German research center IMARE (Institut für Marine Ressourcen GmbH) in Bremerhaven.[12, 13] However, most of the research efforts have focused on North Sea wind parks and on windmill foundation types which are not common in the Baltic Sea.

In Denmark some research has been done at the Danish Technical University (DTU Aqua) mainly in an assessment study on the possibilities of farming of fish and shellfish in areas in between wind turbines, using the farm south of Nysted as a pilot case[14] and a small mussel project has been carried out at the Swedish west coast.[5]

With certainty, one important technical consideration regarding the possibility of combining uses is the choice of windmill foundations, which is in turn related to sea depth. A number of different types of foundations for offshore windmills have been developed: monopile foundations, gravity foundations, tripods and floating foundations.[15]

Tripods and floating foundations are for use in very deep water (over 100 m). In view of the rather shallow water depths (10–30 m) in which current and projected wind parks are located in the Baltic Sea, such tripod foundations are exclusively found in the German and Danish EEZ of the North Sea and in the UK EEZ.

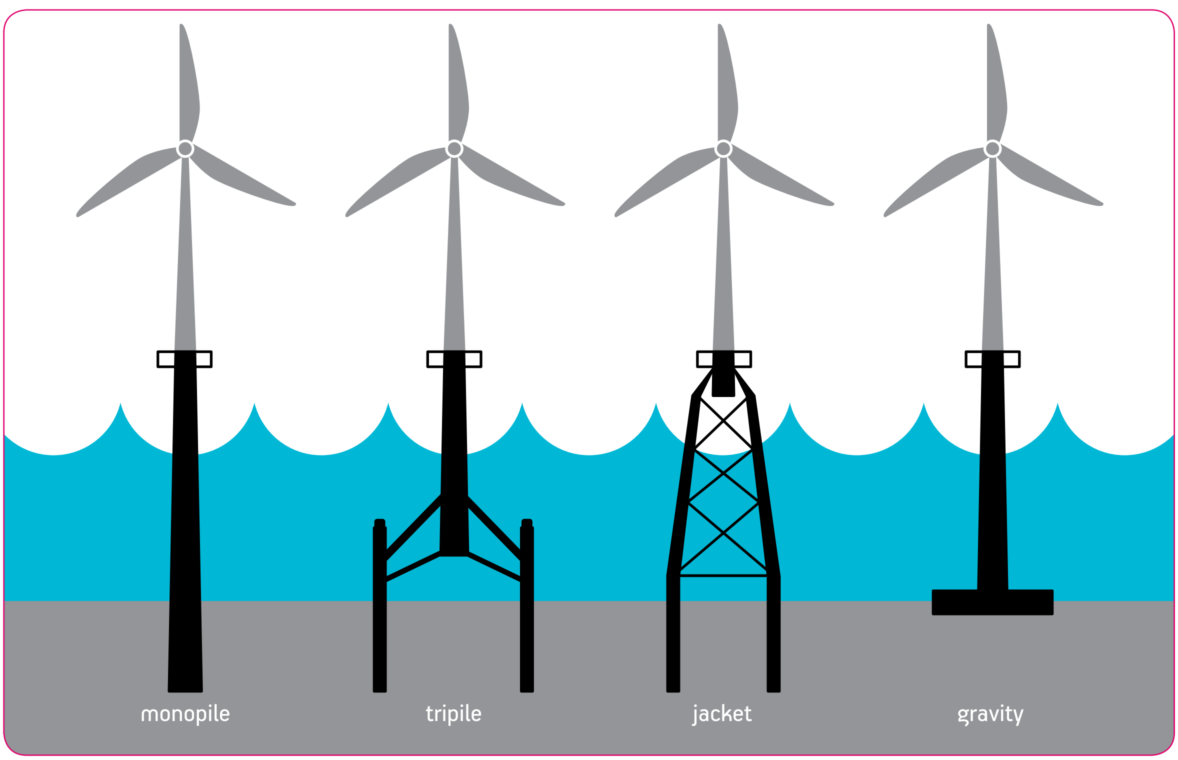
Two types of foundations are suitable at shallower depths: the monopile and the gravity foundations. A monopile is in essence a long steel rod that is hammered into the seabed. Offshore wind farms such as Horns Rev and Samsø in the Danish Baltic Sea have monopile foundations. To prevent sediment erosion large protection boulders are placed around the monopile turbine within a diameter of 20 m. A common distance between today's turbines is approximately 500 m. This implies that turbines and their boulder protection occupy less than 0.3 % of the total area of the windmill farm.

Gravity foundations can be made of either concrete or steel, concrete being the most common. The idea is to have a base structure heavy enough to support the tower and engine housing solely by its own weight. The technique is similar to that used in bridge construction and is therefore very well known. Gravity foundations are transported to the site on barges and lowered onto the seabed. The foundation often contains compartments, filled with ballast rocks to increase the total weight, which is typically a couple of thousand tons. Rødsand 2, Nysted and Middelgrunden in the Danish Baltic Sea are examples of wind farms that have gravity foundations. These kinds of foundations are expected to be the most commonly used in future Baltic Sea Region wind parks.

Other important aspects to consider from a technological perspective relate to the environmental conditions and how to best control and the impacts of storms, waves, currents and other elements. Windmill farms are generally located in areas with strong winds and often also high waves, which can hamper operations for mariculture and ship traffic. Experiences from the Horns Rev I wind farm in the North Sea show that operations are possible at wind speeds below 8 m per second, which is the case between 51–64 % of the time at the wind farms of Horns Rev, Anholt and Nysted (Denmark). Wind speeds between 8–14 m per second make operation possible only sometimes (depending on other factors), while wind speeds above 14 m per second as well as wave heights exceeding 1.2 meters hamper operations altogether. Estimates suggest

Figure 8: Test cultivation line at Rødsand II: 90 windmills, 207 MW, 75–80 km cables, area of 34 km^2 plus surrounding restricted area.

Figure 9: Offshore foundation options for windmills. Monopile and gravity foundations are suitable for shallow waters of the Baltic Sea.



that operation of offshore windmill parks in the Baltic Sea Region is possible up to 80 % of the time.

An accurate prediction of the effects of windmill structures on surface ocean circulation is of great importance to assess the suitability of wind farm installations as sites for aquaculture activities. Windmill structures will naturally have an interaction with the surface and tidal waves, which can be important in regulating local water circulation patterns. Another important factors to consider is ice cover during the winter, which can prevent or limit the operation of nearshore aquaculture sites.

Competence Centres in the Baltic Sea Region

Although the Baltic Sea Region is a leader in the world wind industry, research into the combination of uses in offshore wind farms is still at a very early stage and thus only a few actors are involved in the field. The most substantial amount of research has taken place in the United States at NASA. In Germany, IMARE hosts test facilities at a laboratory scale and undertakes research on the development of equipment suitable for the North Sea environment. In Denmark, the Green Center has been involved in research in co-localisation in the Baltic Sea Region and has very recently set up a small test site in Rødsand II (Eon) in cooperation with the local operation and maintenance unit in Rødbyhavn and the Swedish company Kingfisher.

Table 2: Research institutions, projects and companies dealing with combined uses in the Baltic Sea Region.

Research Institutes / Projects / Companies	**Focus area**
Danish Technical University DTU-Aqua (Denmark)	Offshore wind farms and their potential for shellfish aquaculture and restocking Feasibility studies on mussel cultivation in the Nysted wind park in Denmark
Algae Innovation Center (Green Center) (Denmark)	Demonstration and test facilities for algae cultivation. Test site for estimation of biomass potential in Rødsand II. Research on algae potential for different applications Contribution to local and regional development
Institut für Marine Ressourcen GmbH, IMARE (Germany)	Research on extensive open ocean aquaculture development within wind farms in the German EEZ of the North Sea Offshore co-management, legal constraints and management strategies for governing wind farm-mariculture integration, including sociological constraints
Offshore Center Denmark	Offshore cluster organisation
Kingfisher (Sweden)	Testing of equipment for offshore mussel and algae cultivation, including in offshore wind parks
Krog Consult (Denmark)	Assessment studies on the possibilities for cultivation of fish and shellfish in areas with offshore windmills. Pilot study using the wind park at Nysted.
University of Klaipeda (Lithuania)	Pilot case on co-location of wind mills and wave energy generation equipment

Environmental Assessment

Since on a practical level the concept of combining offshore wind farms with other uses is in its infancy, information on environmental impacts is limited. The following evaluation of impacts on the environment pertains to the co-localisation of windmill parks and aquaculture production facilities (e.g. algae, bivalves, fish). The possible effects of wave energy installations combined with offshore wind farms are discussed in the chapter on wave energy.

General Considerations

Marine space is nowadays considered a valuable asset in itself and increased efforts are being undertaken to keep as much of it as possible unused by promoting co-uses in spaces which are already being utilised.

From a spatial perspective, combining offshore wind farms with other uses is expected to result in a number of positive impacts such as:

- Less and better optimised use of a limited amount of space.
- Mariculture installations can be more or less hidden within offshore wind parks, minimising their impacts on the landscape.
- Benefits from the use of the existing offshore infrastructure (service harbours, boats, vehicles, electricity supply, anchorage possibilities), possibly also common operation and management facilities, resulting in reduced emissions from transport and handling.

However combinations may also lead to increased spatial problems including:

- Increased traffic intensity for operation and management, with consequent wear on waterways and increased risk of accidents with related risks to the environment.
- Disturbance of the "windmill landscape".

Furthermore, it has been shown that windmill installations function as resting places for birds and mammals as well as create artificial reefs and related biotopes, providing new habitats and substrates for marine organisms. Any kind of added uses to the wind park may therefore lead to disturbance of the new biotopes created or the mammals and birds that have found resting places between or on the windmill foundations. However, due to the lack of real data many open questions remain about potential impacts on marine mammals and sea birds, as well as the shading of local ecosystems. The overall impact may well be positive but further research is needed.

Considerations on Specific Combinations

While many of the impacts of mussel, macroalgae and fish (IMTA) aquaculture in offshore wind farms will be similar to those expected for near shore cultivation (outside wind parks), the offshore location with its increased water depth and higher exposure to storms, high winds and wave activity creates some additional concerns regarding the sustainability of the cultures. There is also an expected increase in the carbon footprint associated with offshore cultivation in wind parks when compared to nearshore cultivation as a result of higher costs associated with harvesting and transport of biomass.

WATER QUALITY

Harvesting of natural fouling agents and the combination of mussel and/or macroalgae cultivation with wind parks is potentially an attractive means to improving water quality and mitigating against eutrophication. Conversely, the combination of fish aquaculture with offshore wind parks will most likely have unfavourable impacts on water quality by adding more nutrients to a nutrient-rich environment (even with IMTA systems, which mitigate the excess nutrients problem but do not eliminate it).

HABITAT / SPECIES PROTECTION

Given the relatively shallow water depth (c. 30 m) under consideration, many of the environmental benefits that can be realized by moving mariculture offshore (e.g. to water depths >50 m)[16] would only be moderately realized in this scenario, as coupling

Table 3: Overview of the potential different impacts of harvesting natural fouling agents, cultivating mussels and / or macroalgae and combining offshore IMTA technology (i.e. finfish, mussel and macroalgae combination) with wind parks on environmental objectives and priorities.

Environmental Objective	Environmental Priority	Harvesting of natural fouling agents	Macroalgae Cultivation	Mussel Cultivation	Fish Aquaculture in IMTA	Comments
Water quality	Bathing quality					
	Water transparency	strongly supportive	moderately supportive	strongly supportive	moderately not supportive, neutral	
	Eutrophication	strongly supportive	strongly supportive	strongly supportive	moderately not supportive, neutral	
	Biogeochemical cycles	strongly supportive	moderately not supportive, moderately supportive ?	moderately not supportive	moderately not supportive	Beneath the site
Habitat / Species protection	Food web dynamics	?	moderately not supportive, moderately supportive ?	moderately not supportive ?	moderately not supportive	Phyto-zooplankton interactions
	Biodiversity	?	moderately not supportive, moderately supportive ?	moderately not supportive, moderately supportive	moderately not supportive	Benthos and anoxia
	Benthic habitats	?	moderately not supportive	moderately not supportive, moderately supportive	moderately not supportive	Anoxia versus shelter, food
	Bird habitats	?	strongly supportive	strongly supportive	moderately not supportive	Natural stocks used for feed
	Fisheries	?	strongly supportive	strongly supportive	strongly not supportive	Natural stocks used for feed
	Marine mammals	?	moderately not supportive	moderately not supportive	moderately not supportive	Depends on location
	Marine noise	?	moderately not supportive	moderately not supportive	moderately not supportive	Harvesting, transport effort
Coastal protection	Coastal morphology					
	Scenery					
Climate protection	CO_2 emission reduction	moderately not supportive	moderately not supportive, moderately supportive	moderately not supportive	moderately not supportive	Harvesting, transport costs versus biogas production

strongly supportive
moderately supportive
strongly not supportive
moderately not supportive
neutral
? gaps in information;
blank not applicable

between benthic and water column processes will remain an issue. For mussel and macroalgae cultivations, the environmental impacts are similar to those detailed in the near-shore assessments covered in the respective chapters with some moderation of the unfavourable impacts assumed due to some increase in water depth and location offshore. Of greater concern, is the deployment of fish aquaculture (IMTAs) in offshore wind parks. Increased organic pollution and sedimentation will be an issue (albeit also somewhat moderated as compared to nearshore installations) and the increased exposure to the elements at offshore locations increases the risk of escape of cultured fish into the natural environment and interactions with wild fish and predators. Furthermore, various chemicals and medicines are used in mariculture which accumulate in the benthic organisms and sediments below the net cages.[17, 18] Little is know on the sensitivity of benthic habitats to these environmental hazards and medicines and there is a need for local knowledge of the prevailing currents in order to assess the full impact on the benthos.

CLIMATE PROTECTION

There will be an increase in the carbon footprint as farming moves offshore due to increased harvesting and transport costs. On the other hand, a potential co-use of existing infrastructure, operation and management facilities could actually result in reduced emissions from transport and handling.

Overall, the culture of mussels and macroalgae in combination with offshore wind parks can be encouraged as a water quality remediation effort. On the other hand, not enough is known about the real impact on water quality of deploying new open fish cages as part of an IMTA system within an offshore wind park and this can therefore not be recommended for the time being.

Socioeconomic Aspects

Offshore wind energy is a market with great potential. Much of the technology is currently concentrated around Northern Europe and Denmark in particular. To date, 90 % of all installed offshore capacity in the world has been delivered by the Danish wind power industry and a substantial expansion of the market is expected in coming years.

Investment costs are by far the most important factor. Operation and management costs are estimated to be approximately € 0.012–0.015 per kWh of produced wind power, corresponding to 2–3 % of total turnkey investment costs in the early years of the farm and around 5 % at the end of the lifetime.

Currently offshore wind energy remains more expensive to produce than conventional energy. This is publicly and politically accepted given renewable

IMPORTANT ASPECT FOR THE BALTIC SEA REGION

Maritime Clusters: A Path to Promoting Combined Wind Farm Development?

In the port cities of Bremerhaven (Germany) and Esbjerg (Denmark) comprehensive offshore wind farm supply chains have been built up with numerous companies producing the different elements for the offshore wind farms (e.g. towers, blades, engines). Location close to the harbour makes construction of wind farms a faster and more efficient process. While these clusters are currently located in the North Sea, such solutions could prove not only viable in the Baltic Sea but also an important tool in offering model solutions for combined uses in future wind parks.

energy targets. The additional costs of producing electricity with wind turbines, including offshore ones, are paid by the electricity consumers.

Even though some wind power companies are interested in potentially combining other uses in the same space, operation and maintenance of the turbines and installations have highest priority. This involves small boats, larger barges, cranes and other equipment and is a challenge to the design possibilities and management of potential mariculture systems within the same spaces.

While it is possible that positive synergistic effects resulting from the additional uses of areas underneath or between the mills may outweigh the additional cost associated with them, this is unlikely to be the case. Thus, if combined uses can be successfully implemented in offshore wind farms, options to reward the costs attributable to any derived bioremediation or other environmental and societal benefits (such as nutrient removal, increasing fish stocks, jobs in rural areas) are needed. This would also improve public approval. In order to create attractive incentives for combined uses resulting in bioremediation, compensation for providing ecosystem services (e.g. nutrient trading schemes) will need to be introduced as otherwise the costs of combining uses would probably be prohibitive.

Regulatory Framework

Even though spatial efficiency is a concept promoted by maritime spatial planning, in current planning reality "combined" uses are much more difficult to be approve than singular uses. In Germany and Denmark there is, for instance, a comprehensive regulatory framework in place for offshore wind energy, but a less developed regulatory framework for the different forms of aquaculture. It should be noted that so far there is no case where licensing agencies had to decide on an application for aquaculture within an offshore wind park. It is therefore necessary to have a satisfactory regulatory framework which is able to deal with the special situation of aquaculture within an existing or planned offshore wind farm, especially taking the technical interface between these two uses into account. Otherwise the establishment of mariculture operations in very suitable locations in the Baltic Sea could be hindered if these places are taken by wind farms without the possibility to have at the same time or later a co-use with aquaculture.

ADDITIONAL POINT

The Danish Legal Framework

In Denmark, the Danish Energy Agency is the authority responsible for planning and implementation of offshore wind turbines.[19, 20, 21] It acts as a "one-stop shop to provide all necessary approvals and licences. Relative to the administrative processes in other countries, the Danish model has created a quick and cost-effective process benefiting both individual projects and the development of offshore wind industry as a whole. The consent procedure includes steps of political decision-making at the national level, tendering, concession to the successful tender, license to pre-investigate the sites, environmental impact assessment, construction consent (with conditions) and license to produce electricity.In order to ensure that the future development of offshore wind turbines does not clash with other major public interests and that it is carried out with the most appropriate socioeconomic prioritisation, the Danish Energy Agency, in conjunction with the other relevant authorities, has mapped the most suitable sites for future offshore wind farms and also carried out a strategic environmental assessment[19] in order to prevent any future conflicts with environmental and natural interests. However, co-localisation or combination of uses have not been considered in this process.

Even though a similar process is needed for approval of an aquaculture production facility offshore, the legal authorities involved differ depending on the type of organisms cultivated and locality of the planned aquaculture site (distance from shore). For mussels and other bivalves, the Danish Directorate of Fisheries is the legal authority. The focus is on sailing routes, buoys and anchoring and disturbance of fishing grounds. Feed and chemicals are not approved. However, in recent years no new approvals for marine fish productions have been issued due to environmental uncertainties and potential consequences on the implementation of the EU Water Framework Directive.

The legal framework for approving the cultivation of macroalgae is somewhat similar, though installations close to the coast may be approved by the local municipality.

SWOT Analysis

STRENGTHS	WEAKNESSES
• Optimises use of restricted space in the Baltic Sea • Can deliver multiple products (e.g. biogas, fertilizer, seafood) and services (e.g. energy, wastewater treatment, carbon sequestration) from the same space • Can help meet the increasing need to shift from fisheries to marine aquaculture while not losing jobs • May provide economies of scale and cooperation • Contributes to various Baltic Sea Region goals to: sustainably use marine resources, reduce environmental impacts, use space better and develop the mariculture sector • Can promote the development of economically less developed (rural) areas along the Baltic coasts	• Technology is still on an experimental stage and research is mostly focused on waters deeper than the Baltic Sea • Lack of concrete examples worldwide • Engineering challenges remain pertaining to e.g. enclosure systems, materials, corrosion, strength and longevity • Knowledge gaps remain concerning sectorial cooperation and environmental impacts • Mariculture tradition in the Baltic Sea Region is limited • Limited areas with suitable conditions for wind parks • No tradition for cooperation between the aquaculture and offshore wind sectors • Resistance from both the wind and mariculture industries

OPPORTUNITIES	THREATS
• Spatial efficiency has been introduced as a principle of maritime spatial planning in the Baltic Sea Region and is thus promoted by planning procedures • Growing development in innovation and technological progress • University and training courses already exist which can provide qualified employees in some of the necessary areas • EU support EU 2020 policies concerning e.g. renewable energy, climate change, Integrated Maritime Policy, structural funds • Growing demand for energy from alternative sources • Growing prices for traditional energy carriers	• Difficult and long approval procedures • Potentially increasing nature protection requirements • Resistance to new licences for marine aquaculture in general • Potential for conflict between opposing stakeholder interests • Lack of political support at national level in the form e.g. of national energy policies ensuring stable level of energy prices from renewable sources • Lack of investment and financial support due to the actual economic and financial crisis • Lack of political demand, public awareness and support

Knowledge Gaps

The combined use of wind farms with other applications in the Baltic region is still an innovative vision. There are still a myriad issues to be elucidated before the vision can be realised since there is an almost complete lack of practical experiences on the establishment, operation and maintenance of combined uses.

There is a need for further knowledge and experiences on:

- Economies in common operation and management
- Economic feasibility of co-localisation in general
- Technical solutions for cultivation systems, as we know very little about the technical feasibility of the aquaculture different systems (strings, nets, anchoring, mountings) in connection with the windmill foundations (particularly with gravity foundations) or in “empty” spaces between the windmills.
- Information regarding whether the windmill constructions would need to be changed to resist additional drag from the equipment posed on them.
- Information about what are the most suitable sites for aquaculture within the wind parks (e.g. bottom cultures)
- Comparative data on the cost of removing nitrogen from the ocean vs. still on land?
- Environmental impacts:
    - Effects on surface circulation, local circulation, possible reduction of wind stress in farms
    - Remediation potential
    - Shading of the local ecosystem
    - Effects on marine mammals and birds
    - For harvesting natural fouling agents, monitoring the local ecology regularly and assessing the efficiency of communities to re-establish themselves after harvesting and the impact of harvesting on food web dynamics and biodiversity.
- Information on the extent to which the same energy grids can be used for combined wind and wave energy in the parks

- Could the energy produced by the windmills on site be used for the operation of other parallel productions on the site? Is there an easy access to sustainable energy for running the combined production facilities?

Conclusions

The aim of developing combined uses in wind farms in the Baltic Sea Region is the contribution to the production of sustainable healthy food, jobs, scientific and technical experience, and environmental benefits such nutrient uptake while making the best possible use of space, a restricted resource in the region. The concept of combining uses is tied to the core principles of a "Blue Economy": using what you have, looking for multiple benefits and keeping it simple. The ideas that stand behind the concept thus fit perfectly within the recently adopted strategy for a sustainable bioeconomy in the EU.

The potential area for implementation of the combined uses in the Baltic by 2030 is roughly calculated to be at least 850 km^2 and probably much more. Implementation of the concept has the potential to aid in the development of less economically developed (rural) areas along the Baltic coast and to create a base for the development of new industrial and knowledge clusters. This knowledge can then be exported to other areas with similar conditions such as the Big Lakes in the United States, the Gulf of Mexico, or South East Asia.

However, there is a lack of tradition among wind power companies and the aquaculture sector to cooperate for the use of space and for operation and management. Whereas aquaculture is struggling to find suitable locations for new activities, the wind companies are the first to move into the areas. For wind farm developers the focus is – other things being equal – to produce the highest rate of electricity at the lowest cost. Even though management of offshore wind energy sites at the local level may in many instances agree with the perspectives of combined uses, the corporate management level usually blocks such initiatives.

The implementation of combined uses in the Baltic Sea Region would first require convincing evidence from demonstration plants and pilot tests with respect to environmental results, economy of cooperation and scale and technical evidence (suitable production systems). While it remains an open question whether positive synergistic effects of parallel uses would outweigh the additional costs associated, it is clear that political support by means of incentives for new solutions could do much to help promote the concept.

Recommendations

While it is abundantly clear that further research on the overall impact of combined uses is necessary to cover many knowledge gaps relating to this very innovative concept, the following recommendations can also be suggested:

- Work with offshore wind energy companies on the topic of corporate social responsibility with regards to combined uses should be initiated.
- The possibilities and conditions for establishing collaborative relationships with local wind organizations should be explored.
- Experimental sites in the new parks planned should be set up to target knowledge gaps on the feasibility of proposed combined uses (social, technological, economic, environmental, remediation potential, biomass potential).
- There is a need for political and legislative attention. The discussion on establishing legal and planning incentives to promote co-locating other productions within offshore wind farms should be undertaken at the Baltic Sea Region and EU levels.
- In order to create attractive incentives for combining wind farms with uses, which provide water quality remediation benefits, compensation for providing ecosystem services, e.g. nutrient trading schemes, should be considered as a means of bringing down prohibitively expensive costs.