MERMAID

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Site specific impact of policies: report on identification, impact and selection of planning and design options in study sites with implication for policies and regulations

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Chapter 1: Introduction and scope of the deliverable

1.1 Goals and objectives of the deliverable

The main objective of this report is to assess site-specific impact of policies, reporting on the identification, impact and selection of planning and design options in study sites with implication for policies and regulations. In specific, this deliverable has the following objectives:

- Explain how the final design was selected.
- Explain if there is or if there is not an appropriate administrative framework.

1.2 Relationship to overall project objectives

The aim of this deliverable is to report on the identification, impact and selection of planning and design options in study sites with implication for policies and regulations that are related explicitly or implicitly to the development and adoption of selected offshore wind farms and aquaculture projects. It is acknowledged that a very strict environmental legislation could be an obstacle faced by developers interested in large-scale projects. The identification of restrictive procedures within the EU legislation concerning offshore wind farms and aquaculture is of vital importance for the success of the MERMAID project. One of the major challenges of the MERMAID project is to provide recommendations and guidelines for the development, operation and exploitation of multi-use platforms (MUOPs) in each case study and in the EU in general. This report constitutes a critical input in the socio-economic analysis performed within the context of MERMAID project.

1.3 Outline for the reader

The document is divided into 8 different chapters. Chapter 2 provides the general framework of analysis, provides a short description of each case study and describes the MUOP selection tool. Chapter 3 explains the relation between the MUOP selection tool and international and European Union legislation and policies on wind farms and aquaculture on coastal and offshore areas. Chapters 4 to 7 outline the proposed designs of MUOPs and the most influential legislative framework for each case study separately. Chapter 8 offers concluding remarks and recommendations.

Chapter 2: General Framework of Analysis

2.1 Short description of case studies areas.

The MERMAID project focuses on four regional seas (see figure 1): 1) Baltic Sea, 2) North Sea and the Wadden Sea, 3) Atlantic Sea and 4) Mediterranean Sea. They represent regional European waters where there are requirements for sustainable and profitable activity for a large number of EU Member States and their governments through multiple sectors including transport, fisheries, renewable energy, tourists, commerce and local stakeholders. The four regions have both common as well as unique drivers of change that impact ecosystem services. The regional case studies are designed to operationalize geographically the integrated understanding developed through the MERMAID project. Thus, novel innovative design approaches should address many different physical conditions in order to make the best use of the ocean space. Going from deep water (north of Spain) to shallow water with high morphological activity (the North and Wadden Sea) and further to inner waters like the inner Danish/Baltic areas and the Adriatic sea changes the focus from a strong physical aspect to environmental impact on a very delicate marine environment. This will allow developing, testing and integrating different technologies through innovative coupling of various activities and services. Table 1 presents a brief summary of the environmental characteristics, design types and specific issues in each MERMAID site.

Figure 1 Map of Europe with close-up at the Four MERMAID Sites

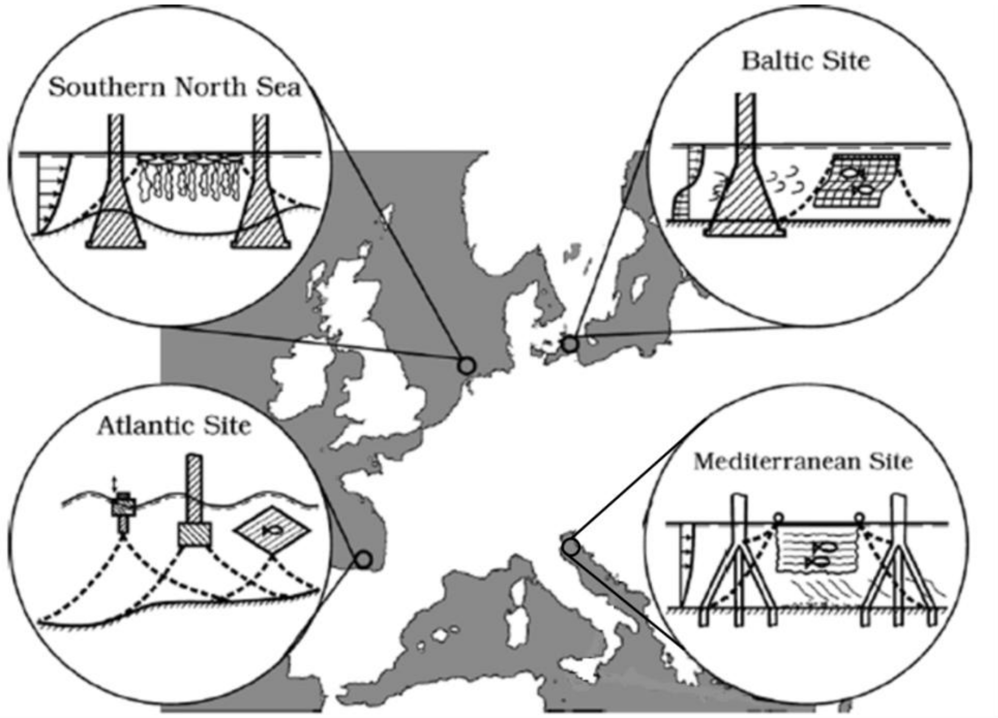


Table 1. Environmental Characteristics, Design Types and Specific Issues in each MERMAID Site

Site, Sea	Environmental characteristics	Design type	Specific issues
Krieger flaks, Estuarine site, Baltic sea	• Cold brackish waters with optimum salinities for temperate fish • Location on the pathway for exchange flow between Baltic proper and the North Sea • high wind energy potential	• Steel driven monopoles or gravity based turbine foundations • extensive mariculture	• Dredging • Mariculture spills • Sandmining in the area
North Sea	• Waters with optimum salinities, temperate and nutrients for seaweed • Area where there is exchange of sediment between the North Sea and the Wadden Sea • high wind energy potential	• gravity based turbine foundations • extensive aquaculture	• Economic feasibility • Scour and backfilling processes • Environmental impact
Ubiarco and Santoña, Far Offshore area, Atlantic Ocean	• Very high wind energy potential • Very high wave energy potential	• floating platform (100 m depth) • multiple energy converters, i.e. wind and waves	• grid connections • mooring systems
Acqua Alta platform, Venice, Mediterranean Sea	• moderate wind energy potential • moderate wave energy potential	• gravity based foundations (16 m depth) • multiple energy converters, , i.e. wind and waves • algae culture	• Grid connections • Mooring systems • Environmental impact • Biodiversity • Economic feasibility

Source: MERMAID Project (based on project's Document of Work)

2.2 Description of the MUOP assessment tool

The MERMAID project experts designed and implemented the MUOP assessment tool described in this chapter. The MUOP assessment tool is a framework of elements and questions that should be taken into account during different stages of research and design. It was created with the input of work packages 7 and 8 and was implemented by work package 2 during meetings with experts and stakeholder's roundtables. The importance of this tool lies on its outputs and its capacity to provide a guideline to support decision-making. The MUOP assessment tool was implemented in all four case studies and attempts to help all the stages of the research by indicating the pathway of the research and to provide researchers with all necessary information in order to achieve the main goals of the project. At the same time, the tool helps to identify costs and benefits emerging from the MUOP specific design and thus provides important information for the Social Cost Benefit

Analysis (SCBA). The assessment tool collects and systematizes multidisciplinary information in order to derive, for each case study:

A) Technical Feasibility Assessment,
B) Environmental Impact Assessment,
C) Financial and Economic Assessment and
D) Social Cost Benefit Analysis.

All the previously mentioned assessment processes face some crucial questions and may be influenced by some very important risks that are described in the following sections.

2.2.1 Technical Feasibility Assessment

The Technical Feasibility Assessment (TFA) section of the assessment tool asks the experts to identify if the MUOP design is feasible taking into account legal and technical considerations. Experts are also required to make estimations of financial costs and revenues of the installation and operation of the platform, to define the project's time horizon, to identify any existing possibilities of combined use and finally to identify if there are any options for technological upgrades. Simultaneously, a set of risks should be identified and taken into account. The set of risks include the following items: technical uncertainty, financial uncertainty, impact diffusion (i.e. correlated risks between functions), political uncertainty and unclear definition of property rights. It is important to mention that if the expert's assessment concluded that the MUOP design was not technically feasible then no further assessment was required. The table below presents the questions posed to experts and stakeholders and the set of risks to be identified.

Table 2. Technical Feasibility Assessment (TFA) and Significant Risks

A. Technical Feasibility Assessment (TFA)	
a.	Is placement possible? (Take into account legal considerations)
b.	Is placement possible? (Take into account technical considerations)
c.	Approximations to production parameters (Costs: capital, O&M, administration costs and revenues)
d.	Definition of project's time horizon
e.	Possibilities of combined use
f.	Possibility for technological upgrades
Please identify Significant Risks:	
R.A.1	Uncertainty about reliability of the techniques used

R.A.2	Uncertainty about estimates of costs and revenues
R.A.3	Impact diffusion (correlated risks between functions)
R.A.4	Political uncertainty
R.A.5	Unclear definition of property rights
Important: If the suggested MUOP does not pass the threshold for criterion (A) then no further assessment is needed. Please stop here.	

2.2.2 Environmental Impact Assessment

Regarding the Environmental Impact Assessment (EIA), MERMAID project researchers were asked to identify all significant positive and/or negative environmental impacts (at local, regional and global level). Also, they were asked if there is an EIA available for similar project(s) in the region. The set risks identified for this section refer to the uncertainty about climate change and other environmental parameters, the identification of non-linear environmental effects and threshold identification and to identify the cause of likely irreversible environmental effects of the operation of the platforms. The table below presents the questions posed to experts and stakeholders and the set of risks to be identified.

Table 3. Environmental Impacts Assessment (EIA) and Significant Risks

B. Environmental Impacts Assessment (EIA)	
a.	Significant negative environmental impact (local, regional, global)
b.	Significant positive environmental impact (local, regional, global)
c.	EIA available for similar project in the region
Please identify Significant Risks:	
R.B.1	Uncertainty about Climate Change and other environmental parameters
R.B.2	Non linear environmental effects & threshold identification
R.B.3	Irreversible environmental effects

2.2.3 Financial and Economic Assessment

The Financial and Economic Assessment (FEA) section of the tool attempts to extract the estimated financial costs (capital, operations & management, administrative) of the MUOPs. This section also asks to estimate potential financial revenues as well as efficiency gains from combined use of the platform and to identify any regulatory or institutional restrictions to the installation and operation of the platforms. This section also asks if it is possible to run a sustainable business plan, to calculate efficiency prices for inputs and outputs of the investment, to determine indirect and induced effects (i.e. creation of jobs, increased economic activity, increased incomes, etc.), to discount investment's cash flows and to identify economic efficiency indicators. On the other hand, the set of risks in this assessment concern to the sensitivity to changes of output/input prices and the difficulty in time horizon and interest rate definition. The table below presents the questions posed to experts and stakeholders and the set of risks to be identified.

Table 4. Financial and Economic Assessment (FEA) and Significant Risks

C. Financial and Economic Assessment (FEA)	
Financial Assessment	
a.	Estimated financial costs: capital, O&M, Administrative
b.	Estimated financial revenues
c.	Efficiency gains from combined use
d.	Regulatory/Institutional Restrictions
e.	Sustainable Business Plan (time horizon plays an important role)
Economic Assessment	
f.	Calculation of efficiency prices for the inputs and outputs of the investment.
g.	Determination of indirect and induced effects (creation of jobs, increased economic activity, increased incomes, etc.)
h.	Discount of the investment's cash flows
i.	Economic efficiency indicators
Please identify Significant Risks:	
R.C.1	Sensitivity to changes of output/input prices
R.C.2	Difficulty in time horizon and interest rate definition

2.2.4 Social Cost Benefit Analysis

The Social Cost Benefit analysis (SCBA) section of the tool attempts to answer questions regarding the monetary valuation of environmental externalities (using the ecosystem services approach), the monetary evaluation of health and other externalities (e.g. educational), the monetary evaluation of local accessibility effects and the perceived stakeholders' fairness of distribution of costs and benefits (between income groups, spatial and intergenerational). The risks that may influence the results of this assessment concern the uncertainty and missing information in estimation of external effects and in perception formation as well. The table below presents the questions posed to experts and stakeholders and the set of risks to be identified.

Table 5. Social Cost Benefit Analysis and Significant Risks

D. Social Cost Benefit Analysis	
a.	Monetary evaluation of environmental externalities: provisioning services; regulating services; cultural services, supporting services.
b.	Monetary evaluation of health and other (e.g. educational) externalities
c.	Monetary evaluation of local accessibility effects
d.	Perceived Stakeholders' Fairness of Distribution of Costs and Benefits (between income groups; spatial; intergenerational)
Please identify Significant Risks:	
R.D.1	Uncertainty and missing information in estimation of external effects
R.D.2	Uncertainty and missing information in perception formation

Chapter 3 The MUOP Selection Tool and EU legislation and policies on wind farms and aquaculture on coastal and offshore areas

In the previous section we described the design of the MUOP assessment tool, the elements for each section and the set of risks that should be identified in terms of TFA, EIA, FEA and SCBA. It is evident that each of those assessments should take into consideration not only technical aspects but also the institutional and legislative framework and policies relevant for the selected designs in each region. In this chapter, the starting point of the analysis is the EU legislation and policies on wind farms and aquaculture on coastal and offshore areas. The EU has produced a set of initiatives, strategies, innovative ideas and regulations in order to respond to global concerns on fresh water scarcity and land degradation (and its implications for food security), both substantial elements of humans' and ecosystem's life. These regulations provide the framework that allows and promotes developing sustainable policies and business operations. Therefore, water significance is highly ranked since it is the earth's absolute life source. Through the directives and strategies described below, the EU sets concrete targets and requires specific results. The targets require the implementation of relevant measures. It should be highlighted that in the EU water policy framework, the most important strategies are also related to the marine environment. All these strategies are entirely conjoint to the European economic growth, always taking into account the aspect of sustainability. The EU continuously produces relevant policies and gradually enhances and completes their content. Therefore, the communicated idea becomes clearer to the receivers and the framework ensures environmental limits.

In September 2000, the EU launched a general framework regarding the water status of river basins and associated coastal areas, called the "Water Framework Directive" (WFD). The WFD's main target is to achieve a "good environmental status" (GES) for all European waters by 2015, in its first implementation (2009-2015). The WFD is characterized also as potentially groundbreaking legislation (Moss B., 2008), and this "potentially" is because of its complexity along with high standards in the achievement of GES. Despite its complexity, still remains a very important legislation since it sets the concept of precise water management, according to River Basin Management Plans that Member states were indebted to create.

In June 2008, another significant directive came into force: the Marine Strategy Framework Directive (MSFD), which extends environmental protection beyond coastal waters. The EU clearly understanding, on the one side, the context of developing marine offshore operations and, on the other, the great importance of a healthy sea environment to the ecosystem equilibrium, launched this directive with the purpose to assure sustainability in marine exploitation. The MSFD requires the achievement of a "Good Environmental Status" (GES) by 2020, but this time the GES refers to the EU marine waters. The EU declares that Members States must undertake only cost-effective measures in the implementation of MSFD, thus a cost-benefit analysis of suggested measures is required. In 2010, the EU inaugurated an ambitious strategy to make Europe the world-leading example of sustainability and development. The Europe 2020 Strategy[1] for smart, sustainable and inclusive growth, apart from driving Europe out of crisis, envisage to realize its title, by 2020, through five headline targets and seven flagship initiatives. The Europe's 2020 headline targets include employment, research and development, climate/energy, education, social inclusion and poverty reduction. On the purpose to incarnate these, a group of seven flagship initiatives compose the supporting framework. These priorities refer to innovation, digital economy, employment, youth, industrial policy, poverty and resource efficiency. The EU emphasizes the meaning of energy sector by launching a relevant strategy. In the framework of "Europe 2020 for smart sustainable and inclusive growth" strategy, the EU included the "Energy 2020" strategy, in 2010, setting the "20-20-20" targets. These objectives are the reduction of greenhouse gas emissions by 20%, increase of the renewable energy share to 20% and achievement of 20% energy efficiency, all by 2020. "Energy 2020" strategy is the necessary path to cross, in order to achieve the "Energy roadmap 2050" goals, where intense energy sector decarbonisation along with security and competitiveness take place.

Another significant strategy, the "Blue Growth" (launched in October 2012) is also in line with "Europe 2020". With the "blue growth" term, the EU aims to underline the strong need to take advantage of European's "blue" potential. The "Blue Growth" strategy encloses all economic activities developing -or with potential to be develop- on European seas, oceans and coasts. In this way, the EU aims to expand its economy in a sector with great potential, such as by producing employment positions, growing nutritional choices (enhancing aquaculture capability) and promoting energy production alternatives friendly to environment and in line with "Energy 2020" targets.

[1] http://ec.europa.eu/

A number of regulations have been produced regarding EU wind energy production and aquaculture activities. The wind energy sector is introduced in a wider framework concerning electricity produced by renewable sources in general. The EC Directive 2001/77/EC of the European parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market regulates the renewable energy sector. The renewable Energy Directive replaced the Directive during 2010 and 2011. Furthermore, the EU maritime wind energy sector was supplemented by the third “internal energy market package” (October 2007) and by the “energy and climate” (January 2008) and is expected to be EU’s bases on offshore wind energy promotion. The main challenge faced in the sector of offshore power generation is the lack of integrated strategic planning and cross-country coordination between member states, also recognized by recent European commission Communications. Regarding especially the offshore wind farm development, the EU requires two assessment processes to be extracted by the governments while developing offshore wind farms, according to EC law. These are the “Environmental Impact Assessment (EIA)” and the “Strategic Environmental Assessment” (SEA), under the Directive 2001/42/EC, dealing with the effects of certain actions and programs on the environment. On the other hand, regarding coastal wind energy production, certain concerns arise in the framework of potential impacts of wind farms in bird and bat populations of the relevant area. However, these impacts can be reduced through mitigation measures. To that purpose, the EU, in order to serve the goals of environmental preservation, has launched the Habitats Directive in 1992 and the Birds Directive in 2009.

The most important EU laws relevant to aquaculture are a) Rules 1263/1999 and 2792/1999 related to funding, b) Rule 1685/2000 related to the selection of acceptable projects as well as c) various decrees and circulars associated with the processing of structural funds and specialized grants for aquaculture sector development including peripheral areas. However, Regulations No 1263/1999 and No 2792/1999 laying down the detailed rules and arrangements regarding Community structural assistance in the fisheries sector, were replaced as part of the Common Fisheries Policy (CFP) by Regulations (EC) No 2371/2002, No 2369/2002, No 179/2002, 1421/2004 and No 485/2005. The offshore aquaculture sector is also attractive to stakeholders as they have already moved or plan to move “offshore” into the Exclusive Economic Zone (EEZ) with the aim of avoiding spatial competition and strict regulations applied in the coastal area (Buck et al, 2004). There are also doubts regarding whether directives, like Birds and Habitats Directives, should also apply beyond 12-mile zone. At present, these regulations are juristically not relevant to the EEZ area (D 2.1). However, the MSFD and the WFD are of particular relevance to this sector.

Chapter 4 Atlantic Site

4.1 Atlantic Site Conditions

The Multi-Use Offshore platform in the Atlantic Ocean is located in the Bay of Biscay and specifically in the area of Cantabria. The MUOP design is located in Cantabria's offshore area and named by the MERMAID project experts "Cantabrian Offshore Site" (COS). The COS has a rectangular shape, it is a medium size site with a surface of 100 km^2 and the distance from the nearest coast ranges from 3 to 20 km. The site's depths vary from 50 to 250 m, respectively standing off the coastline 3km to 20km. The site is characterized "challenging" because of its very hard wind and wave conditions (D 7.1, 2013). The COS is 7 km far from the capital city of Santander and its port. Furthermore, other considerable facilities and infrastructure are provided in the larger area, such as all basic communication facilities (motorway, airport and train). The project's experts carefully selected the site without this offshore area being subject to any environmental, cultural, political or infrastructure theme. It is also noticed that "the closest area is an unpopulated area with gravel and rocky beaches and small cliffs" (D 7.1, 2013).

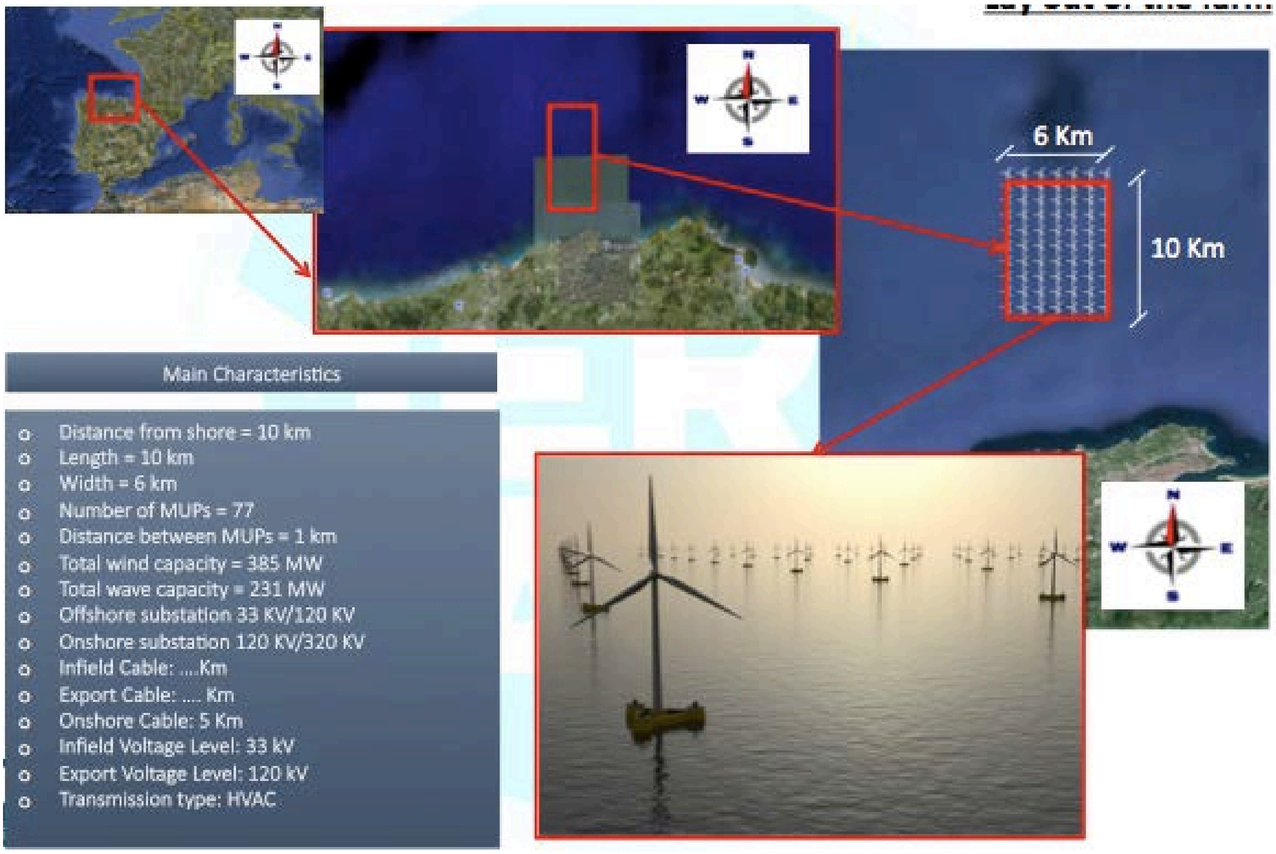
4.2.1 Layout of the platform

The MERMAID project experts have examined all possible uses to be included in the design of the MUOP. In the Atlantic, the MUOP will consist of wind and wave energy infrastructures. The site location (open ocean) is suitable for these uses and with great potential for wave energy production. Furthermore, wind power production is expanded in Spain. In 2013, wind farms became the first source of electricity while also at the same year it was installed the first offshore wind turbine in Spain, in a Canary Islands area.[2] In contrast, aquaculture activities were deemed not feasible. Although, marine aquaculture has been practiced in Spain since 1973 and inland aquaculture expands significantly year by year,[3] the water conditions is not appropriate for aquaculture as "the site is exposed to energetic seas and swells and located in a cold water area" (D 7.1, 2013). The layout of the farm has the following characteristics: It is located at 10 km of distance from shore. It has a length of 10 km and 6 km width. The number of MUOPs will be 77 and the distance between MUOPs is 1 km. The total wind capacity is 385 MW and the total wave capacity is 231 MW. The

[2] http://www.gamesacorp.com
[3] http://www.fao.org/

offshore substation has 33 KV/120 KV and the onshore substation 120 KV/320 KV. The onshore cable is 5 Km. The Infield Voltage Level is 33 kV, the export Voltage Level 120 kV and the transmission type is HVAC.

Figure 2 Layout of the farm in the Atlantic Sea



4.2.2 Technical Aspects

The following technical aspects are considered:

1. Semisumersible concrete MUP: **Wind + Waves**

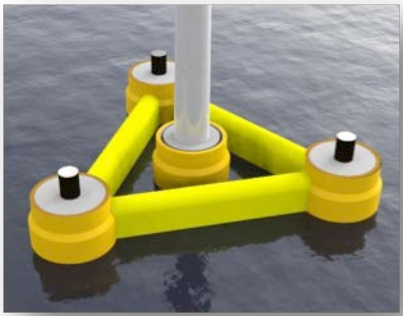
The performance benefits identified include a flexible layout and its structural integrity and robustness. The motions and accelerations can be optimized. It has a flexible payload and this is a multipurpose platform. In terms of materials this design has lower prices and a well-known performance. There is a long experience in the marine environment. It can be produced at industrial levels and has low maintenance. In terms of logistics, it is fully equipped at the port of departure. It has less dependency on weather windows and installation vessels. There is no shipyard dependency and allows faster and locally manufacturing.

Figure 3 Triangular Semisubmersible Concrete Platform: 5mw Concept

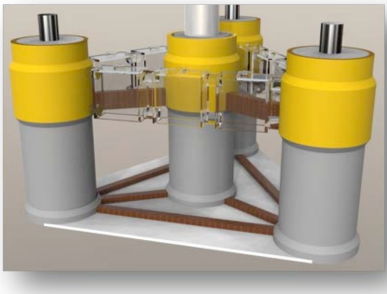
Source: Spanish and international patent. Semisumersible platform for use in the open sea. PCT/ES2013/000165. WO2014/013098A1. UC-FIHAC. Guanche et al (2014).

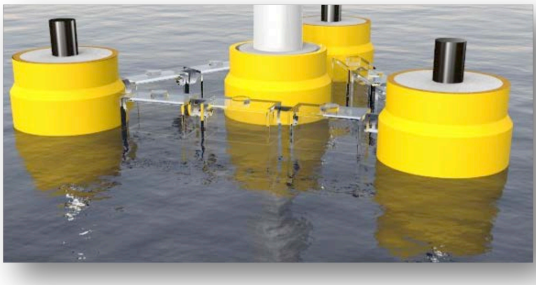
General Description: Wind + Waves MUP (Concrete Structure)

Equilateral triangle and four cylinders (one cylinders at each vertex and one in the center of the triangle).

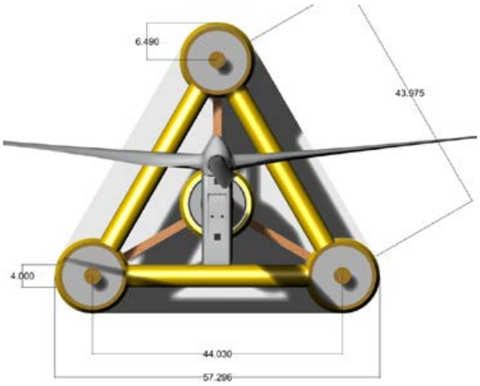


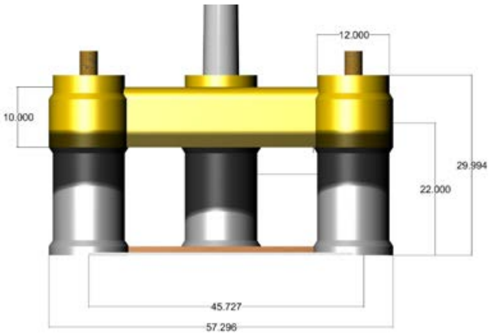
Beams link the external cylinders. Each beam is formed by 3 different Oscillating Water Column (OWC). The central cylinder supports a 5MW wind turbine. A heave plate gives more stability to the structure and supports the four cylinders.





Key numbers





- Triangular Top View (Side = 44 m).
- Draft = 22 m.
- OWC in each side
- NREL 5 MW (DTU 10Mw?):
  Hub height = 90 m.
  Rotor diameter = 126 m.

Total Weight	7.250 Tons
Draft	22 Meters
Concrete volume	4815 m^3
Passive Reinforced Steel	375 Tons
Active Reinforced Steel	64,050 Tons
Heave oscillation period	17 Seconds
Pitch oscillation period	21 Seconds
Roll oscillation period	21 Seconds

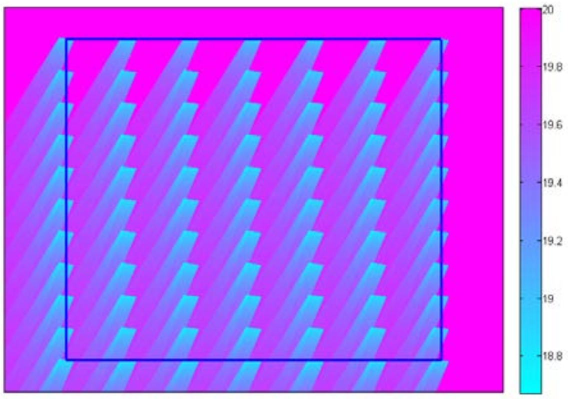
Wind energy production

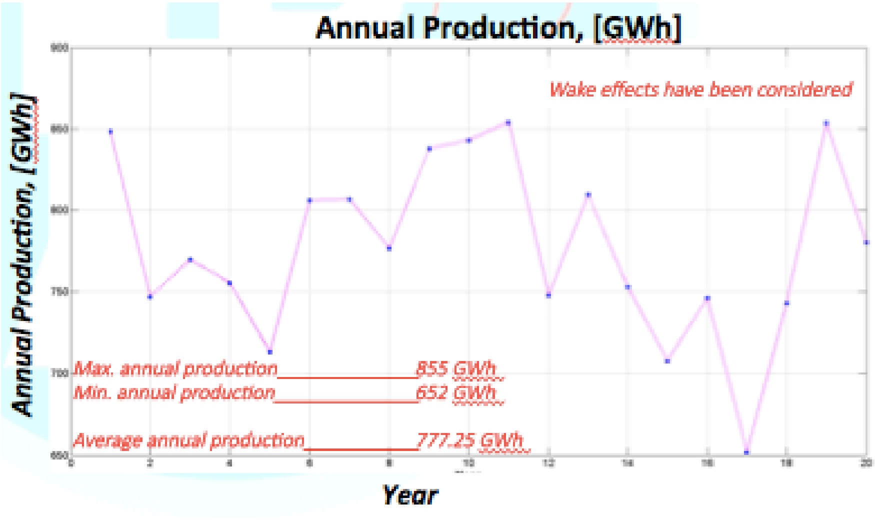
There will be 77 turbines for wind energy production. The total installed capacity is estimated at 385 MW with a rated power per turbine of 5 MW. The design life is 20 years. The Platform Production Mode considers a Maximum Significant Wave Height of 5m.

Turbine Performance (NREL 5Mw):

- Cut-in Wind Speed 4 m/s
- Rated Wind Speed 11,4 m/s
- Cut-out Wind Speed 25 m/s
- Rotor diameter 126 m
- Hub height 90 m (above SWL)

Wake effect: Wind Speed 20 m/s Dir-30 deg





Wave energy production

- Number of OWC 9 X 77
- Total Installed Capacity 231 MW
- Rated Power Per Turbine 0.33 MW
- Design Life 20 Years
- Platform Production Mode:

  Max. Chamber Amplitude Oscillation: 3m

Figure 4. Mean annual production: 1,2056 GWh/year

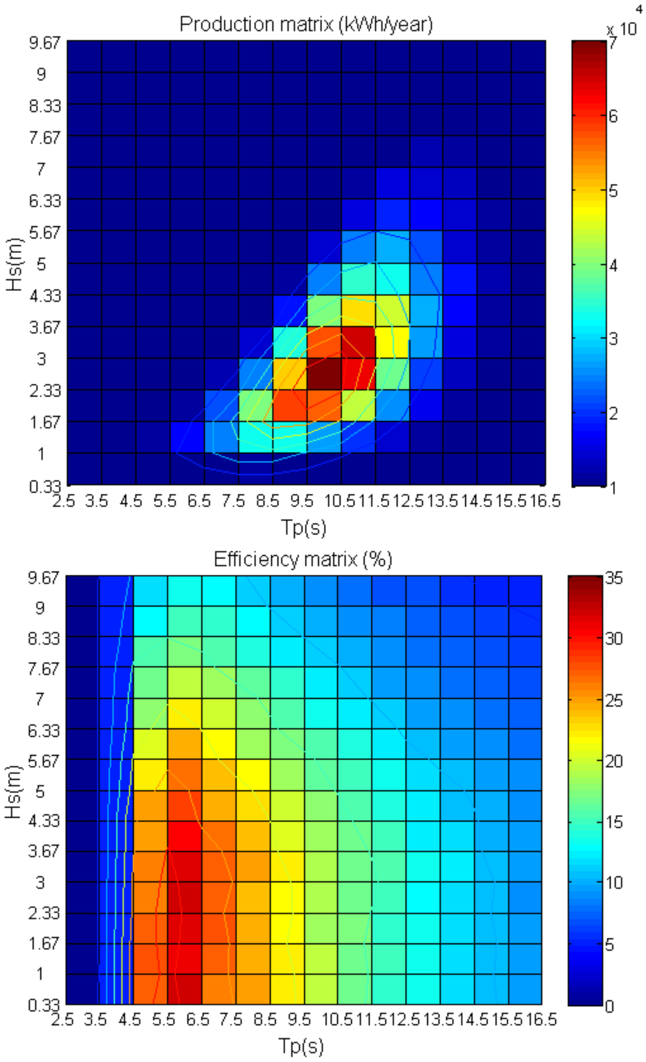
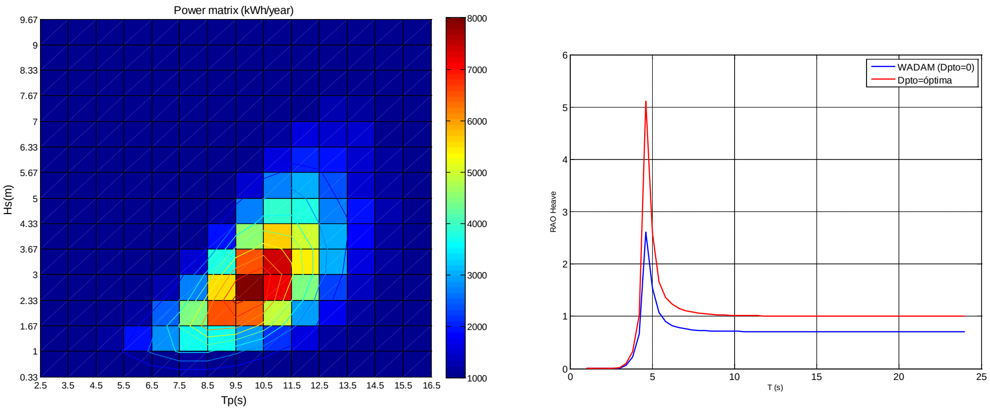


Figure 5 Single platform: Mean anual production: 0,144 GWh/year



4.2.3 Environmental Aspects

The environmental restrictions that have to be considered in the area are related with:

a) Windmill impacts on birds
b) Soil effect due to interconnections
c) Electrical interaction with local fauna
d) Natural mobility disruption

4.2.4 Financial Aspects

The estimated financial costs for wind only are the following for a concrete platform manufacturing cost breakdown / 1st UNIT are as follows (these are pure preliminary results as the final design has just been finished). It has to be noted that some of the basic information produced for the MUOP are required to be modified as the final design produced have rejected the combined uses with aquaculture. The mutual synergies have to be reconsidered then.

The basic requirement of materials and costs required for LCA and financial estimates are:

Light Concrete	500	€/m³
Passive reinforced steel	1	€/Kg
Active reinforced steel	3,67	€/kg
Equipment assembly	10%	Total manufacturing costs

Concrete volume	4.815	m³
Passive reinforced steel	375.000	Kg
Active reinforced steel	64.050	Kg

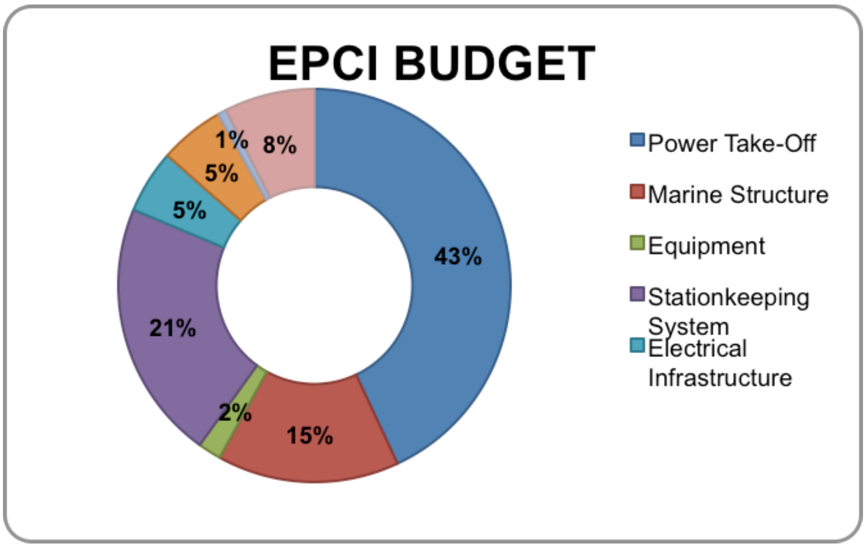
Hence the estimate budget for the project is

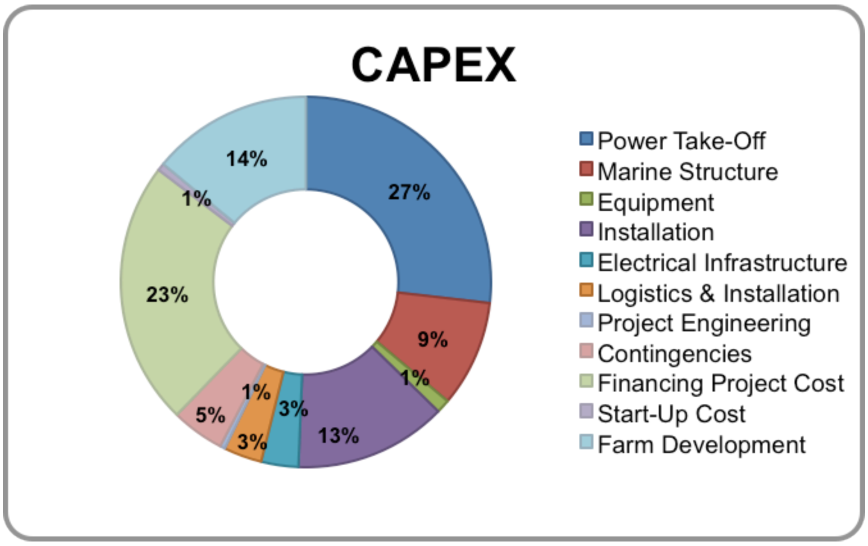
Concrete manufacturing cost	2.407.500	€
Passive reinforced steel cost	374.967	€
Active reinforced steel cost	235.030	€
Equipment assembly	301.750	€
Total manufacturing cost	**3.319.247**	**€**

Summarizing the investment costs we can observe:

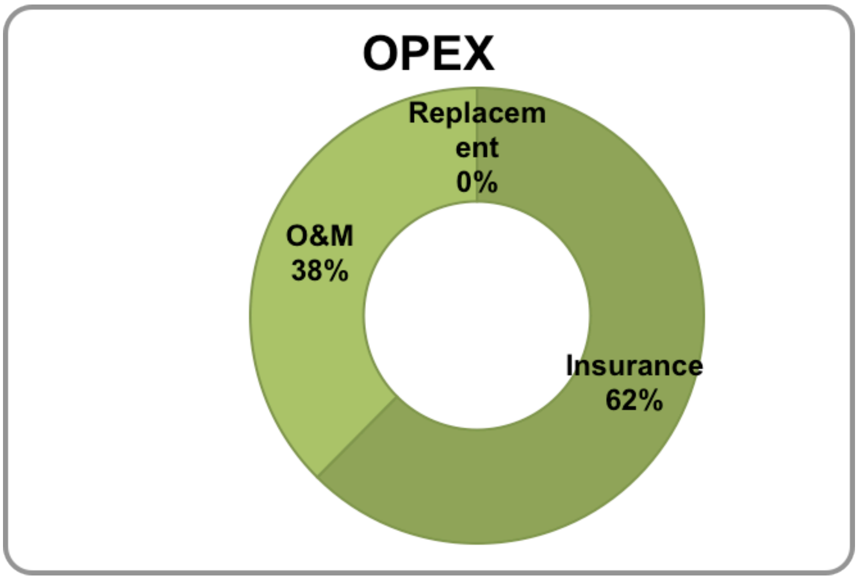
- 40% of the physical investment is driven to supply electrical facilities
- 33% is dedicated to physical structures
- 25% is derived to launching the connection

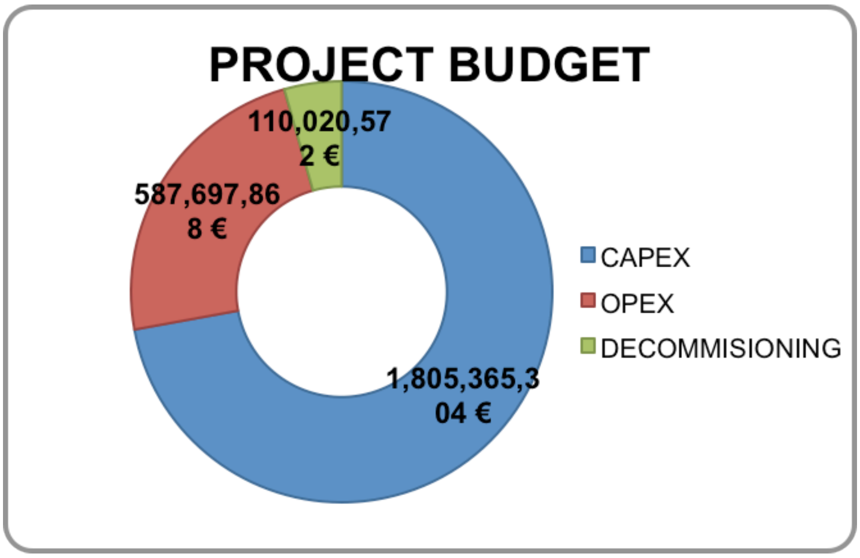
On the capital budget we can observe that direct investment driven by available technologies require just two thirds of the capital needs, being the last third related with the business component of the project as development, project contingencies, and financial costs.





About operating expenses we can observe that two thirds of them are related with insurance, that is are related with uncertainty and the need to levelize its consequences to a fixed cost, and one third of them are connected with actual operating expenses. These estimates although vary according with physical parameters of the facility look rather stable in proportion. On the comparative between investment and operating costs we can observe that the global value of the investment represents three times the operating cost. The actual figures will be updated once the final design is totally designed.





4.2.5 Socio-economic Aspects

a) Site description

Located on the north coast of Spain, Cantabria offers a good opportunity for offshore technology deployment, with a reasonable combination of depth and distance. The availability of natural port facilities constitutes an additional advantage for the deployment of the selected activities.

b) Human capital and Knowledge

There exists a rich set of possibilities to be exploited with the combination of university clusters, energy production companies (hydroelectric, and wind farms), and marine expertise. There exist also at least four areas on the nearby coast where testing activities for marine renewables are been undergone.

- The IH-Cantabria research facilities,
- The Santoña Test Site
- The Ubiarco Test and Demonstration Site
- The Biscay Marine Platform Site

c) Local energy production planning is based on local hydroelectric plants, coal and fuel consuming plants and cogeneration plants on industrial areas. There is not a local supply deficit or a distribution restriction that would justify additional production at the local level. Nevertheless Spanish dependence on foreign energy suppliers is a key limitation to rely on present energy policy, and no contribution is negligible.

d) Strategic review:

The main issues to be considered can be summarized under two categories:

1. Threats and weaknesses (restrictions)
2. Strengths and opportunities

Under the section of restrictions that summarize both threats and weaknesses, we can the following set of limitations for the designed facility to be successfully operated in the area.

1. Social sensitivity towards aesthetic and functional impact of the facilities. Social perception on uncertain consequences.
2. Uncertainty on the regulatory policy
3. Uncertainty on spatial planning regulations
4. Availability of funding
5. Environmental requirements
6. Mutual restriction among users

1. Social sensitivity towards aesthetic and functional impact of the facilities: Social attitudes towards marine environment perceives coastal sea areas as free access areas. Hence any restriction, actual or presumed, are traditionally perceived as a private appropriation of public areas and receive heavy public opposition. This is extensive both to coastal facilities on ground, on sea, and to normative restriction for other activities affected. Previous proposals developed in the area involving on ground facilities have been abandoned or restricted due to this attitude (e.g. fracking, oil drilling and land windmills). The lack of local energy availability and the strong energy dependence of the country does not guarantee public interest and support of the activity. Uncertainty over future impacts is also an important source of rejection of private settlements on public areas.

2. Uncertainty on the regulatory conditions for the affected sectors. The proposals made for the Atlantic site were by large oriented to energy production. This represents an important restriction for our case, on one hand because there is no possibility to share costs among sectors, and on the other because the actual financial conditions where the business will operate depend critically on policy regulations determined by the public sector. Previous experience of situations where the expected direct subsidies and price guarantees have been removed, have been assumed as a natural characteristic of emerging sectors, and represent a visible barrier for the industry to successfully operate. The lack of a clear and stable scenario is a pre-requisite for any investment, especially in emerging areas as expressed by stakeholders.

3. Uncertainty on spatial planning regulations: the purpose of spatial planning procedures has traditionally been the efficient assignment of resources, but the experience shows that planning procedures are heavily contested when large sensible areas are involved. The experience shows that the needed guarantees for long term investments are never provided, and initial approvals can easily be rejected, hence we face here another barrier that discourages investments through uncertainty.

4. Availability of funding: uncertainty in the availability of funding will have an impact on the potential development of the infrastructure

5. Environmental requirements: the eventual consequences of deployment new activities in such a sensible areas have shown to be an important restriction for newcomers to be welcomed in such areas. The unexpected environmental consequences of new activities have been perceived as a limitation and barrier for newcomers as expressed by stakeholders in the meetings.

6. The uncertain character of the activities involved in the sites represent a serious restriction for financial agents that would require financial guarantees to assume their participation in the funding.

The comparable land activities have been developed with a broad set of instruments as project finance that require a robust knowledge corpus to be adopted. The experiences obtained under this project will be critical to develop an expertise that could eventually be transferred to promoters through the adequate business models.

Under the categories of opportunities, the stakeholders are concerned about the following set of value sources for business:

1. Inter-sectorial Technological transfers
2. Competitive advantages for the area

3. Regional Benefit Split

1. Technological transfers between sectors: The preexistent sectors that may develop new business expertise due to past accumulation experience in related areas is a relevant source of benefits for the projects. Expertise in metallic building, shipyards for building and repairing, navigation, and other electric related sectors can reasonably be transferred to new industries. Experience on aquaculture were initially considered as a relevant source of value but unfortunately as technical restriction obliged to discard this alternatives in the platforms, the possibility of this major source of value to be captured had to be discarded.

2. Competitive advantages could be obtained from the available facilities existing in the area that can be included in the following categories:

- Knowledge expertise developed under the industrial and university cluster in renewable energies and marine environment
- Availability of technological support between nearby institutions on the Atlantic coast
- Scale economies derived the accumulation of connected activities in the surrounding areas

3. Regional Benefit diffusion: based on the previously cited advantages, we are expected to derive a quota of value add through the participation on building and maintenance costs towards local agents. The eventual spin-offs that can be derived from these activities will be reinforced by knowledge transfer from technology leaders attracted to local sites.

4.3 Current policy, management and planning strategy

The potential barriers in the implementation of the project can be identified in international, national and regional level (D 2.1) so far have been:

1st Lack of social consensus that guarantee the acceptability of the project. This consensus is critical for stakeholder to assume the compromises involved and as past experiences have shown the importance of this issue to be addressed

2nd Spatial and environmental procedures to be followed by the project should be required to create a certain scenario where time scheduling for decisions is clearly and definitely determined, the intermediate steps are consistently and definitely closed as process advance. And finally legal modification that eventually emerge during the developing period should offer legal protection to bona fide investors.

3rd Regulatory risks connected with energy policy in Spain and Europe is the key issue to keep under control, past experiences in energy production industries show that strategic options have been the subject of never ending discussions with cyclical options been adopted. As a result, it is always unclear that the tariff scenario would persist as initially defined. The dependence of this site on energy production activities makes this issue critical.

4th Present controversies on external energy dependence may produce a favorable map for marine energy in the future, but it is far from been clear that the objectives connected with EU Blue Growth initiatives will be include as part of financial support offered to renewable energies.

4.3.1 International, national and regional legislative obstacles

The international Marine Spatial Planning (MSP) instruments set up the provisions influencing the legislative and procedural requirements for Offshore Renewable Energy and the related grid infrastructure. It should be noted that the maritime spatial planning is closely related to a legal framework. In addition, the priority principle for navigation has been firmly anchored in the United Nations Convention on the Law of the Sea (UNCLOS) and reflects the dominant position of the shipping sector. The fundamental right to lay submarine cables is firmly anchored in the UNCLOS.

On the other hand, there is a lack of clarity of information, specific uncertainty related to grid capacity reinforcements in Spain. Finally, cross-border cooperation on MSP would support projects crossing several EEZ such as large-scale offshore wind projects, and the interconnectors of the future pan-European grid.

4.3.2 Institutional/administrative obstacles

Among the identified institutional and administrative obstacles, it should be mentioned that the current procedure to get permissions is complex. There is also insufficient coordination between ministries and complex bureaucratic procedures are pointed out as barriers for offshore grid development. It should be mentioned that the length of permissions varies greatly depending on type of administration.

4.3.3 Societal objections

In terms of environmental legislation, the existing legislation does not explicitly exclude offshore renewable energy installations/infrastructure. Further, different interpretation of the legislation exists: some countries consider the protected areas as « NO-GO-areas » for offshore renewable energy. Environmental legislation may slow down or hamper in some specific cases the deployment of offshore renewable energy installations/infrastructure.

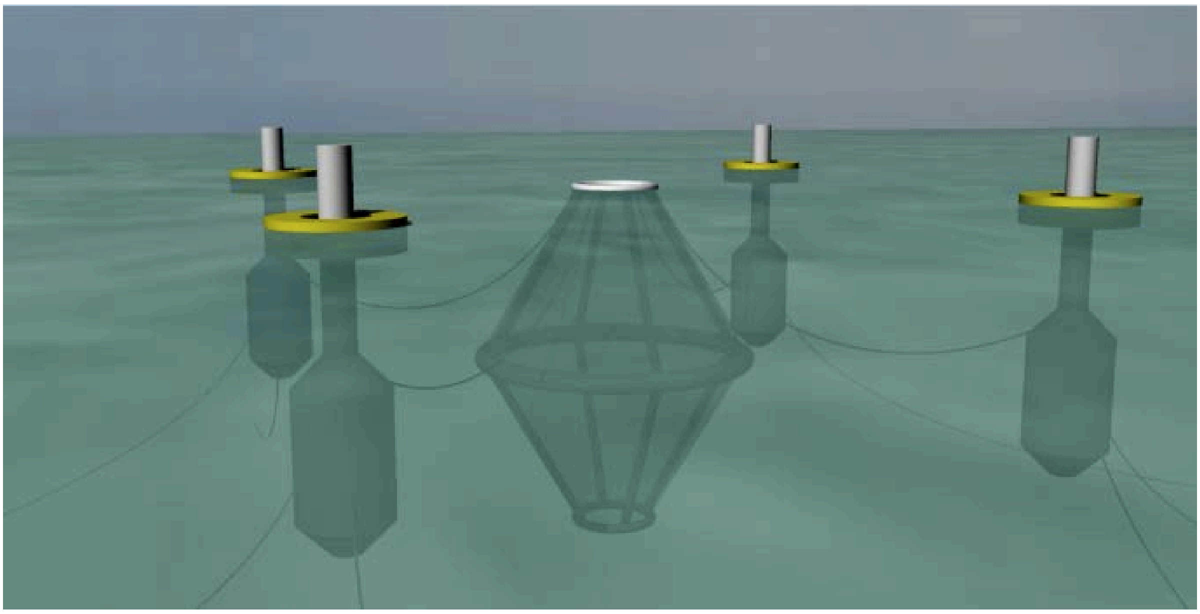
4.4 Stakeholder views and their influence on the draft design

The participatory design followed a stepwise approach. In the phase 1, short meetings and interviews with key stakeholders were conducted. In phase 2 round tables were conducted. The stakeholders involved include the aquaculture sector, research institutes, the civil engineering sector, the government and environmental institutions. Some of the key issues considered during the design stage from the stakeholders perspective include the following:

- Sea conditions: Survivability
- Unpredicted costs
- Technical demands
- Ecological interferences
- Opportunity for bringing more employment
- Importance of non interferences with the
- Local fishing community
- Short and Long term permits
- Government regulations
- Difficult attraction of funds

The following alternatives were offered during this stage and discussed with the stakeholders:

Alternative 1: Wave Energy + Aquaculture



This design includes the following features:

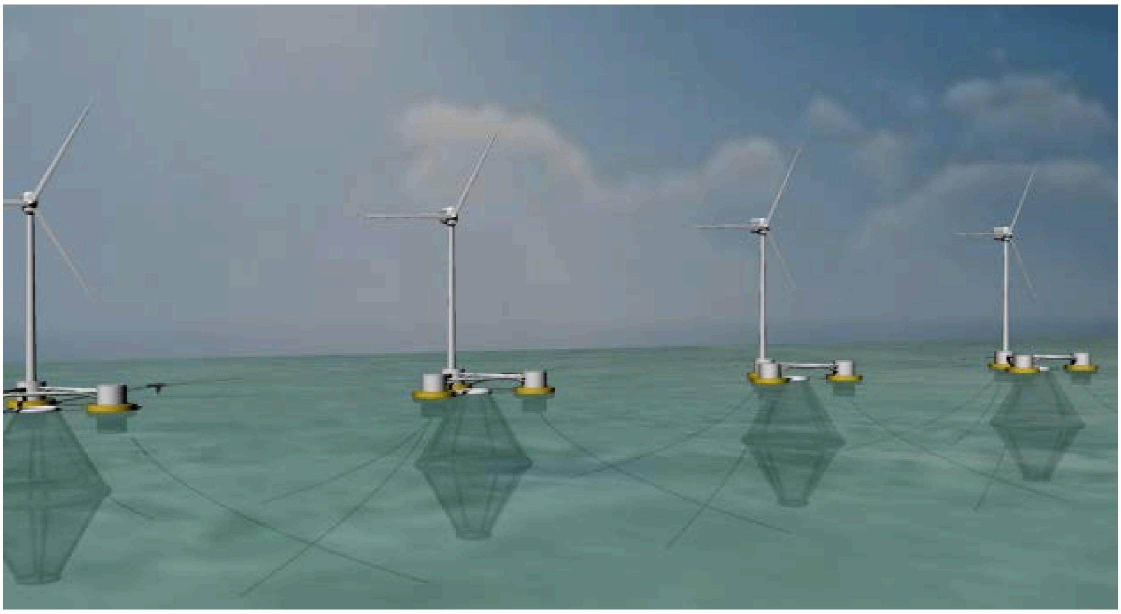
- Low economies of scale
- Very Low visual and environmental impacts
- Non interferences with birdlife
- Early stage of technique development
- Low energy production

Alternative 2: Wind Energy + Aquaculture

This design includes the following features:

- Medium economies of scale
- Low and environmental impacts
- Low interferences with birdlife
- Technique high developed
- High energy production
- High water depth is needed

Alternative 3: Wind Energy + Wave Energy + Aquaculture



This design includes the following features:

- High economies of scale
- Low visual and environmental impacts
- Low interferences with birdlife
- Technique high developed
- Very high energy production

MUOP contribution:

The stakeholders were interviewed at a very early stage of the elaboration of the MUOP, hence it was their contribution as basic ideas and quantitative estimates that were captured and supply to the

MUOP. Once their feed - back for design was compiled the final version of MUOP was prepared to present in the final round with stakeholders, where they would be required to validate and apply to the final assessment of the solution.

Chapter 5 Baltic Sea Site

5.1 Baltic Sea Site Conditions

5.1 Baltic Sea Site Conditions

One of four MERMAID sites is the Kriegers Flak, a marine area in the Baltic Sea. The Kriegers Flak is a large sandy shoal with a sand layer thickness of up to 8 m located in the Western Baltic Sea between Denmark, Sweden and Germany (figure 6). The area of Krigers Flak is approximately 250 KM2. The central plain is located at 18-20 m depth gently sloping to more than 40 m to the N, E and S. The major part of the sandy plain is located within the Danish Economic Zone. At the neighboring German territory an OWF Baltic II is currently under construction, while pre-investigations for an OWF have already been carried out at Swedish territory, however further construction is currently on standby.

The MUOP in the Baltic Sea case study is designed to be applied within the Danish EEZ and covers an area of approximately 180 km^2. Denmark has designated the area of the Kriegers Flak to install an offshore wind farm of 600 MW, which is planned to be fully operational in 2022. Centrally in the area 28 km^2 is reserved for sand extraction with no permission for technical OWF components to be installed. Hence, wind turbines will be separated in an Eastern (110 km2) and Western (69 km2) wind farm, with a planned production of 200 MW on the western part, and 400 MW on the eastern part. Furthermore, an offshore power grid is planned to be created in the area, in the purpose to link Germany and Denmark and facilitate the exchange of electricity between the countries[4]. The grid connection facility must be ready to transport electricity from the offshore wind turbines 2018.

[4] https://www.energinet.dk/

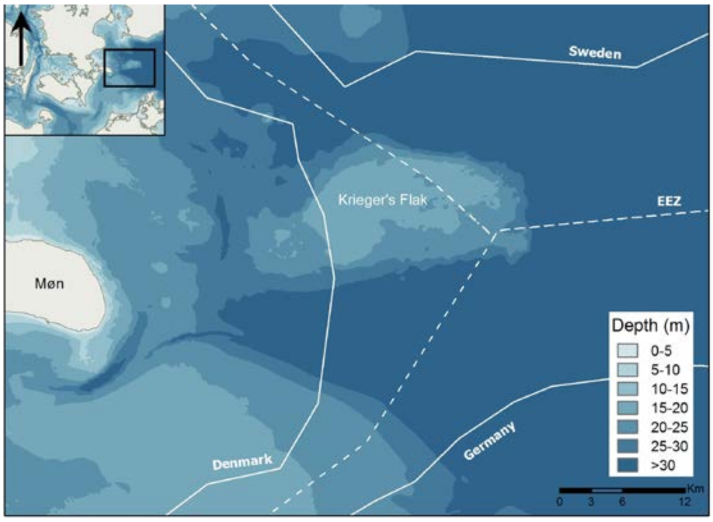


Figure 6 Location of Kriegers Flak depicting territorial and EEZ of Denmark, Sweden and Germany.

5.1 Design concept

The Baltic site differs from the other sites, since the off-shore windmill park and grid connection is already decided to be constructed and fully operational in respectively 2022 and 2018. Thus one of the elements for an off-shore multiuse platform already exists. Moreover, at this stage of the planning phase for the coming off-shore windmill park means that numerous assessments of the physical and biological conditions in the area along with public hearings has been or is planned to be conducted as part of the process. Besides a technical design concept description has been developed by the Danish Energy Agency to facilitate future concessionaires and provide a framework for coming EIA´s.

One of the suggested design layout for the windmill park with 8.0 MW turbines is shown in figure 7 below.

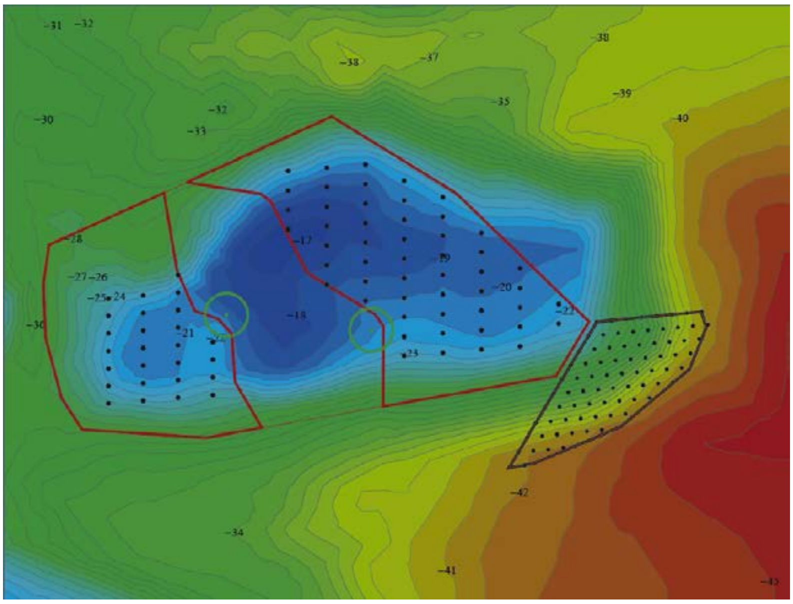


Figure 7 Possible OWF layout for turbines at the eastern and western part (red polygons) of the Kriegers Flak at Danish territory.

Green circles indicate the position of the offshore platforms. In the south-western part of the map (brown polygon) turbines within the German Baltic II OWF are shown. Source: Danish Energy Agency.

5.2 Platform design and planning

5.2.1 Layout of the platform

The MERMAID project experts have examined possible additional uses in combination with the planned off-shore windmill farm. The additional uses assessed included aquaculture of fish (rainbow trout and/or Atlantic salmon), seaweed and shellfish farming (see figure 8 below). The adequateness of possible commercial additional uses for a MUP in the Baltic site are shortly summarised below.

Fish Aquaculture

The abiotic and environmental conditions at the Baltic site are excellent for production of Salmonids, especially rainbow trout and salmon. The salinity is stable and almost equal to the osmolality of fish plasma. These conditions means that energy expenditure to osmoregulation in fish is low, which results in high growth efficiency. The low salinity at the Baltic site will also prevent infections by sea lice. Moreover, lethal algae blooms have not been documented in the Western part of the Baltic. The regular high waves and currents at this site will also reduce the environmental impact from fish farming, as a result of high dilution and transport of nutrients and particulate matter. Model simulation of fish farming at the Baltic site showed that Nitrogen release from production of 5000 tons rainbow trout would result in release of 200 ton Nitrogen. After a distance of 1500 meters the concentration of Nitrogen was found insignificant due to dilution. A combination of wind energy and aquaculture are considered highly relevant commercial activities for a possible MUP at the Baltic site.

Shell fish farming

Populations of blue mussels lives widespread in the Baltic Sea at salinities above 4-5 ‰. The growth rate, meat content and shell length of blue mussels decreases with decreasing salinity. Calculation of potential growth of blue mussels showed that with a farm area of 3 km^3 a yield of 45 tons wet weight/hectare/year and removal 0.6-0.7 tons nitrogen/hectare/year can be obtained in a best case scenario. The slow growth rates caused by the environmental conditions and the resulting low market potential imply that commercial production of mussels is not considered adequate at the Baltic site.

Seaweed farming

Commercial production of seaweed at the Baltic site may, beside the economic value, result in added value in form of some protection of cages against wave load by dissipation some of the wave energy and uptake of some of the excreted ammonia from the fish farm. Commercial valuable macroalgaes are uncommon in the Baltic Sea, because low salinity prevents growth of many species. The valuable red algae *Furcellaria Lumbricalis* is generally wide-spread in the Baltic Sea and have previously been exploited commercially. Calculations of harvest potential showed that seaweed farming in an 5 km^2 area in best case can result in harvest of 6 tons dryweight/ha/y and the removal of 0.2-0.4 tons N/ha/Y.

The use of macroalgal culturing for wave damping at a commercial scale offshore will be a serious challenge and require both innovation and pilot testing, before such an activity can be included as a commercial activity at the Baltic site.

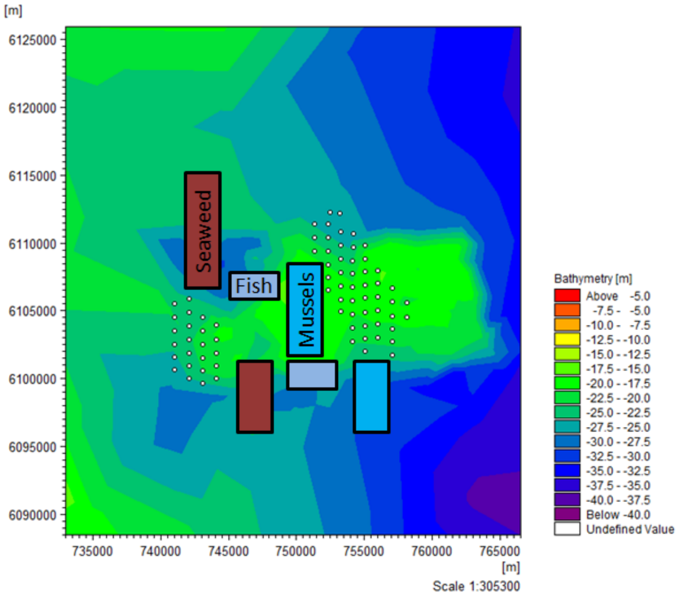


Figure 8 Possible MUP layout and model set-up for combining multiple uses

Based on the performed assessment and model simulations performed by the MERMAID experts it was concluded that the Kriegers Flak is suitable for multi-use. The general picture is that wind energy in combination with aquaculture will be the most viable option, generating the highest benefits. Both of these commercial activities builds on well proven technologies and can be operationalized within a reasonable time horizon. In the future this combination can serve as a start design and provide basis for applying additional commercial activities such as seaweed farming.

Another consideration that lead to the recommended MUP combination is that with many commercial activities at the site, the risk for damage of equipment and installations will increase.

5.2.2 Technical Aspects

The recommended initial layout for a multiuse platform at the Baltic site is to start with a combination of wind energy and aquaculture. A future additional use may be culturing of *Furcellaria*.

The planned 600 MW offshore wind farm is located approximately 15 km east of the Danish coast in the southern part of the Baltic Sea. The central part of Kriegers Flak is reserved for sand extraction (28 km^2) and the establishment of an OWF is not allowed in this area. The final design of the windmill farm will be determined by the concessionaire, but it is anticipated that the windmill park will be divided into two clusters in order to allow for sand extraction. Hence the wind turbines will most likely be separated in an Eastern and Western cluster covering an area of 110 km^2 and 69 km^2, respectively.

To reduce risk of damage of equipment and installations under operations, the fish farming is planned as two separate facilities located between the two groups of wind turbines. To be economic feasible to farm fish offshore a production of around 10000 tons of salmonids is anticipated. Each of the two fish farm sections will consist of 12-14 round cages with a diameter of 45 m and a feeding barge. It should be noted that no offshore aquaculture activities do exist in the Danish EEZ so far and thus there is a lack of information regarding offshore aquaculture operations in the area.

The layout of the MUP for the Baltic site is shown in the figure 9 below.

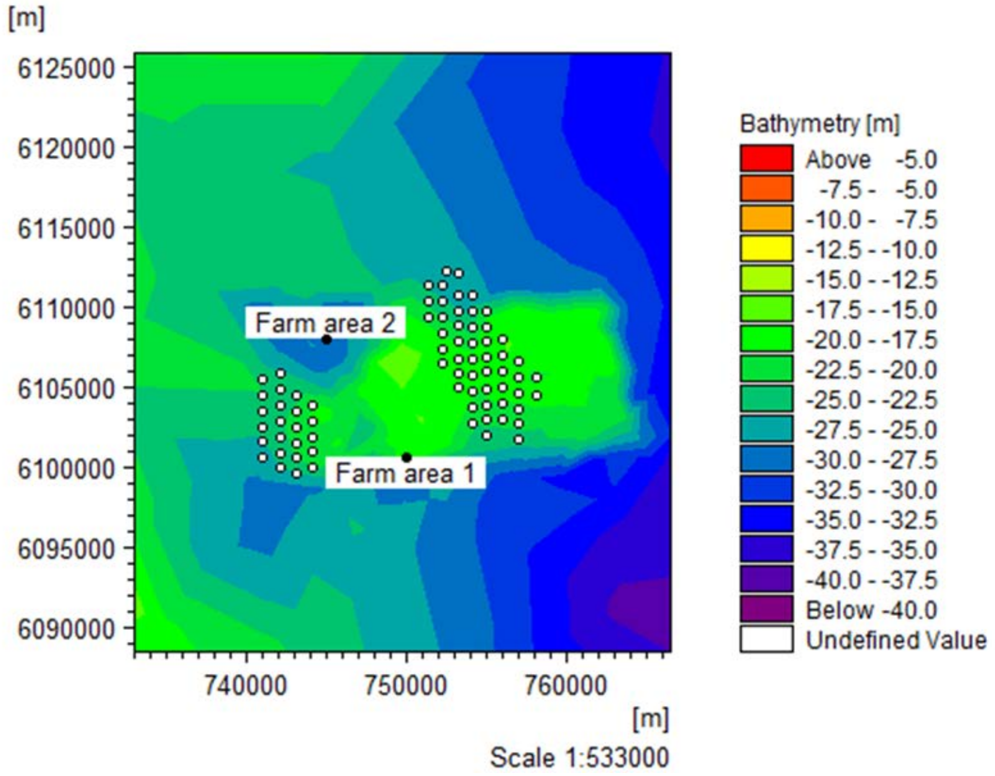


Figure 9 Layout of multiuse platform at the Baltic site

The final technical design of the OWF will be defined by the future concessionaire. As mentioned above the Danish Energy Agency has developed a technical design concept note (Danish Energy Agency - Document no. 13-93260-684) to guide the tender process and assess the environmental aspects, which is a prerequisite prior to construction of the windmill park. The technical concept note contains a realistic outline of technical aspects encompassed in the development of the Kriegers Flak Offshore Wind Farm. This includes possible technical solutions regarding wind turbines and foundations, internal site area cables, transformer station and sub-marine cable for power export to shore. Each of these components is described with respect to construction, operation and decommissioning. The technical aspects of the wind farm is shortly summarised in the following.

Wind farm
The optimal technical design will depend on a range of factors such as turbine type, cost of cables, foundations costs and shadow effects. Of major importance is that foundation costs grow exponentially with depth.

In the project description for Kriegers Flak five different turbine sizes is found plausible for the coming wind farm. The possible coming turbines ranges from 3 MW (smallest) to 10 MW being the largest. To fulfill the planned capacity of 600 MW, this result in 200 and 60 turbines, respectively. In addition two extra turbines are allowed to assure adequate production in periods when turbines are out of service due to repair. The minor turbines have been installed in various existing wind farms, but both the newly developed 8 MW and 10 MW is found relevant for a future wind farm at Kriegers Flak. Maximum tip height for the largest turbine type (10 MW) will be 230 meter above sea level.

The foundations of the turbines can comprise different solutions such as gravity based foundation, driven steel monopoles and bucket foundations (figure 10). Driven steel mono piles have been used in a large number of wind farms in Denmark and the United Kingdom and is likely to be used in a final design.

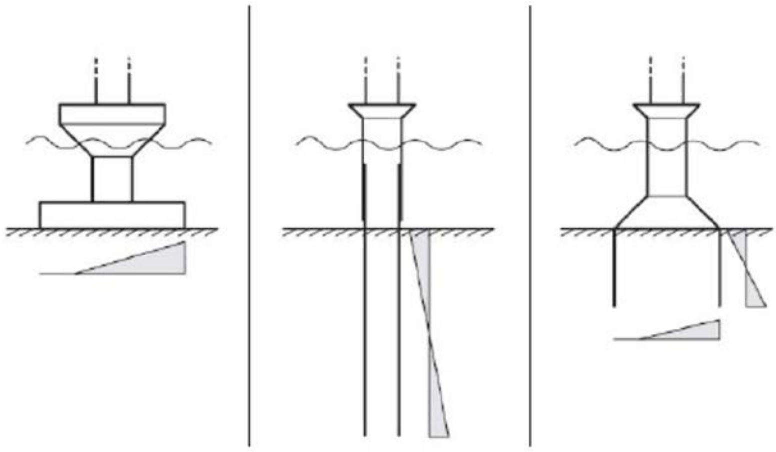


Figure 10 Illustration of gravity based, driven steel monopile and bucket foundation of turbines

To support the foundation from erosion by currents the final design of the foundation most likely will include scour protection, such as rocks or fronded mattresses around the installation.

Substations and export cables to shore will consists of two 220 kV offshore transformer platforms that collect power from the 600 MW offshore wind turbines. The two platforms are interconnected by a submarine cable. Each platform will be connected to shore south of Rødvig on Sealand by one approx. 45 km long 220 kV submarine cable. The final construction is planned to be a ‘traditional’ AC grid connection facility for the offshore wind farm at Krieger's Flak. This means that the grid connection will be based on alternating current, in the same way as the existing Danish offshore wind farms are connected to the grid.

The fish farming are planned as two separate facilities located between the two groups of turbines to gain some physical protection from the foundations and the wind turbines. Each fish farm section will consist of 12-14 round cages with a diameter of 45 m and a feeding barge delivering feed by compressed air through tubes to each cage. The depth of the net cages will be 12-15 m.

The net type of the cages, ballast and mooring equipment will be designed in accordance to the actual physical conditions and will especially depend on the depth of the locations for the fish farms. To comply with the rough offshore conditions the net type will most likely be Dyneema, which is a polyethylene fiber with a maximum strength combined with minimum weight. In contrary to the wind farm, where it is preferable with low water depths to reduce construction costs, fish farms do not need shallow water. It actual be an advantage with deeper water and typical designs needs a depth around 30 – 40 m. Therefore the installations of fish cages could be set-up in the vicinity of the offshore wind farm without a direct contact to the offshore wind turbines.

The cages can either be developed as floating cages or cages that can be submerged under rough weather conditions. In-situ test of cages (reported under WP4) showed that cages can comply with extreme events such as storms/hurricanes without being damaged. However, it may be an advance with submergible cages to reduce wearing of the equipment and stress of the fish under hard weather conditions. An illustration of submergible cage is given below in figure 11.

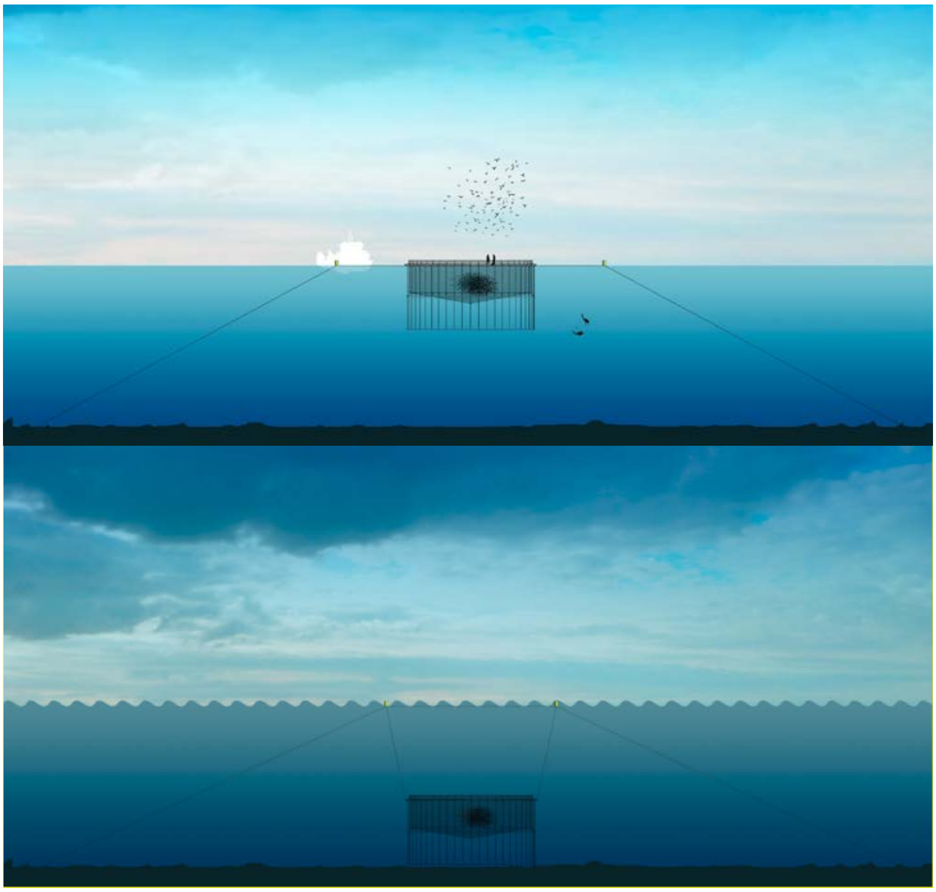


Figure 11 Schematic presentation of the submersible offshore cage

As pointed out under the layout of the MUP, seaweed farming has been identified as a future additional commercial activity that can be combined with wind energy and fish farming. A preliminary outline for farming *Furcellaria Lumbricalis* is shortly described in the following. Under optimal conditions F. lumbricalis can attain growth rate up to 1% d-1, which is markedly lower than other cultivated seaweed species, but the fact that *F. lumbricalis* grow equally well attached to hard substrates or lose-drifting above the seabed probably allows to apply a cost-effective growth system. The proposed system is novel for *F. lumbricalis* using long-lines with attached "mussel-socks" of an appropriate mesh size filled with fragmented thalli of *F. lumbricalis* prior to deployment. The growth system should be submerged (e.g. below 5 m) to avoid overgrowth with annual green and brown algae. The mesh-size of socks should be scaled to the size of thalli fragments minimizing loss but allow distal growth ends easily to penetrate through meshes. Pilot growth experiments have confirmed that fragments of *F. lumbricalis* can growth unattached in mesh-bags. Besides providing a sink (trap) for excreted ammonia from cultured fish the macroalgal culture system could provide some protection of fish cages against wave load by dissipation some of the wave energy.

Future farming of *F. Lumbricalis* at large commercial scale at the Baltic site will require considerable efforts in both innovation and field testing. Moreover, feasibility studies should be conducted.

5.2.3 Environmental Aspects

Environmental considerations are an integral part of constructing wind farms and establishment of fish farms. Presently extensive studies of the influence of a wind park on the environment have been made or are planned for Kriegers flak. These studies include the effect of the plant on fish, birds, marine mammals and seabed flora. The risk of changes to the sedimentation and flow conditions is also being explored.

The major environmental concerns from the wind farm include aspects such as sediment spill and noise under the construction phase, after construction the turbines can pose a risk to migrating birds.

The environmental aspects from fish farming include the spill of nutrients, antifouling and medicaments. From the modelling of nutrient release from fish farming at the Baltic site it was found that after just 1500 m, the concentration of nutrients were insignificant due to dilution.

It is noticed that as part of the MERMAID project developing an EIA guideline will be developed, so that environmental aspects of multiuser platform can be appropriately assessed in the future.

5.2.4 Financial Aspects

The planned windmill park is expected to create 10,000 jobs during the construction phase. After construction the operation and maintenance of the wind and aquaculture farm will secure jobs and will at the same time act as an international window for Danish know how. The total price for the wind farm is expected to be between 15-20 billion DKK, whereof the grid connection is budgeted to cost 3.5 billion DKK.

Within 3-4 years about 10.000 tons of rainbow trout or Atlantic salmon can be produced yearly at a value of € 40 mill. The total capacity for fish production is markedly higher at approximately 100.000 tons. The capacity for seaweed production and economic feasibility is unknown.

Both aquaculture and wind energy extraction will benefit from sharing seabed area, primarily in terms cost sharing of transportation (for M&O), housing (e.g. using the feeding barge as "hotel" during extended maintenance on wind turbines).

In addition it is likely that pylons and foundation for turbines would provide a new habitat for sessile filter-feeders and that they would be able to sequester part of the waste lost from the fish farms, thereby reducing the environments impact of fish production

5.2.5 Socio-economic Aspects

Attitudes towards offshore wind farms were measured both at national and at local levels. The socioeconomic study showed positive attitudes towards wind farms and a willingness to pay to place future farms away from the shore to minimize visual impacts. As mentioned the establishment of the wind farm and future operation and maintenance will create additional jobs in the region. Establishment of a large fish farm, will also create additional jobs in the area and exploit the export potential for fish.

Exploring renewable energy sources will also have future positive effects on mitigation of climate change. Moreover, regionally benefits will be achieved through the possibility for power exchange between countries.

5.3 Current policy, management and planning strategy

As mentioned above the Kriegers Flak has already been selected and approved by the Danish parliament as the next large offshore wind farm (600 MW) planned to be in operation in 2022. For the sake of a timely EIA process a preliminary Technical Project Description for the Danish wind farm has been drafted the 15th of October 2013 (Danish Energy Agency - Document no. 13-93260-684). Presently EIA´s are being finalized for the grid connection to shore, which is planned to be operational prior to the wind farm. Public hearings for this part of the farm is planned to be held November/December in 2015.

In Denmark, aquaculture is regulated as an integrated part of the Danish fisheries sector and as such it is mainly covered by the Fisheries Act under the Ministry of Food, Agriculture and Fisheries. The overarching legal framework for marine farming is the Water Framework Directive, implemented in Danish legislation as consolidated act. No. 932 issued April 24th 2009. Marine farming is only partly covered by this directive. The ecological status applies for coastal waters up to 1 nautical mile whereas the chemical status applies for coastal waters up to 12 nautical miles. The most critical issue in this directive is the discharge of nitrogen that must not been increased making it impossible for farms to increase the production without an increase of nitrogen load. If marine farmers want to increase their production they can apply for a part of the total nitrogen quota. But the permit is only granted under the condition that the increase in the discharge of nitrogen is eliminated by compensatory farming e.g. by farming of macroalgae. However, it is not clear if the compensation should eliminate the discharge of nitrogen fully or only partly. It is still being discussed. At present, no offshore aquaculture farms do exist in Danish EEZ and practices how to administer offshore aquaculture production have not been developed.

5.3.1 Policy obstacles

For development and establish of offshore wind park projects in Denmark, three licenses are required. All licenses are granted by the Danish Energy Agency (Danish Energy Agency, 2012):

1. License to carry out preliminary investigations

2. License to establish the offshore wind turbines (only given if preliminary investigations show that the project is compatible with the relevant interests at sea)

3. License to exploit wind power for a given number of years, and – in the case of wind farms of more than 25 MW – an approval for electricity production. (given that the project comply with conditions stated in the license).

There are noise and spacing rules that need to be followed as well as an EIA (Environment Impact Assessment has to be carried out that includes visual impact, noise, shadow, the effects of lighting, impacts on nature, etc. Local municipalities should seek to limit these nuisances. Moreover, the process includes public hearings as part of the process to obtain a license.

Danish aquaculture is strictly regulated by national, international and regional environmental, planning and nature rules and directives. Despite of this, the Danish government has a very ambitious plan for expansion in aquaculture, including a 3-4 doubling in the sea aquaculture. Before establishing or extending a fish farm in Denmark an EIA (Environment Impact Assessment), HIA (Habitat Impact Assessments), eventual a permission for water use and a permission for placement in land or sea must be obtained. Quite a lot of information is required for getting a premising to start a sea aquaculture farm in Denmark. The process will include several public hearings, and experience is that the process takes more than one year.

5.3.2 Institutional/administrative obstacles

Multi Use platforms are a new area in Danish planning. But due to the implementation of the Water Framework Directive and Marine Strategy Directive, Denmark has just started to look at spatial planning of the sea areas with a focus on the different interest and stakeholders. So presently there is no policy about Multi Use Platforms. There is no common framework to discuss and assess the risks associated with third-party access. This increases uncertainty. It also explains recurring discussions on the insurance of MUOPs. There are inconsistencies between offshore renewable energy plans and existing Marine Spatial Planning (MSP) instruments.

5.3.3 Societal objections

Aquaculture has great opportunities in remote areas in Denmark in terms of growth and jobs. However, there is some opposition to aquaculture from NGO’s especially about emission of nutrients and interaction with habitats and species. Primary focus areas from the NGO’s are the discharge of nutrients and the use of antifouling to the nets.

5.4 Stakeholder views and their influence on the draft design

The Baltic site is special being so far in the planning process for establishment of the 600 MW offshore wind farm. Thus several baseline studies, feasibility studies, business cases and EIA´s have been conducted or are planned to be conducted. Part of the planning includes a well-defined process of public hearings were stakeholders at all levels have the opportunity interfere.

Public hearings will take place in two phases.

1. An idea phase of 4-8 weeks, which will be held prior to the development of an EIA. During this phase stakeholders can contribute ideas and suggestions to the project and the coming EIA investigations.
2. Public hearing phase of 8 weeks on finalization of the EIA. During this phase there will be held public meetings, where authorities, non-governmental organizations and private citizens can participate in the hearing process.
3.

Presently an EIA is being finalised for the grid connection and a public hearing is planned to take place in 2015. Based on the technical concept description of the wind farm an EIA will be conducted in the near future and public hearings will also take place as part of the process. If a future fish farm is included as part of the MUP, this will also be subject for an EIA and a public hearing process prior to an permit can be issued.

Being so long in the planning process the developed tool for designing the multiuse platform at the Baltic site was used as a guidance paper for discussion for combining the planned windfarm with additional commercial activities. The discussions took place at meetings were 16 stakeholders were present, representing 7 organizations involved in the MERMAID project. The outcome of the stakeholder discussion are shortly summarized in the following.

Technical feasibility

The technical feasibility of the MUPs is analysed within the different work packages of the MERMAID project. At Kriegers Flak, it is suggested to focus on a combination of gravity or jacket based wind turbines and offshore aquaculture. These commercial activities both build on well proven technical solutions.

An issue raised is that when a wind farm and fish farm are combined, more ships will enter the area, which means more traffic and higher risks of accidents for the people and technology involved.
In order to reduce the risks, the MUP should be clearly marked out and will be armed with technical monitoring equipment. Also a risk assessment is needed. Possibly two shipping routes that pass Kriegers Flak need to be changed, for instance the Ferry to Travemunde. Second, when fish cages are located between the wind turbines this means that transportation is more restricted. Good guidelines and rules need to be endorsed to ensure safety of the people, the vessels, the cages and wind turbines involved.

Environmental impacts

No specific considerations were made on the environmental impacts. However, some environmental considerations were discussed. It was concluded that the MUP needs to have the following characteristics for environmental reasons:

- Located on the path for deep water renewal of the Baltic
- Located on the main path for nutrient transport out of the Baltic

Environmental aspect is an integral part of the planning and construction phase and will be conducted.

Financial and economic impacts

The financial and economic impacts for establishing a MUP at the Baltic site are assessed for offshore wind energy. The inclusion of commercial fishfarming will be conducted as part of WP8.

Socio-economic impacts

A MUP will affect the landscape to a greater or lesser extent. In the view of the participants there should not be any effect on views from shore. However, this will depend on the final design, but it is anticipated that the wind turbines will be below the horizon since the farm is located are located around 30 km off shore. Depending on the weather conditions, the farm will seldom be clearly visible from the coast.

Perceptions of the public and the image of wind turbines and fish farms are variable. Fish farms and aquaculture at sea are less accepted by the audience then wind farms. However, public images can change. There is a debate that argues that aquaculture is not polluting and produces healthy food in an environmentally very efficient and correct way.

Conclusion and recommendations

It was concluded that the Kriegers Flak is suitable for multi-use. The general picture is that wind energy in combination with aquaculture is considered to be the most viable option, generating the highest benefits.

Recommendations made during the experts meetings included the following issues:

- It will be more practical and economically efficient to divide the area in the sea and separate some of the physical installations, for example the cages and wind turbines, and then combine others, such as feeding stations and the maintenance ships.
- Potential risk analysis for damage of equipment and people due increased activities in the area must be assessed.
- Good guidelines and rules need to be endorsed to ensure the safety for the people, the vessels, the cages and the wind turbines involved.
- In establishing the MUP it should be done with respect to the best combination of production and nature values and decrease the negative impacts on the ecosystem.
- The possible ecological gains from an MUP should be investigated e.g. the benefit from artificial reefs from turbine foundation and scour protection.
- The disturbance of artificial reefs from fishfarming shall be avoided through placing the cages at distance from the turbines.
- To reduce costs it is recommended to use the same ships for transport and maintenance. Fish farms have big vessels for feed and these can possibly be used by the energy businesses as well. Another option is to build a platform where both crewmembers can work and the feeding of the fish can be done.
- To build trust between the parties involved concerning the financial aspects of building a MUP there must be developed clear agreements of roles and contracts on logistics and risks.
- It was recommended that clear procedures for stakeholder involvement among the countries involved are developed in form of a cross-boundary Marine Spatial Plan that includes the zoning of Kriegers Flak for different multi-use purposes.

- It is an obstacle for the fish farm companies on how to get the right permits for the economic exploitation of the sea. It is recommended to develop new guidelines for the administration of the sea territory within relevant authorities
- Developing a MUP can create social acceptance but also opposition for developing more intensive economic activities at sea and therefore all relevant parties should be involved in the process. Thus, a broad range of stakeholder should be involved in the process of establishing a possible future MUP.

Chapter 6 North Sea Site

6.1 North Sea Site Conditions

The MUOP case study is located in the sub-area of the Wadden Sea (see figure 12). The Wadden Sea is the area stretched to the north coasts of the Netherlands, Germany and Denmark. The three countries have signed in 1982 a trilateral cooperation based on the "Joint Declaration on the Protection of the Wadden –Sea".[5] The Dutch and the German part of the Wadden Sea, about 66% of the total Wadden Sea area, were inscribed in the UNESCO's World Heritage List, in 2009.[6] The exact location of the MUOP is in the North of the Netherlands, north of the Wadden Sea, above the Wadden Sea Islands, in an already licensed site to develop offshore wind farm, named Gemini. The Dutch MERMAID partners have "unanimously decided" that this is the most appropriate area as a study case under MERMAID (D 7.1, 2013), specifically because at the start of the MERMAID project construction of the wind farm was expected to start during the course of the MERMAID project. This would enhance the ability to interact with the wind farm developer in terms of getting site data and feedback during the MUOP design process. It is located at one of the best offshore wind locations in the Netherlands with average wind speeds of 10 m/s (confirmed by, amongst others, Garrad Hassan). A geophysical study by Fugro confirmed excellent soil conditions in the area. There is an on shore grid connection owned by Tennet in Eemshaven close to land fall. The Gemini is permitted only to single use activities.In The Netherlands no permits of multi use have been granted so far. Nevertheless, the MERMAID project is also developing multi-use designs because stakeholders have shown their interested (D 7.1, 2013). The offshore wind park "Gemini", which is about to be constructed and be fully operational by 2017, is of 600MW total capacity[7] powering more than 650,000 Dutch households per annum which equals a reduction in emissions of 1,250,000 Ton CO_2. The MERMAID project will also include uses and activities like wave energy convertors, electricity connection, aquaculture, especially fish farming (Bluefin Tuna), mussels and seaweed farming, and aquaculture transport (D 2.1, 2012 and D 7.1, 2013). In particular, the Project Gemini consists of 2 X 300 MW permitted offshore wind farms in the Netherlands. This implies an estimated annual production for 600MW: 2,300 GWh. On the other hand, Buitengaats (300MW)

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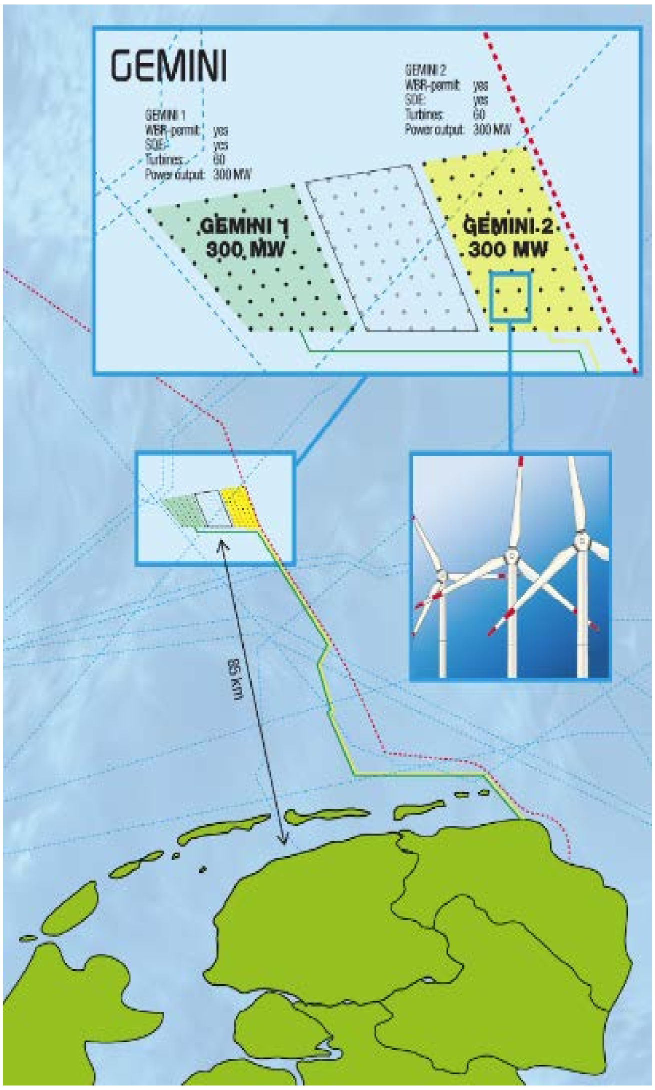
[5] http://www.waddensea-secretariat.org
[6] http://whc.unesco.org
[7] http://www.4coffshore.com

and ZeeEnergie (300MW) have both an approved permit (“Wet beheer rijkswaterstaatswerken”) and a feed-in tariff (“SDE”) granted by the Dutch government. The awarded SDE totals a maximum subsidy of €4.4 billion. This means a guaranteed income over a period of 15 years. The Project Gemini’s revenues consists of a combination of (1) the Wholesale electricity sales under the Public-Private Association (PPA), plus (2) the subsidy income, together resulting in an annual fixed revenue stream. Project Gemini will most likely be the only large Dutch offshore wind project in the northern Dutch offshore waters. Subsequent years will focus on the developement of offshore wind farms close to the boarder of Belgium continental flat. The search is called Borssele Offshore Wind Farm Zone.

Figure 12. Gemini Project



6.2 Platform design and planning

6.2.1 Design concept

A design concept was produced and has the following features:

a. Location: The designed platform will be located in the Gemini offshore wind farm in an area of 2x34km^2. The turbine spacing is 750m. For maintenance purposes access to open space is necessary around the turbines (200m). This results in 55% area available for other use. Thus, the total available area for use is: 0,55x2x34km^2 + 34km^2 = 71,4km^2. On the other hand, the area of substrate for seaweed within the available space is 30% for the seaweed system is: 0,3*71,4km^2: 24,4km^2

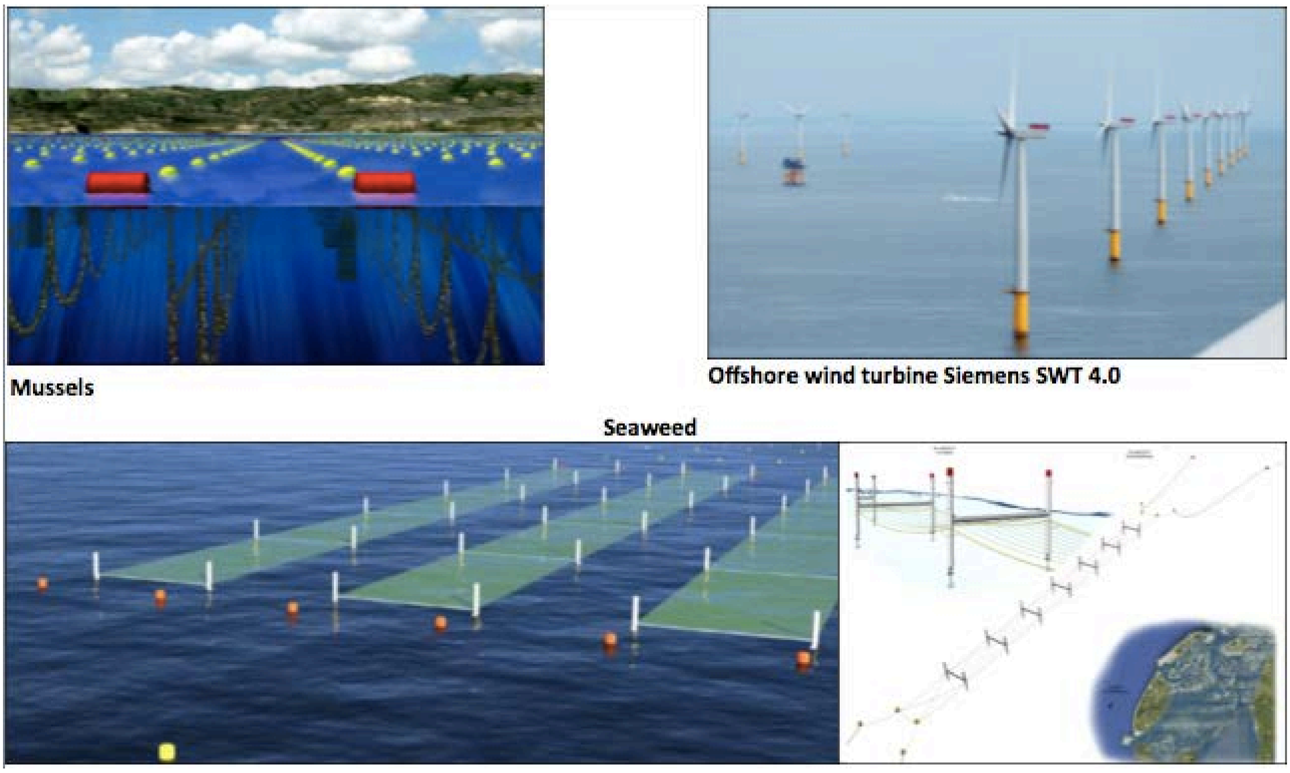
b. The following user functions and production capacity per year were estimated:
   - Wind energy: 600 MW (2,300 GWh)
   - Shellfish mussels: 3kg WW/m^2 (16,8 kton)
   - Seaweed: 5kg WW/m^2 (320 kton)

c. Possible synergies have been identified in the following items:
   - Logistics
   - O&M costs
   - Wave attenuation = optimise design
   - Reduce damage and costs (fatigue)
   - Improve longevity of material
   - Less waves inside the OWF, enhances O&M
   - Mussel cultivation cleans seawater
   - Mussel cultivation may reduce ongrowth on other structures within IMTA

6.2.2 Layout of the platform

Figure 13 presents the proposed platform. It will contain offshore wind turbines, mussel and seaweed production. It will also include an offshore hotel and support center.

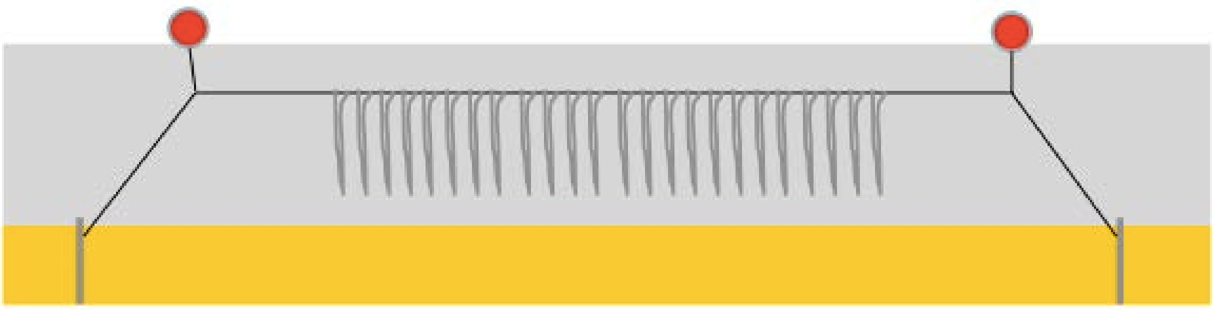
Figure 13 Design of the 3 Individual Functions



Mussel cultivation

For mussel cultivation, the layout designed and its specifications are presented in Figure 14:

Figure 14 Mussel cultivation specifications

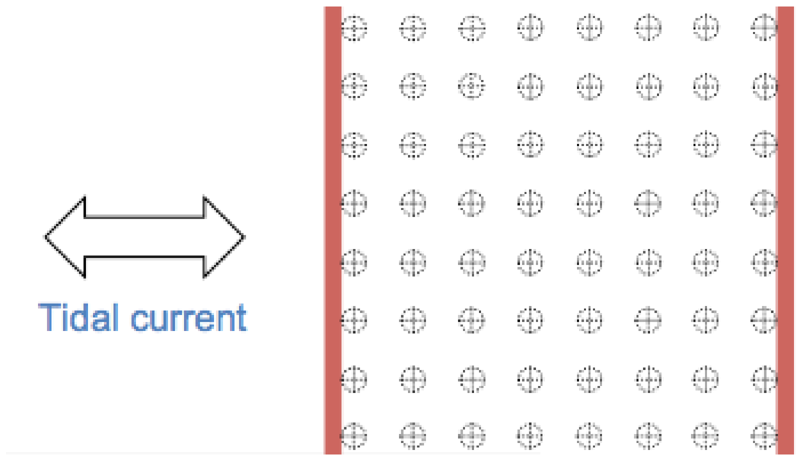


- Longline, 120m, structure on a depth of 3 meter
- Kept under tension by buoys at the ends
- Longline spacing 20m
- Droplines for mussel cultivation

- Yield 4 kg/m dropline
- 35 tpa per ha = 3,5 kg/m^2

It is considered that mussel cultivation cleans seawater. At the same time, mussel cultivation may reduce ongrowth on other structures within IMTA.

Figure 15 Position of Mussel Cultivation



- On the outside of the turbine matrix it is perpendicular to the major (tidal) current
- Mussel area 4 x 8km x 150m = 4800000 m^2
- Mussel production = 16800 ton/yr
- Approx 33% Dutch capacity

In terms of Seaweed Cultivation, the following species were considered:

-L. digitata, very flexible, leaf tears easily in broad or small strokes, dependent on their exposure. This specie can cope with heavy wave forces, but also fully moves along with the waves. Therefore all forces are being avoided due to the flexibility of the plant. And only limited force is being transferred to the holdfast (A holdfast is a root-like structure that anchors seaweed to the substrate).

-L. hyperborea, flexible, with a thick rigid stem. And goes a bit deeper in the water and therefore has more interaction with the flow compared to L. dig. The Specie can eventually also be cultivated on an artificial string. It is expected that this kind could results in most wave attenuation. Grows slowly.

-Saccharina: long leaf, grows naturally outside the zone where waves are active, but can handle flow (currents). As long as the plants are not to large they can be cultivated in areas with waves ~

1-2 m. It is expected that if the waves are more severe problems will occur with the attachment of the holdfast. If the thallus becomes larger in combination with heavy wave forces this will tear off. They have less capability to adjust to more heavy circumstances and therefore they could have a larger effect on wave attenuation (when considering relative small waves).

All **3 species could be used together**, but they should be cultivated **in a row**: A front with L. dig, then L. hyp and behind a large field of Sacch. We could also apply this **vertically**: Upper 1 meter L. dig, below the L. hyp and underneath 3-4 m Sacch.

Offshore hotel and support center

This will contain Accommodation for more then 100 persons would be needed mainly for the shellfish farm, safe storage of small vessels needed; boat elevator under platform. There are important synergy possibilities, reduction of costs for wind and seaweed.

Figure 16 Offshore Hotel and Support Centre

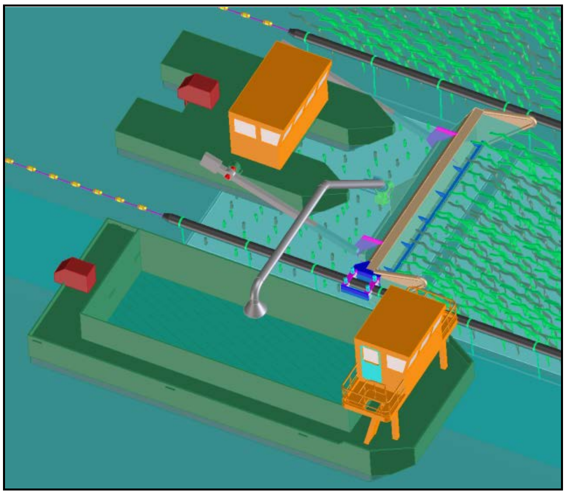
220-crew accommodation platform from Keppel Corporation, contracted price: 82 M$(US)

Basic seaweed farm

It has the following characteristics:

- The substrate should stay offshore during 5 to 10 years
- The preparation and seeding of the substrate is assumed to be done by a service vessel that could navigate over the substrate
- Harvest is done by a similar vessel (see figure)
- Harvested seaweed is removed by small barges navigating over the fields and brought to a transport vessel and/or storage

Figure 17 Seaweed farm



6.3 Current policy, management and planning strategy

Once the situation and perspectives of the relevant actors was investigated, the following conclusions were drawn, based on the review of (scientific) publications and government documents:

1. The Dutch marine spatial policy stresses two main principles: (1) the need for **space-efficient use**, such as multiple use of offshore platforms (e.g. offshore wind farms), and (2) the need to follow an **ecosystem approach**.
2. The wind energy sector committed itself to a substantial **cost reduction** of 40% of the total costs per MWh (cf. section 3.2.1). To achieve this, every discipline involved in offshore energy production is kept under constant review.
3. The Dutch mussel sector sees market opportunities for a total yearly production of 100,000 tons of mussels; this is almost twice as much as the current production and can only be achieved if new areas for **mussel production** become available.
4. There are opportunities to achieve the different objectives of all actors (the government, the wind sector, and the mussel sector) by combining **offshore wind energy** production with **offshore aquaculture**.

Potential barriers in the implementation of the project can be identified in policy terms, in the institutional framework and in stakeholders' behavior against the MUOP (D 2.1):

6.2.1 Policy obstacles

In Dutch policies, multi-use platforms are mentioned as a promising way to make the most out of scarce available space (Beleidsnota Noordzee 2009-2015). However, in practice there is no demand for multi-use platforms since there are no companies willing to construct them. Energy companies have and will build various offshore wind parks but an offshore aquaculture sector is absent. Consequently, policy-makers and regulators have not been challenged to handle request for permits and a regulatory framework for MUOPs is missing. Also, in the spatial plans for the North Sea, there is no area designated for aquaculture. Current practice for offshore wind parks is to forbid other vessels to enter the designated parks, thereby avoiding question on risks and responsibilities. A major obstacle to the development of MUOPs is that the new renewable energy subsidy program no longer includes offshore wind developments.

6.2.2 Institutional and administrative obstacles

Although policy-makers recognize the potential of MUOPs, current practice of regulators is to forbid third-party access to the offshore wind parks. Differing insights can be an obstacle to further development. There is no common framework to discuss and assess the risks associated with third-party access. This increases uncertainty and also explains recurring discussions on the insurance of MUOPs.

6.2.3 Societal objections

Results for the first interviews reveal a lack of trust between offshore wind sector and the fishery community. Fishermen fear reduction in the area available for fishing and object to offshore wind park development. The energy sector fears that it is difficult to come to agreements with the fishing communities, believing that they often do not adhere to rules and regulations. NGO’s are exploring the feasibility of MUOPs. Up to now, they are interested in the potential of realizing ecological valuable zones within the wind parks. Some scientists feed this discussion, arguing that high ecological values can be realized within the wind parks.

6.2.4 Social perceptions and constraints

It was concluded that the Gemini Park might not be as suitable for multi-use as was expected. **Location for aquaculture is not ideal**. When starting multi-use, it is important that the location is suitable for other user functions as well. It must be further study whether the Gemini location is suitable for other functions. It was concluded that the best way to start multi-use at sea was to look at the different **business models** of the different user functions and see where they overlap. The location where overlap occurs might be the best suited location for multi-use. This is a new way of looking at multi-use instead of trying hard to add activities/new functions to already existing activities/platforms. Wever et al. (2015) (see table below) summarize potentials and constraints of the combination of offshore wind and aquaculture production, based on interaction with stakeholders.

Table 6 Work Group Results: Potentials and Constraints of Marine Aquaculture - offshore wind energy co-use as perceived by stakeholders

	Potentials	Constraints
Theme 1 **Biology and ecology**	• Favourable hydrographic conditions (water quality, strong water exchange) • Lesser environmental impacts than nearshore aquaculture • Seasonal models with alternating species depending on seasonal or life-cycle requirements and environmental conditions (e.g. warm water species in summer and cold water species in winter; or cultivation only in summer)	• Harsh environmental conditions: high temperature variation, strong currents – habitable for only very limited number of species, low growth rate, higher risk of infection • Interactions between caged fish and wild fish • Potential impacts on marine environment (nutrient input, noise impacts) • Fouling
Theme 2 **Socio-economics & legal frameworks**	• Additional income for the region • Well developed legal framework for offshore wind energy facilities – need to adapt/extend framework to marine aquaculture requirements • Additional "selling point" for offshore wind operators when applying for permit→improving acceptance of the public and the permit granting agency	• Conflicting views on favourable uses or non-uses • High investment cost, therefore not attractive for individual fishermen; possibly only marginal income effects • Very limited know-how of aquaculture farming in Germany • Legal uncertainties with respect to e.g. property rights in the EEZ, legal definitions versus customary use of terms such as "offshore", "harmful effects", applicability of laws and regulations in the EEZ • Uncertainty with respect to liability and insurance issues and legal tenure arrangements
Theme 3 **Economic viability & operation**	• Cost reduction potential by co-use of infrastructure (shared maintenance costs) • Target premium segment, high-quality, organic production • Identify selling points (e.g. high quality, organic certification, local production) • Develop technological leadership, pioneering spirit – open up export markets • Mussel and seaweed cultivation more promising in terms of economic return than fish cultivation • Bio-engineering, bio-extraction of mussel and macro algae products and by-products	• High risk/uncertainty with respect to price developments • High costs of investment • Range of species very limited due to biological requirements
Theme 4 **Technology & design**	• Reduced costs for maintenance and cleaning works (sharing of fixed costs e.g. for vessels) • Tension leg systems for detached systems • Development of novel technical solutions for potential export	• Higher cost in development & application process • Safety concerns for workers • Smoothness of operations of wind energy facility possibly impaired • Uncertainty with respect to stability/robustness of tripile when cage is attached (do tripiles have to be reinforced to withstand tractive forces of aquaculture cage? At what addition costs?)

Source: Wever et al. (2015)

6.5 Stakeholder views and their influence on the draft design

How did you take into account the stakeholder views in your choice for the draft design (process)?

- a participatory design process was developed that focuses on involving all relevant stakeholders in the design process

We contacted and invited all relevant types of stakeholders (i.e. from all relevant sectors) to both, the first (interview) and the second step (round table) of the MERMAID participatory design approach. In the first step, x stakeholders were interviewed. The second step, i.e., the round table meeting, 9 out of 26 invited stakeholders attended. It should be noted that stakeholders from the mussel sector and the construction companies did not respond to our invitation for the round table and were therefore absent.

What recommendations of the stakeholders did you specifically address and how (technical, environmental, financial, socio-economic)?

In the following, we summarize the main input and comments that we received from stakeholders and how we have taken up these comments or why we have not.

Technical aspects:

- According to stakeholders' suggestions, fish culture is excluded from any MUOP design in this Dutch part of North Sea, because of the relatively shallow water depth in combination with a too high water temperature during the summer. Some stakeholders noted, though, that it might be possible in the near future to include fish aquaculture, if a different type of fish species can be found that can be cultivated in these conditions.
- Several stakeholders suggested that the Gemini location has limited potential for wave- and tidal energy converters. Hence, these types were excluded.
- Aquaculture support structure attached to the OWT is feasible from a construction point of view. However, to leave significant space around the offshore wind turbines and cables for O&M, the design takes into account a safety zone with a diameter of 100 m around each wind turbine. Because of this, it was decided to integrate aquaculture installations inside the wind farm, i.e. between the wind turbines, in the design instead of just installing the aquaculture just outside the farm.
- For successful aquaculture, nutrient rich and clear water is required. As a result, we carried out a technical study on the feasibility of aquaculture at this offshore site. According to our initial study, nutrient concentrations should be just high enough to enable offshore aquaculture at the Gemini site (Deltares 2014). The final design takes into account that nutrient concentrations might be around the lower limit for aquaculture. There was no decision on whether to go for mussel or see weed farming. Therefore, mussel culture is included in the design only at the outer edges of the wind farms (i.e. 4 lines of mussel culture), whereas seaweed culture is integrated between the wind turbines and in the area in between the two Gemini sites. Moreover, a combination of seaweed and mussel culture represents an IMTA.

Financial aspects:

- The North Sea has a good potential for growing seaweed: enough space and sufficient nutrients. Moreover, there is a demand for - specifically wet – seaweed, which cannot be imported from outside Europe. Therefore it is included in the design.
- There is a demand for an increase of yearly mussel production. Currently, the production of mussels is declining, however the demand is increasing. The Dutch mussel sector sees market opportunities for a total yearly production of 100,000 tons of mussels; this is almost twice as much as the currently declining production and can only be achieved if new areas for mussel production become available (Lagerveld et al. 2014).

Environmental aspects:

- An environmental impact assessment must take place to see potential effects on the environment. Based on experiences from existing wind parks and aquaculture, non-major negative impacts on the environment are expected. Therefore, it was decided to finalize a MUOP concept for the Gemini location.

Socio-economic aspects:

- No comments on social, and therefore no influence on the final design.

Chapter 7 Mediterranean Site

7.1 Mediterranean Sea Site Conditions

The selected site for the MUP is close to the Acqua Alta monitoring platform (Coordinates: latitude: 45°18’51’’ North; longitude: 12°30’30’’ East), due to the number of available met-ocean and physical information. The Acqua Alta (location and monitoring tower in Figure 18) is a research platform held by the Italian National Research Centre[8] and it is located 16 km off the coastline of Venice, on 16 m of depth.

Figure 18 CNR Acqua Alta - Venice

The climate of this offshore area is mild, which limits the marine renewable energy harvesting but on the other hand it makes perfect conditions for safe operations (D 7.1, 2013).

[8] http://www.ismar.cnr.it/infrastructures/piattaforma-acqua-alta?set_language=en&cl=en

The aquaculture practice is well developed near-shore but the high anthropogenic pressure in the area induced by maritime routes and economic activities suggests to explore the potential of an off-shore installation even if the sea temperature and physical conditions are not as favourable as in other areas of the Mediterranean.

The MUOP concept is therefore based on the idea to integrate renewable energy production and aquaculture, which would be both not feasible for single purpose installations. Marine renewable energy may include both wind and waves. Wave energy converters (WECs) selected for this area can be either floating devices (DEXA) or fixed system on piles (WaveStar) with floaters (D7.1, 2013).

As for wind, large wind mono-pile turbines can be installed wither with fixed or floating WECs while small and mini-wind can be considered in combination in combination with the WaveStar only, and cables and sea cages for fish farming.

Exploiting more than one uses of the platform we benefit more from the installation. The purpose of these pages is to identify at least two alternative platform designs to be analysed in detail and to be compared, as required by the Document of Work of the MERMAID project. Note that we will look for the best design options “to be analysed and compared” as opposed “to be implemented”.

This choice depends on objective (direct and indirect) factors (see section 2 for environmental issues, section 3 for social issues, section 4 for economic issues, section 5 for financial issues), on subjective preferences (see section 6.1 for preferences by stakeholders and section 6.2 for preferences by experts) related to possible detrimental or beneficial impacts, and on institutional constraints (e.g. permits for producing mussels in section 7.1) and technical constraints (e.g. unfeasible combination of micro-wind and floating wave in section 7.2).

7.2 The MUP concepts

Based on the analysis carried out within D7.1 the MUP conceptual design includes

- extraction of power from waves, either through a fixed or a floating installation adopting WaveStar or Dexa devices respectively; the annual wave energy production is rather limited due to the mild climate and limited device efficiency, and therefore a minimum marine space of 1 km^2 is required;
- extraction of power from wind; since the available annual resources is very limited, this function will be designed only in combination with the wave farm,

  - by means of micro-wind systems placed on top of the fixed WaveStar arms and/or of large wind turbines on top of the piles supporting the WaveStar installation;
  - by placing few large turbines at the boundaries of the Dexa floating farm;
- fish farming, through the development of a combined design with the wave farm installation in order to optimize the use of the cables and of the moorings;
- energy transfer to shore and standing-alone solutions; the latter is particularly promising due to the relatively high distance from shore if the energy is essentially used for the needs of the fish, wind and wave farms and the remaining energy is locally stored.

7.3 Environmental issues

A preliminary environmental impact assessment (EIA) shows non-significant effects from nutrients used in fish farming (at least outside the 500 m clear zone around wave or wind farms), due to the distance from the coast and the prevailing currents. Indeed, most nutrients will sediment on the sea bottom. However, the platform will be designed to be as green as possible, by reducing structural impacts with appropriate algae, by mitigating nitrification with sea weed, by espousing an eco-system service approach (i.e. intermediate services such as primary production, nutrient cycling, food chain dynamics and final services such as biodiversity conservation, GHG regulation, commercial fish harvest) in considering 4 main environmental functions (i.e. provisioning, cultural, regulating, supporting) at regional rather than at local level. In other words, we will evaluate and optimise the changes in ecosystem services (i.e. maximising benefits and minimising detriments) rather than minimising environmental impacts (under the assumption that the status quo is the best condition). For example, an increase in biodiversity is not estimated by the large number of species at local level, but by the homogeneity of species at regional level (Adriatic Sea) or at least by the small increase in invasive species and the large persistence of native species at local level. Meaning that if the sea use is optimised then no mitigation is needed. Note that due to continuous technological improvements, and consequently the short time horizon (say, 25 years) to be adopted, environmental issues might be linked to construction and decommission periods to a greater extent than to the operation period. Thus, environmental issues do *not* exclude any option, while moulding all options.

7.4 Social issues

A preliminary Input-Output Analysis shows non-significant differences in direct and indirect employment at regional level arising from alternative platforms, at least to justify the discharge or the choice of a specific design: the yearly increase in regional employment on average over 25 years, by considering both construction, operation and decommission periods, is estimated to be around 0.24% and 0.11% for fish farming and energy farming, respectively. Thus, social issues do *not* exclude any option, although they will be crucial in evaluating the chosen and detailed options.

7.5 Economic issues

A preliminary Input-Output Analysis shows non-significant differences in direct and indirect GDP at regional level arising from alternative platforms, at least to justify the discharge or the choice of a specific design: the yearly increase in regional GDP on average over the 25 years, by considering both construction, operation and decommission periods, is estimated to be around 0.03% and 0.02% for fish farming and energy farming, respectively. Thus, economic issues do *not* exclude any option, although they will be crucial in evaluating the chosen and detailed options.

7.6 Financial issues

A preliminary financial analysis shows non-significant differences in internal rate of return (IRR) or pay-back periods (PBP) arising from alternative energy production options (i.e. fixed wave, floating wave, micro wind), at least to justify the discharge or the choice of a specific design: IRR and PBP for fixed and floating wave are estimated to be around 1% and 28 years; IRR and PBP for micro wind are estimated to be around 4% and 21 years. Note that negative results are consistent with DOW, although a possible way out should be identified. Thus, unsatisfactory financial aspects do *not* exclude any energy option, although they will be crucial in evaluating the chosen and detailed options.

However, a detailed analysis of local markets (e.g. all boats belonging to few families based in Chioggia) leads to conclude that a monopolistic market prevails for mussels: this was confirmed by the first round meeting with stakeholders. Consequently, alternative fish productions such as sea bass or sea bream are focused on, as the most suitable in the Northern Adriatic Sea. Indeed, a preliminary financial analysis on the supply side leads to the conclusion that an efficient farm can produce around 2,000 tons of sea bass or sea bream per year at an average cost of around 6 €/kg. Moreover, a preliminary analysis on the demand side shows that 20 kg per capita is the fish consumption observed in Italy in 2011, 80% from abroad, with 4,937,854 people living in Veneto: this means that 2,000 tons of sea bass or sea bream represent around 2% of regional fish consumption (98,757 tons), with an expected selling price higher than the (Greek) price being around at 6.25 €/kg. Finally, a preliminary financial analysis on both demand and supply sides leads to an IRR of 5% and a PBP of 15 years for the required (3 years) total investment (17 Million €): future technological advances are likely to reduce (say, by 25%) fish feeding costs (i.e. around 60% of fish farm costs), with a significant increase in IRR (say, from 5% to 30%) and a significant reduction in PBP (say, from 15 to 10 years). Thus, opening a sea bass or sea bream market could rely on a local demand, by reducing transport costs and avoiding monopolistic conditions prevailing in the local market for mussels, although financial aspects will be crucial in evaluating the detailed option.

However, while the off-shore energy consumption of a fish farm (i.e. around 140 kWh for each fish farm unit), since packaging is performed on land, does not justify a Multi-Use Platform, a lack of knowledge and experience on off-shore fish farming at 20 km from the coast line requires a fish farm to be combined with an energy farm, in order to have fishery cages been protected from extreme events by energy structures. Note that advantages from import substitution will be considered in performing a CBA. Moreover, a change in consumption pattern (from meat to fish) could imply an environmental benefit. Finally, normal conditions are analysed for financial analysis, while extreme conditions will be considered for risk analysis.

7.7 Preferences

The use of the assessment tool during the second meeting with experts and stakeholders, held in Venice on the 14th January 2014, allowed us to include the preferences by experts and stakeholders in the selection process of designs to be detailed and compared. In particular, we recorded information on qualitative (0/1) and quantitative (0/5) assessments, on weighted (stakeholders) and un-weighted (experts) assessments, on 50% and 66% majority rules, and on agree and non-disagree voting rules. Moreover, we interviewed 7 experts (2 in engineering, ecology, economics, fishery, climatology and energy) and 6 stakeholders (CNR, Region, Municipality, environment and energy consultants and naval league), by scrutinizing all feasible single uses (i.e. micro vs. macro wind, fixed vs. floating wave, fish farming). Finally, we elaborated answers for 3 economic, 2 social, 3 environmental assessment questions as well as for 2 economic, 3 social, 2 environmental risks, distinguished in turn into 6 beneficial and 9 detrimental features.

Note that we did not elicit relative weights for technical issues during the first meeting with experts and stakeholders, held in Venice on the 13th December 2013, so we allocated technical features among economic, social and environmental features. Moreover, in order to increase the number of comparisons, we introduced 5 and 0 in quantitative assessments, in case of 1 and 0 in qualitative assessments and vice versa, since many stakeholders autonomously did. Finally, social impacts mainly refer to today issues, while environmental impacts mainly refer to future issues: in other words, some social issues actually are current environmental impacts, while some environmental impacts actually are future social impacts.

The following sections will summarise insights about stakeholders' and experts' preferences, respectively, where the following analytical approaches will be implemented:

- A weighted majority is preferred to an un-weighted majority, because many irrelevant detrimental features cannot lead to disregard some design options
- Weighted majorities are preferred to weighted scores, because high scores in one feature cannot compensate low scores in other features
- A quantitative approach is preferred to a qualitative approach, because the former was adopted by most stakeholders and experts
- Agree voting rules are preferred to non-disagree voting rules, because the latter could be due to lack of information

Note that we did not ask stakeholders or experts how to use their knowledge and opinions, in order to independently check for robustness of decision or majority rules as well as for lack of information about each single issue.

7.7.1 Stakeholder Views

By considering only quantitative 50% majorities, a preference for MacWin (0.24) over FloWav (0.23) over FisFar (0.00) is obtained. However, legal issues for implementing a FixWav and a MacWin platform should be emphasised, together with expected undesirable social impacts from MacWin.

Table 7. Assessments by stakeholders.

	MIicWin	MIicWin	FixWav	FixWav	MacWin	MacWin	FloWav	FloWav	FisFar	FisFar
	0/1	0/5	0/1	0/5	0/1	0/5	0/1	0/5	0/1	0/5
Is placement possible in legal terms? +	0	1	0	**0**	0	**0**	0	1	0	1

Is placement possible in technical terms? +	0	1	0	1	0	1	0	1	0	1
Any revenues consistent with costs (capital, O&M, administration costs)? +	0	0	0	0	0	0	0	0	0	0
Any expected undesirable environmental impacts? -	0	0	0	0	0	0	0	0	1	0
Any expected undesirable social impacts? -	0	0	0	0	0	**1**	0	0	0	0
Is there a reasonable definition of project time horizon? +	0	0	0	0	0	0	0	0	0	0
Any possibilities of combined use? +	0	0	0	0	0	0	0	0	0	0
Any possibility for technological upgrades? +	0	0	1	0	0	0	0	0	0	0
OTHER DETERMINANTS										
Uncertainty about reliability of technique? -	0	1	0	0	0	0	0	0	0	0
Uncertainty about estimates of costs and revenues -	0	1	0	1	0	1	1	1	0	1
Uncertainty about estimates of environmental impacts? -	0	0	0	0	0	1	0	1	0	1
Uncertainty about estimates of social impacts? -	0	0	0	0	0	1	0	0	0	0
Any correlated risks between functions? -	0	0	0	0	0	1	0	0	0	0
Political uncertainty -	0	1	0	0	0	1	0	1	0	1
Unclear definition of property rights -	0	0	0	0	0	0	0	0	0	0
OTHER RISKS										
Unweighted majority	0.00	0.00	0.17	0.06	0.00	-0.50	-0.11	0.00	-0.11	0.00
Weighted majority	0.00	0.21	0.05	0.08	0.00	0.24	0.03	0.23	0.05	0.23
Unweighted scores (% maximum score)	0.39	-0.04	0.33	0.00	-0.44	-0.35	0.11	0.02	-0.28	-0.10
Weighted scores (% maximum score)	0.12	-0.04	0.11	0.00	-0.17	-0.36	0.08	0.02	-0.08	-0.09

Note that none of the stakeholders are MERMAID project partners and, consequently, only institutional and NGO stakeholders participated to the second meeting, also because the first meeting highlighted the lack of private or public investment in the short-run as well as the presence of technological and institutional uncertainty in the mid and long-term. Consequently, the large concern for social and environmental issues is not surprising.

7.7.2 Experts

By considering only quantitative 50% majorities, a preference for MicWin (0.27) over FixWav (0.25) over FisFar (0.10) is obtained. However, the absence of detrimental environmental impacts from MicWin with no uncertainty should be emphasised, together with expected undesirable environmental impacts from FisFar with no uncertainty, and the lack of potentials in combined uses for FloWaw.

Table 8. Assessments by experts.

	MIicWin	MIicWin	FixWav	FixWav	MacWin	MacWin	FloWav	FloWav	FisFar	FisFar
	0/1	0/5	0/1	0/5	0/1	0/5	0/1	0/5	0/1	0/5
Is placement possible in legal terms? +	1	1	1	0	1	0	1	0	1	0
Is placement possible in technical terms? +	1	1	1	1	1	0	1	1	1	0
Any revenues consistent with costs (capital, O&M, administration costs)? +	0	0	0	0	0	0	0	0	0	0
Any expected undesirable environmental impacts? -	1	**0**	1	1	1	1	1	1	1	**1**
Any expected undesirable social impacts? -	0	0	0	0	0	0	0	0	0	0
Is there a reasonable definition of project time horizon? +	1	1	0	0	1	1	0	0	1	0
Any possibilities of combined use? +	1	1	1	1	1	1	1	**0**	1	1
Any possibility for technological upgrades? +	1	0	1	0	1	0	1	0	1	0
OTHER DETERMINANTS										
Uncertainty about reliability of technique? -	0	0	0	0	0	0	1	0	0	0
Uncertainty about estimates of costs and revenues -	1	1	1	1	1	1	1	1	1	0
Uncertainty about estimates of environmental impacts? -	1	**0**	1	1	1	1	1	1	1	**0**
Uncertainty about estimates of social impacts? -	0	0	1	0	1	0	1	0	1	0
Any correlated risks between functions? -	0	0	0	0	0	0	0	0	0	0
Political uncertainty -	1	0	1	1	1	0	1	1	0	0
Unclear definition of property rights -	0	0	0	0	0	0	0	0	0	0
OTHER RISKS										
Unweighted majority	0.39	0.56	0.11	-0.11	0.28	0.00	0.00	-0.28	0.39	0.06
Weighted majority	0.45	0.27	0.40	0.25	0.48	0.25	0.44	0.21	0.45	0.10
Unweighted scores	2.13	0.59	0.67	0.19	0.94	0.17	0.24	0.03	1.18	0.47
Weighted scores	0.69	0.60	0.14	0.13	0.29	0.16	0.04	0.01	0.35	0.44

7.8 Constraints

The following sections will briefly discuss the main institutional and technical constraints, respectively, to be faced in implementing a potential MUOP.

7.8.1. Institutional

Within the European framework (in particular, about social and environmental issues) and the National framework (in particular, about incentives and subsidies), the Legislative Decree No. 112 of 1998 on Regional responsibility for maritime State property (Conferimento di funzioni e compiti amministrativi dello Stato alle regioni ed agli enti locali) transfers to peripheral regional agencies all functions related to maritime State property (i.e. within 12 Maritime Miles). The Italian off-shore case study is nearby the CNR platform in the Adriatic Sea in front of Venice, within 12 Maritime Miles: we will refer to legislation of the Veneto Region, where the Regional Law No.11 of 2001 implements the Legislative Decree No.112 del 1998, and the Deliberation of the Regional Government (Giunta Regionale del Veneto) No. 454 of 2002 on Responsibilities assigned to central and peripheral regional agencies about the maritime State property (Definizioni dei compiti assegnati alle strutture regionali centrali e periferiche nel settore del demanio marittimo) specifies to refer to peripheral offices of Genio Civile for concession demands for using the maritime State property.

Concessions for fishery

As for types, Legislative Decree No.154 of 2004, Art. 12 (7) on Modernization of the fisheries and aquaculture sectors (Modernizzazione del settore pesca e acquacoltura – Misure di conservazione e gestione delle risorse ittiche) states that "As for marine aquaculture carried out in coastal areas with essential ecological relevance for the conservation of biodiversity and of biological resources, with impacts on the maritime fishery such as ponds, lagoons, marshes (Comacchio, Delta del Po, Venice lagoon, Marano lagoon and Grado lagoon), peculiar dispositions are set up to control for environmental impact and to avoid water pollution".

Next, Legislative Decree No.11954 of 2010, Art. 4 (1) on Production of marine animals and algae by biological aquaculture (Produzione di animali e di alghe marine dell'acquacoltura biologica) states that "… in order to reduce impacts on the sea bed and on rounding sea water, current must be greater than 2 cm/second on average per year and sea depth must be greater than 20 m … These conditions do not apply to shell-culture". Our case study is characterized by a sea depth of 16 m and a current of 30 cm/second.

Thus, as for sites of fish farming, our (multi-purpose) plant should not be develop too close to the Acqua Alta CNR platform, in order to reach a 20 m sea depth. However, Legislative Decree No.154 of 2004, Art. 10 (1) on Modernization of the fisheries and aquaculture sectors (Modernizzazione del settore pesca e acquacoltura – Commissioni consultive locali per la pesca e l'acquacoltura) states that "Regions set up consulting local commissions …".

Next, Legislative Decree No.11954 of 2010, Art. 2 (1) on Production of marine animals and algae by biological aquaculture (Produzione di animali e di alghe marine dell'acquacoltura biologica) states that "Regions are in charge of authorization for aquaculture activities …"

Thus, as for types of fish farming, our (multi-purpose) plant could develop biological and non-biological fishery activities, either algae or sea bass or sea bream, with similar ex-ante and ex-post controls on environmental issues by the peripheral offices of Genio Civile, together with the Consulting Regional Commissions.

Indeed, all types of aquaculture will refer to the same EU legislation (710/2009; 1005/2008; 889/2008; 834/2007), to the same control agencies (i.e. regional authorities for sustainable management) and to the same EU principles implemented by national legislation (Legislative Decree No.11954 of 2010, Art. 1 (1) on Production of marine animals and algae by biological aquaculture; Legislative Decree No. 226 of 2001 on Guidelines and organization of fisheries and aquaculture sectors):

a. Environmental monitoring, with focus on water quality and nutrient discharges, …
b. Protocols for production phases
c. Production capacity
d. Assessment of wild biomass
e. Data on yearly nutrient discharges per production plant
f. Regeneration of marine algae
g. Multi-culture systems
h. Maintenance and repair of technical equipment
i. Waste reduction
j. Document keeping

As regards sizes, the Deliberation of the Regional Government (Giunta Regionale del Veneto) No.412 of 2009 eliminates the maximum increase (10% of the extension of 2600 ha) specified by the Deliberation of the Regional Government No. 1754 of 2008, which increased the maximum increase (3% of the extension of 2600 ha) specified by the Deliberation of the Regional Government No.2948 of 2007 on Integrative dispositions about maritime state property concession release for fish and aquaculture activities (Disposizioni concernenti il rilascio delle concessioni demaniali marittime per attività di pesca e acquacoltura), by introducing ex-ante assessments at macro-system level such as:

- Environmental sustainability of impacts on marine ecosystems, by taking into account the fishery relying on coastal resources
- Optimal location of plants, by considering the alternative uses of the maritime State property (e.g. production activities, infrastructure, services, environmental protection, …) within a planning approach involving the whole coastal areas
- Impacts of increased production on prices, employment and profitability of aquaculture activities

Thus, as for sizes of fish farming, our (multi-purpose) plant should be weakly constrained. Note that the Legislative Decree No. 4 of 2012, Art.7 (1) on Dispositions for reorganization of normative framework on fisheries and aquaculture (Misure per il riassetto della normative in materia di pesca e acquacoltura) introduces fines and temporary suspension up to permanent withdraw of concessions in order to preserve marine biological resources as well as to prevent, discourage and eliminate illegal, undeclared or unregulated fishery.

Funds for fishery

As for incentives, for insurance, within EU Regulation No.1263 of 1999 on the Financial instrument for fisheries guidance, the Legislative Decree No.100 of 2005 on Further provisions for the modernization of the fisheries and aquaculture sectors (Ulteriori disposizioni per la modernizzazione dei settori della pesca e dell'acquacoltura), in order to favor insurance contracts covering structural risks linked to natural events, meteorological conditions and prices fluctuations, states that "up to 80% of insurance premium can be refunded by the State …", by specifying conditions to be met. As for subsidies, for investments, within EU Regulation No.2792 of 1999 on Community structural assistance in the fisheries sector, the Deliberation of the Regional Government (Giunta Regionale del Veneto) No. 3316 of 2007 on Subsidies for fish and aquaculture activities (Interventi nel settore della pesca e dell'acquacoltura, complemento di programmazione regionale cofinanziato dallo SFOP) states that "up to 50% of expenditures can be reimbursed by the Region …", by specifying conditions to be met. We will consider both incentives and subsidies for fish farming in our detailed CBA.

Concessions for energy

As for sizes and sites, the Circular Letter No. 40 of 2012 by the General Direction of the Ministry of Infrastructures and Transports on off-shore plants for energy production from renewable resources

(Razionalizzazione e semplificazione delle procedure autorizzative fonti energetiche rinnovabili), actually focused on wind plants, states that authorisations for construction and operation is issued by the Ministry of Infrastructures and Transports, once consulted the Ministry of Economic Development and the Ministry of the Environment, … provided concessions of the maritime State property use by the peripheral offices of Genio Civile (Law No. 244 of 2007, which modifies the Legislative Decree No.387 of 2003). Thus, as for sizes and sites of energy farming, our (multi-purpose) plant should be weakly constrained.

Funds for energy

As for incentives, Legislative Decree No. 28 of 2011 on Incentives for energy from renewable sources, which implements the Directive No. 28 of 2009 on the Promotion of the use of energy from renewable sources, ensures 0.34 € per kWh for all plants smaller than 5 MW producing energy from marine renewable sources. Note that the unique working plant in Italy is of 50 kW. As for subsidies, there is no national or regional legislation on that. We will consider both incentives and subsidies for energy farming in our detailed CBA.

7.8.2 Technical

The small IRRs and large PBPs obtained from preliminary financial analyses applied to each single use suggested to focus on multi-use platforms. However, micro-wind must be coupled with fixed wave, while both fixed and floating energy plants provide a necessary shield/protection/defence for fish cages. Thus, Table 9 highlights with X all illogical combinations of uses, where the unfeasible combination of micro-wind and floating wave is marked by Y. Blank cells show feasible combination of uses.

Table 9. Technically (Y) and illogically (X) unfeasible multi-use platforms.

	FixWav	FloWav	MicWin	MacWin	FisFar
FixWav		X			
FloWav	X		Y		
MicWin		Y			
MacWin			X		
FisFar					

7.9 Conclusions

Statements from the previous sections led to identify a design option if environmental/social impacts are stressed, and an alternative option if legal conditions are emphasised.

In particular, *design option 1) Fixed wave + Micro-wind + Fish farm* is supported by the following decision rules (Table 10):

- exclude macro-wind due to environmental/social impacts for stakeholders and experts at 50%, although both fixed and floating wave have environmental/social impacts for experts at 50%; next, exclude floating wave due to lack of potentials for experts at 50%, although no potentials are highlighted by stakeholders.

Table 10. Technically (Y) and illogically (X) unfeasible multi-use platforms, together with preferences (Z).

	FixWav	FloWav	MicWin	MacWin	FisFar
FixWav		X		Z	
FloWav	X		Y	Z	Z
MicWin		Y			
MacWin	Z	Z			Z
FisFar		Z		Z	

By contrast, *design option 2) Floating wave + Fish farm* is supported by the following decision rules (Table 11):

- exclude fixed wave and macro-wind due to legal issues for stakeholders and experts at 50%, although also floating wave and fish farm has legal issues for experts at 50%; next, exclude micro-wind due to inconsistencies between macro-wind and floating wave. This agrees with lack of potentials of floating wave for experts at 50%, although no potentials are highlighted by stakeholders.

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Table 11. Technically (Y) and illogically (X) unfeasible multi-use platforms, together with preferences (Z).

	FixWav	FloWav	MicWin	MacWin	FisFar
FixWav	X	X	Z	Z	Z

FloWav	X	X	Y	Z	
MicWin	Z	Y	X	X	Z
MacWin	Z	Z	X	X	Z
FisFar	Z		Z	Z	X

Note that crucial issues to be discussed in detail relate to Energy Storage and Energy Transportation. Moreover, the subsidisation of both energy and fish markets, and consequently the potential and abrupt change in the political context, suggests to take with cautious any scenario, where alternative subsidies for energy and/or fish productions should be considered.

Chapter 8 Conclusions

This document presented the results of the identification, impact and selection of planning and design options in study sites along with the implication for policies and regulations that are related explicitly or implicitly to the development and adoption of selected designs. We can observe obstacles grouped in policy, institutional and stakeholders' terms. In general, the marine spatial planning dictates the development of MUOPs in all the four case studies. Furthermore, in all four sites, environmental and ecological issues were very important in the process of design and development of the MUOPs. Elements coming from the North Sea case study, declare the existence of an implicit conflict of interest between fishermen and developers of offshore wind parks in terms of reducing the available fishing area. Another important element concerning the North Sea is that offshore wind development has been excluded from the recent renewable energy subsidy program, contrary to what is applicable in the Mediterranean Sea case study. The requirement of several licenses in order to start an offshore aquaculture or wind energy project is observed in both the Atlantic and the Baltic case studies. Another aspect that needs to be taken account is the capacity of the electricity grid regarding energy production from the offshore energy sector. Finally, several concerns emerge regards the affection of tourism and trade activities by the development of MUOPs near the coastline as well as there is criticism from the side of certain NGOs related to emission of nutrients and interaction with habitats and species with respect to aquaculture. All these issues should be taken into account by potential developers.

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