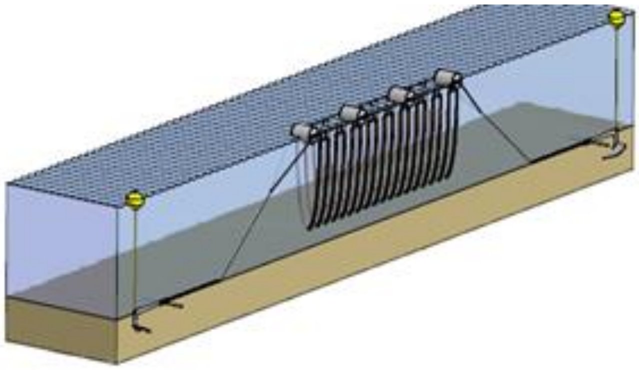
Mussel aquaculture in Borssele offshore wind parks
Mermaid H2020



Source: Machinefabriek Bakker

1.1 Introduction

1.1.1 Combination type

<u>Combines:</u> Fixed wind and mussel aquaculture

<u>Space share type:</u> Multi-use of space

1.1.2 Project description and background

The FP7 research project MERMAID designed multiple use concepts for four European basins, either multiple use of space or multiple-use platforms. This was done through a participatory design process, involving companies, authorities and civil society (Stuiver et al., 2016; van den Burg et al., 2016). The designs were evaluated, among others through societal cost-benefit analysis. One of the most promising designs for the North Sea included wind farms with bottom-fixed offshore wind turbines and mussel aquaculture. The envisaged system is a multi-use of space (MUS) only. The turbine foundations are not used to attach the mussel aquaculture systems. Given the promise of this combination and discussions in Dutch government about requiring joint use of space this concept is further explored in the hope that companies will adopt this multi-use of space.

1.1.3 Combination project description

1.1.3.1 Current status

The current technology for fixed offshore wind is beyond TRL 9 with commercial expansion taking place. The technology for offshore mussel seed collection and production of consumption-sized mussels it at TRL7. Experiences with mussel seed collection in the (more sheltered) Wadden Sea are evidence of feasibility of mussel seed collection in the marine environment. The corresponding Technology Performance Level (TPL) cannot be estimated as there are no comparable technologies available for the North Sea environment. The Investment Readiness Level (IRL) positioning is at IRL 6.

1.1.3.2 Strategic Roadmap to commercialisation

The commercial development plan for the technology has three key stages. To generate further knowledge on the potential risks of mussel aquaculture in the offshore wind park, a first test (pre-pilot) should experiment with offshore cultivation outside a wind park. This can for example generate information about the routes taken by the vessels, without extra risk for a wind park operator. The second stage is the first multi-use pilot to provide evidence for safe and feasible operating practices, as well as contribute to fine-tuning of technologies for offshore maintenance and harvesting. To this end, a mussel aquaculture farm the size of 9 ha is suggested in the existing wind park Amalia. The third stage includes full-scale commercial operations.

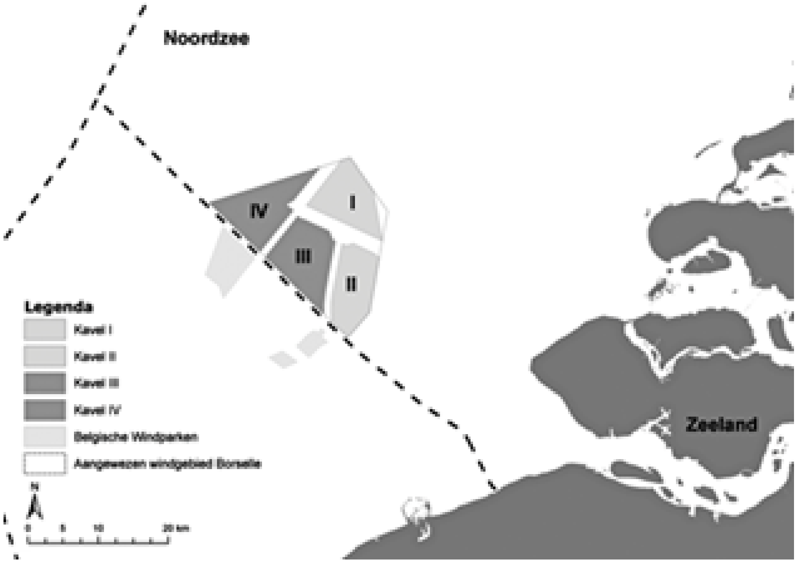


Figure 1: Potential location of project

1.2 Technical Brief with Planned Phases of Development

1.2.1 Overview

The further development of offshore wind parks in the North Sea is a given, now that Belgian and Dutch governments have established support schemes and regulations. Various wind parks are projected off the coast of Belgium and the Netherlands. This technical brief focuses on the windpark Borssele (see Figure). This wind park consists of 4 plots. The total site area equals 344 km². Due to existing pipelines and cables that cross the site, the plot has been subdivided into 4 parcels (25.2 km², 17.8 km², 2.1 km², and 4.1 km²). Plot II does not have cables or pipelines crossing this site; it consists of one parcel with an effective area of 63.5 km². It is located 12 nautical miles (22-39 km) offshore. Grid connection is scheduled to be ready 31 August 2019. The tender document provides detailed information on routing of the underwater cables and land connection. Delivering this is the responsibility of the Dutch offshore grid operator, Tennet, and not part of the tender.

The development builds upon experience with existing wind parks, and technologies for offshore wind are available and tested. The permitted foundations are monopile, tripod, jacket, gravity based and suction bucket for turbines in the range of 4 to 10 MW. The government support scheme is a contract-for-difference (CFD).

In this combination, multi-use of the wind parks includes the production of mussels. Due to the growing pattern of mussel aquaculture mussel seed, half-grown and full-size consumption mussels are produced. The Dutch Mussel industry and NGO's have agreed collect mussel using long-lines. Although these devices are mainly used in the Wadden Sea, it is expected that by 2020, 5.5 million kg of mussel seed is to be collected annually in the North Sea. In the commercialisation phase of the project the installation of 98 ha of mussel aquaculture units is proposed. This equates to 98 ha of support lines. The wind park development is guaranteed.

1.2.1.1 EU proposed pilot: TRL7, IRL6

- ❖ *Aim: Prove Feasibility of Offshore Combination*
- ❖ *Comprises of:*
- \- *Wind park: use existing wind park Amalia*
- \- *Aquaculture: Target Output of 0.5 million kg mussel seed*
- ❖ *Footprint: Wind park 49,5 km², mussel seed aquaculture 21.4 ha*
- ❖ *Located: 23 km off the coast of Netherlands*
- ❖ *Water depth: 19 - 24 m*
- ❖ *Fabricated at:*
  - ➢ *Wind turbines: 60 Vestas V80, 2MW turbines*
  - ➢ *Aquaculture system: Machinefabriek Bakker or comparable*
- ❖ *Brought to location and installed by:*
  - ➢ *Wind turbines: marine contractor (already complete)*
  - ➢ *Aquaculture system: marine contractor*
- ❖ *Moorings:*
  - ➢ *Wind turbines: monopiles (already complete)*
  - ➢ *Aquaculture: anchors*
- ❖ *Target deployment in:*
  - ➢ *Wind turbines: Completed in 2018*
  - ➢ *Aquaculture system: 2017*
- ❖ *Total Cost: Costs for the pilot are not modelled as no companies are involved in this combination. No detailed estimate can be done but given the scale of project CAPEX is likely to be in the order of €12 million so grant funding required in the order of €5 million.*

1.2.1.2 Commercial TRL9

- ❖ ***Aim:*** *Commercialization*
- ❖ ***Comprises of:***
  - ➢ *Wind park: 380 MW installed capacity using 4 to 10 MW turbines*

- *Aquaculture: Target Output 5.5 million kg mussel seed*

- ***Footprint:*** *Wind park 49,5 km², mussel seed aquaculture 235 ha*
- ***Located:*** *22-38 km off the coast of Netherlands and Belgium*
- ***Water depth:*** *15 to 35 m*
- ***Fabricated at:***
  - *Wind turbines: Siemens, Vestas or comparable*
  - *Aquaculture system: Machinefabriek Bakker (SME) or comparable*
- ***Brought to location and installed by:***
  - *Wind turbines: marine contractor*
  - *Aquaculture system: marine contractor*
- ***Moorings:***
  - *Wind turbines: monopiles, tripod, jacket, gravity based or suction bucket*
  - *Aquaculture: anchors*
- ***Target deployment in:***
  - *Wind turbines: 2019*
  - *Aquaculture system: 2019*

Gantt chart for commercialisation roadmap

Table 1: Roadmap to commercialisation.

		2017	2018	2019	2020	2021	2022	2023
TRL7	**Test outside offshore wind park**							
TRL8	**Commercial farm**							
TRL9	**Full scale commercial deployment**							

1.2.1.3 Other technical project details

- The relevant system in this case study has a culture on simple structures such as ropes and frames (Christie et al., 2014). This shellfish production consists of subsea lines as shown in Figure above. These lines are connected to the sea bottom through a mooring system. Installation time for this option is less than a week (He et al., 2015).
- Key components in this design are listed below. It is also indicated how much of these devices is needed for production unit
  - Anchors to secure the system remains in place: 2
  - Support lines to which the drooping long-lines are attached: 500m
  - Longlines on which the mussel grow: 6400m
  - Floating supports: 4
  - Market buoys: 2
- A new vessel is needed for offshore operations. This vessel can be a multi-purpose vessel, also put to use in transport to and/or operations and maintenance in the offshore wind park.

- It is assumed that the mussels are not restocked during growth (i.e. taken of the longline and put back with greater distance between them). Instead, the system is thinned out. The resultant mussel spat and half-growns are transported to the Eastern Scheldt to grow further.
- Based on the literature the estimated production per unit is as follows, in two years:
    - 14064 kg of mussel seed, harvested in autumn
    - 14064 kg of half-growns, harvested in early spring
    - 9376 kg of consumption size mussels, harvested in autumn

1.2.2 Advantage of combination

1.2.2.1 General for both sectors

- General socio-economic societal benefit, as 100% renewable sources with low carbon footprint including low overall environmental impact due to MUP design
- Cost reduction by integration of offshore activities and O&M costs due to shared facilities - such as weather stations - and possibly shared vessel.
- As technology is not geographically/morphologically site-specific can be moored at various locations avoiding conflicts with other sectors (such as fishing, aquaculture, tourism, leisure (marinas) and port/shipping).

1.2.2.2 Mussel Aquaculture

- The wind park provides the mussel companies with an area not accessible for large other vessels, reducing risk that the mussel facilities are negatively affected by these vessels.

1.2.2.3 Wind

- Mussel aquaculture makes area less accessible for other vessels, reducing risk of collisions with unfamiliar vessels.
- Mussel aquaculture can have a wave dampening effect, reducing fatigue and resultant O&M for wind farm structures. Dampened seas will also enable access for O&M for longer periods increasing wind farm availability.

1.3 Business section

1.3.1 Competition

Table 2: Key Competitors.

Competitor	**Key Differentiators**	**Competitive Threat Rating (1-5)***
Conventional Mussel Farming	One of the advantages of this combination is the multiple use of space. This gives the combination an advantage over conventional mussel farming, especially in countries which have increasing demands on limited space.	**4**
Floating offshore wind	Fixed offshore wind is the most cost-effective technology given the low water depths in this area. Other foundations are not eligible under the prevailing subsidy scheme.	**1**
Wave and/or tidal energy	Both wave and tidal energy are not cost-competitive as they are much more expensive the fixed offshore wind. They are also not eligible under the prevailing subsidy scheme.	**1**
Wave energy/aquaculture concept (e.g. Albatern WaveNET)	The Albatern WaveNET devices may not be suitable for the conditions found at the mussel farms. It would also take up space that could be more suitable for fixed offshore wind. Wave energy is not eligible under the prevailing subsidy scheme.	**1**

***Competitive threat based on companies' appraisal of perceived threat with 5 being severe competitive threat.**

1.3.2 Business Model

Two independent companies will operate each sector (fixed offshore wind and aquaculture) separately. The offshore wind energy company (Company A) will be an offshore wind project developer who source, install and operate offshore wind farms. Examples of such companies include DONG Energy, Vattenfall, etc. The aquaculture company (Company B) will be a company who has experience in operating aquaculture farms. Examples of such a company include Prins & Dingemans, Delta Mosselen, Roem van Yerseke, etc. While both companies will remain separate and not form a joint venture or special purpose vehicle (SPV), both companies will have a legal agreement to install and operate wind farms with integrated aquaculture installations (most likely mussel farms in this case). Company A will sell electricity with revenue from CFD supplied by government for 15 years, and Company B will sell mussels with revenue from mussel markets.

Table 3: Business Model Canvas Building Blocks.

1. **Customer Segments**

- Company A – Customers of Company A will be buyers of electricity for the national and international grids. Examples of these include Greenchoice (Netherlands), ENECO and Qurrent (Netherlands)
- Company B – Customers for Company B will be wholesale and retail companies of mussels. Examples of these include Mosselcentrale NV (Belgium), Mosselman Seafood (Belgium), Hanos (Netherlands), etc.

2. **Value Proposition**

- Company A – reliable, less expensive renewable electricity due to combination, more sustainable image, possibility of easier consenting if government policy advocated more efficient use of space. Concept is easily transferrable to other sites once concept is proven.
- Company B – cheaper mussels due to combination, more sustainable image, mussels with less toxins, increase in the areas available to the industry to utilise.

3. **Channels**

- Company A – Electricity has grid preference. Less focused needed for sales. Distribution is via grid.
- Company B – mussels auctioned at Yerseke. No direct sales channels are needed. Sales performed by auction. Distribution only to Yerseke.

4. **Customer Relationships**

- Company A – relationship with customers will be distant as electricity has grid preference.
- Company B – will not need to build very close relationships with customers due to auctions. It is possible that a high turnover of customer will be envisaged.

5. **Revenue Streams**

- Company A – Sale of electricity to the previous customers highlighted. This will be subsidized via a CFD support scheme.
- Company B – Sale of mussels at auction at Yerseke. This includes three different categories for mussels: seeds, half-grown and consumption size.

6. **Key Resources**

- Company A – Safe and reliable technology, vessels suitable for both industries, permitted area for MUS, workforce, grid connection
- Company B – Safe and reliable technology, vessels suitable for both industries, permitted area for MUS, clean ecosystem, workforce, close proximity to market

7. **Key Activities**

- Company A – Operating and monitoring wind farm, maintaining high levels of production
- Company B – Operating and monitoring mussel farm, harvesting mussels, R&D

8. **Key Partners** (*)

- Company A – main partner will be Company B (operational partner focused on operational savings), Siemens (Technology Supplier), Greenchoice (Customer)

9. Cost Structure ❖ Company A and Company B – Insurance expenditure, Daily operations such as harvesting (Company B) and wind farm monitoring (Company A), Equipment O&M contracts, overheads, equipment replacement.	❖ Company B – main partner will be Company A (operational partner focused on operational savings), Machinefabriek Bakker (Technology Supplier), Hanos (Customer), EPA Netherlands (Environmental). A close partnership will also be needed with both local and national government to ensure buy-in at all levels for the combination concept. (*) company names are indicative as no companies were involved in elaborating this combination

1.4 Management Section

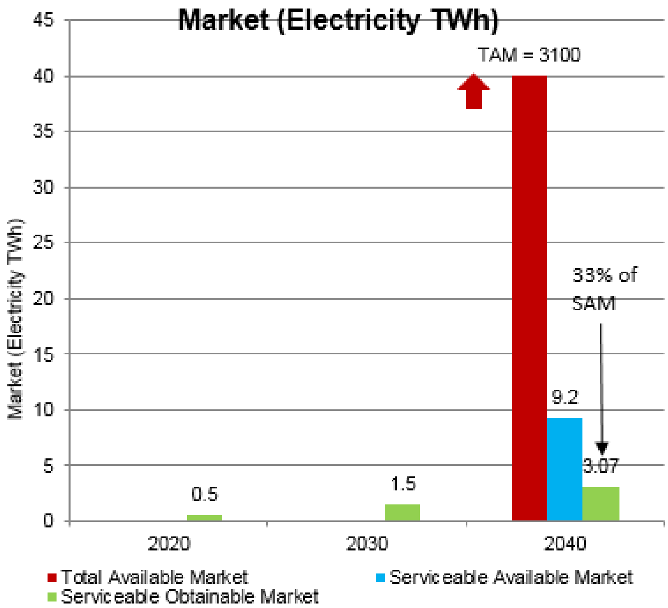
This section is not included are there are no companies involved in elaborating this combination.

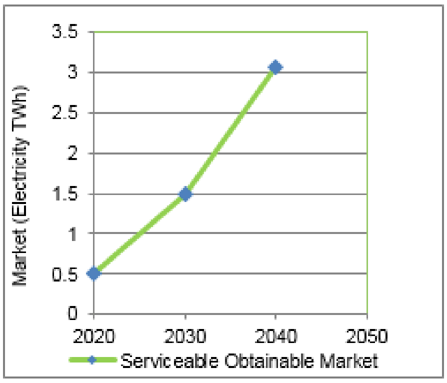
1.5 Market Section: Market Share from 2020 until 2040

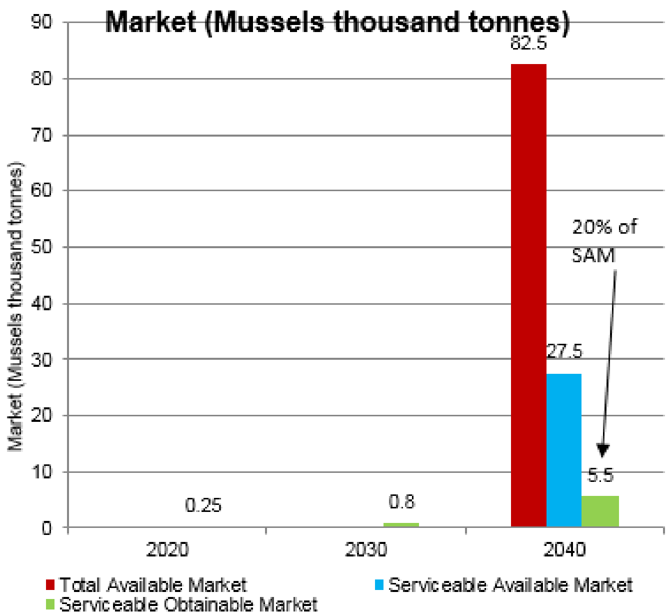
1.5.1 Market Analysis

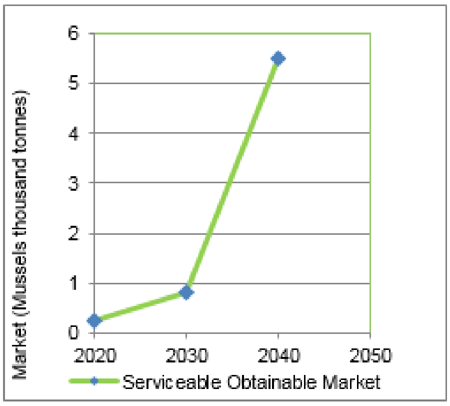
The market for this combination is twofold: Electricity wholesale market and mussel wholesale market. In the Netherlands, electricity production capacity equals 31.5 GW, out of which 20.1 GW consists of centralised production (i.e. powerplants) and 11,4 GW is decentralised production. In 2014, total installed wind capacity in the Netherlands equalled 2.7 GW. This capacity was used to produce 5.627 million kWh of electricity from wind, making it the second-largest source of renewable electricity.

The aquaculture sector of the Netherlands can be divided into two different sectors, namely shellfish and finfish. The shellfish sector is an older and more established sector, and consists of 50 companies growing blue mussels which result in between 50,000 to 60,000 tonnes of mussels per year. Shellfish culture takes place in the estuarine waters in the southwest Netherlands and in the shallow Wadden Sea in the North of the country. The mussel wholesale market is based in Yerseke where mussels are auctioned.









1.5.2 List of investors and sources of funding

For this combination to progress from concept to pilot and on to a possible commercial basis, some form of public funding will be required. It is unlikely that existing wind farm developer or mussel farming companies have the resources available to conduct a pilot ‘experiment’. However once the concept is proven, it is envisaged that it is within the resources of existing companies to implement the combination on a commercial basis.

1.5.2.1 Grant funds required and potential sources

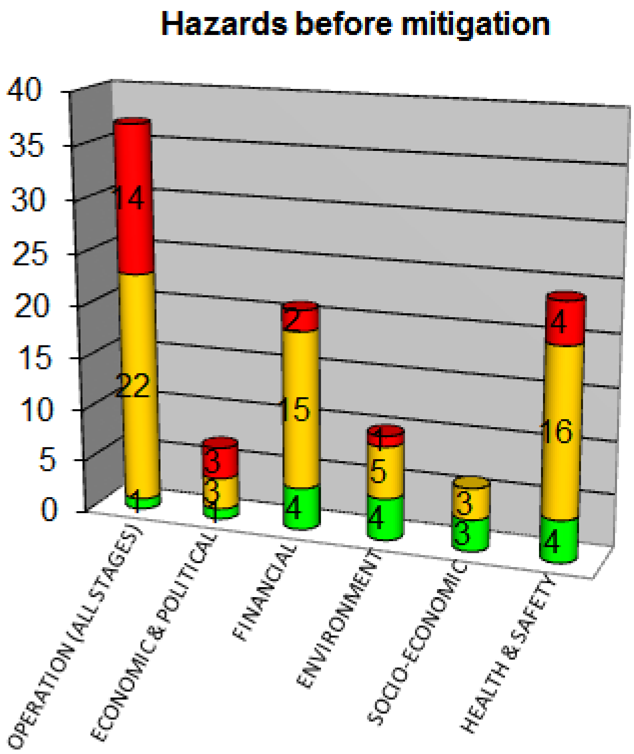
- European Maritime and Fisheries Fund - The EMFF is the fund for the EU's maritime and fisheries policies for 2014-2020. The total available funding available for the Netherlands is €101.5 million for the entire period.

- Horizon2020 call BG-04-2017. Call is aimed at the multi-use of space within the European maritime economy. Total funding available for the entire period is €8 million.
- INTERREG North Sea Region Programme 2014 – 2020 is a European regional development fund.

1.7 Risk section

1.7.1 Hazards description

- 105 Hazards identified under six categories: 1. Operation - all stages, 2. Economic and Political, 3. Financial, 4. Environment, 5. Socio-economic, 6. Health and Safety.
- Hazards were colour coded (risk matrix 1-25) depending on risk magnitude revealing **24 High (red)**, **64 Medium (orange)** and **17 Low (green)**.
- Issues and causes described for each hazard, including the effect (-/+) of multiple industry and technology co-location.
- A ranking (1-5) used to quantify Consequence and Likelihood with resultant risk magnitude for each hazard.
- Risk response strategy proposed and residual risk magnitude quantified for each hazard.



1.7.2 High risk (red) hazards identified pre/post mitigation

Hazard Category		Issue	Sum
1. Operation	Pre-construction	Site Problems and Licensing	2
		Insurance	3
	Construction	Weather conditions	1
	Operational	Component/system failure less product output	1
		Component/system accidental damage	1
		Pollution	1
		Maintenance and logistics Issues	1
		Emergency response	1
	Decommissioning	Device removal	2
		Environmental impacts	1
2. Economic and Political	Public sector support	Grants and subsidies	1
		Applied price forecast	1
	Competition	Issues entering market and organic farming activity	1
3. Financial	Financial support	Lack of investment	2

4. Environment	Physical environment	Environmental effects by introduction of noise	1
5. Socio-economics			0
6. Health and Safety	Personal Injury	Ergonomics	1
	Personal Injury	Ports and Mobilisation	1
	Personal Injury	Subsea Operations	1
	Personal Injury	Working at Height	1
		Total	24

1.7.3 Commercial High Risk Response

Operation (all stages)

Description: The Operational risks account for approximately 58% of all red-category risks identified. "Site problems and licensing" issues relate to site compliance from environmental perspective, and granting of licence process as regulation and legislation may prove more complex than expected coupled to a prolonged process. Currently intensive aquaculture for shellfish has a long licensing process (circa 1 year) with numerous environmental and biological studies needed to validate the site suitability. In addition, granted license duration may be too short to guarantee safe return on investment and hence discourage investors. These risks can result in higher costs and delays.

Insurance issues may be encountered due to the perceived increased complexity and unproven nature of technology combination resulting in over-cautious approach which could severely limit the scale of the aquaculture deployment. In addition, over-cautiousness on the potential impact from each industry to the other may result in prohibitively high insurance quotation. These risks can result in higher costs, delays and even project failure.

Risk response: Risk avoidance strategy will include employing competent and experienced environmental manager and team and pre-plan as early as possible for a thorough EIA study.

Wind farm licensing requires having adaptive management procedures in place to avoid conflict with the aquaculture site (additional temporary licensing during construction). Several additional environmental and biological data will be collected by both industries to validate spat fall, and carrying capacity (environmental effects). Plans will be in place to mitigate against delays associated with a prolonged licensing process which as understood is likely to fall within a statutory timeframe.

Working closely with licensing authorities and investment community will help overcome the risk of limited license duration for aquaculture activities as in order to meet requirements for investment and ensure a healthy return on aquaculture operations.

Existing experience on insurance does not cover the combination (i.e. unique) hence insurance risks will be tackled by liaising closely with the insurance industry from the early planning stages of the commercial deployment. This will ensure that both sectors' requirements are fully understood and appropriately addressed.

Description: During construction phase adverse weather conditions may prevent access during allocated construction/installation shortening time window and increase downtime. If deployment of wind farm is undertaken at the same time as aquaculture by sharing resources to keep costs down, adverse weather may result in unexpected construction issues affecting wind farm construction. These issues could result in delays and higher costs.

Risk response: This risk will be thoroughly considered in the project planning stage. The aquaculture mussel cultivating farm will be assembled in a shore-based sheltered area located close to the deployment location which reduces the risk of running into bad weather.

Good connectivity and access to an established local supply chain of experienced contractors including specialist vessel operators will mitigate the risk and will enable aquaculture farm components to installation even at harsh conditions. Detailed analysis on weather downtime with weather forecast models will be undertaken during preparation for installation.

Working closely with the wind farm installation contractors will enable coordination of activities to avoid conflict and reduce costs where applicable.

Description: At operational stage the biggest risks are associated with downtime/breakdowns or frequent grid outages (not normally compensated for). Issues of technological nature can present with failure at component or system level (e.g. reliability, fatigue, fouling, corrosion, weakening of structures) which is mainly risks associated with fixed offshore wind farm element of the combination.

Component failures may present themselves during extreme weather conditions (e.g. mooring failure on aquaculture farm). This could be significant risk to the nearby wind farm from collision of aquaculture farm drifting components with wind farm fixed structures.

Bad weather may also increase downtime and shorten maintenance time windows. The consequence of the above risks is less revenue generated, redesign efforts, higher costs and project failure if not addressed appropriately.

Risk response: Complete Failure Mode and Effect Analysis of all components will be undertaken so that all failures will be properly understood. Extensive testing will be undertaken at component and system level considering presence of aquaculture type activities and possible adverse effects (e.g. accelerated corrosion), determining safe distance between the two operations. Knowledge from the fixed offshore wind sector will be incorporated as many such commercial developments exist, but not in combination.

Moorings extensive testing and fail-safe solutions by the aquaculture farm will reduce the risks associated with this particular issue which could pose a collision risk to the wind farm. The aquaculture shellfish production involves ropes rather than solid cages which from a hydrodynamic perspective is expected to incur less stress by waves and currents and less likely for moorings to fail. In addition, the flexibility in structure would be less likely to cause an impact during a possible collision with a solid wind turbine structure.

Description: At operational stage pollution and emergency response issues that may result in ceasing power production, higher costs and delays and implications to potential injured personnel/subcontractors.

At extreme circumstances pollution (e.g. from leaked chemicals) from wind turbine components could destroy or contaminate fish populations affecting nearby aquaculture or even fisheries industries resulting in liable losses.

Distance of site from emergency response and increased offshore activity will increase (risk for) incidents and therefore increased need for extra capacity (i.e. more pressure) on emergency response services at national level.

Risk response: Insurance cover will transfer the aforementioned risks while the insurance sector involvement will ensure that the risk response measures are adequate for the scale of the intended operation.

Employing an experienced environmental manager and team and monitoring of wild population with already established water monitoring techniques/regimes (e.g. solid phase adsorption toxin tracking -SPATT collectors) will ensure enough reaction time is available to all industries.

Adaptive monitoring programme will be established that in an event of any chemical spill rapid action and elimination of risk will be undertaken.

The aquaculture and wind farm will be located relative in a secure distance one to another to minimise any harm to each other. This distance will be agreed by mutual consent to ensure that cost reduction benefits can also be realised.

Regarding issues of accelerated corrosion as a result of exposure to aquaculture activities standard protection techniques are already in use in the offshore wind sector with sacrificial anode blocks or impressed current cathodic protection becoming standard practice in foundation design for wind turbines. Maintenance and inspection regimes will be revisited to ensure that any adverse effects will be captured early and acted upon (e.g. can increase distance between the deployments with aquaculture farm location change).

Issues in relation to emergency response will be adequately addressed before starting the construction phase because the legislation requires this as part of consent process. The proximity of the deployment site from emergency response station at shore will help mitigate the relevant risk identified. Employing experience manager and response team and development and implementation of in-house emergency response and cooperation plan will define the response of all parties involved in foreseeable emergencies. This will be carried out in cooperation with the authority responsible for the provision of response procedures designed to deal with any emergency at sea.

Description: During decommissioning risks associated with the lack of experience with the process due to novelty around combination of these sectors, coupled to potential changes in the decommissioning responsibility/process (politically driven) could result in higher costs or fines. Removal of marine structures may result in pollution and disturbance of established habitats on the structures. Specifically, removal of moorings and fixed foundations may present a higher risk.

Risk response: Adequate decommissioning and contingency funds have been costed to be allocated. Standard decommissioning measures for the removal of offshore marine structures will be followed with regard to: the Best Practicable Environmental Option (BPEO); safety of surface and subsurface navigation; other users of the sea; health and safety considerations.

Mooring may be a possible problem during decommissioning. Adequate contingency funds will be allocated and the possibility to allow the mooring to be left behind will be examined with the relevant authorities following a navigational risk assessment. For piled foundations it is envisaged that pile can be left in situ by cutting below the natural level of the seabed. This is an option available to wind farm owners and aligned with the standards set out by the International Maritime Organisation (IMO) that specify an installation or structure need not be entirely removed if: it is not technically feasible (however, the design and construction should be such that entire removal would be feasible); it would involve extreme cost; it would involve an unacceptable risk to personnel; it would involve an unacceptable risk to the environment.

Regarding decommissioning of turbine components, any hazardous or potentially polluting fluids or materials are removed from the nacelle if they are considered to be posing a potential hazard to the environment during turbine dismantling.

The design of the aquaculture elements allows conducting dis-assembly segment by segment and transferred to a shore-based decommissioning site. It is envisaged that no specialist vessels will be required to meet the decommissioning needs. It is expected that the experience of the offshore oil & gas and offshore wind sectors will be beneficial. Funds for the decommissioning have been costed into the project budget.

Economic and Political

Description: Potential issues identified under "public sector support" and "competition" subcategories. Grants and subsidies issues could arise from change in policy direction and appetite for renewables, conditions of Feed-in-Tariff eligibility criteria (inc. value and period) could affect the financial projections for the wind farm. The financial modelling results could also be affected from other factors including sensitivity analysis, exposure to market risk, long-term price forecast and divergence in the expectations for power prices. For aquaculture, variations in consumer preferences, potential major shellfish disease outbreak, improvement of capture fisheries productivity and effect of climate change could affect product demand and pricing. This could result in less revenue generated affecting rates of return on capital investment.

Other factors in relation to issues around market entry due to intense competition including against established sectors such as fossil fuels and nuclear vs offshore wind and fisheries vs aquaculture shellfish. Competition against other renewables or organic farming would add magnitude to the risk. The "organic farming" brand name could be compromised due to combination of aquaculture-shellfish with a wind park on "industrial" production setting. The above risks could ultimately result in higher costs and/or lower revenue generated.

Risk response: Accepting the above risks will include careful monitoring for possible escalations. The current trend dictates that the renewable energy sectors (including ocean energy) need to grow if national governments are to meet obligations around emissions (mitigate climate change), security of energy supply and energy cost reduction. Therefore, it is expected that the need for growth will negate the risk of removal or phase-out of subsidies. The Paris Climate Agreement has targets to combat climate change by carbon reduction which can only be met by reducing fossil fuels and increasing renewables and nuclear.

The aquaculture sector including offshore aquaculture is expected to grow significantly in order to meet the global demand for protein source to satisfy fast growing global population. I is projected that by 2030 aquaculture will overtake fisheries and cover over 60% of global total fish demand as projected by FAO.

Financial

Description: "Financial support" related potential issues were identified that could develop due to lack of (or removal of) investment which could be triggered due to a number of possible causes:

- many wait-and-see investors who do not invest due to risk of losing development costs and due to little benchmark data
- finance instruments related problems
- poor lending appetite from banks due to low economic climate
- lender fail to comply with financial legislation/regulation (Basel III, Solvency II)

Risk response: In the absence of benchmark data, clearly demonstrable results from studies undertaken during pre-commercial TRL stages validated during early pilots and commercial deployments. Flexibility to form Special Purpose Vehicle with partner/investor organisations will reduce financial risk exposure.

Environment

Description: Risks to the physical environment have been identified due to potential destruction to the local environment. Issues around introduction of noise during pile driving operations would affect marine mammals, herring and other species.

Risk response: Comply with relevant directives such as MSFD (GES -Good Environmental Status) which are being implemented in all EU member countries particularly sections referring to energy introduction (i.e. noise production limits) to the sea environment. Good practices for noise mitigation can be adopted from existing offshore wind deployed farms, for instance pile driving for fixed foundations to be carried out outside breeding season to reduce the impact on marine species.

Health & Safety

Description: Red risk identified under several subcategories which could lead to personal injury including:

- Ergonomics (difficult to construct design; moving around system: slips, trips and falls; restricted movement: lack of space to access components; lifting: hoisting parts and tools into position)
- Ports and Mobilisation (vessel movements: collision; port operations: material handling, refuelling, waste disposal; unsuitable facilities: quayside loading limits)
- Subsea Operations (entrapment, falling objects, decompression sickness, use of tools underwater
- Working at Height (falls, dropped objects)

Risk response:

- Ergonomics
    - Rigorous safety plan for fabrication and construction which must be adhered to including preliminary safety plan including risk analysis from all designers.
    - Fully resourced, site specific construction safety plan including programme for the works
    - Independent onsite safety team with marine safety experience
    - Regular independent equipment inspections
- Ports and Mobilisation
    - Port traffic management plan enforced by harbour master.
    - Adequate site safety plan
    - In-port medical facility including medical helicopter for emergency evacuation
    - Warning notices re loading limits clearly visible and communicated

- Subsea Operations
    - Minor requirement for divers to be met using fully certified, reputable dive company with accident free track record are used.
    - Ensure this company produces and complies with high level safety plan for the work being undertaken
- Working at Height
    - All work to take account of the principles of prevention in relation to working at height. Risks to be taken account of and mitigated against in safety plan for the project.
    - All workers to undergo certified working at height training.
    - Safety cages to be installed around all ladders
    - Fall arrest systems (harness etc.) to be employed in all risk areas.

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